EVALUATION OF PAVEMENT PERFORMANCE ON DEL 23

Shad Sargand and staff

Prepared in cooperation with the
Ohio Department of Transportation
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and the
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16. Abstract

In 1994, a ramp containing two AC and two PCC sections in the SPS-8 experiment was constructed on the Ohio SHRP Test Road. In 1996, 36 more sections in the SPS-1, SPS-2 and SPS-9 experiments were opened to traffic on the mainline pavement. The response and performance of these sections, climatic information from an on-site weather station, subsurface environmental conditions from sensors installed in several test sections, and traffic loading from an on-site weigh-in-motion (WIM) system have been monitored and incorporated into the national LTPP database. Analyses of these data have been published in a number of reports, technical papers and bulletins. The research project documented in this report was the latest effort by ODOT to continue monitoring the response and performance of many of the original 40 test sections and several sections constructed later to replace the lighter designs which, as anticipated, showed early distress. Data in this report cover the years 2000 - 2005. In addition to the new response and performance data obtained on the test road, this report includes: an analysis of current methodologies to mathematically model AC and PCC pavement structures, a petrographic analysis of concrete from three different PCC pavement mixes and a lean concrete base, and an in-depth analysis of WIM data.

Three other experimental pavements have been constructed on ATH 50, LOG 33 and ERI/LOR 2 to evaluate the response and performance of specific parameters of interest to ODOT. These parameters included: high performance concrete containing ground granulated blast furnace slag and different types of dowel bars on ATH 50, different types of base material under flexible pavement on LOG 33, and different types of base material under rigid pavement on ERI/LOR 2. This report also contains data collected on these three pavements during 2000 - 2005.

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SI* (MODERN METRIC) CONVERSION FACTORS

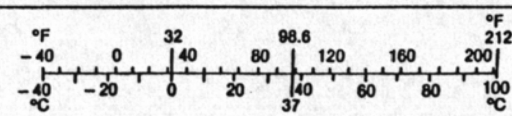
APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimetres	mm
ft	feet	0.305	metres	m
yd	yards	0.914	metres	m
mi	miles	1.61	kilometres	km
		AREA		
in^2	square inches	645.2	millimetres squared	mm^2
ft^2	square feet	0.093	metres squared	m^2
yd^2	square yards	0.836	metres squared	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	kilometres squared	km^2
		VOLUME		
fl oz	fluid ounces	29.57	millilitres	mL
gal	gallons	3.785	litres	L
ft^3	cubic feet	0.028	metres cubed	m^3
yd^3	cubic yards	0.765	metres cubed	m^3
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5(F-32)/9	Celcius temperature	°C

NOTE: Volumes greater than 1000 L shall be shown in m^3.

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimetres	0.039	inches	in
m	metres	3.28	feet	ft
m	metres	1.09	yards	yd
km	kilometres	0.621	miles	mi
		AREA		
mm^2	millimetres squared	0.0016	square inches	in^2
m^2	metres squared	10.764	square feet	ft^2
ha	hectares	2.47	acres	ac
km^2	kilometres squared	0.386	square miles	mi^2
		VOLUME		
mL	millilitres	0.034	fluid ounces	fl oz
L	litres	0.264	gallons	gal
m^3	metres cubed	35.315	cubic feet	ft^3
m^3	metres cubed	1.308	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.102	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celcius temperature	1.8C + 32	Fahrenheit temperature	°F



* SI is the symbol for the International System of Measurement

(Revised April 1989)

EVALUATION OF PAVEMENT PERFORMANCE ON DEL 23

Final Report

Sponsored by

OHIO DEPARTMENT OF TRANSPORTATION

and

FEDERAL HIGHWAY ADMINISTRATION

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"Prepared in cooperation with the Ohio Department of Transportation and the U.S. Department of Transportation, Federal Highway Administration"

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ACKNOWLEDGEMENTS

The value of an experimental pavement increases over time. Pavement sections which fail after limited service provide early data for developing preliminary performance trends, while data from sections which retain good serviceability for an extended period of time are used to extend the range of the earlier trends, and features constructed into these better performing sections are closely monitored for potential implementation. The actual monetary value of an experimental pavement increases over time as it includes the initial cost of construction, and the continued investment in time and resources required for monitoring and evaluation during its service life. These costs are offset by savings accumulated on subsequent construction through the implementation of findings accrued from the experimental installation.

The intrinsic value of an experimental pavement also increases over time as, the longer it provides good service, the greater potential it has for economic returns and the more attention it receives from the public and from engineers and researchers across the state and around the country. If an experimental pavement is not monitored properly or is lost prematurely, the financial investments, the promotional benefits, the time spent monitoring the project, and the potential savings realized from implementation on other projects are essentially lost. ODOT is to be commended for its long-standing support for constructing experimental pavements to evaluate new materials or features which offer a good chance for improving statewide performance, and for its commitment to properly monitor these pavements for extended periods of time and through times of changing organizational structure, management, policies and priorities.

The authors wish to thank many people for their contributions to the Ohio SHRP Test Road and other instrumented pavements located around the state of Ohio. This includes many individuals from ODOT, various LTPP regional contractors, ORITE and several universities in Ohio who, for the past several years, have tirelessly traveled to the sites in all types of weather and collected data vital to the evaluation of these experimental pavement sections. Special thanks go to the ODOT District 3, 6, 7 and 10 Field Offices for their continued support in providing the required funding, traffic control, materials and personnel to properly monitor and maintain these experimental pavements, Roger Green at ODOT for his overall coordination of these efforts and for his continued interest in extracting useful findings from these projects for statewide implementation, Dwayne McKinney at ODOT who conducted the FWD testing, Brad Young who, until his recent promotion in ODOT, performed much of the busy work associated with monitoring the pavements, and Issam Khoury and Mike Krumlauf at ORITE for their work installing instrumentation and recording data.

Dr. Shie-Shin Wu, formerly with the North Carolina Department of Transportation, provided the analyses in Chapters 4 and 5 of this report regarding the use of various techniques commonly used to model pavement response and performance. His prior experiences with pavement modeling in North Carolina proved to be invaluable on this research project.

Dr. David R. Lankard of Lankard Materials Laboratory, Inc., in Columbus Ohio, performed the petrographic analysis of concrete cores from the Ohio SHRP Test Road and authored the discussion of this analysis in Chapter 6. This work provided valuable insight into differences in the microstructure of the three PCC pavement mixes and the lean concrete base used on the Ohio SHRP Test Road.

Dr. Ludwig Figueroa, formerly on the faculty at Case Western Reserve University (CWRU) and currently on the faculty at Ohio University, has conscientiously collected data from a number of environmental sections, and coordinated the processing of data from all environmental sections and the weather station since the inception of the test road in 1994. His input provided the basis for Section 2.3 in this report.

ABSTRACT

In 1994, a ramp containing two AC and two PCC sections in the SPS-8 experiment was constructed on the Ohio SHRP Test Road. In 1996, 36 more sections in the SPS-1, SPS-2 and SPS-9 experiments were opened to traffic on the mainline pavement. The response and performance of these sections, climatic information from an on-site weather station, subsurface environmental conditions from sensors installed in several test sections, and traffic loading from an on-site weigh-in-motion (WIM) system have been monitored and incorporated into the national LTPP database. Analyses of these data have been published in a number of reports, technical papers and bulletins. The research project documented in this report was the latest effort by ODOT to continue monitoring the response and performance of many of the original 40 test sections and several sections constructed later to replace the lighter designs which, as anticipated, showed early distress. Data in this report covers the years of 2000 - 2005. In addition to the new response and performance data obtained on the test road, this report includes: an analysis of current methodologies to mathematically modeling AC and PCC pavement structures, a petrographic analysis of concrete from three different PCC pavement mixes and a lean concrete base, and an in-depth analysis of WIM data.

Three other experimental pavements were constructed in the past on ATH 50, LOG 33 and ERI/LOR 2 to evaluate the response and performance of specific parameters of interest to ODOT. These parameters included: high performance concrete containing ground granulated blast furnace slag and different types of dowel bars on ATH 50, different types of base material under flexible pavement on LOG 33, and different types of base material under rigid pavement on ERI/LOR 2. This report also contains data collected on these three pavements during 2000 - 2005.

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Beginning in 1992, Ohio University (OU), under contract with the Ohio Department of Transportation (ODOT) and the Federal Highway Administration (FHWA), undertook several research projects to monitor the response and performance of various rigid and flexible highway pavement structures in Ohio. While the focal point of this effort was the Ohio SHRP Test Road on US 23 in Delaware County (DEL 23), pavements located on ATH 50, LOG 33 and ERI/LOR 2 also provided valuable information. Response data collected on these pavements included output from strain gauges, LVDTs, pressure cells and environmental sensors monitored during controlled vehicle loading with moving trucks and nondestructive testing with the Falling Weight Deflectometer (FWD) and Dynaflect. Performance data included periodic roughness measurements, skid tests, and visual observations of distress. Data gathered from these projects have been used to refine and improve pavement design and construction procedures in Ohio.

To extend the monitoring of these test pavements beyond the initial contract, a research project entitled "Continued Monitoring of Instrumented Pavement in Ohio" (1) was initiated with OU on September 3, 1996. The purpose of this project was to build upon earlier work through extended monitoring and testing of these pavements, integration of old and new data for validation, and further implementation of the research findings. A final report documenting the results of this project was published in December 2002. The research project being documented in this report was initiated in 2000 to extend the evaluation of these test pavements through 2005.

1.2 OBJECTIVES

1. Develop a comprehensive database for the Ohio SHRP Test Road, and enter all pertinent descriptive information and data obtained from this facility prior to and during this project into the database.

2. Coordinate the collection of five types of data used to assess the structural performance of pavement sections on the Ohio SHRP Test Road. These data include: roughness measurements obtained by ODOT, nondestructive surface deflections

obtained by ODOT with the Dynaflect and Falling Weight Deflectometer, visual distress surveys conducted by ODOT and Ohio University, rut depths measured with the dipstick, and controlled vehicle tests performed cooperatively by ODOT and OU annually unless directed otherwise by ODOT. OU will enter all data into the database.

3. Enter other survey data collected by ODOT on US 23, including profiles, weigh-in-motion and skid resistance into the database.

4. Continue to coordinate the collection of environmental data on US 23. While three other universities will likely be sharing in the collection activities, OU will be responsible for: a) maintaining the environmental sensors at the site and the data acquisition equipment, b) verifying that the other universities are fulfilling their responsibilities with regard to gathering the data and c) entering all environmental data into the database.

5. Using all available data and pavement models from AASHTO, PCA, the Asphalt Institute, and elsewhere, predict the expected performance of each test section constructed on the Ohio SHRP Test Road. This will include replacement sections.

6. As test sections fail and are removed from service on US 23, conduct up to three forensic investigations to determine the specific causes of the failures. ODOT will furnish all equipment and personnel required to dig and repair the trenches. OU will perform all tests necessary to identify the cause(s) of failure.

7. OU will continue to monitor the performance of active experimental pavement installations on ATH 50, LOG 33 and LOR 2. This will include annual distress surveys and the analysis of NDT tests conducted with the Dynaflect and FWD.

8. Develop a separate database to store data from the ATH 50, LOG 33 and LOR 2 experimental field installations, and enter all pertinent data collected in the past and throughout the duration of this project. The format of the database and the medium of storage will be determined jointly by ODOT and OU.

In an addendum dated October 19, 2005, ORITE agreed to perform the following additional tasks on this project:

1. Provide environmental and climatic data collection on the Ohio SHRP Test Road between March 2005 and April 2006. This task was previously assigned to CWRU.

2. Process all environmental and climatic data on the test road in accordance with SHRP guidelines.

3. Prepare environmental and climatic data on the test road for direct access and downloading.

4. Perform a forensic investigation of a distressed PCC pavement on MEG 33 to determine the causes of slab cracking and slab movements.

5. Prepare spreadsheets using EXCEL and ACCESS software to process data obtained from weigh-in-motion systems on the test road.

1.3 OHIO SHRP TEST ROAD (DEL 23)

ODOT constructed an experimental pavement for the Strategic Highway Research Program (SHRP) on U.S. 23 north of Delaware Ohio, which contained 19 asphalt concrete test sections and 21 Portland cement concrete test sections in the SPS-1, 2, 8 and 9 experiments. These test sections contained various combinations of pavement thickness, base type, base thickness, and drainage provisions. Original plans for the Ohio SHRP Test Road called for four SPS-9 sections identified as 390901, 390902, 390904 and 390905. As construction neared, Section 390905 was deleted and Section 390904 was changed to Section 390903. Data discussed in this report were limited that collected by OU and ODOT. Other data obtained by SHRP over the years are provided in the LTPP national database.

To enhance the value of the DEL 23 pavement, environmental sensors were installed in 20 test sections to continuously monitor temperature, moisture and frost within the pavement structure, and 33 test sections were instrumented with response sensors to monitor strain, deflection and pressure generated by dynamic loading and environmental cycling. Two environmental sections in the SPS-8 experiment were removed because of problems with ground water and with placing the above-ground box in a location convenient to local residents. Two weigh-in-motion systems and a weather station were installed to continuously gather traffic and climatic information necessary to properly interpret the response and performance data. Six universities, including the University of Akron (UA), Case Western Reserve University (CWRU), the University of Cincinnati (UC), Ohio University (OU), Ohio State University (OSU) and the University of Toledo (UT) were responsible for installing and monitoring the instrumentation. OU was assigned the responsibility for coordinating the instrumentation effort (2) (3). Nondestructive testing conducted with an FWD and Dynaflect, and controlled vehicle tests were utilized to measure the response of these pavement sections to dynamic loading.

1.4 ATH 50

In 1997, an experimental high-performance jointed concrete pavement was constructed on US 50 east of Athens, Ohio. In this pavement, 25% of the Portland cement was replaced with ground granulated blast furnace slag and epoxy-coated steel dowel bars were used throughout most of the project to transfer load across the joints. Fiberglass dowels and stainless steel tubes filled with concrete were installed in a few joints to compare their effectiveness with the epoxy-coated bars. A limited number of epoxy-coated steel and fiberglass bars were instrumented with strain gauges to measure bending moments and vertical shear induced in the bars as the concrete cured, during environmental cycling of moisture and temperature in the concrete slabs, and as a Falling Weight Deflectometer applied dynamic loads near the pavement joints. Time-Domain Reflectometry (TDR) probes were installed to measure subgrade moisture, thermocouples were installed to monitor temperature at different depths in the concrete layer during the strain measurements, and a weather station was installed on site to monitor climatic conditions.

1.5 LOG 33

This asphalt concrete pavement was constructed on U.S. 33 in Logan County to evaluate the effect of different base materials on flexible pavement response and performance. Sensors were installed to monitor environmental conditions and dynamic response. Test section base designs included: 4” of asphalt-treated base over 4” of 304 DGAB, 4” cement-treated base over 4” of 304 DGAB, 4” of New Jersey base over 4” of 304 DGAB, 4” of Iowa base over 4” of 304 DGAB, 6” of 304 DGAB, and 8” of 304 DGAB base. All sections were paved with 11 inches of asphalt concrete, except the section with 6” of 304 DGAB, which had 13 inches of asphalt concrete. Upon completion of the test sections, moisture, temperature, vertical deflection, pressure, and strain were monitored as dynamic loads were applied with a Falling Weight Deflectometer.

1.6 ERI/LOR 2

The purpose of constructing this project was to evaluate the effects of different base materials and joint spacings on the response and performance of Portland cement concrete pavement. Comprehensive field instrumentation was installed to measure in-situ responses of test sections as they were subjected to FWD loading and changing environmental conditions. Measured responses included slab strain and vertical slab deflection. Environmental conditions monitored included: temperature gradients through the pavement slabs, moisture in the base and subgrade, and pressure at the PCC slab-base interface. Distress was also monitored periodically to evaluate of the various design parameters on performance.

CHAPTER 2
DATA COLLECTION AND ANALYSIS ON DEL 23

2.1 GENERAL

In 1994-96, ODOT constructed forty test sections along a 3.5-mile length of US 23 in Delaware County for SPS-1, 2, 8 and 9 experiments in the Strategic Highway Research Program (SHRP). This test pavement was comprised of four new lanes of pavement constructed in the median of an existing four lane pavement. The SPS-1 and SPS-9 experiments were located in the southbound driving lane of the new pavement, the SPS-2 experiment was located in the northbound driving lane of the new pavement, and the SPS-8 experiment was constructed on a ramp coming south from the village of Norton onto the original southbound lanes of U.S. 23. The new pavement carries mainline traffic, while the original lanes serve as a service road for local residents and as alternate mainline lanes when traffic needs to be diverted from the test pavement. Since the project was opened to traffic, a number of sections have become distressed, as anticipated, and replaced with other designs of interest to ODOT.

Figure 2.1 shows the original project layout and replacement sections, Tables 2.1 and 2.2 summarize the build-up of all test sections constructed and planned as of the date of this report, and Tables 2.3 and 2.4 show other miscellaneous attributes of the AC and PCC replacement sections not included in the original SPS experiments. Section numbers have been abbreviated in this report by eliminating the common 390 prefix. Data contained in this report was divided into the following main categories: environmental, dynamic response and performance.

- Environmental data: Seasonal sensors installed in the pavement sections to record subsurface temperature, moisture and frost depth; piezometers located along the test road to measure water table elevations; and an on-site weather station to record precipitation, solar radiation, air temperature, wind speed and direction, and relative humidity.

- Dynamic response data: Controlled vehicle testing where trucks of known geometry, weight and speed run over dynamic response sensors installed in the pavement; and non-destructive testing with the Falling Weight Deflectometer and Dynaflect.

- Performance data: Observations of various parameters indicative of overall condition and serviceability, such as: roughness, rut depth, cracking, skid resistance and faulting.

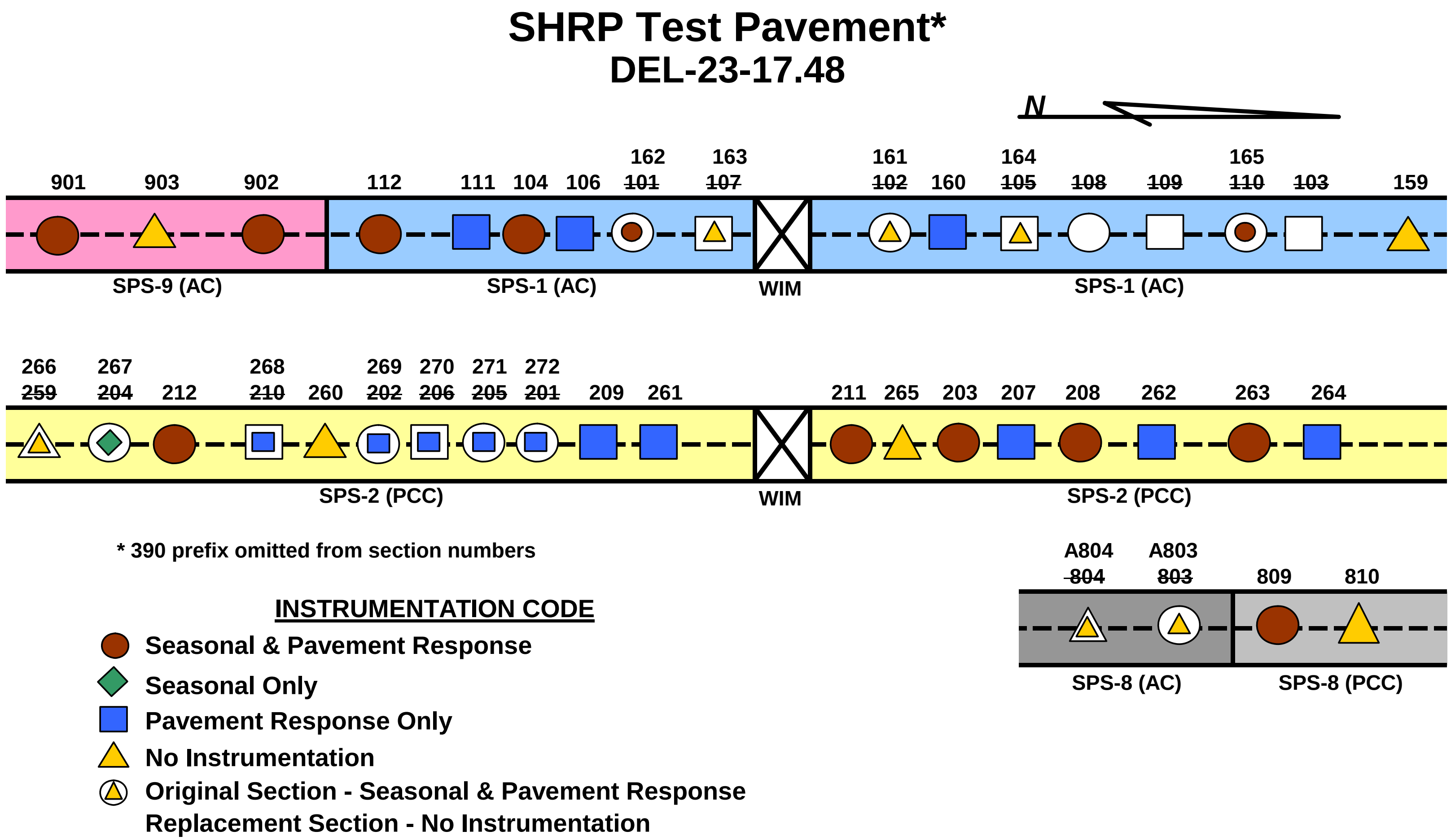

Figure 2.1 Layout of the Ohio SHRP Test Road

Table 2.1 Location and Design of Asphalt Concrete Test Sections

LOCATION AND DESIGN OF ASPHALT CONCRETE TEST SECTIONS				
Section	**Station**	**AC Pvt. Thickness (in.)**	**Base Type/Thickness**	**Drains**
SPS-1 (Southbound)				
101*	355+00-350+00	7	8" DGAB	No
102*	375+00-370+00	4	12" DGAB	No
103**	420+75-415+75	4	8" ATB	No
104	341+00-336+00	7	12" ATB	No
105*	392+50-387+50	4	4" ATB/4" DGAB	No
106	348+00-343+00	7	8" ATB/4" DGAB	No
107*	363+00-358+00	4	4" PATB/4"DGAB	Yes
108**	399+75-394+75	7	4" ATB/8" DGAB	Yes
109**	406+50-401+50	7	4" PATB/12" DGAB	Yes
110**	413+50-408+50	7	4" ATB/4" PATB	Yes
111	333+00-328+00	4	8" ATB/4" PATB	Yes
112	325+00-320+00	4	12" ATB/4" PATB	Yes
159	433+00-428+00	4	15" ATB/4" PCTB/6" DGAB	Yes
160	382+00-377+00	4	11" ATB/4"DGAB	Yes
161***	375+00-370+00	3	12" ATB/4"PATB/6"DGAB****	Yes
162***	363+00-358+00	3	12" ATB/4"PATB/6"DGAB****	Yes
163***	355+00-350+00	3	12" ATB/4"PATB/6"DGAB****	Yes
164***	392+50-387+50	7 (PG64-28)	7"PATB/8"DGAB	Yes
165***	413+50-408+50	3.25	9.5" ATB/4"NJ/6"DGAB****	Yes
SPS-8 (Ramp)				
803*	19+90-14+90	4	8" DGAB	No
804*	13+50-8+50	7	12" DGAB	No
A803***	19+90-14+90	4	8" DGAB****	No
A804***	13+50-8+50	7	12" DGAB****	No
SPS-9 (Southbound)				
901	282+75-277+75	4 (AC-20)	12" ATB/4" PATB/6" DGAB	Yes
902	302+50-297+50	4 (PG58-28)	12" ATB/4" PATB/6" DGAB	Yes
903	291+00-286+00	4 (PG64-28)	12" ATB/4" PATB/6" DGAB	Yes

* First group of distressed sections removed and replaced
** Second group of distressed sections removed and replaced
***Replacement section
**** Subgrade stabilized

Table 2.2 Location and Design of Portland Cement Concrete Test Sections

LOCATION AND DESIGN OF PORTLAND CEMENT CONCRETE TEST SECTIONS						
Section	Station	PCC Layer		Lane Width (ft.)	Base Type and Thickness	Drain
		Strength (psi)	Thickness (in.)			
SPS-2 (Northbound)						
201*	343+00-348+00	ODOT	8	12	6" DGAB	No
202*	319+00-324+00	900	8	14	6" DGAB	No
203	384+00-389+00	ODOT	11	14	6" DGAB	No
204*	275+50-280+50	900	11	12	6" DGAB	No
205*	335+75-340+75	ODOT	8	12	6" LCB	No
206*	327+50-332+50	900	8	14	6" LCB	No
207	391+25-396+25	ODOT	11	14	6" LCB	No
208	397+75-402+75	900	11	12	6" LCB	No
209	350+25-355+25	ODOT	8	12	4" PATB/4" DGAB	Yes
210*	303+50-308+50	900	8	14	4" PATB/4" DGAB	Yes
211	369+00-374+00	ODOT	11	14	4" PATB/4" DGAB	Yes
212	294+00-299+00	900	11	12	4" PATB/4" DGAB	Yes
259*	265+50-270+50	900	11	12	6" DGAB	Yes
260	311+50-316+50	ODOT	11	12	4" PATB/4" DGAB	Yes
261	357+75-362+75	ODOT	11	14	4" PCTB/4" DGAB	Yes
262	405+25-410+25	ODOT	11	12	4" PCTB/4" DGAB	Yes
263	414+50-419+50	ODOT	11	14	6" DGAB	Yes
264	422+50-427+50	ODOT	11	12	6" DGAB	Yes
265	376+10-381+10	ODOT	11	12	4" PATB/4" DGAB	Yes
266**	265+50-270+50	ODOT***	11	12	4” ATB/4” DGAB****	Yes
267**	275+50-280+50	ODOT***	11	12	8” DGAB****	Yes
268**	303+50-308+50	ODOT***	11	14	4” ATB/4” DGAB****	Yes
269**	319+00-324+00	ODOT***	11	14	4” ATB/4” DGAB****	Yes
270**	327+50-332+50	ODOT***	11	14	4” ATB/4” DGAB****	Yes
271**	335+75-340+75	ODOT***	11	14	4” ATB/4” DGAB****	Yes
272**	343+00-348+00	ODOT***	11	14	4” ATB/4” DGAB****	Yes
SPS-8 (Ramp)						
809	25+90-20+90	550	8	11	6" DGAB	No
810	32+50-27+50	550	11	11	6" DGAB	No

* First group of distressed sections removed and replaced
** Replacement section
*** Contractor designed 4000 psi concrete mix to avoid shrinkage
**** Sections on 18” of lime-stabilized subgrade

2.2 REPLACEMENT SECTIONS

A total of six AC test sections failed after limited service and were replaced with more robust sections of interest to ODOT. The six failed sections included: three SPS-1 sections (102, 107, and 101) and two SPS-8 sections (803 and 804) closed in late 1996, and Section 105 replaced after about 19 months. The two SPS-8 sections were replaced with identical designs, except that the subgrade was removed to a depth of about four feet and stabilized with lime to improve the stiffness of that layer.

In April 2002, the southbound lanes were closed because of an imminent failure in Section 103 and high FWD deflection measurements in Sections 108, 109 and 110. These four contiguous sections were all replaced with one buildup designed for extended service and the location of the 500 foot long test section representing this design was between Stations 413+50 to 408+50, which was the original location of Section 110. Various attributes of the AC replacement sections are summarized in Table 2.3.

On February 16, 2006, ODOT closed the northbound test lanes at the request of the Ohio Highway Patrol which indicated a few accidents had occurred in the area of Sections 205 and 206. A review of all SPS-2 sections showed that Sections 201, 202, 204, 205, 206, 210 and 259 were distressed and in need of replacement. This list included five of the six sections with an 8-inch thick pavement and five of the seven sections containing high strength concrete. The two distressed sections with 11-inch thick pavement were both constructed with high strength concrete and placed on six-inch DGAB base (204 and 259). The two high strength concrete sections not needing replacement (208 and 212) were 11 inches thick and had 12-foot wide lanes. Section 208 was on LCB and Section 212 was on PATB. Construction plans are now being processed to replace the seven SPS-2 sections.

All PCC replacement sections will have 18" of lime-treated subgrade, will be 11 inches thick and will have a base consisting of four inches of ODOT 301 ATB over four inches of ODOT 304 DGAB, except Section 267 which will have only eight inches of ODOT 304 DGAB. Table 2.4 shows other attributes of the PCC replacement sections, including aggregate size for the PCC, lane width, slab length, and sections which had dynamic and environmental sensors added for future monitoring.

Table 2.3

Attributes of AC Replacement Sections

OTHER ATTRIBUTES OF AC REPLACEMENT SECTIONS			
Original Section	**Replace-ment Section**	**Design and Materials for Replacement Sections***	**Special Material Requirements**
803	A803	1.75” TI/ 2.25” TII/8” DGAB	No recycled material. Lime stabilized subgrade.
804	A804	1.75” TI/ 5.25” TII/12” DGAB	No recycled material. Lime stabilized subgrade
102**	161	1.25” TI/1.75” TII/12” ATB/ 4” PATB/6” DGAB.	SUPERPAVE Level I design & 20% RAP in both TI and TII. Lime stabilized subgrade.
107**	162	1.25” TI/1.75” TII/12” ATB/ 4” PATB/6” DGAB	Gravel coarse aggregate & no recycled material in TI and TII. Lime stabilized subgrade.
101**	163	1.25” TIH/1.75” TII/12” ATB/ 4” PATB/6” DGAB	Polymer and no recycled material in TIH. Lime stabilized subgrade.
105**	164	1.75” TI/5.25” TII/4” PATB/ 8” DGAB Unstapled Tensar BX1100 Geogrid	PG 64-28 binder and no recycled material in TI and TII. Tack coat between TI and TII. Prime coat between TII and PATB.
103		1.25” TI/2.0” TII/9.5” ATB/ 4” NJ/6” DGAB	16” cement treated subgrade
108			
109			
110	165		

* TI - AC surface course; TIH - TI w/coarse aggregate; TII - AC intermediate course
** Underdrains added

Table 2.4

Attributes of PCC Replacement Sections

OTHER ATTRIBUTES OF PCC REPLACEMENT SECTIONS				
Original Section	**Replacement Section**	**Lane Width (ft.)**	**PCC Aggregate Size**	**Slab Length (ft.)**
259	266	12	467	15
204*	267	12	467	15
210	268	14	467	14
202*	269	14	57	13
206*	270	14	57	15
205*	271	14	57	14
201*	272	14	367	14

* Underdrains added

2.3 ENVIRONMENTAL DATA

Seasonal monitoring on the Ohio SHRP Test Road consisted of the periodic measurement of temperature, moisture, and frost depth to a depth of six feet below the pavement surface at 17 original pavement sections and two replacement pavement sections. These data were collected by CWRU, OSU, UT and OU. Table 2.5 shows how section responsibility was distributed among the universities, how the ONSITE temperature records were organized by Julian day and year, and how well the sensors performed. Tables A-1 and A-2 in Appendix A show Julian dates for regular and leap years, and Appendices B and C show MOBFIELD moisture files for ten AC and nine PCC pavement sections, respectively. Other environmental data included water table elevations and a weather station.

Pavement temperatures were recorded hourly using a datalogger and the necessary electronic components required for automatic on-site data storage. Because moisture content and frost levels were not expected to vary much throughout the day, these readings were recorded monthly with mobile monitoring equipment. With mobile equipment, the user connects all necessary cables to monitor and download the data to a personal computer. This equipment consisted of a cable tester - datalogger/controller; and two multiplexers plus an interface board for resistivity measurements. Lead cables from the soil and base moisture sensors were connected to the multiplexers, and the corresponding traces were displayed on the cable tester screen. The datalogger communicated with the cable tester and multiplexers to monitor and record data. Data were then downloaded to the microcomputer from the mobile unit using specialized software.

Table 2.5

ONSITE Data Records

Section	ID	University	Dates (Julian) in ONSITE Record						
			1	2	3	4	5	6	7
390204	B	UT*	193/96-290/96	325/96-218/97	242/97-20/98	42/98-134/98	138/98-288/98	329/98-245/99	287/99-356/99
390212	C	OU**	164/96-153/01	200/01-209/01	227/01-188/02	262/02-53/04	85/05-4-90/05	125/05-194/05	234/05-244/05
390202	D	UT*	193/96-197/26	142/97-156/97	254/97-351/97				
390205	E	OU**	164/96-168/97	205/97-140/98	211/98-79/01	123/01-210/04			
390201	F	OSU	255/96-99/01	114/01-233/01	263/01-167/02	194/02-314/02	334/02-353/02	22/03-64/03	65/03-75/03
390211	G	OSU	250/96-346/96	100/02-119/02	266/02-181/03	255/03-160/04	274/04-119/05		
390203	H	OU**	164/96-79/99	113/99-312/05					
390208	I	OU	191/96-228/96	23/97-161/98	190/98-287/98	297/98-100/02	150/02-204/02	255/02-121/03	182/03-22/04
390263	J	OSU	268/96-246/97	302/97-16/98	105/98-49/99	74/99-89/99	109/99-14/00	47/00-356/03	94/04-244/04
390901	K	OU**	165/96-275/00	347/00-66/01	101/01-232/02	245/02-24/03	55/03-144/03	317/03-328/04	
390904	L	OSU	250/96-49/99	74/99-120/99	323/99-246/00	251/00-114/01	137/01-282/01	310/01-15/03	74/03-244/04
390112	M	UT*	193/96-218/97	296/97-134/98	138/98-151/98				
390104	N	UT*	193/96-290/96	325/96-114/98	137/98-67/00	83/00-220/02	257/02-351/02		
390101	O	Failed-UT	193/96-263/96	326/96-356/96	361/96-85/97	100/97-135/97	Section Failed		
390102	P	Failed-CWRU	161/96-248/96	Section Failed					
390108	Q	OSU	250/96-247/97	303/97-17/98	107/98-49/99	120/99-47/00	82/00-187/01	263/01-170/02	207/02-293/03
390110	R	Failed-OU	191/96-113/01	152/01-173/01	235/01-72/02	122/02-176/02	Section Failed		
390165	X	OU	293/03-49/05	90/05-158/05					
390162	Z	OU	346/97-107/98	182/98-134/99	148/99-281/00	355/00-47/01	73/01-106/01	152/01-71/02	150/02-205/02

Section	ID	University	Dates (Julian) in ONSITE Record					Sensor Disabled
			8	9	10	11	12	
390204	B	UT*	359/99-17/00	72/00-200/00	316/00-361/01	8/02-168/02	388/02-351/02	
390212	C	OU**	258/05-Present					
390202	D	UT*						
390205	E	OU**						S1,S2,S3 - 350/98
390201	F	OSU	84/03-181/03	Stopped				S3 - 209/00
390211	G	OSU						
390203	H	OU**						
390208	I	OU	36/04-49/04	58/04-133/04	137/04-90/05	103/05-Present		S3 - 214/98, S2 - 245/98
390263	J	OSU						S1 - 86/97, S2 - 86/98, S3 - 9/99
390901	K	OU**						*** See below
390904	L	OSU						S1,S2 - 250/96, S3 - 353/98, S4 - 22/00
390112	M	UT*						S1 - 193/96
390104	N	UT*						S1 - 193/96
390101	O	Failed-UT						S1,S2,S3 - 193/96
390102	P	Failed-CWRU						S2 - 181/96
390108	Q	OSU	300/03-148/04					S1 - 283/98, S1 Repaired 30/99,
390110	R	Failed-OU						
390165	X	OU						S1 - 293/03, S2,S3 intermittent from 342/03
390162	Z	OU						S1,S2 160/99, S4 intermittent, S3 281/00

* Not Monitored since 2003
** Previously assigned to CWRU

***Section K
Repaired S1,S2,S3 350/99 — Disabled S1 273/00, S2 137/01, S3 137/01
Repaired S1,S2,S3 249/01 — Disabled S1,S2,S3 353/01
Repaired S1,S2,S3 150/02 — Disabled S1,S2,S3 317/03

2.3.1 Temperature

It is important that temperature be monitored in subgrade and base layers to determine the depth to which these layers are frozen. Temperature also plays a major role in the deflection and fatigue life of flexible pavements, as it directly affects the resilient modulus and ultimate tensile strength of asphalt concrete. On Portland cement concrete slabs, temperature gradients cause curling or warping which impacts support from the underlying layers and magnifies load related stresses under certain conditions. In addition, changes in temperature also result in slab expansion and contraction which affects transverse cracking and joint performance.

Pavement temperatures on the test road were monitored with thermistors, or temperature-sensitive resistors which consist of individual, but interconnected probes for both pavement and soil temperature measurements. A metal rod containing up to four thermistors was used for the pavement layers followed by a six-foot long, clear PVC pipe housing 15 thermistors for temperature measurements lower in the pavement structure. Slight changes in temperature create major variations in thermistor resistance. To find this resistance, a known voltage is applied to the thermistor and the output voltage is read between the thermistor leads. Temperature was calculated with a correlation equation. Some problems occurred with the thermistors, as discussed below:

1. *Damage during installation*. Some thermistors assembled in the metal rod experienced damage during installation in five of the asphalt concrete sections (101, 104, 112, 165 and 904). It is interesting to note that installation damage only occurred in probes embedded in asphalt concrete pavement sections. It is not known if this damage can be attributed to possible exposure of the wire connecting the metal and the acrylic rod to excessive heat as the asphalt concrete is compacted.

2. *Damage during the operating period*. Some or all thermistors assembled in the metal rod stopped working in five additional PCC or asphalt concrete sections at different times throughout the monitoring project. Coincidentally, some of the thermistors embedded in asphalt concrete sections failed during the summer months when the asphalt concrete was softer. It appears that increased deflection near the probe location during the summer months promotes their damage. Damage of the upper three

thermistors in Section 205 (PCC + LCB) may be attributed to the development of pumping, faulting and cracking which may have occurred in the vicinity of the probe.

3. *Data logger malfunction*. This may be the result of:
   - Lack of AC power. At times, the circuit breakers were tripped (possibly by lightning in the neighborhood of the project or by short circuiting caused by rising water) near the site boxes or transformers. The CR10 battery only provides sufficient power for data collection for a few days without recharging. Once the AC power was reestablished, the logger operation continued normally.
   - Damage to the logger battery. In some instances the logger battery reached its useful life and needed replacement. Normal logger operation was reestablished after the installation of a new battery.
   - Damage to the logger. Several CR10 logger units were damaged either by possible lightning in the neighborhood of the project or by short circuiting caused by water. Circuit breakers apparently did not prevent the sudden current spikes. Logger units needed complete replacement before data collection was reestablished.

4. *Damage by pests*. Mice gnawing on wires and/or nesting inside the logger boxes led to logger damage. Logger operation was reestablished after repair and complete sealing.

2.3.2 Volumetric Moisture Content

The moisture content of soil is required for many important design considerations, such as resilient modulus, freeze-thaw capacity and settlement. Based upon the results obtained from other test pavements, time-domain reflectometry probes (TDR) were chosen as the best instrument available to monitor volumetric moisture content. Installed every six to twelve inches down to a depth of about six feet, TDR probes consist of a coaxial cable leading to a three-pronged probe installed in the subgrade. When an electromagnetic wave is carried to the probe, the time for a pulse to travel from one end of the probe to the other is recorded. The pulse is displayed graphically by a cable tester where an initial inflection point represents the wave entering the probe. A second inflection point is produced when the signal reflects at the end of the probe. The time required to travel between these two points is a function of the dielectric constant of the soil, which is calibrated with volumetric moisture. TDR performance has been extremely satisfactory throughout the duration of the project. From over 180 TDR probes installed, less than five have ceased working. Seasonal instrumentation installed in Sections 101, 102 and 110 was not monitored after the sections were replaced.

Figure 2.2 shows subsurface moisture plotted over time in Section 104, and Figure 2.3 shows vertical moisture profiles on two dates representing periods of high and low moisture, and the average profile for all dates. Figures 2.4 and 2.5 show comparable data for Section 108. In general, Section 104, which is located in the southern half of the project, was wetter than Section 108, which is in the northern half of the project. Both sections show clear seasonal oscillations in moisture, but the TDRs in Section 104 ranged between 35 - 43%, while those in the Section 108 subgrade were lower at 22 - 40%. The top TDR in Section 108, located 15" below the pavement surface and mid-depth in the DGAB layer, ranged from 15-22%. TDRs at depths of 33-57" in Section 108 increased gradually over a three-year period after the test road was opened to traffic in August 1996. The vertical moisture gradients in Figures 2.3 and 2.5 illustrate that, while the moisture content may vary, the shape of the moisture profiles at each location tended to remain relatively constant over time. While moisture levels vary from section to section, there does appear to be a trend of maximum moisture occurring in July and August, and minimum moisture occurring in January and February.

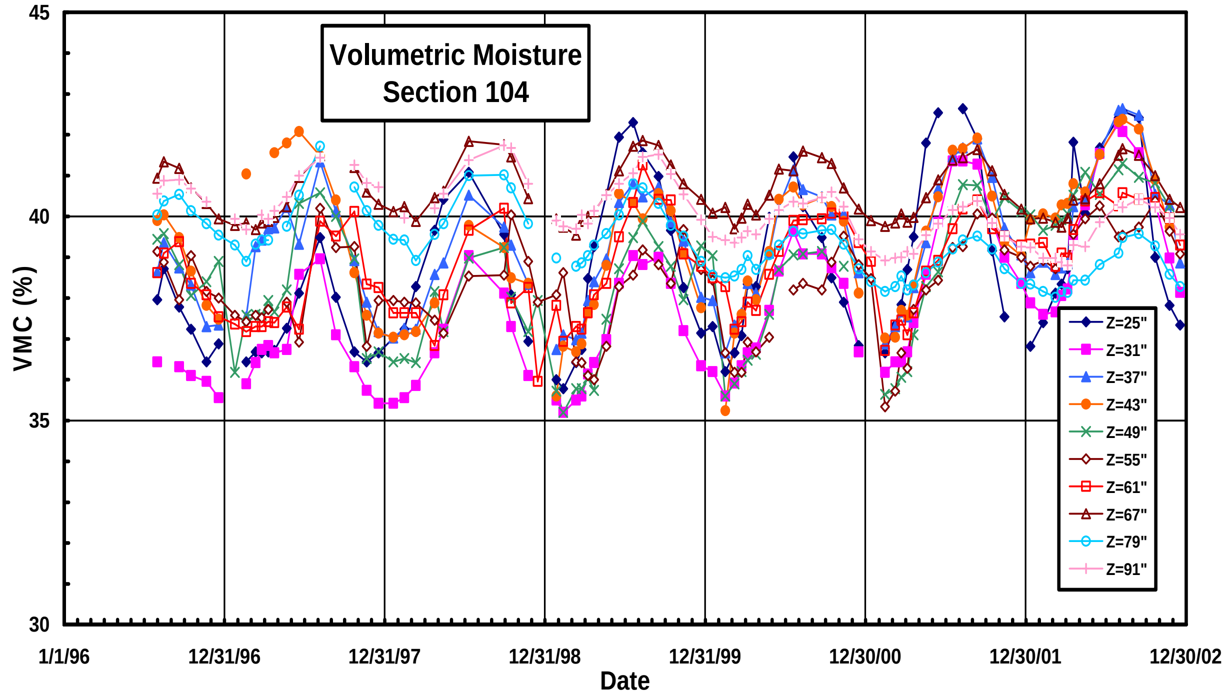

Figure 2.2 - Seasonal Changes in Volumetric Moisture - Section 104

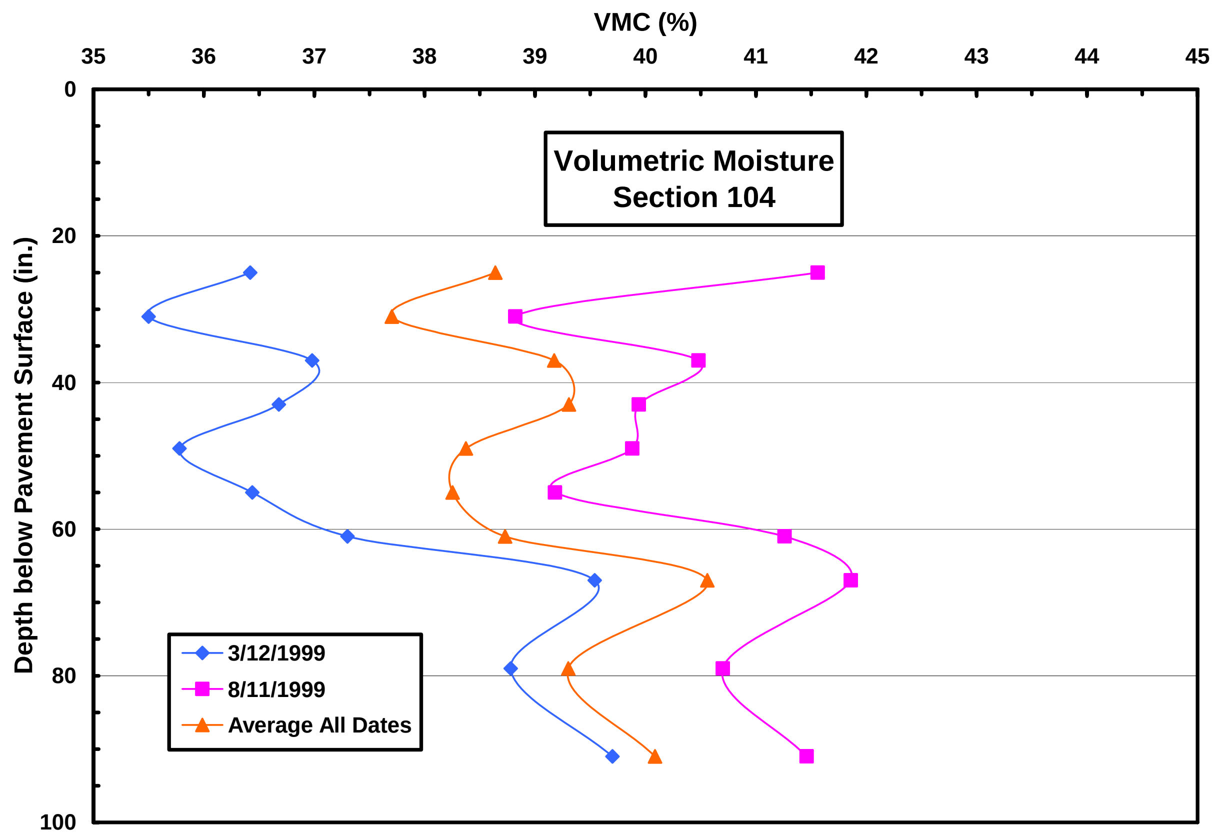

Figure 2.3 – Volumetric Moisture Profiles in Sections 104

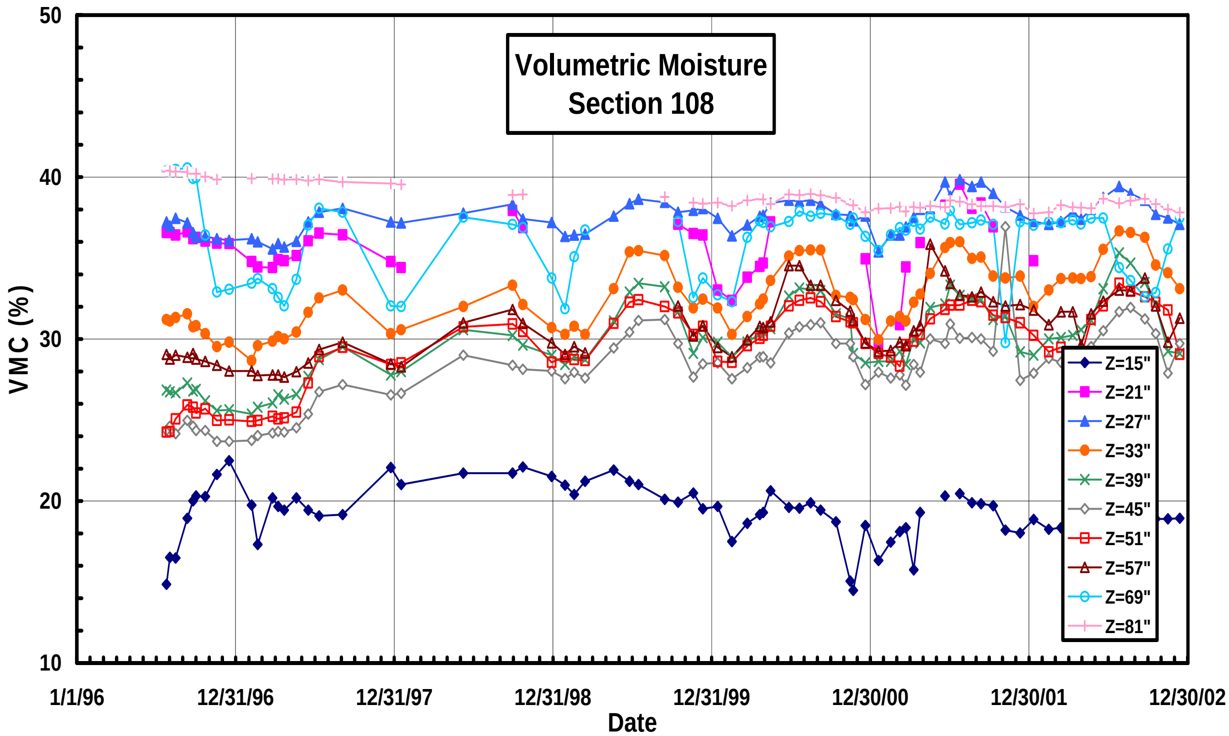

Figure 2.4 - Seasonal Changes in Volumetric Moisture - Section 108

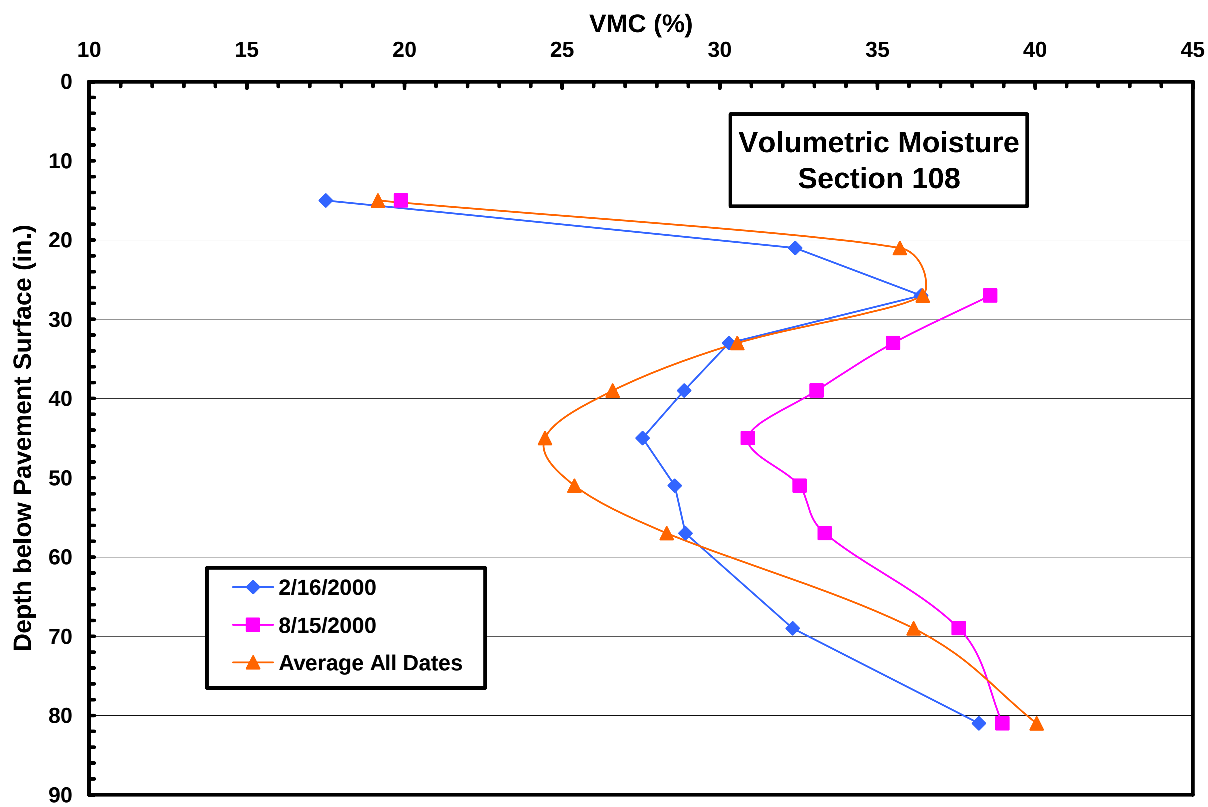

Figure 2.5 – Volumetric Moisture Profiles in Section 108

2.3.3 Frost Depth

Since the Ohio SHRP Test Road is located in a geographic area that experiences multiple freeze/thaw cycles during the winter season, it was necessary to measure the depth of frost penetration in the subgrade soil and the number of freeze/thaw cycles. This depth is important in determining the thickness of base layers required to limit frost penetration into the soil. Also, since soil stiffness tends to decrease after a freeze/thaw cycle, mechanistic design procedures will need to account for frost in order to provide more durable pavement designs.

After studying the various methods available for monitoring frost depth, the FHWA considered electrical resistance and resistivity methods to be the most reliable for SHRP. A probe developed by the U.S. Army Corps of Engineers' CRREL was chosen for the program. This probe consisted of a 73-inch long solid PVC pipe upon which 36 metal wire electrodes were spaced every two inches (Rada et al, SMP 1994, II-8). When a function generator created an AC current in two outer electrodes, voltage drop and resistance were measured and compared across the two inside electrodes. Bulk, or apparent, resistivity was then be computed by the product of the resistance times the geometric factor for the electrode array. Since ice has a much greater electrical resistivity than water, areas of high resistivity corresponded to frozen layers in the subgrade soil.

Data collected from resistivity probes do not appear to provide any useful information. Resistivity is high in many instances, even when it is well known that the subgrade soil is unfrozen. Redesign of the probe and/or electronic interface with the data logger is recommended.

2.3.4 Ground Water Table

Fourteen and one-half foot long, slotted observation piezometers were used to measure depth to the water table along the outside pavement shoulder. These piezometers consisted of two 1-inch diameter sections of PVC pipe coupled together and threaded to a metal floor flange anchored at the bottom of a bore-hole. This pipe also served as a swell-free benchmark for surface level measurements. A total of nine piezometers were installed at the locations shown in Table 2.6. Figures 2.6 and 2.7 show water table elevations and depths below the pavement surface measured from these piezometers.

Figures 2.6 and 2.7 present the same basic water table information in two formats: actual elevations of the water tables and distances of the water tables below the top of the subgrade. These figures illustrate two major points. First, the highest ground water tables occurred from April – June and the lowest ground water tables occurred from October – November. Second, the water table was consistently nearest to the subgrade surface in Section 104, with Sections 201 and 212 not far behind. Water tables in the remaining sections were lower in the ground and experienced more seasonal oscillation. Section 201 had the most uniform water table depth of all sections monitored at about four feet below the subgrade surface. Section 101, where excess water was observed during a forensic investigation, is only 900 feet north of Section 104. Sections 205 and 206, both of which are 8" PCC pavements on 6" of undrained lean concrete base, and which exhibited early cracking and pumping, are located next to Section 201. These observations suggest that SPS-1 and SPS-2 sections south of the WIM scales were exposed to more subsurface water than pavement sections north of the WIM scales. This trend agrees with TDR measurements discussed earlier where moisture under Section 104 was higher than under Section 108. It is interesting that high and low peaks for ground water elevation occurred about two months earlier than peaks for volumetric moisture content.

Table 2.6

Piezometer Locations

Southbound Lane			Northbound Lane		
Section	Station	Avg. Pavement Elevation*	Section	Station	Avg. Pavement Elevation*
103	417+02	955.4	204	279+85	955.6
108	397+00	953.4	212	298+01	957.2
102	372+00	953.7	201	346+00	954.9
104	337+00	956.0	208	401+00	954.4
901	279+50	955.2			

* Pavement elevation nearest piezometer well head, ft. above sea level

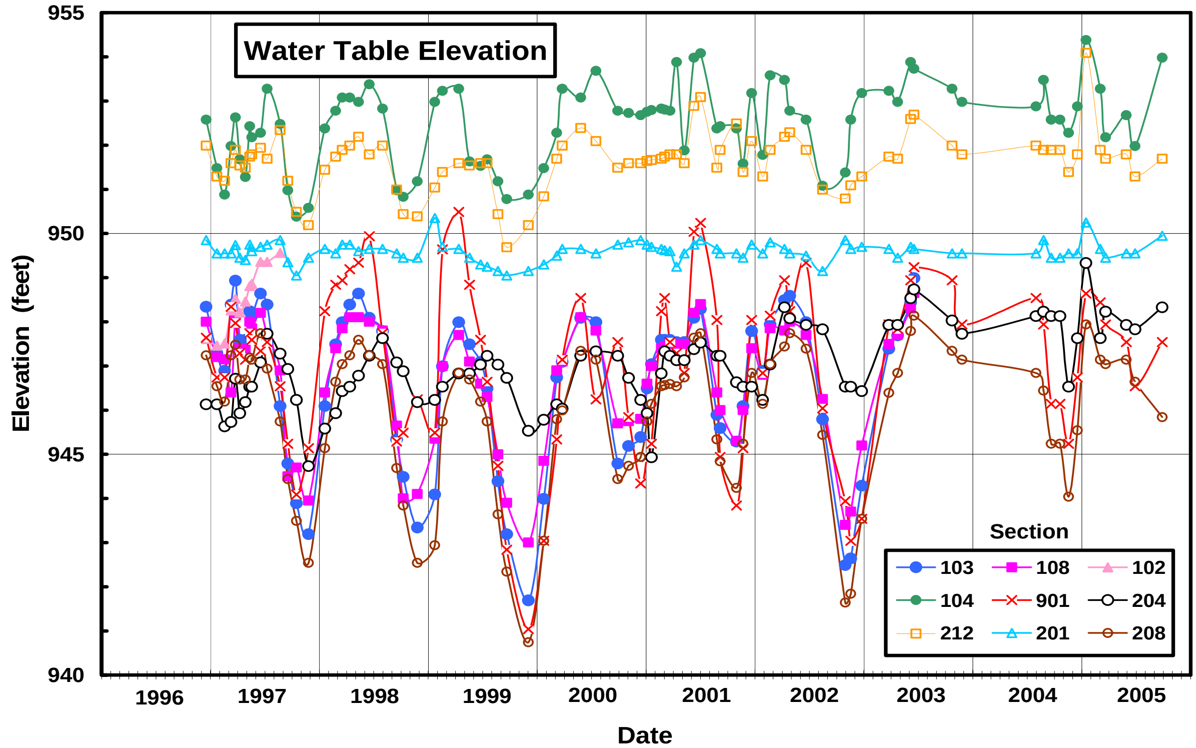

Figure 2.6 - Water Table Elevations

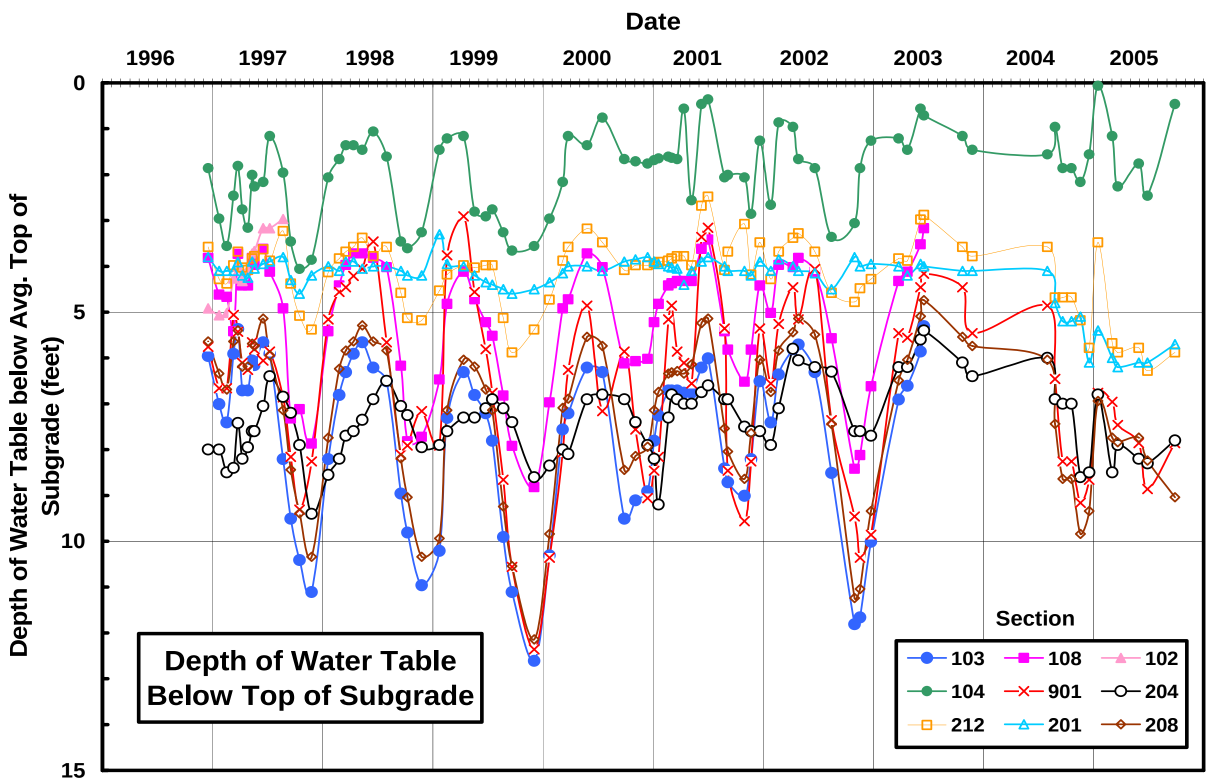

Figure 2.7 – Depth of Water Table

2.3.5 Weather Station

To assist in monitoring climatic changes along the test road, a weather station was installed near the north end of the project and along the east side of the test road to monitor solar radiation, air temperature, wind speed, wind direction, relative humidity, and rainfall. Air temperature and relative humidity were monitored with one probe containing a thermistor and a capacitive relative humidity sensor. A cable was connected to a datalogger, which monitored and stored all weather-related measurements.

A pulse-type tipping bucket rain gauge was installed a few feet away from the weather station to monitor rainfall. The bucket was equipped with a heating device to melt accumulated snowfall. A propeller type gauge was used to measure wind speed and direction. As the propeller rotated, sine wave signals were produced with a frequency proportional to wind speed. Wind direction was determined by the azimuth angle of the vane. As the vane rotated, a potentiometer produced an output voltage proportional to the angle. A pyranometer was used to monitor incoming solar radiation in terms of energy per surface area. This conversion was performed with a silicon photovoltaic detector that produced an output current based on levels of radiation. A cable resistor converted this current to a voltage recorded by the datalogger.

Data from the weather station has been recorded continuously from July 13, 1994 to the present, with the exception of a period in 1995 when the CR10 ring memory was filled prior to downloading and some data were lost. It was then determined that a maximum of six months could be safely stored on the CR10. Dr. Ludwig Figueroa, formerly with CWRU and now with OU, collected and processed all data obtained from the weather station.

Weather station performance has been quite satisfactory. The relative humidity sensor needed replacement since it was measuring RH values in excess of 100%. Preventative replacement of all weather station sensors was performed by STANTEC in 2004 under LTPP contract.

2.4 DYNAMIC RESPONSE DATA

2.4.1 Response Sensors

When SHRP established plans for collecting dynamic response data on four core sections in each of the SPS-1 and SPS-2 experiments, they devised minimum requirements for instrumenting the sections with Dynatest strain gauges, LVDTs and pressure cells. Based upon past experience of instrumenting pavements in Ohio, ODOT added more sensors to the sections and, to take advantage of the opportunity to obtain dynamic response data from a wide range of pavement sections in one location, instrumented 25 additional sections for monitoring. Figures 2.8 and 2.9 show a general layout of dynamic sensors prescribed by SHRP and those added by ODOT on typical AC and PCC pavements. These layouts varied somewhat, depending upon the build-up of the sections.

2.4.2 Controlled Vehicle Testing

In recent years, much attention has been given to developing accurate mechanistic empirical design procedures for AC and PCC pavements, where the construction of an adequate highway pavement is based upon mechanical properties of the materials, environmental conditions typical of the location, and anticipated traffic loading. To develop, calibrate and verify accurate mechanistic models, multiple parameters including strain, deflection and pressure are essential to accurately describe response over a wide range of conditions. Environmental conditions, such as temperature, moisture and frost depth, also have a profound effect on response and must be integrated into the design process.

Due to the numerous parameters known to affect response, the size of a test matrix required to examine all load associated parameters in a series of controlled vehicle tests would not be practical. SHRP, therefore, reduced the number of test variables to a few of the more significant parameters on a limited number of sections, including, load, speed, axle configuration and temperature. During these tests, vehicles were weighed and measured, pavement temperature and subsurface moisture were monitored, and lateral positioning of the trucks was recorded on each run as they passed over the instrumented sections. Since completion of the Ohio SHRP Test Road in 1996, nine series of controlled vehicle tests have been run to monitor dynamic response under known vehicle parameters and environmental conditions.

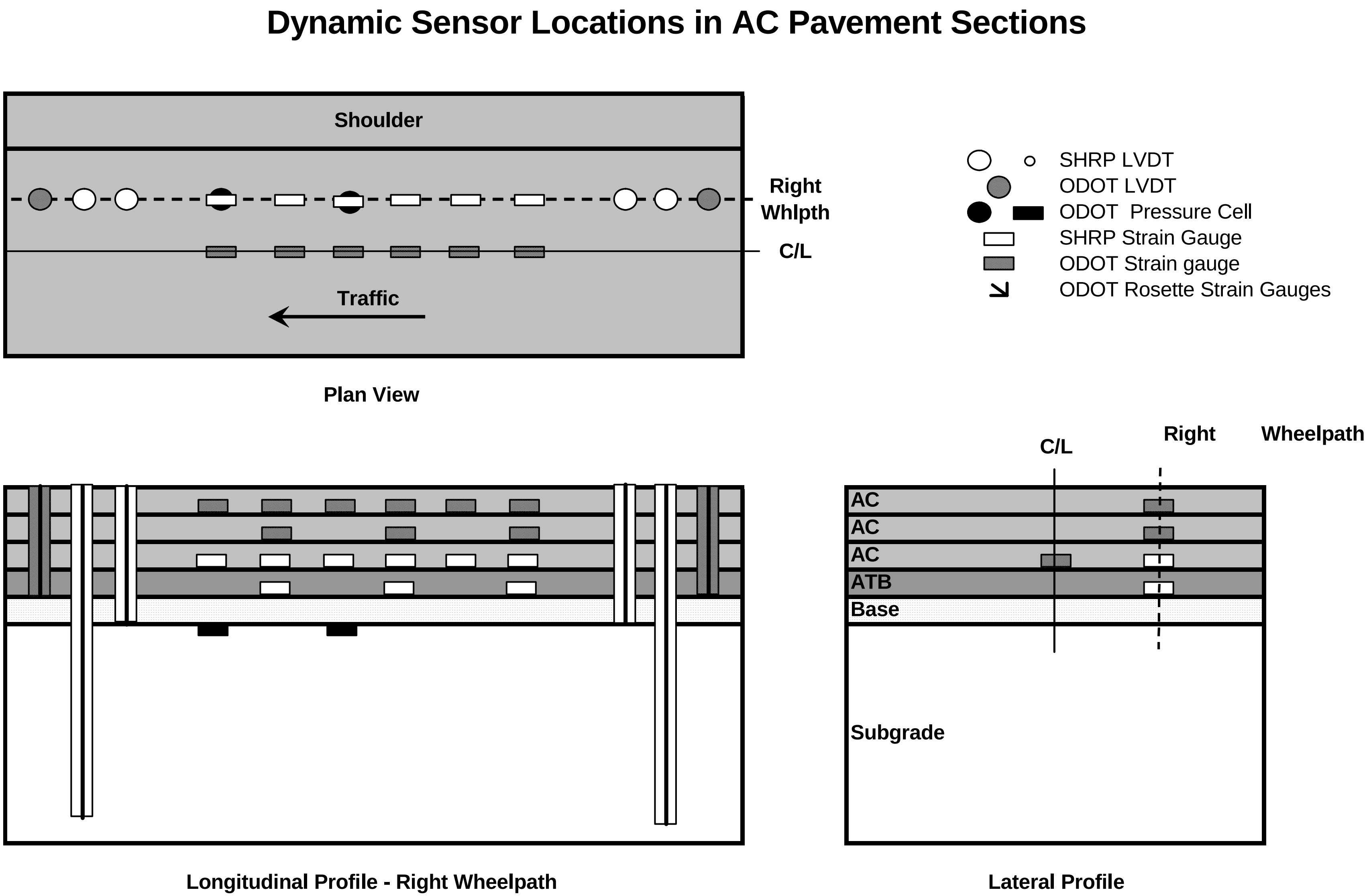

Figure 2.8 - Typical Instrumentation Placed in AC Pavement Sections

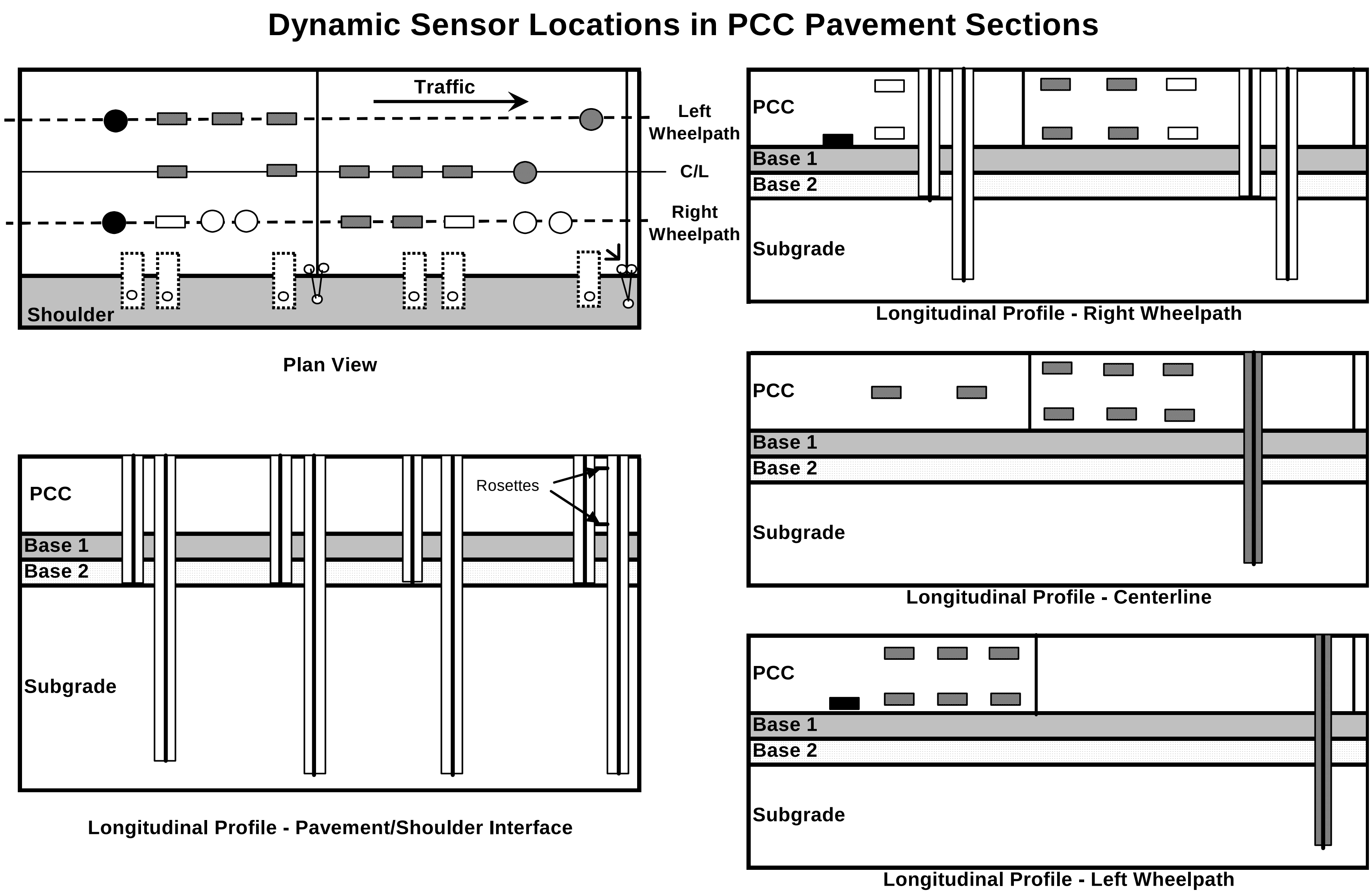

Figure 2.9 - Typical Instrumentation Placed in PCC Pavement Sections

SHRP targeted four core sections in each of the SPS-1 and SPS-2 experiments for the installation of sensors to monitor dynamic pavement response during controlled vehicle testing. These included Sections 102, 104, 108, and 110 in SPS-1; and Sections 201, 205, 208, and 212 in SPS-2. Tests were to be performed with single and tandem-axle dump trucks. The rear axle on the single-axle truck was to be loaded to approximately 18 and 22 kips, while total loads on the rear axles of the tandem-axle dump truck were to be approximately 32 and 42 kips. The trucks ran 50 (30), 65 (40), and 80 (50) km/hr (mph) in the morning and afternoon to determine the effects of speed and temperature on response, and the trucks were to be positioned laterally such that the right rear dual tires would straddle the sensors. With a minimum of three repetitions being required for each combination of parameters in the matrix, a total of 72 runs were necessary to complete a series of tests with the two trucks. ODOT also included a few passes at 8 (5) km/hr (mph) to obtain low speed response data.

SHRP requested states to perform these tests in the spring and summer when moisture in the base and subgrade, and temperature in the pavement layer are typically quite different. The ODOT goal was to follow the SHRP testing protocol on the eight core sections and to include as many of the other 25 instrumented sections as possible at the time controlled vehicle tests were run. FHWA conducted the Series I tests on the SPS-8 pavement sections with a special tank truck furnished by the Canadian National Research Council (CNRC), shown in Figure 2.10. The CNRC truck was equipped with lead weights on the rear of the trailer and baffles in the tank to provide flexibility in loading axles. Water was added to various compartments in the trailer and the lead weights were adjusted to achieve the desired weights on selected axles. ODOT also used the CNRC truck in the Series III tests to gather supplementary information on the effects of tridem axles, axle spacing, and dual versus super single tires.

Table 2.7 summarizes the basic variables included in each series of controlled vehicle tests and Table 2.8 shows the sections monitored during the tests. Weights for the ODOT test trucks and the CNRC truck are shown for all test series in Tables D-1 to D-4 of Appendix D. Truck geometries are shown in Tables D-5 and D-6. In the Series II - Series V tests, tires were checked visually and air was added to under-inflated tires, but individual pressures were not measured during the tests. Tire pressures for the Series VI - IX tests in 1999, 2001 and 2003 are shown in Table D-7. Pavement temperature, soil moisture and lateral position of the truck are inherent variables that cannot be controlled precisely, but must be monitored during the tests.

Figure 2.10 - Canadian National Research Council Truck

Table 2.7 Summary of Controlled Vehicle Test Parameters

Controlled Vehicle Tests												
Test Date	Test Series	Truck	No. of Truck Passes		No. Sections Monitored		Dynamic Parameters*					
			AC Sections	PCC Sections	AC	PCC	Load	Speed	No. Axles	Axle Spacing	Tires	Vehicle Dynamics
12/5/95 to 3/16/96	I**	CNRC-Tan-Dual	79		1	1	X	X	X	X	X	
		CNRC-Tri-Dual	33									
		CNRC-Tri-SS	32									
8/96	II	Single Dump	41	44	6	5	X	X	X			
		Tandem Dump	59	29								
6/97	III	CNRC-Tan-SS	5		3		Sand Calibration					
		CNRC-Tan-Dual	47	34	7	8	X	X	X	X	X	X**
		CNRC-Tan-SS	55	55								
		CNRC-Tri-SS	20	20								
		Tandem Dump	122	109								
7,8/97	IV	Single Dump	38	39	12	14	X	X	X			
		Tandem Dump	38	39								
10/98	V	Single Dump	24	48	8	9	X	X	X			
		Tandem Dump	12	48								
9/99	VI	Single Dump	43	43	8	8	X	X	X			
		Tandem Dump	43	43								
10/99	VII	Single Dump	30-60 runs/section		7	7	X	X	X			
		Tandem Dump	30-60 runs/section									
		FWD	50 drops/section		7	7						
		Dynaflect	20 readings/section		7	7						
4,5/01	VIII	Single Dump	40	40	10	12	X	X	X			
		Tandem Dump	40	40								
10/03	IX	Single Dump	45	0	3	0	X	X	X			
		Tandem Dump	45	0								

* Pavement temperature, soil moisture and lateral truck position were monitored during each series of tests
**Funded by FHWA

Table 2.8 Summary of Sections Tested in Controlled Vehicle Tests

	Controlled Vehicle Test Series								
	I	II	III	IV	V	VI	VII	VIII	IX
Date	12/95, 3/96	8/96	6/97	7/97	10/98	9-10/99	10/99	4-5/01	10/03
Section	SPS-1								
101			x	Section removed from service					
102*		x		Section removed from service					
103				x					
104*		x	x	x	x	x	x	x	
105		x	x	x	Section removed from service				
106			x	x	x	x	x	x	
107		x		Section removed from service					
108*		x	x	x	x	x	x	x	
109				x	x	x	x	x	
110*		x		x	x	x	x	x	
111			x	x		x	x	x	
112			x	x		x		x	
160				x				x	
162**					x				
165**									x
	SPS-2								
201*		x	x	x	x	x		x	
202			x	x		x		x	
203				x			x		
204				x	x		x	x	
205*		x	x	x	x	x		x	
206			x	x		x		x	
207				x			x		
208*		x		x	x	x		x	
209		x	x		x				
210			x	x	x	x		x	
211				x			x		
212*		x	x	x	x	x		x	
261			x		x		x		
262				x	x	x		x	
263				x			x	x	
264				x			x	x	
	SPS-8								
803	x			Section removed from service					
809	x								
	SPS-9								
901				x					x
902				x	x				x

* SHRP Core Section ** Replacement section

2.4.2.1 Series I Testing - FHWA/CNRC (12/95 and 3/96)

Toward the end of 1995, FHWA requested permission to conduct a series of controlled vehicle tests on Sections 803 (AC) and 809 (PCC) constructed and instrumented the previous year for SPS-8. They were in the process of preparing a document on size and weight regulations for commercial trucks in which axle configuration and types of tires were to be included. Dynamic response data obtained from these sections would provide valuable input as to how these parameters affect pavement performance. ODOT agreed and a special research truck was brought down from the Canadian National Research Council (CNRC) to perform the tests. This truck can be configured with tandem or tridem axles on the trailer, axle spacing can be adjusted, and either dual or super single tires can be mounted on the trailer axles. Specified axle weights are achieved by filling selected tanks in the trailer with water and by adjusting lead weights on the rear of the trailer. Weights carried by this truck in some runs were at or above the legal limits, which generated premature distress in the thin AC pavement sections. For this series of tests, tandem axles were typically spaced 48 inches on centers, with a few tests being run at 96 and 114-inch spacings. A tridem axle configuration was achieved by lowering the lift axle and spacing it 54 inches in front of the 48-inch spaced tandem axles. Standard dual tires were used with the tandem configuration, and both standard dual and super single tires were used with the tridem configuration. Tire pressure was set at 100 psi for all tests. Tables 2.9 and 2.10 show test parameters for the CNRC tandem and tridem-axle configurations in Series I.

Table 2.9

Series I Controlled Vehicle Test Parameters - Tandem Axle CNRC Truck

Date	Tandem Axle Spacing 'A' (in.)	Tire Type	Nominal Load (Kips)	Tandem Axle Loads (Kips)		Nominal Speed (mph)	Load I.D.	Run No.
				Lead	Rear			
SPS-8 sections monitored: 390803 (AC) and 390809 (PCC)								
12/5/95	48	Duals	36	18.00	18.30	Sand Cal.	A	1-12
12/6/95	48	Duals	36	18.00	18.30	45	A	13-18
12/6/95	48	Duals	38	19.80	20.00	45	B	1-5
12/7/95	48	Duals	34	17.10	17.40	15,30,45	C	1-19
12/8/95	114	Duals	40	21.40	21.40	15,30,45	D	1-13
12/11/95	96	Duals	38	19.80	20.00	15,30,45	E	1-10
12/14/95	96	Duals	38	19.80	20.00	15,30,45	E	11-24

Table 2.10

Series I Controlled Vehicle Parameters - Tridem Axle CNRC Truck

Series I Controlled Vehicle Tests - Tridem Axle CNRC Test Truck									
Date	Axle Spac. (in.)	Tire Type	Nom. Load (Kips)	Total Rear Axle Loads (Kips)			Nom. Speed (mph)	Load I.D.	Run No.
				Lead	Mid	Rear			
SPS-8 sections monitored: 390803 (AC) and 390809 (PCC)									
12/15/95	54-48	Duals	42	14.30	14.30	14.40	15,30,45	F	1-12
3/13/96	54-48	Duals	48	16.10	16.40	16.70	15,45	H	1-9
3/13/96	54-48	Duals	54	18.10	18.20	18.60	15,45	I	1-8
3/14/96	54-48	Duals	54	18.10	18.20	18.60	45	I	9-11
3/15/96	54-48	S. Singles	54	17.90	18.10	18.40	C,15,30,45	J	1-15
3/16/96	54-48	S. Singles	42	14.40	14.00	14.20	15,45	K	1-8
3/16/96	54-48	S.Singles	48	16.20	16.10	16.60	15,45	L	1-9

2.4.2.2 Series II Testing - ODOT Dump Trucks (8/96)

ODOT conducted a series of basic SHRP controlled vehicle tests on the SPS-1 and SPS-2 core sections using ODOT single and tandem-axle dump trucks just prior to the test pavement being opened to traffic. Because of the anticipated early distress in Sections 105 and 107, however, they were added to this test series so data could be obtained before those gauges became inoperative and the sections failed. Test sections in the SPS-1 and SPS-9 experiments were opened to main-line traffic on August 14, 1996. The SPS-2 sections were opened one day later. Approximately three weeks after being opened to traffic, Sections 101, 102, and 107 in the SPS-1 (AC) experiment began to exhibit measurable wheel path rutting. Tables 2.11 and 2.12 summarize test parameters for the Series II tests.

Table 2.11

Series II Controlled Vehicle Parameters - Single-Axle Dump Truck

Series II Controlled Vehicle Tests - Single Axle Dump					
Date	Nom. Load (K)	Rear Axle Load (K)	Nom. Speed (mph)	Load I.D. (1)	Run No.
AC Sections 102, 104, 105, 107, 108 and 110					
8/6/96	18	18.45	C,30,40,50	EF	1-14
8/7/96	18	18.45	C,30,40,50	EF	1-14
8/9/96	22	22.23	C,30,40,50	G	1-13 (2)
PCC Sections 201, 205, 208, 209 and 212					
8/12/96	22	22.23	C,30,40,50	H	1-30 (3)
8/13/96	22	22.23	C,30,40,50	I	1-27 (3)
8/14/96	18	18.10	30,40,50	J	1-15 (4)

(1) Load I.D.s changed for database
(2) No morning runs for 22K load on SPS-1
(3) Run numbers include single and tandem-axle trucks
(4) No afternoon runs for 18K load on SPS-2

Table 2.12

Series II Controlled Vehicle Parameters - Tandem-Axle Dump Truck

Series II Controlled Vehicle Tests - Tandem Axle Dump						
Date	Nom. Load (K)	Total Rear Axle Loads (K)		Nom. Speed (mph)	Load I.D. (1)	Run No.
		Lead	Rear			
AC Sections - 102, 104, 105, 107, 108 and 110						
8/2/96	32	16.62	16.23	C,30,40,50	AB	1-17
8/3/96	32	16.62	16.23	C,30,40,50	AB	1-15
8/5/96	42	21.14	21.38	C,30,40	CD	1-11
8/6/96	42	21.14	21.38	30,40,50	CD	1-16
PCC Sections - 201, 205, 208, 209 and 212						
8/12/96	42	21.14	21.38	C,30,40,50	HI	1-30 (2)
8/13/96	42	21.14	21.38	C,30,40,50	HI	1-27 (2)
8/14/96	32	16.54	16	(3)	J	(3)

(1) Load I.D.s changed for database
(2) Run numbers include single and tandem-axle trucks
(3) Tandem-axle dump truck broke down; no data available

2.4.2.3 Series III Testing - CNRC and ODOT Tandem Dump Truck (6/97)

Because of the high quality of pavement response data obtained on the two SPS-8 sections during Series I testing with the CNRC truck in 1996, and because 31 additional instrumented test sections were available on the mainline pavement, ODOT contracted with the Canadian National Research Council to bring their research tank truck back to Ohio for an expanded series of tests in June 1997. One month of testing was believed to be adequate to complete a comprehensive matrix of truck parameters, including number of axles, axle spacing, load, speed, tire configuration, and lateral position on the pavement. FHWA also funded the monitoring of vehicle dynamics on the CNRC truck for a few runs during this series of tests. Unfortunately, this was an extremely wet time in Ohio and testing could not be performed while it was raining because of potential damage to the data acquisition systems. Even most of the weekends were wet.

It soon became apparent that the planned testing sequence would have to be modified to accommodate the inclement weather and still obtain the maximum benefit from the CNRC truck within the allotted time. The first step taken was to select the optimum number of sections in SPS-1 and SPS-2 that could be monitored simultaneously with the nine data acquisitions available. There was not going to be sufficient time to conduct one complete series of tests on SPS-1 and another on SPS-2 as originally planned. By monitoring sections as the truck traveled northbound and southbound, seven and eight of the highest priority sections in SPS-1 and SPS-2, respectively, could be monitored within a few minutes of each other.

Because the ODOT tandem-axle dump truck was planned to be used in all controlled vehicle tests conducted on the test road, it was run with the CNRC truck in the Series III tests to serve as a control vehicle. Axle load and speed on the ODOT truck were adjusted to simulate conditions for the CNRC truck as closely as possible. With this arrangement, the CNRC truck would make a pass on the SPS-1 sections and return over the SPS-2 sections. The ODOT truck would follow behind in such a way as to be traveling in the opposite direction of the CNRC truck. Pavement response was monitored on both sides of the highway. The time differential between comparable runs for the two vehicles was typically less than 10 minutes.

For the CNRC truck, it was most efficient to perform all tests with the same arrangement of lead weights on the back of the trailer and only change the distribution of water in the trailer.

Consequentially, three of the four boxes of weights were evenly distributed across the back of the truck throughout the Series III tests. Tests were grouped to minimize the movement of axles and the changing of tires. Tanks of water were filled at the District 6 garage so the heaviest load would be run first. One or two tanks were then emptied into a catch basin at the site in preparation for the next lightest axle load. This procedure minimized the necessity of having to return to the district garage to fill tanks. Similarly, the ODOT tandem-axle dump truck was loaded heavy in the morning at a nearby maintenance garage and unloaded as necessary by returning to this garage. While not as efficient as dumping material at the site, this process reduced the potential problem of finding an equipment operator at the garage to load the truck during the day when most everyone was out. Unloading typically takes less time than loading. Also, the trucks were gassed up either in the morning or at the end of the day to reduce down time. Wheel loads on the trucks were weighed with portable PAT scales in the test lane where any effects of pavement slope would be taken into account. Tables 2.13 - 2.15 summarize truck parameters used in this series of tests.

Table 2.13

Series III Controlled Vehicle Parameters - Tandem-Axle Dump Truck

Series III Controlled Vehicle Tests - Tandem Axle Dump						
Date	Nom. Load (K)	Total Rear Axle Loads (K)		Nom. Speed (mph)	Load I.D.	Run No.
		Lead	Rear			
AC Sections 101, 104, 105, 106, 108, 111 and 112						
PCC Sections 201, 202, 205, 206, 209, 210, 212 and 261						
6/4,5/97	40	20.80	19.10	C,30,40,50	A	1-12
6/9,10/97	32	16.90	16.20	C,30,40,50	B	1-12
6/9,10/97	32	16.90	16.20	C,30,40,50	BA	1-13 (1)
6/19/97	32	16.90	16.20	C,30,40,50	BY (2)	1-12
6/20/97	32	16.90	16.20	C,30,40,50	Z	1-13
6/23/97	32	16.90	16.20	C,30,40,50	C	1-12
6/24/97	32	16.90	16.20	C,30,40,50	D	1-10
6/24/97	20	10.00	9.50	C,30,40,50	E	1-10
6/25/97	20	10.00	9.50	30,40,50	F	1-9
6/25/97	12	6.60	6.00	30,40,50	G	1-9
6/26/97	12	6.60	6.00	C,30,40,50	H	1-10

(1) AC sections only
(2) Load I.D. changed for database

Table 2.14

Series III Controlled Vehicle Parameters - Tandem-Axle CNRC Truck

Series III Controlled Vehicle Tests - Tandem Axle CNRC Truck								
Date	Axle Spac. (in.)	Tire Type	Nom. Load (K)	Total Rear Axle Loads (K)		Nom. Speed (mph)	Load I.D.	Run No.
				Lead	Rear			
AC Sections - 101, 104, 105, 106, 108, 111 and 112								
PCC Sections - 201, 202, 205, 206, 209, 210, 212 and 261								
6/4,5/97	48	Duals	50	25.70	25.50	C,30,40,50	A	1-12
6/9,10/97	48	Duals	36	18.10	18.20	C,30,40,50	B	1-12
6/9,10/97	48	Duals	36	18.10	18.20	C,30,40,50	BA	1-13 (1)
6/17/97	48	S. Singles	36	18.10	17.90	Sand Cal.	BX (2)	1-5 (3)
6/19/97	48	S. Singles	36	18.10	17.90	C,30,40,50	BY (2)	1-12
6/20/97	146	S. Singles	40	20.20	19.70	C,10,30,50	BZ (2)	1-13
6/23/97	96.5	S. Singles	40	18.90	18.80	C,10,30,50	C	1-12
6/25/97	48	S. Singles	32	16.20	16.00	30,40,50	F	1-9
6/25/97	48	S. Singles	26	13.30	13.50	30,40,50	G	1-9
6/26/97	48	Duals	26	13.60	13.80	C,30,40,50	H	1-10

(1) AC sections only
(2) Load I.D.s changed for database
(3) Sections 390104, 390105, and 390111 only

Table 2.15

Series III Controlled Vehicle Parameters - Tridem-Axle CNRC Truck

Date	Tandem Axle Spacing 'A' (in.)	Tire Type	Nominal Load (Kips)	Tridem Axle Loads (Kips)			Nominal Speed (mph)	Load I.D.	Run No.
				Lead	Mid	Rear			
AC Sections - 101, 104, 105, 106, 108, 111 and 112									
PCC Sections - 201, 202, 205, 206, 209, 210, 212 and 261									
6/24/97	48	S.Singles	50	16.60	16.90	17.10	C,10,30,50	D	1-10
6/24/97	48	S.Singles	32	11.50	11.60	11.60	C,30,40,50	E	1-10

2.4.2.4 Series IV Testing - ODOT Dump Trucks (7/8/97)

The fourth series of truck tests was performed to fulfill SHRP requirements. However, it was also an excellent opportunity to monitor a number of other pavement sections along with the eight core sections. To complete these tests, 12 sections in the SPS-1 experiment were monitored first. Single and tandem-axle dump trucks were loaded with the light load, and all speeds and repetitions were run in the morning and afternoon of July 2, 1997. The load was increased on July 3 and the same test sequence was performed. A similar procedure was followed for 14 sections in SPS-2 later in July and early August. Tables 2.16 and 2.17 show truck parameters used in the Series IV tests.

Table 2.16

Series IV Controlled Vehicle Parameters - Single Axle Dump Truck

Date	Nom. Load (K)	Rear Axle Load (K)	Nom. Speed (mph)	Load I.D.	Run No.
AC Sections - 103, 104, 105, 106, 108, 109, 110, 111, 112, 160, 901 and 902					
7/2/97	18	17.35	C,30,40,50	K	1-20
7/3/97	22	24.95	C,30,40,50	L	1-18
PCC Sections - 201, 202, 203, 204, 205, 206, 207, 208, 210, 211, 212, 262, 263 and 264					
7/29/97	18	21.45	C,30,40,50	M	1-10
7/30/97	18	21.45	30,40,50	N	1-9
7/30/97	22	25.35	30,40,50	O	1-9
8/6/97	22	25.35	C,30,40,50	P	1-11

Table 2.17

Series IV Controlled Vehicle Parameters - Tandem Axle Dump Truck

Date	Nom. Load (K)	Rear Axle Loads (K)		Nom. Speed (mph)	Load I.D.	Run No.
		Lead	Rear			
AC Sections - 103, 104, 105, 106, 108, 109, 110, 111, 112, 160, 901 and 902						
7/2/97	32	16.90	16.10	C,30,40,50	K	1-20
7/3/97	42	25.15	24.30	C,30,40,50	L	1-18
PCC Sections - 201, 202, 203, 204, 205, 206, 207, 208, 210, 211, 212, 262, 263 and 264						
7/29/97	32	18.35	17.50	C,30,40,50	M	1-10
7/30/97	32	18.35	17.50	30,40,50	N	1-9
7/30/97	42	23.05	22.05	30,40,50	O	1-9
8/6/97	42	23.05	22.05	C,30,40,50	P	1-11

2.4.2.5 Series V Testing - ODOT Dump Trucks (10/98)

The Series V controlled vehicle tests were also performed for SHRP. All core sections, with the exception of Section 102 which was removed and replaced earlier as Section 161, were included along with a few additional sections to obtain supplementary data. By the time these tests were run, there had been a significant drop in the number of sensors that were still operable. In the thinner SPS-1 sections, very few strain gauges were functional, except for Section 162 (replacement for 107), which was constructed in the fall of 1997. Overall, the pressure cells appeared to be performing satisfactorily and 90% of the LVDTs, which had been removed after the last series of truck tests and remounted for these tests, provided acceptable data. As noted in the earlier tests, a higher percentage of sensors were operational in the thicker pavement sections. In the PCC sections (SPS-2), the number of operable pressure cells and LVDTs was comparable to that in the thicker AC sections. None of the rosettes, about half of the Dynatest gauges, and approximately 90% of the KMB-100 gauges were operational.

The full SHRP matrix of load parameters was completed on nine SPS-2 sections. Because of time constraints and mechanical problems, only a few runs were completed with the tandem-axle truck on the eight AC sections being monitored. Tables 2.18 and 2.19 show the test variables for Series V.

Table 2.18

Series V Controlled Vehicle Parameters - Single-Axle Dump Truck

Date	Nom. Load (K)	Total Rear Axle Load (K)	Nom. Speed (mph)	Load I.D.	Run No.
AC Sections - 104, 106, 108, 109, 110, 162, 165 and 902					
10/19/98	22	24	C,30,40,50	98E	1-24(1)
10/20/98	18	20.65	C,30,40,50	98F	1-12
PCC Sections - 201, 204, 205, 208, 209, 210, 212, 261 and 262					
10/9/98	18	18.4	C,30,40,50	98A	1-24(1)
10/14/98	18	18.4	C,30,40,50	98B	1-24(2)
10/14/98	22	24	C,30,40,50	98C	1-24(2)
10/15/98	22	24	C,30,40,50	98D	1-24(2)(3)

(1) Even numbers
(2) Odd numbers
(3) One creep run along pavement edge

Table 2.19

Series V Controlled Vehicle Parameters - Tandem-Axle Dump Truck

Date	Nom. Load (K)	Rear Axle Loads (K)		Nom. Speed (mph)	Load I.D.	Run No.
		Lead	Rear			
AC Sections - 104, 106, 108, 109, 110, 162, 165 and 902						
10/19/98	32	19.6	18.75	C,30,40,50	98E	1-24(1)
PCC Sections 201, 204, 205, 208, 209, 210, 261 and 262						
10/9/98	32	16.55	15.75	C,30,40,50	98A	1-24(1)
10/14/98	32	16.55	15.75	C,30,40,50	98B	1-24(2)
10/14/98	42	19.6	18.75	C,30,40,50	98C	1-24(2)
10/15/98	42	19.6	18.75	C,30,40,50	98D	1-24(2)

(1) Odd numbers
(2) Even numbers

2.4.2.6 Series VI Testing - ODOT Dump Trucks (9, 10/99)

The Series VI controlled vehicle tests were also performed for SHRP. All core sections, with the exception of Section 102, which was removed and replaced earlier, were included along with a few additional sections to obtain supplementary data. By the time these tests were conducted, the pavement sections were four years old. Because the life expectancy of most gauges was one to two years, there had been a significant drop in the number of sensors that were still operable, especially in the thinner SPS-1 sections. Overall, the pressure cells were performing satisfactorily and 80% of the LVDTs, which had been removed after the last series of truck tests and remounted for these tests, provided valid data. In the PCC sections (SPS-2), none of the rosettes, about 40% of Dynatest gauges, and approximately 70% of the KMB-100 gauges remained operational.

In addition to the sensors still functioning, surface mounted strain gauges were installed on all core SPS-1 and SPS-2 sections being monitored in accordance with SHRP/LTPP guidelines. Sensors installed in the non-core sections were mounted at critical locations in the wheel path to measure maximum stress as trucks passed over the sections. Additional gauges were mounted transversely in Sections 206, 205, and 208. The full SHRP matrix of load parameters was completed on eight SPS-1 and eight SPS-2 sections. Tables 2.20 and 2.21 summarize runs completed during the sixth series of controlled vehicle tests.

Table 2.20

Series VI Truck Parameters - ODOT Single-Axle Dump Truck

Date	Nominal Load (K)	Rear Axle (K)	Nominal Speed (mph)	Load I.D.	Run No.
AC Sections - 104, 106, 108, 109, 110,111,112, 902					
9/27/99	22	20.00	C,30,40,50	99A	1-44 (1)
10/20/99	18	16.30	C,30,40,50	99B	1-42 (1)
PCC Sections - 201, 202, 205, 206, 208, 210, 212, 262					
10/1/99	22	20.60	C,30,40,50	99C	1-42 (1)
10/5/99	18	17.00	C,30,40,50	99D	1-44 (1)

(1) Even Numbers

Table 2.21

Series VI Truck Parameters - ODOT Tandem-Axle Dump Truck

Date	Nominal Load (K)	Rear Axle Loads (K)		Nominal Speed (mph)	Load I.D.	Run No.
		Lead	Rear			
AC Sections - 104, 106, 108, 109, 110, 112, 902						
9/27/99	42	18.60	18.35	C,30,40,50	99A	1-44 (2)
10/20/99	32	15.40	15.05	C,30,40,50	99B	1-42 (2)
PCC Sections - 201, 202, 205, 206, 208, 210, 212, 262						
10/1/99	42	18.95	18.95	C,30,40,50	99C	1-42 (2)
10/5/99	32	15.50	15.35	C,30,40,50	99D	1-44 (2)

(2) Odd Numbers

2.4.2.7 Series VII - ODOT Dump Trucks, FWD and Dynaflect (10/99)

The Series VII tests were a special investigative effort performed for ODOT on six SPS-1, one SPS-9, and seven SPS-2 sections. FWD and Dynaflect loads were applied over embedded and surface gauges, as in the Series VI tests, and followed by single and tandem-axle dump truck runs at 8 (5), 50 (30), 65 (40), and 80(50) km/hr (mph). Strain gauge responses and lateral tire offsets, where applicable, were recorded for all dynamic loading conditions.

2.4.2.8 Series VIII – ODOT Dump Trucks (4, 5/01)

This series of tests were run mainly for SHRP. Surface gauges were mounted on 10 AC sections and 11 PCC sections prior to testing. Runs included those specified by SHRP with the addition of creep speed. All sections monitored had remained in service since the test road was opened to traffic in 1996, and some were showing signs of distress. Tables 2.22 and 2.23 show test runs made during this series of tests.

Table 2.22

Series VIII Truck Parameters - ODOT Single-Axle Dump Truck

Date	Nominal Load (K)	Rear Axle (K)	Nominal Speed (mph)	Load I.D.	Run No.
PCC Sections - 201, 202, 204, 205, 206, 208, 210, 212, 262, 263, 264					
4/27/01	22	21.65	C,30,40,50	01A	1-40 (1)
4/30/01	18	18.40	C,30,40,50	01B	1-40 (1)
AC Sections - 104, 106, 108, 109, 110, 111, 112, 160, 901, 902					
5/1/01	18	18.4	C,30,40,50	01C	1-40 (2)
5/2/01	22	22.7	C,30,40,50	01D	1-40 (2)

(1) Even Number Runs
(2) Odd Number Runs

Table 2.23

Series VIII Truck Parameters - ODOT Tandem-Axle Dump Truck

Date	Nominal Load (K)	Rear Axle Loads (K)		Nominal Speed (mph)	Load I.D.	Run No.
		Lead	Rear			
PCC Sections - 201, 202, 204, 205, 206, 208, 210, 212, 262, 263, 264						
4/27/01	42	17.50	17.35	C,30,40,50	01A	1-40 (2)
4/30/01	32	14.85	14.55	C,30,40,50	01B	1-40 (2)
AC Sections - 104, 106, 108, 109, 110, 111, 112, 160, 901, 902						
5/1/01	32	14.85	14.55	C,30,40,50	01C	1-40 (1)
5/2/01	42	22.75	23.05	C,30,40,50	01D	1-40 (1)

(1) Even Number Runs
(2) Odd Number Runs

2.4.2.9 Series IX - ODOT Single and Tandem-Axle Dump Trucks (10/03)

This series of tests was run to obtain response data on Sections 901 and 902, and on newly constructed Section 165, which replaced Sections 103, 108, 109 and 110. A 72-run LTPP matrix consisting of two temperatures, three speeds, two loads and three repetitions of each cell in the matrix were conducted on the three AC sections with single and tandem-axle dump trucks. A few additional runs at creep speed (~5 mph) brought the total number of runs to 90 in each of the three sections. Load 03A was conducted on Sections 901 and 902 during the afternoon of October 20, 2003. Load 03B was conducted on the morning of October 21, 2003 and included the two SPS-9 sections and Section 165. Load 03B was continued in the afternoon of October 21 on Section 165 to collect data not obtained the previous day. Truck weights were reduced and controlled vehicle tests were conducted on all three sections during the afternoon of October 21, 2003 (Load 03C). On October 22, 2003, morning runs were conducted on all three sections with the light weight trucks (Load 03D). Tables 2.24 and 2.25 summarize the run parameters.

Table 2.24

Series IX Truck Parameters - ODOT Single-Axle Dump Truck

Date	Nominal Load (K)	Rear Axle (K)	Nominal Speed (mph)	Load I.D.	Run No.
AC Sections - 165, 901, 902					
10/20/03	22	24.05	C,30,40,50	03A	1-24 (1)
10/21/03	22	24.05	C,30,40,50	03B	1-22 (1)
10/21/03	18	15.6	C,30,40,50	03C	1-22 (1)
10/22/03	18	15.6	C,30,40,50	03D	1-22 (1)

(1) Odd Number Runs

Table 2.25

Series IX Truck Parameters - ODOT Tandem-Axle Dump Truck

Date	Nominal Load (K)	Rear Axle Loads (K)		Nominal Speed (mph)	Load I.D.	Run No.
		Lead	Rear			
AC Sections - 165, 901, 902						
10/20/03	42	18.55	18.00	C,30,40,50	03A	1-24 (2)
10/21/03	42	18.55	18.00	C,30,40,50	03B	1-22 (2)
10/21/03	32	13.50	13.150	C,30,40,50	03C	1-22 (2)
10/22/03	32	13.50	13.15	C,30,40,50	03D	1-22 (2)

(2) Even Number Runs

2.4.2.10 Dynamic Response Data

As test trucks approached an instrumented section of pavement during a controlled vehicle test, the data acquisition systems were turned on and left on until the truck had exited the section. Each response sensor in the section provided a continuous trace of strain, deflection or pressure response for the entire pass, recorded at a rate of about 400 data points/second. Sensor peaks were generally recorded for each axle on tandem and tridem-axle vehicles, as shown in Figure 2.11, while sensors lower in the pavement structure or those in stiffer pavement structures tended to record a broader single peak (Figure 2.12). Grouped axles on PCC sections often yielded a single peak. After trucks passed the section, their lateral positioning was measured as the average distance from the centerline of the line of sensors in the right wheelpath to the outside edge of the rear tires as recorded by prints left in damp sand, as shown in Figure 2.13. If, as planned, the driver was able to precisely straddle the sensors with the rear dual tires, the distance from the centerline of the sensors to the outside edge of the outside tire in the sand was equal to the width of the outside tire plus one-half of the spacing between the dual tires. In Figure 2.13, the outside edge of the tire is actually a few inches inside the line of sensors as the truck traveled from left to right.

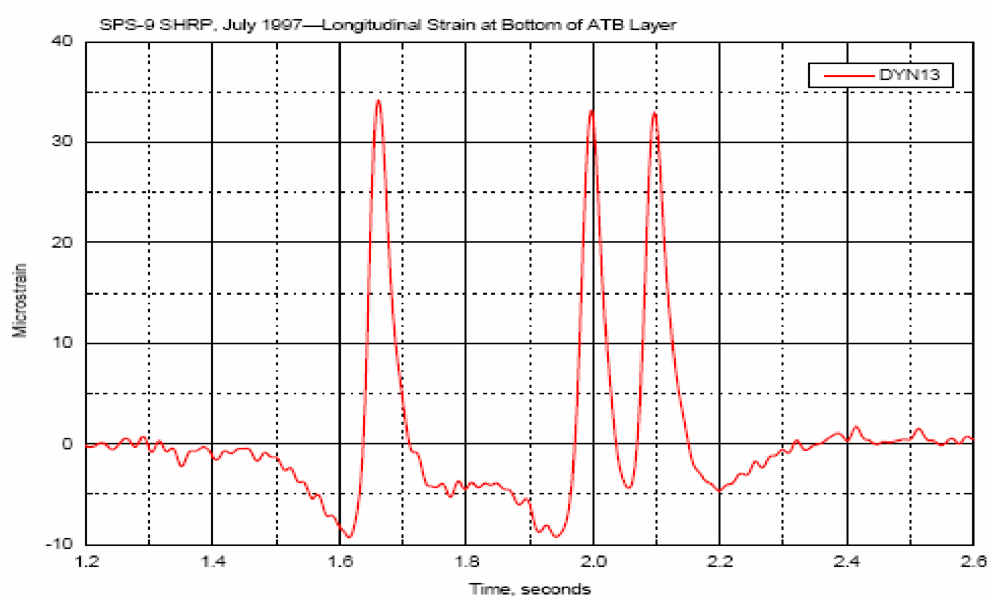

Figure 2.11 - Two Peak Response for Tandem Axles

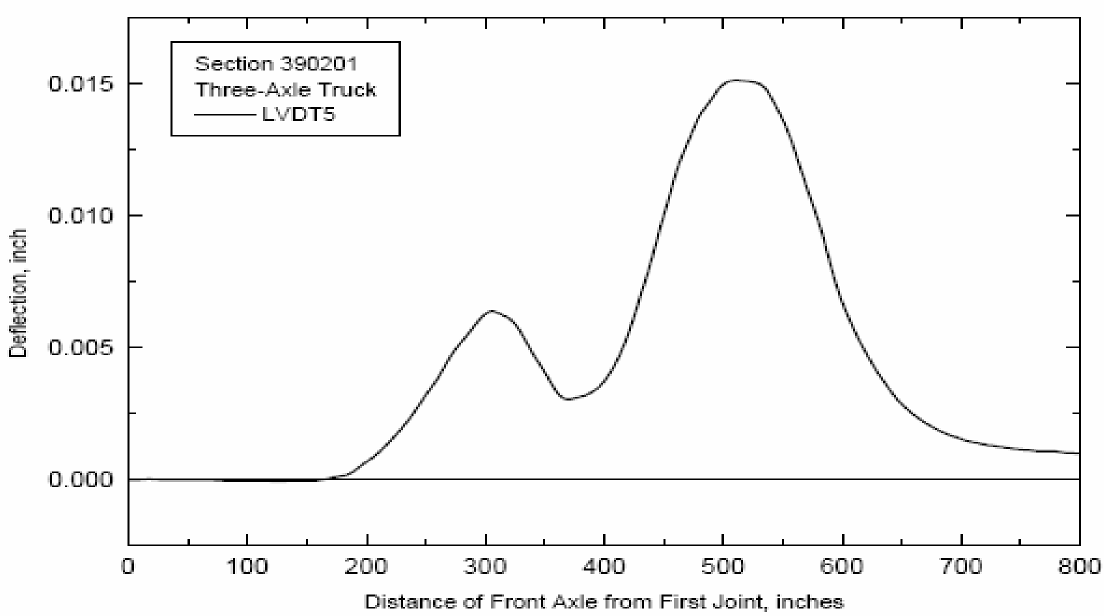

Figure 2.12 - Single Peak Response for Tandem Axles

Figure 2.13 - Tire Print in Sand

The number of runs completed during a controlled vehicle test series was the total number of times both trucks passed over a group of AC sections in the SPS-1/SPS-9, a group of PCC sections in SPS-2, or the two instrumented sections in SPS-8. The SPS-1 and SPS-9 experiments were lumped together because they were the same basic pavement type and because they were located adjacent to each other in the southbound lanes. The actual number of runs planned for a series depended upon the number of loads, speeds, temperatures and repetitions in the test matrix, and the SPS experiments being monitored. The SHRP matrix consisted of two loads, three speeds, two temperatures and three repetitions or 36 runs per truck per group of SPS sections. ODOT added a few runs at creep speed (~5 mph) and an occasional extra run was required to get a third repetition when the driver missed the wheelpath target by an excessive distance, which happened occasionally at the higher speeds.

Single and tandem-axle dump trucks ran together in seven of the nine test series on the Ohio SHRP Test Road. In Series I, the CNRC truck was configured with a tandem-axle trailer and dual tires, and with a tridem-axle trailer with dual and super single tires. In Series III, a tandem-axle dump truck ran with the CNRC truck, configured as a tandem-axle trailer with dual and super single tires, and as a tridem-axle trailer with super single tires.

The total number of sensor traces obtained during a series of tests was the product of all sensors in all sections being monitored times the number of runs through the sections. Again, ODOT exceeded the basic SHRP requirements in terms of truck runs by adding creep speed to the run matrix, in terms of the number of sections being monitored by instrumenting 33 sections instead of eight, and in terms of the number of dynamic responses per section by about doubling the quantity of sensors to approximately 35 per section.

Using the data in Table 2.7 and assuming 35 operable sensors per section, the maximum number of response sensor traces that could be collected during each test series was 10,080 for Series I, 33,775 for Series II, 121,345 for Series III, 70,140 for Series IV, 40,320 for Series V, 48,160 for Series VI, 61,600 for Series VIII and 9,450 for Series IX. This would have totaled 394,870 traces, if all sensors were operable. Series VII was not included as it was a special group of tests comparing the dynamic response measured with single and tandem-axle dump trucks to those measured with the FWD and Dynaflect. Obviously, the number of traces calculated above must be tempered somewhat because, as time passed, more and more strain gauges became inoperative, thus reducing the number of valid traces, especially after the Series V tests in 1998.

Techniques used to install response sensors in the SPS-1, SPS-2, SPS-8, and SPS-9 pavement sections were quite successful with over 95% surviving construction, over 90% of those still functional after one year, and a significant number of surviving in the thicker pavement sections after two years. Strain gauges failed quickest in the thinner SPS-1 (AC) sections with no drainage. Repeated heavy loads applied by mainline traffic on these sections overstressed the transducers and caused visible distress in the pavement after a rather short period of time.

All response traces collected during the nine series of controlled vehicle tests have been preserved and are available through ODOT. Tables of positive and negative peak values are currently being completed by ORITE. Considering that each trace contained from two (single-axle dump) to six (CNRC tridem) positive axle peaks and a number of negative peaks between the axles, this table will be quite large, but immensely valuable as a source of actual field response measurements with material properties, soil moisture, pavement temperature and lateral positioning of the test trucks available.

Prior to processing, each individual sensor trace was examined visually to ensure it had a shape that reasonably reflected the type of truck generating the pulses, and had a minimal number of outlier points and electronic noise. The traces were then filtered in the frequency domain with a finite-impulse-response low-pass filter, which was designed by applying a Kaiser window to the ideal low-pass frequency response. The pass band was 30 to 55 Hz, depending upon truck speed, and the cutoff frequency was 55 Hz to eliminate 60 Hz noise. Customized software was developed by ORITE to automate the trace filtering operation. The complete original traces have been preserved for engineers and researchers needing this information.

2.4.3 Non-Destructive Testing (NDT)

Test sections on DEL 23 were arranged by material type and design features to facilitate construction and traffic control operations. During 1994-96, the FWD was used to test each material layer in each test section throughout construction. Because completion dates for the various layers and sections occurred over an extended period of time, any comparison of FWD measurements between sections and layers must be made cautiously. The most obvious parameters which have a significant impact on FWD measurements are pavement temperature and subgrade moisture. While driving and passing lanes were constructed identically in both directions, the SHRP test sections were located in the driving lane. All NDT data collected on DEL 23 were obtained in the right wheelpath and centerline of the driving lane.

A report entitled "Coordination of Load Response Instrumentation of SHRP Pavements – Ohio University," (2) documented ODOT and university efforts to install sensors and sample materials on the Ohio SHRP Test Road (DEL 23) during construction, and to conduct early response measurements with ODOT dump trucks and the FWD through 1998. FWD and Dynaflect data on the newly completed pavement sections were summarized in Appendix E and FWD data on the completed subgrade were shown in Appendix F of that report. In another report entitled "Determination of Pavement Layer Stiffness on the Ohio SHRP Test Road Using Non-Destructive Testing Techniques," (4) FWD measurements obtained on each material layer of Sections 101, 102, 105 and 107 during construction were summarized in Appendix A. A third report entitled "Continued Monitoring of Instrumented Pavement in Ohio," (1) documents subsequent monitoring efforts on the Ohio SHRP Test Road and other instrumented Ohio pavements into 2002. Appendix E of that report showed FWD data collected in May 1998, and Appendix F contained FWD and Dynaflect data collected in April 2001.

Appendix E of this report summarizes all FWD data on all material layers during construction. Section averages calculated for each of three FWD loads in May 1998, September 1999, September 2000, April 2001, May 2001 and at various times in 2002 are shown in Appendices F – K. Table K-1 shows the FWD section profiles for 2002. Tables 2.26 and 2.27 show a summary of average normalized maximum deflection (Df1) and Spreadability (SPR) measured on AC sections through 2002. Table 2.28 shows similar midslab data for the PCC sections, and Table 2.29 shows load transfer (LT) and Joint Support Ratios (JSR) obtained at joints on the PCC sections. All data in these tables were obtained at loads of about 9,000 lbs.

Table 2.26

Summary of Average Df1 on AC Sections

Ohio SHRP Test Road - FWD Measurements, AC Sections														
Normalized Df1 (mils/kip)														
Section	Centerline							Right Wheelpath						
	New 6/96	5/98	9/99	9/00	4/01	5/01	3/02	New 6/96	5/98	9/99	9/00	4/01	5/01	3/02
Original AC Sections														
101*	1.63	Removed from service						1.60	Removed from service					
102*	3.46	Removed from service						3.21	Removed from service					
103*	1.11	0.74	1.16	0.97	1.24		1.24	1.25	0.80	1.17	0.98	1.27		1.08
104*	0.45		0.52	0.40	0.54		0.43	0.46	0.40	0.53	0.41	0.51		0.42
105*	1.33		Removed from service					1.40	1.52	Removed from service				
106*	0.56		0.62	0.50	0.68		0.54	0.58	0.49	0.63	0.48	0.65		0.54
107	2.11	Removed from service						1.90	Removed from service					
108	0.94	0.85	1.02	1.01	1.22		1.03	0.96	0.93	1.10	1.16	1.31		1.33
109	0.97	0.77	0.94	0.88	0.98		0.84	1.02	0.86	0.98	0.97	1.05		1.05
110	0.95	0.58	0.69	0.66	0.77		0.67	1.03	0.57	0.72	0.69	0.84		0.73
111	0.68		0.78	0.64	0.76		0.70	0.70	0.63	0.82	0.63	0.77		0.67
112	0.53		0.45	0.45	0.52		0.46	0.49	0.48	0.46	0.44	0.52		0.46
159		0.20		0.22					0.20		0.22			
160	0.50		0.55	0.51	0.61		0.52	0.50	0.50	0.55	0.49	0.57		0.49
901	0.40		0.36		0.40		0.33	0.41	0.37	0.37		0.42		0.35
902	0.45		0.31		0.30		0.27	0.45	0.35	0.31		0.30		0.27
903	0.45		0.41		0.46		0.37	0.45	0.44	0.42		0.45		0.37
	11/94													
803*	2.04							2.09						
804*	1.10							1.07						
Replacement AC Sections														
161	11/97 0.30		0.50	0.40	0.47		0.42	11/97 0.31	0.51	0.50	0.41	0.46		0.41
162	10/97 0.28		0.36	0.28	0.32		0.28	10/97 0.31	0.40	0.34	0.26	0.29		0.28
163	10/97 0.30		0.39	0.31	0.35		0.31	10/97 0.30	0.44	0.37	0.29	0.34		0.29
164	10/98 1.27		1.22	0.97	0.94		0.82	10/98 1.30		1.21	1.00	0.94		0.82
165														
	10/97													
A803*	1.81			1.11			1.74				1.07			1.55
A804*	1.07			0.56			1.10	1.12			0.61			1.12

* Section undrained

Table 2.27

Summary of Average SPR on AC Sections

Ohio SHRP Test Road - FWD Measurements, AC Sections														
Spreadability (%)														
Section	Centerline							Right Wheelpath						
	New 6/96	5/98	9/99	9/00	4/01	5/01	3/02	New 6/96	5/98	9/99	9/00	4/01	5/01	3/02
Original AC Sections														
101*	54.8	Removed from service						54.5	Removed from service					
102*	46.7	Removed from service						47.0	Removed from service					
103*	63.6	69.4	65.7	71.3	69.6		69.6	61.9	67.3	66.0	69.5	67.2		69.0
104*	70.7		67.6	70.9	66.0		70.0	69.3	69.5	67.9	69.3	68.0		70.6
105*	59.6		Removed from service					60.1	60.9	Removed from service				
106*	69.4		65.9	70.2	66.5		69.0	68.2	67.6	65.8	71.2	66.7		68.7
107	50.3	Removed from service						50.9	Removed from service					
108	59.7	62.9	62.0	63.3	59.7		63.0	60.4	61.2	60.2	60.2	58.3		58.4
109	60.5	62.8	63.1	64.5	60.4		63.6	61.5	61.9	62.8	63.2	59.7		61.3
110	63.4	67.9	69.0	70.7	68.7		69.3	62.3	68.2	68.3	69.5	66.7		68.4
111	66.3		66.9	69.5	66.2		67.9	66.7	68.9	66.3	70.5	65.7		69.3
112	69.7		71.0	70.9	68.2		70.8	70.0	70.9	70.5	72.0	68.4		70.9
159		75.7		67.2					73.2		68.5			
160	71.3		69.6	71.7	68.4		71.5	70.7	67.5	69.7	72.2	69.7		72.4
901	67.4		66.1		61.8		66.8	67.6	64.9	65.7		60.8		65.3
902	64.6		67.5		68.0		70.2	65.1	64.7	67.3		67.2		70.3
903	68.6		67.0		63.2		68.9	69.0	64.0	66.9		62.9		68.7
	11/94													
803*	49.6							50.4						
804*	62.4							63.5						
Replacement AC Sections														
161	11/97 73.8		65.9	69.6	65.6		68.5	11/97 71.5	65.1	65.5	68.9	65.7		68.8
162	10/97 66.7		60.3	66.4	60.8		64.4	10/97 65.9	60.1	61.0	67.5	62.7		63.7
163	10/97 66.4		56.4	61.7	56.4		60.5	10/97 66.7	54.3	56.0	62.6	55.4		59.1
164	10/98 66.6		63.9	64.4	61.8		63.7	10/98 67.0		64.6	65.1	63.3		64.9
165														
	10/97													
A803*	31.0			36.9			28.4				35.4			28.4
A804*	42.7			47.0			32.8	42.5			45.7			32.4

* Section undrained

Table 2.28

Summary of Average Df1 and SPR on PCC Sections

Ohio SHRP Test Road - Midslab FWD Measurements, PCC Sections														
Section	Centerline							Right Wheelpath						
	New 6/96	5/98	9/99	9/00	4/01	5/01	3/02	New 6/96	5/98	9/99	9/00	4/01	5/01	3/02
Midslab Normalized Df1 (mils/kip)														
201*	0.51	0.65	0.65		0.54	0.52	0.73							
202*	0.49	0.62	0.69		0.67	0.51	0.68		0.88					
203*	0.29	0.43	0.32		0.33	0.34								
204*	0.22	0.31	0.27		0.27	0.28			0.51					
205*	0.40	0.48	0.54		0.51	0.55								
206*	0.42	0.48	0.55		0.50	0.50								
207*	0.20		0.25		0.27	0.29			0.34					
208*	0.24		0.26		0.30	0.29			0.41					
209	0.38		0.42		0.46	0.44			0.54					
210	0.35	0.43	0.45		0.40	0.43			0.51					
211	0.27	0.40	0.28		0.27	0.28								
212	0.24	0.37	0.28		0.26	0.27			0.46					
259	0.25	0.30	0.32		0.31	0.32			0.45					
260	0.23	0.33	0.27		0.25	0.26			0.41					
261	0.21	0.30	0.23		0.23	0.23								
262	0.22	0.32	0.24		0.24	0.23								
263	0.28	0.53	0.32		0.42	0.37								
264		0.47	0.35		0.36	0.35								
265	0.25		0.28		0.26	0.28			0.33					
	10/94													
809*	0.48			0.64	0.80		0.66							
810*	0.33			0.39	0.41		0.38							
Midslab Spreadability (%)														
201*	80.9	72.8	80.2		80.5	78.3	74.9							
202*	81.0	73.3	81.5		82.9	79.0	77.3		73.1					
203*	80.3	68.0	79.9		81.8	81.5								
204*	84.0	71.0	80.3		82.5	80.7			74.8					
205*	78.9	71.1	77.3		78.7	78.8								
206*	81.7	74.4	78.5		81.0	79.4								
207*	78.3		81.4		83.2	82.1			67.7					
208*	75.0		83.9		84.2	82.9			61.5					
209	71.6		77.0		80.1	78.1			68.6					
210	75.9	67.5	77.7		78.9	76.2			69.7					
211	70.3	62.2	79.9		83.2	82.5								
212	82.1	61.3	81.7		83.4	81.6			70.5					
259	78.6	71.8	81.5		83.3	82.7			73.7					
260	87.6	65.2	80.2		82.6	80.6			66.8					
261	77.5	66.6	82.5		83.9	83.6								
262	81.0	66.1	82.2		83.8	84.6								
263	79.9	69.1	81.3		85.9	83.4								
264		69.6	81.0		85.0	84.2								
265	79.7		79.7		83.0	81.5			81.0					
	10/94													
809*	72.1			74.0	75.2		75.0							
810*	77.9			79.6	82.2		81.3							

* Section undrained

Table 2.29

Summary of Average LT and JSR on PCC Sections

Ohio SHRP Test Road - Joint FWD Measurements, PCC Sections														
Section	Centerline							Right Wheelpath						
	New 6/96	5/98	9/99	9/00	4/01	5/01	3/02	New 6/96	5/98	9/99	9/00	4/01	5/01	3/02
Joint Load Transfer (%)														
201*	80.0							98.1		95.9		85.9	96.6	48.2
202*								96.5	83.9	93.7		96.0	95.1	53.2
203*								92.1		97.3		83.6	94.3	
204*								92.2	73.6	95.4		84.9	96.7	
205*	83.7							95.7		75.5		89.8	94.3	
206*								97.1		93.9		90.0	94.0	
207*								89.1		92.1		84.0	89.9	
208*								89.1		95.1		89.5	91.5	
209								93.8	76.7	91.6		92.7	93.2	
210								91.1	80.7	88.1		90.4	93.0	
211								87.5		88.4		90.4	91.4	
212								89.5	79.6	92.4		97.4	95.6	
259								94.8	86.0	95.6		95.5	96.9	
260								106.4	77.1	92.2		90.3	93.6	
261								85.2		91.9		90.1	93.0	
262								92.0		97.4		90.6	93.0	
263								91.5		96.9		80.3	92.3	
264										97.8		93.3	95.5	
265								95.6		90.9		91.2	93.7	
809*											92.9	93.2		89.3
810*											92.8	92.8		93.2
Joint Support Ratio														
201*	0.85							1.04		0.95		0.96	1.03	0.95
202*								1.01	0.96	0.95		0.95	1.02	0.93
203*								1.07		0.89		0.94	0.98	
204*								1.00	0.97	0.90		1.06	0.99	
205*	0.92							1.00		0.79		0.96	0.98	
206*								1.05		0.94		0.96	0.99	
207*								1.04		0.92		0.91	0.94	
208*								1.08		0.92		0.93	0.95	
209								1.04	0.94	0.95		0.91	1.00	
210								1.03	0.92	0.92		0.95	1.00	
211								1.05		0.94		0.95	0.98	
212								1.05	1.07	0.99		0.99	1.03	
259								0.99	1.02	1.01		0.98	0.97	
260								1.07	1.01	0.96		0.91	1.00	
261								0.94		0.97		0.97	0.96	
262								1.08		0.92		0.93	1.04	
263								0.95		0.91		0.92	0.96	
264										1.01		0.95	0.99	
265								1.12		0.98		0.93	0.99	
809*											1.01	1.12		1.00
810*											1.04	1.02		0.95

* Section undrained

In reviewing the deflection data in Appendix F and in Tables 2.26 and 2.27, certain trends are of interest on the AC pavement sections, as follows:

1. Table F-1 in Appendix F shows some unusual trends in Df1 and SPR during the 1998 FWD measurements on AC sections. Normalized DF1 typically increased slightly and SPR decreased slightly with increasing load, as can be seen in the later measurements. In 1998, Df1 often was substantially lower and SPR was substantially higher at the lowest load than at the two higher loads. During these calculations, it was noted that Df1 was often lower than Df2 and sometimes lower than Df3. As the FWD load increased, the magnitude of Df1 appeared to be more in proportion with the other geophones. The unusually low Df1 at low loads also accounts for the high SPR as Df1 is in the denominator of the SPR equation. Values of Df1 obtained on the AC sections in 1998, especially those measured at the lower load, should be used cautiously.

2. In Appendices G-K, a general trend of slightly higher normalized deflections and slightly higher SPR were evident with increasing load, although there were a few exceptions, probably attributable to localized variations in material. Higher deflections with load were indicative a strain-softening response of the pavement structure and higher SPR with load indicated an increased E_1/E_2 ratio, suggesting that strain softening was likely in the subgrade.

3. From 1996, when the original SPS sections were new, until 2002, when FWD measurements were last taken, Df1 and SPR varied from year to year, but the general trend of lighter sections having higher deflection and lower SPR remained relatively consistent over the years.

4. The fist tier of AC sections requiring replacement after a few months of service included Sections 102, 107, and 101. Section 105 was added one year when a localized failure required it be replaced in the fall of 1998. Maximum normalized deflections measured on these four sections before they were opened to traffic in August of 1996 ranged from 1.33 - 3.46 mils/kip. The second tier of sections replaced in 2002 was Sections 103, 108, 109 and 110. Maximum normalized deflections in this group ranged from 0.94 – 1.25 mils/kip

at the time of opening. Six remaining sections in the SPS-1 experiment and the three SPS-9 sections had initial maximum normalized deflections ranging from 0.20 – 0.70 mils/kip.

5. A similar trend noted in the previous paragraph for deflection on weaker sections was also present for Spreadability (SPR), where SPR is a measure of the shape of the deflection basin and is defined as:

$$SPR\ (\%) = \frac{100 * \Sigma\ (Df1, Df2, Df3, Df4, Df5, Df6, Df7)}{7 * Df1}$$

Higher SPR is indicative of a flatter deflection basin caused by an increased E_1/E_2 ratio, which suggests stiffer pavements and/or weaker supporting layers. During the initial set of FWD measurements on the completed AC test sections in 1996, SPR ranged from 46.7% – 60.1% on the first tier of sections to be replaced, from 59.7% – 63.6% on the second tier of sections, and from 64.6% – 70.7% on sections remaining in service today.

6. Pavement build-ups offer some insights regarding performance trends observed on the AC sections. The combined depth of AC pavement and ATB ranged from 4 – 8 inches on the first tier of sections to be replaced, from 7 – 12 inches on the second tier of replaced sections, and from 12 – 19 inches on sections still remaining in service.

7. Replacement Sections 161 – 164 are also of interest. Sections 161, 162 and 163 had low initial deflections and high initial SPR consistent with the combined 15 inches of AC and ATB in these sections. Section 164 had a high initial deflection of 1.27 mils/kip, also consistent with the 7 inches of AC in that section, but the initial SPR of 66.8% was higher than that observed on the lighter original sections. This may be due to the addition of Tensar BX1100, a geo-fabric placed on the subgrade to distribute load and reduce vertical stress. While SPR appears to be adequate, the high deflection is of concern. This section should continue to be monitored closely.

In reviewing the data in Appendix F and in Tables 2.28 and 2.29, certain other trends are of interest on the PCC pavement sections, as follows:

1. The problem observed in Appendix F with Df1 at low loads on AC sections during the 1998 FWD measurements was reversed on the PCC sections. If anything, Df1 was abnormally high and, consequently, SPR was abnormally low at the lower loads. No explanation for these trends can be offered except a malfunctioning geophone at the center of the load plate, although it is not clear why the errors are in different directions on AC and PCC pavements.

2. A clear trend in Df1 was evident on the new PCC sections concerning thickness of the concrete pavement. Midslab Df1 ranged from 0.35-0.51 on sections with 8 inches of concrete and from 0.20-0.29 on sections with 11 inches of concrete. After six years of FWD measurements and, while annual deflections varied by section and time, values of Df1 at midslab were consistently higher on 8-inch concrete pavements than on 11-inch pavements. The effect of increased pavement thickness on SPR was less evident, possibly due to a lesser effect of PCC thickness on SPR and to the effects of curling and warping of the concrete slabs on dynamic response.

3. Load transfer (100* Df3/Df1) remained very good in all sections, at least through 2001. The low load transfer measured in Sections 201 and 202 in 2002 looks a bit suspicious, but readings anticipated for 2006 will either confirm or refute those results. The lower results in 1998 were probably caused by the problem with Df1 noted above.

4. Joint Support Ratio (Df_{1L}/Df_{1A}) is a parameter used to evaluate the relative support under the approach and leave sides of a joint. Maximum deflections would be expected to be about the same on both sides of the joint, giving a JSR of 1.00. If there is some loss of support under one side or the other, JSR will vary accordingly. After many years of service, support material sometimes migrates from under the leave side of PCC joints, thereby reducing support and increasing deflection. When this occurs, JSR will increase above 1.00. JSR appears to be very good in all sections through 2002.

2.5 PERFORMANCE DATA

2.5.1 Test Section Arrangement

In general, SPS-1 and SPS-2 test sections on the Ohio SHRP Test Road were located such that those expected to fail early were located toward the middle of the project, except where sections containing a common design feature or material were grouped to facilitate construction. Sections with a longest life expectancy were located at the ends of the project where traffic control at the intersection of the old and new lanes would be more difficult during rehabilitation or reconstruction.

2.5.2 Projected Performance of SPS Sections

Projected services lives of SPS-1 and SPS-2 sections included in the SHRP matrix were initially calculated from AASHTO equations using assumed structural properties for materials to be incorporated into the pavement sections. These service lives were subject to considerable error due to the design assumptions involved and the lack of accurate in-situ material properties. Once these in-situ properties became available, the predicted service lives were adjusted accordingly, as shown in Table 2.30. Obviously, the extremely long lives predicted for some of the stiffer sections are unrealistic. Actual material properties, in-situ stiffness and environmental data obtained after construction brought the calculated service lives of the failed sections much closer to observed performance. State sections added by ODOT to the SPS-1 and SPS-2 experiments were designed to provide performance information for standard ODOT designs. It should be noted that the first four sections to fail in the SPS-1 experiment were the four sections listed below with the shortest projected service lives and the second group of original sections to be replaced were the next four sections on the list. Section 164 is the replacement section containing a geo-fabric to reduce stress on the subgrade. As a point of reference, it is determined later in this report that the northbound driving lane (SPS-2) carries about 620,000 ESALs annually and the southbound driving lane (SPS-1) carries about 515,000 ESALs annually.

Table 2.30

Estimated Design Lives of Test Sections using In-Situ Soil Properties

SPS-1		SPS-2	
Section No.	**ESAL (million)**	**Section No.**	**ESAL (million)**
107	0.07	201	0.93
102	0.25	205	1.13
105	0.44	209	3.20
101	0.65	202	6.75
108	1.72	206	7.84
103	1.93	203	10.7
164	2.32	207	12.2
110	2.70	210	23.2
109	4.17	204	32.7
111	4.63	208	36.5
106	20.3	211	36.9
160	20.3	264	64.8
165*	20.6	260	85.7
112	31.8	262	85.7
104	58.0	265	85.7
161*	58.0	263	102
162*	58.0	259	111
163*	58.0	212	112
159	215	261	135

* Replacement section

2.5.3 Cost Effectiveness

One measure of the effectiveness of the various test sections on the Ohio SHRP Test Road in carrying traffic is to compare the cost of construction with the predicted service life. To determine section cost, unit prices bid by the contractor were used to calculate the cost of base and pavement layers in the 500-foot long test sections, including drains along both edges of the pavement where appropriate. These section costs were then reduced to a unit cost per square yard for easy comparison with other construction costs. Subgrade construction and certain other items were not included in these calculations either because of their commonality to all sections, or their site specific variability. Therefore, the actual cost of constructing the SHRP sections was more than the costs shown here for base, pavement and edge drains only. Table 2.31 summarizes the original unit prices bid for furnishing and placing five base materials, four AC pavements, six PCC pavements and edge drains.

