TEXAS TECH UNIVERSITY

Multidisciplinary Research in Transportation

Project Level Performance Database for Rigid Pavements in Texas, II

Pangil Choi, Sungwoo Ryu, Wujun Zhou, Sureel Saraf,
Jungheum Yeon, Soojun Ha, Moon Won

Texas Department of Transportation

Research Project #: 0-6274
Research Report #: 0-6274-2
www.techmrt.ttu.edu/reports.php

October 2014

NOTICE

<table>
<tr><td>1. Report No.
FHWA/TX-14-0-6274-2</td><td>2. Government Accession No.:</td><td colspan="2">3. Recipient's Catalog No.:</td></tr>
<tr><td colspan="2">4. Title and Subtitle:
Project Level Performance Database for Rigid Pavements in Texas, II</td><td colspan="2">5. Report Date:
August 2013</td></tr>
<tr><td colspan="2">7. Authors: Pangil Choi, Sungwoo Ryu, Wujun Zhou, Sureel Saraf, Jungheum Yeon, Soojun Ha, Moon Won</td><td colspan="2">8. Performing Organization Report No. 0-6274-2</td></tr>
<tr><td colspan="2" rowspan="2">9. Performing Organization Name and Address:
Texas Tech University
Center for Multidisciplinary Research in Transportation
Box 41023
Lubbock, Texas 79409-1023</td><td colspan="2">10. Work Unit No.(TRAIS):</td></tr>
<tr><td colspan="2">11. Contract or Grant No.:
Project 0-6274</td></tr>
<tr><td colspan="2" rowspan="2">12. Sponsoring Agency Name And Address
Texas Department Of Transportation
Research and Technology Implementation Office
P.O. Box 5080
Austin, TX 78763-5080</td><td colspan="2">13. Type of Report and Period Cover: Technical Report
09/2008-08/2013</td></tr>
<tr><td colspan="2">14. Sponsoring Agency Code:</td></tr>
<tr><td colspan="4">15. Supplementary Notes: Project performed in cooperation with Texas Department of Transportation and the Federal Highway Administration</td></tr>
<tr><td colspan="4">16. Abstract: The primary objectives of this project included the collection of information on continuously reinforced concrete pavement (CRCP) behavior and performance in Texas to calibrate the mechanistic-empirical pavement design procedure for CRCP developed under TxDOT research study 0-5832, and the overall evaluation of rigid pavement performance in Texas, including special and experimental sections. To achieve the objectives, extensive field evaluations were conducted to identify the mechanisms of structural distress in CRCP and to investigate CRCP behavior at transverse cracks using falling weight deflectometer (FWD). Calibration of the distress prediction model in the new CRCP design procedure was made with a development of a transfer function. It was also observed that the most of the distresses in CRCP were due to the quality control issue of materials and construction. Jointed concrete pavement (CPCD) performance is satisfactory, except that most of the distresses were at transverse contraction joints, indicating construction quality issues. In addition, field evaluations were conducted on various experimental sections where the effects of design (steel percentages), materials (coarse aggregate type), and construction (placement season, early-entry saw cuts) variables on CRCP structural responses and performance were investigated. Furthermore, research efforts were made to examine the performance and behavior of a number of special test sections TxDOT has built over the years. The special PCC sections addressed in this project include post-tensioned concrete pavement (PTCP), precast PTCP, bonded (BCO) and unbonded (UBCO) concrete overlays, fast-track concrete pavement (FTCP), whitetopping sections, 100% recycled concrete aggregate (RCA) concrete pavement, and roller-compacted concrete (RCC) pavement sections. Lastly, this project developed an advanced and user-friendly database called the Texas Rigid Pavement Database (TxRPDB). This database is webbased, GIS-oriented, and application-integrated. This database includes all the information obtained in this project in an organized manner, with a query function.</td></tr>
<tr><td>17. Key Words:
CRCP database, pavement distress, forensic evaluations, LTE, transfer function</td><td colspan="3">18. Distribution Statement
No Restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA 22161, www.ntis.gov</td></tr>
<tr><td>19. Security Classif. (of this report)
Unclassified</td><td>20. Security Classif. (of this page)
Unclassified</td><td>21. No. Of Pages
318</td><td>22. Price</td></tr>
</table>

Project Level Performance Database for Rigid Pavements in Texas, II

Pangil Choi

Sungwoo Ryu

Wujun Zhou

Sureel Saraf

Jungheum Yeon

Soojun Ha

Moon Won

Research Report Number 0-6274-R2
Project Number 0-6274

Conducted for the Texas Department of Transportation

Center for Multidisciplinary Research in Transportation
Texas Tech University

AUTHOR'S DISCLAIMER

The contents of this report reflect the views of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view of policies of the Texas Department of Transportation or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

PATENT DISCLAIMER

There was no invention or discovery conceived or first actually reduced to practice in the course of or under this contract, including any art, method, process, machine, manufacture, design or composition of matter, or any new useful improvement thereof, or any variety of plant which is or may be patentable under the patent laws of the United States of America or any foreign country.

ENGINEERING DISCLAIMER

Not intended for construction, bidding, or permit purposes.

TRADE NAMES AND MANUFACTURERS' NAMES

The United States Government and the State of Texas do not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the object of this report.

ACKNOWLEDGMENTS

This research study was sponsored by the Texas Department of Transportation in cooperation with the Federal Highway Administration. The authors express their gratitude to Ms. Hua Chen, project director, PMC members, and RTI Program Manager, Mr. Cary Choate. In addition, the authors acknowledge the support provided by the TxDOT District personnel for traffic control during field testing.

Table of Contents

List of Tables

List of Figures

Chapter 1 Introduction

There are a number of variables affecting Portland cement concrete (PCC) pavement behavior and performance. PCC pavement systems consist of various materials – subgrade, base, concrete, and steel in the case of CRCP – with two types of loading – environmental (temperature and moisture variations) and wheel loading. In addition, it takes a long time, as long as several decades, before the effects of some variables become noticeable. Accordingly, it is quite difficult to fully understand the interactions among the variables in the PCC pavement system and the long-term behavior of PCC pavements. To overcome these challenges, PCC pavement system is theoretically modeled with simplified assumptions and the pavement behavior is investigated with proper interpretations of the data from the models. Potential problems with this approach are (1) how real the assumptions made in the models are, (2) how accurate the mechanistic models are in simulating the interactions among all the variables in the PCC pavement system, and (3) the reasonableness of constitutive equations of materials, not only within one material, but at the interface between two different materials. Accordingly, the accuracy of any theoretical models in predicting pavement behavior and performance may not be fully known, and to improve the accuracy of the predictions from theoretical models, a process of calibration is employed. For proper calibration of any theoretical models, a large amount of accurate field performance information is needed. It becomes clear that developing reasonable pavement design procedures requires not only correct theoretical models but large amounts of accurate field information. This research project aimed to obtain sufficient PCC pavement information in terms of its mechanistic behavior as well as long-term performance. Other objectives included (1) the evaluation of overall performance of PCC pavement in Texas, including special and experimental sections and (2) the expansion of the existing rigid pavement database (RPDB) and the development of an advanced and user-friendly database to track the performance of typical and special concrete pavements in Texas.

As of 2012, there are 13,388 lane miles of CRCP and 3,948 lane miles of CPCD in Texas, which is the most extensive PCC pavement system in the US. Achieving the objectives described above on this extensive network of pavement system is a challenge. To facilitate the work required more efficiently, this project was divided into the following tasks:

Task 1 – Level 2 and level 3 field performance data collection for CRCP
Task 2 – Performance evaluation of experimental sections
Task 3 – Performance evaluation of special pavement sections
Task 4 – Continued refinement of database

Task 5 – Performance evaluation of CRCP/CPCD sections
Task 6 – In-depth evaluation of CRCP behavior and performance

The overall goal of Task 1 was to obtain an accurate punchout development mechanism in CRCP in Texas. For any mechanistic-based CRCP design program to work, the failure mechanism should be accurately identified and modeled. The difficulty of obtaining an accurate punchout development mechanism stems from the fact that it takes quite a long time for damages to accumulate, and once punchouts occur, they are repaired rather quickly. Once the punchouts are repaired, it's not easy to ascertain its mechanisms, or whether the distress repaired was a punchout or something else, and what the structural condition was prior to punchouts. It would be best if sections that are about to experience punchouts were identified and detailed evaluations were conducted before the occurrence of punchouts. Achieving this task was not easy, primarily because distresses in a preliminary stage of punchouts did not progress into punchouts within the timeframe of this research study. However, sufficient information was obtained, which provided valuable evidence for an accurate punchout development mechanism.

Over the years, TxDOT constructed a number of experimental and special pavement sections, primarily in the Houston and Waco Districts. Some variables included in those sections were percent of longitudinal steel, rebar size, concrete placement season, coarse aggregate type, various curing methods, and concrete mixing sequence. Some sections were built as early as 1985, and provide quite valuable information. In Tasks 2 and 3, the performance of those sections was evaluated largely by visual surveys.

In Task 4, database structure was further improved and refined. During the period of this research study, TxDOT switched its operating system for maps from one system to another, and the system in the rigid pavement database also had to be changed to make it compatible with TxDOT's. Other refinements included the development and inclusion of search function and other features.

Since the mechanistic-empirical pavement design procedure developed under 0-5832 was for CRCP only, more extensive information was collected for CRCP than Jointed Plain Concrete Pavement (CPCD), and this was achieved in Task 5. In this task, Texas was divided into four environmental regions – freeze-wet, freeze-dry, no freeze-wet, and no freeze-dry – and a total of 27 CRCP sections were selected for detailed investigation of CRCP behavior. The behavior items investigated included the variations of load transfer efficiency (LTE) at different transverse crack spacing and at different temperature conditions over time. This effort started in 2005 under project 0-5445, and the data collection lasted for eight years. This information on CRCP behavior is the most extensive in the world. In addition, all the punchouts listed in the TxDOT PMIS (pavement management information system) were investigated, except those in the El

Paso and Beaumont Districts. Also, the performance of CPCD was evaluated in this task mostly by visual surveys.

In Task 6, detailed CRCP behavior, such as variations of crack width over time and the effect of steel placement depth on CRCP behavior and performance, was investigated. Primary motivation for this task was the published information on the importance of crack width on CRCP performance, as well as on the significant effect of steel placement depth on CRCP performance. TxDOT places longitudinal steel at the mid-depth of the slab, while Illinois DOT places longitudinal steel closer to the surface of the slab. Coincidentally, Texas and Illinois are those who use the most CRCP in the nation. Reports on the significance of steel placement depth on CRCP performance were developed by researchers affiliated with University of Illinois. To resolve the issue of optimum steel placement depth was investigated in this task.

Scope of the Report

This report consists of eight chapters.

Chapter 2 discusses the overview of PCC pavement in Texas, including the performance of CPCD and CRCP, which is the result of the work conducted in Task 5.

In Chapter 3, detailed investigations conducted to identify CRCP behavior are described. The items discussed include crack spacing and deflections, LTEs, base friction, and slab support, which is the result of the work conducted in Tasks 1 and 5.

Chapter 4 presents performance evaluations of experimental sections conducted in Task 2. The experimental sections evaluated in this study include sections constructed to investigate the effects of steel percentage, concrete placement season, coarse aggregate type, coarse aggregate gradation, different concrete mix sequence, and curing methods.

Chapter 5 discusses the performance evaluations conducted on special pavement sections, which include fast-track concrete pavement, cast-in-place post-tensioned concrete pavement, precast concrete pavement, bonded and unbounded concrete pavement, whitetopping, sections with 100 % recycled concrete aggregate, and roller-compacted concrete pavement.

Chapter 6 provides detailed information on the architecture of the rigid pavement database.

In Chapter 7, efforts made to develop a transfer function for ME CRCP design procedure developed in 0-5832 are described.

Chapter 8 presents the findings and conclusions from this study, along with recommendations to TxDOT regarding future efforts to further improve PCC pavement performance in Texas.

Chapter 2 Overview of Rigid Pavement Performance in Texas

2.1 CPCD in Texas

2.1.1 Distress Classification from TxDOT PMIS (CPCD)

Both CPCD and CRCP show good performance at early ages in Texas. However, with time CRCP appears to maintain better performance than CPCD. The overall performance of CPCD is described in terms of distress types and their mechanisms based on TxDOT PMIS (Pavement Management Information System) and field survey results.

According to TxDOT PMIS, TxDOT had about 4,233 lane miles of CPCD in service in 2005, whereas about 3,954 lane miles in 2010, a decrease of 279 lane miles in 5 years. It appears that the decrease is due to mostly asphalt overlays or reconstruction. In TxDOT PMIS, jointed pavements, both CPCD and jointed reinforced concrete pavement (JRCP), are recorded as “J, PVMNT_TYPE_BOARD_CODE” in the “PMIS_JCP_RATING”. Since “J” refers to CPCD and JRCP in PMIS, 3,954 lane miles of CPCD include JRCP as well. The lane mile was calculated by ‘SECT_LNGTH_RDBD_OLD_MEAS’ times ‘NUMBER_THRU_LANES’ (Texas Department of Transportation 2010).

Table 2.1 illustrates the lane miles, the number of distress and the total distresses per lane mile of CPCD sections in each district. In Texas, there are 7,516 failed joint cracks, 6,642 failures, 84 shattered slabs, 5,431 longitudinal cracks, and 15,133 Portland cement concrete patches (PCP), which is equivalent to 8.8 distresses per lane mile. As can be seen in Table 2.1, there are no CPCD sections in the San Angelo, Abilene, Austin, San Antonio, Corpus Christi, Brownwood, and El Paso Districts. On the other hand, the Dallas and Beaumont Districts have the most CPCD in Texas.

Table 2.1 Lane Mile and Distress Information for Districtwide (CPCD)

District	Lane Mile [mile]	2010 PMIS - CPCD Distresses						Total Distresses per lane mile [ea/lane mile]
		JCP _FAILED _JNTS _CRACKS _QTY	JCP_ FAILURES _QTY	JCP_ SHATTERED _SLABS _QTY	JCP_ LONGITUDE_ CRACKS _QTY	JCP_PCC _PATCHES _QTY	Total	
Paris	129	277	249	0	96	1,146	1,768	13.7
Fort Worth	61	139	47	24	135	71	416	6.8
Wichita Falls	82	457	260	23	353	774	1,867	22.8
Amarillo	1	5	1	0	9	0	15	15.0
Lubbock	1	0	0	0	0	0	0	0.0
Odessa	10	117	79	13	0	37	246	24.1
Waco	73	231	8	7	58	196	500	6.8
Taylor	38	63	53	0	28	2	146	3.9
Lufkin	13	20	4	0	23	4	51	4.0
Houston	569	1,870	752	4	101	2,667	5,394	9.5
Yoakum	2	0	2	0	4	20	26	10.8
Bryan	28	6	0	0	0	97	103	3.7
Dallas	2,049	2,446	4,651	13	4,550	8,069	19,729	9.6
Atlanta	91	252	52	0	29	424	757	8.3
Beaumont	748	835	130	0	22	1,622	2,609	3.5
Pharr	0	5	0	0	0	0	5	12.5
Laredo	4	0	0	0	0	0	0	0.0
Childress	53	793	354	0	23	4	1,174	22.2
Total	3,954	7,516	6,642	84	5,431	15,133	34,806	8.80

2.1.2 Field Evaluation of CPCD in Texas

Although CRCP performs better than CPCD, the initial construction cost of CRCP is higher than that of CPCD and there might be a need to use CPCD than CRCP in some projects due to budget constraints and locally available coarse aggregate types. Identifying the causes of good or poor performance and understanding what worked and what didn't in Texas will help improve CPCD designs and construction specifications. Those Districts that have used CPCD extensively include the Dallas and Beaumont Districts. Visual surveys were conducted in those districts to evaluate pavement performance.

The research effort focused on identifying whether CPCD sections have structural distresses such as mid-slab cracking and faulting. Figures 2.1 and 2.2 show the map of pavements investigated in the Dallas and the Beaumont Districts.

The candidates for CPCD survey sections were selected from TxDOT 2010 PMIS. In this research, two types of methodology were applied for selection of CPCD survey sections. The first method which was applied in the Dallas District is based on the analysis of the pavement condition score. The second method applied in the Beaumont District is to use the pavement maintenance cost.

A brief description of distresses in CPCD in Texas observed during the field evaluations is provided, along with potential causes and mechanisms.

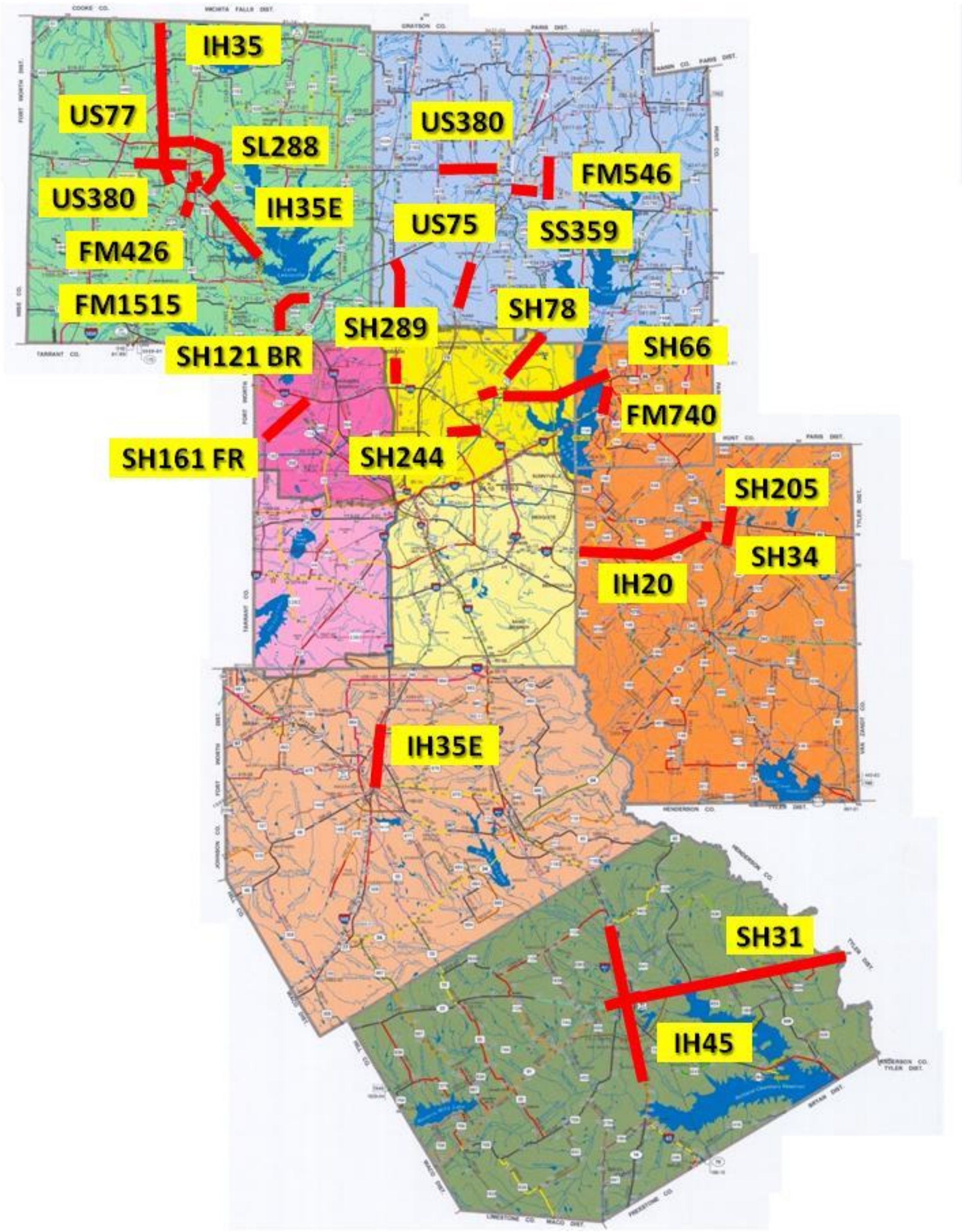


Figure 2.1 CPCD Survey Map in the Dallas District

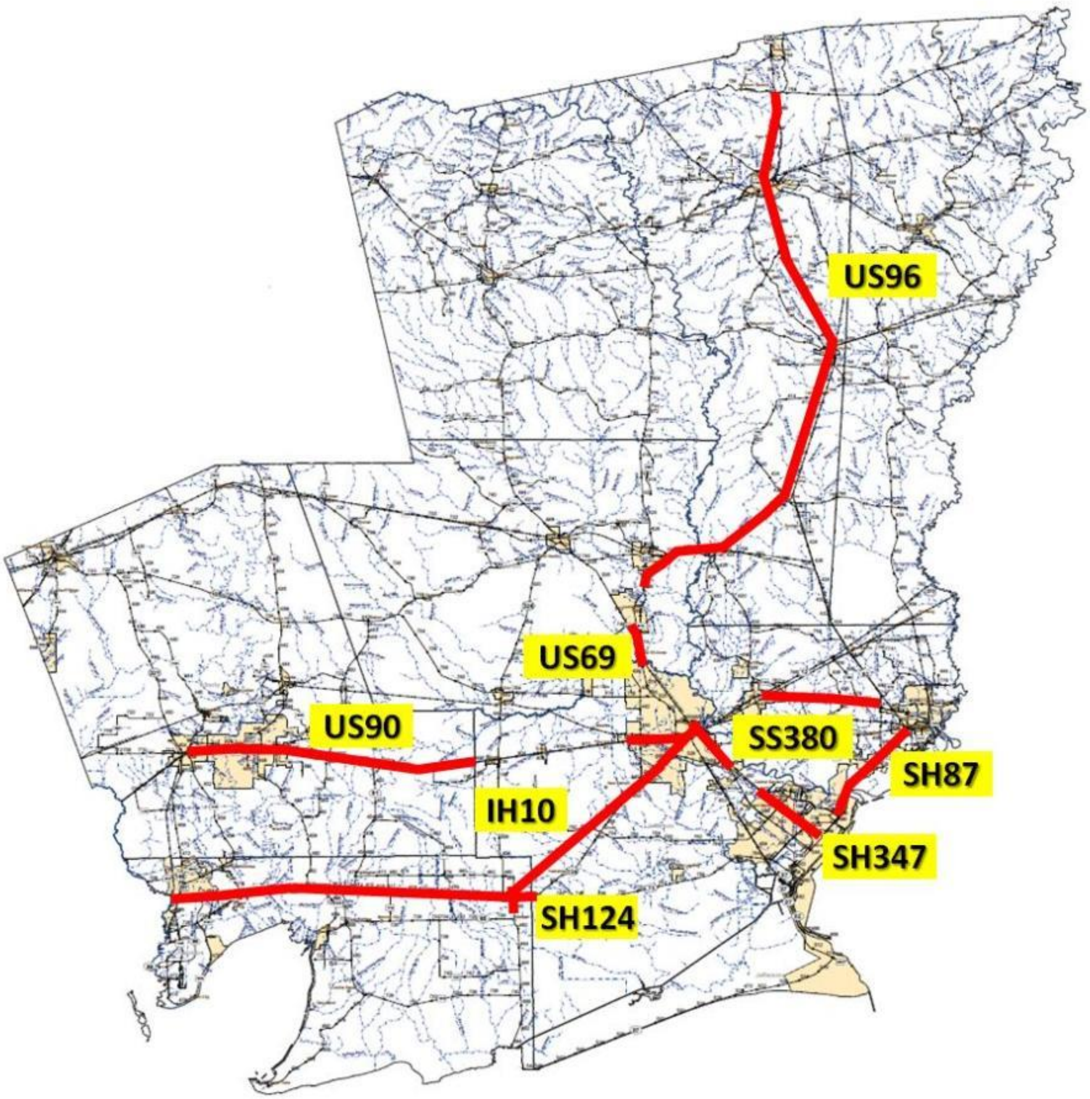


Figure 2.2 CPCD Survey Map in the Beaumont District

2.1.2.1 Distress Due to Volume Changes

Figures 2.3 and 2.4 illustrate distresses due to the volume changes in base or subgrade. During the field survey, it appeared that the majority of CPCD distresses were due to volume changes in the base or subgrade.

Figure 2.3 SL 288 - Dallas District-Denton County

Figure 2.4 US 90 - Beaumont District, Jefferson County

2.1.2.2 Distress Due to Saw Cut Depth and Time

Concrete undergoes volume changes due to temperature and moisture variations. If these volume changes are not controlled properly, excessive stresses will develop, resulting in uncontrolled cracks. These cracks can be the source of distresses and need to be controlled. Joints can be considered as intentional cracks and are provided where the cracking is most likely. These joints relieve stresses, thus preventing uncontrolled cracks (TxDOT 2011).

Figures 2.5 and 2.6 illustrate distresses due to delayed saw cut, which means the saw cut joint did not propagate to the full depth. This distress can occur due to shallow saw cut depth or delayed saw cut. Shallow saw cut depth is more prevalent when siliceous river gravel (SRG) is used as coarse aggregate, due to the difficulty of saw cutting when hard rocks like SRG are used.

Figure 2.5 US 380 - Dallas District, Collin County

Figure 2.6 FM 1515 - Dallas District-Denton County

2.1.2.3 Distress Due to Wheel Load

Figures 2.7 and 2.8 illustrate typical distresses at the joint due to wheel load. The distresses are located in the wheel paths. Figure 2.8 shows a section on IH 35 in Dallas District, Denton County. In 1988, this section was overlaid with 11-in CPCD over a 2-in asphalt concrete layer level, which was on top of existing 10-in CPCD. It can be considered that support condition in this unbounded overlay was good. The original CPCD was built in 1960, which means that the 10-in CPCD provided 28 years of service before the unbounded overlay was applied. Figure 2.9 shows the typical section of both the original and the current section. The research team surveyed the entire section and could not find any other types of distresses including faulting. Accordingly, it is considered that truck traffic and/or concrete materials/construction were the cause of this distress. Traffic analysis was conducted and Figure 2.10 illustrates the cumulative truck traffic. The cumulative ESALs were evaluated to be more than 35 million, which is rather large considering the age of unbounded overlay pavement. On the other hand, there are a number of CPCD sections with high ESAL applications but with no distress of this type. It is believed that concrete materials/construction was a primary cause for this distress, with heavy traffic potentially exacerbating the problem.

Figure 2.7 SH 78 - Dallas District, Dallas County

Figure 2.8 IH 35 - Dallas District, Denton County

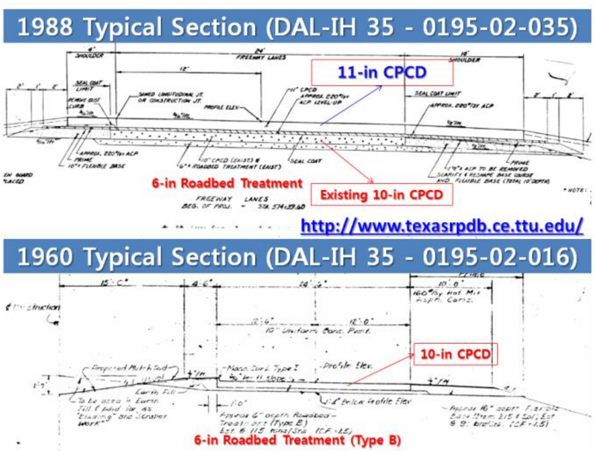


Figure 2.9 Typical Section of IH 35 in Dallas District-Denton County

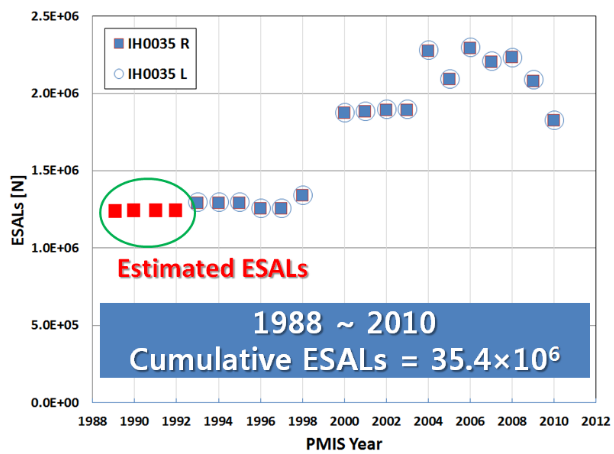


Figure 2.10 Truck Traffic Analysis on IH 35 in Dallas District

2.1.2.4 Distress Due to Inadequate Saw Cut Design

Figures 2.11 and 2.12 illustrate distresses due to skewed transverse joint. This joint type was considered a good design because both wheels in one axle are not placed in one side of the joint, thus relieving wheel load stresses and deflections in the joint area. This CPCD is on IH 10 in Chambers County, Beaumont District. As can be seen in Figure 2.11, concrete at acute angle experienced corner cracking. Figure 2.12 shows concrete cracking along the skewed joint.

Figure 2.11 IH 10 L RM 816±5 - Beaumont District, Chambers County

Figure 2.12 IH 10 R RM 813±5 - Beaumont District, Chambers County

2.1.2.5 Faulting – Outside TxDOT System Pavements

Since TxDOT CPCD design has required the use of dowels since the 1940s, faulting at transverse contraction joints has not been a problem in Texas, except where dowels were not placed for unknown reasons. On the other hand, severe faulting was observed in a city street in Dallas. Figure 2.13 shows the faulting example on a city road at Samuell Blvd in Dallas. In this project, dowels were not used.

Figure 2.13 Samuell Blvd – Dallas City Road

2.2 CRCP in Texas

2.2.1 Distress Classification from TxDOT PMIS (CRCP)

Continuously reinforced concrete pavement has performed considerably well in Texas. According to TxDOT 2010 PMIS, TxDOT has 12,199 lane miles of CRCP surveyed and recorded. Table 2.2 illustrates the lane mile, number of distress and the total distresses per lane mile of CRCP sections in each district. There are 8,573 spallings, 1,472 puchouts (PCH), 561 asphalt concrete patchs (ACP), and 7,205 Portland cement concrete patchs (PCP), which is equivalent to 1.5 distresses per lane miles. However, this number also includes spalling, which is regarded as a non-structural distress in CRCP. If spalling is discarded from the analysis, the equivalent number of distresses per lane miles is 0.8. This analysis indicates that the equivalent distress of CRCP is much less than that of CPCD. From the simple comparison, even though the number of PCP and ACP also includes spalling repairs in CRCP, the distress rate per lane mile of CPCD is 11 times higher than that of CRCP.

Spalling accounts for about 48 percent of all the distresses observed in Texas. A total of 5,283 spallings were recorded in the Houston District as of 2010, which indicates that 62 percent of the spalling in Texas has been observed in the Houston District. A research study (0-6681) conducted to identify the causes of spalling problems identified a strong correlation between spalling and CoTE.

Table 2.2 Lane Mile and Distress Information for Districtwide (CRCP)

District	Lane Mile [Mile]	2010 PMIS - CRCP Distresses				Total Distresses per lane mile	
		CRCP_SPALLED _CRACKS _QTY [SPL]	CRCP _PUNCHOUT _QTY [PCH]	CRCP_ACP _PATCHES _QTY [ACP]	CRCP_PCC _PATCHES _QTY [PCP]	PCH+ ACP+ PCP	SPL+ PCH+ ACP+ PCP
Paris	137.2	88	79	1	884	7.0	7.7
Fort Worth	1691	503	101	377	894	0.8	1.1
Wichita Falls	291.6	70	58	0	255	1.1	1.3
Amarillo	463.3	130	27	13	270	0.7	0.9
Lubbock	465.3	82	116	15	955	2.3	2.5
Odessa	4	0	0	0	0	0.0	0.0
San Angelo	0.4	0	0	0	0	0.0	0.0
Abilene	22.8	0	0	0	1	0.0	0.0
Waco	148.7	217	6	0	208	1.4	2.9
Tyler	62.9	8	3	1	38	0.7	0.8
Lufkin	11.3	0	0	0	0	0.0	0.0
Houston	5,087.6	5,283	816	9	2,434	0.6	1.7
Yoakum	64.6	513	7	1	11	0.3	8.2
Austin	479.8	12	2	0	1	0.0	0.0
San Antonio	74.5	3	0	0	0	0.0	0.0
Corpus Christi	-	-	-	-	-	-	-
Bryan	48.2	0	0	0	0	0.0	0.0
Dallas	1,829	971	77	7	742	0.5	1.0
Atlanta	75.8	329	7	1	20	0.4	4.7
Beaumont	285.2	256	3	0	136	0.5	1.4
Pharr	6.2	4	0	0	0	0.0	0.6
Laredo	23.6	1	0	0	0	0.0	0.0
Brownwood	-	-	-	-	-	-	-
El Paso	800.1	68	95	136	348	0.7	0.8
Childress	126	35	27	0	8	0.3	0.6
Total	12,199	8,573	1,424	561	7,205	0.8	1.5
Rate		48%	8%	3%	41%	-	-

2.2.2 Punchout Evaluation of CRCP in Texas

CRCP distresses recorded in TxDOT PMIS were evaluated by visual survey to identify the causes of the distresses. There were 1,424 punchouts in 2010 TxDOT PMIS and a total of 232 punchouts were investigated and evaluated. Visual surveys were not possible for a number of punchouts due to their locations (inside lanes) and high traffic.

Table 2.3 presents the results of field evaluations of punchouts in Amarillo, Childress, Dallas, Fort Worth, Wichita Falls and Houston Districts. In Table 2.3, "PCH" indicates punchouts under the wheel path or center lane of the road. "E-PCH" denotes punchouts observed at pavement edge, some with pumping evidence and some without. "PCH-CJ" indicates the punchouts at the construction joint. "PCH-RJ" means that punchouts were observed in the adjacent repaired slab. "BS-PCW" represents the big spalling or surface distress related to material and construction issues.

Table 2.3 shows that among the punchouts evaluated, those that appeared to have been caused by structural deficiency of CRCP accounted for about 14.2 percent of all the punchouts evaluated (PCH + E-PCH + E-PCH-PTB). It appears that the remaining, about 86 percent, of the punchouts evaluated were caused by non-structural issues, such as construction or material quality control issues.

Figure 2.14 shows the punchout classification and percentages based on field survey result. TxDOT sponsored several research studies to address distress types in CRCP due to materials and construction issues. The implementation of the findings from those studies will reduce the occurrence of non-structural type distress. The implementation of mechanistic-empirical CRCP design procedure, along with close attention to providing quality support, is believed to further improve CRCP performance in Texas.

Table 2.3 Detailed Classification of Punchouts - Statewide

District	Punchout Classification						
	PCH	E-PCH	E-PCH-PTB	PCH-CJ	PCH-RJ	BS-PCW	TOTAL
Amarillo	0	0	4	2	6	6	18
Childress	0	0	0	2	0	1	3
Dallas	9	8	1	7	9	7	41
Fort Worth	0	0	0	6	10	12	28
Wichita Falls	1	3	6	10	0	5	25
Houston	1	0	0	21	18	77	117
Sub Total	11	11	11	48	43	108	232
Ratio	4.7%	4.7%	4.7%	20.7%	18.5%	46.6%	100%

PCH: punchout, E-PCH: edge punchout, E-PCH-PTB: edge punchout with poor tie bar, PCH-CJ: punchout at construction joint, PCH-RJ: punchout at repair joint, BS-PCW: big spalling with poor concrete work

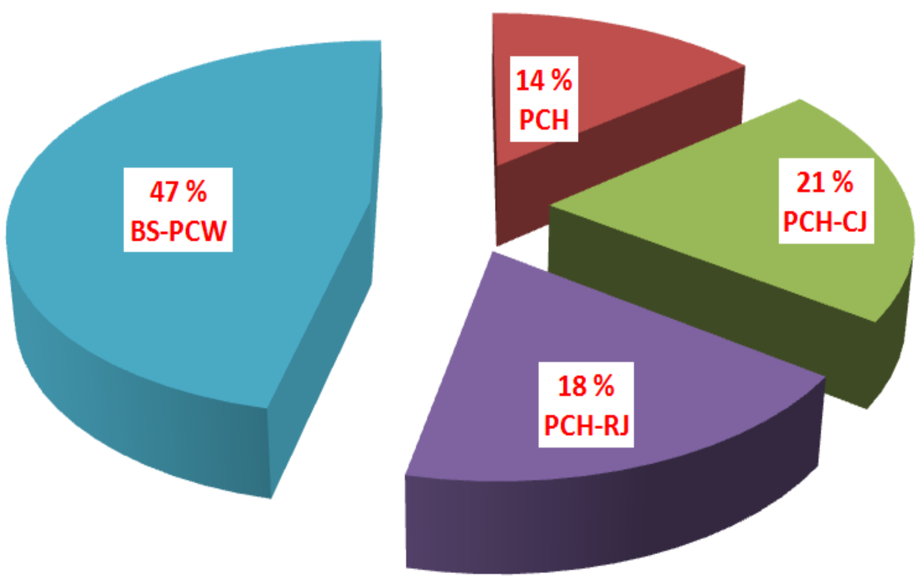


Figure 2.14 Punchout Classification

2.2.3 Punchout Description in LTPP and Its Limitations

The description of punchout as stated in the LTTP is the area enclosed by two closely spaced (usually < 2 ft) transverse cracks, a short longitudinal crack, and the edge of the pavement or a longitudinal joint. This also includes "Y" cracks that exhibit spalling, breakup, or faulting (Miller and Bellinger 2003).

Even though 'Distress Identification Manual for the LTPP' illustrates that punchout occurs due to narrow crack spacing and longitudinal crack due to wheel load, as will be discussed in the next chapter, CRCP segments with short crack spacing are not necessarily prone to punchout.

Figures 2.15 (a), (b), (c), and (d) illustrate the chronological progress of an E-PCH on IH 45 in the Dallas District during a three-year period. This CRCP was constructed in 1975 with an 8-in. thick slab on top of soil cement base. As can be seen in Figure 2.15 (a), there is only one transverse crack and no longitudinal crack as observed on 09/13/2009. One year later on 09/17/2010, this E-PCH was evaluated again and there was no difference at two different times. To further evaluate the cause of the distress, field testing including FWD and LTE were conducted on November 10th, 2010.

Figure 2.16 illustrates the FWD deflections at every 10 ft. along the test section. The average deflection evaluated is 3.8 mils, which is similar to general 8-in. CRCP deflection. However, the deflections around the punchout slab were measured at two times higher than the average deflection. This result shows that the overall support condition of the punchout area is weaker than other areas.

LTE tests were performed upstream and downstream of the punchout slab as shown in Figure 2.15 (c). LTE values of about 100 were obtained as shown in Figure 2.17. As will be discussed in the next chapter, LTE is not the most important indicator of CRCP performance.

Even though LTPP states that Y-crack is a distress, field evaluations conducted in this study indicate that is not the case. Figure 2.18 shows the Y-crack and narrow crack on US 81 built in 1972 in the Wichita Falls District. Based on the widths of the cracks, those cracks appear to have existed for more than 40 years, without developing into distresses under relatively heavy truck traffic.

It appears that the descriptions of punchouts in LTPP are not accurate. In the next section, punchout mechanisms are briefly described based on field evaluations.

(a) E-PCH Picture (Sep. 23rd, 2009)

(b) E-PCH Picture (Sep. 17th, 2010)

(c) E-PCH Picture (Nov. 10th, 2010)

(d) E-PCH Picture (Mar. 16th, 2012)

Figure 2.15 E-PCH Progress History on IH 45 in the Dallas District

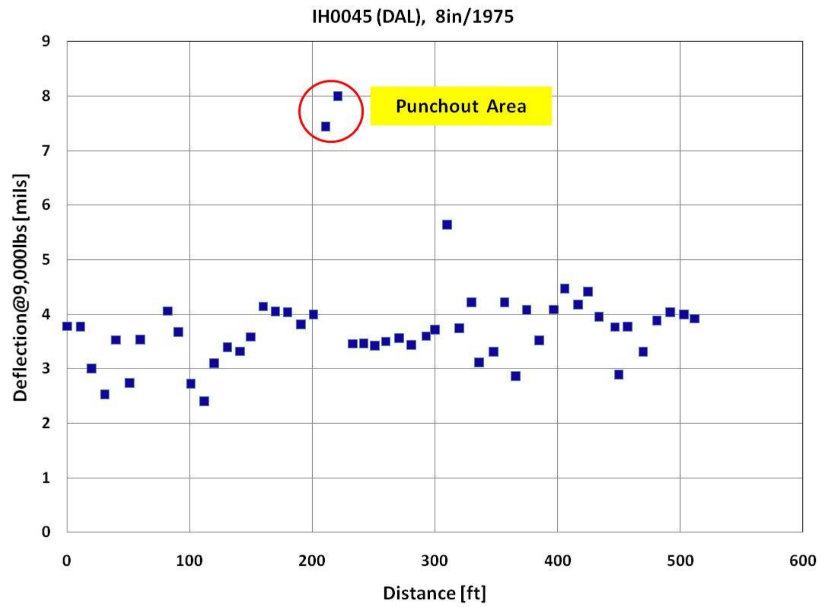


Figure 2.16 FWD Results of Investigated Section

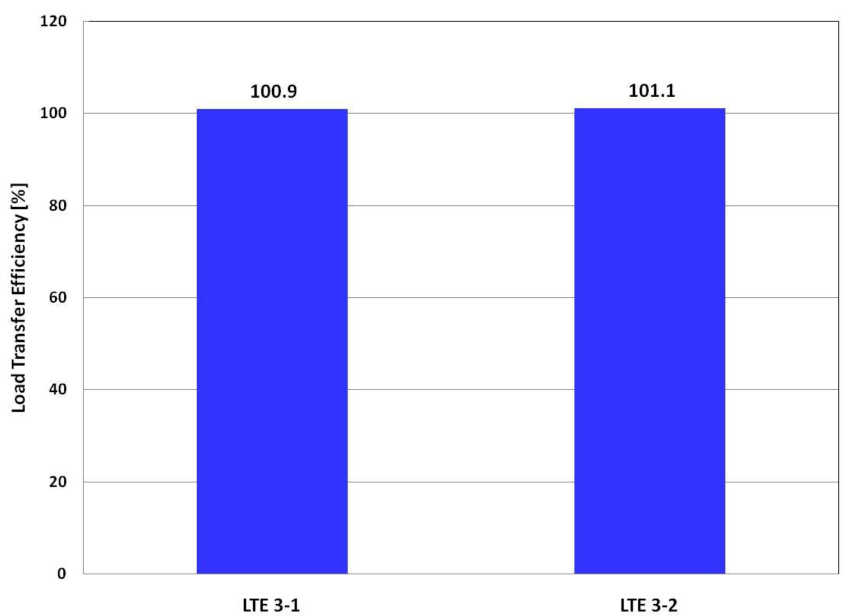


Figure 2.17 LTE in Upstream and Downstream of Punchout Slab

Figure 2.18 Y-Crack and Narrow Crack on US 81 in the Wichita Falls District

2.2.4 Punchout Classifications in CRCP

2.2.4.1 Punchout (PCH)

Figure 2.19 illustrates the typical punchout due to pumping and resulting in loose base on IH 45 in the Houston District. Spalling is not observed in the inside lane. However, chipping in cracks is observed in the middle lane. Since trucks usually pass through the outside lane, a distress such as structural punchout due to traffic loadings should occur in the outside lane first. However, the punchouts were observed at the middle lane as shown in Figure 2.19. This finding indicates that a major cause of punchouts in Figure 2.19 is not only traffic loading, but the loose support condition. The pumping material was also observed. This type of distress is classified as PCH in Table 2.3.

Figure 2.19 PCH (IH 45, Houston District)

2.2.4.2 Edge Punchout (E-PCH)

Figure 2.20 (a) illustrates an example of typical edge punchout on US 287 in the Wichita Falls District. As shown in Figure 2.20, the shoulder type is asphalt concrete. Since the traffic loading cannot be transferred to the shoulder, the pavement edge deflection due to traffic loading is relatively larger than when there is a tied concrete shoulder. Evidence of pumping between the outside lane and asphalt concrete shoulder was observed and settlement of asphalt shoulder was also observed, as shown in Figure 2.20 (b). This finding indicates that there was a deficiency in the slab support. This can be classified as the typical edge punchout (E-PCH).

Since tied concrete shoulder and stabilized base are required for CRCP in Texas, the frequency of this type of distress in Texas will diminish.

a. Typical edge punchout b. Joint separation and slab settlement

Figure 2.20 E-PCH (US 287, Wichita Falls District)

2.2.4.3 Edge Punchout Due to Poor Tie Bar (E-PCH-PTB)

Figures 2.21 (a) and (b) illustrate the distresses in the form of edge punchout due to inadequate installation of tie bars and poor base support. As can be seen in Figure 21 (b), longitudinal joint faulting was also observed, which indicates that the load transfer efficiency must be low and support condition was also poor. Hence, the primary reason for the distress would be a poor load transfer from deficient tie bar installations, and also poor slab support.

a. E-PCH-PTB (IH 40, Amarillo District) b. E-PCH-PTB (IH 30, Dallas District)

Figure 2.21 Edge Punchout Due to Inadequate Tie bar Design and Installation

2.2.4.4 Punchout at Construction Joint (PCH-CJ)

As discussed in Table 2.3, about 21 percent of the total punchouts surveyed in CRCP were observed at the transverse construction joint (TCJ). Figure 2.22 (a) illustrates a typical punchout at TCJ, and PCH-CJ is usually observed at a distance of two feet from the TCJ.

Another cause for the distresses at TCJ could be the quality of the in-place concrete. The concrete placed in the morning is the first batch of concrete of the day, and its quality might differ slightly from that of the later batches. The concrete placement in this area, including consolidation, is done primarily by manual work. A larger amount of longitudinal steel at a TCJ (regular steel plus additional steel) might hinder proper consolidation of concrete. Figures 2.22 (b) shows distresses possibly due to inadequate construction practices or poor concrete material and resulting in distresses at TCJ.

a. PCH-CJ (IH 35, Wichita Falls District) b. PCH-CJ (IH 35, Wichita Falls District)

Figure 2.22 Punchout at Construction (PCH-CJ)

2.2.4.5 Punchout at Repair Joint (PCH-RJ)

About 19 percent of the total punchouts surveyed in CRCP were observed at the repair joint. TxDOT research project 0-6611 investigated the causes of punchouts at repair joints (Ryu et al. 2013). According to the research results, the primary cause of the distress at repair joints is poor full-depth repair work. General characteristics of poorly performing full-depth repairs were large deflections at transverse repair joints. Poor bond between tie bars and the surrounding concrete at repair joints contribute to large deflections and poor performance. This finding indicates that punchout at repair joints is not also structural capacity related. Figures 2.23 (a) and (b) show distresses at the repair joints. Well-organized special specifications, guidelines and design standards were developed under the research project 0-6611, and it's believed their implementation will reduce the frequency of the punchouts at repair joints in Texas.

a. PCH-RJ (IH 30, Dallas District) b. PCH-RJ (IH 30, Paris District)

Figure 2.23 Punchout at Repair Joint (PCH-RJ)

2.2.4.6 Big Spalling with Poor Concrete Work

According to the current TxDOT Pavement Management Information System Rater's Manual, a surface defect greater than 12-in long or wide is rated as a punchout (TxDOT, 2009). Figures 2.24 (a) and (b) illustrate surface defects that were greater than 12-in long or wide and therefore rated as punchout in the TxDOT PMIS condition survey. These distresses should be classified as spalling. Figures 2.24 (a) and (b) are the surface defects on IH 35 in the Wichita Falls District and on SH 114 in the Dallas District. As shown in Figure 2.24, the surface defects are not related to transverse cracks. Normally, spalling occurs at transverse cracks. It is believed that this distress occurred due to construction quality issues during concrete placement. Accordingly, BS-PCW also is not a structural related distress.

a. BS-PCW (IH 35, Wichita Falls District)

b. BS-PCW (SH 114, Dallas District)

Figure 2.24 Big Spalling with Poor Concrete Work

2.3 Pavement Score Issue for CPCD

Pavement score, especially condition score, is becoming more important for TxDOT operations, since TxDOT has set a goal to achieve a certain level of pavement score. The research team evaluated CPCD distress and pavement score in the Dallas District. The results show that there is a large discrepancy between pavement performance and pavement score. Pavement condition score is calculated using the below equation (TxDOT 2010):

$$\text{Condition Score} = \text{Distress Score} \times U_{Ride}\ (\text{Ride score})$$

The pavement condition score is a function of distress score and ride score, which means that once the distress score goes down, pavement condition score cannot exceed the distress score. Figure 2.25 shows the distress score calculation procedure and Figure 2.26 illustrates CPCD distress utility values. As can be seen in Figure 2.26, utility values of concrete patches are lower than those of failed joints and cracks. This means that once the pavement is repaired, pavement distress score goes down further than prior to repairs. In other words, the pavement score of the section that is not repaired is higher than the repaired section. This is not a reasonable scenario and the utility value functions need to be revised to make it more reasonable.

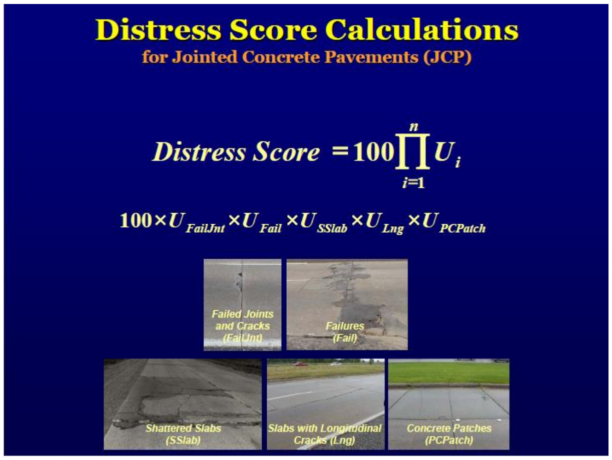


Figure 2.25 Distress Score Calculation

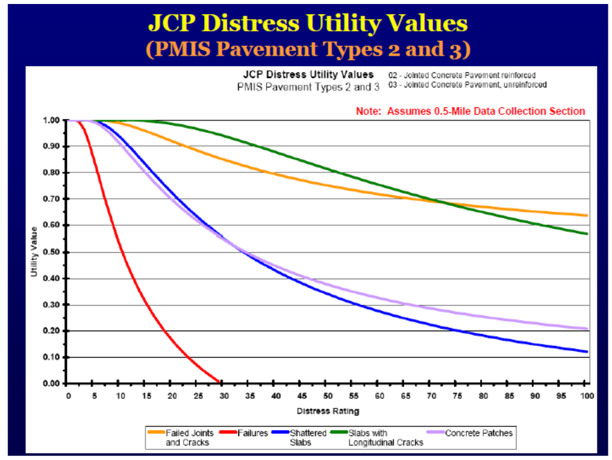
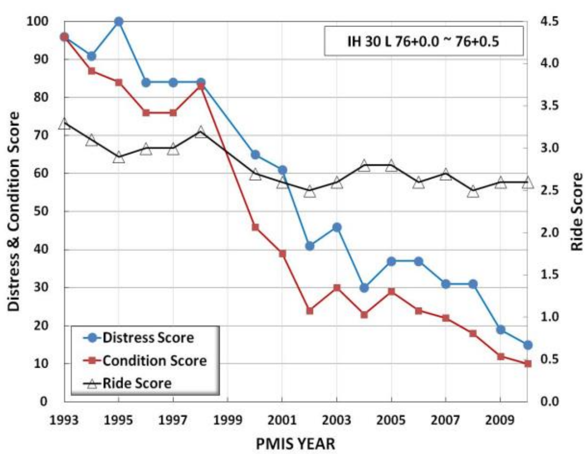


Figure 2.26 CPCD Distress Utility Value

Figure 2.27 shows the example of typical pavement score history including condition, distress and ride scores on IH 30 in the Dallas District. The pavement score has decreased gradually over 20 years. Figure 2.28 shows unusual pavement score history. The pavement score went down suddenly in 2003 and went up in 2006. Table 2.4 shows the number of distresses recorded in 2010 TxDOT PMIS for those sections shown in Figure 2.28. As can be seen in Table 2.4, since there are five PCC patches in 2003, the pavement score went down substantially along with the low ride score. However, the pavement score went up in 2006 because of the combined PCC patches. There are 17 PCC patches in 2005 and six PCC patches in 2006, which means that the existing PCC patches were combined.



