Forensic Investigation of AC and PCC Pavements with Extended Service Life

Volume 1

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16. Abstract

The purpose of this research was to identify flexible and rigid pavements in Ohio with average and above average performance, and determine the reasons for these differences in performance. The identification and implementation of factors linked to extended service life will improve performance statewide. FWD and ride quality profiles were measured to evaluate project uniformity, and material samples were obtained from a selected location on each project and tested in the laboratory to determine material properties. Volume 1 of the report includes: the project selection process, FWD and ride quality data, laboratory results of testing on base, subgrade and asphalt concrete pavement samples, and projected service lives using FWD data and the MEPDG. Volume 2 provides results of the laboratory tests and petrographic examinations of the Portland cement concrete cores. Volume 3 contains petrographic analysis of PCC pavement specimens in Cuyahoga County, Ohio containing Blast Furnace Slag Aggregate.

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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 yards	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)		
°F	Fahrenheit temperature	5(°F-32)/9 or (°F-32)/1.8	Celsius temperature	°C
		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 or psi	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	35.71	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)		
°C	Celsius temperature	1.8°C + 32	Fahrenheit temperature	°F
		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 or psi

* SI is the symbol for the International Symbol of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.

(Revised September 1993)

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Abstract

The purpose of this research was to identify flexible and rigid pavements in Ohio with average and above average performance, and determine the reasons for these differences in performance. The identification and implementation of factors linked to extended service life will improve performance statewide. FWD and ride quality profiles were measured to evaluate project uniformity, and material samples were obtained from a selected location on each project and tested in the laboratory to determine material properties. Volume 1 of the report includes: the project selection process, FWD and ride quality data, laboratory results of testing on base, subgrade and asphalt concrete pavement samples, and projected services lives using FWD data and the MEPDG. Volume 2 provides results of the laboratory tests and petrographic examinations of the Portland cement concrete cores. Volume 3 contains petrographic analysis of PCC pavement specimens in Cuyahoga County, Ohio containing Blast Furnace Slag Aggregate.

Flexible and rigid pavements in Ohio having no structural maintenance show an average condition rating of 68 after 20 and 30 years of service, respectively. This performance, coupled with the general lack of structural distress observed on pavements selected for study indicates pavement design procedures used in Ohio are meeting expectations. Practices recommended to improve pavement performance include: 1) constructing stiffer and more uniform subgrades to provide better support and minimize localized failures, 2) reducing amounts of Portland cement and using larger aggregate in 451 and 452 concrete, while continuing to screen aggregate for D-cracking susceptibility, 3) increasing emphasis on ensuring that dowel bars maintain proper alignment during PC concrete placement, and 4) continuing the use of performance grading, smaller aggregate and polymers in AC mixes on heavily traveled pavements. Other observations regarding data used to reach these conclusions include: keeping the PMIS database current, retaining construction records for at least the design life of the pavements, being aware that the effect of surface cracks on flexible pavement performance depends upon whether the cracks are top-down or bottom-up, and keeping the PMIS and straight-line diagrams consistent in identifying project limits, project numbers and paving materials.

Chapter 1
Introduction

Background

The Ohio Department of Transportation (ODOT) is responsible for maintaining an extensive network of interstate, primary and secondary highways across the State of Ohio which encompasses a wide range of pavement designs, paving materials, traffic loading, topography, and subgrade support conditions. While pavement designs, paving materials and traffic loading estimates have evolved rather systematically over time, surface topography and subgrade support remain quite diverse in Ohio with topography ranging from flat to hilly, soil types ranging from fine clay to granular, and soil moisture ranging from well drained to wet. Climatic conditions range from the snow belt near Lake Erie to more moderate temperatures south along the Ohio River. Much of the state has fine-grained A4 – A6 clay subgrade with pockets of granular material deposited by glaciers. Localized subgrade variability can cause wide ranges in pavement support, even within a single construction project. The southern and eastern parts of Ohio are generally unglaciated and hilly, while the remainder of the state is largely glaciated and flat.

When designing highway pavements, ODOT engineers strive to provide pavement structures that carry projected traffic loading for 15 to 20 years with little to no maintenance. Design procedures have evolved to include: empirical analyses based on past pavement performance, equations developed from the AASHO Road Test, mathematical representations based on elastic layer theory and finite element procedures, and mechanistic procedures developed with data obtained from the Strategic Highway Research Program (SHRP). Previous solutions to localized problems, such as subgrade undercutting and soil stabilization to improve pavement support, have also proven to be quite effective.

Considering the wide range of parameters involved in pavement design, and adding in potential material, construction, climate and traffic variability, it is not surprising that pavement performance varies widely across the state. In general, pavement performance can be broadly categorized as poor, average or exceptional within a population of similar pavement types, herein described as being either flexible (asphalt concrete or AC), rigid (Portland cement concrete or PCC), or composite (AC over PCC). Poor performance is exhibited by condition falling well below a best-fit trendline calculated for a population of data for similar pavement structures, and various types of premature distress. These distresses can usually be attributed to design oversights, poor materials, substandard construction techniques, or underestimated traffic loading. Average pavement performance is that falling near the best-fit trendline calculated for a population of performance data. These pavements would be expected to require moderate to extensive maintenance near the end of their design lives. Exceptional pavements are those considered to be providing service above the best-fit trendline for performance with little to no maintenance being required until well beyond their design lives.

Pavement Monitoring

Highway pavements in Ohio are typically designed and constructed to safely carry site specific traffic loading under in-situ subgrade and environmental conditions for a period of 15-20 years without costly maintenance. To achieve this level of service, pavement structures must: 1) maintain acceptable magnitudes of stress throughout all material layers under the continued application of dynamic traffic loads and environmental cycling, 2) retain material integrity in all layers, and 3) provide a smooth safe riding surface for the design period. ODOT strives to monitor the status of these three functional requirements by measuring various physical attributes of the pavement which, directly or indirectly, are indicative of current condition. Statistical trends of these condition measurements over time are used to develop patterns of performance with respect to specific attributes. These condition measurements include: nondestructive testing with a Dynaflect or Falling Weight Deflectometer (FWD) to monitor structural stiffness, ride quality with a non-contact profilometer to monitor surface smoothness and rideability, surface friction with a skid trailer to monitor skid resistance, and pavement condition ratings (PCR) to monitor the progression of surface distresses over time. PCR ratings are performed periodically to monitor performance trends, while ride quality, nondestructive testing and skid testing are performed on an as needed basis to evaluate specific condition issues.

Pavement deterioration begins as soon as they are constructed and exposed to traffic and the environment. As time passes, various physical attributes degrade at different rates depending largely upon accumulated stress distributions experienced throughout the pavement structure and the ability of materials within the pavement to resist those stresses. The rate at which pavement condition deteriorates over time describes the performance of the pavement.

ODOT PMIS

During the development of Ohio's Pavement Management Information System (PMIS) in the 1990's, the Pavement Condition Rating (PCR) system being used at the time to quantify surface distress was adopted as the lone parameter to judge condition, calculate performance and manage ODOT's pavement infrastructure. Pavement Condition Ratings are determined through a visual assessment of the severity and extent of various distresses appearing on the pavement surface. These distress ratings are then weighted according to their impact on overall condition and remaining service life. While the PCR system attempts to properly account for the effects of structural and nonstructural distress on pavement condition, it is limited by what the raters see, how well the raters interpret the distresses, and how accurately the rating system weights the various types of distress. For instance, top-down cracking on flexible pavements, usually indicative of aging or oxidation of the bituminous surface, progresses slowly and does not seriously impact the structural capacity of the pavement. Bottom-up cracking, however, generally progresses upward rapidly and spreads to reduce the structural capacity of the pavement. It is often difficult for raters to differentiate between these types of cracks from visual inspections alone.

These factors, plus the fact that certain types of nonstructural maintenance used to repair, replace or merely cover existing distress have been observed to sharply increase condition ratings, indicate that ratings are highly influenced by cosmetic appearance. The PCR system has been revised at times to better account for structural considerations in flexible and rigid pavements.

Objectives

The purpose of this research project is to identify flexible, rigid and composite pavements that have not received any structural maintenance since construction and are considered to be performing either average or exceptional, and determine reasons why exceptional pavements perform better than average pavements. By identifying these reasons and implementing them into standard practice, the overall performance of pavements in Ohio can be improved in the future. Specific objectives for this project include:

1. Review the ODOT pavement database to determine current performance expectations on highway pavements in Ohio. In this statistical analysis, pavements will be divided according to: material type (asphalt concrete, Portland cement concrete and composite); classification (interstate, four-lane non-interstate and two-lane); geographical region in the state; original construction or resurfaced; and traffic volume. Composite pavements will be limited to those constructed as composite pavements and not concrete pavements overlaid with AC. Measures upon which performance will be judged include: distress, roughness, age, traffic loading (ESALs), and rutting on AC pavements.

2. From the statistical analyses performed in Objective 1, a final selection of ten asphalt concrete (AC) and ten Portland cement concrete (PCC) projects performing as expected, and ten AC and ten PCC projects performing beyond expectations will be made by representatives from ODOT, Ohio University (OU) and industry. A few composite pavements may be included, as deemed appropriate. Pavements which appear to be performing poorly in this analysis also will be identified for review by ODOT.

3. ODOT District Offices responsible for those pavements selected as performing as expected and better than expected will be visited to discuss the selection process and to gain input regarding past performance.

4. Inspect each of the selected sites and perform a suite of tests to develop response and performance profiles along the project lengths. These site inspections will include, at a minimum, Pavement Distress Survey (SHRP-P-338), Pavement Condition Ratings (PCR), Falling Weight Deflectometer (FWD) readings, Dynamic Cone Penetrometer (DCP) measurements, Ground Penetrating Radar (GPR) measurements, roughness measurements, lateral profiles on AC surfaces, cores, and the collection of representative material samples. From these data, areas of differing performance will be located within each site.

5. Conduct a historical review of each project to determine: age, environmental conditions, original specifications, construction documentation, original test data, traffic volumes

and weights accumulated since being opened to traffic, and previous condition information collected by ODOT (PCR, FWD, roughness, etc.). Personnel associated with the design and/or construction of the study pavements will be contacted to determine if they recall any particular decisions or events that might have affected performance. ODOT will provide access to the required files and ORITE will search the files for pertinent data.

6. Conduct laboratory tests to determine the current physical properties of pavement, base and subgrade materials in the study pavements. Compare these current properties with properties measured at the time of construction. In addition to this battery of standard tests, the PCC cores will undergo an extensive petrographic examination to ascertain compliance with original specifications and current micro structural condition.

7. Perform mathematical analyses to assess theoretical structural performance based on distress and thickness using various performance prediction procedures, historical data and in-situ material properties. At a minimum, equations developed under NCHRP 1-26, software developed under NCHRP 1-37A and 1993 AASHTO procedures will be used to predict performance.

8. Identify design, construction and material features which appear to extend pavement life on superior pavements, and recommend procedures for improving the longevity of pavements in Ohio by implementing these features into practice. Document all work in a final report.

Documentation

Results of this research project are documented in a three volume set of reports. Volume 1 discusses the project selection process, field investigations, modeling for the MEPDG, and laboratory testing associated with the both flexible and rigid pavements. Volume 2 presents the petrographic examination of rigid pavement cores at Lankard Materials Laboratory, and Volume 3 provides the findings of a contract extension into rigid pavements containing slag aggregate.

Chapter 2

Project Selection from the ODOT PMIS

PMIS Overview

To effectively manage Ohio's major pavement network, ODOT developed a Pavement Management Information System (PMIS) in the 1990's which divided the network into sections defined initially by limits of construction and maintenance projects, and provided various types of design and construction information for those projects. As traffic loading, pavement condition ratings, ride quality and other performance data were added to the PMIS, projects were subdivided to maintain section uniformity. With this computerized system, ODOT is able to monitor the condition of Ohio's pavement network and determine future courses of action throughout the state by analyzing data in the PMIS.

The ODOT PMIS is an ACCESS database containing data gathered on the network of Interstate, federal and state highways constructed and maintained by ODOT throughout the State of Ohio. This database was developed as a cooperative effort between ODOT and faculty in the Department of Civil Engineering at the University of Toledo led by Dr. Eddie Chou. The PMIS consists of two principal ACCESS tables; 1) DATA_Project History which breaks the pavement network into a chronological list of project segments from original construction through the most recent maintenance and provides basic information about individual segments, including project number, pavement type, pavement build up, pavement width, number of lanes, pavement classification, project cost, and activity codes describing the types of construction and maintenance, and 2) DATA_ODOT which provides various types of data collected to monitor performance of the uniform pavement sections, including traffic loading (ADT and ESALs), pavement condition ratings (PCR), ride quality (IRI), and serviceability (PSI). Section limits are identified by county, route, straight-line mileage and direction of travel.

Activity codes in the DATA_Project History table describe the types of construction and maintenance associated with each uniform pavement section. To evaluate performance, it is necessary to identify pavement sections of interest in this table, and determine trends in accumulated traffic loading, surface distress and/or roughness for those sections in the DATA_ODOT table. A list of activity codes used in the DATA_Project History table for new construction and maintenance projects is shown in Table 2.1.

Table 2.1
PMIS Activity Codes

Treatment Class	Activity Code	Description
Maintenance	10	Reactive Maintenance
	20	Crack Sealing
	25	Chip Seal
	30	Micro-Surfacing
	31	Double Application Micro-Sealing
	35	Nova-Chip Resurfacing
	38	Fine Graded Polymer AC Overlay
	40	CPR
Minor	45	Intermediate Course Recycled AC
	50	AC Overlay without Repairs
	52	AC Inlay
	55	Double Chip Seal
	60	AC Overlay with Repairs
Major	70	Crack and Seat
	73	Break and Seat
	77	Rubblize and Roll
	80	Whitetopping
	90	Unbonded Concrete Overlay
	95	Unbonded Composite Overlay
	100	New Flexible Pavement
	110	New Rigid Pavement
	120	New Composite Pavement

At the time this research project was initiated in January 2006, ODOT furnished ORITE with a copy of the 2002 PMIS, which was the latest version available at the time. After reviewing the PMIS and activity codes (AC) assigned to various types of construction and maintenance, basic selection criteria were established to limit projects in this study to those constructed as new flexible (AC 100), new rigid (AC 110) or new composite (AC 120) pavements not receiving any type of structural maintenance since construction. Structural maintenance was defined as projects having an AC > 40. Double chip seals, with an AC of 55, were not considered structural but, since they are rarely used by ODOT on major highways, this inconsistency did not present a serious problem.

A 2004 version of the PMIS became available while the initial project search was in progress. The 2002 DATA_Project History table included projects dating back to 1911, while the 2004 DATA_Project History table only included projects sold after 1979. Both DATA_ODOT tables contained performance data from 1985, when PCR data were first collected statewide. Consequently, while two more years of performance data were available in the 2004 DATA_ODOT table, the deletion of all projects sold before 1980 in the 2004 DATA_Project History table eliminated many in-service projects from consideration, and reduced the number of projects available for study. Therefore, all projects sold up through 2002 potentially were in the 2002 PMIS, while only projects sold between 1980 and 2004 were in the 2004 PMIS.

Numerous pavement segments were either missing or identified as having unknown construction and maintenance activities in both versions of the PMIS. Table 2.2 shows a summary of the most common activity codes contained in the 2002 and 2004 DATA_Project History tables. While the total number of entries increased from 13,499 to 15,532 in 2004, the numbers of new flexible, new rigid and new composite pavements all decreased due to the elimination of projects sold before 1980. As expected, this deletion of projects had the greatest impact on rigid pavements because of their longer service lives and the greater number of these projects sold prior to 1980. The number of projects with Activity Codes 888, 995 and 999 all increased dramatically in 2004 and, in both versions of the PMIS, almost half of the table entries were assigned activity codes 777, 888, 995 or 999, which indicated incomplete data and precluded them from use in this research project.

Table 2.2
Distribution of Activity Codes in PMIS

Activity Code	**Activity**	**2002 PMIS**		**2004 PMIS**	
		Number	**%**	**Number**	**%**
DATA_Project History Table					
	Total Entries	13,499		15,532	
50	AC Overlay Without Repairs	4470	33.1	4909	31.6
60	AC Overlay with Repairs	945	7.0	1357	8.7
100	New Flexible Pavement	375	2.8	290	1.9
110	New Rigid Pavement	754	5.6	137	0.9
120	New Composite Pavement	81	0.6	49	0.3
777	Known Project Number, Unknown Activity	893	6.6	194	1.3
888	Known Project Number, Condition Jump	655	4.9	1383	8.9
995	Unknown Project 5 -10 point Condition Jump	1815	13.4	2445	15.7
999	Unknown Project, 10+ point Condition Jump	2701	20.0	3241	20.9
	Σ 777-999	6064	44.9	7263	46.8
DATA_ODOT Table					
		2002 PMIS		**2004 PMIS**	
	Total Entries	375,611		587,189	

Traffic Loading

Initially, long term pavement performance was to be determined with plots of Pavement Condition Rating (PCR) versus accumulated traffic loading (ESALs) on pavements constructed as AC 100, 110 or 120, and which had not received maintenance above AC 40. Basic data would consist of annual condition ratings plotted against ESALs accumulated from construction to the year of the ratings. Plots would provide performance trends for each pavement type with a best-fit trendline defining the average decline in PCR with accumulated traffic loading. Parallel lines drawn above and below the best-fit line would define the zones of average performance as that falling between the parallel lines, and excellent performance as that falling above the top parallel line. The parallel lines would be equally spaced from the best-fit line to provide symmetry around the best-fit line and sufficiently close to the best-fit trendline to allow an adequate number of pavement sections with average and excellent performance.

While it was possible to sort out pavement projects which appeared to be viable candidates using the DATA_Project History tables, a problem occurred when a quick check was performed on traffic data in the DATA_ODOT tables. Daily ESALs were divided by average daily truck volumes to determine an average number of ESALs per truck. These values were calculated annually on sections of arbitrarily selected routes through a few counties from 1982-2000. Some routes consistently maintained values between 0.50 to 1.00 ESALs/truck, which was reasonable, while other routes had values ranging from 0.20 to almost 3.00 ESALs/truck. Figure 2.1 shows good data on I-70 through Madison County, an interstate route carrying a high volume of trucks, and Figure 2.2 shows highly variable data on US 33 through Athens County, a primary route carrying light truck traffic. Based on the wide variations in ESALs/truck calculated over time and over various other routes, it was decided that traffic loading data were unreliable in the PMIS, and plans were altered to use pavement condition ratings versus age instead of pavement condition ratings versus accumulated traffic loading to evaluate pavement performance. This procedural change of using age rather than traffic loading to select pavement projects was not expected to have a significant impact on the outcome of the research since pavement designs are based on B&C truck volumes estimated for the design life of the pavement.

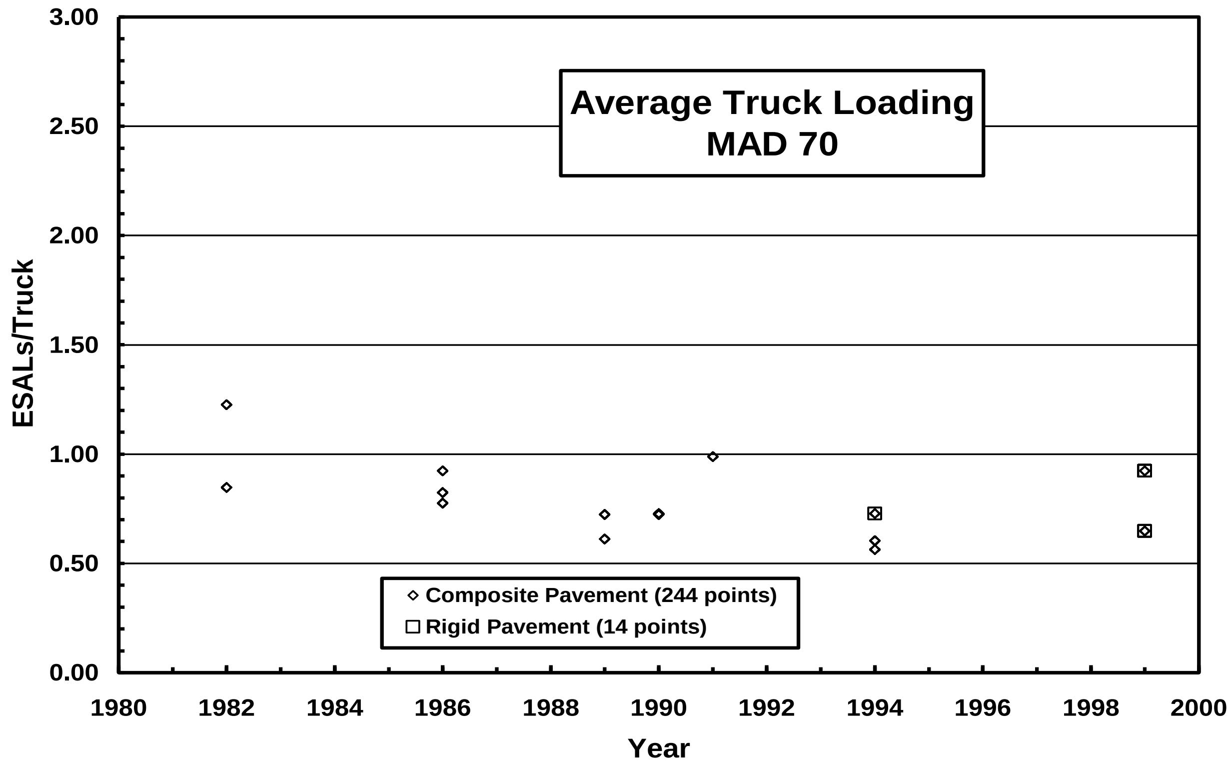


Figure 2.1 – ESALs/Truck Calculated on MAD 70

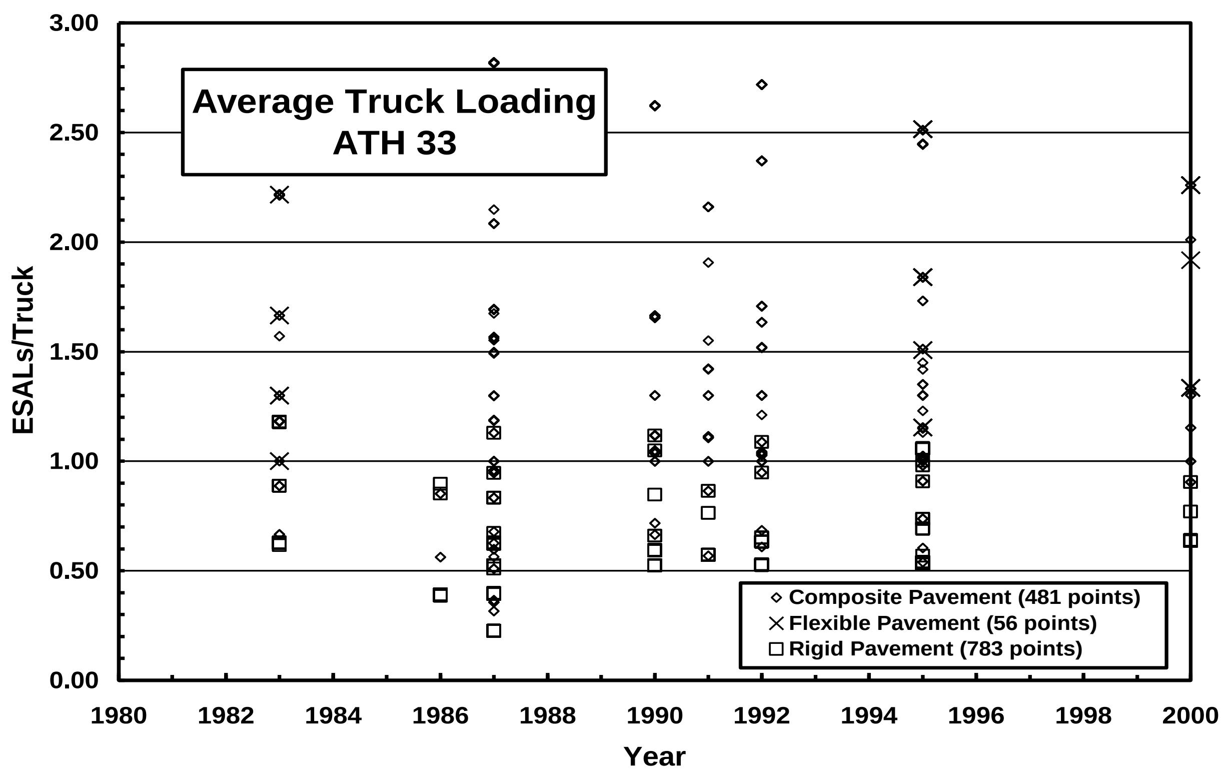


Figure 2.2 – ESALs/Truck Calculated on ATH 33

Pavement Condition Ratings (PCR)

Because of problems discussed above with truck ESALs in the PMIS, it was decided to use pavement age instead of accumulated traffic loading to measure performance. Statewide plots of PCR vs. pavement age derived from the project number were developed for pavements constructed as new flexible (AC 100), new rigid (AC 110) or new composite (AC 120) pavement projects which had not received any maintenance with an Activity Code > 40. Data in the 2002 DATA_Project History and 2002 DATA_ODOT tables initially provided by ORITE were sorted, but could not be merged because of different construction, maintenance and monitoring log points in the two ACCESS tables. ODOT then provided ORITE with the entire PMIS. Again, ORITE tried to locate candidate projects, but could not because of the need for two internal tables required to run the PMIS. Once those tables were received and the PMIS was running, the same issue arose as to how to coordinate the identification of pavement sections originally constructed between one set of log points, but maintained and monitored between different log points over time.

ODOT addressed the problem of differing log points by dividing the entire highway network into 0.01 mile long segments, but the reconstruction of this process for the mainframe computer in Athens would have involved much effort by ORITE, and this expanded PMIS would have been too large to run on a PC. Consequently, the 2002 DATA_Project History table was sorted by NLFID (count/route), Station (up or down) and Blog (beginning log) to consolidate routes and list pavement segments by straight-line mileage, and the 13,499 lines of data were reviewed manually to identify AC 100, AC 110 and AC 120 projects which had not received maintenance greater than AC 40. Among items limiting the number of projects that could be considered for study included: 1) pavement segments not listed in the PMIS, 2) pavement sections with Activity Codes of 777, 888, 995 and 999, and 3) inconsistent data, such as different projects shown as being constructed at the same location and at about the same time.

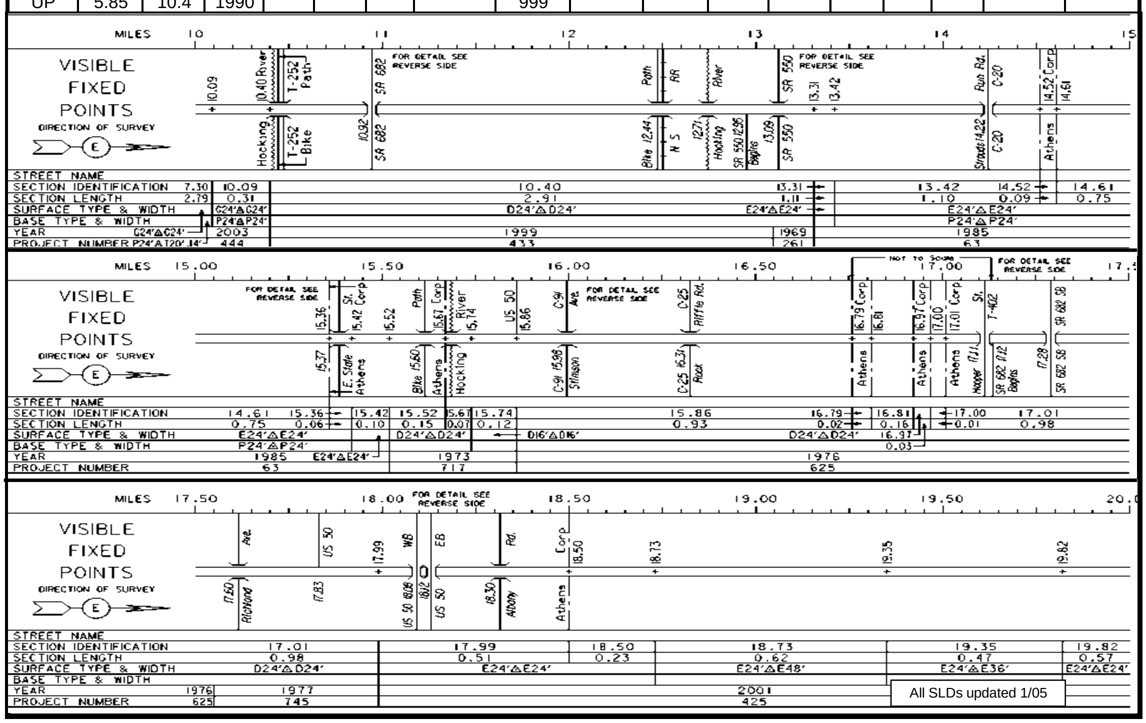
The preliminary list of acceptable projects in the 2002 PMIS included 89 flexible, 160 rigid and 31 composite projects. By comparing the 160 rigid projects identified with a separate internal listing of all exposed rigid projects assembled by ODOT in 2005 and 2006, the number of potential rigid projects was reduced to 71.

The 2002 DATA_ODOT table, which comprised 375,611 lines of data, was sorted by NLFID (count/route), Blog (beginning log) and Year, and searched manually to find PCR data for the selected projects. New problems emerged as many project numbers did not appear to be updated as PCR values were added to the table. About this time, a 2004 version of the PMIS was released by ODOT. Much of the original manual search process was repeated with the 2004 PMIS, which contained 15,532 lines of data on the DATA_Project History table and 587,189 lines of data on the DATA_ODOT table. While the 2004 PMIS provided some updated project numbers and additional PCR data, projects sold prior to 1980 had been removed. Consequently, DATA_Project History tables from both versions of the PMIS were used for project selection.

During the search for valid PCR data, straight-line diagrams (SLDs) were used as a reference to resolve differences in project numbers and boundaries on the DATA_Project History and DATA_ODOT tables. Unfortunately, there were significant differences between the three sources of data. Table 2.3 shows some typical problems encountered with searching the PMIS using selected columns for all ATH 33 entries in the 2002 and 2004 DATA_Project History table, and 2005 SLDs containing the most recent projects on ATH 33 between MP 10 and 20. In the tables, Station is the direction of travel; APP BLOG, APP ELOG, and APP YEAR are potential revisions to the original logs and years entered as Blog, Elog, and Year; Project Number is the number of project sold with the year of sale in parentheses; and Activity Code describes the type of construction or maintenance. In the SLDs, Surface D is reinforced concrete and Surface E is plain concrete, both of which are coded as AC 110 in the PMIS. A few problems encountered with these sources of data in Table 2.3 included: 1) Projects 625(76) and 745(77) in the 2002 PMIS were removed from the 2004 PMIS, but remain as exposed concrete pavement on the SLD and in the field, 2) Project 717(73) on the SLD was not shown in either version of the PMIS, 3) beginning and ending logs in the PMIS for Projects 261(69), 625(76) 745(77) and 425(01) disagreed with those shown on the SLDs, 4) many projects have Activity Codes of 888, 995 or 999, and 5) Project 235(58) in the 2002 PMIS was overlaid (AC 50) with Project 341(96), and received CPR maintenance (AC 40) for rigid pavement on Project 433(99). While Project 235(58) was deleted from the 2004 PMIS, the same two maintenance projects are shown, but the pavement remains as exposed concrete in the field with all joints replaced. Other inconsistencies noted during the search for suitable projects are summarized in Appendices A and B. These inconsistencies likely only represent a small portion of the PMIS since they were associated with projects having activity codes of 100, 110 and 120.

Table 2.3
PMIS and SLD Data for ATH 33

DATA_Project History Spreadsheet and Straight-Line Diagrams - ATH 33																	
2002 PMIS									2004 PMIS								
Station	APP BLOG	APP ELOG	APP YEAR	Blog	Elog	Year	Project Number	Activity Code	Station	APP BLOG	APP ELOG	APP YEAR	Blog	Elog	Year	Project Number	Activity Code
DOWN	10.41	12.95	1987					995	DOWN	13.31	15.54	1998					995
DOWN	10.41	12.95	1998					995	DOWN	10.41	13.19	1998					995
DOWN	12.95	13.19	1998					995	DOWN	17.83	17.85	2001					995
DOWN	17.83	17.85	2001					995	U/D	0	4.21	1982	0	4.21	1982	126-82	50
DOWN	15.53	15.54	1999					995	U/D	5.48	10.4	1998	5.34	10.4	1998	5003-98	30
DOWN	13.31	15.53	1998					995	U/D	5.48	10.4	1996	5.34	13.1	1996	341-96	50
U/D				0	4.21	1982	126-82	50	U/D	1.88	10.4	2003	5.73	10.4	2003	444-03	30
U/D	5.48	10.4	1996	5.34	13.1	1996	341-96	50	U/D	5.85	7.3	1983	5.85	7.3	1983	718-83	50
U/D				5.34	10.4	1998	5003-98	30	U/D	10.41	15.38	1984	10.4	13.3	1984	698-84	888
U/D				5.85	10.4	1965	1-65	110	U/D	10.4	13.31	1999	10.4	13.3	1999	433-99	40
U/D	5.85	9.09	1986	5.85	7.3	1983	718-83	50	U/D	12.95	15.39	1986	13.4	15.7	1985	63-85	90
U/D				10.2	13.1	1958	235-58	110	U/D	15.54	15.9	1994	15.4	15.5	1993	905-93	110
U/D	10.4	13.31	2000	10.4	13.3	1999	433-99	40	U/D	19.25	20.59	1990	19.3	20.4	1990		50
U/D	10.41	13.19	1985	10.4	13.3	1984	698-84	888	U/D	19.66	20.59	2001	19.3	25.5	2001	425-01	110
U/D				13.3	13.4	1969	261-69	110	U/D	20.59	24.57	1999	20	21.2	1998	489-98	60
U/D	12.95	15.39	1987	13.4	15.7	1985	63-85	90	U/D	20.59	29.1	1992	20.4	29.1	1992	287-92	50
U/D				15.4	16.4	1973	518-73	110	U/D	20.4	29.1	1985	20.4	29.1	1985		50
U/D	15.53	15.9	1995	15.4	15.5	1993	905-93	110	U/D	20.4	29.1	1981	20.4	29.1	1985		50
U/D				16.8	18.2	1976	625-76	110	U/D				23.9	24.1	1991	619-91	100
U/D				18.2	18.3	1977	745-77	110	U/D				25.5	28.2	2001	246-01	110
U/D	19.25	20.59	1990	19.3	20.4	1990		50	U/D	15.39	15.54	1989					999
U/D				19.3	25.5	2001	425-01	110	U/D	13.19	13.31	1996					995
U/D	20.59	29.1	1992	20.4	29.1	1992	287-92	50	U/D	15.54	15.9	1990					999
U/D				23.9	24.1	1991	619-91	100	U/D	15.67	15.9	1987					995
U/D	13.19	13.31	1996					999	U/D	15.9	18.43	1989					999
U/D	15.39	15.9	1987					995	U/D	13.31	17.83	2004					995
U/D	15.39	15.53	1989					999	U/D	15.39	15.67	1987					995
U/D	15.53	15.9	1990					999	UP	0	5.48	1987					999
U/D	15.9	18.43	1989					999	UP	10.18	12.95	1987					995
U/D	10.4	10.41	1989					995	UP	5.85	10.4	1990					995
U/D	19.66	20.59	2001					999	UP	5.85	10.4	1995					995
UP	10.41	12.95	1987					999	UP	15.9	17.62	1986					995
UP	5.85	10.4	1995					995									
UP	20.59	24.36	1999					995									
UP	24.36	24.57	1999					999									
UP	5.85	10.4	1990					999									



A second major problem involved the review of project numbers in the DATA_ODOT tables which, apparently, were not always updated as new PCR data were added, thereby causing project numbers and the corresponding PCRs to be incompatible. Viable projects identified in the DATA_Project History tables were located in the DATA_ODOT tables, and project numbers were verified and corrected as necessary using the DATA_Project History tables, SLDs and a considerable amount of engineering judgment. PCRs for those projects were reviewed to verify that they increased soon after construction and then degraded gradually over time as expected. This review involved the sorting and manual searching through almost one million lines of data in the 2002 and 2004 DATA_ODOT tables. During this process, it became apparent certain maintenance projects with Activity Codes $\leq$ 40, while not contributing structurally, have a profound impact on PCR values. Increased PCR data resulting from nonstructural maintenance were removed from consideration. Because of the enormous amount of time required to manually review and resolve inconsistent data in the PMIS tables, a decision was made to eliminate composite pavements (AC 120) from the study.

Figures 2.3 and 2.4 show plots of raw, uncorrected PCR data versus project age for AC 100 and AC 110 projects, respectively, with age being determined from the year of project sale. While some data scatter was expected in these plots, the actual ranges of data were much more than expected, with specific concerns including: projects with negative years of service, the large number of older projects with high PCR ratings, many new projects with low PCR ratings, and the large number of very old projects apparently still in service. Many of these problems resulted from the project number/PCR inconsistencies discussed earlier. A few negative and extreme ages were caused by an extra zero being added to project numbers as they were entered into the PMIS.

To resolve many errors and improve the quality of data in the PMIS, dates and mileage limits for all candidate projects were reviewed on straight-line diagrams (SLDs), which generally agreed with mileage breakdowns in the PCR ratings. PCR ratings tended to increase sharply within a year or so of project sale years on the SLDs, and then taper down over time until the next maintenance activity. While most PMIS projects were on current SLDs, some older projects had to be verified with older SLDs in the archives. A few SLDs not updated for several years did not show newer projects indicated by project information listed in the PMIS. Project limits for PCR ratings in the PMIS sometimes spanned across two projects on the SLD. These data were discounted because the ratings could not be clearly identified with one specific project.

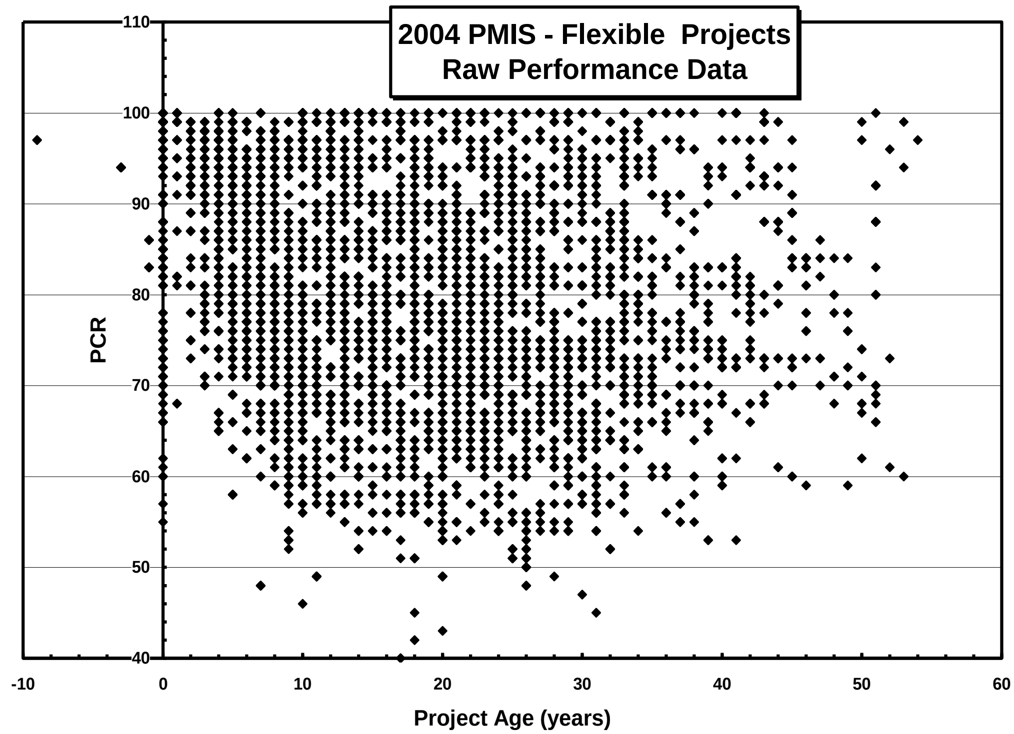


Figure 2.3 – Raw Performance of Flexible Pavements

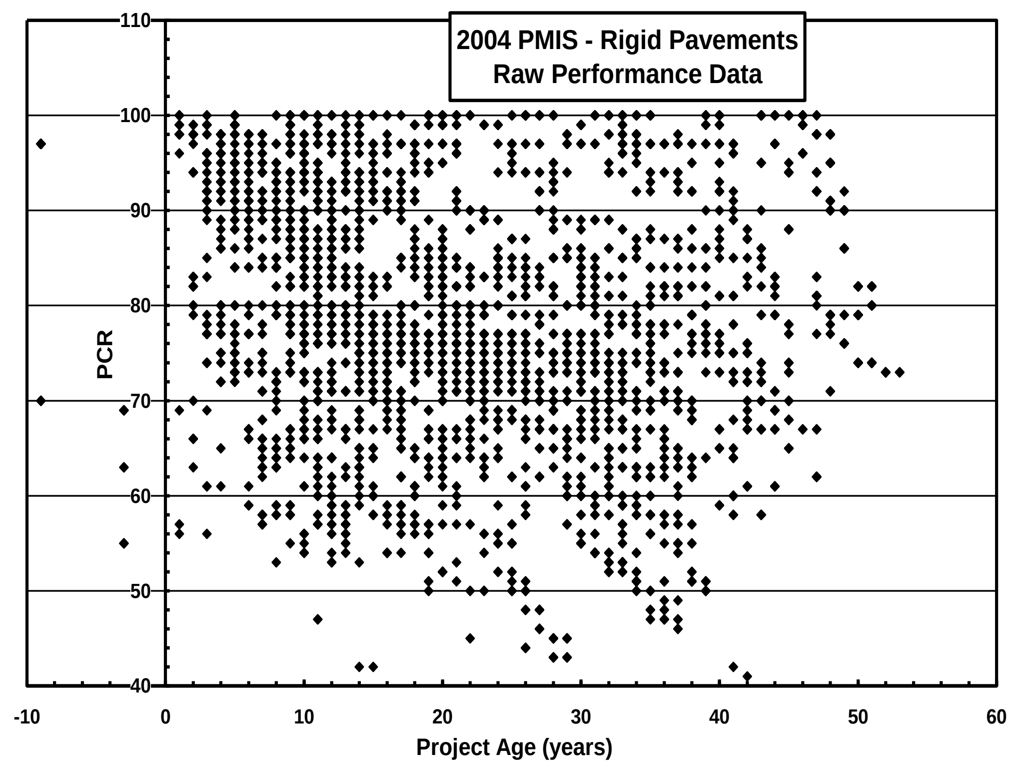


Figure 2.4 – Raw Performance of Rigid Pavements

Figures 2.5 and 2.6 show corrected PCR performance data for flexible and rigid pavements as determined from the 2004 PMIS with linear and second order polynomial trendlines, performance trends developed by E. Chou on an earlier research project, and performance equations from the ODOT Design Manual. The three assessments of performance agree rather well with E. Chou's data being the most pessimistic for both flexible and rigid pavements. The ODOT Manual is more optimistic than the PMIS data for rigid pavements and less optimistic for flexible pavements. From linear trendlines for the PMIS data, new flexible and rigid pavements in Ohio not receiving structural maintenance can be summarized as maintaining PCRs above 67 for approximately 20 and 30 years, respectively. Figures 2.7 and 2.8 show zones of average and excellent performance determined from the corrected data in Figures 2.5 and 2.6. These performance zones were determined by adjusting the parallel lines, drawn equidistant from the trendline, until a sufficient number of projects above the top parallel line could be classified as excellent, and a sufficient number of projects between the parallel lines could be classified as average. Figures 2.5 through 2.8 fulfill the requirements of Objective 1:

> *Objective 1 - Review the ODOT pavement database to determine current performance expectations on highway pavements in Ohio. In this statistical analysis, pavements will be divided according to: material type (asphalt concrete, Portland cement concrete and composite); classification (interstate, four-lane non-interstate and two-lane); geographical region in the state; original construction or resurfaced; and traffic volume. Composite pavements will be limited to those constructed as composite pavements and not concrete pavements overlaid with asphalt concrete. Measures upon which performance will be judged include: distress, roughness, age, traffic loading (ESALs), and rutting as a separate criteria on asphalt concrete pavements.*

While the rather limited number of projects in the 2002 and 2004 PMIS meeting the selection criteria of new construction with no structural maintenance prevented the inclusion of classification, geographical location and traffic loading as specific variables in the test matrix, differences were represented within each of these three parameters. Interstate, four-lane primary and two-lane, rural and urban routes were selected in 20 of Ohio's 88 counties from the Ohio River to Lake Erie and from the Indiana to West Virginia borders. Daily traffic volumes ranged from 190 B&C trucks on ATH 682 near Athens to over 12,000 B&C trucks on I-76 in Akron.

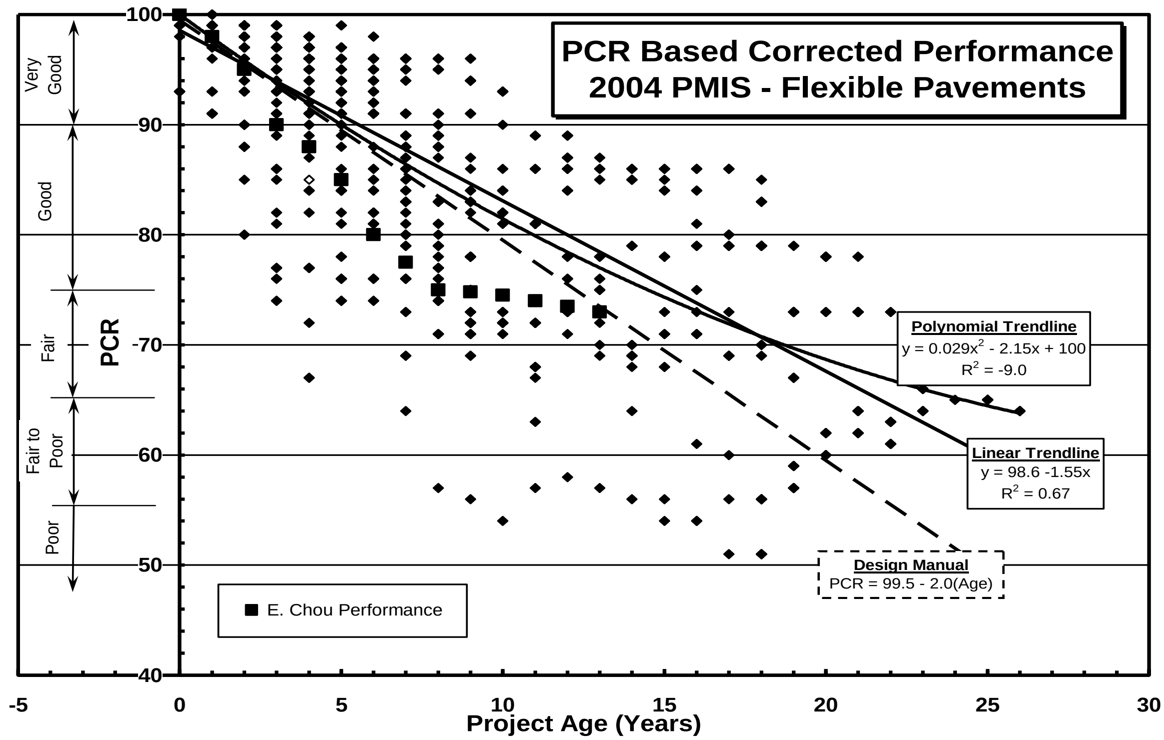


Figure 2.5 – Corrected Performance of Flexible Pavements

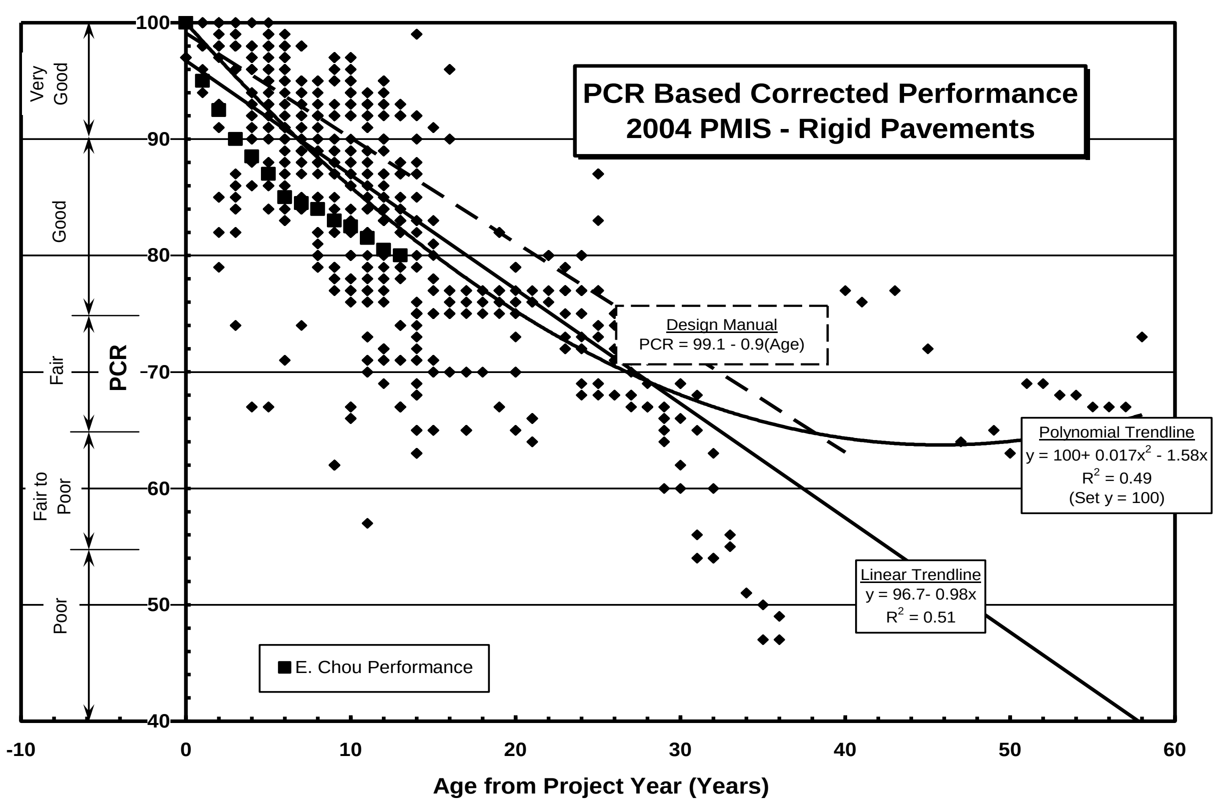


Figure 2.6 – Corrected Performance of Rigid Pavements

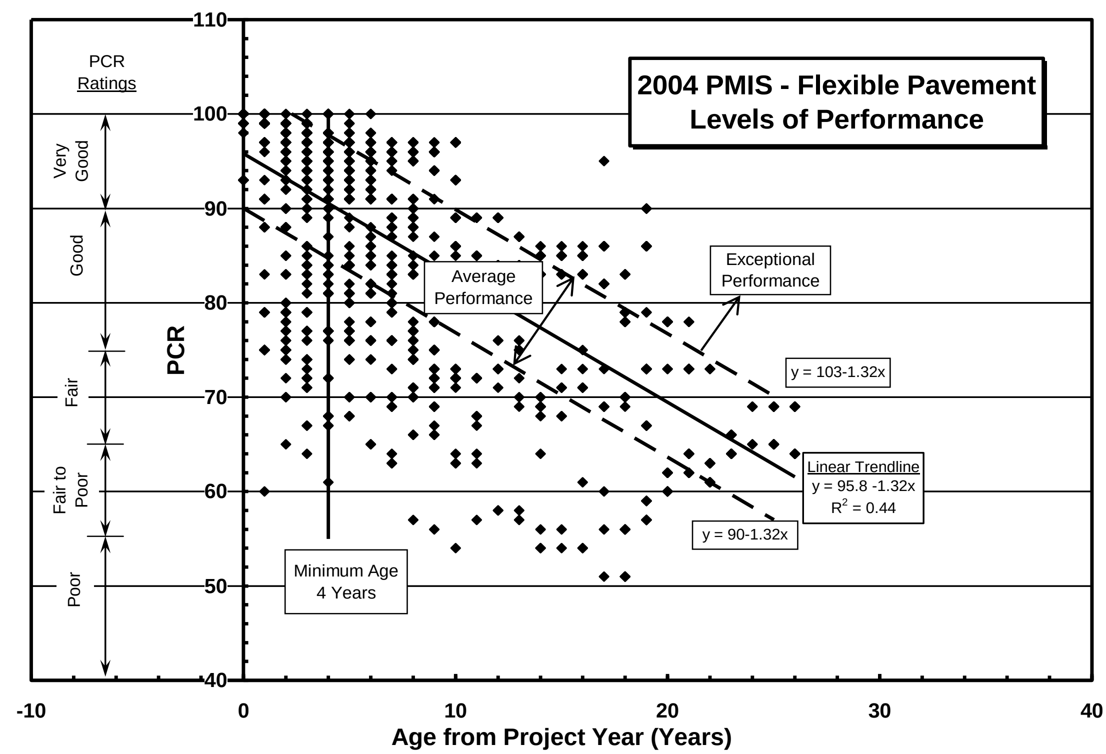


Figure 2.7 – Performance Levels for Flexible Pavements

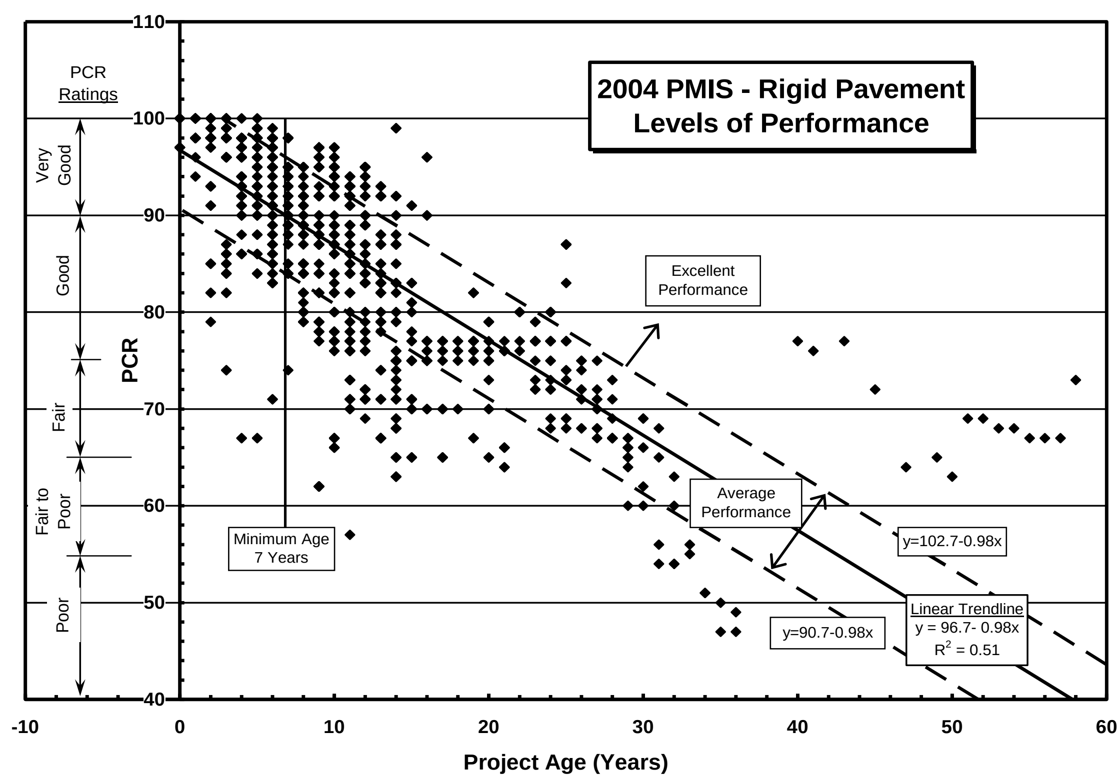


Figure 2.8 – Performance Levels for Rigid Pavements

Figure 2.9 shows the layout of field districts in ODOT, and Figures 2.10 and 2.11 show the performance of flexible and rigid pavements by district. While the trends in Figures 2.10 and 2.11 are interesting, they represent very limited data and cannot, therefore, be considered as reliable indicators of district performance. Figure 2.10 consists of about 1,700 ratings from 42 sections of flexible pavement in ten counties, and Figure 2.11 consists of about 1,700 ratings from 30 sections of rigid pavement in eleven counties.

Figure 2.9 – ODOT Field Districts

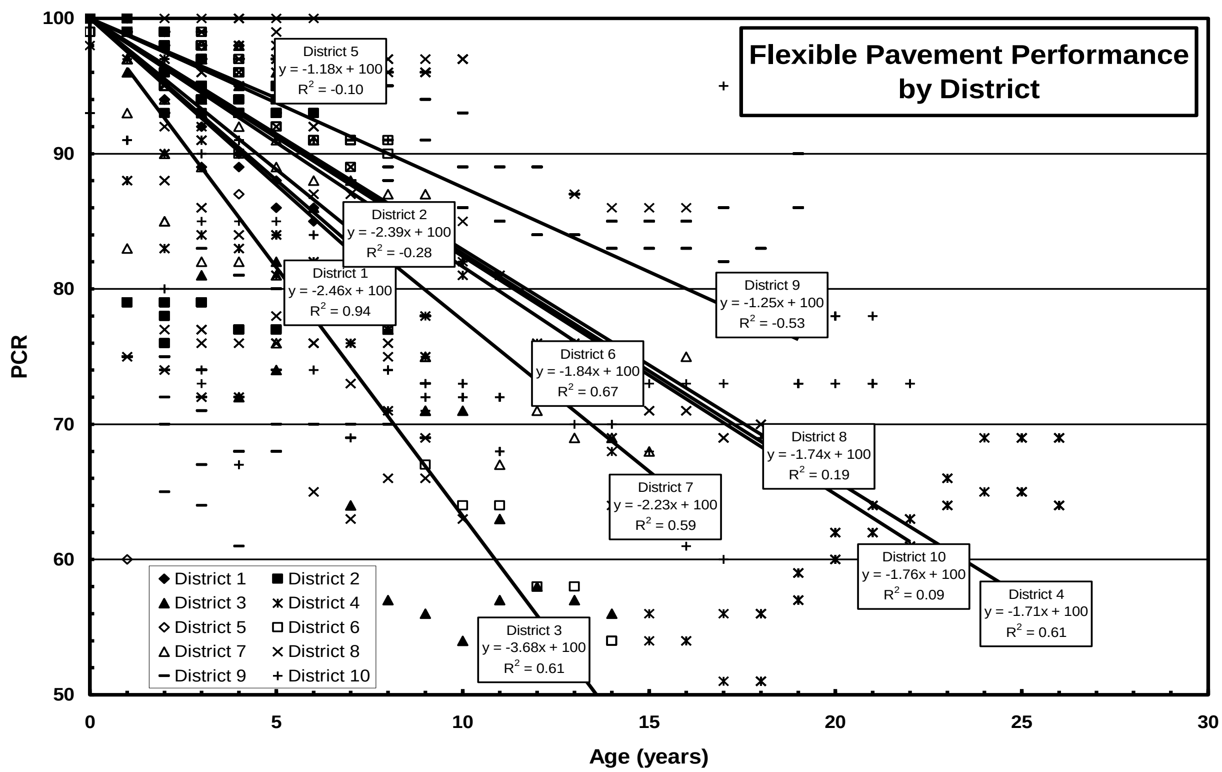


Figure 2.10 – Flexible Pavement Performance by District

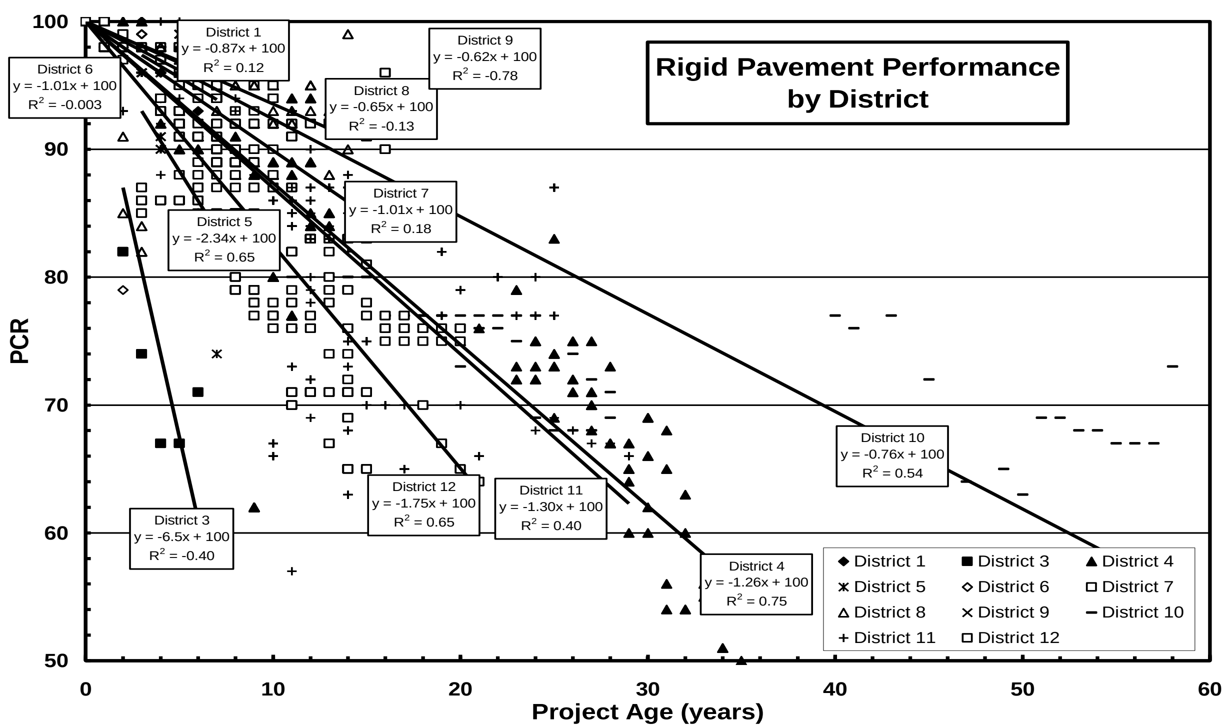


Figure 2.11 – Rigid Pavement Performance by District

Another approach to assessing pavement performance is by using age at initial maintenance of any type as a measure of service life. The application of first maintenance, while another indicator of performance, can be influenced by other conditions, such as district culture regarding pavement maintenance, personal practices of those managing the pavement infrastructure, and funding issues. Due to the longer service lives typical on rigid pavements, these data were obtained from the 2002 PMIS, which contained many projects constructed before 1980. The 2004 PMIS was used for flexible pavements. Asphalt concrete overlays without repairs (AC 50) and with repairs (AC 60) are the dominant types of initial pavement maintenance used in Ohio to improve pavement stiffness and restore rideability and, together, comprised 64% and 80% of the initial maintenance work on flexible and rigid pavements, respectively. Figure 2.12 shows the statewide distribution of age for all initial maintenance on flexible pavements, and Figure 2.13 shows the distribution for AC 50 and AC 60 initial maintenance on flexible pavements. Figures 2.14 and 2.15 show similar data for rigid pavements. The high percentage of AC 50 and AC 60 projects results in the two distributions for each pavement type being quite similar. A few projects existed beyond the maximum times shown in the plots, but they were excluded to provide a better resolution of the majority of data. These plots required a separate search through the two versions of the PMIS because the first search was made to identify projects receiving no structural maintenance, and this search was to identify projects receiving any maintenance.

Figures 2.12 and 2.13 show maintenance being performed on flexible pavements over the first 10 years after construction and then tapering off. Figures 2.14 and 2.15 show that, while a few rigid pavements received maintenance soon after construction, most of the maintenance occurred 15 – 25 years after construction and then tapered off over the next 15 years. Figures 2.16 and 2.17 show the data in Figures 2.12 – 2.15 expressed as cumulative percentages of all initial maintenance and AC 50/60 initial maintenance. Figures 2.18 and 2.19 show the cumulative percentages separated out by district with data points being removed to clarify the polynomial trendlines. As discussed earlier, many factors other than performance can affect the timing of pavement maintenance in the ODOT districts. These factors, plus the limited number of projects available in individual districts, restrict the reliability of the district trendlines, especially for flexible pavements. The high percentage of AC 50 and AC 60 maintenance projects dominate the bar charts and cumulative distributions statewide.

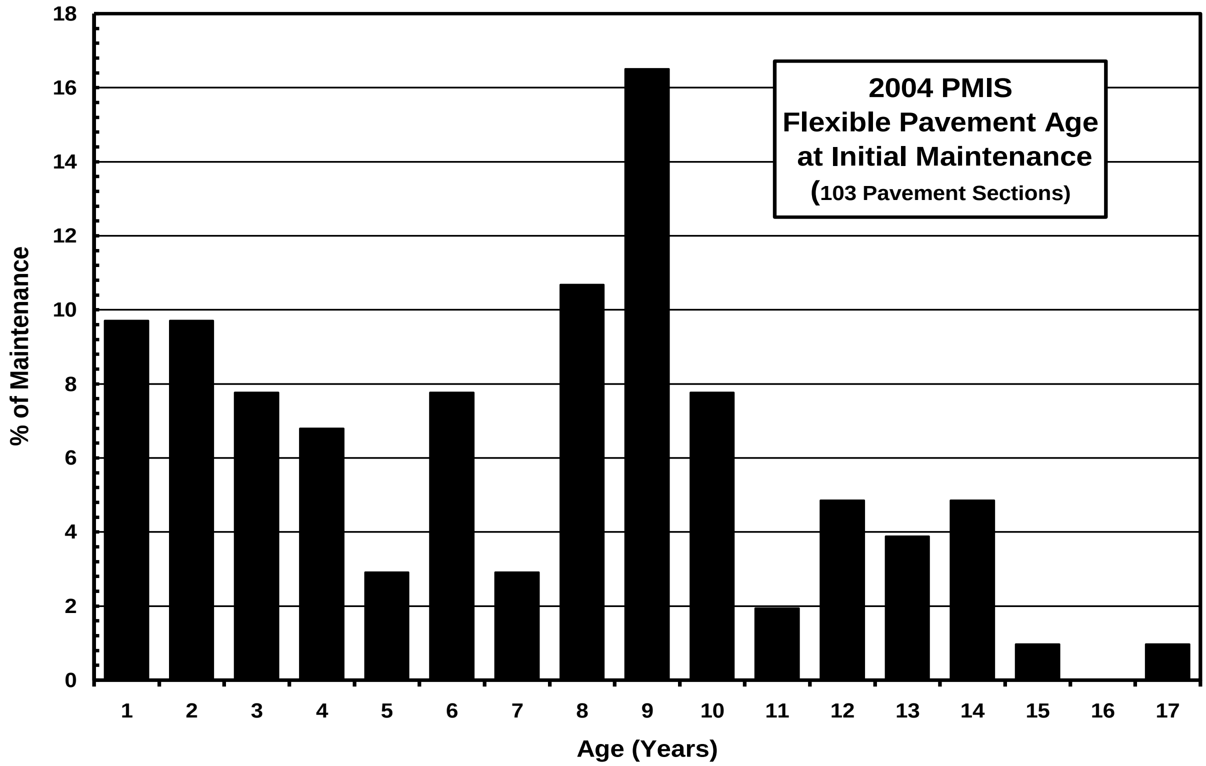


Figure 2.12 - Frequency of Initial Maintenance on Flexible Pavements

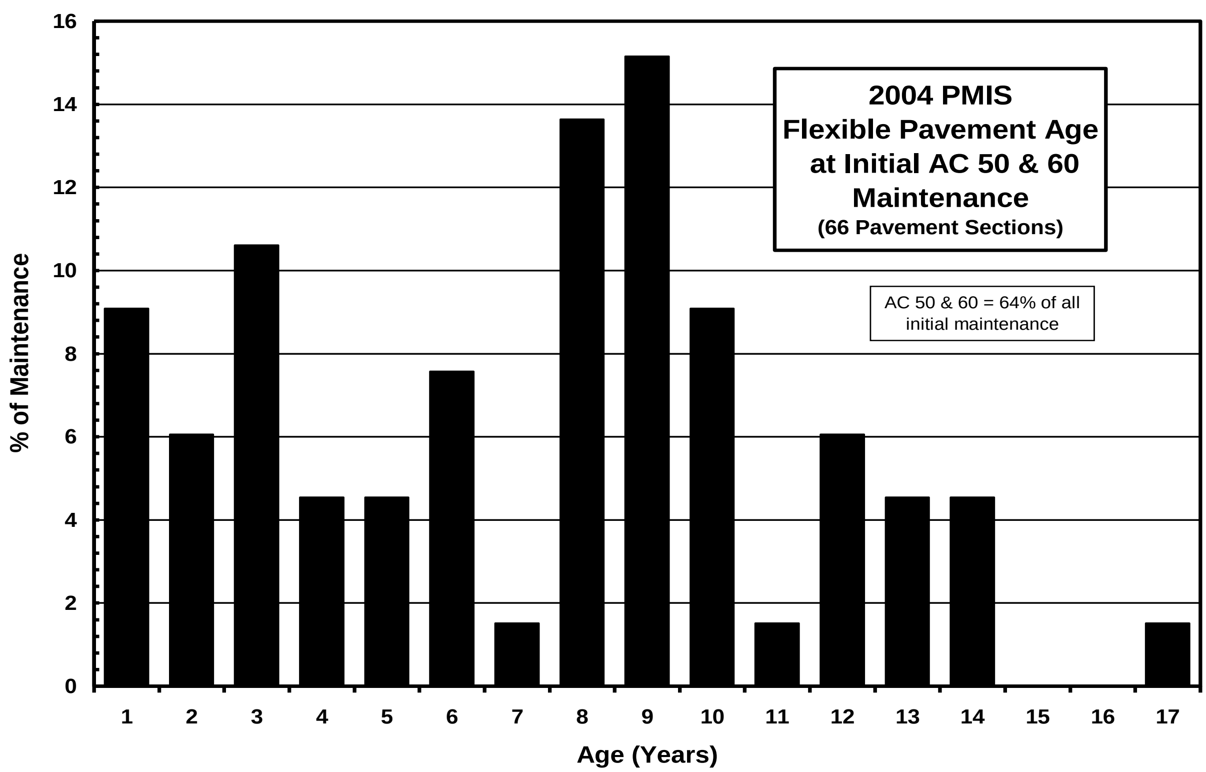


Figure 2.13 - Frequency of Initial AC 50 & 60 Maintenance on Flexible Pavements

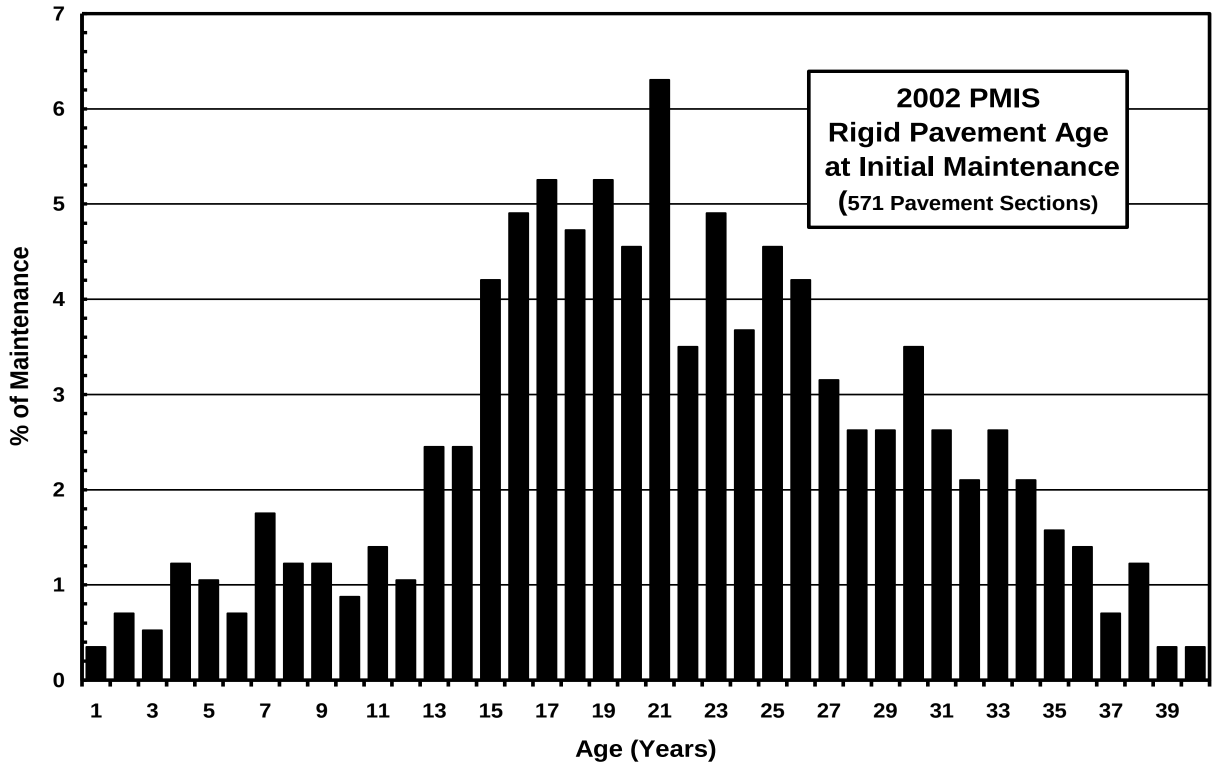


Figure 2.14 – Frequency of Initial Maintenance on Rigid Pavement

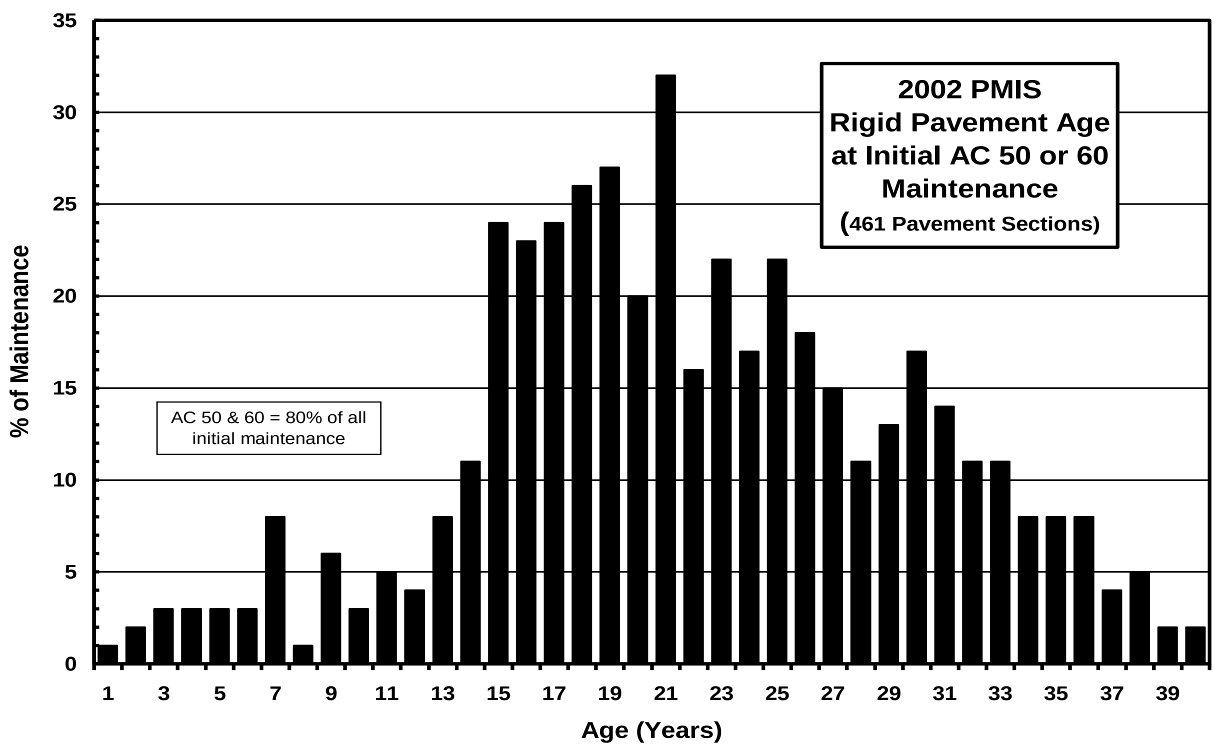


Figure 2.15 - Frequency of Initial AC 50 & 60 Maintenance on Rigid Pavement

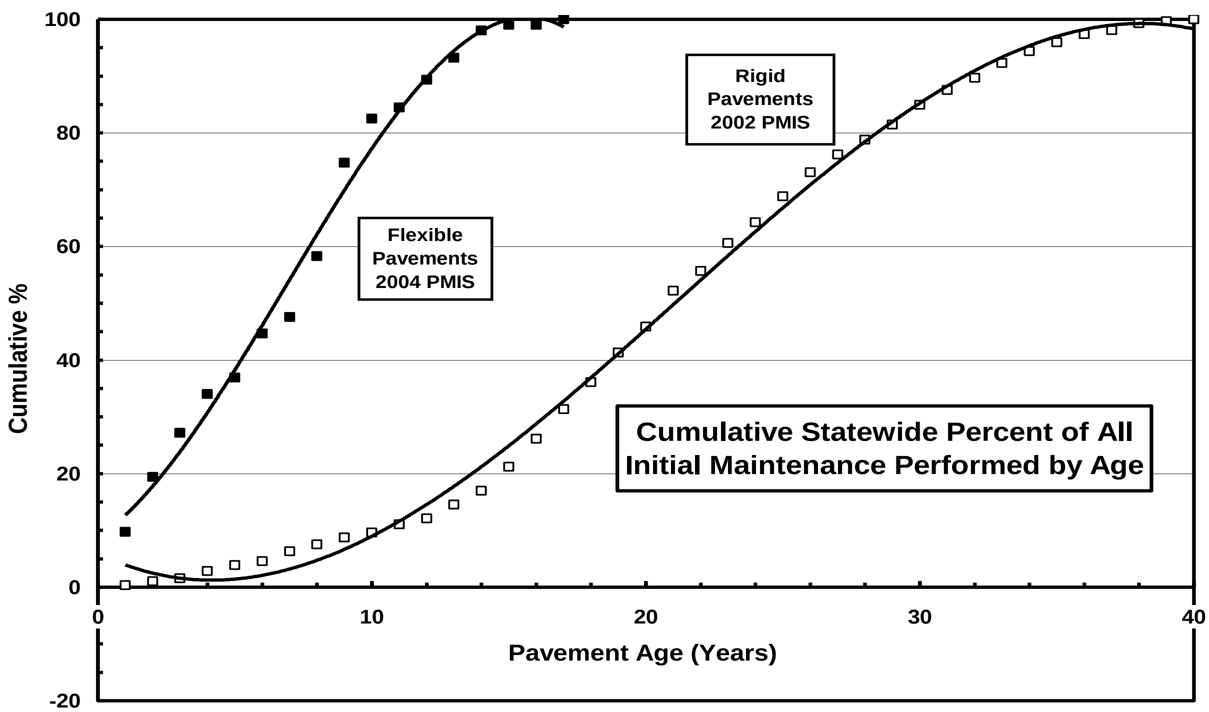


Figure 2.16 – Cumulative Distributions of All Initial Maintenance

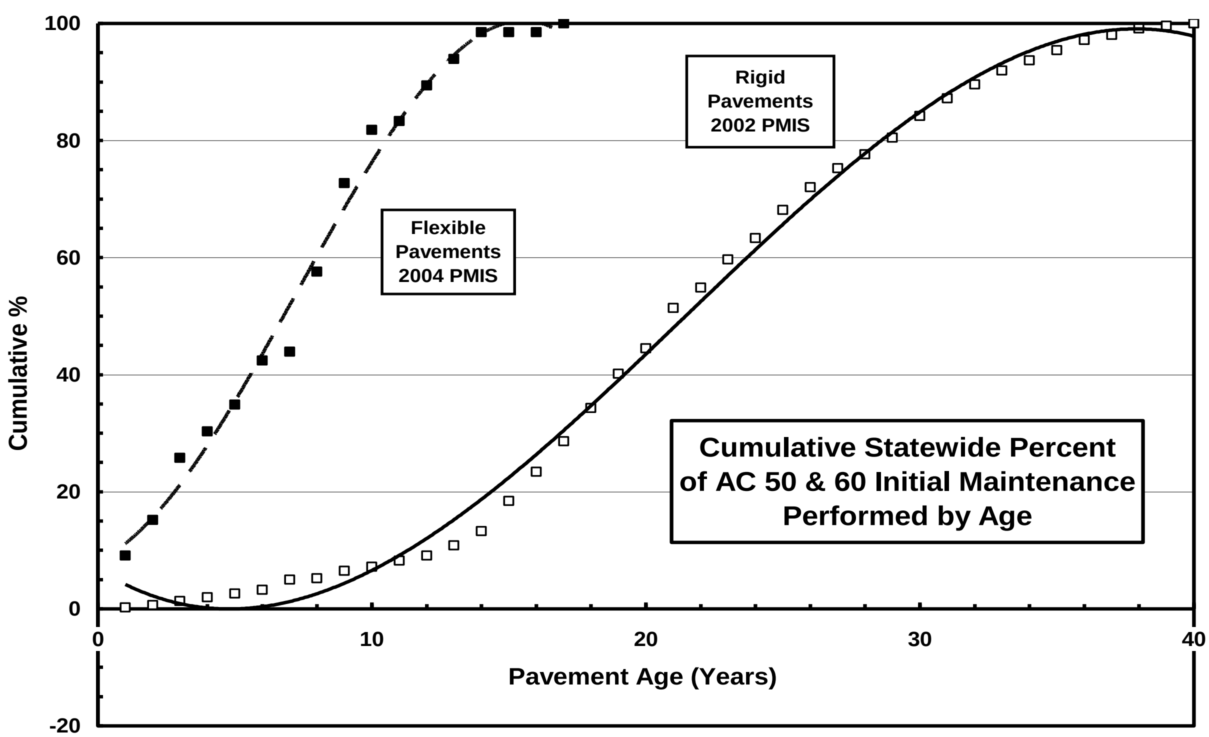


Figure 2.17 – Cumulative Distributions of AC 50 & 60 Initial Maintenance

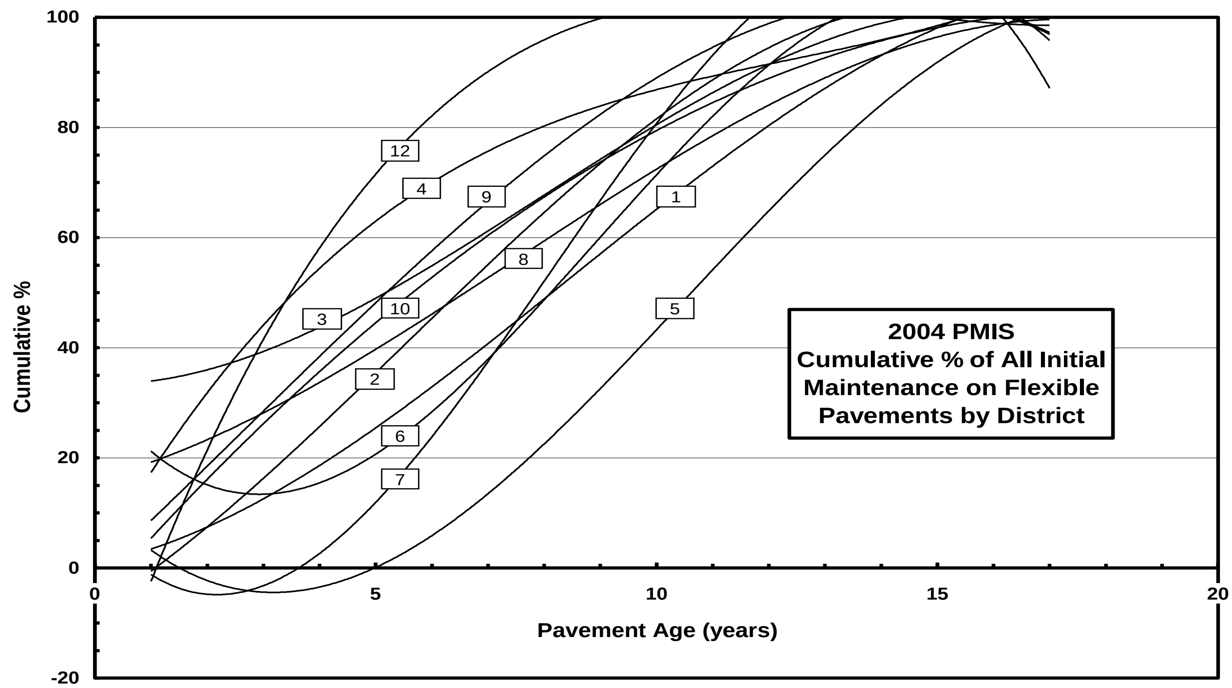


Figure 2.18 - Cumulative Distribution of All Flexible Maintenance by District

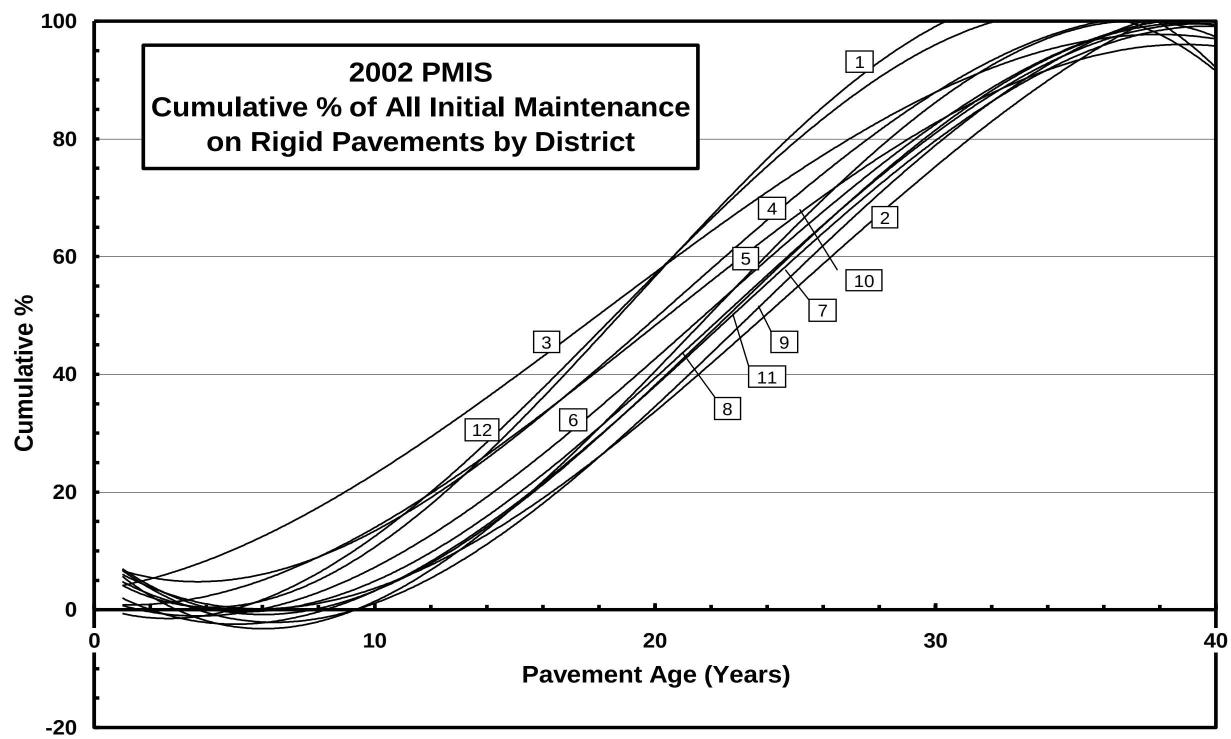


Figure 2.19 - Cumulative Distribution of All Rigid Maintenance by District

Project Selection

From the data shown in Figures 2.7 and 2.8, flexible and rigid pavements with average and excellent performance were selected for study as required in Objective 2 of the research proposal. District offices were asked if the projects were still exposed and if they were aware of any other projects which should be considered for study. One rigid and one flexible pavement had been overlaid within the past two years but, because all performance data in the PMIS were obtained prior to the overlays, and to avoid further delays with this research, these projects were retained and the recent asphalt concrete overlays were removed prior to laboratory testing.

Inquiries about alternate sites were also made in ODOT Central Office and from industry representatives. ODOT suggested two very old rigid pavements; Project 352(46) on SR 7 in Gallia County, and Project 235(58) on US 33 in Athens County. The GAL 7 project had some joint and transverse crack replacements, but also had long sections of pavement which have remained in excellent condition for more than 60 years. All joints on the ATH 33 project were replaced and the pavement was ground but, except for minor transverse cracks in about half of the slabs, the original concrete was in very good condition. Sections 112 and 902 on the Ohio DEL 23 SHRP Test Road were suggested as flexible candidates because of their similar designs and differing performance histories. Section 112 was constructed with standard AC materials, while PG grade asphalt cement was used for surface and intermediate layers in Section 902.

Two rigid and five flexible pavement projects contained sections with both average and excellent performance. One additional rigid pavement, Project 305(96) on CUY 176, contained two significantly different levels of ride quality. Projects with these paired sections of differing performance were selected because of the many variables they had in common and, by eliminating these variables, the causes of differing performance might become more apparent. In accordance with Objective 2 below, Tables 2.4 and 2.5 list projects selected for study.

> *Objective 2 - From the statistical analyses performed in Objective 1, a final selection of ten asphalt concrete (AC) and ten Portland cement concrete (PCC) projects performing as expected, and ten AC and ten PCC projects performing beyond expectations will be made by representatives from ODOT, Ohio University (OU) and industry. A few composite pavements may be included, as deemed appropriate. Pavements which appear to be performing poorly in this analysis also will be identified for review by ODOT.*

Table 2.4
Flexible Pavement Sections Selected for Study

Flexible Pavement Sections Selected for Study - Activity Code 100							
Co-Rte	**SLM Limits**	**Direction (Upstation or Downstation)**	**Project Number**	**District**	**Condition**	**Surface Exposed 3/09**	**Condition Comments**
BUT 129	17.96-24.00	D	9330(98)	8	Average	Partial	Resurfaced 15.89-20.45 in 2000. 20.45-24.00 still exposed.
	17.83-24.00	U			Excellent	Partial	
BUT 129	24.00-24.73	DU	9327(98)	8	Average	Yes	Crack sealing 17.96-25.74 in 2005
CHP 68	1.27-1.82	U	233(98)	7	Excellent	Yes	
	1.82-2.16	U			Average	Yes	
CLA 41	3.86-4.06	U	63(95)	7	Excellent	Yes	
	4.06-4.47	U			Average	Yes	
DEL 23*	17.85-20.78 SHRP Pvt.	D (Sect. 112)	380(94)	6	Average	Yes	
		D (Sect. 902)			Excellent	Yes	
GRE 35	20.95-26.21	DU	259(98)	8	Excellent	No	Polymer Modified Asphalt, Item 424
HAM 126	7.09-11.35	DU		8	Excellent	Yes	2006 crack sealing
HAM 747	0.04-0.94	U	347(85)	8	Average	Yes	
LAW 7	1.4-2.28	DU	17(85)	9	Average	No	Overlayed by Project 9(07)
LUC 2	21.39-27.25	U	141(99)	2	Average	Yes	
LUC 25	10.01-11.28	DU	665(97)	2	Excellent	Yes	
PIK 32	13.43-16.08	D	443(94)	9	Excellent	Yes	
	16.08-20.47	D	552(95)		Average	Yes	
		U			Excellent	Yes	
ROS 35	0-4.38	DU	298(96)	9	Excellent	Yes	
VAN 30	15.97-21.18	DU	219(97)	1	Average	No	Overlayed by Project 572(08)

* Special selection Upstation - NB or EB Downstation - SB or WB

Table 2.5
Rigid Pavement Sections Selected for Study

Rigid Pavement Sections Selected for Study - Activity Code 110							
Co-Rte	**SLM Limits**	**Direction (Upstation or Downstation)**	**Project Number**	**District**	**Condition**	**Surface Exposed 3/09**	**Condition Comments**
ALL 30	20.16-24.05	DU	746(97)	1	Excellent	Yes	
ATH 33*	10.40-13.09	DU	235(58)	10	Average	Yes	
ATH 682	0.16-0.64	DU	625(76)	10	Average	Yes	
CUY 82	2.05-3.82	U	438(94)	12	Excellent	Yes	
CUY 176	10.13-10.87	DU	683(94)	12	Average	Yes	
	10.87-12.83	DU	305(96)		Average	Yes	10.87-12.15 Low IRI
					Average		12.15-12.83 High and variable IRI
CUY 252	3.47-4.18	U	901(84)	12	Average	No	Overlayed by Project 294(05) for noise
CUY 322	8.68-11.98	U	1019(93)	12	Excellent	Yes	
GAL 7*	5.71-10.21	U	352(46)	10	Excellent	Yes	
GRE 35	14.45-20.95	DU	19(97)	8	Excellent	Yes	
HAM 126	11.35-13.31	DU	997(90)	8	Excellent	Partial	Dowel bar retrofit & grinding in 2006
JEF 7	18.9-19.21	D	8008(90)	11	Excellent	Yes	
JEF 22	15.02-16.32	U	8008(90)	11	Average	Yes	
LOG 33	21.79-25.63	D	845(94)	7	Average	Yes	SLM 25.11-25.63 Excellent
MOT 35	14.37-15.07	DU	343(88)	7	Excellent	Yes	
MOT 202	2-3.25	U	678(91)	7	Excellent	Yes	
SUM 76	13.32-15.32	D	996(93)	4	Excellent	Yes	
		U			Average	Yes	
TUS 39	2.84-7.12	U	907(90)	11	Average	Yes	

* Special selection Upstation - NB or EB Downstation - SB or WB

From an initial pool of new flexible pavement projects in 47 counties around Ohio, the final 20 sites selected were in eleven counties in ODOT Districts 1, 2, 6, 7, 8 and 9. From an initial pool of new rigid pavement projects in 31 counties around Ohio, the final 20 sites selected were located in eleven counties in ODOT Districts 1, 4, 7, 8, 10, 11 and 12. Rigid pavement sites were more widely distributed across the state than counties with flexible pavement sites, as shown in Figures 2.20 and 2.21. Seventeen flexible pavement sites were located in the southwestern quadrant of Ohio, two sites were in Toledo, and another site in Van Wert county, shown as flexible in the PMIS, was found to be composite. The twenty rigid pavement sites were distributed along north/south corridors in the eastern and western parts of the state. These distributions of average to excellent performing pavements strongly suggest geographical biases likely influenced by historical design, construction and maintenance preferences in the districts, the quality of locally available materials, etc. It can not be assumed from these rather limited distributions of flexible and rigid sites that pavements in these areas perform any differently than pavements in the remainder of the state. PCR is largely based on visual appearance of the pavement surface, which may not be entirely indicative of the structural integrity of the pavement structure and which can be affected by district maintenance policies and practices. These policies and practices are influenced by available funding and local culture as to the timing and types of maintenance used to correct various distresses.

The project selection process developed for this research, while applied uniformly across the state, introduced some performance biases by limiting the study to older projects constructed with earlier versions of the specifications. This was especially true on flexible pavements where SHRP specifications began to be adopted in the late 1990's. Despite this bias in project selection, a broad range of variables were represented in the final lists of flexible and rigid projects, the conditions of selected sites were consistent with the PCR ratings, and best-fit trendlines of PCR vs. Age appeared to be quite reasonable compared to other data. While some joints and transverse cracks on the GAL 7 rigid pavement have been replaced, and while the results of various tests suggest its current condition may be substandard compared to other newer rigid pavements selected for study, its ability to withstand more than 60 years of freeze/thaw cycling, deicing chemicals and local traffic loading qualified it as having excellent performance at that location. The ATH 33 rigid pavement site was similar with 50 years of service but, because all joints had been replaced, was considered to have average performance.

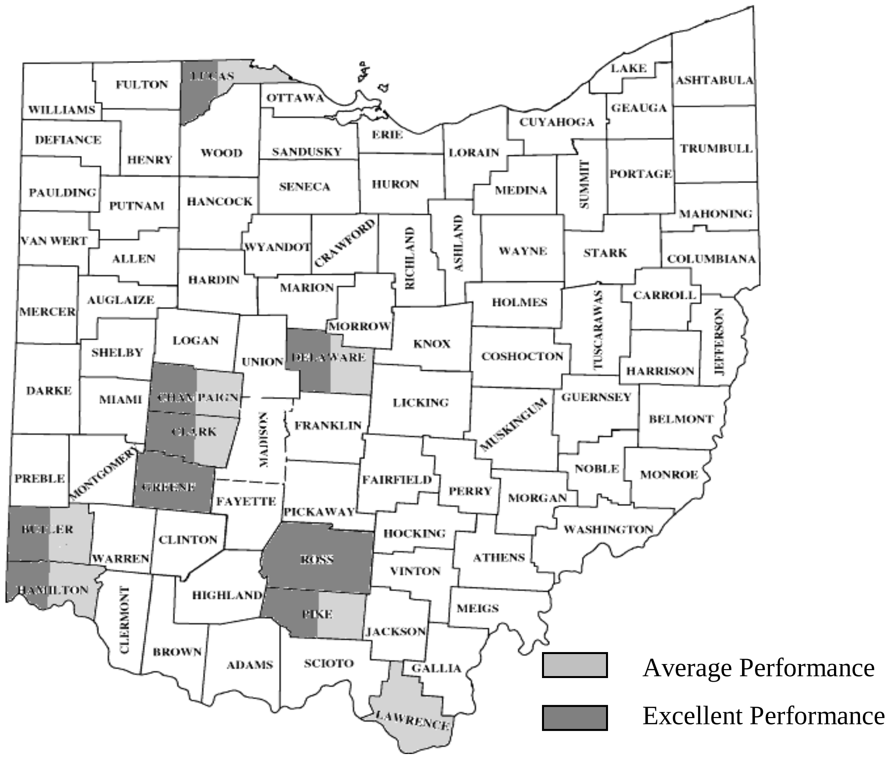


Figure 2.20 – Geographical Distribution of Selected Flexible Pavements

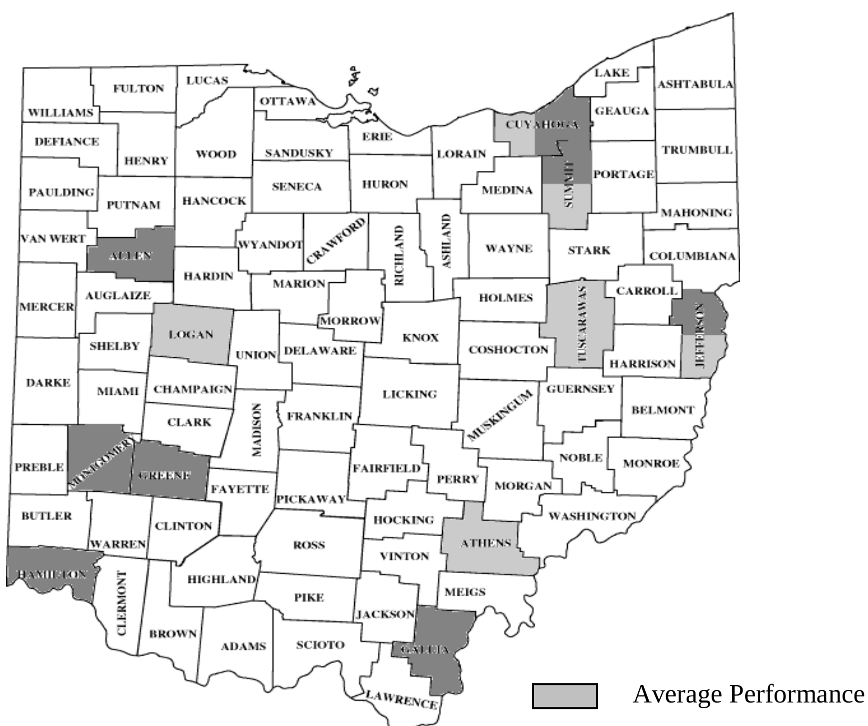


Figure 2.21 – Geographical Distribution of Selected Rigid Pavements

Objective 3 - ODOT District Offices responsible for those pavements selected as performing as expected and better than expected will be visited to discuss the selection process and to gain input regarding past performance.

The District 10 field office was visited to collect background information and supplement performance ratings in the PMIS. From this visit and from discussions with other ODOT personnel, it was determined that many historical construction records have been discarded, and many "old timers" who might have been involved in these projects have retired. It was unlikely, therefore, that much useful information would be gleaned by visiting other district offices. During the site visits for sampling and testing, supervisors and maintenance workers providing traffic control were asked about how projects had performed since construction and if there were any unique features related to the projects which might affect performance. These personnel, who were generally responsible for maintaining state, federal and interstate highways within their county, are knowledgeable about local conditions that might have affected performance. Their comments are included in the site discussions contained in Appendices E and F.

Objective 5 - Conduct a historical review of each project to determine: age, environmental conditions, original specifications, construction documentation, original test data, traffic volumes and weights accumulated since being opened to traffic, and previous condition information collected by ODOT (PCR, FWD, roughness, etc.). Personnel associated with the design and/or construction of the study pavements will be contacted to determine if they recall any particular decisions or events that might have affected performance. ODOT will provide access to the required files and ORITE will search the files for pertinent data.

Tables 2.6 and 2.7 summarize PCR data and distress deductions for the 40 selected pavement sites recorded in the DATA_ODOT table of the 2004 PMIS by pavement type and level of performance, and Tables 2.8 and 2.9 summarize the most likely causes of these distresses. Based on information in these tables, excellent performing flexible pavements had less cracking than average flexible pavements, and excellent performing rigid pavements had less patching deterioration, faulting and longitudinal joint spalling than average rigid pavements.

Table 2.6

PCR Distresses on Flexible Pavements

2004 PCR Distresses and Deducts for Flexible Pavements																																	
Co./Rte.	MP/Dir.	Project No.	Distress Severity/Extent for Code															Deduction by Code															PCR
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
Average Performance																																	
BUT 129	22 W	9330(98)	LE		HO								LO					3	0	3	0	0	0	0	0	0	0	1	0	0	0	0	93
BUT 129	25 W	9327(98)	LE										LO					3	0	0	0	0	0	0	0	0	0	1	0	0	0	0	96
CHP 68	2.5 N	233(98)	LF					LE					LF			LO		2.4	0	0	0	0	3	0	0	0	0	1.4	0	0	2	0	91
CLA 41	4 N	63(95)	LE		MO		F	LE			MO	LO	HO			MO		3	0	1.8	0	4	3	0	0	5.3	2	2.5	0	0	3.5	0	75
DEL 23	18 S (112)	380(94)																															
HAM 747	1 S*	347(85)	LE		MO		E	LE			MO	LE	MF	MO		MF		3	0	1.8	0	5	3	0	0	5.3	4	2.5	3.5	0	4.9	0	67
LAW 527	2 N	17(85)	LE		HO	LO					LF	LF						3	0	3	1	0	0	0	0	4.2	2.8	0	0	0	0	0	86
LUC 2	22 E	141(99)	LE					LE					LO					3	0	0	0	0	3	0	0	0	0	1	0	0	0	0	93
PIK 32	19 W	552(95)	LE								LO	LO	LO					3	0	0	0	0	0	0	0	3	2	1	0	0	0	0	91
VAN 30	18 E	219(97)	LE				LE	O				LE		MF	MO			3	0	0	0	3	3	0	0	0	2.4	0	2.4	1.5	0	0	85
Excellent Performance																																	
BUT 129	22 E	9330 (98)	LE										LO					3	0	0	0	0	0	0	0	0	0	1	0	0	0	0	96
CHP 68	2 N	233(98)	LE										LF					3	0	0	0	0	0	0	0	0	0	1.4	0	0	0	0	96
CLA 41	3 N	63(95)	LE				O	LF				LO	HF					3	0	0	0	2.5	2.4	0	0	0	2	3.5	0	0	0	0	87
DEL 23	17 S (902)	380(94)																															
GRE 35	21 E	259(98)	LE										LO					3	0	0	0	0	0	0	0	0	0	1	0	0	0	0	96
HAM 126	11 E	645(94)	LE															3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	97
LUC 25	10 S*	665(97)	LE						LO				LF					3	0	0	0	0	0	2.5	0	0	0	1.4	0	0	0	0	93
PIK 32	15 W	443(94)	LE								LO		LO					3	0	0	0	0	0	0	0	3	0	1	0	0	0	0	93
PIK 32	19 E	552(95)	LE										LO					3	0	0	0	0	0	0	0	0	0	1	0	0	0	0	96
ROS 35	1 W	298(96)	LE										LO					3	0	0	0	0	0	0	0	0	0	1	0	0	0	0	96

* PCR in NB direction

Flexible Pavement Distress Codes			
1	Raveling	8	Corrugations
2	Bleeding	9	Wheel track cracking
3	Patching deterioration	10	Block and transverse cracking
4	Surface disintegration/debonding	11	Longitudinal joint cracking
5	Crack sealing deficiency	12	Edge cracking
6	Rutting	13	Random cracking
7	Settlement	14	Thermal cracking
		15	Potholes

Distress Descriptors	
Severity	**Extent**
L - Low	O - Occasional
M - Medium	F - Frequent
H - High	E - Extensive

Table 2.7

PCR Distresses on Rigid Pavements

2004 PCR Distresses and Deducts for Rigid Pavements																															
Co./Rte.	**MP/Dir.**	**Project No.**	**Distress Severity/Extent for Code**														**Deduction by Code**														**PCR**
			1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	
Average Performance																															
ATH 33	13 E	235(58)	LE		LO							MO	MO	MO	LO		4	0	2	0	0	0	0	0	0	4.8	2.8	4	1.2	0	81
ATH 682	1 N	625(76)	LE		LO		MO		MO			MF	MO	MO	MO		4	0	2	0	3.5	0	3.5	0	0	9.6	2.8	4	2.1	0	69
CUY 176	10 S	683(94)	LO						LO								2.4	0	0	0	0	0	2	0	0	0	0	0	0	0	96
CUY 176	11 S	305(96)													LF		0	0	0	0	0	0	0	0	0	0	0	0	1.6	0	98
CUY 176	12 S	305(96)													LF		0	0	0	0	0	0	0	0	0	0	0	0	1.6	0	98
CUY 252	4 N	901(84)	LO		LO		LO		LO		O	MF	LO		LO		2.4	0	2	0	2	0	2	0	2.5	9.6	2	0	1.2	0	76
JEF 22	15 E	8008(90)	LE				LO					LF		HO	LO		4	0	0	0	2	0	0	0	0	1.2	0	5	1.2	0	87
LOG 33*	24 W	845(94)	LO		LO		LO								LO		2.4	0	2	0	2	0	0	0	0	0	0	0	1.2	0	92
SUM 76	15 E	996(93)	LO		LO		LO		LO			LO			MO		2.4	0	2	0	2	0	2	0	0	0.6	0	0	2.1	0	89
TUS 39	4 E	907(90)	LO						LO			LF	MO	HO	LO		2.4	0	0	0	0	0	2	0	0	1.2	2.8	5	1.2	0	85
Excellent Performance																															
ALL 30	22 E	746(97)	LO														2.4	0	0	0	0	0	0	0	0	0	0	0	0	0	98
CUY 82	3 E	438(94)	LO		LO				LO			LF	LO				2.4	0	2	0	0	0	2	0	0	1.2	2	0	0	0	90
CUY 322	10 E	1019(93)	LF						LO			LO	LO		LO		3.2	0	0	0	0	0	2	0	0	0.6	2	0	1.2	0	91
GAL 7	8 N	352(46)	LE		MO		MF	LO	MO			MO		MO	LO		4	0	3.5	0	5.6	0	3.5	0	0	4.8	0	4	1.2	0	73
GRE 35	19 W	19(97)	LO														2.4	0	0	0	0	0	0	0	0	0	0	0	0	0	98
HAM 126	12 E	997(90)										MO		HO			0	0	0	0	0	0	0	0	0	4.8	0	5	0	0	90
JEF 7	19 S	8008(90)	LO						LO			LF	LO	MO			2.4	0	0	0	0	0	2	0	0	1.2	2	4	0	0	88
MOT 35*	14 W	343(88)	LO						LO								2.4	0	0	0	0	0	2	0	0	0	0	0	0	0	96
MOT 202*	3 N	678(91)	LO				LO		LO				LO				2.4	0	0	0	2	0	2	0	0	0	2	0	0	0	92
SUM 76	15 W	996(93)	LO						LO			LO			LO		2.4	0	0	0	0	0	2	0	0	0.6	0	0	1.2	0	94

* ODOT 452 non-reinforced PC concrete pavement

Rigid Pavement Distress Codes			
1	Surface deterioration	8	Joint sealant damage
2	Popouts	9	Pressure damage
3	Patching deterioration	10	Transverse cracking - R/C
4	Pumping	11	Longitudinal cracking
5	Faulting	12	Corner breaks
6	Settlement	13	Longitudinal joint spalling
7	Joint spalling	14	Transverse cracking - P/C

Distress Descriptors	
Severity	**Extent**
L - Low	O - Occasional
M - Medium	F - Frequent
H - High	E - Extensive

Table 2.8
Causes of Flexible Pavement Distress

ODOT PCR Flexible Pavement Distresses		
Distress Code	**Flexible Pavement Distress**	**Possible Causes of Distress**
1	Raveling	Low content/oxidized asphalt cement; Aggregate segregation; High air voids
2	Bleeding	Excessive asphalt cement in AC mix; Low air voids
3	Patching Deterioration	Ineffective patching material; Poor adhesion to existing AC
4	Surface Disintegration	Low content/oxidized asphalt cement; Debonding
5	Crack Sealing Deficiency	Poor intrusion/adhesion of sealant
6	Rutting	Low AC stability; Low AC content, Low AC, base or subgrade density; Weak subgrade
7	Settlement	Weak subgrade; Slope slippage
8	Corrugations	Low AC stability at high temperatures where traffic brakes
9	Wheel Track Cracking	Weak subgrade; Brittle/oxidized AC mix
10	Block/Transv. Cracking	Brittle AC mix; Weak subgrade
11	Long. Joint Cracking	Poorly constructed joint between adjacent paver passes
12	Edge Cracking	Ineffective support along pavement edge
13	Random Cracking	Weak subgrade; Brittle/oxidized AC mix
14	Thermal Cracking	Asphalt concrete brittle at low temperatures
15	Potholes	Freeze/thaw w/moisture, AC degradation, Weak base/subgrade

Table 2.9
Causes of Rigid Pavement Distress

ODOT PCR Rigid Pavement Distresses		
Distress Code	**Rigid Pavement Distress**	**Possible Causes of Distress**
1	Surface Deterioration	Excessive surface moisture during concrete placement
2	Popouts	Deleterious aggregate in concrete
3	Patching Deterioration	Ineffective patching material; Poor adhesion to existing concrete
4	Pumping	Excessive moisture in subgrade; Migrating fines in base material
5	Joint/Crack Faulting	Excessive moisture in subgrade; Migrating fines in base material
6	Settlement	Weak subgrade; Slope slippage
7	Joint Spalling	Transverse joint deterioration from D-cracking or coning
8	Joint Sealant Damage	Ineffective adhesion of sealers in joints
9	Pressure Damage	Incompressibles in joints causing fractures as slabs expand; Expansion boards improperly installed at transverse joints
10	Transverse Crack.- R/C	Tight cracks expected; Broken steel if cracks open and faulted
11	Longitudinal Cracking	Weak subgrade; High steel in R/C slabs
12	Corner Breaks	Loss of corner support as slabs curl; inflexible base material
13	Long. Joint Spalling	Longitudinal joint deterioration from D-cracking or coning
14	Transverse Crack.- P/C	Ineffective slab curing/joint sawing; Shrinkage; Brittle concrete

Flexible Pavement Performance Based on 2004 PMIS

From PCR data shown in Table 2.6, all flexible sites in this study, except the two DEL 23 sections which were not rated, showed extensive low severity raveling (Distress Code 1), and most had some degree of longitudinal joint cracking (Code 11), suggesting these to be common distresses on flexible pavements constructed in Ohio before 1999. Signs of raveling include cavities on the pavement surface where aggregate particles were removed by passing traffic and/or by asphalt coated aggregate particles lying along the pavement. Raveling is usually caused by segregated aggregate, low asphalt cement contents and/or high air contents in the surface mix. Longitudinal joint cracking is caused by the ineffective sealing of joints between adjacent paver passes during construction. Because widespread raveling and longitudinal joint problems were not observed on any selected projects during the site visits, it may be that these distresses are being judged too harshly during PCR ratings on flexible pavements. This issue should be reviewed by ODOT.

When raveling and longitudinal joint cracking are removed as common distresses assigned to flexible pavements selected for study, differences between average and excellent performing flexible pavements can largely be attributed to the six types of cracking defined by PCR codes 9-14. Other distresses more prevalent in average than excellent flexible pavements included: patching deterioration (Distress Code 3), crack sealing deficiency (Code 5) and rutting (Code 6). While not directly attributable to original construction, patching and crack sealing are distressed treatments used to correct primary distresses associated with the original construction. Rutting is usually caused by low stability or density in an AC layer, or subgrade.

Flexible pavement cracking can be broadly categorized as being top-down if initiated on the pavement surface or bottom-up if initiated at the bottom of the AC layers. Top-down cracking, which progresses very slowly and has little effect on the structural capacity of the pavement, is usually associated with coarse aggregate gradations, low asphalt cement contents or oxidized asphalt cement in the surface layer. Surface mixes with finer aggregate and higher asphalt cement contents are more resistant to cracking, but less stable and, therefore, more prone to rutting. Bottom-up cracking in flexible pavements, often caused by high stresses resulting from weak base or subgrade layers, tends to expand as the intact portion of the structure is exposed to higher stresses. Since the selected projects showed no signs of progressive structural deterioration, cracking observed during the field visits was believed to be top-down.

Because bleeding (Code 2), surface disintegration/debonding (Code 4), settlement (Code 7), corrugations (Code 8) and random cracking (Code 13) were observed on no more than one project, they are not considered to be common distresses on flexible pavements with average to excellent performance in Ohio.

Section 112 on the DEL 23 site, constructed with conventional ODOT 446 T1 and 446 T2 surface and intermediate mixes containing AC 20 asphalt cement, showed considerable surface distress (Figure E11), while Section 902, constructed with the same mixes containing PG 58-30 asphalt cement, had little surface distress (Figure E10). These sections lend support to the anticipation that the ongoing transition to SHRP based asphalt specifications since 1999 will improve overall flexible pavement durability and performance.

Rigid Pavement Performance Based on 2004 PMIS

Table 2.7 shows surface deterioration (Distress Code 1) to be quite common on most average and excellent performing rigid pavements constructed in Ohio before 1997. This deterioration may be caused by excess moisture migrating to the concrete surface as it is placed and finished, which increases the water/cement ratio, reduces the strength and durability of the concrete matrix and, thereby, accelerates surface erosion and the loss of surface texture. Durability of the surface can be improved by closely monitoring moisture in the concrete as it is delivered to the project and finished at the time of construction. The lack of surface deterioration observed during the field visits suggested that rigid pavement surfaces may be judged rather harshly for various types of nonstructural surface distresses.

Transverse joint spalling (Code 7) and various types of slab cracking (Transverse R/C - Code 10, Longitudinal – Code 11, and Corner breaks – Code 12), were frequently noted on both average and excellent performing rigid pavements during the PCR ratings. Transverse joint spalling, as evidenced by D-cracking or coning, is caused by excess moisture and freeze-thaw cycling on moisture susceptible aggregate, or in cement matrices susceptible to the build up of ettringite in air voids. Transverse and longitudinal cracking are frequently caused by a weak subgrade which often reflects excess moisture. Corner breaks are indicative of fines migrating from under the slabs or a rigid base layer which causes slab corners to loose support as they curl upward. Improved subgrade quality and drainage would reduce joint spalling and slab cracking, and inflexible bases should be avoided on rigid pavements.

Patching deterioration (Code 3), faulting (Code 5), and longitudinal joint spalling (Code 13), by being more predominant on average performing rigid pavements, were distresses mainly responsible for differentiating them from excellent performing rigid pavements. As with flexible pavements, patching deterioration reflects a distressed treatment used to correct an unknown primary distress. Faulting results from heavy traffic loads combining with excess moisture under slabs to cause fines to migrate from under slab ends, and longitudinal joint spalling often results from D-cracking or coning along the longitudinal joint. Again, pavement performance can be elevated by improving subgrade stiffness and reducing subgrade moisture through enhanced drainage. Surface deterioration can be reduced by closely monitoring concrete moisture during construction to improve performance even more.

By being observed on no more than one of the selected projects in 2004, popouts (Code 2), pumping (Code 4), slab settlement (Code 6), joint sealant damage (Code 8), pressure damage (Code 9) and transverse cracking on 452 plain concrete (Code 14) are not considered to be common distresses on pavements with average to excellent performance.

Estimated Service Lives

Tables 2.10 and 2.11 show recent traffic counts for selected flexible and rigid pavement sections. Tables 2.12 and 2.13 summarize the percent of theoretical service lives used by 2010 based on 20-year designs for flexible and rigid pavements, and based on total ESALs carried to 2010 compared to the calculated ESAL capacity using AASHTO equations. Because much of the original data for base and free draining base stiffness were unavailable, various assumptions were necessary to complete the calculations. The sections are grouped by pavement type and level of performance for ease of comparison. Averages by pavement type and performance level are not shown because of extreme ESAL counts calculated for various projects, including the older ATH 33 and GAL 7 projects.

Table 2.10

Traffic Counts for Flexible Pavements

Traffic Counts on Flexible Pavements - Both Directions											
Pavement Section	Project No.	B&C Trucks in Year					Total Traffic in Year				
		2009	2008	2007	2006	2005	2009	2008	2007	2006	2005
BUT 129 22E, 22W	9330(98)			2730					36420		
BUT 129 25W	9327(98)			3120					38640		
CHP 68 2N, 2.5N	233(98)		1210			1410		12430			13290
CLA 41 3N, 4N	63(95)		410			370		2070			1630
DEL 23 17S, 18S	380(94)		4580					23800			
GRE 35 21E	259(98)		2690					8380			
HAM 126 11E	645(94)					1750					40220
HAM 747 1S	347(85)					490					10620
LAW 527 2N	17(85)	450				660	12010				13010
LUC 2 22E	141(99)			3330					29370		
LUC 25 10S	665(97)			290					8610		
PIK 32 15W	443(94)			1200					9000		
PIK 32 19E, 19W	552(95)			1030					6470		
ROS 35 1W	298(96)				2520					8010	

Table 2.11

Traffic Counts for Rigid Pavements

Traffic Counts on Rigid Pavements - Both Directions											
Pavement Section	Project No.	B&C Trucks in Year					Total Traffic in Year				
		2009	2008	2007	2006	2005	2009	2008	2007	2006	2005
ALL 30 22E	746(97)		3650			3730		6700			6120
ATH 33 13E	235(58)	1570			1560		17840			18140	
ATH 682 1N	625(76)	190			190		6400			6500	
CUY 82 3E	438(94)			1740					32860		
CUY 176 10S	683(94)			3100					76480		
CUY 176 11S, 12S	305(96)			3030					75020		
CUY 252 4N	901(84)			540					15200		
CUY 322 10E	1019(93)			450					21490		
GAL 7 8N	352(46)	210			400		2700			2400	
GRE 35 19W	19(97)		2900					10410			
HAM 126 12E	997(90)					2110					53340
JEF 7 19S	8008(90)			1770		1480			15280		13480
JEF 22 15E	8008(90)			3570		3240			35520		33120
LOG 33 24W	845(94)			4180		3930			19850		18120
MOT 35 14W	343(88)	2770			2780		47560			52310	
MOT 202 3N	678(91)	510			440		10840			10670	
SUM 76 15E, 15W	996(93)			12210					65050		
TUS 39 4E	907(90)				880					9080	

Table 2.12

Estimated Service Lives of Flexible Pavements

Route	Project No.	Surface and Intermediate Material	Base Material	Subbase Type	SN	Soil Classification	Soil Value Mr	Calculated ESAL's [1]	ESAL's Carried to 2009	% Life (Years)	% Life (ESAL's)
Estimated Service Lives of Flexible Pavements Based on Age and ESALs											
Average Performance											
BUT-129-17.83 [2]	9330(98)	1.25"/1.75" 446	10" 302	4" ATFDB	5.45	Design Build	6000 [5]	62,600,000	4,250,000	60	7
BUT-129-24.00	9327(98)	1.25"/1.75" 446	8" 302	4" 304	5.17	Design Build	6000 [5]	42,000,000	4,500,000	60	11
CHP-68-1.82	233(98)	1.5"H/1.75" 448	6" 301	6" 304	4.40	Design Build	6000 [5]	13,300,000	4,360,000	60	33
CLA-41-4.06	63(95)	3" 404/402	7" 301	5" 304	4.51	A-6 [3]	7750	28,500,000	1,030,000	75	4
DEL-23-(212) [2]	380(94)	1.75"/2.25" 446	12" 302	4" ATFDB	6.60	A-6 [3]	7750	497,000,000	19,540,000	80	4
HAM-747-0.04	347(85)	2" 404/403	9" 301		4.10		6000 [5]	8,200,000	7,500,000	125	91
LAW-527-0.19	17(85)	2.75" 404/402	9" 301		4.42		6000 [5]	13,600,000	2,160,000	125	16
LUC-2-21.39	141(99)	1.25"H/1.75" 446	10" 301	6" 304	5.73	GI = 13 [4]	6000	91,000,000	4,720,000	55	5
PIK-32-16.08	552(95)	1.25"/1.75" 446	12" 301	4" ATFDB/ 4" 304	6.73	GI = 5.68 [4]	9000	819,000,000	4,130,000	75	1
									Average	78	19
Excellent Performance											
BUT-129-17.83 [2]	9330(98)	1.25"/1.75" 446	10" 302	4" ATFDB	5.45	Design Build	6000 [5]	62,600,000	4,250,000	60	7
CHP-68-1.27	233(98)	1.5"H/1.75" 446	6" 301	6" 304	4.40	Design Build	6000 [5]	13,300,000	4,360,000	60	33
CLA-41-3.86	63(95)	3" 404/402	7" 301	5" 304	4.51	A-6 [3]	7750	28,500,000	740,000	75	3
DEL-23-(902) [2]	380(94)	1.75"/2.25" 446	12" 302	4" ATFDB/ 6" 304	7.44	A-6 [3]	7750	1,290,000,000	19,540,000	80	2
GRE-35-20.95	259(98)	1.5"H/1.75" 448	7.5" 301	6" 304	4.94	A-4 [3]	9400 [6]	85,000,000	7,280,000	60	9
HAM-126-7.09	645(94)	1.25"/1.75" 446	10" 301	6" 304 / 6" 310	6.39	A-6 [3]	6000 [6]	211,000,000	4,110,000	80	2
LUC-25-10.01	665(97)	1.25"/1.75" 446	7" 301	8" 304 / 6" 310	5.59	GI = 7.8 [4]	8000	146,500,000	1,100,000	65	1
PIK-32-13.43	443(94)	1.25"/1.75" 446	9" 301	4" 304	5.09	A-6/A-4 [3]	8400	81,500,000	5,170,000	80	6
PIK-32-16.08 [2]	552(95)	1.25"/1.75" 446	12" 301	4" ATFDB/ 4" 304	6.73	GI = 5.68 [4]	9000	819,500,000	4,130,000	75	1
ROS-35-0.00 [2]	298(96)	1.25"/1.75" 446	10" 301	4" 306 / 8" 304	6.57	A-6 [3]	7750 [6]	475,000,000	7,650,000	70	2
									Average	70.5	6

Design Assumptions - R = 50%, PSI I = 4.2, PSI t = 2.5, Modulus Of Rupture = 700 psi, Elastic Modulus of Slab = 5,000,000 psi,
Overall Standard Deviation = 0.39, Drainage Coefficent = 1.0

[1] Calculated ESALs are based on standard design assumptions of the pavement including the calculated SN and soil value

[2] Actual strength of FDB is likely underestimated. More work would need to be done to correctly characterize the pavement buildup. Correct characterization of pavement would yield slightly higher calculated ESAL's, thus reducing the % life (ESAL's) reported.

[3] Soil classifications taken from OU research. Used average Group Index for this classification.

[4] Group Index taken from subsurface investigation found in original construction plans

[5] No soils info found. Used an average value based on experience.

[6] Subgrade Modification is difficult to characterize. If long term stabilization exists, calculated ESAL's could more than double.

Table 2.13

Estimated Service Lives of Rigid Pavements

Route	Project No.	Rigid Thickness in (cm)	Subbase Type	Soil Value	Load Transfer J	Back-calculated ESALs [1]	ESALs Carried to 2009	% Life (Years)	% Life (ESAL's)
Estimated Service Lives of Rigid Pavements Based on Age and ESALs									
Average Performance									
ATH-33-10.40	235(58)	9	8" 310	6000 [2]	3.2	13,850,000	14,770,000	260	107
ATH-682-0.16	625(76)	9	6" 310	6000 [2]	3.2	13,500,000	2,110,000	170	16
CUY-176-10.13	683(94)	12	6" 310 Type 2	6000 [2]	2.7	88,500,000	11,000,000	80	12
CUY-176-10.87	305(96)	12	6" 310 Type 2	6000 [2]	2.7	88,500,000	8,800,000	80	10
CUY-252-3.47	901(84)	9	6" 310 Type 2	6000 [2]	2.7	24,250,000	3,590,000	130	15
JEF-22-15.02	8008(90)	9	6" 310 Type 2	6000 [2]	2.7	24,250,000	12,190,000	100	50
LOG-33-21.79	845(94)	12	4"+6" nsfdb/ACT1/304 [3]	6000 [2]	2.7	291,000,000	27,670,000	80	10
SUM-76-13.41	996(93)	11	1"403/3"301/4"304	6000 [2]	2.7	132,500,000	61,190,000	85	46
TUS-39-2.84	907(90)	9	6" 310 Type 2	6000 [2]	2.7	24,250,000	8,360,000	100	34
							Average	121	33
Excellent Performance									
ALL-30-20.16	746(97)	11	4"+6" atfdb/304	6600	2.7	131,000,000	20,080,000	65	15
CUY-82-2.05	438(94)	11	6" 304	6000 [2]	2.7	88,500,000	6,160,000	80	7
CUY-322-8.68	1019(93)	10	6" 310	5520	2.7	46,600,000	1,210,000	85	3
GAL-7-5.71	352(46)	8	6" - 12" ss112	6000 [2]	3.2	7,100,000	3,930,000	320	55
GRE-35-14.45	19(97)	10	4"+6" nsfdb/304 [3]	5400	2.7	69,500,000	12,140,000	65	17
HAM-126-11.35	997(90)	10	6" 310 Type 2	6000 [2]	2.7	47,500,000	6,120,000	100	13
JEF-7-18.90	8008(90)	9	6" 310 Type 2	6000 [2]	2.7	24,200,000	19,030,000	100	79
MOT-35-14.37	343(88)	10	4" 301 / 4" 304	7200	2.7	79,000,000	11,760,000	110	15
MOT-202-2.00	678(91)	9	6" 310 Type 2	6000 [2]	2.7	24,200,000	2,460,000	95	10
SUM-76-13.41	996(93)	11	1"403/3"301/4"304	6000 [2]	2.7	132,500,000	61,190,000	85	46
							Average	111	26

Design Assumptions - R = 50%, PSI, I = 4.2, PSI, t = 2.5, Modulus Of Rupture = 700 psi, Elastic Modulus of Slab = 5,000,000 psi, Overall Standard Deviation = 0.39, Drainage Coefficent = 1.0

(1) Calculated ESALs are based on standard design assumptions of the pavement including the slab thickness and soil value

(2) No soils information found. Rigid pavements not particularly sensitive to this variable. Used an average value based on experience.

(3) Actual strength of FDB is likely underestimated. More work would need to be done to correctly characterize the pavement buildup. Correct characterization of pavement would yield slightly higher backcalculated ESAL's, and reduce % life (ESAL's).

Summary

Because 2002 and 2004 versions of the PMIS were both used to maximize the available data, because manual searches were required through the PMIS DATA_Project History and DATA_ODOT tables in both versions instead of electronic searches, and because extensive corrections were required to assign proper project numbers to pavement condition ratings (PCR), a considerable amount of additional time was required to complete the project selection phase of this study and composite pavements (AC 120) were not included in the study. Specific conclusions from this phase of the project include:

1. The 2002 version of the PMIS provides a good historical record of original pavement construction with projects going back as early as 1911. While this inventory does not provide a complete listing of all projects, the information provided is a valuable resource that should be retained for future reference. One approach to keeping these data would be to maintain: 1) an active PMIS containing only original construction and subsequent maintenance information for pavement projects currently in service, and 2) an archival PMIS where information is moved for historical information when projects are removed from service.

2. The 2004 PMIS provides additional construction and performance data not in the 2002 PMIS, but only contained construction projects sold after 1979, which limited its value as a historical reference for older pavements.

3. When reviewing the 2002 and 2004 PMIS, some sections of various highway routes were missing and, of the entries shown, almost half were assigned activity codes of 777, 888, 995 or 999, which precluded them from consideration in this study because the types of construction and maintenance were unknown.

4. PCR data in 2002 and 2004 versions of the PMIS were often inconsistent with the projects numbers provided. This problem can lead to erroneous conclusions being drawn from the data. Project numbers should be updated whenever new PCR, traffic, and ride quality data are added to the PMIS.

5. In an initial attempt to measure performance by correlating ESAL loading with Pavement Condition Ratings (PCR), average ESAL loadings per truck in the PMIS were found to be highly variable on some routes.

6. During the pavement selection process, levels of performance were determined by plotting PCR values versus age for flexible and rigid pavements not receiving any structural maintenance above an activity code (AC) of 40. In reviewing PCR data for eligible projects, it became apparent that some maintenance with activity codes equal to or less than 40 can have a dramatic effect on PCR. Specific examples include: Micro-Surfacing (AC 30), Nova-Chip Resurfacing (AC 35), and Fine Graded Polymer Overlay (AC 38). Since PCR is determined by the extent and severity of visible distresses, it is highly influenced by cosmetic appearance. As distresses are patched or covered over, long term projections of service life from PCR ratings can become unreliable. High PCRs resulting from non-structural maintenance were removed for this research.

7. New versions of the PMIS should be released only when appropriate project numbers are shown for the data and the data have been randomly checked for accuracy. Departmental policies and decisions based on analyses of incomplete data can create serious problems.

8. Straight-line diagrams (SLDs) are a valuable source of information for quickly determining the age and types of materials currently in the ODOT pavement infrastructure. Unfortunately, project information on the SLDs often does not agree with data in the PMIS and, with activity codes not being shown on the SLDs, it difficult to differentiate between the original project and subsequent maintenance. It would be convenient if PMIS activity codes were added to the SLDs. Project numbers, mileage limits and pavement materials in the PMIS need to be consistent with those shown on the SLDs. Both sources of information are valuable, with the PMIS being used for data analyses, and the SLDs being used by ODOT and non-ODOT personnel as a quick reference.

9. The limited number of projects available for consideration in the PMIS did not permit the systematic inclusion of roadway classification, geographical location and traffic as specific variables in the pavement selection process. The flexible and rigid pavement sites selected, however, represented two-lane, four-lane primary and interstate highways around the state with a range of build-ups and traffic loadings. Flexible pavements included several surface and intermediate materials, 301 and 302 bases, and seven sites with ATFDB. Rigid pavements had a wide range of joint spacings with both reinforced and non-reinforced concrete pavements being represented. A visual examination of the cores indicated that various aggregate sizes and types were also included for both flexible and rigid pavements.

10. The geographical distribution of sites selected as having average and excellent flexible and rigid pavement performance can be influenced by traffic loading, localized subgrade and climatic conditions, locally available aggregates, and various factors unique to individual field districts, including funding allocations, policies regarding pavement design, construction and maintenance, etc. Traffic loading is taken into account during design and, therefore, should have a minimal effect on performance. Northern Ohio has a harsher climate than southern Ohio with colder temperatures, more freeze/thaw cycles, and increased amounts of snow and snow removal activities. The apparent effects of climate on performance were evident with a couple of very old rigid pavements found in southern Ohio and flexible pavement sites being largely limited to southwest Ohio. Most rigid pavements selected for study followed north/south corridors in the eastern and western parts of the state known for having higher quality aggregate.

11. Based on pavement condition ratings alone, raveling and longitudinal joint cracking are common distresses on most flexible pavements constructed in Ohio before 1999. Because these distresses were not observed during the field visits, however, ODOT should verify that they are being properly evaluated in the PCR ratings. When raveling and longitudinal joint cracking are removed as common distresses on all flexible pavements, differences between average and excellent performing flexible pavements can largely be attributed to the six types of cracking defined by PCR codes 9-14. Other distresses more prevalent in

average than excellent flexible pavements included: patching deterioration (Distress Code 3), crack sealing deficiency (Code 5) and rutting (Code 6). Differences in performance between Sections 17S and 18S on the DEL 23 Test Road suggest the ongoing transition to SHRP asphalt concrete specifications will continue to improve flexible pavement durability and performance.

12. Pavement condition ratings indicate surface deterioration is relatively common on rigid pavements constructed in Ohio before 1997. Since this problem is usually related to tire wear in the wheelpaths, perhaps it should be identified specifically as wheelpath wear. Deterioration of the remaining surface, which could be left as surface deterioration, would most likely be due to freeze/thaw cycling or scaling, both of which are caused by excess water migrating to the concrete surface during placement. Elevated water/cement ratios reduce the strength and durability of concrete grout.

    Patching deterioration, faulting and longitudinal joint spalling occurred more frequently on average performing rigid pavements than on excellent performing rigid pavements and, therefore, can be cited as distresses which often differentiate between average and excellent performance in Ohio. Faulting and joint spalling result from excess moisture under the pavement, as does transverse joint spalling and various types of cracking which were rather common on both average and excellent performing rigid pavements. Good drainage will reduce moisture under the pavement and, from other research, the use of non-rigid base layers will reduce the loss of support from slab curling.

Chapter 3

Field Sampling and Testing of Selected Pavements

Task 4 - Inspect each of the selected sites and perform a suite of tests to develop response and performance profiles along the project lengths. These site inspections will include, at a minimum, Pavement Distress Survey (SHRP-P-338), Pavement Condition Ratings (PCR), Falling Weight Deflectometer (FWD) readings, Dynamic Cone Penetrometer (DCP) measurements, Ground Penetrating Radar (GPR) measurements, roughness measurements, lateral profiles on AC surfaces, cores, and the collection of representative material samples. From these data, areas of differing performance will be located within each site.

FWD

Tables 3.1 and 3.2 summarize average FWD data for the selected flexible and rigid pavements, respectively, calculated at the load nearest 9,000 lbs. (4082 kg), normalized to 9,000 lbs. (4082 kg), and grouped by level of performance. Normalized deflections are expressed as mils/kip, Spreadability is the average deflection measured by all seven geophones normalized to deflection at the first geophone, and Joint Support Ratio is the ratio of leave to approach deflections (JL/JA) measured at the control joints. Individual parameters are plotted over project lengths in Appendix C. FWD data were not collected on a few projects because of their late inclusion into this research study. Historically, ratios of W1/W5 $\leq$ 3.0 measured with the Dynaflect at midslab indicated that a layer of PC concrete was located somewhere in the pavement structure. Ratios above 3.0 indicated full depth AC. Based on the limited data in Tables 3.1 and 3.2, it appears this ratio should be adjusted to 3.4 for Df1/Df7 with the FWD using an 11.8 inch (300 mm) diameter load plate and Df7 located at Z = 60 inches (1.52 m).

The relatively few number of projects and the variability between projects prevented any firm conclusions from being drawn about differences in deflection parameters between average and excellent performing pavements or between paired sections. The one parameter of note was average Df7, which was $\leq$ 0.20 mils/kip (114 mm/MN) on all projects, indicating the in-situ subgrade moduli on all selected projects were very good at over 20,000 psi (137.8 mPa).

Table 3.1
FWD Summary for Flexible Pavements

Flexible Pavement FWD Summary									
County/ Route	Proj. No.	Upstation*				Downstation*			
		Norm. Defl. (mils/kip)		SPR (%)	Df1/Df7	Norm. Defl. (mils/kip)		SPR (%)	Df1/Df7
		Df1	Df7			Df1	Df7		
Average Performance									
BUT 129	9330(98)					0.25	0.07	55.2	3.8
BUT 129	9327(98)	0.39	0.12	63.0	3.4	0.36	0.11	61.1	3.4
CHP 68	233(98)	0.84	0.13	49.3	6.2				
CLA 41	63(95)	Not tested							
DEL 23 (112)	380(94)					0.30	0.09	58.1	3.6
HAM 747	347(85)	1.16	0.10	48.5	11.1				
LAW 527	17(85)	0.79	0.12	53.6	6.7				
LUC 2	141(99)	0.68	0.20	64.1	3.4				
PIK 32	552(95)					0.38	0.11	62.6	3.5
VAN 30	219(97)	Not Tested							
	Average	0.77	0.13	55.7	5.8	0.32	0.09	59.3	3.5
Excellent Performance									
BUT 129	9330(98)	0.25	0.07	55.6	3.9				
CHP 68	233(98)	0.75	0.08	46.0	9.5	0.69	0.08	48.4	8.4
CLA 41	63(95)	Not tested							
DEL 23 (902)	380(94)					0.42	0.09	57.1	4.7
GRE 35	259(95)	0.94	0.12	51.8	7.6				
HAM 126	645(94)	0.56	0.10	53.9	5.9	0.58	0.10	55.2	5.7
LUC 25	665(97)	0.46	0.08	51.3	5.5	0.44	0.07	50.0	6.0
PIK 32	443(94)					0.37	0.10	60.1	3.9
PIK 32	552(95)	0.45	0.13	62.0	3.4				
ROS 35	298(96)	0.76	0.09	49.0	8.4	0.67	0.09	50.3	7.8
	Average	0.60	0.10	52.8	6.2	0.53	0.09	53.5	6.0

* Upstation = NB or EB, Downstation = SB or WB   1 mil/kip = 5.71 mm/MN

Table 3.2
FWD Summary for Rigid Pavements

Rigid Pavement FWD Summary																			
County/ Route	Proj. No.	Upstation*									Downstation*								
		Midslab				Joints					Midslab				Joints				
		Norm. Defl. (mils/kip)		SPR (%)	Df1/Df7	Norm. Defl. (mils/kip)		Load Transfer (%)		JSR (JL/JA)	Norm. Defl. (mils/kip)		SPR (%)	Df1/Df7	Norm. Defl. (mils/kip)		Load Transfer (%)		JSR (JL/JA)
		Df1	Df7			$Df1_{JA}$	$Df1_{JL}$	JA	JL		Df1	Df7			$Df1_{JA}$	$Df1_{JL}$	JA	JL	
Average Performance																			
ATH-33-10.40**	235(58)										0.52	0.17	73.3	3.0	0.88	0.82	84.9	86.5	0.93
ATH-682-0.16	625(76)	0.46	0.15	72.0	3.2	0.61	0.57	90.1	92.8	0.93	0.41	0.12	69.9	3.6	0.43	0.41	87.6	89.2	0.95
CUY-176-10.13	683(94)										0.25	0.11	77.7	2.2	0.23	0.23	89.8	88.5	0.98
CUY-176-10.87***	305(96)										0.17	0.08	74.2	2.1	0.21	0.20	85.8	90.6	0.93
CUY-176-10.87****	305(96)										0.16	0.08	76.9	2.0	0.31	0.25	80.6	93.3	0.79
CUY-252-3.47	901(84)	0.36	0.13	68.5	2.8	0.33	0.34	80.5	77.4	1.04									
JEF-22-15.02	8008(90)	0.38	0.12	70.2	3.3	0.49	0.59	98.9	81.4	1.19									
LOG-33-21.79	845(94)	0.31	0.14	76.5	2.2	0.61	0.57	85.8	88.3	0.95	0.28	0.13	77.0	2.2	0.47	0.43	82.6	86.0	0.94
SUM-76-13.41	996(93)	0.23	0.11	76.9	2.2	0.24	0.22	79.1	80.7	0.93									
TUS-39-2.84	907(90)	0.51	0.19	74.9	2.6	0.74	0.79	92.4	87.0	1.06									
	Average	0.38	0.14	73.2	2.7	0.50	0.51	87.8	84.6	1.02	0.30	0.12	74.8	2.5	0.42	0.39	85.2	89.0	0.92
Excellent Performance																			
ALL-30-20.16	746(97)	Not Tested																	
CUY-82-2.05	438(94)	0.27	0.11	74.5	2.4	0.52	0.48	82.8	86.2	0.91	0.29	0.14	77.9	2.1	0.46	0.44	82.5	84.6	0.95
CUY-322-8.68	1019(93)	0.42	0.20	80.0	2.1	0.42	0.41	91.6	90.4	0.99									
GAL-7-5.71	352(46)	0.55	0.18	72.1	3.1	1.05	1.06	43.5	44.8	1.00									
GRE-35-14.45	19(97)	Not Tested																	
HAM-126-11.35	997(90)	0.24	0.10	74.7	2.5	0.44	0.47	94.5	87.0	1.06	0.28	0.12	74.9	2.4	0.82	0.85	98.8	94.8	1.05
JEF-7-18.90	8008(90)										0.37	0.11	69.9	3.3	0.41	0.44	84.3	75.6	1.08
MOT-35-14.37	343(88)	0.24	0.08	71.3	3.0	0.40	0.38	84.7	84.1	0.98	0.22	0.08	73.1	2.8	0.30	0.29	83.0	80.9	0.96
MOT-202-2.00	678(91)	0.49	0.19	75.2	2.6	0.52	0.51	92.8	92.4	0.98									
SUM-76-13.41	996(93)										0.19	0.08	74.5	2.3	0.22	0.22	82.8	82.9	0.97
	Average All	0.37	0.14	74.6	2.6	0.56	0.55	81.7	80.8	0.99	0.27	0.11	74.1	2.6	0.44	0.45	86.3	83.8	1.00
	Avg. w/o GAL 7	0.31	0.13	75.0	2.5	0.4202	0.41	88.2	87.2	0.98	(1 mil/kip = 5.71 mm/MN)								

* Upstation = NB or EB, Downstation = SB or WB

** Joints replaced

*** Smooth portion of Project 305(96), 10.87-12.15

**** Rough portion of Project 305(96), 12.15-12.83

Flexible pavement sections BUT 129 22E, BUT 129 22W, DEL 23 17S, DEL 23 18S, PIK 32 15W, PIK 32 19E and PIK 32 19W each contained a 4-inch (100 mm) thick layer of ATFDB. Table 3.3 shows the presence of ATFDB to have a positive structural effect on flexible pavement response by lowering FWD Df1 deflection and increasing Spreadability.

Table 3.3

Effect of ATFDB on FWD – Flexible Pavements

Effect of ATFDB on FWD Data - Flexible Sections				
Flexible Sections with and without ATFDB	**Norm. Defl. (mils/kip)**		**SPR (%)**	**Df1/Df7**
	Df1	**Df7**		
Average Performance				
Sections with ATFDB	0.32	0.09	58.9	3.6
Sections w/o ATFDB	0.74	0.13	55.3	6.1
Excellent Performance				
Sections with ATFDB	0.46	0.09	56.0	5.0
Sections w/o ATFDB	0.62	0.09	52.0	6.8

For rigid pavements, GAL 7, at more than 60 years old, and ATH 33, with more than 50 years of service, had the highest midslab and joint deflections. GAL 7 had low load transfer, but is carrying local traffic quite well. The high load transfer on ATH 33 can be attributed to all joints being replaced in the 1990s. With the exception of the GAL 7 and ATH 33 projects, all other midslab and joint deflections were $\leq$ 0.51 mils/kip (2.91 mm/MN) and $\leq$ 0.79 mils/kip (4.50 mm/MN), respectively. There were no consistent differences of significance in FWD response between the average and excellent performing pavements or between paired sections.

Ride Quality

Table 3.4 shows a summary of ride quality data for the selected flexible and rigid pavements. Data were not available for the CLA 41, DEL 23 and VAN 30 flexible pavement sites which were late additions to the project list. At other sites, data were only available in one direction because of time constraints in the field. Appendix D contains individual ride quality profiles for the selected projects in alphabetical order by county and route.

Table 3.4 shows that, on average, ride quality was consistently better on flexible pavements than on rigid pavements, and about the same on average and excellent performing flexible pavements, especially on paired sections from the same projects. Average performing rigid pavements were smoother than excellent performing rigid pavements. Average ride quality was affected by localized distress, and high standard deviations made it difficult to draw any definite conclusions about correlations between pavement ride quality and performance. Only the direction of interest is shown in the table unless the other direction was the only data collected, as noted. Of particular interest was CUY-176-10.87, where ride quality between SLM 12.53 and SLM 12.83 downstation was much higher than the other portions of the project.

Table 3.4

Summary of Ride Quality Measurements

Ride Quality Summary									
Flexible Pavement					**Rigid Pavement**				
County/ Route/Log	**Upstation***		**Downstation***		**County/ Route/Log**	**Upstation***		**Downstation***	
	Avg.	**Std. Dev.**	**Avg.**	**Std. Dev.**		**Avg.**	**Std. Dev.**	**Avg.**	**Std. Dev.**
Average Performance					**Average Performance**				
BUT-129-17.83			78.3	51.3	ATH-33-10.40**	93.1	30.8	86.1	29.0
BUT-129-24.00	87.1	71.0	86.8	41.6	ATH-682-0.16	192.1	44.9	211.5	60.8
CHP-68-1.82	101.6	38.2	78.6	38.1	CUY-176-10.13	246.6	79.6	125.5	76.2
CLA-41-4.06					CUY-176-10.87***	92.0	42.9	92.0	22.0
DEL 23 (112)					CUY-176-10.87****	93.7	95.7	228.0	82.3
HAM-747-0.04	209.0	106.5			CUY-252-3.47	112.3	59.7		
LAW-527-0.19	160.4	87.8	153.8	81.8	JEF-22-15.02	141.5	84.5		
LUC-2-21.39	105.4	46.6			LOG-33-21.79	79.5	26.7	88.5	29.9
PIK-32-16.08			67.6	45.6	SUM-76-13.41	119.0	58.3		
VAN-30-15.97					TUS-39-2.84	119.5	52.4	105.3	34.4
Average	132.7	70.0	93.0	51.7	Average	128.9	57.6	133.8	47.8
Excellent Performance					**Excellent Performance**				
BUT-129-17.83	77.9	50.9	78.3	51.3	ALL-30-20.16	80.3	35.7	78.7	33.2
CHP-68-1.27	101.6	38.2	78.6	38.1	CUY-82-2.05	196.0	73.3	223.4	79.0
CLA-41-3.86					CUY-322-8.68	166.7	65.8		
DEL 23 (902)					GAL-7-5.71	173.1	53.8		
GRE-35-20.95	162.8	155.3	144.3	117.9	GRE-35-14.45	139.5	119.3	170.9	160.4
HAM-126-7.09	71.2	39.8	73.1	51.7	HAM-126-11.35	73.5	52.0	82.5	56.0
LUC-25-10.01	84.5	47.6	87.6	33.7	JEF-7-18.90			117.0	42.7
PIK-32-13.43			88.3	55.1	MOT-35-14.37			166.4	92.0
PIK-32-16.08	66.0	45.3			MOT-202-2.00	187.5	60.8		
ROS-35-0.00	122.6	139.1	91.8	111.3	SUM-76-13.41			128.4	86.5
Average	98.1	73.7	91.7	65.6	Average	145.2	65.8	138.2	78.5

* Upstation = NB or EB, Downstation = SB or WB

** Joints replaced

*** Smooth portion of Project 305(96), 10.87-12.17

**** Rough portion of Project 305(96), 12.53-12.83

Site Visits - Coring

The coring crew took copies of the ride quality and FWD profiles in the field to aid in the identification of specific locations for sampling and testing. Upon arrival at the site, the crew scanned the project by driving the full length in both directions and observing surface distresses, topographical conditions, and any localized features that could affect performance. Areas where traffic control might result in congestion or an unsafe work environment were avoided. To maintain a clear distinction between average and excellent performing projects sampling and testing locations on average pavements contained representative distress, while locations on excellent projects were confined to areas with little to no distress. Two flexible sections were adjusted in the field as follows: 1) HAM 747 0.04-0.94 upstation was changed to the downstation side because of the existence of a longitudinal utility trench in the upstation lane, and 2) LAW 7 1.4-2.28 downstation was changed to a section of LAW 527 downstation where it splits with SR7 at SLM 2.28 because LAW 7 reduces to one lane at the split. Both new sections were on the same projects and were comparable in condition to the original sections. Tables 3.5 and 3.6 summarize the location of the sampling and testing sections, or core code, by mile marker and direction of travel.

Cores were cut in the pavements and samples of unstabilized base and subgrade materials were removed for laboratory testing. Dynamic Cone Penetrometer (DCP) measurements were taken in three or four holes to determine base and subgrade stiffness to a depth of about two feet (0.6 m). Figure 3.1 shows coring patterns used on flexible and rigid pavements, and numbers identifying the individual cores. These patterns were developed after consultation with personnel at ORITE, ODOT and Lankard Material Laboratories (LML) to determine the number and diameters of cores needed for the required testing. Aside from the two flexible cores for ODOT and the two rigid cores for LML shown in Figure 3.1, all other cores were nominally spaced 40 feet (12.2 m) along the lane centerline to allow coring, DCP testing and base/subgrade sampling to be performed simultaneously. When traffic conditions dictated a shorter spacing, random distances used for the ODOT cores on flexible pavements were adjusted accordingly. Cores were usually taken along the centerline of the driving lane, but occasionally were moved to the right wheelpath to maintain a safer distance from traffic in the adjacent lane. Four and six-inch (10.2 and 15.2 cm) diameter cores were both cut to accommodate standard testing protocols and maintain adequate core diameters when large aggregate were present.

Table 3.5
Flexible Pavements Selected for Study

Summary of Flexible Pavements Selected for Forensic Study Activity Code 100										
Route	**Project No.**	**Location Code**	**Material Layer**						**ADT**	
			1	**2**	**3**	**4**	**5**	**Subg.**	**Year**	**B&C**
Average Performance										
BUT 129	9330(98)	22 W	1.25” 446 T1	1.75” 446 T2	10” 302	4” ATFDB			2007 1996	2375 1530
BUT 129	9327(98)	25 W	1.25” 446 T1	1.75” 446 T2	8” 302	4” 304			2007 1996	2375 1670
CHP 68	233(98)	2.5 N	1.50” 448 T1H	1.75” 448 T2	6” 301	6” 304			2008 1998	1210 1110
CLA 41	63(95)	4 N	1.25” 404	1.75” 402	7” 301	5” 304			2008 1994	425 320
DEL 23*	380(94)	18 S (112)	1.75” 446 T1 AC 20	2.25” 446 T2 AC 20	12” 302	4” ATFDB w/filter			2008 1994	4580 4240
HAM 747	347(85)	1 S	1” 404	1” 403	9” 301				2005 1994	660 750
LAW 527	17(85)	2 N	1.25” 404	1.50” 402	9” 301				2005	550
LUC 2	141(99)	22 E	1.25” 446 T1H	1.75” 446 T2	10” 301	6” 304			2007 2000	3330 2420
PIK 32	552(95)	19 W	1.25” 446 T1	1.75” 446 T2	12” 301	4” ATFDB	4” 304		2007 1992	1120 790
VAN 30	219(97)	18 E	1.5” 446 T1H	2.5” 446 T2	9” 451			6” 206	2006 1997	4520 4180
Excellent Performance										
BUT 129	9330(98)	22 E	1.25” 446 T1	1.75” 446 T2	10” 302	4” ATFDB			2007 1996	2375 1530
CHP 68	233(98)	2 N	1.50” 448 T1H	1.75” 448 T2	6” 301	6” 304			2008 1998	1210 1110
CLA 41	63(95)	3 N	1.25” 404	1.75” 402	7” 301	5” 304			2008 1994	425 320
DEL 23*	380(94)	17 S (902)	1.75” 446 T1 PG 58-30	2.25” 446 T2 PG 58-30	12” 302	4” ATFDB	6” 304		2007 1994	2460 960
GRE 35	259(98)	21 E	1.50” 448 T1H	1.75” 448 T2	7.5” 301	6” 304		206	2008 2000	2760 1410
HAM 126	645(94)	11 E	1.25” 446 T1	1.75” 446 T2	10” 301	6” 304	6” 310	6” 206	2005 1994	1750 1410
LUC 25	665(97)	10 S	1.25” 446 T1	1.75” 446 T2	7” 301	8” 304	6” 310		2007 2000	290 820
PIK 32	443(94)	15 W	1.25” 446 T1	1.75” 446 T2	9” 301	4” ATFDB	6” 304		2007 1992	1210 1080
PIK 32	552(95)	19 E	1.25” 446 T1	1.75” 446 T2	12” 301	4” ATFDB	4” 304		2007 1992	1120 790
ROS 35	298(96)	1 W	1.25” 446 T1	1.75” 446 T2	10” 301	4” 307 NJ	8” 304	8” 206	2006 2000	2520 1740

* Recent AC overlay, 451 PCC base   1 inch = 2.54 cm

Table 3.6
Rigid Pavements Selected for Study

Summary of Rigid Pavements Selected for Forensic Study Activity Code 110												
Route	**Project No.**	**Location Code**	**Material Layer**						**Joint Spacing**	**ADT**	
			1	**2**	**3**	**4**	**5**	**Subg.**		**Year**	**B&C**
Average Performance												
ATH 33*	235(58)	13 E	9” 451	8” 310					60’	2006 1980	1535 750
ATH 682	625(76)	1 N	9” 451	6” 310					40’	2008 1986	190 270
CUY 176	683(94)	10 S	12” 451	6” 310 T2					21’	2007 1991	2975 3200
CUY 176	305(96)	11 S	12” 451	6” 310 T2					21’	2007 1991	2975 3100
CUY 176	305(96)	12 S	12” 451	6” 310 T2					21’	2007 1991	2975 3100
CUY 252	901(84)	4 N	9” 451	6” 310 T2					27’	2007 1984	540 330
JEF 22	8008(90)	15 E	9” 451	6” 310 T2					27’ Skewed	2007 1992	3750 1710
LOG 33	845(94)	24 W	12” 452	4” 307 IA	AC T1	304			15’	2005 1994	3950 2210
SUM 76	996(93)	15 E	11” 451	1” 403	3” 301	4” 304			21’	2007 1992	12210 9290
TUS 39	907(90)	4 E	9” 451	6” 310 T2					27’ Skewed	2007 1988	930 610
Excellent Performance												
ALL 30	746(97)	22 E	11” 451	4” ATFDB	6” 304				21’	2008 1999	3650 3920
CUY 82	438(94)	3 E	11” 451	6” 304					21’	2007 1991	1740 1600
CUY 322	1019(93)	10 E	10” 451	6” 310					21’	2007 1992	600 530
GAL 7*	352(46)	8 N	8” T-71	6–12” SS 112					40’	2006 1988	400 260
GRE 35	19(97)	19 W	10” 451	4” 307 NJ	6” 304			6” 206	21’	2008 2000	2900 1450
HAM 126	997(90)	12 E	10” 451	6” 310 T2					27’ Skewed	2005 1990	2110 1650
JEF 7	8008(90)	19 S	9” 451	6” 310 T2					27’ Skewed	2007 1992	1980 2380
MOT 35	343(88)	14 W	10” 452	4” 301	4” 304				15’	2006 1994	2780 2110
MOT 202	678(91)	3 N	9” 452	6” 310 T2					15’	2006 1994	440 670
SUM 76	996(93)	15 W	11” 451	1” 403	3” 301	4” 304			21’	2007 1992	12210 9290

* Recent AC overlay 1 inch = 2.54 cm

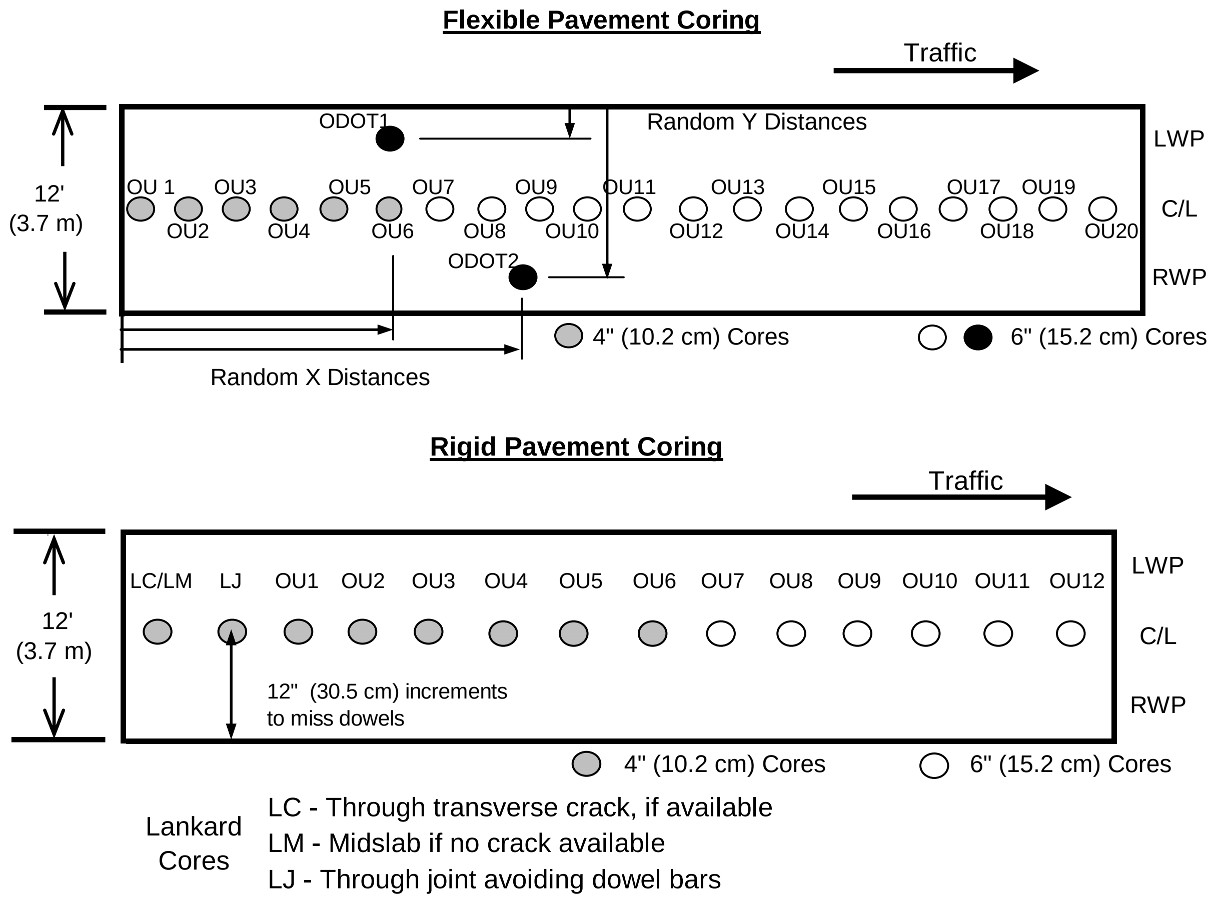


Figure 3.1 – Coring Patterns on Flexible and Rigid Pavements

Figure 3.2 shows the core rig fabricated by ORITE for ODOT. After cutting, the cores were dried, labeled by county, route, nearest mile marker, direction of travel and core number, and wrapped in bubble wrap to minimize damage during transit to the laboratory. Pictures were taken of any unusual features at the site and on the cores. After coring was completed at each site, samples of base and subgrade material were removed from two or three core holes along the section length with a hand trowel and auger. A Dynamic Cone Penetrometer (DCP) was used to determine the stiffness of the base and subgrade in three to five other holes down to a depth of about 2-3 feet (0.6-0.9 m). Hard base material or large rocks in the subgrade sometimes limited the depth of DCP testing. The Ground Penetrating Radar (GPR) device at ORITE was not functional for scanning the sampling and testing area, and a 6 foot (1.8 m) long straightedge with a graduated wedge was used to measure rut depths on flexible pavements.

Figure 3.2 – Core Rig Fabricated by ORITE

Two cores from each flexible pavement went to the ODOT Central Laboratory and two cores from each rigid pavement went to Lankard Materials Laboratory (LML) for testing. The ODOT flexible cores were located by random distances from the beginning of the section and the left edge of the lane. Cores for LML were cut across a control joint between dowel bars and on a transverse midslab crack, if available. When no midslab cracks were present, a core was cut in the center of a slab. All other cores were transported to the ORITE Laboratory in Athens, Ohio. The ORITE (OU) cores on rigid pavement were all cut near midslab. Identification codes for the sampling and testing sites were county/route/nearest mile marker and direction of travel.

Among problems encountered during the coring were a couple of build-ups inconsistent with those shown in the PMIS, and PC concrete base being found at the VAN 30 18E site identified as being flexible in the PMIS, via an activity code of 100 and a structural base of 301 AC. Notes from the flexible and rigid pavement site visits are summarized in Appendices E and F, respectively, and specific details of the VAN 30 18E site are discussed in Appendix E. Other projects were observed during the project selection process which, like VAN 30 18E, had activity codes of 100 in the PMIS, and G/N build ups, or AC over PCC, on the SLDs. It would seem that pavements containing a substantial thickness of PC concrete will perform more like rigid pavements than flexible pavements and should be identified as rigid or composite.

Site Visits - Dynamic Cone Penetrometer (DCP)

The DCP unit used on this research project is shown in Figure 3.3. The steel cylindrical weight near the top of the picture, weighing 17.6 lbs. (8 kg), is raised and repeatedly dropped 22.6 inches (574 mm) onto a smaller cylindrical piece of steel affixed to the long penetration rod until the rod reaches its full depth of penetration or until something hard is encountered which stops the rod. The penetration rate (PR) is determined as the vertical depth attained per blow of the weight. Data were collected in up to five core holes at each site to determine the vertical resilient modulus profile of unbound aggregate and subgrade supporting the pavement to a depth of up to ~36 in. (91.4 cm) below the pavement. Because these materials are non-homogeneous, penetration rates varied with depth. Before in-situ soil stiffness can be determined, there must be a reduction of noise in the trace, usually caused by the rod hitting stones, and a definition of "uniform" layers. Noise reduction is accomplished by removing any single blow penetration of 1 mm (.04 in.) or less, and any reading less than one-fourth of the adjacent two readings. PR is then recalculated for the adjusted number of blows with large spikes in modulus being removed.

Figure 3.3 – DCP Owned and Operated by ORITE

A procedure described as delineating statistically homogeneous units by the Cumulative Difference Method in the AASHTO Pavement Design Guide was used to define the boundaries for statistically uniform layers within the subgrade. The principle of this method is to compare differences between areas accumulated under the actual penetration traces with average area of the entire trace summed to the same depth of penetration. This difference in areas is known as Z, and layer boundaries are defined as depths where the slope of Z changes from positive to negative or vice versa, as shown in Figures 3.4 and 3.5.

With individual layer boundaries identified, resilient moduli can be calculated for the layers by converting DCP to CBR and CBR to M_R , as shown below:

$$CBR = \frac{292}{DCP^{1.12}}$$ …………..………………….. (USACE Waterways Experiment Station)

$$M_R = 1500 * CBR$$ ………………………………….…... (1993 AASHTO Design Guide)

CBR and M_R were calculated for each layer in each hole tested, and an average M_R for the hole was calculated over the full depth of penetration. An average M_R for each site was then calculated by combining averages for all holes tested at the sites. Figures 3.4 and 3.5 show DCP measurements at the CHP 2N site. Table 3.7 shows results of the individual DCP tests, Table 3.8 summarizes average site results by pavement type and level of performance, and Table 3.9 provides a comparison of average subgrade M_R calculated over entire project lengths using Df7 on the FWD and average subgrade M_R of support materials determined with the DCP at project sampling and testing sites. The DCP was not used on HAM 747 and LUC 2 because of the probability of utilities being located under the pavement.

M_R measured with the DCP varied widely between pavement sites and, as expected, tended to decrease with the depth of penetration. Figure 3.6 shows average M_R decreasing with increasing depths of DCP penetration and why, at depths greater than 24 inches (61 cm), M_R determined with the DCP agreed better with M_R determined with the FWD. This pattern was reasonable since base materials are generally stiffer and more granular than subgrade materials, and subgrade surfaces are compacted during construction. While differences in the two types of measurements, test areas represented by the measurements, and the range in depths of DCP penetration all contributed to variations between M_R for the FWD and DCP in Table 3.9, there was better agreement at greater DCP depths.

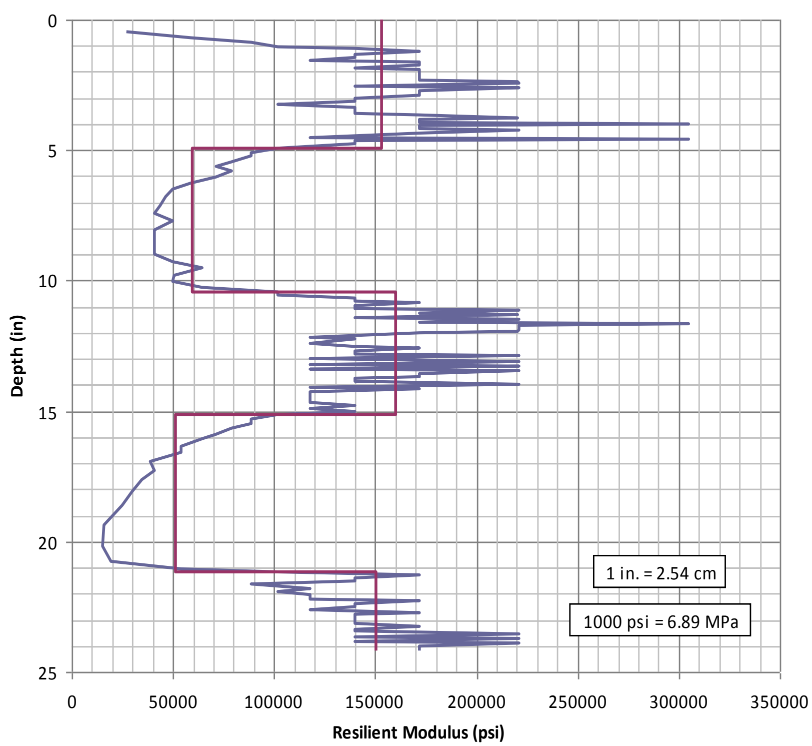


Figure 3.4 - M_R vs. DCP Depth at CHP 68 2N

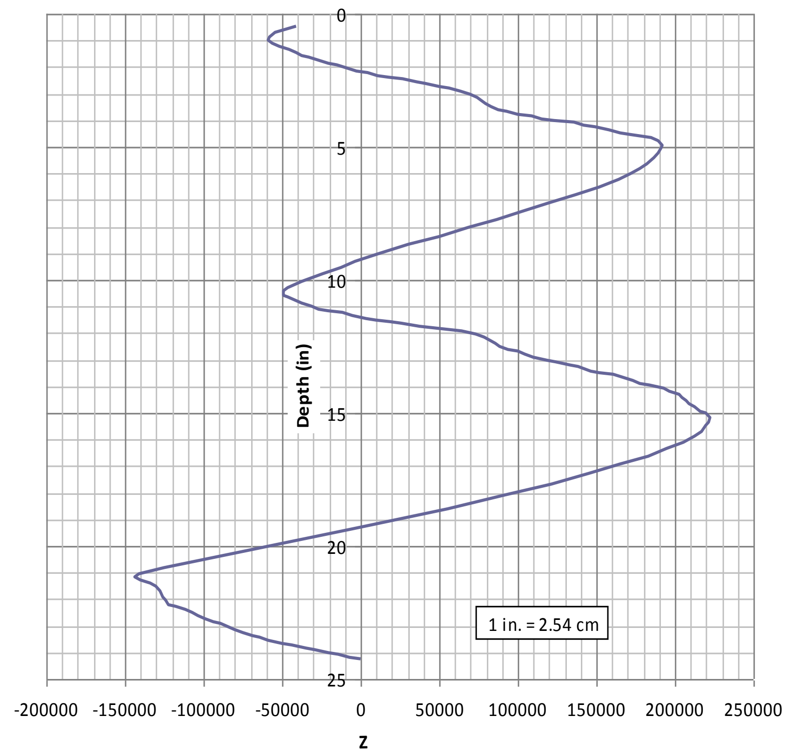


Figure 3.5 - Plot of Z vs. DCP Depth at CHP 68 2N

Table 3.7

DCP Test Summary

Summary of DCP Tests												
Site	Test 1		Test 2		Test 3		Test 4		Test 5		Average	
	Depth (in.)	MR (ksi)	Depth (in.)	MR (ksi)	Depth (in.)	MR (ksi)	Depth (in.)	MR (ksi)	Depth (in.)	MR (ksi)	Depth (in.)	MR (ksi)
ALL 30 22E	27.3	173.2	27.6	116.9	27.7	78	29.3	98.6			27.98	116.68
ATH 33 13E	34.7	21	33.3	15.3	34	12.7	32.8	14.7			33.70	15.93
ATH 682 1N	36.2	46.9	9.5	223.1	35.5	25.3	36.3	42.9	36.0	21.1	30.70	71.86
BUT 129 22E	2.85	367.5	2.81	232.5	2.41	370.6	2.12	346.1	2.69	429.8	2.58	349.30
BUT 129 22W	2.96	242.5	3.05	202.2	2.90	324.8	2.94	343.7	2.83	253.4	2.94	273.32
BUT 129 25W	3.36	334.4	2.39	473.9	1.98	417.4	1.80	384.1	1.78	310.6	2.26	384.08
CHP 68 2N	18.3	171.7	14.0	193.4	5.33	245.6	12.0	190.0	24.2	136.7	14.77	187.48
CHP 68 2.5N	7.02	237.5	6.53	220.2	4.63	121.6	14.4	146.4	5.84	155.1	7.68	176.16
CLA 41 3N	32.8	40.6	30.3	35.7	32.4	38.6	32.5	31.7	32.9	40.7	32.18	37.46
CLA 41 4N	32.0	152.0	32.8	49.4	32.9	52.5	33.3	61.0			32.75	78.73
CUY 82 3E	31.3	77.2	31.2	53.4	31.4	48.4	1.78	220.8	3.90	281.2	19.92	136.20
CUY176 10S	13.8	70.3	24.1	304.6							18.95	187.45
CUY 176 11E	7.20	220.8	5.73	631.7	6.06	220.8	7.29	1045.2			6.57	529.63
CUY 176 12E	3.76	350.5	5.48	1042.6	3.54	304.6	4.84	172.0			4.41	467.43
CUY 252 4N	31.2	115.4	31.2	86.8	31.3	59.7	5.75	172.0	8.96	220.7	21.68	130.92
CUY 322 10E	33.6	78.5	6.26	189.5	5.08	159.3	30.2	115.8	13.7	220.8	17.77	152.78
DEL 23 17S	24.7	59.4	23.3	42.0	22.4	28.4	23.2	34.1			23.40	40.98
DEL 23 18S	24.2	43.6	24.4	18.6	23.2	27.0	25.2	23.8	22.7	15.1	23.94	25.62
GAL 7 8N	33.1	15.9	34.9	29.1	35.2	28.1	35.8	21.9	35.8	31.4	34.96	25.28
GRE 35 19W	32.4	138.7	15.3	269.8	10.5	119.9	25.3	146.4			20.88	168.70
GRE 35 21E	48.6	119.7	32.6	89.6	31.7	92.6	28.2	105.8	25.9	167.6	33.40	115.06
HAM 126 11E	29.8	456.8	30.3	86.9	29.4	130.3	26.5	195.1	31.9	93.3	29.58	192.48
HAM 126 12E												
HAM 747 1S												
JEF 7 19S	31.8	90.2	24.2	220.7	31.2	99.8	19.6	172.0			26.70	145.68
JEF 22 15E	14.0	140.2	18.6	172.0	18.9	304.9	2.99	304.6	3.32	304.6	11.56	245.26
LAW 527 2N	30.6	51.2	31.0	65.4	29.7	24.1	29.8	15.2	29.4	16.7	30.10	34.52
LOG 33 24W	26.3	89.1	28.0	97.4	19.6	304.6	30.6	99.5			26.13	147.65
LUC 2 22E												
LUC 25 10S	2.65	392.3	7.18	480.3	4.10	761.5	5.73	304.9	6.80	304.9	5.29	448.78
MOT 35 14W	11.7	172.0	20.3	110.4	15.3	144.3					15.77	142.23
MOT 202 3N	22.3	23.9	7.87	62.8	27.0	100.2	10.1	246.3			16.82	108.30
PIK 32 15W	16.3	172.0	10.9	304.9	17.2	16.1	25.1	134.8	26.1	128.3	19.12	151.22
PIK 32 19E	25.6	36.7	26.7	45.2	25.2	133.9	27.6	53.0	26.2	56.4	26.26	65.04
PIK 32 19W	26.0	46.5	26.4	40.5	26.7	32.0	25.9	34.7			26.25	38.43
ROS 35 1W	30.4	80.9	31.1	64.2	29.4	68.9	30.8	119.2	30.6	45.5	30.46	75.74
SUM 76 15E	20.1	54.5									20.1	54.5
SUM 76 15W												
TUS 39 4E	32.3	38.8	32.9	13.7	34.1	19.9	31.2	23.0			32.63	23.85
VAN 30 18E	30.6	15.4	31.1	15.6	30.8	10.1	30.2	17.0	29.9	14.4	30.52	14.50

1 inch = 2.54 cm 1 ksi = 6.89 MPa

Table 3.8

DCP Site Averages by Pavement Type and Performance Level

DCP Penetration and M_R by Project							
Flexible Pavements				**Rigid Pavements**			
Site	**No. Tests**	**Total Depth in. (cm)**	**Average M_R ksi (MPa)**	**Site**	**No. Tests**	**Total Depth in. (cm)**	**Average M_R ksi (MPa)**
Average Performance				**Average Performance**			
BUT 129 22W*	5	2.94 (7.5)	273 (1885)	ATH 33 13E	4	33.7 (85.6)	15.9 (110)
BUT 129 25W	5	2.26 (5.7)	384 (2648)	ATH 682 1N	5	30.7 (78.0)	71.9 (495)
CHP 68 2.5N*	5	7.68 (19.5)	176 (1215)	CUY176 10S	2	19.0 (48.3)	187 (1292)
CLA 41 4N*	4	32.8 (83.2)	78.7 (543)	CUY 176 11E	4	6.57 (16.7)	530 (3652)
DEL 23 18S*	5	23.9 (60.8)	25.6 (177)	CUY 176 12E	4	4.41 (11.2)	467 (3223)
HAM 747 1S				CUY 252 4N	5	21.7 (55.1)	131 (903)
LAW 527 2N	5	30.1 (76.5)	34.5 (238)	JEF 22 15E*	5	11.6 (29.5)	245 (1691)
LUC 2 22E				LOG 33 24W	4	26.1 (66.3)	148 (1018)
PIK 32 19W*	4	26.3 (66.7)	38.4 (265)	SUM 76 15E*	1	20.1 (51.1)	54.5 (376)
VAN 30 18E	5	30.5 (77.5)	14.5 (100)	TUS 39 4E	4	32.6 (82.8)	23.9 (164)
Average All		19.6 (49.7)	128 (884)	Average All		20.6 (52.5)	187 (1292)
Paired Average		18.7 (47.6)	118 (815)	Paired Average		15.9 (40.3)	150 (1037)
Excellent Performance				**Excellent Performance**			
BUT 129 22E*	5	2.58 (6.5)	349 (2408)	ALL 30 22E	4	28.0 (71.1)	117 (804)
CHP 68 2N*	5	14.8 (37.5)	187 (1293)	CUY 82 3E	5	19.9 (50.6)	136 (939)
CLA 41 3N*	5	32.2 (81.7)	37.5 (258)	CUY 322 10E	5	17.8 (45.1)	153 (1053)
DEL 23 17S*	4	23.4 (59.4)	41.0 (283)	GAL 7 8N	5	35.0 (88.8)	25.3 (174)
GRE 35 21E	5	33.4 (84.8)	115 (793)	GRE 35 19W	4	20.9 (53.0)	169 (1163)
HAM 126 11E	5	29.6 (75.1)	193 (1327)	HAM 126 12E			
LUC 25 10S	5	5.29 (13.4)	449 (3094)	JEF 7 19S*	4	26.7 (67.8)	146 (1004)
PIK 32 15W	5	19.1 (48.6)	151 (1043)	MOT 35 14W	3	15.8 (40.0)	142 (981)
PIK 32 19E*	5	26.3 (66.7)	65.0 (448)	MOT 202 3N	4	16.8 (42.7)	108 (747)
ROS 35 1W	5	30.5 (77.4)	75.7 (522)	SUM 76 15W*			
Average All		21.7 (55.1)	166 (1147)	Average All		22.6 (57.4)	125 (858)
Paired Average		19.9 (50.4)	136 (940)	Paired Average			

* Paired section

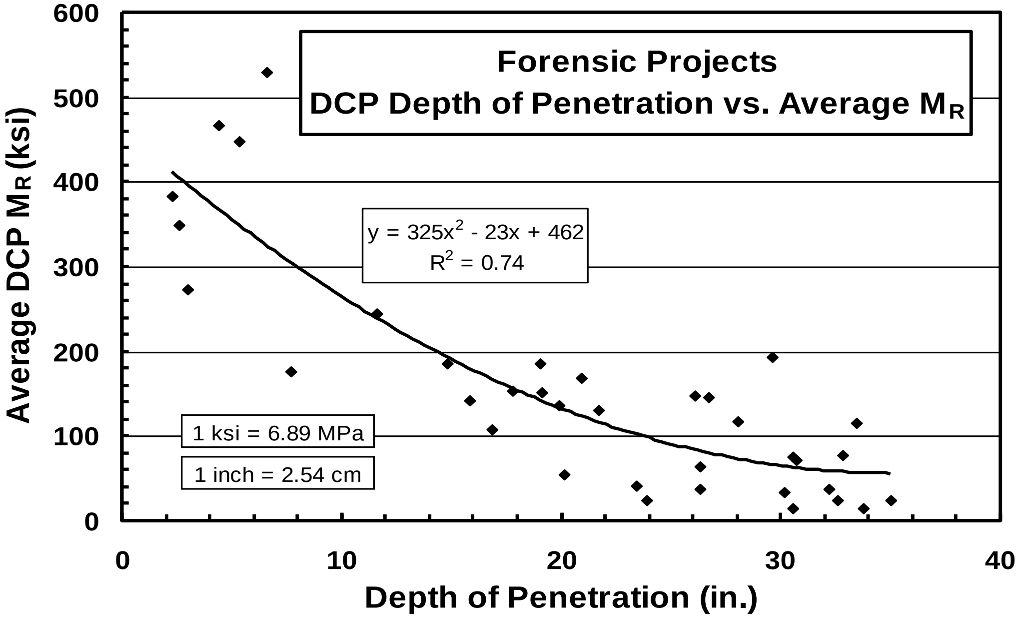


Figure 3.6 – DCP Penetration vs. Average M_R

Table 3.9
Pavement Support – FWD vs. DCP

Pavement Support - Project Average w/FWD vs. Site Average w/DCP													
Flexible Pavements							Rigid Pavements						
Site	Base Class.	Subgrade Class.	FWD		DCP		Site	Base Class.	Subgrade Class.	FWD		DCP	
			Df7 mils/kip	M_R (ksi)	Depth (in.)	M_R (ksi)				Df7 mils/kip	M_R (ksi)	Depth (in.)	M_R (ksi)
Average Performance							Average Performance						
BUT 129 22W*	A-1-a		0.07	63.8	2.9	273	ATH 33 13E	A-1-b	A-6	0.17	26.3	33.7	16
BUT 129 25W	A-1-a		0.12	37.2	2.3	384	ATH 682 1N	A-1-a	A-6	0.14	31.9	30.7	72
CHP 68 2.5N*			0.13	34.4	7.7	176	CUY176 10S			0.11	40.6	19.0	187
CLA 41 4N*	A-1-a	A-6			32.8	79	CUY 176 11S	A-1-a		0.08	55.8	6.6	530
DEL 23 18S*		A-6	0.09	49.6	23.9	26	CUY 176 12S	A-1-a		0.08	55.8	4.4	467
HAM 747 1S	A-1-a		0.10	44.7			CUY 252 4N	A-1-a	A-6	0.13	34.4	21.7	131
LAW 527 2N			0.12	37.2	30.1	35	JEF 22 15E*			0.12	37.2	11.6	245
LUC 2 22E	A-1-a		0.20	22.3			LOG 33 24W	A-1-a	A-6	0.14	31.9	26.1	148
PIK 32 19W*	A-1-a	A-6	0.11	40.6	26.3	38	SUM 76 15E*			0.11	40.6	20.1	55
VAN 30 18E		A-7-6			30.5	15	TUS 39 4E	A-1-a	A-4	0.19	23.5	32.6	24
Average All			0.12	41.2	19.6	128	Average All			0.13	37.8	20.6	187
Paired Average			0.10	47.1	18.7	118	Paired Average			0.12	43.8	15.9	150
Excellent Performance							Excellent Performance						
BUT 129 22E*	A-1-a		0.07	63.8	2.6	349	ALL 30 22E	A-1-a				28.0	117
CHP 68 2N*	A-1-b		0.08	55.8	14.8	187	CUY 82 3E	A-1-a	A-6	0.13	34.4	19.9	136
CLA 41 3N*	A-1-a				32.2	38	CUY 322 10E	A-1-b	A-6	0.20	22.3	17.8	153
DEL 23 17S*	A-1-a	A-6	0.09	49.6	23.4	41	GAL 7 8N	A-1-b	A-6	0.18	24.8	35.0	25
GRE 35 21E	A-1-a	A-4	0.12	37.2	33.4	115	GRE 35 19W	A-1-a				20.9	169
HAM 126 11E	A-1-b	A-6	0.10	44.7	29.6	193	HAM 126 12E	A-1-b	A-4	0.10	44.7		
LUC 25 10S	A-1-a		0.08	55.8	5.3	449	JEF 7 19S*	A-1-a	A-6	0.11	40.6	26.7	146
PIK 32 15W	A-1-a	A-4	0.10	44.7	19.1	151	MOT 35 14W	A-1-a	A-6	0.08	55.8	15.8	142
PIK 32 19E*	A-1-a	A-6	0.13	34.4	26.3	65	MOT 202 3N	A-1-a		0.19	23.5	16.8	108
ROS 35 1W	A-1-a	A-6	0.09	49.6	30.5	76	SUM 76 15W*			0.08	55.8		
Average All			0.10	48.4	21.7	166	Average All			0.13	37.7	22.6	125
Paired Average			0.09	46.3	19.9	136	Paired Average			0.10	23.6	26.7	146

* Paired section (1 mil/kip = 5.71 mm/MN) 1 ksi = 6.89 MPa 1 inch = 2.54 cm

Site Visits - Rut Depths

During the site visits, rut depths were measured at several locations in the right wheelpaths of flexible pavement sampling and testing sections with a 6 foot (1.83 m) long straight edge and averaged to obtain the data shown in Table 3.10. With the exception of the ¼ inch (6.4 mm) deep ruts in Section LUC 2 22E, rut depths were ≤ 1/8 inch (3.2 mm) in all other sections, which is consistent with average to excellent performance. Ponded water from coring and the straightedge in Figure E6 of Appendix E show differences between rut depths in the right and left wheelpath ruts of a short section of CHP 68 2.5N. There was no obvious reason why left wheelpath ruts were significantly deeper than right wheelpath ruts, though some type of localized longitudinal weakness caused by excess moisture and/or lack of density in the subgrade or base layers may have been to blame.

Table 3.10
Flexible Pavement Rut Depths

Flexible Pavement Rut Depths							
Pavement Section	Project No.	Avg. Rut Depth		Pavement Section	Project No.	Avg. Rut Depth	
		(in.)	(mm)			(in.)	(mm)
Average Performance				Excellent Performance			
BUT 129 22W	9330(98)	0.09	2.4	BUT 129 22E	9330 (98)	0.03	0.8
BUT 129 25W	9327(98)	0.06	1.6	CHP 68 2N	233(98)	0.09	2.4
CHP 68 2.5N*	233(98)	0.13	3.2	CLA 41 3N	63(95)	0.09	2.4
CLA 41 4N	63(95)	0.09	2.4	DEL 23 17S	380(94)	0.06	1.6
DEL 23 18S	380(94)	0.06	1.6	GRE 35 21E	259(98)	0.02	0.4
HAM 747 1S	347(85)	0.06	1.6	HAM 126 11E	645(94)	0.13	3.2
LAW 527 2N	17(85)	New overlay		LUC 25 10S	665(97)	0.06	1.6
LUC 2 22E	141(99)	0.25	6.4	PIK 32 15W	443(94)	0.03	0.8
PIK 32 19W	552(95)	0.13	3.2	PIK 32 19E	552(95)	0.09	2.4
VAN 30 18E	219(97)	Composite		ROS 35 1W	298(96)	0.08	2.0

* LWP - 0.50 in. (12.7 mm)

Non-Reinforced Rigid Pavement Sites

Of the twenty rigid pavement sites, seventeen were constructed with reinforced concrete (ODOT 451) and the following three projects were constructed with non-reinforced concrete (ODOT 452); LOG 33 rated average, and MOT 35 and MOT 202 rated excellent based on PCR data through 2004. By 2009, the condition of the LOG 33 site agreed quite well with that shown in the 2004 PMIS. There were some deteriorated patches scattered along the longitudinal joints and at least one slab settlement, as described in Appendix F. The 4 inch (10 cm) thick 307 IA base drained core holes in the sampling and testing section well and evidently over most of the project based on the excellent condition of the pavement. Water did not drain from a core hole cut through a patch in the longitudinal joint about a half mile (0.8 km) west of the sampling and testing site near MP 24 WB, and the core consisted of rubble at the bottom of the pavement, suggesting some localized drainage problems leading to deterioration of the concrete. ODOT traffic control personnel confirmed that natural springs have created drainage issues in the area.

The 300 foot (91 m) long sampling and testing section near MP 14 WB on MOT 35 was located in a cut near the McGee Blvd. bridge over US 35, but the area directly under the bridge was avoided. While no cracking was noted in the 2004 PMIS condition ratings, two tight transverse cracks were observed in the sampling and testing section in 2009. Thickness of the PC concrete progressively increased from about 10 inches (25 cm) to 13 ¼ inches (34 cm) over the last 12 – 15 slabs before the project end at SLM 14.37. This taper may have been necessary to meet an existing grade in the abutting project. Overall, the 10 inches (25 cm) of 452 / 4 inches (10 cm) of 301 / 4 inches (10 cm) of 304 design appears to be performing quite well.

Project 678(91) on MOT 202 was located on a three-lane residential street. While only minor longitudinal cracking was noted in the 2004 PMIS, tight transverse cracks were observed in most slabs in 2009. This 9 inch (23 cm) thick 452 pavement was constructed on 6 inches (15 cm) of 310 T2 aggregate base and is performing reasonably well.

Summary

1. To maintain measurable differences in performance between the average and excellent performing pavements, average pavements were cored in areas with representative distress while excellent pavements were cored in areas with little to no distress.

2. Overall, the condition of selected pavement sections during the 2009 site visits was largely consistent with the average and excellent performance ratings assigned to them during the selection process. The only two possible exceptions were ATH 682 and JEF 7, two rigid pavements which had moderate to severe transverse midslab cracking at the time of the visits. The latest PCR data used to determine the ratings were collected in 2004, so the amount of deterioration which occurred between 2004 and 2009 is unknown.

3. Tables 3.1 and 3.2 show average subgrade stiffness, as indicated by Df7 readings on the FWD, was very good on all pavements selected as providing average to excellent performance, with flexible pavements having slightly lower average midslab Df7 deflections than rigid pavements. Average normalized Df7 on the flexible projects ranged from 0.07-0.20 mils/kip (0.40-1.14 mm/MN) and averaged 0.10 mils/kip (0.57 mm/MN), while average normalized Df7 on the rigid pavements ranged from 0.08-0.20 mils/kip (0.46-1.14 mm/MN) and averaged 0.13 mils/kip (0.74 mm/MN). Subgrades under the excellent pavements were slightly stiffer than subgrades under the average pavements. The consistent low values for Df7 on all projects do, however, emphasize the need for uniform stiff subgrades. It is recommended that ODOT implement procedures to control subgrade stiffness during construction with various devices like the standard FWD, lightweight portable FWD, Humboldt tester, or DCP. The standard FWD averages stiffness to a considerable depth and over a rather broad area where the effect of occasional small to medium rocks is negated. The lightweight FWD and Humboldt tester, by applying lighter loads, measure stiffness to a shallower depth and over a smaller area. The DCP measures stiffness to a depth of 3 feet (0.91 m) and at a very specific point where rocks can have a significant effect on the results. By being faster, applying a larger load, and averaging stiffness over a broader area and to a greater depth, the standard FWD provides a much better statistical representation of subgrade stiffness within a given period of time.

4. During the site visits, it became apparent that many cracking patterns appear on flexible pavements, and these patterns are generally associated with particular types of structural, construction, or material distress. These patterns are identified and rated accordingly during the PCR evaluations. Unfortunately, it is difficult to visually determine the severity of certain cracks with regard to how they will impact remaining service life.

   Pavement cracks tend to progress either from the bottom up or from the top down. Bottom up cracks are generally initiated by excessive dynamic tensile stresses and/or material degradation in the lower portions of the pavement layer, in the base or in the subgrade. These cracks progress rapidly toward the surface and proliferate as the effective stiffness of the pavement structure diminishes. Top down cracks are generally initiated by oxidation of the asphalt binder on the pavement surface as it ages, which causes it to become brittle and less resistant to climatic changes. Top down cracks are less severe than bottom up cracks because they grow very slowly and have a minimal effect on the overall capacity of the pavement structure to carry traffic. Another form of flexible pavement cracks are induced thermally when cold temperatures cause transverse cracks to appear in the surface at regularly spaced intervals. Thermal cracking does not occur frequently, but can develop on projects where the asphalt concrete becomes brittle at low temperatures. While these cracks can accelerate distress by permitting water to infiltrate the pavement structure, further cracking is unlikely once the thermally induced tensile stresses are relieved.

5. Differences in performance on flexible pavement sites DEL 23 17S (SHRP 902) and DEL 23 18S (SHRP 112) illustrate the importance of the surface course mix. The two sites were constructed on the Ohio SHRP Test Road in 1996 and have very similar buildups, with both having 4” (10.2 cm) of surface and intermediate AC, 12” (30.5 cm) of ATB, and 4” (10.2 cm) of PATB. SHRP 902 had an additional 6” (15.2 cm) of DGAB. The sites are located adjacent to each other in the southbound direction. The surface of SHRP 902 was in excellent condition while SHRP 112 had moderate cracking of various types. The surface of SHRP 112 was a standard ODOT mix, while the SHRP 902 mix used PG asphalt cement grading and polymers. This comparison of Sections 112 and 902 on the Ohio SHRP Test Road supports the continued use of SHRP procedures and polymers to design AC mixes on heavily traveled flexible pavements.

6. With the exception of GAL 7, which was more than 60 years old, average load transfer on all rigid pavements ranged from 75.6-98.9%. Load transfer on GAL 7 was about 44%. When GAL 7 is removed from the group averages, midslab deflection and load transfer were slightly better on the excellent pavements than the average pavements, but the difference is not considered significant. Generalized FWD indicators of good to excellent rigid pavement performance on this project were maximum normalized midslab deflection (Df1) being $\leq$ 0.50 mils/kip (2.9 mm/MN) and joint load transfer being $\geq$ 80%. The ATH 33 project, which is 50 years old but had all joints replaced, had above average

midslab and joint deflections, but excellent load transfer. One core taken at the interface of the replacement and original concrete showed the newer concrete to be deteriorated at the bottom of the pavement. See Figures F6 and F7 in Appendix F. The extent of this problem should be investigated further.

7. DCP measurements used to calculate average subgrade M_R should be taken to a minimum depth of 24 inches (61 cm) to obtain values compatible with those determined with the FWD.

8. Of the 20 rigid pavement projects, 17 were constructed with 451 reinforced concrete pavement and three were constructed with 452 plain concrete pavement. Of the 452 projects, LOG 33 project had some drainage issues which caused localized longitudinal joint deterioration and may have resulted in the project being rated average, while the MOT 35 and MOT 202 projects were excellent. From these three projects, the 452 plain concrete projects are performing quite well.

Chapter 4
Laboratory Testing

General

Twenty-two cores were collected at each flexible pavement site for laboratory testing. Two of these cores were sent to the Asphalt Section in the ODOT Office of Materials Management in Columbus for the determination of mix parameters, including bulk specific gravity, maximum specific gravity, % air voids, % density, % asphalt cement and aggregate gradation for the different material layers in the cores. F/A is a calculated parameter used to express the ratio of percent material passing the #200 sieve divided by percent asphalt cement in the mix. This ratio is an indicator of how much fine material is present per unit volume of asphalt cement and, therefore, how much asphalt cement may be used to coat the fine aggregate and unavailable to bind the larger aggregate. ODOT limits F/A ratios to a maximum of 1.2 for surface and intermediate materials, but no limits are placed on base materials.

The other 20 flexible cores were taken to the ORITE lab in Athens for the determination of various structural properties, including indirect tensile strength, creep compliance, dynamic modulus, Poisson's Ratio and resilient modulus of the various pavement layers. Equipment problems were encountered when trying to maintain the creep compliance specimens at temperatures of 0°, -10° and -20° C (32°, 14° and -4° F) during testing, so results presented in this chapter are limited to a few of the better examples from the intermediate and base layers. Linear and log-log plots for all creep compliance tests and a table of applied loads for each project are shown in Appendix G. Since the flexible projects ranged from 11 to 25 years in age, results presented herein reflect aged asphalt concrete which has oxidized and changed its structural properties to some extent from the time it was placed.

Fourteen cores were collected at each rigid pavement site. Two, including one at a midslab crack (if available) and one across a joint between dowel bars, were sent to Lankard Materials Laboratory (LML) in Columbus for a petrographic examination, and the remaining 12 cores were sent to the ORITE lab for a determination of structural properties of the Portland cement concrete, including unit weight, compressive strength, static modulus, split tensile strength, Poisson's Ratio, and Coefficient of Thermal Expansion.

The 451 PC concrete was reinforced with wire mesh. Because of difficulties associated with avoiding the mesh when coring, especially for 6 inch (15.2 cm) diameter cores, cores in 451 concrete were taken without regard for the mesh. Mesh did not affect the petrographic examinations, and a single strand of mesh had little effect on structural properties. Cores with intersecting strands of mesh were not tested.

Pavement cores were generally intact as they were removed from the holes but, occasionally, environmental conditions and/or material problems resulted in the cores being delaminated at AC layer interfaces, or sufficiently deteriorated that zones near the bottoms of both types of cores were either broken in pieces or reduced to rubble. All pavement material recovered from the core holes was retained and included with the intact portion of the cores.

Results of mix parameter and aggregate gradation testing of AC materials at the ODOT laboratory, and structural testing of the flexible cores at ORITE are presented in this chapter. Test results for the rigid cores are also briefly summarized in this chapter, but in-depth analyses and discussions of the petrographic examinations at LML and the structural data from ORITE have been incorporated into Volume 2 of this report. Coefficients of Thermal Expansion for concrete cores are included at the end of this chapter. Samples of unstabilized base and subgrade materials retrieved from the cores holes were tested in the ORITE laboratory in Athens, and these results are also included in this chapter.

Laboratory Testing of AC Surface Layers

Mix Parameters

Asphalt concrete surface courses must provide a smooth riding surface and be sufficiently durable to resist high vertical tire pressures, horizontal shear forces, and harsh climatic conditions. The older ODOT 404 surface mixes performed reasonably well for many years but, as traffic loading steadily increased, it became necessary to upgrade to more durable 446 and 448 mixes, some of which were modified to T1, T2 and T1H mixes with higher percentages of larger aggregate. Polymers were added on heavily traveled routes to further enhance performance. As SHRP products became available in the late 1990's, states were urged to begin implementing new procedures for grading asphalt cements and specifying asphalt concrete mixes. ODOT has closely monitored these developments over the years, and implemented and improved them as appropriate for conditions in Ohio.

Top down cracking on flexible pavements is common on older surfaces as they age and become more brittle. This process is rather slow and, while these cracks affect PCR ratings, they are not an indicator of serious deterioration or loss of stiffness deeper in the pavement structure. Bottom up cracking, however, is usually associated with some type of structural failure or material problem in the base course or subgrade. One exception is infrequent transverse low temperature thermal cracking which provides paths for water to enter the base/subgrade, but does not necessarily lead to premature failure. When bottom up structural cracks begin to appear, pavement material around the distressed area becomes increasingly overstressed and the distress progresses at an ever increasing rate until maintenance is soon required. Cracks on flexible pavements performing as expected or better than expected are likely to be top down, while bottom up cracking is usually a sign of serious problems on poorly performing pavements.

Table G1 in Appendix G shows mix parameters and aggregate gradations determined at the ODOT Laboratory for individual layers in the flexible pavement cores, and Table G2 summarizes data for surface materials by AC mix type and level of performance. Table 4.1 provides a summary of average surface mix parameters in Table G2 by level of performance for the four mix types and for paired sections on the same projects having average and excellent performance. While there are no clear and consistent differences in parameters between average and excellent performing sections by mix type or within paired sections, averages of all sections show excellent performing flexible pavements had higher air voids, lower density, and lower asphalt cement content than average performing pavements, and both had the same F/A ratio. The density results were somewhat surprising in that higher densities are usually associated with better performance. Since raveling was noted as a common distress on most average and excellent performing flexible sections selected for study, an argument could be made for slightly increasing asphalt contents in all surface mixes to reduce raveling and improve performance. Conversely, minimal raveling has little structural effect on performance, it maintains good texture for skid resistance, lean mixes rut less, and raveling was not noted during the site visits.

As expected, asphalt contents for average performing pavements were lower for the 446 T1H and 448 T1H mixes than the 446 T1 mix. This trend was reversed, however, on the excellent pavements with average asphalt contents on 446 T1 and 448 T1H mixes being 5.44% and 6.32%, respectively. This reversal on the excellent pavements was caused by asphalt contents less than 5% being measured on BUT 129 22E and HAM 126 11E with 446 T1 mixes, and 6.94% being measured on GRE 35 21E with a 448 T1H mix. Although gravel mixes typically have lower absorption and lower binder contents than limestone mixes, BUT 129 22E and GRE 35 21E had limestone aggregate and HAM 126 11E contained a gravel/ limestone blend of aggregate.

Table 4.1

Flexible Surface Layers - Mix Parameter Summary

Average Surface Mix Parameters by Category and Performance (Average / Excellent Performance)				
Category	**% Air Voids**	**% Density**	**% Asphalt**	**F/A Ratio**
All sections	5.4 / 6.0	94.7 / 94.1	5.67 / 5.65	0.8 / 0.9
Mix Type - All Sections				
446 T1	6.0 / 6.2	94.0 / 93.9	6.01 / 5.52	0.9 / 0.8
446 T1H	5.6 / ---	94.4 / ---	5.71 / ---	0.8 / ---
448 T1H	6.2 / 5.5	93.8 / 94.6	5.30 / 6.32	0.6 / 1.0
404	4.6 / 5.8	95.4 / 94.2	5.33 / 5.26	0.9 / 0.7
Paired Sections				
BUT 129 22W/E	5.1 / 4.9	94.9 / 95.2	4.82 / 4.68	1.0 / 0.3
CHP 68 2.5N/2N	6.2 / 4.2	93.8 / 95.9	5.30 / 5.69	0.6 / 0.8
CLA 41 4N/3N	5.1 / 5.8	94.9 / 94.2	5.42 / 5.26	0.8 / 0.7
DEL 23 18S/17S	8.4 / 5.6	91.6 / 94.5	6.48 / 6.25	1.0 / 0.8
PIK 32 19W/E	--- / 4.9	--- / 95.1	6.40 / 6.03	0.8 / 1.0

While aggregate selection is largely a function of local availability, experience has shown limestone to provide slightly better overall performance than gravel on flexible pavement surfaces statewide. Of the flexible projects selected for this research, however, surface mixes containing both types of aggregate separately and in combination are providing average and excellent performance. Figure 4.1 shows average gradations for each mix type and performance level represented by the various surface mixes. Gradations shown in bold lines as providing excellent performance have a midrange hump characterized by higher percentages of aggregate passing the #8 to #30 sieves.

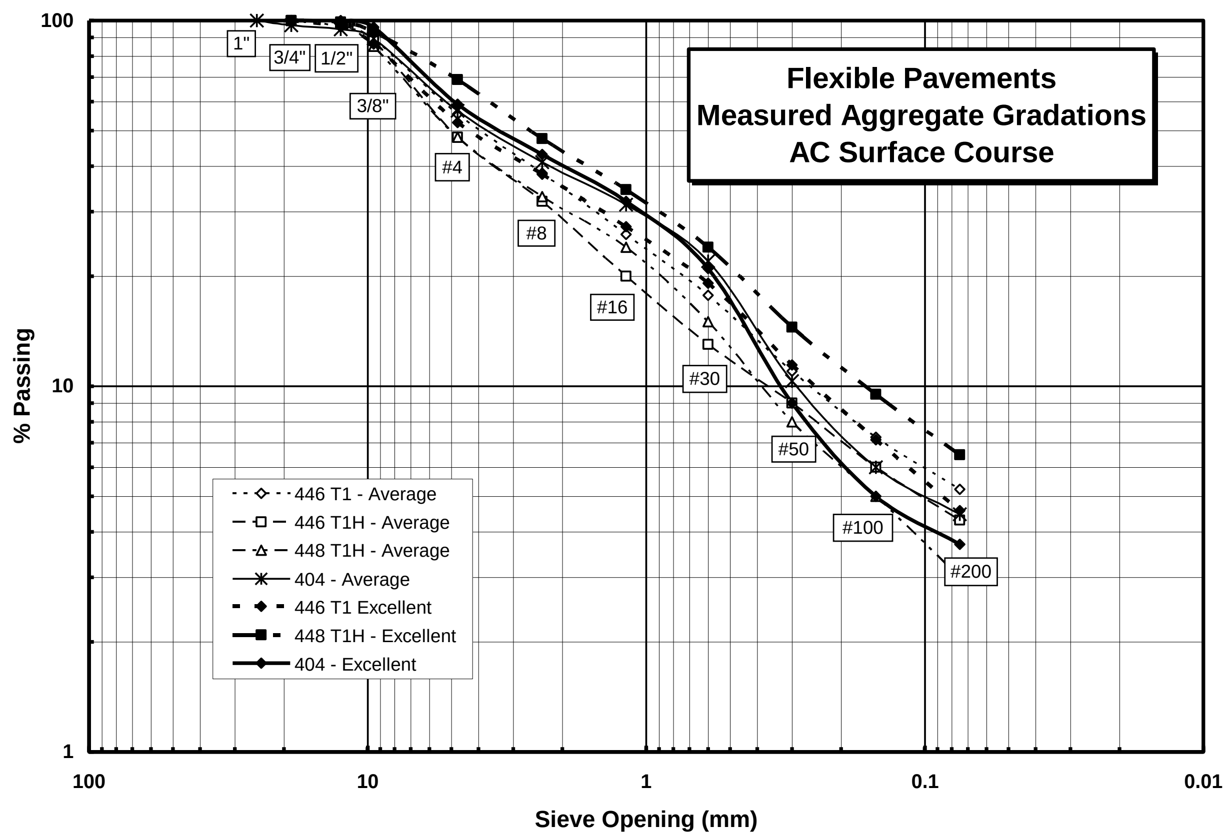


Figure 4.1 – Flexible Surface Layers - Aggregate Gradations

Indirect Tensile Strength

Table 4.2 provides the results of indirect tensile strength (ITS) tests performed at ORITE on surface layers with 4 inch (102 mm) diameter cores at 25° C (77° F) in accordance with SHRP P07. Average dry and wet ITS, and Tensile Strength Ratio (TSR) varied considerably within paired sections and performance groups, but mean values for the average and excellent performing pavements were essentially the same. TSR, calculated as wet ITS divided by dry ITS, serves as an indicator of how moisture affects tensile strength of the mix by stripping asphalt cement from the aggregate and reducing the bond between aggregate particles. Approximately half of the sections in each performance group had TSRs above 75%, which is considered to be a lower limit for good stripping resistance. DEL 23 18S, with average performance, and HAM 126 11E and ROS 35 1W, with excellent performance, had surface TSRs below 60%. DEL 23 18S and ROS 35 1W contained limestone aggregate, while HAM 126 11E had a limestone/gravel blend, so TSR does not appear to affect level of performance or be affected by aggregate type.