Table 2.31

Unit Prices Bid for Base, Pavement and Edge Drains on Original Construction

Unit Costs Bid for Constructing Original Pavement Sections Project 940380						
Base Material						
Type	DGAB	PATB	ATB	PCTB	LCB	
Item No.	304	690	301	690	305	
Extention	20001	00120	10002	00130	19000	
Quantity	26,286	84,198	7,710	14,939	20,041	
Units of Measure	cu. yd.	sq. yd.	cu. yd.	sq. yd.	sq. yd.	
Unit Bid Price	$21.00	$4.60	$41.25	$8.84	$12.16	
AC Pavement						
Mix	Type 2		Type 1			
Asphalt Cement	AC-20	PG 58-30	AC-20	PG 58-30		
Item No.	446	446	446	446		
Extention	1401	90000	01401	90000		
Quantity	7,581	441	4,886	567		
Units of Measure	cu. yd.	cu. yd.	cu. yd.	cu. yd.		
Unit Bid Price	$48.00	$56.00	$49.00	$51.00		
PCC Pavement						
Pvt. Thickness	8"			11"		
Conc. Strength	550	900 psi	ODOT	550	900 psi	ODOT
Item No.	452	452	452	452	452	452
Extention	12001	12001	12001	14101	14101	14101
Quantity	1467*	6,788	5,800*	1723*	16,694	30,735*
Units of Measure	sq. yd.	sq. yd.	sq. yd.	sq. yd.	sq. yd.	sq. yd.
Unit Bid Price	$21.95	$23.95	23.29*	$27.76	$30.98	30.38*
Typical price for Item 605 - Edge Drains			**$3.75/lin. ft.**			

* Includes change order modifying 550 psi concrete to Class C on mainline pavement

These unit bid prices were applied to the calculated quantity of materials used in each test section and divided by 666.7 sq. yd. per section to obtain the total costs per square yard shown in Table 2.32 based upon a uniform 12-foot lane width. Costs shown for the SPS-8 sections were expanded to a 12-foot lane width even though the actual width of these sections was 11 feet, and total costs calculated for the 14-foot wide lanes in SPS-2 were divided by a 12-foot lane width to account for the additional two-foot of pavement width. Also, prices varied along the project for edge drains, probably due to the variability in conditions at the different locations. An average price of $3.75 per linear foot was used in these calculations.

Figure 2.14 shows a plot of unit section cost versus projected service life, using AASHTO equations, for the 24 SHRP and nine supplemental sections in the SPS-1 and SPS-2 experiments, with the more cost effective sections in each experiment, as indicated by the steeper

Table 2.32

Unit Costs for Base, Pavement and Edge Drains on Original Construction

	Unit Costs of Constructing Original Pavement Sections - Project 940380																
	Quantity of Base Material					Quantity of AC Pavement				Quantity of PCC Pavement						Edge Drain	Unit Cost ($/yd.^{2})
Layer Material	DGAB	PATB	PCTB	ATB	LCB	Type 2 AC 20	Type 2 58-30	Type 1 AC 20	Type 1 58-30	8" 550 psi	8" 900 psi	8" Class C	11" 550 psi	11" 900 psi	11" Class C		
Item No.	304	690	690	301	305	446	446	446	446	452	452	452	452	452	452	605	
Bid Units	cu.yd.	sq.yd.	sq.yd.	cu.yd.	sq.yd.	cu.yd.	cu.yd.	cu.yd.	cu.yd.	sq.yd.	sq.yd.	sq.yd.	sq.yd.	sq.yd.	sq.yd.	lin. ft.	
Unit Cost	21.00	4.60	8.84	41.25	12.16	48.00	56.00	49.00	51.00	21.95	23.95	23.29	27.76	30.98	30.57	3.75	
Section	AC Sections - SPS-1																
101	148.2					97.2		32.4									$ 14.05
102	222.2					41.7		32.4									$ 12.38
103				148.2		41.7		32.4									$ 14.55
104				222.2		97.2		32.4									$ 23.13
105	74.1			74.1		41.7		32.4									$ 12.30
106	74.1			148.2		97.2		32.4									$ 20.88
107	74.1	666.7				41.7		32.4								1000	$ 17.94
108	148.2	666.7				97.2		32.4								1000	$ 24.27
109	222.2	666.7				97.2		32.4								1000	$ 26.60
110		666.7		74.1		97.2		32.4								1000	$ 24.19
111		666.7		148.2		41.7		32.4								1000	$ 24.78
112		666.7		222.2		41.7		32.4								1000	$ 29.36
159	111.1		666.7	277.8		41.7		32.4								1000	$ 40.54
160	74.1			203.7		41.7		32.4								1000	$ 25.95
	AC Sections - SPS-9																
901	111.1	666.7		222.2		41.7		32.4								1000	$ 32.86
902	111.1	666.7		222.2			41.7		32.4							1000	$ 33.45
903	111.1	666.7		222.2			41.7		32.4							1000	$ 33.45
	AC Sections - SPS-8																
803*	148.2					41.7		32.4									$ 10.05
804*	222.2					97.2		32.4									$ 16.38
	PCC Sections - SPS-2																
201	111.1											666.7					$ 26.79
202	129.6										777.8						$ 32.02
203	129.6														777.8		$ 39.75
204	111.1													666.7			$ 34.48
205					666.7							666.7					$ 35.45
206					777.8						777.8						$ 42.13
207					777.8										777.8		$ 49.85
208					666.7									666.7			$ 43.14
209	74.1	666.7										666.7				1000	$ 35.85
210	86.5	777.8									777.8					1000	$ 41.66
211	86.5	777.8													777.8	1000	$ 49.38
212	74.1	666.7												666.7		1000	$ 43.54
259	111.1													666.7		1000	$ 40.11
260	74.1	666.7													666.7	1000	$ 43.13
261	86.5		777.8												777.8	1000	$ 54.33
262	74.1		666.7												666.7	1000	$ 47.37
263	129.6														777.8	1000	$ 45.37
264	111.1														666.7	1000	$ 39.70
265	74.1	666.7													666.7	1000	$ 43.13
	PCC Sections - SPS-2																
809*	111.1									666.7							$ 25.45
810*	111.1												666.7				$ 31.26

* Section quantities adjusted to 12' lane width

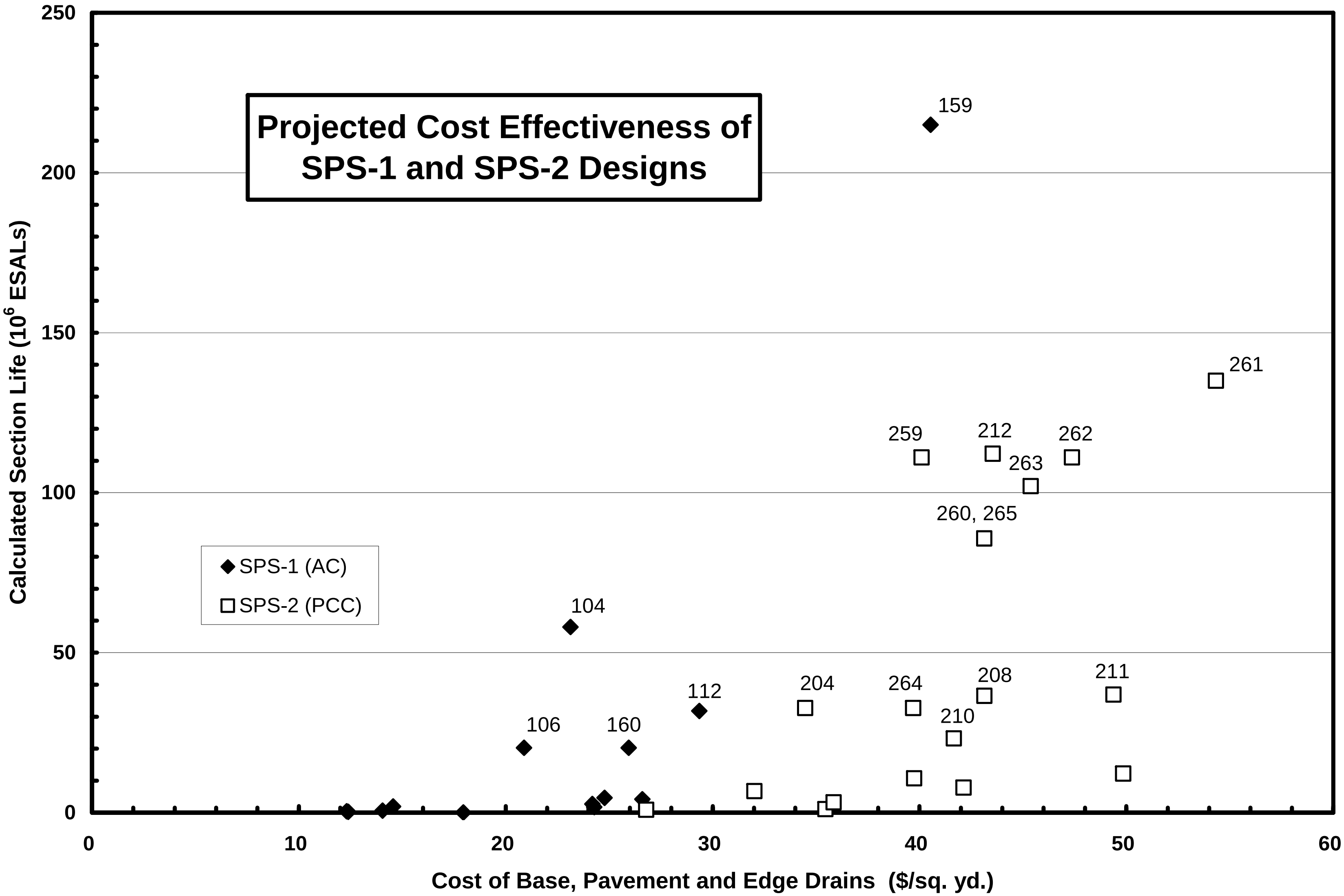

Figure 2.14 – Section Cost vs. Calculated Life for SPS-1 and SPS-2 Sections

slopes from the origin, being identified by number on the plot. The clearly best SPS-1 sections were 159 and 104, both of which contained 19 inches of AC pavement and ATB combined, followed by 106, 112 and 160 with 15 inches, 16 inches and 15 inches of AC and ATB, respectively. The remaining SPS-1 sections contained no more than 12 inches of AC and either ATB or PATB combined.

The best SPS-2 section was 259 with six other sections following close behind. All were drained with an 11-inch pavement thickness, all but one section contained standard strength concrete and, surprisingly, all but two sections had 12-foot wide lanes. This result suggests that, if the AASHTO equations provide good estimates of performance and if the contractors bid prices were reasonable, the use of high strength concrete and 14-foot wide lanes on rigid pavement may not be cost effective. It is also interesting to note that Section 159 was the most cost effective of all 33 SPS-1 and SPS-2 sections. While a final determination of cost effectiveness will depend upon actual in-service performance, which will require some time to assess on the more robust sections, Figure 2.14 offers some interesting trends. One other factor that must be taken into account in considering cost effectiveness is subgrade quality. While the subgrade was fine grained throughout this project, it did include A-4, A-6 and A-7-6 soils, which can affect the estimations of performance to some degree.

Tables 2.33, 2.34 and 2.35 show the cost per square yard for constructing the replacement sections in SPS-1 and SPS-8. Additional costs for subgrade enhancements were included here because of their intended purpose of improving pavement performance. These enhancements were lime-modified soil in Sections A803 and A804, Geogrid in Section 164, and cement-treated soil in Section 165. The cost effectiveness of these replacement sections cannot be compared directly with that of the original sections because of differences in the time of construction.

Table 2.33

Unit Prices Bid for Base, Pavement and Edge Drains on Sections 161, 162, 163, A803 and A804

Unit Prices Bid for Replacement Sections 161, 162, 163, A803 and A804 Project 970335							
Base Material							
Type	DGAB	PATB	ATB				
Item No.	304	690	301(64-22)				
Extention	20001	00120	46000				
Quantity	3,101	10,755	2,579				
Units of Measure	cu. yd.	sq. yd.	cu. yd.				
Unit Bid Price	$21.34	$4.09	$51.58				
AC Pavement							
Mix	Type 2			Type 1			
Asphalt Cement	64-28 (A)	64-28 (B)	64-28 (C)	64-28 (A)	64-28 (B)	64-28 (C)	64-28 (D)
Item No.	446	446	446	446	446	446	446-1H
Extention	46041	46041	46041	47011	47011	47011	50001
Quantity	191	154	1,162	136	111	616	110
Units of Measure	cu. yd.	cu. yd.	cu. yd.	cu. yd.	cu. yd.	cu. yd.	cu. yd.
Unit Bid Price	$78.10	$78.10	$70.16	$82.27	$82.27	$76.89	$76.89
Typical price for Item 605 - Edge Drains $3.75/lin. ft. (390161, 390162 and 390163)							
Item 203 - Excavation, compaction, lime-mod. soil and lime- $34.69/cu. yd. (A803, A804)							

Table 2.34

Unit Prices Bid for Base, Pavement and Edge Drains on Section 164

Unit Prices Bid for Replacement Section 164 Project 985010				
Base Material				
Type	DGAB	PATB		
Item No.	304	690		
Extention	20001	120		
Quantity	794	3,484		
Units of Measure	cu. yd.	sq. yd.		
Unit Bid Price	$50.00	$7.00		
AC Pavement				
Mix	Type 2	Type 1		
Asphalt Cement	64-28 (A)	64-28 (A)		
Item No.	446	446		
Extention	46041	47011		
Quantity	496	185		
Units of Measure	cu. yd.	cu. yd.		
Unit Bid Price	$90.00	$90.00		
Item 690 - Geogrid $2.47/sq. yd.				
Typical price for Item 605 - Edge Drains $3.75/lin. ft.				

Table 2.35

Unit Costs for Base, Pavement and Edge Drains on Section 165

Unit Prices Bid for Replacement Section 165 Project 020528				
Base Material				
Type	ATB	DGAB	DGAB-NJ	
Item No.	302(64-22)	304	307	
Extention	46000	20000	10000	
Quantity	3,260	2,166	12,681	
Units of Measure	cu. yd.	cu. yd.	sq. yd.	
Unit Bid Price	$45.50	$14.70	$3.50	
AC Pavement				
Mix	Type 2	Type 1H		
Asphalt Cement	64-28 (A)	AC-20		
Item No.	446	446		
Extention	46040	50001		
Quantity	582	999		
Units of Measure	cu. yd.	cu. yd.		
Unit Bid Price	$60.00	$75.00		
Item 804 - Cement Stabilized Subgrade			**$3.00/sq. yd.**	
Typical price for Item 605 - Edge Drains			**$3.75/lin. Ft.**	

2.5.4 Visual Distress - SPS-1

Construction of the SPS-1 and SPS-9 sections was functionally complete and mainline traffic was moved onto the test pavement on August 14, 1996. Within a few days, noticeable rutting was detected in Sections 102 and 107 in SPS-1 and there was concern these sections might deteriorate rapidly over the upcoming Labor Day weekend. Fortunately, there were no serious problems, but there was considerable doubt as to whether the sections would remain intact through the winter. The prospect of having to perform emergency repairs on a major highway during the winter or early spring while the weather was cold and wet, and access to materials was limited prompted the consideration of some type of immediate remedial action. After some deliberation, it was decided to remove the 4-inch thick AC pavement layer and some base material from both sections and replace these materials with a thicker layer of temporary AC pavement to get them through the winter. The southbound lanes were closed on September 3, 1996 to complete this work. A total removal of the temporary pavement and replacement with more robust supplemental sections of interest to the state was planned for 1997. While the distress in Sections 102 and 107 occurred somewhat earlier than expected using ODOT design parameters, the AASHTO equations did forecast these sections to be the first to fail.

During the rehabilitation of Section 107, a portion of the underdrains originally installed to drain the pavement were observed to be not connected to outlet pipes, thus making the section partially drained and partially undrained. SHRP was notified of this oversight so it would be properly documented and accounted for in the database. Shortly after placement of the temporary pavement in Sections 102 and 107, and reopening of the southbound lanes on September 11, 1996, rutting also began to develop in Section 101. To avoid a midwinter or early spring failure in this section and to preserve the integrity of dynamic response sensors in the thinner AC sections for the 1997 controlled vehicle tests, the southbound lanes were closed again on December 3, 1996.

During the winter of 1996-97, plans were prepared for removal of the three distressed SPS-1 sections and construction of heavier sections similar to those in SPS-9. Replacement of the two distressed SPS-8 AC sections was also included in the same contract. Prior to preparation of the construction drawings, ODOT contacted SHRP to see if there was any interest in having the sections rehabilitated in some particular way to further achieve their goals. ODOT was informed that SHRP had no follow-up plans for distressed sections in SPS-1 or SPS-2. Project 335(97) was sold on May 21, 1997 to replace Sections 101, 102, 107, 803 and 804 with Sections 163, 161, 162, A803 and A804, respectively. The southbound lanes were re-opened to traffic on November 11, 1997.

Visual observations of the three distressed SPS-1 sections indicated severe rutting throughout, with localized areas also exhibiting wheel path cracking. Because it was not possible visually to determine the specific causes of the distress, ODOT personnel and ORITE staff and students conducted a forensic investigation to more clearly define the failure mechanisms in Section 101. Results of the forensic study showed the following:

- Essentially all of the rutting could be attributed to the DGAB and subgrade, with none being observed in the AC layers.
- Lifts in the AC pavement were observed to be debonding in the most severely distressed areas. The AC lifts were not tacked during construction.
- Subgrade moisture was consistently higher than anticipated throughout the short life of the section.

Judging by the nature and timing of distress in Sections 102 and 107, their modes of failure were likely to be very similar.

A sudden and rather dramatic failure occurred at Station 2+30 in Section 105. Within a few hours after the distress was first reported to ODOT by passing motorists on May 29, 1998, considerable AC material from an area approximately 20 feet long and covering the right half of the right lane had been removed by traffic and scattered along the roadside. The two lifts of AC had debonded from the ATB and from each other over a 3-foot wide by 6-foot long oval at the center of the failed area. The ATB was also broken and in danger of being removed at that point. Away from the most distressed area, debonding was still evident, but less severe. Heavy rain the previous day likely precipitated the failure.

Section 105 was closed to traffic and an ODOT maintenance crew removed the severely debonded AC over a 6-foot wide by 40-foot long area in the right side of the lane, and patched it with hot mix AC. Severe rutting was noted in other areas of the section and in the instrumented area immediately preceding the section. Consequently, other portions of the section were expected to fail in a short period of time. FWD and Dynaflect measurements obtained three weeks prior to this failure confirmed the area between Stations 2+00 and 2+50 to be particularly weak in the right wheelpath, with mid-lane measurements showing good uniformity throughout the section length.

Under Project 5010(98) sold on August 5, 1998, Section 105 was removed and replaced with a pavement identical to Section 108, but with the addition of underdrains and a geosynthetic fabric placed on the finished subgrade. That is, a 7-inch thick asphalt concrete pavement (1-3/4" ODOT 446, Type I AC over 5-1/4" ODOT 446, Type II AC) was placed on a 12-inch thick base (4" PATB/8" DGAB) with Geogrid on the subgrade. The Geogrid was not stapled or otherwise affixed to the subgrade prior to placement of the base. This replacement section was identified as Section 164.

To facilitate construction and permit completion of a fifth series of controlled truck tests, the entire test pavement was shut down and traffic diverted back to the original lanes between September 8 and October 20, 1998. Overall, surface raveling and longitudinal cracking, which appeared to be related to construction techniques used in placement of the AC, were common throughout the SPS-1 sections. These cracks were very straight, and located between the lane centerline and wheelpath where high tensile stresses would not be expected to occur. They probably reflect the segregation of aggregate along the edge of the conveyor belt as hot asphalt concrete was transported from the paver hopper to the auger and the auger gear box.

Localized distress in Section 103 became severe enough by March 8, 2002 that it was closed to traffic. Upon further investigation, FWD measurements in Sections 108, 109 and 110 had progressed to the point where distress was expected in the near future and the entire southbound lane was closed on April 24, 2002. On May 28, 2002, Project 528(02) was sold to replace these four contiguous sections with a single design represented by Section 165 located at the site of original Section 110. The lanes were reopened to traffic on November 21, 2003.

2.5.5 Visual Distress - SPS-2

The SPS-2 test sections were opened to traffic on August 15, 1996. Traffic was moved back to the original lanes on December 2, 1996 for testing and rehabilitation of distressed SPS-1 sections. To facilitate completion of the fifth series of controlled vehicle tests, traffic was removed from the SPS-2 sections between September 8 and October 20, 1998. During the 1998 truck tests, early signs of distress were observed in Sections 205 and 206, both of which had an 8-inch thick PCC pavement on six inches of lean concrete base (LCB). Among the types of distress noted were transverse cracking, longitudinal cracking, faulting, and pumping.

Various aspects of the distresses observed in Sections 205 and 206 are of interest. As noted above, both sections had a 6-inch thick LCB. Section 205 had a 12-foot lane width and ODOT Class C concrete, while Section 206 had a 14-foot lane width and high strength concrete. Both sections showed evidence of pumping at contraction joints and along the pavement/shoulder interface. Both sections contained a longitudinal crack that started near the pavement edge and passed continuously through several slabs as it moved to the right wheel path and back near the pavement edge. The location of a transverse crack at SHRP Station 4+38 in Section 205 appeared to correspond to the location of a transverse crack noted in the lean concrete base prior to placement of the PCC pavement. As of the summer of 2002, distress in these sections had progressed, but not to the point of being dangerous or objectionable to motorists. The other SPS-2 sections did not show any distress by the fall of 2002.

In February 2003, researchers visiting the site observed numerous transverse cracks in Sections 201, 202, 209 and 210, all of which had eight-inch thick pavement. Section 212, which had an eleven-inch thick pavement, also had a few transverse cracks. Table 2.36 summarizes the results of crack surveys on the SPS-2 sections. On February 16, 2006, the PCC lanes were closed for repair after a number of accidents were reported near the location of Sections 205 and 206.

Table 2.36

Crack Surveys on SPS-2

Crack History on PCC Sections					
SHRP ID	Survey Date	% Slabs with Cracking			
		Low	Medium	High	Total
201	12/14/96	0	0	0	0
	9/8/99	0	0	0	0
	4/5/01	0	0	0	0
	10/23/02	27	3	0	30
	11/18/02	36	3	0	39
	11/12/03	36	3	0	39
	2/7/05				45
	6/29/05				48
	11/21/05				48
202	12/14/96	0	0	0	0
	9/8/99	0	0	0	0
	4/4/01	6	0	0	6
	10/23/02	36	6	0	42
	11/18/02	39	6	0	45
	11/12/03	45	6	0	51
	2/7/05				64
	6/29/05				94
	11/21/05				94
203	12/14/96	0	0	0	0
	9/9/99	0	0	0	0
	4/10/01	0	0	0	0
	10/23/02	0	0	0	0
	11/12/03	0	0	0	0
	2/7/05				0
	6/29/05				0
	11/21/05				0
204	12/13/96	0	0	0	0
	9/29/98	0	0	0	0
	9/8/99	0	0	0	0
	4/3/01	3	0	0	3
	10/22/02	3	6	0	9
	11/12/03	24	6	18	48
	2/7/05				58
	6/29/05				61
	11/21/05				64
205	12/14/96	0	0	0	0
	9/8/99	6	3	0	9
	4/4/01	18	3	0	21
	10/23/02	45	24	6	75
	11/12/03	45	30	12	87
	2/7/05				97
	6/29/05				97
	11/21/05				97
206	12/14/96	0	0	0	0
	9/8/99	0	0	0	0
	10/23/02	30	12	0	42
	11/12/03	30	12	0	42
	2/7/05				73
	6/29/05				82
	11/21/05				88
207	12/14/96	0	0	0	0
	9/9/99	0	0	0	0
	4/13/01	0	0	0	0
	11/12/03	0	0	0	0
	2/7/05				0
	6/29/05				0
	11/21/05				0
208	12/14/96	0	0	0	0
	9/9/99	0	0	0	0
	4/13/01	0	0	0	0
	11/12/03	0	0	0	0
	2/7/05				0
	6/29/05				3
	11/21/05				0
209	12/14/96	0	0	0	0
	9/8/99	0	0	0	0
	4/5/01	0	0	0	0
	10/23/02	0	0	0	0
	11/12/03	6	0	0	6
	2/7/05				9
	6/29/05				12
	11/21/05				15
210	12/14/96	0	0	0	0
	9/8/99	0	0	0	0
	4/3/01	0	0	0	0
	10/22/02	0	12	0	12
	11/12/03	12	9	0	21
	2/7/05				27
	6/29/05				36
	11/21/05				36
211	12/14/96	0	0	0	0
	9/9/99	0	0	0	0
	4/10/01	0	0	0	0
	10/23/02	0	0	0	0
	11/12/03	0	0	0	0
	2/7/05				0
	6/29/05				0
	11/21/05				0
212	12/14/96	0	0	0	0
	9/8/99	0	0	0	0
	4/3/01	0	0	0	0
	10/22/02	0	3	0	3
	11/12/03	3	3	0	6
	2/7/05				6
	6/29/05				21
	11/21/05				21
259	12/13/96	3	0	3	6
	9/8/99	6	0	0	6
	4/3/01	6	0	0	6
	11/12/03	6	6	0	12
	2/7/05				18
	6/29/05				24
	11/21/05				27
260	12/14/96	0	0	0	0
	9/8/99	0	0	0	0
	4/4/01	0	0	0	0
	11/12/03	0	0	0	0
	2/7/05				0
	6/29/05				0
	11/21/05				0
261	12/14/96	0	0	0	0
	9/9/99	0	0	0	0
	4/5/01	0	0	0	0
	11/12/03	0	0	0	0
	2/7/05				0
	6/29/05				0
	11/21/05				0
262	12/14/96	0	0	0	0
	9/9/99	0	0	0	0
	4/13/01	0	0	0	0
	11/12/03	0	0	0	0
	2/7/05				0
	6/29/05				0
	11/21/05				0
263	12/14/96	0	0	0	0
	9/9/99	0	0	0	0
	4/13/01	0	0	0	0
	2/7/05				0
	6/29/05				0
	11/21/05				0
264	12/14/96	0	0	0	0
	9/9/99	0	0	0	0
	4/10/01	0	0	0	0
	2/7/05				0
	6/29/05				3
	11/21/05				3
265	12/14/96	0	0	0	0
	9/9/99	0	0	0	0
	4/10/01	0	0	0	0
	11/12/03	0	0	0	0
	2/7/05				0
	6/29/05				3
	11/21/05				3

2.5.6 Visual Distress - SPS-8

The four test sections in SPS-8 were opened to traffic on November 18, 1994. Sections 803 and 804 (AC) displayed premature rutting very quickly. While these sections were exposed to a very low volume of truck traffic during 1995, the Series I controlled vehicle tests performed for FHWA in December 1995 and March 1996 accelerated the rutting process through the repeated application of some very heavy loads. ORITE staff completed a set of Cone Penetrometer Tests (CPT) tests along both sections and discovered a layer of poorly consolidated clay subgrade approximately four feet below the pavement surface. This was the depth of undercutting required in the area during construction and the level for placement of the first lift of material. CPT tests suggested the compaction effort on this first lift was inadequate. Also, subgrade under the SPS-8 sections was undrained and appeared to be quite wet most of the time. The presence of excessive moisture, poorly compacted subgrade, and heavy trucks performing tests for FHWA all contributed to the premature rutting of these sections.

In August of 1997, Sections 803 and 804 were removed and replaced with sections similar to the original SPS-8 AC construction, except that the subgrade was undercut to a depth of about 48 inches and treated with lime as it was replaced. The surface and leveling courses were both constructed of ODOT Type I AC. An array of response sensors similar to those incorporated in the other AC sections was installed just outside both replaced sections, and one additional environmental array was placed near the interface of the two sections. Because of pavement geometry on the ramp where this SPS-8 experiment was located, only local traffic could use Section 809 and 810 while Sections 803 and 804 were being replaced. This included some construction traffic. The ramp was re-opened on October 15, 1998.

By 2002, surfaces of the PCC sections in SPS-8 had scaled quite noticeably. These sections were constructed with 550 psi concrete, which was included in the SHRP matrix as a material variable. To achieve this low strength, fly ash was added as a replacement for cement until the texture of the mix became rather coarse and porous. Because of concerns regarding the ability of this low strength mix to resist freeze-thaw cycling on the mainline pavement, ODOT, with SHRP concurrence, used standard ODOT Class C concrete in lieu of the low strength mix on the mainline pavement. A 900 psi concrete was developed for the high strength mix. The difference in strength between the ODOT Class C concrete and the high strength concrete satisfied the intent of SHRP to construct pavements with two distinct concrete strengths.

2.5.7 Visual Distress - SPS-9

The three SPS-9 sections were constructed with a 22-inch thick base to provide extended service. The only difference between these sections was the grade of asphalt cement used in the 4-inch thick pavement layer. Section 901 contained standard AC-20, Section 902 contained PG 58-28, and Section 903 contained PG 64-28. The AC surface course mix designed for Section

903 with Superpave Level I specifications resulted in an extremely fine mix resembling sand asphalt which raised concerns about surface friction. Skid resistance, as measured with the ODOT K.J. Law Skid Trailer, has remained well above 40 on all three sections. Aside from the fine surface texture noted on Section 903, no problems have been observed on the SPS-9 sections through 2005.

2.5.8 Pavement Roughness

Another indicator of pavement performance is how long it retains a good ride quality or smoothness. As pavements degrade, they tend to become rougher and more uncomfortable for motorists and passengers. A K.J. Law Non-Contact Profilometer was used by ODOT at the completion of the SPS sections and periodically thereafter to monitor section roughness. Data shown in Tables 2.37 and 2.38 represent a summary of section roughness measured by ODOT in Mays and PSI numbers when the pavement was new and at various times through 2000.

Mays numbers appeared to be far more sensitive to changes in surface roughness than PSI on AC pavements and somewhat more sensitive on PCC pavements. During the first four years of service, Mays numbers tended to increase more over time on the AC sections than on the PCC sections and especially on the first group of sections that needed to be replaced (107, 102, 101 and 105). The second tier of distressed AC pavements (103, 108, 109 and 110) also showed a large increase in Mays numbers. Other sections (104, 106 and 160) appear to be rough but, from visual observations, had not reached the end of their serviceability. The three SPS-9 sections were among the smoothest pavement sections when the test road was new and even more so after four years of service. Replacement Sections 161, 162 and 163 are quite smooth, while replacement Section 164, which has the Geogrid fabric, is rather rough after only two years. While there were some exceptions, AC sections tended to require replacement as the Mays Ride Number neared 100.

The PCC sections generally had higher Mays numbers than the AC sections when they were new but, over time, they degraded at a slower rate. While some sections became rougher than others during the first four years of service, the first group of sections to be replaced in 2006 (201, 202, 204, 205, 206, 210 and 259) was not consistently rougher than the other sections as of May 2000.

Table 2.37 Pavement Roughness - Mays

Section No.	Mays Ride Number (in./mile)							
	8/16/96	8/27/96	9/18/96	10/28/96	11/28/97	6/4/98	5/17/99	5/31/00
SPS-1 (AC)								
101	86.8	111.8	134.7	189.2	Section removed from service			
102	83.1	146.0	Section removed from service					
103							126.3	137.3
104	45.2	47.2	48.0	46.8	74.0	91.2	74.8	104.8
105	57.3	60.6	75.1	75.9	97.7	126.3	Section removed	
106	71.2	71.3	73.9	76.7	140.9	123.0	115.0	134.3
107	70.4	81.5	Section removed from service					
108	53.3	53.4	55.9	67.6	72.4	87.1	110.3	107.1
109	43.0	43.3	45.0	46.3	49.7	61.6	76.3	95.3
110	68.1	68.8	71.6	72.9	64.8	79.3	88.4	86.8
111	44.3	45.5	46.8	45.3	58.9	64.1	68.3	74.2
112	53.7	53.0	53.8	52.3	71.2	83.3	88.2	87.7
159							58.4	68.6
160	63.1	65.8	65.0	69.4	110.1	108.2	125.4	121.7
161*					58.4	48.6	43.8	57.1
162*					49.5	45.8	47.5	48.1
163*					75.3	64.8	65.5	68.3
164*							98.0	107.9
165*								
SPS-2 (PCC)								
201	71.8	70.8	71.9	71.4	79.1	78.0	87.0	91.5
202	71.6	79.1	70.7	71.4	80.7	86.9	88.1	90.5
203	63.1	61.1	60.1	56.2	65.5	65.6	64.0	61.0
204	51.4	61.2	53.4	50.9	55.2	49.3	53.4	61.3
205	69.8	68.3	67.1	65.9	69.5	66.6	77.1	77.3
206	76.3	70.1	69.6	68.0	79.3	86.0	89.4	84.5
207	80.0	77.1	74.8	74.5	76.8	84.7	86.4	82.8
208	79.9	79.1	79.0	75.1	81.8	89.3	88.4	83.0
209	59.9	58.3	58.9	57.0	64.9	65.7	71.0	65.5
210	65.3	73.1	61.5	58.7	66.9	71.6	78.7	79.3
211	85.6	83.1	80.1	80.3	86.4	84.1	91.7	85.3
212	67.9	71.3	62.2	60.7	68.3	74.9	72.2	69.2
259							54.0	52.7
260	66.6	73.4	64.0	61.1	66.3	68.1	70.4	64.9
261	76.3	75.8	76.1	74.4	87.8	93.4	75.2	85.1
262	75.0	73.1	73.6	66.1	74.6	78.7	77.2	62.7
263							76.8	75.4
264							78.1	113.0
265	84.0	81.3	82.5	80.1	86.6	86.4	96.0	95.9
SPS-8								
803 (AC)								
804 (AC)								
809 (PCC)								
810 (PCC)								
A803 (AC)*								
A804 (AC)*								
SPS-9 (AC)								
901	46.7	46.5	47.9	47.0	46.1	48.5	50.4	53.7
902	47.4	47.2	48.0	47.5	45.7	49.6	49.2	50.7
903	41.7	40.8	41.6	41.0	45.9	49.1	54.6	51.9

* Replacement section

Table 2.38 Pavement Roughness - PSI

Section No.	Present Servicability Index (PSI)							
	8/16/96	8/27/96	9/18/96	10/28/96	11/28/97	6/4/98	5/17/99	5/31/00
SPS-1 (AC)								
101	3.92	3.62	3.35	2.77	Section removed from service			
102	3.92	3.22	Section removed from service					
103							3.3	3.2
104	4.05	4.04	4.03	4.08	4.08	3.90	4.0	3.8
105	4.00	4.01	3.81	3.80	3.67	3.28	Section removed	
106	3.95	3.98	3.94	3.95	3.85	3.68	3.9	3.8
107	4.06	3.84	Section removed from service					
108	4.09	4.13	4.07	3.98	4.15	3.83	3.6	3.7
109	4.18	4.20	4.17	4.19	4.28	4.02	4.0	3.7
110	3.97	3.99	3.94	3.94	4.07	3.79	3.7	3.7
111	4.10	4.10	4.06	4.11	4.15	3.99	4.0	3.9
112	3.93	3.96	3.94	3.96	4.01	3.86	3.8	3.8
159							4.1	4.1
160	4.04	4.04	4.00	4.00	4.09	3.81	3.7	3.8
161*					4.57	4.31	4.3	4.2
162*					4.43	4.28	4.3	4.2
163*					4.41	4.12	4.1	4.1
164*							3.8	3.8
165*								
SPS-2 (PCC)								
201	4.02	4.05	4.02	4.06	4.03	4.05	4.0	4.0
202	4.02	4.00	4.07	4.11	4.06	4.00	4.0	4.0
203	3.96	4.01	4.02	4.08	4.01	3.98	4.0	4.0
204	4.08	3.88	4.05	4.07	4.05	4.12	4.1	3.9
205	3.96	4.00	4.03	4.06	4.03	4.00	3.9	3.9
206	3.85	3.96	3.97	3.99	3.91	3.82	3.8	3.9
207	3.81	3.86	3.88	3.89	3.90	3.80	3.8	3.8
208	3.77	3.79	3.82	3.87	3.82	3.76	3.7	3.7
209	4.05	4.09	4.08	4.12	4.06	4.07	4.0	4.1
210	3.92	3.85	4.00	4.06	3.96	3.89	3.8	3.8
211	3.81	3.85	3.89	3.90	3.87	3.88	3.7	3.8
212	3.94	3.90	4.05	4.06	3.96	3.91	3.9	4.0
259							4.2	4.2
260	3.86	3.76	3.93	4.00	3.91	3.89	3.8	3.9
261	3.94	3.97	3.97	4.00	3.93	3.90	3.9	4.0
262	3.82	3.88	3.84	4.01	3.86	3.85	3.8	4.1
263							3.9	3.9
264							3.7	3.5
265	3.77	3.83	3.82	3.89	3.80	3.79	3.7	3.8
SPS-8								
803 (AC)								
804 (AC)								
809 (PCC)								
810 (PCC)								
A803 (AC)								
A804 (AC)								
SPS-9 (AC)								
901	3.95	3.98	3.96	3.97	4.25	4.02	4.0	4.0
902	3.89	3.95	3.93	3.95	4.08	3.95	4.0	4.0
903	4.15	4.19	4.17	4.22	4.26	4.13	4.1	4.2

* Replacement section

Roughness of the SHRP sections was also measured by LTPP as average IRI in the right and left wheel paths, as is shown in Table 2.39. Because ODOT and LTPP measurements were taken at different times, and because some measurements may have been taken while sections were closed to traffic, the various maintenance and testing activities being conducted behind the closures may have precluded one unit or the other from obtaining data on a particular section in a given year. Consequently, there may appear to be some inconsistencies in the ODOT and LTPP data regarding dates as to when sections were available for testing. As with the ODOT data, there was no clear roughness threshold as to when sections should be closed to traffic, but sections requiring closure generally had higher IRI numbers than those remaining open. As a preliminary guide, an IRI of 1.80 and 1.50 m/km on AC and PCC pavements, respectively, might be considered as approaching terminal serviceability, although AC sections were generally closed for excessive rutting and PCC sections were generally closed for cracking and/or roughness.

Table 2.39 - Pavement Roughness - IRI

Pavement Type	Section	IRI in Year (m/km)					
		1997	1998	1999	2000	2002	2003
AC	101	1.41	4.09				
	102	1.26					
	103		1.73	2.71	2.78	3.07	
	104	0.74	0.83	1.21	1.31	1.42	1.37
	105	1.09	1.78				
	106	1.13	1.23	1.75	1.78	1.84	1.81
	107	1.76					
	108	0.89	1.21	1.88	1.98	2.13	
	109	0.72	0.83	1.47	1.60	1.69	
	110	1.20	1.32	1.60	1.68	1.78	
	111	0.78	0.88	1.27	1.36	1.45	1.34
	112	0.91	0.96	1.40	1.52	1.59	1.50
PCC	201	1.24	1.30	1.45	1.44	1.55	1.55
	202	1.14	1.14	1.34	1.39	1.52	1.56
	203	1.09	1.01	1.10	1.04	1.19	1.14
	204		0.83	0.95	0.86	1.21	1.14
	205	1.25	1.20	1.35	1.38	1.53	1.44
	206	1.23	1.24	1.33	1.41	1.50	1.52
	207	1.38	1.36	1.24	1.44	1.27	1.64
	208	1.50	1.47	1.29	1.46	1.36	1.53
	209	0.99	0.96	1.12	1.08	1.15	1.21
	210	1.08	0.98	1.03	1.17	1.09	1.38
	211	1.39	1.29	1.35	1.35	1.33	1.47
	212	1.12	1.23	1.01	1.04	1.03	1.23

2.5.9 Rut Depth

Table 2.40 presents rut depths measured in the right wheel path of the northern SPS-1 sections with a straightedge and a rolling-wheel profilometer developed by ORITE. Straightedge measurements are maximum depth to the bottom of the rut measured from the bottom of a straightedge laid across the right wheel path. The 4/29/99 and 12/20/00 data were measured by ODOT with a six-foot long aluminum bar.

The 9/14/01 data were obtained with the Ohio University rolling-wheel profilometer using the edge of the right paint line as the starting point. This instrument produces a set of elevations to +/- 0.01 inch approximately every ½ inch over a nine-foot long track. Rut depths shown in Table 2.40 are the maximum of the set of calculated distances between elevations measured in the right wheel path and the nearest point on a “virtual” straightedge resting on the right edge of the travel lane and tangent to the hump between the left and right wheel paths. The point where the virtual straight edge is tangent to the hump was determined by maximizing the slope of the line (the virtual straightedge) between the right lane edge (represented by the first member of the set of elevations produced by the profilometer) and measured elevations in a range of elevations determined by examination to represent the hump of the profile plot. The range of elevations defining the rut was likewise determined by examination, because not all plots were typical W-shaped rut profiles. The data reduction program first smoothed the profilometer data by substituting for the raw data a running average of two adjacent elevations.

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Table 2.40

SPS-1 Rut Depth Measurements

SHRP Section	Station	RWP Rut Depth (in.)				SHRP Section	Station	RWP Rut Depth (in.)			
		4/29/99	12/20/00	9/14/01	7/24/02			4/29/99	12/20/00	9/14/01	7/24/02
	0+00			0.40	0.41		0+00			0.01	
	1+00	<2/16	0.2	0.29	0.27		1+00	<1/16		N.A.	
	2+00		0.1	0.32	0.27		2+00			0.17	
103	3+00		0.3	0.40	0.41	160	3+00			0.08	
	4+00		0.5	0.64	0.53		4+00			0.06	
	5+00			0.48	0.43		5+00			0.06	
	Average		0.3	0.42	0.39		Average			0.13	
	0+00			0.57	0.58		0+00			0.18	
	1+00	>4/16	0.4	0.57	0.44		1+00	<1/16		0.08	
	2+00		0.3	0.47	0.42		2+00			0.05	
108	3+00		0.2	0.31	0.30	161	3+00			0.05	
	4+00		0.3	0.36	0.35		4+00			0.10	
	5+00			0.50	0.47		5+00			0.07	
	Average		0.3	0.46	0.43		Average			0.09	
	0+00			0.41	0.43		0+00			0.20	
	1+00	>1/16	0.2	0.17	0.20		1+00	<1/16		0.17	
	2+00		0.3	0.33	0.31		2+00			0.22	
109	3+00		0.2	0.32	0.26	162	3+00			0.24	
	4+00		0.1	0.12	0.16		4+00			0.25	
	5+00			0.22	0.22		5+00			0.24	
	Average		0.2	0.26	0.26		Average			0.22	
	0+00			0.12	0.06		0+00			0.20	
	1+00	>1/16	0.1	0.25	0.20		1+00	<1/16	0.1	0.20	
	2+00		0.1	0.20	0.13		2+00		0.1	0.22	
110	3+00		0.0	0.09	0.07	164	3+00		0.3	0.26	
	4+00		0.0	0.11	0.07		4+00		0.2	0.27	
	5+00			0.21	0.11		5+00			0.29	
	Average		0.0	0.16	0.11		Average		0.18	0.24	

2.5.10 Skid Resistance

Skid resistance is a measure of the friction generated by a locked test tire skidding across a pre-wetted pavement surface under standard ASTM E-274 test conditions. It is expressed as skid number or SN40 when testing at the standard speed of 40 mph. Skid resistance is affected by many variables, including the texture of the pavement surface and the abrasive properties of the coarse and fine aggregates. AC and PCC surfaces generally exhibit high skid resistance soon after being opened to traffic. On AC pavements, friction can increase during the first few weeks as the bituminous coating is worn from the surface of the aggregate particles and then decrease over time as tires abraded the aggregate. Also, on AC pavements with high asphalt contents, a film of asphalt cement tracked on to the aggregate particles in hot weather can temporarily reduce friction. On PCC pavements, friction decreases as the initial texture and aggregate surfaces wear down over time. Seasonal variations of 3-5 skid numbers are common on both types of pavement as grits used for snow and ice control in the winter months roughen the surface and increase skid resistance. In the summer, friction drops off as this roughness is worn down.

Table 2.41 summarizes skid data obtained to date on individual sections at 40 mph and Figures 2.15 shows a plot of how skid resistance changed in the four SPS experiments over time. The following trends emerged:

- Skid resistance on the high-strength PCC pavement sections was consistently 10 skid numbers lower than on sections with standard ODOT Class C concrete. While the Class C sections had adequate friction with a SN40 of about 40, the high-strength sections had a SN40 of just above 30, which is considered marginal.

- Skid resistance on sections with AC-20 binder and sections with PG binders was about the same.

- The initial drop in skid resistance on all AC and PCC sections over the first year was typical as initial texture was worn down to a steady-state level.

- The sharp increase in SN40 on the SPS-1 and SPS-9 sections during the 6/19/02 tests was highly unusual, first because of the magnitude of the increase, second because the same jump was not present on the SPS-2 and SPS-8 sections (including AC) and, third because the higher skid numbers were duplicated on 5/29/03. This can possibly be explained by the southbound lane closure lasting from 4/24/02 to 11/21/03, which may have allowed the AC surface to adjust in some way to temporarily increase the level of friction. This improvement was lost, however, by 11/22/04 when the next tests were run.

Table 2.41 Skid Resistance on Ohio SHRP Test Road

Section Number	Skid Number (SN_{40})												
	5/6/97	5/5/98	10/27/98	5/13/99	11/5/99	7/28/00	10/23/00	6/19/01	12/4/01	6/19/02	5/29/03	11/22/04	7/7/05
SPS-1 (AC)													
101	72.0	Section out of service											
102	68.0	Section out of service											
103	67.3	54.4	55.7	48.4	50.5	44.9	44.5	47.1	43.8	56.8	Section out of service		
104	65.7	55.7	53.5	52.3	52.5	50.0	51.9	50.7	46.9	56.8	66.5	45.9	49.1
105	72.0	53.1	Section out of service										
106	70.3	56.1	55.0	51.2	53.4	50.7	53.0	50.1	45.5	57.4	65.8	46.5	48.6
107	63.0	Section out of service											
108	69.0	55.7	55.5	50.0	52.6	50.3	51.2	48.1	45.4	56.2	Section out of service		
109	70.0	54.3	55.1	49.8	52.0	49.2	49.5	49.0	43.3	54.6	Section out of service		
110	69.7	56.0	57.2	50.5	51.5	51.5	50.3	47.7	47.3	56.9	Section out of service		
111	69.7	55.7	55.2	51.0	52.8	51.3	52.5	49.7	45.7	57.0	68.0	48.3	49.2
112	71.7	56.3	54.1	51.5	52.7	50.9	51.0	49.1	46.0	57.4	65.6	47.3	48.5
159	50.3	53.0	48.8	47.9	45.0	46.7	48.5	42.5	43.7	47.0		44.5	48.1
160	71.0	57.0	49.2	50.0	52.5	49.7	50.0	49.3	47.5	54.8	67.9	45.8	48.5
Average	67.9	55.4	54.2	50.3	51.7	49.6	50.1	48.4	45.6	55.8	66.9	46.8	49.1
161**		54.7	34.7	43.3	46.0	42.7	43.8	43.5	39.8	50.6	59.1	40.5	43.2
162**		51.6	39.9	44.1	43.9	42.9	43.1	44.0	40.3	50.2	58.1	42.0	43.5
163**		52.7	41.6	41.8	44.4	41.3	41.4	43.4	37.5	53.1	62.2	38.1	42.0
Average**		53.0	38.7	43.1	44.8	42.3	42.8	43.6	39.2	51.3	59.8	40.2	42.9
164**			52.1	50.2	49.3	44.6	45.0	45.4	41.5	52.8	63.1	42.3	46.3
165**												46.7	49.9
SPS-2 (PCC)													
201	59.7	47.1	36.2	39.9	37.6	38.9	40.0	42.5	40.0	43.3	45.1	39.8	42.1
202*	54.0	40.1	26.4	31.2	28.8	31.4	30.6	31.0	31.4	31.1	32.1	30.0	33.7
203	59.0	48.0	38.8	42.0	39.6	42.2	42.7	44.9	42.6	44.2	45.4	41.8	45.9
204*	52.3	42.3	29.7	34.3	30.7	31.0	32.0	29.8	32.2	32.4	35.5	32.0	34.2
205	61.0	53.9	42.0	44.7	41.7	40.7	42.7	43.3	40.6	39.8	41.1	36.6	37.5
206*	54.0	41.9	28.7	32.9	29.2	30.3	29.8	30.7	28.5	29.1	28.9	25.8	26.0
207	57.3	53.6	43.2	44.2	42.4	41.7	42.0	43.0	40.6	43.6	44.1	39.6	44.0
208*	54.0	38.3	30.3	32.6	30.1	32.0	31.4	34.2	33.5	34.1	34.6	33.5	36.7
209	59.7	49.6	39.1	41.5	40.1	41.2	42.7	42.6	42.2	43.1	43.0	41.7	45.8
210*	60.7	49.2	32.6	34.8	33.6	31.5	31.9	30.5	31.9	32.1	32.0	29.4	31.5
211	57.0	50.0	37.7	40.6	38.5	40.3	40.1	42.4	40.5	43.2	43.3	41.1	45.7
212*	58.7	46.8	32.7	32.2	32.0	31.9	31.8	30.0	32.3	31.7	30.5	29.6	32.6
259*	49.3	39.9	32.1	35.2	33.7	33.2	33.5	31.0	33.8	35.8	37.5	34.9	36.8
260	61.0	53.0	41.1	42.6	40.3	39.9	40.7	39.9	39.6	40.3	41.1	38.0	41.2
261	58.3	49.0	38.2	40.0	38.9	41.1	41.3	42.2	40.7	43.1	44.4	40.0	44.9
262	58.3	55.8	44.6	47.9	44.6	44.6	44.3	44.8	41.0	44.1	43.4	39.5	44.4
263	58.0	50.6	40.1	43.0	40.7	42.8	43.4	43.9	42.1	45.0	47.2	42.2	47.7
264	55.3	52.9	43.2	45.5	41.1	47.5	45.0	41.7	41.1	43.0	43.4	40.5	45.0
265	59.3	50.0	40.0	43.1	40.4	41.6	40.2	43.0	39.5	42.5	43.1	39.7	42.8
Average	58.7	51.1	40.4	42.9	40.5	41.9	42.1	42.8	40.9	42.9	43.7	40.0	43.9
Average*	54.7	42.6	30.4	33.3	31.2	31.6	31.6	31.0	31.9	32.3	33.0	30.7	33.1
SPS-8													
803 (AC)		Section out of service											
804 (AC)		Section out of service											
A803 (AC)**		68.3	64.7	67.9	62.5	68.1	70.6	63.2	68.0	68.1	64.0	67.8	71.6
A804 (AC)**		65.3	63.1	65.2	63.6	66.5	67.1	63.3	67.8	68.6	63.8	66.5	66.6
Average**		66.8	63.9	66.6	63.1	67.3	68.9	63.3	67.9	68.4	63.9	67.1	69.1
809 (PCC)		63.1	57.1	61.3	59.5	63.5	63.8	58.1	64.7	62.7	58.1	63.3	64.0
810 (PCC)		61.9	57.3	59.3	57.4	59.8	62.6	55.3	62.9	60.7	55.7	61.9	65.2
Average		62.5	57.2	60.3	58.4	61.6	63.2	56.7	63.8	61.7	56.9	62.6	64.6
SPS-9 (AC)													
901	69.3	57.5	57.1	51.2	52.6	49.9	48.6	49.4	46.4	58.8	67.9	49.1	51.5
902 (PG58-28)	67.0	52.8	55.7	50.2	52.3	47.4	48.8	49.6	43.3	60.7	66.2	44.8	47.9
903 (PG64-28)	74.0	57.9	56.3	51.0	50.7	50.6	51.8	49.4	48.6	57.7	68.0	49.9	50.6
Average	70.5	55.4	56.0	50.6	51.5	49.0	50.3	49.5	45.9	59.2	67.1	47.3	49.3

* High strength concrete
** Replacement section

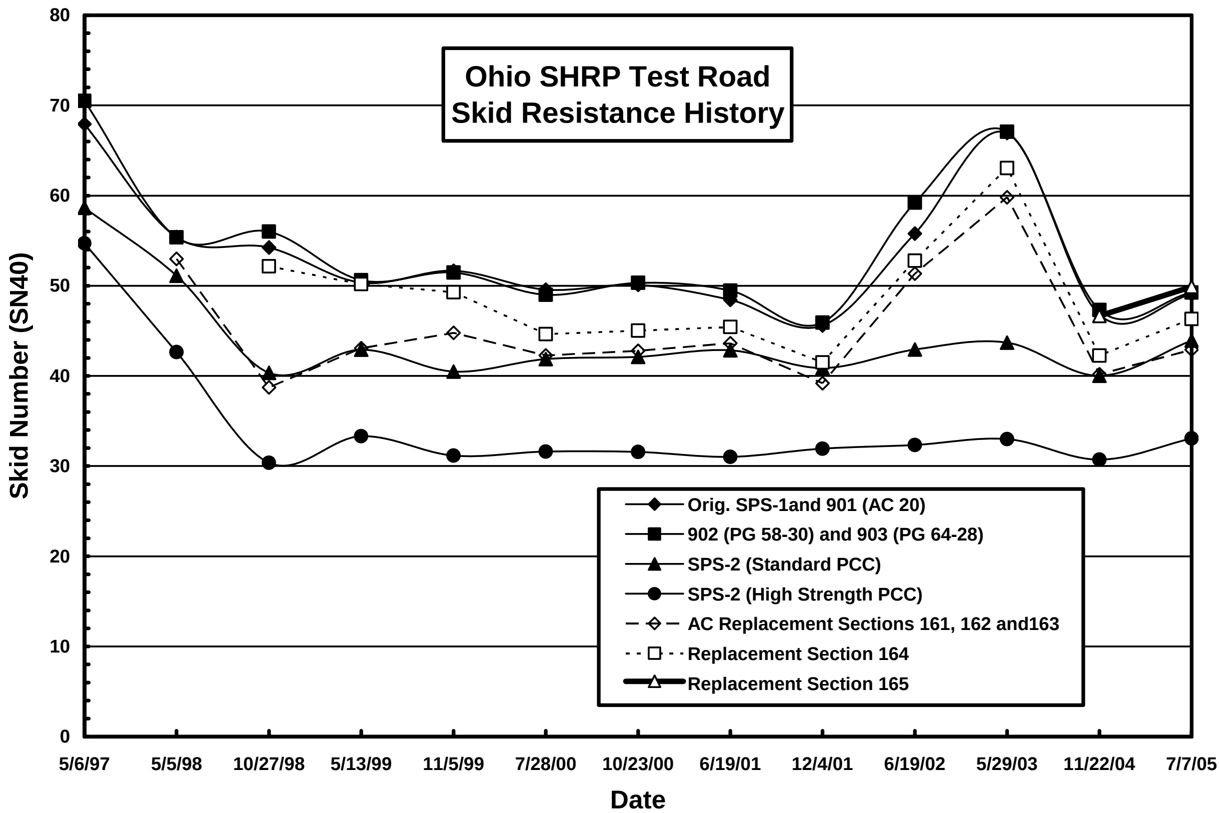


Figure 2.15 - Skid Resistance History

2.6 IN-SITU TESTING

2.6.1 DCP Testing

Performance of the various test sections is closely tied to subgrade stiffness. While FWD testing provides information on the composite stiffness of the subgrade and of the total pavement structure, the Dynamic Cone Penetrometer (DCP) records a profile of unstabilized base and subgrade stiffness as the incremental penetration of a 3/4-inch diameter steel rod is measured after each blow of known force. After cores in the stabilized materials were removed, DCP testing was initiated at the top of the unstabilized materials, either DGAB, if it was present, or subgrade. The DCP rod was driven to depths of up to four feet below the pavement surface. One DCP profile was taken just outside the limits of most mainline test sections in May 2001, with data from seven sections being obtained in September 2001. Replacement Sections 161, 162, 163 and 164 were included in these measurements. Figure 2.16 shows a rather typical DCP profile from Section 109 which has a few interesting features. First, the profile oscillates sharply through the 200 mm of DGAB, even though the DGAB thickness was 12 inches (300 mm) in Section 109, indicating that layer boundaries are be precisely defined with the DCP. This oscillation in the DGAB is believed to be caused by the DCP rod alternately impacting fine and large aggregate particles. Second, although FWD measurements detected little difference in stiffness after the addition of a layer of DGAB over the subgrade, DCP measurements suggest the DGAB does add stiffness to the pavement structure. Third, a layer of a material somewhat stiffer than the in-situ subgrade was detected 400 mm below the top of the DGAB. This layer may be a naturally occurring material, which again looks like aggregate, but with smaller particles than the DGAB, or it may have been material imported during preparation of the subgrade. Profiles for the other test section are shown in Appendix L.

A second set of DCP measurements were made at the north end of Section 103 in September 2003 when the NJ base, DGAB and cement treated subgrade had been placed for the replacement of Sections 103, 108, 109 and 110. These profiles are shown in Appendix M.

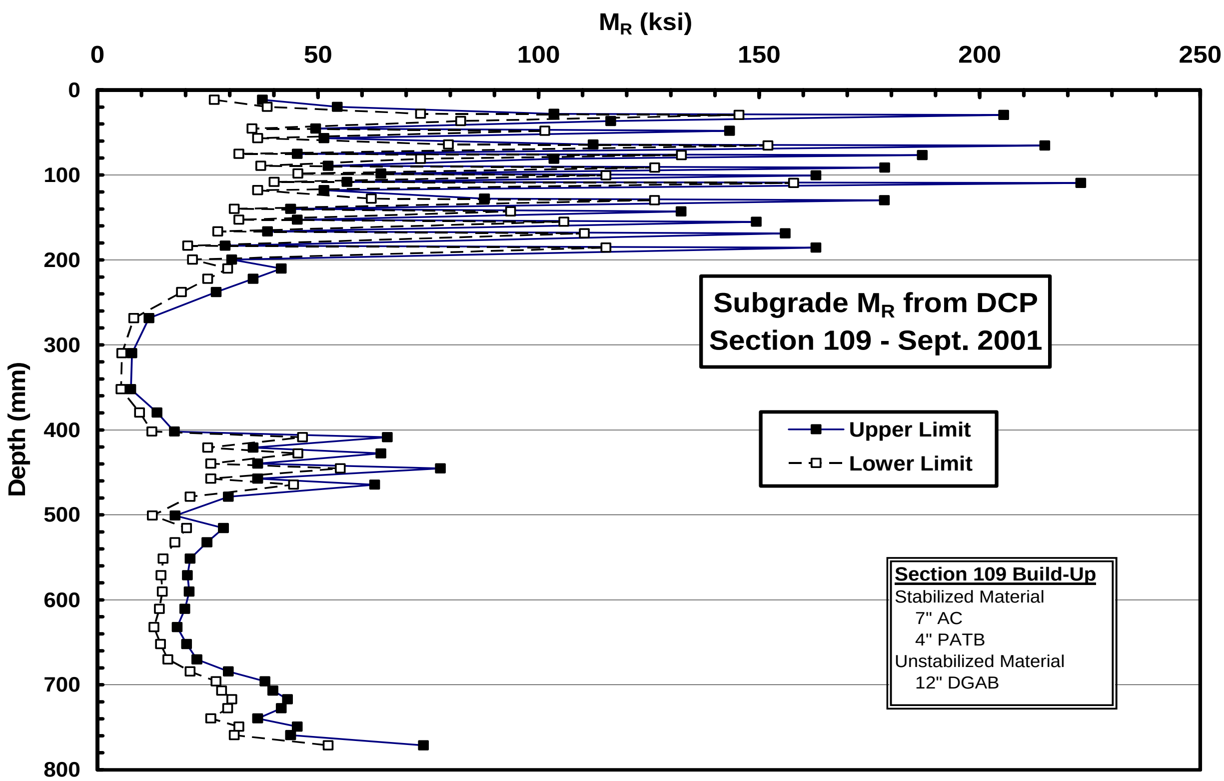


Figure 2.16 - DCP Profile from Section 109

2.6.2 CPT Testing to Bedrock

A Cone Penetrometer Truck (CPT) operated by ORITE was used to measure the depth to bedrock below the surface of pavement sections along the outside edge of the northbound lanes on the test road. In general, the depth of bedrock is at least 20 feet throughout the project, with the southern half of the project extending down to 50 feet.

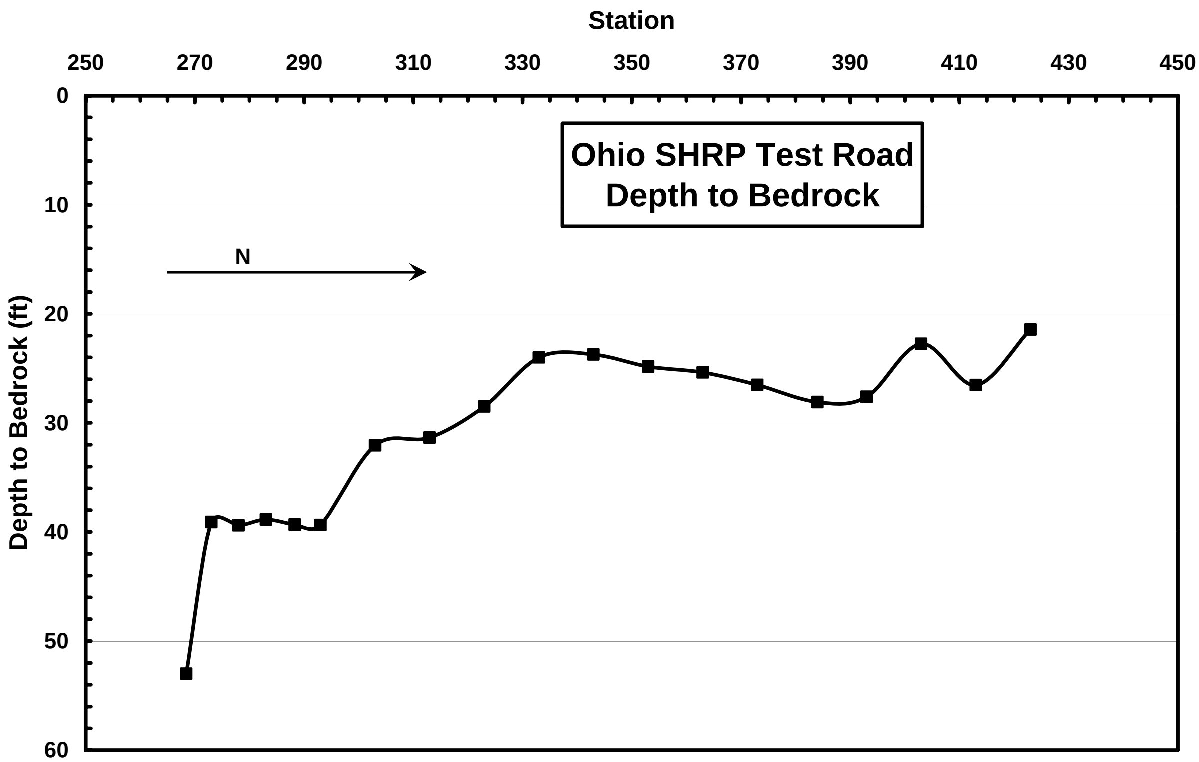


Figure 2.17 - Depth to Bedrock

CHAPTER 3
TRAFFIC LOADING

3.1 GENERAL

A Mettler-Toledo weigh-in-motion (WIM) system was installed on the Ohio SHRP Test Road at the time of construction (1996) to continuously monitor traffic loading in all four mainline pavement lanes. In 1999, ODOT reported a truck loading of approximately 46,700 ESALs per month or 560,400 ESALs per year in the southbound driving lane and approximately 88,000 ESALs per month or 1,056,000 ESALs per year in the northbound driving lane between November 1997 and July 1998. In 2002, these estimates were revised to approximately 38,500 ESALs per month or 462,000 ESALs per year in both driving lanes between November 1997 and December 2001. In a subsequent report by ORITE entitled "Accelerated Testing of Ohio SHRP Sections 390101, 390102, 390105 and 390107" and dated December 2004 (5), ESAL loading in both driving lanes was estimated to be 620,000 ESALs per year from August 1996 to January 1999. These differences in calculated loading were due to the rather sporadic operation of the WIM system early on and, consequently, a lack of consistent data. As more data become available, loading estimates improved and trends were developed with greater confidence. This report extends the analysis of WIM data from W-cards collected through April 2005 using one week of good data each month to represent the loading rate for that month. This procedure improved the estimates of accumulated traffic loading carried by these SPS test sections from August 1996 to April 2005. Excel spreadsheets were developed to review the quality of WIM data, to select the best daily files, to fill in missing data when necessary, and to provide the required output.

Each vehicle crossing the WIM load plates in the pavement generated a row of data delineated by fixed column widths in a daily file, as shown in Figure 3.1. Data included gross weight, classification, date and hour of crossing, and the weight and spacing of individual vehicle axles. Some files contained only Class 4-13 trucks, while others contained all thirteen vehicle classes. Additional spaces are available in the files to record more than the five axle weights and four axle spacings shown in Figure 3.1. Lanes are identified as NB driving (11), NB passing (12), SB passing (52) and SB driving (51), and all units are metric (kilograms or meters).

Typical Truck File: W39000721519803290409000025805045034055013052100052012053

Number of Digits in Data Fields																			
W39	000721	51 (SBD), 52 (SBP), 11 (NBD), 12 (NBP)	98	03	29	04	09	000 (or three blanks)	0258 (2580 kg)	05	045 (4500 kg)	034 (3.4 m)	055 (5500 kg)	013 (1.3 m)	052 (5200 kg)	100 (10.0 m)	052 (5200 kg)	012 (1.2 m)	053 (5300 kg)
Card - State	Site	Dir. - Lane	Year	Month	Day	Hour	Vehicle Class	Open	Gross Wt.	No. Axles	W1	S1	W2	S2	W3	S3	W4	S4	W5

Figure 3.1 - WIM Data Format

3.2 DATA FILES

Southbound lanes of the test road were opened to traffic on Wednesday, August 14, 1996 and the northbound lanes were opened the following day. The WIM system was calibrated on August 15, 1996. The first WIM file recorded by ODOT was dated Thursday, August 22, 1996. On this date, a total of 2,464 trucks were recorded in all four lanes during Hours 09-15 and in the southbound passing lane and northbound driving lane during Hours 16-23. From August 23 to October 27, 1996, data were only collected in the southbound passing lane. Subsequent daily WIM files displayed a variety of problems which generally can be categorized as being either systematic or sporadic. Systematic problems are those which appear to have been caused by the improper setting of WIM parameters at the site, such as lane numbers, ESAL parameters, etc. They tended to persist until the errors were corrected during a subsequent visit to the site. Table 3.1 summarizes a number of systematic errors noted in the files along with suggestions for permanently correcting the errors to facilitate future analyses.

Sporadic errors are those where data collection stopped and started randomly, resulting in lost data, as indicated by smaller than expected daily files and/or hourly counts. These problems were intermittent and tended to occur from a few minutes to several hours during the day. Sporadic outages did not appear to persist from one day to the next, as though the WIM system automatically reset itself each midnight. The vast majority of sporadic problems occurred in Lane 11, suggesting some type of chronic intermittent electrical or mechanical problem.

Table 3.1 Systematic WIM Errors

Dates	Problem	Recommended Action
11/25/97 - 12/9/98	SB lane numbers reversed	Change Lane 51 to 52 and Lane 52 to 51
11/25/97 – 3/13/98	Class 1, 2 and 3 vehicles included in count	Remove Class 1, 2 and 3 vehicles, if desired
12/1/00 – 12/31/00	Incorrect site code	Change code from 021 to 721
12/1/00 – 12/31/00	Incorrect lane numbers	Change Lanes 13, 54 and 56 to Lanes 12, 52 and 51, respectively.
12/4/00 – 12/8/00	Class 3 vehicles included in count	Remove Class 3 vehicles, if desired
11/13/03 – 4/30/05	Class 1, 2 and 3 vehicles included in count	Remove Class 1, 2 and 3 vehicles, if desired

There was a problem early on with electrical surges from nearby lightning strikes entering the WIM and shutting it down. This happened shortly after the test road was opened to traffic and a few times thereafter until Mettler-Toledo devised an adequate protection system. These surges and other problems caused the system to perform poorly until November 1997 when data became more consistent. Other problems occurred after that time, but they were generally for a limited duration. This review of WIM data includes an overall assessment of system functionality and an analysis of traffic loading from August 1996 through April 2005.

Another factor which affected traffic loading on the test road was lane closures for maintenance and testing activities. During these closures, certain lanes did not carry traffic, and any projections of accumulated loading should take extended closures lasting longer than a few days into account. Table 3.2 documents the major closures. During times when the SPS experiments were closed for extended maintenance or data collection, traffic was diverted to adjacent service lanes where there was no monitoring. On dates when the test road was open, traffic in the driving lanes was occasionally moved to the passing lanes a few hours for short term maintenance or testing. These short term diversions were not accounted for in the calculation of accumulated traffic loadings.

Table 3.2

Extended Lane Closure Dates

Closure Dates	Direction	Reason for Closure
9/3/96-9/10/96	SB	Temporary repair of Sections 102 and 107
12/2/96-11/10/97	NB & SB	Replacement of Sections 101, 102 and 107
9/8/98-10/19/98	NB & SB	Replacement of Section 105
3/28/01-6/1/01	NB & SB	Controlled vehicle testing
4/24/02-11/21/03	SB	Replacement of Sections 103, 108, 109 and 110
2/16/06 -	NB	Replacement of Sections 201, 202, 204, 205, 206, 210 and 259

Table 3.3 summarizes the size of the daily WIM files recorded in all four lanes from original opening of the test road through April 2005. Complete weekday files of Class 4-13 trucks routinely contained 200-300 kb of data, while weekend and holiday files typically contained half this amount of data or less. Data files including all thirteen classes of vehicles were 3 – 4 times larger than files with just Class 4 – 13 trucks, such as those obtained from November 1997 until March 1998.

One week of data was selected each month as an appropriate sample size to represent traffic loading for that month. This weekly sample consisted of the best grouping of data for the seven days of the week, as determined by running daily WIM files through an EXCEL spreadsheet to review hourly loading by lane. While file size provides a clue to completeness, hourly loading patterns provide a much more detailed picture of file integrity. It was important that each day of the week be represented in the sample to account for lower weekend counts and repetitive traffic cycles commonly associated with local delivery patterns. Ideally, the weekly sample should consist of seven consecutive days but, on occasion, nonconsecutive days were selected over a period of a couple of weeks to provide the best data quality.

A coding system was devised in Table 3.3 to show which daily files were run through the WIMWtESAL spreadsheet for data validation and archived in the WIMFileSize23 spreadsheet, which dates were selected for the weekly sample, which daily files required adjustment for missing data, and which dates lanes were closed for extended periods of time. While some obvious errors, such as reversed lane numbers or the inclusion of Class 1-3 vehicles, were corrected in the files, incomplete or obviously incorrect data were replaced with valid data from the same hours/days in adjacent days or weeks.

Table 3.3 Magnitude of Daily WIM Files

Date	WIM File Size (kb)																														
	1996					1997		1998												1999											
	Aug	Sept	Oct	Nov	Dec	Nov	Dec	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1		2	6	79	114		973	518	836	893	290	270	**258**	42	96	**287**	1	79	276	21	133	134	253	114	233	7	85	270		**258**	25
2		2	0	145	201		991	932	899	952	289	95	**278**	178	72	**289**	1	**252**	280	15	247	175	202	80	285	234	240	288		**273**	234
3		13	58	112	56		1020	842	933	952	270	80	**287**	130	65	**291**	0	**271**	285	18	147	234	76	210	285	88	267	268		**280**	80
4		12	13	281	1		1030	818	939	988	95	261	**291**	43	260	**262**	0	**279**	261	5	147	274	58	281	264	50	167	89		**287**	25
5		19	4		1		1060	877	862	474	83	282	**263**	66	277	**87**	1	**278**	95	134	134	265	**236**	289	101	94	273	45		247	76
6		15	6		1		811	719	1110	1240	**254**	**278**	**107**	121	268	**52**	0	**253**	69	59	51	55	**275**	83	58	224	256	18		**108**	**271**
7		4	13	0	0		726	916	867	1000	**294**	**272**	**83**	251	256	81	0	**97**	**252**	149	35	75	**287**	259	251	273	102	197		78	**288**
8		2	6	292	0		939	939	804	863	**292**	**266**	259	266	104	206	1	**76**	**276**	81	135	167	232	103	278	277	87	86		255	**293**
9		12	42	135	0		964	1020	422	930	**288**	**102**	280	259	66	1	2	257	**274**	60	145	140	**268**	58		29	245	1		285	**287**
10		12	13	33	0		987	808	993	923	**207**	**77**	288	248	72	1	0	81	**271**	38	71	149	**104**	265		99	266	0		146	**259**
11		10	6	**265**	0		1000	738	981	973	**71**	**264**	64	**95**	**272**	1	0	282	**260**	123	146	149	**76**	287		73	268	1		211	60
12		15	0	**298**			1120	873	999	1050	**53**	**288**	258	**88**	**294**	1	0	270	**93**	147	129	139	263	121		**251**	280	1		228	**74**
13		13	4	**308**		0	875	920	1160	570	242		103	**241**	**269**	0	0	248	**76**	121	47	53	276	34		**260**	254	1		102	234
14		6	13	**304**		0	782	962	**908**	90	273		91	**250**	**263**	1	2	91	248	125	32	59	288	141		**275**	106	1		60	17
15		4	15	**285**		0	**969**	896	**893**	33	284		258	**268**	**108**	1	2	75	278	137	131	**236**	271	108		**267**	88	1		232	281
16		11	57	**132**			**1010**	1110	**1010**	31	240		31	**253**	**96**	1	1	257	279	65	152	228	249	89		**239**	**249**	0		279	18
17		13	13	**107**		0	**1020**	812	**951**	157	265		95	**237**	152	1	0	277	277	40	145	220	64	214		**106**	**277**	0		290	
18		3	14	199			**1060**	741	**958**	344	104		271	96	8	3	0	286	253	131	149	173	54	272		**83**	**283**	0		284	8
19		13	4	294			1150	**960**	**1000**	283	77		252	14	291	0	2	281	94	145	137	**261**	257	283		57	**280**	0		17	52
20		15	2	297			**978**	**939**	**1150**	257	258		102	233	283	0	58	271	73	146	50	96	281	21		118	**262**	0		103	147
21		5	6	310			**879**	**946**	608	**87**	285		73	252	260	1	290	105	253	143	36	74	284	75		123	**105**	0		85	272
22	137	5	13	289			1020	**944**	896	**76**	165		253	260	103	0	283	83	255	125	129	151	230	**107**		266	74	0		264	261
23	10	25	32	143			905	**1050**	931	**260**	296		272	259	86	0	258	258	238	51	144	276	275	**89**		4	254	0		215	206
24	6	10	13	115			1050	**816**	942	**292**	270		278	242	42	1	106	290	79	23	151	116	99	**256**		64	90	0		263	52
25	2	68	13	303		1120	749	**693**	513	**288**	64		278	99	182	1	80	149	9	70	137	213	72	**279**		87	273	0		50	9
26	10	7	5	311			1070	910	1000	**285**	78		262	85	278	2	257	53	19	143	138	261	231	270		242	283	0	19	103	45
27	6	10	4	286		1030	1030	928	1190	**259**	265	299	99		281	0	291	96	29	141	51	101	289	**288**		237	264		36	58	182
28	11	3	107	82		1020	979	952	936	27	294	298	10	244	259	2	290	62	111	139	40	66	297	**262**		140	100		283	79	204
29	12	5	91	141		1060	991	953		70	294	59	222	260	104	3	288	72	128	135		216	292	84	280	264	79		235	254	226
30	14	12	221	106		1200	932	1120		253	291	118	177	256	83	3	248	249	117	47		33	284	41	279	223	158		96	0	115
31	6		0				896	894		268		23		242	**256**		95		96	35		291		90		99	270		77		82

Bold Type - Complete daily file | Hourly data in database | Complete 7-day sample | Adjusted 7-day sample | NB closed | SB closed | NB & SB closed

Table 3.3 Magnitude of Daily WIM Files

Date	2000												2001											
	WIM File Size (kb)																							
	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1	79	283	294	102	191	296	116			94	272	250	36	260	259			242	77	161	64	186	214	
2	50	163	280	41	293	265	71		0	260	293	88	187	215	243			87	224	42	48	206	225	
3		277	24	270	270	109	153		46	271	222	69	238	76	78			76	153	226	90	223	45	246
4		253	97	288	265	88	86		82	247	97	343	253		61			**230**	72	72	197	198	64	257
5		96	72	230	271	**256**	157		250	257	79	432	227	233	237			**257**	188	85	236	193	218	258
6	9	66	236	286	110	**280**	268		232	142	262	456	84	249				**247**			212	82	237	19
7	7	253	212	24	87	**282**	294		271	31	281	456	60	267	150			**265**	76		230	79	245	19
8		273	273	**94**	**273**	**294**	**105**	1	**269**	82	290	350	232	259	265			212	76	30	44	210	213	2
9		283	288	56	**293**	**271**	**90**	100	66	213	278	89	243	227	238			**90**	215	3	70	243		6
10		201	269	**259**	**290**	**109**	**249**	280	85	211	260	12	260	73	78			**90**	214	1	**248**	238		238
11		254	85	**279**	**297**	**92**	**270**	191	246	248	92	6	248	65	65			235	165		187	255	61	248
12		90	51	**283**	**269**	202	**269**	80	264	187	70	229	229	213	246			252	256		212	232	**234**	250
13		72	**264**	**287**	**97**	279	241	60	**285**	195	**271**	192		218	264			19	**250**		179	54	**249**	
14		238	278	**277**	**81**	85	**251**	185	207	91	**276**	256	42		276			9	87		205	**81**	**270**	247
15		293	**292**	82	262	292	83	267		86	268	240	**215**	164	271			234	**89**		65	202	**257**	80
16		**289**	**292**	45	21	263	99	217	0	261	288	**89**	**246**	232				65	151		**73**	192	**235**	63
17		**282**	208	266	284	95	256	176	6	265	**256**	**65**	**253**	81				80	265		235	7	**95**	**228**
18		**236**	93	252	287	126	256	207	216		**90**	**230**	**259**	63	70			235	225		195	2	**72**	**251**
19		**94**	**74**	294	272	262	265	89	113		74	**257**	**222**	**233**	**256**			256	27		216	236	246	**249**
20		**63**	251	224	98	288	0	18	266	0	146	**258**	**77**	**250**	**275**			248	190		234	6	219	**249**
21		**252**	280	171	91	283	246	264	234	81	286	234	**61**	**255**	**264**			36	73		233	73	231	**204**
22	89	274	93	63	270	293	95	266	235	70	260	**200**	92	**250**	**268**			232	72		86	226	42	**82**
23	66	286	231	59	289	264		267	82	224	55	61		**241**	**241**			89	7		74	234	104	**40**
24	**231**	269	219	232	288	106		140	87	256	94	22	259	**78**	**82**			24	239		233	45	2	45
25	**268**	221	94	236	298	86		41	253	209	51	12	248	**59**	**65**			235	248		255	247	65	13
26	**256**	99	71	294	266	263		90	232	219	70	131	90	239	254			235			187	165	237	149
27	**256**	73	265	301	90	287		121	280	**242**		198	74	263	205			255			261	77	255	195
28	**233**	177	148	265	47	290		241	223	93		203	62	261				242	82		188	46	266	197
29	**90**	235	293	102	85	198		239	217	**83**		182	228				55	231	65		1	235	249	83
30	**66**		230	59	270	266		**286**	98	204	274	71	243				201	118	46		66	249	226	45
31	238		230		296			271		278		31	252				255		215			241		76

Bold Type - Complete daily file | Hourly data in database | Complete 7-day sample | Adjusted 7-day sample | NB closed | SB closed | NB & SB closed

Table 3.3 Magnitude of Daily WIM Files

WIM File Size (kb)

Date	2002												2003											
	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1	38	212	18	232		50	81	85	22	121	118	36	2	39	43	137	127	50	137	104	29	**139**	12	1012
2	199	78	76	253		32	71	59	16	145	44	122	103	37	34	131	130	124	149	5	125	**138**	38	1042
3	232	58	62			119	116	58	79	123	36	133	105	119	122	10	32	126	129	39	126	132	115	1077
4	227		225			114	50	47	39	128	**124**	47	39	126	138	120	2	105	45	55	66	**47**	112	1075
5	79		256	**246**		**131**	71	**123**	132	78	**128**	126	36	126	109	43	115	57	1	63	60	**48**	73	1087
6	59	252	261		135	**141**	54	102	135	49	**134**		117	126	134	40	**127**	125	46	101	55	**127**	136	920
7	**217**	58	112			**157**	1	133	23	**131**	**132**		133	110	125	**126**	129	14	17	96	30	**134**	134	813
8	**234**	201	242	**237**		43	85	**138**	17	**136**	**121**		133	42	42	**132**	123	43	106	42	109	92	47	**987**
9	**236**	76	25	**258**		**63**	78	**125**	103	**140**	**45**		127	33	32	**137**	**138**	**127**	**129**	52	112	75	38	**1017**
10	**246**	60	68	255		113	108	37	89	**143**	**35**		116	**121**	132	**114**	41	120	86	21	138	130	**120**	**1059**
11	**218**	**234**	242	**264**		138	36	**47**	133	**128**	59		38	**134**	139	**130**	41	**139**	108	17	133	36	**130**	**1098**
12	**74**	**251**	95	54		135	20	103	95	**44**	131		34	**134**	146	**46**	125	**139**	43	131	132	10	284	**1206**
13	56	**244**	268	85		131	11	**128**	111	**45**	138	121	**121**	**133**	45	**42**	30	110	38	123	59	135	298	**987**
14		**237**	244	**73**		99	18	**145**	51	123	131	45	**130**	**122**	127	125	99	**46**	114	**150**	49	132	**608**	**730**
15		**232**	239	243		39	**129**	15	37	138	118	41	**133**	**40**	47	131	19	40	**123**	115	114	98	**523**	985
16	247	**74**	83	246	3	52	**124**	128	129	137	39		**127**	**27**	36	147	114	10	93	23	**140**	136	**522**	767
17	243	**56**	66	244		90	109	42	65	138	37		**113**	73	126	129	48	140	8	**59**	**153**	114	495	1078
18	118	224	**243**			135	125	21	129	120	122		**38**	131	140	95	53	143	123	115	134	37	447	1114
19	70	77	216	0		110	79	75	116	45	139		**33**	136	78	44	115	143	46	3	**135**	34	**539**	1238
20	57	251	**257**	93	74	19	58	138	80	43	132		118	134	134	30	104	133	**50**	83	**48**	127	**553**	1050
21	216	147	**264**	74	89	129	51	70	35	127	137		123	127	112	121	97	57	115	135	**50**	29	1072	928
22	239	261	**246**	257	77	48	38	67	33	138	42		131	49	4	132	123	56	131	124	125	141	903	1139
23	251	79	**86**	267	135	43	86	22	51	136	47		125	38	38	131	132	141	41	47	113	136	851	784
24		65	**70**		131	71	134	34	106	137	45		118	116	118	133	5	150	68	53	133	114	822	1118
25	221	246	227	209	4	80	137	44	134	121	135		42	134	136	123	46	39	78	142	115	46	1195	777
26	69	245	126	112	28		42	88	133	48	140		33	131	148	28	45	148	43	4	107	42	1542	1142
27	59	250	268	40	55	26	40	80	118	47	120		115	132	**147**	48	113	133	39	121	47	7	1135	1079
28	224		277	15	126	101	14	51	45	126	23		130	117	**132**	126	146	13	95	139	36	139	1115	1052
29	248		191	129	30	41	78	142	54	21	46		127		**48**	165	109	40	118	124	128	131	130	1061
30	240		71	138	143	21	95	133	63	136	30		128		**37**	140	97	130	91	43	97	108	1248	1102
31	232		55		124		91	8		131			122		133		48		141	30		108		995

Bold Type - Complete daily file | Hourly data in database | Complete 7-day sample | Adjusted 7-day sample | NB closed | SB closed | NB & SB closed

Table 3.3 Magnitude of Daily WIM Files

WIM File Size (kb)																								
Date	2004												2005											
	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1	598	754	951	1061	1074	1107	514	1198	693	1394	662	1046	681	939	865	1243								
2	794	943	880	1275	980	1135	960	**1137**	1231	1064	1000	1088	926	704	948	858								
3	773	934	1045	1067	1055	1197	1100	967	1572	1076	1083	1203	912	1009	1041	798								
4	929	1013	1033	945	1013	1366	915	**1067**	1277	1057	1090	975	969	961	1276	1002								
5	591	950		994	1122	1152	1179	**1252**	1092	1066	1362	**837**	824	941	775	1010								
6	865	1135		1064	1123	1095	1119	**1424**	1145	1088	1103	**982**	863	800	688	1072								
7	901	905		466	1209	1006	1124	**1180**	364	1150	1037	**1024**	1087	957	971	996								
8	948	868		795	1180	1126	1107	1220	1093	670	**1042**	**1092**	773	966	990	1289								
9	1076	**967**		1406	1135	1188	1399	527	1139	1208	**1068**	**1108**	810	943	770	1083								
10	837	**982**		822	**1107**	1227	1018	1031	287	1149	**1116**	**1222**	0	999	1059	1014								
11	809	**1015**		1237	**1110**	219	1223	1181	1232	1095	**1068**	**953**	941	1181	1195									
12	**958**	**1034**		283	**1138**	909	1103	1217	1153	672	**1234**	784	1010	925	**968**	1030								
13	**972**	**1241**		1053	**1130**	1239	**1126**	1428	1042	396	**1045**	968	1031	860	**859**	2870								
14	**957**	**964**		568	**1357**	1076	1141	1202	609	1113	**977**	1023	1178	**950**	**975**	1095								
15	**1001**	**866**	0	3813	**1038**	413	**1157**	446	1131	1373	1051	1070	909	**1027**	**995**	1319								
16	**1202**	1038	809	1281	999	1141	1191	1184	**1176**	1060	1068	1098	722	**985**	**1083**	1088								
17	**725**	993	482	1070	618	1166	1136	1164	**1333**	1021	1090	1267	784	**1045**	**1174**	981								
18	**760**	1030	1103	1060	1045	1221	1169	789	**1079**	624	1128	1051	958	**1255**	**1285**	**1022**								
19	996	550	1307	**1049**	921	1202	**1095**	436	**1163**	**1068**	1405	834	902	**1018**	491	**1012**								
20	982	1120	1022	**1055**	1093	1288	1056	1412	**1094**	**1112**	1048	1025	970	**815**	895	900								
21	964	927	**939**	**1083**		**1178**	**1135**	1226	1122	**1134**	929	1136	1156	1022	759	**1085**								
22	1005	892	**1009**	**1105**		1034	869	1130	1183	**1389**	1046	915	387	987	1008	**1279**								
23	1027	971	**1053**	**1321**		**1188**	**1417**	57	151	**1143**	1239	361	565	1020	1024	617								
24	810	992	**910**	1021		1094	**1215**	1155	1467	**1104**	1500	911	690	1040	1159	**856**								
25	600	1026	**967**	**1004**		1016	**1221**	937	1168	**1046**	1144	713	964	1219	1229	826								
26	910	1068	**1316**	1035	0	**1143**	565	1184	1134	776	1143	1045	1009	1009	936	1007								
27	683	1204	**1112**	1051	1206	1209	1113	1332	1074	1070	1114	1073	1009	789	1147	1074								
28	612	963	887	1097	1400	1075	1167	919	643	1131	1237	1067	1179	949	1108	1039								
29	987	955	1001	1156	1129	978	1209	978	278	1324	1012	0	885		1063	1103								
30	1118		1009	1361	985	1119	1338	755	889	997	1048	1130	814		1081	1013								
31	873		699		1074		757	1129		1011		924	915		1095									

Bold Type - Complete daily file | Hourly data in database | Complete 7-day sample | Adjusted 7-day sample | NB closed | SB closed | NB & SB closed

3.3 EXCEL SPREADSHEETS

Three EXCEL spreadsheets were developed to calculate the following five traffic parameters from the daily WIM files: 1) volume by hour and lane, 2) classifications by hour for all four lanes, 3) total weight by hour and lane, 4) total ESALs by hour and lane, and 5) modified daily load spectra of single, tandem, tridem and quad/penta/hex axles for all truck classifications. Volume and classifications were determined from the spreadsheet identified as WIMVolClass, weight and ESALs were determined from a spreadsheet identified as WIMWtESAL, and the combined load spectra was determined from a spreadsheet identified as WIMLoadSpectra. Two versions of each spreadsheet were developed to process north-south and east-west routes.

Due to limitations in the size of EXCEL spreadsheets, vehicle geometry in the spreadsheets was limited to a maximum of seven axles for the calculation of ESALs and load spectra. On trucks with more than seven axles, of which there were only a few each day, the first seven axles were counted as a vehicle, so the only data lost were those past the seventh axle. Considering the low number of trucks with more than seven axles and the fact that many of these trucks were not fully loaded, the impact of not counting these few axles was very minor. ESALs and load spectra were calculated for vehicles with axle configurations shown in Table 3.4, which represent essentially all trucks using the test road. In Table 3.4, 1 is a single axle, 2 is a dual axle, 3 is a tridem axle, etc., so a 1-2 truck is a Class 6 dual-axle dump or box truck and a 1-2-2 truck is a classic Class 9 18-wheeler.

Table 3.4

Truck Configurations for ESAL and Load Spectra Calculations

Truck Configurations by Number of Axle Groups				
2	**3**	**4**	**5**	**6**
1-1	1-1-1	1-1-1-1	1-1-1-1-1	1-1-1-1-1-1
1-2	1-1-2	1-2-1-1	1-2-1-1-1	1-1-1-1-2-1
1-3	1-2-1	1-2-1-2	1-1-1-1-2	
1-4	1-2-2			
1-5	1-2-3			
1-6	1-2-4			

To run the spreadsheets, daily WIM files were opened in EXCEL and parsed out into fixed column widths (Figure 1) to the seventh axle. Columns A - X in the parsed data were then copied and pasted into the spreadsheets for calculation of the various parameters. The spreadsheets removed trucks having zero weight on the first or second axles, and any Class 1, 2 and 3 vehicles (motorcycles, cars and pick-up trucks) which may have been included in the data. A very few vehicles with zero weight on the first or second axle were observed in a cursory review of the raw WIM files. Class 14 and 15 trucks include those that do not fit into standard criteria defined for Classes 4-13 and are, therefore, considered to be unconventional. While a few unconventional trucks do occasionally use the road, they are rare and any more than two or three per day may be an indication that the WIM system was not operating properly.

Daily file integrity was determined by observing the hourly distribution of trucks in all four lanes, and weekly files were assembled by combining complete daily WIM files for all seven days of the week. These files were run through the three spreadsheets and weekly summaries for each loading parameter were archived by day of the week, month and year in a separate database named WIMWeeklySummaries721(DEL23). Daily outputs were then summed for weekly totals in that spreadsheet. When necessary, missing or incorrect hourly data were adjusted by importing data from the same time and day in an adjacent week, the same time in a comparable day in the same week, or lanes in the opposite direction on the same time and day. These adjustments were made prior to running the spreadsheets and notes regarding the adjustments were added to the spreadsheet outputs. Daily files should be run routinely every few weeks as data are being collected to monitor hourly truck counts, truck weights, and axle configurations, and verify that the WIM system is operating properly.

Table 3.5 shows sample volume and classification output from the WIMVolClass spreadsheet, Tables 3.6 and 3.7 show sample weight and ESAL output from the two-page WIMWtESAL spreadsheet, and Table 3.8 shows sample load spectra output from the WIMLoadSpectra spreadsheet. Although notes added to the spreadsheets indicated that lane numbers for Lanes 51 and 52 were reversed in the raw data on 6/1/98, the quality of the corrected WIM data was very good. When possible, systematic errors were corrected prior to running the data through the spreadsheets. In the spreadsheets, volume was determined by the number of truck files, classifications, gross weights and axle weights were determined by that determined by the WIM, and ESALs and load spectra were calculated in the spreadsheets.

Table 3.5 Truck Count/Classification Spreadsheet Output from WIMVolClass Spreadsheet

MONDAY																			
HOURLY WIM COUNT/CLASSIFICATION SUMMARY - All Lanes																			
Card:	W39	Site	721	Date:	6	1	98	Location:	DEL 23										
Hour	Number of Vehicles by Lane				Total Number of Vehicles by Classification in All Lanes												Total No. Vehicles All Lanes	% Class 9 All Lanes
	11	12	52	51	4	5	6	7	8	9	10	11	12	13	14	15		
0	57	2	0	47	3	4	1	0	2	89	0	5	1	1	0	0	106	84.0
1	57	3	0	37	0	2	1	0	1	84	6	2	0	1	0	0	97	86.6
2	56	5	1	24	1	5	1	0	5	71	0	2	0	1	0	0	86	82.6
3	66	2	0	38	1	6	0	0	2	94	0	2	0	1	0	0	106	88.7
4	61	3	2	43	3	1	4	1	10	84	1	3	2	0	0	0	109	77.1
5	46	0	3	59	1	11	3	0	7	82	1	3	0	0	0	0	108	75.9
6	76	7	11	59	1	10	11	1	10	114	1	3	0	2	0	0	153	74.5
7	83	6	6	82	5	24	6	5	15	117	3	1	0	0	0	0	177	66.1
8	97	7	13	94	4	28	8	2	18	143	4	2	0	1	0	1	211	67.8
9	117	14	8	105	2	27	12	3	13	173	10	3	0	0	0	0	244	70.9
10	126	21	12	99	4	24	13	4	21	181	6	4	0	0	1	0	258	70.2
11	142	11	10	125	3	20	12	2	16	222	10	1	1	0	0	0	288	77.1
12	125	20	15	116	0	21	9	3	25	215	2	1	0	0	0	0	276	77.9
13	109	26	15	124	1	22	14	3	24	200	5	1	0	3	0	0	274	73.0
14	123	36	19	155	4	34	16	1	16	248	9	2	0	1	0	1	333	74.5
15	119	6	13	124	6	26	7	6	17	190	4	4	1	0	1	0	262	72.5
16	105	20	17	126	6	24	13	0	22	196	2	3	1	1	0	0	268	73.1
17	82	17	16	106	2	20	11	2	20	160	3	1	0	1	0	0	221	72.4
18	73	15	15	109	2	17	5	0	18	164	3	1	1	0	0	0	212	77.4
19	74	9	6	102	2	8	3	1	15	152	3	3	1	1	0	0	191	79.6
20	69	12	8	91	1	7	8	0	17	137	6	3	1	0	0	0	180	76.1
21	74	8	3	86	0	6	5	0	7	141	6	5	0	0	0	0	171	82.5
22	70	5	2	84	2	6	1	0	8	129	3	12	0	0	0	0	161	80.1
23	74	3	0	88	5	6	2	0	1	140	1	5	1	3	0	0	165	84.8
Total	2081	258	195	2123	59	359	166	34	310	3526	89	72	10	17	2	2	4657	75.7
% of Total	44.7	5.5	4.2	45.6	1.3	7.7	3.6	0.7	6.7	75.7	1.9	1.5	0.2	0.4	0.0	0.0		

Lanes 51 and 52 reversed

Table 3.6 Truck Weight Spreadsheet Output from WIMWtESAL Spreadsheet

MONDAY													
DAILY/HOURLY WEIGHT SUMMARY													
Card:	W39	Site	721	Date:	6	1	98	Location:	DEL 23				
Hourly Weight Summary													
Hour	Total Vehicle Wt. (K)	Total Number Vehicles	Wt. per Vehicle (K)	Total Weight by Lane (kips)				% Weight by Lane				Total Class 9 Wt. (K)	% Wt. Class 9
				11	12	52	51	11	12	52	51		
0	5780	106	54.5	3032	77	0	2670	52.5	1.3	0.0	46.2	5064	87.6
1	5593	97	57.7	3052	117	0	2425	54.6	2.1	0.0	43.4	4759	85.1
2	4612	86	53.6	3129	223	27	1233	67.8	4.8	0.6	26.7	4107	89.0
3	5978	106	56.4	3772	122	0	2083	63.1	2.0	0.0	34.9	5554	92.9
4	5981	109	54.9	3408	104	140	2328	57.0	1.7	2.3	38.9	5096	85.2
5	5705	108	52.8	2253	0	188	3264	39.5	0.0	3.3	57.2	4835	84.7
6	7955	153	52.0	3564	313	496	3580	44.8	3.9	6.2	45.0	6644	83.5
7	8744	177	49.4	4158	387	267	3931	47.6	4.4	3.1	45.0	6782	77.6
8	10199	211	48.3	4683	298	733	4486	45.9	2.9	7.2	44.0	8140	79.8
9	11474	244	47.0	5083	644	446	5301	44.3	5.6	3.9	46.2	9261	80.7
10	12278	258	47.6	5818	1198	369	4893	47.4	9.8	3.0	39.9	9964	81.2
11	13168	288	45.7	6134	488	508	6038	46.6	3.7	3.9	45.9	10980	83.4
12	12356	276	44.8	5519	901	690	5246	44.7	7.3	5.6	42.5	10645	86.2
13	12413	274	45.3	4859	1172	648	5735	39.1	9.4	5.2	46.2	10383	83.6
14	15050	333	45.2	5316	1396	931	7408	35.3	9.3	6.2	49.2	12786	85.0
15	11703	262	44.7	5222	229	540	5712	44.6	2.0	4.6	48.8	9603	82.1
16	11984	268	44.7	4603	786	680	5915	38.4	6.6	5.7	49.4	9950	83.0
17	9989	221	45.2	3780	720	658	4832	37.8	7.2	6.6	48.4	8416	84.3
18	10150	212	47.9	3425	744	610	5371	33.7	7.3	6.0	52.9	9036	89.0
19	9069	191	47.5	3311	321	213	5224	36.5	3.5	2.3	57.6	7998	88.2
20	9262	180	51.5	3073	527	352	5311	33.2	5.7	3.8	57.3	7863	84.9
21	8927	171	52.2	3759	420	86	4662	42.1	4.7	1.0	52.2	7838	87.8
22	8851	161	55.0	3809	264	113	4666	43.0	3.0	1.3	52.7	7423	83.9
23	9272	165	56.2	4004	116	0	5152	43.2	1.3	0.0	55.6	8116	87.5
Total	226494	4657	48.6	98764	11567	8695	107468					191246	
Average (%)								43.6	5.1	3.8	47.4		84.4
Lanes 51 and 52 reversed.													

Daily Volume/Weight Summary												
Parameter	Daily Volume						Daily Weight (Kips, Kips/Vehicle)					
	Lane					All	Lane					All
	All	11	12	52	51	Class 9	All	11	12	52	51	Class 9
Total	4657	2081	258	195	2123	3526	226494	98764	11567	8695	107468	191246
%		44.7	5.5	4.2	45.6	75.7		43.6	5.1	3.8	47.4	84.4
Per Vehicle							48.64	47.46	44.83	44.59	50.62	54.24

Table 3.7 Truck ESAL Spreadsheet Output from WIMWtESAL Spreadsheet

MONDAY

DAILY/HOURLY ESAL SUMMARY

Card:	W39	Site:	721	Date:	6	1	98	Location:	DEL 23

ESAL Input

Concrete	
D (in.)	9.5
pi (initial)	4.2
pt (terminal)	2.5
p (failure)	1.5
Asphalt	
Structural No.	4.75
pi (initial)	4.5
pt (terminal)	2.5
p (failure)	1.5
Reference Load	
Ref. Wt. (K)	18
Ref. Axles	1

Pavement Type Code

Lane ID (Max - 4 Lanes)	AC - 1 PCC - 2
11	2
12	2
52	1
51	1

Hourly ESAL Summary

Hour	Total Vehicle ESALs	Total Number Vehicles	ESALs per Vehicle	Total ESALs by Lane 11	12	52	51	% ESALs by Lane 11	12	52	51
0	136	106	1.28	81	2	0	52	59.8	1.6	0.0	38.5
1	141	97	1.45	77	1	0	63	54.5	0.6	0.0	44.9
2	118	86	1.38	89	3	0	26	75.5	2.8	0.0	21.6
3	152	106	1.43	110	3	0	40	72.2	1.7	0.0	26.0
4	166	109	1.53	100	4	3	59	60.1	2.2	1.9	35.7
5	147	108	1.36	55	0	19	73	37.4	0.0	12.9	49.7
6	193	153	1.26	92	9	10	82	47.6	4.6	5.3	42.4
7	230	177	1.30	113	12	5	99	49.4	5.2	2.0	43.3
8	243	211	1.15	142	8	19	74	58.4	3.1	7.9	30.5
9	254	244	1.04	127	17	9	100	50.0	6.8	3.6	39.5
10	306	258	1.18	167	40	2	97	54.5	13.1	0.7	31.8
11	257	288	0.89	133	12	8	103	52.0	4.7	3.1	40.2
12	250	276	0.91	132	22	8	88	52.8	8.7	3.3	35.2
13	252	274	0.92	124	27	14	87	49.3	10.6	5.5	34.6
14	297	333	0.89	116	23	18	140	38.9	7.8	6.2	47.1
15	219	262	0.84	101	5	12	101	46.1	2.3	5.4	46.3
16	231	268	0.86	95	15	13	108	41.1	6.6	5.7	46.7
17	207	221	0.94	99	17	8	84	47.6	8.1	3.7	40.6
18	210	212	0.99	79	28	8	95	37.7	13.5	3.7	45.1
19	171	191	0.90	80	3	3	85	46.5	2.0	1.8	49.7
20	219	180	1.22	74	20	7	118	33.7	9.4	3.2	53.7
21	198	171	1.16	90	8	0	99	45.7	4.2	0.2	50.0
22	218	161	1.35	108	9	1	100	49.6	4.0	0.5	45.8
23	229	165	1.39	116	1	0	112	50.8	0.3	0.0	48.9
Total	5043	4657	1.08	2500	289	168	2086				
Average (%)								49.6	5.7	3.3	41.4

Lanes 51 and 52 reversed.

Lane Code

Lane No.	Lane Description
11	NB Driving
12	NB Passing
52	SB Passing
51	SB Driving

Daily ESAL Summary

Daily Loading (ESALs, ESALs/Vehicle) Parameter	Lane All	11	12	52	51
Total ESALs	5043	2500	289	168	2086
% in Lane		49.6	5.7	3.3	41.4
ESALs/Truck	1.08	1.20	1.12	0.86	0.98

Daily Class 9 Loading (ESALs, ESALs/Vehicle) Parameter	Lane All	11	12	52	51
ESALs	4319	2150	261	150	1758
No. 9 Veh.	3526	1582	195	141	1607
ESAL/Veh.	1.22	1.36	1.34	1.07	1.09

Daily Weight Distribution

Load Range (K)	Number of Trucks in Range – Lane 11	12	52	51	Class 9 All lanes
0-10	52	12	12	43	3
10-20	148	35	21	134	18
20-30	188	17	19	138	124
30-40	547	59	43	525	1003
40-50	266	38	36	323	576
50-60	210	24	15	213	420
60-70	187	19	11	151	321
70-80	416	32	16	330	757
80-90	56	21	20	234	292
90-100	4	0	1	9	6
100-110	1	0	0	4	4
110-120	1	0	0	8	1
120-130	0	0	1	2	1
130-140	0	0	0	0	0
140-150	0	0	0	0	0
150-160	0	0	0	0	0

Daily ESAL Distribution

ESALs Truck	No. Trucks in Range 11	12	52	51	Class 9
0-2	1468	176	143	1606	2506
2-4	446	39	31	431	868
4-6	96	20	3	16	119
6-8	6	1	0	4	6
8-10	2	0	0	3	3
10-12	0	0	0	2	2
12-14	0	0	0	1	1
14-16	1	0	0	0	1
16-18	0	0	0	0	0
18-20	0	0	1	0	1
20-22	0	0	0	0	0
22-24	0	0	0	0	0
24-26	0	0	0	0	0
26-28	0	0	0	0	0
28-30	0	0	0	0	0

Table 3.8 Truck Load Spectra Summary Output from WIMLoadSpectra Spreadsheet

MONDAY

DAILY LOAD SPECTRA SUMMARY

Card:	W39	Site	721	Date:	6	1	98	Location:	DEL 23

Single Axle						Tandem Axles					
Wt.	Lane				Sum	Wt.	Lane				Sum
	11	12	52	51			11	12	52	51	
3	91	21	21	39	172	6	8	8	5	9	30
4	107	20	14	63	204	8	53	10	7	5	75
5	68	19	12	87	186	10	171	13	10	75	269
6	77	15	19	79	190	12	353	38	23	323	737
7	75	12	10	57	154	14	412	53	33	370	868
8	145	18	10	94	267	16	264	41	36	343	684
9	304	32	18	151	505	18	207	30	29	242	508
10	713	58	26	387	1184	20	169	30	18	213	430
11	641	81	60	549	1331	22	139	21	17	165	342
12	299	48	56	758	1161	24	134	17	16	141	308
13	63	5	14	227	309	26	135	12	9	134	290
14	88	1	2	107	198	28	142	12	6	145	305
15	44	2	0	51	97	30	199	10	10	159	378
16	61	2	4	67	134	32	246	24	14	200	484
17	68	3	1	67	139	34	280	34	14	299	627
18	53	6	2	76	137	36	160	26	21	287	494
19	58	9	5	82	154	38	40	6	9	92	147
20	10	2	1	37	50	40	14	3	2	29	48
21	14	3	5	18	40	42	3	1	1	8	13
22	5	1	4	7	17	44	5	0	0	1	6
23	2	1	0	6	9	46	1	0	0	3	4
24	4	0	0	1	5	48	0	0	0	2	2
25	0	0	1	5	6	50	2	0	0	3	5
26	1	0	0	4	5	52	0	0	0	0	0
27	0	0	1	2	3	54	0	0	1	0	1
28	0	0	0	1	1	56	0	0	0	0	0
29	1	0	0	0	1	58	0	0	0	0	0
30	0	0	0	0	0	60	0	0	0	0	0
31	0	0	1	0	1	62	0	0	0	0	0
32	0	0	0	0	0	64	0	0	0	0	0
33	0	0	0	0	0	66	0	0	0	0	0
34	0	0	0	0	0	68	0	0	0	0	0
35	0	0	0	0	0	70	0	0	0	0	0
36	0	0	0	0	0	72	0	0	0	0	0
37	0	0	0	0	0	74	0	0	0	0	0
38	0	0	0	0	0	76	0	0	0	0	0
39	0	0	0	0	0	78	0	0	0	0	0
40	0	0	0	0	0	80	0	0	0	0	0
Sum	2992	359	287	3022	6660		3137	389	281	3248	7055

Tridem Axles						Quad Axles						Penta Axles						Hex Axles					
Wt.	Lane				Sum	Wt.	Lane				Sum	Wt.	Lane				Sum	Wt.	Lane				Sum
	11	12	52	51			11	12	52	51			11	12	52	51			11	12	52	51	
12	0	0	0	0	0	12	0	0	0	0	0	12	0	0	0	0	0	12	0	0	0	0	0
15	3	0	0	2	5	15	0	0	0	0	0	15	0	0	0	0	0	15	0	0	0	0	0
18	1	1	0	3	5	18	0	0	0	0	0	18	0	0	0	0	0	18	0	0	0	0	0
21	2	0	1	7	10	21	0	0	0	0	0	21	0	0	0	0	0	21	0	0	0	0	0
24	1	0	1	2	4	24	0	0	0	0	0	24	0	0	0	0	0	24	0	0	0	0	0
27	0	0	0	0	0	27	0	0	0	0	0	27	0	0	0	0	0	27	0	0	0	0	0
30	2	0	0	0	2	30	0	0	0	0	0	30	0	0	0	0	0	30	0	0	0	0	0
33	0	0	0	1	1	33	0	0	0	0	0	33	0	0	0	0	0	33	0	0	0	0	0
36	2	0	0	0	2	36	0	0	0	0	0	36	0	0	0	0	0	36	0	0	0	0	0
39	3	0	0	2	5	39	0	0	0	0	0	39	0	0	0	0	0	39	0	0	0	0	0
42	11	1	0	3	15	42	0	0	0	0	0	42	0	0	0	0	0	42	0	0	0	0	0
45	8	3	1	6	18	45	1	0	0	0	1	45	0	0	0	0	0	45	0	0	0	0	0
48	3	0	0	2	5	48	0	0	0	0	0	48	0	0	0	0	0	48	0	0	0	0	0
51	2	0	1	2	5	51	4	0	0	0	4	51	0	0	0	0	0	51	0	0	0	0	0
54	0	0	0	0	0	54	6	0	0	0	6	54	1	0	0	0	1	54	0	0	0	0	0
57	0	0	0	0	0	57	4	1	0	0	5	57	3	1	0	0	4	57	0	0	0	0	0
60	0	0	0	1	1	60	2	0	0	0	2	60	0	0	0	0	0	60	0	0	0	0	0
63	0	0	0	0	0	63	2	0	0	0	2	63	0	0	0	0	0	63	0	0	0	0	0
66	0	0	0	0	0	66	0	0	0	0	0	66	0	0	0	0	0	66	0	0	0	0	0
69	0	0	0	0	0	69	0	0	0	0	0	69	3	0	0	1	4	69	0	0	0	0	0
72	0	0	0	0	0	72	0	0	0	0	0	72	1	0	0	0	1	72	0	0	0	0	0
75	0	0	0	0	0	75	0	0	0	0	0	75	1	0	0	0	1	75	0	0	0	1	1
78	0	0	0	0	0	78	0	0	0	0	0	78	0	0	0	0	0	78	0	0	0	0	0
81	0	0	0	0	0	81	0	0	0	0	0	81	0	0	0	0	0	81	0	0	0	1	1
84	0	0	0	0	0	84	0	0	0	0	0	84	0	0	0	0	0	84	0	0	0	1	1
87	0	0	0	0	0	87	0	0	0	0	0	87	0	0	0	0	0	87	0	0	0	0	0
90	0	0	0	0	0	90	0	0	0	0	0	90	0	0	0	0	0	90	0	0	0	0	0
93	0	0	0	0	0	93	0	0	0	0	0	93	0	0	0	0	0	93	0	0	0	0	0
96	0	0	0	0	0	96	0	0	0	0	0	96	0	0	0	0	0	96	0	0	0	0	0
99	0	0	0	0	0	99	0	0	0	0	0	99	0	0	0	0	0	99	0	0	0	0	0
102	0	0	0	0	0	102	0	0	0	0	0	102	0	0	0	0	0	102	0	0	0	0	0
Sum	38	5	4	31	78		19	1	0	0	20		9	1	0	1	11		0	0	0	3	3

Lanes 51 and 52 reversed

3.4 TRUCK VOLUME

One basic parameter used to evaluate pavement loading is the volume of truck traffic carried by the pavement. While volume is not a direct measure of load, it does provide some relative indication as to whether the loading was light, medium or heavy, and how it varied over time. Also, the operational performance of WIM systems can be monitored by periodically reviewing the recorded hourly truck volumes by hour and by lane.

Figure 3.2 shows hourly truck volumes plotted over a typical one week period for each of the four lanes on DEL 23 using the WIMVolClass spreadsheet, which performed the calculations as follows: 1) delete trucks with Class=1, 2 or 3, W1=0, W2=0, 2) convert weights and spacings on the remaining trucks to English units by dividing weight (W) by 4.536 to obtain kips and dividing distance (S) by 3.048 to obtain feet, 3) sort vehicles by lane and class, and 4) calculate volume by lane and hour, and classification totals by hour. In general, hourly traffic counts showed distinctive 24-hour daily cycles, with the weekend volumes being half or less of the weekday volumes. It is interesting that peaks in the southbound driving lane (Lane 51) were about two hours later than peaks in the northbound driving lane (Lane 11). This lag may have been caused by the difference in driving time between the WIM site and potential departure locations from the south in Columbus and from the north in the Toledo/Detroit area.

Figure 3.3 shows weekly truck volumes plotted from 1/98 to 4/05. Missing data points in the plots reflect an insufficient amount of data available that month to calculate loading, either because the lane was closed for maintenance or testing, or because the WIM was not operating properly. Data missing in Lane 51 between 4/02 and 12/03 was due to the southbound lanes being closed for replacement of the second set of four distressed SPS-1 sections. In summary, the volumes shown for Lanes 11 and 51 were quite similar in shape with both lanes having a slight concave shape and Lane 11 carrying a slightly higher volume than Lane 51. There were some unusually high counts in 2004, especially in Lane 11, and counts in all four lanes were very high in 2005. Trendlines do not include the high volumes recorded in 2005 and the Lane 11 trendline also excludes the high counts recorded from April through September 2004. X in the trendline equations is the number of months after January 1998, which was the starting month in the figure.

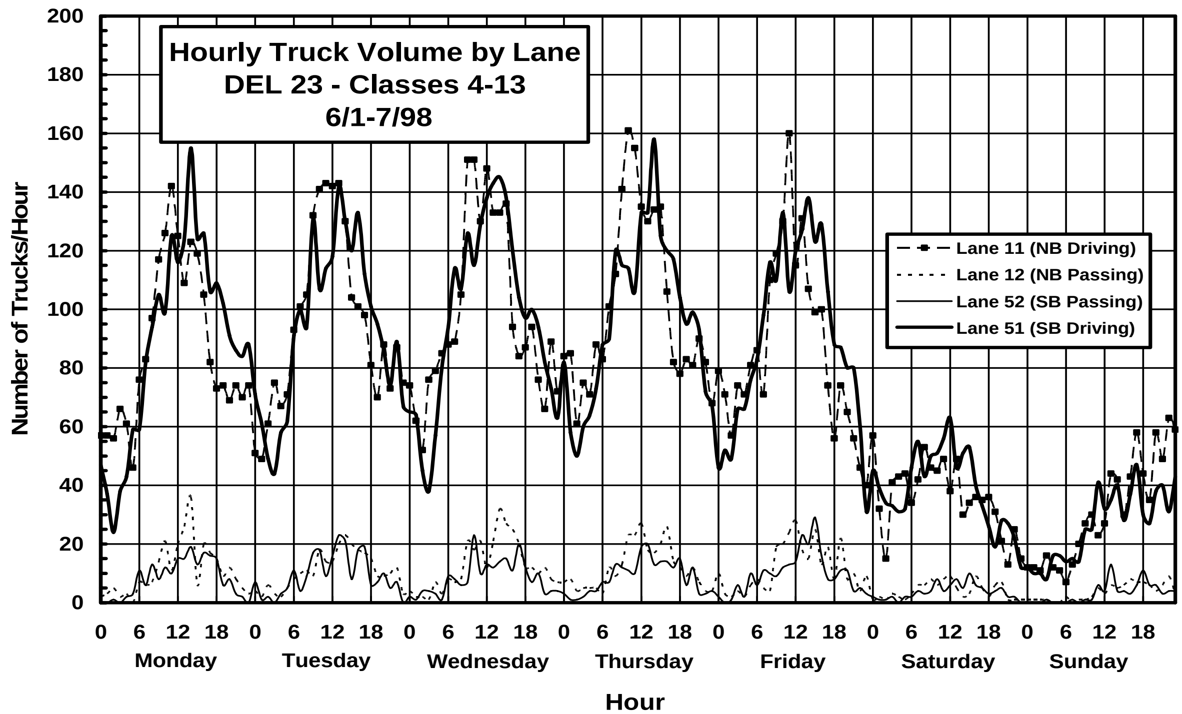


Figure 3.2 – Hourly Truck Volume by Lane

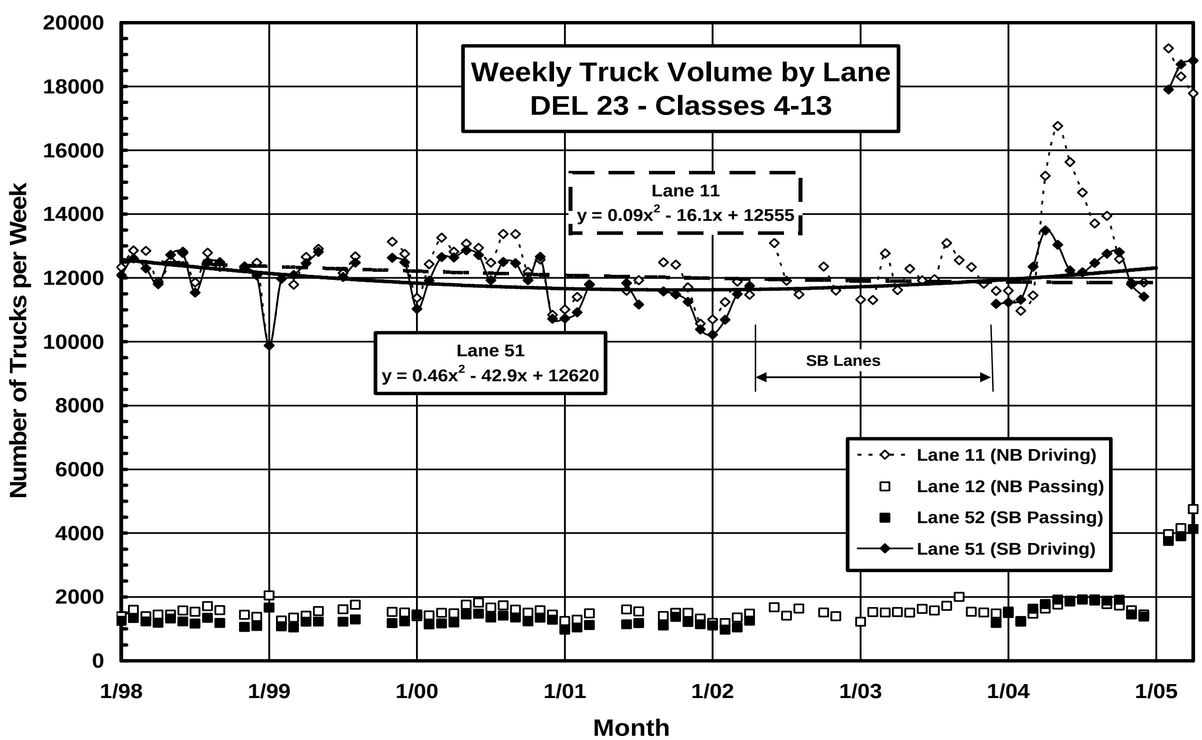


Figure 3.3 – Weekly Truck Volume by Lane

3.5 TRUCK CLASSIFICATION

A second parameter related to pavement loading is the composition of truck classes comprising the traffic stream. Hourly classification data were obtained with the WIMVolClass spreadsheet, which shows the distribution of truck classes by hour of the day and for all four lanes combined. Figure 3.4 shows plots of total weekly truck volumes for all lanes delineated by class. Volume of the various classes of trucks remained relatively constant until the end of 2000 when the number of Class 4 trucks increased and the number of Class 6 trucks decreased. In 2002, the numbers of all classifications fell as the southbound lanes were closed. In 2003, the counts again remained stable. In 2004, the number of Class 4 trucks fell back to pre-2000 levels, and the number of Class 5, 6, 7, 10, 13, 14, and 15 trucks increased substantially. In 2005, all classes returned to what might be considered a normal volume except the Class 4 and 5 trucks which increased dramatically and would account for the increased volumes in Figure 3.3. During the southbound closure from April 2002 – December 2003, total truck counts were reduced and some unexplained spikes appeared for Class 13 trucks.

Because actual changes in traffic loading would tend to develop slowly over time, sudden changes noted for volume and certain classifications of trucks were likely caused either by lane closures, or changes in the WIM system which affected how trucks were classified. WIM problems could have been either a electrical/mechanical malfunction or software changes. To confirm this supposition, ranges of S1 (distance between the first two axles) were plotted in Figure 3.5 for Class 4 and 5 trucks on 2/19/98 when the data appear to be "normal," on 8/5/04 when some significant changes in volume were noted in a number of truck classes, and on 4/21/05 when the volume of Class 4 and 5 trucks jumped dramatically. This figure shows that the range of S1 for Class 4 and 5 trucks in 2005 included vehicles with wheelbases up to four feet shorter than in 1998 and 2004, suggesting that many Class 1, 2 and 3 vehicles may have been included as Class 4 and 5 trucks. ODOT indicated that a number of software alterations had been incorporated into the WIM software since 2001. These changes likely accounted for many of the variations observed here for truck volumes and truck classifications.

Two other items of interest appear in Figure 3.4; 1) a well defined seasonal cycling of Class 8 trucks prior to 2001 when summer peak volumes were twice the magnitude of the winter valleys, and 2) a relatively constant percentage of Class 9 trucks in the traffic stream.

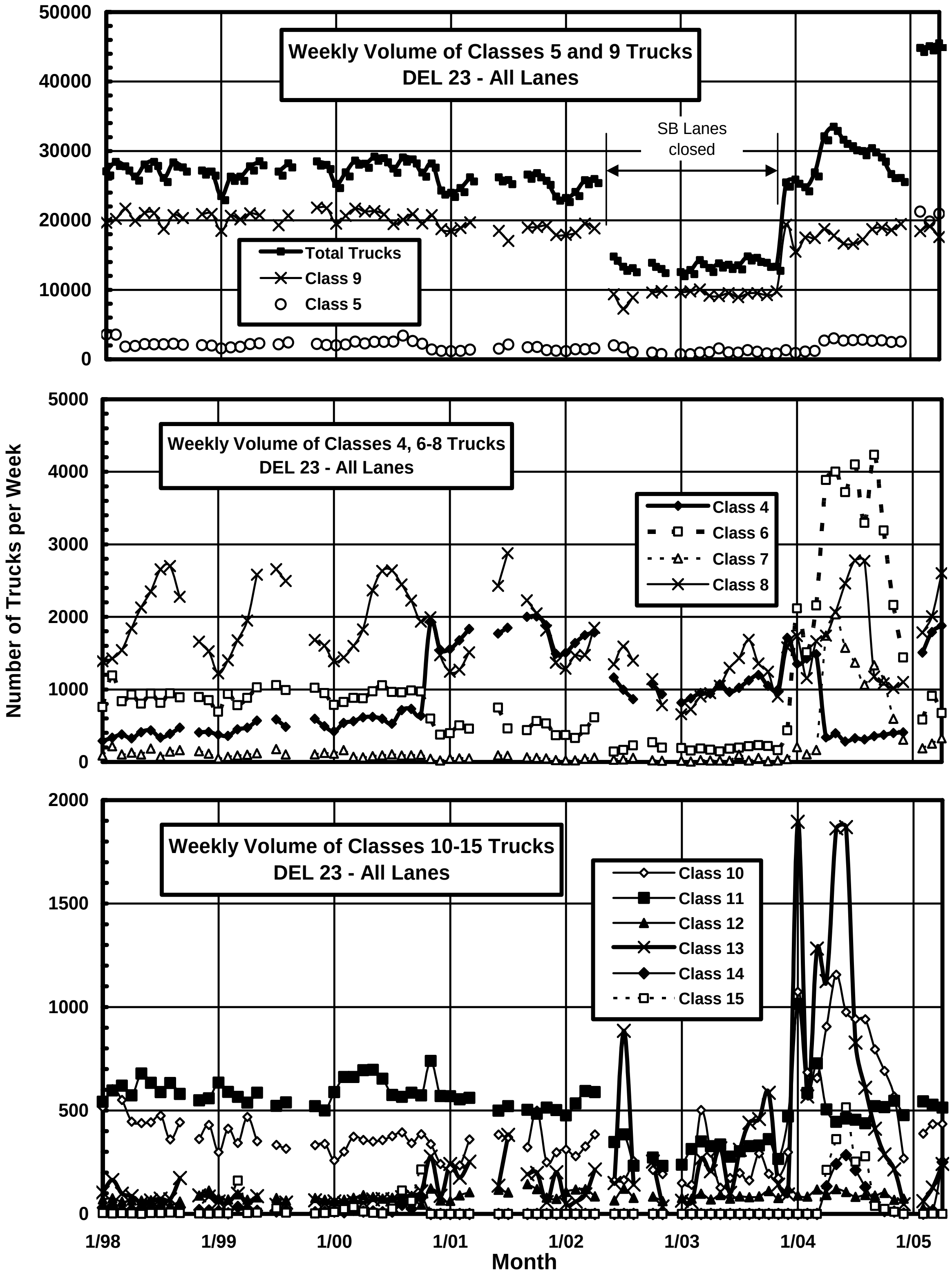


Figure 3.4 – Weekly Truck Volume by Classification

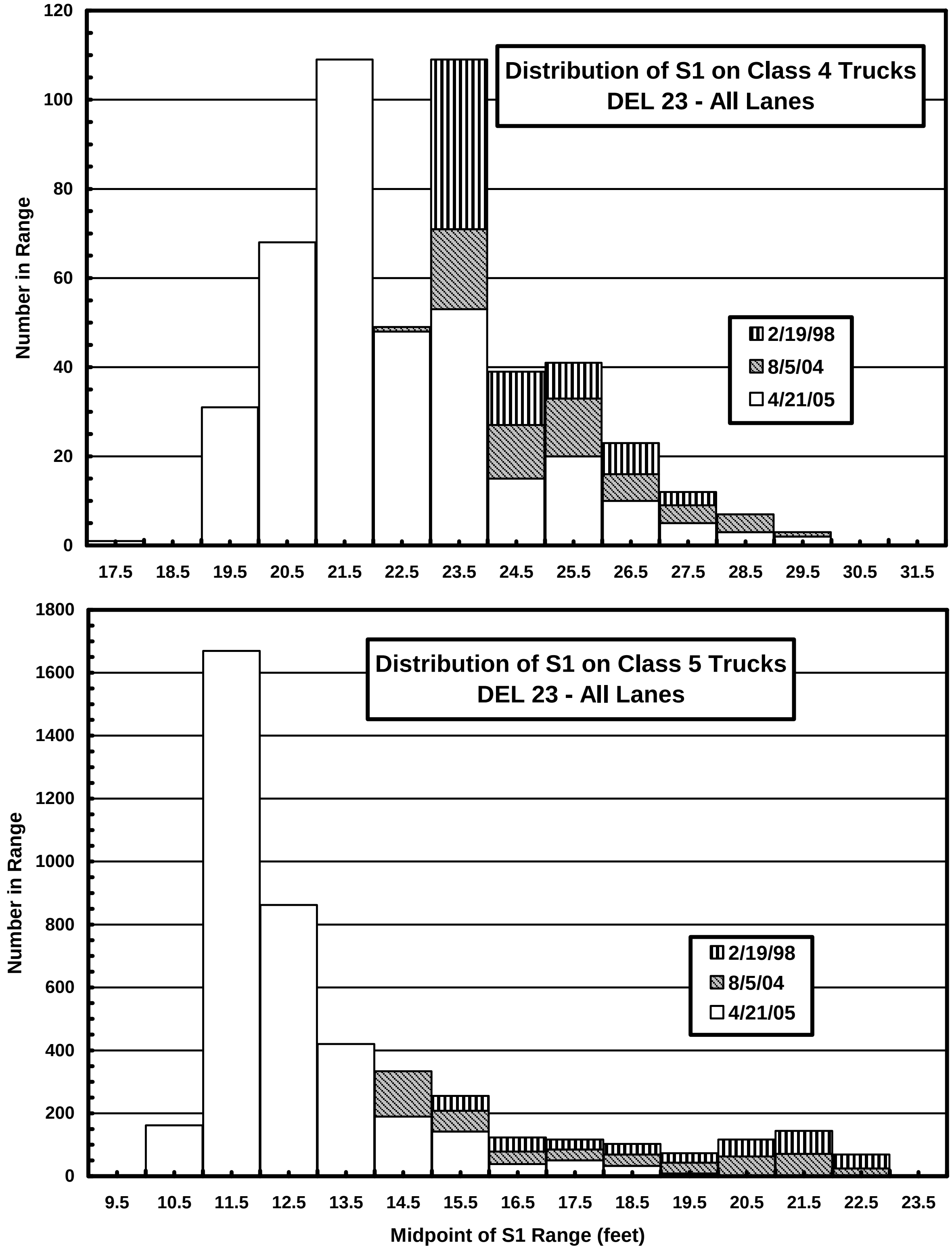


Figure 3.5 – Range of S1 for Class 4 and 5 Trucks

3.6 TRUCK WEIGHT

Total accumulated truck weight is a more direct parameter for quantifying pavement loading than volume or classification, though it does not address the issue of grouped axles (single, tandem, tridem, etc) to distribute load. Figure 3.6 shows the variation of total hourly truck weight carried in each of the four lanes of traffic for a typical week. Hourly weight was determined by sorting gross vehicle weight by lane and by hour. As with volume, there were distinctive 24-hour cycles, with weekend weights being less than half of the weekdays. The two-hour lag in southbound peaks noted for volume was also present for weight.

Figure 3.7 shows accumulated weekly weights plotted over the seven-year long collection period. The gentle concave shape of the plots is similar to that shown earlier for volume. These data indicate that more weight was consistently carried in Lane 51 than in Lane 11, even though there were fewer trucks in Lane 51, indicating that the average truck weight was higher in Lane 51 than in Lane 11. This is confirmed in Figure 3.8 where average weight per truck is plotted for Lanes 11 and 51, with the average weight for Class 9 trucks in all lanes being added for comparison. Because irregularities in the weekly truck volumes and classifications for 2004 and 2005 are not apparent in the weight data, they were likely associated with the lighter vehicles.

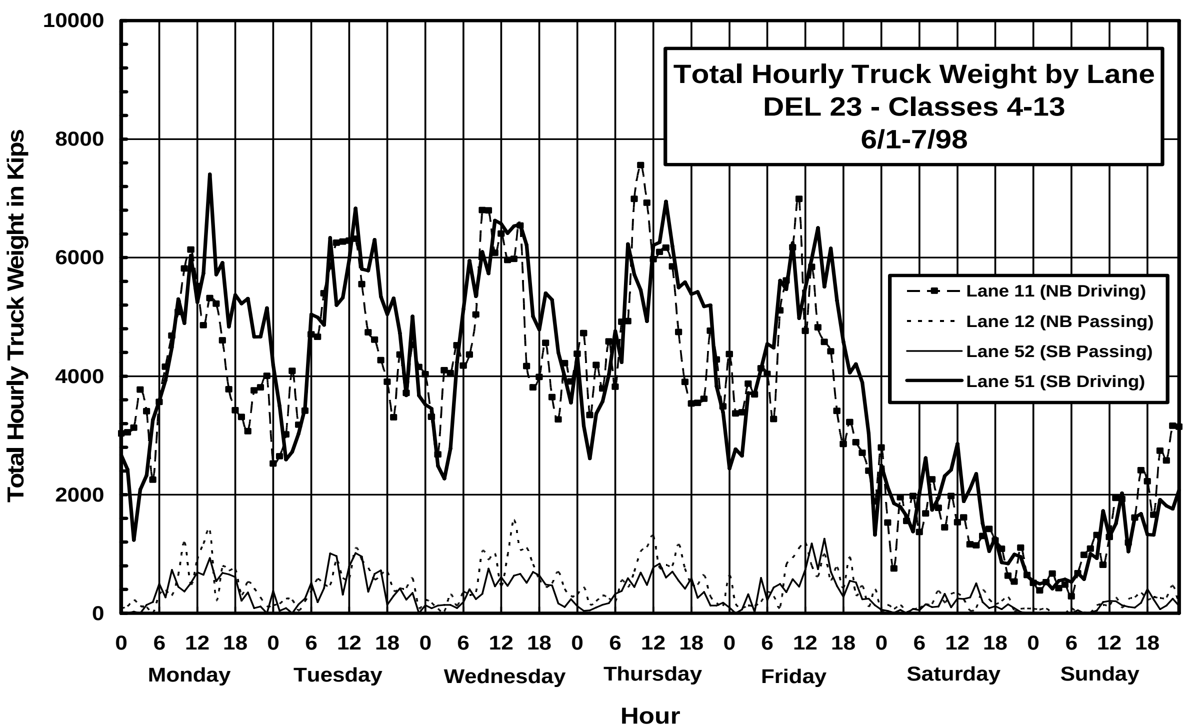


Figure 3.6 - Total Hourly Vehicle Weight Carried by Lane

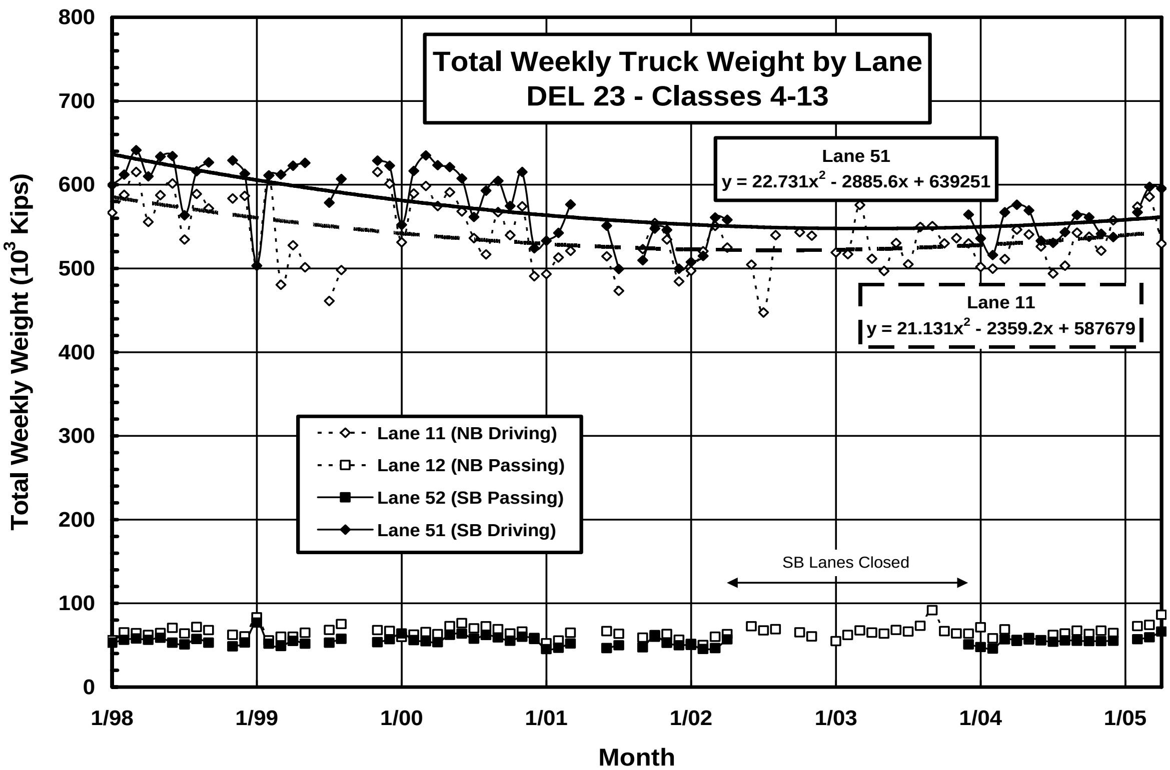


Figure 3.7 - Total Weekly Truck Weight by Lane

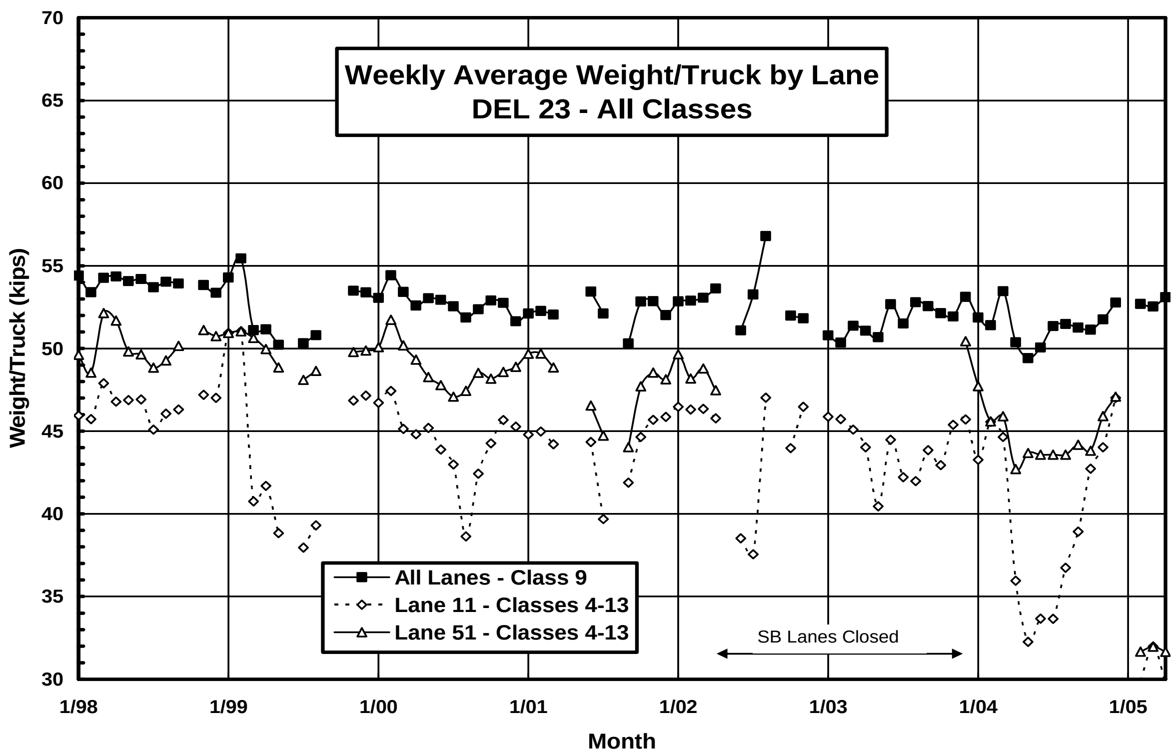


Figure 3.8 – Average Truck Weight

3.7 TRUCK ESALS

ESALs were developed from the AASHO Road Test in the 1960's as a methodology for comparing the effects of different axle configurations and loads with the effects of a single-axle 18-kip load on pavement performance. In the WIMWtESAL spreadsheet, ESALs were calculated by: 1) grouping valid truck axles using eight feet as the maximum distance between grouped axles, 2) summing the weights within each axle grouping, 3) calculating ESALs for each axle grouping using AASHTO equations, average structural parameters for the AC (SPS-1) and PCC (SPS-2) pavement sections, total group weight and the number of axles in the group, and 4) summing ESALs for each truck.