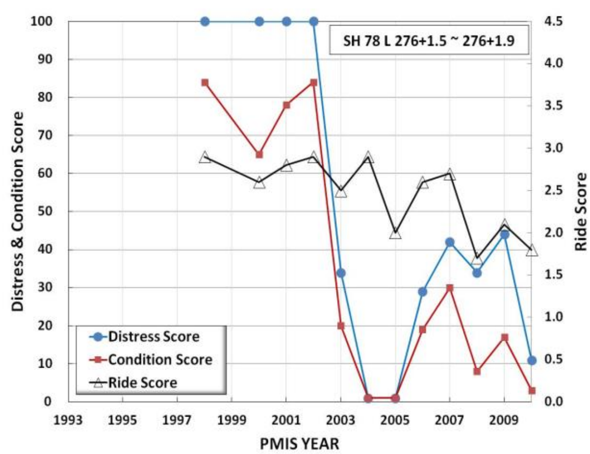


Figure 2.27 Typical Pavement Score History **Figure 2.28 Unusual Pavement Score History**

Table 2.4 Distress and Pavement Score History (SH 78 L 276+1.5 ~ 276+1.9)

Number of Distress and Pavement Score	2002 PMIS	2003 PMIS	2005 PMIS	2006 PMIS
JCP_FAILED_JNTS_CRACKS_QTY	0	0	0	0
JCP_FAILURES_QTY	0	0	8	0
JCP_SHATTERED_SLABS_QTY	0	0	0	0
JCP_LONGITUDE_CRACKS_QTY	0	0	9	0
JCP_PCC_PATCHES_QTY	0	5	17	6
Distress Score	100	34	1	29
Condition Score	84	20	1	19
Ride Score	2.9	2.5	2	2.6

Chapter 3 Evaluation of CRCP Behavior and Performance

In CRCP research, two types of loading – environmental (temperature and moisture variations) and wheel loading – are considered for pavement behavior modeling and analysis. Further, stresses in concrete from both loading conditions are super-positioned for pavement analysis. Because of the way concrete stresses from both loading conditions are combined, results from mechanistic analysis of CRCP could indicate that weaker slab support might result in better performance, as indicated from the designs with mechanistic-empirical pavement design guide (MEPDG). It is partly due to the over-estimated effect of base support on curling stress. In real pavement projects, CRCP with weaker base support does not perform as well as CRCP with stronger base support does. This discrepancy indicates the shortcomings of current thinking on slab curling and its effects on overall CRCP performance. Another issue with current CRCP research is that environmental loading has substantial effects on crack width and load transfer efficiency (LTE), ultimately on punchout development. In-depth evaluations conducted in this study indicate minimal effects, if any, of environmental condition on LTE and CRCP performance. It has been stated in a number of journal papers, research reports, and even textbooks that crack spacing is a good indicator of CRCP performance. The logic behind this statement is that, as the crack spacing becomes larger, so will the crack width. Larger crack width will result in lower LTE and more damage to CRCP, eventually leading to punchout. Field testing was conducted to evaluate the effect of crack spacing on various CRCP behaviors, including LTE. A total of 27 sections, each 1,000 ft long, were selected and field evaluation, including FWD testing and visual survey, conducted twice a year (summer and winter) for the first 3 years of this project and once a year for the remainder of this project. In this chapter, field testing conducted on FM 1938 in the Fort Worth District is described, since extensive testing was conducted to evaluate detailed behavior of concrete slab, which provides valuable information on early-age CRCP behavior.

3.1 Environmental Loading and Curling

TxDOT constructed a 2.6 mile CRCP project on FM 1938 in the Fort Worth District that consists of six lanes from SH 114 to Dove Road and four lanes from Dove Road to Randol Mill Road. A number of testing variables were included in this project – four different base types, two different concrete mix designs, three different curing compounds, and four different surface textures.

The effect of various base types, or base support conditions, on CRCP slab curling was evaluated. Concrete displacement gages, called crackmeters, were installed at CRCP slab edges as shown in

Figure 3.1. Customized steel plate box were installed to protect crackmeters. Table 3.1 shows the information on the base type used for each section.

Figure 3.2 shows curling of concrete slabs at different base types for about 3 month period. It illustrates that, in general, as the concrete temperature decreases, daily slab curling was reduced. It appears that the slab edge was lifted due to the lower concrete temperature. It also indicates that the slab on the stiffest base support (Section #2) underwent most daily curling movements, while the slab on the least stiff base support (Section #3) experienced the least daily curling movements. The information in Figure 3.2 clearly illustrates the effects of base stiffness on curling – the stiffer the base support, the larger the curling movements. However, it should be noted that the curling was measured at the edge of the slab. Actual wheel loading is applied at some distance from the slab edge.

Figure 3.1 Crackmeter Installation

Table 3.1 Base Types for Each Test Section

Test section #	2	3	4
Base type	1-in. AC over 6-in. CSB	Geotextile over 6-in. CSB	4-in. AC

Figures 3.3 (a) and (b) show variations of FWD slab deflections in the transverse direction in the morning and in the afternoon, respectively. They show that, as long as wheel loading is at a distance of 5 ft in the morning and 4 ft in the evening, curling effect is almost completely diminished. Since TxDOT requires the use of tied-concrete shoulder, the effect of curling should not be included in the pavement design procedures. In other words, the effect of base stiffness on curling stress does not need to be included in the CRCP design procedure. Another reason why curling stress should not be included in the CRCP design procedure is that the environmental loading rate for curling stress – about 1.5 °F/hr – is quite small and there will be stress relaxation or creep of concrete, and the actual curling stress will be much smaller than the analysis using elasticity theory will predict.

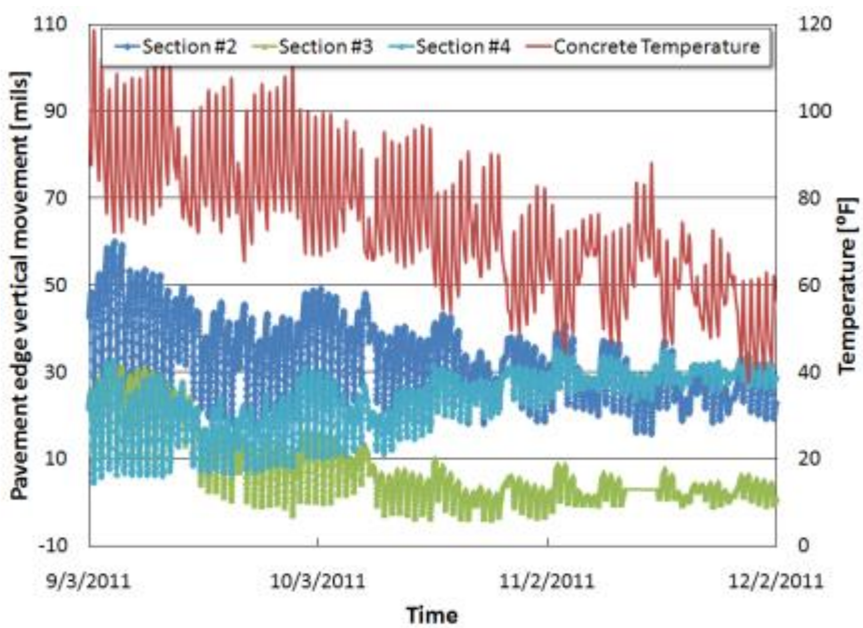
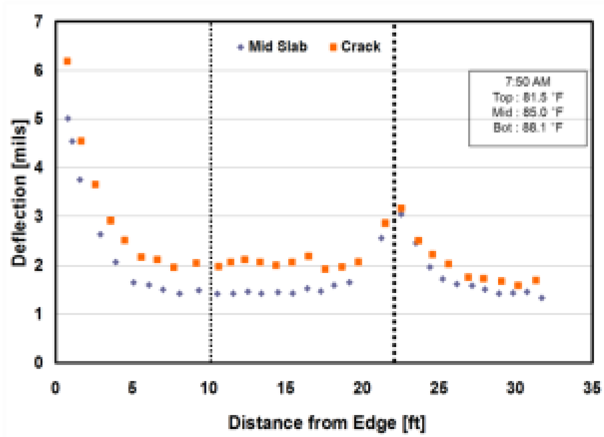
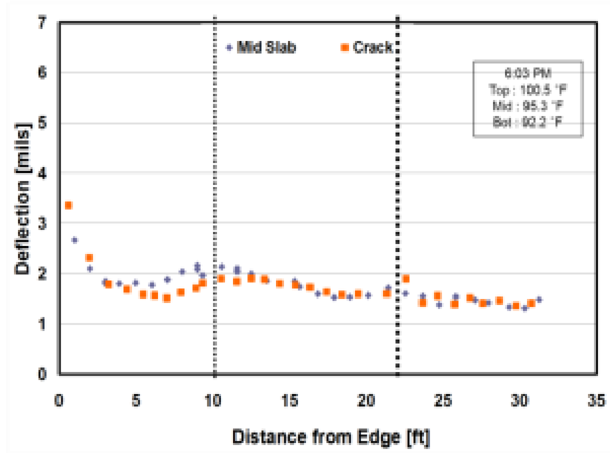


Figure 3.2 Pavement edge vertical movements



a. Slab deflections in the morning



b. Slab deflections in the evening

Figure 3.3 Slab Deflections (morning & evening)

3.2 Transverse Crack Spacing

In CRCP, like any concrete structures, concrete undergoes volume changes due to temperature and moisture variations. The volume changes are restrained by 3 elements – its own weight, longitudinal reinforcing steel, and base friction. On the other hand, in CPCD, the volume changes in concrete are restrained by only one element, its own weight. In CPCD, transverse joints are provided to relieve concrete stresses due to volume changes from temperature variations. Compared with CPCD, concrete stresses due to volume changes from temperature and moisture variations in CRCP will be larger, since the concrete is restrained more than in CPCD and no stress-relieving joints are provided. Accordingly, numerous transverse cracks will develop to relieve stresses in concrete. In Texas, an average transverse crack spacing of about 4 ft and 6 ft was observed in CRCP with SRG and crushed limestone (LS) coarse aggregates, respectively. This difference in average crack spacing is primarily due to the coefficient of thermal expansion (CTE) and modulus of elasticity. In Texas, concrete with SRG coarse aggregate has higher CTE and modulus values than concrete with LS coarse aggregate. Coincidently, the performance of CRCP with SRG has not been as good as that of CRCP with LS. The difference in CRCP performance was in terms of severe spalling, not in terms of structural distress such as full-depth punchout.

In CRCP research, it has been assumed that transverse crack spacing plays an important role in determining CRCP behavior and performance. For the longitudinal reinforcement design, 1993 AASHTO Guide for Design of Pavement Structures (AASHTO 1993), referred to as the AASHTO Guide in this report, recommends a minimum crack spacing of 3.5 ft and maximum of

8 ft. The minimum spacing of 3.5 ft is recommended to minimize the occurrence of punchouts, and the maximum spacing of 8 ft is to minimize the incidence of spalling. In CRCP design algorithms incorporated in both the AASHTO Guide and MEPDG, transverse crack spacing plays an important role in determining performance and, therefore, in designing pavement structures. This concept of narrow crack spacing more prone to punchout has been accepted among researchers, and to some extent practitioners as well, for so long that all the available CRCP design algorithms are based on this concept. However, extensive field evaluations conducted in this (0-6274) and previous (0-5445) studies for the last 8 years indicate otherwise (Medina-Chavez and Won 2006). Figure 3.4 (a) illustrates a typical punchout in Texas when base was not stabilized with cement or asphalt and asphalt shoulder was used. This 8-in CRCP on cement stabilized soil section is located on IH 35W in Denton and was built in 1966. Evidence of pumping and depression of the slab segment is shown. In this project, there were numerous slab segments with smaller crack spacing than shown in this Figure, but with no distress

1. From the asphalt patching (more asphalt patching material was placed near the wheel path than at pavement edge), it appears that the slab was pushed down by the traffic loading at the location of wheel path.
2. The condition of transverse cracks in the left half of the outside lane is excellent – cracks are tight with no indication of spalls.
3. The overall shape of the depressed slab is that of a half-moon.
4. It appears that the deteriorated transverse cracks were a product of the distress, not the cause of the distress.

The distress shown in Figure 3.4 (b) is 6-in. cast-in-place post-tensioned concrete pavement in Missouri. In this project, post-tension was applied in the longitudinal direction to eliminate transverse cracking and to reduce slab thickness. This distress was not caused by transverse crack; rather, it was due to the localized inadequate slab support. From the Figures 3.4 (a) and (b), it can be hypothesized that those distresses were due to inadequate slab support confined to that location, and were not related to transverse cracks.

a. Typical punchout distress in Texas

b. Distress in post-tensioned pavement

Figure 3.4 Typical Punchout Distress and Distress in Post-Tensioned Pavement

The objective of the previous study (0-5445) was to collect detailed yet sufficient amount of information on CRCP behavior for the calibration of MEPDG for Texas. Since crack spacing and resulting LTE variations at transverse cracks are the crux of the punchout development model in MEPDG, a total 27 sections were selected and detailed field testing conducted. Table 3.2 shows the list of initially selected 27 sections, called Level I sections in this study. Later on, some sections were removed due to the widening of lanes, which made the FWD testing quite dangerous.

Table 3.2 List of Level I Test Sections

District	Highway	Construction Year	Slab Thickness (in.)	Shoulder Type	ESAL (million)
Ft. Worth	IH35W	1978	13	Asphalt	33.3
Ft. Worth	IH820	1976	8	Asphalt	13.1
Wichita Falls	IH35	1991	13	Tied Concrete	12.8
Wichita Falls	US287	1970	8	Asphalt	12.0
Wichita Falls	US287	2003	8	Tied Concrete	3.2
Amarillo	IH40	1997	11	Tied Concrete	6.4
Lubbock	IH27	1982	9	Tied Concrete	4.6
Lubbock	Loop289	2004	10	Tied Concrete	2.9
Waco	IH35	2004	15	Tied Concrete	9.8
Waco	IH35	1999	14	Tied Concrete	25.4
Houston	IH45	1990	15	Tied Concrete	25.5
Houston	US290	1992	10	Tied Concrete	6.7
Houston	US290	1992	10	Tied Concrete	6.7
Houston	US290	1992	10	Tied Concrete	6.7
Houston	SH6	1989	11	Curb & Gutter	7.7
Houston	SH6	1989	11	Curb & Gutter	7.7
Dallas	IH30	2006	13	Tied Concrete	6.9
Dallas	IH45	1975	8	Asphalt	34.6
Atlanta	US59	2001	12	Tied Concrete	3.4
Atlanta	US59	2001	12	Tied Concrete	7.3
Beaumont	IH10	2007	15	Tied Concrete	3.8
El Paso	IH10	1995	13	Tied Concrete	17.1
El Paso	IH10	1995	13	Tied Concrete	17.1
El Paso	IH10	1995	13	Tied Concrete	7.4
El Paso	IH10	1995	13	Tied Concrete	10.8
Childress	IH40	2000	10	Tied Concrete	7.0
Childress	IH40	1999	10	Tied Concrete	7.0

The length of each test section is 1,000 ft, with a transverse construction joint at the middle of the section. The reason for this setup was to include the effects of concrete setting temperature on CRCP performance. According to MEPDG, concrete setting temperature, or zero-stress temperature, even though they are not the same but quite close to each other, has substantial effects on CRCP performance, and required slab thickness. Since concretes at both sides of the transverse construction joint (TCJ) were placed at quite different temperature condition – temperature at concrete placement was increasing on one side (morning placement) while decreasing on the other side (evening placement) – the evaluation of both sides would provide valuable information on the effect of concrete setting temperature on CRCP performance.

Since crack spacing, LTE and concrete setting temperature were among the variables whose values needed to be obtained for the calibration of MEPDG model for TxDOT's use, which was the initial intent of 0-5445, slab segments with small, medium, and large crack spacing were selected. A total 12 slab segments – 2 of each small, medium, and large crack spacing at one side of the TCJ – were selected for each test section. The crack spacing for small spaced cracks is 2-3 feet, for medium spaced cracks 4-6 feet and for large spaced cracks 7-10 feet. To evaluate the behavior of a transverse crack with a specific crack spacing, two slab segments with comparable spacing at both sides of the crack were selected. Figures 3.5 (a), 3.5 (b), and 3.5 (c) show slab segments selected for the evaluation of a transverse crack with small, medium, and large crack spacing, respectively.

Field data collection involved evaluating the deflection of each test section using Falling Weight Deflectometer (FWD) at every 50 feet from the beginning of the test section, calculating LTE of the transverse cracks along the test section as well as collecting visual evaluation data in the form of photos of the test section and the condition of transverse cracks. The direction of the FWD test was along the direction of traffic. For LTE evaluation, the FWD drops were made at the mid-slab of the upstream section, at the upstream of the crack, at the downstream of the crack and at the mid-slab of the downstream section for each crack. This setup was used for slab segments with medium and large crack spacing. For slab segments with small crack spacing, the difference in locations between mid-slab and upstream or downstream drops was so small that the drop at the mid-slab was not conducted.

In order to determine the effect of temperature on the average slab deflection as well as the LTE of the transverse cracks, FWD testing was conducted twice a year for all the sections, once in the summer and once in the winter for all the test sections. The summer testing was conducted from June through September and the winter testing cycle was conducted from December through February. This "2-cycle" testing was conducted for the first 3 years of the projects; however, the information collected for the first 6 years (3 years under 0-5445 and 3 years under 0-6274) clearly indicated no temperature effects on LTE. With the concurrence of the project monitoring committee (PMC), the FWD testing was conducted only once per year for the remainder of the project. At the same time, there were issues with FWD availability and FWD hardware and software adjustments, and there were few sections where regularly scheduled FWD testing was not conducted.

a. Crack with short crack spacing

b. Crack with medium crack spacing

c. Crack with large crack spacing

d. LTE evaluation at downstream

Figure 3.5 FWD Test for Small Medium, and Large Crack Spacing

3.2.1 Effect of Crack Spacing on Deflections

Figure 3.6 illustrates overall average deflections evaluated near cracks (upstream and downstream) at small, medium and large crack spacing in summer and winter. Accordingly, the deflections shown here include all the deflections at upstream and downstream of cracks obtained in this and previous (0-5445) projects, with slab thicknesses from 8 to 15 inches. Illustrating information on a specific test section may not represent the overall trend, and all the data points were combined to minimize statistical bias. Figure 3.6 also includes the average deflections at TCJs for the Level-I test sections, in other words, upstream and downstream deflections. The overall average deflections in the summer at small, medium and large spaced cracks are 2.5, 2.5 and 2.4 mils, respectively whereas in the winter the average deflections at small, medium and large spaced cracks are 2.4, 2.3 and 2.2 mils respectively. Little difference is noted in average deflections among cracks with different spacing. It is postulated that the restraint on the concrete volume changes by longitudinal steel reduced the curling of concrete slab at cracks, thus minimizing the effect of crack spacing on the deflections near the cracks. There is a consistent trend in deflections obtained in the summer and in the winter. Deflections measured in the winter are consistently smaller than those obtained in the summer. From a theoretical standpoint, in the winter, larger deflections are expected for cracks with larger spacing, primarily due to the contraction of slabs from the temperature drop. However, the data obtained shows otherwise. There could be several reasons, one of them possibly being the difference in timeframe of FWD testing with an average of 6 months. Even though FWD sensors are calibrated in accordance with the established schedule, there could have been some exceptions. However, it should be noted that, the repeatability testing of FWD within few minutes showed consistent results for a specific unit. For the FWD testing in this project, efforts were made to utilized one FWD unit for all the testing; however, due to the availability of the unit and the distance between the locations of test section and the unit, sometimes different FWD units were utilized for the testing. Figure 3.6 also shows that the deflections at TCJs are larger than those at cracks, which is expected, since there is no aggregate interlock provided at TCJs, even though at some TCJs, no discontinuity exists between concretes placed at different days.

Figure 3.7 illustrates the average deflection at mid-slabs between two adjacent cracks of slab segments with small, medium and large spacing. Average deflections of small, medium and large spaced cracks in the winter are 2.5, 2.3 and 2.2 mils respectively, whereas in summer they were 2.4, 2.3 and 2.1 mils respectively. Compared with the information in Figure 3.6, there is little difference in deflections near the cracks and at mid-slab, which again illustrates the effects of restraint by longitudinal steel on the concrete volume changes or curling amount.

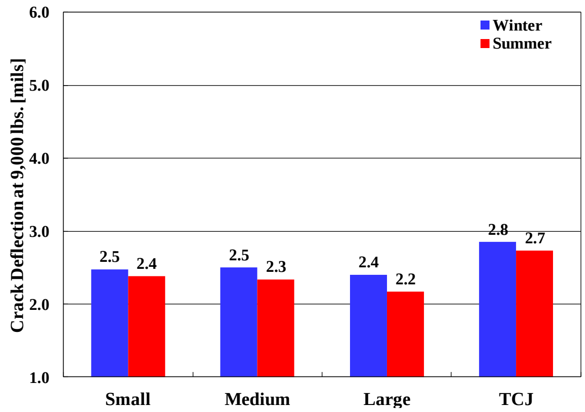


Figure 3.6 Crack Deflections at Level-I Test Sections

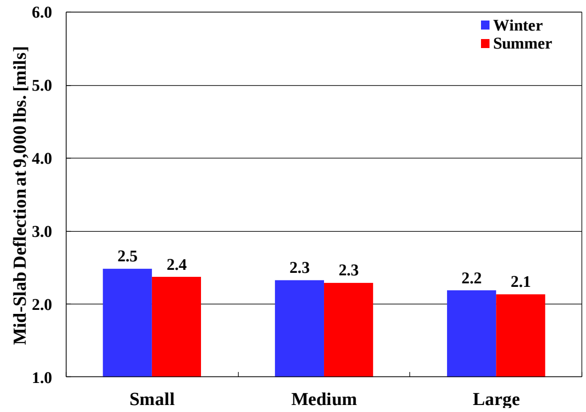


Figure 3.7 Deflections at Cracks - Mid Slab at Level-I Test Sections

The information in Figures 3.6 and 3.7 is somewhat contradictory to the information shown in Figure 3.3 (a). In Figure 3.3 (a), the difference in deflections at a crack and a mid-slab is rather substantial in the morning. The section in Figure 3.3 (a) was quite new, early-age drying shrinkage could have lifted slabs near the crack, resulting in larger deflections near the crack. With time, creep of concrete could reduce the “lift” of the slab, resulting in little difference in deflections at a crack and a mid-slab.

3.2.2 Effect of Crack Spacing & Time of Testing on LTE

The reason why crack spacing has been selected as a performance criteria is its effect on LTE. The reasoning is that, the larger the crack spacing is, the greater the crack width, resulting in the decrease of LTE and subsequent punchouts. Figure 3.8 illustrates the information obtained in this study. The LTE values are the average of all the values obtained for a specific condition. LTE values of all the cracks evaluated in this study were near 100 percent. From a practical standpoint, there was no effect of crack spacing on LTE, which is contradictory to the established premise of a good correlation between crack spacing and LTE. Figure 3.9 illustrates the only data available on crack spacing and LTE from LTPP database (Tayabji et al. 1999). No clear trend is observed between crack spacing and LTE. If a trend exists, it appears that there is positive relation between crack spacing and LTE, i.e., the larger the crack spacing is, the higher the LTE, which again is contradictory to the established premise of a reverse correlation between crack spacing and LTE. Figure 3.9 also indicates that 96 percent of all the cracks (48 out of 50 points) evaluated had LTE over 90 percent. The LTPP report does not provide information on the age of the CRCP sections or season of testing for the LTE evaluations. However, based on the CRCP sections included in LTPP, it appears that these sections are not new, and have been under service for a while. High level of LTE at cracks in CRCP regardless of crack spacing indicates the need for improvements to the current premise that crack widths are approximately proportional to crack spacing, larger crack widths result in lower LTE, and lower LTE is a precursor for punchout.

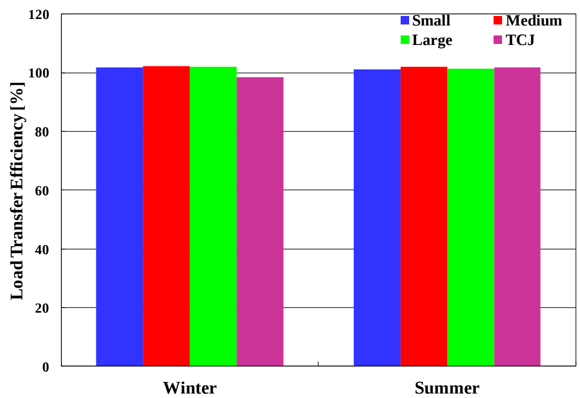


Figure 3.8 LTE at various crack spacing and TCJ at two different seasons

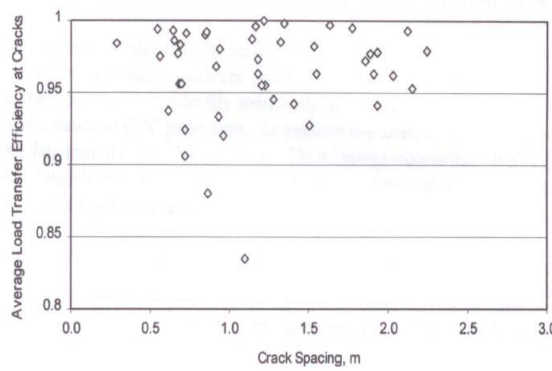
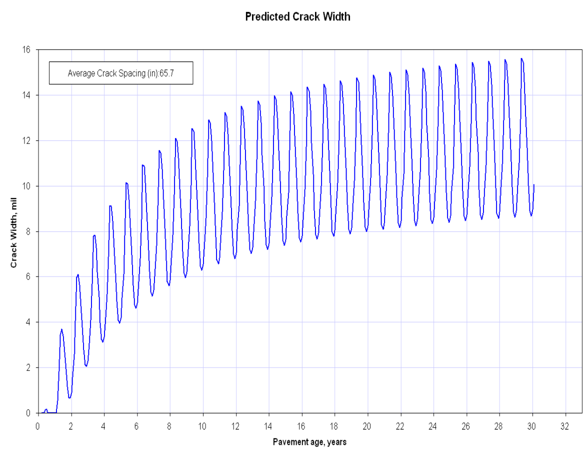
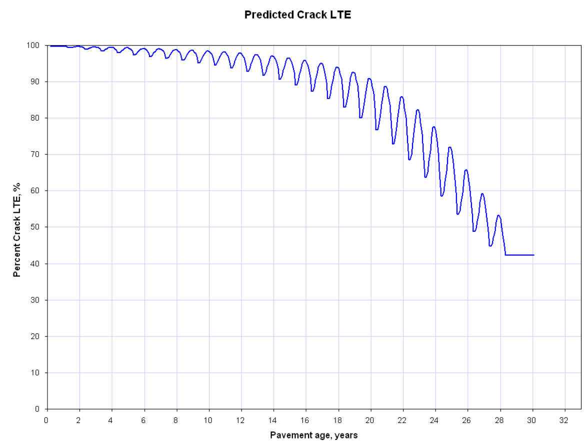


Figure 3.9 Correlation between crack spacing and LTE (Tayabji et al. 1999)

Figure 3.8 also shows that LTE values were maintained at quite a high level regardless of the season of the testing. Another premise made in CRCP research is that crack widths and LTE depend on the concrete temperature. Figure 3.10 (a) illustrates the variations of crack width over time from MEPDG. It clearly shows the variations of crack widths over time – crack widths increase over time due to continued drying shrinkage of concrete, and vary depending on the temperature of concrete, i.e., crack widths get smaller in the summer, and larger in the winter. Figure 3.10 (b) shows the variations of LTE corresponding to the crack widths shown in Figure 3.10 (a). LTE fluctuates due to the variations of crack widths. In general, LTE decreases over time, and the rate of decrease accelerates after about 18 years, and the final LTE prior to punchout in 30 years is just below 45 percent. The information collected in this study shows that LTE values of all the cracks evaluated remained constant regardless of the season of the testing and the age of the pavement. LTE values were evaluated in Illinois for 8 year time period. Table 3.3 illustrates that the average LTE values evaluated at 10 different times were all above 90 percent (Roesler and Huntley 2009). It also shows that concrete temperature has no effect on LTE. The concrete temperature variations ranged from 36 ˚F to 90 ˚F for 7.5 months; however, the difference in LTE between those time period was 0.6 %. It should be noted that the testing was conducted at the same pavement section. The data shown in Table 3.3 clearly indicates, from a practical standpoint, no effect of concrete temperature on LTE, which contradicts the output from MEPDG shown in Figure 3.10 (b).



a. Variations of crack width over time



b. Variations of LTE over time

Figure 3.10 Variations of Crack Width and LTE over Time

Part of the reason for the sensitivity of LTE on temperature in MEPDG is the assumption that transverse cracks go through the slab depth, as is the case for transverse contraction joint in CPCD. Another reason is the over-prediction of crack width in MEPDG. Figures 3.11 (a) and (b) show that transverse crack stopped at few inches from the concrete surface, even though the crack opened in the surface. This 10-in CRCP section on US 290 was built in 1977, and provided excellent structural performance except for spalling issues. This picture was taken on February 20, 2010, and the ambient temperature on that day varied from 46 ˚F to 70 ˚F. Even though this temperature range is not low, but not that high either in Houston area. Regardless, the crack was still quite tight. It doesn't appear that this crack width will vary as much as shown in Figure 3.10 (a). As a matter of fact, the concrete about 2 inches below the surface didn't even crack. Considering the crack width variations shown in Figure 3.10 (a) are at the location of longitudinal steel, it is not easy to visualize the crack in Figure 3.11 (b) will experience as large variations as shown in Figure 3.10 (a).

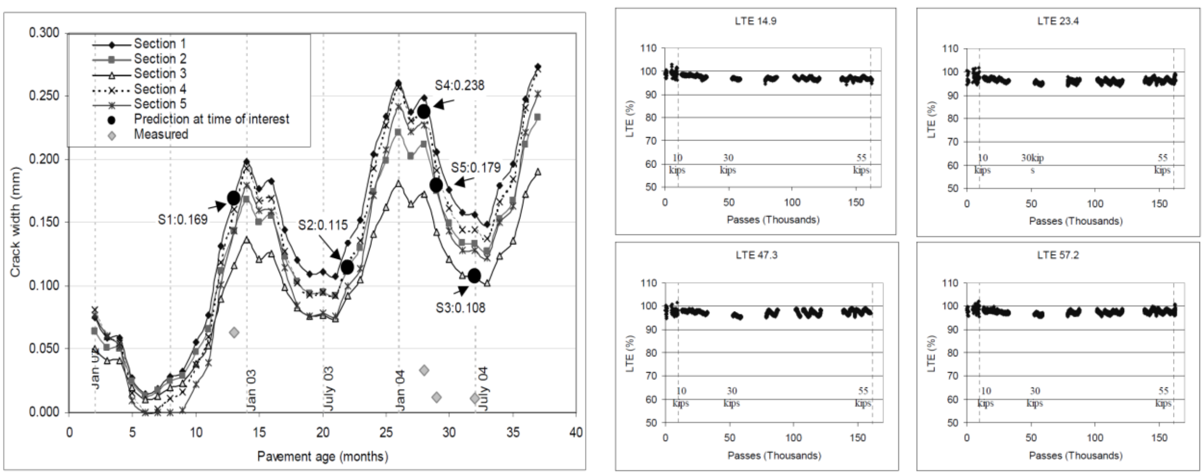
Table 3.3 Average LTE over the Past 20Years (Roesler and Huntley 2009)

	Date	Direction	No. of Tests	Pav. Temp(°F)	LTE (%)	COV (%)
Average Northbound LTE -Outer Whell Path	5/30/2006	NB	42	88	91.9	2.7
	8/21/2001	NB	62	88	92	1.5
	8/25/1999	NB	69	78	92.3	1.7
	4/29/1997	NB	96	N/A	91.7	1.9
	5/15/1995	NB	30	76	93.2	1.3
	4/1/1990	NB	102	36	92.3	3.4
	8/29/1989	NB	51	90	92.3	3.3
	3/29/1989	NB	102	48	92.6	2.2
				Overall Average	92.3	2.2
Average Southbound LTE -Outer Whell Path	5/30/2006	SB	45	88	91	2.7
	8/23/2001	SB	70	88	91.4	1.6
	9/20/1999	SB	70	78	91.2	1.9
	4/30/1997	SB	96	N/A	89.9	6.7
	5/16/1995	SB	32	70	91.5	2.1
	4/1/1990	SB	105	44	92.4	4.6
	8/31/1989	SB	72	76	91	3.6
	3/30/1989	SB	72	40	92.9	2.3
				Overall Average	91.4	3.2

a. Transverse crack on the surface　　b. Tight crack width below the surface

Figure 3.11 Transverse Crack (Surface and below Surface)

A study was conducted in Illinois (Kohler 2005) to identify failure mechanisms in CRCP. In this study, actual CRCP was built and many design and construction variables were tightly controlled to accurately evaluate CRCP behavior. Figure 3.12 (a) shows the variations of predicted crack widths from MEPDG and actually measured ones. It shows that the predicted crack widths are much larger than the values actually measured. Figure 3.12 (b) illustrates measured LTE values up to punchout development. LTE values were maintained at quite a high level. Information in Figures 3.12 (a) and (b) indicate the discrepancy between MEPDG predictions and actual CRCP behavior.



a. Crack widths from MEPDG and measure values

b. Variations of LTE

Figure 3.12 Crack Widths from MEPDG and Measure Values and Variations of LTE (Kohler 2005)

3.2.3 Comparison between Crack Spacing and Backcalculated *k*-value

Figure 3.13 illustrates a frequency of backcalculated *k*-value from AREA method for all Level 1 sections. CRCP overlay sections over existing pavement were excluded for the analysis. For the evaluation of pavement support condition, AREA method A4 suggested by Hall et al was used (Hall 1991). In this method, AREA is defined as follows:

$$\text{AREA} = 6 + 12\left(\frac{d_{12}}{d_0}\right) + 12\left(\frac{d_{24}}{d_0}\right) + 6\left(\frac{d_{36}}{d_0}\right)$$

where, d*i* is the deflection in mm at 40.1 kN at distance 2.54*i* cm from the loading plate.

AREA thus determined is a non-dimensional parameter, which is determined by the shape of the deflection bowl. The shape of the deflection bowl depends on the relative stiffness of the concrete layer and the layers below. Thus, a unique relationship exists between AREA and the radius of relative stiffness, as shown below, which was suggested by Hall et al. (1997):

$$\text{Radius of relative stiffness } l = \left(\frac{ln\left(\frac{36 - AREA}{1812.279}\right)}{-2.559} \right)^{4.387}$$

Once the radius of relative stiffness is determined, *k*-value is estimated as follows (Ioannides et al. 1989):

$$k = \left[\frac{\mathrm{d_0}}{\mathrm{D_0}}\right]\left[\frac{\mathrm{P}}{l^2}\right]$$

where, P is load magnitude [lbs];d_0 denotes non-dimensional sensor deflections corresponding to the measured deflection D_0:

$$\mathrm{d_0} = \frac{\mathrm{D_0 D}}{\mathrm{P}l^2} = \frac{\mathrm{D_0} k l^2}{\mathrm{P}}$$

where, D is the slab flexural stiffness, given by

$$\mathrm{D} = \frac{\mathrm{Eh^3}}{12(1 - \mathrm{u}^2)}$$

where, E is concrete modulus of elasticity[psi]; h is PCC slab thickness [in.]; u is concrete Poisson’s ratio.

The above equations for *k* indicate that back-calculated *k*-values depend on the radius of relative stiffness, maximum deflection value corresponding to applied loading, and a non-dimensional parameter that is related to Westergaard’s deflection in the interior condition. The non-dimensional parameter d_0 is a function of the radius of relative stiffness, and the value is almost constant, between 0.121 and 0.124, for practical ranges of the radius of relative stiffness. Since the maximum deflection for a given pavement structure is proportional to the applied loading, from a practical standpoint, two variables – maximum deflection and the radius of relative stiffness – determine the back-calculated *k*-values. The larger the maximum deflection or the radius of relative stiffness, the smaller the *k*-value.

Figure 3.13 shows that the range of overall *k*-value ranges from 100 psi/in to 500 psi/in. Figure 3.14 illustrates the backcalculated k-values comparison between those using deflections measured at every 50ft and FWD deflections evaluated at the middle of large crack spacing for all Level I sections. As shown in Figure 3.14, the backcalculated *k*-values are close to each other regardless of the deflection measurement schemes. Figure 3.15 illustrates the backcalculated *k*-values comparison between those with FWD deflections at small crack spacing and those with FWD deflections at the middle of large crack spacing. Figures 3.14 and 3.15 indicate that backcalculated *k*-values are somewhat insensitive to the locations of FWD drops. In other words, it appears that the curling effect of concrete slab in CRCP may not introduce substantial errors in computing backcalculated *k* -values using AREA method.

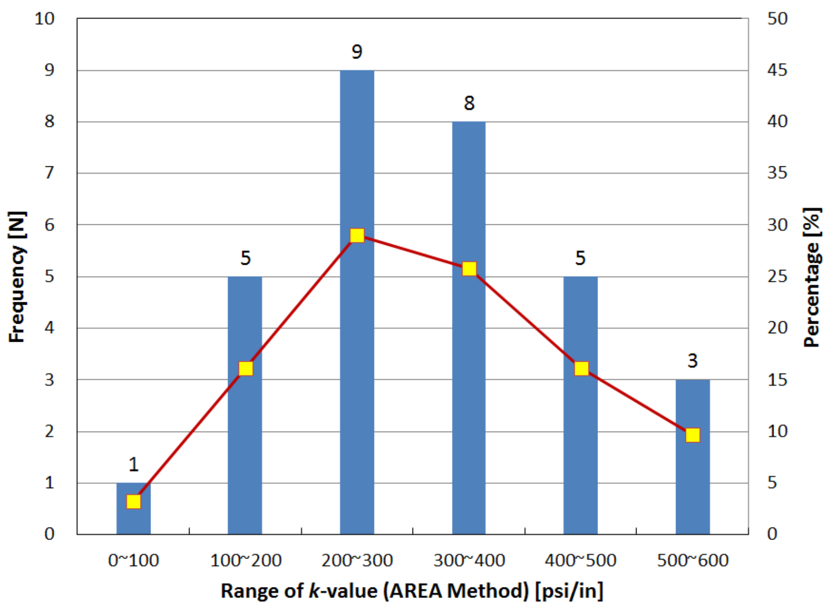


Figure 3.13 Backcalculated *k*-value Distribution of Level I Sections

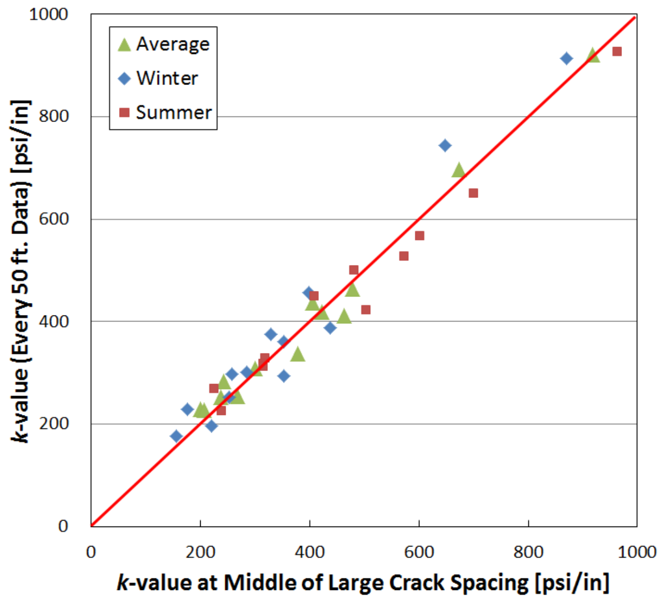


Figure 3.14 *k*-value Comparison between Deflection from Large Crack Spacing and Deflection from Every 50 ft

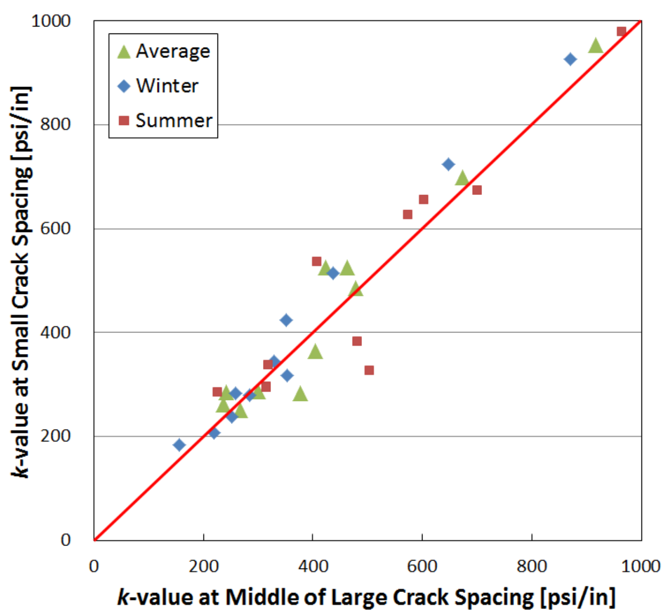


Figure 3.15 *k*-value Comparison between Deflection from Large Crack Spacing and Deflection from Small Crack Spacing

Figure 3.16 shows the variations of *k*-value obtained with the AREA method with pavement age. This data includes CRCP sections with various slab thicknesses, base, subgrade, and shoulder types. Even though various base types are included in the data set, it appears that there is an overall decrease in *k*-value with pavement age. Part of the reason is that the base type used in quite old CRCP was soil cement, while other base types were asphalt or cement stabilized base.

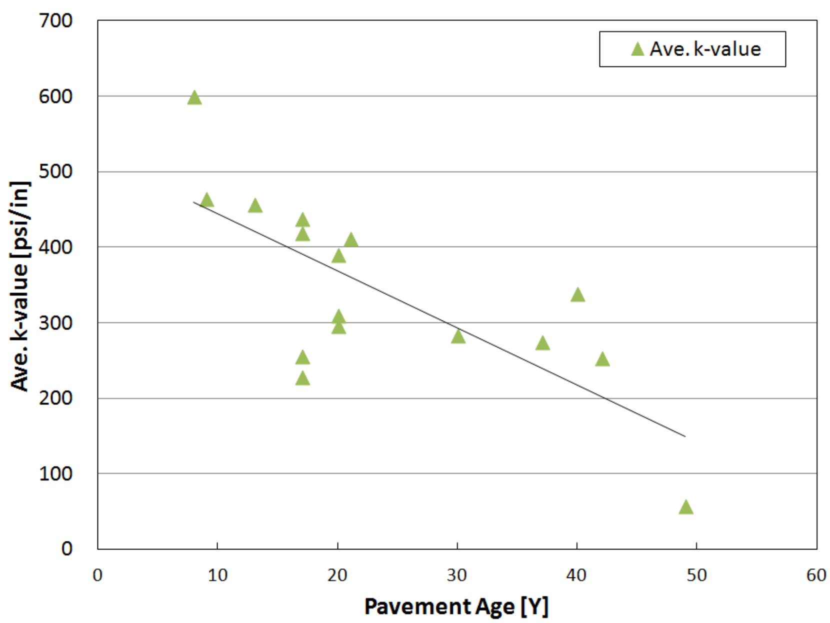


Figure 3.16 *k*-value Variations with Pavement Age

3.3 Base Friction

3.3.1 CRCP

Two distinctive base types, Type D hot mix (second test section) and non-woven geotextile (third test section), were used to evaluate base friction as illustrated in Figure 3.17. Figure 3.18 represents the schematic for friction test prisms. VWSGs were installed to monitor concrete strain changes at the bottom of concrete prism. Relative humidity (RH) sensors were installed inside and outside of concrete prisms to monitor RH variations. Figure 3.19 illustrates the casting procedure of prisms. Two different sizes of prism were also prepared to evaluate the size effect.

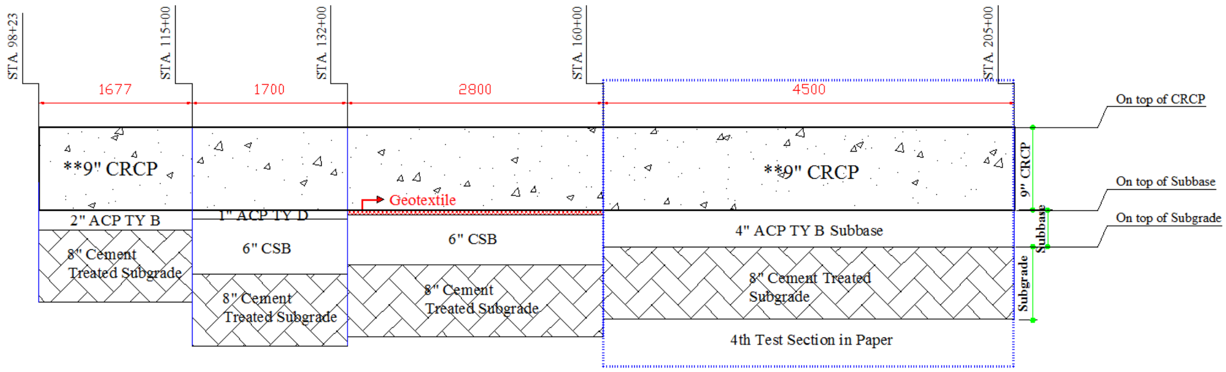


Figure 3.17 Test Section layout

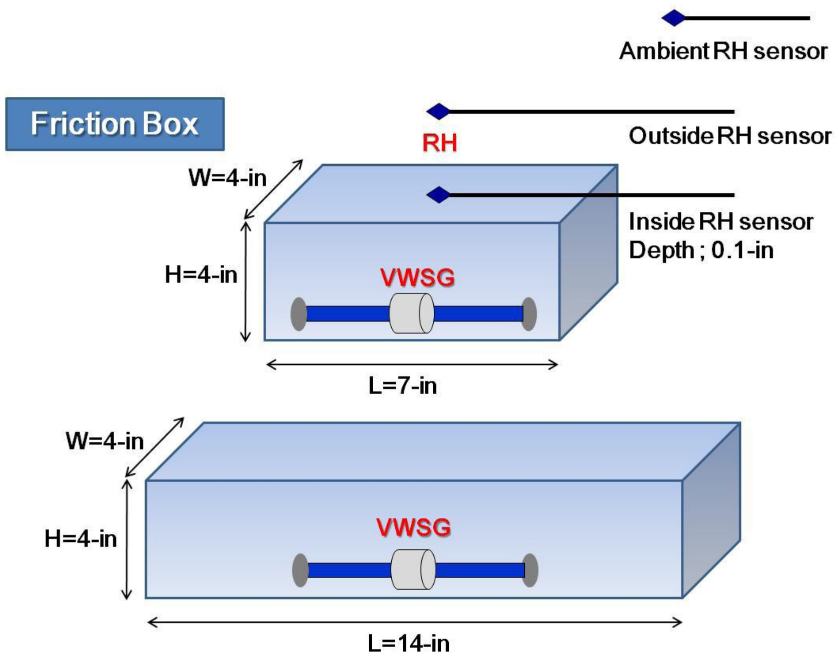


Figure 3.18 Concrete Prisms for Friction Evaluation

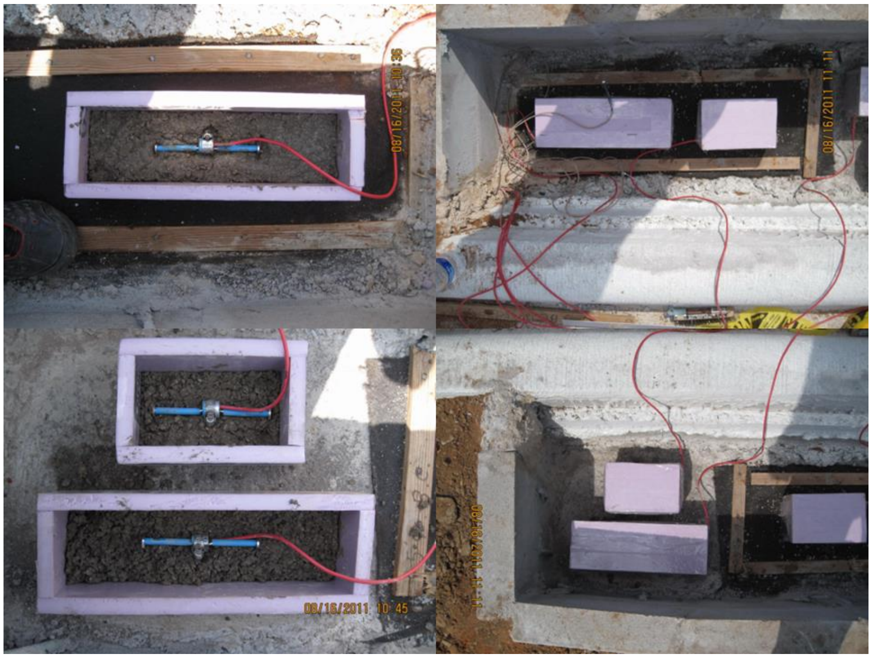


Figure 3.19 Concrete Prisms

Testing results are shown in Figure 3.20. Since relative humidity of inside prisms was recorded over 100%, it can be assumed that there is no drying shrinkage in the prisms. Accordingly, the total strain changes from VWSGs simply indicate the frictional effect.

Test results show the concrete strain variations in the concrete prisms on nonwoven geotextile are much larger than those on Type D hot mix surface. It indicates that the friction on Type D hot mix surface is larger than that on nonwoven geotextile. With less friction, restraints from base will be smaller and concrete prisms can move more freely. When larger size specimens are used, the smaller values are obtained due to the size effect of prism.

Figure 3.21 shows transverse crack spacing distributions between the two sections. As can be seen Figure 3.21, the portion of crack spacing larger than 10 ft is greater in the third section than in the second section. Higher restraint caused by hot mix surface produced a higher stress level in concrete, resulting in more transverse cracks or cracks with shorter crack spacing.

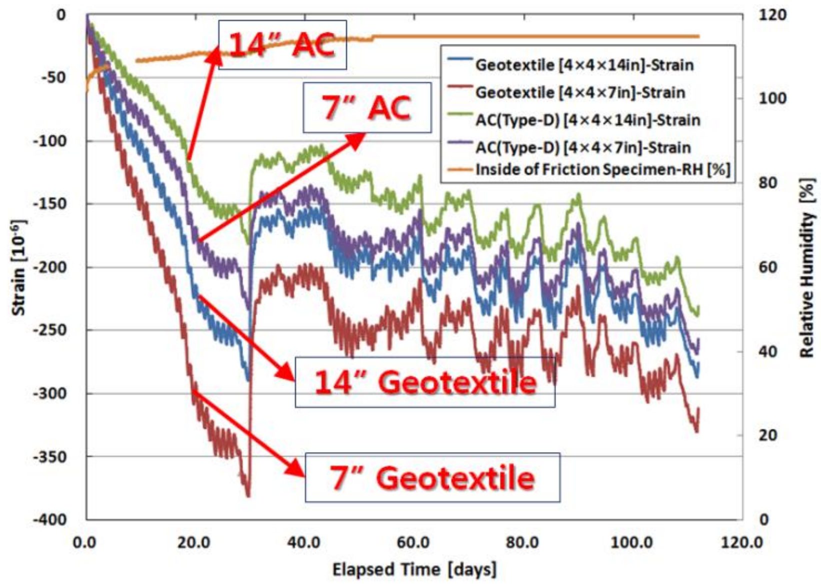


Figure 3.20 Concrete Prisms Strain

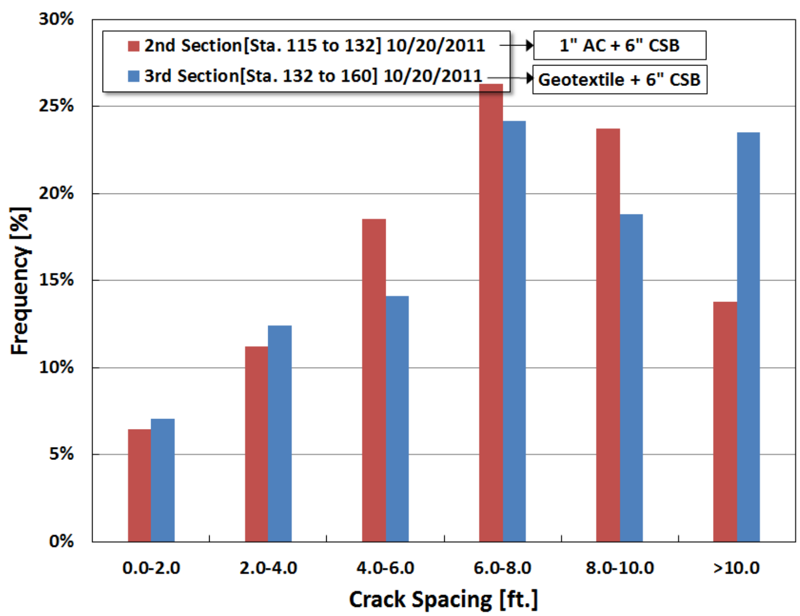


Figure 3.21 Transverse Cracking Pattern

3.4 Effect of Various Slab Support

3.4.1 Support Characteristics with Different Base Type on FM 1938

Various field tests were implemented to derive the correlations between *k*-values from plate bearing test (PBT) testing and FWD deflections on FM 1938 in the Fort Worth District. Test section layout is shown in Figure 3.17. The four types of different base are as follows;

1. 2-in. Type-B Asphalt Concrete base (AC)
2. 1-in. Type-D AC over 6-in. Cement Stabilized Base (CSB),
3. Geotextile over 6-in. CSB
4. 4-in. Type-B AC.