Table 4.2

Flexible Surface Layers – Indirect Tensile Strength

Indirect Tensile Strength - Surface Layer, 4" (102 mm) Cores, 25° C (77° F)								
Flexible Pavement Section (Co/Rte/SLM/Dir)	Surface Material	Aggregate Type	% AC	Dry ITS Average Strength		Wet ITS Average Strength		Tensile Strength Ratio* (%)
				Mpa	psi	Mpa	psi	
Average Performance								
BUT 129 22W**	446 T1	LS	4.82	0.823	119			
BUT 129 25W	446 T1	LS/GR	6.33	1.182	172	0.914	133	77.3
CHP 68 2.5N**	448 T1H	LS/GR	5.30	1.008	146	0.685	99	67.9
CLA 41 4N**	404	GR	5.42	1.124	163	1.037	150	92.2
DEL 23 18S**	446 T1	LS	6.48	1.129	164	0.605	88	53.6
HAM 747 1S	404	LS	5.60	1.134	165	1.024	149	90.3
LAW 527 2N	404	LS	4.97	0.825	120	0.519	75	62.9
LUC 2 22E	446 T1H	LS	5.71	0.630	91	0.474	69	75.2
PIK 32 19W**	446 T1	LS	6.40	1.204	175	0.898	130	74.6
VAN 30 18E	Composite Pavement							
		Average	5.67	1.007	146	0.769	112	76.4
		Std. Dev.	0.62	0.201	29	0.226	33	13.0
Excellent Performance								
BUT 129 22E**	446 T1	LS	4.68	0.866	126	0.767	111	88.5
CHP 68 2N**	448 T1H	LS/GR	5.69	0.799	116	0.588	85	73.5
CLA 41 3N**	404	GR	5.26	1.284	186	1.029	149	80.1
DEL 23 17S**	446 T1 Spec.	LS/SL	6.25	1.024	149	0.726	105	70.9
GRE 35 21E	448 T1H	LS	6.94	0.664	96	0.595	86	89.6
HAM 126 11E	446 T1	LS/GR	4.79	1.067	155	0.582	85	54.6
LUC 25 10S	446 T1	LS	5.66	0.926	134	0.919	133	99.2
PIK 32 15W	446 T1	LS	5.90	1.086	158	0.765	111	70.5
PIK 32 19E**	446 T1	LS/GR	6.03	1.051	153	0.971	141	92.3
ROS 35 1W	446 T1	LS	5.32	1.150	167	0.677	98	58.9
		Average	5.65	0.992	144	0.762	111	76.8
		Std. Dev.	0.68	0.181	26	0.163	24	14.7

* Wet ITS/ Dry ITS ** One of two paired sections on the same project

Laboratory Testing of AC Intermediate Layers

Mix Parameters

Intermediate AC courses are covered by the surface course and, therefore, less exposed to severe loading and environmental conditions, and designed primarily to provide structural support for the surface layer and transfer load to the base layer. Table G3 in Appendix G shows mix parameters for the intermediate layers, and Table 4.3 provides a summary of mix results for four intermediate materials and the five flexible projects with paired sections of differing performance on the same project. Mix parameters for all average and excellent performing sections showed similar trends as the surface materials; air voids were higher, density was slightly lower and asphalt content was lower on the excellent sections than on the average sections. In four of the five paired sections, this trend was reversed. The one consistent set of paired sections was at the DEL 23 site where the excellent performing SHRP mix in Section 17S (SHRP 902) had higher air voids, lower density and lower asphalt content than the average performing standard ODOT mix in Section 18S (SHRP 112).

Figure 4.2 shows a midrange hump in all aggregate gradations for the different intermediate materials and levels of performance. The only outlier was 403 base on HAM 747 1S, which follows the other curves but, because it is above the other gradations, is finer throughout than the 446 T2, 448 T2 and 402 mixes used on other projects.

Table 4.3

Flexible Intermediate Layers - Mix Parameter Summary

Average Intermediate Mix Parameters by Category and Performance (Average / Excellent Performance)				
Category	**% Air Voids**	**% Density**	**% Asphalt**	**F/A Ratio**
All sections	5.5 / 5.7	94.5 / 94.3	5.22 / 5.03	0.8 / 0.8
Mix Type - All Sections				
446 T2	5.4 / 5.8	94.6 / 94.3	5.37 / 4.93	0.8 / 0.9
448 T2	5.0 / 5.5	95.1 / 94.6	4.51 / 5.28	1.0 / 0.7
402	5.8 / 5.6	94.3 / 94.4	5.02 / 5.20	0.7 / 0.6
403	6.0 / ---	94.0 / ---	5.54 / ---	0.9 / ---
Paired Sections				
BUT 129 22W/E	5.6 / 3.6	94.4 / 96.5	4.71 / 5.01	0.6 / 0.7
CHP 68 2.5N/2N	5.0 / 3.8	95.1 / 96.2	4.51 / 4.68	1.0 / 1.0
CLA 41 4N/3N	7.8 / 5.6	92.2 / 94.4	4.50 / 5.20	0.7 / 0.6
DEL 23 18S/17S	6.5 / 7.0	93.5 / 93.0	6.10 / 5.75	1.0 / 1.0
PIK 32 19W/E	5.3 / 4.2	94.7 / 95.9	5.01 / 5.21	0.6 / 0.8

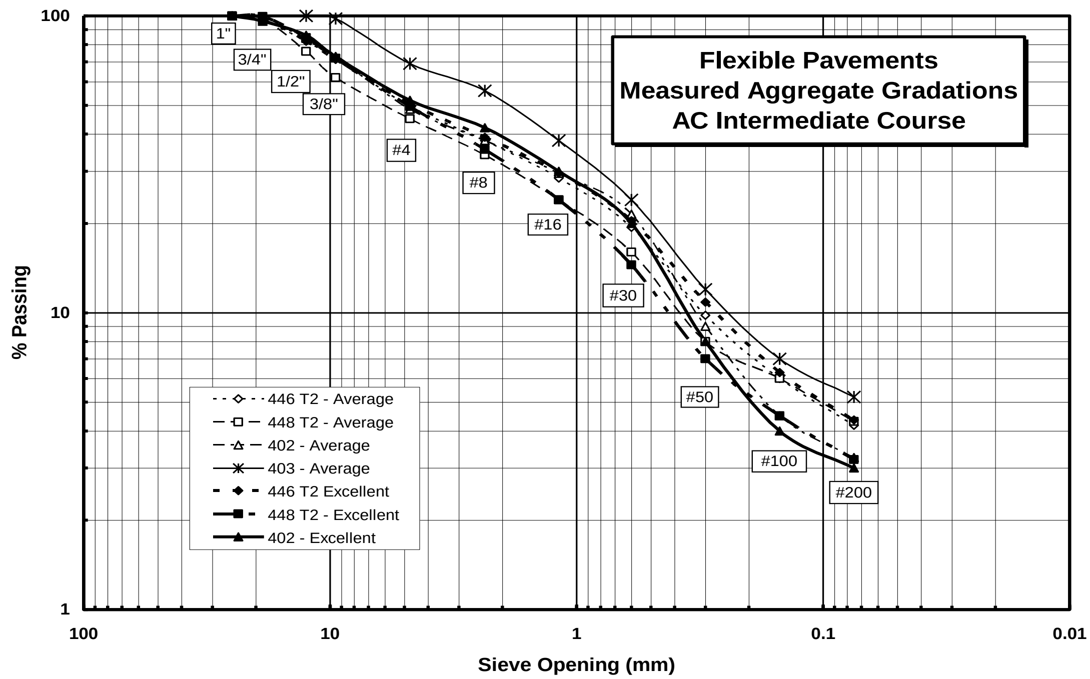


Figure 4.2 – Flexible Intermediate Layers - Aggregate Gradations

Indirect Tensile Strength

Table 4.4 provides a summary of Indirect Tensile Strengths (ITS) measured on intermediate layers with 4 inch (102 mm) diameter cores at 25° C (77° F), and cold strengths measured with 6 inch (152 mm) diameter cores at 0°, -10° and -20° C (32°, 14° and -4° F) in accordance with SHRP P07. There were wide variations in tensile strength and Tensile Strength Ratio (TSR) at 25° C (77° F) within both groups of average and excellent performing pavements, but averages for the two groups were similar. TSRs above 75% at 25° C (77° F) are indicative of good resistance to asphalt stripping. On paired sections, the excellent performing sections tended to have higher dry and wet ITS, and higher TSR. Dry ITS was 94 psi on CHP 68 2.5N (average performance) and 60 psi on CHP 68 2N (excellent performance) which, when combined with wet ITS of 56 and 57 psi, respectively, resulted in a much higher TSR on the excellent pavement.

While TSR varied widely within both performance groups and each group had a few sections with TSR above the 75% level of acceptance, the majority of sections in both groups were below 75%. CHP 68 2.5N, with average performance, and HAM 126 11E and ROS 35 1W, both with excellent performance, had TSRs below 60% in the intermediate layers. HAM 126 11E and ROS 35 1W both also had TSRs below 60% in the surface layers. CHP 68 2.5N and HAM 126 11E had gravel aggregate, while ROS 35 1W had limestone aggregate.

Table 4.4

Flexible Intermediate Layers - Indirect Tensile Strength

Indirect Tensile Strength - Intermediate Layer											
Flexible Pavement Section (Co/Rte/SLM/Dir)	Intermediate Material	Aggregate Type	% AC	Dry ITS Average Strength*		Wet ITS Average Strength*		Tensile Strength Ratio** (%)	ITS Cold Strength Temp. (°C)	Average Strength***	
				Mpa	psi	Mpa	psi			Mpa	psi
Average Performance											
BUT 129 22W	446 T2	LS	4.71	0.549	80						
BUT 129 25W	446 T2	LS/GR	5.28	1.065	155	0.739	107	69.4	-20	2.973	431
									-10	2.759	400
									0	2.407	349
CHP 68 2.5N	448 T2	GR	4.51	0.646	94	0.384	56	59.5	-20	2.358	342
									-10	2.322	337
									0	1.657	241
CLA 41 4N	402	LS/GR	4.50	0.995	144	0.803	117	80.8			
DEL 23 18S	446 T2	LS	6.10	0.812	118	0.535	78	65.9	-20	3.250	472
									-10	2.718	395
									0	2.344	340
HAM 747 1S	403	GR	5.54	1.021	148	0.905	131	88.7			
LAW 527 2N	402	LS	5.53	0.525	76	0.384	56	73.3			
LUC 2 22E	446 T2	LS	5.76	0.436	63	0.399	58	91.4			
PIK 32 19W	446 T2	LS	5.01	1.223	177	0.758	110	62.0			
VAN 30 18E	Composite Pavement										
		Average	5.22	0.808	117	0.613	89	75.9	-20	2.860	415
									-10	2.600	377
									0	2.136	310
Excellent Performance											
BUT 129 22E	446 T2	LS	5.00	0.793	115	0.541	79	68.2	-20	2.368	344
									-10	2.800	406
									0	1.806	262
CHP 68 2N	448 T2	LS/GR	4.68	0.417	60	0.392	57	94.2			
CLA 41 3N	402	GR	5.20	1.127	164	0.786	114	69.7			
DEL 23 17S	446 T2 Spec.	LS/SL	5.75	0.977	142	0.680	99	69.6	-20	3.384	491
									-10	2.916	423
									0	2.404	349
GRE 35 21E	448 T2	LS	5.88	0.660	96	0.421	61	63.8			
HAM 126 11E	446 T2	GR	4.15	0.917	133	0.547	79	59.7			
LUC 25 10S	446 T2	LS/GR	4.86	0.740	107	0.713	104	96.4			
PIK 32 15W	446 T2	GR	5.15	0.859	125	0.649	94	75.6			
PIK 32 19E	446 T2	LS	5.21	1.222	177	0.947	137	77.5			
ROS 35 1W	446 T2	LS	4.91	1.056	153	0.535	78	50.7			
		Average	5.08	0.877	127	0.621	90	70.9	-20	2.876	417
									-10	2.858	415
									0	2.105	305

* 4" cores, 25° C ** Wet ITS/ Dry ITS *** 6" cores 25.4 mm = 1 inch °F = 9/5 (°C) + 3

Figure 4.3 shows cold strengths of the intermediate layers tended to consistently increase with decreasing temperature, which is indicative of good resistance to thermal cracking. The lone exception to this trend was BUT 129 22E with excellent performance. With only two excellent sections tested for cold strength, the BUT 129 22E project caused average strength for the excellent performing projects to also drop off with decreasing temperature. The two paired sections on DEL 23 had the best overall ITS at cold temperatures. Dashed lines were used for average performing projects and solid lines were used for excellent performing projects.

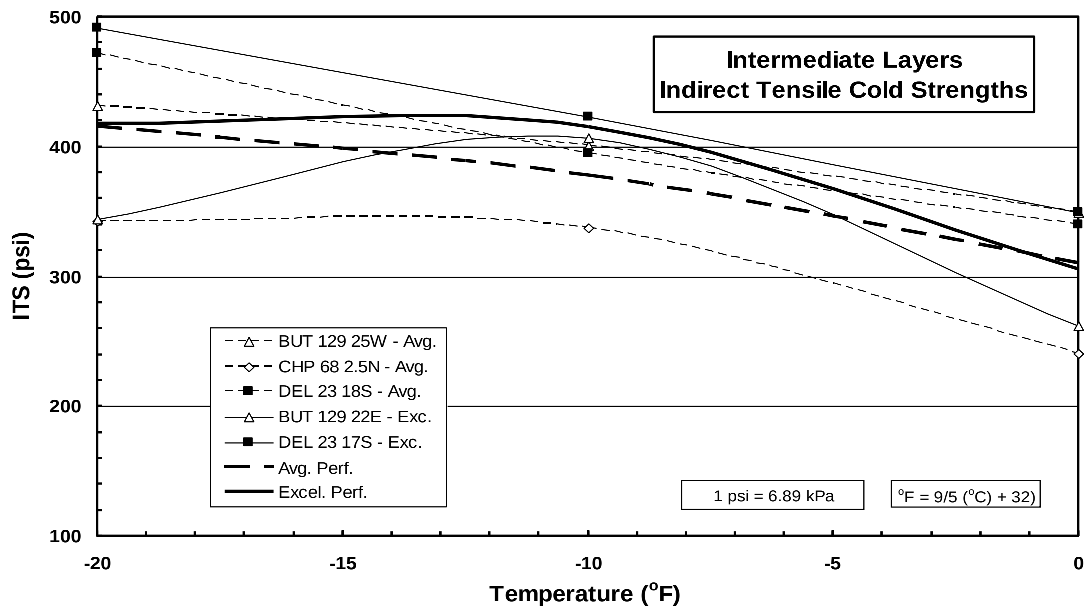


Figure 4.3 – Flexible Intermediate Layers - Cold Strengths

Creep Compliance

Creep compliance tests were used to measure the ability of intermediate and base materials to resist thermal cracking at cold temperatures, with higher values of creep indicating an increased resistance to thermal cracking. Tests were performed at 0° (32° F), -10° C (14° F), and -20° C (-4° F) per SHRP P07. Total test time was 600 seconds with deformations recorded every 0.1 second up to 20 seconds, and then every second up to 600 seconds. Because equipment problems made it difficult to maintain sample temperatures, results of creep compliance tests for intermediate and base layers on this research project should be used cautiously. Loads applied during the tests are shown in Table G8. The data shown, however, provide some estimates of creep compliance D(t) calculated conceptually as follows and in units of 10^{-7}/psi or 1/GPa:

$$\text{Creep Compliance } D(t) = \frac{\text{measured strain x correction factor}}{\text{applied stress}} = \frac{\text{correction factor}}{\text{modulus}}$$

This equation shows that: 1) since the applied load was held constant during the tests, applied stress was also constant and creep compliance increased as viscoelastic strain increased during each test, and 2) creep compliance increased as higher temperatures reduced asphalt moduli. By using the average of three different samples for each temperature curve and calculating correction factors for each sample, material variability also affected the results.

Figure 4.4 shows linear and log-log plots of creep compliance on the DEL 23 17S intermediate layer where, as expected, creep compliance increased with time and temperature. Power trendlines of the form $y = Ax^B$, where A is the creep at one second and B is the slope of the curves on log-log plots, describe short and long term creep, respectively. Constants A and B should both increase with rising temperature. Because creep compliance measured in the first second was consistently low, and because R^2 on all creep compliance trendlines calculated between two and 600 seconds ranged between 0.97 and 1.00, the trendlines were extrapolated back to calculate creep at one second. The DEL 23 17S data were most consistent of the intermediate layer materials tested for order and spacing of the temperature curves. All intermediate and base creep compliance plots are shown in Appendix G.

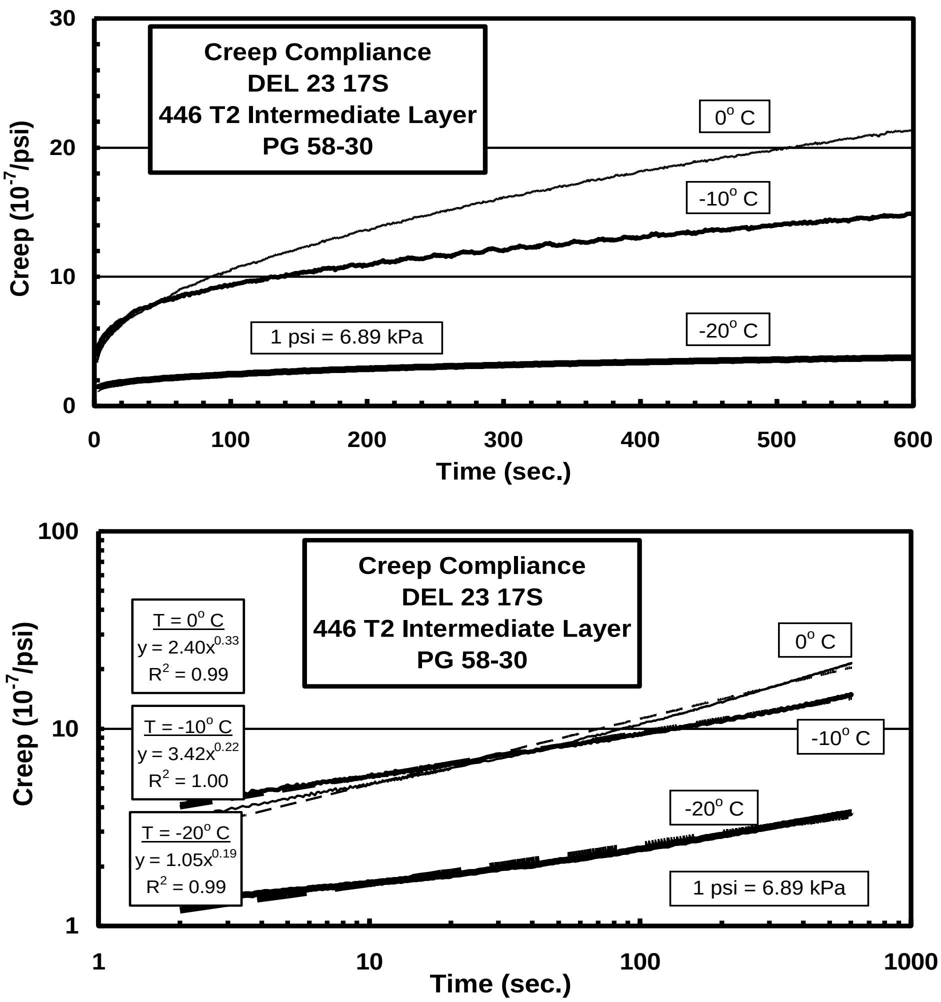


Figure 4.4 – Creep Compliance on DEL 23 17S

Table 4.5 summarizes creep compliance measured for intermediate layers at 1, 2, 5, 10, 20, 50 and 100 seconds at 0° (32° F), -10° C (14° F), and -20° C (-4° F), and the resulting averages by level of performance. These times and temperatures are used as input to the MEPDG Thermal Cracking Module. This table shows the unusually low measurements recorded at one second, a consistent trend of increasing creep compliance with time, a general trend of higher creep compliance at higher temperatures (especially at longer test times), and possible outliers on BUT 129 22E where unusually high creep compliance was recorded at 0^o C (32^o F) and unusually low creep compliance was recorded at -10^o C (14^o F).

Table 4.5

Measured Creep Compliance for Intermediate Layers

Measured Creep Compliance for Flexible Intermediate Pavement Layers - 10^{-7}/ psi								
Pavement Section	Temp. (^{o}C)	Time in Seconds						
		1	2	5	10	20	50	100
Average Performance								
BUT 129 25W	0	0.172	3.048	4.350	5.470	6.873	9.588	12.630
	-10	0.283	1.820	2.327	2.688	3.213	4.157	5.324
	-20	-0.113	4.035	5.152	5.951	7.031	8.854	11.070
CHP 68 2.5N	0	0.261	2.684	4.082	5.238	7.083	10.280	14.100
	-10	0.616	4.617	5.914	6.916	8.567	11.630	14.670
	-20	0.221	2.959	3.488	3.891	4.293	4.949	5.844
DEL 23 18S (PG 58-30 AC)	0	0.230	2.808	3.569	4.272	5.110	6.846	8.812
	-10	0.032	3.904	4.886	5.517	6.290	7.683	9.428
	-20	0.100	3.318	3.797	4.156	4.591	5.457	6.424
Average	0	0.221	2.847	4.000	4.993	6.355	8.905	11.847
	-10	0.310	3.447	4.376	5.040	6.023	7.823	9.807
	-20	0.069	3.437	4.146	4.666	5.305	6.420	7.779
Excellent Performance								
BUT 129 22E	0	-0.801	8.372	12.760	15.930	19.720	26.280	33.050
	-10	0.017	0.908	1.208	1.384	1.588	1.944	2.311
	-20	0.018	2.331	2.979	3.433	3.912	4.849	5.839
DEL 23 17S (PG 58-30 AC)	0	0.645	3.364	4.365	5.177	6.337	8.280	10.610
	-10	-0.096	4.143	5.142	5.719	6.668	8.130	9.341
	-20	0.123	1.311	1.502	1.648	1.820	2.149	2.458
Average	0	-0.078	5.868	8.563	10.554	13.029	17.280	21.830
	-10	-0.039	2.526	3.175	3.552	4.128	5.037	5.826
	-20	0.071	1.821	2.241	2.541	2.866	3.499	4.149

$1/10^{-7}$psi = .0145/Gpa 0^o C = 32^o F, -10^o C = 14^o F, -20^o C = -4^o F

Table 4.6 summarizes constants A and B calculated with power trendlines, R^2 for the trendlines, creep compliance calculated from the trendlines for MEPDG input times and temperatures, and MEPDG defaults for PG 64-28 hot mixed asphalt. Since trendlines approximate the actual measurements so well, the same trends noted for measured data apply to the calculated data. Constants A and B, and R^2 shown in Table 4.6 for the MEPDG defaults were calculated from power trendlines drawn through the defaults.

Table 4.6

Calculated Creep Compliance for Intermediate Layers

Calculated Creep Compliance for Flexible Intermediate Pavement Layers - 10^{-7}/psi											
Pavement Section	Temp. (^oC)	Trendline Constants		R^2	Creep Compliance $Y = AX^B$ at Time X in Seconds						
		A	B		1	2	5	10	20	50	100
Average Performance											
BUT 129 25W	0	2.14	0.40	0.99	2.14	2.824	4.074	5.375	7.093	10.274	13.529
	-10	1.26	0.33	0.99	1.26	1.584	2.143	2.694	3.386	4.597	5.769
	-20	3.07	0.29	0.99	3.07	3.754	4.896	5.986	7.319	9.574	11.689
CHP 68 2.5N	0	1.82	0.46	1.00	1.82	2.503	3.816	5.249	7.220	11.056	15.173
	-10	3.11	0.35	0.99	3.11	3.964	5.463	6.962	8.874	12.272	15.614
	-20	2.38	0.21	0.99	2.38	2.753	3.337	3.860	4.465	5.423	6.267
DEL 23 18S (PG 58-30 AC)	0	1.86	0.36	0.99	1.86	2.387	3.320	4.261	5.469	7.633	9.779
	-10	2.88	0.27	0.99	2.88	3.473	4.447	5.363	6.467	8.304	9.999
	-20	2.59	0.20	0.99	2.59	2.975	3.573	4.105	4.715	5.675	6.512
Average	0	1.94	0.41	0.99	1.940	2.571	3.737	4.962	6.594	9.654	12.827
	-10	2.42	0.32	0.99	2.417	3.007	4.018	5.006	6.242	8.391	10.461
	-20	2.91	0.26	0.99	2.680	3.161	3.936	4.650	5.500	6.891	8.156
Excellent Performance											
BUT 129 22E	0	6.90	0.35	1.00	6.90	8.794	12.120	15.447	19.688	27.227	34.642
	-10	0.74	0.26	0.99	0.74	0.886	1.125	1.347	1.612	2.052	2.454
	-20	1.86	0.26	0.99	1.86	2.227	2.826	3.385	4.053	5.157	6.167
DEL 23 17S (PG 58-30 AC)	0	2.40	0.33	0.99	2.40	3.017	4.082	5.131	6.450	8.756	10.988
	-10	3.42	0.22	1.00	3.42	3.983	4.873	5.676	6.611	8.105	9.430
	-20	1.05	0.19	0.99	1.05	1.198	1.426	1.626	1.855	2.212	2.521
Average	0	4.65	0.34	1.00	4.650	5.906	8.101	10.289	13.069	17.991	22.815
	-10	2.08	0.24	1.00	2.080	2.435	2.999	3.511	4.112	5.078	5.942
	-20	1.46	0.23	0.99	1.455	1.713	2.126	2.505	2.954	3.684	4.344
MEPDG Default for PG 64-28 AC	0	7.80	0.39	1.00	7.80	10.22	14.63	19.18	25.14	35.97	47.16
	-10	5.45	0.24	1.00	5.45	6.46	8.07	9.55	11.30	14.11	16.69
	-20	3.19	0.16	1.00	3.19	3.55	4.10	4.56	5.08	5.86	6.53

$1/10^{-7}$psi = .0145/Gpa 0^o C = 32^o F, -10^o C = 14^o F, -20^o C = -4^o F

Figure 4.5 shows the excellent correlation between measured and calculated creep compliance values for intermediate layer materials having average and excellent performance, except at one second when many measurements were exceptionally low. Figure 4.6 combines average creep by temperature for average and excellent projects and MEPDG defaults.

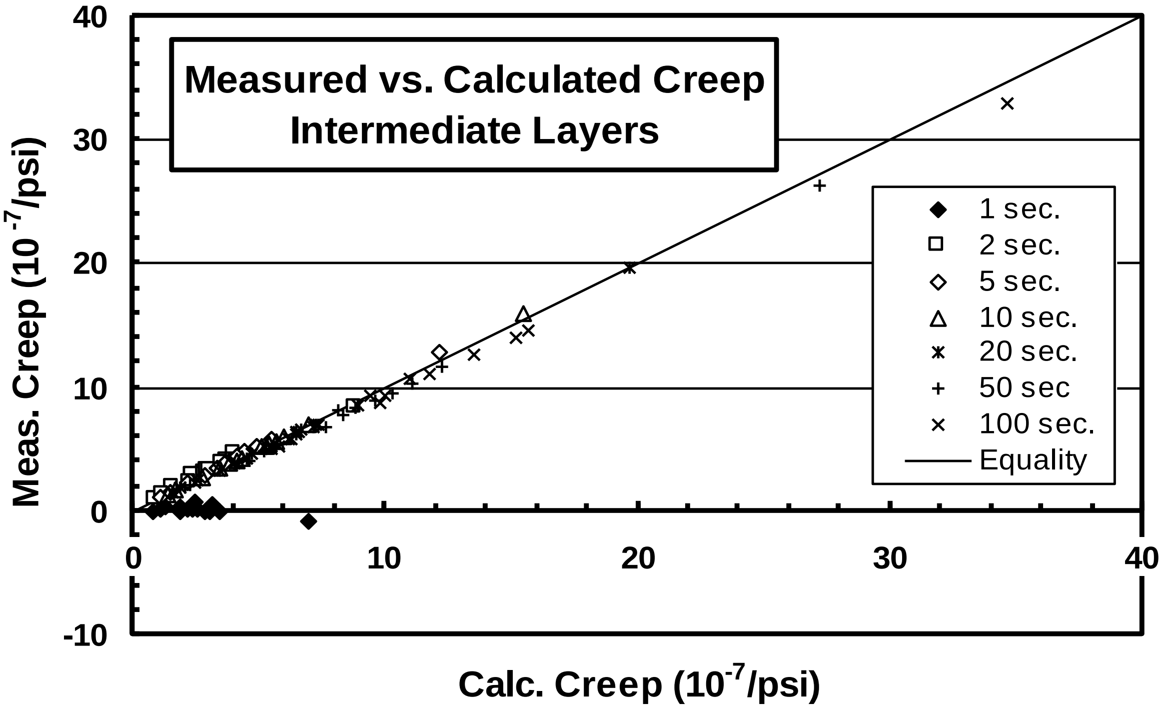


Figure 4.5 - Measured vs. Calculated Intermediate Creep

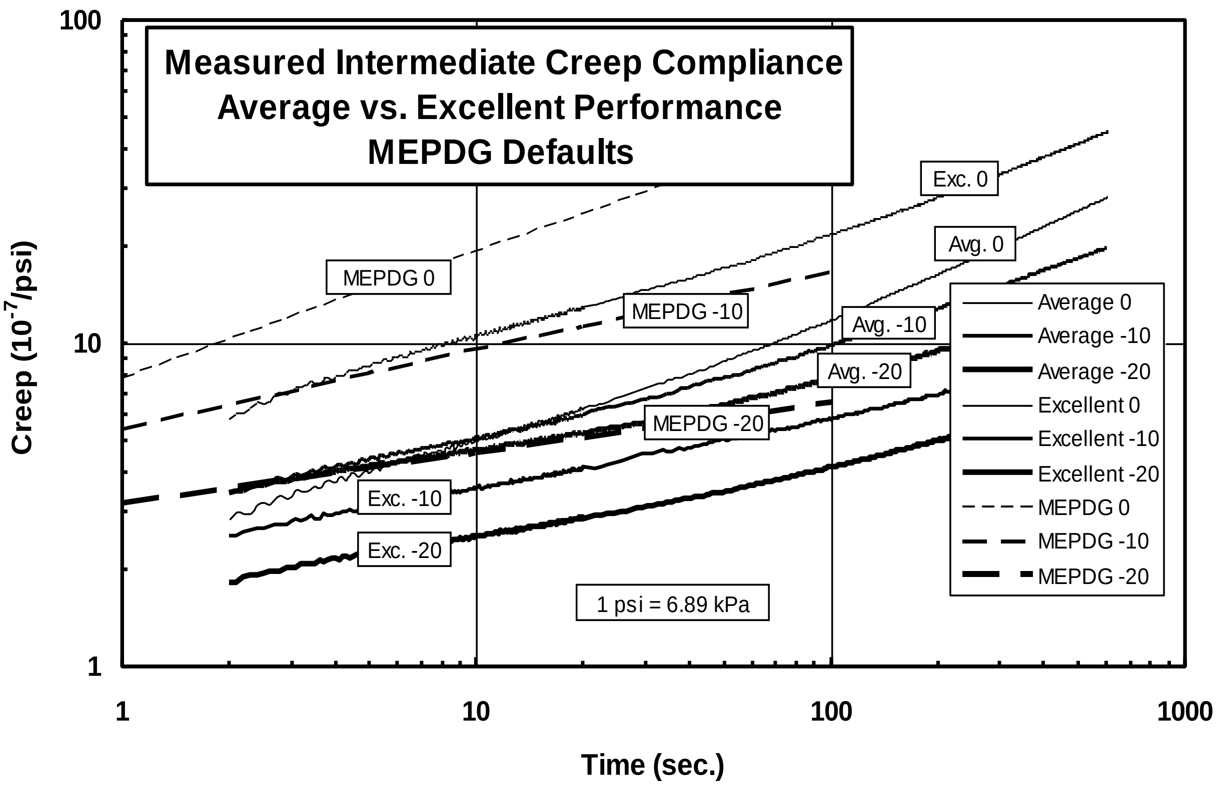


Figure 4.6 – Comparison of Creep Compliance for Intermediate Layers

With only five projects represented, creep compliance consistently increased with time during all tests, but was somewhat inconsistent with temperature. This inconsistency was likely due to equipment problems encountered when trying to maintain constant sample temperatures, and material variability with different samples being used for each site and temperature. While these problems made it difficult to compare creep compliance for different levels of performance, it can be noted that thermal cracking was not observed on any of the average and excellent projects selected for study and, therefore, all results could be considered to be above the threshold where thermal cracking is likely to occur. Figure 4.6 shows that, with the exception of the average performing projects at -20° C (-4° F), average creep compliance for all other temperatures and levels of performance were lower than the MEPDG default values which is, at least partially, due to the specimens being from aged asphalt concrete. Temperature curves were more closely spaced on the average sections than the excellent sections, but the few samples tested limit confidence in these conclusions.

Laboratory Testing of AC Base Layers

Mix Parameters

ODOT 301 and 302 asphalt concrete bases have been used about equally in Ohio. BUT 129 22E/W, BUT 129 25W, and DEL 23 17S/18S were the only sites selected for this research with 302 base. Table G4 in Appendix G lists mix parameters and aggregate gradations measured for base materials at the ODOT Laboratory, and Table 4.7 summarizes average mix parameters by level of performance, mix type and for paired sections on the same project. Considering all sections, air voids and asphalt content were slightly higher on the excellent performing sections than on the average performing sections. 302 mixes in excellent performing pavements had higher air voids, lower density and about the same asphalt content as 302 mixes in average performing pavements. 301 mixes in excellent performing pavements had higher asphalt contents than 301 bases in average pavements. Results were varied on the paired sections with unusually low asphalt contents being measured on both BUT 129 22 sections with 302 base.

Figure 4.7 shows average aggregate gradations for 301 and 302 base mixes in the average and excellent performing pavements. There is not much difference in gradation to separate average sites from excellent sites for each base material, but the 302 mixes were coarser than the 301 mixes and the 301 mixes had a more pronounced midrange hump.

Table 4.7

Flexible Base Layers - Mix Parameter Summary

Average Base Mix Parameters by Category and Performance (Average / Excellent Performance)				
Category	**% Air Voids**	**% Density**	**% Asphalt**	**F/A Ratio**
All sections	5.4 / 5.5	94.6 / 94.5	4.50 / 4.75	1.0 / 1.1
Mix Type - All Sections				
302	5.8 / 6.4	94.3 / 94.7	4.26 / 3.99	1.3 / 1.4
301	5.3 / 5.3	94.8 / 94.7	4.62 / 4.93	0.9 / 1.0
Paired Sections				
BUT 129 22W/E	4.6 / 6.6	95.5 / 93.4	3.71 / 3.48	1.2 / 1.2
CHP 68 2.5N/2N	6.2 / 4.8	93.9 / 95.2	4.51 / 4.90	1.0 / 1.0
CLA 41 4N/3N	5.3 / 6.8	94.6 / 93.2	4.63 / 4.71	0.9 / 0.7
DEL 23 18S/17S	8.5 / 6.1	91.5 / 93.9	5.64 / 4.50	1.3 / 1.5
PIK 32 19W/E	6.4 / 3.6	93.7 / 96.4	4.54 / 5.13	0.7 / 0.8

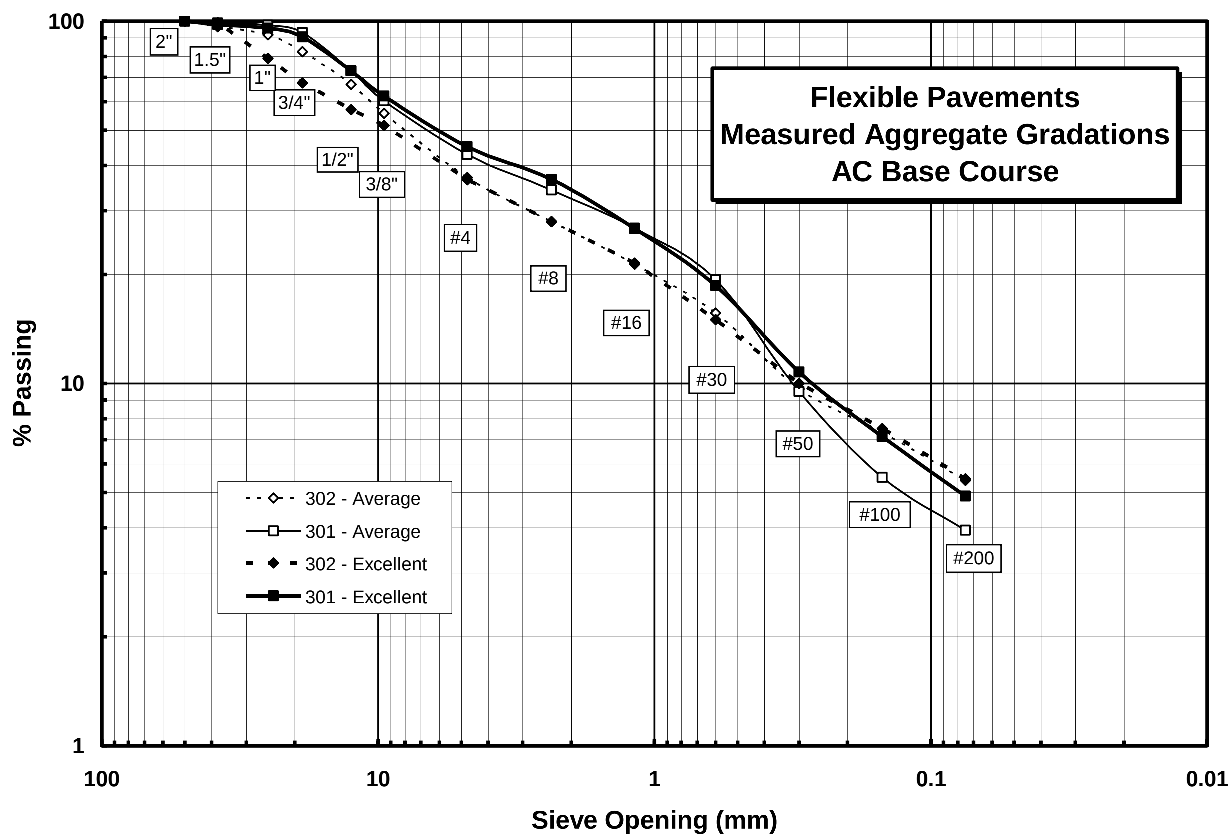


Figure 4.7 - Flexible Base Layers - Aggregate Gradations

Indirect Tensile Strength

Tables 4.8 and 4.9 provide a summary of Indirect Tensile Strengths (ITS) measured with 4 inch (10.2 cm) diameter cores at 25° C (77° F), and cold Indirect Tensile Strengths measured with 6 inch (15.2 cm) diameter cores at 0°, -10° and -20° C (32°, 14° and -4° F) for average and excellent performing pavements, respectively. There were wide variations in tensile strengths and Tensile Strength Ratios (TSR) at 25° C (77° F) for both levels of performance, but group averages were very similar. On the paired sections, dry and wet ITS were mixed, but TSR was higher on four of the five excellent performing sections. While average TSR was below 75% for both levels of performance, three of the nine average performing sections and six of the ten excellent performing sections had TSRs above 75%, indicating good stripping resistance.

Figures 4.8 and 4.9 show cold ITS on average and excellent performing base layers generally increased with decreasing temperature, which is indicative of good resistance to thermal cracking. While all but two sections increased in strength from 0° C (32° F) to -10° C (14° F), two average and five excellent sections, and four of the five excellent paired sections dropped in strength from -10° C (14° F) to -20° C (-4° F), indicating some potential susceptibility to thermal cracking.

Table 4.8

Flexible Base Layers - Indirect Tensile Strength, Average Performance

Indirect Tensile Strength, Base Layer, Average Performance											
Flexible Pavement Section (Co/Rte/SLM/Dir)	Base Material	Aggregate Type	% AC	Dry ITS Average Strength		Wet ITS Average Strength		Tensile Strength Ratio* (%)	ITS Cold Strength		
				Mpa	psi	Mpa	psi		Temp. (°C)	Average Strength Mpa	psi
BUT 129 22W (302)	302	LS	3.71	1.014	147	0.528	77	52.1	-20	2.839	412
									-10	2.831	411
									0	2.198	319
BUT 129 25W (302)	302	LS	3.43	1.176	171	1.016	147	86.4	-20	2.917	423
									-10	3.617	525
									0	2.937	426
CHP 68 2.5N	301	LS, LS/GR	4.51	0.317	46	0.221	32	69.7	-20	3.203	465
									-10	2.155	313
									0	1.970	286
CLA 41 4N	301	GR	4.63	1.095	159	0.700	102	64.0	-20	3.424	497
									-10	3.318	482
									0	2.841	412
DEL 23 18S (302)	302	LS	5.64	0.607	88	0.357	52	58.8	-20	2.397	348
									-10	2.865	416
									0	2.218	322
HAM 747 1S	301	GR	4.75	0.582	85	0.452	66	77.6	-20	3.474	504
									-10	2.842	412
									0	2.545	369
LAW 527 2N	301	LS	5.06	0.757	110	0.662	96	87.5	-20	3.281	476
									-10	2.947	428
									0	2.543	369
LUC 2 22E	301	LS	4.24	0.596	87	0.374	54	62.8	-20	2.851	414
									-10	1.576	229
									0	1.742	253
PIK 32 19W	301	LS	4.54	1.169	170	0.734	106	62.8	-20	2.970	431
									-10	2.626	381
									0	2.507	364
VAN 30 18E	Composite Pavement										
		Average	4.50	0.813	118	0.561	81	69.0	-20	3.040	441
									-10	2.753	400
									0	2.389	347

* Wet ITS/ Dry ITS 25.4 mm = 1 inch °F = 9/5 (°C) + 32

Table 4.9

Flexible Base Layers - Indirect Tensile Strength, Excellent Performance

Indirect Tensile Strength, Base Layer, Excellent Performance											
Flexible Pavement Section (Co/Rte/SLM/Dir)	Base Material	Aggregate Type	% AC	Dry ITS Average Strength		Wet ITS Average Strength		Tensile Strength Ratio* (%)	ITS Cold Strength		
									Temp. (°C)	Average Strength	
				Mpa	psi	Mpa	psi			Mpa	psi
BUT 129 22E (302)	302	LS	3.48	0.815	118	0.620	90	76.1	-20	2.224	323
									-10	2.547	378
									0	2.602	370
CHP 68 2N	301	LS/GR	4.90	0.444	64	0.263	38	59.2	-20	3.642	529
									-10	2.551	483
									0	3.329	370
CLA 41 3N	301	GR	4.71	0.815	118	0.641	93	78.6	-20	2.488	361
									-10	2.580	418
									0	2.883	374
DEL 23 17S (302)	302	LS	4.50	0.903	131	0.565	82	62.6	-20	2.794	406
									-10	3.051	531
									0	3.659	443
GRE 35 21E	301	LS	5.39	0.633	92	0.456	66	72.1	-20	2.820	409
									-10	1.701	325
									0	2.241	247
HAM 126 11E	301	GR	4.97	0.825	120	0.674	98	81.6	-20	4.080	592
									-10	2.970	509
									0	3.509	431
LUC 25 10S	301	LS	4.86	0.532	77	0.409	59	76.9	-20	3.830	556
									-10	2.716	475
									0	3.274	394
PIK 32 15W	301	LS	5.42	0.610	89	0.471	68	77.2	-20	2.113	307
									-10	1.703	238
									0	1.642	247
PIK 32 19E	301	LS/GR	5.13	0.828	120	0.623	90	75.3	-20	3.502	508
									-10	2.939	523
									0	3.607	427
ROS 35 1W	301	LS	4.09	0.794	115	0.492	71	61.9	-20	2.269	329
									-10	2.040	357
									0	2.463	296
		Average	4.75	0.720	104	0.521	76	72.4	-20	3.055	432
									-10	2.529	424
									0	2.972	360

* Wet ITS/ Dry ITS 25.4 mm = 1 inch °F = 9/5 (°C) + 32

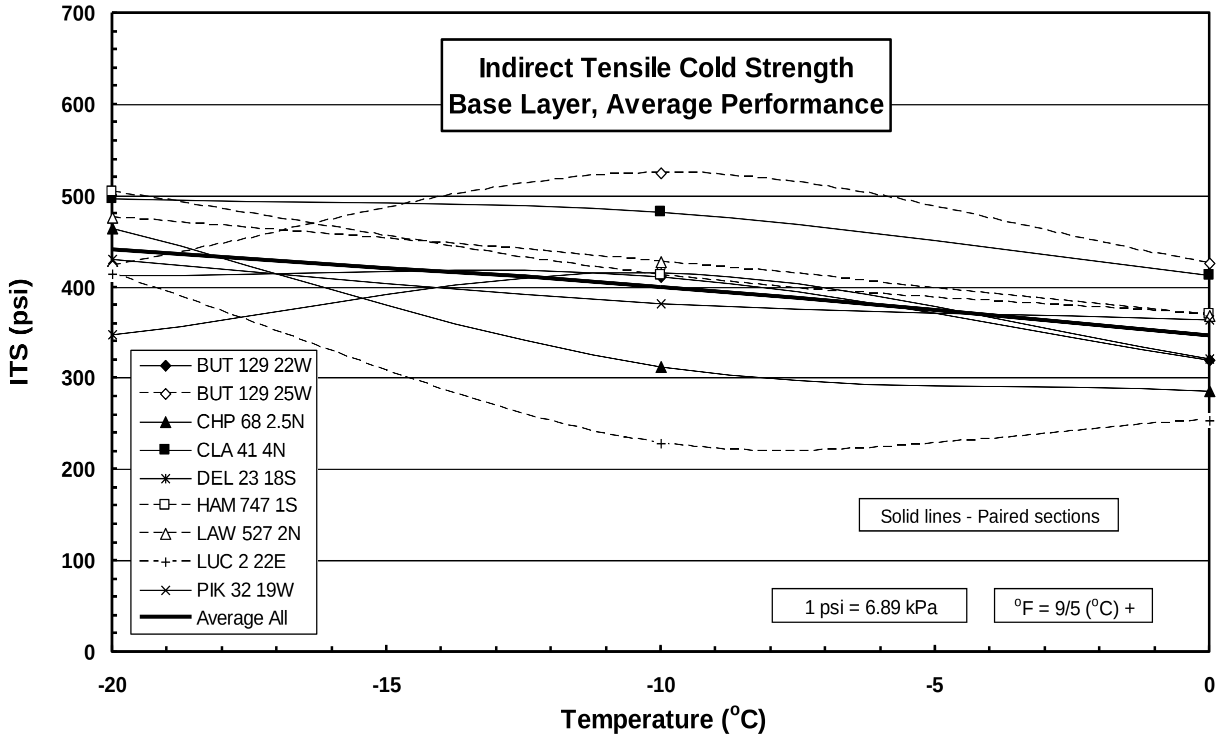


Figure 4.8 – Flexible Base Layers - Cold Strengths, Average Performance

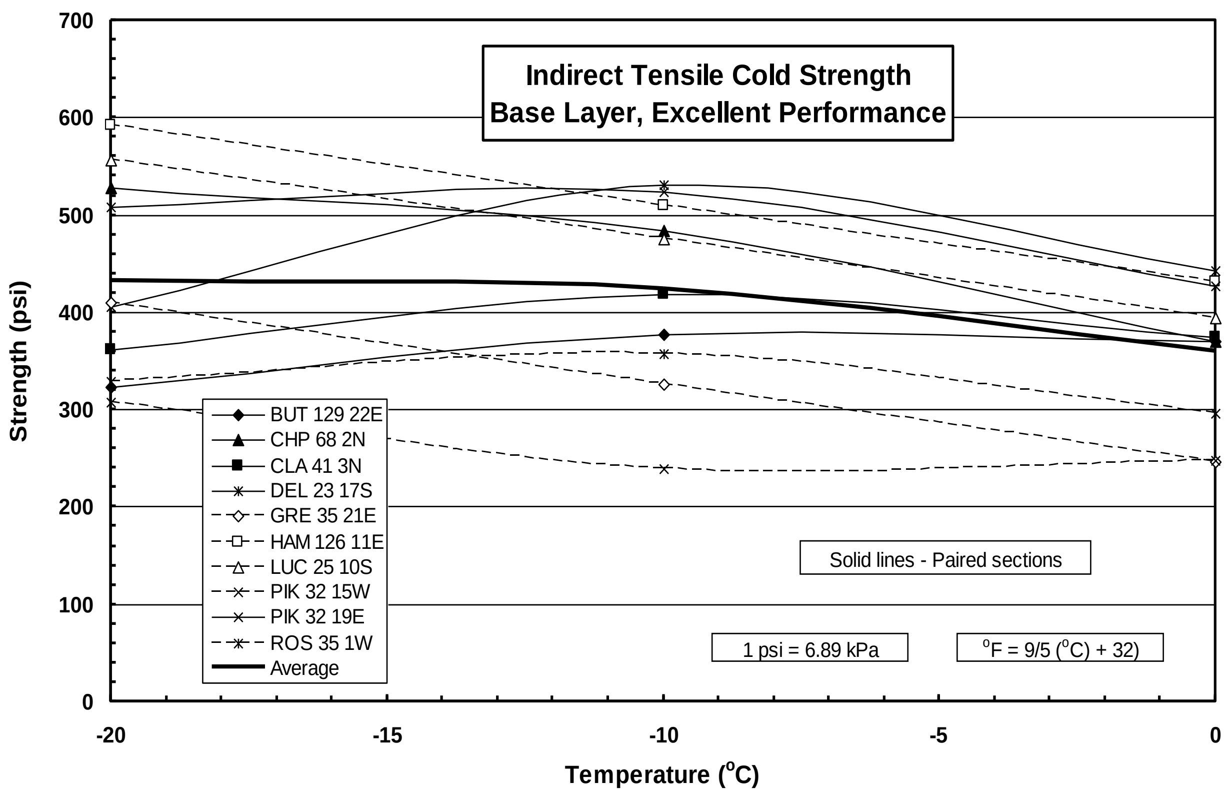


Figure 4.9 – Flexible Base Layers - Cold Strengths, Excellent Performance

Poisson’s Ratios and Resilient Moduli

Table 4.10 summarizes Poisson’s Ratio and resilient moduli measured at 5° C (41° F), 25° C (77°F) and 40° C (104° F) for flexible base materials, and the MEPDG Level 3 default values for Poisson’s Ratio. Figures 4.10 and 4.11 show 302 bases, with the exception of DEL 23 18S at 40° C (104° F), to consistently have higher resilient moduli than 301 bases, and bases on the excellent performing pavements to have higher average resilient moduli than the average performing pavements at all temperatures. Average Poisson’s Ratios were similar for the average and excellent performing pavements with all averages being below the MEPDG defaults.

Table 4.10 – Flexible Base Layers - Resilient Modulus & Poisson’s Ratio

Base Layer - Poisson's Ratio and Resilient Modulus								
Route	Project Number	Base Spec.	Poisson's Ratio			Resilient Modulus (ksi)		
			5° C (41° F)	25° C (77° F)	40° C (104° F)	5° C (41° F)	25° C (77° F)	40° C (104° F)
Average Performance								
BUT 129 22W	9330(98)	302						
BUT 129 25W	9327(98)	302	0.06	0.25	0.30	1214	1077	526
CHP 68 2.5 N	233(98)	301	0.06	0.42	0.50	1248	491	287
CLA 41 4N	63(95)	301	0.07	0.26	0.40	1005	654	474
DEL 23 18S (112)	380(94)	302	0.06	0.26	0.34	1324	702	425
HAM 747 1S	347(85)	301	0.03	0.34	0.50	1065	649	318
LAW 527 2N	17(85)	301	0.05	0.40	0.50	1071	479	271
LUC 2 22E	141(99)	301	0.04	0.25	0.35	1048	622	351
PIK 32 19W	552(95)	301						
VAN 30 18E	219(97)	301	Composite Pavement					
		Average	0.05	0.31	0.41	1139	668	379
		Std. Dev.	0.01	0.07	0.09	121	199	98
Excellent Performance								
BUT 129 22E	9330(98)	302	0.00	0.25	0.27	1416	1124	536
CHP 68 2N	233(98)	301	0.08	0.40	0.50	1210	480	422
CLA 41 3N	63(95)	301	0.03	0.25	0.28	1209	830	359
DEL 23 17S (902)	380(94)	302	0.11	0.25	0.34	2162	987	555
GRE 35 21E	259(98)	301	0.06	0.36	0.50	1190	676	262
HAM 126 11E	645(94)	301						
LUC 25 10S	665(97)	301	0.04	0.45	0.50	1198	577	311
PIK 32 15W	443(94)	301	0.02	0.25	0.44	1160	544	352
PIK 32 19E	552(95)	301						
ROS 35 1W	298(96)	301	0.04	0.25	0.30	1308	947	511
		Average	0.05	0.31	0.39	1356	771	414
		Std. Dev.	0.04	0.08	0.10	336	236	110
		MEPDG Level 3 Default	0.25	0.35	0.45			

1 ksi = 6.89 Mpa

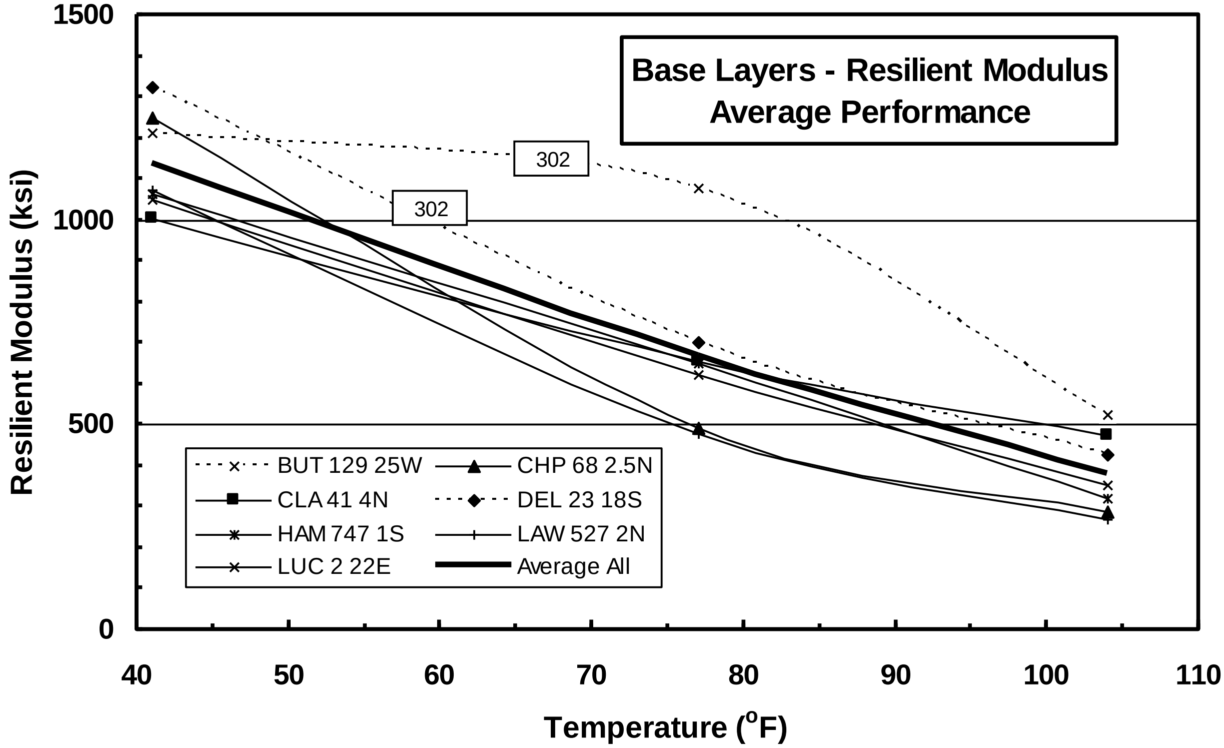


Figure 4.10 – Flexible Base Layers - Resilient Moduli, Average Performance

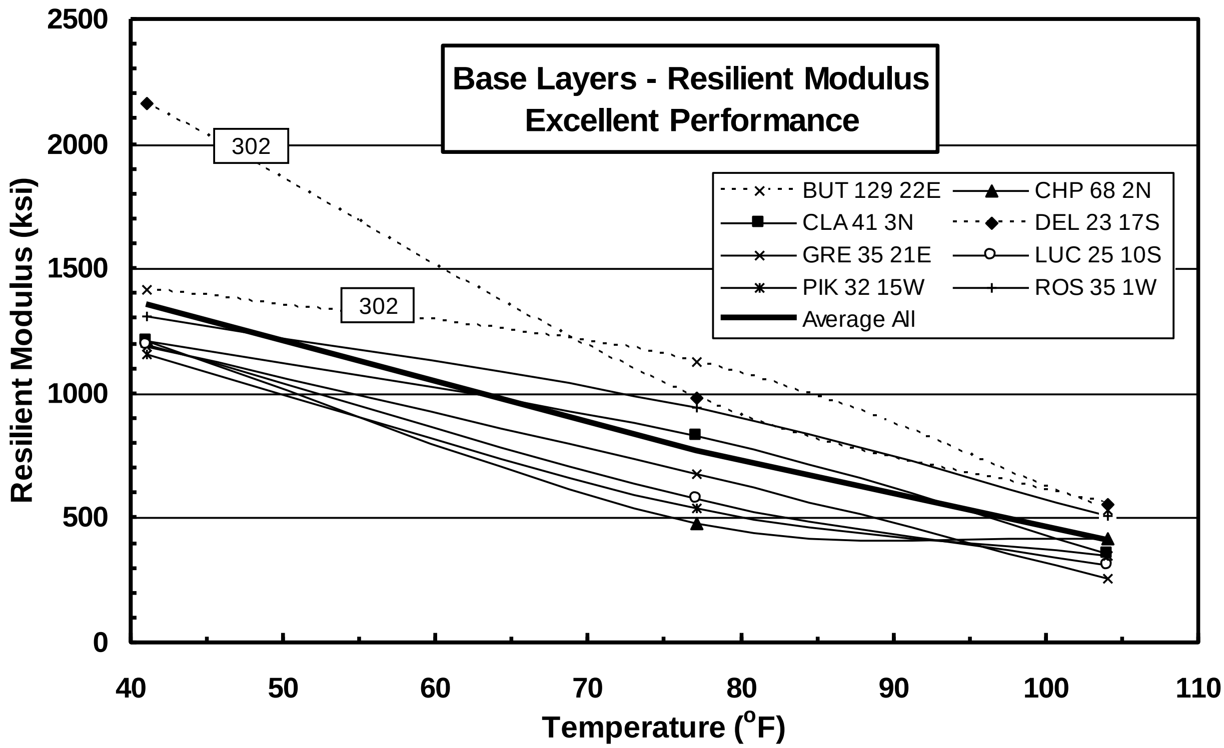


Figure 4.11 – Flexible Base Layers - Resilient Moduli, Excellent Performance

Creep Compliance

Tables 4.11 and 4.12 summarize measured creep compliance for base layers at 1, 2, 5, 10, 20, 50 and 100 seconds on nine flexible projects with average performance and ten flexible projects with excellent performance, respectively. As with the intermediate layer measurements, creep compliance recorded at one second was unusually low and quite erratic. Both figures show considerable variation between sites and inconsistent trends with temperature within sites.

Table 4.11

Measured Creep Compliance for Base Layers – Average Performance

Measured Creep Compliance for Flexible Base Layers, 10^{-7}/ psi Average Performance								
Pavement Section	Temp. (^{o}C)	Time in Seconds						
		1	2	5	10	20	50	100
BUT 129 22W (302)	0	-0.222	2.020	2.654	3.132	3.611	4.808	6.017
	-10	0.133	1.080	1.251	1.391	1.508	1.772	2.042
	-20	0.216	3.042	3.506	3.869	4.214	4.845	5.340
BUT 129 25W* (302)	0	0.329	1.910	2.448	2.921	3.425	4.515	5.707
	-10	0.111	1.895	2.384	2.703	3.135	3.880	4.691
	-20	0.164	1.126	1.262	1.370	1.522	1.731	1.950
CHP 68 2.5N*	0	0.685	3.911	5.578	7.123	9.191	12.899	17.244
	-10	0.121	5.336	6.949	7.905	9.603	12.039	14.982
	-20	-0.090	2.232	2.670	2.965	3.272	3.853	4.517
CLA 41 4N	0	0.120	2.313	2.921	3.329	3.779	4.927	6.052
	-10	0.217	3.291	3.908	4.286	4.805	5.692	6.373
	-20	0.033	2.318	2.652	2.853	3.045	3.533	4.053
DEL 23 18S (302)	0	0.003	2.090	2.639	3.014	3.681	4.997	6.319
	-10	0.001	3.088	3.806	4.220	4.713	5.794	7.019
	-20	-0.024	2.558	3.002	3.339	3.677	4.285	4.875
HAM 747 1S	0	-0.432	4.005	6.322	7.928	9.761	13.825	17.881
	-10	.-3853	2.635	3.716	4.546	5.396	7.389	9.566
	-20	0.015	0.089	0.115	0.134	0.154	0.194	0.239
LAW 527 2N	0	-0.171	3.949	5.447	6.552	7.701	10.345	13.003
	-10	0.076	1.869	2.361	2.751	3.111	4.039	4.994
	-20	0.110	2.805	3.423	3.909	4.504	5.636	6.845
LUC 2 22E*	0	0.039	3.885	5.415	6.810	7.942	10.491	14.112
	-10	-1.007	2.343	3.581	4.456	5.590	7.254	8.740
	-20	0.182	0.790	1.464	1.707	2.020	2.587	3.231
PIK 32 19W*	0	0.740	3.533	4.407	5.050	6.032	7.798	9.703
	-10	-0.024	2.938	3.631	4.099	4.612	5.419	6.169
	-20	0.138	1.542	1.814	1.979	2.224	2.568	2.960
Average	0	0.121	3.068	4.203	5.095	6.125	8.289	10.671
	-10	-0.046	2.719	3.510	4.040	4.719	5.920	7.175
	-20	0.083	1.834	2.212	2.458	2.737	3.248	3.779

$1/10^{-7}$psi = .0145/Gpa 0^{o} C = 32^{o} F, -10^{o} C = 14^{o} F, -20^{o} C = -4^{o} F

* Trendlines show good spacing between temperature curves

Table 4.12

Measured Creep Compliance for Base Layers – Excellent Performance

Measured Creep Compliance for Flexible Base Layers, 10^{-7}/ psi Excellent Performance								
Pavement Section	**Temp. (°C)**	**Time in Seconds**						
		1	**2**	**5**	**10**	**20**	**50**	**100**
BUT 129 22E (302)	0	-0.365	3.031	3.936	4.434	5.099	6.499	7.755
	-10	0.111	1.895	2.384	2.703	3.135	3.880	4.691
	-20	0.063	4.473	5.750	6.391	7.205	9.064	10.778
CHP 68 2N*	0	-0.083	4.937	8.242	11.108	14.732	21.602	29.681
	-10	0.760	1.208	2.737	3.760	4.851	6.963	9.472
	-20	0.220	0.920	1.185	1.371	1.662	2.219	2.806
CLA 41 3N	0	0.458	4.366	5.887	6.990	8.529	10.814	13.284
	-10	-0.004	0.358	0.425	0.468	0.524	0.650	0.767
	-20	0.064	2.828	3.233	3.517	3.881	4.578	5.167
DEL 23 17S (302)	0	0.358	3.958	5.000	5.647	6.326	7.975	9.639
	-10	-0.189	2.727	3.265	3.601	3.913	4.379	4.931
	-20	0.227	4.388	4.913	5.188	5.488	5.988	6.329
GRE 35 21E	0	-0.011	1.951	3.044	3.790	5.063	6.895	9.211
	-10	0.680	5.279	7.380	9.242	11.295	16.053	20.347
	-20	0.002	1.529	1.818	2.019	2.339	2.780	3.239
HAM 126 11E*	0	0.0509	1.318	2.061	2.663	3.37	4.836	6.490
	-10	-0.008	1.234	1.621	1.909	2.271	2.985	3.718
	-20	0.013	1.130	1.413	1.622	1.809	2.184	2.618
LUC 25 10S*	0	1.340	3.972	5.570	6.764	8.530	11.505	15.808
	-10	0.947	3.087	3.873	4.534	5.585	8.122	10.325
	-20	0.679	3.016	3.643	3.980	4.503	5.380	6.310
PIK 32 15W	0	-1.018	4.707	7.357	9.119	11.354	15.731	20.631
	-10	0.504	2.000	2.657	3.151	3.881	5.328	7.245
	-20	-0.614	5.989	7.764	9.167	10.755	13.515	16.282
PIK 32 19E	0	0.209	1.567	2.120	2.582	3.192	4.374	5.743
	-10	0.266	1.611	1.898	2.092	2.412	2.862	3.401
	-20	0.487	5.173	6.049	6.750	7.698	9.411	11.374
ROS 35 1W	0	0.540	2.485	3.714	4.250	5.000	6.255	7.649
	-10	0.050	2.259	2.557	2.788	2.991	3.440	3.945
	-20	-0.055	4.225	4.621	4.864	5.166	5.572	5.999
Average	0	0.148	3.229	4.693	5.735	7.120	9.649	12.589
	-10	0.312	2.166	2.880	3.425	4.086	5.466	6.884
	-20	0.109	3.367	4.039	4.487	5.051	6.069	7.090

$1/10^{-7}$psi = .0145/Gpa 0^o C = 32^o F, -10^o C = 14^o F, -20^o C = -4^o F

* Trendlines show good spacing between temperature curves

Tables 4.13 and 4.14 show trendline parameters and creep compliance calculated from these trendlines for MEPDG input times. Again, calculated creep at one second was calculated by extrapolating trendlines developed between 2 and 600 seconds back to one second.

Table 4.13

Calculated Creep Compliance for Base Layers – Average Performance

Calculated Creep Compliance for Flexible Base Layers - 10^{-7}/psi Average Performance												
Pavement Section	Temp. (°C)	Trendline Constants		Trendline R^2	Creep Compliance $Y = AX^B$ at Time X in Seconds							
		A	B		1	2	5	10	20	50	100
BUT 129 22W (302)	0	1.46	0.32	0.99	1.460	1.823	2.444	3.050	3.808	5.105	6.373
	-10	0.80	0.22	0.98	0.800	0.932	1.140	1.328	1.546	1.892	2.203
	-20	2.65	0.16	0.99	2.650	2.961	3.428	3.830	4.280	4.955	5.537
BUT 129 25W* (302)	0	1.32	0.33	0.99	1.320	1.659	2.245	2.822	3.547	4.800	6.034
	-10	1.47	0.26	1.00	1.470	1.760	2.234	2.675	3.203	4.065	4.868
	-20	0.84	0.21	0.97	0.840	0.972	1.178	1.362	1.576	1.910	2.209
CHP 68 2.5N*	0	2.56	0.43	0.99	2.560	3.449	5.114	6.890	9.283	13.766	18.546
	-10	4.07	0.29	0.99	4.070	4.976	6.491	7.936	9.703	12.656	15.474
	-20	1.73	0.23	0.98	1.730	2.029	2.505	2.938	3.446	4.254	4.989
CLA 41 4N	0	1.67	0.29	0.99	1.670	2.042	2.663	3.256	3.981	5.193	6.349
	-10	2.63	0.21	0.99	2.630	3.042	3.688	4.265	4.934	5.981	6.918
	-20	1.83	0.18	0.99	1.830	2.073	2.445	2.770	3.138	3.701	4.192
DEL 23 18S (302)	0	1.39	0.34	0.99	1.390	1.759	2.403	3.041	3.849	5.256	6.653
	-10	2.22	0.27	0.98	2.220	2.677	3.428	4.134	4.985	6.384	7.698
	-20	2.10	0.19	0.99	2.100	2.396	2.851	3.253	3.710	4.416	5.038
HAM 747 1S	0	3.14	0.39	1.00	3.140	4.115	5.882	7.708	10.100	14.439	18.920
	-10	1.92	0.36	0.99	1.920	2.464	3.427	4.398	5.645	7.851	10.076
	-20	0.07	0.28	1.00	0.070	0.085	0.110	0.133	0.162	0.209	0.254
LAW 527 2N	0	2.88	0.34	0.99	2.880	3.645	4.978	6.301	7.975	10.890	13.785
	-10	1.38	0.29	0.99	1.380	1.687	2.201	2.691	3.290	4.291	5.247
	-20	2.12	0.26	0.99	2.120	2.539	3.222	3.858	4.620	5.862	7.020
LUC 2 22E*	0	2.71	0.37	0.99	2.710	3.502	4.916	6.353	8.210	11.524	14.893
	-10	2.05	0.33	0.99	2.050	2.577	3.487	4.383	5.509	7.454	9.370
	-20	0.86	0.29	1.00	0.860	1.051	1.372	1.677	2.050	2.674	3.270
PIK 32 19W*	0	2.50	0.31	0.99	2.500	3.099	4.117	5.104	6.328	8.407	10.422
	-10	2.56	0.20	1.00	2.560	2.941	3.532	4.057	4.661	5.598	6.430
	-20	1.24	0.20	0.99	1.240	1.424	1.711	1.965	2.257	2.712	3.115
Average	0	2.18	0.35	0.99	2.181	2.776	3.817	4.858	6.182	8.502	10.820
	-10	2.12	0.27	0.99	2.122	2.561	3.283	3.962	4.781	6.129	7.396
	-20	1.49	0.22	0.99	1.493	1.743	2.139	2.497	2.916	3.578	4.177
MEPDG Defaults for PG 64-22 HMA	0	7.83	0.34	1.00	7.83	9.92	13.58	17.22	21.84	29.89	37.90
	-10	5.48	0.22	1.00	5.48	6.36	7.81	9.09	10.58	12.93	15.05
	-20	3.21	0.13	1.00	3.21	3.52	3.98	4.37	4.79	5.42	5.95

$1/10^{-7}$psi = .0145/Gpa   0° C = 32° F, -10° C = 14° F, -20° C = -4° F

* Trendlines show good spacing between temperature curves

Table 4.14

Calculated Creep Compliance for Base Layers – Excellent Performance

Calculated Creep Compliance for Flexible Base Layers - 10^{-7}/psi Excellent Performance											
Pavement Section	Temp. (°C)	Trendline Constants			Creep Compliance Y = AX^B at Time X in Seconds						
		A	B	R^2	1	2	5	10	20	50	100
BUT 129 22E (302)	0	2.06	0.32	0.98	2.060	2.572	3.448	4.304	5.373	7.203	8.992
	-10	1.47	0.26	1.00	1.470	1.760	2.234	2.675	3.203	4.065	4.868
	-20	3.45	0.26	0.99	3.450	4.131	5.243	6.278	7.518	9.540	11.424
CHP 68 2N*	0	3.71	0.46	1.00	3.710	5.103	7.779	10.700	14.718	22.434	30.858
	-10	1.33	0.43	1.00	1.330	1.792	2.657	3.580	4.823	7.152	9.635
	-20	0.63	0.34	0.99	0.630	0.797	1.089	1.378	1.745	2.382	3.015
CLA 41 3N	0	3.34	0.31	0.99	3.340	4.141	5.501	6.819	8.454	11.231	13.923
	-10	0.27	0.23	0.99	0.270	0.317	0.391	0.459	0.538	0.664	0.779
	-20	2.26	0.19	1.00	2.260	2.578	3.068	3.500	3.993	4.752	5.421
DEL 23 17S (302)	0	2.95	0.27	0.99	2.950	3.557	4.556	5.493	6.624	8.483	10.229
	-10	2.35	0.17	0.98	2.350	2.644	3.090	3.476	3.911	4.570	5.141
	-20	3.81	0.13	0.97	3.810	4.169	4.697	5.140	5.624	6.336	6.933
GRE 35 21E	0	1.49	0.40	1.00	1.490	1.966	2.836	3.743	4.939	7.125	9.401
	-10	3.96	0.36	1.00	3.960	5.082	7.068	9.072	11.643	16.193	20.782
	-20	1.22	0.22	0.99	1.220	1.421	1.738	2.025	2.358	2.885	3.360
HAM 126 11E*	0	0.94	0.44	0.99	0.940	1.275	1.908	2.589	3.512	5.256	7.131
	-10	0.89	0.33	0.99	0.890	1.119	1.514	1.903	2.392	3.236	4.068
	-20	0.89	0.25	0.99	0.890	1.058	1.331	1.583	1.882	2.367	2.814
LUC 25 10S*	0	2.60	0.41	0.99	2.600	3.455	5.030	6.683	8.880	12.929	17.178
	-10	1.97	0.37	1.00	1.970	2.546	3.573	4.618	5.968	8.377	10.826
	-20	2.43	0.21	0.99	2.430	2.811	3.407	3.941	4.559	5.526	6.392
PIK 32 15W	0	3.52	0.40	0.99	3.520	4.645	6.701	8.842	11.667	16.832	22.210
	-10	1.26	0.40	0.99	1.260	1.663	2.399	3.165	4.176	6.025	7.950
	-20	4.62	0.29	0.99	4.620	5.649	7.368	9.008	11.014	14.366	17.565
PIK 32 19E	0	1.03	0.39	0.99	1.030	1.350	1.929	2.528	3.313	4.736	6.206
	-10	1.23	0.23	0.99	1.230	1.443	1.781	2.089	2.450	3.025	3.547
	-20	3.86	0.24	0.99	3.860	4.559	5.680	6.708	7.922	9.871	11.657
ROS 35 1W	0	2.09	0.30	0.99	2.090	2.573	3.387	4.170	5.134	6.758	8.320
	-10	1.81	0.18	0.99	1.810	2.051	2.418	2.740	3.104	3.660	4.146
	-20	3.85	0.10	0.99	3.850	4.126	4.522	4.847	5.195	5.693	6.102
Average	0	2.37	0.37	0.99	2.373	3.067	4.304	5.563	7.189	10.091	13.041
	-10	1.65	0.30	0.99	1.654	2.031	2.663	3.270	4.015	5.265	6.465
	-20	2.70	0.22	0.99	2.702	3.154	3.869	4.515	5.270	6.465	7.545
MEPDG Defaults for PG 64-22 HMA	0	7.83	0.34	1.00	7.83	9.92	13.58	17.22	21.84	29.89	37.90
	-10	5.48	0.22	1.00	5.48	6.36	7.81	9.09	10.58	12.93	15.05
	-20	3.21	0.13	1.00	3.21	3.52	3.98	4.37	4.79	5.42	5.95

$1/10^{-7}$psi = .0145/Gpa   0° C = 32° F, -10° C = 14° F, -20° C = -4° F

* Trendlines show good spacing between temperature curves

Figures 4.12 and 4.13 show excellent correlations between measured and calculated creep compliance for flexible base layers between 2 and 600 seconds, but equipment issues caused problems with the one second base measurements as they did with the intermediate layers. At times above 10 seconds, calculated creep was somewhat greater than measured creep.

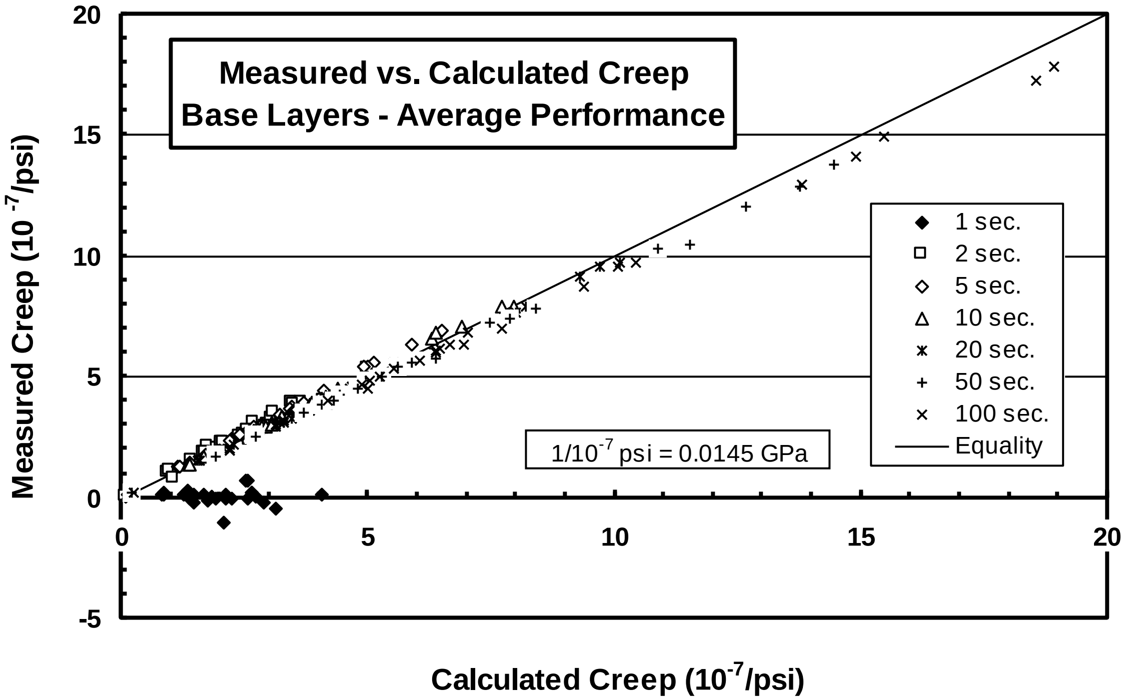


Figure 4.12 – Measured vs. Calculated Creep – Base Layers, Average Performance

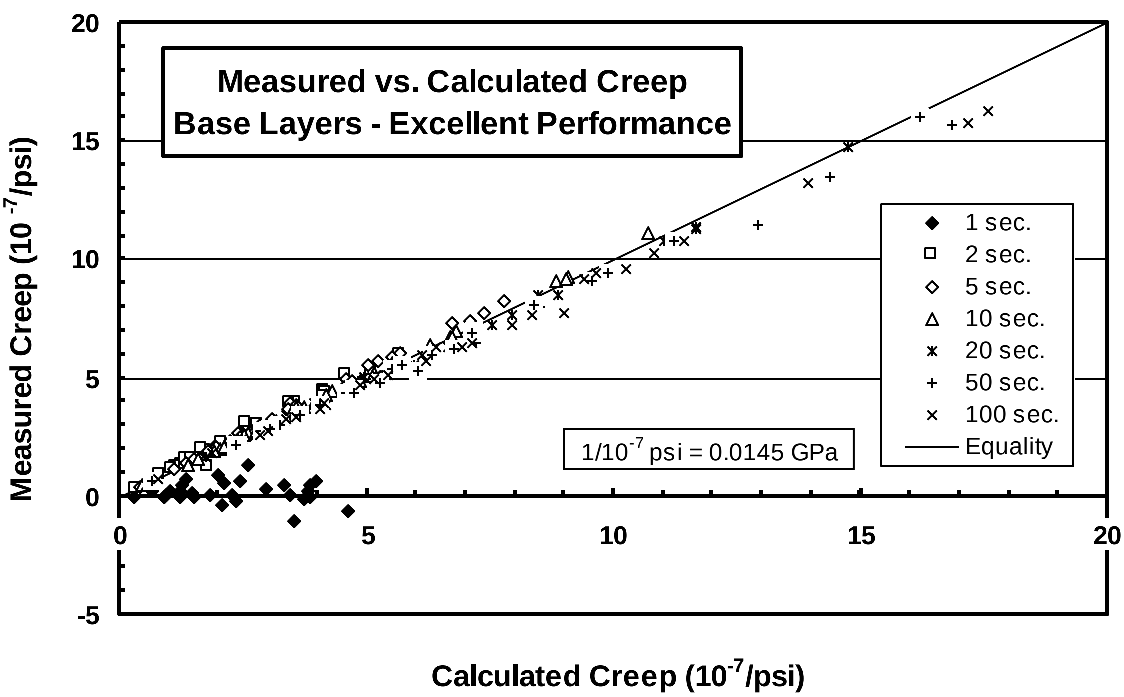


Figure 4.13 – Measured vs. Calculated Creep – Base Layers, Excellent Performance

Figures 4.14 to 4.19 show measured creep compliance for individual base layers grouped by temperature and level of performance on log-log plots with heavy lines representing group averages and the appropriate MEPDG default. Differences in the appearance of lines between 2 to 20 and 20 to 600 seconds were caused by the 0.1 and 1.0 second data acquisition rates used during the two time intervals. Figure 4.20 shows average creep compliance curves for the three temperatures at the two levels of performance and the MEPDG defaults. Data in the figures indicate:

1. Overall, measured creep compliance was lower than MEPDG defaults, but this difference, which was probably due to the asphalt concrete specimens becoming more brittle with age, decreased with lower temperature. Average creep compliance for the excellent performing pavements at -20° C (-4° F) was very close to the MEPDG defaults.
2. From Figure 4.20, temperature curves for average creep compliance of average performing pavements were about equally spaced and in the proper order.
3. Creep compliance was higher for the excellent performing pavements than the average performing pavements at 0° C (32° F) and -20° C (-4° F). At -10° C (14° F), average performing pavements were higher from 2 to a little over 100 seconds and then crossed over lower past 100+ seconds.
4. CLA 41 3N, with excellent performance, might be considered an outlier at -10° C (14° F) with unusually low creep compliance, and HAM 747 1S, with average performance, appears to be a low outlier at -20° C (-4° F), except that HAM 747 1S was noted as having thermal cracking in the PMIS.
5. Despite measured creep compliance being lower than MEPDG defaults, thermal cracking was only noted on CHP 68 2.5N, CLA 41 4N and HAM 747 1S in the PMIS, all average performing pavements.

Note: Problems maintaining specimen temperatures, especially at -20° C (-4° F), may have affected the creep compliance results to some degree.

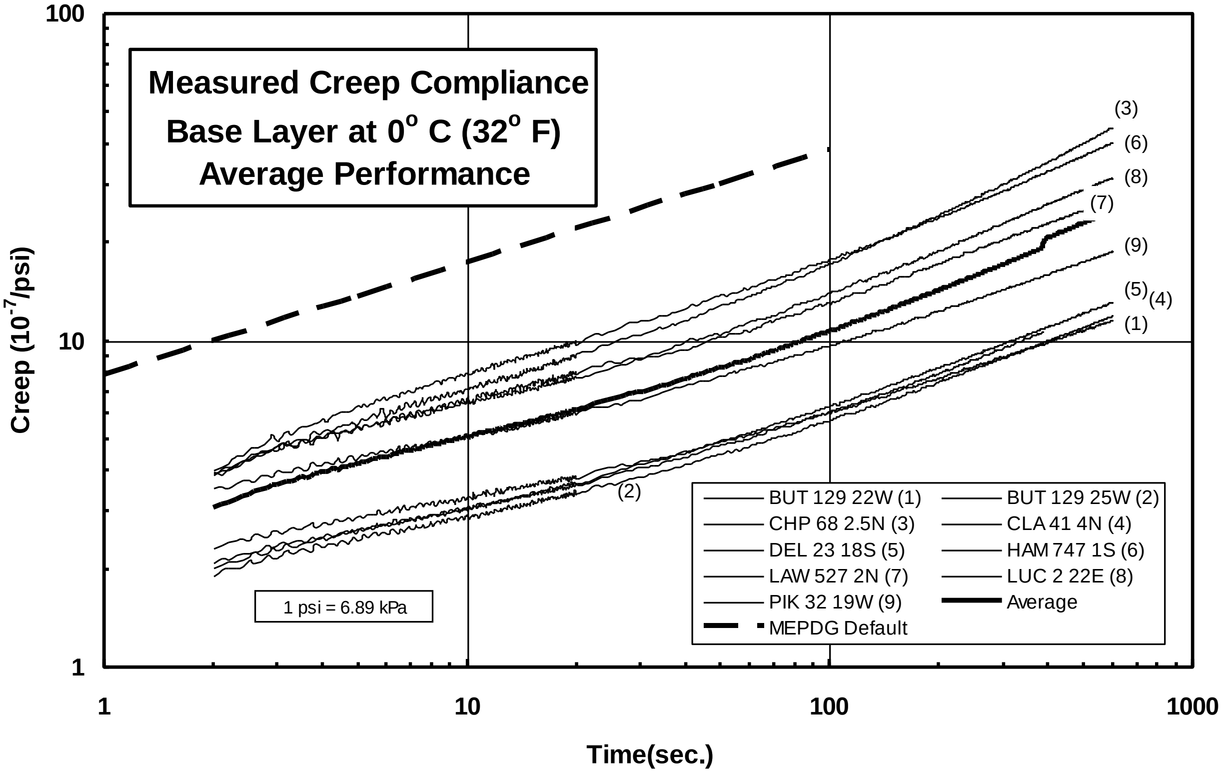


Figure 4.14 – Base Creep Compliance at 0° C, Average Performance

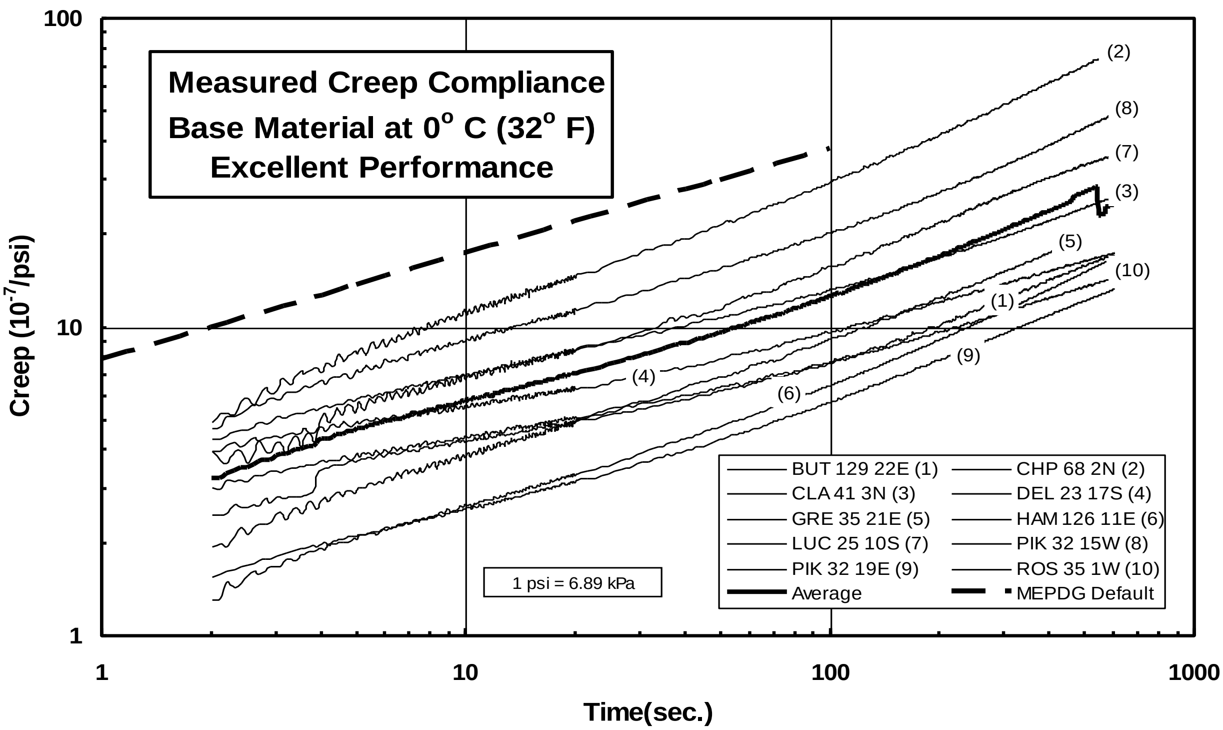


Figure 4.15 - Base Creep Compliance at 0° C, Excellent Performance

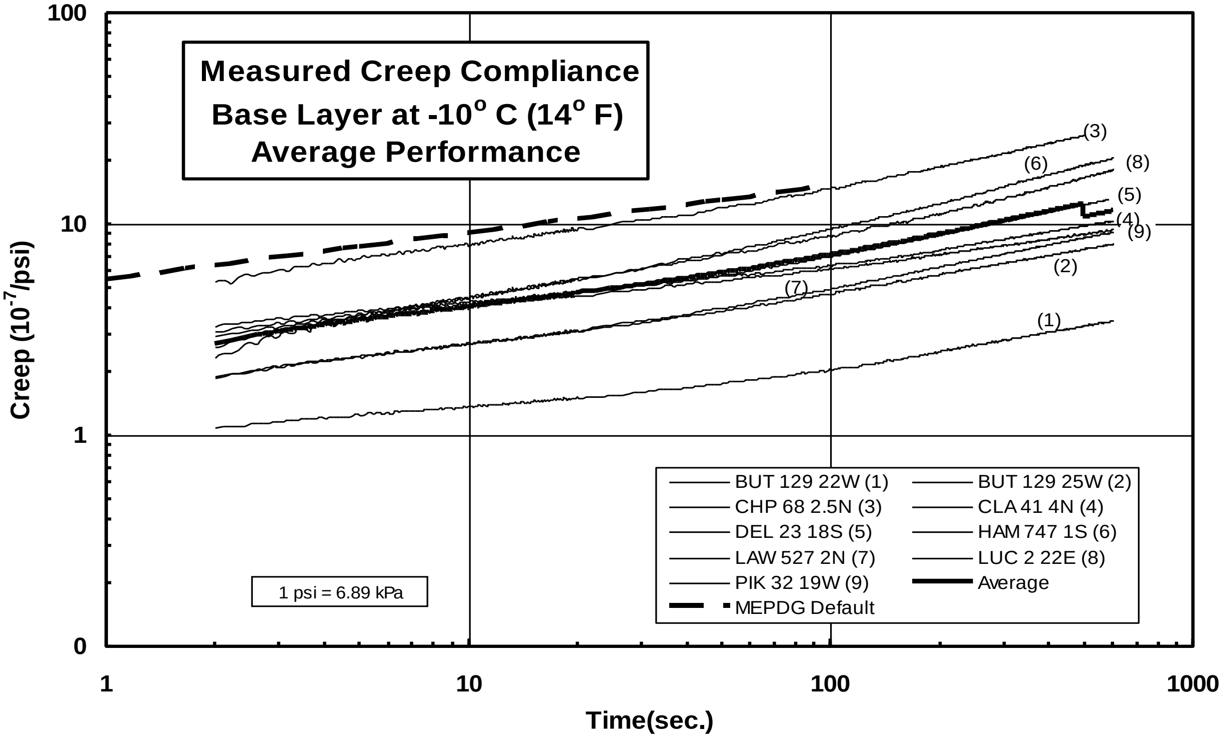


Figure 4.16 - Base Creep Compliance at -10° C, Average Performance

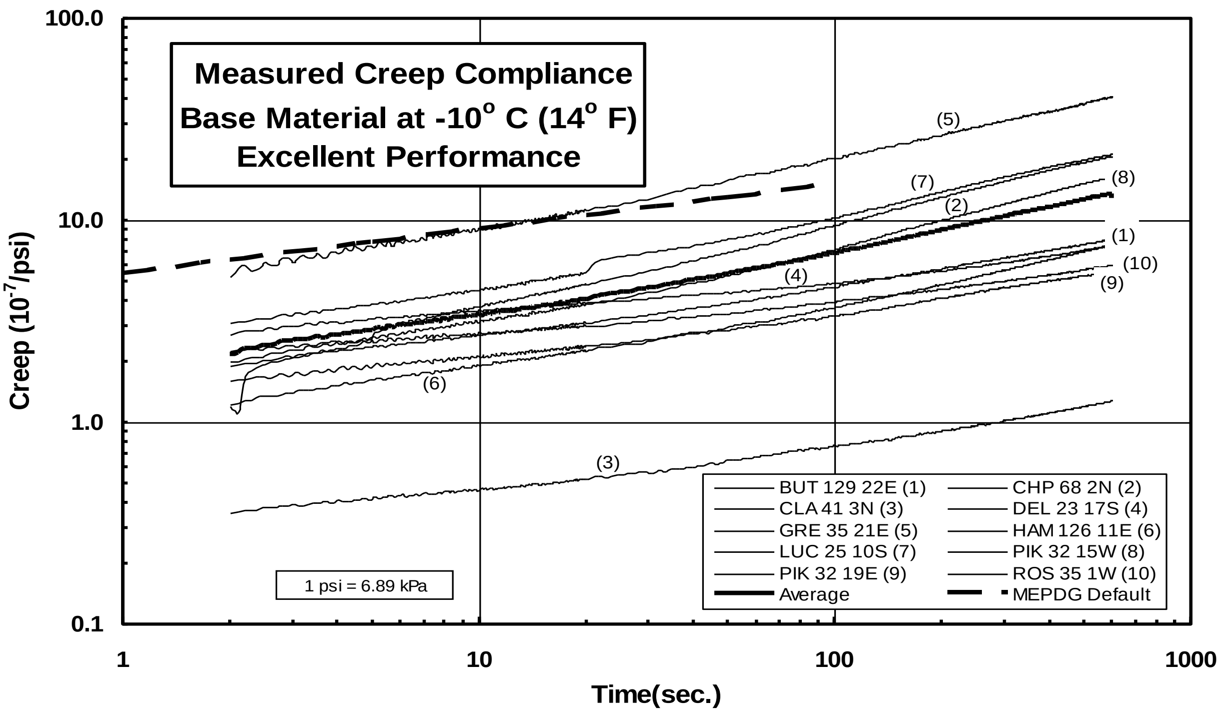


Figure 4.17 - Base Creep Compliance at -10° C, Excellent Performance

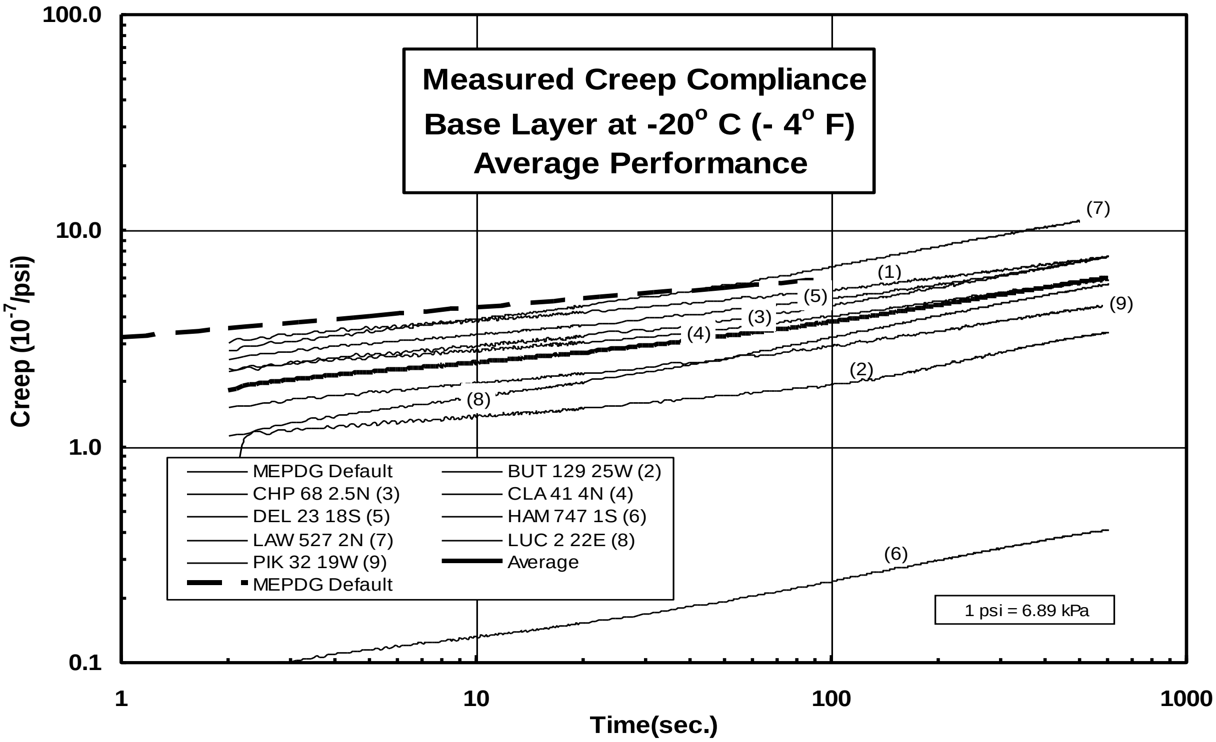


Figure 4.18 - Base Creep Compliance at -20° C, Average Performance

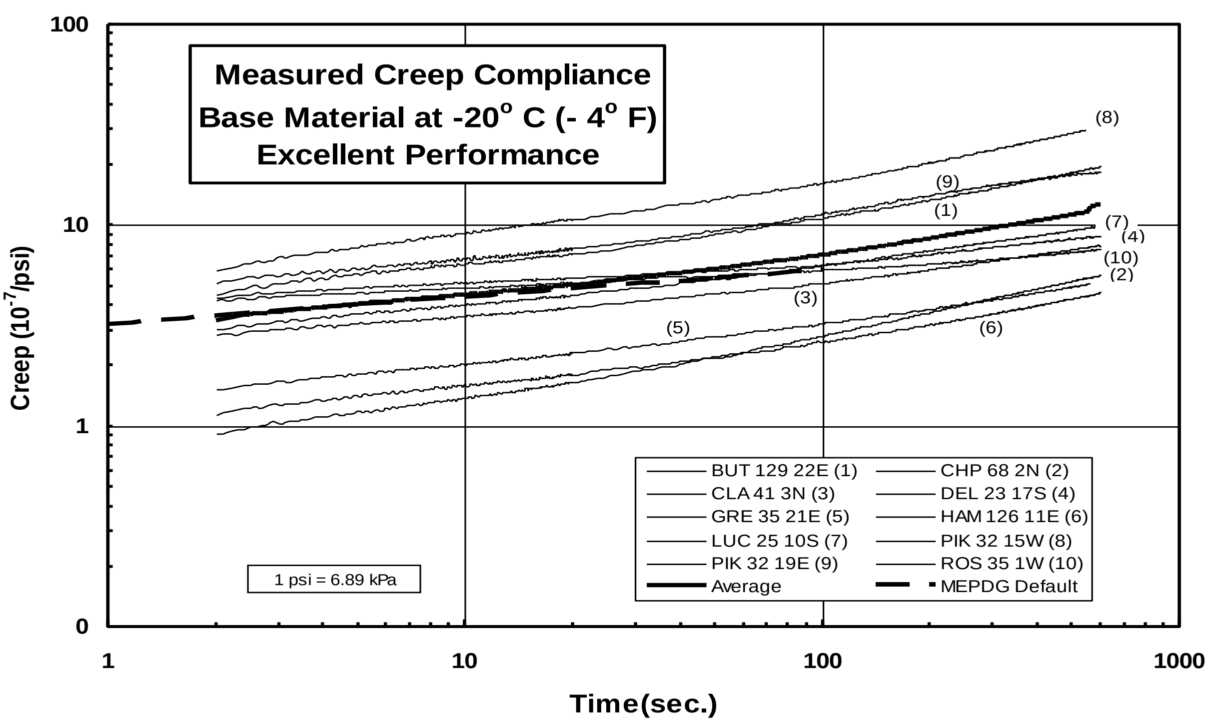


Figure 4.19 - Base Creep Compliance at -20° C, Excellent Performance

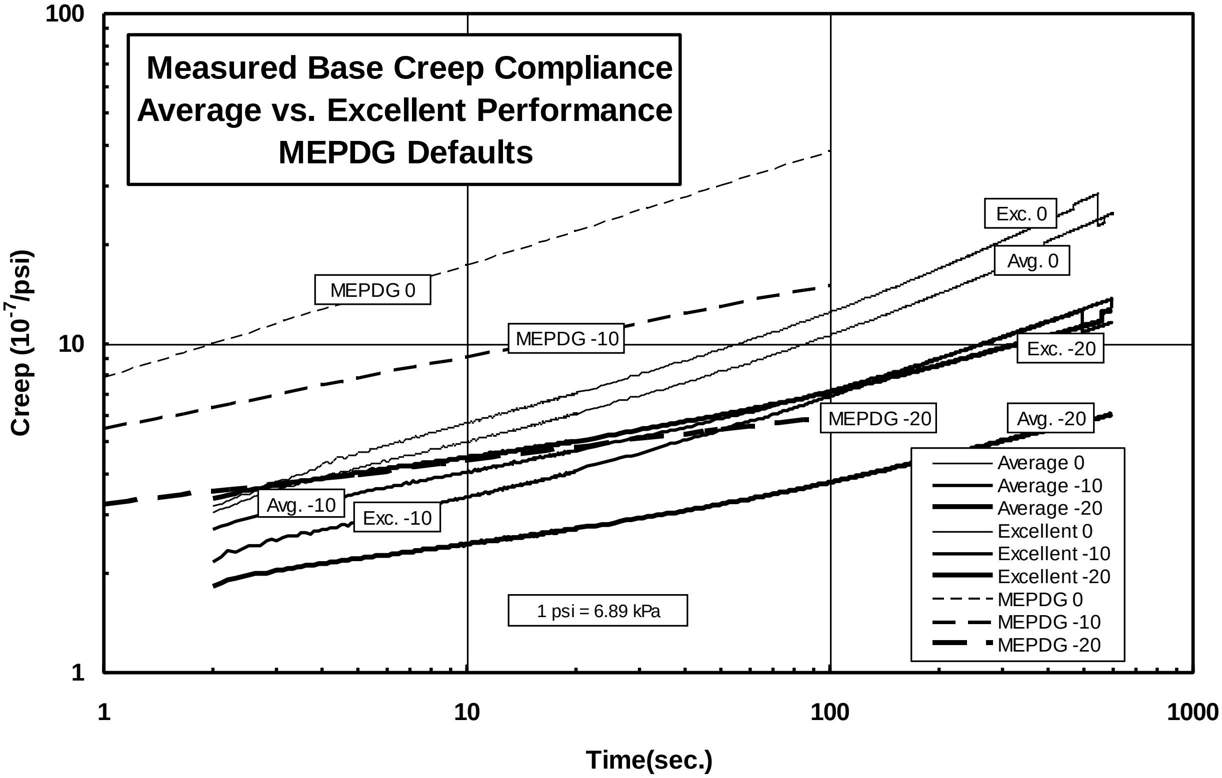


Figure 4.20 – Comparison of Average Creep Compliances for Base Layers

Laboratory Testing of ATFDB Layers

ODOT 308 Asphalt Treated Free Draining Bases (ATFDB) were only constructed in Ohio between 1994 and 1998. This material generally drained well, but an internal evaluation by ODOT found free draining bases were not cost effective and their use was discontinued. Table G5 in Appendix G summarizes mix parameters and aggregate gradations for ATFDB in the three average and four excellent performing flexible sections containing this material. Table 4.15 summarizes asphalt contents and F/A ratios for all sections by level of performance and by projects having paired sections with both levels of performance. With the exception of the paired sections at PIK 32 19W/E, the excellent performing sections had slightly higher asphalt contents and lower F/A ratios than the average performing sections. Figure 4.19 shows the excellent sites to have a finer aggregate gradation in the ATFDB than the average sites. No structural tests could be performed on the ATFDB materials.

Table 4.15

Flexible ATFDB Layers - Mix Parameter Summary

ATFDB by Level of Performance				
Category	**% Air Voids**	**% Density**	**% Asphalt**	**F/A Ratio**
All Sections	na	na	2.20 / 2.33	1.4 / 1.2
Paired Sections				
BUT 129 22W/E	na	na	1.75 / 2.16	1.6 / 1.3
DEL 23 18S/17S	na	na	2.13 / 2.26	1.6 / 1.4
PIK 32 19W/E	na	na	2.46 / 2.34	1.1 / 1.2

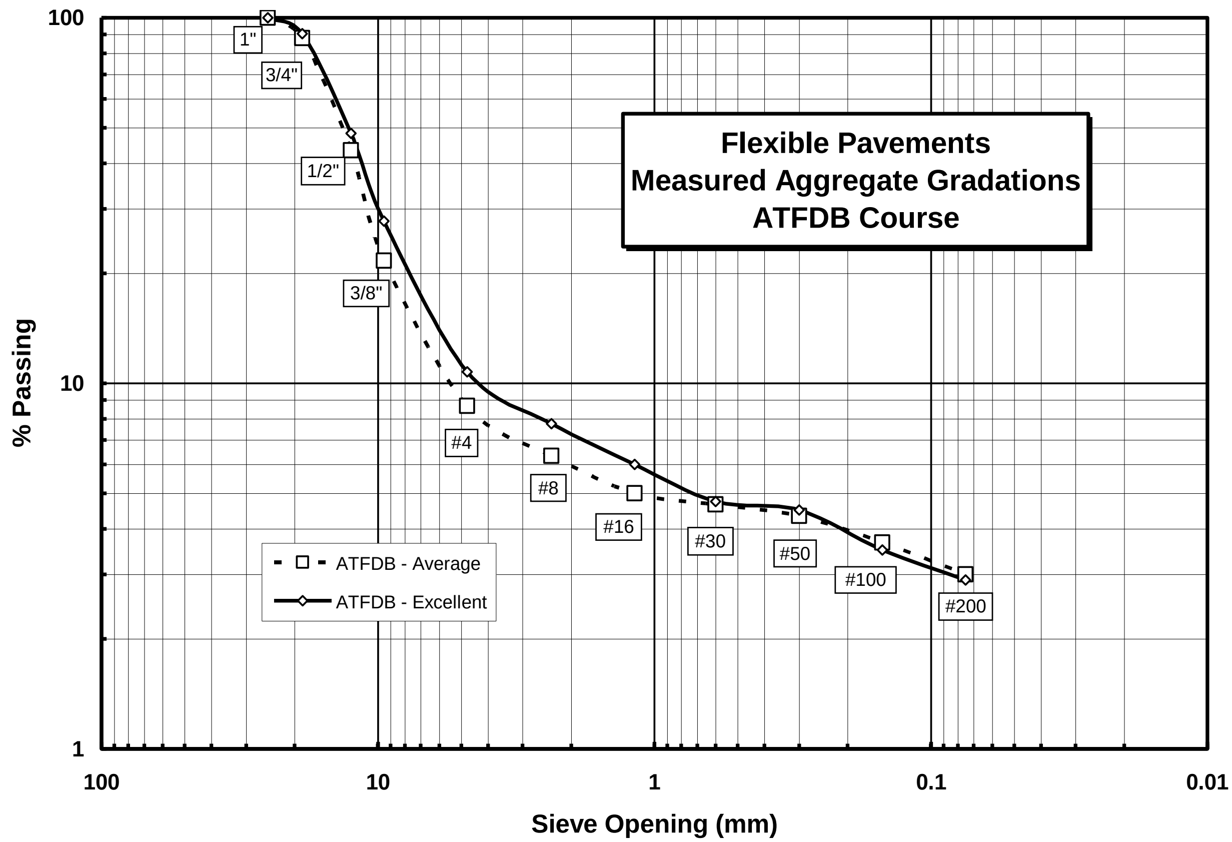


Figure 4.21 - Aggregate Gradations in Flexible ATFDB Mixes

AC Layer and Mix Summary

Table 4.16 summarizes aggregate gradation requirements specified in the 1997 ODOT Construction and Material Specifications, which is around the time most of the selected flexible projects were constructed. Tables 4.17 and 4.18 provide a summary of average flexible pavement mix parameters and aggregate gradations measured in the ODOT Laboratory and grouped by layer, material type and level of performance. While the finer gradations in Figure 4.1 for excellent performing surfaces mixes were compelling, there are no clear trends regarding the impact of asphalt content and aggregate gradation on performance in any other pavement layers. These parameters have been tweaked a bit over the years, and Type 1H mixes have been replaced by Superpave 442 mixes in the ODOT Pavement Design Manual.

Table 4.16

1997 ODOT Flexible Aggregate Gradation Specifications

AC Aggregate Gradations - 1997 ODOT Specifications									
% Passing	Surface Mixes				Intermediate Mixes			Base Mixes	
	404	446 and 448			402	446 and 448			
		T1H	T1	T2		T1	T2	301	302
2"								100	100
1 1/2"				100	100		100		85-100
1"				95-100	95-100		95-100	75-100	68-88*
3/4"		100		85-100			85-100		56-80*
1/2"	100	95-100	100	65-85	60-90	100	65-85	50-85	44-68*
3/8"	90-100	70-85	90-100			90-100			37-60*
#4	45-75	38-50	45-57	35-60	35-65	50-72	35-60	25-60	22-45
#8		20-37	30-45	25-48		30-55	25-48	15-45	14-35
#16	15-45	14-30	17-35	16-36	15-45	17-40	16-36	10-35	8-25
#30		10-22	12-25	12-30		12-30	12-30		6-18
#50	3-22	6-15	5-18	5-8	3-22	5-20	5-18	3-18	4-13
#100		4-10	2-10	2-10		2-12	2-10		
#200	0-8	2-6			0-8			1-7	2-6
AC (%)	4.5-12.0	5.2-10.0	5.0-10.0	4.0-9.0	4.0-12.0	5.0-10.0	4.0-9.0	4-8	3-8

*A minimum of 7% material shall be retained on each of these sieves.

Table 4.17

Summary of Flexible Material Parameters

Average AC Mix Parameters by Layer, Material Specification and Level of Performance														
Material Specification	Layer Thickness (in.)		AC Mix Parameters											
			Bulk Spec. Gravity		Max Spec. Gravity		% Air Voids		% Density		% Asphalt		F/A Ratio (%#200 / %Asphalt)	
	Avg. (*)	Range	Avg. (*)	Range	Avg. (*)	Range	Avg. (*)	Range	Avg. (*)	Range	Avg. (*)	Range	Avg. (*)	Range
Surface Layer														
Average Performance														
Average 446 T1	1.50 (3)	1.29-1.71	2.35 (3)	2.27-2.39	2.50 (4)	2.48-2.52	6.0 (3)	4.4-8.4	94.0 (3)	91.6-95.6	6.01 (4)	4.82-6.48	0.9 (4)	0.7-1.0
Average 446 T1H	1.29 (1)	1.29	2.44 (1)	2.44	2.56 (1)	2.56	4.9 (1)	4.9	95.1 (1)	95.1	5.71 (1)	5.71	0.8 (1)	0.8
Average 448 T1H	1.42 (1)	1.42	2.35 (1)	2.35	2.51 (1)	2.51	6.2 (1)	6.2	93.8 (1)	93.8	5.30 (1)	5.3	0.8 (1)	0.8
Average 404	1.58 (3)	1.14-2.13	2.39 (3)	2.39-2.40	2.51 (3)	2.48-2.53	4.6 (3)	3.4-5.3	95.4 (3)	93.8-96.6	5.33 (3)	4.97-5.60	0.9 (3)	0.8-1.0
Excellent Performance														
Average 446 T1	1.49 (7)	1.11-1.91	2.38 (7)	2.32-2.41	2.53 (7)	2.48-2.58	6.2 (7)	4.9-8.1	93.9 (7)	91.5-95.2	5.52 (7)	4.68-6.25	0.8 (12)	0.2-1.1
Average 448 T1H	1.67 (2)	1.65-1.69	2.35 (2)	2.31-2.39	2.48 (2)	2.47-2.49	5.5 (2)	4.2-6.7	94.6 (2)	93.3-95.9	6.32 (2)	5.69-6.94	1.0 (2)	0.8-1.2
Average 404	1.13 (1)	1.13	2.40 (1)	2.40	2.55 (1)	2.55	5.8 (1)	5.8	94.2 (1)	94.2	5.26 (1)	5.26	0.7 (1)	0.7
Intermediate Layer														
Average Performance														
Average 446 T2	2.02 (5)	1.43-2.42	2.38 (5)	2.33-2.47	2.50 (5)	2.48-2.54	5.4 (5)	4.3-6.5	94.6 (5)	93.5-97.6	5.37 (5)	4.71-6.10	0.8 (5)	0.6-1.0
Average 448 T2	1.94 (1)	1.94	2.39 (1)	2.39	2.51 (1)	2.51	5.0 (1)	5.0	95.1 (1)	95.0-95.1	4.51 (1)	4.51	1.0 (1)	1
Average 402	1.78 (2)	1.67-1.89	2.36 (2)	2.35-2.37	2.51 (2)	2.47-2.55	5.8 (2)	3.7-7.8	94.3 (2)	91.3-96.3	5.02 (2)	4.50-5.53	0.7 (2)	0.6-0.7
Average 403	1.85 (1)	1.85	2.34 (1)	2.34	2.49 (1)	2.49	6.0 (1)	6.0	94.0 (1)	94.0	5.54 (1)	5.54	0.9 (1)	0.9
Excellent Performance														
Average 446 T2	1.90 (7)	1.55-2.27	2.36 (7)	2.31-2.42	2.51 (7)	2.42-2.57	5.8 (7)	3.6-8.1	94.3 (7)	91.9-96.5	4.93 (7)	3.64-5.75	0.9 (7)	0.6-1.4
Average 448 T2	1.66 (2)	1.64-1.67	2.35 (2)	2.31-2.40	2.49 (2)	2.48-2.50	5.5 (2)	3.8-7.6	94.6 (2)	92.9-96.2	5.28 (2)	4.68-5.88	0.7 (2)	0.3-1.0
Average 402	2.19 (1)	2.19	2.39 (1)	2.39	2.53 (1)	2.53	5.6 (1)	5.6	94.4 (1)	94.4	5.20 (1)		0.6 (1)	
Base Layer														
Average Performance														
Average 302	3.91 (3)	3.52-4.11	2.37 (3)	2.26-2.45	2.51 (3)	2.47-2.57	5.8 (3)	4.2-8.5	94.8 (5)	91.5-95.8	4.26 (3)	3.43-5.64	1.3 (3)	1.2-1.3
Average 301	3.21 (6)	2.05-4.51	2.39 (6)	2.33-2.45	2.51 (6)	2.47-2.57	5.3 (6)	3.1-6.4	94.6 (6)	93.7-96.9	4.62 (6)	4.24-5.06	0.9 (6)	0.5-1.2
Excellent Performance														
Average 302	3.96 (2)	3.16-4.76	2.35 (2)	2.32-2.38	2.50 (2)	2.46-2.57	6.4 (2)	6.1-6.6	93.7 (2)	93.4-93.9	3.99 (2)	2.48-4.50	1.4 (2)	1.2-1.5
Average 301	4.03 (8)	2.53-5.36	2.37 (8)	2.30-2.45	2.50 (8)	2.44-2.55	5.3 (8)	2.1-9.1	94.7 (8)	90.9-98.0	4.93 (8)	4.09-5.42	1.0 (8)	0.7-1.6
ATFDB Material														
Average Performance														
Average 308	N.A.		N.A.		N.A.		N.A.		N.A.		2.11 (3)	1.75-2.46	1.4 (3)	1.1-1.6
Excellent Performance														
Average 308	3.30 (1)	3.30	N.A.		N.A.		N.A.		N.A.		2.34(4)	2.23-2.51	1.3 (4)	1.1-1.4

* Number of site averages in calculation 1 inch = 25.4 mm

Table 4.18 – Summary of Flexible Aggregate Gradations

Average AC Aggregate Gradations by Layer, Material Specification and Level of Performance																
Material Specification	**Layer Thickness (in.)**		**% Aggregate Passing Sieve (inches or sieve number/mm)**													
			2.0"	**1.5"**	**1.0"**	**3/4"**	**1/2"**	**3/8"**	**#4**	**#8**	**#16**	**#30**	**#50**	**#100**	**#200**
	Avg. (no.*)	**Range**	**50**	**38**	**25**	**18.8**	**12.5**	**9.5**	**4.75**	**2.36**	**1.18**	**0.60**	**0.30**	**0.15**	**0.075**
Surface Layer																
Average Performance																
Average 446 T1	1.45 (4)	1.26-1.71				100	96.3	89.0	55.5	38.3	26.0	17.8	11.0	7.3	5.2
Average 446 T1H	1.48 (1)	1.26-1.69				100	98.0	88.0	48.0	32.0	20.0	13.0	9.0	6.0	4.3
Average 448 T1H	1.42 (1)					100	98.0	85.0	48.0	33.0	24.0	15.0	8.0	5.0	3.0
Average 404	1.58 (3)	1.14-2.13			100	97.0	94.7	89.3	56.7	41.0	31.3	22.0	10.3	6.0	4.5
Excellent Performance																
Average 446 T1	1.50 (7)	1.07-2.03				100	96.1	86.3	52.6	38.0	27.3	19.1	11.4	7.1	4.6
Average 448 T1H	1.66 (2)	0.98-2.38				100	99.0	93.0	69.0	47.5	34.5	24.0	14.5	9.5	6.5
Average 404	2.13 (1)	1.87-2.39					100	96.0	59.0	43.0	32.0	21.0	9.0	5.0	3.7
Intermediate Layer																
Average Performance																
Average 446 T2	2.22 (5)	1.43-2.86			100	96.8	82.2	71.6	49.6	38.0	28.4	19.4	9.8	6.0	4.2
Average 448 T2	1.93 (1)	1.85-2.02			100	98.0	76.0	62.0	45.0	34.0	24.0	16.0	8.0	6.0	4.3
Average 402	1.82 (2)	1.67-2.10			100	97.0	84.0	73.0	48.5	38.0	29.5	21.5	9.0	4.5	3.3
Average 403	1.85 (1)						100	98.0	69.0	56.0	38.0	24.0	12.0	7.0	5.2
Excellent Performance																
Average 446 T2	1.92 (7)	1.54-2.30			100	98.7	82.4	71.3	50.6	39.0	29.6	20.4	10.9	6.3	4.4
Average 448 T2	1.65 (2)	1.58-1.74			100	99.5	84.5	72.0	49.5	35.5	24.0	14.5	7.0	4.5	3.2
Average 402	2.19 (1)	1.30-3.07			100	96.0	86.0	73.0	52.0	42.0	30.0	20.0	8.0	4.0	3.0
Base Layer																
Average Performance																
Average 302	3.87 (3)	3.18-4.60	100	96.7	91.7	82.3	67.0	55.7	37.0	28.0	21.3	15.7	9.7	7.3	5.4
Average 301	3.19 (6)	1.50-5.74	100	98.8	97.5	93.0	73.0	60.3	42.8	34.2	26.8	19.3	9.5	5.5	3.9
Excellent Performance																
Average 302	3.82 (2)	3.01-4.96	100	99.0	79.0	67.5	57.0	51.5	36.5	28.0	21.5	15.0	10.0	7.5	5.5
Average 301	3.94 (8)	1.46-5.66	100	98.0	95.6	90.5	73.0	62.1	45.0	36.6	26.8	18.6	10.8	7.1	4.9
308 ATFDB																
Average Performance																
Average ATFDB	N.A. (3)	N.A.			100	88.0	43.3	21.7	8.7	6.3	5.0	4.7	4.3	3.7	3.0
Excellent Performance																
Average ATFDB	3.30 (4)	3.20-3.39			100	90.5	48.3	27.8	10.8	7.8	6.0	4.8	4.5	3.5	2.9

1 inch = 2.5 cm * Number of site averages in calculation

While asphalt contents vary from project to project, they all tend to be toward the lower end of the allowable range. This is logical since any cost incurred by contractors for unneeded asphalt cement negatively impacts their bid prices and profit margin. Asphalt binder contents also tend toward the low end of the design range because current mix design procedures and criteria yield these contents. The high end of the asphalt binder content range is unrealistic and would lead to excessively rutted pavements. ODOT asphalt binder contents are comparable with other states and higher than most states for Superpave 442 mixes. Since the 1997 specifications, ODOT has increased the lower limit of asphalt binder contents for Type 1H, 442 and 302 base mixes. In addition, T1 and 302 base mixes have been altered to include minimum virgin asphalt binder content requirements. T2 mixes may also benefit from having higher minimum asphalt binder contents but, since the data does not support this as being an issue with pavement performance, the associated cost increases may not be justified.

Figure 4.22 shows dry ITS plotted versus average asphalt content for surface, intermediate and base layers on the selected flexible projects. While there is considerable scatter in the data, the second order polynomial trendlines suggest that layer strength decreases from surface to intermediate to base layers, optimal asphalt content for maximum ITS also decreases with depth, and asphalt contents in all three layers tend to be above optimal on most projects.

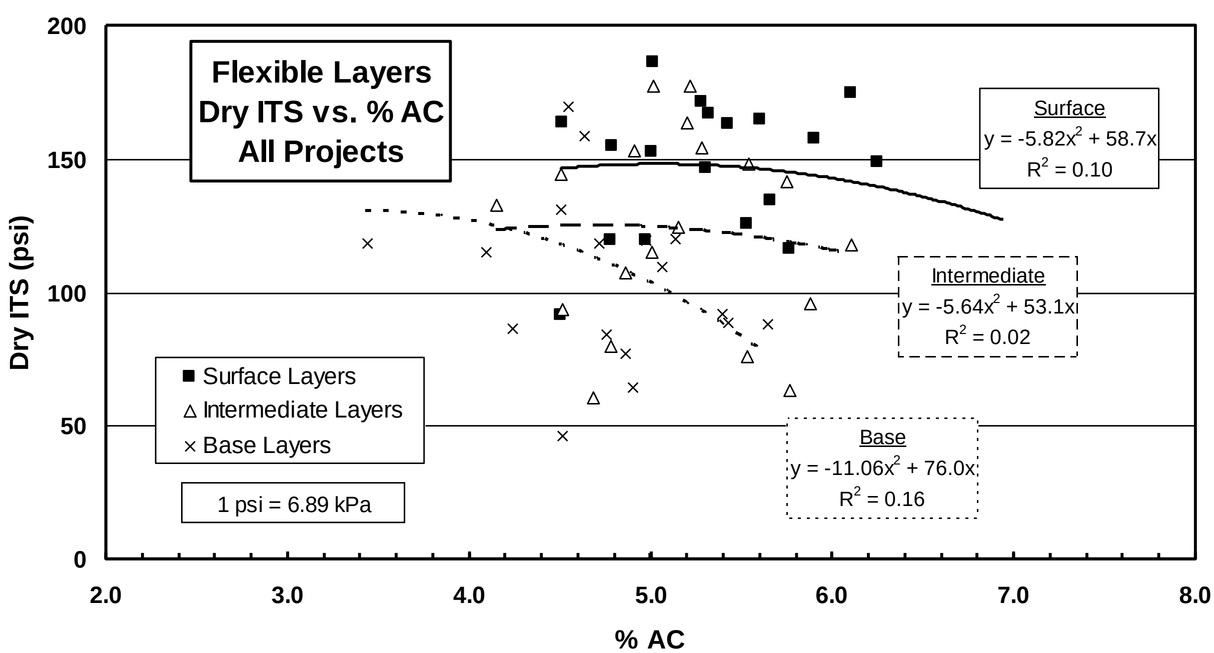


Figure 4.22 - % Asphalt Cement vs. Indirect Tensile Strength by Layer

Figure 4.23 shows the same data in Figure 4.22, but broken down by level of performance. With fewer points available for each group of data, the trends become more uncertain, although R^2 for the average and excellent performing surface courses are much better than the combined data in Figure 4.22. The trendline for average performance on the surface layer, while having an improved R^2, has an entirely different shape than the other trendlines.

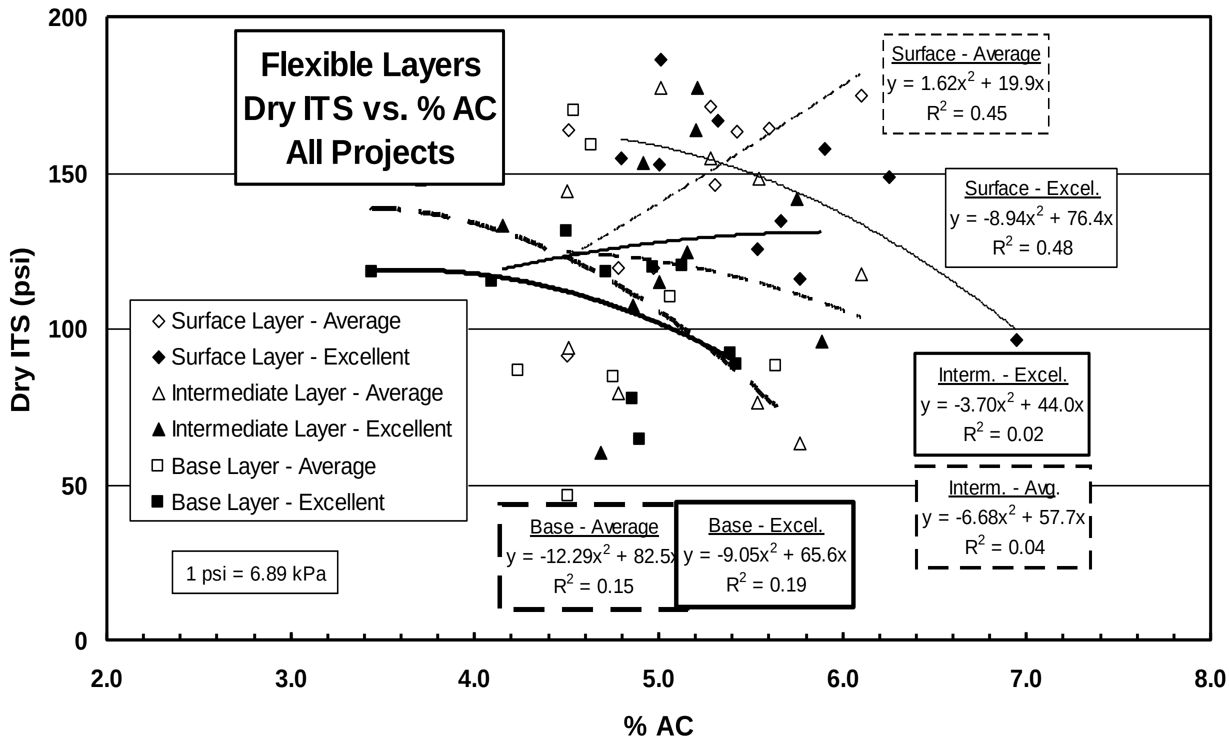


Figure 4.23 - % Asphalt Cement vs. Indirect Tensile Strength by Layer and Performance

Laboratory Testing of Rigid Pavement Cores

Mix parameters determined at Lankard Materials Laboratory and structural properties measured in the ORITE laboratory for the Portland cement concrete cores are summarized below in Tables 4.19 and 4.20, respectively. These results have been integrated into results of the petrographic analysis performed by Dave Lankard at Lankard Materials Laboratory, and are discussed in greater detail in Volume 2. Table 4.21 shows the sources of aggregate used in the selected rigid pavement projects.

Table 4.19

Rigid Pavement Mix Parameters

Summary of Rigid Pavement Core Data					
Project	**Project No.**	**Coarse Aggregate***	**Air Voids (%)**	**W/C Ratio**	**Paste/Aggr. Bond**
Average Performance					
ATH 33 13E	235(58)	1” Ls	6.64	0.45	Fair
ATH 682 1N	625(76)	3/8” Gr	7.55	0.45	Excellent
CUY 176 10S	683(94)	1” Slag	1.93	0.44	Good
CUY 176 11S	305(96)	3/8” Ls	8.35	0.43	Poor
CUY 176 12S	305(96)	3/8” Ls	8.44	0.43	Fair
CUY 252 4N	901(84)	3/8” Ls	8.18	0.45	Low
JEF 22 15E	8008(90)	1” Slag	5.16	0.42	Good
LOG 33 24W	845(94)	3/8” Ls	7.47	0.46	Fair
SUM 76 15E	996(93)	3/8” Ls	6.30	0.44	Fair
TUS 39 4E	907(90)	3/4” Gr	7.62	0.43	Good
Excellent Performance					
ALL 30 22E	746(97)	3/4” Ls	5.16	0.42	Fair/Low
CUY 82 3E	438(94)	3/8” Ls	6.92	0.48	Good
CUY 322 10E	1019(93)	3/8” Ls	9.16	0.46	Poor
GAL 7 8N	352(46)	2” Gr	3.44	0.48	Good
GRE 35 19W	19(97)	3/4” Ls	4.24	0.48	Good
HAM 126 12E	997(90)	1” Gr	5.03	0.45	Good
JEF 7 19S	8008(90)	3/4” Slag	6.10	0.46	Good
MOT 35 14W	343(88)	3/8” Gr	5.03	0.45	Fair
MOT 202 3N	678(91)	3/8” Gr	8.34	0.47	Fair
SUM 76 15W	996(93)	3/8” Ls	6.96	0.44	Good

* Ls = Limestone   Gr = Gravel

1 psi = 6.89 kPa

Table 4.20

Structural Results for Concrete Cores

Structural Testing of PCC Cores											
Project	Project No.	Maximum Coarse Aggregate	Nominal Core Diameter (in.)	Average Core Length (in.)	Approx. L/D	Unit Weight (pcf) (ASTM C 642)	Compressive Strength (ksi) (ASTM C 39)	Static Modulus (10^6 psi) (ASTM C 469)	Poisson's Ratio (ASTM C 469)	Split Tensile Strength (psi) (ASTM C 496)	Coefficient of Thermal Expansion ($10^{-6}/^oC$)
Average Performance											
ATH 33 13E	235(58)	1" Ls	4	8.6	2.18	142.3	6.85	4.102	0.130	617.7	9.99
			6	8.5	1.43	140.8	6.97 (6.62*)	3.397	0.150	N.A.	
ATH 682 1N	625(76)	3/8" Gr	4	9.0	2.29	139.6	7.99	4.295	0.164	632.0	
			6	8.8	1.49	137.1	8.24 (7.91*)	3.845	0.194	N.A.	
CUY 176 10S	683(94)	1" Slag	4	9.0	2.29	143.4	6.26	4.428	0.221	609.5	10.49
CUY 176 11S	305(96)	3/8" Ls	4	9.0	2.29	137.4	3.76	3.828	0.182	602.8	
CUY 176 12S	305(96)	3/8" Ls	4	9.0	2.29	136.7	3.82	3.600	0.188	541.7	8.85
CUY 252 4N	901(84)	3/8" Ls	4	8.6	2.19	136.3	5.55	2.720	0.209	570.1	7.73
JEF 22 15E	8008(90)	1" Slag	4	9.0	2.31	147.8	7.34	5.761	0.229	491.7	9.39
LOG 33 24W	845(94)	3/8" Ls	4	9.4	2.35	140.5	8.72	4.910	0.217	706.7	11.41
SUM 76 15E	996(93)	3/8" Ls	4	8.9	2.23	141.5	5.65	5.436	0.216	630.2	
TUS 39 4E	907(90)	3/4" Gr	4	9.0	2.29	147.5	6.86	4.172	0.155	643.8	9.63
Average - 4" Cores			4	8.96	2.27	141.3	6.28	4.325	0.191	604.6	9.64
Standard deviation - 4" Cores				0.22	0.05	4.1	1.63	0.886	0.033	59.1	1.18
Excellent Performance											
ALL 30 22E	746(97)	3/4" Ls	4	8.9	2.54	151.2	8.41	5.540	0.216	711.4	10.61
CUY 82 3E	438(94)	3/8" Ls	4	9.0	2.29	142.2	5.74	5.250	0.209	515.5	10.51
CUY 322 10E	1019(93)	3/8" Ls	4	8.8	2.24	136.3	5.05	4.371	0.245	596.0	9.58
GAL 7 8N	352(46)	2" Gr	4	7.9	2.01	144.3	7.85	3.957	N.A.	660.0	9.54
GRE 35 19W	19(97)	3/4" Ls	4	9.0	2.32	149.9	6.11	5.895	0.234	574.5	9.46
HAM 126 12E	997(90)	1" Gr	4	8.9	2.28	149.4	6.49	6.902	0.279	635.4	10.44
JEF 7 19S	8008(90)	3/4" Slag	4	9.1	2.36	146.6	6.82	5.318	0.180	538.5	10.45
MOT 35 14W	343(88)	3/8" Gr	4	9.0	2.29	148.4	4.88	7.157	0.268	830.7	11.01
MOT 202 3N	678(91)	3/8" Gr	4	8.9	2.25	140.7	4.93	5.079	0.223	613.4	8.69
SUM 76 15W	996(93)	3/8" Ls	4	8.9	2.23	139.6	5.49	5.705	0.221	624.6	11.49
Average			4	8.85	2.28	144.9	6.18	5.517	0.231	630.0	10.18
Standard deviation				0.34	0.13	5.0	1.22	0.991	0.030	90.6	0.84
Average all 3/8" limestone (8**)			4	9.0	2.26	138.8	5.47	4.478	0.211	598.4	9.93
Average all 3/4" limestone (2**)			4	9.0	2.43	150.6	7.26	5.717	0.225	642.9	10.04
Average all 1" limestone (1**)			4	8.6	2.18	142.3	6.85	4.102	0.130	617.7	9.99
Average all 3/8" gravel (3**)			4	9.0	2.28	142.9	5.93	5.510	0.218	692.0	9.85
Average all 3/4" gravel (1**)			4	9.0	2.29	147.5	6.86	4.172	0.155	643.8	9.63
Average all 1" gravel (1**)			4	8.9	2.28	149.4	6.49	6.902	0.279	635.4	10.44
Average all 2" gravel (1**)			4	7.9	2.01	144.3	7.85	3.957	N.A.	660.0	9.54
Average all 3/4" slag (1**)			4	9.1	2.36	146.6	6.82	5.318	0.180	538.5	10.45
Average all 1" slag (2**)			4	9.0	2.30	145.6	6.80	5.095	0.225	550.6	9.94

* Corrected for L/D per AASHTO T-24 ** Number of projects 1 inch = 2.54 cm 1 pcf = 16.02 kg/m3 1 psi = 6.89 kPa

Table 4.21

Concrete Aggregate Sources

Material Suppliers for Concrete Pavements							
Co./Rt.	**Project**	**General Contractor**	**Cement**	**Sand**	**Coarse Aggregate**	**Fly Ash**	**Comments**
ALL 30	746(97)		State Materials	National, Napoleon	#57 Crushed, National, Lima	Class F, State Matls.	JMF
ATH 33	235(58)	Data not available					
ATH 682	625(76)	Great Lakes	Marquette	Blazer, Chauncey	#8 Gravel, Richards, Apple Grove		
CUY 82	438(94)		Lafarge	Lafarge, Shalersville	#8 Limestone, National at Carey		JMF
CUY 176	683(94)	Great Lakes	ESSROC, Bessemer	Lafarge, Shalersville	Slag, Lafarge, LTV, Cleveland		
CUY 176	305(96)		Lafarge	Lafarge, Shalersville	#8 Limestone, Lafarge at Marblehead		JMF
CUY 252	901(84)	Great Lakes	Dundee	Std. Slag, Shalersville	#8 Limestone, Marblehead Stone		
CUY 322	1019(93)		St. Marys	Lafarge, Shalersville	#8 Limestone, Marblehead Stone		JMF
GAL 7	352(46)	Holderman	Columbia	Ohio River S&G, New Martinsville, WV	Ohio River S&G, New Martinsville, WV		
GRE 35	19(97)		Cemex	Phillips S & G, Alpha	#57 Limestone, Melvin in Melvin	Class F, Duke Energy	JMF
HAM 126	997(90)	Geupel	Lehigh	America Aggr., Fairfield	#57 Gravel, American Aggr., Fairfield		
JEF 7, 22	8008(90)	Kokosing	ESSROC	Spring Industries, Midvale	#57 Slag, Std. Larfarge, Weirton WV		
LOG 33	845(94)	Miller Bros.	Medusa	Union Aggregates, Prospect	#8 Limestone, East Liberty		
MOT 35	343(88)	Ruhlin	Southwest	American Aggr., Xenia	#57 Limestone, Amererican Aggr., Xenia		
MOT 202	678(91)	Data not available					
SUM 76	996(93)		Cemex	Allied Corp., Massilon	#8 Limestone, Martin Marietta, Woodville	Class F, Clev. Ill	JMF
TUS 39	907(90)	Holloway	Medusa	SR 416 S & G, New Phil.	# 57 Gravel, SR 416 S & G, New Phil.		

Gradation and Classification of Base and Subgrade

Unbonded granular base samples were analyzed at 34 sites for grain size per ASTM D 422 and at 32 sites for AASHTO Soil Classification per ASTM D 3282. Samples of subgrade soil from 21 sites were analyzed for liquid limit and plastic limit per ASTM D 4318, and AASHTO Soil Classification per ASTM D 3282. Total thickness of the pavement and base layers and/or the strength of the base material precluded the collection of soil samples at a few locations. Table 4.22 summarizes the results of these tests by pavement type and level of performance. These tests complete Object 6, as follows:

> *Objective 6 - Conduct laboratory tests to determine the current physical properties of pavement, base and subgrade materials in the study pavements. Compare these current properties with properties measured at the time of construction. In addition to this battery of standard tests, the PCC cores will undergo an extensive petrographic examination to ascertain compliance with original specifications and current micro-structural condition.*

Table 4.22

Base and Subgrade Classifications

Base and Subgrade Properties											
Site	Base Material						Subgrade				
	Maximum Grain Size		% Passing #10	% Passing #40	% Passing #200	Class.	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	Class.
	in.	cm								
Flexible Pavements - Average Performance										
BUT 129 22W	1.5	3.8	39.8	20.8	10.1	A-1-a				
BUT 129 25W	1.0	2.5	34.6	17.5	9.8	A-1-a				
CHP 68 2.5N										
CLA 41 4N	1.0	2.5	36.0	20.5	11.4	A-1-a	22.4	14.2	8.2	A-6
DEL 23 18S							27.7	16.3	11.4	A-6
HAM 747 1S	2.0	5.0	25.8	6.7	0.2	A-1-a				
LAW 527 2N	1.0	2.5	79.6	70.9	63.9					
LUC 2 22E	1.0	2.5	30.9	11.3	0.5	A-1-a				
PIK 32 19W	1.0	2.5	20.4	11.2	5.6	A-1-a	29.9	18.1	11.8	A-6
Flexible Pavements - Excellent Performance										
BUT 129 22E	1.5	3.8	48.1	24.8	11.2	A-1-a				
CHP 68 2N	1.0	2.5	35.0	24.6	15.5	A-1-b				
CLA 41 3N	1.0	2.5	29.0	17.2	9.7	A-1-a				
DEL 23 17S	1.0	2.5	25.8	16.6	11.4	A-1-a	28.8	17.3	11.5	A-6
GRE 35 21E	1.0	2.5	20.2	8.7	0.5	A-1-a	20.4	12.8	7.6	A-4
HAM 126 11E	1.0	2.5	51.3	18.8	8.5	A-1-b	31.1	18.6	12.5	A-6
LUC 25 10S	1.0	2.5	29.9	1.6	0.5	A-1-a				
PIK 32 15W	1.0	2.5	17.5	9.5	5.6	A-1-a	14.3	9.5	4.8	A-4
PIK 32 19E	1.5	3.8	21.8	14.4	9.6	A-1-a	19.6	17.9	11.7	A-6
ROS 35 1W	1.5	3.8	10.4	2.4	0.5	A-1-a	28.4	16.8	11.6	A-6
Rigid Pavements - Average Performance										
ATH 33 13E	1.0	2.5	67.3	18.2	10.4	A-1-b	32.3	19.4	12.9	A-6
ATH 682 1N	1.5	3.8	16.8	9.6	6.3	A-1-a	33.9	18.9	15.0	A-6
CUY176 10S										
CUY 176 11S	1.0	2.5	41.3	14.7	0.5	A-1-a				
CUY 176 12S	0.5	1.3	46.3	10.4	0.3	A-1-a				
CUY 252 4N	0.5	1.3	53.6	28.5	14.6	A-1-a	28.1	13.3	14.8	A-6
JEF 22 15E										
LOG 33 24W	1.0	2.5	17.1	6.1	0.2	A-1-a	27.0	14.4	12.6	A-6
SUM 76 15E										
TUS 39 4E	1.5	3.8	43.2	12.3	0.4	A-1-a	24.2	16.6	7.6	A-4
Rigid Pavements - Excellent Performance										
ALL 30 22E	1.0	2.5	22.6	6.5	0.3	A-1-a	29.6	17.2	12.4	A-6
CUY 82 3E	1.5	3.8	26.5	7.9	0.2	A-1-a	32.3	16.1	16.2	A-6
CUY 322 10E	0.5	1.3	52.9	14.7	0.5	A-1-b	36.4	20.0	16.4	A-6
GAL 7 8N	1.0	2.5	60.5	13.5	8.8	A-1-b				
GRE 35 19W	1.0	2.5	17.8	6.6	0.3	A-1-a	20.9	18.4	2.5	A-4
HAM 126 12E	1.0	2.5	25.7	7.9	0.4	A-1-b	25.3	14.5	10.8	A-6
JEF 7 19S	0.5	1.3	52.7	0.3	0.0	A-1-a	28.5	16.0	12.5	A-6
MOT 35 14W	1.0	2.5	20.9	12.0	7.7	A-1-a				
MOT 202 3N	1.5	3.8	28.0	11.0	3.8	A-1-a				
SUM 76 15W										

Summary

1. Of the mix parameters and aggregate gradations determined for flexible pavement cores in this study, major differences between average and excellent performing sites included asphalt content and gradation of aggregate in the surface mixes. Average asphalt contents were 5.16% and 5.62% for the average and excellent performing pavements, respectively. Excellent pavements had a pronounced hump between the #4 and #50 sieves where more small material passed these sieves. Similar humps occurred in the AC intermediate and base mixes for both average and excellent performing flexible pavements. Aggregate gradations in the surface mix have evolved in this direction since the 1990s when many of these pavements were constructed. As a result, the coarser Type 1H mix has been replaced with finer graded Superpave 442 mixes.

2. Since raveling was noted as a common distress on most average and excellent performing flexible sections selected for study in the PMIS, low asphalt contents are mentioned as a possible concern on flexible pavements. This can occur as contractors bid for projects and maintain profitability by reducing their cost of producing and placing asphalt concrete. Asphalt contents have been closely monitored by ODOT and adjustments have been made to design and QC requirements since 1997. In addition, the Superpave 442 mix design requirements have been altered from the national standard to yield higher asphalt binder contents. Ohio is one of only a few states to require these higher asphalt binder contents.

3. In the PMIS, low severity raveling was noted as existing on all flexible pavement sections, except the two DEL 23 sections which were not rated, and surface deterioration was noted on 17 of the 20 rigid pavement sections with average and excellent performance. These distresses were not obvious during the site visits and ODOT should review how these distresses are being rated.

4. While not obvious from Table 4.1, limestone aggregate tends to provide slightly better long term performance than gravel aggregate on flexible pavements. This issue is not

considered to be serious in most areas and, since the price of hauling aggregate has a significant impact on construction costs, locally available sources should be used whenever possible. However, some very poor performing glacial gravel is present in Ohio, as documented in a recent study by the University of Toledo, and specific restrictions on these aggregates have been implemented. One solution is to require that limestone aggregate be incorporated into mixes containing poor quality gravel.

5. Except for the excellent performing projects at -20° C (-4° F), average measured creep compliance was consistently below defaults suggested in the MEPDG. Average creep compliance for the excellent performing pavements at -20° C (-4° F) was very close to the MEPDG defaults.

6. Creep compliance was consistently higher for the excellent performing pavements than the average performing pavements at 0° C (32° F) and -20° C (-4° F). At -10° C (14° F), average performing pavements were higher from 2 to a little over 100 seconds and then crossed over lower beyond 100+ seconds.

7. Despite measured creep compliance being lower than MEPDG defaults, thermal cracking was only noted on CHP 68 2.5N, CLA 41 4N and HAM 747 1S in the PMIS, all average performing pavements.

8. Equipment problems made it difficult to keep creep compliance samples at the proper temperature during testing. Since air in the laboratory warmed the samples as sensors were adjusted prior to loading, measured creep compliance tended to be slightly higher than if the samples had remained at the desired test temperatures. Creep compliance results were consistently lower than the recommended MEPDG defaults, and this difference would have been even greater if sample temperatures had remained constant during the tests. The low values of creep compliance may have been caused by aging of the asphalt concrete samples which were 11 to 25 years old.

Chapter 5

Predicted Pavement Performance

Objective 7 - Perform mathematical analyses to assess theoretical structural performance based on distress and thickness using various performance prediction procedures, historical data and in-situ material properties. At a minimum, equations developed under NCHRP 1-26, software developed under NCHRP 1-37A and 1993 AASHTO procedures will be used to predict performance.

General

As indicated in the objectives, historical data and in-situ material properties were to be used with various procedures to assess the performance of flexible and rigid pavements selected for study. The problems discussed earlier with having to manually search the 2002 and 2004 PMIS databases required this task be delayed until the selection process was completed and material samples collected in the field were tested to obtain the required physical properties. A preliminary list of projects was assembled in the spring of 2008 and forwarded to ODOT for FWD and ride quality measurements. As these tests were proceeding, a few sites were visited to ensure that they would be suitable for study. A few projects were eliminated from further consideration based on these visits. It became apparent, as new projects were added to replace the deleted projects, there would not be sufficient time to complete the FWD and ride quality testing, coring, laboratory testing, and performance evaluation within the original time schedule. Another problem occurred when ODOT was unable to perform the coring as initially planned and ORITE had to fabricate a rig to cut the cores. Consequently, the performance prediction requirements were completed by using known pavement build-ups for projects on the preliminary list of projects, layer moduli backcalculated from the FWD measurements, and various structural parameters measured with the FWD to define performance with the Mechanistic-Empirical Pavement Design Guide (MEPDG).

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Preliminary Pavement Lists

The preliminary list of projects assembled from the initial manual search of the 2002 and 2004 PMIS databases included eighteen flexible pavement sections from fourteen projects, and fifteen rigid pavement sections from thirteen projects, as shown in Tables 5.1 and 5.2. These lists vary somewhat from project lists in other chapters because this work was well under way while the extensive manual searches of the PMIS were in progress.

Table 5.1
Flexible Pavement Build Ups

Flexible Pavements Build Ups - Activity Code 100											
Proj. ID	Co-Rte	SLM Limits	Direction	Length mi. (km)	Project No.	Rating	Layer Thickness (in.(cm)) and Material Type				
1	BUT 129	17.96-24.00	D	6.04 (9.7)	9330(98)	Average	1.25 (3.2)	1.75 (4.4)	8 (20.3)	4 (10.2)	6 (15.2)
		17.83-24.00	U	6.17 (9.9)		Excellent	AC	AC	ATB	ATFDB	DGAB
2	BUT 129	24.00-24.73	DU	0.73 (1.2)	9327(98)	Average	1.25 (3.2)	1.75 (4.4)	8 (20.3)	4 (10.2)	6 (15.2)
							AC	AC	ATB	ATFDB	DGAB
3	CHP 68	1.27-1.74	D	0.47 (0.8)	233(98)	Excellent	1.5 (3.8)	1.75 (4.4)	6 (15.2)	6 (15.2)	
		1.27-1.82	U	0.55 (0.9)		Excellent					
		1.82-2.16	U	0.34 (0.5)		Average	AC	AC	ATB	DGAB	
4	FAY 35	17.57-24.05	DU	6.48 (10.4)	298(96)	Average	3 (7.6)	10 (25.4)	4 (10.2)	6 (15.2)	7.5 (19.1)
							AC	ATB	CTFDB	DGAB	Lime Soil
5	GRE 35	20.95-26.21	DU	5.26 (8.5)	259(98)	Excellent	1.5 (3.8)	4 (10.2)	8 (20.3)		
							AC	ATB	DGAB		
6	HAM 126	6.83-7.09	DU	0.26 (0.4)	645(94)	Average	1.25 (3.2)	1.75 (4.4)	10 (25.4)	6 (15.2)	6 (15.2)
		7.09-11.35	DU	4.26 (6.9)		Excellent	AC	AC	ATB	DGAB	310
7	HAM 747	0.04-0.94	U	0.90 (1.4)	347(85)	Average	1 (2.5)	1 (2.5)	9 (22.9)		
							AC	AC	ATB		
8	LAW 7	1.4-2.28	DU	0.88 (1.4)	17(85)	Excellent	1.25 (3.2)	1.5 (3.8)	9 (22.9)		
							AC	AC	ATB		
9	LIC 16	19.72-20.38	DU	0.66 (1.1)	6010(99)	Average	1.25 (3.2)	1.75 (4.4)	9 (22.9)	6 (15.2)	6 (15.2)?
							AC	AC	ATB	DGAB	310
10	LUC 2	21.39-27.25	U	5.86 (9.4)	141(99)	Average	1.25 (3.2)	1.75 (4.4)	10 (25.4)	6 (15.2)	
							AC	AC	ATB	DGAB	
11	LUC 25	10.01-11.28	DU	1.27 (2.0)	665(97)	Excellent	1.25 (3.2)	1.75 (4.4)	7 (17.8)	8 (20.3)	6 (15.2)
							AC	AC	ATB	DGAB	310
12	PIK 32	13.43-16.08	D	2.65 (4.3)	443(94)	Excellent	1.25 (3.2)	1.75 (4.4)	9 (22.9)	4 (10.2)	6 (15.2)
							AC	AC	ATB	ATFDB	DGAB
13		16.08-20.47	D	4.39 (7.1)	552(95)	Average	1.25 (3.2)	1.75 (4.4)	9 (22.9)	4 (10.2)	6 (15.2)
			U			Excellent	AC	AC	ATB	ATFDB	DGAB
14	ROS 35	0-4.38	DU	4.38 (7.1)	298(96)	Excellent	3 (7.6)	10 (25.4)	4 (10.2)	6 (15.2)	8 (20.3)
							AC	ATB	CTFDB	DGAB	Lime Soil

Table 5.2

Rigid Pavement Build Ups

Rigid Pavement Build Ups - Activity Code 110									
Proj. ID	Co-Rte	SLM Limits	Direction	Length mi. (km)	Project No.	Rating	Layer Thickness (in.(cm)) and Material Type		
15	ATH 50	11.46-11.8	U	0.34 (0.5)	700(86)	Average	9 (22.9)	6 (15.2)	
							JRC	310	
16	ATH 682	0.16-0.64	DU	0.48 (0.8)	625(76)	Average	9 (22.9)	6 (15.2)	
							JRC	310	
17	CUY 82	3.22-3.66	D	0.44 (0.3)	438(94)	Excellent	11 (27.9)	6 (15.2)	
		2.05-3.82	U	1.77 (2.8)		Excellent	JRC	DGAB	
18	GAL 7	5.71-10.21	U	4.5 (7.2)	352(46)	Excellent	11 (27.9)	6 (15.2)	
							JRC	DGAB	
19	HAM 126	11.35-13.31	DU	1.96 (3.2)	997(90)	Excellent	10 (25.4)	6 (15.2)	
							JRC	ATB	
20	JEF 7	18.9-19.21	D	0.31 (0.5)	8008(90)	Average	9 (22.9)	6 (15.2)	
							JRC	310	
21	JEF 22	15.02-16.32	U	1.3 (2.1)	8008(90)	Average	9 (22.9)	6 (15.2)	
							JRC	310	
22	LOG 33	21.79-25.63	D	3.84 (6.2)	845(94)	Average	12 (30.5)	4 (10.2)	4 (10.2)
		21.51-25.63	U	4.12 (6.6)		Excellent	PCC	307 IA	DGAB
23	MOT 35	14.37-15.07	DU	0.7 (1.1)	343(88)	Excellent	9 (22.9)	6 (15.2)	
							PCC	310	
24	MOT 202	2-3.25	U	1.25 (2.0)	678(91)	Excellent	9 (22.9)	10 (25.4)	
							PCC	310	
25	SUM 76	11.8-13.32	D	1.52 (2.4)	844(92)	Excellent	11 (27.9)	4 (10.2)	
			U			Average	JRC	ATB	
26	SUM 76	13.32-15.32	D	2.00 (3.2)	996(93)	Excellent	11 (27.9)	4 (10.2)	4 (10.2)
			U			Average	JRC	ATB	DGAB
27	TUS 39	2.84-7.12	U	4.28 (6.9)	907(90)	Average	9 (22.9)	6 (15.2)	
							PCC	310	

<u>Material Classifications</u>

A brief explanation of the various specification designations used to describe materials shown above for the selected projects is provided in the following discussion:

ODOT Specification 441, Contractor Mix Design and Quality Control - General, describes asphalt layer composition, aggregate and asphalt binder.

ODOT 446 has the same material specifications as ODOT 441, but different procedures were used for quality control. At the time these routes were constructed, densities of the compacted mixes were required to be between 91.0 to 94.9% the maximum specific gravity.

ODOT 448 has the same material specifications as ODOT 441 but the procedures for quality control are more rigorous.

ODOT 301, Bituminous Aggregate Base, describes base layers consisting of asphalt stabilized aggregate mixed with binder. This item is required to meet ODOT 401 except for some modifications such as the aggregate graduation, and the spreading and finishing. By the time of the construction of these routes, the binder content percentage was required to be between 4.0-8.0%. For proper compaction, the maximum depth of the bituminous aggregate base layer was required to be less than 6 inches (150 mm).

ODOT 302, "Bituminous Aggregate Base", describes the base pavement layer composition; this base layer consists of aggregate source material mixed with asphalt binder. This item is required to meet the ODOT 441 except for some modifications such as the aggregate graduation, and the spreading and finishing. By the time of the construction of these routes, the air voids percent and the binder content was required to be between 3.0 and 8.0%. In order to be compacted, the depth of the bituminous aggregate base layer was required to be between 100 mm (4 inches) and 200 mm (8 inches), and the temperature of the mix was required to be at least 250º F (120º C) when dumped in the paver.

ODOT 304, "Aggregate Base", describes the composition of aggregate base layers using one or more types of aggregate. The base layer thickness after compaction is required to not exceed 150 mm (6 inches).

ODOT 306, "Cement Treated Free Drainage Base", consists of a mix of course aggregate, cement, and water; the water/cement ratio must be approximately 0.36. The minimum cement content is limited to 148 kg and 130 kg when using #57 and #67 aggregate respectively.

ODOT 307, "Non-Stabilized Drainage Base", is classified into three categories, Type 'NJ' for New Jersey, Type 'IA' for Iowa, and Type 'CE'. After compaction, the base layer thickness was required to not exceed 100 mm (4 inches) for Types NJ and IA, and 150 mm (6 inches) for Type 'CE'.

ODOT 310 is divided into Types I and II subbase based on gradation. Maximum liquid limit and plastic index for aggregate passing the #40 sieve was to be less than 30 and 6, respectively.

ODOT 451, "Reinforced Portland Cement Concrete Pavement", covered all the aspects such as description, materials, equipment, placing concrete, curing, joints, sealing joints, etc. of reinforced concrete pavements.

ODOT 452, "Plain Portland Cement Concrete Pavement", have the same basic requirements of ODOT 451, except: a) reinforcing steel mats are not required, b) dowel bars are required in transverse contraction joints, and c) contraction joints shall be spaced no more than 4.6 meters (15 feet) apart.

Predicted Remaining Service Life

The expected remaining service lives for most of the selected sections were calculated with the Mechanistic-Empirical Pavement Design Guide (MEPDG). This procedure combined models based on mechanistic equations in conjunction with databases assembled over several decades. The major advantage of using MEPDG software is that the influence of environmental conditions and material properties are accounted for in the analysis. It was not, however, calibrated for the analysis of jointed reinforced concrete pavement (JRCP), so the following analyses of JRCP sections were for comparative purposes only. Input data necessary to model asphalt concrete pavement performance are listed below (ARA, Inc. ERES Consultant Division, 2004 b):

1. General information
    - Design life
    - Pavement, base and subbase construction date
    - Traffic open month
    - Type of design
2. Site/project identification
    - Location
    - Project ID and section ID
    - Date
    - Traffic direction

3. Analysis parameters
    - Initial IRI
    - Performance criteria
4. Traffic parameters
    - Design life and opening date
    - Initial two-way AADTT
    - Number of lanes in the design direction
    - Percentage of trucks in the design direction
    - Percentage of trucks in design lane
    - Operational speed
    - Traffic volume adjustment
    - Axle load distribution factor
    - General traffic input
    - Traffic growth and truck configuration
5. Climate
6. Pavement Structure

The MEPDG software predicts performance for a variety of distress mechanisms, such as longitudinal cracking, alligator cracking, transverse cracking, total rutting, and terminal international roughness index on flexible and rigid pavements. In addition, faulting and the percentage of slab cracked can also be used to predict rigid pavement performance. Maximum values for distress mechanisms in these pavement sections are listed in Table 5.3. Tables 2.6 and 2.7 show specific distresses from the 2004 PMIS for selected flexible and rigid pavements.

Table 5.3
Maximum Allowable Distresses

Performance Criteria	Limit	Reliability
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

Traffic count data for the sections was obtained from the ODOT web site (ODOT, n.d., b). The annual average daily truck traffic (AADTT) and the growth rate factors for both flexible and rigid pavements were calculated and listed below in Table 5.4. Typical plots showing the reliability of predicted longitudinal cracking, transverse cracking, and international roughness index for flexible Project 3 - CHP 68 (Project 233-98) are shown in Figures 5.1, 5.2, and 5.3. The reliability of predicted faulting, percentage of slabs cracked, and international roughness index for rigid Project 16 – ATH 682 (Project 625-76) are presented in Figures 5.4, 5.5, and 5.6.

As predicted by MEPDG software, CHP 68 is expected to reach maximum longitudinal cracking at 20.7 years (reliability), maximum transverse cracking at 17.0 years (reliability), and 22.0 years (predicted). CHP 68 is not expected to develop alligator cracking and rutting distress mechanisms during its design life and the maximum IRI is not reached until after 25 years. This pavement was opened in 1998 and has been in service since that time. The first distress threshold expected to be reached on this pavement is transverse cracking in 2015.

Figure 5.4 shows maximum faulting on ATH 682 is expected to be reached after 50 years (reliability and predicted) of service and maximum reliability IRI distress is expected to be reached at 47.0 years. From Figure 5.5, the maximum percentage of slabs cracked allowed during the design life is expected to be reached at 48.0 years. This pavement section was opened in 1976 and has been in service more than 30 years. Based on MEPDG results, this project is expected to function until 2023 when the maximum threshold is reached for IRI. From Table 2.6, the pavement condition assigned to this section was “average” and the explanation of why the condition has not been worse is because of a steady decline of about 61% in annual average daily truck traffic since 1995 (AADTT $\approx$ 190 – year 2006) (ODOT, n.d., b).

The performance of 19 asphalt concrete pavement sections, divided into fourteen projects; and 21 portland cement concrete pavement sections, divided into 13 projects, were predicted using the MEPDG software. The results of the most relevant distress mechanisms acting on the pavement sections are presented in Appendices H and I for AC and PCC pavements respectively.

Table 5.4

Traffic Counts and Growth Rates

Project ID	Co-Rte	SLM Limits	Direction	Project No.	Initial AADTT	Growth Rate (%)
Flexible Pavements						
1	BUT 129	17.96-24.00	D	9330(98)	1419	5.8
		17.83-24.00	U		802	4.1
2	BUT 129	24.00-24.73	DU	9327(98)	1492	5.8
3	CHP 68	1.27-1.74	D	233(98)	1110	3.5
		1.27-1.82	U		1000	2.4
		1.82-2.16	U		1000	2.4
4	FAY 35	17.57-24.05	DU	298(96)	1598	5.5
5	GRE 35	20.95-26.21	DU	259(98)	1482	9.0
6	HAM 126	6.83-7.09	DU	645(94)	1320	3.2
		7.09-11.35	DU		1550	1.5
7	HAM 747	0.04-0.94	U	347(85)	318	3.7
8	LAW 7	1.4-2.28	DU	17(85)	556	1.6
9	LIC 16	19.72-20.38	DU	6010(99)	2671	9.0
10	LUC 2	21.39-27.25	U	141(99)	2316	4.5
11	LUC 25	10.01-11.28	DU	665(97)	796	1.0
12	PIK 32	13.43-16.08	D	443(94)	1240	2.0
13		16.08-20.47	D	552(95)	898	3.5
			U		898	3.5
14	ROS 35	0-4.38	DU	298(96)	1266	8.3
Rigid Pavements						
15	ATH 50	11.46-11.8	U	700(86)	414	3.6
16	ATH 682	0.16-0.64	DU	625(76)	198	1.0
17	CUY 82	3.22-3.66	D	438(94)	1666	1.0
		2.05-3.82	U		1666	1.0
18	GAL 7	5.71-10.21	U	352(46)	240	1.3
19	HAM 126	11.35-13.31	DU	997(90)	1474	2.5
20	JEF 7	18.9-19.21	D	8008(90)	2471	1.0
21	JEF 22	15.02-16.32	U	8008(90)	1194	7.5
22	LOG 33	21.79-25.63	D	845(94)	3440	1.6
		21.51-25.63	U		3440	1.6
23	MOT 35	14.37-15.07	DU	343(88)	1790	2.6
24	MOT 202	2-3.25	U	678(91)	624	2.5
25	SUM 76	11.8-13.32	D	844(92)	11041	2.0
			U		11041	2.0
26		13.32-15.32	D	996(93)	10893	2.3
			U		10893	2.5
27	TUS 39	2.84-7.12	U	907(90)	769	4.0

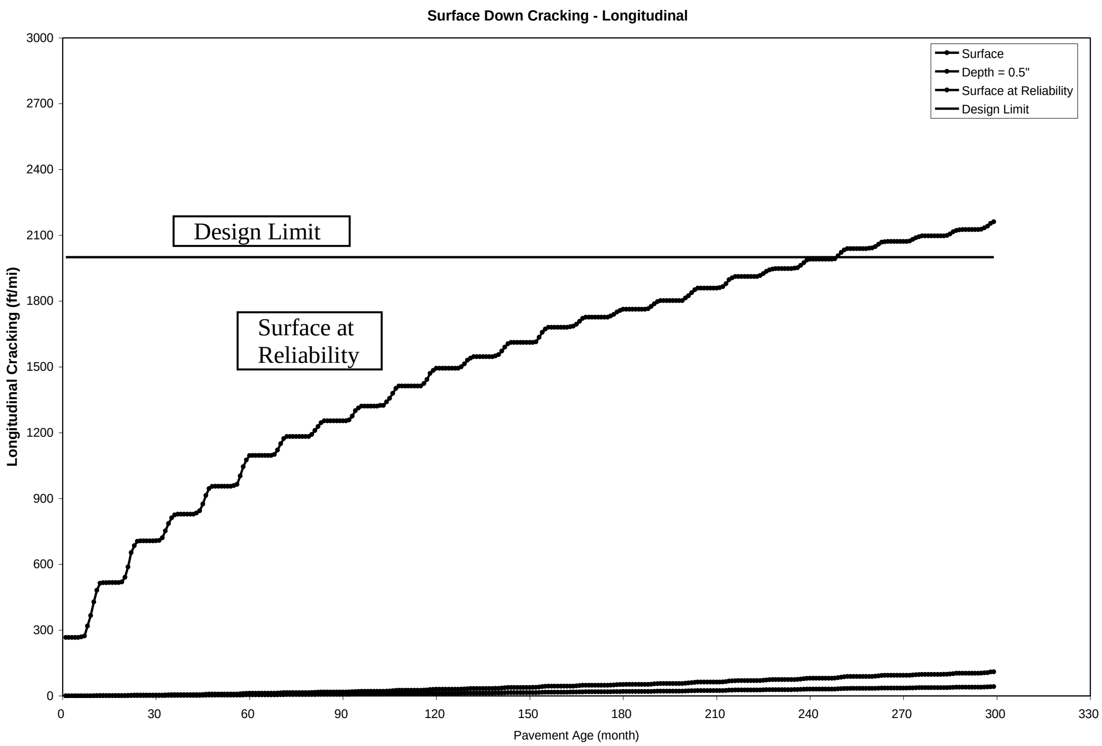

Figure 5.2 - Longitudinal Cracking on CHP 68

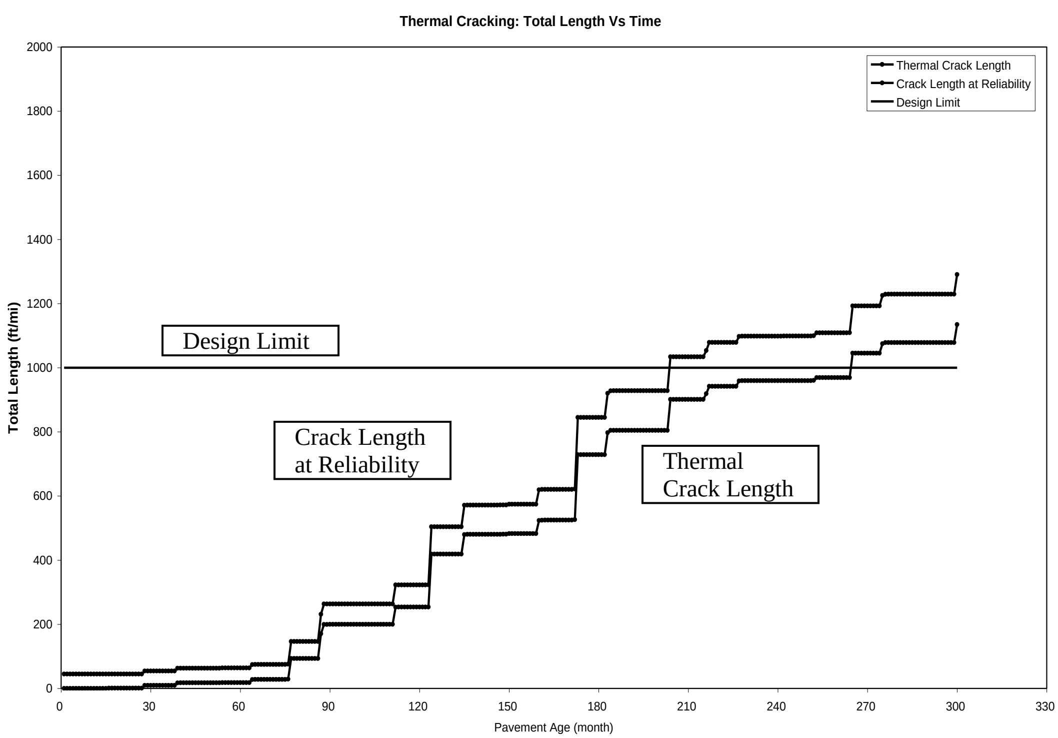

Figure 5.2 - Transverse Cracking on CHP 68

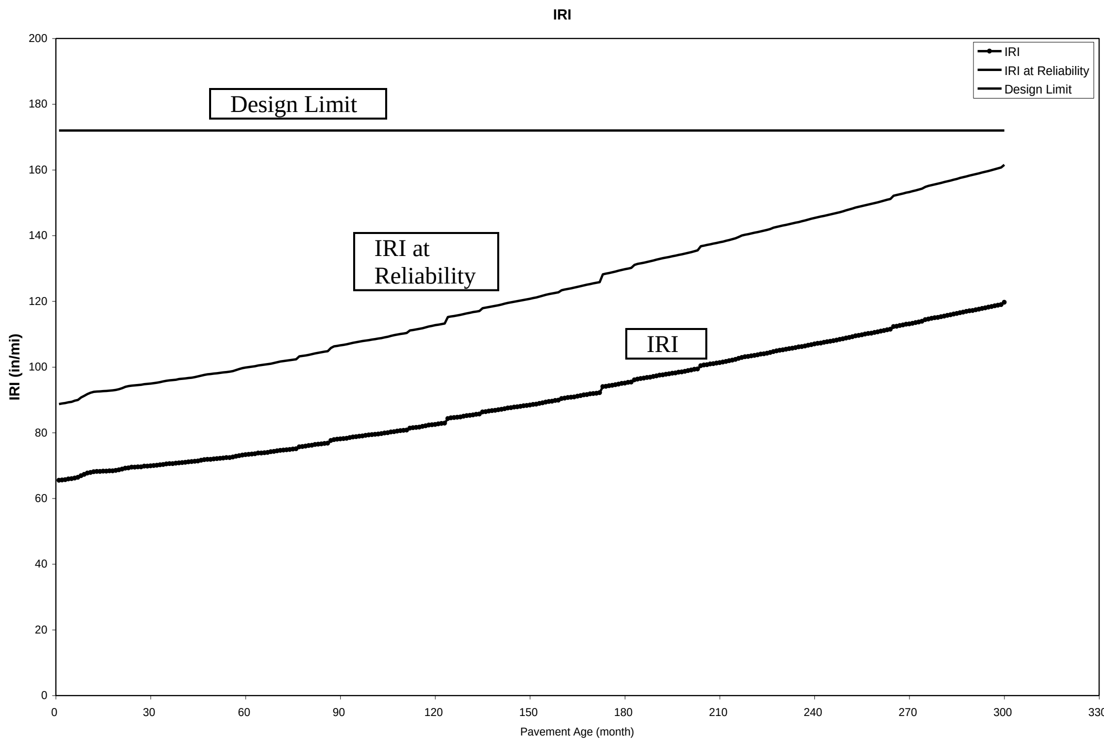

Figure 5.3 - International Roughness Index on CHP 68

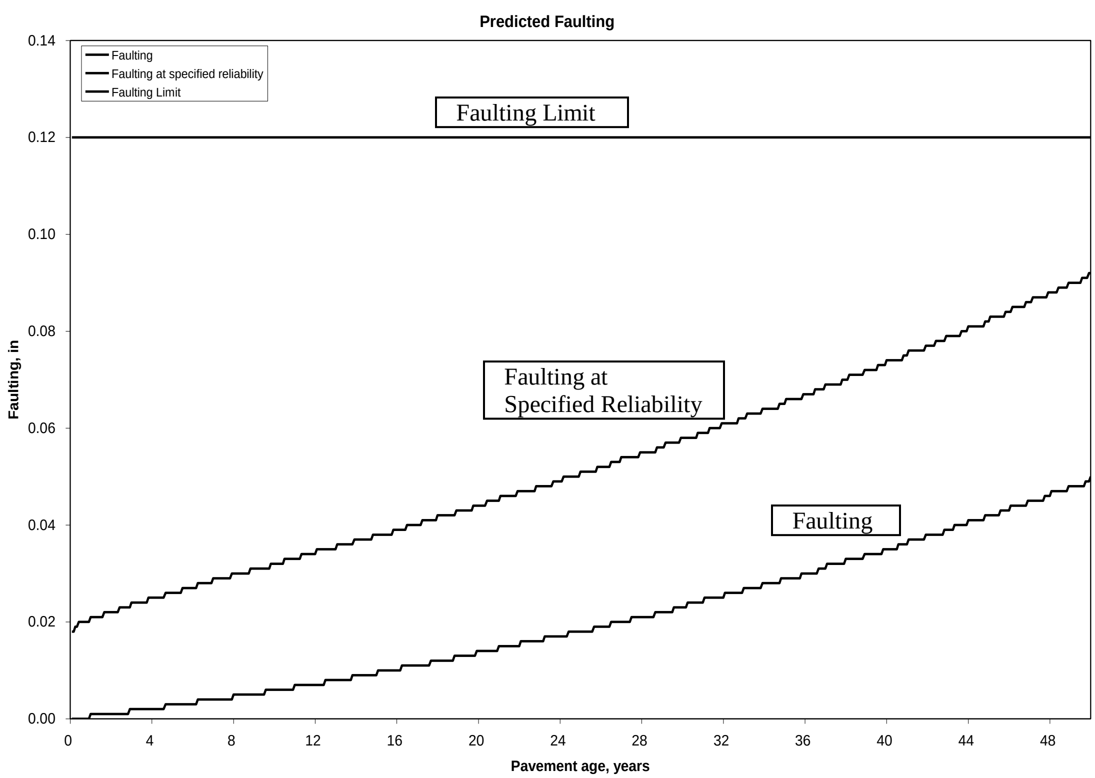

Figure 5.4 - Predicted Faulting on ATH 682

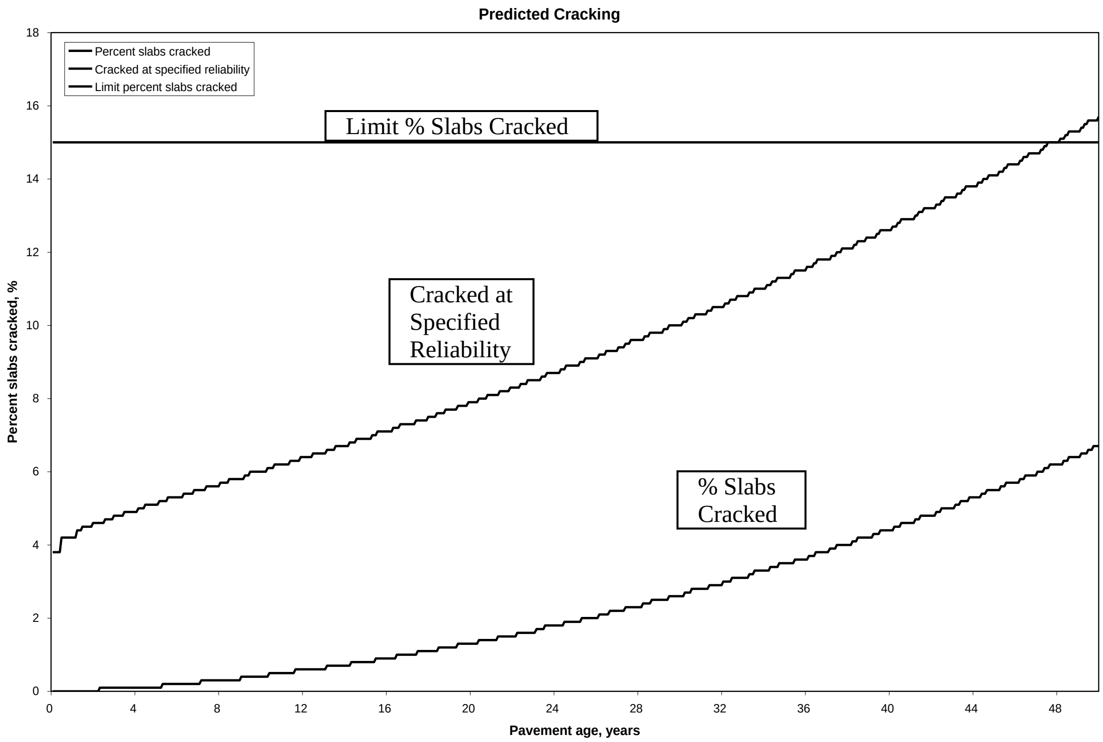

Figure 5.5 - Percentage of Slabs Cracked on ATH 682

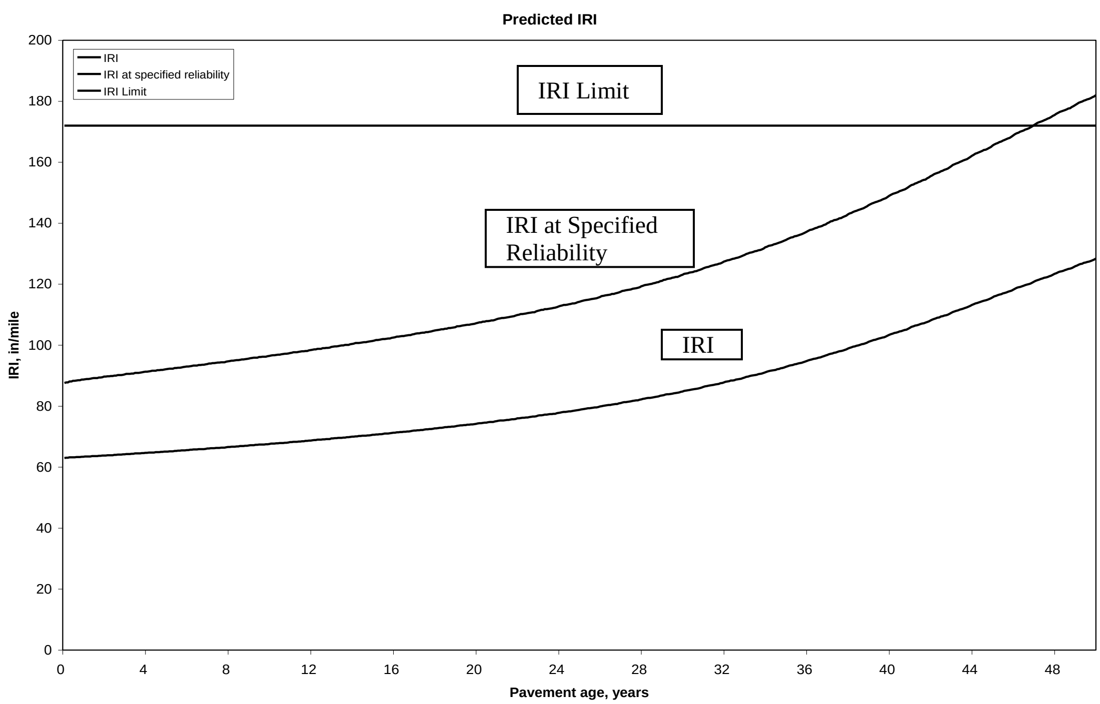

Figure 5.6 - International Roughness Index on ATH 682

Projected Performance from FWD Measurements

Data collected with the FWD was used with MODCOMP5.1 to backcalculate the modulus of elasticity for each pavement layer in each project. This program has been used by researchers for many years, and the results have been quite reliable. This software uses a backcalculation procedure to approximate layer stiffness with up to 12 sensors and 12 layers. The program provides two mechanisms to verify whether the results are reliable or not; first is “sensitivity” and the second is root mean square error (RMSE). The results can be considered reliable if the RMSE is less than 2%, and the layer is sensitive to the assigned sensor and assigned deflection. Moduli of elasticity obtained for the flexible pavement sections are listed in Table 5.5 and results obtained for the rigid pavement sections are listed in Table 5.6. Tables 5.7 shows the distribution of midslab condition over flexible and rigid pavement lengths based on deflection and Spreadability, and Tables 5.8, 5.9 and 5.10 show similar distributions for rigid pavement condition based on joint deflection, joint load transfer and Joint Support Ratio. When two numbers are shown, they refer to the downstation (D) and upstation (U) directions indicated in the tables. The ratings in Tables 5.7 to 5.10 came from Dynaflect and FWD data accumulated over several years, and empirically divided into levels of performance based on experience and expectations. Lower Spreadability ratings may result from the formation of micro-cracks over time on in-service pavements, which limits their ability to distribute loads more than resist vertical loads.

Table 5.5

Moduli of Elasticity – Flexible Pavements

Material Layer/Thickness/ Calculated Moduli for Flexible Pavements

Project 1 - BUT 129 9330(98)					
Layer	AC	ATB	ATFDB	DGAB	SUBGRADE
Thickness (in.)	3	8	4	6	N/A
Modulus (ksi)	424	4,065	36.2	87.9	86.7 (85.8)

Project 2 - BUT 129 9327(98)					
Layer	AC	ATB	ATFDB	DGAB	SUBGRADE
Thickness (in.)	3	8	4	6	N/A
Modulus (ksi)	530	1,560	89.2	97.4	46.2 (46.0)

Project 3 - CHP 68 233(98) D				
Layer	AC	ATB	DGAB	SUBGRADE
Thickness (in.)	3.25	6	6	N/A
Modulus (ksi)	164.5	939	24.1	44.0 (48.0)

Project 3 - CHP 68 233(98) U				
Layer	AC	ATB	DGAB	SUBGRADE
Thickness (in.)	3.25	6	6	N/A
Modulus (ksi)	120	957	19.4	38.6 (34.4)

Project 4 - FAY 35 298(96)*					
Layer	AC	ATB	CTFDB	DGAB	LSS
Thickness (in.)	3	10	4	6	7.5
Modulus (ksi)	280	680	96.9	38.2	11.7

Project 5 - GRE 35 259(98)				
Layer	AC	ATB	DGAB	SUBGRADE
Thickness (in.)	1.5	4	8	N/A
Modulus (ksi)	366	1,500	92.7	30.8 (29.4)

Project 6 - HAM 126 645(94) Average Condition				
Layer	AC	ATB	DGAB	SUBGRADE
Thickness (in.)	3	10	12	N/A
Modulus (ksi)	455	248	32.6	21.5 (23.5)

Project 6 - HAM 126 645(94) Excellent Condition				
Layer	AC	ATB	DGAB	SUBGRADE
Thickness (in.)	3	10	12	N/A
Modulus (ksi)	381	663	33	44.8 (44.6)

Project 7 - HAM 747347(85)			
Layer	AC	ATB	SUBGRADE
Thickness (in.)	2	9	N/A
Modulus (ksi)	399	1,090	27.9 (28.4)

Project 8 - LAW 527 17(85) U			
Layer	AC	ATB	SUBGRADE
Thickness (in.)	2.75	9	N/A
Modulus (ksi)	484	2,590	35.6 (35.9)

Project 8 - LAW 527 17(85) (D)			
Layer	AC	ATB	SUBGRADE
Thickness (in.)	2.75	9	N/A
Modulus (ksi)	357	1,170	47.4 (47.5)

Project 9 - LIC 16 6010(99)				
Layer	AC	ATB	DGAB and 310	SUBGRADE
Thickness (in.)	3	9	12	N/A
Modulus (ksi)	680	1.68	54.8	70.2 (63.0)

Project 10 - LUC 2 141(99)				
Layer	AC	ATB	DGAB	SUBGRADE
Thickness (in.)	3	10	6	N/A
Modulus (ksi)	415	948	27.9	26.3 (24.3)

Project 11 - LUC 25 665(97)				
Layer	AC	ATB	304 and 310	SUBGRADE
Thickness (in.)	2	7	14	N/A
Modulus (ksi)	171	1.11	125	62.0 (60.0)

Project 12 - PIK 32 443(94)					
Layer	AC	ATB	NSDB	DGAB	SUBGRADE
Thickness (in.)	3	9	4	6	N/A
Modulus (ksi)	505	1.763	28.7	35.4	56.1 (48.9)

Project 13 - PIK 32 552(95)					
Layer	AC	ATB	ATFDB	DGAB	SUBGRADE
Thickness (in.)	3	9	4	6	N/A
Modulus (ksi)	342	2.28	30.3	600	36.2 (36.1)

Project 14 - ROS 35 298(96) **					
Layer	AC	ATB	CTFDB	DGAB	LSS
Thickness (in.)	3	10	4	8	8
Modulus (ksi)	155	483	486	10.6	125

* Subgrade Modulus 48.3 (38.7) ksi

** Subgrade Modulus 50.9 (49.0) ksi

Table 5.6

Moduli of Elasticity – Rigid Pavements

Material Layer/Thickness/ Calculated Moduli for Rigid Pavements							
Project.15 - ATH 50 700(86)				**Project.21 - JEF 22 8008(90)**			
Layer	JRC	310	SUBGRADE	JRC	310	SUBGRADE	
Thickness (in.)	9	6	N/A	9	6	N/A	
Modulus (ksi)	2,930	137	21.4 (22.5)	3,830	93	40.4 (39.4)	
Project.16 - ATH 682 625(76)				**Project.22 - LOG 33 845(94)**			
Layer	JRC	310	SUBGRADE	PCC	307 IA	DGAB	SUBGRADE
Thickness (in.)	9	6	N/A	12	4	4	N/A
Modulus (ksi)	3,790	61	36.9 (36.0)	3,530	467	150	37.0 (39.5)
Project.17 - CUY 82 438(94)				**Project.23 - MOT 35 343(88)**			
Layer	JRC	DGAB	SUBGRADE	PCC	310	SUBGRADE	
Thickness (in.)	11	6	N/A	9	6	N/A	
Modulus (ksi)	3,800	183	39.75 (39.0)	3,820	368	60.0 (59.0)	
Project.18 - GAL 7 352(46)				**Project.24 - MOT 202 678(91)**			
Layer	JRC	310	SUBGRADE	PCC	310	SUBGRADE	
Thickness (in.)	9	6	N/A	9	10	N/A	
Modulus (ksi)	2,750	82	24.9 (25.1)	3,560	79	23.7 (24.8)	
Project.19 - HAM 126 997(90)				**Project.25 - SUM 76 844(92)**			
Layer	JRC	ATB	SUBGRADE	JRC	ATB	SUBGRADE	
Thickness (in.)	10	6	N/A	11	4	N/A	
Modulus (ksi)	4,510	746	46.9 (50.0)	5,580	1,420	35.0 (42.0)	
Project.20 - JEF 7 8008(90)				**Project.26 - SUM 76 996(93)**			
Layer	JRC	310	SUBGRADE	JRC	ATB	DGAB	SUBGRADE
Thickness (in.)	9	6	N/A	11	4	4	N/A
Modulus (ksi)	3,390	159	42.8 (41.8)	2,210	177	414	69.9 (68.0)
				Project.27 - TUS 39 907(90)			
Layer				JRC	310	SUBGRADE	
Thickness (in.)				9	6	N/A	
Modulus (ksi)				4,150	124	24.2 (24.1)	

Table 5.7

Pavement Condition Based on FWD Deflection

Distribution of Flexible and Rigid Midslab Pavement Condition (% of Length)																		
Project ID	Direction	Length	Deflection								Spreadability							
		miles (km)	Excellent		Good		Fair		Poor		Excellent		Good		Fair		Poor	
1	D	6.04 (9.7)	100		-		-		-		-		57.7		38.5		3.8	
	U	6.17 (9.9)	100		-		-		-		0.9		66.4		28.0		4.7	
2	DU	0.73 (1.2)	100	100	-		-		-		-	28.0	96.2	72.0	3.8	-	-	-
3	D	0.47 (0.8)	5.6		55.6		38.9		-		-		-		100		-	
	U	0.55 (0.9)	5.6		27.8		66.7		-		-		-		77.8		22.2	
	U	0.34 (0.5)	5.9		5.9		64.7		23.5		-		-		100		-	
4	U	6.48 (10.4)	26		54.5		14.6		4.9		-		45.5		53.7		0.8	
5	U	5.26 (8.5)	100		7.2		47.4		44.3		-		19.6		80.4		-	
6	DU	0.26 (0.4)	-	-	-	40.0	20.0	20.0	80.0	40.0	-	-	58.1	60.0	41.9	40.0	-	-
	DU	4.26 (6.9)	32.4	35.4	66.2	64.6	1.4	-	-	-	-	-	47.7	60.0	49.2	40.0	3.1	-
7	U	0.90 (1.4)	-		11.1		11.1		77.8		-		11.1		77.8		11.1	
8	DU	0.88 (1.4)	73.3	90.9	26.7	9.1	-	-	-	-	6.7		53.3	100	40.0	-	-	-
9	DU	0.66 (1.1)	100	96.8	-	3.2	-	-	-	-	3.2	3.2	64.5	45.2	32.3	51.6	-	-
10	U	5.86 (9.4)	8.7		54.4		35.9		1		43.7		53.4		2.9		-	
11	DU	1.27 (2.0)	87.0	79.2	13.0	16.7	-	4.2	-	-	-	-	13.0	20.8	82.6	79.2	4.3	-
12	D	2.65 (4.3)	100		-		-		-		-		2.6		89.7		7.7	
13	D	4.39 (7.1)	98.2		1.8		-		-		38.6		56.1		5.3		-	
	U		87.7		12.3		-		-		16.4		78.1		5.5		-	
14	DU	4.38 (7.1)	13.7	3.7	47.9	37.0	37.0	48.1	1.4	11.1	-	-	9.6	11.1	80.8	70.4	9.6	18.5
15	U	0.34 (0.5)	9.1		54.5		27.3		9.1		-		72.7		27.3		-	
16	DU	0.48 (0.8)	57.1	27.8	35.7	61.1	7.1	11.1			-	-	21.4	61.1	71.4	33.3	7.1	5.6
17	D	0.44 (0.3)	94.7		5.3		-		-		26.3		63.2		10.5		-	
	U	1.77 (2.8)	100		-		-		-		93.8		6.3		-		-	
18	U	4.5 (7.2)	2.7		55		35.6		6.8		6.7		46.3		40.3		6.7	
19	DU	1.96 (3.2)	100	100	-	-	-	-	-	-	-	20.0	75.0	60.0	25.0	20.0	-	-
20	D	0.31 (0.5)	81.8		18.2		-		-		-		36.4		63.6		-	
21	U	1.3 (2.1)	84.6		7.7		7.7		-		-		23.1		76.9		-	
22	D	3.84 (6.2)	85.7		14.3		-		-		14.3		78.6		7.1		-	
	U	4.12 (6.6)	92.9		7.1		-		-		22.2		77.8		-		-	
23	DU	0.7 (1.1)	100	100	-	-	-	-	-	-	-	-	69.2	55.6	30.8	44.4	-	-
24	U	1.25 (2.0)	10		90		-		-		-		90.0		10.0		-	
25	D	1.52 (2.4)	100		-		-		-		28.6		64.3		7.1		-	
	U	1.52 (2.4)	90.9		9.1		-		-		18.2		81.8		-		-	
26	D	2.00 (3.2)	100		-		-		-		-		68.8		31.3		-	
	U	2.00 (3.2)	100		-		-		-		23.5		64.7		11.8		-	
27	U	4.28 (6.9)	9.9		74.3		15.8		-		7.0		79.0		14.0		-	

Table 5.8

Joint Deflection Condition Based on FWD Deflection

Distribution of Joint Deflection Condition on Rigid Pavements (% of Length)										
Project ID	**Direction**	**Length miles (km)**	**Joint Approach**				**Joint Leave**			
			Excellent	**Good**	**Fair**	**Poor**	**Excellent**	**Good**	**Fair**	**Poor**
15	U	0.34 (0.5)	27.3	45.5	27.3	-	-	63.6	36.4	-
16	DU	0.48 (0.8)	100 / 44.4	- / 50.0	- / -	- / 5.6	100 / 72.2	- / 22.2	- / 5.6	- / -
	D	0.44 (0.3)	94.7	5.3	-	-	94.7	-	5.3	-
17	U	1.77 (2.8)	81.3	18.8	-	-	100	-	-	-
18	U	4.5 (7.2)	-	7.2	25.3	67.5	2.3	23.0	6.8	67.9
19	DU	1.96 (3.2)	18.8 / 90.0	31.3 / 10.0	25.0 / 25.0	- / -	25.0 / 85.0	31.3 / 15.0	31.3 / -	12.5
20	D	0.31 (0.5)	100	-	-	-	100	-	-	-
21	U	1.3 (2.1)	92.3	7.7	-	-	53.8	46.2	-	-
	D	3.84 (6.2)	50.0	25.0	25.0	-	71.4	28.6	-	-
22	U	4.12 (6.6)	100	-	-	-	-	100	-	-
23	DU	0.7 (1.1)	100 / 88.9	- / 11.1	- / -	- / -	100 / 88.9	- / 11.1	- / -	- / -
24	U	1.25 (2.0)	80.0	20.0	-	-	1.0	10.0	-	-
	D	1.52 (2.4)	100	-	-	-	100	-	-	-
25	U	1.52 (2.4)	100	-	-	-	100	-	-	-
	D	2.00 (3.2)	100	-	-	-	100	-	-	-
26	U	2.00 (3.2)	100	-	-	-	100	-	-	-
27	U	4.28 (6.9)	32.4	37.8	13.6	16.2	40.5	27.0	13.5	19.0

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Table 5.9

Joint Load Transfer Condition Based on FWD Deflection

Distribution of Joint Load Transfer Condition on Rigid Pavements (% of Length)										
Project ID	**Direction**	**Length miles (km)**	**Load Transfer Approach**				**Load Transfer Leave**			
			Excellent	**Good**	**Fair**	**Poor**	**Excellent**	**Good**	**Fair**	**Poor**
15	U	0.34 (0.5)	81.8	18.2	-	-	90.0	9.1	-	-
16	DU	0.48 (0.8)	85.7 / 83.3	14.3 / 16.7	- / -	- / -	85.7 / 94.4	14.3 / 5.6	- / -	- / -
	D	0.44 (0.3)	63.2	31.6	-	5.3	78.9	15.8	-	5.3
17	U	1.77 (2.8)	62.5	25.0	12.5	-	68.8	18.8	12.5	-
18	U	4.5 (7.2)	4.7	2.4	19.0	73.8	9.5	2.4	16.7	71.4
19	DU	1.96 (3.2)	93.8 / 100	6.3 / -	- / -	- / -	81.3 / 75.0	12.5 / 25.0	6.3 / -	- / -
20	D	0.31 (0.5)	27.3	-	72.7	-	9.1	81.8	9.1	-
21	U	1.3 (2.1)	100	-	-	-	30.8	69.2	-	-
	D	3.84 (6.2)	28.5	35.7	35.7	-	28.6	50.0	21.4	-
22	U	4.12 (6.6)	100	-	-	-	100	-	-	-
23	DU	0.7 (1.1)	61.5 / 66.7	30.8 / 33.3	- / -	7.7 / -	53.8 / 55.6	30.8 / 44.4	15.4 / -	- / -
24	U	1.25 (2.0)	100	-	-	-	100	-	-	-
	D	1.52 (2.4)	14.3	78.6	7.1	-	21.4	64.3	14.3	-
25	U	1.52 (2.4)	54.5	45.5	-	-	44.4	44.4	11.1	-
	D	2.00 (3.2)	50.0	50.0	-	-	37.5	62.5	-	-
26	U	2.00 (3.2)	5.9	94.1	-	-	23.5	70.6	5.9	-
27	U	4.28 (6.9)	83.3	16.7	-	-	61.1	38.9	-	-

Table 5.10

Joint Support Ratio Condition Based on FWD Deflection

Distribution of Joint Support Ratio Condition on Rigid Pavements (% of Length)						
Project ID	Direction	Length miles (km)	JSR			
			Excellent	Good	Fair	Poor
15	U	0.34 (0.5)	63.6	36.4	-	-
16	DU	0.48 (0.8)	85.7 61.1	14.3 38.9	- -	- -
	D	0.44 (0.3)	84.2	15.8	-	-
17	U	1.77 (2.8)	62.5	37.5	-	-
18	U	4.5 (7.2)	56.0	44.0	-	-
19	DU	1.96 (3.2)	62.5 70.0	37.5 30.0	- -	- -
20	D	0.31 (0.5)	-	63.6	27.3	9.1
21	U	1.3 (2.1)	15.4	53.8	30.8	-
	D	3.84 (6.2)	64.3	35.7	-	-
22	U	4.12 (6.6)	100	-	-	-
23	DU	0.7 (1.1)	76.9 100	23.1 -	- -	- -
24	U	1.25 (2.0)	100	100	-	-
	D	1.52 (2.4)	78.6	21.4	-	-
25	U	1.52 (2.4)	72.7	27.3	-	-
	D	2.00 (3.2)	92.2	7.1	-	-
26	U	2.00 (3.2)	70.6	29.4	-	-
27	U	4.28 (6.9)	81.1	13.5	5.4	-

Service Lives of Flexible Pavements

FWD plots for flexible pavements are shown in Appendix J and the following narratives contain estimates of remaining service life based on the FWD data.

Project 1 – BUT 129 (Project 9330-98)

Deflections were consistently low over the project length. In general, the structural condition of this pavement is excellent (Figures J1 and J2). Pavement stiffness for this section can be classified as good in both directions and is highly influenced by the subgrade modulus. The subgrade modulus increases as spreadability decreases, as shown in Figures J3 and J4. The expected remaining service life in the upstation and downstation directions is 12.3 and 7.0 years, respectively, based on deflection.

Project 2 – BUT 129 (Project 9327-98)

This section is adjacent to Project 1 above. These deflections are also low in both directions indicating excellent condition in terms of stiffness as can be observed in Figure J5. The pavement structural condition is better in the downstation direction than upstation (Figures J5 and J8). The subgrade is sharply stiffer in the downstation direction than upstation (Figure J8). The expected remaining service life in both directions is 2.5 years.

Project 3 – CHP 68 (Project 233-98)

The AC layer structural condition can be classified as good between SLM 1.27-1.82, whereas the section between SLM 1.82-2.16 can be considered as fair (Figures J9 and J10). These sections are able to transmit load to the subgrade layer as shown in Figures J11 and J12. The expected remaining service life in both directions is 7.0 years.

Project 4 – FAY 35 (Project 298-96)

In general, the structural condition of this project can be classified as fair in the upstation direction and good to fair in the downstation direction, except for two short sections located between SLM 17.9-18.1 and SLM 23.55-24.00 (Figure H13) classified as poor. The problematic layer between these two sections seems to be the subgrade layer which is sharply weaker in these intervals as shown in Figures J13 and J16. Pavement stiffness (Figure J15) can be classified as fair in both directions. At least two types of soil are present over the section length. The expected remaining service life is 13.0 years.

Project 5 – GRE 35 (Project 259-98)

Figure J17 shows the normalized deflection is highly irregular over the section indicating a wide range of pavement stiffness. The structural condition of the AC pavement layer can be classified as poor ($Df_1 > 0.94$) and it can be validated from the results shown in Figure J19 where the spreadability is classified as fair (SPR$\approx$ 80.4%). This pavement deficiency might be due to the thickness of the AC layer ($t = 1.5 in.$) and the variable soil underneath this section (Figure J20). The remaining expected service life is 5.4 years.

Project 6 – HAM 126 (Project 645-94)

The AC layer structural condition can be classified as good to fair, except between SLM 6.83-7.15 which is considered as poor (Figure J21). Figures J22 and J23 show a combination of two soil types in both directions after SLM 9.65. The lack of pavement stiffness is due to the weaker base and subgrade (Table 5.7 and Figure J24). Spreadability is consistent in both directions and can be classified as good to fair. The expected remaining service life is 11.8 and 12.7 years for sections located between SLM 6.83-7.09 and SLM 7.09-11.35, respectively.

Project 7 – HAM 747 (Project 347-85)

The AC layer structural condition for this project is classified as poor because of high deflections, average $Df_1 \approx 1.16$, recorded in the asphalt concrete layer (Figures J25 and J26). Spreadability (Figure J27) can be considered fair while the subgrade (Figure J28) is excellent. The problematic layer on this project is the AC layer and the expected remaining service life is 4.5 years.

Project 8 – LAW 527 (Project 17-85)

In general, the asphalt concrete and subgrade layers on this project can be classified as excellent except in the section after SLM 2.0 where the AC layer is classified as good (Figures J29 and J30). Spreadability is inconsistent over the section and can be classified as good in the upstation direction and fair to good in the downstation direction (Figure J31). The subgrade layer is stiffer in the downstation direction than upstation (Figure J32), probably due to the downstation side being cut into the side of a hill and the upstation side being on a fill. The expected remaining service life is 6 years.

Project 9 – LIC 16 (Project 6010-99)

The structural condition of this LIC 16 project can be considered as good (Figures J33 and J34). Spreadability is good between SLM 19.92-20.20 and fair in the rest of the section (Figure J35). Soil within the previously mentioned interval is considerable weaker than the rest of the section (Figure J36), suggesting another soil type in this area. The expected remaining service life is 13.0 years.

Project 10 – LUC 2 (Project 141-99)

From Figures J37 and J38, the AC structural condition on LUC 2 is classified as good (average $Df_1 \approx 0.68$), while the pavement's ability to transmit loads is considered good to excellent (Figure J39). Figure J40 shows the subgrade to be excellent (average $Df_7 \approx 0.20$). The average soil modulus is 24.3 ksi and the expected remaining service life is 13.0 years.

Project 11 – LUC 25 (Project 665-97)

The AC layer structural condition can be classified as good in both directions on LUC 25 between SLM 10.01-10.40, and excellent between SLM 10.40-11.28 in the upstation direction and good downstation (Figures J41 and J42). Spreadability can be considered fair (Figure J43) and this fluctuation is due to the variation in the subgrade properties layer (Figures J42 and J44). On the other hand, the subgrade layer can be classified as excellent throughout the section (Figure J41). The expected remaining life is 9.0 years.

Project 12 – PIK 32 (Project 443-94)

Figures J45 and J46 show this section to be in excellent structural condition. Deflections for the asphalt concrete and subgrade layers are less than 0.52 and 0.21 mils/kips, respectively. Spreadability is fair (Figure J47) indicating a lack of stiffness in the base and/or subbase layers. The subgrade modulus is 48.9 ksi (Figure J48) and the expected remaining life is 0.5 years.

Project 13 – PIK 32 (Project 552-95)

In general, this project can be classified as excellent except in the section between SLM 17.85-18.30 which is classified as good (Figure J49). Areas of low stiffness might be indicative of a weaker subgrade (Figures J50 and J52). The expected remaining life is 1.5 years.

Project 14 – ROS 35 (Project 298-96)

The AC layer structural condition is inconsistent and varies from good to poor over the section length, whereas the subgrade condition can be classified as excellent (Figures J53 and J54). From Figure J56, it can be concluded that there are at least two different types of soils underneath the section. The asphalt concrete layer has a better performance in the places where the soil is stiffer (Figure J53 and J56). The expected remaining service life is 13.0 years.

Service Lives of Rigid Pavements

FWD plots for rigid pavements are shown in Appendix K and the following paragraphs contain estimates of remaining service life based on the FWD data.

Project 15 – ATH 50 (Project 700-86)

The PCC layer structural condition on this project can be classified as fair to good (average $Df_1 \approx$ 0.57) while the subgrade layer is excellent (Figure K1). Pavement stiffness can be classified as good except in sections between SLM 11.51-11.53 and SLM 11.60-11.63 which were fair (Figure K2). Sections classified as fair coincided with sections where the subgrade layer was stiffer (Figure K6). Maximum joint deflections in the approach position can be classified fair to excellent (Figure K3), while maximum joint deflections in the leave position were fair to good. Load transfer between slabs and the pavement condition under the slabs can be classified as excellent indicating excellent joint performance (Figures K4 and K5). The expected remaining service life is 5.5 years.

Project 16 – ATH 682 (Project 625-76)

The PCC layer condition was structurally good to excellent in both directions, whereas the subgrade layer condition was excellent (Figure K7). Pavement stiffness was fair to good with the upstation direction being better than the downstation (Figure K8). Normalized joint deflections in the downstation direction were excellent and good to excellent upstation (Figure K9). Load transfer across joints and the pavement condition underneath the slabs can be classified as excellent and good, respectively (Figures K10 and K11). The expected remaining service life is 15.0 years.

Project 17 – CUY 82 (Project 438-94)

The pavement structural can be classified as excellent in both directions. However, the section between SLM 3.27-3.79 is sharply better in the upstation direction than downstation (Figure K13). Spreadability is excellent upstation and good downstation, and decreases as the soil stiffness increases (Figures K14 and K18). Normalized joint deflections at the approach and leave positions, and Joint Support Ratio can be classified as excellent (Figures K5 and K17), indicating uniform support under the joints. Joint load transfer is good to excellent in both directions, except between SLM 3.43 - 3.77, where load transfer is classified as fair (Figure K16). This localized deficiency in load transfer might be due to a lack of aggregate interlock or/and a problem with the dowel bars. The expected remaining service life is 25.4 years.

<u>Project 18 – GAL 7 (Project 352-46)</u>

The PCC layer structural condition is very inconsistent over the length and its condition varies from good to poor. Half of the PCC structure condition can be considered as good whereas the other half can be considered fair to poor. On the other hand, the subgrade can be classified as excellent to good (Figure K19). Spreadability was good to fair (Figure K20). Maximum joint deflections and load transfer can be classified as good to poor (Figures K21 and K22). From Figures K21 and K22, it can be concluded that the joints are in poor condition, probably due to the lack of load transfer at the joints. The structural condition underneath the slab is somewhat inconsistent, but can generally be classified as good (Figure K23).

In conclusion, this pavement is in poor structural condition, likely it has been in service for over 60 years. From Table 2.5, the original pavement classification for this section was excellent, based on its ability to carry traffic, resist deicing chemicals, and withstand freeze/thaw cycling for this extended period of time. The expected remaining service life is 9.0 years.

<u>Project 19 – HAM 126 (Project 997-90)</u>

This pavement can be considered excellent in both directions (Figure K25). Spreadability can be classified as good except between SLM 11.90-12.30, which is fair and coincided with section where the soil is stiffer (Figures K26 and K30). In general, approximately 90% of the joints had excellent load transfer at the approach and leave positions in both directions (Figure K28). Maximum joint deflections in the upstation direction were excellent at the approach and leave positions, whereas deflections in the downstation direction varied from excellent to poor, with the section between SLM 11.60-12.20 being the worst (Figure K27). The expected remaining service life is 18.0 years.

<u>Project 20 – JEF 7 (Project 8008-90)</u>

This PCC layer structural condition can be classified as excellent except in two short sections located between SLM 19.11-19.13 and SLM 19.18-11.20, which were classified as good

(Figure K31). On average, Spreadability for this project was classified as fair (Figure K32). Load transfer was classified as excellent to good, while maximum joint deflections were excellent (Figures K33 and K34). The expected remaining service life is 6.0 years.

Project 21- JEF 22 (Project 8008-90)

This pavement can be classified as excellent except in the PCC layer between SLM 16.08-16.15 which is classified as fair (Figure K37). Pavement stiffness is fair between SLM 15.20-15.90 and SLM 11.08-16.15 and as good over the rest of the section (Figure K38). Maximum joint deflections can be considered excellent in both the approach and leave positions; however, there was an increase in deflection between SLM 15.90-16.15 in the leave position (Figure K39). In general, the pavement's ability to transmit applied load across joints can be considered excellent in both the approach and leave positions. (Figure K40). Pavement support can be considered good (Figure K41). The expected remaining service life is 7.0 years.

Project 22 – LOG 33 (Project 845-94)

The pavement on LOG 33 can be classified as excellent in both directions (Figures K43 and K44). Load transfer and maximum joint deflections are excellent in the upstation direction (Figures K45 and K46), while the downstation direction can be considered as fair to good. Higher deflections in the downstation direction might be caused by lower load transfer across the joints (Figure K46). Pavement support under the slab is better in the upstation direction than the downstation direction (Figure K47). The expected remaining service life is 19.0 years.

Project 23 – MOT 35 (Project 343-88)

The pavement on MOT 35 can be classified as excellent in both directions (Figure K49). Spreadability is inconsistent over the section and can be considered fair to good, but better in the downstation direction than the upstation direction (Figure K50). Load transfer can be considered good to excellent in both the approach and leave positions with the section between SLM 13.38-14.67 being better than the section between SLM 14.67-15.06 (Figure K52). Maximum joint deflections were excellent, except the joint located in the upstation direction at SLM 14.65 which is significantly different than the other joints (Figure K51). Support under the slabs was good (Figure K53). The expected remaining service life is 3.5 years.

Project 24 – MOT 202 (Project 678-91)

This PCC pavement can be classified good, while the subgrade condition was excellent (Figure K55). Load transfer, maximum joint deflection, and joint support ratio were as excellent indicating excellent joint performance (Figures K57, K58, and K59). In general, Spreadability can be classified as good except at the section between SLM 2.03-2.18, where the subgrade is stiffer than the rest of the project (Figures K56 and K60). The expected remaining service life is 18.3 years.

Project 25 – SUM 76 (Project 844-92)

The pavement on this project can be considered excellent in both directions (Figure K61), except in the upstation section between SLM 12.21-12.54, which varies significantly from the rest of the project. This variation was due to a lack of soil stiffness, as shown in Figure K66. The pavement seems to be in a better condition in the downstation direction than in the upstation direction (Figures K61 and K63). Load transfer can be classified as good to excellent in both directions (Figure K64). Maximum joint deflections and joint support ratios were excellent (Figures K63 and K65). The expected remaining service life is 11.6 years.

Project 26 – SUM 76 (Project 996-93)

Pavement condition on this project can be considered excellent in both directions, but better downstation than upstation (Figure K67). Load transfer across joints and pavement support can be considered good indicating a good joint performance (Figures K69, K70, and K71). The expected remaining service life is 15.3 years.

Project 27 – TUS 39 (Project 907-90)

This pavement varied from fair to good, while the subgrade varied from good to excellent (Figure K73). Load transfer was excellent in both directions, except for several short sections which can be classified as good (Figure K76). Maximum joint deflection was inconsistent and ranged from poor to excellent (Figure K75). Pavement support good (Figure K77). In general, pavement stiffness can be considered good (SPR $\approx$ 79%), and the expected remaining service life is 15.2 years.

Projected Performance Using the MEPDG

FWD deflection profiles for flexible and rigid pavements are shown in Appendices J and K, respectively, and the corresponding remaining service lives for these pavements calculated with these data and the MEPDG program are summarized in Tables 5.11 and 5.12.