Figure 3.9 shows total hourly ESALs calculated for the week of June 1-7, 1998 and Figure 3.10 shows total weekly ESALs collected from 1/98 to 4/05. The concave shape for total weekly ESALs shown for Lane 11 in Figure 3.10 agrees better with corresponding trends for volume and weight than does the trend of ESALs in Lane 51 which continued to decrease over time. While much of the difference between the number of ESALs in Lanes 11 and 51 is in how ESALs are calculated for PCC and AC pavement, the problems noted above for classifications in 2004 and 2005 may have contributed to the difference by affecting how axles were grouped and ESALs calculated using various logarithmic and power functions in the formulae. The trendline shown for Lane 11 does not include the erratic data in 1999 and neither trendline includes the 2005 data. Figure 3.11 shows the average weekly number of ESALs per truck by lane for all truck classes and for Class 9 trucks. Again, the differences between Lane 11 and Lane 51 are, at least partially, due to differences in the formulae used to calculate ESALs on flexible and rigid pavements.

ESALs were calculated using the following structural parameters for concrete: thickness (D) = 9.5" (24.1 cm), which was the average of the 8 and 11-inch (20.3 and 27.9 cm) thick pavements in the SPS-2 experiment, initial serviceability (p_i) = 4.2, terminal serviceability (p_t) = 2.5, and serviceability at failure (p) = 1.5. Asphalt pavement parameters included a structural number (SN) of 4.75, which was average for build-ups in the SPS-1 experiment, p_i = 4.5, p_t = 2.5, and p = 1.5. These parameters are included as input to the WIMWtESAL spreadsheet and can be changed at any time.

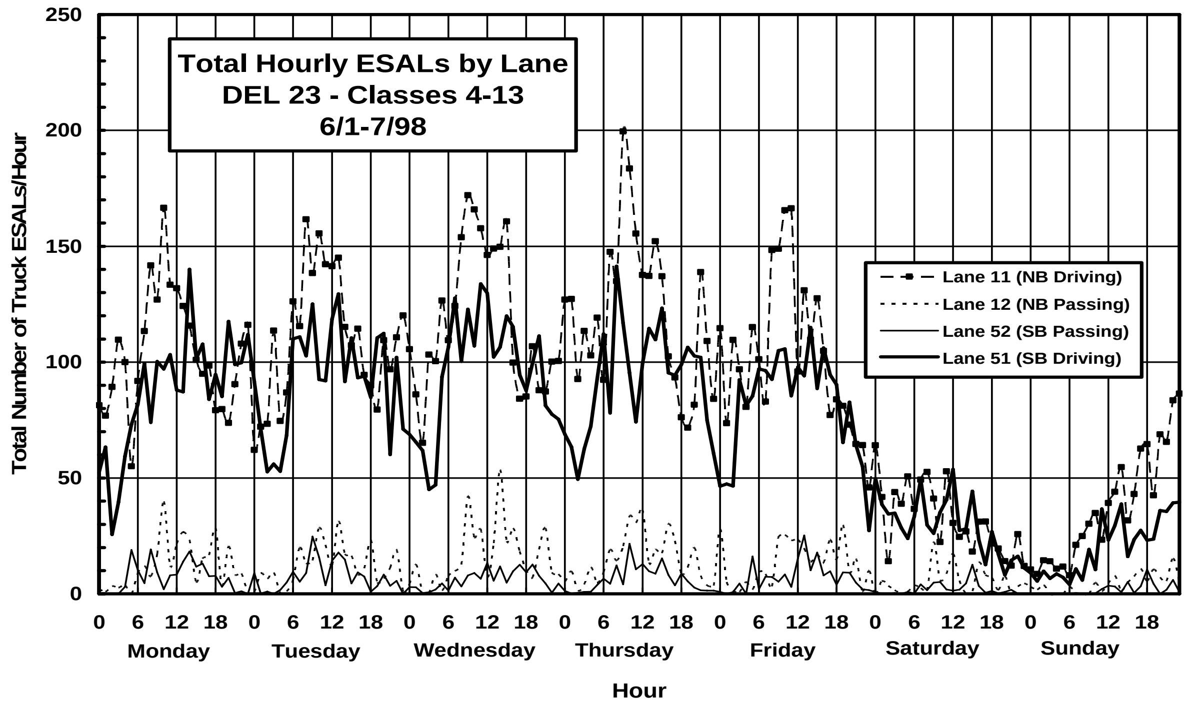


Figure 3.9 - Total Hourly ESALs Carried by Lane

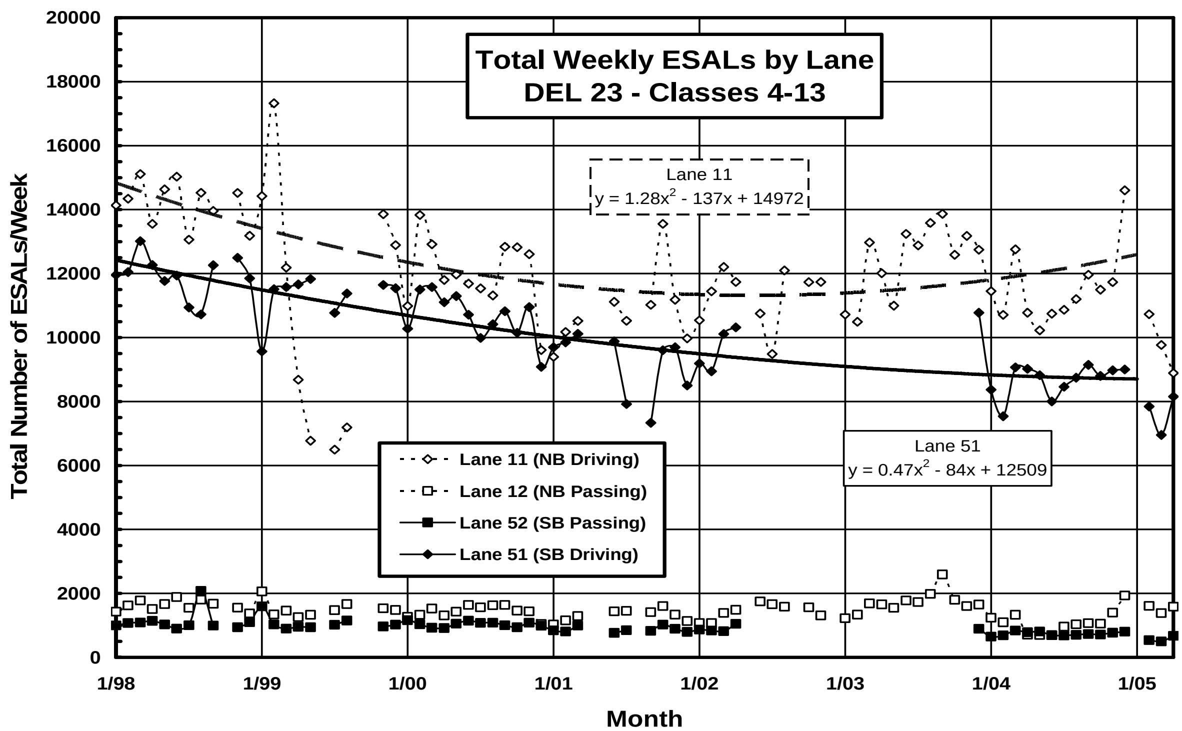


Figure 3.10 - Total Weekly ESALs by Lane

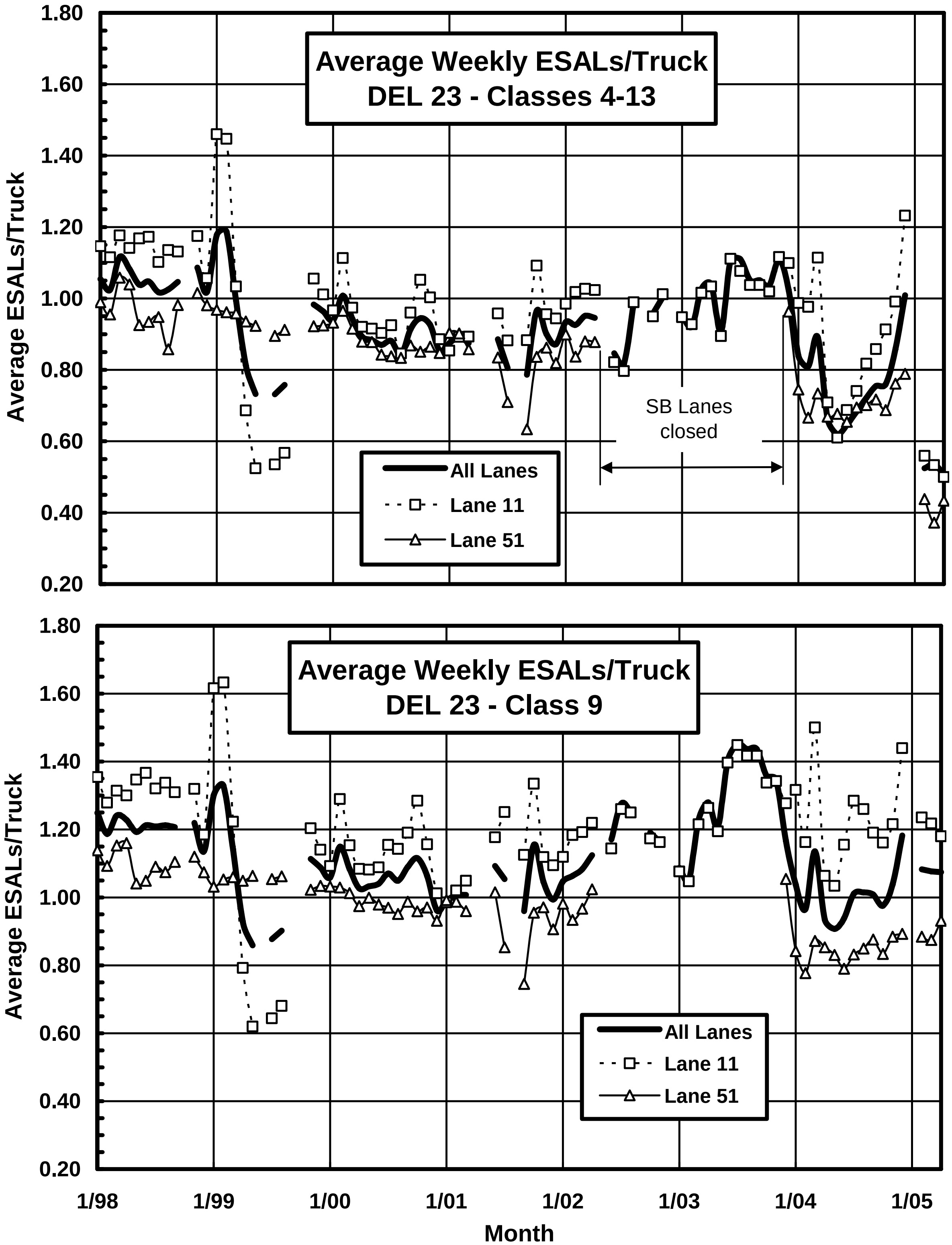


Figure 3.11 – Average ESALs per Truck

3.8 TRUCK LOAD SPECTRA

Load spectra is another approach to account for the effects of grouped axles on pavement performance by determining, for each truck classification, the number of single, tandem, tridem, quad, penta and hex axles that fall within various bins of a standard loading array established for each axle configuration. In this study, a modified load spectra, where all truck classifications and all tridem, quad, penta and hex axles were combined, was used to evaluate pavement loading. Load spectra trends were evaluated by monitoring the weekly totals for each axle configuration, and the weekly distributions of axles in the various load bins assigned to each axle configuration.

To calculate load spectra with the WIMLoadSpectra spreadsheet, all truck axles were assigned a configuration (single, tandem, etc.) by using eight feet as the maximum distance between grouped axles, and each configuration was assigned a group number based upon truck axle geometry and the position of that grouping on the truck. These axle configurations and groupings were then sorted by lane. Frequency distributions were run to assign each axle grouping under each axle configuration and lane into predetermined loading bins. Bins for the same axle grouping and configuration were summed to obtain a total number of axle configurations for each bin in each lane.

An analysis was performed to evaluate trends of how weekly bin totals for the various individual axle configurations varied over time. Plots of the total weekly number of axle configurations for all truck classes are shown in Figures 3.12, 3.13 and 3.14. These data show: 1) a slight concave shape for single axles with a sharp increase in 2005 for both lanes, 2) a steady decline in tandem axles, 3) a concave shape for tridem axles with increased variability and a higher number of tridem axles in 2004, 4) a low but somewhat variable number of quad axles, especially in Lane 11, 5) with the exception of Lane 11 in March and April of 2003 and during most of 2004, a relative small but stable number of penta axles, and 6) a small, but variable number of hex axles with an increase in 2004. With the exception of a few months, the number of axles recorded for each configuration was similar in Lanes 11 and 51, especially for single, tandem and tridem axles. The number of quad, penta and hex axles was rather small, leaving variability between the lanes to be more pronounced. The increase of single axles in 2005 resulted from the increase in Class 4 and Class 5 trucks discussed earlier.

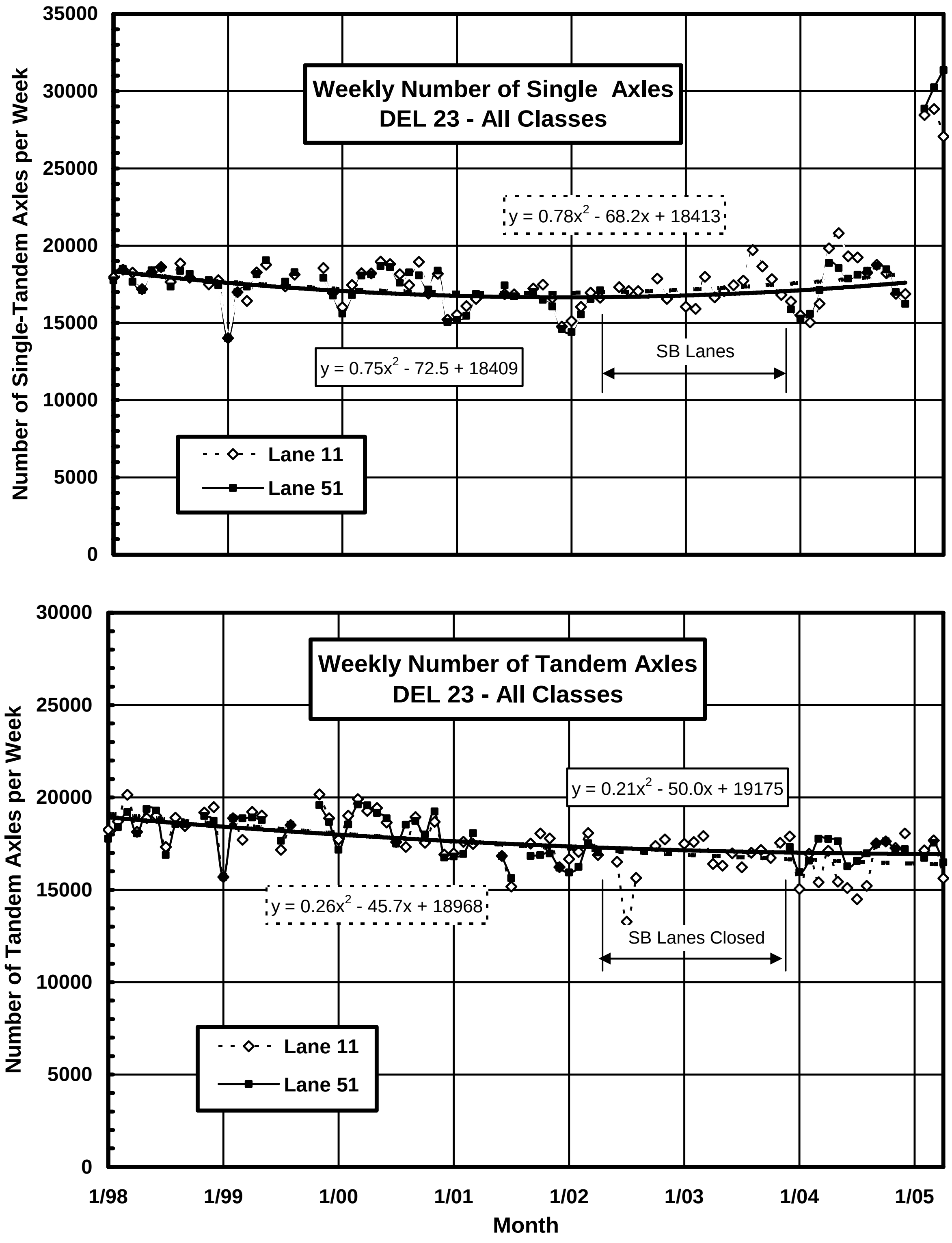


Figure 3.12 – Weekly Volumes of Single and Tandem Axles

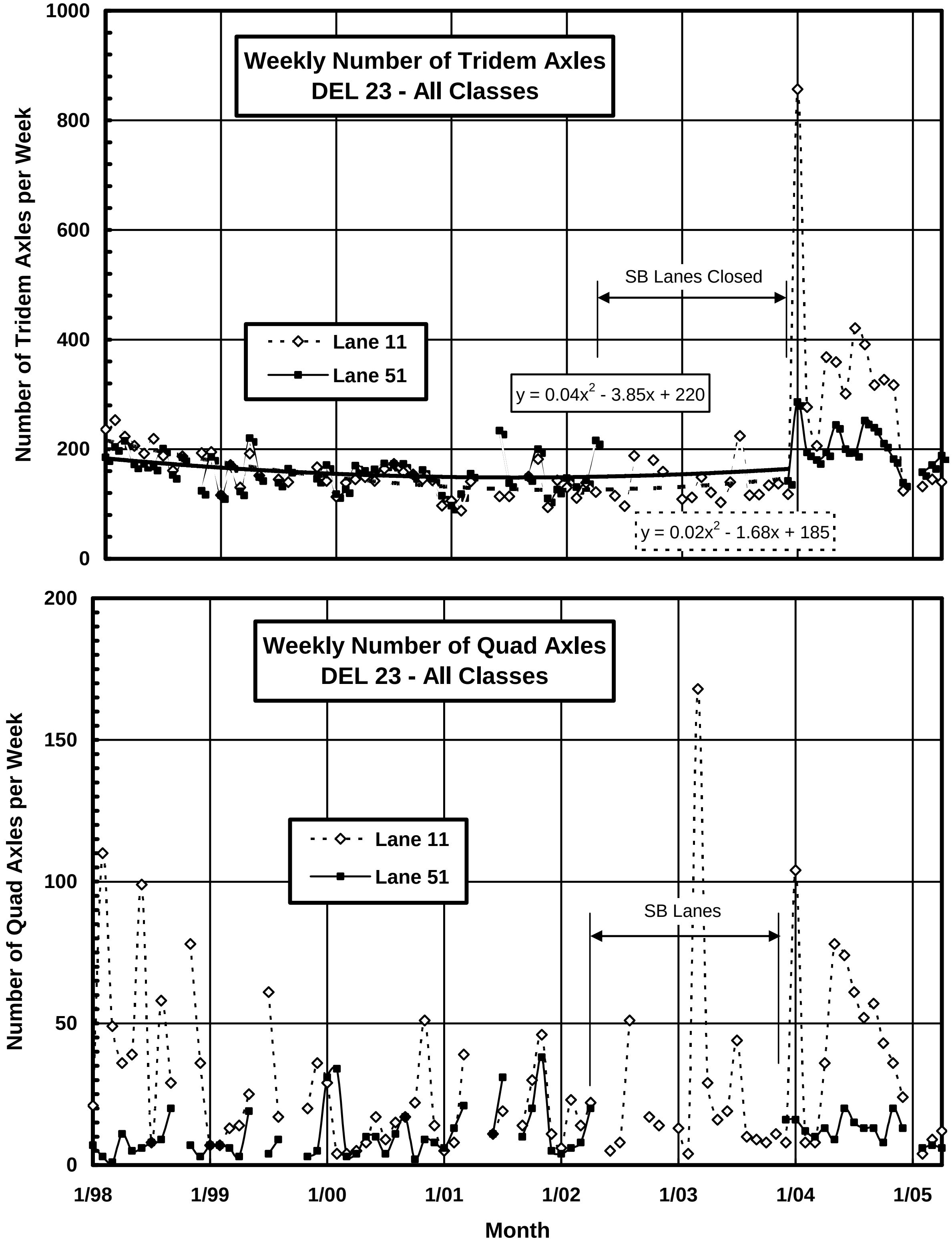


Figure 3.13 – Weekly Volumes of Tridem and Quad Axles

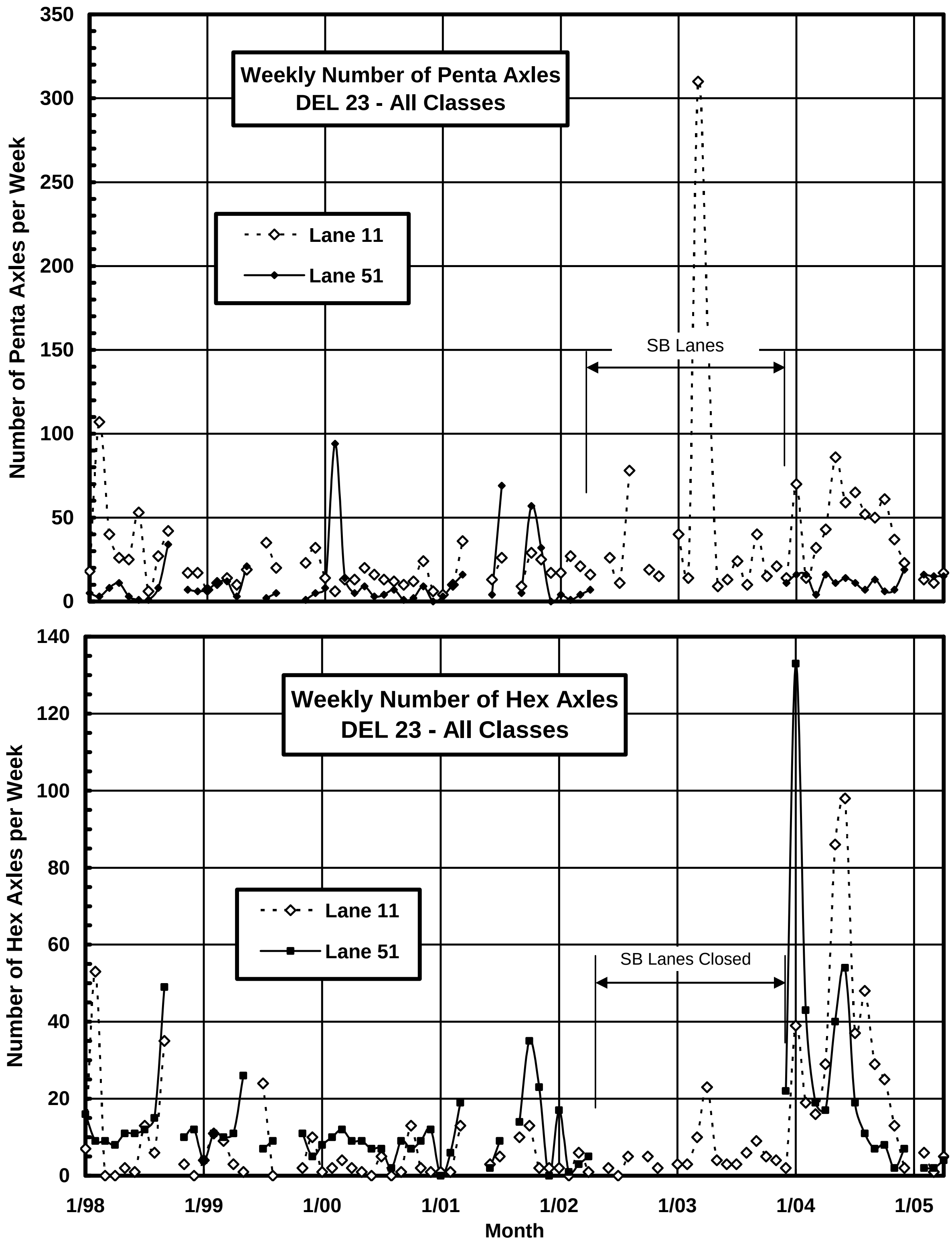


Figure 3.14 - Weekly Volumes of Penta and Hex Axles

Load spectra data are commonly viewed as histograms showing the population of load bins for various axle configurations in each truck classification. Changes in bins with the highest population of axles are indicative of changes in average truck weight, especially for Class 9 trucks which often comprise most of the truck traffic on many pavements. Of particular interest are single axle data which include the steering axles on Class 9 trucks. Unfortunately, only a few data sets can be viewed on a one histogram, whether they consist of hourly, daily, weekly, monthly or yearly data. Continuous plots of the load bins with the higher populations provide the ability to view more data, and determine trends over time. Selected dates can then be observed in histograms.

Figure 3.15 shows weekly single-axle load spectra for all trucks in Lanes 11 and 51 plotted over the seven-year test period. Low volume load bins were omitted from the graphs to reduce clutter and provide a better view of the more prominent bins. The 10 and 11 kip bins for single axles in Lane 11 were about equal and contained the highest weekly volume of axles. These bins also showed the same concave shape over time as did the total weekly volume and weight plots presented earlier. Also of interest in this plot is: 1) the short-term drop in the number of axles in the 10 and 11 kip bins and the increase in the number of axles in the 9 and 12 kip bins early in February and March of 1999, 2) the increase in the number of 3 and 4 kip axles in both lanes in 2004, 3) the reversal of the 11 and 12 kip bins in Lane 51 in 2004, and 4) the dramatic increase in the number of 3 and 4 kip axles in both lanes again in 2005. The highest populated bins in Lane 51 were consistently heavier than the highest populated bins in Lane 11, indicating a higher average truck weight in Lane 51.

Multiple-axle groupings typically have two peaks in the array of loading bins, one for unloaded conditions and one for loaded conditions. Figure 3.16 shows bins having the highest number of unloaded tandem axles in Lanes 11 and 51, and Figure 3.17 shows bins having the highest number of loaded tandem axles in Lanes 11 and 51. While both lanes have about the same number of unloaded tandem axles in the 12 and 14 kip bins, Lane 51 has more axles in the 16 kip bin and fewer axles in the 10 kip bin. For loaded tandem axles, Lane 51 has fewer 32 kip tandem axles, but more 36 kip tandem axles. This trend again suggests higher truck weights in Lane 51. The same short-term aberrations observed for single axles in Lane 11 in early 1999 and for both lanes in 2004 repeated for tandem axles, but the sharp increases in 2005 did not occur.

The relatively small numbers of tridem, quad, penta and hex axles were combined for simplicity of discussion and, as with the tandem axles, they have peaks representing loaded and unloaded conditions. Figures 3.18 and 3.19 show the heaviest populated load spectra bins for unloaded and loaded tridem-hex axles, respectively, in Lanes 11 and 51. Again, the low volume bins are not shown to reduce clutter. Figure 3.18 shows a very consistent number of unloaded tridem-hex axles from 1998 through 2003. In 2004, there were large increases in the number of axles for all bins shown. In Lane 11, the number of 12 and 14 kip axles was about equal and comprised the largest numbers of unloaded tandems. Lane 51 consistently had a higher number of 18 kip axles than Lane 11, again suggesting higher accumulated truck weights in Lane 51. For loaded tandems in Figure 3.19, the population of the various load bins was similar, but somewhat variable in Lanes 11 and 51, with the exception of the first half of 1998 when there was an unusually high number of 42 kip axle configurations in Lane 11, and in 2004 and 2005 when there was a large number of 42 kip axle configurations in Lane 51.

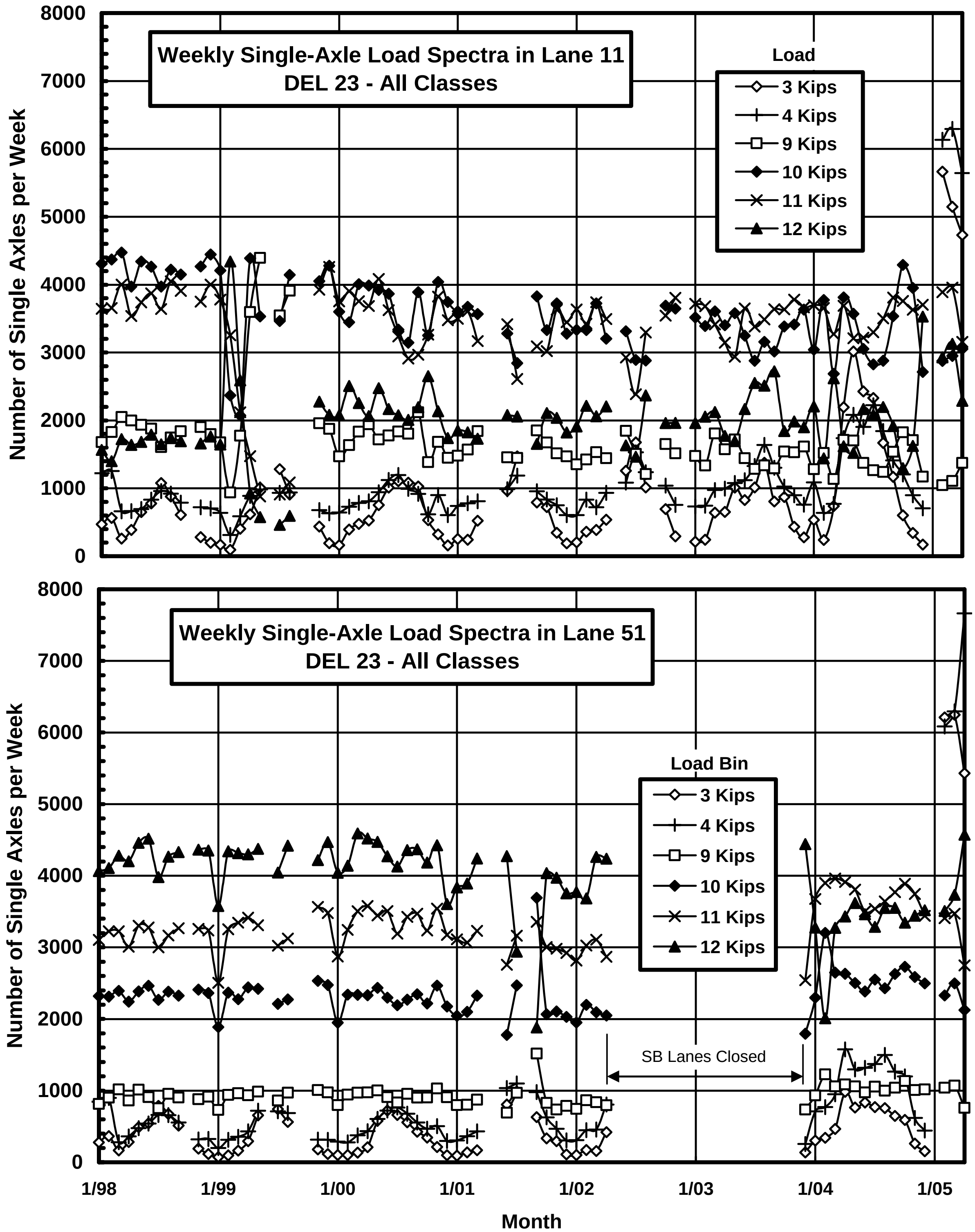


Figure 3.15 – Single-Axle Load Spectra

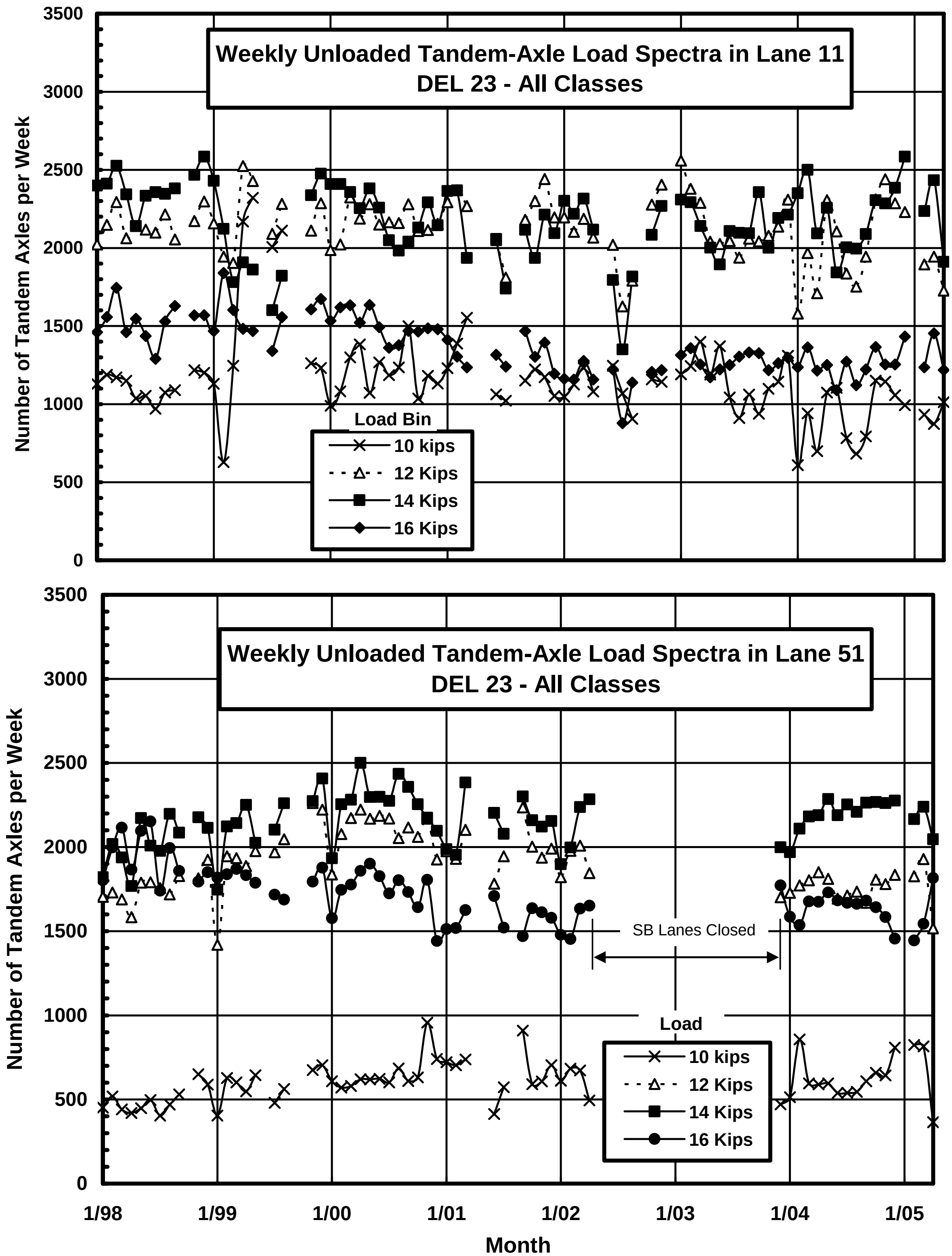


Figure 3.16 – Unloaded Tandem-Axle Load Spectra

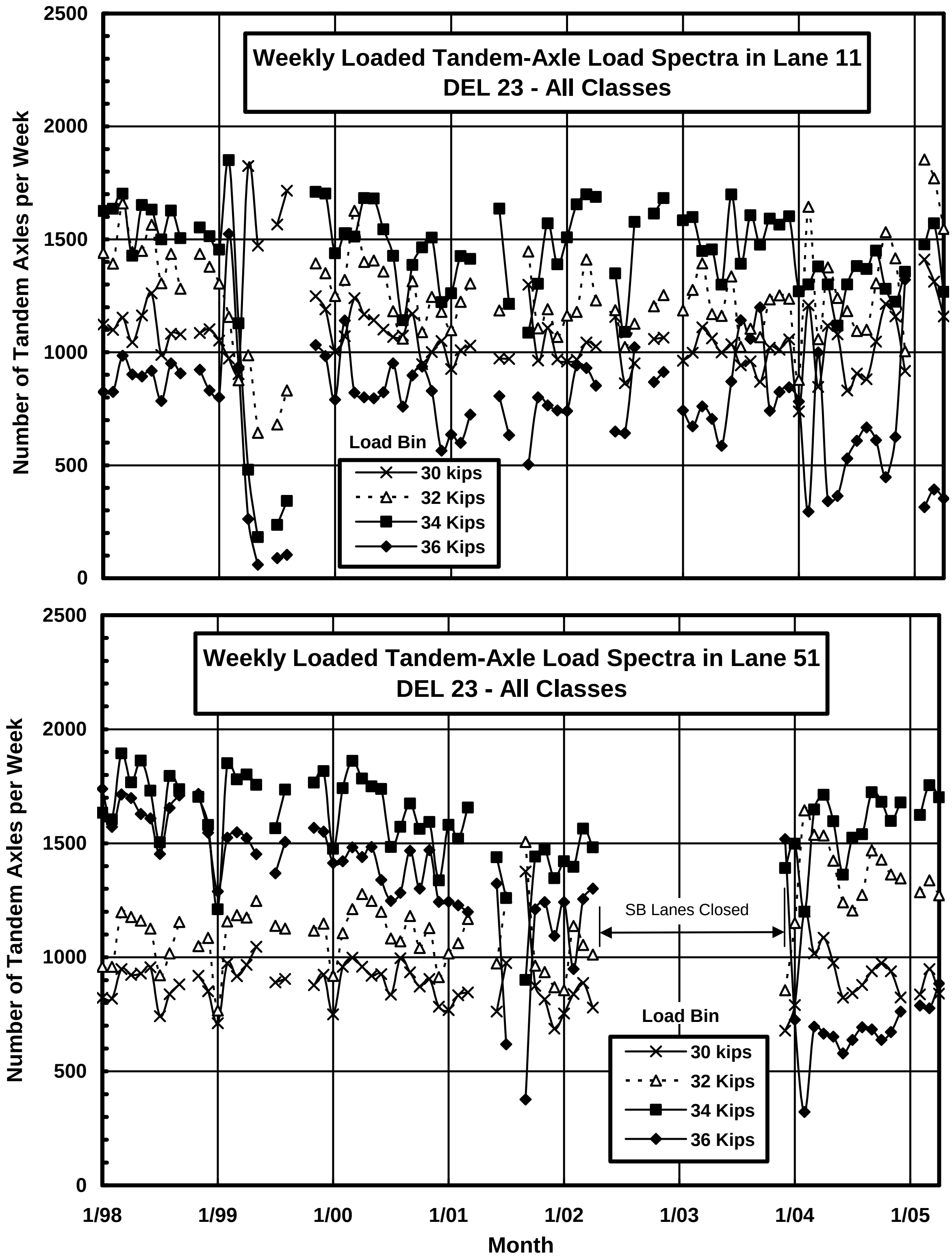


Figure 3.17 – Loaded Tandem-Axle Load Spectra

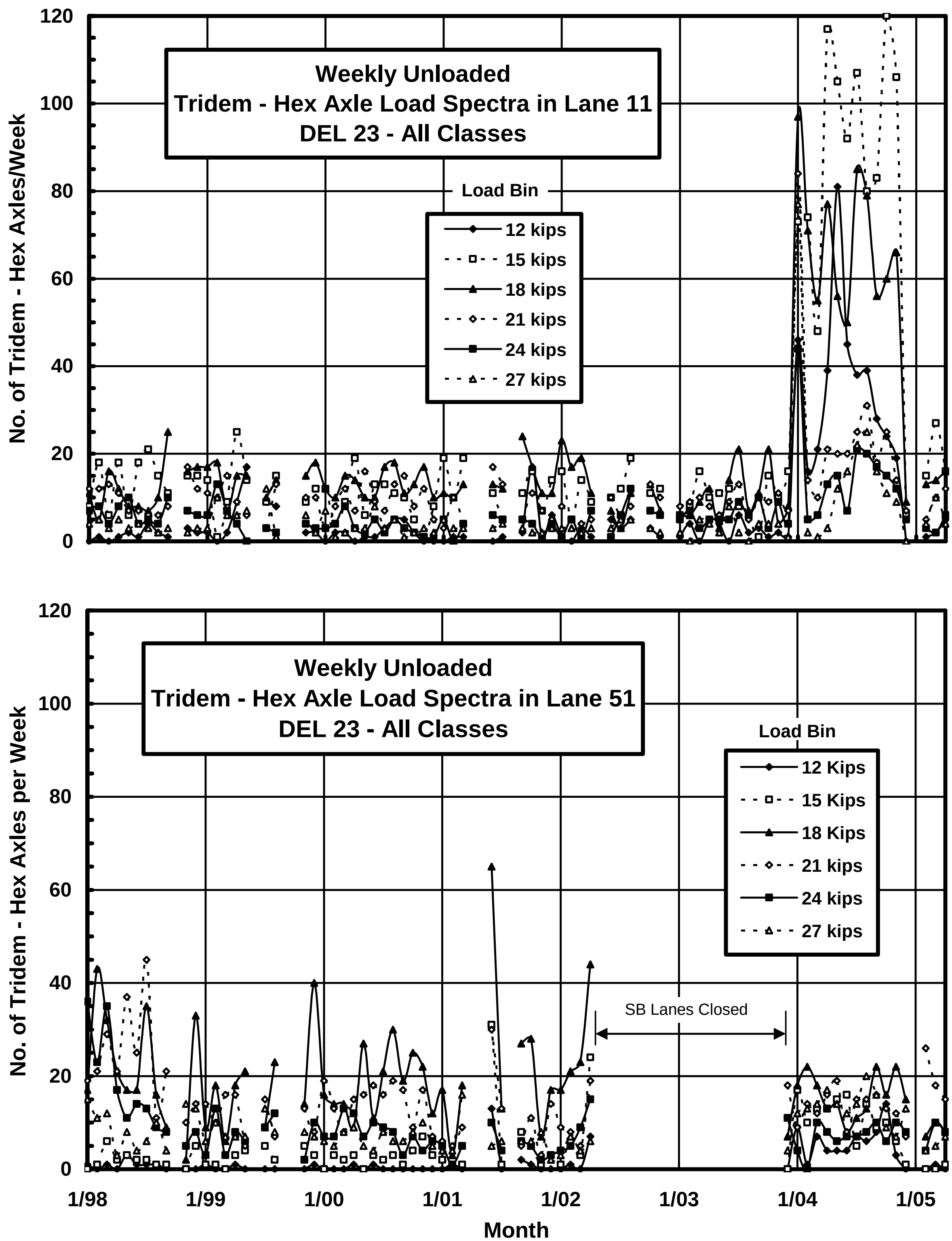


Figure 3.18 – Unloaded Tridem–Hex Axle Load Spectra

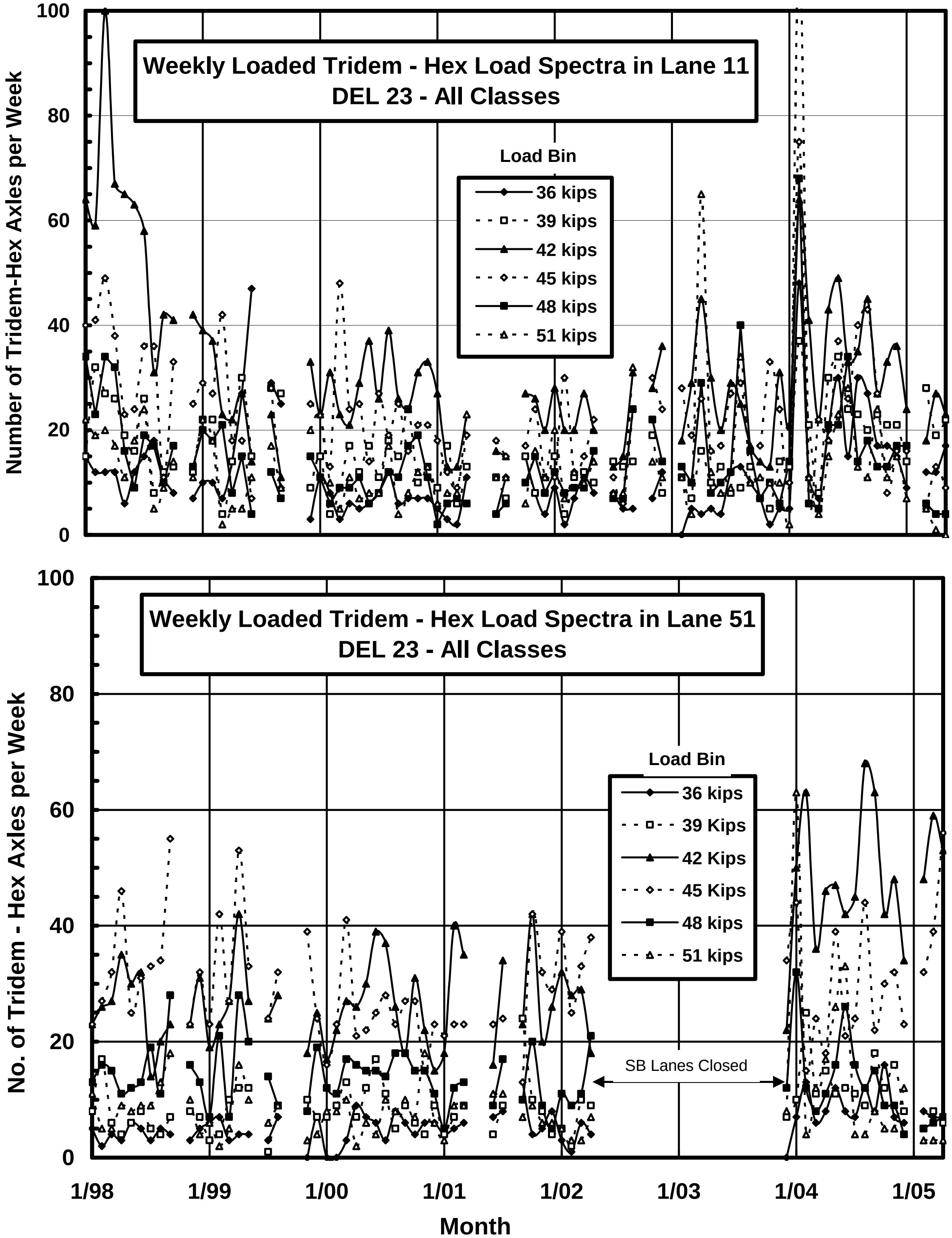


Figure 3.19 – Loaded Tridem–Hex Axle Load Spectra

3.9 SUMMARY OF CONCLUSIONS FROM TIME PLOTS

In the time graphs presented above where weekly volume, classification, weight, ESALs and load spectra are plotted over time, there are various trends and changes that offer some insight as to traffic loading on the Ohio SHRP Test Road from January 1998 to April 2005, and to the functionality of the WIM during that period of time. In general, there were three types of changes observed in the data; 1) actual changes in traffic loading characterized either by gradual trends over a period of years or repeatable annual cycles, 2) statistical variations characterized by a uniform scattering of data over time, and 3) abrupt changes associated with electrical or mechanical malfunctions, or with new software installed in the WIM. WIM problems persisted until changed or corrected in the field. When changes occurred, it then becomes necessary to determine whether the data obtained before or after the change are most accurate. Figures 3.2 - 3.18 may be summarized, as follows:

Figures 3.2, 3.6 and 3.9 - These hourly plots of volume, weight and ESALs over a week show daily cycles with peak loading occurring at midday and minimum loading occurring very early in the morning. Weekdays are heavier than weekends.

Figure 3.3 - Weekly truck volumes were high in 2004, especially in Lane 11, and much higher in all four lanes in 2005. These increases appear to be related to the inclusion of Class 1, 2 and 3 vehicles as trucks.

Figure 3.4 - In November 2000, the volume of Class 4 trucks increased dramatically and the number of Class 6 trucks dropped. The number of Class 14 and 15 trucks also fell to zero, indicating a change in the way the WIM classified trucks. In 2004, the volume of Class 4 trucks dropped off and the number of Class 5, 6, 7, 10 and 13 trucks increased. Class 14 and 15 trucks also showed an increase. In 2005, the number of Class 4 and 5 trucks showed a sharp increase and the number of Class 6 and 7 trucks fell. Figure 3.5 shows a clear shift toward vehicles with shorter wheelbases being included as Class 4 and 5 trucks in 2005.

Figure 3.7 - This plot of weekly lane weights shows a gradual concave shape with what appears to be normal statistical variation along the curves. This shape is consistent

with trends observed at other sites around the state and is considered to be indicative of loading at this site. A few low points were present in 1999.

Figure 3.8 - The calculated weights per truck appear to be reasonably accurate, with a few low points showing up in Lane 11. These low points are consistent with corresponding points for Lane 11 in Figure 3.7.

Figure 3.10 - Weekly ESALs had an overall shape similar to volume and weight with low ESAL counts showing up for Lane 11 in 1999 and 2005. The shape for Lane 51 was also consistent with volume and weight, except for low counts in 2004 and 2005. The main difference between ESALs carried in the northbound lanes (11 and 12) and the southbound lanes (51 and 52) was the formula used to calculate ESALs which gives more credit to concrete pavement.

Figure 3.12, 3.13 and 3.14 - Regarding load spectra on the test road, the number of single axles was very high in both driving lanes in 2005, probably due to smaller vehicles being classified as trucks. While the volume of tandems was stable throughout, tridems were high in 2004, especially in Lane 11, more quad and penta axles consistently appeared in Lane 11 than in Lane 51, and the number of hex axles was quite high in both driving lanes in 2004.

Figure 3.15 - The volume of lightweight single axles (3-4 kips) was high in 2005, consistent with the increased number of Class 4 and 5 trucks.

Figure 3.17 - The number of loaded tandem axles counted in Lane 11 took a sharp drop in 1999, consistent with the reduced number of ESALs calculated in that lane.

Figure 3.18 - In Lane 11, the number of lightweight tridem-hex axles was exceptionally high in 2004. In Lane 51, the number of 42 kip tridem-hex axles also increased, but not as much as in Lane 11.

While most of the problems with traffic loading on the test road occurred in 2004 and 2005, and seemed to be attributable to misclassification by the WIM, it is not known whether the problem was caused by system malfunctions or incorrect programming at the site. Overall, the curves in Figure 3.7 showing total weekly weight appear to be a reliable indicator of loading.

3.10 ACCUMULATED ESALS

The most obvious method for calculating accumulated ESALs is to expand total weekly ESALs for the entire month and sum the monthly totals. The potential problem with this approach is the steady decline of weekly ESALs in Lane 51 after the year 2000 without similar declines being noted in Lane 11 ESALs or in Lane 51 weight. Another approach is to plot weekly ESALs versus weekly weight which appears to be reasonably valid throughout and, if a reasonable correlation exists, calculate weekly ESALs from weekly weight, adjust weekly ESALs for the month and sum the monthly totals. Figure 3.20 shows excellent correlations between weekly ESALs and weekly weight for AC and PCC pavements, with the AC pavements showing more weight and PCC pavements showing more ESALs. The AC correlation included only 1998-2000 data to avoid the questionable data in Lane 51 after 2000.

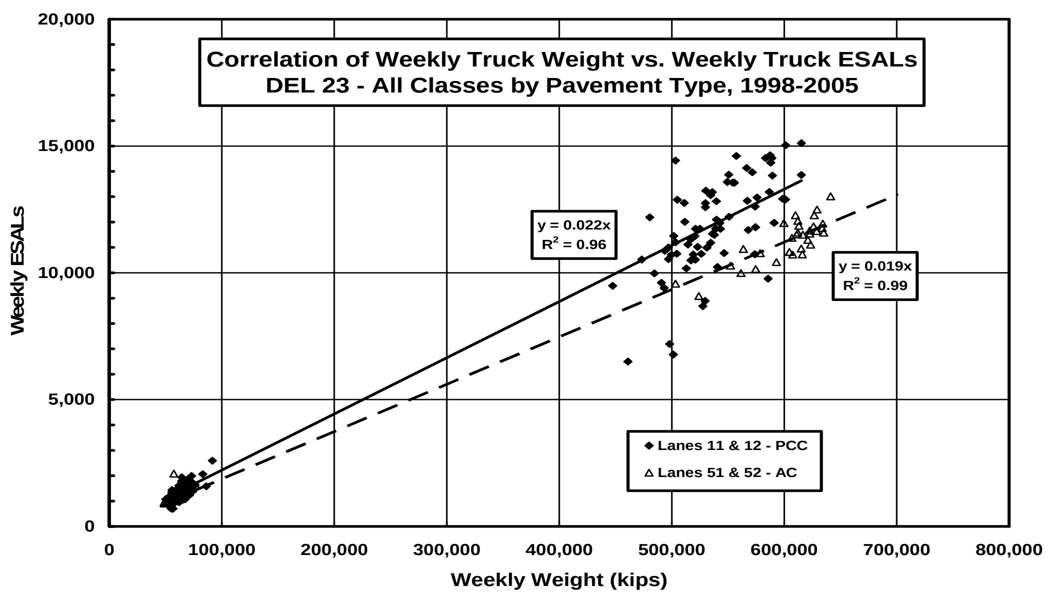


Figure 3.20 – Weekly ESALs vs. Weekly Truck Weight

Using the relationships shown in Figure 3.20 for weekly ESALs and weights, and the corresponding equations for weekly weight versus time shown in Figure 3.7, the number of calculated ESALs accumulated over time in Lanes 11 and 51 are shown in Figure 3.21. On an earlier research project (5), it was estimated that 857,800 and 807,000 ESALs had accumulated in Lanes 11 and 51, respectively, by 12/31/98, which is where these updated projections begin.

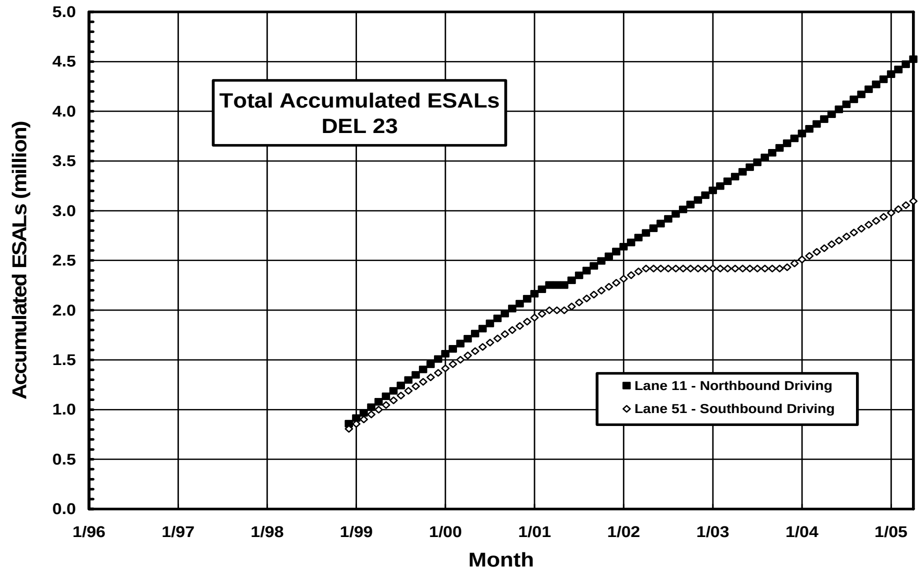


Figure 3.21 – Accumulated ESALs

It is estimated that, by April 30, 2005, a total of 4,523,400 and 3,096,100 ESALs had been carried in Lanes 11 and 51, respectively, using the weight vs. ESAL correlations in Figure 3.20, while totals using the ESAL equations in Figure 3.10 exclusively from 1/1/99 were higher at 4,698,900 and 3,165,100 ESALs. Although ESAL loadings were slightly nonlinear in both lanes, they can be roughly approximated at 620,000 ESALs/year in Lane 11 and 515,000 ESALs/year in Lane 51. Using the ESAL loading shown in Figure 3.21 for Lane 51, the total number of ESALs accumulated to the time eight distressed SPS-1 sections were closed for replacement is shown in Table 3.9. By 2/16/06, when the northbound lanes were closed for replacement of seven SPS-2 sections, 5,014,200 ESALs had been accumulated in Lane 11.

Table 3.9

ESAL Loading to Failure for SPS Sections

Section No.	Structural Number SN	Date Closed	Total Accumulated ESALs	Section No.	Structural Number SN	Date Closed	Total Accumulated ESALs
390102	4.16	9/3/96	33,000	390103	4.20	4/24/02	2,413,200
390107	2.52	9/3/96	33,000	390108	4.13	4/24/02	2,413,200
390101	3.57	12/3/96	170,000	390109	4.69	4/24/02	2,413,200
390105	3.36	5/29/98	510,000	390110	4.41	4/24/02	2,413,200

3.11 CLASS 9 TRUCKS

As observed earlier, Class 9 trucks (i.e. standard 18 wheelers) comprised the vast majority of trucks in the DEL 23 traffic stream. Figure 3.22 summarizes the percentage of Class 9 loading for all lanes combined on the test road expressed as volume, weight and ESALs. Class 9 weight and ESALs were more than 80% of the total, with the percentage of ESALs being slightly higher than the percentage of weight. The volume of Class 9 trucks varied from 70-80% with a definite seasonal cycling probably caused by a higher number of smaller trucks on the road during the warm months. These trends were relatively consistent from 1998-2000, less consistent in 2001-2003 as weight and volume percentages became somewhat variable, and highly inconsistent in 2004 and 2005 when the percentages dropped off further, probably from the increased number of Class 4 and 5 trucks. From the trends shown earlier, the first four to five years would seem to provide the most accurate information on Class 9 loading.

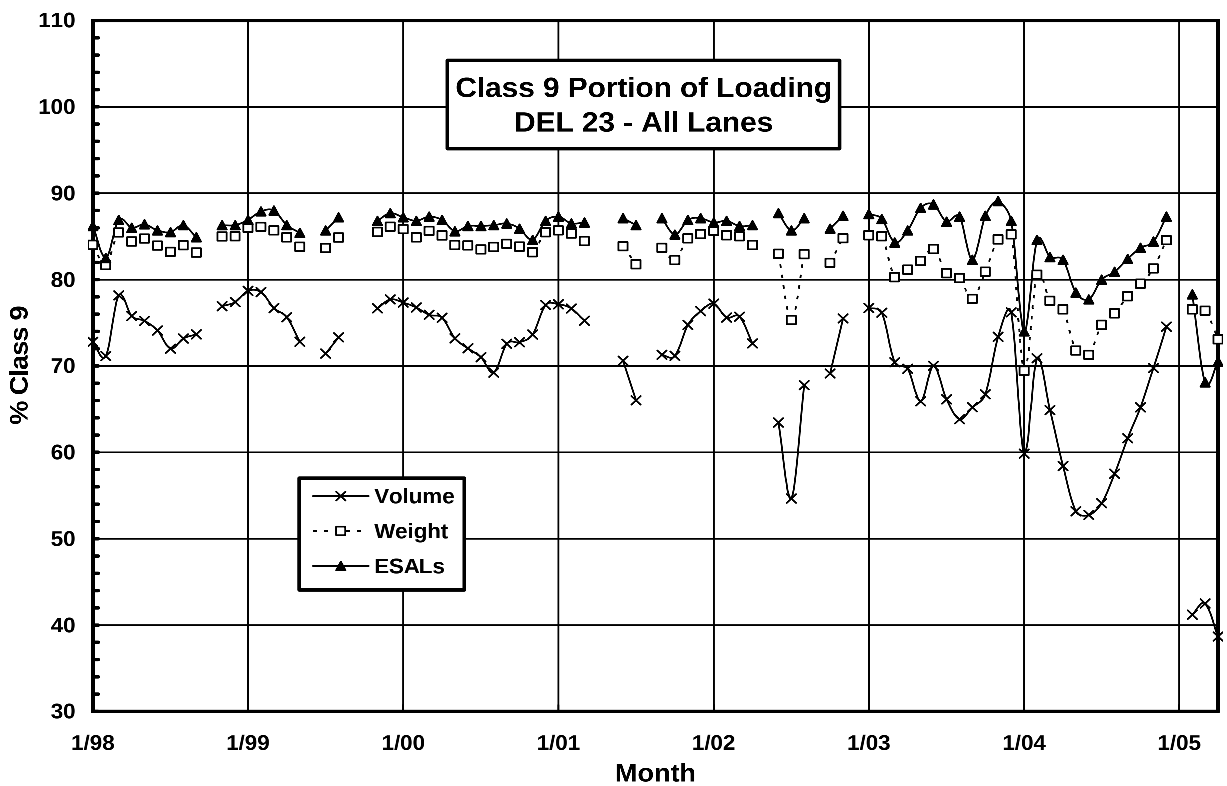


Figure 3.22 – Percentage of Class 9 Loading

Because of the high percentage of Class 9 trucks in the traffic stream and because of their relatively consistent geometry, the frequency distribution of axle weights and axle spacings of these trucks were compared on three dates when the weekly data appear to be quite different, as follows; 2/19/98, 8/5/04 and 4/21/05. While all three dates were on a Thursday, the particular day is not important, since the parameters being investigated were only associated with individual Class 9 trucks and not with accumulated totals. The total numbers of Class 9 trucks recorded on these dates were: 1712 and 1667 in Lanes 11 (NB Driving) and 51 (SB Driving) on 2/19/98, 1444 and 1491 in Lanes 11 and 51 on 8/5/04, and 1487 and 1490 in Lanes 11 and 51 on 4/21/05.

All Class 9 trucks were sorted from the daily files and frequency distributions were run on the axle weights and axle spacings shown in Figure 3.23. Since W2 and W3 had similar weights, and W4 and W5 had similar weights, they were combined as tandem axles in the weight distributions. Figures 3.24 – 3.30 show the distributions for each Class 9 truck parameter in Lanes 11 and 51 with the percentages in each bin shown for each date. Percentages were used in the bins rather than the actual number of trucks to remove the variability in daily counts.

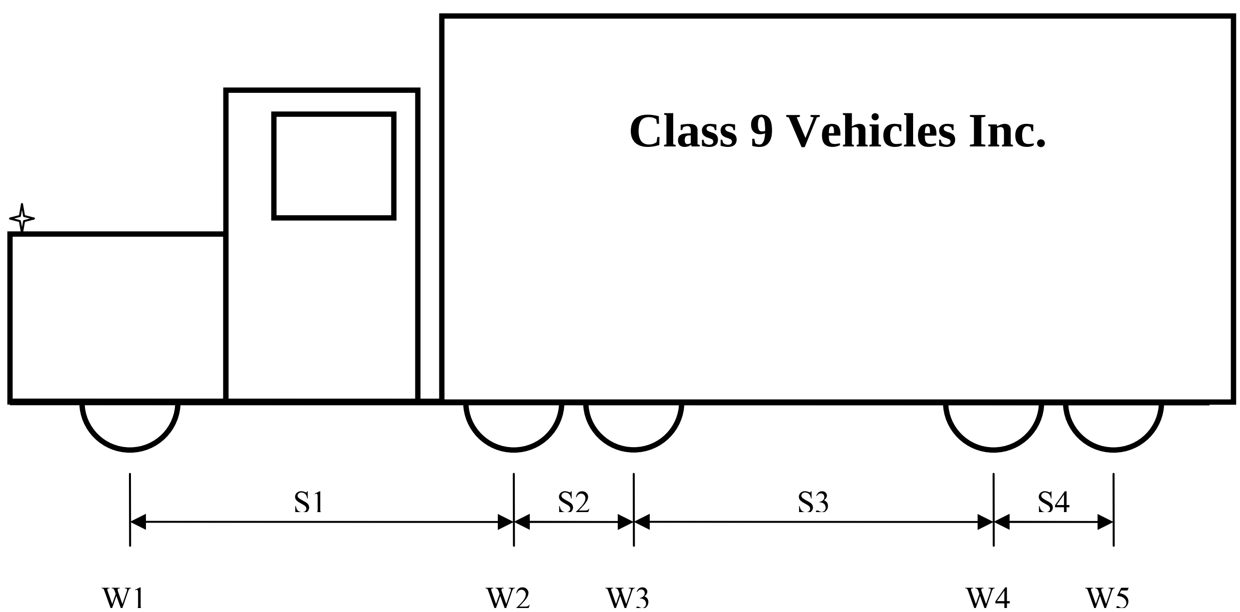


Figure 3.23 – Typical Class 9 Truck

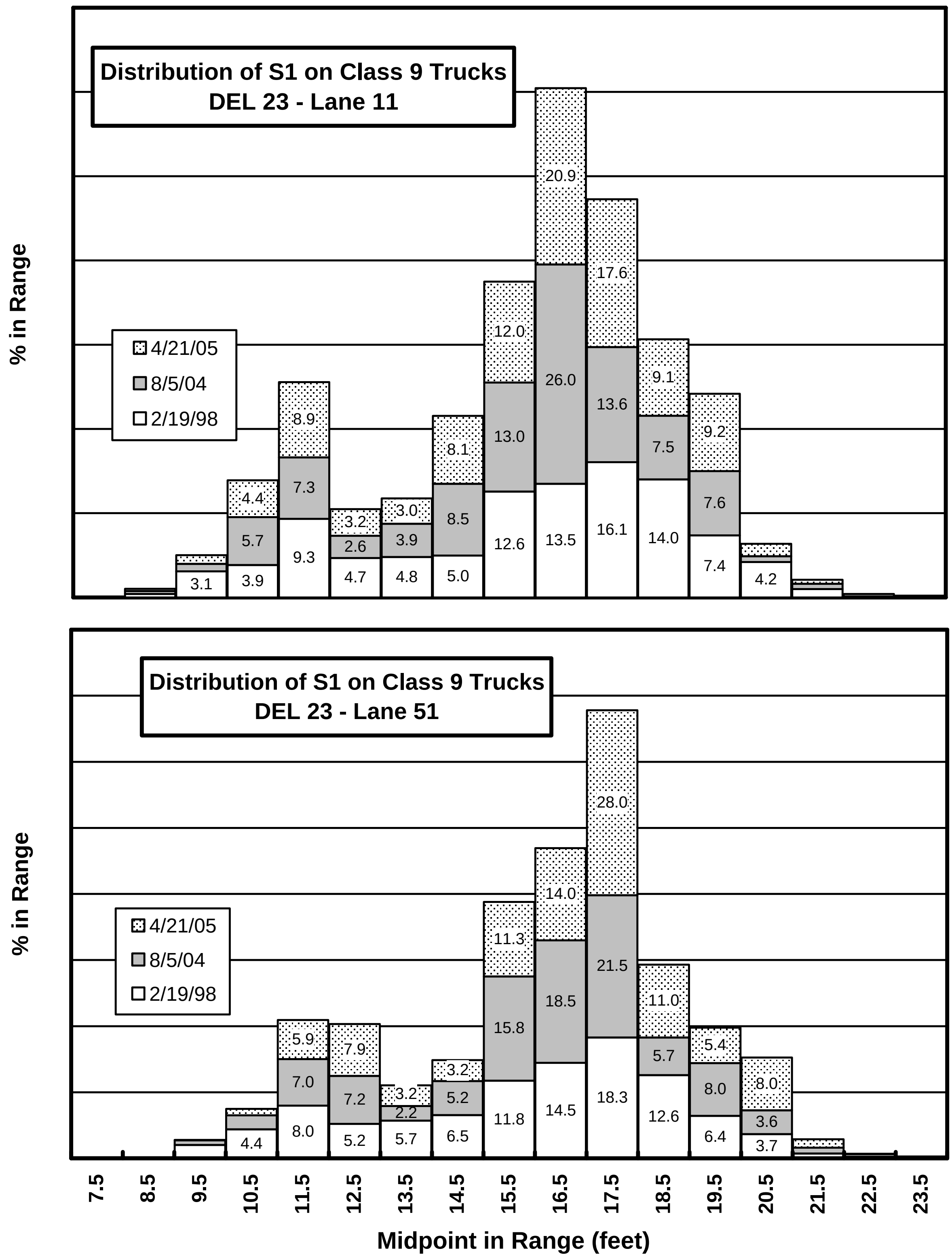


Figure 3.24 – Distribution of S1 on Class 9 Trucks

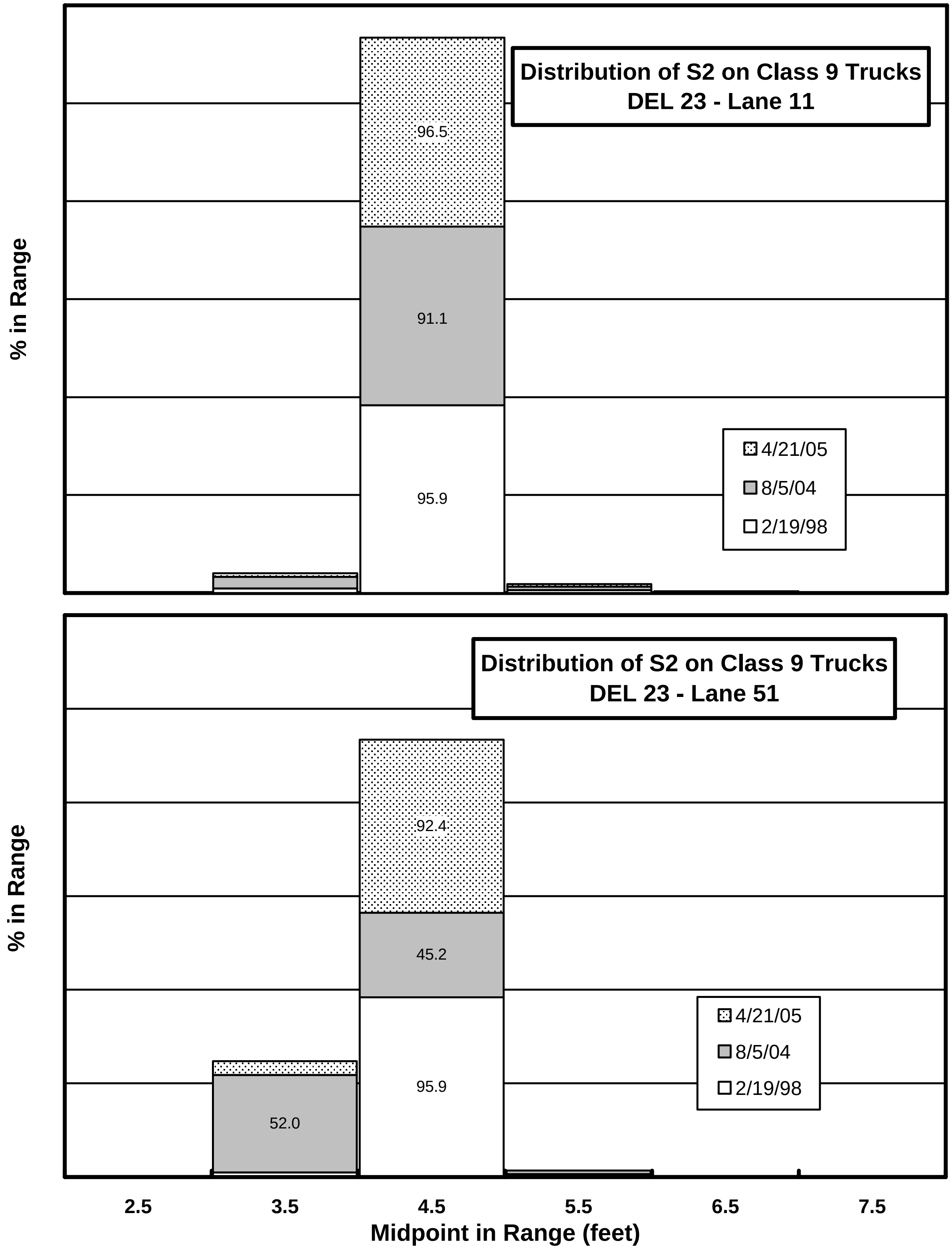


Figure 3.25 – Distribution of S2 on Class 9 Trucks

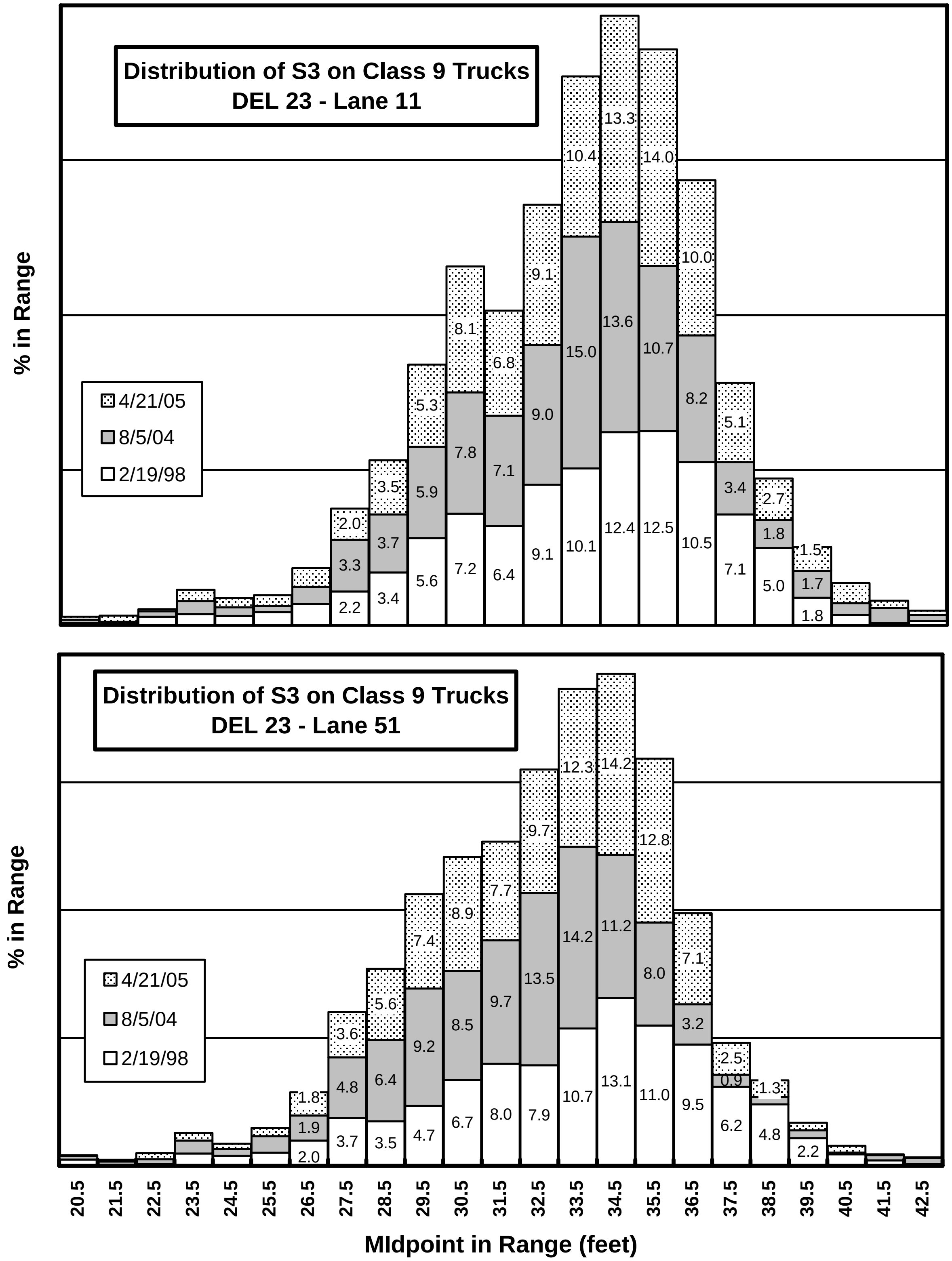


Figure 3.26 – Distribution of S3 on Class 9 Trucks

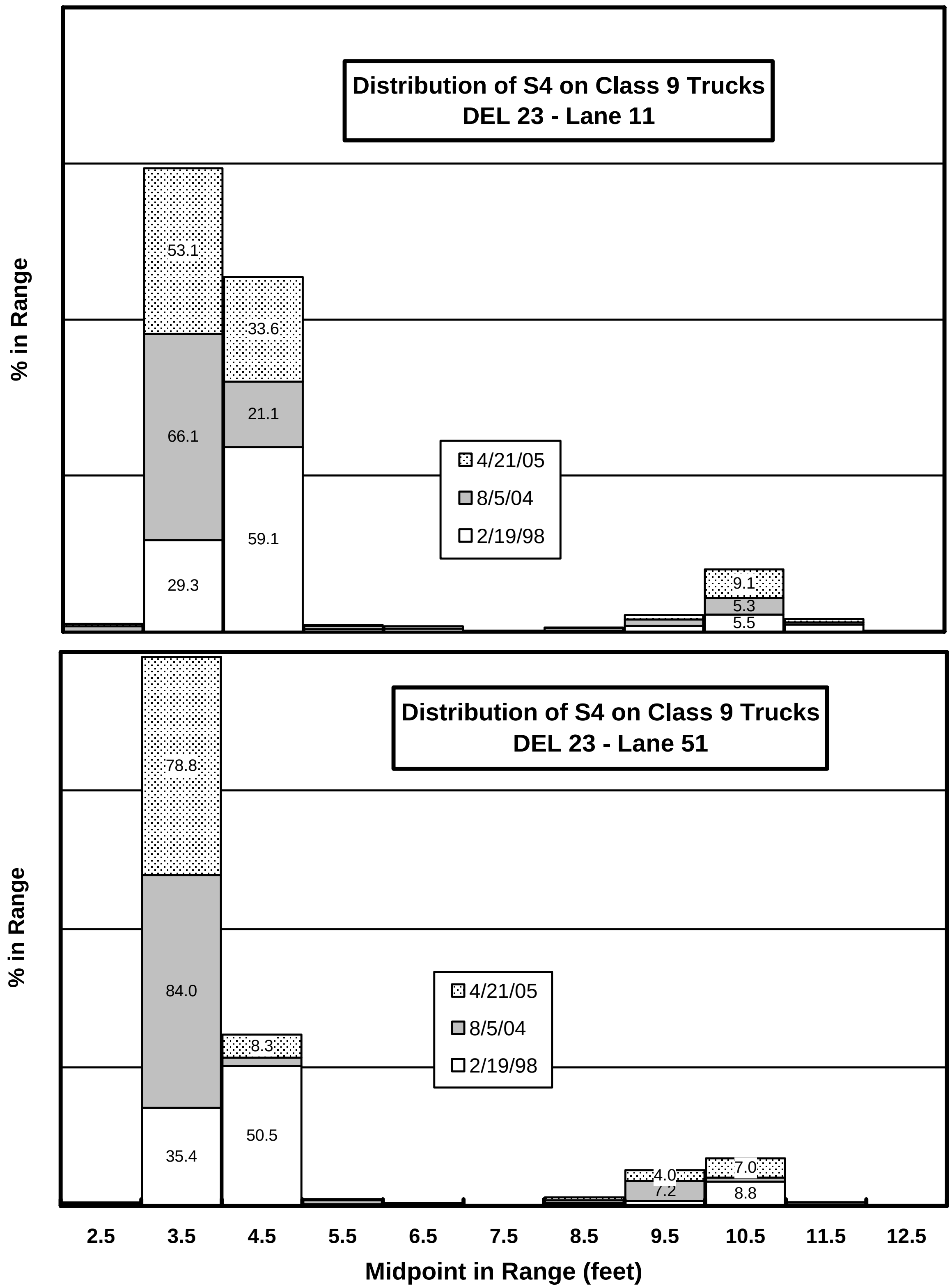


Figure 3.27 – Distribution of S4 on Class 9 Trucks

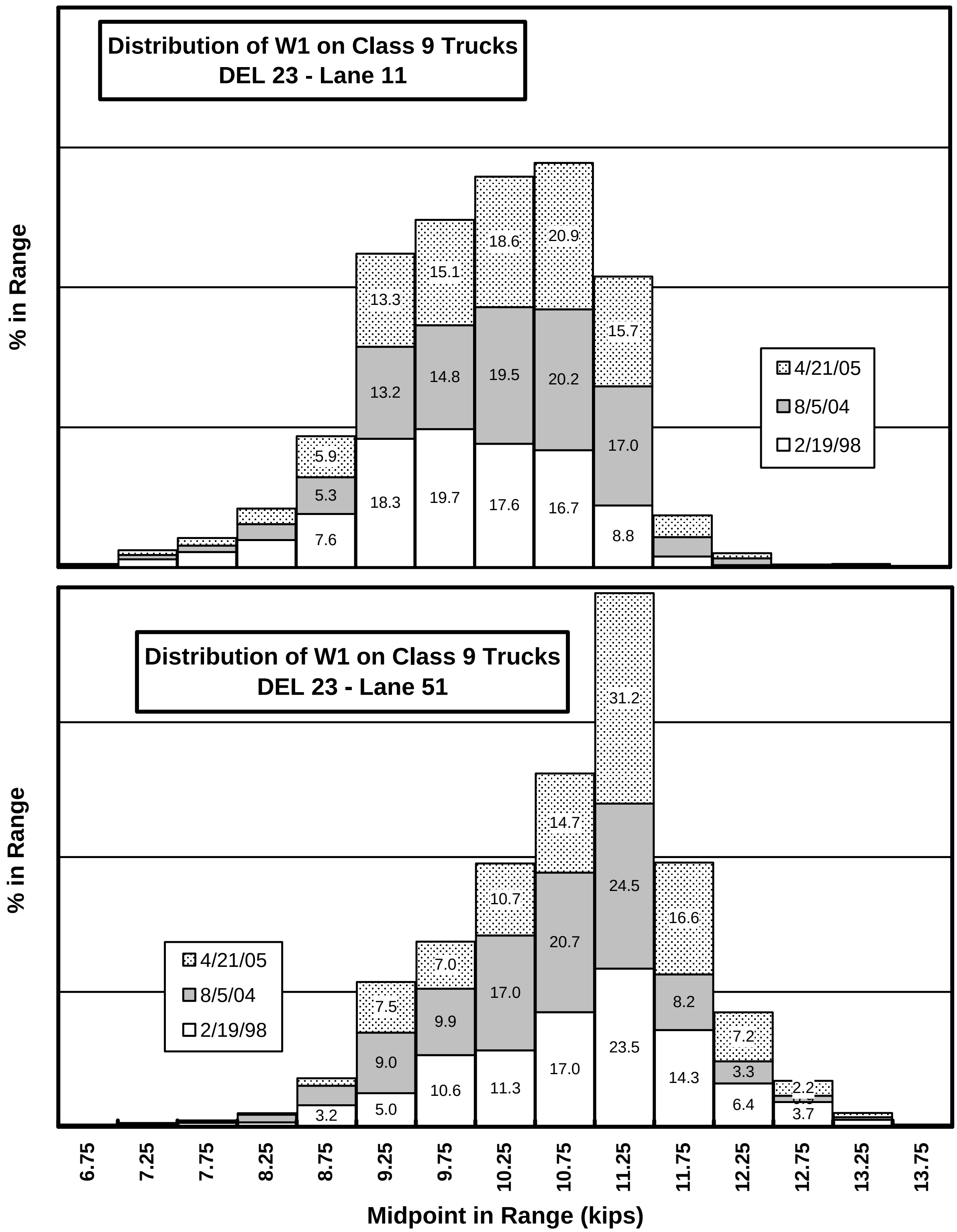


Figure 3.28 – Distribution of W1 on Class 9 Trucks

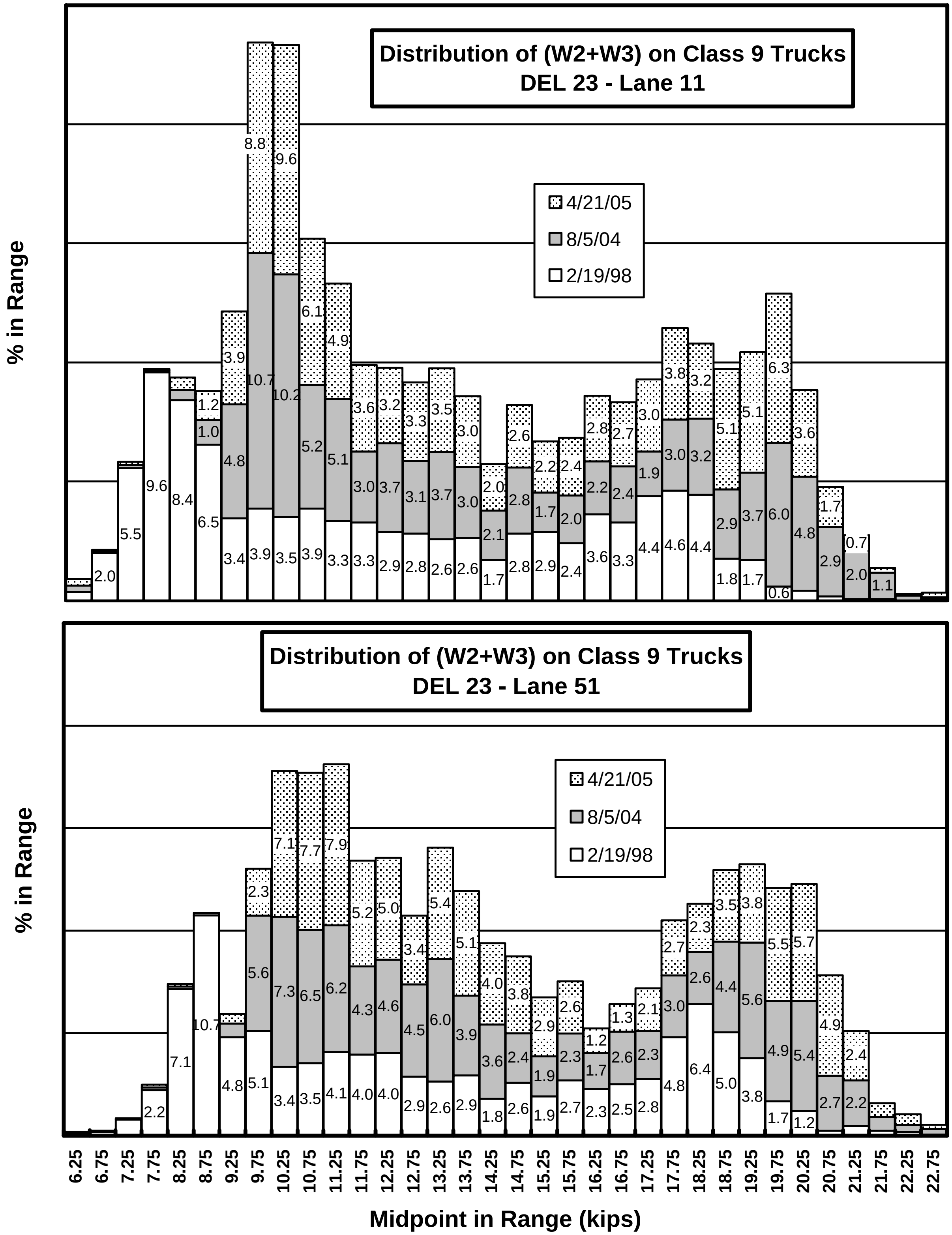


Figure 3.29 – Distribution of (W2+W3) on Class 9 Trucks

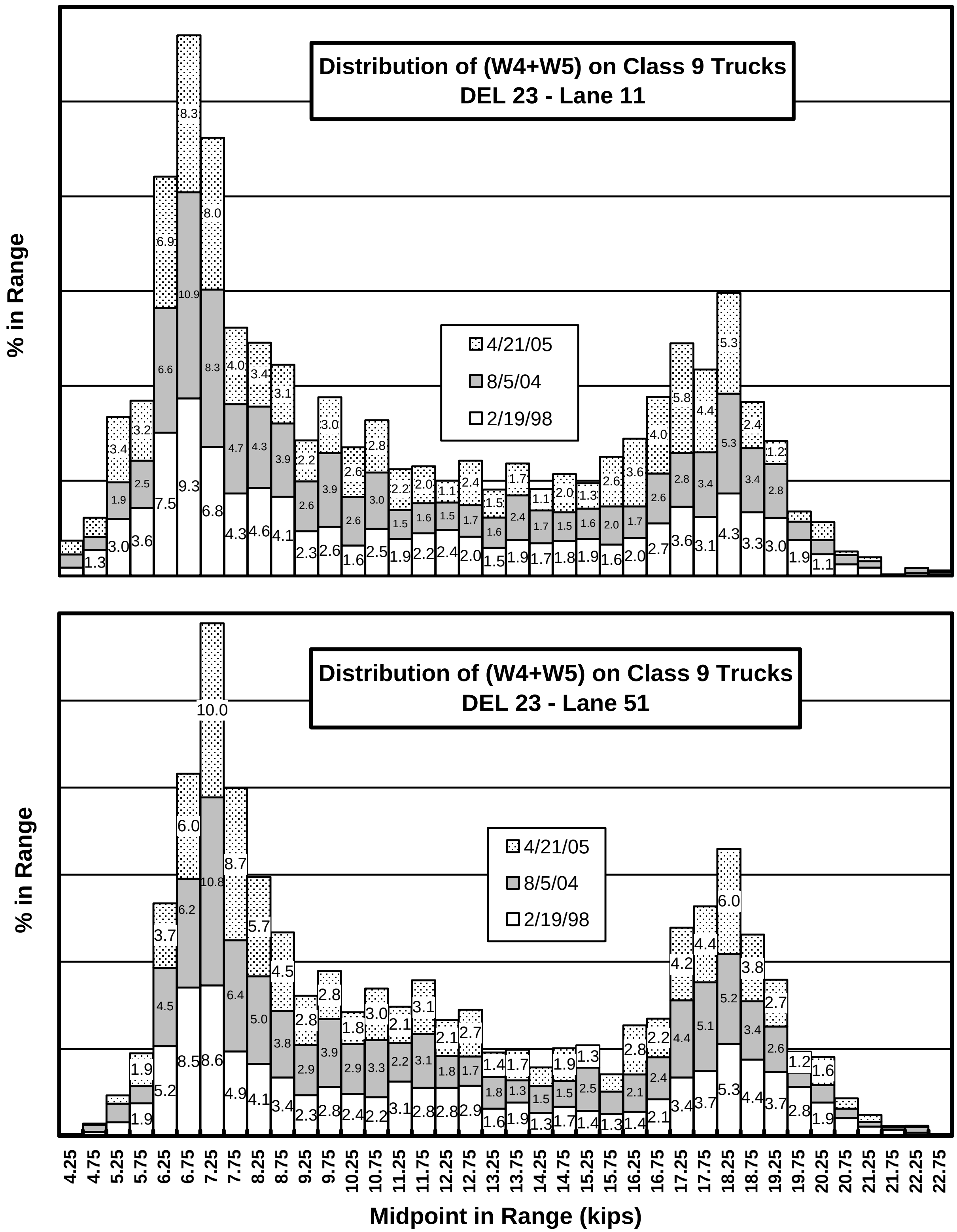


Figure 3.30 – Distribution of (W4+W5) on Class 9 Trucks

3.12 CONCLUSIONS FROM CLASS 9 AXLE WEIGHT AND SPACING DISTRIBUTIONS

There are several interesting observations regarding the bin percentages shown in Figures 3.24 – 3.30 for trucks being classified as Class 9 by the WIM, as follows:

Figure 3.24 (S1) – There were two peaks for both lanes and on all three dates representing tractors with (15-18 feet) and without (11-13 feet) sleeper cabs.

Figure 3.25 (S2) – While almost all tractor tandems had a spacing of 4 - 5 feet in both lanes on 2/19/98 and 4/21/05, 52% fell in the 3-4 foot bin in Lane 51 on 8/5/04.

Figure 3.26 (S3) - While the most populous bins for S3 ranged from 33-36 feet in both lanes and on all dates, the distributions in Lane 11 were shifted toward slightly higher axle spacings than in Lane 51.

Figure 3.27 (S4) –The rear tandem axles (S4) on Class 9 trailers were generally located a bit closer together than tractor tandems (S2). Occasionally, they are moved closer to accommodate the smaller tires on trailers with lower beds, or spread beyond the 8-foot tandem limit to distribute load over a broader area, as indicated by the second peaks between 9 and 11 feet. Figure 3.27 shows that, for both lanes, the most common tandem axle spacings were in the 4-5 foot bin on 2/19/98 and in the 3-4 foot bin on 8/5/04 and 4/21/05.

Figure 3.28 (W1) – In Lane 11, peak steering axle weights (W1) were about equally distributed in bins from 9.0 to 11.5 kips and, in Lane 51, bin percentages increased steadily to a peak in the 11.0-11.5 kip bin on all three dates.

Figure 3.29 (W2+W3) – Individual axles within tandem groupings typically had very similar weights and so the combined weight of both axles was used for this analysis. Weight distributions on tractor tandems (W2+W3) had two peaks representing unloaded and loaded conditions. These peaks were rather broad with the 8/5/04 and 4/21/05 peaks being about two kips higher than those on 2/19/98.

Figure 3.30 (W4+W5) –Peak bins for trailer tandem axles (W4+W5) were better defined than those for tractor tandems (W2+W3) and fell within the same range on all three dates. Peak bins were 6-8 kips for unloaded trailers and 17-19 kips for loaded trailers in both lanes on the three dates.

3.13 COMPARISON OF WIM DISTRIBUTIONS BY LANE AND DATE

Some differences in the distribution of axle weights and axle spacings shown previously for Class 9 trucks appear to be more than statistical variation; e.g., 1) the lower peak values for (W2+W3) in both lanes on 2/19/98 than on 8/5/04 and 4/21/05, and 2) the high percentage of tractor tandem axles having an S2 spacing of 3-4 feet in Lane 51 on 8/5/04. Another method to compare and, perhaps, quantify differences in the WIM measurements is through the use of cumulative distributions where the number of measurements is summed over increments of weight and distance. Figure 3.31 shows cumulative distributions for S1, S2, S3, W1, (W2+W3), and (W4+W5) in the two driving lanes on three dates. S4 was not included so the plots would fit on one page. If the six curves in each plot were identical and fell within reasonable limits accepted for Class 9 vehicles, it could be assumed with reasonable confidence that the data were accurate. Since the curves are not identical, it then becomes a question as to whether the differences were due to actual changes in truck weight/geometry, inaccuracies in the WIM measurements, and/or normal statistical variation.

While the axle spacings for Class 9 trucks would be expected to be very similar for northbound (Lane 11) and southbound (Lane 51) traffic, certain changes in truck configuration over time, such as an increased use of sleeper cabs or longer trailers, would gradually alter bin percentages for S1 and S3. With the exception of the Lane 51 - 8/5/04 curve for S2 in Figure 3.31, which clearly shows a significant percentage of 3-4 foot axle spacings, the remaining curves for S1, S2 and S3 maintained approximately the same general shape, but were shifted horizontally, indicating slightly longer axle spacings in Lane 11 than in Lane 51.

The distribution of W1, which is relatively consistent for loaded and unloaded Class 9 trucks, may offer some clues regarding weight accuracy. W1 is the weight on the front steering axle and is affected minimally by load in the trailer, as shown by the rather narrow distributions in Figure 3.28, especially for Lane 51. Lane 11 had a lower and wider distribution of peak W1 values than Lane 51 on all three dates, and the peaks in Lane 11 occurred at lighter loads on 2/19/98 than on 8/5/04 and 4/21/05, suggesting some difference in weight between lanes on the three dates and between dates in Lane 11. Similar trends showed up in Figure 3.31 for W1, (W2+W3) and (W4+W5), although the magnitude of the differences varies by axle group.

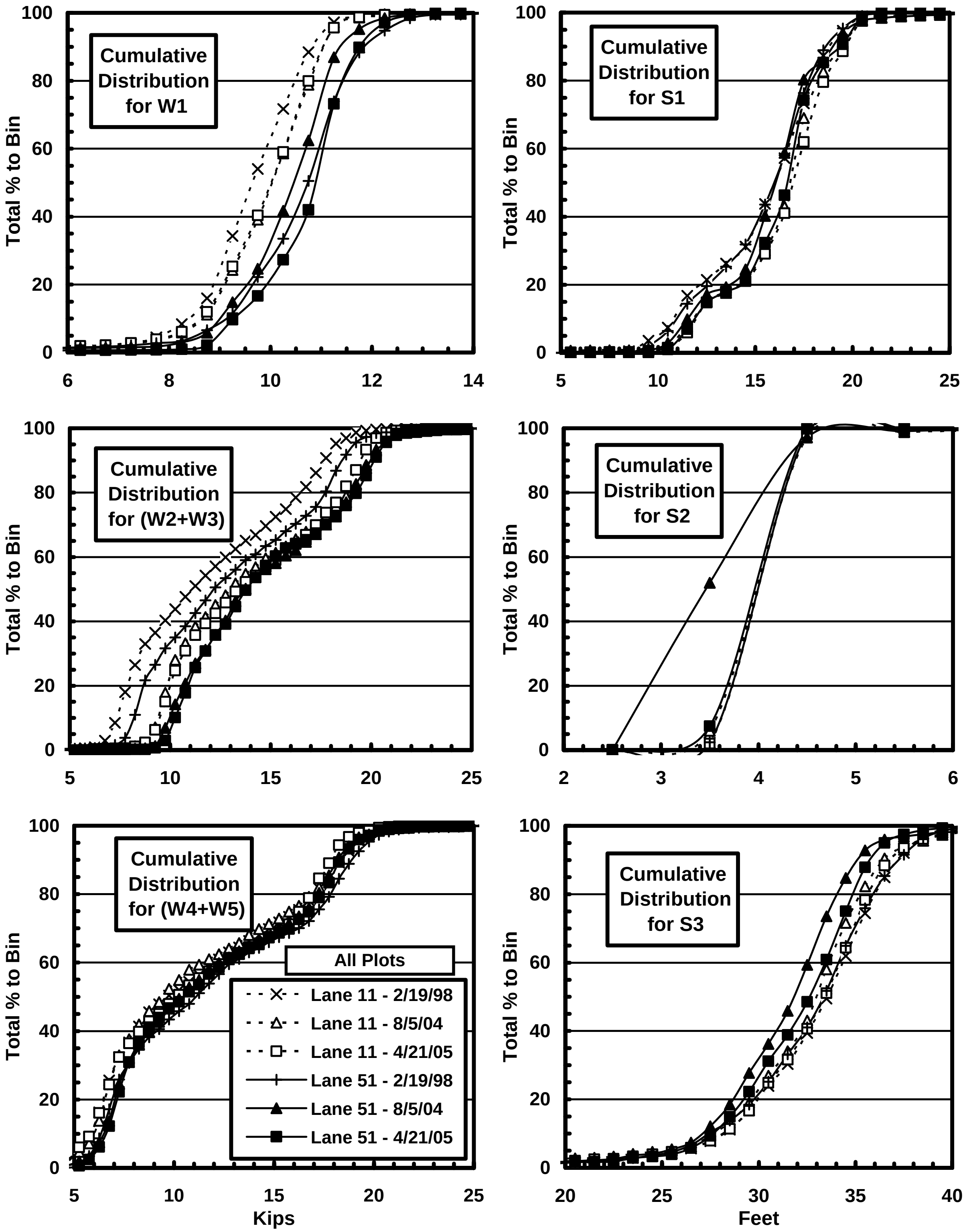


Figure 3.31 - Cumulative Distribution of Truck Parameters for Class 9 Trucks

Table 3.10 shows the median axle weight and median axle spacing as measured at the 50 percentile level on the cumulative distributions for Class 9 trucks. The values for S4 are shown, even though they were not included in Figure 3.31. Because the median values are indicative of where the distributions are centered along the X-axis, they are reflective of truck axle weight/spacing and/or WIM measurements in the two lanes and on the three dates. While these median values do not reflect average values or peak bins, especially when there are two peak conditions, such as for loaded and unloaded axles, and axle spacing on tractors with and without sleeper cabs, they do provide a measure of differences between distributions. In summary, there are some differences between lanes and dates for axle weight and axle spacing, but it is doubtful that the magnitude of these differences is sufficient to significantly affect loading calculations on the test road.

Table 3.10

Median Values of Weight and Distance for Class 9 Trucks

Lane	**Date**	**Median Weight (kips)**			**Median Distance (feet)**			
		W1	**(W2+W3)**	**(W4+W5)**	**S1**	**S2**	**S3**	**S4**
11	2/19/98	9.63	11.2	9.70	16.0	4.00	33.5	3.85
	8/5/04	10.0	13.0	9.50	16.8	3.99	33.0	3.19
	4/21/05	10.0	13.4	10.2	16.9	4.00	33.4	3.40
51	2/19/98	10.7	12.2	11.1	16.0	4.00	33.4	3.80
	8/5/04	10.5	13.7	10.3	16.0	3.46	31.9	3.01
	4/21/05	10.9	13.7	10.5	16.7	3.97	32.6	3.05
Average Median		10.3	12.9	10.2	16.4	3.90	33.0	3.38

While the extent to which W1 was affected by load in the trailer would be evident in a correlation between W1 and total gross truck weight on Class 9 trucks, the placement of load in the trailer would also affect the correlation. Figure 3.32 shows this correlation for each of the two lanes on each of the three dates along with trendlines for the data. The trendlines were quite similar for both lanes on 2/19/98 and 8/5/04, but there were differences for both lanes on 4/21/05, suggesting some difference in weights measured on 4/21/05. These plots illustrate the typical amount of data scatter and the number of points that might be considered as outliers when comparing W1 and gross vehicle weight. Again, the extent to which this difference in weight measurements affects calculated loading does not appear to be significant.

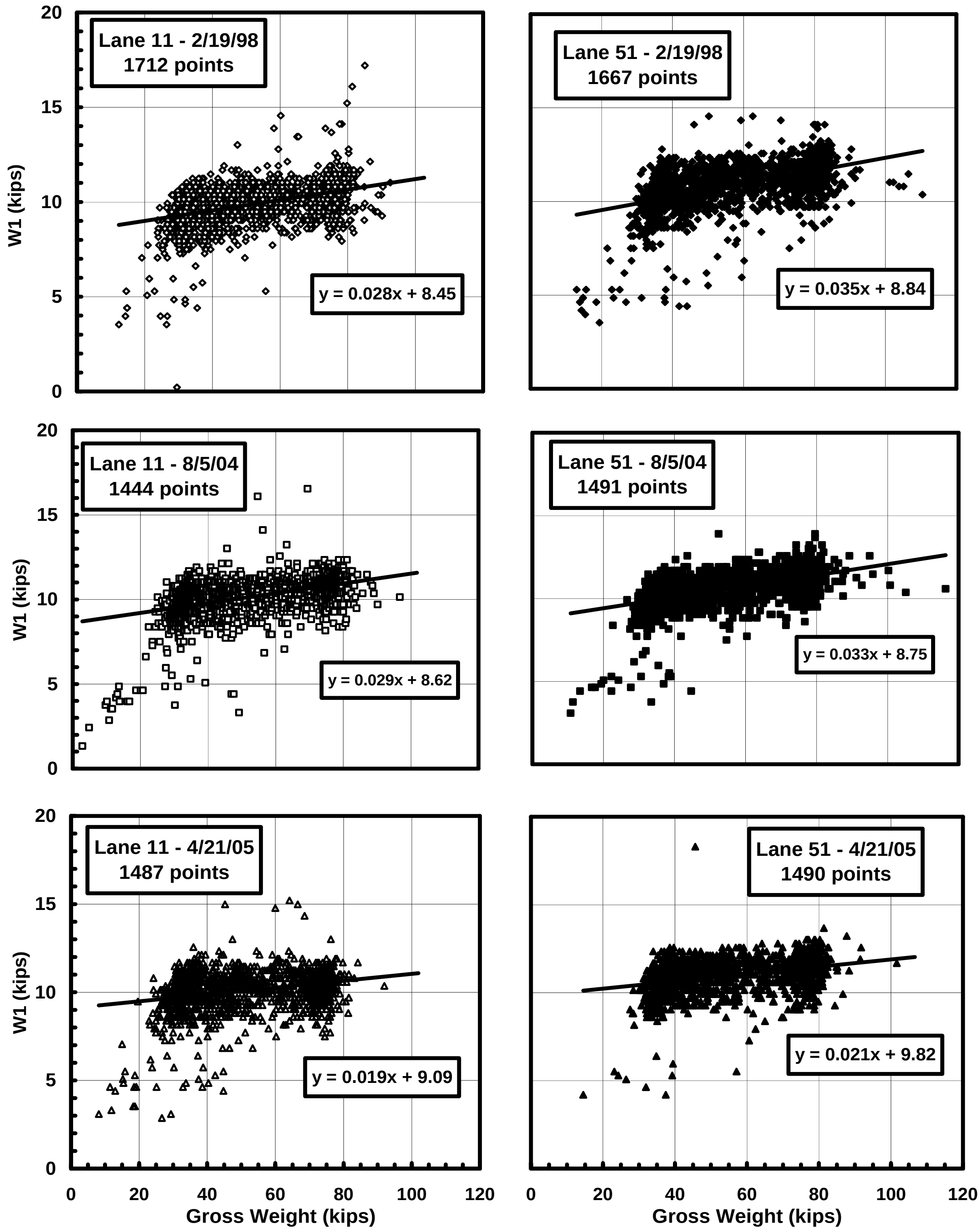


Figure 3.32 - W1 vs. Gross Weight for Class 9 Trucks

3.14 TRAFFIC CONCLUSIONS

The following are conclusions gleaned from WIM data collected on the test road:

1. Daily WIM files should be sampled and reviewed monthly to ensure that WIM systems are operating properly. This review should include hourly trends for volume, weight and ESALs in all lanes.
2. Prior to using daily WIM files to calculate truck loading, they should be run through a quality assurance procedure to ensure that the files are complete and the data are reasonable. This should include a review of hourly volumes, classifications, weights, ESALs and load spectra. From calculations performed with spreadsheets developed on this project, truck weight seems to be the most reliable indicator of pavement loading since it is not affected by axle grouping, classification, or the calculation of ESALs, all of which require additional WIM processing and are possible sources of error. A check of average weight on the front axle, spacing between the front tandem axles, average weight per truck and average ESALs per truck on Class 9 trucks would also be helpful in evaluating data quality.
3. Class 9 trucks made up approximately 75% of the volume, and 85% of the total weight and ESALs applied by Class 4-13 trucks on the Ohio SHRP Test Road.
4. Passing lanes carried approximately 10% of the volume of Class 4-13 trucks carried in the driving lanes.
5. The southbound driving lane (Lane 51) carried fewer Class 4-13 trucks, but more average daily weight than the northbound driving lane (Lane 11). This resulted in a higher average weight/truck in Lane 51. However, Lane 11 carried more total ESALs and had a higher number of ESALs per truck than Lane 51, at least partially due to the equations used to calculate ESALs on rigid and flexible pavement. Average annual pavement loadings varied slightly over time, but averaged about 620,000 ESALs in Lane 11 (NB concrete) and 515,000 ESALs in Lane 51 (SB asphalt).
6. Abrupt changes in the 2004 and 2005 data appear to be attributable to WIM software being changed at the site.

CHAPTER 4
PAVEMENT MODELING

4.1 GENERAL

Build-ups for pavement sections on the Ohio SHRP Test Road were established by LTPP from a predetermined matrix to provide data for verifying and improving the accuracy of existing pavement performance models, and developing new models to better reflect actual in-service traffic and environmental conditions. Extensive monitoring and testing were performed periodically on the test road by ODOT and LTPP to gather information on material properties, environmental conditions, traffic, and pavement condition. Pavement models developed by AASHTO, the Portland Cement Association (PCA), and the Asphalt Institute (AI) were used to predict design loading using parameters measured in the field. These calculations were then compared to actual traffic loading measured with an on-site weigh-in-motion (WIM) system.

One major issue regarding the accuracy of design models is the quality of data gathered on the pavement sections. Parameters required for most models include: subgrade properties, layer material properties, drainage capacity, traffic loading, joint properties for jointed concrete pavement (JCP), construction quality, etc. Some material properties, such as modulus of rupture or compressive strength, are easier to measure than others. Processed materials, such as asphalt concrete and Portland cement concrete, are more uniform than naturally occurring subgrade materials. Other variability is associated with the quality of construction, such as material mixing and placement.

To compare pavement design life projected with models verses actual field performance, in-situ design parameters must be applied to the models. Some in-situ parameters can be obtained by non-destruction testing. Some can be obtained by extensive sampling and testing during construction. Laboratory test results may not be the same as the as-built material properties. Some parameters can only be obtained through destructive testing. The ideal situation is to test materials in the field soon after the placement is complete.

In-situ stiffness measured with the Falling Weight Deflectometer (FWD) is a widely accepted methodology to obtain layer material moduli through a number of backcalculation techniques. While it is important to know how backcalculation results affect the output of a design model, it is also important to understand the sensitivity of various other parameters on these models. Environmental effects, especially moisture, is one of the more important parameters related to pavement performance. The curling of JCP slabs is another parameter that has been well documented in the literature and, because curling affects slab support, the type of base material also affects performance. Data collected from the Ohio SHRP Test Road and various other projects were used to relate environmental effects to performance.

4.2 MEASURED DESIGN PARAMETERS AND PERFORMANCE

A number of design parameters were measured during construction and after the pavements were opened to traffic. Environmental, traffic and climatological data were collected continuously on the test road and performance information was monitored periodically by ODOT and LTPP. Performance related data collected on this project are described in detail in the following sections.

4.2.1 FWD Data

FWD tests were performed on each material layer as it was finished and accepted by ODOT during construction. Two runs, one in the center of the lane and one in the right wheel path, were made at 50-foot intervals along the 500-foot section lengths. The same locations in the test paths were tested as subsequent material layers were added. Table 4.1 shows total deflection at the first FWD geophone (Df1) with a nominal 9000 lb. load by material layer and thickness.

Two points worthy of note in this table.

1. Subgrade deflections were widely spread with a Coefficient of Variation (COV) of 0.71. Since subgrade acceptance was based on nuclear-density tests having a COV of 0.14, nondestructive testing may be a better method to determine subgrade quality.
2. FWD uniformity improves with increasing layer stiffness and thickness.

Table 4.1

Ranges of Df1 on Different Material Layers

Material Layer	Average Df1 (mils)	Max. Df1 (mils)	Min. Df1 (mils)	Std. Dev. (mils)	COV	No. Data Points
SG	53.97	278.15	10.97	38.58	0.71	357
DGAB4”	61.20	122.26	28.07	22.05	0.36	139
DGAB6”	47.85	105.24	22.76	17.32	0.36	56
DGAB8”	41.10	88.68	24.51	13.78	0.34	41
DGAB12”	33.29	55.65	19.81	6.69	0.20	31
LCB6”	6.73	15.53	4.21	1.97	0.29	79
PATB(S)	41.30	71.75	26.72	10.24	0.25	62
PATB(G)	35.29	69.19	23.78	7.87	0.22	82
ATB4”(B)	23.07	31.60	13.97	3.15	0.14	21
ATB8”(S)	11.93	17.18	9.43	1.97	0.17	20
ATB8”(B)	6.55	8.39	4.76	0.79	0.12	21
ATB12”	4.83	5.90	3.94	0.39	0.08	32
AC4”(G)	29.16	37.91	22.05	3.87	0.13	21
AC7”(G)	13.71	18.37	11.74	1.68	0.12	21
AC4”	8.08	14.40	3.88	3.10	0.38	84
AC7”	7.25	9.80	3.46	2.04	0.28	95

(S) on subgrade, (G) on DGAB, (B) on DGAB or PATB

FWD data were used with different procedures in this study to backcalculate dynamic modulus and the modulus of subgrade reaction k. Figure 4.1 is a plot of maximum, minimum and average deflection measured with the geophone at the center of the FWD load plate on different DGAB thicknesses. This plot clearly indicates that, while minimum deflection did not change with DGAB thickness, maximum deflection decreased greatly with thickness and average deflection decreased a moderate amount.

The AASHTO Pavement Design Guide uses resilient modulus to characterize subgrade soil stiffness. Resilient modulus can be obtained by testing soil samples in the lab using AASHTO T 274, or by the backcalculation of FWD deflection data.

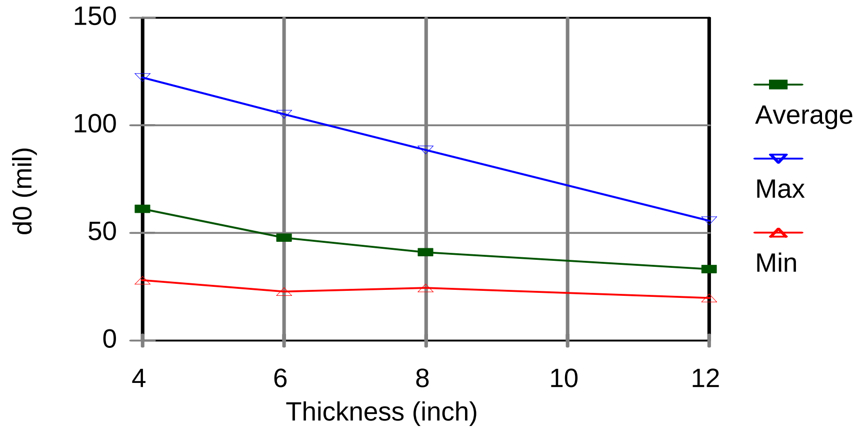


Figure 4.1 - Deflection versus DGAB Thickness

4.2.2 Material Properties

The properties of paving materials were measured by two methods: 1) samples collected during construction and tested in the ODOT and ORITE material testing laboratories, and 2) backcalculation of FWD data obtained on the completed pavement sections before they were opened to traffic. MODULUS4.2 (Sargand, 2002) was used to backcalculate moduli from the FWD measurements because the results more closely agreed with the measured deflection basins and it was less user dependent than other programs, including MODCOMP3 and EVERCALC5.0. For detailed information, refer to report FHWA/OH 2002/31 (Sargand, 2002). Table 4.2 summarizes material moduli obtained with both procedures.

Table 4.2 Material Moduli

Material	Average Modulus (ksi)	
	Laboratory Testing	Backcalculation from FWD
Asphalt concrete	678	527
Asphalt treated base	10	52
Cement treated base	2,800	1,096
New Jersey DGAB	16	61
Iowa DGAB	15	6
Standard 304 DGAB	15	18

4.3 BACKCALCULATION OF FWD DATA

4.3.1 FWD Testing on Subgrade (Boussinesq)

Upon completion and acceptance of the subgrade, FWD tests were performed with two drops at each of four load levels at 50-foot intervals along the right wheel path and the center of the lane. These data were used to calculate in-situ subgrade resilient moduli with the Boussinesq equations for layered elastic theory first published in 1885. Since FWD tests were performed on finished subgrade and since the subgrade is considered to be a one-layer system, this approach was suitable for calculating subgrade elastic modulus. Over the years, the original equations have been modified to fit different loading conditions, including the 300 mm diameter FWD load plate, as follows:

$$d_0 = \frac{2(1-\mu^2)\sigma_0 * a}{E}$$

where: d_0 = deflection at center of the load plate (mils)

μ = Poisson's ratio

σ_0 = Stress on surface (MPa)

a = plate radius (mm)

E = elastic modulus (MPa)

Sargand (Sargand, 2002, FHWA/OH-2002/035) used Boussinesq equations to calculate a composite subgrade modulus of elasticity from deflections measured at the center of the FWD load plate. Table 4.3 shows deflections measured on the Ohio SHRP SPS-1 and SPS-2 sections where the individual data points within each section were highly variable. Subgrade moduli were calculated for each load level and then normalized linearly to a 2,200 lb load, as shown in Table 4.4, to compare the results from different loads. A 2,200 lb load was used because it represents a standard axle load on the subgrade.

FWD tests were performed at 50-foot intervals in the right wheel track and centerline of the finished pavement lanes. Target loads were 6000, 9000, and 12000 lbs with two drops at each load. Evercalc and the 36" Offset methods were used to backcalculate layer moduli with these data, as described in the following sections.

Table 4.3

Maximum Deflection on Subgrade

SPS-1				SPS-2			
Section No.	Average Df1 (mils)	Std. Dev. (mils)	COV	Section No.	Average Df1 (mils)	Std. Dev. (mils)	COV
101	11.69	5.81	0.50	201	9.05	4.15	0.46
102	20.37	8.45	0.41	202	17.89	10.15	0.57
103	15.69	4.38	0.28	203	14.94	4.09	0.27
104	16.85	7.06	0.42	204	29.77	13.83	0.46
105	15.54	3.31	0.21	205	9.32	5.38	0.58
106	17.88	5.93	0.33	206	12.73	6.68	0.53
107	16.76	5.71	0.34	207	17.08	5.25	0.31
108	18.95	6.38	0.34	208	16.34	5.66	0.35
109	11.51	5.68	0.49	209	10.38	7.84	0.76
110	12.95	5.44	0.42	210	10.31	4.55	0.44
111	18.08	8.99	0.50	211	15.85	3.07	0.19
112	13.82	6.28	0.45	212	20.43	7.11	0.35

Table 4.4

Subgrade Modulus per Boussinesq

Section No.	Subgrade Mr (ksi)					Section No.	Subgrade Mr (ksi)				
	Avg.	Std. Dev.	COV	Max	Min		Avg.	Std Dev.	COV	Max	Min
101	16.5	6.9	0.4	28.1	5.8	201	13.1	5.3	0.4	22.9	3.4
102	27.1	9.4	0.3	48.1	13.8	202	24.8	13.4	0.5	53.9	5.1
103	20.1	5.6	0.3	33.7	8.9	203	19.6	5.9	0.3	34.6	10.9
104	23.6	6.0	0.3	35.6	14.1	204	40.3	17.5	0.4	73.4	13.0
105	19.5	4.9	0.3	29.9	13.1	205	13.2	7.1	0.5	29.5	3.5
106	23.2	7.7	0.3	37.2	9.1	206	19.9	9.4	0.5	35.3	3.3
107	23.1	5.5	0.2	36.6	16.7	207	21.4	7.5	0.3	38.7	11.9
108	26.3	7.9	0.3	39.4	12.9	208	20.6	7.2	0.3	40.4	11.5
109	15.0	7.2	0.5	35.4	5.0	209	13.5	9.2	0.7	31.2	3.3
110	16.4	6.9	0.4	30.6	6.4	210	14.4	6.2	0.4	28.6	4.7
111	23.9	10.7	0.4	48.1	9.4	211	21.1	4.7	0.2	30.2	15.3
112	22.1	6.7	0.3	35.0	4.8	212	26.9	9.1	0.3	47.1	12.0

4.3.2 Backcalculation by Evercalc

Evercalc is software developed by the Washington DOT (WsDOT) to backcalculate layer moduli from FWD test results. Like other backcalculation methods, it is necessary to assume an initial modulus for each layer. Layer thickness was the measured in-situ thickness. Deflections on the AC layer were adjusted to a standard temperature of 25^{o} C and the AC surface and ATB layers were combined into one layer. Backcalculated moduli for the different layers are summarized in Tables 4.5 to 4.7.

Backcalculated base layer moduli were highly variable within each section. Deflection tests performed on the finished bases were more uniform than on the subgrade. This result implies that moduli of the base layer should be more uniform than subgrade moduli. Results shown in Tables 4.6 and 4.7 contradict this hypothesis, which raises a question regarding the credibility and reliability of backcalculated moduli.

Table 4.5

AC Layer Moduli by Evercalc

Section No.	AC Moduli by Evercalc (ksi)				
	Avg.	Std. Dev.	COV	Max	Min.
101	411.9	80.6	0.2	622.3	300.1
102	461.6	96.2	0.2	677.5	304.8
103	295.0	52.5	0.2	425.0	223.6
104	464.4	57.1	0.1	576.8	367.9
105	446.7	69.0	0.2	630.1	363.6
106	539.9	74.1	0.1	663.0	365.3
107	158.3	14.7	0.1	181.9	128.8
108	308.3	90.6	0.3	630.7	208.3
109	320.1	42.3	0.1	445.1	258.5
110	959.9	110.8	0.1	1182.3	789.0
111	612.1	74.1	0.1	762.3	477.0
112	606.1	67.7	0.1	736.8	448.2

Table 4.6

Base Layer Moduli by Evercalc

Section No.	Base Type	Base Moduli by Evercalc (ksi)				
		Avg.	Std. Dev.	COV	Max	Min.
101	DGAB	7.1	3.4	0.5	15.1	2.5
102	DGAB	5.2	1.7	0.3	9.4	2.5
105	DGAB	2.5	2.1	0.8	10.4	1.2
106	DGAB	20.0	28.4	1.4	124.4	0.8
107	PATB/DGAB	3.6	2.0	0.6	9.0	1.5
108	PATB/DGAB	28.4	17.2	0.6	66.7	9.6
109	PATB/DGAB	11.5	4.2	0.4	19.8	3.2
110	PATB	2.4	1.0	0.4	5.9	1.1
111	PATB	35.5	60.8	1.7	247.2	1.4
112	PATB	115.2	128.1	1.1	371.7	2.0

Table 4.7

Subgrade Modulus by Evercalc

Section No.	Subgrade Moduli by Evercalc (ksi)				
	Avg.	Std. Dev.	COV	Max	Min.
101	24.8	5.4	0.2	34.7	16.1
102	18.9	2.3	0.1	24.2	15.2
103	20.2	2.0	0.1	26.0	17.4
104	31.0	3.9	0.1	42.9	26.2
105	27.8	5.9	0.2	37.2	17.1
106	37.6	10.4	0.3	74.1	28.3
107	23.4	2.2	0.1	27.7	18.9
108	27.2	3.7	0.1	34.8	21.0
109	33.5	8.7	0.3	63.1	25.8
110	34.4	11.3	0.3	57.4	21.6
111	33.3	6.4	0.2	49.2	23.1
112	35.2	5.8	0.2	55.0	26.1

4.3.3 Backcalculation by 36" Offset Deflection

This method was derived from the Boussinesq equations to compute stresses and deflections in a halfspace composed of homogeneous, isotropic, and linearly elastic material. Surface deflection 36" from the center of the load plate is:

$$D_{36} = \frac{(1-\mu^2)\ P}{36\pi E}$$

Based on the theory of load distribution, surface deflection 36 inches from the center of the load depends solely upon the physical properties of the subgrade. Therefore, this equation can be used to compute subgrade modulus from FWD geophones located 36 inches from the center of the load plate. NCDOT uses this approach to calculate subgrade moduli on all rehabilitation projects. Subgrade moduli backcalculated with Offset36 on the DEL 23 project are summarized in Table 4.8.

Table 4.8

Subgrade Modulus (Offset36)

Section No.	Subgrade Moduli by Offset36 (ksi)				
	Avg.	Std. Dev.	COV	Max	Min.
101	17.6	2.9	0.2	23.0	11.1
102	16.4	2.9	0.2	23.7	13.4
103	15.8	1.5	0.1	19.9	13.5
104	27.9	2.4	0.1	34.4	25.1
105	16.3	1.9	0.1	20.5	12.5
106	23.9	1.5	0.1	26.9	21.5
107	18.3	1.9	0.1	21.4	15.4
108	21.8	3.0	0.1	27.9	17.1
109	20.7	3.1	0.1	25.9	14.7
110	17.7	2.9	0.2	25.3	13.6
111	22.9	3.2	0.1	29.3	17.5
112	25.6	2.3	0.1	30.9	22.3

4.3.4 Comparison of Moduli from Different Methodologies

Subgrade moduli calculated with different methodologies are summarized for the SPS-1 sections in Table 4.9. These results show that the methods yield different results and there are no consistent trends as to their order. Table 4.10 shows the correlation of paired results from the different methods. Only the Boussinesq and ODOT results show reasonably good correlation (see Figure 4.2). Figure 4.3 compares Boussinesq results with Evercalc and Offset36, and Figure 4.4 compares Offset36 and Evercalc. Although Evercalc and Offset36 used the same input data, there was not much of a correlation. The ODOT method is described in a report entitled, "Evaluation of Initial Subgrade Variability on the Ohio SHRP Test Road" (17).

Table 4.9

Average SPS-1 Subgrade Moduli Derived by Different Methods

Section No.	Average Subgrade Moduli by Method (ksi)			
	Boussinesq	ODOT	Offset36	Evercalc
101	16.86	11.69	17.58	24.76
102	27.42	20.37	16.39	18.88
103	20.44	15.69	15.80	20.17
104	23.48	16.85	27.93	30.95
105	19.60	15.54	16.25	27.85
106	23.02	17.88	23.94	37.55
107	23.30	16.76	18.32	23.36
108	26.84	18.95	21.80	27.22
109	15.30	11.51	20.73	33.53
110	16.54	12.95	17.67	34.37
111	23.87	18.08	22.90	33.30
112	22.81	13.82	25.58	35.16

Table 4.10
Subgrade Modulus Correlation Coefficient for Different Methods

Method	ODOT	Offset36	Evercalc
Boussinesq	0.86	0.09	0.05
ODOT		0.01	0.08
Offset36			0.44

Subgrade moduli calculated with the Boussinesq, Evercalc, and Offset36 methods were compared with the Paired-Sampling T-test. The correlation coefficient, t-test results, and 2-tailed significant level are summarized in Table 4.11. There was very little correlation between the Boussinesq and Offset36 methods and, based upon the Student-t test results, ten out of the twelve sections were significantly different. There was also no correlation between the Boussinesq and Evercalc backcalculated moduli as the Student-t test results indicated that calculated moduli from these two methods were significant different for all sections.

The same data were used with Evercalc and Offset36 for backcalculation. Only four out of twelve sections showed some correlation with R^2 greater than 0.5. The Student-t test results indicated that backcalculated moduli by these two methods were different for all sections at a 99% confident level.

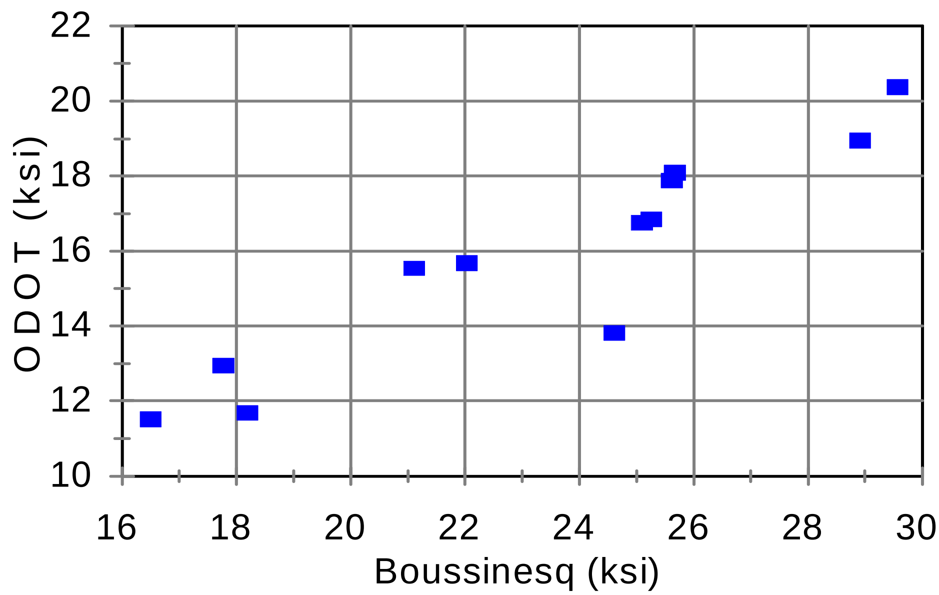


Figure 4.2 - Average Subgrade Modulus, Boussinesq vs. ODOT

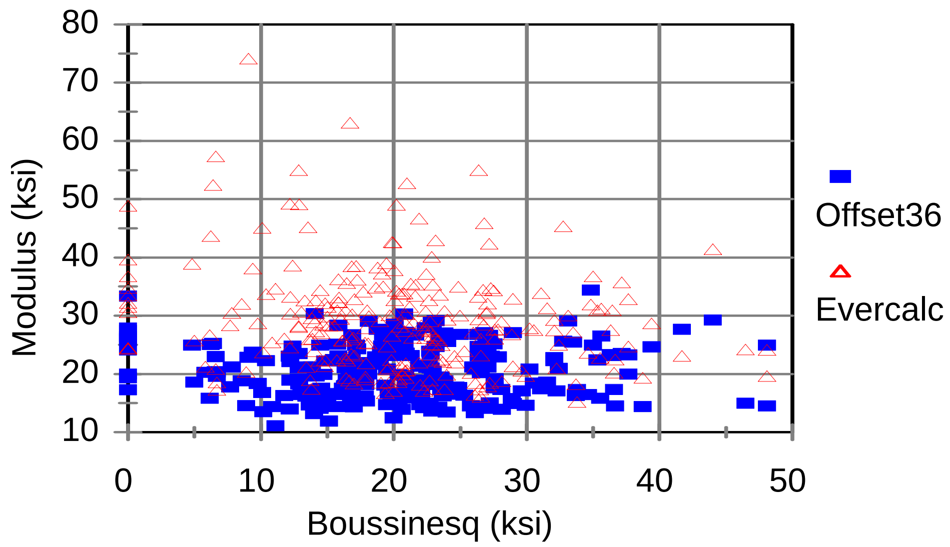


Figure 4.3 - Average Subgrade Modulus, Boussinesq vs. Offset36 and Evercalc

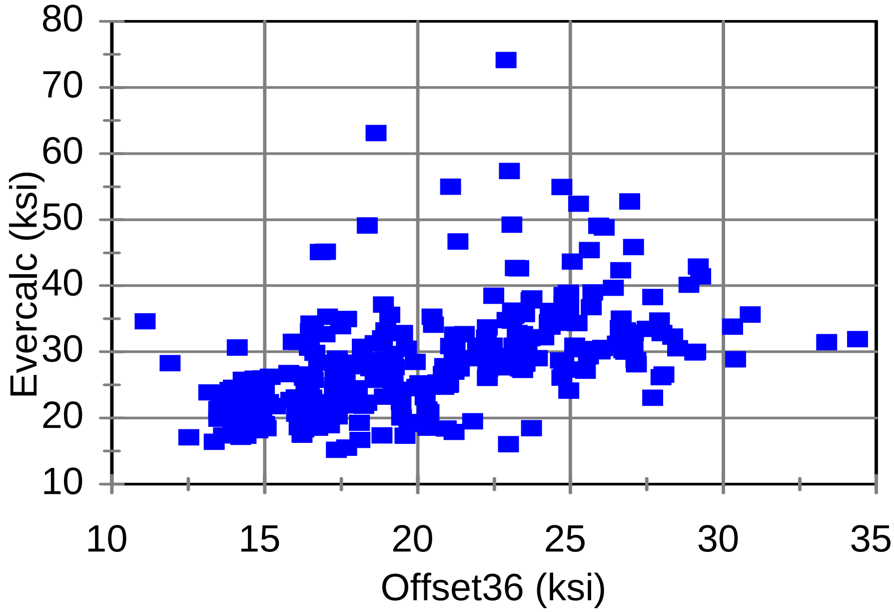


Figure 4.4 - Average Subgrade Modulus, Offset36 vs. Evercalc

Table 4.11

Comparison of Methods to Compute Subgrade Moduli

Section No.	Methods Compared								
	Boussinesq/36" Offset			Boussinesq/Evercalc			36" Offset/Evercalc		
	R^2	t	Confidence Level (%)	R^2	t	Confidence Level (%)	R^2	t	Confidence Level (%)
101	-0.46	0.31	25	0.29	3.86	99	-0.59	-4.37	99
102	-0.31	5.01	99	0.45	4.82	99	-0.15	-2.86	99
103	0.01	4.23	99	-0.47	1.32	80	-0.41	-6.69	99
104	0.00	-1.70	89	0.00	-3.35	99	0.24	-3.38	99
105	0.35	4.05	99	0.09	-4.34	99	0.79	-11.70	99
106	0.34	0.93	63	-0.37	-2.91	99	0.29	-6.19	99
107	0.16	4.58	99	-0.13	1.12	73	0.75	-15.70	99
108	0.11	3.22	99	0.26	0.86	60	0.92	-16.60	99
109	0.32	-2.48	98	0.07	-6.53	99	0.46	-7.54	99
110	-0.18	-0.02	2	-0.45	-4.63	99	0.78	-8.27	99
111	0.39	1.21	76	-0.27	-2.49	98	0.13	-7.08	99
112	0.11	-0.60	44	-0.25	-4.45	99	0.10	-7.29	99

Applying individual data points to these approaches, three sets of moduli data were obtained. The difference between pairs of these three approaches can be compared using the Student-t test. It is found that the three pairs of data were significant different at a 99% level. It was also found that, except for the Evercalc-Offset36 pair which showed some correlation, the other two pairs showed no correlation at all. Table 4.12 summarizes these results.

Table 4.12
Paired-Samples Test Results

Parameter	Methods Compared		
	Boussinesq/36" Offset	Boussinesq/Evercalc	36" Offset/Evercalc
Correlation	0.127	-0.154	0.499
Degrees of Freedom	240	240	263
t	-4.8	6.5	18.3
Significance	0	0	0

4.4 VALUES OF K USING FWD DATA

Hall, Darter, and Khazanovich (1997) found that the AREA method to estimate k is close to the best-fit method. Since the AREA method is simpler to use than the best-fit method, it was selected as the procedure of choice to estimate values of k for this study.