Ten locations were selected for support condition evaluations at each section. However, five locations were selected in the second section due to larger vertical slope of the pavement. Dynamic Cone Penetrometer (DCP), PBT and FWD testing were conducted at the same locations on top of different layers during different construction phases as shown in Figure 3.22. DCP testing was conducted at natural subgrade and cement treated subgrade. PBT testing was conducted on natural and cement treated subgrade and base. FWD testing was conducted on all layers.

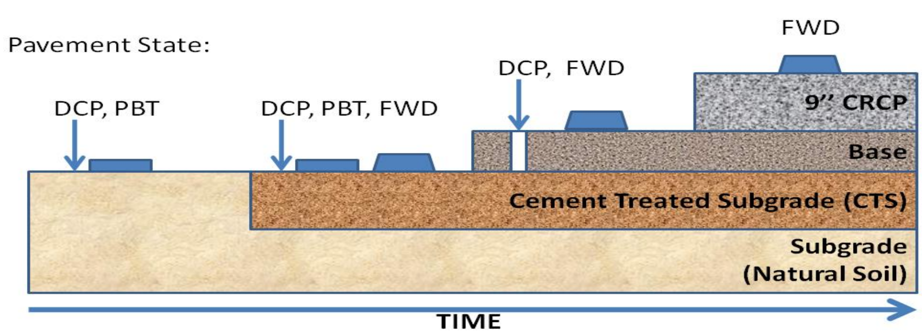


Figure 3.22 Field Testing

3.4.2 Relationship among FWD, PBT, and DCP

DCP test was conducted in accordance with ASTM D 6951-03 (ASTM Standard D6951-03 2003) on subgrade both before and after cement stabilization. Penetration rate (PR) in mm/blow was determined based on a plot of measured depth and cumulative blows. PR was converted to elastic modulus for different layers by using the correlation suggested by the TxDOT Pavement Design Guide Manual (TxDOT 2011).

A steel bearing plate is pressed into the surface by a hydraulic jack in plate bearing test (PBT) in accordance with ASTM D 1196-93 (ASTM Standard D1196-93 2004). The surface deflection and load level are measured by LVDTs and load cell, respectively, and recorded automatically for modulus of subgrade reaction *k*-value calculation.

Deflection data on top of CRCP obtained by FWD testing was used to backcalculate modulus of subgrade reaction *k*-value in accordance with AREA method (Hall 1991). Figure 3.23 illustrates DCP, PBT, and FWD testing in the field.

Figure 3.24 shows the relationship between elastic modulus of upper and lower layers of the natural subgrade and *k*-values obtained on top of natural subgrade by PBT. *k*-values obtained from PBT are significantly influenced by the stiffness of the layer right underneath PBT loading plate. It appears that *k*-values obtained from PBT cannot represent overall support condition.

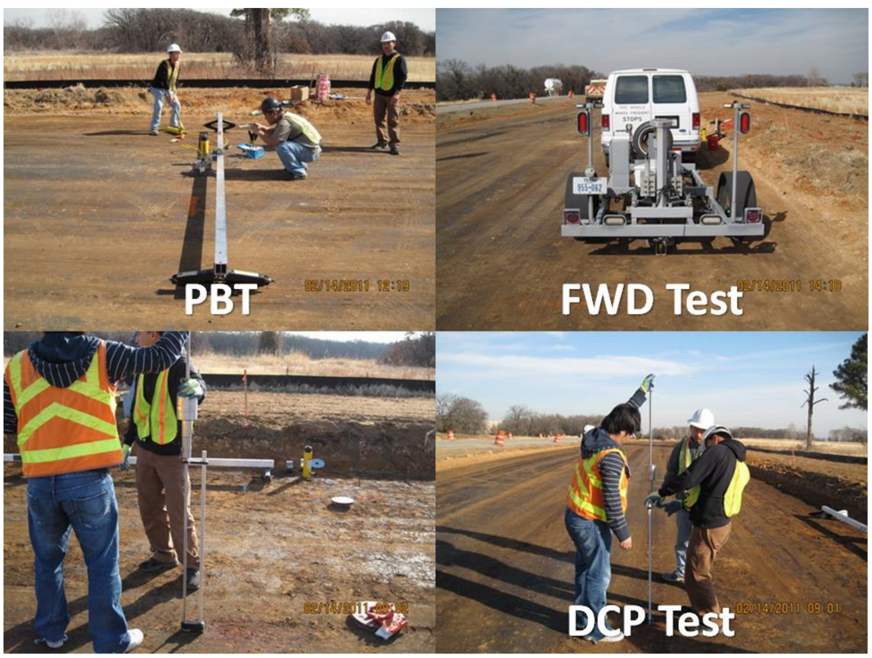


Figure 3.23 Various Field Testings

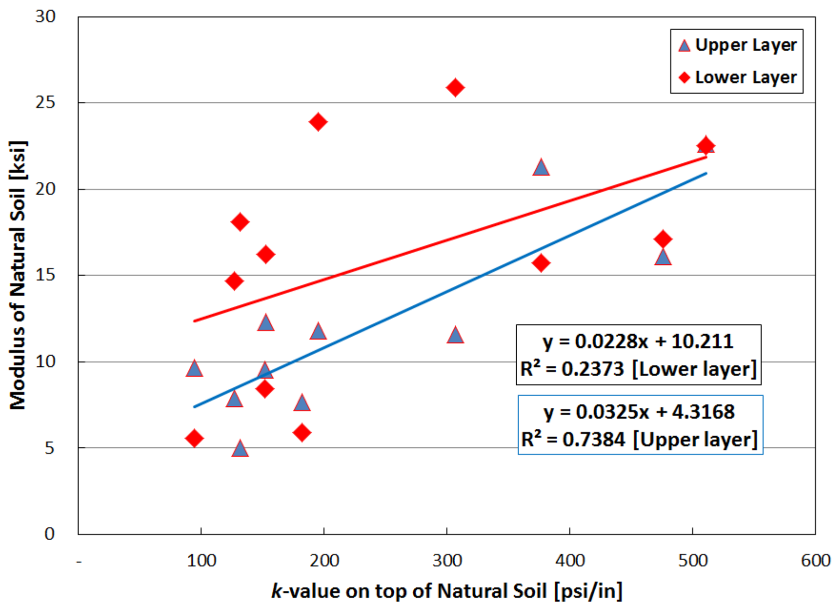


Figure 3.24 Comparison between *k*-value and Elastic Modulus on Natural Soil

Figure 3.25 represents the deflection comparison among four different base types. Even though base static *k*-value of non-woven geotextile section is larger than others as shown in Figure 3.26, the largest deflection was measured in this section. Non-woven geotextile seems to play a role in the increase in deflection. It indicates that CRCP deflections are significantly influenced by the material right underneath the slab. Since smaller deflection is desirable for the CRCP structural performance, the use of geotextile in CRCP needs further evaluations.

Figure 3.27 shows the correlation between FWD deflection and static *k*-value obtained with PBT in four different base types. It appears that there are no correlations between FWD deflection and static *k*-value with PBT. As mentioned above, since CRCP performance is significantly influenced by slab deflection, static k-value from PBT on top of base may not represent the overall support condition of base during construction. A new evaluation method for slab support condition needs to be developed as a quality control test.

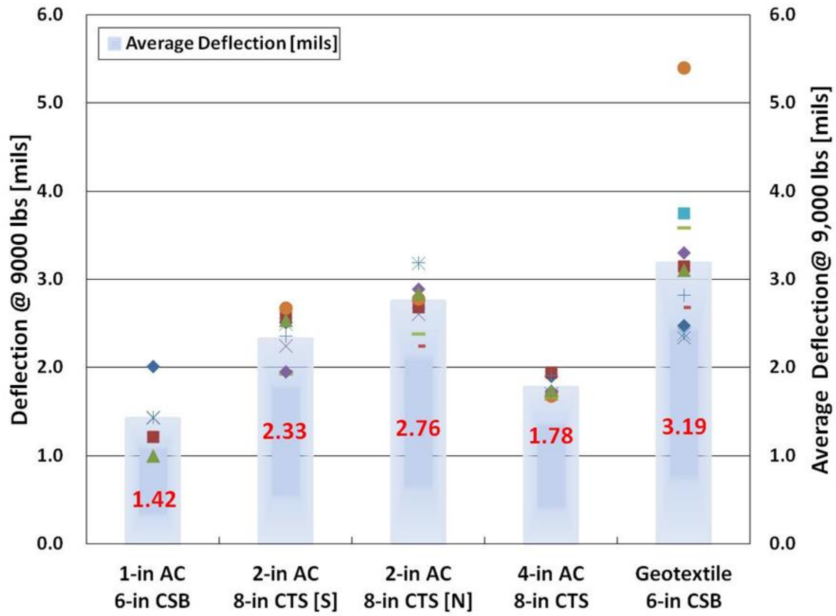


Figure 3.25 FWD Deflection Comparison with Different Base Types

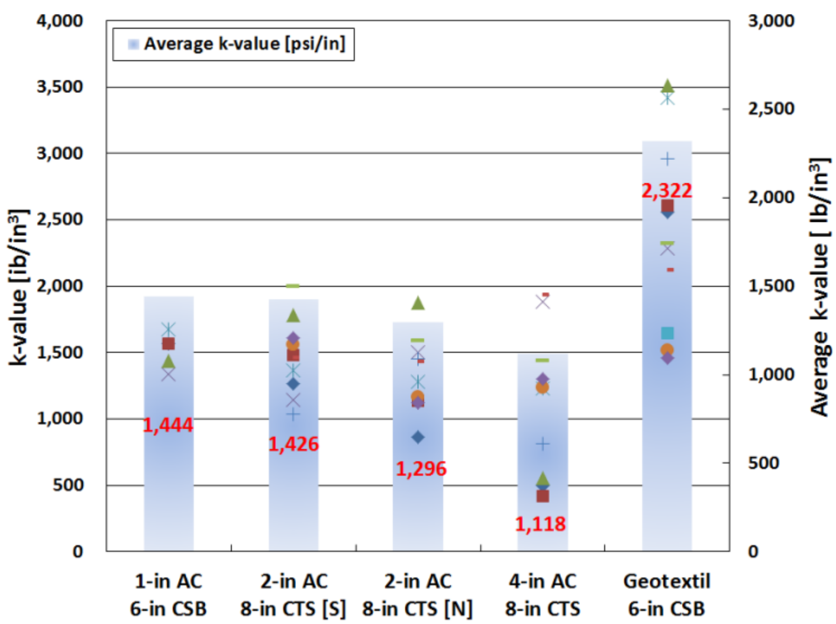


Figure 3.26 *k*-Value Comparison with Different Base Types

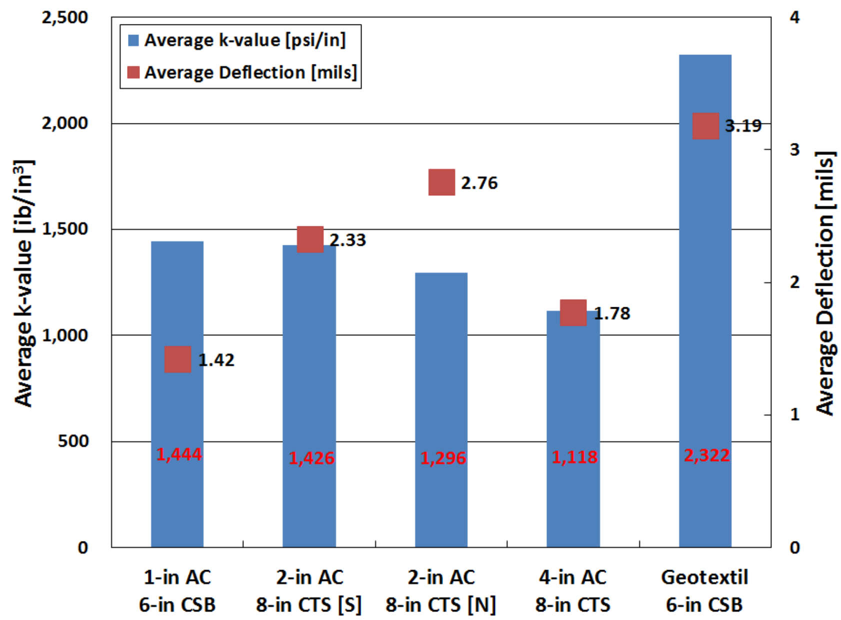


Figure 3.27 *k*-Value and Average Deflection with Different Base Types

3.4.3 Suggestion for Support Condition Evaluation

Since FWD deflection data on CRCP are needed for the AREA backcalculated *k*-values, slab support condition in terms of *k*-values cannot be evaluated until concrete is placed and cured adequately. However, for quality control purposes of base construction, FWD deflection basin on base can provide good information regarding its support condition. AREA concept was originated from asphalt concrete pavement research and, if AREA and maximum deflection D_0 are known on top of asphalt layer, *k*-values can be reasonably estimated.

As shown in Figure 3.28, the x-axis comprises of a parameter combining AREA obtained on top of the base layer and maximum deflection on the base, D_0. Y-axis represents backcalculated *k*-values based on FWD deflections measured on CRCP. Relative good correlations are observed for both base types (4-in. AC over 8-in. CTS and 1-in. AC over 6-in. CSB).

Figure 3.28 indicates that *k*-values on top of base can be estimated from FWD deflections on top of base, which will allow field verification of *k*-values used in the pavement design, before concrete placement. This could be used as a job control testing for base construction. Even though this method presents a reasonable method for the estimation of *k*-values for base, more data is needed to validate the reasonableness of this method. Efforts will be made to conduct more extensive field testing. Once sufficient data are obtained, they will be analyzed to finalize the combined form of AREA and deflections on the base for the prediction of backcalculated *k*-values.

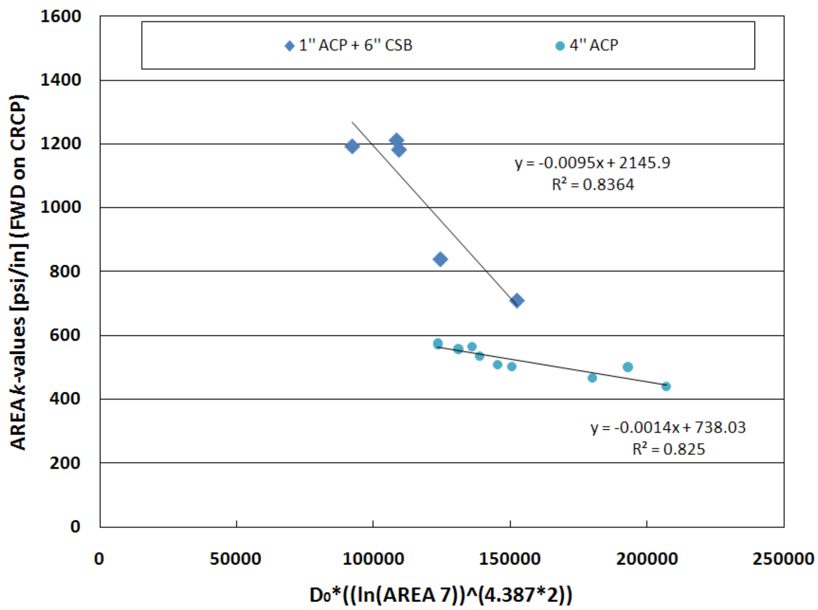


Figure 3.28 AREA *k*-value versus Combined Parameter for Two Base Types

3.5 Summary

The findings described in this chapter present valuable information on the behavior and performance of CRCP. Findings described in this chapter can be summarized as follows:

1) Transverse cracking in CRCP does not present weakest element in CRCP, nor is a cause for distresses. Load transfer efficiency (LTE) at transverse cracks remains at a high level in CRCP, providing structural continuity through the cracks.
2) Punchout distress in CRCP in Texas is mostly due to the localized poor slab support. It does not follow traditional punchout mechanism, which is, LTE is decreased and slab segment with a short crack spacing behaves as if a cantilever beam, with maximum wheel load stress in the transverse direction, resulting in punchout.
3) LTE in CRCP stays at a high level regardless of crack spacing and concrete temperature. The assumption made in the development of MEPDG that LTE varies with concrete temperature and crack spacing was not validated in this study.

4) There is a large difference in predicted crack widths from MEPDG and those measured. MEPDG over-predicts crack widths and thus under-estimates CRCP performance, resulting in quite conservative pavement design.
5) Crack widths are kept quite tight in CRCP, which is responsible for a high level of LTE and good performance of CRCP.
6) Non-woven geotextile provides much smaller base friction than asphalt base, resulting in larger crack spacing.
7) FWD deflections on top of base could be used to estimate in-situ modulus of subgrade reaction using AREA method, which can be used as a job control testing for base construction, or verification testing for pavement design.

Chapter 4 Performance Evaluations of Experimental Sections

4.1 Overview

Over the years, TxDOT built a number of experimental sections to investigate the effects of design, material, and construction variables on CRCP behavior and performance. Table 4.1 lists the experimental sections investigated under this project. The condition of these pavement sections in terms of punchouts, spalling, repairs and other distresses has been evaluated by visual observations on a yearly basis. In addition, structural condition of the sections was evaluated with FWD.

Table 4.1 Experimental Pavement Sections

TxDOT Research Project	Specific Purpose
0-1244	Effect of the amount of longitudinal steel, bar size, coarse aggregate type, and season of concrete placement
0-1700	Effect of concrete placement temperature
5-9026	Benefits of optimized aggregate gradation
0-4826	Effectiveness of various concrete mix designs and curing
LTPP Sections	General performance

4.2 Sections Built Under TxDOT Research Project 0-1244

Four CRCP experimental sections were constructed in the Houston District under TxDOT Research Project 0-1244 (Suh et al. 1992), i.e., IH 45 in Spring Creek, Beltway 8 frontage road, and two locations on SH 6. The objectives of project 0-1244 included the identification of coarse aggregate and steel reinforcement effects on CRCP performance. Figure 4.1 illustrates the locations of experimental sections in the Houston District.

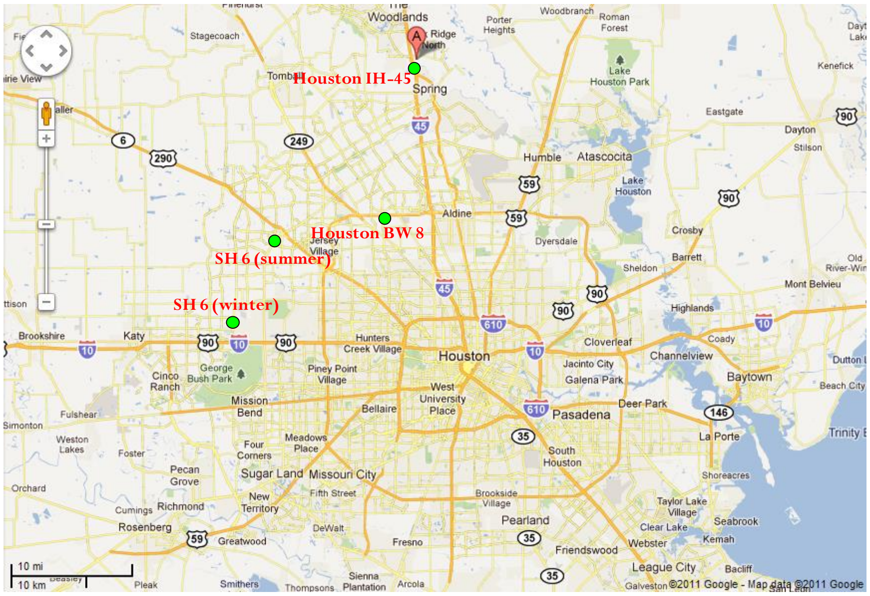


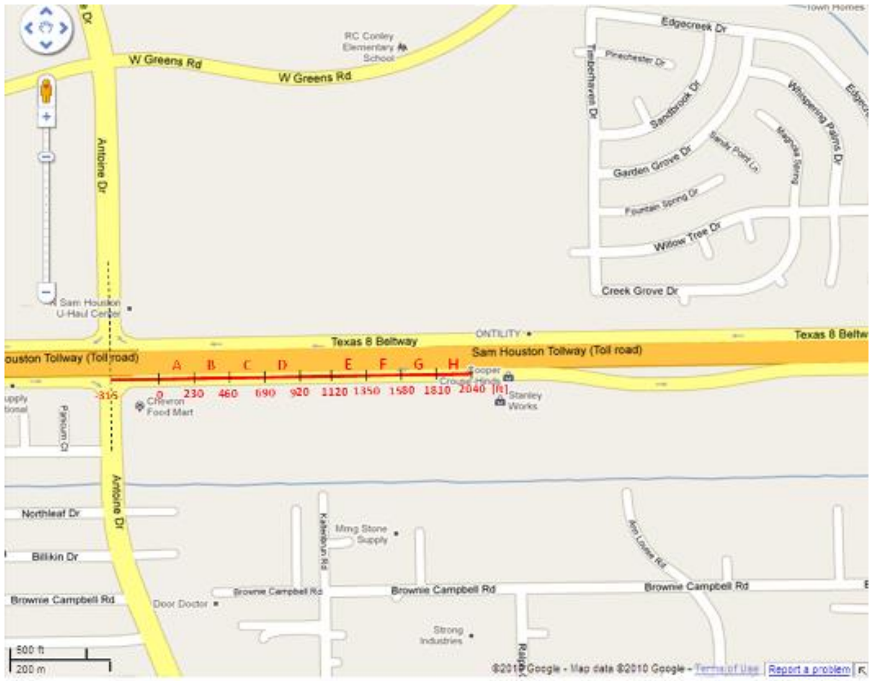
Figure 4.1 Experimental Sections in Houston Built Under Project 0-1244

Among the four sections, two on SH 6 were asphalt overlaid with hot mix asphalt in the mid-2000s due to severe spalling problems, as shown in Figure 4.2. The other two experimental sections–one on the IH 45 in Spring Creek and the other on the BW 8 frontage road–are in good condition except for spalling problems on sections containing siliceous river gravel (SRG) as coarse aggregate, and thus field evaluations were conducted in the remaining two locations: BW 8 and IH 45. Both of them were constructed in the late 1989 and early 1990, and have been in service for more than 23 years.

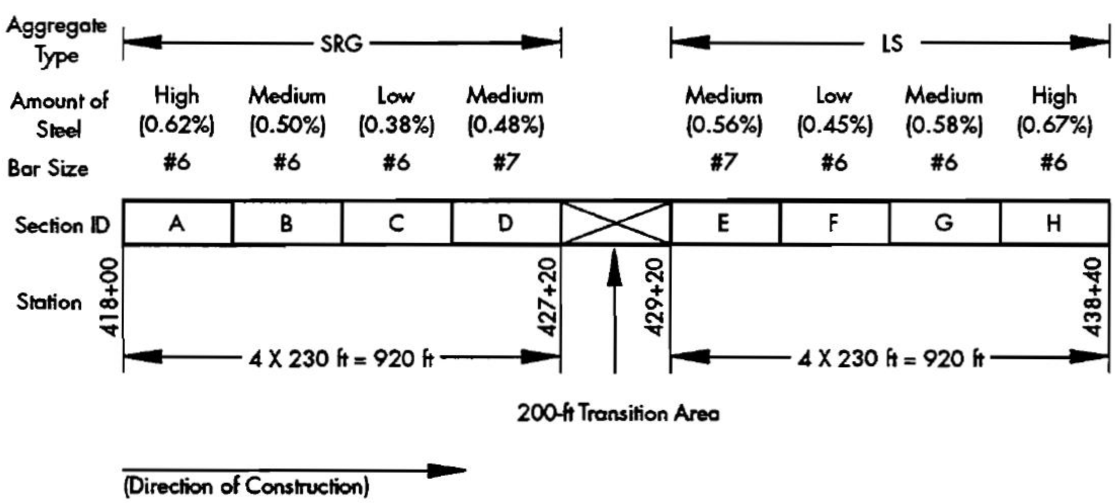
Figure 4.2 SH 6 Section Overlaid with Asphalt

4.2.1 BW 8 Section

This section is located in the frontage road of Beltway 8 eastbound, just east of Antoine Rd. The GPS coordinate for this test section is 29.937122, -95.482736. This section was placed on November 24 and November 25, 1989. Two coarse aggregate types (SRG and LS) and four different reinforcement designs (low, two mediums, and high) were used. Figures 4.3 (a) and (b) illustrate the location and plan layout of the test sections, respectively. It is 10 in.-CRCP with 1 in.-asphalt concrete base (bond breaker) over 6-in. cement stabilized base. For concrete mixtures, 5.2-sack cement with a 25 % replacement of fly ash was used for both SRG and LS sections. The water-to-cement ratio was 0.44 and 0.45 for the SRG and LS sections, respectively.



(a) Location



(b) Layout of Test Sections

Figure 4.3 Test Sections in BW 8 Frontage Road

This section provided an excellent opportunity to investigate the effects of coarse aggregate type and steel percentages. At the writing of this report, the section is 23 and 0.5 years old, and thus sufficient environmental loading (temperature and moisture variations) was applied. It is quite difficult to investigate the effects of longitudinal steel amounts on CRCP performance in typical CRCP projects, because CRCPs are constructed with a fixed steel amount per design standards, resulting in little variations in the amount of longitudinal steel among projects.

4.2.1.1 Crack Spacing

Figures 4.4 and 4.5 illustrate the average crack spacing distributions for all eight subsections. The findings on crack spacing are summarized as follows:

1. Crack spacing varies with the amount of longitudinal steel – the more steel, the smaller the crack spacing, which is consistent with the findings in other studies and with theoretical analysis. The exceptions are crack spacing in Sections G and H. Section H has a larger amount of steel than Section G, but similar crack spacing is observed for both sections.

2. Coarse aggregate type does not appear to affect crack spacing. This is somewhat different from the findings elsewhere. Normally, concrete with LS has larger crack spacing than concrete with SRG. On the other hand, environmental conditions during and right after construction have substantial effects on cracking development. Cracking information at early ages (up to 30 days after construction) shows no difference between the SRG and LS section for high steel and #7 bar sections. For low steel percentage sections, the LS section had larger crack spacing than the SRG section. It appears that the trend still continues after 20 years.

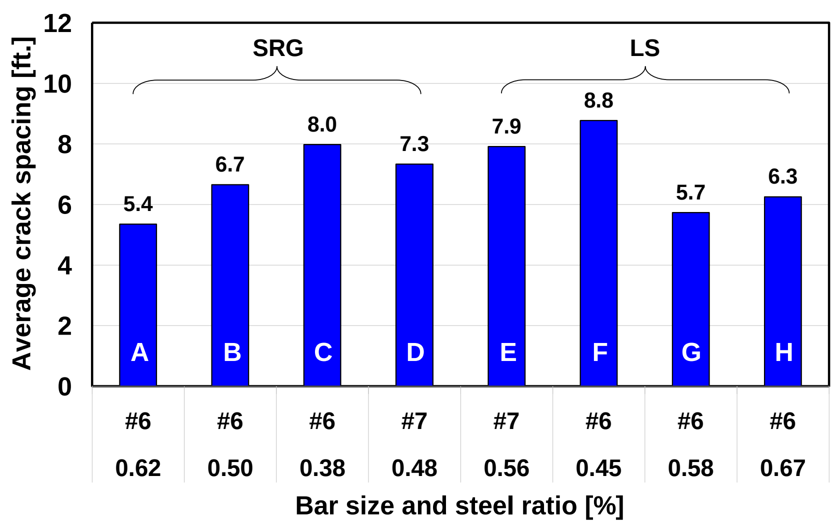


Figure 4.4 Average Crack Spacing of All Sections in BW 8 Frontage Road

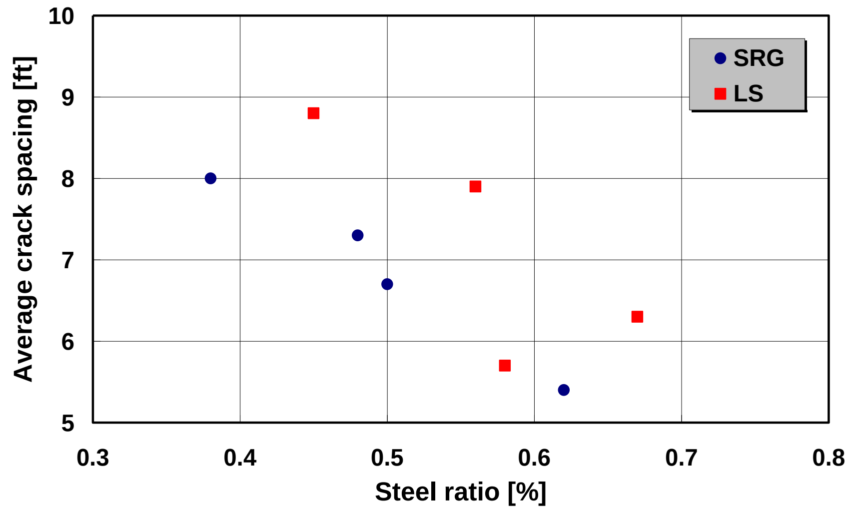


Figure 4.5 Correlation between Steel Percentage and Crack Spacing in BW 8 Section

4.2.1.2 General Condition

A series of field investigations revealed that there was even no single punchout distress found in both LS and SRG sections. However, there was a huge difference in the surface condition between those sections; while the SRG section had numerous deep spallings and spalling repairs, general condition of the LS section was highly fair and sound. Figures 4.6, 4.7 and 4.8 show the general surface condition of the LS section, deep spalling in the SRG section and close-up view of spall repairs, respectively. In Figure 4.7, it is important to note that another spalling begins to develop right next to the existing deep spalling repair.

Figure 4.6 General Condition of LS Section

Figure 4.7 Deep Spalling in SRG Section

Figure 4.8 Close-Up View of Spall Repairs

The number of transverse cracks and spalling/spall repairs for the inside two lanes of the SRG section is summarized in Table 4.2. Figure 4.9 depicts the spalling ratio evaluated for the SRG section based on the number of transverse cracks and spalling/spalling repairs. Also, Figure 4.10 shows the correlation between the steel percentage and spalling ratio for the SRG sections.

Table 4.2 Number of Transverse Cracks and Spalling Repairs in BW 8 Frontage Road

Test Section	A	B	C	D
No. of Transverse Cracks	41	35	29	31
No. of Spalling/ Spall Repairs	17	20	22	13

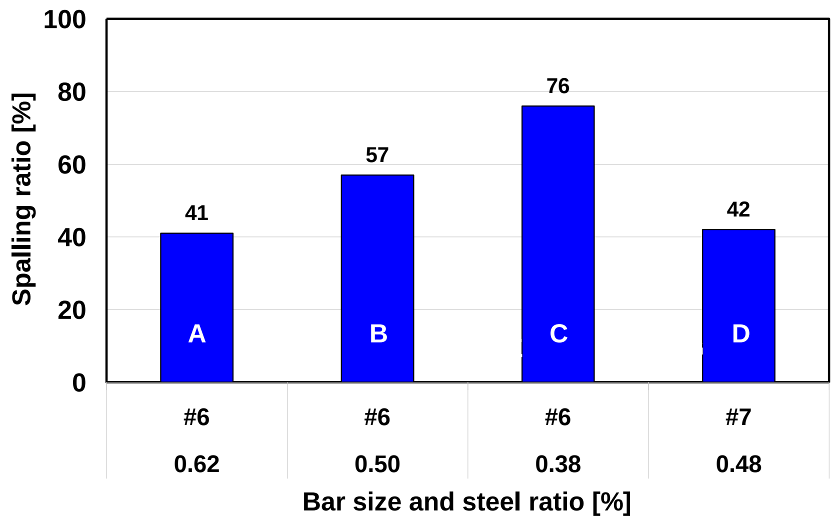


Figure 4.9 Spalling Ratio for SRG Sections

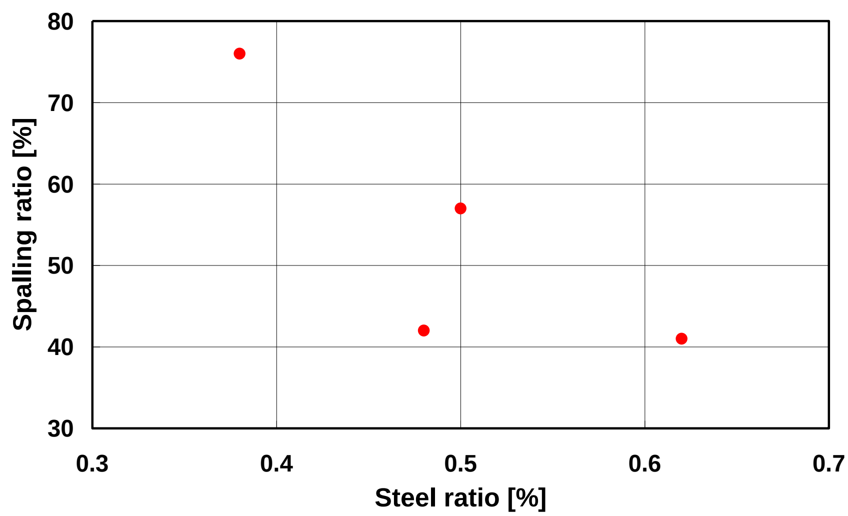


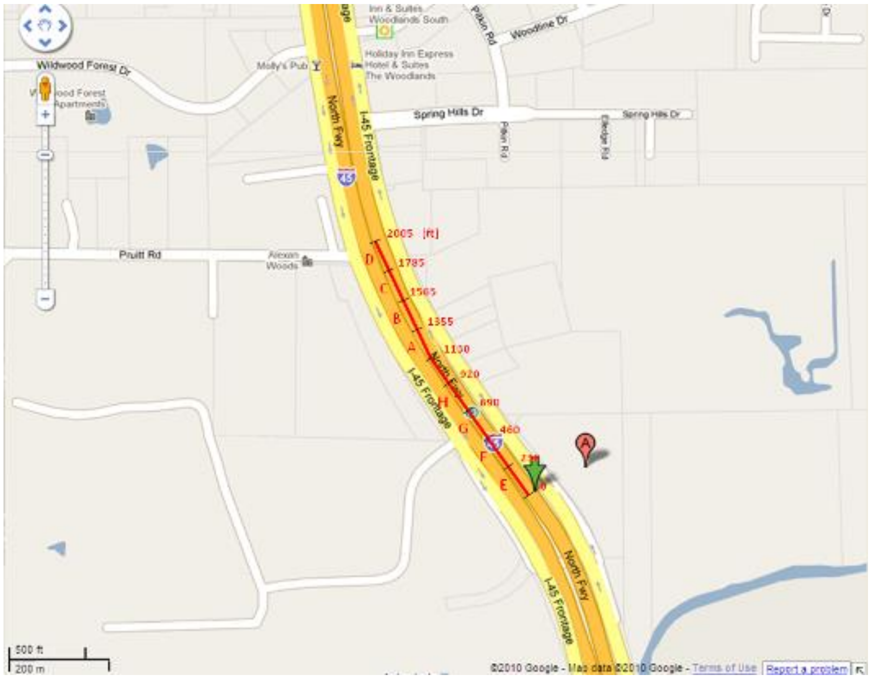
Figure 4.10 Relationship between Steel Percentage and Spalling Ratio for SRG Sections

The finding strongly indicates that there is a fairly good correlation between steel percentage and spalling potential in concrete with spalling susceptible coarse aggregate. Section A had the highest steel percentage, and Section C had the lowest steel percentage among SRG sections. It appears that a larger amount of steel restrains concrete movement at transverse cracks, thus reducing spalling occurrence. On the other hand, a lower steel amount does not restrain concrete volume changes sufficiently, and larger concrete displacements at cracks eventually lead to spalling. This finding is supported by the fact that spalling in this section did not take place at early ages; it took a long while before deep spalling took place. It appears that large concrete displacements at cracks in sections with a low steel percentage accumulate fatigue damage due to temperature and moisture variations, and eventually with traffic wheel loading applications, resulting in spalling. Observation of spalling in this section indicates the problem has been getting worse over the years. This section will be monitored periodically to document the spalling progress. The finding in this section suggests that a larger amount of steel may be needed for concrete with SRG as a coarse aggregate type, even though the frequency of spalling with a high steel amount is not acceptable. One of the distinctive properties of concrete containing SRG in the Houston area is a high coefficient of thermal expansion (CoTE). The potential issue would be that, with a larger steel percentage for concrete with high CoTE, there will be more transverse cracks. From a theoretical standpoint, short crack spacing shouldn't be a problem. This finding does not indicate that concrete with a high CoTE can be used safely with a larger steel amount. There were 17 spall repairs or spalls in Section A, where a high steel percentage was used. There was no spalling in the LS section. As for the performance in terms of punchouts, there was no punchout in either SRG or LS sections after more than 20 years.

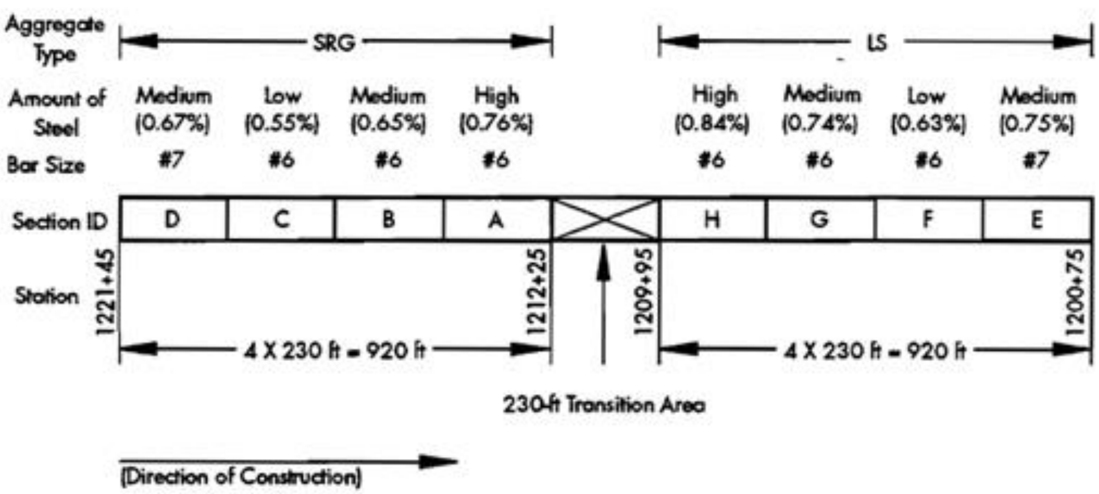
4.2.2 IH 45 Section

This section is located in the main lanes of IH 45 northbound, just north of Spring Creek, and was constructed on January 14 (SRG section) and on January 21 (LS section), 1990. It is 15-in. CRCP with 1-in. asphalt concrete base (bond breaker) over 6-in. cement stabilized base. The field test section is the inside two lanes, and its GPS coordinate is 30.115378, -95.438511. Figures 4.11(a) and (b) illustrate the location map and design layout of the test section, respectively. For concrete material mixtures, a 5.7-sack cement factor with 30 % fly ash and a 5.3-sack cement and 25 % fly ash were used for the SRG section and LS section, respectively. The water-to-cement ratio was 0.41 and 0.44 for each of the SRG and LS sections.

When the design of the experimental sections was developed, TxDOT was considering the use of less steel in concrete with a high CoTE. The idea was that, by doing so, comparable average crack spacing would be achieved and CRCP sections with comparable average crack spacing would provide approximately the same performance, which, as discussed in Chapter 3, is not the case.



(a) Location



(b) Layout of Test Sections

Figure 4.11 Test Sections in IH 45 in Spring Creek

4.2.2.1 Crack Spacing

Figure 4.12 displays the average crack spacing distributions for the eight subsections. Furthermore, Figure 4.13 presents the relationship between steel percentage and crack spacing. The result shows that the effect of steel percentage on crack spacing is less consistent compared with the BW 8 section. Also, there was no difference in crack spacing between sections with SRG and LS, as in the BW 8 section discussed earlier. It is noted that, even though the slab is 15-in., crack spacings are rather small. Since the slab thickness was 15-in., two layers of steel was used. The layer of steel is closer to the concrete surface, providing more restraints on concrete volume changes due to temperature and moisture changes, resulting in higher concrete stress and smaller crack spacing. This indicates that cracks in this section are primarily due to temperature and moisture variations, because the slab is 15 in.-thick and concrete stresses due to wheel loading are quite small.

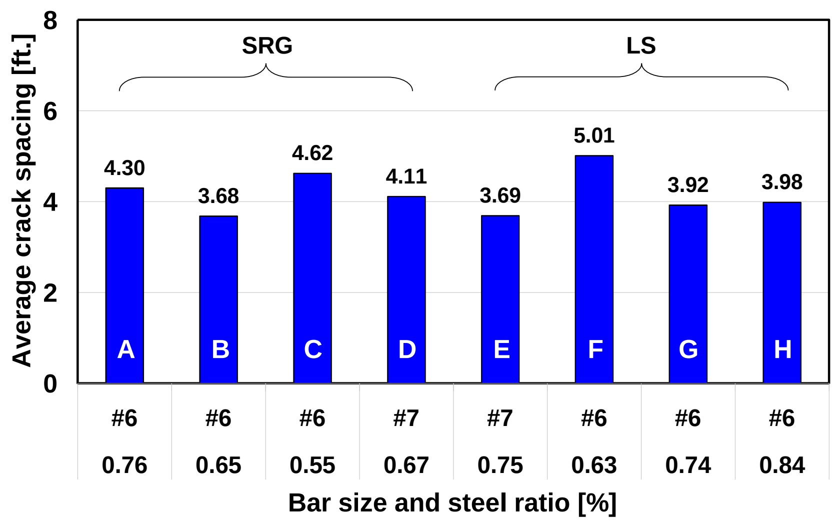


Figure 4.12 Average Crack Spacing in Various Sections

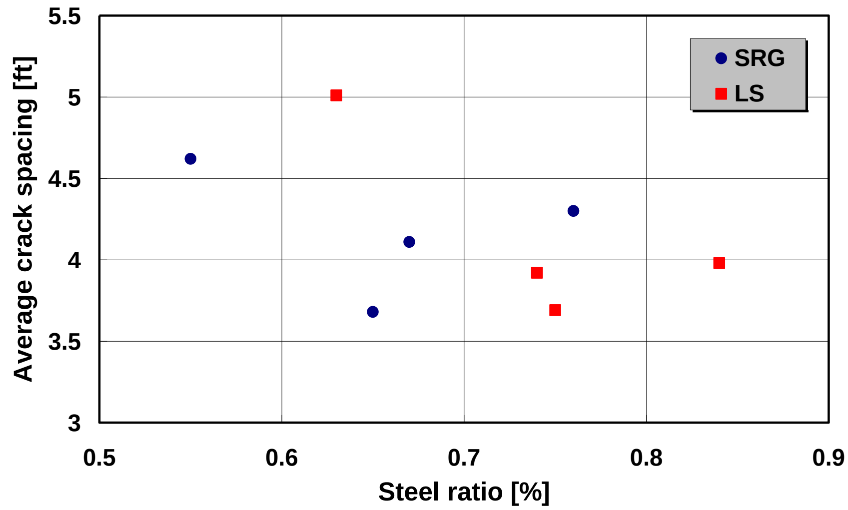


Figure 4.13 Relationship between Steel Percentage and Crack Spacing in SH 45 Section

4.2.2.2 General Condition

There was no punchout in the section. The only distress observed was some spallings in the SRG section. There was no spalling recorded until 2004, when the director of construction at the Houston District first observed spalling 14 years after construction. Since then, more spalling occurred and spalling conditions worsened. Figure 4.14 shows the spalling repairs in this section. This section was repaired using Fibercrete and has performed exceptionally well. However, when driving the repaired sections with a vehicle, an excessive level of noise was detected. This indicates that fibercrete repair could degrade the rideability, as opposed to its excellent durability. The spalling in the SRG sections seems to be solely due to a materials issue, or possibly due to construction quality. However, because the same construction crews built both the LS and SRG test sections, and no spalling was found in the LS sections as shown in Figure 4.15, it appears that the spalling is closely related to the coarse aggregate used, as the BW 8 section was.

Figure 4.14 Spalling Repairs in SRG Section

Figure 4.15 Condition of LS Section

Table 4.3 summarizes the number of transverse cracks and spalling/spalling repairs for the inside two lanes of the SRG section, as of February, 2012. Again, there was no single spalling observed in the LS section. Figure 4.16 presents the spalling ratio evaluated based on the recorded number of transverse cracks and spalling/spalling repairs.

Contrary to the result of the BW 8 section, any clear correlation between steel percentage and spalling potential is not found in the SH 45 Spring Creek test section, as shown in Figure 4.17. It appears that other factors such as two layers of steel, base support condition and traffic loading were more dominant for the behavior of response of this section, rather than the effect of steel percentage.

Table 4.3 Number of Transverse Cracks and Spalling Repairs in IH 45 in Spring Creek

Test Section	A	B	C	D
No. of Transverse Cracks	52	58	47	54
No. of Spalling Repairs	16	12	16	12

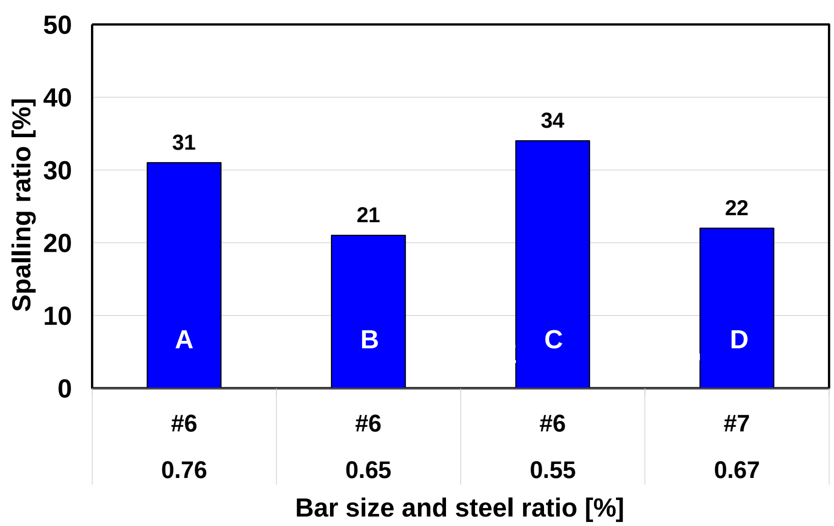


Figure 4.16 Spalling Ratio for SRG Sections

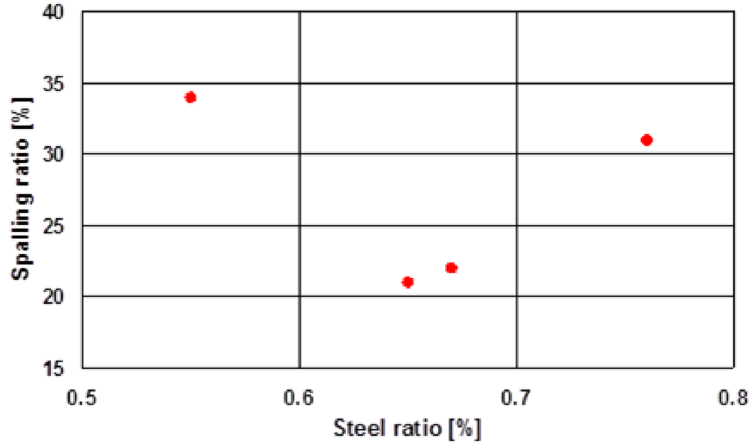


Figure 4.17 Relationship between Steel Percentage and Spalling Ratio for SRG Sections

4.3 Experimental Sections Built Under TxDOT Research Project 0-1700

The primary objectives of project 0-1700 (Schindler et al. 2002) included the identification of temperature effects on CRCP performance. Experimental sections were constructed at five locations in the state, i.e., Austin, Cleveland, Houston, Baytown and Van Horn. Figure 4.18 illustrates the locations, along with slab thicknesses and construction dates.

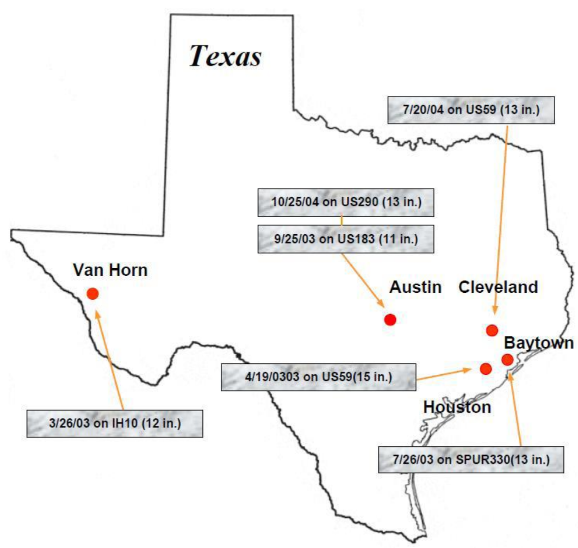


Figure 4.18 Locations of Experimental Section under Project 0-1700

Field evaluations were performed in three sections constructed in the Houston area, i.e., SPUR 330 in Baytown, US 59 in Houston, and US 59 in Cleveland. Concrete mixture designs and pavement thickness for each of the three sections are listed in Table 4.4. In all sections, crushed LS was used as coarse aggregates.

Table 4.4 Mix Design for Test Sections in Baytown, Cleveland, and Van Horn

Project	Baytown SPUR 330	Cleveland US 59	Van Horn IH 10
Pavement Thickness (in.)	13	13	12
Cement (lbs/yd^3)	362	362	246
SCM (lbs/yd^3)	129	131	224
Coarse Aggregate (lbs/yd^3)	1695	1848	2000
Fine Aggregate (lbs/yd^3)	1413	1265	1161
Air Content (%)	5	5	6
Water (lbs/yd^3)	220	215	240
SCM (Replacement Ratio)	Class C Fly Ash (30%)	Class F Fly Ash (30%)	GGBFS (50%)
Cement Type	Type I/II	Type I/II	Type I
Coarse Aggregate Type	Limestone	Limestone	Limestone

Concrete temperatures for all three sections were measured using *i*-buttons. *i*-buttons were installed at various longitudinal and transverse locations of the pavement as well as various depths of the pavement to comprehensively identify the temperature patterns in the concrete pavement. Air temperatures were also measured using *i*-buttons. The temperatures were collected every 30 minutes during at least the first 72 hours after concrete placement. After 72 hours, the temperatures were collected every two hours.

4.3.1 Field Testing Sections

4.3.1.1 Baytown SPUR 330 Section

The Baytown SPUR 330 section is 13 in.-thick CRCP located northwest of Baytown. It is 725-ft long and is at the inside main lane on SPUR 330 between Baker Rd. and Little Rd. The GPS coordinate for this section is 29.776037, -95.018799. The section was placed at 7:30 am on July 26th, 2000. Figures 4.19, 4.20, and 4.21 present the location map, overview, and close-up view of the test section, respectively.

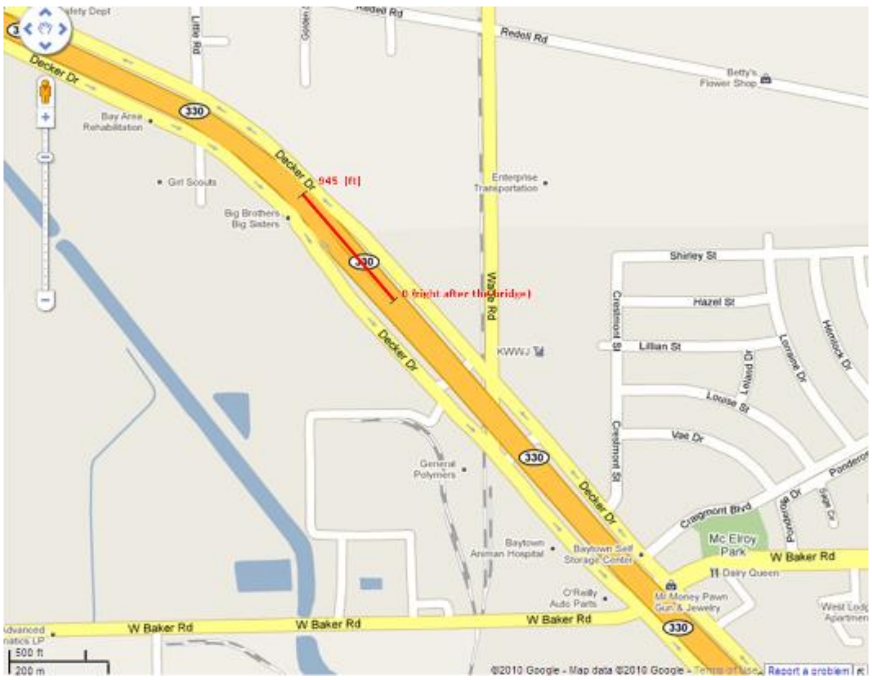


Figure 4.19 Field Location of Baytown SPUR 330 Section

Figure 4.20 Overview of Baytown Section

Figure 4.21 Close-Up View of Baytown

The concrete material used incorporated 5.2-sack cementitious material with 30% Class C fly ash replacement. The coarse aggregate type was crushed LS, as previously described. The water-to-cement ratio of the mixture was 0.45. Figure 4.22 displays the early-age concrete temperature evolutions monitored at the top 1 in., mid-depth, and bottom 1 in. of the test section. The measured temperatures show that the maximum concrete temperature at the first day was approximately 110°F, while the fresh concrete temperature was about 80°F.