Table 5.11

Service Lives of Flexible Pavements Using MEPDG

Service Life of Flexible Pavements with MEPDG (Years)										
Co./Rte.	Project ID	Calculation	Long. Cracking	Trans. Cracking	Alligator	Total Rutting	IRI	FWD Measurements	
								Expected Serv. Life	Remaining Serv. Life
BUT 129	1 D	Reliability	-	23.0	17.5	17.0	20.5	17.0	7.0
		Predicted	-	-	-	-	-		
	1 U	Reliability	22.7	25.0	23.0	24.0	22.3	22.3	12.3
		Predicted	-	-	-	-	-		
BUT 129	2	Reliability	-	23.0	15.0	13.7	19.2	12.5	2.5
		Predicted	12.5	-	-	23.7	-		
CHP 68	3 D	Reliability	20.7	17.0	-	-	-	17.0	7.0
		Predicted	-	22.0	-	-	-		
	3 U	Reliability	23.3	17.1	-	-	-	17.1	7.1
		Predicted	-	22.1	-	-	-		
FAY 35	4	Reliability	-	-	-	-	25.0	25.0	13.0
		Predicted	-	-	-	-	-		
GRE 35	5	Reliability	-	15.4	-	-	21.0	15.4	5.4
		Predicted	-	-	-	-	-		
HAM 126	6	Reliability	-	-	-	-	25.8	25.8	11.8
		Predicted	-	-	-	-	-		
	6*	Reliability	-	-	-	-	26.7	26.7	12.7
		Predicted	-	-	-	-	-		
HAM 747	7	Reliability	-	-	-	-	27.5	27.5	4.5
		Predicted	-	-	-	-	-		
LAW 7	8	Reliability	-	-	-	-	29.0	18.6	6.0
		Predicted	-	-	-	-	-		
LIC 16	9	Reliability	-	22.0	-	-	23.6	22.0	13.0
		Predicted	-	-	-	-	-		
LUC 2	10	Reliability	-	22.0	-	-	25.0	22.0	13.0
		Predicted	-	-	-	-	-		
LUC 25	11	Reliability	-	20.0	-	-	25.0	20.0	9.0
		Predicted	-	-	-		-		
PIK 32	12	Reliability	-	14.5	-	-	25.0	14.5	0.5
		Predicted	-	25.6	-	-	-		
	13	Reliability	-	14.5	-	-	25.5	14.5	1.5
		Predicted	-	25.4	-	-	-		
ROS 35	14	Reliability	-	-	25.0	-	-	25.0	13.0
		Predicted	-	-	-	-	-		

* SLM 7.09-11.35

Table 5.12

Service Lives of Rigid Pavements Using MEPDG

Service Life of Rigid Pavements with MEPDG (Years)							
						FWD Measurements	
Co./Rte.	Project ID	Calculation	Faulting	% Slab Cracked	IRI	Expected Serv. Life	Remaining Serv. Life
ATH 50	15	Reliability	27.5	-	28.0	27.5	5.5
		Predicted	32.0	-	41.1		
ATH 682	16	Reliability	-	48.0	47.0	47.0	15.0
		Predicted	-	-	-		
CUY 82	17	Reliability	39.4	-	41.7	39.4	25.4
		Predicted	-	-	-		
GAL 7	18	Reliability	60.0	-	56.7	56.7	-5.3
		Predicted	66.0	-	66.0		
HAM 126	19	Reliability	36.0	-	40.0	36.0	18.0
		Predicted	58.0	-	61.0		
JEF 7	20	Reliability	24.0	-	29.8	24.0	6.0
		Predicted	-	-	-		
JEF 22	21	Reliability	25.0	-	30.0	25.0	7.0
		Predicted	-	-	-		
LOG 33	22	Reliability	33.0	-	40.0	33.0	19.0
		Predicted	57.7	-	-		
MOT 35	23	Reliability	24.4	17.5	23.0	17.5	3.5
		Predicted	-	19.4	-		
MOT 202	24	Reliability	35.3	43.7	36.8	35.3	18.3
		Predicted	48.1	-	-		
SUM 76	25	Reliability	28.6	-	-	28.6	11.6
		Predicted	-	-	-		
	26	Reliability	33.3	-	39.0	33.3	15.3
		Predicted	-	-	-		
TUS 39	27	Reliability	33.2	36.7	35.0	33.2	15.2
		Predicted	46.0	-	48.7		

Pavement condition ratings (PCR) have been widely used to quantify pavement performance. The PCR method describes pavement distress mechanisms in terms of severity and frequency, and is calculated as: $PCR = 100 - \sum^{n} Deduct_i$, where n is the number of observable distresses, and deduct = (weight for distress)(weight for severity)(weight for extend). Pavement condition ratings are measured on a scale from 0 to 100 with 0 being very poor and 100 being excellent. The PCR scale is shown in Figure 5.7.

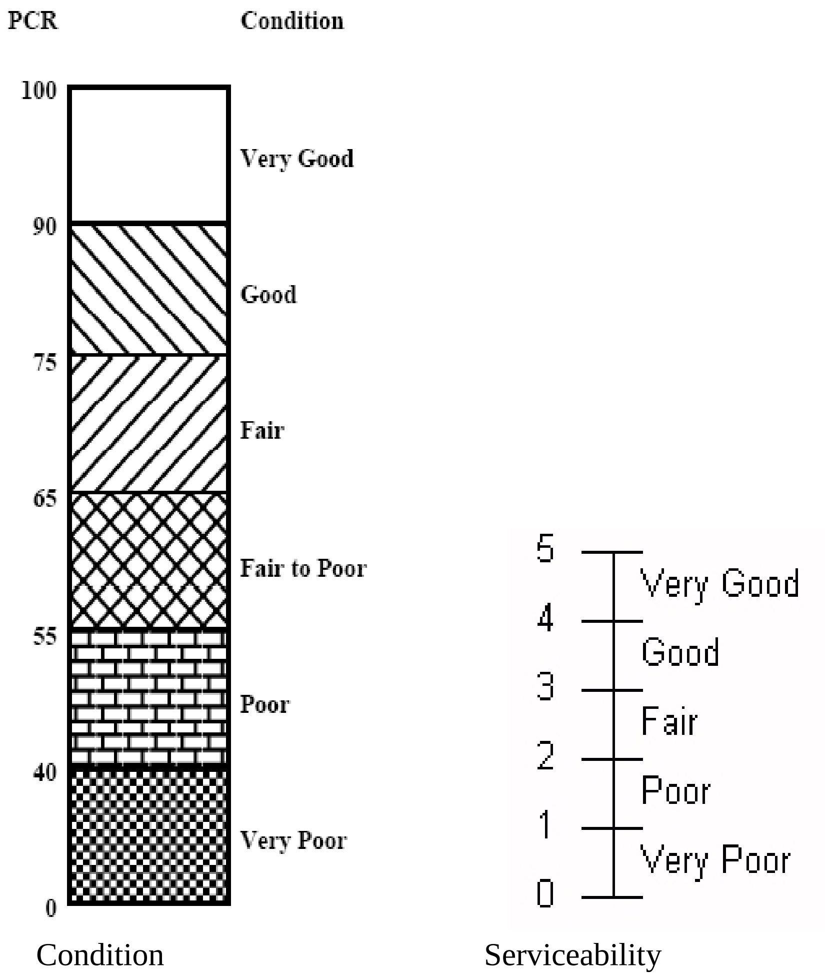

Figure 5.7 - Pavement Condition and Serviceability Rating Scales

In addition, the MEPDG was used to determine current pavement serviceability ratings (PSR) for each section, as follows:

$PSR = 5.697 - 0.264(IRI)^{0.5}$ IRI (in./miles) - AC sections

$PSR = 6.634 - 0.353(IRI)^{0.5}$ IRI (in./miles) - PCC sections

The PSR scale is also shown in Figure 5.7.

A comparison of the pavement condition classification for the asphalt concrete sections was conducted by using actual PCR values from the field and the PSR values from the program. These values are listed in Table 5.13.

Table 5.13

Comparison between PCR and PSR – Flexible Sections

Comparison between PCR and PSR – AC Sections					
Project ID	**PCR (2007)**	**PCR (Classif.)**	**IRI MEPDG (in./mile)**	**PSR (2007) MEPDG**	**PSR (Classif)**
1	90	Good	112.2	2.9	Fair-Good
2	95*	Very good	111.9	2.9	Fair-Good
3	83 D - 86 U	Good	95.3	3.1	Good
4	90	Good	102.3	3	Good
5	89	Good	106.7	3	Good
6	83 U - 71 D	Good(U)-Fair(D)	113.9	2.9	Fair-Good
7	66	Fair	130.3	2.7	Fair
8	99*	Very good	127.5	2.7	Fair
9	88	Good	98.8	3.1	Good
10	90	Good	96.2	3.1	Good
11	87	Good	110	2.9	Fair-Good
12	94*	Very Good	108.4	2.9	Fair-Good
13	88 D - 91 U	Good-Very good	107.5	3	Good
14	91	Very Good	92.2	3.2	Good

(*) These sections most likely were overlaid recently.

A comparison of the pavement condition classification for the rigid pavement sections was conducted by using the actual PCRs values from the field and the PSR values from the program. See Table 5.14.

Table 5.14

Comparison between PCR and PSR – Rigid Sections

Comparison between PCR and PSR – AC Sections					
Project ID	**PCR (2007)**	**PCR (Classif.)**	**IRI MEPDG (in./miles)**	**PSR (2007) MEPDG**	**PSR (Classif)**
15	64	Fair to poor	119.2	2.8	Fair
16	63	Fair to poor	105.55	2.9	Fair
17	91 84 (2.5-3.22)U	Very good Good	93.1	3.2	Good
18	65	Poor	173	2	Poor-Fair
19	88U 93D	Good Very good	92.05	3.2	Good
20	75	Good	105.2	3	Good
21	82	Good	97.35	3.2	Good
22	85D	Good Very good	84.15	3.4	Good
23	79D-75U	Good	125.6	2.7	Fair
24	77	Good	94.65	3.2	Good
25	87	Good	107.05	3	Good
26	87	Good	98.85	3.1	Good
27	83	Good	95.05	3.2	Good

Projected Performance Using the 1993 AASHTO Design Equations

Tables 5.15 and 5.16 show estimated service lives for the selected flexible and rigid pavement projects calculated with the 1993 AASHTO Design Equation and various design assumptions listed in the table headings. Among those assumptions was a reliability factor of 50%, which is well below the 80 – 95% normally used by ODOT for design, but was used here to normalize the range of pavement classifications. Had more realistic reliability factors been used for each project, the number of calculated ESALs to failure would have been lower and the percent of life used based on actual ESALs would have been higher, but it would have been more difficult to compare projects. Overall, there was little difference in service lives between average and excellent pavements of both types, but the rigid projects had higher percentages of service lives used than the flexible projects because of their age. These tables indicate that Ohio's pavements are designed conservatively, and differences in performance are likely due to construction factors rather than design.

Table 5.15
Calculated Service Lives for Flexible Pavements

Calculated Service Lives on Flexible Pavements
Standard Design Assumptions: R = 50%, PSI i = 4.5, PSI t = 2.5, Overall Standard Deviation = 0.49, Drainage Coefficient = 1.0

Route	Project No.	Surface/ Intermediate Layers	Base Layer	Subbase Layer	SN	Soil Classification	Soil Value Mr	Calculated ESAL Capacity (1)	Number of ESAL's Carried	Percent Life (Years)	Percent Life (ESAL's)
Average Performance											
BUT-129-17.83	9330(98)	1.25"/1.75" 446	10" 302	4" ATFDB	5.45	Design Build	6000 (3)	62,600,000	4,250,000	60	7 (2)
BUT-129-24.00	9327(98)	1.25"/1.75" 446	8" 302	4" 304	5.17	Design Build	6000 (3)	42,000,000	4,500,000	60	11
CHP-68-1.82	233(98)	1.5"H/1.75" 448	6" 301	6" 304	4.40	Design Build	6000 (3)	13,300,000	4,360,000	60	33
CLA-41-4.06	63(95)	1.25" 404/1.75" 402	7" 301	5" 304	4.51	A-6 (4)	7750	28,500,000	1,030,000	75	4
DEL-23-(112)	380(94)	1.75"/2.25" 446	12" 302	4" ATFDB	6.60	A-6 (4)	7750	497,000,000	19,540,000	80	4 (2)
HAM-747-0.04	347(85)	1" 404/1" 403	9" 301		4.10		6000 (3)	8,200,000	7,500,000	125	91
LAW-527-0.19	17(85)	1.25" 404/1.5" 402	9" 301		4.42		6000 (3)	13,600,000	2,160,000	125	16
LUC-2-21.39	141(99)	1.25"H/1.75" 446	10" 301	6" 304	5.73	GI = 13 (6)	6000	91,000,000	4,720,000	55	5
PIK-32-16.08	552(95)	1.25"/1.75" 446	12" 301	4" ATFDB/ 4" 304	6.73	GI = 5.68 (6)	9000	819,500,000	4,130,000	75	1 (2)
VAN-30-15.97	219(97)	1.5"H/2.5" 446	9" 301 (7)		4.96	A-7-6 (4)	6300	35,000,000	13,350,000	65	38
									Average	**78**	**21**
Excellent Performance											
BUT-129-17.83	9330(98)	1.25"/1.75" 446	10" 302	4" ATFDB	5.45	Design Build	6000 (3)	62,600,000	4,250,000	60	7 (2)
CHP-68-1.27	233(98)	1.5"H/1.75" 448	6" 301	6" 304	4.40	Design Build	6000 (3)	13,300,000	4,360,000	60	33
CLA-41-3.86	63(95)	1.25" 404/1.75" 402	7" 301	5" 304	4.51	A-6 (4)	7750	28,500,000	740,000	75	3
DEL-23-(902)	380(94)	1.75"/2.25" 446	12" 302	4" ATFDB/ 6" 304	7.44	A-6 (4)	7750	1,290,000,000	19,540,000	80	2 (2)
GRE-35-20.95	259(98)	1.5"H/1.75" 448	7.5" 301	6" 304	4.94	A-4 (4)	9400 (5)	85,000,000	7,280,000	60	9
HAM-126-7.09	645(94)	1.25"/1.75" 446	10" 301	6" 304 / 6" 310	6.39	A-6 (4)	6000 (5)	211,000,000	4,110,000	80	2
LUC-25-10.01	665(97)	1.25"/1.75" 446	7" 301	8" 304 / 6" 310	5.59	GI = 7.8 (6)	8000	146,500,000	1,100,000	65	1
PIK-32-13.43	443(94)	1.25"/1.75" 446	9" 301	4" 304	5.09	A-6/A-4 (6)	8400	81,500,000	5,170,000	80	6
PIK-32-16.08	552(95)	1.25"/1.75" 446	12" 301	4" ATFDB/ 4" 304	6.73	GI = 5.68 (6)	9000	819,500,000	4,130,000	75	1 (2)
ROS-35-0.00	298(96)	1.25"/1.75" 446	10" 301	4" 306 / 8" 304	6.57	A-6 (4)	7750 (5)	475,000,000	7,650,000	70	2 (2)
									Average	**71**	**6**

(1) Calculated ESALs are based on standard design assumptions of the pavement including the calculated SN and soil value
(2)Actual strength of ATFDB is likely underestimated. More work would need to be done to correctly characterize the pavement buildup - Correct characterization of pavement would yield slightly higher calculated ESAL's, thus reducing the % life (ESAL's) reported.
(3) No soils information found. Used an average value based on experience.
(4) Soil classifications taken from OU research. Used average Group Index for this classification.
(5) Subgrade Modification is difficult to characterize. If long term stabilization exists, calculated ESAL's could more than double.
(6) Group Index taken from subsurface investigation found in original construction plans
(7) 301 AC base in PMIS was 451 PCC in field

Table 5.16
Calculated Service Lives for Rigid Pavements

Calculated Service Lives on Rigid Pavements									
Standard Design Assumptions: R = 50%, PSI i = 4.2, PSI t = 2.5, Modulus of Rupture = 700 psi, Elastic Modulus of Slab = 5,000,000 psi, Overall Standard Deviation = 0.39, Drainage Coefficient = 1.0									
Route	**Project No.**	**Rigid Thickness**	**Subbase Layer**	**Soil Value Mr**	**Load Transfer J**	**Calculated ESAL Capacity (1)**	**Number of ESAL's Carried**	**Percent Life (Years)**	**Percent Life (ESAL's)**
Average Performance									
ATH-33-10.40	235(58)	9"	8" 310	6000 (3)	3.2	13,850,000	14,770,000	260	107
ATH-682-0.16	625(76)	9"	6" 310	6000 (3)	3.2	13,500,000	2,110,000	170	16
CUY-176-10.13	683(94)	12"	6" 310 Type 2	6000 (3)	2.7	88,500,000	11,000,000	80	12
CUY-176-10.87	305(96)	12"	6" 310 Type 2	6000 (3)	2.7	88,500,000	8,800,000	80	10
CUY-252-3.47	901(84)	9"	6" 310 Type 2	6000 (3)	2.7	24,250,000	3,590,000	130	15
JEF-22-15.02	8008(90)	9"	6" 310 Type 2	6000 (3)	2.7	24,250,000	12,190,000	100	50
LOG-33-21.79	845(94)	12"	4" NSFDB/AC T1/6" 304 (2)	6000 (3)	2.7	291,000,000	27,670,000	80	10
SUM-76-13.41	996(93)	11"	1"403/3"301/4"304	6000 (3)	2.7	132,500,000	61,190,000	85	46
TUS-39-2.84	907(90)	9"	6" 310 Type 2	6000 (3)	2.7	24,250,000	8,360,000	100	34
							Average	**121**	**33**
Excellent Performance									
ALL-30-20.16	746(97)	11"	4" ATFDB/6" 304 (2)	6600	2.7	131,000,000	20,080,000	65	15
CUY-82-2.05	438(94)	11"	6" 304	6000 (3)	2.7	88,500,000	6,160,000	80	7
CUY-322-8.68	1019(93)	10"	6" 310	5520	2.7	46,600,000	1,210,000	85	3
GAL-7-5.71	352(46)	8"	6" - 12" SS112	6000 (3)	3.2	7,100,000	3,930,000	320	55
GRE-35-14.45	19(97)	10"	6" NSFDB/6" 304 (2)	5400	2.7	69,500,000	12,140,000	65	17
HAM-126-11.35	997(90)	10"	6" 310 Type 2	6000 (3)	2.7	47,500,000	6,120,000	100	13
JEF-7-18.90	8008(90)	9"	6" 310 Type 2	6000 (3)	2.7	24,250,000	19,030,000	100	78
MOT-35-14.37	343(88)	10"	4" 301 / 4" 304	7200	2.7	79,000,000	11,760,000	110	15
MOT-202-2.00	678(91)	9"	6" 310 Type 2	6000 (3)	2.7	24,200,000	2,460,000	95	10
SUM-76-13.41	996(93)	11"	1"403/3"301/4"304	6000 (3)	2.7	132,500,000	61,190,000	85	46
							Average	**111**	**26**

(1) Calculated ESALs are based on standard design assumptions of the pavement including the slab thickness and soil value
(2) Actual strength of FDB is likely underestimated. More work would need to be done to correctly characterize the pavement buildup - Correct characterization of pavement would yield slightly higher calculated ESAL's, thus reducing the % life (ESAL's) reported.
(3) No soils information found. Rigid pavements not particularly sensitive to this variable. Used an average value based on experience.

Conclusions

Long term performance and expected remaining life of flexible and rigid pavements in Ohio showed performance is highly affected by factors, such as: climate, material properties, pavement thickness, construction practices, traffic loads, etc. The Falling Weight Deflectometer was used to determine pavement structural condition. Results obtained from the FWD tests were used to determine which sections had lower levels of performance, thereby providing helpful information to select the best rehabilitation alternatives.

Fourteen flexible and thirteen rigid projects were studied with total accumulated lengths of 68.4 and 35.5 miles, respectively. The structural condition of the pavement sections was divided into four categories: Excellent, Good, Fair, and Poor. Primary distress mechanisms most likely will develop in sections where the structural condition was classified as poor or fair. This classification was used to identify core locations to determine why sections behave differently with similar material properties and traffic loading. Conclusions include the following:

1. A summary of the structural condition of the flexible pavement sections showed: 51.6% (35.3 miles), 26.9% (18.4 miles), 15.2% (10.4 miles), and 6.4% (4.3 miles) of the asphalt concrete layers were classified as excellent, good, fair, and poor respectively, while 7.8% (5.3 miles), 44.3% (30.3 miles), 44.4% (30.3 miles), and 3.5% (2.4 miles) of the pavement ability to distribute applied loads from the surface to the subgrade were classified as excellent, good, fair, and poor, respectively. In general terms, distresses on the pavement surface most likely were due to a deficiency in stiffness of the base and/or subbase layers, rather than a stiffness deficiency in the asphalt concrete or subgrade layers. Among the flexible sections, projects showing a stiffness deficiency in the AC layer included: CHP 68U, GRE 35, HAM 126, HAM 747 and ROS 35U.

2. A summary of the structural condition of the rigid pavement sections show: 67.6% (24.0 miles), 24.2% (8.6 miles), 7.2% (2.5 miles), and 1.0% (0.4 miles) of the PCC layers were classified as excellent, good, fair, and poor respectively, while 15.8% (5.6 miles), 63.9% (22.7 miles), 19.3% (6.8 miles), and 1.0% (0.4 miles) of the pavement stiffnesses were classified as excellent, good, fair, and poor respectively.

3. Pavement sections with low layer stiffnesses do not necessarily exhibit fair or poor performance. Performance is highly influenced by structural condition and traffic loading. Some projects classified as having average performance (from the PCR trendline) have an excellent or good structural condition and vice versa.

4. Base stiffness has a significant influence on pavement response. While stiffer base layers generally improve the performance of flexible and rigid pavements, very stiff bases can have a negative effect on rigid pavement performance. The structural condition of rigid pavement sections was classified as good. Pavement performance increased considerably with thicker surface layers, as evidenced on HAM 126, JEF 7 and JEF 22. In general, load transfer and soil stiffness at joints can be considered to be good in these sections.

5. From 2007 PCR ratings and MEPDG software, the structural condition of GAL 7 was classified as poor. The ability of this section to resist and transmit the applied traffic loads through the slabs was classified as poor. The expected remaining service life of this project was -5.3 years, indicating this section already exceeded its service life. However, this pavement has performed very well for over 60 years and was classified as excellent.

6. Records of test samples and construction procedures utilized at the time of construction are not retained longer than seven years by ODOT, making it difficult to predict the expected remaining service life of pavements more than seven years old. Consequently, it was necessary to make several assumptions to run the Mechanistic-Empirical Pavement Design Guide program (MEPDG). This policy to destroy construction records after seven years makes it very difficult to go back and review past practices, and to know how to improve upon those practices. Even if paper records are not retained, the information should be stored in computerized files.

7. Calculations of service life indicate Ohio's pavement design procedures are conservative and, theoretically, should provide pavements that perform well up to and beyond their design lives. Differences in pavement performance are caused by a wide range of factors which affect material and structural integrity to various degrees over time.

Chapter 6

Conclusions and Recommendations

Objective 8 - Identify design, construction and material features which appear to extend pavement life on superior pavements, and recommend procedures for improving the longevity of pavements in Ohio by implementing these features into practice. Document all work in a final report.

When plotting the performance histories of highway pavements to categorize average and excellent performance, small differences often separated the two groups. Consequently, in trying to identify specific factors responsible for differences in performance, there were rarely clear and consistent reasons for the separation but, rather, trends where more pavements in the one group had certain attributes than pavements in the other group. These data, plus discussions with ODOT personnel in District and Central Offices and with others knowledgeable in pavement design, construction and maintenance were sources for the following conclusions and recommendations for Volume 1. Conclusions for rigid pavements are presented in Volume 2.

Paired Section Observations

JEF 7/22 Project 8008(90) – The JEF 7 portion of this project with excellent performance was constructed along a retaining wall backfilled with natural sand to elevate the pavement above the Ohio River. The JEF 22 portion of this project with average performance was constructed on natural fine grained subgrade which limited drainage from the 6 inch (15.2 cm) thick 310 T2 slag base. The natural sand backfill on JEF 7 was required for the retaining wall. Other projects on SR 7 constructed with slag bases on natural subgrade in the same area have a history of poor performance. Concrete pavement performance on slag base can be adversely affected when aggregate particles in the base: 1) bond together to form a non-uniform stiff support layer which drains poorly, and 2) adhere to the concrete pavement and limit the ability of slabs to expand and contract freely under moisture and temperature cycling. A report entitled "Truck/Pavement/Economic Modeling and In-Situ Field Test Data Analysis Applications" by Sargand, Wu and Figueroa indicates thick bases tend to result in more uniform support and encourage drainage.

Conclusion 1 – Good drainage improves pavement performance

Conclusion 2 – Slag aggregate bases have an adverse effect on pavement performance.

Recommendation – Provide good drainage in areas known to retain moisture and avoid the use of slag aggregate bases, especially under rigid pavements.

CUY 176 Project 305(96) – This project was constructed with an incentive/disincentive provision for surface smoothness. That portion of the project between SLM 10.87 and 12.17, which had good ride quality in both directions, was completed in 1997, while the adjacent portion of the project from SLM 12.17 to 12.83, which had highly variable ride quality in the downstation (southbound) direction, was completed in 1998. The contractor's crew made a concerted effort to construct smooth pavement in 1997 by constantly checking the paver and making frequent adjustments. Different personnel were on the job in 1998. When financial incentive/disincentives are attached to pavement smoothness, contractors decide directly or indirectly the quality of workmanship they are going to provide for the expected level of payment. This decision depends upon many variables, including: contractor attitudes toward quality, equipment condition, capability of on-site supervisors and crews, need for resources on other projects, and the extent to which financial incentives are worth the additional effort.

Conclusion – Contractors are motivated by money or pride to construct smooth pavements.

Recommendation - If elevated levels of ride quality are desired, place the requirement in the plans as an option. The additional cost, as determined by the contractor in preparing the bid, can be accepted or rejected.

SUM 76 Project 996(93) – The westbound lanes were placed immediately after the eastbound lanes and, on both sides, the driving lane and outside berm were placed first followed by the remaining two lanes and inside berm. All pavement was placed in 1995-96. Undercutting with some cement stabilization was performed as a change order on the downstation (westbound) side to stiffen subgrade between Market St. and SR 91. This additional work likely contributed to these lanes having excellent performance, while the eastbound lanes had average performance.

Conclusion – Subgrade undercutting and stabilization improve pavement performance.

Recommendation - Use the FWD or other stiffness devices to control subgrade quality and uniformity during construction, as suggested in previous ORITE work.

DEL 23 Project 380(94) – Flexible pavement Sections 112 and 902 were constructed adjacent to each other in the southbound lanes of the Ohio SHRP Test Road. Both sections had 20 inches (50.8 cm) of asphalt concrete, but Section 902 had an additional 4 inches (10 cm) of 304 aggregate base. Section 112 in SPS-1, with conventional materials in the surface and intermediate layers, had more surface cracking and rutting than Section 902 in SPS-9, which contained SHRP mixes in the surface and intermediate layers. Photographs of both sections are shown in Appendix E.

Conclusion – PG grade asphalt cements and polymers improve the performance of flexible pavements carrying heavy traffic.

Recommendation – Incorporate PG grade asphalt cements and polymers into surface and intermediate asphalt concrete mixes on interstate and primary routes.

Other Conclusions

Chapter 2 – Project Selection, PMIS

1. The 2002 PMIS provides a historical record of original pavement construction going back as early as 1911. While this database does not provide a complete listing of all projects, the information is a valuable resource that should be retained for future reference. The 2004 PMIS added recent construction, maintenance and performance data not in the 2002 PMIS, but only contains projects sold after 1979, which limits its value as a historical reference.

   Conclusion – 2002 and 2004 versions of the PMIS contain different historical data.

   Recommendation 1 – Provide summaries of what types and years of data are available in the different versions of the PMIS and retain the different versions for future reference.

   Recommendation 2 – Maintain: 1) a current PMIS containing information for all active construction and maintenance projects in service, and 2) an archival PMIS where data are stored permanently after projects are removed from service, or obsolete versions of the PMIS are updated (as mentioned above in Recommendation 1).

2. When reviewing the 2002 and 2004 PMIS, some highway sections were missing and, of the sections listed, almost half were assigned activity codes of 777, 888, 995 or 999, which precluded them from consideration in this research study because the types of construction and maintenance were unknown.

Conclusion – Activity codes were unknown for essentially half of the PMIS entries and entries for several other sections were missing.

Recommendation – Fill in the missing pavement sections and update 777, 888, 995 and 995 entries in the PMIS.

3. PCR data in the 2002 and 2004 PMIS were often not consistent with assigned projects numbers. Departmental policies and decisions based on analyses of incomplete PMIS data can lead to serious problems.

Conclusion – Project numbers assigned to performance data in the PMIS must be checked for consistency.

Recommendation 1 - Project numbers should be updated when new PCR, traffic, and ride quality data are added to the PMIS.

Recommendation 2 - New versions of the PMIS should be released only when appropriate project numbers are shown for the data and all data have been randomly checked for accuracy.

4. In an attempt to evaluate performance by correlating ESAL loading with Pavement Condition Ratings (PCR), average ESALs calculated per truck were highly variable on some routes randomly selected in the PMIS.

Conclusion – Use ESAL counts in the PMIS cautiously during pavement analyses.

Recommendation – Review ESAL data in the PMIS and make appropriate corrections.

Chapter 2 – Project Selection, Pavement Condition Ratings

5. During the pavement selection process, levels of performance were determined by plotting PCR values versus age for flexible and rigid pavements not receiving any structural

maintenance above an activity code (AC) of 40. In reviewing PCR data for eligible projects, it became apparent that maintenance with activity codes less than 40 can dramatically increase PCR without providing structural benefits. Specific examples include: Micro-Surfacing (AC 30), Nova-Chip Resurfacing (AC 35), and Fine Graded Polymer Overlay (AC 38). Since PCR is determined largely by ratings based on visual appearance, it can become highly influenced by cosmetic appearance as distresses are patched or covered over, and long term projections of remaining service life from PCR ratings can become over optimistic.

Conclusion – Nonstructural maintenance, which has little effect on service life, can affect PCR ratings and have a dramatic affect performance analyses.

Recommendation – Properly account for PCRs associated with nonstructural maintenance when analyzing pavement performance.

Chapter 2 – Project Selection, Straight-Line Diagrams

6. Straight-line diagrams (SLDs) are a valuable source of information for quickly determining the age and types of materials currently in the ODOT pavement infrastructure. Unfortunately, project information on the SLDs often does not agree with data in the PMIS and, with activity codes not being shown on the SLDs, it is difficult to differentiate between the original project and subsequent maintenance activities. It would be convenient if project activity codes could be shown on the SLDs. Project numbers, mileage limits and pavement materials in the PMIS need to be consistent with those shown on the SLDs. Both sources of information are valuable, with the PMIS being used for data analyses, and the SLDs being used as a quick reference by technical personnel to identify material types and ages.

Conclusion – Straight-line diagrams may not always agree with the PMIS.

Recommendation 1 – Reconcile data in the PMIS with data on the SLD.

Recommendation 2 – Show PMIS activity codes on the SLDs.

Chapter 2 – Project Selection, Record Retention

7. Many construction and maintenance records are routinely being discarded by ODOT offices a few years after projects are completed which makes it difficult to review projects and determine the causes of good or bad performance in the future.

Conclusion – It is often difficult to locate engineering data for pavements in Ohio.

Recommendation – Retain all engineering records, including laboratory data, field measurements and personnel diaries for all construction and maintenance projects while they remain in service.

<u>Chapter 3 – Site Visits, Subgrade</u>

8. Subgrade stiffness, as indicated by Df7 readings on the FWD, was very good on all flexible and rigid pavements selected as providing average to excellent performance, with an overall range of 0.07-0.20 mils/kip (0.40-1.14 mm/MN). Average Df7 on flexible pavements was 0.12 mils/kip (0.69 mm/MN) for average performance and 0.09 (0.51 mm/MN) for excellent performance. Corresponding averages for rigid pavement were 0.13 mils/kip (0.74 mm/MN) and 0.12 mils/kip (0.69 mm/MN). While differences between pavement types and levels of performance are not considered significant, the consistent low values of Df7 for all selected pavement sections emphasize the value of uniform stiff subgrades.

Conclusion – Maintain minimum subgrade stiffness for good pavement performance.

Recommendation - Test subgrade stiffness with the FWD or other device as part of the construction acceptance process.

<u>Chapter 3 – Site Visits, Pavements</u>

9. Overall, the observed condition of selected pavement sections was largely consistent with the average and excellent performance ratings assigned to them during the selection process. The only two possible exceptions were ATH 682 and JEF 7, two rigid pavement projects which had moderate to severe transverse midslab cracking at the time of the 2009 site visits. The latest PCR data used to determine the ratings were collected in 2004, so the amount of deterioration which occurred between 2004 and 2009 was unknown.

Conclusion – When used carefully, the PMIS provides reasonable assessments of pavement condition.

Recommendation – Always check that project numbers and ages shown for the various types of performance data are correct in the PMIS.

10. During the site visits, it became apparent that surface cracking patterns on flexible pavements were generally associated with particular types of structural, construction, or material distress

identified and rated according to the PCR manual. Unfortunately, it is difficult to visually determine the causes and severity of certain types of cracks with regard to how they impact remaining service life.

Flexible pavement cracks tend to progress either from the bottom up or from the top down. Bottom up cracks are generally initiated by excessive dynamic tensile stresses and/or material degradation in the pavement, or base layers. These cracks progress rapidly toward the surface and proliferate as the effective stiffness of the pavement structure diminishes in the cracked area. Top down cracks are generally initiated by oxidation of the asphalt binder on the pavement surface as it ages, which causes it to become brittle and less resistant to environmental changes. Top down cracks are less severe than bottom up cracks because they are shallow and grow very slowly, and they have little to no effect on the overall capacity of the pavement structure to carry traffic.

Another type of surface cracks are induced thermally when sudden cold temperatures cause transverse cracks to appear in the surface at regularly spaced intervals. Thermal cracking does not occur frequently, but can develop on projects where the asphalt concrete becomes brittle at low temperatures. While these cracks can accelerate distress by permitting water to infiltrate the pavement structure, further thermal cracking is minimal once the initial tensile stresses are relieved.

Conclusion – Ratings of surface cracking on flexible pavements without regard for origin may not reflect their true impact on service life.

Recommendation 1 – Modify the PCR ratings to differentiate between top down and bottom up cracking on flexible pavements, and apply appropriate weighting factors for each type of cracking.

Recommendation 2 – While thermal cracking of flexible pavements is not common in Ohio, ODOT should develop a procedure for avoiding susceptible asphalt concrete mixes, such as cold ITS or creep compliance tests.

Recommendation 3 – When conducting site evaluations of flexible pavement performance, a few cores should be cut to determine the origin and depth of predominant types of cracks.

11. The two flexible pavement sections on DEL 23 (SHRP 902 and 112) illustrate the importance of surface and intermediate course mixes on performance. The two sites were constructed adjacent to each other in the southbound lanes of the Ohio SHRP Test Road in 1996 and have very similar buildups. Both have 4" (10.2 cm) of surface and intermediate AC, 12 inches (30.5 cm) of ATB, and 4 inches (10.2 cm) of ATFDB. SHRP 902 has an additional 6 inches (15.2 cm) of 304 DGAB. The SHRP 112 surface and intermediate layers, with moderate cracking of various types, contained standard ODOT mixes, while the SHRP 902 surface and intermediate mixes, in excellent condition after 13 years of service, contained PG asphalt cement, smaller aggregate and polymers. Photos of these sections are shown in Appendix E.

Conclusion – Use PG asphalt grading, smaller aggregate and polymers for surface and intermediate layers on flexible pavements with high traffic loading.

Recommendation – Continue the use of SHRP mixes and polymers for AC surface mixes on heavily traveled highways.

12. The ATH 33 project, being more than 50 years old and having all joints replaced, had elevated midslab and joint deflections, but excellent load transfer. While the original concrete has some localized breakage at these replacements, cores taken at the interface of the replacement and original concrete showed the newer concrete to be badly deteriorated at the bottom of the pavement and the original concrete to be very much intact. Almost every slab of original concrete has a tight transverse crack. Photographs are shown in Appendix F.

Conclusion 1 –Original pavement concrete on Project 235(58) is still performing well.

Conclusion 2 – Concrete used to replace joints is degrading at the bottom of the repairs.

Recommendation – Investigate the extent of deterioration in concrete used to replace distressed joints on this ATH 33 project and check the concrete mix parameters.

<u>Chapter 4 – Laboratory Testing, Asphalt Concrete</u>

13. Of the various mix parameters and aggregate gradations used for flexible pavements in this study, the major difference between average and excellent performing sites was gradation of aggregate in the surface mixes. Excellent pavements had a pronounced hump between the #4 and #50 sieves where increased amounts of finer material passed these sieves. Similar humps

occurred in the AC intermediate and base mixes for both average and excellent performing flexible pavements. Efforts to improve aggregate gradations in the surface mix have progressed since many of the study projects were constructed in the 1990s. The coarse Type 1H mixes have been replaced with finer graded Superpave 442 mixes.

Conclusion – Finer aggregate improves the performance of AC surface mixes and ODOT has moved in this direction since the SHRP specifications were introduced.

Recommendation – Continue monitoring the effects of aggregate gradation on the performance of AC surface mixes and implement any findings to improve performance.

14. While not obvious from the data on this project, low asphalt binder contents are often mentioned as a concern associated with raveling or premature surface cracking on flexible pavements. This can occur as contractors attempt to stay competitive in the bidding wars and maintain profitability by reducing the cost of producing and placing asphalt concrete. One major factor in this cost reduction strategy is to minimize the quantity of asphalt cement in AC mixes toward lower limits permitted in the specifications. ODOT has closely monitored this situation and made adjustments to control AC binder content through design and QC requirements since 1997. In addition, the ODOT Superpave 442 mix design requirements have been modified to yield higher asphalt binder contents than specified in national standards. ODOT is one of only a few state agencies with these higher asphalt binder requirements.

Conclusion – Financial pressures tend to push binder contents toward the lean side of mix requirements.

Recommendation – Continue monitoring the effects of binder content on flexible pavement performance and continue to make appropriate adjustments as necessary.

15. Creep compliance measurements on intermediate and base layers generally fell below default values in the MEPDG.

Conclusion – 1. Overall, measured creep compliance was lower than MEPDG defaults at all temperatures, but much of this difference was probably caused by the asphalt concrete materials becoming more brittle with age. This difference between measured creep and MEPDG defaults decreased with falling temperatures.

Conclusion 2. Creep compliance was higher for the excellent performing pavements than the average performing pavements at 0° C (32° F) and -20° C (-4° F). At -10° C (14° F), average performing pavements were higher from 2 to a little over 100 seconds and then crossed over lower than the excellent performing pavements past 100+ seconds.

Conclusion 3. Despite measured creep compliance being lower than MEPDG defaults, thermal cracking was only noted on sections CHP 68 2.5N, CLA 41 4N and HAM 747 1S in the PMIS, all of which were considered to have average performance. CLA 41 3N, with excellent performance, might be considered an outlier at -10° C (14° F) with unusually low creep compliance, and HAM 747 1S, with average performance, appears to be a low outlier at -20° C (-4° F).

Conclusion 4. Equipment problems during the creep compliance tests may have affected the test results, especially at -20° C (-4° F).

Recommendation – Further testing needs to be performed on a wide range of asphalt concrete specimens to determine the effects of aging, temperature and equipment on creep compliance measurements.

Chapter 5 – Predicted Pavement Performance

16. From FWD deflections along entire project lengths, 51.6% (35.3 miles), 26.9% (18.4 miles), 15.2% (10.4 miles), and 6.4% (4.3 miles) of the flexible pavements were classified as excellent, good, fair, and poor in pavement stiffness response, respectively, while Spreadability on 7.8% (5.3 miles), 44.3% (30.3 miles), 44.4% (30.3 miles), and 3.5% (2.4 miles) of the pavements indicated excellent, good, fair, and poor ability, respectively, to distribute applied loads from the surface to the subgrade. These deflection and Spreadability ratings came from data accumulated over several years with the Dynaflect and FWD, and

empirically divided into levels of performance based on experience and expectations. Lower Spreadability ratings may result from the formation of micro-cracks over time on in-service pavements, which limits their ability to distribute loads more than resist vertical loads.

Conclusion – Over time, flexible pavements maintain the ability to resist vertical traffic loads better than distribute those loads through the pavement structure.

Recommendation – Account for the loss of load distribution in overlay designs.

17. From FWD maximum deflections along entire rigid pavement lengths, 67.6% (24.0 miles), 24.2% (8.6 miles), 7.2% (2.5 miles), and 1.0% (0.4 miles) of the PCC layers were classified as excellent, good, fair, and poor, respectively, while 15.8% (5.6 miles), 63.9% (22.7 miles), 19.3% (6.8 miles), and 1.0% (0.4 miles) of the PCC layers showed excellent, good, fair, and poor ability, respectively, to distribute load via Spreadability. While deflections are typically lower and Spreadabilities are typically higher on rigid pavements, the same possibility of pavement micro-cracks reducing the capacity to distribute of loads discussed in Conclusion 16 for flexible pavements appears to hold true for rigid pavements as well.

    Conclusion – Over time, rigid pavements maintain the ability to resist vertical traffic loads better than distribute those loads through the pavement structure.

    Recommendation - Account for the loss of load distribution in overlay designs.

18. Pavement sections with low layer stiffnesses do not always exhibit inferior performance. Performance is highly influenced by stiffness and traffic loading. Projects with low stiffness can be classified as having excellent performance if the traffic is light and projects with high stiffness can have average performance if the traffic is well above expectations.

    Conclusion – Since pavement condition is largely determined by visual distresses and rideability, FWD data are more of an indicator to explain condition than to measure it.

    Recommendation – Use PCR and IRI as principal measures of pavement condition.

19. Base stiffness has a significant influence on pavement response. While stiffer base layers generally improve the performance of flexible and rigid pavements, very stiff bases can have a negative effect on rigid pavement performance when slabs curl and lose contact with the base. Pavement performance increased considerably with thicker surface layers, as evidenced

on HAM 126, JEF 7 and JEF 22. Load transfer and soil stiffness at joints were generally good in these sections.

Conclusion – Stiff bases under rigid pavements can generate higher stresses in the concrete which adversely affect condition and performance.

Recommendation – Do not construct concrete pavements on stiff bases.

20. From 2007 PCR ratings and MEPDG software, the structural ability of GAL 7 to resist and transmit applied traffic loads through the slabs was classified as poor. The expected remaining service life of this project was -5.3 years, indicating it has exceeded its service life. While FWD midslab and joint deflections suggest GAL 7 is in poor condition when compared to similar measurements on other rigid pavements around the state, it continues to resist freeze/thaw cycling and carry local traffic after more than 60 years.

Conclusion – Traffic loading is an important consideration in evaluating performance as a change in condition over time.

Recommendation – Traffic loading should be used as a primary variable in evaluating pavement performance.

21. Calculations of service life indicate Ohio's pavement design procedures are conservative and differences in performance may be caused by variations in climate, materials, subgrade, and/or construction practices.

Conclusion – Variations in pavement performance can be caused by a wide range of factors.

Recommendation – In addition to inspecting projects, and enforcing specifications and design notes during construction, ODOT should encourage contractors to become aware of technical advancements by participating in conferences and meetings.

<u>Volume 2 - Petrographic Analyses of Concrete Cores, General</u>

22. Concrete in all 20 selected rigid pavement sites contained the following desirable attributes:

a. Good quality cementitious binder with a low water/cement ratio (0.42-0.48).

b. Good quality coarse aggregate resistant to freeze/thaw cycling.

c. Good quality fine aggregate consisting of chemically resistant natural sand with hard quartz particles as the dominant phase.

d. Entrained air.

Conclusion - High quality concrete observed at these sites indicated ODOT is doing a good job of designing and controlling concrete mixes.

Recommendation – While concrete quality is good, comments at construction sites suggest placement techniques vary widely by contractor and location in the state. ODOT should sponsor meetings to discuss concrete pavement construction issues with their own personnel and contractors. This may be especially important as contractors become busier in a recovering economy and begin hiring new personnel to replace established workers who were laid off.

23. Based on examinations of older rigid pavements during this research study and experience gained on the Ohio SHRP Test Road, the quantity of Portland cement can be reduced and larger sized, D-cracking resistant aggregate should be incorporated in 451 and 452 concrete mixes. The use of supplementary cementitious materials like fly ash will also benefit concrete mixes.

Conclusion – Portland cement concrete specifications for 451 and 452 pavements should be modified to reduce the quantity of Portland cement, add fly ash and increase aggregate size.

Recommendation – Develop specifications for pavement concrete using less cement, supplementary cementitious materials, and larger aggregate. Try these new requirements initially on smaller projects.

24. Increased emphasis should be given to maintaining the alignment of dowel bars during placement of the concrete. While there is no direct evidence that misaligned bars are a problem, the large steel bars currently being used will certainly generate large longitudinal tensile stresses in the concrete during curing and/or falling temperatures if the concrete slabs are not free to move on the bars. Misalignments of a few degrees could contribute to the continuing problem of transverse cracking on short slabs.

Conclusion – Dowel bar misalignment may cause transverse cracking of short slabs.

Recommendation - The severity of dowel bar misalignment can be examined by: 1) carefully measuring dowel bar alignment on a few new concrete pavement jobs just prior to concrete placement to check installation procedures, 2) carefully exposing, measuring and examining dowel bars in cracked and uncracked concrete slabs scheduled for removal to check in-service alignment and condition, and/or 3) measuring tensile loads required to pull dowel bars from existing slabs to check how well they were functioning.

Note: Refer to Volumes 2 and 3 of this report for in-depth analyses and additional conclusions for the rigid pavement cores.

Chapter 7
Implementation

The following items of implementation are suggested as responses to major conclusions discussed in Chapter 6:

1. Assemble personnel who are familiar with and/or frequent users of the PMIS and Straight-Line Diagrams to review Conclusions 1-6 in Chapter 6 and other problems mentioned in Chapter 2. Consider how applicable these issues are with the current PMIS and SLDs, and take actions to improve areas that continue to need improvement.

2. PCR data in 2002 and 2004 versions of the PMIS were often not consistent with the assigned projects numbers. This problem can lead to incorrect ages being assigned to condition data. Develop a procedure for updating project numbers whenever new PCR, traffic, and ride quality data are added to the PMIS tables.

3. PCR raters interpret crack patterns on pavement surfaces, and assign levels of severity and extent to each type of crack. Bottom up cracks are more detrimental to structural condition and pavement life than top down cracks and, therefore, should be rated more severely. Develop a procedure for determining whether cracks are bottom up or top down, and rating them separately.

4. Consider developing a procedure for specifying some minimum level of subgrade stiffness during construction and monitoring to see that the requirement is met. This suggestion has been made on other ORITE research projects where subgrade stiffness was found to have a significant impact on performance.

5. Continue to design drainage features for removing excess moisture from pavement structures and the underlying subgrades. While this has long been a priority with ODOT, various comments are still heard about instances where moisture is causing pavement problems.

6. ODOT has done a good job of implementing and improving SHRP asphalt specifications which tend to follow conclusions noted herein for improving conventional mixes used in the selected flexible sections, including the use of smaller aggregate in surface and intermediate mixes to improve durability, and modified ODOT 442 Superpave mix design requirements to yield higher than specified asphalt binder contents to maximize performance. Continue to monitor new developments from SHRP and adapt them for Ohio conditions.

7. Review the recommendations contained in Volumes 1 and 2 for reducing cement content, using fly ash and increasing the size of large aggregate in concrete mixes for rigid pavement. Construct a few small sections around the state and monitor their performance closely.

8. In accordance with Conclusion 7, reevaluate the current retention policy for construction and maintenance records. In order to evaluate completed projects for either good or bad performance, it is vital that pertinent data and diaries associated with those projects be available for review.

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APPENDIX A

Comparison of 2002 PMIS, 2004 PMIS, and SLD for Flexible Pavements

Table A1 – SLD Legend and PMIS Activity Codes

Legend for Straight Line Diagrams			
Surface Classifications		Base Classifications	
Code	Description	Code	Description
B	Brick	F	Crack and Seat - Concrete
D	Reinforced Concrete	H	Rubblize and Roll - Concrete
E	Plain Concrete	I	304 Aggregate Base
G	~404 Bituminous Concrete	K	Water Bound Macadam
K	~406 Bituminous Concrete	L	301 Bituminous Concrete
		N	Plain Concrete
		P	Reinforced Concrete
		D	Reinforced Concrete
		E	Plain Concrete

PMIS Activity Codes	
AC	Structural Activity
45	Intermediate Course Recycled AC
50	AC Overlay without Repairs
52	AC Inlay
55	Double Chip Seal
60	AC Overlay with Repairs
70	Crack and Seat
73	Break and Seat
77	Rubblize and Roll
80	Whitetopping
90	Unbonded Concrete Overlay
95	Unbonded Composite Overlay
100	New Flexible Pavement
110	New Rigid Pavement
120	New Composite Pavement

Table A2 – Comparison of 2002 PMIS, 2004 PMIS, and SLD for Flexible Pavements (1/4)

Comparison of Flexible Pavement Data in PMIS and SLD													1/4
Co/Rt/Dir	2002 PMIS			2004 PMIS			SLD				Core Site		Comments
	SLM Limits	PN	AC	SLM Limits	PN	AC	SLM Limits	PN	Pavement/ Base	Rev. Date	Project No.	SLM	
ALL 75 UD	0.00-9.08	470(96)	100	0.00-9.08	470(96)	100	0.2-8.75	470(96)	G/P	1/05			
				0.21-9.6	487(03)	52	0.2-9.6	487(03)	G/P				
ASD 250 UD	16.1-16.3	637(91)	100	16.1-16.3	637(91)	100	16.10-16.30	637(91)	G/L	1/07			Ramp
ATB 7 UD	28.45-30.67	734(78)	100				28.3-30.88	734(78)	G/L	1/06			
				28.45-30.67	467(04)	50	27.22-30.88	467(04)	G/L				
ATH 50 UD	2.46-4.99	262(69)	100	1.75-4.3	700(86)	100	11.18-11.46	700(86)	G/L				
	4.97-10.71	700(86)	100	4.97-11.68	683(90)	50	1.74-11.18	527(98)	G/L	1/06,05			SLMs for 700(86) and 683(90) in PMIS and on SLD?
	1.75-4.3	683(90)	50	1.74-11.46	527(98)	30	1.74-11.56	547(03)	G/P				Pavement realigned - 700(86) removed.
	1.75-11.47	527(98)	30	1.74-11.46	547(03)	38							
BRO 62 UD	19.66-20.87	304(00)	100	19.66-20.87	304(00)	100	16.94-18.13	304(00)	G/L	1/05			SLMs for 304(00)?
				18.07-28.31	467(03)	50	18.13-28.33	467(03)	G/I				
BUT 4 UD	4.24-4.68	1989	100	4.24-4.68	1989	100	4.1-5.25	736(90)	G/P	1/06			Project number in 2002 and 2004 PMIS?
				2-5.83	451(03)	60	2.03-5.77	451(03)	G/P				
BUT 129 UD	17.74-23.25	1995	100	17.74-23.25	1995	100	15.30-17.96	9329(98)	D, G/L				9329(98) and 9330(98) not in 2002 or 2004 PMIS?
	23.99-24.5	1994	100	23.99-24.5	1994	100	17.96-24	9330(98)	G/L	1/01	9330(98)	22W, 22E	Project 3004(98) not in 2002 PMIS or SLD?
	23.9-25.86	9327(98)	888	23.16-25.86	3004(98)	100	24-25.86	9327(98)	G/L		9327(98)	25W	
BUT 177 D	2.91-3.77	220(91)	888	2.91-3.77	220(91)	888	2.20-3.69	823(67)	G/I				
	1.59-3	985(92)	50	1.59-3	985(92)	50	3-3.77	220(91)	G/I	1/01			AC for 220(91) in PMIS?
							1.59-3	985(92)	G/I				
BUT 202 UD				1.48-1.74	16(99)	100							No BUT 202 in 2002 PMIS and SLD
BUT 747 UD	4.86-5.03	1993	100	4.86-5.03	1993	100	4.79-5.21	259(94)	G/L	1/06, 05			Project numbers in PMIS? 259(94) not in PMIS?
BUT 27 UD	4.24-4.69	1990	100	4.24-4.69	1990	100							
	3.35-5.66	1077(91)	30	3.35-5.66	1077(91)	30	3.35-5.65	1077(91)	G/I, G/L	1/05,03			Project numbers in PMIS and SLD?
				0-6.21	358(01)	60	3.35-6.21	358(01)	G/L				358(01) not in 2002 PMIS?
	7.95-8.15	1989	100	7.95-8.15	1989	100	7.95-8.18	935(90)	G/L	1/03			
	16.32-16.57	1999	100	16.32-16.57	672(98)	100	16.32-16.57	No PN	B/N	1/92			
CHP 68 UD	1.28-2.11	233(98)	100	1.28-2.11	233(98)	100	0-1.82	233(98)	D, G/P	1/05	233(98)	2N, 2.5N	233(98) SLMs in PMIS vs. SLD?
							1.82-2.1	12(94)	G/N				
CLA 41 UD	3.83-4.44	63(95)	100	3.83-4.44	63(95)	100	3.86-4.47	63(95)	G/I	1/06	63(95)	3 N, 4N	
CLE 133 UD	12.78-13.85	1996	995	12.78-13.85	625(95)	100	12.78-13.40	53(93)	G/I	1/99			Project number and AC in 2002 PMIS?
							13.40-13.85	43(88)	G/I				625(95) in PMIS vs. 53(93) and 43(88) on SLD?
COS 36 U	19.98-26.12	278(96)	50	19.71-26.12	278(96)	50, 77,	19.5-26.1	278(96)	G/L				
						100				1/99			Different SLMs and AC for 278(96) and 139(97) in PMIS and SLD?
	32.82-33.59	139(97)	50	27.53-34.05	139(97)	100	26.1-32.82	139(97)	G/L				
CUY 271 UD	0-3.8	687(83)	60	0-3.8	687(83)	60	0-3.8	687(93)	G/P				
	0-3.03	984(93)	100	0-3.03	984(93)	100							687(83) in PMIS vs. 687(93) on SLD?
	6.8-10.2	379(94)	100	6.8-10.2	379(94)	100	7.6-10.2	379(94)	G/P, G/L	1/00, 08			
	6.41-14.84	582(99)	30	6.41-14.84	582(99)	30	6.47-16.65	582(99)	G/P, G/L				
DAR 185 UD	10.29-10.84	686(95)	100	10.29-10.84	686(95)	100	10.3-10.84	686(95)	G/L	1/00,97			
	9.58-10.39	423(96)	100	9.58-10.39	423(96)	100	9.51-10.3	423(96)	G/L				
DEL 23 D	SHRP Test Road										380(94)	18S, 17S	Sections 212D and 902D

Table A2 – Comparison of 2002 PMIS, 2004 PMIS, and SLD for Flexible Pavements (2/4)

Comparison of Flexible Pavement Data in PMIS and SLD													2/4
Co/Rt/Dir	2002 PMIS			2004 PMIS			SLD				Core Site		Comments
	SLM Limits	PN	AC	SLM Limits	PN	AC	SLM Limits	PN	Pavement/ Base	Rev. Date	Project No.	SLM	
DEL 750 UD	8.43-8.82 8.39-8.43	8006(90) 165(95)	100 100	8.43-8.82 8.39-8.43	8006(90) 165(95)	100 100	8.43-8.61 5.43-8.43	8006(90) 165(95)	G/L G/L	1/07			
ERI 2 UD	1.78-7.80	148(99)	100	1.78-7.80	148(99)	100	1.78-7.79	148(99)	G/L	1/02			
FAY 35 UD	17.68-24.01	298(96)	100	17.68-24.01	298(96)	100	17.6-24.05	298(96)	G/L	1/06			
FRA 70 UD	7.60-11.21 3.31-8.27	276(94) 538(99)	50 60	7.60-11.21 3.31-8.27	276(94) 538(99)	100 60	7.6-11.21 3.29-7.6	276(94) 538(99)	G/L G/P	1/05,04			276(94) AC 50 in 2002 PMIS vs. AC 100 in 2004 PMIS?
GAL 35 UD	0.75-4.75 0-3.5 8.37-14.00	740(90) 343(99) 8004(90)	50 40 100	1.03-4.75 1.03-3.5 12.15-14.00	740(90) 343(99) 8004(90)	100 999 100	0.2-3.8 0-3.8 1.03-3.8 8.3-13.96	740(90) 343(99) 479(04) 8004(90)	G/H, G/L G/H, G/L G/H, G/L G/L	1/06			AC for 740(90) and 343(99)?
GRE 35 UD	21.14-26.41 20.68-21.52	259(89) 243(02)	100 50	21.14-26.41 21.14-26.41 20.68-21.52	259(89) 259(98) 243(02)	100 100 50	20.95-26.2	259(98)	G/L	1/03,04	259(98)	21 E	Project 259(89) or 259(98)?
GRE 835 UD	1.28-2.09	814(85)	100	1.28-2.09 0-2.05	814(85) 373(04)	100 60	1.28-2.06 0-2.06	814(85) 373(04)	G/N G/N	1/06			
HAM 71 UD	0.54-1.17	181(95)	100	0.54-1.17	181(95)	100	0-1.34	VAR.	G/L	1/03,02			
HAM 275 UD	39.8-41.6	295(97)	100	39.8-41.6	295(97)	100	39.81-41.36	295(97)	G/P	1/07,99			
HAM 22 D	13.23-13.86	893(96)	100	13.23-13.86	893(96)	100	13.24-13.38	383(80)	D/	1/06			893(96) not on SLD?
HAM 747 UD	0.04-0.96	347(85)	100	0.04-0.96	347(85)	100	0.04-0.94	347(85)	G/K	1/97	347(85)	1 S	
HAM 126 UD	6.61-10.79 11.68-13	645(94) 1995	100 100	6.61-10.79 6.83-13.31	645(94) 516(96)	100 100	6.83-11.35 11.35-13.3	645(94) 997(90)	G/L D/	1/03,98	645(94)	11 E	Project number in 2002 PMIS? 645(94) and 516(96) two years apart in 2004 PMIS? 516(96) not on SLD?
HIG 32 UD	0-0.78 0-0.58	893(78) 619(90)	100 50	 0-0.58	 619(90)	 100	0-0.58 0-0.58	883(78) 619(90)	G/L G/L	1/95			893(78) or 883(78)? 0.58 is BRO Co. line on SLD. 619(90) AC 50 in 2002
JAC 35 UD	1.68-2.76 8.48-11.46 11.46-13.25	757(92) 660(86) 732(86)	100 100 100	1.68-2.76 8.48-11.46 11.46-13.25	757(92) 660(86) 732(86)	100 100 100	1.69-8.35 8.4-11.4 11.4-13.23	757(92) 660(86) 732(86)	G/L G/L G/L	1/95 1/95,06 1/06			
JEF 7 UD	19.94-23.48 22.97-24.7	435(68) 843(94)	100 50	22.97-24.7 19.21-22.97	843(94) 110(03)	50 38	19.21-22.97 19.21-22.97	843(94) 110(03)	G/L G/L	1/04			19.94-22.97 435(68) in 2002 PMIS?
KNO 13 UD	16-20.69 16.02-20.69	523(65) 696(90)	100 888	16.02-20.69 16-20.68	696(90) 402(00)	888 35	 16.05-20.74	 402(00)	 G/I	1/05			696(90) AC 888 in PMIS? 696(90) not on SLD?
LAW 7 UD	1.4-3.0 1.65-2.28 1.40-2.29	17(85) 370(86) 1989	100 777 100	1.40-2.30 1.65-2.28 1.40-2.29	17(85) 370(86) 1989	100 777 100	1.40-2.30	17(85)	G/L	1/07			AC 777 for 370(86) in PMIS? Project number for 1.40-2.29 in PMIS?
LAW 218 D	0-2.42	485(90)	888	0-2.42	485(90)	888	0-2.42	485(90)	G/I	1/91			485(90) AC 888 in PMIS?
LAW 243 UD	11.52-11.82	406(95)	100	11.52-11.82	406(95)	100	11.69-18.39 11.39-11.69	878(91) 406(95)	G/I G/L	1/04			878(91) not in PMIS?
LAW 373 UD	0-3.39	486(90)	888	0-3.39	486(90)	888	0-3.39	486(90)	G/I	1/97			486(90) AC 888 in PMIS?
LAW 378 UD	0-0.8	1994	100	0-0.8 0-4.95	1994 497(04)	100 50	0-0.9 0-4.95	406(95) 497(04)	G/I G/I	1/06			Project numbers for 0-0.8 in PMIS ? 406(95) not in PMIS?

Table A2 – Comparison of 2002 PMIS, 2004 PMIS, and SLD for Flexible Pavements (3/4)

Comparison of Flexible Pavement Data in PMIS and SLD													3/4
Co/Rt/Dir	2002 PMIS			2004 PMIS			SLD				Core Site		Comments
	SLM Limits	PN	AC	SLM Limits	PN	AC	SLM Limits	PN	Pavement/ Base	Rev. Date	Project No.	SLM	
LAW 527 UD	0.19-0.69	17(85)	100	0.19-0.69	17(85)	100	0.00-0.56	17(85)	G/L	1/90	17(85)	2 N	
LIC 16 UD	0.00-0.48	16(91)	100	0.00-0.48	16(91)	100	0.00-0.48	16(91)	G/L, G/K	1/04, 06			6010(99) AC 888 in 2002 PMIS and not in 2004
	19.75-21.06	5001(90)	100	19.75-21.06	5001(90)	100	19.72-21.44	6010(99)	G/L				PMIS? 5001(90) not on SLD?
	19.79-21.69	6010(99)	888				21.44-24.27	6010(99)	G/P				SLMs for 6010(99) in 2002 PMIS and SLD?
LIC 79 UD	4.6-4.75	879(94)	100	4.6-4.75	879(94)	100	4.36-6.6	879(94)	G/L	1/04			
				4.6-6.56	14(03)	50	4.60-6.44	14(03)	G/L				6010(99) not in PMIS?
	12.46-14.02	839(85)	100	12.46-14.02	839(85)	100	12.46-13.81	839(85)	G/L	1/06			
							12.46-13.81	6010(99)	G/L				
LOG 33 U	15.77-18.03	1991	100	15.89-17.76	333(92)	100	15.78-17.8	333(92)	G/I, G/L	1/02, 05			Project numbers in 2002 PMIS?
	17.82-21.53	1992	100	17.74-21.51	758(92)	888	17.8-21.51	758(92)	G/L				AC for 890(94) in 2002 PMIS and 758(92) in 2004
	15.89-21.5	890(94)	888				19.5-20.3	890(94)	G/L				PMIS?
	15.78-21.5	329(01)	25	15.78-21.5	329(01)	35	15.9-21.51	329(01)	G/I, G/L				890(94) not in 2004 PMIS?
LOG 33 UD	26.97-29.71	375(96)	100	25.63-29.52	375(96)	100	25.63-29.65	375(96)	G/L	1/08			
LOR 90 UD	9.48-13.01	406(92)	50	9.48-13.01	406(92)	50	10.76-17.85	406(92)	G/P	1/06			332(97) AC 888 in 2002 PMIS?
	9.48-11.96	332(97)	100	10.76-12.02	3015(00)	50,100							3015(00) not in 2002 PMIS?
	19.96-23.33	332(97)	888	19.92-23.88	332(97)	100	19.96-23.33	332(97)	G/P				SLMs for 3015(00) in 2004 PMIS and SLD?
							17.86-23.33	3015(00)	G/P, G/L				
LUC 2 UD	21.24-27.8	141(99)	100	21.24-27.8	141(99)	100	21.2-27.25	141(99)	G/L	1/02	141(99)	22 E	
LUC 25 UD	10.03-11.29	665(97)	100	10.03-11.29	665(97)	100	10.01-11.54	665(97)	G/L	1/04	665(97)	10 S	
MAH 62 UD	17.49-19.97	213(92)	888	17.49-19.97	213(92)	100	Various older AC and PCC projects						213(92) not on SLD?
MAH 224 UD	0.08-0.19	257(01)	100	0.08-0.19	257(01)	100	0.1-0.2	540(01)	G/N	1/03			257(01) not on SLD?
													540(01) not in PMIS?
MEG 32 UD	0-3.82	618(90)	50	0-3.82	618(90)	50	0-3.82	618(90)	G/L	1/01			Project number in 2002 and 2004 PMIS?
	0-3.82	1996	100	0-3.82	1996	100							AC 100 project not on SLD?
	0-3.82	170(00)	35	0-3.82	170(00)	35	0-3.82	170(00)	G/L				
MOT 40 UD	12.14-12.57	304(95)	100	12.14-12.57	304(95)	100	12.13-12.54	304(95)	G/L	1/06			
				12.13-13.34	455(04)	60	12.13-13.34	455(04)	G/L, G/N				
MOT 48 UD	5.45-6.49	505(84)	100	5.45-6.49	505(84)	100	4.33-6.04	545(99)	N/P, L/N	1/02			SLM for 545(99) and 241(00)?
	4.33-5.45	545(99)	50	3.26-5.21	545(99)	50	6.04-6.94	241(00)	G/L				241(00) not in PMIS? 505(84) not on SLD?
MOT 835 UD	1.83-3.17	1985	100	1.83-3.17	1985	100				1/04			1985 project numbers in 2002 and 2004 PMIS?
	0.61-1.27	783(85)	777	0.61-1.27	783(85)	777	1.71-3.05	783(85)	G/L				783(85) AC 777 in 2002 and 2004 PMIS
				1.27-3.16	393(03)	50	1.71-3.16	393(03)	G/L				
MUS 16 U	0.3-2.66	368(98)	888	0.63-2.66	368(98)	100	0.31-2.61	368(98)	G/L	1/03			368(98) AC 888 in 2002 PMIS?
	2.62-10.86	606(99)	100	1.74-10.86	2001	999	2.61-7.1	606(99)	G/L				606(99) one year after 368(98)?
	7.16-11.72	136(00)	100	7.16-11.72	136(00)	100	7.1-11.70	136(00)	G/L				606(99) not in 2004 PMIS?
PIK 32 UD	13.55-16.17	433(94)	100	13.55-16.17	433(94)	100	13.43-16.08	433(94)	G/L	1/06	433(94)	15 W	
	16.05-20.49	552(95)	100	16.05-20.49	552(95)	100	16.08-20.47	552(95)	G/L	1/06	552(95)	19W, 19E	
POR 303 UD	6.83-7.23	497(99)	100	6.83-7.23	497(99)	100	6.02-8.5	21(05)	G/I, G/L	1/06			497(99) not on SLD? Nothing older than (05) on SLD.
ROS 35 UD	0-4.36	298(96)	100	0-4.36	298(96)	100	0-4.3	298(96)	G/L	1/07	298(96)	1 W	

Table A2 – Comparison of 2002 PMIS, 2004 PMIS, and SLD for Flexible Pavements (4/4)

Comparison of Flexible Pavement Data in PMIS and SLD													4/4
Co/Rt/Dir	2002 PMIS			2004 PMIS			SLD				Core Site		Comments
	SLM Limits	PN	AC	SLM Limits	PN	AC	SLM Limits	PN	Pavement/ Base	Rev. Date	Project No.	SLM	
SAN 20 UD	18.57-19.17	1149(90)	100	18.57-19.17 18.68-24.28	1149(90) 476(03)	100 60	18.68-19.1 18.68-24.28	1149(90) 476(03)	G/P G/P	1/06			
SCI 73 UD	23.8-25.11	888(96)	100	23.8-25.11	888(96)	100	24.02-24.84	888(96)	G/L	1/07			SLMs for 888(96) in PMIS vs. SLD?
STA 30 D	12.45-16.95	1044(93)	100	12.45-16.95	1044(93)	100	12.5-16.9	1044(93)	G/L	1/07			
SUM 18 UD	13.22-14.56	413(98)	100	13.22-14.56	413(98)	100	13.2-13.4 13.4-13.7 13.7-14.47	413(98) 681(92) Muni(71)	G/T G/T G/T	1/01			681(92) not in PMIS?
UNI 38 UD	8.68-15.58 8.98-9.74	295(99) 451(99)	50 100	8.98-9.74	451(99)	100	9.4-9.57	451(99)	G/L	1/07			295(99) and 451(99) same year?
UNI 33 UD	4.17-7.3 0-0.28	439(86) 644(95)	100 50	4.17-7.3 0-1.99	439(86) 644(95)	100 50	4.1-7.2 0.2-8.74	439(86) 644(95)	G/L G/L	1/98,02			SLMs for 644(95)?
VAN 30 UD	15.97-21.18	219(97)	100	15.97-21.18	219(97)	100	16.16-21.2	219(97)	G/N	1/07	219(97)	18 E	Cores show composite pavement
VIN 50 UD	7.91-8.33	667(95)	100	7.91-8.33	667(95)	100	8.20-8.63	667(95)	G/L	1/08			
WAR 741 UD				15.53-17.55	206(98)	100	15.67-17.69	206(98)	G/L	1/07			206(98) not in 2002 PMIS?
WAS 7 UD	39-49.56 47.59-48.32 39-49.53	557(92) 407(96) 2002	50 100 60	39-49.56 47.59-48.32 39-49.53	557(92) 407(96) 88(03)	50 100 50	39.00-49.53 39.00-49.53	557(92) 88(03)	G/K, G/N G/N, G/K	1/04			407(96) not on SLD?
WAY 83 UD	8.97-10.96 14.78-25.36	369(78) 576(96)	100 40	13.75-14.85 0-9.06	576(96) 464(04)	40 60	9.06-10.88 10.88-10.96 0-9.26+	369(78) 576(96) 464(04)	G/L D/, D/I G/I, G/T	1/07,06			9.26-10.66 on SLD = 13.90-12.50 on US 250. SLMs for 369(78) and 576(96)?
WAY 585 UD	10.79-11.04	87(89)	100	10.79-11.04	87(89)	100	10.79-11.04 8.83-11.9	87(89) 547(02)	G/T G/T	1/05			547(02) not in PMIS?
WOO 25 U	20.14-26.42 15.75-22.58	1946 874(90)	100 50	15.75-22.58 21.03-21.29 15.68-20.02	874(90) 530(97) 22(03)	50 50 52	15.68-22.57 21.01-21.15 15.8-19.9 20.01-20.22	874(90) 530(97) 22(03) 20(04)	G/K G/L G/K G/I, G/L	1/07,06			23.03 is LUC Co. line on SLD. Realignment/changing SLM since 1946?
WOO 75 U	26.08-32.88	157(98)	888	26.08-30.84	157(98)	100	26.07-30.7	157(98)	G/L	1/03,02			157(98) AC 888 in 2002 PMIS?
WOO 795 UD	0.44-4.59 0.61-5 2.02-3.01	425(67) 358(81) 1104(92)	100 50 888	0.61-5 2.02-3.01	358(81) 1104(92)	50 888	0.22-0.69 0.69-2.02 2.1-2.69 2.69-3.2	767(87) 40(95) 1104(92) 358(81)	G/K G/I G/I, G/L G/I	1/05			425(67) not on SLD? SLMs for 358(81) in PMIS vs. SLD? 1104(92) AC 888 in PMIS? 767(87) and 40(95) not in PMIS?

APPENDIX B

Comparison of 2002 PMIS, 2004 PMIS, and SLD for Rigid Pavements

Table B1 – SLD Legend and PMIS Activity Codes

Legend for Straight Line Diagrams			
Surface Classifications		Base Classifications	
Code	Description	Code	Description
B	Brick	F	Crack and Seat - Concrete
D	Reinforced Concrete	H	Rubblize and Roll - Concrete
E	Plain Concrete	I	304 Aggregate Base
G	~404 Bituminous Concrete	K	Water Bound Macadam
K	~406 Bituminous Concrete	L	301 Bituminous Concrete
		N	Plain Concrete
		P	Reinforced Concrete
		D	Reinforced Concrete
		E	Plain Concrete

PMIS Activity Codes	
AC	Structural Activity
45	Intermediate Course Recycled AC
50	AC Overlay without Repairs
52	AC Inlay
55	Double Chip Seal
60	AC Overlay with Repairs
70	Crack and Seat
73	Break and Seat
77	Rubblize and Roll
80	Whitetopping
90	Unbonded Concrete Overlay
95	Unbonded Composite Overlay
100	New Flexible Pavement
110	New Rigid Pavement
120	New Composite Pavement

Table B2 – Comparison of 2002 PMIS, 2004 PMIS, and SLD for Rigid Pavements (1/8)

Comparison of Rigid Pavement Data in PMIS, SLD and Internal ODOT List															1/8
Co/Rt/Dir	2002 PMIS			2004 PMIS			SLD				2006 ODOT List		Core Site		Comments
	SLM Limits	Proj. No.	AC	SLM Limits	Proj. No.	AC	SLM Limits	Proj. No.	Pvt. / Base	Rev. Date	SLM Limits	Proj. No.	Proj. No.	SLM	
ALL 30 UD	20.15-24.17	746(97)	110	20.15-24.17	746(97)	110	19.82-24.05	746(97)	D/	1/00	19.01-24.05	119(99)	746(97)	22 E	746(97) in PMIS/SLD vs. 119(99) on ODOT list?
ASD 30 UD	0.00-3.82	119(98)	90	0.00-3.82	119(98)	90	0.00-3.82	119(98)	D/	1/02	0.00-3.82 0.13-4.93	119(98) 119(98)			AC 90 is unbonded PCC overlay in PMIS. 0.13-4.93 shown as PCC overlay on ODOT list.
ATB 11 UD	0-3.04 0-2.18	154(70) 331(01)	110 50	0-2.18	331(01)	50	0-2.2 2.2-13.3	331(01) M&R(94)	G/P G/P	1/05	Not listed				2.18-3.04 in 154(70) surface G on SLD and not on ODOT list
	3.04-14	470(69)	110				2.2-13.3	M&R(94)	G/P	1/05	Not listed				SLMs in 2002 PMIS and SLD?
ATB 20 UD	11.99-12.7 12-12.38	445(64) 215(63)	110 110				11.99-12.7 12.1-12.2	445(64) 488(03)	D/ D/	1/06	Not listed				445(64) one year after 215(63) in 2002 PMIS? 445(64) and 215(63) not on ODOT list?
ATH 33 UD	10.2-13.09	235(58)	110				10.4-13.31	433(99)	D/	1/05	13.31-	84(92)	235(58)	13 E	
	16.79-18.2 18.2-18.32 15.53-15.9 19.25-25.46	625(76) 745(77) 905(93) 425(01)	110 110 110 110	15.53-15.9 19.66-20.59	905(93) 425(01)	110 110	15.52-15.86 15.86-17.55 17.55-17.99 17.99-24.60	717(73) 625(76) 745(77) 425(01)	D/ D/ D/ E/	1/05 1/05 1/05 1/05	Not listed				235(58), 625(76), 745(77), 425(01) not on ODOT list? 905(93) not on SLD?
ATH 50 UD	4.99-11.68 1.75-2.5 4.97-10.71	491(55) 745(77) 700(86)	110 50 100	4.97-11.68 1.74-11.46	700(86) 547(03)	100 38	11.56-12.17 11.18-11.46 1.74-11.56	745(77) 700(86) 547(03)	D/ G G/L	1/05,06	Not listed				745(77) AC 50 in 2002 PMIS v. Surface D on SLD? SLMs for 745(77)? AC 38 is polymer asphalt overlay
				17.5-25.66	180(97)	110	17.5-24.0	180(97)	D/	1/01,03		180(97)			180(97) not in 2002 PMIS.
				25.66-26.2	8001(98)	110	24.0-26.2	8001(98)	D/	1/01	Not listed				8001(98) not in 2002 PMIS or on ODOT list?
	25.66-30.8	705(98)	888	26.2-30.8	705(98)	110	26.2-30.7	705(98)	D/	1/01					705(98) AC 888 in 2002 PMIS, and not on list?
	34.2-40.02 34.2-34.74	742(61) 95(61)	110 110	34.07-39.04	79(01)	35	33.22-39.04	79(01)	G/P	1/04,02					AC 35 in 2004 PMIS is Nova-Chip resurfacing
ATH 682 UD	0.14-2.08 0.66-4.41	625(76) 560(97)	110 50	0-0.14 0.64-4.41	84(92) 560(97)	50 50	0-0.64 0.64-0.69 0.69-2.98	625(76) 305(87) 560(97)	D/ D/ G/L	1/04	Not listed		625(76)	1 S	625(76) not on ODOT list. 305(87) not in PMIS or on ODOT list.
BEL 7 UD	12.05-14.26 11.9-14.17 17.71-17.86 16.68-17.65	741(81) 543(90) 14(91) 529(98)	50 110 110 110	12.05-14.26 11.9-14.17 17.71-17.86 16.9-18.87 16.68-17.65	741(81) 543(90) 14(91) 305(97) 529(98)	50 110 110 110 110	1.87-14.09 4.09-15.6 16.6-17.7 15.6-16.6	741(81) 543(90) 305(97) 14(91)	E/ D/ D/ D/	1/05, 07	14.17-16.65 16.65-17.71	305(97) 529(88)			741(81) AC 50 in 2002 and 2004 PMIS vs. Surface E on SLD? SLMs? 529(98) one year after 305(97) in 2004 PMIS? 528(98) in PMIS or 529(88) on ODOT list? SLMs for 305(97) and 529(98)?
BEL 7J UD	15.63-16.39	543(90)	110				No SLD for BEL 7J				Not listed				
BEL 149 UD	16.8-30.81	312(99)	50	16.8-30.81	312(99)	50	15.7-17.15 17.15-18.92	395(92) 14(94)	G/N D/	1/04	16.57-18.34	14(94)			AC 50 in PMIS vs. concrete on SLD and ODOT list?
BUT 122 UD	5.75-6.13	1991	110	5.75-6.13	1991	110	5.74-6.13 6.13-6.33	451(78) Br. Deck	G/P D/	1/04	Not listed				Project number in 2002 and 2004 PMIS? 1991 project not on ODOT list?
BUT 127 UD							5.77-6.55	923(92)	D/	1/08	5.67-6.87	923(92)			923(92) not in PMIS?
CHP 68 UD	0-1.28	233(98)	110	0-1.28	233(98)	110	0-1.27	233(98)	D/	1/05	0-1.28	233(98)			
CLA 40 UD	10.33-11.7	51(97)	110	10.33-11.7	51(97)	110	9.76-13.19	51(97)	G/P, G/N	1/04	Not listed				AC 110 in PMIS vs. Surface G on SLD?
CLE 52 UD	3.31-3.62 0-6.72	39(64) 253(91)	110 888	0-6.72	253(91)	50	3.3-6.52 0-6.72	39(64) 253(91)	D/ G/P	1/95,07	Not listed				253(91) AC 888 in 2002 PMIS
CLI 71 UD	4.26-7.25	269(85)	90	4.26-7.26 4.26-7.26	269(85) 334(03)	90 40	4.26-7.26 4.26-7.26	269(85) 334(03)	D/P D/P	1/05	4.26-7.26	269(85)			AC 90 is unbonded concrete overlay in PMIS. 269(85) shown as PCC overlay on ODOT list.

Table B2 – Comparison of 2002 PMIS, 2004 PMIS, and SLD for Rigid Pavements (2/8)

Comparison of Rigid Pavement Data in PMIS, SLD and Internal ODOT List															2/8
	2002 PMIS			2004 PMIS			SLD				2006 ODOT List		Core Site		
Co/Rt/Dir	SLM Limits	Proj. No.	AC	SLM Limits	Proj. No.	AC	SLM Limits	Proj. No.	Pvt. / Base	Rev. Date	SLM Limits	Proj. No.	Proj. No.	SLM	Comments
COL 39 UD	18.22-18.42 18.22-18.42	778(60) 546(71)	110 110				18.22-18.40 18.22-18.40	778(60) 447(72)	D/ G/P	1/04	Not listed				546(71) not on SLD? 447(72) not in PMIS?
COL 39 UD	19.2-21.7 20.53-21.7 19.82-20.83 20.83-23.01	778(60) 1016(77) 819(96) 308(96)	110 100 50 50	19.82-20.83 20.83-23.01	819(96) 308(96)	50 50	18.42-20.53 20.53-20.67 20.67-22.6	819(96) 1016(77) 7019(02)	G/L G/L G/T	1/04	Not listed				18.42-19.82 US 30 overlap on SLD. 7019(02) not in PMIS?
COS 16 UD	9.91-10.05	563(97)	110	9.91-10.05	563(97)	110	9.8-10.05	563(97)	G/P	1/07	Not listed				AC 110 in PMIS vs. surface G on SLD?
CUY 3 UD	6.24-7.71		995	6.24-7.71		995	6.22-7.67	750(86)	D/	1/08	6.24-7.71	750(86)			AC 995 in PMIS.
CUY 17 UD	4.75-5.22 3.13-7.1	220(72) 838(93)	110 888	3.19-7.04 3.2-4.43	838(93) 7012(01)	60 888	4.3-5.17 5.25-7.02 3.20-4.43	838(93) 838(93) 7012(01)	G/P, T, L G/P, G/T D/	1/04	3.20-4.39				7012(01) not in 2002 PMIS, AC 888 in 2004 PMIS and concrete on SLD.
CUY 21 UD	10.04-10.23	417(73)	777				10.04-10.23	417(73)	D/	1/95	Not listed				417(73) not on ODOT list?
CUY 42 U	4.39-4.8	420(96)	888	1.95-2.67 4.39-4.67	750(85) 420(96)	888 110	1.95-2.58 4.39-4.67	750(85) 156(01)	D/ D/	1/04 1/04	Not listed				Three short sections of concrete on 156(01). 750(85) not on ODOT list?
CUY 42 UD	15.3-15.37	274(65)	110				15.30-15.57	274(65)	D/	1/00	Not listed				274(65) not on ODOT list
CUY 82 UD	2.05-3.81 7.63-11.73	438(94) 23(98)	110 888	2.05-3.81 7.63-11.73	438(94) 23(98)	110 110	2.03-3.82 8.21-9.80 10.9-11.70	438(94) 23(98) 23(98)	D/ G/P G/T, G/L	1/06 1/05	Not listed		438(94)	3 E	438(94) not on ODOT list? 23(98) AC 110 in 2004 PMIS vs. surface G on SLD?
CUY 90 UD	8.43-13.41 9.63-10.39 6.67-9.9 9.68-13.41	58(74) 539(74) 261(88) 180(99)	110 110 60 60	6.67-9.9 9.68-13.41	261(88) 180(99)	60 60	12.34-13.23	180(99)	D/	1/07,03	Not listed				180(99) - other sections G/P on SLD. 58(74) or 539(74) in 2002 PMIS? 180(99) AC 60 in PMIS vs. concrete on SLD? Nothing on ODOT list?
CUY 91 UD	0-2.45	38(02)	110	0-2.45	38(02)	110	0-2.45	38(02)	D/	1/04	0.65-2.05				Proj. No. not shown on ODOT list.
CUY 175 UD				2.06-2.75 2.75-3.12 3.12-3.4 3.4-4.75 5.76-7.38	161(99) 275(94) 348(98) 727(98) 271(90)	888 888 888 888 888	1.9-2.7 2.75-3.08 3.08-3.6 3.6-4.75 5.68-7.30 7.30-8.51	161(99) 275(94) 348(98) 727(98) 271(90) 371(84)	D/ D/ D/ D/ D/ D/	1/01, 1/08, 1/03	5.68-7.30	271(90)			Nothing before SLM 9.91 in 2002 PMIS? Activity codes in 2004 PMIS? 161(99), 275(94), 348(98), 727(98), and 371(84) not on ODOT list?
	10.02-10.98 10.02-10.98 9.83-10.98	103(66) 103(66) 2002	110 777 999	9.87-11	7016(01)	888	9.87-10.33 9.87-10.9	103(66) 7016(01)	D/ G/P	1/03	Not listed				103(66) AC 110 & 777 in 2002 PMIS. 7016(01) not in 2002 PMIS. 7016(01) AC 888 in 2004 PMIS.
CUY 176 UD	10.14-10.88	683(94)	110	10.14-10.88	683(94)	110	10.13-10.9 10.9-12.83	683(94) 305(96)	D/ D/	1/02	10.87-12.83	305(96)	683(94) 305(96)	10 S 11S, 12S	305(96) not in PMIS. 683(94) not on ODOT list?
CUY 237 UD				10.53-12.66	180(01)	888	8.50-8.90 10.53-12.66	220(72) 180(01)	D/ D/	1/04	10.53-12.66	180(01)			220(72) not in PMIS and not on ODOT list? AC 888 for 180(01) in 2004 PMIS?
CUY 252 UD	4.18-4.54 3.55-4.24 8.65-8.95	454(78) 901(84) 774(73)	777 110 777	3.42-5.11 8.07-9.12	901(84) 162(99)	110 888	3.42-4.18 4.18-4.54 8.65-8.93 8.65-8.93	901(84) 454(78) 774(73) 162(99)	D/ D/ D/ D/	1/03, 1/06	Not listed		901(84)	4 N	SLMs for 901(84) in PMIS and SLD? 454(78) and 774(73) AC 777 in 2002 PMIS? 162(99) not in 2002 PMIS and AC 888 in 2004 PMIS No SLD sections on ODOT list?

Table B2 – Comparison of 2002 PMIS, 2004 PMIS, and SLD for Rigid Pavements (3/8)

Comparison of Rigid Pavement Data in PMIS, SLD and Internal ODOT List															3/8
Co/Rt/Dir	2002 PMIS			2004 PMIS			SLD				2006 ODOT List		Core Site		Comments
	SLM Limits	Proj. No.	AC	SLM Limits	Proj. No.	AC	SLM Limits	Proj. No.	Pvt. / Base	Rev. Date	SLM Limits	Proj. No.	Proj. No.	SLM	
CUY 322 UD	8.66-11.94 11.97-14.14	1019(93) 872(92)	110 777	8.66-11.97 11.97-14.14	1019(93) 872(94)	110 110	8.68-11.98 11.98-12.52 12.52-14.15	1019(93) 872(94)	D/ D/ G/P	1/00,02	8.68-11.98	1019(93)	1019(93)	10 E	872(92) in 2002 PMIS or 872(94) in 2004 PMIS? 872(92) or (94) not on ODOT list? SLM for 872(94)?
CUY 490 UD	0.47-0.99 0-0.4	745(84) 108(01)	110 50	0.47-0.99 0-0.4	745(84) 108(01)	110 50	0.5-1.00 0-1.00	745(84) 108(01)	D/ D/	1/03	Not listed				745(84), 108(01) not on ODOT list? 108(01) AC 50 in PMIS vs. concrete on SLD?
DAR 127 UD	9.57-9.69	731(67)	110				9.57-9.69	109(01)	G/P	1/02	Not listed				109(01) not in 2002 and 2004 PMIS
DEL 23	17.85-20.78 19.24-19.75	380(94) 335(97)	10 120	17.85-20.78 19.24-19.75	380(94) 335(97)	10 120					17.48-20.85	67(94)			SHRP pavement, 67(94) on list should be 380(94)U. PMIS and SLD shows service road and
DEL 42 UD	0-7.27 7.29-8.37 6.7-7.27	621(95) 198(99) 140(01)	888 50 888	0-7.29 0-7.27 7.29-8.37	168(85) 621(95) 198(99)	888 888 50	7.29-7.47 7.47-8.37	140(01) 198(99)	D/ G/P	1/06	Not listed				140(01) not in 2004 PMIS or on ODOT list? 7.29-7.47 AC 50 in PMIS, concrete on SLD?
ERI 250 UD	0.48-4.05 3.78-5.08	20(68) 299(89)	110 50	0.95-1.13 3.78-5.08	297(04) 299(89)	50 50	0-0.48 0.48-1.14	Muni(69) 297(04)	D/ G/P	1/07	Not listed				0.48-0.95 and 1 .13-3.78 in PMIS not on ODOT list? 0-0.48 on SLD not on ODOT list?
	11.3-14.85 10.44-13.53	723(60) 87(95)	110 50	10.44-13.53	87(95)	50	9.49-12.47	87(95)	G/P	1/04					13.53-14.85 in 2002 PMIS not on ODOT list? 12.47 HUR Co. line on SLD? SLMs for 87(95)?
FRA 23 U	22.69-22.85 22.46-22.69	275(65) 302(98)	110 50	22.46-22.69	302(98)	50	22.3-24.65	302(98)	G/P, G/L	1/00	Not listed				SLMs for 302(98) in PMIS and on SLD?
FRA 33 UD	14.68-16.19 14.68-15.6	713(97) 902(77)	888 777	14.68-16.19	713(97)	110	14.67-15.6 15.6-16.2	713(97) 903(77)	G/N G/P	1/01,02	Not listed				713(97) PCC in PMIS and surface G on SLD? 902(77) in 2002 PMIS or 903(77) on SLD?
	22.46-25.96 25.9-30.21	737(62) 693(86)	110 50	25.9-30.21	693(86)	50	22.1-25.9 21.39-31.23	737(62) 693(86)	D/ G/P	1/07					SLMs for 693(86) in PMIS and SLD?
FRA 270 D	2.41-10.03 29.11-31.7 29.53-33.96 31.7-33.88	451(88) 510(68) 267(87) 497(95)	90 110 50 888	2.41-10.03 29.53-33.96 31.7-33.88	451(88) 267(87) 497(95)	90 50 888	2.60-9.30 29.38-31 31-31.7 31.70-33.88	451(88) 654(92) 585(95) 497(95)	E/P, H, F G/P G/P E/P	1/06, 03 1/01	2.60-10.15 31.70-33.62	451(88) 267(87)			AC 90 on 451(88) is unbonded PCC overlay in PMIS. 267(87) AC 50 in PMIS vs. PCC on list? 267(87) not on SLD? 451(88) and 267(87) PCC overlays on ODOT list.
GAL 7 UD							5.71-10.21	352(46)	D/	1/97	Not listed		352(46)	8 N	352(46) not in PMIS or on ODOT list?
GAL 35 UD	0-0.31 0.31-1.03 1.03-3.8	446(81) 343(99) 740(90)	110 40 50	0-5.56 1.03-3.79 1.03-3.79	446(81) 479(04) 740(90)	50 60 50	0.3-3.8 0-1.03 1.03-3.7	740(90) 343(99) 479(04)	G/P, H, L G/P G/H, G/L	1/06	Not listed				446(81) AC 110 in 2002 PMIS and AC 50 in 2004 PMIS?
GEA 422 UD	3.19-9.38	857(86)	110	2.18-9.13 0-3.2	143(89) 205(01)	110 888	3.19-9.38 0-3.19	143(89) 205(01)	D/ G/P	1/03,04	3.20-9.38	143(89)			857(86) in 2002 PMIS or 143(89) in 2004 PMIS? 143(89) three years after 857(86)?
GRE 35 UD	0-1.07 14.39-20.85	655(92) 1997	50 110	0-1.07 14.39-20.85	655(92) 19(97)	50 110	0.11-1.07 D 14.45-20.95	655(92) 19(97)	D/ D/	1/04 1/03	0-1.11 14.46-20.92	655(93) 19(97)	19(97)	19 W	655(92) AC 50 in PMIS vs. 655(93) concrete on SLD and ODOT list?
GRE 675 UD	15.4-29.98 9.48-17.67 15.46-17.67	243(73) 350(93) 391(02)	110 50 50	9.48-17.67 15.46-17.67	350(93) 391(02)	50 50	15.4-17.67	391(02)	G/P	1/04	Not listed				17.67 CLA Co. line on SLD. Realignment after 243(73)?
GRE 844 UD	0.77-2.25	151(87)	777	0.77-2.25	151(87)	888	0.77-2.25	151(87)	D/	1/01	0.70-2.32	151(87)			AC 777 and 888 in PMIS?
HAM 74 UD	18.92-19.87 11.12-19.5	556(69) 284(02)	110 50	11.1-19.5	284(02)	50	11.1-19.47	284(02)	G/P	1/03	Not listed				SLM 19.5-19.87 not on ODOT list?

Table B2 – Comparison of 2002 PMIS, 2004 PMIS, and SLD for Rigid Pavements (4/8)

Comparison of Rigid Pavement Data in PMIS, SLD and Internal ODOT List															4/8
Co/Rt/Dir	2002 PMIS			2004 PMIS			SLD				2006 ODOT List		Core Site		Comments
	SLM Limits	Proj. No.	AC	SLM Limits	Proj. No.	AC	SLM Limits	Proj. No.	Pvt. / Base	Rev. Date	SLM Limits	Proj. No.	Proj. No.	SLM	
HAM 126 UD	13-19.89 11.35-13.31 13.03-14.38	659(86) 997(90) 896(93)	110 110 50	13-19.89 12.92-13.58 13.03-14.38	659(86) 997(90) 896(93)	110 110 50	13.31-15.64 11.35-13.31	659(86) 997(90)	D/ D/	1/08	11.35-13.31	997(90)	997(90)	12 E	896(93) AC 50 in PMIS vs. PCC surface on SLD. 896(93) not on SLD?
HAM 275 UD	39.8-41.6 39.94-41.6	599(92) 295(97)	888 100	39.8-41.6 39.94-41.6	599(92) 295(97)	110 100	37.51-39.81 39.81-41.36	599(92) 295(97)	D/ G/P	1/07,99	Not listed				SLMs for 599(92) in PMIS and on SLD?
HEN 24 UD	9.61-10.99 9.61-10.99 9.6-10.57	634(65) 951(85) 78(99)	110 50 60	9.61-10.99 9.61-10.57	951(85) 78(99)	50 888	5.95-10.91 5.95-10.91	951(85) 78(99)	G/P G/P	1/94,03	Not listed				SLMs for 634(65) in PMIS and on SLD? 11.32-15.95 on US 6 overlap 4.98-9.61 on US 24 on SLD.
HOC 33 UD	15.16-17.69	861(93)	888	14.68-17.69	861(93)	110	14.69-16.82D	861(93)	D/P	1/06	15.16-17.29	861(93)			SLMs for 861(93)?
JEF 7 UD	0.17-0.19 0.24-5.57 4.77-5.57	555(74) 900(75) 570(87)	110 110 50	4.77-5.57	570(87)	50	0-0.20 0.20-4.76 4.76-5.57	618(98) 900(75) 590(04)	G/P D/ G/P	1/06	Not listed				618(98) not in PMIS? 900(75) not on ODOT list?
	18.08-19.43	8008(90)	110	18.08-19.43	8008(90)	110	18.90-19.21	8008(90)	D/	1/98,04			8008(90)	19 S	Beginning SLM for 8008(90) SLD vs. PMIS?
JEF 22 UD	9.39-10.21 7.33-10.21 12.32-13.49 13.49-15.02 15.02-16.44 9.6-12.32 3.85-7.33	478(86) 478(87) 520(89) 602(90) 8008(90) 404(92) 645(96)	777 50 110 110 110 110 888	7.33-11.08 12.32-13.49 13.49-15.02 15.02-16.79 7.33-9.6 3.48-7.33 9.6-16.87	478(86) 520(89) 602(90) 8008(90) 404(92) 645(96) 784(97)	110 110 110 110 50 90 50	3.86-7.33 7.33-10.1 10.1-13.2 13.2-15.02 15.02-16.44	645(96) 478(86) 520(89) 602(90) 8008(90)	D/ D/ D/ D/ D/	1/08	3.86-7.33 7.33-10.21 10.21-13.25 13.25-15.02 15.02-16.32	645(96) 478(86) 520(89) 602(90) 8008(90)	8008(90)	15 E	478(86) vs. 478(87) in PMIS? 478(86) on SLD & list. SLMs for 478(86)? 478(87), 404(92) and 784(97) overlays in PMIS vs. PCC on SLD and ODOT list? 784(97) not in 2002 PMIS, SLD or list? 16.44 WVA state line on SLD.
JEF 151 UD	16.09-16.33 16.09-16.33	551(73) 516(81)	110 777	16.09-16.33	516(81)	777	16.16-16.43	437(69)	G/K	1/06	Not listed				551(73) and 516(81) not on SLD? 437(69) and 516(81) AC 777 in PMIS?
LAK 90 UD	6.47-12.97 6.97-10.43 7.58-11.58 12.95-29.29 7.97-12.98	172(60) 172(60) 172(60) 198(88) 748(90)	777 110 110 50 60	12.95-29.29 1.88-12.96 6.71-7.99	198(88) 748(90) 80(03)	50 60 52	6.7-7.74 7.74-11.86 11.86-21.5	80(03) 748(90) 198(88)	G/P G/P G/P	1/04,07	Not listed				SLMs for 172(60) in 2002 PMIS? SLMs for 748(90) in 2002 and 2004 PMIS?
LAK 306 UD	5.12-5.26	328(83)	110	5.12-5.26	328(83)	110	4.74-5.12	328(83)	D/	1/01, 93	7.06-9.46	1148(90)			SLMs for 328(83) in PMIS vs. SLD? 328(83) not on ODOT list?
	7.06-9.46	1148(90)	888	7.06-9.46	1148(90)	888	7.1-9.46	1148(90)	D/	1/00					1148(90) AC 888 in PMIS?
LAK 615 UD							1.57-2.82 2.82-3.32	8004(02) 184(01)	D/ D/	1/08	2.18-3.32				Nothing in PMIS.
LAW 527 UD	0-0.12 0.19-0.69	807(67) 17(85)	110 100	0.19-0.69	17(85)	100	0-0.19	17(85)	G/I	1/90	Not listed				807(67) in 2002 PMIS not on ODOT list? SLMs for 17(85)?
LIC 16 UD	14.26-17.93	400(99)	50	14.26-17.93	400(99)	50	16.63-16.94	400(99)	E/	1/04	16.63-16.94				400(99) AC 50 in PMIS vs. PCC on SLD and list?
	20.04-21.53 19.75-21.06 19.79-21.69	465(69) 5001(90) 6010(99)	110 100 888	19.75-21.06	5001(90)	100	19.72-23.63	6010(99)	G/P, G/L		Not listed				21.06-21.53 not on 2008 ODOT list? 6010(99) AC 888 in 2002 PMIS? SLMs for 6010(99) in 2002 PMIS and SLD?
	29.26-33.82 31.78-33.14U 32.57-33.14D	46(69) 359(97)	110 110 50	28.07-32.44 31.78-33.14U 32.57-33.14D	566(03) 359(97)	52 110 50	28.07-31.8 31.8-32.44 32.44-33.14	566(03) 667(90) 359(97)	G/H G/H G/I	1/05	Not listed				33.14 MUS Co. line on SLD.

Table B2 – Comparison of 2002 PMIS, 2004 PMIS, and SLD for Rigid Pavements (5/8)

Comparison of Rigid Pavement Data in PMIS, SLD and Internal ODOT List															5/8
Co/Rt/Dir	2002 PMIS			2004 PMIS			SLD				2006 ODOT List		Core Site		Comments
	SLM Limits	Proj. No.	AC	SLM Limits	Proj. No.	AC	SLM Limits	Proj. No.	Pvt. / Base	Rev. Date	SLM Limits	Proj. No.	Proj. No.	SLM	
LOG 33 UD	21.51-21.63	845(94)	110	21.51-21.63	845(94)	110	21.51-25.63	845(94)	E/	1/05	21.51-25.11	845(94)	845(94)	24 W	Spec. 452 PCC
LOR 6 UD	3.37-6.41	524(65)	110	3.37-6.41 6.48-12.36	441(03) 441(03)	50 52	3.37-12.36	441(03)	G/N, G/K	1/06	Not listed				
LOR 57 D	12.19-18.11	347(61)	777				12.19-16.17	347(61)	D/	1/99,05	Not listed				347(61) AC 777 in 2002 PMIS and not on ODOT list? 12.93-16.17 on US 20
LOR 90 UD	17.86-19.97 19.95-23.33 19.92-23.33	781(66) 564(68) 332(97)	110 110 888	10.76-12.02 19.95-23.88	3015(00) 332(97)	50 100	10.76-23.33	3015(00)	G/P, G/L	1/06	Not listed				781(66) not on ODOT list? 3015(00) not in 2002 PMIS? SLMs for 3015 (00) in 2004 PMIS and SLD?
LOR 254 UD	0-4.64 0-2.83	565(64) 281(98)	110 50	0-2.83 2.83-8.85	281(98) 241(03)	50 50	0-2.83 2.83-8.85	281(98) 241(03)	G/Var. G/N, G/L	1/05	Not listed				
LOR 301 UD				25.36-26.66	836(93)	110	25.4-26.21 26.71-27.36	836(93) 528(80)	D/ D/	1/97	25.11-26.71	836(93)			836(93) and 528(80) not in 2002 PMIS. SLMs for 836(93) in PMIS, SLD and ODOT list?
LOR 611 UD	5.66-11.28 5.66-9.76 10.1-11.28	968(93) 281(98) 281(98)	110 50 50	5.66-11.28	281(98)	50	5.70-8.58 8.58-9.63 9.63-9.97 9.97-11.13	539(88) 968(93) 781(66) 281(98)	G/P D/ D/ G/P	1/05,04	Not listed				539(88) and 781(66) not in PMIS? 281(98) AC 50 in PMIS vs. 968(93) and 781(66) surface D on SLD?
LUC 23 UD	9.51-12.28 9.63-12.65	814(60) 863(92)	110 50	9.63-12.65	863(92)	50	8.97-9.63 9.63-12.65	1029(93) 863(92)	G/P G/P	1/94, 04	Not listed				1029(93) not in PMIS? 9.51-9.63 in 2002 PMIS not on ODOT list?
LUC 280 UD	3.28-5.04 4.43-5.92 2.06-3.79 2.06-3.44 4.25-5.08 1.64-2.11 4.67-5.49	155(54) 451(56) 102(70) 1028(93) 665(97) 280(01) 29(01)	110 110 50 50 60 110 110	2.06-3.44 4.25-5.08 1.64-2.11 4.67-5.49	1028(93) 665(97) 280(01) 29(01)	50 60 110 110	1.69-2.20 2.20-2.70 2.70-4.65 4.65-5.50 5.50-5.75	280(01) 311(01) 493(02) 59(01) 325(02)	E/	1/08, 05, 00	Not listed				311(01), 493(02), 59(01) and 325(02) on SLD not in PMIS and not on ODOT list? 280(01) and 29(01) not on ODOT list? I-280 ends at I-75 (SLM 5.78) on SLD.
MAD 70 UD	0-6.25 0-6.25 0-8.88 8.88-15.58	506(68) 509(83) 378(99) 295(99)	110 60 60 95	0-6.25 0-8.88 8.68-15.58 0-8.68	509(83) 378(99) 295(99) 5002(03)	60 60 90 10	0-8.88 8.88-15.58 0-8.88	378(99) 295(99) 5002(03)	G/P E/P G/P	1/01	8.88-	295(99)			295(99) AC 90 (PCC overlay) vs. AC 95 (composite overlay) in PMIS? SLMs for 509(83), 378(99) and 295(99) in PMIS? 295(99) PCC overlay on ODOT list.
MAH 62J UD	0-0.54 0.36-0.54 0-0.36	663(78) 84(82) 194(97)	110 110 50	0.36-0.54 0-0.36	84(82) 194(97)	110 50	No MAH 62J in SLD				Not listed				0.36-0.54 PCC not on ODOT list?
MAH 62 UD	20.3-20.8 18.65-20.08	13(68) 663(78)	110 110	17.49-19.97	213(92)	100	18.65-19.36	663(78)	D/	1/08	Not listed				213(92) not in 2002 PMIS. 213(92) AC 100 in PMIS vs. 663(78) PCC on SLD?
MAH 76 UD	6.94-8.65	444(98)	888	6.94-8.65	444(98)	110	6.95-8.65	444(98)	E/	1/06	6.94-8.65				444(98) AC 888 in 2002 PMIS.
MAH 616 U				2.58-3.34	181(99)	888	2.94-3.33	181(99)	E/	1/02	Not listed				181(99) PCC on SLD not on ODOT list?
MAH 680 UD	11.85-14.28 14.28-16.43 11.85-16.43 15.56-15.62	3(74) 27(74) 389(89) 776(93)	110 110 50 110	11.85-16.43 15.56-15.62	389(89) 776(93)	50 110	11.43-16.43	389(89)	G/P	1/06	Not listed				776(93) not on SLD or ODOT list?

Table B2 – Comparison of 2002 PMIS, 2004 PMIS, and SLD for Rigid Pavements (6/8)

Comparison of Rigid Pavement Data in PMIS, SLD and Internal ODOT List															6/8
Co/Rt/Dir	2002 PMIS			2004 PMIS			SLD				2006 ODOT List		Core Site		Comments
	SLM Limits	Proj. No.	AC	SLM Limits	Proj. No.	AC	SLM Limits	Proj. No.	Pvt. / Base	Rev. Date	SLM Limits	Proj. No.	Proj. No.	SLM	
MED 71 D	24.35-24.78 17.46-26.68	531(94) 531(94)	110 888	24.35-24.78 17.46-26.68 15.78-26.69	531(94) 531(94) 239(00)	110 888 100	15.78-26.68	239(00)	G/L	1/04	Not listed				531(94) AC 110 and 888 in PMIS? 239(00) not in 2002 PMIS?
MIA 75	5.08-17.78	649(96)	50	5.08-17.78	649(96)	50	5.3-10.98 5.08-10.98	649(96) 3001(99)	G/P G/P, G/L	1/06, 08	5.14-10.89	649(96)			649(96) asphalt in PMIS & SLD vs. PCC on list? 3001(99) is widening project.
MOT 35 UD	10.23-11.24 9.89-11.33 9.11-12.25 13.57-14.27 14.37-15.07 14.91-18.3	1098(92) 787(94) 348(95) 1988 343(88) 320(94)	110 110 50 110 110 50	10.32-14.26 9.89-11.33 9.11-12.25 13.57-14.34 14.34-15.07 14.91-18.3	1098(92) 787(94) 348(95) Muni 88 343(88) 320(94)	110 110 50 50 110 50	9.1-10.19 10.19-11.7 11.7-14.37 14.37-15.07 15.07-18.27	348(95) 787(94) 1098(92) 343(88) 320(94)	G/T D/ D/ E/L G/P	1/06	10.32-11.75 11.75-14.37	787(94) 348(95)	343(88)	14 W	1098(92) and 787(94) in PMIS two years apart? 348(95) on ODOT list vs. 1098(92) on SLD? 348(95) asphalt in PMIS and SLD vs. PCC on list? SLMs for 1098(92)? 14.34-14.91, 343(88) from PMIS not on ODOT list? 343(88) not on ODOT list? Spec. 452 in PMIS.
MOT 202 UD	2-3.15	1991	110	2-3.15 1.18-3.25	1991 392(03)	110 50	2.01-3.25	678(91)	E/	1/06	2.00-3.25	678(91)	678(91)	3 N	392(03) AC 50 in 2004 PMIS vs. E on SLD, ODOT list, and core site. Spec. 452 PCC in PMIS.
MUS 208 UD	0-0.3	121(97)	110	0-0.3	121(97)	110	0-0.3	121(97)	G/I	1/07	Not listed				121(97) - AC 110 in PMIS vs. Surface G on SLD
NOB 77 U	16.1-18.92 16.1-18.92 1.36-6.25 8.15-10.87 10.87-13.81 11.22-18.92 1.56-6.43 11.22-18.92 6.43-11.02	591(65) 3(66) 27(66) 533(66) 72(66) 732(66) 86(97) 94(98) 3001(00)	110 110 110 110 110 110 90 60 90	1.56-6.42 11.22-18.92 6.42-11.05	86(97) 94(98) 3001(00)	90 60 90	0.00-1.36 1.56-6.42 6.42-11.05 11.2-18.92	27(66) 86(97) 3001(00) 94(98)	D/ D/ D/ G/P	1/99	1.39-6.88 D 6.22-11.01	86(97) 3001(00)			3(66) one year after 591(65)? Overlap of 72(66) and 732(66) in 2002 PMIS? AC 90 is unbonded concrete overlay in PMIS. 27(66) on SLD not on ODOT list? SLMs? 86(97) and 3001(00) are PCC overlays on ODOT list.
PIK 23 UD	11.35-13.39	211(99)	110	11.35-13.39	211(99)	110	11.62-13.42	211(99)	D/	1/04	Not listed				211(99) not on ODOT list?
PRE 70 UD	1.85-9.46 9.46-14.1	711(62) 733(60)	110 110	0-17.67	3003(00)	50	0-17.67	3003(00)	G/H	1/03	Not listed				3003(00) not in 2002 PMIS
RIC 13 UD	7.25-10.84	8001(92)	110	7.26-14.39 5.6-10.83	8001(92) 8001(92)	110 888	5.58-10.8	8001(92)	G/F	1/03,99	Not listed				8001(92) AC 110 in PMIS vs. surface G on SLD and not on ODOT list?
	16.82-32.3 16.82-18.25	599(97) 503(98)	50 110	16.82-32.3 16.82-18.25	599(97) 503(98)	50 110	16.95-32.66	599(97)	G/R, /N, /K	1/00,99					503(98) not on SLD or ODOT list? 503(98) one year after 599(97) in PMIS?
RIC 30 UD	3.74-19.17	887(96)	110	3.74-19.17	887(96)	110	4.2-19.19	887(96)	G/L, G/P	1/06,07	Not listed				887(96) AC 110 in PMIS vs. surface G on SLD and not on ODOT list?
RIC 309 UD	8.01-9.02	600(97)	110	6.09-9.04	600(97)	110	6.09-8.7 8.7-9.04	600(97) 56(89)	G/P G/L	1/07	Not listed				600(97) AC 110 in PMIS vs. surface G on SLD and not on ODOT list?
ROS 23 UD	8.37-10.95 8.39-10.89	638(70) 1037(93)	110 77	8.39-10.89	1037(93)	77	8.39-9.37 9.37-10.9	1037(93)	G/P D/	1/07,06	9.37-10.79	1037(93)			AC 77 in PMIS is rubblize and roll? 1037(93) has AC and PCC surface?
	19.14-24.34 16.26-22.16	496(55) 706(90)	110 50	16.26-22.16	706(90)	50	16.49-22.1	706(90)	G/P		Not listed				22.16-24.34 in 2002 PMIS not on ODOT list? 22.20 PIC Co. line on SLD

Table B2 – Comparison of 2002 PMIS, 2004 PMIS, and SLD for Rigid Pavements (7/8)

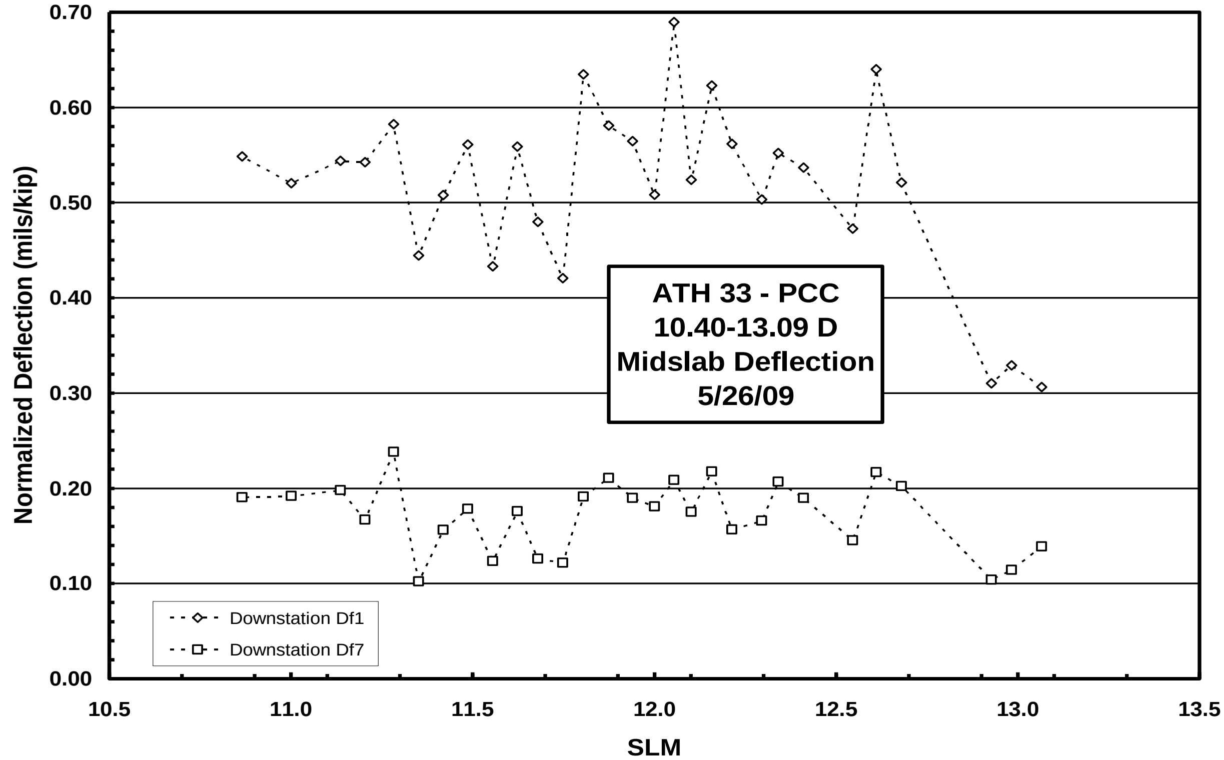
Comparison of Rigid Pavement Data in PMIS, SLD and Internal ODOT List															7/8
	2002 PMIS			2004 PMIS			SLD				2006 ODOT List		Core Site		
Co/Rt/Dir	SLM Limits	Proj. No.	AC	SLM Limits	Proj. No.	AC	SLM Limits	Proj. No.	Pvt. / Base	Rev. Date	SLM Limits	Proj. No.	Proj. No.	SLM	Comments
ROS 35 UD	15.82-20.42	495(62)	110												
	19.92-21.23	143(65)	110												446(90) AC 888 in PMIS?
	16.36-19.66	71(80)	60	16.36-19.66	71(80)	60									19.66- 21.23 not on ODOT list?
	18.51-25.28	446(90)	888	18.51-25.28	446(90)	888	18.4-20.56	446(90)	G/P						SLMs for 638(90) in PMIS vs. SLD?
	10.42-18.51	638(90)	60	10.42-18.51	638(90)	60	16.8-18.4	638(90)	G/P	1/05,06,07	Not listed				
	34.38-37.95	497(58)	110												
	25.05-26.21	318(69)	110												SLMs for 374(91) and 151(02) in PMIS vs. SLD?
	35.44-37.95	374(91)	50	35.44-37.95	374(91)	50	34.50-36.98	374(91)	G/P						318(69) not on ODOT list?
	26.17-35.63	151(02)	100	26.17-35.63	151(02)	100	25.01-34.50	151(02)	G/L						
SAN 20 UD	14.6-20.53	549(55)	110	18.57-19.17	1149(90)	100									
	19.02-24.36	284(90)	60	19.02-24.36	284(90)	60	15.29-24.28	476(03)	G/P	1/06,07	Not listed				
				14.59-24.28	476(03)	60									
SAN 53 UD	7.67-10.23	1959	110				7.67-10.15	476(03)	G/P	1/04	Not listed				7.67-12.62 PCC in PMIS vs. asphalt in SLD?
	10.52-13.23	1956	110	12.62-13.23	753(89)	50	10.52-12.86	393(93)	G/P						476(03) and 393(93) not in PMIS
SCI 52 UD	34.56-40.33	723 (61)	110							1/04	Not listed				44(91) SLMs in PMIS vs. SLD?
	34.38-40.17	44(91)	50	34.38-40.17	44(91)	50	33.9-39.63	44(91)	G/P						40.17-40.33 not on ODOT list?
STA 62 UD	20.83-23.42	644(58)	110				20.31-21.48	191(92)	G/P	1/08,06	Not listed				20.83-21.51 not on ODOT list?
	21.51-23.42	459(80)	50	21.51-23.42	459(80)	50	21.48-22.85	3008(00)	G/L						191(92) and 3008(00) not in PMIS?
	34-38.38	650(72)	110												
	29.28-34.84	635(88)	70	29.28-34.84	635(88)	70	30.12-35.72	635(88)	G/H						AC 70 in PMIS is crack and seat.
	34.22-38.36	421(90)	50	34.22-38.36	421(90)	50	35.72-40.00	778(90)	G/L, G/T	1/06	Not listed				34-34.22 not on ODOT list?
	34.22-38.36	778(90)	50	34.22-38.36	778(90)	50	35.6-38.6	304(04)	G/L						421(90) & 778(90) same AC and SLM in PMIS?
SUM 8 UD	7.96-13.3	109(85)	777	19.77-22.54	109(85)	50	8.06-10.66	109(85)	D/	1/07,04	7.96-13.30	109(85)			SLMs for 975(83) & 109(85) in all references?
	7.96-13.3	975(83)	777	22.55-25.12	975(83)	50	10.66-13.30	975(83)	D/						AC 50 in PMIS vs. PCC on SLD and on ODOT list?
SUM 59 UD	1.39-2.05	84(70)	110				0-0.74	330(84)	D/						
	0.74-2.45	330(84)	110				0.74-1.78	711(78)	G/L	1/03,08	Not listed				SLMs for 330(84) and 84(70) in PMIS and on SLD?
							1.78-2.45	84(70)	D/						330(84) and 84(70) not on ODOT list?
							2.45-2.65	84(70)	D/						
SUM 59J UD	0-2.45	771(78)	777				No SUM 59J on SLD				Not listed				330(84) not on ODOT list?
	0.74-2.45	330(84)	110	0.74-2.45	330(84)	110									
SUM 76 D	11.8-15.32	844(92)	777	11.8-15.32	844(92)	110	11.80-13.4	844(92)	D/	1/01				15E, 15W	844(92) and 996(93) one year apart.
	11.8-15.32	996(93)	777	11.44-15.32	996(93)	110	13.4-15.32	996(93)	D/		11.80-15.32	996(93)	996(93)		SLMs for 844(92) and 996(93) in PMIS and SLD?
	15.32-17.98	323(00)	110	15.32-17.98	323(00)	110	15.61-17.98	323(00)	D/	1/04	15.32-17.98	323(00)			844(92) not on ODOT list?
TRU 422 UD	12.59-13.18	591(72)	110				12.59-13.18	591(72)	D/	1/99	Not listed				591(72) and/or 528(05) not on ODOT list?
TUS 39 U							2.94-7.14	907(90)	D/	1/05,	2.84-7.12	907(90)	907(90)	4 E	Section and project not in PMIS?
TUS 250 UD	11.88-14.12	347(64)	110												
	11.88-12.79	526(81)	777	11.88-12.79	526(81)	50									AC 777 for 374(86) and 526(81) in 2002 PMIS?
	12.79-17.32	263(02)	50	11.88-12.79	456(03)	50	11.88-12.79	456(03)	G/P						287(97) not in 2002 PMIS and AC 888 in 2004
	17.32-21.38	657(66)	110	12.79-17.32	263(02)	50	12.79-17.32	263(02)	G/P	1/05,07	17.32-21.49	1056(91)			PMIS?
	23.39-23.46	5(66)	110	17.28-23.46	374(86)	50	17.32-21.4	1056(91)	D/						AC 40 for 1056(91) in PMIS is CPR.
	21.38-23.46	374(86)	777	22.09-27.15	287(97)	888	21.42-23.39	287(97)	D/						287(97) not on ODOT list?
	16.83-21.38	1056(91)	40	16.83-21.38	1056(91)	40									

Table B2 – Comparison of 2002 PMIS, 2004 PMIS, and SLD for Rigid Pavements (8/8)

Comparison of Rigid Pavement Data in PMIS, SLD and Internal ODOT List															8/8
Co/Rt/Dir	2002 PMIS			2004 PMIS			SLD				2006 ODOT List		Core Site		Comments
	SLM Limits	Proj. No.	AC	SLM Limits	Proj. No.	AC	SLM Limits	Proj. No.	Pvt. / Base	Rev. Date	SLM Limits	Proj. No.	Proj. No.	SLM	
TUS 800 UD	17.55-18.06 3.4-30.48	5(66) 565(83)	110 777	3.4-30.48	565(83)	777	17.57-18.14	257(98)	G/L	1/05	Not listed				565(83) AC 777 in PMIS? 5(66) not on ODOT list? 257(98) not in
UNI 739 UD	0.02-2.01 0.26-0.58	35(90) 325(00)	110 50	0.02-2.01 0.26-0.58	35(90) 325(00)	110 50	0-0.58 0.58-2.6	438(89) 35(90)	G/L D/	1/07	0.58-2.63	35(90)			SLMs for 35(90)? 438(89) not in PMIS?
	1.91-5.48	8007(94)	110	0.63-5.95	8007(94)	110	2.5-5.94	8007(94)	D/	1/07,06	2.63-5.95	8007(94)			SLMs for 8007(94)?
WAS 7 UD	10.15-14.06 10.1-14.05	282(66) 219(89)	110 888	10.1-14.06	219(89)	888	10.15-14.06	219(89)	G/P	1/06	Not listed				219(89) AC 888 in PMIS?
WAS 77 UD	6.59-17.59 16.41-17.59 6.59-12.08 12.22-17.59	413(65) 27(66) 248(00) 123(99)	110 110 90 90	6.59-12.58 12.22-16.37	248(00) 123(99)	90 90	16.37-17.59 6.59-12.0 12.1-16.37	27(66) 248(00) 123(99)	D/ D/ D/	1/08	6.59-12.08 D 12.07-16.34 D	123(99)			SLMs for 123(99) in PMIS? 27(66) one year after 413(65) in 2002 PMIS? 27(66) not on ODOT list? Both sections on ODOT list are PCC overlays.
WAS 618 UD	0-3.15 0-1.39 0-1.39 1.39-3.92	330(55) 701(82) 284(92) 1012(90)	110 60 50 888	0-1.39 0-1.39 1.39-3.92	701(82) 284(92) 1012(90)	60 50 888	0-1.39 1.39-3.15	284(92) 1012(90)	G/P G/N	1/06	Not listed				1012(90) AC 888 in PMIS
WAY 83 UD	13.75-14.78 12.99-23.56 14.78-25.36	277(66) 560(92) 576(96)	110 50 40	12.99-23.56 14.78-25.36	560(92) 576(96)	50 40	13.75-14.71	576(96)	D/I, D/N	1/06	Not listed				AC 40 (CPR) on AC 50 in PMIS after four years? Surface D on SLD and ODOT list vs. PMIS? 13.75-14.78 not on ODOT list?
WAY 250 UD	5.5-8.09 5.5-8.09	785(60) 870(78)	110 777	5.5-8.09	829(90)	888	5.51-8.10	829(90)	G/P	1/06	Not listed				870(78) AC 777 in 2002 PMIS? 829(90) AC 888 in 2004 PMIS?
WOO 75 U	4.81-9.95 7.82-7.89 U	929(90) 507(94)	50 110	4.81-9.95 7.82-7.89	929(90) 507(94)	50 110	5.06-9.92	929(90)	G/K	1/97	Not listed				507(94) not on SLD or ODOT list?

APPENDIX C

FWD Profiles



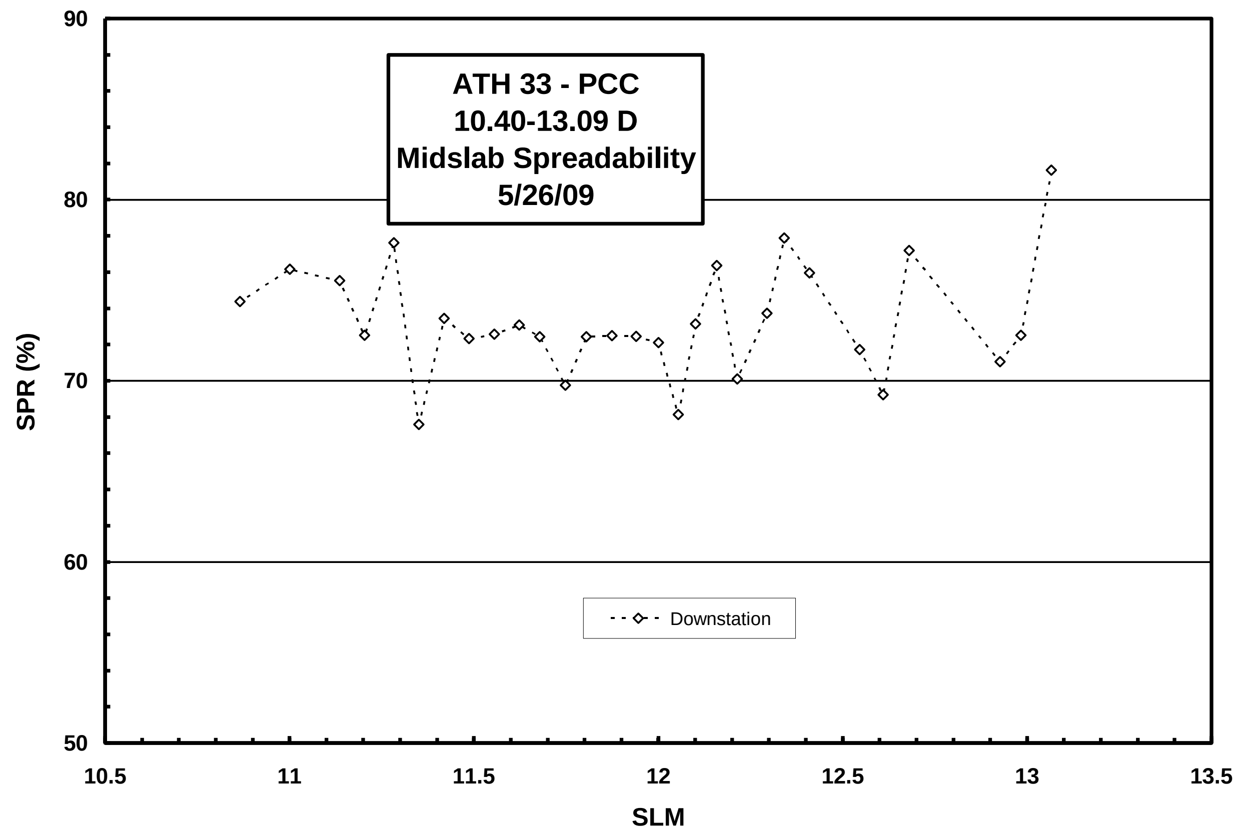
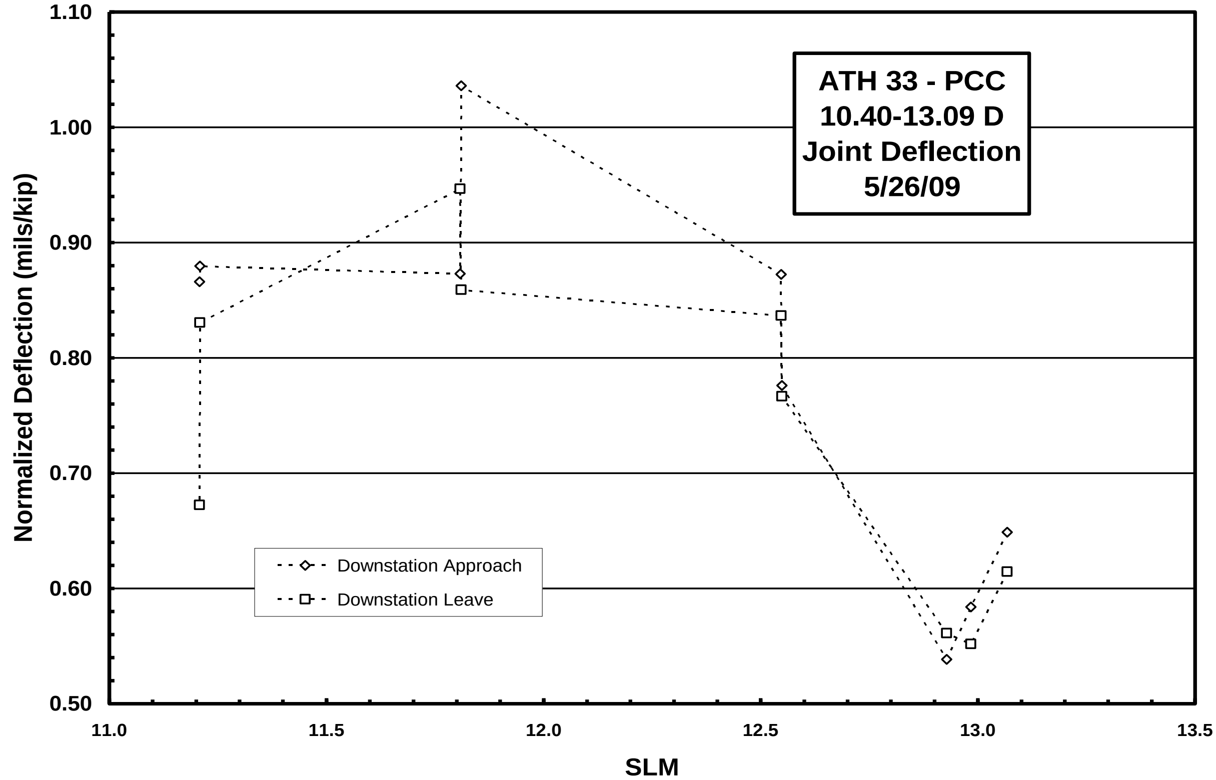


Figure C1a – ATH 33 FWD Midslab Deflection



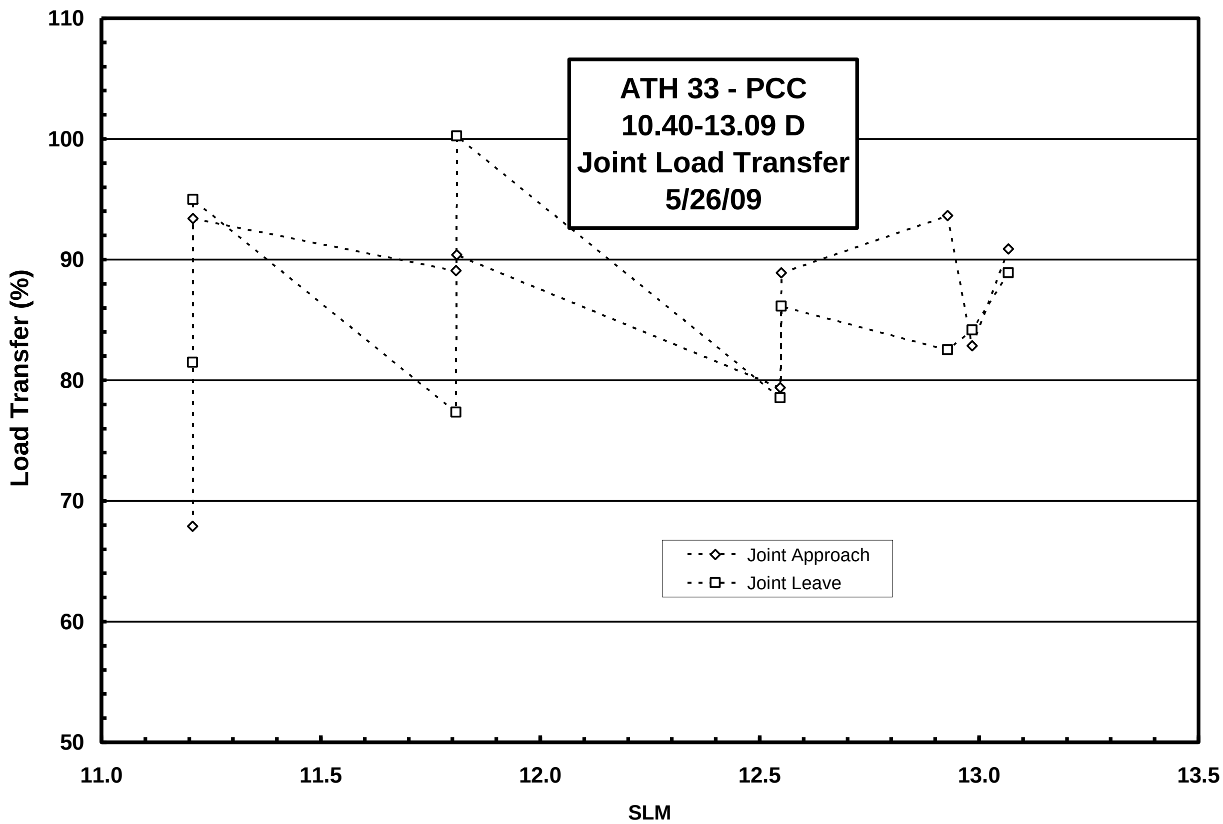
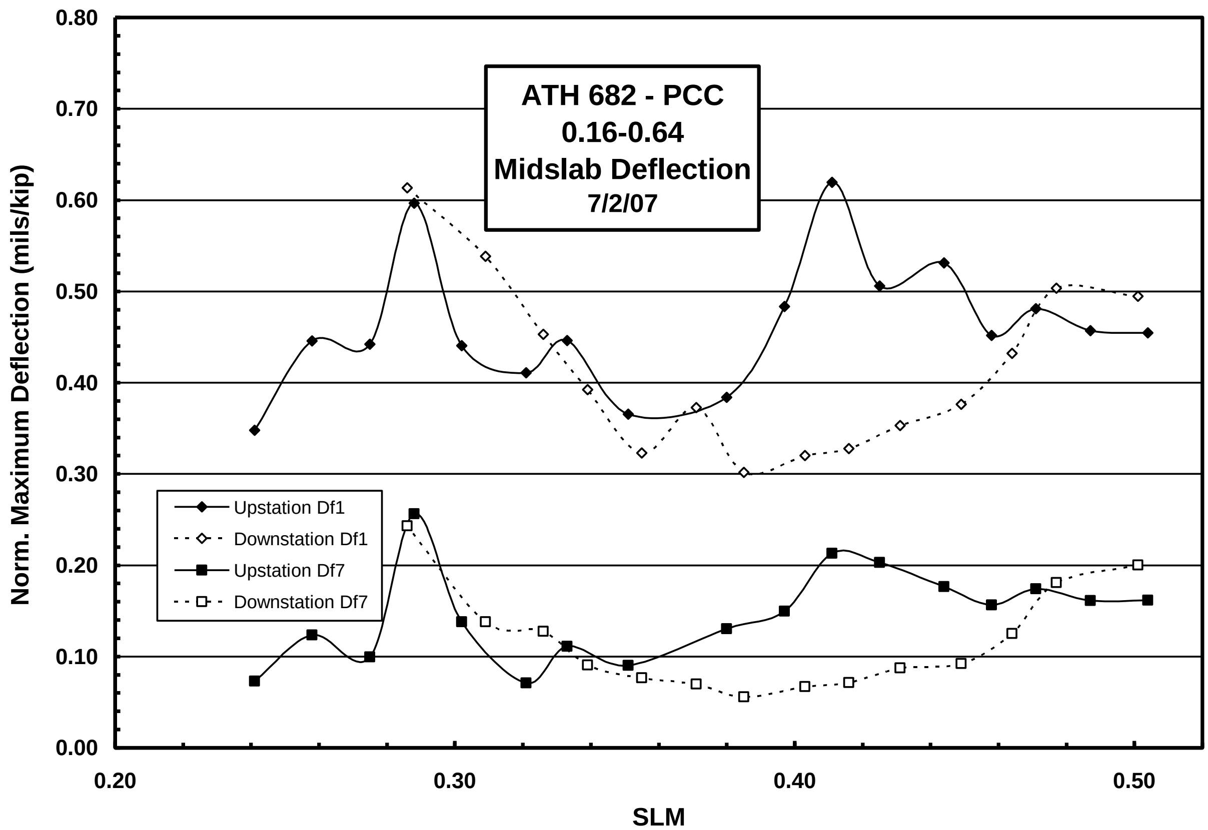


Figure C1b – ATH 33 FWD Joint Deflection



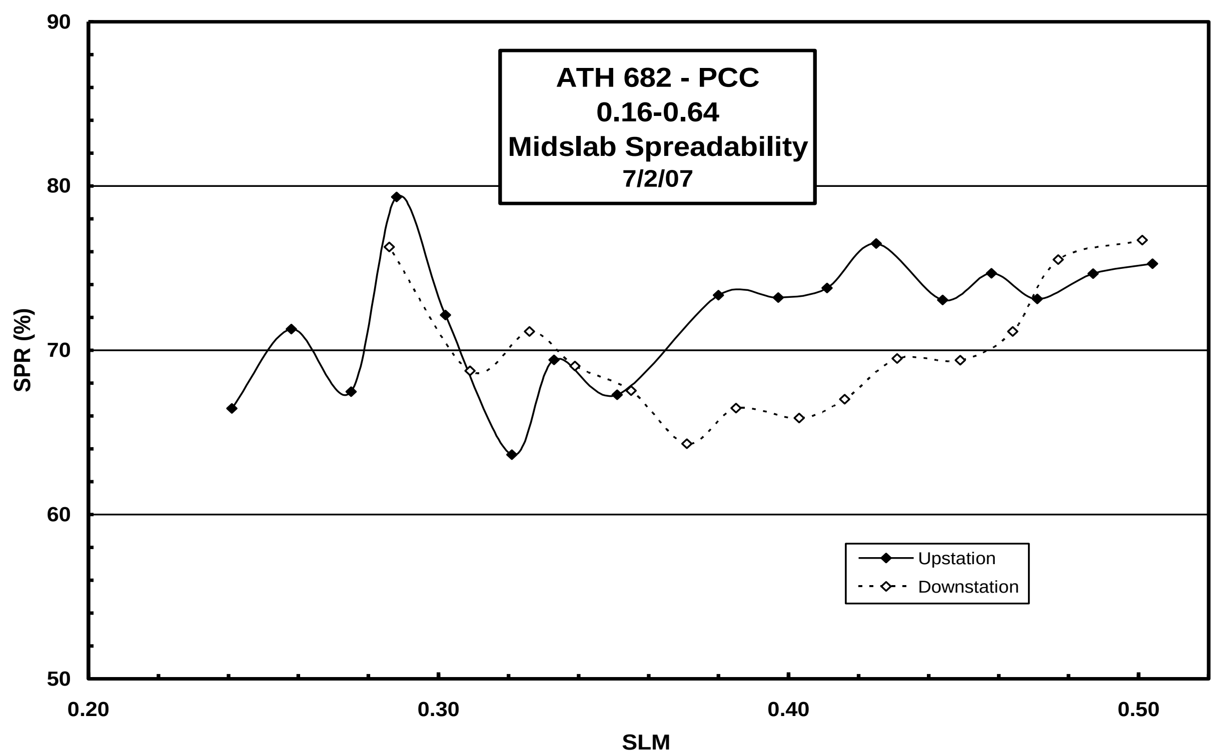
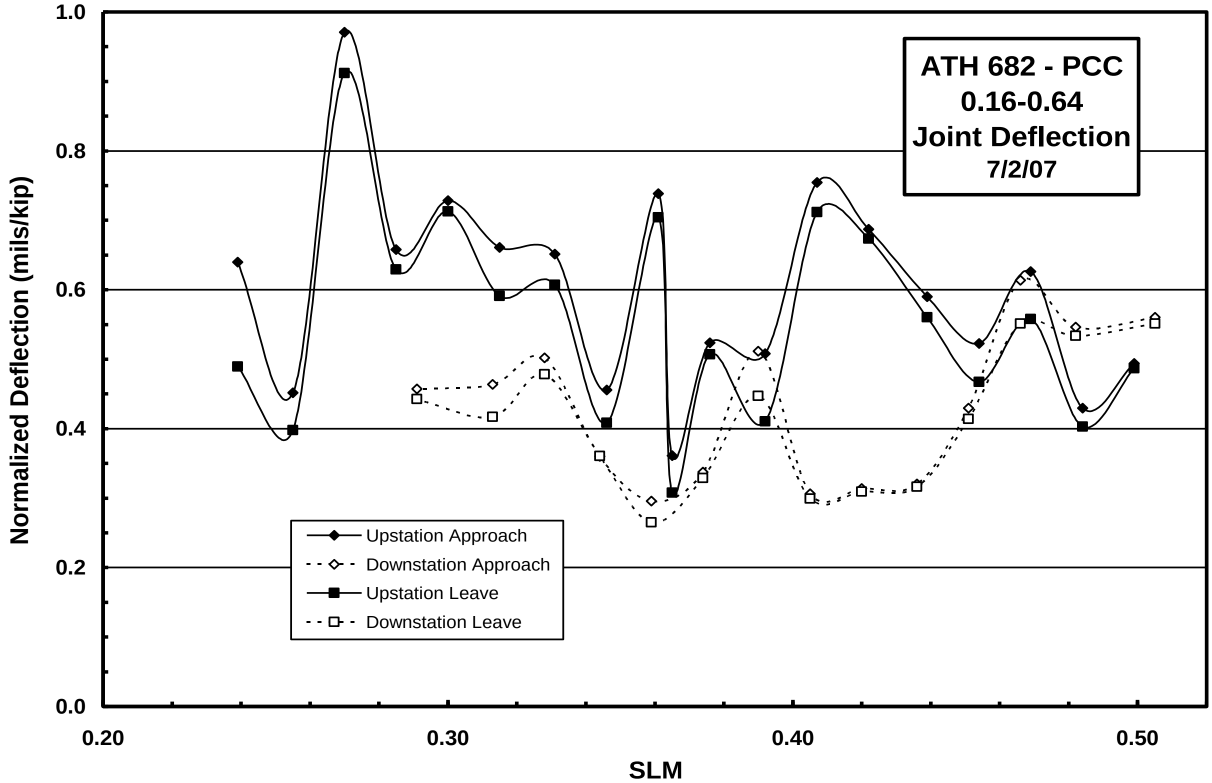


Figure C2a – ATH 682 FWD Midslab Deflection



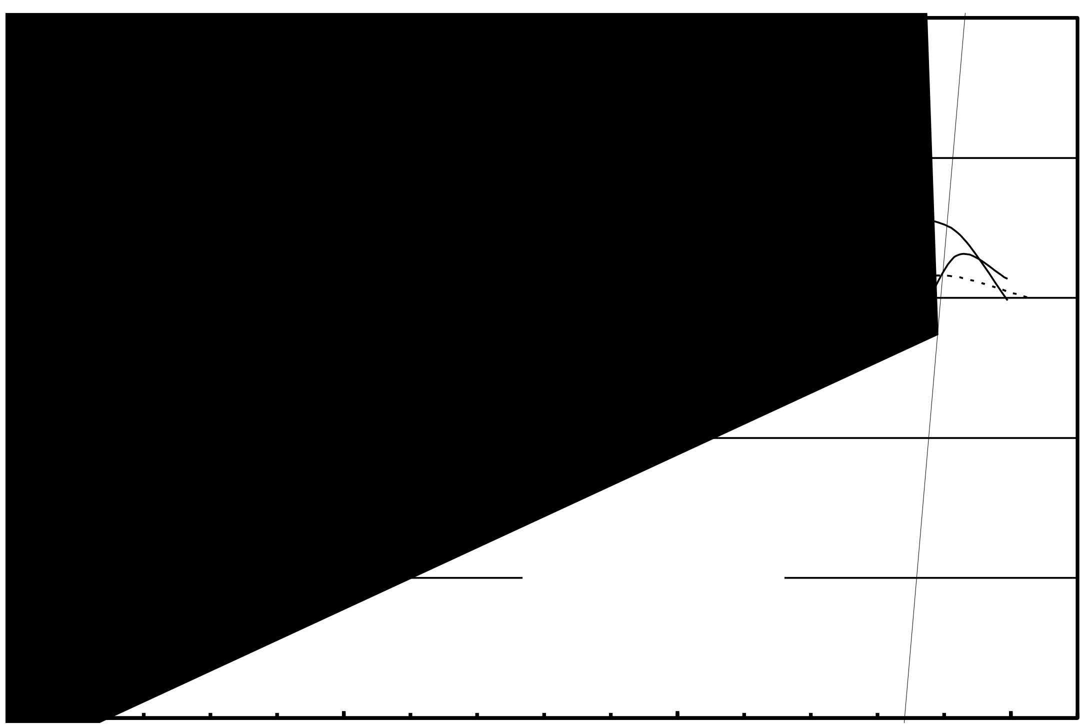
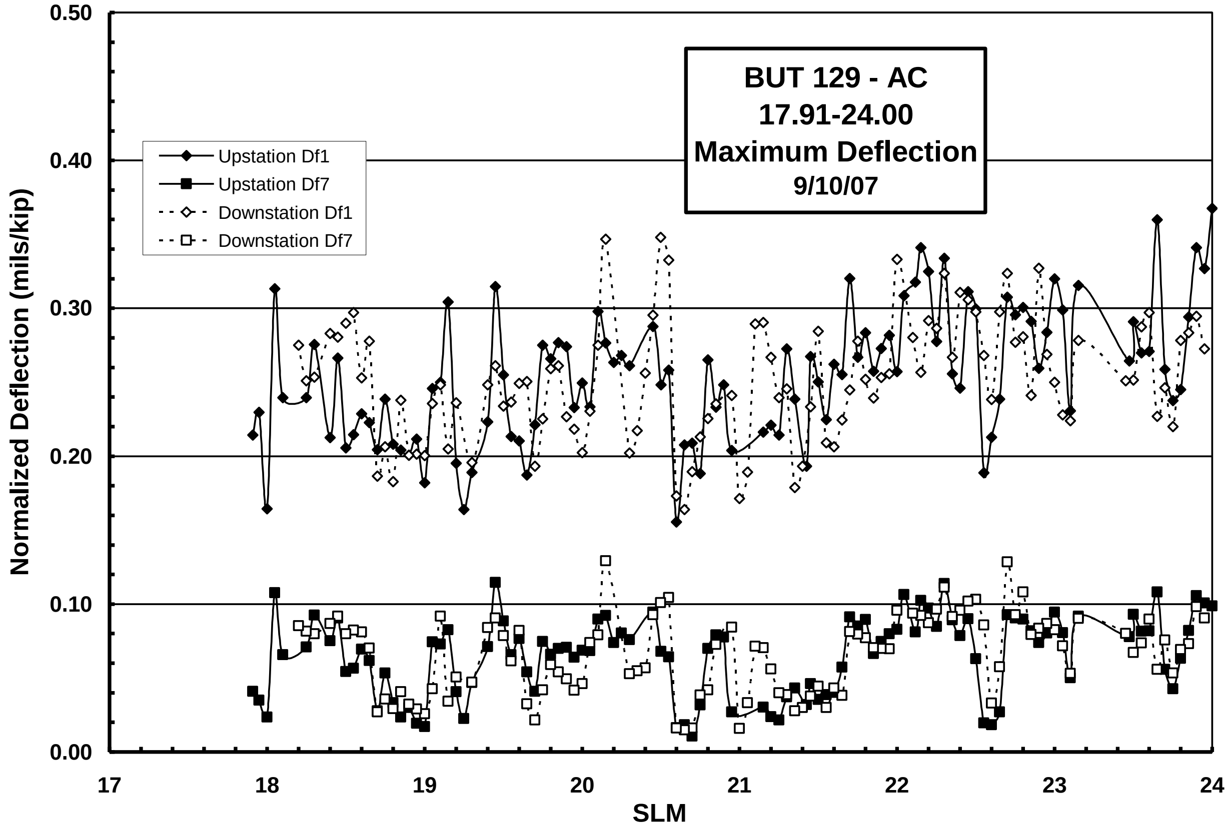


Figure C2b – ATH 682 FWD Joint Deflection



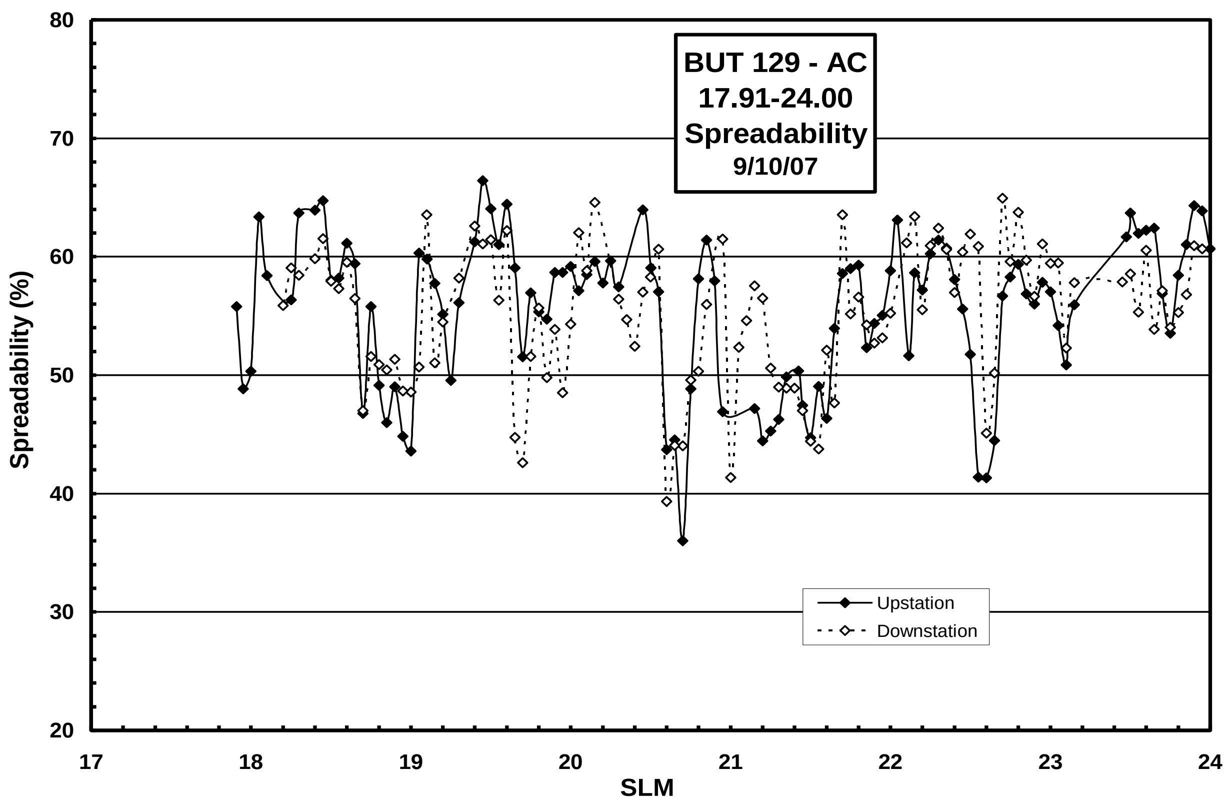
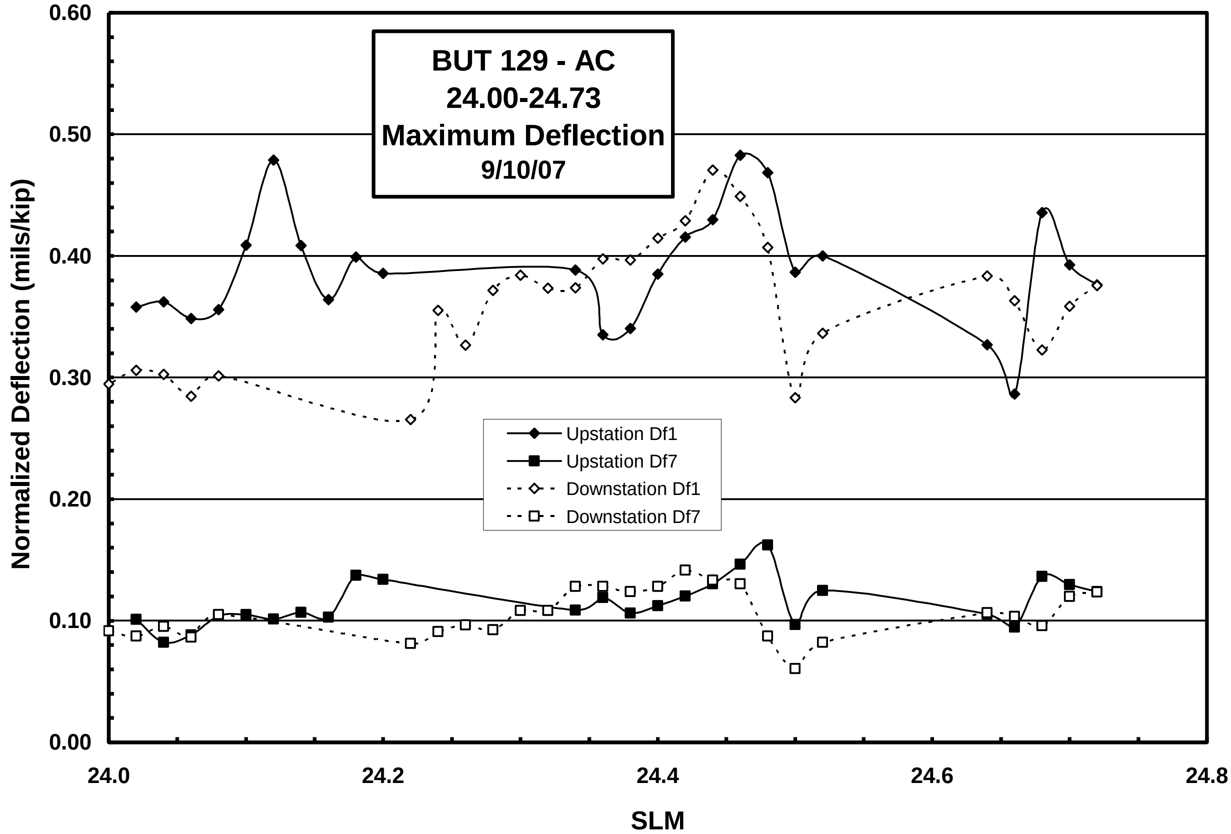


Figure C3 – BUT 129, 17.91-24.00 FWD Deflection



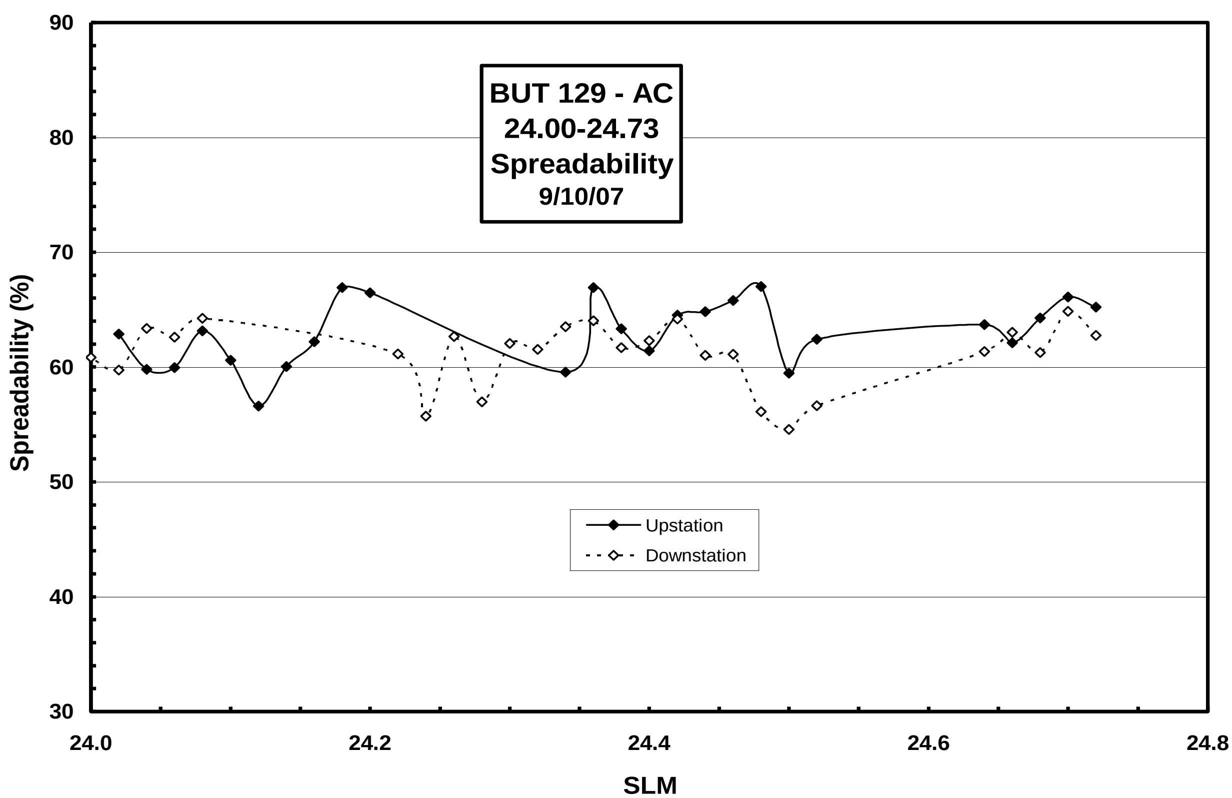
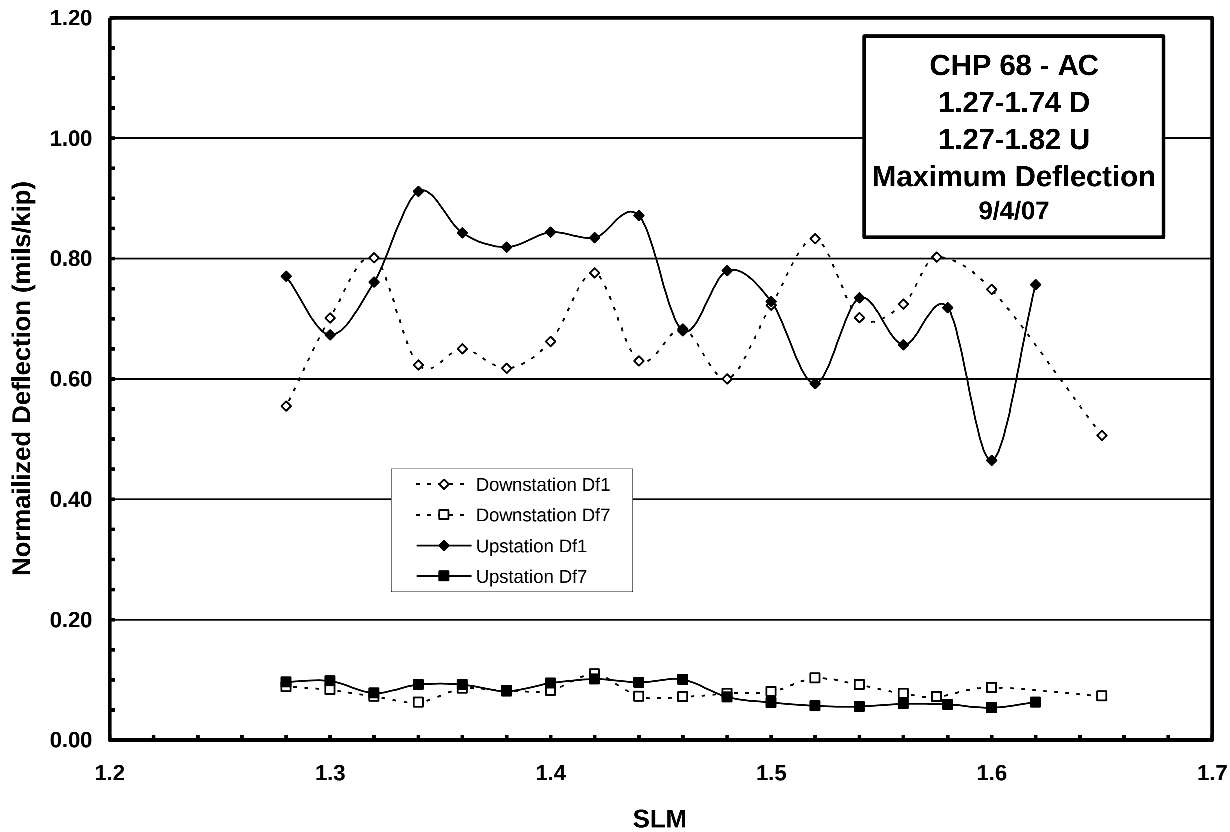


Figure C4 – BUT 129, 24.00-24.73 FWD Deflection



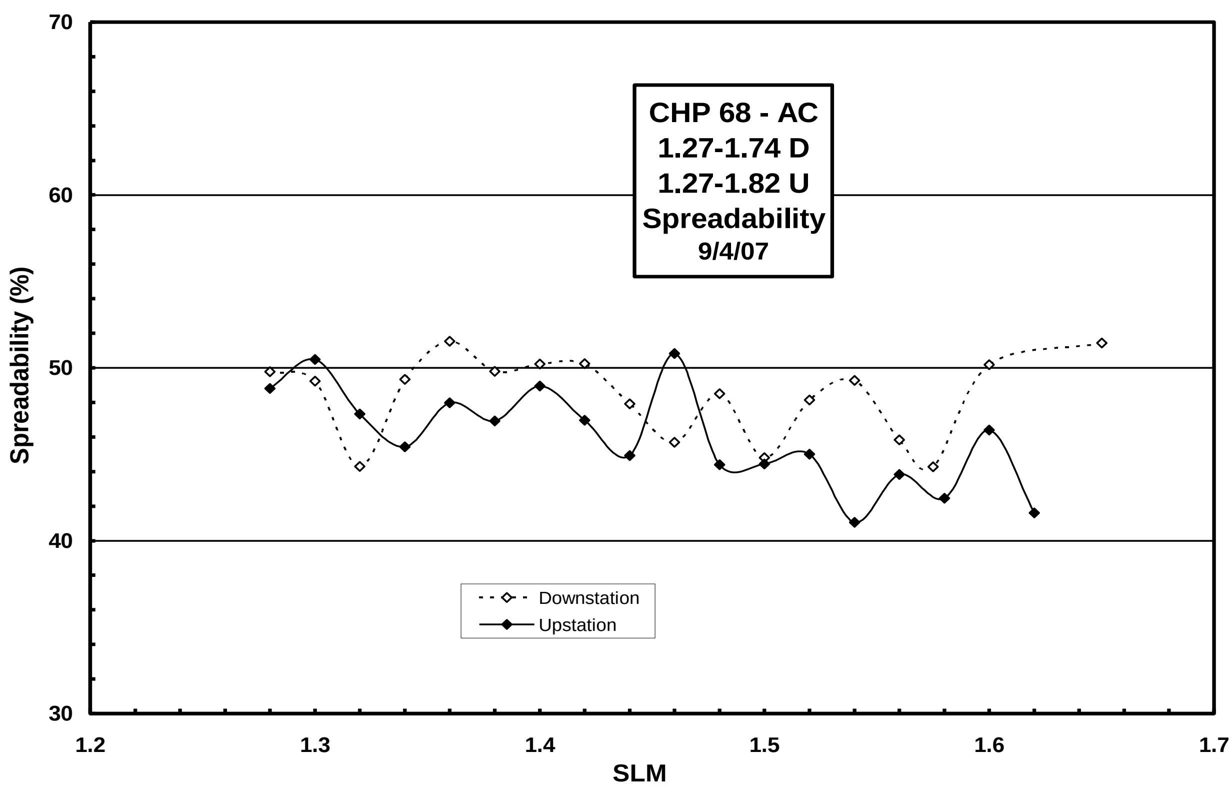


Figure C5 – CHP 68, 1.27-1.82 FWD Deflection

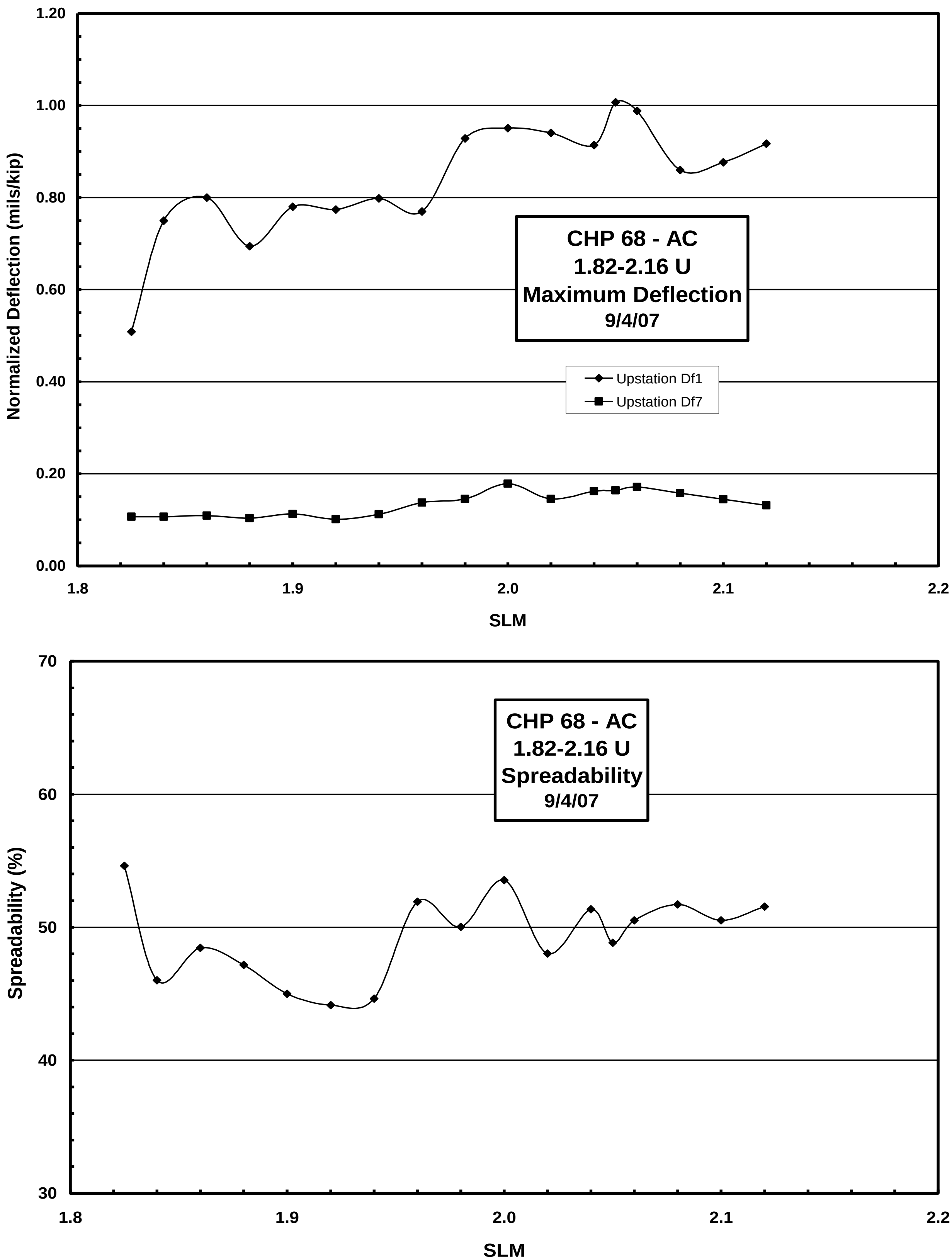
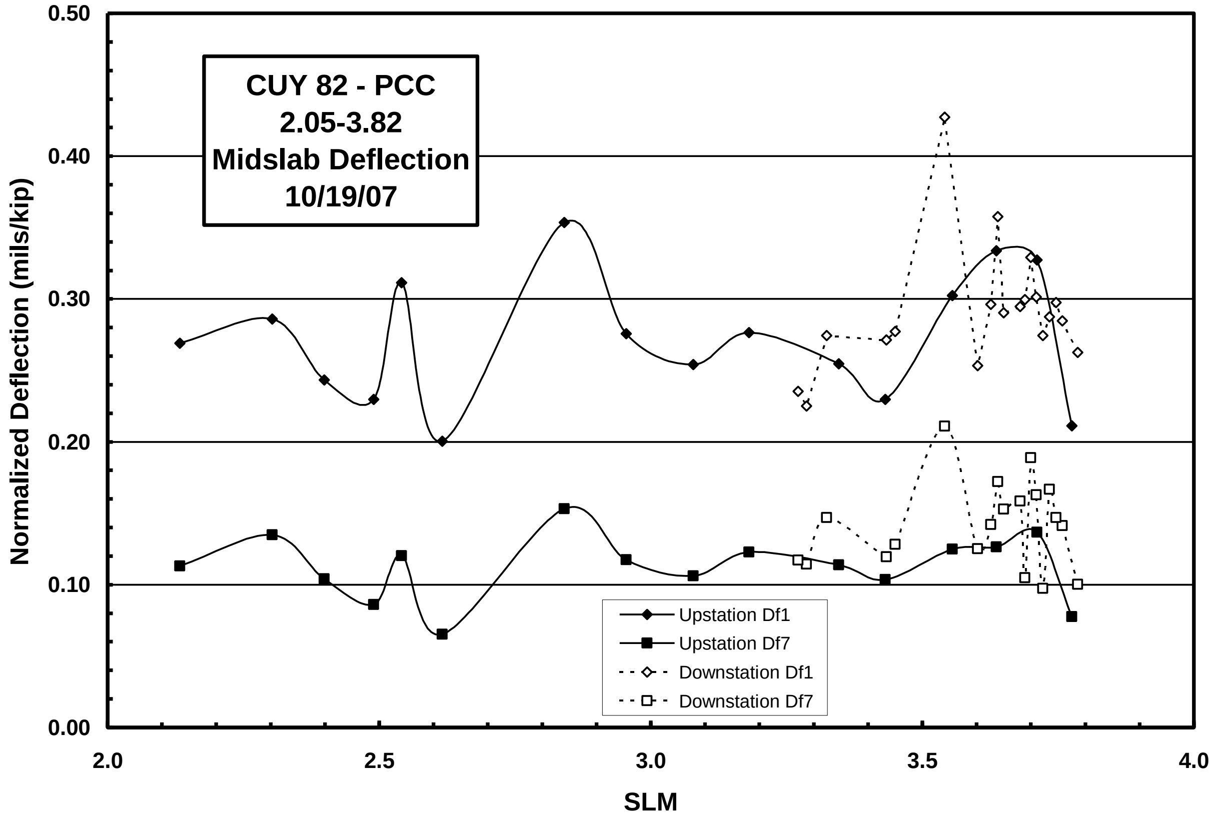


Figure C6 – CHP 68, 1.82-2.16 FWD Deflection



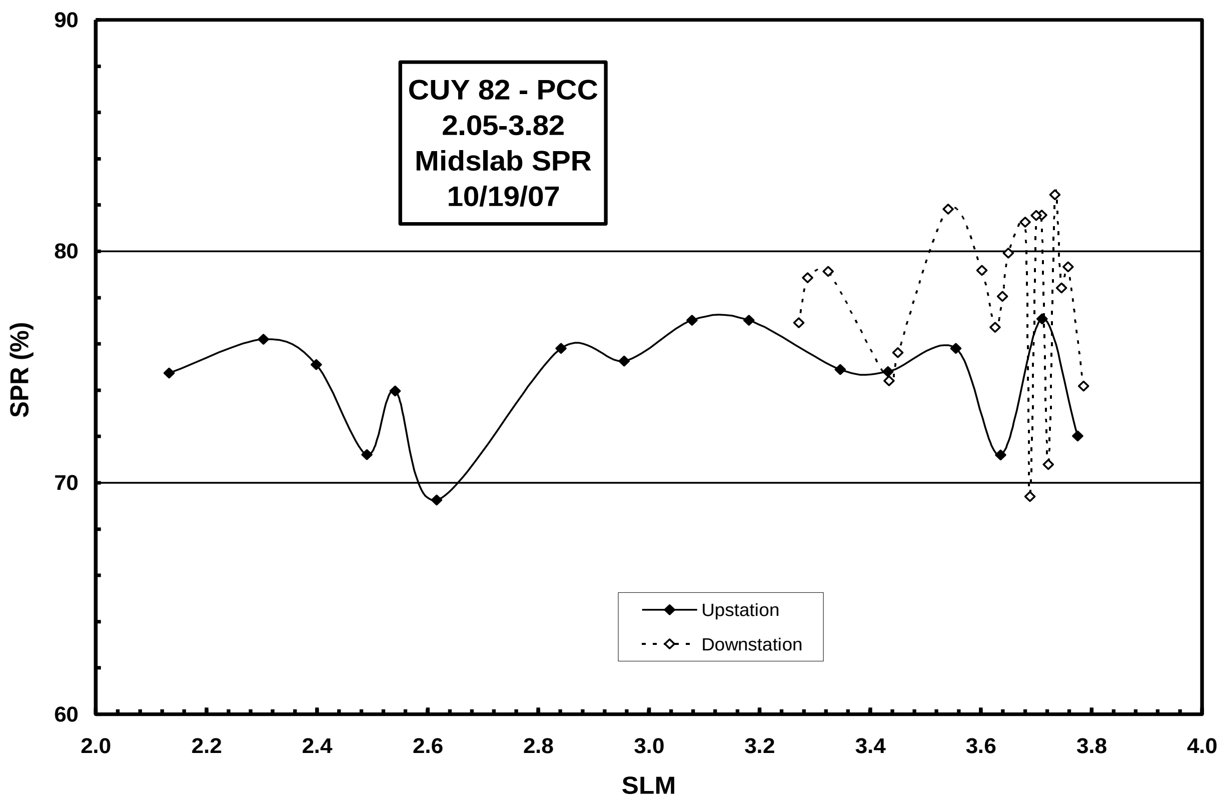
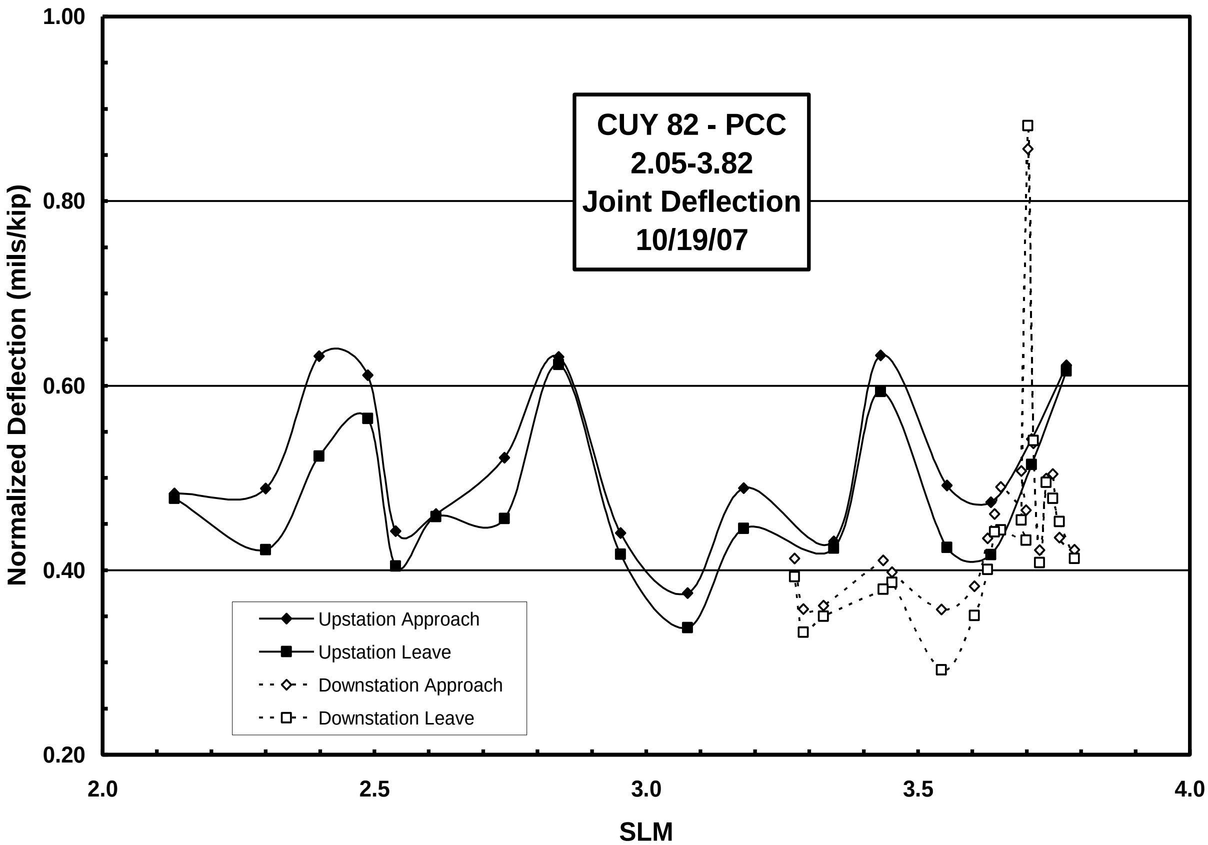


Figure C7a – CUY 82 FWD Midslab Deflection



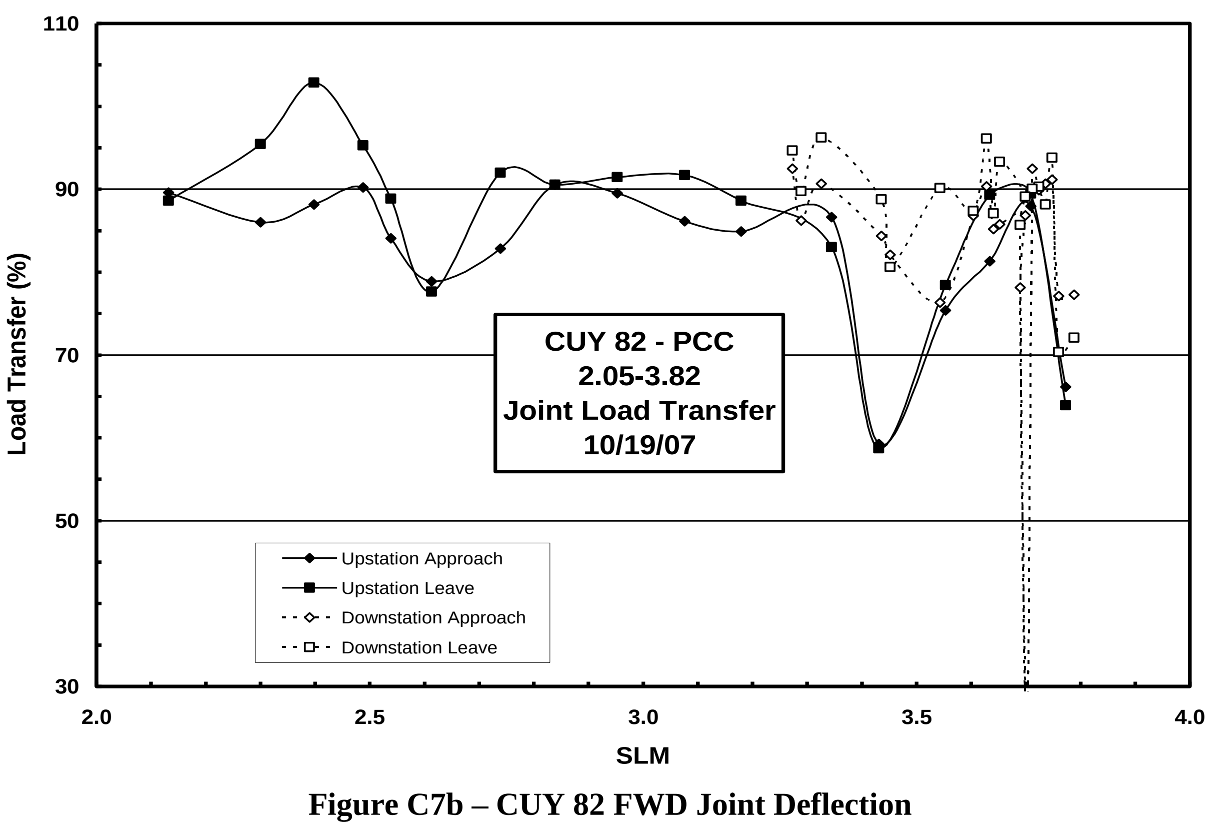
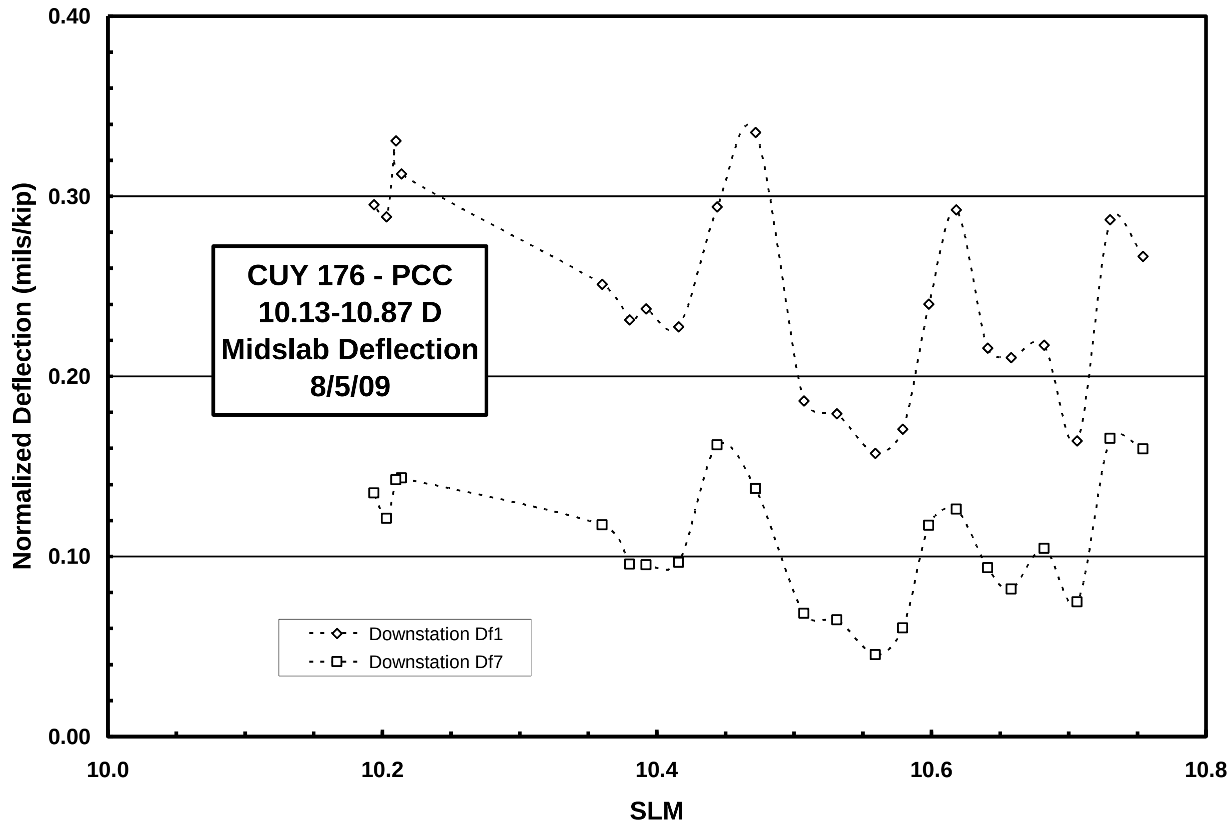


Figure C7b – CUY 82 FWD Joint Deflection



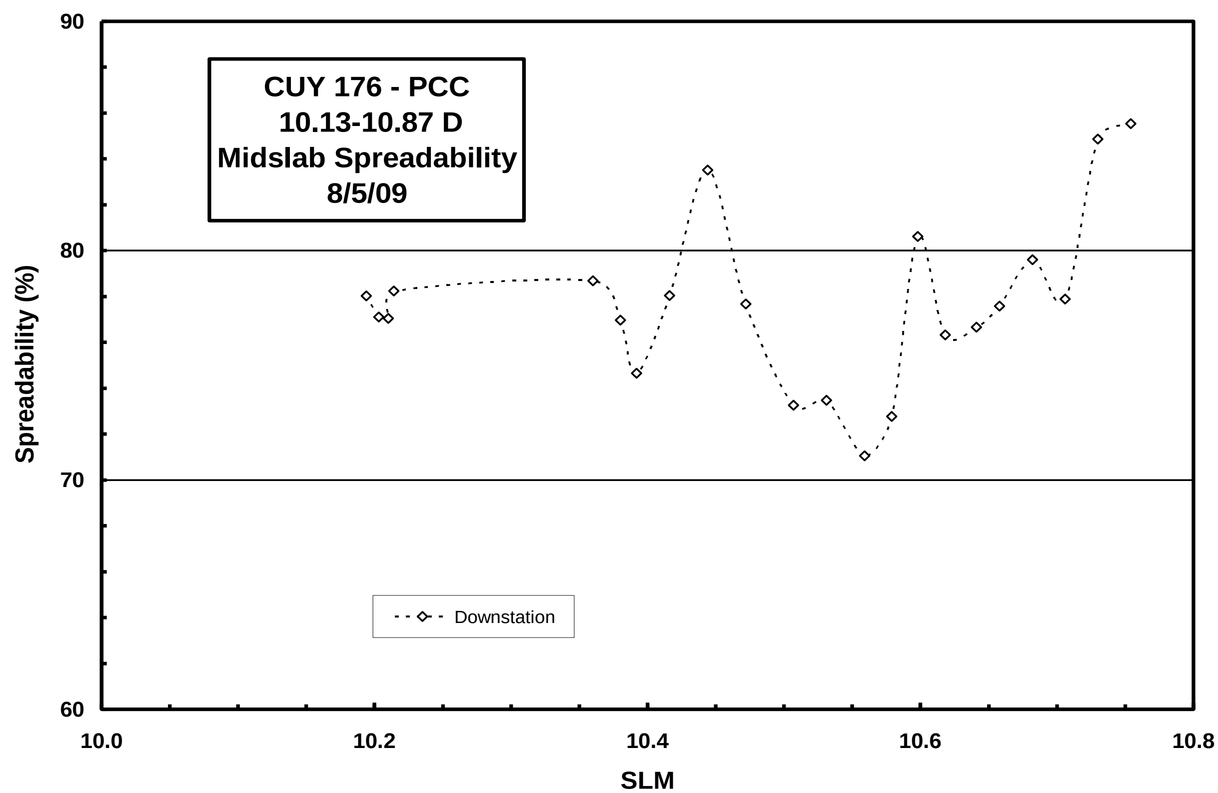
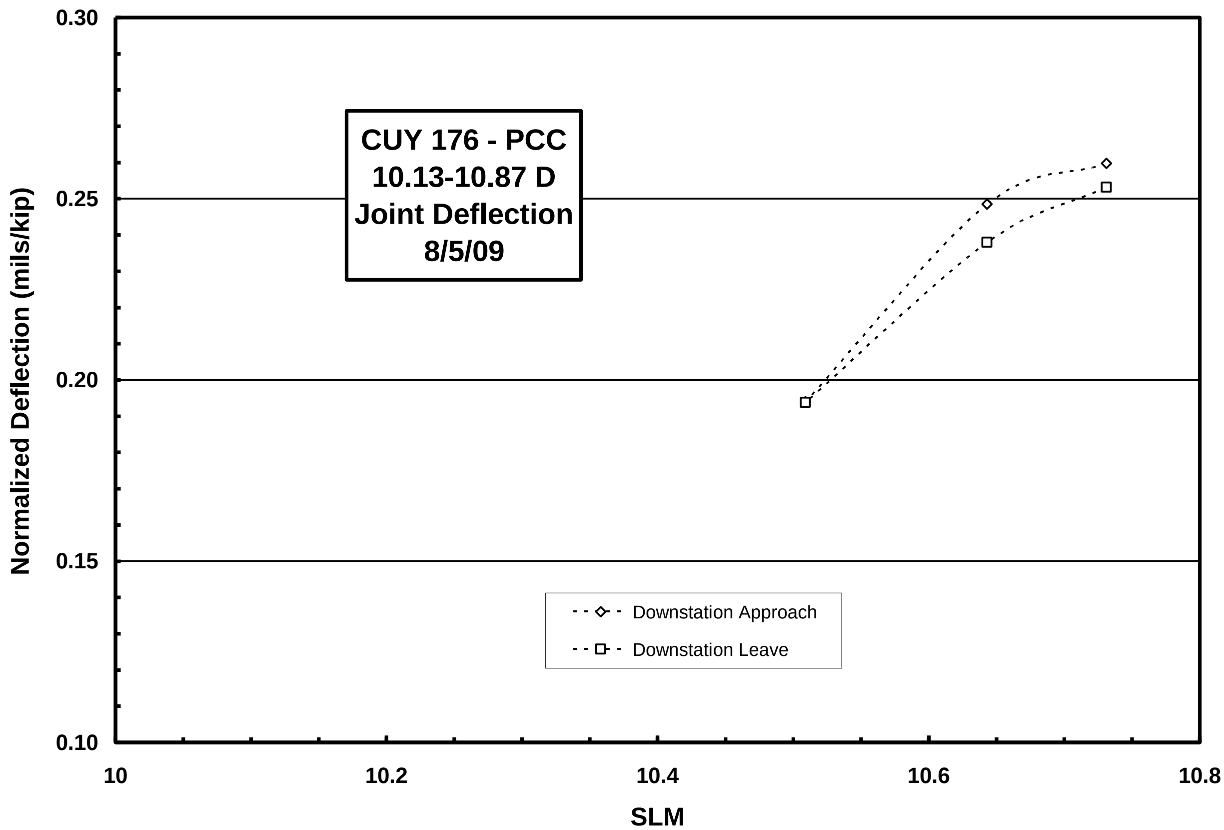


Figure C8a – CUY 176, 10.13-10.87 FWD Midslab Deflection



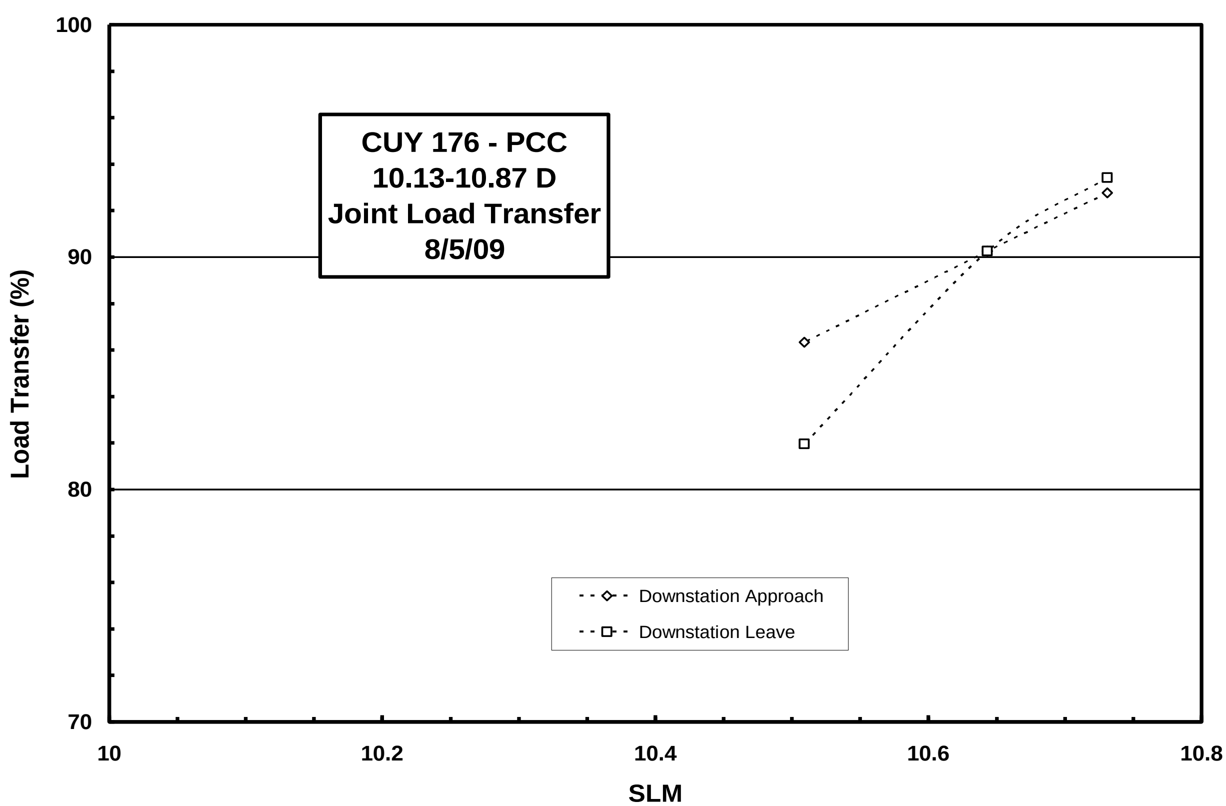


Figure C8b – CUY 176, 10.13-10.87 FWD Joint Deflection

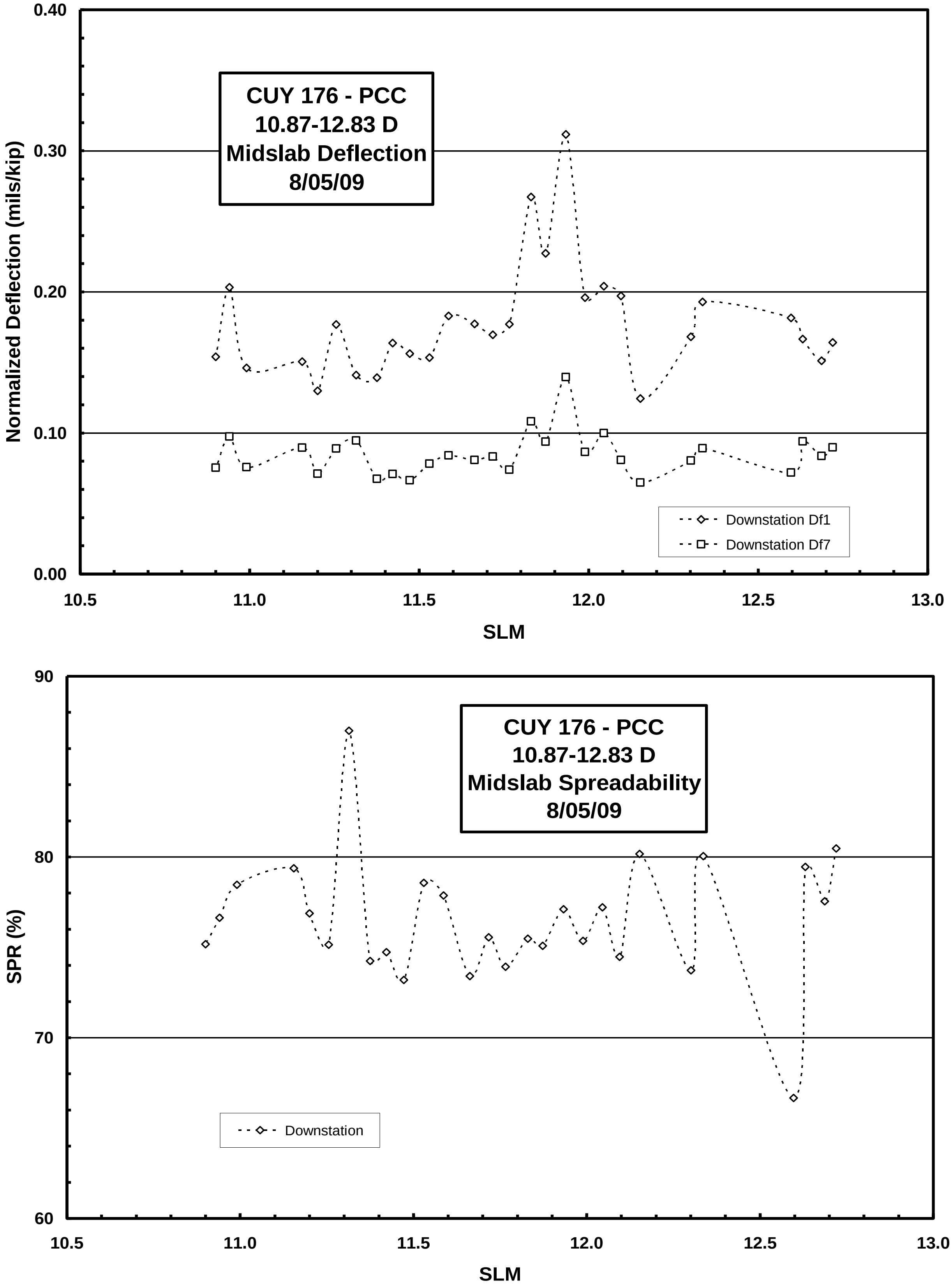
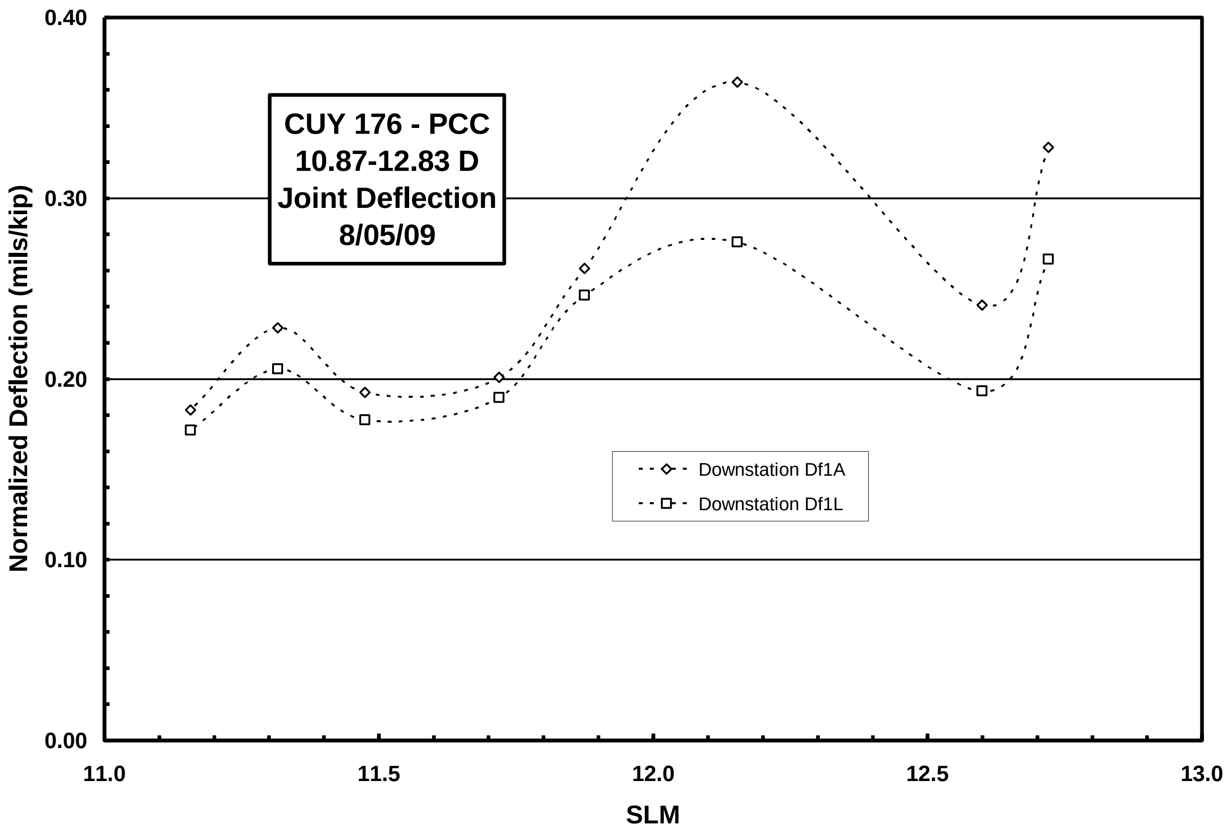


Figure C9a – CUY 176, 10.87-12.83 FWD Midslab Deflection



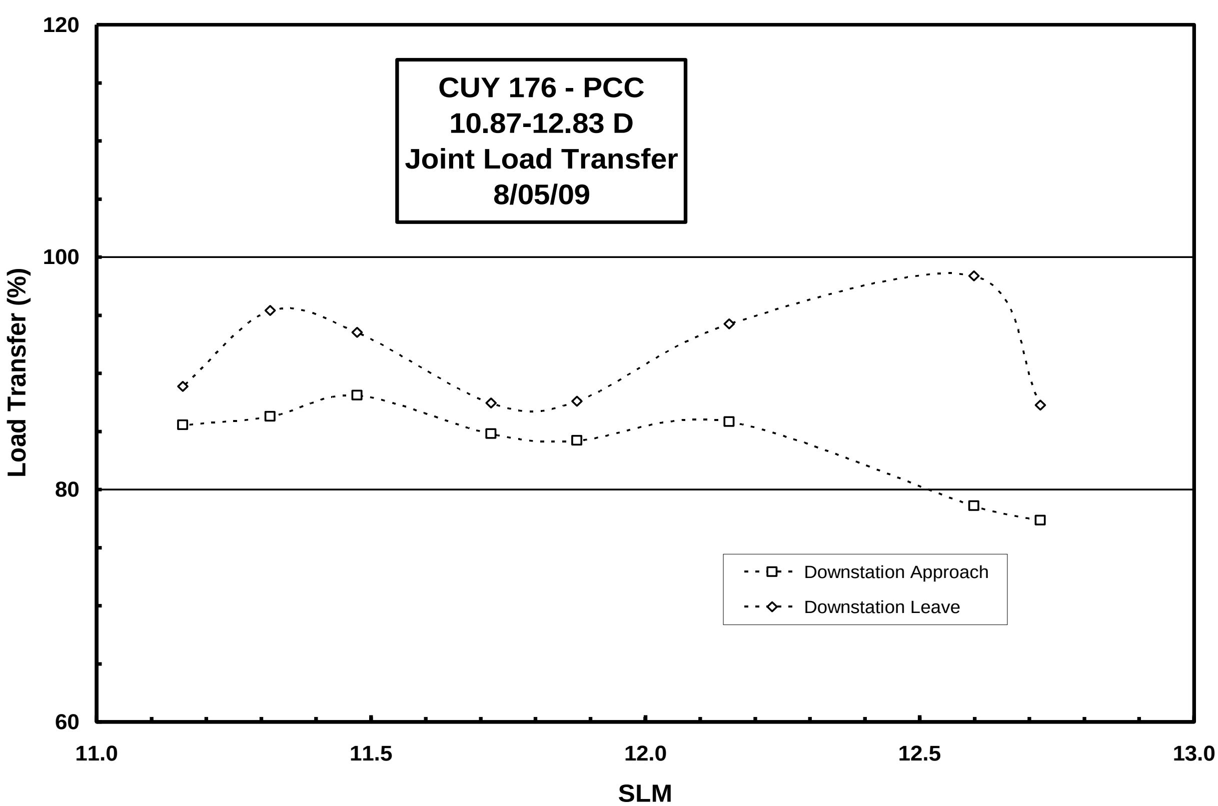
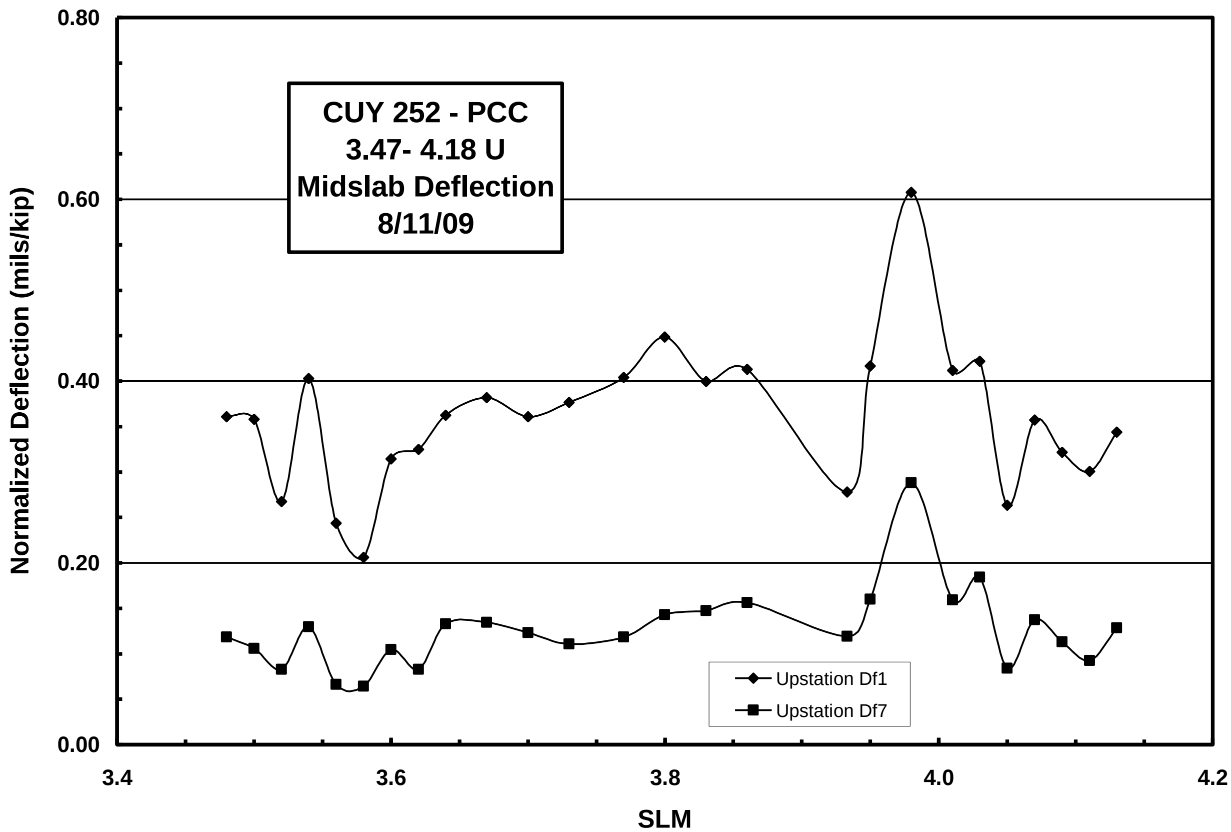