4.4.1 AREA Algorithm

FWD tests were performed on finished JCP surfaces with one drop at target loads of 6000, 9000, and 12000 pounds. Two approaches, namely AREA7 and AREA5, were used to calculate k in the SPS-2 experiment. AREA7 uses all seven sensors spaced from 0 to 60 inches from the center of the load plate. AREA5 skips the first two sensors and uses the five sensors spaced 12 to 60 inches from the center of the load plate. Area of the deflection basin, which is normalized to the first deflection (d_0 for AREA7 and d_{12} for AREA5) is calculated by the following equations:

$$A7 = 4 + 6\,(d8/d0) + 5\,(d12/d0) + 6\,(d18/d0) + 9\,(d24/d0) + 18\,(d36/d0) + 12\,(d60/d0).$$

$$A5 = 3 + 6\,(d18/d12) + 9\,(d24/d12) + 18\,(d36/d12) + 12\,(d60/d12)$$

Where: A7 is the area for AREA7, A5 is the area for AREA5

From the estimated areas, the radii of relative stiffness (L) can be approximated from the following equations,

$$L = \ln\left((60 - A7) / 289.708\right) / -0.689)^{2.566} \qquad \text{(AREA7)}$$

$$L = \ln\left((48 - A5) / 158.4\right) / -0.476)^{2.22} \qquad \text{(AREA5)}$$

The next step is to calculate elastic k using the following equation;

$$k = P\, d_r^* / (d_r\, L^2)$$

where: P = load, d_r = defl. at distance r, d_r^* = defl. coefficient for distance r

and: for r = 0 $\quad d_r^* = 0.1245\ e\ (-0.14707\ e^{-0.07565\,L})$ (AREA7)

for r = 12” $\quad d_r^* = 0.12188\ e\ (\,-0.79432\ e^{-0.07074\,L})$ (AREA5)

Values of k calculated from the AREA7 and AREA5 methods are summarized in Table 4.13.

Figure 4.5 is a plot of the maximum and minimum values of k calculated with AREA5 and AREA7. Paired-Samples T-tests were performed using SPSS software on these values of k. These results are summarized in Table 4.14. For most sections, values of k calculated by AREA5 and AREA7 were, statistically speaking, highly different. Section 209 showed the best agreement.

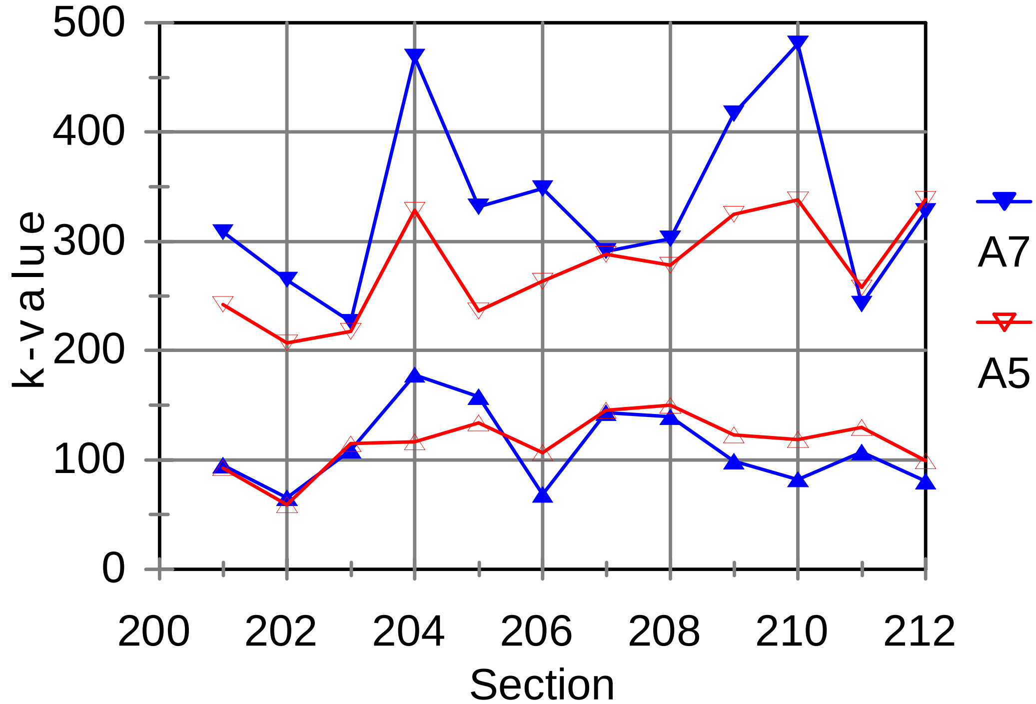


Figure 4.5 - Range of k Using AREA5 and AREA7

Table 4.13 Subgrade Reaction Backcalculated by AREA Methods

Section No.	AREA Method	Subgrade Reaction k				
		Average	Std. Dev.	COV	Maximum	Minimum
201	7	170.3	58.8	0.3	308.6	95.1
	5	155.7	40.4	0.3	242.4	92.8
202	7	141.9	42.4	0.3	264.9	65.6
	5	126.1	28.4	0.2	207.0	58.9
203	7	167.4	29.3	0.2	226.5	108.9
	5	154.1	23.8	0.2	217.6	115.1
204	7	277.5	66.3	0.2	469.1	178.1
	5	218.1	41.4	0.2	328.6	116.4
205	7	226.4	47.6	0.2	331.8	157.9
	5	190.4	22.0	0.1	236.5	133.7
206	7	189.0	68.0	0.4	348.3	68.6
	5	163.8	41.8	0.3	264.0	107.1
207	7	216.6	41.8	0.2	291.1	143.6
	5	211.5	36.5	0.2	288.5	145.5
208	7	197.5	42.1	0.2	302.7	139.3
	5	198.3	35.2	0.2	278.3	150.0
209	7	181.3	74.0	0.4	417.4	98.6
	5	182.6	49.8	0.3	324.9	122.8
210	7	265.5	75.5	0.3	481.1	82.4
	5	233.8	47.2	0.2	338.4	118.8
211	7	189.9	36.9	0.2	242.9	107.2
	5	189.1	27.7	0.1	257.7	129.9
212	7	213.4	68.4	0.3	327.5	80.9
	5	196.4	46.8	0.2	338.7	99.2

Table 4.14 AREA5/AREA7 Paired-Samples Student-t Test Results

Section	t	Degrees of Freedom	Significance
201	4.10	26	0.00
202	3.12	32	0.00
203	3.38	12	0.01
204	5.73	28	0.00
205	4.66	18	0.00
206	1.60	14	0.13
207	1.87	11	0.09
208	1.30	10	0.21
209	0.43	26	0.67
210	3.50	40	0.00
211	1.30	8	0.23
212	2.43	21	0.02

4.4.2 Estimated Values of k from Modulus

Yoder and Witczak (1975) suggested that the most representative values for k can be obtained using a load of 10 psi. For a 12" diameter plate, this load is approximately 1100 lb. Since the lowest target load level with the FWD on subgrade was 2500 lb., it was decided to calculate k at a load level of 2200 lb. Five sets of k derived by different methods were available for this study. Two sets of k were derived from FWD data tested on the finished subgrade and base, and the Boussinesq equations were used to calculate dynamic modulus. Dynamic moduli derived from FWD data were first converted to static modulus by dividing the dynamic modulus by two and then to k in accordance with the AASHTO recommendation of dividing static modulus by 19.4.

Two sets of k were derived using the AREA5 and AREA7 methods on FWD data collected on the finished JCP surface. The other set of data was provided by ODOT. Table 4.15 is a summary of k values derived from the different approaches. Results shown in Table 4.15 did not show much of a relationship between the different methods and Table 4.16 presents the correlation coefficient of pairing these methods.

Table 4.15

Average Values of k Derived by Different Approaches

Section No.	k (ksi) Calculated by Different Methodologies				
	FWD on Subgrade	FWD on Base	ODOT	AREA7	AREA5
201	337.0	370.0	466.5	170.3	155.7
202	637.9	550.3	922.2	141.9	126.1
203	504.2		770.1	167.4	154.1
204	1038.2	526.5	1534.5	277.5	218.1
205	339.0	3326.6	480.4	226.4	190.4
206	512.7	2741.5	656.2	189.0	163.8
207	551.6	4997.2	880.4	216.6	211.5
208	530.3	4827.9	842.3	197.5	198.3
209	347.0	612.4	535.1	181.3	182.6
210	371.4	529.3	531.4	265.5	233.8
211	546.1	576.6	817.0	189.9	189.1
212	692.1	761.6	1053.1	213.4	196.4

Table 4.16

Correlation Coefficients for the Different Approaches

Method	Base	ODOT	AREA7	AREA5
Subgrade	0.018	0.978	0.122	0.029
Base		0.007	0.002	0.040
ODOT			0.122	0.048
AREA7				0.814

Paired-Samples t-tests were performed on four of the five sets of k values for subgrade, base, AREA5 and AREA7. The ODOT data set was excluded because it is essential that the subgrade data be identical. The only pair that appeared to have some correlation was the AREA7/AREA5 pair with a correlation coefficient of 0.814. All other pairs showed no correlation. The Student-t test results indicated that these paired data sets, even the AREA5/AREA7 pair, were different at a 99% significance level. Table 4.17 shows these results.

Table 4.17

Paired-Samples Test Results (All Data Points)

Data Sets	No of Data Points	Correlation	Student-t	Significance (2-tailed)
Subgrade/Base	213	-0.101	-10.4	0.000
Subgrade/A7	155	0.173	12.9	0.000
Subgrade/A5	180	0.069	14.8	0.000
Base/A7	147	0.004	10.0	0.000
Base/A5	170	0.078	11.1	0.000
A7/A5	161	0.815	6.9	0.000

Paired-samples tests were then performed against data sets grouped by base type. There are four sections per base type. Correlation results were similar to the previous tests. Student-t test indicated that all these data pairs were different from each other at 99% significant level. Table 4.18 summarizes these analysis results.

Table 4.18 Paired-Sample Test Results by Base Type

Base Type	Data Set	No of Data Points	Correlation	Student-t	Significance (2-tailed)
DGAB	Subgrade/Base	58	0.402	4.2	0.000
	Subgrade/A7	62	0.456	9.7	0.000
	Subgrade/A5	68	0.330	10.2	0.000
	Base/A7	54	0.041	12.3	0.000
	Base/A5	57	-0.048	13.9	0.000
	A7/A5	64	0.856	5.4	0.000
LCB	Subgrade/Base	82	0.154	-32.0	0.000
	Subgrade/A7	40	-0.394	7.0	0.000
	Subgrade/A5	46	-0.245	8.6	0.000
	Base/A7	40	-0.093	23.0	0.000
	Base/A5	46	0.287	26.1	0.000
	A7/A5	40	0.634	3.4	0.002
PATB	Subgrade/Base	73	0.519	-5.6	0.000
	Subgrade/A7	53	0.049	6.6	0.000
	Subgrade/A5	66	0.080	9.2	0.000
	Base/A7	53	-0.228	17.4	0.000
	Base/A5	67	-0.216	22.2	0.000
	A7/A5	57	0.826	3.1	0.003

4.4.3 Curling Effect on Backcalculation of k Values

Changing temperature gradients in JCP slabs cause daily curling cycles. Long term temperature monitoring records collected in North Carolina (NC) indicated that maximum negative gradients (cold surface and hot bottom) occur prior to sunrise and maximum positive gradients (hot surface and cold bottom) occur in the afternoon. To explore the effect of slab curling on deflection, the NCDOT performed FWD tests on SPS-2 sections on US 52 in Lexington, NC at different slab locations and different times of the day. Deflections were obtained at the ends and quarter points of the slabs along the centerline (CL) and outside edge (OE). Three load levels (6000, 9000, and 12000 lbs) were applied at each test location on 2/9/99, and geophones were located 0, 12, 24, 36, 48, 60 and 72 inches from the center of the load plate. Tests were performed at dawn (6:30), morning (10:00), noon (13:00), and afternoon (16:00). At these times, air temperatures were 32, 53, 64 and 64, and temperature gradients in the slab were -16, +6.5, +22, and +13º F, respectively.

The concrete slabs were 12 feet wide and 15 feet long, resulting in the six-foot deflection basin extending beyond the joint at test locations 4, 5, 9, and 10 in Figure 4.6, which are the third quarter and the approach side of the joint. Because these basins included the joint, which is a discontinuity, they were excluded from the data analysis.

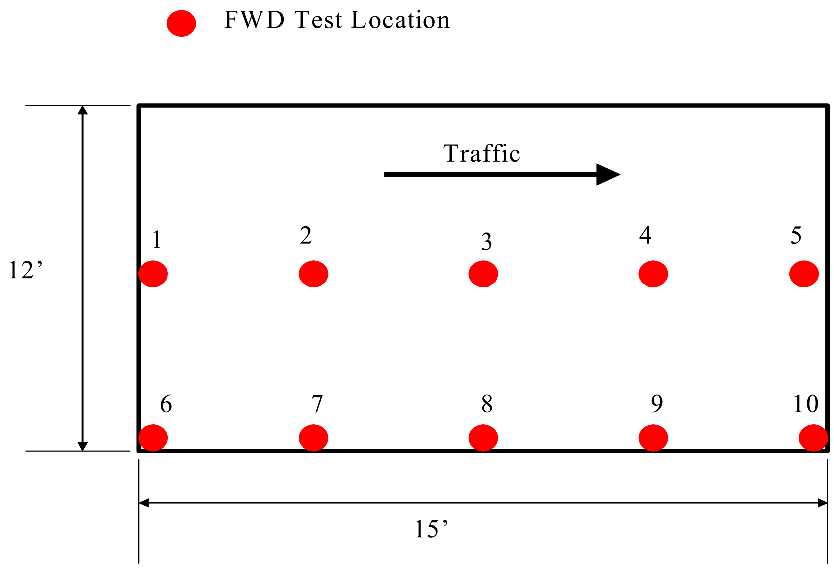


Figure 4.6 - FWD Test Locations on JCP Slab

The AREA5 and AREA7 methods were utilized to generate two sets of k values; namely, k-A5 and k-A7. Table 4.19 summarizes the average results for four times during the day at each of the ten locations in Figure 4.6, and Table 4.20 summarizes backcalculated k values for three locations along the centerline and edge of the slabs. For both k-A5 and k-A7, variation during the day was minimal when testing at the center of the slab near the joint. The Paired comparison also shows k-A5 to be greater than k-A7. This difference increases with distance from the joint and the largest k values were consistently on the leave side of the joints. In general, the variation in k-A7 was greater than the variation of k-A5. Table 4.21 summarizes results obtained in different slab paths. The coefficient of variation (COV) clearly indicates that, in spite of the position on the slab, results obtained along the center line of the slab were more consistent with the AREA5 method than with the AREA7 method. This suggests the k-A7 method was more sensitive to location than the k-A5 method. While base type had little effect on backcalculated k values, PATB had the lowest k values and LCB was more sensitive to test location.

Table 4.19

Backcalculated Values of k at Different Test Locations and Times

SPS	Location	k (ksi) by Slab Location and Time							
		Dawn A5	Dawn A7	am A5	am A7	Noon A5	Noon A7	pm A5	pm A7
203	1	188	169	177	163	188	157	198	167
	2	180	101	181	100	149	52	149	55
	3	159	10	166	68	152	59	153	56
	4	45		81	5	131	40	116	30
	5	216	47	261	72	203	171	316	103
	6	68	48	88	71	116	84	128	97
	7	60	27	81	35	86	27	91	35
	8	47	1	66	17	83	22	92	25
	9	25		38	3	68	23	110	50
	10	98	23	146	48	153	121	222	86
207	1	197	188	187	172	183	147	181	149
	2	150	83	165	97	164	65	163	77
	3	79		85	4	142	23	144	33
	4	37		55		88	13	76	11
	5	379	171	407	175	455	183	440	184
	6	61	48	76	67	121	105	128	110
	7	67	43	74	50	84	33	85	28
	8	30		35		72	10	67	12
	9	26		43	4	47	3	88	14
	10	97	35	134	54	277	100	273	105
260	1	202	185	171	112	180	86	171	93
	2	163	18	164	59	173	49	159	58
	3	103		133	11	149	13	130	24
	4	35		55		69		66	
	5	502	68	295	56	238	36	227	64
	6	94	70	91	69	104	58	104	63
	7	73	36	71	27	80	31	84	35
	8	34		51	7	81	20	70	26
	9	22		43	4	76	16	69	20
	10	218	96	125	157	285	104	329	113
211	1	154	123	134	106	134	101	140	107
	2	120	50	114	41	105	32	102	39
	3	116	11	114	31	111	36	100	46
	4	40		59	3	76	12	77	12
	5	254	86	254	81	267	88	152	159
	6	98	74	88	63	114	83	124	99
	7	65	9	61	16	86	21	76	18
	8	50		46	2	76	14	66	8
	9	25		33	1	58	15	56	12
	10	198	84	112	164	210	81	229	92

Note: Null cells indicate calculation error

Table 4.20 Variation in k for Bases by Slab Location

Base Type	Test Path	Test Location	k (ksi) by AREA5			k (ksi) by AREA7		
			Average	Std	COV	Average	Std	COV
DGAB	Centerline	1	187.7	12.6	0.07	252.1	15.3	0.06
		2	164.9	17.6	0.11	192.5	31.3	0.16
		3	157.7	10.3	0.07	159.2	33.6	0.21
	Edge	6	100.0	24.1	0.24	128.2	33.7	0.26
		7	79.4	13.8	0.17	92.2	13.0	0.14
		8	71.6	18.1	0.25	74.1	19.4	0.26
LCB	Centerline	1	187.0	16.5	0.09	257.3	16.8	0.07
		2	160.4	19.4	0.12	207.6	29.0	0.14
		3	112.3	31.5	0.28	116.8	28.6	0.25
	Edge	6	96.3	29.1	0.30	123.8	42.2	0.34
		7	77.6	8.7	0.11	98.9	9.3	0.09
		8	51.0	19.1	0.37	53.5	22.5	0.42
ATB	Centerline	1	181.2	17.4	0.10	265.5	36.6	0.14
		2	164.9	12.4	0.07	205.9	37.7	0.18
		3	128.5	18.1	0.14	145.7	57.3	0.39
	Edge	6	98.5	7.8	0.08	142.6	20.2	0.14
		7	77.0	7.5	0.10	115.7	18.3	0.16
		8	58.9	18.6	0.32	89.7	35.3	0.39
PATB	Centerline	1	140.5	10.7	0.08	188.9	13.8	0.07
		2	110.1	10.1	0.09	132.4	14.1	0.11
		3	110.3	8.7	0.08	121.3	17.9	0.15
	Edge	6	105.9	16.3	0.15	141.1	23.0	0.16
		7	71.9	11.1	0.15	79.1	13.5	0.17
		8	59.7	13.1	0.22	57.3	17.1	0.30

Table 4.21 Variation in k by Test Path

Base Type	Test Path	k (ksi) Calculated by Method					
		AREA5			AREA7		
		Average	Std Dev	COV	Average	Std Dev	COV
DGAB	Centerline	170.1	18.8	0.11	201.2	47.5	0.24
	Edge	83.7	22.6	0.27	98.2	32.7	0.33
LCB	Centerline	153.2	38.8	0.25	193.9	63.5	0.33
	Edge	75.0	27.8	0.37	92.1	40.4	0.44
ATB	Centerline	158.2	27.3	0.17	205.7	66.4	0.32
	Edge	78.1	20.4	0.26	116.0	33.6	0.29
PATB	Centerline	120.3	17.4	0.14	147.5	33.3	0.23
	Edge	79.2	23.8	0.30	92.5	39.9	0.43

Figures 4.7 and 4.8 are plots of average k calculated by AREA5 and AREA7 using FWD data taken at dawn and at mid-afternoon when curling was most pronounced. Figure 4.7 shows data collected along the center of the slab at the joint (Location 1), at the quarter point of the slab (Location 2) and at midslab (Location 3). Figure 4.8 shows the same information along the edge of the slab. From these two plots, it is clear that calculated values of k are more sensitive to the effects of curling along the edge of the slab than along the centerline of the slab.

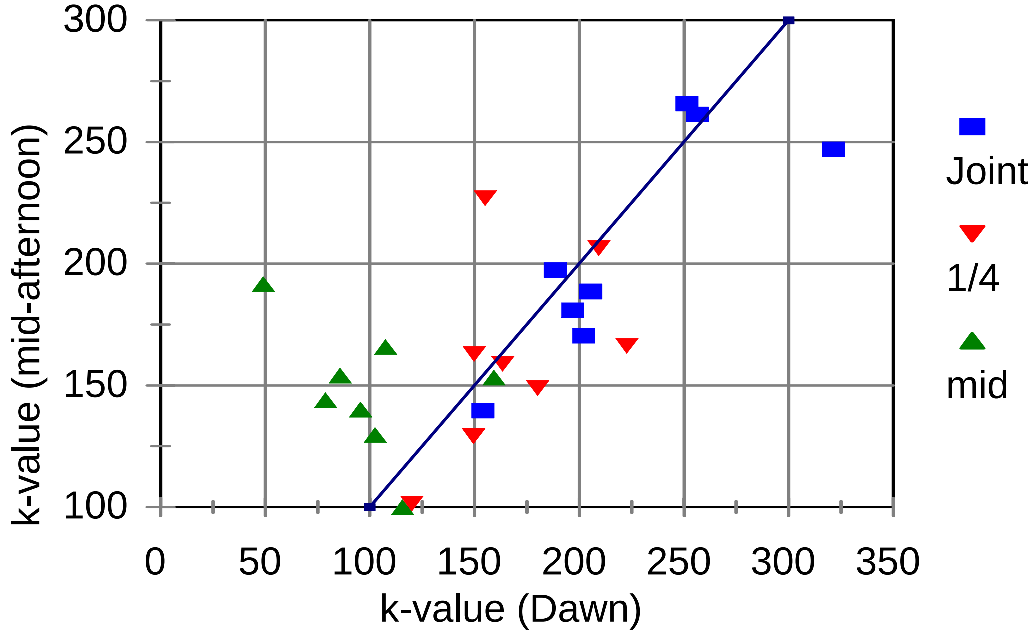


Figure 4.7 - Curling Effect on k-Value along Slab Centerline

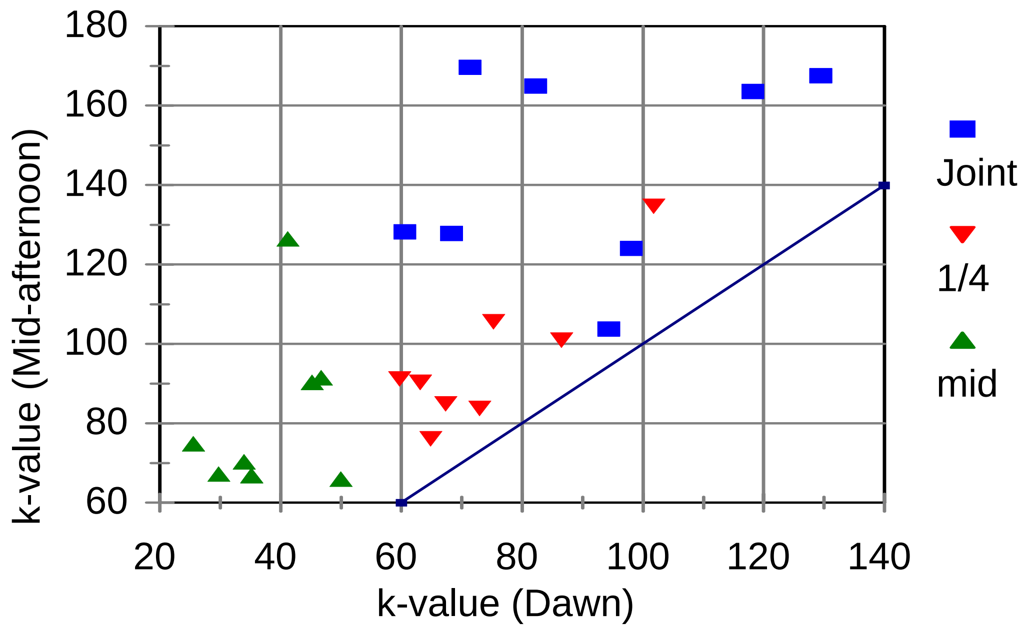


Figure 4.8 -Curling Effect on k-value along Slab Edge

It is assumed that FWD deflection within the test range was linear with load. Therefore, k values backcalculated by the AREA methods are not load dependent. Figures 4.9 to 4.34 are plots of backcalculated results for the three load levels. In theory, data points at different load levels should be identical. From plots at different times of day, it was found that, for all base types, k values measured at dawn were more sensitive to location than those measured at noon and afternoon. It was also indicated that k-A7 was more sensitive to location than k-A5.

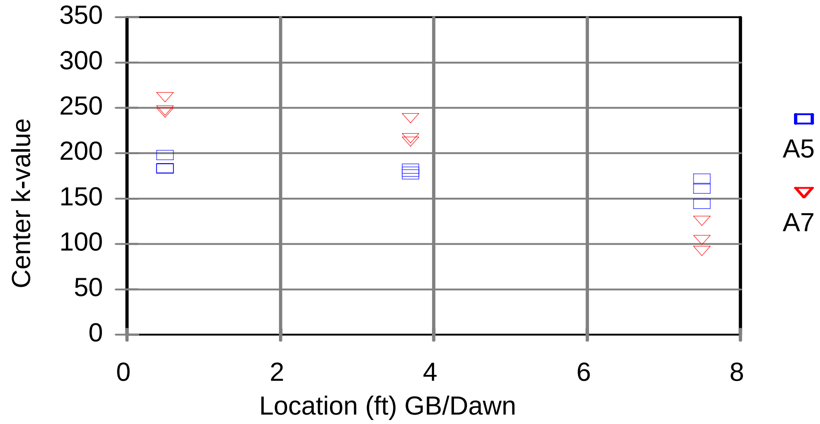


Figure 4.9 - K-value Along the Center of the Slab (DGAB at Dawn)

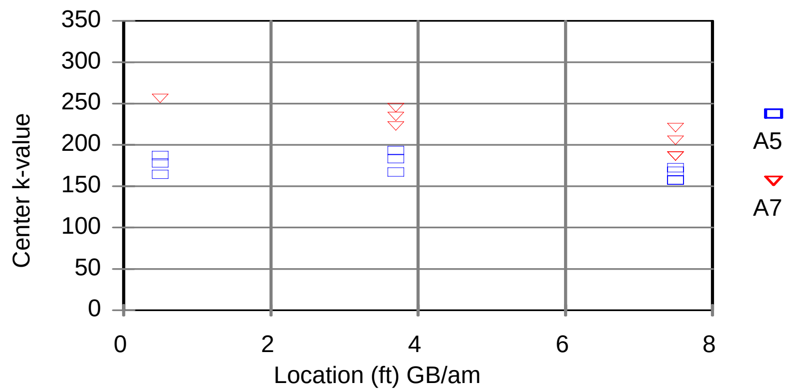


Figure 4.10 - K-value Along the Center of the Slab (DGAB in the Morning)

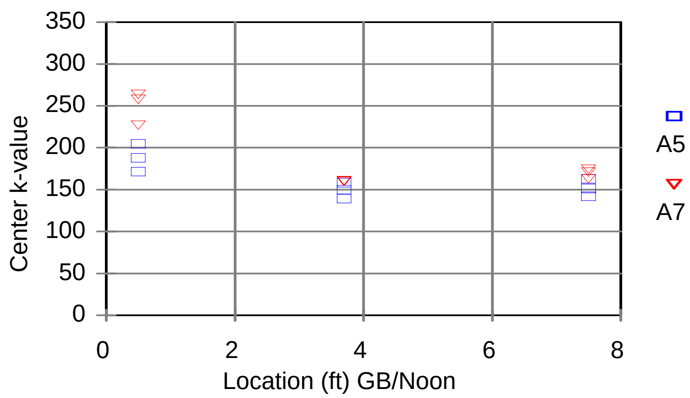


Figure 4.11 - K-value Along the Center of the Slab (DGAB at Noon)

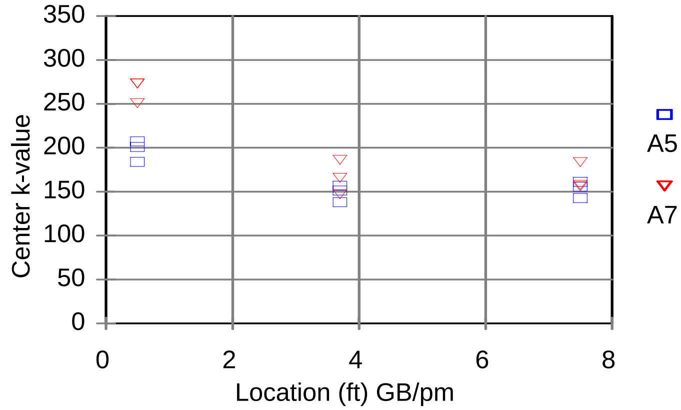


Figure 4.12 - K-value Along the Center of the Slab (DGAB in the Afternoon)

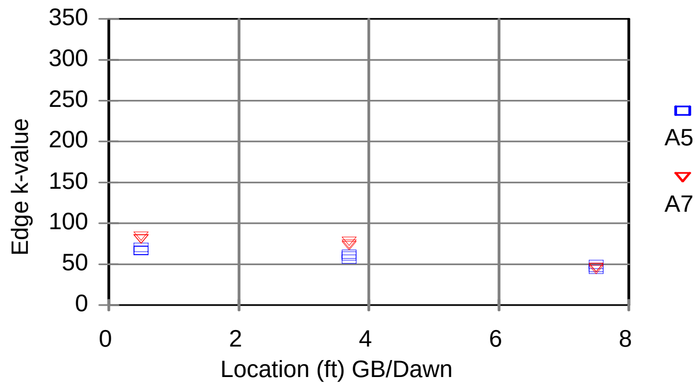


Figure 4.13 - K-value Along the Edge of the Slab (DGAB at Dawn)

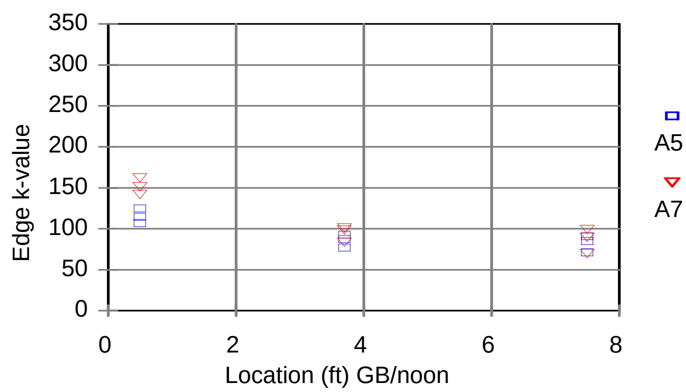


Figure 4.14 - K-value Along the Edge of the Slab (DGAB at Noon)

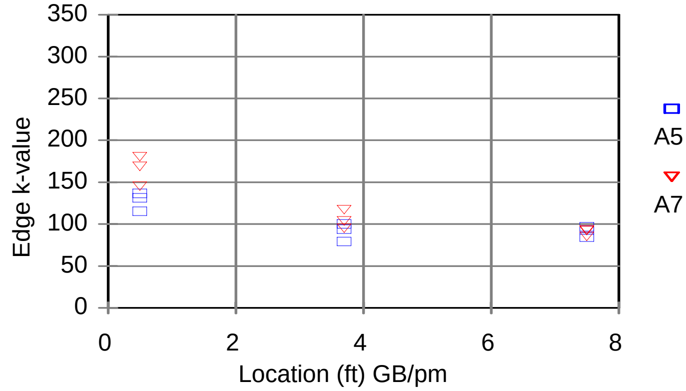


Figure 4.15 - K-value Along the Edge of the Slab (DGAB in the Afternoon)

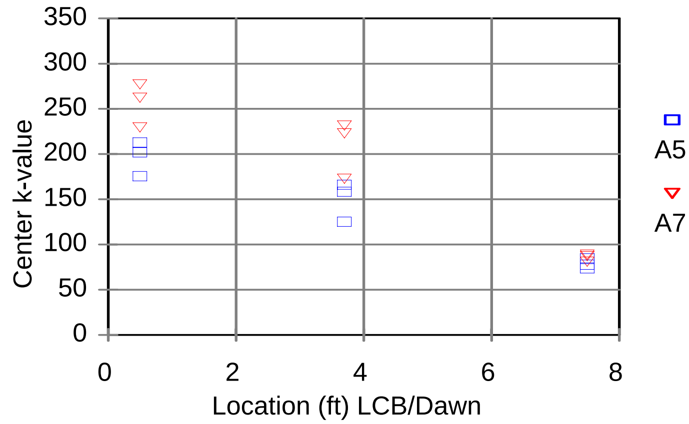


Figure 4.16 - K-value Along the Center of the Slab (LCB at Dawn)

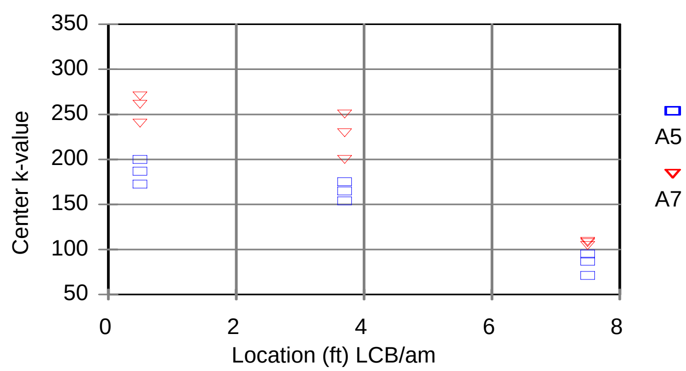


Figure 4.17 - K-value Along the Center of the Slab (LCB in the Morning)

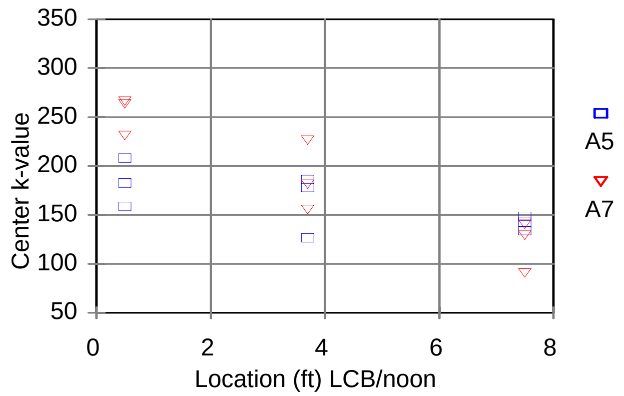


Figure 4.18 - K-value Along the Center of the Slab (LCB at Noon)

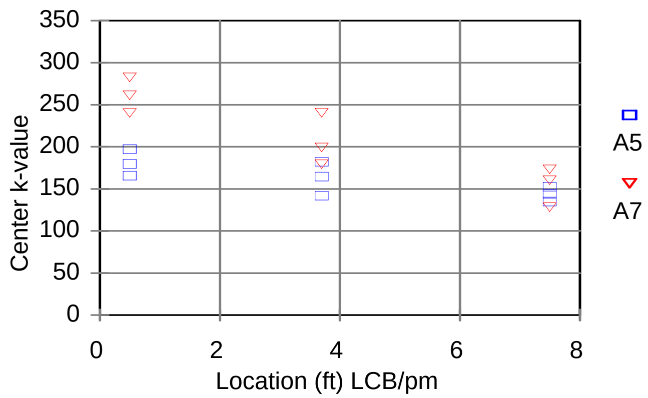


Figure 4.19 - K-value Along the Center of the Slab (LCB in the Afternoon)

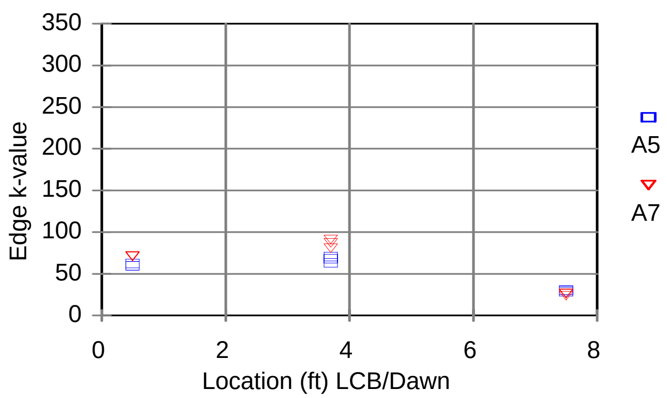


Figure 4.20 - K-value Along the Edge of the Slab (LCB at Dawn)

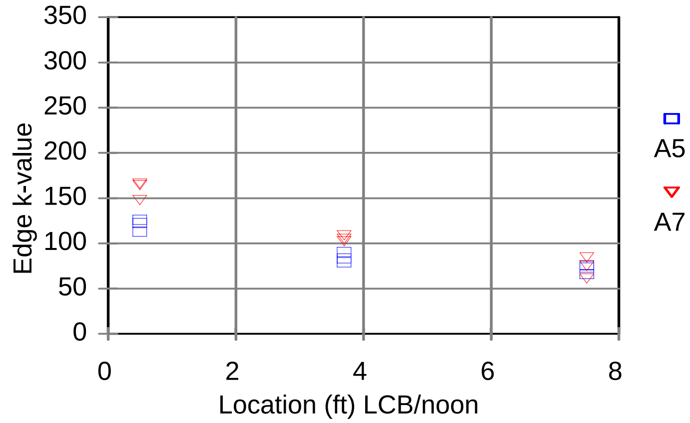


Figure 4.21 - K-value Along the Edge of the Slab (LCB at Noon)

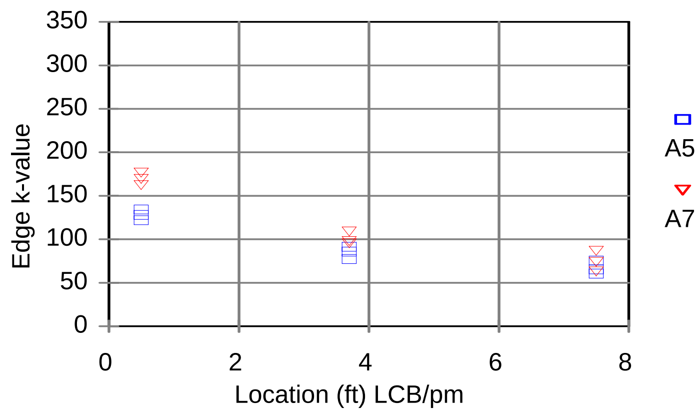


Figure 4.22 - K-value Along the Edge of the Slab (LCB in the Afternoon)

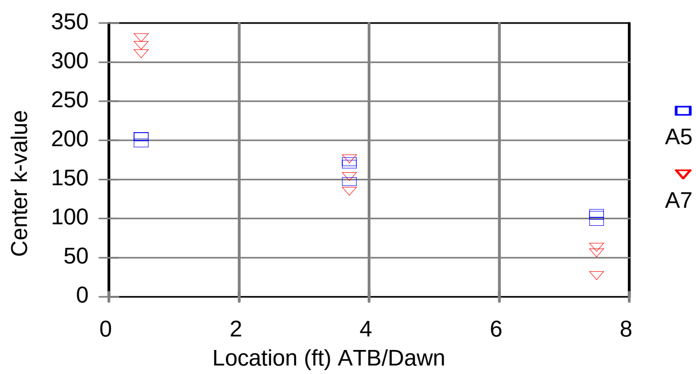


Figure 4.23 - K-value Along the Center of the Slab (ATB at Dawn)

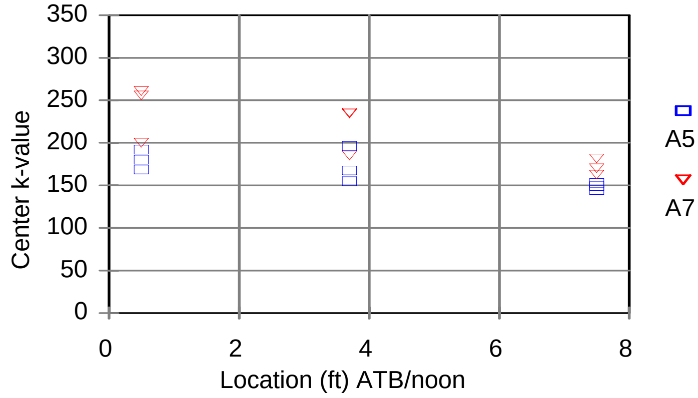


Figure 4.24 - K-value Along the Center of the Slab (ATB at Noon)

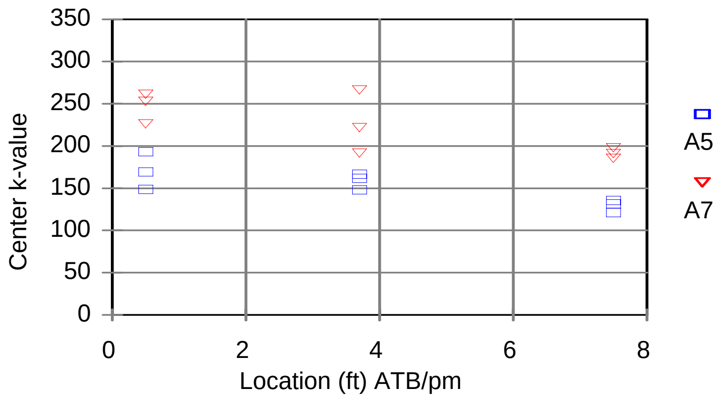


Figure 4.25 - K-value Along the Center of the Slab (ATB in the Afternoon)

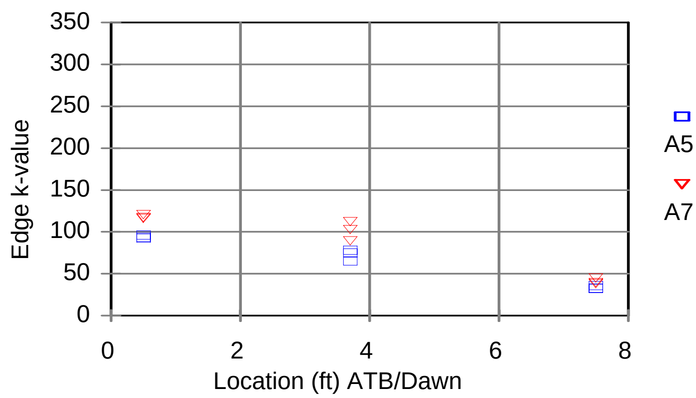


Figure 4.26 - K-value Along the Edge of the Slab (ATB at Dawn)

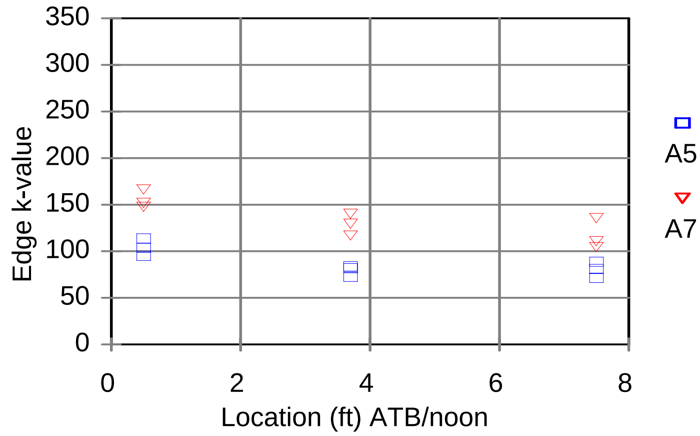


Figure 4.27 - K-value Along the Edge of the Slab (ATB at Noon)

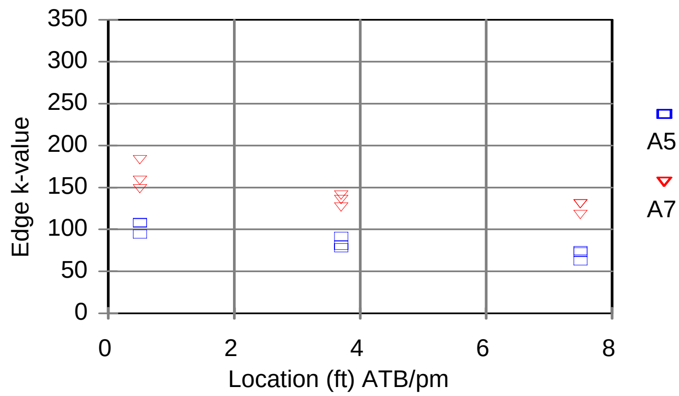


Figure 4.28 - K-value Along the Edge of the Slab (ATB in the Afternoon)

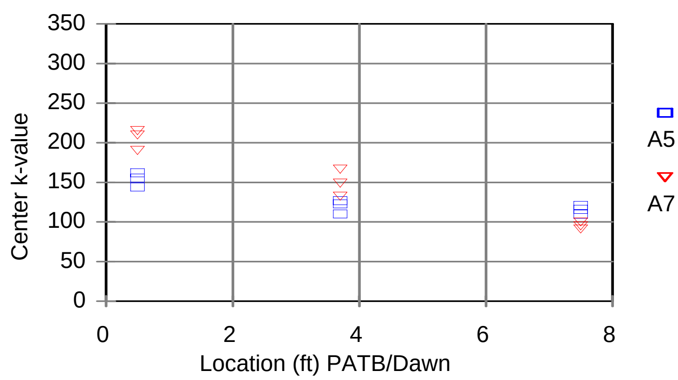


Figure 4.29 - K-value Along the Center of the Slab (PATB at Dawn)

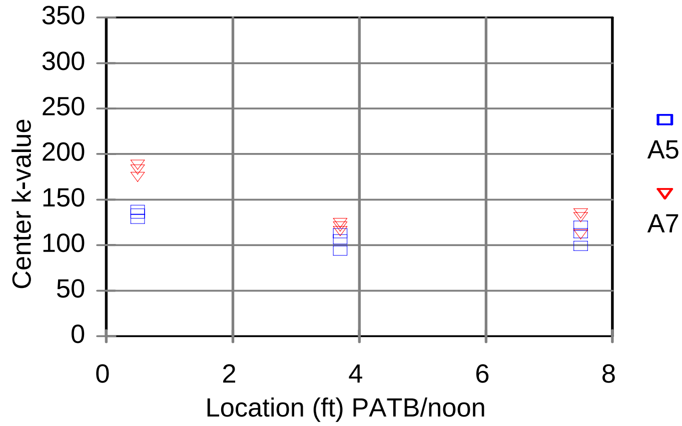


Figure 4.30 - K-value Along the Center of the Slab (PATB at Noon)

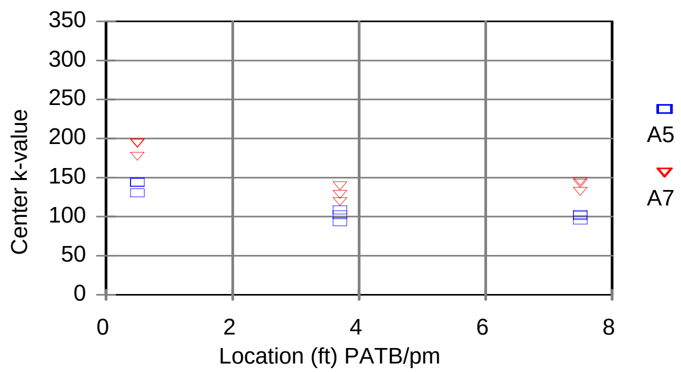


Figure 4.31 - K-value Along the Center of the Slab (PATB in the Afternoon)

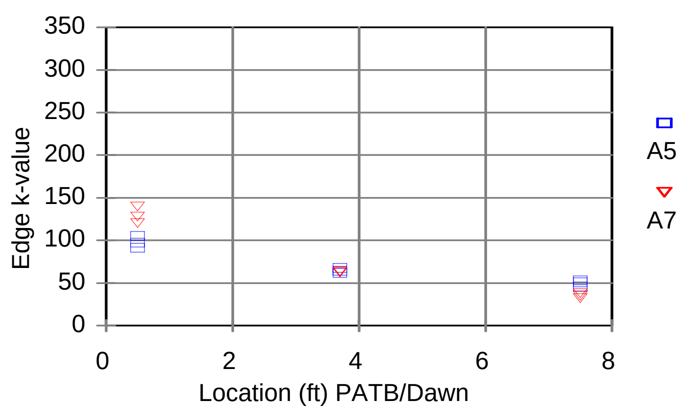


Figure 4.32 - K-value Along the Edge of the Slab (PATB at Dawn)

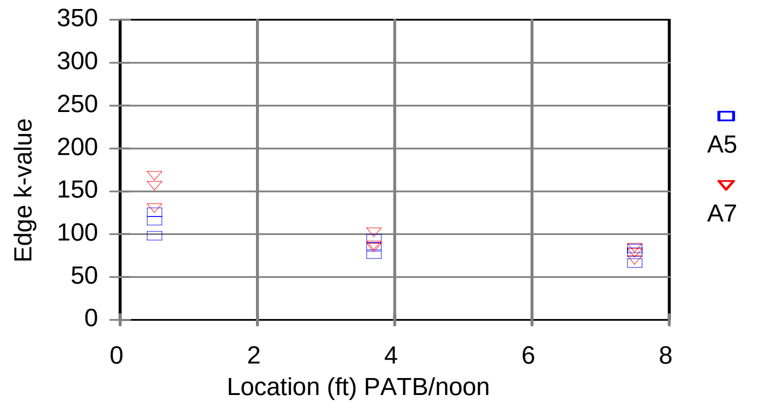


Figure 4.33 - K-value Along the Edge of the Slab (PATB at Noon)

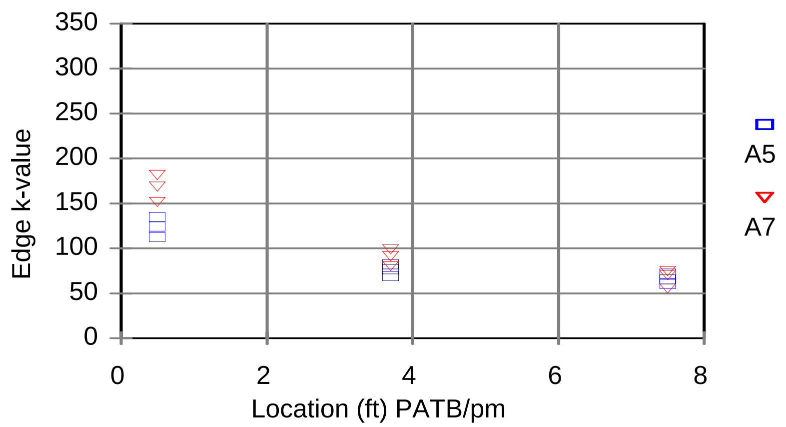


Figure 4.34 - K-value Along the Edge of the Slab (PATB in the Afternoon)

4.5 TRAFFIC LOADING FROM WEIGH-IN-MOTION

The on-site weight-in-motion (WIM) system started collecting traffic data in Lanes 11 (NB) and 51 (SB) in June 1996. A CD containing WIM data from 1998 to 2003 was obtained from ODOT. These data sets were used to study traffic weight distribution characteristics of the DEL 23 site. Weight spectrum data were provided by the Traffic Monitoring Section of ODOT in a table showing the daily average number of axles per month in 2 kip intervals grouped by axle type. Axle types included front axle, single axle (which excludes the front axle), tandem, triple and quadruple. This analysis of WIM data was made prior to the development of the various loading spreadsheets described earlier in this report.

4.5.1 Data Analysis

Axles with a spacing of less than 2.4 meters are considered to be a "group" axle. All axles were considered either front, single, tandem, or triple axle. Axle groups with greater than three axles were included with the triple axles. For multiple axles groups, the average axle weights were stored in two-kip bins. Total weight of the group, therefore, was the number of axles times the average axle weight.

To examine axle weight distribution pattern, two consecutive 14-day data was picked randomly. Figure 4.35 and 4.36 are sample of plots shown the difference of axle weight distribution between weekday and weekend. Data points from 1 to 8 are 11/97, 1/98, 3/98, 6/98, 1/2002, 6/2002, 1/2003, and 6/2003. Daily weight distribution, which is the percent of axle at each weight bin, was calculated. It is found that, in these 14 days, weekday daily axle weight distribution patterns for each axle type are similar. Due to much lower traffic volume during weekend, weight distribution pattern variations were much greater and the single day plot of weight distribution pattern is very different from that of weekday. But average weekend daily axle weight distribution is similar to the weekday axle weight distribution. Therefore, it is no need to distinct weekday and weekend traffic while calculating daily average. Weight distribution pattern indicated that over the years, daily axle weight pattern stay the same (see Figures 4.37 to 4.44). These figures are used to show that from year to year, the weight distribution is not changing much. Tridem and quad axle weight distribution (Figures 4.42 to 4.44) did not follow the same trend from year to year. The reason is because very low numbers of axle data of these types were collected for year 1997 and 2003. Small sample size can cause high variation. From these figures, it is safe to assume that average daily axle weight over these years is a good representation of the daily axle weight distribution pattern.

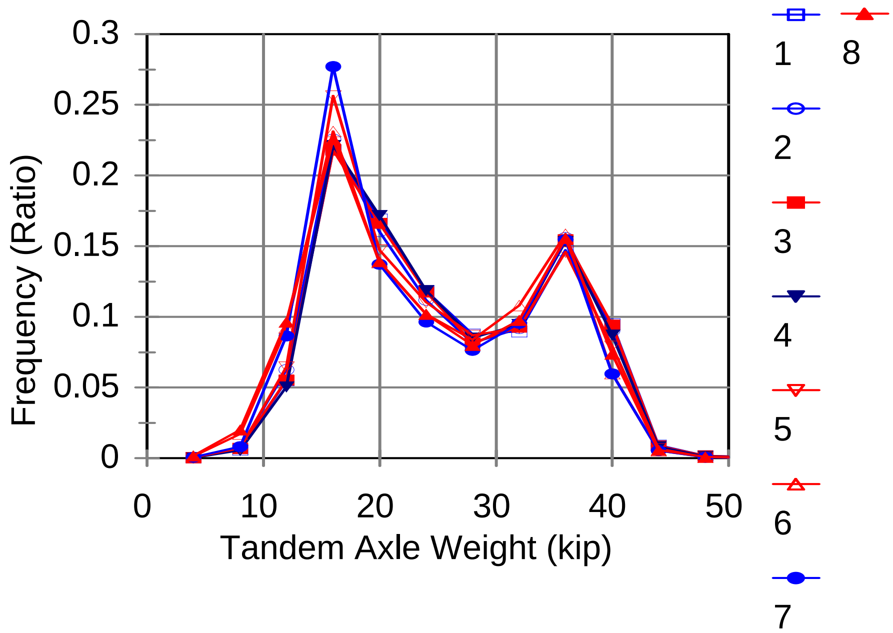


Figure 4.35 - Weekday Tandem Axle Distribution

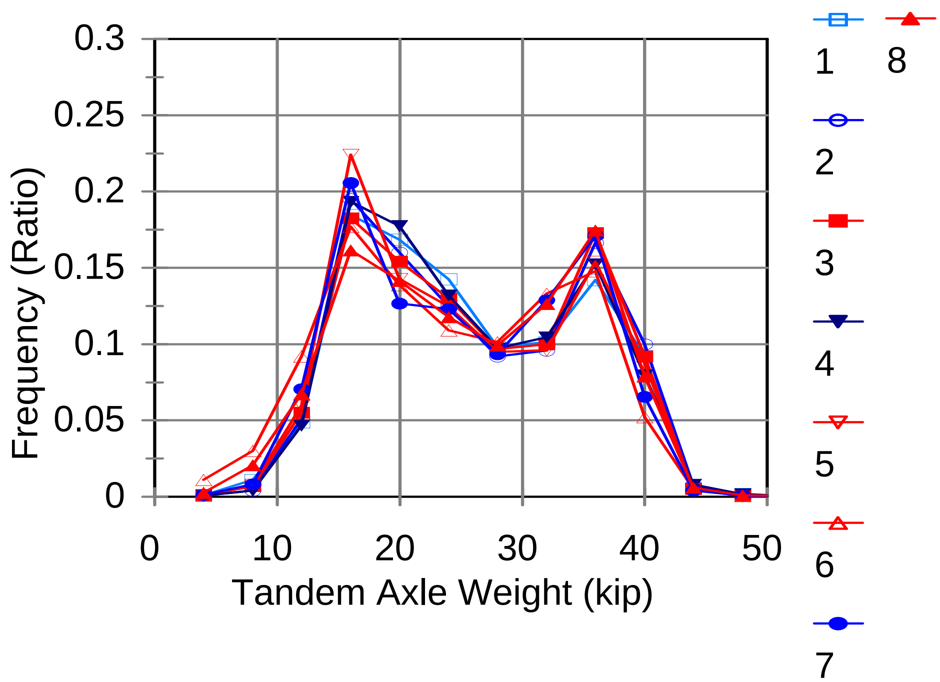


Figure 4.36 - Weekend Tandem Axle Distribution

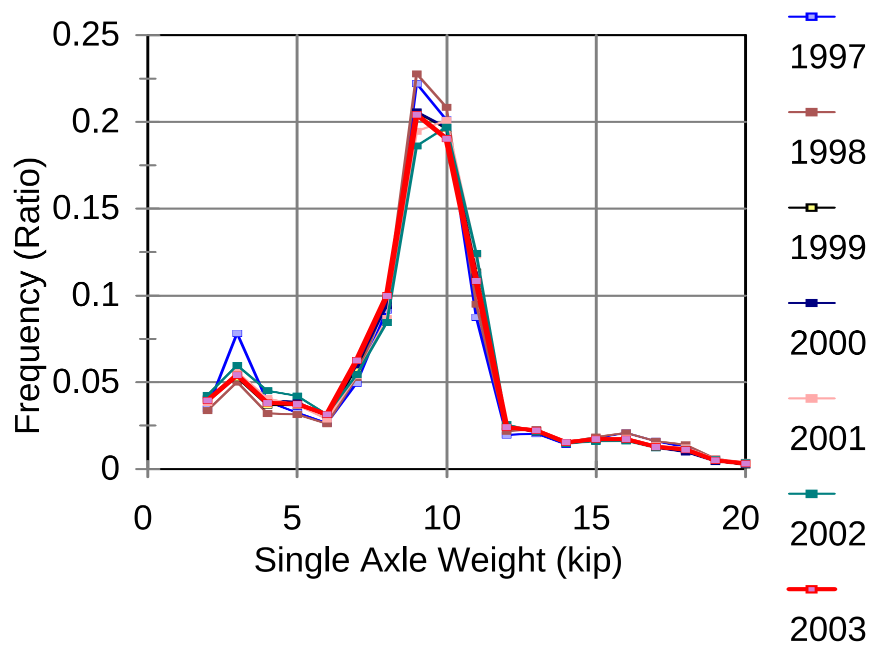


Figure 4.37 - Northbound Single Axle Weight Distribution

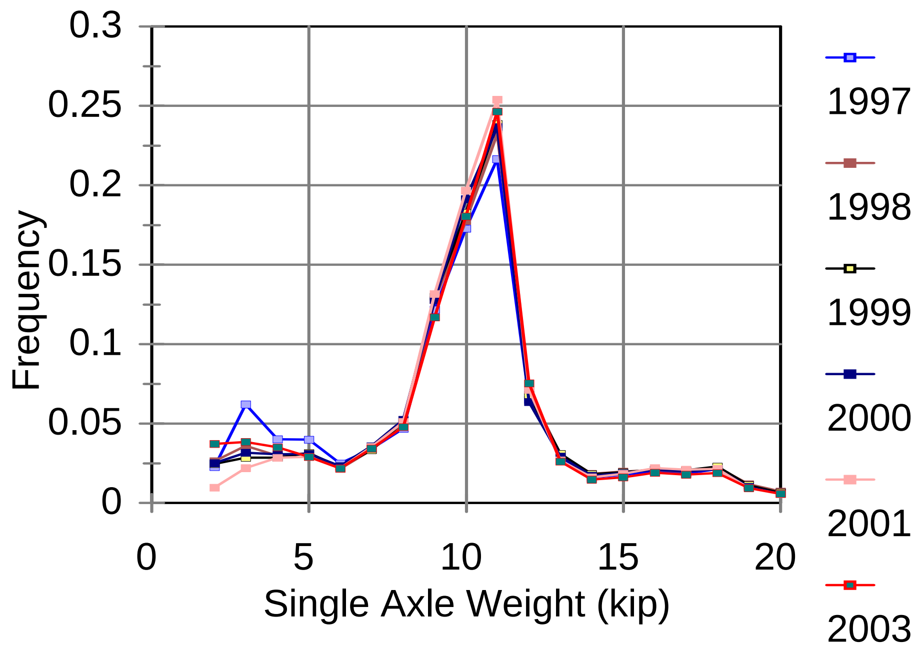


Figure 4.38 - Southbound Single Axle Weight Distribution

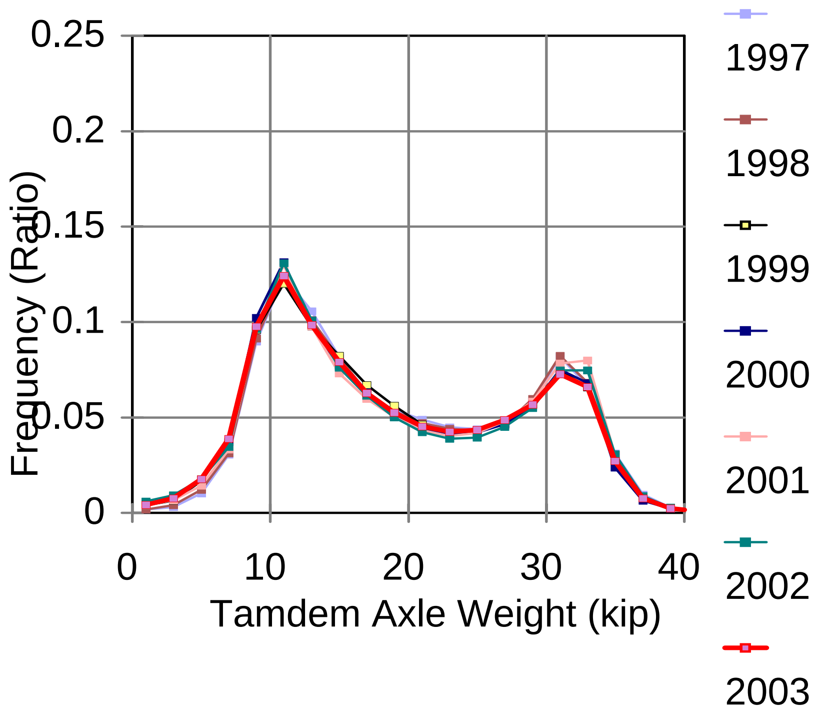


Figure 4.39 - Northbound Tandem Axle Weight Distribution

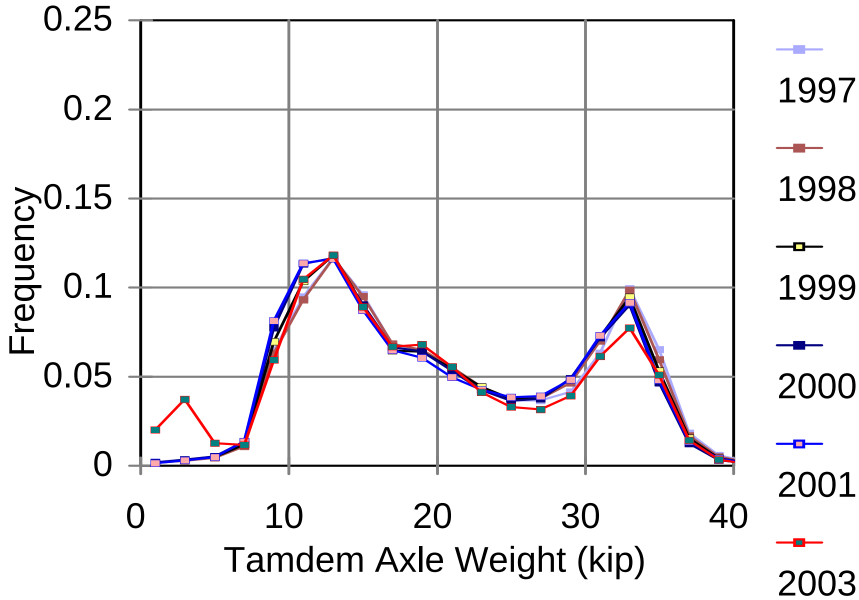


Figure 4.40 - Southbound Tandem Axle Weight Distribution

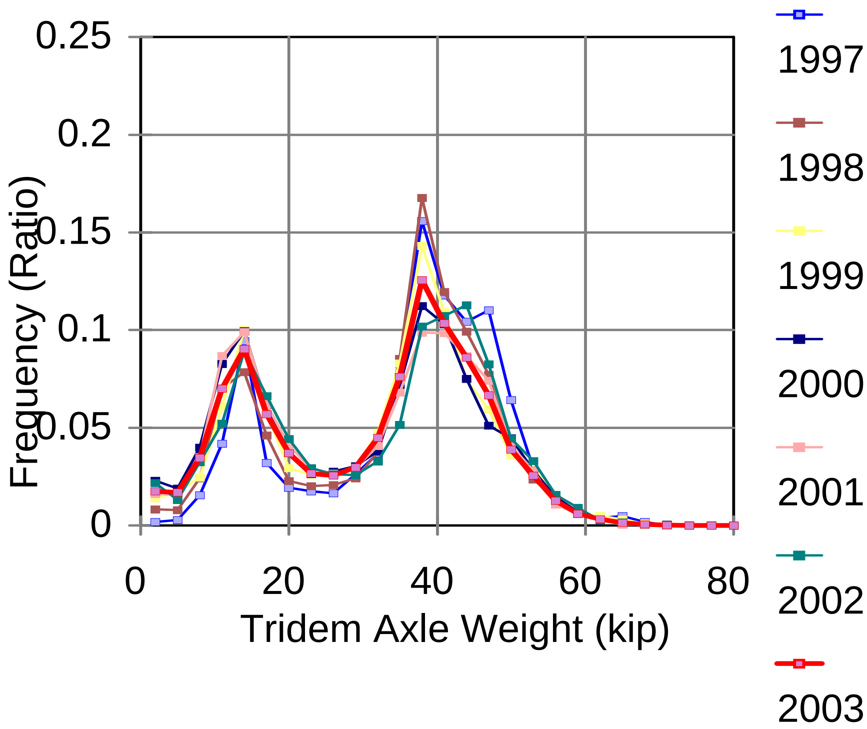


Figure 4.41 - Northbound Tridem Axle Weight Distribution

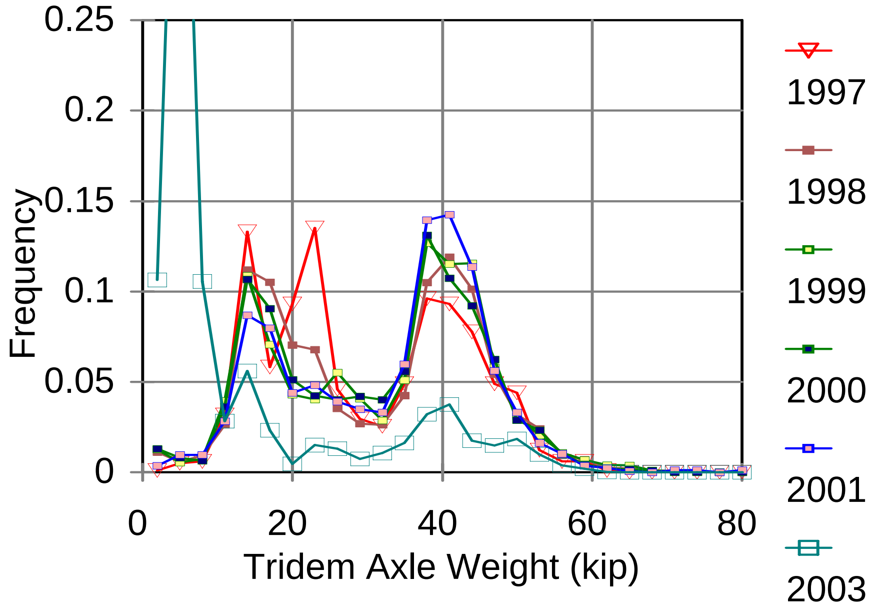


Figure 4.42 - Southbound Tridem Axle Weight Distribution

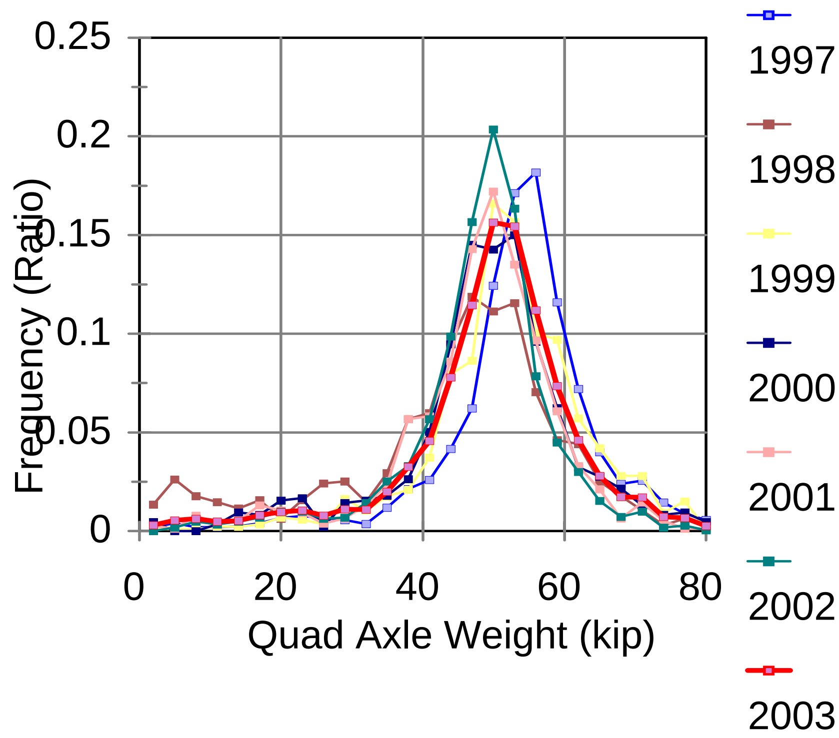


Figure 4.43 - Northbound Quad Axle Weight Distribution

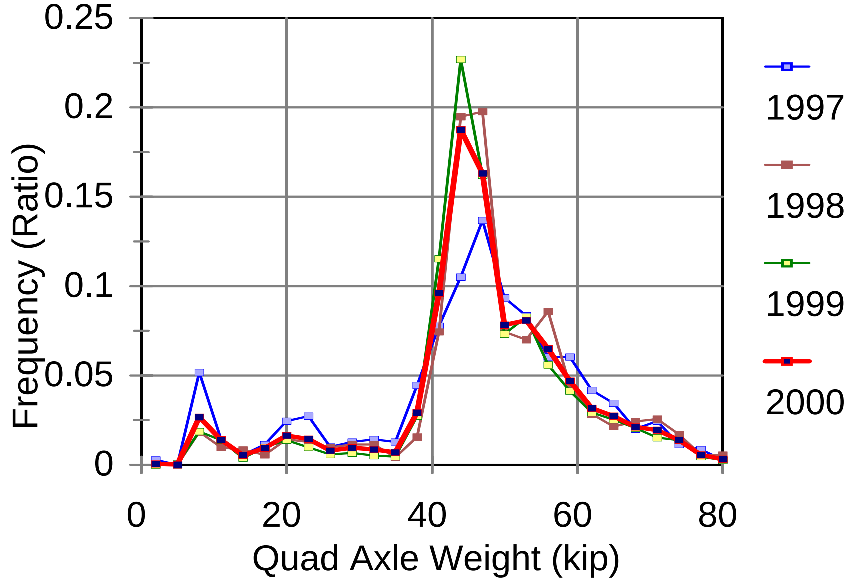


Figure 4.44 - Southbound Quad Axle Weight Distribution

Annual daily truck traffic (ADTT) was calculated using these two sets of data. Between April 24, 2002 and November 20, 2003, Lane 51 (SB) was closed down for the replacement of a second set of four sections which failed. Total ADTT was estimated by doubling the traffic in Lane 11 (NB) (assuming 50% directional distribution). It was found that truck volume declined for the first three years and then increased at an annual rate of approximately 3% , as shown in Figure 4.45. Table 4.22 presents estimated annual ADTT and accumulated truck traffic to 2015.

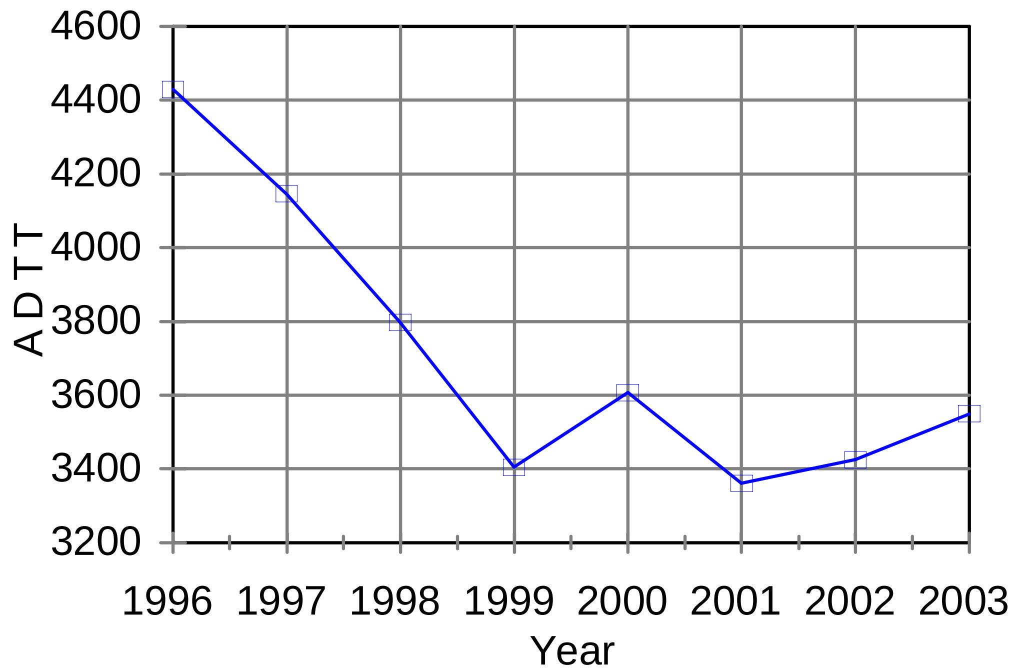


Figure 4.45 - Average Daily Truck Traffic

Table 4.22

Projected Truck Traffic

Year	WIM ADTT	Projected ADTT	Accumulated # of Trucks (1000)	Average Design Year # of Trucks
1996	4430	4430	1617	4430
1997	4147	4147	3131	4289
1998	3798	3798	4517	4125
1999	3405	3405	5760	3945
2000	3607	3607	7076	3877
2001	3361	3361	8303	3791
2002	3425	3425	9553	3739
2003	3550	3528	10841	3713
2004		3634	12167	3704
2005		3743	13533	3708
2006		3855	14940	3721
2007		3971	16389	3742
2008		4090	17882	3769
2009		4212	19420	3800
2010		4339	21003	3836
2011		4469	22634	3876
2012		4603	24314	3919
2013		4741	26045	3964
2014		4883	27827	4013
2015		5030	29663	4063

4.5.2 Truck Weight Distribution

The Portland Cement Association (PCA) design procedure uses axle weight spectrum for life prediction while the Asphalt Institute (AI) design procedure uses the AASHTO ESAL concept for axle load consideration. Table 4.23 shows the average daily axle weight distribution for single, tandem, and triple axles. The PCA design procedure requires the input of truck weight distribution based on the number of axles per 1000 trucks, as shown in Table 4.24. Using the AASHTO equivalent load factor, it was determined that one truck equals 1.4 and 2.2 ESALs for flexible and rigid pavements, respectively.

Table 4.23 Average Daily Number of Axles

Wt./Axle (kips)	Axle Grouping		
	Single	Tandem	Triple
2	88	5	0
4	383	60	2
6	575	360	8
8	363	1188	8
10	675	839	4
12	1823	618	5
14	1036	460	13
16	285	506	13
18	186	755	7
20	172	413	3
22	70	59	1
24	26	30	1
26	13	20	0
28	7	9	0
30	3	4	0

Table 4.24 Average Daily Number of Axle per 1000 Trucks

Wt./Axle (kips)	Axle Grouping		
	Single	Tandem	Triple
2	24	1	0
4	103	16	0
6	155	97	2
8	98	320	2
10	182	226	1
12	491	166	1
14	279	124	3
16	77	136	4
18	50	203	2
20	46	111	1
22	19	16	0
24	7	8	0
26	3	5	0
28	2	2	0
30	1	1	0

4.6 SURFACE DISTRESS SURVEY

Surface distress data were retrieved from the LTPP DataPave database. Table 4.25 is a summary of the latest surface distress for the SPS-1 flexible pavement sections on DEL 23. Sections 101, 102, and 107 failed soon after they were opened to traffic. Section 105 failed a couple of years later. Table 4.26 is a summary of 2003 surface distresses on the SPS-2 rigid pavement sections. The data clearly shows that rigid sections with PATB base (390209 to 390212) experienced the least surface distress, while sections with LCB base (390205 to 390208) experienced the most distress, in the form of pumping and transverse cracking. Of the three bases under rigid pavement, LCB is the only one with pumping and DGAB sections (390201 to 390204) performed somewhere between PATB and LCB. Table 4.27, which summarizes total surface distress by base type, shows the effect of base type on JCP performance.

Table 4.25

Latest SPS-1 Surface Distress Record

		Distress						
		LongCrk (wlpth)		LongCrk (nonwlpth)		Alligator Cracking		Patch
Severity		Mod.	Low	Mod.	Low	Mod.	Low	Low
Section	Year	(m)	(m)	(m)	(m)	(m^2)	(m^2)	(m^2)
101	1996	0	0	0	0	0	0	0
102	1996	0	0	0	0	0	0	0
103	2001	10.1	164.2	217	50.8	0	32.6	0
104	2002	0	0	166.8	37.2	1.7	13.5	0
105	1998	0	0	0	0	0	0	27.4
106	2002	61.7	161.7	52.5	173.6	5.2	57.6	0
107	1996	0	0	0	0	0	0	0
108	2001	124.5	71	8.8	219.9	0	66.4	0
109	2001	0	244.1	0	38.4	0	0	0
110	2001	26.3	185.2	0	0	0	31.2	0
111	2002	4.3	8.7	37.1	30.2	8.6	19.9	0
112	2002	23.9	13.9	0	44.9	0	20.5	0

Table 4.26

2003 SPS-2 Surface Distress by Section

Section	Distress and Severity					
	Longitudinal Cracking	Longitudinal Spalling	Transverse Cracking			Pumping
	Moderate	Low	High	Moderate	Low	
	(m)	(m)	(m)	(m)	(m)	(m^2)
201	0	0	0	3.6	36.6	0
202	0	0	0	8.6	51.6	0
203	0	5.3	0	0	0	0
204	0	0	0	11.0	36.7	0
205	0	0	7.4	29.6	55.5	152.4
206	20.9	0	0	17.1	42.8	77.8
207	0	2.3	0	0	0	0
208	0	1.5	0	0	0	0
209	0	0	0	0	3.6	0
210	0	0	0	25.6	4.2	0
211	0	0	0	0	0	0
212	0	0	0	3.6	3.6	0

Table 4.27

2003 SPS-2 Surface Distress by Base Type

Base Type	Longitudinal Cracking	Transverse Cracking	Longitudinal Spalling	Pumping
	(m)	(m)	(m)	(m^2)
DGAB	0	148.1	5.3	0
LCB	20.9	152.4	3.8	230.2
PATB	0	40.6	0	0

4.7 ROUGHNESS MEASUREMENTS

Section roughness data were retrieved from the LTPP DataPave database. Table 4.28 summarizes average IRI (in m/km) in the left and the right wheel paths.

Table 4.28

Average IRI

Section	Year					
	1997	1998	1999	2000	2002	2003
101	1.41	4.09				
102	1.26					
103		1.73	2.71	2.78	3.07	
104	0.74	0.83	1.21	1.31	1.42	1.37
105	1.09	1.78				
106	1.13	1.23	1.75	1.78	1.84	1.81
107	1.76					
108	0.89	1.21	1.88	1.98	2.13	
109	0.72	0.83	1.47	1.60	1.69	
110	1.20	1.32	1.60	1.68	1.78	
111	0.78	0.88	1.27	1.36	1.45	1.34
112	0.91	0.96	1.40	1.52	1.59	1.50
201	1.24	1.30	1.45	1.44	1.55	1.55
202	1.14	1.14	1.34	1.39	1.52	1.56
203	1.09	1.01	1.10	1.04	1.19	1.14
204		0.83	0.95	0.86	1.21	1.14
205	1.25	1.20	1.35	1.38	1.53	1.44
206	1.23	1.24	1.33	1.41	1.50	1.52
207	1.38	1.36	1.24	1.44	1.27	1.64
208	1.50	1.47	1.29	1.46	1.36	1.53
209	0.99	0.96	1.12	1.08	1.15	1.21
210	1.08	0.98	1.03	1.17	1.09	1.38
211	1.39	1.29	1.35	1.35	1.33	1.47
212	1.12	1.23	1.01	1.04	1.03	1.23

4.8 PAVEMENT DESIGN MODELS

There are many pavement structure design models, but only a few are widely adopted by transportation agencies. The more common design models are the Asphalt Institute (AI) method for flexible pavement, the AASHTO methods for flexible and rigid pavement, and the Portland Cement Associate (PCA) method for rigid pavement. The SPS-1 and SPS-2 design thicknesses and field collected parameters were applied to these models to determine the estimated design life of the different sections. The results were compared to the original ODOT calculations.

4.8.1 Flexible Pavement

4.8.1.1 Asphalt Institute (AI)

To simplify this analysis, the AI design procedure was compressed into a few design charts with the following input:

1. Traffic value in ESAL which used the same ESAL factor developed by AASHTO.
2. Subgrade resilient modulus. AI suggests that the design modulus shall be the 87.5 percentile of moduli data collected in the section. The Mr applied to the design procedure for different sections are summarized on Table 4.29.
3. Surface and base types.

When these data is selected, the thickness of the AC layer can be determined from the appropriate chart.

Table 4.29

AI 85th Percentile Modulus Input

Section	**101**	**102**	**103**	**104**	**105**	**106**
Mr (ksi)	4.3	8.1	6.8	8.3	6.9	7.2
Section	**107**	**108**	**109**	**110**	**111**	**112**
Mr (ksi)	8.4	8.6	3.4	4.2	5.8	7.2

4.8.1.2 AASHTO

The AASHTO design procedure was developed from data on the AASHO Road Test in the late 1950s. An artificial semi-subjective parameter, present service index (PSI), was defined as a measurement scale for pavement performance and another artificial parameter, structural number (SN), was used to measure flexible pavement strength. Performance equations were developed for each parameter using regression techniques. Over the years, the procedure has been modified and improved, but the fundamental concepts have remained intact. WinPAS, a software package developed by ACPA, is based on the AASHTO pavement structure design procedure and is used to calculate design loading for rigid pavement structures.

The primary input parameters are:

Initial serviceability: 4.2

Terminal serviceability: 2.5

Reliability: 90%

Overall deviation: 49%

Layer coefficients:

AC	0.44
ATB	0.30
DGAB	0.14
CTB	0.28

In accordance with AASHTO recommendations, average static moduli were used for these calculations. Moduli backcalculated from FWD measurements are dynamic moduli and, since design models typically use static moduli for calculation, the dynamic moduli were reduced by 50%. Table 4.30 summarizes design lives calculated with the AASHTO design model.

Table 4.30

Design Life of AASHTO Design Model

Section No.	Mr (ksi)	Design Life (10^3 ESALs)
101	8,200	3,585
102	13,500	3,271
103	10,000	5,341
104	11,800	232,229
105	9,700	1,748
106	11,500	100,708
107	11,500	770
108	13,100	24,423
109	7,500	14,620
110	8,200	9,236
111	11,900	18,449
112	11,000	78,074

4.8.1.3 ODOT

AASHTO equations were used to calculate design lives for SPS-1 sections using the following parameters:

Layer coefficients: 0.35 for AC and 0.14 for DGAB

Initial serviceability: 4.5

Terminal serviceability: 2.5

Reliability: 50%

Overall deviation: 0.49

4.8.1.4 Comparison of Flexible Pavement Results

Using the parameters described above, design life derived from the AI and AASHTO procedures are summarized for the SPS-1 sections in Table 4.31. Regression analyses showed that the correlation coefficients for AASHTO vs. AI and AASHTO vs. ODOT design lives were 0.93 and 0.94 respectively. Since ODOT follows the AASHTO design procedure, AASHTO and ODOT results were almost 1:1. AASHTO and AI results were bias. Figure 4.46 shows model correlations and Figure 4.47 shows design lives using the various design procedures.

Table 4.31

Design Lives for Different Flexible Pavement Design Models

Section No.	Design Life (10^3 ESALs)		
	ODOT	AASHTO	AI
101	2,400	3,585	220
102	900	3,271	290
103	7,200	5341	4,600
104	215,400	232,229	60,000
105	1,600	1,748	950
106	75,200	100,708	24,000
107	200	770	150
108	6,400	24,423	1,600
109	15,500	14,620	340
110	10,000	9,236	2,300
111	17,200	18,449	5,200
112	118,100	78,074	36,000

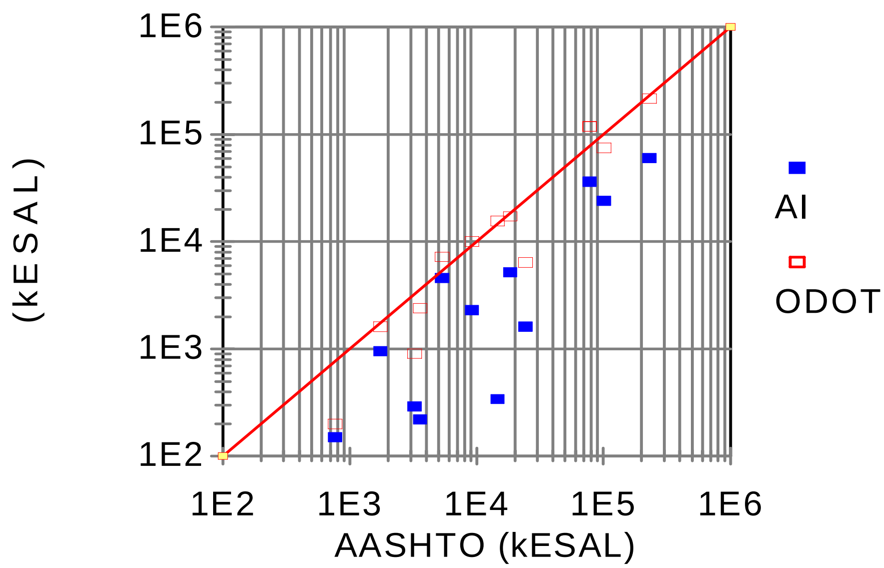


Figure 4.46 - Flexible Pavement Design Life

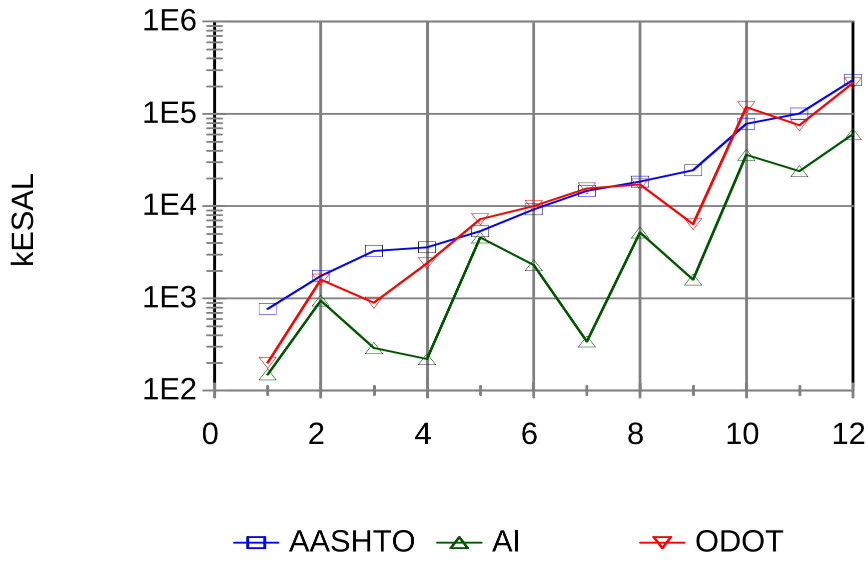


Figure 4.47 - Flexible Pavement Design Life from Different Design Method

4.8.2 Rigid Pavement

4.8.2.1 Portland Cement Association (PCA)

The PCA design method is a stress-based mechanistic design procedure. Slab thickness design is determined by two failure modes; fatigue and drainage. Fatigue life is a function of the stress/strength ratio and drainage life is a function of the corner and edge deflections. These two failure modes are used to determine slab thickness. PCA developed PCAPav software to perform the calculations.

Input data for the program are:

Modulus of rupture: 550 and 900 psi

Young's modulus: 4,000,000 psi

Axle weight distribution: see Table 4.35

Average daily truck traffic: see Table 4.36

Design life

Load transfer: with dowels

Load safety factor: 1.2

The PCA design model requires truck weight distribution as input. Two types of axles were specified; namely, single, and tandem axles. Units are the number of axles per 1000 trucks. Table 4.24 summarizes the number of axles for each weight bin per 1000 trucks. Output of the program includes percent of fatigue and drainage life consumed for the given slab thickness. Design lives for each of the SPS-2 test sections based on the PCA design model are summarized in Table 4.32.

Table 4.32

PCA Design Results for SPS-2 Sections

Section No.	k	ADTT	Life (years)	% Consumption	
				Fatigue	Drainage
201	156	4,430	0.01	100	1
202	126	3,945	4	9	100
203	154	4,289	24	96	36
204	218	7,173	55	0	95
205	190	4,430	0.02	100	0
206	163	3,945	4	4	93
207	211	6,794	52	96	88
208	198	6,917	53	0	98
209	182	4,430	0.02	100	0
210	233	3,877	5	1	92
211	189	5,512	40	93	62
212	196	6,794	52	0	96

4.8.2.2 AASHTO

The AASHTO design procedure is based on results from the 1950's AASHO Road Test. WinPAS software is used to perform the calculations. Input data are:

Design parameter:

Load transfer: 3.2 (Joint with dowels)

Drainage: 1.1 for GB and LCB, 1.25 for PATB

Initial service index: 4.2

Final service index 2.5

Reliability: 90 %

Overall deviation: 49%

k: See Table 4.32

Modulus of rupture: 550 and 900 psi

Modulus of elasticity: 4,000,000 psi

From these data, design lives are summarized in Table 4.33.

Table 4.33

AASHTO k Values and Design Lives

Section No.	k (AREA5)	Design Life (10^3 ESALs)
201	156	1,127
202	126	5,623
203	154	8,027
204	218	47,785
205	190	1,218
206	163	6,179
207	211	8,781
208	198	46,431
209	182	1,853
210	233	11,074
211	189	13,161
212	196	71,677

4.8.2.3 ODOT

The AASHTO Guide (AASHTO 1993) suggests that k be estimated from Mr with the equation: $k = Mr / 19.4$

Values of Mr reported by Sargand (Sargand, et al., 2000) were used to calculate k for different sections. Table 4.15 shows k for all SPS-2 sections. These values, as well as the following input parameters, were applied to AASHTO design model. The resulting design parameters were used by ODOT for the original estimates of performance.

Reliability: 50%

Deviation: 49%

Initial Service Index: 4.5

Final Service Index: 2.5

Load Transfer: 3.8

Drainage Factor: 0.8

4.8.2.4 Comparison of Rigid Pavement Results

Design results using the three approaches are summarized in Table 4.34. The PCA design lives in years were converted to kESALs for comparison purposes.

Table 4.34

Design Life of Different Rigid Pavement Design Models

Section No.	Design Life (10^3 ESALs)		
	ODOT	AASHTO	PCA
201	900	1,127	36
202	6,700	5,623	12,671
203	10,700	8,027	82,658
204	32,700	47,785	316,796
205	1,100	1,218	71
206	7,800	6,179	12,671
207	12,200	8,781	283,690
208	36,500	46,431	294,381
209	3,200	1,853	71
210	23,200	11.074	15,566
211	36,900	13,161	177,045
212	112,200	71,677	283,690

Regression analyses showed that the correlation coefficients for AASHTO vs. PCA and AASHTO vs. ODOT design lives were 0.62 and 0.79, respectively. Again, AASHTO and ODOT results were almost 1:1. AASHTO and PCA results were somewhat correlated but biased. Figure 4.48 shows model correlations and Figure 4.49 compares design lives for the three procedures.

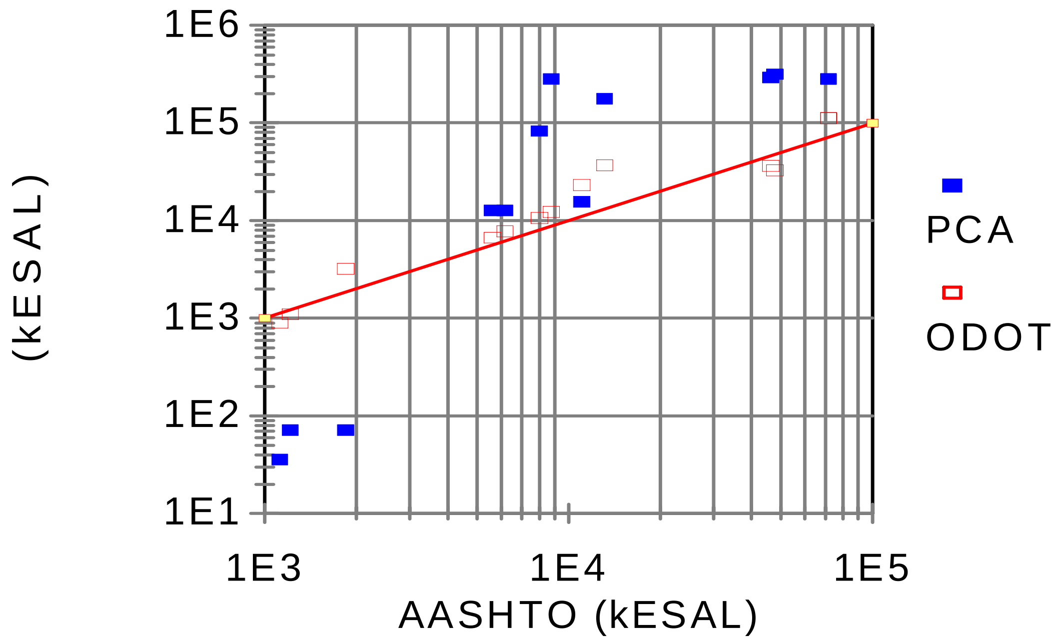


Figure 4.48 - Rigid Pavement Design Life

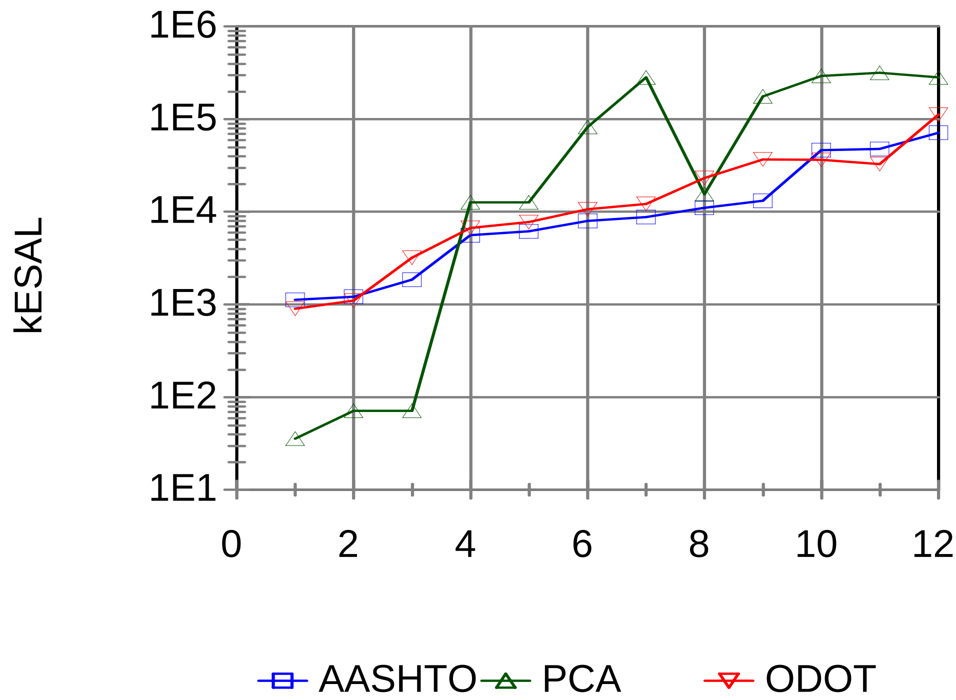


Figure 4.49 - Rigid Pavement Design Life from Different Design Method

<u>4.8.2.5 Comparison of Design Load and Actual Load</u>

Pavement structural design procedures are based upon pavement performance models, but performance models are not presented in the design manual. Hence, design procedures offer only two points in the performance history of the pavement; when the pavement is new and when it reaches its design life. Since most of the pavement sections on DEL 23 are still in service, it was not possible to carry out a good comparison of predicted performance and actual performance. A sensitivity study was performed to compare the effects of structure strength and soil support on the design lives of flexible and rigid pavements.

<u>4.8.2.6 Sensitivity Analysis on Flexible Pavement</u>

The results of a sensitivity analysis of subgrade modulus and structural strength (SN) on the design lives of flexible pavements. The results of design life under different SN are summarized in Table 4.35. These two tables clearly show that AASHTO design results are more liberal than AI procedure.

Table 4.35

Comparison of Design Lives for Flexible Pavement

Design Life (10^3 ESALs)					
Method	**SN**	**Subgrade Modulus (ksi)**			
		7	**9**	**11**	**13**
AASHTO	2.88	274	491	783	1153
	4.76	7782	13943	22210	32723
	6.68	101103	181126	288515	425096
AI	2.88	136	245	330	470
	4.76	1100	1450	1800	2150
	6.68	5800	7200	8600	10000

To compare effects of the different factors, design life (number of repeated load applications) was normalized to the lowest value for that factor and defined as Increase Rate (IR). IR represents the rate of design life increase as that factor increased. Table 4.36 summarizes the effects of subgrade moduli on Increase Rate at different SN. It was found that:

1. The AASHTO design procedure was more sensitive to subgrade modulus than the AI procedure. AASHTO results were from two to forty times higher than the AI results, depending upon structure strength and the subgrade modulus.
2. Using the AASHTO model, structural strength did not affect the IR of subgrade modulus.
3. The effect of subgrade strength on structural strength was different for the AI design model, in that weaker pavements (lower SN) had a greater effect on subgrade modulus.
4. The effect of SN to IR derived from the AI model was much greater than from AASHTO model , as shown in Table 4.37.
5. Subgrade modulus did not influence the effect of SN on IR derived from the AASHTO model. The effect of SN on AI in the AI model was affected by subgrade modulus. The weaker the subgrade, the greater the effect.

Table 4.36

Effect of Subgrade Modulus on Increase Rate

Method	SN	Increase Rate for Subgrade Modulus (ksi)			
		7	9	11	13
AASHTO	2.88	1.0	1.8	2.9	4.2
	4.76	1.0	1.8	2.9	4.2
	6.68	1.0	1.8	2.9	4.2
AI	2.88	1.0	1.8	2.4	3.5
	4.76	1.0	1.3	1.6	2.0
	6.68	1.0	1.2	1.5	1.7

Table 4.37

Effect of Structure Strength on Increase Rate

Method	SN	Increase Rate for Subgrade Modulus (ksi)			
		7	9	11	13
AASHTO	2.88	1	1	1	1
	4.76	8	6	5	5
	6.68	43	29	26	21
AI	2.88	1	1	1	1
	4.76	28	28	28	28
	6.68	369	369	368	369

4.8.2.7 Sensitivity Analysis on Rigid Pavement

The sensitivity of base support (k), structure strength (slab thickness), and concrete strength (modulus of rupture) on design life were studied for the AASHTO and PCA design models. Results are summarized in Tables 4.38 and 4.39.

Table 4.38

AASHTO Model Design Load Repetitions

Mr (psi)	**Slab Thickness (in.)**	**ESALs (10^3) for k (pci)**			
		100	**150**	**200**	**250**
550	8	966	1111	1244	1369
	10	3869	4326	4730	5100
	12	12801	14058	15141	16119
900	8	5204	5988	6703	7379
	10	20849	23315	25486	27483
	12	68980	75752	81589	86861

Table 4.39

PCA Model Design Load Repetitions

Mr (psi)	**Slab Thickness (in.)**	**k (pci)**							
		100	**150**	**200**	**250**	**100**	**150**	**200**	**250**
		No. of Trucks (10^6)				**Failure Mode**			
550	8	0.007	0.010	0.037	0.088	F	F	F	F
	10	1.0	5.0	13.7	27.7	F	F	F	F
	12	53.3	496.4	905.2	1095.0	F	F	D	D
900	8	12.3	15.3	18.3	20.4	D	D	D	D
	10	80.3	124.1	160.6	189.9	D	D	D	D
	12	451.7	686.6	885.3	1120.2	D	D	D	D

Failure Mode: F - Fatigue D - Drainage

Design life was sensitive to concrete strength and thickness in the AASHTO and PCA procedures. From Table 4.38, increasing the concrete modulus of rupture from 550 psi to 900 psi increased the AASHTO design life 5.4 times. As modulus of rupture (Mr) increased (stronger slab), the failure mode shifted from fatigue to drainage in the PCA procedure. The PCA design procedure was much more sensitive to slab strength (modulus of rupture and/or thickness) on design (fatigue) life than the AASHTO procedure. When slabs were predicted to fail in a drainage mode, increasing the concrete modulus of rupture from 550 to 900 psi did not affect the design life.

In a structural system with low overall strength (combination of thickness, modulus of rupture and k), the PCA design is more conservative. As the structure strength increases, however, the AASHTO design model is much more conservative than the PCA model. The effect of pavement thickness is much greater for the PCA design than for the AASHTO design, as shown in Table 4.40. Table 4.41 shows that the PCA design is more sensitive to k at all thicknesses than the AASHTO design. This effect increases with thickness but, for the AASHTO design, the effect of k is the same for all thicknesses.

Table 4.40

Effect of Thickness on Increase Rate at Mr = 550 psi

Slab Thickness (in.)	k (pci)							
	AASHTO				PCA			
	100	150	200	250	100	150	200	250
8	1	1	1	1	1	1	1	1
10	4	4	4	4	140	469	373	317
12	13	13	12	12	7,300	46,874	24,800*	12,195*

* Drainage failure

Table 4.41

Effect of k on Increase Rate at Mr = 550 psi

Method	Slab Thickness (in.)	k (pci)			
		100	150	200	250
AASHTO	8	1.0	1.2	1.3	1.4
	10	1.0	1.1	1.2	1.3
	12	1.0	1.1	1.2	1.3
PCA	8	1.0	1.5	5.0	12.3
	10	1.0	4.9	13.3	27.8
	12	1.0	9.3	17.0*	20.5*

* Drainage failure

Compared to PCA, the effect of k on design life using the AASHTO design procedure for all thicknesses is relatively minor. From a sensitivity study of the AASHTO and PCA design procedures, it was found that:

1. The effect of structural strength (thickness) on IR is the same for all levels of k with the AASHTO model.
2. Results from the PCA design procedure showed that, for stronger slabs, the greater the effect of k on IR.
3. The PCA model showed a much greater effect of thickness on service life than the AASHTO model.
4. For all thicknesses, the PCA procedure showed a much greater effect of k on design life than the AASHTO procedure.
5. The AASHTO design results indicated that, as the modulus of rupture of concrete increases from 550 psi to 900 psi, design life increase by a factor of 5.4 for all thicknesses and values of k. As the modulus of rupture of concrete increased from 550 to 900 psi, the PCA design failure mode shifted from fatigue failure to drainage failure. The effect of concrete strength on design life with the PCA procedure can not be logically derived.

4.9 FINDINGS

The main objective of this study was to compare and evaluate the existing pavement structural design procedures. Three most common design procedures were included in this study, the Asphalt Institute and the AASHTO design procedures for flexible pavement and the Portland Cement Association and the AASHTO design procedures for rigid pavement. In the course of this evaluation, several findings were made, as follows:

Layer Effect

1. The placement of additional layers of material improved pavement uniformity.
2. Depending upon subgrade stiffness, the finished DGAB was not consistently stiffer than the subgrade.
3. Although the average deflection of the 4" DGAB was greater than that for the subgrade, it greatly improved uniformity at that stage of construction.
4. Thicker DGAB layers did not reduce minimum deflection much, but they greatly reduced maximum deflection and hence, reduced average deflection and improved uniformity.

Design Models

1. Calculated design lives were model dependent. While some correlations could be made between the models, in some cases there were significant differences.
2. Based upon the AASHTO design model, the effect of subgrade modulus on rate of design life increase was not affected by SN.
3. Based upon the AI design model, the effect of subgrade modulus on rate of design life increase was affected by SN.
4. In general, the weaker the pavement structure, the greater the effect of subgrade strength on the rate of design life change.
5. The effect of subgrade strength on the rate of design life change derived from the AASHTO design model was much less than either the AI or PCA models.
6. Independent of slab thickness, the effect of k on the rate of design life change by AASHTO was minor.

7. The effect of k on the rate of design life change by PCA was significant for thinner slabs, but declined with increasing slab thickness.
8. The PCA fatigue failure model was highly depended upon the stress-strength ratio. As the slab thickness approached 12 inches, the stress-strength ratio (based on the input axle load) was so low that the fatigue life was about infinity.

<u>Backcalculation Methods</u>

1. Subgrade moduli backcalculated using different approaches were statistically different at the 99% significant level.
2. Values of k backcalculated by the AREA5 and AREA7 methods were bias with good correlation (R^2 = 0.81). Student-t test results indicated that k calculated from these two approaches are statistically the same at a 95% confidence level.
3. Slab curling affects the backcalculation of k.
4. AREA5 is less sensitive to testing location and time than AREA7, which very often can not be controlled. This implies that AREA5 is a more reliable method than AREA7.
5. For the backcalculation of k, FWD tests along the center of the slab are more reliable than those along the edge of the slab.
6. Except for PATB, the effect of base type on backcalculated k was negligible.
7. Two sets of k backcalculated with FWD data collected under different curling conditions were significantly different with the AREA5 and AREA7 methods.

<u>Performance</u>

1. None of the design models distinguished the effect of different base materials on JCP performance. Surface distress data indicated that the effect of base type on performance was significant.
2. Roughness data were not taken frequently enough to catch the end of the service period of the four failed SPS-1 sections. Therefore, IRI data did not show the whole life record of those pavement sections.

4.10 CONCLUSIONS AND RECOMMENDATIONS

There are several important factors affecting pavement structural design. Based on the findings discussed above, it is concluded that:

1. Subgrade moduli derived from different procedures were highly variable. A more comprehensive study is needed to select the most appropriate procedure for the backcalculation of subgrade moduli.
2. Values of k backcalculated by the AREA7 and AREA5 procedures were statistically the same. Plots of FWD basins collected on JCP, however, often showed abrupt deflection changes in D0 that did not match the rest of the basin. AREA5 avoids the use of D0 and may be a more reliable procedure for backcalculating k.
3. For the backcalculation of k, the best path for FWD testing is along the center of the slab and the best location is near the joint. The effects of curling are minimal at that location. AREA5 is less sensitive to the effects of curling. Hence, AREA5 is a better method for backcalculating the modulus of subgrade reaction (k).
4. Sensitivity study results indicated that the AASHTO design model was very different from the AI and PCA models. LTPP data can be used to verify and calibrate these models.
5. Results backcalculated with Evercalc showed a highly variable weak base with a strong uniform subgrade. These results contradicted FWD data collected on the subgrade and base layers. Further study is needed to clarify this anomaly.

CHAPTER 5

AC PAVEMENT PERFORMANCE BY ASPHALT INSTITUTE (DAMA)

5.1 INTRODUCTION

The Ohio SHRP Test Road contains four experiments in the Specific Pavement Studies (SPS). In the SPS-1 experiment, twelve flexible pavement test sections were constructed using two thicknesses of asphalt concrete pavement, twelve different combinations of base materials and thicknesses, and edge drains in some sections to determine the effects of these parameters on structural performance. These twelve sections represented half of the factorial design for the experiment. Data from all states with SPS experiments are added to the LTPP DataPave database.

An on-site weigh-in-motion (WIM) system was constructed at the Ohio site to collect truck weight data. Time domain reflectometry (TDR) probes were installed to monitor volumetric moisture content at different depths in the pavement sections. Volumetric moisture contents were determined from TDR traces by one of several established procedures. In turn, gravimetric moisture content was calculated from volumetric moisture content using the dry density of soil and density of water. Falling Weight Deflectometer (FWD) tests were performed on the finished subgrade, base and pavement layers to measure incremental stiffness as material layers were completed in the test sections. Extensive laboratory tests were performed to characterize the physical properties of all materials used in these pavement structures.

LTPP contractors monitored pavement surface distress periodically by manual surveys and filming. Manual surveys consisted of a team walking the sections and recording all observed surface distress. Filming consisted of trained technicians taking pictures of the pavement surface from a vehicle-mounted camera, reviewing the projected images in the office, and recording surface distress. Longitudinal profiles were also collected with a profiler. These data were also verified and uploaded into DataPave.

The Asphalt Institute's DAMA software (Asphalt Institute, 1993) is a multi-layered elastic program designed to analyze pavement structures using the calculated design life of each material layer. For AC layers, the failure mode is fatigue, and for subgrade, the failure mode is deformation. There are no failure predictions for granular base. The objective of this study was to compare the actual service life of sections on the Ohio SHRP Test Road with those projected by DAMA.

5.2 INPUT DATA

5.2.1 Climatic Data

The DAMA user's manual (Asphalt Institute, 1993) includes a table of maximum and minimum monthly temperatures for all states. The average of these two temperatures is considered to be the average monthly temperature, as summarized for Ohio in Table 5.1.

Table 5.1

DAMA Monthly Temperatures in Ohio

Month	Maximum Temp. (ºF)	Minimum Temp. (ºF)	Average Temp. (ºF)
1	36.4	20.4	28.4
2	39.2	21.4	30.3
3	49.3	29.1	39.2
4	62.8	39.5	51.2
5	72.9	49.3	61.1
6	81.9	58.9	70.4
7	84.8	62.4	73.6
8	83.7	60.1	71.9
9	77.6	52.7	65.2
10	66.4	42.0	54.2
11	50.9	32.4	41.7
12	38.7	22.7	30.7

5.2.2 Traffic Loading

A Mettler-Toledo weigh-in-motion (WIM) system was installed to monitor traffic loading in all four lanes of the test road. The system started collecting useful axle weight data toward the end of October, 1996 and continues to the present time. Unadjusted monthly summaries of WIM data were obtained from the Ohio DOT. Axle weights were summarized into tables by axle grouping (single, tandem, tridem, quad, and five and more axles), vehicle class, and number of axles within a weight bin. Because ESALs for groupings of three or more axles were extrapolated from tandem axles, and because there were very few axles greater than tridem recorded, only single, tandem and tridem axles were considered in this study. Excel spreadsheets developed for this project were completed after this analysis.

The ODOT table listed the number of axles for different vehicle classes. All axles in the same weight bin were summed to determine the total number of axles within a given weight bin for each axle single, tandem and tridem grouping. Axle weight distribution is described by the ratio of axles falling within individual weight bins, i.e., the number of axles in a weight bin divided by the total number of axles. Figures 5.1 to 5.3 show the southbound monthly axle weight distributions for single, tandem and tridem axles in 1999. The monthly distributions for single and tandem axles were relatively constant while, due to the low number of axles recorded, monthly distributions for the tridem axle grouping varied from month to month. This was true for all recorded years.

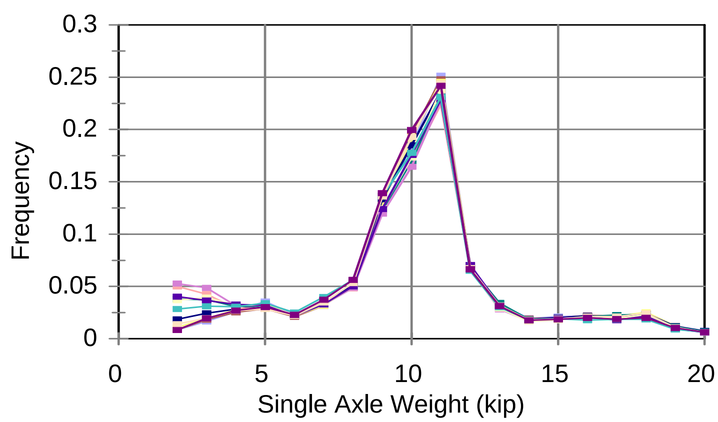


Figure 5.1 - Single Axle Monthly Weight Distribution (1999)

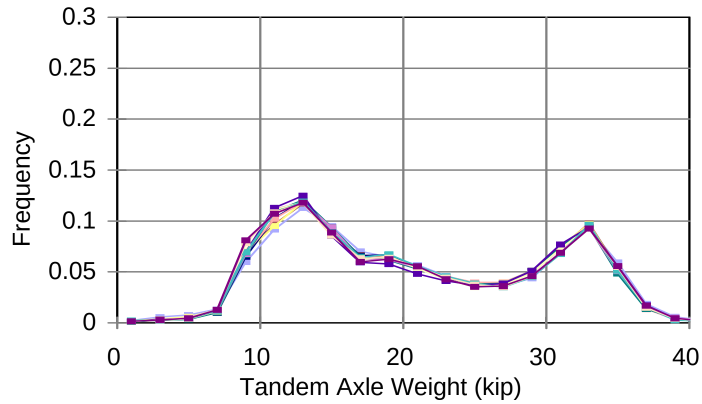


Figure 5.2 - Tandem Axle Monthly Weight Distribution (1999)

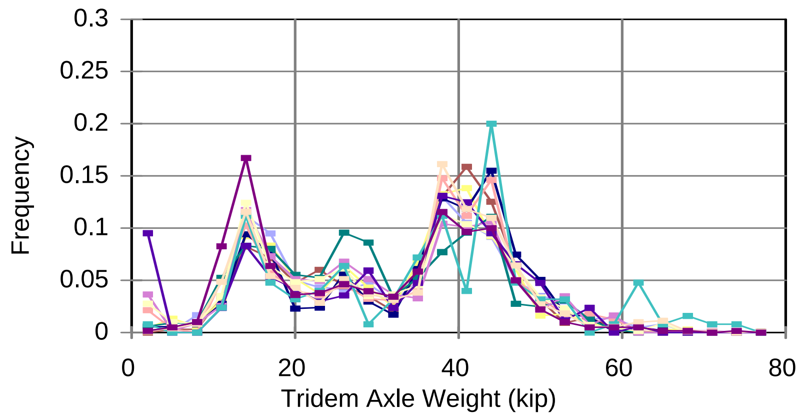


Figure 5.3 - Tridem Axle Monthly Weight Distribution (1999)

In this study, yearly weight distributions were derived for single, tandem and tridem axles in 1997, 1998, 1999, 2000 and 2003. Figure 5.4 shows the yearly weight distributions for single axles to be quite similar for the five years, while Figure 5.5 shows the same for tandem axles. Figure 5.6 shows tridem axles in 1997 and 2003 to be different than in 1998, 1999 and 2000. In 1997 and 2003, the WIM recorded only two months of data which, with the low number of tridem axles recorded, likely contributed to this variation in weight distribution. Figures 5.7 and 5.8 show the average daily number of axles recorded for each axle type.

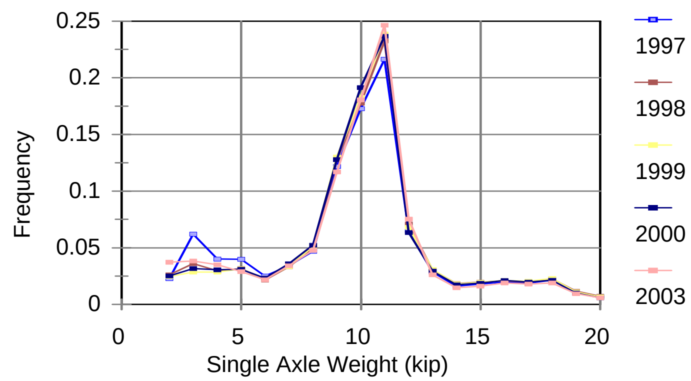


Figure 5.4 - Single Axle Yearly Weight Distribution

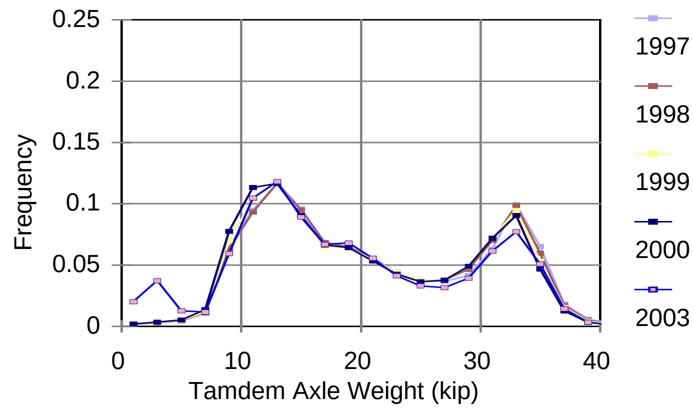


Figure 5.5 - Tandem Axle Yearly Weight Distribution

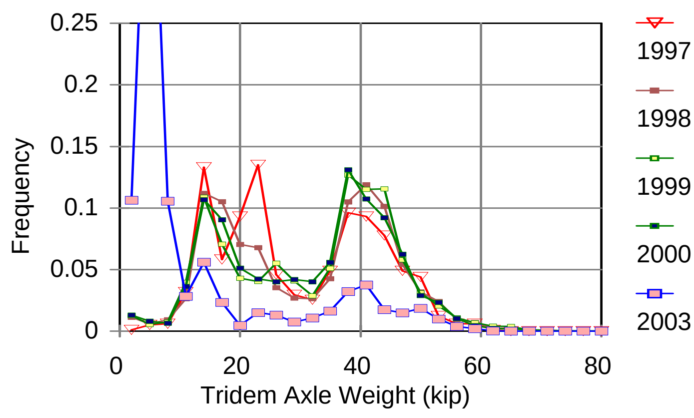


Figure 5.6 - Tridem Axle Yearly Weight Distribution

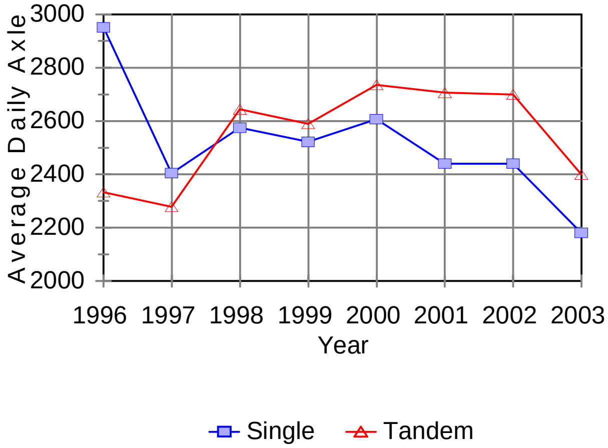


Figure 5.7 - Annual Average Daily Axles

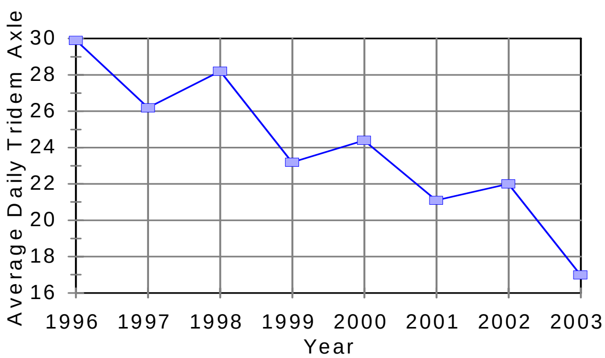


Figure 5.8 - Annual Average Daily Tridem Axles

AASHTO equations for calculating equivalent single axle loads (ESAL) were applied to the yearly weight distributions to determine the average number of ESALs per axle for each axle type. Table 5.2 summarizes the average yearly equivalent ESALs per axle type and Table 5.3 shows the number of days the southbound lanes were opened to traffic.

Table 5.2

Average ESALs per Axle Type by Year

Year	1996	1997	1998	1999	2000	2001	2002*	2003
Single Axles	0.228	0.190	0.200	0.190	0.178	0.184	0.184	0.179
Tandem Axles	0.528	0.367	0.363	0.346	0.321	0.329	0.329	0.301
Tridem Axles	0.578	0.329	0.397	0.427	0.395	0.427	0.427	0.429

* No WIM data - 2002 assumed to be the same as 2001

Table 5.3

Number of Days Southbound Lanes Opened to Traffic

Year	Days	Year	Days
1996	103	2000	366
1997	50	2001	299
1998	322	2002	113
1999	365	2003	40

The daily number of axles multiplied by the equivalent ESALs per axle equals the total daily ESALs. Table 5.4 shows these values extrapolated out to average monthly ESALs in the southbound lane by year. Figure 5.9 is a plot of this estimated accumulated standard axle loading in the southbound lane.

Table 5.4

Monthly ESAL Loading by Year

Year	kESALs	Year	kESALs
1996	198.08	2000	495.22
1997	64.99	2001	403.45
1998	478.64	2002	152.17
1999	505.47	2003	44.76

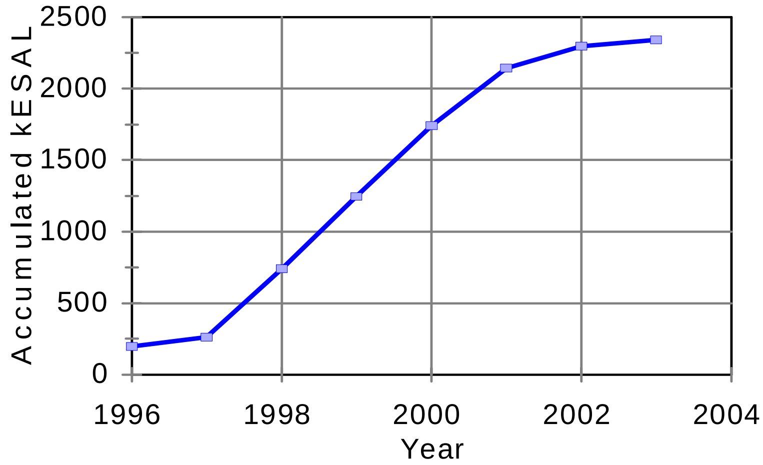


Figure 5.9 - Accumulated Axle Loads

5.2.3 Subgrade

Subgrade resilient modulus Mr is dependent upon the moisture content of the soil. Sargand et. al.., (Sargand et. al., 2000) developed the following regression equation for Mr, with $R^2 = 0.36$, based upon field samples collected on the Ohio SHRP Test Road.

$$Mr = 20.7 - 0.8 * m \qquad \text{Mr in ksi}$$

m = % gravimetric moisture content

Data from on-site environmental monitoring stations indicated that soil moisture cycles annually, as shown in Figure 5.10. Moisture 0.07 to 0.23 meters (3 to 9 inches) from the top of the subgrade oscillated between 17% and 21% with peaks in July and lows in January. See Figure 5.11.

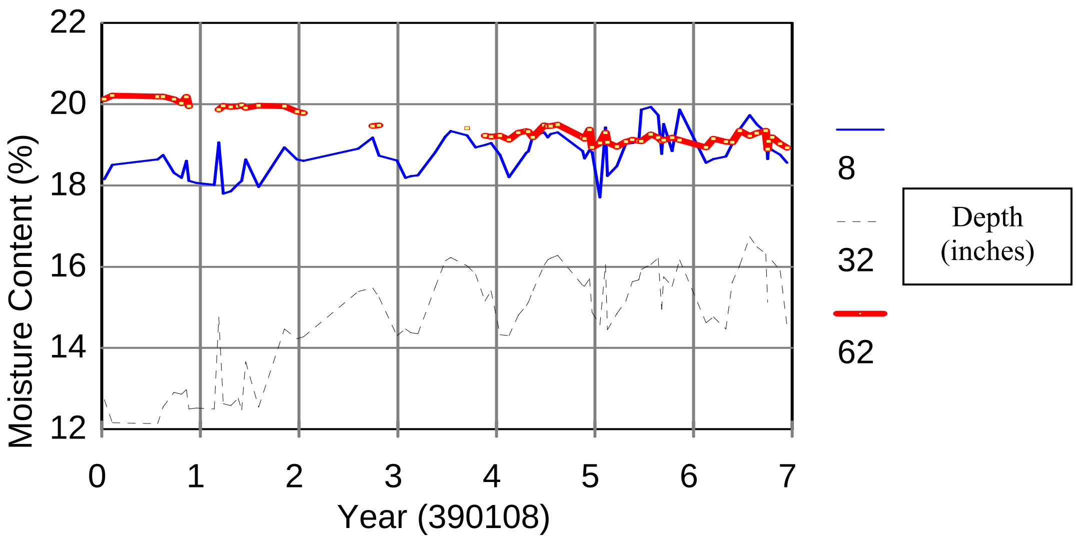


Figure 5.10 - Annual Subgrade Moisture Cycles at Different Depths

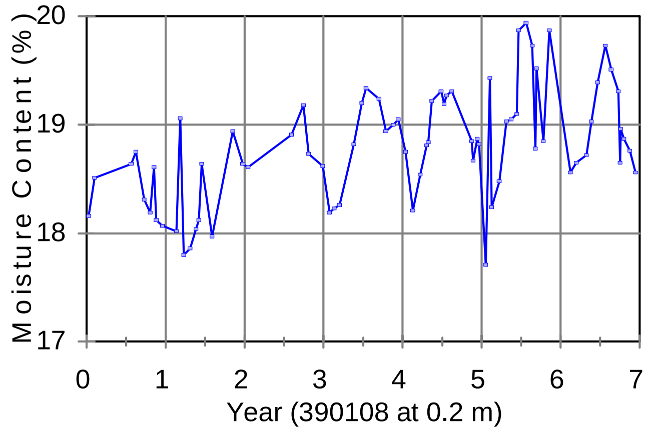


Figure 5.11 - Annual Subgrade Moisture Cycles

Based upon this information, monthly subgrade moisture contents were determined for each section, as shown in Figure 5.12. For sections with no data available, soil moisture contents were assigned according to soil type and proximity to the closest moisture measurements. The assigned monthly moisture contents are summarized in Table 5.5.

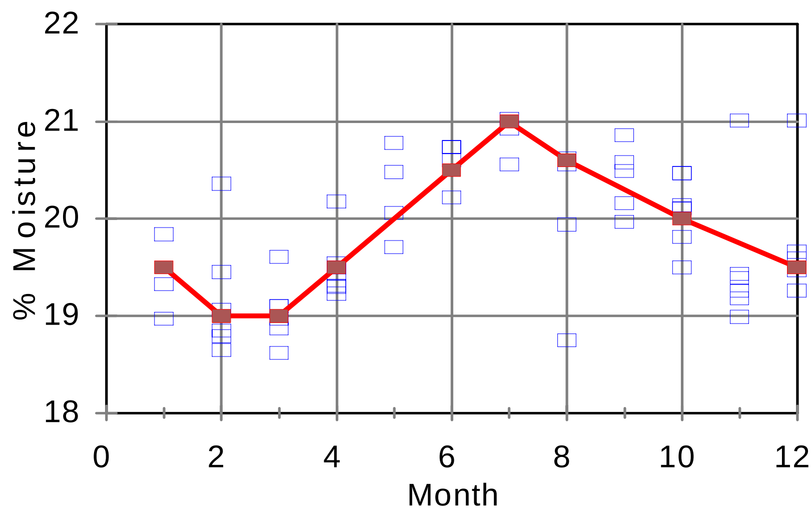


Figure 5.12 - Monthly Subgrade Moisture Contents

Table 5.5
Assigned Monthly Soil Moisture Contents

Section	Average Gravimetric Moisture Content in Month (%)											
	1	2	3	4	5	6	7	8	9	10	11	12
101	19.0	19.5	18.0	18.2	18.5	20.0	20.0	20.5	20.0	19.5	19.0	19.0
102	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0
103	18.1	18.1	18.5	19.1	19.3	20.0	20.0	20.0	19.9	19.0	19.0	18.7
104	18.1	18.1	18.5	19.1	19.3	20.0	20.0	20.0	19.9	19.0	19.0	18.7
105	17.6	17.8	17.8	17.9	18.4	18.9	19.3	19.8	18.8	18.3	18.0	17.8
106	17.6	17.8	17.8	17.9	18.4	18.9	19.3	19.8	18.8	18.3	18.0	17.8
107	17.6	17.8	17.8	17.9	18.4	18.9	19.3	19.8	18.8	18.3	18.0	17.8
108	18.0	18.5	18.5	18.5	18.7	19.0	19.2	19.0	19.0	18.5	18.5	18.5
109	18.5	18.8	18.8	19.2	20.0	20.5	21.0	20.0	20.3	19.9	19.5	18.7
110	18.5	18.8	18.8	19.2	20.0	20.5	21.0	20.0	20.3	19.9	19.5	18.7
111	18.1	18.1	18.5	19.1	19.3	20.0	20.0	20.0	19.9	19.0	19.0	18.7
112	17.0	17.5	17.7	18.1	18.3	19.0	19.2	19.0	19.0	18.8	18.5	18.0

Based upon the reported resilient modulus-moisture data from various soil types, Sargand et. al. developed linear regressions between Mr and moisture content as described earlier. Accordingly, subgrade moduli were calculated monthly from these equations, as summarized in Table 5.6.

Table 5.6
Assigned Monthly Soil Resilient Modulus

Section	Average Subgrade Resilient Modulus in Month (psi)											
	1	2	3	4	5	6	7	8	9	10	11	12
101	7089	6345	8578	8280	7834	5600	5600	4855	5600	6345	7089	7089
102	5460	5460	5460	5460	5460	5460	5460	5460	5460	5460	5460	5460
103	10047	10047	9995	9917	9891	9800	9800	9800	9813	9930	9930	9969
104	10047	10047	9995	9917	9891	9800	9800	9800	9813	9930	9930	9969
105	9174	8876	8876	8727	7982	7238	6642	5898	7387	8131	8578	8876
106	9174	8876	8876	8727	7982	7238	6642	5898	7387	8131	8578	8876
107	7572	7266	7266	7113	6348	5583	4971	4206	5736	6501	6960	7266
108	5460	4920	4920	4920	4704	4380	4164	4380	4380	4920	4920	4920
109	4920	4596	4596	4164	3300	2760	2220	3300	2976	3408	3840	4704
110	7310	7208	7208	7072	6800	6630	6460	6800	6698	6834	6970	7242
111	10047	10047	9995	9917	9891	9800	9800	9800	9813	9930	9930	9969
112	10190	10125	10099	10047	10021	9930	9904	9930	9930	9956	9995	10060

5.2.4 Asphalt Cement

There are two ways to input the physical properties of plant-mixed asphalt (PMA) to DAMA. The first is to assign layer moduli for different times of the year. The other is to calculate moduli from detailed material properties, such as percent AC, percent air voids, % passing the #200 sieve, and AC viscosity.

The ORITE (ORITE, 2002) and DataPave databases contained asphalt cement viscosity test results. These results were significantly different. When ORITE data were used in DAMA, the results showed extremely high values for calculated PMA moduli. When viscosity data from the DataPave database were used, the DAMA calculated PMA moduli were more reasonable. These results are shown in Table 5.7.

Table 5.7

Asphalt Cement Viscosity Test Results

Viscosity (ORITE) (poises)		Viscosity (SHRP) (poises)	
140° F	275° F	140° F	275° F
5456	544	2043	392
5384	528	2043	392
5746	540	2043	392
6232	572	2043	392
4949	499	2043	392
5384	528	2043	392
5384	528	2043	392
5384	528	2043	392
5384	528	2043	392
5384	528	2043	392
6232	572	2043	392
6232	572	2043	392

5.2.5 Base Materials

5.2.5.1 Granular Base

FWD tests were performed on the finished granular base (GB). Deflections at the center of the load plate (D0) were applied to the Boussinesq equation to backcalculate composite modulus for the two layer system. Moduli backcalculated from the FWD are dynamic, which can be converted to static moduli by multiplying by 0.5.

Moisture data showed very little variation the middle of the granular base (GB) layers. Therefore, no seasonal adjustment was needed and a constant GB modulus was used throughout the year. Table 5.8 summarizes the GB input data.

Table 5.8

Granular Base Input Data

Section	Mr	Poisson Ratio	Thickness	
			Design	Actual
101	10800	0.4	8	8.02
102	11400	0.4	12	11.84
105	22600	0.4	4	4.03
106	60400	0.4	4	3.85
107	9300	0.4	4	4.07
108	10700	0.4	8	8.04
109	10700	0.4	12	11.98

5.2.5.2 Asphalt Treated Base (ATB)

The ORITE database (ORITE, 2002) included ATB core test results. ATB moduli were tested at 5, 25, and 40º C (41, 77, and 104º F). A long-term PMA study collected temperatures at different PMA depths in central North Carolina. Data showed that PMA temperatures 200 mm (8”) below the surface were always higher than air temperature. During spring (March to May) and fall (September to November), PMA temperature was 10º F higher than air temperature. In the summer (June to August), this difference reached 40º F and, in the winter (December to February), the difference was 20º F.

Monthly ATB temperatures were calculated by adding these differences to the monthly average temperature. ATB moduli were calculated from ATB temperature and the regression of laboratory test results. Table 5.9 is a summary of the assigned ATB monthly moduli. Table 5.10 shows Poisson's ratios determined from core samples.