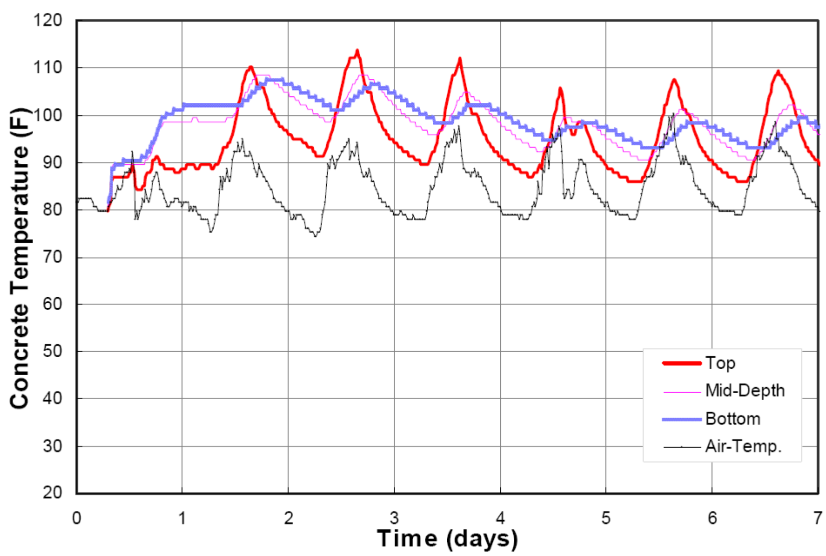


Figure 4.22 Early-Age Temperature History for Baytown SPUR 330 Section

4.3.1.2 Cleveland US 59 Section

The Cleveland US 59 section was 13 in.-thick CRCP located in the Houston District south of Cleveland. The section was part of the US 59 northbound outside shoulder and is 3.668 miles long extending from FM 2090 south to Fosteria Road. The GPS coordinate for this section is 30.253637, -95.149133. Construction of this section began to be constructed at 9:00 am on July 20th, 2004. Field survey were done only for the initial 805 ft because of a heavy traffic issue around the exit area. Figures 4.23, 4.24 and 4.25 indicate the location map, overview, and close-up view of the section, respectively.

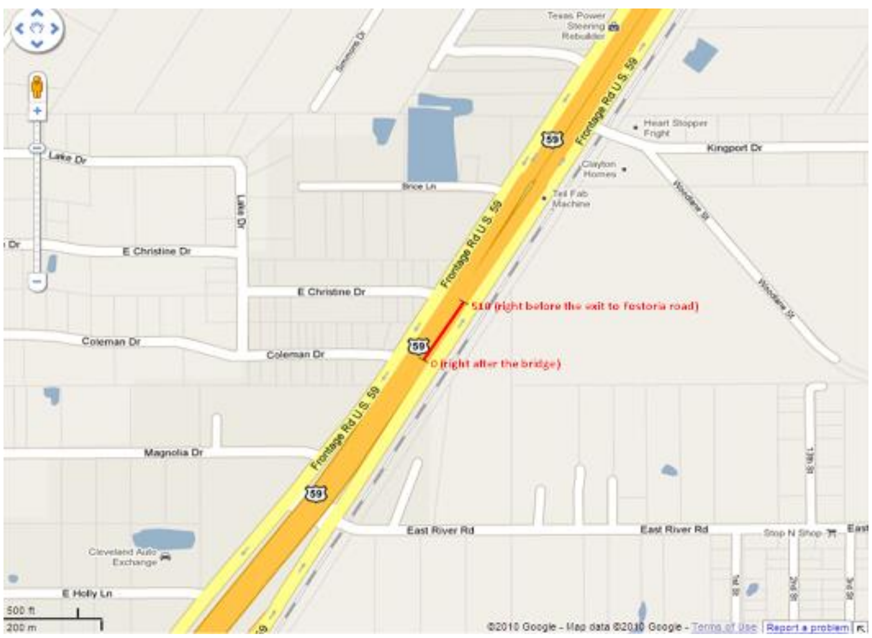


Figure 4.23 Field location of Cleveland US 59 section

Figure 4.24 Overview of Cleveland US 59 Section

Figure 4.25 Close-Up View of Cleveland US 59

The concrete material for this section used 5.25-sack cementitious material with a 30 % Class F fly ash replacement. The type of coarse aggregate was crushed LS. The water-to-cement ratio of the mixture was 0.44. Figure 4.26 shows the early-age temperature history collected at the top 1 in., mid-depth, and bottom 1 in. of the test section. The measured temperature history presents that the maximum concrete temperature at the first day after concrete placement was approximately 110°F, while the fresh concrete temperature was about 88°F.

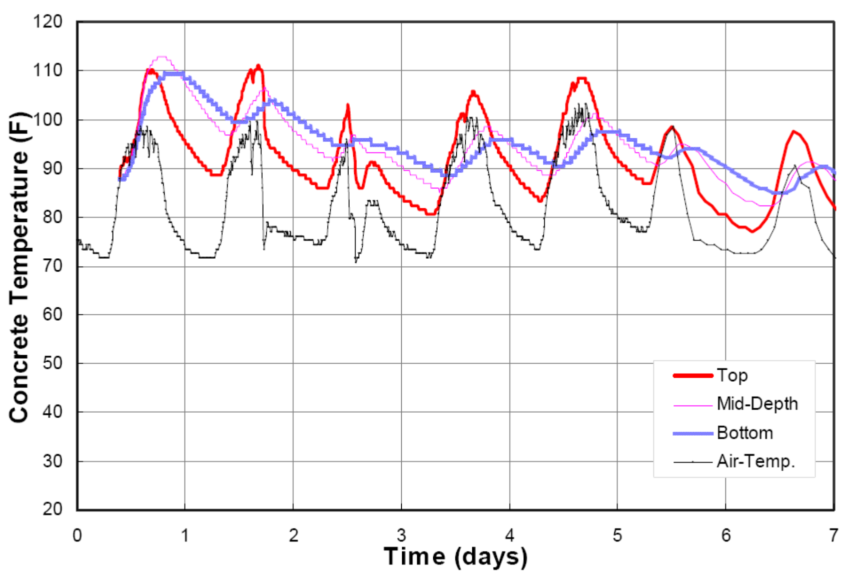


Figure 4.26 Early-Age Temperature History for Cleveland US 59 Section

4.3.1.3 Van Horn IH 10 Section

The Van Horn IH 10 section is 12 in.-thick CRCP located approximately 15 miles west of Van Horn. Concrete placement was initiated at 8:00 am on March 26th, 2003. The section started 1,225 ft before the "mile post 125" on the westbound of IH-10 and extended 2,400 ft from the starting point. The GPS coordinate is 31.09469,-105.070179, and the location map is shown in Figure 4.27. Only a 500-ft part out of total 2,400 ft was investigated because of safety concerns.

The mixture used in this section incorporated 5-sack cement replaced with 50% slag, which is different from the other sections included in this report. The type of coarse aggregate was crushed LS. The water-to-cement ratio of the concrete was 0.50. The early-age concrete temperature evolutions monitored at the top, middle, and bottom of the slab are shown in Figure 4.28. The measured temperature data shows that the maximum concrete temperature at the first day was about 70 °F, while the fresh concrete temperature was about 65 °F.

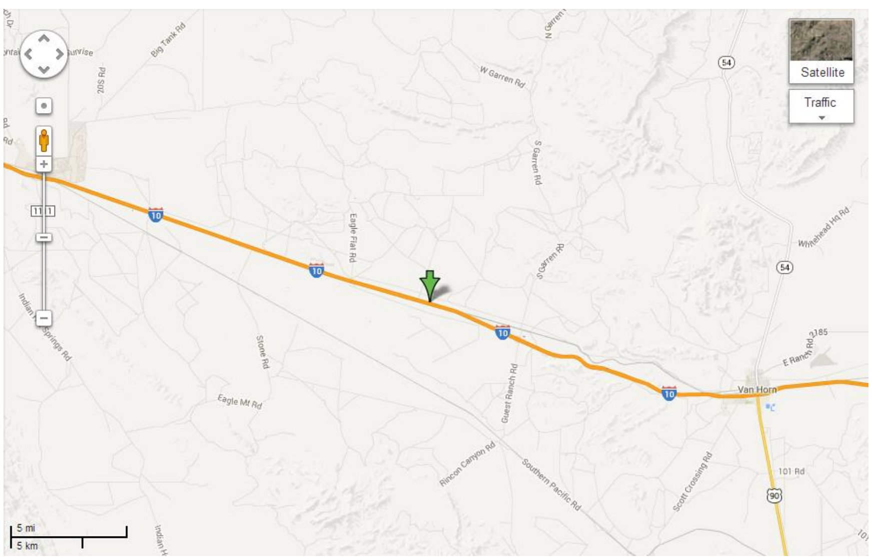


Figure 4.27 Field location of Van Horn IH 10 Section

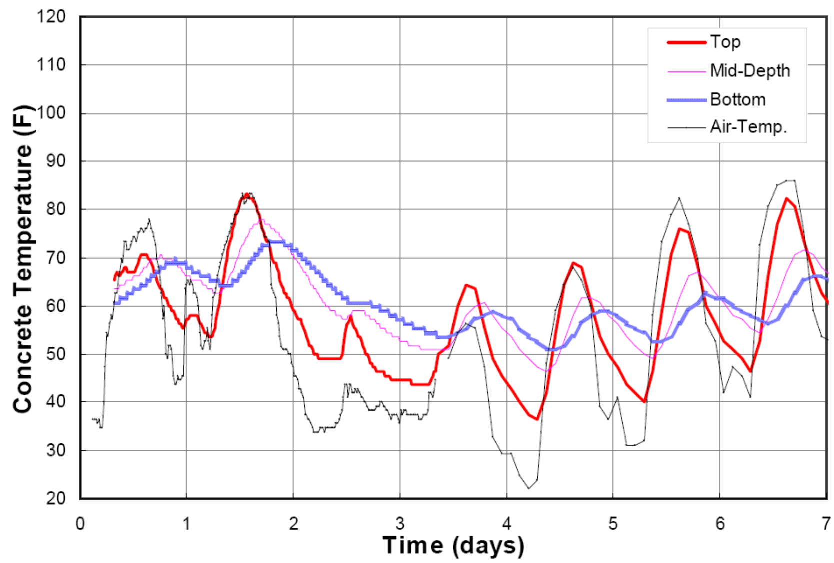


Figure 4.28 Early-Age Temperature History for Van Horn IH 10 Section

4.3.2 Crack Spacing and General Condition

Figure 4.29 shows the variations of average crack spacing over time measured for both Baytown and Cleveland sections in 2003. The average crack spacing patterns were very similar; cracking developed at a rapid rate within three weeks after construction, and the rate slowed down significantly afterwards.

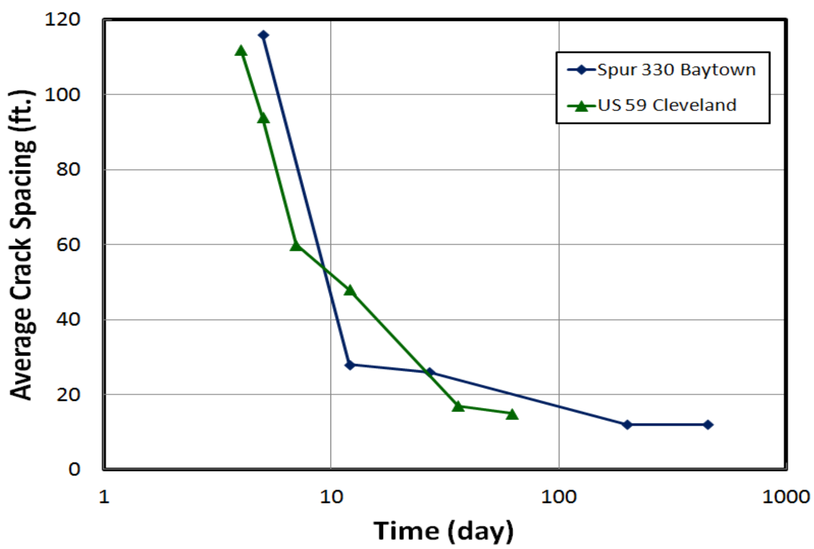


Figure 4.29 Average Crack Spacing Variations in Baytown and Cleveland (Nam 2005)

Additional crack spacing measurements were conducted in November 2010 and March 2012 for the Baytown and Cleveland sections, but not for the Houston section. It was quite difficult to measure crack spacing in the Houston section due to heavy traffic.

The average crack spacing for the Cleveland section was 6.3 ft with a standard deviation of 3.0 ft in November 2010 (about 2300th day after construction) and 4.4 ft with a standard deviation of 2.5 ft in March 2012 (about 2800th day after construction). As compared to the information in Figure 4.29, there were additional transverse cracks developed after three months after construction, probably due to continued drying shrinkage and traffic loading. Figure 4.30 shows the crack spacing distributions of the Cleveland section in March 2012. About 10 percent of cracks had more than 8 ft crack spacing; still, no spalling was observed even after eight years of service. The idea that large crack spacing could cause spalling was not verified in this project. Recall that the coarse aggregate type used in this project was LS. No punchouts or other distresses were observed.

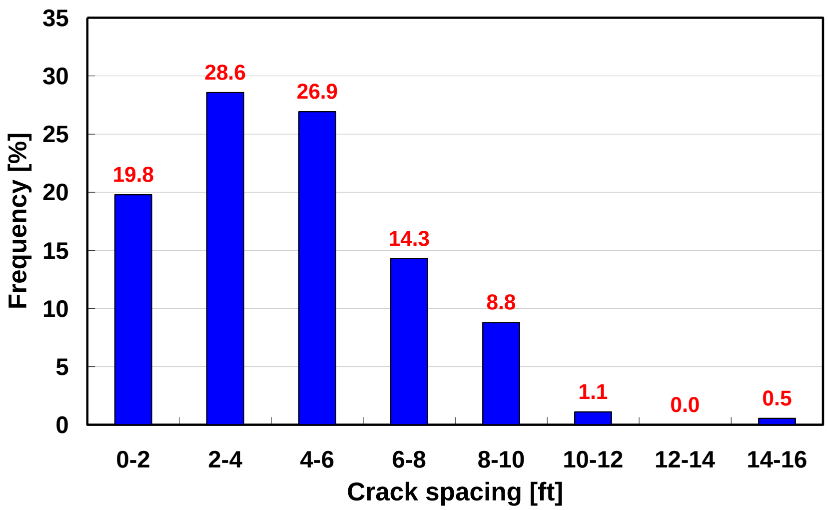


Figure 4.30 Crack Spacing Distributions in US 59 Cleveland Section in 2012

The average crack spacing for the Baytown SPUR 330 section was 10.0 ft with a standard deviation of 4.5 ft in November 2010 (about 2700th day after construction) and 9.2 ft with a standard deviation of 4.1 ft in March 2012 (about 3150th day after construction). As compared to the information in Figure 4.29, there were additional transverse cracks developed after four months of construction as expected. About 62 percent of cracks were more than 8 ft crack spacing as shown in Figure 4.31, and still no spalling was observed even after nine years of service with heavy traffic. Again, the idea that large crack spacing could cause spalling is not verified in this project.

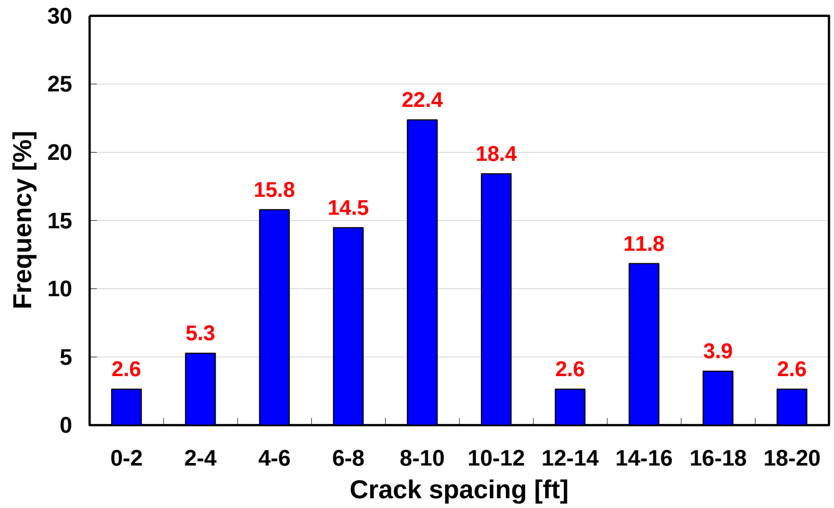


Figure 4.31 Crack Spacing Distributions in SPUR 330 Section in 2012

In Texas, most of the spalling problems occur when coarse aggregates with a high CoTE are used. Coarse aggregates with a high CoTE might have other properties that make them more prone to spalling. Identifying those other properties is not an easy task. Over the years, TxDOT has sponsored a number of research projects to improve CRCP performance when spalling-prone aggregates are used. So far, no solution has been found. In this project, no punchouts or other distresses were observed.

In the Van Horn IH 10 Section, there were a total of 68 transverse cracks in the 500 ft section, as of November, 2010. Figure 4.32 illustrates the transverse crack spacing distributions in this section. The average crack spacing and standard deviation were 7.36 ft and 3.47 ft, respectively. When concrete was placed, it was expected that average crack spacing in this section could be substantially large, because this section employed LS as coarse aggregates and concrete setting temperature (or zero-stress temperature) was quite low. However, a field evaluation showed that this section had normal transverse crack spacing when compared to the other sections. This finding might be somewhat related to the low tensile strength of concrete at early ages, because this section used a 50% slag replacement for a concrete mixture design.

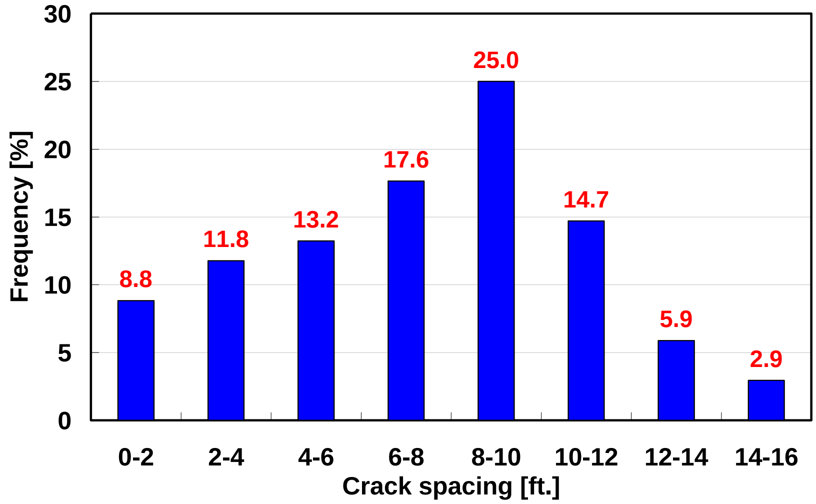


Figure 4.32 Crack Spacing Distributions in in Van Horn IH 10 Section

Even though this CRCP section was placed in the winter and had been in service for only eight-and-a-half years at the time of the latest field evaluation, the surface crack width was larger than the other sections, which is not consistent with the commonly accepted belief that the lower the setting temperature (or zero-stress temperature), the tighter the crack width. Also, it is interesting to note that even though this section employed LS as coarse aggregates, a few shallow spalling distresses already occurred and some indication of probable spalling distresses was observed at transverse cracks. Figures 4.33 and 4.34 show the typical condition of transverse cracks and shallow spalling distress found in the section.

Figure 4.33 Transverse Cracks in Van Horn IH 10

Figure 4.34 Spalling Distress in Van Horn IH 10

Figure 4.35 displays the relationship between the measured average transverse crack spacing and zero-stress temperature, which was established based on the information obtained from Baytown SPUR 330, Cleveland US 59, and Van Horn IH 10 sections. Herein, it was assumed that the zero-stress temperature was 90% of the maximum temperature. The result shows that there is no strong correlation between the zero-stress temperature and average transverse crack spacing. Perhaps this is because some other factors such as geometry, pavement age, base friction, steel amount, material properties, and drying shrinkage had more dominant effects on the cracking behavior of CRCP. Further data on average crack spacing and early-age concrete temperature needs to be collected for better identification of their relation.

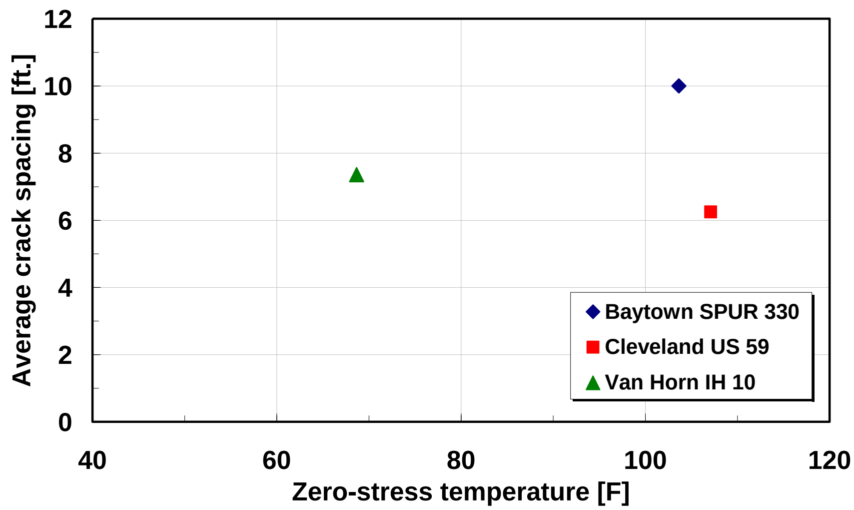


Figure 4.35 Average Transverse Crack Spacing vs. Zero-Stress Temperature

4.4 Experimental Section Built Under TxDOT Research Project 0-4826

4.4.1 Experimental Sections Built on SH 288 in the Houston District

The main objective of project 0-4826 is to investigate the effectiveness of various curing and construction techniques on preventing or minimizing spalling potential for concrete pavements using SRG (Liu et al. 2009). It is expected that the findings from this section provide quite meaningful information whether SRG—which is highly spalling-susceptible—can be continually used for CRCP. The experimental section was constructed on SH 288 in the Houston District in

November 2005 with various curing methods, mixture designs (fly ash content), and batching sequences; the details of the experimental variables are discussed in the later part of this section.

This section is 12 in.-thick CRCP located south of Houston near Pearland. It is 1747 ft-long and is at the inside main lane on SH 288 southbound, just south of Croix Road. The GPS coordinate of this section is 29.506624, -95.388193. The section was placed on November 16th, 2005. Figure 4.36, 4.37, and 4.38 depict the location map, overview, and close-up view of the test section by construction sequence, respectively.

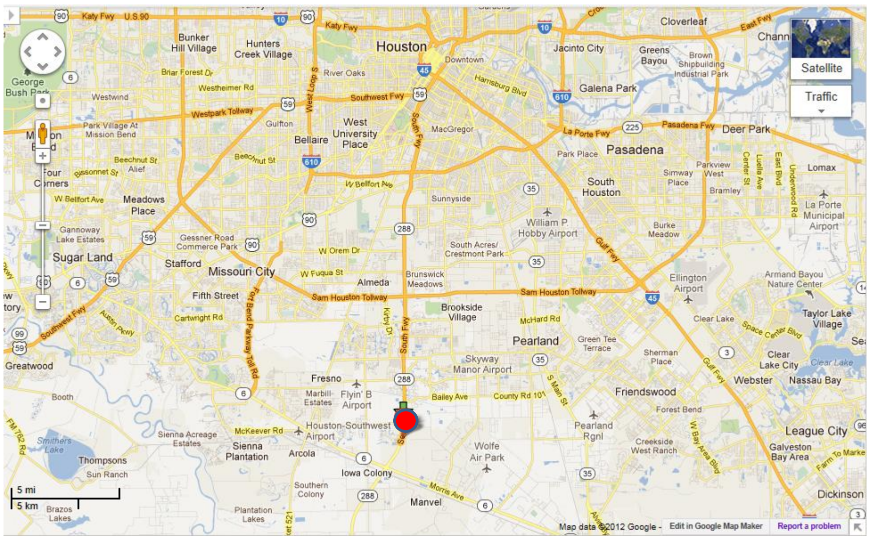


Figure 4.36 Location of Houston Pearland SH 288 Section

Figure 4.37 Overview of Pearland SH 288 Sections

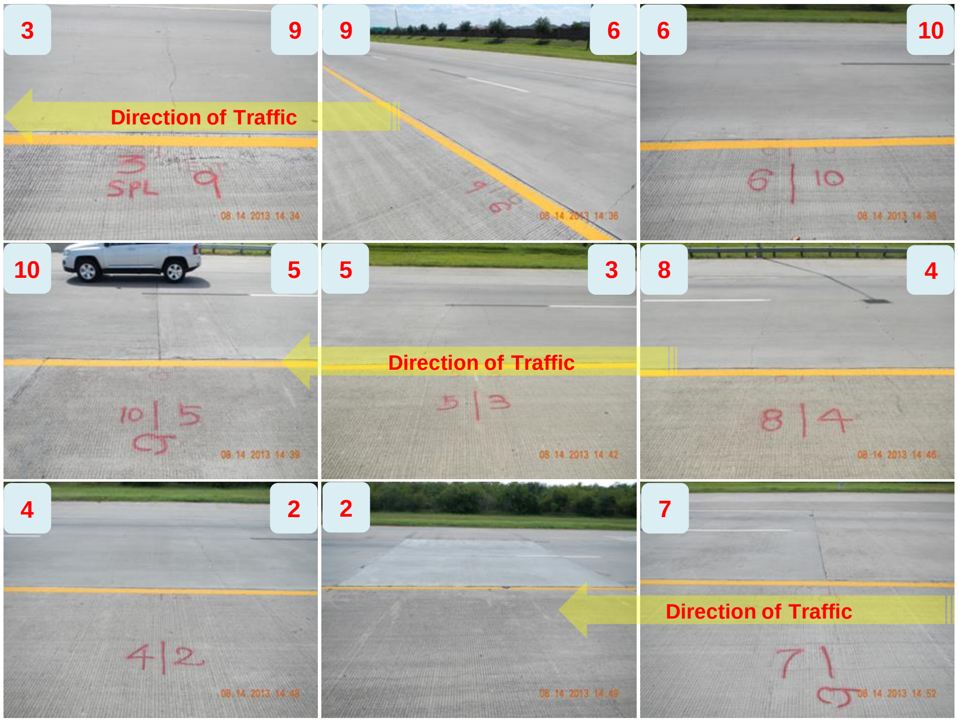


Figure 4.38 Photos of Subsections by Construction Sequence

Figure 4.39 depicts the configuration of SH 288 section. A total of 10 subsections were constructed with different variables throughout three consecutive days. Table 4.5 summarizes the details of experimental variables for each subsection. As can be seen in the table, the variables investigated in this project were: (1) curing method (normal resin-based curing compound vs. high reflective resin-based curing compound vs. wet mat curing); (2) fly ash replacement (10% ultra-fine fly ash+15% Class F fly ash vs. 25% Class F fly ash); and (3) batching sequence (normal vs. modified). The normal batching method was simply based on ASTM C192/C 192M, whereas the modified batching method involved the following sequences: (1) adding sand, cementitious materials (cement and fly ash) along with 75 to 80% of total water in the mixer and then mixing for 50 seconds; (2) charging coarse and intermediate size aggregates and then mixing for an additional 30 seconds; and (3) adding the rest of the water and then mixing for another 50 seconds. The idea was that, by employing the above sequences, available water at the aggregate-paste interface can be minimized, ensuring better bonding between hydrate matrices and aggregates. The concrete material used basically had the following mixture parameters: (1) dense aggregate gradation; (2) water-to-cementitious ratio of 0.41; and (3) cement factor of six.

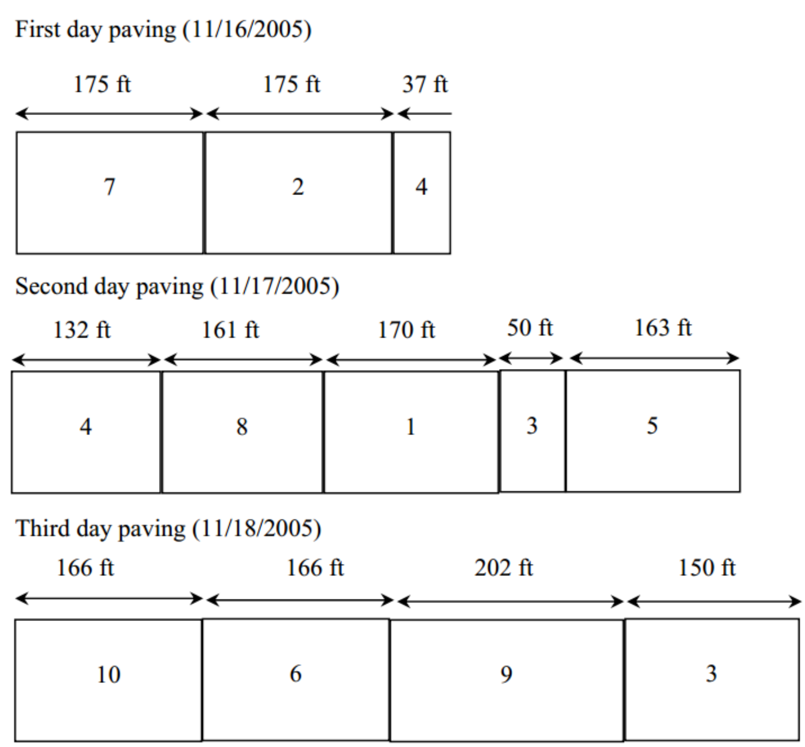


Figure 4.39 Configuration of Pearland SH 288 Section (Liu et al. 2009)

Table 4.5 Summary of Experimental Variables (Liu et al. 2009)

Test Section	FA Replacement (%)	Curing	Charging sequence
1	(10+15) *	HRC	Normal
2	(10+15)	HRC	Modified
3	(10+15)	NC	Normal
4	(10+15)	NC	Modified
5	25 **	HRC	Normal
6	25	Wet Mat	Modified
7	25	NC	Normal
8	25	NC	Modified
9	(10+15)	Wet Mat	Normal
10	25	Wet Mat	Normal

** 10% ultra-fine fly ash and 15% Class F fly ash*
*** 25% Class F fly ash*
HRC = High Reflective Curing Compound, and NC = Normal Curing Compound.

4.4.2 Crack Spacing and General Condition

Figure 4.40 presents the average crack spacing distributions for Pearland SH 288 section. In the figure, "1" denotes the mixture with 10% ultra-fine fly ash and 15% Class F fly ash while "2" indicates the mixture solely with 25% Class F fly ash. Also, NC, HR, and WM denote the normal curing, high reflective curing, and wet mat curing, respectively. Lastly, the notation N means the normal batching sequence, whereas M implies the modified batching sequence.

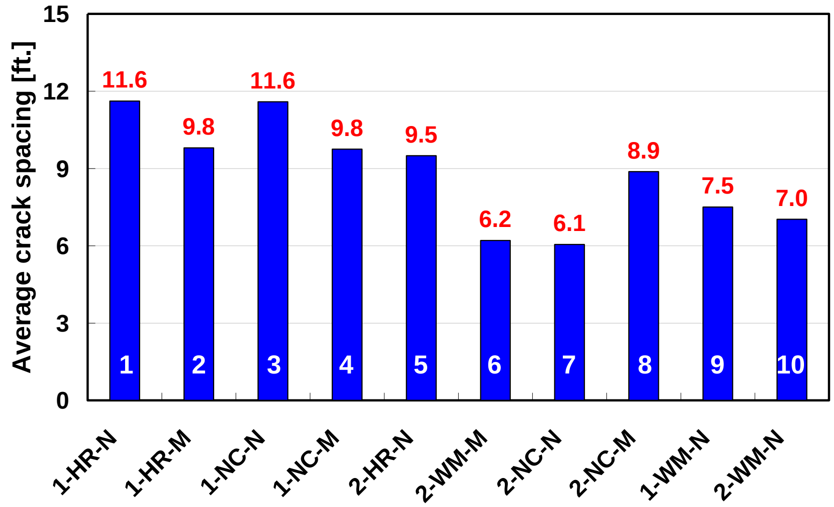


Figure 4.40 Average Crack Spacing Distributions for Pearland SH 288 Section

The effect of batching method on crack spacing was evaluated by comparing 1-HR-N with 1-HR-M, 1-NC-N with 1-NC-M, 2-WM-N with 2-WM-M, and 2-NC-N with 2-NC-M, as plotted in Figure 4.41. The result shows that crack spacing for the normal batch sections is 13 to 18% greater than that for the modified batch sections, except in the cases of 2-NC-N and 2-NC-M where the modified batch section had 46% larger average cracking spacing.

Again, the primary object of using the modified batching method was to minimize spalling potential by reducing trapped water at the interfacial transition zone. If the measure works properly, it is expected that the behavior of a modified batching section would be somewhat different from that of a normal batching section. However, it appears that the batching sequence does not have a strong correlation, at least, with crack spacing as there was no consistent tendency among the cases.

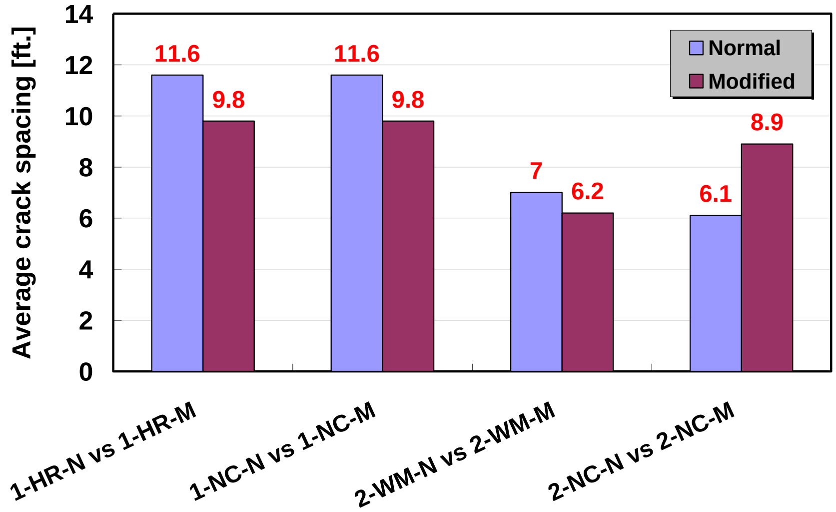


Figure 4.41 Effect of Batching Method on Average Crack Spacing

Cases 1-HR-N and 2-HR-N, 1-NC-N and 2-NC-N, 1-NC-M and 2-NC-M, and 1-WM-N and 2-WM-N were compared with each other to see the effect of fly ash replacement on crack spacing, as shown in Figure 4.42. The 10+15% cases (10% ultra-fine fly ash+15% Class F fly ash) had larger crack spacing in three out of four cases, but the reversed result was obtained for 1-WM-N and 2-WM-N. The finding indicates that there is no obvious relationship between fly ash replacement and average crack spacing, which is similar to the effect of batching method.

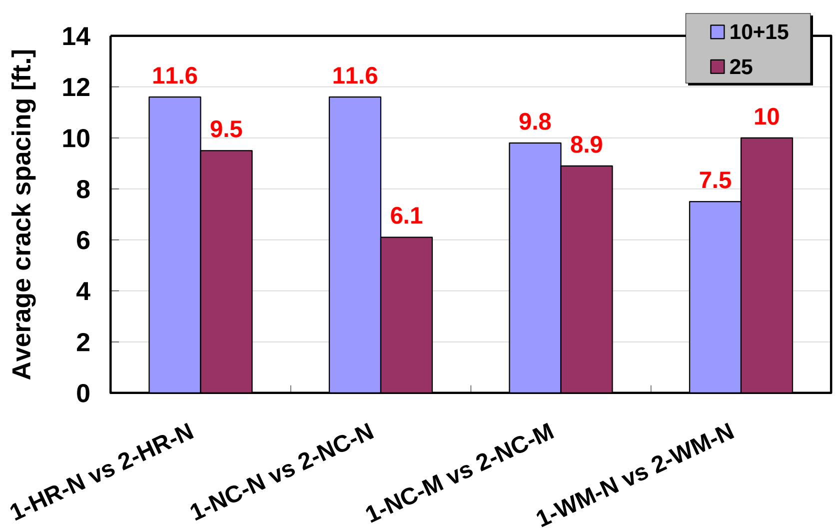


Figure 4.42 Effect of Fly Ash Replacement on Average Crack Spacing

The influence of curing method on crack spacing of CRCP was examined. For this purpose, Cases 1-NC-N and 1-HR-N, 1-NC-M and 1-HR-M, and 2-NC-N and 2-HR-N were compared with each other, as shown in Figure 4.43. It is interesting to note that the first two comparison cases had exactly the same values even though those sections were treated with different curing methods. On the other hand, the last comparison case showed a crack spacing difference of 3.4 ft. Based on the obtained result, curing method also does not seem to be strongly correlated with crack spacing of CRCP, at least for the cases investigated in this project.

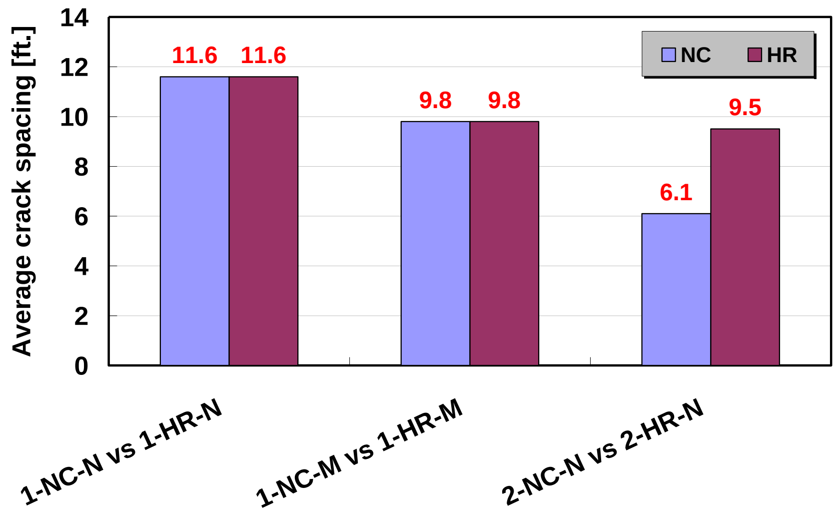
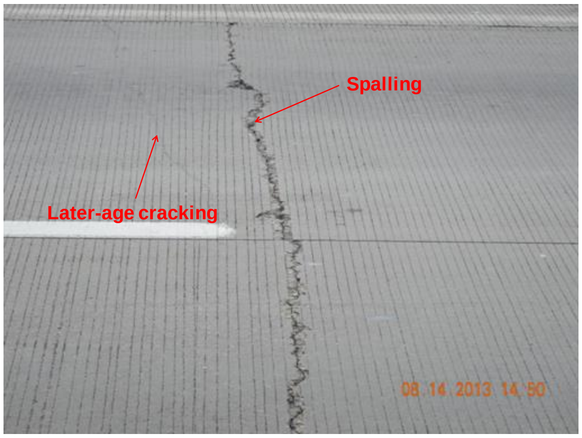


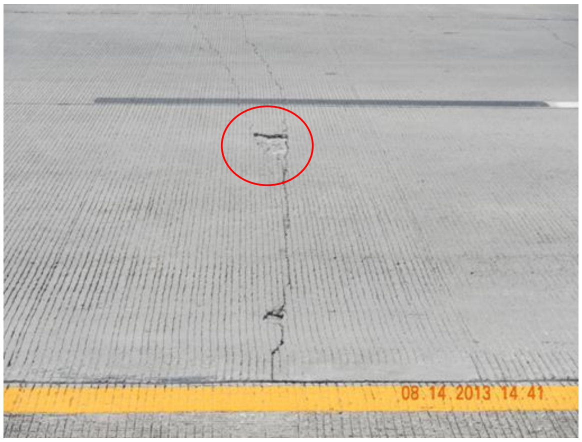
Figure 4.43 Effect of Curing Method on Average Crack Spacing

Again, the findings in this project indicate that there are no clear effects of batching method, fly ash replacement, and curing method on crack spacing of CRCP; rather the effects were quite random. This is probably because concrete was placed at different times of a day, forming different zero-stress temperatures that have a substantial effect on cracking tendency of early-age concrete. This effect might be more dominant than that of the test variables. The effect of zero-stress temperature is not verified in the scope of this project.

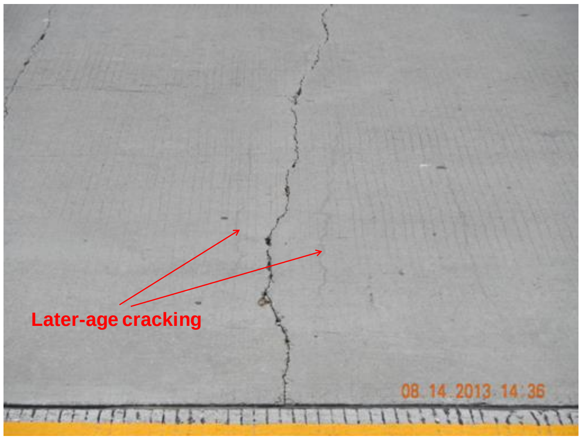
As for the CRCP performance, no punchout distress was observed at the time of the latest field condition survey. However, there were a number of spalling distresses and later-age cracks in this test section. Figure 4.44 (a) shows the general condition of Section 7, which employed conventional material design, mixing sequence, and curing method. As can be seen, the spalling distress in this section was somewhat severe. Also, later-age cracking occurred near the exiting transverse crack, which could be deep spalling and partial-depth delamination. Sections 5 and 6 also showed the similar type of distress or pre-distress behavior as noted in Figures 4.44 (b) and (c), respectively. Particularly in Section 5, shallow-depth delamination was already developed to some extent, which is not a good sign for the long-term performance. In Section 2, there was a full-depth repair as shown in Figure 4.44 (d). It is not confirmed whether the full-depth repair in Section 2 was due to severe spalling or punchout distress, and if one or both was the reason. The field condition survey revealed that the overall condition of all the sections is in the process of spalling distress. In other words, it can be concluded that, irrespective of batching sequence, mixture design, and curing method, this test section exhibited severe spalling distresses as well as a high risk of partial-depth delamination, and this appears to be closely related to the coarse aggregate used, SRG. Based on the findings to date, mixture design (fly ash replacement), curing method, and batching sequence do not seem to have significant effects on the spalling prevention in CRCP. To examine the effects of the variables on the spalling and delamination distresses more clearly, this section needs to be continually monitored on a regular basis.



(a) Section 7



(b) Section 5



(c) Section 6

(d) Section 2

(e) Section 9

(f) Section 3

Figure 4.44 Close-Up View of Pearland SH 288

4.5 Experimental Sections Built Under 0-3925 in the Houston District

4.5.1 Field Section and Experimental Variables

In the 0-3925 project, the effects of several experimental variables such as aggregate type (SRG, LS, and blended), number of steel mats, curing method (standard, double coating, and poly sheeting), saw cut, and paving time (day and night) on the crack spacing distributions and performance of CRCP were investigated (McCullough et al. 2000). The section was constructed on US 290 west and eastbound in the Houston District near Hempstead, in the summer of 1995. It comprises of three subsections—herein, they are named US290SPS-1E, US290-2E, and US290-3W. There was another test section (i.e., US290-1E) that has been investigated about 1,000 ft away from "Liendo Pkwy Exit ½" mile post of US 290 eastbound, but owing to dangerous traffic flow around this location, the investigation could not be continued and thus is not covered in this report; rather, the section was relocated to a safer location and then was renamed as US290SPS-1E. Figures 4.45 and 4.46 illustrate the overall location map and detailed locations of each of the test sections, respectively.

The GPS coordinate for US290SPS-1E is 30.093863, -96.035228, for US290-2E is 30.083399, -96.004187, and for US290-3W is 30.082612, -96.001003. All these test sections were at the outermost lane.

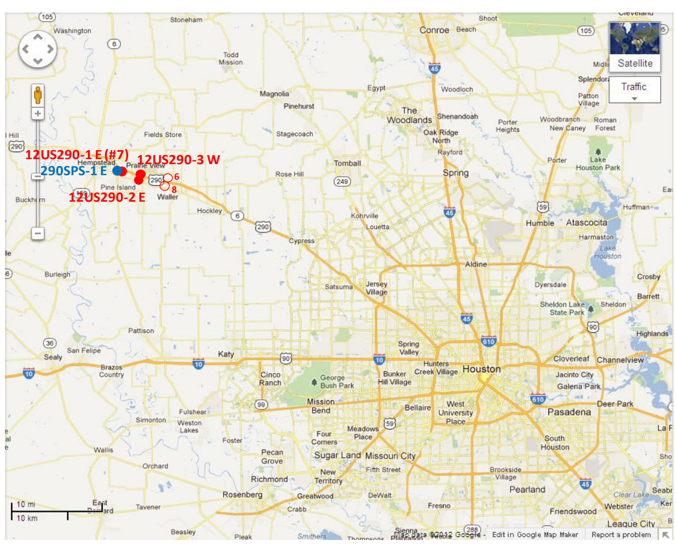
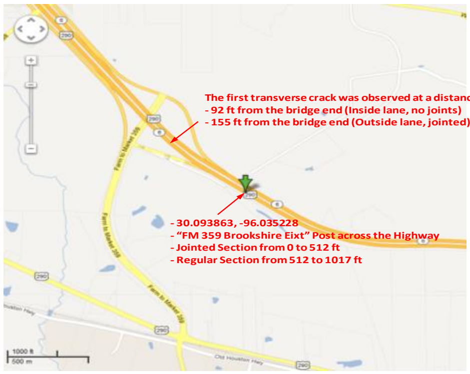
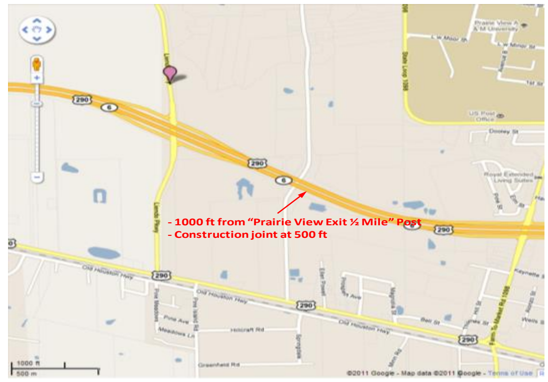


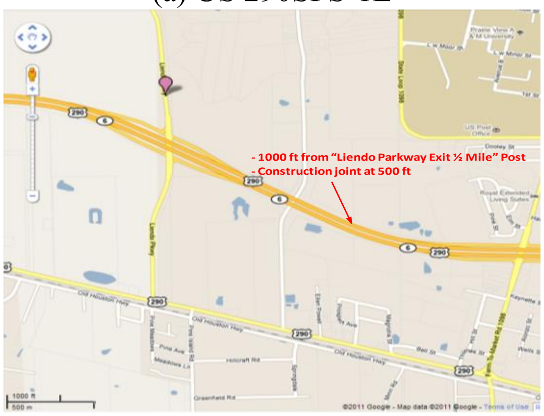
Figure 4.45 Field Locations of Hempstead US 290 Sections



(a) US 290SPS-1E



(b) US 290-2E



(c) US 290-3W

(d) Overview

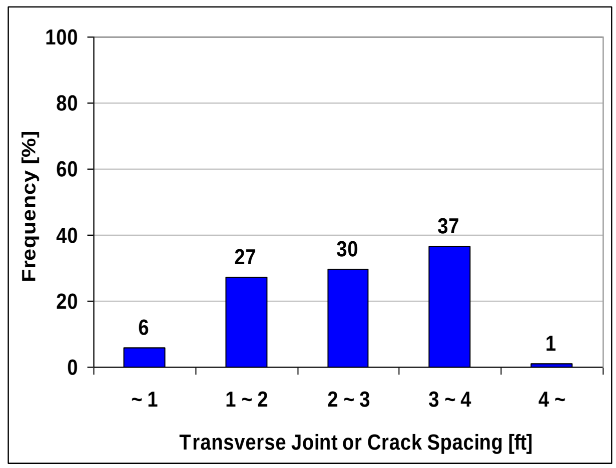
Figure 4.46 Detailed Field Locations and Overview

4.5.2 Crack Spacing and General Condition

4.5.2.1 US290SPS-1E

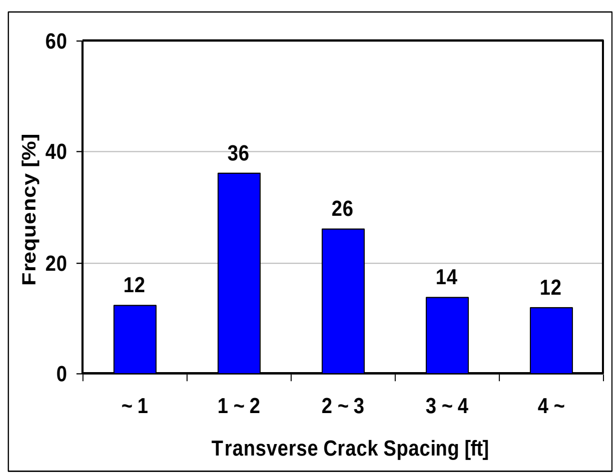
The first half (500 ft) of US290SPS-1E section introduced saw cuts with an almost consistent spacing (6 ft) at the initial construction stage, while the rest of the section did not. Figure 4.47 (a) indicates the existence of transverse saw cuts in this test section. The transverse joint or crack spacing information (see Figure 4.47 (b)) shows that majority of joint or crack spacing fell between 1 and 4 ft. Also, the calculated average joint or crack spacing was 2.44 ft, which implies that, on average, each slab segment had at least one transverse crack around the mid-slab. In this saw cut section, no punchout distress was found. However, there was some indication of spalling distress, either at the saw cut joint or natural transverse cracks. In the mid of 2000s, 10 years after construction, there was no visible spalling distress at the saw cut joint. Since then, spalling and joint failure started to be visible. It appears that these spalling and joint failures evolved from the micro-damage cumulated when the saw cut was introduced, and it worsened as the pavement exposed to successive climate changes and traffic loads.

The general condition and crack spacing distributions for US290SPS-1E regular (uncut) section are presented in Figure 4.48. The crack spacing information shows that about 62 percent of transverse crack spacing fell between 1 and 3 ft, which is quite short, but there was no punchout distress found in this section. When it comes to spalling, there was no severe and deep spalling recorded. However, almost every transverse crack started to show clear indication of early-age spalls that can develop into severe spalling distress. It seems that these spalling distresses are due to the use of SRG which has a smoother surface texture and high CoTE, as previously described.