Figure C9b – CUY 176, 10.87-12.83 FWD Joint Deflection



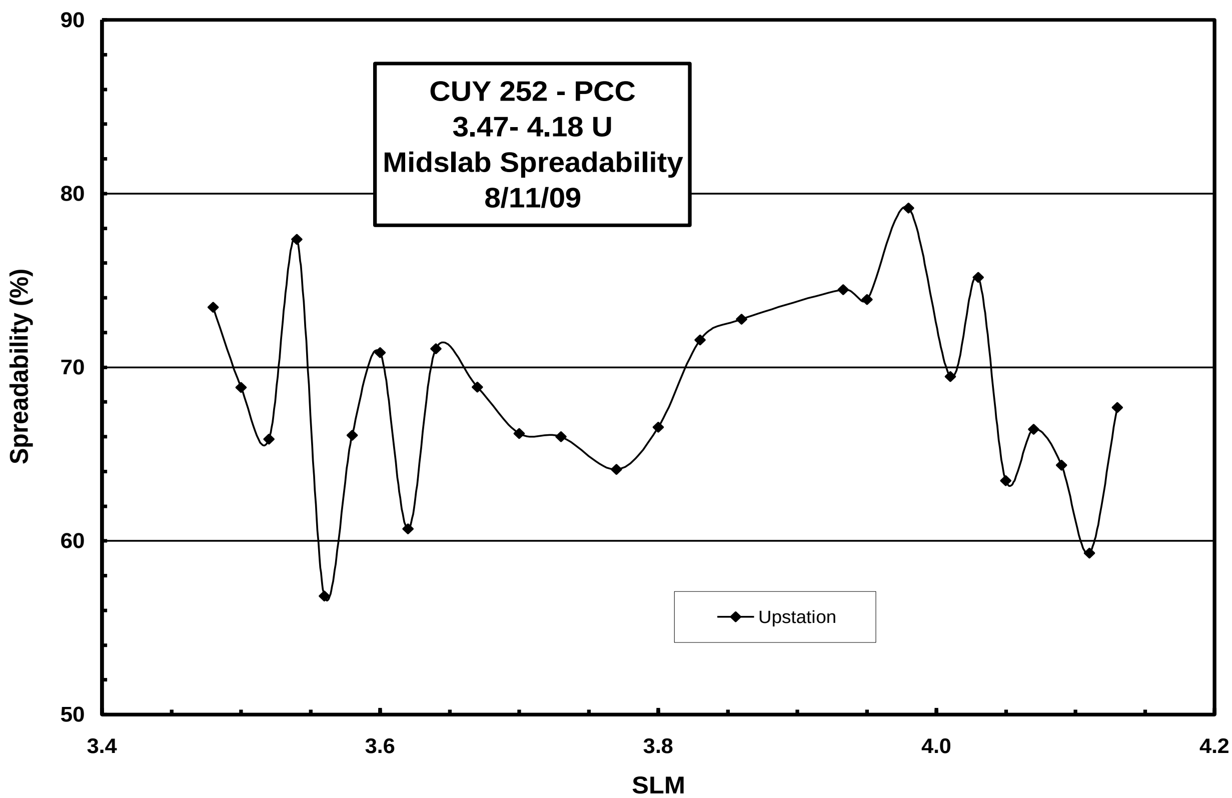
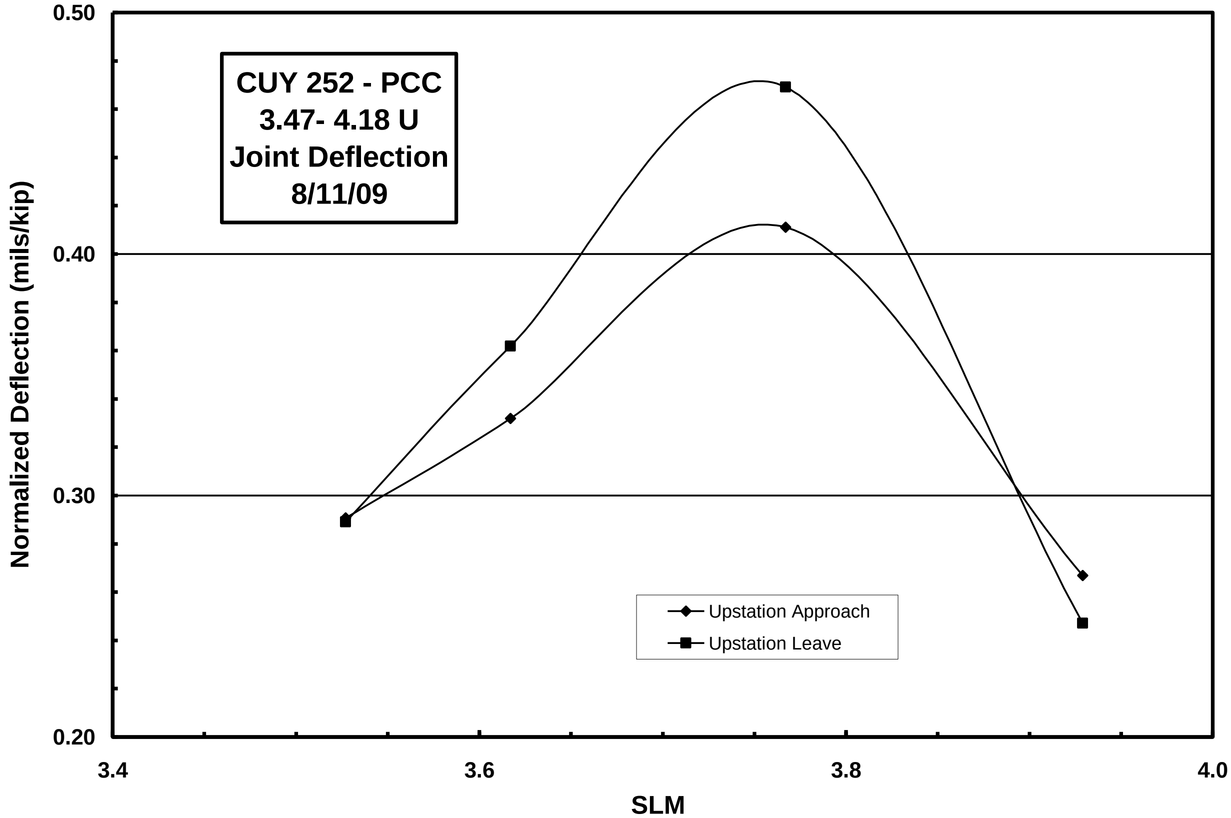


Figure C10a – CUY 252, 3.47-4.18 FWD Midslab Deflection



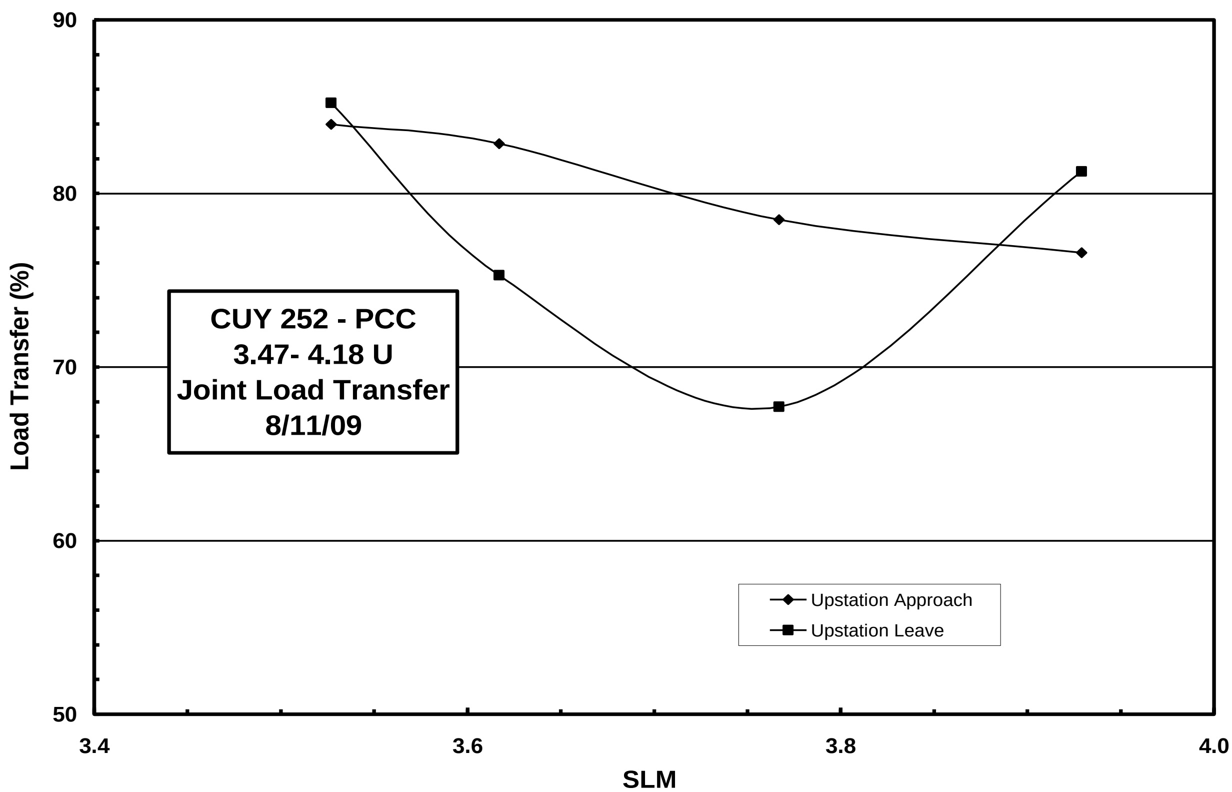
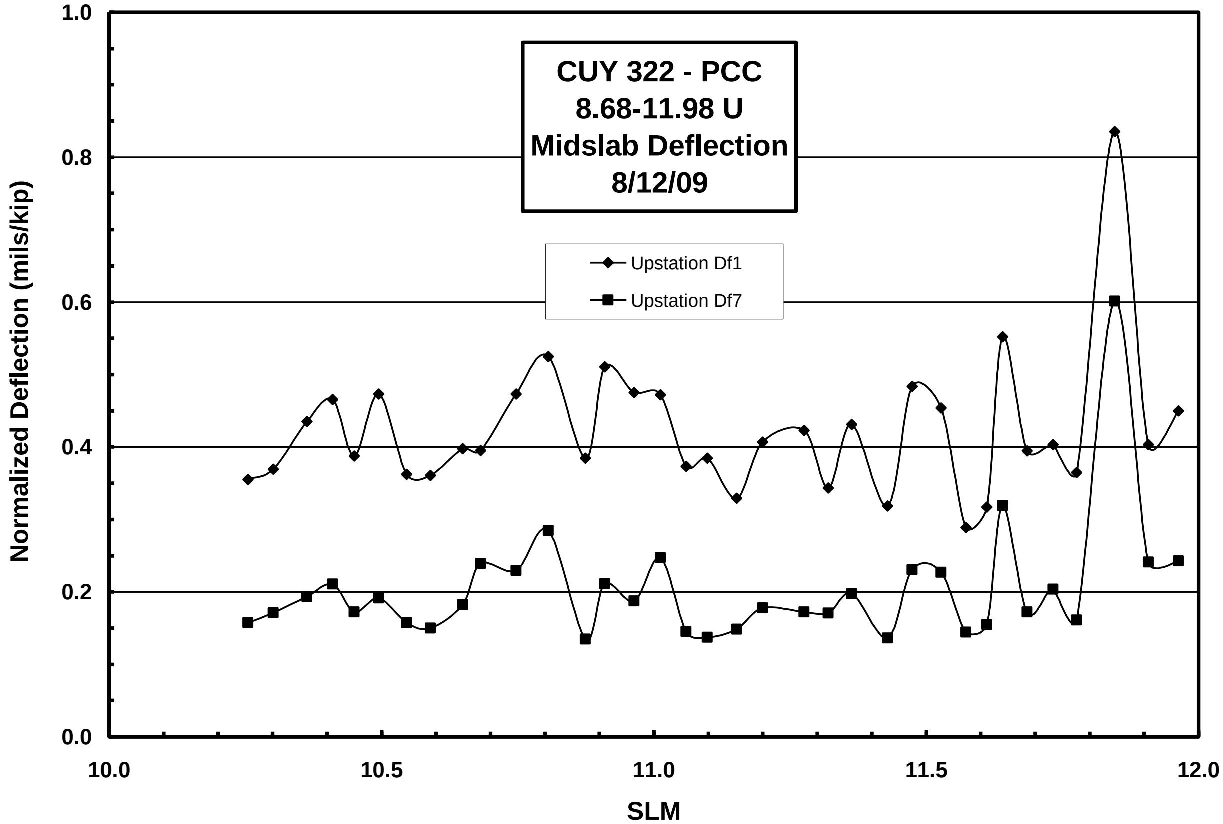


Figure C10b – CUY 252, 3.47-4.18 FWD Joint Deflection



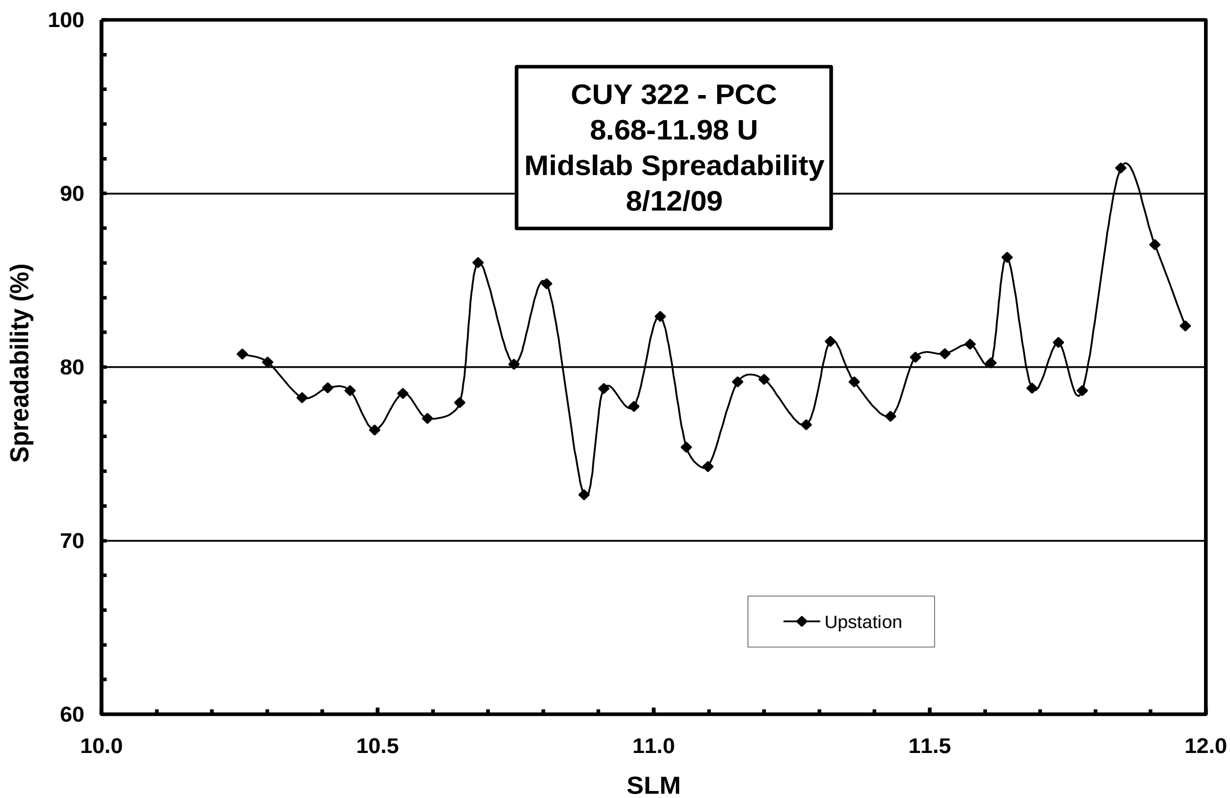
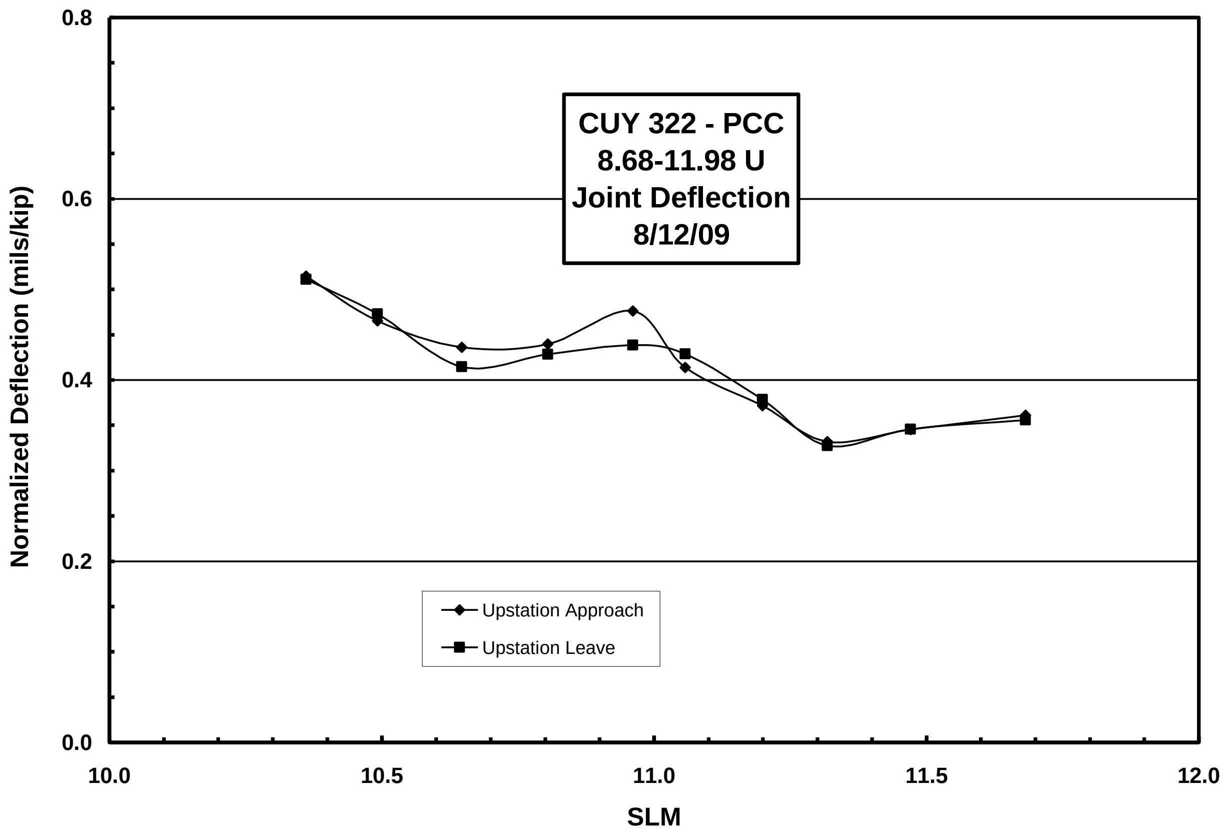


Figure C11a – CUY 322, 8.68-11.98 FWD Midslab Deflection



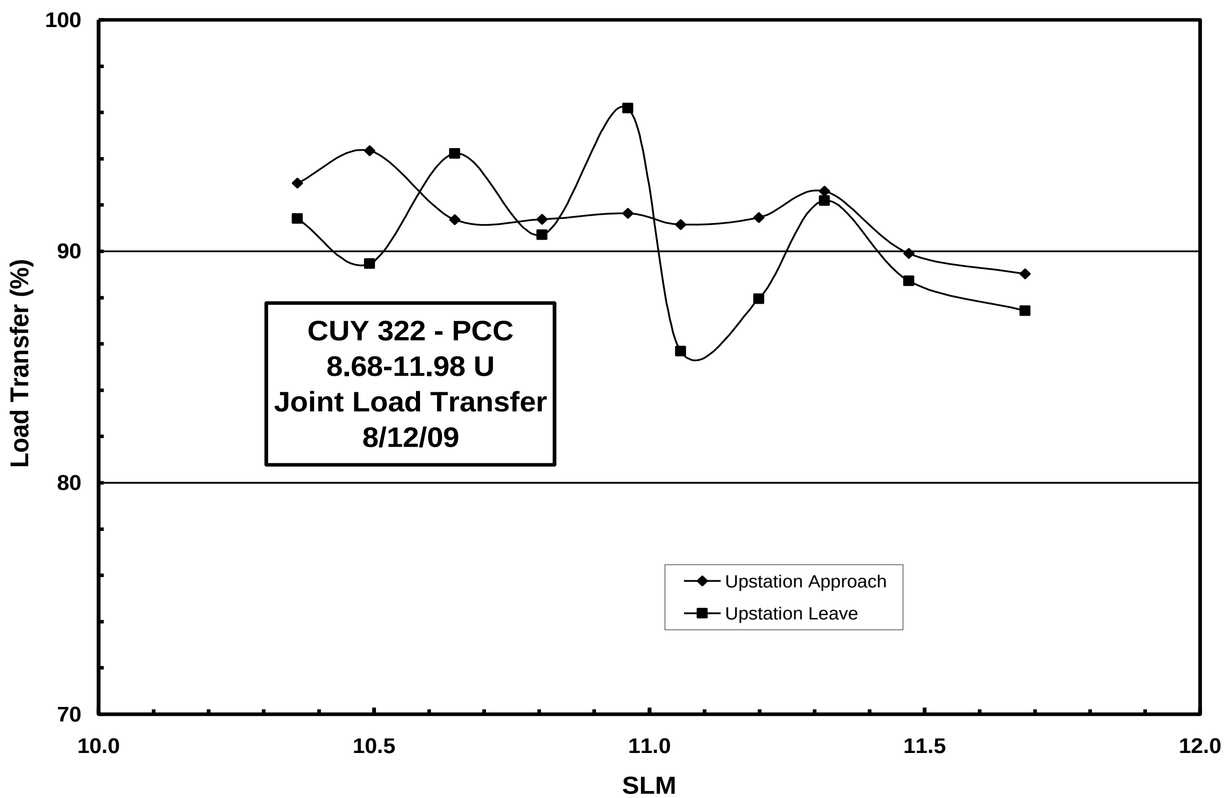
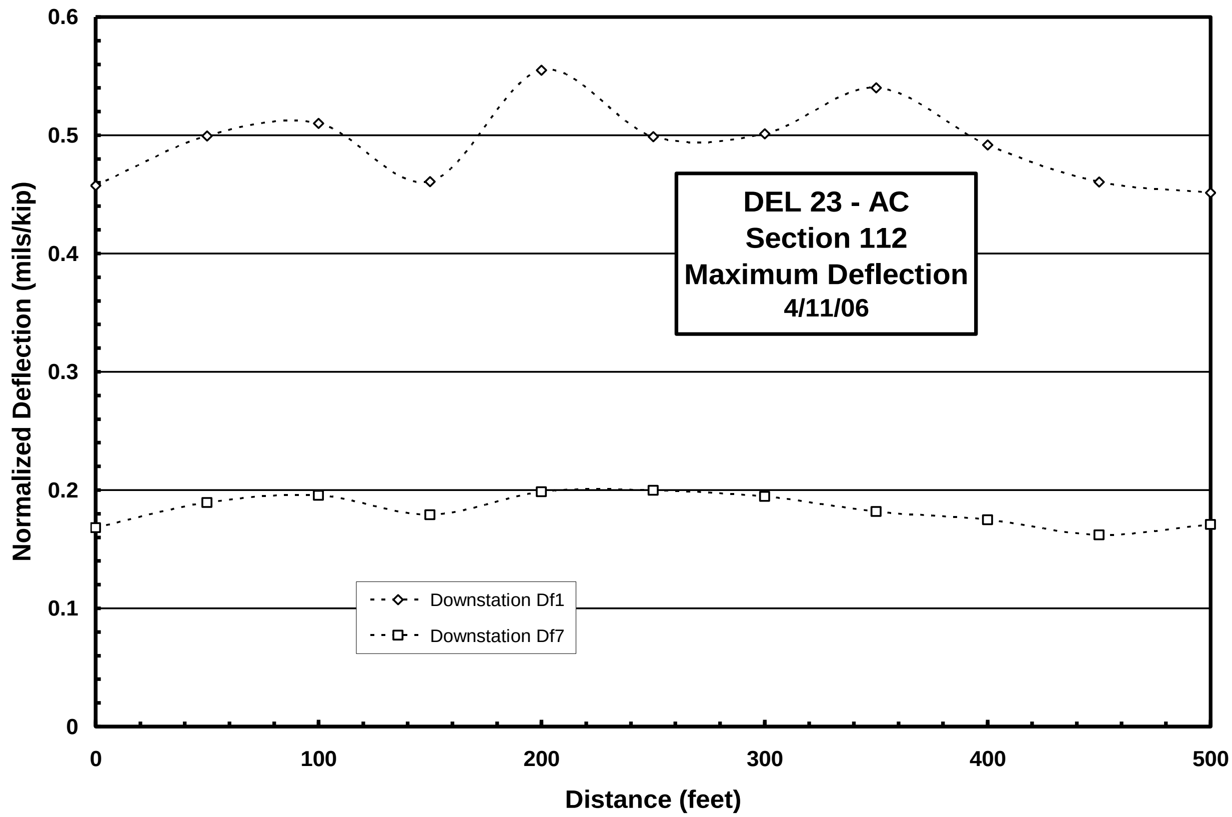


Figure C11b – CUY 322, 8.68-11.98 FWD Joint Deflection



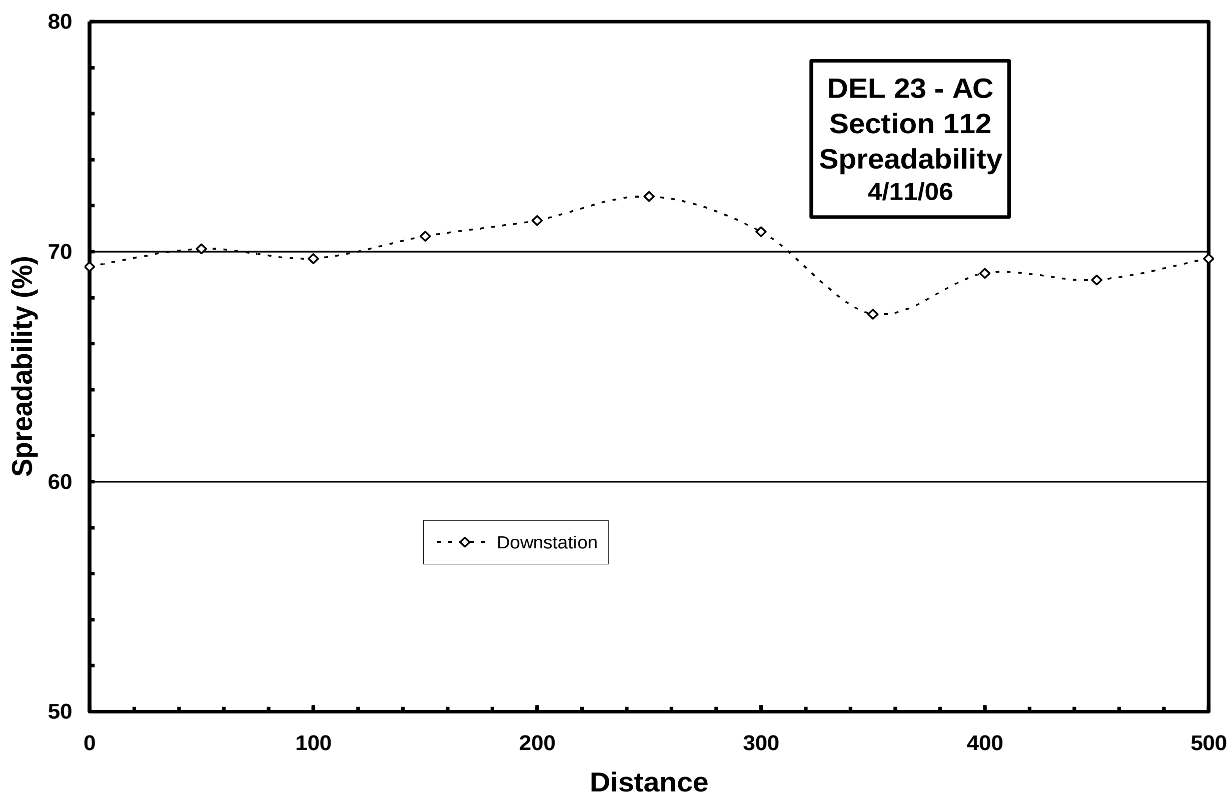
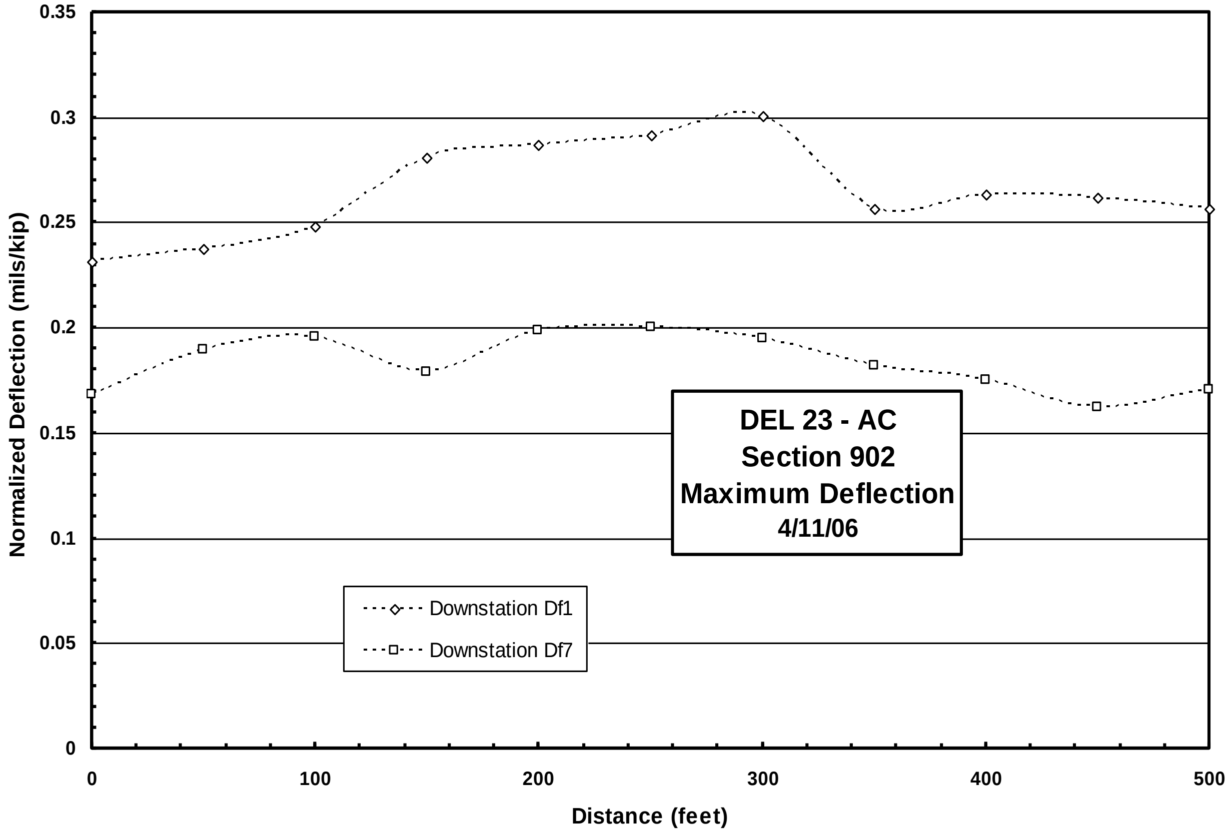


Figure 12 – DEL 23 (Section 112) Deflection



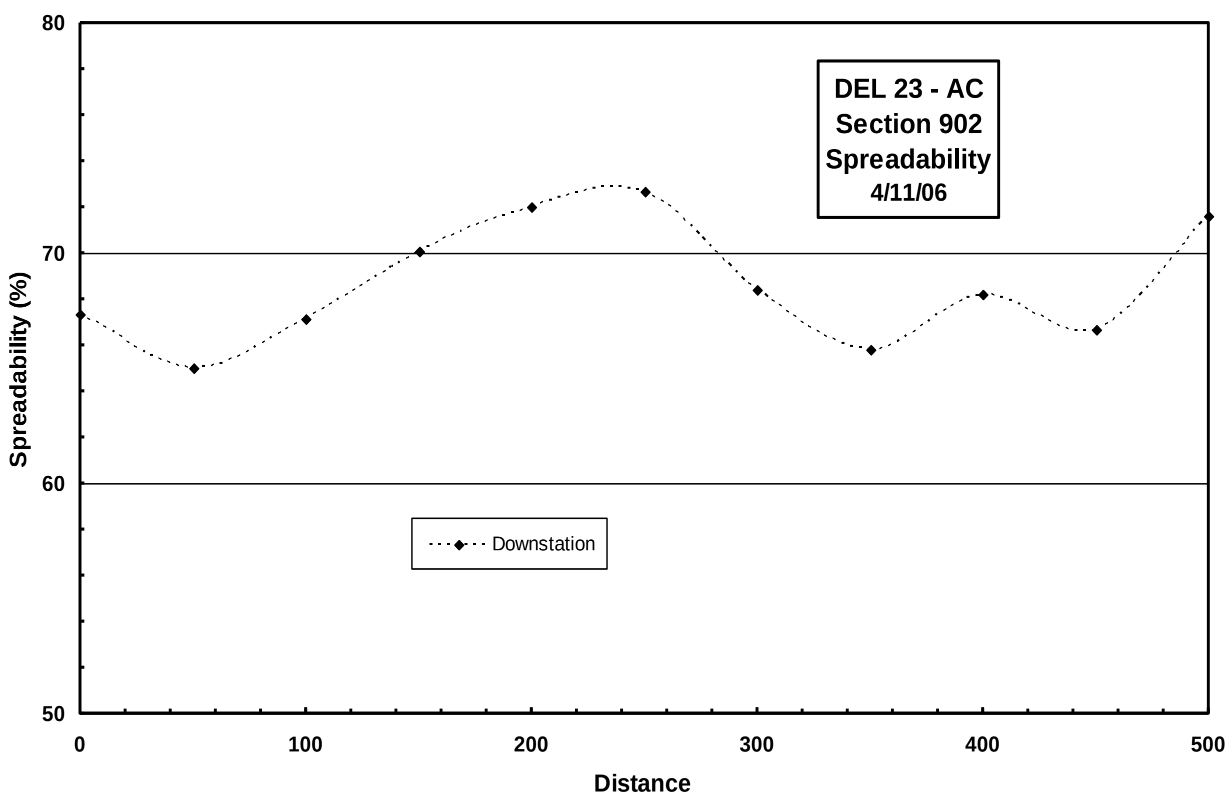
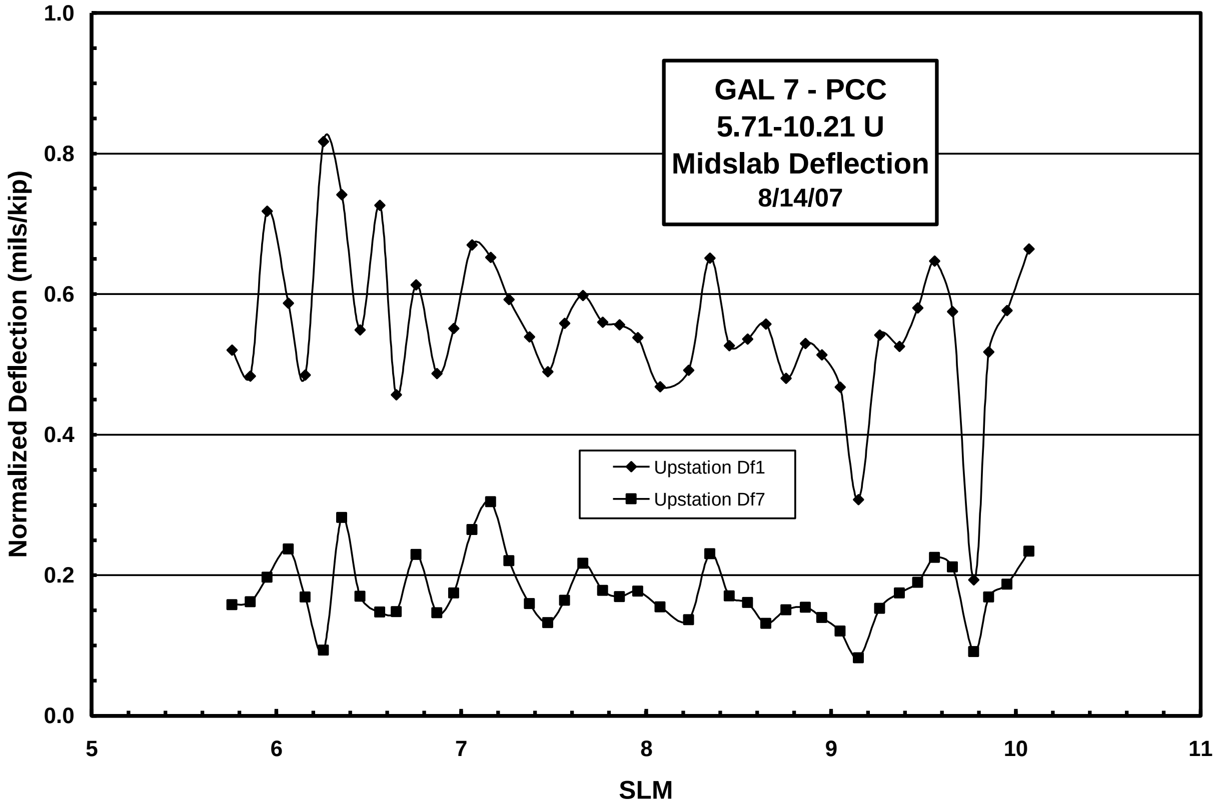


Figure 13 – DEL 23 (Section 902) Deflection



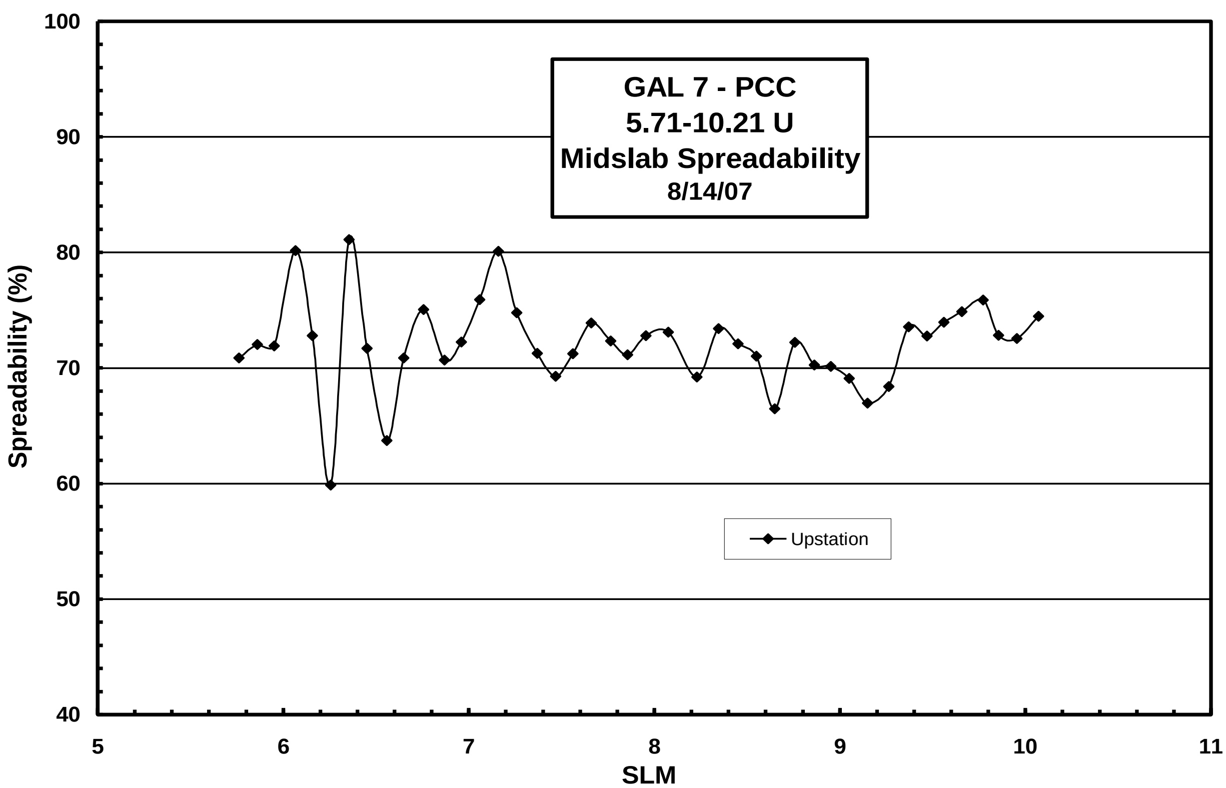
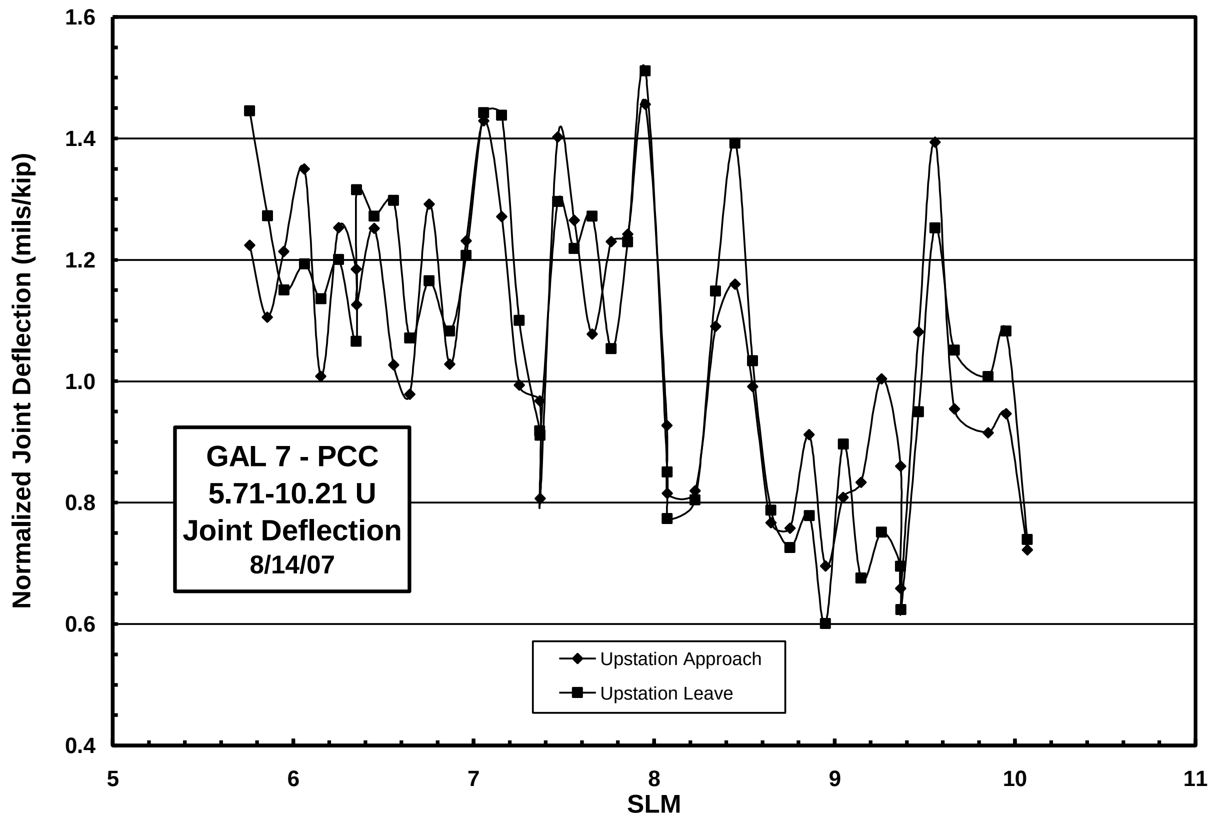


Figure C14a – GAL 7 FWD Midslab Deflection



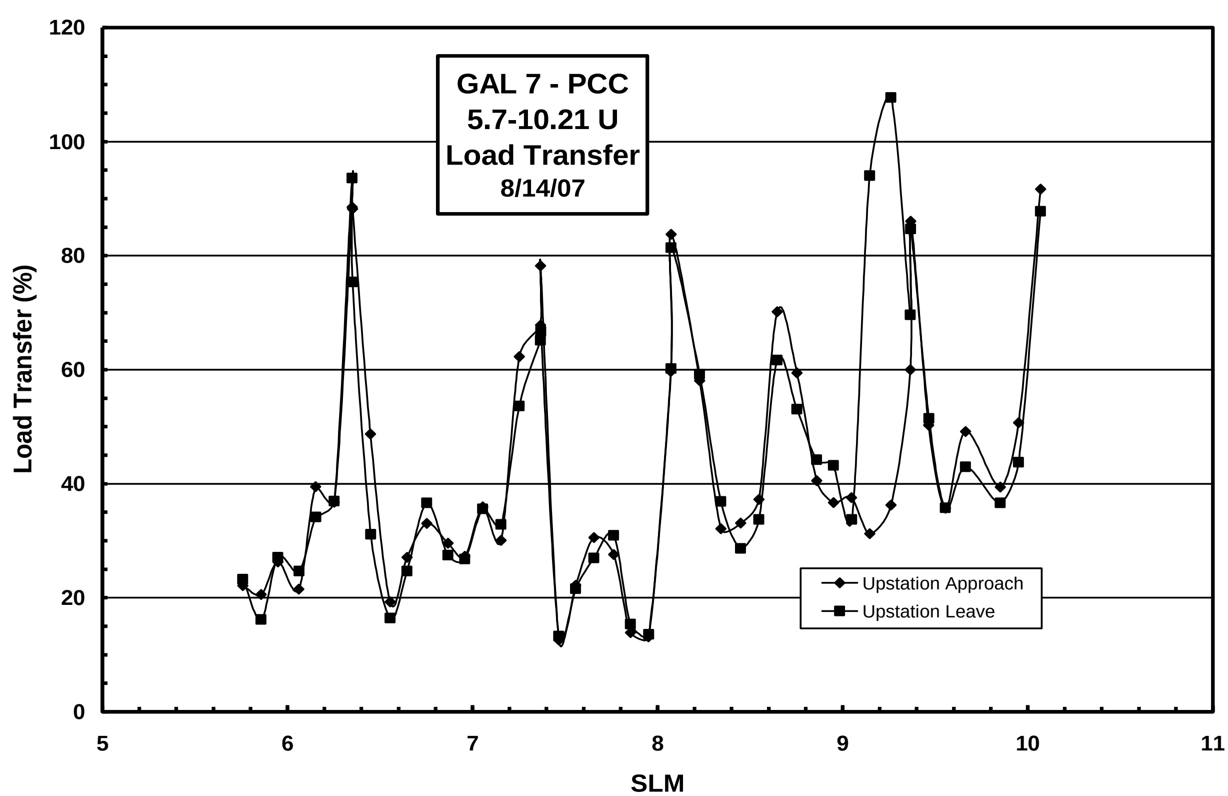
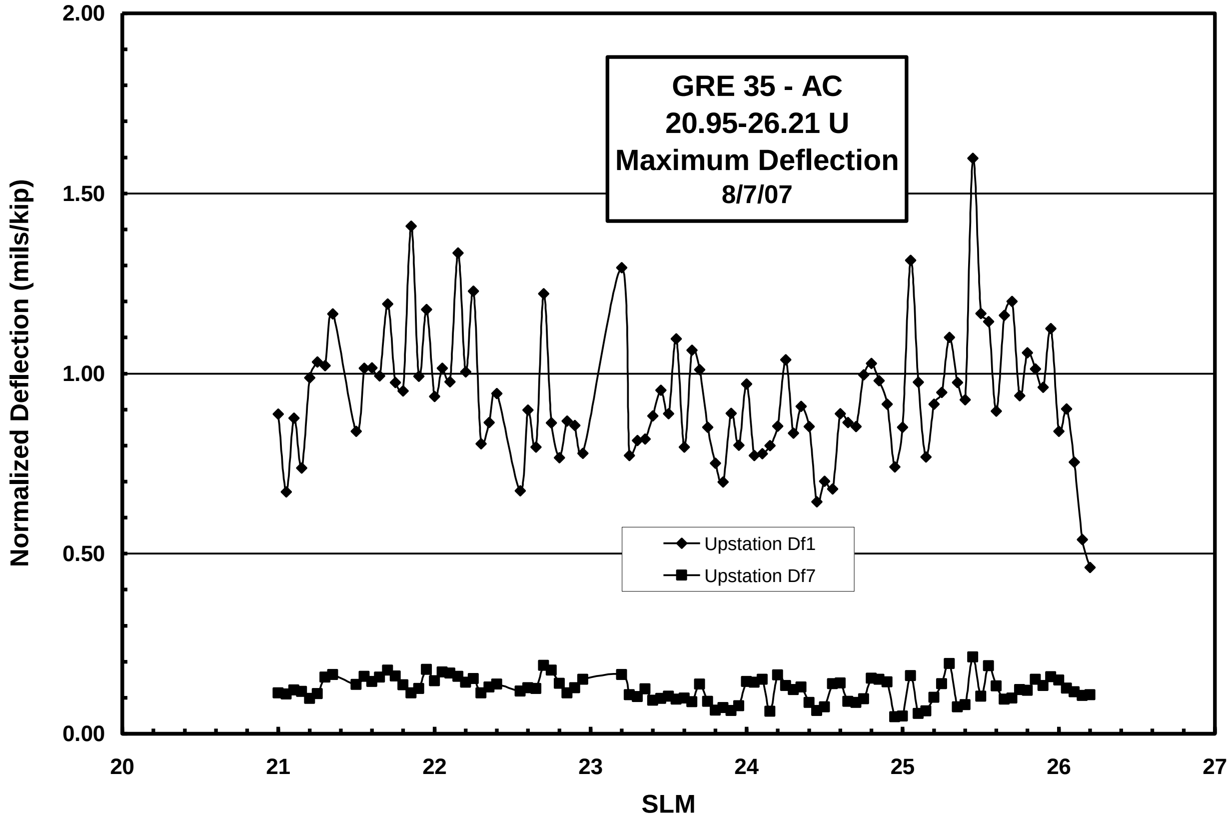


Figure C14b – GAL 7 FWD Joint Deflection



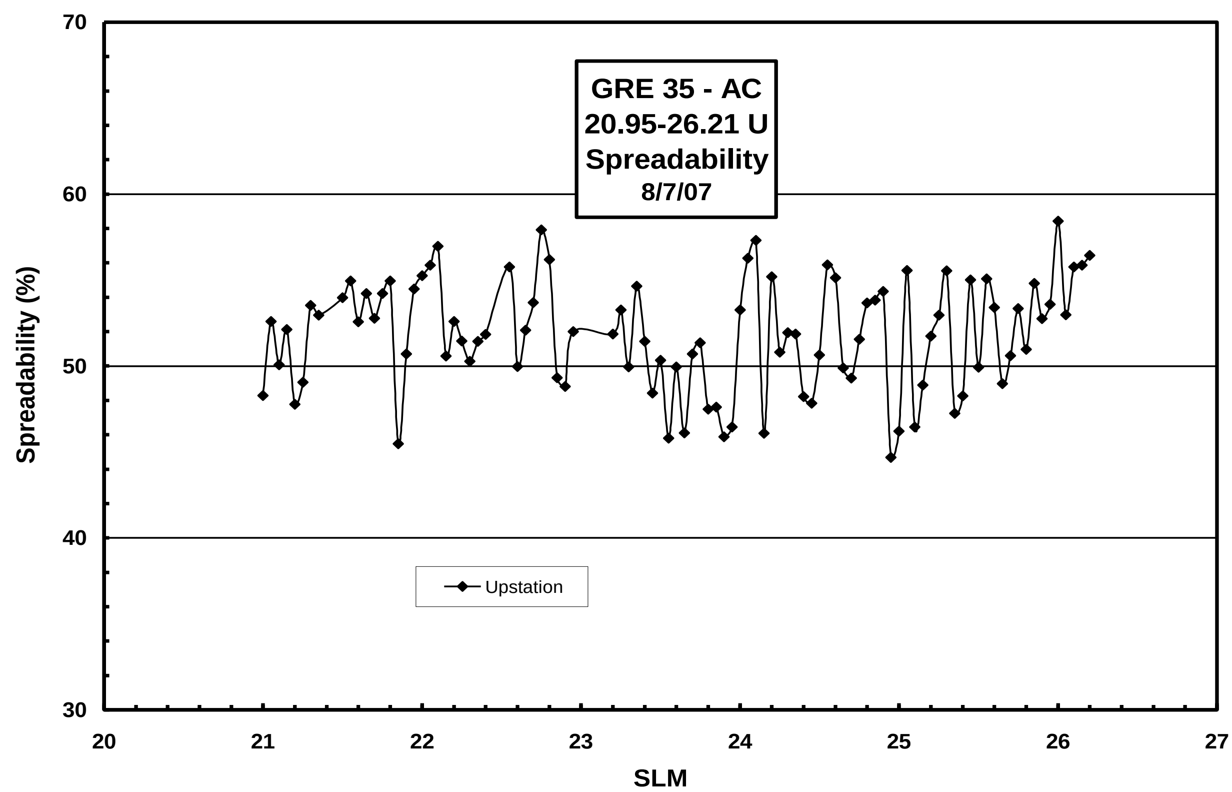
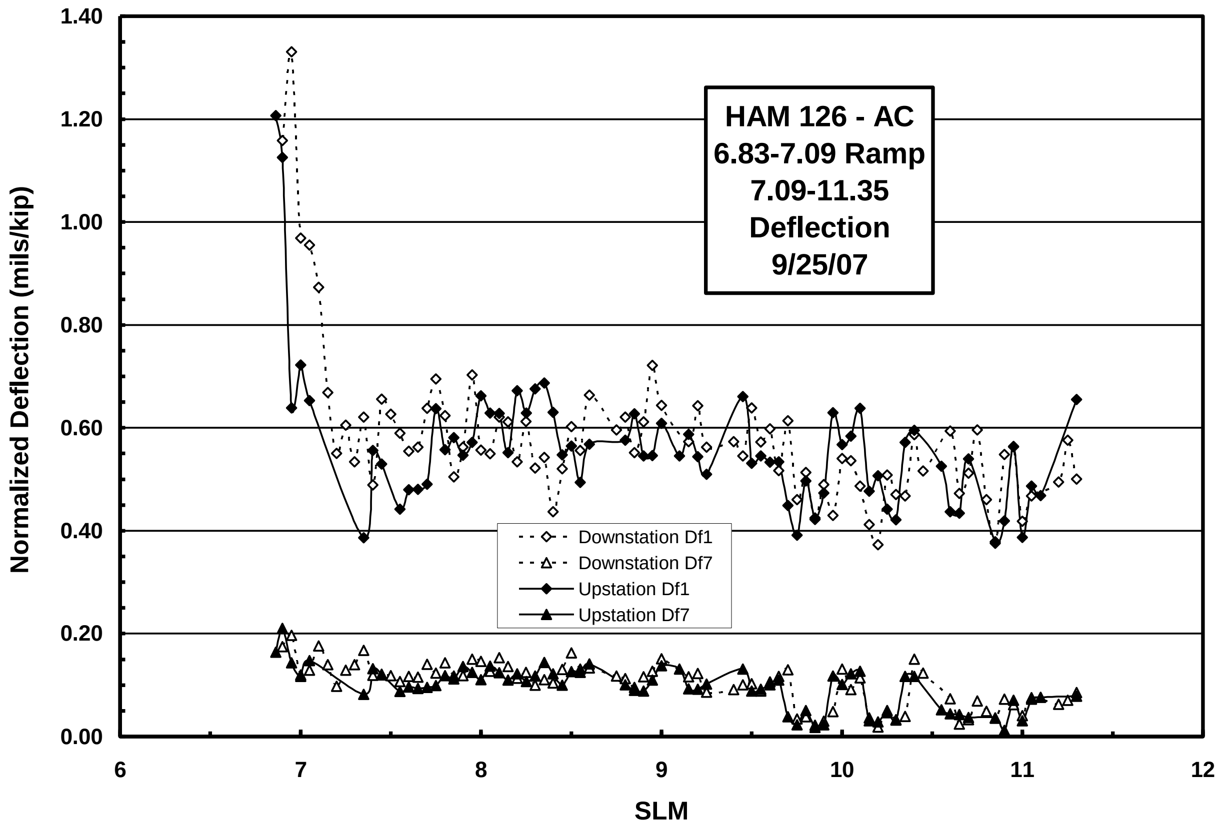


Figure C15 – GRE 35 FWD Deflection



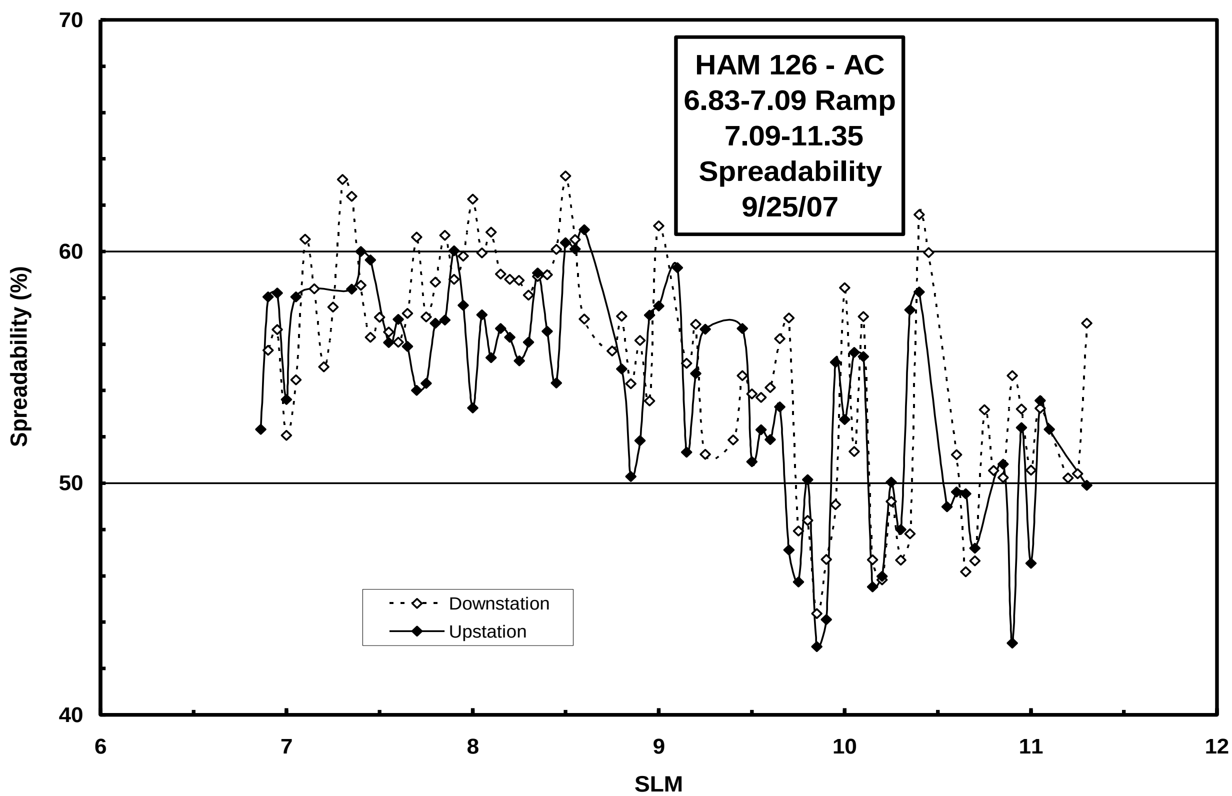
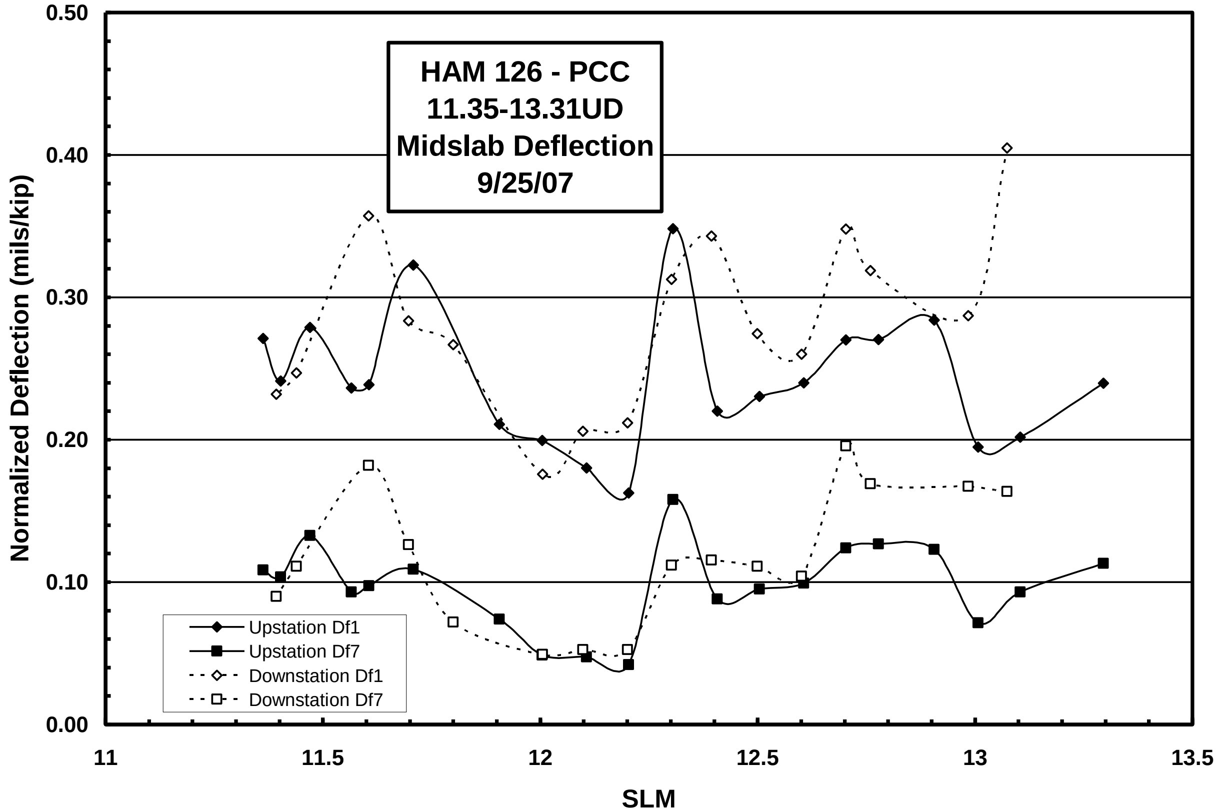


Figure C16 – HAM 126 6.83-11.35 FWD Deflection



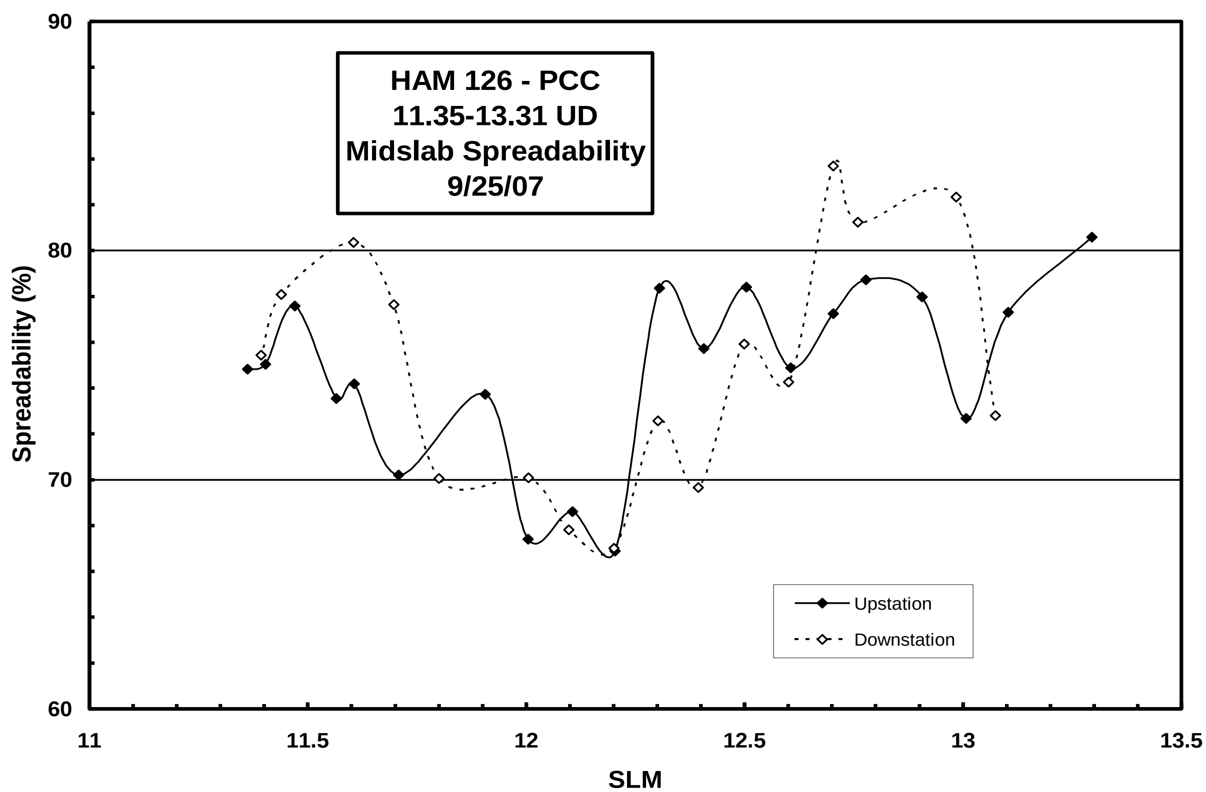
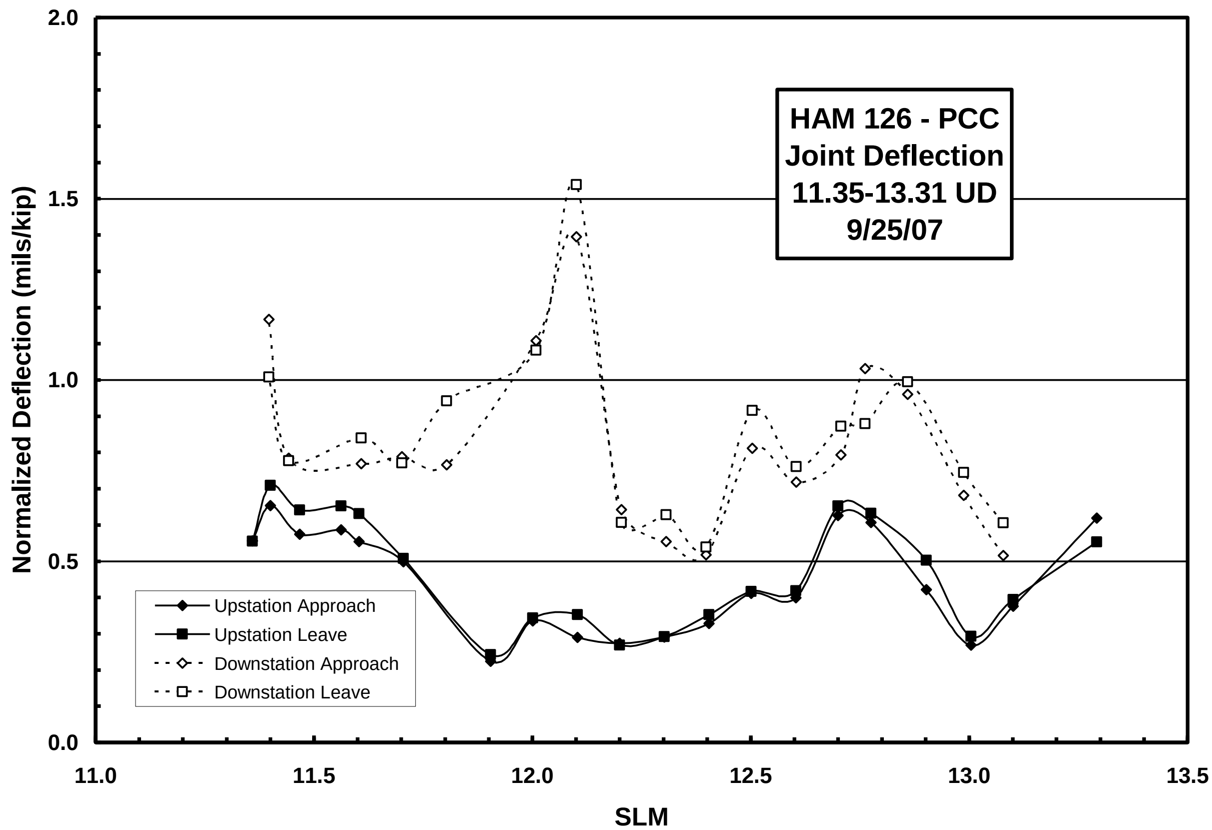


Figure C17a – HAM 126 11.35-13.31 FWD Midslab Deflection



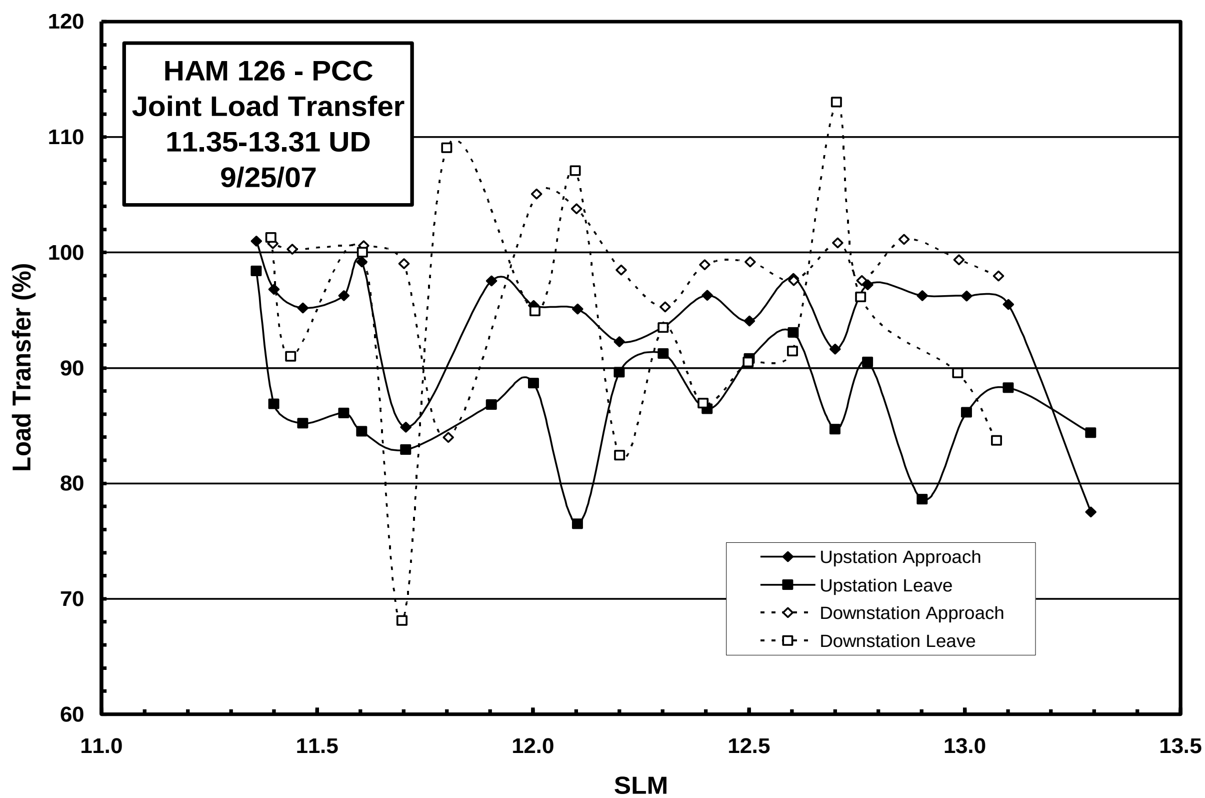
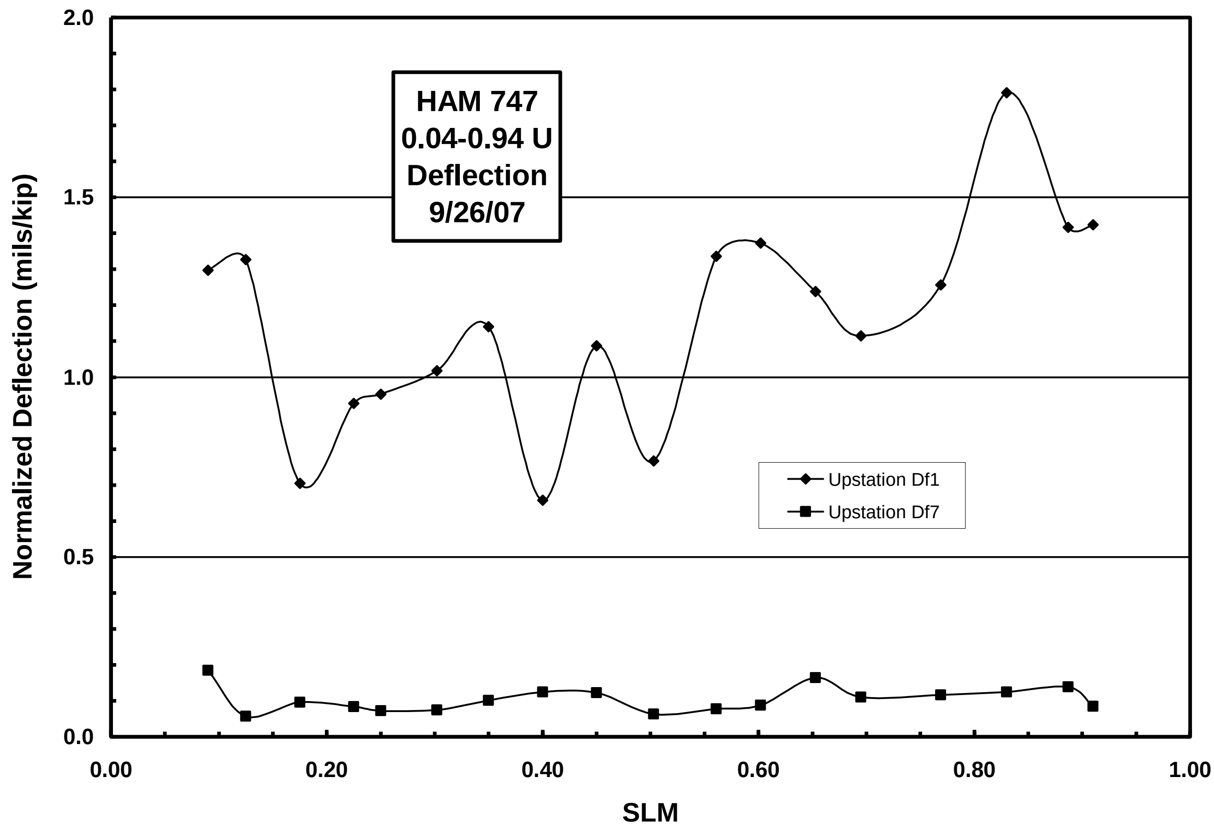


Figure C17b – HAM 126 11.35-13.31 FWD Joint Deflection



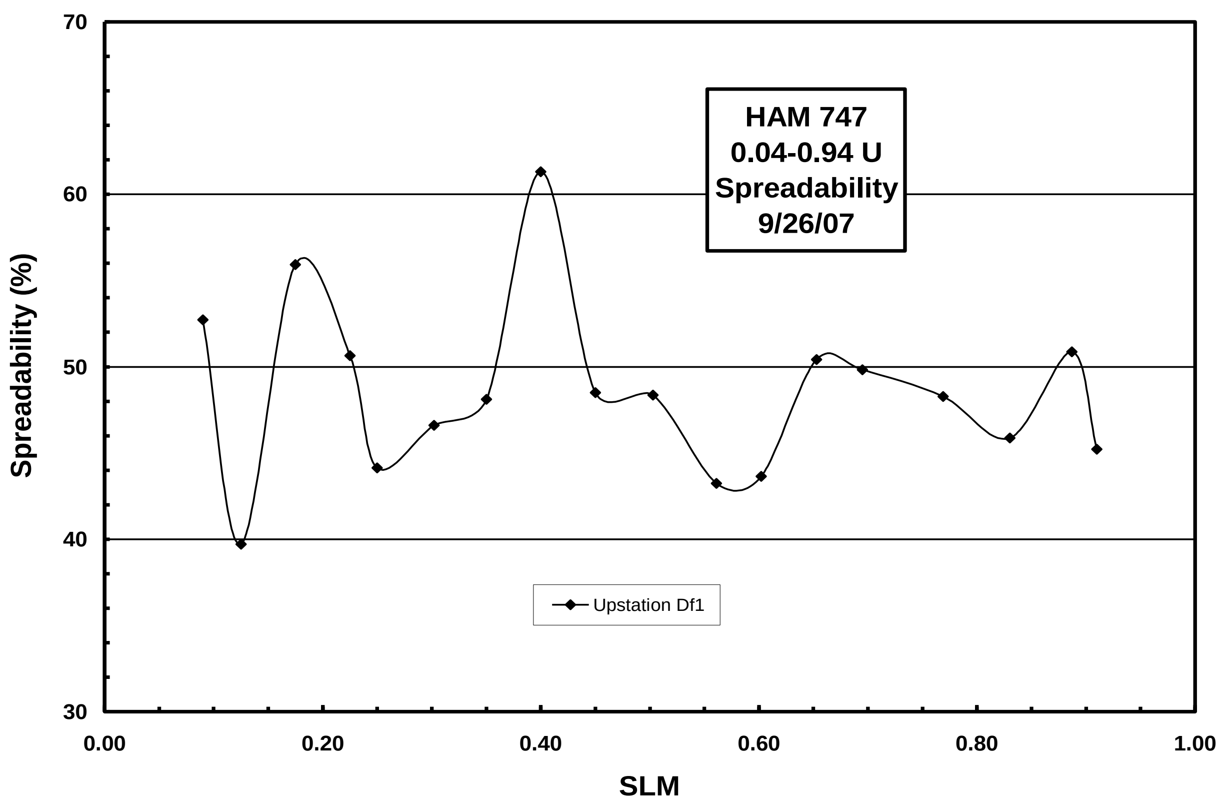
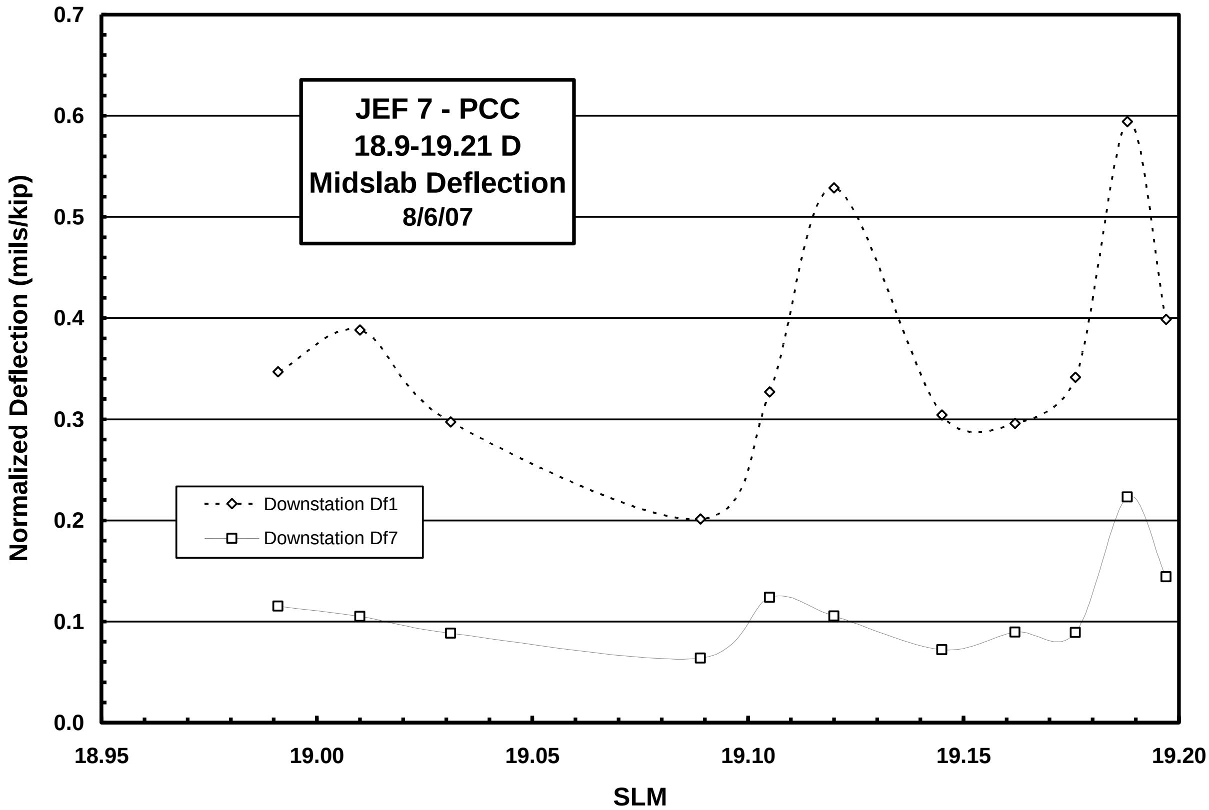


Figure C18 – HAM 747 FWD Deflection



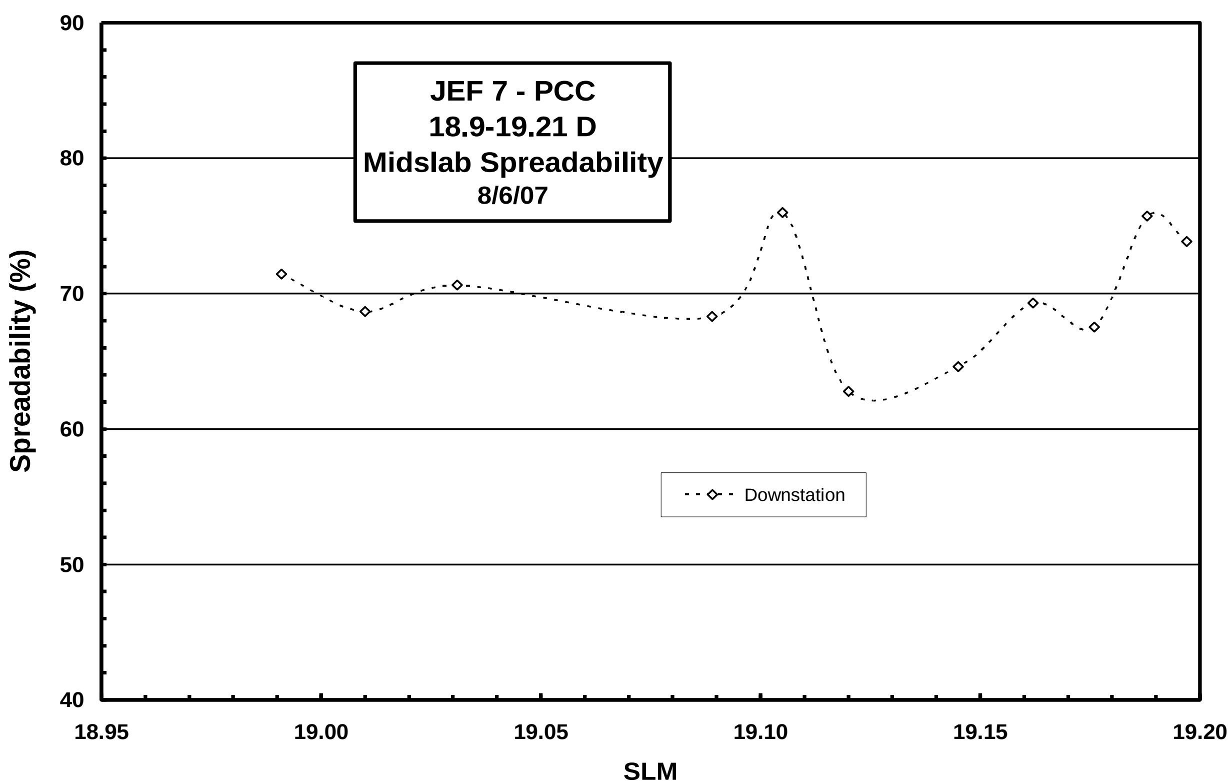
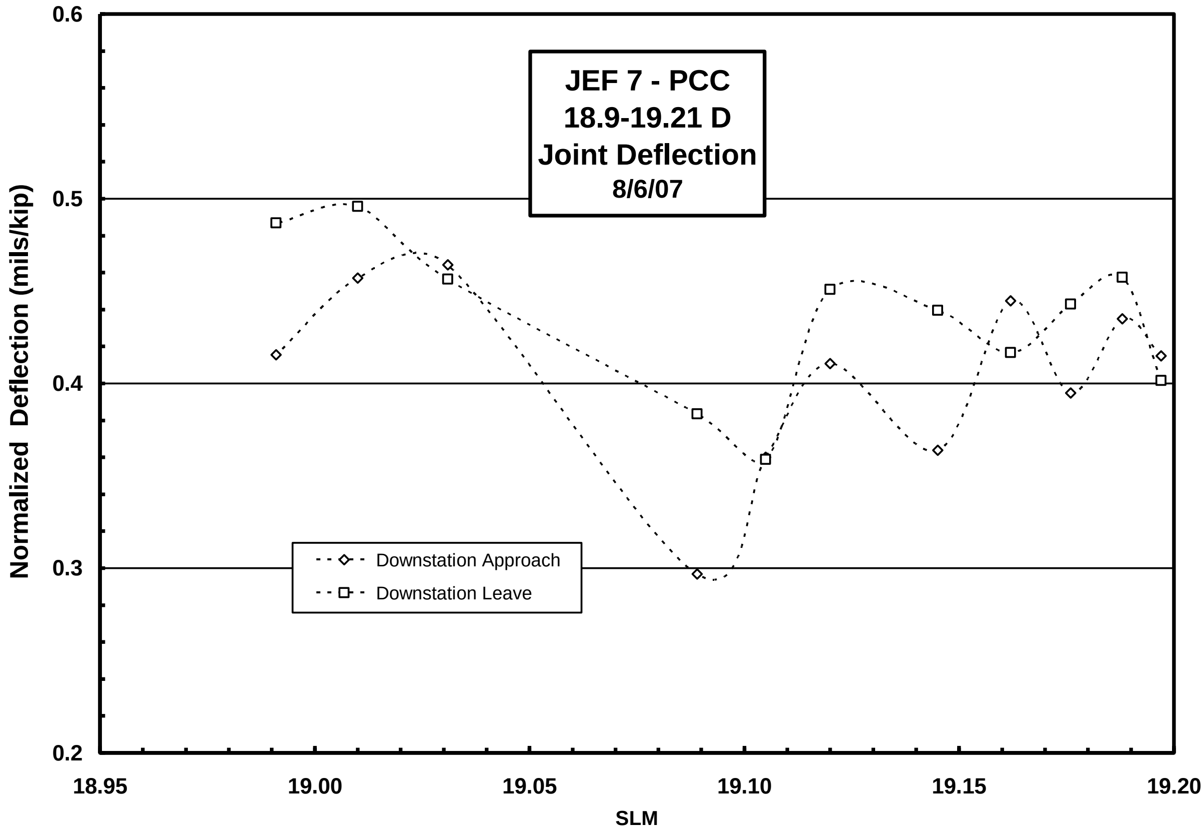


Figure C19a – JEF 7 FWD Midslab Deflection



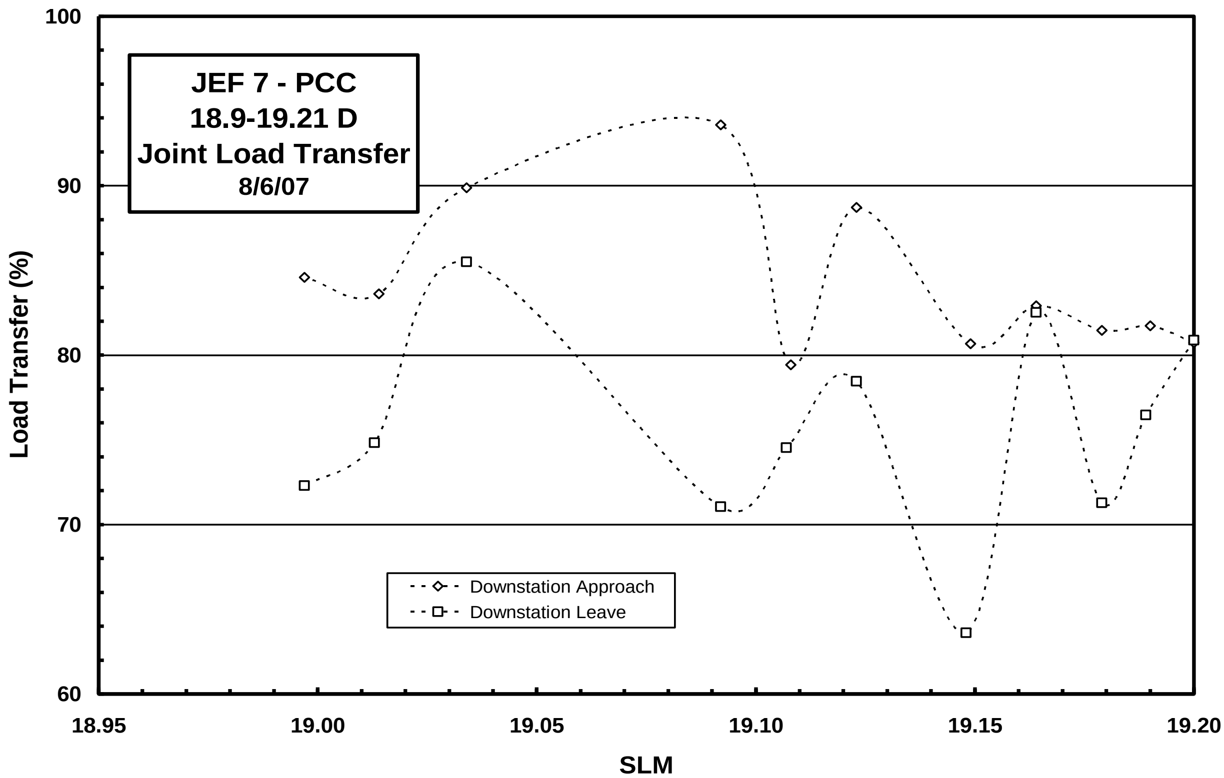
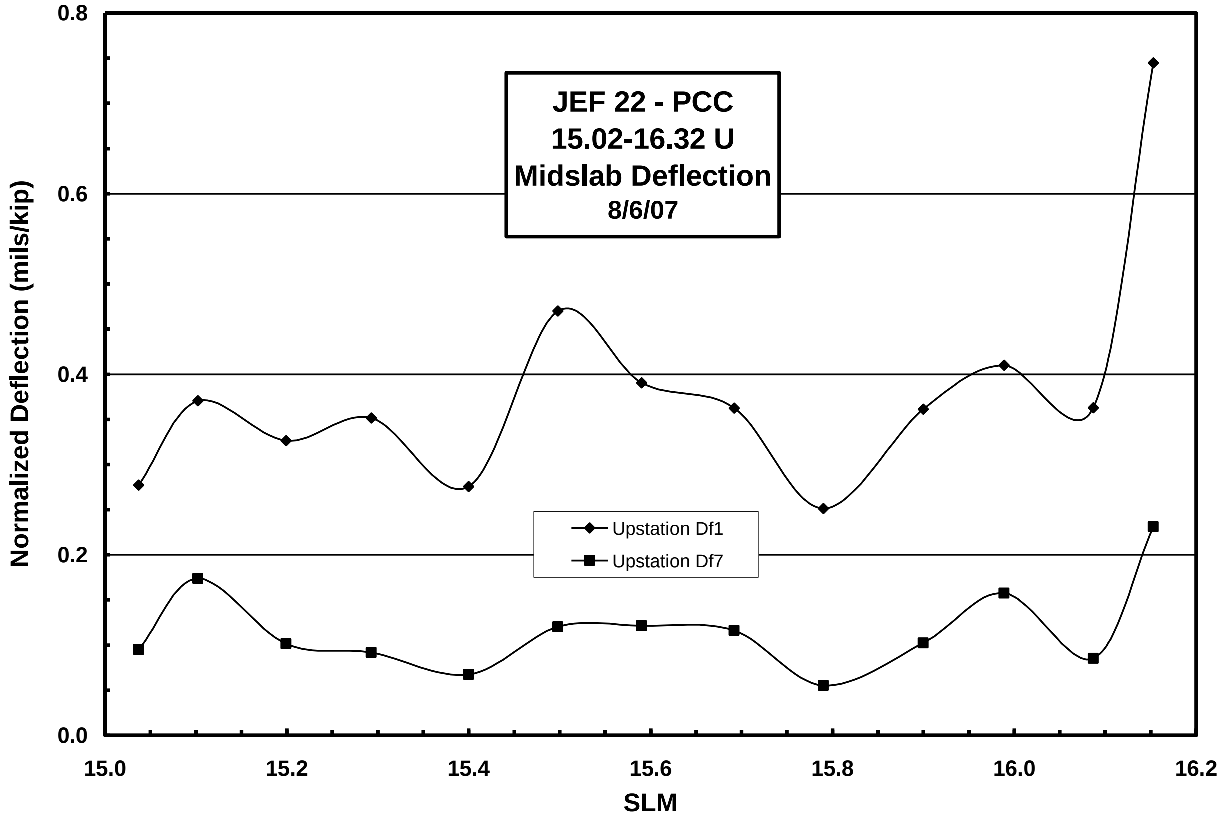


Figure C19b – JEF 7 FWD Joint Deflection



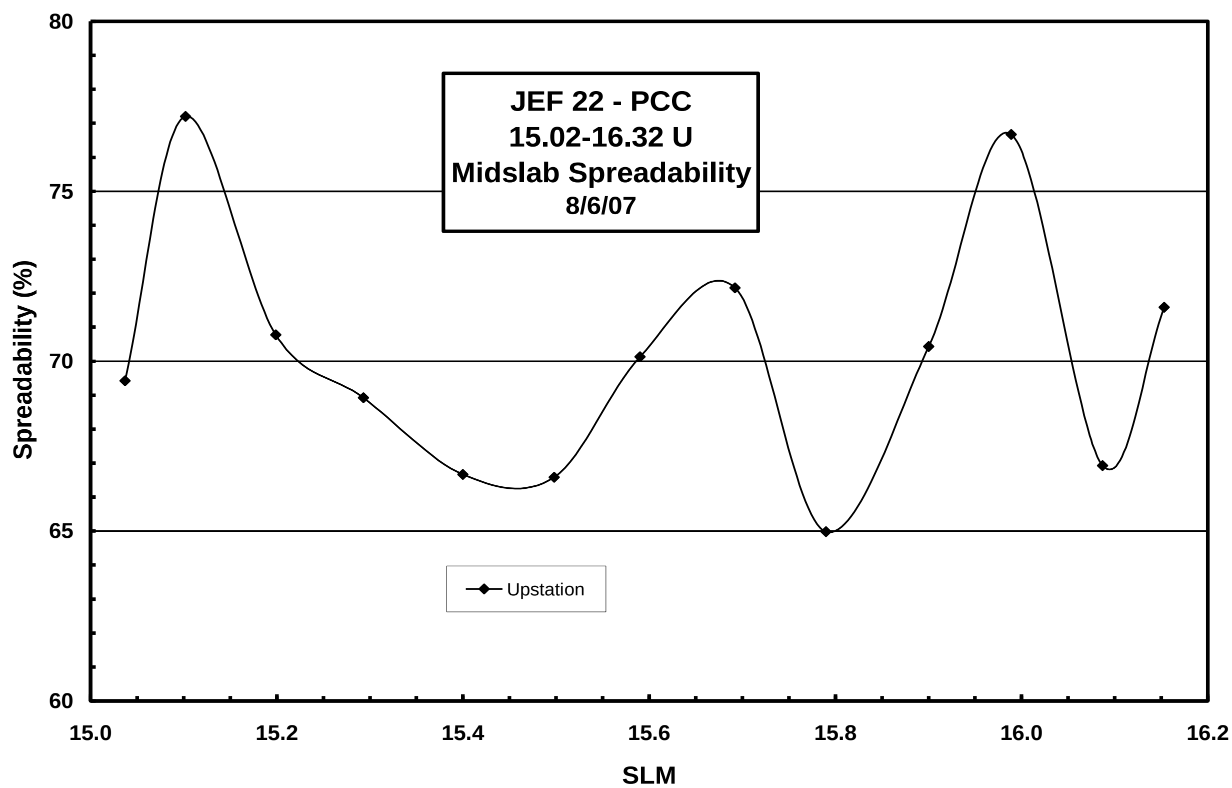
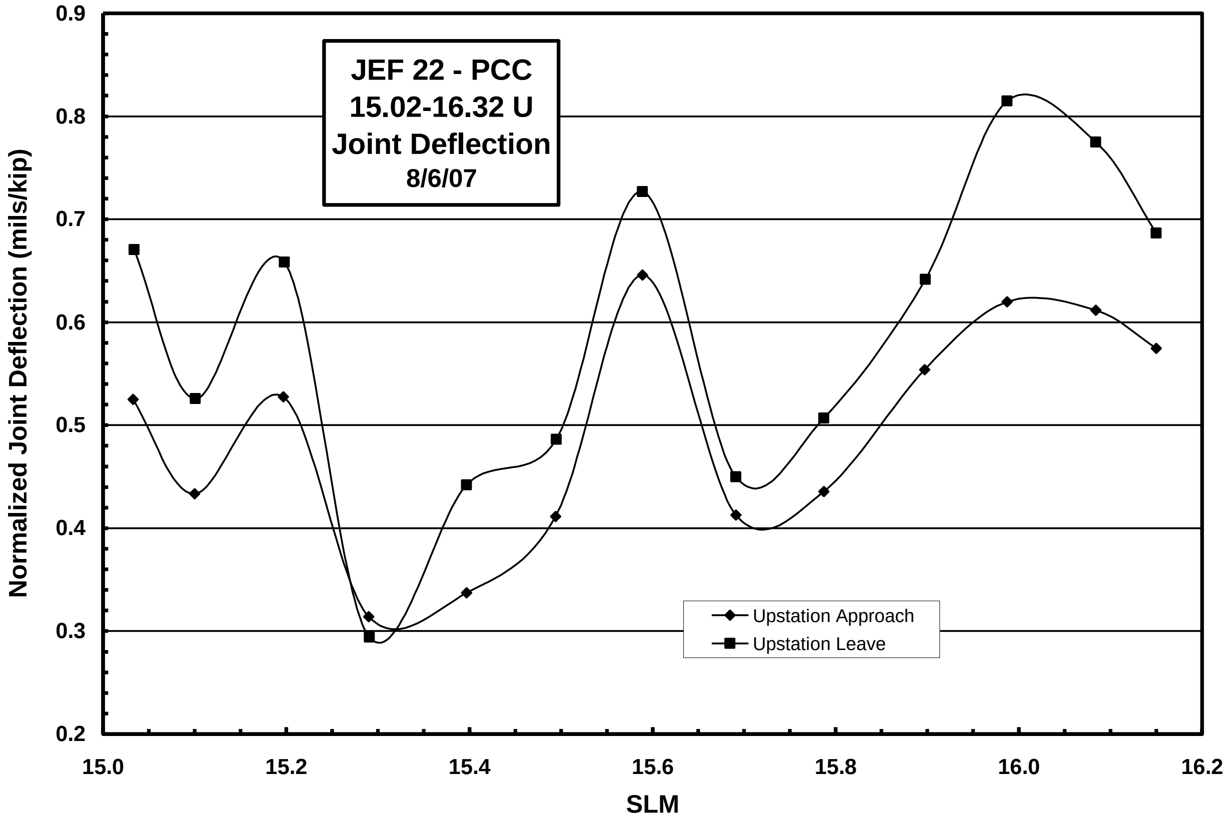


Figure C20a – JEF 22 FWD Midslab Deflection



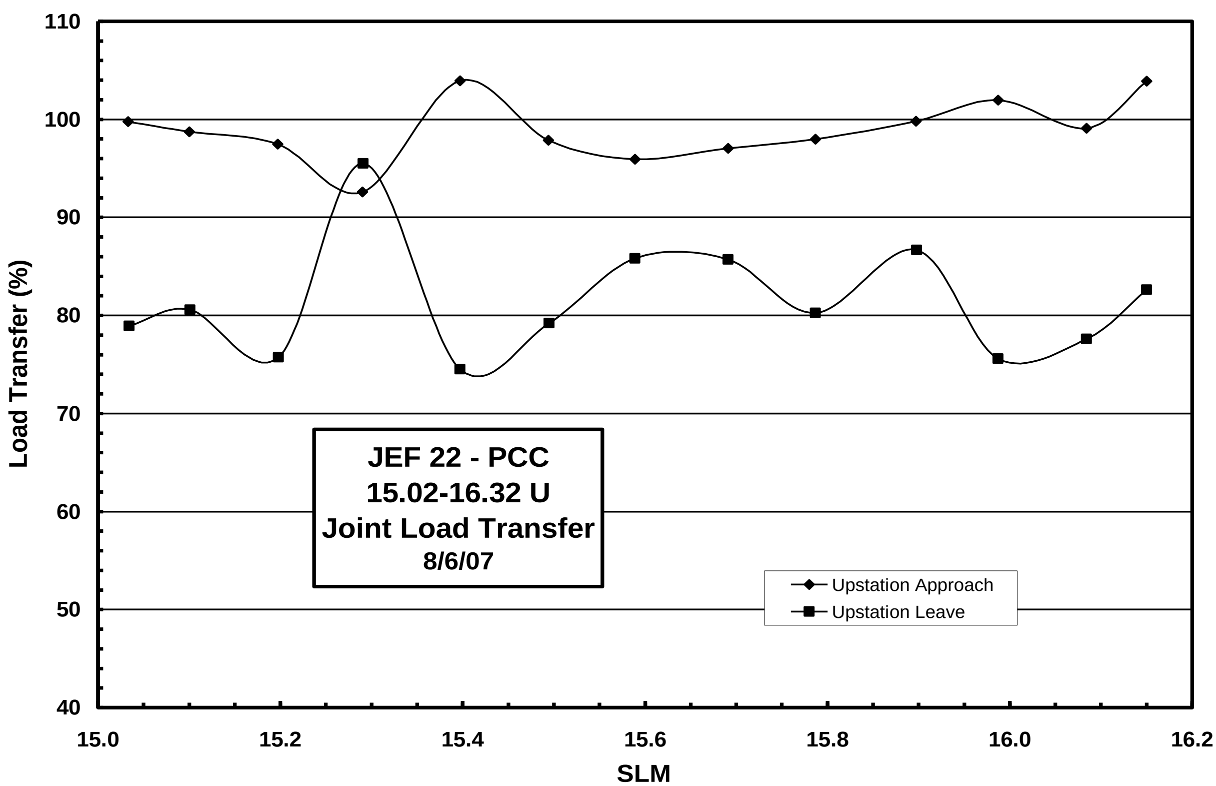
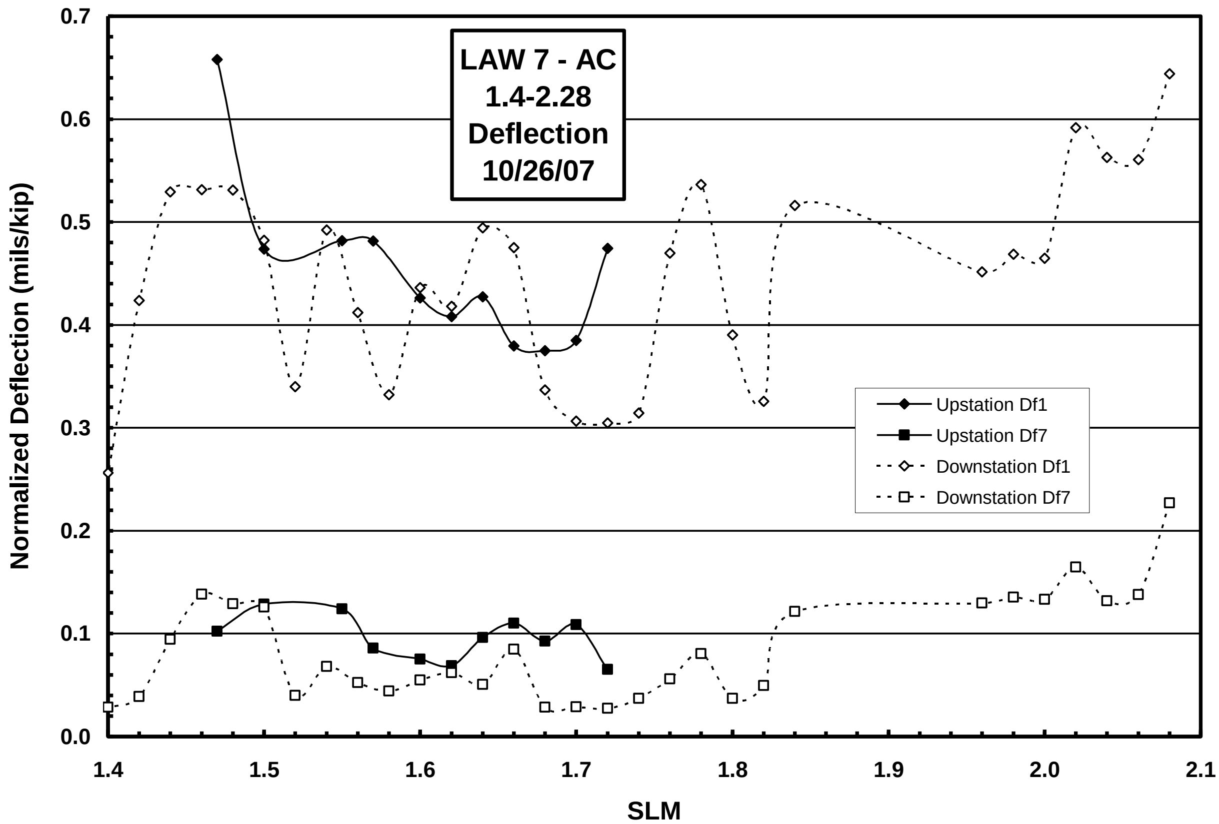


Figure C20b – JEF 22 FWD Joint Deflection



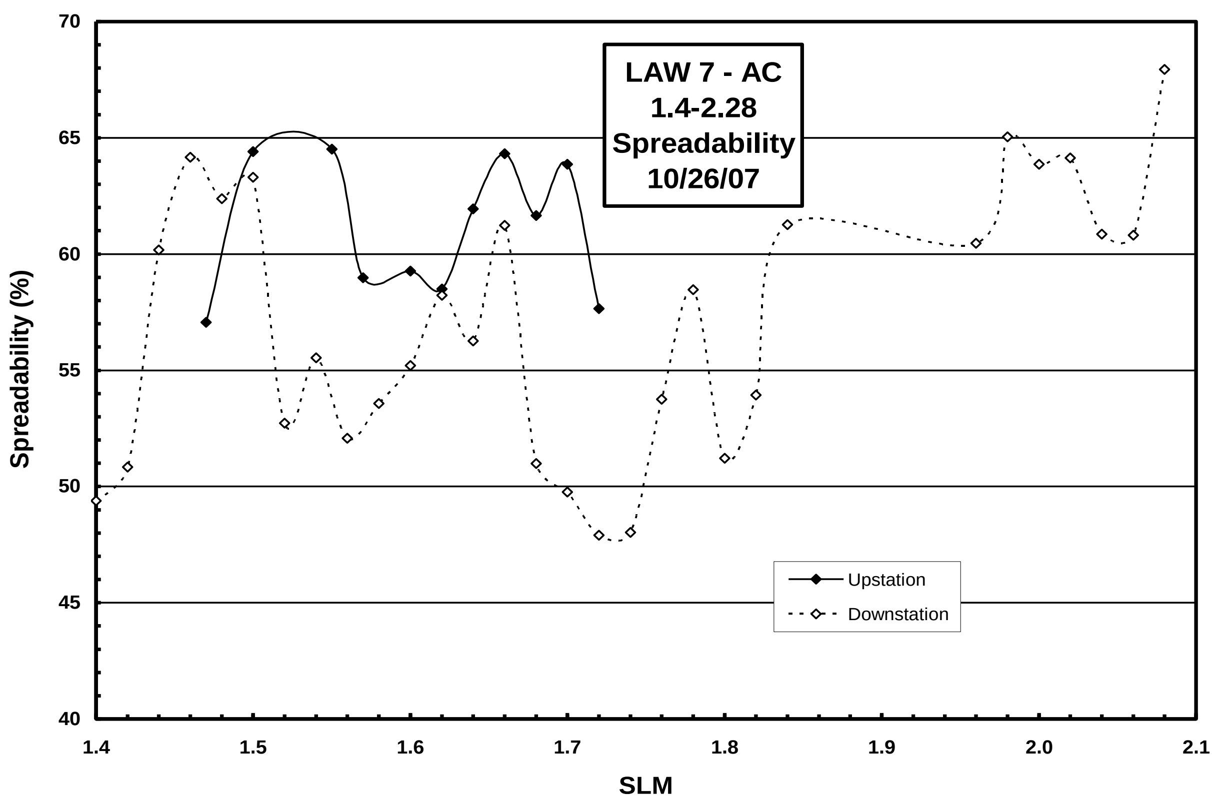
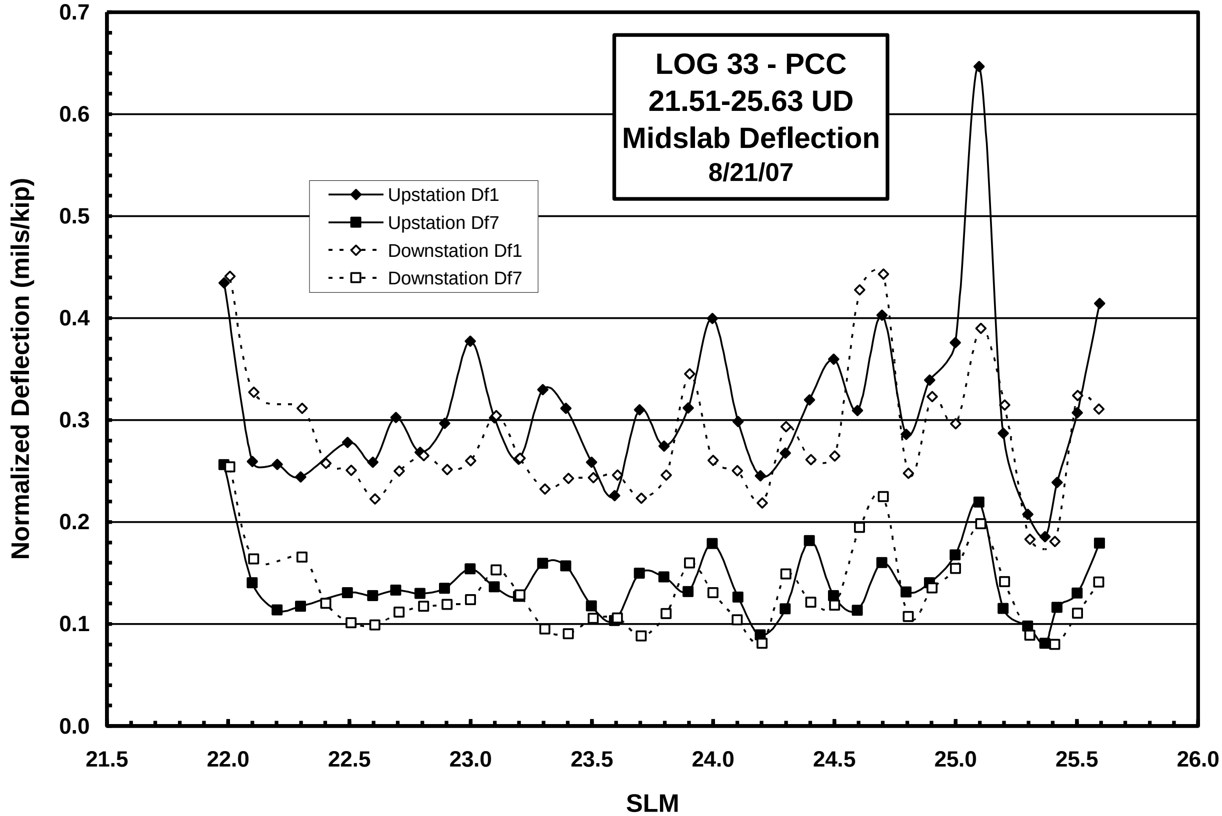


Figure C21 – LAW 7 FWD Deflection



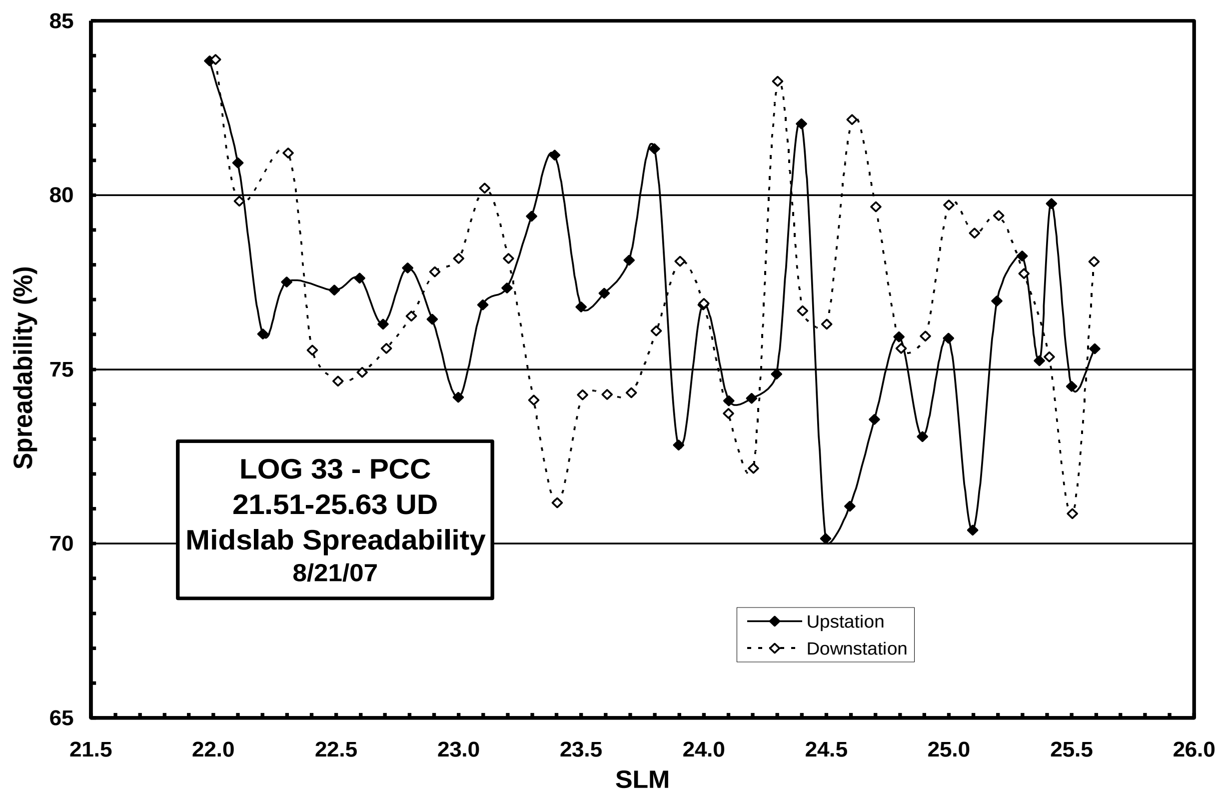
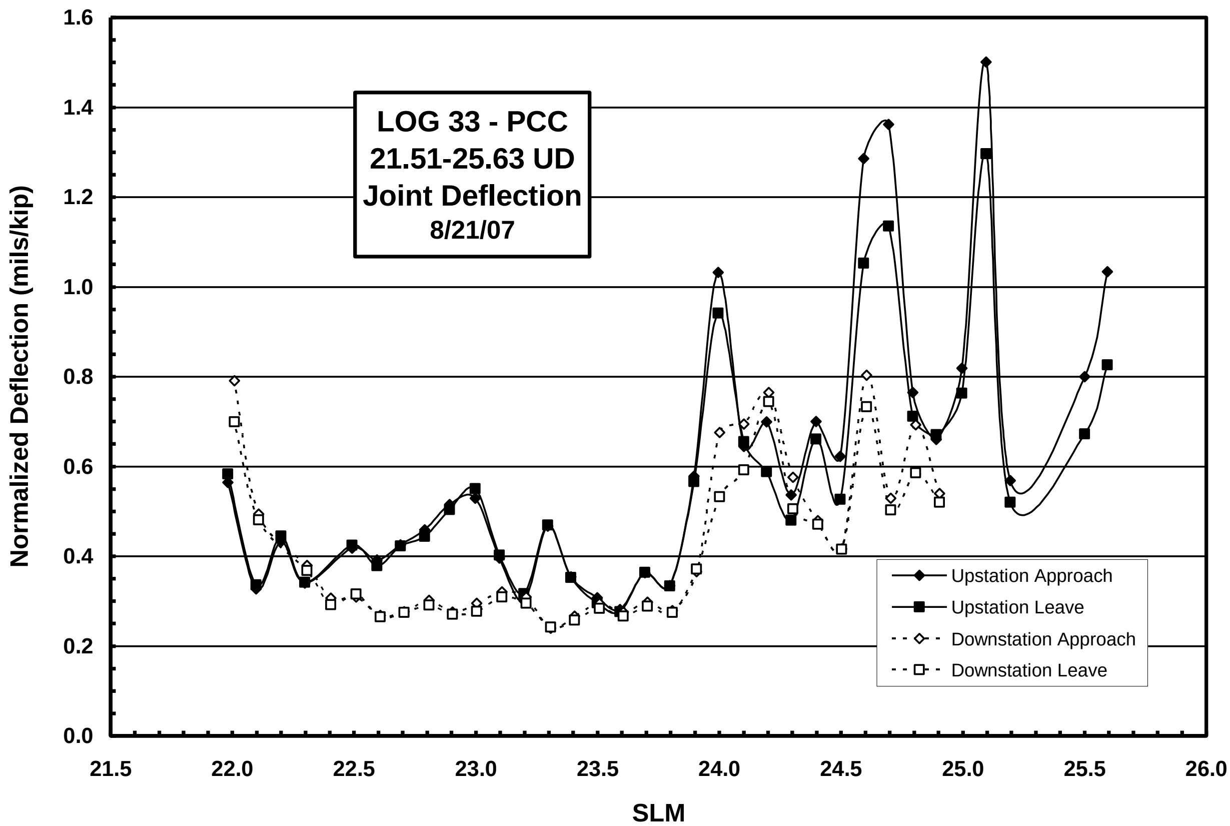


Figure C22a – LOG 33 FWD Midslab Deflection



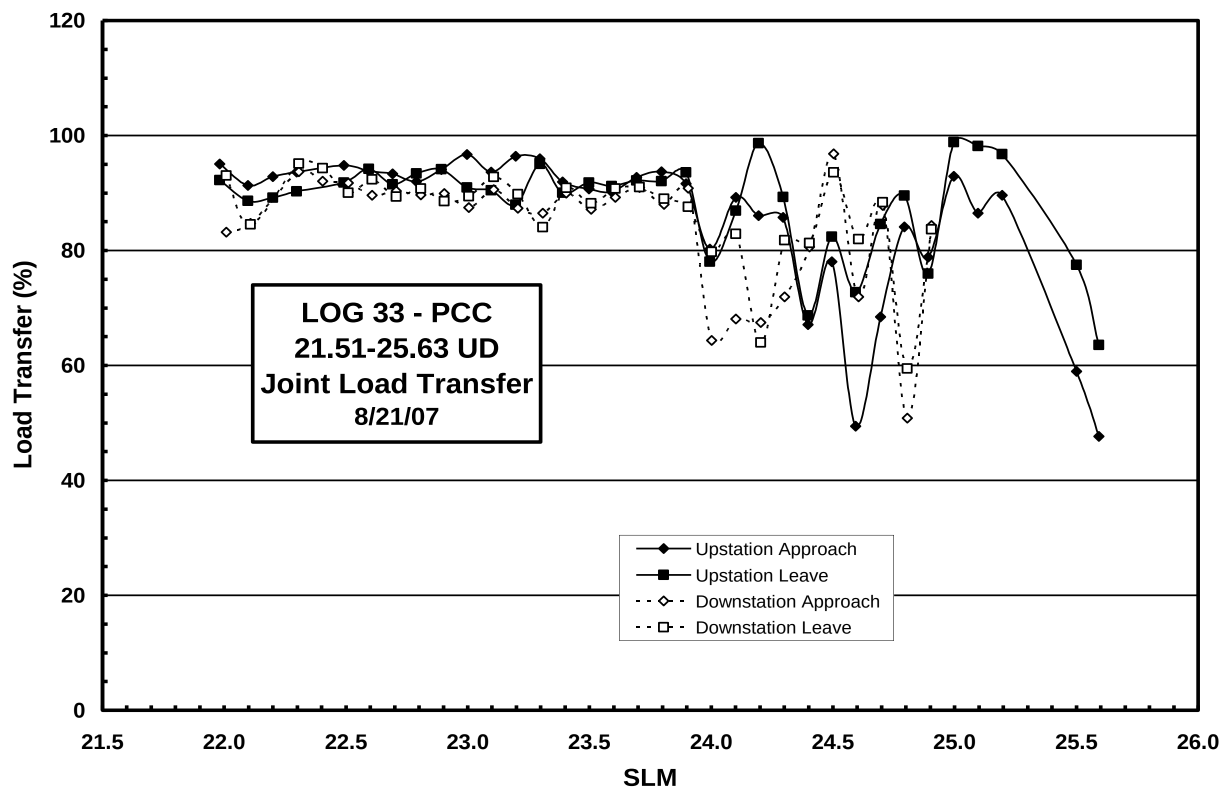
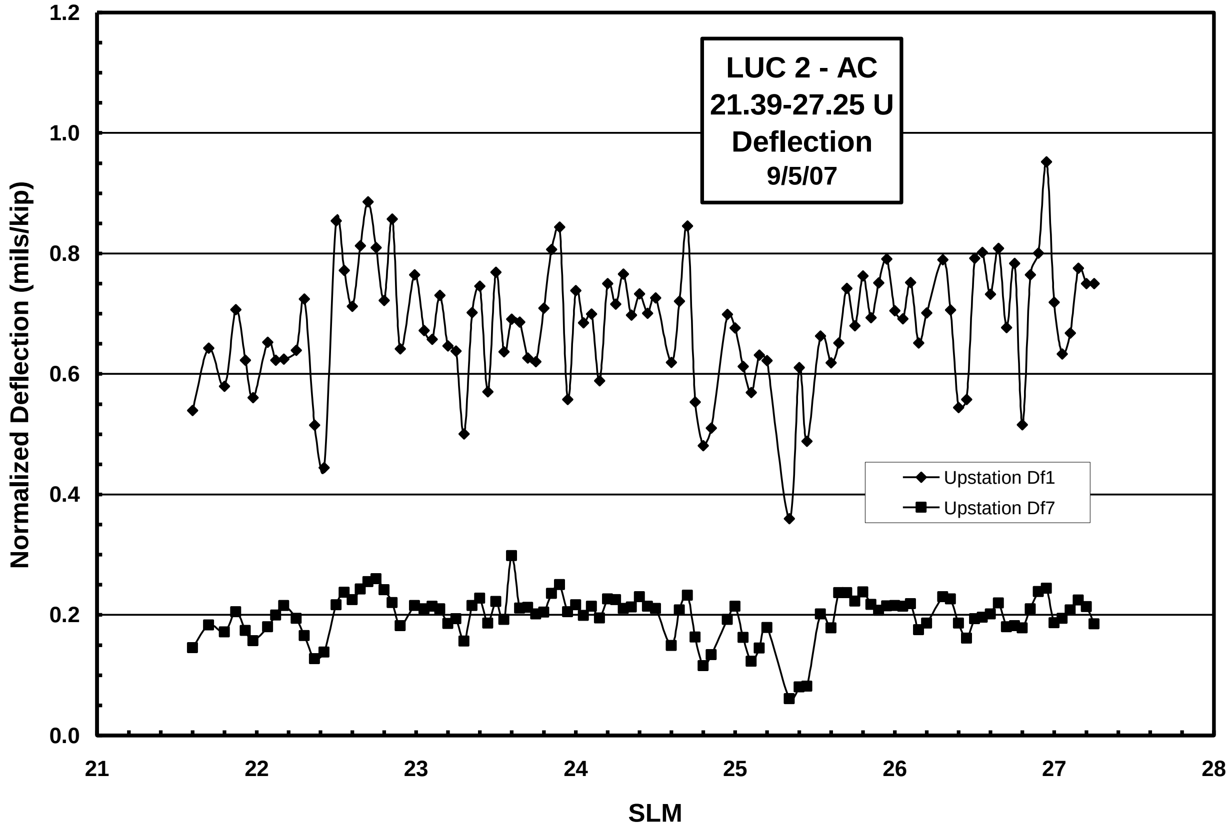


Figure C22b – LOG 33 FWD Joint Deflection



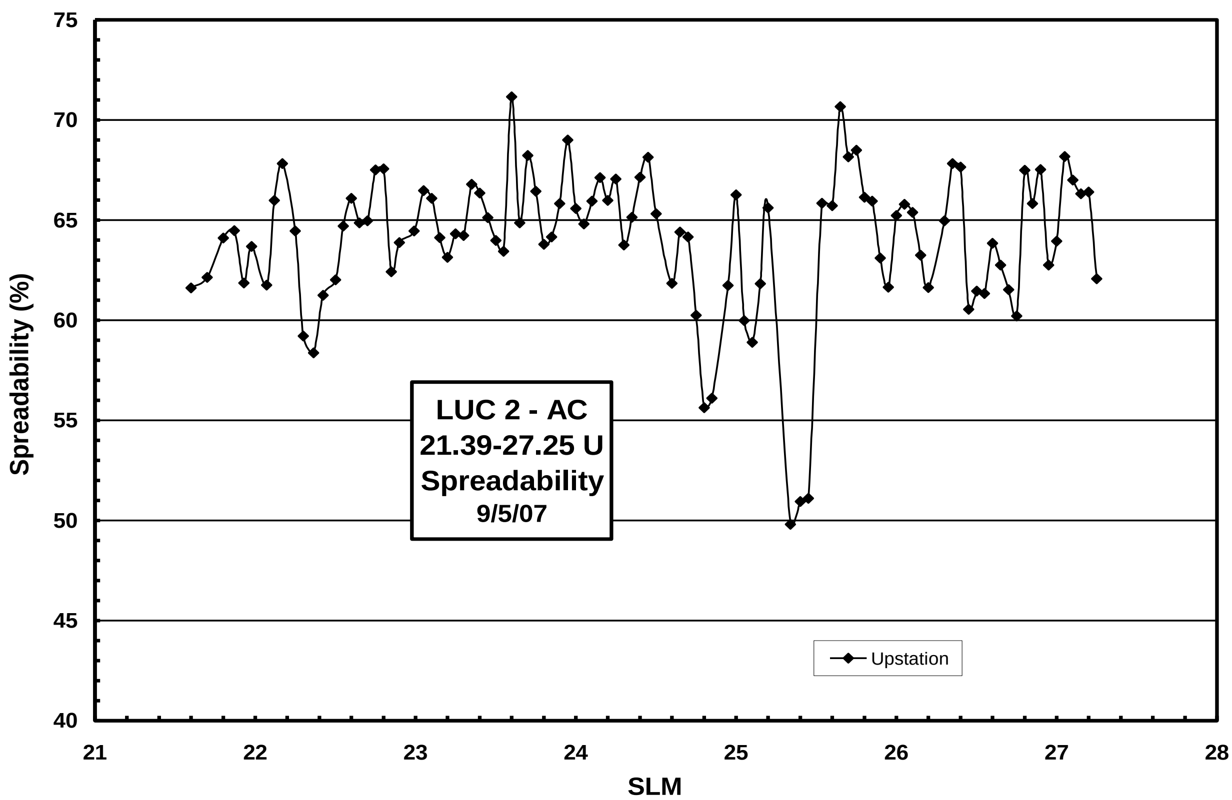
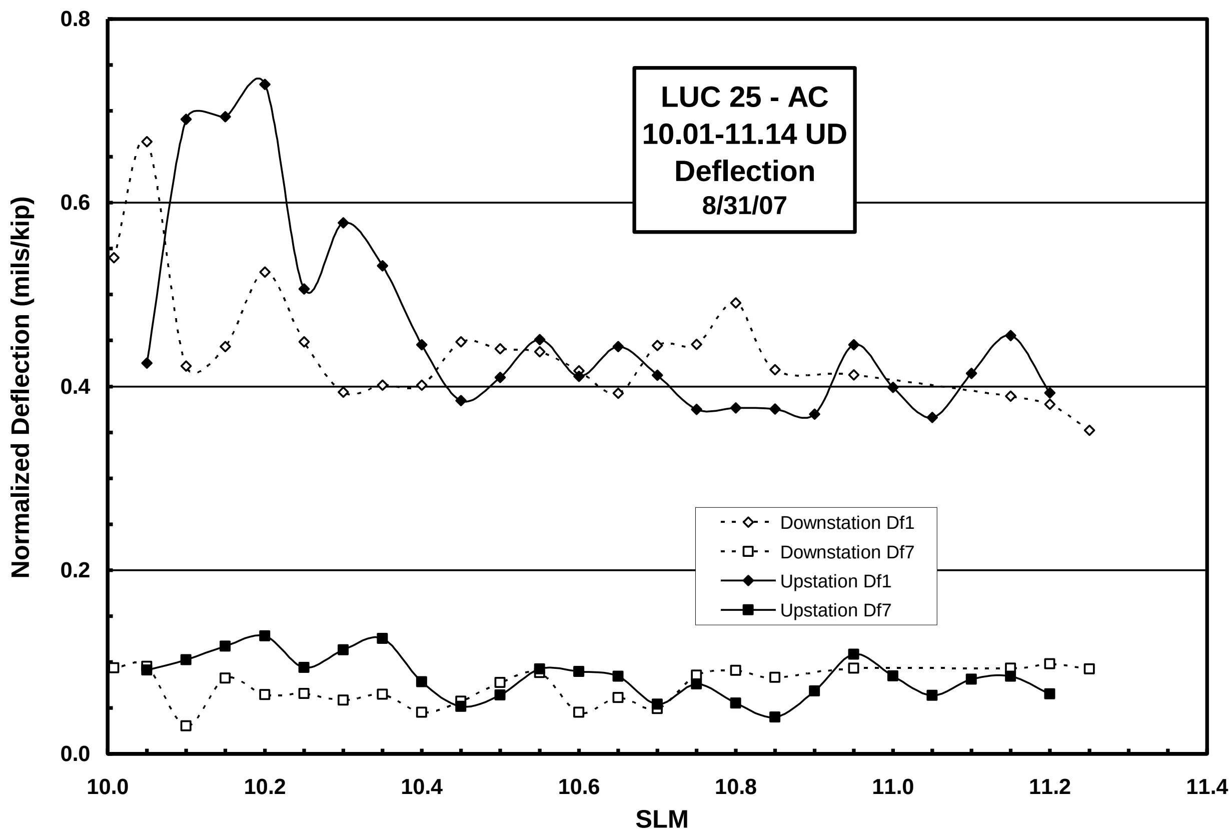


Figure C23 – LUC 2 FWD Deflection



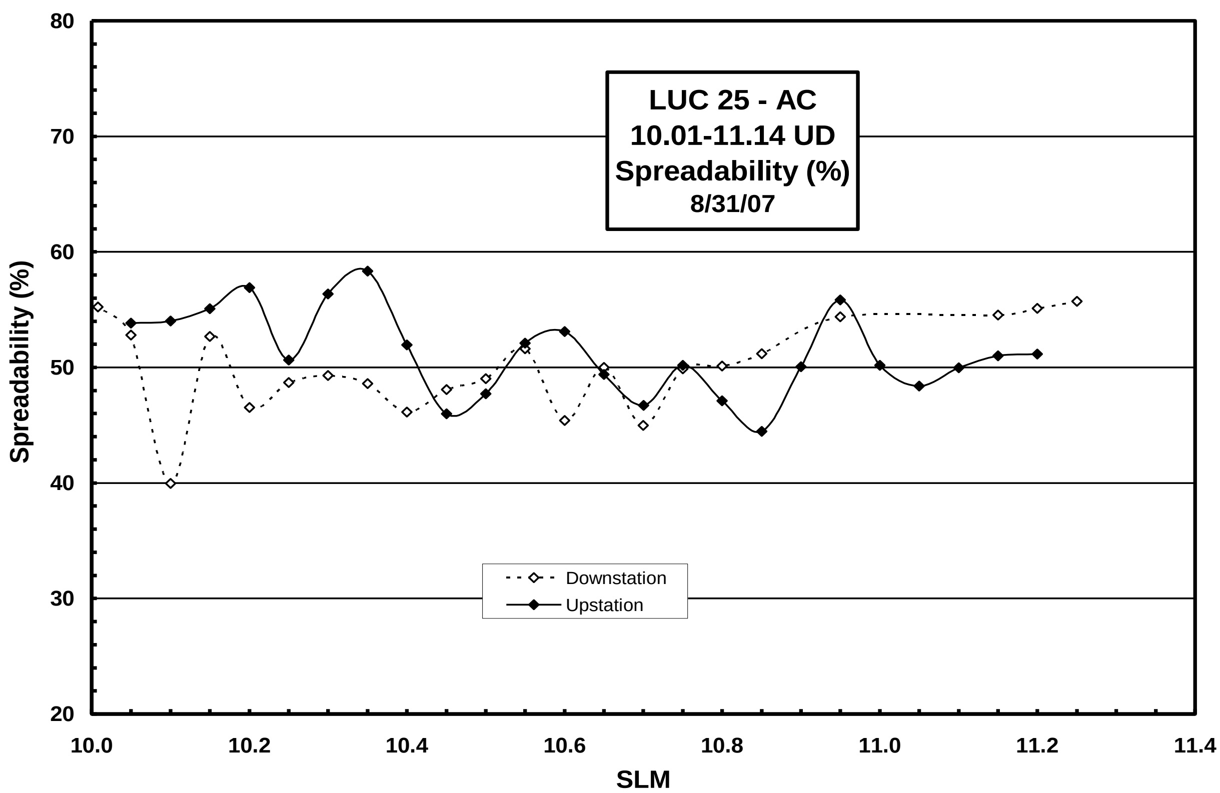
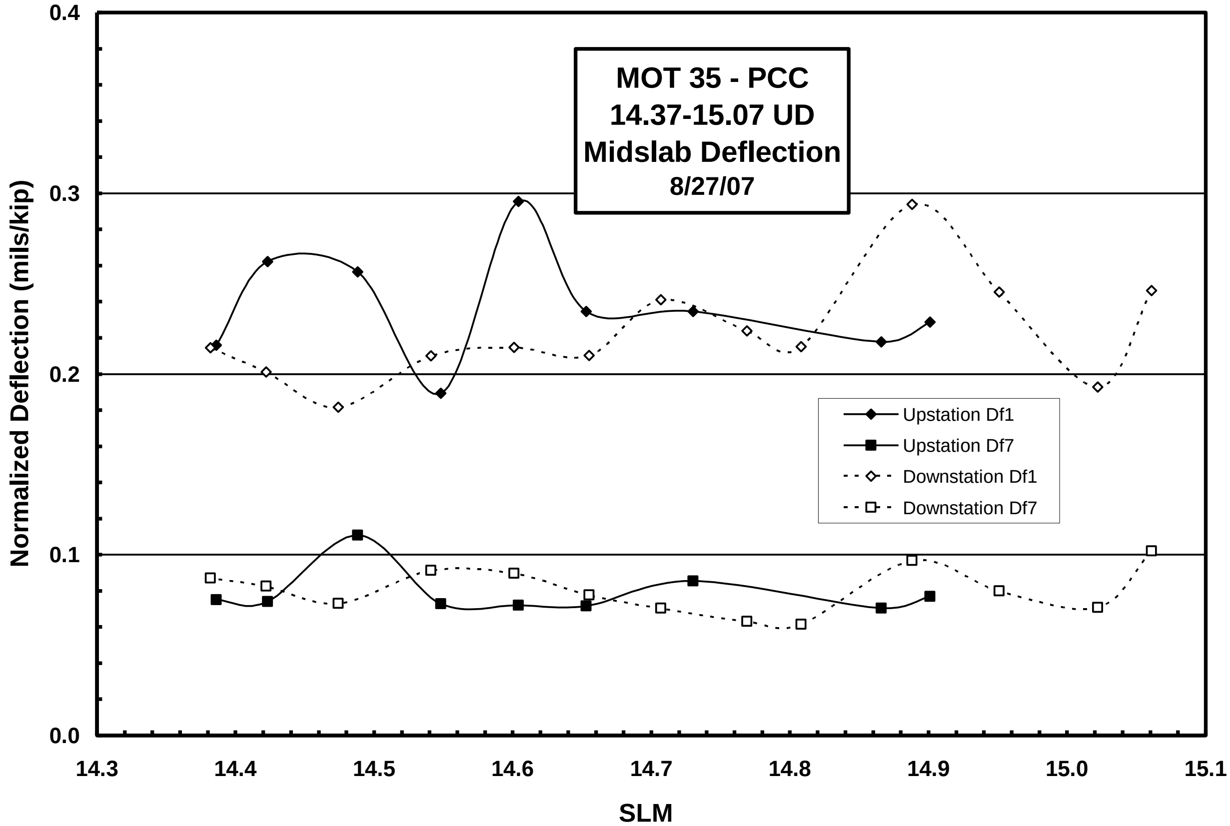


Figure C24 – LUC 25 FWD Deflection



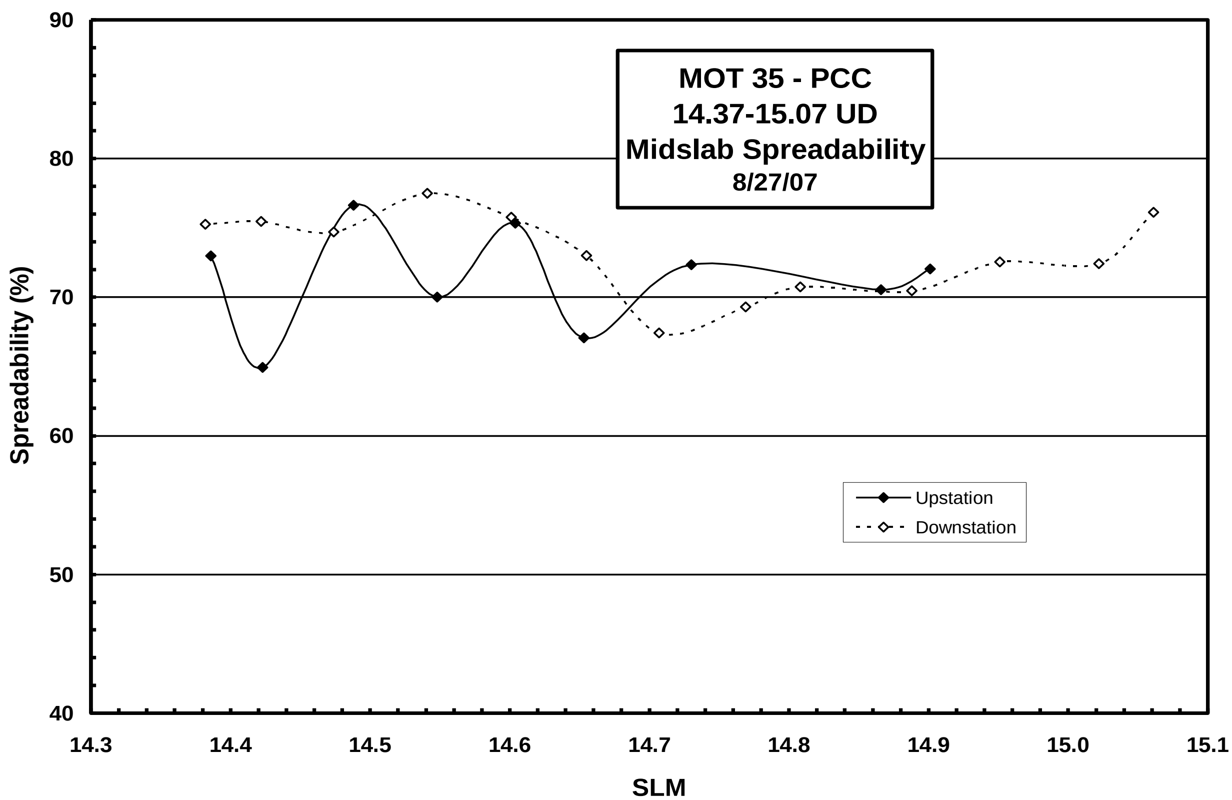
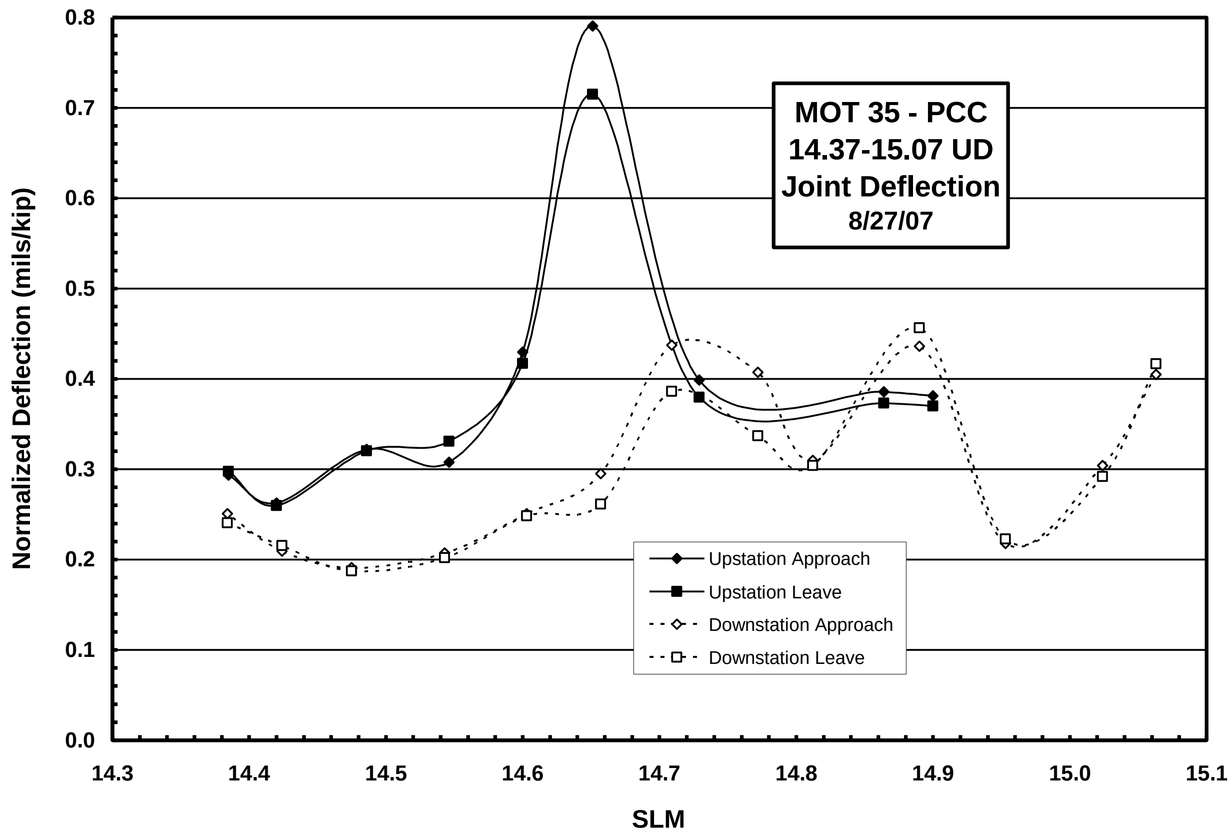


Figure C25a – MOT 35 FWD Midslab Deflection



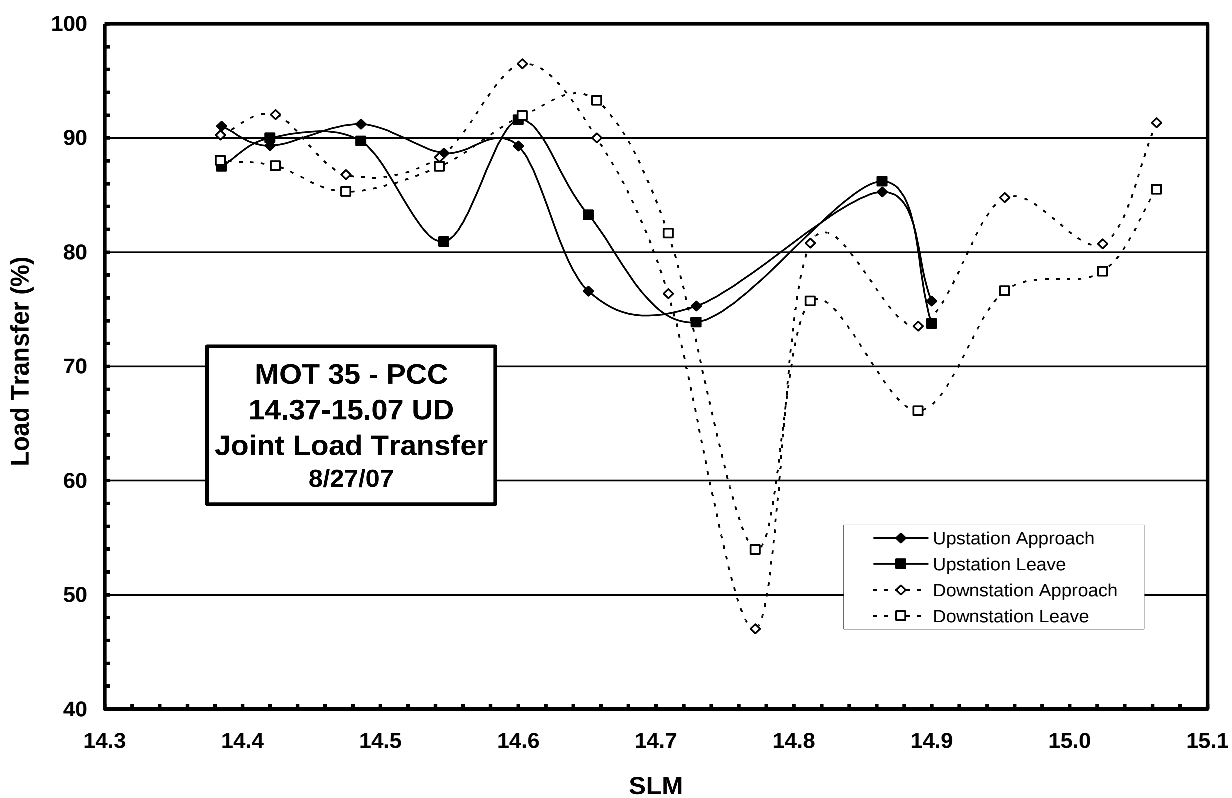
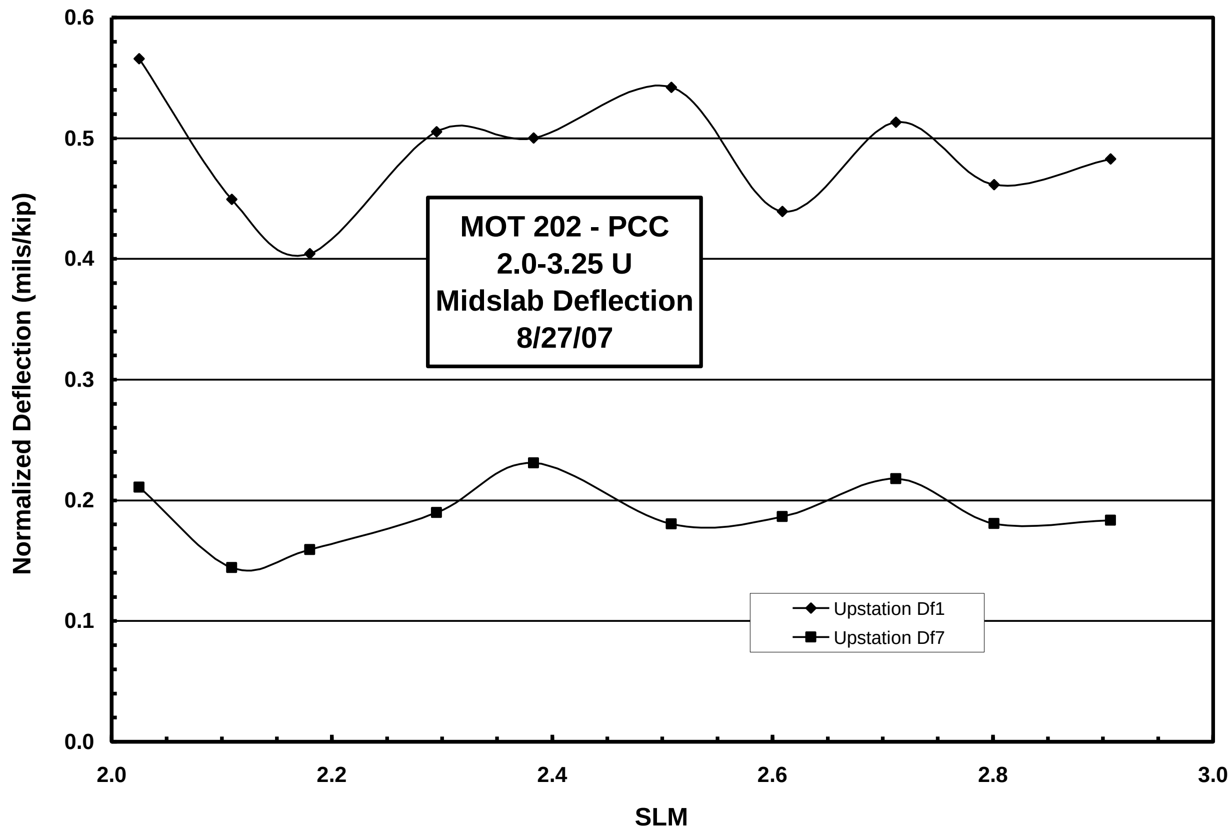


Figure C25b – MOT 35 FWD Joint Deflection



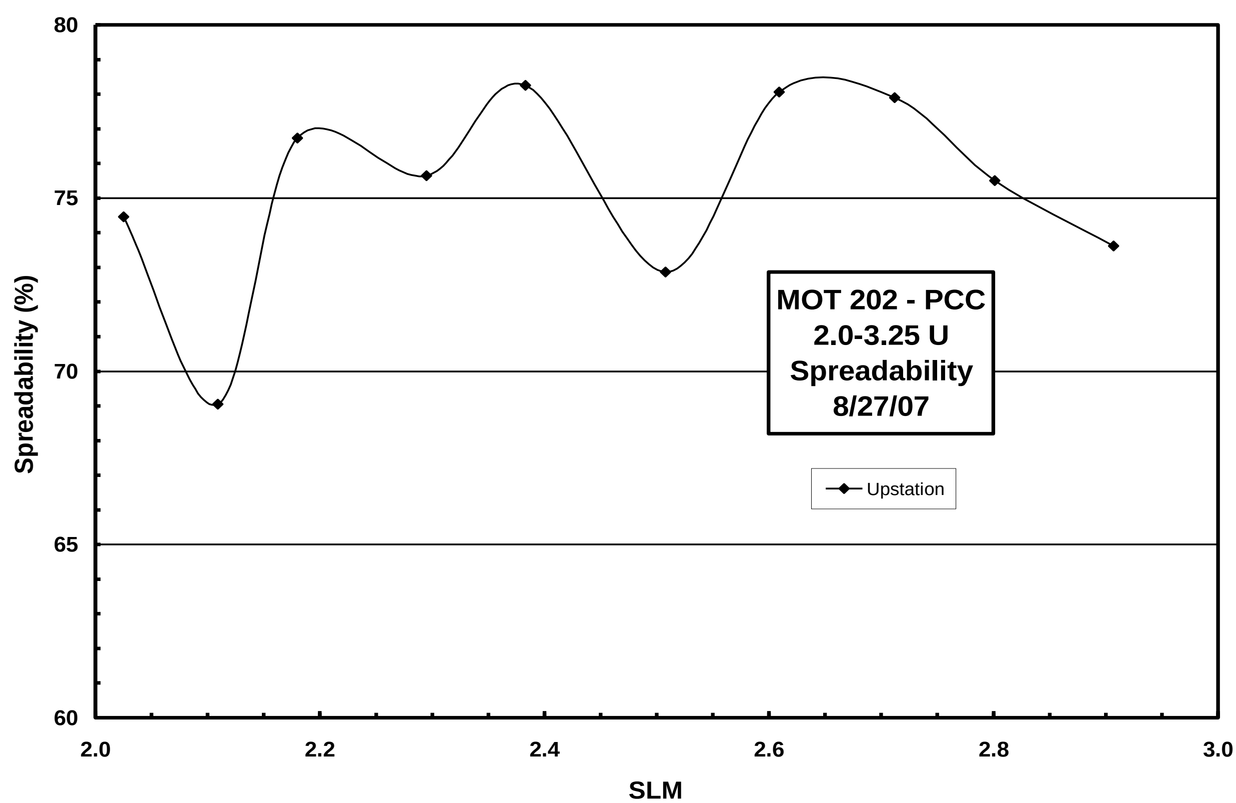
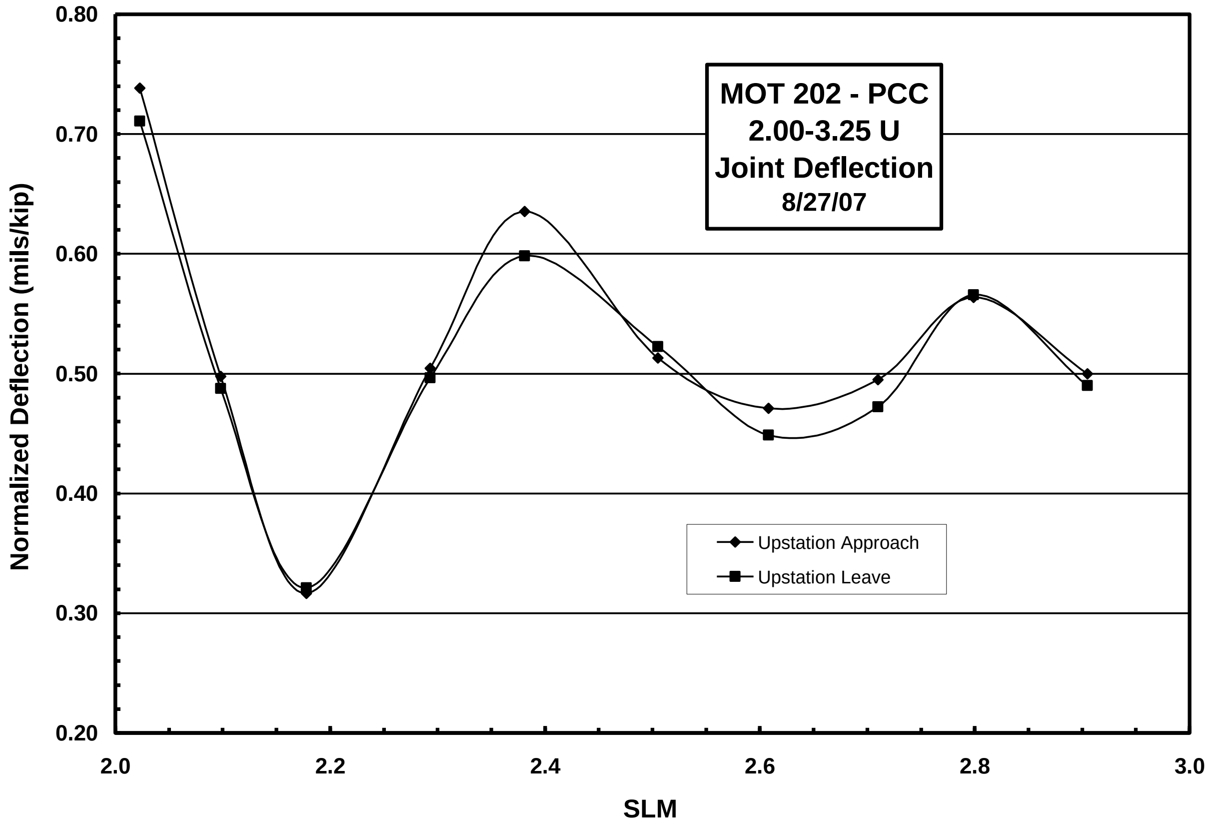


Figure C26a – MOT 202 FWD Midslab Deflection



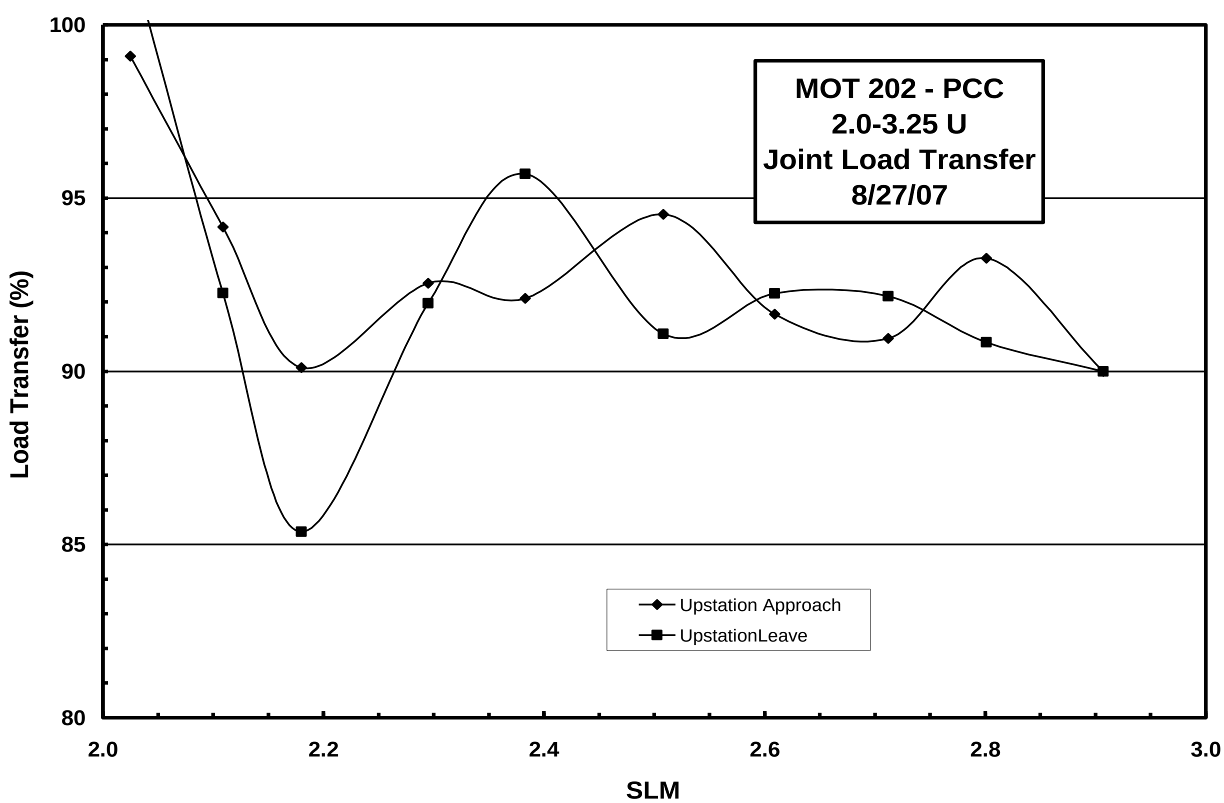
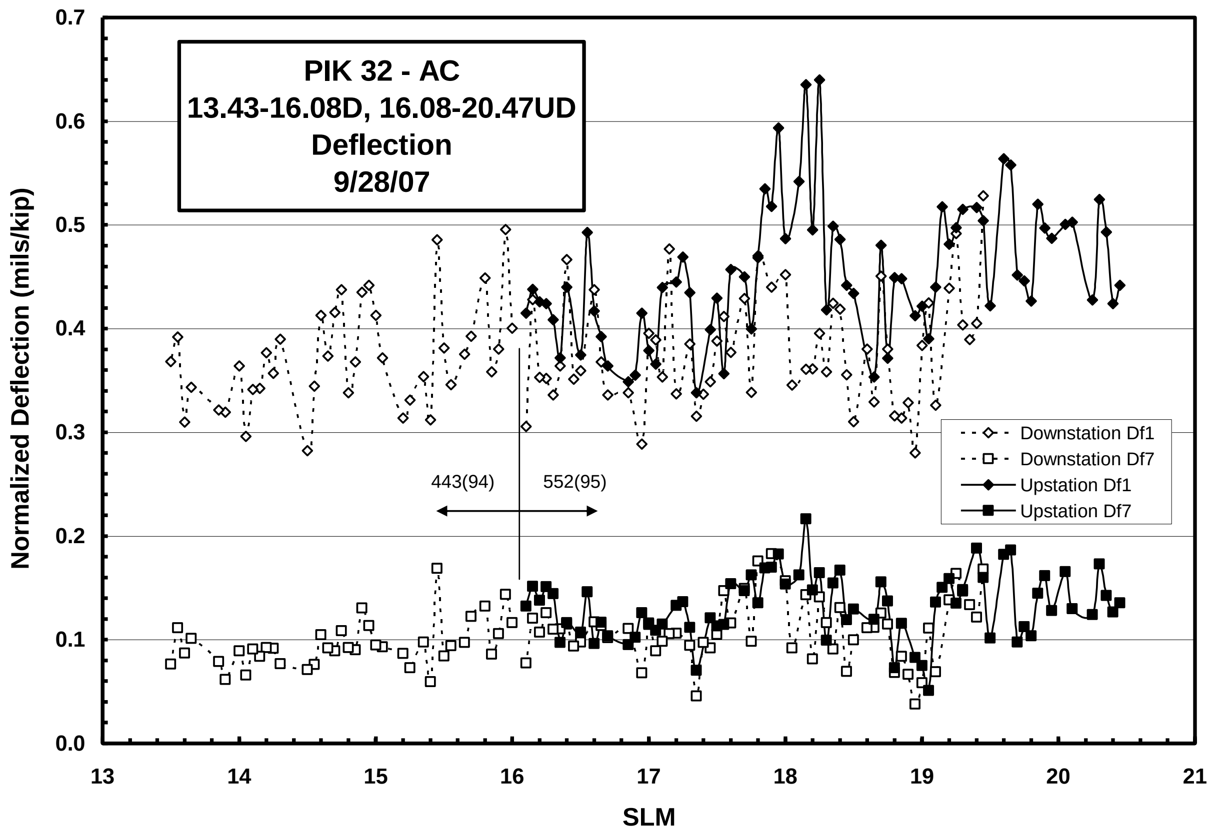


Figure C26b – MOT 202 FWD Joint Deflection



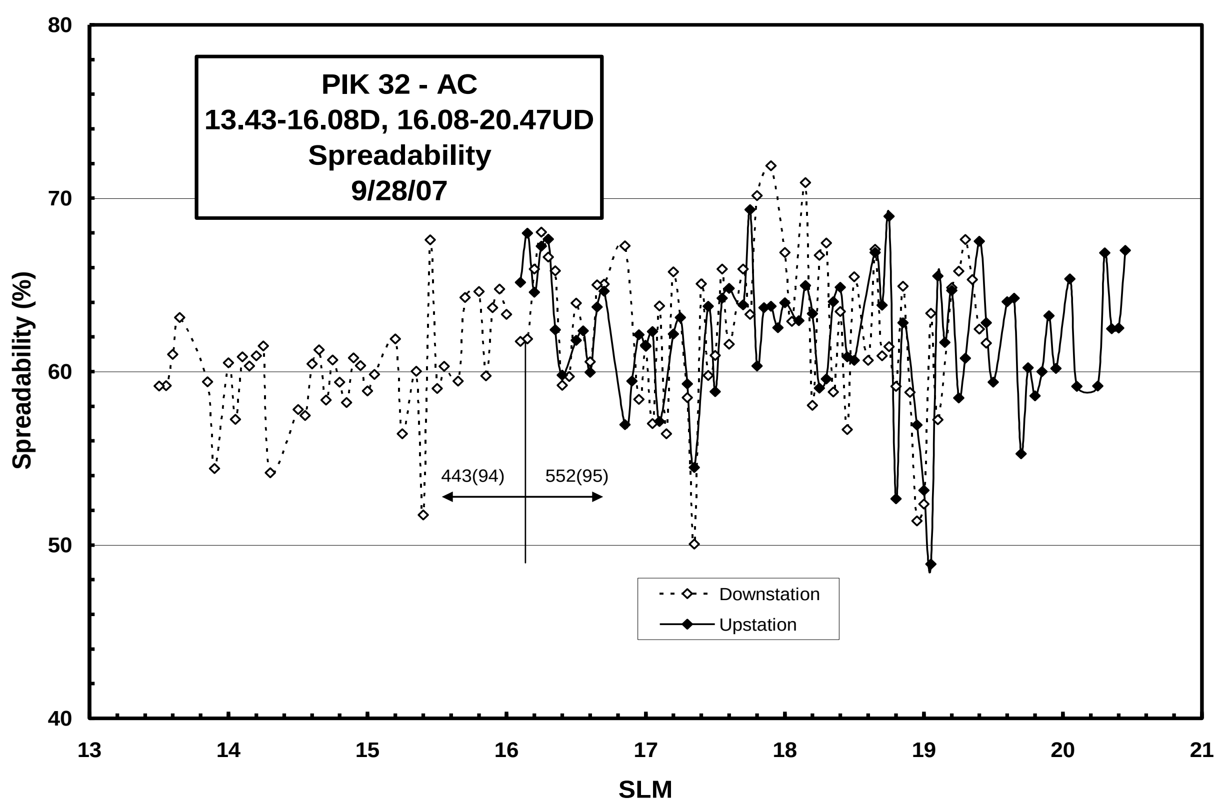
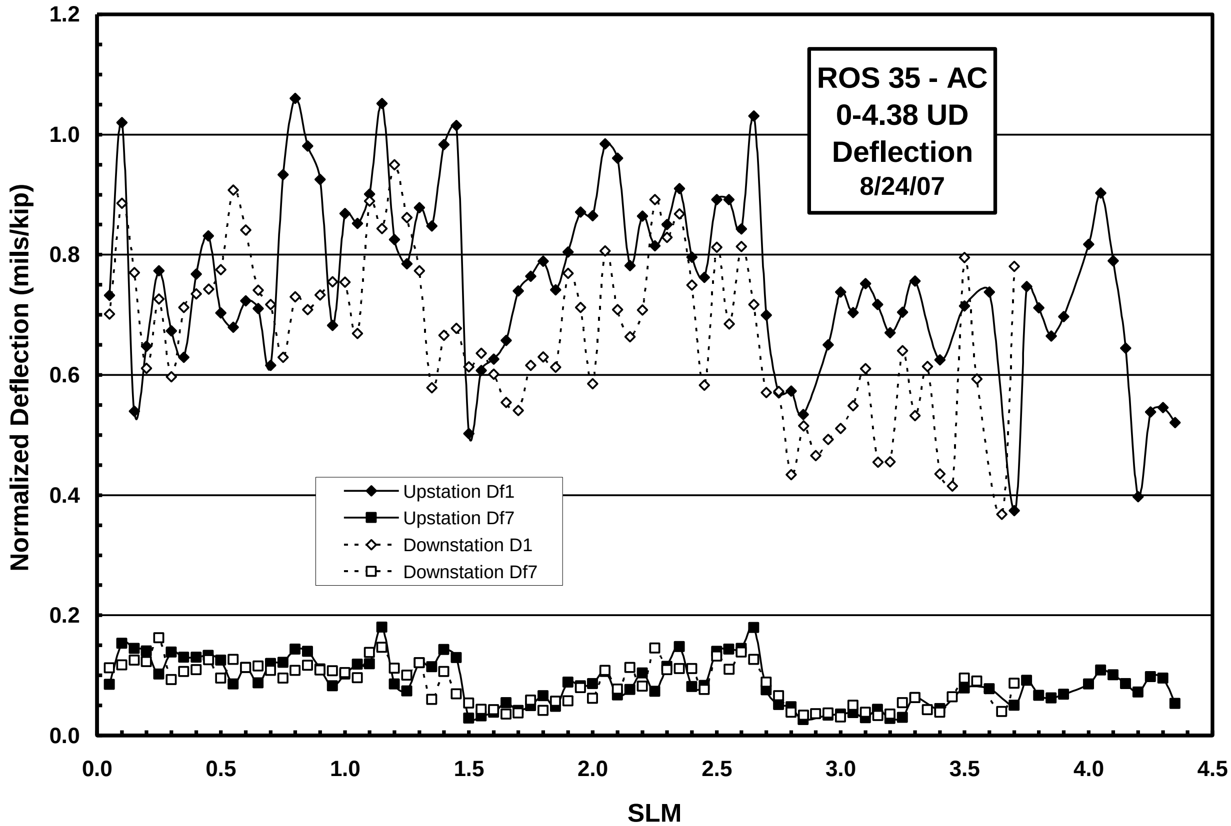


Figure C27 – PIK 32 FWD Deflection



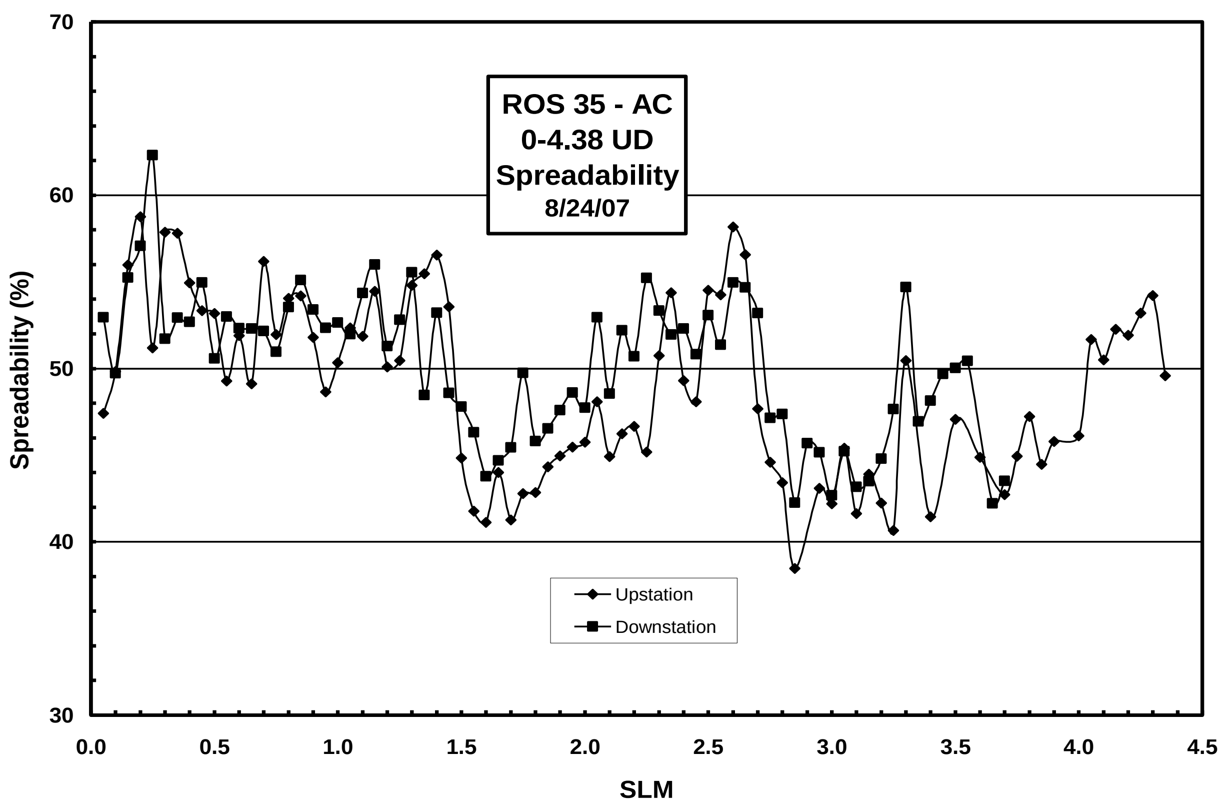
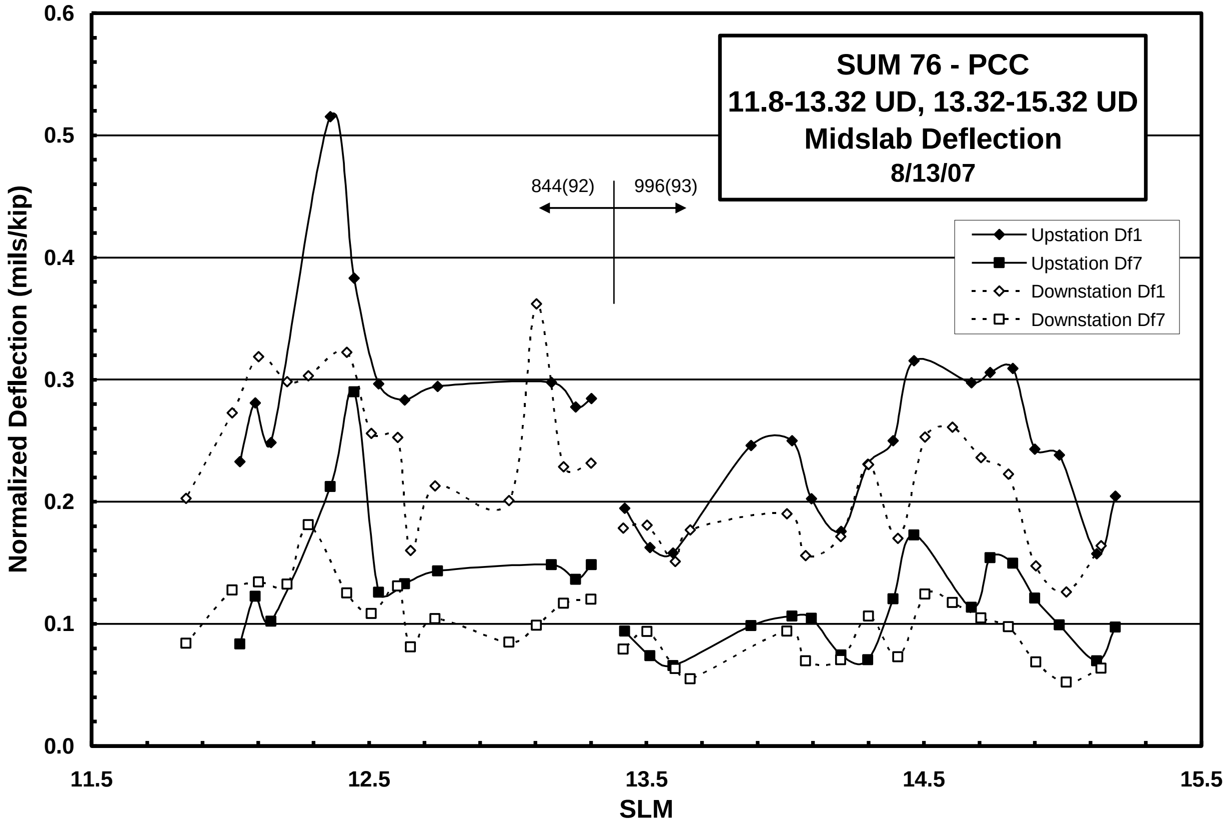


Figure C28 – ROS 35 FWD Deflection



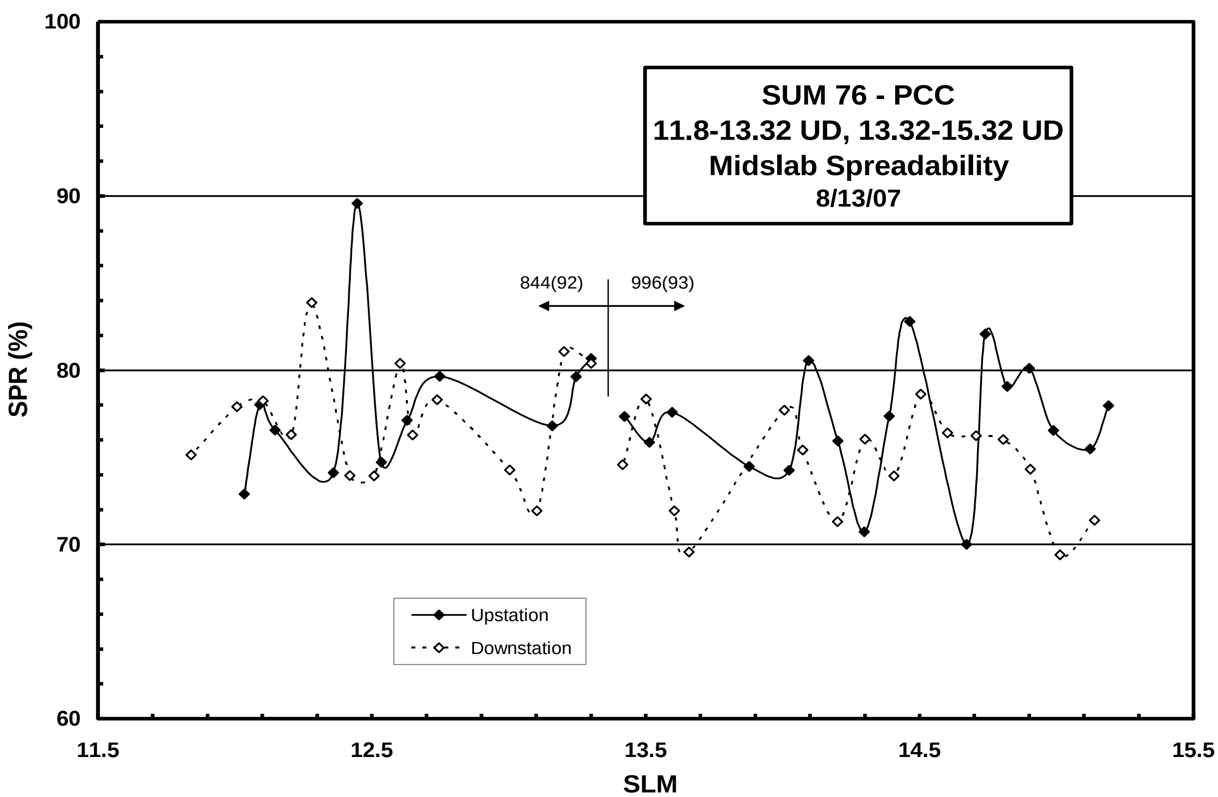
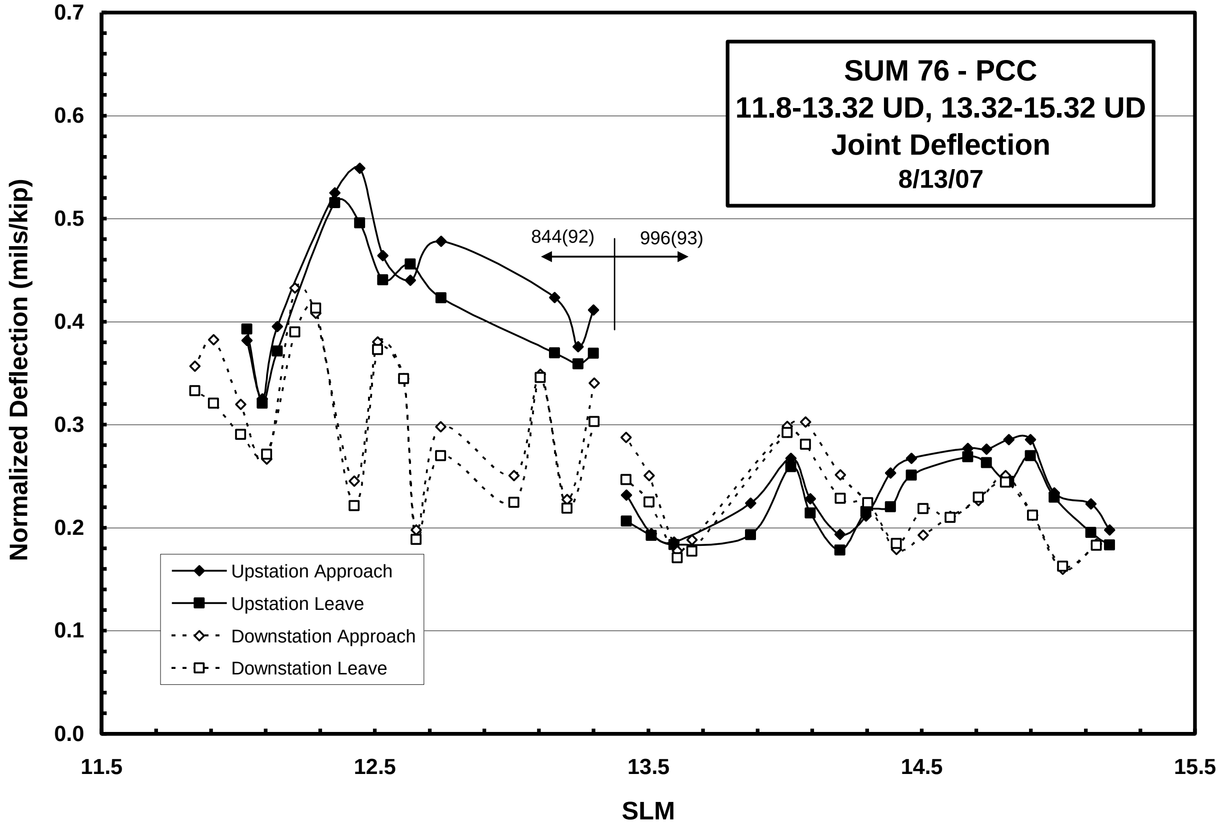


Figure C29a – SUM 76 FWD Midslab Deflection



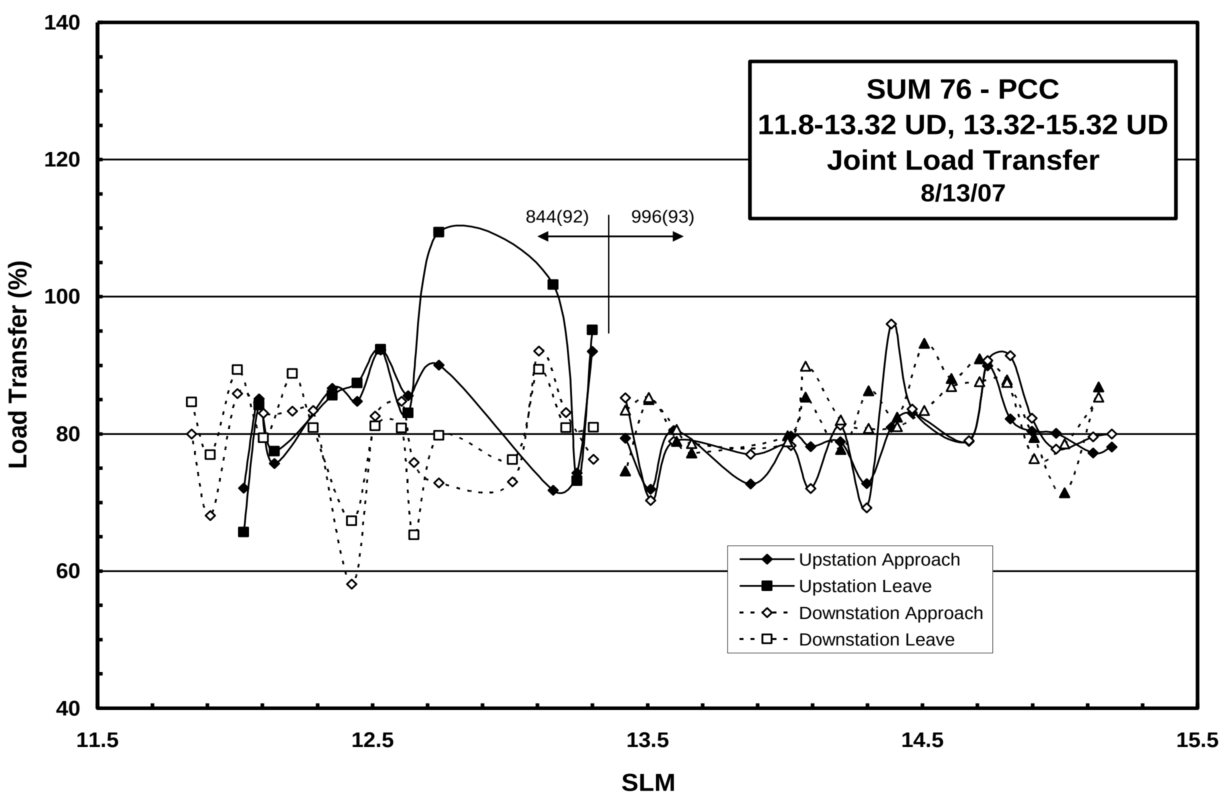
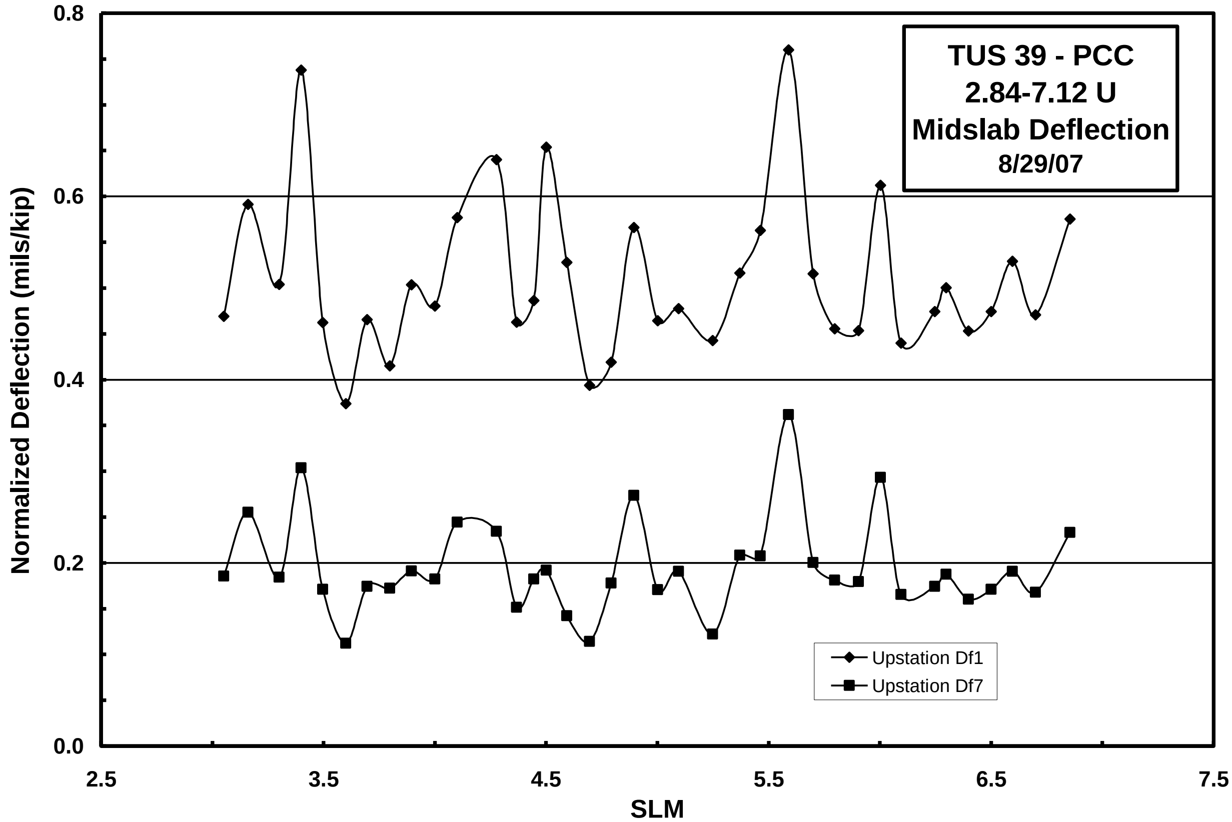


Figure C29b – SUM 76 FWD Joint Deflection



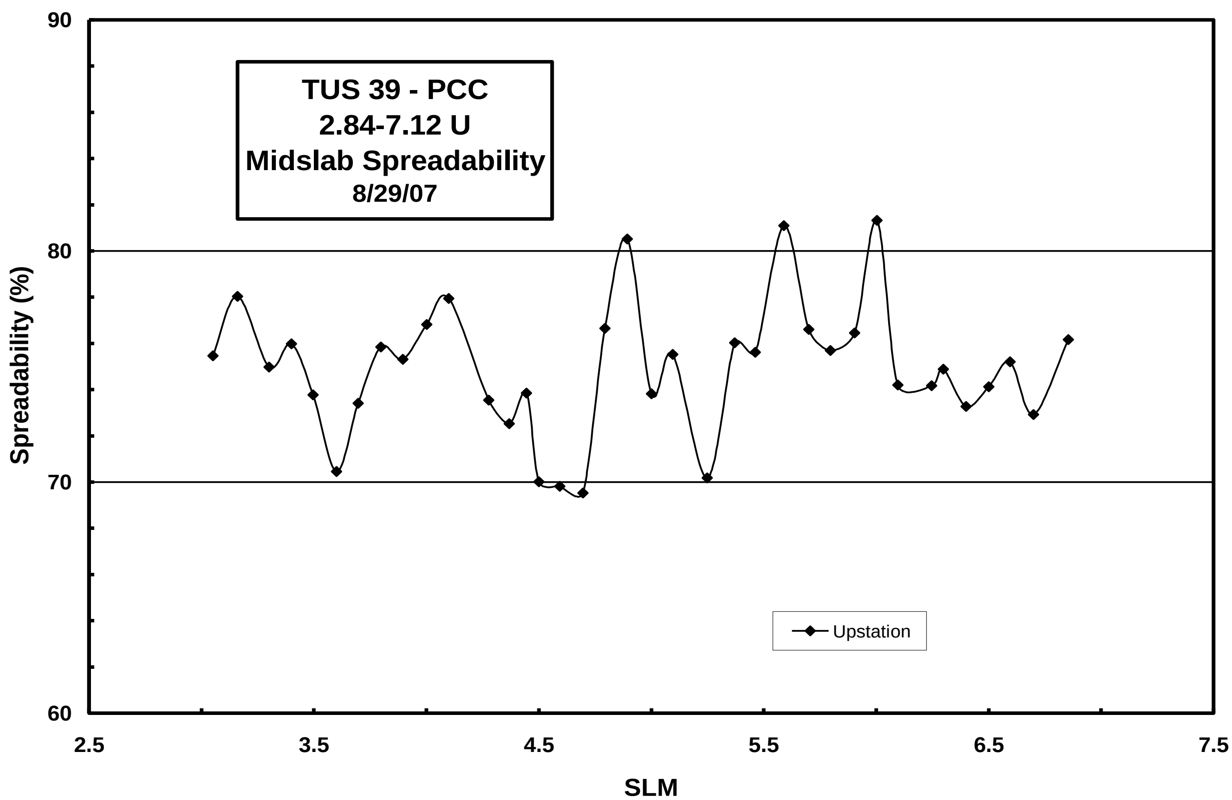
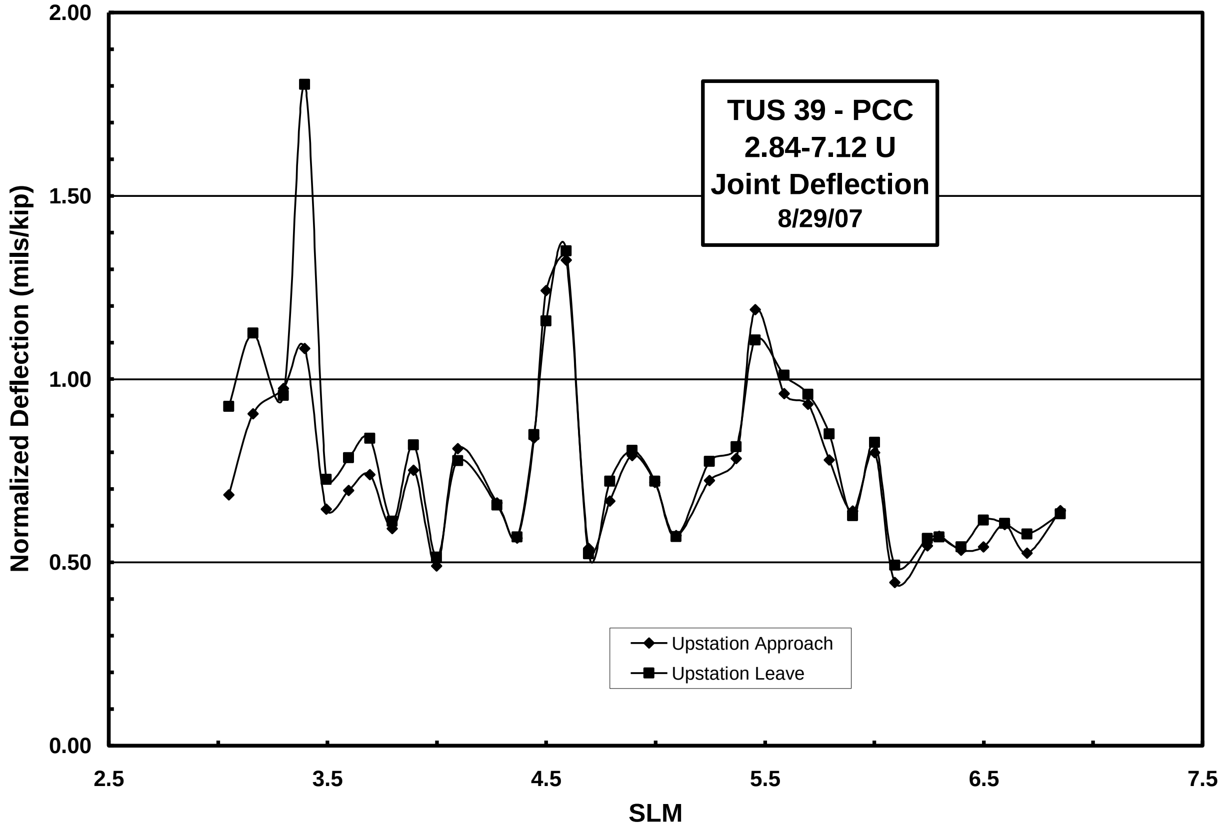