Table 5.9

ATB Input Monthly Modulus

Month	Air Temp. (° F)	ATB Temp. (° F)	ATB Modulus in Section (ksi)							
			103	104	105	106	108	110	111	112
1	28.4	48.4	998.6	998.6	934.1	954.2	934.1	1001.6	1001.6	1131.4
2	30.3	50.3	975.3	975.3	912.0	930.8	912.0	978.3	978.3	1104.8
3	39.2	49.2	988.8	988.8	924.8	944.3	924.8	991.8	991.8	1120.2
4	51.2	61.2	842.7	842.7	785.6	797.2	785.6	845.7	845.7	953.1
5	61.1	71.7	721.1	721.1	669.7	674.8	669.7	724.2	724.2	814.0
6	70.4	110.4	240.9	240.9	211.8	191.0	211.8	243.9	243.9	264.6
7	73.6	113.6	201.8	201.8	174.6	151.6	174.6	204.8	204.8	219.9
8	71.9	111.9	222.6	222.6	194.4	172.5	194.4	225.6	225.6	243.6
9	65.2	75.2	671.7	671.7	622.5	624.9	622.5	674.7	674.7	757.4
10	54.2	64.2	805.5	805.5	750.1	759.7	750.1	808.5	808.5	910.5
11	41.7	51.7	958.8	958.8	896.3	914.2	896.3	961.8	961.8	1085.9
12	30.7	50.7	970.4	970.4	907.3	925.9	907.3	973.4	973.4	1099.2

Table 5.10

ATB Poisson's Ratio

Section	Poisson's Ratio
103	0.23
104	0.23
105	0.26
106	0.19
110	0.23
111	0.23
112	0.28

5.2.5.3 Permeable Asphalt Treated Base (PATB)

FWD tests were performed on top of the finished Permeable Asphalt Treated Base (PATB) and the Boussinesq single layer equation was used to backcalculate composite moduli for all materials in place at the time of the measurements. It was assumed that the moduli of materials below the PATB were somewhat less than that of the PATB, i.e., the PATB modulus was greater than the backcalculated composite modulus of all materials. Therefore, the input PATB moduli were assigned a somewhat higher value. Table 5.11 summarizes PATB moduli calculated from FWD test results and input moduli assigned for this study.

Table 5.11

Permeable Asphalt Treated Base Input Moduli

Section	Composite FWD Modulus (psi)	PATB Input Modulus (psi)
107	17632	19000
109	21042	23000
110	18463	20000
111	19627	21000
112	22278	24000

5.2.6 AC Intermediate and Surface Courses

Test results determined from cores of asphalt stabilized materials (ORITE, 2002) included percent air void, percent asphalt content, and actual thickness. A forensic report on Section 101 (Sargand, Young, Khoury, Wasniak, and Goldsberry, 1998) included aggregate gradations for the surface and intermediate layers. Amounts passing the #200 sieve were 6.3% for the surface course and 5.8% for the intermediate layer. Tables 5.12 and 5.13 summarize input data for these pavement layers.

Table 5.12

Surface AC Course Input Data

Section	Thickness (in)		% Air Voids	Asphalt Cement (%)	% Passing #200	Poisson's Ratio
	Design	Actual				
101	1.75	1.75	6.1	6.7	6.3	0.45
102	1.75	1.70	6.6	6.6	6.3	0.41
103	1.75	1.71	7.1	6.4	6.3	0.22
104	1.75	1.65	6.9	6.7	6.3	0.41
105	1.75	1.88	6.6	6.7	6.3	0.33
106	1.75	1.77	6.6	6.6	6.3	0.35
107	1.75	1.73	6.6	6.6	6.3	0.41
108	1.75	1.70	6.6	6.6	6.3	0.22
109	1.75	1.80	6.6	6.6	6.3	0.22
110	1.75	1.83	6.6	6.6	6.3	0.22
111	1.75	1.74	6.9	6.7	6.3	0.49
112	1.75	1.66	6.9	6.7	6.3	0.33

Table 5.13

Intermediate AC Course Input Data

Section	Thickness (in)		% Air Voids	Asphalt Cement (%)	% Passing #200	Poisson's Ratio
	Design	Actual				
101	5.25	5.08	6.2	6.3	5.8	0.49
102	2.25	2.18	7.2	5.3	5.8	0.44
103	2.25	2.16	6.6	5.3	5.8	0.38
104	5.25	5.32	6.2	6.4	5.8	0.44
105	2.25	2.14	7.7	5.3	5.8	0.44
106	5.25	5.00	6.2	6.3	5.8	0.42
107	2.25	2.10	6.2	6.3	5.8	0.42
108	5.25	4.85	7.2	5.3	5.8	0.38
109	5.25	5.17	7.2	5.3	5.8	0.38
110	5.25	5.51	7.2	5.3	5.8	0.42
111	2.25	2.29	6.2	6.4	5.8	0.50
112	2.25	2.27	6.2	6.4	5.8	0.34

5.3 DAMA RESULTS AND FINDINGS

The DOS version of the DAMA software was used for this study. According to AI, the DOS version and the newer Windows based version both use the same damage calculation routine, which is written in Fortran IV. The only improvement in the Windows version is the simplified interface for inputting data.

DAMA calculates the number of sustained repeated loadings on each layer of the pavement structure from surface to subgrade. The software first calculates stresses induced on all layers from a single input wheel load. Damage from the calculated stresses is then estimated for each layer. Seasonal variations in material properties are considered when calculating stress and damage. The number of load repetitions can be converted to years of life using the input truck volume. For ease of description, the pavement layer with the shortest calculated life is defined as the critical layer, and service life estimated for that layer is the critical life of the pavement structure.

DAMA results in Table 5.14 showed that, with the exception of Sections 101 and 102, critical layers on the SPS-1 sections in Ohio were the base layers. Layer service lives estimated by DAMA and the actual service lives observed on the test road are also summarized in Table 5.14. Eight of the twelve test sections had been replaced by April 2002. Figure 5.13 shows a plot of the DAMA predicted service lives verses actual service lives for the eight failed sections. It was not surprising that most points fell far from the line of equality, because it takes time for distresses in the lower pavement layers to migrate to the surface. This migration time depends upon the thickness and strength of layers covering distress in the critical layer.

Table 5.14

DAMA Result of Layers Design Lives

Section	Design Life Estimated by DAMA (years)						
	Surface AC	Intermediate AC	ATB	PATB	Subgrade	Critical Life	Actual Life
101	17.1	3.2			1	1	0.3
102	23	0.8			0.6	0.6	0.05
103	2935	2772	0.8		39	0.8	5.3
104	211	8134	5.5		1020	5.5	
105	166	217	0.2		1.4	0.2	2.07
106	832	2199	2.1		82	2.1	
107	44	30		0.1	1	0.1	0.05
108	156	431	0.7		7.8	0.7	5.1
109	723	3.1		0.8	1.9	0.8	5.7
110	3556	325	0.8	7	15	0.8	5.5
111	43	456	0.8	0.8	60	0.8	
112	688	24597	2.7	1	367	1	

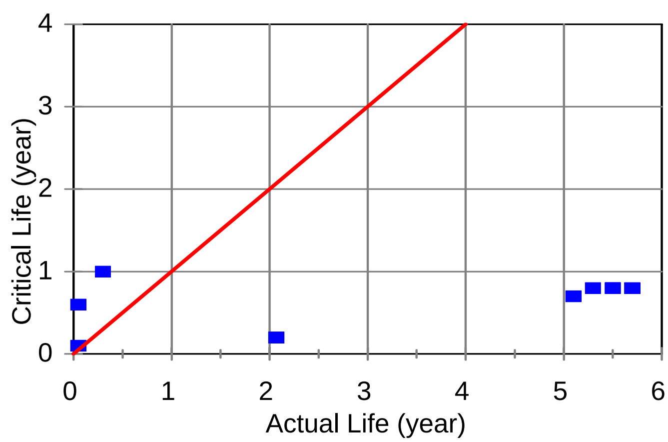


Figure 5.13 - Actual Section Life verses Critical Life

A Windows-based statistics packages, SPSS (SPSS, 1998), was used to derive a linear regression equation relating failure of the pavement structure to the life of individual layers. Independent variables included estimated service lives of the surface course, intermediate course, and base course, and the dependent variable was actual service life. This regression equation is;

Pavement Service Life = 0.883 + (0.001 * Surface Life) + (1.764 * Base Life) ($R^2 = 0.47$)

The total service lives of the combined pavement structures were calculated using this equation. Figure 5.14 is a plot of calculated combined service life verses actual section life. Results indicated that combined life correlated better with actual life than did critical life. This result illustrates the need to combine layer lives from the AI procedure to describe pavement life.

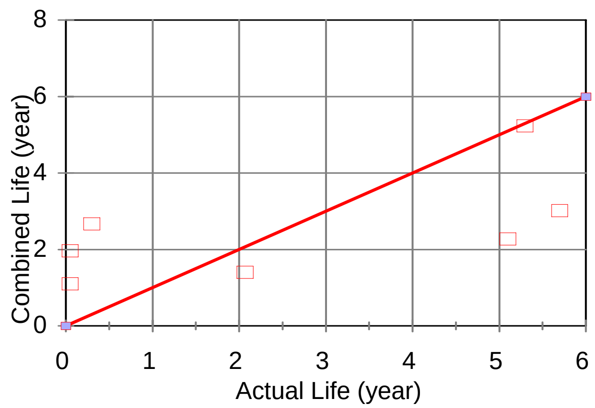


Figure 5.14 - Combined Life verses Actual Life

5.4 RECOMMENDATIONS

Based upon the findings of this study, the following recommendations are made:

1. DAMA is a mechanistic multi-layered elastic analysis procedure that can accommodate the effects of climate on layer material properties and wheel load damage. The critical life of individual layers, however, does not correlate well with actual pavement service life determined by surface distress. It is necessary, therefore, to develop a procedure for improving the correlation between critical layer life and pavement performance.

2. Current ODOT procedures summarize axle weight information by combining all single axles, including front and rear single axles, into one table. In fact, these two axles are very different. The front axle is equipped with single tires while the rear axle always has dual tires. BISAR was used to calculate stresses under single and dual tires at two axle weights. Table 5.15 summarizes these results which indicate that, for the same axle weight, tensile stresses at the bottom of the AC under single tires are 15 - 20 % higher

than those under dual tires. This difference in stress has a significant effect on the fatigue life of AC layers and, hence, on pavement performance. For pavement design purposes, therefore, front and rear axles should not be grouped into one table. It is recommended that the processing of WIM data be modified so traffic loading is divided into two tables; namely, a front single axle table and a rear dual axle table.

Table 5.15

BISAR Single/Dual Tire Stress Difference

Axle Load (kips)	AC Pavement Type	Tire Configuration	AC Tensile Stress (psi)		Subgrade Compressive Stress (psi)	
		Subgrade Mr (psi)	5000	10000	5000	10000
9	Full Depth	Dual	13.0	11.0	0.529	0.823
		Single	14.9	12.7	0.585	0.931
		% difference	+15	+15	+11	+13
	Granular Base	Dual	7.29	5.03	1.27	1.86
		Single	8.62	6.09	1.46	2.21
		% difference	+18	+21	+15	+19
18	Full Depth	Dual	26.1	22.0	1.06	1.65
		Single	29.7	25.4	1.17	1.85
		% difference	+14	+15	+10	+12
	Granular Base	Dual	14.6	10.1	2.54	3.72
		Single	17.2	12.2	2.93	4.41
		% difference	+18	+21	+15	+19

CHAPTER 6

PETROGRAPHIC EXAMINATION OF CONCRETE CORES

6.1 BACKGROUND

The 3-mile long Ohio SHRP Test Road is located on US 23, 25-miles north of Columbus, Ohio, in Delaware County. The project contains test sections on the northbound and southbound lanes of the mainline pavement and on a southbound ramp from the village of Norton. Northbound lanes of the mainline pavement contained Portland cement concrete (PCC) sections in the SPS-2 experiment, southbound lanes of the mainline pavement contained asphalt concrete (AC) sections in the SPS-1 and SPS-9 experiments, and the ramp from Norton contained PCC and AC sections in the SPS-8 experiment. Construction of the ramp was completed in 1994 and the mainline pavement was completed in 1996. Discussion in this chapter is limited to PCC sections in the SPS-2 and SPS-8 experiments.

Main variables for the PCC pavement sections were pavement thickness (8-inches and 11-inches), and the base material and design (lean concrete base, dense graded aggregate base, asphalt treated base, permeable asphalt treated base, and permeable cement treated base). Six-inch and 8-inch thick bases were used, and some were designed to drain, while others were not.

During 1999, longitudinal cracking was observed in mainline Sections 205 and 206. Since then, cracking has continued to progress in these sections and has developed in other sections. Currently, all of the 8-inch PCC sections show some cracking, and the 11-inch thick PCC on lean concrete base has developed cracking.

A number of cores were taken from Sections 205 and 206 in October 1999. The cores were not examined until recently when they were provided to Lankard Materials Laboratory (LML) for a petrographic examination. One of the main items of concern here is whether or not material deficiencies or shortcomings played a role in the pavement cracking distress. Beyond this, it is desired to determine, if possible, the origin of the cracking distress. This chapter describes the results and findings of this investigation.

6.2 DESCRIPTION OF CORES

Six-inch diameter cores were taken at four locations including: (1) Section 205, (2) Section 206, (3) Section 809, and (4) Section 810. Test Sections 205 and 206 are both mainline concrete pavement with 8-inches of Portland cement concrete (PCC) on 6-inches of lean concrete base (LCB). The LCB for both sections was placed on August 19, 1995. The PCC for Section 205 was placed on September 11, 1995; that for Section 206 on September 18, 1995. Cores taken in these sections were taken through both the PCC and the LCB slabs. Sections 809 and 810 are in the PCC sections on the southbound ramp and were placed in 1994.

6.2.1 Test Section 206

This test section, which has a lane width of 14-feet, is in the southern half of the project. The high strength concrete for this test section is identified as "Mix 900", which is shown in Table 6.1. This is an air-entrained concrete containing 750 pounds of Portland cement and 113 pounds of fly ash per cubic yard. The "900" refers to a target 14-day flexural strength of 900 psi for this concrete. Some of the project documents refer to this concrete as the "Plan B Concrete Mix Design".

Three cores were provided to LML from Section 206 (identified as Cores PCC-1, PCC-2, and PCC-3) and the sites for these cores are identified in Table 6.2. Table 6.2 also shows the length of the PCC and LCB cores at each coring site. The PCC target thickness value of 8-inches was met or slightly exceeded for all three PCC cores, and the LCB target thickness of 6-inches was met or slightly exceeded by all three of the LCB cores. Comments on the condition of the cores as-received at LML are also provided in Table 6.2. All cores were received intact, with the exception of Core PCC-1. This core was received in two pieces, separated along a full-width, full-depth crack fracture plane. This is a longitudinal crack (slightly skewed) in this pavement section. Figures 6.1, 6.2, and 6.3 show photographs of Cores PCC-1, PCC-2, and PCC-3, respectively. Cracks are delineated with a black marking pen.

Table 6.1

Pavement Concrete in Section 206

Concrete Constituent	Pounds of Constituent per Cubic Yard
Portland Cement	750
Fly Ash	113
Sand	950
#57 Limestone	1850
Water	270
Air (6%)	----
Total Weight	3933

NOTE: The mix design shown here is identified in Bowser-Morner, Inc. (Dayton, Ohio), Report No. 303901, dated April 7, 1995. The concrete is identified in this report as "Plan B Concrete Mix Design ODOT DEL 23-17.48". The aggregate weights shown are saturated surface dry (SSD) weights. At 6% air, the theoretical unit weight of this concrete is 145.7 lb/ft^3. The theoretical water to cementitious material ratio is 0.31.

Table 6.2

Core Retrieval Data for Cores from Sections 206 and 205

Core	Test Section	Coring Site	Core Length, in.		Comments
			PCC	LCB	
PCC-1	206	STA. 334+00,1-foot west of edge line, mid panel	8¼	6	Core PCC-1 was in two pieces. It contains a full-width, full-depth crack.
PCC-2	206	2-feet north and 1-foot east of Core 1, 6-inches west of edge line, 1-foot from joint	8c	6c	Both cores were received intact.
PCC-3	206	17-feet north and 1½-feet west of Core PCC-2, 2-feet from joint and 2-feet west of edge line	8c	6½	Both cores were received intact.
PCC-4	205	STA. 5+15-OL 5-feet from center line	8	5¾	Core LCB-4 was received in two pieces. It contains a full-width, full-depth crack. The wearing surface of the core is grooved.

NOTE: Two cores were taken at each coring site, including the Portland cement concrete (PCC) wearing course and the lean concrete base (LCB).

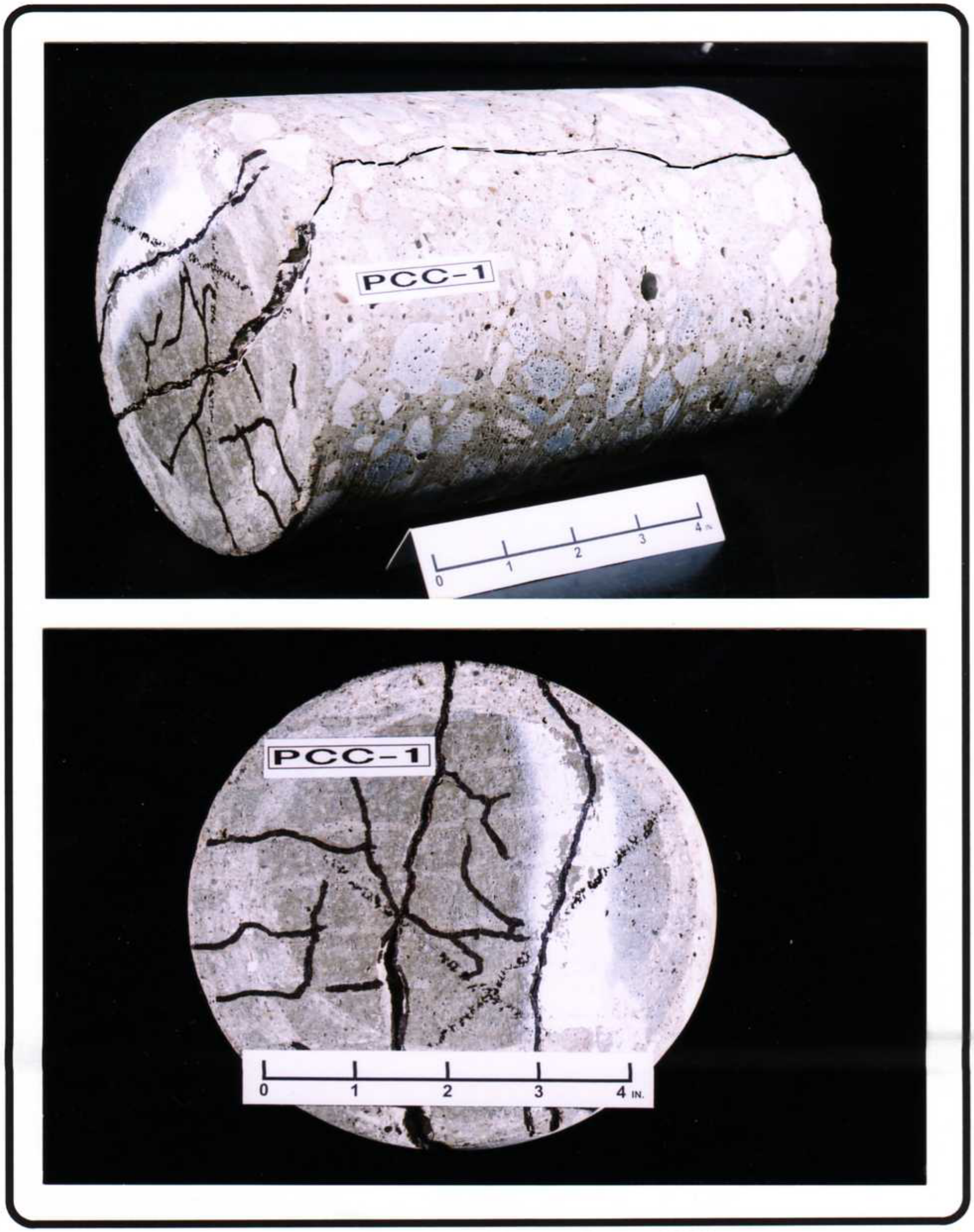


Figure 6.1 - Photograph of Core PCC-1

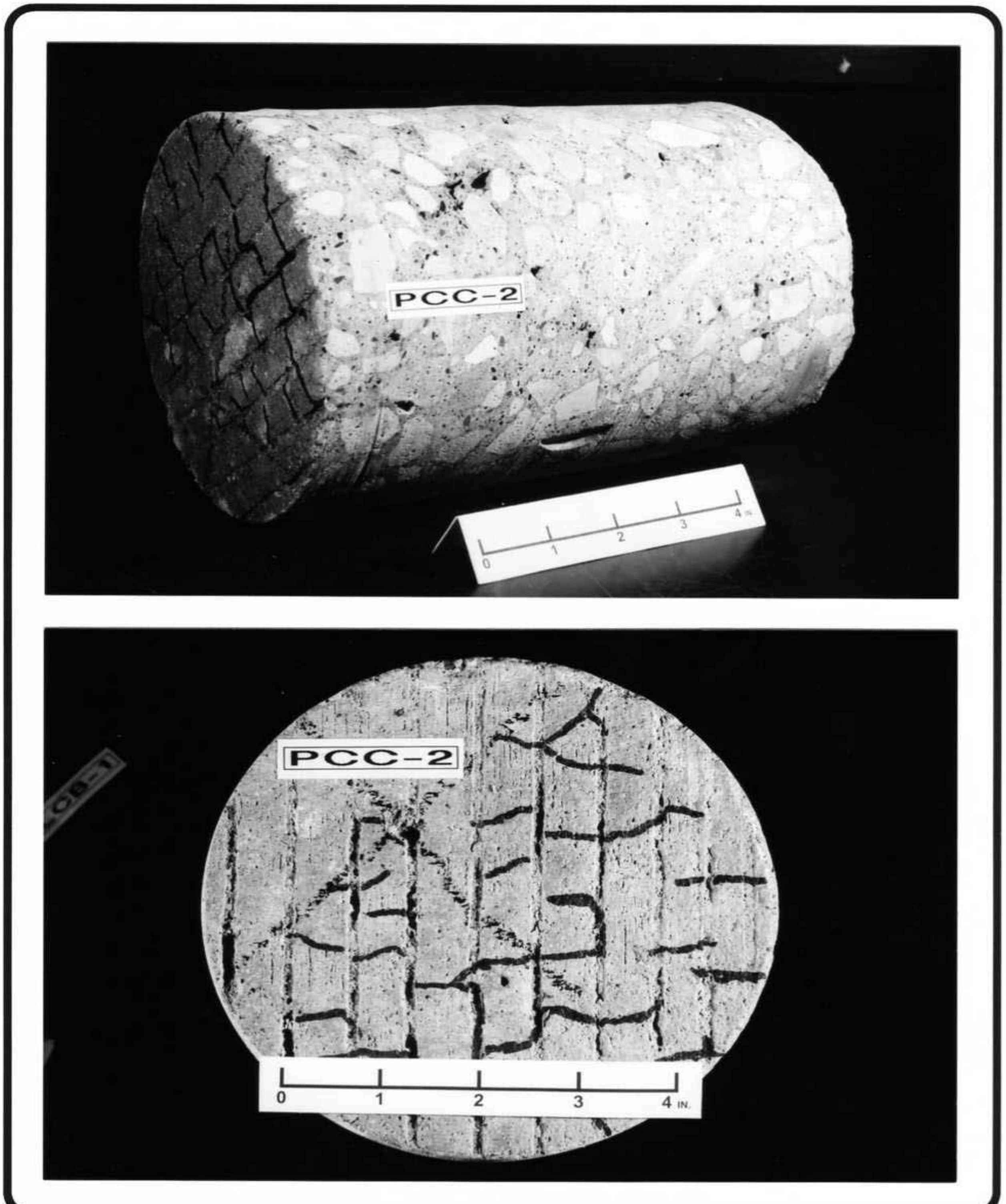


Figure 6.2 - Photograph of Core PCC-2

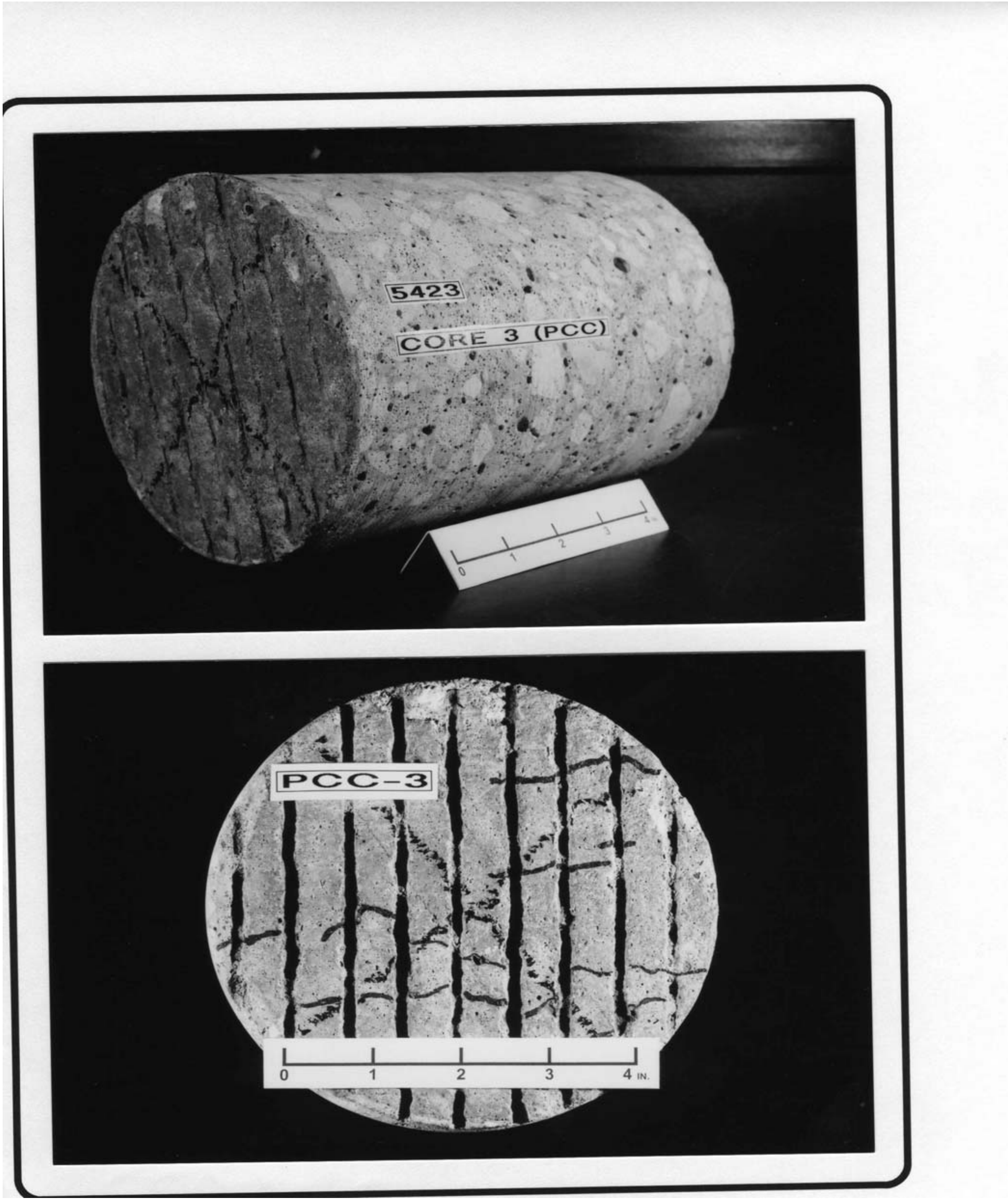


Figure 6.3 - Photograph of Core PCC-3

Photographs of Cores LCB-1, LCB-2, and LCB-3, are shown in Figures 6.4, 6.5, and 6.6. One end surface of the PCC cores is the grooved wearing surface of the test pavement. The other end surface of the PCC cores is the bottom of the pavement slab cast on the LCB base. The bottom surface of the LCB cores represents the bottom of these slabs cast on the sub-base.

The mix design for the lean concrete base (LCB) is shown in Table 6.3. This mix design is reported by Bowser-Morner, Inc. (Dayton, Ohio), for the trial mix work. The LCB actually used on the project had an increased sand content (1762 pounds versus 1465 pounds); a reduced coarse aggregate content (1450 pounds versus 2000 pounds); and 48 pounds of Class C fly ash in addition to the 160 pounds of Portland cement. Information on the project concrete proportioning was taken from an ODOT Concrete Inspectors Report. The lean concrete base was placed without joints at a thickness of 6-inches. The PCC wearing course was constructed one month after placement of the LCB. During this interval, some cracking occurred in the LCB.

Table 6.3

Mix Design for Lean Concrete Base (LCB) in Sections 205 and 206

Concrete Constituent	Pounds of Constituent per Cubic Yard
Portland Cement	160
Sand	1465
#57 Limestone	2000
Water	235
Air (6%)	----
Total Weight	3860

NOTE: The mix design shown here is taken from Bowser-Morner, Inc. (Dayton, Ohio), Laboratory Report No. 303842, dated March 8, 1995. The concrete is described as "lean concrete base (LCB) Project DEL 23-17.48". An ODOT Concrete Inspector's Daily Report dated 8/19/95, shows a reduced coarse aggregate content (1450 pounds), and increased sand content (1762 pounds), and 48 pounds of Class F fly ash per cubic yard. The mix design shown above has a theoretical unit weight of 143.0 lb/ft3, and a theoretical water-cement ratio greater than 1.0.

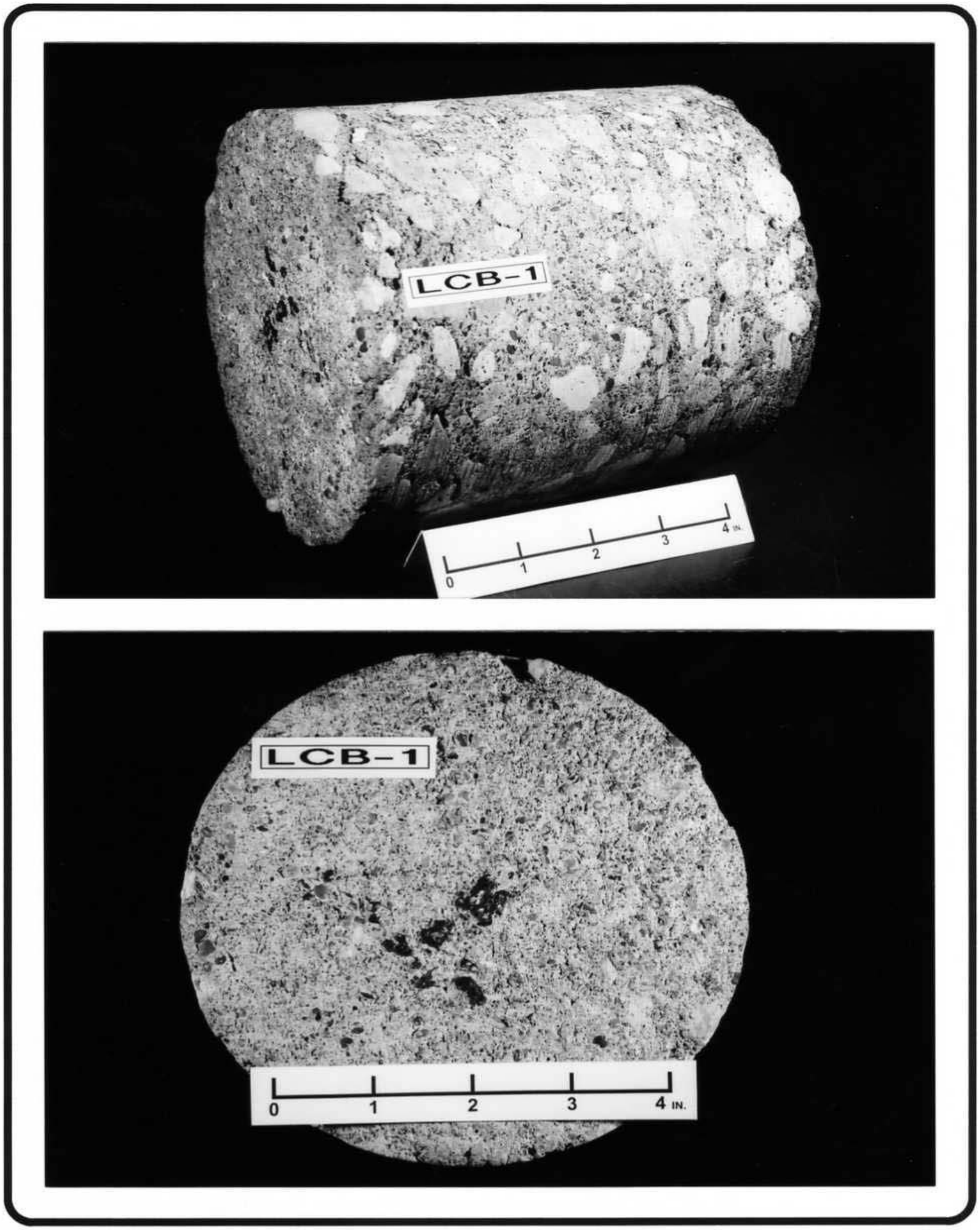


Figure 6.4 - Photograph of Core LCB-1

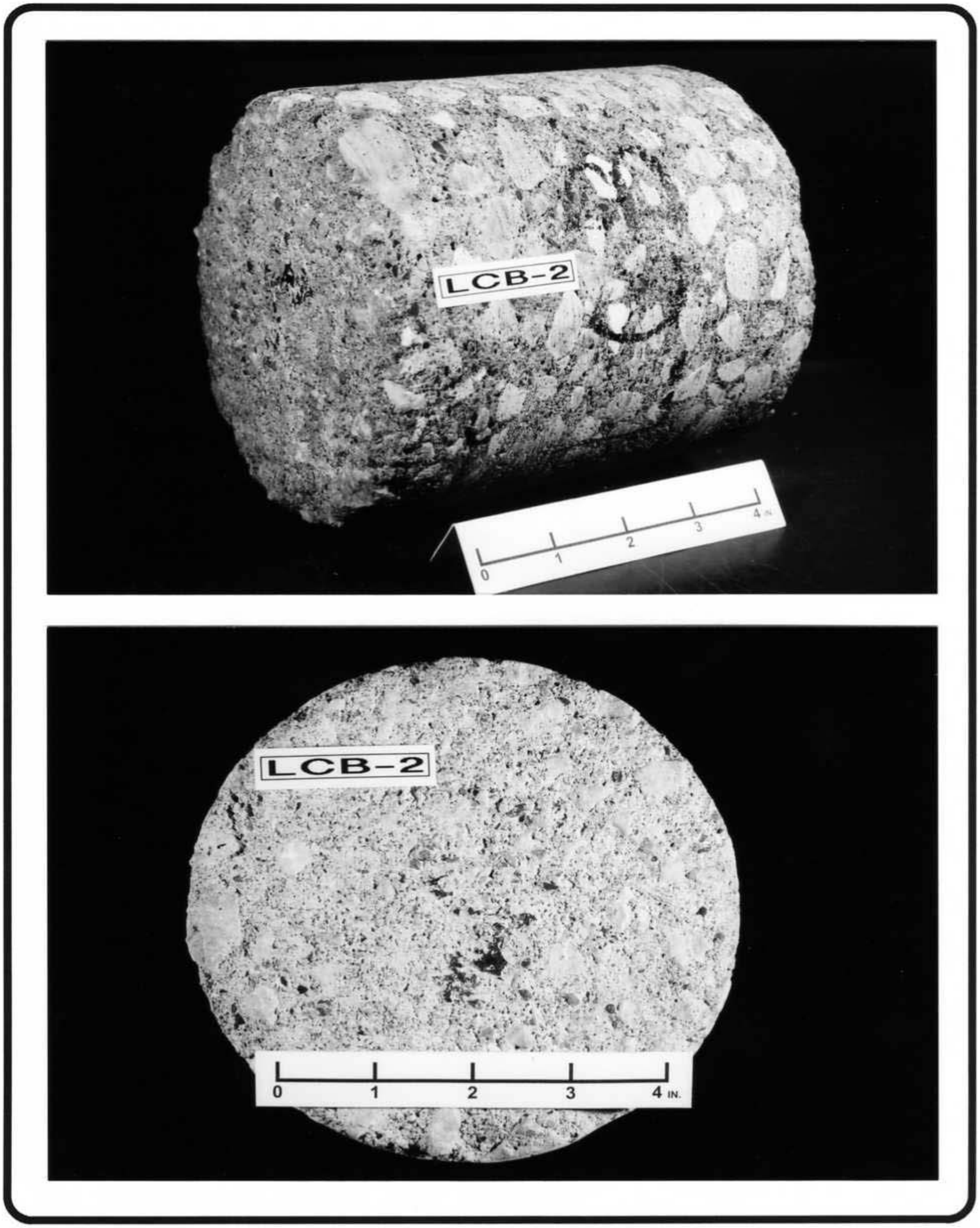


Figure 6.5 - Photograph of Core LCB-2

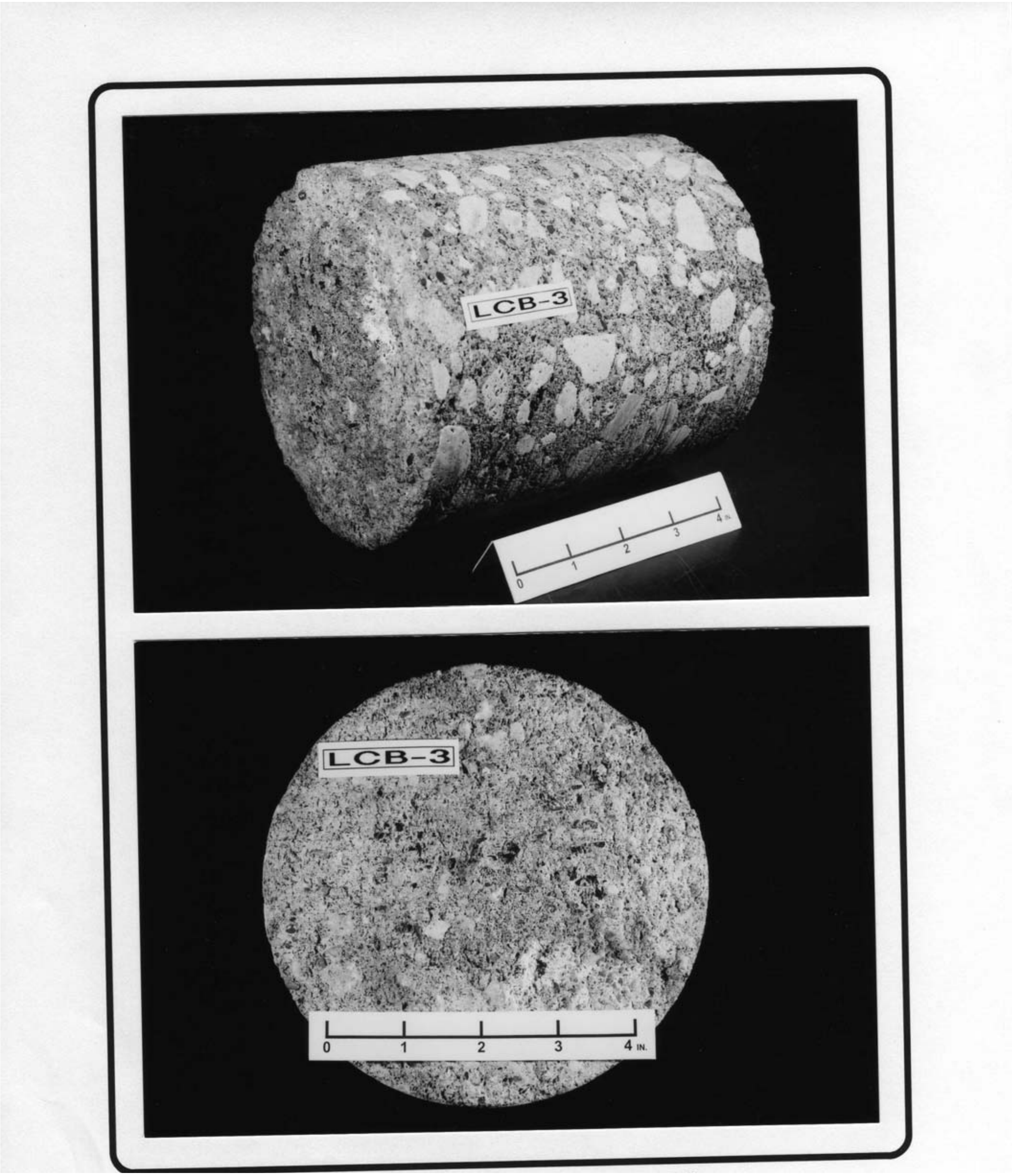


Figure 6.6 - Photograph of Core LCB-3

6.2.2 Test Section 205

Section 205, which has a lane width of 12-feet, is just north of Section 206. It contains 8-inches of ODOT Class C, Option 1 Concrete pavement on 6-inches of LCB. The mix design for ODOT Class C, Option 1 Concrete is shown in Table 6.4. This is an air-entrained concrete containing 510 pounds of Portland cement and 90 pounds of fly ash per cubic yard. "Normal" Class C, Option 1 Concrete had a maximum water to cementitious material ratio (w/cm) of 0.5. The concrete placed in Section 205 had a target w/cm of 0.40.

Table 6.4 - Mix Design for Pavement Concrete in Section 205

Concrete Constituent	Pounds of Constituent per Cubic Yard
Portland Cement	510
Fly Ash	90
Fine Aggregate	1260
Limestone	1595
Water	300
Air (6%)	----
Total Weight	3755

NOTE: This mix design is taken from the ODOT Construction and Materials Specifications. Trial batches made at Bowser-Morner (Dayton, Ohio) show a water-cement ratio of 0.40 for the concrete intended for use on the Test Pavement. To accommodate this change, the ODOT Concrete Inspector's Daily Report for 09/11/95 shows an increase in coarse aggregate content.

There is only a single coring site in Section 205. This PCC core (PCC-4) meets the target thickness of 8-inches, while the LCB core (LCB-4) is slightly under the target thickness of 6-inches, at 5¾-inches. Data for these cores are shown in Table 6.2. Photographs of Core PCC-4 are shown in Figure 6.7, and photographs of Core LCB-4 are shown in Figure 6.8. Core PCC-4 was taken through a transverse crack (slightly skewed) in Pavement Section 205, but the core was received intact. Core LCB-4 was received in two pieces, separated by a full-width, full-depth crack. The wearing surface in both Core PCC-4 and Core LCB-4 is grooved. The grooved surface in Core LCB-4 was sawed into the surface. As intended, in none of the cores provided from Sections 205 and 206 was the concrete pavement bonded to the lean concrete base. Two treatments of membrane curing compound served as a bond-breaker.

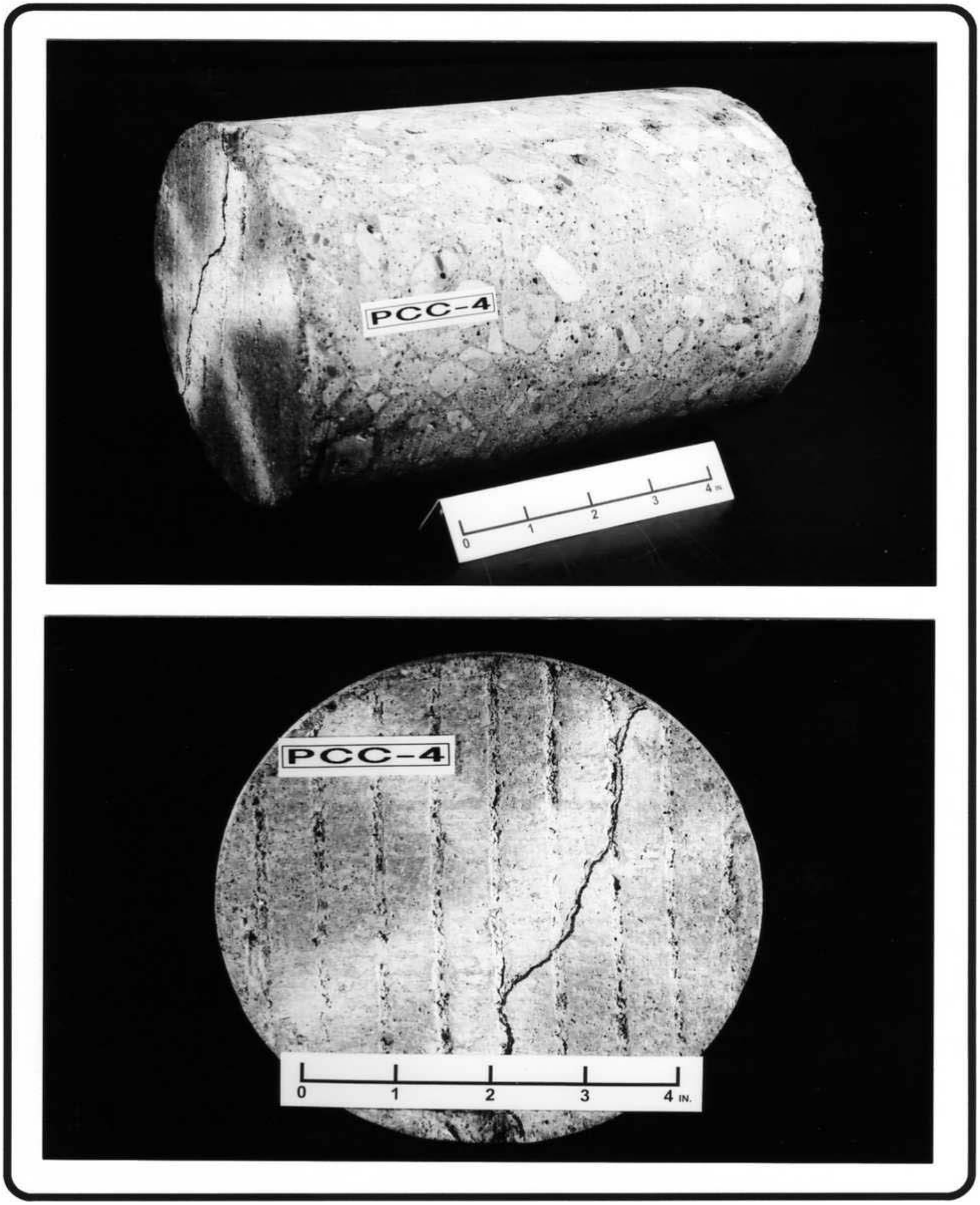


Figure 6.7 - Photograph of Core PCC-4

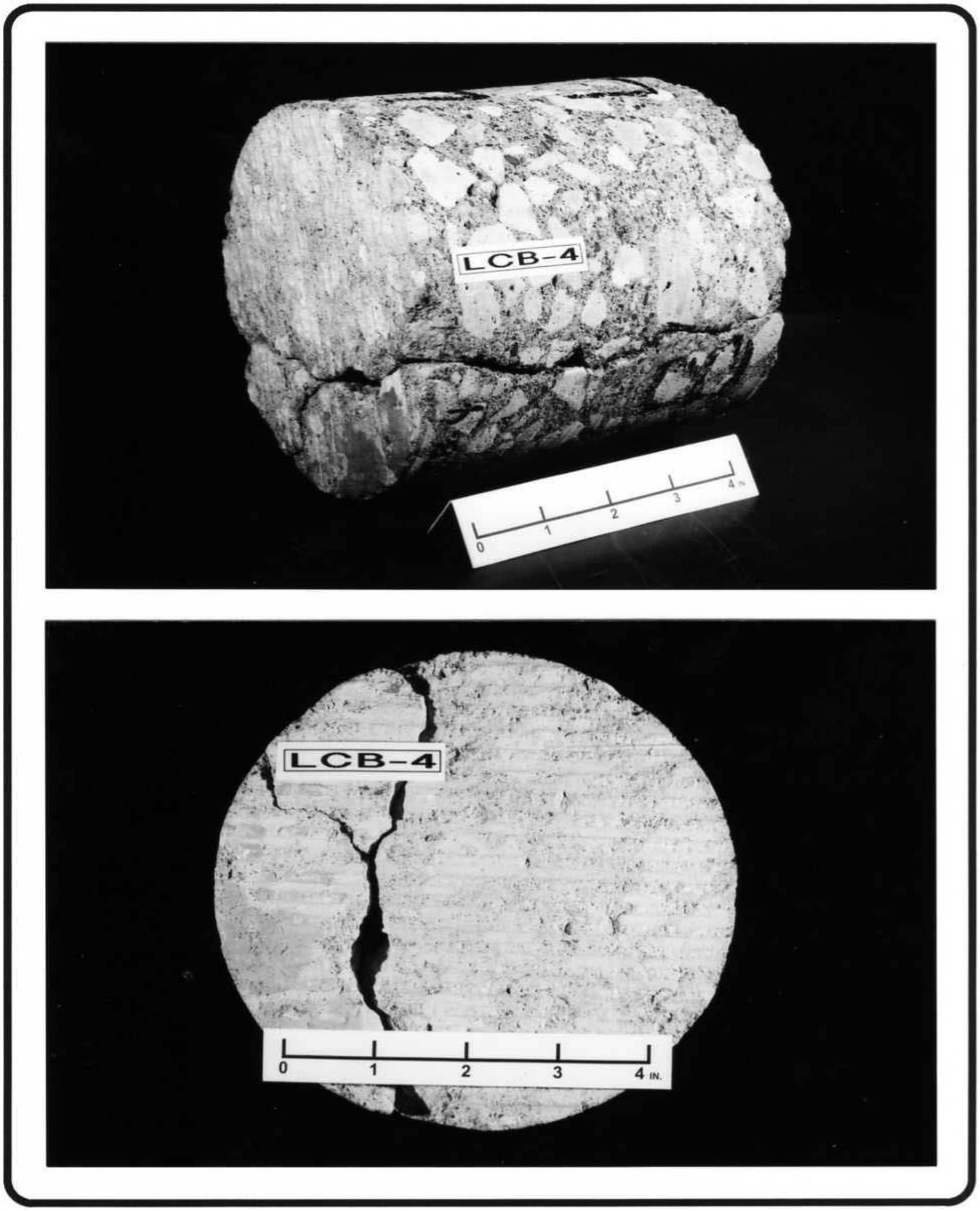


Figure 6.8 - Photograph of Core LCB-4

6.2.3 Test Sections 809 And 810

These test sections are located on the southbound ramp from Norton. Both test sections have a lane width of 11-feet. The same concrete, identified as "Mix 550", was used in both of these test sections and is described in Table 6.5. This is an air-entrained concrete containing 350 pounds of Portland cement and 120 pounds of Class F fly ash per cubic yard. The target thickness of Section 809 is 8-inches and the target thickness of Section 810 is 11-inches. Both of these test slabs were cast on 6-inches of dense graded aggregate base (DGAB).

One full-depth core was taken from each of these test sections and identified in this report as Cores 809 and 810. The site for the 8-inch core in Test Section 809 is identified as "Station 26 + 40". The site for the 11-inch core in Test Section 810 is identified as "Station 26 + 90". The pavement target thickness values were met by both of these cores. Photographs of the cores are shown in Figure 6.9. Both of these cores were receive intact, and neither was taken through a crack in the ramp pavement. One end surface of the cores is the existing grooved wearing surface of the test pavement slabs. The other end surface is the bottom of the cores cast on the DGAB. The southbound ramp pavement shows only a small amount of cracking.

Table 6.5

Mix Design for Pavement Concrete in Sections 809 and 810

Concrete Constituent	Pounds of Constituent per Cubic Yard
Portland Cement	350
Class F Fly Ash	120
Fine Aggregate	1335
Coarse Aggregate	1800
Water	235
Air (6%)	----
Total Weight	3840

NOTE: The mix design shown here is reported on Bowser-Morner, Inc. (Dayton, Ohio) Laboratory Report No. 226390 dated 09/14/94. It is identified as "Concrete Mix Design ODOT DEL 23-17.48 (350 Plan A)". The theoretical unit weight of this concrete is 142.2 lb/ft^3, and the theoretical water to cementitious material ratio is 0.50. ODOT Concrete Inspector's Daily Report dated, 10/07/94, shows a reduced fly ash content for the concrete as-placed (52 lb/yd^3), with a water to cementitious material ratio of 0.58.

Figure 6.9 - Photographs of Cores 809 and 810

6.3 CONCRETE TEST DATA

Property measurements were made on core and cylinder specimens through a one-year period following construction of the pavements. These tests were conducted at ODOT and Ohio University. Twenty-eight day and one-year measurements made of compressive strength, splitting tensile strength, and flexural strength of the Portland cement concretes are shown in Table 6.6. These data were provided to LML by ODOT personnel in the Office of Pavement Engineering. Modulus of elasticity data was also reported for the concrete in Section 205, and the concrete in Sections 809 and 810.

Twenty-eight day and one-year compressive strength data were also provided for the lean concrete base from Sections 205 and 206. These values ranged from 1080 psi to 1880 psi at 28-days, and from 1390 psi to 2490 psi at 1-year.

Table 6.6

ODOT Data on Pavement Concrete in Sections 205, 206, 809, and 810

Test Section	Compressive Strength (psi)		Split Tensile or Flexural Strength (psi)		Modulus of Elasticity (10^6 psi)
	28-day	1-year	28-day	1-year	
205	5930 (a)	7915 (a)	545	750	7.3 (b)
206	8165 (c)	8120 (a)	425	620	---
809, 810	2910 (d)	4880 (d)	755 (c)	795 (c)	3.4 to 3.8

(a) Average for three cores (b) 1-year (c) Flexural strength (d) Average for six cores and cylinders

6.3.1 Petrographic Examination Procedures

All ten PCC cores were given a detailed preliminary visual and stereomicroscopic examination on as-cored surfaces, on end surfaces, and on existing fracture surfaces. The cores were then sectioned (diamond saw) as shown in Figure 6.10. The initial cut on the cores was made at midpoint (relative to length) to provide samples of a length suitable for subsequent sample preparation. Immediately following the cutting, an indicating solution was applied to the fresh saw cut surfaces to identify the extent of concrete carbonation. The indicating solution in this case is phenolphthalein, which shows a distinctive color change at a pH of about 9.8.

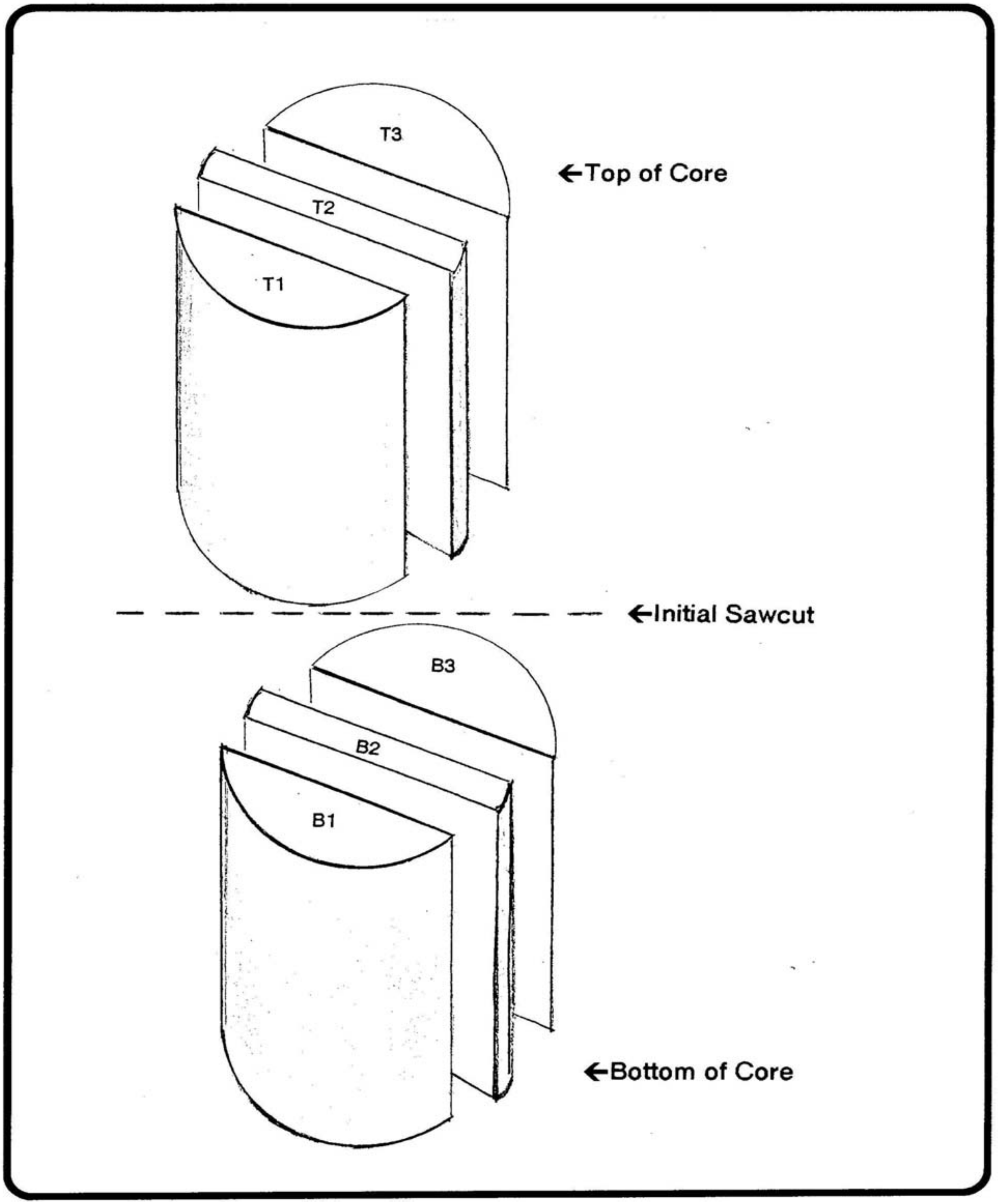


Figure 6.10 - Sampling Diagram for PCC Cores

The core sections identified as "T2" and "B2" in Figure 6.10 were used to prepare lapped surfaces for the petrographic examination. The petrographic examination was conducted on all cores following the guidelines of ASTM C 856, "The Standard Practice for Petrographic Examination of Hardened Concrete" (Optical Microscopy Procedures). Examinations were made on the lapped surfaces of Core Sections T2 and B2 and on fresh fracture surfaces of Core Sections T1 and B1.

The examination of lapped surfaces provided: (1) identification of the cementitious and aggregate constituents of the concrete, (2) an estimate of the water to cementitious material ratio (w/cm) of the concrete, (3) an assessment of the cement paste/aggregate bond, (4) an opportunity to observe any cracking, delamination, softening, or other forms of microstructural distress, (5) an assessment of the consolidation features of the concrete, and (6) an assessment of the extent of moisture cycling in the concrete.

Further opportunities to identify distress features were obtained by subjecting Core Sections T1 and B1 to loading in a 400,000-pound Universal Testing Machine using a modification of ASTM C 496, "The Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens". Here, the loading was done on the partial core sections identified as T1 and B1 in Figure 6.10. When tested to complete failure using this procedure, numerous fracture surfaces are created. It is anticipated that, if the concrete contains distress in the form of microcracking, freeze/thaw damage, or cement-aggregate reactions, the fracture will occur preferentially through these planes of weakness. Subsequent microscopic examination of these fracture surfaces will reveal these distress features if they exist. Conversely, fractures which reflect principally fresh cement paste and aggregate fractures will help to confirm that no hidden defects are present in the concrete.

Measurements of cement paste content and air content (entrained and entrapped) were made in all cores using ASTM C 457, "The Standard Practice for Microscopical Determination of Air Void Content and Parameters of the Air Void System in Hardened Concrete" (Modified Point Count Method). These measurements were made on both the top and bottom sections of the cores (Figure 6.10).

Density measurements on Core Sections T3 and B3 (Figure 6.10) were made in accordance with guidelines of ASTM C 642, "The Standard Test Method for Specific Gravity, Absorption, and Voids in Hardened Concrete" (Water Immersion Procedure) following a 48-hour water soaking period. A density measurement made on water saturated concrete is expected to correlate with the original unit weight of the concrete.

The salient observations and findings of the examinations/tests are discussed below. For clarity, the results are presented separately for each of the four concretes represented by the cores examined here. These are identified as (1) Mix 900 (Table 6.1); (2) ODOT Class C, Option 1 Concrete (Table 6.4); (3) Mix 550 (Table 6.5) and (4) Lean Concrete Base (Table 6.3). Coarse aggregate used in all concretes is identified as "Carey Stone", produced by National Lime in Carey Ohio, and fine aggregate in all of the concretes is "Prospect Sand".

The coarse aggregate is a crushed dolomitic limestone with a nominal maximum particle size of 1-inch. The angular particles are compact to platy in shape. The dolomitic limestone particles are typically very light gray to medium light gray in color. Relative to other regional sources of limestone/dolomitic limestone, this rock is quite hard and typically shows a low rate of water absorption. The presence of irregularly shaped porosity is a common feature in these aggregate particles. The pores typically range from 0.1 mm to 2 mm in size. The presence of this macro porosity provides an excellent surface for bonding to the cementitious phase in concretes.

The fine aggregate in the concretes represented by these cores is a natural sand composed of both carbonate and siliceous rock/mineral types. Carbonate rocks include both limestone and dolomitic limestone. Siliceous rock/minerals include quartz, sandstones, siltstones, shale, igneous lithics, and chert. Chert is a very finely crystalline form of silica (SiO_2) which can, under some conditions, be involved in alkali-silica reactions (ASR). In the cores examined, the chert content of the fine aggregate phase is estimated at less than 1%.

In all cores examined here, including the LCB cores, the coarse aggregate particles are uniformly distributed from top to bottom in the core.

6.3.2 RESULTS: MIX 900

This concrete mix was used in Section 206 of the mainline PCC pavement and includes Cores PCC-1, PCC-2, and PCC-3. Unless otherwise stated, the observations and features described here pertain to the concrete represented by all three cores.

6.3.2.1 Cementitious Phase

The cementitious phase in this concrete is composed of both well hydrated Portland cement and fly ash. The cement paste phase is medium gray in color and very hard. When probed, the cement paste shows a high degree of luster and is difficult to scratch.

The target water to cementitious material ratio (w/cm) for this concrete is 0.31. The color, texture, hardness, and fracture characteristics of the cement paste in these cores indicate that the w/cm of this concrete is in conformance with the target value. The measured (ASTM C 457) cement paste content ranges from 35.0% to 35.5% in these cores (see Table 6.7).

Table 6.7

Characterization Data Obtained on Cores PCC-1, 2, 3, and 4

Core	Estimated Water To Cementitious Material Ratio	Air [(a)] Content (%)	Saturated Density (lb./ft^3)	Cement Paste Content (%)	Depth of Carbonation On Wearing Surface (mm)
PCC-1	0.30	2.5	146.7	35.5	0
PCC-2	0.30	2.2	147.8	35.1	0
PCC-3	0.30	6.6	140.4	35.0	0
PCC-4	0.40	2.5	147.3	27.0	0

[(a)] ASTM C 457

6.3.2.2 Air Content

Although it is judged that an air-entraining agent was used in the concrete represented by all three of these cores, the total air content falls well below the target value of 6% in Cores PCC-1 and PCC-2 (2.5% and 2.2%). Indications that the concrete contained an air-entraining admixture are based on the size range of the air voids that are present, which fall well within the entrained air void size category. The total air void content in Core PCC-3 is 6.6%, which is very close to the target value of 6%.

In all of these cores, the entrained air voids are uniformly distributed from top to bottom in the cores, including the wearing surface layer.

6.3.2.3 Density

The density of the concrete represented by these cores was measured following a 48-hour water soaking period which is expected to correlate with the original unit weight of the concrete. The density of concrete represented by Cores PCC-1 and PCC-2 is 146.7 lb/ft^3 and 147.8 lb/ft^3. In Core PCC-3, which has an air content of 6.6%, the saturated density is 140.4 lb/ft^3. The lower density of Core PCC-3 reflects the higher air content relative to Cores PCC-1 and PCC-2.

6.3.2.4 Carbonation

The depth of carbonation of the wearing surface was measured by applying an indicating solution (phenolphthalein) to fresh cut surfaces. In all three cores, there is virtually no carbonation of the wearing surface, reflecting the low w/cm of the cementitious phase.

6.3.2.5 Cement Paste/Aggregate Bond

In all three cores, a tight, uninterrupted bond persists between the cementitious phase and the coarse aggregate particles. In the present investigation, split tensile test fractures made on portions of these cores show 100% coarse aggregate fracture as the failure mode, reflecting the excellent quality of the cementitious phase, as well as the good bonding qualities of the coarse aggregate particles. Compressive strength measurements made at an age of 1-year on cores taken from Section 206 were over 8000 psi (see Table 6.6).

6.3.2.6 Moisture Migration

As water moves into and out of concrete, soluble constituents derived from the cementitious phases can be deposited on free surfaces such as air void surfaces and crack surfaces. These deposits are referred to as "secondary deposits", and they are not typically viewed as a distress feature. Secondary deposits are common in the cores examined here, indicating that there has been a considerable amount of moisture cycling in these concretes. Many of the entrained air voids that are under 50-μm in size, are completely filled with secondary deposits in these cores.

6.3.2.7 Cement-Aggregate Reactions

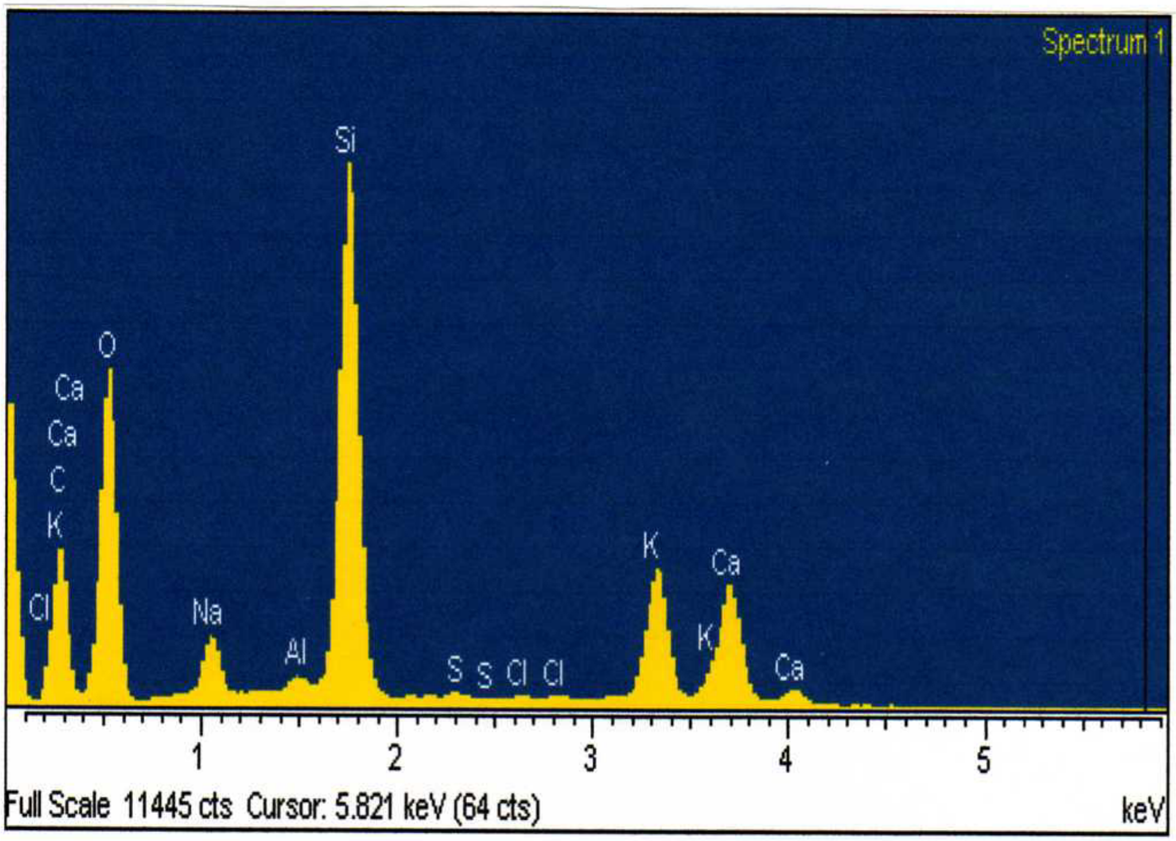
The fine aggregate phase in these concretes contains a small amount of chert, a very finely crystalline form of silica that is known to participate in cement-aggregate reactions. In rocks and minerals containing silica, this cement-aggregate reaction is referred to as alkali-silica reaction (ASR).

Historically, ASR activity is indicated by a number of microstructural features which include: (1) reaction rims around reacting aggregate particles, (2) distinctive internal cracking in reacting aggregate particles, (3) cracking in cement paste adjacent to reacting aggregate particles, and (4) the presence of ASR reaction product, typically referred to as "gel".

In the three cores examined here, there is evidence of ASR activity. Water is used to carry abrasive grains used to lap/polish the cut surfaces of concretes for reflected light microscope examination. Following this lapping operation, water that was absorbed is evaporated. In some cases, soluble constituents in the concrete are deposited on the lapped surfaces following this drying step. In the present case, all three cores showed surface deposits following the lapping operation. These deposits were analyzed chemically using energy dispersive x-ray spectroscopy (EDS) procedures. An EDS spectrum obtained on material deposited on the surface of Core PCC-1 is shown in Figure 6.11. This analysis indicates that the material is an alkali-silica reaction product containing calcium (Ca), potassium (K), and sodium (Na) as the cation species.

From a microstructural point of view, the only physical evidence of ASR activity is the presence of rims on chert aggregate particles. However, neither of these particles nor any other siliceous aggregate particles in these concretes show any evidence of cracking either within the aggregate particles themselves, or in the adjacent cement paste phase. Portions of these cores were fractured in the split tensile test and the surfaces carefully examined for any evidence of reacted aggregate particles or ASR gel. Following extensive examinations, no evidence of this type was found.

It is concluded that the ASR activity in these concretes has been very mild and is not of a destructive form. There is no indication that the activity has had any adverse effect on the strength of the concrete, which still shows 100% coarse aggregate fracture as the failure mode.



Element	Weight%	Atomic%	Compd%	Formula	Number of ions
Na K	4.56	4.48	6.15	Na2O	0.61
Al K	0.64	0.53	1.21	Al2O3	0.07
Si K	26.96	21.65	57.68	SiO2	2.97
S K	0.31	0.22	0.77	SO3	0.03
Cl K	0.17	0.11	0.00		0.01
K K	13.04	7.52	15.70	K2O	1.03
Ca K	13.09	7.37	18.31	CaO	1.01
O	41.23	58.13			7.99
Totals	100.00				
				Cation sum	5.74

Figure 6.11 - Energy Dispersive X-ray Spectroscopy (EDS) Spectrum of Material Deposited as Efflorescence - Section 206

6.3.2.8 Distress Features

Cores taken from Section 206 currently shows longitudinal cracks, the plane of which is oriented perpendicular to the plane of the wearing surface of the slabs. One of the cores examined here (PCC-1) was taken through one of these cracks. A plan view of the wearing surface of Core PCC-1 is shown in Figure 6.1. This shows that, in addition to the main full-width longitudinal crack, there is a second full-width crack about 1½-inches from the main crack. Figure 6.12 shows section views, perpendicular to the plane of the wearing surface, of Core PCC-1. The left-hand photograph in Figure 6.12 shows the as-lapped surface, while in the right-hand photograph, cracks in the concrete have been delineated with a black marking pen. An examination of the crack fracture plane shows coarse aggregate fracture predominating, indicating that the concrete had a high degree of its strength at the time the cracking occurred. As shown in Figure 6.12, the main fracture shows a considerable amount of branching, indicating that cracking took place gradually rather than as a single catastrophic event.

In addition to the main fractures in Core PCC-1, there are a few crazing cracks oriented perpendicular to the plane of the wearing surface, and a few micro-cracks randomly oriented in the cementitious matrix. The micro-cracks are very tight, typically less than ¼-inch long when measured in two dimensions. Micro-cracks such as these are not uncommon in concretes which have a high cementitious material content. They occur as a result of self-desiccation of the cement paste as unhydrated cement grains react with pore water in the concrete leading to autogeneous shrinkage.

Beyond the macro and micro-cracking shown in Figure 6.12, there is no other form of cracking distress in the concrete represented by Core PCC-1, in spite of the fact that the concrete has a total air void content of only 2.5%. There is no evidence of any freeze/thaw cracking distress in either the cementitious phase or aggregate particles in this core.

As shown in Figures 6.2 and 6.3, Cores PCC-2 and PCC-3 both show the presence of crazing cracks in the pavement wearing surface. These cracks, however, are tight and shallow (less than 1-inch deep), and are not viewed as a distress feature. Both cores show a small amount of micro-cracking such as was seen in Core PCC-1. Figure 6.13 shows an example of the extent of micro-cracking in Core PCC-2. Beyond these examples, there is no evidence of any other form of cracking or distress in the concretes represented by Cores PCC-2 and PCC-3.

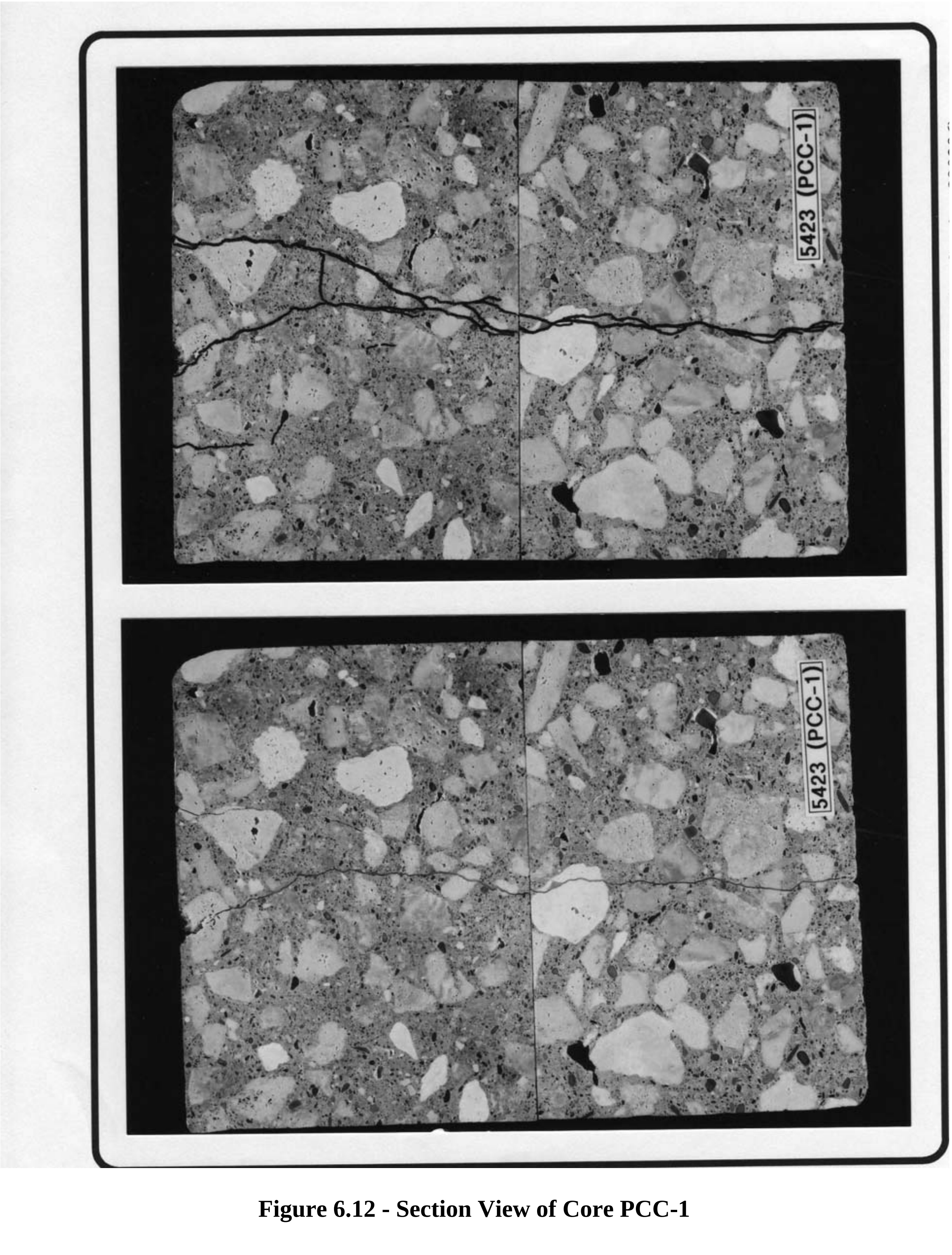


Figure 6.12 - Section View of Core PCC-1

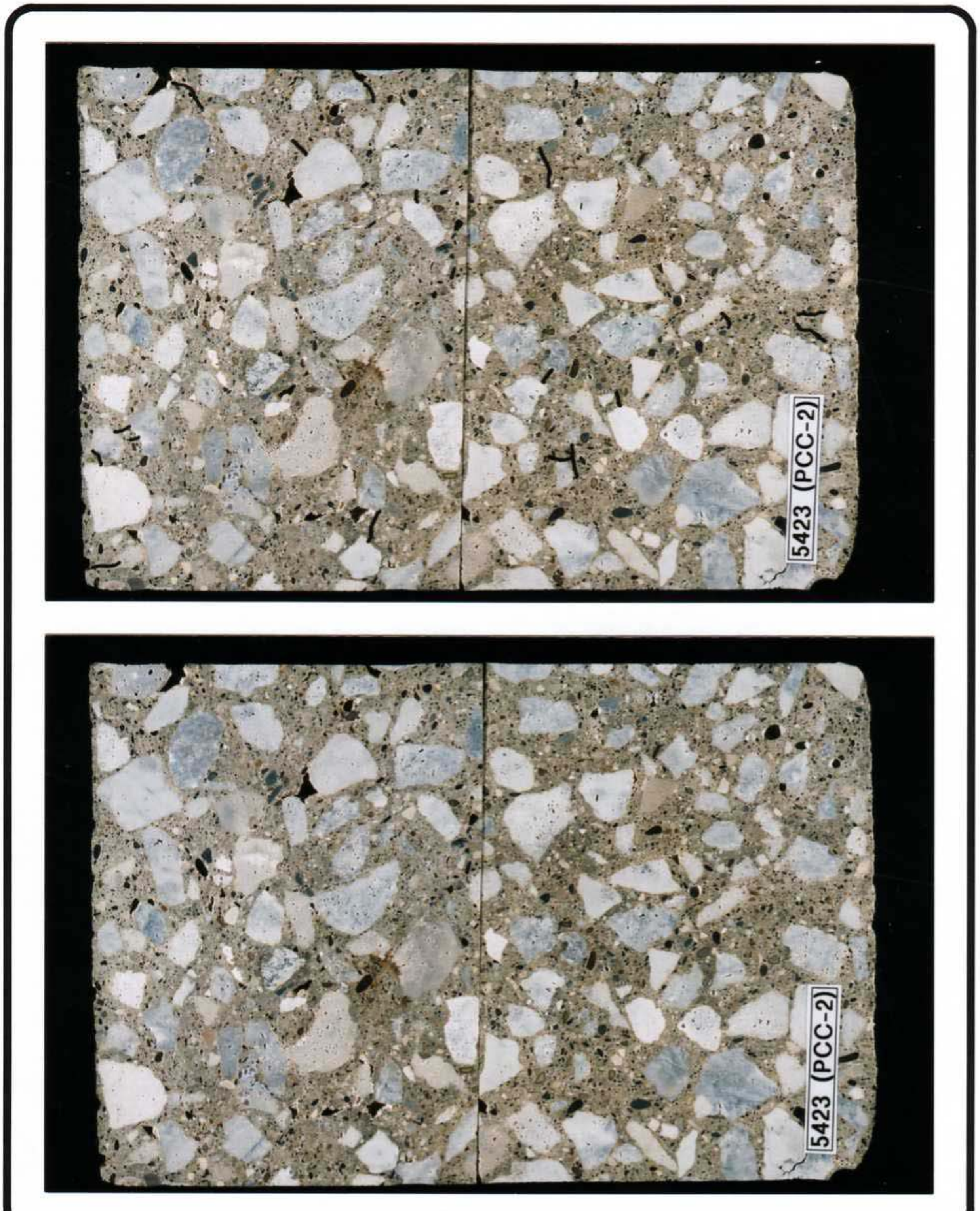


Figure 6.13 - Section View of Core PCC-2

6.3.2.9 Mix 900 Summary

Property data and observations made on Cores PCC-1, PCC-2, and PCC-3, are summarized in Table 6.7. The concrete is judged to be in reasonable compliance with the target values of the mix design for this concrete (Table 6.1), with the exception of the air content. The target air content is 6% ±2%. Two of the cores examined here have air contents of 2.2% and 2.5%.

The main consequence of an inadequate level of air-entrainment is an increase in the risk of freeze/thaw-related damage. However, none of the cores examined here show any freeze/thaw cracking distress either in the cementitious phase or in the coarse aggregate particles.

Core PCC-1 was taken through an existing longitudinal crack in the Section 206 pavement. In both plan view (Figure 6.1) and section view (Figure 6.12), this cracking reflects a branching nature. This condition indicates that the pavement slab received repeated stress loading at this site prior to complete failure, which is characteristic of a fatigue failure.

Beyond the cracking just described, the three cores examined here show a very small amount of microcracking within the cementitious phase, which is not uncommon for concretes with a high cementitious phase content. These microcracks are not viewed as a distress feature in these concretes.

Although there is evidence of ASR activity in these concretes, it has been of a mild form and has not resulted in any degradation or distress in the concretes.

6.3.3 RESULTS: ODOT CLASS C, OPTION 1 CONCRETE

This concrete, described in Table 6.4, was placed in Section 205 in the mainline PCC pavement. Core PCC-4 (Figure 6.7) is the only core from this pavement section examined here.

6.3.3.1 Cementitious Phase

The cementitious phase in this concrete is composed of well hydrated Portland cement and fly ash. The cementitious phase is medium gray in color and shows a good hardness. It is difficult to score the paste when probed with a steel point, and the probe impact area shows good luster. Paste fracture surfaces are clean and sharp.

The target w/cm for this concrete is 0.40. Features of the paste examined in Core PCC-4 indicate that this target value was met. The measured (ASTM C 457) cement paste content of this concrete is 27.0%.

6.3.3.2 Air Content

Although the concrete is air-entrained, the total air void content at 2.5% is well below the target value of 6%. Despite the low total air void content, the majority of air voids are well within the entrained air void size category. Air voids are present from top to bottom in the core, although the top ¼-inch of the core shows a deficiency of air voids relative to the concrete at lower depths.

6.3.3.3 Density

The water saturated density of the concrete represented by Core PCC-4 is 147.3 lb/ft3. This relatively high value reflects the low total air void content of this concrete.

6.3.3.4 Carbonation

There is virtually no carbonation of the wearing surface in this core.

6.3.3.5 Cement Paste/Aggregate Bond

A tight, uninterrupted bond persists between the coarse aggregate particles and the cementitious phase in this concrete. Intentional fracturing of portions of this core (split tensile test) show 100% coarse aggregate fracture as the failure mode.

6.3.3.6 Moisture Migration

The presence and extent of secondary deposits in this core indicate a moderate amount of moisture cycling in this pavement section. As was observed in cores taken from Section 206, many of the air voids smaller than 50 μm are completely filled with secondary deposits.

6.3.3.7 Cement-Aggregate Reactions

As observed in the concretes from Pavement Section 206, this core from Pavement Section 205 also contains a small amount of chert in the fine aggregate phase (less than 1%). These chert particles also show an outer rim. Despite this there is no cracking associated with these chert aggregate particles, and no cracking in the cement paste adjacent to these aggregate particles. In addition, post-lapping drying of the lapped surface of Core PCC-4 did not yield any ASR reaction product.

6.3.3.8 Distress Features

As shown in Figure 6.7, Core PCC-4 was taken through a crack in the pavement that can be seen with the unaided eye (although it is tight). As expressed on this core, this crack is partially a transverse crack (oriented parallel to the groove lines) and then skews slightly to the diagonal of this orientation. Figure 6.14 shows section views, perpendicular to the plane of the wearing surface, of Core PCC-4. Two section views are shown, which are separated from each other by a distance of 1-inch. One section shows two fractures penetrating a distance of about 3¼-inches into this 8-inch long core, while less than an inch away, there is only one fracture penetrating a distance of about 4¼-inches. These fracture planes are wider at the top of the core relative to their bottom end termination (0.13-mm versus 0.03-mm). The fractures typically pass through, rather than around, coarse aggregate particles. Unlike the longitudinal fractures shown in Core PCC-1, these cracks show virtually no branching. In addition to these main fractures, there are a number of shallow crazing cracks in this core as well, as shown in Figure 6.14. No microcracking was observed, and no cracking that could be traced to the effects of freeze/thaw cycling of this concrete was observed either.

6.3.3.9 ODOT Class C, Option 1 Concrete Summary

Property measurements and observations made on Core PCC-4 are summarized in Table 6.7. Based on these measurements made on Core PCC-4, the in-place concrete in Section 205 is in compliance with the target mix design values (Table 6.4) with the exception of the air content. The target air content is 6% ±2%, while the actual air content is 2.5%. Although the maximum w/cm of ODOT Class C, Option 1 Concrete is 0.50, the target w/cm of this concrete on this project was 0.40. The in-place concrete is in compliance with this target value.

The core from Section 205 shows tight transverse cracking which originates at the wearing surface and penetrates to about half of the depth of this 8-inch thick slab. The nature of this cracking indicates that it is primarily related to drying shrinkage strain. The cracking occurred at a time that the concrete had achieved a considerable strength level.

Beyond this cracking, and the presence of minor craze cracking, the concrete represented by the core examined here shows no other cracking or distress of any type. Despite having a total air void content well below the target value, there is no evidence of freeze/thaw-related damage in either the cementitious phase or the coarse aggregate phase.

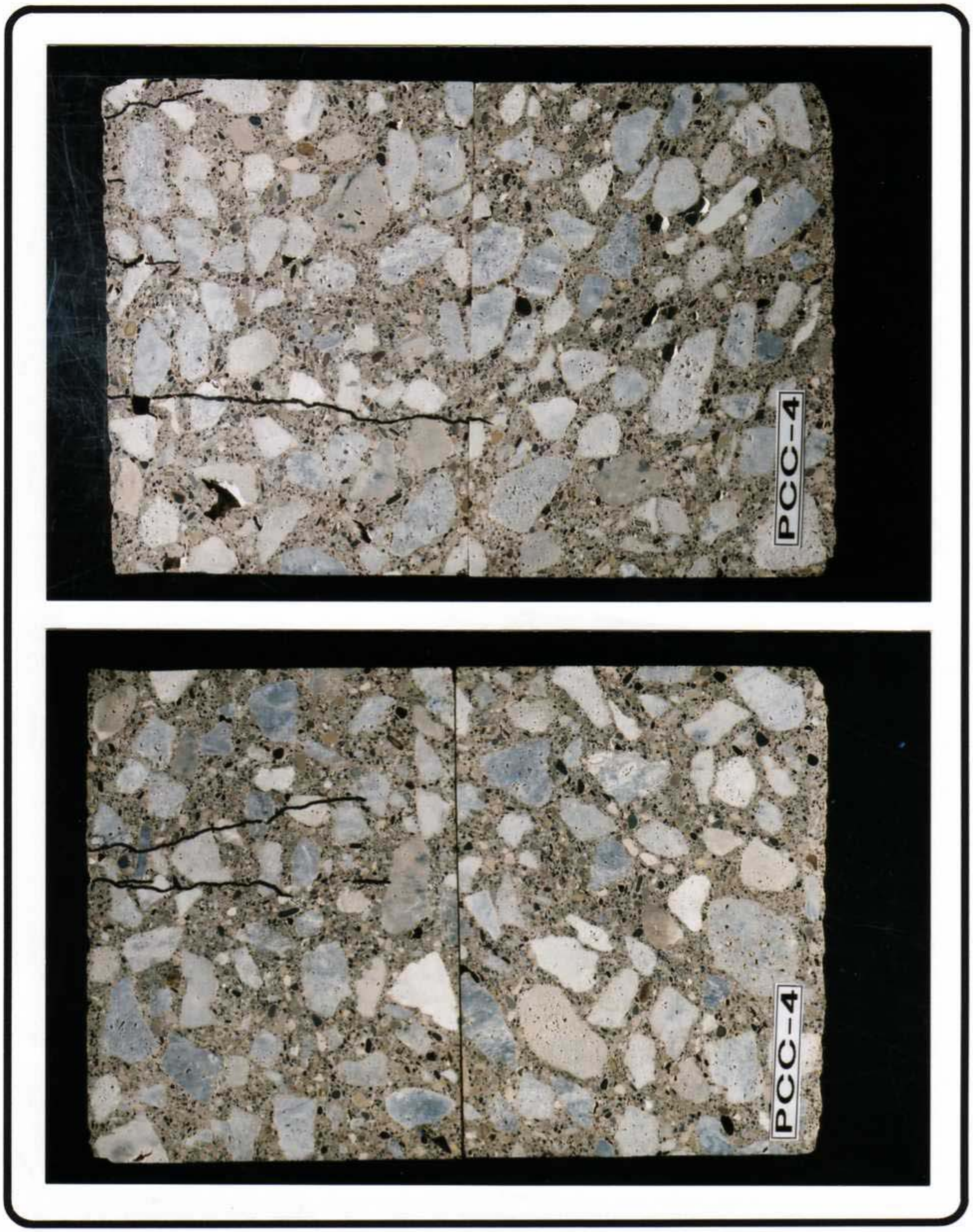


Figure 6.14 - Section View of Core PCC-4

6.3.4 RESULTS: SOUTHBOUND RAMP CONCRETE

Cores 809 and 810, shown in Figure 6.8, were taken from the 8-inch section and 11-section of the ramp, respectively. Concrete for the ramp was intended to be an air-entrained concrete containing both Portland cement and fly ash as cementitious ingredients. As shown in Table 6.5, the target cement content is 350 pounds per cubic yard, and the target fly ash content is 120 pounds per cubic yard. These values reflect the mix design evaluated as the "trial mix". The ODOT Concrete Inspector's Report indicates that the fly ash content actually used was 52 pounds per cubic yard, with a concrete w/cm of 0.58.

Table 6.8

Characterization Data for Cores 809 and 810

Core	Estimated Water To Cementitious Material Ratio (%)	Air Content (%)			Cement Paste Content	Density (lb./ft^3)	Depth of Carbonation (mm)
		<1 mm	> 1 mm	Total			
809	0.55 - 0.58	4.6	2.8	7.4	20.4	140.5	3 - 6
810	0.45 - 0.52	4.5	2.5	7.0	20.7	140.8	3 - 5

[(a)] ASTM C 457

6.3.4.1 Cementitious Phase

The cementitious phase in Core 809 is composed of well hydrated Portland cement and fly ash. The cementitious phase shows a moderate degree of hardness with a water to cementitious material ratio (w/cm) estimated at 0.55 to 0.58. The measured cement paste content in Core 809 is 20.4%.

In Core 810, the cementitious phase is also composed of both well hydrated Portland cement and fly ash, with the bulk of the top 8-inches of the core having a w/cm estimated at 0.52. In the bottom 3-inches of this 11-inch core, the w/cm is considerably lower estimated at 0.45. The measured cement paste content in Core 810 is 20.7%.

6.3.4.2 Air Content

The concrete represented by both cores is air-entrained. The total air void content in Core 809 is 7.4% and the total air void content in Core 810 is 7.0%. As shown in Table 6.9, about 35% of the total air void content is represented by entrapped air voids having a diameter greater than 1-mm. In Core 810, which is 11-inches long, the air content is not uniform from top to bottom in the core. In the top half of the core, the total air void content is 5.7%, while in the bottom half of the core the total air void content is 8.2%.

6.3.4.3 Density

Density measurements were made following a 48-hour water soaking period. The water saturated density of Core 809 is 140.5 lb/ft^3, while that of Core 810 is 140.8 lb/ft^3.

6.3.4.4 Carbonation

The depth of carbonation of the wearing surface of Core 809 is a maximum of 6-mm with a typical carbonation depth of 3-mm to 4-mm. The wearing surface of Core 810 shows a carbonation depth of 3-mm to 5-mm.

6.3.4.5 Cement Paste/Aggregate Bond

As was observed in all of the other cores examined on this project, a tight, uninterrupted bond has persisted between the coarse aggregate particles and the cementitious phase over the 7-year service life of the ramp pavement slabs. In both cores, the mode of failure of the concrete in the split tensile test was 100% coarse aggregate fracture.

6.3.4.6 Moisture Migration

In Core 809, the top 5-inch thickness of this 8-inch long core shows very light secondary deposits. In the bottom 3-inches of the core, secondary deposits are light to moderate. This condition just described for Core 809 also holds for Core 810, with the greatest accumulation of secondary deposits in the bottom third of the core.

6.3.4.7 Cement-Aggregate Reactions

There is no indication of any ASR activity in the concrete represented by these cores.

6.3.4.8 Distress Features

The wearing surface in both cores retains the original grooved texture. However, in both cores, although not necessarily viewed as a distress feature, a thin (less than 0.5-mm) layer of cement paste has been lost revealing the surfaces of fine aggregate particles over the entire wearing surface. Neither of these cores shows any evidence of cracking distress or any other type of distress.

6.3.4.9 Ramp Concrete Summary

Measurements made on two cores in the present investigation indicate reasonable compliance of the in-place concrete with the concrete mix design as reflected in the ODOT Concrete Inspector's Report for this concrete. The latter shows a Portland cement content of 350 pounds per cubic yard and a fly ash content of 52 pounds per cubic yard with a w/cm of 0.58. The concrete is air-entrained and the target air content value of 6% ±2% was met. Neither of the two cores examined here show cracking distress or distress of any other type.

6.3.5 RESULTS: LEAN CONCRETE BASE (LCB)

In each of the three coring sites in Section 206 (Cores PCC-1, PCC-2, and PCC-3), and at the coring site in Section 205 (Core PCC-4), the core was taken through the 8-inch PCC slab and through the 6-inch LCB base material. In all cases the LCB cores examined here represent the base material directly under the PCC cores. Photographs of Cores LCB-1, LCB-2, and LCB-3 are shown in Figures 6.4, 6.5, and 6.6, while photographs of Core LCB-4 are shown in Figure 6.8. The mix design for the lean concrete base material is shown in Table 6.3. As discussed in the "Note" section of Table 6.3, the as-placed concrete contains fly ash as a constituent of the cementitious phase. Unless otherwise stated, the observations discussed below are common to all four LCB cores examined.

6.3.5.1 Cementitious Phase

The cementitious phase in these cores is comprised solely of well hydrated Portland cement and fly ash. The cement paste is light in color, is soft and porous, and shows an earthy texture when fractured or probed. As shown in Table 6.3, the water-cement ratio (w/c) for this concrete is 1.5. Features of the cement paste examined here indicate that the w/c is in excess of 1.0. The cement paste content in these cores ranges from 16.3% to 19.2% (see Table 6.8), with an average value of 18.3%.

6.3.5.2 Air Content

The target air content in the lean concrete base is 6% ±2%. The measured air content in these cores ranges from 7.3% to 11.0%. As shown in Table 6.9, around half of the total air void content in Cores LCB-1, LCB-2, and LCB-3 (Section 205) is entrapped air (air void diameter greater than 1-mm). In Core LCB-4 (Section 205), 70% of the total air void content represents entrapped air voids.

Incomplete consolidation of this concrete has left irregularly shaped voids ranging from 1-mm up to 6-mm or so. These voids frequently occur along the boundaries of fine or coarse aggregate particles. Figure 6.15 shows enlarged (10X) section views of LCB cores showing examples of these voids.

Table 6.9

Characterization Data from LCB Cores LCB-1, 2, 3, and 4

Core	Air Content (%)			Cement Paste Content (%)	Density (lb./ft.^{3})	Depth of Carbonation (mm)
	< 1 mm	> 1 mm	Total			
LCB-1	3.9	3.7	7.6	18.8	141.8	Complete carbonation except for the geometric center of the core
LCB-2	4.9	4.5	9.4	19.0	139.7	Complete carbonation except for the geometric center of the core
LCB-3	4.8	6.2	11.0	16.3	139.3	Complete carbonation except for the geometric center of the core
LCB-4	2.2	5.1	7.3	19.2	143.8	Complete carbonation except for the geometric center of the core

[(a)] ASTM C 457

6.3.5.3 Density

The saturated density values measured on the four cores of LCB range from 139.3 lb/ft^3 to 143.8 lb/ft^3, with an average of 141.2 lb/ft^3, as shown in Table 6.8. The lower density values occur in the cores containing the highest total air contents.

6.3.5.4 Carbonation

The LCB cores showed complete carbonation except for the geometric center of the core. These measurements, however, are very likely not reflective of the actual carbonation situation of these cores in service. The reason for this is that the cores were taken almost four years ago, and most of the carbonation is likely due to the exposure of these highly porous concretes to atmospheric carbon dioxide, which would not occur in service.

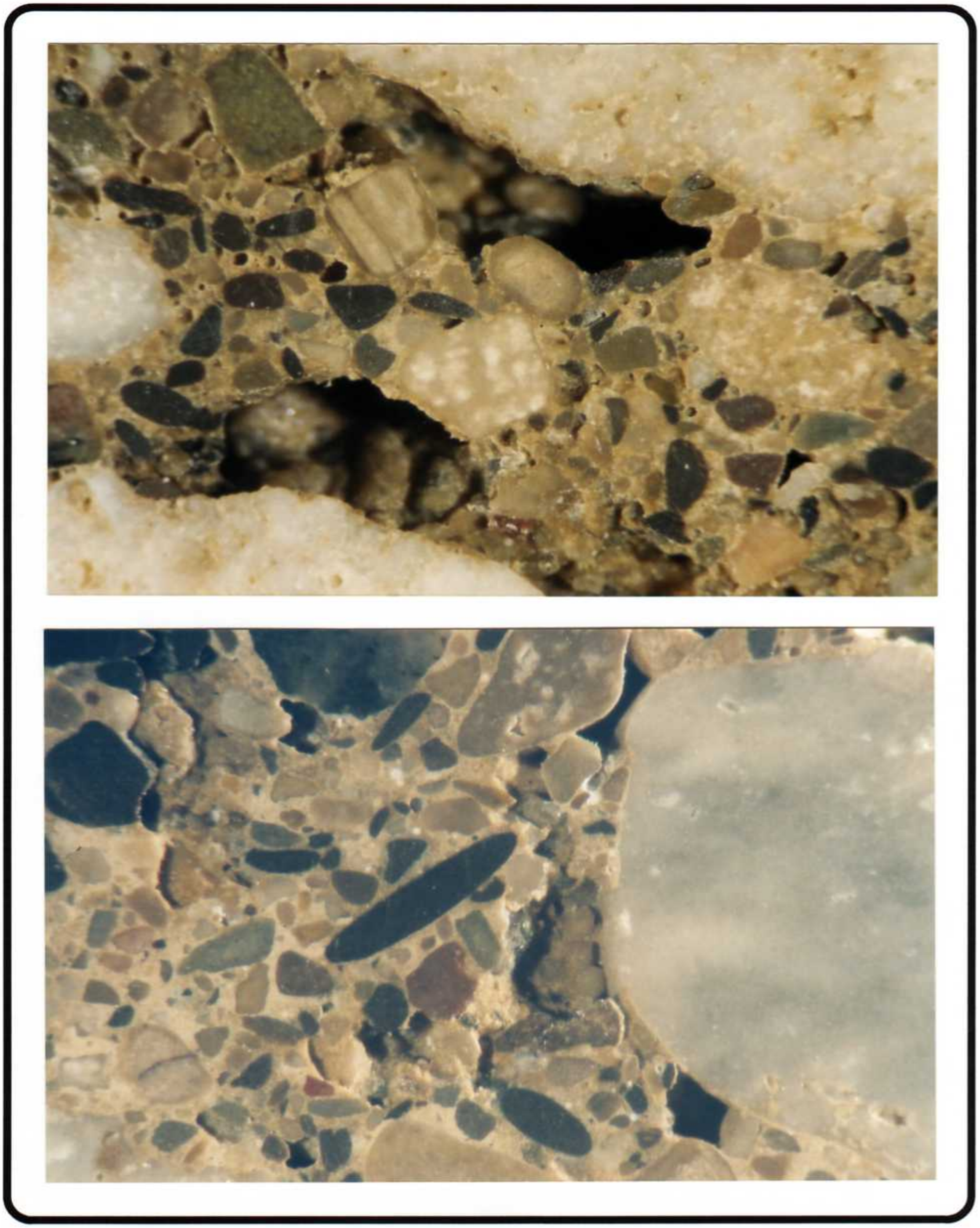


Figure 6.15 - Enlarged Section View of LCB Core Showing Gross Porosity

6.3.5.5 Cement Paste/Aggregate Bond

Despite the high w/cm in these concretes, a tight, uninterrupted bond persists between the cement paste and the coarse aggregate particles. Intentional fracturing (split tensile test) of portions of these cores in the present investigation actually showed that 10% to 20% of the coarse aggregate particles fractured. This reflects, in large part, the excellent bonding surfaces of the coarse aggregate particles.

6.3.5.6 Moisture Migration

Despite the highly porous nature of this lean concrete, there is very little evidence of secondary deposits in these concrete microstructures. This is true even for Core LCB-1, which in service is located directly under Core PCC-1, which contains a full-depth crack.

The indication of little moisture cycling in the lean concrete base suggests one of two possible conditions that could account for this. Either the concrete has been relatively dry over its 8-year exposure time, or it has remained relatively saturated. Observations made in the present investigation, as well as moisture measurements made at the project site, suggest that the latter condition (ongoing saturation) has been in effect.

6.3.5.7 Cement-Aggregate Reactions

The only indication of ASR activity in the concrete represented by these cores is the presence of rims on chert aggregate particles. There is, however, no cracking distress associated with these aggregate particles, and no ASR reaction product was expelled from these cores during their preparation for the microscopic examination.

6.3.5.8 Distress Features

Portland cement concrete Core PCC-1 from Section 206 was taken through a full-depth longitudinal crack in the pavement. This crack in the pavement slab did not propagate into the lean concrete base (Core LCB-1). All three LCB cores from Section 206 show no cracking distress of any type (Cores LCB-1, LCB-2, and LCB-3).

As shown in Figure 6.8, Core LCB-4, taken from Section 205, had a full-depth crack in service. The Portland cement concrete overlying Core LCB-4 also shows a crack perpendicular to the wearing surface (Core PCC-4, Figure 6.7). However, in Core PCC-4, the crack does not pass through the full thickness of the core (see Figure 6.14). The fracture surface in Core LCB-4 shows mainly coarse aggregate pullout.

In Core LCB-4, the wearing surface was grooved after the concrete had hardened and prior to the placement of the PCC pavement slab. This treatment of the wearing surface of the LCB was done to correct a local construction defect and was not used elsewhere on the LCB.

6.3.5.9 Lean Concrete Base (LCB) Summary

The concrete evaluated in the trial mix design work contained only Portland cement as the cementitious phase. The in-place concrete contained both Portland cement and fly ash as the cementitious phase. ODOT Concrete Inspection Reports indicate that the lean concrete base was placed with 160 pounds of Portland cement and 48 pounds of Class C fly ash. It is judged that the in-place concrete is in reasonable compliance to these values of cementitious ingredients.

The target air content of the lean concrete base is 6% ±2%. When considering only the entrained air content (air voids less than 1-mm in diameter), the three cores representing LCB from the Section 206 pavement meet the target value, while the single core from Section 205 has an entrained air void content below the target value (2.2%). The four LCB cores showed relatively high levels of air voids larger than 1-mm, ranging from 3.7% to 6.2%. These large voids represent both entrapped air voids and incomplete consolidation of the concrete.

The incomplete consolidation of the lean concrete base, combined with the high w/cm, indicates that this concrete has a high permeability. This condition is in keeping with the observation that this base material in service was saturated much of the time. Despite this condition, the LCB cores examined here do not show any cracking distress that could be attributed to freeze/thaw cycling. The LCB core from Section 205 contains a full-depth fracture, the plane of which is oriented perpendicular to the plane of the wearing surface. This crack may have occurred as a result of restrained drying shrinkage of the base slab which was placed without joints and remained uncovered for at least a month prior to placement of the PCC wearing course.

6.4 SUMMARY AND CONCLUSIONS

Mainline pavement on the Ohio SHRP Test Road on US 23 near Delaware, Ohio, was constructed during 1995, and completed in 1996. Longitudinal cracking developed in Sections 205 and 206 in 1999. These sections are constructed of 8-inches of Portland cement concrete (PCC) on 6-inches of lean concrete base (LCB). Subsequent to 1999, cracking has developed in all of the other 8-inch thick PCC sections on the test road, as well as in the 11-inch PCC section over lean concrete base.

A petrographic examination was conducted to learn the effect of the Portland cement concrete proportioning and properties on this cracking distress. Beyond this issue, there is an interest in learning what factors are involved in the cracking. The examination was conducted on ten, 6-inch diameter cores obtained from three of the PCC test sections. Eight cores were taken from mainline Sections 205 and 206 in October 1999. These are the PCC sections which showed early longitudinal cracking. Four coring sites were selected in the mainline pavement sections, yielding four 8-inch thick PCC cores and four 6-inch thick lean concrete base (LCB) cores.

More recently, two cores were taken from PCC pavement in the southbound ramp lane on the project. An 8-inch thick core was taken in Section 809, and an 11-inch core was taken in Section 810.

The significant observations and conclusions derived from this examination are summarized below.

6.4.1 Longitudinal Cracking

The fracture plane in Core PCC-1 was oriented perpendicular to the plane of the wearing surface. This was not a single, simple crack. There was actually more than one crack involved, and these cracks exhibited a significant amount of branching. The cracks passed through, rather than around, coarse aggregate particles. These features are shown in Figures 6.1 and 6.12. The nature of this cracking indicated that it occurred as a result of repeated stress applications over a period of time. This pattern suggested that it was a fatigue failure. It is judged that these cracks initiated at the wearing surface elevation on the slab and propagated down into the slab.

A failure of this type would require either a failure of the LCB base material, or curling in the PCC slab itself. Observations made in the present investigation, as well as data generated on the project site itself, suggested that the latter (PCC slab curling) was most likely to be involved. There was no evidence indicating that either the lean concrete base or the sub-base had failed.

The curling of Portland cement concrete slabs occurs as a result of differential movement (strains) in the top of the slab relative to the bottom. These strains can be a result of either differential temperatures in the top and bottom of the slab, as well as differential moisture contents in the top and bottom of the slab. Both of these features are operative here.

The overall orientation of the test road is north-south. Transverse joints in the PCC pavement slabs, the lines of which follow an east-west axis, are doweled. The presence of the dowels is expected to reduce the loss of support due to curling, although curling strains at slab corners likely occurred. With respect to vehicle wheel loads, any loss of support could lead to tensile stresses that could produce a longitudinal crack in the slab. Fatigue failure occurs at stress levels well below those required to fail the concrete under static loading conditions.

One factor that may be involved in exaggerating the amount of curl in the PCC slabs over the lean concrete base is the likelihood of a high degree of water saturation in the LCB on an ongoing basis. Due to this condition, the bottom of the PCC slab would also experience a constant high degree of water saturation. The top of the PCC slab would experience dimensional changes in response to the loss and gain of surface water. During periods of drying and temperature cycling, movement (strains) in the top of the slab would be expected to be high relative to the moisture saturated bottom.

As discussed earlier, although the 8-inch thick PCC slabs on the lean concrete base were the first to show longitudinal cracking, subsequent longitudinal cracking in the 11-inch PCC concrete sections has only occurred to date in those slabs placed on the lean concrete base. It is expected that the magnitude of curling will decrease as a function of an increase in slab thickness. All four of the PCC cores examined here achieved, or slightly exceeded the target pavement thickness of 8 inches.

6.4.2 Role of Concrete Composition and Proportioning Cracking

Ten cores examined here represent four different air-entrained concrete mixes, including:

1. High strength concrete containing 750 pounds of Portland cement and 113 pounds of Class C fly ash per cubic yard, with a w/cm of 0.31. This concrete represents the PCC wearing course in seven test sections, including Section 206.

2. ODOT Class C, Option 1 concrete containing 510 pounds of Portland cement and 90 pounds of Class C fly ash per cubic yard, with a w/cm of 0.4. This concrete represents the PCC wearing course in twelve test sections, including Section 205.

3. Concrete containing 350 pounds of Portland cement and 52 pounds of Class F fly ash per cubic yard, with a w/cm of 0.58. This concrete was used as the wearing course in Sections 809 and 810 on the ramp from Norton to the southbound service pavement.

4. Lean concrete base (LCB) containing 160 pounds of Portland cement and 48 pounds of Class C fly ash per cubic yard, with a w/cm around 1.1. This concrete was used as the base under four PCC sections, including Sections 205 and 206.

All of the concrete mixes were intended to be air-entrained with a total air void content of 6% ±2%. The coarse aggregate was the same in all of the concretes (Carey-National Lime). The fine aggregate was also the same in all of the concretes (Prospect Sand). Issues relating to compliance of the in-place concretes with the compositional requirements and the proportioning target values are summarized below. This assessment is made with knowledge that the mix proportions for the lean concrete base (LCB) and the southbound ramp concrete were modified slightly from the trial mix proportions.

1. All concrete mixes contained the same fine and coarse aggregates.

2. The cementitious phase in all concretes is composed of both well hydrated Portland cement and fly ash. Fly ash was an intended ingredient in all of the concretes except the lean concrete base. Trial mix work done on the lean concrete base showed only Portland cement as the cementitious phase.

3. The w/cm of all concretes is in reasonable compliance with the mix designs of the as-placed concretes.

4. All of the concrete mixes were air-entrained. Two of the three cores taken from Section 206, and the one core taken from Section 205, showed a total air void content well below the specified minimum value of 4% (2.2% to 2.5%). Two LCB cores had total air void contents in excess of the target maximum value of 8% (9.4% and 11.0%).

5. The cementitious materials content is judged to be in reasonable compliance with the as-placed values in all four of the concretes.

Based on the above assessments, the major noncompliance issues include (1) the lower than desired air content in the mainline PCC concretes, and (2) the higher than desired air content in the lean concrete base. The low air void content in the mainline PCC concrete would not be expected to have contributed to the longitudinal cracking problem. As a variable, air content is expected to have little or no effect on the magnitude of curling strains, and decreases in air content are expected to increase both flexural and compressive strength.

The high total air void content in some of the LCB cores appears, in part, as a result of incomplete consolidation of these concretes, resulting in pockets of gross porosity. This may have had the effect of increasing the permeability and porosity of these concretes, and contributing to conditions leading to high moisture retention levels of the base concrete in service.

6.4.3 Overall Performance of In-Service Concrete

The principal concern with the PCC mainline pavement on the test road is the occurrence of longitudinal cracking. Only one of the four mainline PCC cores examined here was taken through a longitudinal crack. The only other occurrence of cracking distress in these four cores is a tight, partial-depth crack in Core PCC-4 attributed to restrained drying shrinkage strain. Beyond these issues, all PCC concretes represented by the cores examined here show no evidence of any other distress or degradation features.

Despite the fact that portions of the mainline Portland cement concrete wearing courses had a low level of air-entrainment, there is no evidence of any freeze/thaw related cracking in these concretes. This result is attributed to the fact that the concretes have some level of air entrainment and to the good quality (low w/cm) of the aggregates and the cementitious phase. Similarly, none of the LCB cores show any evidence of freeze/thaw-related cracking.

Three of the four LCB cores examined here show no evidence of distress of any type. One of the LCB cores contains a full-depth fracture oriented perpendicular to the plane of the wearing surface of the core. This fracture resulted from restrained drying shrinkage strain prior to placement of the PCC wearing course.

The coarse aggregate in all of the concretes is a hard dolomitic limestone with a low rate of water absorption. This aggregate has shown excellent durability over the 7-year service life of these pavements. In all four of the concretes examined here, the quality of the bond between the cement paste phase and the aggregate particles is judged to be excellent.

As discussed in the body of this report, there is an indication of alkali-silica reaction activity in the high strength concrete in Section 206. This activity is characterized as being very mild and has resulted in no distress or degradation of this concrete. The absence of this activity in the other concretes suggests that it is the high level of cementitious phase in this concrete that has contributed to this result (high alkali level). Although it is unlikely that this activity will lead to future distress in these pavement slabs, this feature should be considered in future surveys.

Compressive strength measurements made on cores taken from Sections 205 and 206 at 1-year showed values around 8000 psi. Observations made on PCC cores taken from these sections indicate that these strength levels are currently being maintained. This assessment is based on the observed mode of failure for portions of the cores intentionally fractured in the present investigation, along with an assessment of the quality of the cementitious phase and on the absence of any degradation/distress features in these concretes. Beyond the longitudinal cracking issue, which is the subject of the present investigation, the mainline PCC cores examined here have shown excellent durability over their 7-year service life.

CHAPTER 7
OTHER PAVEMENTS

7.1 GENERAL

ODOT has been monitoring the performance of three other experimental pavements in Ohio during the past few years. These pavements included sections of ATH 50, LOG 33 and ERI/LOR 2. As part of this current research project to document work on DEL 23, ORITE agreed to continue monitoring the other three projects by observing these pavements and recording any new data or findings not included in earlier reports.

7.2 ATH 50

In 1997, an experimental high-performance jointed concrete pavement was constructed on US 50 east of Athens, Ohio. In this pavement, 25% of the Portland cement was replaced with ground granulated blast furnace slag and epoxy-coated steel dowel bars were used throughout most of the project to transfer load across the joints. Fiberglass dowels and stainless steel tubes filled with concrete were installed in a few joints to compare their effectiveness with the epoxy-coated bars.

A limited number of epoxy-coated steel and fiberglass bars were instrumented with strain gauges to measure bending moments and vertical shear induced in the bars as the concrete cured, during environmental cycling of moisture and temperature in the concrete slabs, and as a Falling Weight Deflectometer applied dynamic loads near the pavement joints. The strain data indicated that: 1) significant stresses were generated in the dowel bars and in the concrete surrounding the dowel bars soon after the concrete was placed, 2) temperature gradients in the concrete slabs caused high stresses in the bars, and 3) stress levels in the fiberglass dowel bars were less than those in the epoxy-coated steel bars. Falling temperatures during the evening the eastbound lanes were placed caused some very early transverse cracking near the joints.

Time-Domain Reflectometry (TDR) probes were installed to measure subgrade moisture, thermocouples were installed to monitor temperature at different depths in the concrete layer during the strain measurements, and a weather station was installed on site to monitor climatic conditions. These environmental data are available through ODOT.

7.2.1 DCP Profiles on ATH 50

Dynamic Cone Penetrometer (DCP) profiles were collected in the eastbound driving lane between Stations 381 and 463 on May 25, 2004 to determine the cause of some severe slab cracking after two years of service. In general, the 4-inch thick layers of NJ and 304 DGAB showed an oscillating DCP response typically observed in aggregate layers and essentially the same magnitude of stiffness in both materials. With the exception of a few profiles (Stations 439, 444 and 463), where an aggregate type of response extended the full length of the profiles, subgrade below the aggregate bases was a rather uniform, but weak, 10-20 ksi. This weak subgrade was believed to be the cause of the slab cracking and, consequently, the contractor replaced the pavement and subgrade in that portion of the project. Seventeen DCP profiles obtained for this task are shown in Appendix N.

7.2.2 FWD Measurements on ATH 50

On May 24, 2004, a comprehensive set of FWD measurements were made on various experimental features incorporated into the ATH 50 project. Table 7.1 shows the results of these measurements on sections with sealed and unsealed joints. After six or seven years, all joints, except those in Sections D and F, appear to be performing quite well. The repairs in Section D and the crack in Section F also have good load transfer and low deflections.

Sections with the epoxy coated steel, concrete-filled stainless steel tube, and fiberglass dowel bars have been monitored frequently with the FWD. The results of these measurements are summarized in Table 7.2. Also included in this table are readings taken in the centerline and along the right edge of the slabs on May 24, 2005. Early on, the fiberglass bars showed slightly higher deflections and slightly lower load transfers than the other two types of bars. While the higher fiberglass deflections could be attributed to a softer subgrade at that location, the lower load transfers are likely associated with the type of material. By May 2005, deflection was about the same for all dowel bars, but load transfer in the fiberglass bars had deteriorated to being half or less than that provided by the standard epoxy-coated steel bars and the concrete-filled stainless steel tubes. The same trends were present along the centerline and along the right edge of the slabs, although deflections in all three sections were two to three times higher along the edge than on the centerline. These larger deflections likely can be attributed to a loss of support from slab curling and warping.

Table 7.1
Summary of Non-Dowel FWD Measurements on ATH 50

ATH 50 FWD Measurements - 5/24/04												
Joint	Section D (Sealed joints) - 85° F				Section E (Unsealed joints) - 87° F				Section F (Sealed joints) - 89° F			
	Joint Approach		Joint Leave		Joint Approach		Joint Leave		Joint Approach		Joint Leave	
	Df1 (mils/kip)	LT (%)	Df1 (mils/kip)	LT (%)	Df1 (mils/kip)	LT (%)	Df1 (mils/kip)	LT (%)	Df1 (mils/kip)	LT (%)	Df1 (mils/kip)	LT (%)
1	0.40	94.8	0.41	89.3	0.53	96.6	0.58	90.3	1.06	97.9	1.01	101.1
2	0.37	94.4	0.39	86.8	0.51	95.1	0.52	93.2	0.35	92.3	0.37	82.8
3					0.51	96.7	0.54	92.5	0.32	91.6	0.35	85.4
4	0.37	96.0	0.39	89.8	0.56	99.6	0.63	90.5	0.34	84.3	0.38	73.6
5					0.46	98.6	0.51	87.5	0.33	93.0	0.37	81.3
6	0.36	95.1	0.41	83.4	0.45	99.5	0.49	90.6	0.39	88.9	0.44	76.9
7	0.40	94.5	0.42	84.7	0.44	97.7	0.47	90.6	0.33	90.5	0.37	78.1
8					0.40	96.1	0.44	85.0	0.34	94.2	0.37	86.4
9	0.38	94.1	0.39	88.0	0.47	98.0	0.53	84.0	0.37	94.9	0.40	85.8
10	0.36	95.1	0.36	90.8	0.56	97.4	0.59	93.3	0.38	92.7	0.41	82.4
Avg.	0.38	94.9	0.40	87.6	0.49	97.5	0.53	89.7	0.42	92.0	0.45	83.4
Joint	Patch Approach		Patch Leave						Crack Approach		Crack Leave	
	Df1 (mils/kip)	LT (%)	Df1 (mils/kip)	LT (%)					Df1 (mils/kip)	LT (%)	Df1 (mils/kip)	LT (%)
1									0.42	92.9	0.46	85.7
3	0.39	90.3	0.37	93.3								
3	0.34	93.4	0.36	85.2								
5	0.56	94.6	0.58	91.3								
5	0.44	94.0	0.46	87.0								
8	0.45	94.9	0.47	90.8								
8	0.41	96.2	0.43	87.7								
Avg.	0.43	93.9	0.45	89.2					0.42	92.9	0.46	85.7

ATH 50 FWD Measurements - 5/24/04												
Joint	Section G (Sealed joints) - 90° F				Section H (Sealed joints) - 90° F				Section I (Sealed joints) - 91° F			
	Joint Approach		Joint Leave		Joint Approach		Joint Leave		Joint Approach		Joint Leave	
	Df1 (mils/kip)	LT (%)	Df1 (mils/kip)	LT (%)	Df1 (mils/kip)	LT (%)	Df1 (mils/kip)	LT (%)	Df1 (mils/kip)	LT (%)	Df1 (mils/kip)	LT (%)
1	0.46	84.3	0.47	84.3	0.39	93.8	0.39	88.7	0.31	93.6	0.32	87.1
2	0.44	70.1	0.47	68.6	0.32	92.6	0.33	87.7	0.33	90.7	0.32	91.3
3	0.47	81.9	0.52	74.0	0.32	92.2	0.33	87.8	0.38	93.7	0.40	88.2
4	0.40	82.9	0.40	76.6	0.29	90.3	0.28	89.1	0.39	92.7	0.40	88.3
5	0.46	84.7	0.52	75.7	0.43	95.6	0.44	91.7	0.35	94.9	0.38	87.2
6	0.47	81.7	0.49	76.8	0.29	91.0	0.30	84.5	0.32	94.2	0.35	85.1
7	0.45	87.4	0.45	81.6	0.27	90.5	0.27	87.1	0.34	95.7	0.37	86.3
8	0.47	78.0	0.50	72.3	0.24	91.3	0.25	89.7	0.28	92.8	0.30	84.3
9	0.38	84.6	0.43	68.4								
10	0.48	70.0	0.49	71.3								
Avg.	0.45	80.5	0.47	75.0	0.32	92.2	0.33	88.3	0.34	93.5	0.35	87.2

ATH 50 FWD Measurements - 5/24/04																
Joint	Section J (Sealed joints) - 91° F				Section K (Sealed joints) - 96° F				Section L (Unsealed joints) - 98° F				Section M (Sealed joints) - 102° F			
	Joint Approach		Joint Leave		Joint Approach		Joint Leave		Joint Approach		Joint Leave		Joint Approach		Joint Leave	
	Df1 (mils/kip)	LT (%)	Df1 (mils/kip)	LT (%)	Df1 (mils/kip)	LT (%)	Df1 (mils/kip)	LT (%)	Df1 (mils/kip)	LT (%)	Df1 (mils/kip)	LT (%)	Df1 (mils/kip)	LT (%)	Df1 (mils/kip)	LT (%)
1	0.27	93.4	0.29	86.2	0.31	91.2	0.30	92.7	0.49	94.8	0.48	94.3	0.36	91.3	0.35	90.4
2	0.25	92.2	0.26	88.6	0.30	88.5	0.29	87.7	0.48	96.1	0.49	91.9	0.35	90.6	0.34	89.5
3	0.29	91.6	0.30	85.6	0.77	99.0	0.80	94.8	0.34	94.5	0.35	86.7	0.35	92.4	0.35	89.4
4	0.24	90.8	0.25	88.1	0.24	89.1	0.24	88.5	0.42	93.5	0.42	93.8	0.36	91.6	0.35	92.0
5	0.28	91.0	0.29	87.7	1.28	105.0	1.44	93.2	0.39	93.2	0.40	88.2	0.33	90.1	0.32	88.6
6	0.29	90.9	0.30	81.2	0.32	86.5	0.36	76.6	0.42	97.0	0.44	92.3				
7	0.28	91.4	0.30	86.1	1.35	99.5	1.35	97.3	0.37	91.2	0.36	91.3				
8	0.28	92.8	0.30	85.5	0.27	91.2	0.28	87.9	0.39	93.5	0.39	88.7				
Avg.	0.27	91.8	0.28	86.1	0.61	93.76	0.63	89.8	0.41	94.2	0.42	90.9	0.35	91.2	0.34	90.0

Table 7.2

Summary of FWD Measurements on Dowel Bars on ATH 50

FWD Measurements on ATH 50 Dowel Bars - Load ~ 12,000 - 13,000lbs																
Joint Number	11/6/97 - 42° F - RWP				11/15/99 - 38° F - RWP				8/02/01 - 86° F - RWP				12/8/03 - 34° F - RWP			
	Joint Approach		Joint Leave		Joint Approach		Joint Leave		Joint Approach		Joint Leave		Joint Approach		Joint Leave	
	Df1 (mils/kip)	LT (%)	Df1 (mils/kip)	LT (%)	Df1 (mils/kip)	LT (%)	Df1 (mils/kip)	LT (%)	Df1 (mils/kip)	LT (%)	Df1 (mils/kip)	LT (%)	Df1 (mils/kip)	LT (%)	Df1 (mils/kip)	LT (%)
Standard Epoxy-Coated Steel Dowels - Station 101+95																
1	0.40	87.4	0.42	83.7	1.51	100.9	1.49	99.8	0.47*	89.8*	0.45*	93.0*	0.61	88.0	0.65	80.4
2	0.46	96.5	0.58	73.7	2.02	100.7	2.00	100.8	0.40*	93.0*	0.40*	90.5*	0.50	83.9	0.47	87.8
3	0.45	81.3	0.42	82.0	1.83	85.2	1.67	92.6	0.60*	91.3*	0.61*	90.0*	0.65	93.0	0.68	92.0
4	0.36	86.4	0.38	79.9	1.82	87.5	1.73	94.0	0.43*	89.2*	0.42*	91.2*	0.81	89.8	0.81	92.5
5	0.37	82.6	0.31	108.5	1.04	85.4	0.93	95.8	0.67*	92.9	0.64*	96.9*	0.73	91.1	0.74	90.3
6	0.35	88.4	0.36	111.2	1.28	92.3	1.10	107.8	0.63*	93.3*	0.60*	95.2*	0.47	91.1	0.50	82.9
Avg.	0.40	87.1	0.41	89.8	1.58	92.0	1.49	98.5	0.53*	91.6*	0.52*	92.8*	0.63	89.5	0.64	87.7
Concrete-Filled Stainless Steel Tube Dowels - Station 103+41																
1	0.39	78.3	0.42	74.8	1.54	100.4	1.68	96.5	0.51	90.6	0.50	91.5	0.43	85.8	0.47	75.8
2	0.48	78.5	0.48	83.5	1.78	97.6	1.86	96.1	0.52	88.8	0.52	89.5	0.56	93.7	0.62	83.2
3	0.38	92.6			1.82	90.9	1.94	78.7	0.54	91.4			0.44	82.9	0.46	79.8
4	0.45	79.2	0.47	76.0	1.49	86.8	1.42	95.9			0.52	93.4	0.57	96.7	0.61	90.0
5	0.44	86.5	0.43	74.3	1.55	87.8	1.47	94.0	0.70	84.3	0.67	89.9	0.63	82.5	0.64	84.1
6									0.52	91.6	0.50	94.8	0.74	83.0	0.68	91.5
Avg.	0.43	83.0	0.45	77.2	1.64	92.7	1.67	92.2	0.56	89.3	0.54	91.8	0.56	87.4	0.58	84.1
Orange Fiberglass Dowels - Station 106+71																
1	0.57	22.3**	0.54	69.8	1.95	73.8	1.73	92.6	1.26	64.6	1.02	88.7	0.75	88.3	0.80	88.5
2	0.48	88.0	0.53	86.9	1.47	82.5	1.34	92.1	0.50	90.9	0.47	94.4	0.43	81.5	0.45	78.1
3	0.59	63.9	0.62	65.7	1.43	87.5	1.68	69.2	0.87	81.7	0.87	75.2	0.48	92.2	0.50	88.9
4	0.41	65.7	0.37	59.7	1.63	59.0	1.46	81.5	0.68	77.7	0.61	92.2	0.46	94.0	0.52	84.1
5	0.48	60.0	0.46	65.5	1.40	61.7	1.14	90.2	1.02	40.9	0.83	76.5	0.93	28.7	1.15	45.3
6	0.72	81.8	0.88	73.4	1.88	82.8	1.71	89.9	0.71	91.1	0.70	91.1	0.86	63.8	0.88	67.2
Avg.	0.54	71.9	0.57	70.2	1.63	74.6	1.51	85.9	0.84	74.5	0.75	86.4	0.65	74.8	0.72	75.4

* Section begins at Station 108
** Not included in average
Temperature is pavement surface

FWD Measurements on ATH 50 Dowel Bars - Load ~ 12,000 - 13,000lbs																
Joint Number	5/24/04 - 82° F - RWP				1/13/05 - 57° F - RWP				5/24/05 - 66° F - C/L				5/24/05 - 66° F - Rt Edge			
	Joint Approach		Joint Leave		Joint Approach		Joint Leave		Joint Approach		Joint Leave		Joint Approach		Joint Leave	
	Df1 (mils/kip)	LT (%)	Df1 (mils/kip)	LT (%)	Df1 (mils/kip)	LT (%)	Df1 (mils/kip)	LT (%)	Df1 (mils/kip)	LT (%)	Df1 (mils/kip)	LT (%)	Df1 (mils/kip)	LT (%)	Df1 (mils/kip)	LT (%)
Standard Epoxy-Coated Steel Dowels - Station 101+95																
1	0.49	91.5	0.48	90.2					0.61	81.9	0.56	89.9	1.48	82.8	1.40	94.6
2	0.45	91.7	0.44	92.4					0.48	80.6	0.46	85.8	1.56	76.3	1.65	81.3
3	0.49	90.4	0.50	85.9	0.74	92.5	0.75	90.6	0.73	87.5	0.69	94.2	1.85	94.0	1.85	98.6
4	0.57	88.6	0.58	83.7	0.76	82.5	0.71	87.7	0.83	83.9	0.78	90.4	2.09	85.1	1.91	101.3
5	0.44	90.2	0.45	87.8	0.54	78.6	0.28	87.0	0.74	81.7	0.70	89.1	1.71	89.4	1.66	97.9
6	0.40	88.8	0.39	88.7					0.49	80.7	0.43	89.8	1.23	79.4	1.16	90.6
7									0.45	78.3	0.40	87.5	1.01	84.5	0.97	90.7
Avg.	0.47	90.2	0.47	88.1	0.68	84.5	0.58	88.4	0.62	82.1	0.57	89.5	1.56	84.5	1.51	93.6
Concrete-Filled Stainless Steel Tube Dowels - Station 103+41																
1					0.45	76.6	0.29	84.7	0.50	83.5	0.46	87.9	1.19	93.7	1.18	101.0
2					0.48	76.1	0.29	86.5	0.64	83.2	0.61	86.5	1.64	64.9	1.55	76.8
3					0.49	76.7	0.30	86.7	0.52	87.9	0.52	87.0	1.28	79.8	1.24	83.0
4									0.81	74.6	0.69	90.2	1.43	74.6	1.29	88.1
5									0.78	78.7	0.71	89.1	0.95	79.9	0.91	85.5
6									0.45	80.3	0.40	89.4	0.68	92.7	0.69	91.2
7									0.60	82.8	0.58	84.7	1.36	74.9	1.34	84.9
Avg.					0.47	76.5	0.29	86.0	0.61	81.6	0.57	87.8	1.22	80.1	1.17	87.2
Orange Fiberglass Dowels - Station 106+71																
1	0.46	87.5	0.46	88.5	0.38	77.5	0.29	86.2	0.78	25.2	0.62	46.1	1.78	14.6	1.73	22.8
2	0.37	92.7	0.38	87.7	0.75	74.4	0.30	82.4	0.58	55.1	0.49	65.5	1.04	68.4	1.01	61.3
3	0.38	92.3	0.37	92.1	0.51	75.4	0.35	81.6	0.64	38.3	0.61	40.4	1.30	31.4	1.52	21.3
4	0.34	90.2	0.35	86.2					0.79	25.3	0.77	27.7	1.66	26.1	1.60	19.5
5	0.66	84.6	0.68	85.0					0.67	36.6	0.65	41.7	1.46	24.2	1.51	33.4
6	0.49	56.2	0.50	63.0					0.58	59.9	0.56	62.0	1.84	28.7	1.77	46.3
Avg.	0.45	83.9	0.46	83.8	0.55	75.8	0.31	83.4	0.67	40.1	0.62	47.2	1.51	32.2	1.52	34.1

Temperature is pavement surface

7.3 LOG 33

Five test sections were constructed on LOG 33 to evaluate the effects of different drainable bases on the overall performance of AC pavement. All sections had an 11-inch AC pavement thickness. Base materials included: asphalt-treated free-draining base (ATFDB), cement-treated free-draining base (CTFDB), ODOT 307 aggregate with a New Jersey gradation (307NJ), ODOT 307 aggregate with an Iowa gradation (307IA), and ODOT 304 aggregate. Monitoring was halted after Novachip was placed on all sections after the 2001 evaluation.

7.3.1 FWD on LOG 33

The results of FWD measurements taken on April 11, 2002 and May 17, 2004 are summarized in Table 7.3. While the CTFDB gives the lowest deflections and highest SPR on both dates, deflections on the other bases in April 2002 were similar except for the 307IA base, which was also low. Increasing pavement temperature in May 2004 appeared to increase deflection and reduce SPR. To assess the impact of subgrade stiffness on average deflections shown in Table 7.3, normalized DF7 in 2002, which is an indicator of subgrade stiffness, is plotted along the five test sections in Figure 7.1. This figure shows the 307IA section having the stiffest subgrade of the five sections, which would reduce Df1 in that section. Figure 7.2 shows the corresponding profile for Df1 in 2002. As expected, the CTFDB section had the lowest deflection followed by the 307IA section. Had all subgrades had the same subgrade stiffness, deflections in the 307IA section would have been similar to the ATFDB, 307NJ and 304 sections.