(a) Close-Up View (b) Joint or Crack Spacing Distributions

Figure 4.47 US 290SPS-1E Jointed Section

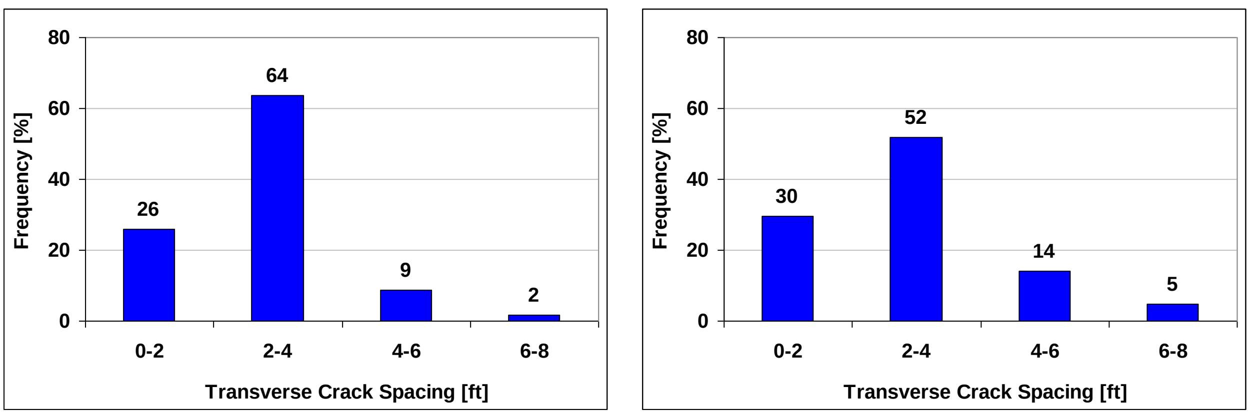


(a) Close-up View (b) Crack Spacing Distributions

Figure 4.48 US 290SPS-1E Regular Section

4.5.2.2 US290-2E

Figure 4.49 depicts the average crack spacing distributions for the US290-2E section. Herein, Section I denotes the 500-ft test section west of the construction joint, while Section II indicates the other 500-ft section east of the construction joint. It is interesting to note that those sections showed quite similar crack spacing distributions even though they were constructed at different times of a day (night and morning). Both sections indicated over 80 to 90 percent of cracks had crack spacing less than 4 ft, which is quite narrow. The average crack spacing for Section I and Section II was 2.75 and 2.83 ft, respectively. Also, it should be noted that there were 32 Y-cracks in this test section.



(a) Section I (b) Section II

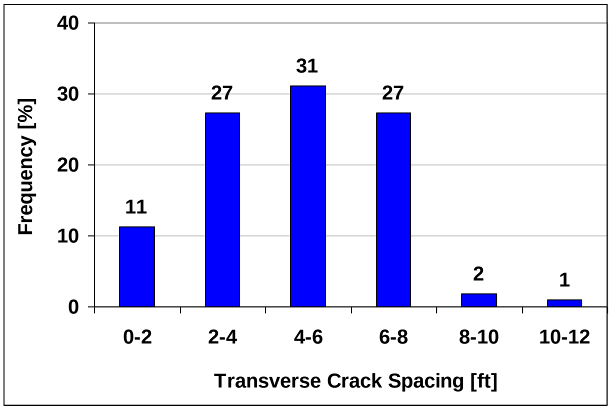
Figure 4.49 Crack Spacing Distribution of US 290-2E Section

The US290-2E section also used SRG as coarse aggregates, and showed a high risk of severe spalling distress. Moreover, there were many longitudinal cracks especially almost parallel with the longitudinal saw cut joint as shown in Figure 4.50. This is most likely because the longitudinal saw cut was introduced too late with an inappropriate depth. There were several longitudinal cracks in the main lanes as well. However, the US290-2E section did not reveal any punchout distress while transverse crack spacing was quite narrow and carrying a significant portion of heavy trucks as well.

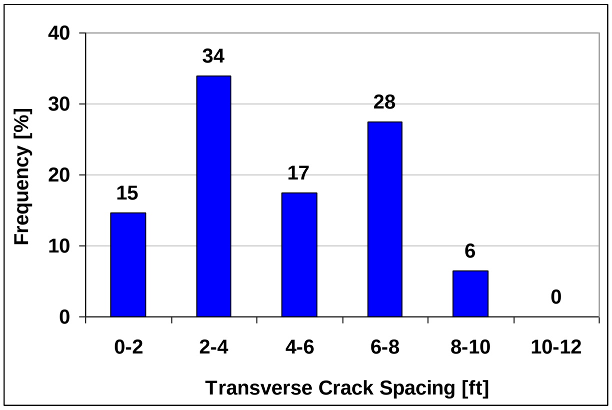
Figure 4.50 Close-up View of US 290-2E Section

4.5.2.3 US290-3W

The average crack spacing distributions for US290-3W section are shown in Figure 4.51. Herein, Section I and Section II denote each 500-ft test section placed east and west of the construction joint, respectively. In contrast to US290SPS-1 and US290-2, this section used LS instead of SRG as coarse aggregates. As can be seen in Figures 4.51 (a) and (b), crack spacing was overall wider than that of US290SPS-1 and US290-2; the average crack spacing for Section I and Section II was 4.56 and 4.62 ft, respectively. It appears that the use of LS led to much wider crack spacing. Also, it is interesting to note that there was a slight discrepancy in the crack spacing distributions between Section I and Section II, which is different from the data from the US290-2 section.



(a) Section I



(b) Section II

Figure 4.51 Crack Spacing Distribution of US290-3W Section

As for the pavement distress, this section showed much better performance compared to US290SPS-1E and US290-2E, as can be seen in Figure 4.52. This is because this section used LS, which has a lower CoTE, modulus of elasticity and strong bond characteristic between coarse aggregate and cement paste, which resulted in better integrity of the material. Also, different from the previous section, this section did not show any indication of spalling distress and almost every crack was kept quite tight. No punchout distress was found in this test section. As of February 2013, there were twenty Y-cracks in this section.

Figure 4.52 Close-up View of US 290-3W Section

4.6 Experimental Section Built on IH 35 in the Waco District

4.6.1 Field Section and Experimental Variables

This section was built on IH 35 northbound in the Waco District near exit post 333B. The section used LS as coarse aggregates and the section length is 1,000 ft across a transverse construction joint. The GPS coordinate is 31.522439,-97.134853. Figures 4.53, 4.54, and 4.55 present the detailed location information, overview, and close-up view of the I-35 Waco test section, respectively. The test section was at the outermost lane. The measurement items for field evaluations were transverse crack spacing, deflection, and performance in terms of punchout and spalling distresses.

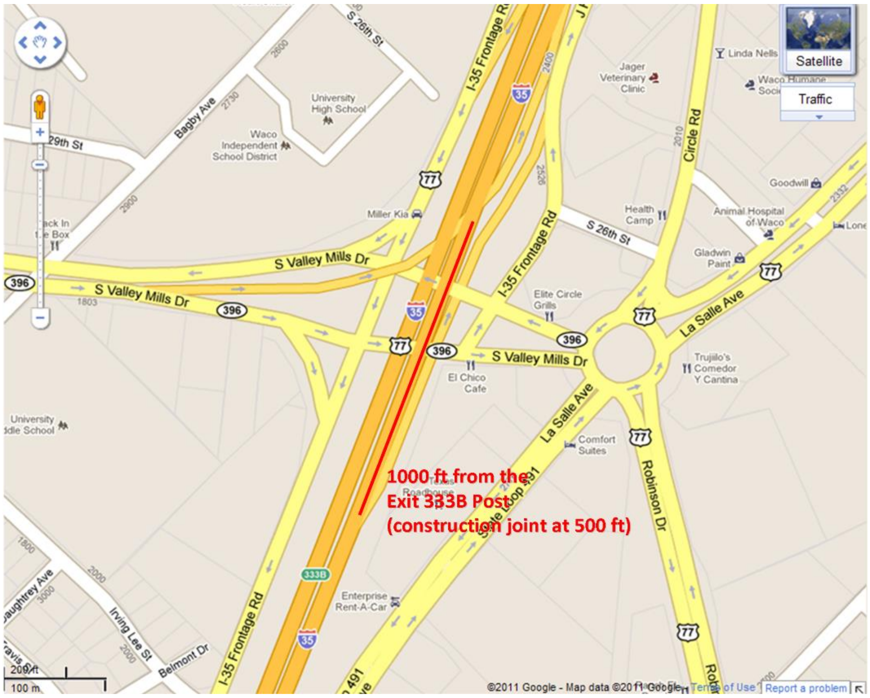


Figure 4.53 Field Location of Waco IH 35 Section

Figure 4.54 Overview of Waco IH 35 Section

Figure 4.55 Close-Up View of Waco IH 35 Section

4.6.2 Crack Spacing and General Condition

Figure 4.56 illustrates the crack spacing distributions for the IH 35 Waco section. As the Figure 4.56 shows, the majority of crack spacing (i.e., about 60%) was shorter than 4 ft as of April 2011.

The average crack spacing was 3.7 ft with a standard deviation of 2.5 ft. Additional field evaluations afterwards revealed that there were few cracks developed beyond the last crack spacing investigation. In this section, there was no punchout or spalling distresses found even though crack spacing was quite short compared to other sections and the section had been in service with heavy traffic, which does not agree with NCHRP MEPDG's assertion. Also, this CRCP section showed a fairly good appearance without any indication of spalling distress. Recall that LS concrete is much less susceptible for spalling distress compared to SRG concrete.

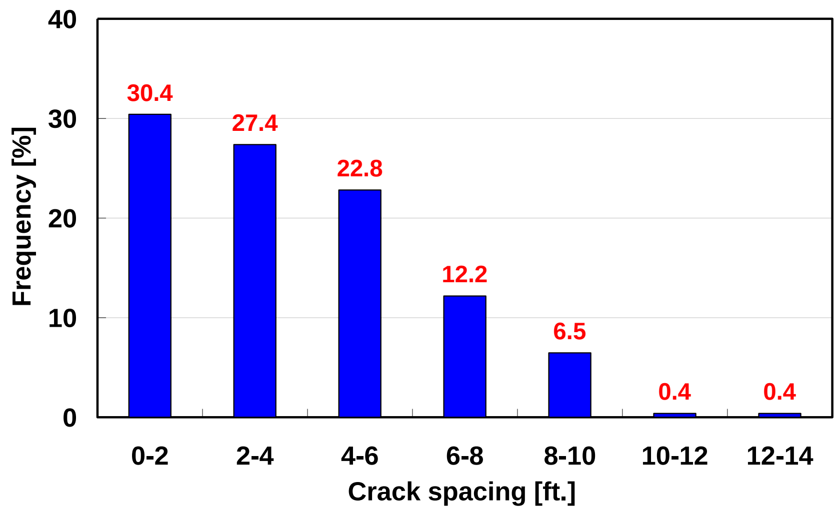


Figure 4.56 Crack Spacing Distributions for Waco IH 35 Section

4.7 Experimental Sections Built on US 59 in the Houston District

4.7.1 Field Section and Experimental Variables

This experimental section is located in the outermost lane on US 59 south bound in the Houston District near Kendleton. The GPS coordinate for this section is 29.446241, -96.000091. It is 15 in.-thick CRCP with SRG coarse aggregates and was constructed in 2007. Figures 4.57 and 4.58 show the location and the general condition of the section, respectively. The field surveyed section extends 1,210 ft from the wide flange in the south.

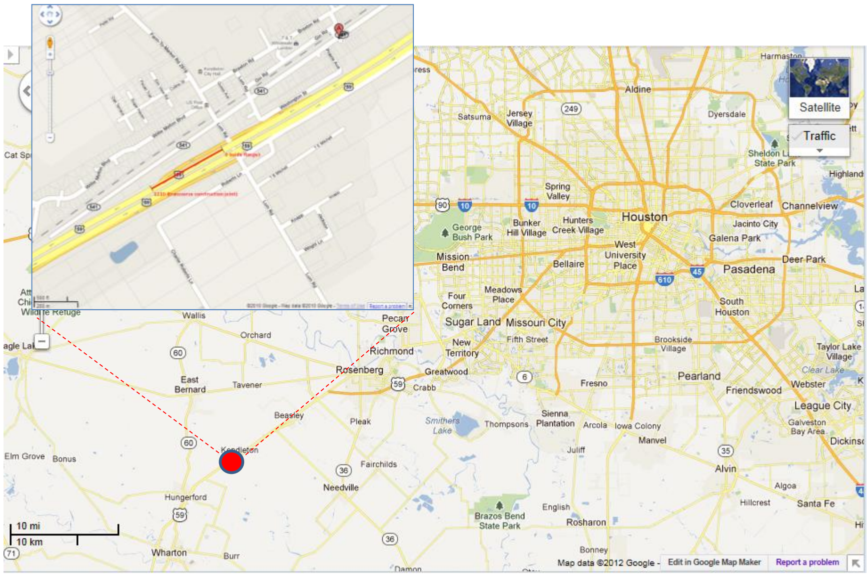


Figure 4.57 Field Location of Kendleton US 59S Section

Figure 4.58 General Condition of Kendleton US 59S Section

4.7.2 Crack Spacing and General Condition

Figure 4.59 presents the crack spacing information obtained from field evaluations. The average transverse crack spacing for this section was 6 ft as of March 2012. Note that about 25 percent of cracks had a spacing of less than 2 ft. At the time of field evaluations, the section had been in service for about six years with significantly heavy traffic. However, as with the IH-35 Waco section, no punchout distress has been found in this section yet, although crack spacing was relatively short compared to other sections. This section showed no spalling distress either, although spalling-susceptible coarse aggregate (i.e., SRG) was used.

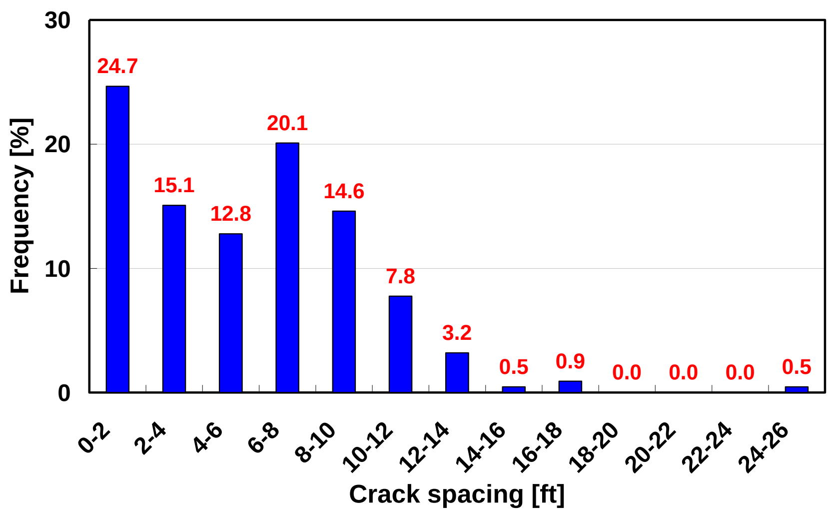


Figure 4.59 Crack Spacing Distributions for Kendleton US 59S Section

4.8 Long-Term Pavement Performance (LTPP) Sections in Texas

According to the LTPP database, there are eight LTPP CRCP sections in the state. Among them, the following four LTPP sections were evaluated:

(1) Section ID 485336 located on IH 27 southbound in the Amarillo District;

(2) Section ID 485323 located on IH 40 eastbound in the Amarillo District;

(3) Section ID 483569 located on IH 30 eastbound in the Paris District; and

(4) Section ID 485154 located on IH 10 eastbound in the Yoakum District.

Field evaluations revealed no structural and functional distresses existed in LTPP-485336 section (see Figure 4.60). On the other hand, two sections—LTPP-485323 in the Amarillo District and LTPP-485141 in the Yoakum District—were overlaid with asphalt concrete as indicated in Figures 4.61 and 4.62, respectively, and thus the condition of the concrete layer itself cannot be monitored. Figure 4.63 shows the overview of LTPP-483569, wherein one full-depth repair was recorded.

Figure 4.60 LTPP-485336 Section on IH 27 in the Amarillo District

Figure 4.61 LTPP-485323 Section on IH 40 in the Amarillo District

Figure 4.62 LTPP-485154 Section on IH 10 in the Yoakum District

Figure 4.63 LTPP-483569 Section on IH 30 in the Paris District

Because a contractor hired by the FHWA conducts detailed evaluations on these sections, primary evaluations made under the current research project include only visual condition surveys. No structural or functional distresses were observed in either section.

4.9 Summary

The findings described in this chapter provide valuable information on the effects of various design and construction variables such as (1) coarse aggregate type, (2) longitudinal steel amount, (3) curing method, (4) mixture design, and (5) placement temperature on the behavior and performance of CRCP. It should be noted that even though detailed descriptions were made on crack spacing in the test sections, as discussed in Chapter 3, crack spacing itself is not the most important variable affecting CRCP performance. Findings can be summarized as follows:

1) Concrete with SRG had a higher potential of spalling distress than that with LS. Most of the SRG sections showed or just stared to show spalling distresses at transverse cracks, while the sections with LS concrete showed quite sound performance without any indication of possible spalling distress even after 20 years of service. This is mostly because SRG concrete typically has a higher CoTE and modulus and much smoother surface texture than LS, preventing good bond between the aggregate and cement paste.
2) For concrete with spalling susceptible coarse aggregate (i.e., SRG), there is a strong correlation between steel percentage and spalling potential. The larger the steel amount, the lower the frequency of spalling. However, this does not imply that TxDOT can utilize spalling-susceptible coarse aggregate in CRCP with a larger amount of longitudinal steel. The frequency of spalling in CRCP with spalling-prone coarse aggregate and larger longitudinal steel is still much higher than that in CRCP with less spalling-prone coarse aggregate. On the other hand, for concrete with coarse aggregate with lower spalling potential, the effect of transverse crack spacing or longitudinal steel amount on spalling is non-existent.
3) The current MEPDG states that transverse crack spacing in CRCP is affected by equivalent temperature loading. However, any clear tendency could not be found between the measured early-age concrete temperature and transverse crack spacing. This is most likely because the combined effect of other factors such as pavement age, geometry, steel amount, material property, restraint condition, and environmental conditions were more dominant than that of temperature itself. A more systemic experimental evaluation is required to identify the effect of early-age temperature on crack spacing.
4) There were no obvious effects of batching method, fly ash replacement, and curing method on average transverse crack spacing and performance of CRCP.

Chapter 5 Performance Evaluation of Special Pavement Sections

Over the years, TxDOT has built a number of PCC pavement sections with unique design and material features, other than CRCP or CPCD. They include:

1) Fast track CRCP (FT-CRCP)
2) Cast-in-place post-tensioned concrete pavement (PTCP)
3) Precast concrete pavement (PCP)
4) Bonded concrete overlays (BCO)
5) Unbonded concrete overlays (UBCO)
6) Whitetopping
7) CRCP with 100% recycled concrete aggregates (RCA)
8) Roller-compacted concrete pavement (RCC)

The pavement types listed above are utilized in special circumstances and thus accordingly are not widely used. As a result, information on the design, construction, and performance of these pavement types has not been as well-known as that of normal pavement types such as CPCD or CRCP. The primary objective of this chapter was to collect performance information that could be used to improve design and construction practices.

5.1 Fast-Track CRCP (FT-CRCP)

FT-CRCP is commonly placed in the sections where early opening to traffic is required, such as intersections. In Texas, FT-CRCP is primarily used in the Houston District. The use of FT-CRCP in the Houston District has increased steadily since 1986, due to the need to open the sections quickly to minimize traffic delays. Currently, there are no pavement design procedures for FT-CRCP. For FT-CRCP slab thickness, the Houston District increases the slab thickness by three inches over the required slab thickness from TxDOT's normal design procedures because, in this specific type of pavement, stabilized subbase is omitted to save time of construction. The Houston District has design standards for FT-CRCP, as shown in Figure 5.1.

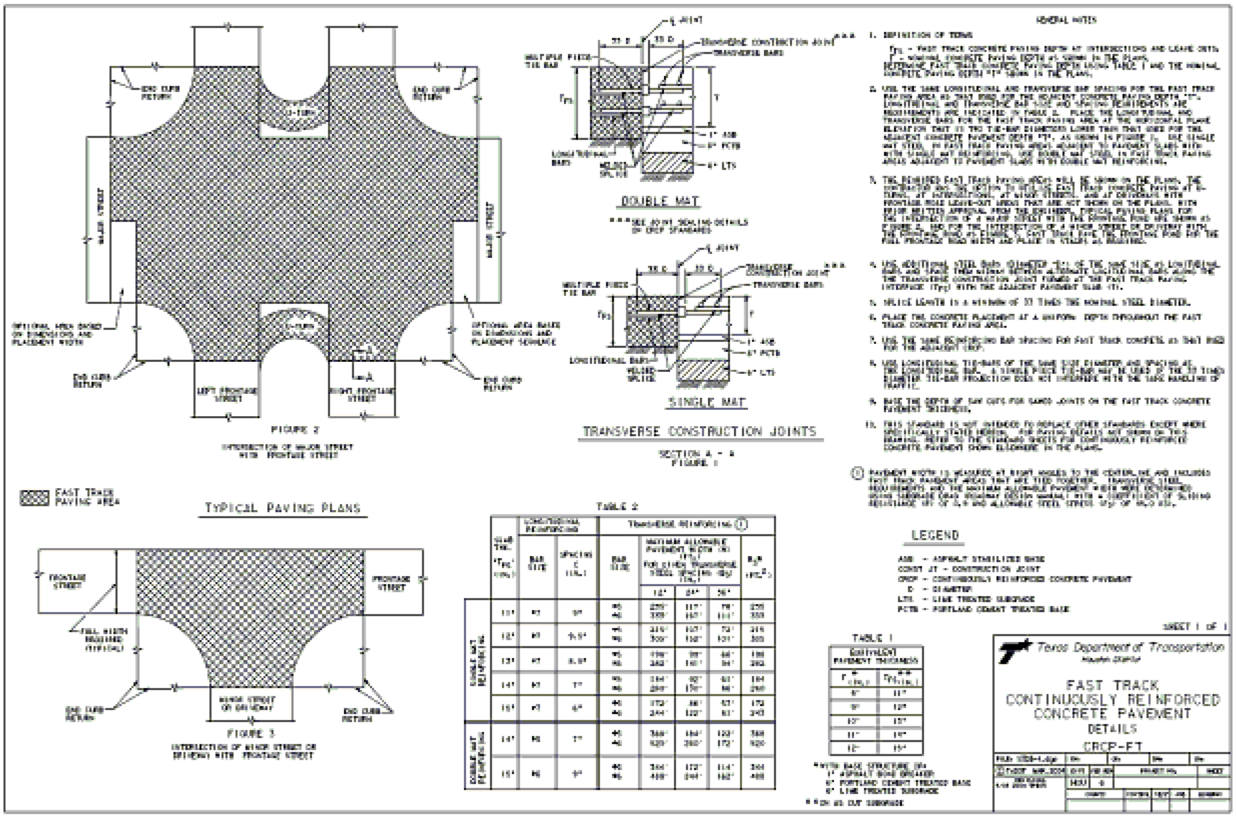


Figure 5.1 Fast-Track CRCP Design Standards

The unique nature of FT-CRCP is the placement of concrete slab on top of natural subgrade soil. This construction practice of FT-CRCP is quite different from well-established practice of placing stabilized, non-erodible base between natural subgrade and concrete slab. The answer to the question of whether placing concrete slab directly on top of subgrade will provide good performance can be found only from field performance.

The Houston District FT-CRCP sections evaluated in this study were:

1) Spring Cypress Rd. intersection with SH 249
2) IH45 frontage road (both north- and south-bound) from BW8 to Greens Rd.
3) JFK Blvd at BW8 frontage road (south-side of the intersection)
4) Spur 261 (North Shepherd Dr) at the Metro Park & Ride lot
5) SH 6 under US59 South
6) Williams Trace at SH 6

- The Spring Cypress Rd with SH 249 was built in 2002. Crushed limestone was used. The performance has been good.

- IH 45 frontage road was built in 1993, which makes this section almost 20 years old. The section is in a good condition, except for tight longitudinal cracks, as shown in Figure 5.2.
- JFK Blvd at BW 8 section was built in 1992. This section is in the embankment, and some wide cracks were observed, probably due to the volume changes in the embankment.
- Spur 2691 section was built from 1986 to 1989. Even though it is in the heavy Metro bus route, the performance has been good.
- The SH 6 under US59 South section is unique in that siliceous river gravel was used as coarse aggregate. Also, the concrete was cured for 24-hours with wet-mat curing. This section was built in 2001. The section is now 11 years old and in excellent condition, as shown in Figure 5.3. A possible reason for the excellent performance could be to the low temperature variations of the section under the bridge.
- Williams Trace at SH 6 section was built in 1993 with limestone aggregate. It is almost 20 years old and in an excellent condition as seen in Figure 5.4.

Figure 5.2 FT-CRCP Section on IH 45 Frontage Road (GPS Coordinate: 29.943761,-95.414565)

Figure 5.3 FT-CRCP Section on IH 6 at US 59 (GPS Coordinate: 29.598354,-95.621965)

Figure 5.4 FT-CRCP Section on William Trace at SH 6
(GPS Coordinate: 29.59215,-95.604903)

As of summer 2013, the performance of FT-CRCP sections is quite satisfactory without any structural distresses. However, it should be noted that the traffic in the most FT-CRCP evaluated is primarily passenger vehicles with minimum trucks. If heavy truck traffic is minimal, FT-CRCP could be a good candidate pavement type, if the pavement needs to be opened rather quickly. These sections need to keep being monitored for more comprehensive evaluations of long-term performance of FT-CRCP.

5.2 Cast-in-Place Post-Tensioned Concrete Pavement (PTCP)

There are two PTCP sections in Texas. Both of them are on IH 35 in the Waco District. One section was built in 1985 (Chavez et al. 2003) and the other in 2008 (Choi and Won 2010). The section built in 1985 has 6-in slab thickness with 240-ft and 440-ft slab lengths, while the section built in 2008 has 9-in slab thickness with 300-ft slab length. The one built in 1985 was placed in West on IH 35 southbound in the Waco District (McLennon County, just 15 miles north of Waco (See Figure 5.5)). The GPS coordinate for this section is 31.7678,-97.10412.

The section built in 1985 was constructed as a test section to evaluate the viability of applying post-tensioning technology to concrete pavement. The performance has been satisfactory for the last 28 years, except longitudinal cracks in some slabs and a couple of joint failures in the shoulder as shown in Figures 5.6 and 5.7, respectively. The joint failures in the shoulder appear to result from the restrained expansion of the slabs due to infiltration of impressible materials into the joint openings, while the restrainers in the main lanes seem to be automatically removed as the high-speed of vehicles cleans them up by forming sectional turbulent trajectories.

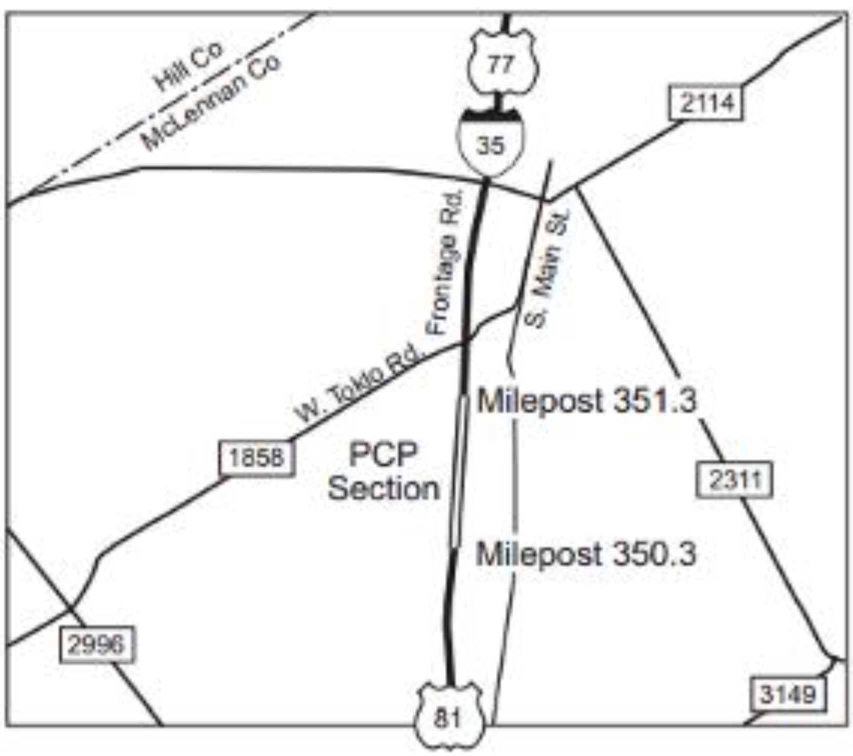


Figure 5.5 Location of Waco PTCP Section

Figure 5.6 Longitudinal Cracks (built in 1985)

Figure 5.7 Joint Failure in Shoulder (built in 1985)

Encouraged by the satisfactory performance of the test pavement, TxDOT built a section of over seven miles on IH 35 near Hillsboro, about 30 miles north of Waco. The GPS coordinate of this section is 32.007939,-97.095398. In the Hillsboro PTCP project, concrete was placed between transverse armor joints 300 ft apart. Subsequently, post-tensioning was introduced through the central stressing pockets two separate times in the longitudinal direction at the ages of 0.56 and 3.06 days, respectively (see Figure 5.8). In addition, transverse post-tensioning was introduced at 7.10 days after concrete placement as shown in Figure 5.9.

Figure 5.8 Post-Tension (longitudinal)

Figure 5.9 Post-Tension (transverse)

Falling weight deflection (FWD) testing was conducted in the section, and the average deflection was a little larger than that of 9-in CRCP. A 14-in CRCP section was built next to 9-in PTCP, with the objective being to compare life-cycle costs (LCC) of both pavements. LCC comparisons will require the performance evaluations for at least 20 to 30 years. The task in this study is to evaluate performance in terms of visual observations. So far, no structural and/or functional distresses have been observed in the 9-in PTCP section, performing in an exceptional condition even with a high level of heavy truck traffic. Figure 5.10 shows the overview of PTCP in Hillsboro.

Figure 5.10 PTCP Section Built in 2008 in Hillsboro

5.3 Precast Concrete Pavement (PCP)

Currently, there are two types of PCP–one is a proprietary type by Fort Miller Company and the other developed at CTR. The major difference between these two types is that the one developed at CTR applies post-tensioning to keep the slabs in compression, while the proprietary type uses dowels. One section of PCP was built in the northbound frontage road of IH 35 between Airport Road and SH 195 in Georgetown, using the method developed by CTR (Merritt et al. 2002). The GPS Coordinate of this section is 30.687526,-97.656608, and the detailed location is indicated in Figure 5.11.

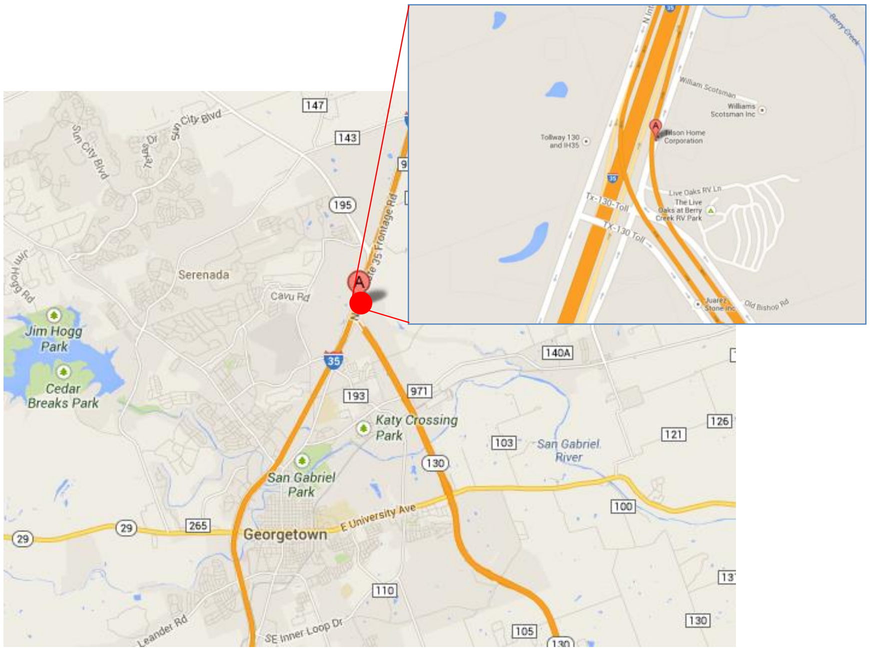


Figure 5.11 Location of Georgetown PCP Section

Figure 5.12 (a) shows the condition of the southern part of the PCP section in Georgetown. As can be seen Figure 5.12 (b), there were some joint failures and faulting across the slabs. These distresses do not seem to be related to traffic because this section has been a part of service road, carrying a quite light traffic to date. Rather, it probably appears that the existence of voids underneath the slabs might play a role in this deteriorative behavior. Figure 5.13 (a) and (b) present the condition of the northern part of the PCP section in Georgetown, showing the existence of longitudinal cracks in the slabs. Since there is no longitudinal joint to release warping and curling stress, longitudinal cracks seem to occur. Figure 5.14 shows the asphalt concrete patch at joint.

Although the level of traffic has been quite low in this test section, distresses have started to appear. Even though these distresses may be regarded as minor distresses, they are not good sign for pavement performance. Hence, the performance of this section needs to be continually monitored for better understanding of PCP's long-term behavior.

a. Overview b. Joint faulting

Figure 5.12 PCP in Georgetown (South)

a. Longitudinal crack (outside lane) b. Longitudinal crack (inside lane)

Figure 5.13 PCP in Georgetown (North)

Figure 5.14 Asphalt Concrete Patch at Joint (North)

5.4 Bonded Concrete Overlays (BCO)

Many miles of PCC pavement in Texas are approaching their design lives and require rehabilitation. Bonded concrete overlay (BCO) could be good candidates for cost-effective rehabilitations. TxDOT tried BCOs in a number of projects. The performance of the following BCO sections was evaluated:

1) US 281 in the Wichita Falls District (built in 2002)
2) US 287, Bowie in Wichita Falls District (built in 2012)
3) SH 146 in the Houston District
4) Loop 610 in the Houston District
5) US 75 in the Paris District
6) US 288 in the Houston District

5.4.1 US 281 in the Wichita Falls District (built in 2002)

Four inches BCO was placed in 2002 on US 281 just south of the city of Wichita Falls. Figure 5.15 shows that longitudinal steel was placed on top of transverse steel, which is sitting directly on top of existing concrete slab. Figure 5.16 depicts the overall condition after 11 years of construction. Overall, the performance has been quite excellent.

Figure 5.15 4-in BCO construction

Figure 5.16 Condition of 11-Year Old BCO

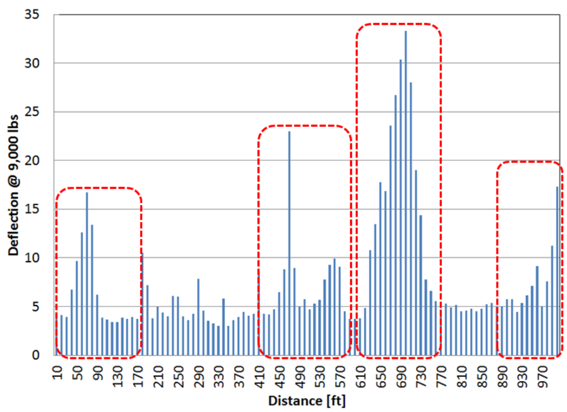
5.4.2 US 287, Bowie in the Wichita Falls District (built in 2012)

US 287 was originally built in 1972 with 8-in slab thickness in the Wichita Falls District. The shoulder type was constructed with asphalt shoulder so that most of the distresses were observed at the outside lane, as shown in Figure 5.17 (a). Figure 5.17 (b) shows the FWD testing picture and the test was conducted at every 40 ft. FWD test results were illustrated in Figure 5.17 (c) and significant deflection variations were observed in 1,000 ft long test section, as marked with red chain lines. The deflections were estimated larger than 20 mils at the 650 ft location in the FWD test section, and a DCP test was conducted at the same point with high deflection area. Test results showed that the modulus of base is also low as shown in Figure 5.17 (d).

As shown in Figure 5.18 (a), longitudinal steel was placed on top of transverse steel as it was in the US 281 section, and tie bars were placed on top of longitudinal steel at 4 ft spacing. BCO was constructed in 2012 as shown in Figure 5.18 (b).

a. Pavement condition before BCO

b. FWD testing before BCO



c. FWD test result

Bowie DCP Test(US 81 - 220M - R-direction)

R-Driection(Bowie, US81) RM 220		Condition	Time	Drilling Depth (in)	Layer	mm / blow	CBR	Modulus (ksi)	Average Modulus [ksi]
DCP 2	Distance from Start ; 567'	Good Section	12/03/2010 09:48	8.5	1	0.56	554	145	67
					2	3.11	82	43	
					3	16.07	13	13	
DCP 1	Distance from Start ; 488'	Bad Section	12/03/2010 10:07	10.3	1	1.66	166	67	49
					2	5.05	48	30	
					3				
DCP 3	Distance from Start ; 137'	Good Section	12/03/2010 10:30	9.3	1	2.29	116	53	32
					2	21.35	9	11	
					3				
DCP 4	Distance from Start ; 485'	Bad Section		9.5	1	1.68	163	66	48
					2	5.15	47	30	
					3				
DCP 5	Distance from Start ; 490'	Bad Section	12/03/2010 11:08	9.25	1	1.53	181	71	49
					2	5.98	39	27	
					3				
DCP 6	Distance from Start ; 656'	Bad Section	12/03/2010 11:38	8.6	1	1.80	151	63	29
					2	8.76	26	20	
					3	72.14	2	4	

d. DCP test result

Figure 5.17 4-in BCO Construction

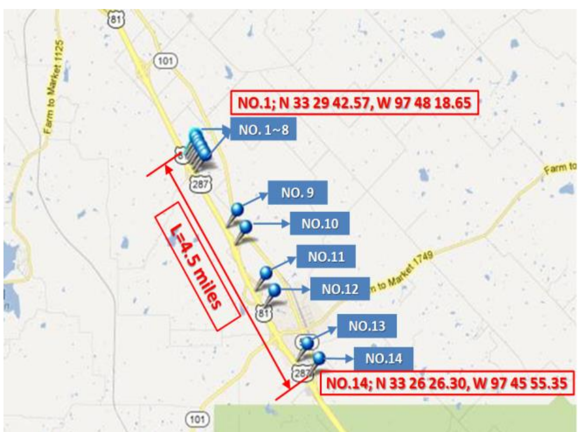
a. Steel placement

b. 4-in. bonded concrete overlay

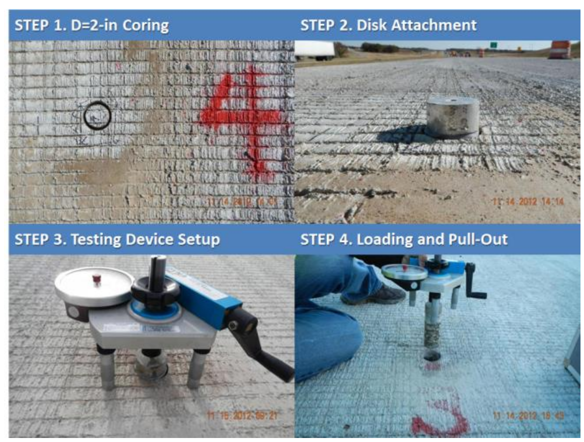
Figure 5.18 4-in BCO construction

The bond strength was evaluated between existing concrete and overlaid concrete throughout the BCO section (4.5 miles). Figure 5.19 (a) and (b) shows the test locations and testing pictures for the bond strength test, respectively. Figure 5.19 (c) illustrates the bond strength test result. Among 14 test locations, two locations were failed during coring and one location was broken in interface during the bond strength test, which is test No.1 at the beginning location of BCO. The result shows that old CRCP and new BCO were bonded well except in test No.1.

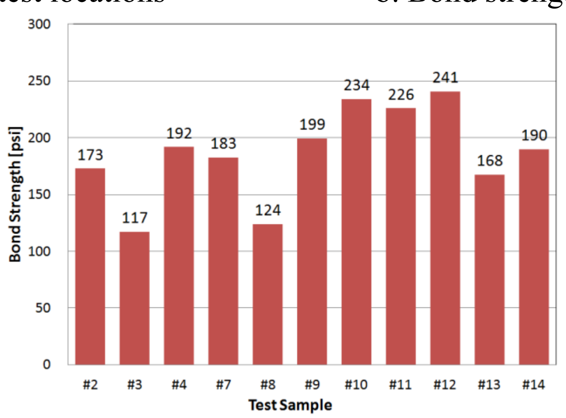
Figure 5.20 (a) and (b) show the pictures taken August 13th, 2013, which is nine months after BCO construction. The distresses have been already observed at the beginning of BCO location and outside lane. As can be seen in Figure 5.20 (b), longitudinal crack and distress were observed at the outside lane. Since the base support condition was not good, the existing distresses seem to be reflected under repetitive truck traffic similar to Figure 5.17 (a). This means that BCO design should include criteria for base support condition.



a. Bond strength test locations



b. Bond strength testing procedure



c. Bond strength test result

Figure 5.19 Bond Strength Test

a. Beginning of BCO   b. Edge distress and longitudinal crack

Figure 5.20 Distresses in BCO

5.4.3 SH 146 in the Houston District

Two-in BCO was placed in the late 2000s and the performance has been quite poor. Eventually, the section was overlaid with asphalt. Figure 5.21 shows typical distresses observed. Because it was 2-in BCO, no longitudinal reinforcement was used. As will be discussed later, BCOs without longitudinal reinforcement with steel bar show quite poor performance, and their use should be discouraged.

Figure 5.21 Distress in 2-in BCO on SH 146

5.4.4 Loop 610 in the Houston District

Two inches BCO was placed on Loop 610 S, and the performance has been poor, as can be seen in Figures 5.22 (a) and (b). Longitudinal steel was not used; instead, steel fiber was used. Figure 5.22 (b) shows that steel fiber is not effective in preventing chipping of concrete.

a. BCO distress on SH 146 b. Close-up view

Figure 5.22 Distress in 2-in BCO on SH 146

5.4.5 US 75 in the Paris District

Seven inches CRCP BCO was placed on US 75 in Sherman in 2010. The existing pavement is 10-in CPCD with 15-ft joint spacing, which was built in 1984. The performance of CPCD was quite poor, requiring an average of between 0.5 and 1.0 million dollars every year. The 7-in CRCP BCO performance has been satisfactory, even though there were distresses at five locations, as shown in Figure 5.23. Repair had to be performed in 2012. Figure 5.24 shows the concrete after the loose particles were removed. The distresses were directly over the existing transverse contraction joints. Non-woven fabric was placed to retard any reflection cracking, and it appears that the fabric increased deflections and caused deteriorations of concrete in the overlay. There were control section where fabric was not placed, and no distresses occurred at the section. Based on the performance so far, the fabric should not be placed at transverse contraction joints.

Figure 5.23 Distress in BCO

Figure 5.24 Concrete after Removal of Distressed Concrete

5.4.6 US 288 in the Houston District

Two inches BCO in the southbound lanes in SH 288 south of Beltway 8 in the Houston District experienced distresses as shown in Figures 5.25 and 5.26. In this section, longitudinal steel was not used. Figure 5.25 shows that severe delaminations occurred. As discussed earlier, longitudinal reinforcement should be used in BCOs.

Figure 5.25 Delaminations in BCO

Figure 5.26 Distresses in BCO

5.4.7 BCO Summary

Field evaluations of CRCP BCO performance indicate a large difference in the performance between 2-in and 4-in BCOs. It appears that the primary difference is whether longitudinal reinforcement was used. For 2-in BCO, longitudinal reinforcement is not used, and concrete volume changes in the new concrete due to temperature and moisture variations are not fully restrained, causing debonding between old and new concrete. On the other hand, if the BCO thickness is equal to or greater than four inches, longitudinal steel is used, which restrains concrete volume changes and ensures good bond. It is strongly recommended that TxDOT always use longitudinal reinforcement regardless of BCO slab thickness.

However, when the base support condition is not enough to carry the expected traffic, BCO is not recommended. In other words, the new BCO design needs to be developed considering design criteria for base support condition.

5.5 Unbonded Concrete Overlays (UBCO)

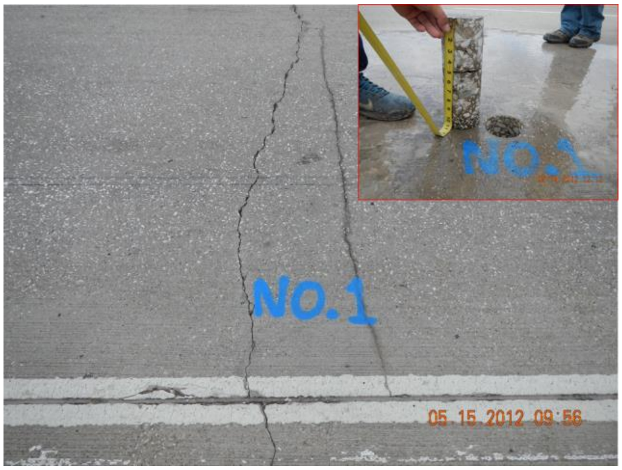
UBCO is usually used when the existing pavement is severely deteriorated. A thin layer of asphalt concrete is designed to minimize the reflection of distresses from existing slabs. Unbonded concrete overlay (UBCO) could also be good candidates for cost-effective rehabilitations such as BCO. TxDOT tried BCOs in a number of projects. Since the performance of IH 35 in the Dallas District was described in Chapter 2-2.1.2.3 (Unbonded CPCD overlay), the performance of IH 35 in the Laredo District (Unbonded CRCP overlay) was described in this chapter.

The section is located on IH 35, northbound from mileposts 51 to 52. Two main lanes and outside and inside tied concrete shoulder with 9-in thick slab were placed on top of existing asphalt pavement in 2002 as a test section to demonstrate the viability of concrete overlay on existing asphalt pavement. Initial performance of this one-mile section was reported as excellent; however, distresses in the form of Y-cracks and punchouts were observed as early as 2009.

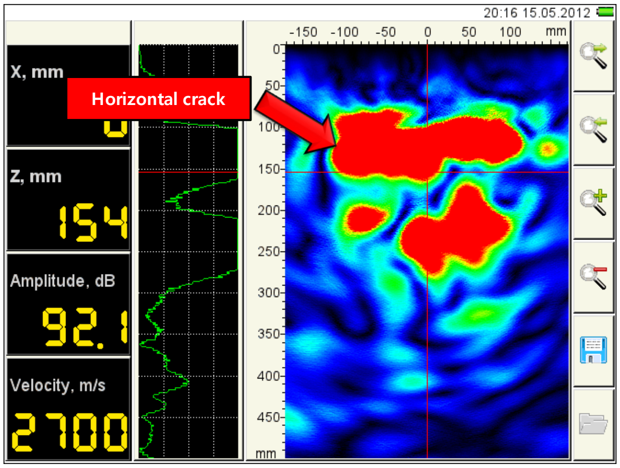
When the section was constructed, concrete material qualities including curing process were controlled very tightly and limestone aggregate was used as well to prevent premature distresses and spalling. However, the distresses were observed as shown in Figure 5.27. Test section was selected as shown in Figure 5.28 (a). The crack on the left is a natural CRCP crack due to environmental loading, while the crack on the right is due to horizontal cracking. Hence, the test location was selected and MIRA test was conducted to evaluate the distress mechanisms. Figure 5.28 (b) shows the MIRA analysis and image, illustrating the existence of horizontal cracking.

The red color illustrates delamination in the concrete. To confirm MIRA analysis results, coring was made and horizontal cracking was observed, as shown inside picture of Figure 5.28 (a). This indicates that most of distresses are shallow punchout due to horizontal cracking.

Figure 5.27 Distresses in BCO



a. Horizontal crack in narrow transverse crack



b. MIRA analysis image

Figure 5.28 Horizontal Crack in Narrow Transverse Crack (IH 35 in the Laredo District)

Traffic information was analyzed from WIM data to determine the reason of horizontal cracking as shown in Figure 5.29. Analyzed results show that overweight trucks passed through this section. The CoTE value of concrete core in this section was evaluated to 3.9 microstrain/°F as well, which indicates that the distresses are not related to a CoTE issue. Hence, it is believed that the horizontal cracking occurred due to overweight truck loadings.

Since the distresses occurred due to an unpredictable cause, the performance of UBCO over asphalt concrete was not able to be evaluated.

97831	11454	3	531m02yr2011.txt	75284	4	1847	1	136	3	600	2	454	2	443		
97832	11455	0	531m02yr2011.txt	75284	4	1847	1	136	3	600	2	454	2	443		
97833	46829	3	531m03yr2011.txt	130948	4	1422	1	131	3	600	2	348	1	185		
97834	46830	0	531m03yr2011.txt	130948	4	1422	1	131	3	600	2	348	1	185		
97835	21414	2	531m02yr2011.txt	127949	4	1308	1	105	2	602	1	298	1	303		
97836	21415	0	531m02yr2011.txt	127949	4	1308	1	105	2	602	1	298	1	303		
97837	26675	2	531m02yr2011.txt	163842	4	1942	1	155	2	603	2	596	2	420		
97838	26676	0	531m02yr2011.txt	163842	4	1942	1	155	2	603	2	596	2	420		
97839	73978	2	531m05yr2011.txt	21127	3	1236	1	145	2	603	2	488				
97840	73979	0	531m05yr2011.txt	21127	3	1236	1	145	2	603	2	488				
97841	17749	2	531m02yr2011.txt	108703	2	766	1	160	2	606						
97842	63515	3	531m04yr2011.txt	75923	4	1254	1	97	3	606	2	288	1	139		
97843	63516	0	531m04yr2011.txt	75923	4	1254	1	97	3	606	2	288	1	139		
97844	30948	3	531m03yr2011.txt	21682	4	1353	1	153	3	607	2	290	1	161		
97845	30949	0	531m03yr2011.txt	21682	4	1353	1	153	3	607	2	290	1	161		
97846	15441	1	531m02yr2011.txt	96991	5	1659	1	182	3	608	2	381	1	188	1	152
97847	15442	0	531m02yr2011.txt	96991	5	1659	1	182	3	608	2	381	1	188	1	152
97848	41603	3	531m03yr2011.txt	99395	3	1301	1	103	3	609	2	412				
97849	41604	0	531m03yr2011.txt	99395	3	1301	1	103	3	609	2	412				
97850	73142	2	531m05yr2011.txt	14630	3	1347	1	120	2	609	2	440				
97851	73143	0	531m05yr2011.txt	14630	3	1347	1	120	2	609	2	440				
97852	78533	3	531m05yr2011.txt	56052	3	1329	1	143	3	609	2	406				
97853	78534	0	531m05yr2011.txt	56052	3	1329	1	143	3	609	2	406				

total steering axle 2 axle 3

Last record Total vehicle weight 132.9 kips steering 14.3 kips tridem 60.9 kips tandem 40.6 kips

Figure 5.29 WIM data on IH 35 in the Laredo District

5.6 Whitetopping

In Texas, whitetopping was primarily constructed in two Districts–Abilene and Odessa - and two sections were constructed in the Paris District in 2011 and 2012. Since the two sections in the Paris District were constructed recently, the performance of the Odessa and the Abilene Districts were evaluated.

5.6.1 Whitetopping in the Abilene District

As Figure 5.30 shows, the Abilene whitetopping section on SH 36 at FM 1750 (GPS coordinate: N 32º26’11.38”, W99º42’45.53”) performed relatively well, even though some diagonal cracks were observed across the joints, as shown in Figure 5.31. The poor support condition might contribute to this failure mode in the concrete layer. Moreover, at some locations, a wide joint opening was discovered as the slab segments moved away from each other due to sliding—the bond between the existing asphalt and concrete appears to be broken. However, the extent of the sliding was not as severe as the ones in Odessa and Midland, as will be presented later. The other whitetopping section on SH 226 at SH 279 (GPS coordinate: N 32.106715, W 99.168434) also performed fairly well as shown in Figure 5.32, although there were a number of cracks along the joints as shown in Figure 5.33. These joint failures seem to be associated with inappropriate saw cut installation related to time or depth, rather than traffic, because this section has been under a low level of traffic. Figure 5.34 shows that some of the saw cut joints did not pop, which indicates that a 4 ft by 4 ft spacing of saw cut would not function as suitable design spacing.