Figure C30a – TUS 39 FWD Midslab Deflection



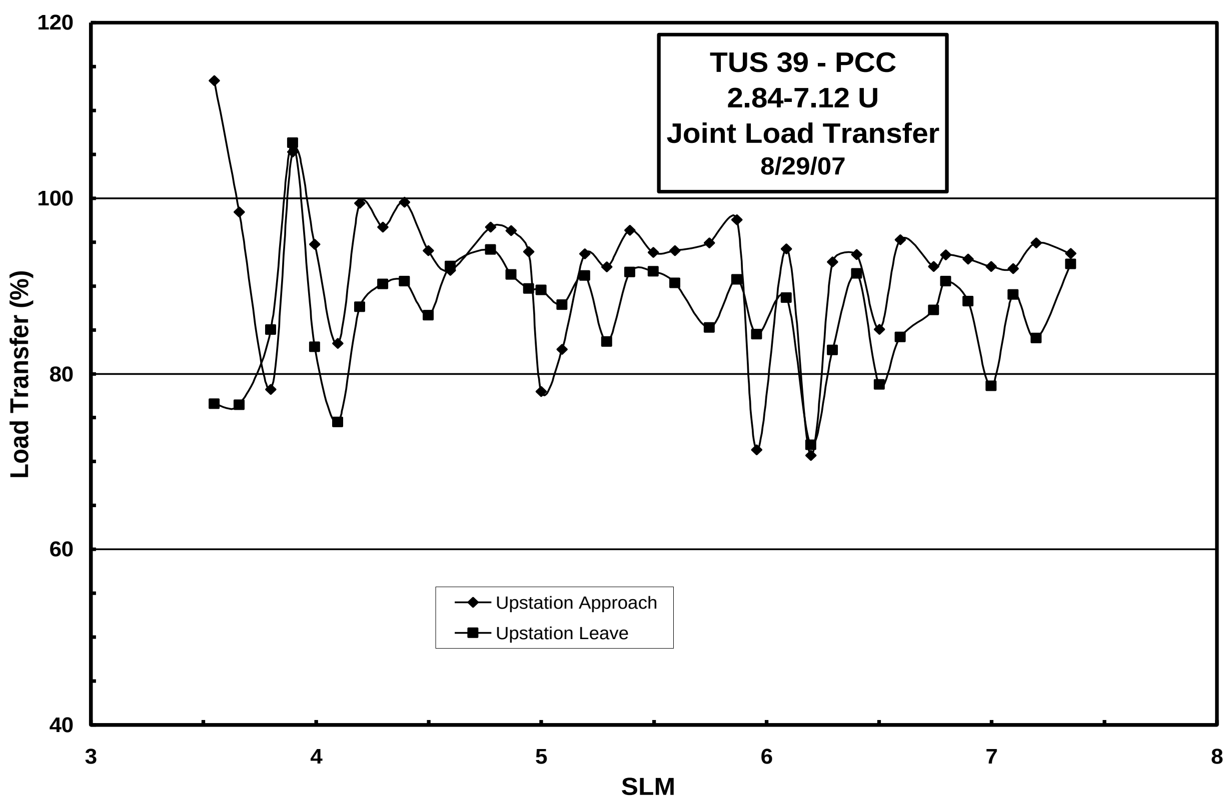


Figure C30b – TUS 39 FWD Joint Deflection

APPENDIX D

Ride Quality Profiles

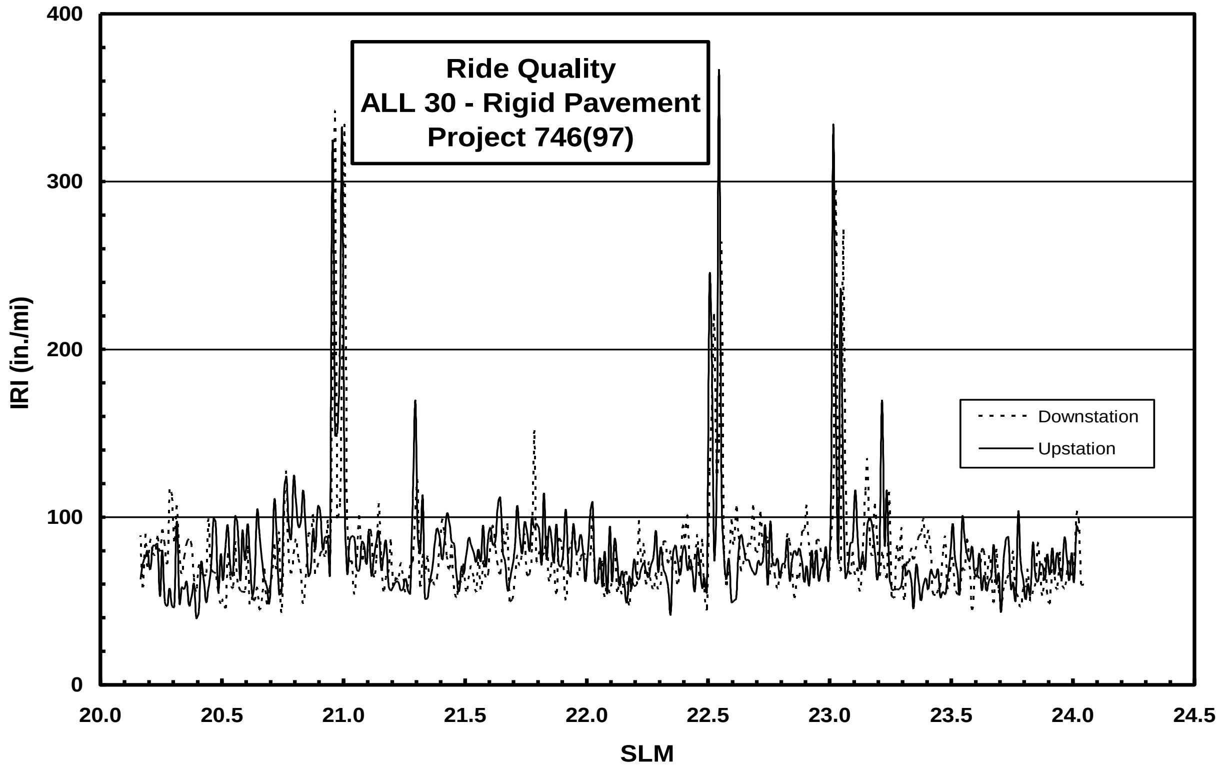


Figure D1 – Ride Quality on ALL 30

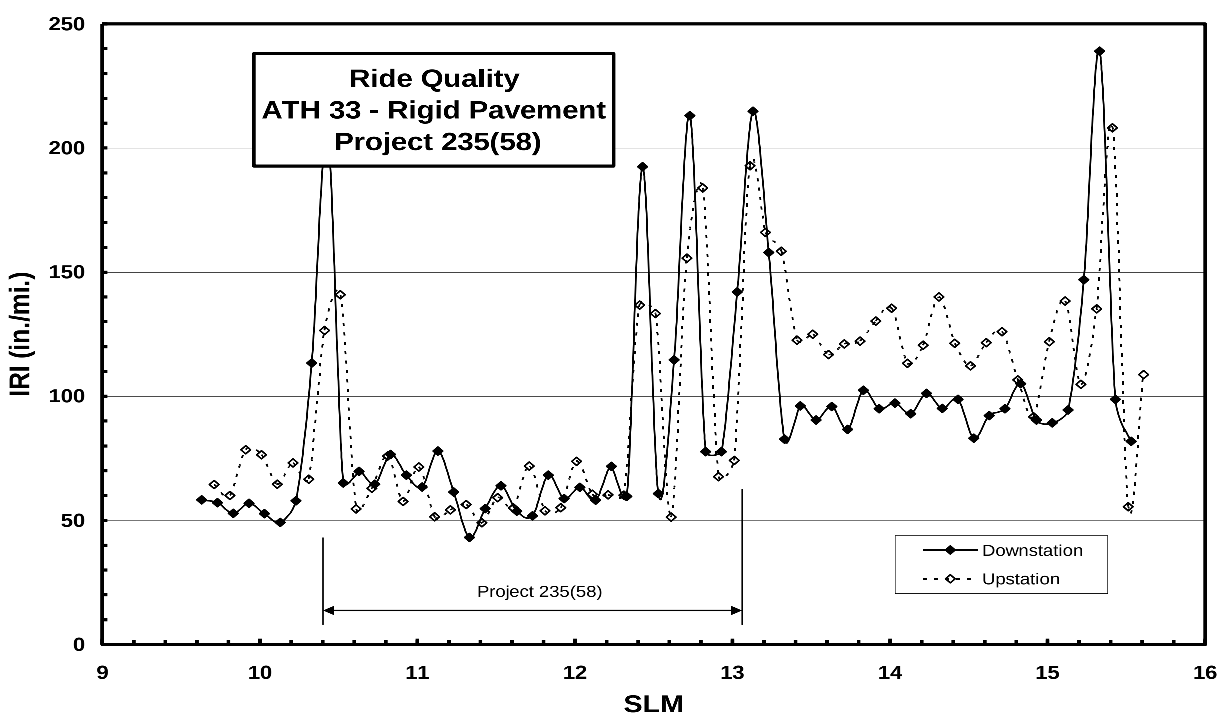


Figure D2 – Ride Quality on ATH 33

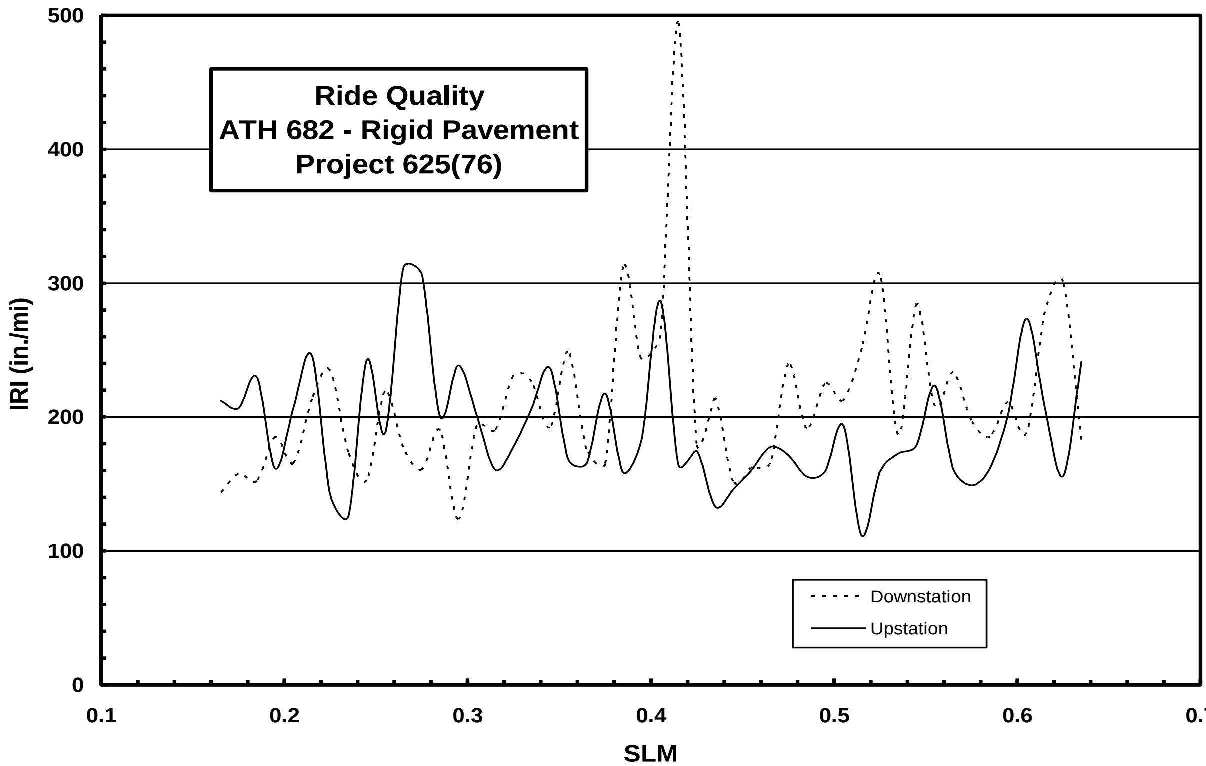


Figure D3 – Ride Quality on ATH 682

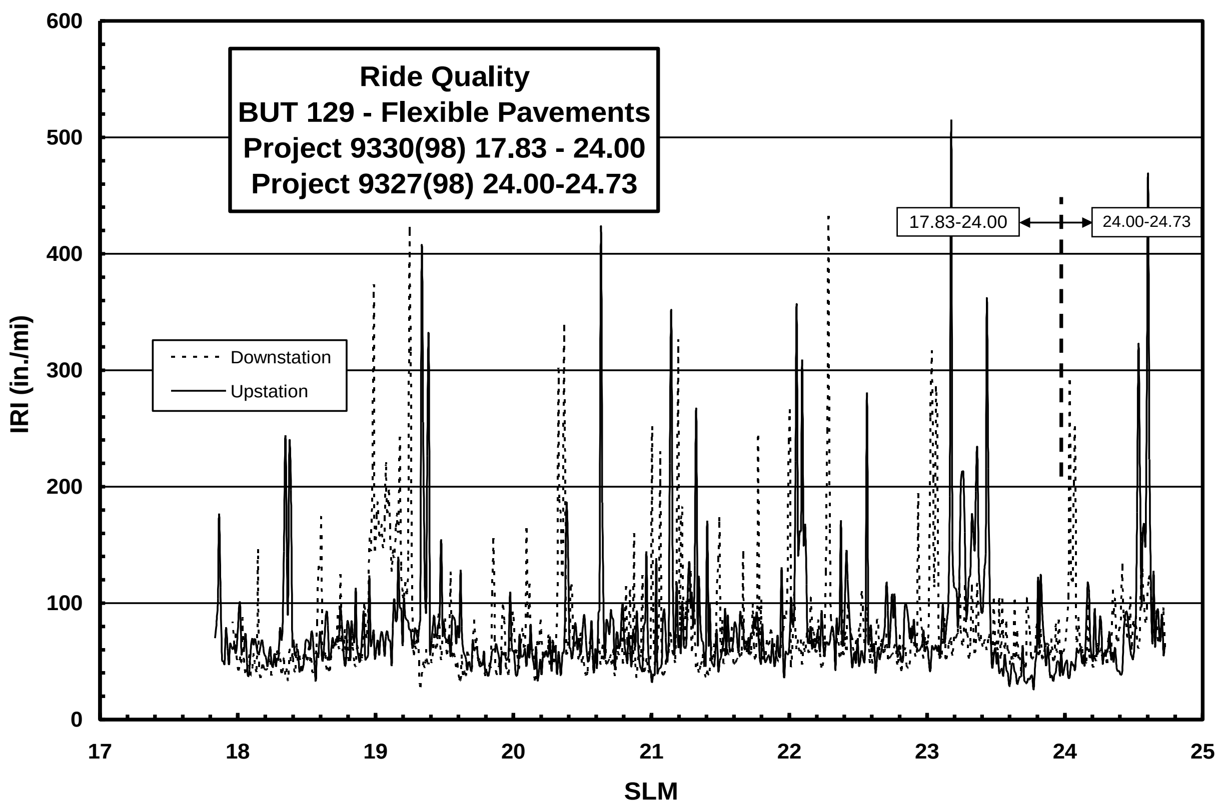


Figure D4 – Ride Quality on BUT 129

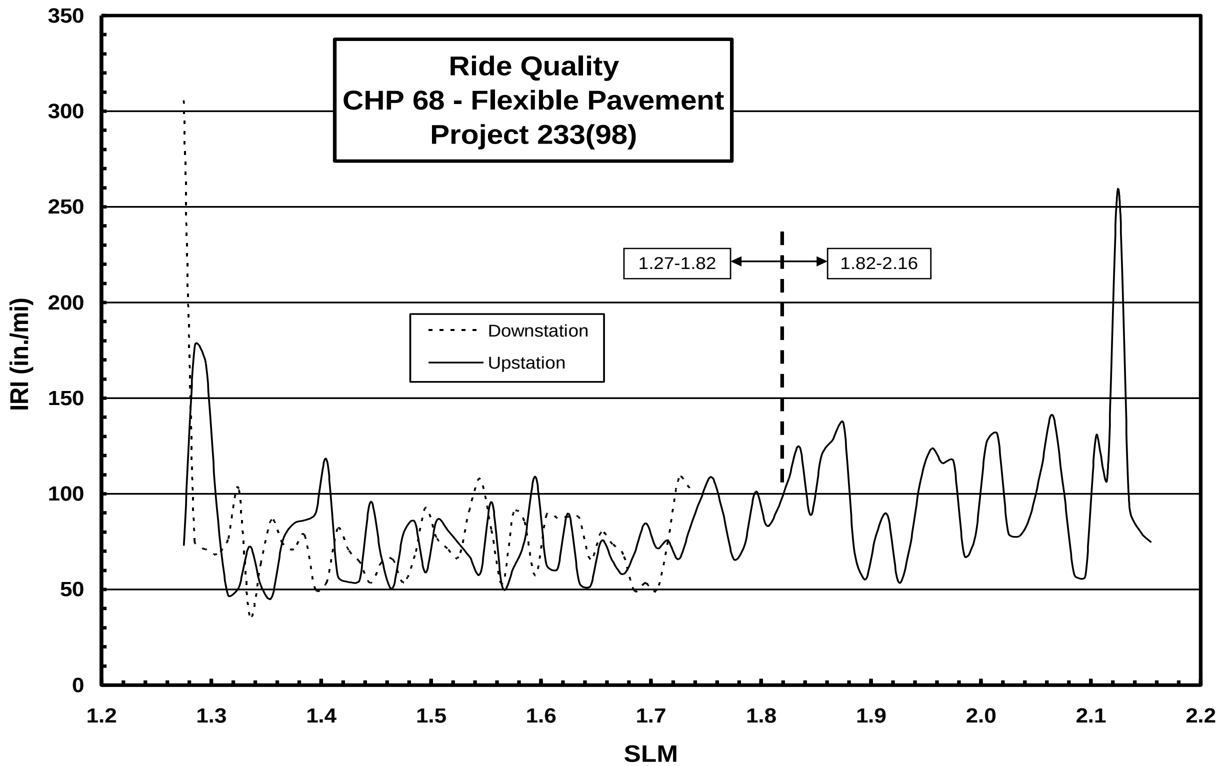


Figure D5 – Ride Quality on CHP 68

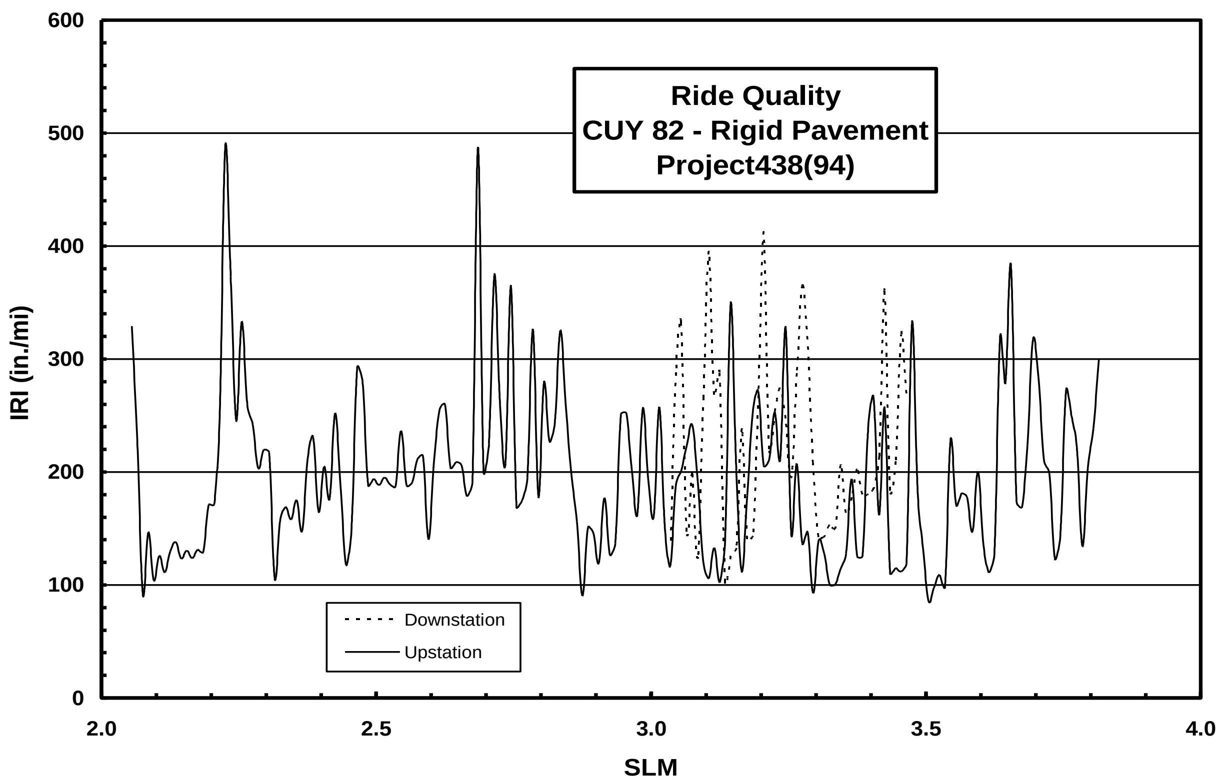


Figure D6 – Ride Quality on CUY 82

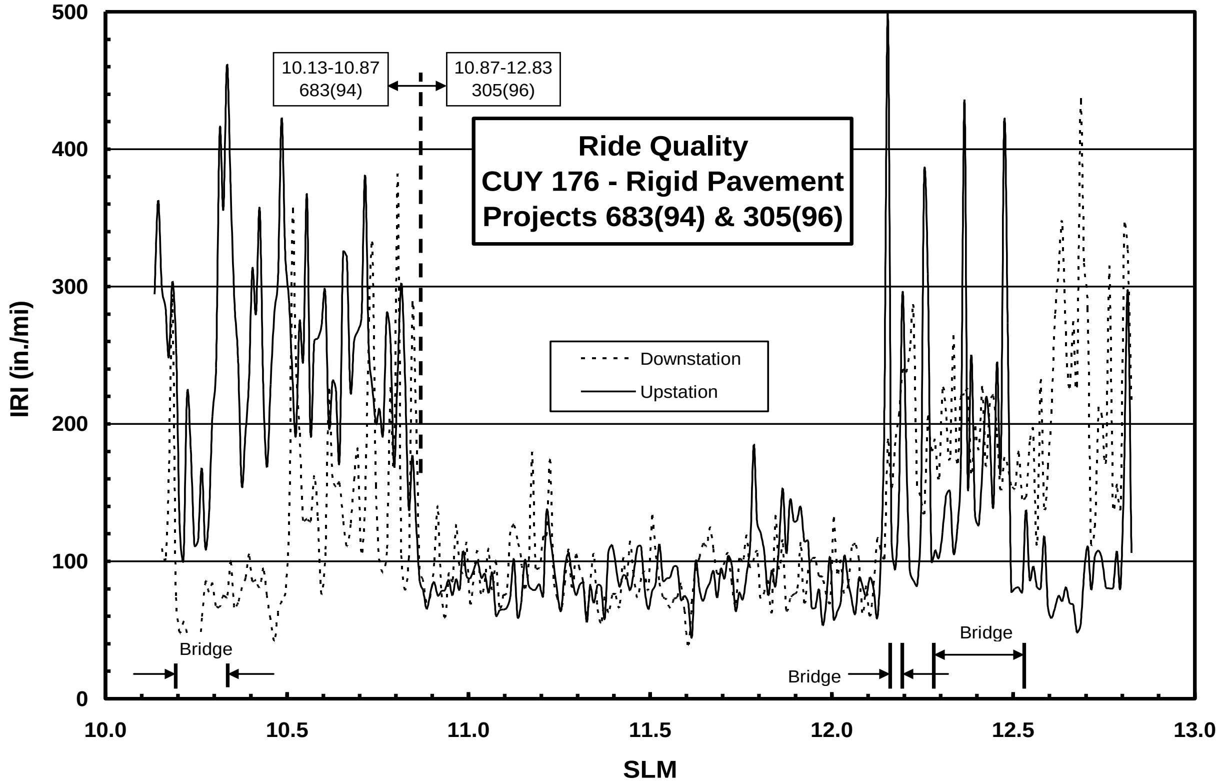


Figure D7 – Ride Quality on CUY 176

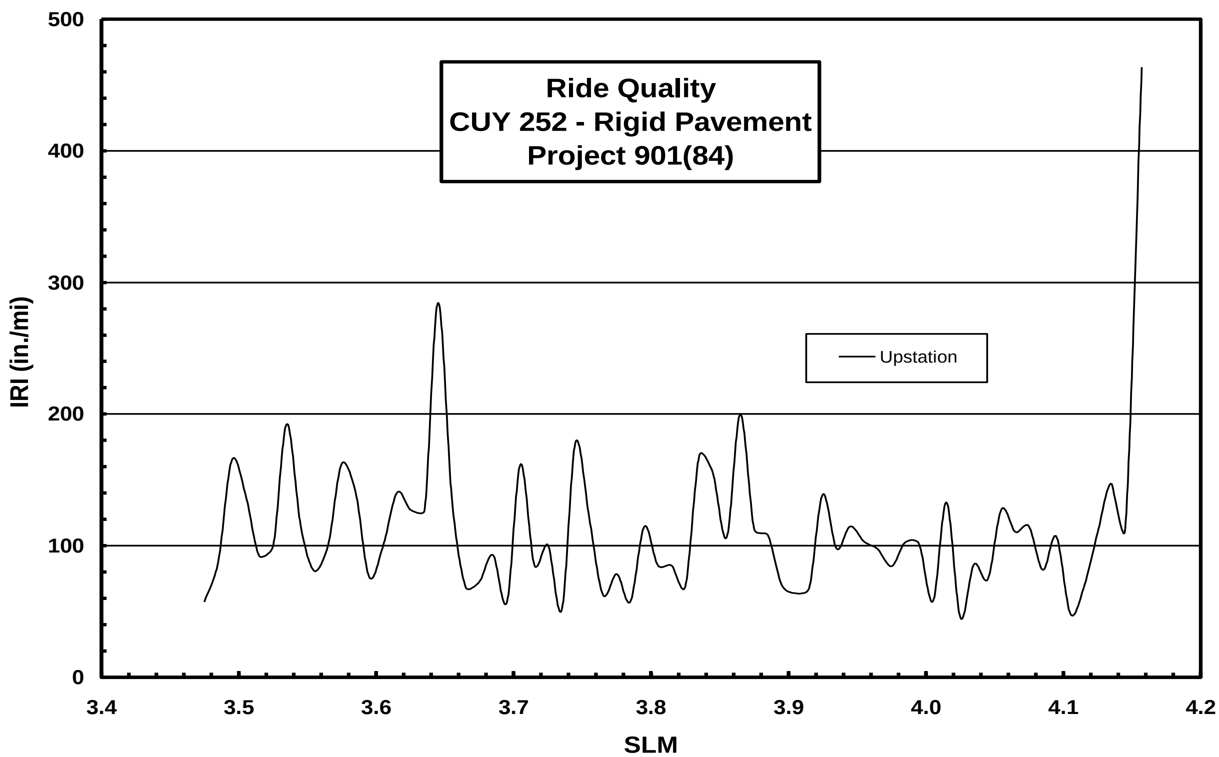


Figure D8 – Ride Quality on CUY 252

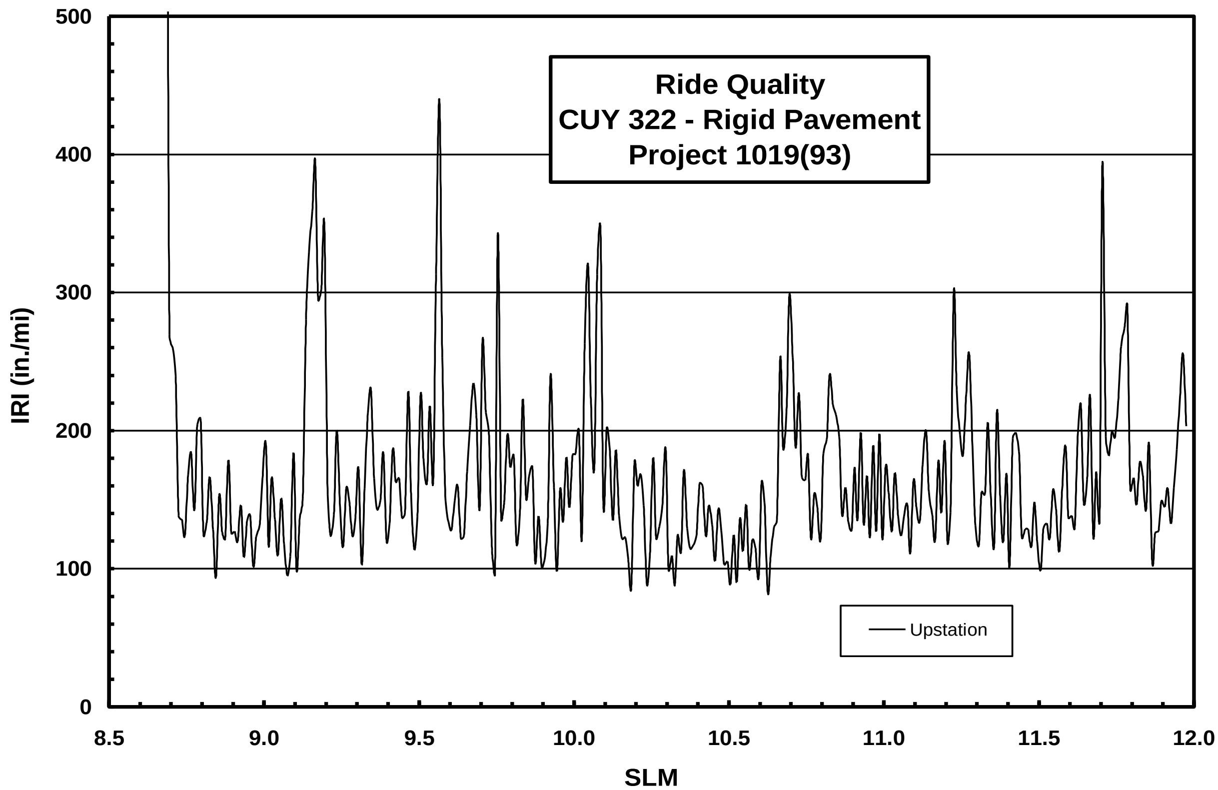


Figure D9 – Ride Quality on CUY 322

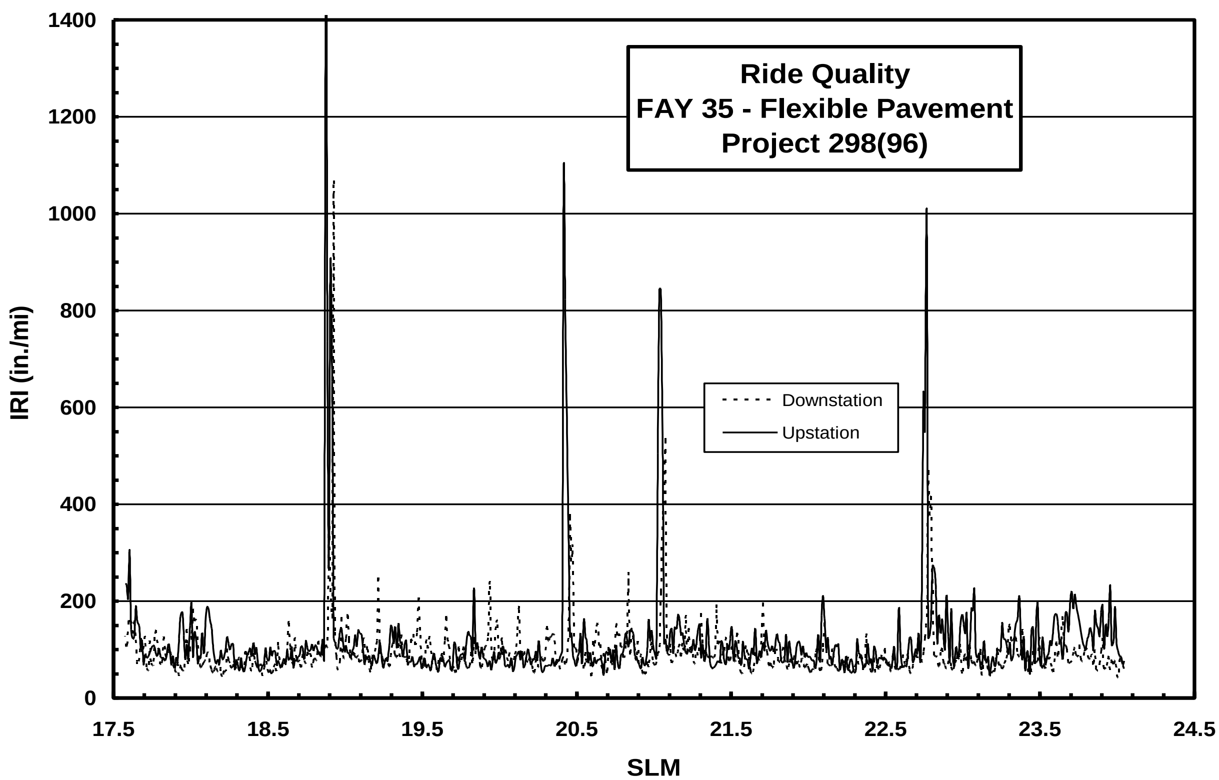


Figure D10 – Ride Quality on FAY 35

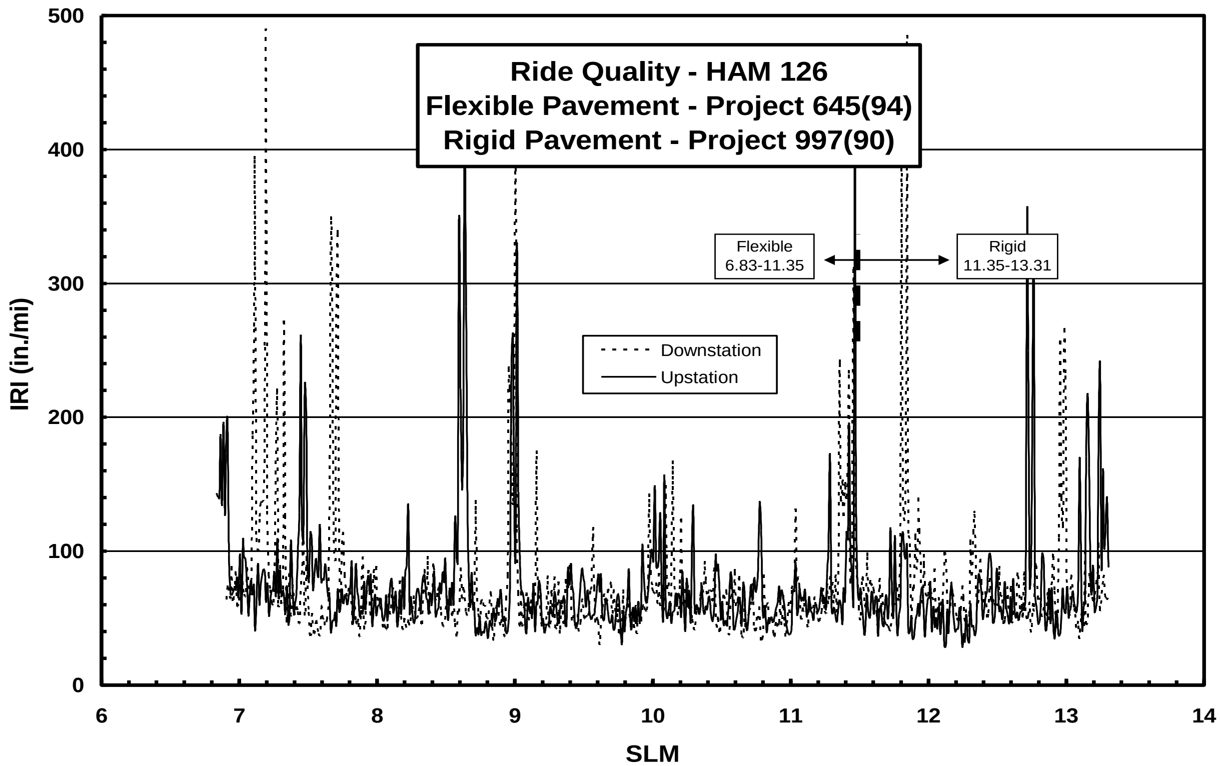


Figure D11 – Ride Quality on HAM 126

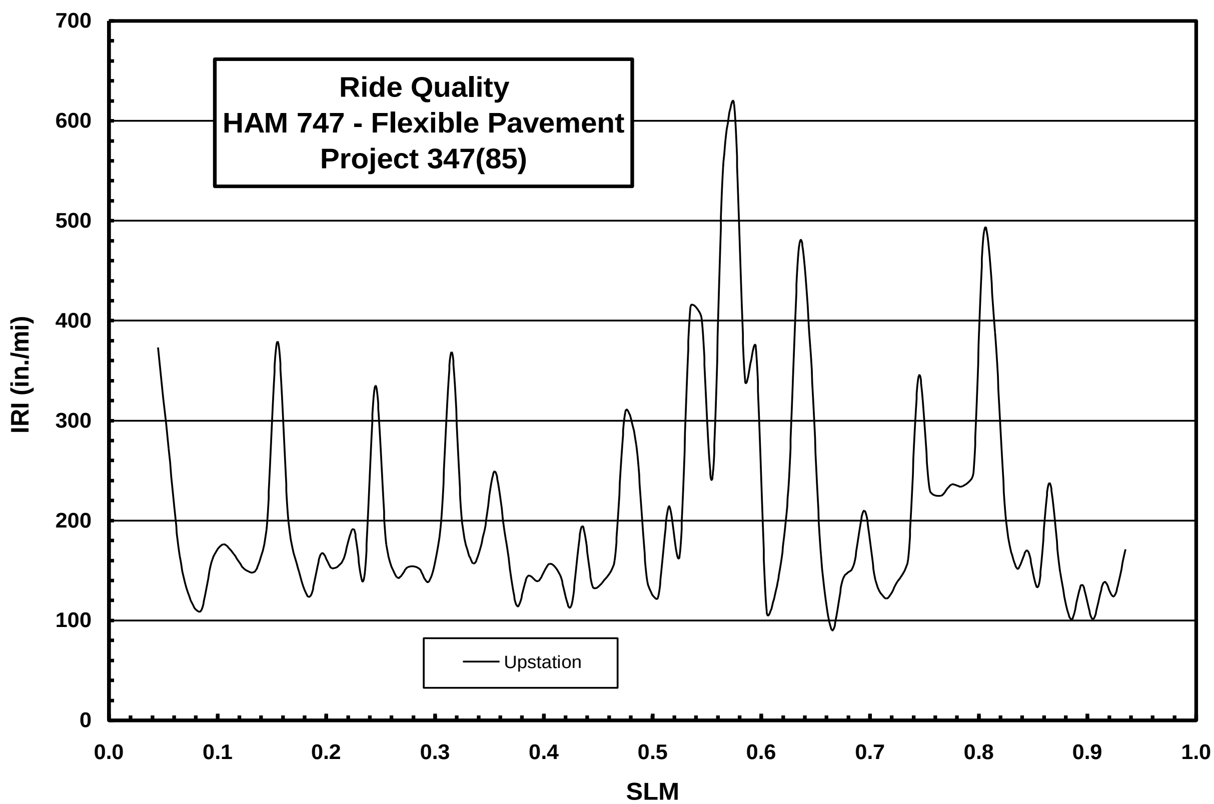


Figure D12 – Ride Quality on HAM 747

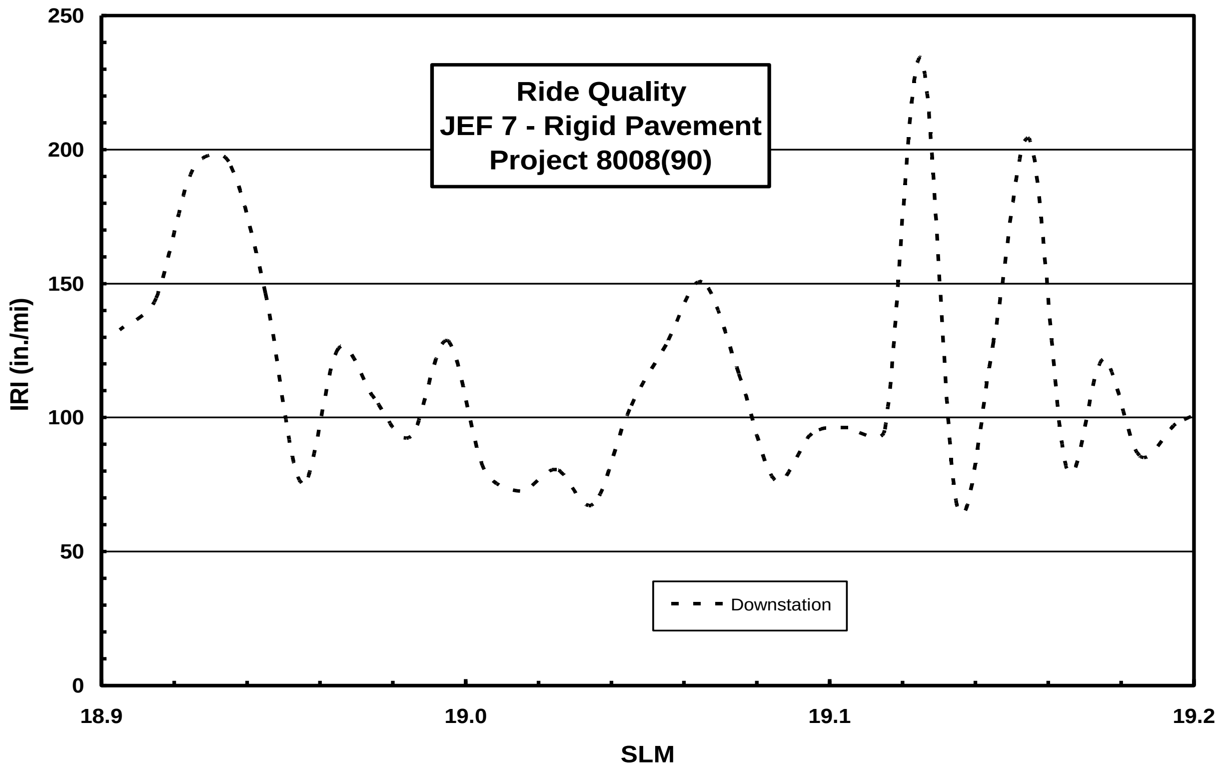


Figure D13 – Ride Quality on JEF 7

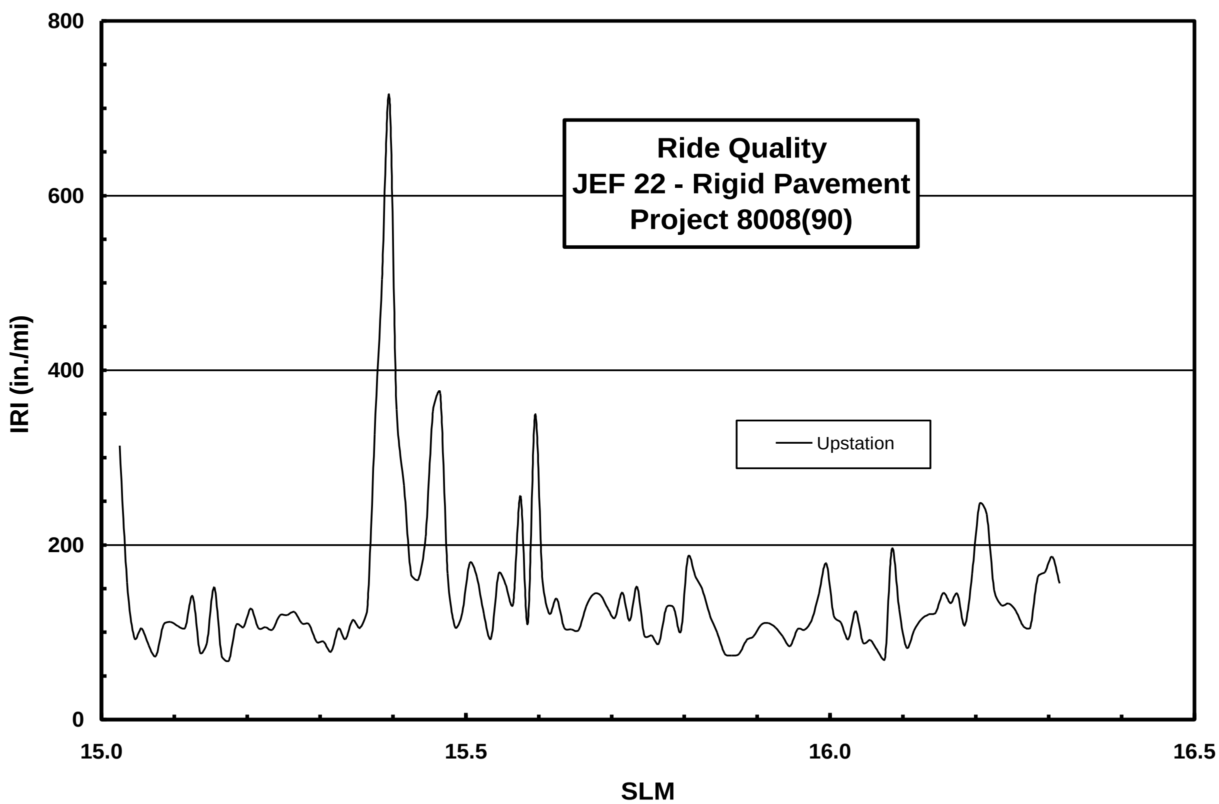


Figure D14 – Ride Quality on JEF 22

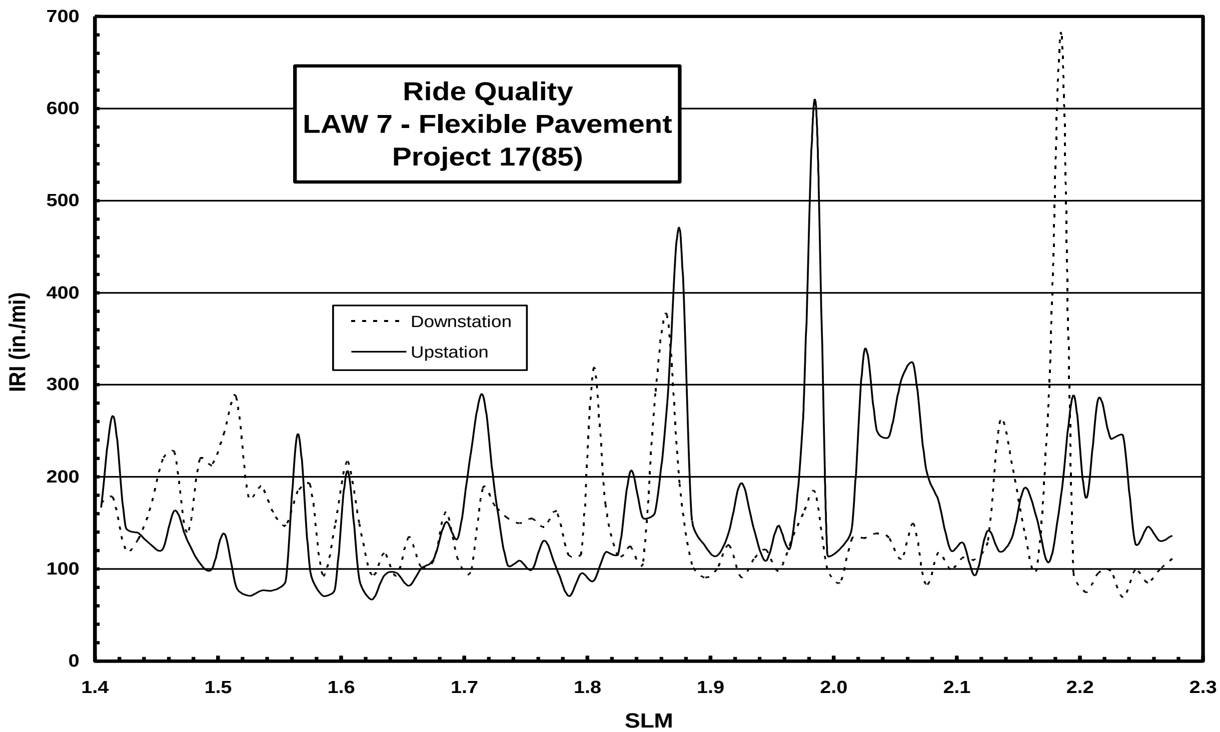


Figure D15 – Ride Quality on LAW 7

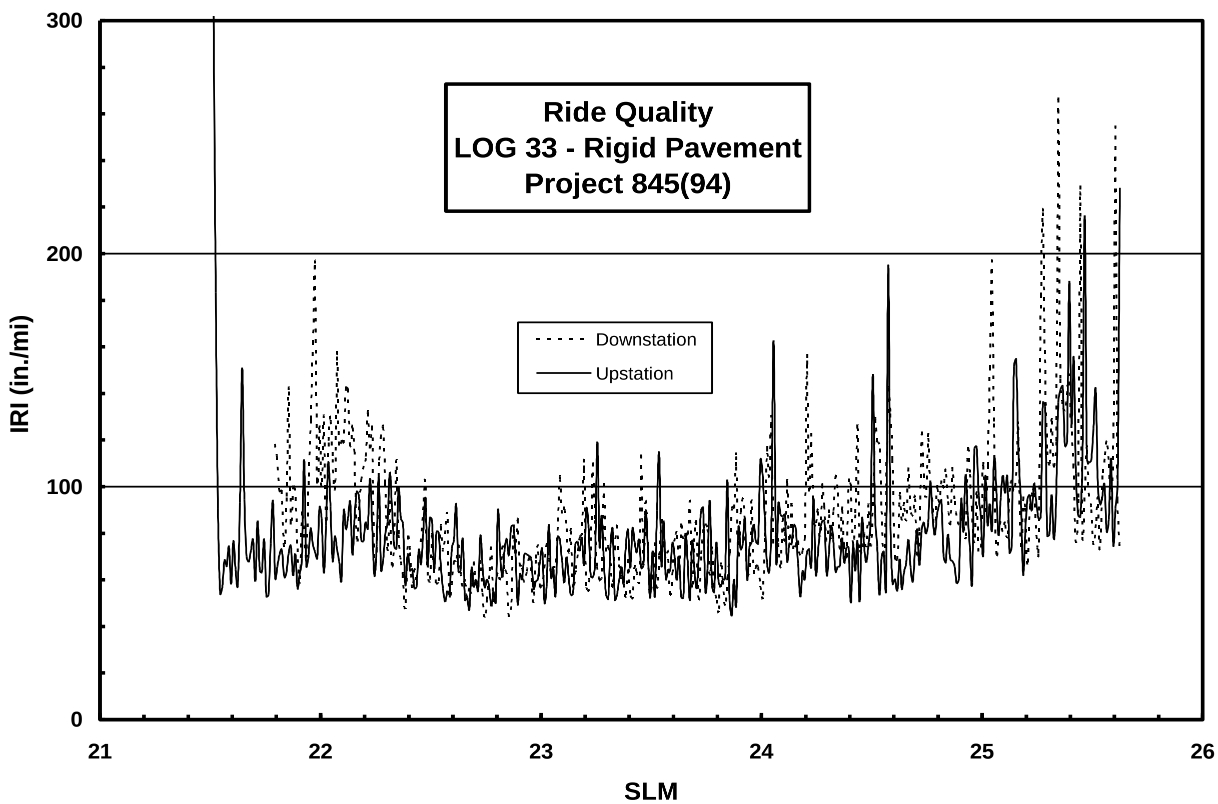


Figure D16 – Ride Quality on LOG 33

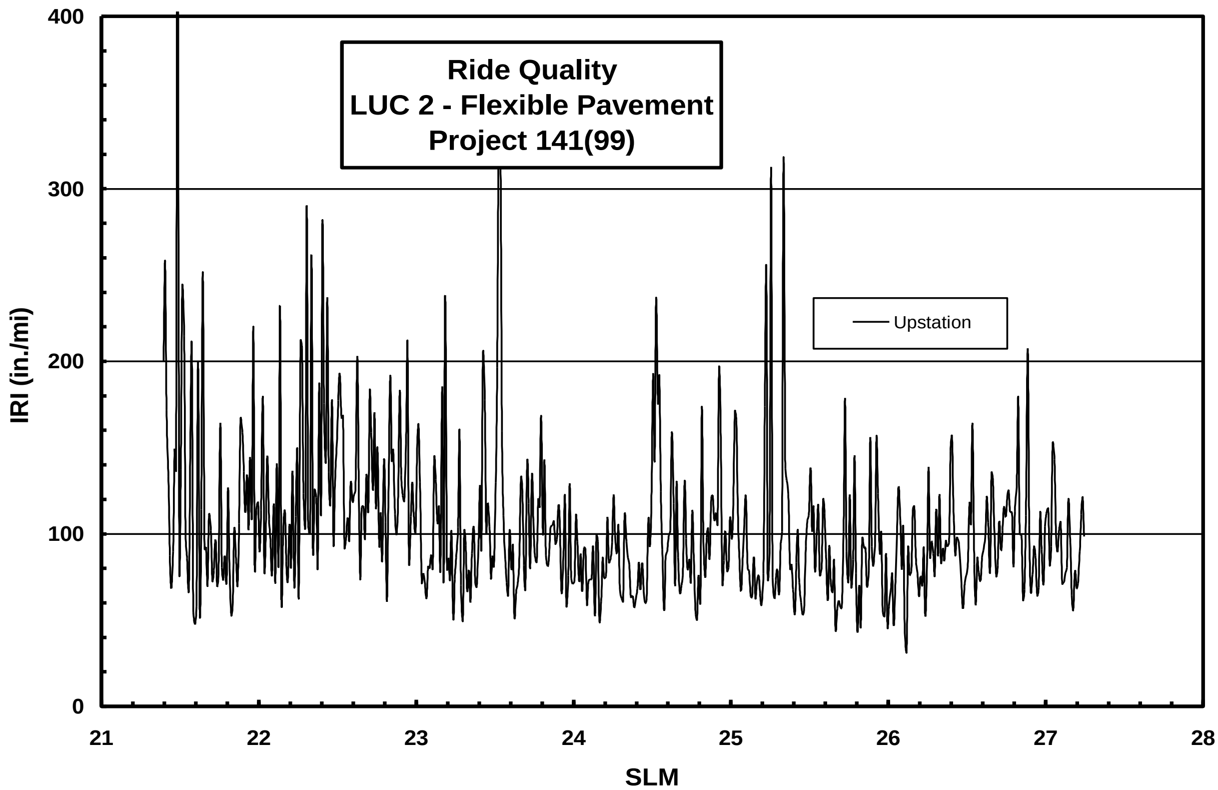


Figure D17 – Ride Quality on LUC 2

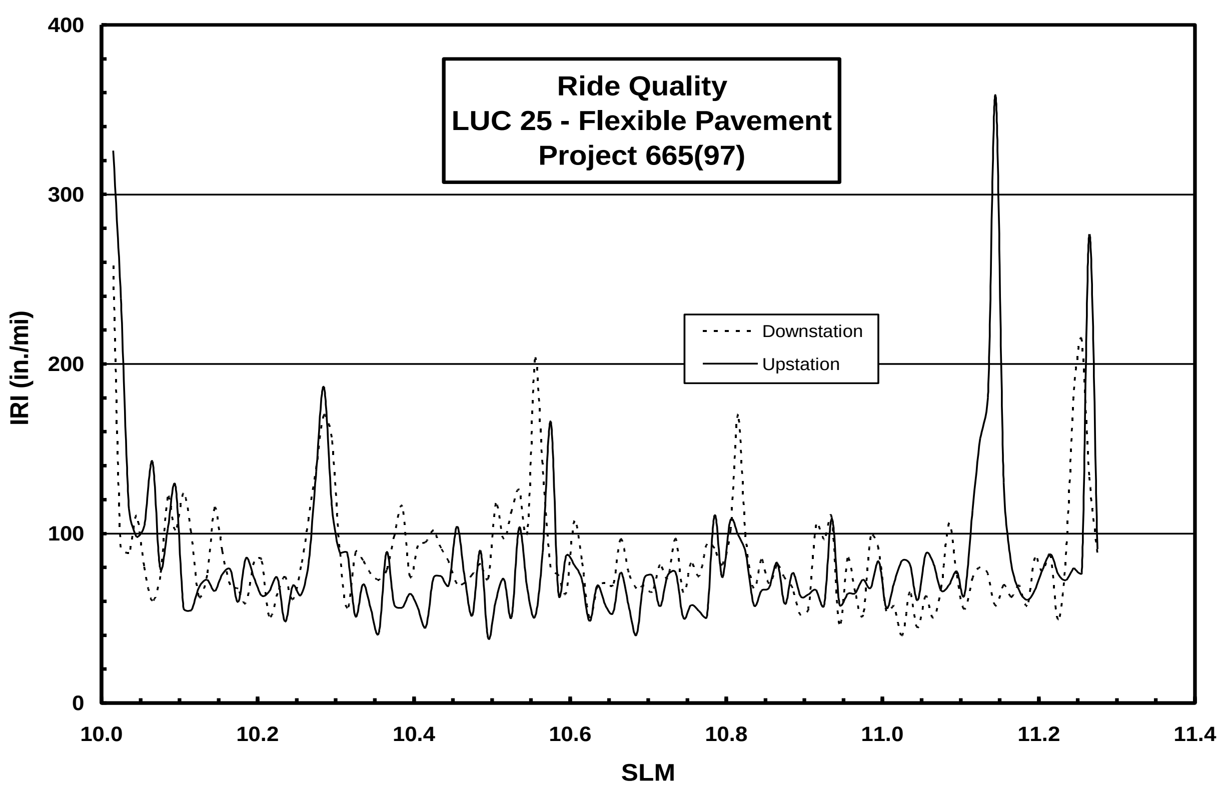


Figure D18 – Ride Quality on LUC 25

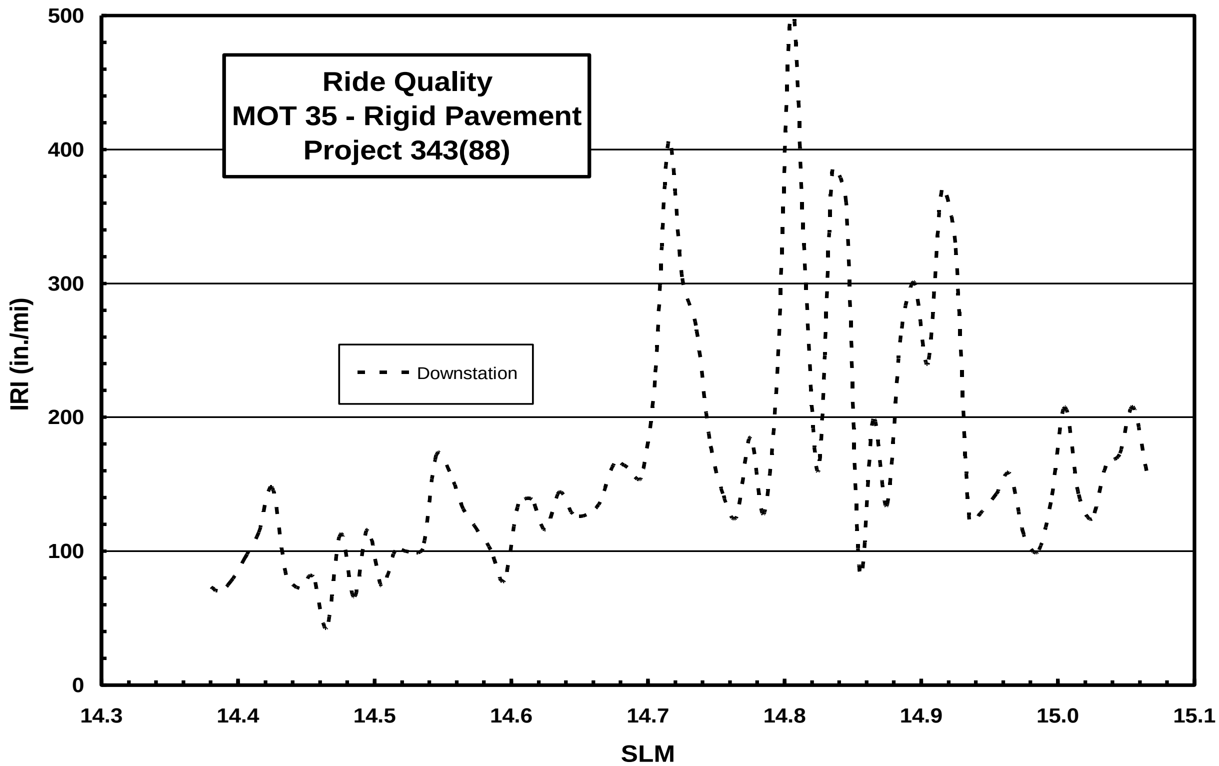


Figure D19 – Ride Quality on MOT 35

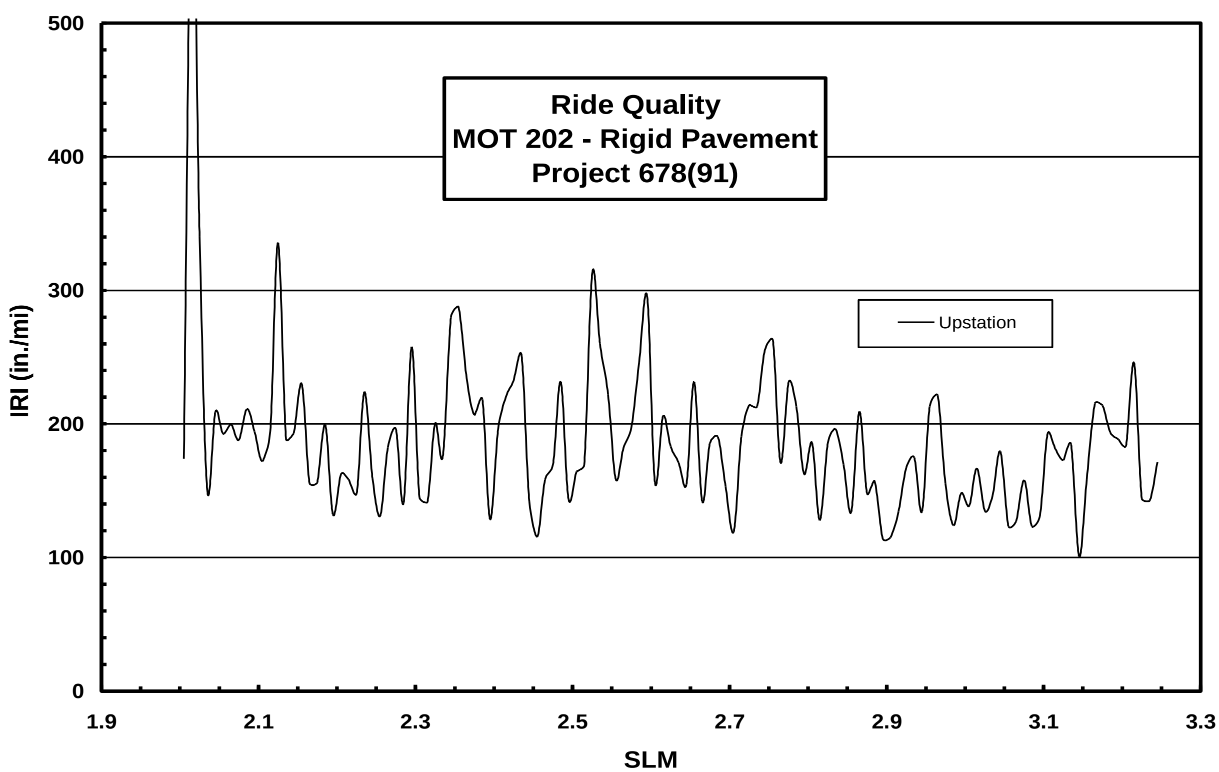


Figure D20 – Ride Quality on MOT 202

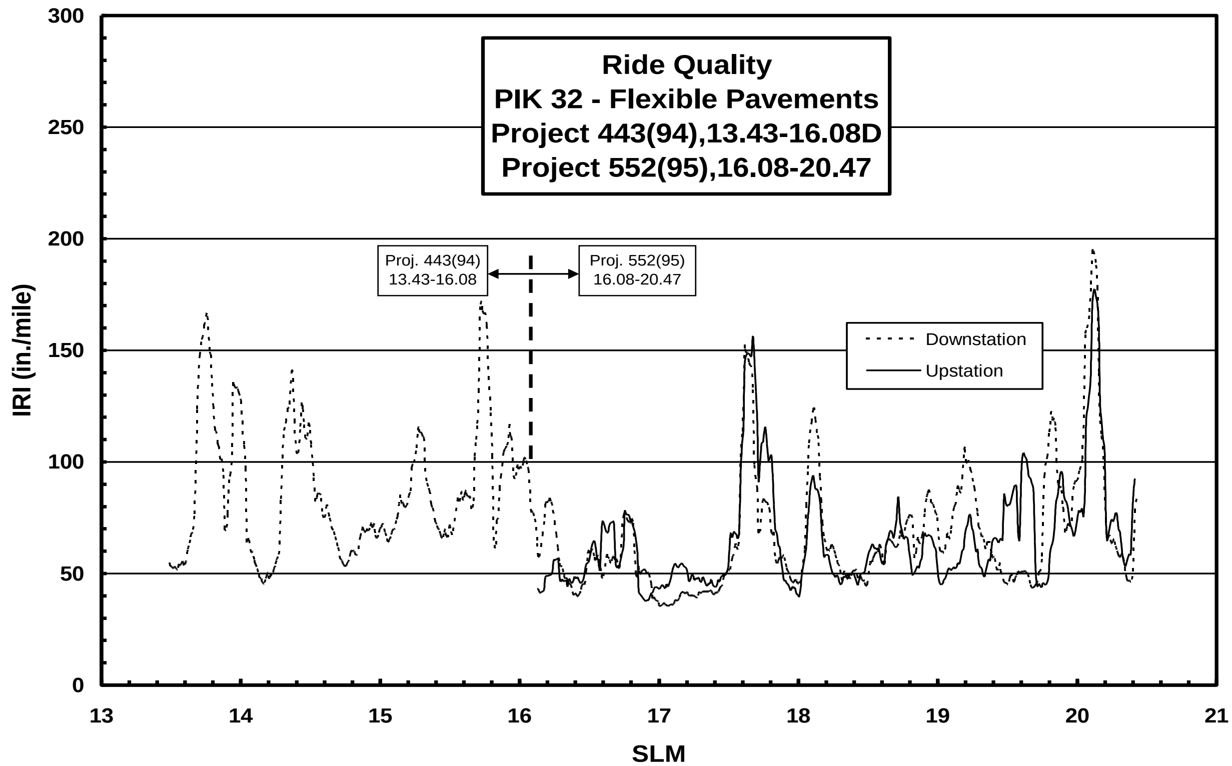


Figure D21 – Ride Quality on PIK 32

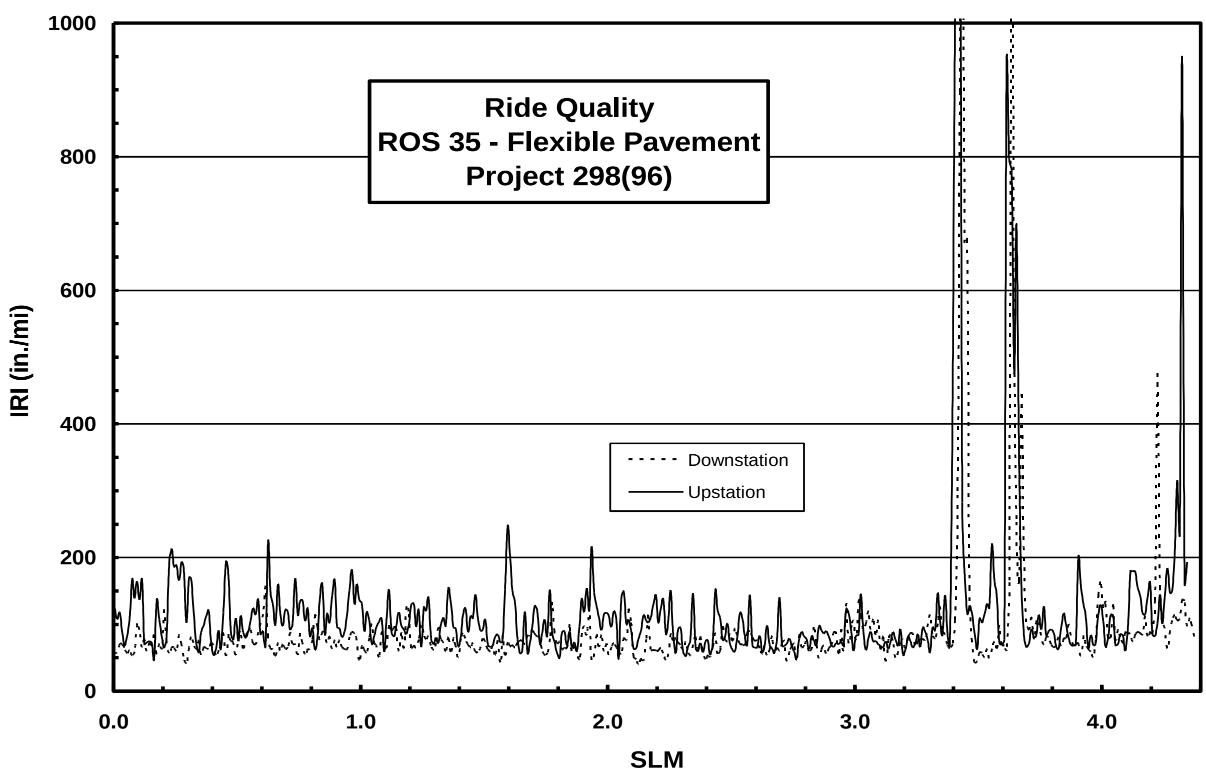


Figure D22 – Ride Quality on ROS 35

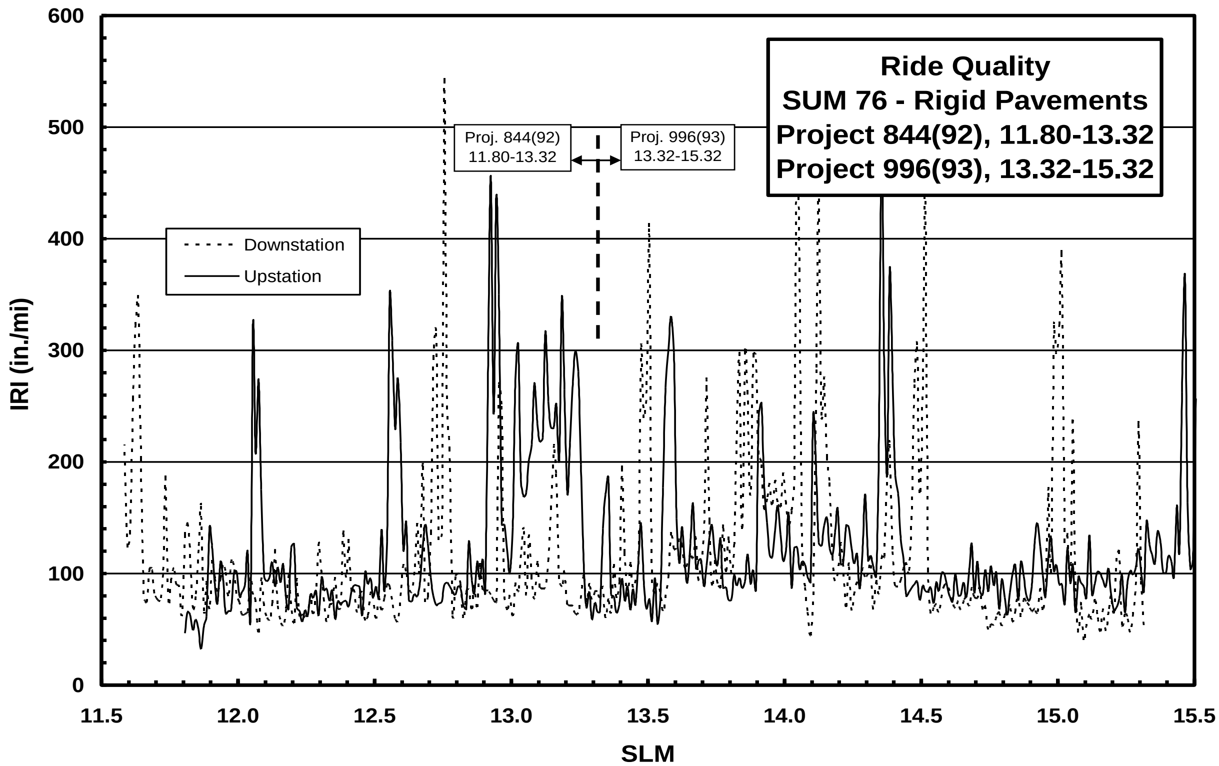


Figure D23 – Ride Quality on SUM 76

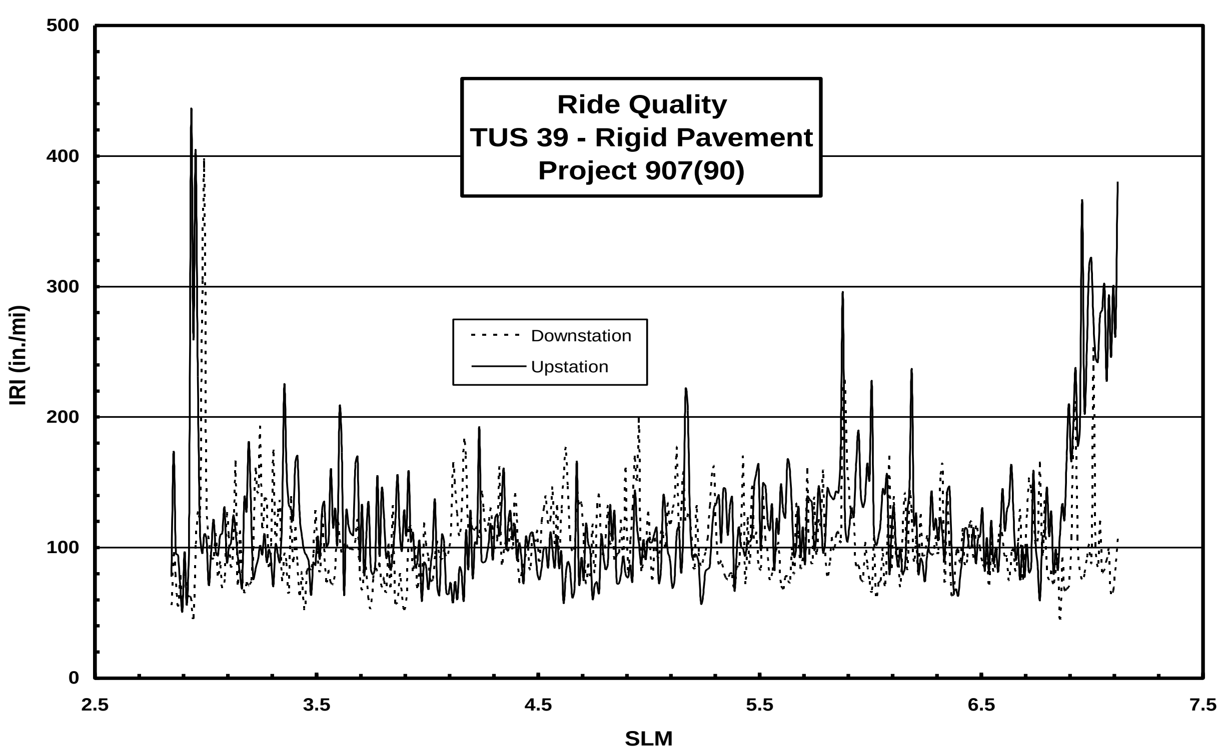


Figure D24 – Ride Quality on TUS 39

APPENDIX E

Field Sampling and Testing of Flexible Pavements

BUT 129 22 E

Pavement Type: Flexible **Project:** 9330(98) **SLM:** 17.83-24.00 EB **Performance:** Excellent

Build Up: 1.25” 446 T1/ 1.75” 446 T2/ 10” 302/ 4” ATFDB (3.2 cm/ 4.4 cm/ 25.4 cm/ 10.2 cm)

BUT 129 22E and BUT 129 22W were selected as paired sections because of their differing performance under similar location and design conditions. The sites was located over an 800 feet (244 m) length of pavement west of MP 22. As determined with the PCR rankings, this eastbound pavement was in excellent condition, as shown in Figure E1. No measurable distress was visible and rutting in the right wheelpath was less than 1/16 inch (2 mm). On one core, the 446 layers delaminated from the 302 layer.

Figure E1. – BUT 129 22 E Surface

BUT 129 22 W

Pavement Type: Flexible **Project:** 9330(98) **SLM:** 17.83-24.00 WB **Performance:** Average

Build Up: 1.25" 446 T1/ 1.75" 446 T2/ 10" 302/ 4" ATFDB (3.2 cm/ 4.4 cm/ 25.4 cm/ 10.2 cm)

These westbound lanes had some longitudinal cracking along the centerline of the pavement. Some of this cracking had been sealed, as shown in Figure E2, and some unsealed cracks had evidently developed since the sealing. Rutting in the right wheelpath was slightly more in the westbound lanes than in the eastbound lanes, at 1-2/16 inch (2-3 mm). One core delaminated between the 302 lifts, as shown in Figure E3. This figure also shows the ATFD base at the bottom of the core.

Figure E2. – Longitudinal Centerline Cracking on BUT 129 22 W

Figure E3. – Delaminated 302 over ATFD Base

BUT 129 25 W

Pavement Type: Flexible **Project:** 9327(98) **SLM:** 24.00-24.73 WB **Performance:** Average
Build Up: 1.25” 446 T1/ 1.75” 446 T2/ 8” 302/ 4” 304 (3.2 cm/ 4.4 cm/ 20.3 cm/ 10.2 cm)

This project was just west and adjacent to Project 9330(98), and the sampling and testing site was located just east of MP 24 on the westbound side. It contained some minor cracking and rutting in the right wheelpath was about 1/16 inch (2 mm) deep. Over the 100 feet just east of MP 24, rut depths increased to 5/32 inches (4 mm). The PMIS indicated that 4 inches (10.2 cm) of 304 aggregate supported 11 inches (27.9 cm) of asphalt concrete material. Cores ranged from 15-16 inches (38.1-40.6 cm) in thickness, suggesting some inconsistency in AC thickness with the PMIS. After removing the core, the underlying material was cementious and could not be removed after pounding on it with a steel pry bar.

CHP 68 2 N

Pavement Type: Flexible **Project:** 233(98) **SLM:** 1.27-1.82 NB **Performance:** Excellent

Build Up: 1.50” 448 T1H/ 1.75” 448 T2/ 6” 301/ 6” 304 (3.8 cm/ 4.4 cm/ 15.2 cm/ 15.2 cm)

This rural pavement was in excellent condition, as determined from the performance ratings. The site selected for sampling and testing was in an area where a four lane pavement was transitioning to a two lane pavement. Section CHP 68 2.5N served as a paired complement of this section providing average performance. Figure E4 shows some minor longitudinal cracking along the pavement edge, which likely was the joint separating the pavement and shoulder. There was also some slight random cracking. Rutting in the right wheelpath ranged from 1-2/16 inches (2-3 mm).

Figure E4. – Minor edge cracking on CHP 2 N

CHP 68 2.5 N

Pavement Type: Flexible **Project:** 233(98) **SLM:** 1.82-2.16 NB **Performance:** Average

Build Up: 1.50” 448 T1H/ 1.75” 448 T2/ 6” 301/ 6” 304 (3.8 cm/ 4.4 cm/ 15.2 cm/ 15.2 cm)

This section was a two lane complement immediately north of Section CHP 68 2N, which showed excellent performance. Distresses included moderate cracking along the pavement centerline, as shown in Figure E5, and other cracking along the center and edge of the lane. Rutting in the right wheelpath was approximately 2/16 inches (3 mm) deep. As cores were cut, it became apparent that the left wheelpath was more severely rutted than the right wheelpath. Figure E6 shows the differences in rutting between the right and left wheelpaths, and how water ponded in the left wheelpath, but not the right wheelpath. The cores suggested some possible problems with consolidation in the 301 base. Figure E7 shows large voids at the joint between two lifts of 301and some of the 301at the bottom of other cores crumbled as the cores were being cut. The worst zone of crumbling was over a 50 foot (15.2 m) length of pavement nearest MP 2.

Figure E5. – Surface Cracking on CHP 68 2.5N

Figure E6. – Rutting in CHP 68 2.5N

Figure E7. – Voids in 301 AC Base

CLA 41 3 N

Pavement Type: Flexible **Project:** 63(95) **SLM:** 3.87-4.05 NB **Performance:** Excellent

Build Up: 1.25" 404 / 1.75" 402 / 7" 301 / 5" 304 (3.2 cm/ 4.4 cm/ 17.8 cm/ 12.7 cm)

The CLA 41 3 N site was located on a residential portion of northbound SR 41 near the south edge of South Charleston which lead to a grain storage facility and the center of town. Loaded trucks use this route in the fall to deliver grain from fields in the area. Figure E8 shows some minor longitudinal cracking in the left wheelpath and a transverse crack at a manhole along the right edge of the pavement, which was bounded by a concrete curb and gutter. This 20 foot (6.1 m) wide pavement lane was able to provide parallel parking along the curb. Rutting in the right wheelpath was minimal at 1-3/32 inches (0.8-2.4 mm). Core thicknesses varied from 9 ¾ - 12 ½ inches (24.8-31.8 cm).

Figure E8. – Surface Cracking on CLA 41 3N

<u>CLA 41 4 N</u>

<u>Pavement Type:</u> Flexible **<u>Project:</u>** 63(95) **<u>SLM:</u>** 4.05-4.46 NB **<u>Performance:</u>** Average

<u>Build Up:</u> 1.25” 404/ 1.75” 402/ 7” 301/5” 304 (3.2 cm/ 4.4 cm/ 17.8 cm/ 12.7 cm)

This pavement section is a complement of CLA 41 3N, which is around the corner in Figure E9 where the core and DCP vehicles are coming into view. The grain storage facility in the background was mentioned in the discussion for CLA 41 3N. A long longitudinal crack, which appeared to be a construction joint, was present over the length of the section. Rut depths ranged from 1-5/32 inches (1-4 mm) along the project.

Figure E9. – Layout of CLA 41 4N

DEL 23 17 S

Pavement Type: Flexible **Project:** 380(94) **SLM:** SHRP 902 **Performance:** Excellent

Build Up: 1.75” 446 T1 (PG 58-30) / 2.25” 446 T2 (PG 58-30) / 12” 302 / 4” ATFDB / 6” 304 (4.4 / 5.7 / 30.5 / 10.2 / 15.2 cm)

This original section in the SPS-9 experiment on the DEL 23 SHRP Test Road has remained in excellent condition since construction in 1984, as shown in Figure E10. Asphalt cement in this section was PG 58-28. Maximum rutting measured in the right wheelpath of this 500 ft. (152 m) long section was 1/8 “ (3 mm). All cores were taken outside the SHRP section to retain its research value.

Figure E10. – Surface of Section 902 on DEL 23

DEL 23 18 S

Pavement Type: Flexible **Project:** 380(94) **SLM:** SHRP 112 **Performance:** Average

Build Up: 1.75” 446T1 / 2.25” 446T2 / 12” 302 / 4” ATFDB (4.4 / 5.7 / 30.5 / 10.2 cm)

This section was part of the SPS-1 experiment on the DEL 23 SHRP Test Road. The build up on this section is very similar to Section 902 discussed above, except that the asphalt cement was standard AC 20 rather than PG 58-28 in Section 902, and there was no 304 aggregate layer on the bottom. Cores were removed outside the 500 ft. (152 m) long SHRP section and rutting was limited to 1/16” (2 mm). Figure E11 shows patterns of longitudinal cracking made more evident by moisture from the coring operation. Cores removed from Section 112 showed various degrees of distress from delamination at a 301 lift line to deterioration of the 446 T1 near a longitudinal crack shown in Figure E11. Figure E12 shows delamination of a 301 lift and Figure E13 shows how the surface course had deteriorated in the cracked areas. These distresses were not present in Section 902 on DEL 23, as shown in Figure E10.

Figure E11. – Surface of Section 112 on DEL 23

Figure E12. – Delamination of Core in Section 112 on DEL 23

Figure E13. – Deterioration of 446 T1 in Section 112

<u>GRE 35 21 E</u>

<u>Pavement Type:</u> Flexible **<u>Project:</u>** 259(98) **<u>SLM:</u>** 20.9-26.21 EB **<u>Performance:</u>** Excellent

<u>Build Up:</u> 1.5" 448 T1H / 1.75" 448 T2 / 7.5" 301 / 6" 304 / LSS (3.8 / 4.4 / 19.1 / 15.2 cm)

This pavement received a 1 inch (2.5 cm) thick overlay of asphalt concrete in 2008 but, since all performance data were prior to 2004, it was retained in the study. The one inch (2.5 cm) AC overlay was removed before testing. A couple of cores delaminated between the two lifts of 301, as shown in Figure E14.

Figure E14. – Delamination of 301 on GRE 35 21E

HAM 126 11 E

Pavement Type: Flexible **Project:** 645(94) **SLM:** 7.09-11.35 EB **Performance:** Excellent
Build Up: 1.25" 446 T1/1.75" 446 T2/10" 301/6" 304/6" 310/6"LSS (3.2/4.4/25.4/15.2/15.2cm)

This pavement was located on a lightly traveled section of HAM 126 approximately three miles (4.83 km) west of I-75. The pavement had sealed longitudinal cracks shown in Figure E15 but, otherwise, was in good condition. Ruts were approximately 1/8" (3 mm) deep.

Figure E15. – Surface on HAM 126 11E

HAM 747 1 S

Pavement Type: Flexible **Project:** 347(85) **SLM:** 0.04-0.94 SB **Performance:** Average

Build Up: 1.00” 404 / 1.00” 403 / 9” 301 (2.5 / 2.5 / 22.9 cm)

Project 347(85) was located on SR 747 south of I-275 in a residential section of Glendale, a suburb of Cincinnati, as shown in Figure E16. This older pavement had numerous patches, including the extended longitudinal patch in the northbound lane, and random cracking.

Figure E16. – HAM 747 1S Coring Site

LAW 527 2 N

Pavement Type: Flexible **Project:** 17(85) **SLM:** 0.04-0.94 SB **Performance:** Average

Build Up: 1.25” 404 / 1.50” 402 / 9” 301 (3.2 / 3.8 / 22.9 cm)

Project 17(85) included sections of SR7 and SR 527. The original section of pavement selected for Project 17(85) was on SR 7 between SLMs 1.4 and 2.28. When visiting the site for sampling and testing in 2009, the entire project had recently been overlaid with about 3” (7.6 cm) of AC. Since all performance data were collected prior to the overlay, the cores were cut and the new overlay was removed before testing in the laboratory. Figure E17 is looking south in the northbound lanes and the exit ramp in the background is where SR 527 ends at SR 7. SR 7 exits on the ramp into Chesapeake. Because of traffic considerations and because these sections of SR 7 and SR 527 were constructed under the same project, the cores were cut on SR 527 north of where SR 7 exits into Chesapeake. Figure E18 shows a typical core with the new overlay intact.

Figure E17. – LAW 527 2N Coring Site

Figure E18. – Core from LAW 527 2N

<u>LUC 2 22 E</u>

<u>Pavement Type:</u> Flexible **<u>Project:</u>** 141(99) **<u>SLM:</u>** 21.39-27.25 EB **<u>Performance:</u>** Average
<u>Build Up:</u> 1.25" 446 T1H / 1.75" 446 T2 / 10" 301 / 6" 304 (3.2 / 4.4 / 25.4 / 15.2 cm)

This project was located in a business area with considerable utilities buried under the pavement, an AT&T routing station just west of the coring site and a high pressure gas line just east of the site. OOPS was called to locate the utilities and cores were cut at a safe distance from the OOPS marks, as shown in Figure E19. Manholes and catch basins indicated storm sewers were also present. To avoid any unpleasant surprises with buried fixtures, DCP tests were not conducted at this site. FWD measurements were available for determining base and subgrade stiffness. Rut depths were about ¼" (6 mm) in the right wheelpath and cores ranged from 11 ½ - 13 ½" (29.2–34.3 cm).

Figure E19. – LUC 2 22E Coring Site

LUC 25 10 S

Pavement Type: Flexible **Project:** 665(97) **SLM:** 10.01-11.14 SB **Performance:** Excellent
Build Up: 1.25” 446 / 1.75” 446 / 7” 301 / 8” 304 / 6” 310 (3.2 / 4.4 / 17.8 / 20.3 / 15.2 cm)

This pavement project was rated as providing excellent performance in 2004. It was a two-lane flexible pavement with an 8’ (2.4 m) shoulder, and concrete curb and gutter, as shown in Figure E20. Cracks in the northbound lanes had recently been sealed and the southbound lanes were to be sealed soon. Figure E21 shows typical cracking in the southbound lanes and ruts in the right wheelpath were only about 1/16” (2 mm). The 304 base was compacted very well and was too hard for the DCP to penetrate.

Figure E20. – LUC 25 10S Site

Figure E21. – Surface Distress

PIK 32 15 W

Pavement Type: Flexible **Project:** 443(94) **SLM:** 13.43-16.08 WB **Performance:** Excellent

Build Up: 1.25” 446 / 1.75” 446 / 9” 301 / 4” PATB / 4” 304 (3.2 / 4.4 / 22.9 / 10.2 / 10.2 cm)

This project, just west of US 23, was in very good condition with only minimal longitudinal cracks appearing in the centerline and wheelpaths. Rutting was limited to 1/16” (2 mm). The PMIS showed the build up to be as indicated above without the PATB, but PATB was in the cores.

Figure E22. – PIK 32 15W Coring Site

PIK 32 19 W

Pavement Type: Flexible **Project:** 552(95) **SLM:** 16.08-20.47 WB **Performance:** Average
Build Up: 1.25” 446 / 1.75” 446 / 12” 301 / 4” ATFDB / 4” 304 (3.2/ 4.4 / 22.9 / 10.2/ 10.2 cm)

With the exception of longitudinal cracking in the right wheelpath, the westbound lanes of this project was in generally good condition. Figure E23 shows the coring site starting approximately ¼ mile (400 m) west of Tipton Lane, and Figure E24 shows the longitudinal cracking. Rutting varied from 1-5/16” (2-8 mm) in the right wheelpath. The PMIS showed the build up to be 3” (7.6 cm) of 446 over a total thickness of 12” (22.9 cm) of 301 and ATFDB over 4” (10.2 cm) of 304. Cores indicated there was 11” (27.9 cm) of 301 and 4” (10.2 cm) of ATFDB instead of a combined thickness of 12” (22.9 cm) of 301 and ATFDB, as shown in Figure E25. Four cores delaminated at the interface between the two 301 lifts, suggesting poor bonding at this level, and the upper 301 lift in the ODOT2 core came out of the core bit as rubble.

Figure E23. – PIK 32 19W Site

Figure E24. – Wheelpath Cracking

Figure E25. – Intact Core Showing Material Layers

PIK 32 19 E

Pavement Type: Flexible **Project:** 552(95) **SLM:** 16.08-20.47 EB **Performance:** Excellent
Build Up: 1.25" 446 / 1.75" 446 / 12" 301 / 4" ATFDB / 4" 304 (3.2/ 4.4 / 22.9 / 10.2/ 10.2 cm)

The eastbound lanes of Project 552(95) were in better condition than the westbound lanes and there was no delamination of the cores. Rutting ranged from 2-5/32" (0.8-4.0 mm). A minor longitudinal crack was observed about 4' (1.2 m) in from the center paint line.

ROS 35 1 W

Pavement Type: Flexible **Project:** 298(96) **SLM:** 0-4.38 WB **Performance:** Excellent
Build Up: 1.25" 446 T1 / 1.75" 446 T2 / 10" 301 / 4" 306 / 6" 304 / 8" LSS (3.2 / 4.4 / 25.4 / 10.2 / 15.2/ 20.3 cm)

This rural pavement was in very good condition with only minor longitudinal cracking along the centerline of the lane. Figure E26 shows the ROS 35 1W site and Figure E27 shows the cracking. Rutting was minimal at less than 2/16" (3 mm). The 306 cement treated base layer indicated in the PMIS was not present in the cores. The core bit jumped around when coring started, as though the aggregate was unusually hard, and considerable delamination occurred at all material boundaries and midway through the 301 during the coring operation, suggesting insufficient tack was applied. On Core 13, the 446/301 boundary and the lift between the 301 lifts all delaminated, and aggregate in the 301 was stripped in Core 12.

Figure E26. – ROS 35 1W Site

Figure E27. – Centerline Cracking

VAN 30 18 E

Pavement Type: Flexible **Project:** 219(97) **SLM:** 16.16-21.2 EB **Performance:** Average
Build Up: 1.50” 446 / 2.50” 446 / 9” 301 / 9” 304 (3.8 / 6.4 / 22.9 / 22.9 cm)

When arriving at this site on August 25, 2009, a new AC overlay had just been completed on August 7, as shown in Figure E28. Since all performance data used to determine this as an average performing flexible pavement was collected prior to the overlay in 2004, it was decided to keep this project in the study and remove the new overlay before testing the original pavement cores in the laboratory. With the new surface, there were no distresses evident and no rutting. This pavement was described as flexible in the PMIS with an Activity Code of 100, but contained a 9” (22.9 cm) thick layer of PC concrete. A check of the straight-line diagrams showed the paving materials to be described as G over N where G is bituminous concrete and N is plain concrete. This inconsistency between the PMIS and the SLD is discussed further in Chapter 1. Figure E29 shows a typical core turned over with AC over PCC and an asphalt underseal material on the bottom. Figure E30 is a close up showing new gray AC on the original brownish AC. An investigation into this project led to the following explanations:

2002 and 2004 PMIS (Project 219(97) - Remove existing pavement of 1.5” (3.8 cm) AC, 9” (22.9 cm) 451, and 6” (15.2 cm) LSS. Replace with new pavement of 1.5” (3.8 cm) 446, 2.5” (6.4 cm) of 446, 9” (22.9 cm) of 301 and 9” (22.9 cm) of 304.

ODOT Files – Constructed in 1977 with 2.5” (6.4 cm) AC, 9” (22.9 cm) plain concrete and lime stabilized subgrade. Project 369(86) undersealed the pavement, placed fabric on the joints and added a 1.5” (3.8 cm) AC overlay. Project 219(97) removed and replaced the 4” (10.2 cm) of AC. Project 572(08) milled and filled 1.5” (3.8 cm) of AC.

2009 Cores – 1.5” (3.8 cm) new AC, 2.5” (6.4 cm) old AC, 9” (22.9 cm) PC concrete, and asphalt underseal.

Cores removed in 2009 largely support the history of this project assembled from ODOT files, although there would not be joints on plain concrete covered with AC. The PMIS identifies the activity code for Project 219(97) as being 100 (flexible) and the structural base as being 301.

Figure E28. – VAN 30 18E Coring Site

Figure E29. – Core from VAN 30 18E

Figure E30. – New and Old AC on VAN 30

APPENDIX F

Field Sampling and Testing of Rigid Pavements

ALL 30 22E

Pavement Type: Rigid **Project:** 746(97) **SLM:** 20.16 – 24.05 EB **Performance:** Excellent
Joint Spacing: 21' (6.4 m) **Build Up:** 11" 451/ 4" ATFDB/ 6" 304 (27.9 cm/ 10.2 cm/ 15.2 cm)

The pavement appeared to be in excellent condition throughout. The sampling and testing site was located in the eastbound direction at the 22 mile marker (~Sta. 1162). Upon closer examination of this site, a few minor longitudinal cracks were observed over dowel bars and longitudinal reinforcement strands approximately 24 inches (61 cm) in from the outer edge of the pavement, especially between Stations 1163+90 and 1166+42. Figures F1 and F2 show these cracks. A severely distressed slab beginning at Station 1166+42 appeared to be the beginning of a new days pour in which no longitudinal cracks were found. Figure F3 shows this slab with a transverse crack caused by severe distress at the construction joint, and Figure F4 shows considerable concrete being removed around the dowel bar in the core taken at the arrow in Figure F3. Figure F5 shows horizontal cracking observed at dowel bars on the leave side of a core removed during the same day for another project near joints at Stations 1163+40 and 1164+00.

Figure F1. – Longitudinal Crack over Dowel Bar on ALL 30

Figure F2. – Longitudinal Crack over Mesh Reinforcement

Figure F3. – Distressed Slab at Beginning of New Pour

Figure F4. – Void around Dowel Bar at Construction Joint

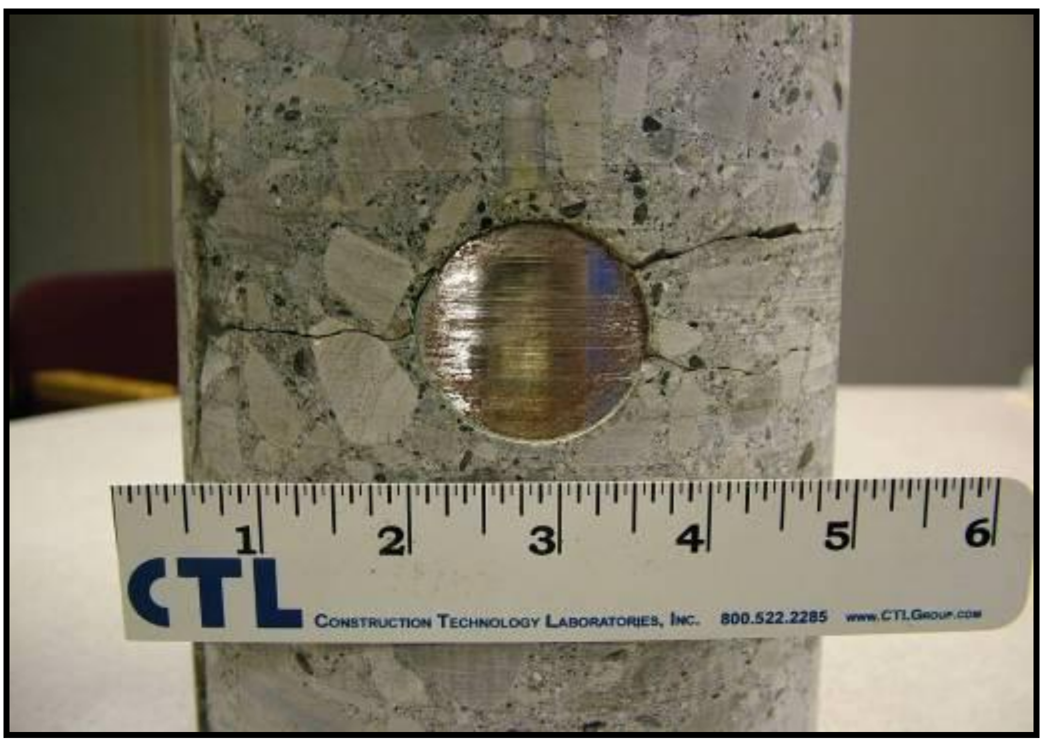


Figure F5. – Horizontal Cracking at Dowel Bar

ATH 33 12 E

Pavement Type: Rigid **Project:** 235(58) **SLM:** 10.40-13.09 EB **Performance:** Average

Joint Spacing: 60’ (18.3 m) **Build Up:** 9” 451/ 8” 310 (22.9 cm/ 20.3 cm)

This project was selected for study because of the time it has carried moderate truck traffic on a primary route in southeastern Ohio. Essentially all of the joints were replaced and the surface was ground in 1999 due to deterioration and faulting of the joints. The site selected for sampling and testing was near on the eastbound side near MP 12. The length of the joint replacements at the site varied from 4-5 feet (1.2-1-5 m) to 10-12 feet (2.5-3.7 m). The original concrete between the replaced joints remains in excellent condition with tight transverse cracks appearing in about every other slab. Some spalling is present along he longitudinal and transverse joints, and some areas over high reinforcing mesh have popped out. Figure F6 shows a joint replacement and Figure F7 shows how the replacement concrete has deteriorated while the original concrete remains intact.

Figure F6. – Joint Replacements on ATH 33

Figure F7. – Deteriorated Concrete in Joint Replacement

ATH 682 1 N

Pavement Type: Rigid **Project:** 625(76) **SLM:** 0.16-0.64 NB **Performance:** Average

Joint Spacing: 40’ (12.2 m) **Build Up:** 9” 451/ 6” 310 (22.9 cm/ 15.2 cm)

This short section of SR 682 connects US 33 with Richmond Avenue which is the main south entrance to the Ohio University campus. The entire section contained moderate to severe transverse cracking in every slab and spalling along many joints. With average performance being determined in 2004, the pavement has deteriorated rapidly since then. Only a few trucks were observed using this route during the sampling and testing, but the traffic control crew indicated that loaded trucks transported coal to the OU campus in the northbound lanes and left empty in the southbound lanes. Figure F8 shows a transverse crack with a core removed for Lankard Material Laboratories, Figure F9 shows deteriorated concrete on the bottom of the slabs, and Figure F10 shows # 8 gravel aggregate in a midslab core.

Figure F8. – Transverse Crack on ATH 682

Figure F9. – Deteriorated Concrete at Bottom of Joint

Figure F10. - #8 Gravel Aggregate in Midslab Core

<u>CUY 82 3 E</u>

<u>Pavement Type:</u> Rigid **<u>Project:</u>** 438(94) **<u>SLM:</u>** 2.05-3.82 EB **<u>Performance:</u>** Excellent

<u>Joint Spacing:</u> 21' (6.4 m) **<u>Build Up:</u>** 11" 451 / 6" 304 (27.9 cm / 15.2 cm)

This pavement section was located in a business area just west of I 71. The pavement was in excellent condition with very tight transverse cracks in most slabs. There was no faulting at the joints. Figures F11 and F12 show the pavement surface with integrated curb and gutter, and a close-up of a transverse crack. Figure F13 shows the green slurry caused by the slag aggregate base as the core bit cut through the pavement. #8 aggregate was used in this pavement.

Figure F11. – Layout of CUY 82 3E

Figure F12. – Transverse Crack

Figure F13. – Green Slurry from Slag Aggregate

CUY 176 10 S

Pavement Type: Rigid **Project:** 683(94) **SLM:** 10.13-10.87 SB **Performance:** Excellent

Joint Spacing: 21’ (6.4 m) **Build Up:** 12” 451 / 6” 310 T2 (30.5 cm / 15.2 cm)

The section of Project 683(94) selected for sampling and testing was the southbound ramp to SR 17 shown in Figure F14. Cores ranged from 11 ½ to 12 ½ inches (29.2-31.8 cm) in length, and there was no faulting at the joints. There were a couple of moderate transverse midslab cracks. One unusual feature was the presence of multiple, randomly spaced longitudinal hairline cracks distributed throughout the slabs. Cores indicated these cracks did not appear to be associated with reinforcing mesh in the pavement and may have been caused by insufficient moisture during curing. These cracks stand out in Figures F15 and F16 as moisture from the coring operation remained in the cracks. These figures were taken side by side at the same location. Cores taken at joints for another project showed horizontal cracking at dowel bars on the approach side of the joints.

Figure F14. – Sampling and Testing Site on CUY 176 10S

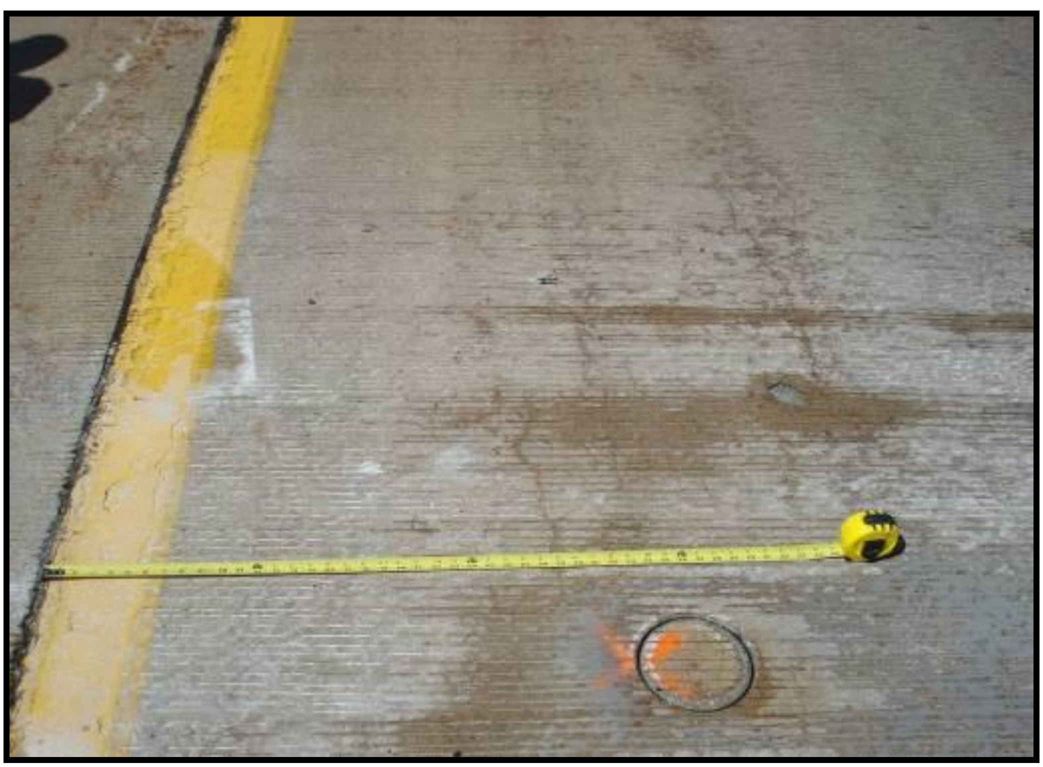


Figure F15. – Longitudinal Hairline Cracking along Pavement Edge

Figure F16. - Longitudinal Hairline Cracking in Center of Slab

CUY 176 11 S

Pavement Type: Rigid **Project:** 305(96) **SLM:** 10.87-12.83 SB **Performance:** Average

Joint Spacing: 21' (6.4 m) **Build Up:** 12" 451 / 6" 310 T2 (30.5 / 15.2 cm)

Figure F17 shows ride quality profiles measured on Projects 683(94) and 305(96) on CUY 176. Upstation is northbound and downstation is southbound on the profiles. Of particular interest is the clear difference in ride quality before and after SLM 12.15 on Project 305(96). Because the cause of this difference in ride quality may be a factor in improving pavement performance, sampling and testing sections were selected from areas near SLM 11 (CUY 176 11S) and SLM 12.7 (CUY 176 12S). There was no faulting and no transverse cracking at these locations. Hydrated slag aggregate in the 310 base was attached to the cores when they were removed from the pavement and the DCP could not penetrate this material. The smoother section of Project 305(96) had three lanes of traffic in both directions while the rougher section to the north had two lanes in both directions. Figure F18 shows horizontal cracking at dowel bars on the approach side of joints near Station 192 in the CUY 176 11S section.

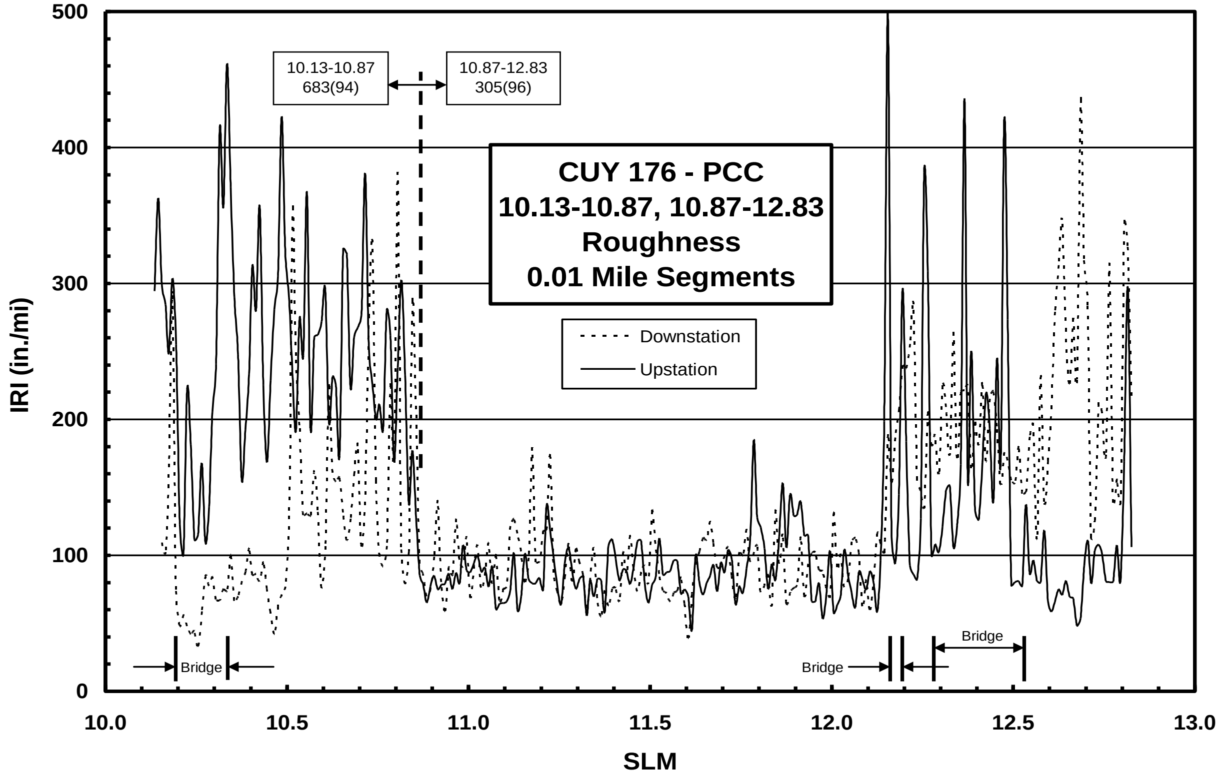


Figure F17. – Roughness Profiles Measured on CUY 176

Figure F18. – Horizontal Cracking at Dowel Bars

CUY 176 12 S

Pavement Type: Rigid **Project:** 305(96) **SLM:** 10.87-12.83 SB **Performance:** Average
Joint Spacing: 21' (6.4 m) **Build Up:** 12" 451 / 6" 310 T2 (30.5 / 15.2 cm)

This site was the complement of Section CUY 176 11S and represented the rougher portion of Project 305(96). Neither of these sections had any particular distress on the surface. Figure F19 shows numerous air voids in the cores which was common at this site. Some of the hydrated 310 base can also be seen on the bottom of the core.

Figure F19. – Air Voids in CUY 176 12 S Core

CUY 252 4 N

Pavement Type: Rigid **Project:** 901(84) **SLM:** 3.47-4.18 NB **Performance:** Average
Joint Spacing: 27' (8.2 m) **Build Up:** 9" 451 / 6" 310 T2 (22.9 cm / 15.2 cm)

This was a residential section of pavement recently overlaid with 3 inches (7.6 cm) of asphalt concrete. The 27 foot (8.2 m) concrete joint spacing was estimated from a few reflective cracks on the surface. The AC overlay easily separated from the PC concrete cores, probably because of a lack of tack coat being applied with the overlay. Since all data used to determine performance were obtained prior to the overlay, the section was considered valid, the AC was removed from the cores and the remaining concrete was tested as though the overlay had not been applied. On the one core cut through a joint, concrete at the bottom had broken into horizontal layers. Plans for Project 901(84) indicated the wire mesh was 6" x 6" (15.2 cm x 15.2 cm) with #10 strands.

CUY 322 10 E

Pavement Type: Rigid **Project:** 1019(93) **SLM:** 8.68-11.98 EB **Performance:** Excellent
Joint Spacing: 21' (6.4 m) **Build Up:** 10" 451 / 6" 310 (25.4 / 15.2 cm)

This section of rigid pavement was located in an area of local businesses and strip malls. The pavement was in excellent condition with no transverse cracking or faulting, although some minor corner spalling was present.

GAL 7 8 N

Pavement Type: Rigid **Project:** 352(46) **SLM:** 5.71-10.21 NB **Performance:** Excellent
Joint Spacing: 40' (12.2 m) **Build Up:** 8" T-71 / 6-12" SS-112 (20.3 / 15.2-30.4 cm)

This pavement, constructed in 1946, was the oldest rigid pavement included in the study. It was located in a rural area along the Ohio River in Gallia County. Although this pavement carries little heavy truck traffic, it is only 8 inches (20.3 cm) thick and has endured more than 60 years of freeze-thaw cycling while carrying local traffic. Some areas along the pavement had replaced joints and transverse cracking, but many other areas, like the one selected for sampling and testing in Figure F20, were in excellent condition. There was no faulting and only occasional minor transverse cracking and spalling at the location in Figure F20. The extremely hard river gravel in this mix made coring difficult. Figure F21 and F22 show how transverse cracks went around the large aggregate particles. One core cut at a joint showed the dowel bar to be rusted through. The joint core in Figure F23 shows: 1) the formed joint with sealant containing fine aggregate, 2) the depth to which the sealant flowed into the crack, and 3) coning on the bottom of the pavement at the joint which has been observed on other much newer rigid pavements.

Figure F20. – Surface of GAL 7 8N

Figure F21. – Transverse Crack through Core

Figure F22. – Fracture Plane in Core

Figure F23. – Side of Core at Joint

GRE 35 19 W

Pavement Type: Rigid **Project:** 19(97) **SLM:** 14.45-20.95 WB **Performance:** Excellent
Joint Spacing: 21’ (6.4 m) **Build Up:** 10” 451 / 4” NSDB / 6” 304 (25.4 / 10.2 / 15.2 cm)

This pavement was in excellent condition with good surface texture, no faulting, and only a couple of minor transverse cracks, one of which was a partial crack initiated at the centerline joint. Occasional popouts from high reinforcing mesh were also visible, as shown in Figure F24.

Figure F24. – Popouts from High Steel on GRE 35 19W

HAM 126 12 E

Pavement Type: Rigid **Project:** 997(90) **SLM:** 11.35-13.31 EB **Performance:** Excellent
Joint Spacing: 27' skewed (8.2 m) **Build Up:** 10" 451 / 6" 310 T2 (25.4 / 15.2 cm)

This pavement was in excellent condition. ODOT assisted with the coring on days when one traffic control zone was used to protect two sampling and testing sections. The core bit on their truck mounted unit is shown in Figure F25. The pavement appeared to have been ground at some point which was probably associated with dowel bar replacements scattered along the project. No dowels had been replaced in the sampling and testing section which was located on a high fill. There was no faulting in the sampling and testing zone and only one transverse crack shown in Figure F26. Core lengths ranged from 11 – 11 ½ inches (27.9 - 29.2 cm) which was well above the 10 inch (25.4 cm) design thickness.

Figure F25. – ODOT Core Rig on HAM 126 12E

Figure F26. – Transverse Crack

<u>JEF 7 19 S</u>

<u>Pavement Type:</u> Rigid **<u>Project:</u>** 8008(90) **<u>SLM:</u>** 18.90-19.21 SB **<u>Performance:</u>** Excellent
<u>Joint Spacing:</u> 27’ skewed (8.2 m) **<u>Build Up:</u>** 9” 451 / 6” 310 T2 (22.9 / 15.2 cm)

Based on PMIS data prior to 2004, this pavement was rated as providing excellent performance. By 2009 when the cores were removed, however, moderate to severe transverse cracks, faulting and spalling were widespread on the project. The project, shown in Figure F27, is in a heavily industrial area where coal is shipped in on barges for power plants and other facilities along the Ohio River. Many heavy trucks use this route to haul coal and other products. One of the more severe transverse cracks in the sampling and testing section is shown in Figure F28. The 310 base material was quite loose under this pavement.

Figure F27. – JEF 7 19S Site

Figure F28. – Severe Transverse Crack

<u>JEF 22 15 E</u>

<u>Pavement Type:</u> Rigid **<u>Project:</u>** 8008(90) **<u>SLM:</u>** 15.02-16.32 EB **<u>Performance:</u>** Average

<u>Joint Spacing:</u> 27' skewed (8.2 m) **<u>Build Up:</u>** 9" 451 / 6" 310 T2 (22.9 / 15.2 cm)

This section of US 22 was constructed under the same project as the preceding section on JEF 7. It was rated as providing average performance, although transverse cracking and spalling were quite common, but not as severe as on the SR 7 section. See Figure F29. There was no faulting at construction joints but the left lane, where cores were cut, had dropped about ¼ inch (6 mm) below the adjacent lane in one area. The 310 base was compacted very well and DCP measurements indicated the base and subgrade had similar stiffnesses.

Figure F29. – JEF 22 15E Site

LOG 33 24 W

Pavement Type: Rigid **Project:** 845(94) **SLM:** 21.51-25.63 WB **Performance:** Average

Joint Spacing: 15' (4.6 m) **Build Up:** 12" 452 / 4" NSDB (30.5 / 10.2 cm)

While this project appeared to be in very good condition, there were some dowel bar repairs and longitudinal joint patches scattered along the project. More of these distresses were observed in the westbound lanes than in the eastbound lanes. The section selected for sampling and testing on Project 845(94) started at MP 24 WB. Figure F30 shows the 24 MP in the background and shows how the right edge of this driving lane was depressed below the concrete shoulder over a distance of about five slabs and to a maximum depth of about 1inch (2.5 cm). The pavement surface had excellent texture and there was no cracking or joint faulting. Cores removed from this section contained numerous voids, as shown in Figure F31. Figure F32 shows distress and a patch along the longitudinal joint at a transverse joint approximately ½ mile (0.8 km) west of the sampling site. This core hole retained water from the coring, while core holes in the sampling section drained quite well, suggesting some type of drainage problem around the distress. The traffic control crew indicated that natural springs were in the area.

Figure F30. – Pavement Surface on LOG 33 24W

Figure F31. – Voids in Core

Figure F32. – Distress along Longitudinal Joint

MOT 35 14 W

Pavement Type: Rigid **Project:** 343(88) **SLM:** 14.37-15.07 WB **Performance:** Excellent

Joint Spacing: 15' (4.6 m) **Build Up:** 10" 452 / 4" 301 / 4" 304 (25.4 / 10.2 / 10.2 cm)

This sampling and testing site for Project 343(88) started just east of the McGee Blvd. bridge over US 35 in the westbound direction, as shown in Figure F33. Two cores were cut before the bridge and the remaining cores were cut after the bridge to avoid abnormal environmental conditions and distresses that sometimes occur under bridge decks. No distresses were evident on the cored slabs, but thickness of the PC concrete progressively increased from 10 inches (25.4 cm) on the east side of the bridge to 13 ¼ inches (33.7 cm) at the last core on the west side of the bridge. All cores were in excellent shape when remover from the holes.

Figure F33. – Coring Site at MOT 35 14W

MOT 202 3 N

Pavement Type: Rigid **Project:** 678(91) **SLM:** 2.00-3.25 NB **Performance:** Excellent
Joint Spacing: 15’ (4.6 m) **Build Up:** 9” 452 / 6” 310 T2 (22.9 / 10.2 / 15.2 cm)

Project 678(91) was a three-lane pavement with an integral curb and gutter just north of SR 4 in Dayton. It was in excellent condition at the time of coring with most slabs having one tight transverse crack. Two joints were cored; one had a tight crack extending from the bottom of the saw kerf to the bottom of the concrete slab and the other had only some small micro-cracks which would probably have developed into a crack.

Figure F34. – MOT 202 3N Site

SUM 76 15 E

Pavement Type: Rigid **Project:** 996(93) **SLM:** 13.32-15.32 EB **Performance:** Average
Joint Spacing: 21’ (6.4 m) **Build Up:** 11” 451/1” 403/6” 301/6” 304 (27.9/ 2.5/ 15.2/ 15.2 cm)

Two adjoining projects on I 76 in Summit County, 844(92) and 996(93), both emerged as potential average performing rigid pavements. Project 844(92) was just west of Project 996(93) and had a slightly higher priority of the two projects because of its age. The very heavy traffic volume, the pavement alignment, and the complex traffic patterns associated with interchanges on Project 844(92), however, showed Project 996(93) to be the safer project to study. For safety reasons, the sampling and testing section on Project 996(93) was located in an area with relatively straight alignment and good sight distance for motorists approaching the work zone. Because of heavy traffic in the lane adjacent to the work zone, site work was expedited as much as possible to complete the work quickly and minimize the exposure to traffic. A few transverse cracks were observed in the right lane which also was about ¼ inch (6 mm) lower than the center lane. Cores taken at the joints showed some horizontal cracking at the dowel bars. Eight inches (20.3 cm) of AC base was often attached to the PC concrete when cores were removed from the pavement. Samples of the 304 base and subgrade could not be obtained due to thicknesses of the 451 and 301.

SUM 76 15 W

Pavement Type: Rigid **Project:** 996(93) **SLM:** 13.32-15.32 EB **Performance:** Excellent
Joint Spacing: 21’ (6.4 m) **Build Up:** 11” 451/1” 403/6” 301/6” 304 (27.9/ 2.5/ 15.2/ 15.2 cm)

This westbound complement of SUM 76 15E was in better condition than the eastbound side. While there were no transverse cracks, there was some minor spalling and corner breaks in the left two lanes. Cores often had a one-inch (3 mm) thick layer of what appeared to be tack coat on the bottom which stuck to the concrete better than the 301. As on the eastbound side, samples of the 304 base and subgrade were not collected

<u>TUS 39 4 E</u>

<u>Pavement Type:</u> Rigid **<u>Project:</u>** 907(90) **<u>SLM:</u>** 2.84-7.12 EB **<u>Performance:</u>** Average

<u>Joint Spacing:</u> 27' (6.4 m) skewed **<u>Build Up:</u>** 9" 451 / ?" 310 (22.9/ ? cm)

This project was located on SR 39 just east of Sugarcreek and the sampling and testing site started about 200 feet (61 m) east of CR 139, as shown in Figure F35. A few minor to moderate transverse cracks were observed in the slabs and coring was difficult, possibly because of hard aggregate. After seven cores were cut, the core bit got stuck and had to be removed manually. One more core was then cut with some difficulty. By this time, the sampling and testing section was on a vertical grade which had caused coring problems in the past. The crew moved to a flatter section of pavement about ¼ mile down the road to complete the coring. The condition of the pavement at this new location was similar to the original location with minor to moderate transverse cracking. After cutting three 6" (15.2 cm) diameter cores, diamonds worn from the bit and, since another 6" (15.2 cm) bit was not available, the remaining cores were cut with a 4" (10.2 cm) diameter bit.

Figure F35. – First Site on TUS 39 4E

Summary

Of the twenty rigid pavement sites, seventeen projects were constructed with reinforced concrete (ODOT 451) and the following three projects were constructed with non-reinforced concrete (ODOT 452); LOG 33 was rated average, and MOT 35 and MOT 202 were rated excellent based on PCR data through 2004. By 2009, the condition of the sampling and testing section at MP 24 WB on LOG 33 in 2009 agreed quite well with the 2004 PMIS. There were some deteriorated patches scattered along the longitudinal joint outside the section and slab settlement in the section, as described in Appendix F. The 4 inch (10 cm) thick 307 IA base drained the core holes in the sampling and testing section well and evidently over most of the project based on the excellent condition of the pavement. Water did not drain from a core hole cut through a patch in the longitudinal joint about a half mile (0.8 km) west, and the core consisted of rubble at the bottom of the pavement, suggesting some localized drainage problems. ODOT personnel confirmed that natural springs had created some drainage issues in the area.

The 300 foot (91 m) long sampling and testing section near MP 14 WB on MOT 35 was located in a cut under a bridge, but the area directly under the bridge was avoided. While no cracking was noted in the 2004 PMIS condition ratings, two tight transverse cracks were observed in the sampling and testing section in 2009. Overall, the 10 inches (25 cm) of 452 / 4 inches (10 cm) of 301 / 4 inches (10 cm) 304 design appears to be performing quite well. Project 678(91) on MOT 202 was located on a three-lane residential street. While only minor longitudinal cracking was noted in the 2004 PMIS, tight transverse cracks were observed in most slabs in 2009. This 9 inch (23 cm) thick 452 pavement was constructed on 6 inches (15 cm) of 310 T2 aggregate base and is performing reasonably well.

APPENDIX G

Asphalt Test Data and
Concrete Aggregate Sources

Table G1

Asphalt Parameters and Aggregate Gradations by ODOT (1/4)

Flexible Pavement Mix Parameters and Aggregate Gradation - ODOT Laboratory																											1/4
Co./Rt.	Core Site Perf.	Project	Field Core No.	ODOT Lab Core No.	ODOT AC Layer	PMIS Layer Spec.	Prin. Coarse Aggr. Type	Layer Thickness (in)	AC Mix Parameters: Bulk Spec. Gravity	Max Spec. Gravity	Air Void %	Density %	% AC	F/A Ratio (%#200/%AC)	% Aggregate Passing Sieve (inches or sieve number/mm): 2.0" (50)	1.5" (37.5)	1.0" (25)	3/4" (19)	1/2" (12.5)	3/8" (9.5)	#4 (4.75)	#8 (2.36)	#16 (1.18)	#30 (0.60)	#50 (0.30)	#100 (0.15	#200 (0.075)
BUT 129	22E Excel.	9330(98)	1	9	Surf.	446 T1	LS	1.07	2.42	2.50	3.3	96.7	4.92	0.2				100	93	77	46	29	16	8	4	2	1.1
					Inter.	446 T2	LS	1.55	2.42	2.49	3.0	97.0	5.09	0.6			100	96	81	69	48	40	30	18	8	4	3.0
					Base	302	LS	4.56	2.35	2.57	8.4	91.6	3.35	1.2	100	97	87	76	63	58	41	33	25	17	8	5	4.1
					ATFDB	308	LS	broken	n/a	n/a	n/a	n/a	1.93	1.5			100	89	42	18	7	5	4	4	4	3	2.9
			2	10	Surf.	446 T1	LS	1.15	2.36	2.52	6.4	93.6	4.43	0.4				100	90	77	46	33	19	11	6	3	1.7
					Inter.	446 T2	LS	1.54	2.42	2.52	4.1	95.9	4.90	0.7				100	84	73	49	41	30	19	8	4	3.1
					Base	302	LS	4.96	2.38	2.53	6.0	94.0	3.52	1.2		100	87	82	69	62	44	34	26	17	9	6	4.3
					ATFDB	302	LS	broken	n/a	n/a	n/a	n/a	2.39	1.1			100	88	38	17	7	6	5	4	4	3	2.7
	22W Avg.	9330(98)	1	13	Surf.	446 T1	LS	1.56	2.40	2.52	4.8	95.2	4.82	1.0				100	92	80	54	38	25	17	11	7	4.7
					Inter.	446 T2	LS	broken	n/a	2.51	n/a	n/a	4.71	0.6			100	96	81	69	51	43	34	21	8	4	3.0
					Base	302	LS	3.62	2.43	2.57	5.3	94.7	3.71	1.2	100	94	94	86	74	67	47	37	28	19	9	6	4.6
					ATFDB	308	LS	n/a	n/a	n/a	n/a	n/a	1.75	1.6			100	92	49	21	7	5	4	4	4	3	2.8
			2	14	Surf.	446 T1	LS	1.41	2.38	2.52	5.4	94.6	n/a	n/a			n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
					Inter.	446 T2	LS	2.04	2.34	2.48	5.6	94.4	n/a	n/a			n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
					Base	302	LS	4.60	2.47	2.57	3.8	96.2	n/a	n/a			n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	25W Avg.	9327(98)	1	11	Surf.	446 T1	LS/GR	1.26	2.37	2.49	4.7	95.3	6.33	0.7				100	96	87	51	35	25	17	10	6	4.6
					Inter.	446 T2	LS/GR	2.03	2.39	2.48	3.7	96.3	5.28	0.7			100	99	88	73	53	43	33	22	10	5	3.6
					Base	302	LS	4.09	2.42	2.50	3.3	96.7	4.19	1.0		100	90	81	68	58	38	31	25	18	9	6	4.3
					Base	302	LS	n/a	n/a	n/a	n/a	n/a	2.66	1.6			100	94	61	31	15	11	9	8	6	5	4.3
			2	12	Surf.	446 T1	LS/GR	1.32	2.41	2.51	4.1	95.9	n/a	n/a		n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
					Inter.	446 T2	LS/GR	2.02	2.42	2.59	6.5	93.5	n/a	n/a			n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
					Base	302	LS	3.86	2.37	2.49	5.1	94.9	n/a	n/a			n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
CHP 68	2N Excel.	233(98)	1	27	Surf.	448 T1H	LS/GR	1.64	2.40	2.49	3.4	96.6	5.69	0.8				100	98	88	51	35	25	16	9	6	4.4
					Inter.	448 T2	LS/GR	1.74	2.42	2.52	3.9	96.1	4.68	1.0			100	99	77	60	45	35	26	17	9	6	4.7
					Base	301	LS/GR	2.62	2.41	2.51	4.0	96.0	4.90	1.0			100	98	74	64	49	39	29	20	11	7	5.1
			2	28	Surf.	448 T1H	LS/GR	1.66	2.37	2.49	4.8	95.2	n/a	n/a			n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
					Inter.	448 T2	LS/GR	1.60	2.38	2.47	3.7	96.3	n/a	n/a			n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
					Base	301	LS/GR	2.44	2.40	2.55	5.6	94.4	n/a	n/a			n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	2.5N Avg.	233(98)	1	31	Surf.	448 T1H	LS/GR	broken	n/a	2.50	n/a	n/a	5.32	0.5				100	97	84	49	34	24	15	7	4	2.6
					Inter.	448 T2	GR	2.02	2.39	2.51	4.9	95.1	4.58	0.9			100	99	78	63	45	34	24	16	8	6	4.2
					Base	301	LS/GR	2.28	2.33	2.53	8.1	91.9	3.80	1.2			100	96	60	41	31	26	20	14	9	6	4.4
					Base	301	GR	3.93	2.36	2.50	5.8	94.2	4.63	0.9		100	99	97	59	43	38	32	24	16	9	6	4.0
			2	32	Surf.	448 T1H	LS/GR	1.42	2.35	2.51	6.2	93.8	5.27	0.6				100	98	85	46	32	23	15	8	5	3.4
					Inter.	448 T2	GR	1.85	2.38	2.50	5.0	95.0	4.43	1.0			100	96	74	61	44	34	24	16	8	6	4.3
					Base	301	LS/GR	2.37	2.36	2.50	5.6	94.4	4.75	1.1				100	76	59	45	36	27	19	10	7	5.3
					Base	301	GR	4.00	2.38	2.51	5.1	94.9	4.86	0.8			100	98	68	54	43	34	25	16	8	5	4.1

1 inch = 2.54 cm

Table G1

Asphalt Parameters and Aggregate Gradations by ODOT (2/4)

Flexible Pavement Mix Parameters and Aggregate Gradation - ODOT Laboratory																											2/4
Co./Rt.	Core Site Perf.	Project	Field Core No.	ODOT Lab Core No.	ODOT AC Layer	PMIS Layer Spec.	Prin. Coarse Aggr. Type	Layer Thickness (in)	AC Mix Parameters: Bulk Spec. Gravity	Max Spec. Gravity	Air Void %	Density %	% AC	F/A Ratio (%#200/%AC)	% Aggregate Passing Sieve (inches or sieve number/mm): 2.0" (50)	1.5" (37.5)	1.0" (25)	3/4" (19)	1/2" (12.5)	3/8" (9.5)	#4 (4.75)	#8 (2.36)	#16 (1.18)	#30 (0.60)	#50 (0.30)	#100 (0.15)	#200 (0.075)
CLA 41	3N Excel.	63(95)	1	25	Surf.	404	GR	1.87	2.37	2.50	5.1	94.9	5.26	0.7					100	96	59	43	32	21	9	5	3.7
					Inter.	402	GR	1.30	2.37	2.50	5.3	94.7	5.20	0.6			100	96	86	73	52	42	30	20	8	4	3.0
					Base	301	GR	2.05	2.36	2.52	6.3	93.7	4.71	0.7		100	98	96	84	70	48	38	27	18	8	5	3.5
			2	26	Surf.	404	GR	2.39	2.43	2.60	6.5	93.5	n/a	n/a		n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
					Inter.	402	GR	3.07	2.40	2.56	5.9	94.1	n/a	n/a		n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
					Base	301	GR	5.15	2.37	2.55	7.3	92.7	n/a	n/a		n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	4N Avg.	63(95)	1	29	Surf.	404	GR	1.14	2.42	2.51	3.6	96.4	5.42	0.8					100	97	63	n/a	32	21	9	5	4.1
					Inter.	402	LS/GR	2.10	2.35	2.52	6.9	93.1	4.50	0.7			100	98	85	75	53	n/a	32	22	8	4	3.2
					Base	301	GR	1.50	2.38	2.52	5.4	94.6	4.53	0.9			100	96	84	72	52	n/a	27	18	8	5	4.2
					Base	301	GR	5.04	2.40	2.52	4.8	95.2	4.72	0.8		100	99	96	85	73	50	n/a	27	17	8	5	3.9
			2	30	Surf.	404	GR	1.24	2.37	2.54	6.6	93.4	n/a	n/a		n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
					Inter.	402	LS/GR	1.68	2.34	2.57	8.7	91.3	n/a	n/a		n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
					Base	301	GR	1.94	2.36	2.50	5.6	94.4	n/a	n/a		n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
					Base	301	GR	5.74	2.37	2.50	5.2	94.8	n/a	n/a		n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
DEL 23	17S Excel.	380(94)	1	37	Surf.	446 T1	LS/SL	1.79	2.40	2.54	5.6	94.4	6.25	0.8				100	97	89	66	n/a	40	27	17	10	5.3
					Inter.	446 T2	LS/SL	2.24	2.33	2.52	7.8	92.2	5.75	1.0			100	98	86	79	62	n/a	35	24	15	9	5.5
					Base	302	LS	3.13	2.28	2.47	7.5	92.5	4.70	1.4	100	97	72	59	50	44	30	n/a	17	13	11	9	6.7
					Base	302	LS	3.12	2.32	2.47	6.3	93.7	4.30	1.5		100	70	53	45	42	29	n/a	16	12	10	9	6.6
					ATFDB	308	LS	n/a	n/a	n/a	n/a	n/a	2.26	1.4			100	85	36	18	9	n/a	6	5	5	4	3.2
			2	38	Surf.	446 T1	LS/SL	2.03	2.40	2.54	5.5	94.5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
					Inter.	446 T2	LS/SL	2.30	2.34	2.50	6.3	93.7	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
					Base	302	LS	3.34	2.33	2.46	5.2	94.8	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
					Base	302	LS	3.01	2.35	2.48	5.3	94.7	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
					ATFDB	308	LS	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	18S Avg.	380(94)	1	39	Surf.	446 T1	LS	1.71	2.27	2.48	8.4	91.6	6.48	1.0				100	97	91	58	n/a	24	16	11	9	6.5
					Inter.	446 T2	LS	2.19	2.33	2.49	6.5	93.5	6.10	1.0			100	96	82	73	52	n/a	23	16	11	9	6.3
					Base	302	LS	3.18	2.26	2.47	8.5	91.5	5.64	1.3	100	96	86	73	62	55	37	n/a	19	15	12	10	7.3
					Base	302	LS	2.44	2.31	2.47	6.3	93.7	5.20	1.5		100	83	71	58	50	34	n/a	19	14	12	10	7.7
					ATFDB	308	LS	n/a	n/a	n/a	n/a	n/a	2.13	1.6			100	79	30	14	8	n/a	6	5	5	4	3.4
GRE 35	21E Excel.	259(98)	1	17	Surf.	448 T1H	LS	0.98	2.30	2.48	7.1	92.9	6.94	1.2					100	98	87	n/a	44	32	20	13	8.6
					Inter.	448 T2	LS	1.70	2.31	2.47	6.6	93.4	5.88	0.3				100	92	84	54	n/a	22	12	5	3	1.7
					Base	301	LS	1.46	2.31	2.50	7.4	92.6	5.48	1.0			100	97	78	69	50	n/a	29	19	12	8	5.4
					Base	301	GR	3.00	2.45	2.50	2.1	97.9	4.86	0.9		100	94	90	75	64	46	n/a	26	18	11	6	4.6
					Base	301	LS	4.75	2.27	2.49	9.1	90.9	5.30	1.1			100	96	72	62	43	n/a	25	18	12	9	5.7
			2	18	Surf.	448 T1H	LS	2.38	2.31	2.46	6.3	93.7	n/a	n/a		n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
					Inter.	448 T2	LS	1.58	2.30	2.49	7.6	92.4	n/a	n/a		n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
					Base	301	LS	1.59	2.29	2.44	6.3	93.7	n/a	n/a		n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
					Base	301	GR	2.85	2.45	2.49	1.7	98.3	n/a	n/a		n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
					Base	301	LS	5.06	2.42	2.50	3.2	96.8	n/a	n/a		n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

1 inch = 2.54 cm

Table G1

Asphalt Parameters and Aggregate Gradations by ODOT (3/4)

Co./Rt.	Core Site Perf.	Project	Field Core No.	ODOT Lab Core No.	ODOT AC Layer	PMIS Layer Spec.	Prin. Coarse Aggr. Type	Layer Thickness (in)	Bulk Spec. Gravity	Max Spec. Gravity	Air Void %	Density %	% AC	F/A Ratio (%#200/%AC)	2.0" (50)	1.5" (37.5)	1.0" (25)	3/4" (19)	1/2" (12.5)	3/8" (9.5)	#4 (4.75)	#8 (2.36)	#16 (1.18)	#30 (0.60)	#50 (0.30)	#100 (0.15	#200 (0.075)
Flexible Pavement Mix Parameters and Aggregate Gradation - ODOT Laboratory									AC Mix Parameters						% Aggregate Passing Sieve (inches or sieve number/mm)												3/4
HAM 126	11E Excel.	645(94)	1	19	Surf.	446 T1	LS/GR	broken	n/a	2.52	n/a	n/a	4.74	1.1				100	97	84	47	n/a	29	21	12	7	5.3
					Inter.	446 T2	GR	1.83	2.40	2.53	5.0	95.0	3.64	0.9			100	96	76	64	38	n/a	26	18	9	5	3.4
					Base	301	GR	4.86	2.42	2.50	3.3	96.7	4.97	0.9			100	98	80	68	43	n/a	25	17	9	6	4.4
			2	20	Surf.	446 T1	LS/GR	1.41	2.41	2.64	8.5	91.5	4.83	0.8				100	96	83	45	n/a	29	20	11	6	4.1
					Inter.	446 T2	GR	1.84	2.40	2.60	7.6	92.4	4.65	0.6			100	98	75	65	39	n/a	28	20	9	4	3.0
					Base	301	GR	4.68	2.44	2.46	0.8	99.2	4.97	0.8			100	95	77	65	41	n/a	24	17	9	5	3.8
HAM 747	1S Avg.	347(85)	1	15	Surf.	404	LS	1.88	2.42	2.48	2.5	97.5	5.60	0.8					100	99	61	46	36	24	10	6	4.5
					Inter.	403	GR	1.85	2.34	2.48	6.0	94.0	5.54	0.9					100	98	69	56	38	24	12	7	5.2
					Base	301	GR	3.32	2.45	2.50	2.3	97.7	4.75	0.9			100	97	79	65	45	37	30	21	10	6	4.3
			2	16	Surf.	404	LS	1.32	2.36	2.47	4.3	95.7	n/a	n/a			n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
					Inter.	403	GR	broken	n/a	2.49	n/a	n/a	n/a	n/a			n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
					Base	301	GR	2.20	2.43	2.53	3.9	96.1	n/a	n/a			n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
LAW 527	2N Avg.	17(85)	1	35	Surf.	404	LS	1.78	2.40	2.52	4.9	95.1	4.97	1.0			100	97	84	72	46	34	26	21	12	7	4.8
					Inter.	402	LS	1.67	2.37	2.46	3.7	96.3	5.53	0.6			100	96	83	71	44	33	27	21	10	5	3.3
					Base	301	LS	3.50	2.34	2.45	4.5	95.5	4.99	0.5			100	97	72	59	44	38	34	27	11	4	2.3
					Base	301	LS	2.99	2.34	2.45	4.7	95.3	5.12	0.5			100	95	74	65	45	36	31	25	10	4	2.8
			2	36	Surf.	404	LS	2.13	2.38	2.52	5.6	94.4	n/a	n/a			n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
					Inter.	402	LS	broken	n/a	2.47	n/a	n/a	n/a	n/a			n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
					Base	301	LS	2.37	2.32	2.48	6.5	93.5	n/a	n/a			n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
					Base	301	LS	4.00	2.30	2.48	7.4	92.6	n/a	n/a			n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
LUC 2	22E Avg.	141(99)	1	21	Surf.	446 T1H	LS	1.32	2.44	2.55	4.6	95.4	5.71	0.8				100	98	88	48	32	20	13	9	6	4.3
					Inter.	446 T2	LS	2.43	2.44	2.55	4.3	95.7	5.76	0.9			100	96	87	79	47	32	22	16	11	8	5.0
					Base	301	LS	4.42	2.43	2.59	6.2	93.8	4.24	1.2	100	95	87	76	60	53	36	29	22	16	11	8	5.1
			2	22	Surf.	446 T1H	LS	1.26	2.43	2.57	5.2	94.8	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
					Inter.	446 T2	LS	2.41	2.50	2.44	2.4	97.6	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
					Base	301	LS	4.60	2.46	2.54	3.5	96.5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
LUC 25	10S Excel.	665(97)	1	23	Surf.	446 T1	LS	1.70	2.40	2.55	5.8	94.2	5.66	0.9				100	97	83	49	31	21	16	11	8	5.0
					Inter.	446 T2	LS/GR	1.63	2.37	2.54	6.7	93.3	4.86	1.4				100	87	79	61	38	27	21	15	10	7.0
					Base	301	LS	3.49	2.44	2.52	3.2	96.8	4.86	1.3	100	94	84	70	58	53	41	31	23	17	12	9	6.3
			2	24	Surf.	446 T1	LS	1.67	2.39	2.56	6.6	93.4	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
					Inter.	446 T2	LS/GR	broken	n/a	2.53	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
					Base	301	LS	3.14	2.45	2.50	2.1	97.9	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

1 inch = 2.54 cm

Table G1

Asphalt Parameters and Aggregate Gradations by ODOT (4/4)

Flexible Pavement Mix Parameters and Aggregate Gradation - ODOT Laboratory																											4/4
									AC Mix Parameters						% Aggregate Passing Sieve (inches or sieve number/mm)												
Co./Rt.	Core Site Perf.	Project	Field Core No.	ODOT Lab Core No.	ODOT AC Layer	PMIS Layer Spec.	Prin. Coarse Aggr. Type	Layer Thickness (in)	Bulk Spec. Gravity	Max Spec. Gravity	Air Void %	Density %	% AC	F/A Ratio (%#200/%AC)	2.0" (50)	1.5" (37.5)	1.0" (25)	3/4" (19)	1/2" (12.5)	3/8" (9.5)	#4 (4.75)	#8 (2.36)	#16 (1.18)	#30 (0.60)	#50 (0.30)	#100 (0.15	#200 (0.075)
PIK 32	15W Excel.	443(94)	1	1	Surf.	446 T1	LS	1.44	2.35	2.50	5.8	94.2	5.96	0.7				100	98	91	54	38	28	21	11	6	4.3
					Inter.	446 T2	GR	1.92	2.30	2.41	4.8	95.2	5.12	0.6			100	98	79	67	47	38	31	21	8	4	3.0
					Base	301	LS	4.75	2.32	2.49	6.8	93.2	5.70	0.7			100	98	74	59	49	45	31	20	13	8	4.1
					ATFDB	308	LS	3.20	n/a	n/a	n/a	n/a	2.76	1.1			100	98	77	58	21	12	8	7	5	4	3.1
			2	2	Surf.	446 T1	LS	1.74	2.38	2.48	4.0	96.0	5.84	0.8				100	95	88	53	38	29	21	11	6	4.4
					Inter.	446 T2	GR	2.00	2.32	2.42	4.0	96.0	5.17	0.6			100	99	84	73	50	41	33	22	9	4	2.9
					Base	301	LS	4.59	2.31	2.50	7.4	92.6	5.13	0.7			100	98	71	54	44	40	28	18	12	7	3.8
					ATFDB	308	LS	3.39	n/a	n/a	n/a	n/a	2.26	1.2			100	98	69	46	15	9	7	5	4	4	2.8
	19E Excel.	552(95)	1	5	Surf.	446 T1	GR/LS	broken	n/a	2.49	n/a	n/a	5.77	1.1					100	97	58	41	29	21	12	8	6.1
					Inter.	446 T2	LS	1.89	2.35	2.47	4.9	95.1	4.94	0.8			100	99	79	70	51	39	30	21	9	5	4.1
					Base	301	GR	4.84	2.36	2.44	3.2	96.8	5.48	0.8			100	97	84	71	51	41	33	25	11	5	4.2
					ATFDB	308	LS	n/a	n/a	n/a	n/a	n/a	2.52	1.1			100	90	47	25	10	7	5	4	4	3	2.7
			2	6	Surf.	446 T1	GR	1.40	2.35	2.47	4.9	95.1	6.29	0.9					100	97	60	43	30	21	12	8	5.4
					Inter.	446 T2	LS	2.13	2.37	2.46	3.4	96.6	5.47	0.8			100	98	83	74	53	41	31	21	9	5	4.2
					Base	301	GR	4.73	2.35	2.45	4.0	96.0	4.77	0.8			100	95	80	67	47	37	29	22	9	5	3.7
					ATFDB	308	LS	broken	n/a	n/a	n/a	n/a	2.16	1.2			100	90	41	21	8	6	5	4	3	3	2.5
	19W Avg.	552(95)	1	3	Surf.	446 T1	broken	n/a	n/a	2.49	n/a	n/a	6.4	0.8					100	98	59	42	30	21	12	7	5.1
					Inter.	446 T2	LS	1.43	2.35	2.48	5.3	94.7	5.01	0.6			100	97	73	64	45	36	30	22	9	4	3.0
					Base	301	LS	2.05	2.32	2.51	7.5	92.5	3.86	0.8		100	96	93	70	57	38	30	24	18	8	4	3.1
					ATFDB	308	LS	n/a	n/a	n/a	n/a	n/a	2.41	1.0			100	93	47	26	9	6	5	4	4	3	2.5
			2	4	Surf.	446 T1	broken	n/a	n/a	n/a	n/a	n/a	n/a	n/a			n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
					Inter.	446 T2	broken	n/a	n/a	n/a	n/a	n/a	n/a	n/a			n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
					Base	301	LS	2.05	2.40	2.43	5.2	94.8	5.21	0.6			100	97	79	63	43	33	26	19	8	4	2.9
					ATFDB	308	LS	n/a	n/a	n/a	n/a	n/a	2.50	1.2			100	93	54	33	12	7	5	5	4	4	3.1
ROS 35	1W Excel.	298(96)	1	7	Surf.	446 T1	LS	1.32	2.33	2.52	7.4	92.6	5.00	1.0				100	91	78	43	31	23	17	12	8	5.1
					Inter.	446 T2	LS	2.05	2.31	2.55	9.1	90.9	4.88	0.9			100	99	81	61	41	33	24	16	10	7	4.2
					Base	301	Ls	5.05	2.32	2.53	8.2	91.8	3.99	1.5		100	80	65	52	44	31	26	18	13	9	7	6.0
			2	8	Surf.	446 T1	LS	1.25	2.31	2.53	8.7	91.3	5.64	1.0				100	95	88	52	37	27	19	12	8	5.6
					Inter.	446 T2	LS	2.04	2.34	2.51	7.1	92.9	4.94	1.0				100	83	64	43	34	25	17	11	7	4.7
					Base	301	LS	5.66	2.27	2.53	10.0	90.0	4.18	1.7		100	86	78	65	58	44	37	25	17	12	9	7.0
VAN 30	18E Avg.	219(97)	1	33	Surf.	446 T1H	n/a	1.68	2.38	2.50	5.0	95.0	n/a	n/a			n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
					Inter.	446 T2	n/a	2.86	2.36	2.52	6.3	93.7	n/a	n/a			n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
					Base	451	Composite Pavement																				
			2	34	Surf.	446 T1H	n/a	1.69	2.32	2.51	7.6	92.4	n/a	n/a			n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
					Inter.	446 T2	n/a	2.60	2.41	2.53	4.7	95.3	n/a	n/a			n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
					Base	451	Composite Pavement																				

1 inch = 2.54 cm

Table G2 – AC Surface Layer Parameters

Co./Rt./Site	ODOT Core No.	PMIS Layer Spec.	Prin. Coarse Aggr. Type	Layer Thickness (in.)	Bulk Spec. Gravity	Max Spec. Gravity	Air Voids (%)	Density (%)	% AC	F/A Ratio (%#200/%AC)	2.0" (50)	1.5" (37.5)	1.0" (25)	3/4" (19)	1/2" (12.5)	3/8" (9.5)	#4 (4.75)	#8 (2.36)	#16 (1.18)	#30 (0.60)	#50 (0.30)	#100 (0.15)	#200 (0.075)
Flexible Pavement Mix Parameters & Aggregate Gradation - Surface Layers																							
					Average Flexible Mix Parameters						Aggregate Gradation: % Aggregate Passing Sieve (inches or sieve number/mm)												
Surface Layer - Average Performance																							
BUT 129 22W	13	446 T1	LS	1.56	2.39	2.52	5.1	94.9	4.82	1.0				100	92	80	54	38	25	17	11	7	4.7
	14	446 T1	LS	1.41																			
BUT 129 25W	11	446 T1	LS/GR	1.26	2.39	2.50	4.4	95.6	6.33	0.7				100	96	87	51	35	25	17	10	6	4.6
	12	446 T1	LS/GR	1.32																			
DEL 23 18S	39	446 T1	LS	1.71	2.27	2.48	8.4	91.6	6.48	1.0				100	97	91	58	38	24	16	11	9	6.5
PIK 32 19W	3	446 T1	LS	broken	n/a	2.49	n/a	n/a	6.40	0.8					100	98	59	42	30	21	12	7	5.1
	4	446 T1	LS	broken																			
			Average 446 T1	1.45	2.35	2.50	6.0	94.0	6.01	0.9				100	96	89	56	38	26	18	11	7.3	5.2
LUC 2 22E	21	446 T1H	LS	1.32	2.44	2.56	4.9	95.1	5.71	0.8				100	98	88	48	32	20	13	9	6	4.3
	22	446 T1H	LS	1.26																			
			Average 446 T1H	1.29	2.44	2.56	4.9	95.1	5.71	0.8				100	98	88	48	32	20	13	9.0	6.0	4.3
CHP 68 2.5N	31	448 T1H	LS/GR	broken	2.35	2.51	6.2	93.8	5.30	0.6				100	98	85	48	33	24	15	8	5	3.0
	32	448 T1H	LS/GR	1.42																			
			Average 448 T1H	1.42	2.35	2.51	6.2	93.8	5.30	0.6				100	98	85	48	33	24	15	8.0	5.0	3.0
CLA 41 4N	29	404	GR	1.14	2.40	2.53	5.1	94.9	5.42	0.8					100	97	63	43	32	21	9	5	4.1
	30	404	GR	1.24																			
HAM 747 1S	15	404	LS	1.88	2.39	2.48	3.4	96.6	5.60	0.8					100	99	61	46	36	24	10	6	4.5
	16	404	LS	1.32																			
LAW 527 2N	35	404	LS	1.78	2.39	2.52	5.3	94.8	4.97	1.0			100	97	84	72	46	34	26	21	12	7	4.8
	36	404	LS	2.13																			
			Average 404	1.58	2.39	2.51	4.6	95.4	5.33	0.9			100	97	95	89	57	41	31	22	10	6.0	4.5
			Average All	1.48	2.38	2.51	5.4	94.7	5.67	0.8			100	99.5	96.1	88.6	54.2	37.9	26.9	18.3	10.2	6.4	4.6
Surface Layer - Excellent Performance																							
BUT 129 22E	9	446 T1	LS	1.07	2.39	2.51	4.9	95.2	4.68	0.3				100	92	77	46	31	18	10	5	3	1.4
	10	446 T1	LS	1.15																			
DEL 23 17S	37	446 T1	LS/SL	1.79	2.40	2.54	5.6	94.5	6.25	0.8				100	97	89	66	53	40	27	17	10	5.3
	38	446 T1	LS/SL	2.03																			
HAM 126 11E	19	446 T1	LS/GR	broken	2.41	2.58	8.5	91.5	4.79	1.0				100	97	84	46	37	29	21	12	7	4.7
	20	446 T1	LS/GR	1.41																			
LUC 25 10S	23	446 T1	LS	1.70	2.40	2.56	6.2	93.8	5.66	0.9				100	97	83	49	31	21	16	11	8	5.0
	24	446 T1	LS	1.67																			
PIK 32 15W	1	446 T1	LS	1.44	2.37	2.49	4.9	95.1	5.90	0.8				100	97	91	54	38	28	21	11	6	4.4
	2	446 T1	LS	1.74																			
PIK 32 19E	5	446 T1	LS/GR	broken	2.35	2.48	4.9	95.1	6.03	1.0					100	97	59	42	30	21	12	8	5.8
	6	446 T1	GR	1.40																			
ROS 35 1W	7	446 T1	LS	1.32	2.32	2.53	8.1	92.0	5.32	1.0				100	93	83	48	34	25	18	12	8	5.4
	8	446 T1	LS	1.25																			
			Average 446 T1	1.50	2.38	2.53	6.2	93.9	5.52	0.8				100	96	86	53	38	27	19	11	7.1	4.6
CHP 68 2N	27	448 T1H	LS/GR	1.64	2.39	2.49	4.2	95.9	5.69	0.8				100	98	88	51	35	25	16	9	6	4.4
	28	448 T1H	LS/GR	1.66																			
GRE 35 21E	17	448 T1H	LS	0.98	2.31	2.47	6.7	93.3	6.94	1.2					100	98	87	60	44	32	20	13	8.6
	18	448 T1H	LS	2.38																			
			Average 448 T1H	1.67	2.35	2.48	5.5	94.6	6.32	1.0				100	99	93	69	48	35	24	15	9.5	6.5
CLA 413N	25	404	GR	1.87	2.40	2.55	5.8	94.2	5.26	0.7					100	96	59	43	32	21	9	5	3.7
	26	404	GR	2.39																			
			Average 404	2.13	2.40	2.55	5.8	94.2	5.26	0.7					100	96	59	43	32	21	9.0	5.0	3.7
			Average All	1.61	2.37	2.52	6.0	94.1	5.65	0.9				100	97.1	88.6	56.5	40.4	29.2	20.3	11.8	7.4	4.9

1 inch = 2.54 cm

Table G3 – AC Intermediate Layer Parameters

Flexible Pavement Mix Parameters & Aggregate Gradation - ODOT Lab, Intermediate Layers																							
					Average Flexible Mix Parameters						Aggregate Gradation												
											% Aggregate Passing Sieve (inches or sieve number/mm)												
Co./Rt./Site	ODOT Core No.	PMIS Layer Spec.	Prin. Coarse Aggr. Type	Layer Thickness (in.)	Bulk Spec. Gravity	Max Spec. Gravity	Air Voids (%)	Density (%)	% AC	F/A Ratio (%#200/%AC)	2.0" (50)	1.5" (37.5)	1.0" (25)	3/4" (19)	1/2" (12.5)	3/8" (9.5)	#4 (4.75)	#8 (2.36)	#16 (1.18)	#30 (0.60)	#50 (0.30)	#100 (0.15)	#200 (0.075)
Intermediate Layer - Average Performance																							
BUT 129 22W	13	446 T2	LS	broken	2.34	2.50	5.6	94.4	4.71	0.6			100	96	81	69	51	43	34	21	8	4	3.0
	14	446 T2	LS	2.04																			
BUT 129 25W	11	446 T2	LS/GR	2.03	2.42	2.54	5.1	94.9	5.28	0.7			100	99	88	73	53	43	33	22	10	5	3.6
	12	446 T2	LS/GR	2.02																			
DEL 23 18S	39	446 T2	LS	2.19	2.33	2.49	6.5	93.5	6.10	1.0			100	96	82	73	52	36	23	16	11	9	6.3
PIK 32 19W	3	446 T2	LS	1.43	2.35	2.48	5.3	94.7	5.01	0.6			100	97	73	64	45	36	30	22	9	4	3.0
	4	446 T2	broken	n/a																			
LUC 2 22E	21	446 T2	LS	2.43	2.47	2.50	4.3	95.7	5.76	0.9			100	96	87	79	47	32	22	16	11	8	5.0
	22	446 T2	LS	2.41																			
VAN 30 18E	33	446 T2	n/a	2.86	2.39	2.53	5.5	94.5	n/a	n/a													
	34	446 T2	n/a	2.60																			
			Average 446 T2	2.22	2.38	2.51	5.4	94.6	5.37	0.8			100	96.8	82.2	71.6	49.6	38.0	28.4	19.4	9.8	6.0	4.2
CHP 68 2.5N	31	448 T2	GR	2.02	2.39	2.51	5.0	95.1	4.51	1.0			100	98	76	62	45	34	24	16	8	6	4.3
	32	448 T2	GR	1.85																			
			Average 448 T2	1.94	2.39	2.51	5.0	95.1	4.51	1.0			100	98.0	76.0	62.0	45.0	34.0	24.0	16.0	8.0	6.0	4.3
CLA 41 4N	29	402	LS/GR	2.10	2.35	2.55	7.8	92.2	4.50	0.7			100	98	85	75	53	43	32	22	8	4	3.2
	30	402	LS/GR	1.68																			
LAW 527 2N	35	402	LS	1.67	2.37	2.47	3.7	96.3	5.53	0.6			100	96	83	71	44	33	27	21	10	5	3.3
	36	402	LS	broken																			
			Average 402	1.82	2.36	2.51	5.8	94.3	5.02	0.7			100	97.0	84.0	73.0	48.5	38.0	29.5	21.5	9.0	4.5	3.3
HAM 747 1S	15	403	GR	1.85	2.34	2.49	6.0	94.0	5.54	0.9					100	98	69	56	38	24	12	7	5.2
	16	403	GR	broken																			
			Average 403	1.85	2.34	2.49	6.0	94.0	5.54	0.9					100	98.0	69.0	56.0	38.0	24.0	12.0	7.0	5.2
			Average All	2.08	2.37	2.51	5.5	94.5	5.22	0.8			100	97.0	83.9	73.8	51.0	39.6	29.2	20.0	9.7	5.8	4.1
Intermediate Layer - Excellent Performance																							
BUT 129 22E	9	446 T2	LS	1.55	2.42	2.51	3.6	96.5	5.01	0.7			100	98	83	71	49	41	30	19	8	4	3.1
	10	446 T2	LS	1.54																			
DEL 23 17S	37	446 T2	LS/SL	2.24	2.34	2.51	7.0	93.0	5.75	1.0			100	98	86	79	62	47	35	24	15	9	5.5
	38	446 T2	LS/SL	2.30																			
HAM 126 11E	19	446 T2	GR	1.83	2.40	2.57	6.3	93.7	3.64	0.8			100	97	76	65	39	33	27	19	9	5	3.2
	20	446 T2	GR	1.84																			
LUC 25 10S	23	446 T2	LS/GR	1.63	2.37	2.54	6.7	93.3	4.86	1.4				100	87	79	61	38	27	21	15	10	7.0
	24	446 T2	LS/GR	broken																			
PIK 32 15W	1	446 T2	GR	1.92	2.31	2.42	4.4	95.6	5.15	0.6			100	99	82	70	49	40	32	22	9	4	3.0
	2	446 T2	GR	2.00																			
PIK 32 19E	5	446 T2	LS	1.89	2.36	2.47	4.2	95.9	5.21	0.8			100	99	81	72	52	40	31	21	9	5	4.2
	6	446 T2	LS	2.13																			
ROS 35 1W	7	446 T2	LS	2.05	2.33	2.53	8.1	91.9	4.91	1.0				100	82	63	42	34	25	17	11	7	4.5
	8	446 T2	LS	2.04																			
			Average 446 T2	1.92	2.36	2.51	5.8	94.3	4.93	0.9			100	98.7	82.4	71.3	50.6	39.0	29.6	20.4	10.9	6.3	4.4
CHP 68 2N	27	448 T2	LS/GR	1.74	2.40	2.50	3.8	96.2	4.68	1.0			100	99	77	60	45	35	26	17	9	6	4.7
	28	448 T2	LS/GR	1.60																			
GRE 35 21E	17	448 T2	LS	1.70	2.31	2.48	7.1	92.9	5.88	0.3				100	92	84	54	36	22	12	5	3	1.7
	18	448 T2	LS	1.58																			
			Average 448 T2	1.66	2.35	2.49	5.5	94.6	5.28	0.7			100	99.5	84.5	72.0	49.5	35.5	24.0	14.5	7.0	4.5	3.2
CLA 41 3N	25	402	GR	1.30	2.39	2.53	5.6	94.4	5.20	0.6			100	96	86	73	52	42	30	20	8	4	3.0
	26	402	GR	3.07																			
			Average 402	2.19	2.39	2.53	5.6	94.4	5.20	0.6			100	96.0	86.0	73.0	52.0	42.0	30.0	20.0	8.0	4.0	3.0
			Average All	1.89	2.36	2.51	5.7	94.3	5.03	0.8			100	98.6	83.2	71.6	50.5	38.6	28.5	19.2	9.8	5.7	4.0

1 inch = 2.54 cm

Table G4

AC Base Parameters (1/2)

Flexible Pavement Mix Parameters & Aggregate Gradation - Base Layers																							1/2
					Average Flexible Mix Parameters						Aggregate Gradation												
											% Aggregate Passing Sieve (inches or sieve number/mm)												
Co./Rt./Site	ODOT Core No.	PMIS Layer Spec.	Prin. Coarse Aggr. Type	Layer Thickness (in.)	Bulk Spec. Gravity	Max Spec. Gravity	Air Voids (%)	Density (%)	% AC	F/A Ratio (%#200/%AC)	2.0" (50)	1.5" (37.5)	1.0" (25)	3/4" (19)	1/2" (12.5)	3/8" (9.5)	#4 (4.75)	#8 (2.36)	#16 (1.18)	#30 (0.60)	#50 (0.30)	#100 (0.15)	#200 (0.075)
Base Layer - Average Performance																							
BUT 129 22W	13	302	LS	3.62	2.45	2.57	4.6	95.5	3.71	1.2	100	94	94	86	74	67	47	37	28	19	9	6	4.6
	14	302	LS	4.60																			
BUT 129 25W	11	302	LS	4.09	2.40	2.50	4.2	95.8	3.43	1.3		100	95	88	65	45	27	21	17	13	8	6	4.3
		302	LS	n/a																			
	12	302	LS	3.86																			
DEL 23 18S	39	302	LS	3.18	2.26	2.47	8.5	91.5	5.64	1.3	100	96	86	73	62	55	37	26	19	15	12	10	7.3
Average 302				3.87	2.37	2.51	5.8	94.3	4.26	1.3	100	96.7	91.7	82.3	67.0	55.7	37.0	28.0	21.3	15.7	9.7	7.3	5.4
PIK 32 19W	3	301	LS	2.05	2.36	2.47	6.4	93.7	4.54	0.7		100	98	95	75	60	41	32	25	19	8	4	3.0
	4	301	LS	2.05																			
CHP 68 2.5N	31	301	LS/GR	2.28	2.36	2.51	6.2	93.9	4.51	1.0		100	100	98	66	49	39	32	24	16	9	6	4.5
		301	GR	3.93																			
	32	301	LS/GR	2.37																			
		301	GR	4.00																			
LUC 2 22E	21	301	LS	4.42	2.45	2.57	4.9	95.2	4.24	1.2	100	95	87	76	60	53	36	29	22	16	11	8	5.1
	22	301	LS	4.60																			
CLA 41 4N	29	301	GR	1.50	2.38	2.51	5.3	94.6	4.63	0.9		100	100	96	85	73	51	38	27	18	8	5	4.1
		301	GR	5.04																			
	30	301	GR	1.94																			
		301	GR	5.74																			
HAM 747 1S	15	301	GR	3.32	2.44	2.52	3.1	96.9	4.75	0.9			100	97	79	65	45	37	30	21	10	6	4.3
	16	301	GR	2.20																			
LAW 527 2N	35	301	LS	3.50	2.33	2.47	5.8	94.2	5.06	0.5			100	96	73	62	45	37	33	26	11	4	2.6
		301	LS	2.99																			
	36	301	LS	2.37																			
		301	LS	4.00																			
Average 301				3.24	2.39	2.51	5.3	94.8	4.62	0.9	100	98.8	97.5	93.0	73.0	60.3	42.8	34.2	26.8	19.3	9.5	5.5	3.9
Average All				3.38	2.38	2.51	5.4	94.6	4.50	1.0													

1 inch = 2.54 cm

Table G4

AC Base Parameters by ODOT (2/2)

Co./Rt./Site	ODOT Core No.	PMIS Layer Spec.	Prin. Coarse Aggr. Type	Layer Thickness (in.)	Bulk Spec. Gravity	Max Spec. Gravity	Air Voids %	Density %	% AC	F/A Ratio (%#200/%AC)	2.0" (50)	1.5" (37.5)	1.0" (25)	3/4" (19)	1/2" (12.5)	3/8" (9.5)	#4 (4.75)	#8 (2.36)	#16 (1.18)	#30 (0.60)	#50 (0.30)	#100 (0.15)	#200 (0.075)
Flexible Pavement Mix Parameters & Aggregate Gradation - ODOT Lab, Base Layers (2/2)					**Average Flexible Mix Parameters**						**Aggregate Gradation – % Aggregate Passing Sieve (inches or sieve number/mm)**												
Base Layer - Excellent Performance																							
BUT 129 22E	9	302	LS	4.56	2.38	2.54	6.6	93.4	3.48	1.2	100	99	87	79	66	60	43	34	26	17	9	6	4.2
	10	302	LS	4.96																			
DEL 23 17S	37	302	LS	3.13	2.32	2.47	6.1	93.9	4.50	1.5	100	99	71	56	48	43	30	22	17	13	11	9	6.7
		302	LS	3.12																			
	38	302	LS	3.34																			
		302	LS	3.01																			
Average 302				3.69	2.35	2.50	6.4	93.7	3.99	1.4	100	99.0	79.0	67.5	57.0	51.5	36.5	28.0	21.5	15.0	10.0	7.5	5.5
HAM 126 11E	19	301	GR	4.86	2.43	2.48	2.1	98.0	4.97	0.9			100	97	79	67	42	33	25	17	9	6	4.1
	20	301	GR	4.68																			
LUC 25 10S	23	301	LS	3.49	2.45	2.51	2.7	97.4	4.86	1.3	100	94	84	70	58	53	41	31	23	17	12	9	6.3
	24	301	LS	3.14																			
PIK 32 15W	1	301	LS	4.75	2.32	2.50	7.1	92.9	5.42	0.7			100	98	73	57	47	43	30	19	13	8	4.0
	2	301	LS	4.59																			
PIK 32 19E	5	301	GR	4.84	2.36	2.45	3.6	96.4	5.13	0.8			100	96	82	69	49	39	31	24	10	5	4.0
	6	301	GR	4.73																			
ROS 35 1W	7	301	LS	5.05	2.30	2.53	9.1	90.9	4.09	1.6		100	83	72	59	51	37	32	22	15	11	8	6.5
	8	301	LS	5.66																			
CHP 68 2N	27	301	LS/GR	2.62	2.41	2.53	4.8	95.2	4.90	1.0			100	98	74	64	49	39	29	20	11	7	5.1
	28	301	LS/GR	2.44																			
GRE 35 21E	17	301	LS	1.46	2.32	2.48	6.5	93.5	5.39	1.1			100	97	75	66	47	38	27	19	12	9	5.6
		301	LS	4.75																			
	18	301	LS	1.59																			
		301	LS	5.06																			
CLA 41 3N	25	301	GR	2.05	2.37	2.54	6.8	93.2	4.71	0.7		100	98	96	84	70	48	38	27	18	8	5	3.5
	26	301	GR	5.15																			
Average 301				3.94	2.37	2.50	5.3	94.7	4.93	1.0	100	98.0	95.6	90.5	73.0	62.1	45.0	36.6	26.8	18.6	10.8	7.1	4.9
Average All				3.88	2.37	2.50	5.5	94.5	4.75	1.1	100	98.4	92.3	85.9	69.8	60.0	43.3	34.9	25.7	17.9	10.6	7.2	5.0

1 inch = 2.54 cm

Table G5

ATFDB Parameters

Flexible Pavement Mix Parameters & Aggregate Gradation - ODOT Lab, ATFDB Layer																						
Co./Rt./Site	ODOT Core No.	Prin. Coarse Aggr. Type	Layer Thickness (in.)	Average Flexible Mix Parameters						Aggregate Gradation												
										% Aggregate Passing Sieve (inches or sieve number/mm)												
				Bulk Spec. Gravity	Max Spec. Gravity	Air Voids (%)	Density (%)	% AC	F/A Ratio (%#200/%AC)	2.0" (50)	1.5" (37.5)	1.0" (25)	3/4" (19)	1/2" (12.5)	3/8" (9.5)	#4 (4.75)	#8 (2.36)	#16 (1.18)	#30 (0.60)	#50 (0.30)	#100 (0.15)	#200 (0.075)
ATFDB Layer - Average Performance																						
BUT 129 22W	13	LS	n/a	n/a	n/a	n/a	n/a	1.75	1.6			100	92	49	21	7	5	4	4	4	3	2.8
DEL 23 18S	39	LS	n/a	n/a	n/a	n/a	n/a	2.13	1.6			100	79	30	14	8	7	6	5	5	4	3.4
PIK 32 19W	3	LS	n/a	n/a	n/a	n/a	n/a	2.46	1.1			100	93	51	30	11	7	5	5	4	4	2.8
	4	LS	n/a																			
Average ATFDB								2.11	1.4			100	88.0	43.3	21.7	8.7	6.3	5.0	4.7	4.3	3.7	3.0
ATFDB Layer - Excellent Performance																						
BUT 129 22E	9	LS	broken	n/a	n/a	n/a	n/a	2.23	1.3			100	89	40	18	7	6	5	4	4	3	2.8
	10	LS	broken																			
DEL 23 17S	37	LS	n/a	n/a	n/a	n/a	n/a	2.26	1.4			100	85	36	18	9	7	6	5	5	4	3.2
	38	LS	n/a																			
PIK 32 15W	1	LS	3.20	n/a	n/a	n/a	n/a	2.51	1.2			100	98	73	52	18	11	8	6	5	4	3.0
	2	LS	3.39																			
PIK 32 19E	5	LS	n/a	n/a	n/a	n/a	n/a	2.34	1.1			100	90	44	23	9	7	5	4	4	3	2.6
	6	LS	broken																			
Average ATFDB			3.30					2.34	1.3			100	90.5	48.3	27.8	10.8	7.8	6.0	4.8	4.5	3.5	2.9

1 inch = 2.54 cm

Table G6

Summary of AC Material Parameters by Layer, Performance Level and Mix

Average AC Mix Parameters by Layer, Material Specification and Level of Performance - ODOT Lab														
Material Specification	Layer Thickness (in.)		AC Mix Parameters											
			Bulk Spec. Gravity		Max Spec. Gravity		% Air Voids		% Density		% Asphalt		F/A Ratio (%#200 / %Asphalt)	
	Avg. (*)	Range	Avg. (*)	Range	Avg. (*)	Range	Avg. (*)	Range	Avg. (*)	Range	Avg. (*)	Range	Avg. (*)	Range
Surface Layer														
Average Performance														
Average 446 T1	1.45 (5)	1.26-1.71	2.37 (5)	2.27-2.41	2.50 (6)	2.48-2.52	5.5 (5)	4.1-8.4	94.5 (5)	91.6-95.9	6.01 (4)	4.82-6.48	0.9 (4)	0.7-1.0
Average 446 T1H	1.49 (4)	1.26-1.69	2.39 (4)	2.32-2.44	2.53 (4)	2.50-2.57	5.6 (4)	4.6-7.6	94.4 (4)	92.4-95.4	5.71 (1)		0.8 (1)	
Average 448 T1H	1.42 (1)		2.35 (1)		2.50 (2)	2.50-2.51	6.2 (1)		93.8 (1)		5.30 (2)	5.27-5.32	0.6 (2)	0.5-0.6
Average 404	1.58 (6)	1.14-2.13	2.39 (6)	2.36-2.42	2.51 (6)	2.47-2.54	4.6 (6)	2.5-6.6	95.4 (6)	93.4-97.5	5.33 (3)	4.97-5.60	0.9 (3)	0.8-1.0
Excellent Performance														
Average 446 T1	1.50 (12)	1.07-2.03	2.37 (12)	2.31-2.42	2.52 (14)	2.47-2.64	6.0 (12)	3.3-8.7	94.0 (12)	91.3-96.7	5.44 (12)	4.43-6.29	0.8 (12)	0.2-1.1
Average 448 T1H	1.67 (4)	0.98-2.38	2.35 (4)	2.30-2.40	2.48 (4)	2.46-2.49	5.4 (4)	3.4-7.1	94.6 (4)	92.9-96.6	6.32 (2)	5.69-6.94	1.0 (2)	0.8-1.2
Average 404	2.13 (2)	1.87-2.39	2.40 (2)	2.37-2.43	2.55 (2)	2.50-2.60	5.8 (2)	5.1-6.5	94.2 (2)	93.5-94.9	5.26 (1)		0.7 (1)	
Intermediate Layer														
Average Performance														
Average 446 T2	2.22 (9)	1.43-2.86	2.39 (9)	2.33-2.44	2.51 (10)	2.44-2.59	5.0 (9)	2.4-6.5	95.0 (9)	93.5-97.6	5.37 (5)	4.71-6.10	0.8 (5)	0.6-1.0
Average 448 T2	1.94 (2)	1.85-2.02	2.38 (2)	2.38-2.39	2.51 (2)	2.50-2.51	5.0 (2)	4.9-5.0	95.1 (2)	95.0-95.1	4.51 (2)	4.43-4.58	1.0 (2)	0.9-1.0
Average 402	1.82 (3)	1.67-2.10	2.35 (3)	2.34-2.37	2.51 (4)	2.46-2.57	6.4 (3)	3.7-8.7	93.6 (3)	91.3-96.3	5.02 (2)	4.50-5.53	0.7 (2)	0.6-0.7
Average 403	1.85 (1)		2.34 (1)		2.49 (2)		6.0 (1)		94.0 (1)		5.54 (1)		0.9 (1)	
Excellent Performance														
Average 446 T2	1.92 (13)	1.54-2.30	2.36 (13)	2.30-2.42	2.50 (14)	2.41-2.55	5.7 (13)	3.0-9.1	94.3 (13)	90.9-97.0	4.95 (12)	3.64-5.75	0.8 (12)	0.6-1.4
Average 448 T2	1.66 (4)	1.58-1.74	2.35 (4)	2.30-2.42	2.48 (4)	2.47-2.52	5.5 (4)	3.7-7.6	94.6 (4)	92.4-96.3	5.28 (2)	4.68-5.88	0.7 (2)	0.3-1.0
Average 402	2.19 (2)	1.30-3.07	2.38 (2)	2.37-2.40	2.53 (2)	2.50-2.56	5.6 (2)	5.3-5.9	94.4 (2)	94.1-94.7	5.20 (1)		0.6 (1)	
Base Layer														
Average Performance														
Average 302	3.87 (5)	3.18-4.60	2.39 (5)	2.26-2.47	2.52 (5)	2.47-2.57	5.2 (5)	3.3-8.5	94.8 (5)	91.5-96.7	4.05 (4)	2.66-5.64	1.3 (4)	1.0-1.6
Average 301	3.24 (18)	1.50-5.74	2.37 (18)	2.30-2.46	2.50 (18)	2.43-2.59	5.4 (18)	2.3-8.1	94.6 (18)	91.9-97.7	4.62 (12)	3.80-5.21	0.9 (12)	0.5-1.2
Excellent Performance														
Average 302	3.69 (6)	3.01-4.96	2.33 (6)	2.28-2.38	2.50 (6)	2.46-2.57	6.5 (6)	5.2-8.4	93.6 (6)	91.6-94.8	3.65 (5)	2.39-4.70	1.3 (5)	1.1-1.5
Average 301	3.94 (18)	1.46-5.66	2.36 (18)	2.27-2.45	2.50 (18)	2.44-2.55	5.5 (18)	0.8-10.0	94.5 (18)	90.0-99.2	4.96 (13)	3.99-5.48	1.0 (13)	0.7-1.7
ATFDB Material														
Average Performance														
Average 308	N.A.		N.A.		N.A.		N.A.		N.A.		2.20 (4)	1.75-2.50	1.4 (4)	1.0-1.6
Excellent Performance														
Average 308	3.30 (2)	3.20-3.39	N.A.		N.A.		N.A.		N.A.		2.32 (6)	1.93-2.76	1.3 (6)	1.1-1.5

* Number of cores in calculation 1 inch = 25.4 mm

Table G7

Aggregate Gradations of AC Materials

Average AC Aggregate Gradations by Layer, Material Specification and Level of Performance															
Material Specification	**Layer Thickness (in.)**		**% Aggregate Passing Sieve (inches or sieve number/mm)**												
			2.0"	**1.5"**	**1.0"**	**3/4"**	**1/2"**	**3/8"**	**#4**	**#8**	**#16**	**#30**	**#50**	**#100**	**#200**
	Avg. (no.*)	**Range**	**50**	**38**	**25**	**18.8**	**12.5**	**9.5**	**4.75**	**2.36**	**1.18**	**0.60**	**0.30**	**0.15**	**0.075**
Surface Layer															
Average Performance															
Average 446 T1	1.45 (4)	1.26-1.71				100	96.3	89.0	55.5	38.3	26.0	17.8	11.0	7.3	5.2
Average 446 T1H	1.48 (1)	1.26-1.69				100	98.0	88.0	48.0	32.0	20.0	13.0	9.0	6.0	4.3
Average 448 T1H	1.42 (1)					100	98.0	85.0	48.0	33.0	24.0	15.0	8.0	5.0	3.0
Average 404	1.58 (3)	1.14-2.13			100	97.0	94.7	89.3	56.7	41.0	31.3	22.0	10.3	6.0	4.5
Excellent Performance															
Average 446 T1	1.50 (7)	1.07-2.03				100	96.1	86.3	52.6	38.0	27.3	19.1	11.4	7.1	4.6
Average 448 T1H	1.66 (2)	0.98-2.38				100	99.0	93.0	69.0	47.5	34.5	24.0	14.5	9.5	6.5
Average 404	2.13 (1)	1.87-2.39					100	96.0	59.0	43.0	32.0	21.0	9.0	5.0	3.7
Intermediate Layer															
Average Performance															
Average 446 T2	2.22 (5)	1.43-2.86			100	96.8	82.2	71.6	49.6	38.0	28.4	19.4	9.8	6.0	4.2
Average 448 T2	1.93 (1)	1.85-2.02			100	98.0	76.0	62.0	45.0	34.0	24.0	16.0	8.0	6.0	4.3
Average 402	1.82 (2)	1.67-2.10			100	97.0	84.0	73.0	48.5	38.0	29.5	21.5	9.0	4.5	3.3
Average 403	1.85 (1)						100	98.0	69.0	56.0	38.0	24.0	12.0	7.0	5.2
Excellent Performance															
Average 446 T2	1.92 (7)	1.54-2.30			100	98.7	82.4	71.3	50.6	39.0	29.6	20.4	10.9	6.3	4.4
Average 448 T2	1.65 (2)	1.58-1.74			100	99.5	84.5	72.0	49.5	35.5	24.0	14.5	7.0	4.5	3.2
Average 402	2.19 (1)	1.30-3.07			100	96.0	86.0	73.0	52.0	42.0	30.0	20.0	8.0	4.0	3.0
Base Layer															
Average Performance															
Average 302	3.87 (3)	3.18-4.60	100	96.7	91.7	82.3	67.0	55.7	37.0	28.0	21.3	15.7	9.7	7.3	5.4
Average 301	3.19 (6)	1.50-5.74	100	98.8	97.5	93.0	73.0	60.3	42.8	34.2	26.8	19.3	9.5	5.5	3.9
Excellent Performance															
Average 302	3.82 (2)	3.01-4.96	100	99.0	79.0	67.5	57.0	51.5	36.5	28.0	21.5	15.0	10.0	7.5	5.5
Average 301	3.94 (8)	1.46-5.66	100	98.0	95.6	90.5	73.0	62.1	45.0	36.6	26.8	18.6	10.8	7.1	4.9
308 ATFDB															
Average Performance															
Average ATFDB	N.A. (3)	N.A.			100	88.0	43.3	21.7	8.7	6.3	5.0	4.7	4.3	3.7	3.0
Excellent Performance															
Average ATFDB	3.30 (4)	3.20-3.39			100	90.5	48.3	27.8	10.8	7.8	6.0	4.8	4.5	3.5	2.9

1 inch = 2.5 cm * Number of cores in calculation

Table G8

Summary of Structural Tests on Flexible Pavement Cores

Flexible Pavement Structural Parameters																								
Co./Rt./Site	Surface layer								Intermediate Layer								Base Layer							
	Layer Spec.	Coarse Aggr. Type	Ind. Tens. Str.			Cold Strength (psi)			Layer Spec.	Coarse Aggr. Type	Ind. Tens. Str.			Cold Strength (psi)			Layer Spec.	Coarse Aggr. Type	Ind. Tens. Str.			Cold Strength (psi)		
			Dry (psi)	Wet (psi)	TSR (%)	-20° C (-4° F)	-10° C (14° F)	0° C (32° F)			Dry (psi)	Wet (psi)	TSR (%)	-20° C (-4° F)	-10° C (14° F)	0° C (32° F)			Dry (psi)	Wet (psi)	TSR (%)	-20° C (-4° F)	-10° C (14° F)	0° C (32° F)
Average Performing Pavements																								
BUT 129 22W	446 T1	LS	119						446 T2	LS	80						302	LS	147	77	52.1	412	411	319
BUT 129 25W	446 T1	LS/GR	172	133	77.3				446 T2	LS/GR	155	107	69.4	431	400	349	302	LS	171	147	86.4	423	525	426
DEL 23 18S	446 T1	LS	164	88	53.6				446 T2	LS	118	78	65.9	472	395	340	302	LS	88	52	58.8	348	416	322
PIK 32 19W	446 T1	broken	175	175	74.6				446 T2	LS	177	110	62.0				301	LS	170	106	62.8	431	381	364
Average 446 T1			158	132	68.5																			
LUC 2 22E	446 T1H	LS	91	69	75.2				446 T2	LS	63	58	91.4				301	LS	87	54	62.8	414	229	253
VAN 30 18E	446 T1H	n/a	Composite Pavement						Composite Pavement								Composite Pavement							
Average 446 T1H			91	69	75.2																			
CHP 68 2.5N	448 T1H	LS/GR	146	99	67.9				448 T2	GR	94	56	59.5	342	337	241	301	LS, LS/GR	46	32	69.7	465	313	286
Average 448 T1H			146	99	67.9																			
CLA 41 4N	404	GR	163	150	92.2				402	LS/GR	144	117	80.8				301	GR	159	102	64.0	497	482	412
HAM 747 1S	404	LS	165	149	90.3				403	GR	148	131	88.7				301	GR	85	66	77.6	504	412	369
LAW 527 2N	404	LS	120	75	62.9				402	LS	76	56	73.3				301	LS	110	96	87.5	476	428	369
Average 404			149	125	81.8				**Average 446 T2**		119	88	72.2	452	397	345	**Average 302**		135	92	65.8	394	451	356
Average All			146	117	74.3				**Average 448 T2**		94	56	59.5	342	337	241	**Average 301**		109	76	70.7	465	374	342
									Average 402		110	86	77.0				**Average All**		118	81	69.1	441	400	347
									Average 403		148	131	88.7											
									Average All		117	89	73.9	415	377	310								
Excellent Performing Pavements																								
BUT 129 22E	446 T1	LS	126	111	88.5				446 T2	LS	115	79	68.2	344	406	262	302	LS	118	90	76.1	323	378	370
DEL 23 17S	446 T1	LS/SL	149	105	70.9				446 T2 Spec.	LS/SL	142	99	69.6	491	423	349	302	LS	131	82	62.6	406	531	443
HAM 126 11E	446 T1	LS/GR	155	85	54.6				446 T2	GR	133	79	59.7				301	GR	120	98	81.6	592	509	431
LUC 25 10S	446 T1	LS	134	133	99.2				446 T2	LS/GR	107	104	96.4				301	LS	77	59	76.9	556	475	394
PIK 32 15W	446 T1	LS	158	111	70.5				446 T2	GR	125	94	75.6				301	LS	89	68	77.2	307	238	247
PIK 32 19E	446 T1	LS/GR	153	141	92.3				446 T2	LS	177	137	77.5				301	GR	120	90	75.3	508	523	427
ROS 35 1W	446 T1	LS	167	98	58.9				446 T2	LS	153	78	50.7				301	LS	115	71	61.9	329	357	296
Average 446 T1			149	112	76.4																			
CHP 68 2N	448 T1H	LS/GR	116	85	73.5				448 T2	LS/GR	60	57	94.2				301	LS/GR	64	38	59.2	529	483	370
GRE 35 21E	448 T1H	LS	96	86	89.6				448 T2	LS	96	61	63.8				301	LS	92	66	72.1	409	325	247
Average 448 T1H			106	86	81.5																			
CLA 41 3N	404	GR	186	149	80.1	474	503	472	402	GR	164	114	69.7				301	GR	118	93	78.6	361	418	374
Average 404			186	149	80.1	474	503	472	**Average 446 T2**		136	96	71.1	417	415	305	**Average 302**		125	86	69.3	364	454	406
Average All			144	111	77.8				**Average 448 T2**		78	59	79.0				**Average 301**		99	73	72.8	449	416	348
									Average 402		164	114	69.7				**Average All**		104	76	72.1	432	424	360
									Average All		127	90	72.5											

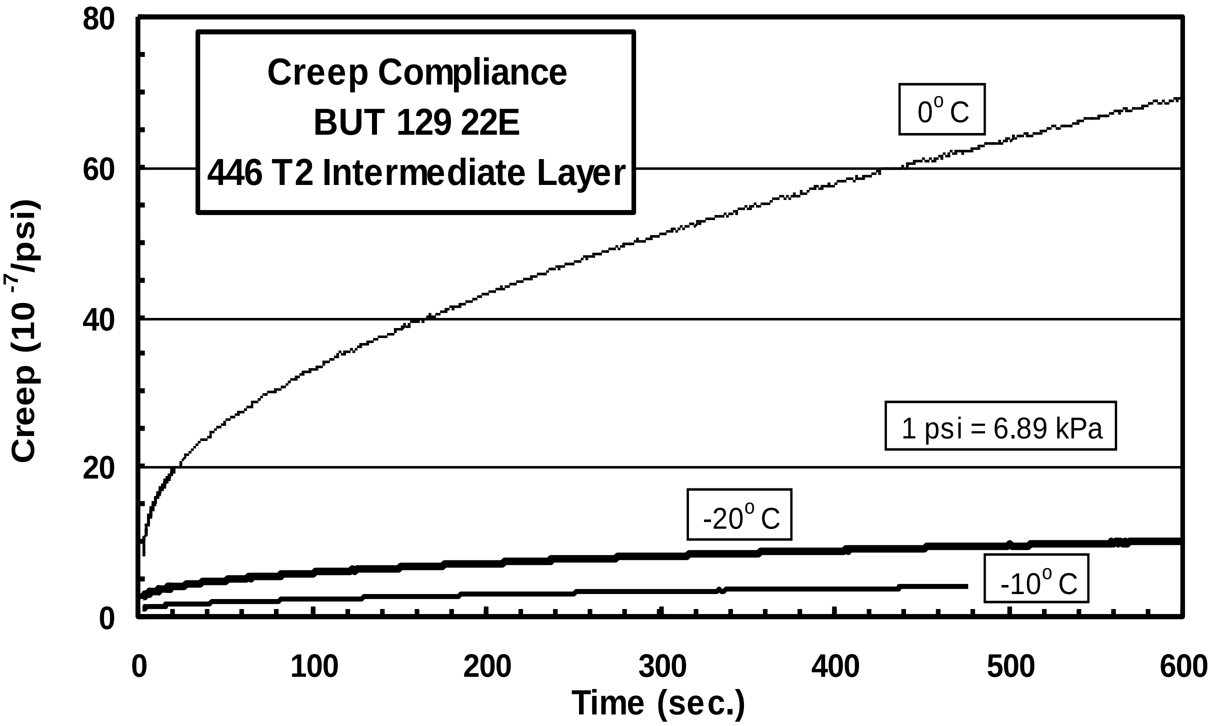
1 inch = 2.54 cm

Table G9

Creep Compliance Loads

Loads for Creep Compliance Tests (lbs.)							
Flexible Pavement Section (Co/Rte/SLM/Dir)	**Project Number**	**Intermediate Layer**			**Base Layer**		
		0° C (32° F)	**-10° C (14° F)**	**-20° C (-4° F)**	**0° C (32° F)**	**-10° C (14° F)**	**-20° C (-4° F)**
Average Performance							
BUT 129 22W	9330(98)				585	986	1003
BUT 129 25W	9327(98)	231	514	1051	569	1140	1472
CHP 68 2.5N	233(98)	196	483	1136	332	678	1224
CLA 41 4N	63(95)				595	1241	1765
DEL 23 18S	380(94)	440	529	1722	569	1519	1579
HAM 747 1S	347(85)				229	414	867
LAW 527 2N	17(85)				361	864	1160
LUC 2 22E	141(99)				266	383	1071
PIK 32 19W	552(95)				518	789	864
VAN 30 18E	219(97)	Composite Pavement					
Excellent Performance							
BUT 129 22E	9330(98)	312	719	854	479	729	555
CHP 68 2N	233(98)				195	415	764
CLA 41 3N	63(95)				426	877	1270
DEL 23 17S**	380(94)	415	715	1612	472	867	1609
GRE 35 21E	259(98)				243	294	1352
HAM 126 11E*	645(94)				417	818	1359
LUC 25 10S*	665(97)				254	570	900
PIK 32 15W	443(94)				313	373	443
PIK 32 19E	552(95)				533	777	713
ROS 35 1W	298(96)				553	1113	1785

1 lb. = 4.448 N



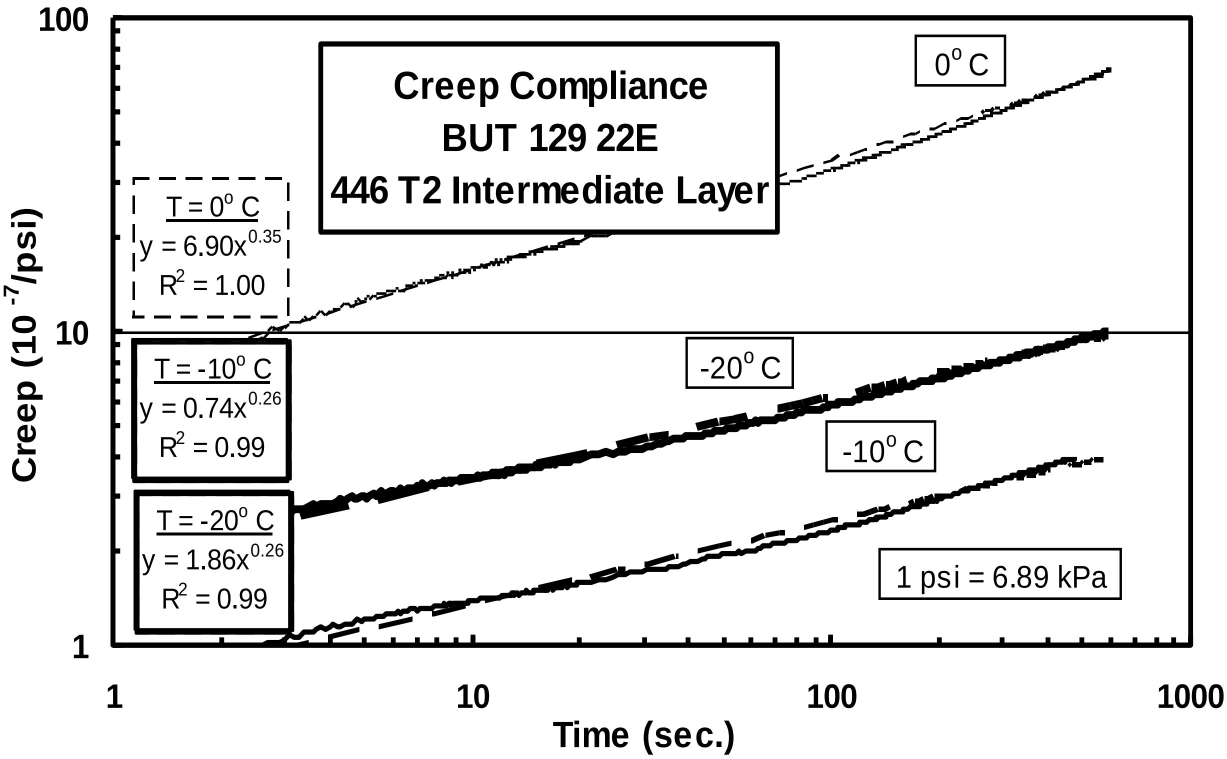
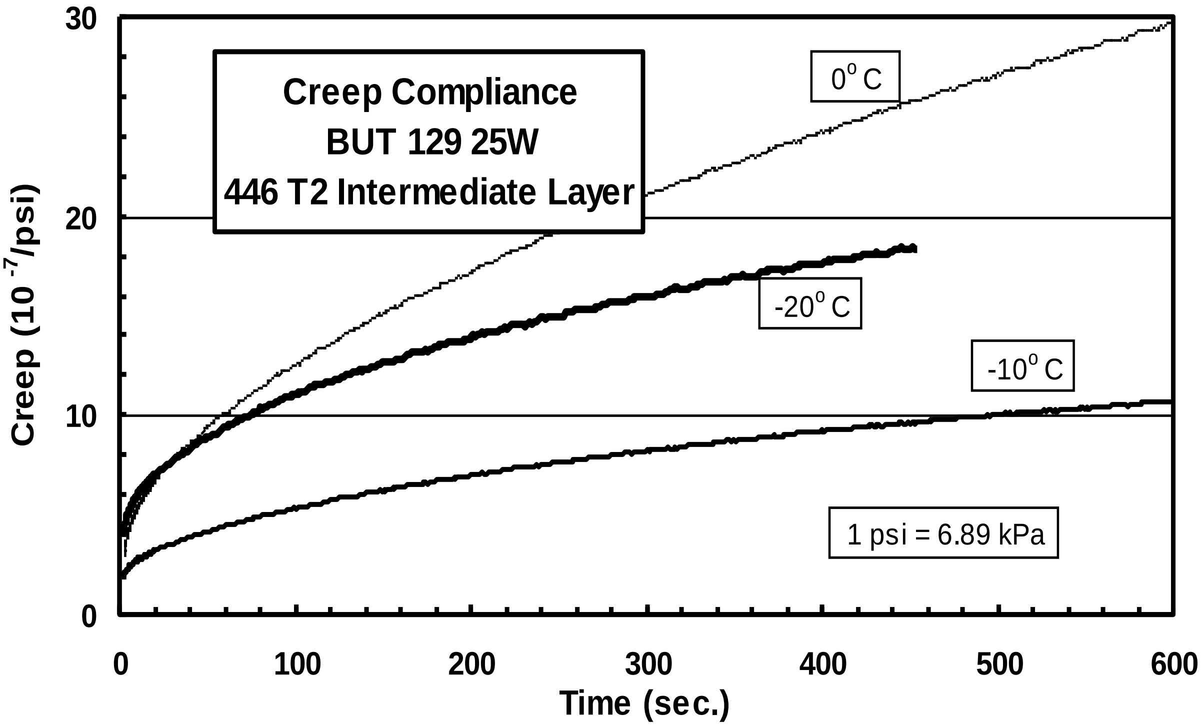


Figure G1 – Measured Creep Compliance for BUT 129 22E Intermediate Layer



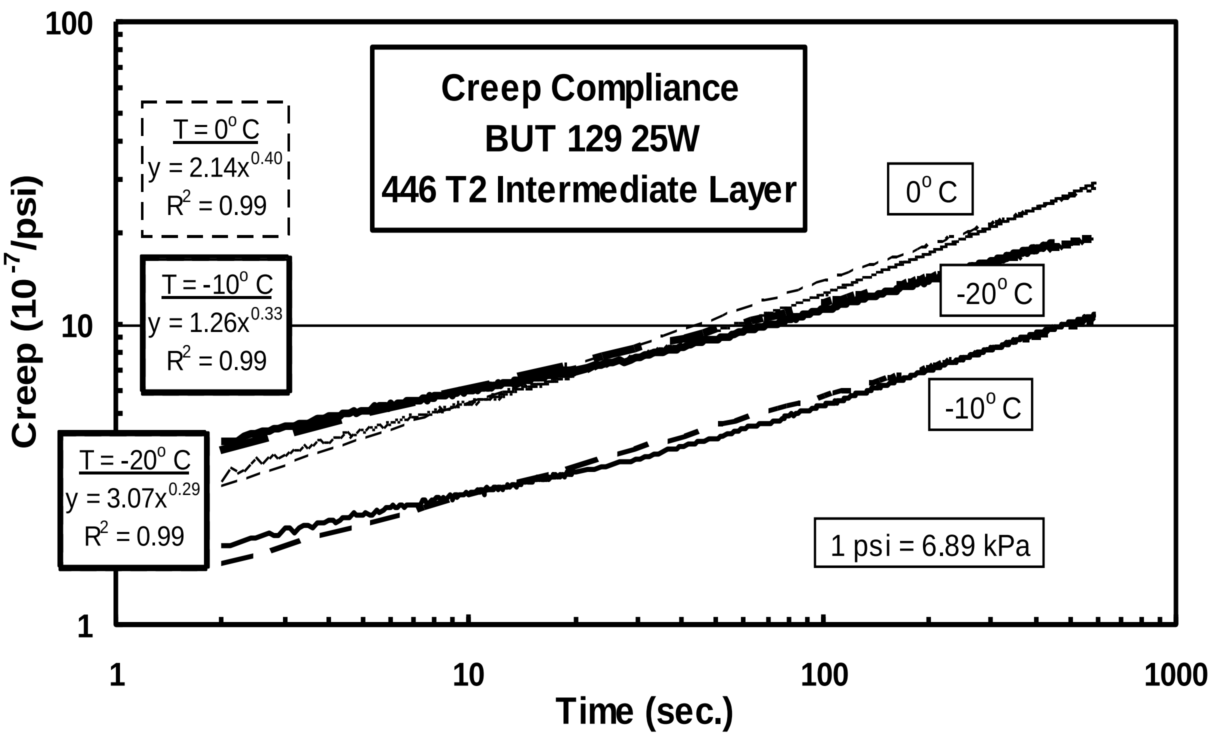
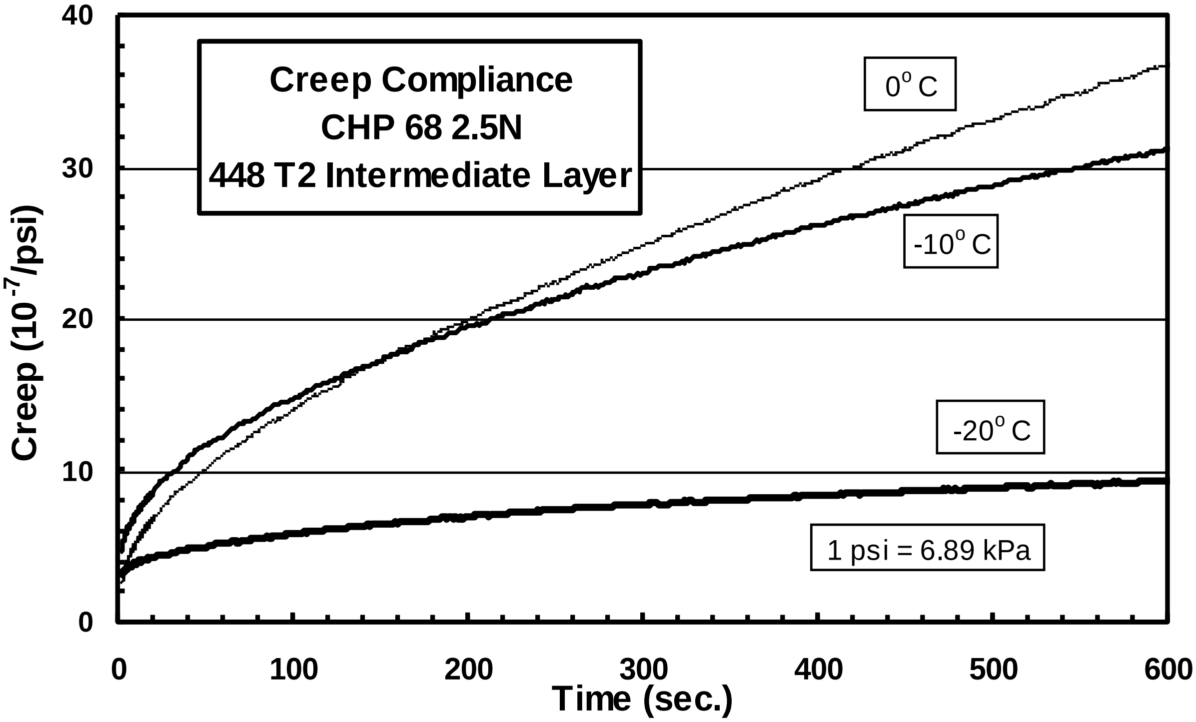


Figure G2 - Measured Creep Compliance for BUT 129 25W Intermediate Layer



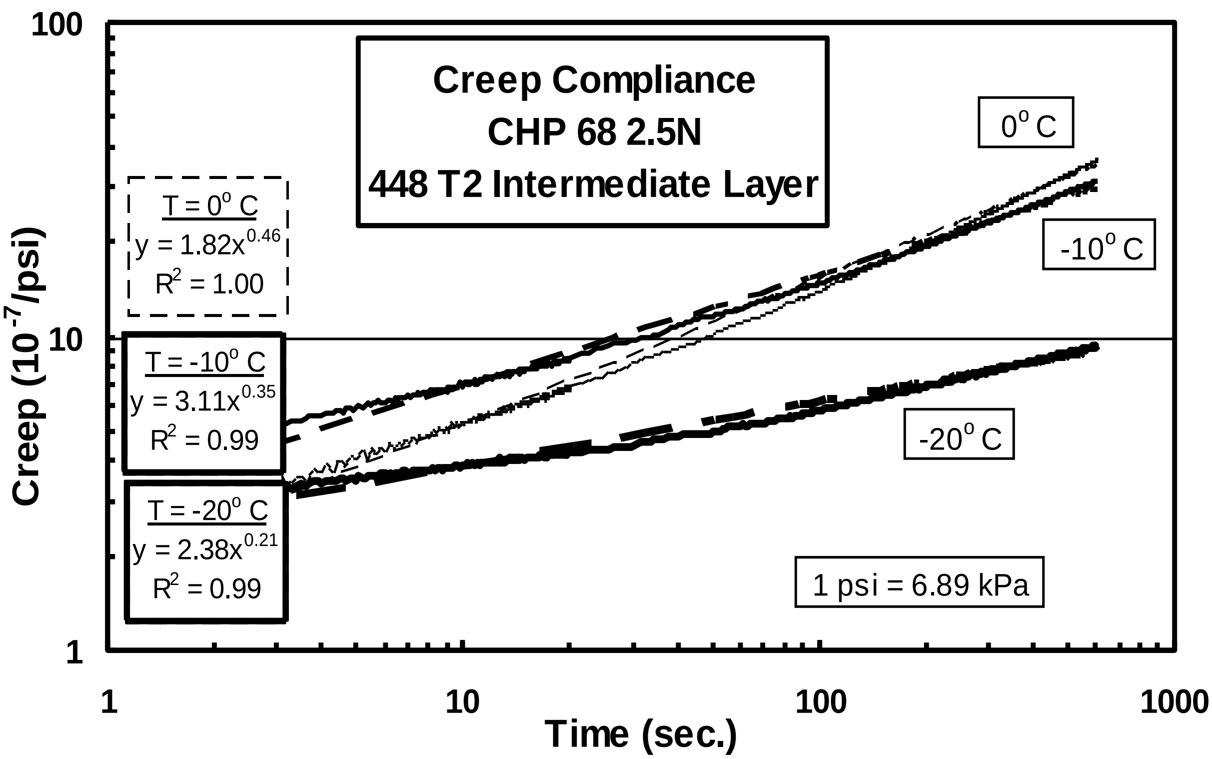
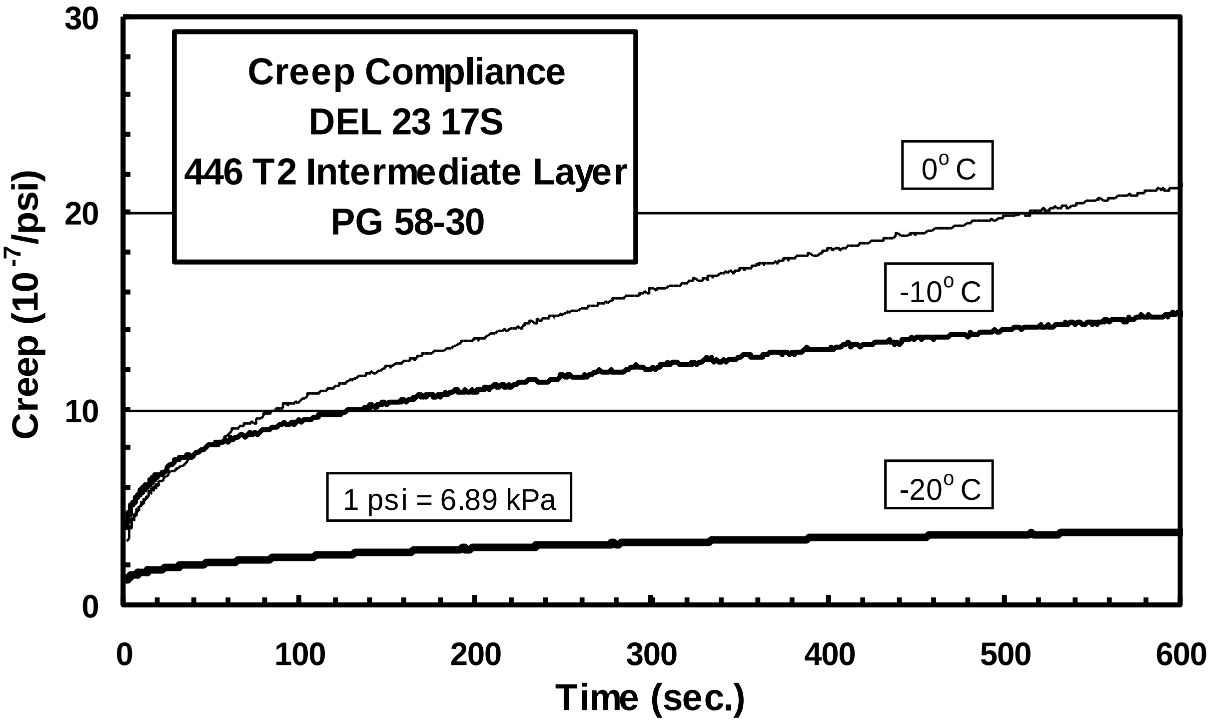


Figure G3 - Measured Creep Compliance for CHP 68 2.5N Intermediate Layer



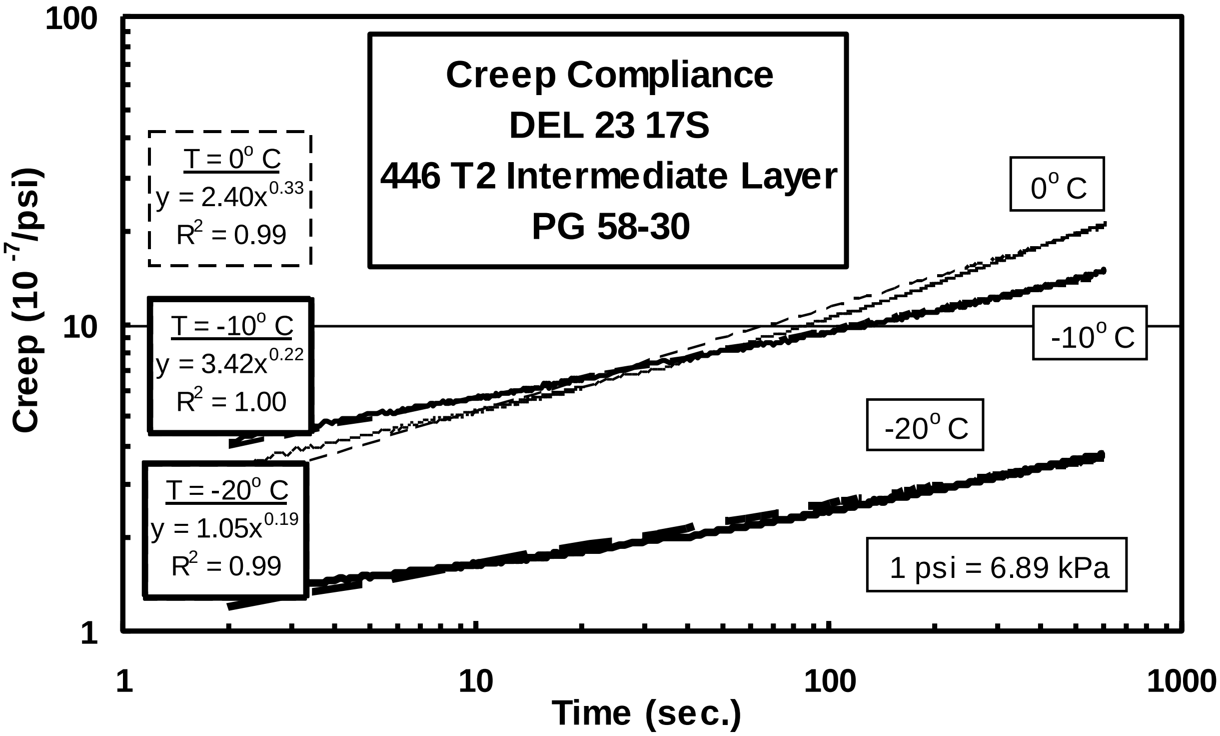


Figure G4 - Measured Creep Compliance for DEL 23 17S Intermediate Layer

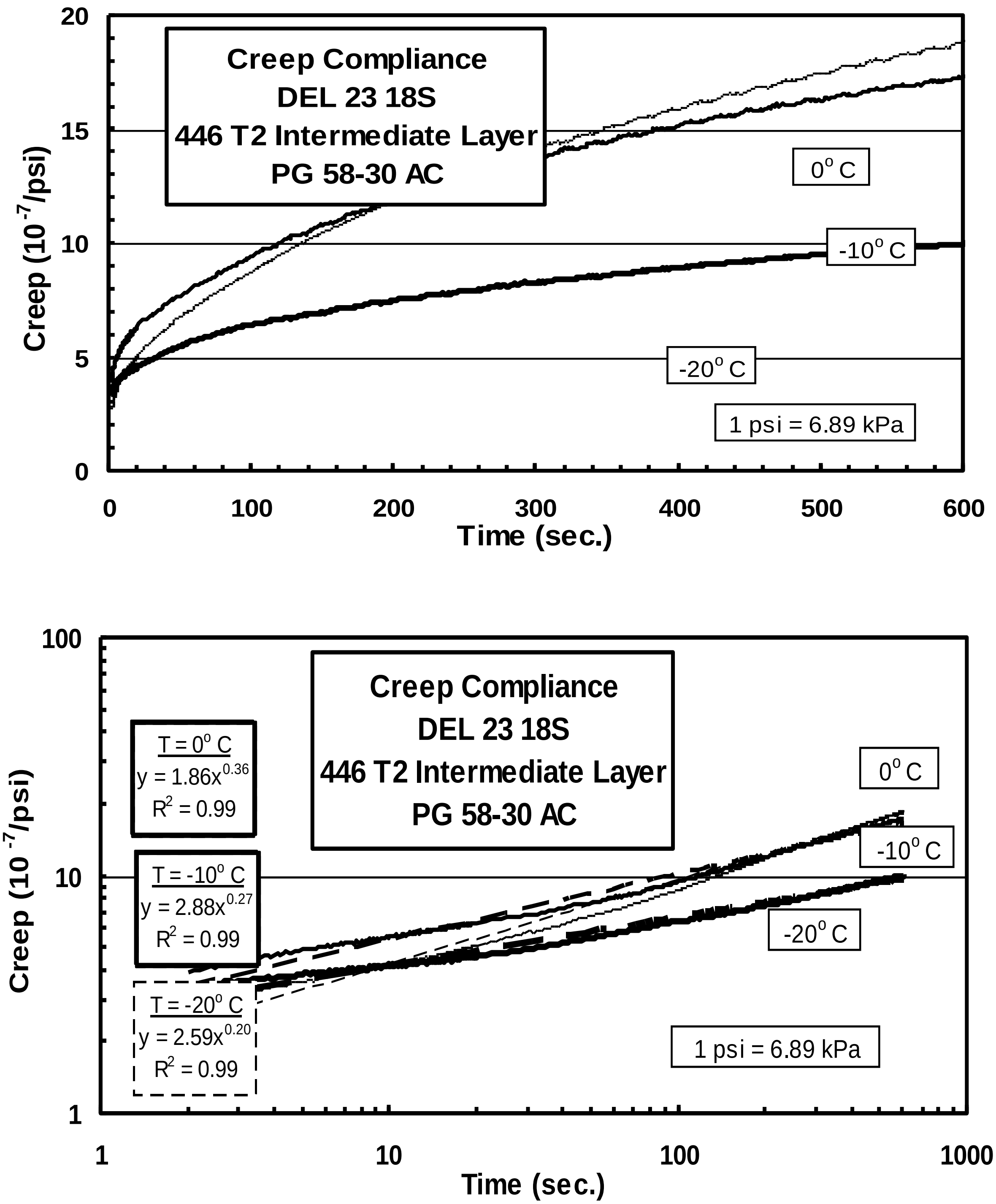
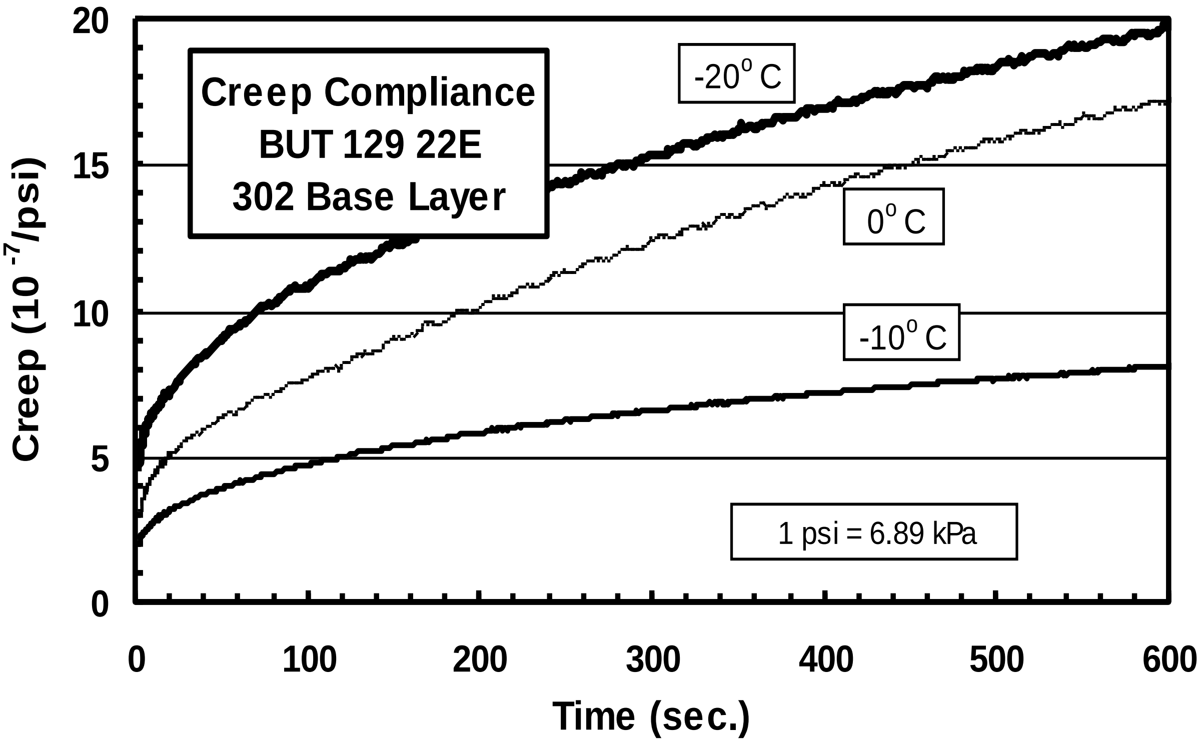