Table 7.3
FWD Summary on LOG 33

Section	Base	4/11/02			5/17/04		
		Pvt. Surf. Temp. (°F)	Norm Df1 (mils/kip)	SPR (%)	Pvt. Surf. Temp. (°F)	Norm Df1 (mils/kip)	SPR (%)
ATFDB	4” ATFDB/ 4” 304	64	0.43	63.2	73	0.45	63.7
CTFDB	4” CTFDB/ 4” 304	54	0.27	68.6	85	0.35	63.9
307 NJ	4” NJ/4” 304	54	0.39	66.2	90	0.53	61.6
307 IA	4” IA/4” 304	54	0.33	60.6	95	0.48	55.3
304	8” 304	64	0.39	64.6	97	0.60	56.9

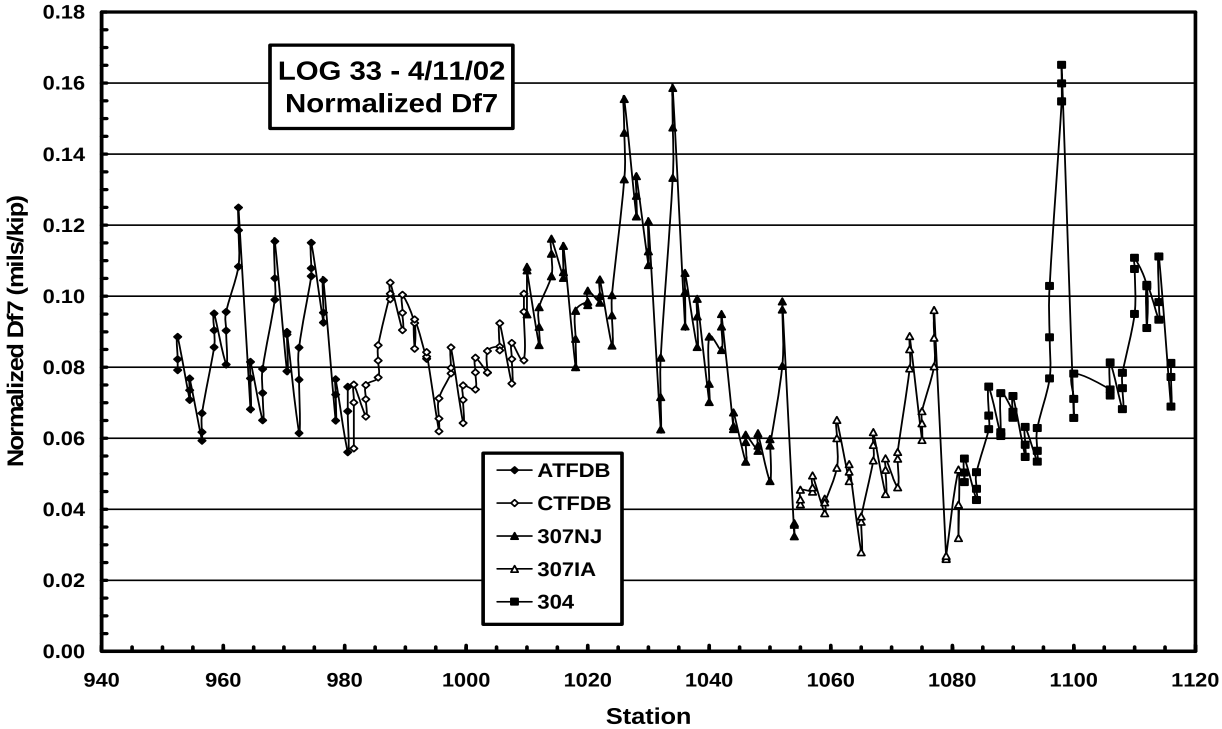


Figure 7.1 - 2002 FWD Df7 Profile on LOG 33

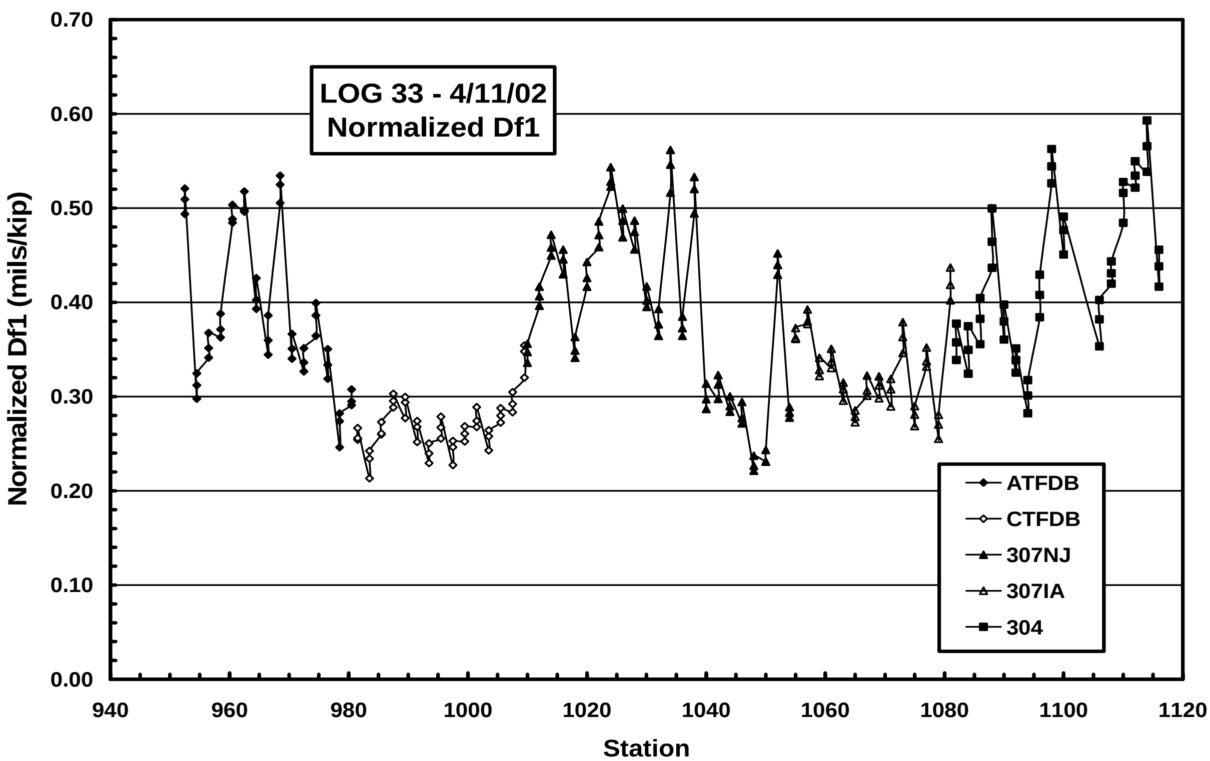


Figure 7.2 - 2002 FWD Df1 Profile on LOG 33

7.3.2 Roughness on LOG 33

Figure 7.3 shows how serviceability trends in the five test sections, as measured by PSI, has remained relatively constant in all five test sections between 1994 and 2001. Much of the original difference between sections was built in at the time of construction and subsequent oscillations observed in all sections were likely associated with the equipment performing the measurements.

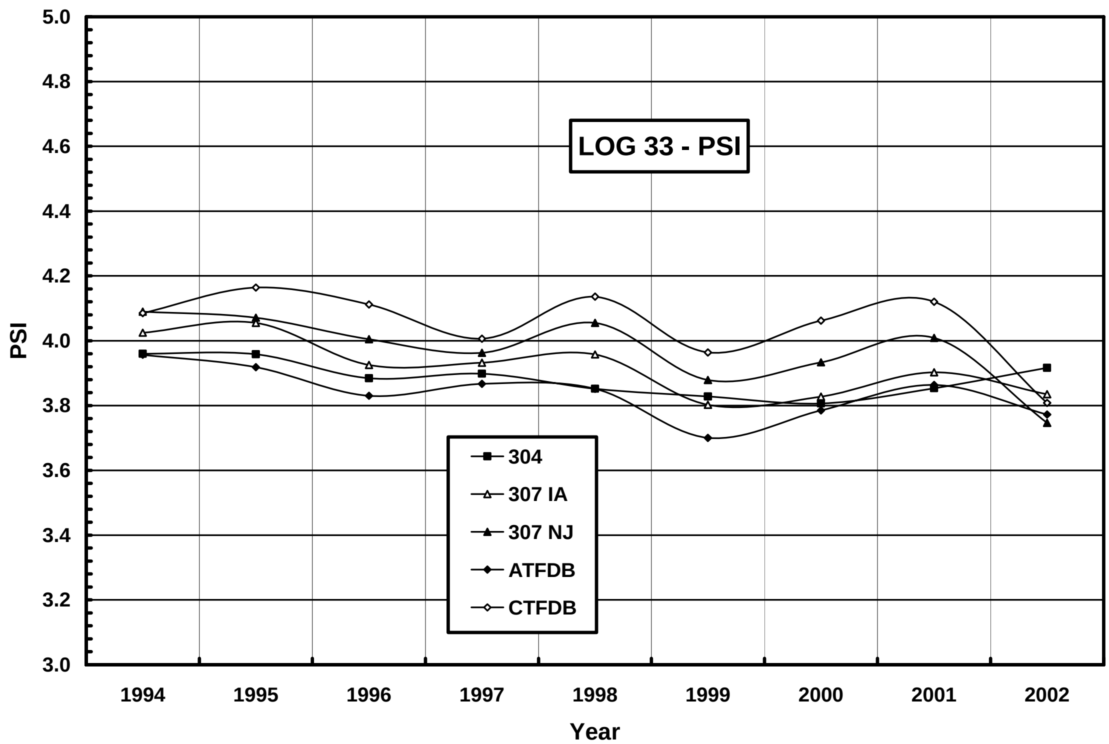


Figure 7.3 - Serviceability Trends on LOG 33

7.3.3 Pavement Condition on LOG 33

Figure 7.4 shows how PCR decreased about the same in all five sections from 1994 to 1999. In 2000, the CTFDB and ATFDB sections increased slightly, the 304 section continued to decrease, and the 307NJ and 307 IA sections remained steady. In 2001, the PCR in all sections dropped with the ATFDB section having a 15 point structural deduct for extensive cracking. The increased PCR values in 2003 were caused by the application of Novachip on all test sections after the 2001 evaluation which covered the surface distresses.

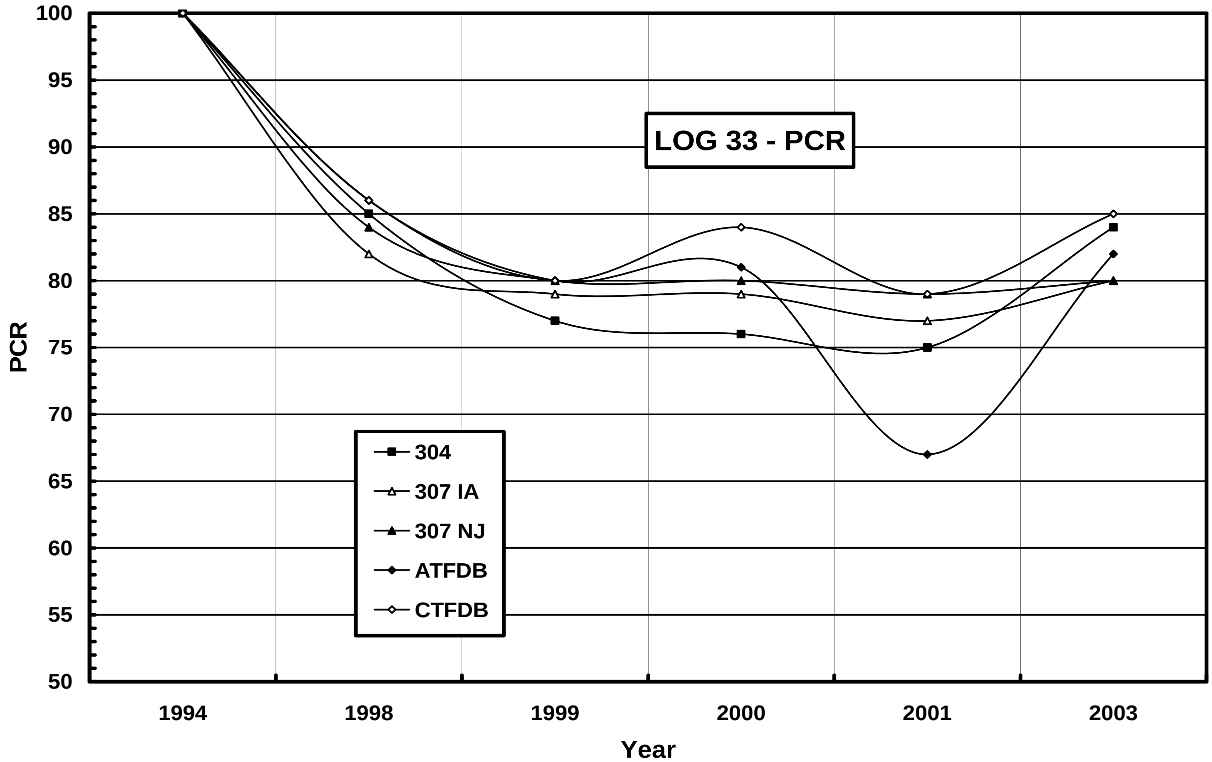


Figure 7.4 - Pavement Condition Ratings on LOG 33

7.4 ERI/LOR 2

This test pavement was constructed in the westbound lanes of ERI/LOR 2 to evaluate the combined effects of 13 and 25-foot joint spacings with different types of base materials on the performance of PCC pavement. Also, a coarse aggregate from Woodsville was incorporated into some sections as a D-cracking resistant coarse aggregate and a coarse aggregate from Parkertown was incorporated into other sections as a D-cracking susceptible coarse aggregate to evaluate their impact on performance. Among the materials used in the bases were asphalt-treated free-draining base (ATFDB), cement-treated free-draining base (CTFDB), and ODOT 304, 310, 307IA and 307NJ aggregates. As of 1999, when the initial crack survey was performed, sections with a 13-foot joint spacing and less stiff bases, such as ATFDB, 304 aggregate and 310 aggregate, were performing better than sections with a 25-foot joint spacing and CTFDB and the 307 bases. These trends continued into 2002. Table 7.4 summarizes the location, the design parameters and the base aggregate associated with the various test sections.

Table 7.4

ERI/LOR 2 Test Section Locations

WB Station Limits (Station / [SLM])			Base/Subbase	Joint Spacing (ft.)	PCC Coarse Aggregate
Begin	**End**	**Length (feet)**	**Material & Thickness (in.)**		
1835+10 [ERI 30.50]	1838+29 (0+00.9) [ERI 30.56]	320	4” 310/6” 304	13	Parkertown (S)
0+00.9 [LOR 0.00]	5+00 [LOR 0.09]	499	4” 310/6” 304	25	Woodville (R)
5+00 [LOR 0.09]	9+80 [LOR 0.19]	480	4” 307IA/6” 304	25	Woodville (R)
9+80 [LOR 0.19]	14+60 (56+06.3) [LOR 0.28]	480	4” 307IA/6” 304	13	Parkertown (S)
56+06.3 [LOR 0.28]	60+33.1 [LOR 0.36]	427	4” 304/6” 304	13	Parkertown (S)
60+33.1 [LOR 0.36]	64+60 [LOR 0.44]	427	4” 304/6” 304	25	Woodville (R)
64+60 [LOR 0.44]	68+87 [LOR 0.52]	427	4” 307NJ/6” 304	25	Woodville (R)
68+87 [LOR 0.52]	73+14 [LOR 0.60]	427	4” 307NJ/6” 304	13	Parkertown (S)
73+14 [LOR 0.60]	77+41 [LOR 0.68]	427	4” ATFDB/6” 304	13	Parkertown (S)
77+41 [LOR 0.68]	81+68 [LOR 0.77]	427	4” ATFDB/6” 304	25	Woodville (R)
81+68 [LOR 0.77]	85+95.5 [LOR 0.85]	428	4” CTFDB/6” 304	25	Woodville (R)
85+95.5 [LOR 0.85]	90+23 [LOR 0.93]	428	4” CTFDB/6” 304	13	Parkertown (S)

(S) D-cracking susceptible aggregate (R) D-cracking resistant aggregate

Base materials on the ERI/LOR 2 project were designed to allow subsurface water to flow to underdrains along the pavement edge and to adequately support the pavement layer. To evaluate the hydraulic conductivity of these six base materials, laboratory tests were run by the University of Toledo on fine, medium and coarse gradations within four specifications and typical gradations for the other two base materials. Field measurements were run in September 1994 at one to three locations in each of the six sections. Table 7.5 summarizes the results.

Table 7.5

Hydraulic Conductivity on ERI/LOR 2

<table>
<tr><th>Base Material</th><th>Gradation</th><th>Laboratory Conductivity (feet/day)</th><th>Field Conductivity (feet/day)</th></tr>
<tr><td rowspan="3">310</td><td>Fine</td><td>20</td><td rowspan="3">44</td></tr>
<tr><td>Medium</td><td>102</td></tr>
<tr><td>Coarse</td><td>12617</td></tr>
<tr><td rowspan="3">304</td><td>Fine</td><td>111</td><td rowspan="3">540</td></tr>
<tr><td>Medium</td><td>201</td></tr>
<tr><td>Coarse</td><td>1179</td></tr>
<tr><td rowspan="3">307IA</td><td>Fine</td><td>1329</td><td rowspan="3">4027</td></tr>
<tr><td>Medium</td><td>2531</td></tr>
<tr><td>Coarse</td><td>9853</td></tr>
<tr><td>307NJ</td><td></td><td>7455</td><td>1732</td></tr>
<tr><td rowspan="3">ATFDB</td><td>Fine</td><td>28400</td><td rowspan="3">10176</td></tr>
<tr><td>Medium</td><td>31800</td></tr>
<tr><td>Coarse</td><td>37500</td></tr>
<tr><td>CTFDB</td><td></td><td>33700</td><td>12591</td></tr>
</table>

7.4.1 FWD Measurements on ERI/LOR 2

FWD measurements obtained on the ERI/LOR 2 test pavement in 2002, 2003 and 2004 are summarized in Table 7.6. While the 2002 and 2003 readings were reasonably consistent with each other and with observed distresses in the various sections, deflections and load transfers measured in 2004 were quite different, especially in the CTB and 307NJ sections which had a record of poor performance. Pavement temperatures were reasonably close during the three measurements and, therefore, would not have contributed to the changes in 2004.

One factor that did impact the 2004 results was the higher than normal degree of variability occurring in many sections and especially in the CTB and 307NJ sections. Typically, data at five or six joints were averaged together to obtain the averages shown in Table 7.6 and, while there has always some variability in the past, the 2004 data were unusual. Load transfer in both CTB sections varied from less than 10% to more than 100% and, because much of the 307NJ sections had been overlaid with AC, they were represented by only one or two joints. It appears that, once PCC slabs become highly distressed, their response to FWD loading becomes quite erratic in ways that are often difficult to explain, such as load transfers of well over 100%.

Table 7.6

ERI/LOR 2 FWD Joint Summary

ERI/LOR 2 - Average FWD Joint Responses										
Top Base Material	Joint Spacing (feet)	4/15/2002			6/2/2003			5/18/2004		
		Temp. (ºF)	DF1 (mils/kip)	LT (%)	Temp. (ºF)	DF1 (mils/kip)	LT (%)	Temp. (ºF)	DF1 (mils/kip)	LT (%)
CTB	13	58	1.04	13.2	46	1.63	5.3	67	1.20	47.6
	25	58	0.98	10.1	46	1.01	4.0	67	0.64	64.2
ATB	25	62	0.27	46.4	46	0.31	58.3	67	0.42	61.0
	13	62	0.42	48.8	46	0.55	58.4	67	0.36	84.9
307NJ	13	66	1.46	20.9	52	2.42	6.6	67	0.47	16.9
	25	66	1.02	10.0	52	1.21	9.7	67	1.21	124.6
304	25	70	0.55	40.6	56	0.61	26.7	67		
	13	70	0.49	45.2	56	0.57	44.1	67	0.49	56.8
307IA	13	60	0.58	58.7	59	0.52	77.8	71	0.46	98.4
	25	60	0.47	65.6	59	0.53	63.1	71	0.38	94.8
310	25	60	0.69	36.2	64	0.64	52.8	71	0.51	84.9
	13	60	0.62	52.1	64	0.70	54.4	71	0.52	82.5

7.4.2 Slab Cracking on ERI/LOR 2

Crack surveys were performed in 1999, 2002, 2003 and 2004. Figure 7.5 shows the results of these surveys in terms of the number of transverse cracks per slab by section. While only transverse cracking was considered in the figure, slabs with several transverse cracks usually contained some longitudinal cracking. The most obvious trend in Figure 7.5 is the consistent higher number of cracks in all sections with a 25-foot joint spacing, as shown with the dashed lines. Sections with the 13-foot joint spacing and stiff bases, such as 307NJ, CTFDB, 307IA and 304, performed better, but not as good as sections with a 13-foot joint spacing and either ATFDB or 310 base. Overall, the 13 foot slabs performed better than the 25 foot slabs on all bases, and 13 foot slabs with ATFDB and 310 performed better than 13 foot slabs with 307NJ, CTFDB, 304 and 307IA bases. These trends suggest that shorter slab lengths with less stiff base material should be used on PCC pavements.

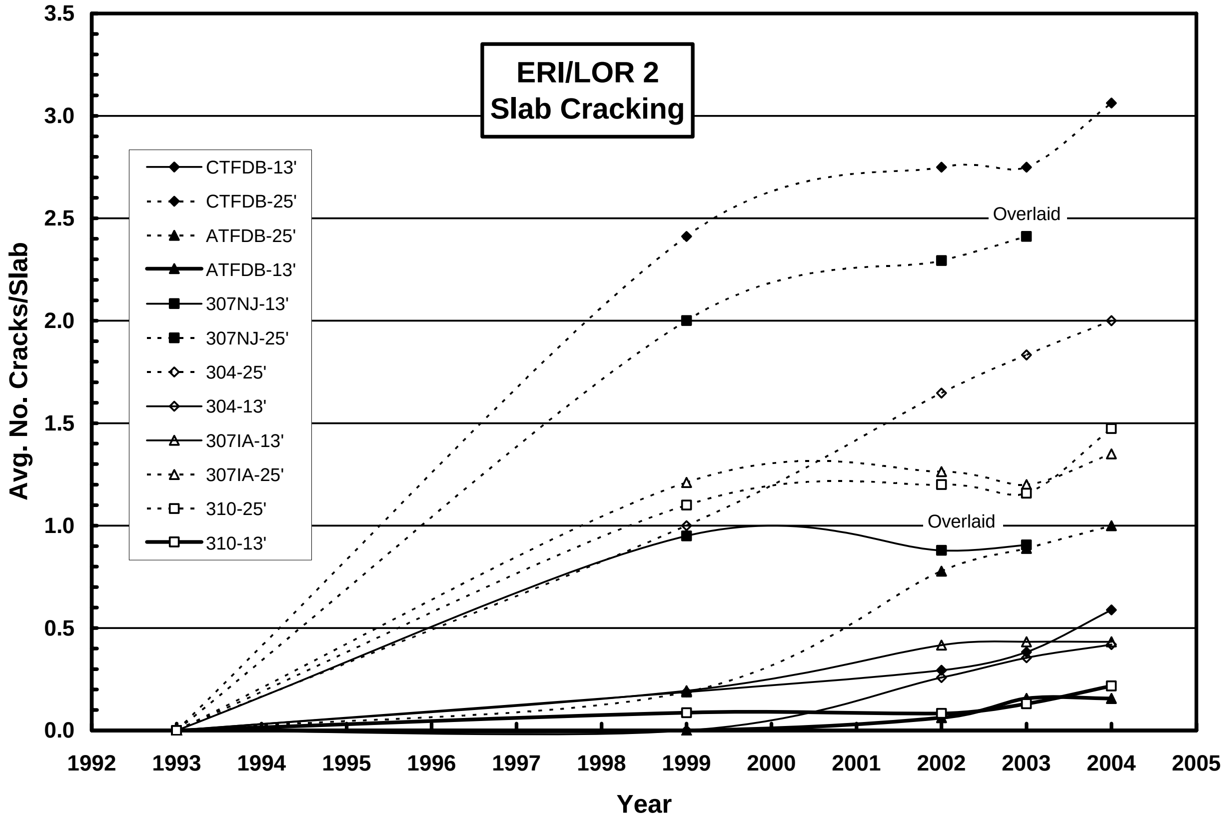


Figure 7.5 - Slab Cracking on ERI/LOR 2

7.4.3 Roughness on ERI/LOR 2

Roughness was monitored by ODOT with a non-contact profilometer through 2002. In these measurements, sections with 13 and 25-foot joint spacings were combined to obtain an overall average for each base type. These results were consistent with other performance parameters, in that sections with CTB showed early degradation which continued into 2002, and sections with 307NJ base showed a later decline which brought both sections to a lower PSI than sections with 304, 307IA, 310, and ATB base. These data are plotted in Figure 7.6.

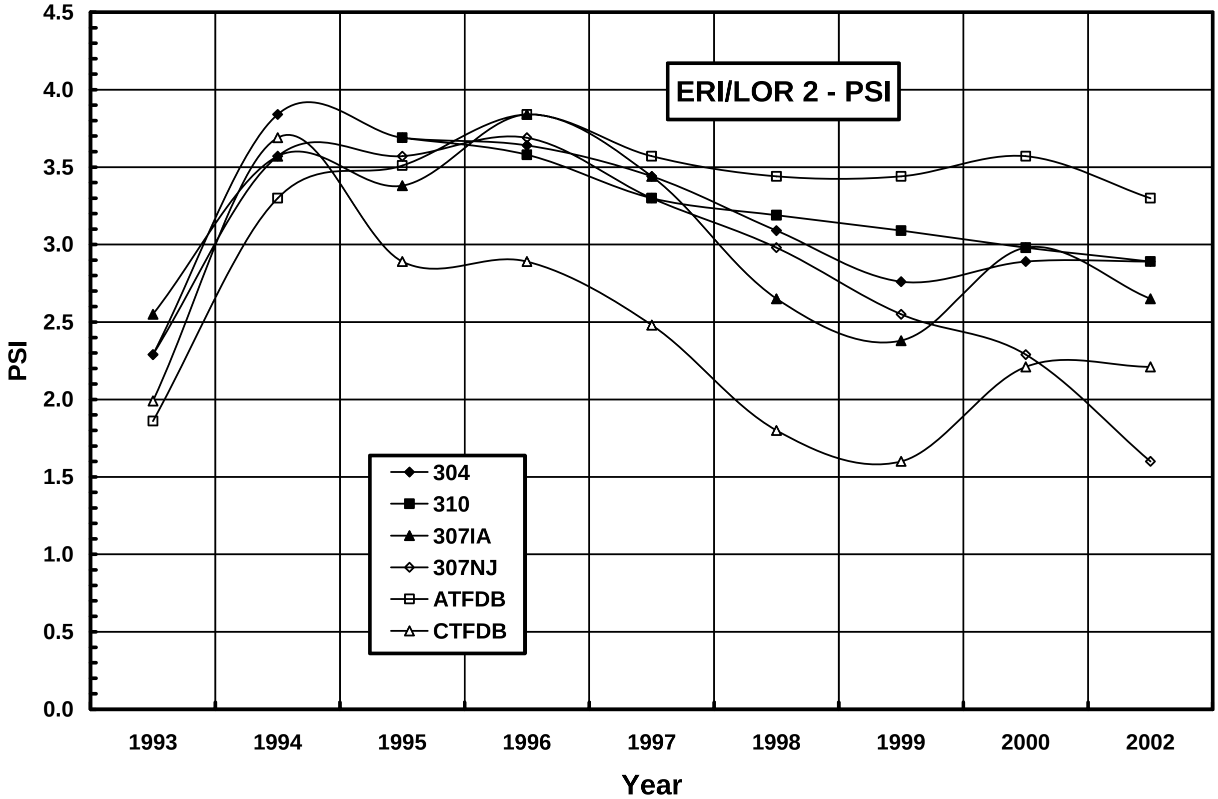


Figure 7.6 Section Roughness on ERI/LOR 2

CHAPTER 8
FINDINGS AND CONCLUSIONS

The following findings and conclusions are summarized below for work provided by ORITE under this research contract:

Ohio SHRP Test Road

1. Subgrade moisture experiences annual cycles with maximum values occurring in July-August and minimum values occurring in January-February.
2. Subgrade moisture was higher at the southern end of the project.
3. Resistivity probes were not reliable for measuring frost depth.
4. Strain, deflection and pressure peaks and valleys measured during the nine controlled vehicle tests are summarized on a CD available through ODOT.
5. From FWD measurements on test sections of the Ohio SHRP Test Road, AC pavements with initial maximum normalized deflections > 1.50 mils/kip had a very short service life, AC pavements with maximum normalized deflections < 1.0 mils/kip continue to remain in service after 10 years, and AC pavements with maximum normalized deflections between 1.0 and 1.5 mils/kip had a limited service life of about five years. These deflections can be used as a guide for estimating the performance of other AC pavements.
6. The first group of four distressed AC sections had a combined thickness of 4-8 inches of asphalt concrete pavement and asphalt treated base (ATB), the second group of sections had a combined thickness of 7-12 inches, and sections which continue to remain in service had a combined thickness of 12-19 inches of AC and ATB.
7. Initial normalized FWD deflections under the load plate on 8-inch thick PCC sections ranged between 0.35 and 0.51 mils/kip, while deflections on the 11-inch PCC sections ranged between 0.20 and 0.29 mils/kip.
8. The northbound driving lane containing the SPS-2 experiment carried about 620,000 ESALs/year, while the southbound driving lane containing the SPS-1 and SPS-9 experiments carried about 515,000 ESALs/year.

9. Estimates of construction costs and predicted service life show Sections 104 and 159 to be the most cost effective AC sections, and Section 259 to be the most cost effective PCC section.
10. PCC sections containing high strength concrete had skid numbers in the low thirties, while sections with standard concrete had skid numbers in the low forties. This ten point difference can be an important safety consideration.
11. Excel spreadsheets were developed to calculate truck volumes by lane and by hour, truck classifications by hour, truck weight by lane and hour, ESALs by lane and hour, and a combined load spectra for all truck classifications. From calculations performed with these spreadsheets, truck weight seems to be the most reliable indicator of pavement loading since it is not affected by axle grouping, classification, or the calculation of ESALs, all of which require additional WIM processing and are possible sources of error. Suspicious changes noted in the volumes of certain classifications appear to have affected the ESAL calculations and load spectra distributions. These changes, especially in 2004 and 2005, appear to be attributable to WIM software adjustments at the site.
12. The northbound driving lane carried more trucks than the southbound driving lane, but the total accumulated weight and the average weight per truck was higher southbound.
13. Class 9 trucks made up approximately 75% of the volume, and 85% of the total weight and ESALs applied by Class 4-13 trucks on the Ohio SHRP Test Road.
14. Passing lanes carried approximately 10% of the volume of Class 4-13 trucks carried in the driving lanes.
15. Daily WIM files should be sampled and reviewed monthly to ensure that the WIM systems are operating properly. This review should include hourly trends for volume, weight and ESALs in all lanes.
16. Prior to using daily WIM files to calculate truck loading, they should be run through a quality assurance procedure to ensure that the files are complete and the data are reasonable. This should include a review of hourly volumes, classifications, weights, ESALs and load spectra. Missing or incorrect data will yield erroneous results. A check of average weight on the front axle, spacing between the front tandem axles, average

weight per truck and average ESALs per truck on Class 9 trucks would also be helpful in evaluating data quality.

17. Subgrade moduli derived from different procedures were highly variable. A more comprehensive study is needed to select the most appropriate procedure for the backcalculation of subgrade moduli.
18. Values of k backcalculated by the AREA7 and AREA5 procedures were statistically the same. Plots of FWD basins collected on JCP, however, often showed abrupt deflection changes in D0 that did not match the rest of the basin. AREA5 avoids the use of D0 and may be a more reliable procedure for backcalculating k.
19. For the backcalculation of k, the best path for FWD testing is along the center of the slab and the best location is near the joint. The effects of curling are minimal at that location. AREA5 is less sensitive to the effects of curling. Hence, AREA5 is a better method for backcalculating the modulus of subgrade reaction (k).
20. Sensitivity study results indicated that the AASHTO design model was very different from the AI and PCA models. LTPP data can be used to verify and calibrate these models.
21. Results backcalculated with Evercalc showed a highly variable weak base on a strong uniform subgrade. These results contradicted FWD data collected on the subgrade and base layers. Further study is needed to clarify this anomaly.
22. DAMA is a mechanistic multi-layered elastic analysis procedure that can accommodate the effects of climate on pavement layer properties and wheel load damage. The critical life of individual layers, however, does not correlate well with actual pavement service life determined by surface distress. It is necessary, therefore, to develop a procedure for improving the correlation between critical layer life and pavement performance.
23. Current ODOT procedures summarize axle weight information by combining all single axles on trucks into one table. In fact, front single axles are very different from other single axles by being equipped with single tires while the trailing single axles nearly always have dual tires. BISAR was used to calculate stresses under single and dual tires at two axle weights. These results indicated that, for the same axle weight, tensile stresses at the bottom of the AC pavement under single tires were 15 - 20 % higher than

under dual tires. This difference in stress has a significant effect on the fatigue life of AC layers and, hence, on pavement performance. For pavement design purposes, therefore, front single axles should be separated from the other single axles. It is recommended that WIM data be modified so single axles will be divided into two groups; one for the front single axles and one for all other single axles.

24. Fracture planes in the PCC cores were oriented perpendicular to the plane of the wearing surface. There was actually more than one crack involved, and these cracks exhibited a significant amount of branching. The cracks passed through, rather than around, coarse aggregate particles. The nature of this cracking indicated that it was a fatigue failure which occurred as a result of repeated stress applications over a period of time. These cracks were initiated at the slab surface and propagated down into the slab.
25. Top-down slab cracking requires either a failure of the base material, and/or curling of the PCC slab. Observations made in the laboratory, as well as data generated at the project site, suggested that slab curling caused by differential temperatures and/or moisture through the slab was the most likely cause of the cracking.
26. Dowel bars are expected to reduce the loss of support at PCC joints. Any loss of support, however, could lead to tensile stresses from vehicle wheel loads sufficient to produce longitudinal cracks in the slab. Fatigue failure occurs at concrete stress levels well below those required under static loading conditions.
27. One factor that may be involved in exaggerating the amount of curl in the PCC slabs over lean concrete base was the likelihood of a high degree of water saturation in the LCB on an ongoing basis. This would cause the bottom of the PCC slab to also experience a constant high degree of water saturation. The top of the PCC slab would experience dimensional changes in response to the loss and gain of surface water. During periods of drying and temperature cycling, movement (strains) in the top of the slab would be expected to be high relative to the moisture saturated bottom.
28. The 8 and 11-inch thick PCC slabs on lean concrete base (LCB) were the first to exhibit longitudinal cracking.

ATH 50

1. DCP measurements in the eastbound driving lane indicated that the severe cracking between Stations 381 and 463 after two years of service was caused by a weak subgrade.
2. Joints with fiberglass dowels had higher deflections and lower load transfers than epoxy coated steel bars and concrete filled stainless steel bars. The higher deflections may have been caused by a weaker subgrade and the lower load transfer was likely due to the physical properties of the fiberglass.

LOG 33

1. Stiff bases such as CTFDB, 307IA and 307NJ, performed better than weaker base materials under this AC pavement. The section with CTFDB had the highest PSI and PCR, while the section with ATFDB had a 15 point PCR deduction for cracking.

ERI/LOR 2

1. PCC sections with a 13-foot joint spacing and less stiff base materials, like ATFDB and 310, performed better than PCC sections with 25-foot joint spacing and/or stiffer bases on this project. Sections with CTFDB and 307NJ bases had the highest FWD deflections and lowest load transfers in 2002 and 2003, more transverse cracking and lower PSI measurements.

CHAPTER 9
IMPLEMENTATION PLAN

1. Consider the routine monitoring of selected AC and PCC pavements with the FWD and/or Dynaflect from the time of construction, and the development of a database to store and analyze the data. These data could be used to provide initial estimates of performance, to identify areas where distresses may be expected to occur, and to plot trends with which to assess condition and project future maintenance activities. Performance estimates and maintenance projections will improve as more NDT data become available.

2. Revise the ODOT Pavement Design Manual as follows:
   a. Divide the single-axle loading table into one table for front single axles and another table for all other single axles to account for the effects of single and dual tires.
   b. Use short slabs on rigid pavement and limit base materials to those which accommodate the curling and warping of PCC slabs, such as PATB, ATB or DGAB.
   c. Use stiff bases, such as 304 NJ, 304 IA, PCTB and LCB, on flexible pavement.
   d. Eliminate the use of high-strength concrete on rigid pavements.
   e. Continue the experimental use of fiberglass dowel bars on PCC pavement until their affect on long-term performance becomes clear.
   f. Incorporate nondestructive testing into the approval of subgrades on high level pavements, and add a pay item for correcting deficient subgrade.

3. Periodically evaluate the output from WIM scales installed across the state. Excel spreadsheets were developed on this project to calculate truck volumes by lane and hour, truck classifications by hour, truck weight by lane and hour, ESALs by lane and hour, and a combined load spectra for all truck classifications. From calculations performed with these spreadsheets, truck weight seems to be the most reliable indicator of pavement loading since it is not affected by axle grouping, classification, or the calculation of ESALs, all of which require additional WIM processing and are possible sources of error.

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APPENDIX A

Julian Time

Table A-1

Julian Time

Date	Julian Date for Calander Date											
	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
1	1	32	60	91	121	152	182	213	244	274	305	335
2	2	33	61	92	122	153	183	214	245	275	306	336
3	3	34	62	93	123	154	184	215	246	276	307	337
4	4	35	63	94	124	155	185	216	247	277	308	338
5	5	36	64	95	125	156	186	217	248	278	309	339
6	6	37	65	96	126	157	187	218	249	279	310	340
7	7	38	66	97	127	158	188	219	250	280	311	341
8	8	39	67	98	128	159	189	220	251	281	312	342
9	9	40	68	99	129	160	190	221	252	282	313	343
10	10	41	69	100	130	161	191	222	253	283	314	344
11	11	42	70	101	131	162	192	223	254	284	315	345
12	12	43	71	102	132	163	193	224	255	285	316	346
13	13	44	72	103	133	164	194	225	256	286	317	347
14	14	45	73	104	134	165	195	226	257	287	318	348
15	15	46	74	105	135	166	196	227	258	288	319	349
16	16	47	75	106	136	167	197	228	259	289	320	350
17	17	48	76	107	137	168	198	229	260	290	321	351
18	18	49	77	108	138	169	199	230	261	291	322	352
19	19	50	78	109	139	170	200	231	262	292	323	353
20	20	51	79	110	140	171	201	232	263	293	324	354
21	21	52	80	111	141	172	202	233	264	294	325	355
22	22	53	81	112	142	173	203	234	265	295	326	356
23	23	54	82	113	143	174	204	235	266	296	327	357
24	24	55	83	114	144	175	205	236	267	297	328	358
25	25	56	84	115	145	176	206	237	268	298	329	359
26	26	57	85	116	146	177	207	238	269	299	330	360
27	27	58	86	117	147	178	208	239	270	300	331	361
28	28	59	87	118	148	179	209	240	271	301	332	362
29	29		88	119	149	180	210	241	272	302	333	363
30	30		89	120	150	181	211	242	273	303	334	364
31	31		90		151		212	243		304		365

Hour	Julian
1	0.0417
2	0.0833
3	0.1250
4	0.1667
5	0.2083
6	0.2500
7	0.2917
8	0.3333
9	0.3750
10	0.4167
11	0.4583
12	0.5000
13	0.5417
14	0.5833
15	0.6250
16	0.6667
17	0.7083
18	0.7500
19	0.7917
20	0.8333
21	0.8750
22	0.9167
23	0.9583
24	1.0000

Table A-2

Julian Time - Leap Year

Date	Julian Date for Calander Date											
	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
1	1	32	61	92	122	153	183	214	245	275	306	336
2	2	33	62	93	123	154	184	215	246	276	307	337
3	3	34	63	94	124	155	185	216	247	277	308	338
4	4	35	64	95	125	156	186	217	248	278	309	339
5	5	36	65	96	126	157	187	218	249	279	310	340
6	6	37	66	97	127	158	188	219	250	280	311	341
7	7	38	67	98	128	159	189	220	251	281	312	342
8	8	39	68	99	129	160	190	221	252	282	313	343
9	9	40	69	100	130	161	191	222	253	283	314	344
10	10	41	70	101	131	162	192	223	254	284	315	345
11	11	42	71	102	132	163	193	224	255	285	316	346
12	12	43	72	103	133	164	194	225	256	286	317	347
13	13	44	73	104	134	165	195	226	257	287	318	348
14	14	45	74	105	135	166	196	227	258	288	319	349
15	15	46	75	106	136	167	197	228	259	289	320	350
16	16	47	76	107	137	168	198	229	260	290	321	351
17	17	48	77	108	138	169	199	230	261	291	322	352
18	18	49	78	109	139	170	200	231	262	292	323	353
19	19	50	79	110	140	171	201	232	263	293	324	354
20	20	51	80	111	141	172	202	233	264	294	325	355
21	21	52	81	112	142	173	203	234	265	295	326	356
22	22	53	82	113	143	174	204	235	266	296	327	357
23	23	54	83	114	144	175	205	236	267	297	328	358
24	24	55	84	115	145	176	206	237	268	298	329	359
25	25	56	85	116	146	177	207	238	269	299	330	360
26	26	57	86	117	147	178	208	239	270	300	331	361
27	27	58	87	118	148	179	209	240	271	301	332	362
28	28	59	88	119	149	180	210	241	272	302	333	363
29	29	60	89	120	150	181	211	242	273	303	334	364
30	30		90	121	151	182	212	243	274	304	335	365
31	31		91		152		213	244		305		366

Hour	Julian
1	0.0417
2	0.0833
3	0.1250
4	0.1667
5	0.2083
6	0.2500
7	0.2917
8	0.3333
9	0.3750
10	0.4167
11	0.4583
12	0.5000
13	0.5417
14	0.5833
15	0.6250
16	0.6667
17	0.7083
18	0.7500
19	0.7917
20	0.8333
21	0.8750
22	0.9167
23	0.9583
24	1.0000

APPENDIX B

MOBFIELD Data File Summary for AC Sections

Table B-1 MOBFIELD Summary for Sections 101 and 102

MOBFIELD FILE SUMMARY Section 101 UT Page 1

NEW FILE	OLD FILE	DATE	NEW FILE	OLD FILE	DATE
DELETE	M390101	7/26/96			
39SO96AG	39SO96AI(2)	7/26/96			
BH	AI(3)	8/2/96			
CH	AI(4)	8/15/96			
DI	AI(5)	9/19/96			
EJ	BJ	10/16/96			
FK	CK	11/20/96			
GL	DL	12/18/96			
DELETE	97AA	NO			
97AB	97BB(2)	2/19/97			
BC	CC	3/12/97			
CC	DC	3/26/97			
DD	ED	4/10/97			
ED	FD	4/24/97			
FE	GE	5/22/97			
GF	HF	6/19/97			

MOBFIELD FILE SUMMARY Section 102 CWRU Page 1

NEW FILE	OLD FILE	DATE	NEW FILE	OLD FILE	DATE
39SP96AG	39SP96AG	7/25/96			
BH	BH	8/2/96			
CH	CH	8/15/96			
PAVEMENT FAILED					

Table B-2 MOBFIELD Summary for Section 104

MOBFIELD FILE SUMMARY Section 104 UT Page 1					
NEW FILE	**OLD FILE**	**DATE**	**NEW FILE**	**OLD FILE**	**DATE**
39SN96AG	39SN96AH(5)	7/31/96	39SN98KL	39SN98KL	12/15/98
BH	AH	8/15/96	99AA	99AA	1/26/99
CI	BI	9/19/96	BB	BB	2/11/99
DJ	CJ	10/16/96	CC	CC	3/12/99
EK	DK	11/20/96	DC	DC	3/25/99
FL	EL	12/18/96	ED	ED	4/8/99
97AA	97AA	1/24/97	FD	FD	4/22/99
BB	BB	2/19/97	GE	GE	5/20/99
CC	CC	3/12/97	HF	HF	6/18/99
DC	DC	3/26/97	IG	IG	7/20/99
ED	ED	4/10/97	JH	JH	8/11/99
FD	FD	4/24/97	KI	KI	9/16/99
GE	GE	5/22/97	LJ	LJ	10/14/99
HF	HF	6/19/97	MK	MK	11/12/99
IH	JH(2)	8/6/97	NL	NL	12/22/99
JI	KI(1)	9/11/97	00AA	00AA	1/17/00
KJ	LJ	10/23/97	BB	BB	2/15/00
LK	MK	11/20/97	CC	CC	3/7/00
ML	NL	12/17/97	DC	DC	3/23/00
98AA	98AA	1/20/98	ED	ED	4/6/00
BB	BB	2/14/98	FD	FD	4/25/00
CC	CC	3/12/98	GE	GE	5/25/00
DD	DD	4/24/98	HF	HF	6/16/00
EE	EE	5/14/98	IG	IG	7/19/00
FG	FG	7/11/98	JH	JH	8/10/00
Bad read. GH	GH	8/12/98	KI	KI	9/22/00
HI	HI	9/29/98	LJ	LJ	10/14/00
IJ	IJ	10/15/98	MK	MK	11/11/00
JK	JK	11/23/98	NL	NL	12/15/00

MOBFIELD FILE SUMMARY Section 104 UT Page 2					
NEW FILE	**OLD FILE**	**DATE**	**NEW FILE**	**OLD FILE**	**DATE**
39SN01AA	39SN 01AA	1/12/01	DELETE	39SN03BB	BAD FILE
BB	BB	2/13/01	39SN03BC	CC	3/14/03
CC	CC	3/8/01	CC	DC	3/27/03
DC	DC	3/22/01	DD	ED	4/10/03
ED	ED	4/5/01	ED	FD	4/24/03
FD	FD	4/19/01	FE	GE	5/28/03
GE	GE	5/17/01	GF	HF	6/25/03
HF	HF	6/14/01	HG	IG	7/17/03
IG	IG	7/17/01	IH	JH	8/12/03
JH	JH	8/9/01	JI	KI	9/23/03
KI	KI	9/11/01	KJ	LJ	10/20/03
LJ	LJ	10/15/01			
MK	MK	11/12/01			
NL	NL	12/20/01			
02AA	02AA	1/10/02			
BB	BB	2/8/02			
CC	CC	3/8/02			
DC	DC	3/22/02			
ED	ED	4/5/02			
FD	FD	4/18/02			
GE	GE	5/15/02			
HF	HF	6/17/02			
IG	IG	7/30/02			
JH	JH	8/8/02			
KI	KI	9/14/02			
LJ	LJ	10/21/02			
MK	MK	11/23/02			
NL	NL	12/17/02			
03AA	03AA	1/18/03			

Table B-3 MOBFIELD Summary for Section 108

MOBFIELD FILE SUMMARY Section 108 OSU Page 1					
NEW FILE	**OLD FILE**	**DATE**	**NEW FILE**	**OLD FILE**	**DATE**
39SQ96AG	39SQ96BH	7/25/96	39SQ99DE	39SQ99QE	5/20/99
BH	BH	8/2/96	EF	RF	6/25/99
CH	CH	8/15/96	FG	SG	7/16/99
DI	DI	9/11/96	DELETE	TH	BAD
EI	EI	9/24/96	GI	UI	9/14/99
FJ	FJ	10/1/96	HJ	VJ	10/15/99
GJ	FJ	10/22/96	IK	VK	11/12/99
HK	GK	11/18/96	JK	WK	11/19/99
IL	HL	12/16/96	00AA	00AA	1/14/00
97AB	97AB	2/6/97	BB	BB	2/16/00
BB	BB	2/20/97	CC	CC	3/22/00
CC	CC	3/26/97	DD	DD	4/20/00
DD	DD	4/8/97	ED	DE	4/28/00
ED	DD	4/22/97	FE	EE	5/15/00
FE	EE	5/20/97	GF	FF	6/26/00
GF	FF	6/16/97	HG	GG	7/20/00
HG	GG	7/11/97	IH	HH	8/15/00
DELETED	HH	NO DATE	JI	II	9/7/00
II	II	9/3/97	KJ	JJ	10/12/00
JL	NL	12/13/97	LK	KK	11/14/00
98AA	98AA	1/16/98	MK	KL	11/21/00
BF	FF	6/8/98	NL	LL	12/19/00
DELETED	GG	BAD FILE	01AA	01AA	1/18/01
CI	II	9/29/98	BB	BB	2/15/01
DJ	JJ	10/23/98	CC	CC	3/8/01
EL	LL	12/28/98	DC	CD	3/22/01
99AA	99MA	1/28/99	ED	DD	4/9/01
BB	NB	2/18/99	FD	DE	4/24/01
CC	OC_1	3/15/99	GE	EE	5/17/01

MOBFIELD FILE SUMMARY Section 108 OSU Page 2					
NEW FILE	**OLD FILE**	**DATE**	**NEW FILE**	**OLD FILE**	**DATE**
39SQ01HF	39SQ01FF	6/20/01	39SQ03II	39SQ03II	9/26/03
IG	GG	7/2/01	JJ	JJ	10/20/03
JG	GH	7/24/01	KK	KK	11/21/03
KH	HH	8/21/01	LL	LL	12/22/03
LI	II	9/11/01	04AF	04FF	6/8/04
MJ	JJ	10/9/01	BF	FG	6/30/04
NK	KL	11/6/01	CG	GG	7/28/04
OL	LL	12/10/01	DH	HH	8/31/04
02AA	02AA	1/10/02	EI	II	9/30/04
BB	BB	2/14/02	FJ	JJ	10/28/04
CC	CC	3/14/02	GK	KK	11/22/04
DD	DD	4/10/02	HL	LL	12/9/04
ED	DE	4/29/02	05AA	05AA	1/10/05
FE	EE	5/22/02	BB	BB	2/4/05
GF	FF	6/19/02	CC	CC	3/16/05
HG	GG	7/26/02	DD	DD	4/29/05
IH	HH	8/21/02	EF	EE	6/1/05
JI	II	9/23/02	FF	FF	6/23/05
KJ	JJ	10/18/02	GG	GG	7/26/05
LK	KK	11/15/02	HI	II	9/2/05
ML	LL	12/18/02	IL	LL	12/14/05
03AA	03AA	1/15/02			
BB	BB	2/20/02			
CD	DD	4/2/03			
DD	ED	4/28/03			
EE	EE	5/30/03			
FF	FF	6/30/03			
GG	GG	7/22/03			
HH	HH	8/26/03			

Table B-4 MOBFIELD Summary for Section 110

MOBFIELD FILE SUMMARY Section 110 OU Page 1					
NEW FILE	OLD FILE	DATE	NEW FILE	OLD FILE	DATE
39SR96AH	39SR96AH	8/2/96	39SR98JK	39SR98TK	11/20/98
BH	AH	8/15/96	KL	UL	12/17/98
CI	BI	9/23/96	99AA	99VM	1/19/99
DJ	CJ	10/15/96	DELETE	WB	NOTHING
EK	DK	11/26/96	BC	XC	3/8/99
FL	EL	12/17/96	CC	YC	3/24/99
97AB	97BB	2/18/97	DD	ZD	4/4/99
BC	CC	3/11/97	ED	AD	4/26/99
CC	DC	3/25/97	FE	BE	5/14/99
DELETE	ED	NOTHING	GF	DF	6/11/99
DD	FD	4/21/97	HG	FG	7/21/99
EE	GE	5/23/97	IH	GH	8/12/99
FF	HF	6/16/97	JI	HI	9/22/99
GG	IG	7/10/97	KJ	IJ	10/15/99
HH	JH	8/5/97	LK	JK	11/19/99
II	KI	9/11/97	00AA	100K	1/4/00
JJ	LJ	10/23/97	BB	100L	2/16/00
KK	MK	11/14/97	CC	100M	3/22/00
LL	NL	12/12/97	DD	100N	4/18/00
98AA	98AA	1/20/98	EE	OE	5/15/00
BB	BB	2/24/98	FF	PF	6/13/00
CC	CC	3/18/98	GG	QG	7/20/00
DD	DD	4/14/98	HI	RI	9/21/00
DELETE	GF	NOTHING	IK	SK	11/16/00
EF	IH	6/18/98	DELETE	TL	Bad 12/20/00
FG	IH	7/9/98	01AA	01UA	1/18/01
GH	IH	8/24/98	BB	VB	2/16/01
HI	SI	9/17/98	CC	WC	3/14/01
IJ	SJ	10/14/98	DD	XD	4/16/01

MOBFIELD FILE SUMMARY Section 110 OU Page 2					
NEW FILE	OLD FILE	DATE	NEW FILE	OLD FILE	DATE
39SR01EF	39SR01YF	6/1/01			
FF	ZF	6/20/01			
GG	AG	7/23/01			
HH	AH	8/23/01			
IJ	BJ	10/18/01			
JK	CK	11/8/01			
KL	DL	12/19/01			
02AA	02EA	1/22/02			
BB	FB	2/19/02			
CC	GC	3/3/02			

Table B-5 MOBFIELD Summary for Section 112

MOBFIELD FILE SUMMARY Section 112 UT Page 1					
NEW FILE	OLD FILE	DATE	NEW FILE	OLD FILE	DATE
39SM96AH	39SM96AI	8/01/96	39SM99ED	39SM99ED	4/8/99
DELETED	BI	BAD DATE	FD	FD	4/22/99
BJ	CJ	10/16/96	GE	GE	5/20/99
CK	DK	11/20/96	HF	HF	6/18/99
DL	EL	12/18/96	IG	IG	7/20/99
97AC	97CC	3/12/97	JH	JH	8/11/99
BC	DC	3/26/97	KI	KI	9/16/99
DELETED	ED	BAD DATE	LJ	LJ	10/14/99
CD	FD	4/24/97	MK	MK	11/12/99
DE	GE	5/22/97	NL	NL	12/22/99
DELETED	HF	BAD DATE	00AA	00AA	1/17/00
EH	JH	8/6/97	BB	BB	2/15/00
FK	MK	11/20/97	CC	CC	3/7/00
GL	NL	12/17/97	DELETED	DC	3/23/00
98AA	98AA	1/20/98	DC	DD	3/23/00
BB	BB	2/14/98	DELETED	ED	BAD
CC	CC	3/12/98	ED	FD	4/25/00
DD	DD	4/24/98	FE	GE	5/25/00
EE	EE	5/14/98	GF	HF	6/16/00
FG	FG	7/11/98	HG	IG	7/19/00
GH	GH	8/12/98	IH	JH	8/10/00
HI	HI	9/29/98	JI	KI	9/23/00
IJ	IJ	10/15/98	KJ	LJ	10/14/00
JK	JK	11/23/98	LK	MK	11/11/00
KL	KL	12/15/98	ML	NL	12/15/00
99AA	99AA	1/26/99	01AA	01AA	1/12/01
BB	BB	2/11/99	BB	BB	2/13/01
CC	CC	3/12/99	CC	CC	3/8/01
DC	DC	3/25/99	DC	DC	3/22/01

MOBFIELD FILE SUMMARY Section 112 UT Page 2					
NEW FILE	OLD FILE	DATE	NEW FILE	OLD FILE	DATE
39SM01ED	39SM01ED	4/5/01	39SM03ED	39SM03FD	4/24/03
FD	FD	4/19/01	FE	GE	5/28/03
GE	GE	5/17/01	GF	HF	6/25/03
HF	HF	6/14/01	HH	JH	8/12/03
IG	IG	7/17/01	II	KI	9/23/03
JH	JH	8/9/01	JJ	LJ	10/20/03
KI	KI	9/11/01			
LJ	LJ	10/15/01			
MK	MK	11/12/01			
NL	NL	12/20/01			
02AA	02AA	1/10/02			
BB	BB	2/8/02			
CC	CC	3/8/02			
DC	DC	3/22/02			
ED	ED	4/5/02			
FD	FD	4/18/02			
GE	GE	5/15/02			
HF	HF	6/17/02			
IG	IG	7/30/02			
JH	JH	8/8/02			
KI	KI	9/14/02			
LJ	LJ	10/21/02			
MK	MK(1)	11/23/02			
NL	NL	12/17/02			
03AA	03AA	1/18/03			
DELETED	BB	BAD FILE			
BC	CC	3/14/03			
CC	DC	3/27/03			
DD	ED	4/10/03			

Table B-6 MOBFIELD Summary for Section 162

MOBFIELD FILE SUMMARY Section 162 OU Page 1					
NEW FILE	OLD FILE	DATE	NEW FILE	OLD FILE	DATE
39SZ97AL	M390162	12/12/97	39SZ00GG	39SZ00NG	7/20/00
98AA	M390162A	1/20/98	HI	PI	9/21/00
BB	M390162B	2/24/98	IJ	QJ	10/11/00
CC	M390162C	3/18/98	JK	QK	11/16/00
DELETE	39SZ98DD	NOTHING	KL	QL	12/20/00
DD	HH	4/17/98	01AA	01RA	1/18/01
EH	HH	8/24/98	BB	SB	2/16/01
FI	AI	9/17/98	CC	SC	3/14/01
GJ	AJ	10/14/98	DD	TD	4/16/01
HK	TK	11/20/98	EF	TF	6/1/01
IL	UL	12/17/98	FF	UF	6/20/01
99AA	VM	1/19/99	GG	VG	7/23/01
BB	WB	2/17/99	HI	XI	9/20/01
CC	WC	3/8/99	IJ	YJ	10/18/01
DC	XC	3/24/99	JK	YK	11/8/01
ED	ZD	4/14/99	KL	ZL	12/19/01
FD	ZD	4/26/99	02AA	02AA	1/22/02
GE	AE	5/14//99	BB	BB	2/19/02
HG	CG	7/21/99	CG	FG	7/24/02
IH	DH	8/12/99	DJ	JJ	10/24/02
JI	EI	9/19/99	EL	KL	12/4/02
KJ	FJ	10/15/99	03AA	03AA	1/8/03
LK	GK	11/19/99	DELETED	BB	BAD FILE
00AA	100H	1/4/00	BC	CC	3/26/03
BB	100I	2/16/00	CD	DD	4/16/03
CC	100J	3/22/00	DE	EE	5/12/03
DD	100K	4/18/00	EF	FF	6/24/03
EE	00LE	5/15/00	FG	GG	7/17/03
FF	MF	6/13/00	GH	HH	8/13/03

MOBFIELD FILE SUMMARY Section 162 OU Page 2					
NEW FILE	OLD FILE	DATE	NEW FILE	OLD FILE	DATE
39SZ03HI	39SZ03II	9/23/03			
IK	KK	11/12/03			
JL	LL	12/19/03			
04AA	04AA	1/22/04			
BB	BB	2/18/04			
CC	CC	3/31/04			
DD	DD	4/21/04			
EE	EE	5/12/04			
FF	FF	6/21/04			
GG	GG	7/28/04			
HH	HH	8/27/04			
II	II	9/23/04			
JJ	JJ	10/20/04			
KK	KK	11/23/04			
05AA	05AA	1/20/05			
BB	BB	2/18/05			
CC	CC	3/31/05			
DE	DE	5/5/05			
EF	EF	6/7/05			
FG	FG	7/13/05			
GI	GI	9/1/05			
HJ	HJ	10/20/05			
IK	IK	11/8/05			
JL	JL	12/12/05			

Table B-7 MOBFIELD Summary for Sections 165 and 901

MOBFIELD FILE SUMMARY Section 165 OU Page 1					
NEW FILE	OLD FILE	DATE	NEW FILE	OLD FILE	DATE
39SX03AK	39SX03KK	11/4/03			
BK	LK	11/12/03			
CL	LL	12/19/03			
04AA	04AA	1/22/04			
BB	BB	2/18/04			
CC	CC	3/31/04			
DD	DD	4/21/04			
EE	EE	5/12/04			
FF	FF	6/21/04			
GG	GG	7/28/04			
HH	HH	8/27/04			
II	II	9/23/04			
JJ	JJ	10/20/04			
KK	KK	11/23/04			
05AA	05AA	1/20/05			
BB	BB	2/18/05			
CC	CC	3/31/05			
DE	DE	5/5/05			
EF	EF	6/07/05			
FG	FG	7/13/05			
GI	GI	9/1/05			
HJ	HJ	10/20/05			
IK	IK	11/8/05			
JL	JL	12/12/05			

MOBFIELD FILE SUMMARY Section 901 CWRU Page 1					
NEW FILE	OLD FILE	DATE	NEW FILE	OLD FILE	DATE
39SK96AH	39SK96AH	8/5/96	FF	FF	6/18/98
BI	BI	9/19/96	GG	GG	7/21/98
CJ	CJ	10/15/96	HH	HH	8/19/98
DK	DK	11/19/96	II	II	9/17/98
EL	EL	12/21/96	JJ	JJ	10/20/98
97AA	97AA	1/16/97	39SK98KK	39SK98KK	11/19/98
BB	BB	2/16/97	LL	LL	12/15/98
CC	CC	3/11/97	99AA	99AA	1/21/99
DC	DC	3/23/97	BB	BB	2/16/99
NOTHING	ED	4/9/97	CC	CC	3/4/99
ED	FD	4/25/97	ED	ED	4/8/99
FE	GE	5/23/97	FD	FD	4/22/99
GF	HF	6/16/97	GE	GE	5/19/99
HG	IG	7/10/97	HF	HF	6/15/99
IH	JH	8/5/97	IG	IG	7/15/99
JI	KI	9/9/27	JH	JH	8/24/99
KJ	LJ	10/16/97	KI	KI	9/16/99
LK	MK	11/20/97	LJ	LJ	10/11/99
NL	NL	12/15/97	MK	MK	11/18/99
98AA	98AA	1/22/98	NL	NL	12/8/99
BB	BB	2/24/98	00AA	00AA	1/13/00
CC	CC	3/26/98	BB	BB	2/12/00
DD	DD	4/17/98	CC	CC	3/7/00
EE	EE	5/20/98	DC	DC	3/23/00
			ED	ED	4/4/00

Table B-8 MOBFIELD Summary for Section 901

MOBFIELD FILE SUMMARY Section 901 CWRU Page 2					
NEW FILE	OLD FILE	DATE	NEW FILE	OLD FILE	DATE
FD	FD	4/20/00	BB	BB	2/22/02
GE	GE	5/22/00	CC	CC	3/7/02
HF	HF	6/19/00	DC	DC	3/22/02
IG	IG	7/21/00	ED	ED	4/5/02
JH	JH	8/16/00	FD	FD	4/25/02
KI	KI	9/18/00	GE	GE	5/16/02
LJ	LJ	10/17/00	HF	HF	6/11/02
MK	MK	11/11/00	IG	IG	7/17/02
39SK00NL	39SK00NL	12/9/00	JH	JH	8/20/02
01AA	01AA	1/11/01	KI	KI	9/19/02
BB	BB	2/13/01	LJ	LJ	10/24/02
CC	CC	3/7/01	MK	MK	11/20/02
DC	DC	3/20/01	NL	NL	12/17/02
ED	ED	4/5/01	39SK03AA	39SK03AA	1/17/03
FD	FD	4/19/01	BB	BB	2/28/03
GE	GE	5/17/01	CC	CC	3/7/03
HF	HF	6/19/01	DC	DC	3/21/03
IG	IG	7/19/01	ED	ED	4/4/03
JH	JH	8/15/01	FD	FD	4/18/03
KI	KI	9/13/01	GE	GE	5/9/03
LJ	LJ	10/11/01	HF	HF	6/16/03
MK	MK	11/15/01	IG	IG	7/16/03
NL	NL	12/19/01	JH	JH	8/14/03
02AA	02AA	1/22/02	KI	KI	9/16/03

MOBFIELD FILE SUMMARY Section 901 CWRU Page 3					
NEW FILE	OLD FILE	DATE	NEW FILE	OLD FILE	DATE
LJ	LJ	10/11/03			
MK	MK	11/13/03			
NL	NL	12/6/03			
04AA	04AA	1/21/04			
BB	BB	2/18/04			
CC	CC	3/25/04			
DD	DD	4/7/04			
EE	EE	5/12/04			
FF	FF	6/21/04			
GG	GG	7/28/04			
HH	HH	8/27/04			
II	II	9/23/04			
JJ	JJ	10/20/04			
KK	KK	11/23/04			
05AA	05AA	1/20/05			
BB	BB	2/18/05			
CC	CC	3/31/95			
DE	DE	5/5/05			
39SK05EF	39SK05EF	6/7/05			
FG	FG	7/13/05			
GI	GI	9/1/05			
HJ	HJ	10/20/05			
IK	IK	11/8/05			
JL	JL	12/12/05			

Table B-9 MOBFIELD Summary for Section 902

MOBFIELD FILE SUMMARY Section 902 OSU Page 1					
NEW FILE	OLD FILE	DATE	NEW FILE	OLD FILE	DATE
39SL96AI	39SL96BI(1)	9/11/96	DD	RD	4/30/99
BI	BI(2)	9/24/96	EE	RE	5/20/99
CJ	CJ	10/1/96	39SL99FF	39SL99RF	6/25/99
DJ	DJ	10/22/96	GG	RG	7/16/99
EK	EK	11/18/96	HH	RH	8/20/99
FL	FL	12/16/96	II	RI	9/14/99
97AB	97AB	2/6/97	JJ	RJ	10/15/99
BB	BB	2/20/97	KK	RK	11/12/99
CC	CC	3/26/97	LL	SL	12/28/99
DD	DD	4/8/97	00AA	00AA	1/14/00
ED	ED	4/22/97	BB	BB	2/16/00
FE	FE	5/20/97	CC	CC	3/22/00
GF	GF	6/16/97	DD	DD	4/20/00
HG	HG	7/11/97	ED	DE	4/28/00
IH	IH	8/6/97	FE	EE	5/15/00
JI	JI	9/3/97	GF	FF	6/26/00
KL	NL	12/23/97	HG	GG	7/20/00
98AD	98FD	4/28/98	IH	HH	8/15/00
BF	GF	6/8/98	JI	II	9/7/00
DELETE	HG	7/31/98	KJ	JJ	10/12/00
CI	JI	9/29/98	LK	KK	11/14/00
DJ	KJ	10/23/98	MK	KL	11/21/00
EL	ML	12/28/98	NL	LL	12/19/00
DELETE	99NA	--	01AA	01AA	1/18/01
99AB	99OB	2/18/99	BB	BB	2/15/01
BC	PC	3/30/99	CC	CC	3/9/01
CD	QD	4/19/99			

MOBFIELD FILE SUMMARY Section 902 OSU Page 2					
NEW FILE	OLD FILE	DATE	NEW FILE	OLD FILE	DATE
DC	CD	3/22/01	BB	BB	2/20/02
ED	DD	4/9/01	CD	DD	4/2/03
FD	DE	4/24/01	DD	ED	4/28/03
GE	EE	5/15/01	EE	EE	5/30/03
HF	FF	6/20/01	FF	FF	6/30/03
39SL01IG	39SL01GG	7/2/01	GG	GG	7/22/03
JG	GH	7/24/01	HH	HH	8/26/03
KH	HH	8/21/01	II	II	9/26/03
LI	II	9/11/01	39SL03JJ	39SL03JJ	10/20/03
MJ	JJ	10/9/01	KK	KK	11/21/03
DELETE	KK		LL	LL	12/22/03
NL	LL	12/10/01	04AF	04FF	6/8/04
02AA	02AA	1/10/02	BG	GG	7/28/04
BB	BB	2/14/02	CH	HH	8/31/04
CC	CC	3/14/02	DI	II	9/30/04
DD	DD	4/10/02	EJ	JJ	10/28/04
ED	DE	4/29/02	FK	KK	11/22/04
FE	EE	5/22/02	GL	LL	12/9/04
GF	FF	6/19/02	05AA	05AA	1/10/05
HG	GG	7/26/02	BC	CC	3/16/05
IH	HH	8/21/02	CD	DD	4/30/05
JI	II	9/23/02	DF	EE	6/1/05
KJ	JJ	10/18/02	EF	FF	6/23/05
LK	KK	11/15/02	FG	GG	7/26/05
ML	LL	12/18/02	GI	II	9/2/05
03AA	03AA	1/15/02	HL	LL	12/14/05

APPENDIX C

MOBFIELD Data File Summary for PCC Sections

Table C-1 MOBFIELD Summary for Section 201

MOBFIELD FILE SUMMARY Section 201 OSU Page 1					
NEW FILE	**OLD FILE**	**DATE**	**NEW FILE**	**OLD FILE**	**DATE**
39SF96AH	39SF96AH	8/15/96	39SF99HH	39SF99JH	8/20/99
BI	BI	9/11/96	II	JI	9/14/99
CI	CI	9/24/96	JK	JK	11/12/99
DJ	DJ	10/22/96	KL	JJ	12/28/99
EK	EK	11/18/96	00AA	00AA	1/14/00
FL	FL	12/31/96	BB	BB	2/16/00
97AA	97AA	1/23/97	CC	CC	3/22/00
BB	BB	2/20/97	DD	DD	4/20/00
CC	CC	3/26/97	ED	DE	4/28/00
DD	DD	4/8/97	FE	EE	5/15/00
ED	ED	4/22/97	GF	FF	6/26/00
FE	FE	5/20/97	HG	GG	7/20/00
GF	GF	6/16/97	Nothing	HH	
HG	HG	7/9/97	IH	II	8/15/00
IH	IH	8/6/97	JI	II	9/7/00
JI	JI	9/3/97	KJ	JJ	10/12/00
KL	NL	12/23/97	LK	KK	11/14/00
98AA	98AA	1/16/98	MK	KL	11/21/00
BI	GI	9/29/98	NL	LL	12/19/00
CJ	HJ	10/23/98	01AA	01AA	1/18/01
DL	JL	12/28/98	BC	CC	3/9/01
99AA	99JA	1/28/99	CC	CD	3/22/01
BB	JB	2/18/99	DD	DD	4/9/01
CC	JC_1	3/15/99	EE	EE	5/17/01
DC	JC	3/30/99	FF	FF	6/20/01
Deleted	JD	3/30/99	GG	GG	7/24/01
EE	JE	5/20/99	HH	HH	8/21/01
FF	JF	6/25/99	II	II	9/11/01
GG	JG	7/16/99	JJ	JJ	10/9/01

MOBFIELD FILE SUMMARY Section 201 OSU Page 2					
NEW FILE	**OLD FILE**	**DATE**	**NEW FILE**	**OLD FILE**	**DATE**
39SF01KK	39SF01KK	11/6/01	39SF04CI	39SF04II	9/30/04
LL	LL	12/10/01	DJ	JJ	10/28/04
02AA	02AA	1/10/02	EK	KK	11/22/04
BB	BB	2/14/02	FL	LL	12/9/04
CC	CC	3/14/02	05AA	05AA	1/10/05
DD	DD	4/10/02	BB	BB	2/4/05
ED	DE	4/29/02	CC	CC	3/16/05
FE	EE	5/22/02	DD	DD	4/30/05
GF	FF	6/19/02	EF	EE	6/1/05
HG	GG	7/26/02	FF	FF	6/23/05
IH	HH	8/21/02	GG	GG	7/26/05
JI	II	9/23/02	HI	II	9/2/05
KJ	JJ	10/18/02	IL	IL	12/14/05
LK	KK	11/15/02			
ML	LL	12/18/02			
03AA	03AA	1/15/03			
BB	BB	2/20/03			
CD	DD	4/2/03			
ED	ED	4/28/03			
FE	EE	5/30/03			
GF	FF	6/30/03			
HG	GG	7/22/03			
IH	HH	8/26/03			
JI	II	9/26/03			
KJ	JJ	10/20/03			
LK	KK	11/21/03			
ML	LL	12/22/03			
04AF	04FF	6/8/04			
BG	GG	7/28/04			

Table C-2 MOBFIELD Summary for Section 202

MOBFIELD FILE SUMMARY Section 202 UT Page 1					
NEW FILE	**OLD FILE**	**DATE**	**NEW FILE**	**OLD FILE**	**DATE**
39SD96AH	39SD96AI	8/1/96	39SD99ED	39SD99ED	4/8/99
BI	BI	9/16/96	FD	FD	4/22/99
No Date	CJ	No Date	GE	GE	5/20/99
CK	DK	11/20/96	Bad data HF	HF	6/18/99
DL	EL	12/18/96	Bad data IG	IG	7/20/99
97AB	97BB	2/19/97	JH	JH	8/11/99
BC	CC	3/12/97	KI	KI	9/16/99
CC	DC	3/26/97	LJ	LJ	10/14/99
DD	ED	4/10/97	MK	MK	11/12/99
ED	FD	4/24/97	NL	NL	12/22/99
FE	GE	5/22/97	00AA	00AA	1/17/00
GH	JH	8/6/97	BB	BB	2/15/00
HJ	LJ	10/23/97	CC	CC	3/7/00
IK	MK	11/20/97	DC	DC	3/23/00
JL	NL	12/17/97	ED	ED	4/6/00
98AA	98AA	1/20/98	FE	GE	5/25/00
BC	CC	3/12/98	GF	HF	6/16/00
CD	DD	4/24/98	HG	IG	7/19/00
DE	EE	5/14/98	IH	JH	8/10/00
EG	FF	7/11/98	JI	KI	9/23/00
FH	GH	8/12/98	KJ	LJ	10/14/00
GI	HI	9/29/98	LK	MK	11/11/00
HJ	IJ	10/15/98	ML	NL	12/15/00
IK	JK	11/23/98	01AA	01AA	1/12/01
JL	KL	12/15/98	BB	BB	2/13/01
99AA	99AA	1/26/99	CC	CC	3/8/01
BB	BB	2/11/99	DC	DC	3/22/01
CC	CC	3/12/99	ED	ED	4/5/01
DC	DC	3/25/99	FD	FD	4/19/01

MOBFIELD FILE SUMMARY Section 202 UT Page 2					
NEW FILE	**OLD FILE**	**DATE**	**NEW FILE**	**OLD FILE**	**DATE**
39SD01GE	39SD01GE	5/17/01	II	KI	9/23/03
HF	HF	6/14/01	BAD FILE	LJ	10/20/03
IG	IG	7/17/01			
JH	JH	8/9/01			
KI	KI	9/11/01			
LJ	LJ	10/15/01			
MK	MK	11/12/01			
Bad Data	NL	12/20/01			
02AA	02AA	1/10/02			
BB	BB	2/8/02			
CC	CC	3/8/02			
DD	ED	4/5/02			
ED	FD	4/18/02			
FE	GE	5/15/02			
HF	HF	6/17/02			
IG	IG	7/30/02			
JH	JH	8/8/02			
KI	KI	9/14/02			
LJ	LJ	10/21/02			
MK	MK	11/23/02			
NL	NL	12/17/02			
03AA	03AA	1/18/03			
BB	BB	2/8/03			
CC	CC	3/14/03			
DC	DC	3/27/03			
ED	ED	4/10/03			
FD	FD	4/24/03			
GF	HF	6/25/03			
HH	JH	8/12/03			

Table C-3 MOBFIELD Summary for Section 203

MOBFIELD FILE SUMMARY Section 203 CWRU Page 1					
NEW FILE	OLD FILE	DATE	NEW FILE	OLD FILE	DATE
39SH96AG	39SH96AG	7/22/96	39SH98JJ	39SH98JJ	10/20/98
BH	BH	8/5/96	KK	KK	11/19/98
CI	CI	9/19/96	LL	LL	12/15/98
DJ	DJ	10/15/96	99AA	99AA	1/21/99
EK	EK	11/19/96	BB	BB	2/16/99
FL	FL	12/21/96	CC	CC	3/4/99
97AA	97AA	1/16/97	DC	DC	3/20/99
BB	BB	2/16/97	ED	ED	4/8/99
CC	CC	3/11/97	FD	FD	4/22/99
DC	DC	3/23/97	GE	GE	5/19/99
ED	ED	4/9/97	HF	HF	6/15/99
FD	FD	4/25/97	IG	IG	7/15/99
GE	GE	5/23/97	JH	JH	8/24/99
HF	HF	6/16/97	KI	KI	9/16/99
IG	IG	7/10/97	LJ	LJ	10/11/99
JH	JH	8/5/97	MK	MK	11/18/99
KI	KI	9/9/27	NL	NL	12/8/99
LJ	LJ	10/16/97	00AA	00AA	1/13/00
MK	MK	11/20/97	BB	BB	2/12/00
NL	NL	12/15/97	CC	CC	3/7/00
98AA	98AA	1/22/98	DC	DC	3/23/00
BB	BB	2/24/98	ED	ED	4/4/00
CC	CC	3/26/98	FD	FD	4/20/00
DD	DD	4/17/98	GE	GE	5/22/00
EE	EE	5/20/98	HF	HF	6/19/00
FF	FF	6/18/98	IG	IG	7/21/00
GG	GG	7/21/98	JH	JH	8/16/00
HH	HH	8/19/98	KI	KI	9/18/00
II	II	9/17/98	LJ	LJ	10/17/00

MOBFIELD FILE SUMMARY Section 203 CWRU Page 2					
NEW FILE	OLD FILE	DATE	NEW FILE	OLD FILE	DATE
39SH00MK	39SH00MK	11/11/00	39SH02NL	39SH02NL	12/17/02
NL	NL	12/9/00	03AA	03AA	1/17/03
01AA	01AA	1/11/01	BB	BB	2/28/03
BB	BB	2/13/01	CC	CC	3/7/03
CC	CC	3/7/01	DC	DC	3/21/03
DC	DC	3/20/01	ED	ED	4/4/03
ED	ED	4/5/01	FD	FD	4/18/03
FD	FD	4/19/01	GE	GE	5/9/03
GE	GE	5/17/01	HF	HF	6/16/03
HF	HF	6/19/01	IG	IG	7/16/03
IG	IG	7/19/01	JH	JH	8/14/03
JH	JH	8/15/01	KI	KI	9/16/03
KI	KI	9/13/01	LJ	LJ	10/11/03
LJ	LJ	10/11/01	MK	MK	11/13/03
MK	MK	11/15/01	NL	NL	12/6/03
NL	NL	12/19/01	04AA	04AA	1/21/04
02AA	02AA	1/22/02	BB	BB	2/18/04
BB	BB	2/22/02	CC	CC	3/25/04
CC	CC	3/7/02	DD	DD	4/7/04
DC	DC	3/22/02	EE	EE	5/12/04
ED	ED	4/5/02	FF	FF	6/21/04
FD	FD	4/25/02	GG	GG	7/28/04
GE	GE	5/16/02	HH	HH	8/27/04
HF	HF	6/11/02	II	II	9/23/04
IG	IG	7/17/02	JJ	JJ	10/24/04
JH	JH	8/20/02	KK	KK	11/23/04
KI	KI	9/19/02	05AA	05AA	1/20/05
LJ	LJ	10/24/02	BB	BB	2/18/05
MK	MK	11/20/02	CC	CC	3/31/05

Table C-4 MOBFIELD Summary for Sections 203 and 204

MOBFIELD FILE SUMMARY Section 203 CWRU Page 3					
NEW FILE	OLD FILE	DATE	NEW FILE	OLD FILE	DATE
39SH05DE	39SH05DE	5/05/05			
EF	EF	6/7/05			
FG	FG	7/13/05			
GI	GI	9/1/05			
HJ	HJ	10/20/05			
IK	IK	11/8/05			
JL	JL	12/12/05			

MOBFIELD FILE SUMMARY Section 204 UT Page 1					
NEW FILE	OLD FILE	DATE	NEW FILE	OLD FILE	DATE
Bad Date	39SB96AI	2/13/96	39SB99CC	39SB99CC	3/12/99
39SB96AJ	39SB96BJ	10/16/96	DC	DC	3/25/99
BL	DL	12/18/96	ED	ED	4/8/99
97AB	BB	2/19/97	FD	FD	4/22/99
BC	CC	3/12/97	GE	GE	5/20/99
CC	DC	3/26/97	HF	HF	6/18/99
DD	ED	4/10/97	IG	IG	7/20/99
ED	FD	4/24/97	JH	JH	8/11/99
FE	GE	5/22/97	KI	KI	9/16/99
GF	HF	6/19/97	LJ	LJ	10/14/99
HH	JH	8/6/97	MK	MK	11/12/99
IJ	LJ	10/23/97	NL	NL	12/22/99
JK	MK	11/20/97	00AA	00AA	1/17/00
KL	NL	12/17/97	Bad File	BB	2/15/00
98AA	98AA	1/20/98	BC	CC	3/7/00
Bad File	BB	2/14/98	CD	ED	4/6/00
BC	CC	3/12/98	DD	FD	4/25/00
CD	DD	4/24/98	EE	GE	5/25/00
DE	EE	5/14/98	FF	HF	6/16/00
Duplicate	FG	7/11/98	GG	IG	7/19/00
EG	GG	7/11/98	HH	JH	8/10/00
Bad File	GH	8/12/98	II	KI	9/23/00
Bad File	HH	8/12/98	JJ	LJ	10/14/00
FI	HI	9/29/98	KK	MK	11/11/00
GJ	IJ	10/15/98	LL	NL	12/15/00
HK	JK	11/23/98	01AA	01AA	1/12/01
IL	KL	12/15/98	BB	BB	2/13/01
99AA	99AA	1/26/99	CC	CC	3/8/01
BB	BB	2/11/99	DC	DC	3/22/01

Table C-5 MOBFIELD Summary for Sections 204 and 205

MOBFIELD FILE SUMMARY Section 204 UT Page 2					
NEW FILE	OLD FILE	DATE	NEW FILE	OLD FILE	DATE
39SB01ED	39SB01ED	4/5/01	39SB03FD	39SB03FD	4/24/03
FD	FD	4/19/01	GE	GE	5/28/03
GE	GE	5/17/01	HF	HF	6/25/03
HF	HF	6/14/01	IH	JH	8/12/03
IG	IG	7/17/01	JI	KI	9/23/03
JH	JH	8/9/01	KJ	LJ	10/20/03
KI	KI	9/11/01			
LJ	LJ	10/15/01			
MK	MK	11/12/01			
NL	NL	12/20/01			
02AA	02AA	1/10/02			
BB	BB	2/8/02			
CC	CC	3/8/02			
DC	DC	3/22/02			
ED	ED	4/5/02			
FD	FD	4/18/02			
GE	GE	5/15/02			
HF	HF	6/17/02			
IG	IG	7/30/02			
JH	JH	8/8/02			
KI	KI	9/14/02			
LJ	LJ	10/21/02			
MK	MK	11/23/02			
NL	NL	12/17/02			
03AA	03AA	1/18/03			
BB	BB	2/8/03			
CC	CC	3/14/03			
DC	DC	3/27/03			
ED	ED	4/10/03			

MOBFIELD FILE SUMMARY Section 205 CWRU Page 1					
NEW FILE	OLD FILE	DATE	NEW FILE	OLD FILE	DATE
39SE96AH	39SE96AH	8/5/96	39SE98JJ	39SE98JJ	10/20/98
BH	BH	8/15/96	KK	KK	11/19/98
CI	CI	9/19/96	LL	LL	12/15/98
DJ	DJ	10/15/96	99AA	99AA	1/21/99
EK	EK	11/19/96	BB	BB	2/16/99
FL	FL	12/21/96	CC	CC	3/4/99
97AA	97AA	1/16/97	DC	DC	3/20/99
BB	BB	2/16/97	ED	ED	4/8/99
CC	CC	3/11/97	FD	FD	4/22/99
DC	DC	3/23/97	GE	GE	5/19/99
Nothing	ED	4/9/97	HF	HF	6/15/99
ED	FD	4/25/97	IG	IG	7/15/99
FE	GE	5/23/97	JH	JH	8/24/99
GF	HF	6/16/97	KI	KI	9/16/99
HG	IG	7/10/97	LJ	LJ	10/11/99
IH	JH	8/15/97	MK	MK	11/18/99
JI	KI	9/9/27	NL	NL	12/8/99
KJ	LJ	10/16/97	00AA	00AA	1/13/00
LK	MK	11/20/97	BB	BB	2/12/00
ML	NL	12/15/97	CC	CC	3/7/00
98AA	98AA	1/22/98	DC	DC	3/23/00
BB	BB	2/24/98	ED	ED	4/4/00
CC	CC	3/26/98	FD	FD	4/20/00
DD	DD	4/17/98	GE	GE	5/22/00
EE	EE	5/20/98	HF	HF	6/19/00
FF	FF	6/18/98	IG	IG	7/21/00
GG	GG	7/21/98	JH	JH	8/16/00
HH	HH	8/19/98	KI	KI	9/18/00
II	II	9/17/98	LJ	LJ	10/17/00

Table C-6 MOBFIELD Summary for Section 205

MOBFIELD FILE SUMMARY Section 205 CWRU Page 2					
NEW FILE	OLD FILE	DATE	NEW FILE	OLD FILE	DATE
39SE00MK	39SE00MK	11/11/00	39SE02NL	39SE02NL	12/17/02
NL	NL	12/9/00	03AA	03AA	1/17/03
01AA	01AA	1/11/01	BB	BB	2/28/03
BB	BB	2/13/01	CC	CC	3/7/03
CC	CC	3/7/01	DC	DC	3/21/03
DC	DC	3/20/01	ED	ED	4/4/03
ED	ED	4/5/01	FD	FD	4/18/03
FD	FD	4/19/01	GE	GE	5/9/03
GE	GE	5/17/01	HF	HF	6/16/03
HF	HF	6/19/01	IG	IG	7/16/03
IG	IG	7/19/01	JH	JH	8/14/03
JH	JH	8/15/01	KI	KI	9/16/03
KI	KI	9/13/01	LK	LK	11/13/03
LJ	LJ	10/11/01	ML	ML	12/6/03
MK	MK	11/15/01	04AA	04AA	1/21/04
NL	NL	12/19/01	BB	BB	2/18/04
02AA	02AA	1/22/02	CC	CC	3/25/04
BB	BB	2/22/02	DD	DD	4/7/04
CC	CC	3/7/02	EE	EE	5/12/04
DC	DC	3/22/02	FG	FG	7/28/04
ED	ED	4/5/02	GH	GH	8/27/04
FD	FD	4/25/02	HI	HI	9/23/04
GE	GE	5/16/02	IJ	IJ	10/20/04
HF	HF	6/11/02	JK	JK	11/23/04
IG	IG	7/17/02	05AA	05AA	1/20/05
JH	JH	8/20/02	BB	BB	2/28/05
KI	KI	9/19/02	CC	CC	3/31/05
LJ	LJ	10/24/02	DE	DE	5/5/05
MK	MK	11/20/02	EF	EF	6/7/05

MOBFIELD FILE SUMMARY Section 205 CWRU Page 3					
NEW FILE	NEW FILE	NEW FILE	NEW FILE	NEW FILE	NEW FILE
39SE05FG	39SE05FG	7/13/05			
GD	GD	9/1/05			
HJ	HJ	10/20/05			
IK	IK	11/8/05			
JL	JL	12/12/05			

Table C-7 MOBFIELD Summary for Section 208

MOBFIELD FILE SUMMARY Section 208 OU Page 1

NEW FILE	OLD FILE	DATE	NEW FILE	OLD FILE	DATE
39SI96AH	39SI96AH	8/15/96	39SI00EE	39SI00ME	5/15/00
97AA	97AA	1/21/97	FF	NF	6/13/00
BB	BB	2/18/97	GG	OG	7/20/00
DELETED	HF	6/16/97	HI	PI	9/19/00
98AD	98DD	4/14/98	IJ	QJ	10/7/00
BF	EF(1)	6/10/98	JJ	RJ	10/11/00
CG	EF(2)	7/9/98	KK	SK	11/16/00
DH	HH	8/24/98	LL	TL	12/20/00
EI	SH98II	9/17/98	01AA	01UA	1/18/01
FJ	SI98JJ	10/14/98	BB	VB	2/16/01
GK	TK	11/20/98	CC	WC	3/14/01
HL	UL	12/17/98	DD	XD	4/16/01
99AA	99VM	1/19/99	EF	YF	6/1/01
BB	WB	2/17/99	FF	ZF	6/20/01
CC	XC	3/8/99	GG	AG	7/23/01
DC	YC	3/24/99	HH	CH	8/23/01
ED	ZD	4/14/99	IJ	DJ	10/18/01
FD	AD	4/26/99	JK	EK	11/8/01
GE	BE	5/14/99	KL	FL	12/19/01
HF	CF	6/11/99	02AA	02GA	1/22/02
IG	DG	7/21/99	BB	HB	2/19/02
JH	EH	8/12/99	CC	IC	3/3/02
KI	FI	9/23/99	DD	JD	4/10/02
LJ	GJ	10/15/99	DELETE	SH02JJ	10/24/02
MK	HK	11/19/99	39SI02EJ	SH02KJ	10/24/02
00AA	100I	1/4/00	FL	SH02LL	11/4/02
BB	100J	2/16/00	03AA	SH03AA	1/8/03
CC	100K	3/22/00	DELETE	SH03BB	2/25/03
DD	100L	4/18/00	BB	SH03CB	2/25/03

MOBFIELD FILE SUMMARY Section 208 OU Page 2

NEW FILE	OLD FILE	DATE	NEW FILE	OLD FILE	DATE
39SI03CC	39SI03DC	3/26/03	39SI05IK	39SI05IK	11/8/05
DD	ED	4/16/03	JL	JL	12/12/05
EE	FE	5/12/03			
FF	GF	6/24/03			
GG	HG	7/17/03			
HH	HH	8/13/03			
II	II	9/23/03			
JK	KK	11/4/03			
KK	LK	11/12/03			
LL	LL	12/19/03			
04AA	04AA	1/22/04			
BB	BB	2/18/04			
CC	CC	3/31/04			
DD	DD	6/21/04			
EE	EE	5/12/04			
FF	FF	6/21/04			
GG	GG	7/28/04			
HH	HH	8/27/04			
II	II	9/23/04			
JJ	JJ	10/20/04			
KK	KK	11/23/04			
05AA	05AA	1/20/05			
BB	BB	2/18/05			
CC	CC	3/31/05			
DE	DE	5/5/05			
EF	EF	6/7/05			
FG	FG	7/13/05			
GI	GI	9/1/05			
HJ	HJ	10/20/05			

Table C-8 MOBFIELD Summary for Section 211

MOBFIELD FILE SUMMARY Section 211 OSU Page 1					
NEW FILE	OLD FILE	DATE	NEW FILE	OLD FILE	DATE
39SG96AI	39SG96BI	9/4/96	39SG99FD	39SG99RD	4/30/99
BI	BI	9/11/96	GE	SE	5/20/99
CI	BI	9/24/96	HG	SG	7/16/99
DJ	CJ	10/22/96	IH	TH	8/20/99
EK	DK	11/18/96	JI	UI	9/14/99
FL	EL	12/31/96	KJ	VJ	10/15/99
97AA	97AB	1/23/97	LK	UK	11/12/99
BB	AB	2/6/97	00AA	00AA	1/14/00
CB	BB	2/20/97	BB	BB	2/16/00
DC	CC	3/26/97	CD	DD	4/28/00
ED	DD	4/8/97	DF	FF	6/26/00
FD	DD	4/22/97	EG	GG	7/20/00
GE	EE	5/20/97	FH	HH	8/15/00
HF	FF	6/16/97	GI	II	9/7/00
IG	GG	7/9/97	HJ	JJ	10/12/00
JH	HH	8/6/97	IK	KK	11/14/00
KI	II	9/3/97	JK	KL	11/21/00
LL	NL	12/23/97	KL	LL	12/19/00
98AA	98AA	1/16/98	Delete Same	01AA	1/18/01
BF	EF	6/8/98	01AA	01AB	1/18/01
CG	GG	7/31/98	BB	BB	2/15/01
DI	II	9/29/98	CC	CC	3/9/01
EJ	JJ	10/23/98	DC	CD	3/22/01
FL	LL	12/28/98	ED	DD	4/9/01
99AA	MA	1/28/99	FF	FF	6/20/01
BB	NB	2/18/99	GG	GG	7/24/01
CC	OC	3/15/99	HH	HH	8/21/01
DC	PC	3/30/99	II	II	9/11/01
ED	QD	4/19/99	JJ	JJ	10/9/01

MOBFIELD FILE SUMMARY Section 211 OSU Page 2					
NEW FILE	OLD FILE	DATE	NEW FILE	OLD FILE	DATE
39SG01KK	39SG01KK	11/6/01	39SG04CH	39SG04HH	8/31/04
LL	LL	12/10/01	BAD FILE	II	
02AA	02AA	1/10/02	DJ	JJ	10/28/04
BB	BB	2/14/02	EK	KK	11/22/04
CC	CC	3/14/02	FL	LL	12/9/04
DD	DD	4/10/02	05AA	05AA	1/10/05
ED	DE	4/29/02	BB	BB	2/4/05
FE	EE	5/22/02	CC	CC	3/16/05
GF	FF	6/19/02	DD	DD	4/30/05
HG	GG	7/26/02	EF	EE	6/1/05
IH	HH	8/21/02	FF	FF	6/23/05
JI	II	9/23/02	GG	GG	7/26/05
KJ	JJ	10/18/02	HI	II	9/2/05
LK	KK	11/15/02	IK	KK	11/29/05
ML	LL	12/18/02			
03AA	03AA	1/15/02			
BB	BB	2/20/02			
CD	DD	4/2/03			
DD	ED	4/28/03			
EE	EE	5/30/03			
FF	FF	6/30/03			
GG	GG	7/22/03			
HH	HH	8/26/03			
II	II	9/26/03			
JJ	JJ	10/20/03			
KK	KK	11/21/03			
LL	LL	12/22/03			
04AF	04FF	6/8/04			
BG	GG	7/28/04			

Table C-9a MOBFIELD Summary for Section 212

MOBFIELD FILE SUMMARY Section 212 CWRU Page 1					
NEW FILE	**OLD FILE**	**DATE**	**NEW FILE**	**OLD FILE**	**DATE**
39SC96AH	39SC96AH	8/5/96	39SC98JJ	39SC98JJ	10/20/98
BH	BH	8/15/96	KK	KK	11/19/98
CI	CI	9/19/96	LL	LL	12/15/98
DJ	DJ	10/15/96	99AA	99AA	1/21/99
EK	EK	11/19/96	BB	BB	2/16/99
FL	FL	12/21/96	CC	CC	3/4/99
97AA	97AA	1/16/97	DC	DC	3/20/99
BB	BB	2/16/97	ED	ED	4/8/99
CC	CC	3/11/97	FD	FD	4/22/99
DC	DC	3/23/97	GE	GE	5/19/99
Nothing	ED	4/9/97	HF	HF	6/15/99
ED	FD	4/25/97	IG	IG	7/15/99
FE	GE	5/23/97	JH	JH	8/24/99
GF	HF	6/16/97	KI	KI	9/16/99
HG	IG	7/10/97	LJ	LJ	10/11/99
IH	JH	8/5/97	MK	MK	11/18/99
JI	KI	9/9/27	NL	NL	12/8/99
KJ	LJ	10/16/97	00AA	00AA	1/13/00
LK	MK	11/20/97	BB	BB	2/12/00
ML	NL	12/15/97	CC	CC	3/7/00
98AA	98AA	1/22/98	DC	DC	3/23/00
BB	BB	2/24/98	ED	ED	4/4/00
CC	CC	3/26/98	FD	FD	4/20/00
DD	DD	4/17/98	GE	GE	5/22/00
EE	EE	5/20/98	HF	HF	6/19/00
FF	FF	6/18/98	IG	IG	7/21/00
GG	GG	7/21/98	JH	JH	8/16/00
HH	HH	8/19/98	KI	KI	9/18/00
II	II	9/17/98	LJ	LJ	10/17/00

Table C-9b MOBFIELD Summary for Section 212

MOBFIELD FILE SUMMARY Section 212 CWRU Page 2					
NEW FILE	OLD FILE	DATE	NEW FILE	OLD FILE	DATE
39SC00MK	39SC00MK	11/11/00	39SC02NL	39SC02NL	12/17/02
NL	NL	12/9/00	03AA	03AA	1/17/03
01AA	01AA	1/11/01	BB	BB	2/28/03
BB	BB	2/13/01	CC	CC	3/7/03
CC	CC	3/7/01	DC	DC	3/21/03
DC	DC	3/20/01	ED	ED	4/4/03
ED	ED	4/5/01	FD	FD	4/18/03
FD	FD	4/19/01	GE	GE	5/9/03
GE	GE	5/17/01	HF	HF	6/16/03
HF	HF	6/19/01	IG	IG	7/16/03
IG	IG	7/19/01	JH	JH	8/14/03
JH	JH	8/15/01	KI	KI	9/16/03
KI	KI	9/13/01	LJ	LJ	10/11/03
LJ	LJ	10/11/01	MK	MK	11/13/03
MK	MK	11/15/01	NL	NL	12/6/03
NL	NL	12/19/01	04AA	04AA	1/21/04
02AA	02AA	1/22/02	BB	BB	2/18/04
BB	BB	2/22/02	CC	CC	3/25/04
CC	CC	3/7/02	DD	DD	4/7/04
DC	DC	3/22/02	EE	EE	5/12/04
ED	ED	4/5/02	FF	FF	6/21/04
FD	FD	4/25/02	GG	GG	7/28/04
GE	GE	5/16/02	HH	HH	8/27/04
HF	HF	6/11/02	II	II	9/23/04
IG	IG	7/17/02	JJ	JJ	10/20/04
JH	JH	8/20/02	KK	KK	11/23/04
KI	KI	9/19/02	05AA	05AA	1/20/05
LJ	LJ	10/24/02	BB	BB	2/18/05
MK	MK	11/20/02	CC	CC	3/31/05

MOBFIELD FILE SUMMARY Section 212 CWRU Page 3					
NEW FILE	OLD FILE	DATE	NEW FILE	OLD FILE	DATE
39SC05DE	39SC05DE	5/5/05			
EF	EF	6/7/05			
FG	FG	7/13/05			
GI	GI	9/1/05			
HJ	HJ	10/20/05			
IK	IK	11/8/05			
JL	JL	12/12/05			

Table C-10 MOBFIELD Summary for Section 263

MOBFIELD FILE SUMMARY   Section 263   OSU Page 1

NEW FILE	OLD FILE	DATE	NEW FILE	OLD FILE	DATE
39SJ96AI	39SJ96BI	9/24/96	39SJ99GH	39SJ99SH	8/20/99
BK	CK	11/1/96	ONS FILE	39SJ99SI	--
CK	DK	11/18/96	39SJ99HI	TI	9/14/99
DL	EL	12/31/96	IJ	TJ	10/28/99
NOTHING	97AB	-	JK	TK	11/12/99
97AB	BB	2/20/97	00AB	00BB	2/16/00
BC	CC	3/26/97	BD	DD	4/28/00
CD	DD	4/8/97	CF	FF	6/26/00
DD	ED	4/22/97	DG	GG	7/20/00
EE	FE	5/20/97	EH	HH	8/15/00
FF	GF	6/16/97	FI	II	9/7/00
GG	HG	7/9/97	GJ	JJ	10/12/00
HH	IH	8/6/97	HK	KK	11/14/00
II	JI	9/3/97	IK	KL	11/21/00
JL	NL	12/23/97	JL	LL	12/19/00
98AA	98AA	1/16/98	01AA	01AA	1/18/01
BF	FF	6/8/98	BB	BB	2/15/01
CG	GG	7/31/98	CC	CC	3/8/01
DI	IJ	9/29/98	DC	CD	3/22/01
EJ	IJ	10/23/98	ED	DD	4/9/01
FK	JK	11/24/98	FD	DE	4/24/01
GL	LL	12/28/98	GE	EE	5/15/01
99AA	99MA	1/28/99	HF	FF	6/20/01
BB	MB	2/8/99	IG	GG	7/2/01
DELETE	NC	3/30/99	JG	GH	7/24/01
CC	OD	3/30/99	KH	HH	8/21/01
DE	OE	5/20/99	LI	II	9/11/01
EF	GF	6/25/99	MJ	JJ	10/19/01
FG	RG	7/16/99	NK	KK	11/6/01

MOBFIELD FILE SUMMARY Section 263 OSU Page 2

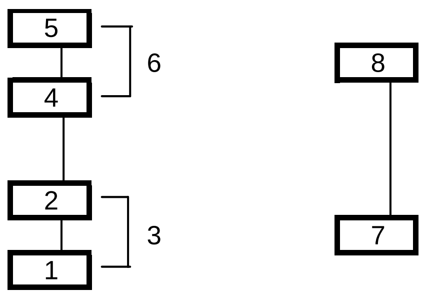
NEW FILE	OLD FILE	DATE	NEW FILE	OLD FILE	DATE
39SJ01OL	39SJ01LL	12/10/01	39SJ04DH	39SJ04HHEI	8/31/04
02AA	02AA	1/10/02	EI	II	9/30/04
BB	BB	2/14/02	FJ	JJ	10/28/04
CC	CC	3/14/02	GK	KK	11/22/04
DD	DD	4/10/02	HL	LL	12/9/04
ED	DE	4/29/02	05AA	05AA	1/10/05
FE	EE	5/22/02	BB	BB	2/4/05
GF	FF	6/19/02	CC	CC	3/16/05
HG	GG	7/26/02	DD	DD	4/29/05
IH	HH	8/21/02	EF	EE	6/1/05
JI	II	9/23/02	FF	FF	6/23/05
KJ	JJ	10/18/02	GG	GG	7/26/05
LK	KK	11/15/02	HI	II	9/2/05
ML	LL	12/12/02	Bad File	LL	12/14/05
03AA	03AA	1/15/03			
BB	BB	2/20/03			
CD	DD	4/2/03			
DD	ED	4/28/03			
EE	EE	5/30/03			
FF	FF	6/30/03			
GG	GG	7/22/03			
HH	HH	8/26/03			
II	II	9/26/03			
JJ	JJ	10/20/03			
KK	KK	11/21/03			
LL	LL	12/22/03			
04AF	04FF	6/8/04			
BF	FG	6/30/04			
CG	GG	7/28/04			

APPENDIX D

Truck Wheel Weights, Wheel Geometry, and Tire Pressures for Controlled Vehicle Tests on the Ohio SHRP Test Road

Table D-1

Controlled Vehicle Tests – Single Axle Dump Weights



Test Series	Load Subseries	Test Date	Wheel Load (lbs.) 1	2	3	4	5	6	Rear Axle	7	8	Front Axle
2	A*	8/2,3/96			3770			3840	7610			
	B*	8/5,6/96			9150			9335	18485	4690	4660	9350
	EF**	8/6,7/96			8870			9580	18450	4760	4850	9610
	G**	8/9/96			10680			11550	22230	4760	4850	9610
2	H**	8/12/96			10680			11550	22230	4760	4850	9610
	I**	8/13/96			10930			10160	21090			
	J**	8/14/96			9290			8810	18100	4690	4820	9510
4	K	7/2/97	3300	5400	8700			8650	17350	4250	4300	8550
	L	7/3/97	5350	7750	13100			11850	24950	4450	4450	8900
	M,N	7/29,30/97	4950	6350	11300			10150	21450	3650	3600	7250
	O,P	7/30,8/6/97	5700	7550	13250			12100	25350	3950	3750	7700
5	A,B	10/9,14/98	4150	5300	9450	4850	4100	8950	18400	4750	4650	9400
	C,D,E	10/14,15,19/98	5300	6750	12050	6700	5250	11950	24000	4800	4600	9400
	F	10/20/98	4650	5800	10450	6000	4200	10200	20650	4900	4750	9650
6	A	9/27/99			10550			9600	20150	4900	4600	9500
	B	9/28/99			8500			7800	16300	5350	4850	10200
	C	10/1/99			11050			9600	20650	5150	4600	9750
	D	10/5/99			8800			8150	16950	5350	4800	10150
7	E,F,G	10/7,12,13/99			10700			9950	20650	5250	4800	10050
8	A	4/27/01	5350	5450	10800	5650	5200	10850	21650	4700	4700	9400
	B	4/30/01	4850	4600	9450	4800	4150	8950	18400	4750	4400	9150
	C	5/1/01	4850	4600	9450	4800	4150	8950	18400	4750	4400	9150
	D	5/2/01	5500	5600	11100	6150	5400	11550	22650	4800	4500	9300
9	A, B	10/20,21/03			11950			12100	24050	4550	4500	9050
	C, D	10/21,22/03			8150			7450	15600	4350***	4350***	8700

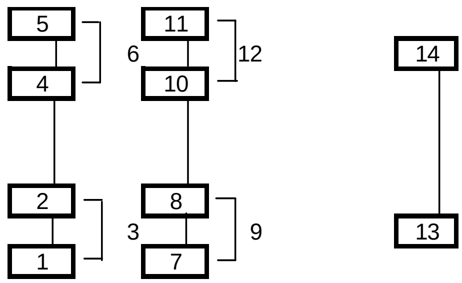
* No runs

** Renamed to conform with response database

*** Estimated from total axle load

Table D-2

Controlled Vehicle Tests - Tandem Axle Dump Weights

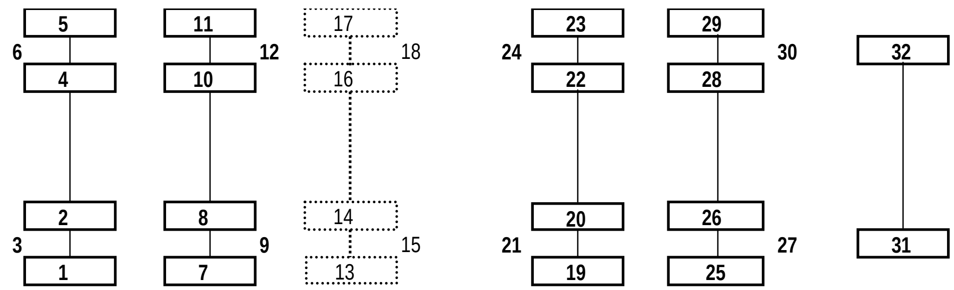


Test Series	Load Subseries	Test Date	Wheel Load (lbs.)													
			1	2	3	4	5	6	7	8	9	10	11	12	13	14
2	AB*	8/2,3/96			8120			8500			8050			8180	7360	7850
	CD*	8/5,6/96			10550			10590			10220			11160	8220	8770
	HI*	8/12,13/96			10220			11160			10550			10590	8220	8770
	J*	8/14/96			7750			8250			8010			8530	7030	7680
3	A	6/4,5/97	6700	3250	9950			9500	4650	6450	11100			9700	8150	8050
	B,BA,BY*	6/9,10,19/97	4000	4350	8350			7800	4250	4600	8850			8000	6600	6450
	BZ*,C,D	6/20,23,24/97	3800	4500	8300			7800	3950	5150	9100			7800	6700	6500
	E,F	6/24,25/97	2200	2700	4900			4550	2400	3400	5800			4200	6000	5800
	G,H	6/25,26/97	1200	1750	2950			3000	1550	2150	3700			2900	5500	5500
4	K	7/2/97	3900	4950	8850			7250	4200	5250	9450			7450	7300	7200
	L	7/3/97	5500	7100	12600			11700	5700	7050	12750			12400	8400	8600
	M,N	7/29,30/97	4050	5200	9250			8250	4350	5400	9750			8600	7550	7550
	O,P	7/30,8/6/97	5300	6000	11300			10750	5900	6350	12250			10800	8350	8250
5	A,B	10/9,14/98	3750	3650	7400	5600	2750	8350	3100	5300	8400	5150	3100	8250	6700	6850
	C,D,E	10/14,15,19/98	4600	4550	9150	6200	3400	9600	3650	5850	9500	6100	4000	10100	7500	7500
6	A	9/27/99			9250			9100			9700			8900	7420	7150
	B	9/28/99			7250			7800			7700			7700	7150	7050
	C	10/1/99			9850			9100			9750			9200	7100	7050
	D	10/5/99			7300			8050			7900			7600	7450	7350
7	E,F,G	10/7,12,13/99			10000			9450			9800			9500	7300	7250
8	A	4/27/01			8400			8950			8700			8800	7500	7500
	B	4/30/01			7350			7200			7800			7050	6750	6550
	C	5/1/01			7350			7200			7800			7050	6750	6550
	D	5/2/01			11550			11500			11050			11700	8400	8050
9	A,B	10/20,21/03			7950			10050			8700			9850	6700	7050
	C,D	10/21,22/03			6300			6850			6400			7100	6350	6600

* Renamed to conform with response database

Table D-3

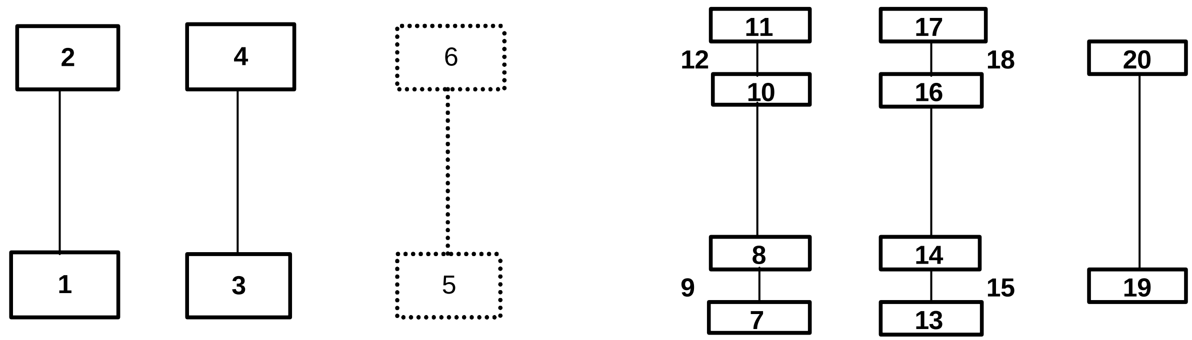
Controlled Vehicle Tests - CNRC Weight with Dual Tires



Test Series	Load Subseries	Date	Wheel Load on Dual Tires (lbs.)																															
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
Tandem																																		
1	A	12/5,6/95	4600	5200	9800	4725	3800	8525	4625	4725	9350	4750	3900	8650									11000			9700			9500			11300	6250	6075
1	B	12/6/95	4850	5350	10200	5050	4000	9050	4500	5300	9800	5200	3700	8900									9700			9725			9900			10050	6150	6450
1	C	12/7/95	4400	4700	9100	4650	3650	8300	4400	4600	9000	4750	3300	8050									11050			10350			10350			11400	6025	6225
1	D	12/8/95	5650	5500	11150	5700	4500	10200	5300	6150	11450	5950	3900	9850									13200			11250			10750			13700	6600	6150
1	E	12/11,14/95	4950	5375	10325	5200	4400	9600	4750	5450	10200	5225	4350	9575									11000			9000			9500			9000	5650	5650
3	A	6/4,5/97	6400	7050	13450			12050	6600	6950	13550			12150							8000	8550	16550			14750	7500	8300	15800			14750	6900	7500
3	B,BA	6/9,10/97	4550	5300	9850			8300	4850	4950	9800			8300							6650	6800	13450			12100	6450	7350	13800			12650	6200	6600
3	H	6/26/97	3350	3850	7200			6550	3550	3650	7200			6350							1800	1700	3500			3400	2050	1950	4000			3300	5300	5500
Tridem																																		
1	F	12/15/95	3200	3600	6800	3600	4000	7600			6850			7400	3350	3500	6850	3650	3800	7450			11325			12750			11900			12350	5650	6950
1	H	3/13/96			7850			8850			8225			8175			8800			7250			5200			4800			5400			5100	5350	5700
1	I	3/13,14/96			8875			9750			8900			9250			9875			8250			6750			7450			7450			6800	5450	5950

Table D-4

Controlled Vehicle Tests - CNRC Weight with Super Single Tires

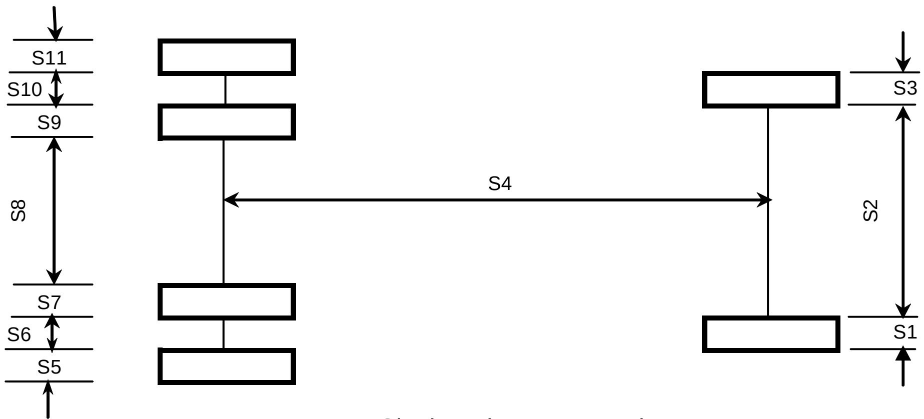


Test Series	Load Subseries	Date	Wheel Load on Super Single Tires (lbs.)																			
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Tandem																						
3	BX*,BY*	6/17,19/97	9850	8000	9650	8400			6600	6950	13550			11200	6400	7650	14050			11850	6700	6750
3	BZ*	6/20/97	10650	9050	10700	9500			6250	6650	12900			11450	6400	6700	13100			11750	6900	7100
3	C	6/23/96	9900	8850	10150	8750			6550	6550	13100			11900	6600	7150	13750			12250	6550	6950
3	F	6/25/96	8400	7600	8400	7750			3000	2900	5900			5400	3100	3150	6250			5100	5850	6300
3	G	6/25/96	6900	6550	7150	6150			1850	1650	3500			3250	1800	1600	3400			3300	5550	5700
Tridem																						
1	J	3/15/96	8650	9700	9250	8800	10100	7750			7100*			7100*			7125*			7125*	5700*	5700*
1	K	3/16/96	7150	7000	7225	6800	7100	7250			11700			13550			12450			10200	5750	7050
1	L	3/16/96	8700	7900	8100	8000	8000	8200			5000			4925			5400			5175	5100	5400
3	D	6/24/97	8950	8150	8750	8100	9000	7550	3900	3750	7650			7000	3800	4350	8150			6850	5650	5950
3	E	6/24/97	6000	5600	5950	5650	6100	5350	2700	2450	5150			4700	2650	2900	5550			4650	5400	5600

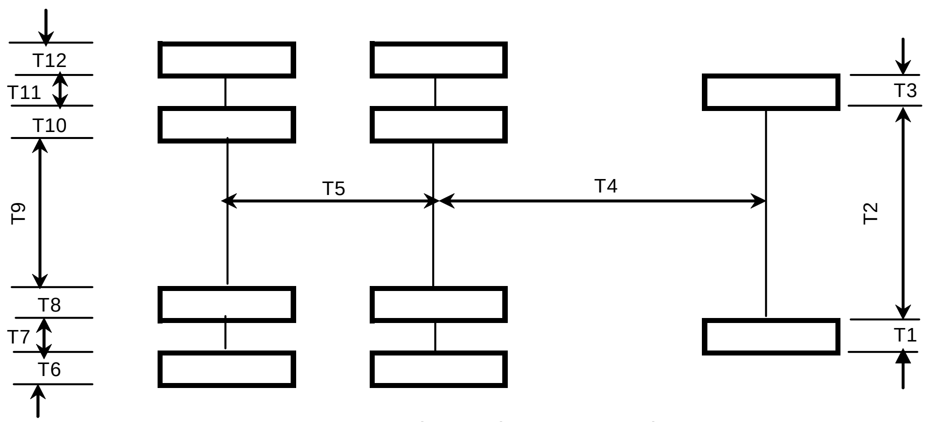
* Renamed to conform with response database

Table D-5

Controlled Vehicle Tests - Dump Truck Dimensions



Single-Axle Dump Truck



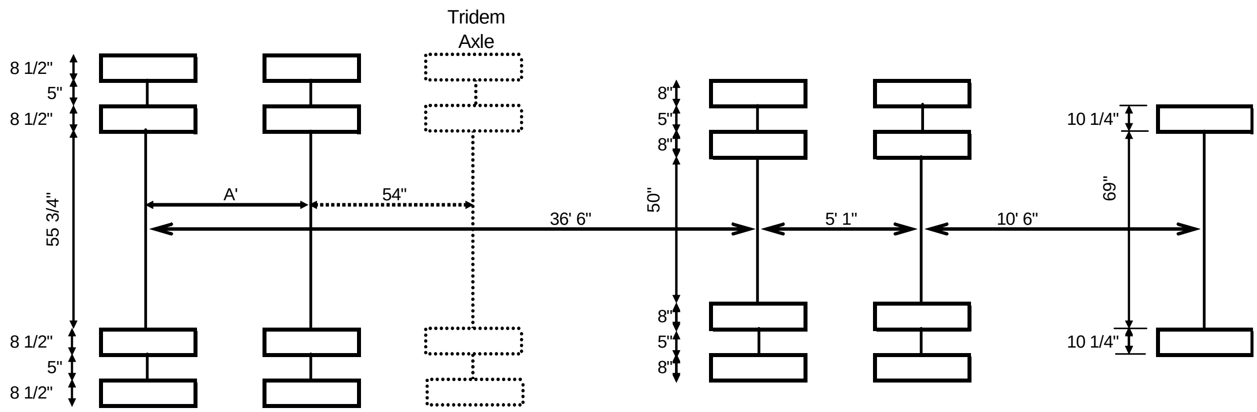
Tandem-Axle Dump Truck

Test	Dimensions on Single-Axle Dump Truck (in.)										
Series	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11
2-4	8.5	70.3	8.5	137.0	9.8	3.0	9.8	50.0	9.8	3.0	9.8
5	9.3	70.0	9.3		8.0	4.8	8.0	51.0	8.0	4.8	8.0
6-7	8.3	71.8	8.3	140.3	8.0	5.3	8.0	51.3	8.0	5.3	8.0
8	8.5	71.0	8.5		8.3	5.0	8.3	51.3	8.3	5.0	8.3
9	8.8	71.0	8.8	141.0	8.5	4.8	8.5	51.0	8.5	4.8	8.5

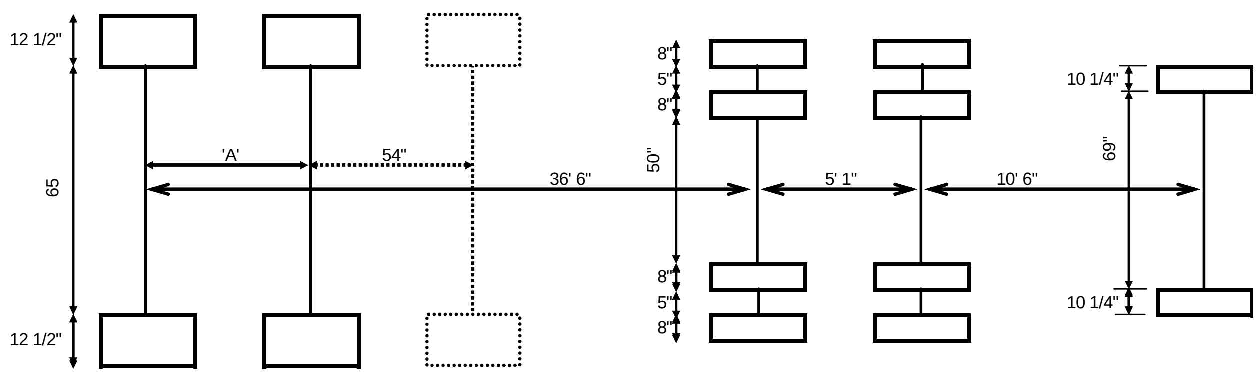
Test	Dimensions on Tandem-Axle Dump Truck (in.)											
Series	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12
1-4	10.5	69.3	10.5	178.8	53.5	9.5	3.0	9.5	49.3	9.5	3.0	9.5
5	11.0	70.0	11.0			9.0	3.6	9.4	49.1	9.3	4.1	8.9
6-7	13.0	67.5	13.0	180.0	54.0	8.5	4.8	8.5	50.5	8.5	4.8	8.5
8	13.0	67.5	13.0			8.3	5.0	8.3	51.3	8.3	5.0	8.3
9	13.5	67.5	13.5	178.0	54.0	8.5	4.8	8.5	51.0	8.5	4.8	8.5

Table D-6

Controlled Vehicle Tests - CNRC Truck Dimensions



Geometry of CNRC Truck with Dual Tires

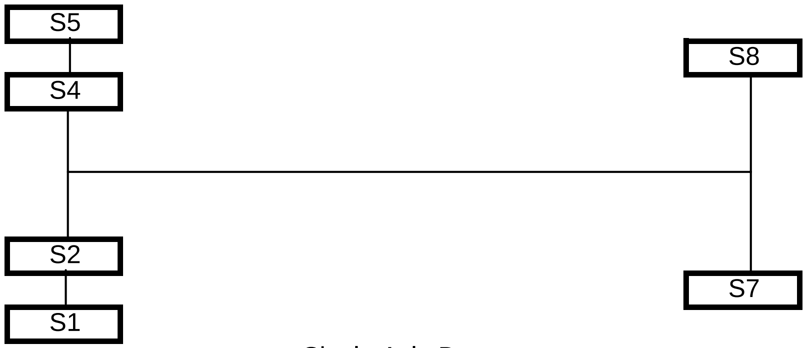


Geometry of CNRC Truck with Super Single Tires

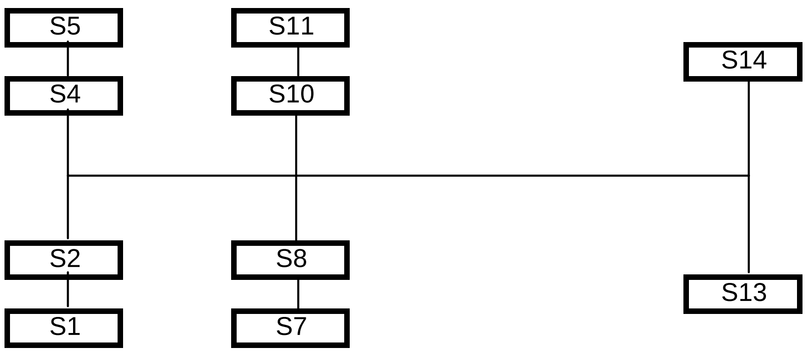
See Tables 2.9, 2.10, 2.14 and 2.15 for Spacing 'A'

Table D-7

Controlled Vehicle Tests - Tire Pressures



Single Axle Dump



Tandem Axle Dump

Date	Tire Pressure in Single Axle Dump Truck (psi)					
	S1	**S2**	**S4**	**S5**	**S7**	**S8**
9,10/99	85	115	110	110	150	130
5/01	79	77	82	83	100	99
10/03	100	80	75	75	95	95

Date	Tire Pressure in Single Axle Dump Truck (psi)									
	S1	**S2**	**S4**	**S5**	**S7**	**S8**	**S10**	**S11**	**S13**	**S14**
9,10/99	140	30*	130	145	140	145	150	140	150	150
5/01	101	98	105	104	103	86	106	104	113	111
10/03	100	25**	85	105	95	95	90	90	95	95

* Increased to 105 psi on 10/1/99

** Increased to 100 psi before testing on 10/21/03

APPENDIX E

1995-96 FWD Layer Profiles During Construction

Table E-1

FWD Measurements on Material Layers during Construction – Sections 101 - 107

OHIO SHRP TEST ROAD - FWD Deflection Profiles																										
Section	Path	Layer	Load (k)	Date	Normalized FWD Df1 Deflection (mils/kip) at Station																					
				Station	0+00	0+25	0+50	0+75	1+00	1+25	1+50	1+75	2+00	2+25	2+50	2+75	3+00	3+25	3+50	3+75	4+00	4+25	4+50	4+75	5+00	Avg.
SPS-1																										
390101*	C/L	Subgrade	5.10	8/29/95		4.06		3.56		3.20		4.54		6.39		6.73		4.18		5.98		18.4		16.0		7.30
		8"DGAB	9.02	9/12/95		3.02		4.19		4.36		2.67		3.18		4.66		3.48		3.40		3.33		4.15		3.64
		7"AC	9.25	6/11/96	1.39		1.59		1.50		1.66		1.56		1.59		2.08		1.52		1.53		1.85		1.85	1.65
	RWP	Subgrade	5.11	8/29/95	8.13		7.16		8.83		10.0		5.41		11.81		9.00		3.41		6.50		16.35		15.3	9.26
		8"DGAB	8.87	9/12/95	4.16		5.49		5.47		4.17		3.69		7.08		5.22		3.80		4.11		5.08		4.83	4.83
		7"AC	9.18	6/11/96	1.46		1.52		1.48		1.53		1.50		1.61		2.17		1.50		1.48		1.68		1.71	1.60
390102*	C/L	Subgrade	5.77	8/29/95		2.43		3.54		4.62		4.78		5.76		9.58		2.90		2.13		2.08		4.10		4.19
		12"DGAB	8.99	9/12/95		3.98		3.23		3.62		4.12		4.19		4.32		3.51		3.32		3.14		3.10		3.65
		4"AC	9.49	6/11/96	3.14		2.78		3.25		3.70		4.00		3.53		3.68		3.13		3.06		4.39		3.86	3.50
	RWP	Subgrade	5.66	8/29/95	2.83		3.09		3.82		7.21		7.20		8.73		3.22		2.18		4.88		2.43		3.18	4.43
		12"DGAB	8.99	9/12/95			3.17		3.99		4.89		4.48		6.06		4.13		3.65		3.02		3.44		3.82	4.07
		4"AC	9.42	6/11/96	3.36		2.82		3.02		3.36		3.63		3.68		3.61		2.75		2.55		3.51		3.11	3.22
390103*	C/L	Subgrade	4.89	8/24/95		5.28		5.01		3.22		5.17		4.25		6.70		4.94		4.94		4.00		6.73		5.02
		8"ATB	9.19	9/22/95		1.46		1.05		1.44		1.03		1.17		1.07		1.34		1.87		1.24		1.45		1.31
		4"AC	9.51	6/11/96	1.22		1.04		1.18		1.09		1.12		0.98		1.03		1.09		1.16		1.15		0.97	1.09
	RWP	Subgrade	4.99	8/24/95	7.31		4.12		3.00		3.58		5.96		4.99		4.38		4.33		3.64		4.15		13.33	5.34
		8"ATB	9.38	9/22/95	1.45		1.24		1.27		1.38		1.25		1.10		1.06		1.21		1.78		1.13		1.40	1.30
		4"AC	9.48	6/11/96	1.42		1.20		1.36		1.27		1.25		1.21		1.19		1.22		1.32		1.26		1.06	1.25
390104*	C/L	Subgrade	5.81	7/19/95		5.67		4.57		6.13		10.9		7.74		5.32		6.61		4.60		2.55				6.01
		12"ATB													No Data											
		7"AC	9.36	6/11/96	0.46		0.41		0.46		0.45		0.47		0.48		0.42		0.48		0.43		0.43		0.41	0.45
	RWP	Subgrade	5.78	7/19/95	6.98		4.49		9.41		4.54		5.37		2.90		4.18		2.11		4.14		2.48		5.26	4.71
		12"ATB	10.29	10/3/95	0.64		0.55		0.61		0.59		0.52		0.55		0.53		0.51		0.55		0.57		0.5	0.56
		7"AC	9.32	6/11/96	0.45		0.42		0.41		0.51		0.48		0.49		0.47		0.46		0.45		0.44		0.48	0.46
390105*	C/L	Subgrade	5.26	8/28/95		5.77		5.97		4.37		4.32		3.95		4.03		4.15		4.38		4.70		5.02		4.67
		4"DGAB	9.21	9/11/95		3.45		4.25		5.82		4.63		4.92		4.82		4.78		5.58		4.84		6.12		4.92
		4"ATB	9.14	9/25/95		2.42		2.10		1.53		1.63		2.24		1.92		1.95		1.74		2.09		2.14		1.98
		4"AC	9.71	6/11/96	1.39		1.27		1.30		1.33		1.20		1.47		1.31		1.26		1.25		1.55		1.61	1.36
	RWP	Subgrade	5.29	8/28/95	4.10		5.26		3.21		3.67		3.65		4.91		5.50		6.22		5.95		5.83		6.04	4.94
		4"DGAB	9.08	9/11/95	4.13		4.70		3.77		4.47		5.30		4.54		5.50				5.09		5.69		7.51	5.07
		4"ATB	9.19	9/25/95	2.37		2.45		2.58		2.30		2.66		2.16		2.10		1.52		1.61		2.05		2.18	2.18
		4"AC	9.47	6/11/96	1.55		1.35		1.44		1.29		1.33		1.47		1.41		1.20		1.34		1.59		1.48	1.41
390106*	C/L	Subgrade	5.50	8/1/95						11.5		4.13		5.19		3.07		3.49		3.74		3.00		5.20		4.92
		4"DGAB	8.58	10/17/95		4.38		6.38		4.46		9.98		11.4		10.1		8.61		6.84		9.28				7.94
		8"ATB	8.49	10/18/95		0.59		0.64		0.60		0.67		0.78		0.68		0.67		0.63		0.60		0.70		0.66
		7"AC	9.36	6/11/96	0.61		0.60		0.60		0.52		0.56		0.53		0.56		0.53		0.50		0.56		0.54	0.56
	RWP	Subgrade	5.62	8/1/95							6.08		5.43		5.82		5.05		3.44		4.99		2.74		2.75	4.54
		4"DGAB	8.88	10/17/95	8.81		5.50		5.77		4.35		10.7		12.9		7.41		8.12		8.25		8.08		10.9	8.24
		8"ATB	9.04	10/18/95	0.65		0.55		0.52		0.54		0.75		0.80		0.65		0.79		0.61		0.59		0.62	0.64
		7"AC	9.26	6/11/96	0.68		0.64		0.60		0.58		0.58		0.53		0.56		0.54		0.58		0.56		0.58	0.58
390107	C/L	Subgrade	5.81	8/29/95		9.39		3.70		6.13		4.00		3.31		3.17		6.67		3.33		7.54		7.36		5.46
		4"DGAB	9.06	9/12/95		7.35		4.23		4.31		5.16		5.54		5.69		9.69		5.40		5.30		4.80		5.75
		4"PATB	8.35	10/19/95		5.97		5.74		5.62		5.51		6.88		5.52		5.97		4.81		5.06		4.69		5.58
		4"AC	9.20	6/11/96	1.90		1.96		2.35		2.09		2.37		1.99		1.87		2.30		1.93		2.34		2.21	2.12
	RWP	Subgrade	5.83	8/29/95	3.99		2.53		3.80		3.35		4.19		5.02		3.20		3.58				9.64		7.98	4.73
		4"DGAB	8.92	9/12/95	6.27		4.79		3.66		4.47		5.32		5.82		4.36		7.98		5.38		5.15			5.32
		4"PATB	8.75	10/19/95	4.50		4.50		4.91		4.65		9.04		5.38		4.11		4.61		4.08		4.76		3.52	4.91
		4"AC	9.19	6/11/96	1.77		1.74		2.25		1.77		2.19		1.74		1.79		1.75		1.79		2.07		2.04	1.90

* Undrained section

Table E-2

FWD Measurements on Material Layers during Construction – Sections 108 - 159

OHIO SHRP TEST ROAD - FWD Deflection Profiles

Section	Path	Layer	Load (k)	Date	Normalized FWD Df1 Deflection (mils/kip) at Station																					
				Station	0+00	0+25	0+50	0+75	1+00	1+25	1+50	1+75	2+00	2+25	2+50	2+75	3+00	3+25	3+50	3+75	4+00	4+25	4+50	4+75	5+00	Avg.
SPS-1																										
390108	C/L	Subgrade	5.64	8/28/95		3.41		2.58		3.90		3.90		3.74		4.43						2.88		3.10		3.49
		8"DGAB	8.78	10/5/95		4.70		5.99		4.57		9.52		11.3		6.81		10.0		7.86				5.23		7.33
		4"PATB	9.19	10/11/95		3.55		3.65		4.42		3.92		6.07		4.11		3.62				3.82		2.83		4.00
		7"AC	9.84	6/11/96	1.11		1.04		1.10		0.85		0.93		0.79		0.87		1.01		0.96		0.77		1.12	0.96
	RWP	Subgrade	5.55	8/28/95	4.94		2.58		4.55		5.98		4.53		4.42						6.03		2.42		3.33	4.31
		8"DGAB	8.77	10/5/95	5.88		5.38		5.65		5.59		10.9		8.50		6.80		13.06		8.23		6.95		4.72	7.42
		4"PATB	9.27	10/11/95	3.31		3.06		3.35		4.41		11.5		7.11		5.22		4.79		3.12		3.43		3.72	4.82
		7"AC	9.80	6/11/96	1.14		1.06		1.10		0.91		0.98		0.85		0.87		0.88		0.91		0.77		1.10	0.96
390109	C/L	Subgrade	4.62	8/25/95		6.60		5.57		5.67		2.78				3.80		4.49		5.77		5.36		5.77		5.09
		12"DGAB	9.18	9/11/95		3.41		2.85		3.16		2.85		3.78		2.16		3.11		2.85		3.55		3.17		3.09
		4"PATB	8.71	9/20/95		3.79		3.53		3.83		4.21		4.62		3.44		3.57		4.50		4.14		3.31		3.89
		7"AC	10.08	6/11/96	1.01		1.07		0.88		0.88		1.10		1.03		0.91		0.88		0.94		1.02		1.10	0.98
	RWP	Subgrade	4.26	8/25/95	11.6		11.9		4.74		8.18		14.4		18.6		6.74		8.12		18.26		5.08		6.70	10.39
		12"DGAB			No Data																					
		4"PATB	8.50	9/20/95	4.61		4.46		3.13		5.02		6.55		7.28		3.74		3.78		5.03		3.72		4.05	4.67
		7"AC	9.78	6/11/96	0.99		1.00		0.92		1.01		1.23		1.19		1.02		0.90		0.94		1.00		1.04	1.02
390110	C/L	Subgrade	4.76	8/25/95		4.60		14.35		4.56		6.98		4.30		5.46		3.30		5.36		5.18		6.94		6.10
		4"PATB	9.18	9/17/95		6.73		5.48		5.34		5.50		3.38		3.61		3.47		4.82		5.36		5.92		4.96
		4"ATB	9.36	9/18/95		3.04		2.59		2.97		2.88		3.32		2.97		2.73		2.73		2.85		3.34		2.94
		7"AC	9.45	6/11/96	0.99		0.86		0.85		0.94		0.85		0.94		1.00		1.01		1.02		1.10		1.12	0.97
	RWP	Subgrade	4.71	8/25/95	8.41		11.5		14.7		6.90		8.20		4.18		3.26		3.28		8.10		5.75		8.06	7.48
		4"PATB	9.39	9/17/95	4.82		4.71		4.76		5.37		6.14		3.45		3.23		3.83		4.63		4.28		7.14	4.76
		4"ATB	9.79	9/18/95	3.10		2.56		2.74		3.16		3.30		2.19		3.06		2.74		2.85		2.79		3.44	2.90
		7"AC	9.65	6/11/96	1.03		0.95		0.95		0.96		1.02		0.97		1.12		1.02		1.04		1.16		1.15	1.03
390111	C/L	Subgrade	5.56	7/19/95		3.41		3.93		5.94		6.03		17.4		9.67		6.68		3.60		3.20		2.26		6.21
		4"PATB	9.33	8/30/95		3.79		4.96		4.55		5.05		5.02		6.73		4.94		4.71		4.80		3.01		4.76
		8"ATB	9.77	10/5/95		0.64		0.70		0.77		0.73		0.75		0.83		0.78		0.76		0.74		0.84		0.75
		4"AC	9.20	6/11/96	0.54		0.62		0.68		0.61		0.62		0.66		0.75		0.71		0.76		0.82		0.73	0.68
	RWP	Subgrade	5.63	7/19/95	2.00		2.36		3.58		5.40		6.81		19.8		5.26		5.29		2.97		4.33		3.00	5.52
		4"PATB	9.43	8/30/95	3.02		3.40		3.88		7.12		6.04		7.81		5.06		4.28		3.44		3.87		3.50	4.67
		8"ATB	9.73	10/5/95	0.64		0.75		0.91		0.78		0.85		0.88		0.87		0.78		0.74		0.77		0.81	0.80
		4"AC	9.22	6/11/96	0.56		0.64		0.68		0.65		0.68		0.71		0.73		0.73		0.77		0.82		0.75	0.70
390112	C/L	Subgrade	5.62	7/20/95		3.74		6.77		6.32		3.52		9.33		4.85		26.5		3.64		9.36		5.33		7.94
		4"PATB	9.39	8/30/95		3.70		3.30		3.67		2.91		3.46		5.24		4.80		3.56		3.89		3.71		3.82
		12"ATB	9.79	10/5/95		0.48		0.49		0.54		0.45		0.50		0.56		0.50		0.47		0.45		0.43		0.49
		4"AC	9.32	6/11/96	0.51		0.57		0.55		0.53		0.57		0.55		0.52		0.48		0.53		0.49		0.52	0.53
	RWP	Subgrade	5.62	7/20/95	2.60		10.3		9.65		5.03		3.75		4.01		5.25		4.67		11.2		5.90		12.6	6.81
		4"PATB	9.24	8/30/95	4.32		3.97		4.01		4.06		3.70		3.66		4.47		4.35		4.08		3.73		4.07	4.04
		12"ATB	9.74	10/5/95	0.53		0.50		0.55		0.55		0.56		0.55		0.58		0.50		0.47		0.50		0.53	0.53
		4"AC	9.36	6/11/96	0.44		0.50		0.52		0.51		0.51		0.53		0.49		0.49		0.52		0.46		0.41	0.49
390159	C/L	Subgrade	3.86	6/28/96		6.29		23.8		22.9		21.8		13.7		24.6		30.7		14.7		12.7		16.0		18.7
		6"DGAB			No Data																					
		4"PCTB			No Data																					
		15"ATB			No Data																					
		4"AC			No Data																					
	RWP	Subgrade	3.84	6/28/96	9.14		6.88		26.9		27.0		23.7		29.0		17.2		8.58		9.07		8.36		9.03	15.9
		6"DGAB			No Data																					
		4"PCTB			No Data																					
		15"ATB			No Data																					
		4"AC			No Data																					