Figure 5.30 Whitetopping in Abilene (SH 36 at FM 1750)

Figure 5.31 Diagonal Failures in Abilene Whitetopping Section (SH 36 at FM 1750)

Figure 5.32 Whitetopping in Abilene (SH 226 at SH 279)

Figure 5.33 Cracking along the Joints in Abilene Whitetopping Section (SH 226 at SH 279)

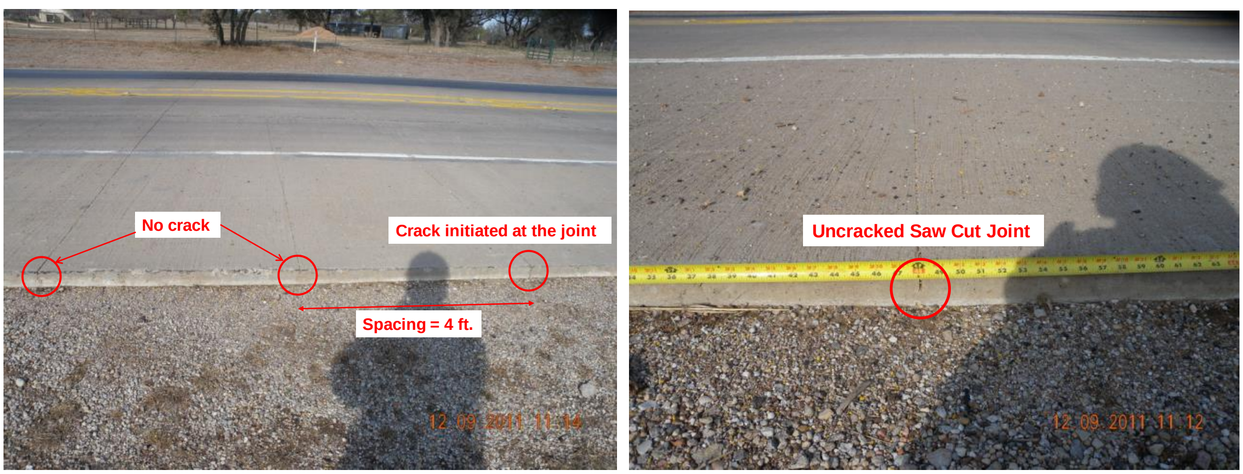


Figure 5.34 Cracked and Uncracked Saw Cut Joints in Abilene Whitetopping Section (SH 226 at SH 279)

5.6.2 Whitetopping in the Odessa District

Three-in thick and 3-ft by 3-ft square whitetopping slabs in Midland and Odessa revealed substantial distresses. The sections in Midland and Odessa were built in 2002. Figures 5.35 and 5.36 show the whitetopping sections in Odessa and Midland respectively. The primary cause for the distresses was sliding of the concrete slabs. Again, it appears that the bond between asphalt and concrete was broken. The current whitetopping design assumes full bond between concrete and asphalt. The design algorithm needs to be revised.

Figure 5.35 Whitetopping in Odessa

Figure 5.36 Whitetopping in Midland

5.6.3 Whitetopping in the Paris District

Whitetopping sections were constructed in two locations under the 5-5482 implementation project in the Paris District, based on the newly developed mechanistic-empirical design procedures developed under the TxDOT Research Project 0-5482.

The first project in Loy Lake is located at the intersection between Loy Lake Drive and US 75 North Frontage Road. Saw cut spacing of this section was 6 ft by 6 ft spacing. The section was constructed in August, 2011.

The other section in Emory is located at the intersection between US 69 and SH 19. Saw cuts were also made at every 6 ft by 6 ft spacing. This section was built in April, 2012. Various gages were installed to monitor the structural response of whitetopping. Figure 5.37 presents the whitetopping section after concrete placement in Emory.

Both sections were built within the last two years, and it is too early to discuss the performance of whitetopping. Hence, the performance of the two projects with 6-ft by 6-ft joint spacing needs to be monitored for the differential slab movements potential.

Figure 5.37 Whitetopping in Emory

5.6.4 Whitetopping Summary

Based on the field performance evaluations in the Abilene and the Odessa Districts, it appears that slab sizes of 3 ft by 3 ft and 4 ft by 4 ft do not function effectively for whitetopping as the sections underwent severe sliding and cracking problems. Rather, the lessons from the Paris District indicate that the use of 6 ft by 6 ft slabs may be beneficial for better-performing whitetopping. However, the performance needs to be monitored for the long term evaluation because the sections in the Paris District were built within the last two years.

Also, since the support condition exhibits a substantial effect on the performance of whitetopping, it needs to be essentially incorporated in whitetopping design considerations.

5.7 Section with 100% Recycled Concrete Aggregates (RCA)

In the mid-1990s, TxDOT built a CRCP section of over 5.8 miles with 100% recycled materials as a reconstruction project (Choi and Won 2009). The section is located on the westbound of IH 10 in Houston between IH 45 and Loop 610 West as shown in Figure 5.38. The GPS coordinate is 29.77763,-95.411335.

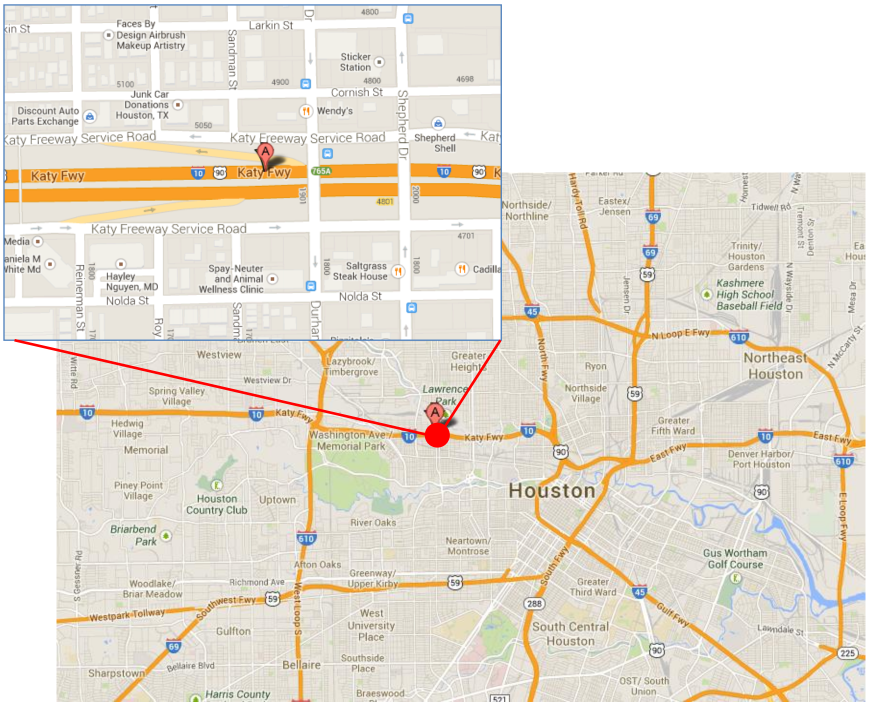


Figure 5.38 Location of Houston RCA Section (stretching 5.8 miles west from this location)

In this project, no virgin aggregates were used. In place of them, crushed concrete was used as both coarse and fine aggregates for concrete. The original aggregate for the recycled concrete was SRG, which is considered to be highly spalling-susceptable. However, as seen in Figure 5.39, overall performance of this section has been satisfactory, with relatively tight crack widths, minor spalling, and no punchout even after 18 years of service with heavy truck traffic. This is surprising since, in most of the cases, spalling distress has been prevalent when SRG was selected for concrete pavings. This favorable performance is most likely because crushed recycled concrete has a rougher and more angular surface texture than virgin SRG, providing good bond between old and new phases. This good bond characteristic could be quite beneficial in increasing spalling resistance. Also, the concrete pieces survived during crushing operations would have a remarkably strong bond between aggregate and paste, performing exceptionally when used as aggregates for concrete.

Figure 5.39 Overview of Houston RCA Section

Another interesting finding is that there was a significant difference in a surface condition between the sections in shaded (under the bridge) and unshaded areas. As seen in Figures 5.40 and 41, the shaded section exhibited a sound performance, while the unshaded one had a lot of cracks in various directions. The probable cause would be that the concrete in the unshaded area has been exposed to much larger temperature fluctuations than the one in the shaded area, and thus experience higher stress variations. In addition, a curing temperature difference between the sections might cause the performance discrepancy because concrete cured at elevated temperature tends to form more unstable matrices, which leads to lower later-age strength. This comparative case again provides important insights about a proper curing operation to ensure better-performing concrete pavements.

Figure 5.40 Condition of Shaded Section

Figure 5.41 Condition of Unshaded Section

5.8 Roller-Compacted Concrete Pavement

Roller compacted concrete (RCC) is a new type of concrete material, with lower water-cement ratio than normal concrete. A section of RCC pavement was built in San Angelo in October, 2011 on Grape Creek Road and in April, 2012 on 50th street. Both pavement structures consist of 6-in RCC on 8-in lime and cement treated subgrade. Figure 5.42 (a) shows the overview of RCC pavement on Grape Creek Road. Since RCC is quite dry mix concrete, adequate level of compaction is needed to obtain surface condition for highways. If the compaction is not adequate, the surface condition shown in Figure 5.42 (b) will result. In this project, dowels were not used for obvious reasons of dry mix. It is not known whether this type of pavement would be applicable to roadways with a high speed. Long-term evaluation is needed before its viability for TxDOT is determined.

a. Overview of RCC pavement in San Angelo

b. Close-up view of RCC surface

Figure 5.42 RCC Pavement in San Angelo

5.9 Summary and Recommendations

The following conclusions and recommendations can be made based on the findings from Chapter 5.

1) The performance of FT-CRCP has been excellent. However, the traffic has been rather light, with a limited number of heavy trucks. Further investigations are needed. It is recommended that the use of FT-CRCP be encouraged where the majority traffic is passenger vehicles and light trucks, and closure time is quite limited.
2) 6-in cast-in-place PTCP performed well for the last 28 years. The benefits of cast-in-place PTCP need to be further evaluated, before a decision is made whether it is a viable alternative to conventional PCCP.
3) BCO performance appears to depend on slab thickness; the thicker the slabs, the better the performance. The longitudinal steel should be placed for the better performance.
4) The new BCO design needs to be developed considering design criteria for base support condition because when the base support condition is not enough to carry the expected traffic, BCO has not functioned well.
5) The use of recycled concrete as coarse aggregates in concrete for CRCP appears to be working well. Where quality virgin coarse aggregate is not available, it would be recommended that the use of RCA is considered.

Chapter 6 Development of Web-Based Rigid Pavement Database

Development of an advanced and user friendly database and web-based interface for easy and convenient access to the pavement performance data was one of the primary objectives of this research project. Accordingly, the Texas Rigid Pavement Database (TxRPDB)was developed as an enterprise platform for sharing design and structural information as well as performance data for concrete pavements in Texas.

6.1 Structure and Anatomy of TxRPDB

Microsoft SQL Server 2008 has been used as a database engine with Windows authentication for TxRPDB database storage. Section data, survey data and user data are the three main categories for TxRPDB database.

6.1.1 Section Data

Section data category contain 6 data tables; "Section Data", "Section Detail", "Construction Information", "Location Information", "Align Detail", and "Section Data Type".

The relation among the data tables is as shown in Figure 6.1.

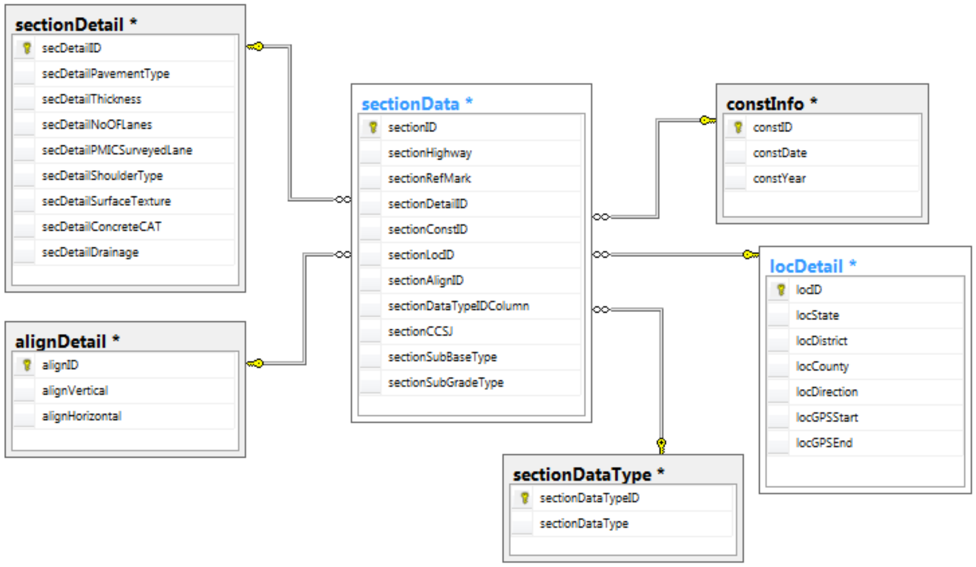


Figure 6.1 TxRPDB Database Architecture

6.1.1.1 Table Name: sectionData

sectionData is a primary table and contains primary information about test sections. "sectionDetail" is the identifier for section information. Data elements "sectionDetailID", "sectionConstID", "sectionLocID", "sectionAlignID" and "sectionDataTypeIDColumn" are useful to fetch section detail information, construction information, location of section, alignment detail and section data type respectively from the secondary tables (Table 6.1).

Table 6.1 sectionData

Data Element	Data Type	Constraints
sectionID	varchar(20)	not null(PK)
sectionHighway	varchar(20)	
sectionRefMark	varchar(20)	
sectionDetailID	int	not null(FK)
sectionConstID	int	not null(FK)
sectionLocID	int	not null(FK)
sectionAlignID	int	not null(FK)
sectionDataTypeIDColumn	int	not null(FK)
sectionCCSJ	varchar(100)	
sectionSubBaseType	varchar(50)	
sectionSubGradeType	varchar(50)	

6.1.1.2 Table Name: sectionDetail

It is the secondary table containing detailed information for the section. Section details are related to the primary section data table through the unique identifier "secDetailID" as shown Table 6.2.

Table 6.2 sectionDetail

Data Element	Data Type	Constraints
secDetailID	int	not null(PK)
secDetailPavementType	varchar(80)	
secDetailThickness	varchar(10)	
secDetailNoOFLanes	varchar(10)	
secDetailPMICSurveyedLane	varchar(80)	
secDetailShoulderType	varchar(80)	
secDetailSurfaceTexture	varchar(80)	
secDetailConcreteCAT	varchar(80)	
secDetailDrainage	varchar(80)	

6.1.1.3 Table Name: sectionDataType

sectionDataType contains a list of data types for the sections. Data types can be like "Level 1 Information", "CPCD", "CRCP", "Fast Track Pavement", "Coarse Aggregate Effects" etc. Section data type relate to primary section data table by its unique identifier "sectionDataTypeID" as shown Table 6.3.

Table 6.3 sectionDataType

Data Element	Data Type	Constraints
sectionDataTypeID	int	not null(PK)
sectionDataType	varchar(50)	

6.1.1.4 Table Name: locDetail

This secondary table contains location details of test section. Location information relate to primary section data table by its unique identifier "locID" (Table 6.4).

Table 6.4 locDetail

Data Element	Data Type	Constraints
locID	int	not null(PK)
locState	varchar(25)	
locDistrict	varchar(25)	
locCounty	varchar(25)	
locDirection	varchar(5)	
locGPSStart	varchar(80)	
locGPSEnd	varchar(80)	

6.1.1.5 Table Name: constInfo

This secondary table contains construction detail of section data. Construction information relate to primary section data table by its unique identifier "constID" (Table 6.5).

Table 6.5 constInfo

Data Element	Data Type	Constraints
constID	int	not null(PK)
constDate	date	
constYear	varchar(10)	

6.1.1.6 Table Name: alignDetail

This secondary table contains alignment detail of section data. Alignment information relate to primary section data table by its unique identifier "alignID" (Table 6.6).

Table 6.6 alignDetail

Data Element	Data Type	Constraints
alignID	int	not null(PK)
alignVertical	varchar(40)	
alignHorizontal	varchar(40)	

6.1.2 Survey Data

Survey category contains 3 data tables; "Survey Data", "Survey Detail", and "Survey Data Type".

6.1.2.1 Table Name: surveyData

surveyData table is the primary table. It contains the information of survey held at for each section or highway. Data element "surveyDataID" is unique identifier for the survey information held on Section/Highway defined by data element "surveySectionID". If Survey held on Section/Highway from "General Section", "Special Section", "Experimental Section", or "CPCD", data element "surveyLevel" be blank. Surveyor names and survey date also are not mandatory field for the database (Table 6.7).

Table 6.7 surveyData

Data Element	Data Type	Constraints
surveyDataID	int	not null(PK)
surveySectionID	varchar(50)	
surveyDate	date	
surveyLevel	varchar(10)	
surveyorNames	varchar(80)	

6.1.2.2 Table Name: surveyDetail

surveyDetail table is the primary table. surveyDetail table contains information of uploaded survey files for surveyed Sections/Highway (Table 6.8). Data element "surveyFileName" contains the names of uploaded files to display on the list of files related to section. Data element "surveyFileDataType" contains the type of survey data. File types can be like, "Load Transfer Information", "Crack Information", "Pictures", etc. Data element "surveyFileType" contains information of file type. File types can be like, "jpg", "gif", "pdf", "doc", "ppt", etc. Data element "surveyFilePath" contains the related path of uploaded file on sever. This path will be used for the download or the view of file functionality.

Table 6.8 surveyDetail

Data Element	Data Type	Constraints
surveyDetailID	int	not null(PK)
surveySectionID	varchar(50)	
surveyFileName	varchar(50)	
surveyFileDataType	varchar(50)	
surveyFileType	varchar(80)	
surveyFilePath	varchar(500)	
surveyDate	date	

6.1.2.3 Table Name: surveyTypeDB

This is a secondary table containing the list of all available type of survey data. These survey types can be like "Crack information", "Deflection", "Distress", "Plans" and "Pictures". Data element "surveyTypeShortName" is useful to assign short name in case of big survey file name (Table 6.9). This field value will be displayed on the web, though data will be stored by the full name of survey type. Data element "surveyTypeDesc" can be used to give the description of the survey type.

Table 6.9 surveyTypeDB

Data Element	Data Type	Constraints
surveyTypeID	int	not null(PK)
surveyType	varchar(50)	
surveyTypeShortName	varchar(50)	
surveyTypeDesc	varchar(80)	

6.1.3 User Data

The User category contains 1 data table; "User Data".

6.1.3.1 Table Name: userData

This is the primary table used to store all user's information including users' name, username, password, email and type of user. Data element "userIsActive" contain two possible values "true" and "false". If value is active means admin has accepted request and that user will be able to access database through website. Data element "userType" has possibly two values "admin" and "user" (Table 6.10).

Table 6.10 userData

Data Element	Data Type	Constraints
userID	int	not null(PK)
userFName	varchar(50)	
userLName	varchar(50)	
userUName	varchar(20)	
userPassword	varchar(20)	
userEmail	varchar(80)	
userIsActive	bit	
userType	varchar(10)	

6.2 Data Storage

Windows Enterprise Server 2008 R2 is used to store the test sections and survey files. For TxRPDB project we have two types of file to store on the server; Section data files and Survey files. Section Data files includes the general information about the sections. Survey data files include the files like pictures, plans, crack information, deflections, etc.

6.2.1 Section Data Files

Section data files are used to import new or update existing data. Section data files must follow the proper format. Section files have to follow several rules such as the header of section data excel file must not be changed; order of excel file must not be altered; section data files should not have any blank field in it, if data is not available it should be replaced by "-" (dash); in case of date field, date must be in proper format (MM/DD/YYYY); and section data type must have the same name as mentioned in Table 6.11.

Table 6.11 Section Data Types

List of Section Data Type	
Section Data Type	Section Data Category
Level 1 Sections	CRCP
Fast Track Pavement	Special Sections
Bonded Overlay	Special Sections
Unbonded Overlay	Special Sections
Whitetopping	Special Sections
Precast Pavement	Special Sections
Cast-in-place prestressed pavement	Special Sections
Recycled Concrete Pavement	Special Sections
CPCD	CPCD
General Sections	CRCP
Coarse Aggregate Effects	Experimental Sections
Steel Percentage Effects	Experimental Sections
Construction Season Effects	Experimental Sections

If the admin wants to add one more type a new excel sheet should be uploaded using "Upload Section Data" tab on TxRPDB website and the new type will be added to the database automatically. While uploading new Section Data excel sheet, if same section data is uploaded, it will not get duplicated in the database but the old section details will be updated by the new detail. A snap-shot of the Section Data excel sheet is shown in Figure 6.2.

	A	B	C	D	E	F	G	H
1	Test Section	Highway	Reference Marker	State	District	County	Direction	GPS (Start)
2	2-I35-1	IH 35W	-	Texas	Ft Worth	Tarrant	-	N32°35'58.7" W097°19'
3	2-I820-1	IH 820	MP 11	Texas	Ft Worth	Tarrant	NE	-
4	3-I35-1	IH 35	MP 484+0.5	Texas	Wichita Falls	Cooke	-	N33°26'41.3" W097°09'
5	3-US287-1	US 287	MP 330	Texas	Wichita Falls	Wichita	N	N33°57'59.7" W098°43'

Figure 6.2 Snapshot of TxRPDB Section Detail Excel Sheet

Naming of section data file will be done by the system. Section data files will be stored on the server for log purpose only. Section data file will be stored in the folder "Section Data".

6.2.2 Survey Data Files

Survey data files are the files which have been generated after survey of Section or Highway. These files can be of any type from the bellowed shown list. Any other extension files apart from the ones shown in Table 6.12 cannot be uploaded.

Table 6.12 File Extensions–Survey Data Files

List of Acceptable File Extension for Survey Data File	
File Type	File Extension
PDF Files	".pdf"
Image Files	".gif", ".png", ".jpg", ".jpeg"
Document Files	".doc", ".docx", ".txt"
Presentation Files	".ppt", ".pptx"
CAD Files	".dxf", ".svg"
Spreadsheet Files	".xls", ".xlsx"

Survey data can be of any type shown in Table 6.13. In the future if more survey types are to be added, it can be done through the page "Admin/DatabaseDirectory.aspx". Link of this page can be also found on "Upload Survey Data" page on TxRPDB website.

Table 6.13 Survey Data Types

List of Survey Data Type	
Survey Data Type	Survey Data Description
Crack Info	Crack Information
Deflections	Deflection Information
Distress	Distress Information
Load Trans Eff	Load Transfer Efficiency
Pictures	Pictures of sections/highway
Plans	Plan sets
Reports	Reports generated from survey
Traffic	Files for traffic information
Other	Other Files

Survey data files store are stored on the server in hierarchical folders. As shown in Figure 6.3, hierarchy can be decided by the survey type, section I.D. and survey data type.

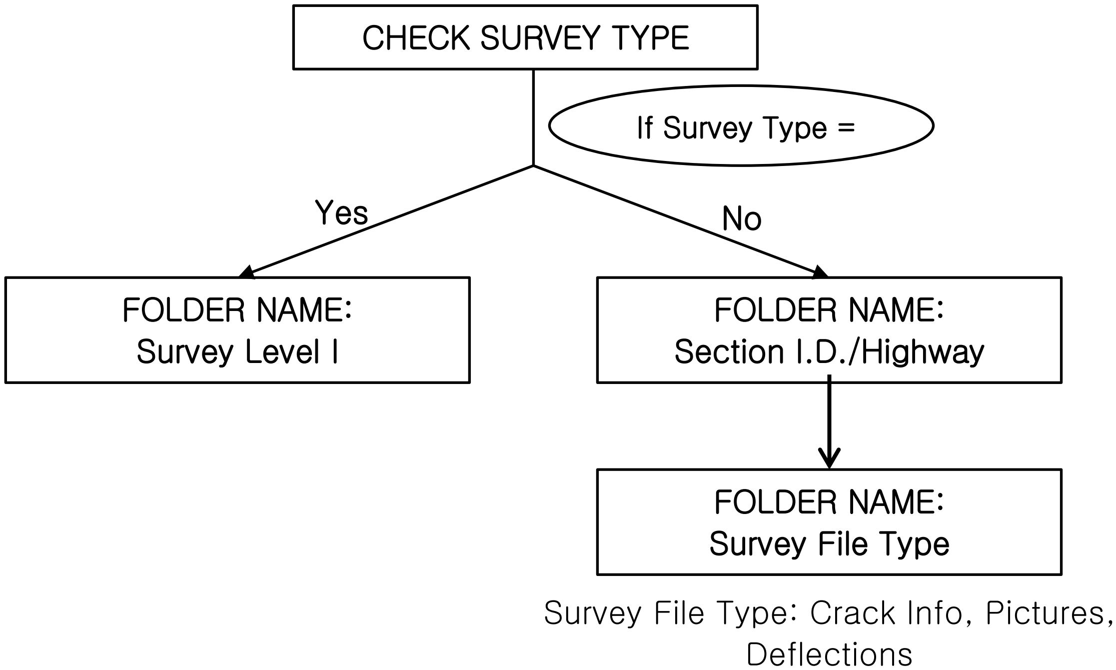


Figure 6.3 Folder Hierarchy for Data Storage

While importing data of survey on "UploadSurvey.aspx" page, it also will generate the folder hierarchy for survey files of Section I.D. This hierarchy of folder depends on the survey type. If it's level survey then parent folder will be the Survey Level. Each section ID will have separate folder where the survey files will be stored under the parent folder named by the Section ID.

For example, if we upload the survey file "crack info.xlsx" and "Pictured.pdf" of Level-1 survey for the section ID "IH 30", the file will be stored into the bellowed shown folder hierarchy,

Level-1>IH 30>Crack Info>Crack Info.xlsx

Level-1>IH 30>Pictures>Pictures.pdf

TxRPDB database contains several store procedures to perform database operations. List of all the store procedures are described in Table 6.14.

Table 6.14 Store Procedures

List of Store-Procedures	
Store_Procedures	Short Description
in_InsertSectionData	To import section data
in_InsertSurveyData	To import survey data
in_InsertSurveyDetail	To import survey detail
in_InsertSurveyType	To import survey type
up_AddUserSession	To add user session
up_InsertUser	To import new user information
up_ValidateUser	To validate user
updateUserActiveData	To active or de-active user
updateUserData	Used to update user data.

6.3 Website Development

TxRPDB website is developed on the Microsoft .NET Framework 4.0. The features of the website have been enriched using AJAX Toolkit, JavaScript, jQuery, OBOUT Suite controls and CSS.

6.3.1 Search Section

Search section provides the functionality of advanced search by providing the facility of selecting multiple attributes and multiple values of same attribute at the same time. jQuery and CSS code have been used to convert single selectable dropdown list to the multi-select dropdown. According to the selection of attributes dynamic query will be formed and will be used to fetch data from the database matching selected attributes. Search result will be grouped according to their attributes and will be displayed in the repeater control.

6.3.2 Section and Survey data view panel

Section and survey data view panel is an oWindows in an obout suite AJAX control. Script has been written to call the oWindow with specific information like Section ID, Survey Data Type, Survey File type, etc.

6.3.3 Section, User and Survey update webpage

Section, User and Survey update webpage contain the grid of list of existing data from the database. Search and multiple delete functionality have been developed by the C# and JavaScript code.

C#, JavaScript and AJAX have been used to perform the data view grid. Search query forms dynamically according to the selection of attributes and imported data is displayed in ASP: Repeater control (Table 6.15).

Table 6.15 Technical Specifications

Title	TxRPDB – Texas Rigid Pavement Database
Technology Used	Asp.Net, AJAX Toolkits and obout suite controls
Scripting Language	C#, JavaScript and jQuery
Database	Microsoft SQL Server 2008
Database Tool	SQL Server Management Studio Express
Designing Tool	Abode Photoshop 5.0
Development Platform	.Net Framework 4.0
Development Environment	Microsoft Visual Studio 2010

6.4 Contents

The type of data that can be accessed via the TxRPDB web interface is enlisted in Table 6.16.

Table 6.16 TxRPDB Data Types

Main Data Type	Sub Data Type	Data Type	File Type
CRCP	Level I	Average Deflection, Load Transfer Efficiency, Crack Spacing, Pictures	.xls, .pdf
	General Sections	Plan Sets, Pictures, Reports	.pdf, .ppt
CPCD		Plan Sets, Pictures, Reports, Plan Sets	.pdf, .ppt
Experimental Sections	Coarse Aggregate	Plan Sets, Pictures, Reports, Plan Sets	.pdf, .ppt
	Steel Percentage		
	Construction Season		
Special Sections	Fast Track pavement	Plan Sets, Pictures, Reports, Plan Sets	.pdf, .ppt
	Bonded Overlay		
	Unbonded Overlay		
	Whitetopping		
	Precast pavement		
	Cast-in-place prestressed pavement		
	Recycled concrete pavement		

6.5 Secure User Access

TxRPDB can be accessed by typing the URL: https://www.texasrpdb.ce.ttu.edu/ into the address bar of an internet browser. The website has been tested to be compatible with all popular internet browsers viz. Internal Explorer, Mozilla Firefox, Google Chrome and Safari.

The URL takes the user to the home screen of TxRPDB as shown in Figure 6.4. The home page provides the user basic introduction to the purpose of TxRPDB. In addition to the "Home" tab, the home screen gives access to four tabs:

- Register
- Update Profile
- About
- Sign In

Figure 6.4 TxRPDB Home Screen

6.5.1 Register

The "Register" tab, as shown in Figure 6.5, provides a first time TxRPDB user an interface to input details in order to create a user account. Specific details requested from the user are user name, first name, last name, email id and password. The password needs to be a minimum of 6 characters in length and could be a combination of alpha-numeric characters. The user at this stage can input whether he/she would like user or admin control of the database. However, granting the user the desired level of access depends only on the admin. Once, the user clicks the "Register Me' button, the user information gets updated in the User List. If the admin considers the user details to be correct and the desired user level to be appropriate, the user account is activated. Once the user is activated in the User List an automated e-mail message stating the user credentials to access TxRPDB, is sent to the e-mail address input by the user.

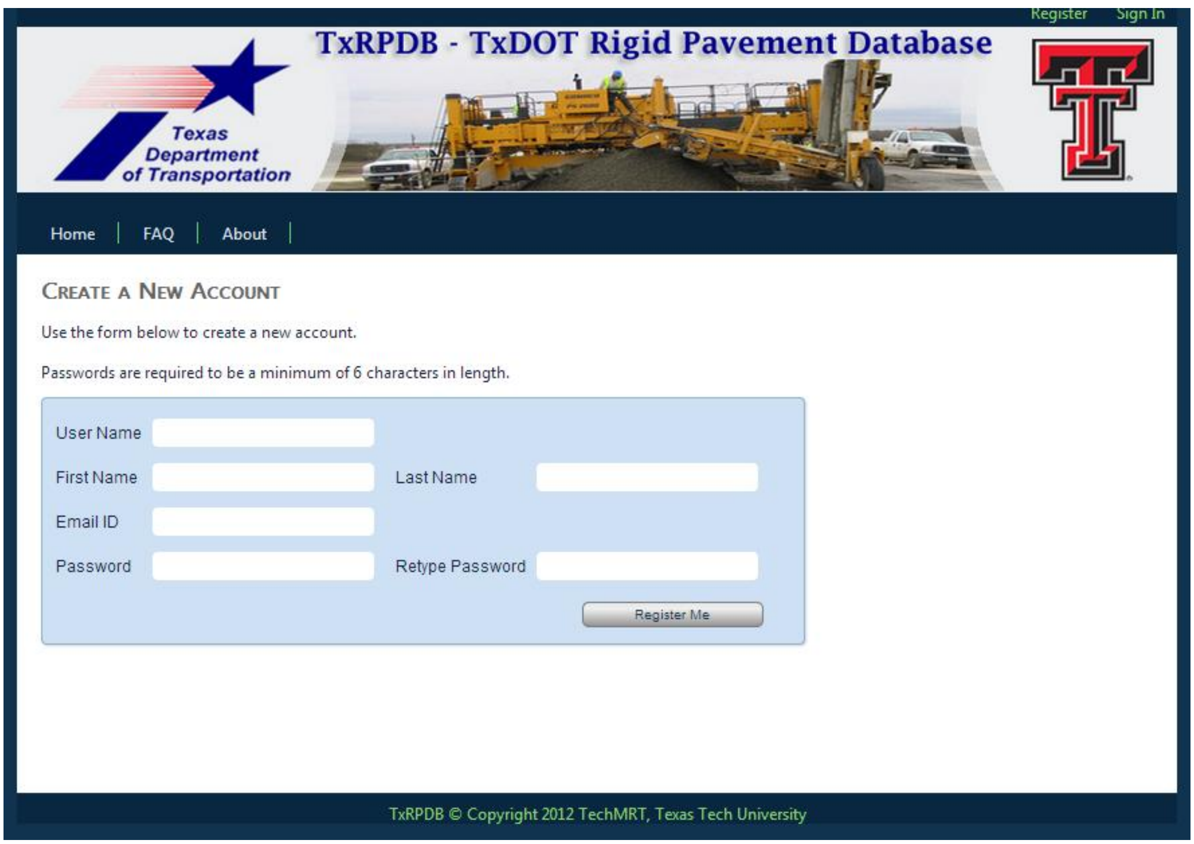


Figure 6.5 TxRPDB- Register Tab

6.5.2 Update Profile

This interface facilitates updating the user information. If an existing user prefers to change the username, password or email address in the User List, "Update Profile" provides him/her to make these updates.

6.5.3 About

The "About" tab describes the type of pavement data stored in the TxRPDB and current capabilities of TxRPDB for data access and querying. The user will also have access to Database user's and admin manuals from here.

6.5.4 Sign In

Once the user has obtained the log-in credentials via email, the "Sign In" tab at the top right corner of the home page is used to log-in to TxRPDB. In case the user forgets the username and/or password, the "Sign In" page also has a "Forgot Password" help page. The "Forgot Password" link prompts the user to provide the email address registered with the user account and the log-in details are subsequently emailed to the user.

6.6 Data Access

As shown in Figure 6.6, "Level I Sections" page allows the user to select a specific district, highway and section I.D. and displays the General Information below.

Figure 6.6 Level I Sections Interface

The page also provides links to deflection, load transfer efficiency, crack information, pictures and a pop-up map depicting the location of that particular section. To access a specific data type, by clicking on the corresponding link a list of test data files for the particular section are displayed in a pop-up window as shown in Figure 6.7.

Figure 6.7 Level I Sections – Data Files

All the data files are named as per their section I.D. and the testing date. The test data files can be downloaded as well as viewed online by clicking on the "viewer" mark or "down-arrow" mark on the right respectively.

"General Sections" follows a data access method similar to "Level I Sections". The user can select the district and highway and the results are displayed below. "General Sections" currently consists of plan sets, pictures and reports that can be downloaded by the user as well as viewed online.

"Experimental Sections" and "Special Sections" follow web interface and data access pattern similar to "General Sections".

6.6.1 Query Interface

"Search" tab provides an interface to perform query functions in TxRPDB. As shown in Figure 6.8, an extensive list of attributes is available to the user to perform query functions. Multiple values for the same attribute can be selected from the attribute drop-down list.

"Search" also allows the user to select the query operator "And" or "Or" for each attribute being queried for. The values for the construction year need to be input manually by the user in the format "YYYY". The "Construction Year" attribute also comes with the flexibility of four additional query operators, "Equals", "Not Equals", "Greater than" and "Less Than".

The query results are displayed on the right side along with general information regarding each result. Also, results for each combination of queried attributes are displayed together as shown in Figure 6.8. The total number of results returned by the query as well as the attributes queried for is displayed in the bottom left corner of the "Search" window.

The test data files and other information for each section in the search results can be accessed by clicking on the test section I.D. besides "More Information" in the results section as shown in Figure 6.8.

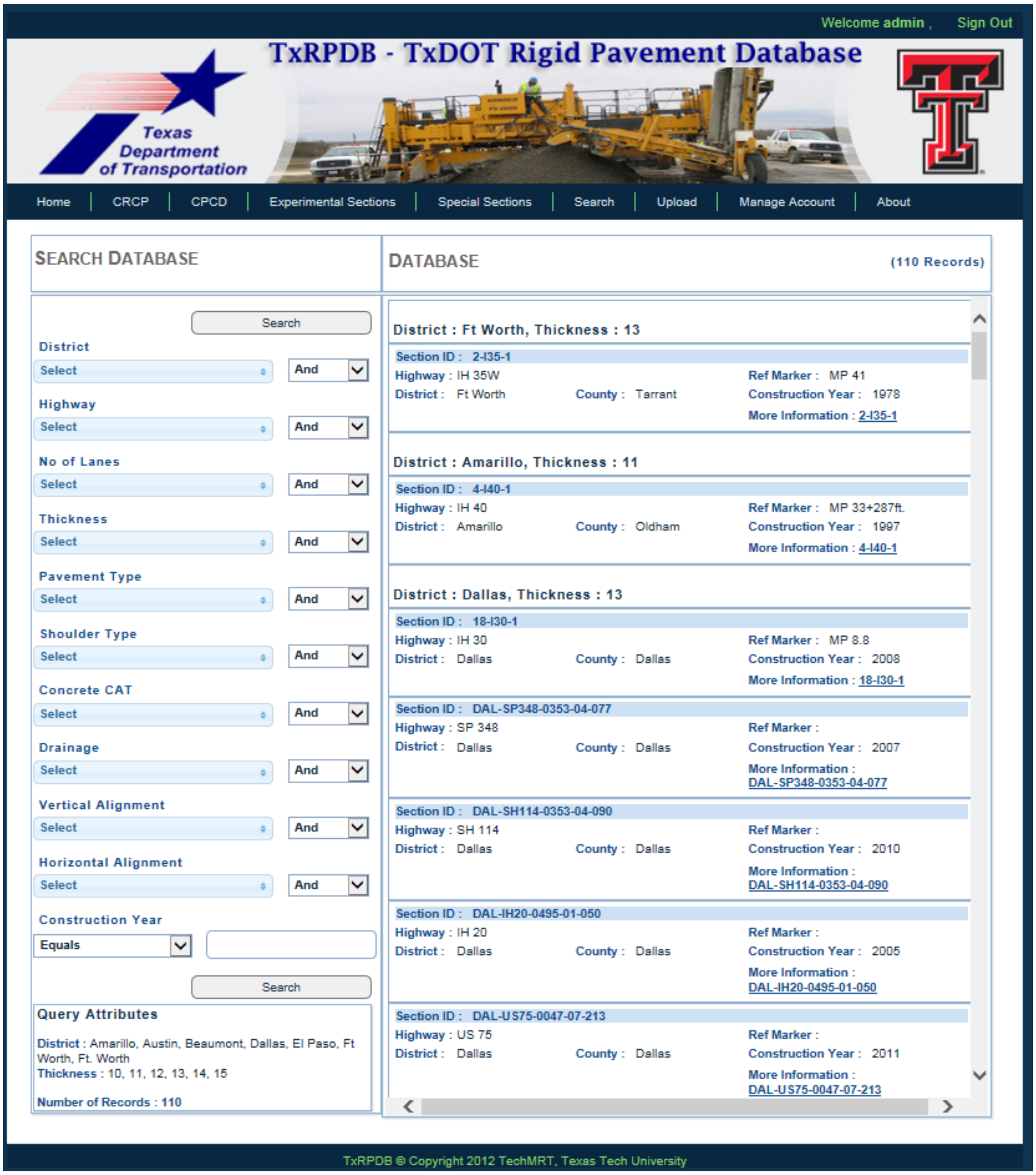


Figure 6.8 Query Function Interface

6.6.2 Test Data File Nomenclature

All test data files being uploaded to the database follow a pre-determined naming format. For easy identification of a particular type of test data file as well as providing correct file name when the data is being uploaded by the admin, Table 6.17 enlists the file nomenclature followed in TxRPDB. The “Testing Date” in naming the data files follows “MMDDYY” format.

Table 6.17 File Nomenclature

File Type	File Name Format
Average Deflection Data	“Section I.D.”GN“Testing Date”
Load Transfer Efficiency Data	“Section I.D.”LTE“Testing Date”
Pictures	“Section I.D.”PD“Testing Date”
Crack Spacing Data	“Section I.D.”CS“Testing Date”
Plan Sets	“Abbreviated District Name”-“Highway”_CCSJ No.

6.6.3 Admin Controls and Data Upload

TxRPDB provides easy data upload and management capabilities to the admin as upload of data files, introduction of new sections into the database as well as deleting unwanted data files can be conducted form within the TxRPDB portal. A user with admin log-in controls gets access to two additional tabs “Upload” and “Manage Account” within TxRPDB.

“Upload” allows the admin to introduce new sections into the database via “Upload Section Data” and add new test data files through “Upload Survey Data”. The admin can add new sections to the master Excel sheet containing information for each section in the database and upload it using “Upload Section Data”.

“Upload Survey Data” follows a two-step process to introduce new test data files as shown in Figure 6.9. Firstly, the admin is prompted to specify section I.D. and type of section, the test data is associated with. By clicking “Check Database”, the database looks for the specific section I.D. in the database. Only if the specific section I.D. exists in the database, a confirmation message is displayed and the admin can upload the test data using “Upload Survey Files”.

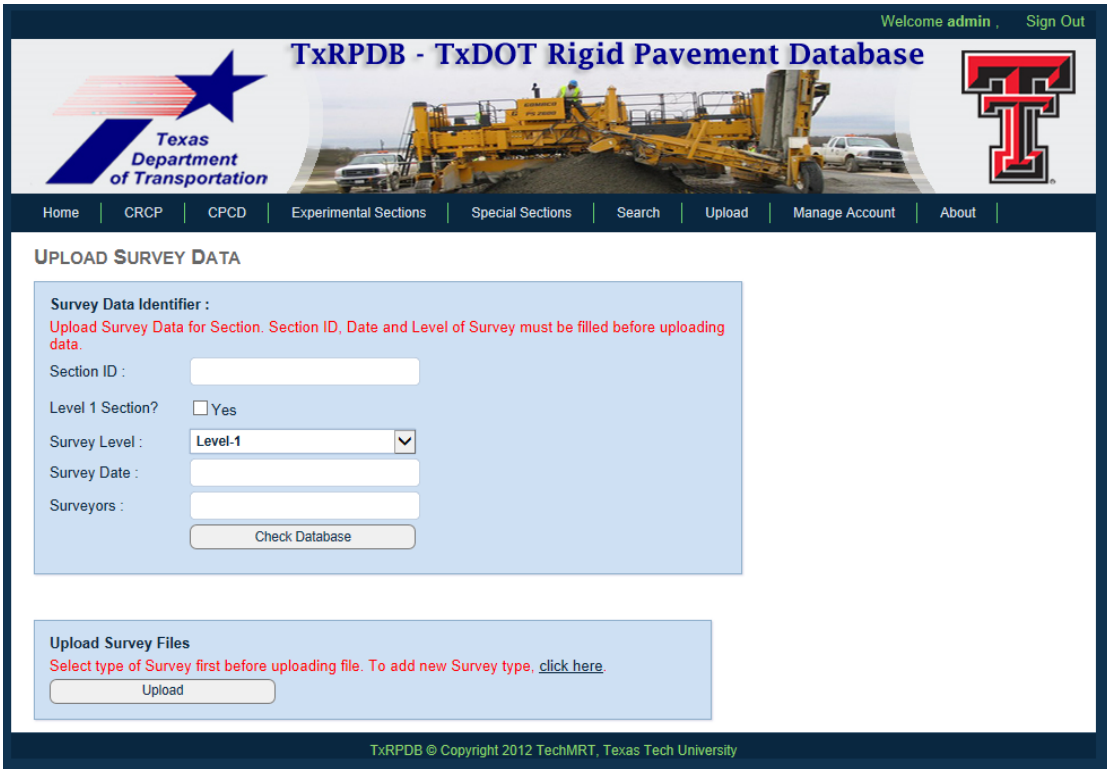


Figure 6.9 Upload Survey Data Identifier Window

Figure 6.10, shows the layout of the window to upload survey data. Once the admin clicks on the "Upload" button shown in Figure 6.9, a new pop-up window opens. The admin needs to input the name of file and file type based on the file nomenclature. The admin then locates the file to be uploaded using the "Browse" button and once the required file is selected, it can be uploaded to the database by clicking the "Upload" button. As shown in Figure 6.10, the list of all test data files existing in the database will be enlisted in the "List of Uploaded Files" below the "Upload Survey Data". The admin also has access to the "Delete" tab on the right side of each file in the "List of Uploaded' files allowing the user to delete unwanted test data files for that particular section.

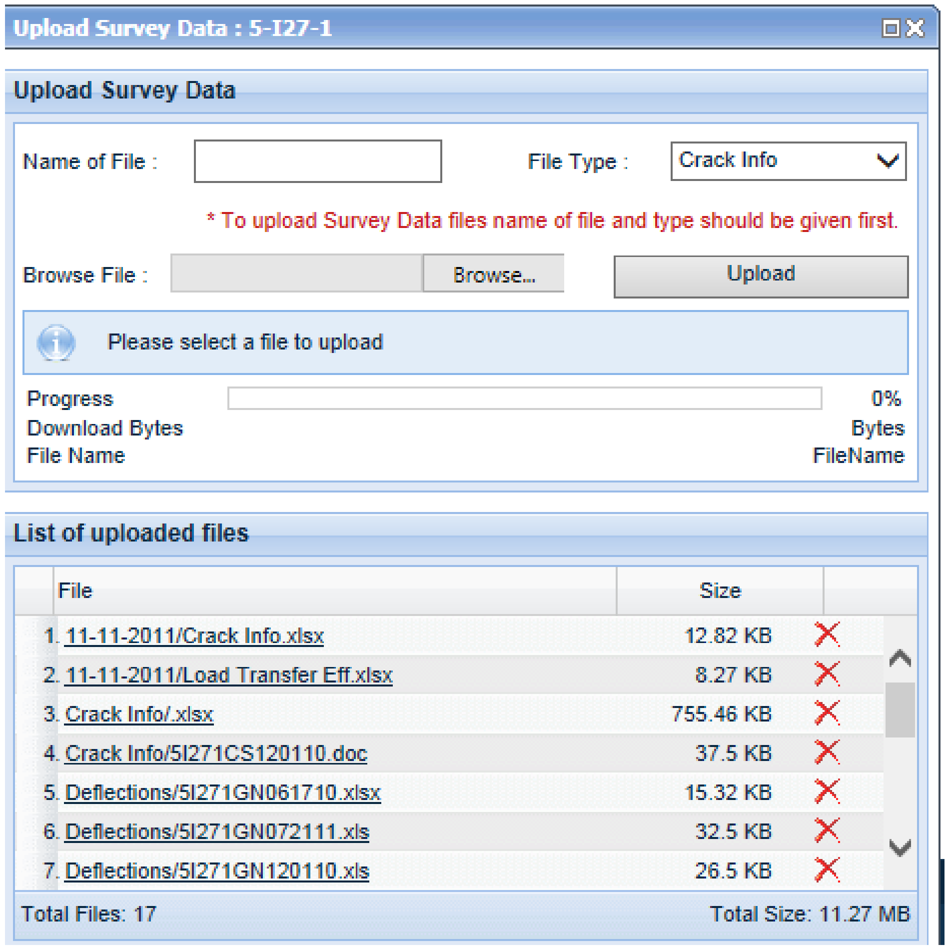
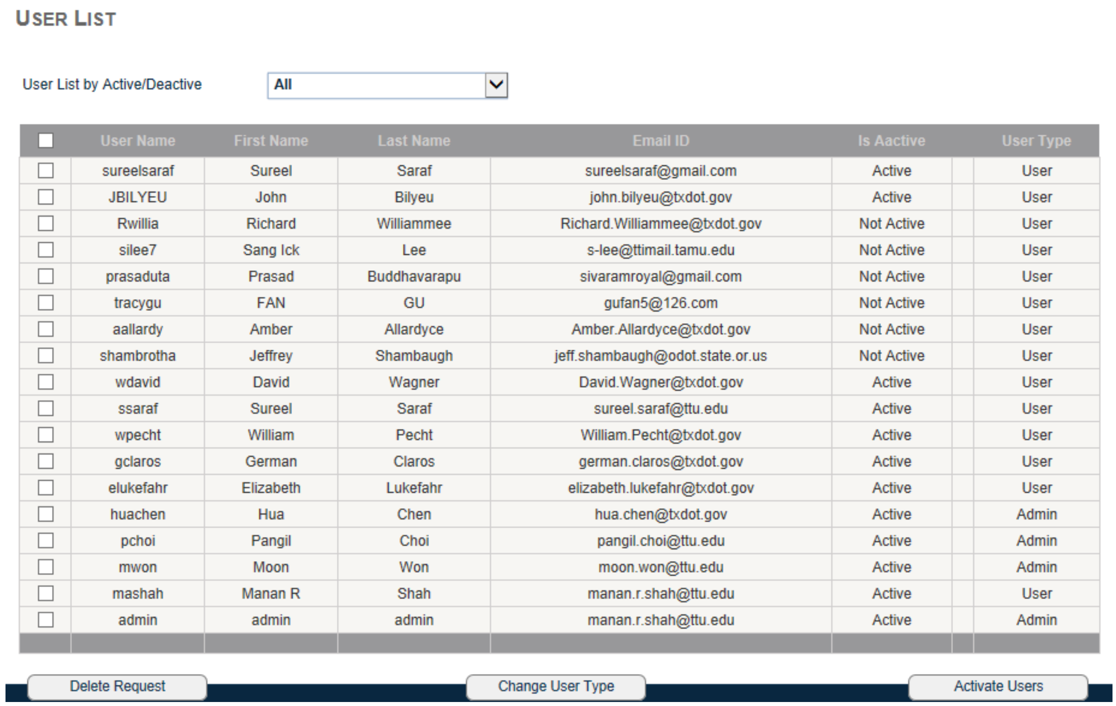


Figure 6.10 Upload Survey Data Interface

“Manage Account” nests three additional capabilities within it, namely “Manage User List”, “Manage Section Data” as well as “Manage Survey Data”. Once a new user registers to access the database, the user details are enlisted in “User List” as shown in Figure 6.11.



USER LIST

User List by Active/Deactive | All

☐	User Name	First Name	Last Name	Email ID	Is Aactive	User Type
☐	sureelsaraf	Sureel	Saraf	sureelsaraf@gmail.com	Active	User
☐	JBILYEU	John	Bilyeu	john.bilyeu@txdot.gov	Active	User
☐	Rwillia	Richard	Williammee	Richard.Williammee@txdot.gov	Not Active	User
☐	silee7	Sang Ick	Lee	s-lee@ttimail.tamu.edu	Not Active	User
☐	prasaduta	Prasad	Buddhavarapu	sivaramroyal@gmail.com	Not Active	User
☐	tracygu	FAN	GU	gufan5@126.com	Not Active	User
☐	aallardy	Amber	Allardyce	Amber.Allardyce@txdot.gov	Not Active	User
☐	shambrotha	Jeffrey	Shambaugh	jeff.shambaugh@odot.state.or.us	Not Active	User
☐	wdavid	David	Wagner	David.Wagner@txdot.gov	Active	User
☐	ssaraf	Sureel	Saraf	sureel.saraf@ttu.edu	Active	User
☐	wpecht	William	Pecht	William.Pecht@txdot.gov	Active	User
☐	gclaros	German	Claros	german.claros@txdot.gov	Active	User
☐	elukefahr	Elizabeth	Lukefahr	elizabeth.lukefahr@txdot.gov	Active	User
☐	huachen	Hua	Chen	hua.chen@txdot.gov	Active	Admin
☐	pchoi	Pangil	Choi	pangil.choi@ttu.edu	Active	Admin
☐	mwon	Moon	Won	moon.won@ttu.edu	Active	Admin
☐	mashah	Manan R	Shah	manan.r.shah@ttu.edu	Active	User
☐	admin	admin	admin	manan.r.shah@ttu.edu	Active	Admin

Delete Request | Change User Type | Activate Users

Figure 6.11 User List Interface

Using “ Manage User List”, the admin can activate new-user accounts by using the “Check Mark” on the left-most of each user-detail and clicking the “Activate Users” button. Multiple users can be check marked and activated at the same time. Existing user accounts or newly created accounts seeing access can also be deleted and denied access respectively from the “User List” by placing check-marks and clicking the “Delete Request” button.

“Manage Section Data” enlists the sections currently in the database as illustrated in Figure 6.12. The admin can remove a section from the database by placing a check-mark in th left-most side “Check-box” and then clicking on the delete symbol on the right side. Multiple sections can be deleted using by placing multiple check marks against the sections to be deleted and clicking the “Delete All” button.