Figure G5 - Measured Creep Compliance for DEL 23 18S Intermediate Layer



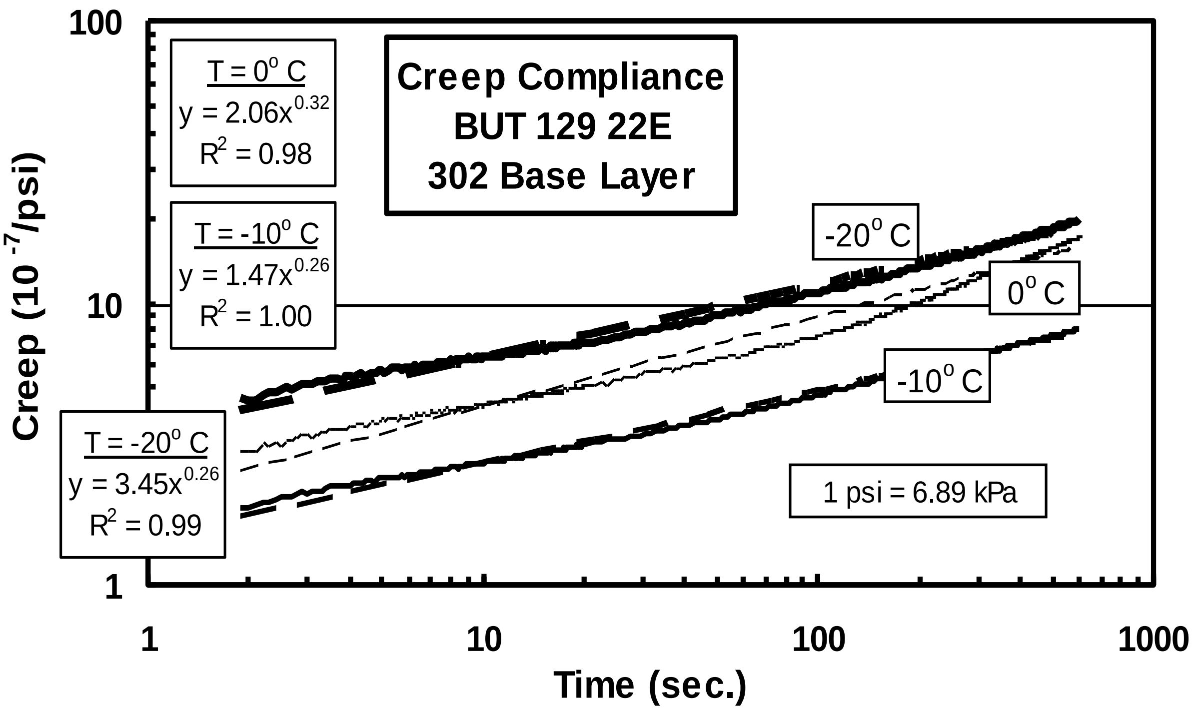
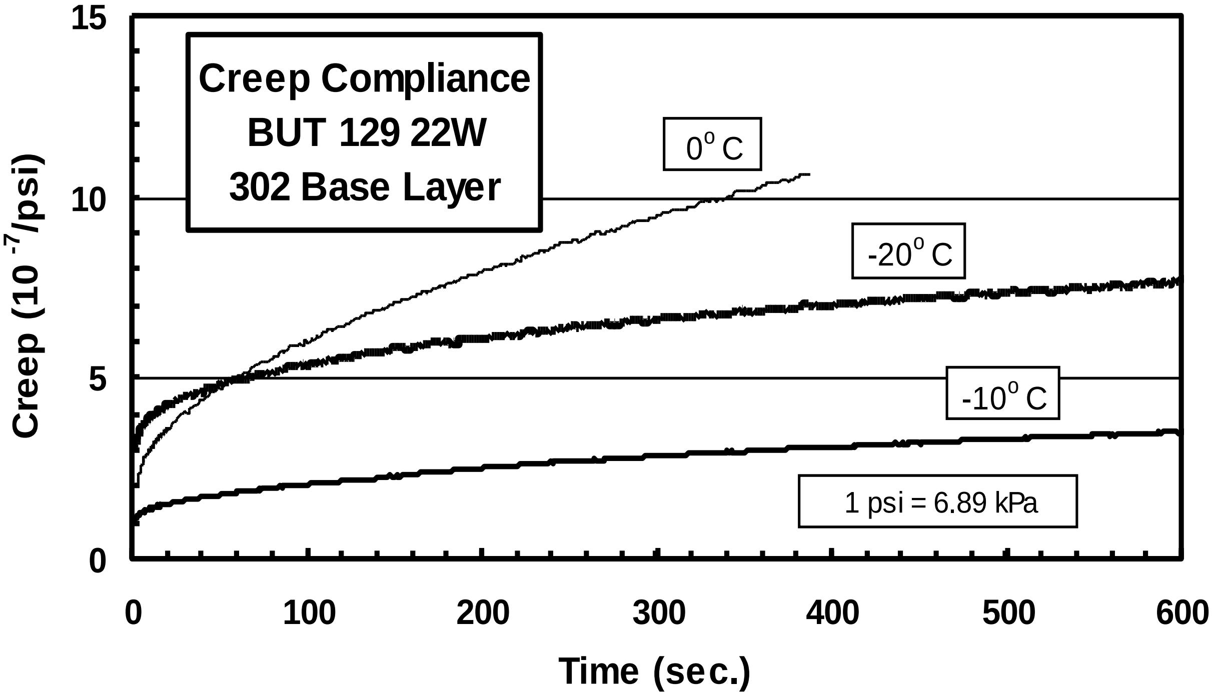


Figure G6 - Measured Creep Compliance for BUT 129 22E Base Layer



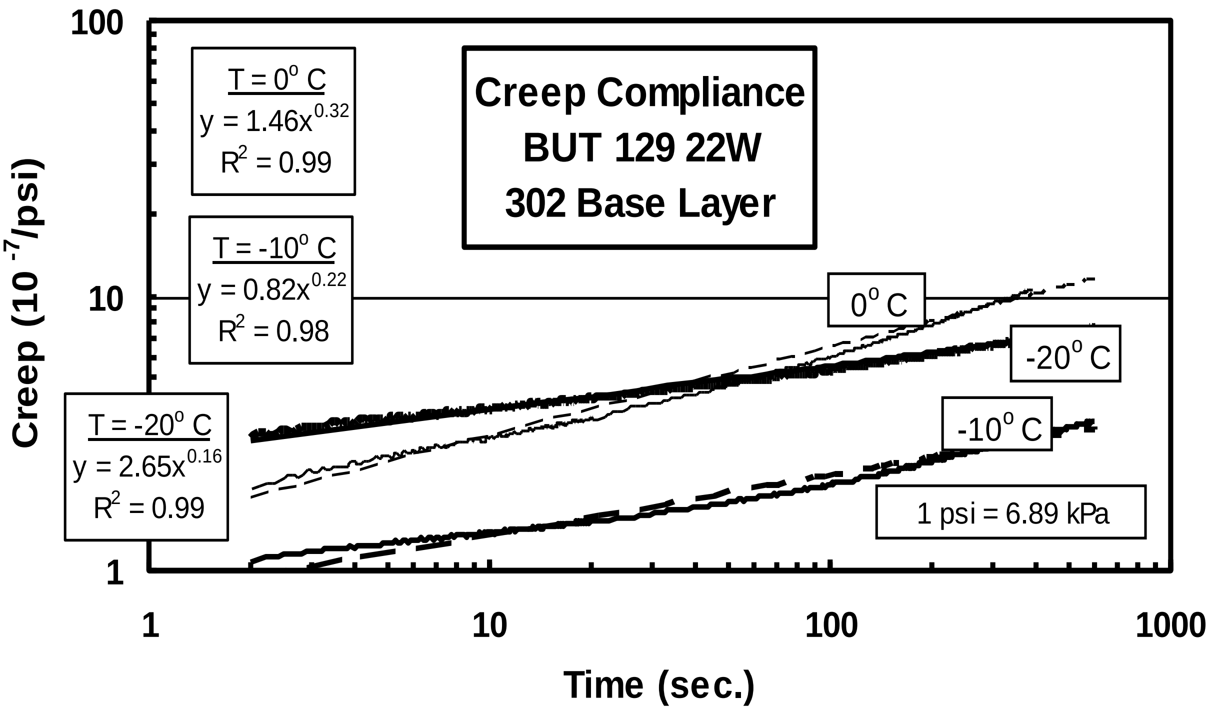
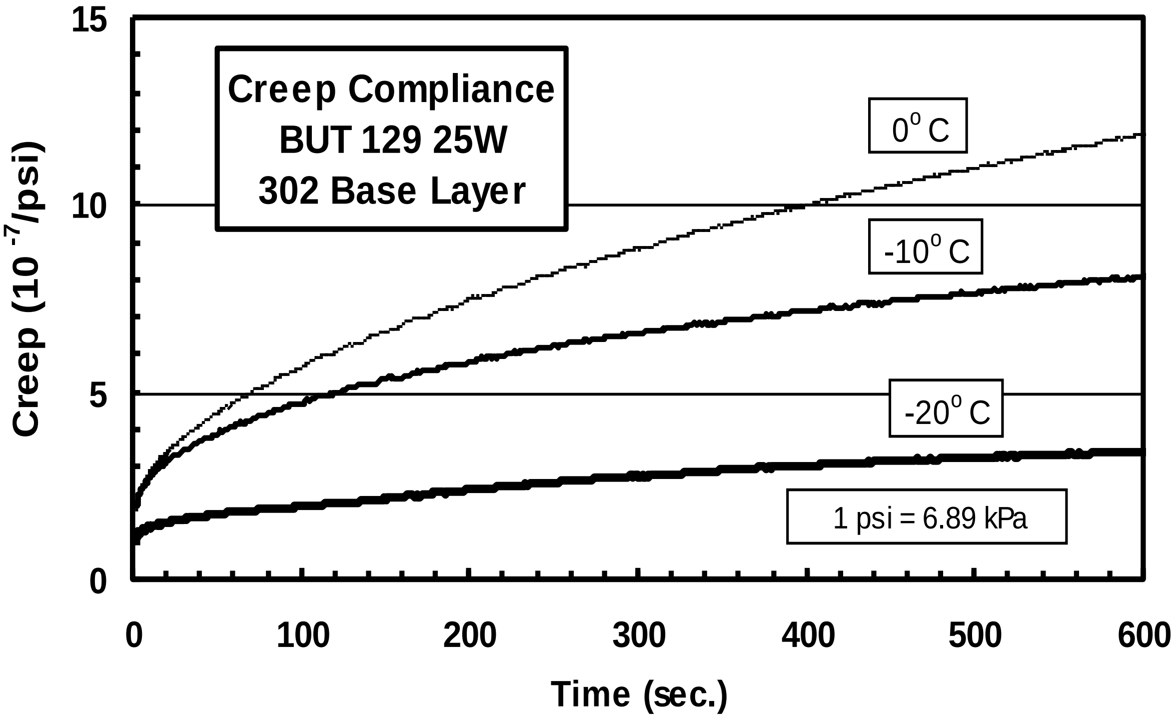


Figure G7 - Measured Creep Compliance for BUT 129 22W Base Layer



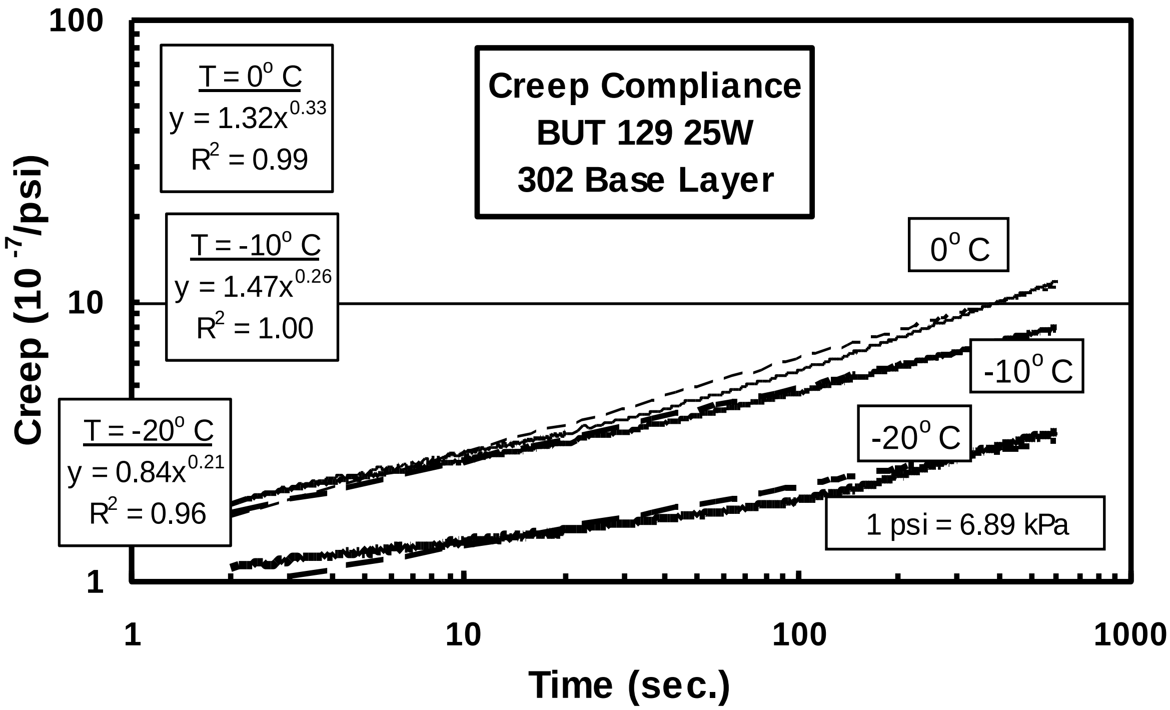
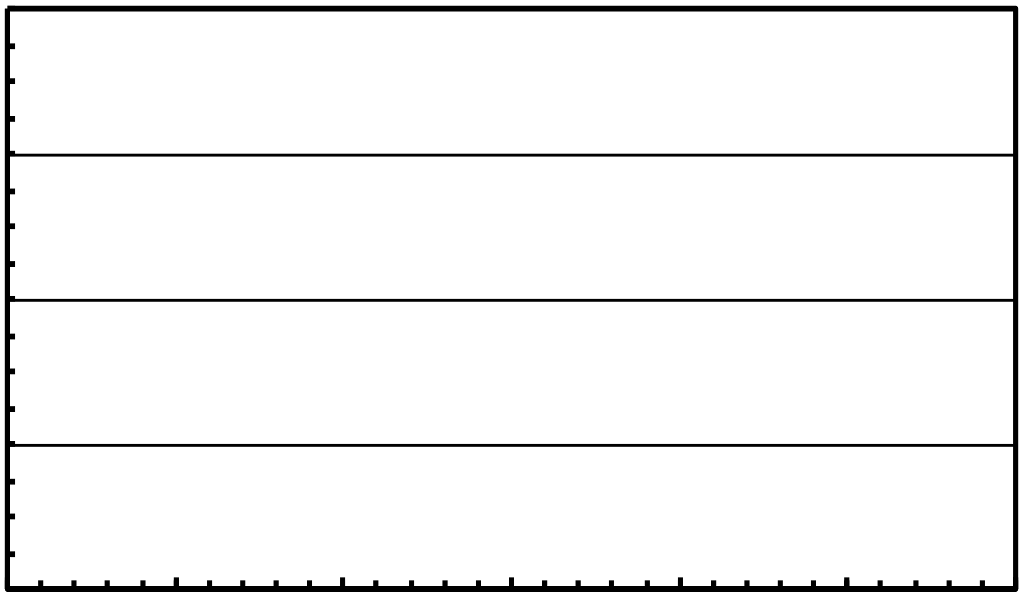


Figure G8 - Measured Creep Compliance for BUT 129 25W Base Layer



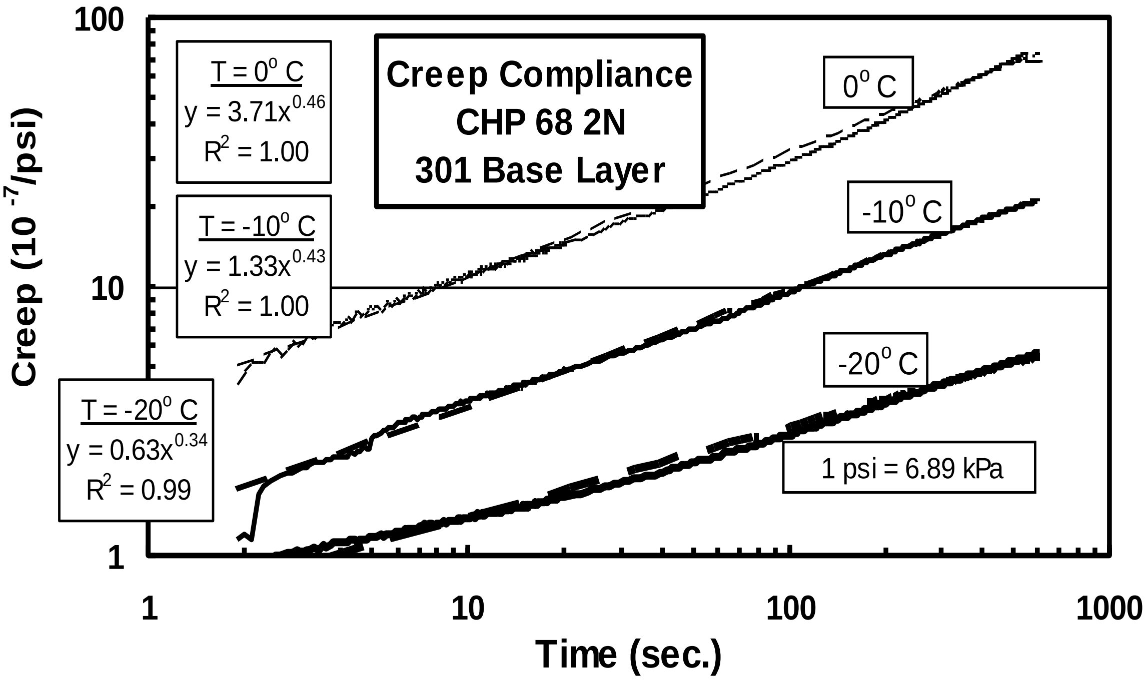
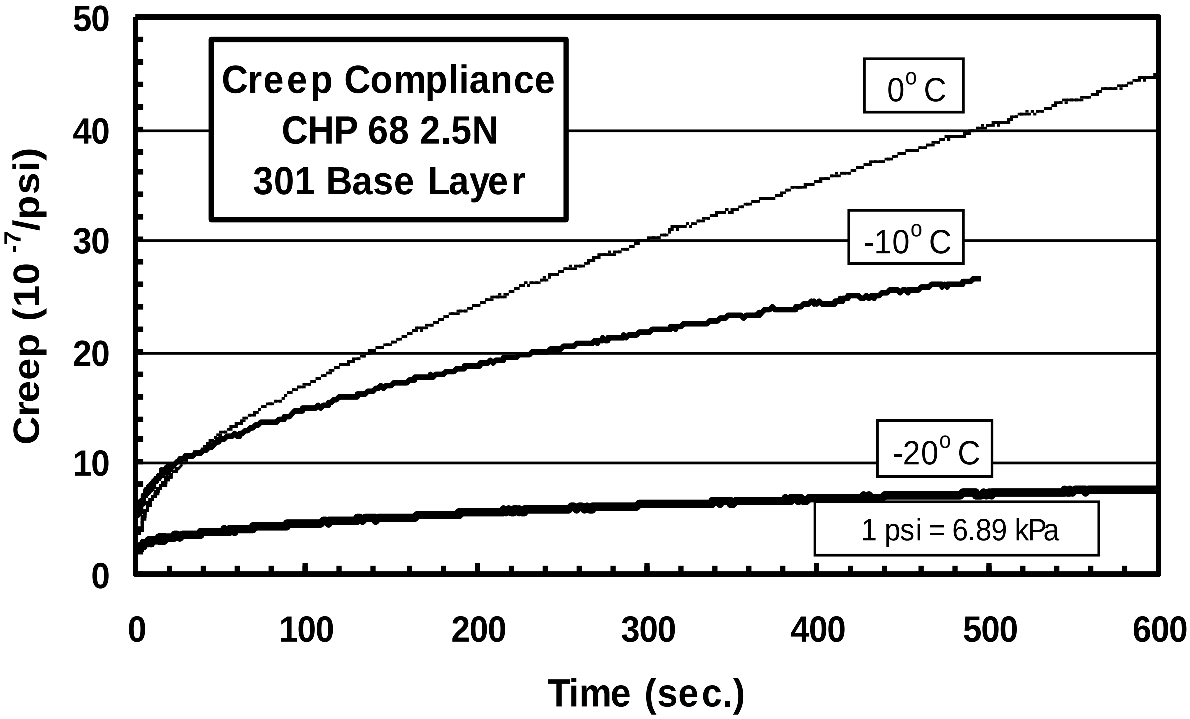


Figure G9 - Measured Creep Compliance for CHP 68 2N Base Layer



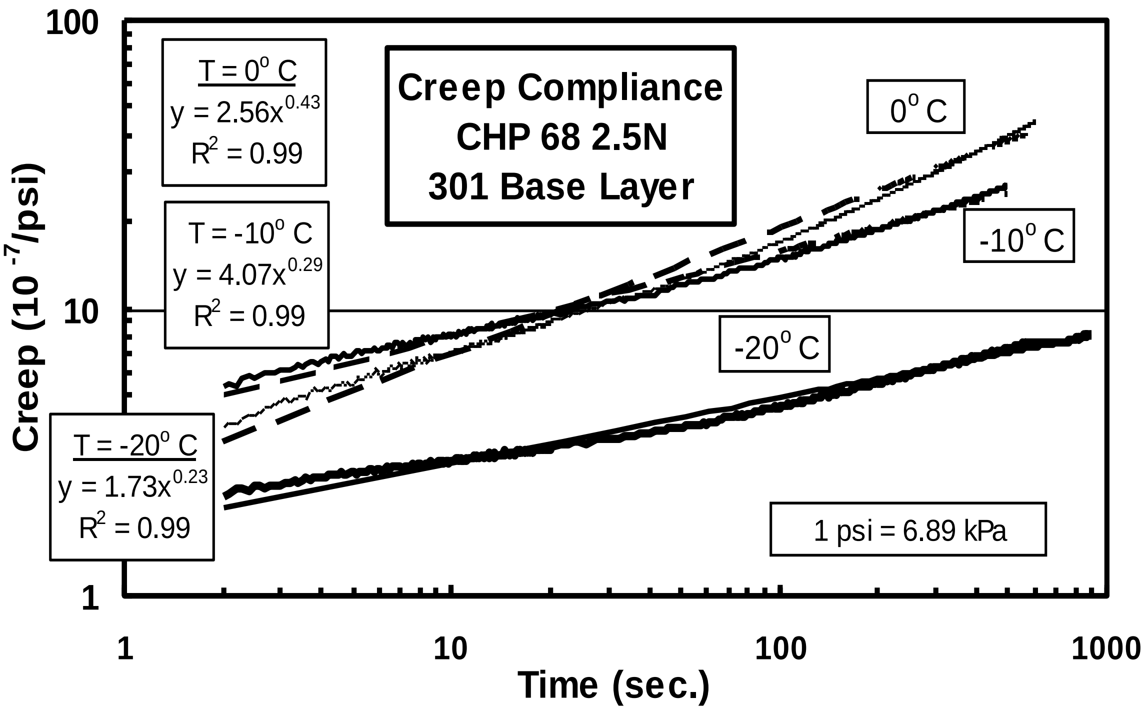


Figure G10 - Measured Creep Compliance for CHP 68 2.5N Base Layer

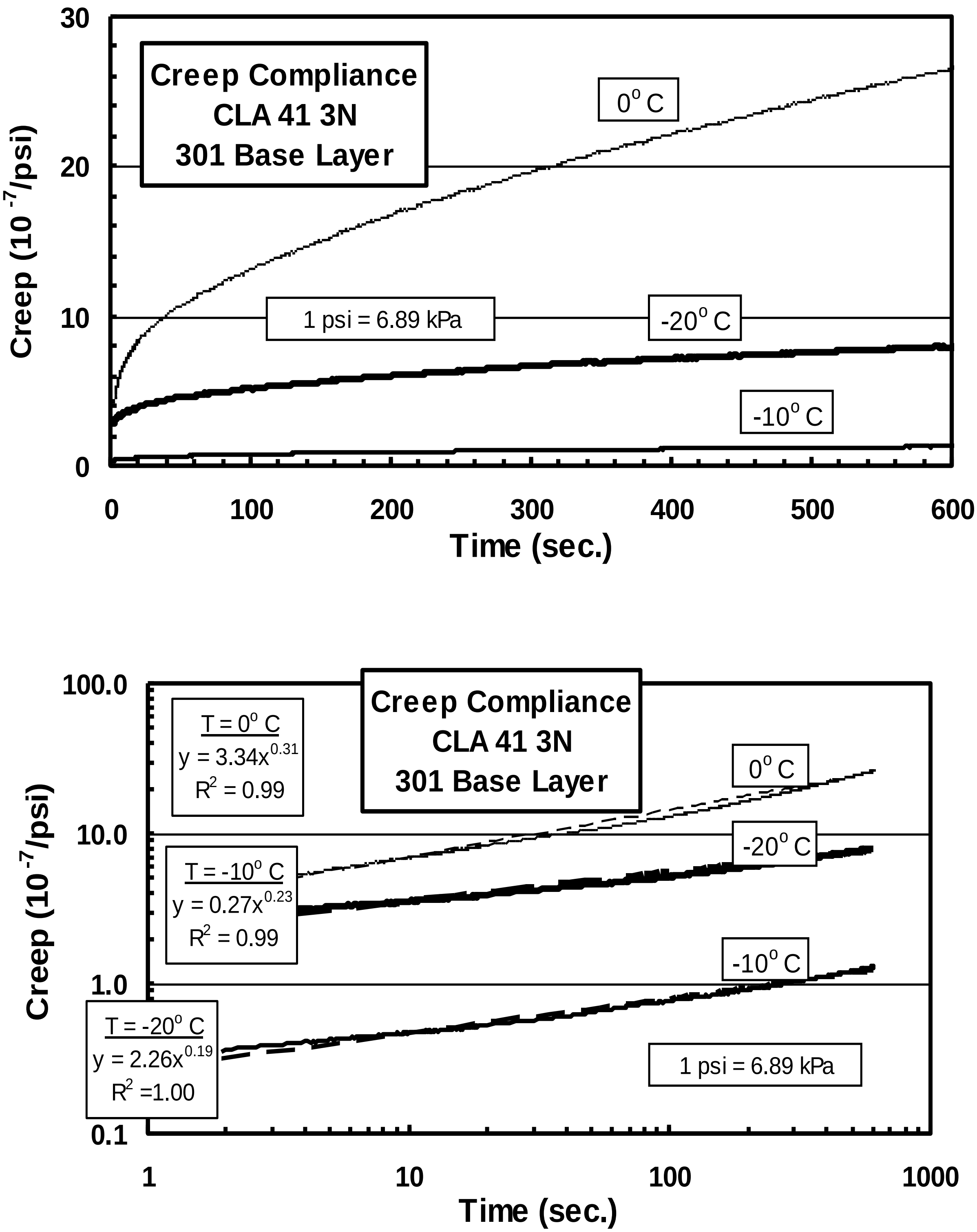
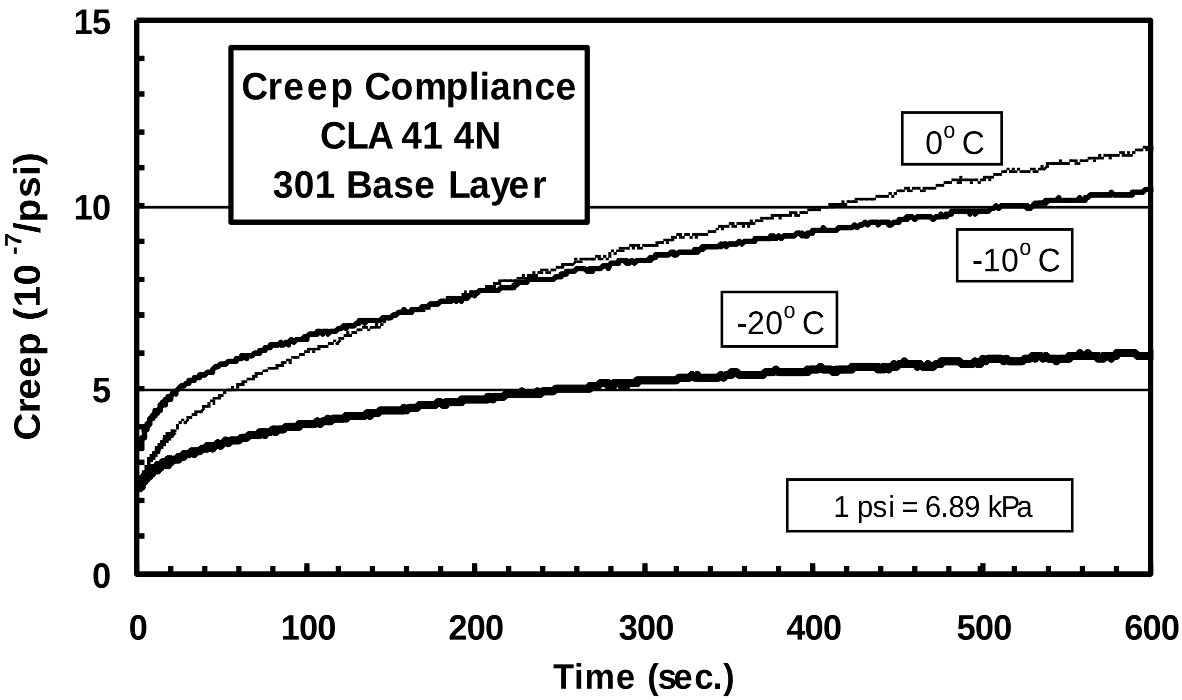


Figure G11 - Measured Creep Compliance for CLA 41 3N Base Layer



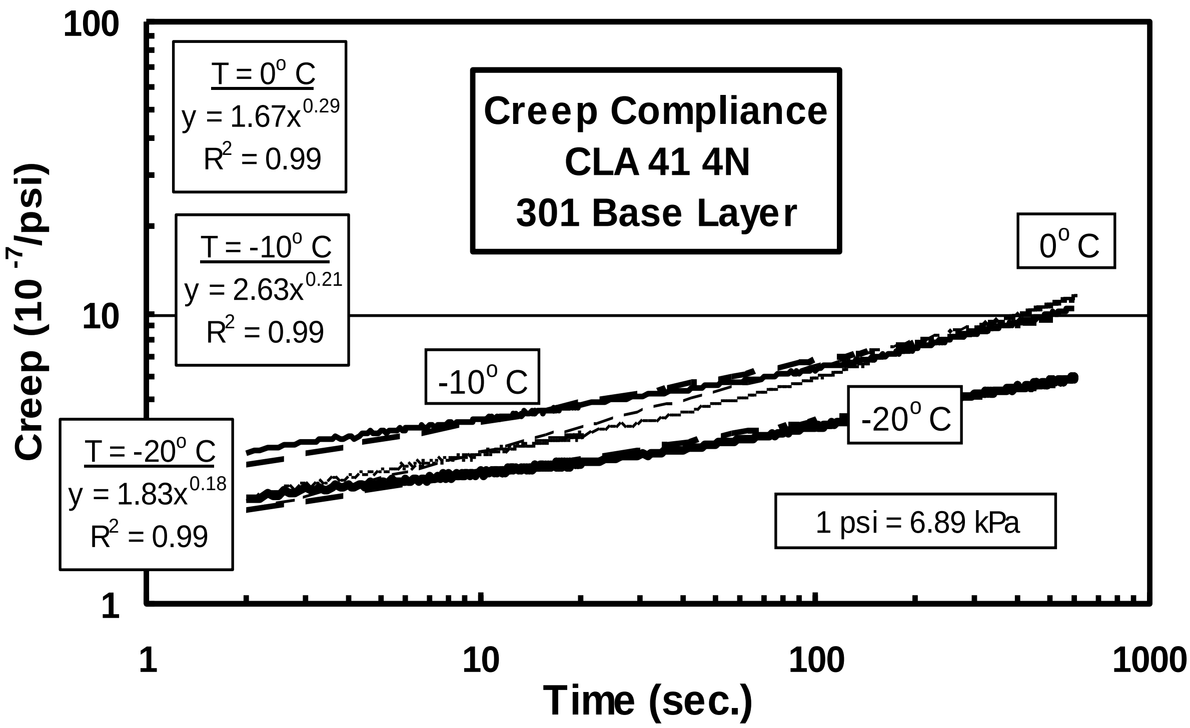
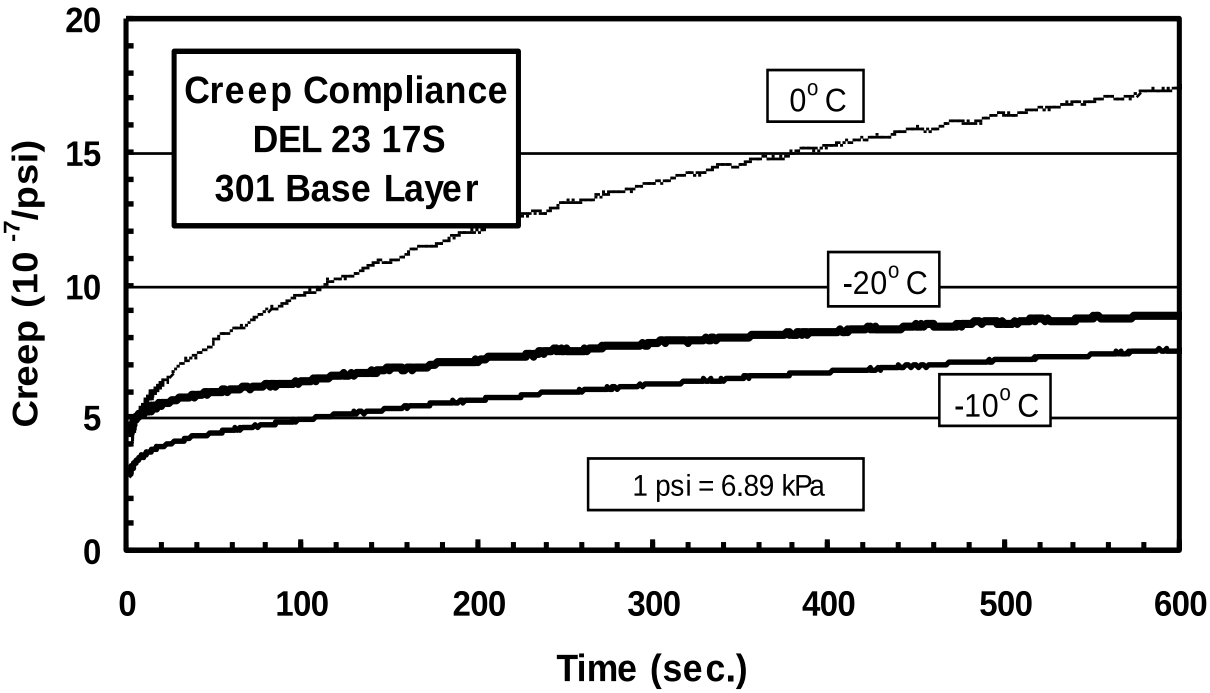


Figure G12 - Measured Creep Compliance for CLA 41 4N Base Layer



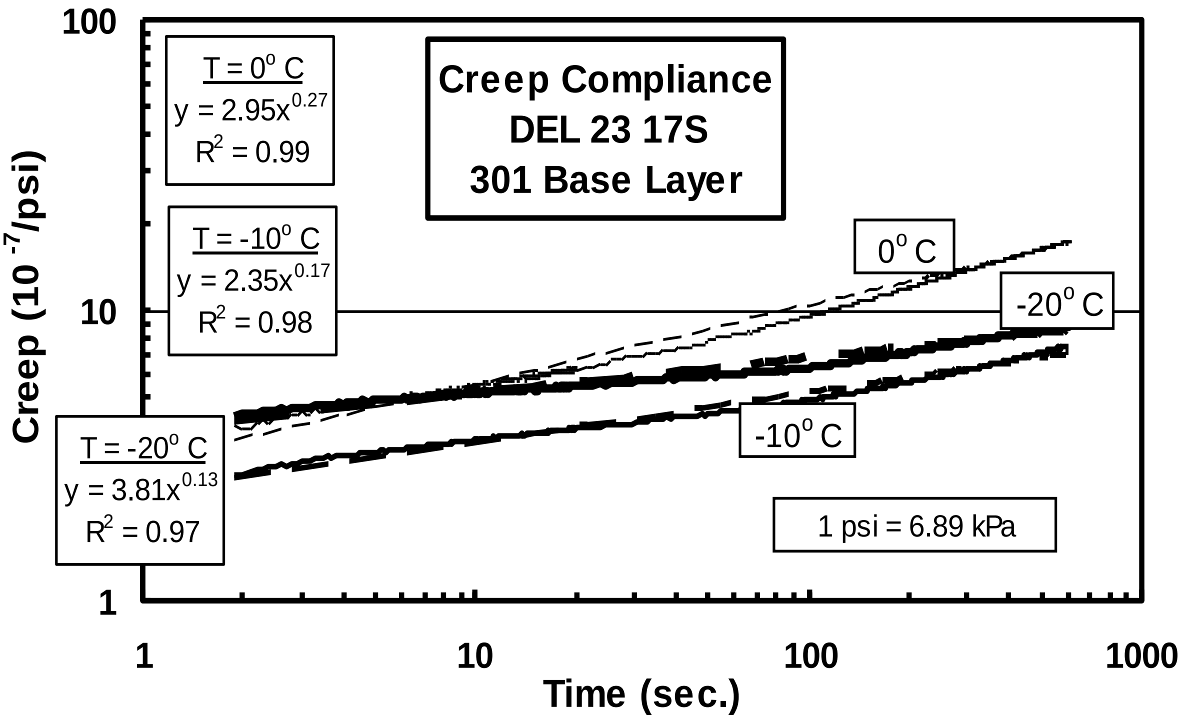


Figure G13 - Measured Creep Compliance for DEL 23 17S Base Layer

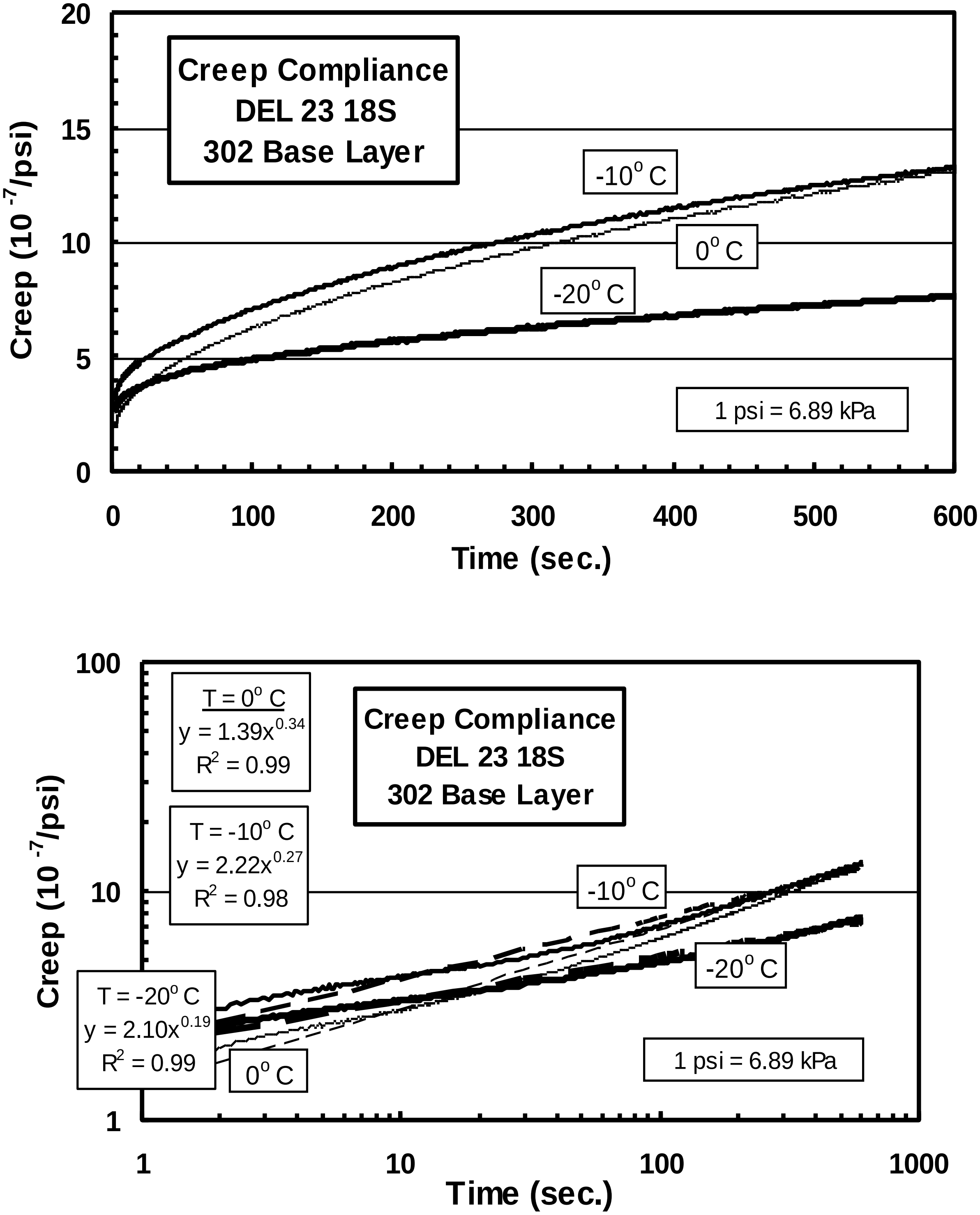
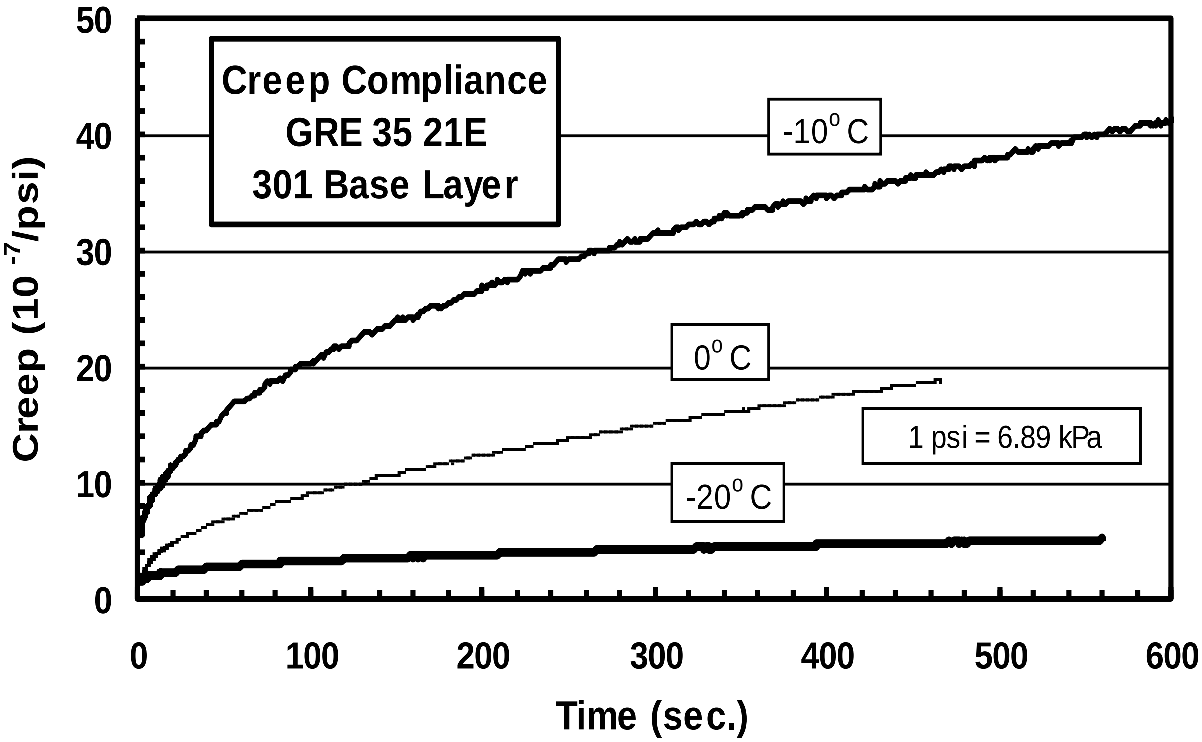


Figure G14 - Measured Creep Compliance for DEL 23 18S Base Layer



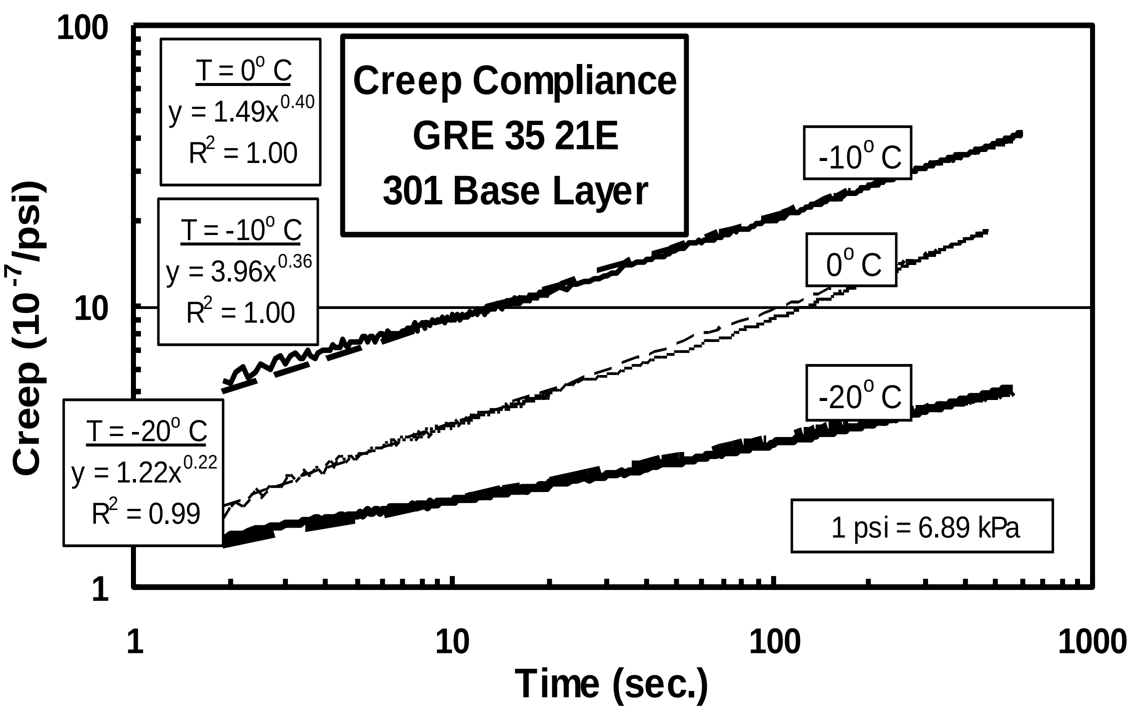


Figure G15 - Measured Creep Compliance for GRE 35 21E Base Layer

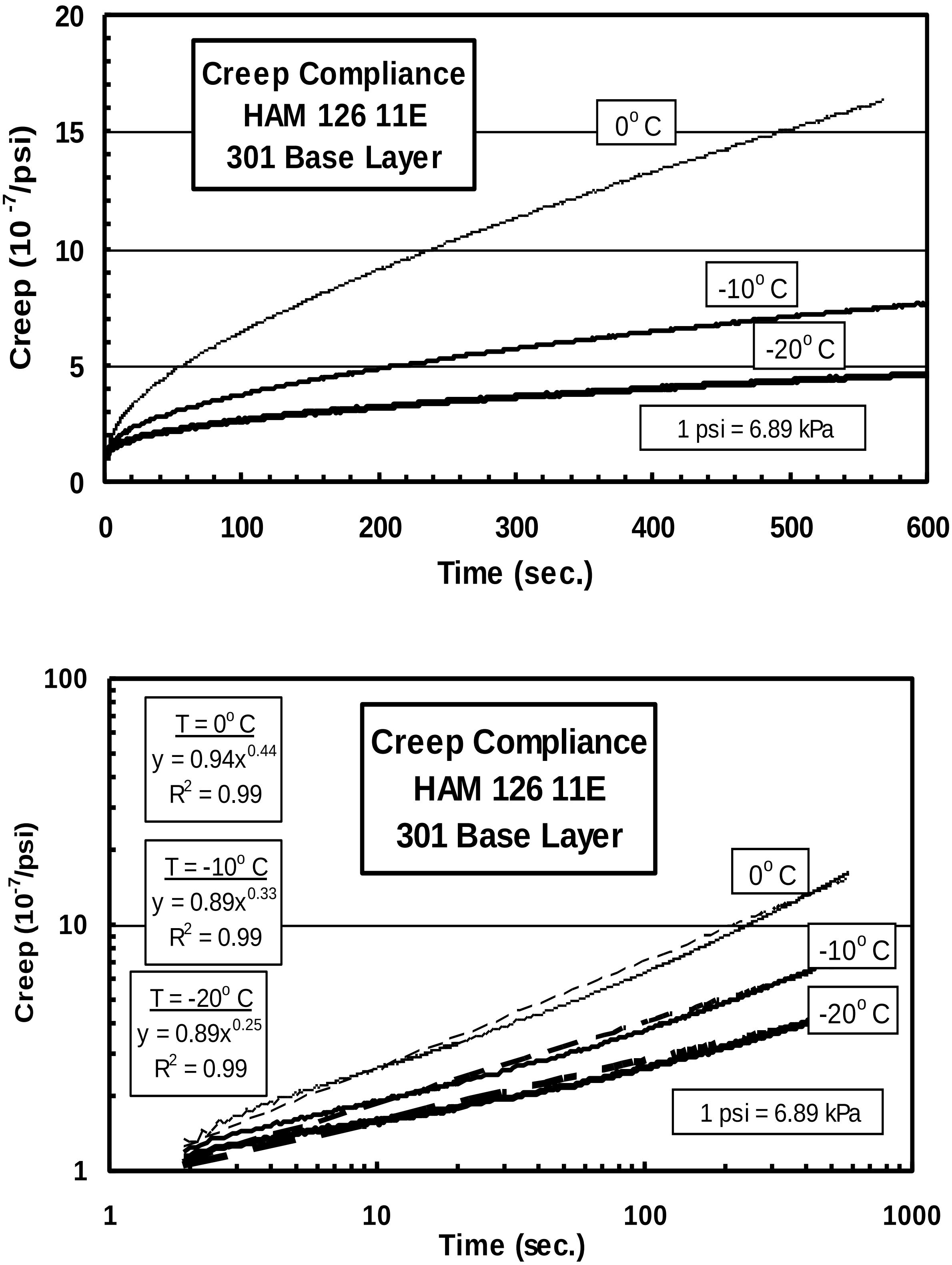
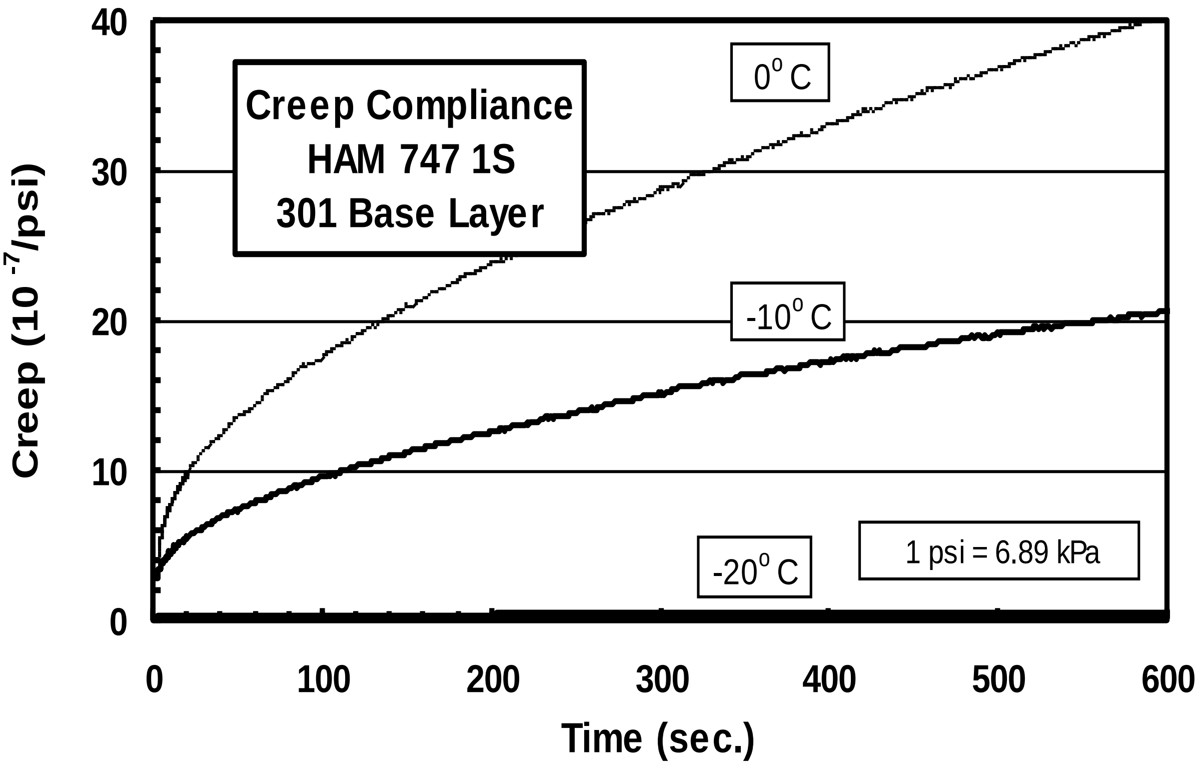


Figure G16 - Measured Creep Compliance for HAM 126 11E Base Layer



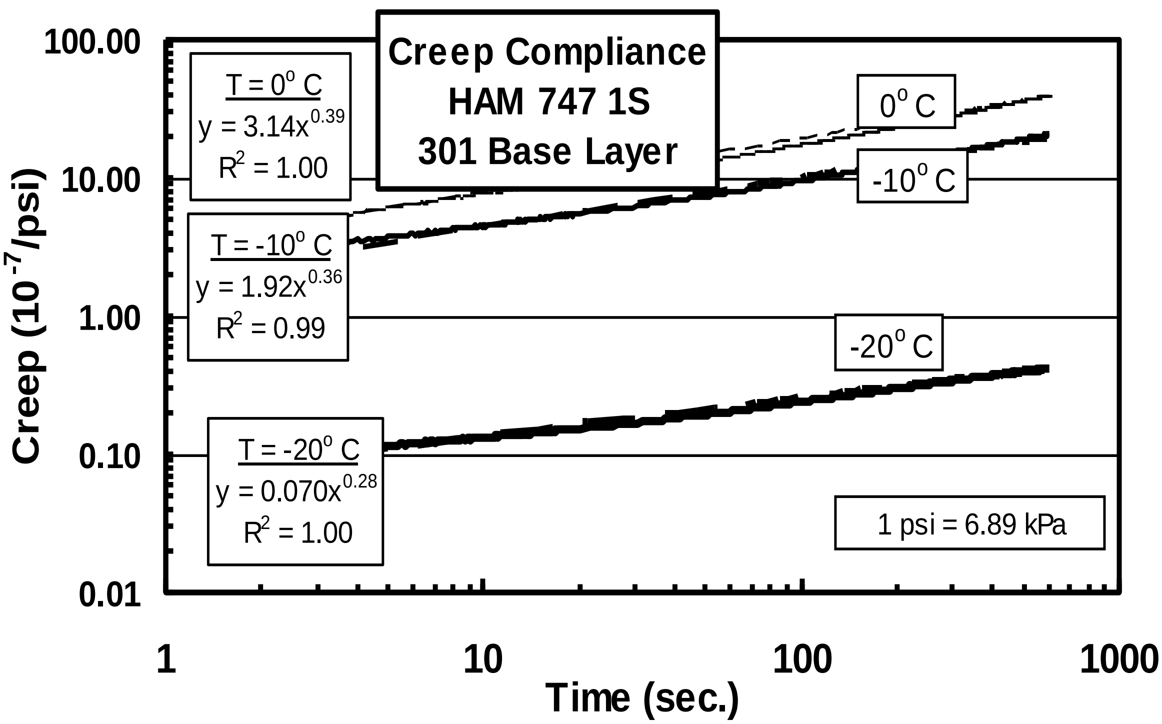
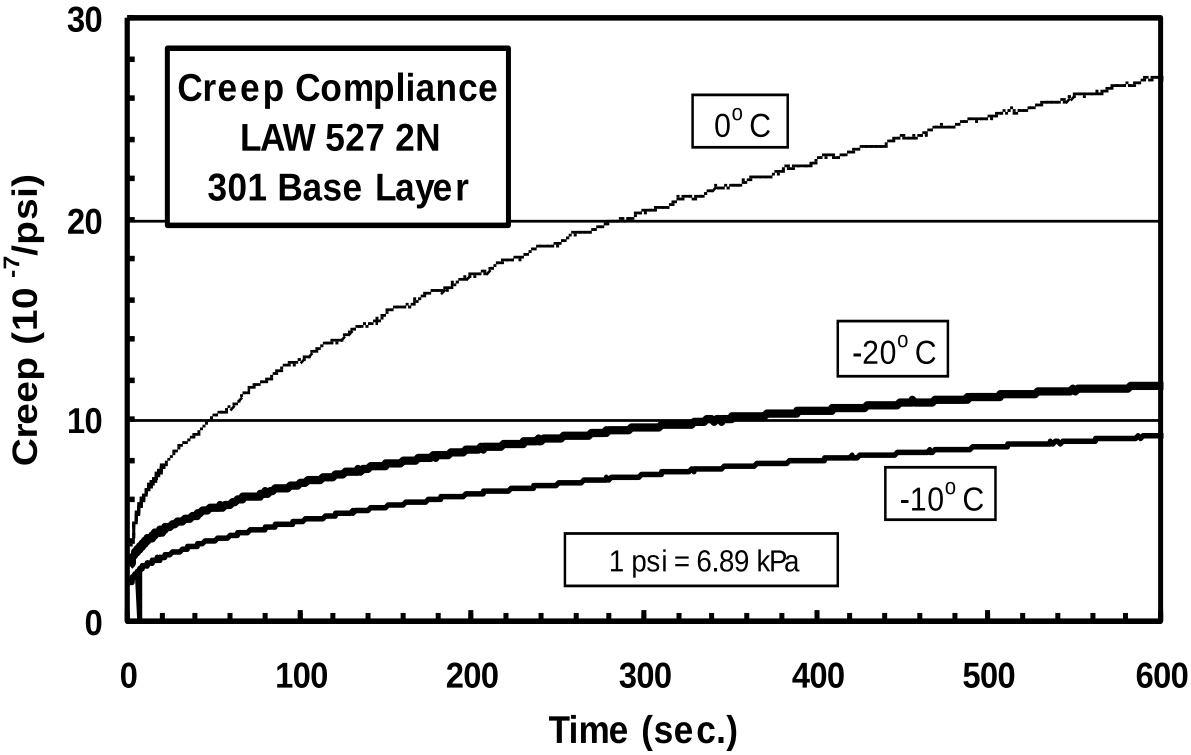


Figure G17 - Measured Creep Compliance for HAM 747 1S Base Layer



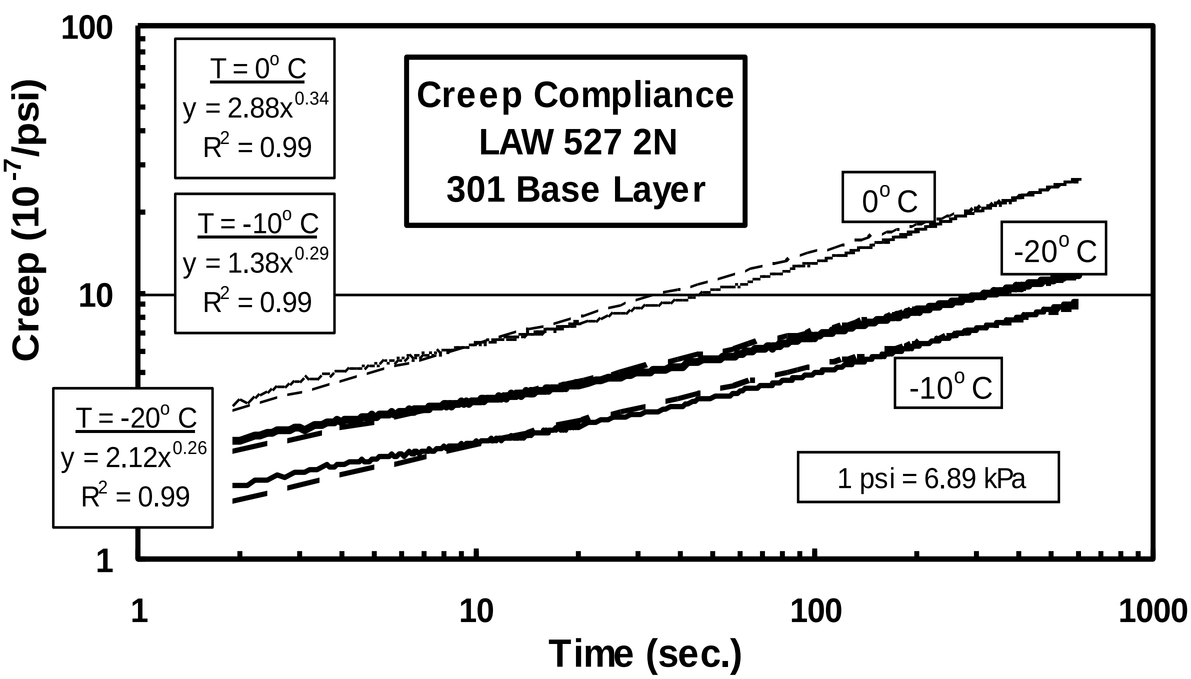
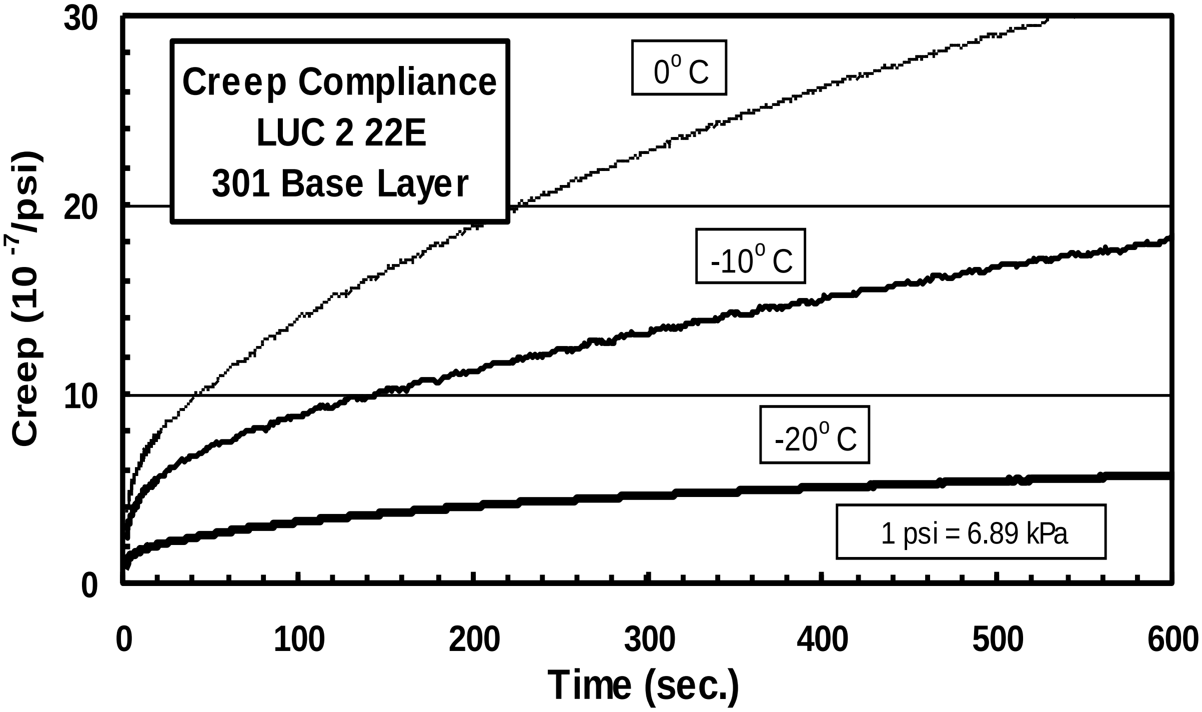


Figure G18 - Measured Creep Compliance for LAW 527 2N Base Layer



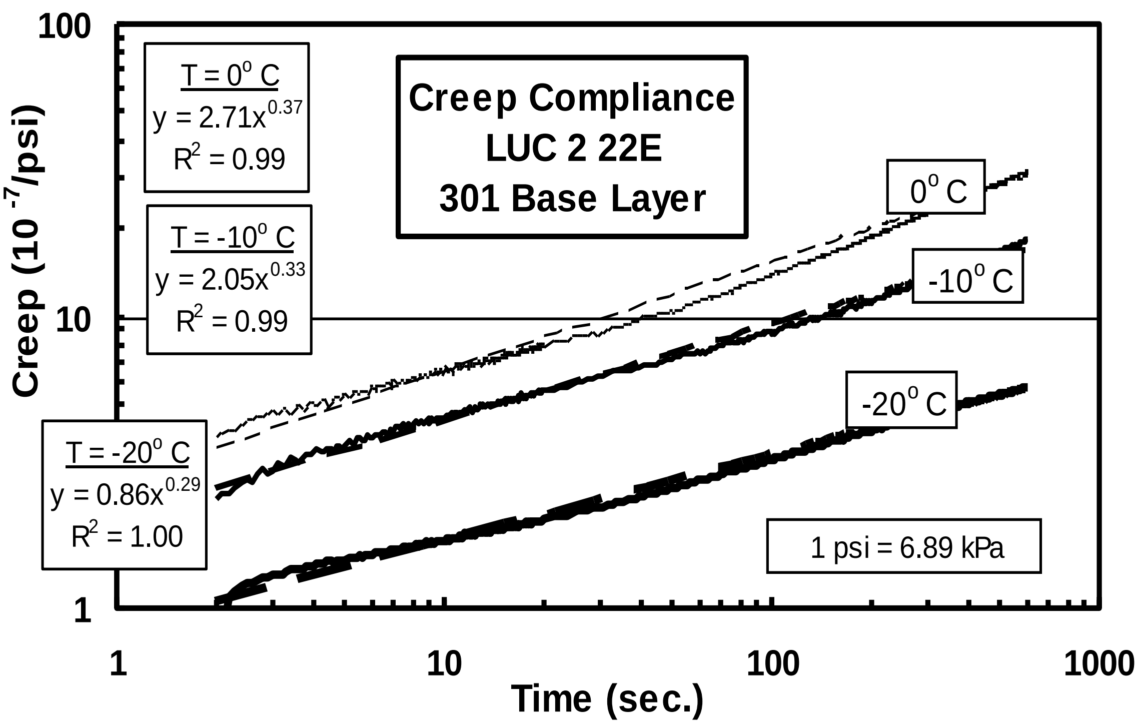
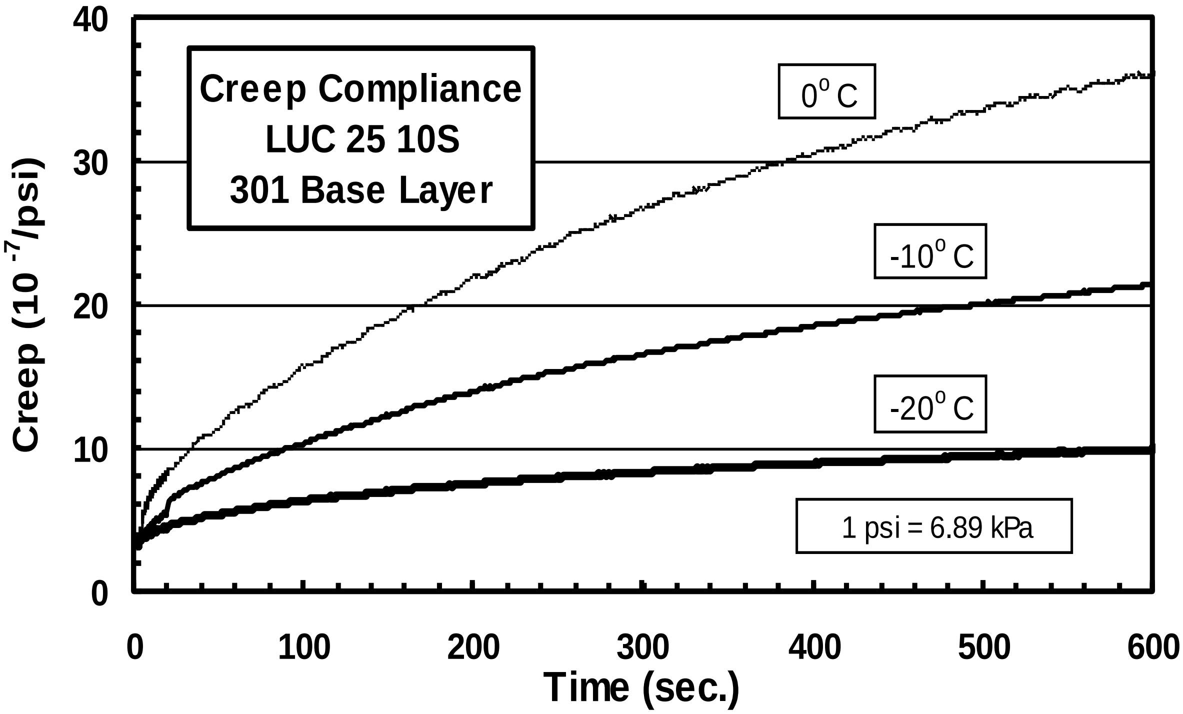


Figure G19 - Measured Creep Compliance for LUC 2 22E Base Layer



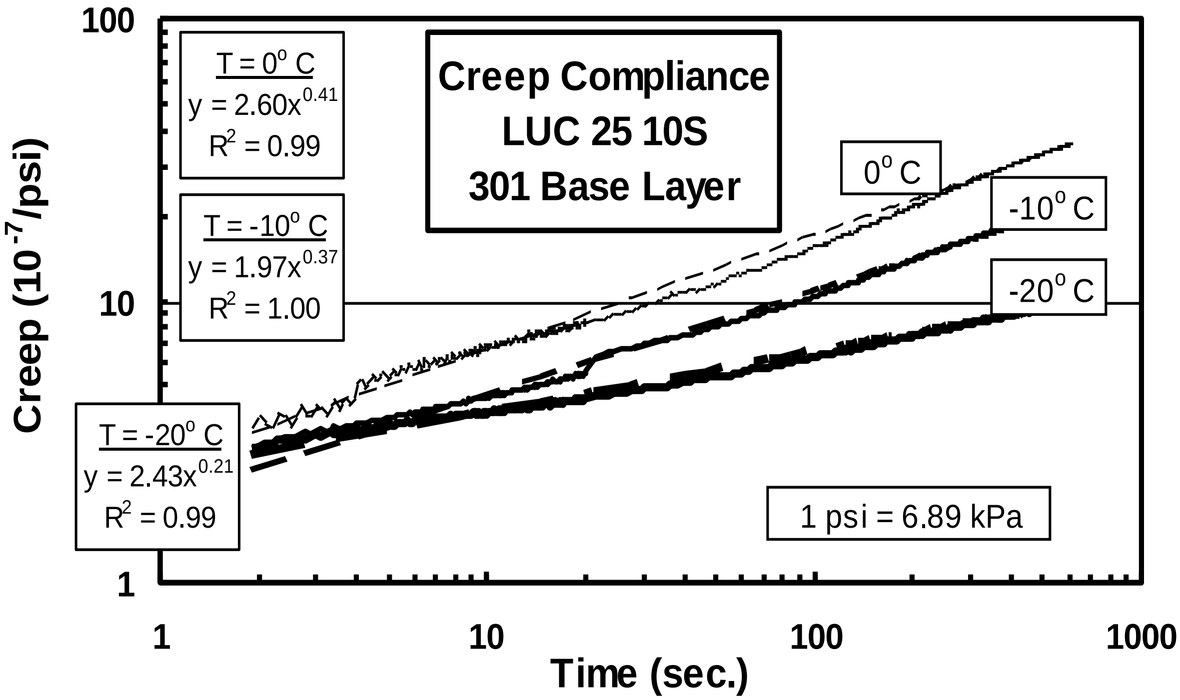
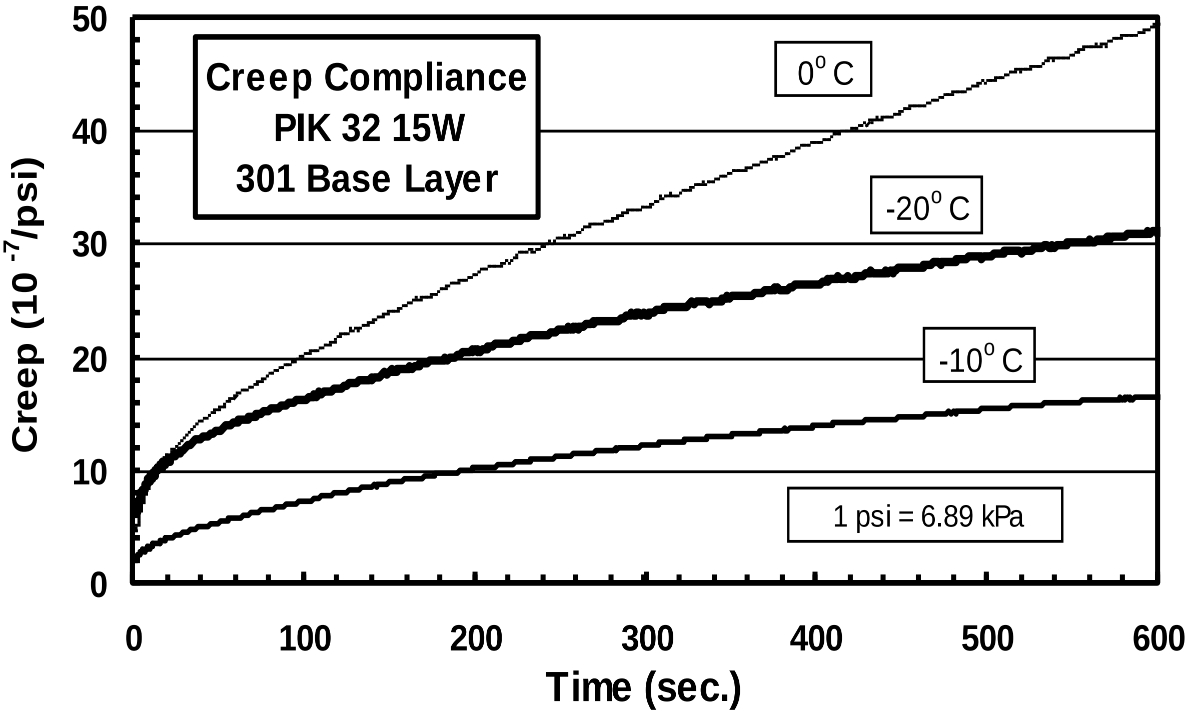


Figure G20 - Measured Creep Compliance for LUC 25 10S Base Layer



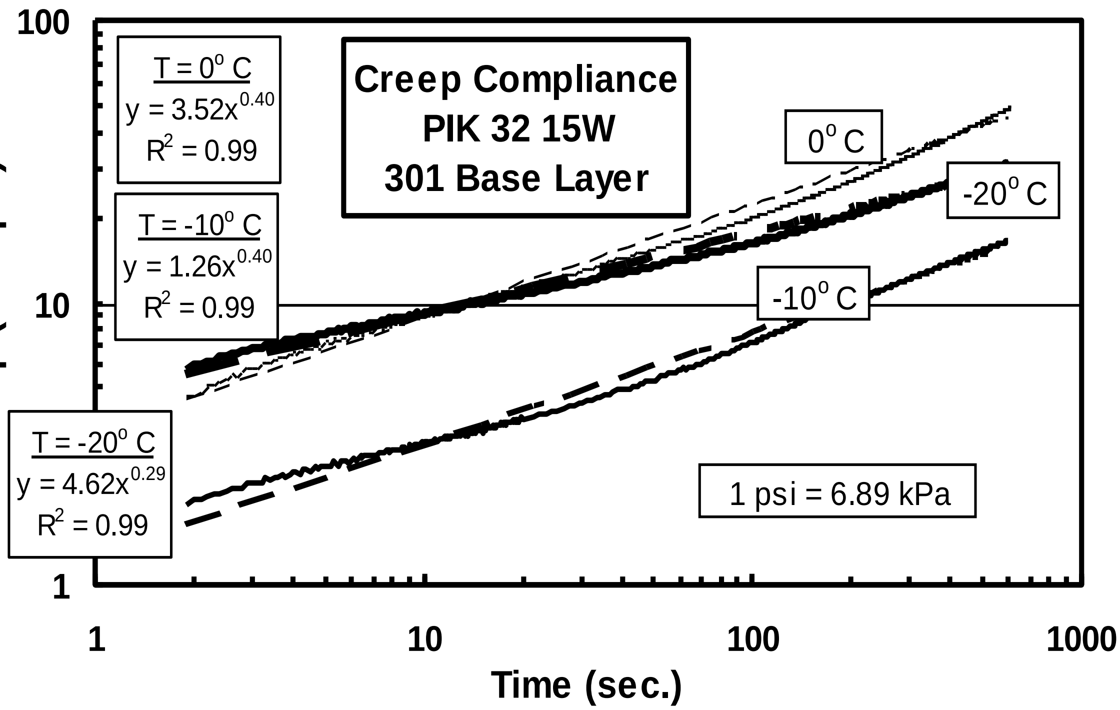
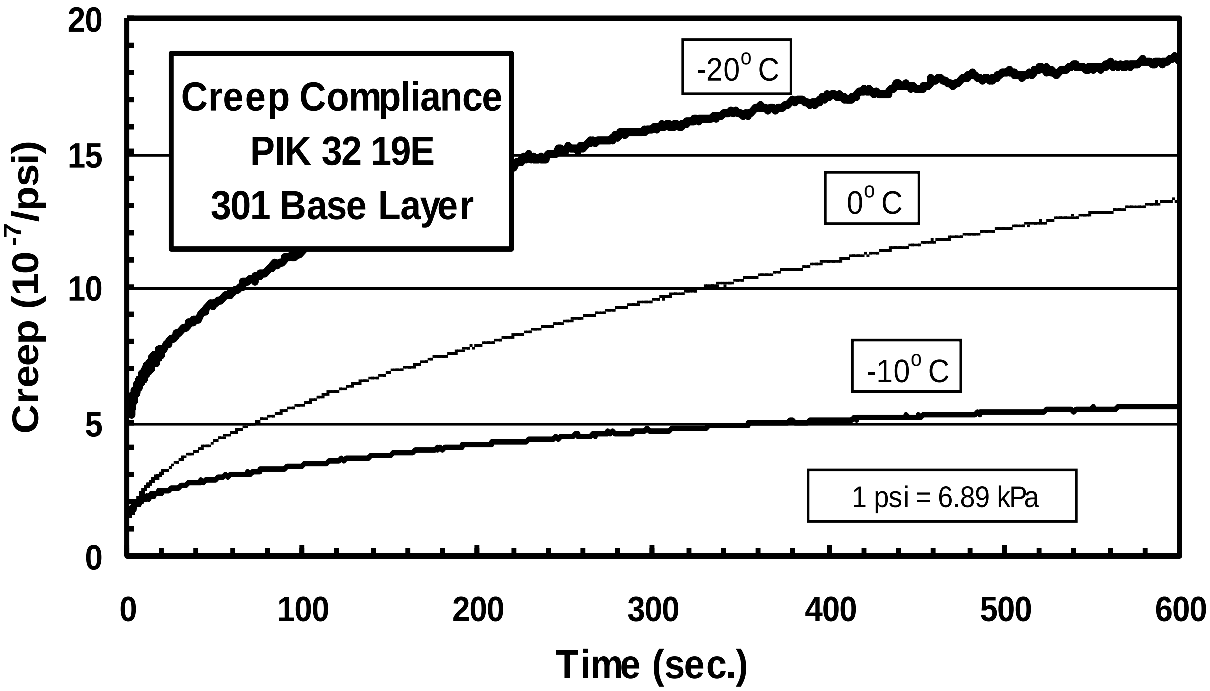


Figure G21 - Measured Creep Compliance for PIK 32 15W Base Layer



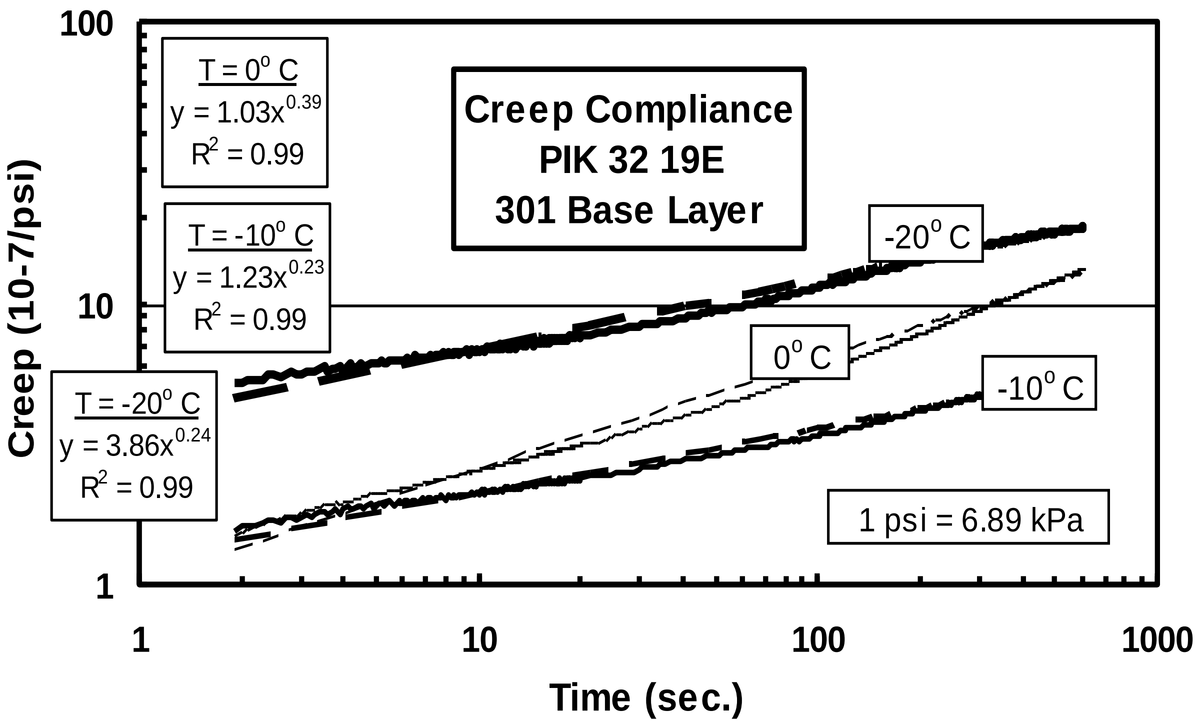
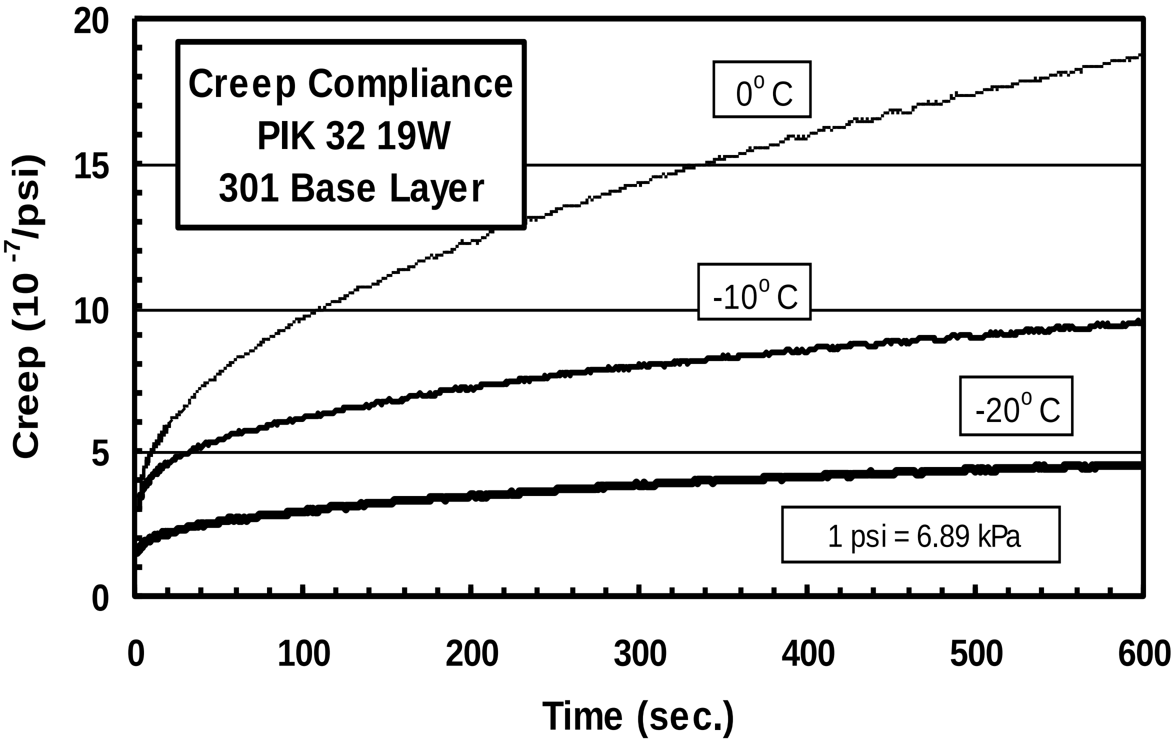


Figure G22 - Measured Creep Compliance for PIK 32 19E Base Layer



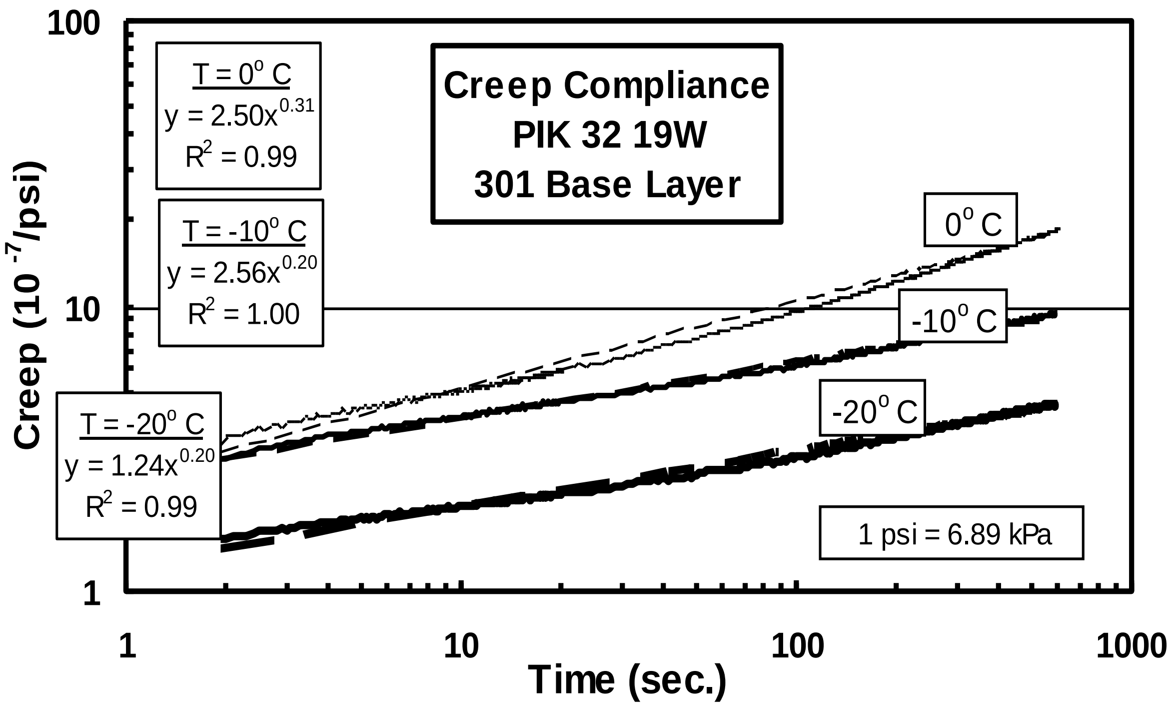
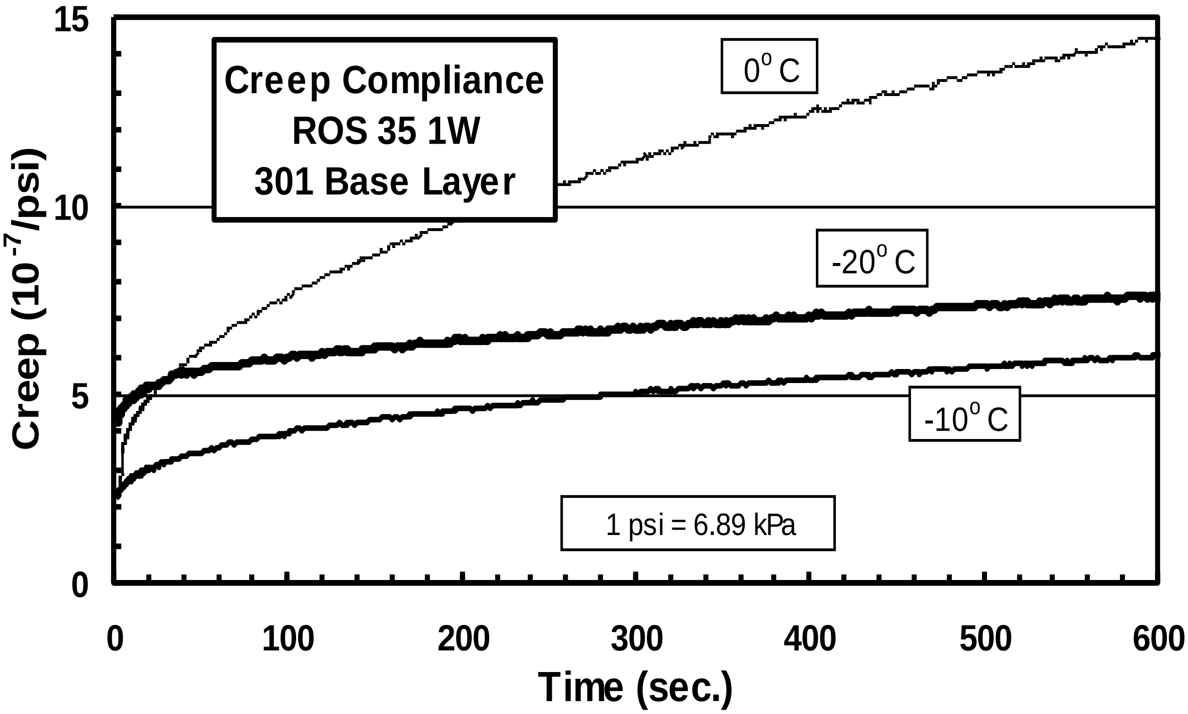


Figure G23 - Measured Creep Compliance for PIK 32 19W Base Layer



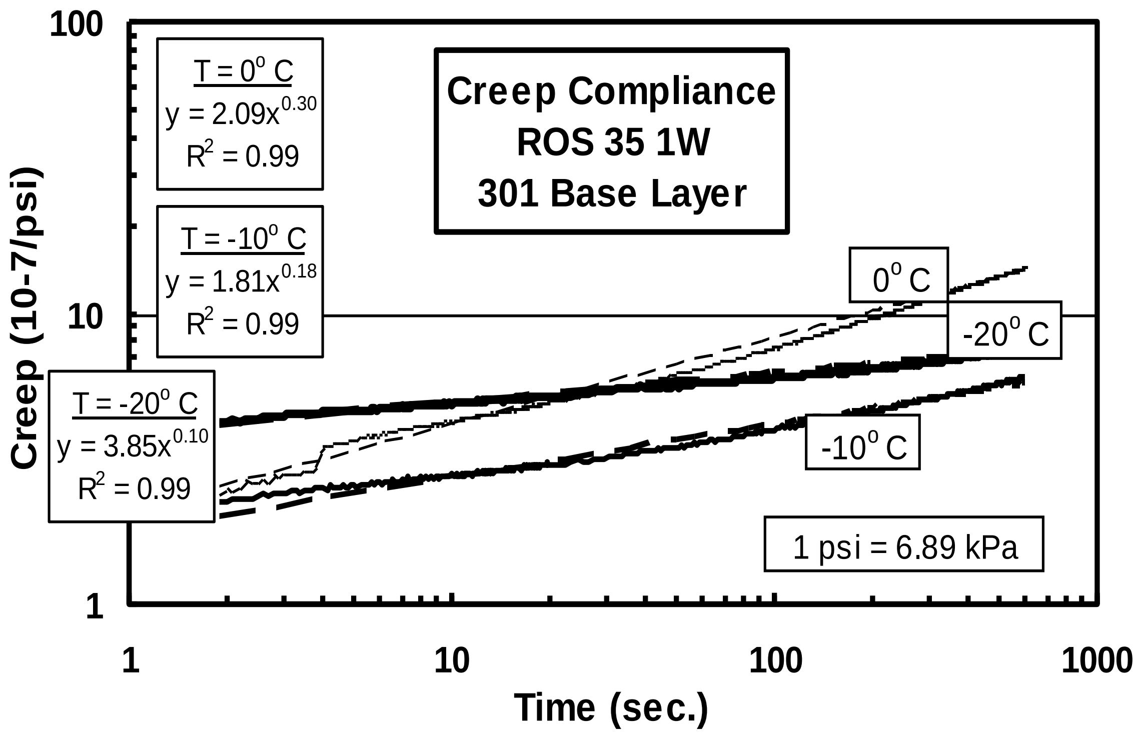


Figure G24 - Measured Creep Compliance for ROS 35 1W Base Layer

APPENDIX H

MEPDG Modeling for Flexible Pavements

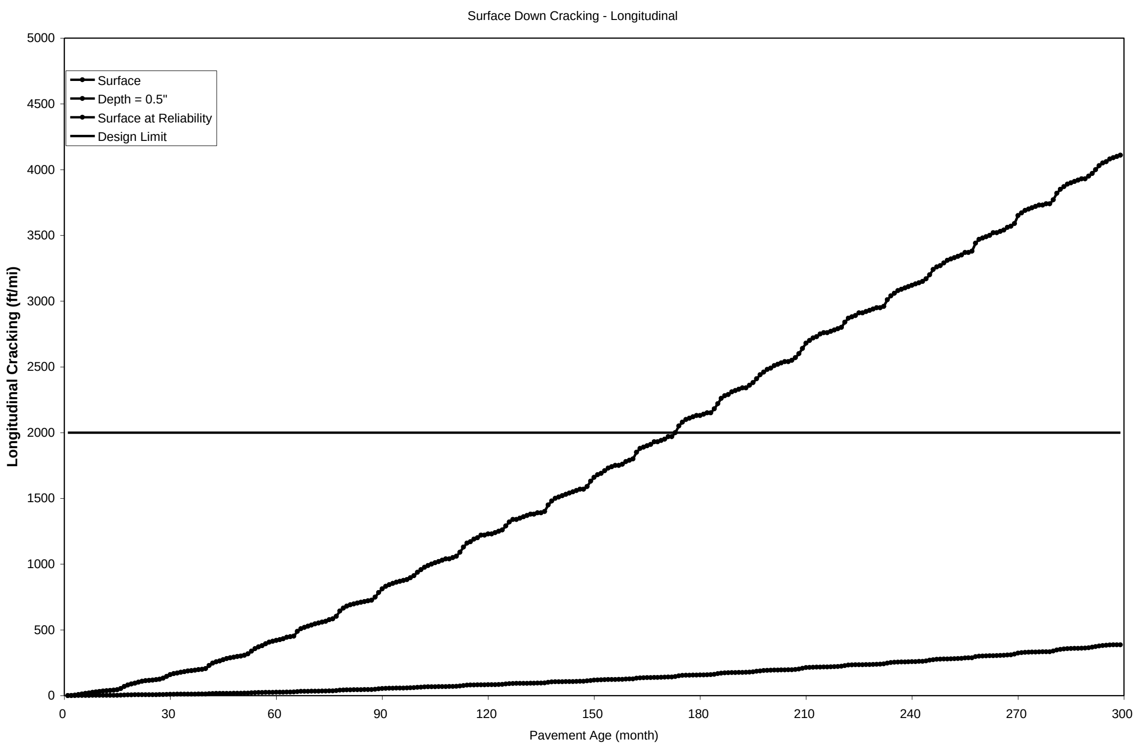


Figure H1. Longitudinal Cracking – Project 1, BUT 129 D (9330-98)

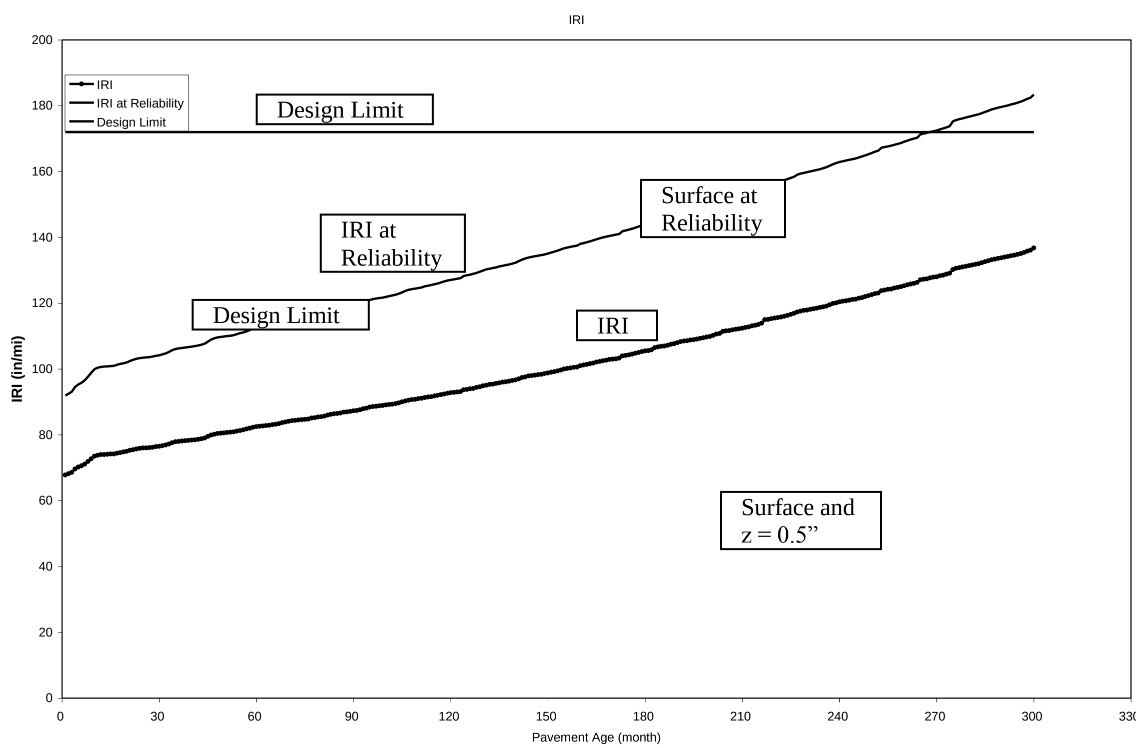


Figure H2. International Roughness Index – Project 1, BUT 129 U (9330-98)

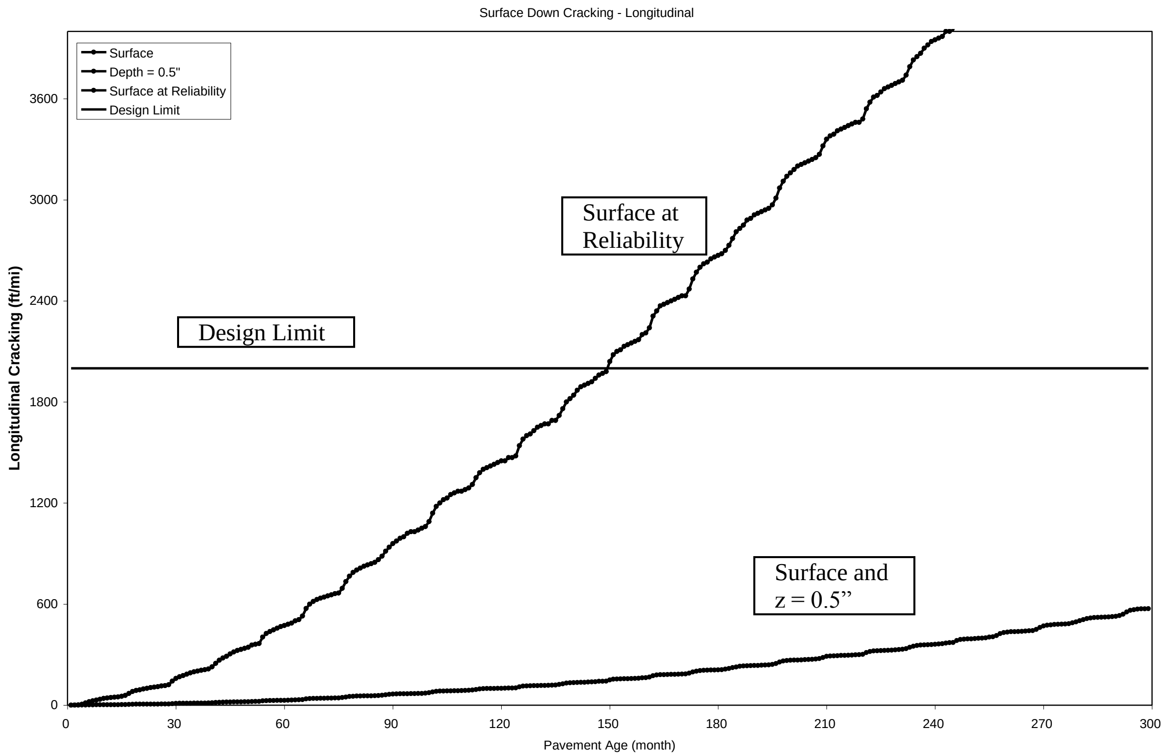


Figure H3. Longitudinal Cracking – Project 2, BUT 129 (9327-98)

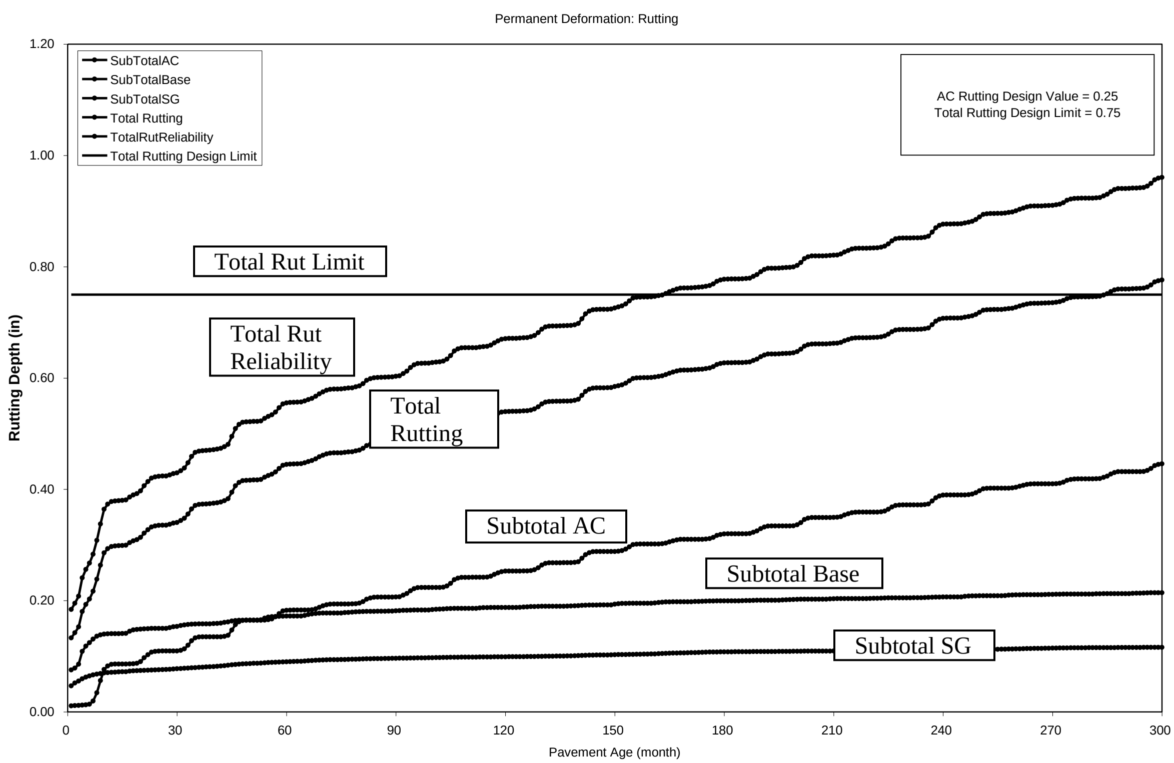


Figure H4. Permanent Deformation - Project 2, BUT 129 (9327-98)

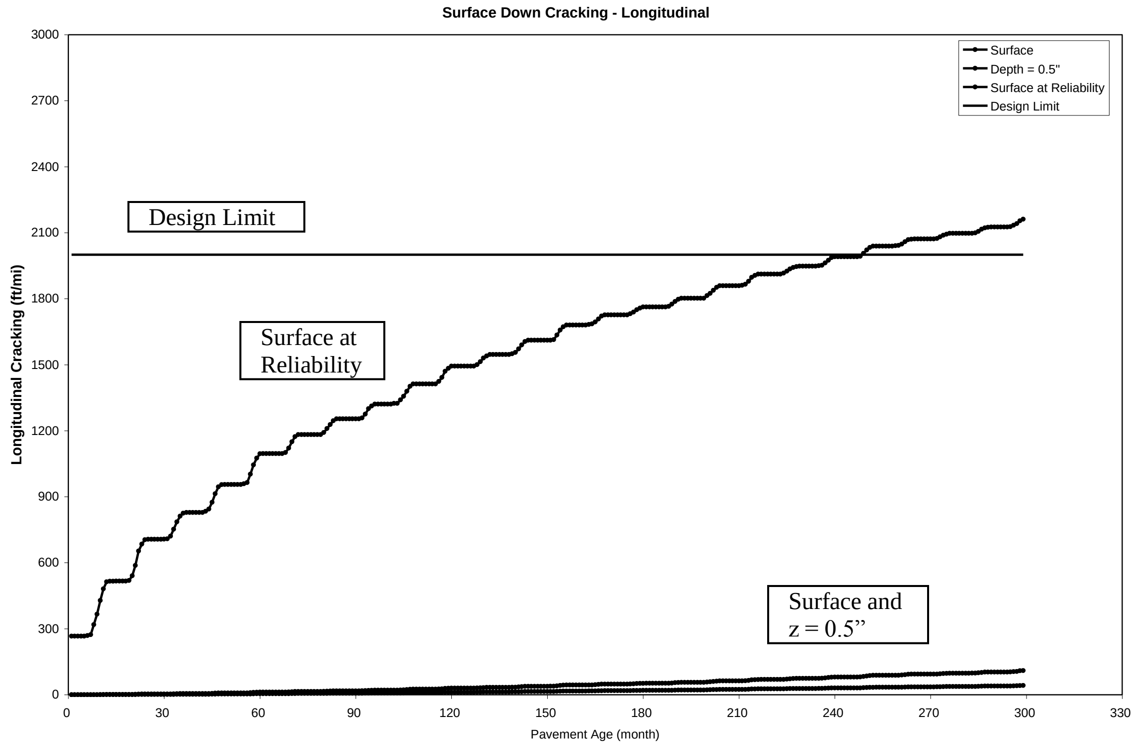


Figure H5. Longitudinal Cracking – Project 3, CHP 68 D (233-98)

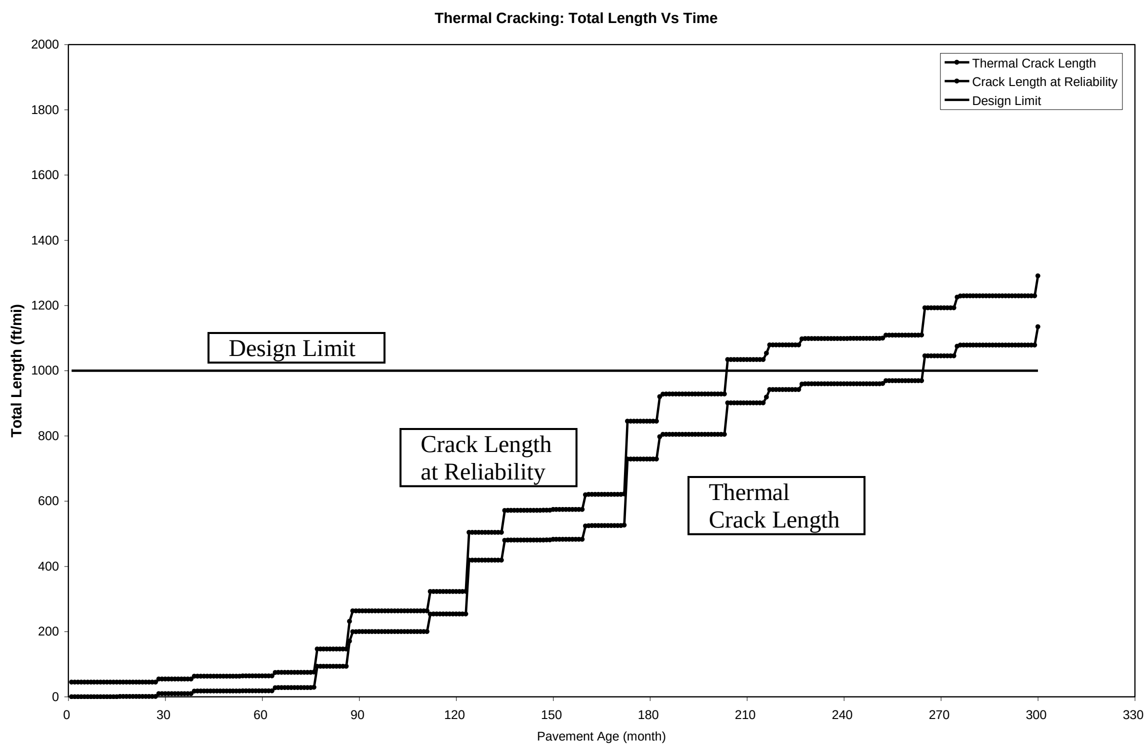


Figure H6. Transverse Cracking – Project 3, CHP 68 U (233-98)

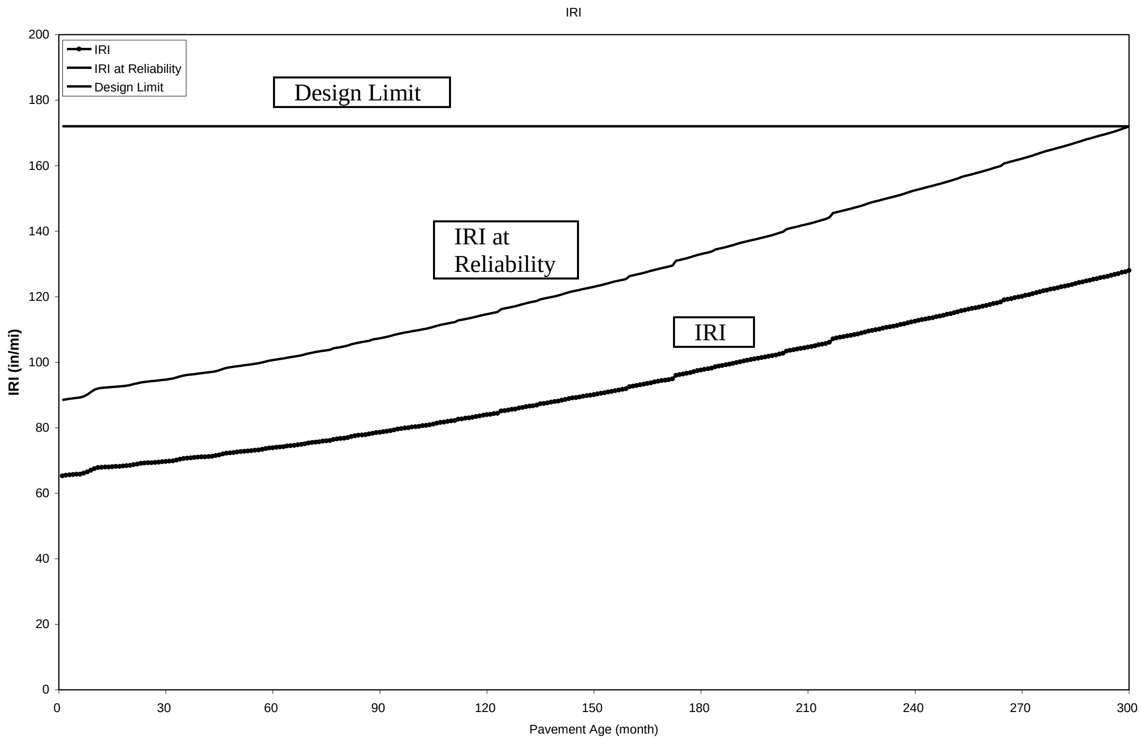


Figure H7. International Roughness Index – Project 4, FAY 35 (298-96)

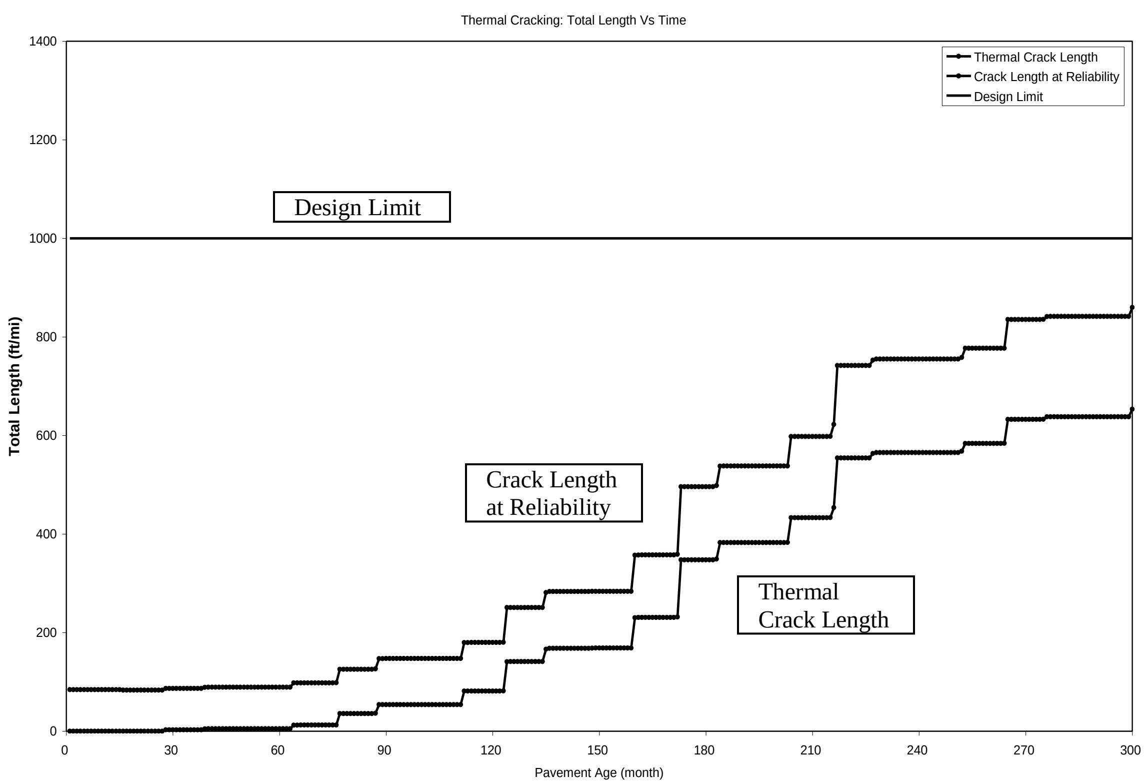


Figure H8. Transverse Cracking – Project 4, FAY 35 (298-96)

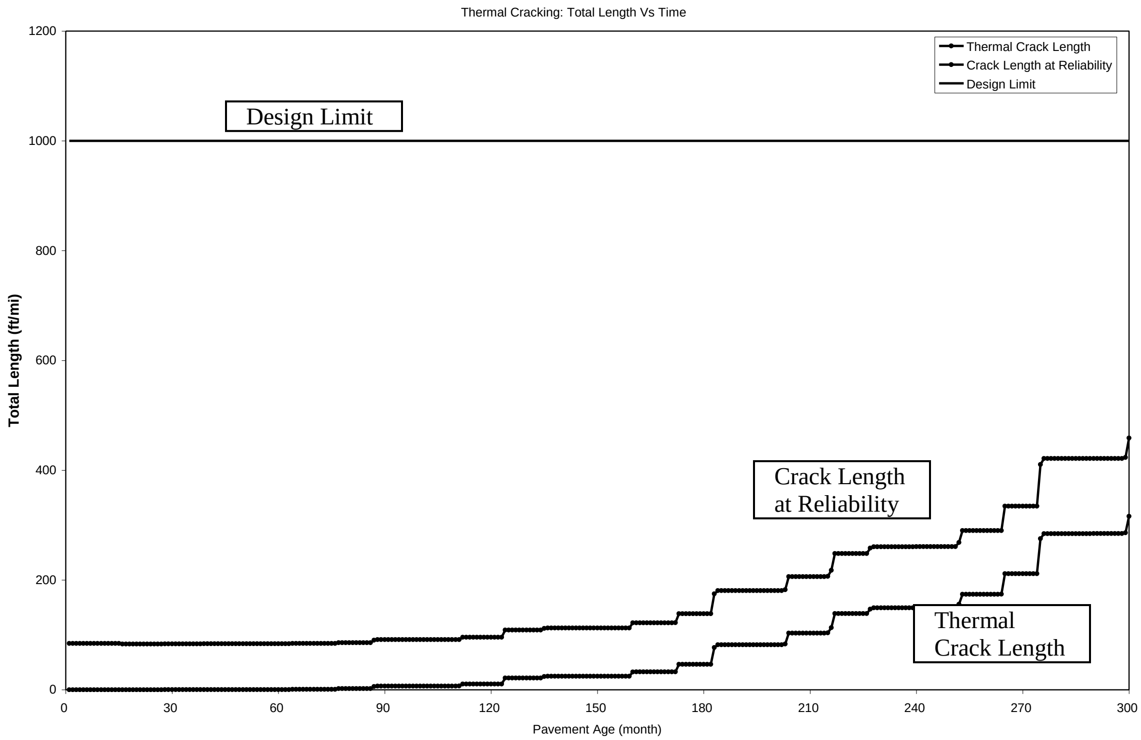


Figure H9. Transverse Cracking – Project 6, HAM 126 (645-94) – Excellent

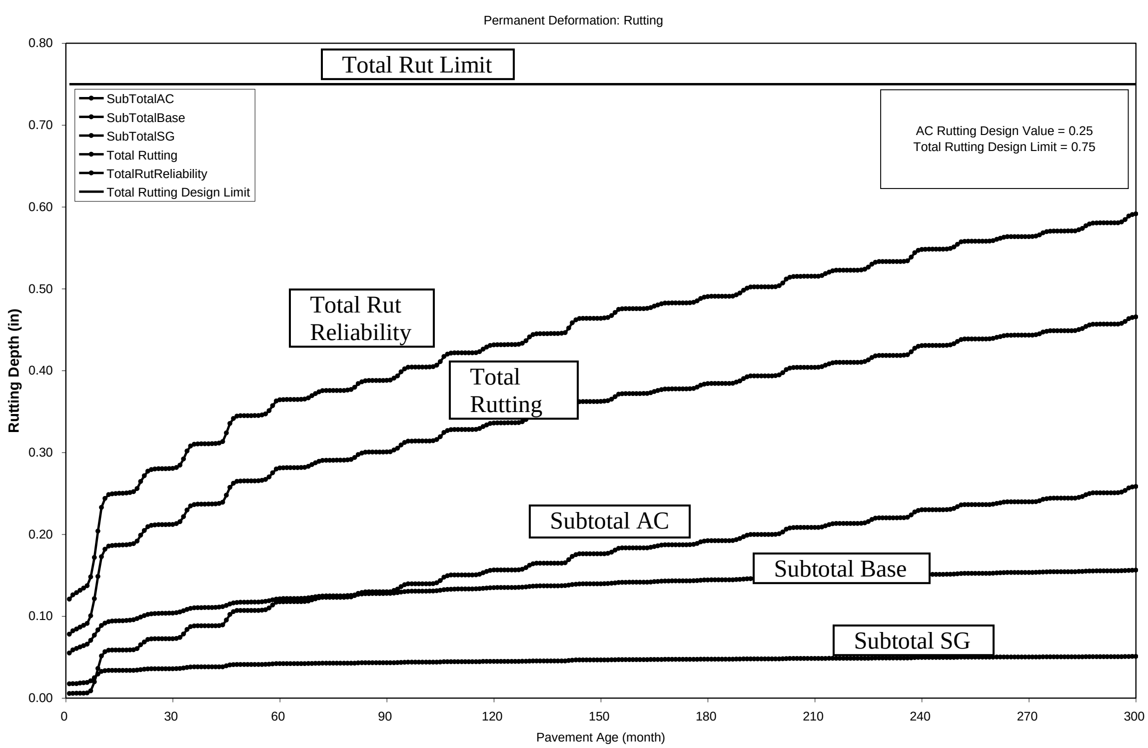


Figure H10. Permanent Deformation - Project 6, HAM 126 (645-94) – Average

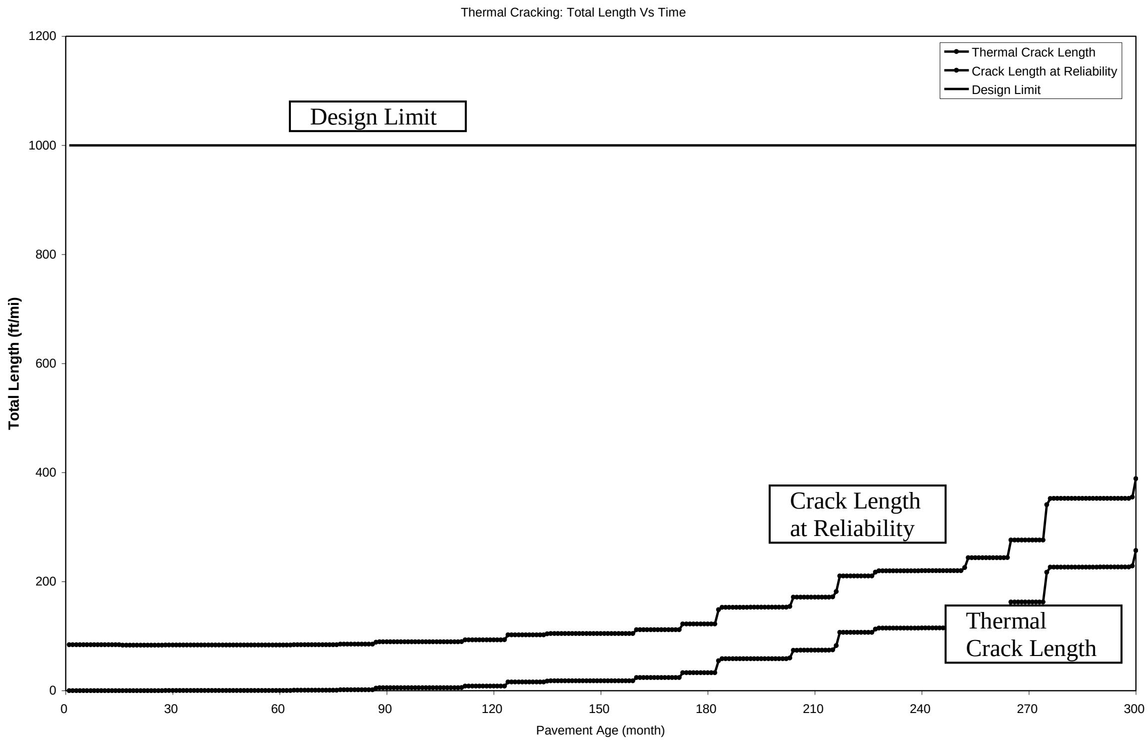


Figure H11. Transverse Cracking - Project 7, HAM 747 (347-85)

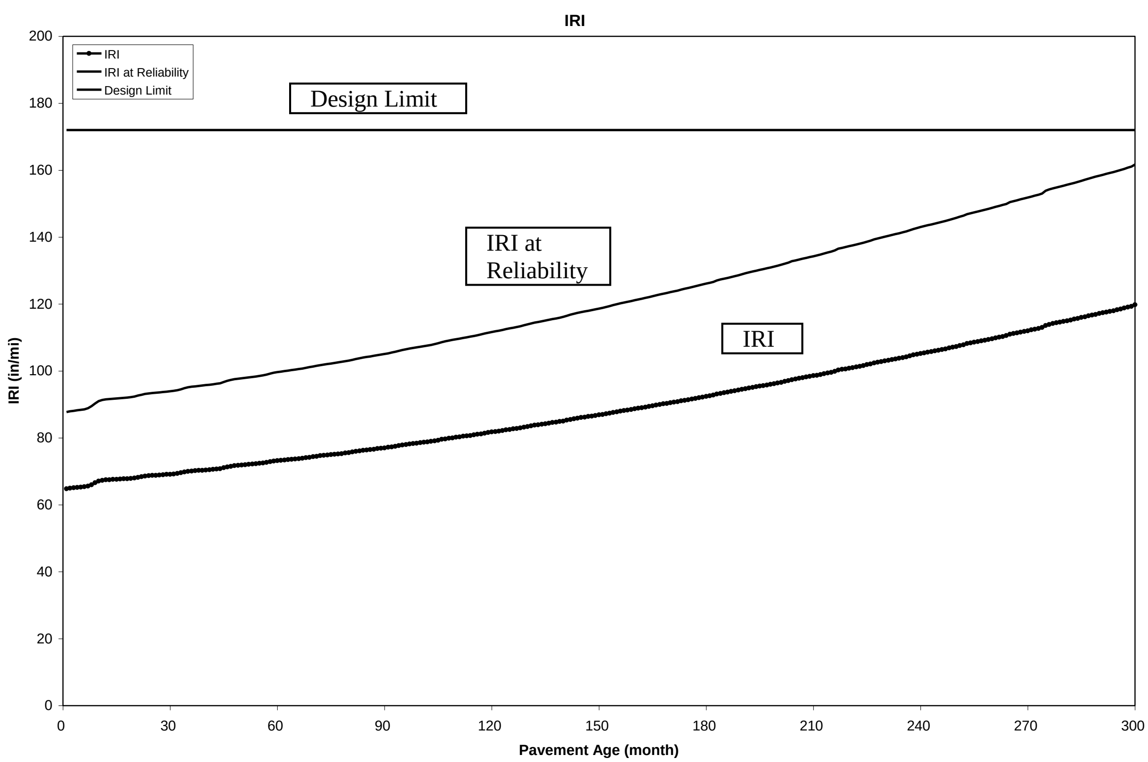


Figure H12. International Roughness Index - Project 7, HAM 747 (347-85)

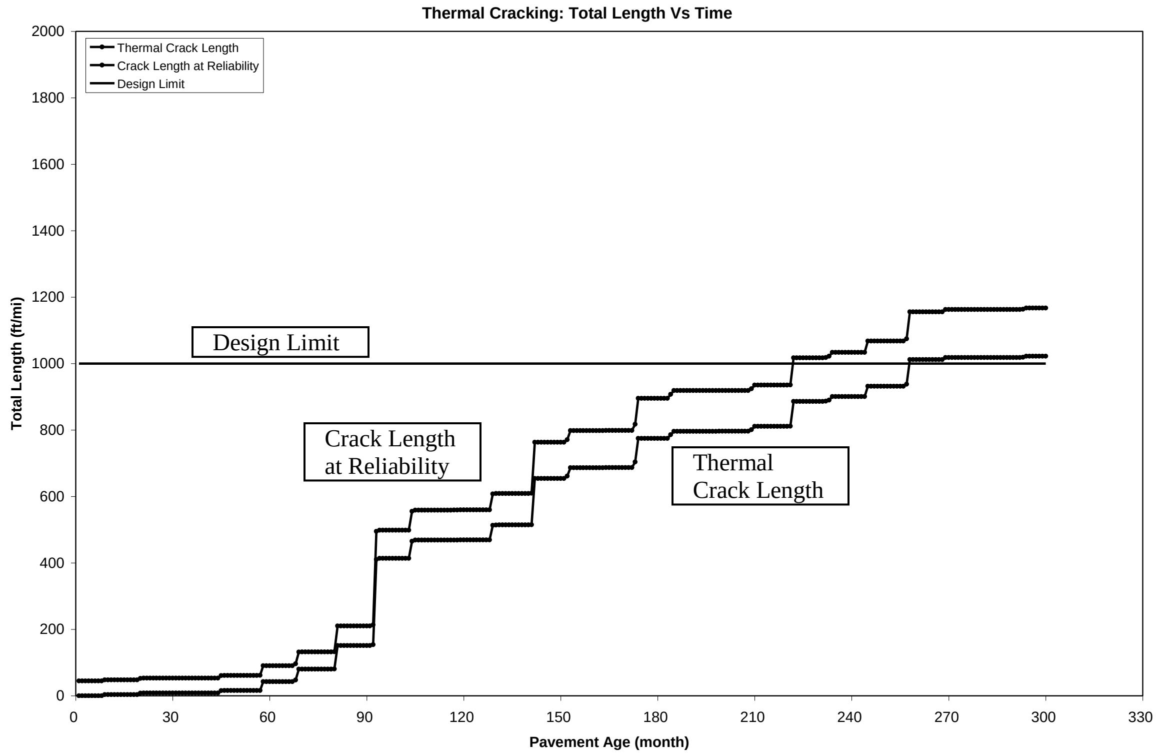


Figure H13. Transverse Cracking - Project 8, LAW 7 (17-85)

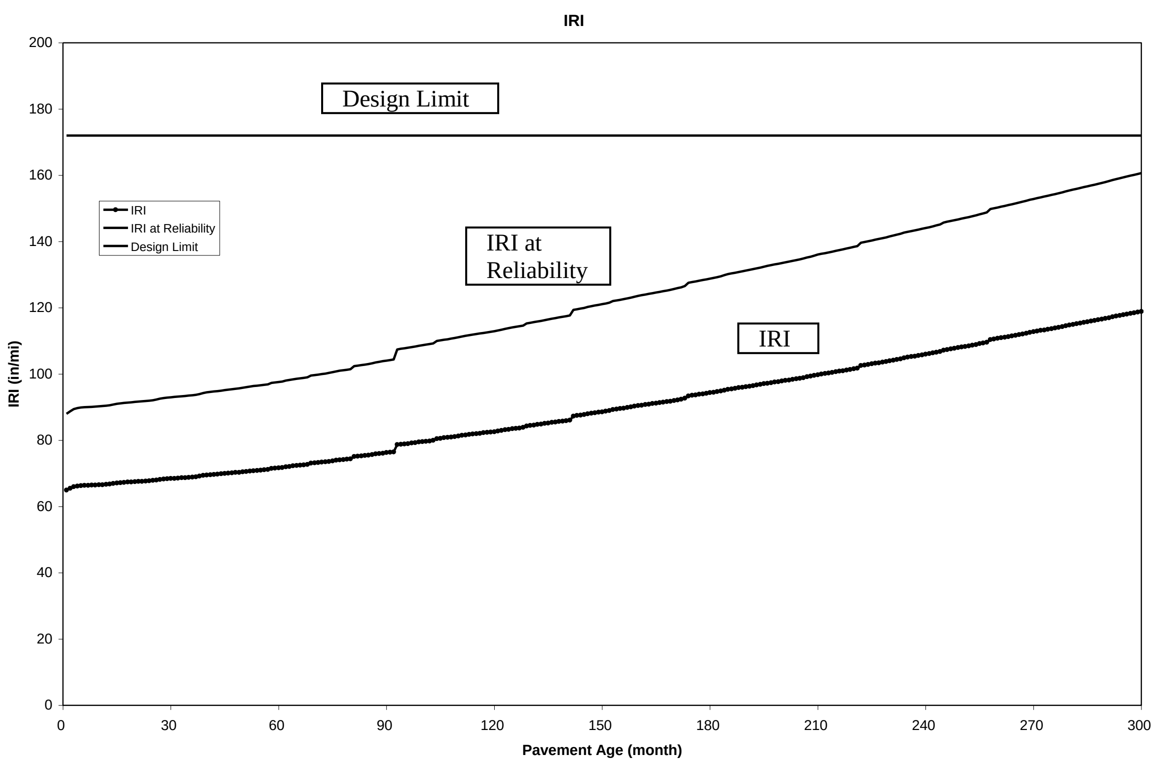


Figure H14. International Roughness Index - Project 8, LAW 7 (17-85)

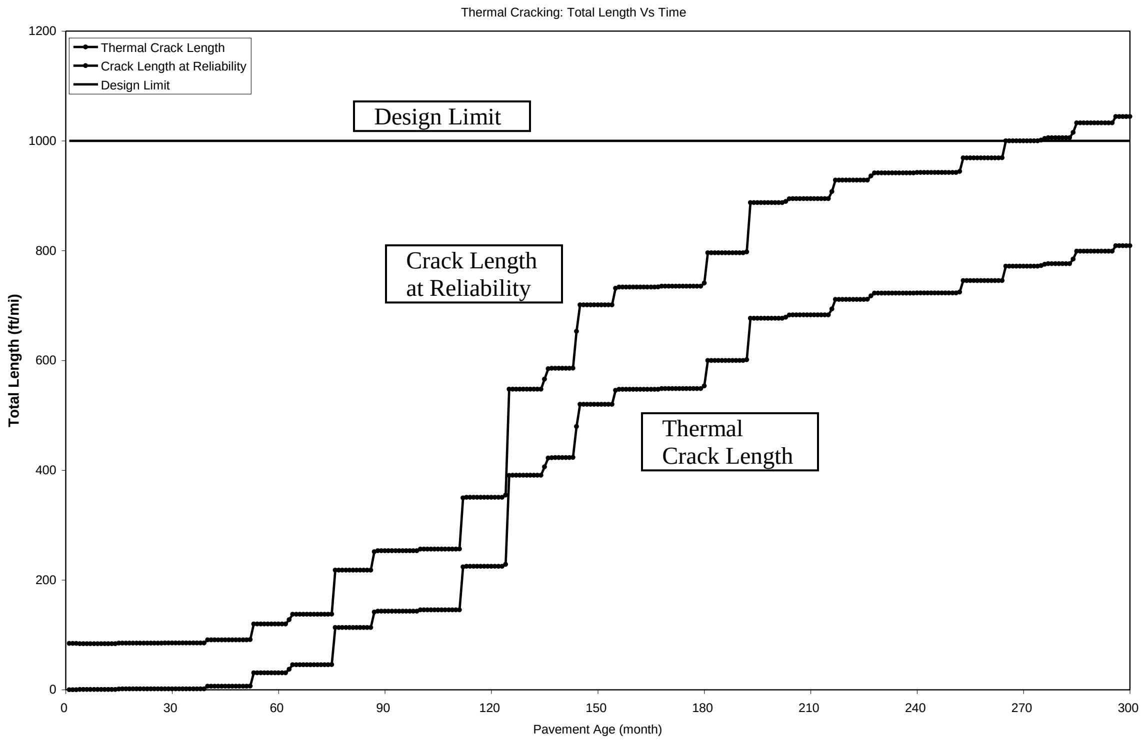


Figure H15. Transverse Cracking - Project 9, LIC 16 (6010-99)

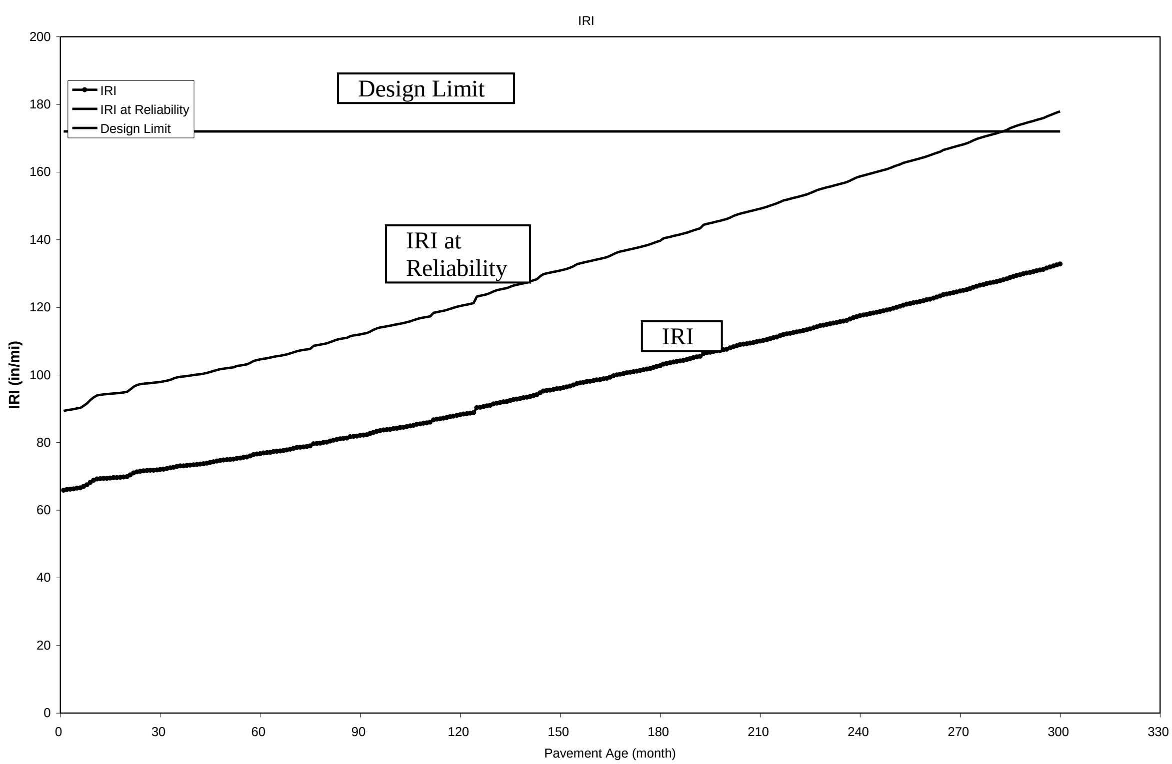


Figure H16. International Roughness Index - Project 9, LIC 16 (6010-99)

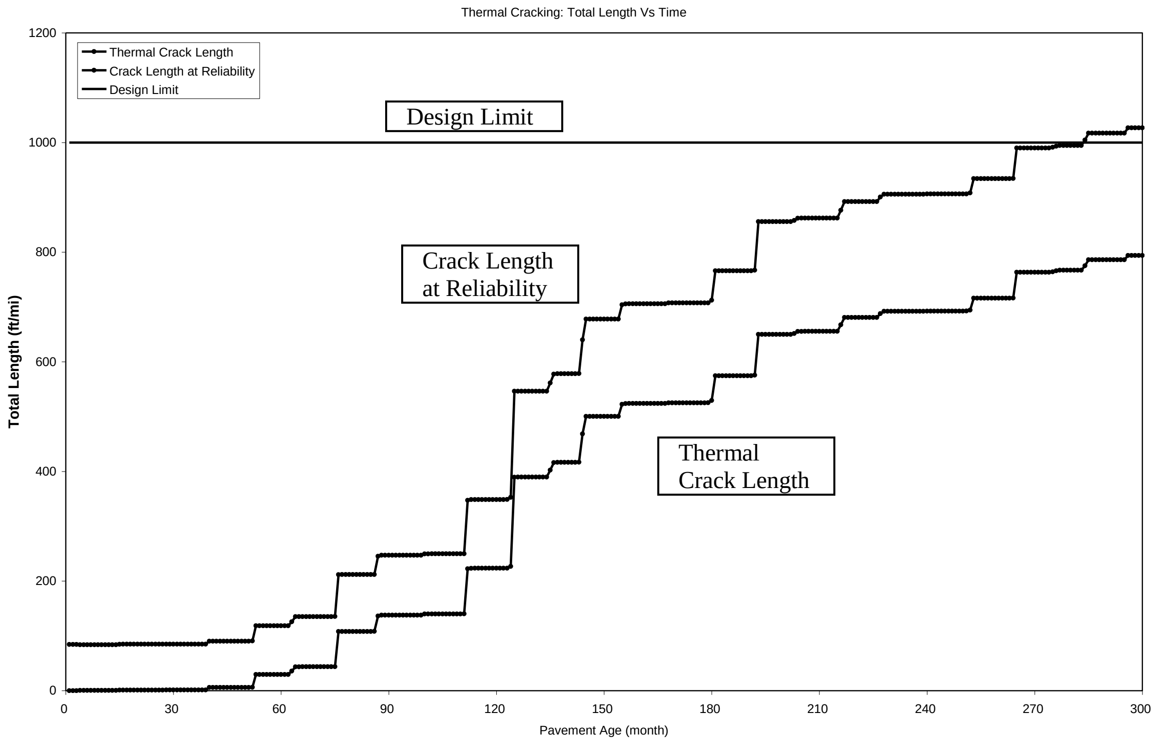


Figure H17. Transverse Cracking - Project 10, LUC 2 (141-99)

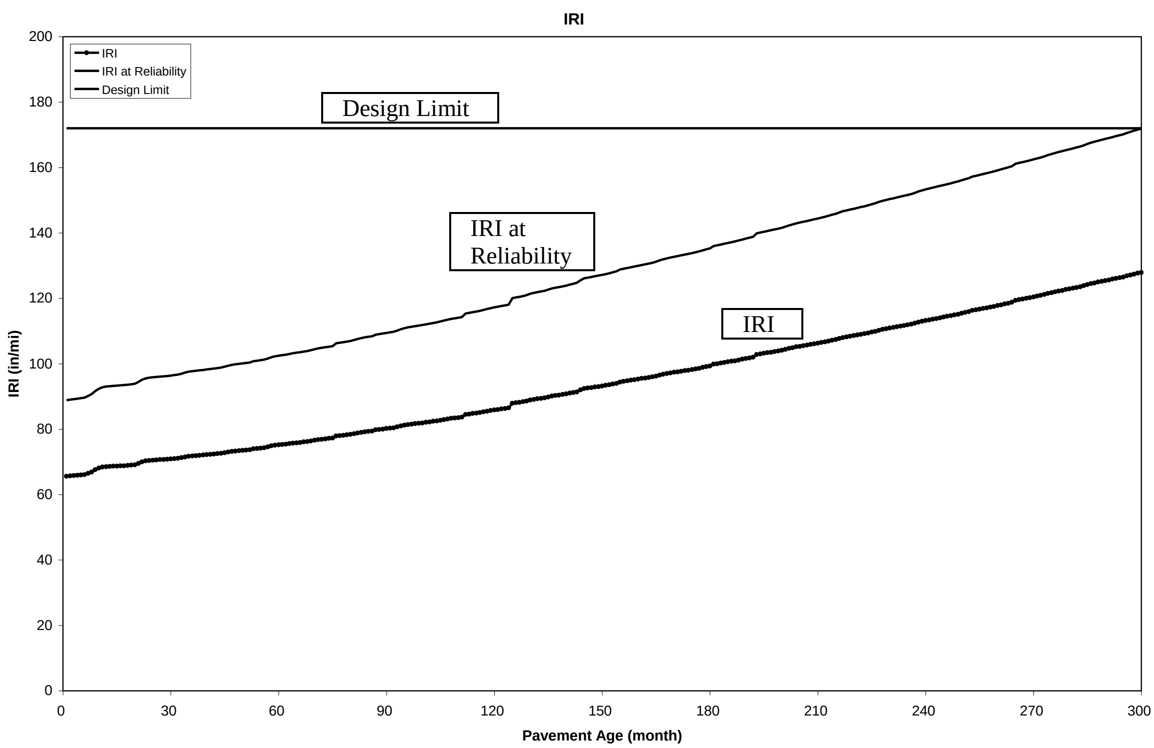


Figure H18. International Roughness Index - Project 10, LUC 2 (141-99)

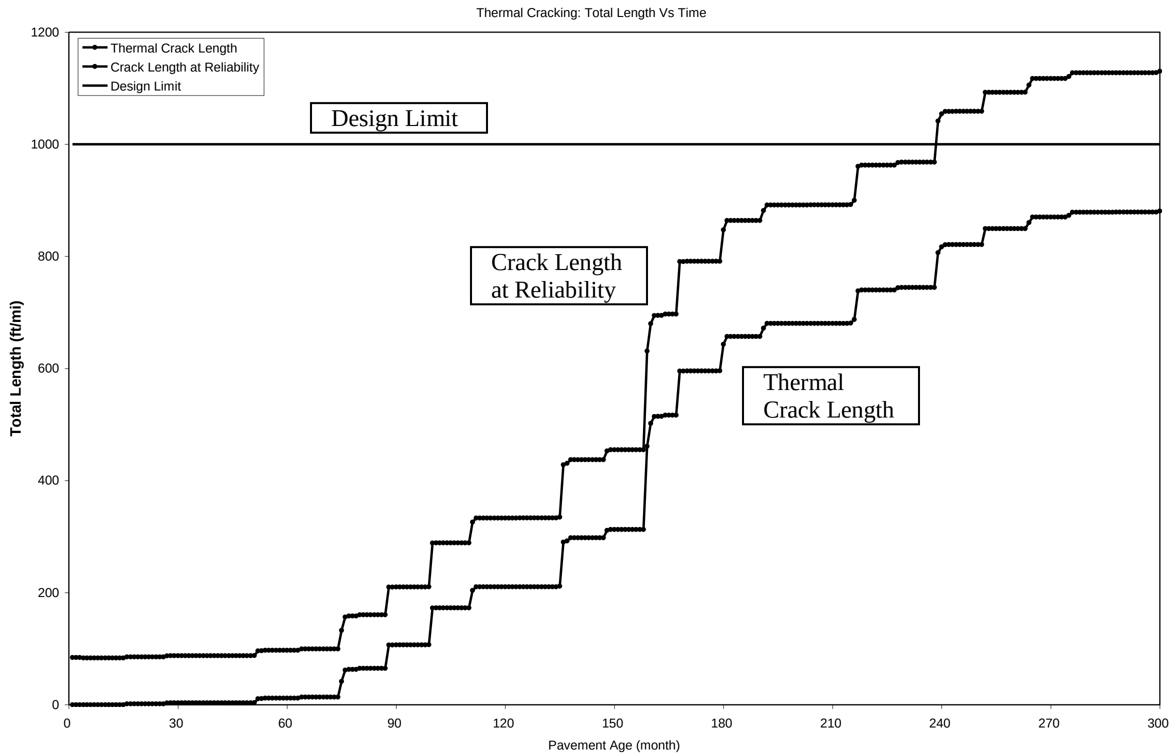


Figure H19. Transverse Cracking - Project 11, LUC 25 (665-97)

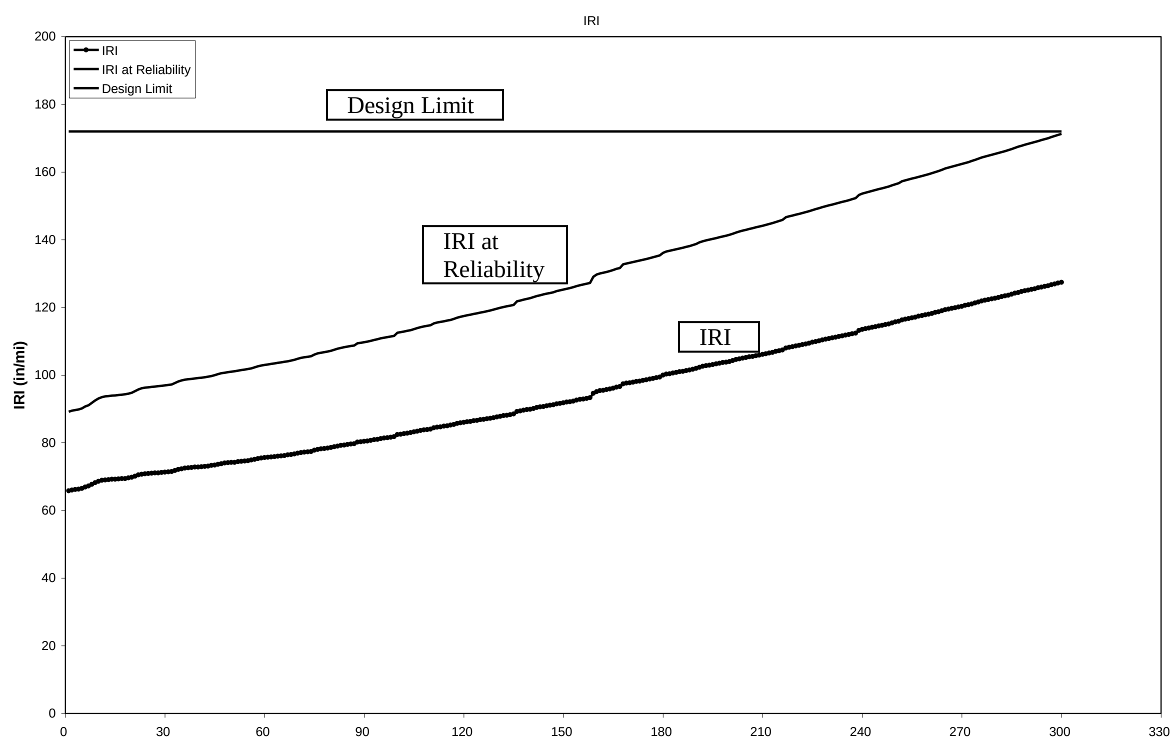


Figure H20. International Roughness Index - Project 11, LUC 25 (665-97)

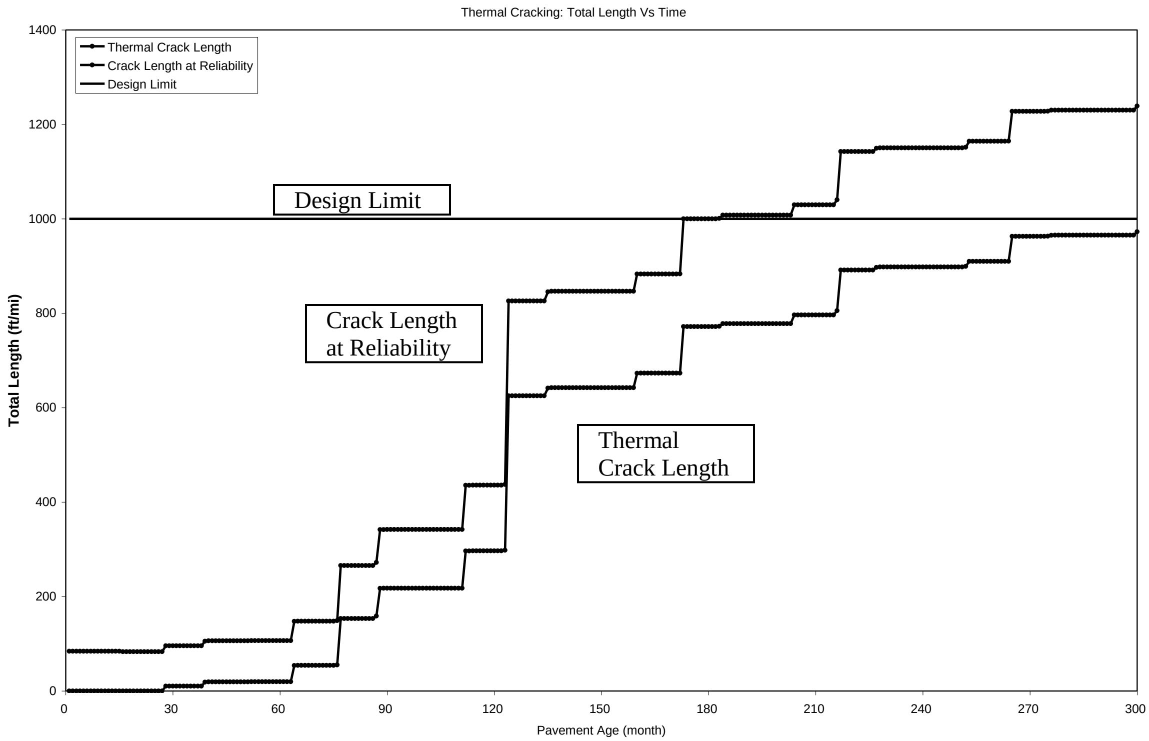


Figure H21. Transverse Cracking - Project 12, PIK 32 (443-94)

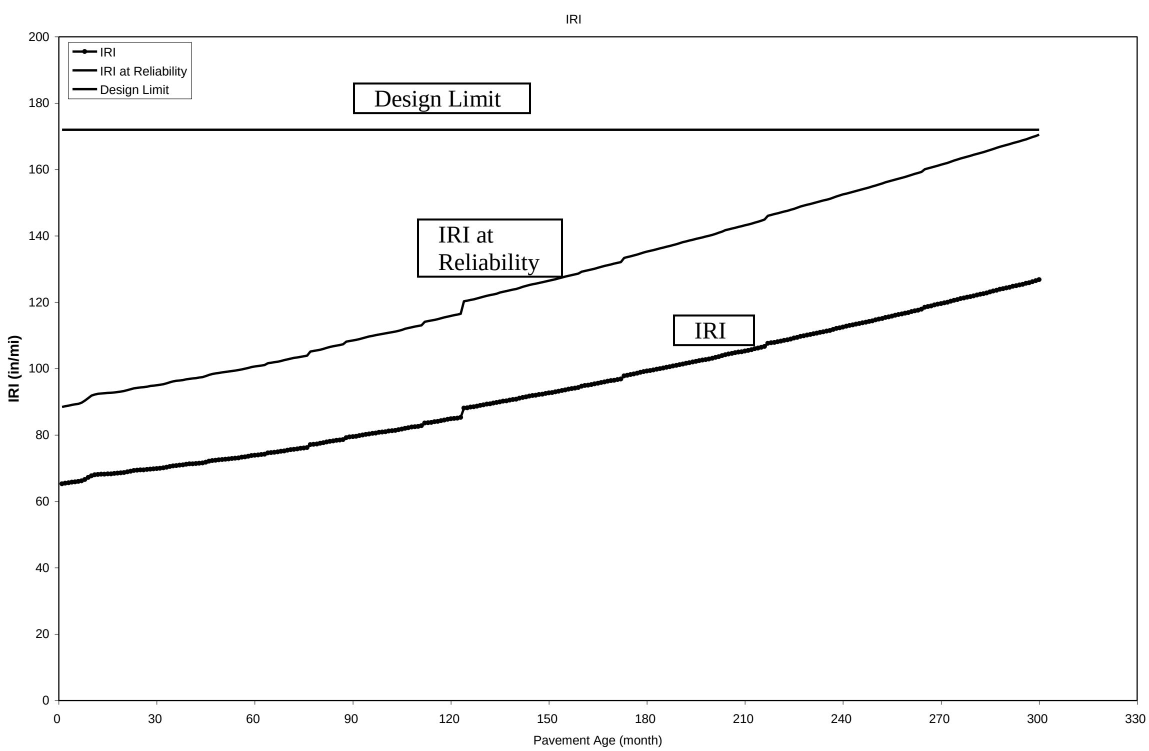


Figure H22. International Roughness Index - Project 12, PIK 32 (443-94)

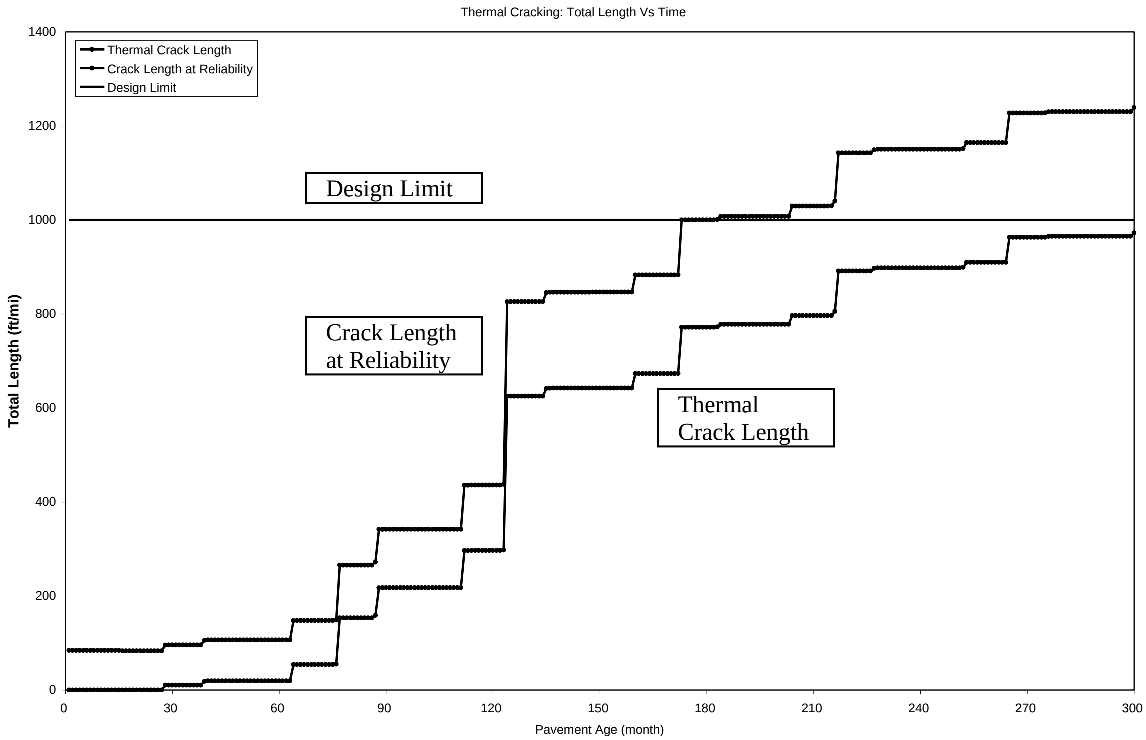


Figure H23. Transverse Cracking - Project 13, PIK 32 (552-95)

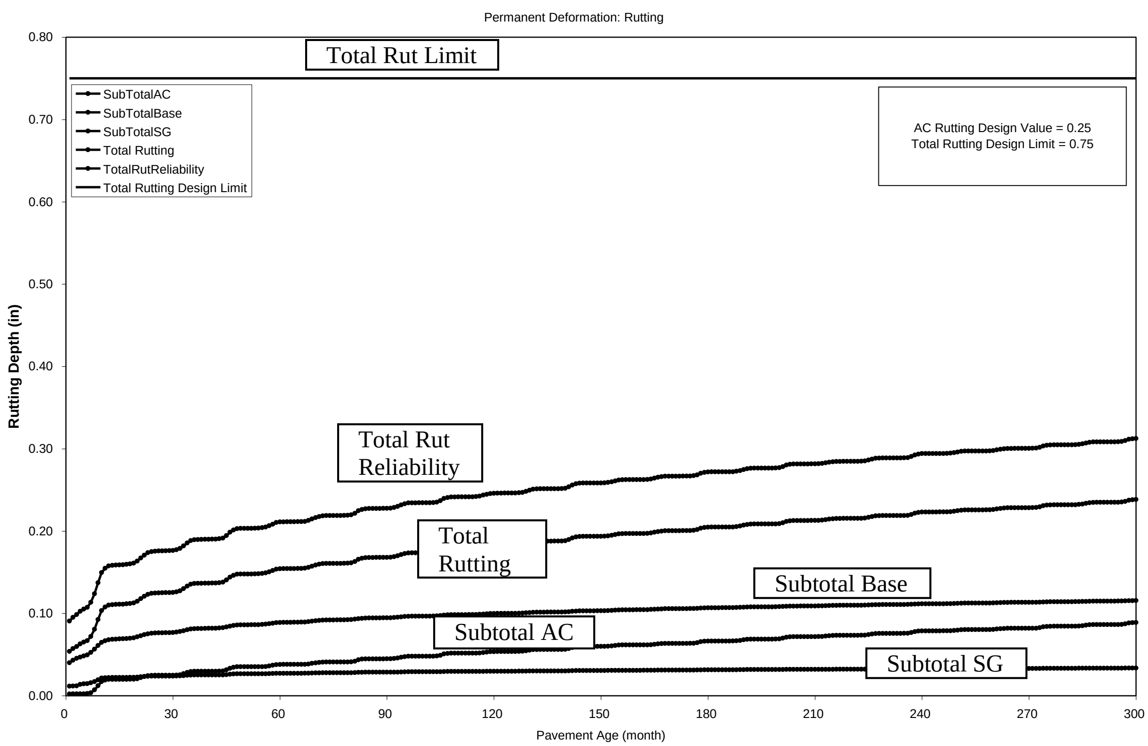


Figure H24. Permanent Deformation - Project 13, PIK 32 (552-95)

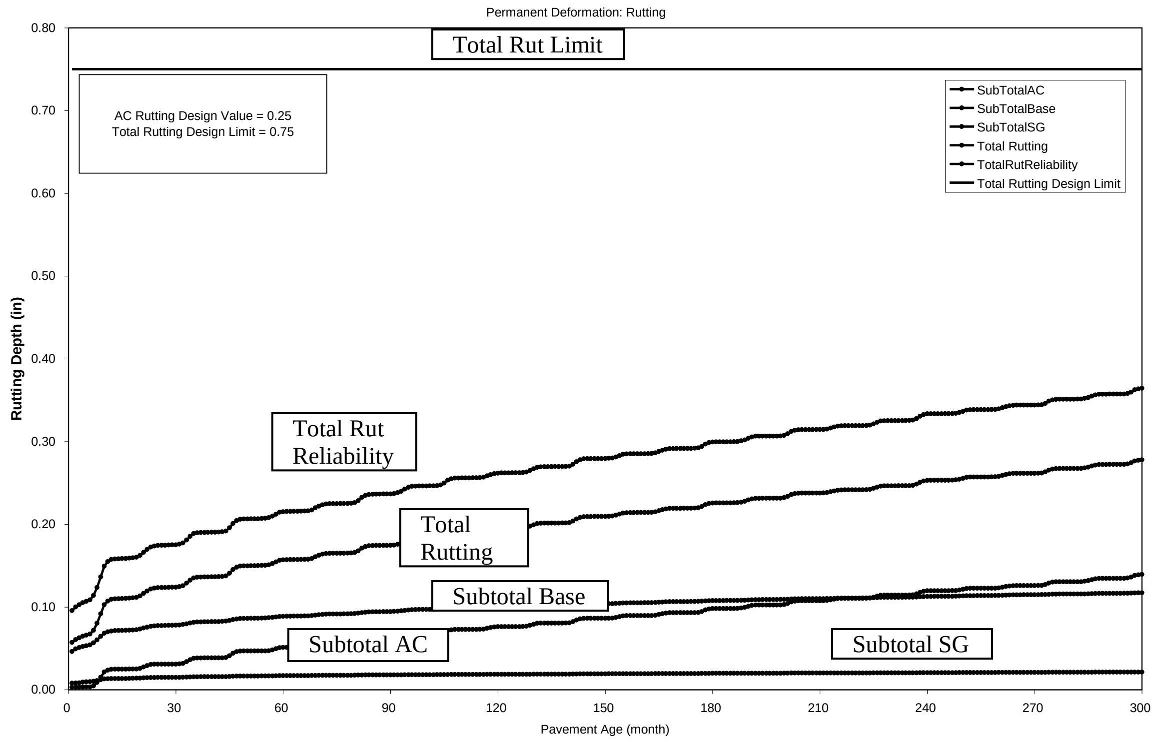


Figure H25. Permanent Deformation - Project 14, ROS 35 (298-96)

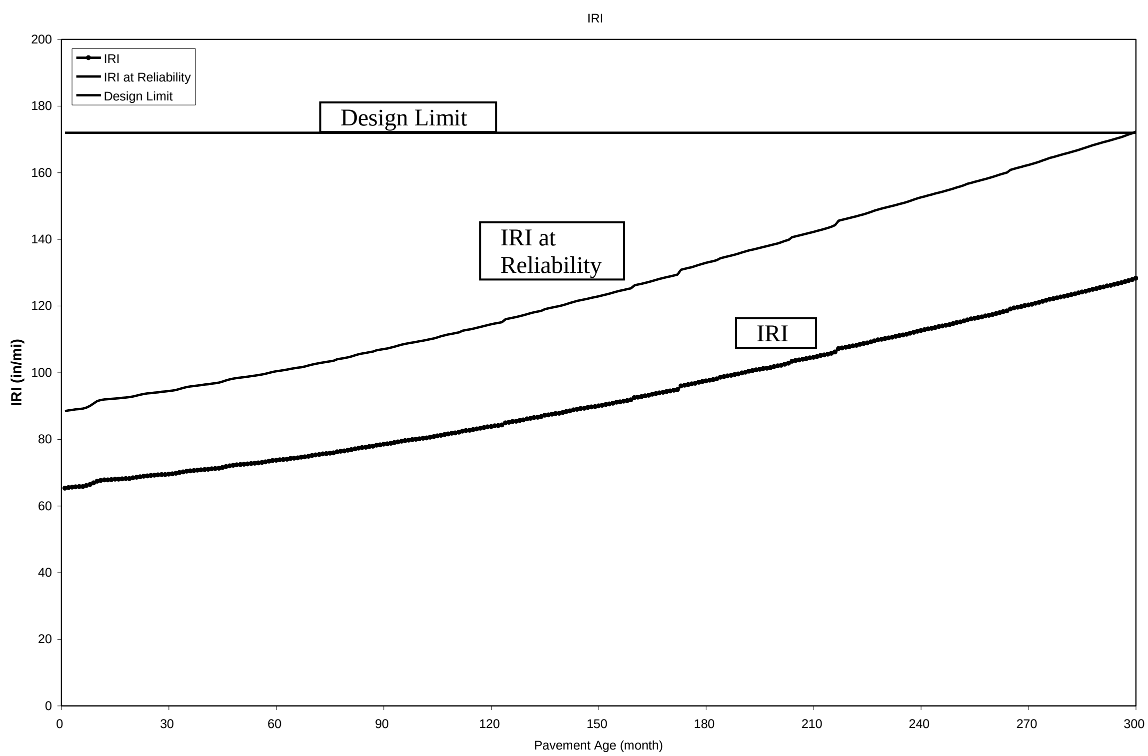


Figure H26. International Roughness Index - Project 14, ROS 35 (298-96)

APPENDIX I

MEPDG Modeling for Rigid Pavements

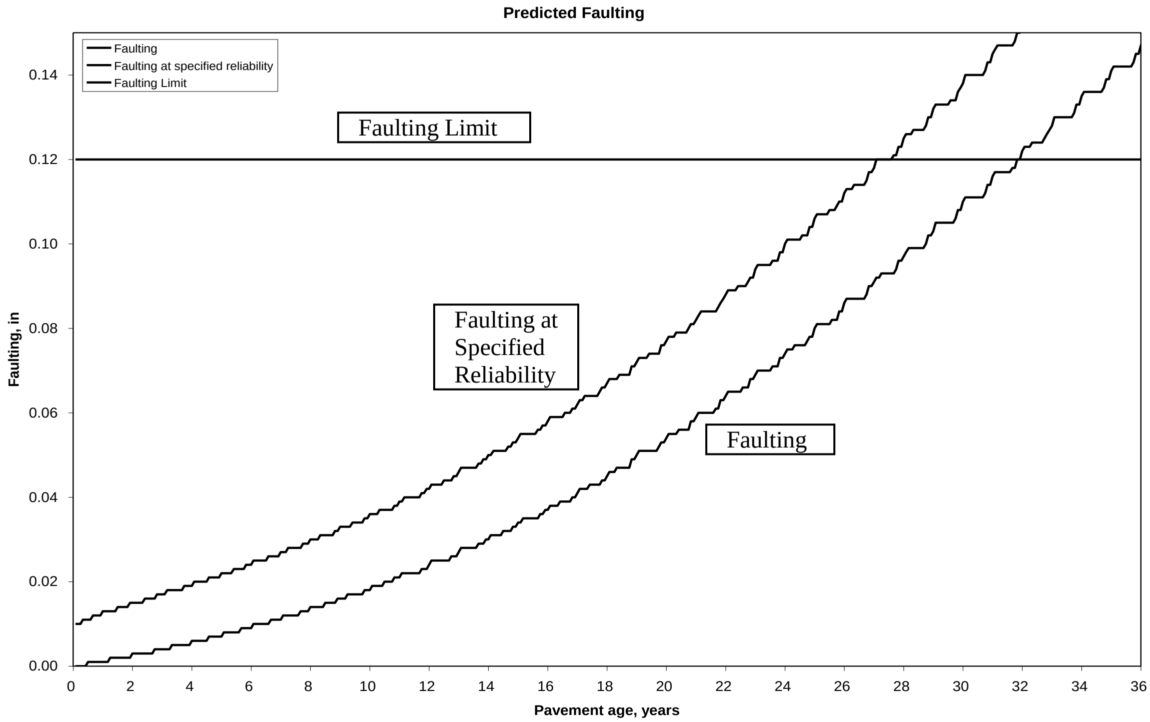


Figure I1. Predicted Faulting – Project 15, ATH 50 (700-86)

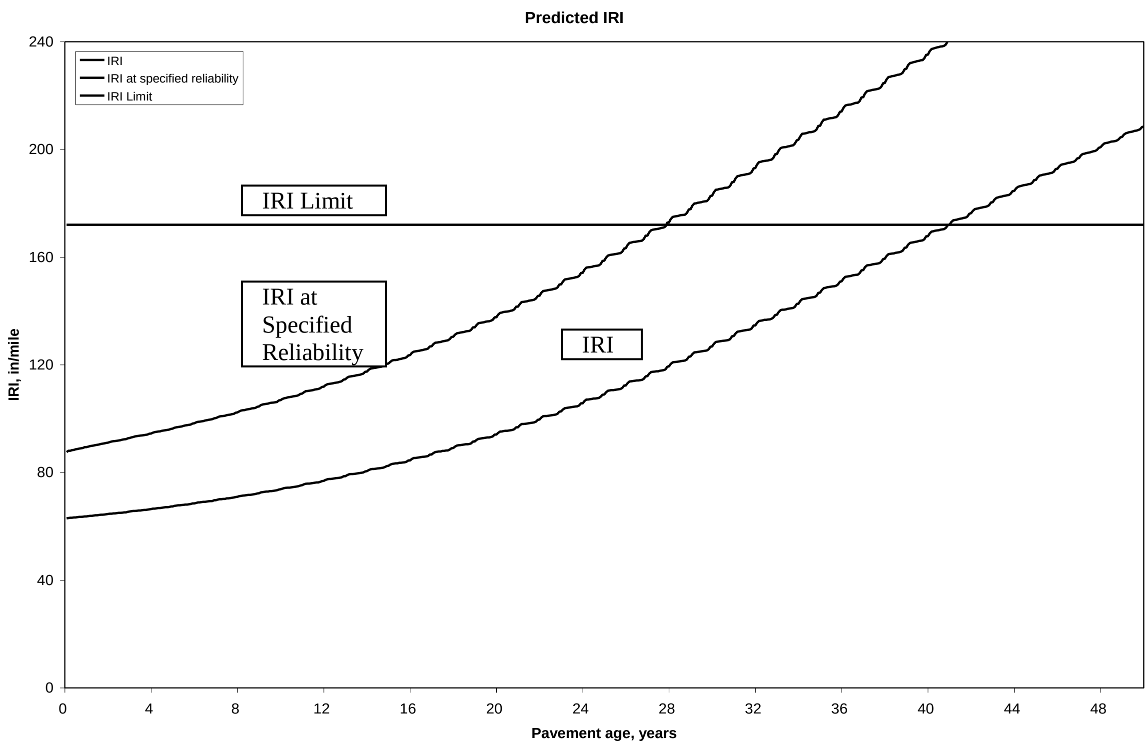


Figure I2. International Roughness Index – Project 15 (700-86)

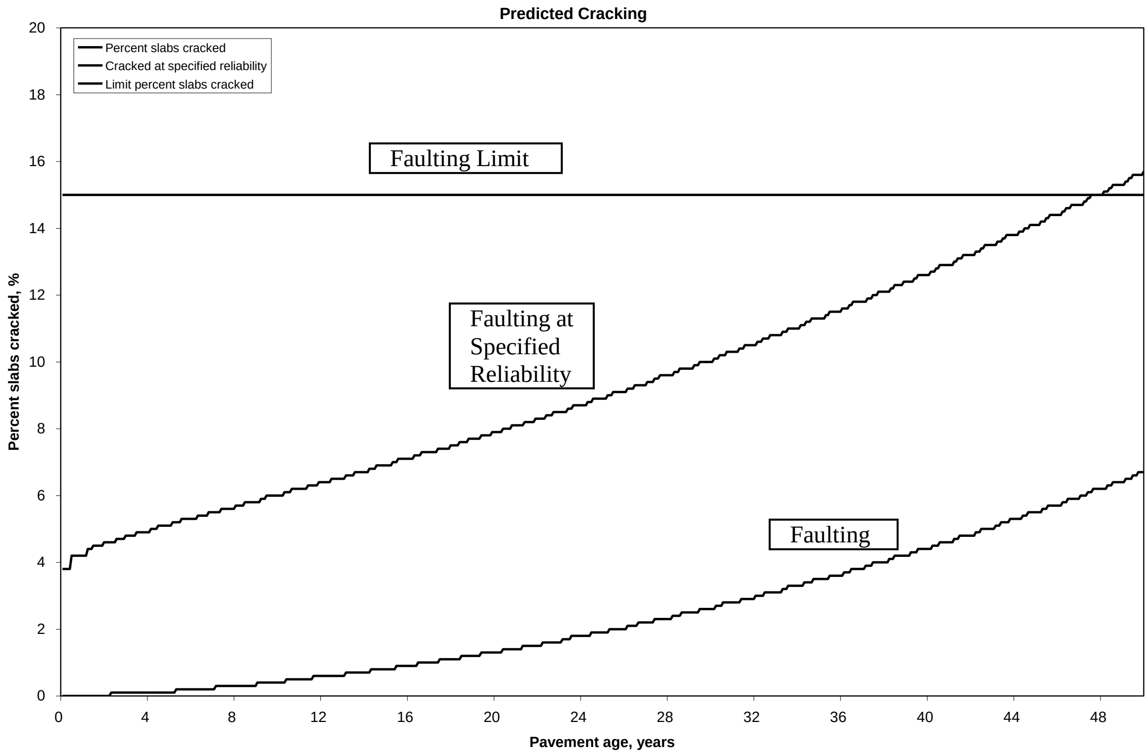


Figure I3. Predicted Faulting – Project 16, ATH 682 (625-76)

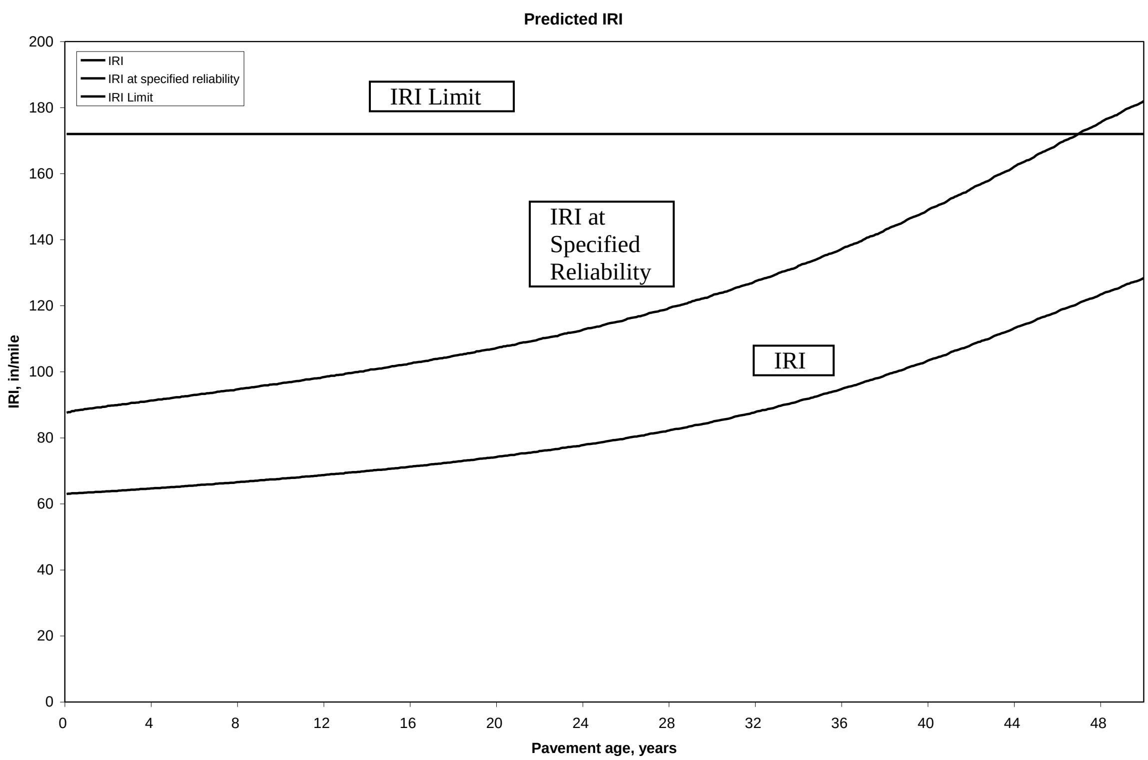


Figure I4. International Roughness Index – Project 16, ATH 682 (625-76)

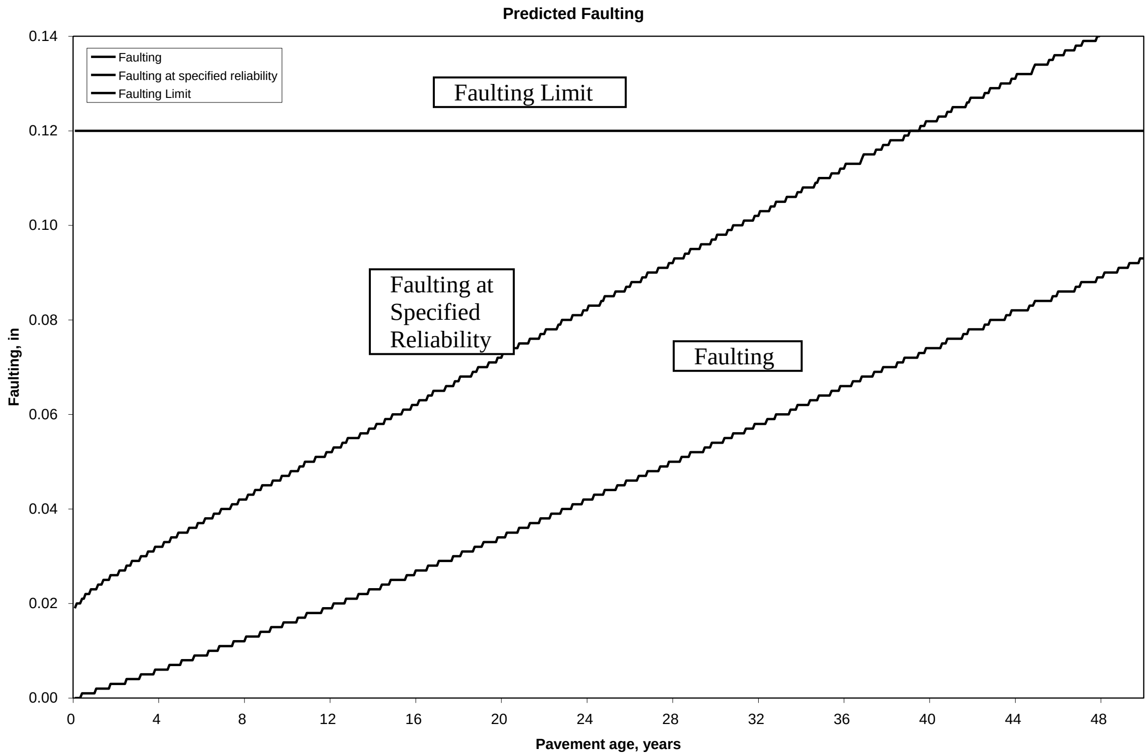


Figure I5. Predicted Faulting – Project 17, CUY 82 (438-94)

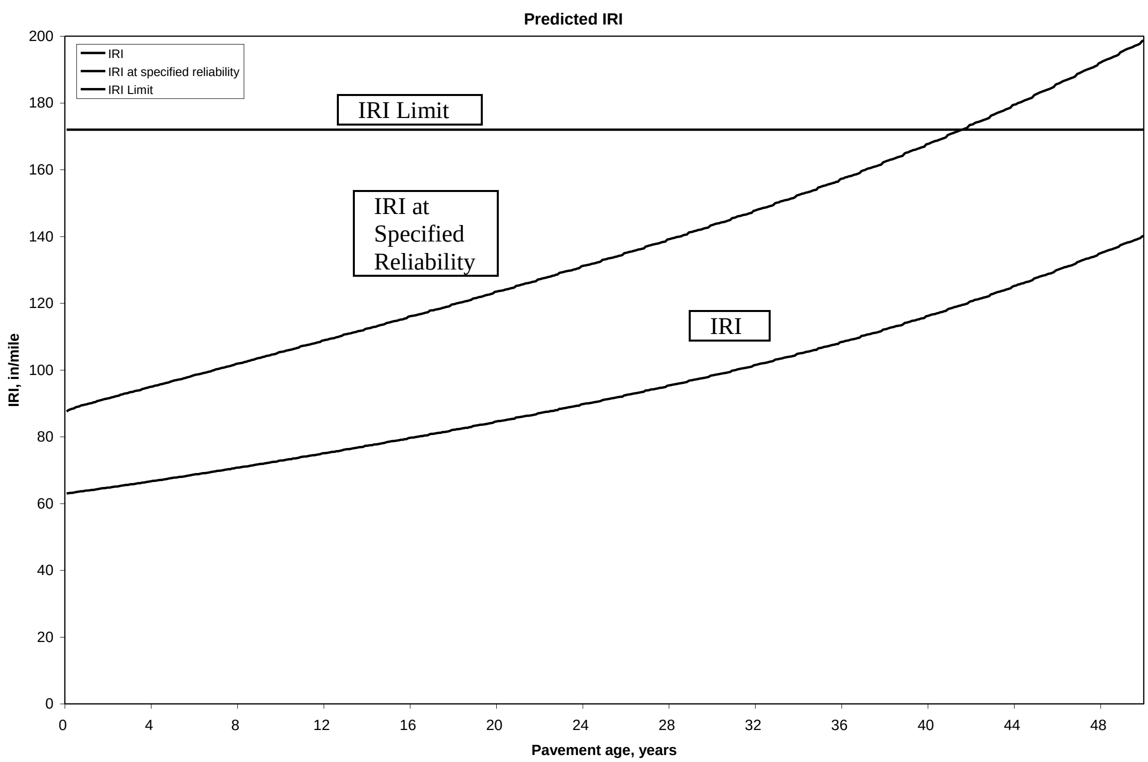


Figure I6. International Roughness Index – Project 17, CUY 82 (438-94)

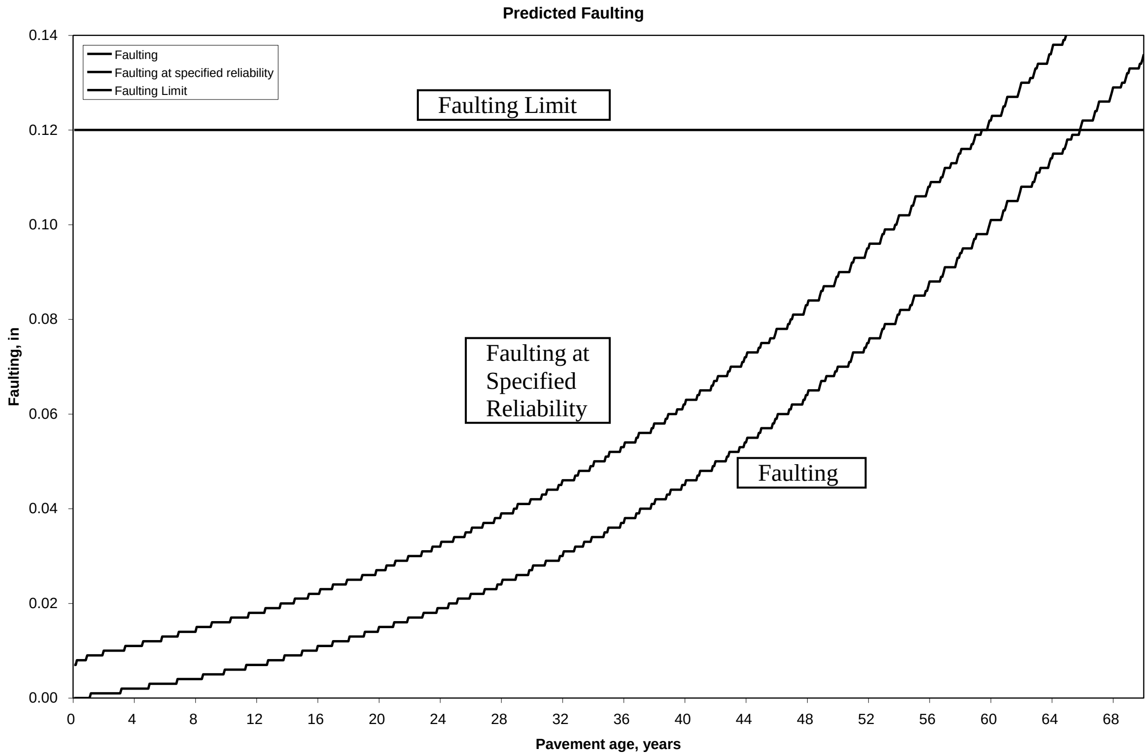


Figure I7. Predicted Faulting – Project 18, GAL 7 (352-46)

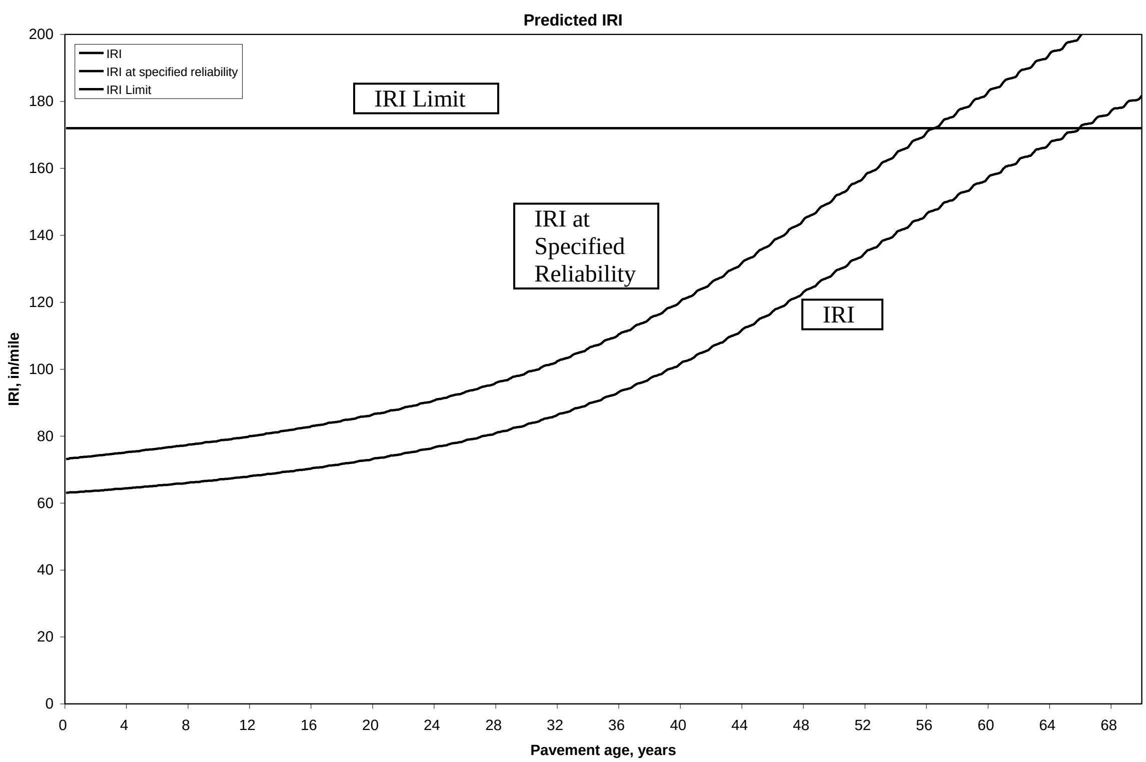


Figure I8. International Roughness Index – Project 18, GAL 7 (352-46)

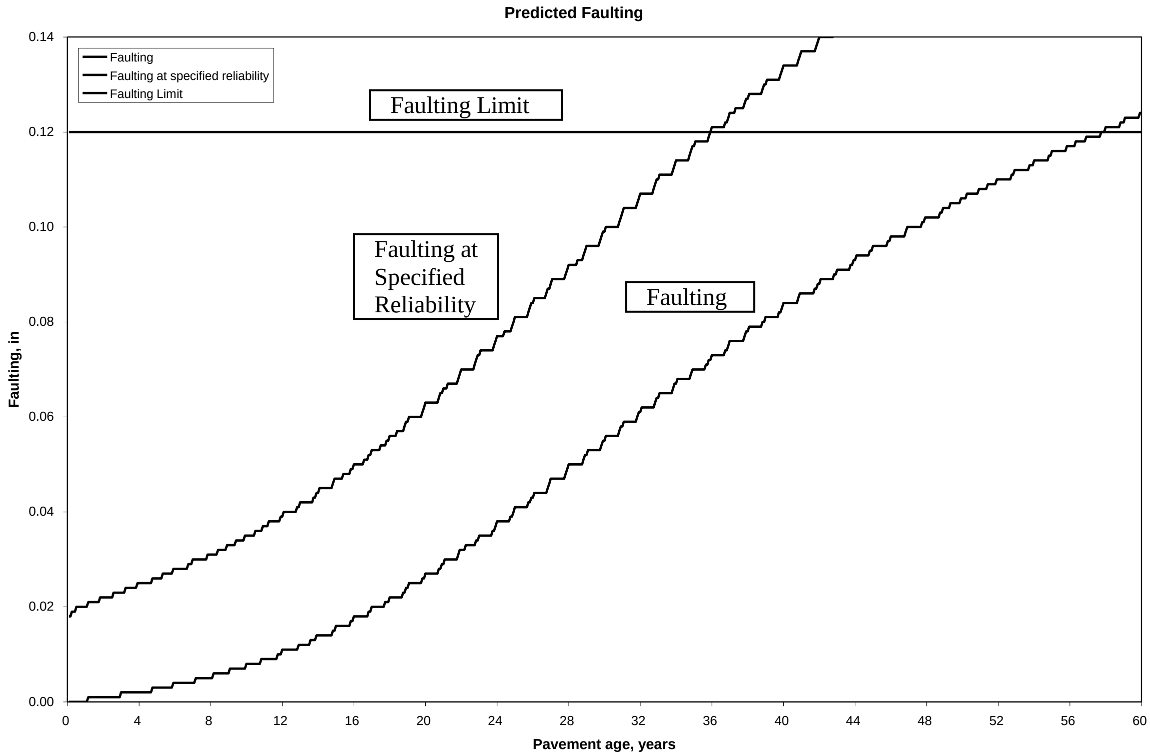


Figure I9. Predicted Faulting – Project 19, HAM 126 (997-90)

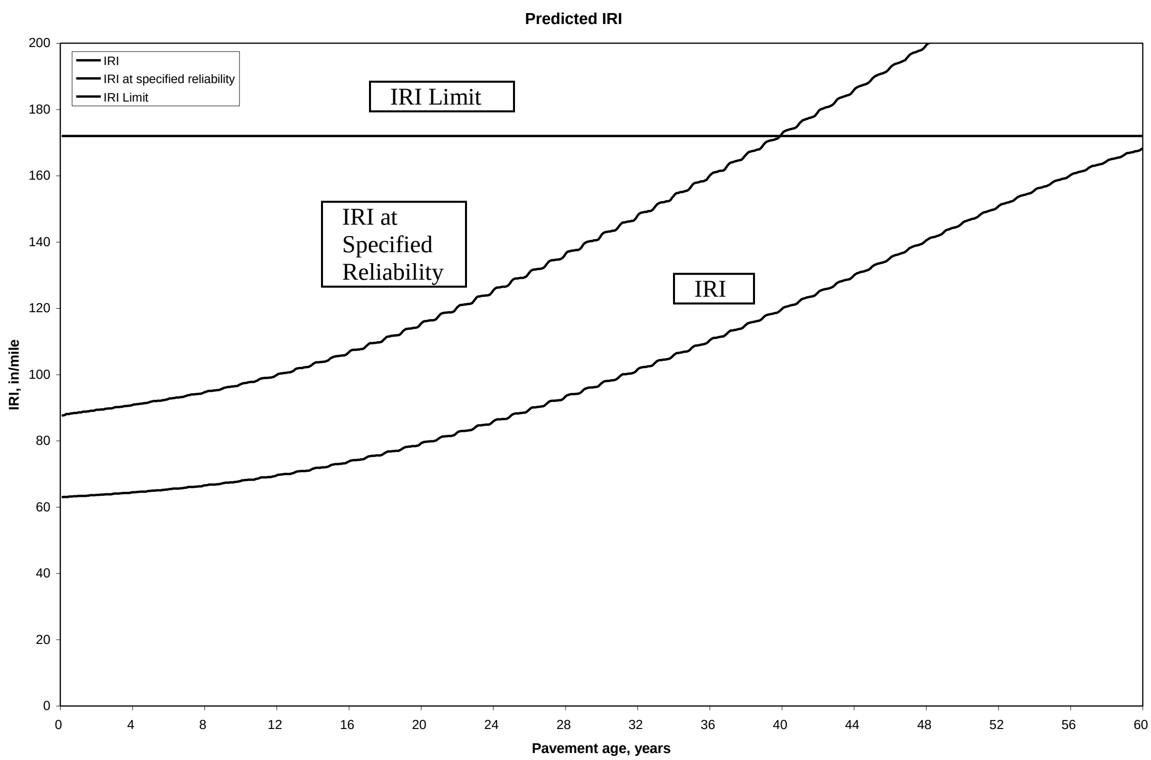


Figure I10. International Roughness Index – Project 19, HAM 126 (997-90)

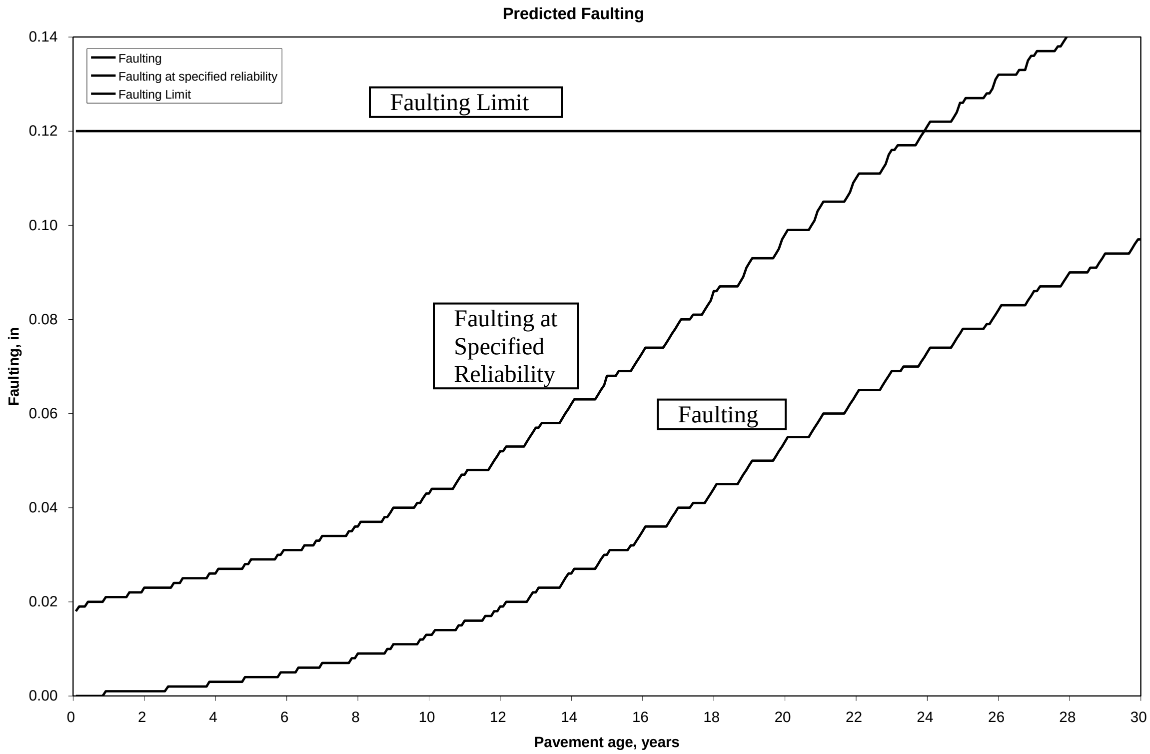


Figure I11. Predicted Faulting – Project 20, JEF 7 (8008-90)

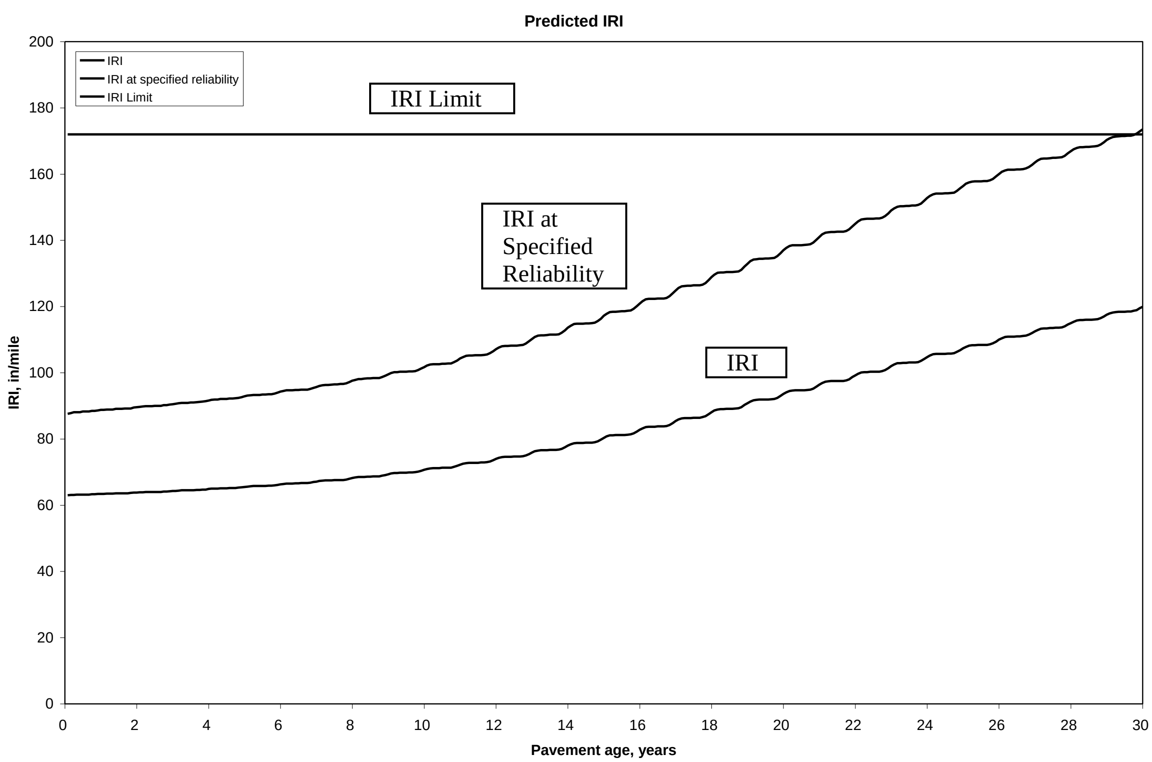


Figure I12. International Roughness Index – Project 20, JEF 7 (8008-90)

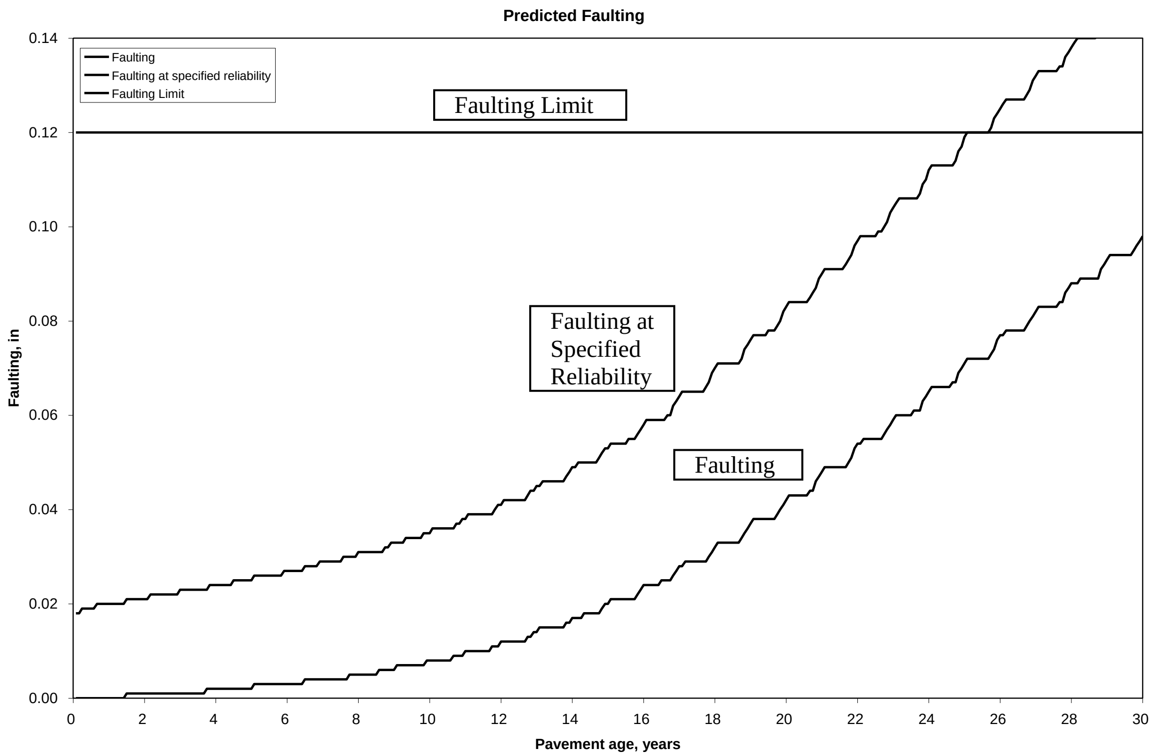


Figure I13. Predicted Faulting – Project 21, JEF 22 (8008-90)

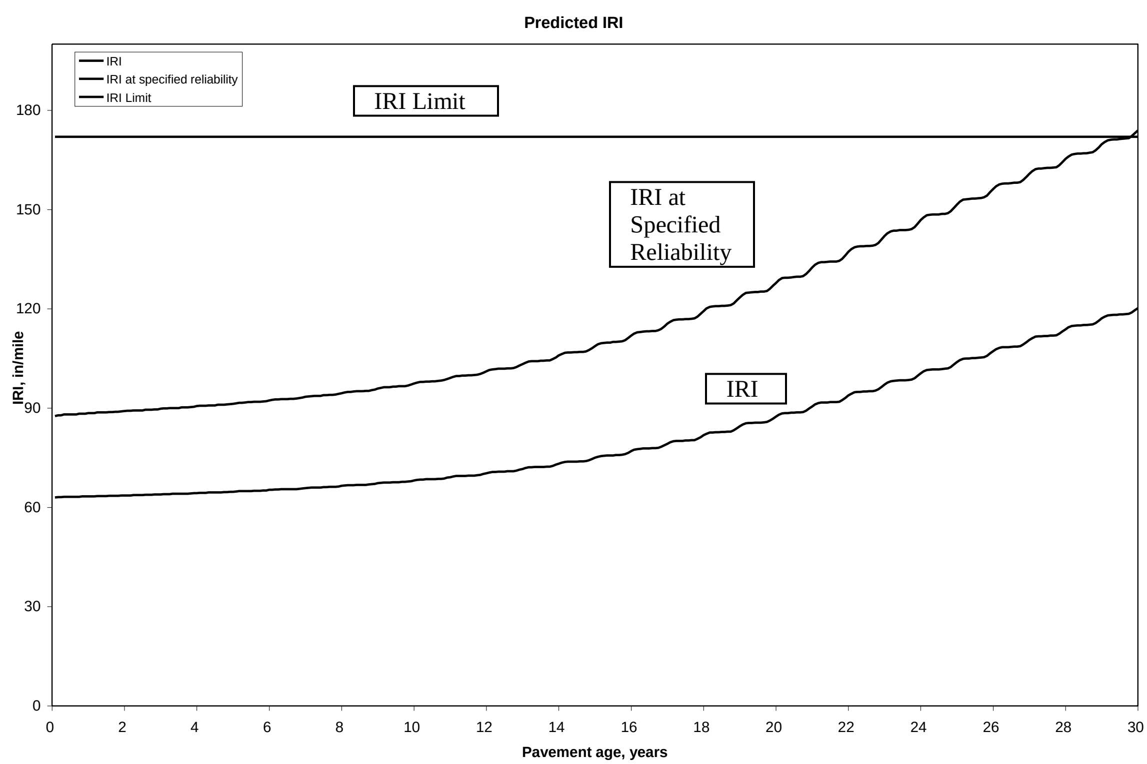


Figure I14. International Roughness Index – Project 21, JEF 22 (8008-90)