Table E-3

FWD Measurements on Material Layers during Construction – Sections 160 – 164

OHIO SHRP TEST ROAD - FWD Deflection Profiles

Section	Path	Layer	Load (k)	Date	Normalized FWD Df1 Deflection (mils/kip) at Station																					
				Station	0+00	0+25	0+50	0+75	1+00	1+25	1+50	1+75	2+00	2+25	2+50	2+75	3+00	3+25	3+50	3+75	4+00	4+25	4+50	4+75	5+00	Avg.
															SPS-1											
390160	C/L	Subgrade	5.27	8/28/95		3.79		6.76				3.10		4.97		2.74		6.69		3.66						4.53
		4"DGAB	9.29	9/18/95		6.34		4.55		4.99		5.54		5.66		5.69		5.85		5.93		5.56		4.90		5.50
		11"ATB	9.71	9/27/95		0.52		0.51		0.64		0.50		0.49		0.51		0.52		0.53		0.70		0.53		0.54
		4"AC	9.84	6/11/96	0.51		0.59		0.52		0.48		0.48		0.48		0.46		0.40		0.59		0.46		0.56	0.50
	RWP	Subgrade	5.45	8/28/95	2.94		5.90		4.13		3.98		2.37		3.99		4.59		3.54						4.31	3.97
		4"DGAB	9.06	9/18/95	8.21		9.04		4.72		4.56		4.74		6.08		6.46		10.4		5.72		5.50		3.60	6.28
		11"ATB	10.51	9/27/95	0.52		0.51		0.53		0.44		0.44		0.47		0.50		0.45		0.55		0.55		0.45	0.49
		4"AC	9.98	6/11/96	0.56		0.61		0.52		0.46		0.47		0.49		0.44		0.37		0.57		0.48		0.55	0.50
390161	C/L	Subgrade	4.93	10/1/97		6.24		6.98		10.1		12.9		6.03		12.0		7.99		4.27		5.04		5.28		7.68
		6"DGAB	5.61	10/2/97		7.77		5.06		12.7		9.73		4.51		3.81		6.13		9.88		8.30		9.97		7.79
		4"PATB	5.58	10/22/97		3.854		2.688		3.311		3.115		2.448		3.152		3.088		2.817		3.227		3.43		3.11
		12"ATB	5.48	10/29/97		1.45		1.30		1.17		1.46		1.23		1.40		1.17		1.11		1.33		1.20		1.28
		3"AC	9.09	11/5/97		0.32		0.32		0.28		0.31		0.29		0.29		0.28		0.29		0.28		0.34		0.30
	RWP	Subgrade	4.88	10/1/97	9.41		10.9		11.1		11.5		8.63		11.3		6.57		4.63		5.35		5.05		7.72	8.38
		6"DGAB	5.71	10/2/97	6.16		6.14		5.90		7.48		4.65		7.74		3.94		3.59		3.13		4.15		7.11	5.45
		4"PATB													No Data											
		12"ATB	5.55	10/29/97	1.80		1.89		1.82		1.65		1.43		1.19		1.32		1.24		1.41		1.28		1.42	1.50
		3"AC	9.38	11/5/97	0.29		0.30		0.34		0.29		0.32		0.32		0.32		0.30		0.33		0.27		0.32	0.31
390162	C/L	Subgrade	5.42	10/6/97		2.74		2.41		6.28		8.65		5.43		3.19		2.86		2.73		1.43		1.64		3.74
		6"DGAB	6.03	10/6/97		1.94		2.29		1.97		3.82		2.54		3.31		2.06		2.72		3.08		1.98		2.57
		4"PATB	5.78	10/20/97		1.85		2.09		1.99		2.32		1.95		2.62		1.65		2.50		2.62		2.11		2.17
		12"ATB	5.73	10/24/97		0.60		0.59		0.58		0.62		0.57		0.64		0.57		0.54		0.78		0.64		0.61
		3"AC	9.93	10/27/97		0.28		0.29		0.29		0.31		0.30		0.28		0.27		0.28		0.28		0.25		0.28
	RWP	Subgrade	5.69	10/6/97	3.02		1.92		5.22		2.83		2.64		2.77		2.64		3.02		3.22		7.23		1.57	3.28
		6"DGAB	6.21	10/6/97	1.93		1.74		1.81		1.93		1.86		2.12		2.17		1.96		2.51		3.03		2.18	2.11
		4"PATB	5.79	10/20/97	1.79		2.13		2.68		2.74		2.30		2.43		2.27		2.36		2.31		2.86		1.73	2.33
		12"ATB	5.80	10/24/97	0.76		0.65		0.65		0.58		0.73		0.63		0.58		0.69		0.56		0.74		0.74	0.66
		3"AC	9.46	10/27/97	0.30		0.30		0.34		0.35		0.35		0.31		0.28		0.31		0.28		0.30		0.29	0.31
390163	C/L	Subgrade	5.61	10/3/97		2.11		1.29		3.77		4.41		2.70		2.73		4.31		4.63		5.69		3.66		3.53
		6"DGAB	5.77	10/7/97		2.37		1.86		2.46		3.26		2.06		3.24		3.33		3.01		3.50		2.44		2.75
		4"PATB	5.65	10/20/97		1.91		1.52		2.17		2.34		1.97		2.93		2.32		2.38		2.68		2.26		2.25
		12"ATB	5.85	10/24/97		0.55		0.45		0.65		0.64		0.70		0.72		0.65		0.66		0.65		0.59		0.63
		3"AC	9.61	10/27/97		0.29		0.24		0.29		0.26		0.30		0.30		0.31		0.29		0.31		0.36		0.30
	RWP	Subgrade	5.39	10/3/97	4.40		3.87		3.03		3.04		2.23		1.85		3.42		3.67		6.27		23.3		8.33	5.76
		6"DGAB	5.85	10/7/97	3.36		2.81		2.19		2.60		2.54		2.95		2.80		3.22		11.7		4.60		3.44	3.83
		4"PATB	5.68	10/20/97	2.16		2.06		1.71		2.04		1.51		2.06		2.39		2.05		2.63		2.87		2.44	2.17
		12"ATB	5.87	10/24/97	0.60		0.46		0.59		0.53		0.53		0.75		0.77		0.61		0.68		0.71		0.67	0.63
		3"AC	9.71	10/27/97	0.29		0.26		0.28		0.26		0.26		0.28		0.32		0.29		0.34		0.34		0.34	0.30
390164	C/L	Subgrade	2.87	9/17/98		35.6		23.9		26.8		24.1		34.8		17.8		22.1		37.2		46.3		54.8		32.3
		Geogrid													No Data											
		8"DGAB	3.67	9/23/98		8.38		6.84		8.75		6.32		8.33		6.68		8.16		12.3		25.6		16.2		10.7
		4"PATB	5.32	9/29/98		8.48		4.55		6.27		3.97		6.96		3.47		4.98		5.13		6.94		7.92		5.87
		7"AC	9.11	10/2/98		1.52		1.53		1.25		1.12		1.05		1.22		1.13		1.46		1.65		1.43		1.34
	RWP	Subgrade	2.94	9/17/98	23.6		16.8		21.4		22.5		25.7		34.0		23.6		22.5		29.6		34.1		43.9	27.1
		Geogrid													No Data											
		8"DGAB	3.62	9/23/98	8.38		6.84		8.24		8.93		5.80		9.55		6.51		7.33		12.1		13.4		12.4	9.04
		4"PATB	4.95	9/29/98	8.21		6.24		6.86		6.95		4.47		7.46		5.60		7.60		5.20		9.25		8.23	6.92
		7"AC	9.23	10/2/98	1.50		1.50		1.41		1.40		1.05		1.21		1.12		1.31		1.50		1.43		1.48	1.35

Table E-4

FWD Measurements on Material Layers during Construction – Sections 901 – 903

OHIO SHRP TEST ROAD - FWD Deflection Profiles																										
Section	Path	Layer	Load (k)	Date	Normalized FWD Df1 Deflection (mils/kip) at Station																					
				Station	0+00	0+25	0+50	0+75	1+00	1+25	1+50	1+75	2+00	2+25	2+50	2+75	3+00	3+25	3+50	3+75	4+00	4+25	4+50	4+75	5+00	Avg.
SPS-9																										
390901	C/L	Subgrade	5.58	8/1/95		5.61		4.82		3.05		1.72		1.29		1.19		3.36		4.18		2.81		2.76		3.08
		6"DGAB	10.17	8/21/95		7.80		5.91		5.82		5.15		4.78		3.64		12.7								6.55
		4"PATB	9.02	9/10/95		4.81		3.88		3.62		2.33		3.48		3.05		3.34		3.35		2.73		2.96		3.36
		12"ATB	9.80	9/15/95		0.67		0.61		0.59		0.53		0.53		0.56		0.57		0.52		0.51		0.55		0.56
		4"AC	9.34	6/11/96	0.45		0.37		0.45		0.42		0.37		0.38		0.39		0.37		0.39		0.39		0.43	0.40
	RWP	Subgrade	5.38	8/1/95	6.84		8.32		4.46		2.01		1.75		1.88		2.32		4.87		3.61		4.46		3.06	3.96
		6"DGAB	9.94	8/21/95	10.8		6.86		4.87		5.85		3.80		5.80		5.91									6.27
		4"PATB	9.17	9/10/95	4.19		3.84		3.78		2.51		2.65		3.69		2.92		3.11		2.54		2.73		2.73	3.16
		12"ATB	9.38	9/15/95	0.66		0.60		0.66		0.52		0.58		0.56		0.54		0.51		0.50		0.51		0.52	0.56
		4"AC	9.29	6/11/96	0.40		0.43		0.46		0.41		0.39		0.39		0.40		0.38		0.42		0.37		0.45	0.41
390902	C/L	Subgrade	5.14	7/20/95		5.78		3.30		4.22		3.08		5.39		3.75		2.43		5.72		7.48		10.7		5.18
		6"DGAB	9.97	8/21/95		7.55		6.78		7.73		6.42		9.45		6.68		7.07		9.74		9.24		7.52		7.82
		4"PATB	9.53	8/25/95		6.10		5.78		5.73		5.01		8.92		5.84		4.45		5.88		8.22		5.06		6.10
		12"ATB	10.08	10/5/95		0.49		0.50		0.54		0.54		0.64		0.63		0.54		0.56		0.50		0.47		0.54
		4"AC	9.36	6/11/96	0.41		0.38		0.46		0.46		0.48		0.51		0.49		0.45		0.44		0.43		0.41	0.45
	RWP	Subgrade	5.38	7/20/95	11.3		9.57		7.80		5.48		5.47		4.61		6.71		6.80		4.40		5.69		8.49	6.93
		6"DGAB	9.82	8/21/95	13.0		10.9		11.1		6.44		7.16		8.80		5.89		12.0		9.36		11.1		9.08	9.54
		4"PATB	9.40	8/25/95	8.15		6.39		8.15		4.83		4.60		6.17		4.68		5.75		7.30		7.36		5.59	6.27
		12"ATB	9.82	10/5/95	0.43		0.48		0.54		0.51		0.52		0.61		0.49		0.46		0.50		0.50		0.48	0.50
		4"AC	9.34	6/11/96	0.43		0.39		0.50		0.46		0.46		0.48		0.47		0.43		0.43		0.44		0.45	0.45
390903	C/L	Subgrade	5.19	7/20/95		3.88		5.63		2.72		4.66		4.30		3.36		2.36		7.48		10.1		7.08		5.16
		6"DGAB	10.19	8/21/95		3.74		5.70		4.59		6.15		7.05		7.50		9.64		3.87						6.03
		4"PATB		8/25/95	No Data																					
		12"ATB	9.78	9/15/95		0.59		0.65		0.61		0.61		0.58		0.56		0.53		0.56		0.51		0.47		0.57
		4"AC	9.60	6/11/96	0.42		0.45		0.51		0.49		0.52		0.44		0.44		0.44		0.42		0.40		0.45	0.45
	RWP	Subgrade	5.18	7/20/95	4.76		4.42		4.54		4.35		4.50		4.07		3.08		6.86		11.1		15.8		14.5	7.09
		6"DGAB	9.96	8/21/95	6.24		5.86		6.31		7.48		7.30		7.23		9.21		8.18		10.38					7.58
		4"PATB	10.02	8/25/95	4.04		4.06		3.93		4.64		4.51													4.24
		12"ATB	9.49	9/15/95	0.50		0.54		0.55		0.56		0.57		0.59		0.57		0.59		0.51		0.54		0.51	0.55
		4"AC	9.58	6/11/96	0.44		0.44		0.45		0.49		0.49		0.46		0.43		0.48		0.43		0.40		0.48	0.45

Table E-5

FWD Measurements on Material Layers during Construction – Sections 803, 804, A803, A804

OHIO SHRP TEST ROAD - FWD Deflection Profiles																										
Section	Path	Layer	Load (k)	Date	Normalized FWD Df1 Deflection (mils/kip) at Station																					
				Station	0+00	0+25	0+50	0+75	1+00	1+25	1+50	1+75	2+00	2+25	2+50	2+75	3+00	3+25	3+50	3+75	4+00	4+25	4+50	4+75	5+00	Avg.
SPS-8 AC																										
390803*	C/L	Subgrade	4.23	10/31/94		5.43		4.57		6.76		4.56		5.30		6.99		6.31		5.83		8.35		3.75		5.79
		8"DGAB													No Data											
		4"AC	9.52	11/16/94		2.36		2.06		2.01		2.45		1.93		2.03		1.76		1.81		1.99		1.97		2.04
	RWP	Subgrade	4.33	10/31/94	6.51		4.72		4.53		3.65		4.49		5.96		6.37		5.84		6.70		5.84		6.60	5.56
		8"DGAB													No Data											
		4"AC	9.80	11/16/94	2.46		2.29		2.10		2.49		2.07		2.01		2.00		2.09		1.92		1.96		1.94	2.12
390804*	C/L	Subgrade	4.34	10/31/94		6.11		6.67		9.37		4.65		6.01		5.82		6.47		6.80		5.08		4.23		6.12
		12"DGAB													No Data											
		7"AC	9.70	11/16/94		1.22		1.11		1.07		1.02		1.11		1.13		1.11		1.02		1.11		1.09		1.10
	RWP	Subgrade	4.28	10/31/94	6.03		12.78		7.39		11.1		8.28		8.26		8.24		5.83		7.05		5.65		7.17	7.98
		12"DGAB													No Data											
		7"AC	9.84	11/16/94	1.15		1.15		1.08		1.00		1.11		1.10		1.05		1.04		1.05		1.05		1.04	1.07
39A803*	C/L	Subgrade	5.45	10/3/97		3.11		2.58		3.20		4.67		1.75		1.72		1.88		1.84		2.61		4.28		2.76
		8"DGAB													No Data											
		4"AC	5.68	10/14/97		2.21		1.68		1.72		1.81		1.83		1.81		1.73		1.96		1.81		1.59		1.81
	RWP	Subgrade	5.22	10/3/97	2.21		2.52		3.31		3.33		1.92		2.42		2.22		2.53		2.25		2.38		3.85	2.63
		8"DGAB													No Data											
		4"AC		10/14/97											No Data											
39A804*	C/L	Subgrade	5.14	10/3/97		4.70		3.25		3.60		4.77		3.99		4.84		9.94		6.07		3.71		3.59		4.85
		12"DGAB													No Data											
		7"AC	5.49	10/14/97		1.51		1.07		1.04		1.15		1.05		1.06		1.02		0.85		0.89		1.05		1.07
	RWP	Subgrade	4.85	10/3/97	3.76		8.31		5.18		6.05		3.54		4.02		24.91		14.9		6.36		11.6		26.9	10.5
		12"DGAB													No Data											
		7"AC	5.77	10/14/97	1.15		1.60		1.18		1.12		1.25		1.03		1.04		1.05		0.95		0.84		1.18	1.13
390809*	C/L	Subgrade	4.19	9/27/94		7.87		3.31		3.74		9.06		12.9		8.14		5.07		4.80		19.0		27.8		10.2
		6"DGAB	9.05	10/6/94		4.96		4.11		4.85		6.89		6.51		3.97		6.28				10.1				5.96
		8"LSPCC	9.32	10/19/94		0.43		0.48		0.52		0.47		0.43		0.46		0.40		0.49		0.62		0.49		0.48
	RWP	Subgrade	4.26	9/27/94	5.52		4.50		4.35		4.62		8.64		8.17		7.87		4.95		8.09		16.8			7.36
		6"DGAB	9.29	10/6/94	5.77		5.35		6.12		7.36		7.93		8.78		6.93		6.13		10.1		9.85			7.43
		8"LSPCC	9.33	10/19/94	0.44		0.50		0.57		0.55		0.52		0.48		0.60		0.55		0.81		0.57			0.56
390810*	C/L	Subgrade	4.14	9/27/94		5.65		8.67		14.73		11.5		5.24		9.82		14.4		7.07		5.35		6.48		8.89
		6"DGAB	8.91	10/6/94		5.83		5.55		7.44		7.34		7.19		6.80		7.84		6.32		5.33		5.33		6.50
		11"LSPCC	9.33	10/19/94		0.38		0.41		0.41		0.28		0.27		0.32		0.28		0.29		0.32		0.32		0.33
	RWP	Subgrade	3.83	9/27/94	14.9		32.8		19.7		11.4		5.68		4.51		5.99		5.29		7.50		7.54			11.5
		12"DGAB	8.89	10/6/94	8.83		14.3		10.0		8.94		7.26		6.53		6.89		9.50		8.08		5.39			8.58
		11"LSPCC	9.69	10/19/94	0.32		0.50		0.40		0.34		0.30		0.29		0.32		0.37		0.38		0.33		0.39	0.36

* Undrained section

Table E-6

FWD Measurements on Material Layers during Construction – Sections 201 – 208

OHIO SHRP TEST ROAD - FWD Deflection Profiles																										
Section	Path	Layer	Load (k)	Date	Normalized FWD Df1 Deflection (mils/kip) at Station																					
				Station	0+00	0+25	0+50	0+75	1+00	1+25	1+50	1+75	2+00	2+25	2+50	2+75	3+00	3+25	3+50	3+75	4+00	4+25	4+50	4+75	5+00	Avg.
SPS-2																										
390201*	C/L	Subgrade	5.24	8/1/95		5.97		23.6		8.90		5.15		8.67		4.36		5.48		6.05						8.52
		6"DGAB	8.60	10/18/95		6.52		10.6		4.99		9.91		8.29		7.68		7.69		3.28		7.61		5.22		7.18
		8"PCC	9.35	6/12/96	0.68		0.47		0.52		0.56		0.52		0.44		0.44		0.50		0.52		0.49		0.44	0.51
	RWP	Subgrade	4.92	8/1/95	11.3		7.65		22.0		7.10		18.5		9.62		15.2		9.64							12.6
		6"DGAB	8.65	10/18/95	5.12		5.26		11.5		6.26		6.48		7.86		7.51		4.16		4.88		8.18		6.45	6.69
		8"PCC		6/12/96	Joint Data Only																					
390202*	C/L	Subgrade	5.50	7/11/95		2.02		2.09		2.04		4.69		6.38		6.99		4.30		5.05		9.95		22.3		6.59
		6"DGAB	9.22	9/5/95		3.77		2.48		4.88		4.25		5.87		8.63		4.50		3.17		4.19		4.99		4.67
		8"HSPCC	9.08	6/12/96	0.40		0.54		0.54		0.44		0.43		0.53		0.52		0.43		0.53		0.53		0.51	0.49
	RWP	Subgrade	5.40	7/11/95	2.22		3.49		4.53		3.51		6.51		4.84		4.65		4.31		16.7		10.8		4.27	5.99
		6"DGAB	9.12	9/5/95	3.56		2.58		10.5		3.87		4.88		3.82		4.42		6.44		7.74		6.79		7.35	5.63
		8"HSPCC		6/12/96	Joint Data Only																					
390203*	C/L	Subgrade	5.11	8/22/95		4.44		6.23		3.36		4.71		4.38		5.34		3.28		5.88		6.70		4.83		4.92
		6"DGAB	8.83	9/5/95		3.55		3.23		4.77		4.70		4.44		4.59		4.68		4.07		3.19		5.22		4.24
		11"PCC	8.74	6/19/96	0.27		0.25		0.34		0.30		0.29		0.29		0.28		0.30		0.30		0.28		0.26	0.29
	RWP	Subgrade	4.95	8/22/95	4.78		3.03		8.67		5.95		4.92		4.92		7.08		5.10		5.85		5.33		5.39	5.55
		6"DGAB			No Data																					
		11"PCC		6/19/96	Joint Data Only																					
390204*	C/L	Subgrade	5.29	6/26/95		3.62		2.81		3.40		2.54		3.99		1.23		1.97		1.40		7.21		1.80		3.00
		6"DGAB	8.49	8/17/95		3.69		4.27		4.38		3.86		4.19		4.80		3.49		3.37		3.02		2.54		3.76
		11"HSPCC	12.22	6/12/96	0.26		0.21		0.24		0.24		0.22		0.21		0.23		0.23		0.18		0.23		0.22	0.22
	RWP	Subgrade	5.24	6/26/95	4.01		4.97		4.29		3.89		2.68		2.38		1.51		1.46		2.77		3.31		3.13	3.13
		6"DGAB	8.35	8/17/95	4.45		4.40		6.07		4.90		5.08		5.92		4.24		5.13		4.24		3.86		3.65	4.72
		11"HSPCC		6/12/96	Joint Data Only																					
390205*	C/L	Subgrade	4.91	7/19/95		5.96		16.6		19.2		5.97		5.51		19.0		8.25		4.50		5.92		6.21		9.71
		6"LCB	9.00	8/29/95		0.72		0.76		0.72		0.74		0.68		0.77		0.75		0.77		0.70		0.78		0.74
		8"PCC	9.47	6/12/96	0.46		0.39		0.38		0.37		0.39		0.35		0.34		0.36		0.47		0.41		0.48	0.40
	RWP	Subgrade	4.62	7/19/95	7.63		19.7		23.6		34.4		18.1		6.01		28.3		9.85		3.42		6.21		5.07	14.75
		6"LCB	9.02	8/29/95	0.69		0.74		0.76		0.80		1.03		0.71		0.80		0.69		0.86		0.90		0.69	0.79
		8"PCC		6/12/96	Joint Data Only																					
390206*	C/L	Subgrade	5.22	7/19/95		8.13		9.73		17.5		5.00		3.21		5.57		3.24		4.42		3.64		6.89		6.73
		6"LCB	9.08	8/29/95		0.87		1.69		1.20		0.83		0.90		0.80		0.83		0.81		0.90		0.86		0.97
		8"HSPCC	9.32	6/12/96	0.45		0.47		0.42		0.45		0.31		0.52		0.49		0.27		0.28		0.38		0.59	0.42
	RWP	Subgrade	5.03	7/19/95	7.85		24.5		10.0		24.0		4.82		5.34		3.94		7.90						3.70	10.2
		6"LCB	9.37	8/29/95	1.04		0.93		1.03		1.35		0.79		0.87		1.00		0.84		0.85		1.08		0.88	0.97
		8"HSPCC		6/12/96	Joint Data Only																					
390207*	C/L	Subgrade	4.52	8/23/95		5.61		3.57		4.31		5.18		5.96		5.43		5.68		7.04		4.40		3.12		5.03
		6"LCB	8.42	10/17/95		0.58		0.54		0.53				0.38		0.48		0.47		0.49		0.52				0.50
		11"PCC	9.16	6/19/96	0.20		0.19		0.20		0.18		0.17		0.18		0.22		0.20		0.25		0.24		0.19	0.20
	RWP	Subgrade	4.82	8/23/95	2.73		2.79		3.68		3.95		3.37		3.75		4.66		7.60		3.39		6.72			4.26
		6"LCB	8.60	10/17/95	0.68		0.58		0.71		0.64		0.56		0.52		0.77		0.82		0.53		0.57		0.53	0.63
		11"PCC		6/19/96	Joint Data Only																					
390208*	C/L	Subgrade	4.70	8/23/95		5.72		6.26		3.83		3.47		2.29		3.46		4.24		2.81		4.17		6.82		4.31
		6"LCB	8.26	10/17/95		0.48		0.51		0.48		0.51		0.51		0.54		0.57		0.66		0.62		0.69		0.56
		11"HSPCC	8.96	6/19/96	0.22		0.30		0.23		0.19		0.29		0.20		0.25		0.24		0.26		0.25		0.24	0.24
	RWP	Subgrade	4.82	8/23/95	3.99		5.58		7.23		5.29		5.74		5.76		3.90		5.24		3.86		6.02		7.16	5.43
		6"LCB	8.28	10/17/95	0.55		0.57		0.70		0.56		0.63		0.59		0.63		0.69		0.66		0.48		0.62	0.61
		11"HSPCC		6/19/96	Joint Data Only																					

* Undrained section

Table E-7

FWD Measurements on Material Layers during Construction – Sections 209 – 260

OHIO SHRP TEST ROAD - FWD Deflection Profiles																										
Section	Path	Layer	Load (k)	Date	Normalized FWD Df1 Deflection (mils/kip) at Station																					
				Station	0+00	0+25	0+50	0+75	1+00	1+25	1+50	1+75	2+00	2+25	2+50	2+75	3+00	3+25	3+50	3+75	4+00	4+25	4+50	4+75	5+00	Avg.
SPS-2																										
390209	C/L	Subgrade	4.31	8/23/95		7.35		13.3		11.7		12.1		24.5		26.7		20.4		3.93		3.77		2.96		12.7
		4"DGAB	9.15	9/11/95		5.90		5.52		5.31		4.68		12.12		6.52		7.23		4.52		5.99		4.82		6.26
		4"PATB	9.10	10/2/95		3.87		3.03		3.14		3.21		5.59		6.18		4.00		3.48		3.42		3.85		3.98
		8"PCC	9.70	6/19/96	0.37		0.40		0.40		0.34		0.42		0.35		0.31		0.38		0.39		0.38		0.39	0.38
	RWP	Subgrade	4.33	8/23/95	5.65		16.9		11.9		20.0		30.3		25.5		10.6		5.23		4.92		2.72		3.07	12.4
		4"DGAB	9.41	9/11/95	10.1		5.24		4.67		5.81		10.8		6.35		6.22		5.77		5.57		9.72		4.49	6.80
		4"PATB	9.31	10/2/95	7.53		3.81		3.50		3.64		3.44		4.20		3.55		3.06		3.63		3.00		3.10	3.86
		8"PCC		6/12/96	Joint Data Only																					
390210	C/L	Subgrade	4.31	6/26/95		17.7		20.1		4.49		9.24		7.40		8.95		9.84		8.63		9.83		24.2		12.0
		4"DGAB	9.60	8/17/95		9.86		8.72		9.09		9.29		9.73		10.8		9.17		9.04		9.04				9.41
		4"PATB	8.73	8/28/95		5.45		3.25		2.83		3.90		3.28		4.12		4.24		4.21		4.37		4.33		4.00
		8"HSPCC	9.42	6/12/96	0.43		0.35		0.33		0.35		0.38		0.35		0.32		0.37		0.32		0.35		0.34	0.35
	RWP	Subgrade	4.67	6/26/95	18.9		5.87		6.06		8.84		6.59		7.21		5.34		5.81		3.99		5.68		4.52	7.16
		4"DGAB	9.81	8/17/95	9.21		8.51				9.92		8.39		8.36				8.09		8.67		8.76		8.72	8.74
		4"PATB	8.78	8/28/95	5.11		3.61		3.90		5.02		4.65		4.87		4.41		5.13		4.57		4.50		4.06	4.53
		8"HSPCC		6/12/96	Joint Data Only																					
390211	C/L	Subgrade	5.02	8/23/95		5.69		4.01		3.60		3.56		3.79		4.25		4.49		4.52		5.12		4.50		4.35
		4"DGAB	9.33	9/18/95		6.70		5.32		5.72		6.71		4.51		6.48		5.86		7.23		5.52		3.92		5.80
		4"PATB	9.28	9/22/95		4.55		4.36		4.00		3.26		3.84		4.44		4.02		3.90		4.34		3.27		4.00
		11"PCC	9.00	6/19/96	0.27		0.25		0.31		0.28		0.32		0.25		0.21		0.28		0.22		0.35		0.26	0.27
	RWP	Subgrade	4.88	8/23/95	4.87		5.37		4.71		5.96		3.58		4.59		3.92		5.85		4.42		4.56		7.70	5.05
		4"DGAB			No Data																					
		4"PATB	9.42	9/22/95	5.02		4.84		3.83		4.20		3.90		3.41		4.25		4.09		4.52		3.06		4.11	4.11
		11"PCC		6/19/96	Joint Data Only																					
390212	C/L	Subgrade	4.89	6/26/95		4.15		3.00		3.48		4.28		2.04		2.94		2.96		3.15		3.95		4.28		3.42
		4"DGAB	9.84	8/17/95		9.01		9.52		5.95				6.76		8.04		7.19		7.95		8.77		8.00		7.91
		4"PATB	9.37	8/28/95		3.17		3.80		3.18		3.31		3.21		3.11		2.69		2.92		2.60		2.90		3.09
		11"HSPCC	8.91	6/12/96	0.25		0.22		0.25		0.25		0.23		0.22		0.24		0.24		0.24		0.27		0.27	0.24
	RWP	Subgrade	4.92	6/26/95	7.42		7.98		5.33		5.15		5.73		2.71		4.42		3.20		3.04		4.78		2.31	4.73
		4"DGAB	9.64	8/17/95	8.96				9.36		9.08		9.75		8.78				9.51		11.3		10.59		9.61	9.66
		4"PATB	9.83	8/28/95	2.81		4.24		3.56		2.83		3.61		2.84		2.96		2.59		3.25		3.31		2.70	3.15
		11"HSPCC		6/12/96	Joint Data Only																					
390259	C/L	Subgrade	5.24	7/11/95		7.47		4.15				5.45		4.03		4.37		10.4		10.8		9.58		7.77		7.11
		6"DGAB	9.99	8/17/95		6.78		7.05		6.53		7.16		6.90		8.15		6.66		5.50		5.98		5.15		6.58
		11"HSPCC	10.26	6/12/96	0.30		0.27		0.23		0.22		0.23		0.26		0.27		0.22		0.23		0.23		0.25	0.25
	RWP	Subgrade	5.31	7/11/95	5.61		5.56		3.79		4.72		6.33		5.75		9.54		28.29		13.6		5.29		22.17	10.1
		6"DGAB	9.66	8/17/95	9.17		7.86		7.13		7.07		6.66		8.42		6.28		7.17		9.71		7.97		10.06	7.96
		11"HSPCC		6/12/96	Joint Data Only																					
390260	C/L	Subgrade	5.30	7/10/95		5.23		4.20		5.23		3.81		5.26				17.9		9.73		3.94		6.95		6.91
		4"DGAB	9.39	9/27/95		6.05		6.72		5.08		7.32		6.10		6.32		4.69		6.83		8.16		7.77		6.50
		4"PATB	9.15	9/28/95		3.50		2.97		3.77		3.75		3.86		5.25		3.26		4.67		4.72		5.20		4.09
		11"PCC	8.95	6/12/96	0.20		0.20		0.24		0.22		0.23		0.24		0.25		0.26		0.23		0.27		0.23	0.23
	RWP	Subgrade	5.40	7/10/95	2.56		4.28		6.89		3.86		4.36						4.45		22.9		4.91		7.51	6.86
		4"DGAB	9.28	9/27/95	6.04		6.11		5.50		9.84		5.20		4.77		5.24		9.11		6.85		5.84		7.50	6.55
		4"PATB	9.29	9/28/95	3.63		3.79		4.14		4.15		3.59		3.54		4.19		5.97		5.11		3.92		4.60	4.24
		11"PCC		6/12/96	Joint Data Only																					

Table E-8

FWD Measurements on Material Layers during Construction – Sections 261 – 265

OHIO SHRP TEST ROAD - FWD Deflection Profiles

Section	Path	Layer	Load	Date	Normalized FWD Df1 Deflection (mils/kip) at Station																					
			(k)	Station	0+00	0+25	0+50	0+75	1+00	1+25	1+50	1+75	2+00	2+25	2+50	2+75	3+00	3+25	3+50	3+75	4+00	4+25	4+50	4+75	5+00	Avg.
SPS-2																										
390261	C/L	Subgrade	5.18	8/23/95		8.02		5.89		4.78		3.84		2.66		4.66		5.19		3.50		3.50		3.49		4.55
		4"DGAB	9.41	9/11/95		4.37		3.99		5.81		3.40		2.96		3.88		4.06		3.06		4.00		4.10		3.96
		4"PCTB	9.97	10/2/95		1.16		0.92		1.35		2.84		1.40		1.03		1.68		1.05		1.79		1.79		1.50
		11"PCC	9.11	6/19/96	0.22		0.21		0.22		0.17		0.16		0.19		0.21		0.24		0.24		0.21		0.20	0.21
	RWP	Subgrade	5.14	8/23/95	22.2		4.02		4.28		2.90		2.28		3.79		4.07		5.06		3.68		3.52		3.74	5.41
		4"DGAB			No Data																					
		4"PCTB	9.66	10/2/95	2.18		1.36		1.37		2.69		2.38		1.66		1.85		1.81		1.46		1.13		1.35	1.75
		11"PCC		6/19/96	Joint Data Only																					
390262	C/L	Subgrade	4.68	8/23/95		3.80		4.44		4.34		5.51		2.30		3.21		7.17		6.24		5.69		6.73		4.94
		4"DGAB	8.58	9/5/95		4.17		5.92		4.95		4.52		4.56		4.57		6.74		8.92		5.28		6.22		5.59
		4"PCTB			No Data																					
		11"PCC	9.06	6/19/96	0.23		0.21		0.20		0.18		0.22		0.22		0.22		0.25		0.24		0.27		0.23	0.22
	RWP	Subgrade	4.62	8/23/95	4.85		4.92		5.32		5.29		2.67		3.63		5.80		6.46		4.46		8.99		12.8	5.92
		4"DGAB	8.46	9/5/95	6.36		4.31		4.71		4.15		6.00		5.77		7.96		8.01		6.09		10.9		9.66	6.72
		4"PCTB			No Data																					
		11"PCC		6/19/96	Joint Data Only																					
390263	C/L	Subgrade	4.53	8/23/95		6.49		18.9		5.97		7.03		3.40		3.58		3.70		4.27		3.61		4.08		6.10
		6"DGAB	8.64	9/5/95		4.62		8.22		4.15		4.99		3.36		3.77		3.11		4.07		4.59		3.86		4.47
		11"PCC	8.99	6/19/96	0.31		0.23		0.30		0.28		0.28		0.29		0.29		0.26		0.26		0.34		0.30	0.29
	RWP	Subgrade	4.26	8/23/95	10.3		7.56		10.2		8.29		20.2		4.85		5.65		9.67		4.56		6.92		2.90	8.28
		6"DGAB	8.58	9/5/95	6.28		4.53		5.51		6.77		8.85		3.82		4.18		4.33		4.67		6.26		4.62	5.44
		11"PCC		6/19/96	Joint Data Only																					
390264	C/L	Subgrade	4.97	6/20/96		9.08		15.3		21.6		18.0		5.95		14.9		18.8		19.9		19.9		18.1		16.2
		6"DGAB			No Data																					
		11"PCC			No Data																					
	RWP	Subgrade	3.68	6/20/96	10.2		14.6		18.1		26.3		14.5		23.8		14.6		22.0		13.2		15.0		24.5	17.9
		6"DGAB			No Data																					
		11"PCC			No Data																					
390265	C/L	Subgrade	5.27	8/22/95												7.51		4.95		5.99		4.46		4.72		5.53
		4"DGAB	8.84	9/18/95	7.43		3.89		4.72		13.8		5.46		4.54		9.94		6.10		6.05		6.73			6.87
		4"PATB	9.25	9/22/95	4.05		2.94		2.59		4.33		3.49		3.51		3.80		3.72		3.81		4.29			3.65
		11"PCC	8.59	6/19/96	0.24		0.26		0.22		0.20		0.24		0.26		0.26		0.27		0.26		0.25		0.27	0.25
	RWP	Subgrade	5.25	8/22/95													7.27		6.97		4.45		5.31		7.37	6.27
		4"DGAB	9.22	9/18/95	5.67		4.25		4.01		8.82		4.90		10.6		4.94		6.20		5.72		8.04		8.45	6.51
		4"PATB	9.10	9/22/95	3.69		3.60		3.10		6.61		3.70		4.79		3.34		3.65		4.34		4.14		3.40	4.03
		11"PCC		6/19/96	Joint Data Only																					

APPENDIX F

1998 FWD Measurements

Table F-1

1998 Average FWD Measurements – AC Sections

Asphalt Concrete										
		Surface	Centerline				Right Wheelpath			
Section	Date	Temp. (ºF)	File	Load (kips)	Df1 (mils/kip)	SPR (%)	File	Load (kips)	Df1 (mils/kip)	SPR (%)
103*	5/5/98	60	390103b1	7175	0.55	83.8	390103b3	7126	0.60	82.8
				9128	0.74	69.4		9071	0.80	67.3
				11991	0.75	75.9		12028	0.79	73.9
104*	5/5/98	85					390104b3	6902	0.31	89.5
								9571	0.40	69.5
								12545	0.38	78.6
105*	5/5/98	71					390105b3	6505	1.27	66.7
								9437	1.52	60.9
								12255	1.65	63.3
106*	5/5/98	85					390106b3	7178	0.35	86.2
								9715	0.49	67.6
								12638	0.47	75.8
108	5/5/98	60	390108b1	5888	0.64	75.3	390108b3	6574	0.72	73.1
				9081	0.85	62.9		9529	0.93	61.2
				11964	0.88	66.1		12383	0.94	66.0
109	5/5/98	60	390109b1	6612	0.58	76.0	390109b3	6548	0.63	76.0
				9503	0.77	62.8		9495	0.86	61.9
				12284	0.79	67.7		12359	0.85	67.4
110	5/5/98	60	390110b1	7041	0.42	88.1	390110b3	7120	0.44	84.6
				9180	0.58	67.9		9258	0.57	68.2
				12116	0.56	76.0		12140	0.58	74.2
111	5/5/98	88					390111b3	6813	0.51	81.6
								9420	0.63	68.9
								12428	0.64	73.1
112	5/5/98	88					390112b3	6889	0.35	88.5
								8935	0.48	70.9
								11800	0.47	78.0
159	5/5/98	60	390159b1	7260	0.09	247.7	390159b3	7228	0.09	239.7
				9298	0.20	75.7		9188	0.20	73.2
				12569	0.18	75.5		12391	0.18	84.4
160	5/5/98	71					390160b3	6991	0.32	96.0
								9589	0.50	67.5
								12501	0.46	79.1
161	5/5/98	71					390161b3	6832	0.37	85.4
								9450	0.51	65.1
								12261	0.48	75.0
162	5/5/98	80					390162b3	7062	0.27	85.5
								9710	0.40	60.1
								12762	0.36	70.2
163	5/5/98	85					390163b3	7047	0.24	91.1
								9629	0.44	54.3
								12689	0.36	68.7
901	5/5/98	80					390901b3	6815	0.24	90.5
								9106	0.37	64.9
								12040	0.35	72.8
902	5/5/98	88					390902b3	6697	0.23	91.6
								9186	0.35	64.7
								12093	0.34	72.1
903	5/5/98	88					390903b3	6780	0.27	92.7
								9243	0.44	64.0
								11975	0.38	77.2

* Section undrained

Table F-2

1998 Average FWD Measurements – Centerline PCC Sections

Portland Cement Concrete - Centerline													
Section	Date	File	Surf. Temp. (ºF)	Midslab			Joint Approach			Joint Leave			
				Load	Df1 (mils/kip)	SPR (%)	Load	Df1 (mils/kip)	LT (%) (Df3/Df1)	Load	Df1 (mils/kip)	JSR (Df1L/Df1A)	
201*	5/4/98	390201b1	65	8966	0.65	72.8	8893	0.68	80.0	8901	0.57	0.85	
				11796	0.60	83.9	11739	0.57	103.8	11773	0.59	1.02	
				15111	0.66	81.6	15141	0.65	97.6	15136	0.61	0.94	
202*	5/4/98	390202b1	65	8887	0.62	73.3							
				11775	0.56	85.8							
				15116	0.61	83.4							
203*	5/4/98	390203b1	71	8570	0.43	68.0							
				11591	0.33	89.1							
				15055	0.36	86.2							
204*	5/4/98	390204b1	58	9825	0.31	71.0							
				12941	0.24	93.2							
				15833	0.30	81.1							
205*	5/4/98	390205b1	65	9270	0.48	71.1	9269	0.51	83.7	9387	0.47	0.92	
				12126	0.47	80.4	12109	0.51	97.2	12237	0.51	1.01	
				15254	0.51	80.0	15325	0.53	98.4	15280	0.55	1.04	
206*	5/4/98	390206b1	65	9215	0.48	74.4							
				12065	0.46	84.3							
				15179	0.51	84.7							
207*													
208*													
209													
210	5/4/98	390210b1	62	9249	0.43	67.5							
				12108	0.36	85.6							
				15324	0.43	79.0							
211	5/4/98	390211b1	71	8969	0.40	62.2							
				11985	0.27	93.0							
				15235	0.31	86.1							
212	5/4/98	390212b1	62	9378	0.37	61.3							
				12306	0.24	94.6							
				15463	0.29	86.3							
259	5/4/98	390259b1	58	10109	0.30	71.8							
				13222	0.28	87.1							
				15938	0.33	82.3							
260	5/4/98	390260b1	65	9087	0.33	65.2							
				11886	0.24	90.6							
				15364	0.27	91.2							
261	5/4/98	390261b1	71	9063	0.30	66.6							
				11883	0.22	94.1							
				15228	0.25	88.1							
262	5/4/98	390262b1	75	9024	0.32	66.1							
				12089	0.20	97.0							
				15387	0.24	88.3							
263	5/4/98	390263b1	82	8657	0.53	69.1							
				11669	0.41	91.1							
				15310	0.42	87.8							
264	5/4/98	390264b1	82	8514	0.47	69.6							
				11344	0.37	89.2							
				15298	0.37	89.1							

* Section undrained

Table F- 3

1998 Average FWD Measurements – RWP PCC Sections

Portland Cement Concrete - Right Wheelpath												
Section	Date	File	Surf. Temp. (ºF)	Midslab			Joint Approach			Joint Leave		
				Load	Df1 (mils/kip)	SPR (%)	Load	Df1 (mils/kip)	LT (%) (Df3/Df1)	Load	Df1 (mils/kip)	JSR (Df1L/Df1A)
201*												
202*	5/4/98	390202b3	65	8629	0.88	73.1	8792	0.86	83.9	8850	0.82	0.96
				11549	0.74	86.6	11798	0.77	99.8	11738	0.79	1.02
				15003	0.84	80.0	15036	0.82	98.4	15040	0.80	0.98
203*												
204*	5/4/98	390204b3	58	9580	0.51	74.8	9416	0.58	73.6	9184	0.56	0.97
				12736	0.43	82.1	12460	0.44	108.8	12204	0.46	1.06
				15592	0.50	78.1	15487	0.54	96.0	15551	0.54	0.99
205*												
206*												
207*	5/4/98	390207b3	75	8893	0.34	67.7						
				11876	0.27	88.4						
				15199	0.30	84.3						
208*	5/4/98	390208b3	75	8914	0.41	61.5						
				11943	0.25	96.7						
				15215	0.31	84.2						
209	5/4/98	390209b3	71	9044	0.54	68.6	8952	0.70	76.7	8836	0.64	0.94
				11948	0.47	85.1	11756	0.57	107.1	11672	0.58	1.01
				15176	0.52	82.1	15152	0.67	96.1	15184	0.61	0.93
210	5/4/98	390210b3	62	8960	0.51	69.7	9069	0.60	80.7	9059	0.56	0.92
				12008	0.44	85.2	11970	0.58	95.4	12040	0.54	0.93
				15284	0.53	76.6	15323	0.62	96.2	15301	0.61	0.98
211												
212	5/4/98	390212b3	62	8732	0.46	70.5	9008	0.56	79.6	8846	0.60	1.07
				11736	0.36	90.2	11986	0.47	107.7	11778	0.44	0.95
				15448	0.38	88.4	15274	0.54	99.4	15363	0.52	0.96
259	5/4/98	390259b3	58	9884	0.45	73.7	9943	0.55	86.0	9684	0.56	1.02
				12924	0.39	89.1	12921	0.53	101.8	12833	0.51	0.95
				15744	0.48	82.5	15688	0.62	99.5	15693	0.59	0.95
260	5/4/98	390260b3	65	8904	0.41	66.8	8789	0.54	77.1	8912	0.55	1.01
				11800	0.34	84.7	11558	0.45	105.6	11680	0.42	0.95
				15432	0.36	82.7	15355	0.49	99.6	15299	0.46	0.94
261												
262												
263												
264												
265	5/4/98	390265b3	71	8673	0.33	81.0						
				11578	0.29	85.2						
				15107	0.31	89.1						

* Section undrained

APPENDIX G

1999 FWD Measurements

Table G-1

1999 Average FWD Measurements – AC Sections

Asphalt Concrete										
Section	Date	Surface Temp. (ºF)	Centerline				Right Wheelpath			
			File	Load (kips)	Df1 (mils/kip)	SPR (%)	File	Load (kips)	Df1 (mils/kip)	SPR (%)
103*	9/13/99	67	390103D1	6084	1.14	65.8	390103D3	5867	1.17	65.6
				9113	1.16	65.7		8975	1.17	66.0
				12491	1.17	66.4		12359	1.19	66.1
				16404	1.19	66.4		16388	1.20	66.3
104*	9/14/99	68	390104A9	6177	0.51	68.5	390104B9	6183	0.52	67.8
				9216	0.52	67.6		9217	0.53	67.9
				12602	0.52	68.6		12558	0.53	68.2
106*	9/14/99	64	390106A9	6151	0.60	66.6	390106B9	6178	0.61	66.1
				9170	0.62	65.9		9183	0.63	65.8
				12572	0.63	66.7		12563	0.64	66.5
108	9/14/99	57	390108A9	6227	0.99	62.2	390108B9	6286	1.07	60.3
				9327	1.02	62.0		9375	1.10	60.2
				12683	1.05	62.4		12713	1.12	60.9
109	9/14/99	57	390109A9	6363	0.91	63.7	390109B9	6307	0.95	62.7
				9489	0.94	63.1		9432	0.98	62.8
				12813	0.97	63.9		12782	1.01	63.5
110	9/14/99	57	390110A9	6416	0.68	69.6	390110B9	6388	0.71	68.7
				9533	0.69	69.0		9532	0.72	68.3
				12881	0.72	69.2		12891	0.74	68.5
111	9/14/99	70	390111A9	6123	0.75	67.3	390111B9	6099	0.80	66.4
				9145	0.78	66.9		9129	0.82	66.3
				12502	0.80	67.6		12509	0.84	66.8
112	9/14/99	69	390112A9	6703	0.43	72.7	390112B9	6583	0.45	71.3
				9783	0.45	71.0		9666	0.46	70.5
				13124	0.46	71.5		13043	0.47	71.0
160	9/14/99	58	390160A9	6229	0.53	70.8	390160B9	6240	0.53	71.1
				9338	0.55	69.6		9326	0.55	69.7
				12752	0.55	70.5		12744	0.56	70.5
161	9/14/99	61	390161A9	6291	0.47	68.1	390161B9	6261	0.47	68.0
				9325	0.50	65.9		9311	0.50	65.5
				12684	0.51	67.0		12676	0.50	66.7
162	9/14/99	62	390162A9	6253	0.33	63.4	390162B9	6332	0.31	63.5
				9306	0.36	60.3		9335	0.34	61.0
				12677	0.37	61.5		12697	0.34	62.3
163	9/14/99	62	390163A9	6250	0.35	59.8	390163B9	6266	0.34	59.2
				9289	0.39	56.4		9286	0.37	56.0
				12610	0.39	57.8		12659	0.37	57.9
164	9/14/99	57	390164A9	6246	1.14	65.2	390164B9	6233	1.15	65.0
				9292	1.22	63.9		9297	1.21	64.6
				12575	1.28	64.8		12665	1.26	65.4
901	9/15/99	57	390901a1	6305	0.35	66.7	390901b9	6266	0.36	66.7
				9360	0.36	66.1		9302	0.37	65.7
				12781	0.36	66.5		12707	0.37	66.2
902	9/15/99	69	390902a1	6544	0.30	69.4	390902b9	6516	0.29	69.3
				9675	0.31	67.5		9619	0.31	67.3
				13195	0.31	68.6		13106	0.31	68.4
903	9/15/99	54	390903a1	6355	0.40	68.0	390903b3	6325	0.41	67.9
				9420	0.41	67.0		9371	0.42	66.9
				12812	0.42	67.5		12743	0.42	67.5

* Section undrained

Table G-2

1998 Average FWD Measurements – PCC Sections

Section	Date Mdslb. RWP	File Mdslb. RWP	Surf. Temp. (°F)	PCC - Centerline			PCC - Right Wheelpath					
				Midslab			Joint Approach			Joint Leave		
				Load	Df1 (mils/kip)	SPR (%)	Load	Df1 (mils/kip)	LT (%) (Df3/Df1)	Load	Df1 (mils/kip)	JSR (Df1L/Df1A)
201*	9/15/99 9/16/99	390201A9 390201B9	71 48	8978	0.65	80.2	9248	2.13	95.9	9272	2.01	0.95
				12279	0.64	80.8	12542	2.15	96.6	12578	2.01	0.94
				16122	0.63	80.6	16177	2.13	96.8	16252	1.99	0.93
202*	9/15/99 9/16/99	390202A9 390202B9	71 64	9044	0.69	81.5	9054	0.61	93.7	9076	0.58	0.95
				12406	0.68	82.1	12478	0.60	95.1	12483	0.59	0.98
				16249	0.67	81.9	16411	0.61	94.4	16439	0.60	0.98
203*	9/16/99 9/17/99	390203A9 390203B9	53 54	9261	0.32	79.9	9265	0.63	97.3	9283	0.56	0.89
				12669	0.31	82.2	12679	0.59	97.4	12700	0.56	0.94
				16509	0.32	81.7	16422	0.60	97.3	16440	0.57	0.95
204*	9/15/99 9/16/99	390204A9 390204B9	59 57	9313	0.27	80.3	9119	0.79	95.4	9099	0.72	0.90
				12574	0.27	81.5	12494	0.77	95.7	12474	0.72	0.93
				16518	0.28	81.1	16238	0.78	95.3	16232	0.74	0.95
205*	9/15/99 9/17/99	390205A9 390205B9	71 48	9003	0.54	77.3	9213	2.39	75.5	9352	1.26	0.79
				12334	0.54	78.4	12463	2.31	75.6	12615	1.26	0.79
				16089	0.55	78.3	16302	2.20	75.4	16540	1.23	0.79
206*	9/15/99 9/17/99	390206A9 390206B9	71 48	9081	0.55	78.5	9470	1.06	93.9	9426	0.99	0.94
				12367	0.55	79.2	12796	1.06	94.6	12763	0.99	0.94
				16099	0.56	78.9	16737	1.03	94.2	16718	0.97	0.94
207*	9/16/99 9/17/99	390207A9 390207B9	55 54	9245	0.25	81.4	9235	0.39	92.1	9274	0.36	0.92
				12680	0.25	83.4	12733	0.38	94.3	12734	0.35	0.94
				16395	0.26	82.5	16383	0.38	94.1	16397	0.37	0.95
208*	9/16/99 9/17/99	390208A9 390208B9	55 54	9224	0.26	83.9	9267	0.49	95.1	9285	0.45	0.92
				12629	0.26	85.6	12709	0.47	96.5	12737	0.45	0.95
				16410	0.27	84.3	16409	0.48	95.1	16494	0.45	0.95
209	9/16/99 9/17/99	390209A9 390209B9	51 49	9430	0.42	77.0	9339	0.87	91.6	9325	0.82	0.95
				12693	0.43	78.9	12641	0.90	92.4	12656	0.84	0.93
				16931	0.43	78.5	16458	0.93	92.5	16424	0.86	0.93
210	9/15/99 9/16/99	390210A9 390210B9	66 61	9154	0.45	77.7	9068	0.61	88.1	9065	0.56	0.92
				12393	0.46	78.6	12391	0.61	89.8	12353	0.57	0.93
				16100	0.47	78.5	16096	0.64	89.6	15993	0.59	0.92
211	9/16/99 9/17/99	390211A9 390211B9	51 49	9297	0.28	79.9	9348	0.44	88.4	9373	0.41	0.94
				12619	0.28	82.9	12676	0.45	90.6	12722	0.43	0.96
				16538	0.28	82.1	16390	0.46	90.1	16373	0.44	0.96
212	9/15/99 9/16/99	390212A9 390212B9	66 61	9254	0.28	81.7	9101	0.52	92.4	9123	0.52	0.99
				12559	0.28	82.4	12453	0.53	95.0	12410	0.52	0.99
				16271	0.29	82.4	16152	0.55	94.5	16094	0.54	0.98
259	9/15/99 9/16/99	390259A9 390259B9	59 57	9207	0.32	81.5	9162	0.85	95.6	9145	0.86	1.01
				12407	0.33	82.4	12440	0.84	96.8	12439	0.85	1.01
				16349	0.33	82.1	16066	0.85	96.5	16031	0.86	1.01
260	9/15/99 9/16/99	390260A9 390260B9	71 64	9182	0.27	80.2	9096	0.44	92.2	9120	0.40	0.96
				12419	0.27	81.0	12409	0.45	94.1	12408	0.40	0.96
				16148	0.28	80.7	15961	0.47	93.6	16099	0.42	0.95
261	9/16/99 9/17/99	390261A9 390261B9	51 49	9442	0.23	82.5	9410	0.33	91.9	9385	0.32	0.97
				12857	0.23	84.1	12852	0.33	93.4	12822	0.32	0.97
				16685	0.23	83.2	16582	0.34	92.6	16483	0.33	0.97
262	9/16/99 9/17/99	390262A9 390262B9	55 57	9224	0.24	82.2	9243	0.49	97.4	9261	0.45	0.92
				12535	0.23	85.8	12579	0.47	99.0	12577	0.45	0.96
				16204	0.23	84.5	16302	0.48	97.5	16299	0.46	0.96
263	9/16/99 9/17/99	390263A9 390263B9	58 57	9194	0.32	81.3	9219	0.51	96.9	9212	0.47	0.91
				12576	0.31	83.5	12609	0.49	97.4	12650	0.47	0.96
				16320	0.32	82.5	16316	0.49	97.2	16333	0.48	0.97
264	9/17/99	390264A9 390264B9	58 61	9203	0.35	81.0	9162	0.68	97.8	9155	0.69	1.01
				12533	0.35	82.7	12530	0.68	98.9	12516	0.67	0.99
				16351	0.35	82.5	16289	0.68	98.8	16326	0.66	0.98
265	9/16/99 9/17/99	390265A9 390265B9	53 49	9296	0.28	79.7	9347	0.45	90.9	9322	0.44	0.98
				12748	0.27	82.7	12774	0.45	93.0	12722	0.44	0.97
				16641	0.28	81.5	16518	0.47	92.7	16505	0.45	0.97

* Section undrained

APPENDIX H

2000 FWD Measurements

Table H-1

2000 Average FWD Measurements – AC Sections

Asphalt Concrete										
Section	Date	Surface Temp. (ºF)	Centerline				Right Wheelpath			
			Files	Load (kips)	Df1 (mils/kip)	SPR (%)	File	Load (kips)	Df1 (mils/kip)	SPR (%)
103*	9/29/00	47	390103A0	6503	0.94	71.2	390103B0	6584	0.95	69.3
				9468	0.97	71.3		9531	0.98	69.5
				12876	0.99	71.3		12826	1.00	70.0
104*	9/26/00	50	390104A0	6464	0.40	70.0	390104B0	6489	0.42	68.6
				9479	0.40	70.9		9463	0.41	69.3
				12887	0.41	70.7		12868	0.42	69.2
106*	9/26/00	50	390106A0	6463	0.50	69.2	390106B0	6497	0.48	69.4
				9455	0.50	70.2		9519	0.48	71.2
				12902	0.51	70.7		12923	0.49	71.4
108	9/26/00	50	390108A0	6424	0.98	62.9	390108B0	6487	1.15	59.3
				9384	1.01	63.3		9436	1.16	60.2
				12814	1.02	63.4		12758	1.17	60.7
109	9/25/00	47	390109A0	6510	0.86	63.7	390109B0	6526	0.94	62.4
				9485	0.88	64.5		9443	0.97	63.2
				12869	0.90	64.8		12787	0.98	63.8
110	9/25/06	47	390110A0	6543	0.65	69.6	390110B0	6604	0.68	68.8
				9503	0.66	70.7		9598	0.69	69.5
				12903	0.67	70.5		12988	0.70	69.5
111	9/26/00	51	390111A0	6361	0.62	69.6	390111B0	6420	0.61	70.0
				9318	0.64	69.5		9418	0.63	70.5
				12783	0.65	69.0		12819	0.65	69.9
112	9/26/00	53	390112A0	6405	0.43	70.9	390112B0	6436	0.44	71.0
				9423	0.45	70.9		9423	0.44	72.0
				12806	0.43	72.4		12789	0.47	70.3
159	9/25/00	47	390159A0	6719	0.22	65.8	390159B0	6659	0.22	67.8
				9731	0.22	67.2		9680	0.22	68.5
				12942	0.23	66.9		12940	0.23	68.1
160	9/25/00	48	390160A0	6502	0.51	70.6	390160B0	6525	0.48	71.2
				9483	0.51	71.7		9523	0.49	72.2
				12881	0.52	71.7		12943	0.49	72.2
161	9/26/00	47	390161A0	6774	0.40	69.2	390161B0	6684	0.41	67.7
				9810	0.40	69.6		9760	0.41	68.9
				13136	0.40	70.5		13047	0.41	69.6
162	9/26/00	47	390162A0	6573	0.29	64.3	390162B0	6666	0.27	65.2
				9623	0.28	66.4		9717	0.26	67.5
				13005	0.29	66.6		13014	0.27	67.5
163	9/26/00	47	390163A0	6491	0.32	59.1	390163B0	6570	0.30	59.3
				9570	0.31	61.7		9622	0.29	62.6
				12902	0.31	61.5		12989	0.30	62.2
164	9/25/00	48	390164A0	6439	0.94	63.7	390164B0	6473	0.95	64.7
				9425	0.97	64.4		9443	1.00	65.1
				12781	1.01	64.5		12808	1.03	65.4
A803*	9/29/00	46	39A803A0	6354	1.19	36.9	390803B0	6430	1.17	35.5
				9369	1.11	36.9		9470	1.07	35.4
				12696	1.03	37.5		12647	1.00	35.8
A804*	9/29/00	49	39A804A0	6504	0.58	46.1	390803B0	6460	0.62	45.6
				9507	0.56	47.0		9453	0.61	45.7
				12897	0.54	47.2		12847	0.60	45.3

* Section undrained

Table H-2

2000 Average FWD Measurements – PCC Sections

Section	Date	File Mdslb. RWP	Surf. Temp. (ºF)	PCC - Centerline			PCC - Right Wheelpath					
				Midslab			Joint Approach			Joint Leave		
				Load	Df1 (mils/kip)	SPR (%)	Load	Df1 (mils/kip)	LT (%) (Df3/Df1)	Load	Df1 (mils/kip)	JSR (Df1L/Df1A)
809*	9/29/00	390809A03 90809B0	43	9467	0.64	74.0	9399	2.03	92.9	9403	2.05	1.01
				12836	0.68	73.0	12755	1.96	93.2	12748	1.97	1.02
				17021	0.69	73.1	16990	1.85	92.4	16997	1.83	0.99
810*	9/29/00	390810A03 90810B0	43	9606	0.39	79.6	9574	1.23	92.8	9551	1.28	1.04
				12982	0.40	80.4	12914	1.24	92.4	12826	1.26	1.02
				17390	0.40	79.7	17615	1.16	92.5	17599	1.17	1.01

* Section undrained

APPENDIX I

April 2001 FWD Measurements

Table I-1

April 2001 Average FWD Measurements – AC Sections

Asphalt Concrete										
Section	Date	Surface Temp. (ºF)	Centerline				Right Wheelpath			
			File	Load (kips)	Df1 (mils/kip)	SPR (%)	File	Load (kips)	Df1 (mils/kip)	SPR (%)
103*	4/11/01	59	390103A1	6269	1.21	69.4	390103B1	6190	1.23	67.0
				9255	1.24	69.6		9199	1.27	67.2
				12673	1.26	70.1		12460	1.30	67.7
104*	4/11/01	70	390104A1	6299	0.53	66.2	390104B1	6359	0.50	68.3
				9269	0.54	66.0		9287	0.51	68.0
				12576	0.55	66.7		12659	0.52	68.5
106*	4/11/01	67	390106A1	6229	0.66	66.4	390106B1	6294	0.64	66.8
				9195	0.68	66.5		9234	0.65	66.7
				12550	0.70	66.8		12579	0.67	67.2
108	4/11/01	64	390108A1	6130	1.18	59.6	390108B1	6224	1.26	58.1
				9051	1.22	59.7		9115	1.31	58.3
				12376	1.26	60.0		12445	1.35	58.9
109	4/11/01	61	390109A1	6144	0.97	59.7	390109B1	6156	1.03	59.3
				9171	0.98	60.4		9086	1.05	59.7
				12547	1.00	60.9		12479	1.06	60.5
110	4/11/01	59	390110A1	6262	0.76	68.1	390110B1	6200	0.83	66.3
				9229	0.77	68.7		9256	0.84	66.7
				12656	0.78	68.9		12631	0.86	67.0
111	4/12/01	68	390111A1	6518	0.75	65.7	390111B1	6345	0.75	65.5
				9481	0.76	66.2		9314	0.77	65.7
				12760	0.79	66.6		12623	0.79	66.6
112	4/12/01	68	390112A1	6259	0.52	67.9	390112B1	6367	0.52	67.8
				9289	0.52	68.2		9357	0.52	68.4
				12632	0.53	68.4		12650	0.53	68.5
160	4/11/01	59	390160A1	6197	0.60	68.5	390160B1	6162	0.57	69.6
				9201	0.61	68.4		9194	0.57	69.7
				12622	0.61	68.9		12616	0.58	70.1
161	4/11/01	59	390161A1	6202	0.47	65.2	390161B1	6218	0.46	65.1
				9236	0.47	65.6		9261	0.46	65.7
				12605	0.48	66.0		12663	0.47	66.2
162	4/11/01	59	390162A1	6255	0.31	59.8	390162B1	6251	0.28	63.4
				9249	0.32	60.8		9242	0.29	62.7
				12635	0.32	61.4		12691	0.29	63.6
163	4/11/01	59	390163A1	6282	0.34	56.1	390163B1	6258	0.33	55.6
				9253	0.35	56.5		9230	0.34	55.4
				12604	0.36	57.0		12675	0.34	56.5
164	4/11/01	59	390164A1	6184	0.91	61.2	390164B1	6126	0.91	62.9
				9175	0.94	61.8		9124	0.94	63.3
				12549	0.98	62.2		12550	0.97	63.7
901	4/12/01	70	390901A1	6228	0.40	61.2	390901B1	6267	0.42	60.1
				9197	0.40	61.8		9240	0.42	60.8
				12565	0.41	62.2		12564	0.42	61.3
902	4/12/01	68	390902A1	6315	0.30	67.1	390902B1	6360	0.30	66.4
				9296	0.30	68.0		9326	0.30	67.2
				12672	0.31	68.2		12703	0.31	67.7
903	4/12/01	79	390903A1	6244	0.46	62.9	390903B1	6299	0.44	63.9
				9201	0.46	63.2		9274	0.45	63.9
				12532	0.47	63.6		12564	0.45	64.8

* Section undrained

Table I-2

April 2001 Average FWD Measurements – SPS-2 (PCC)

Section	Date	File Mdslb. RWP	Surf. Temp. (ºF)	PCC - Centerline			PCC - Right Wheelpath					
				Midslab			Joint Approach			Joint Leave		
				Load	Df1 (mils/kip)	SPR (%)	Load	Df1 (mils/kip)	LT (%) (Df3/Df1)	Load	Df1 (mils/kip)	JSR (Df1L/Df1A)
201*	4/3/01	390201A1 390201B1	54	9131	0.54	80.5	9172	0.88	85.9	9174	0.84	0.96
				12578	0.54	80.9	12559	0.90	86.5	12600	0.86	0.96
				16502	0.56	80.4	16407	0.92	87.2	16544	0.88	0.95
202*	4/3/01	390202A1 390202B1	53	9229	0.67	82.9	9294	0.74	96.0	9279	0.70	0.95
				12633	0.66	83.0	12783	0.76	94.7	12769	0.72	0.96
				16535	0.66	82.7	16664	0.77	95.0	16721	0.74	0.95
203*	4/4/01	390203A1 390203B1	36	9428	0.33	81.8	9363	0.66	83.6	9424	0.62	0.94
				12984	0.32	83.1	12847	0.66	84.6	12926	0.62	0.95
				17205	0.33	82.7	16845	0.67	84.6	16889	0.63	0.94
204*	4/3/01	390204A1 390204B1	39	9493	0.27	82.5	9440	0.70	84.9	9385	0.75	1.06
				12917	0.27	82.4	12845	0.72	83.4	12809	0.76	1.04
				17478	0.27	81.6	16822	0.72	83.7	16770	0.76	1.03
205*	4/3/01	390205A1 390205B1	53	9140	0.51	78.7	9185	0.60	89.8	9240	0.58	0.96
				12580	0.52	79.0	12597	0.62	89.6	12614	0.60	0.97
				16483	0.53	78.7	16438	0.63	89.9	16429	0.62	0.98
206*	4/4/01	390206A1 390206B1	53	9239	0.50	81.0	9303	0.65	90.0	9297	0.62	0.96
				12614	0.51	81.0	12698	0.66	89.7	12695	0.65	0.98
				16435	0.52	80.9	16649	0.67	89.6	16677	0.65	0.97
207*	4/4/01	390207A1 390207B1	36	9438	0.27	83.2	9488	0.46	84.0	9532	0.41	0.91
				12918	0.28	83.8	12871	0.46	84.8	12952	0.42	0.91
				17048	0.28	83.5	16788	0.47	84.5	16876	0.43	0.92
208*	4/4/01	390208A1 390208B1	51	9536	0.30	84.2	9464	0.47	89.5	9471	0.44	0.93
				12851	0.30	84.5	12884	0.48	90.1	12943	0.45	0.94
				16805	0.31	84.3	16881	0.49	90.3	16854	0.46	0.95
209	4/4/01	390209A1 390209B1	54	9096	0.46	80.1	9192	0.69	92.7	9193	0.63	0.91
				12465	0.46	80.8	12560	0.72	92.3	12597	0.65	0.91
				16240	0.48	80.2	16426	0.74	92.6	16404	0.68	0.92
210	4/3/01	390210A13 90210B1	42	9366	0.40	78.9	9341	0.63	90.4	9300	0.60	0.95
				12782	0.41	79.3	12608	0.65	90.6	12624	0.63	0.97
				16961	0.41	78.9	16565	0.67	91.3	16539	0.65	0.96
211	4/4/01	390211A1 390211B1	35	9491	0.27	83.2	9368	0.50	90.4	9390	0.47	0.95
				13030	0.27	83.8	12761	0.50	92.5	12822	0.48	0.97
				17393	0.27	83.3	16927	0.50	92.2	16927	0.47	0.96
212	4/3/01	390212A1 390212B1	39	9473	0.26	83.4	9380	0.57	97.4	9414	0.57	0.99
				12969	0.26	84.1	12828	0.58	96.3	12797	0.59	1.01
				17218	0.26	83.1	16720	0.59	96.8	16808	0.59	1.00
259	4/3/01	390259A1 390259B1	39	9488	0.31	83.3	9269	0.61	95.5	9330	0.60	0.98
				13122	0.31	82.9	12627	0.63	96.0	12662	0.63	1.00
				17808	0.30	82.6	16349	0.66	95.9	16387	0.65	1.00
260	4/3/01	390260A1 390260B1	42	9399	0.25	82.6	9351	0.43	90.3	9300	0.39	0.91
				12776	0.25	83.3	12698	0.44	91.6	12705	0.41	0.94
				16840	0.25	82.4	16556	0.45	91.0	16540	0.42	0.93
261	4/4/01	390261A1 390261B1	35	9530	0.23	83.9	9481	0.45	90.1	9496	0.43	0.97
				13150	0.22	84.9	12992	0.45	90.8	13080	0.43	0.96
				17493	0.22	84.0	17050	0.45	91.0	17015	0.44	0.97
262	4/4/01	390262A1 390262B1	53	9418	0.24	83.8	9450	0.46	90.6	9510	0.43	0.93
				12677	0.24	85.7	12710	0.47	92.8	12821	0.45	0.95
				16759	0.24	85.2	16736	0.48	91.8	16790	0.45	0.95
263	4/4/01	390263A1 390263B1	53	9380	0.42	85.9	9456	0.56	80.3	9488	0.52	0.92
				12812	0.42	86.1	12898	0.56	81.4	12888	0.52	0.93
				16608	0.42	85.6	16814	0.57	81.3	16771	0.52	0.92
264	4/4/01	390264A13 90264B1	53	9421	0.36	85.0	9468	0.60	93.3	9456	0.57	0.95
				12862	0.36	85.0	12885	0.60	94.1	12920	0.58	0.95
				16645	0.36	84.8	16688	0.61	93.9	16754	0.59	0.95
265	4/4/01	390265A1 390265B1	35	9531	0.26	83.0	9466	0.51	91.2	9506	0.48	0.93
				13132	0.26	83.6	12966	0.52	91.6	12960	0.49	0.94
				17331	0.26	83.3	16980	0.52	91.7	16969	0.49	0.94

* Section undrained

Table I-3

April 2001 Average FWD Measurements – SPS-8 (PCC)

Section	Date	File Mdslb. RWP	Surf. Temp. (ºF)	PCC - Centerline Midslab			PCC - Right Wheelpath Joint Approach			PCC - Right Wheelpath Joint Leave		
				Load	Df1 (mils/kip)	SPR (%)	Load	Df1 (mils/kip)	LT (%) (Df3/Df1)	Load	Df1 (mils/kip)	JSR (Df1L/Df1A)
809*	4/5/01	390809A1 390809B1	38	9545	0.80	75.2	9399	2.03	76.7	9403	2.05	1.01
				12982	0.82	75.9	12755	1.96	77.0	12748	1.97	1.02
				17374	0.81	76.0	16990	1.85	76.5	16997	1.83	0.99
810*	4/5/01	390810A1 390810B1	38	9767	0.41	82.2	9482	1.03	84.9	9434	1.05	1.02
				13285	0.41	82.2	12754	1.03	85.0	12871	1.05	1.01
				18100	0.40	82.1	17110	1.00	85.1	17147	1.02	1.02

APPENDIX J

May 2001 FWD Measurements

Table J-1

May 2001 Average FWD Measurements – PCC Sections

Section	Date	File Mdslb. RWP	Surf. Temp. (°F)	PCC - Centerline			PCC - Right Wheelpath					
				Midslab			Joint Approach			Joint Leave		
				Load	Df1 (mils/kip)	SPR (%)	Load	Df1 (mils/kip)	LT (%) (Df3/Df1)	Load	Df1 (mils/kip)	JSR (Df1L/Df1A)
201*	5/7/01	390201C13 90201D1	71	9135	0.52	78.3	9364	1.15	96.6	8974	1.18	1.03
				12527	0.53	78.8	12822	1.14	96.6	12427	1.16	1.03
				16454	0.55	78.7	16567	1.14	96.3	16354	1.14	1.00
202*	5/7/01	390202C13 90202D1	71	9107	0.51	79.0	9179	0.69	95.1	9172	0.70	1.02
				12551	0.52	79.6	12627	0.71	94.4	12581	0.72	1.01
				16464	0.54	79.4	16619	0.71	94.6	16594	0.71	1.01
203*	5/8/01	390203C13 90203D1	59	9315	0.34	81.5	9297	0.49	94.3	9261	0.48	0.98
				12779	0.34	82.7	12787	0.48	95.9	12773	0.48	1.00
				16696	0.34	82.4	16700	0.48	95.6	16789	0.48	0.99
204*	5/7/01	390204C13 90204D1	65	9386	0.28	80.7	9222	0.60	96.7	9273	0.60	0.99
				12626	0.28	81.6	12586	0.61	96.7	12607	0.62	1.01
				16529	0.29	81.0	16477	0.62	96.6	16409	0.63	1.01
205*	5/7/01	390205C13 90205D1	71	9158	0.55	78.8	8997	1.10	94.3	8990	1.07	0.98
				12580	0.55	79.5	12401	1.07	94.5	12391	1.05	0.98
				16363	0.57	79.3	16252	1.06	94.5	16246	1.04	0.99
206*	5/7/01	390206C13 90206D1	71	9137	0.50	79.4	9105	0.76	94.0	9091	0.76	0.99
				12544	0.51	79.8	12563	0.75	93.2	12556	0.75	1.00
				16398	0.52	79.7	16570	0.74	93.6	16619	0.74	1.00
207*	5/8/01	390207C13 90207D1	59	9234	0.29	82.1	9228	0.39	89.9	9277	0.36	0.94
				12679	0.29	84.2	12623	0.38	94.1	12714	0.36	0.97
				16513	0.29	83.7	16535	0.39	92.9	16622	0.37	0.97
208*	5/8/01	390208C13 90208D1	67	9389	0.29	82.9	9237	0.41	91.5	9236	0.39	0.95
				12708	0.29	84.5	12640	0.40	95.8	12693	0.40	0.99
				16463	0.30	83.7	16681	0.41	94.6	16676	0.40	0.98
209	5/7/01	390209C13 90209D1	71	9157	0.44	78.1	9043	0.85	93.2	8992	0.85	1.00
				12485	0.45	78.4	12410	0.88	93.8	12461	0.86	0.98
				16217	0.47	78.4	16316	0.90	93.6	16325	0.88	0.98
210	5/7/01	390210C13 90210D1	65	9270	0.43	76.2	9167	0.56	93.0	9204	0.56	1.00
				12520	0.44	77.3	12500	0.58	92.7	12507	0.58	1.00
				16293	0.46	77.0	16282	0.60	93.1	16286	0.60	1.00
211	5/7/01	390211C13 90211D1	71	9167	0.28	82.5	9158	0.41	91.4	9227	0.41	0.98
				12515	0.29	81.9	12580	0.41	93.2	12660	0.41	0.98
				16305	0.29	82.1	16478	0.42	93.4	16578	0.41	0.98
212	5/7/01	390212C13 90201D1	65	9370	0.27	81.6	9258	0.55	95.6	9210	0.57	1.03
				12709	0.28	82.1	12617	0.58	95.8	12595	0.59	1.02
				16554	0.28	81.7	16396	0.60	95.8	16454	0.60	1.00
259	5/7/01	390259C13 90259D1	65	9518	0.32	82.7	9213	0.83	96.9	9244	0.81	0.97
				12682	0.34	82.8	12538	0.84	96.8	12530	0.83	0.99
				16757	0.34	82.3	16170	0.86	96.5	16180	0.84	0.98
260	5/7/01	390260C13 90260D1	65	9274	0.26	80.6	9209	0.44	93.6	9202	0.44	1.00
				12554	0.26	81.5	12519	0.46	93.8	12497	0.46	1.00
				16304	0.28	81.0	16344	0.48	93.7	16312	0.47	0.99
261	5/7/01	390261C13 90201D1	71	9155	0.23	83.6	9312	0.34	93.0	9315	0.33	0.96
				12600	0.23	83.5	12811	0.34	93.9	12834	0.33	0.98
				16569	0.24	83.1	16586	0.34	93.7	16610	0.34	0.99
262	5/8/01	390262C13 90262D1	67	9332	0.23	84.6	9570	0.36	93.0	9256	0.38	1.04
				12564	0.23	85.1	13001	0.37	95.0	12670	0.38	1.04
				16414	0.24	84.1	16738	0.38	94.4	16446	0.39	1.02
263	5/8/01	390263C13 90263D1	66	9249	0.37	83.4	9274	0.44	92.3	9357	0.42	0.96
				12597	0.36	84.4	12693	0.43	94.7	12734	0.42	0.98
				16418	0.37	83.6	16532	0.44	94.4	16587	0.43	0.98
264	5/8/01	390264C13 90264D1	66	9187	0.35	84.2	9331	0.70	95.5	9232	0.69	0.99
				12572	0.35	84.3	12584	0.71	96.5	12583	0.69	0.98
				16415	0.36	84.1	16467	0.72	96.3	16431	0.69	0.97
265	5/8/01	390265C13 90265D1	59	9464	0.28	81.5	9301	0.43	93.7	9297	0.42	0.99
				12973	0.28	82.3	12813	0.43	94.3	12816	0.42	0.99
				17069	0.28	82.1	16683	0.44	94.1	16730	0.43	0.99

* Section undrained

APPENDIX K

2002 FWD Measurements

Table K-1

2002 FWD Deflection Profiles

Normalized FWD Df1 Profiles on Ohio SHRP Test Road - 2002																	
Section No.	Test Date	Pvt. Surf. Temp. (°F)	Test Path	Avg. Load (K)	Normalized Df1 Measurements (mils) at Station												
					0+00	0+50	1+00	1+50	2+00	2+50	3+00	3+50	4+00	4+50	5+00	Avg. C/L (mils)	Avg. RWP (mils)
Southbound SPS-1 (AC)																	
103	3/19/02	38	Midlane	9.682	0+25	0+75	1+25	1+75	2+25	2+75	3+25	3+75	4+25	4+75			
					1.15	1.20	2.01	1.10	1.13	0.81	0.89	0.96	1.18	1.13		1.16	
			RWP	9.825	1.18	0.93	1.04	1.40	0.96	1.28	1.05	0.83	1.27	0.87	1.05		1.08
104	5/20/02	72	Midlane	9.528	0.44	0.42	0.42	0.40	0.44	0.47	0.47	0.43	0.44	0.45	0.41	0.44	
			RWP	9.547	0.43	0.39	0.39	0.41	0.42	0.44	0.45	0.41	0.42	0.43	0.42		0.42
106	5/20/02	65	Midlane	9.557	0.57	0.55	0.62	0.55	0.55	0.49	0.54	0.49	0.49	0.58	0.56	0.54	
			RWP	9.546	0.57	0.61	0.60	0.53	0.53	0.45	0.56	0.48	0.47	0.58	0.52		0.54
108	3/19/02	41	Midlane	9.597	0+25	0+75	1+25	1+75	2+25	2+75	3+25	3+75	4+25	4+75			
					1.00	1.30	0.92	0.97	1.22	0.79	0.97	1.21	0.89	1.05		1.03	
			RWP	9.635	2.07	1.52	1.55	1.13	1.27	0.97	1.32	1.06	1.25	1.06	1.45		1.33
109	3/19/02	41	Midlane	9.679	0+25	0+75	1+25	1+75	2+25	2+75	3+25	3+75	4+25	4+75			
					0.87	0.88	0.85	0.83	0.81	0.80	0.77	0.80	0.82	0.95		0.84	
			RWP	9.702	1.29	1.08	0.90	0.96	1.03	0.99	1.02	0.82	1.04	1.06	1.34		1.05
110	3/19/02	40	Midlane	9.858	0+25	0+75	1+25	1+75	2+25	2+75	3+25	3+75	4+25	4+75			
					0.62	0.65	0.64	0.69	0.69	0.67	0.76	0.65	0.64	0.71		0.67	
			RWP	9.817	0.71	0.74	0.65	0.66	0.75	0.78	0.70	0.78	0.67	0.71	0.83		0.73
111	5/20/02	74	Midlane	9.404	0.61	0.70	0.63	0.66	0.63	0.62	0.69	0.76	0.82	0.83	0.75	0.70	
			RWP	9.483	0.55	0.65	0.61	0.60	0.54	0.61	0.64	0.71	0.79	0.91	0.71		0.67
112	5/20/02	74	Midlane	9.491	0.40	0.47	0.47	0.44	0.51	0.48	0.47	0.49	0.47	0.44	0.43	0.46	
			RWP	9.536	0.41	0.46	0.46	0.44	0.51	0.48	0.48	0.47	0.47	0.44	0.43		0.46
159			Midlane														
			RWP														
160	5/20/02	51	Midlane	9.621	0.49	0.56	0.52	0.51	0.47	0.46	0.47	0.40	0.65	0.53	0.62	0.52	
			RWP	9.621	0.57	0.57	0.47	0.48	0.47	0.44	0.46	0.38	0.49	0.49	0.54		0.49
161 (102)	5/20/02	56	Midlane	9.736	0.42	0.40	0.40	0.39	0.43	0.43	0.40	0.42	0.45	0.41	0.47	0.42	
			RWP	9.613	0.41	0.38	0.39	0.39	0.42	0.40	0.42	0.43	0.42	0.39	0.45		0.41
162 (107)	5/20/02	56	Midlane	9.668	0.30	0.29	0.31	0.28	0.28	0.26	0.28	0.32	0.23	0.24	0.27	0.28	
			RWP	9.654	0.29	0.26	0.28	0.28	0.28	0.26	0.29	0.31	0.27	0.25	0.28		0.28
163 (101)	5/20/02	62	Midlane	9.63	0.34	0.27	0.27	0.32	0.30	0.30	0.34	0.30	0.30	0.31	0.31	0.31	
			RWP	9.635	0.29	0.25	0.26	0.31	0.25	0.29	0.32	0.30	0.26	0.35	0.34		0.29
164 (105)	5/20/02	50	Midlane	9.595	0.91	0.92	0.92	0.95	0.73	0.72	0.72	0.82	0.81	0.78	0.80	0.83	
			RWP	9.729	0.93	0.94	0.84	0.88	0.76	0.73	0.74	0.85	0.83	0.69	0.80		0.82
Ramp SPS-8 (AC)																	
A803 (803)	6/24/02	102	Midlane	8.892	1.90	2.21	2.02	1.67	2.22	1.19	1.56	1.42	1.33	1.60	1.77	1.72	
			RWP	9.062	1.55	1.95	1.88	1.60	1.65	1.32	1.43	1.35	1.32	1.55	1.50		1.55
A804 (804)	6/24/02	110	Midlane	9.07	0.95	1.03	1.09	0.98	1.43	1.22	1.18	1.14	1.05	0.75	1.24	1.10	
			RWP	9.132	1.17	1.08	1.18	1.08	1.46	1.23	1.33	1.22	0.78	0.79	1.05		1.12
Southbound SPS-9 (AC)																	
901	5/21/02	64	Midlane	9.673	0.33	0.35	0.38	0.35	0.35	0.32	0.32	0.31	0.31	0.31	0.33	0.33	
			RWP	9.666	0.36	0.34	0.38	0.32	0.36	0.32	0.34	0.31	0.39	0.36	0.36		0.35
902	5/21/02	63	Midlane	9.793	0.24	0.24	0.26	0.29	0.29	0.29	0.29	0.25	0.26	0.26	0.27	0.27	
			RWP	9.774	0.24	0.25	0.25	0.28	0.29	0.30	0.30	0.26	0.26	0.26	0.26		0.27
903	5/21/02	64	Midlane	9.644	0.33	0.39	0.40	0.41	0.40	0.37	0.39	0.38	0.33	0.32	0.31	0.37	
			RWP	9.606	0.32	0.37	0.39	0.40	0.40	0.39	0.39	0.38	0.33	0.33	0.34		0.37
Ramp SPS-8 (PCC)																	
809	6/24/02	96	Midlane	9.122	0.66	0.71	0.75	0.73	0.73	0.80	0.59	0.56	0.59	0.55	0.64	0.66	LT
			RWP-LT*	9.006	84.3			84.5		84.2		77		76			81.20
810	6/24/02	95	RWP	9.224	0.51	0.37	0.40	0.33	0.36	0.38	0.32	0.38	0.36	0.41	0.38	0.38	
			RWP-LT*	9.176	90.0			85.7		86.4		88.7		92.0			88.56

* LT = Load Transfer (Df2A/Df1A) in %

Table K-2

2002 Average FWD Measurements – AC Sections

Asphalt Concrete										
Section	Date	Surface Temp. (°F)	Centerline				Right Wheelpath			
			File	Load (kips)	Df1 (mils/kip)	SPR (%)	File	Load (kips)	Df1 (mils/kip)	SPR (%)
103*	5/20/02	59	390103A1	6269	1.21	69.4	390103B3	6536	1.10	68.0
				9255	1.24	69.6		9826	1.08	69.0
				12673	1.26	70.1		13260	1.09	69.5
104*	5/20/02	51	390104A2	6475	0.43	70.0	390104B2	6442	0.42	70.5
				9528	0.43	70.0		9544	0.42	70.6
				13014	0.44	70.3		13023	0.42	70.8
106*	5/20/02	49	390106A2	6397	0.54	68.8	390106B2	6470	0.53	68.4
				9557	0.54	69.0		9546	0.54	68.7
				13041	0.55	69.3		13014	0.54	69.0
108	3/19/02	45	390108B1	6528	1.01	62.8	390108B3	6490	1.36	56.8
				9597	1.03	63.0		9636	1.33	58.4
				13251	1.03	63.4		13122	1.32	59.6
109	3/19/02	45	390109B1	6531	0.83	63.2	390109B3	6611	1.06	59.7
				9680	0.84	63.6		9704	1.05	61.3
				13264	0.84	64.1		13230	1.04	62.4
110	3/19/02	45	390110B1	6654	0.67	69.1	390110B3	6600	0.73	67.7
				9859	0.67	69.3		9820	0.73	68.4
				13416	0.68	69.4		13391	0.72	68.9
111	5/20/02	52	390111A2	6368	0.69	67.5	390111B2	6421	0.65	69.0
				9404	0.70	67.9		9483	0.67	69.3
				12919	0.71	68.4		12975	0.68	69.7
112	5/20/02	52	390112A2	6414	0.46	70.8	390112B2	6465	0.46	70.9
				9491	0.46	70.8		9536	0.46	70.9
				12998	0.46	71.3		13046	0.46	71.3
160	5/20/02	40	390160A2	6485	0.51	71.5	390160B2	6489	0.49	72.3
				9621	0.52	71.5		9621	0.49	72.4
				13169	0.52	71.9		13163	0.49	72.5
161	5/20/02	43	390161A2	6510	0.42	68.5	390161B2	6460	0.41	68.4
				9736	0.42	68.5		9613	0.41	68.8
				13132	0.43	68.9		13137	0.41	69.2
162	5/20/02	45	390162A2	6495	0.28	64.0	390162B2	6473	0.28	63.4
				9668	0.28	64.4		9654	0.28	63.7
				13076	0.29	64.4		12974	0.28	63.9
163	5/20/02	47	390163A2	6501	0.31	59.5	390163B2	6497	0.30	58.1
				9630	0.31	60.5		9635	0.29	59.1
				13003	0.31	60.5		13065	0.30	59.2
164	5/20/02	40	390164A2	6458	0.81	63.7	390164B2	6599	0.81	64.5
				9595	0.82	63.7		9729	0.82	64.9
				13052	0.85	64.0		13195	0.84	65.3
901	5/21/02	45	390901A2	6495	0.33	66.8	390901B2	6542	0.35	65.3
				9673	0.33	66.8		9666	0.35	65.3
				13132	0.33	67.2		13089	0.35	65.5
902	5/21/02	46	390902A2	6538	0.27	70.1	390902B2	6554	0.27	69.9
				9793	0.27	70.2		9774	0.27	70.3
				13363	0.27	70.4		13282	0.27	70.3
903	5/21/02	45	390903A2	6505	0.37	68.8	390903B2	6522	0.37	68.7
				9644	0.37	68.9		9607	0.37	68.7
				12981	0.37	69.1		12933	0.37	68.9
A803*	6/24/02	86	39A803A2	5963	1.89	28.1	39A803B2	6089	1.81	27.8
				8892	1.74	28.4		9062	1.55	28.4
				12213	1.67	28.3		12418	1.41	28.6
A804*	6/24/02	86	39A804A2	6118	1.16	32.7	39A804B2	6145	1.24	32.0
				9070	1.10	32.8		9132	1.12	32.4
				12461	1.06	32.7		12515	1.06	32.4

* Section undrained

Table K-3

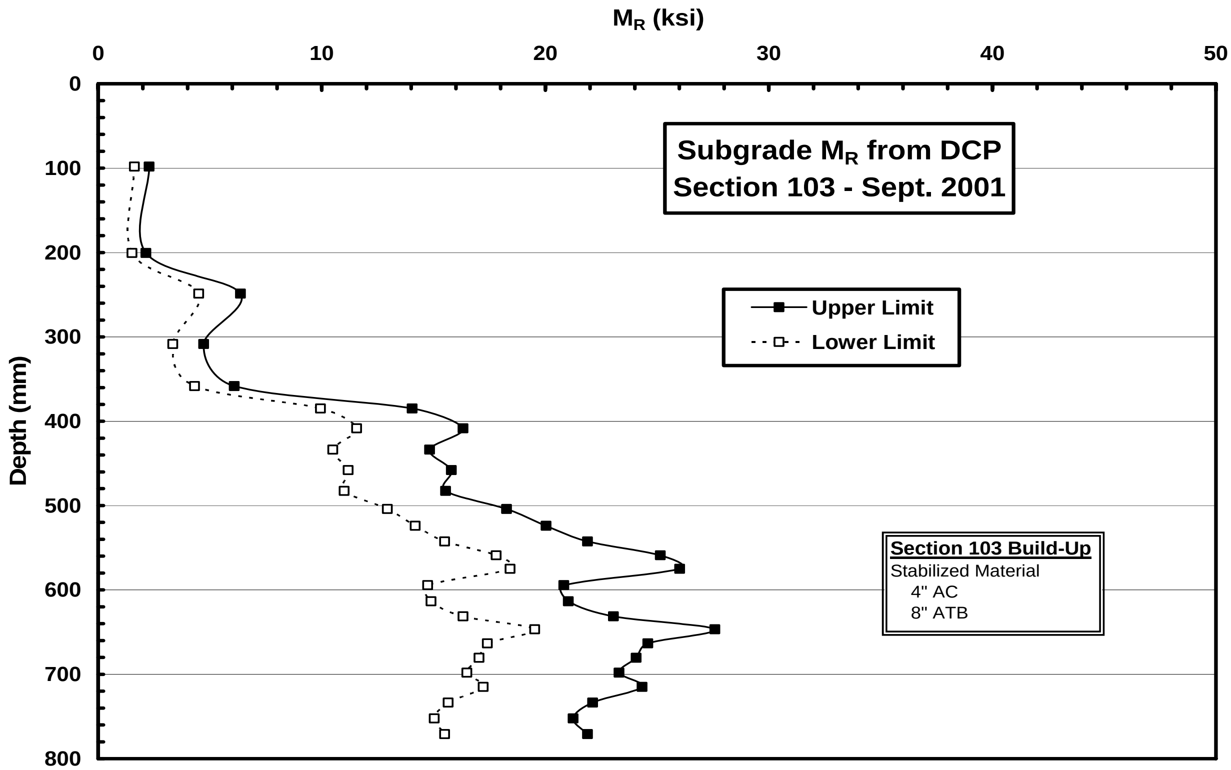
2002 Average FWD Measurements – PCC Sections

Section	Date	File Mdslb. RWP	Surf. Temp. (ºF)	PCC - Centerline			PCC - Right Wheelpath					
				Midslab			Joint Approach			Joint Leave		
				Load	Df1 (mils/kip)	SPR (%)	Load	Df1 (mils/kip)	LT (%) (Df3/Df1)	Load	Df1 (mils/kip)	JSR (Df1L/Df1A)
201*	11/18/02	390201A2 390201B2	29	9696	0.73	74.9	9531	1.30	48.2	9537	1.21	0.95
				13312	0.69	75.9	13123	1.25	49.1	13139	1.13	0.93
				17850	0.65	76.0	17429	1.20	49.8	17515	1.04	0.90
202*	11/18/02	390202A2 390202B2	29	9764	0.68	77.3	9665	1.31	53.2	9710	1.16	0.93
				13456	0.65	77.8	13292	1.26	53.9	13350	1.11	0.92
				18084	0.61	78.0	17712	1.20	54.2	17789	1.04	0.91
809*	6/24/02	390809A2 390809B2	85	9122	0.66	75.0	9011	1.14	89.3	9001	1.14	1.00
				12419	0.68	75.5	12307	1.15	89.8	12312	1.16	1.01
				15841	0.72	75.7	15822	1.20	90.1	15786	1.20	1.00
810*	6/24/02	390810A2 390810B2	84	9224	0.38	81.3	9190	0.63	93.2	9163	0.60	0.95
				12477	0.39	81.5	12414	0.65	93.4	12392	0.62	0.96
				15887	0.41	81.5	15790	0.68	93.9	15802	0.65	0.96

* Section undrained

APPENDIX L

2001 DCP PROFILES



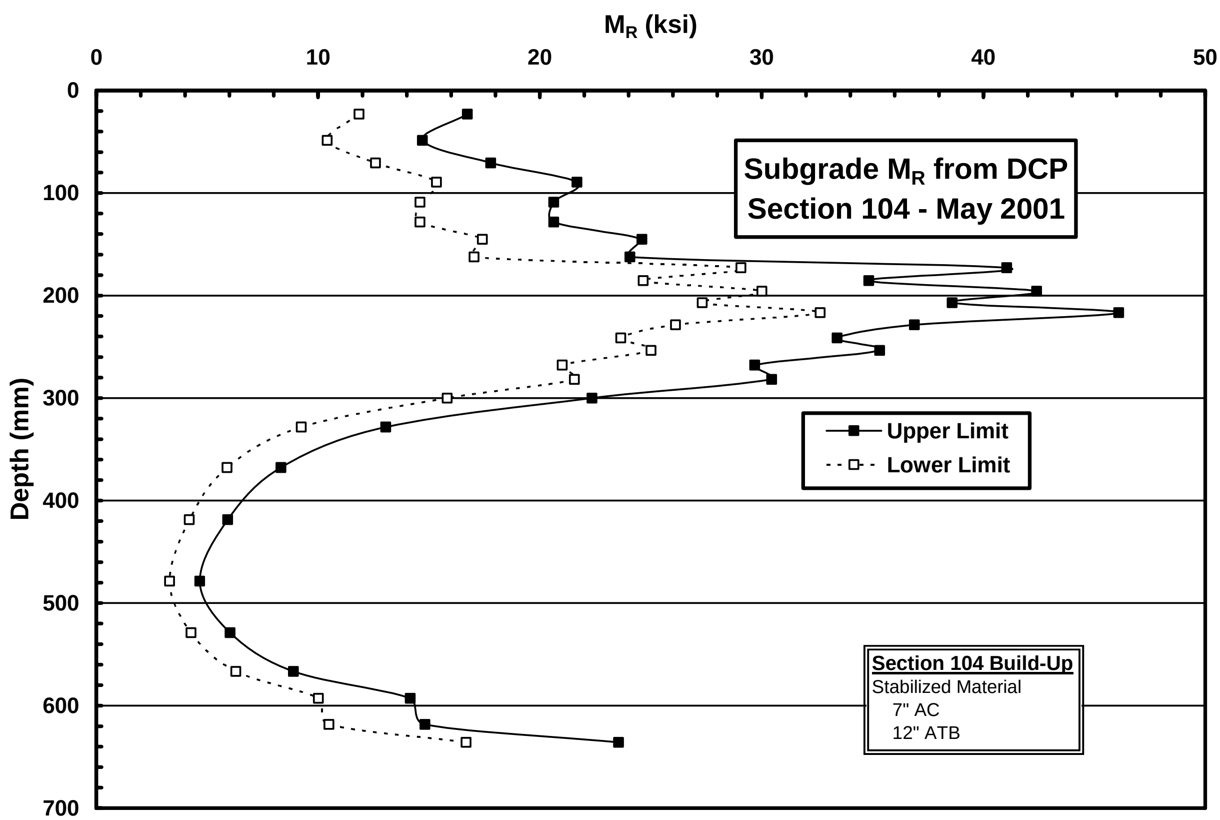
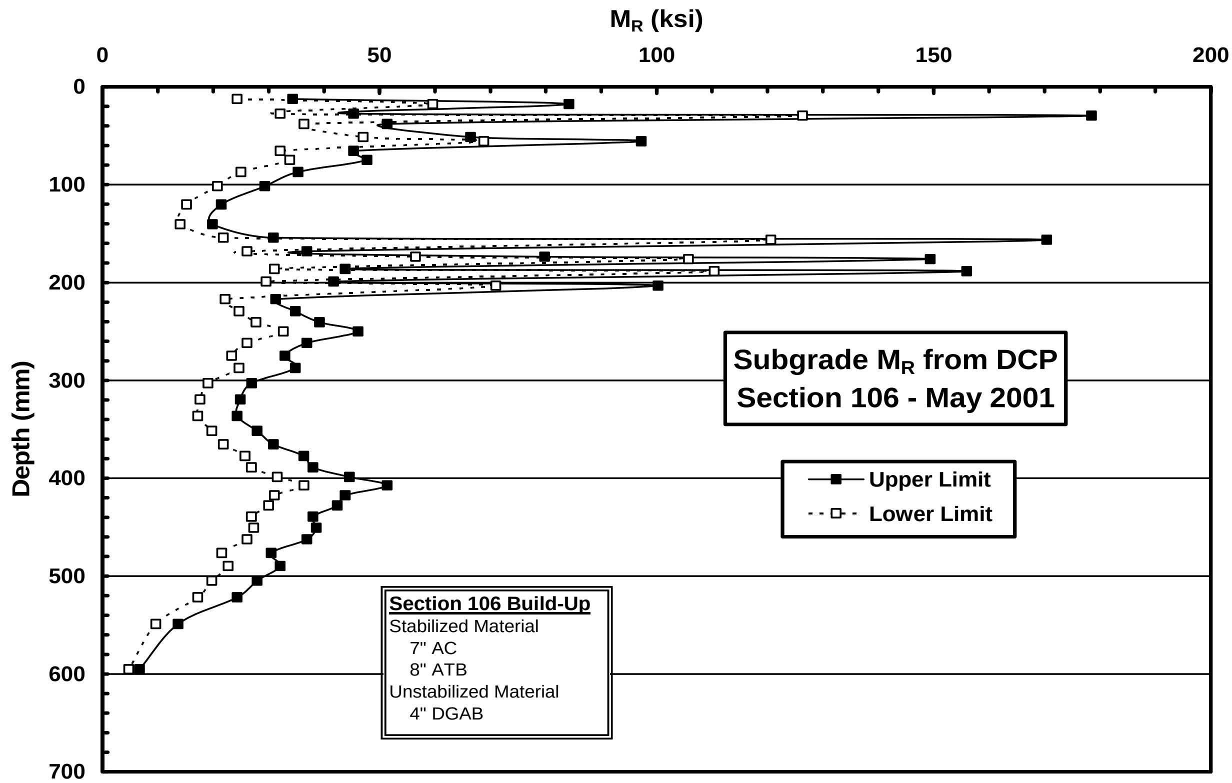


Figure L-1 DCP Profiles for Sections 103 and 104



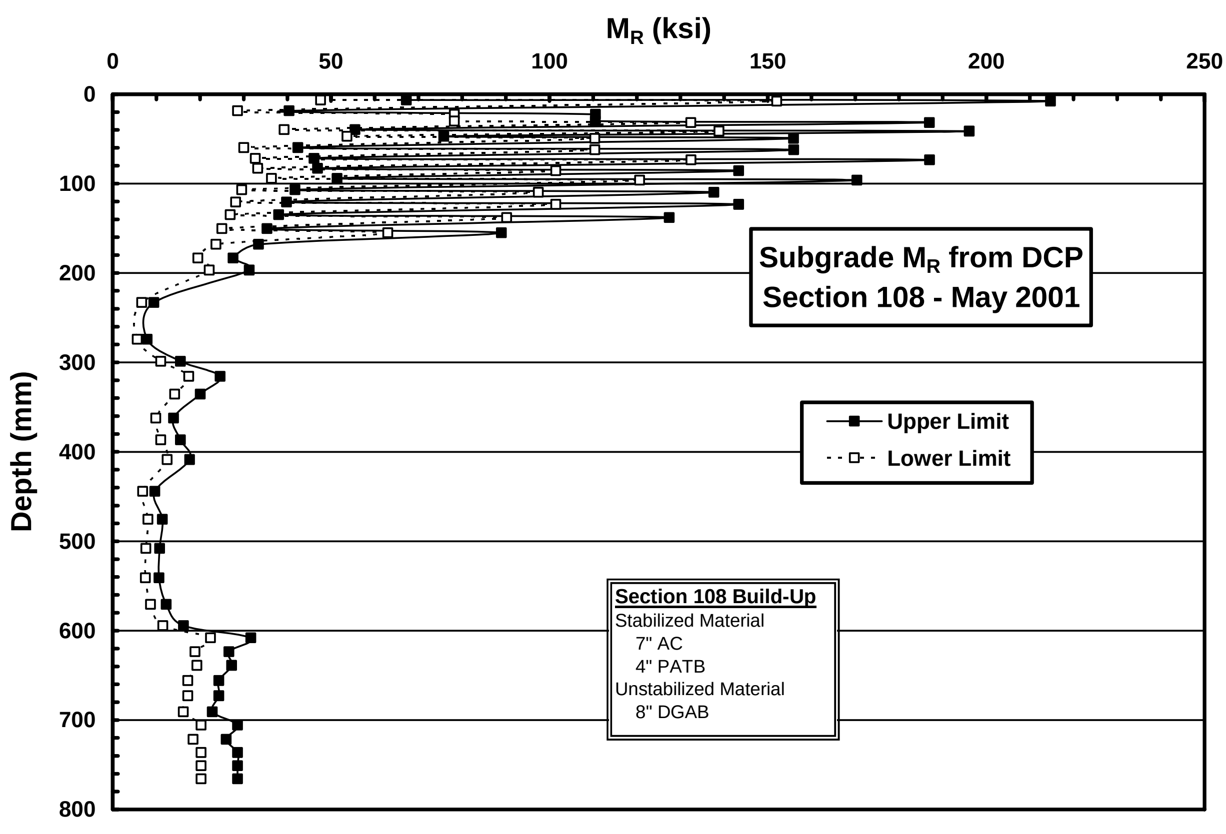
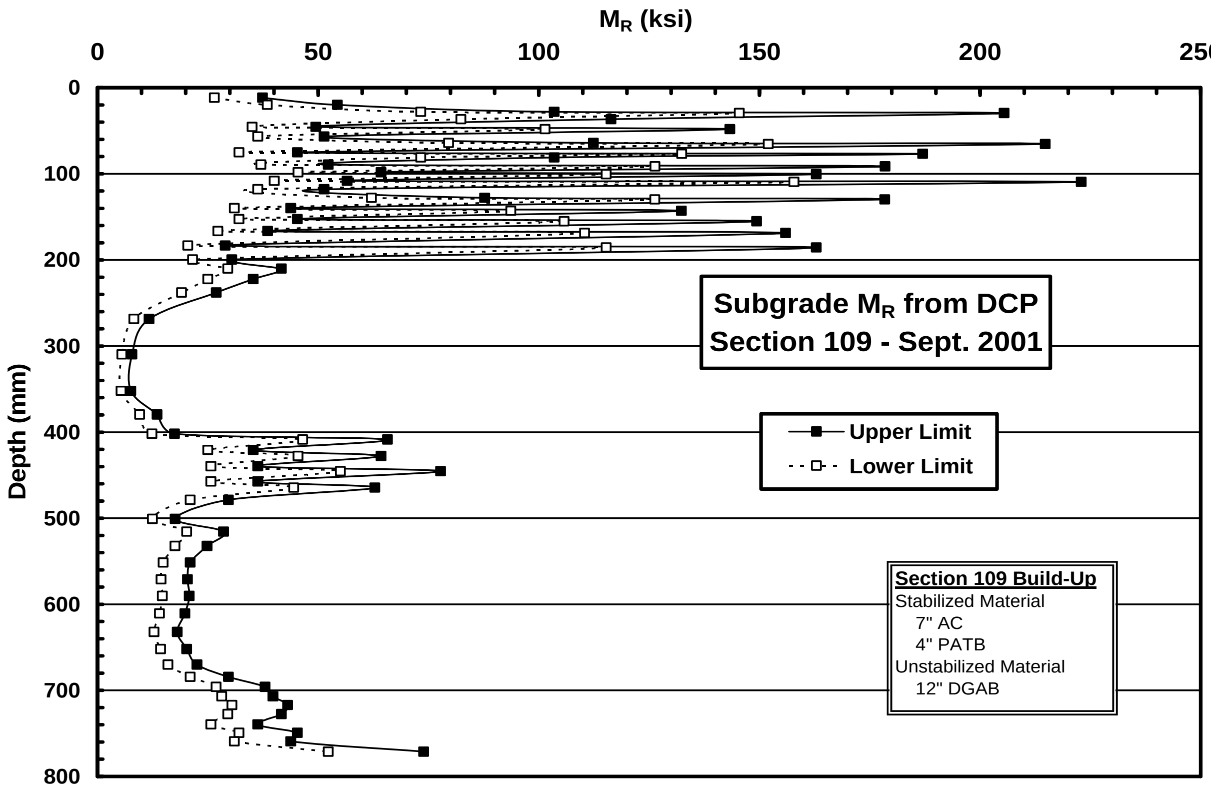


Figure L-2 DCP Profiles for Sections 106 and 108



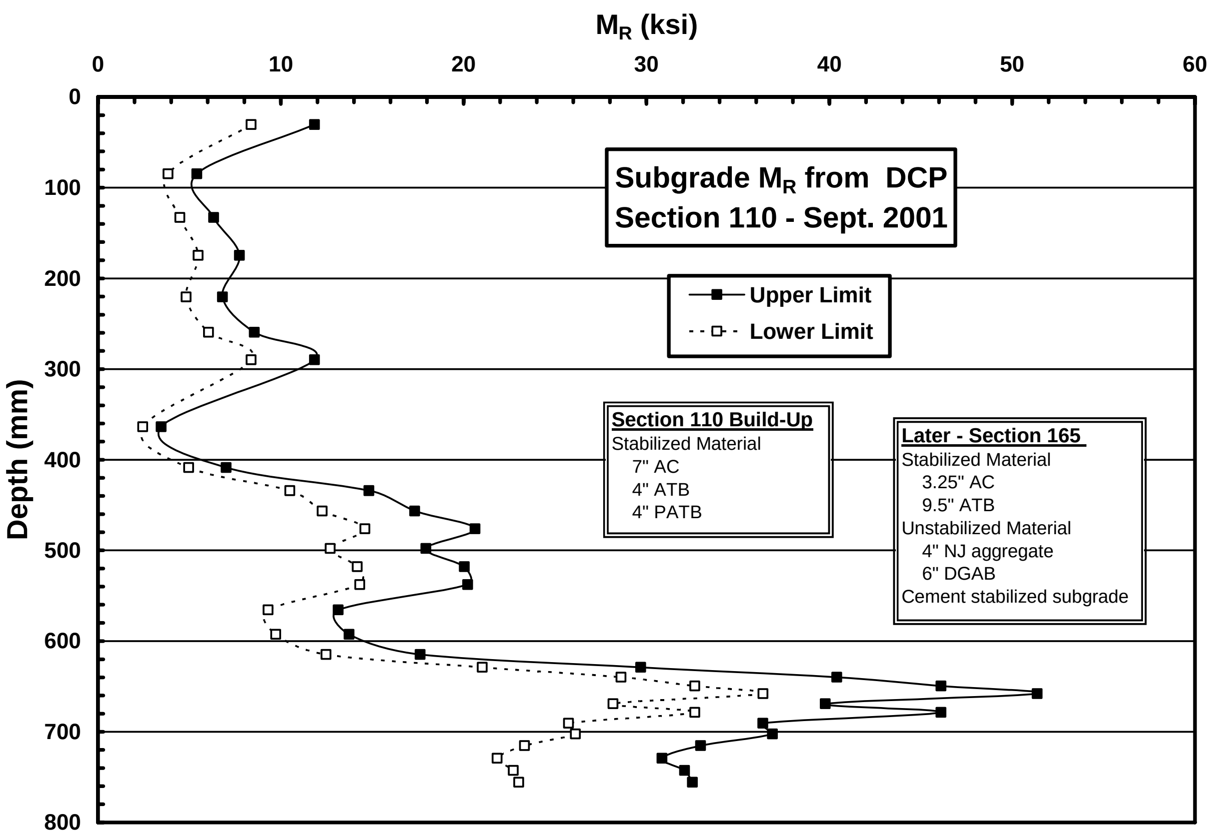
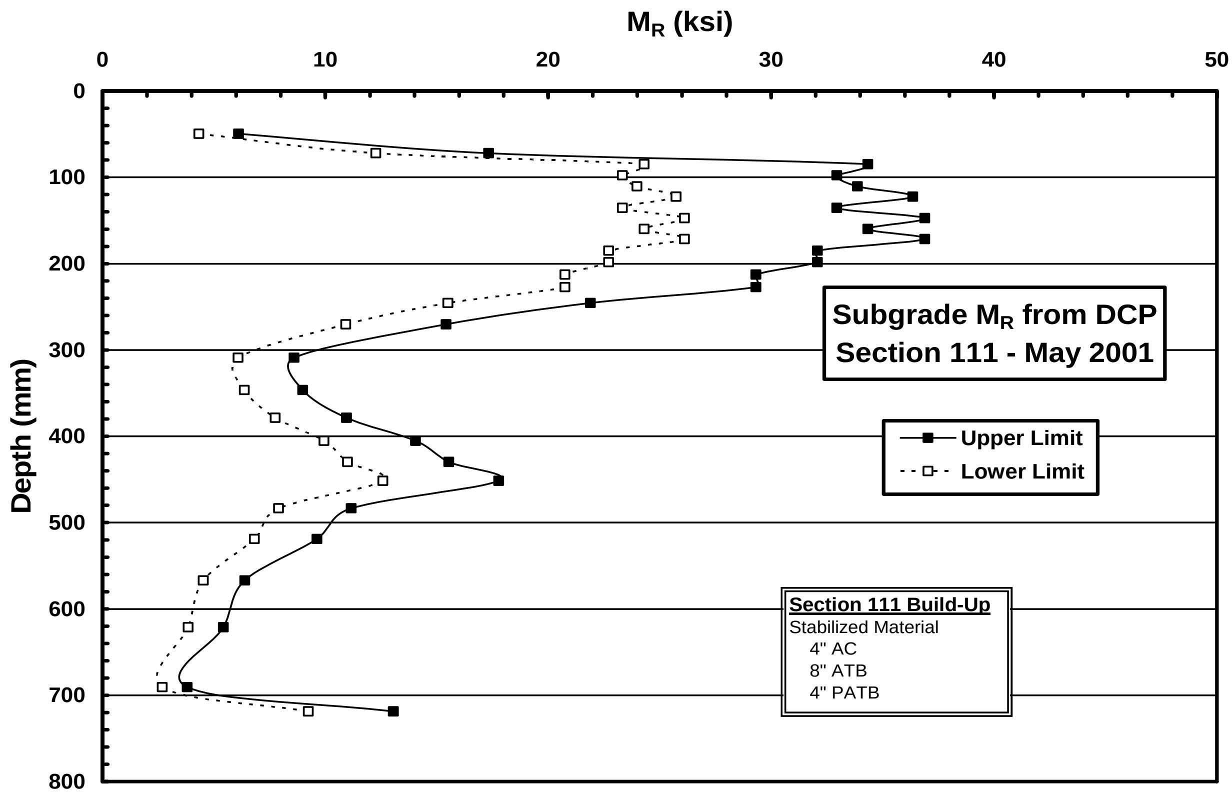


Figure L-3 DCP Profiles for Sections 109 and 110



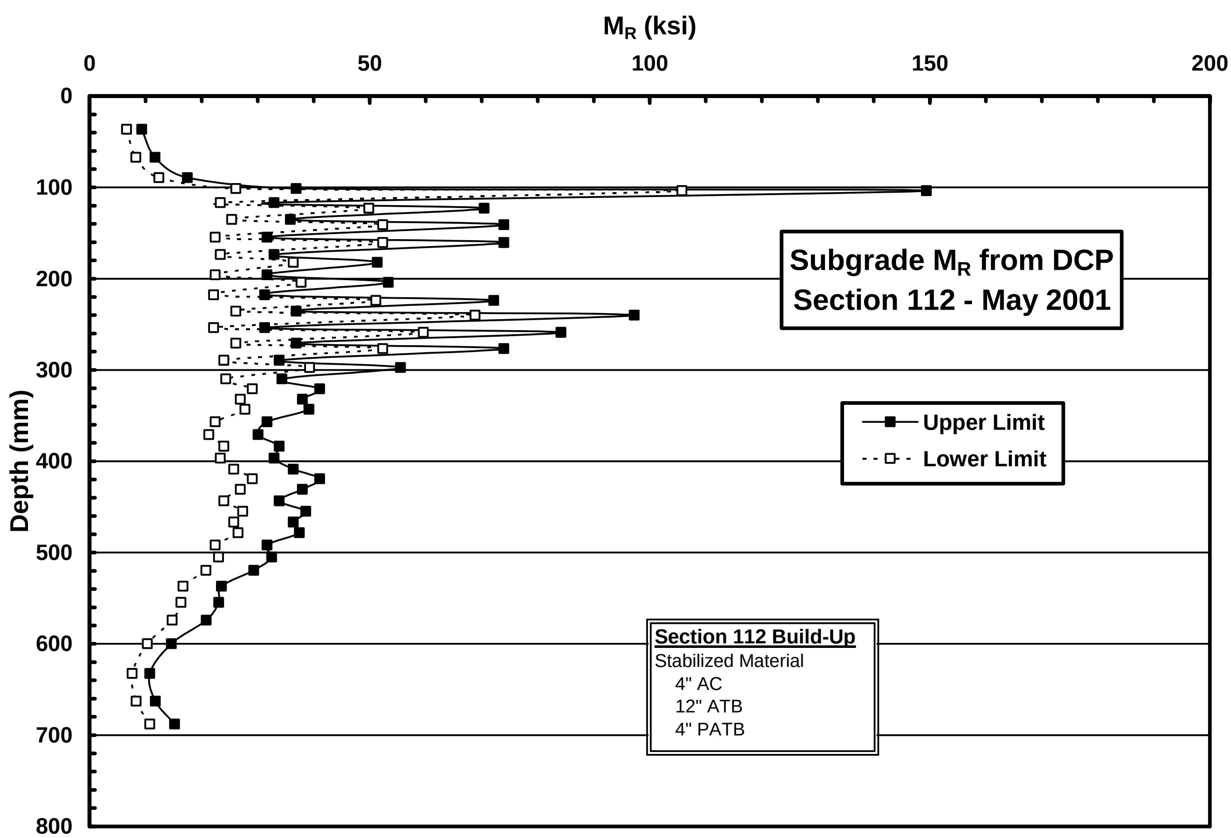
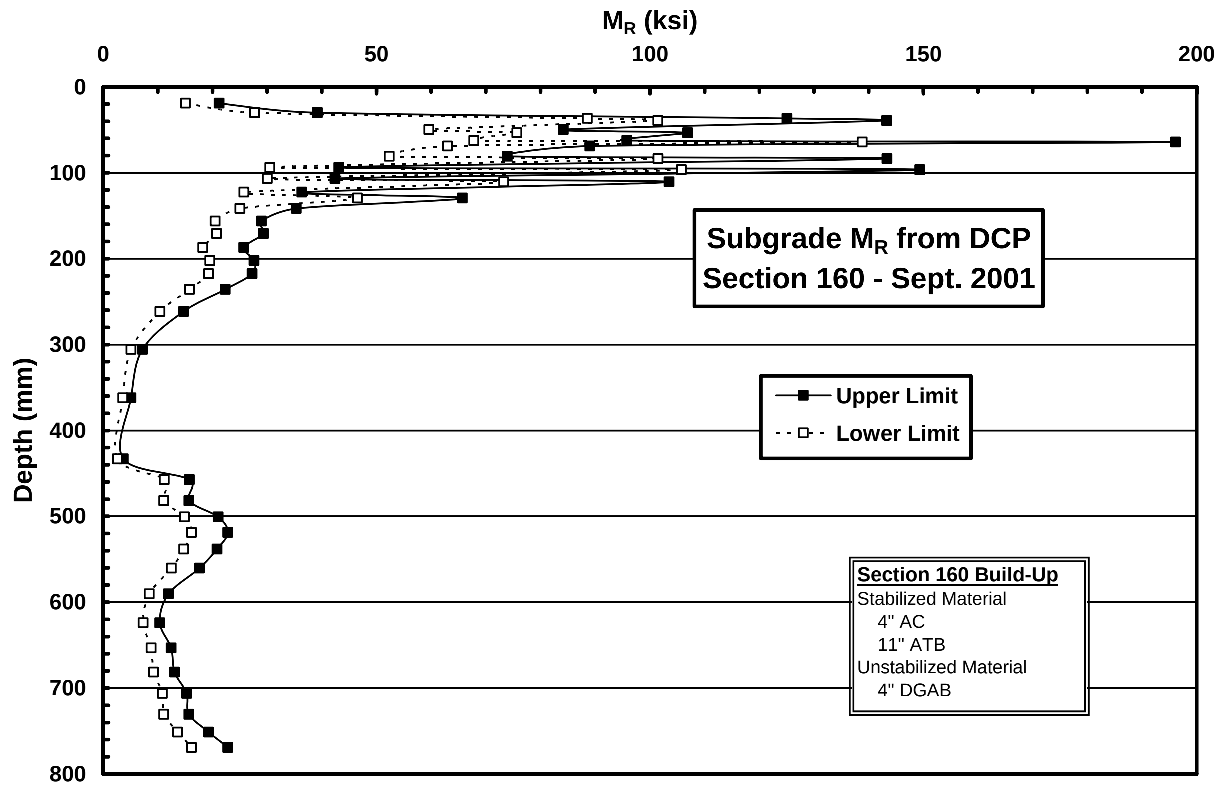


Figure L-4 DCP Profiles for Sections 111 and 112



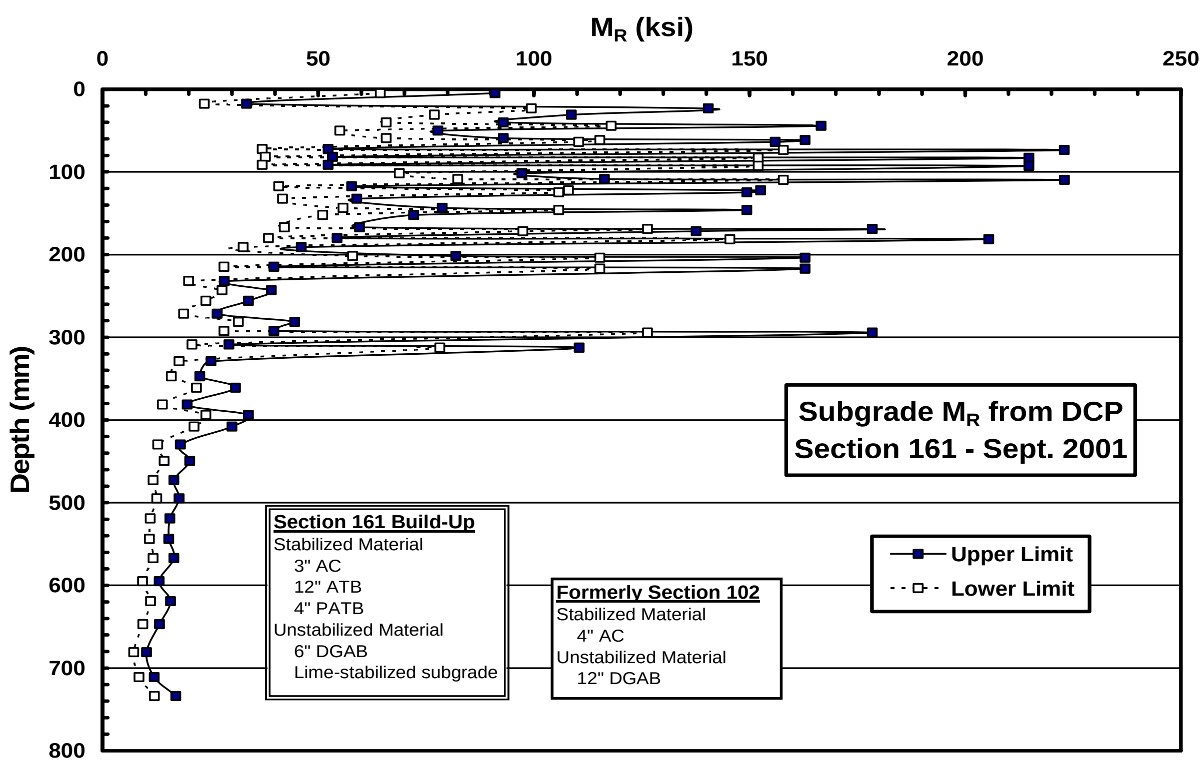
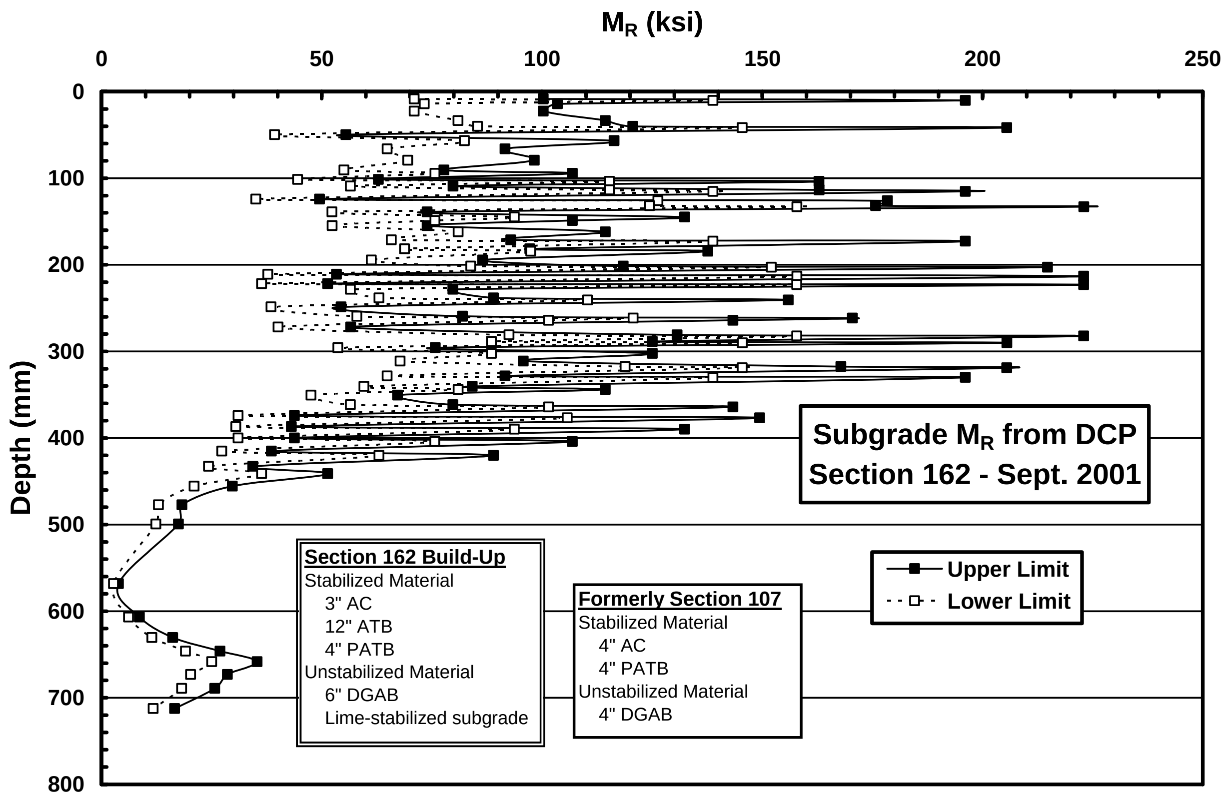


Figure L-5 DCP Profiles for Sections 160 and 161



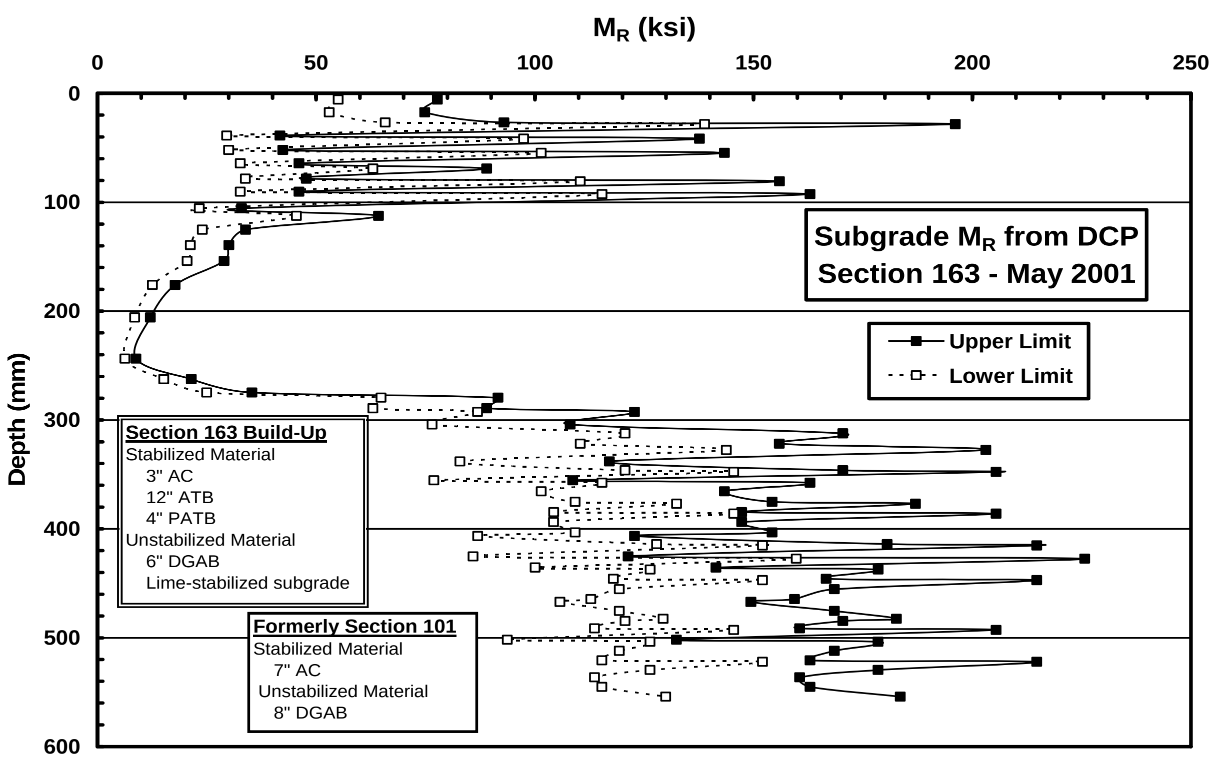
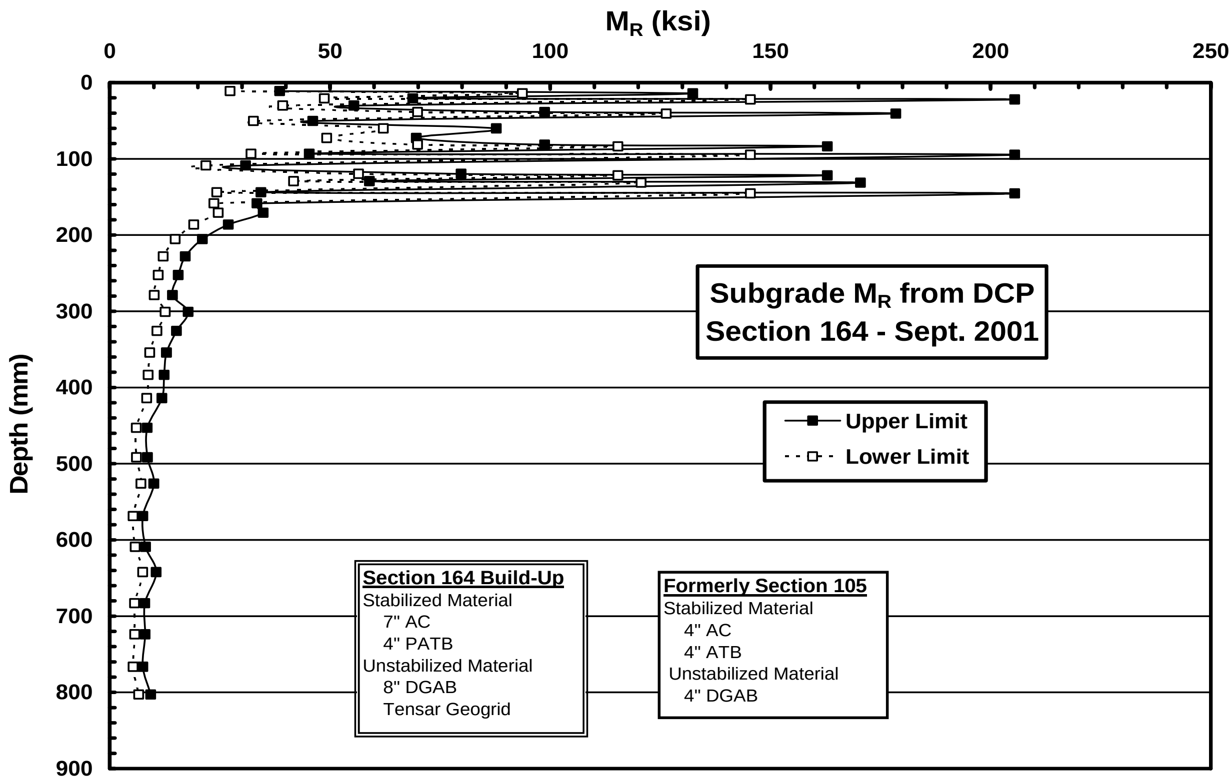


Figure L-6 DCP Profiles for Sections 162 and 163



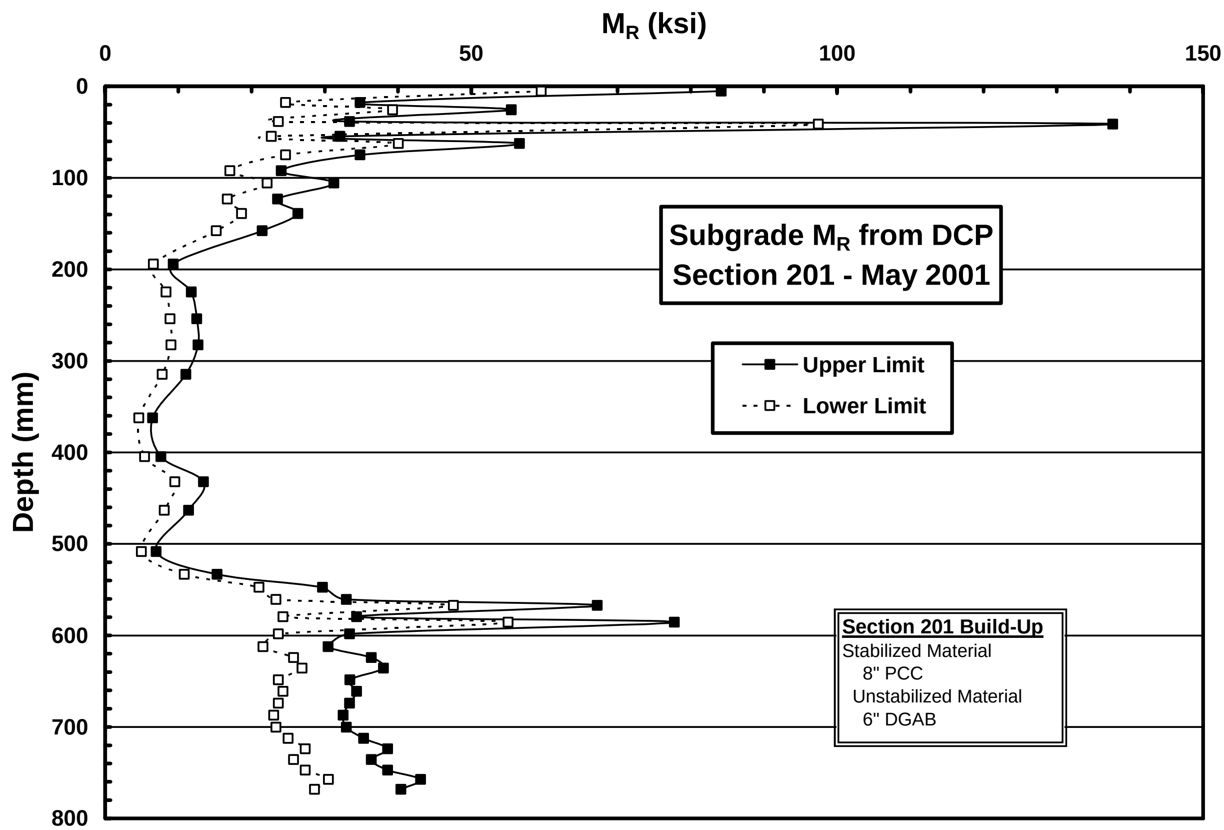
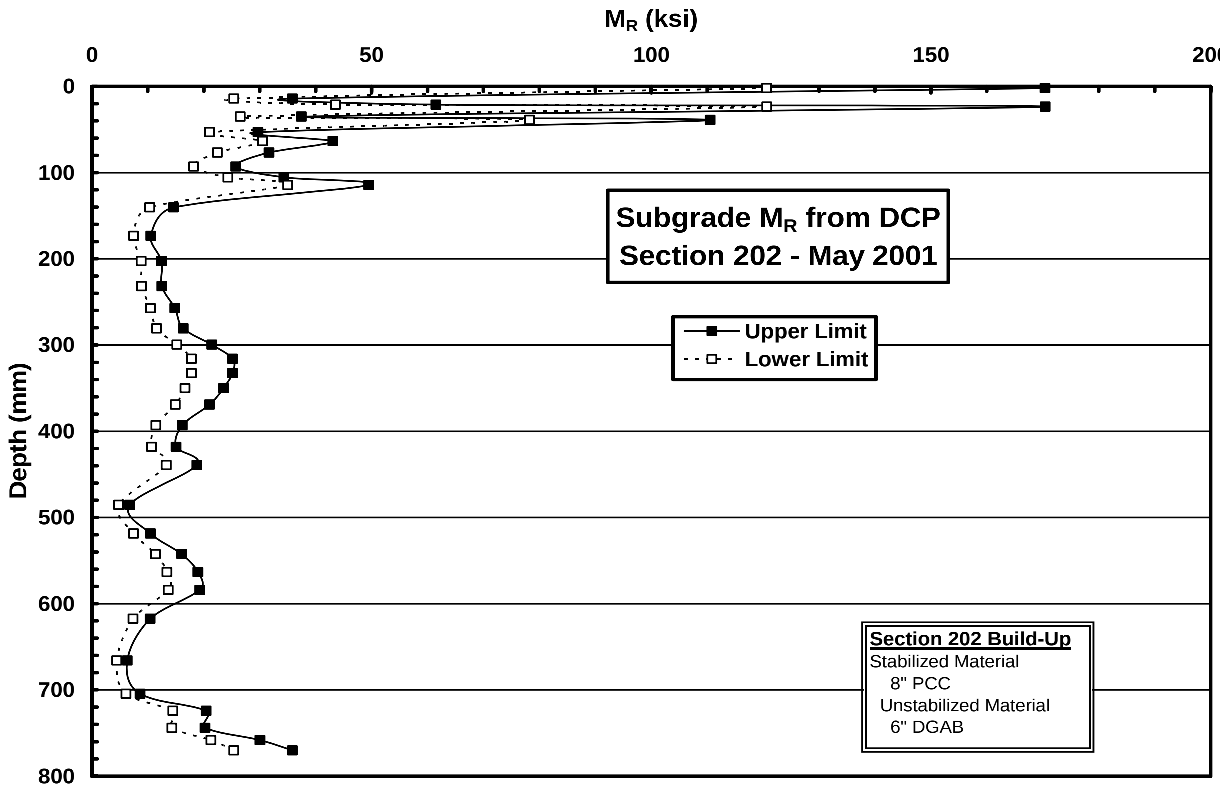