SECTION DETAIL

Search by Section ID : Search / Select All

	Section	Highway	Ref mark	County	District	Data Type	
☐	12-441-1-2	IH 45	Exit 72B	Montgomery	Houston	Level 1 Sections	×
☐	12-US290-1	US 290		Waller	Houston	Level 1 Sections	×
☐	12-US290-2	US 290		Waller	Houston	Level 1 Sections	×
☐	12-US290-3	US 290		Waller	Houston	Level 1 Sections	×
☐	18-I30-1	IH 30	MP 8.8	Dallas	Dallas	Level 1 Sections	×
☐	19-US59-1	US 59	MP 218-0.4	Bowie	Atlanta	Level 1 Sections	×
☐	19-US59-2	US 59	MP 218-0.4	Cass	Atlanta	Level 1 Sections	×
☐	2-I35-1	IH 35W	MP 41	Tarrant	Ft Worth	Level 1 Sections	×
☐	2-I820-1	IH 820	MP 11	Tarrant	Ft Worth	Level 1 Sections	×
☐	20-I10-1	IH 10	MP 858+0.2	Orange	Beaumont	Level 1 Sections	×
☐	24-I10-1	IH 10	MP 36+0.3	El Paso	El Paso	Level 1 Sections	×
☐	24-I10-2	IH 10	MP 39+0.3	El Paso	El Paso	Level 1 Sections	×
☐	24-I10-3	IH 10	MP 45+ 0.1	El Paso	El Paso	Level 1 Sections	×
☐	24-I10-4	IH 10	MP 85	Hudspeth	El Paso	Level 1 Sections	×
☐	25-I40-1	IH 40	MP 158.52	Wheeler	Childress	Level 1 Sections	×
☐	25-I40-2	IH 40	MP 147-0.15	Wheeler	Childress	Level 1 Sections	×
☐	3-I35-1	IH 35	MP 484+0.5	Cooke	Wichita Falls	Level 1 Sections	×
☐	3-US287-1	US 287	MP 330	Wichita	Wichita Falls	Level 1 Sections	×
☐	3-US287-2	US 287		Wichita	Wichita Falls	Level 1 Sections	×
☐	3-US81-1	US 81	MP 220	Montague	Wichita Falls	Level 1 Sections	×
☐	4-I40-1	IH 40	MP 33+287ft.	Oldham	Amarillo	Level 1 Sections	×
☐	48-3569-IH30-LTPP	IH 30	MP 115.3	Hopkins	Paris	LTPP Sections	×
☐	48-5154-IH10-LTPP	IH 10	MP 655.5	Gonzales	Yoakum	LTPP Sections	×
☐	5-I27-1	IH 27	MP 43+0.22	Hale	Lubbock	Level 1 Sections	×
☐	5-Loop_289-1	SL 289		Lubbock	Lubbock	Level 1 Sections	×

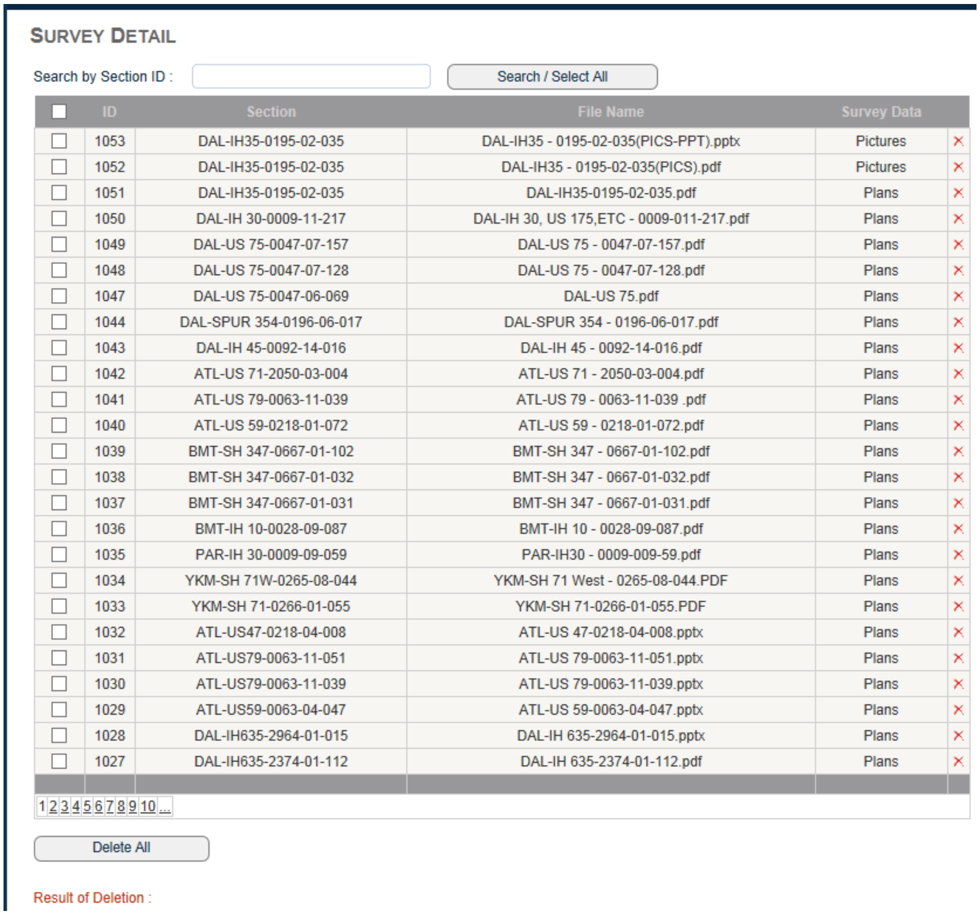
1 2 3 4 5 6 7 8 9 10 ...

Delete All

Result of Deletion :

Figure 6.12 Update Section Data Window

"Manage Survey Data" follows the "Manage Section Data" format as shown in Figure 6.13. It enables the admin to delete test data files that have been uploaded to the database previously.



SURVEY DETAIL

Search by Section ID : Search / Select All

	ID	Section	File Name	Survey Data	
☐	1053	DAL-IH35-0195-02-035	DAL-IH35 - 0195-02-035(PICS-PPT).pptx	Pictures	×
☐	1052	DAL-IH35-0195-02-035	DAL-IH35 - 0195-02-035(PICS).pdf	Pictures	×
☐	1051	DAL-IH35-0195-02-035	DAL-IH35-0195-02-035.pdf	Plans	×
☐	1050	DAL-IH 30-0009-11-217	DAL-IH 30, US 175,ETC - 0009-011-217.pdf	Plans	×
☐	1049	DAL-US 75-0047-07-157	DAL-US 75 - 0047-07-157.pdf	Plans	×
☐	1048	DAL-US 75-0047-07-128	DAL-US 75 - 0047-07-128.pdf	Plans	×
☐	1047	DAL-US 75-0047-06-069	DAL-US 75.pdf	Plans	×
☐	1044	DAL-SPUR 354-0196-06-017	DAL-SPUR 354 - 0196-06-017.pdf	Plans	×
☐	1043	DAL-IH 45-0092-14-016	DAL-IH 45 - 0092-14-016.pdf	Plans	×
☐	1042	ATL-US 71-2050-03-004	ATL-US 71 - 2050-03-004.pdf	Plans	×
☐	1041	ATL-US 79-0063-11-039	ATL-US 79 - 0063-11-039 .pdf	Plans	×
☐	1040	ATL-US 59-0218-01-072	ATL-US 59 - 0218-01-072.pdf	Plans	×
☐	1039	BMT-SH 347-0667-01-102	BMT-SH 347 - 0667-01-102.pdf	Plans	×
☐	1038	BMT-SH 347-0667-01-032	BMT-SH 347 - 0667-01-032.pdf	Plans	×
☐	1037	BMT-SH 347-0667-01-031	BMT-SH 347 - 0667-01-031.pdf	Plans	×
☐	1036	BMT-IH 10-0028-09-087	BMT-IH 10 - 0028-09-087.pdf	Plans	×
☐	1035	PAR-IH 30-0009-09-059	PAR-IH30 - 0009-009-59.pdf	Plans	×
☐	1034	YKM-SH 71W-0265-08-044	YKM-SH 71 West - 0265-08-044.PDF	Plans	×
☐	1033	YKM-SH 71-0266-01-055	YKM-SH 71-0266-01-055.PDF	Plans	×
☐	1032	ATL-US47-0218-04-008	ATL-US 47-0218-04-008.pptx	Plans	×
☐	1031	ATL-US79-0063-11-051	ATL-US 79-0063-11-051.pptx	Plans	×
☐	1030	ATL-US79-0063-11-039	ATL-US 79-0063-11-039.pptx	Plans	×
☐	1029	ATL-US59-0063-04-047	ATL-US 59-0063-04-047.pptx	Plans	×
☐	1028	DAL-IH635-2964-01-015	DAL-IH 635-2964-01-015.pptx	Plans	×
☐	1027	DAL-IH635-2374-01-112	DAL-IH 635-2374-01-112.pdf	Plans	×

1 2 3 4 5 6 7 8 9 10 ...

Delete All

Result of Deletion :

Figure 6.13 Update Survey Data Window

The TxRPDB web-based interface enables the administrators to efficiently upload and update test data to the database and facilitates easy access to the data from a centralized TxRPDB system.

6.7 Summary

In this chapter, details of an advanced and user-friendly database and web-based interface called TxRPDB (Texas Rigid Pavement Database) were described. TxRPDB accommodates easy and convenient access to the pavement performance data. The information collected and analyzed in this research project is expected to be useful for TxDOT in evaluating the effectiveness of and in identifying the areas of needed improvements in their pavement designs, material selection, and construction practices.

Chapter 7 Calibration of TxCRCP-ME

One of the primary objectives of this project is to develop information that can be used to calibrate CRCP mechanistic-empirical design software, called TxCRCP-ME, which was developed under TxDOT research project0-5832. Because it is believed that punchout is the only structural distress in CRCP, development of correct transfer function and proper calibration are essential for the accuracy of TxCRCP-ME. Transfer function relates cumulative damage incurred in concrete pavement to actual occurrence of distresses. In this chapter, the developed transfer function and a user's guide for TxCRCP-ME are provided.

7.1 Transfer Function Developed under 0-5832

A transfer function provides the conversion of cumulative damage in concrete to the number of punchouts per lane mile. In the mechanistic-empirical pavement design procedure, developing an accurate transfer function is quite critical, as it correlates the mechanic phase (i.e., damage) to the empirical phase (i.e., distress) as indicated in Figure 7.1.

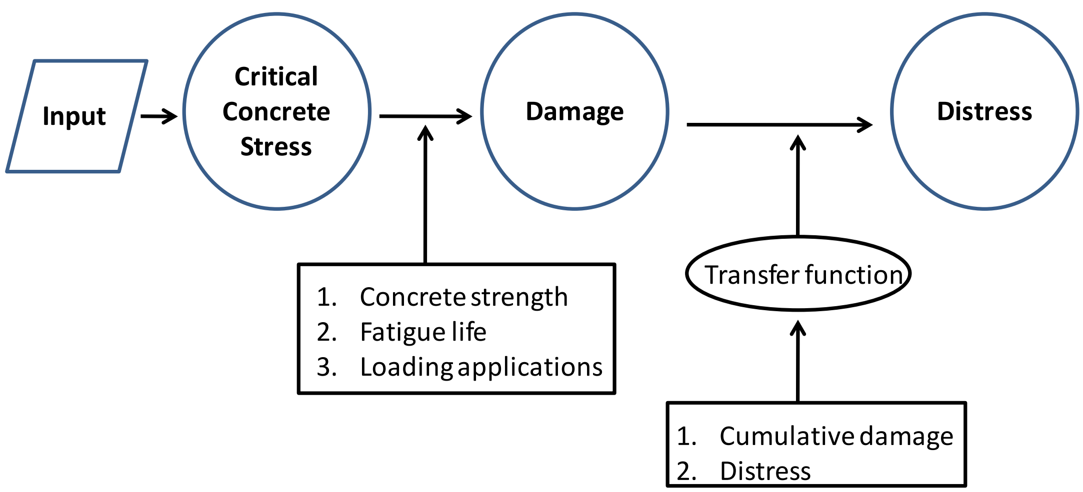


Figure 7.1 Overall algorithm of mechanistic-empirical CRCP design procedure

Under TxDOT Research Project 0-5832 (Develop Mechanistic-Empirical Design for CRCP), an initial version of transfer function was developed based on the traffic information in PMIS.

PMIS provides present annual daily traffic (ADT) and future 20-year ESAL for pavements in Texas. PMIS data from 2009 was used for this purpose. The process used for the development of a transfer function was as follows:

1) CRCP sections with punchout information were selected.
2) Since there was about 2-year time lag between the traffic estimation and PMIS publication, it was assumed that the 20-yr ESAL was determined at 2007.
3) The total ESAL for 20 years from 2007 to 2027 was estimated in terms of one year ESAL at 2007 with an assumption of an annual traffic growth rate of 4 %.
4) For each selected section, the total ESAL from the completion of the project to Year 2009 was estimated, again with an assumption of an annual traffic growth rate of 4 %.
5) TxCRCP-ME was run with proper input values – values of most input variables are actual and not assumed, such as slab thickness, steel design, and subbase type and thickness. The most uncertain input variable was soil type. Assumptions were made on the soil type considering the geology of the surrounding areas. Damages were estimated at the end of 2009 for the selected CRCP sections.
6) The number of punchouts per lane mile was estimated from PMIS punchout data. It was assumed that concrete patches were to repair punchout, and accordingly the number of patches was included as punchouts.
7) With cumulative damage as an independent variable and corresponding the number of punchouts per mile as a dependent variable, a transfer function was developed based on the least sum of error principle.
8) The transfer function thus developed was incorporated in TxCRCP-ME for the prediction of punchouts and CRCP design.

Table 7.1 illustrates the data used for the transfer function development in TxDOT Research Project 0-5832. Since it turned out that the data on US290 in Houston was not quite valid, a transfer function was constructed after the data on US290 section was removed. Figure 7.2 shows an initial version of transfer function developed, which correlates the cumulative damage and the corresponding number of punchout per lane mile.

Table 7.1 Pavement and punchout information used for transfer function development

District	County	Highway	Year Built	RDBD	Slab Thickness	Subbase	Begin	End	Length (Miles)	Traffic (Mil ESAL)	Cum Damage	# PO	#AP	#CP	PO Rate
Atlanta	Bowie	US59	2001	R1	12	4-in AC	0220+01.6	0222+01.5	1.9	12.6	0.90	2	0	0	1.1
Dallas	Dallas	SL12	1963	L1	6	6-in LTS	0628+01.0	0630+00.5	1.5	7.05	7.90	8	0	8	10.7
El Paso	Hudspeth	IH10	1995	L1	13	4-in AC	0096+00.5	0107+00.5	11	36.8	2.00	5	0	12	1.5
Ft Worth	Tarrant	IH 20	1985	R1	8	4-in AC + LTS	0423+00.5	0429+00.5	6	12.5	4.64	11	0	10	3.5
Houston	Harris	US290	1985	R1	10	1-in AC + 6-in CSB	0732+00	0736+00	4	41.3	6.37	19	0	31	12.5
Lubbock	Lubbock	IH27	1982	R1	9	4-in AC	0018+00.0	0021+00.2	3.2	11.2	2.75	11	0	7	5.6
WFS	Wichita	US287	1970	R1	8	4-in AC	0326+00.0	0328+00.6	2.6	34	12.62	6	0	27	12.7

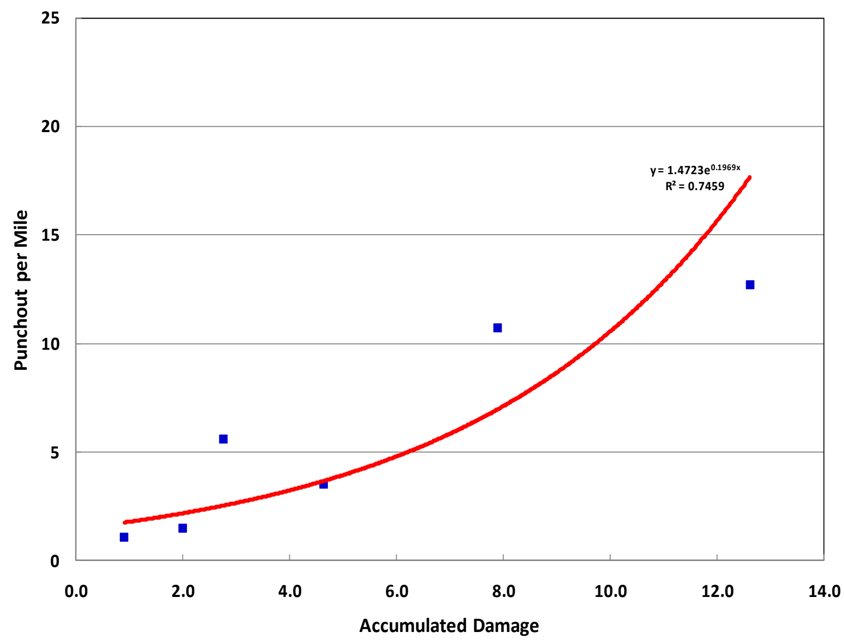


Figure 7.2 Transfer Function in TxDOT Research Project 0-5832

Because the previous version of transfer function only included the limited number of data points, a continued refinement using extensive field data sets has been made in this project to improve the accuracy of a transfer function, and in turn, the reliability of the TxCRCP-ME software.

7.2 Transfer Function Developed under 0-6274

7.2.1 Description of Selected Projects

When the initial transfer function (0-5832) was developed, 26 lane miles were used from five projects. Hence, the limited data was a disadvantage of that. However, 40 projects comprising 139 lane miles were used to develop the improved transfer function in the present research. Figure 7.3 illustrates a number of projects and distribution of the highways used for the improved transfer function development as per the District. As can be seen in Figure 7.3, the highways used are distributed throughout west, east, north, and south Texas. Since there are no CRCPs in the Corpus Christi and the Pharr Districts, it can be considered that environmental factors in Texas would be reflected in the improved transfer function. Hence, it is believed that the highway information for the improved transfer function is enough to represent structural performance of Texas CRCP.

Figure 7.4 also shows the slab thickness distribution with different construction year for the projects. The majority of the projects have a slab thickness of 10 in. or 12 in. The slab thickness has gradually increased over the years. Figure 7.5 illustrates the frequency of the selected projects for each slab thickness. As discussed above there are sixteen projects with 10 in. slab thickness and ten projects with 12 in. slab thickness.

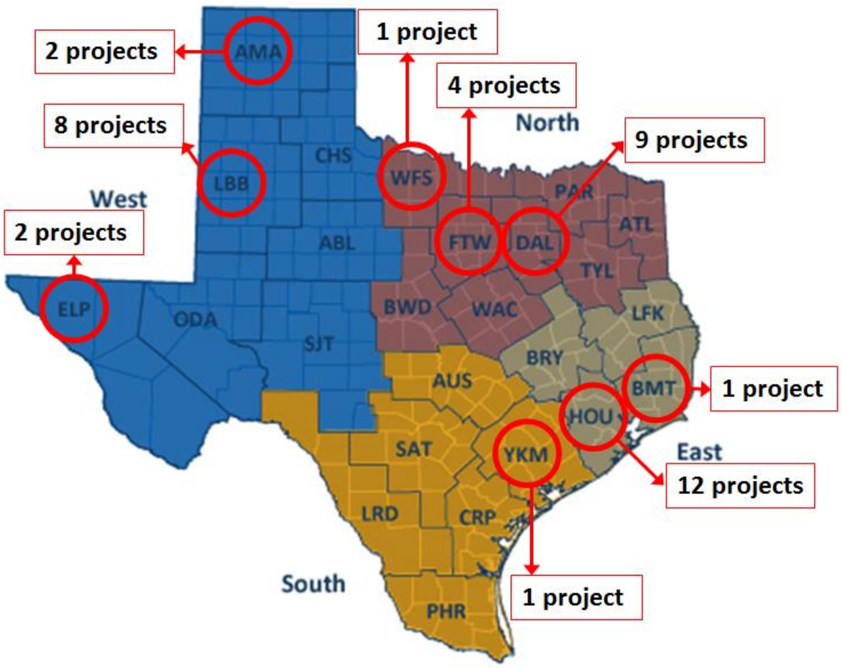


Figure 7.3 Number of Project and Distribution as per District

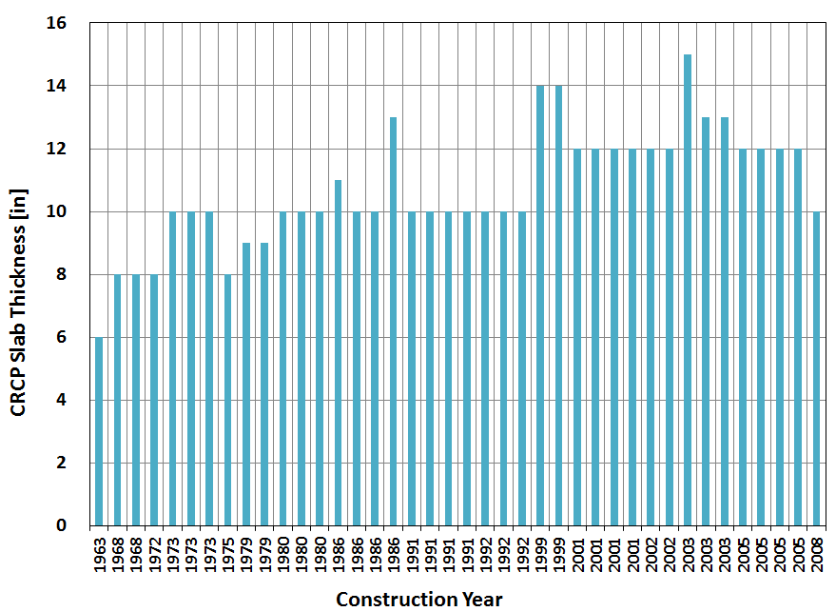


Figure 7.4 Slab Thickness Distribution vs. Construction Year

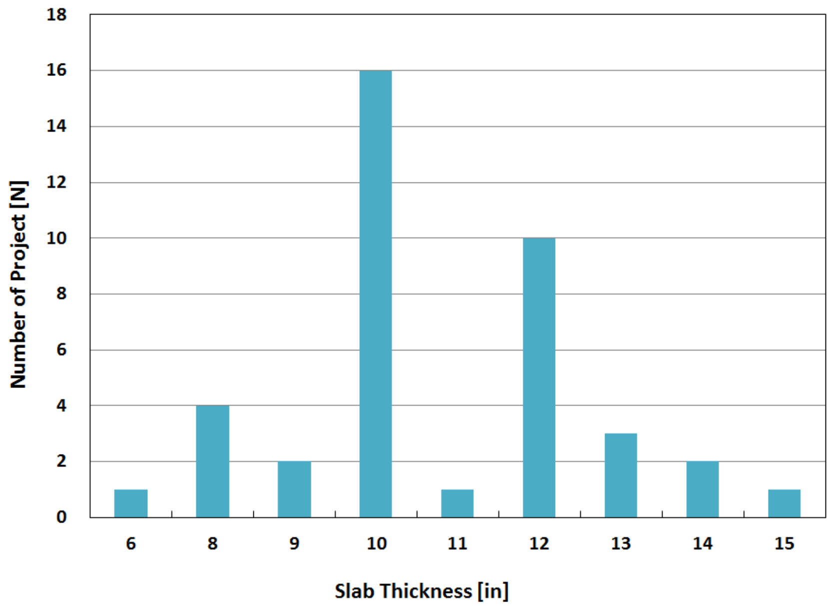


Figure 7.5 Number Project Distribution vs. Slab Thickness

Table 7.2 shows the highway information used to develop the improved transfer function. The information of Table 7.2 includes basic information such as District, County, construction year, highway, reference marker, slab thickness and project length. The detailed information of highways is provided in Appendix B, which includes traffic analysis, distresses information based on 2010 TxDOT PMIS and damage calculation.

Table 7.2 Project Summary for Transfer Function Development (Improved)

NO	Dist.	County	Construction Year	Highway/ Reference Marker	Slab Thickness [in]	Project Length [lane mile]
1	WFS	243	1972	US0287 [RM 322.0-329.0]	8	4.40
2	AMA	33	1979	IH0040 L [RM 110.0-114.5]	9	4.50
3	AMA	91	1979	IH0040 R [RM 110.0-115.5]	9	5.70
4	HOU	85	1986	FM1764 [RM 704.0-708.0]	11	5.50
5	HOU	85	1973	IH0045 L [RM 15.0-18.0]	10	3.00
6	HOU	85	2001	IH0045 L [RM 18.5-21.0]	12	2.50
7	HOU	85	1999	IH0045 L [RM 21.0-23.5]	14	2.50
8	HOU	85	1980	IH0045 R [RM 11.0-12.5]	10	1.50
9	HOU	85	1973	IH0045 R [RM 13.0-15.0]	10	2.00
10	HOU	85	1973	IH0045 R [RM 15.5-18.0]	10	2.50
11	HOU	85	2001	IH0045 R [RM 18.5-21.0]	12	2.50
12	HOU	85	1999	IH0045 R [RM 21.0-23.5]	14	2.50
13	YKM	76	1991	SH0071 [RM 636.0-640.0]	10	8.60
14	DAL	57	1975	IH0045 [RM 279.5-281.5]	8	4.00
15	DAL	57	1963	SL0012 [RM 629.0-632.0]	6	5.00
16	DAL	57	2008	SL0354 [RM 256.0-258.0]	10	4.00
17	DAL	43	1968	US0075 L [RM 249.0-252.0]	8	3.50
18	DAL	43	1968	US0075 R [RM 249.0-252.0]	8	3.00
19	DAL	19	2001	US0059 L [RM 221.6-224.0]	12	2.40
20	DAL	183	2002	US0059 L [RM 313.0-315.0]	12	2.00
21	DAL	19	2001	US0059 R [RM 221.6-224.0]	12	2.40
22	DAL	183	2002	US0059 R [RM 313.0-315.0]	12	2.00
23	BMT	181	2003	IH0010 [RM 855.2-860.8]	15	10.60
24	LBB	152	1991	IH0027 [RM 0.0-1.5]	10	1.50
25	LBB	152	1992	IH0027 L[RM 1.5-4.0]	10	2.50
26	LBB	96	1986	IH0027 L [RM 44.0-49.0]	10	5.00
27	LBB	152	1991	IH0027 R [RM 0.0-1.5]	10	1.50
28	LBB	152	1992	IH0027 R [RM 1.5-4.0]	10	2.50
29	LBB	152	1991	IH0027 R [RM 4.0-5.0]	10	1.00
30	LBB	152	1992	IH0027 R [RM 5.0-6.0]	10	1.00
31	LBB	96	1986	IH0027 R [RM 44.0-49.0]	10	5.00
32	ELP	72	2003	IH0010 L [RM 30.0-35.0]	13	2.50
33	ELP	72	2003	IH0010 R [RM 30.0-35.0]	13	2.50
34	HOU	102	1980	US0290 L [RM 732.0-734.5.5]	10	3.50
35	HOU	102	1986	US0290 R [RM 729.5-730.5]	13	1.00
36	HOU	102	1980	US0290 R [RM 732.0-734.5.5]	10	3.50
37	FTW	182	2005	IH0020 L [RM 376.5-381.5]	12	5.00
38	FTW	182	2005	IH0020 L [RM 381.5-386.5]	12	5.00
39	FTW	182	2005	IH0020 R [RM 377.0-381.5]	12	4.50
40	FTW	182	2005	IH0020 R [RM 381.5-386.5]	12	5.00

7.2.2 Traffic Analysis

The cumulative traffic from the time the project was opened to traffic was estimated using traffic information in the PMIS. The PMIS provides average daily traffic (ADT) and percent trucks for each year from 1993 to 2010. The yearly equivalent single axle load (ESAL) was estimated as follows:

1) Use 1.2 for equivalent axle load factor for trucks, and 0.7 for lane distribution factor
2) Determine daily ESAL by ADT×percent truck×1.2
3) Determine yearly ESAL by daily ESAL×365×0.7

If the construction year is older than 1993, two different ways were applied to estimate the ESAL. For the first, if the annual ESAL estimation follows the trend shown in Figure 7.6, the ESAL values from the construction of the projects to 1993 were estimated by extrapolation with the regression equation. Figure 7.6 shows an example of the annual ESAL variations from 1993 to 2010 for IH 27 in the Lubbock District, along with the regression equation. The second method for the ESAL estimation is to apply 3% growth rates. Figure 7.7 shows the other types of trend for the annual ESAL. Since there is no trend of the annual ESAL, the ESAL values from the construction of the projects to 1993 were estimated by 3% growth rates.

The cumulative traffic for each project was estimated by summing up all the annual ESAL from the opening of the projects to 2010 as illustrated in Appendix B.

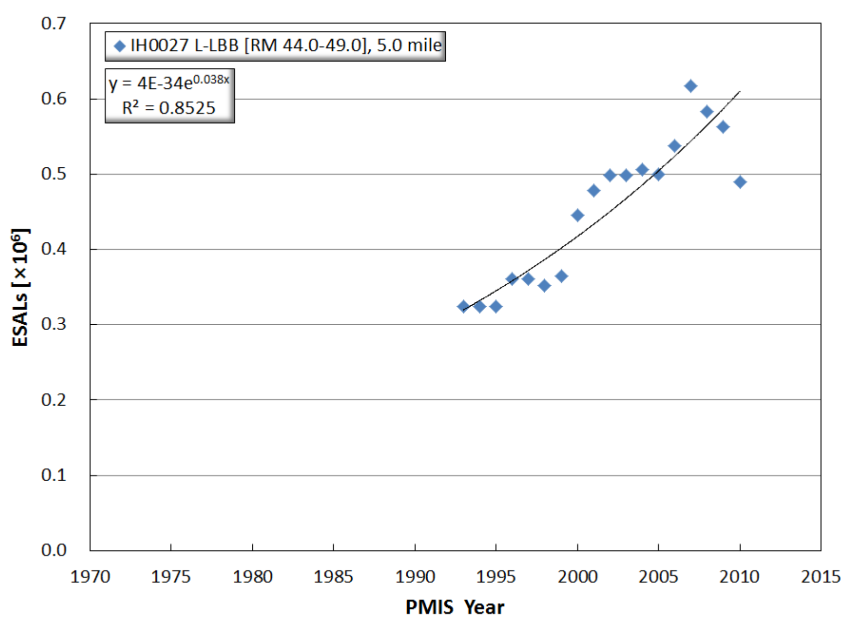


Figure 7.6 Annual ESAL Estimation (regular)

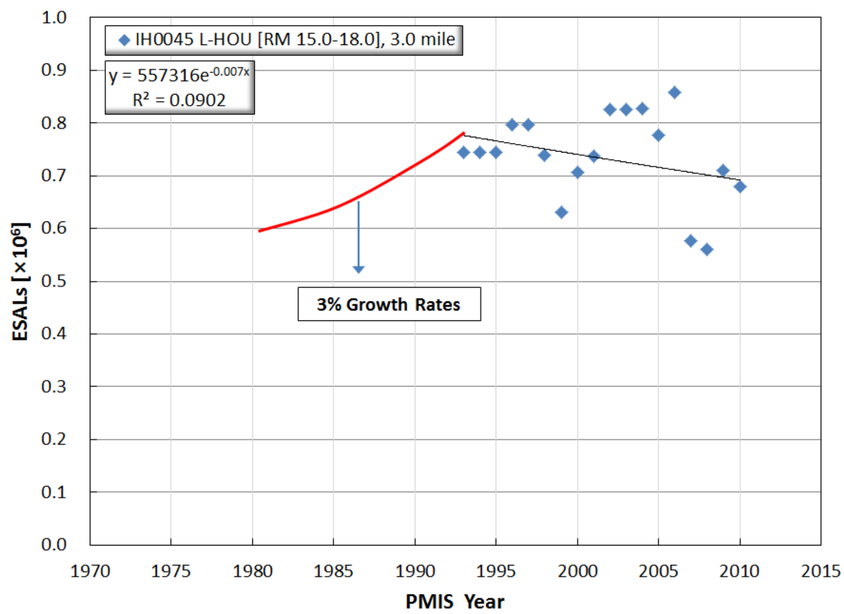


Figure 7.7 Annual ESAL Estimation (irregular)

7.2.3 Transfer Function for TxCRCP-ME

Based on information from Table 7.2, the improved transfer function was developed as shown in Figure 7.8. In Figure 7.8, the Y-axis represents the number of distresses including punchout (PCH), asphalt concrete patch (ACP) and Portland cement concrete patch (PCP) per lane mile, and X-axis represents the cumulative damage due to traffic load. Since the number of distresses includes all distresses except spalling, the improved transfer function is more conservative than the function that can be developed by using real structural punchout values on the basis of the field punchouts survey. As discussed in Chapter 2, only 14.2 % of the punchouts in the PMIS were structural punchouts based on field survey results. From a design standpoint, even though the improved transfer function was developed at 50 % level of reliability, it can be considered that the transfer function contains a safety factor because 14.2 % of punchout recorded in PMIS are structural punchout.

Figure 7.9 shows a comparison between the transfer function developed under 0-5832 and the improved transfer function.

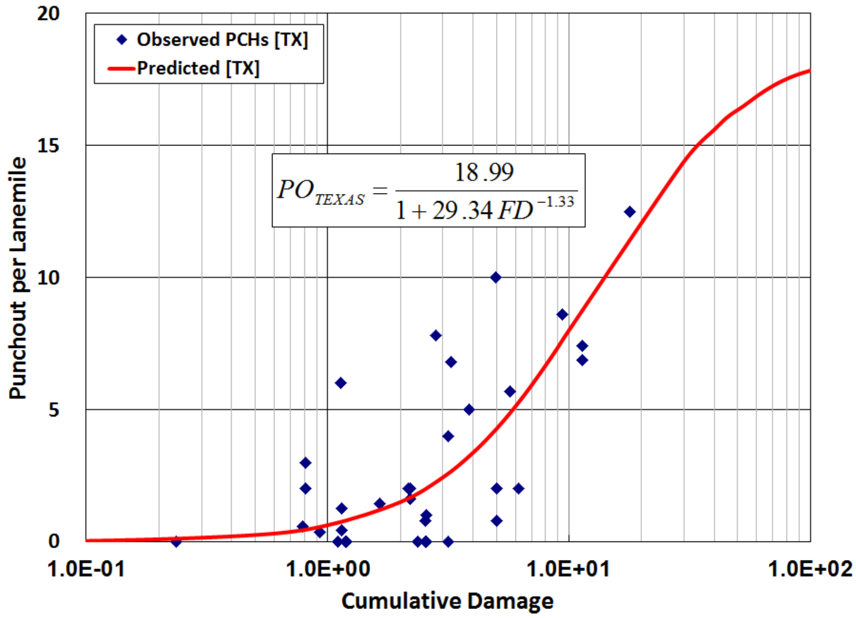


Figure 7.8 Transfer Function for TxCRCP-ME

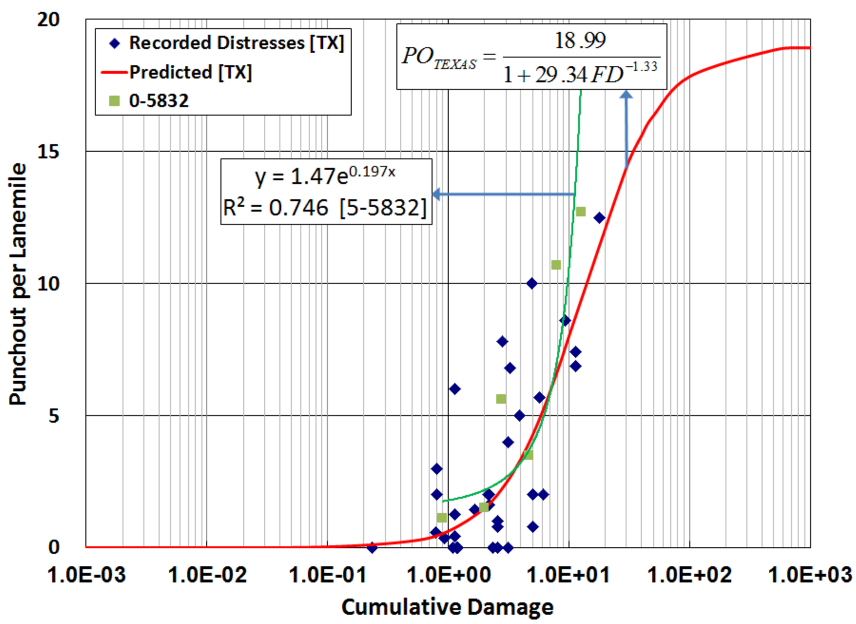


Figure 7.9 Comparison of Transfer Function between LTPP and Texas

7.3 User's Guide for TxCRCP-ME

7.3.1 Updated Features

A complete user's guide for TxCRCP-ME software was developed under TxDOT Research Project 0-5832 (the research report 0-5832-P3). In that project, an elaborate three-dimensional finite element analysis was conducted to identify the mechanisms of punchout distress in CRCP, and the critical stress component that may cause punchout distresses was mechanistically evaluated. A full factorial parametric study was performed for significant input variables to compile the database of the analysis results. A program was written using the 2007 version of Microsoft Excel to perform the analysis of the pavement system for given inputs in estimating the frequency of punchouts, the primary structural distress in CRCP. The conversion from mechanistic structural responses to pavement distress was achieved by a transfer function determined empirically, utilizing data collected from the TxDOT rigid pavement database project. The final results of the software were presented in the form of charts and tables. The file size of the software was about 200 MB, and the execution time for a single operation took up to two minutes.

The TxCRCP-ME was updated under the current project as some needed improvements to the software were detected in its initial version. Most of the contests remain the same with the previous version except for several items. As described previously, the previous version of TxCRCP-ME is operated based on a transfer function with the limited number of data points, which could compromise the reliability of output values. The newer version employed a more elaborate transfer function to improve the accuracy of the software. Another major problem of the initial version was that reading and finding data from the extensive database made the execution and loading times quite long. In the newly developed version, all stress tables, which occupy most of the file size, were replaced with a single interpolation module (see Figure 7.10) to minimize both execution time and file size. The preliminary operations revealed that the interpolation module effectively simplified the process of finding stresses when a certain combination of the inputs was provided. Moreover, the macro functions offered by Microsoft Excel were applied to the newly updated program, which kept the program much lighter. As a result, the file size could be reduced to only 1.6 MB while keeping the exactly identical modules with the initial program. Additional updated features are as follows:

- The execution time is less than 25 seconds with Microsoft Office Package 2007 and is rather prompt with Microsoft Office Package 2010.
- The upper limit of composite *k*-value was extended to 1500 pci (formerly 500 pci) using an extrapolation method as illustrated in Figure 7.11.

K	L	M	N
	Input	L Bound	U Bound
H	6	6	8
Kv	100	100	300
RHO	0.60	0.60	0.70
SHR	300	300	500
CTE	4	4	5.5
Kh	300	300	500

P	Q	R	S	T	U	V	W	X
	H	Kv	RHO	SHR	CTE	Kh	STR_T	STR_E
1	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0
1	6	100	0.6	300	4	300	424.33	138.3
2	6	100	0.6	300	4	500	424.33	138.3
3	0	0	0	0	0	0	0	0
3	6	100	0.6	300	5.5	300	424.33	129.09
4	6	100	0.6	300	5.5	500	424.33	129.09
5	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0
5	6	100	0.6	500	4	300	424.33	137.36

Z	AA	AB	AC	AD	AE	AF	AG	AH	AI
DT	###	H	Kv	RHO	SHR	CTE	Kh	STR_T	STR_E
-55	1	6	100	0.6	300	4.0	300	424.33	138.30
	2	6	100	0.6	300	4.0	500	424.33	138.30
	3	6	100	0.6	300	5.5	300	424.33	129.09
	4	6	100	0.6	300	5.5	500	424.33	129.09
	5	6	100	0.6	500	4.0	300	424.33	137.36
	6	6	100	0.6	500	4.0	500	424.33	137.36
	7	6	100	0.6	500	5.5	300	424.33	128.19
	8	6	100	0.6	500	5.5	500	424.33	128.19
	9	6	100	0.7	300	4.0	300	390.69	139.67
	10	6	100	0.7	300	4.0	500	390.69	139.67
	11	6	100	0.7	300	5.5	300	390.69	130.61
	12	6	100	0.7	300	5.5	500	390.69	130.61
	13	6	100	0.7	500	4.0	300	390.69	138.95
	14	6	100	0.7	500	4.0	500	390.69	138.95
	15	6	100	0.7	500	5.5	300	390.69	129.95
	16	6	100	0.7	500	5.5	500	390.69	129.95
	17	6	300	0.6	300	4.0	300	343.15	138.69
	18	6	300	0.6	300	4.0	500	343.15	138.69
	19	6	300	0.6	300	5.5	300	343.15	129.59
	20	6	300	0.6	300	5.5	500	343.15	129.59
	21	6	300	0.6	500	4.0	300	343.15	137.94
	22	6	300	0.6	500	4.0	500	343.15	137.94
	23	6	300	0.6	500	5.5	300	343.15	128.92
	24	6	300	0.6	500	5.5	500	343.15	128.92
	25	6	300	0.7	300	4.0	300	313.62	140.98
	26	6	300	0.7	300	4.0	500	313.62	140.98
	27	6	300	0.7	300	5.5	300	313.62	132.11
	28	6	300	0.7	300	5.5	500	313.62	132.11
	29	6	300	0.7	500	4.0	300	313.62	140.41
	30	6	300	0.7	500	4.0	500	313.62	140.41
	31	6	300	0.7	500	5.5	300	313.62	131.64
	32	6	300	0.7	500	5.5	500	313.62	131.64
	33	8	100	0.6	300	4.0	300	327.76	138.66
	34	8	100	0.6	300	4.0	500	327.76	138.66
	35	8	100	0.6	300	5.5	300	327.76	129.59
	36	8	100	0.6	300	5.5	500	327.76	129.59
	37	8	100	0.6	500	4.0	300	327.76	138.04
	38	8	100	0.6	500	4.0	500	327.76	138.04

AA	AK	AL	AM	AN	AO	AP	AQ	AR	AS	AT	AU	AV
###	Kh		CTE		SHR		RHO		Kv		H	
1	424.33	138.30	424.33	138.30	424.33	138.30	424.33	138.30	424.33	138.30	424.33	138.30
2												
3	424.33	129.09										
4												
5	424.33	137.36	424.33	137.36								
6												
7	424.33	128.19										
8												
9	390.69	139.67	390.69	139.67	390.69	139.67						
10												
11	390.69	130.61										
12												
13	390.69	138.95	390.69	138.95								
14												
15	390.69	129.95										
16												
17	343.15	138.69	343.15	138.69	343.15	138.69	343.15	138.69				
18												
19	343.15	129.59										
20												
21	343.15	137.94	343.15	137.94								
22												
23	343.15	128.92										
24												
25	313.62	140.98	313.62	140.98	313.62	140.98						
26												
27	313.62	132.11										
28												
29	313.62	140.41	313.62	140.41								
30												
31	313.62	131.64										
32												
33	327.76	138.66	327.76	138.66	327.76	138.66	327.76	138.66	327.76	138.66		
34												
35	327.76	129.59										
36												
37	327.76	138.04	327.76	138.04								
38												

(a)

AX	AY	AZ
FINAL INTERPOLATION RESULTS		
INPUT		
Thickness of Concrete Layer (in.)		6.0
Composite k (psi/in.)		100
Longitudinal Steel (%)		0.60
Ultimate Drying Shrinkage (microstrain)		300
Coefficient of Thermal Expansion (microstrain/F)		4.0
Subbase Friction (psi/in.)		300
28-Day Modulus of Rupture (psi)		620
Variation of Concrete Stresses according to Temperature Change		
Temperature Change (F)	Concrete Stress (T) (psi)	Concrete Stress (E) (psi)
-55	424.33	138.30
-25	424.33	150.14
5	424.33	162.11
35	424.33	174.20
65	424.33	186.41
95	424.33	198.74

(b)

Figure 7.10 Interpolation Module: (a) Worksheet; (b) Final Result

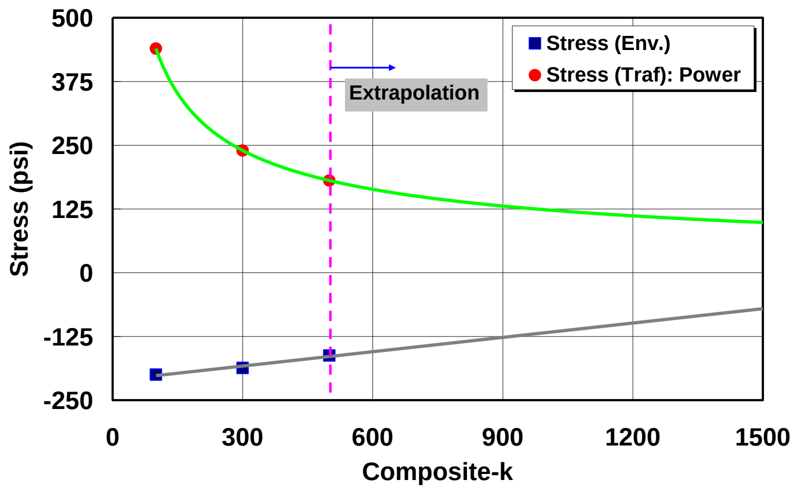


Figure 7.11 Extension of *k*-value Upper Limit Using Extrapolation Method

7.3.2 Framework of TxCRCP-ME

TxCRCP-ME design software is composed of four major operational modules as seen in the flow chart in Figure 7.12.

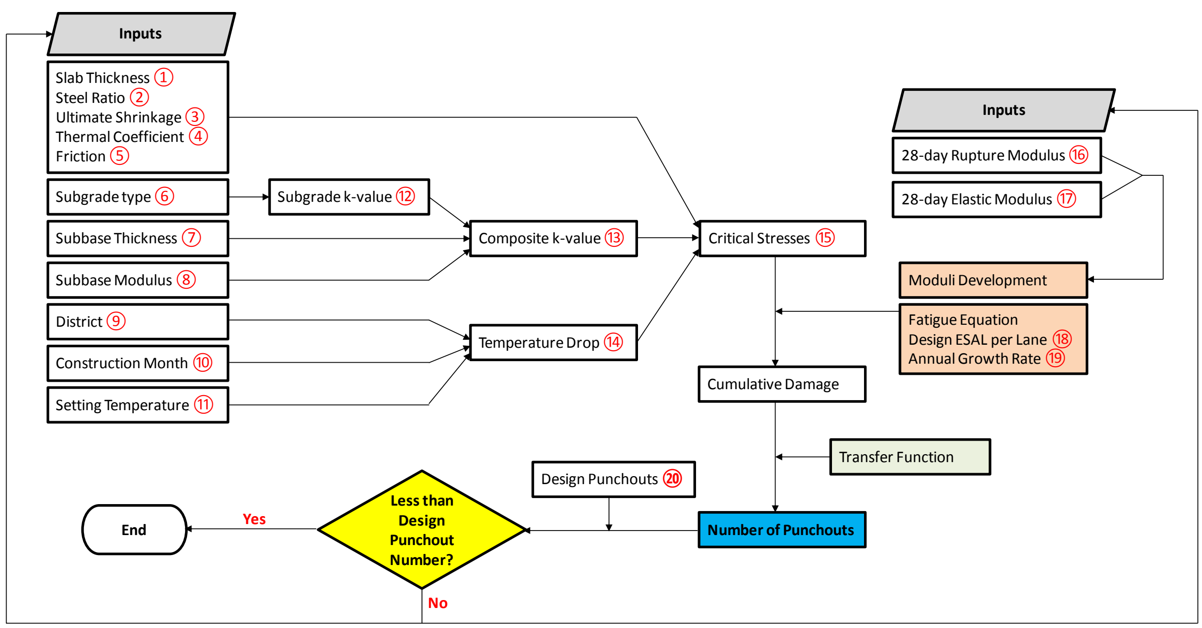


Figure 7.12 Architecture of TxCRCP-ME Software

7.3.2.1 General Inputs

The first step in using this software is to estimate the values for input variables related to material properties, design parameters, climate, and traffic. The required fields are presented in red, and the optional fields are presented in yellow as shown in Figure 7.13. If all the modules operate properly, computed outputs will be presented in appropriate cells in green. For the input variables, a red triangle on the upper right corner of the cell indicates that further helpful information is available for that input variable. To access the information, the user moves the cursor to the red triangle. After a value is typed for an input variable, the user presses the "Enter" key. Once all the input values are provided, "F9" is pressed to execute the program.

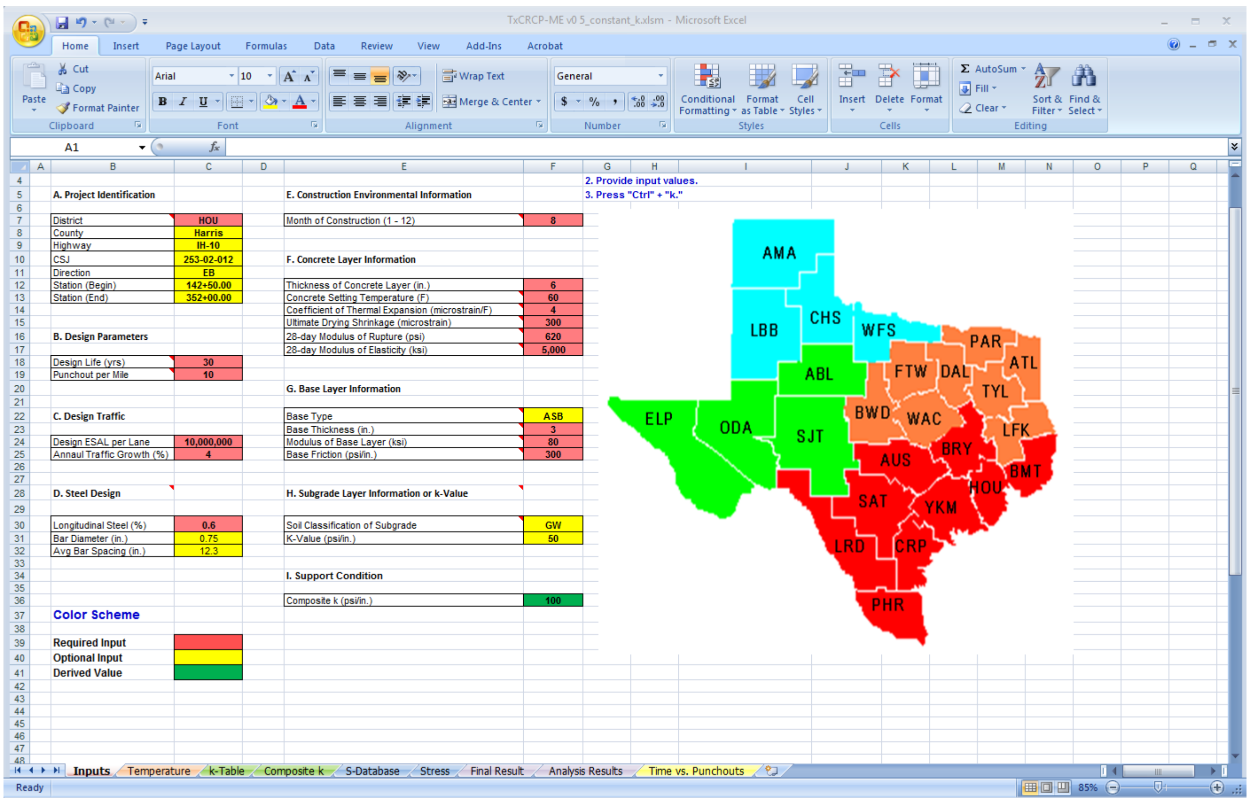


Figure 7.13 Input Screen of TxCRCP-ME

The description of the general input variables is as follows:

A. Project Identification

Provide general information of a project, i.e. district, county, highway, direction of construction, and stations. The "District" field is required to initiate the prescribed climatic data that will be used for the evaluation of stresses due to environmental loading. The input must be per the official abbreviation as shown in Table 7.3. All 25 TxDOT districts in the State of Texas are applicable to the district field. The other fields are optional. Once the design is completed, this screen can be printed for record in the project file.

Table 7.3 District Inputs

District	Abbreviation	District	Abbreviation
Abilene	ABL	Laredo	LRD
Amarillo	AMA	Lubbock	LBB
Atlanta	ATL	Lufkin	LFK
Austin	AUS	Odessa	ODA
Beaumont	BMT	Paris	PAR
Brownfield	BWD	Pharr	PHR
Bryan	BRY	San Angelo	SJT
Childress	CHS	San Antonio	SAT
Corpus Christi	CRP	Tyler	TYL
Dallas	DAL	Waco	WAC
El Paso	ELP	Wichita Falls	WFS
Fort Worth	FTW	Yoakum	YKM
Houston	HOU	-	-

B. Design parameters

Provide the design period in years and the design acceptable number of punchouts per mile. Currently, ten punchouts per mile is a nationally accepted value for the terminal condition of CRCP, even though a designer could select a more appropriate value depending on the importance of the highway system under analysis. The design acceptability will be based on those design parameters; if the predicted number of punchouts at the end of the design period is more than the design value, modification of input(s) is required.

C. Design traffic

Design traffic information is used to estimate the cumulative fatigue damage in a concrete layer. Two inputs must be designated in this part of the spreadsheet: the ESALs in a single design lane, and an annual traffic growth rate to consider the number of load repetitions over the design period. Characterization of traffic loading in terms of ESALs is based on the research study conducted at the University of Illinois, which shows the use of more detailed load spectra analysis does not improve the accuracy of pavement design (Bordelon, 2009).