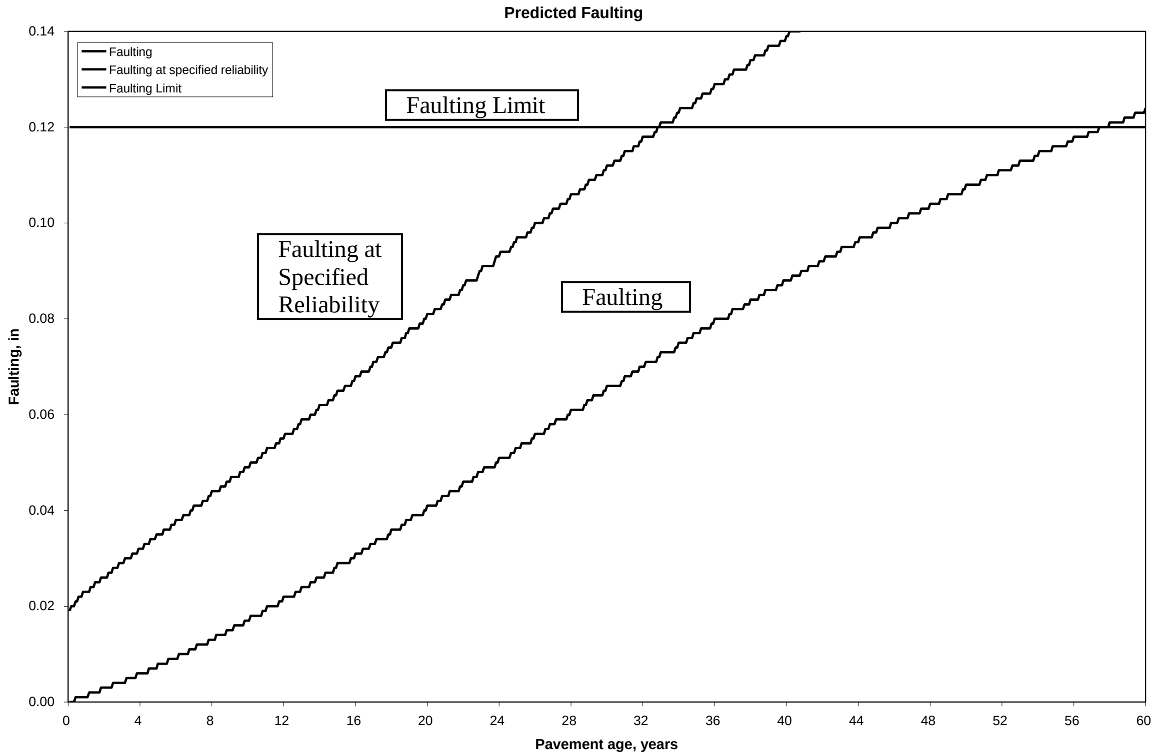


Figure I15. Predicted Faulting – Project 22, LOG 33 (845-94)

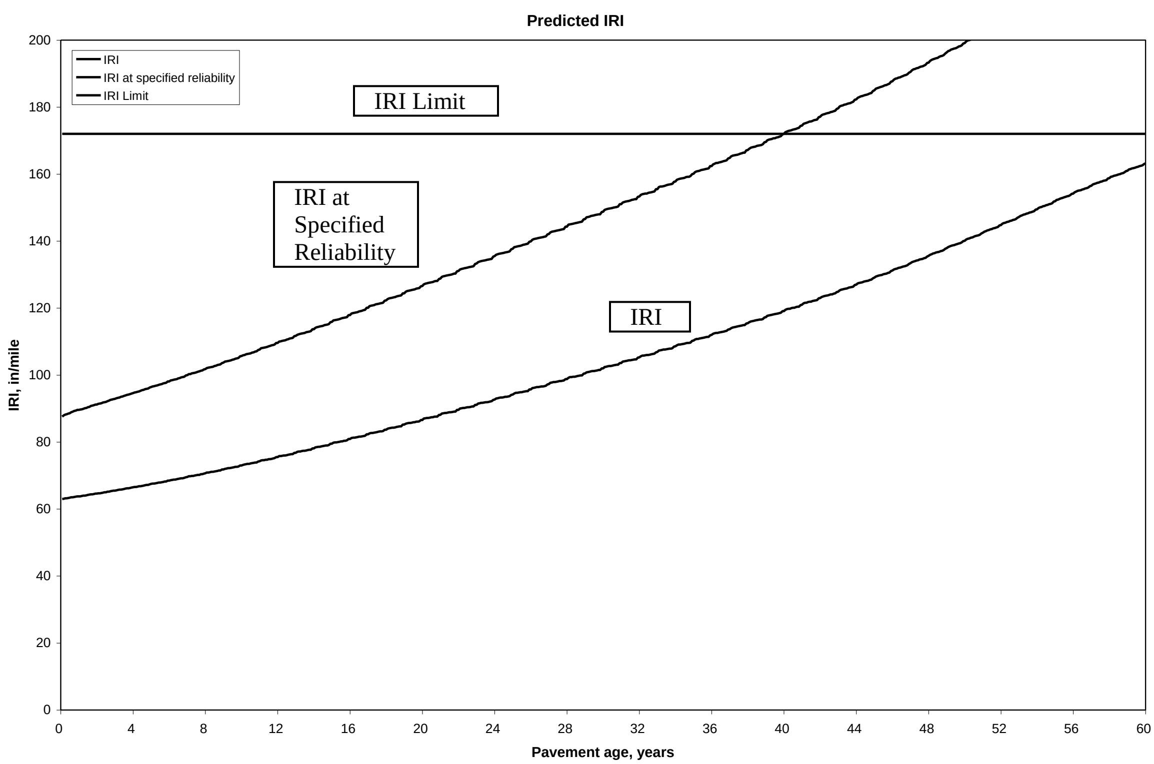


Figure I16. International Roughness Index – Project 22, LOG 33 (845-94)

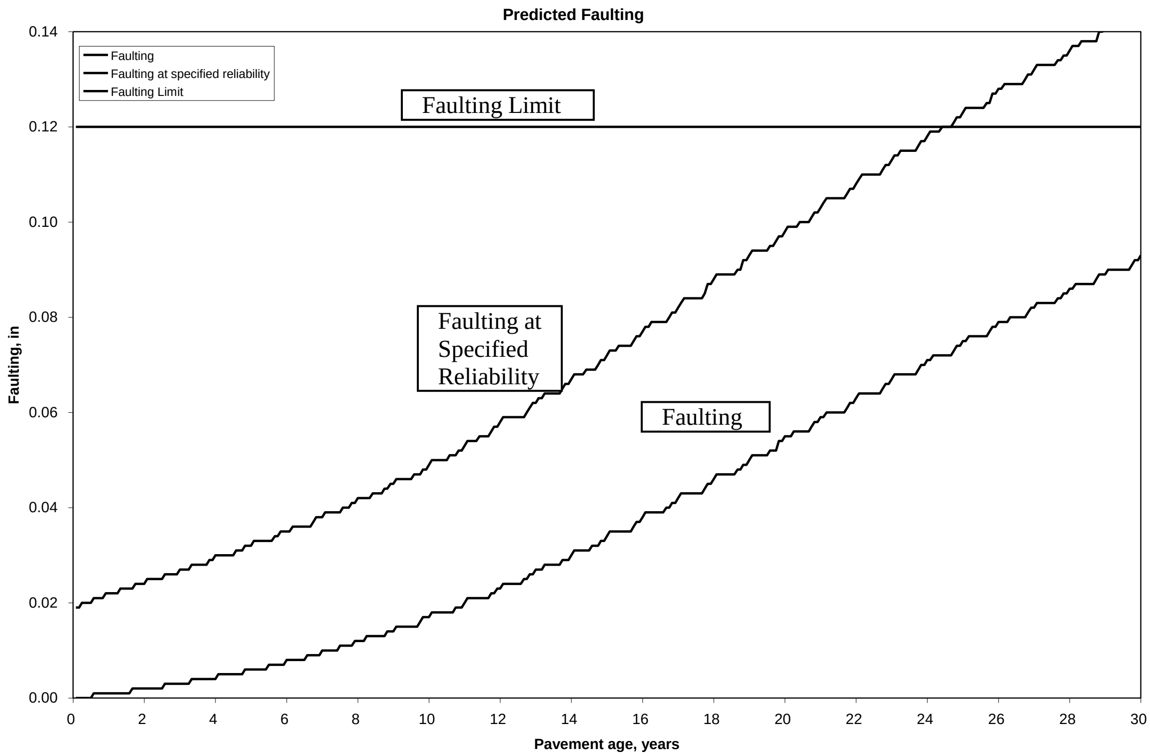


Figure I17. Predicted Faulting – Project 23, MOT 35 (343-88)

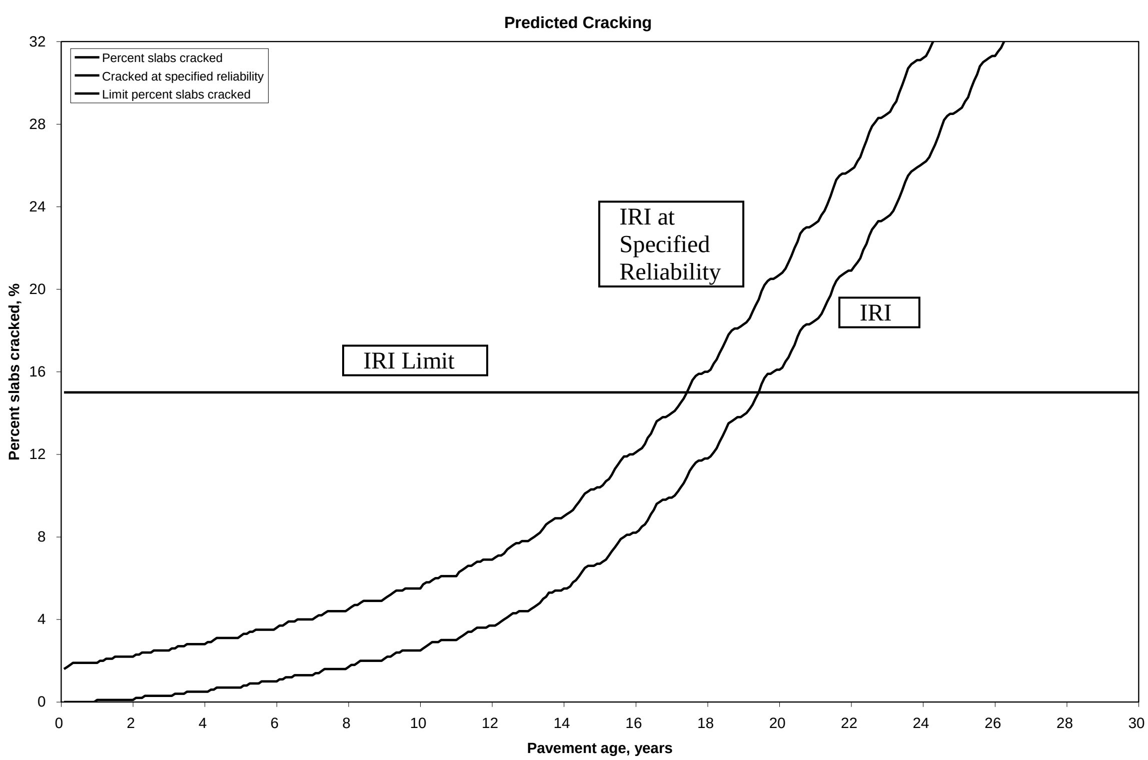


Figure I18. Percentage of Slab Cracked – Project 23, MOT 35 (343-88)

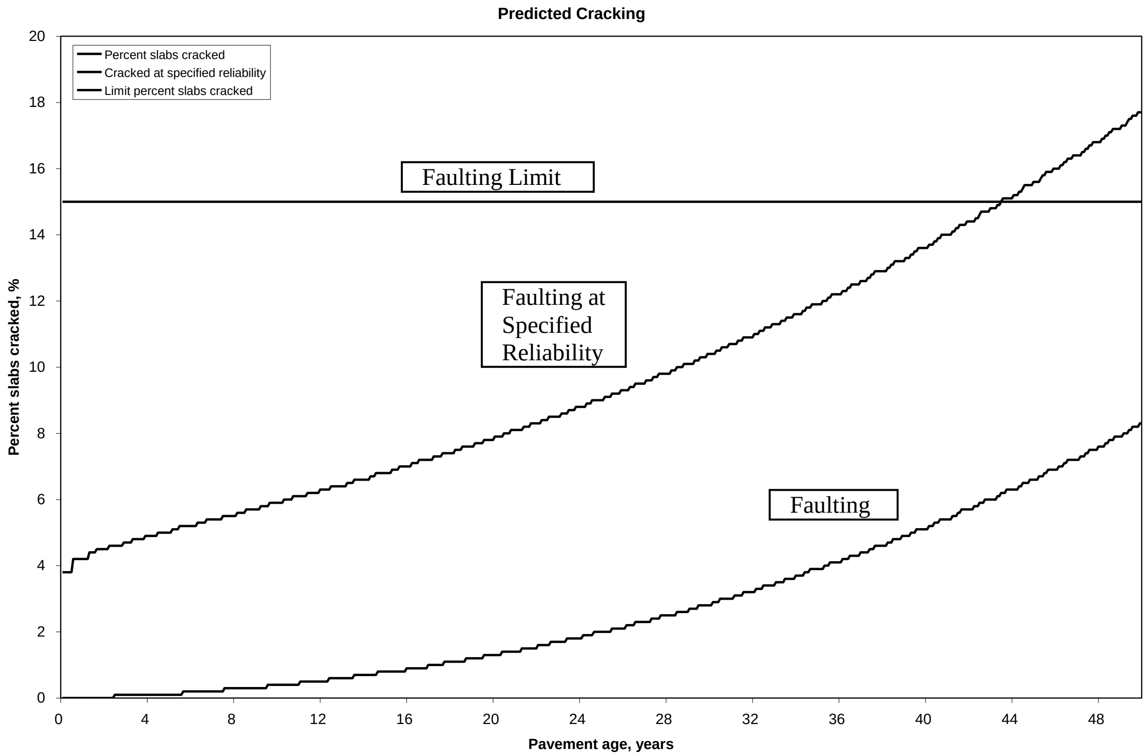


Figure I19. Percentage of Slab Cracked – Project 24, MOT 202 (678-91)

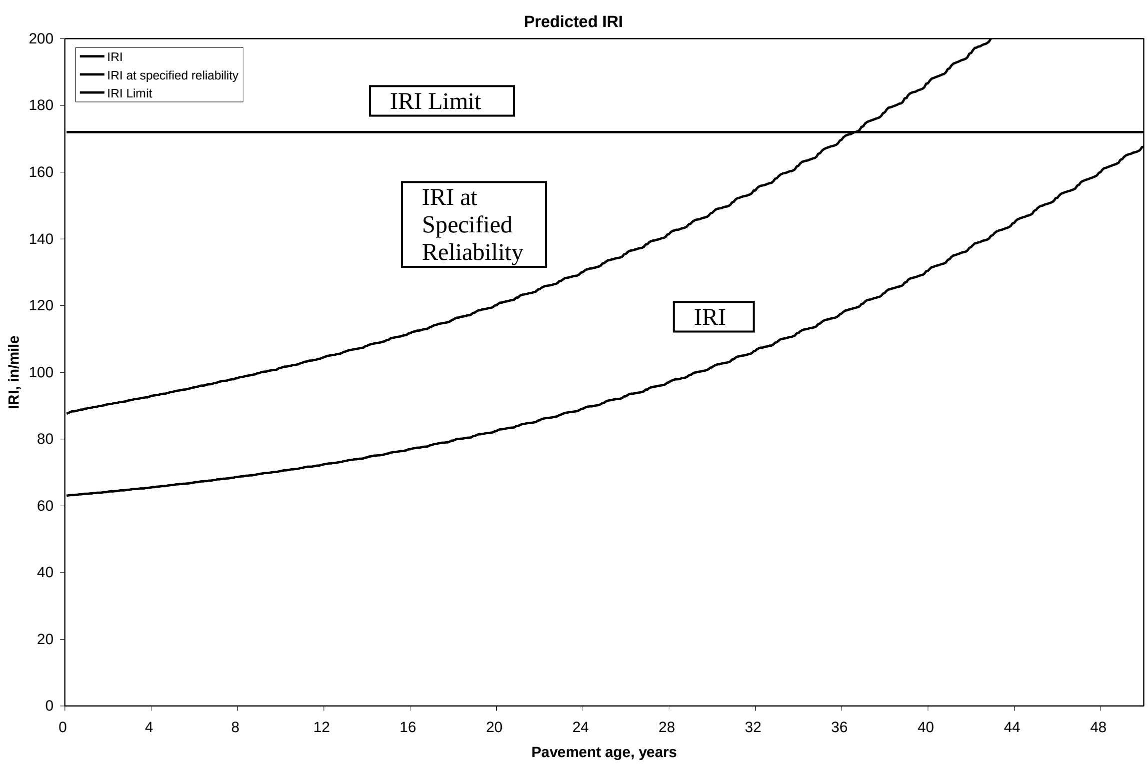


Figure I20. International Roughness Index – Project 24, MOT 202 (678-91)

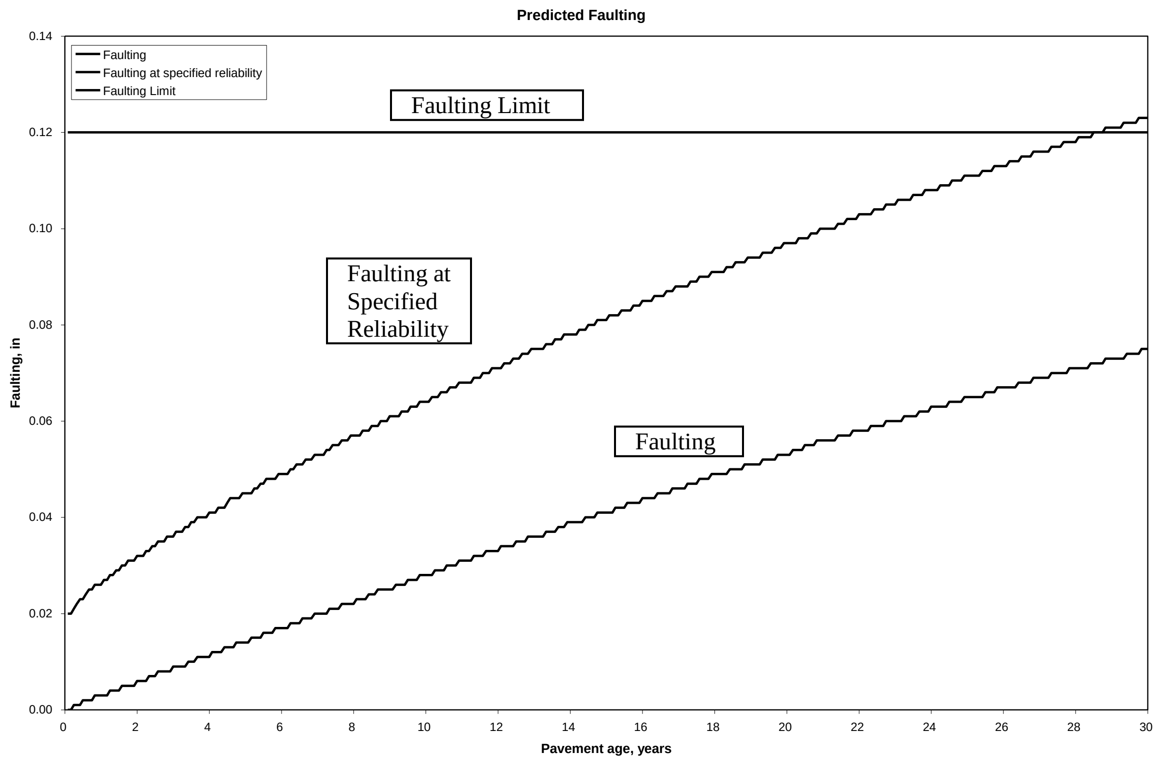


Figure I21. Predicted Faulting – Project 25, SUM 76 (844-92)

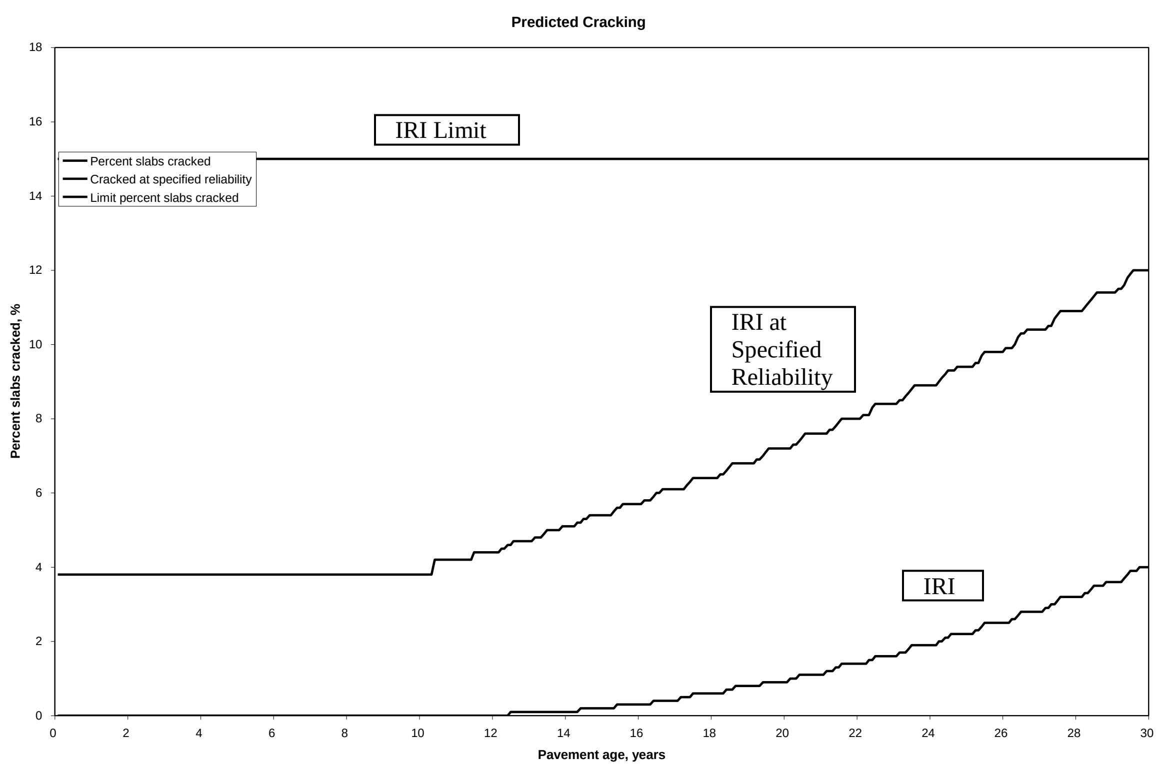


Figure I22. Percentage of Slab Cracked – Project 25, SUM 76 (844-92)

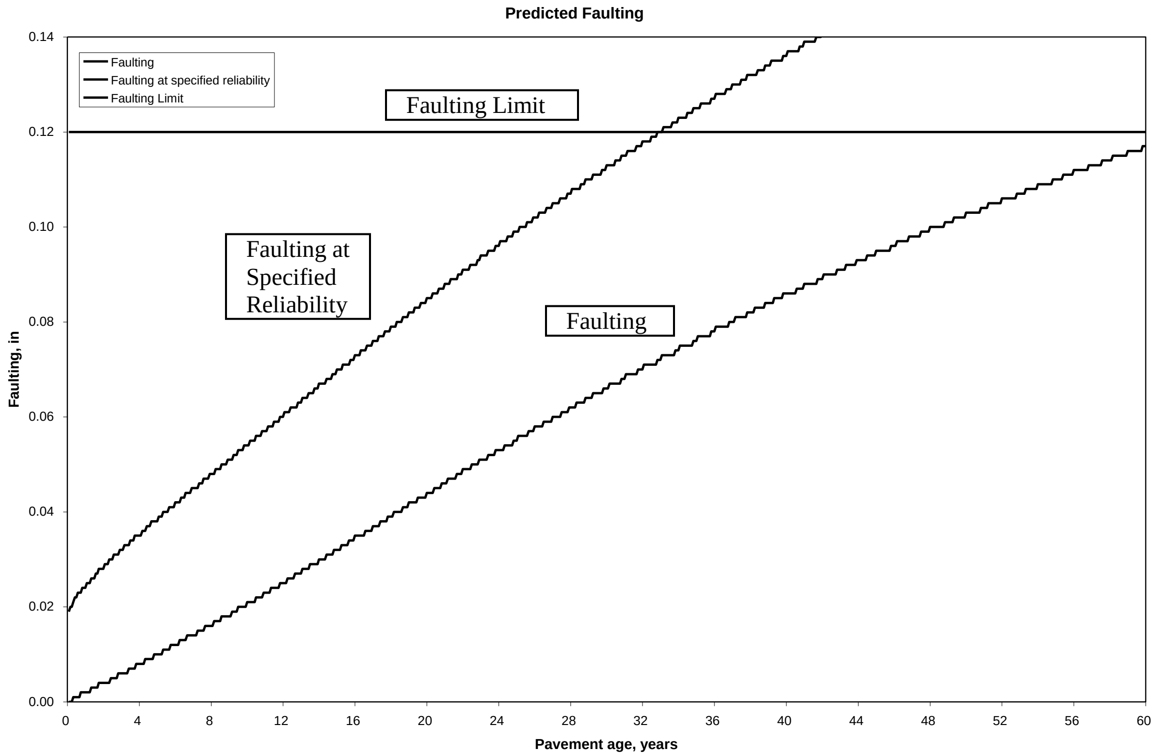


Figure I23. Predicted Faulting – Project 26, SUM 76 (996-93)

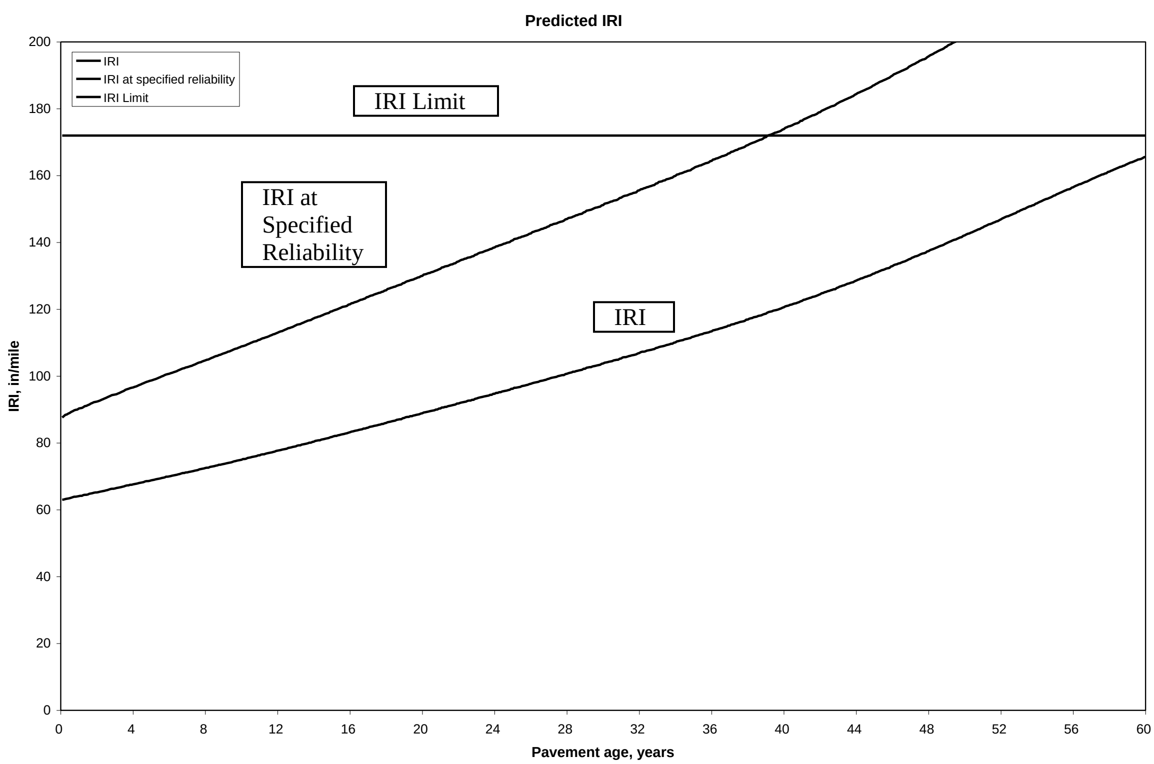


Figure I24. International Roughness Index – Project 26, SUM 76 (996-93)

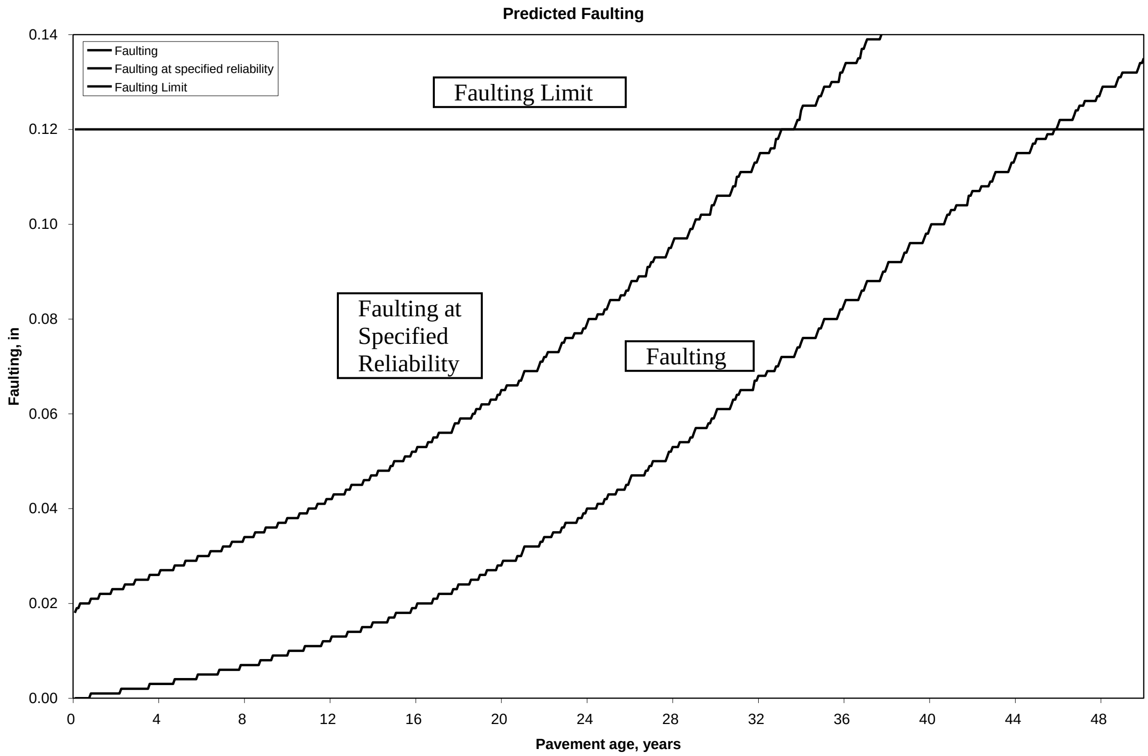


Figure I24. Predicted Faulting – Project 27, TUS 39 (907-90)

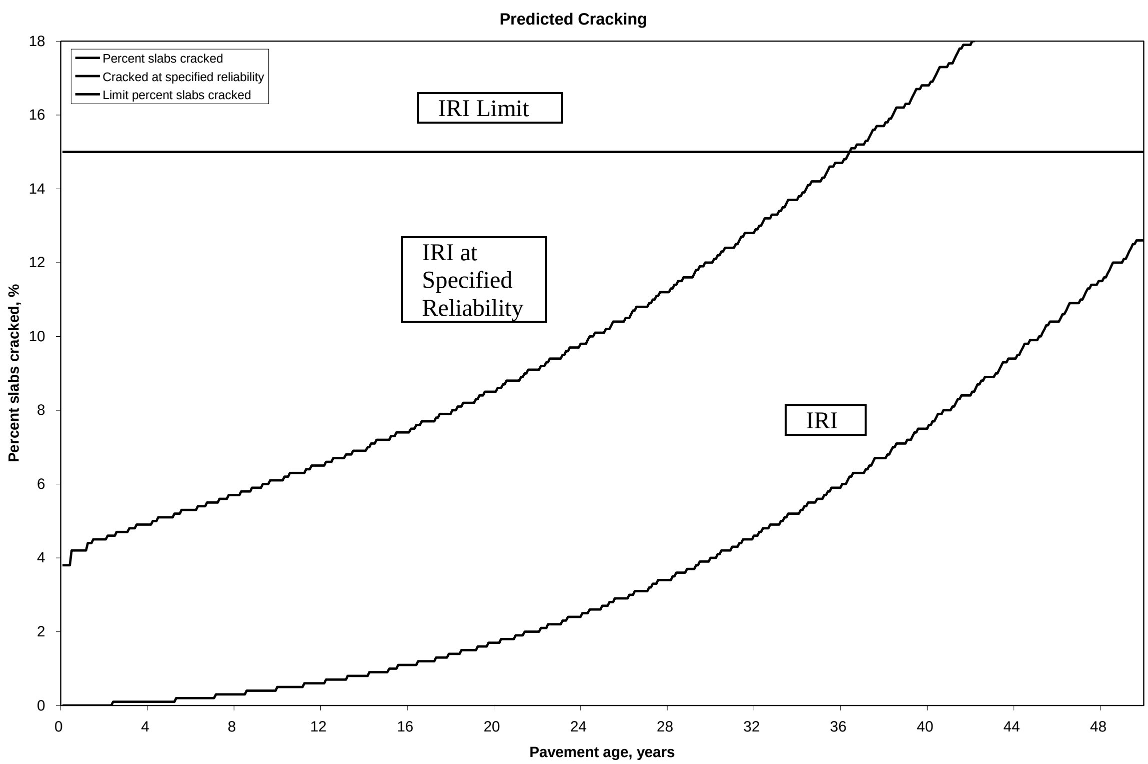


Figure I25. Percentage of Slab Cracked – Project 27, TUS 39 (907-90)

APPENDIX J

FWD Profiles for MEPDG Analysis of Flexible Pavements

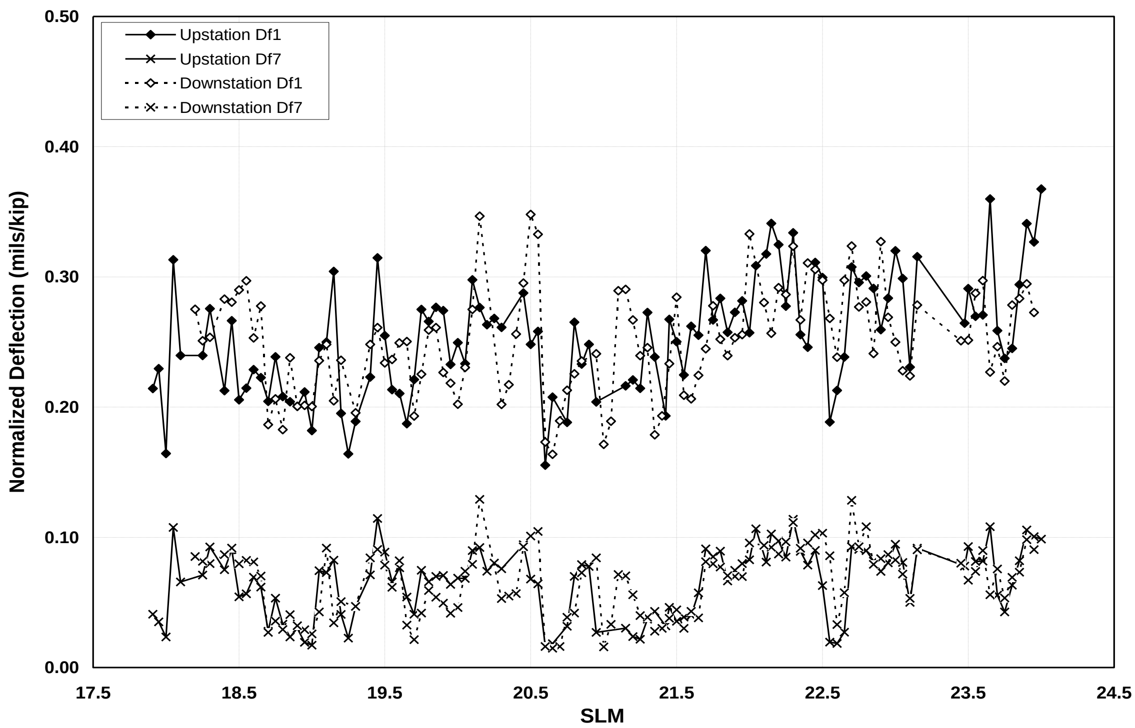


Figure J1. Normalized Deflection – Project 1, BUT 129 (9330-98)

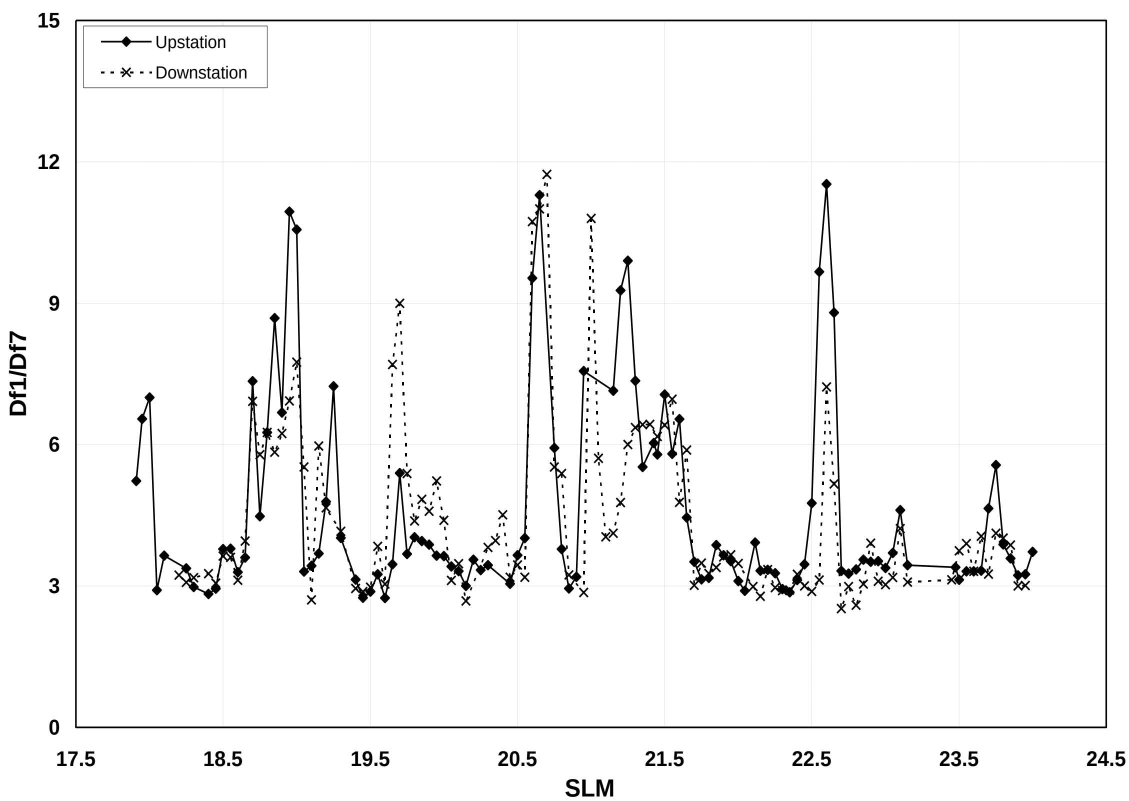


Figure J2. Df1/Df7 – Project 1, BUT 129 (9330-98)

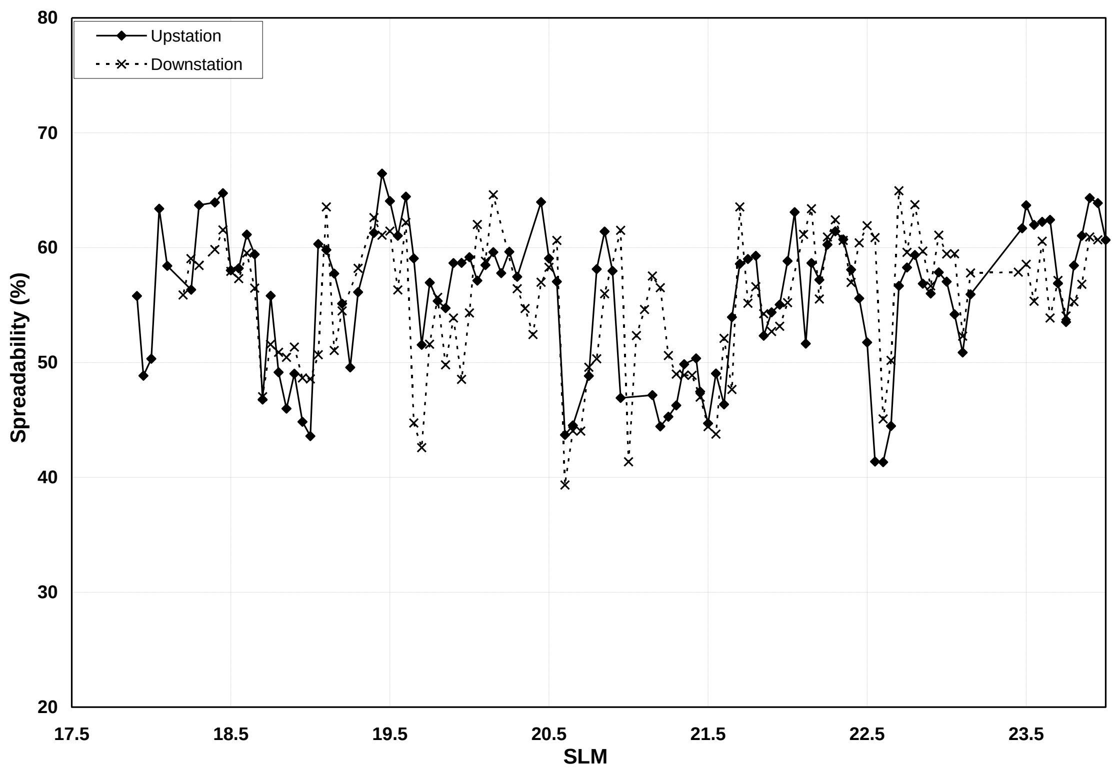


Figure J3. Spreadability – Project 1, BUT 129 (9330-98)

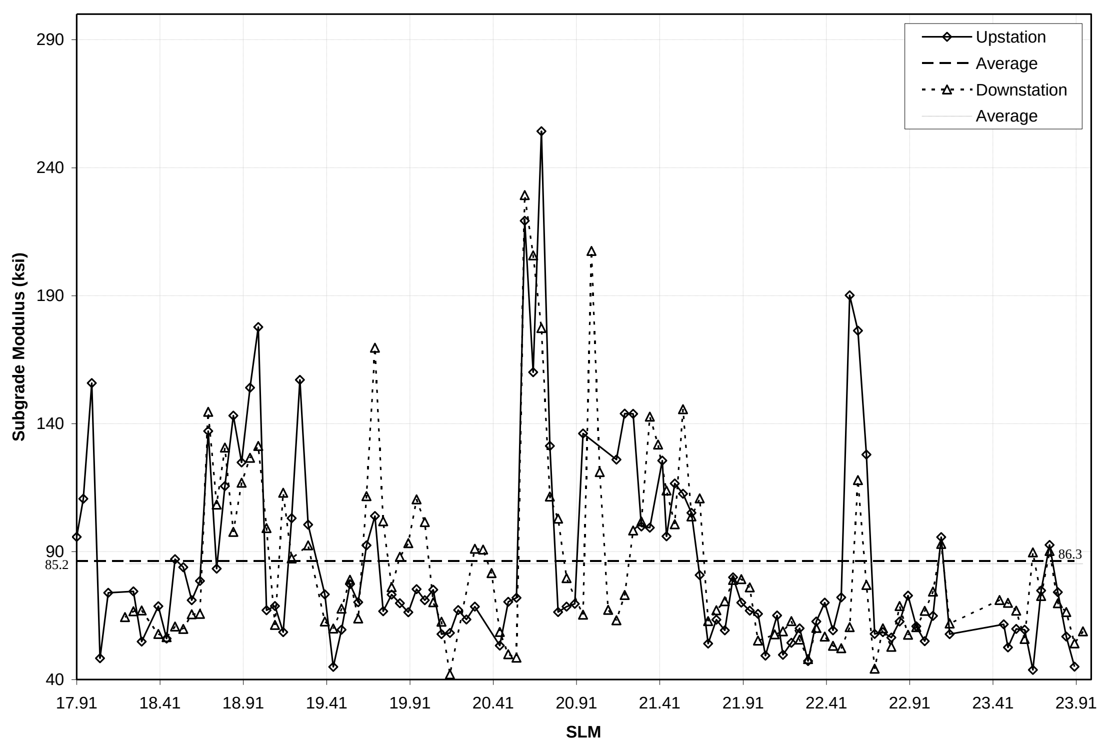


Figure J4. Subgrade Modulus – Project 1, BUT 129 (9330-98)

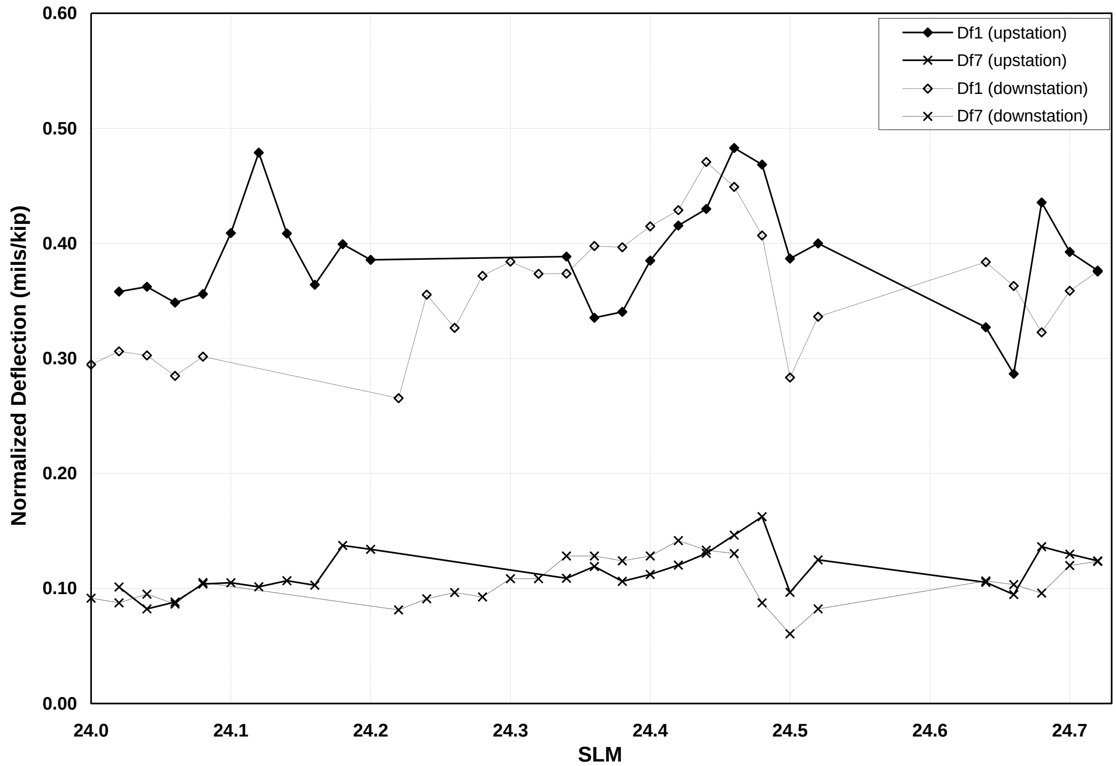


Figure J5. Normalized Deflection – Project 2, BUT 129 (9327-98)

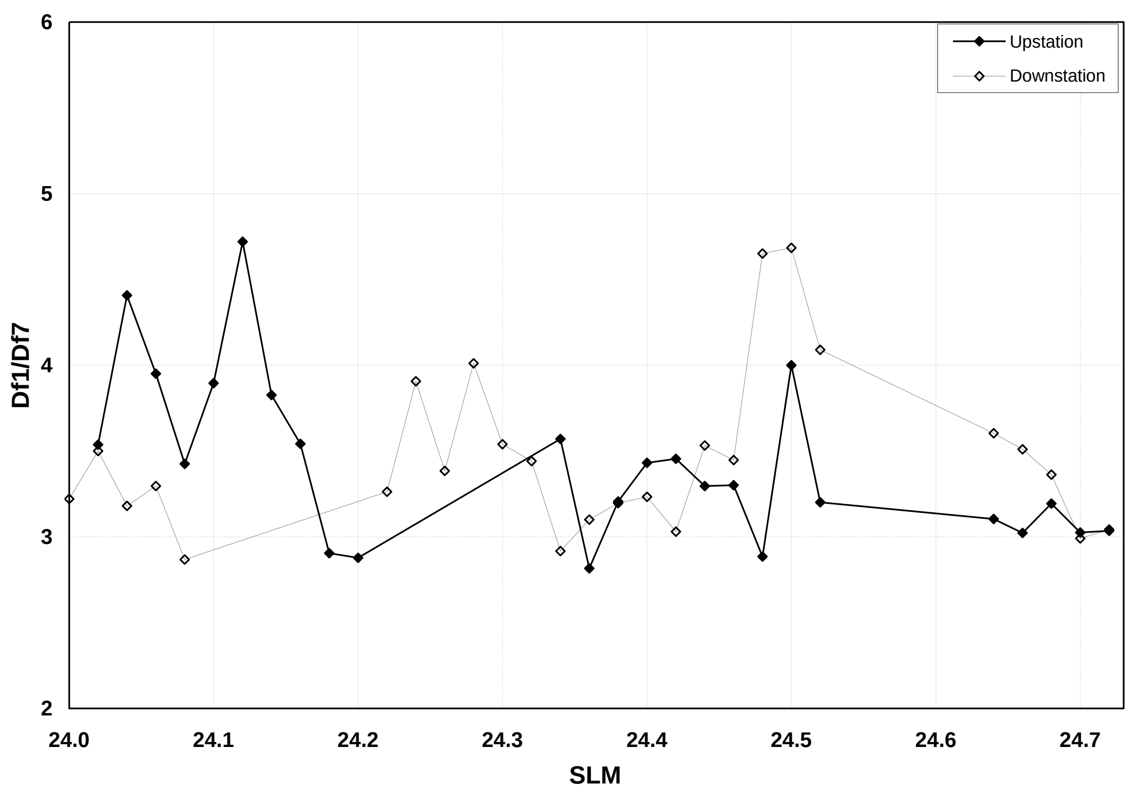


Figure J6. Df1/Df7 – Project 2, BUT 129 (9327-98)

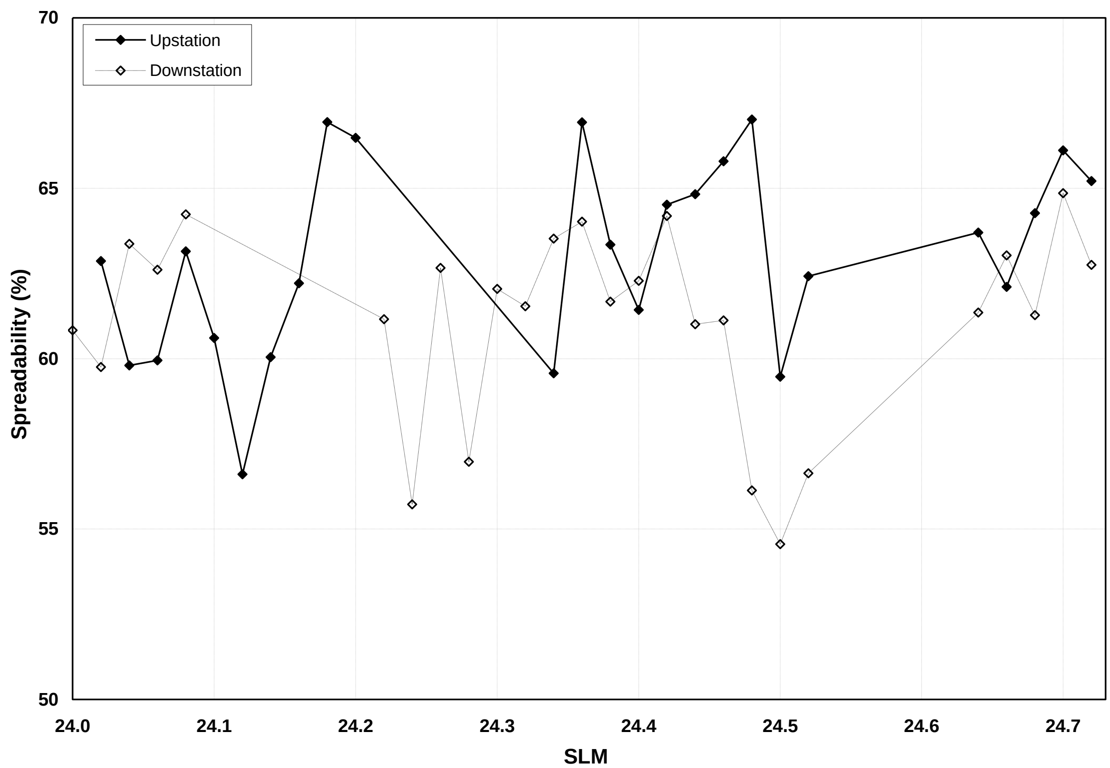


Figure J7. Spreadability – Project 2, BUT 129 (9327-98)

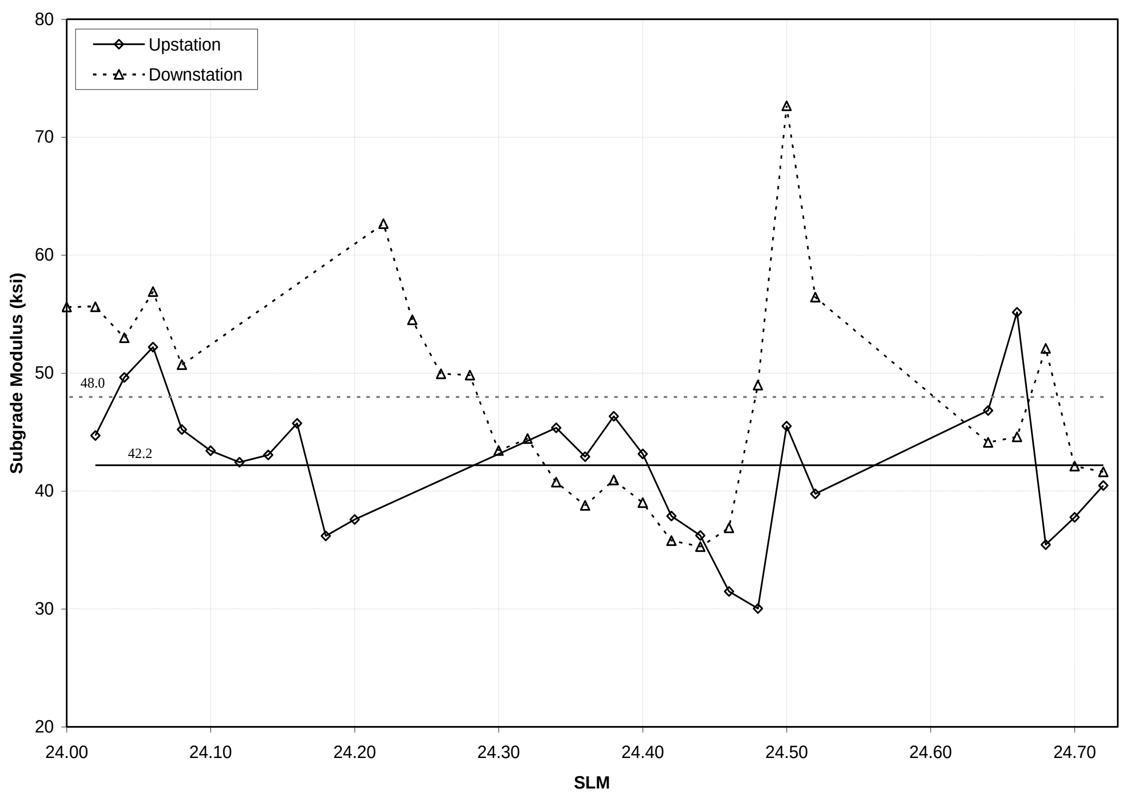


Figure B 8. Subgrade Modulus – Project 2, BUT 129 (9327-98)

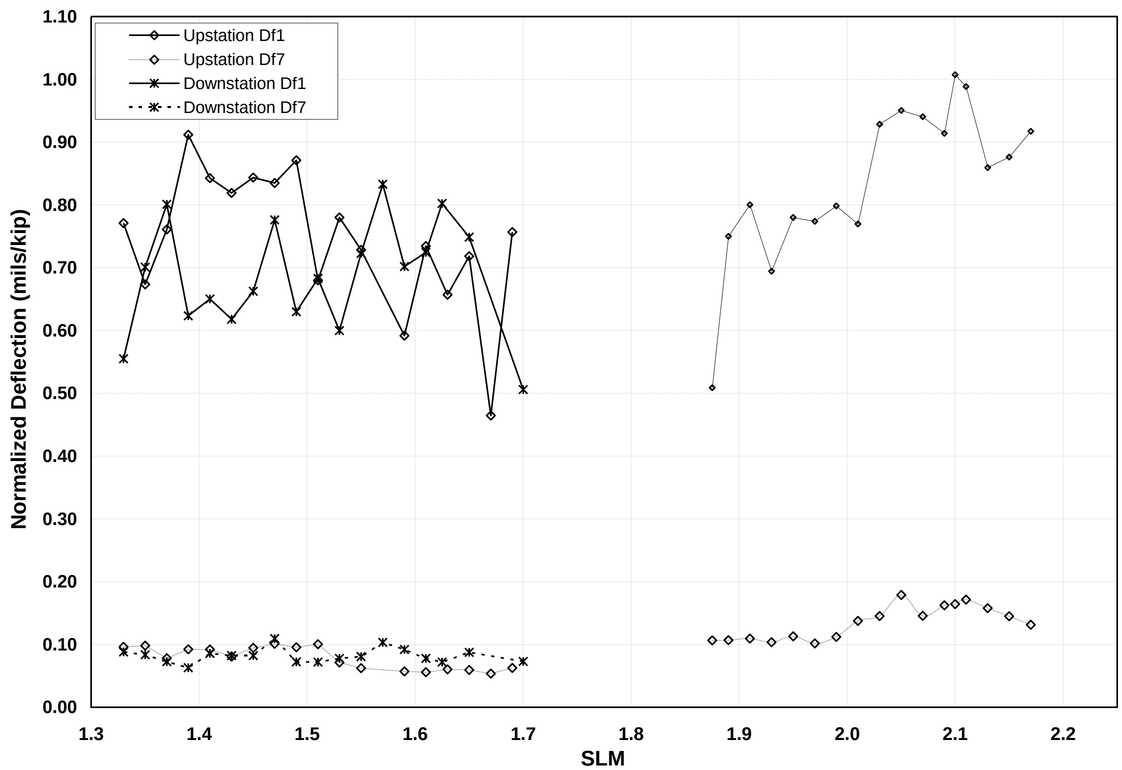


Figure J9. Normalized Deflection – Project 3, CHP 68 (233-98)

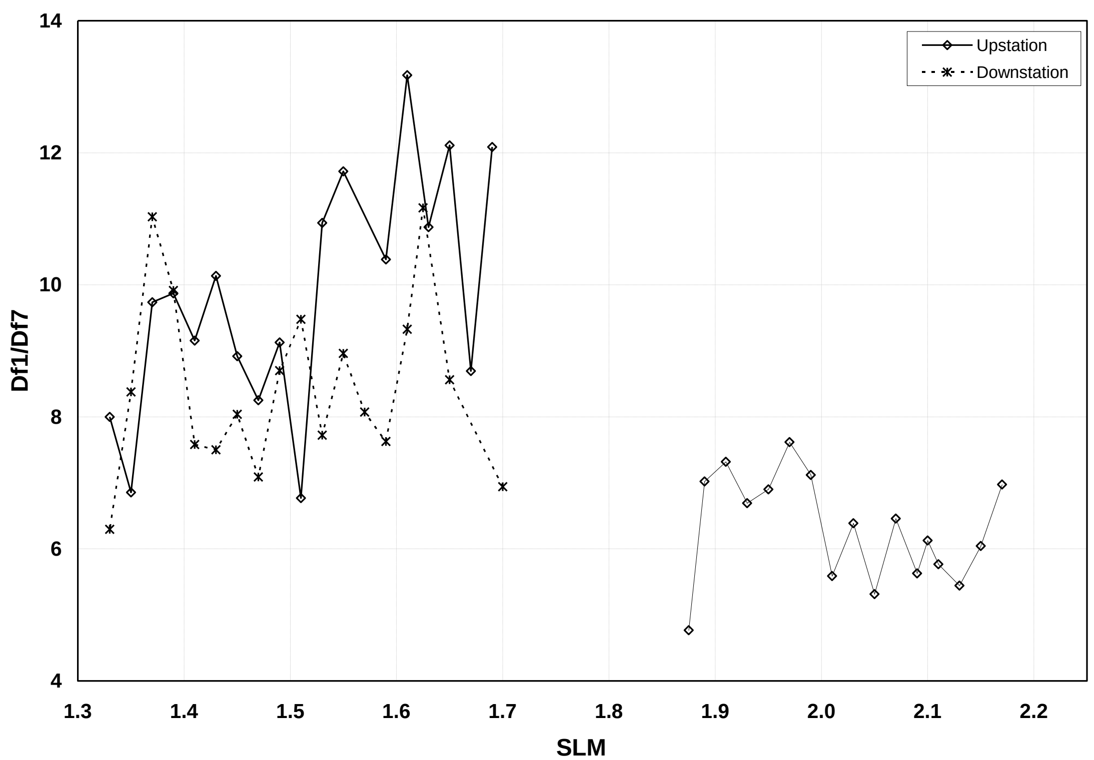


Figure J10. Df1/Df7 – Project 3, CHP 68 (233-98)

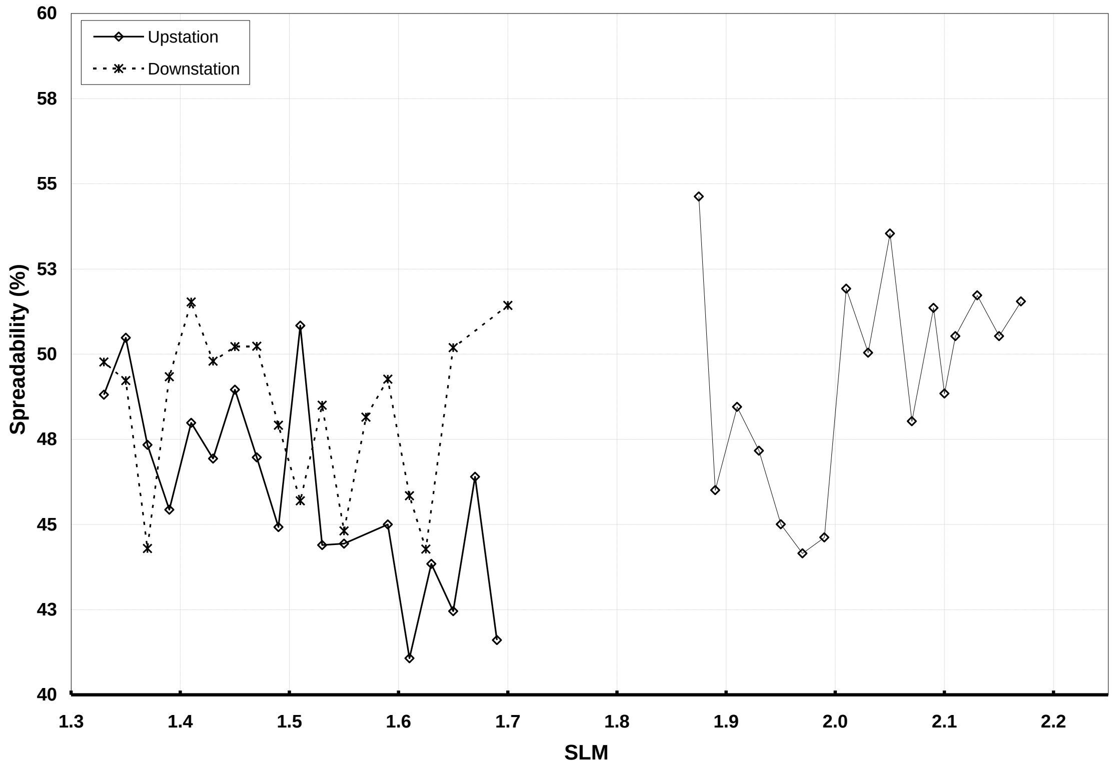


Figure J11. Spreadability – Project 3, CHP 68 (233-98)

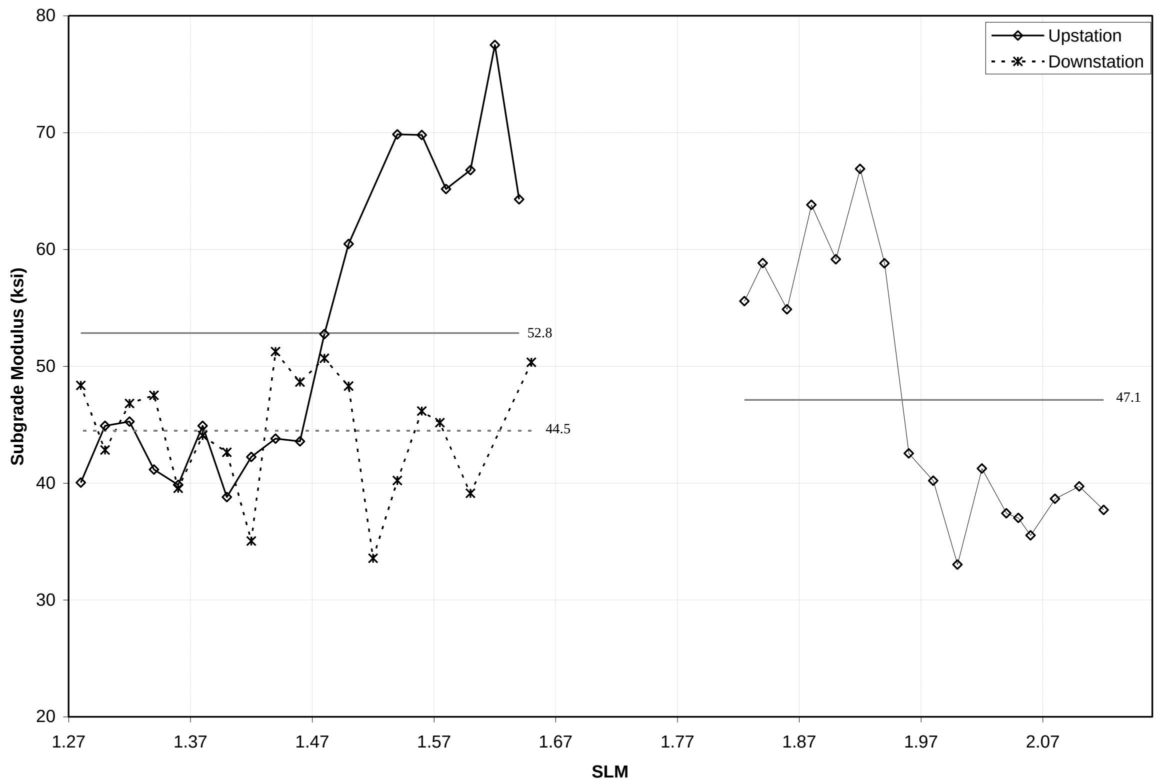


Figure J12. Subgrade Modulus – Project 3, CHP 68 (233-98)

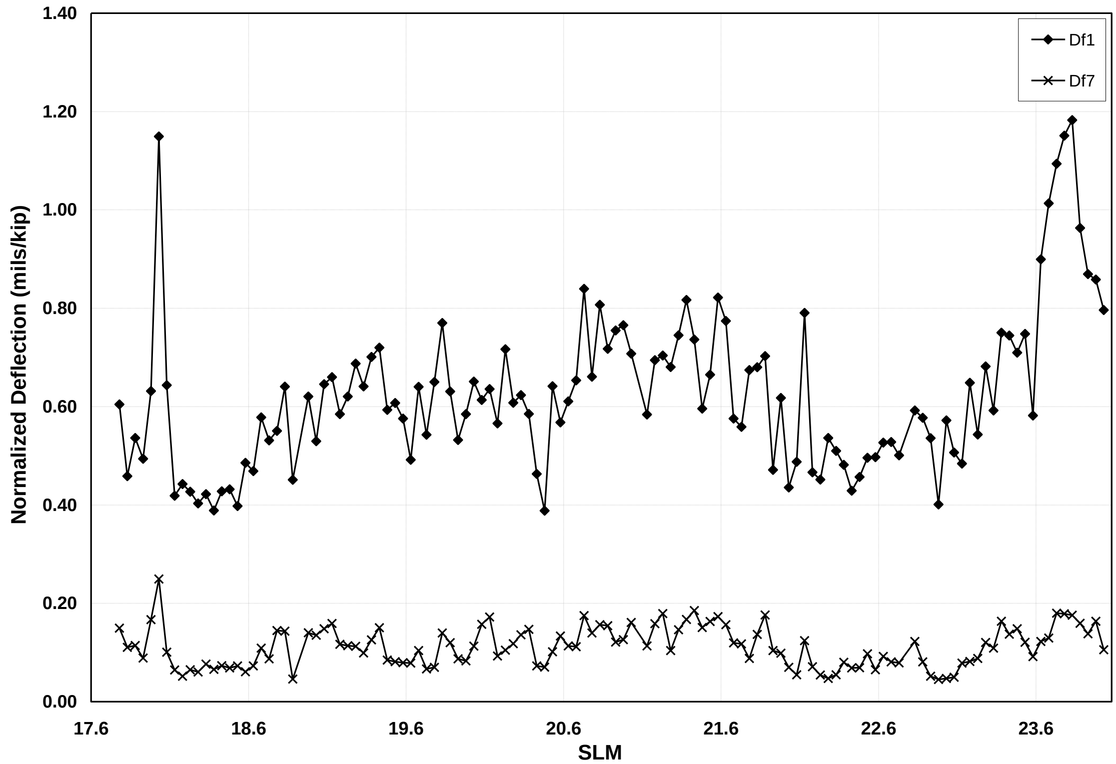


Figure J13. Normalized Deflection – Project 4, ROS 35 (298-96)

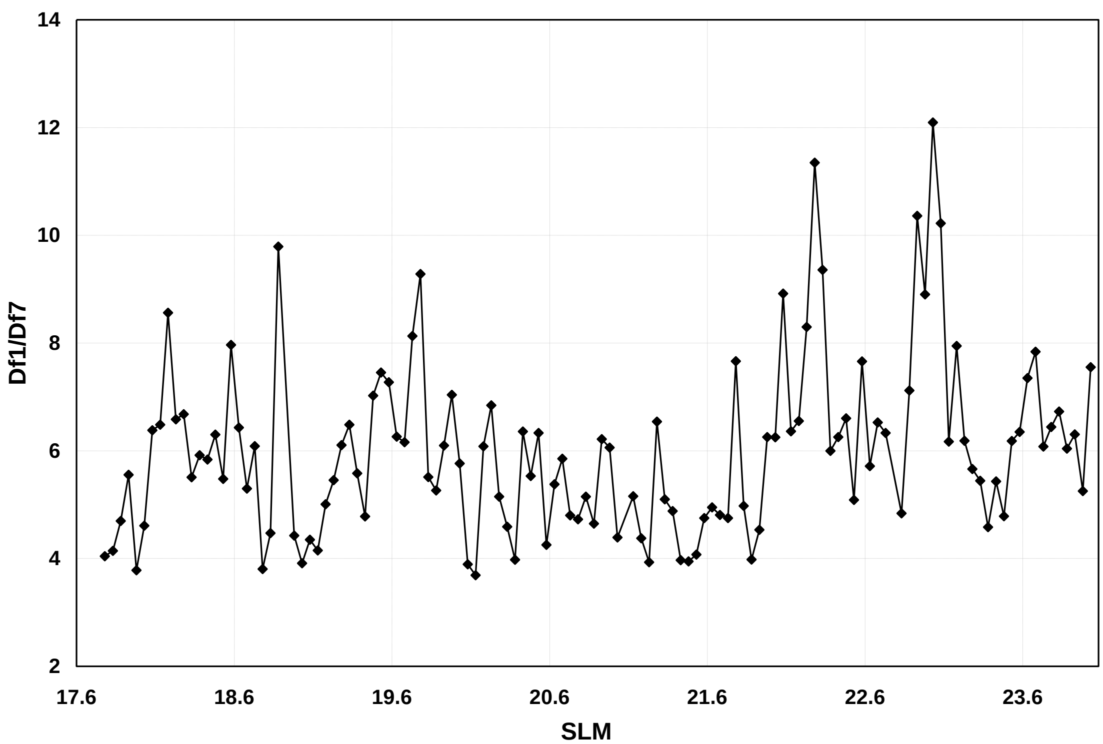


Figure J14. Df1/Df7 – Project 4, ROS 35 (298-96)

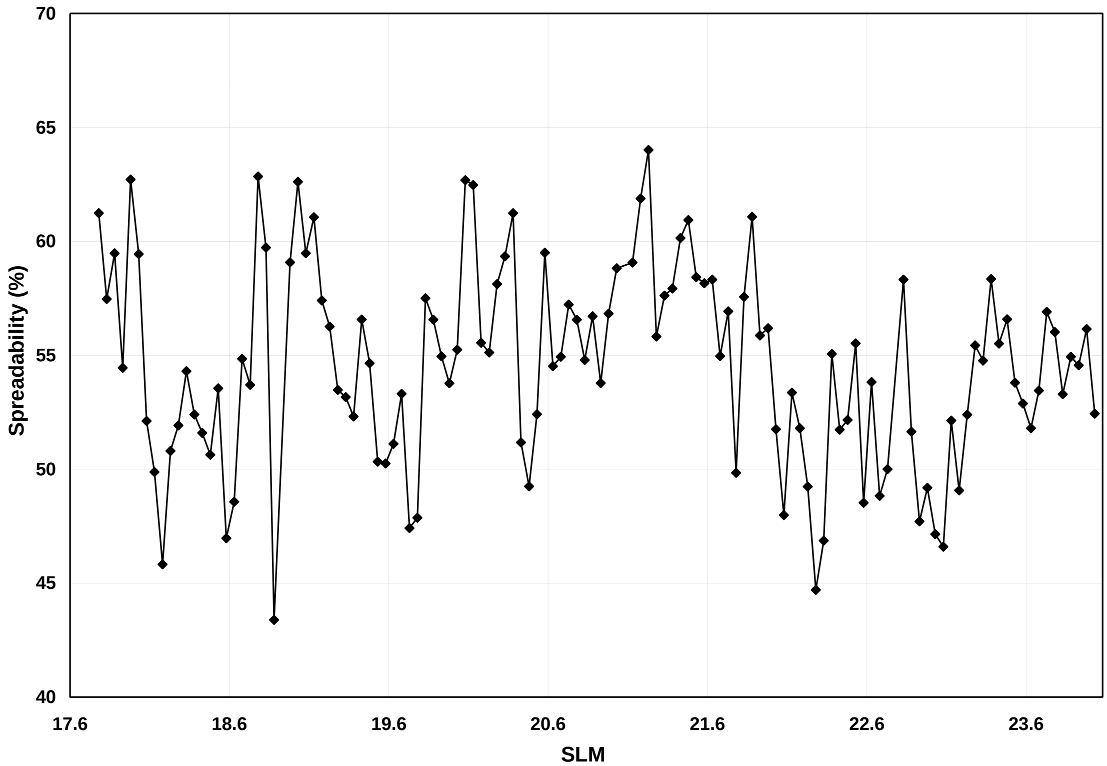


Figure J15. Spreadability – Project 4, ROS 35 (298-96)

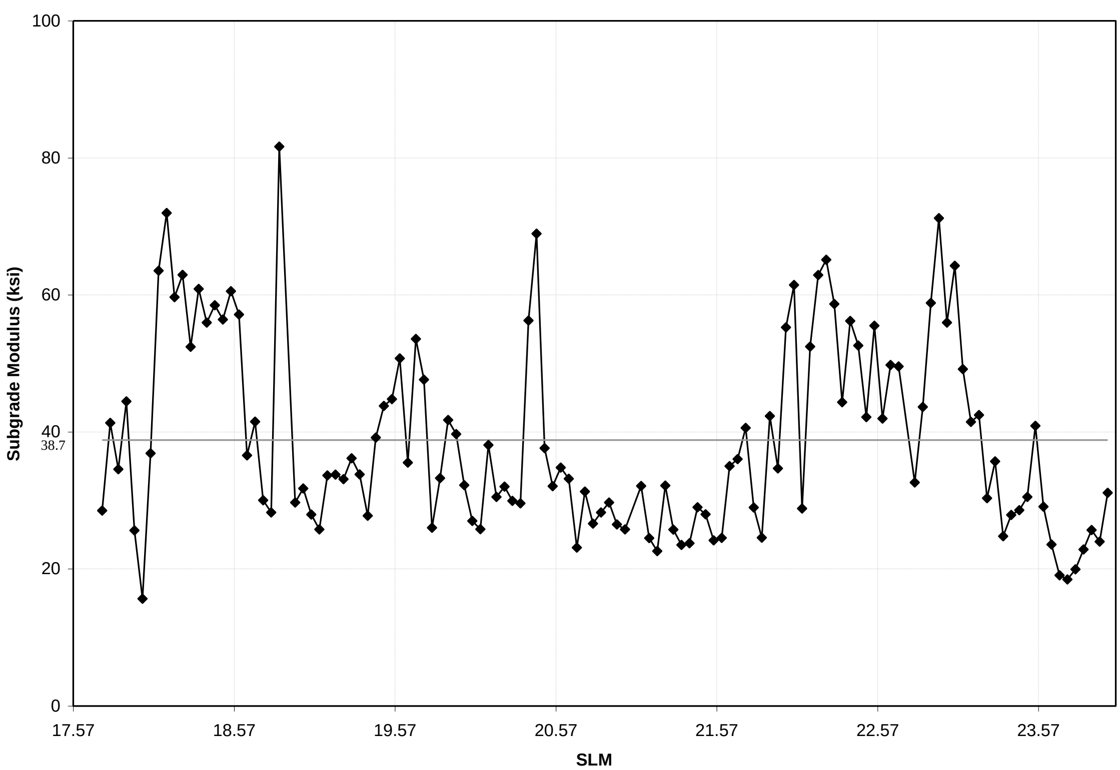


Figure JB 16. Subgrade Modulus – Project 4, ROS 35 (298-96)

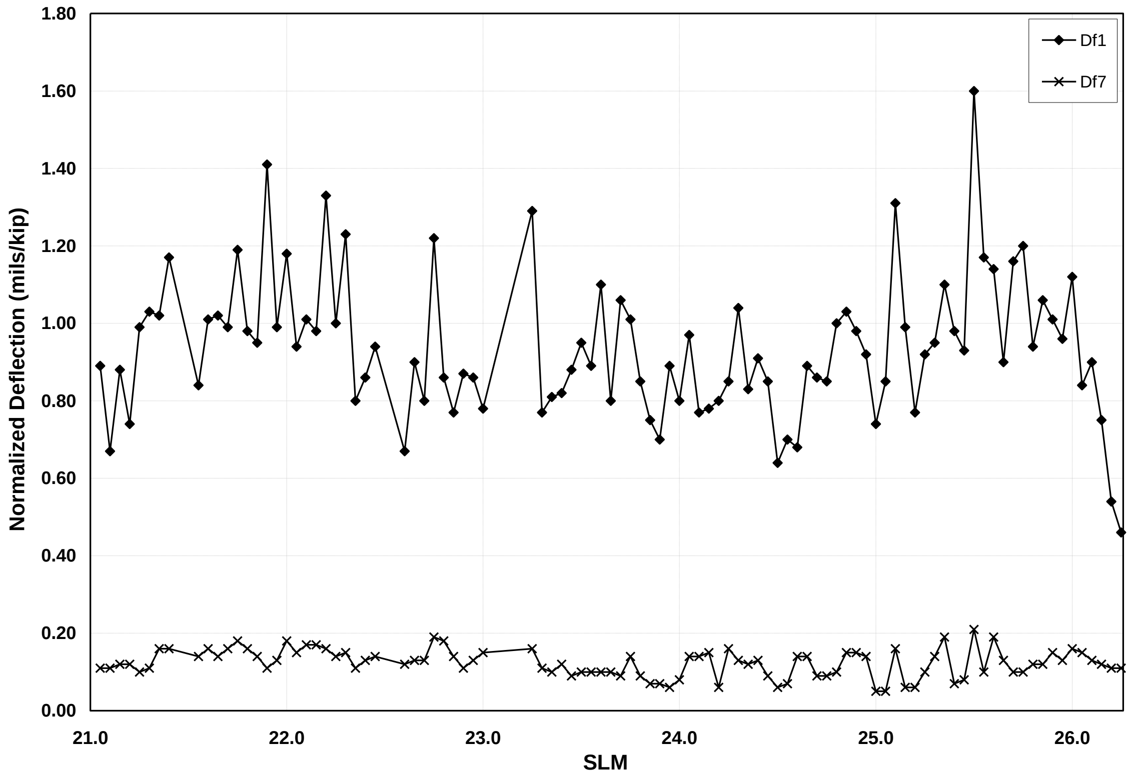


Figure J17. Normalized Deflection – Project 5, GRE 35 (259-98)

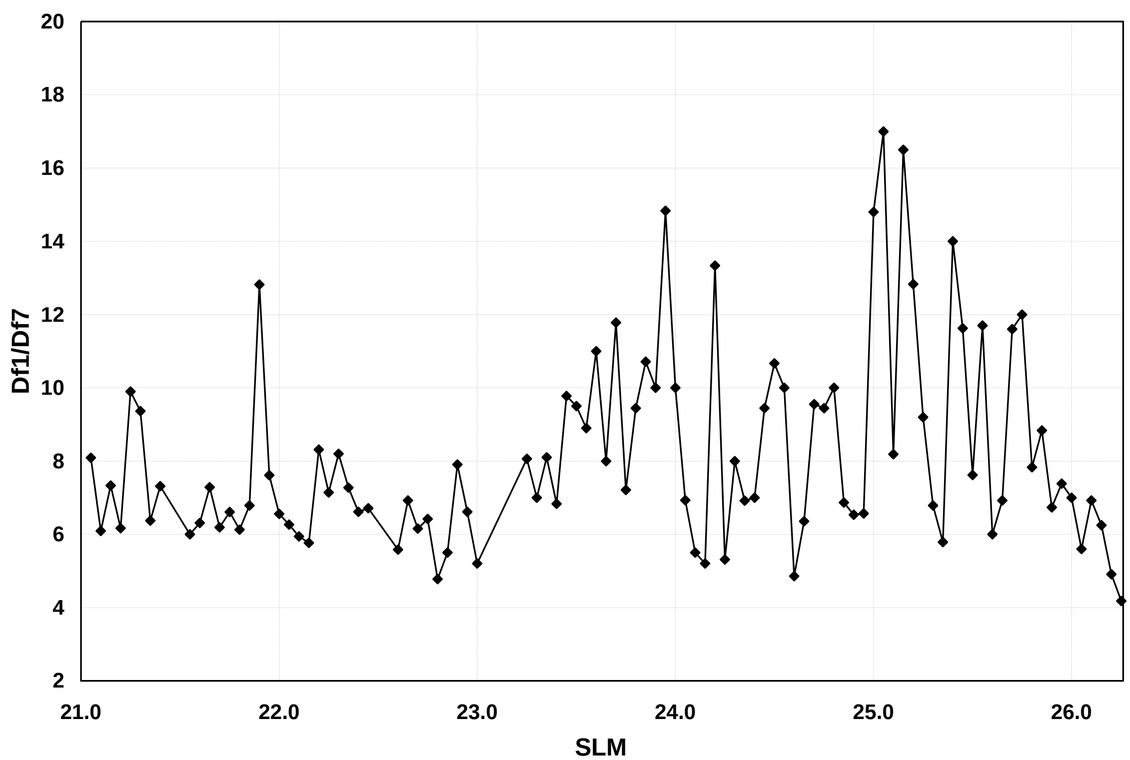


Figure J18. Df1/Df7 – Project 5, GRE 35 (259-98)

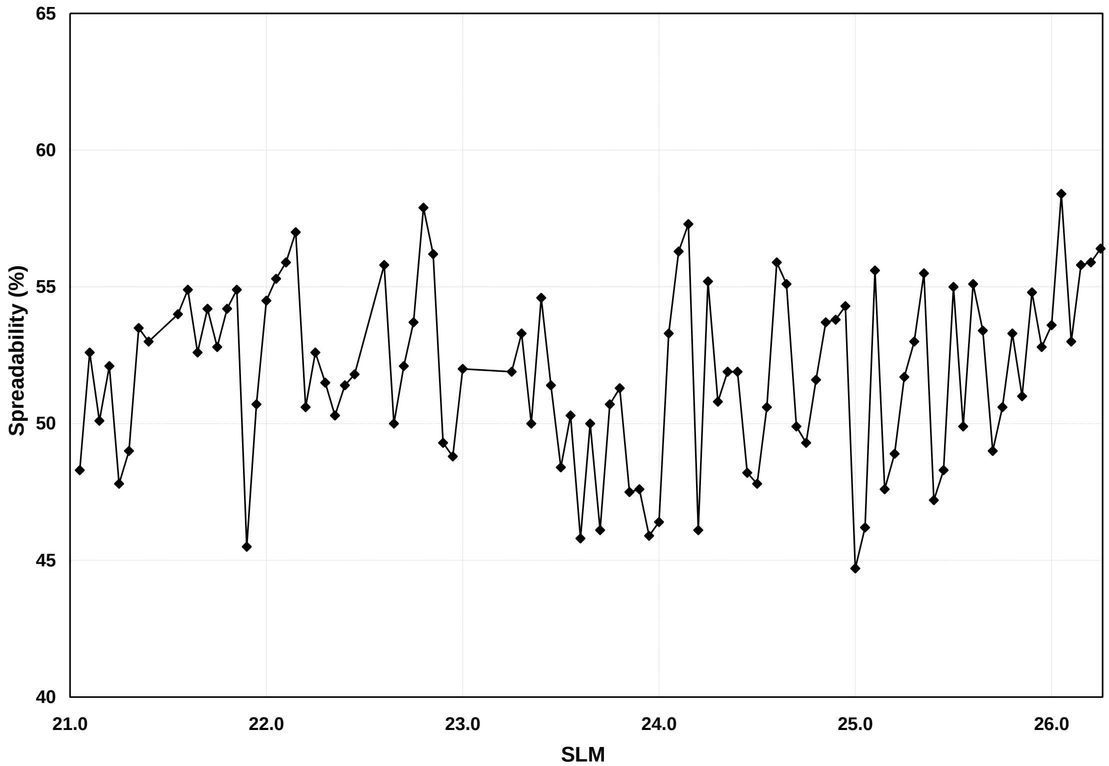


Figure J19. Spreadability – Project 5, GRE 35 (259-98)

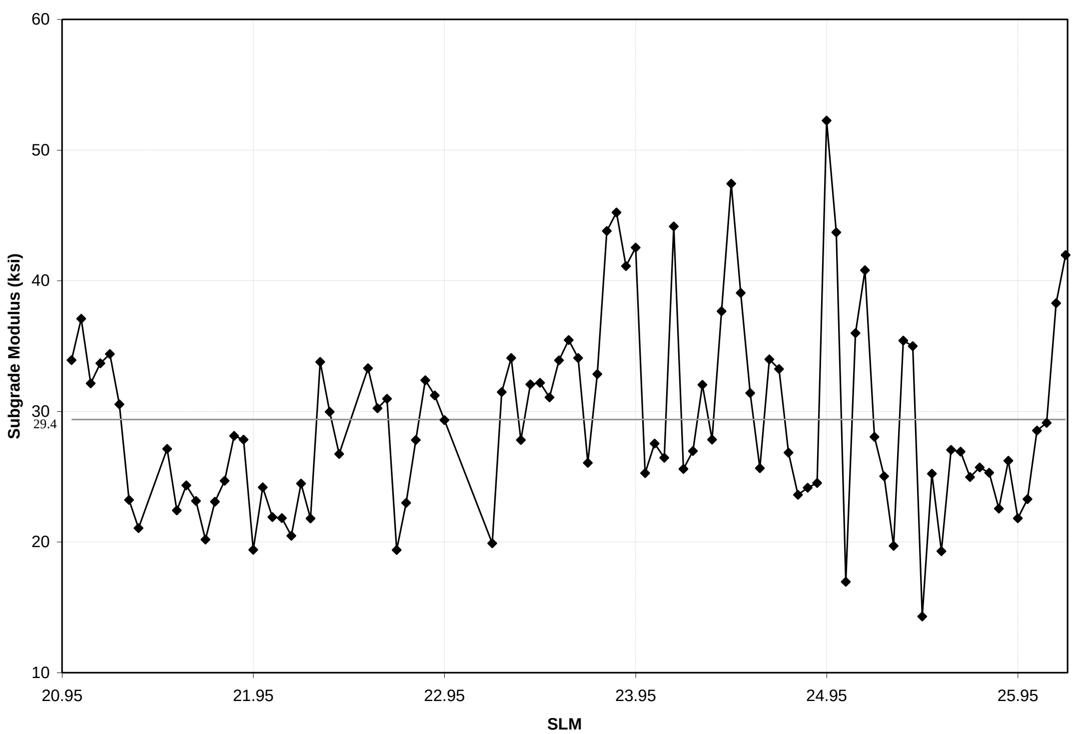


Figure J20. Subgrade Modulus – Project 5, GRE 35 (259-98)

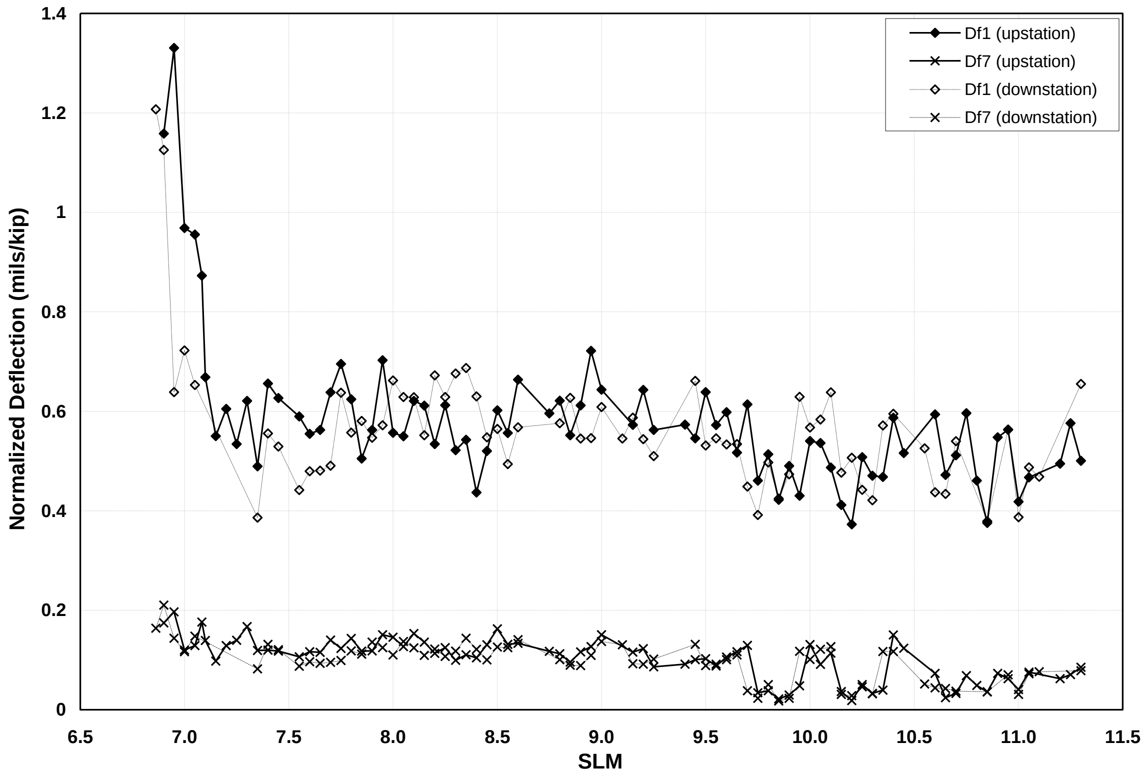


Figure J 21. Normalized Deflection - Project 6, HAM 126 (645-94)

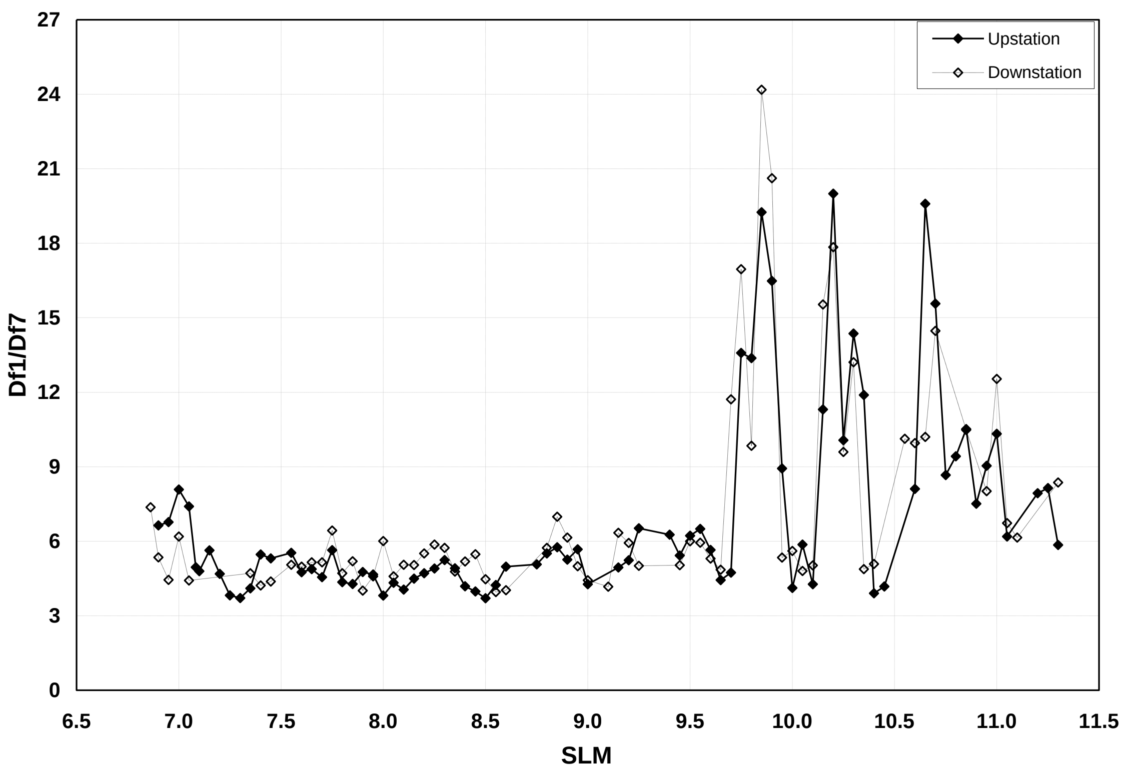


Figure J22. Df1/Df7 – Project 6, HAM 126 (645-94)

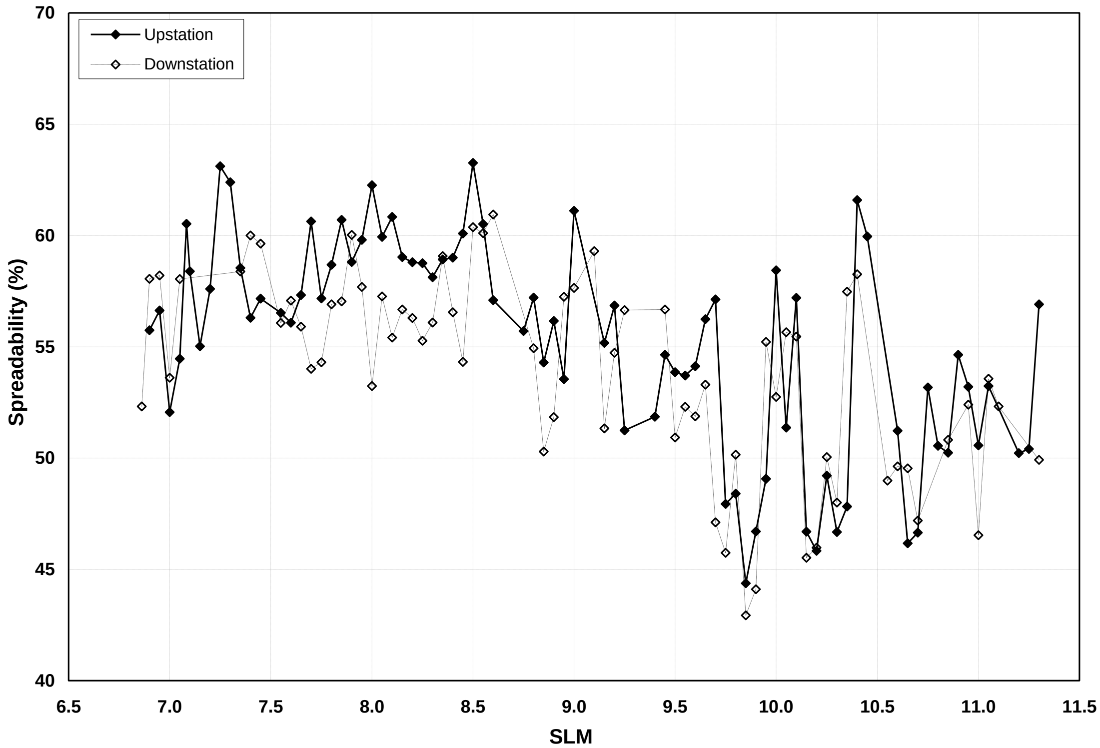


Figure J23. Spreadability – Project 6, HAM 126 (645-94)

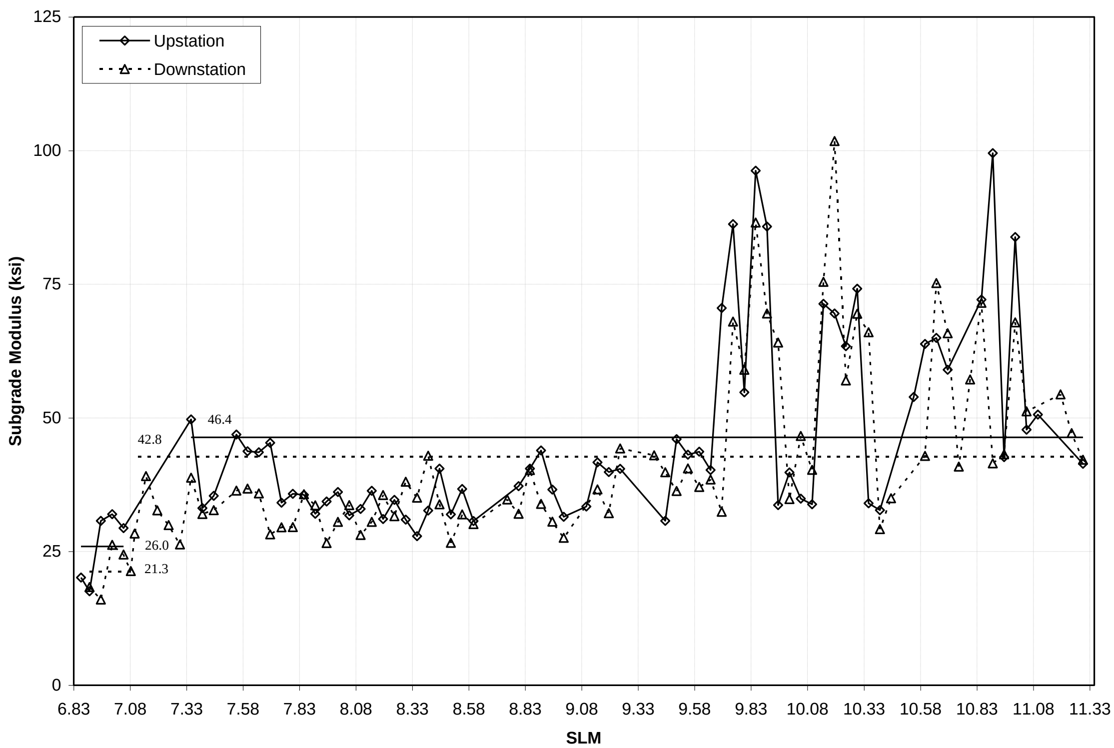


Figure J24. Subgrade Modulus – Project 6, HAM 126 (645-94)

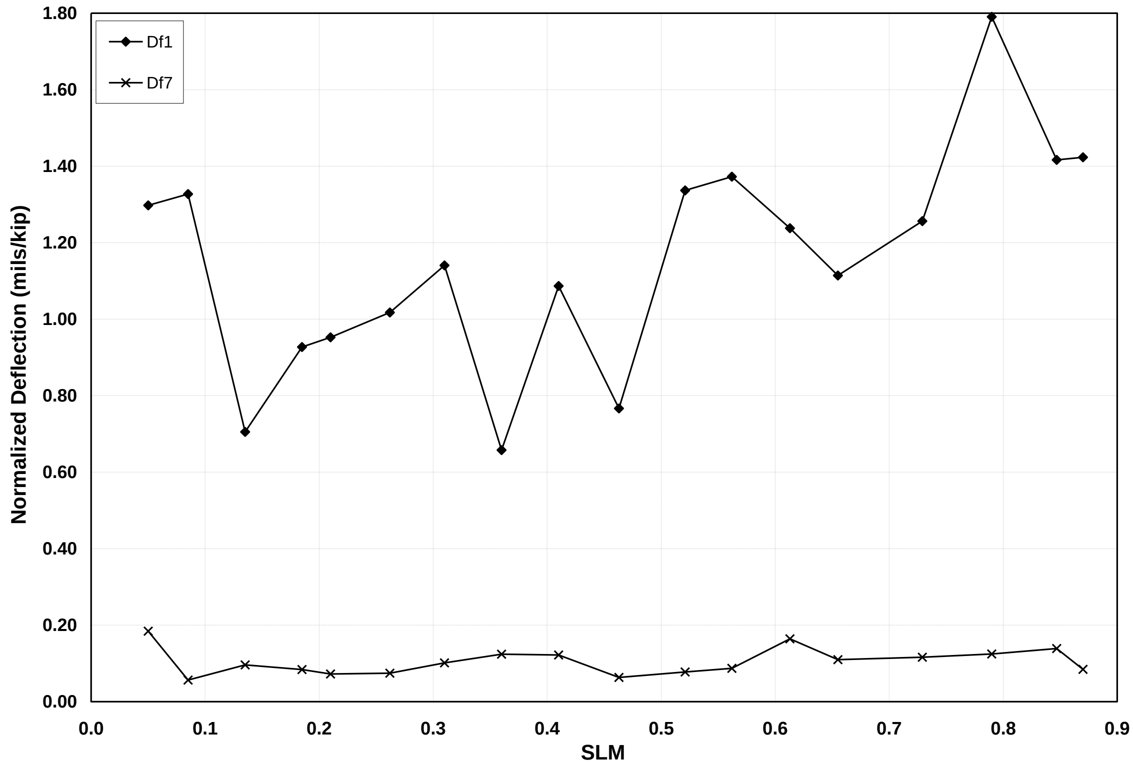


Figure J25. Normalized Deflection - Project 7, HAM 747 (347-85)

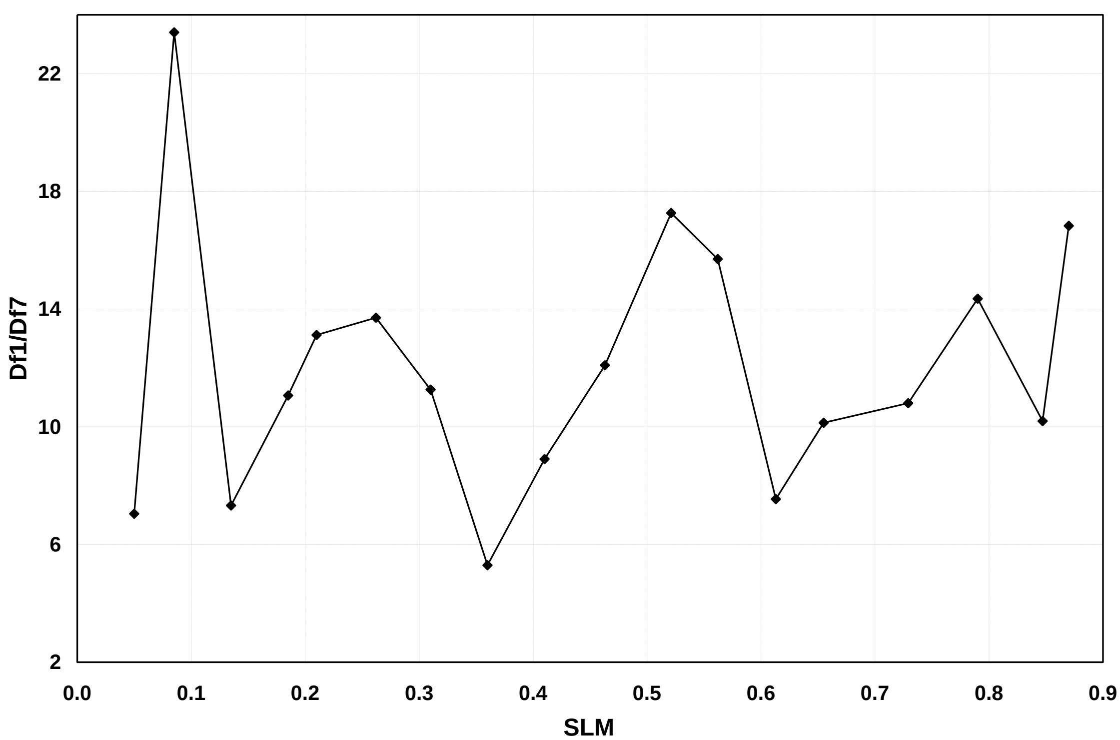


Figure J26. Df1/Df7 – Project 7, HAM 747 (347-85)

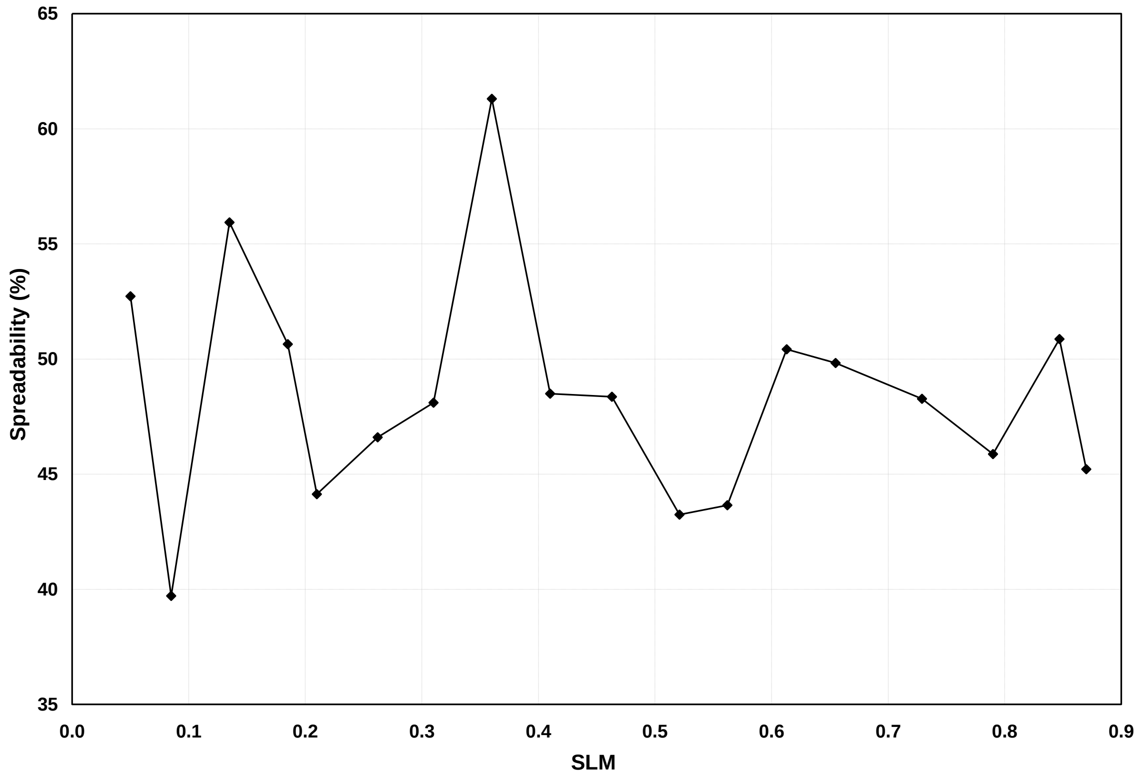


Figure J27. Spreadability – Project 7, HAM 747 (347-85)

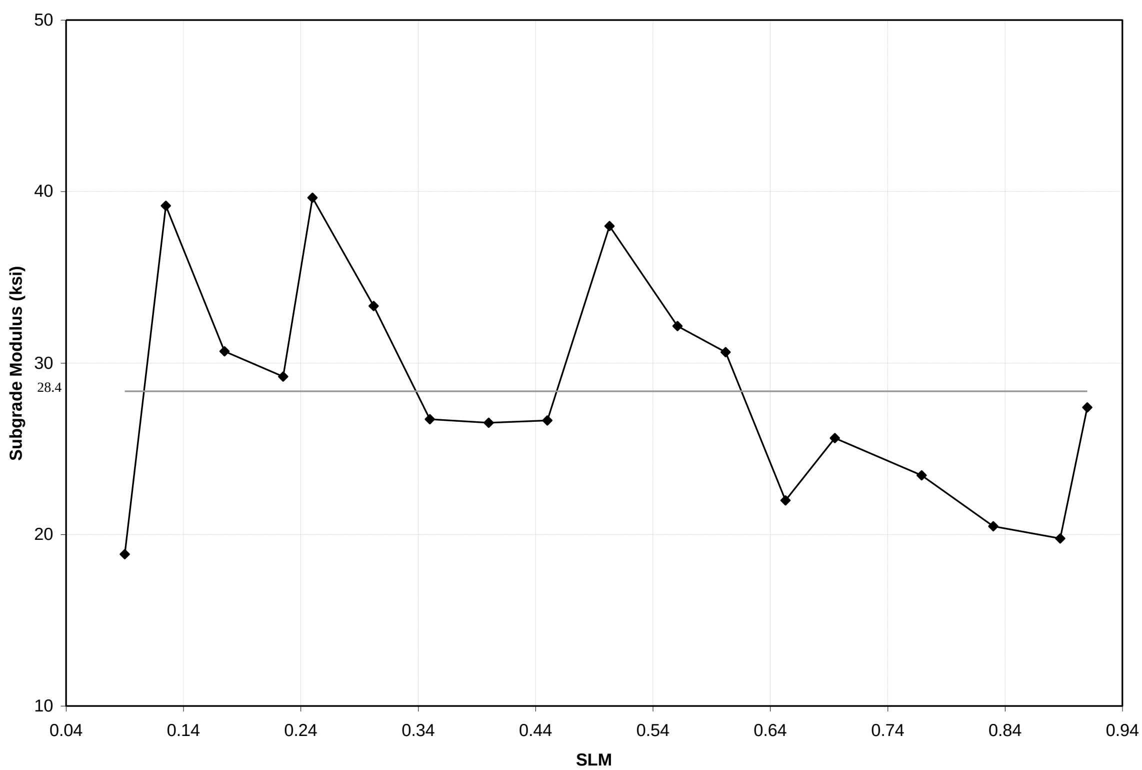


Figure J28. Subgrade Modulus – Project 7, HAM 747 (347-85)

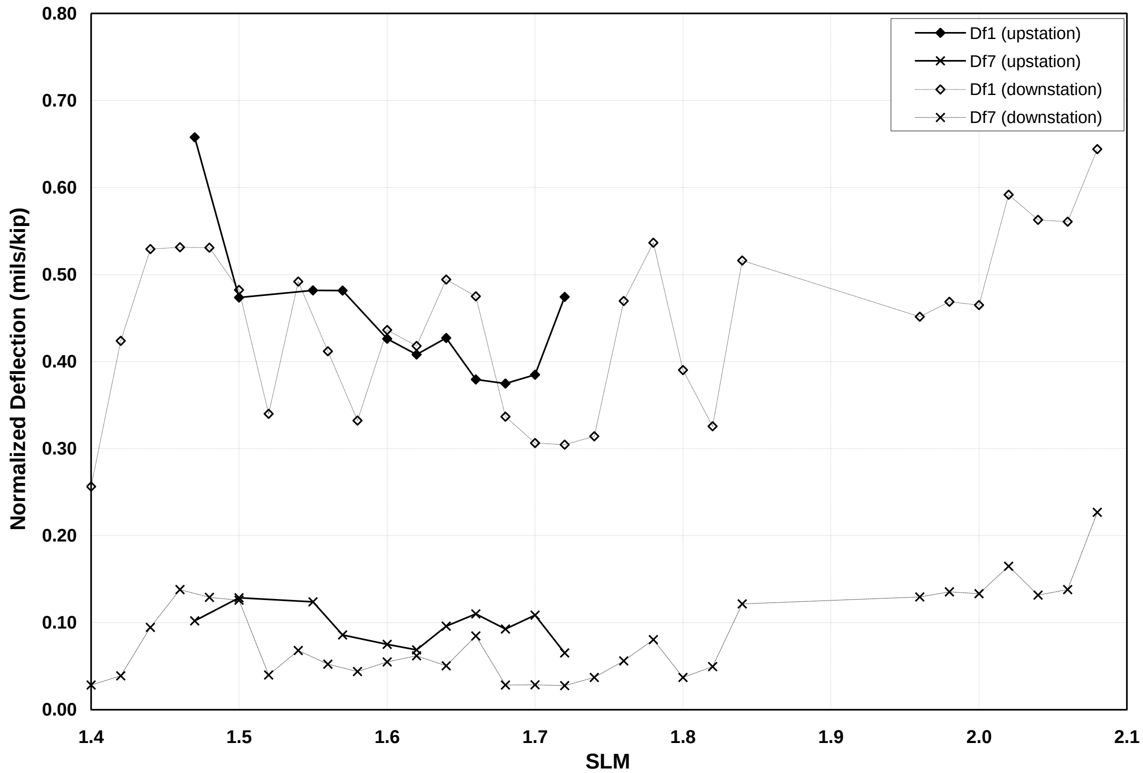


Figure J29. Normalized Deflection - Project 8, LAW 527 (17-85)

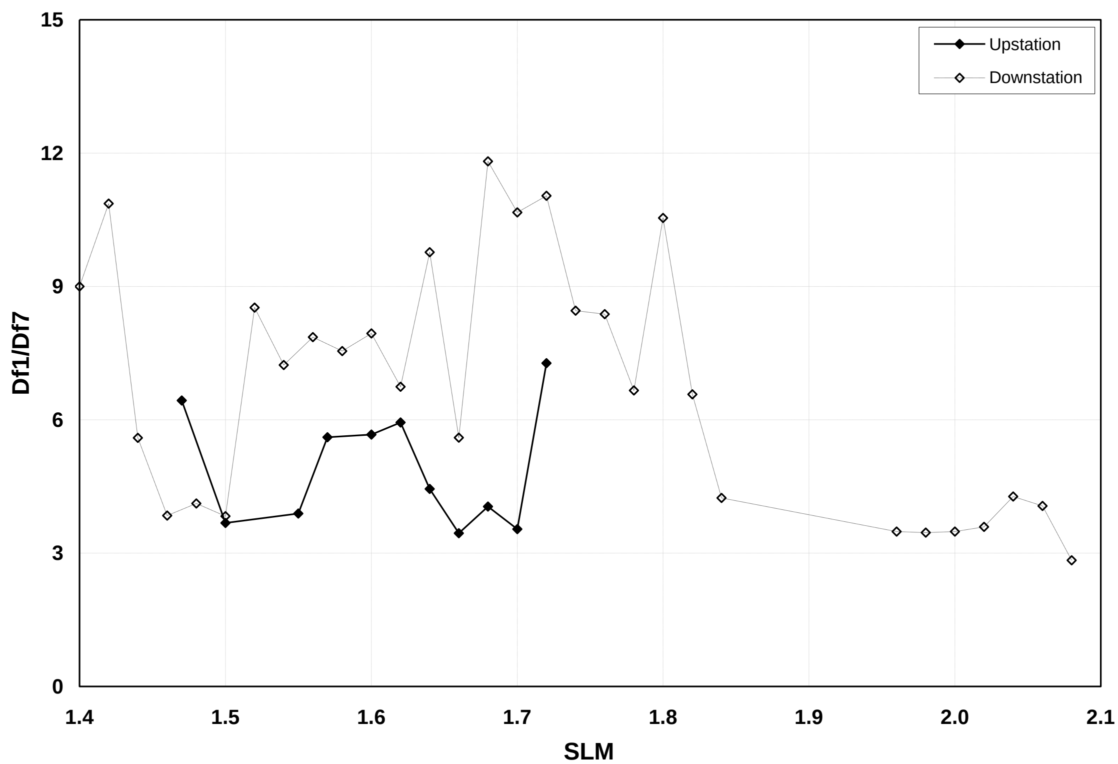


Figure J30. Df1/Df7 – Project 8, LAW 527 (17-85)

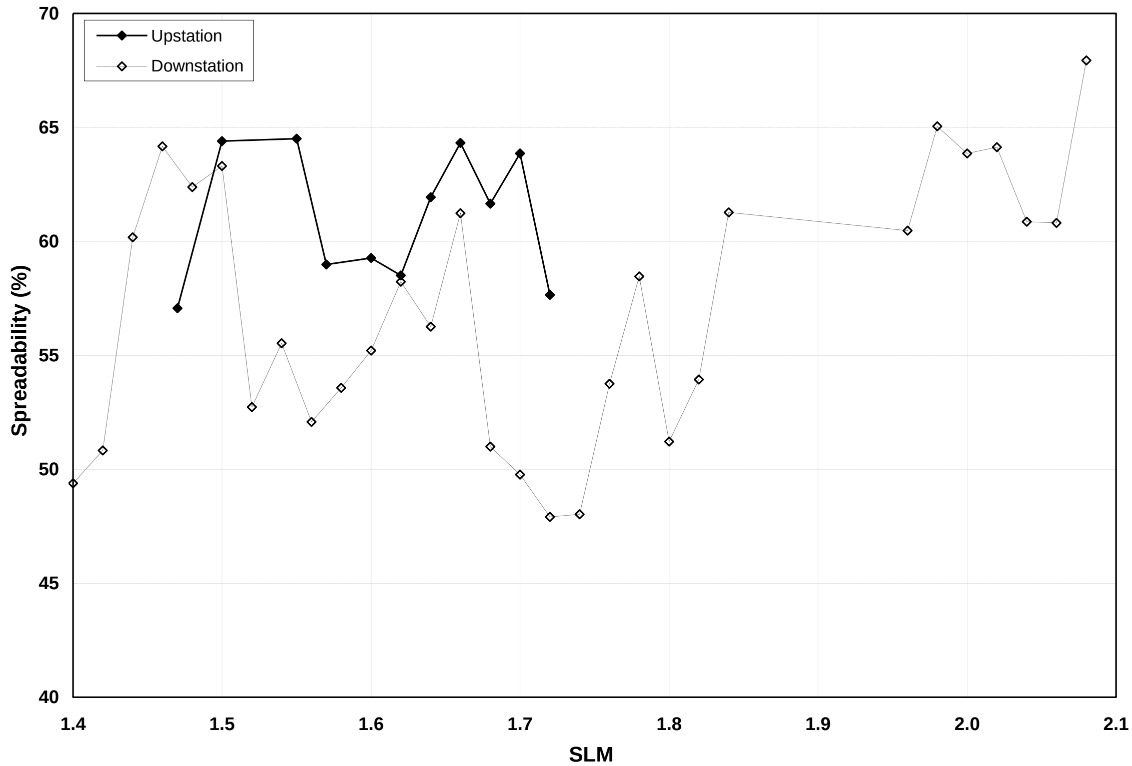


Figure J31. Spreadability – Project 8, LAW 527 (17-85)

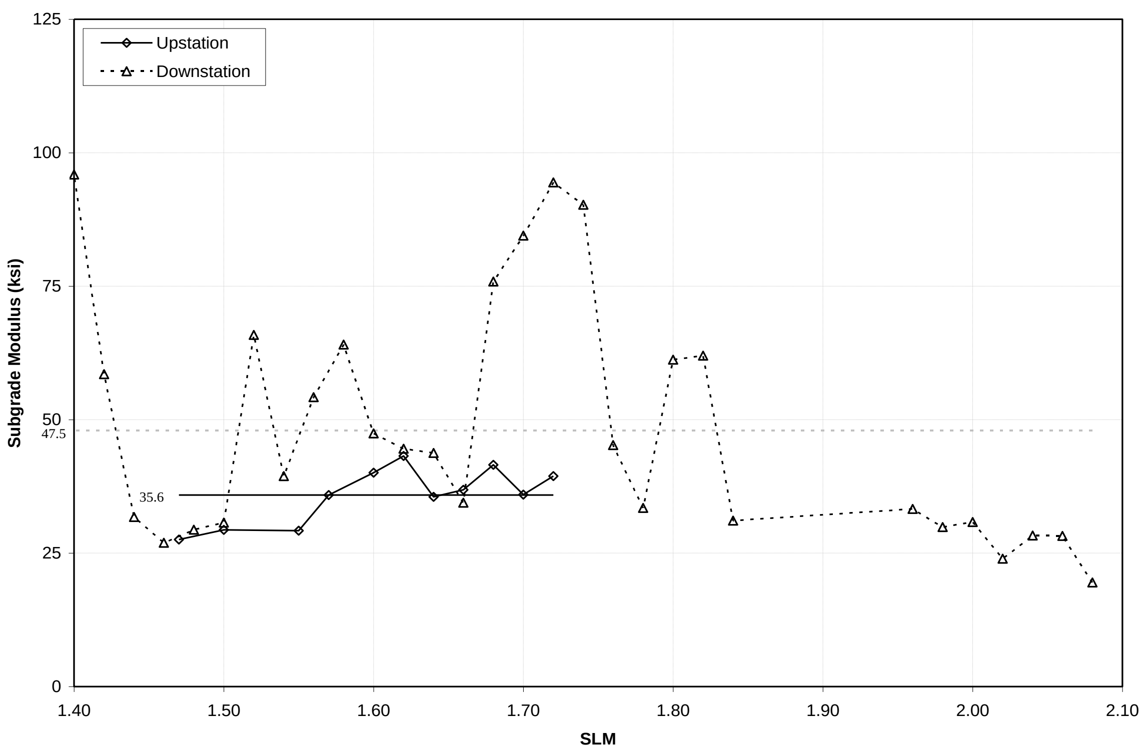


Figure J32. Subgrade Modulus – Project 8, LAW 527 (17-85)

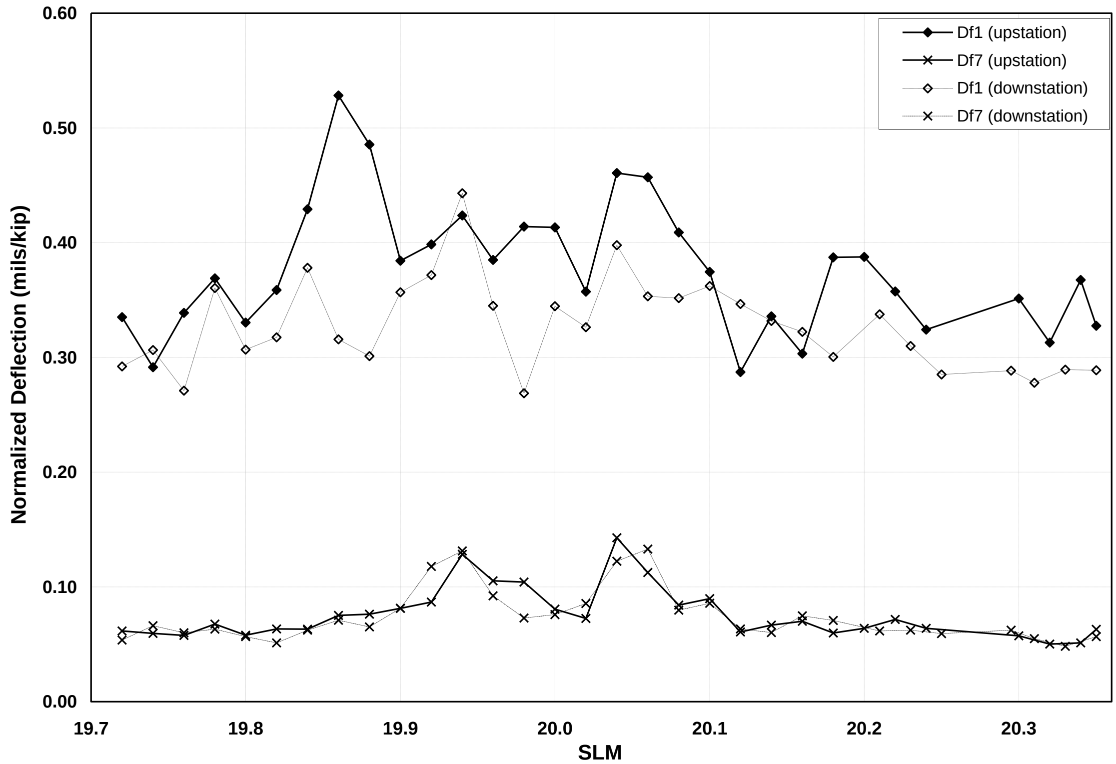


Figure J33. Normalized Deflection - Project 9, LIC 16 (6010-99)

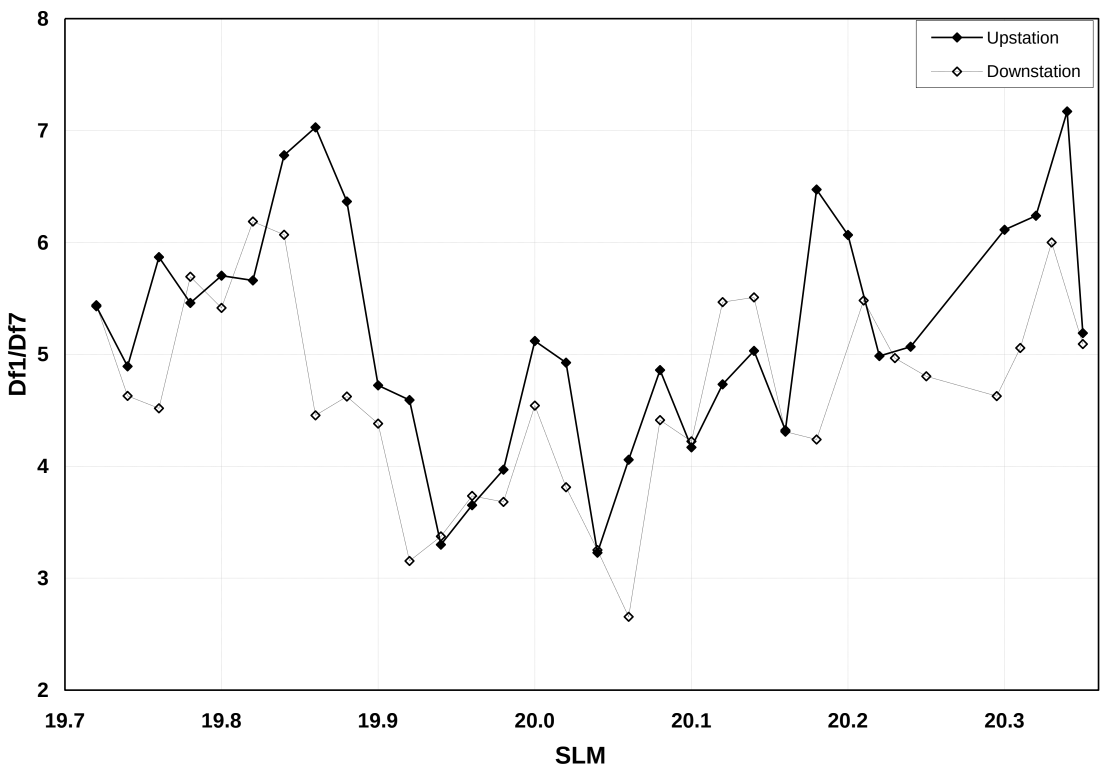


Figure J34. Df1/Df7 – Project 9, LIC 16 (6010-99)

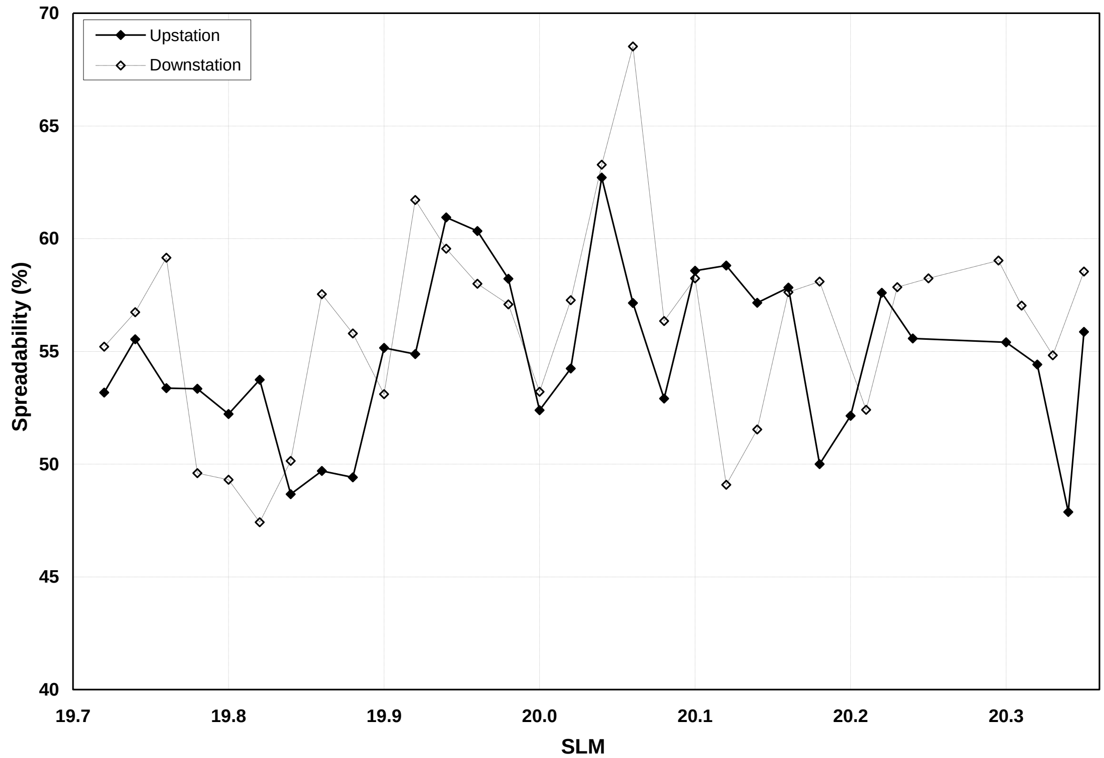


Figure J 35. Spreadability – Project 9, LIC 16 (6010-99)

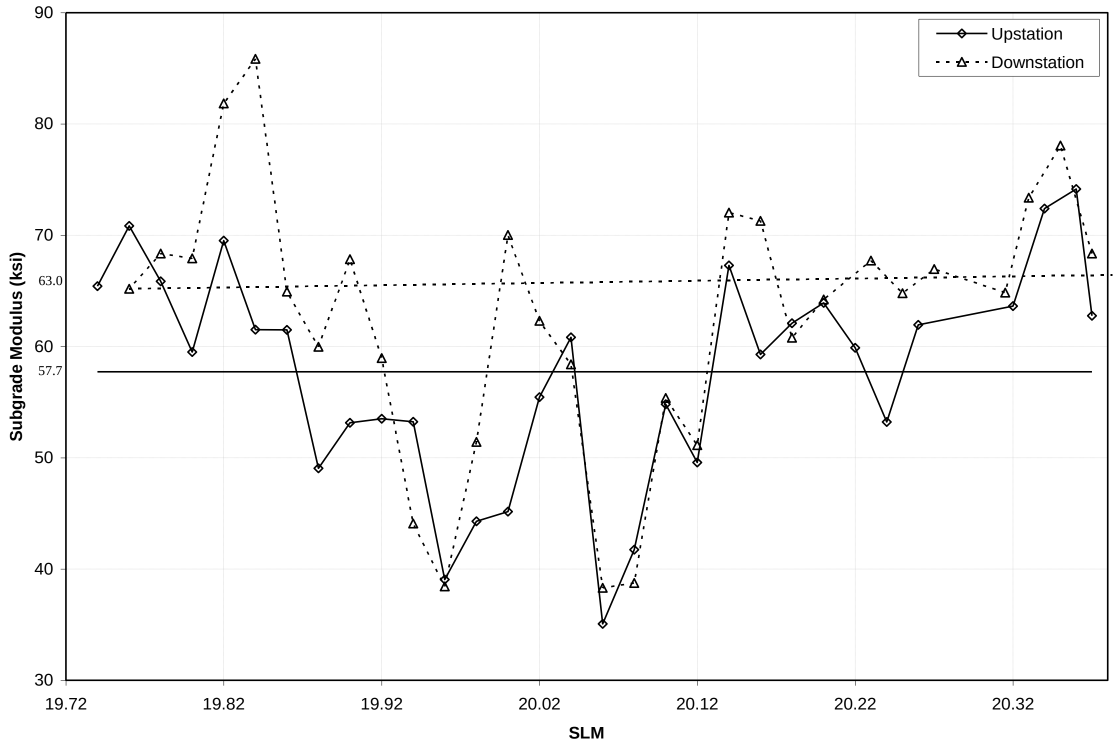


Figure J36. Subgrade Modulus – Project 9, LIC 16 (6010-99)

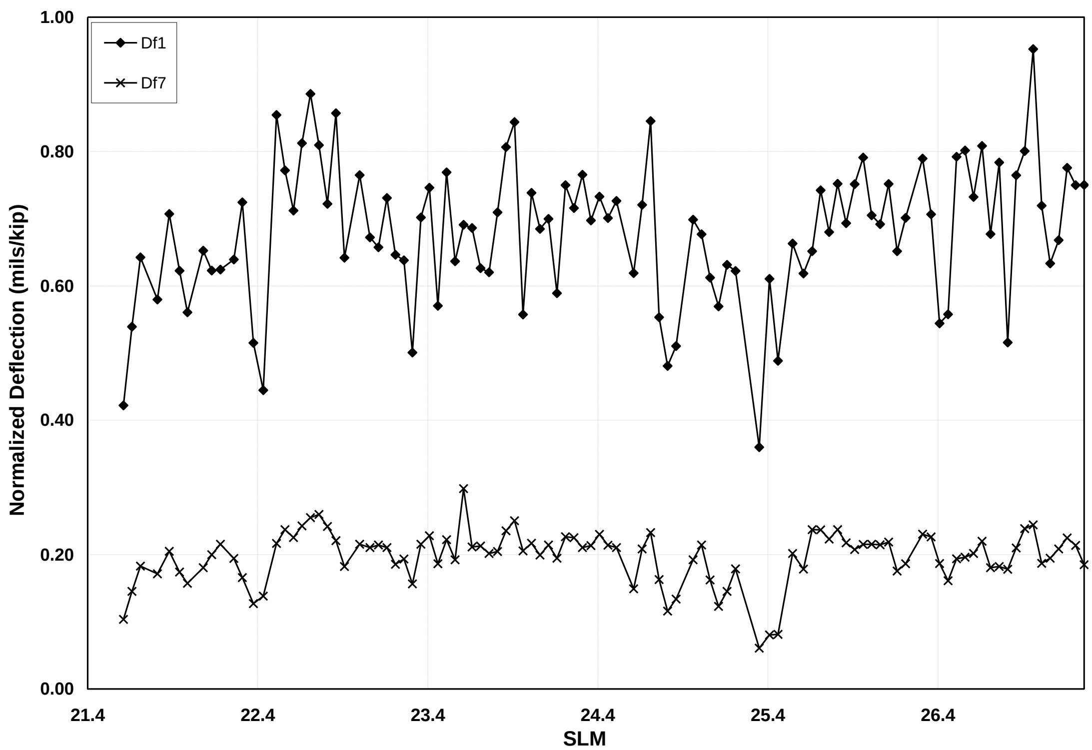


Figure J37. Normalized Deflection - Project 10, LUC 2 (141-99)

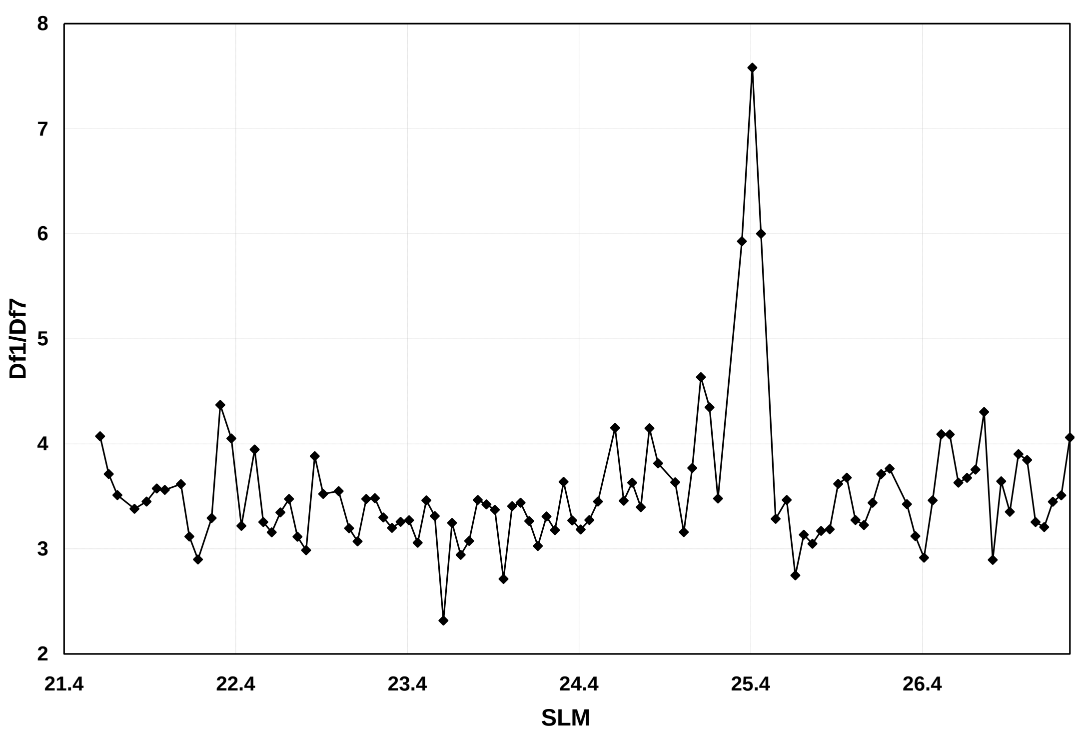


Figure J38. Df1/Df7 – Project 10, LUC 2 (141-99)

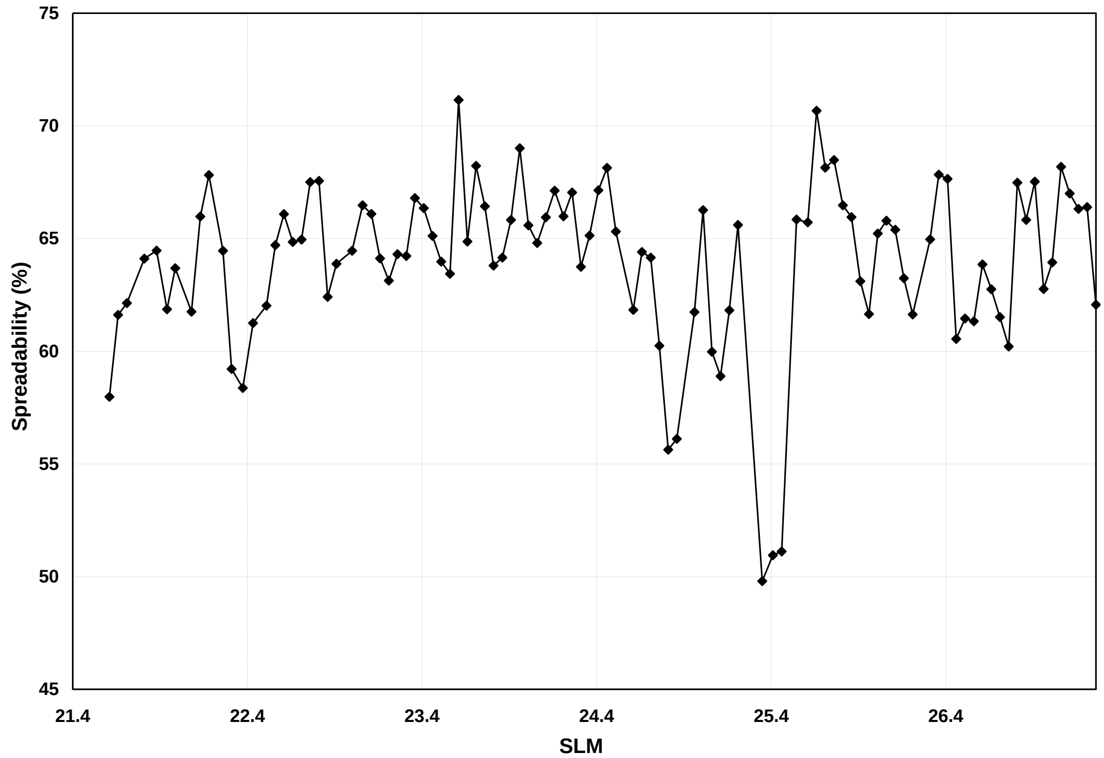


Figure J39. Spreadability – Project 10, LUC 2 (141-99)

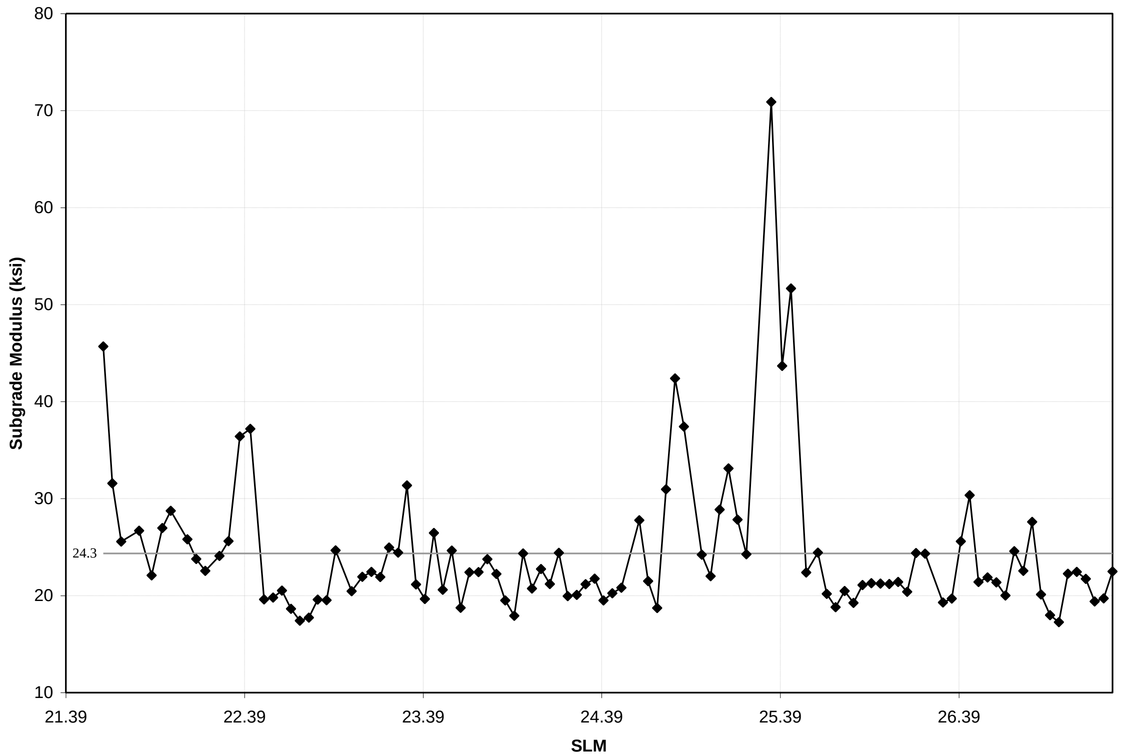


Figure J40. Subgrade Modulus – Project 10, LUC 2 (141-99)

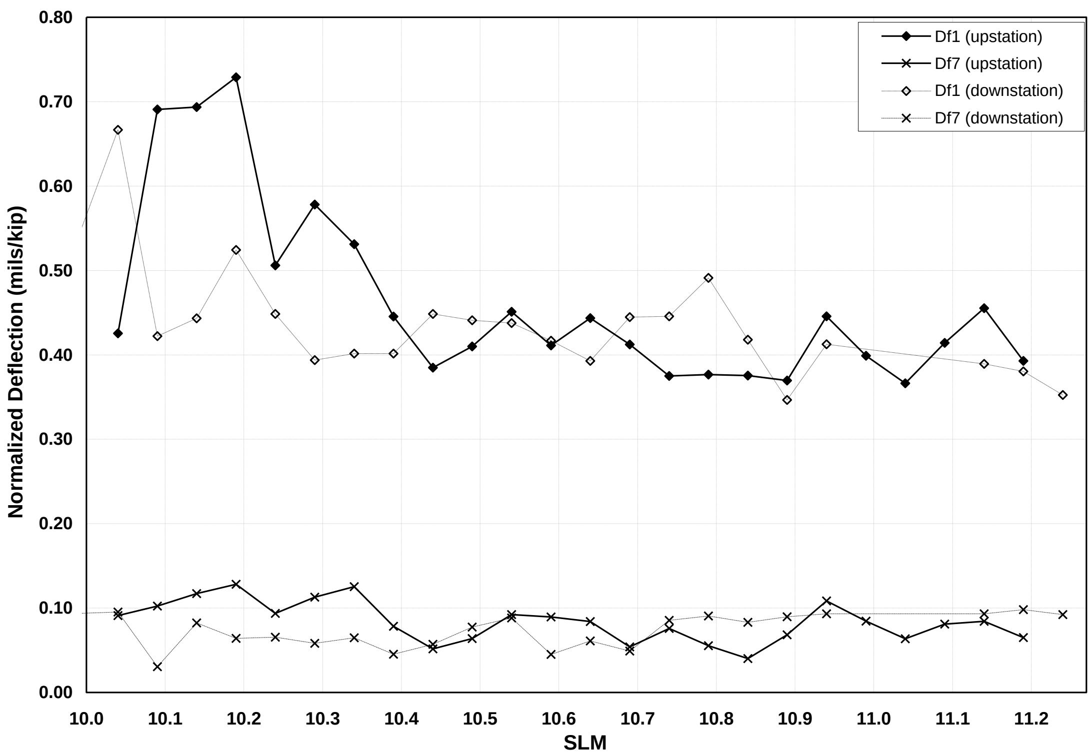


Figure J41. Normalized Deflection - Project 11, LUC 25 (665-97)

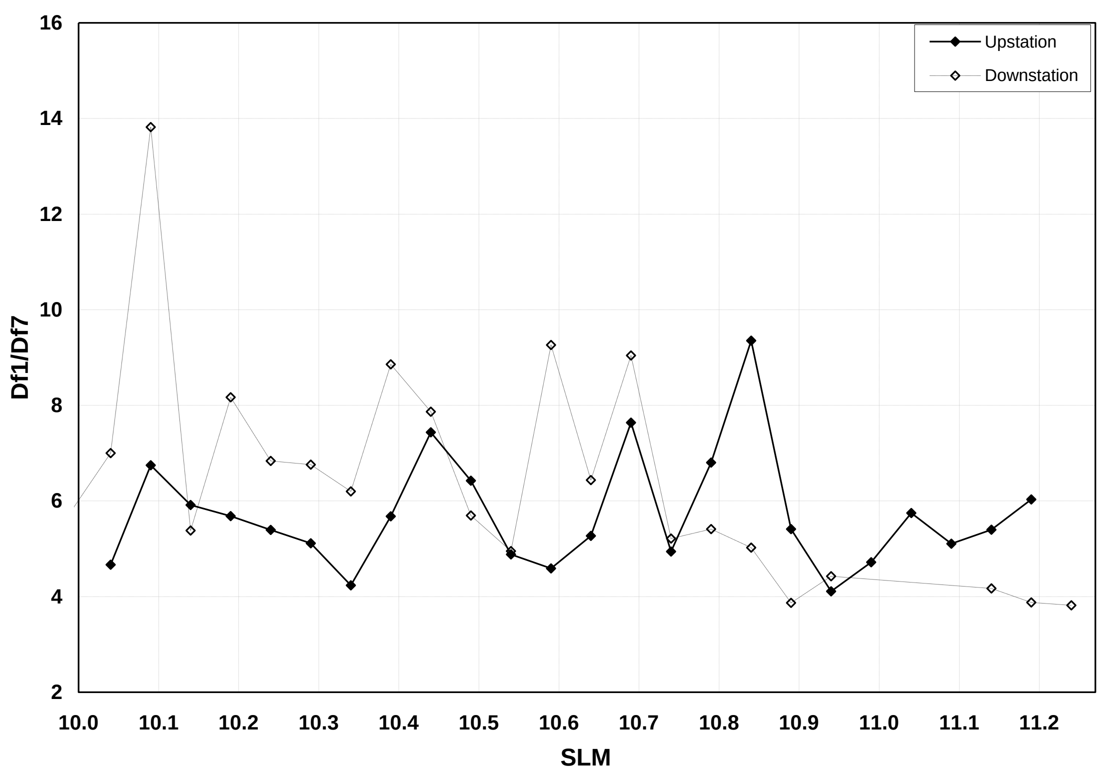


Figure J42. Df1/Df7 – Project 11, LUC 25 (665-97)

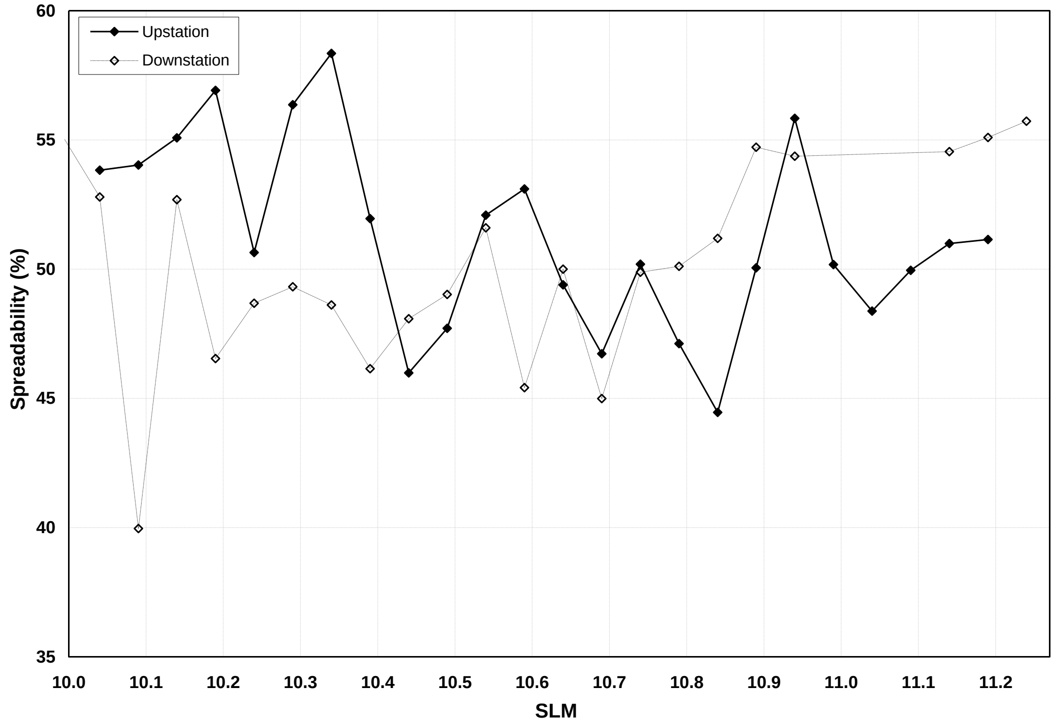


Figure J43. Spreadability - Project 11, LUC 25 (665-97)

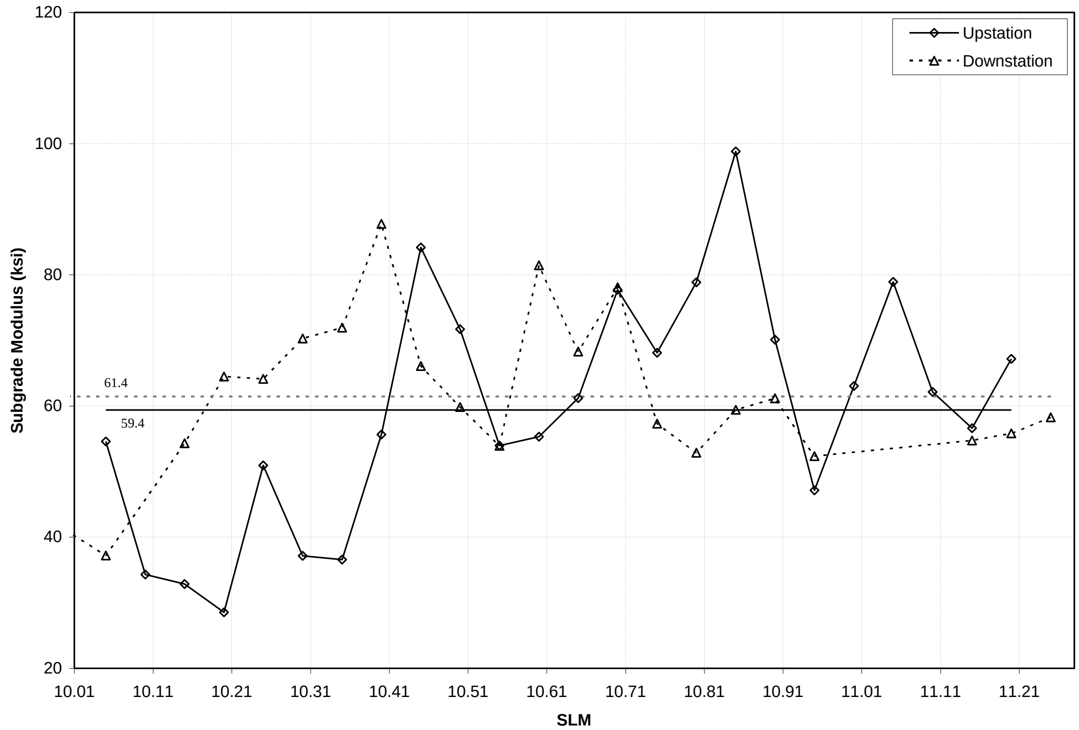


Figure J44. Subgrade Modulus – Project 11, LUC 25 (665-97)

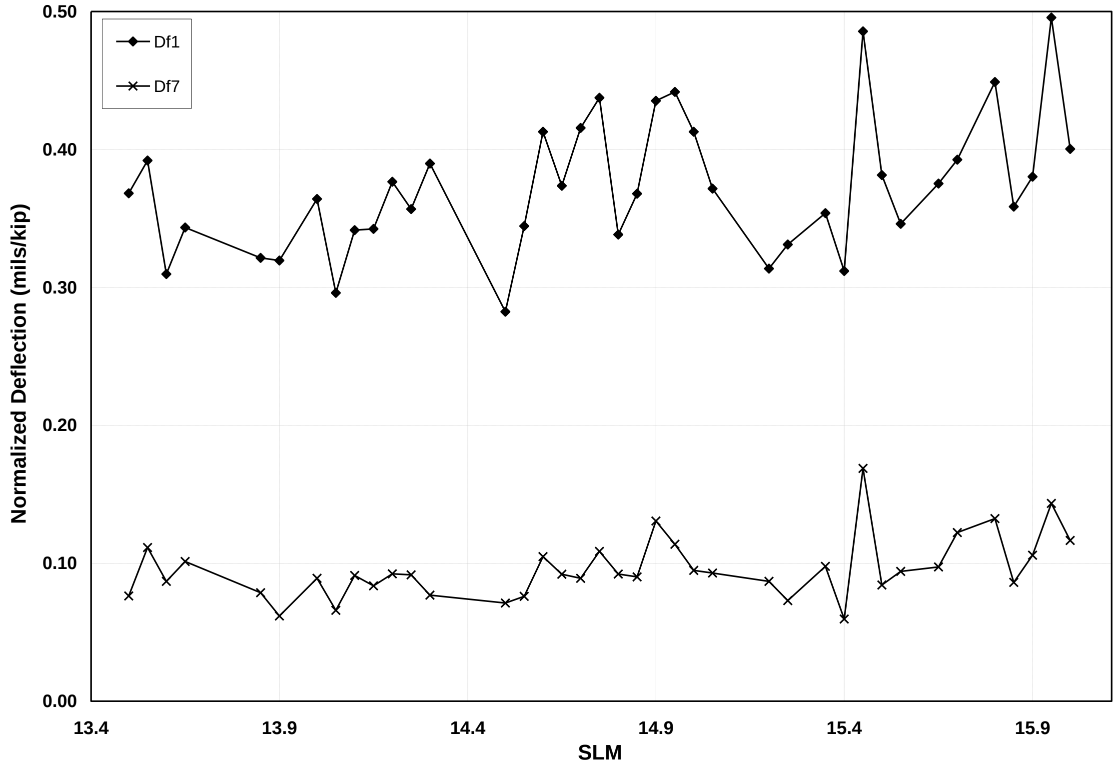


Figure J45. Normalized Deflection - Project 12, PIK 32 (443-94)

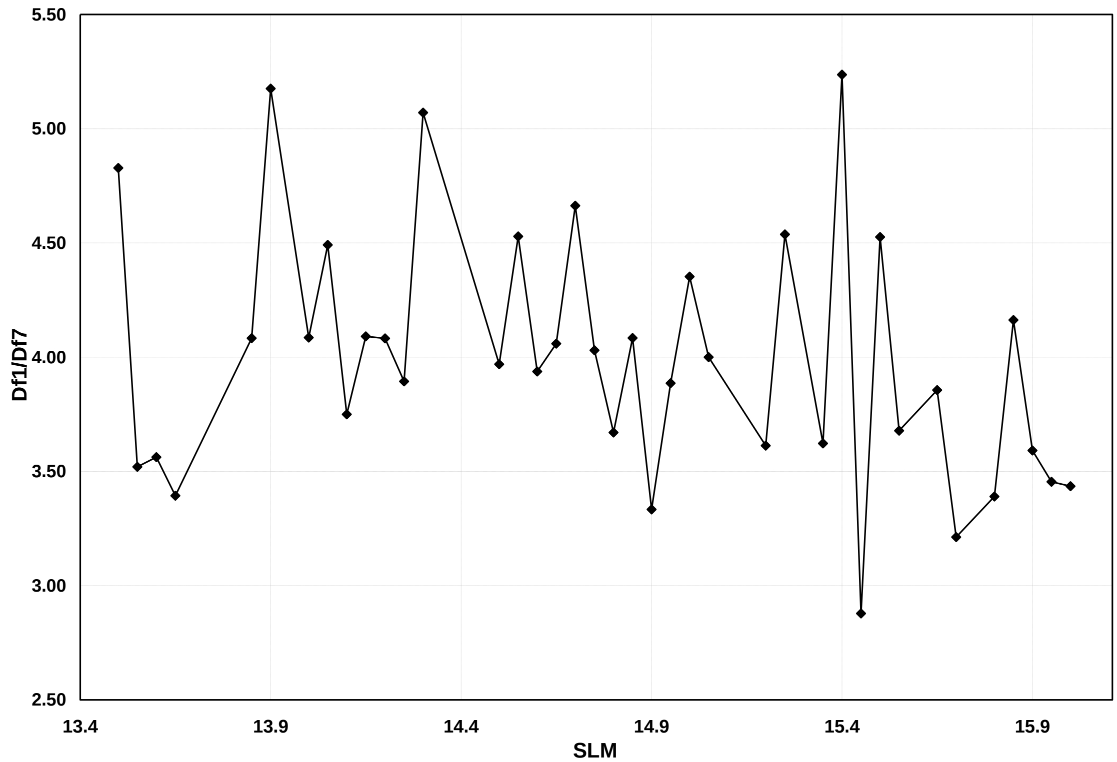


Figure J46. Df1/Df7 Project 12, PIK 32 (443-94)

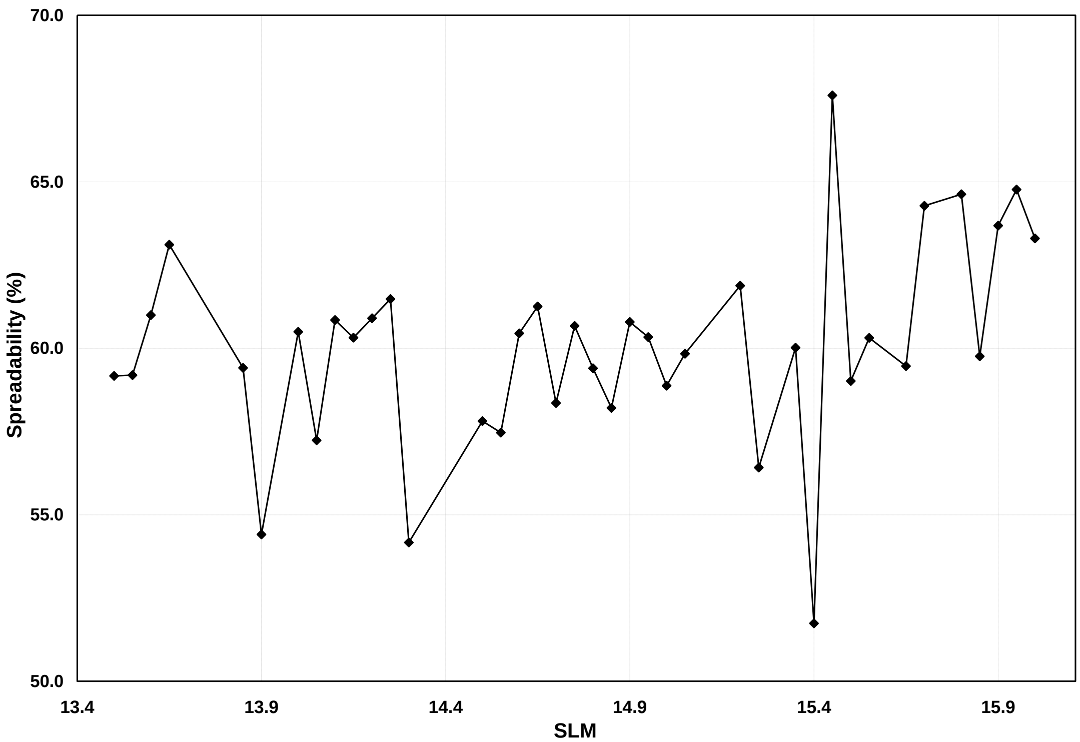


Figure J46. Spreadability – Project 12, PIK 32 (443-94)

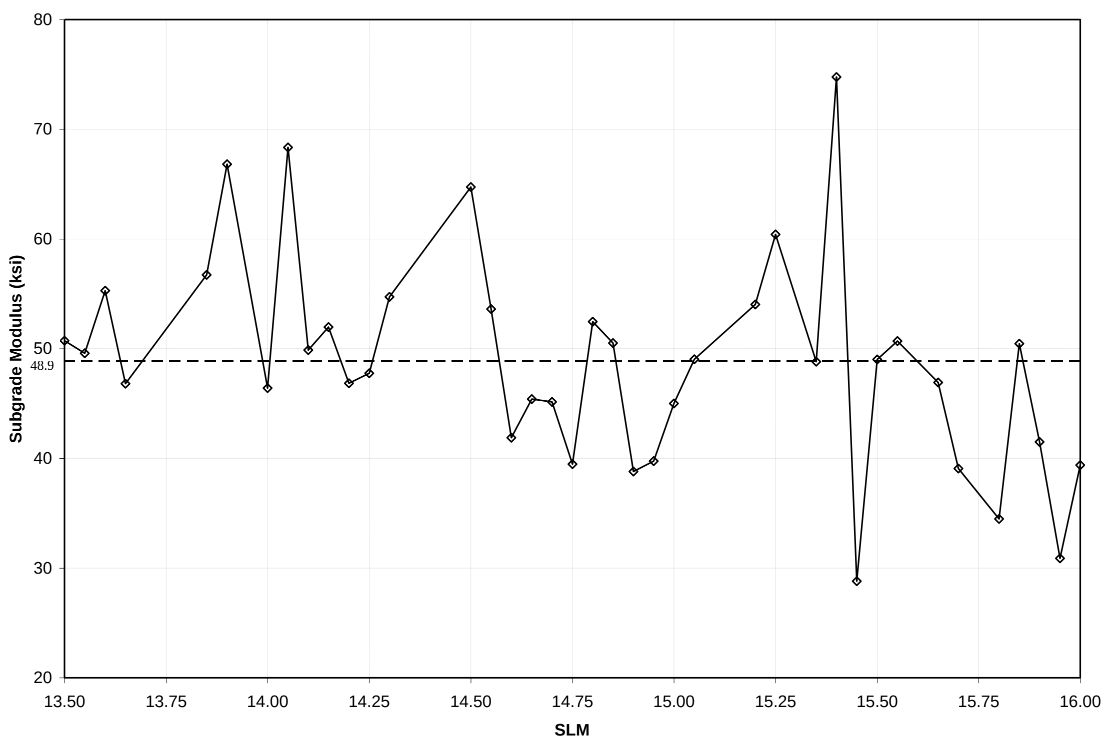


Figure J47. Subgrade Modulus – Project 12, PIK 32 (443-94)

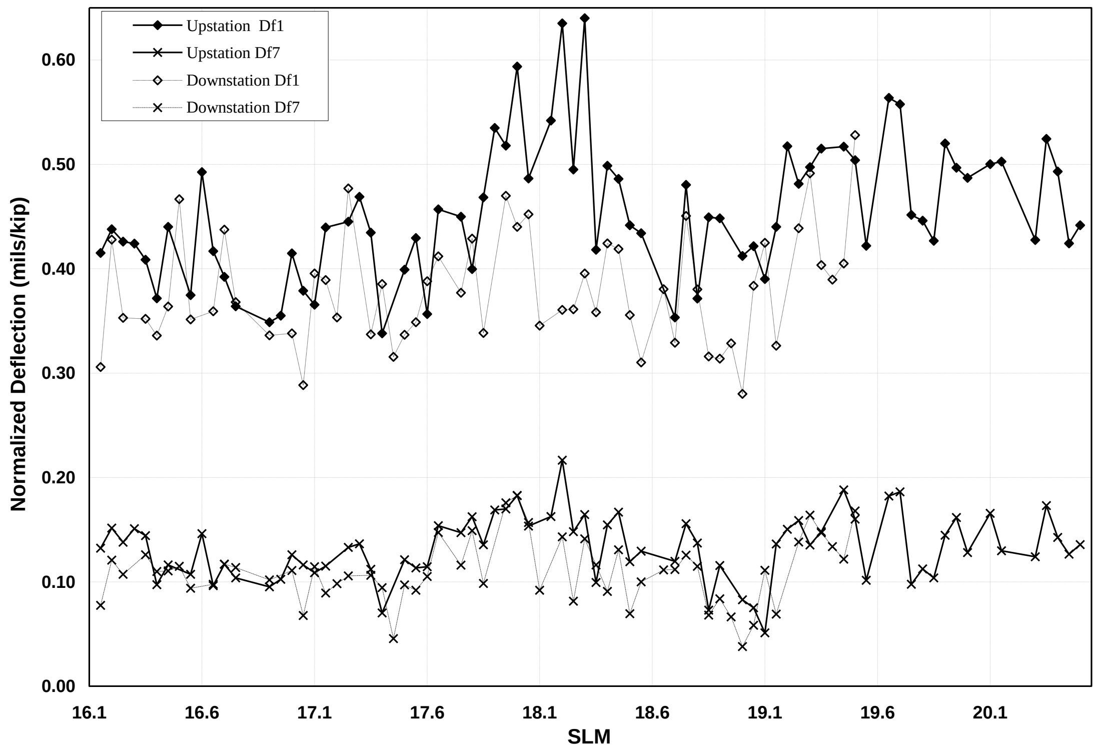


Figure J48. Normalized Deflection – Project 13, PIK 32 (552-95)

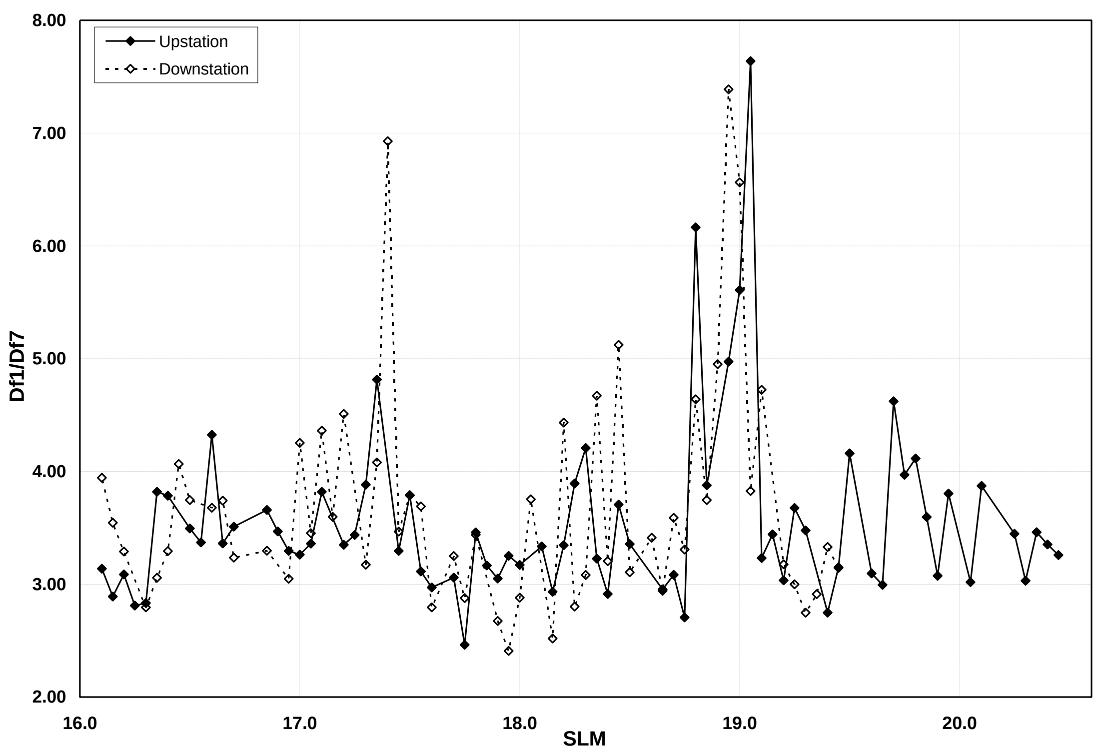


Figure J49. Df1/Df7 – Project 13, PIK 32 (552-95)

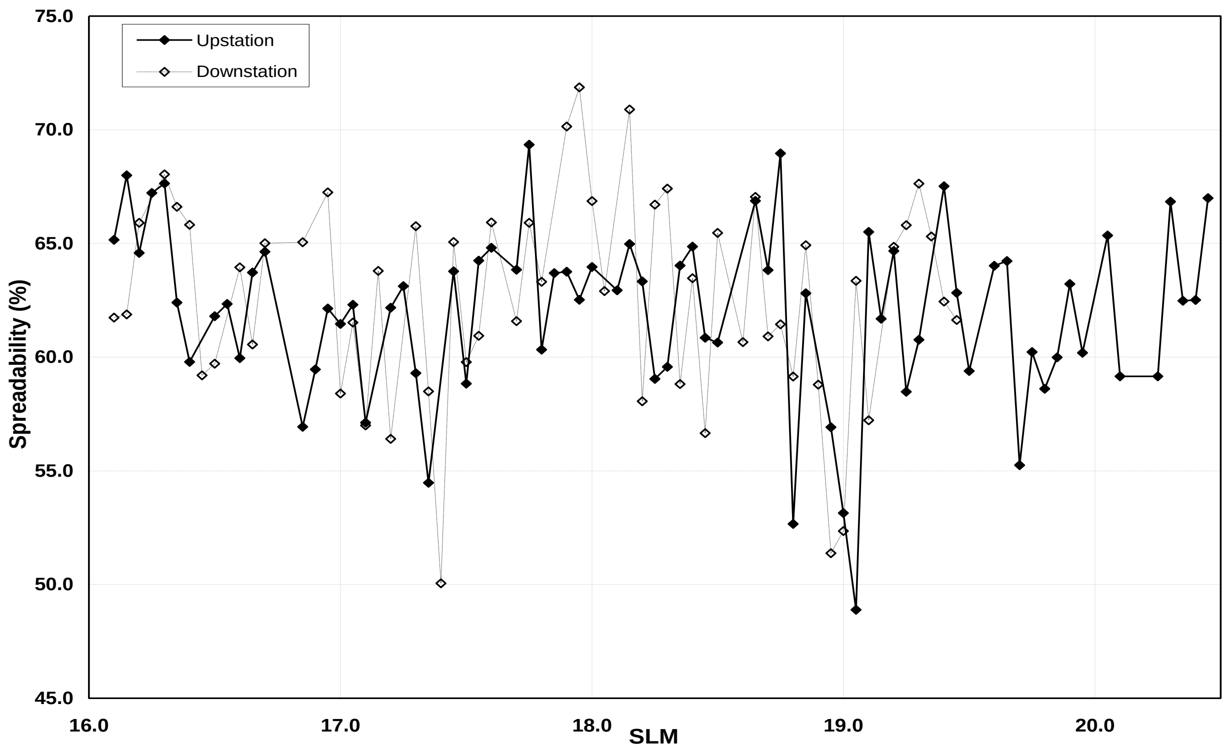


Figure J50. Spreadability – Project 13, PIK 32 (552-95)

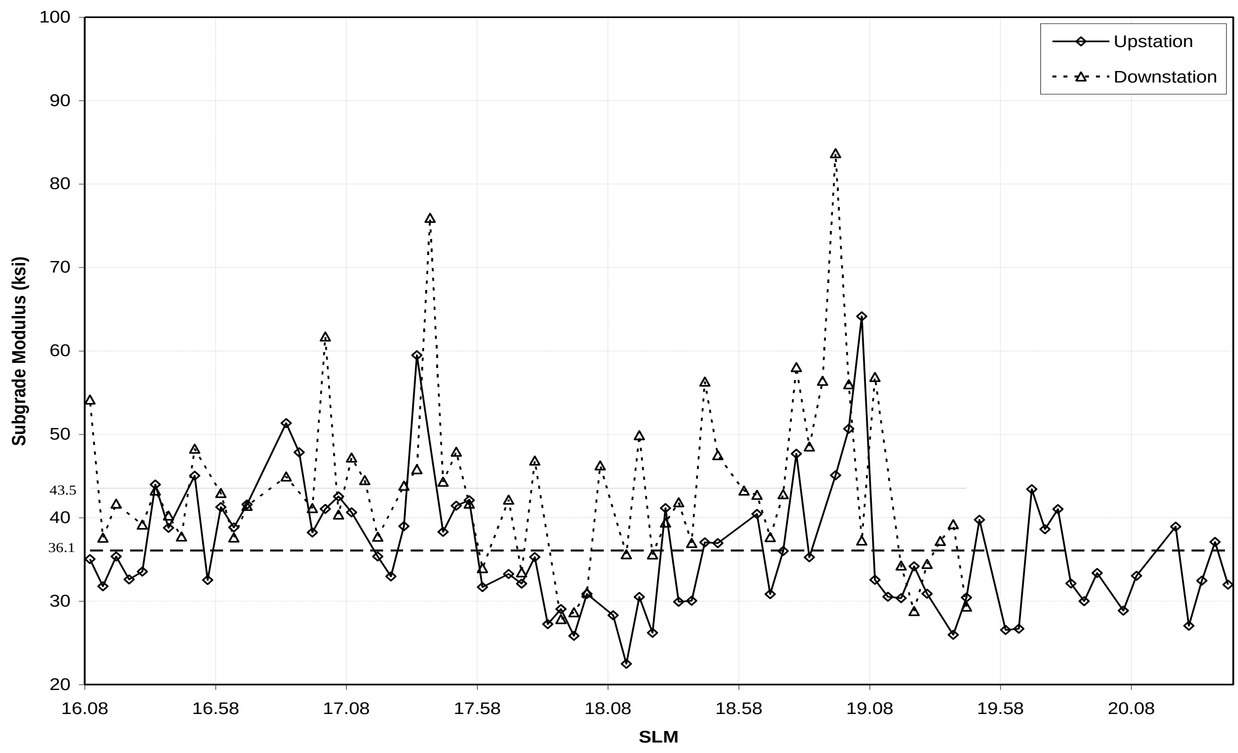


Figure J51. Subgrade Modulus – Project 13, PIK 32 (552-95)

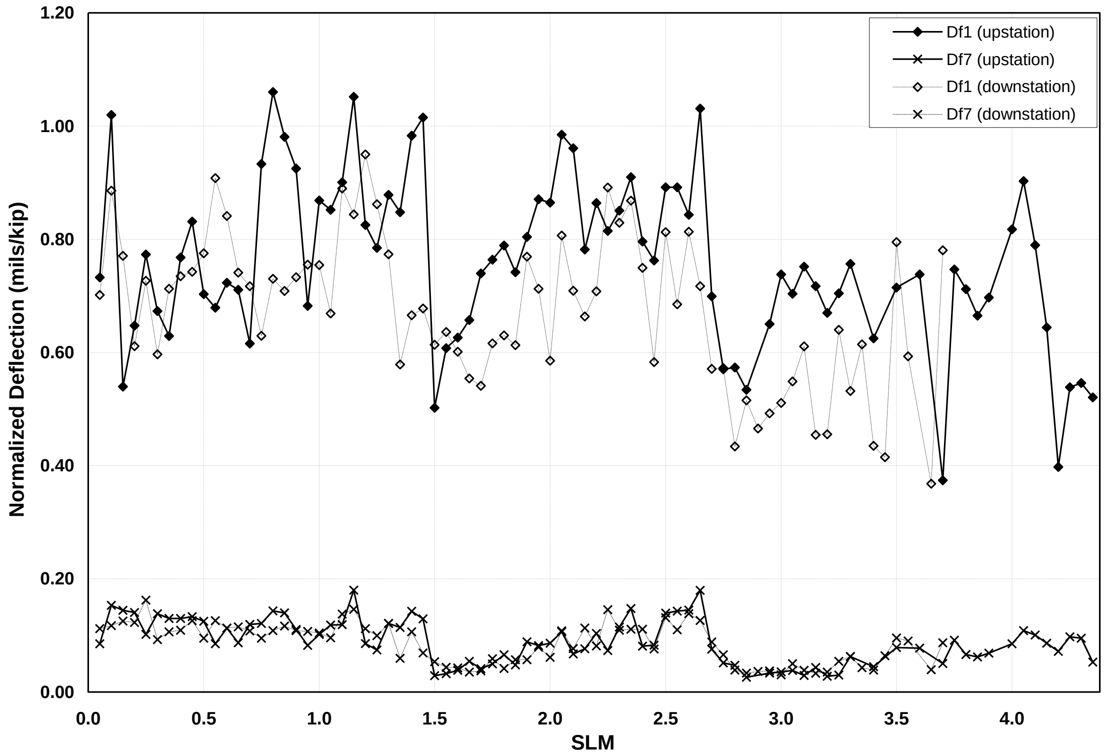


Figure J52. Normalized Deflection – Project 14, FAY 35 (298-96)

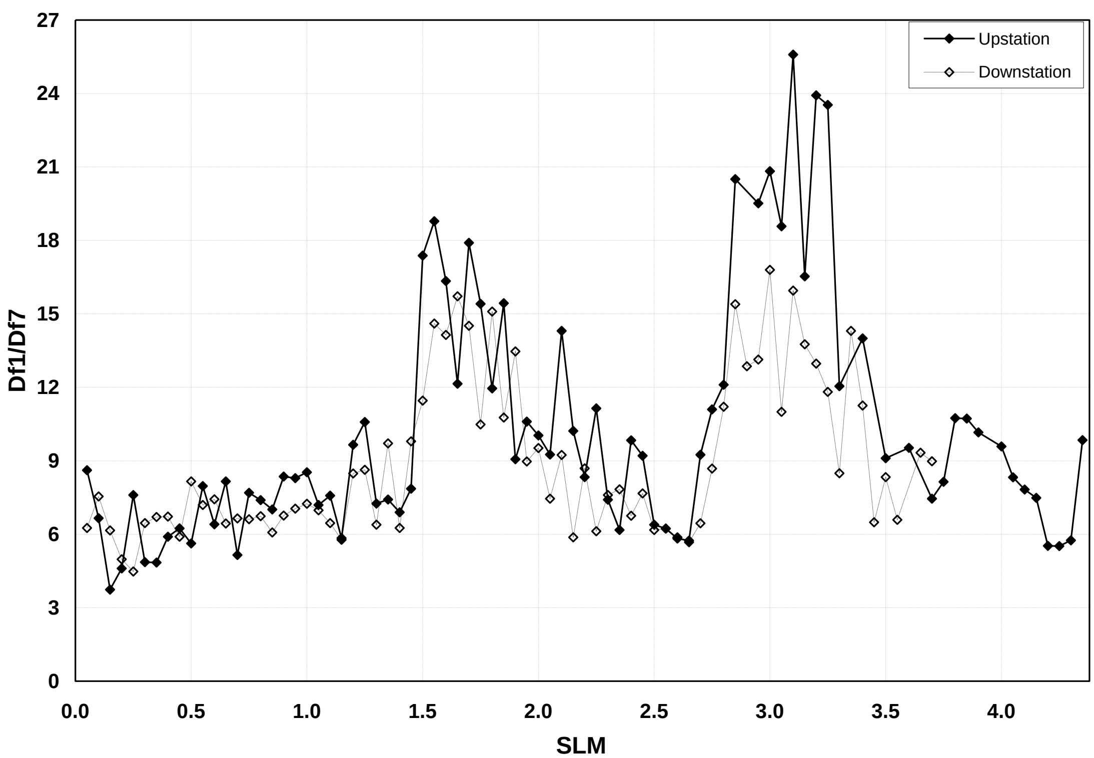


Figure J53. Df1/Df7 – Project 14, FAY 35 (298-96)

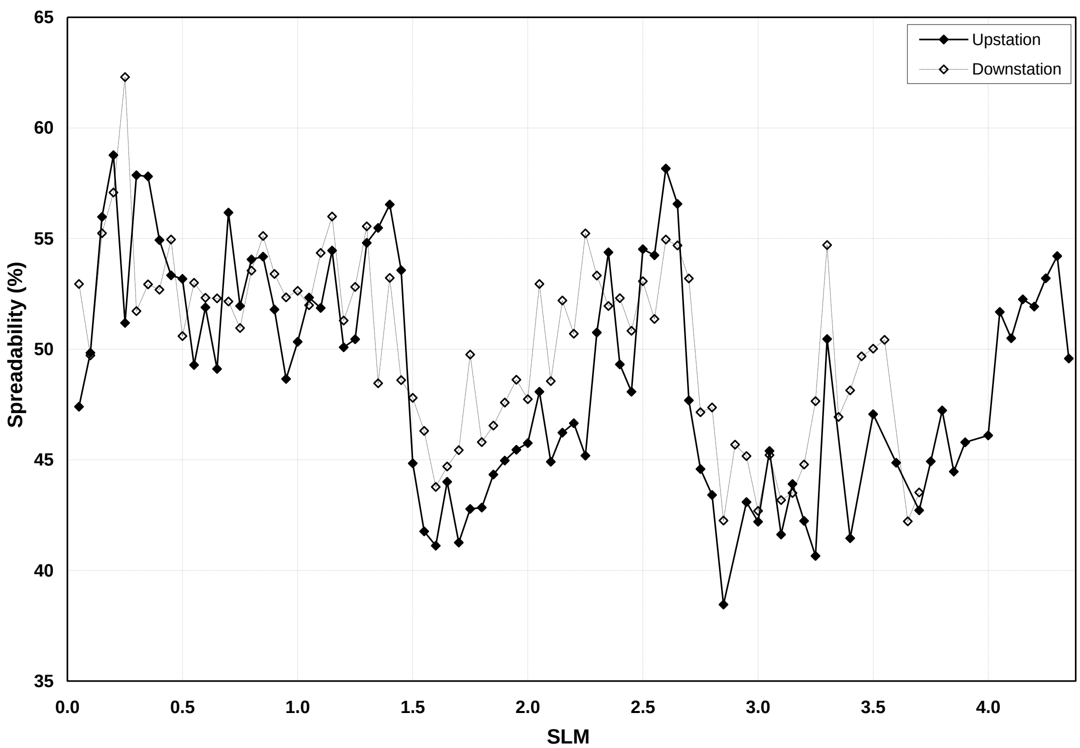
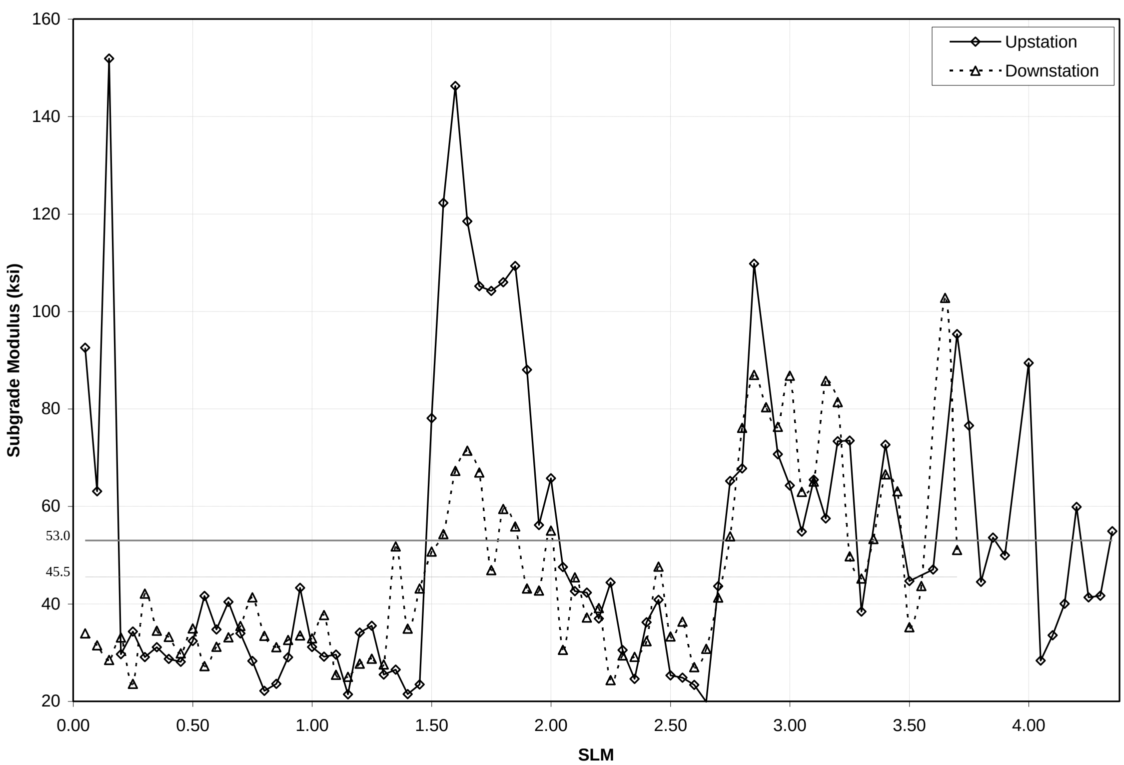


Figure J54. Spreadability – Project 14, FAY 35 (298-96)



FigureJ55. Subgrade Modulus – Project 14, FAY 35 (298-96)

APPENDIX K

FWD Profiles for MEPDG Analysis of Rigid Pavements

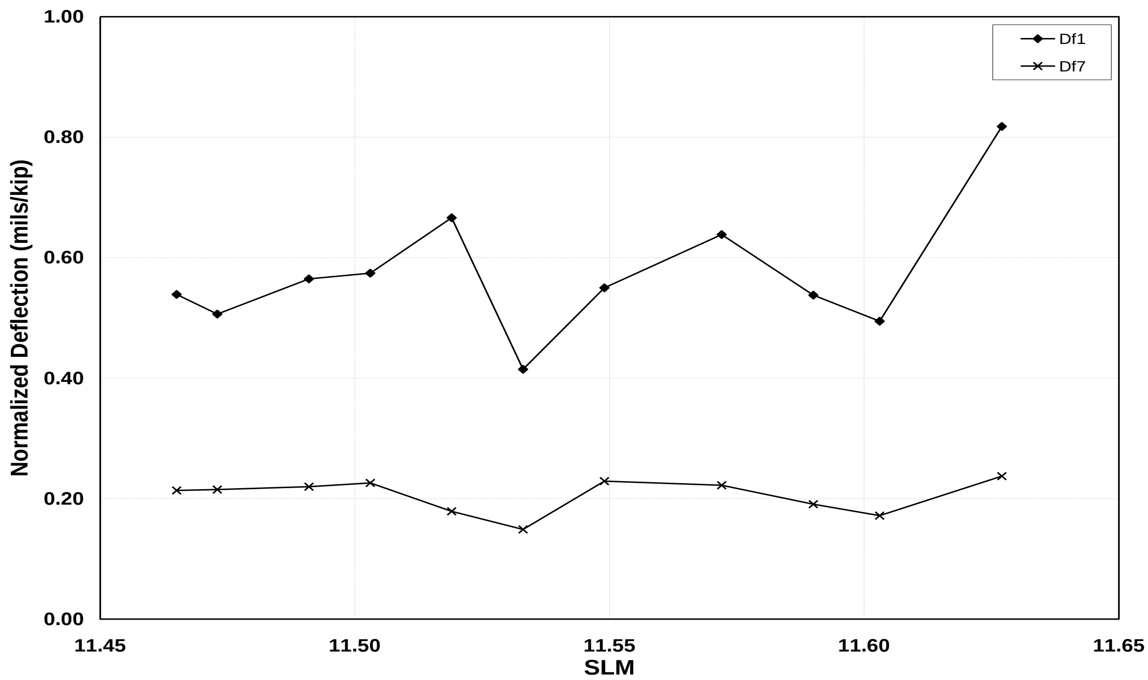


Figure K1. Midslab Deflection – Project 15, ATH 50 (700-86)

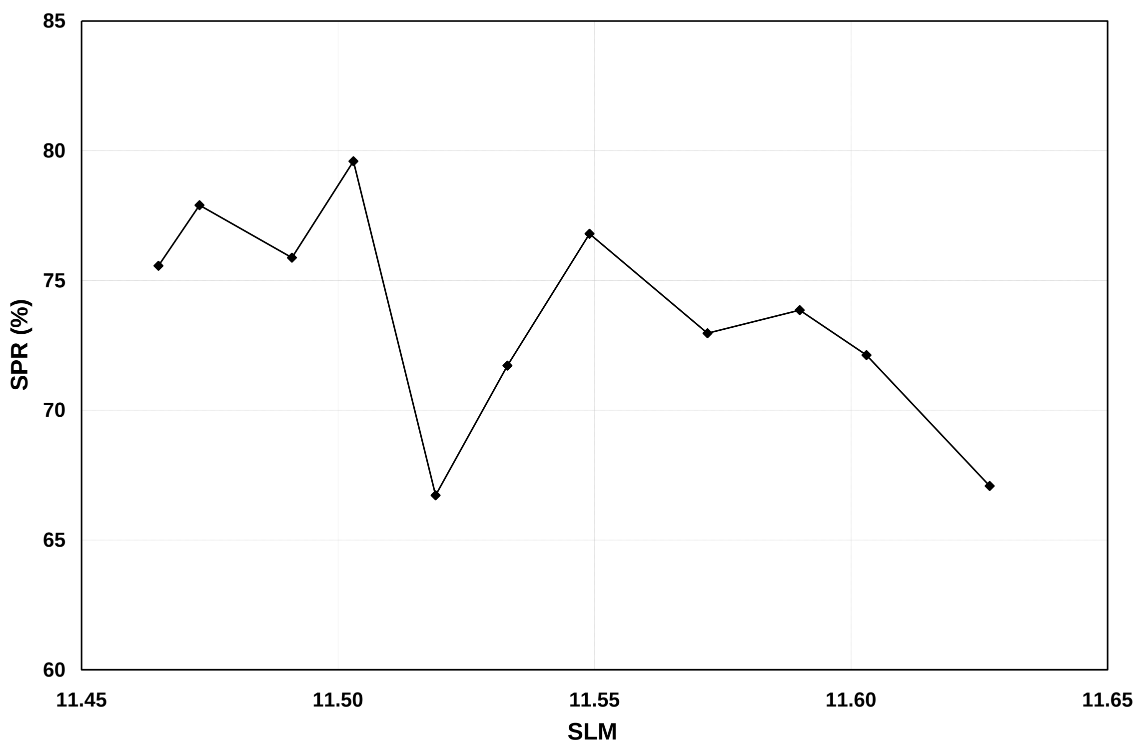


Figure K2. Midslab Spreadability – Project 15, ATH 50 (700-86)

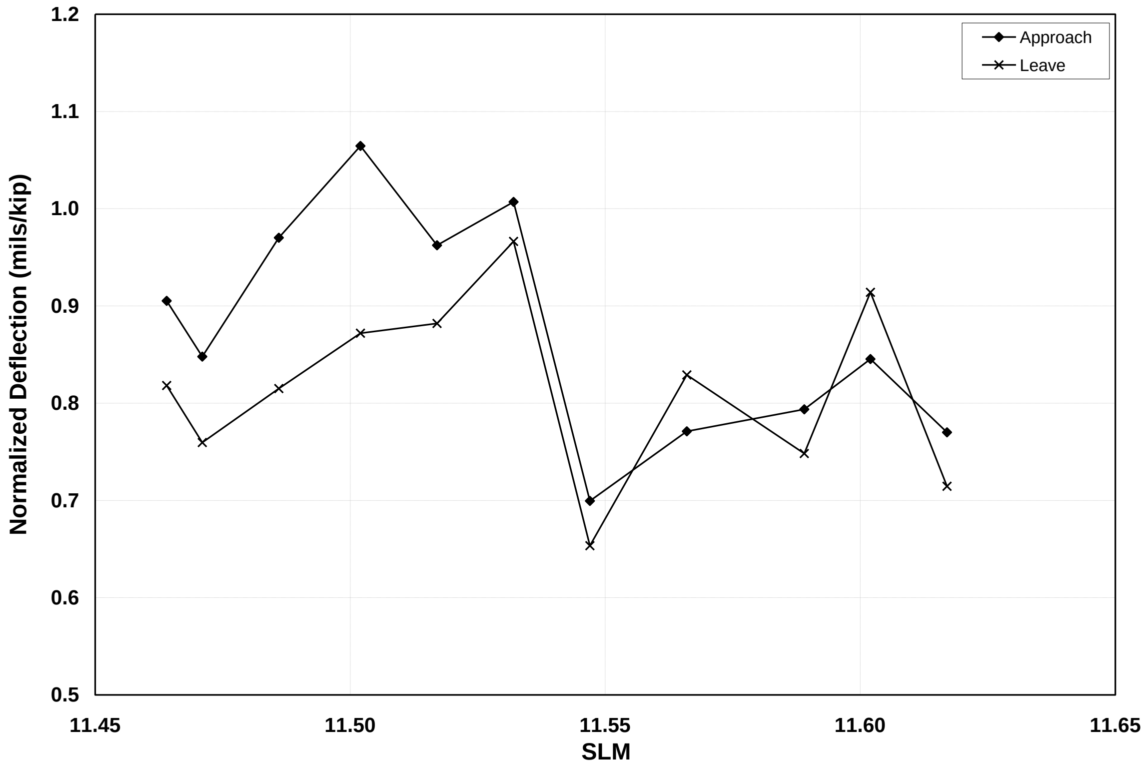


Figure K3. Maximum Joint Deflections – Project 15, ATH 50 (700-86)

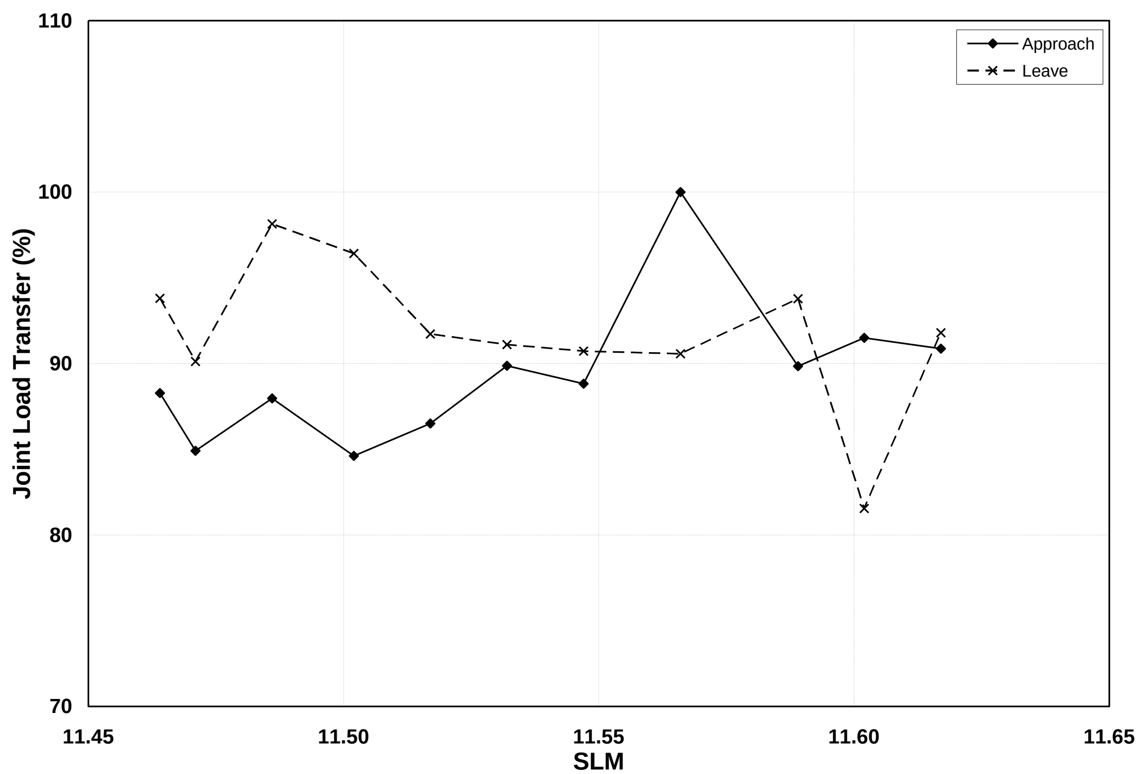


Figure K4. Joint Load Transfer – Project 15, ATH 50 (700-86)L

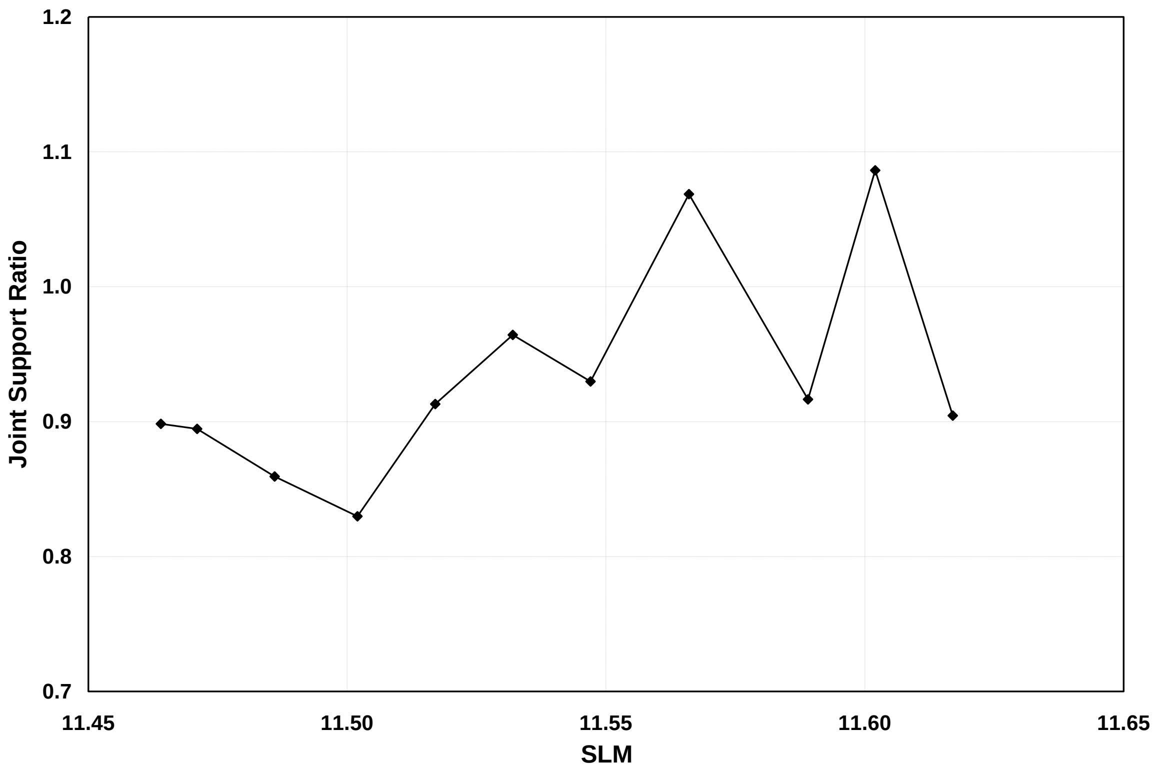


Figure K5. Joint Support Ratio – Project 15, ATH 50 (700-86)

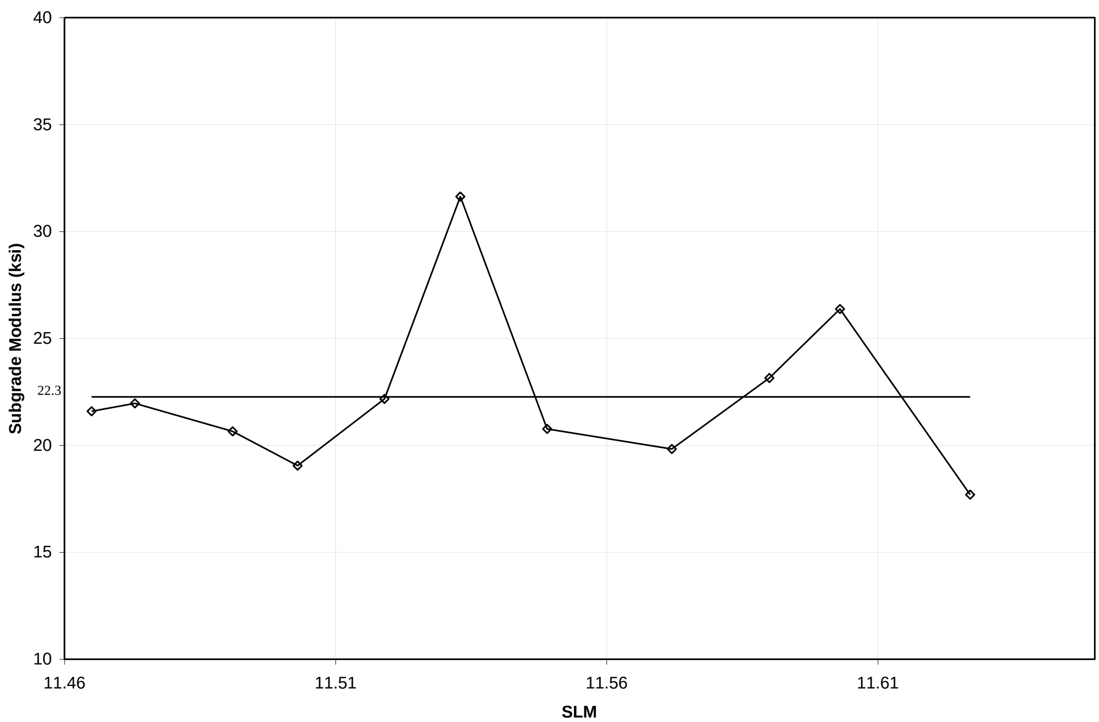


Figure K6. Subgrade Modulus – Project 15, ATH 50 (700-86)

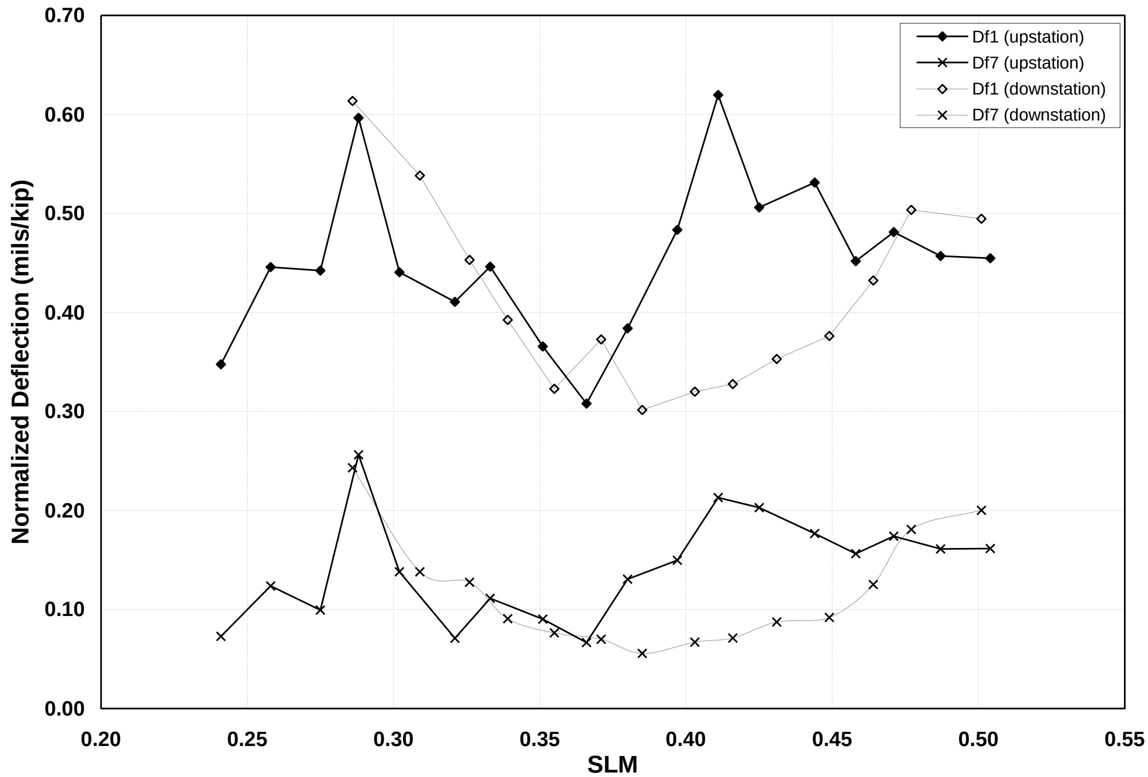


Figure K7. Midslab deflection – Project 16, ATH 682 (625-76)