Figure L-7 DCP Profiles for Sections 164 and 201



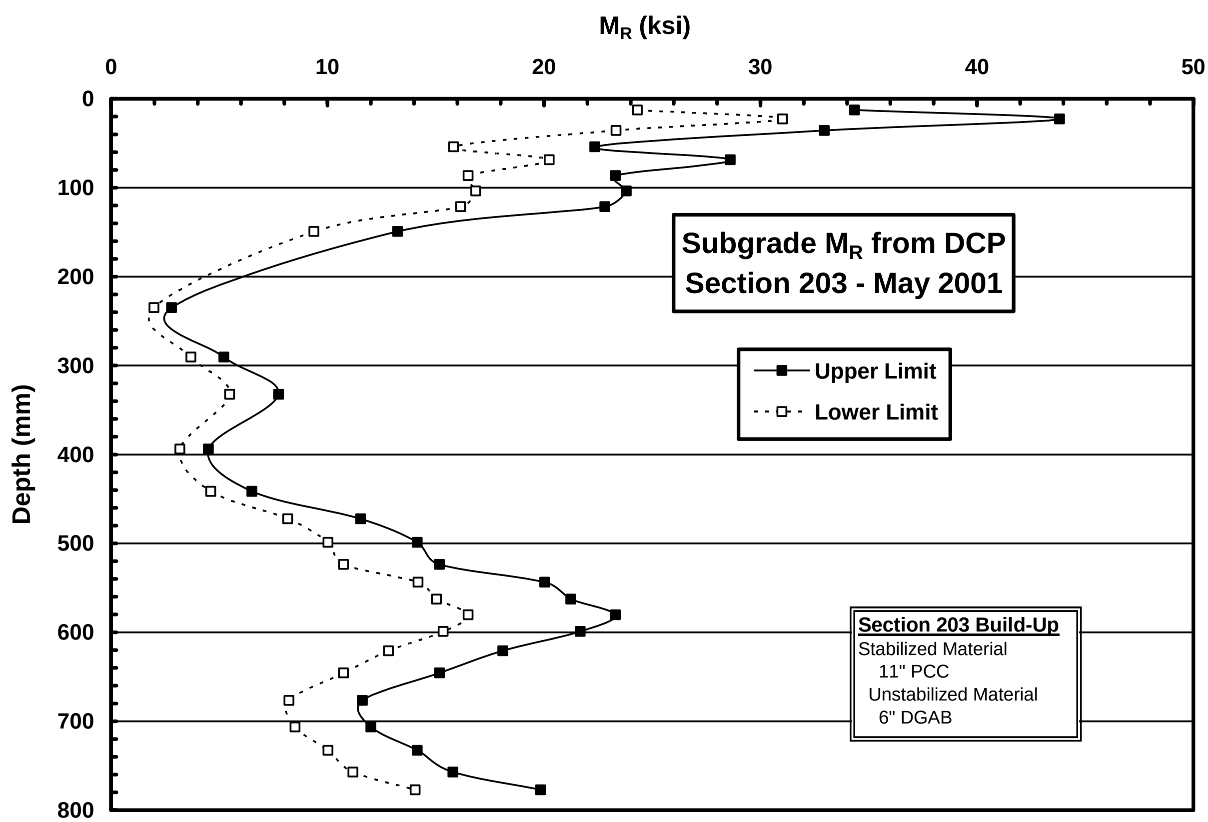
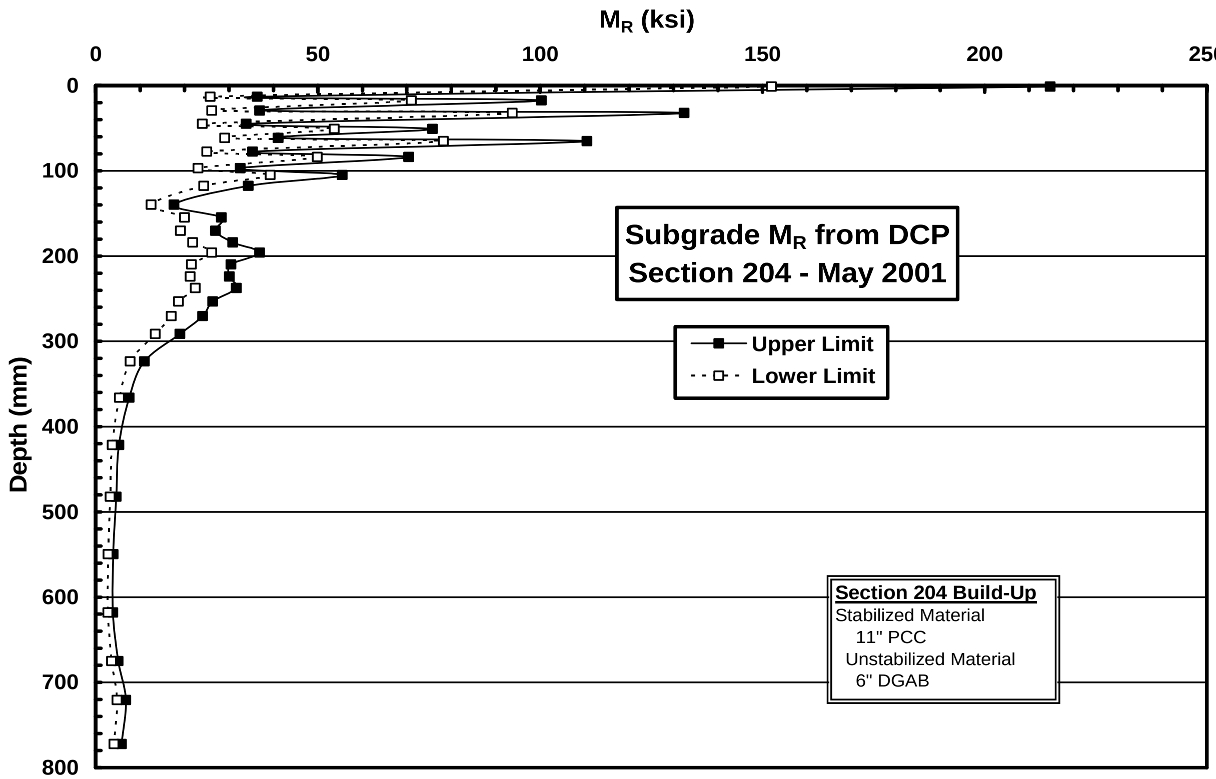


Figure L-8 DCP Profiles for Sections 202 and 203



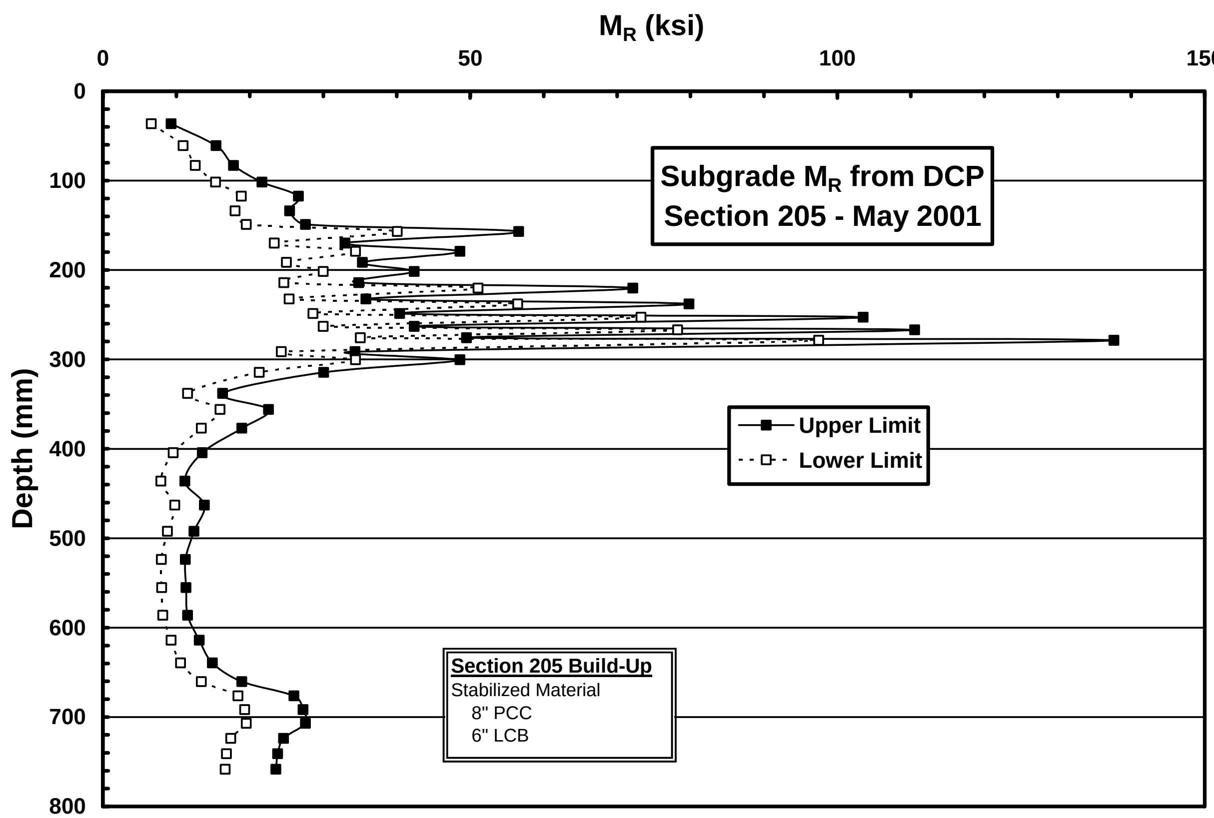
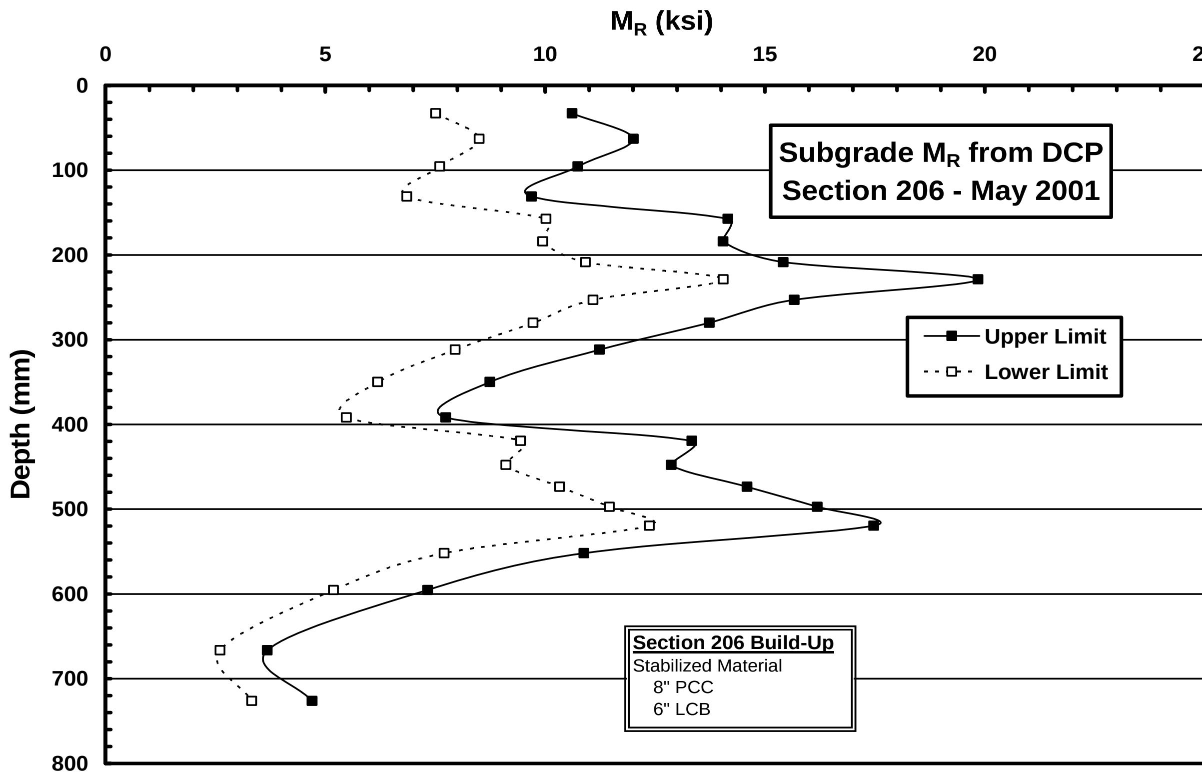


Figure L-9 DCP Profiles for Sections 204 and 205



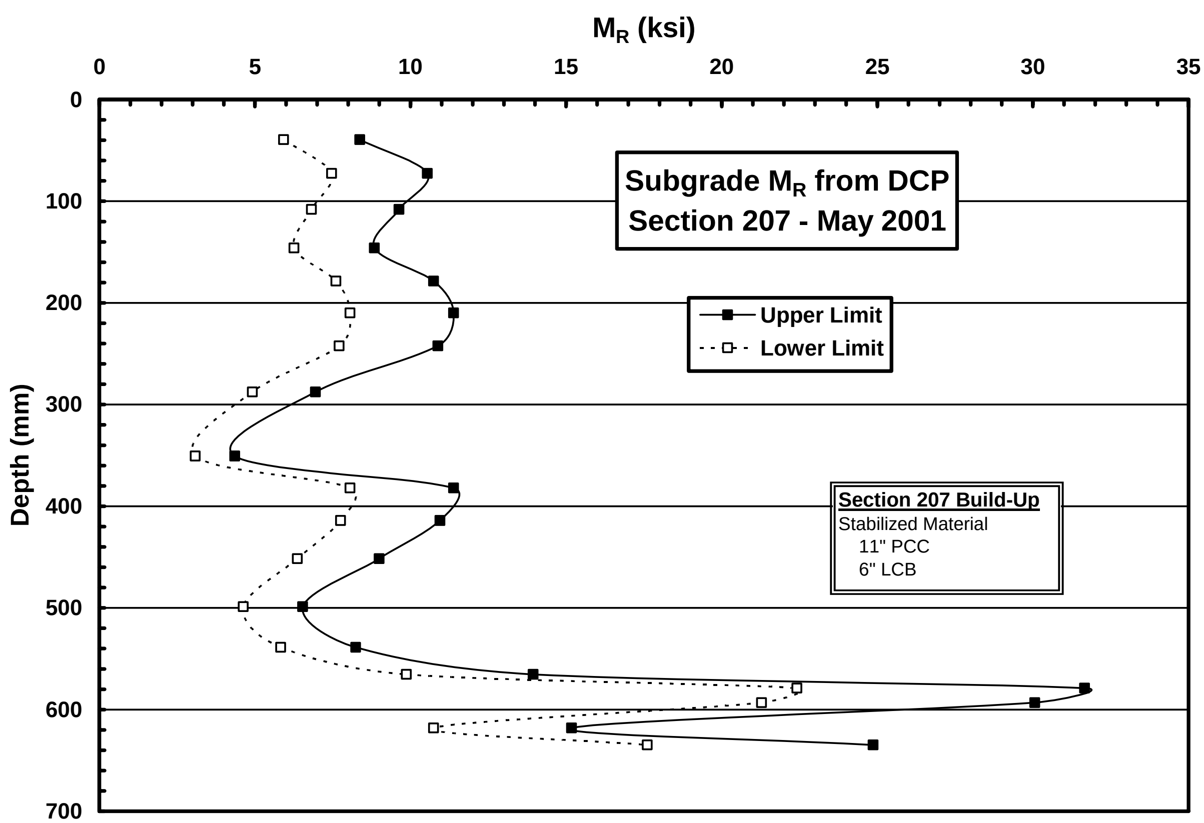
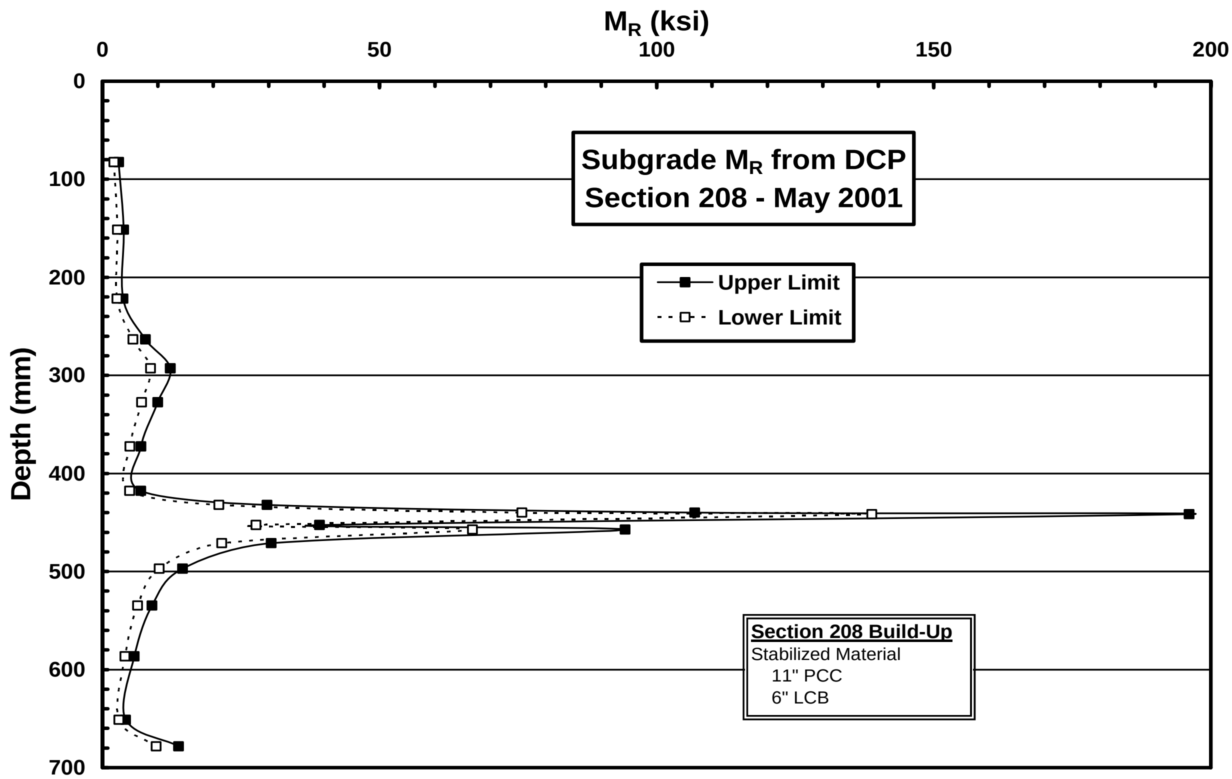


Figure L-10 DCP Profiles for Sections 206 and 207



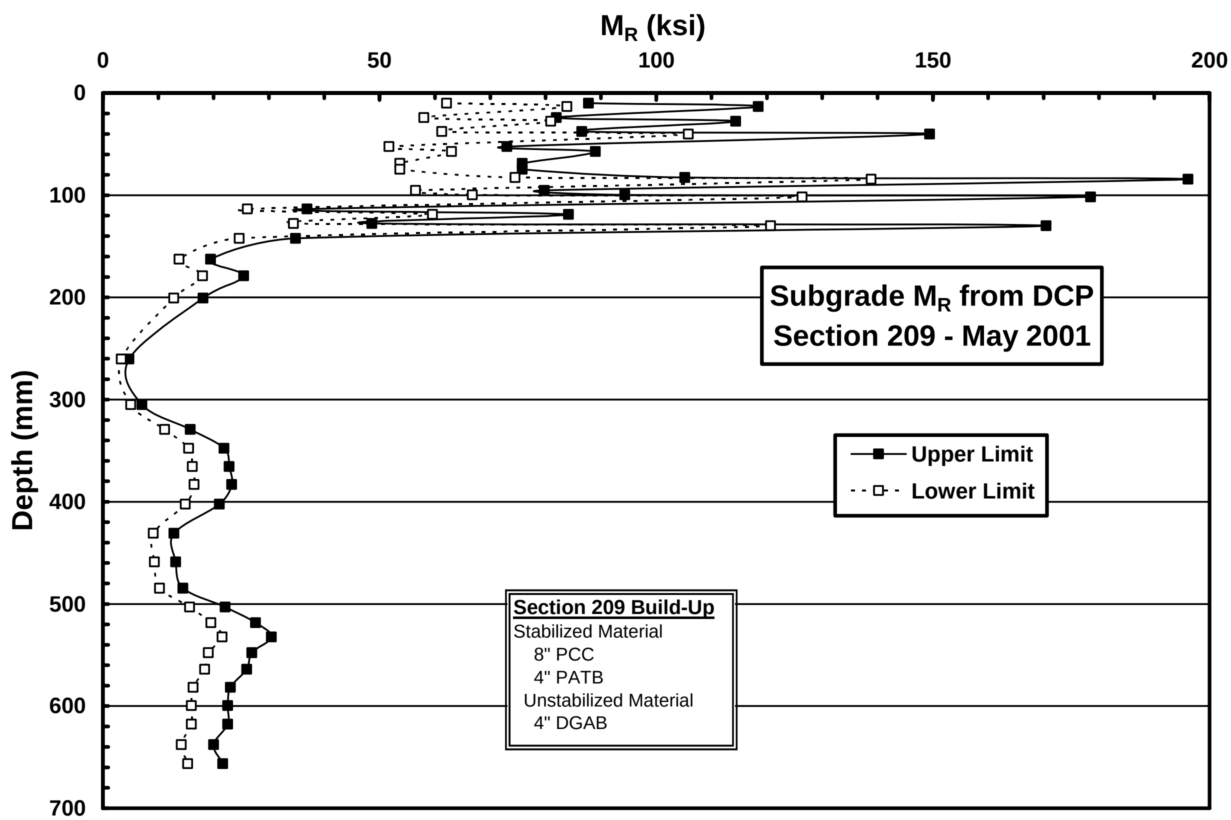
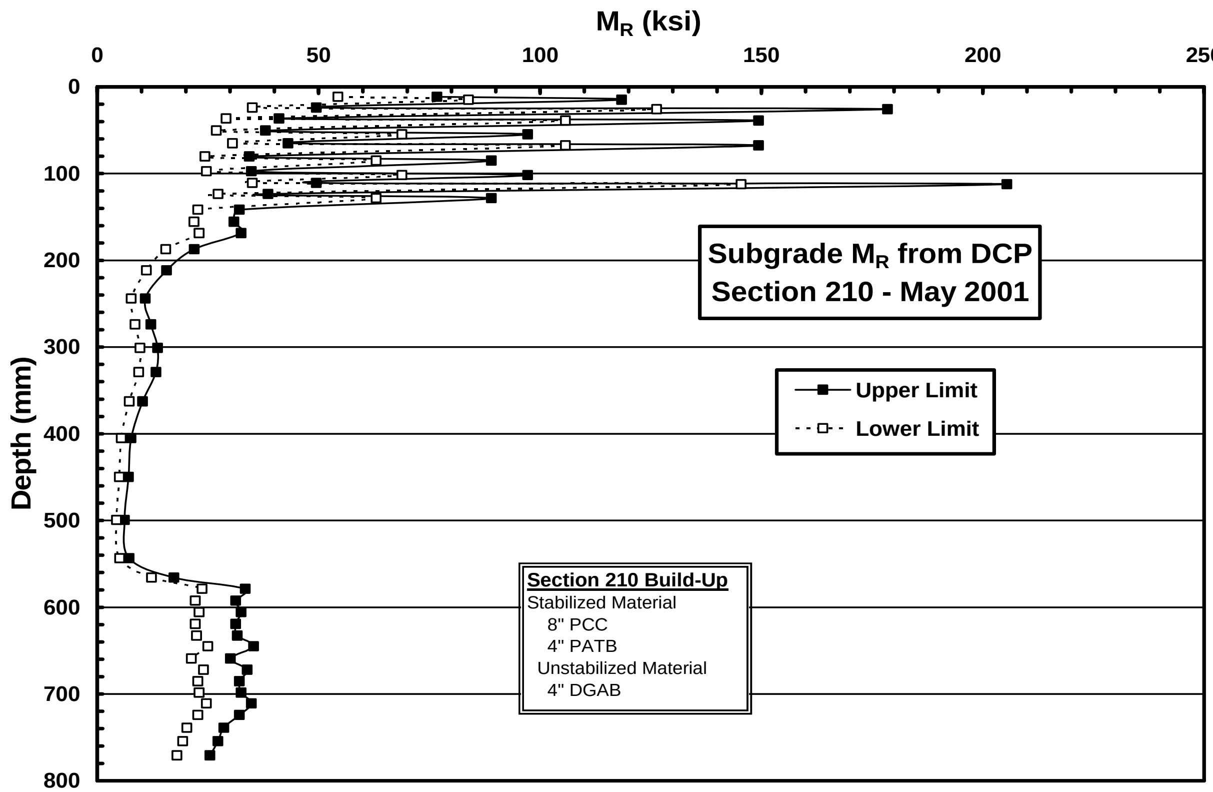


Figure L-11 DCP Profiles for Sections 208 and 209



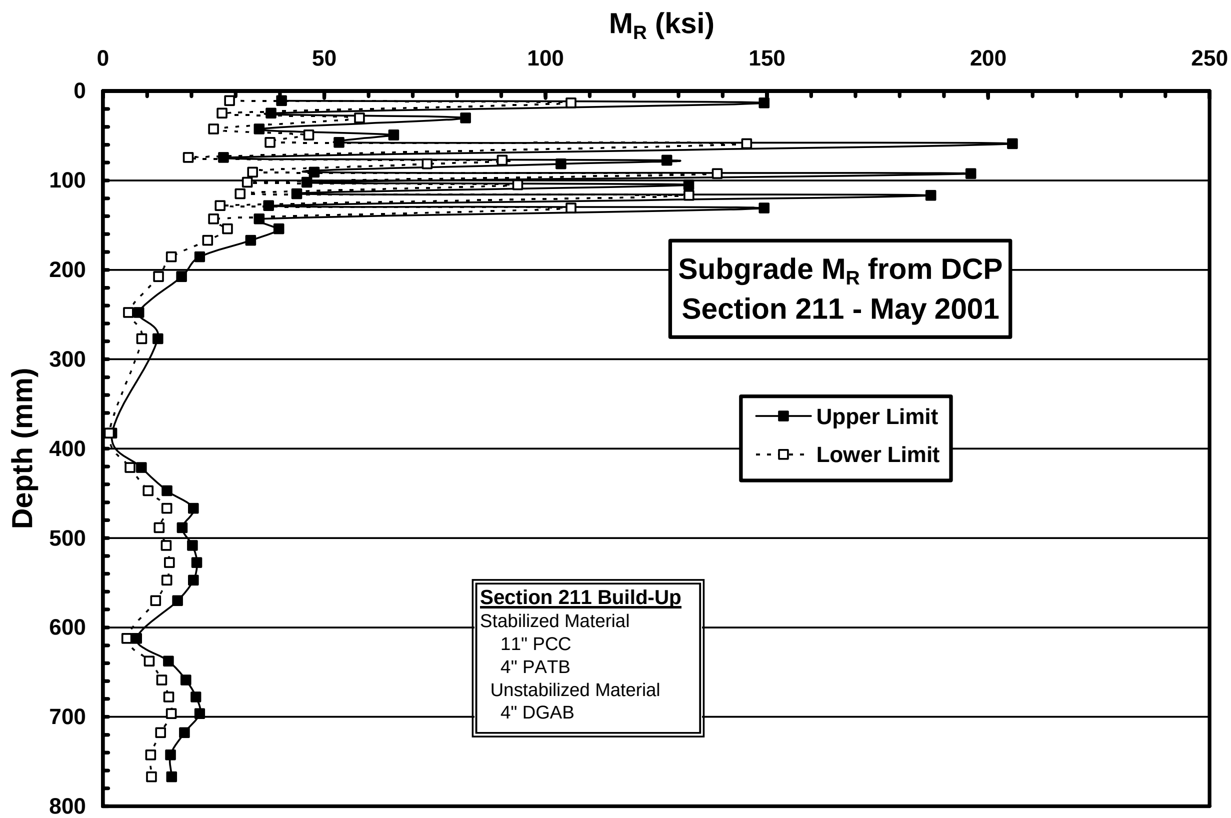
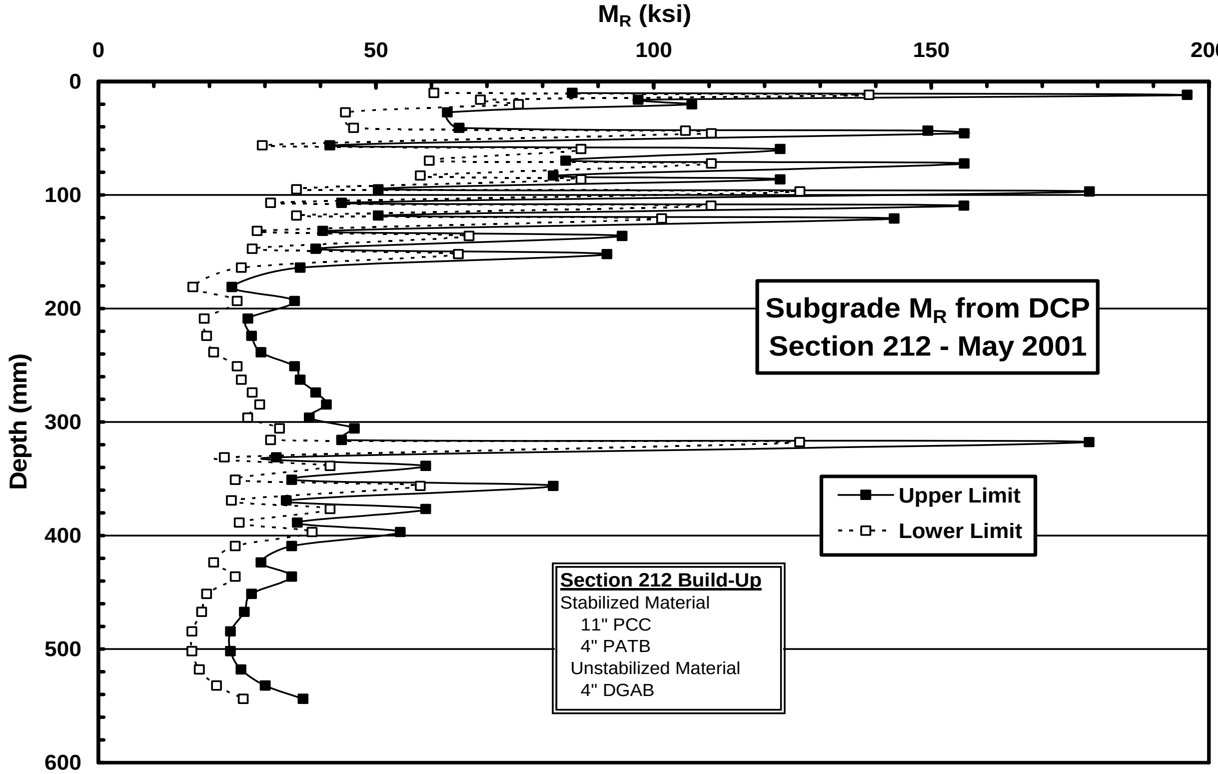


Figure L-12 DCP Profiles for Sections 210 and 211



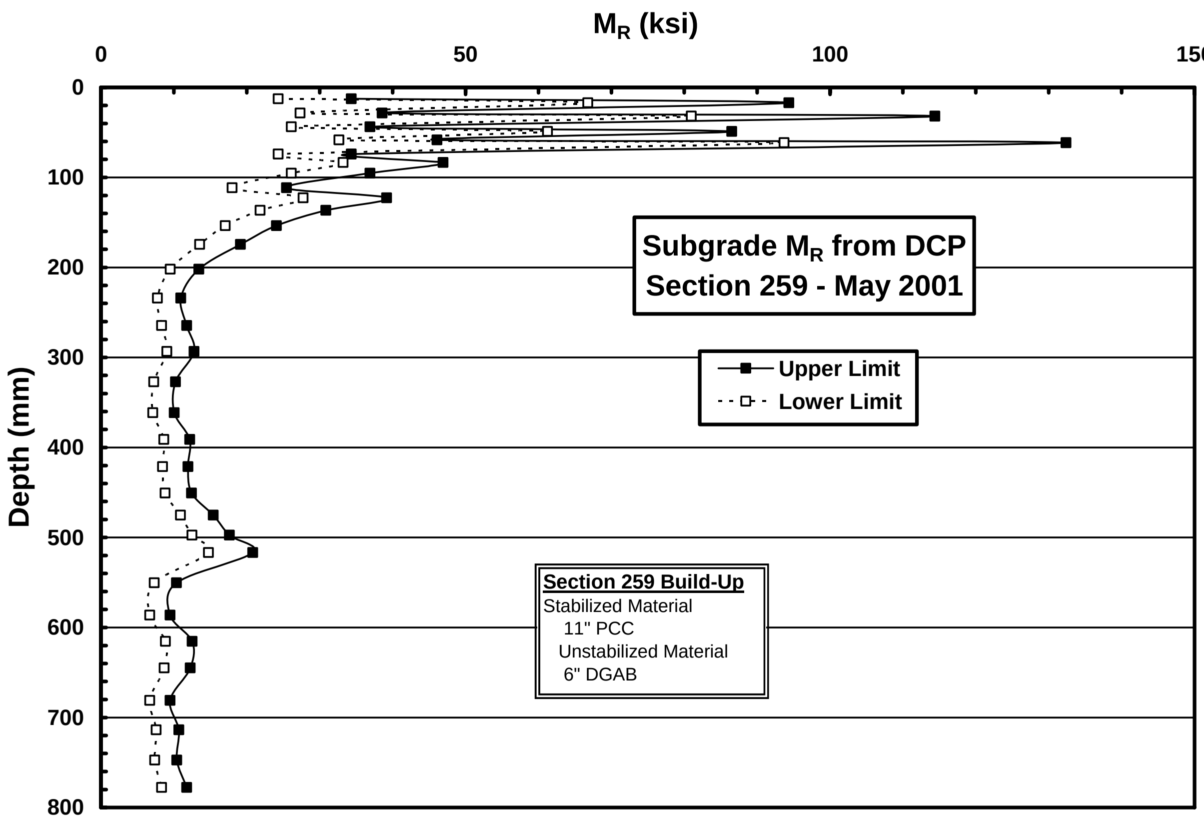
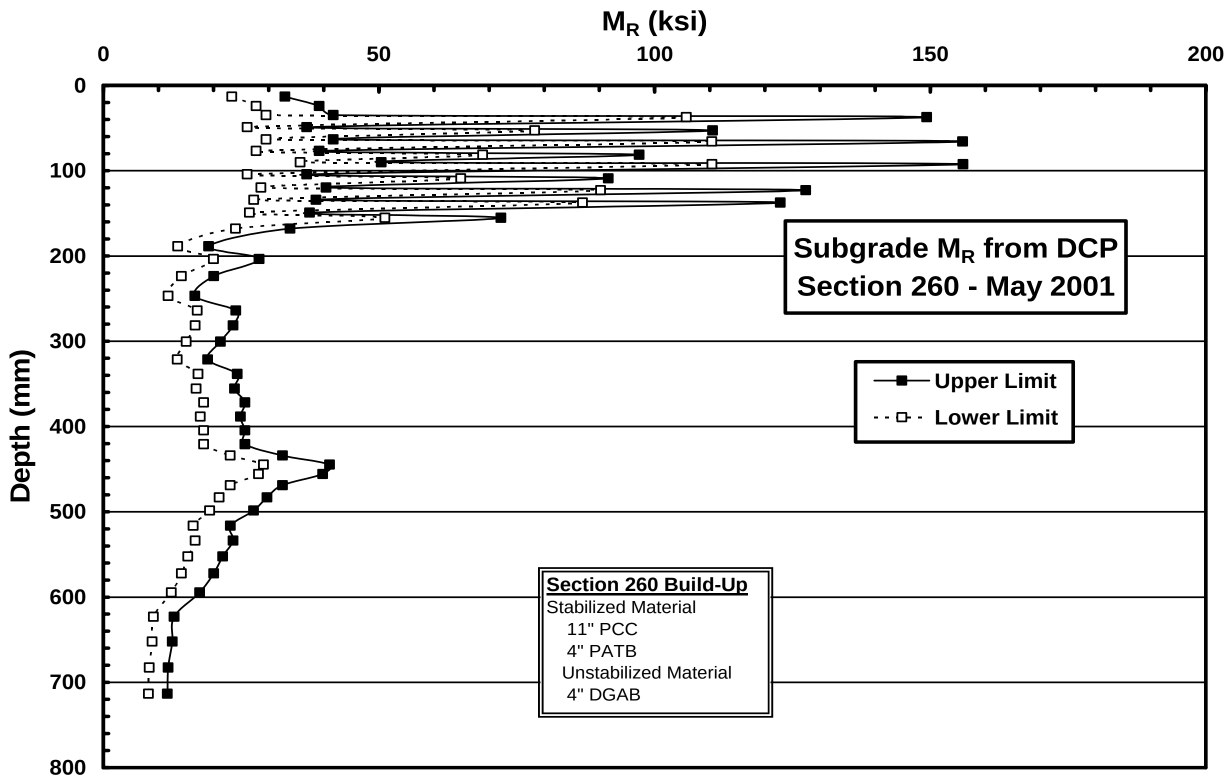


Figure L-13 DCP Profiles for Sections 212 and 259



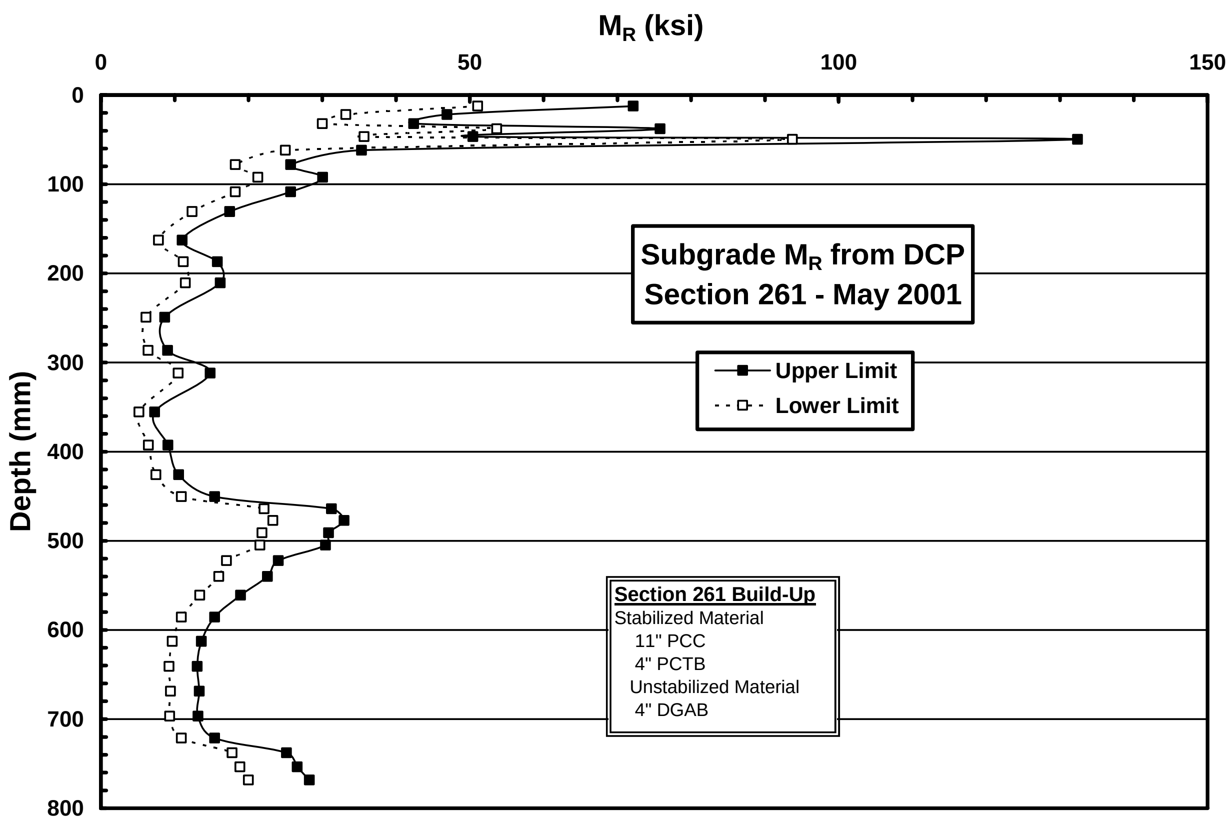
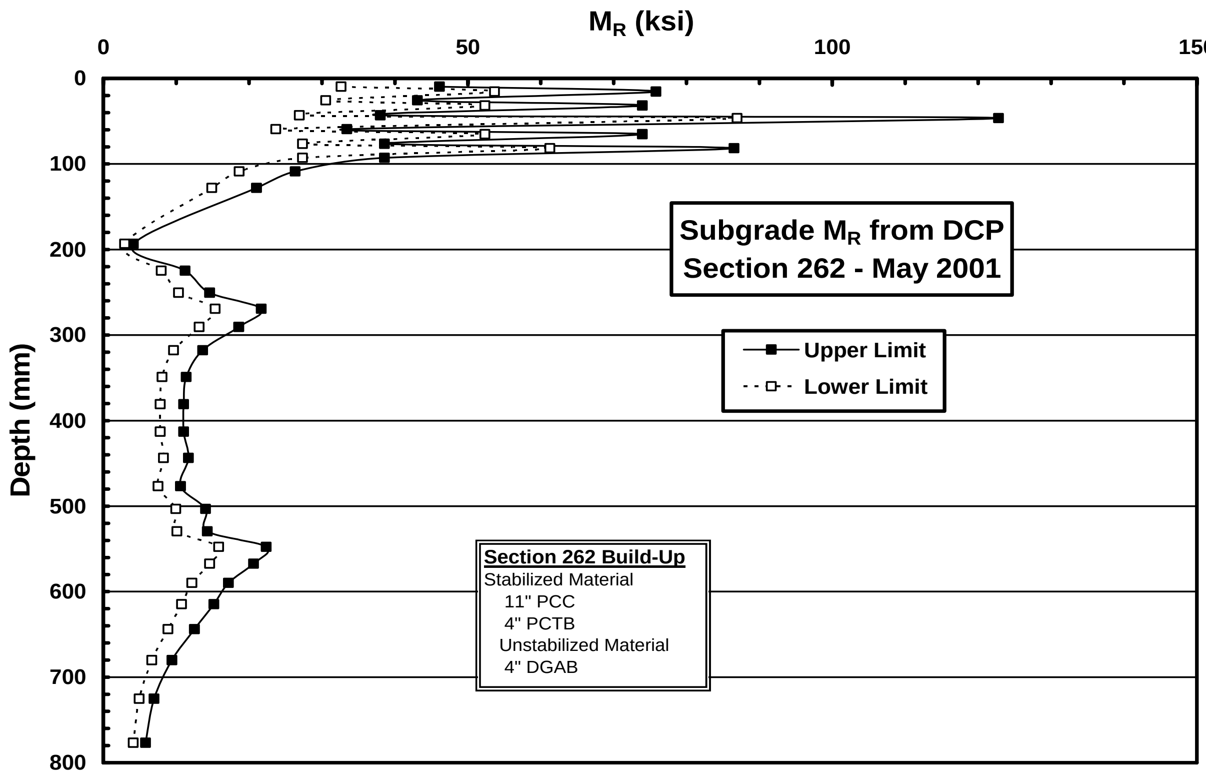


Figure L-14 DCP Profiles for Sections 260 and 261



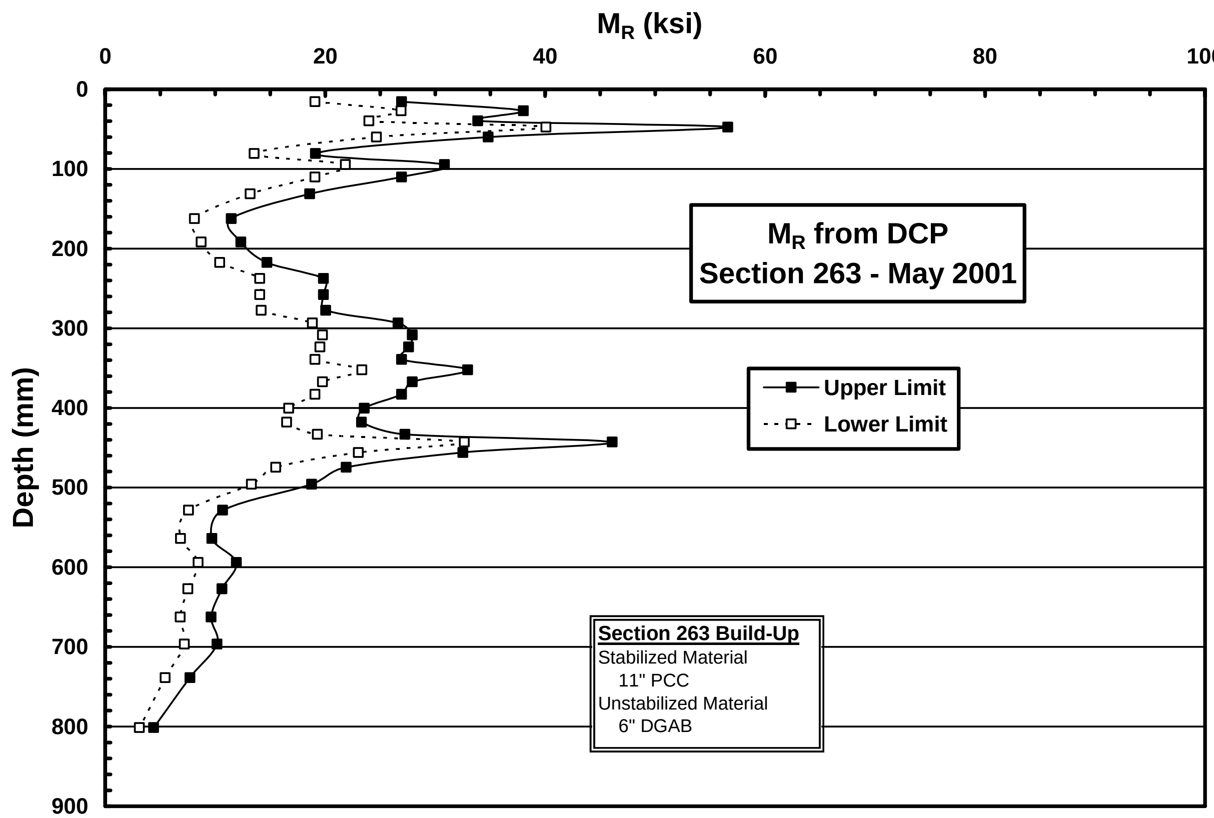
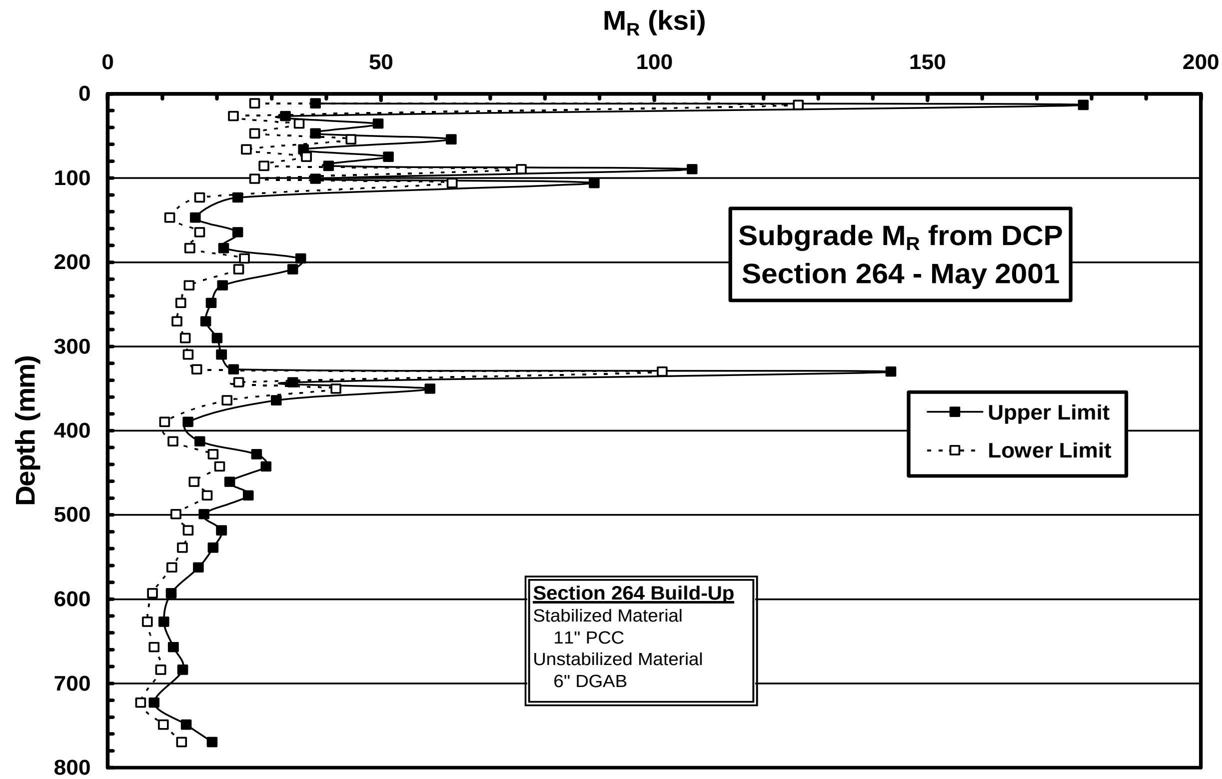


Figure L-15 DCP Profiles for Sections 262 and 263



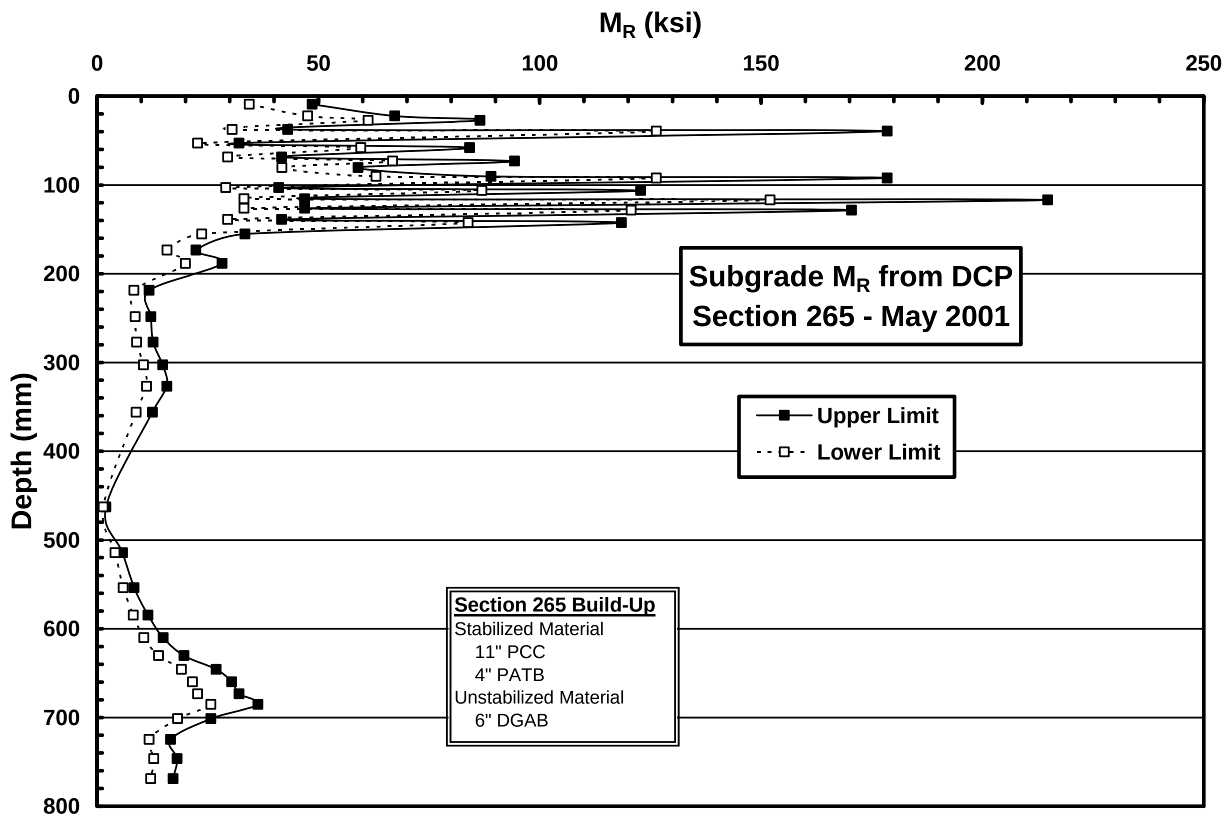
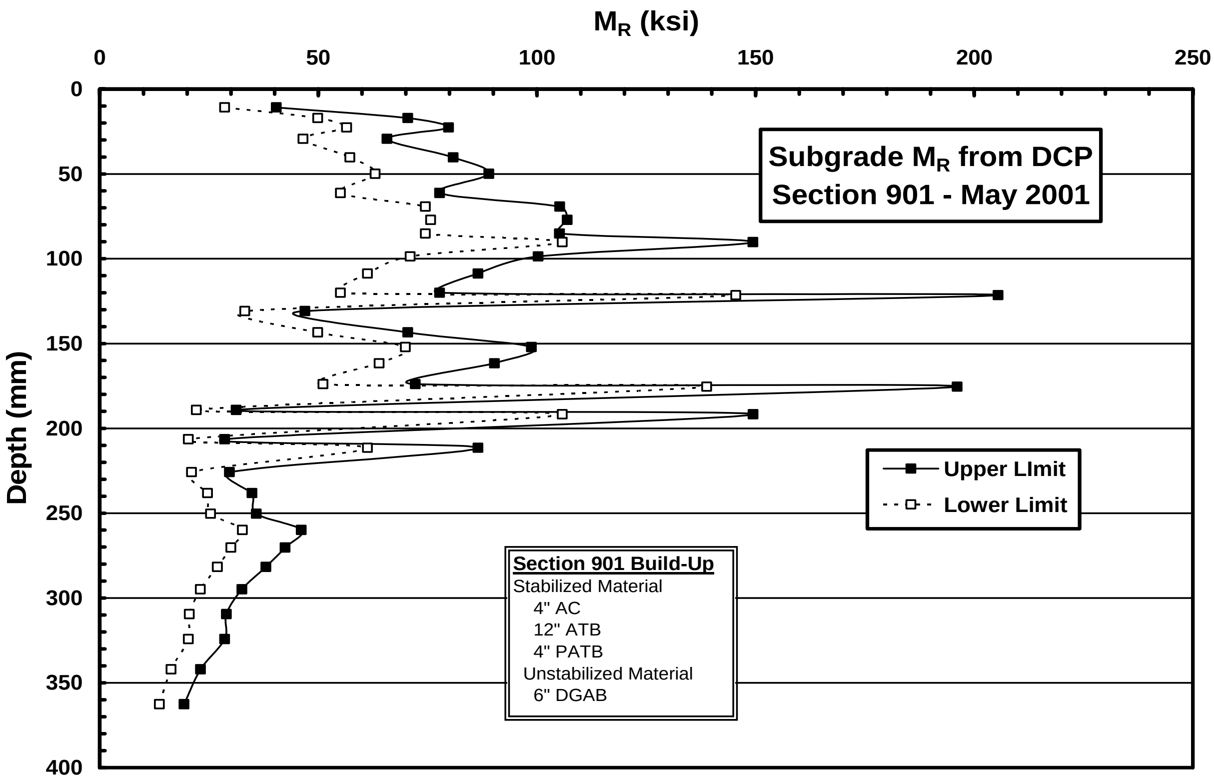


Figure L-16 DCP Profiles for Sections 264 and 265



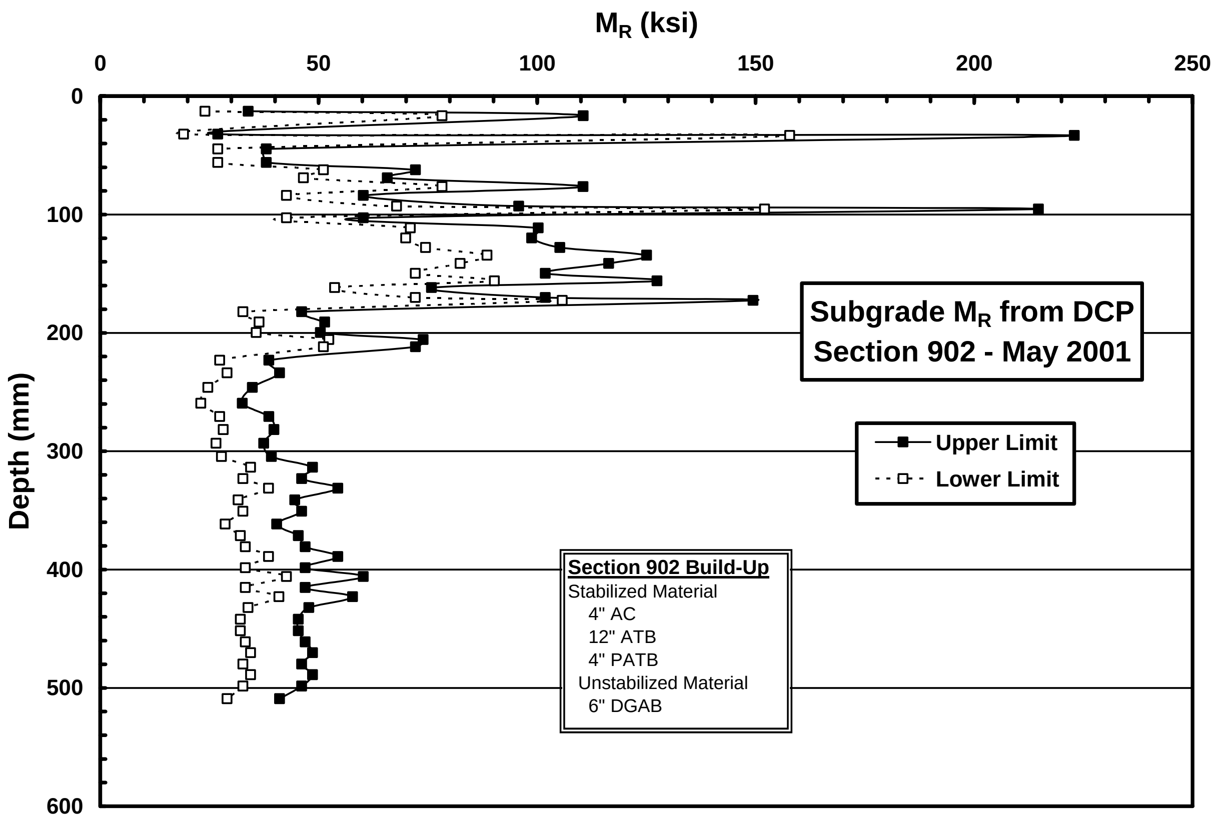


Figure L-17 DCP Profiles for Sections 901 and 902

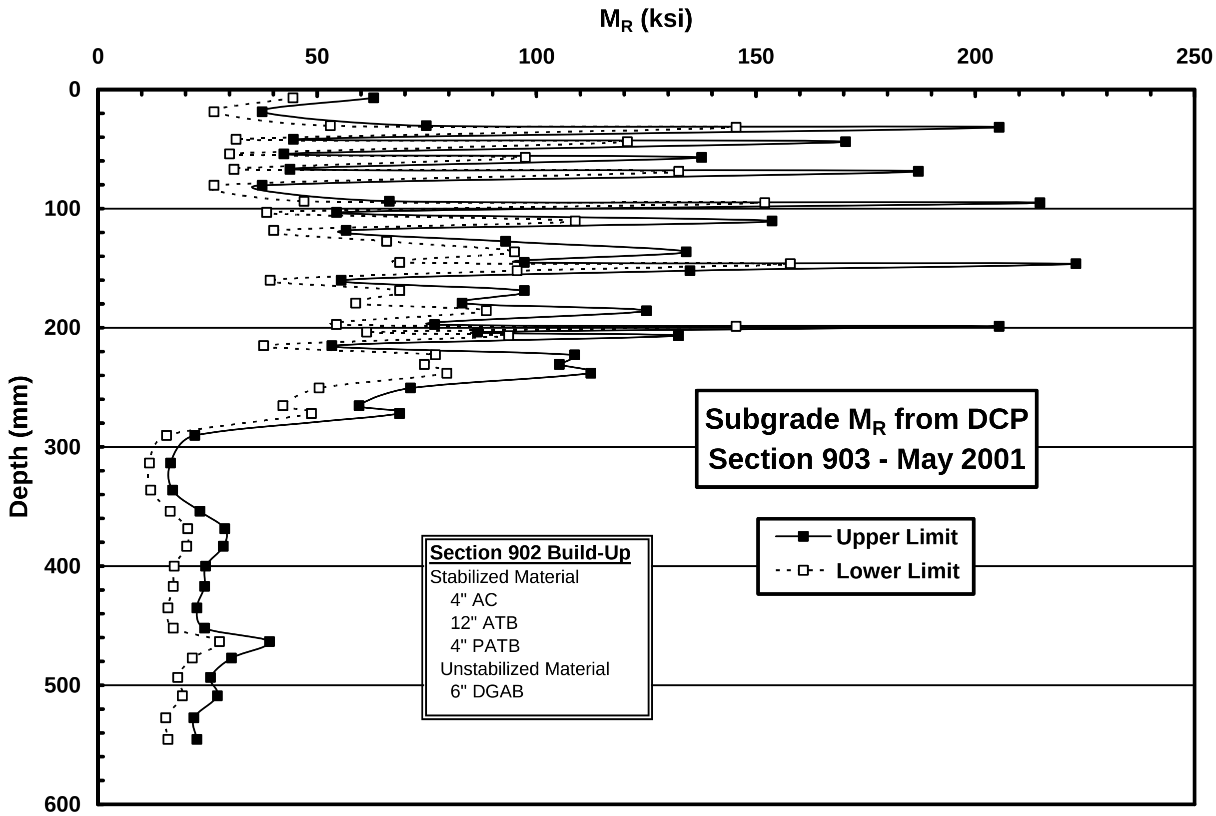
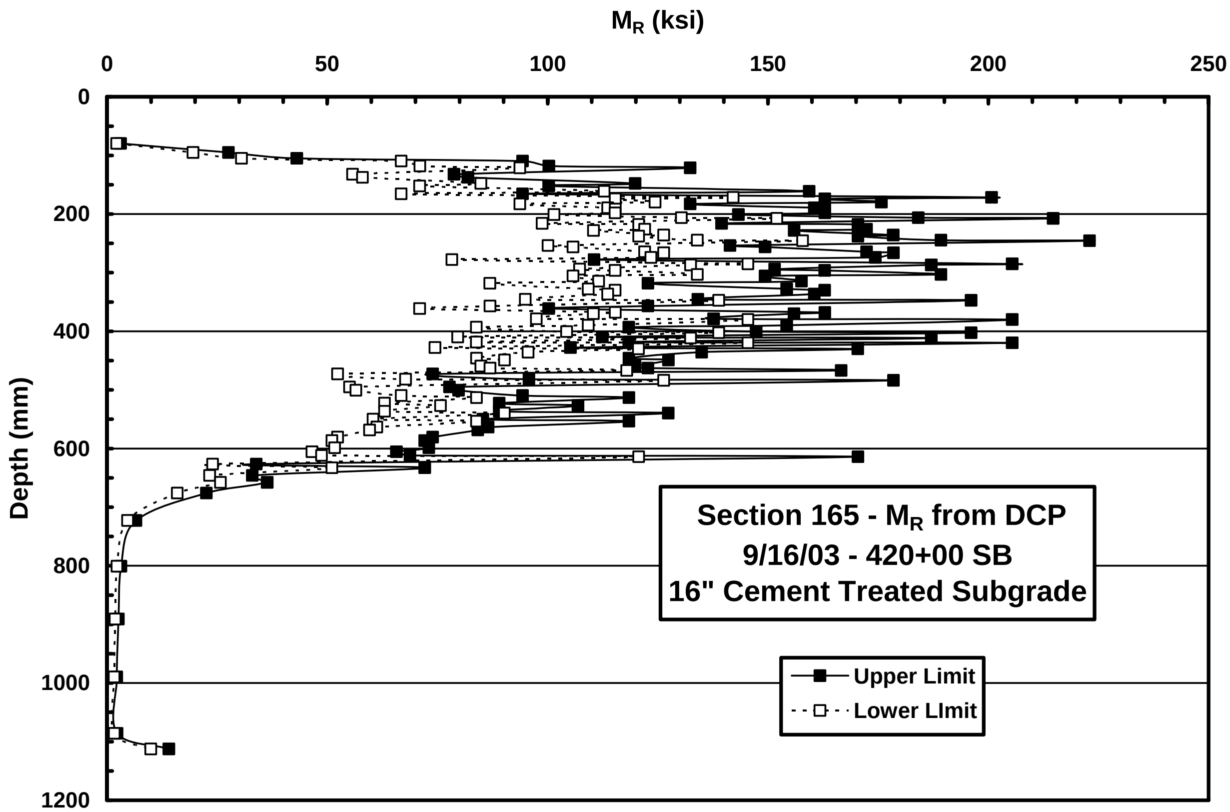


Figure L-18 DCP Profiles for Section 903

APPENDIX M

2003 DCP PROFILES IN SECTION 165



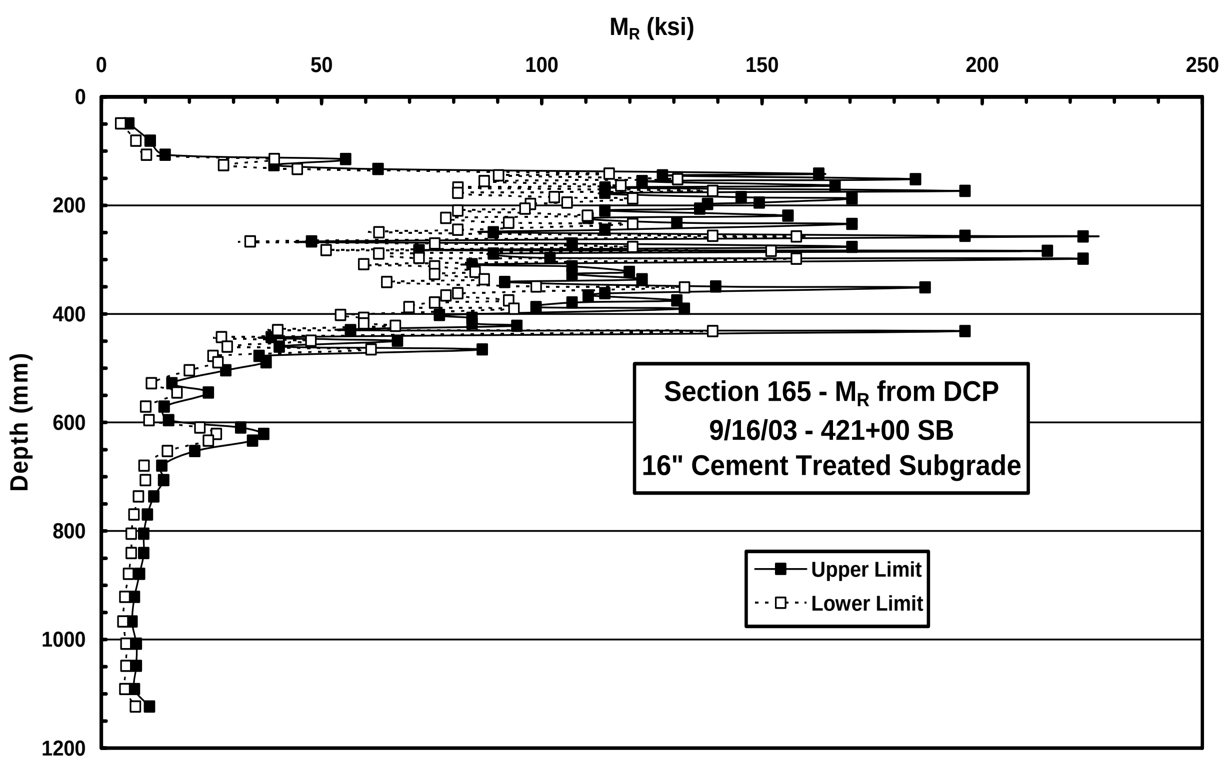
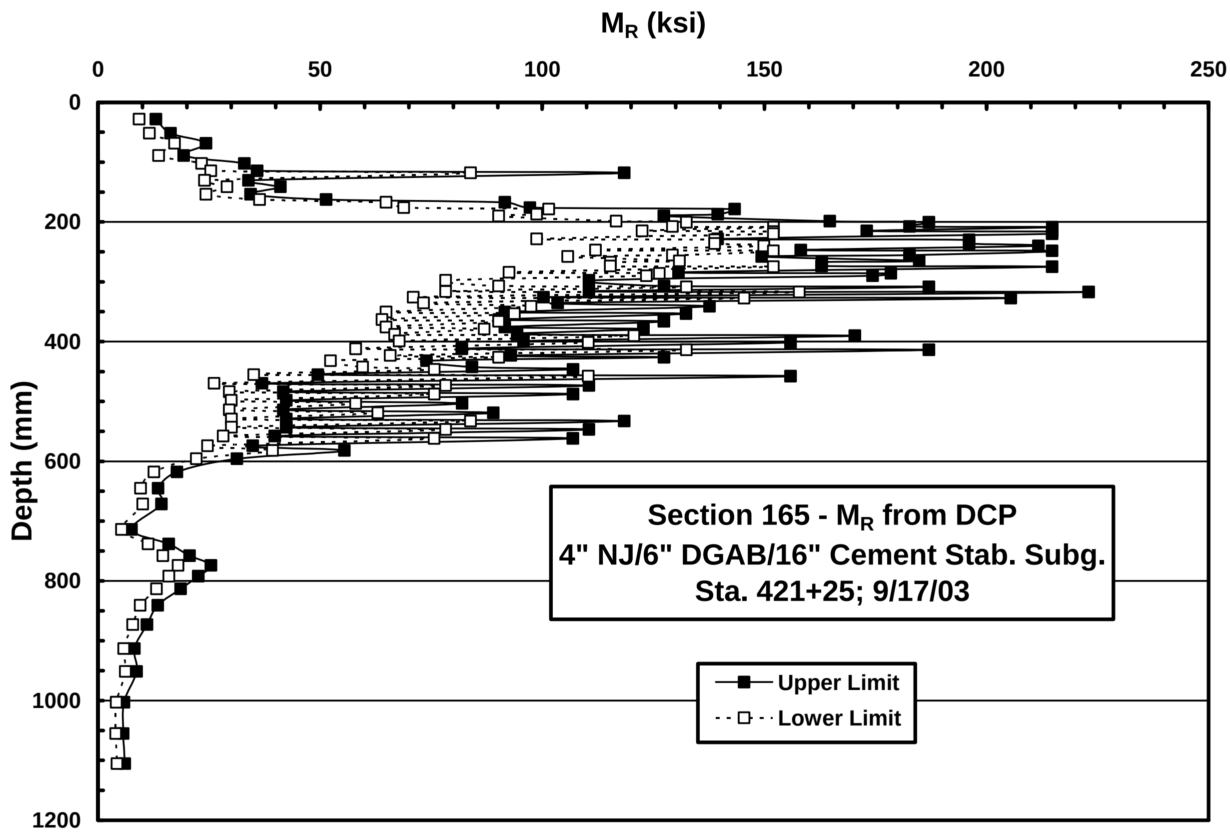


Figure M-1 DCP Profile at Stations 420+00 and 421+00 in Section 165



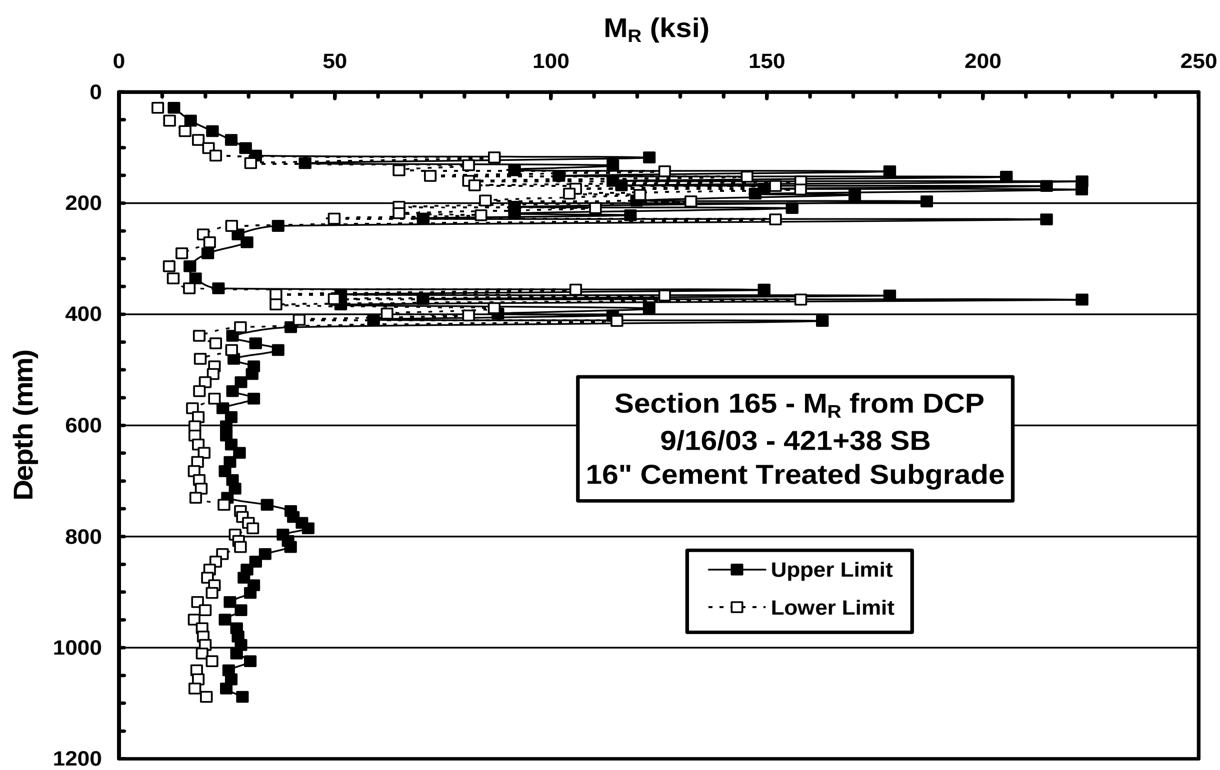
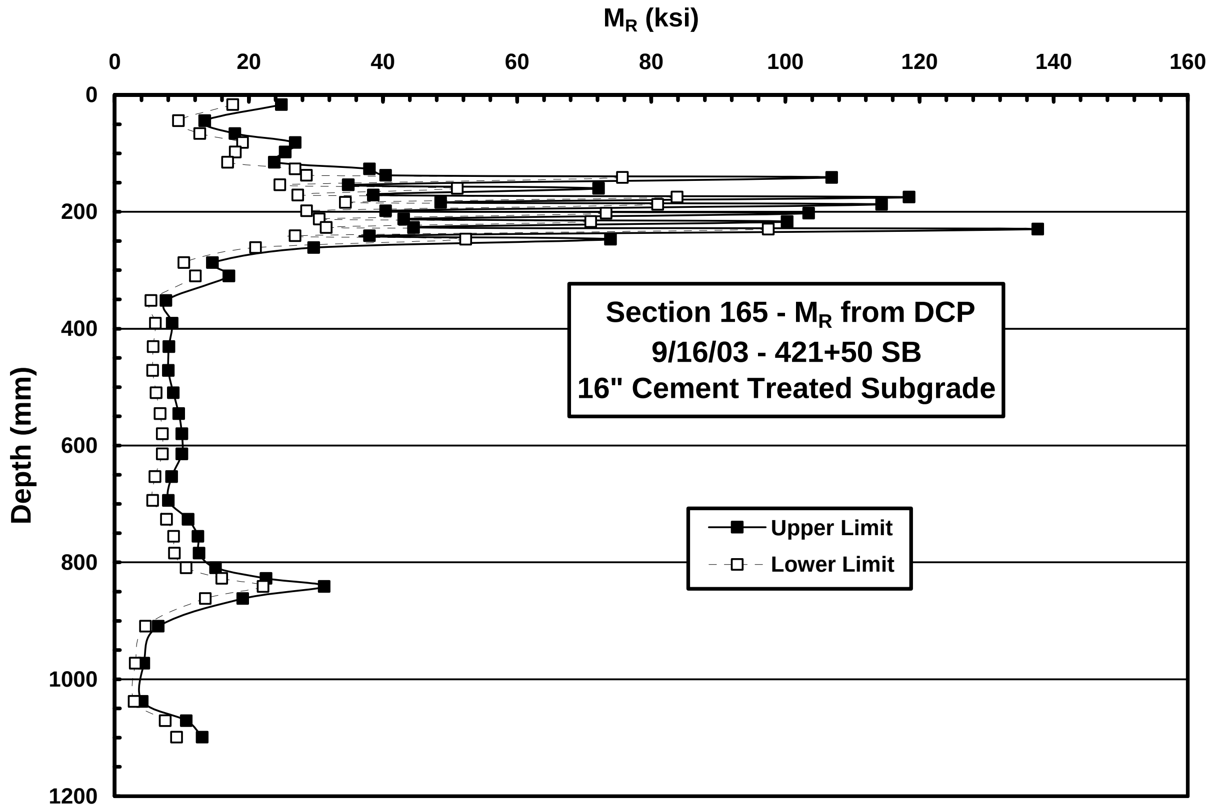


Figure M-2 DCP Profile at Stations 421+25 and 421+38 in Section 165



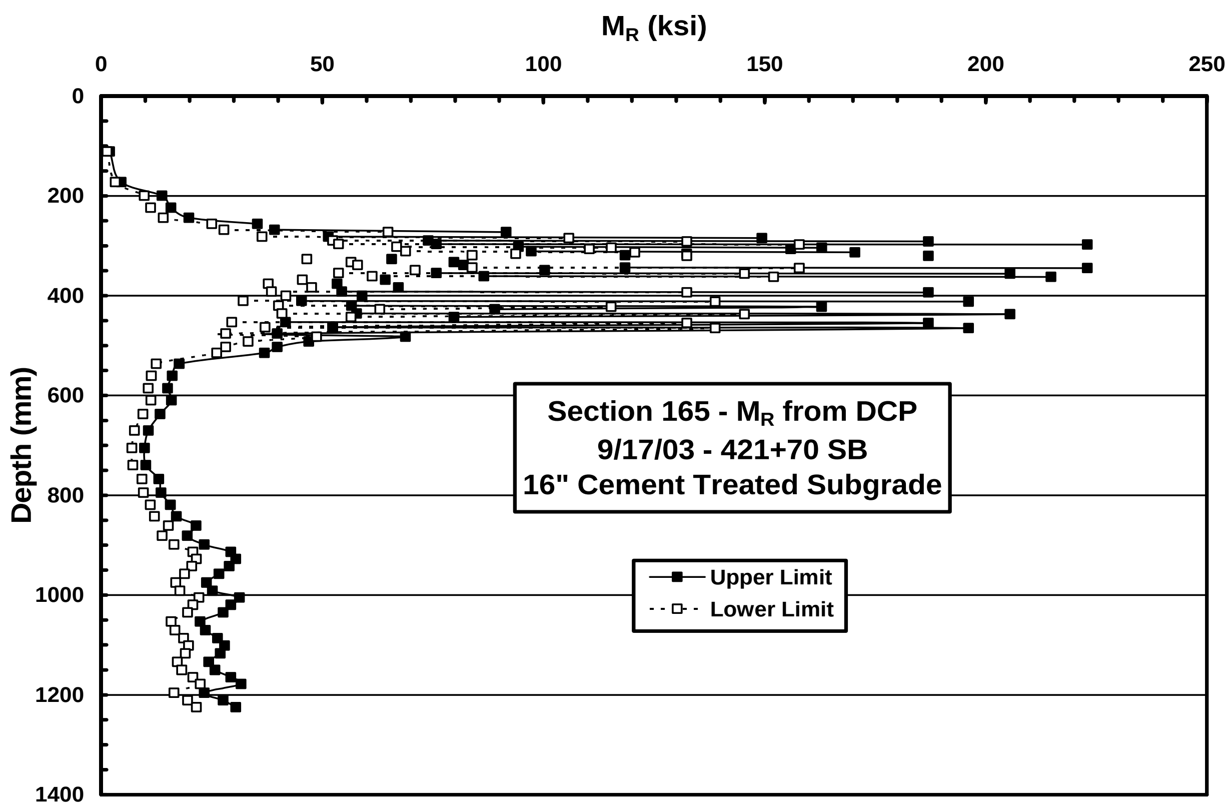
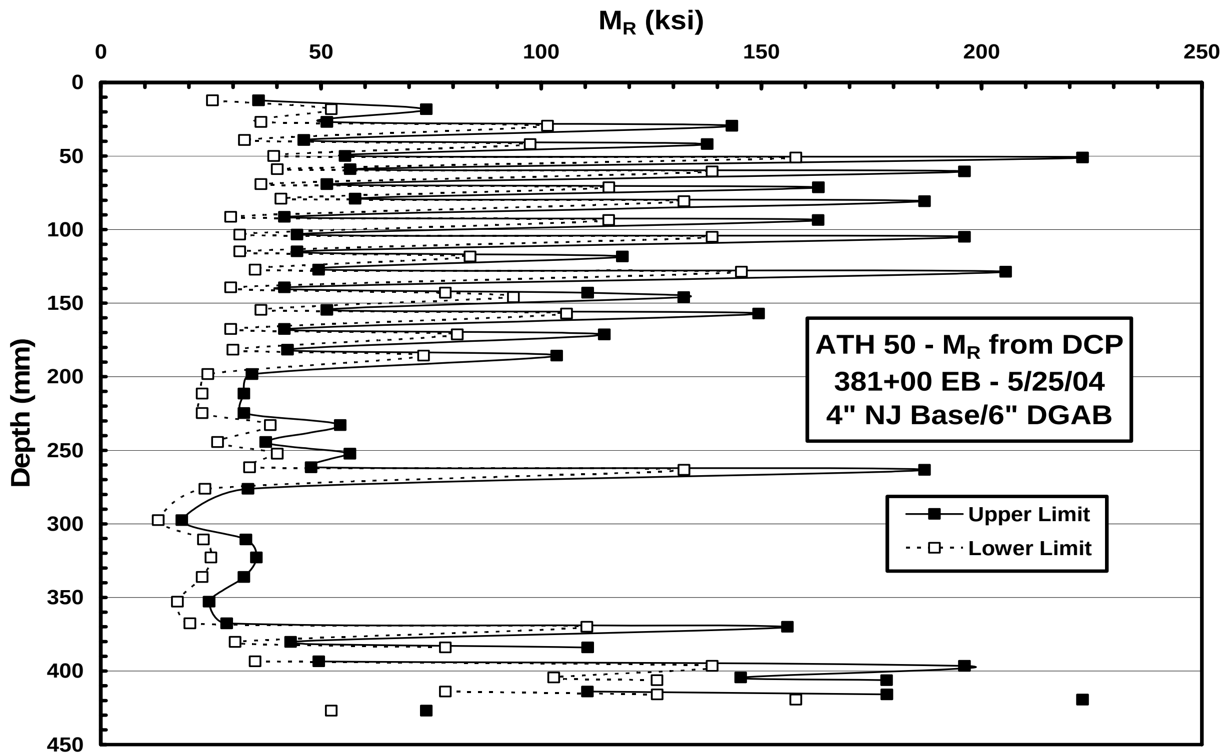


Figure M-3 DCP Profile at Stations 421+50 and 421+70 in Section 165

APPENDIX N

May 2004 DCP Profiles on ATH 50



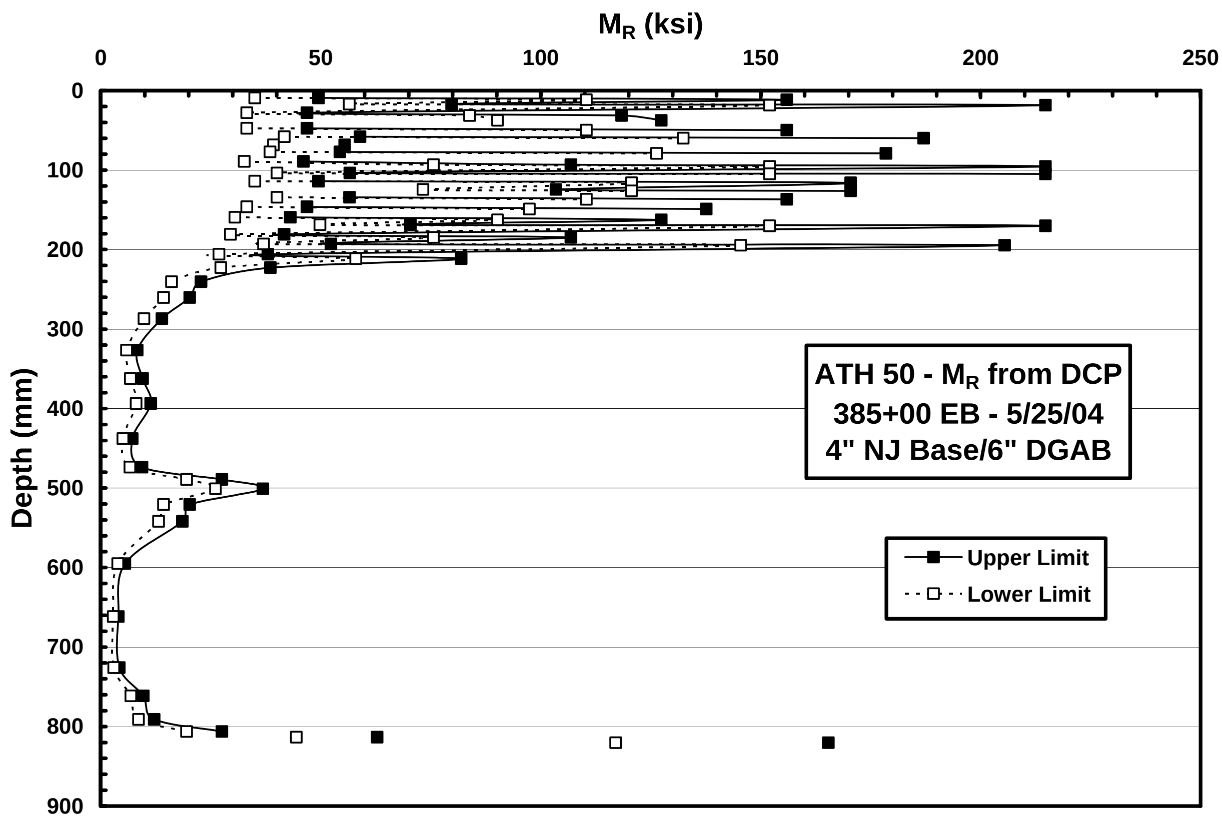
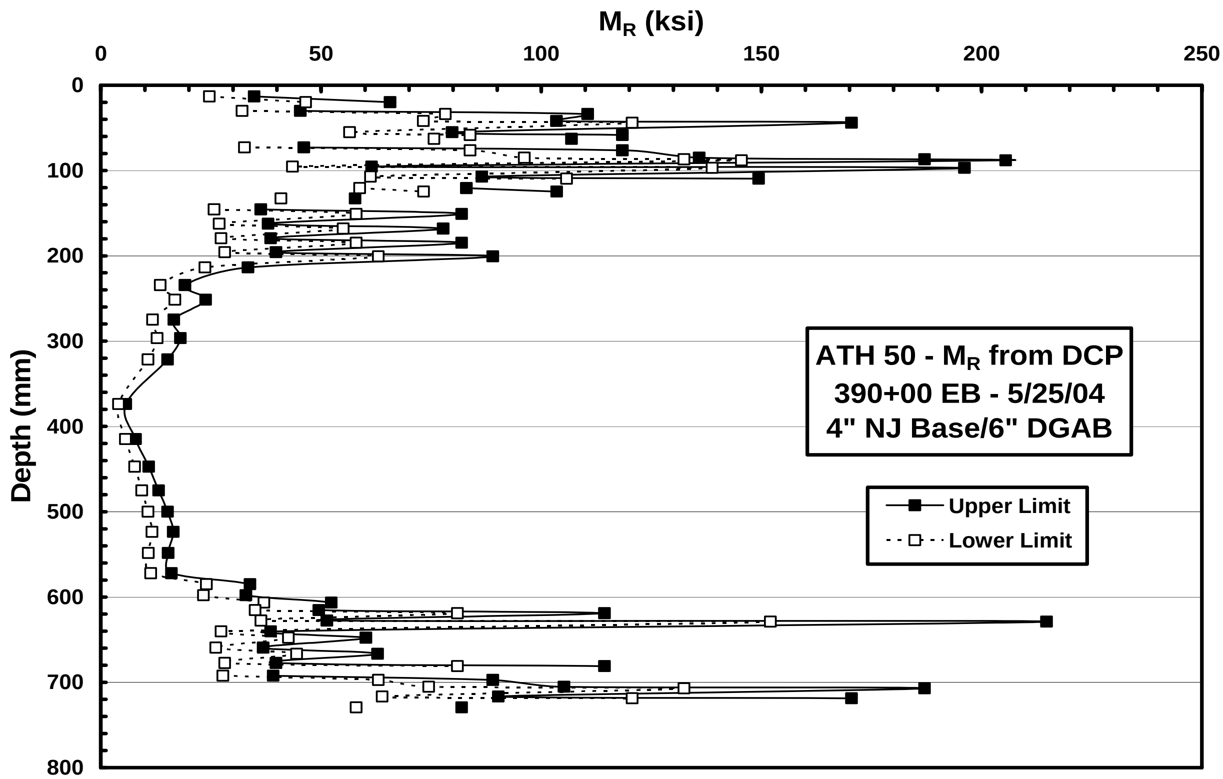


Figure N-1 DCP Profile at Stations 381+00 and 385+00 on ATH 50



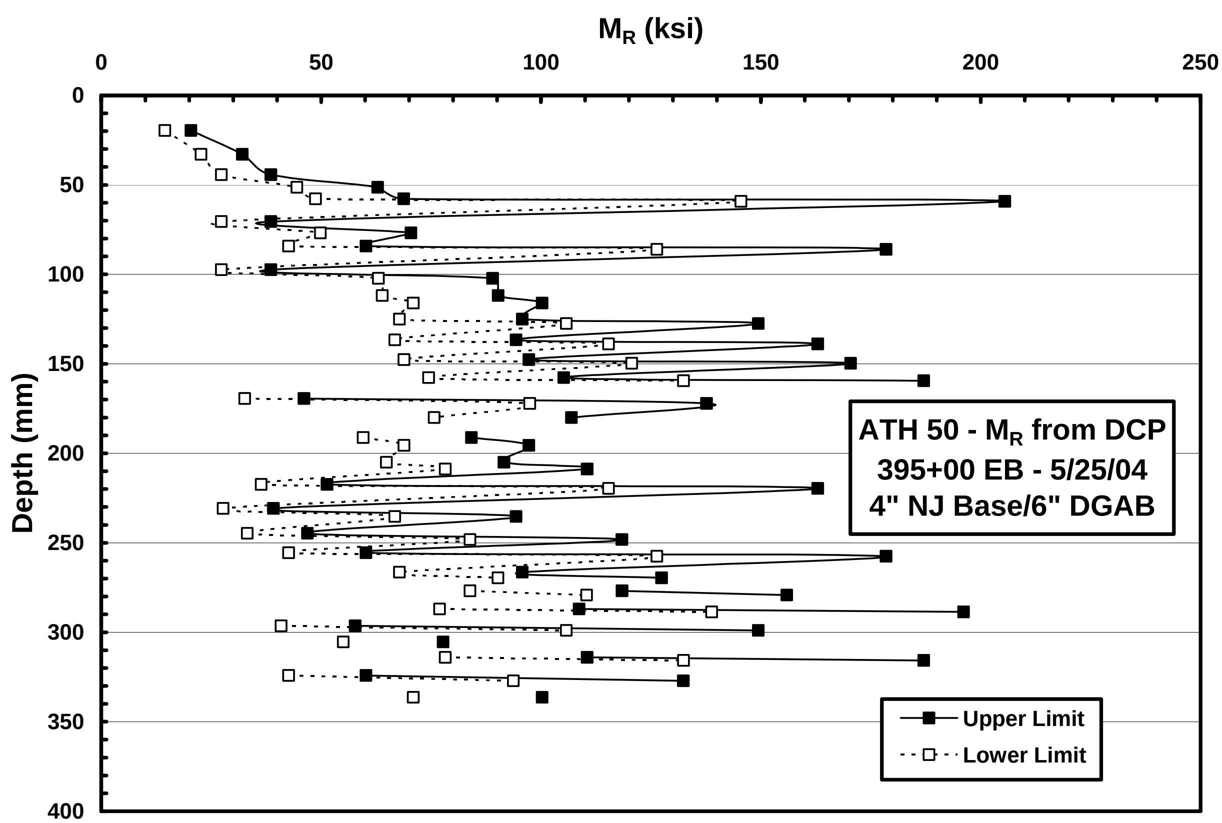
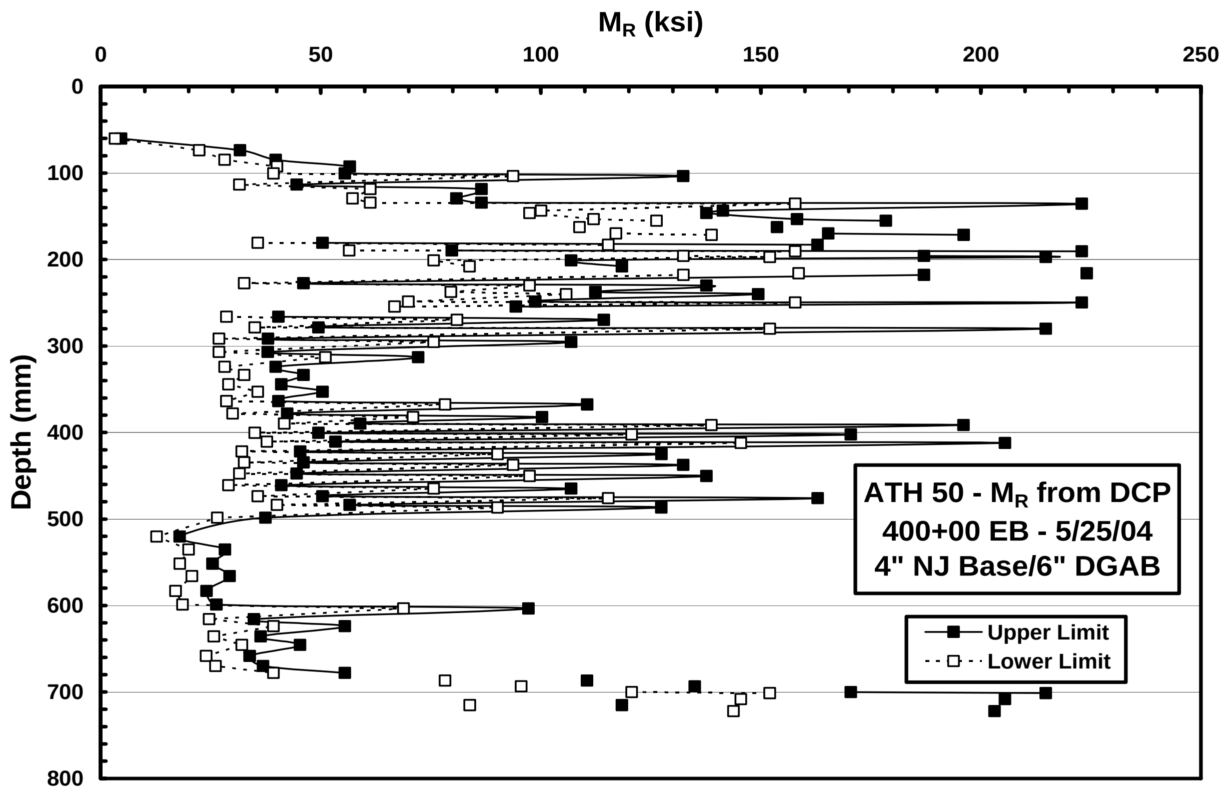


Figure N-2 DCP Profile at Stations 390+00 and 395+00 on ATH 50



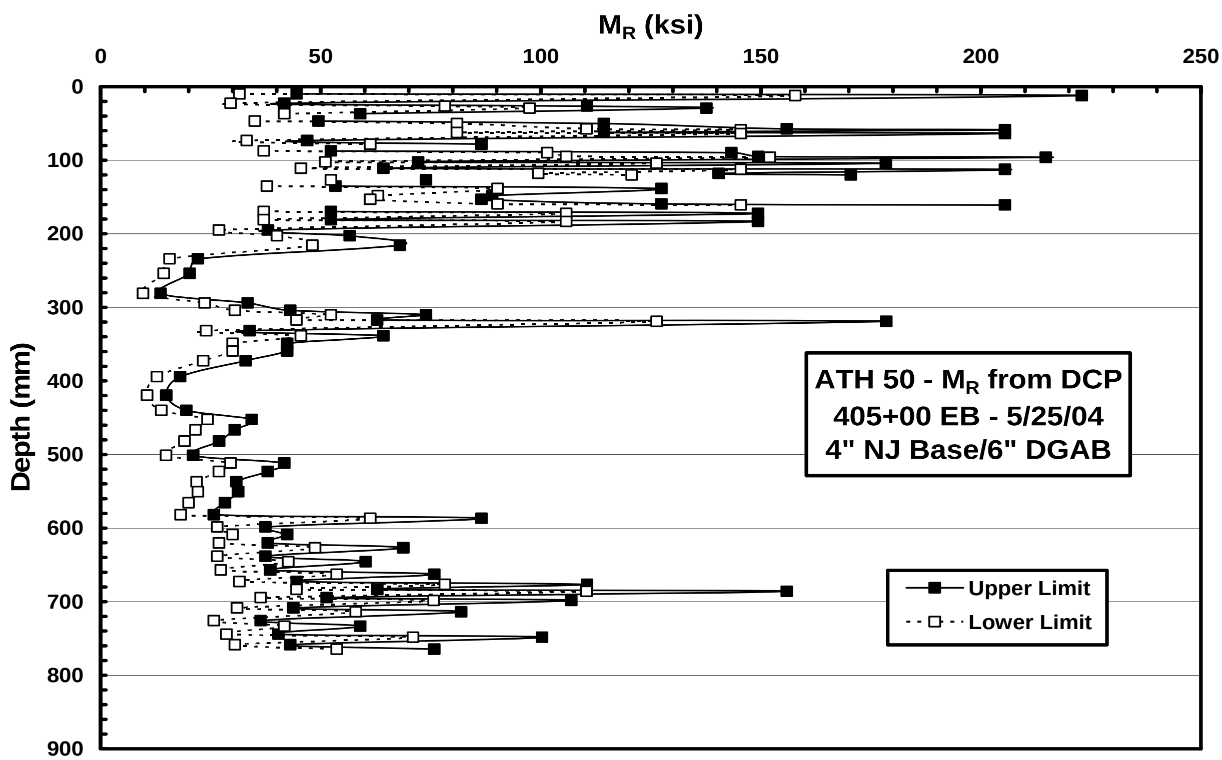
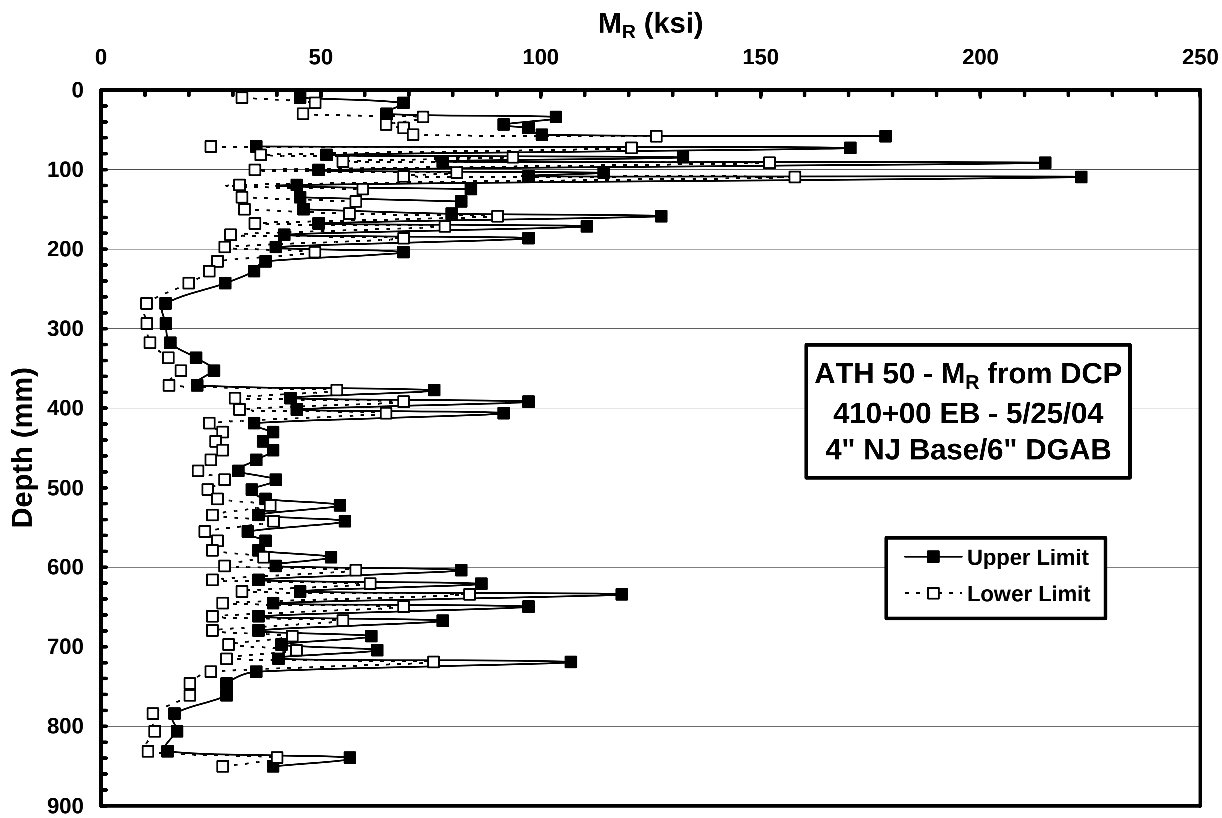


Figure N-3 DCP Profile at Stations 400+00 and 405+00 on ATH 50



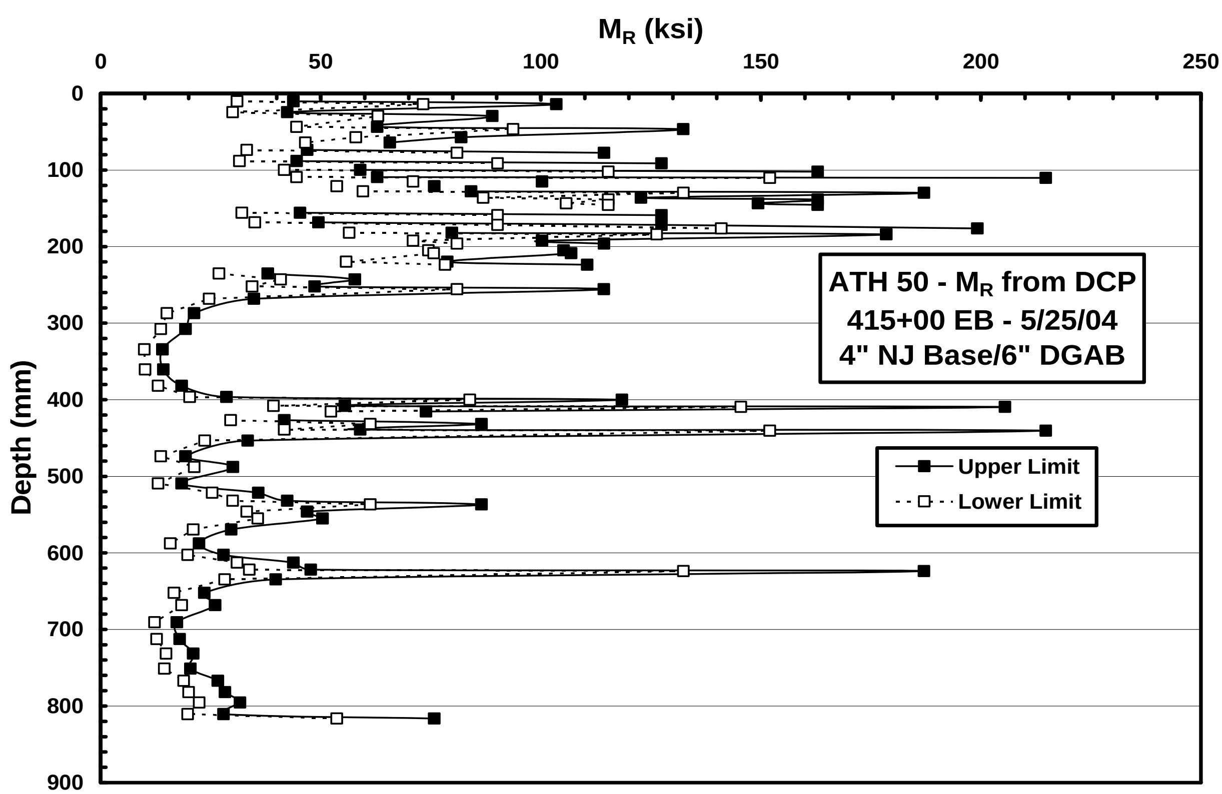
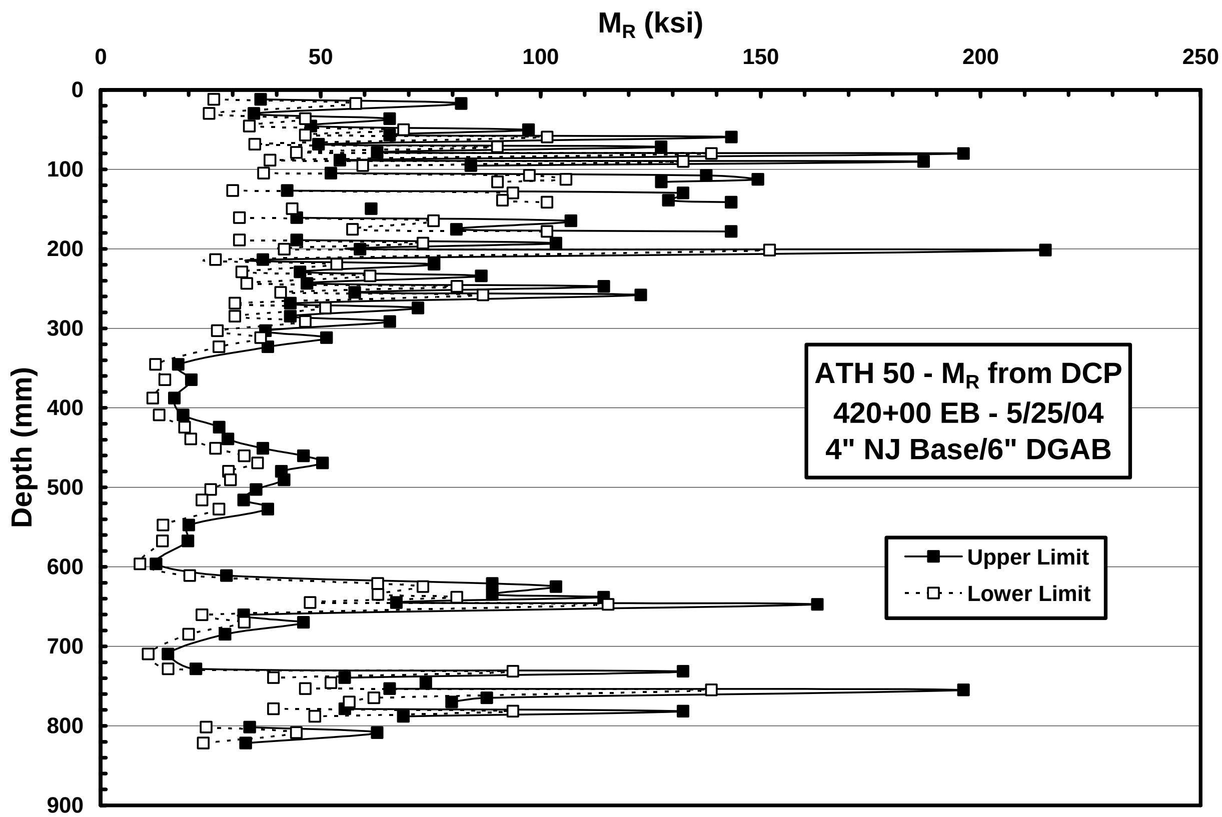


Figure N-4 DCP Profile at Stations 410+00 and 415+00 on ATH 50



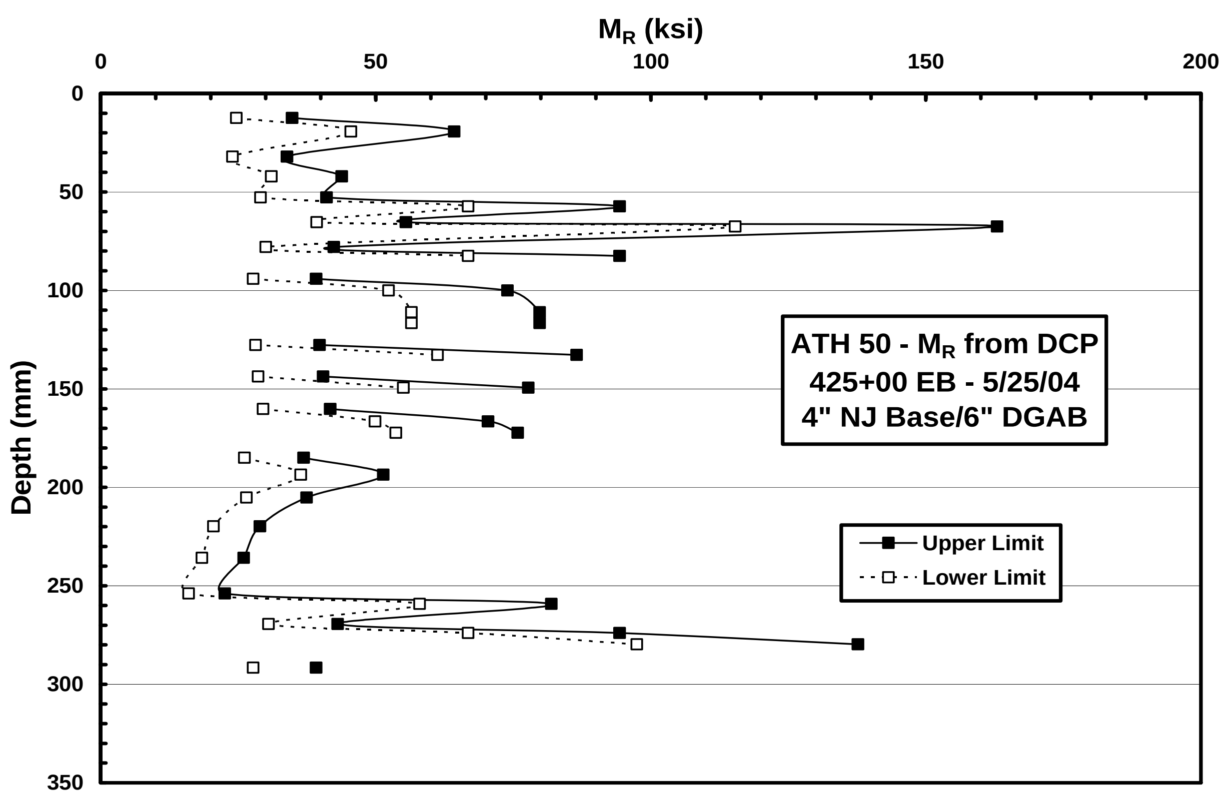
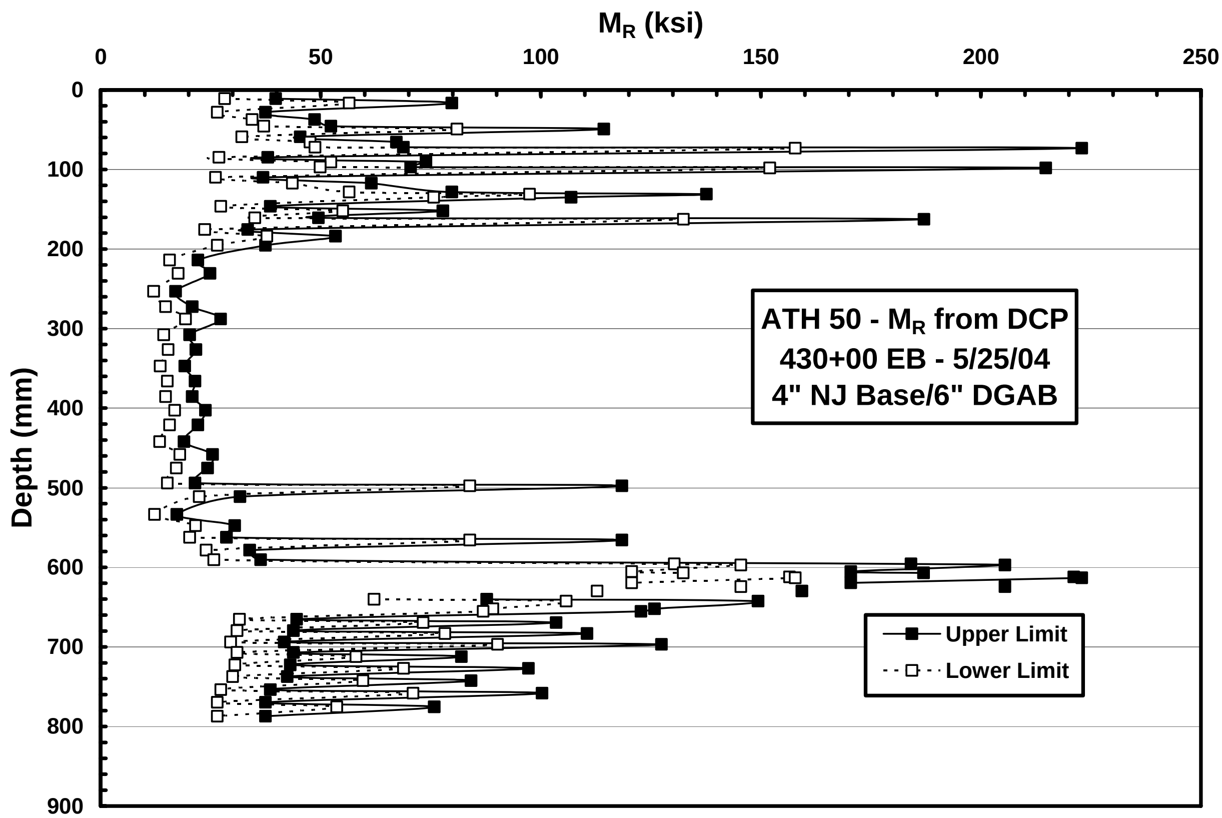


Figure N-5 DCP Profile at Stations 420+00 and 425+00 on ATH 50



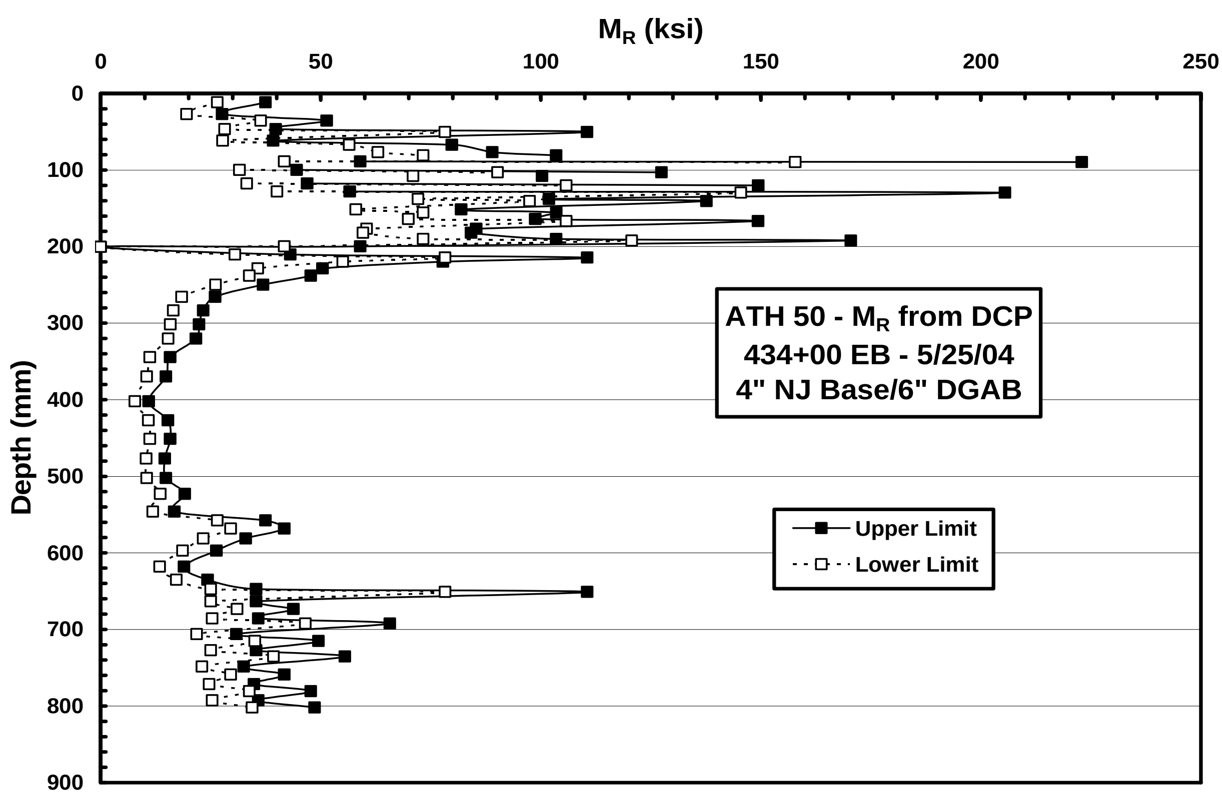
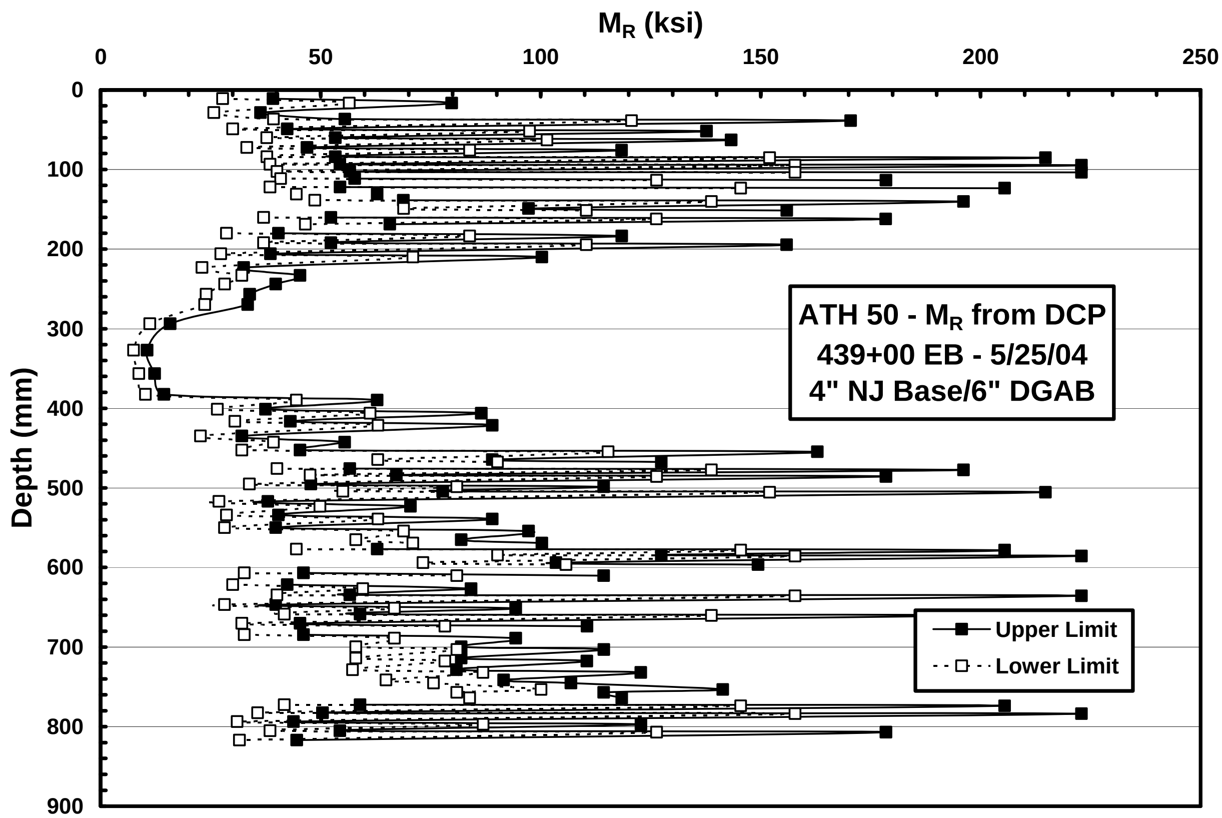


Figure N-6 DCP Profile at Stations 430+00 and 434+00 on ATH 50



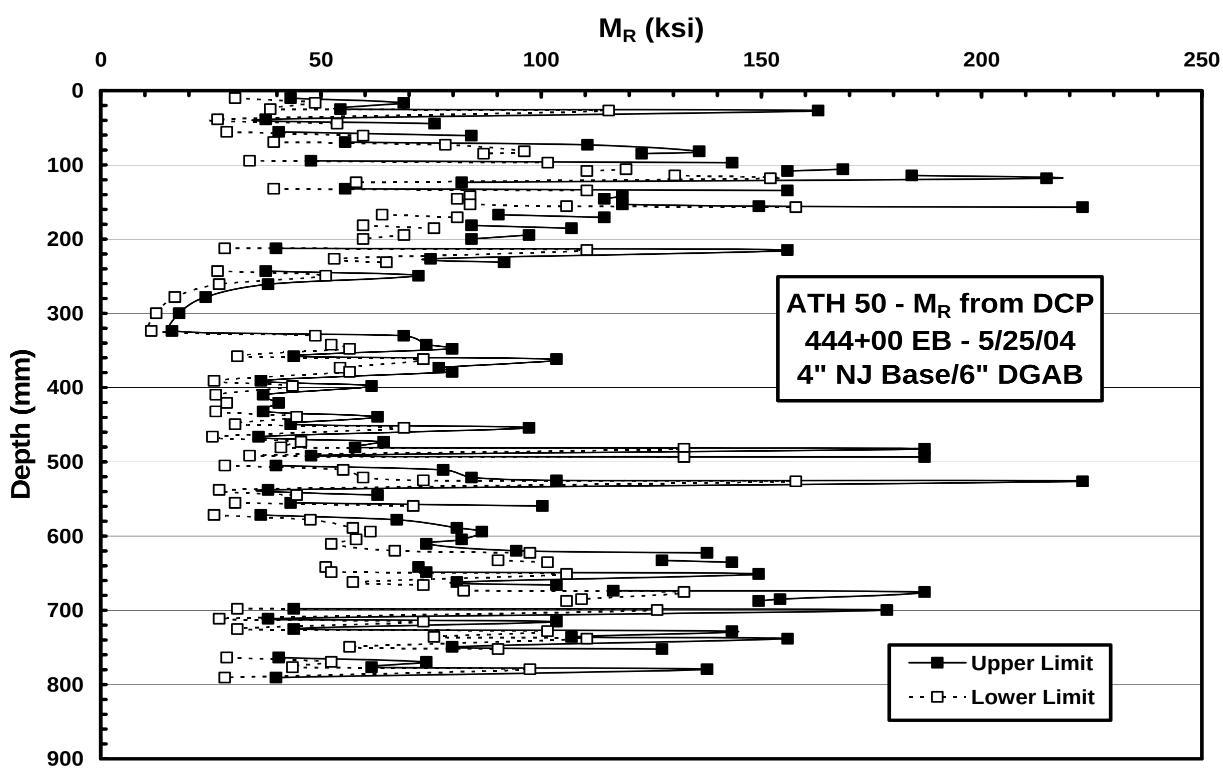
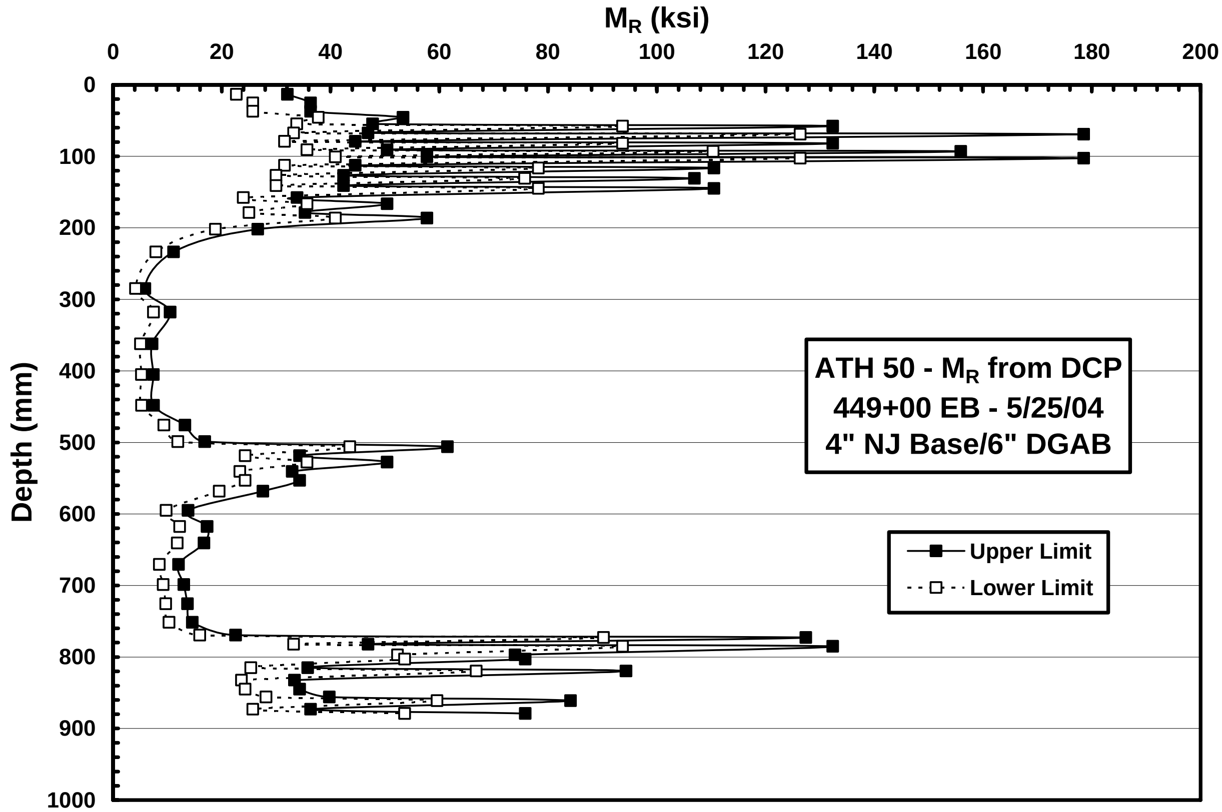


Figure N-7 DCP Profile at Stations 439+00 and 444+00 on ATH 50



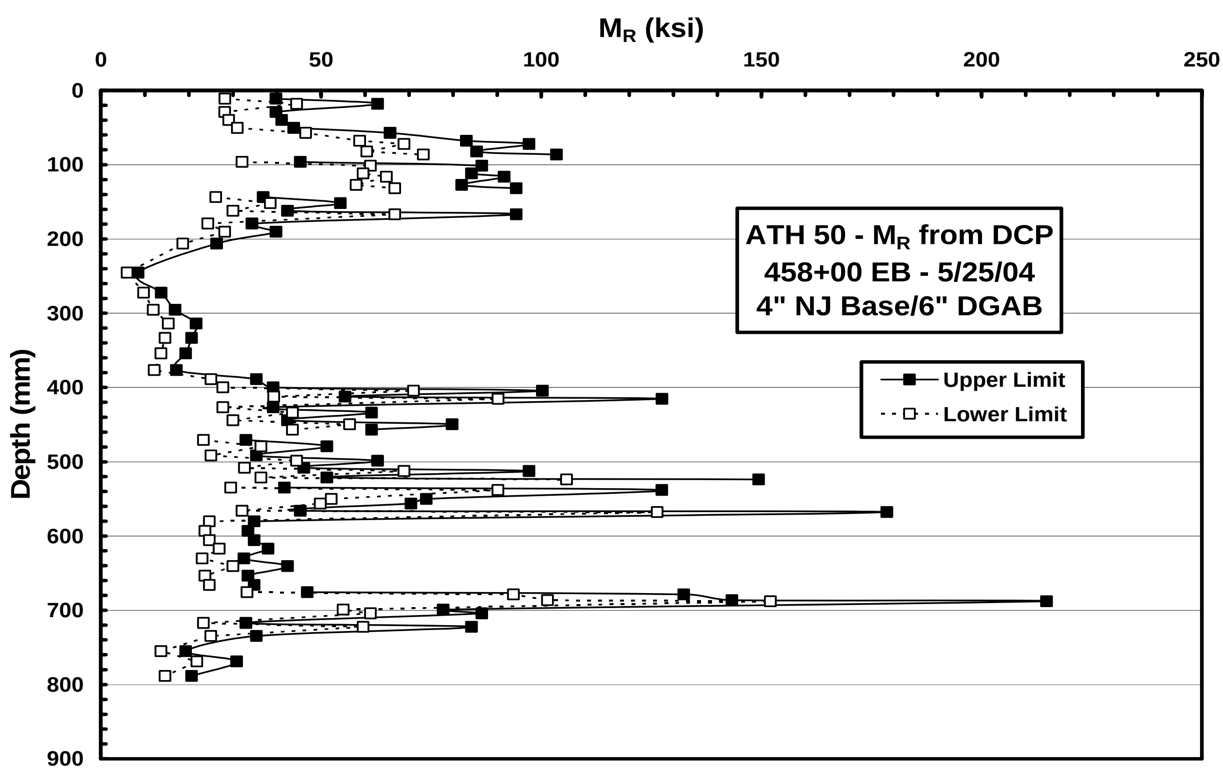


Figure N-8 DCP Profile at Stations 449+00 and 458+00 on ATH 50

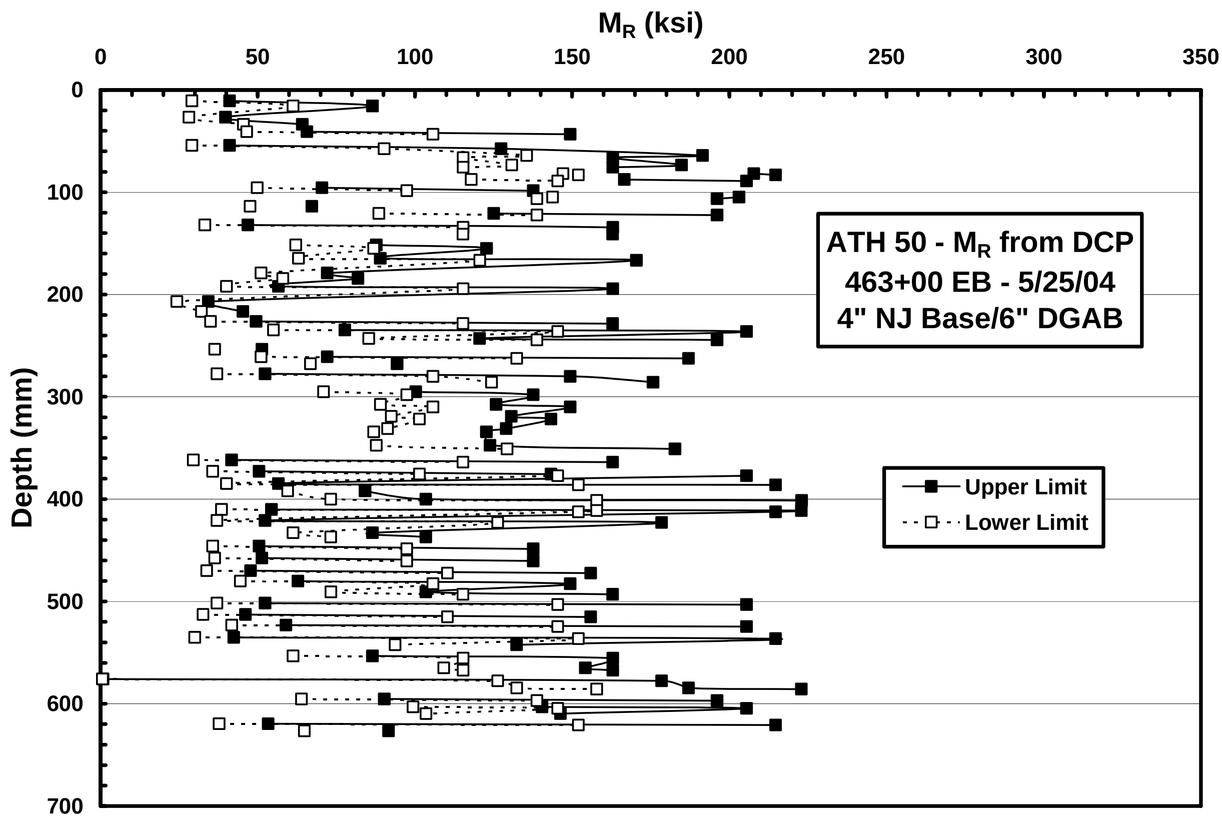


Figure N-9 DCP Profile at Station 463+00 on ATH 50

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