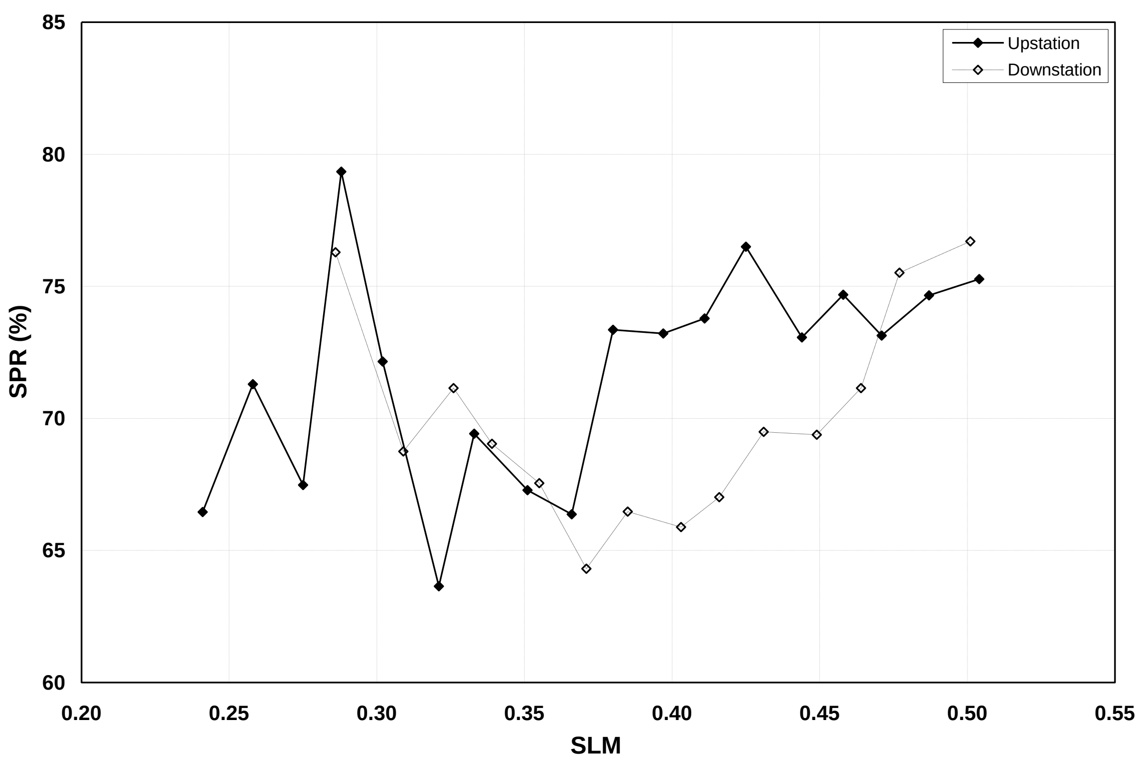


Figure K8. Midslab Spreadability – Project 16, ATH 682 (625-76)

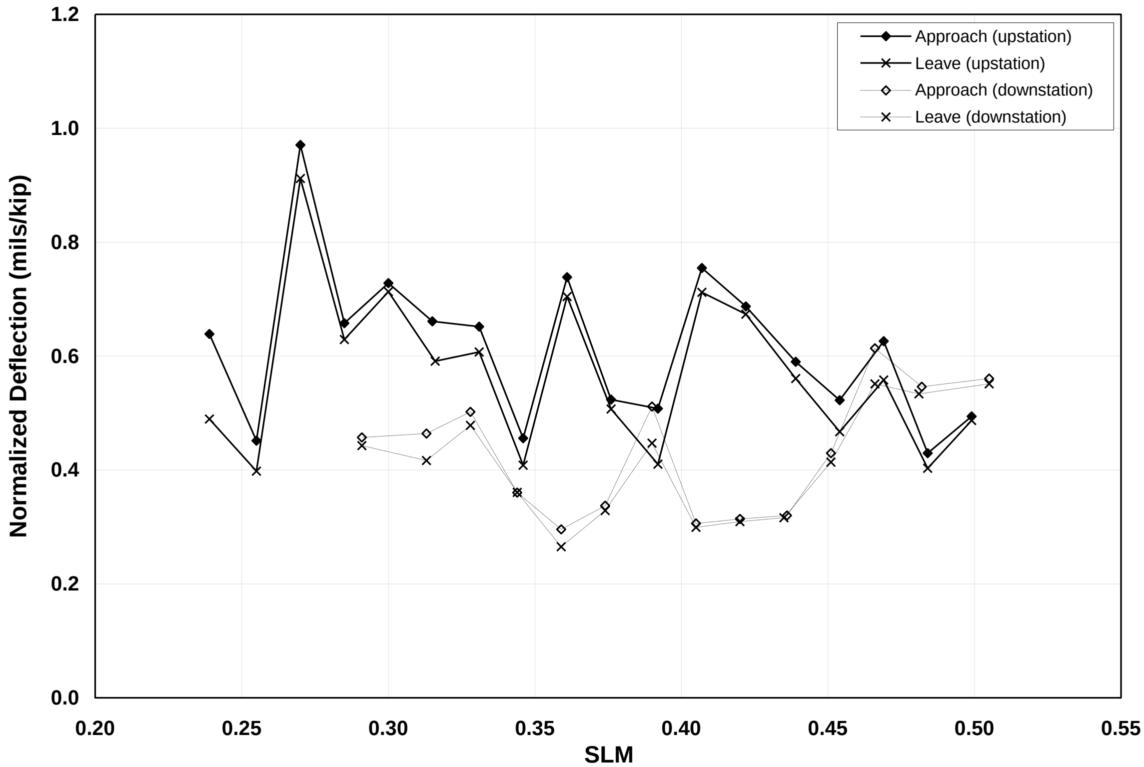


Figure K9. Maximum Joint Deflections – Project 16, ATH 682 (625-76)

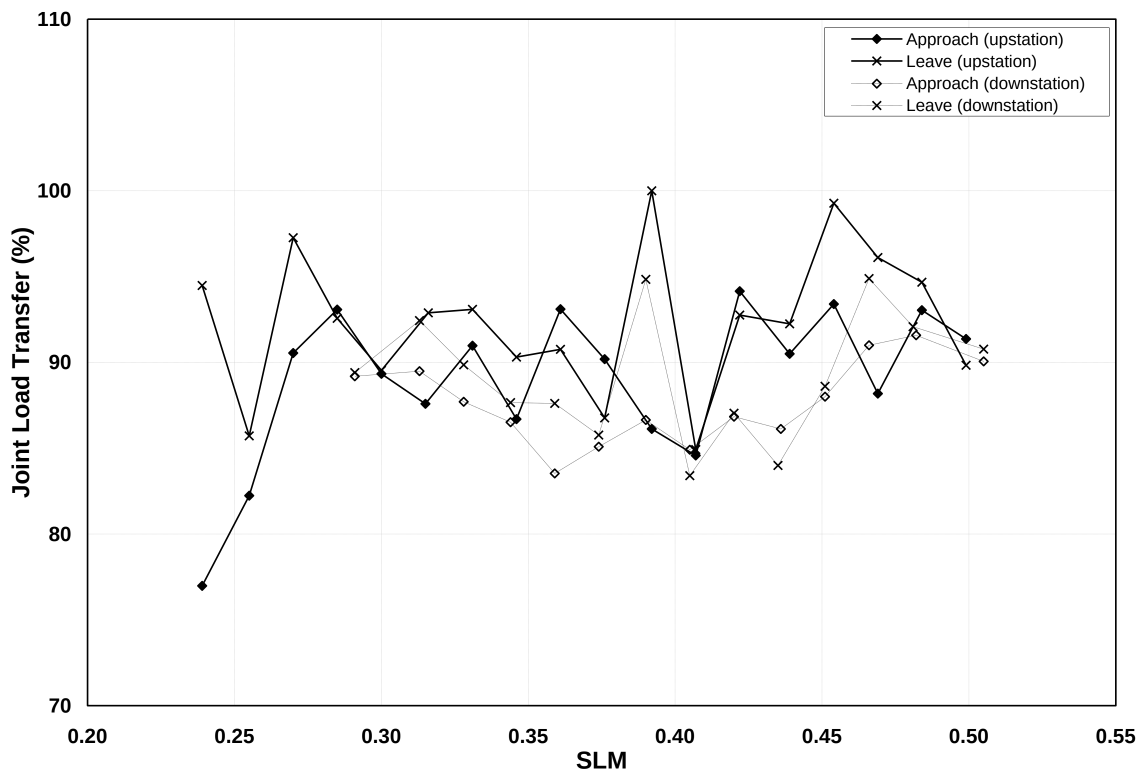


Figure K10. Joint Load Transfer – Project 16, ATH 682 (625-76)

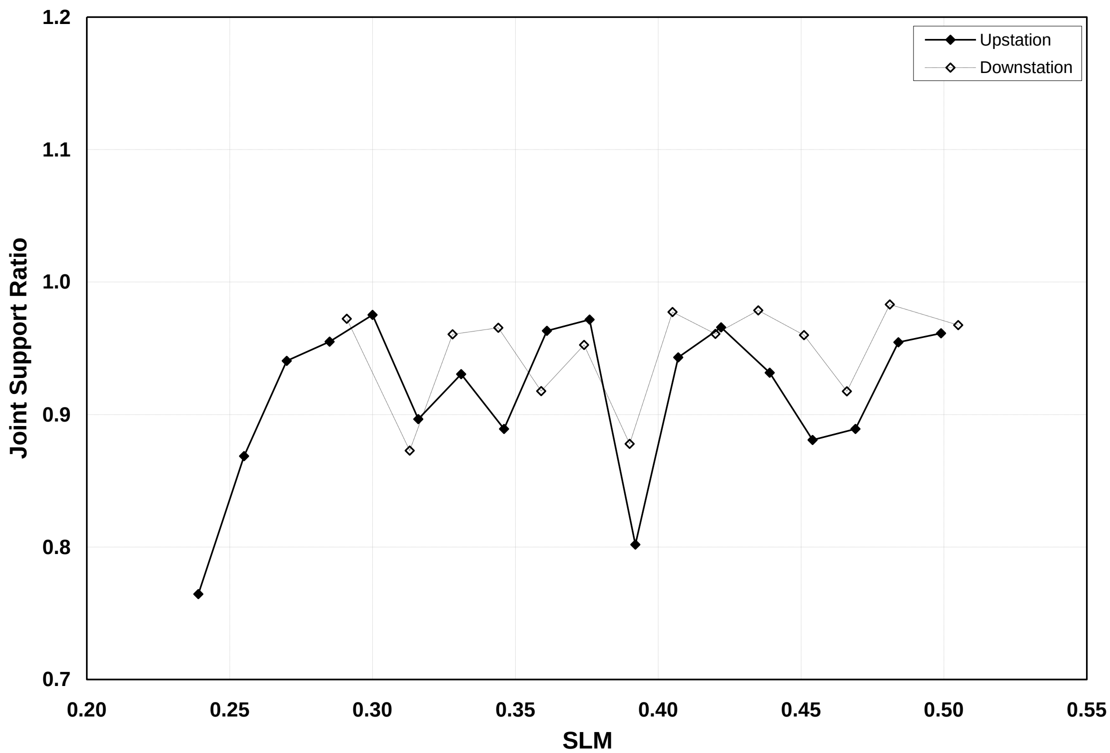


Figure K11. Joint Support Ratio – Project 16, ATH 682 (625-76)

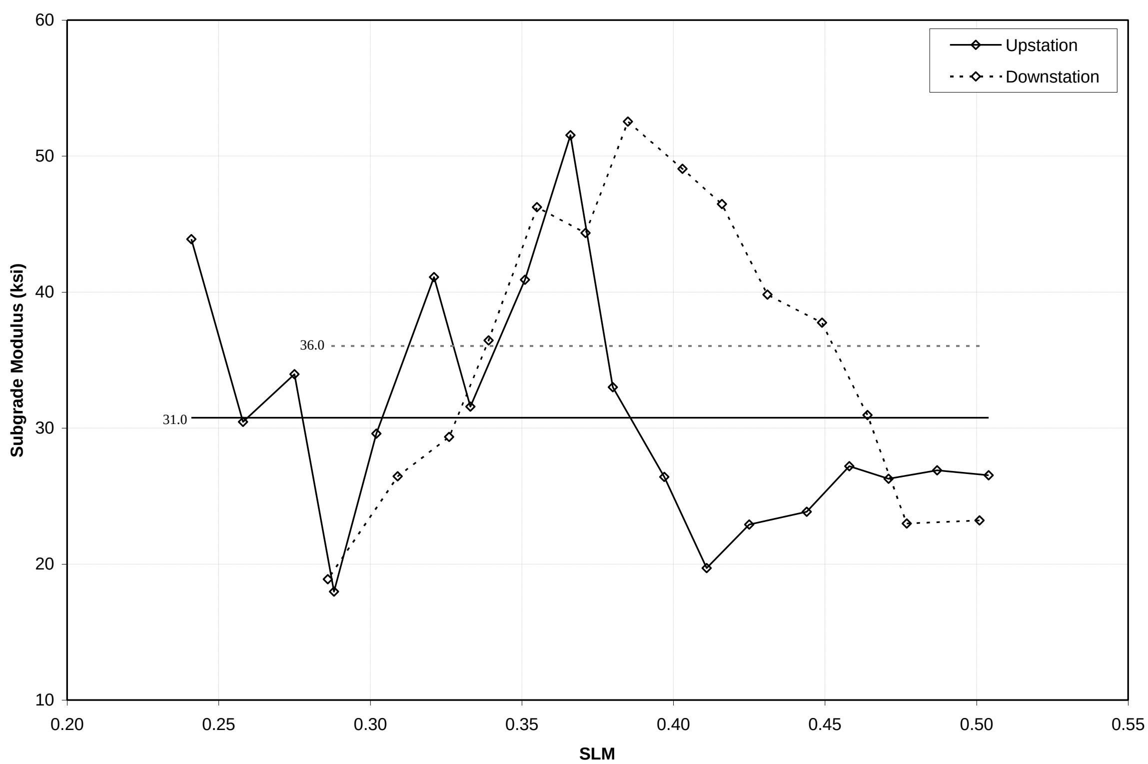


Figure K12. Subgrade Modulus – Project , ATH 682 (625-76)

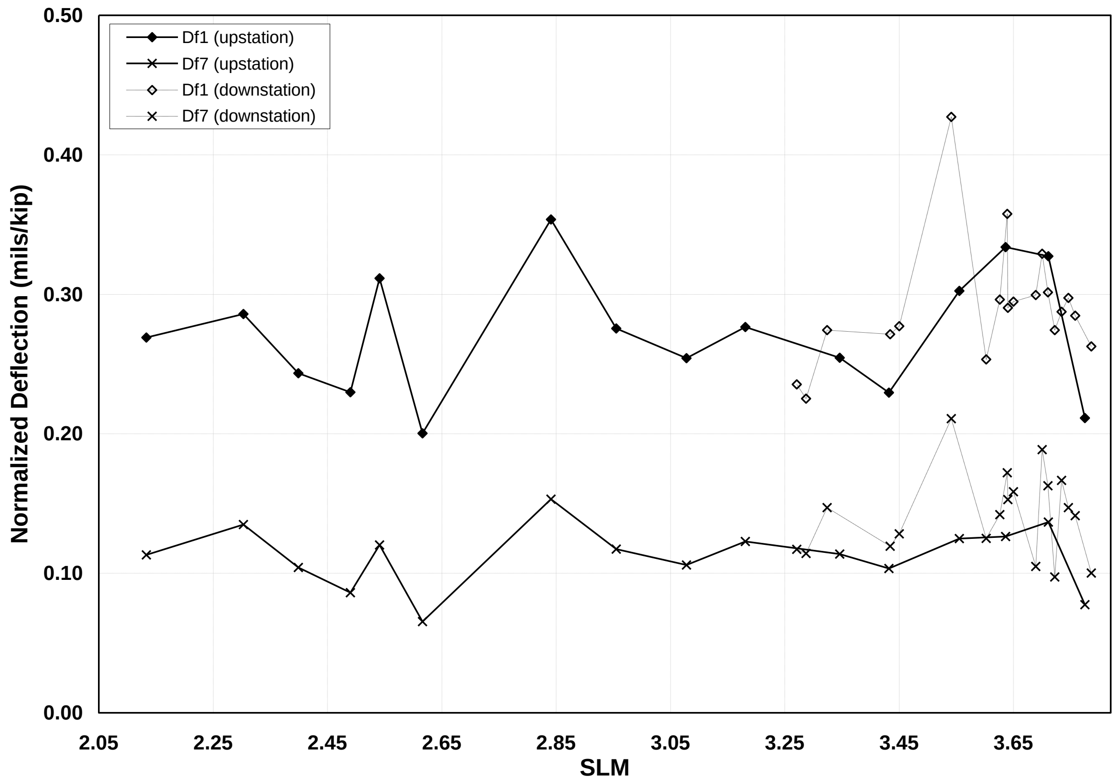


Figure K13. Midslab Deflection – Project 17, CUY 82 (438-94)

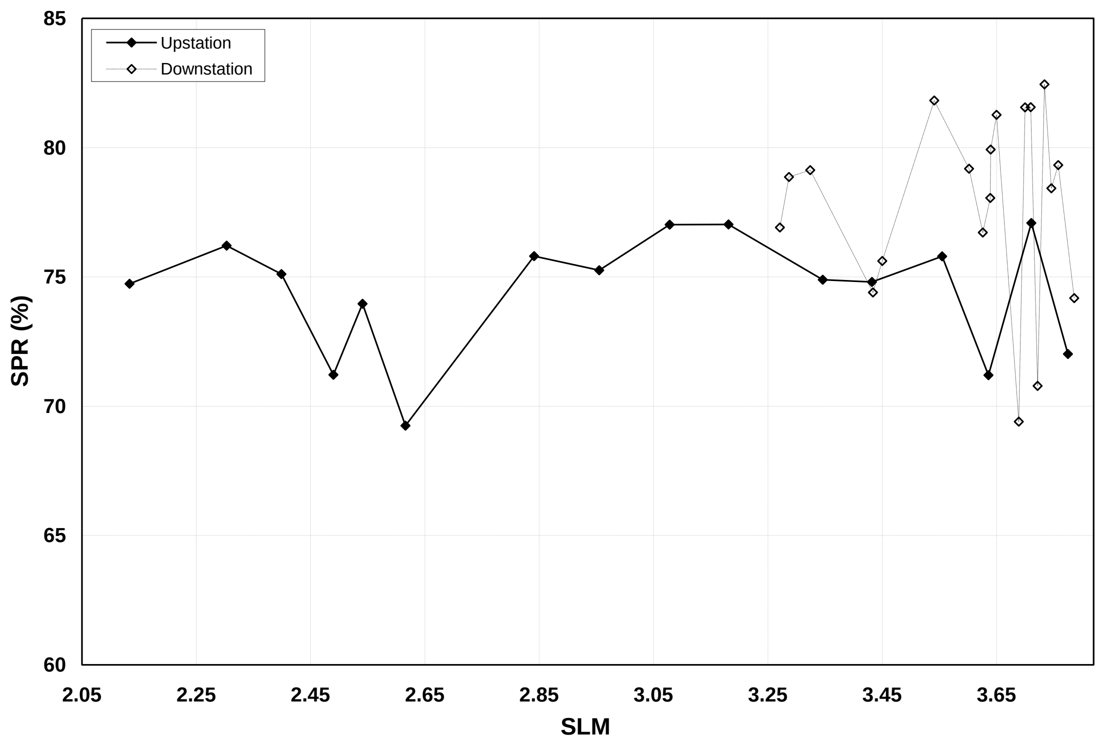


Figure K12. Midslab Spreadability – Project 17, CUY 82 (438-94)

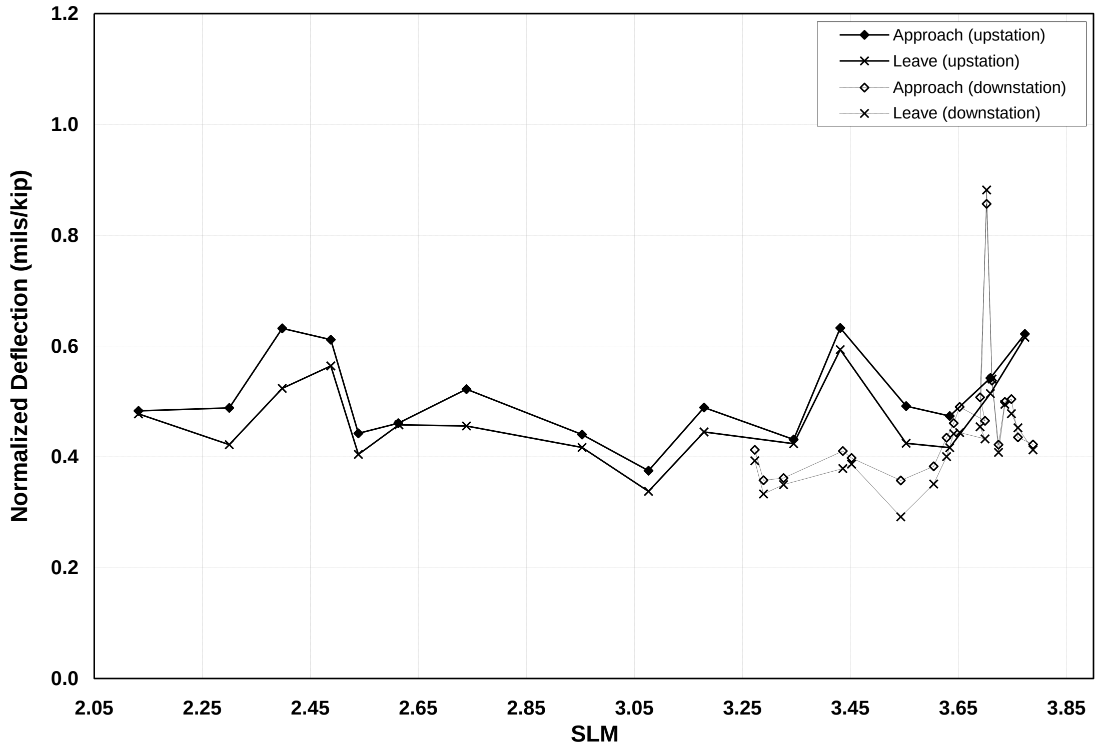


Figure K13. Maximum Joint Deflections – Project 17, CUY 82 (438-94)

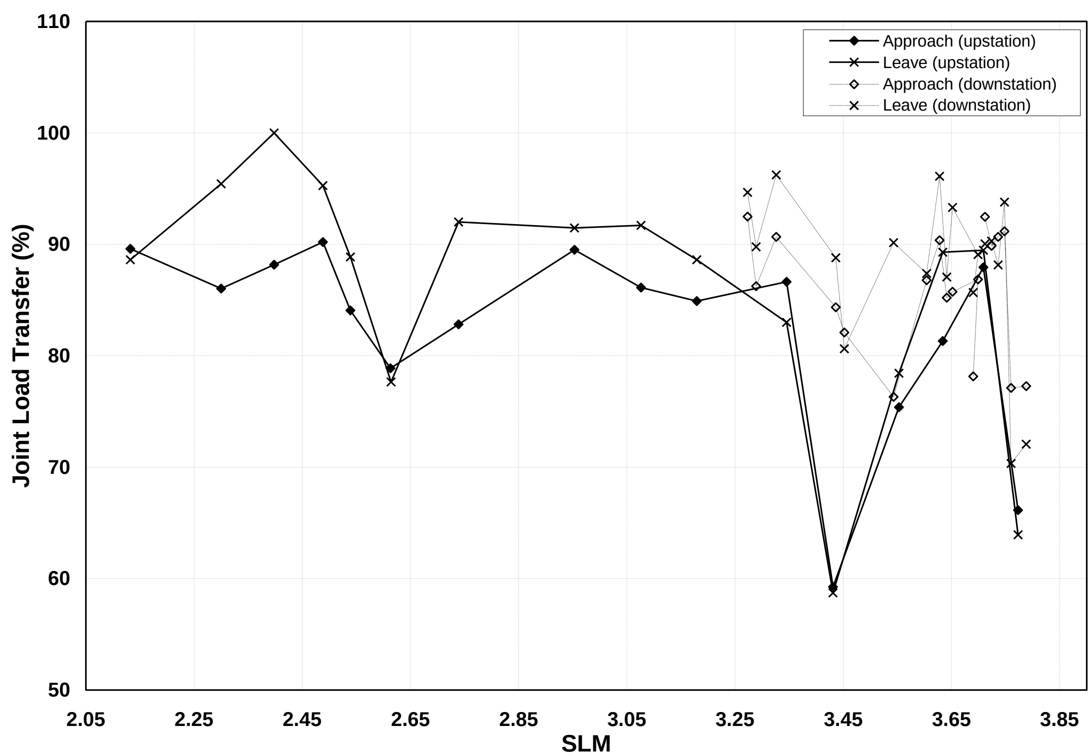


Figure K14. Joint Load Transfer – Project 17, CUY 82 (438-94)

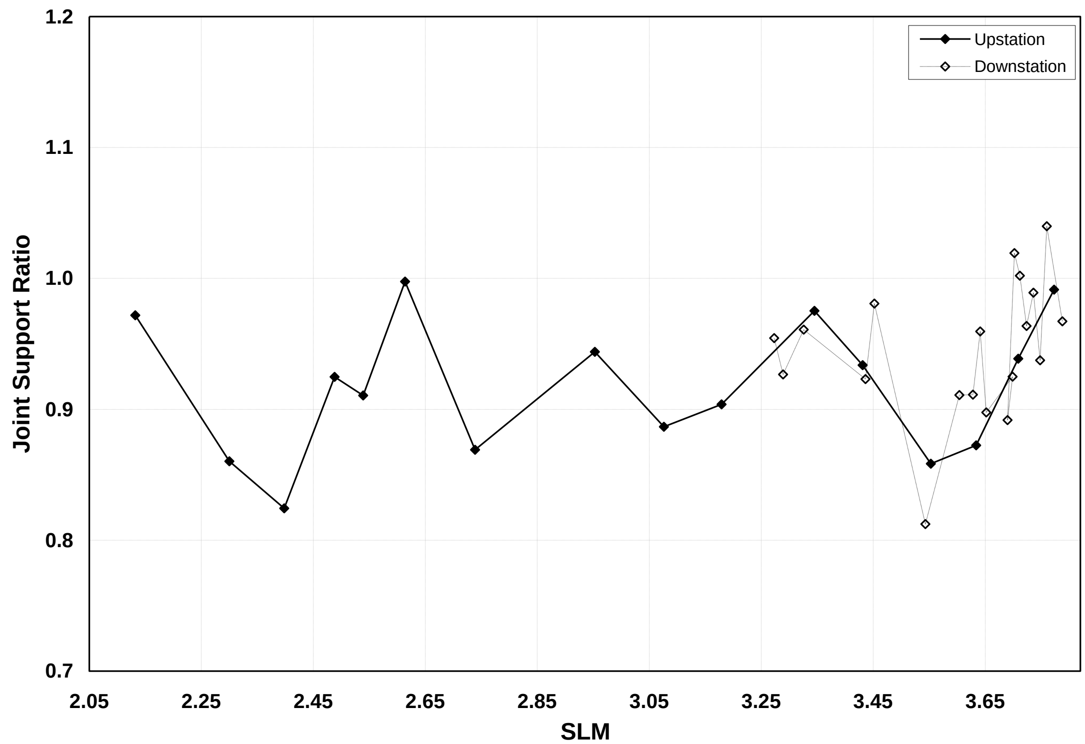


Figure K15. Joint Support Ratio – Project 17, CUY 82 (438-94)

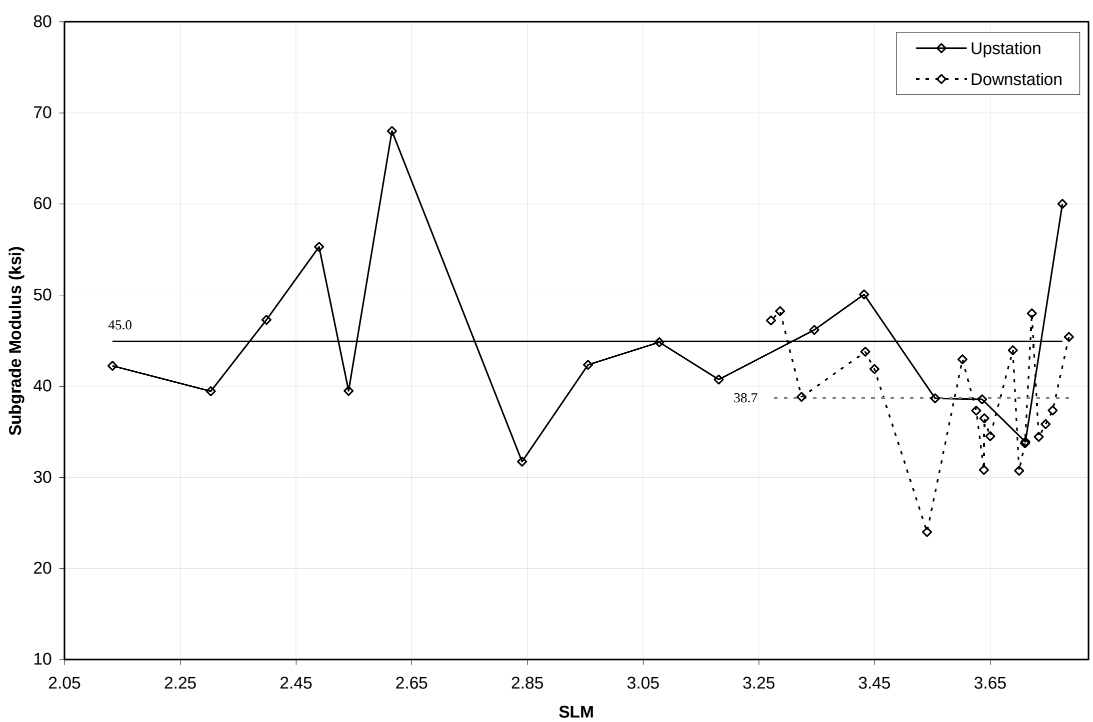


Figure K16. Subgrade Modulus – Project 17, CUY 82 (438-94)

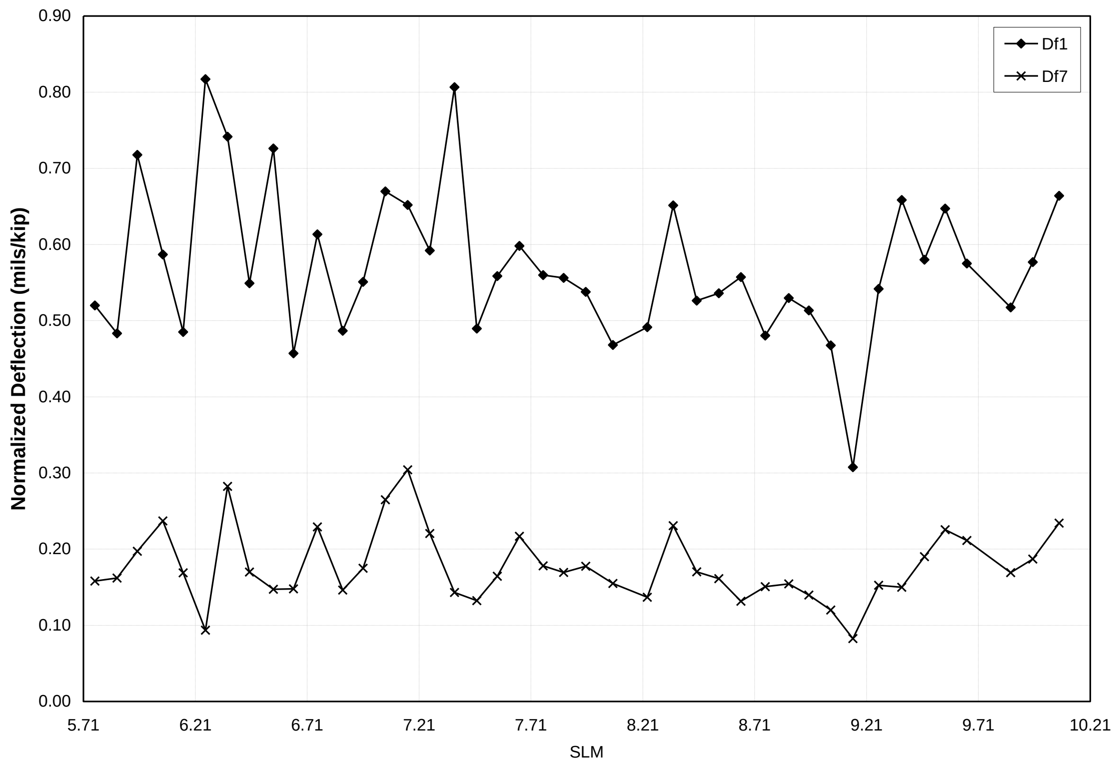


Figure K17. Midslab Deflection – Project 18, GAL 7 (352-46)

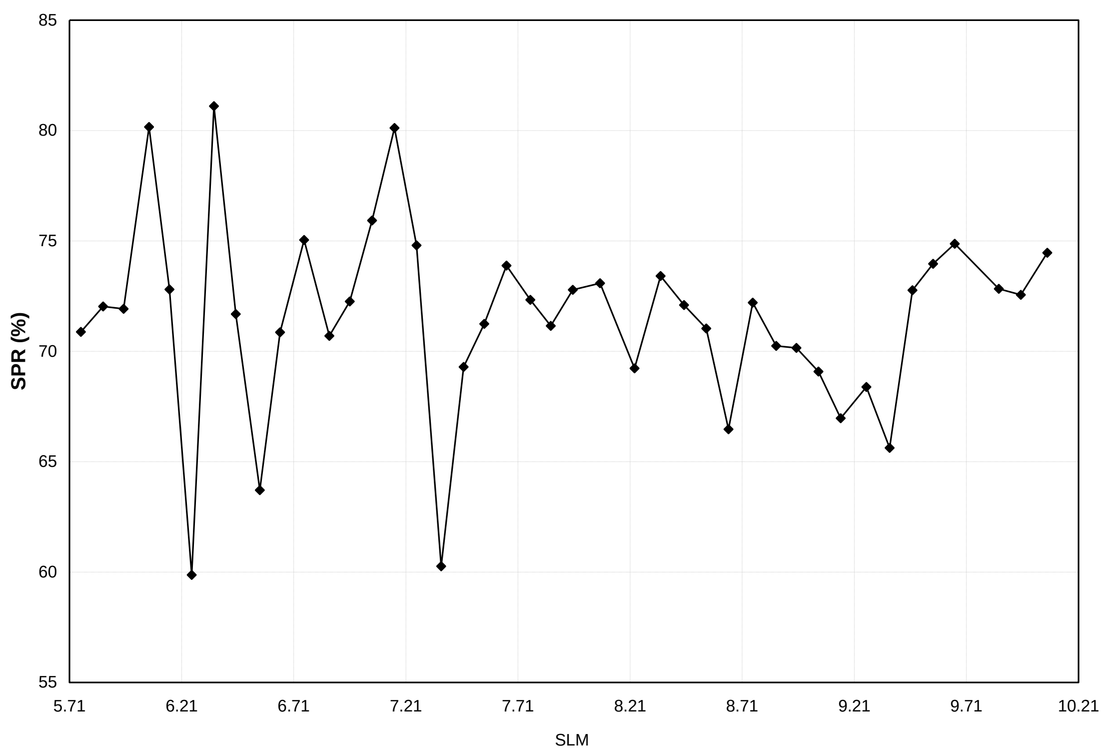


Figure K18. Midslab Spreadability – Project 18, GAL 7 (352-46)

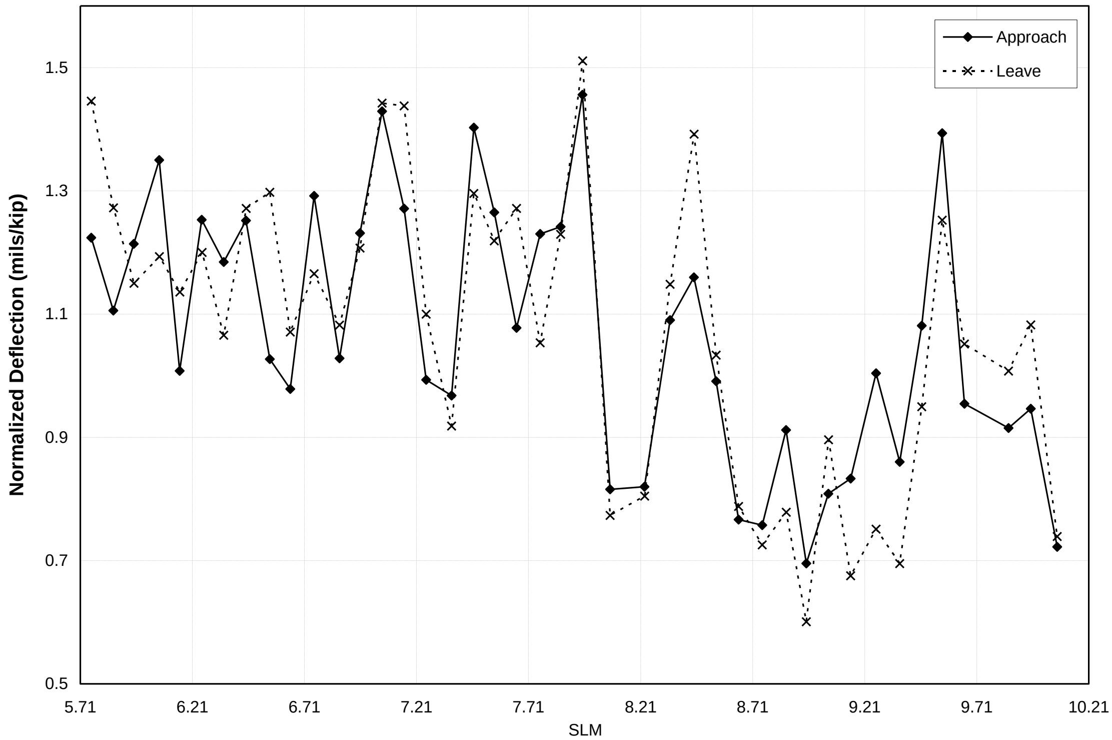


Figure K19. Maximum Joint Deflections – Project 18, GAL 7 (352-46)

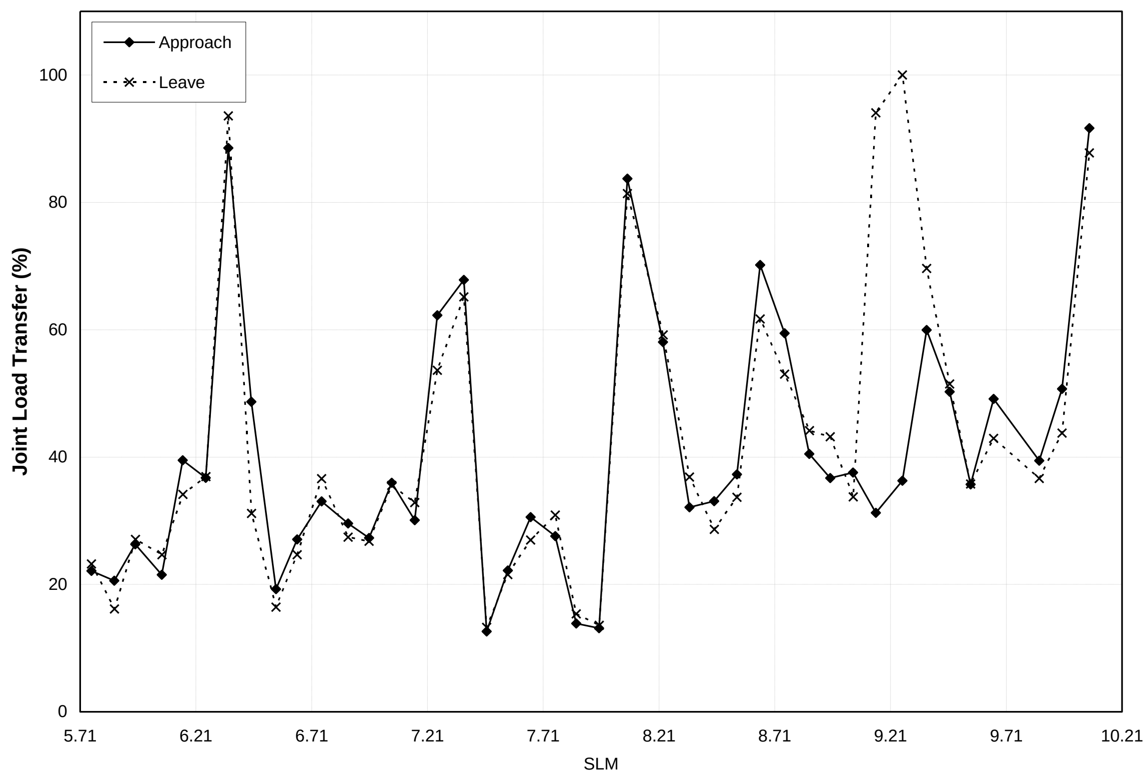


Figure K20. Joint Load Transfer – Project 18, GAL 7 (352-46)

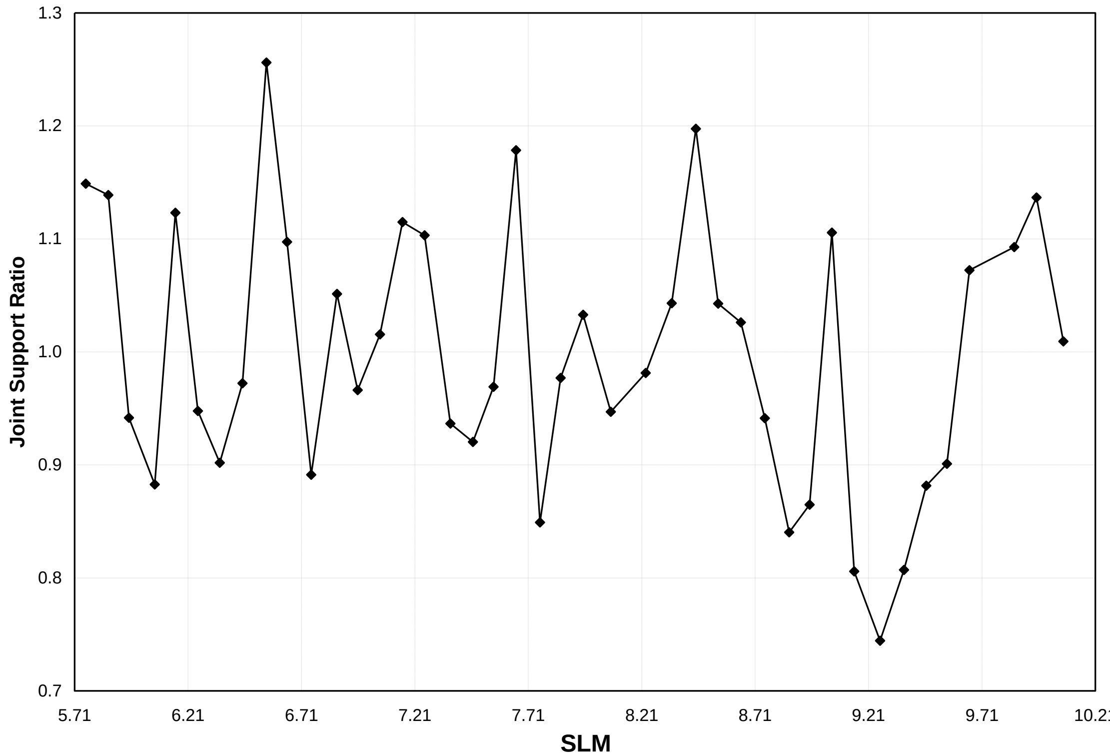


Figure K21. Joint Support Ratio – Project 18, GAL 7 (352-46)

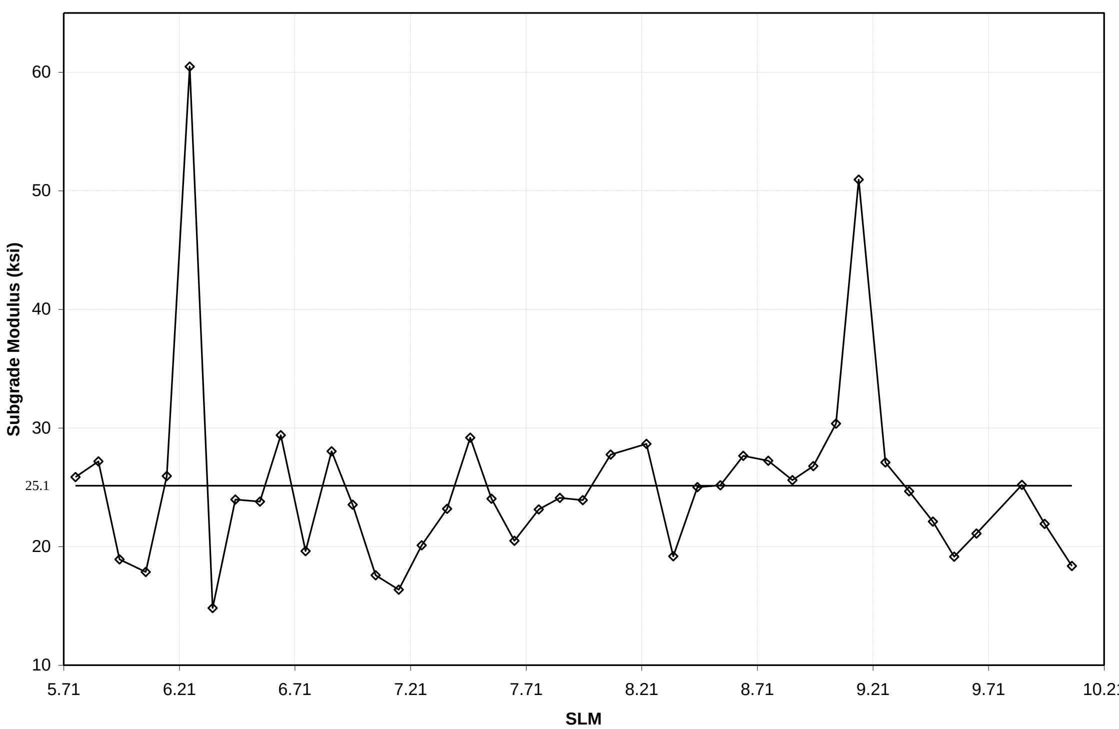


Figure K22. Subgrade Modulus – Project 18, GAL 7 (352-46)

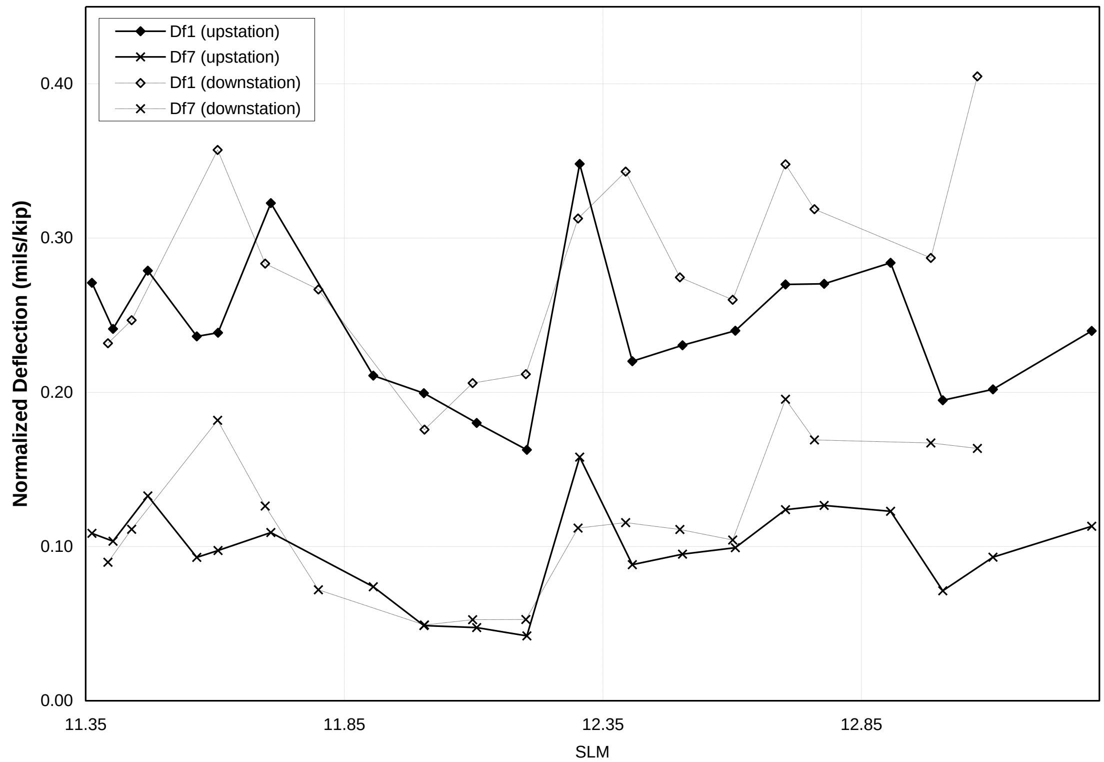


Figure K23. Midslab Deflection – Project 19, HAM 126 (997-90)

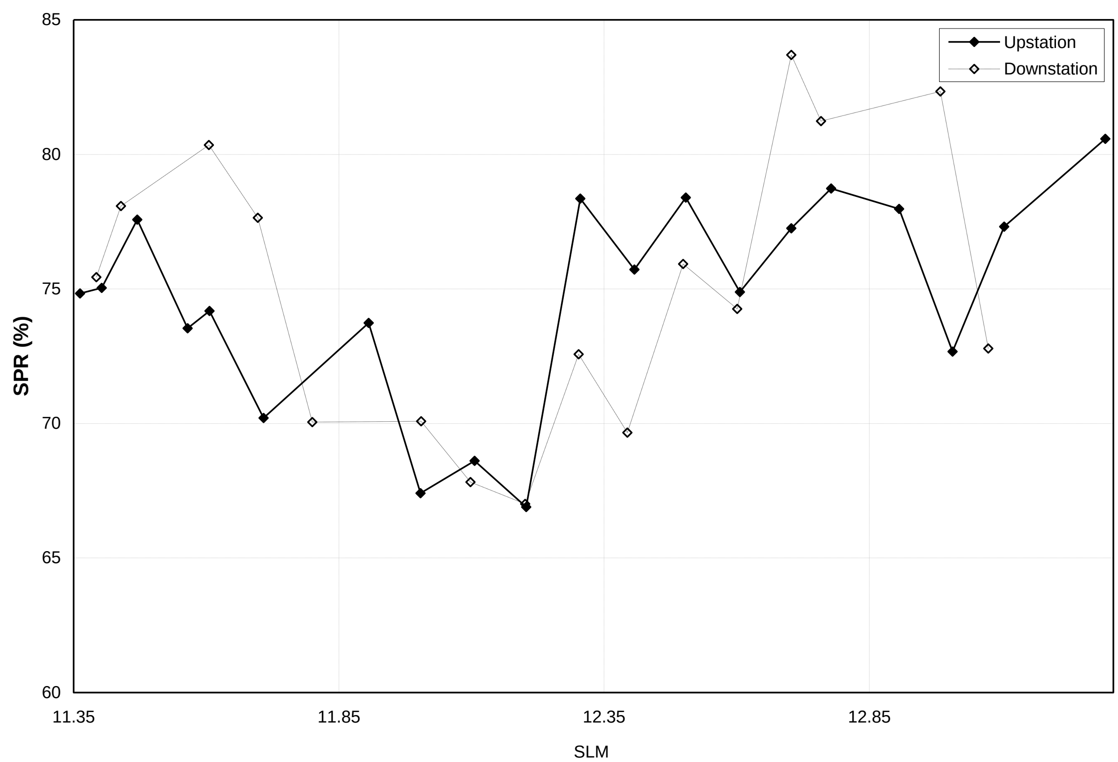


Figure K24. Midslab Spreadability – Project 19, HAM 126 (997-90)

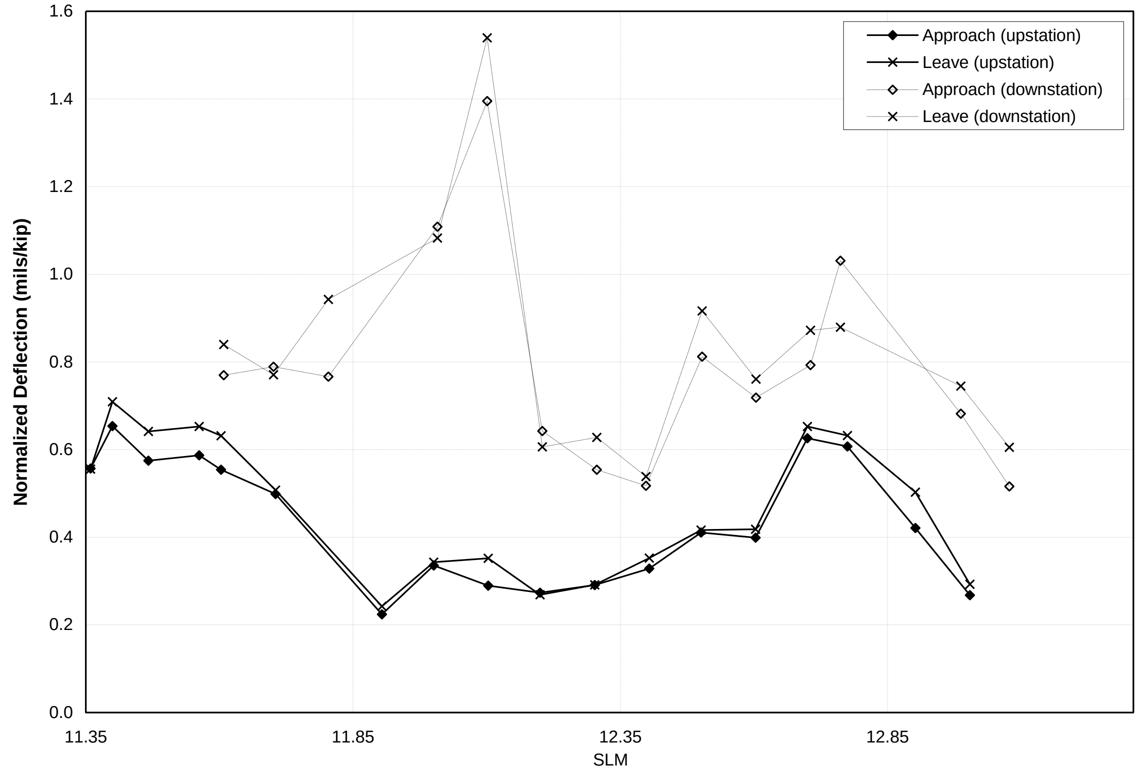


Figure K25. Maximum Joint Deflections – Project 19, HAM 126 (997-90)

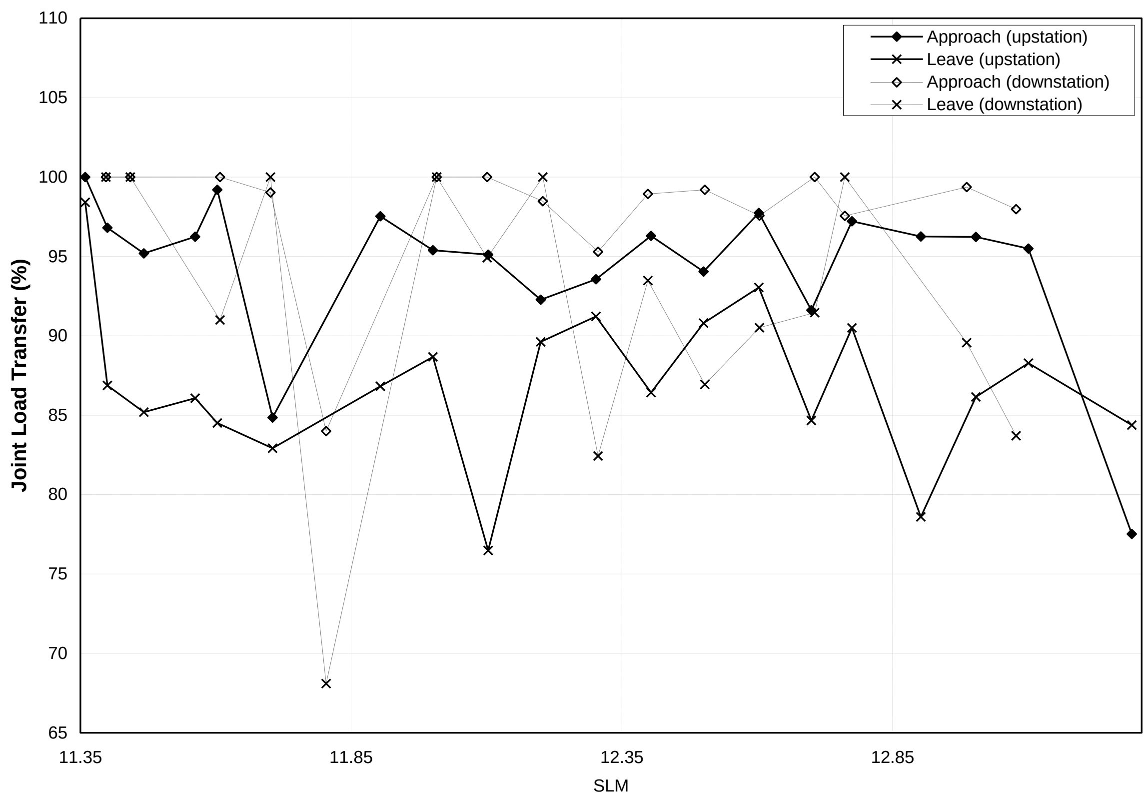


Figure K26. Joint Load Transfer – Project 19, HAM 126 (997-90)

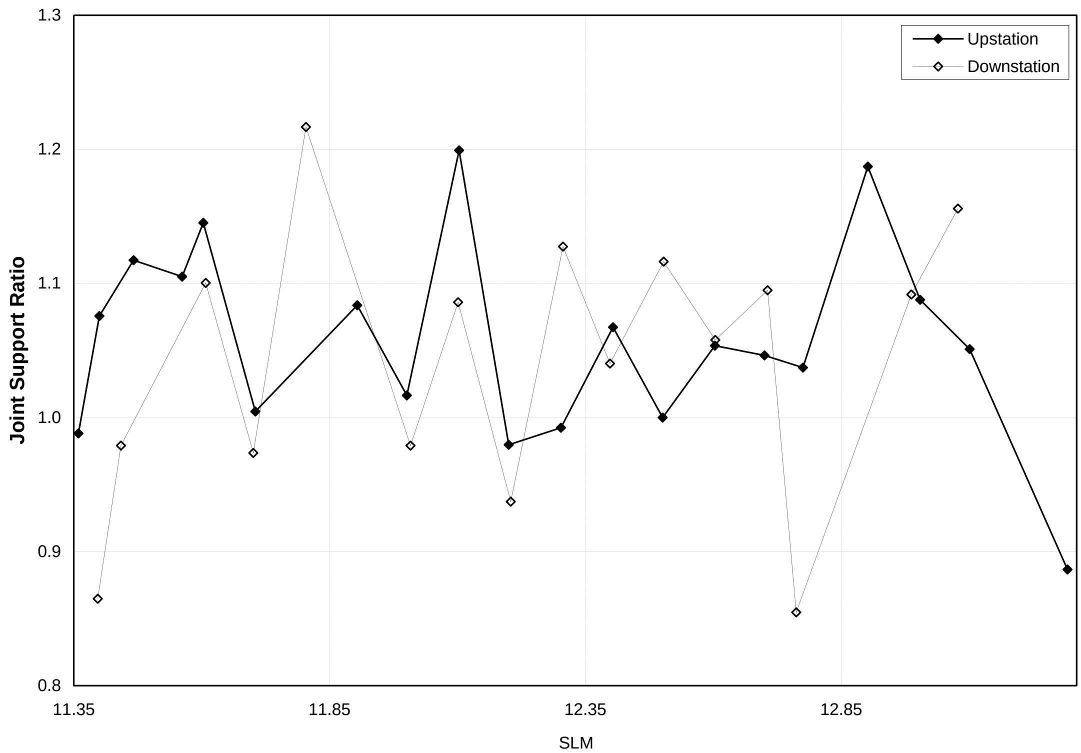


Figure K27. Joint Support Ratio – Project 19, HAM 126 (997-90)

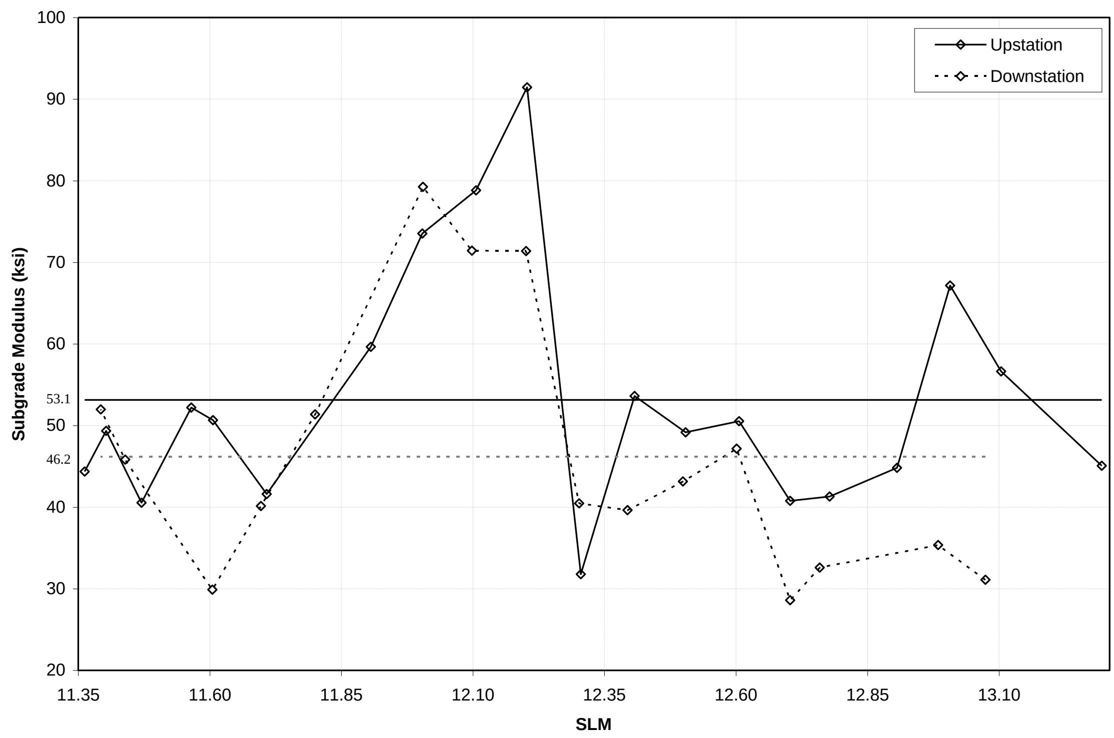


Figure K28. Subgrade Modulus – Project 20, HAM 126 (997-90)

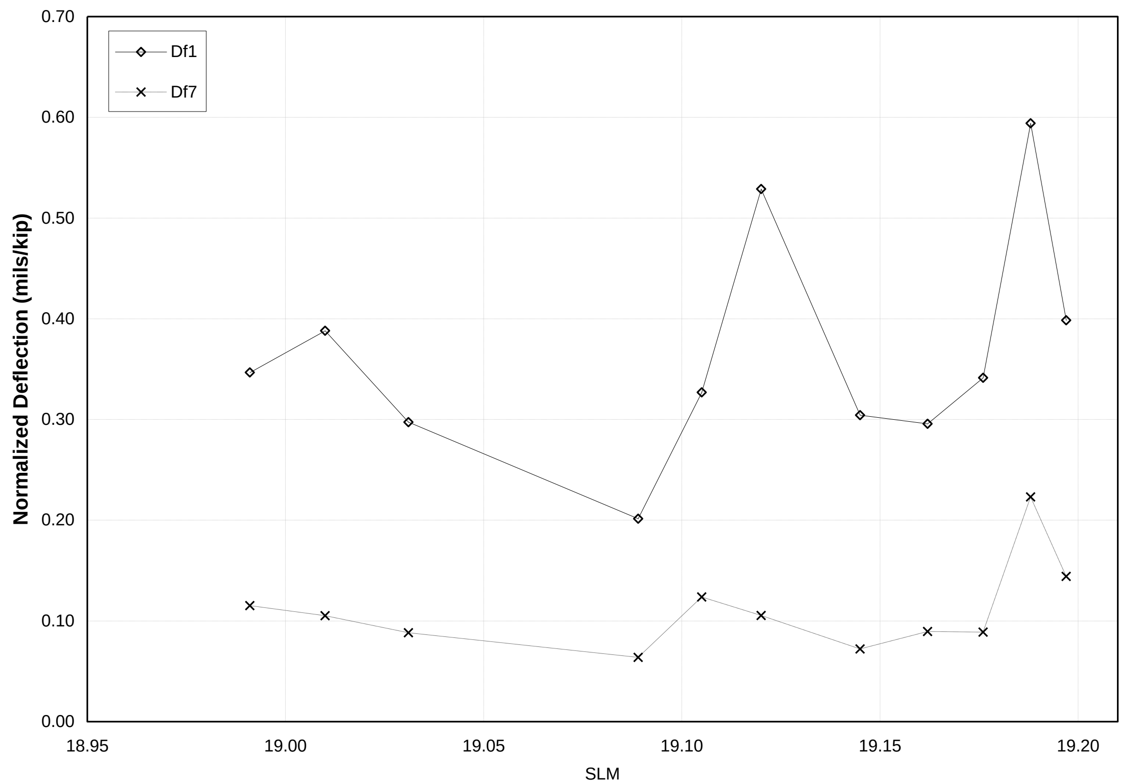


Figure K 29. Midslab Deflection – Project 20, JEF 7 (8008-90)

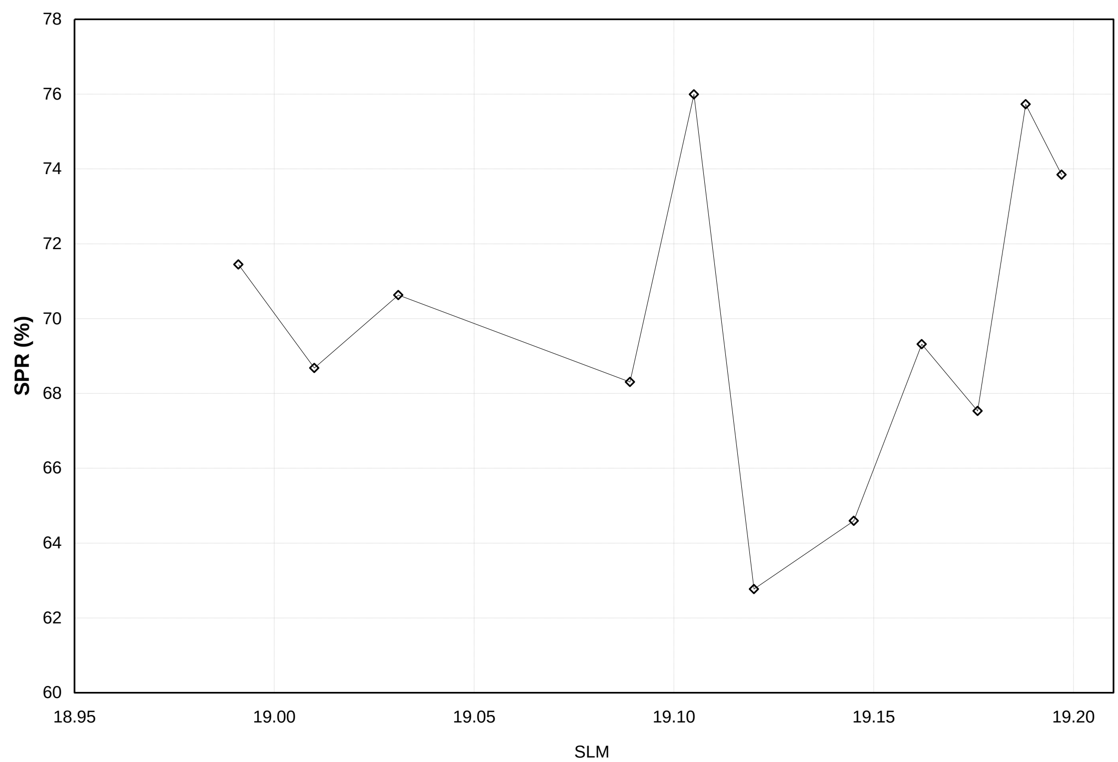


Figure K30. Midslab Spreadability – Project 20, JEF 7 (8008-90)

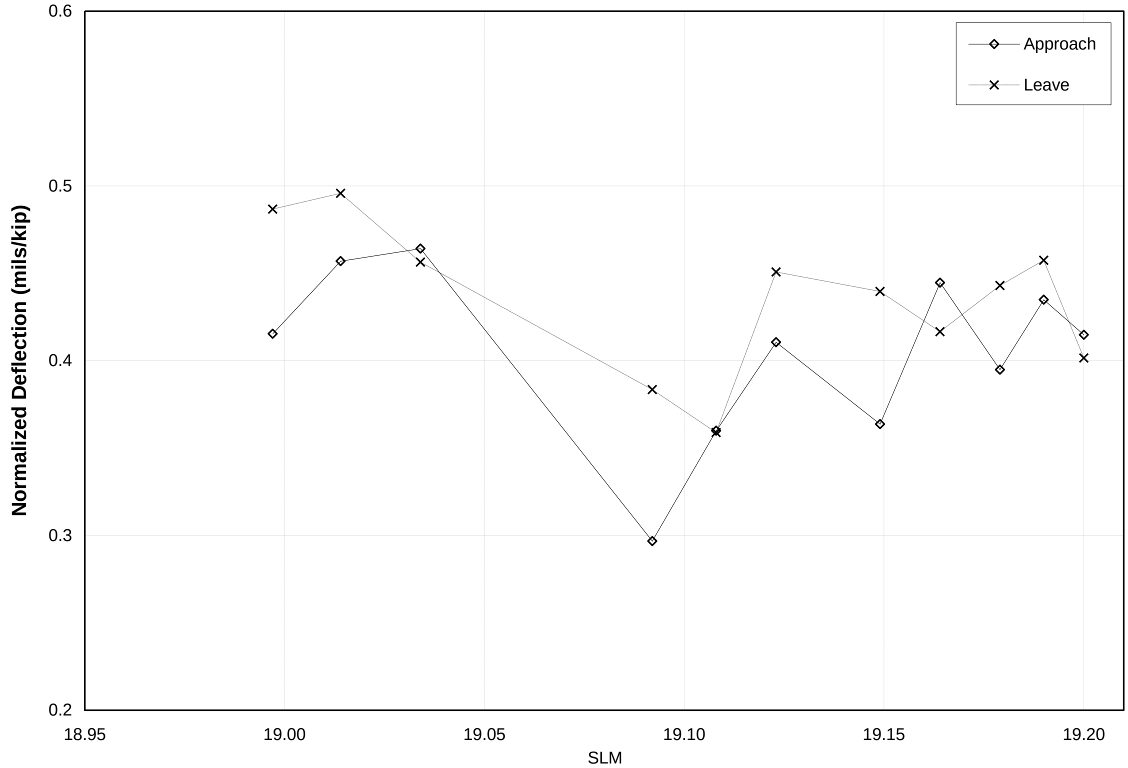


Figure K31. Maximum Joint Deflections – Project 20, JEF 7 (8008-90)

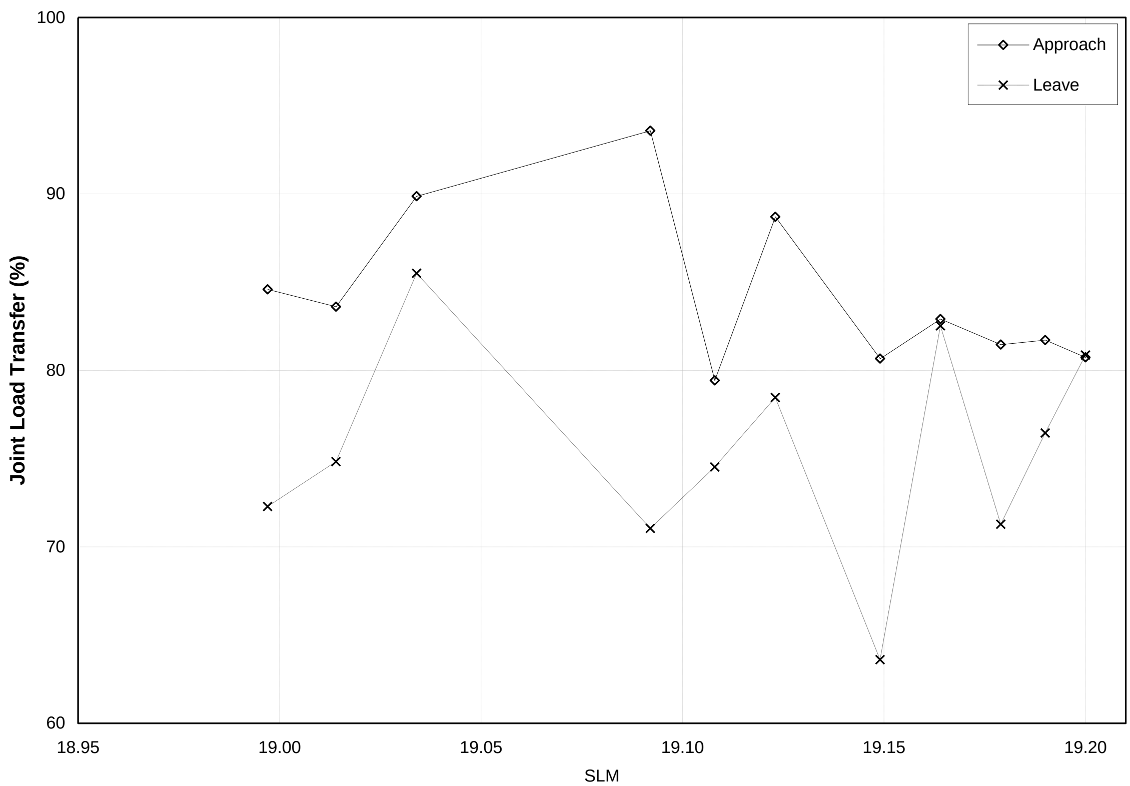


Figure K32. Joint Load Transfer – Project 20, JEF 7 (8008-90)

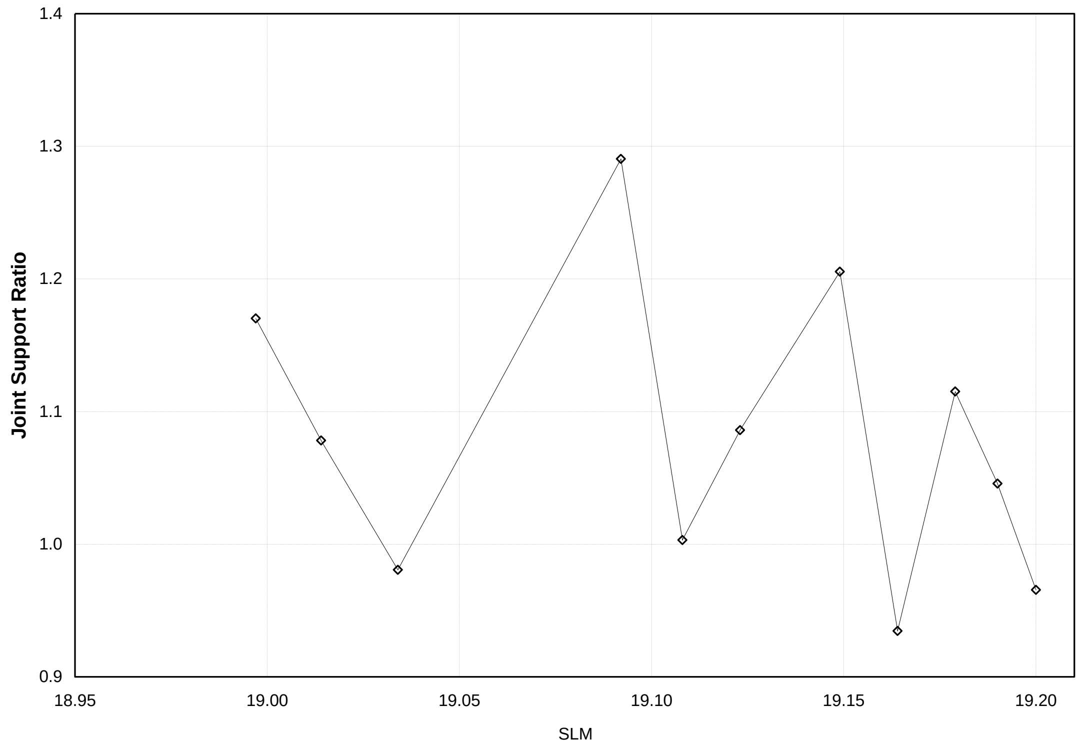


Figure K 33. Joint Support Ratio – Project 20, JEF 7 (8008-90)

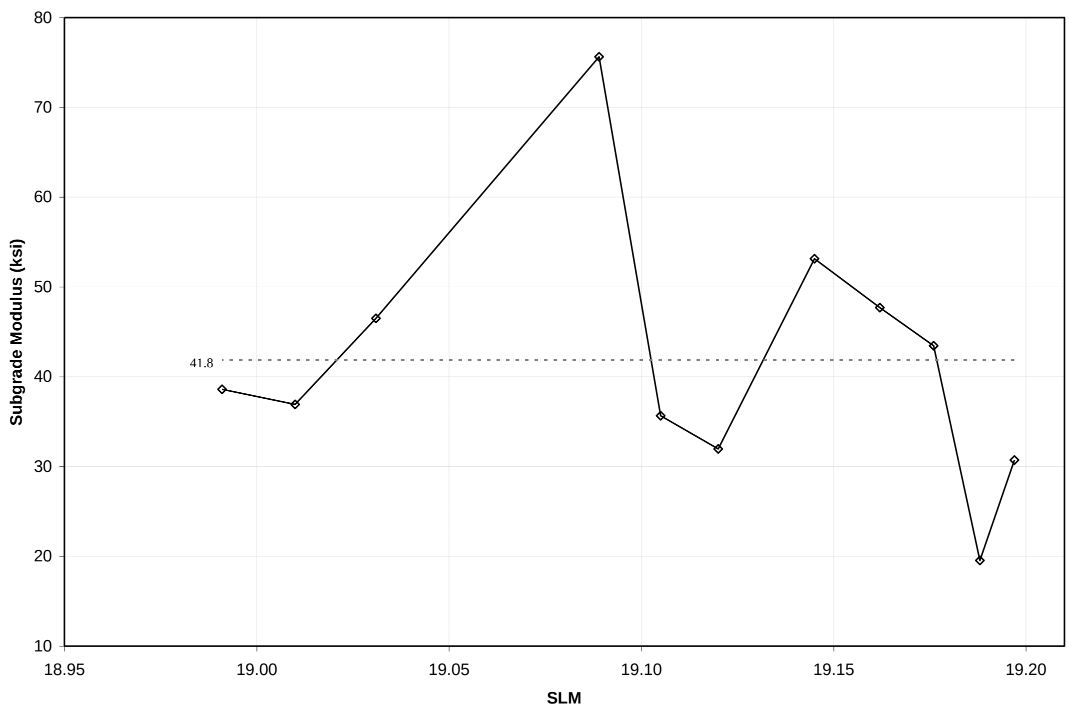


Figure K34. Subgrade Modulus – Project 20, JEF 7 (8008-90)

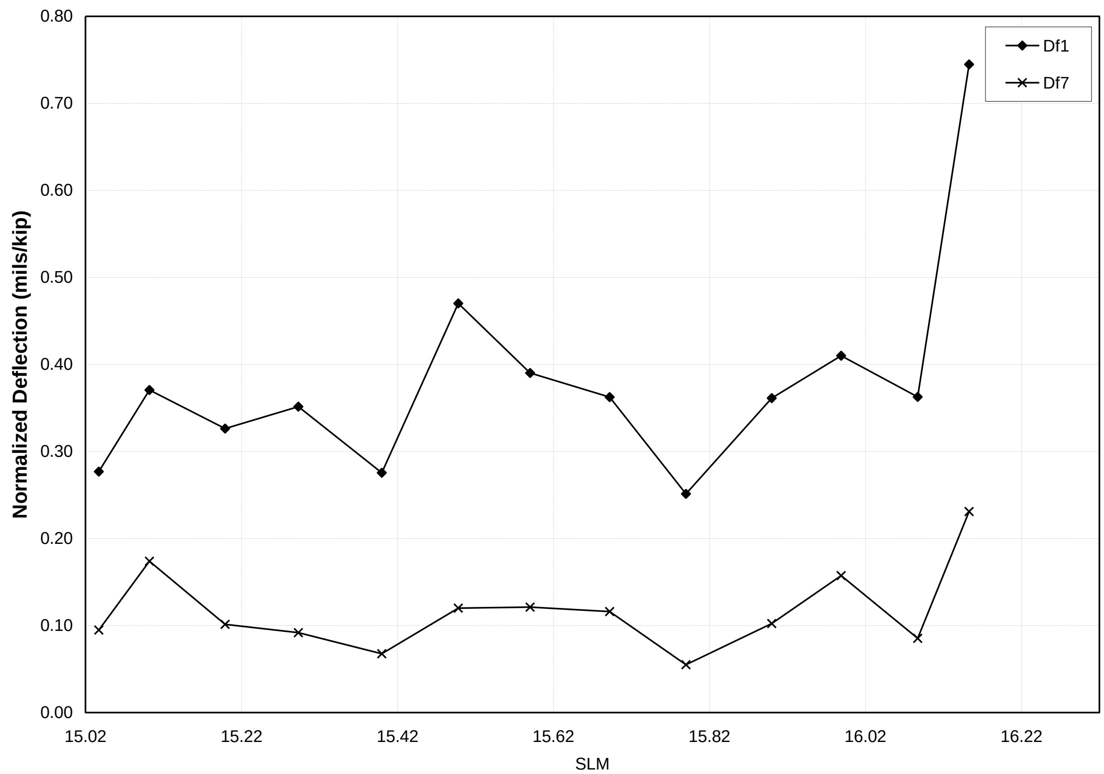


Figure K35. Midslab – Project 21, JEF 22 (8008-90)

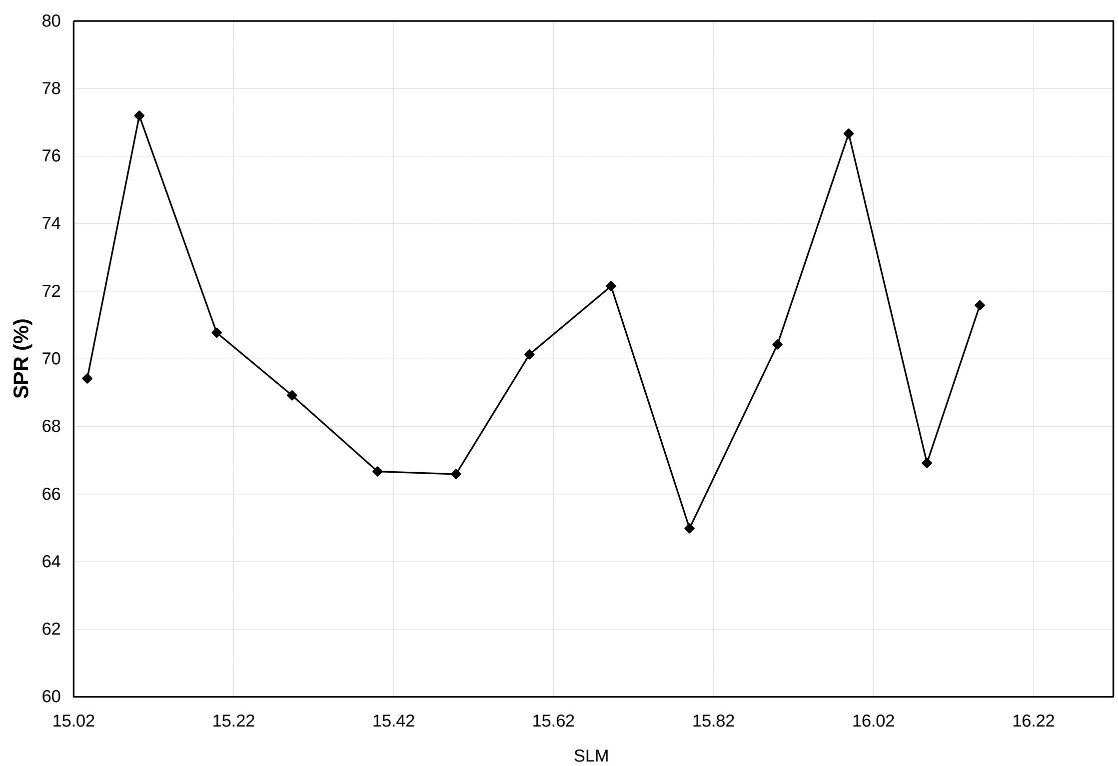


Figure K36. Midslab Spreadability – Project 21, JEF 22 (8008-90)

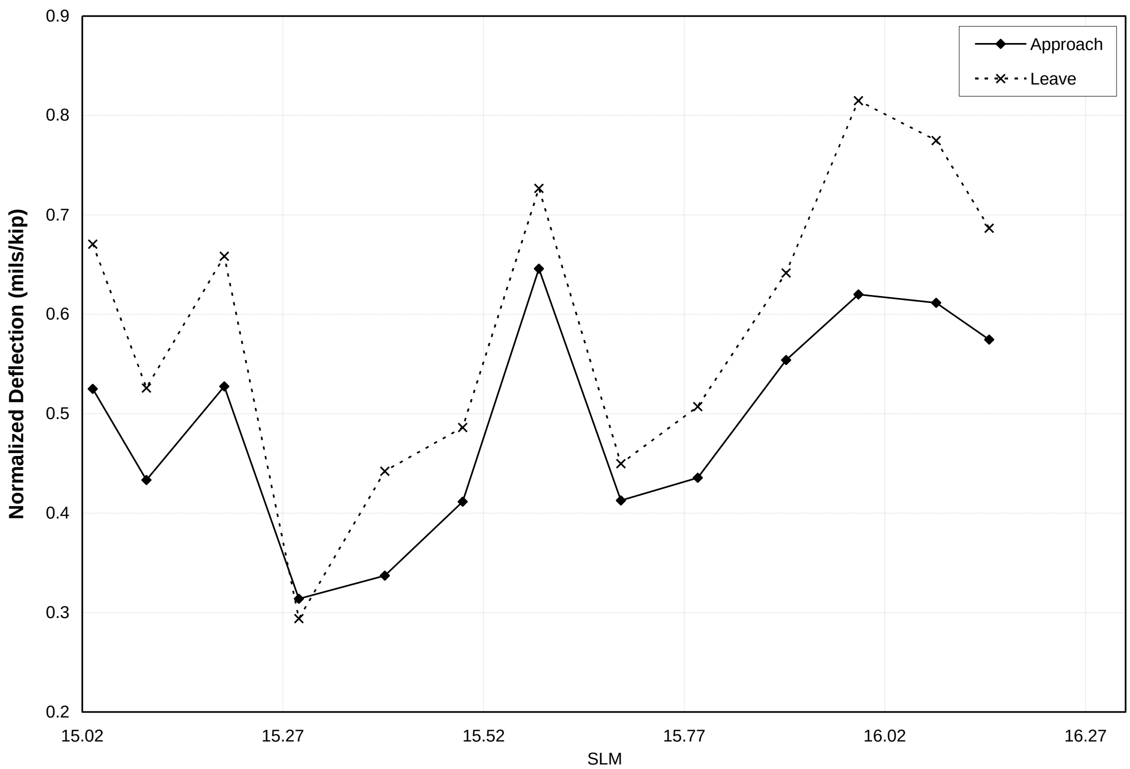


Figure K37. Maximum Joint Deflections – Project 21, JEF 22 (8008-90)

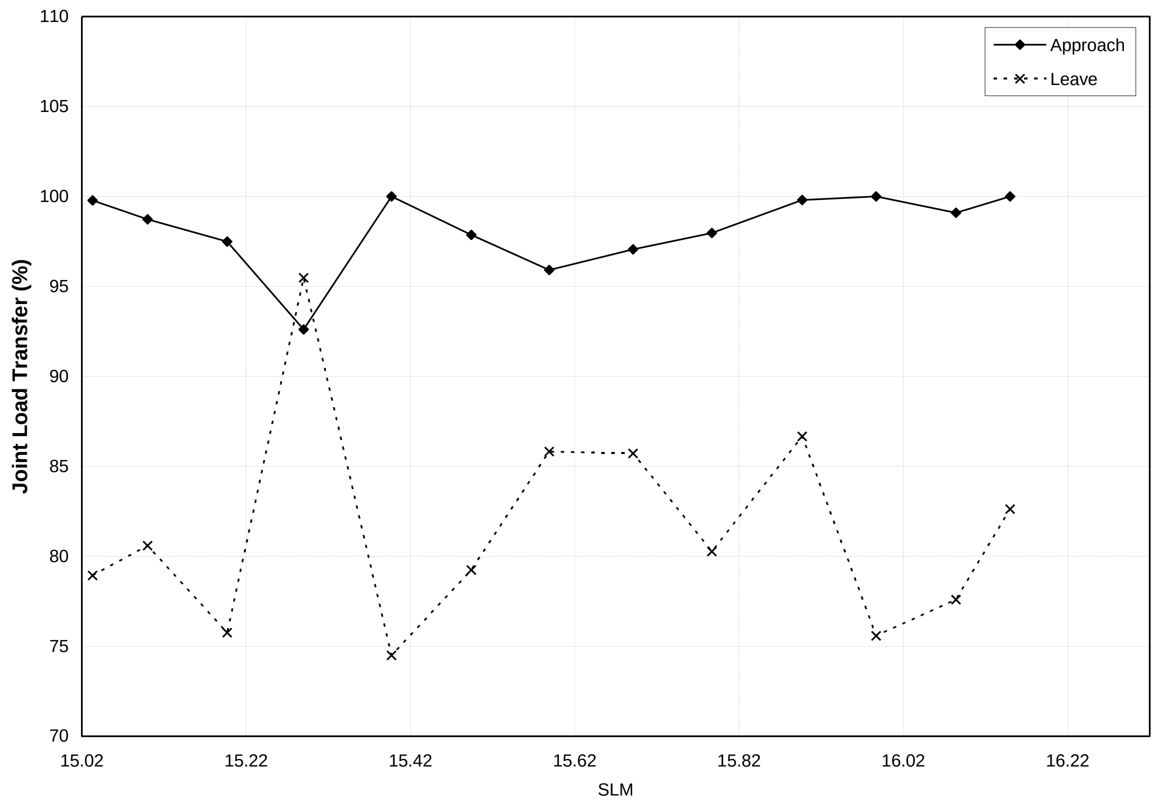


Figure K38. Joint Load Transfer – Project 21, JEF 22 (8008-90)

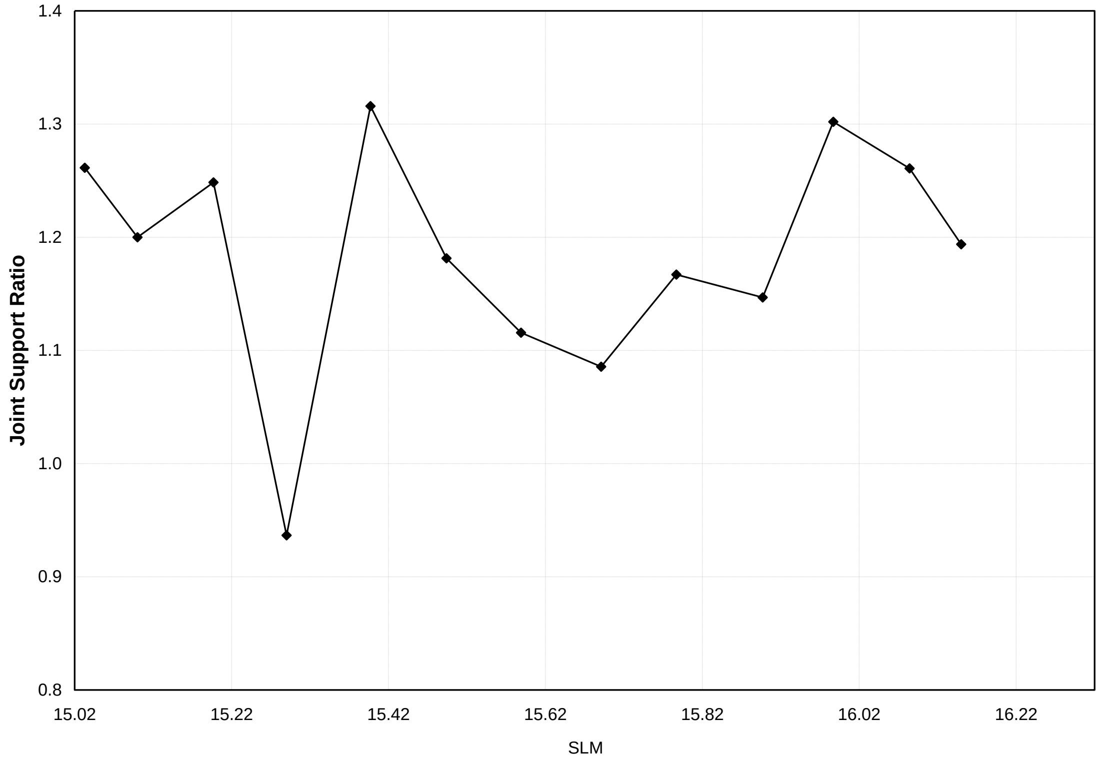


Figure K39. Joint Support Ratio – Project 21, JEF 22 (8008-90)

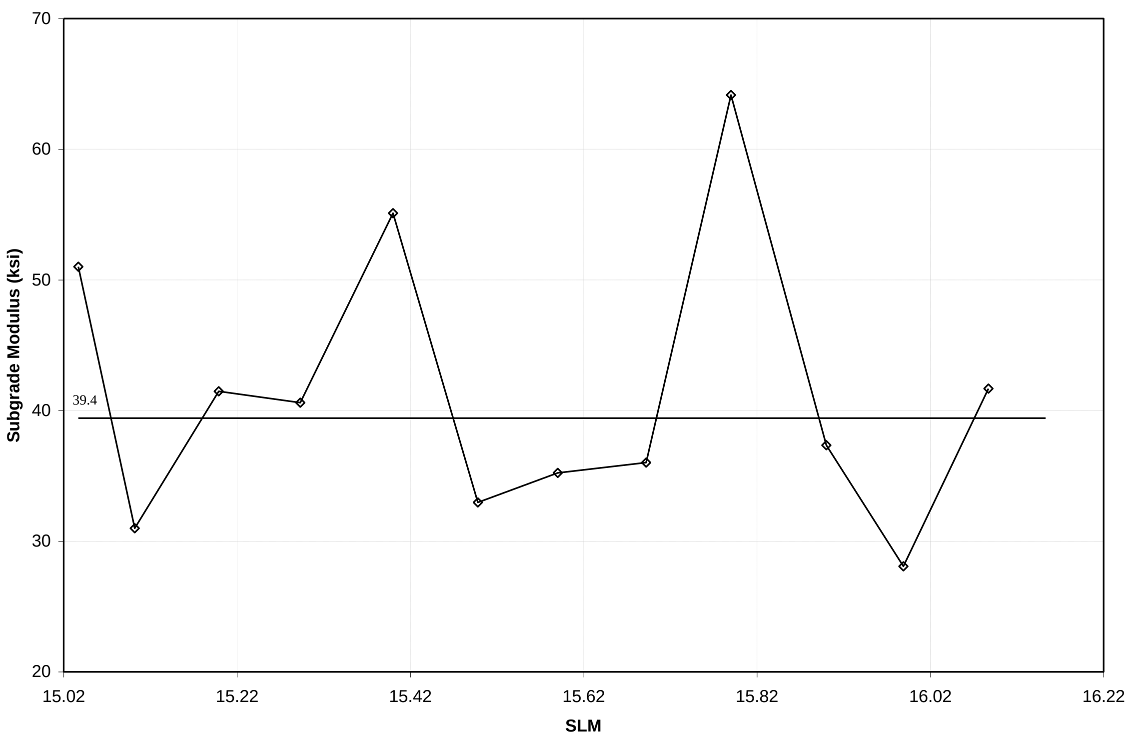


Figure K40. Subgrade Modulus – Project 21, JEF 22 (8008-90)

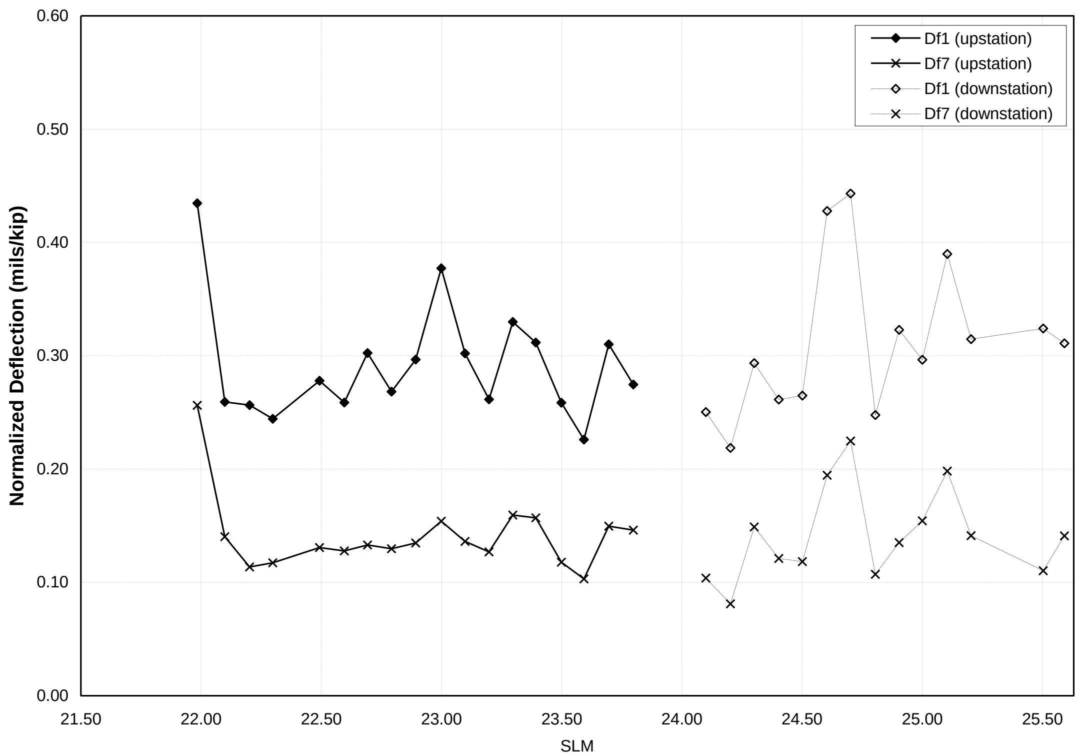


Figure K41. Midslab Deflection – Project 22, LOG 33 (845-94)

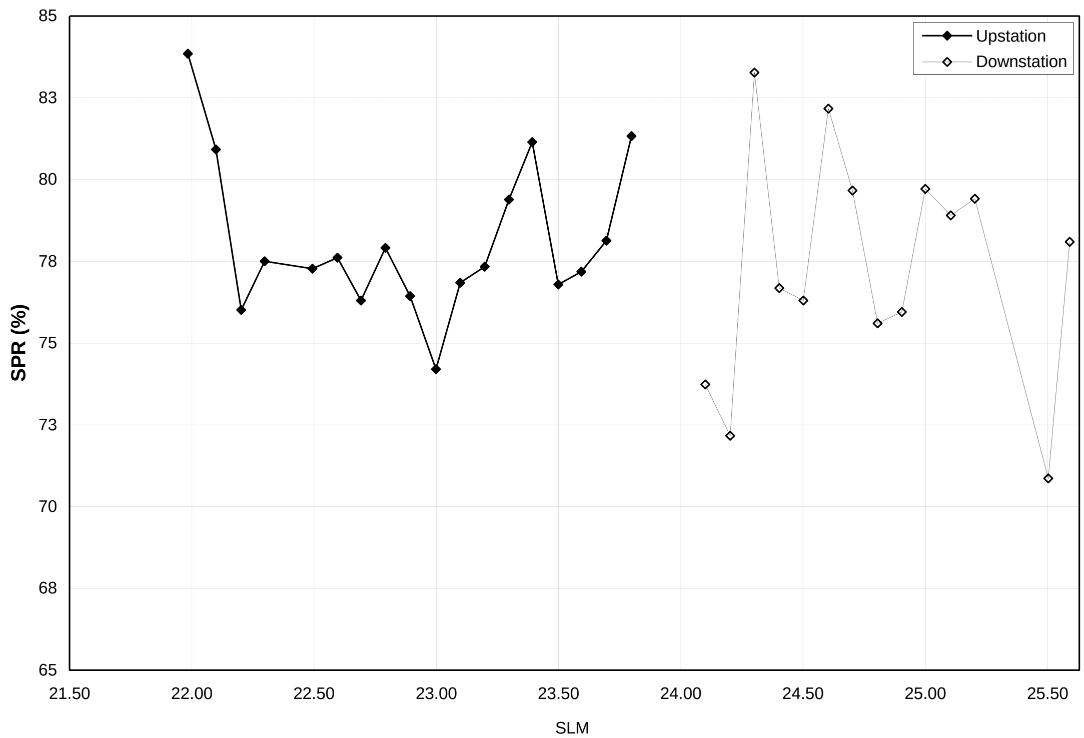


Figure K42. Midslab Spreadability – Project 22, LOG 33 (845-94)

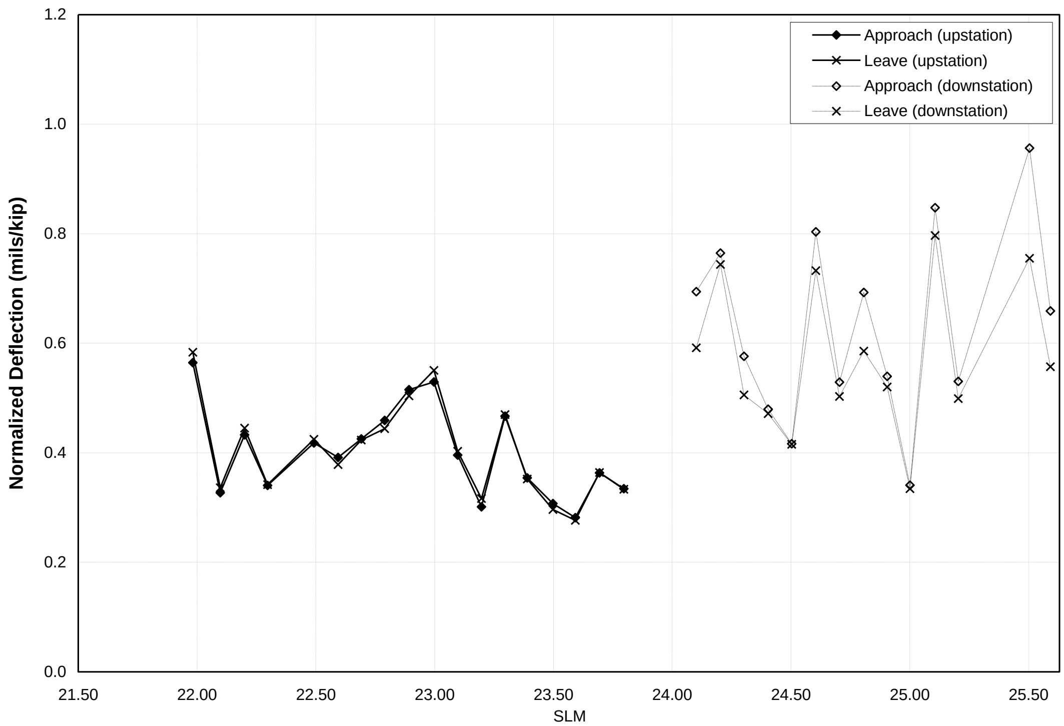


Figure K43. Maximum Joint Deflections – Project 22, LOG 33 (845-94)

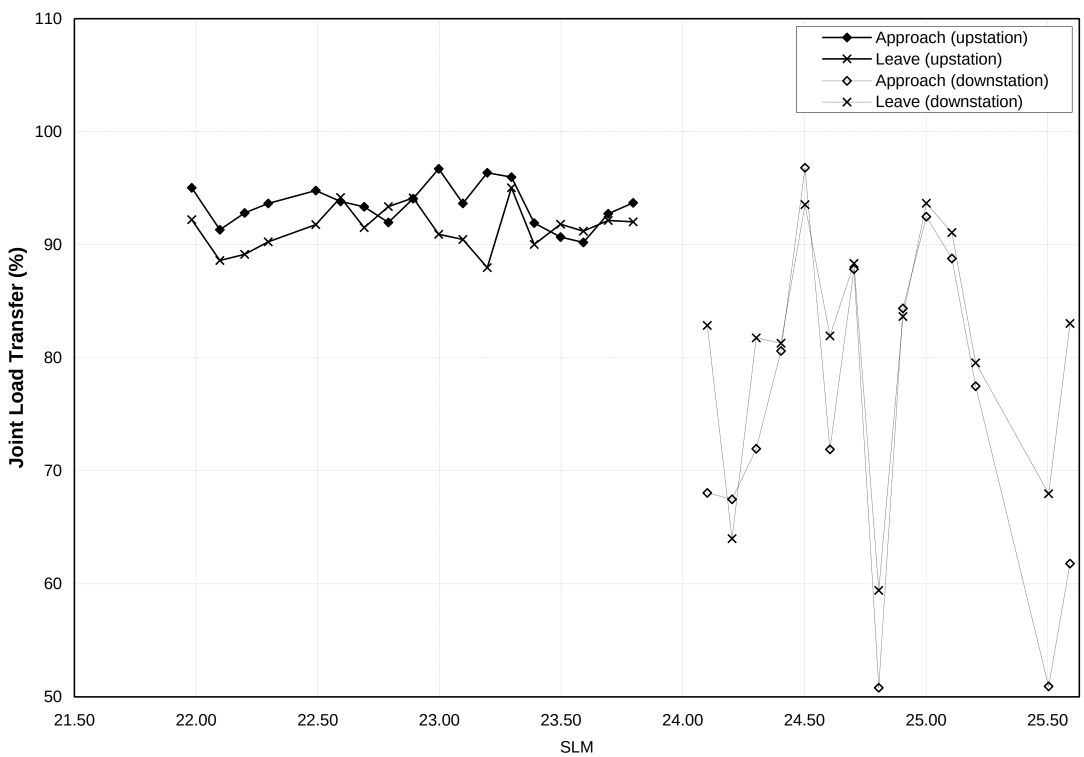


Figure K44. Joint Load Transfer – Project 22, LOG 33 (845-94)

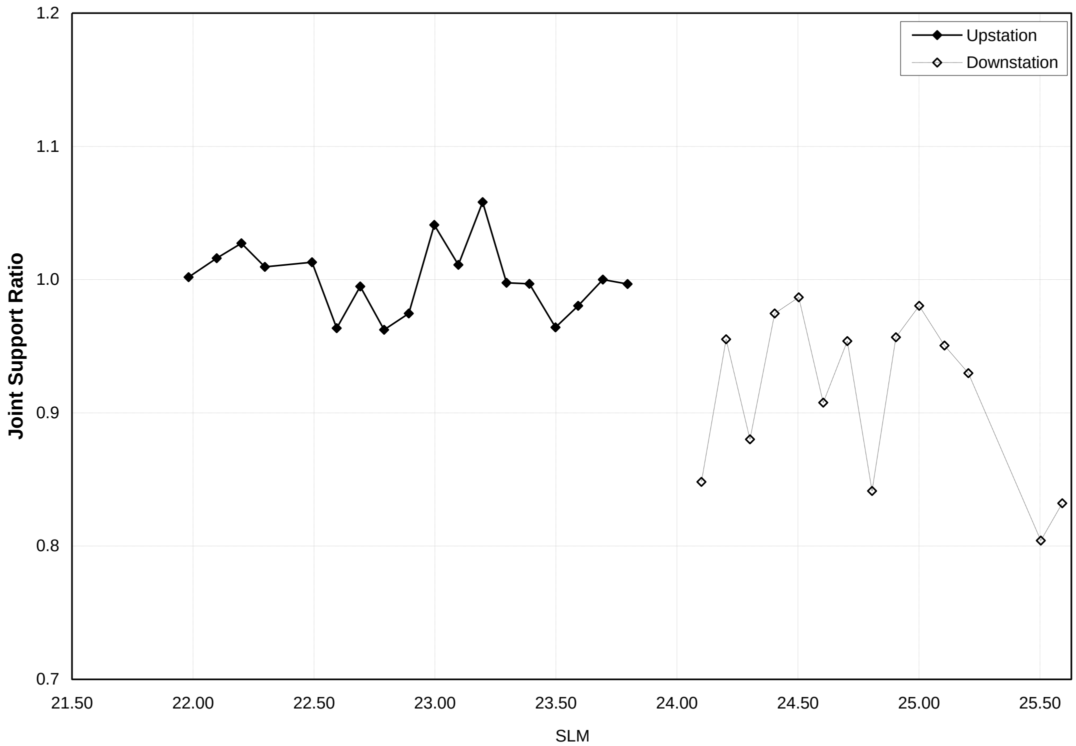


Figure K45. Joint Support Ratio – Project 22, LOG 33 (845-94)

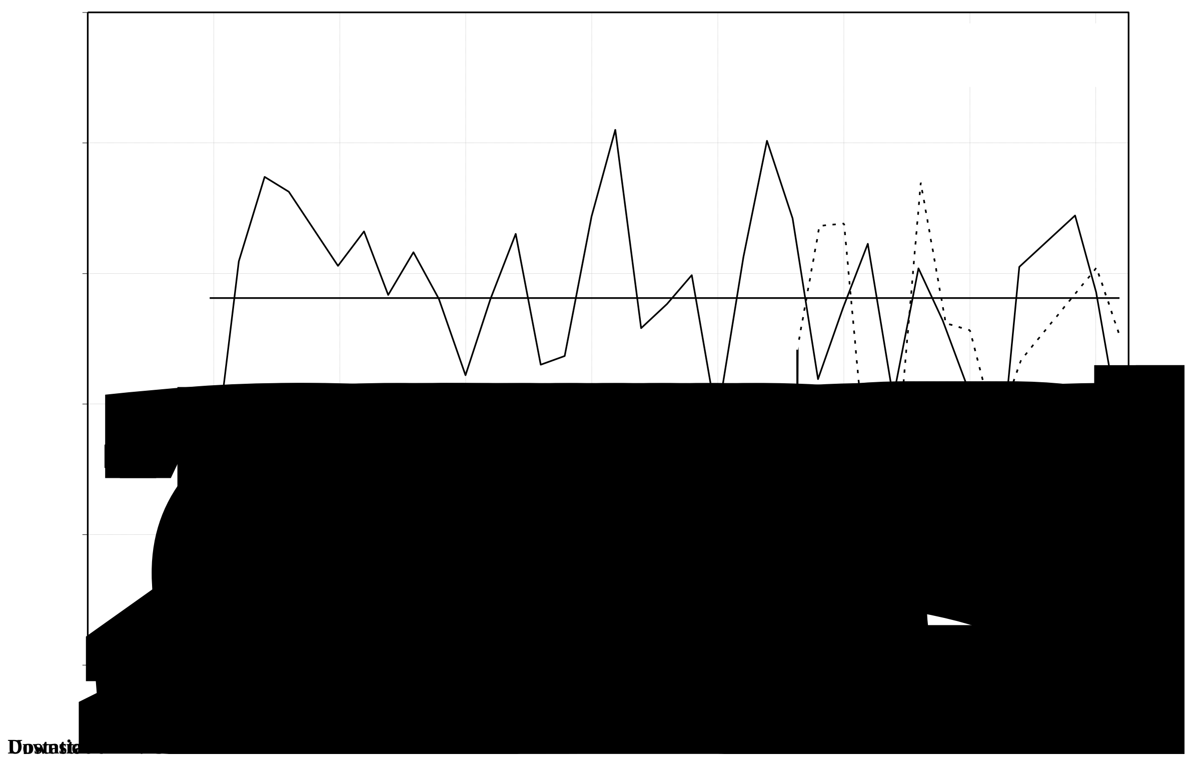


Figure K46. Subgrade Modulus – Project 22, LOG 33 (845-94)

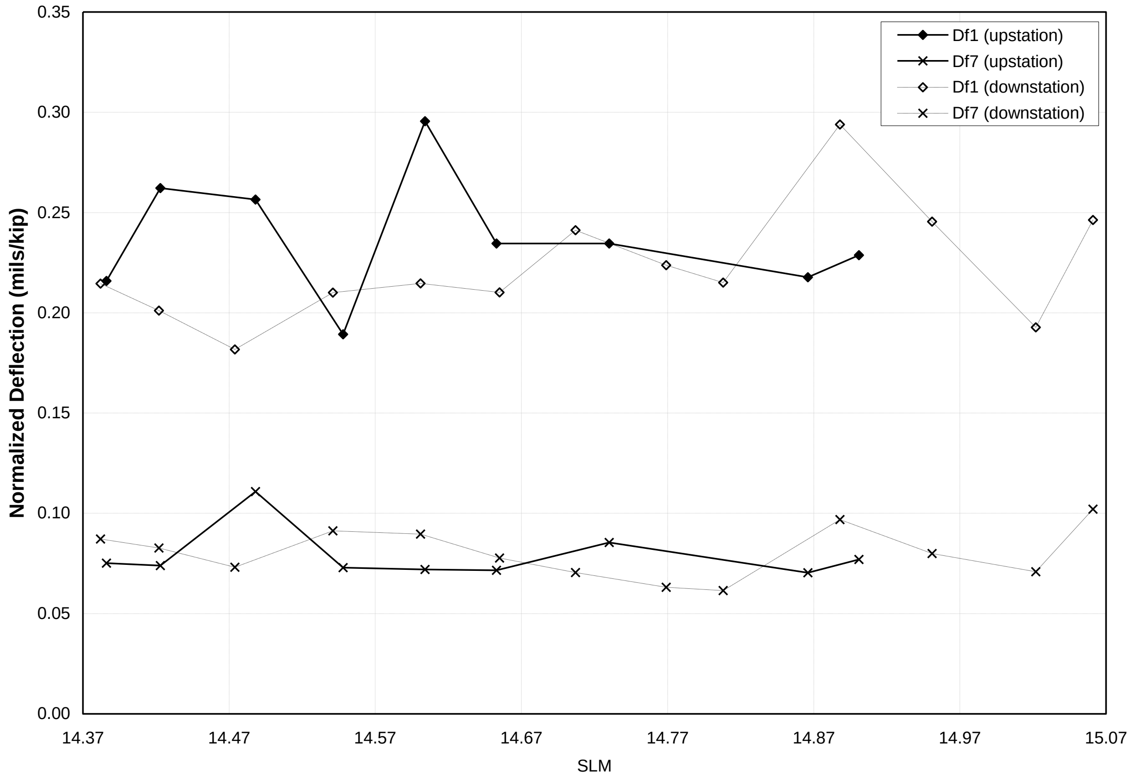


Figure K47. Midslab Deflection – Project 2, MOT 35 (343-88)

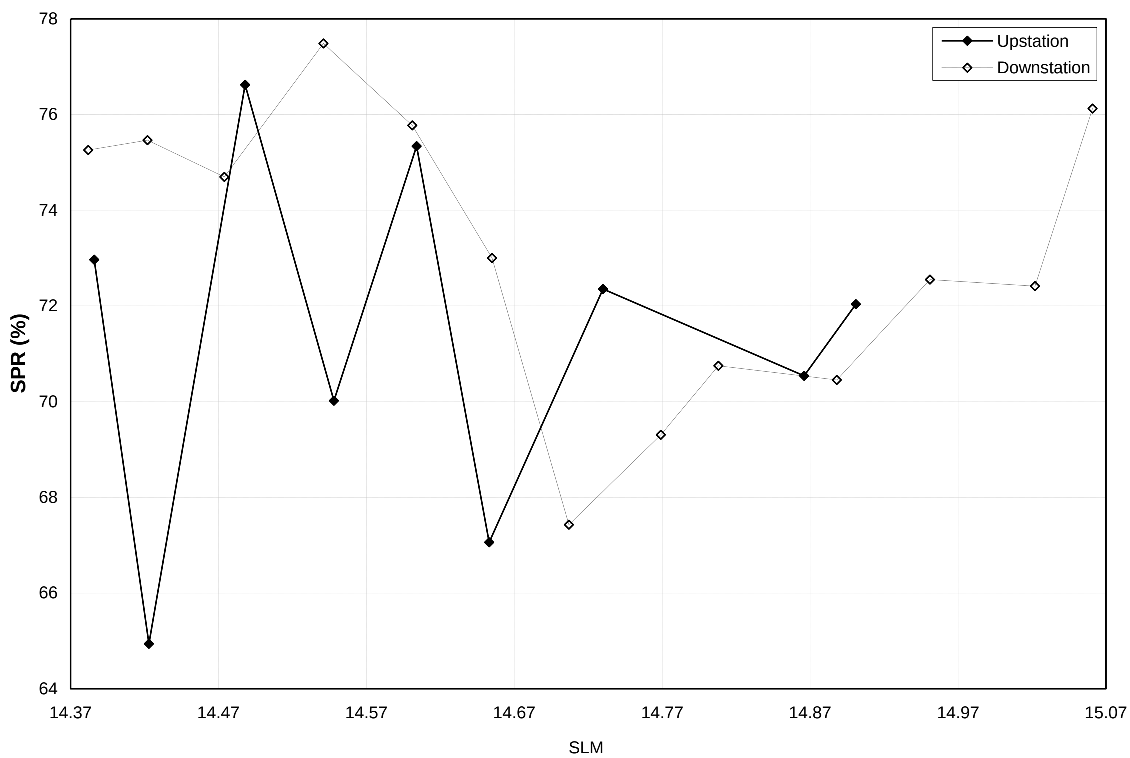


Figure K48. Midslab Spreadability – Project 23, MOT 35 (343-88)

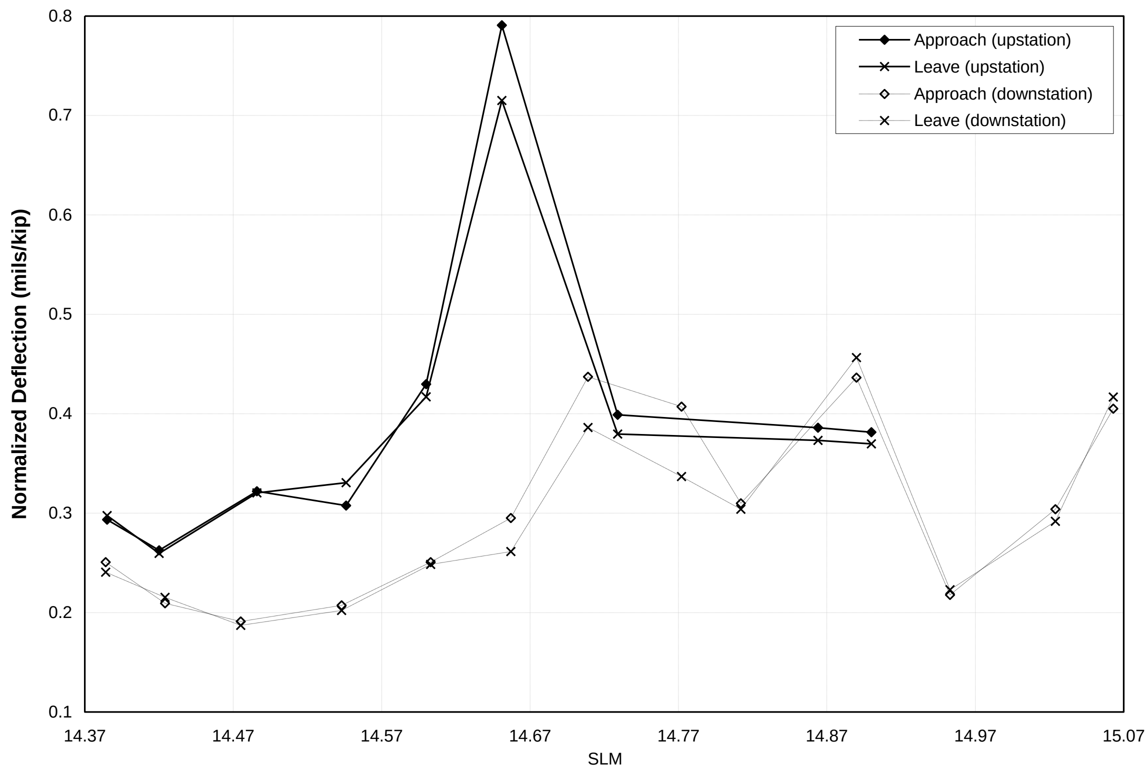


Figure K49. Maximum Joint Deflections – Project 23, MOT 35 (343-88)

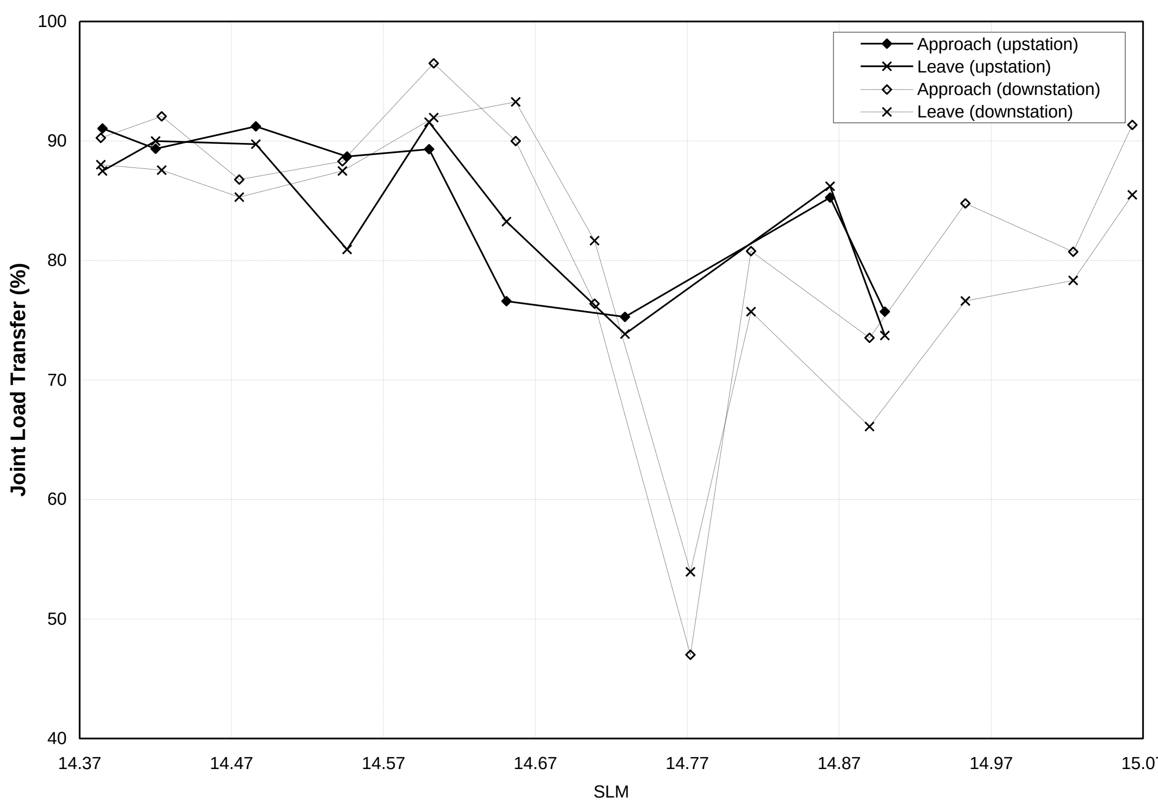


Figure K 50. Joint Load Transfer – Project 23, MOT 35 (343-88)

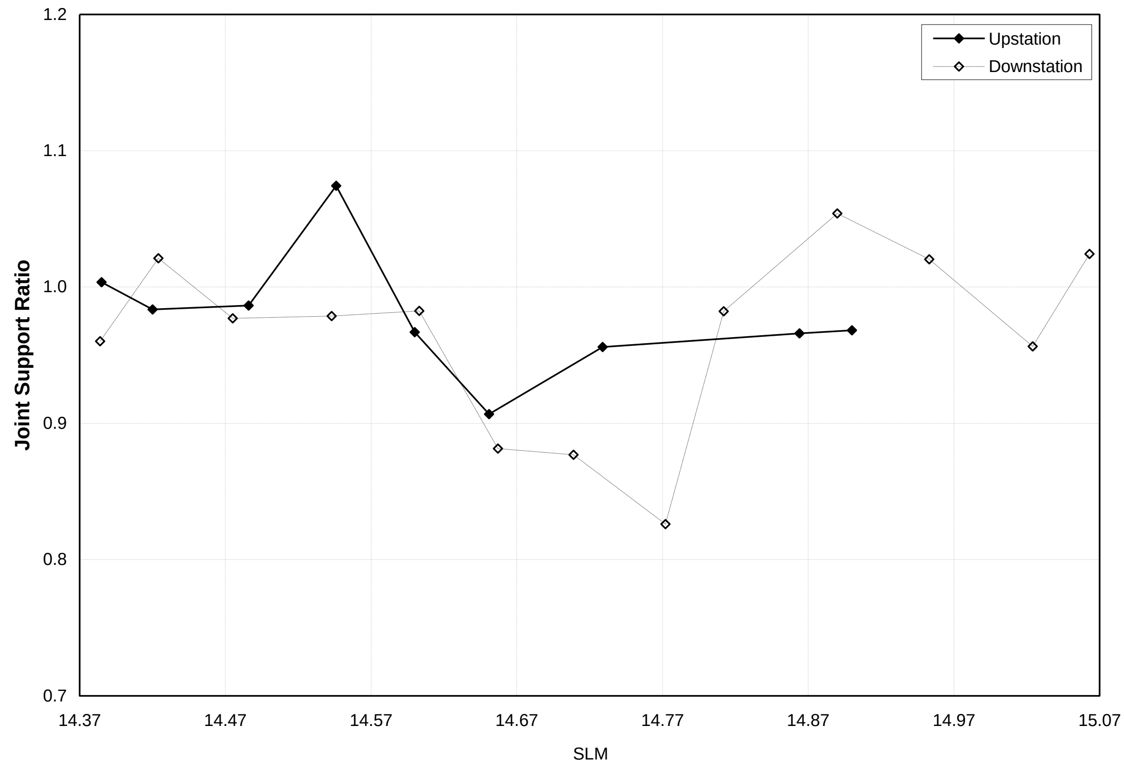


Figure K51. Joint Support Ratio – Project 23, MOT 35 (343-88)

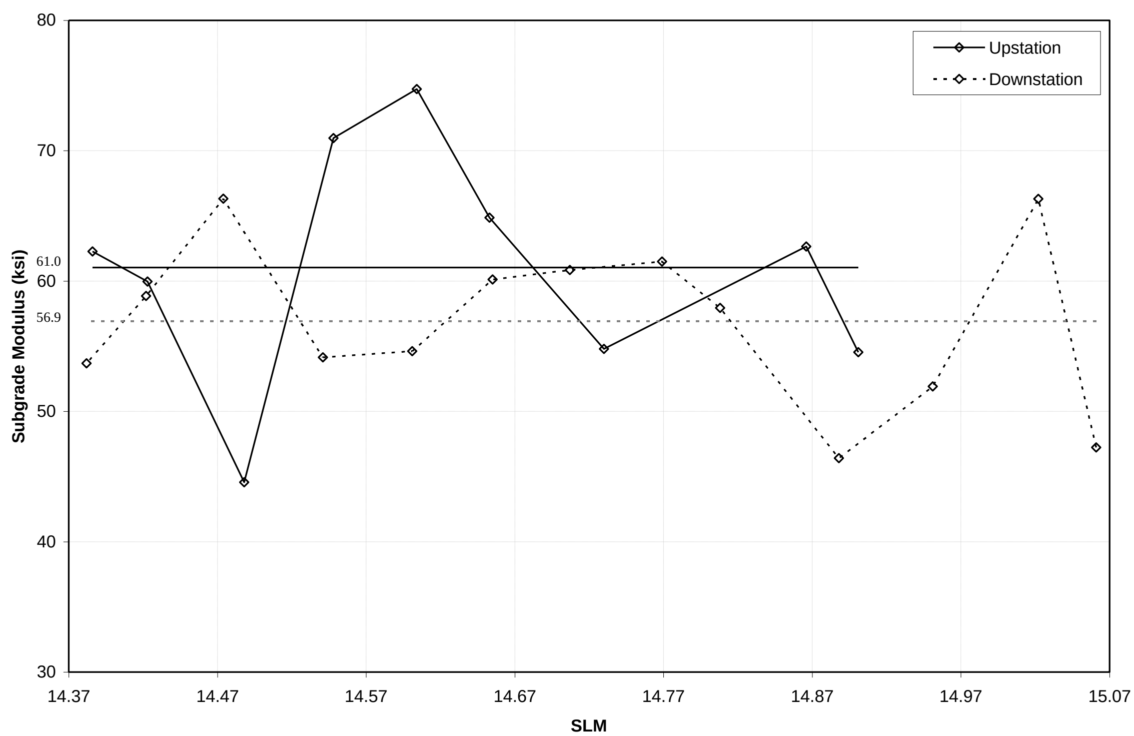


Figure K52. Subgrade Modulus – Project 23, MOT 35 (343-88)

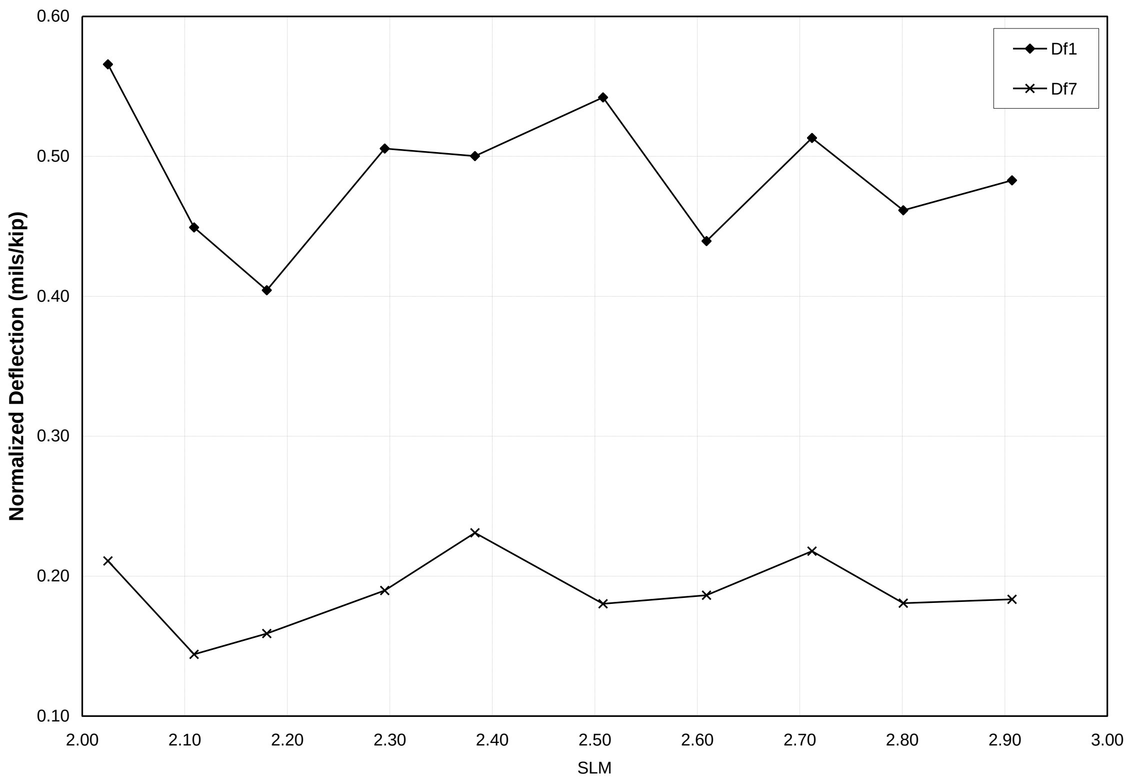


Figure K53. Midslab Deflection – Project 24, MOT 202 (678-91)

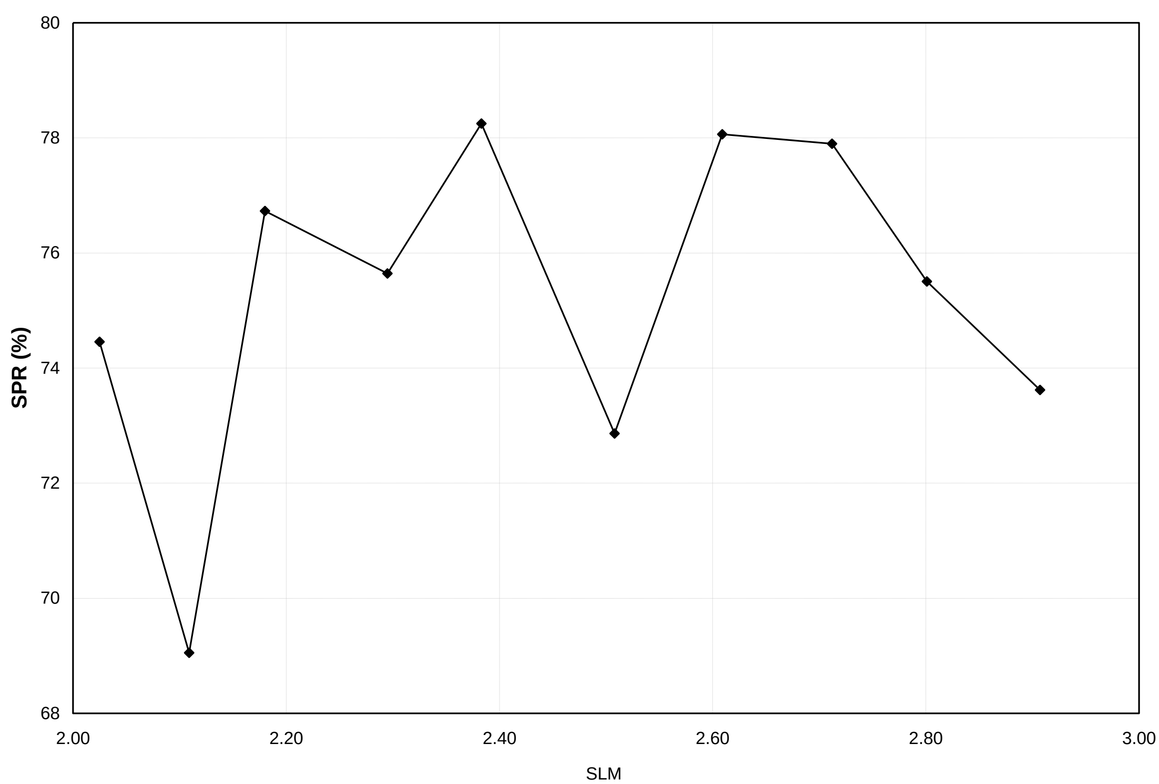


Figure K54. Midslab Spreadability – Project 24, MOT 202 (678-91)

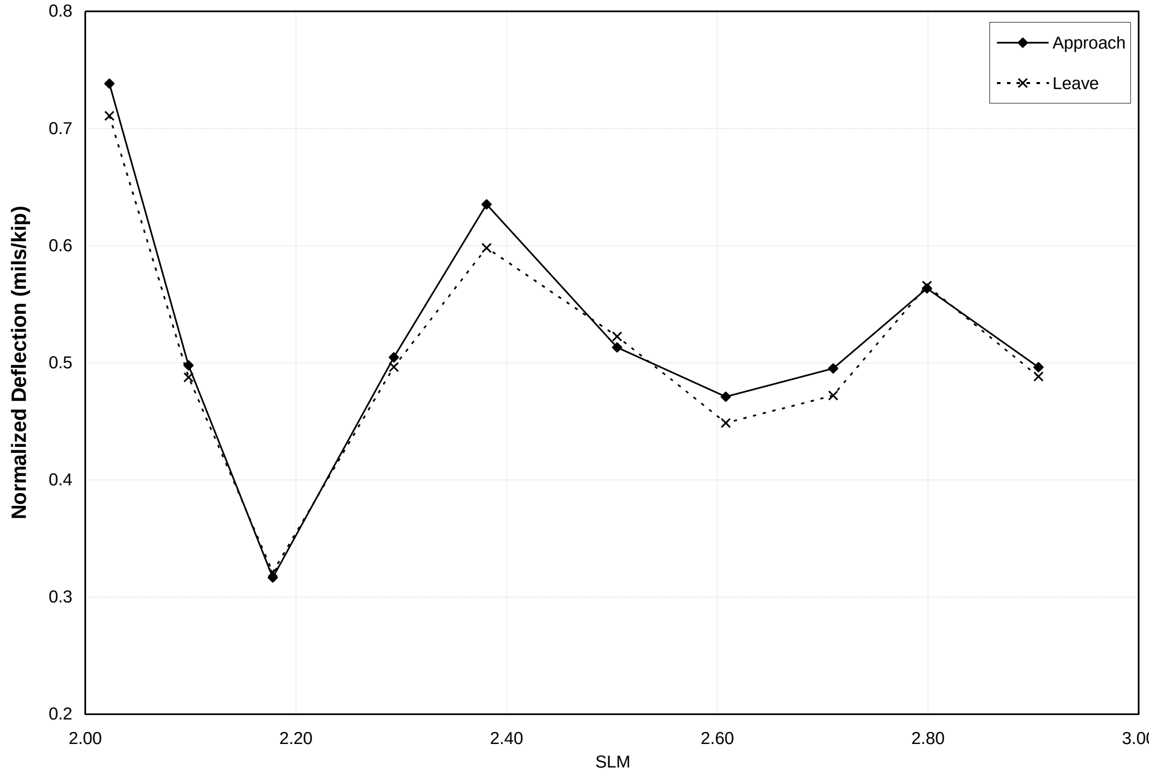


Figure K55. Maximum Joint Deflections – Project 24, MOT 202 (678-91)

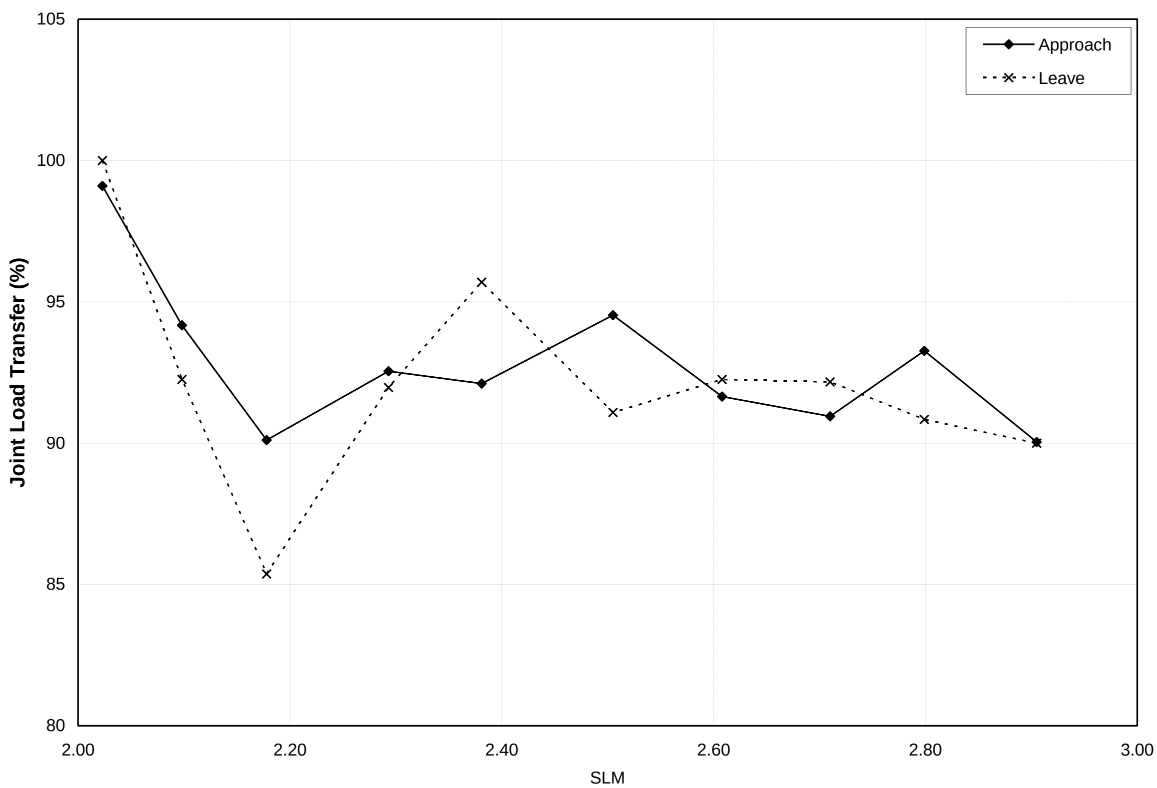


Figure K56. Joint Load Transfer – Project 24, MOT 202 (678-91)

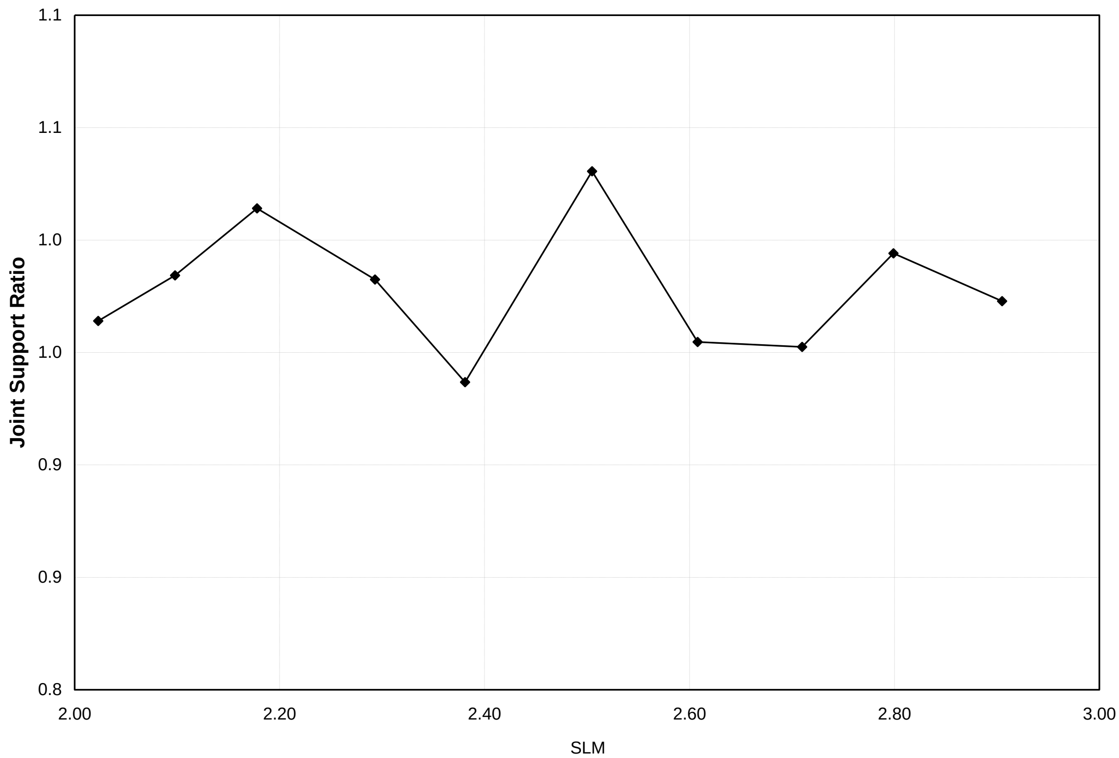


Figure K57. Joint Support Ratio – Project 24, MOT 202 (678-91)

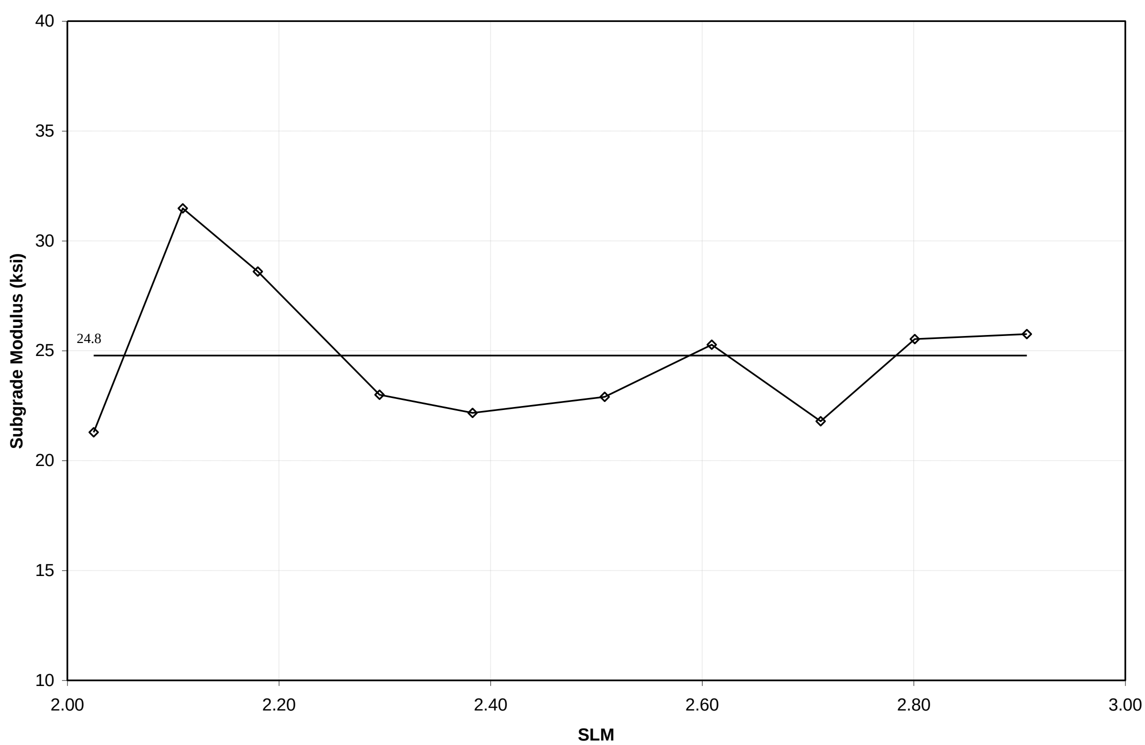


Figure K58. Subgrade Modulus – Project 24, MOT 202 (678-91)

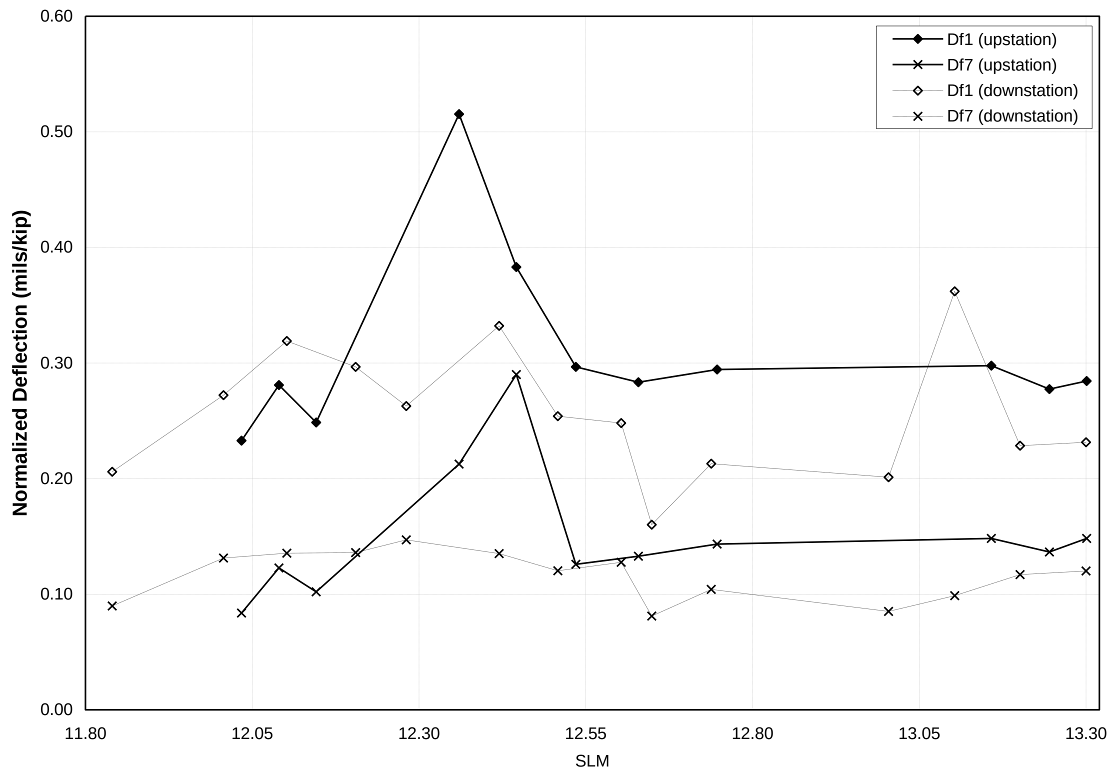


Figure K59. Midslab Deflection – Project 25, SUM 76 (844-92)

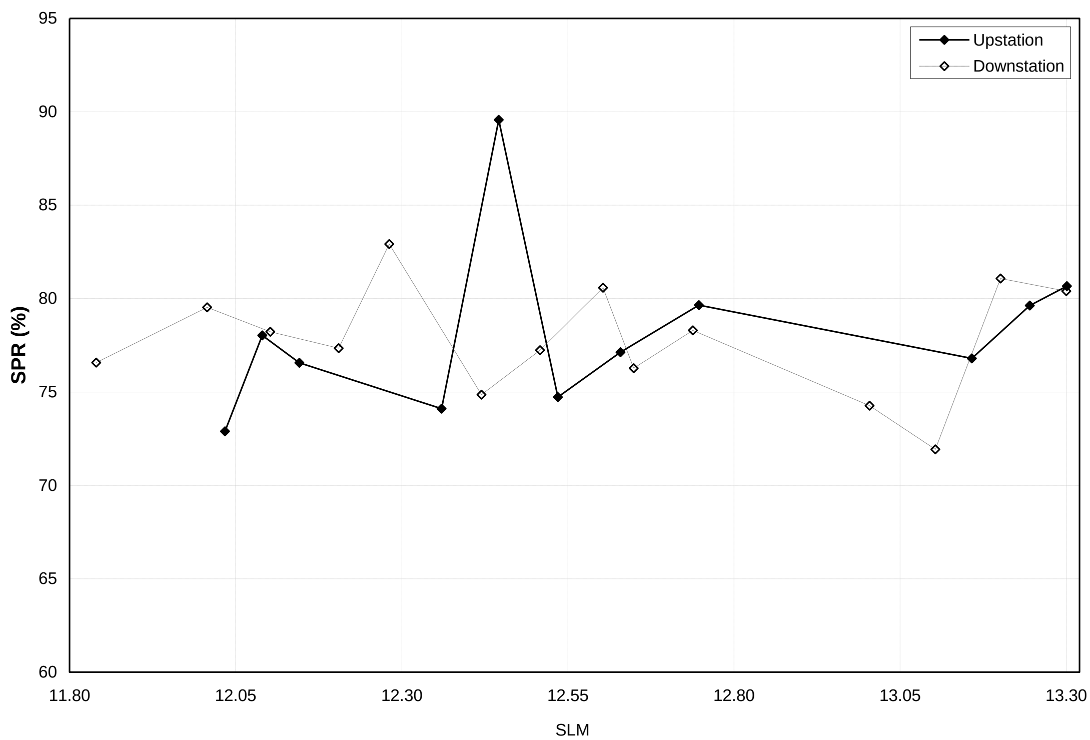


Figure K60. Midslab Spreadability – Project 25, SUM 76 (844-92)

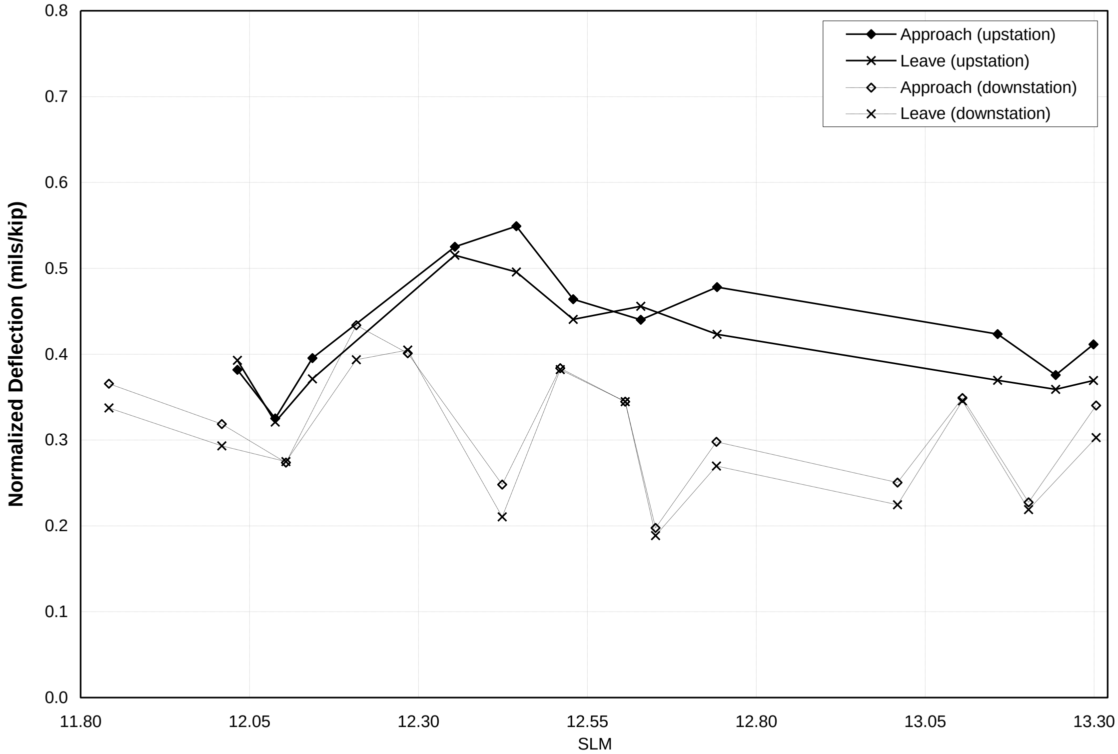


Figure K61. Maximum Joint Deflections – Project 25, SUM 76 (844-92)

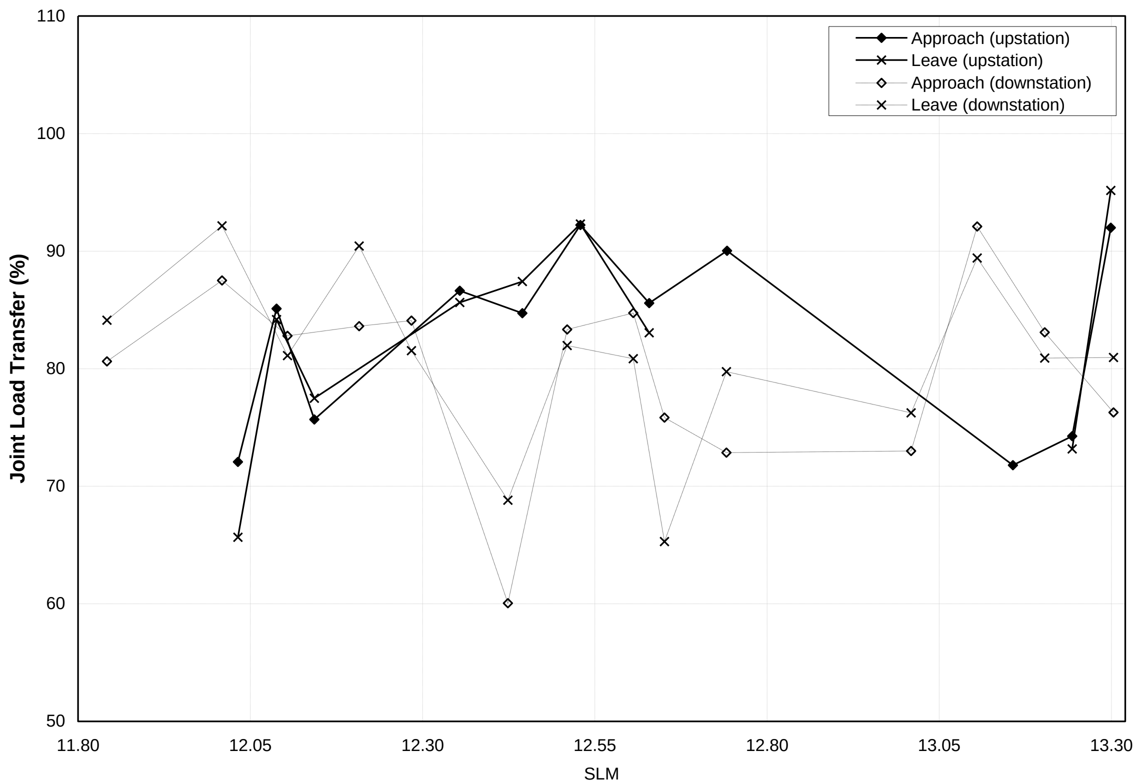


Figure K62. Joint Load Transfer – Project 25, SUM 76 (844-92)

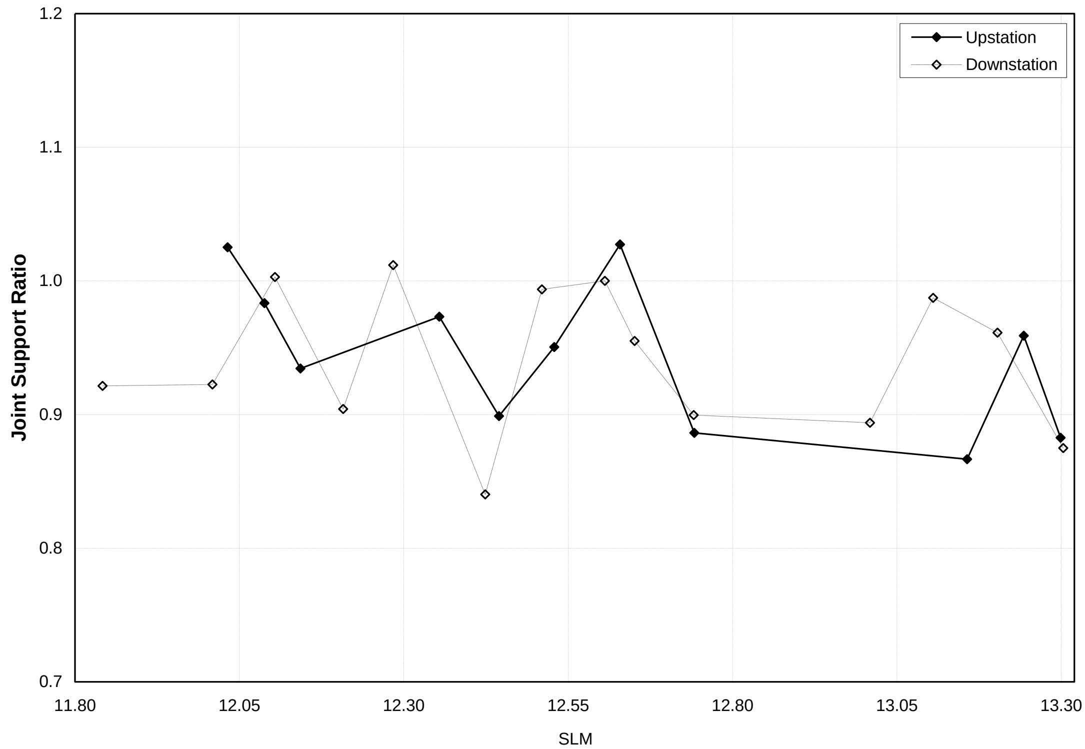


Figure K63. Joint Support Ratio – Project 25, SUM 76 (844-92)

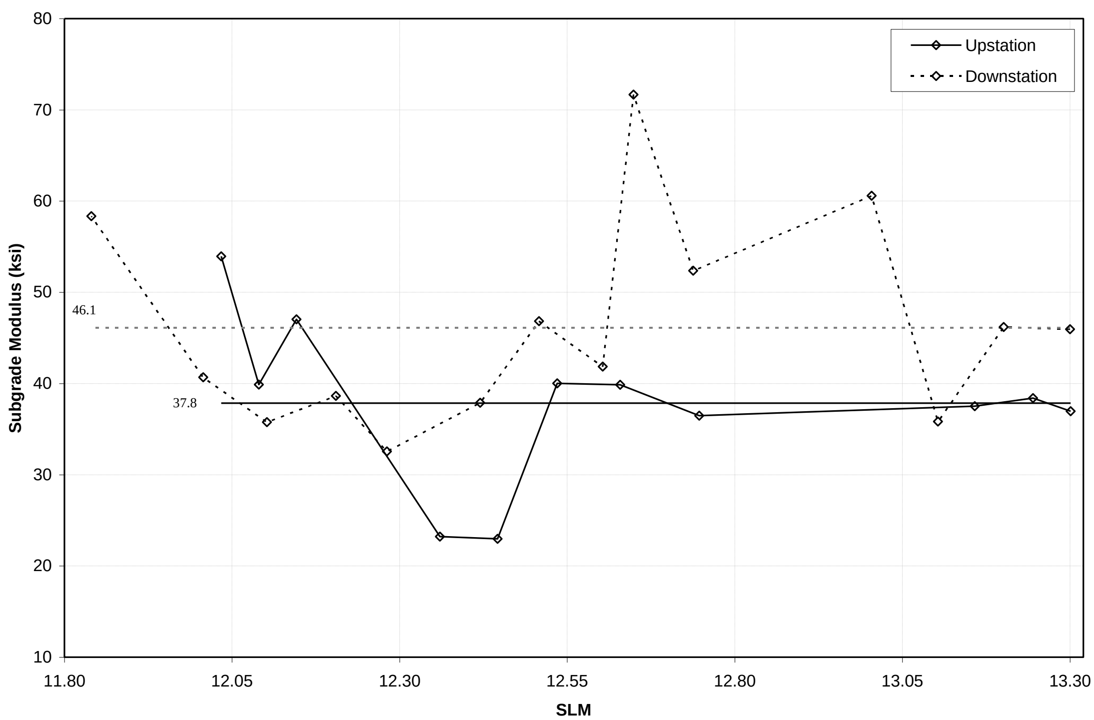


Figure K64. Subgrade Modulus – Project 25, SUM 76 (844-92)

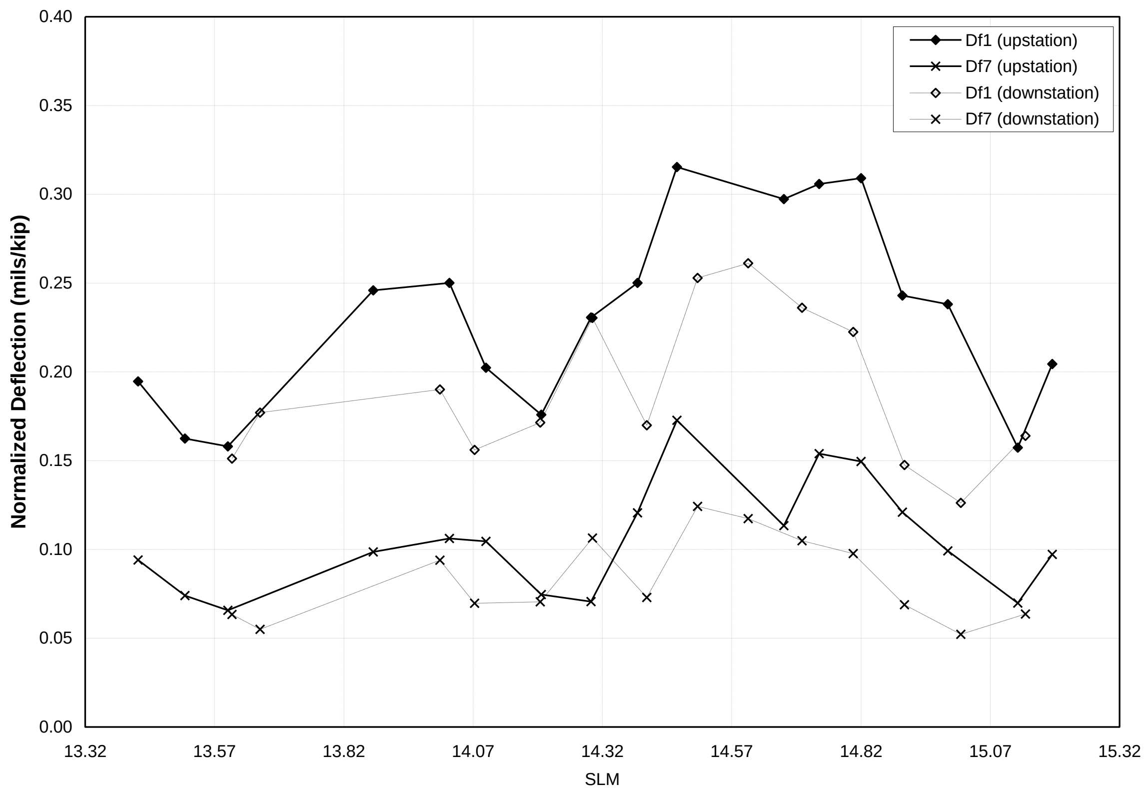


Figure K65. Midslab Deflection – Project 26, SUM 76 (996-93)

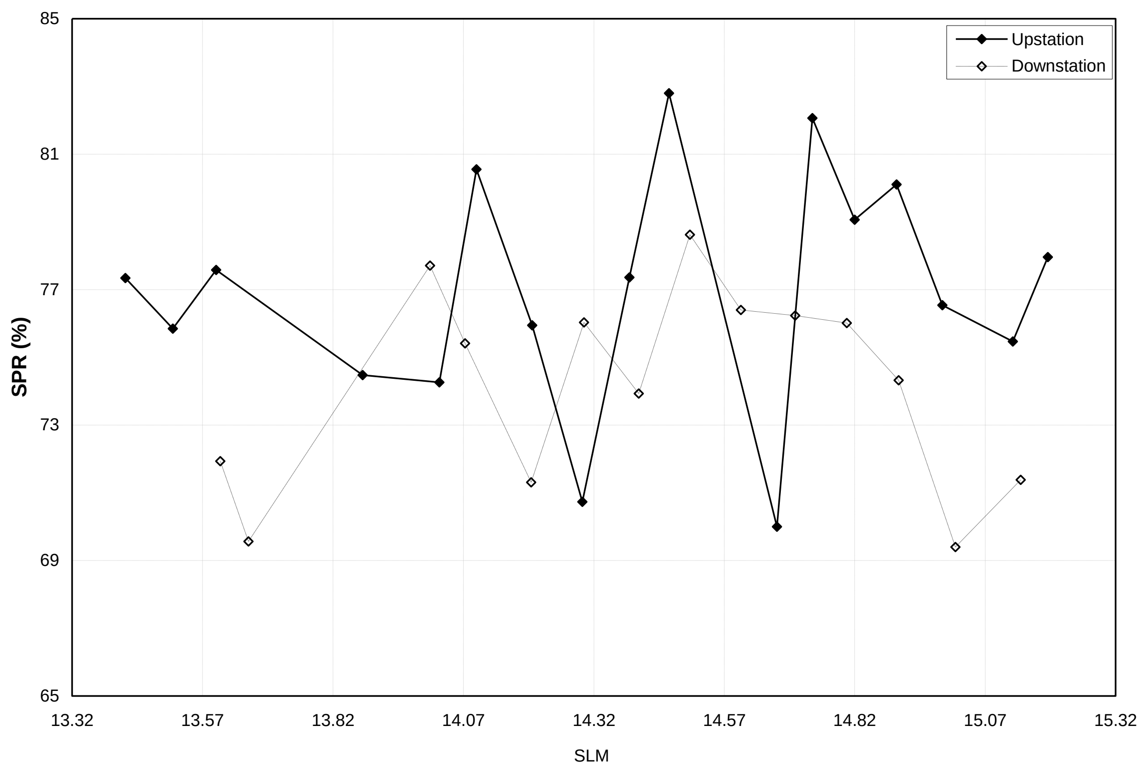


Figure K66. Midslab Spreadability – Project 26, SUM 76 (996-93)

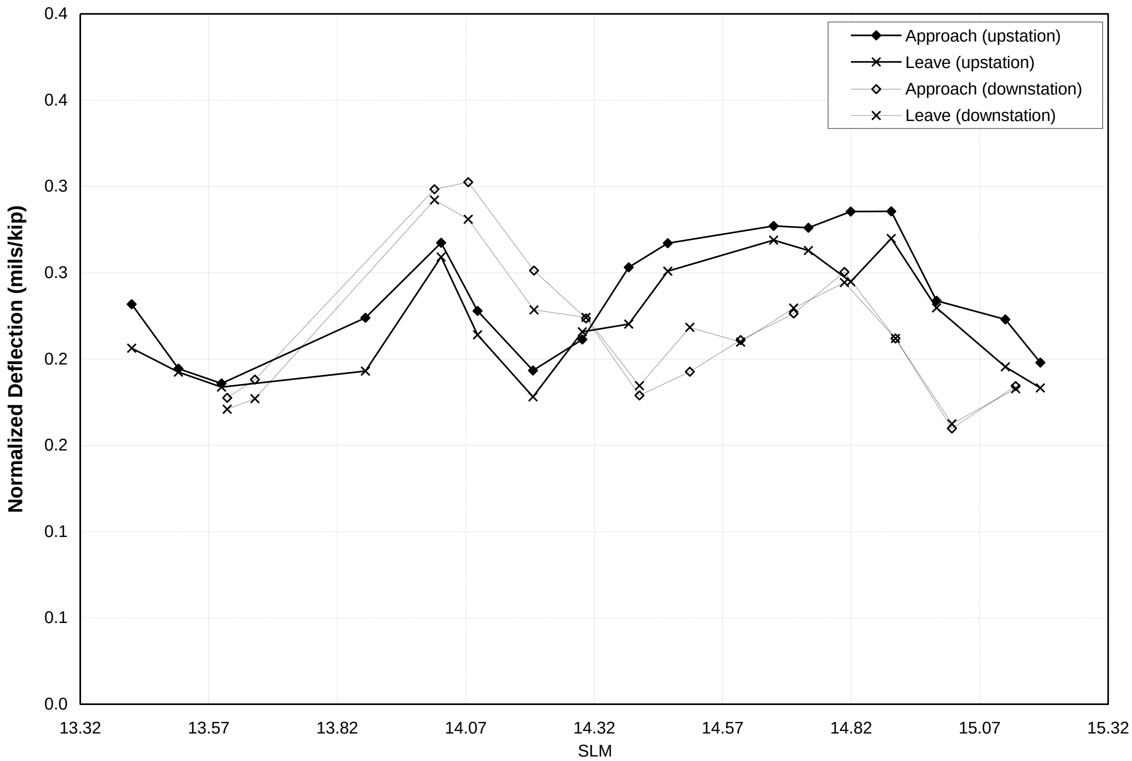


Figure K67. Maximum Joint Deflections – Project 26, SUM 76 (996-93)

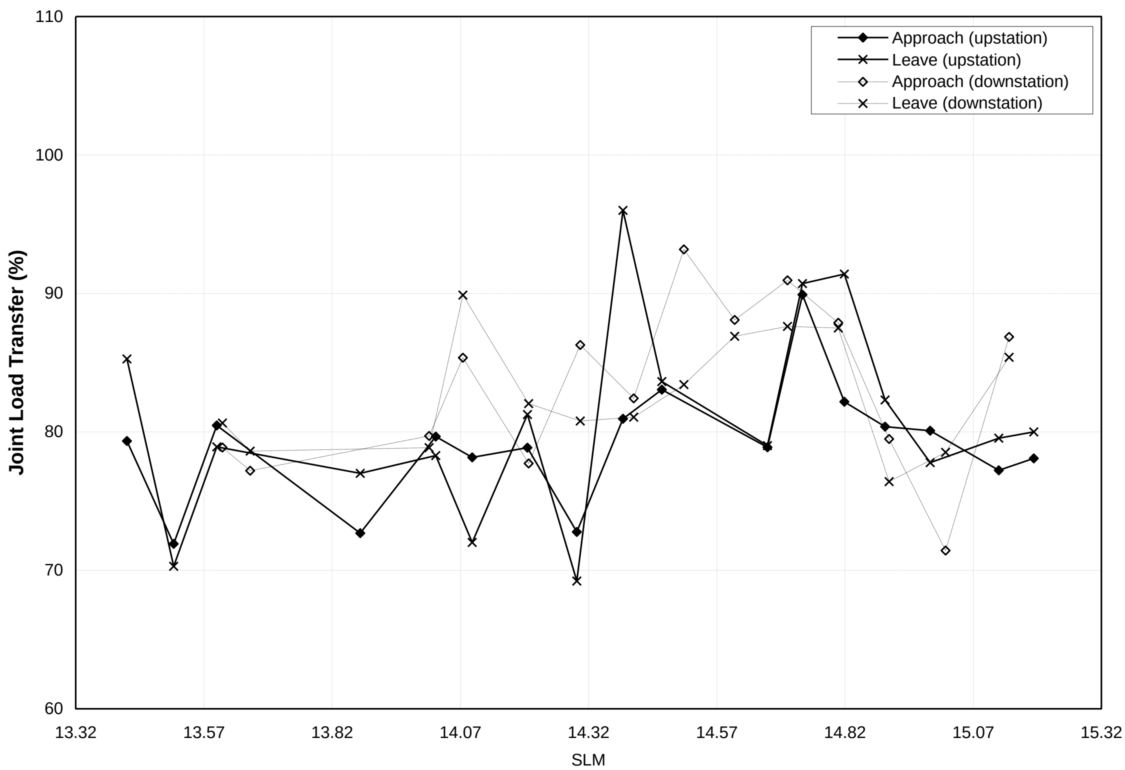


Figure K68. Joint Load Transfer – Project 26, SUM 76 (996-93)

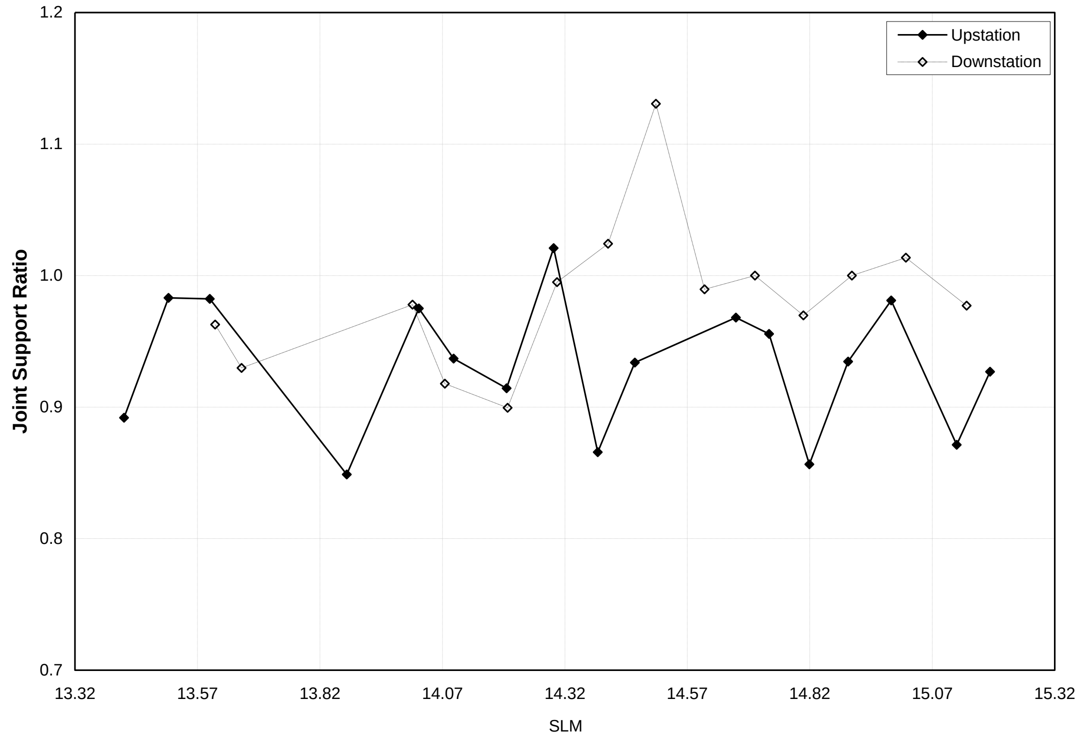


Figure K69. Joint Support Ratio – Project 26, SUM 76 (996-93)

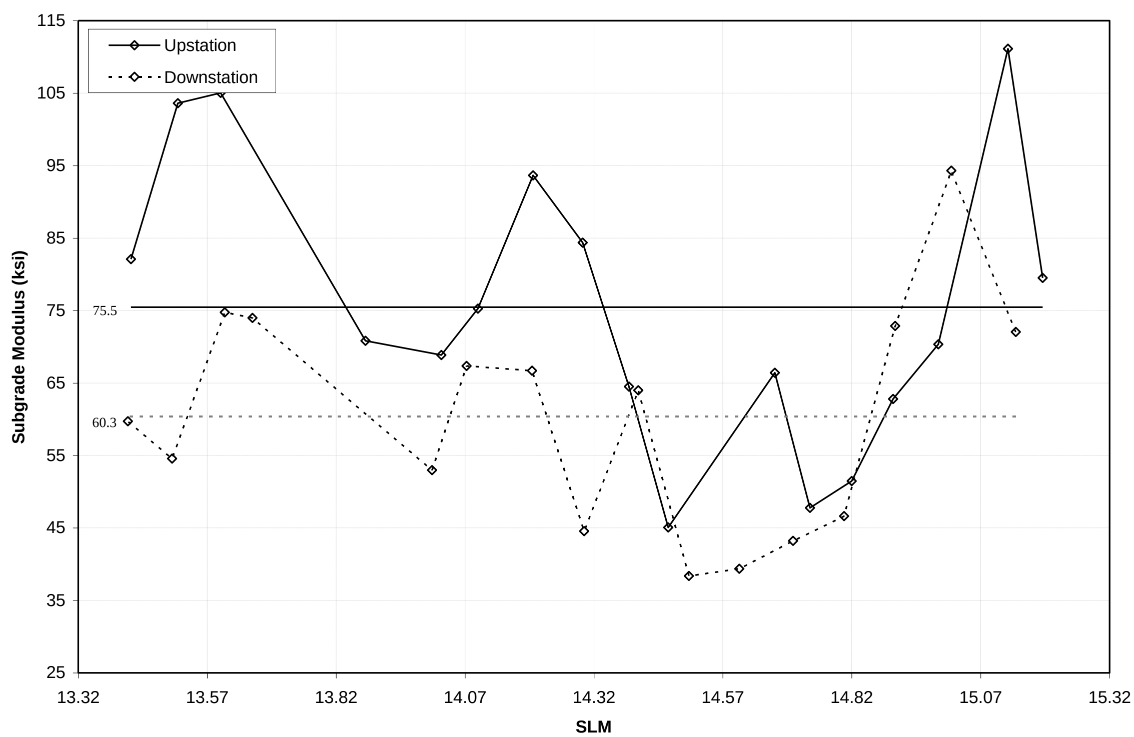


Figure K70. Subgrade Modulus – Project 26, SUM 76 (996-93)

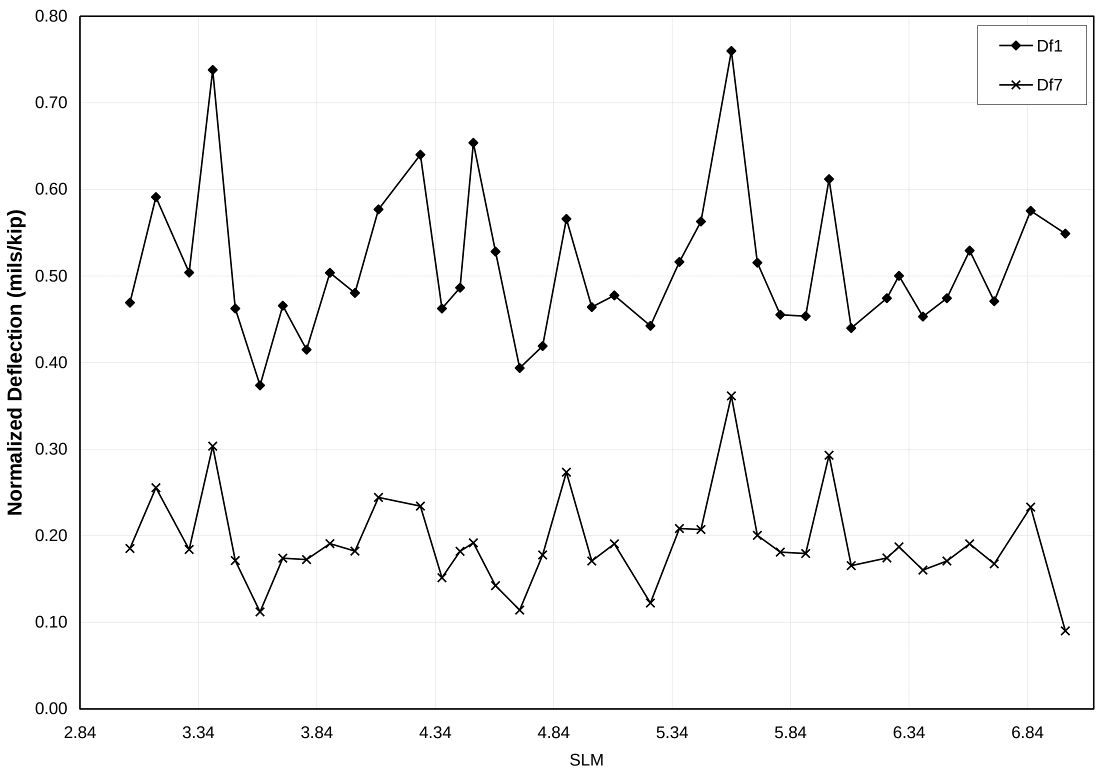


Figure K71. Midslab Deflection – Project 27, TUS 39 (907-90)

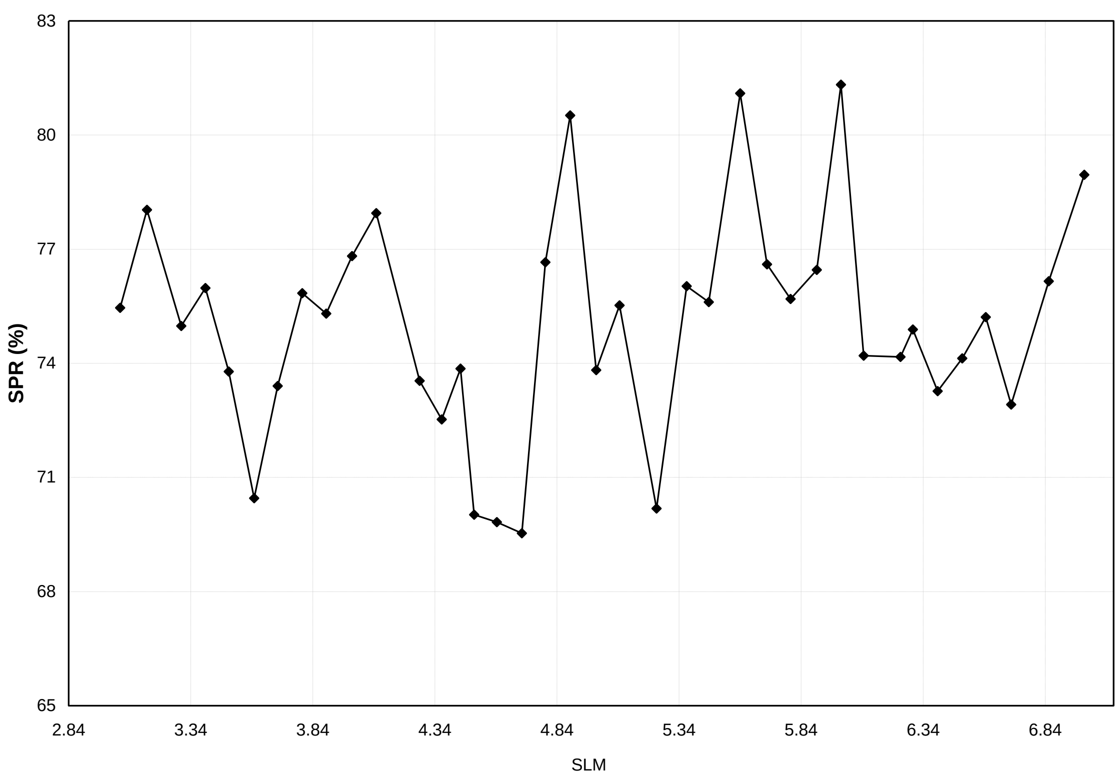


Figure K72. Midslab Spreadability – Project 27, TUS 39 (907-90)

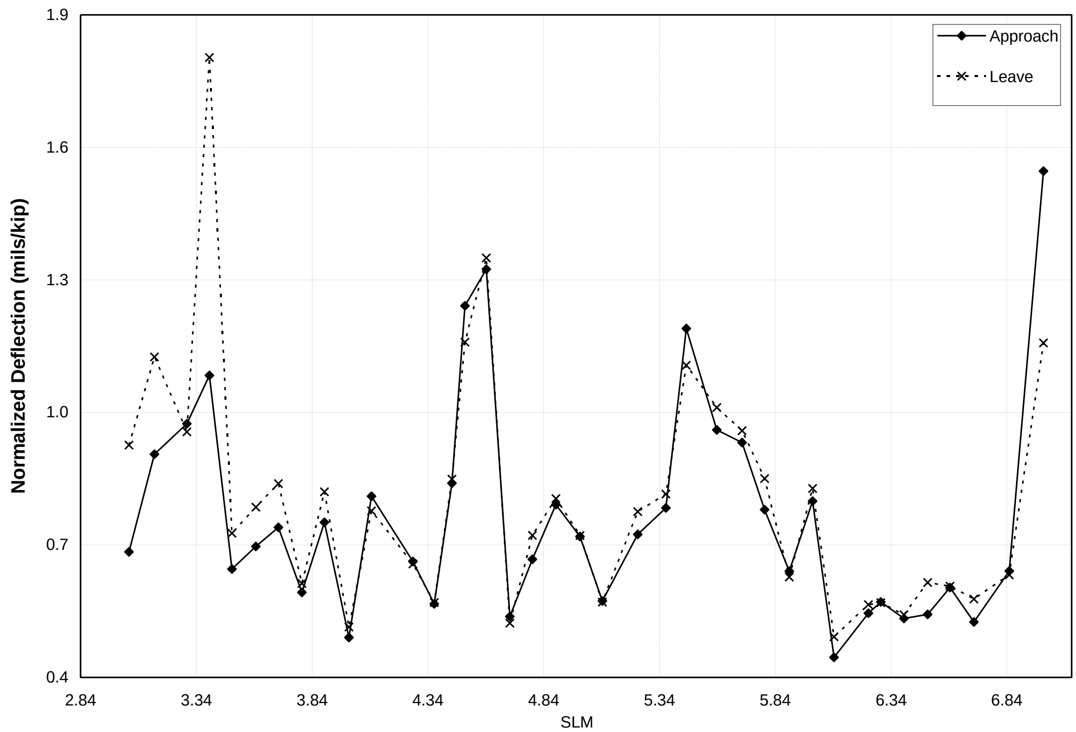


Figure K73. Maximum Joint– Project 27, TUS 39 (907-90)

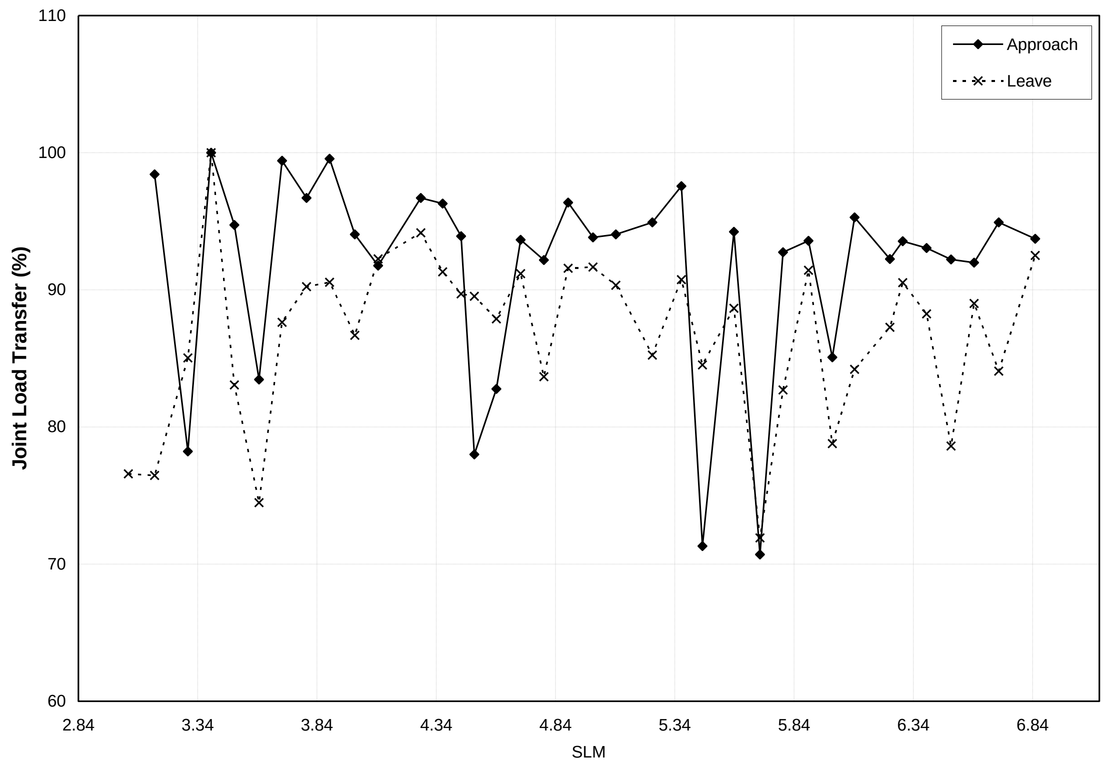


Figure K74. Joint Load Transfer – Project 27, TUS 39 (907-90)

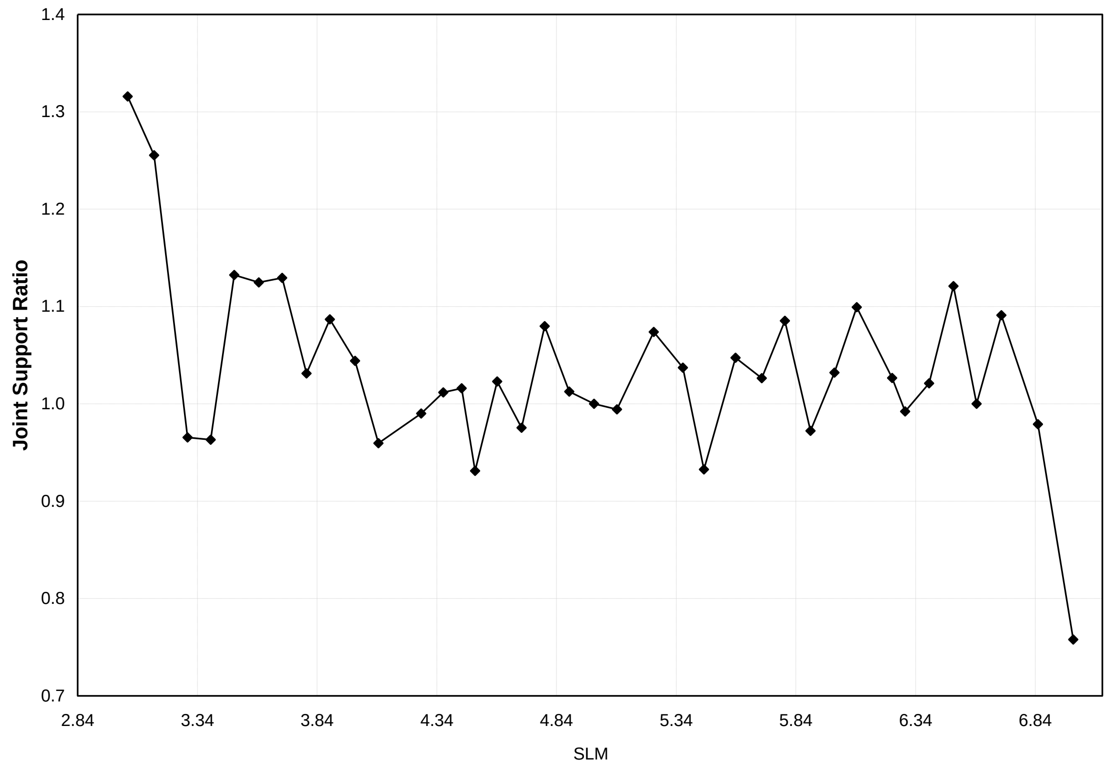


Figure K75. Joint Support Ratio – Project 27, TUS 39 (907-90)

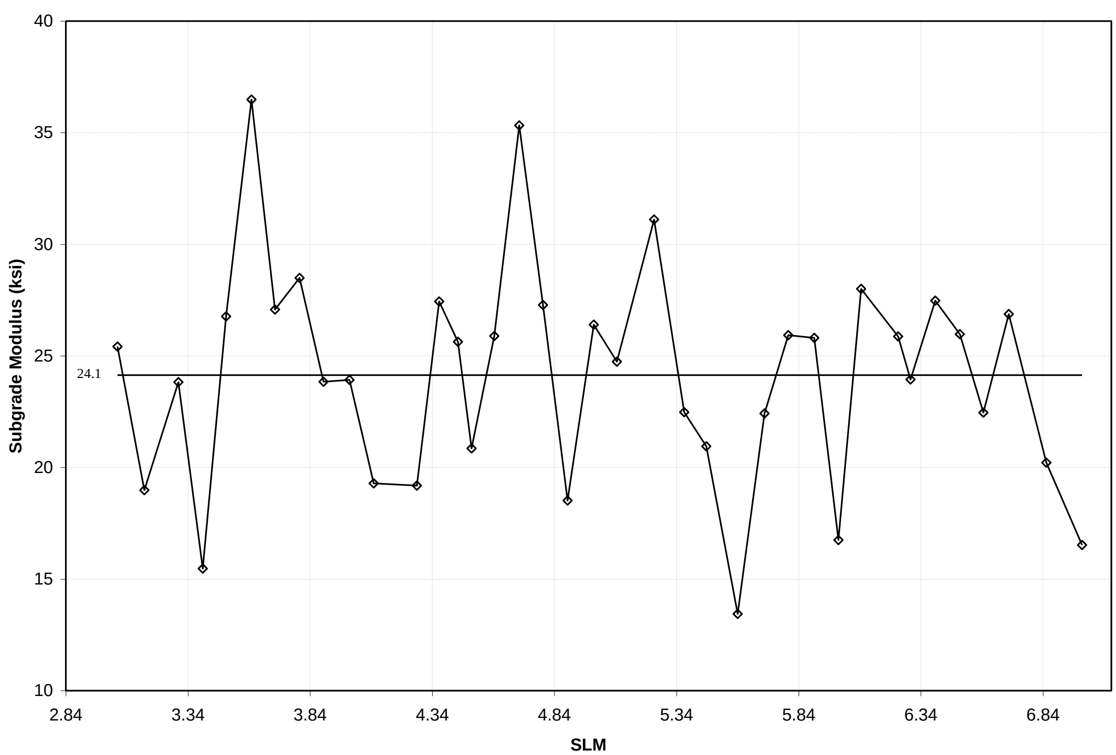


Figure K76. Subgrade Modulus – Project 27, TUS 39 (907-90)

<u>APPENDIX L</u>

Implementation Plan

OHIO DEPARTMENT OF TRANSPORTATION
OFFICE OF PAVEMENT ENGINEERING
RESEARCH IMPLEMENTATION PLAN

Title: **Forensic Investigation of AC and PCC Pavements with Extended Service Life**
State Job Number: 134280
PID Number:
Research Agency: Ohio University
Researcher(s): Shad Sargand and William Edwards
Technical Liaison(s): Roger Green
Research Manager: Jennifer Gallagher
Sponsor(s): ODOT
Study Start Date: January 15, 2006
Study Completion Date: September 15, 2010
Study Duration: 56 Months
Study Cost: $404,571.60
Study Funding Type:

STATEMENT OF NEED:
The purpose of this research project is to identify flexible, rigid and composite pavements that have not received any structural maintenance since construction and are considered to be performing either average or excellent, and determine reasons why excellent pavements perform better than average pavements. By identifying these reasons and implementing them into standard practice, the overall performance of pavements in Ohio can be improved in the future.

RESEARCH OBJECTIVES:
The following are primary objectives of this research:

- Review the ODOT pavement database to determine current performance expectations on highway pavements in Ohio. In this statistical analysis, pavements will be divided according to: type of original construction (flexible, rigid and composite); classification (interstate, four-lane non-interstate and two-lane); geographical region in the state; and traffic volume. Composite pavements will be limited to those constructed as such, and not concrete pavements overlaid later with asphalt concrete. Measures upon which performance will be judged include: distress, roughness, age, traffic loading (ESALs), and rutting as a separate criteria on asphalt concrete pavements.

- From the statistical analyses performed in Objective 1, a final selection of ten asphalt concrete (AC) and ten Portland cement concrete (PCC) projects performing as expected, and ten AC and ten PCC projects performing beyond expectations will be made by representatives from the Ohio Department of Transportation (ODOT), Ohio University (OU), and industry. A few composite pavements may be included, as deemed appropriate. Pavements which appear to be performing poorly in this analysis also will be identified for review by ODOT

- ODOT District Offices responsible for those pavements selected as performing as expected and better than expected will be visited to discuss the selection process and to gain input regarding past performance.

- Inspect each of the selected sites and perform a suite of tests to develop response and performance profiles along the project lengths. These site inspections will include, at a minimum, Pavement Distress Survey (SHRP-P338), Pavement Condition Ratings (PCR), Falling Weight Deflectometer

(FWD) readings, Dynamic Cone Penetrometer measurements (DCP), Ground Penetrating Radar measurements (GPR), roughness measurements, lateral profiles on AC surfaces, cores, and the collection of representative material samples.

- Conduct a historical review of each project to determine: age, environmental conditions, original specifications, construction documentation, original test data, traffic volumes and weights accumulated since being opened to traffic, and previous condition information collected by ODOT (PCR, FWD, ride quality, etc.). Personnel associated with the design and/or construction of the study pavements will be contacted to determine if they recall any particular decisions or events that might have affected performance. ODOT will provide access to the required files and ORITE will search the files for pertinent data.

- Conduct laboratory tests to determine the current physical properties of pavement, base and subgrade materials in the study pavements. Compare these current properties with properties measured at the time of construction. In addition to this battery of standard tests, the PCC cores will undergo an extensive petrographic examination to ascertain compliance with original specifications and current micro structural condition.

- Perform mathematical analyses to assess theoretical structural performance based on distress and thickness using various performance prediction procedures, historical data and in-situ material properties. At a minimum, equations developed under NCHRP 1-26, software developed under NCHRP 1-37A and 1993 AASHTO procedures will be used to predict performance.

- Identify design, construction, and material features which appear to extend pavement life on superior pavements, and recommend procedures for improving the longevity of pavements in Ohio by implementing these features into practice. Document all work in a final report.

RESEARCH TASKS:
Task 1 – Analysis of the ODOT Pavement Database
Task 2 – Selection of the Study Pavements
Task 3 – District Visits
Task 4 - Site Investigation
Task 5 - Historical Review
Task 6 - Laboratory Testing
Task 7 - Data Analysis
Task 8 - Compile a list of design, construction and material elements which, if implemented, would extend pavement life on future projects. Prepare a final report documenting all work on the project and furnish the required number of reports to ODOT.
Additional Task - Petrographic examination of selected PCC cores by subcontractor, including cores from selected pavements in Cuyahoga County with granulated blast furnace slag. Selected laboratory measurements of engineering properties of cores from pavements with slag.

RESEARCH DELIVERABLES:
Final Report (in three volumes), Executive Summary

RESEARCH RECOMMENDATIONS:
Among the items recommended to improve pavement performance include: 1) use performance graded asphalt cement, small sized aggregate and polymers when designing surface and intermediate mixes for heavily traveled flexible pavements, 2) maintain uniform stiff subgrades with improved stiffness controls during construction and thicker base layers, and 3) replace some Portland cement with fly ash and use larger aggregate in pavement concrete, while continuing to test for D-cracking susceptibility.

Other observations regarding the data used to reach these conclusions include: keeping the ODOT PMIS database current, retaining construction records for at least the design life of the pavements, being aware that the effect of surface cracks on flexible pavement performance depends upon whether the cracks are top-down or bottom-up, and the PMIS and straight-line diagrams should be consistent in identifying project limits, project numbers and paving materials.

PROJECT PANEL COMMENTS:

IMPLEMENTATION STEPS and TIME FRAME:

The following items of implementation are suggested as responses to the major conclusions:

9. Assemble personnel who are familiar with and/or frequent users of the PMIS and Straight-Line Diagrams to review Conclusions 1-6 in Chapter 6 of the report and other problems mentioned in Chapter 2. Consider how applicable these issues are with the current PMIS and SLDs, and take actions to improve areas that continue to need improvement.

10. PCR data in 2002 and 2004 versions of the PMIS were often not consistent with the assigned projects numbers. This problem can lead to incorrect ages being assigned to condition data. Develop a procedure for updating project numbers whenever new PCR, traffic, and ride quality data are added to the PMIS tables.

11. PCR raters interpret crack patterns on pavement surfaces, and assign levels of severity and extent to each type of crack. Bottom up cracks are more detrimental to structural condition and pavement life than top down cracks and, therefore, should be rated more severely. Develop a procedure for determining whether cracks are bottom up or top down, and rating them separately.

12. Consider developing a procedure for specifying some minimum level of subgrade stiffness during construction and monitoring to see that the requirement is met. This suggestion has been made on other ORITE research projects where subgrade stiffness was found to have a significant impact on performance.

13. Continue to design drainage features for removing excess moisture from pavement structures and the underlying subgrades. While this has long been a priority with ODOT, various comments are still heard about instances where moisture is causing pavement problems.

14. ODOT has done a good job of implementing and improving SHRP asphalt specifications which tend to follow conclusions noted herein for improving conventional mixes used in the selected flexible sections, including the use of smaller aggregate in surface and intermediate mixes to improve durability, and modified ODOT 442 Superpave mix design requirements to yield higher than specified asphalt binder contents to maximize performance. Continue to monitor new developments from SHRP and adapt them for Ohio conditions.

15. Review the recommendations contained in Volumes 1 and 2 of the Final Report for reducing cement content, using fly ash and increasing the size of large aggregate in concrete mixes for rigid pavement. Construct a few small sections around the state and monitor their performance closely.

16. In accordance with Conclusion 7 of the report, reevaluate the current retention policy for construction and maintenance records. In order to evaluate completed projects for either good or bad performance, it is vital that pertinent data and diaries associated with those projects be available for review.

EXPECTED BENEFITS:

By conducting a forensic investigation of pavements performing as expected and better than expected, differences in design, construction and/or materials can be identified and implemented on future projects. Projects performing as expected would be those showing moderate distress, or a PSI of about 2.5, at the end of their design life, and projects performing beyond expectations would be those showing little distress, and a higher PSI, long after the design life has passed. The identification and implementation of factors contributing to extended pavement life can improve pavement performance and reduce maintenance costs in the future. Many parameters identified as having improved performance likely can be implemented immediately into manuals and/or specifications. Potential items for implementation might include: improved techniques for monitoring the mixing and placement of AC and PCC materials in the field, improved techniques for selecting and placing base materials, and improved techniques for constructing subgrades to minimize variability in stiffness. Other findings might include innovative techniques for draining pavements and treating wet subgrades.

Pavement projects investigated in this study can be used to validate and calibrate past, present and future design procedures. By having specific design, climatic, material, and traffic information on projects where actual performance has been documented over time, the output of various modeling techniques can be compared to actual field experience. At a minimum, these models will include the NCHRP 1-26, NCHRP 1-37A and 1993 AASHTO models.

The Ohio Department of Transportation (ODOT) and other road agencies in the state are regularly encouraged by private industry and others to use “waste” ACBFS as a substitute for aggregate. The material is presented as a way to relieve a waste problem for the industry while saving money on the expense of aggregate.

EXPECTED RISKS, OBSTACLES, and STRATEGIES TO OVERCOME THEM:

OTHER ODOT OFFICES AFFECTED BY THE CHANGE:

PROGRESS REPORTING and TIME FRAME:

TECHNOLOGY TRANSFER METHODS TO BE USED:

IMPLEMENTATION COST and SOURCE OF FUNDING:

Approved By: (attached additional sheets if necessary)

Office Administrator(s):

Signature: ______________________________ Office: _____________ Date: _______________

Signature: ______________________________ Office: Date:

Division Deputy Director(s):

Signature: ______________________________ Division: _____________ Date: ________________

Signature: ______________________________ Division: _____________ Date: ________________

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