D. Steel design

Longitudinal steel ratio is one of the most important factors determining the magnitude of the critical stress in the concrete layer. Any ratio between 0.5 to 0.7 % can be provided by the user. From a practical standpoint, users should start with 0.6 %. Once slab thickness is determined that will satisfy the limits for punchouts at the end of the design life, TxDOT CRCP Design Standards need to be consulted to get the steel design information. The program needs to run again with the steel design information from the TxDOT Design Standards to double-check the acceptability of the design selected. Either bar diameter or average spacing must be provided. The program calculates the other variable.

It should be noted that the inference space used for the development of a transfer function for steel design variables is quite limited. The accuracy of the CRCP design could be compromised if the ranges of the steel design variables are out of the normal ranges used in Texas. It is advised that steel design variables are not used to adjust the required slab thickness. Steel designs for transverse steel and tie bars are not included. They should be governed by TxDOT CRCP Design Standards.

E. Construction environmental information

Provide the month of construction in a numeric value (1 to 12). The information will be used for the evaluation of environmental stresses. During the design phase, it might be difficult to project when the concrete placement will be made. Even in a single project, there could be different phases of construction. From a practical standpoint, it will be quite difficult to determine the month of concrete placement. If the concrete placement month is not known during the design phase, the selection of May or June is recommended as a default input.

F. Concrete layer information

Provide the concrete layer information. The ranges of user-defined concrete properties are presented in Table 7.4.

Table 7.4 Range of Concrete Property Inputs

Property	Range	Unit	Note
Thickness of Concrete Layer	6 to 14	in.	Required
Coarse Aggregate Type in Concrete[1]	SRG, CLS, or GRN	n/a	Optional
Concrete Setting Temperature	No restriction	°F	Required
Coefficient of Thermal Expansion	4 to 7	10^{-6} in./in./°F	Required
Ultimate Drying Shrinkage	500	10^{-6} in./in.	Required
28-day Compressive Strength	300 to 600	psi	Optional
28-day Modulus of Rupture	No restriction	psi	Required
28-day Modulus of Elasticity	No restriction	ksi	Required

Concrete modulus of elasticity depends on concrete strength and coarse aggregate type used. However, the correlation is not precise and there is a large variability. In this version of the program, the modulus of elasticity of concrete is a direct input. For guidance on the selection of this value, contact the Rigid Pavements and Concrete Materials Branch of CSTMP in Austin.

---

[1] If this information is available during pavement design, provide the information: SRG for siliceous river gravel, CLS for calcareous limestone, and GRN for granite.

Slab thickness is an input and should be provided by the user. In that sense, this program is not a design program, but rather an analysis program.

G. Subbase layer information

Provide the subbase type, subbase thickness, modulus of subbase layer, and subbase friction. Table 7.5 shows the input variables and acceptable ranges of the variables.

Table 7.5 Ranges of Subbase Properties

Property	Range	Unit	Note
Subbase Type[2]	ASB, CSB, or OTHER	n/a	Optional
Thickness of Subbase	2 to 6	in.	Required
Modulus of Subbase Layer	50 to 2000	ksi	Required
Subbase Friction	100 to 500	psi/in.	Required

H. Subgrade layer information

Provide the soil classification per AASHTO or Unified Classification System as follows in Table 7.6. If the modulus of subgrade reaction value of the soil is known, provide the number, instead of soil classification. If both soil classification and *k*-value are provided, *k*-value will be automatically utilized.

Table 7.6 Classification of Soil

Description	AASHTO	Unified
Gravel	A-1-a	GW or GP
Coarse Sand	A-1-b	SW
Fine Sand	A-3	SP
Silty Gravel or Sand	A-2-4 or A-2-5	GM or SM
Clayey Gravel or Clayey Sand	A-2-6	GC or SC
Clayey Gravel or Clayey	A-2-7	GC or SC

[2] Type ASB for asphalt stabilized subbase or CSB for cement stabilized subbase. Type OTHER for other types of subbase.

Gravelly Sand		
Sit or Silt/sand/gravel mixture	A-4	ML or OL
Poorly Graded Silt	A-5	MH
Plastic Clay	A-6	CL
Moderately Plastic Elastic Clay	A-7-5	CL or OL
Highly Plastic Elastic Clay	A-7-6	CH or OH

I. Support condition

Composite k-value is derived internally based on the input values provided for the subbase thickness, modulus of subbase layer and subgrade soil type or *k*-value; the details of the composite *k*-value evaluation can be found in Appendix A of the research report, 0-5832-1. In this program, subgrade stiffness is characterized by modulus of subgrade reaction (*k*), and that of the subbase by modulus of elasticity. Once the subbase and subgrade layer information is provided in the spreadsheet, the composite k-value is computed internally.

J. CRCP performance

Combining all the information provided above, the number of punchouts at each month and at the end of the design period is estimated.

7.3.2.2 Critical Concrete Stress

In this module, the concrete stresses due to environmental loads (temperature and moisture variations in concrete) and wheel loads are evaluated. Based on the three-dimensional finite element analysis, it was identified that the critical concrete stress due to wheel loading occurs in the vicinity of longitudinal steel reinforcement (see Figure 7.14) at transverse cracked areas; the detailed scheme of the analysis can be found in Chapter 3 of the research report 0-5832-1 (Ha et al. 2012). The combined concrete stresses due to wheel and environmental loads are used in the fatigue damage estimation in the concrete slab.

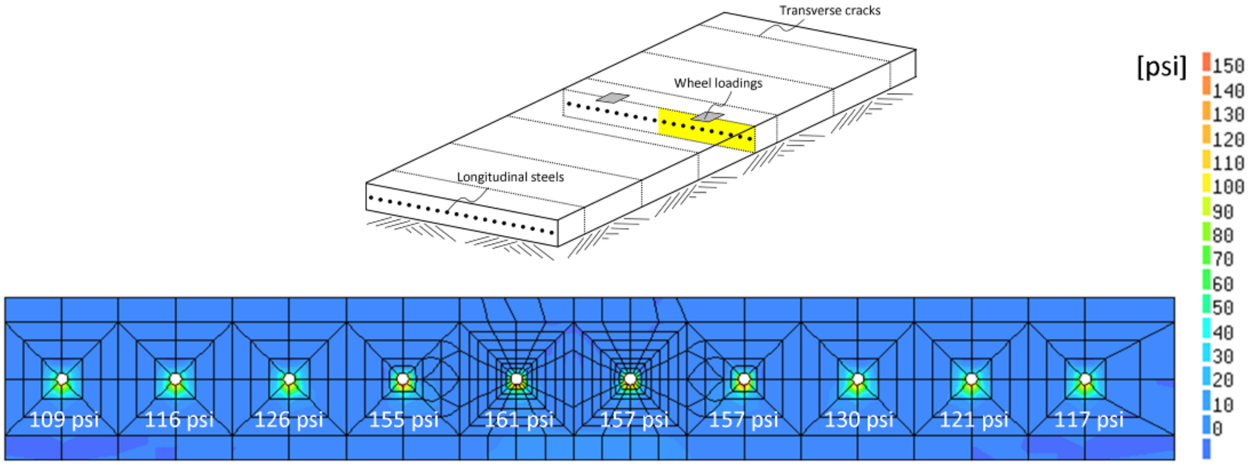


Figure 7.14 Principal Concrete Stresses under Wheel Loading

7.3.2.3 Damage Estimation

In this module, cumulative damage in the concrete slab due to environmental and traffic load applications are evaluated as shown below:

1. Fatigue damage evaluation: To predict the allowable fatigue number of the concrete layer, th e fatigue relationship developed by Vesic (Vesic and Saxena 1969) was employed. As can be seen in Equation (7.1), the fatigue number of concrete is dependent on the stress-strength rati o.

$$N_i = 225{,}000 \left(\frac{\sigma}{MR}\right)^4 \qquad (7.1)$$

where, N_i is the fatigue number; MR is the modulus of rupture (psi); and σ is the tensile concrete stress (psi).

This equation was developed using the modulus of rupture for plain concrete. The fatigue behavior of concrete near longitudinal steel might be slightly different. There are no equations available for the fatigue behavior of concrete near reinforcement due to static and dynamic loading. However, as long as there is no large difference in the shape of the fatigue equations, errors due to not using the exact fatigue equation will be minimized by the selection of a proper transfer function.

For concrete stress, the value in the vicinity of longitudinal steel reinforcement derived from three-dimensional analysis was used for Equation (7.2). To consider the rate of concrete strength development over time, the model proposed by ACI 209 was employed.

$$f'_{c(t)} = f'_{c(28)} \left(\frac{t}{4+0.85t}\right) \qquad (7.2)$$

where, $f'_{c(t)}$ is the compressive strength at age t (psi); $f'_{c(28)}$ is the compressive strength at 28-day (psi); and t is the age in day.

Since the modulus of elasticity of concrete is proportional to the square root of the compressive strength, the rate of increase in modulus of elasticity over time takes the form of the square root of the time factor in Equation (7.2).

2. Cumulative damage estimation: This allowable load repetitions number (fatigue number) in t urn, was used for the damage prediction. The damage ratio–the ratio between the number of l oad repetitions and the allowable number of load repetitions–was calculated for each month a nd summed over every month, up to the end of the design period, to estimate total cumulative damage. To estimate the number of load repetitions over the design period, the design ESAL s and an annual traffic growth rate input values were used. Damage was computed using Equ ation (7.3).

$$D = \sum \frac{n_i}{N_i} \qquad (7.3)$$

where, D is the damage; N_i is the number of load repetitions to failure at the ith specified stress level (psi); and n_i is the number of load repetition at the ith specified stress level (psi).

7.3.2.4 Estimation of Number of Punchouts

To make a conversion from the accumulated damage to the actual number of punchout distresses in CRCP, a transfer function, which provides a relationship between accumulated damage and the number of punchouts per mile, was empirically derived based on the information from the TxDOT rigid pavement database. A transfer function is one of the most important elements in any mechanistic-empirical (ME) pavement design procedure. Reasonableness of any ME pavement design procedure depends to a great extent on the accuracy of a transfer function. Small errors in the estimation of concrete stresses in the “mechanistic” portion of ME design procedures do not necessarily cause inaccuracy in the output of ME designs. Development of a proper transfer function will minimize any errors associated with inaccurate estimation of concrete stress. On the other hand, inaccuracies in a transfer function (“empirical” portion of ME design procedures) will have a direct and pronounced impact on the reasonableness of pavement designs from ME design procedures.

The transfer function suggested in this research project is as follows:

$$PO = \frac{18.99}{1+29.34FD^{-1.33}} \quad (7.4)$$

where, PO is the number of punchouts per lane mile; and FD is the cumulative damage over the period.

7.3.2.5 Output presentation

The last module of this program is the output presentation. The primary output result of this software is to assess the potential of punchout distress in CRCP over the design period. Table 7.7 and Figure 7.15 show examples of the output results.

Table 7.7 shows output results and is divided in the following columns:

1) 1st & 2nd columns: the pavement age in month and year scales, respectively.

2) 3rd & 4th columns: the development of modulus of rupture and modulus of elasticity, respectively.

3) 5th & 6th columns: environmental and wheel loading concrete stresses which were obtained from the three-dimensional finite element analysis. As described earlier, the concrete stress was evaluated in the vicinity of longitudinal steel reinforcement and transverse cracks.

4) 7th column: the sum stresses due to environmental and wheel loadings.

5) 8th column: a maximum stress ratio, the ratio between the critical concrete stress and the modulus of rupture.

6) 9th column: the number of allowable load repetitions to fatigue failure from equation (7.4).

6) 10th column: the number of actual load repetitions calculated from data provided by the user.

7) 11th column: pavement damage estimated for a specific month.

8) 12th column: accumulated pavement damage up to that month.

9) 13th column: the number of punchouts estimated from a transfer function in (7.4).

The output information is also presented in a graphical form for the number of punchouts per mile for various time periods up to the end of the design life. An example is shown in Figure 7.15.

Table 7.7 Output Table

Pavement Month	Age (Year)	Concrete Modulus of Rupture (psi)	Concrete Modulus of Elasticity (ksi)	Concrete Stress (E) (psi)	Concrete Stress (T) (psi)	Concrete Stress (psi)	Maximum Stress Ratio (psi/psi)	Number of Load Repetitions to Failure	Number of Load Repetitions	Pavement Damage	Cumulative Damage	Number of Punchouts per Mile
1	0.08	620	5.00E+03	187.2	52.9	240.2	0.387	3.93E+07	2.88E+05	7.33E-03	7.33E-03	0.02
2	0.17	676	5.45E+03	207.0	52.9	259.9	0.384	4.06E+07	2.89E+05	7.12E-03	1.44E-02	0.04
3	0.25	693	5.59E+03	218.8	52.9	271.7	0.392	3.75E+07	2.90E+05	7.74E-03	2.22E-02	0.06
4	0.33	702	5.66E+03	228.7	52.9	281.7	0.401	3.40E+07	2.91E+05	8.56E-03	3.07E-02	0.08
5	0.42	707	5.70E+03	236.1	52.9	289.0	0.409	3.15E+07	2.92E+05	9.28E-03	4.00E-02	0.11
6	0.50	711	5.73E+03	239.0	52.9	291.9	0.411	3.08E+07	2.93E+05	9.50E-03	4.95E-02	0.14
7	0.58	713	5.75E+03	237.0	52.9	289.9	0.406	3.23E+07	2.94E+05	9.11E-03	5.86E-02	0.17
8	0.67	715	5.77E+03	231.9	52.9	284.8	0.398	3.51E+07	2.95E+05	8.40E-03	6.70E-02	0.19
9	0.75	717	5.78E+03	227.9	52.9	280.9	0.392	3.76E+07	2.96E+05	7.88E-03	7.49E-02	0.22
10	0.83	718	5.79E+03	222.6	52.9	275.5	0.384	4.09E+07	2.97E+05	7.26E-03	8.22E-02	0.24
11	0.92	719	5.80E+03	218.4	52.9	271.3	0.377	4.37E+07	2.98E+05	6.82E-03	8.90E-02	0.26
12	1.00	720	5.81E+03	217.0	52.9	270.0	0.375	4.48E+07	2.99E+05	6.68E-03	9.57E-02	0.28
13	1.08	721	5.81E+03	217.7	52.9	270.6	0.375	4.45E+07	3.00E+05	6.73E-03	1.02E-01	0.30
14	1.17	721	5.82E+03	220.7	52.9	273.6	0.379	4.28E+07	3.01E+05	7.04E-03	1.09E-01	0.33
15	1.25	722	5.82E+03	227.9	52.9	280.8	0.389	3.87E+07	3.02E+05	7.81E-03	1.17E-01	0.35
16	1.33	722	5.83E+03	235.4	52.9	288.3	0.399	3.48E+07	3.03E+05	8.71E-03	1.26E-01	0.38
17	1.42	723	5.83E+03	241.3	52.9	294.2	0.407	3.20E+07	3.04E+05	9.50E-03	1.35E-01	0.41
18	1.50	723	5.83E+03	243.1	52.9	296.0	0.409	3.12E+07	3.05E+05	9.76E-03	1.45E-01	0.44
19	1.58	723	5.83E+03	240.3	52.9	293.2	0.405	3.26E+07	3.06E+05	9.38E-03	1.55E-01	0.47
20	1.67	724	5.84E+03	234.6	52.9	287.6	0.397	3.54E+07	3.07E+05	8.66E-03	1.63E-01	0.50
21	1.75	724	5.84E+03	230.2	52.9	283.1	0.391	3.78E+07	3.08E+05	8.14E-03	1.71E-01	0.53
22	1.83	724	5.84E+03	224.5	52.9	277.4	0.383	4.11E+07	3.09E+05	7.51E-03	1.79E-01	0.56
23	1.92	724	5.84E+03	220.0	52.9	273.0	0.377	4.39E+07	3.10E+05	7.06E-03	1.86E-01	0.58
24	2.00	725	5.84E+03	218.4	52.9	271.4	0.374	4.50E+07	3.11E+05	6.91E-03	1.93E-01	0.60
25	2.08	725	5.85E+03	218.9	52.9	271.8	0.375	4.47E+07	3.12E+05	6.98E-03	2.00E-01	0.62
26	2.17	725	5.85E+03	221.8	52.9	274.8	0.379	4.29E+07	3.13E+05	7.30E-03	2.07E-01	0.65
27	2.25	725	5.85E+03	228.9	52.9	281.8	0.389	3.88E+07	3.14E+05	8.10E-03	2.15E-01	0.68
28	2.33	725	5.85E+03	236.4	52.9	289.3	0.399	3.49E+07	3.15E+05	9.04E-03	2.24E-01	0.71
29	2.42	725	5.85E+03	242.2	52.9	295.1	0.407	3.21E+07	3.16E+05	9.85E-03	2.34E-01	0.74
30	2.50	726	5.85E+03	243.9	52.9	296.9	0.409	3.13E+07	3.17E+05	1.01E-02	2.44E-01	0.77
31	2.58	726	5.85E+03	241.1	52.9	294.0	0.405	3.27E+07	3.18E+05	9.74E-03	2.54E-01	0.81
32	2.67	726	5.85E+03	235.3	52.9	288.2	0.397	3.55E+07	3.19E+05	8.99E-03	2.63E-01	0.84
33	2.75	726	5.85E+03	230.8	52.9	283.7	0.391	3.79E+07	3.21E+05	8.45E-03	2.71E-01	0.86
34	2.83	726	5.86E+03	225.1	52.9	278.0	0.383	4.12E+07	3.22E+05	7.80E-03	2.79E-01	0.89
35	2.92	726	5.86E+03	220.5	52.9	273.5	0.377	4.40E+07	3.23E+05	7.33E-03	2.87E-01	0.91
36	3.00	726	5.86E+03	218.9	52.9	271.8	0.374	4.51E+07	3.24E+05	7.18E-03	2.94E-01	0.94

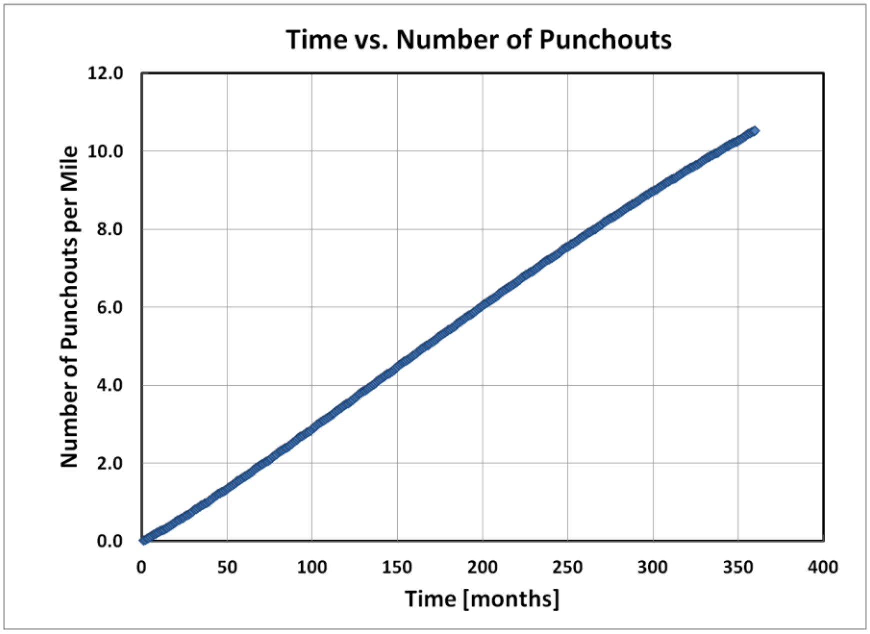


Figure 7.15 Number of Punchouts over the Design Period

Chapter 8 Conclusions and Recommendations

The primary objectives of this project included the collection of information on continuously reinforced concrete pavement (CRCP) behavior and performance in Texas to calibrate the AASHTO mechanistic-empirical pavement design guide (MEPDG) developed under NCHRP 1-37A, and the overall evaluation of rigid pavement performance in Texas, including special and experimental sections. To achieve these objectives, extensive efforts were made, mostly field testing and evaluations, which resulted in quite valuable findings as follows:

1. Overall performance of CRCP in Texas is excellent. The performance of jointed plain concrete pavement (CPCD) is not as good as that of CRCP; however, there are specific reasons for issues in CPCD performance, which could be and should be addressed by future research efforts.
2. The failure mode of CRCP has changed over the years. When the slab thickness, base support and slab edge support were deficient, the primary mode of failure was pumping and edge punchout. TxDOT changed its design and construction practices to address these issues by increasing slab thickness, the use of non-erodible base and tied concrete shoulder. Edge punchout occurs only in CRCP sections built before these changes were incorporated. With these changes implemented in the mid-80's, edge punchout is no longer a failure mode in CRCP sections built since then.
3. Primary failure mode of CRCP sections with improved design features is horizontal cracking followed by breakage of concrete above the mid-depth of the slab near longitudinal construction joints or under the wheel path.
4. In CRCP sections built in accordance with TxDOT CRCP design standards and specification Item 360 requirements, load transfer efficiency (LTE) is maintained at almost 100 percent level, and transverse crack spacing and crack widths existing in typical CRCP in Texas do not have any significant correlation with the pavement performance.
5. The majority of distresses in CRCP has been caused by quality issues of either materials or construction.
6. The effect of slab thickness on CRCP performance does not appear to be as great as some theoretical models or design equations predict. Adequate long-term slab support, along with adequate slab thickness, appears to be the key to good performance of CRCP.
7. The punchout model in MEPDG is not applicable to CRCP in Texas. The assumptions that crack width increases over time, resulting in LTE deterioration were not validated in this study. LTE values at transverse cracks imminent to punchout were maintained at

quite a high level. Also, the assumption of a good correlation between crack spacing and crack width was not validated.

8. The season of concrete placement does not appear to affect CRCP performance, as long as the temperature of the concrete delivered at the job site meets Item 360 requirement.
9. Typical distresses in CPCD are related to transverse contraction joints. Where base support is not adequate or there are volume changes in the base or subgrade, slab cracking is a major distress type in CPCD.
10. The performance of fast-track concrete pavement (FTCP) has been quite satisfactory. This pavement type should remain as an option for pavement type selection for locations where closing the section causes excessive traffic delays and primary traffic consists of light trucks or passenger vehicles.
11. Variations exist in the performance of bonded concrete overlays (BCO). In general, the larger the overlay thickness is, the better the performance. However, it appears that the structural condition of existing CRCP in terms of slab deflections plays an important role in the performance of BCO. If deflections in the existing CRCP are large, BCO may not be a good candidate.
12. The number of cast-in-place post-tensioned concrete pavement projects is quite limited, and positive conclusions cannot be made regarding the long-term performance and cost-effectiveness of that pavement type.

In addition, the following specific conclusions can be drawn based on the field work performed in this project:

1. Concrete with siliceous river gravel (SRG) coarse aggregate had more significant potential for spalling distress than that with limestone (LS), as SRG concrete typically has somewhat higher coefficient of thermal expansion (CTE) and smoother surface texture, resulting in poor bond condition between aggregate and cement paste.
2. For concrete with spalling-susceptible coarse aggregate (i.e., SRG), there was a strong correlation between steel percentage and spalling distress. The larger the steel amount, the lower the frequency of spalling. On the other hand, for concrete with coarse aggregate with lower spalling potential (i.e., LS), the effect of transverse crack spacing or longitudinal steel amount on spalling was non-existent.
3. No clear tendency was found between early-age concrete temperature and transverse crack spacing. It appears that the combined effect of other factors such as age, geometry, steel amount, material property, restraint condition, and environmental conditions was more dominant than that of temperature itself.

4. Modifications in batching sequence, mixture design, and curing method were not effective in mitigating spalling distress in CRCP with SRG. All the subsections showed a number of spalling distresses in progress, irrespective of the test variables.
5. There was no clear correlation between crack spacing and deflections, which indicates the efficiency of longitudinal steel in providing the continuity of slabs at transverse cracks.
6. The 6-in cast-in-place PTCP performed well for the last 28 years, except a couple of minor distresses. The 9-in one built in 2008 showed no structural or functional distresses thus far, performing quite well even with a high level of heavy truck traffic.
7. This project developed a user-friendly web-based database called "Texas Rigid Pavement Database (TxRPDB)" for easy and convenient access to the rigid pavement performance data. The TxRPDB is expected to play a role of an enterprise platform for sharing design and structural information as well as performance data for rigid pavements in Texas, and in turn, make a valuable contribution to enhancing the sustainability of rigid pavements.
8. The information gathered in this project was used for the calibration of Mechanistic-Empirical CRCP design program developed under TxDOT Research Project 0-5832, called TxCRCP-ME, by providing an elaborate and reliable transfer function with sufficient data points. Also, it will be useful for TxDOT in evaluating the effectiveness of and in identifying the areas of needed improvements in their pavement designs, material selection, and construction practices.

Based on the findings from this research study, the following recommendations were made:

TxDOT develops ideal base types from an engineering standpoint and based on the best – yest most cost effective – past performance. Once the base types are determined, catalog type pavement design charts are developed for the pavement slab thickness determination, for both CRCP and CPCD. The current pavement design procedures, either empirical or mechanistic-empirical, have uncertainties in relationships among variables and are more complicated than needed. Also, due to the nature of pavement design procedures, future design traffic has the most significant influence on the required slab thickness or pavement structure. The ability to provide reasonable design traffic for pavement design has not improved for the last several decades. The design catalog should provide ranges for design traffic as an input.

TxDOT currently requires the use of CRCP when a rigid pavement is selected for a project, with few exceptions. However, CPCD has advantages over CRCP in certain situations, such as when the only locally available coarse aggregate type is siliceous river gravel (SRG). The performance of CPCD with SRG is better than that of CRCP with SRG. Over the years, local contractors developed skills and expertise in the construction of CRCP, at the expense of CPCD. TxDOT may want to expand the use of CPCD where appropriate.

References

AASHTO (1993). *Guide for Design of Pavement Structures*, AASHTO.

ASTM Standard D1196-93 (2004). "Nonrepetitive Static Plate Load Tests of Soils and Flexible Pavement Components, for Use in Evaluation and Design of Airport and Highway Pavements to Evaluate Modulus of Subgrade Reaction." *ASTM International*West Conshohocken, PA,.

ASTM Standard D6951-03 (2003). "Standard Test Method for Use of the Dynamic Cone Penetrometer in Shallow Pavement Applications." *ASTM International*West Conshohocken, PA,.

Chavez, C. I. M., McCullough, B. F., and Fowler, D. W. (2003). "Design of a Post-Tensioned Prestressed Concrete Pavement, Construction Guidelines, and Monitoring Plan." Center for Transportation Research, University of Texas at Austin.

Choi, S., and Won, M. C. "Performance of Continuously Reinforced Concrete Pavement Containing Recycled Concrete Aggregate." *Proc., ASCE Conference Proceeding, 2009 GeoHunan International Conference (GSP 196)*, 165-172.

Choi, S., and Won, M. C. (2010). "Construction and Evaluation of Post-Tensioned Pre-Stressed Concrete Pavement." Center for Multidisciplinary Research in Transportation, Texas Tech University.

Ha, S., Yeon, J., Choi, B., Jung, Y., Zollinger, D. G., Wimsatt, A., and Won, M. C. (2012). "Develop Mechanistic-Emprical Design for CRCP." Center for Multidisciplinary Research in Transportation, Texas Tech University.

Hall, K. T. (1991). "Performance, Evaluation, and Rehabilitation of asphalt-overlaid concrete pavements." University of Illinois, Urbana, IL.

Kohler, E. R. (2005). "Experimental Mechanics of Crack Width in Full-Scale Sections of Continuously Reinforced Concrete Pavements." University of Illinois at Urbana-Champaign.

Liu, J., Mukhopadhyay, A. K., Celaya, M., Nazarian, S., and Zollinger, D. G. (2009). "Best practices for the use of siliceous river gravel in concrete paving." Texas Transportation Institute, Texas A & M University System.

McCullough, B. F., Zollinger, D. G., and Dossey, T. (2000). "Evaluation of the performance of Texas pavements made with different coarse aggregates." Center for Transportation Research, The University of Texas at Austin.

Medina-Chavez, C. I., and Won, M. (2006). "Mechanistic-Empirical Data Collection Approach for Rigid Pavements." Center for Transportation Research, The University of Texas at Austin.

Merritt, D. K., McCullough, B. F., and Burns, N. H. (2002). "Construction and Preliminary Monitoring of the Georgetown, Texas Precast Prestressed Concrete Pavement." Center for Transportation Research, The University of Texas at Austin.

Miller, J., and Bellinger, W. (2003). "Distress identification manual for the long-term pavement performance (LTPP) project." FHWA-RD-03.

Nam, J. H. (2005). "Early-Age Behavior of CRCP and Its Implications for Long-Term Performance." Ph.D., The University of Texas at Austin, Austin, Texas.

Roesler, J. R., and Huntley, J. G. (2009). "Performance of I-57 Recycled Concrete Pavements." University of Illinois at Urbana-Champaign, Urbana.

Ryu, S., Choi, P., Zhou, W., Saraf, S., and Won, M. C. (2013). "Improvements of Partial and Full-Depth Repair Practices for CRCP Distresses." Center for Multidisciplinary Research in Transportation, Texas Tech University.

Schindler, A. K., Dossey, T., and McCullough, B. F. (2002). "Temperature control during construction to improve the long term performance of portland cement concrete pavements." Center for Transportation Research, The University of Texas at Austin.

Suh, Y. C., Hankins, K. D., and McCullough, B. F. (1992). "Early-Age Behavior of Continuously Reinforced Concrete Pavement and Calibration of the Failure Prediction Model in the CRCP-7 Program." Center for Transportation Research, University of Texas at Austin.

Tayabji, S., Selezneva, O., and J., J. (1999). "Preliminary Evaluation of LTPP 17 Continuously Reinforced Concrete (CRC) Pavement Test Sections." FHWA, U.S. Department of Transportation, Columbia, MD

Texas Department of Transportation (2010). "2010 TxDOT Pavement Management Information System CD-ROM." TxDOT.

TxDOT (2010). "Pavement Management Information System Rater's Manual Fisical Year 2010." Texas Department of Transportation.

TxDOT (2011). "Pavement Design Guide, Chapter 4 Section 4 Non-Destructive Evaluation of Pavement Structural Properties.".

TxDOT (2011). "Pavement Design Guide, Chapter 9 Section 7 Joints.".

Vesic, A. S., and Saxena, S. K. (1969). "Analysis of Structural Behavior of Road Test Rigid Pavements." *Highway Research Record 291, HRB, National Research Council, Washington, D.C.*, 156-158.

Appendix A. FWD Data

A.1 Deflections at 50-ft Interval

- Deflections at 50-ft Interval Measured in FY2010

Distance	3-I35-1		3-US287-1		3-US287-2		3-US81-1		4-I40-1		5-I27-1		5-LP289-1	
	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
0			4.854							3.093	2.937	3.118	2.795	3.728
50			4.252							3.074	2.945	3.463	3.019	3.880
100			4.829							2.540	3.235	3.538	3.826	4.374
150			5.598							2.882	3.474	3.706	2.819	3.708
200			4.067							2.990	2.708	3.168	3.331	3.738
250			4.379							3.021	3.412	2.654	3.304	3.714
300			3.790							2.563	3.153	3.092	3.617	2.794
350			4.147							2.974	2.897	3.610	2.746	2.745
400			3.412							2.900	3.087	3.164	2.874	3.351
450			3.801							3.085	2.906	3.721	3.542	3.570
500			4.521							2.655	3.610	3.726	3.289	3.695
550			4.108							3.280	3.782	3.377	3.331	3.370
600			4.666							2.819	2.665	3.980	3.188	3.604
650			4.669							2.369	3.270	3.191	3.364	4.351
700			3.997							2.990	2.719	3.162	2.639	2.977
750			3.663							2.937	2.662	3.966	2.682	3.136
800			4.387							2.748	2.773	2.964	2.510	2.925
850			4.111							2.373	3.205	3.793	2.488	2.862
900			3.638							2.960	3.249	2.687	2.334	2.735
950			4.529							3.009	3.238	2.937	2.302	2.853
1000			3.898							2.886	3.212	3.116	2.731	3.047

Distance	9-I35-1		9-I35-2		12-US290-1		12-US290-2		12-US290-3		19-US59-1		19-US59-2	
	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
0					3.154	2.177	2.491	2.696	2.491	2.389	1.861	1.935		1.943
50					2.700	1.948	2.436	2.769	2.436	2.724	1.580	2.041	6.493	2.080
100					2.777	2.322	2.761	2.804	2.761	2.179	1.840	2.068	4.055	2.053
150					2.708	2.098	2.440	2.404	2.440	2.514	1.637	2.166	4.197	1.922
200					2.861	2.117	3.730	2.708	3.730	2.578	1.772	2.348	2.729	1.855
250					3.173	2.377	2.861	2.760	2.861	2.931	1.822	2.091	6.742	2.212
300					3.316	2.740	2.881	2.926	2.881	2.929	1.872	2.167	4.073	1.724
350					3.067	2.603	2.984	2.514	2.984	2.674	1.926	2.141	3.600	1.859
400					3.316	2.353	2.756	2.121	2.756	3.145	1.742	2.083	2.829	1.953
450					2.508	1.739	3.451	2.885	3.451	2.308	2.205	2.214	3.272	1.923
500					2.476	2.245	3.104	2.716	3.104	2.765	2.056	2.313	2.454	1.904
550					2.605	2.101	3.758	2.455	3.758	3.129	1.779	2.130	2.969	2.240
600					2.346	2.020	3.789	3.127	3.789	2.294	2.196	2.267		2.203
650					2.520	2.276	3.396	3.259	3.396	2.759	1.853	3.158	2.392	1.880
700					2.680	2.033	2.901	2.552	2.901	2.420	1.951	2.287	3.642	1.874
750					2.444	2.298	2.630	2.979	2.630	3.384	1.932	2.717	1.869	1.842
800					2.163	2.420	2.739	3.367	2.739	3.022	1.855	2.177	1.942	1.767
850					2.497	2.056	2.406	3.148	2.406	2.752	1.658	2.283	2.605	1.960
900					2.721	2.337	2.764	3.012	2.764	2.821	1.684	2.173	1.794	1.667
950					2.319	2.400	2.861	2.758	2.861	3.047	2.186	2.236	2.906	1.844
1000					2.599	2.610	3.392	3.496	3.392	2.438	1.636	1.929	1.838	1.886

Distance	20-I10-1		24-I10-1		24-I10-2		24-I10-3		24-I10-4		25-I40-1		25-I40-2	
	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
0			1.151	1.440	2.480	2.058	2.014	2.110	1.859	1.807	1.498	1.393	1.173	1.343
50			1.234	1.349	1.985	1.846	1.901	2.072	1.516	1.419	1.191	1.341	1.177	1.564
100			1.127	1.290	2.012	1.691	1.858	1.809	1.720	1.325	1.314	1.386	1.032	1.422
150			1.137	1.263	1.739	1.859	1.893	1.927	1.805	1.402	1.374	1.515	1.169	1.453
200			1.110	1.426	1.937	1.874	1.807	1.824	1.934	1.384	1.183	1.524	1.083	1.451
250			1.144	1.466	2.137	2.220	1.751	1.864	2.479	1.663	1.120	1.564	1.098	1.474
300			1.148	1.463	1.850	1.882	1.923	2.051	1.925	1.772	1.139	1.311	1.329	1.549
350			1.127	1.276	2.053	2.056	1.635	1.672	1.757	1.504	1.207	1.319	1.121	1.453
400			1.124	1.334	2.300	1.761	1.726	1.783	1.569	1.398	1.171	1.277	1.386	1.483
450			1.089	1.222	1.974	1.949	1.744	1.916	1.712	1.550	1.339	1.587	1.081	1.464
500			1.276	1.756	3.094	2.316	2.375	2.220	1.710	1.603	1.115	1.420	1.112	1.491
550			1.088	1.296	2.007	2.014	1.385	1.935	1.686	2.099	1.344	1.412	1.070	1.665
600			1.061	1.146	2.179	2.178	1.555	2.137	1.733	1.712	1.588	1.339	1.225	1.513
650			1.118	1.331	2.014	2.121	1.562	1.949	2.062	1.757	1.369	1.342	1.072	1.614
700			1.118	1.317	2.187	2.070	1.525	1.944	1.396	1.399	1.320	1.352	1.242	1.298
750			1.092	1.373	2.478	2.116	1.776	2.027	1.447	1.473	1.257	1.322	1.213	1.393
800			1.201	1.383	2.368	2.104	1.535	1.929	1.489	1.802	1.242	1.355	1.082	1.476
850			1.107	1.284	2.171	2.175	1.566	1.871	1.973	1.942	1.387	1.396	1.207	1.378
900			1.134	1.302	2.343	2.516	1.644	1.919	1.879	2.080	1.165	1.307	1.175	1.473
950			1.040	1.306	2.114	2.254	1.774	2.105	2.076	2.224	1.276	1.343	1.113	1.494
1000			1.100	1.266	1.170	2.246	1.676	1.957	2.401	2.290	1.178	1.422	1.133	1.509

- Deflections at 50-ft Interval Measured in FY2011

Distance	3-I35-1		3-US287-1		3-US287-2		3-US81-1		4-I40-1		5-I27-1		5-LP289-1	
	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
0	1.509	1.996	4.955	5.398	1.761	2.594	3.935	4.741			3.355	3.411	2.983	4.067
50	1.710	1.893	3.827	4.283	1.441	2.238	3.925	4.584			3.234	3.313	3.115	4.162
100	2.537	2.437	5.272	5.366	1.441	2.277	4.157	5.648			2.843	3.485	3.610	3.954
150	1.969	2.388	5.444	6.352	1.724	2.145	3.567	4.049			3.073	3.903	3.198	4.458
200	2.174	2.325	4.582	5.388	1.909	2.058	4.908	5.293			2.714	3.083	3.201	3.703
250	2.312	2.542	4.663	5.500	1.584	2.467	4.321	5.121			2.547	2.790	3.448	4.038
300	1.957	2.213	4.319	5.111	1.646	2.235	3.459	3.824			2.861	3.258	3.288	3.211
350	2.060	2.267	4.141	4.947	1.757	2.293	3.126	4.330			3.178	3.810	2.714	3.233
400	1.932	2.303	4.658	4.552	1.774	2.379	3.862	3.745			2.640	3.227	2.693	2.774
450	2.059	2.252	4.845	5.157	1.722	2.456	3.533	3.922			3.528	3.481	2.940	3.629
500	2.250	2.604	4.780	5.960	1.780	2.691	4.027	5.455			3.091	3.597	3.627	3.591
550	2.145	2.581	4.820	5.254	1.434	2.065	4.179	4.210			2.638	3.083	3.224	3.417
600	1.945	2.177	4.804	5.588	1.374	2.073	3.394	4.334			3.358	4.463	2.917	3.655
650	2.231	2.303	5.212	5.256	1.636	2.232	5.821	7.562			2.701	3.233	3.166	3.859
700	2.236	2.406	4.588	4.609	1.584	2.386	4.080	5.826			2.841	3.353	2.631	3.659
750	1.959	2.728	4.881	4.668	1.392	2.243	4.654	4.267			3.503	3.992	2.830	3.613
800	2.157	2.336	4.412	4.480	1.396	2.335	3.356	6.150			2.787	3.176	2.609	3.253
850	2.102	2.405	4.304	4.931	1.500	2.448	3.033	3.580			3.361	4.147	2.869	3.123
900	1.827	2.378	3.965	5.524	1.576	2.317	3.635	4.486			2.801	2.907	2.390	2.621
950	2.252	2.444	4.107	5.116	1.512	2.237	4.298	6.097			2.911	3.142	2.268	2.996
1000	2.534	2.410	4.415	4.894	1.646	2.389	6.483	8.432			2.720	3.449	2.949	2.522

Distance	9-I35-1		9-I35-2		12-US290-1		12-US290-2		12-US290-3		19-US59-1		19-US59-2	
	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
0					2.575		3.110		2.986		1.796	2.014	1.977	1.653
50					2.867		3.225		2.893		1.934	2.246	2.035	1.927
100					2.819		3.637		3.186		1.982	2.302	1.832	1.894
150					3.259		3.470		2.958		2.068	2.290	1.848	1.844
200					3.088		3.717		3.129		2.074	2.292	1.816	1.895
250					3.559		3.755		3.092		2.075	2.169	1.821	1.828
300					2.810		3.788		3.262		1.946	2.052	1.581	1.684
350					3.151		3.663		2.769		1.988	2.120	1.677	1.834
400					2.875		3.166		3.499		2.435	2.180	1.772	1.655
450							3.250		2.833		2.013	2.151	1.772	1.829
500							3.691		3.432		2.167	2.364	1.661	1.899
550							3.512		4.284		2.113	2.126	2.306	2.149
600							3.703		3.103		2.267	2.499	1.966	1.937
650							4.527		2.922		2.312	2.549	1.709	1.718
700							3.591		2.868		2.192	2.329	1.659	1.862
750							3.608		2.839		2.459	3.007	1.678	1.711
800							4.262		3.286		2.303	2.547	1.654	1.837
850							4.549		2.828		2.295	2.172	1.776	1.859
900									2.832		2.023	2.332	1.665	1.755
950									2.945		2.033	2.264	1.676	1.843
1000							3.908		2.404		2.068	8.688	1.703	1.912

Distance	20-I10-1		24-I10-1		24-I10-2		24-I10-3		24-I10-4		25-I40-1		25-I40-2	
	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
0			1.350	1.391	2.316	1.906	2.243	2.203	1.983	1.691	0.900		1.251	
50			1.631	1.524	1.771	1.538	2.126	2.092	1.551	1.331	1.054		1.395	
100			1.353	1.452	1.739	1.703	2.032	1.880	1.587	1.547	1.112		1.379	
150			1.328	1.317	1.900	1.757	2.115	1.999	1.756	1.498	1.143		1.282	
200			1.331	1.383	1.984	1.704	1.926	1.844	1.724	1.513	1.263		1.266	
250			1.423	1.354	2.197	1.826	1.931	1.831	2.127	1.898	1.067		1.265	
300			1.438	1.331	1.864	1.786		2.042	2.136	1.869	1.111		1.236	
350			1.310	1.357	2.082	1.885	1.900	1.594	1.756	1.392	1.165		1.638	
400			1.446	1.332	1.846	1.641	1.848	1.797	1.557	1.475	1.330		1.302	
450			1.350	1.101	1.957	1.763	1.981	1.966	1.723	1.689	1.332		1.332	
500			1.847	1.659	2.365	1.880	2.141	2.099	2.037	1.536	1.248		1.418	
550			1.338	1.301	2.230	1.893	1.747	1.763	2.307	2.079	1.178		1.591	
600			1.360	1.277	1.959	1.956	1.982	1.839	2.009	1.857	1.215		1.517	
650			1.358	1.414	1.820	1.884	1.915	1.601	1.967	1.692	1.166		1.436	
700			1.408	1.290	2.121	1.753	1.986	1.628	1.644	1.517	1.283		1.360	
750			1.409	1.309	2.181	1.771	2.154	1.825	1.715	1.492	1.263		1.526	
800			1.350	1.467	2.160	1.773	2.050	1.754	1.988	1.794	1.233		1.573	
850			1.398	1.286	2.166	1.945	1.902	1.595	2.243	1.955	1.114		1.223	
900			1.298	1.217	2.333	1.971	2.083	1.684	2.392	2.169	1.061		1.268	
950			1.338	1.314	2.134	1.829	2.110	1.790	2.379	2.332	1.161		1.221	
1000			1.280	1.350	2.489	2.068	2.190	1.752	2.669	2.520	1.099		1.506	

- Deflections at 50-ft Interval Measured in FY2012

Distance	3-I35-1		3-US287-1		3-US287-2		3-US81-1		4-I40-1		5-I27-1		5-LP289-1	
	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
0		1.594	3.650	3.903	1.629	1.682	4.041	4.043		4.035		2.298		2.954
50		1.696	3.771	3.506	1.383	1.427	4.015	3.859		3.602		2.624		2.981
100		1.819	4.608	3.996	1.261	1.418	4.270	4.397		3.755		2.533		3.308
150			4.824	4.693	1.036	1.575	3.561	3.435		3.200		2.557		3.348
200			5.767	4.387	2.508	1.545	5.050	3.762		3.588		2.734		3.163
250		1.926	4.712	4.418	1.338	1.540	4.276	4.382		3.314		2.738		3.313
300		1.980	4.431	3.936	1.624	1.513	3.319	2.951		3.450		2.452		3.292
350		2.053	3.672	3.682	1.318	1.504	3.242	3.604		3.754		2.185		2.877
400		1.885	3.771	3.659	1.311	1.537	3.996	3.561		3.997		2.383		2.278
450		1.986	4.112	4.044	1.597	1.564	3.867	3.393		3.851		2.479		2.089
500		2.548	4.303	4.487	1.531	1.372	6.021	4.474		3.127		2.495		2.137
550		2.189	3.959	4.707	1.312	1.439	4.800	3.528		4.459		2.559		2.080
600		1.820	5.406	4.364	1.095	1.393	3.586	3.405		3.302		2.402		2.901
650		1.999	4.305	3.987	1.474	1.523	7.379	4.338		2.661		2.342		2.942
700		2.078	4.205	3.800	1.261	1.442	6.038	5.062		3.470		2.700		3.154
750		1.957	4.651	3.831	1.603	1.430	3.675	3.913		3.730				3.051
800		2.070	4.001	3.802	1.483	1.402	5.464	4.417		2.944		2.614		2.801
850		2.202	3.982	3.901	1.311	1.595	2.742	2.926		2.655		2.589		3.025
900		1.987	4.439	3.876	1.192	1.703	3.771	3.752		3.299		2.651		2.914
950		2.138	4.134	4.039	1.588	1.453	5.244	4.395		3.664		2.355		3.182
1000		1.973	4.074	3.823	1.778	1.572	7.552	5.304		3.319		2.461		3.035

Distance	9-I35-1		9-I35-2		12-US290-1		12-US290-2		12-US290-3		19-US59-1		19-US59-2	
	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
0				1.176				3.082		2.063	1.473	1.632	1.482	1.469
50				1.156				3.290		1.979	1.613	2.008	1.545	1.597
100				1.128				3.472		2.034	2.628	2.096	1.525	1.568
150				1.188				3.081		2.154	1.889	1.745	1.435	1.553
200				1.165				3.410		2.350	1.702	1.719	1.529	1.443
250				1.112				3.504		2.202	1.696	1.867	1.546	1.390
300				1.156				3.504		2.179	1.614	1.836	1.460	1.389
350				1.272				3.565		2.014	1.767	1.768	1.441	1.655
400								2.930		2.378	1.586	1.711	1.674	1.485
450								3.148		1.917	1.585	1.814	1.555	1.674
500								3.318		2.390	1.607	1.823	1.472	1.790
550								3.162		2.798	1.574	1.744	1.916	1.887
600								3.222		2.317	1.923	2.089	1.764	1.478
650								4.174		2.082	1.901	1.804	1.466	1.406
700								2.903		2.174	1.642	1.895	1.390	1.511
750								3.267		2.182	1.961	2.497	1.381	1.436
800								3.961		2.443	1.779	1.895	1.476	1.467
850								4.221		1.914	1.676	1.871	1.406	1.453
900								3.154		2.048	2.259	1.873	1.373	1.441
950								3.301		1.996	1.593	1.945	1.358	1.609
1000								3.555		1.833	1.586	3.782	1.398	1.570

Distance	20-I10-1		24-I10-1		24-I10-2		24-I10-3		24-I10-4		25-I40-1		25-I40-2	
	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
0			1.308	1.415	2.391	2.029	2.289	2.246	1.874	1.811		1.372		1.486
50			1.482	1.337	1.772	1.455	2.062	1.964	1.453	1.350		1.413		1.345
100			1.165	1.352	1.703	1.340	1.991	1.916	1.436	1.550		1.451		1.337
150			1.280	1.282	1.808	2.031	1.995	1.873	1.556	1.568		1.427		1.500
200			1.212	1.272	1.936	1.743	1.919	1.877	1.529	1.535		1.558		1.355
250			1.312	1.255	2.170	1.848	1.876	1.888	1.976	1.973		1.415		1.368
300			1.420	1.488	1.913	1.825	1.977	1.782	1.973	1.651		1.272		1.578
350			1.231	1.295	1.861	1.677	1.627	1.532	1.403	1.363		1.370		1.477
400			1.246	1.360	1.837	1.727	1.803	1.793	1.360	1.498		1.574		1.505
450			1.240	1.445	1.944	1.979	1.964	1.836	1.621	1.724		1.461		1.405
500			1.092	1.437	2.360	1.812	2.046	2.030	1.775	1.795		1.552		1.433
550			1.273	1.195	2.190	2.193	1.608	1.909	2.021	1.928		1.279		1.557
600			1.327	1.213	2.017	2.032	1.943	2.173	1.709	1.977		1.373		1.477
650			1.341	1.345	1.956	1.710	1.850	2.277	1.817	1.596		1.378		1.376
700			1.320	1.295	1.889	1.863	1.931	2.099	1.383	1.307		1.312		1.307
750			1.296	1.273	2.291	1.985	2.004	2.209	1.388	1.682		1.297		1.297
800			1.493	1.419	2.212	2.604	1.945	2.144	1.754	1.849		1.360		
850			1.309	1.375	2.319	2.308	1.912	2.044	2.017	1.951		1.364		1.245
900			1.352	1.281	2.327	2.374	1.847	2.412	2.015	2.071		1.336		1.365
950			1.246	1.153	2.242	2.399	2.122	2.508	2.301	2.278		1.270		1.335
1000			1.222	1.262	1.951	2.525	2.087	2.185	2.988	2.613		1.269		1.343

- Deflections at 50-ft Interval Measured in FY2013

Distance	3-I35-1		3-US287-1		3-US287-2		3-US81-1		4-I40-1		5-I27-1		5-LP289-1	
	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
0	1.238		5.949		1.418	1.645	3.721		5.066		2.646		2.664	3.162
50	1.446		4.019		1.165	1.436	3.747		3.578		2.587		3.681	3.243
100	1.715		4.653		1.360	1.539	4.226		3.422		2.501		3.372	3.247
150	1.695		5.130		1.689	1.637	3.116		5.608		2.595		2.695	3.064
200	1.588		4.396		1.403	1.725	3.538		5.495		2.296		2.186	3.440
250	1.685		4.154		1.481	1.945	3.953		3.894		2.166		2.678	2.406
300	1.590		4.245		1.403	1.507	2.493		3.446		2.340		2.990	2.273
350	1.634		3.782		1.268	1.886	3.354		4.110		2.895		2.677	2.113
400	1.583		3.920		1.545	1.754	3.325		6.336		2.267		2.817	3.079
450	1.683		3.780		1.435	1.577	3.295		4.174		2.573		2.848	2.803
500	1.647		4.637		1.293	1.870	5.433		3.213		2.514		2.941	3.029
550	1.851		3.890		1.319	1.641	3.427		4.702		2.265		2.443	3.008
600	1.656		4.294		1.171	1.571	2.948		3.675		2.692		2.519	3.533
650	1.688		4.034		1.471	1.461	5.288		3.397		2.486		2.246	3.160
700	1.594		3.898		1.478	1.725	7.762		3.817		2.388		2.367	2.860
750	1.523		3.913		1.276	1.817	3.172		5.462		2.212		2.373	2.768
800	1.642		3.693		1.435	1.645	3.756		3.422		2.260			2.462
850	1.959		3.920		1.326	1.653	3.121		3.514		2.131			2.276
900	1.620		3.791		1.386	1.793	3.590		3.123		2.394			2.506
950	1.648		4.326		1.126	1.643	6.334		4.480		2.406			2.298
1000	1.593		3.785		1.383	1.621	6.465		5.624		2.600			2.391

Distance	9-I35-1		9-I35-2		12-US290-1		12-US290-2		12-US290-3		19-US59-1		19-US59-2	
	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
0			1.086				1.959		1.930		1.533	1.709	1.319	1.605
50			1.088				2.446		1.864		1.679	2.012	1.511	1.524
100			1.091				2.285		2.074		1.469	1.913	1.555	1.457
150			0.993				2.433		2.011		1.448	1.804	1.687	1.395
200			1.205				2.353		2.037		1.449	1.647	1.688	1.470
250			1.242				2.493		2.018		1.494	1.794	1.886	1.486
300			1.136				2.638		2.137		1.381	1.862	1.770	1.302
350			1.106				2.165		1.861		1.651	1.701	1.560	1.490
400			1.010				2.139		2.320		1.621	1.833	1.595	1.405
450			1.030				2.130		2.212		1.682	1.599	1.379	1.613
500			1.262				2.540		2.193		1.967	2.195	1.583	1.628
550			1.205				2.392		2.862		1.896	1.758	1.498	1.587
600			1.246				2.610		2.622		1.800	2.211	1.654	1.415
650			1.331				2.754		1.918		1.465	2.020	1.684	1.316
700			1.253				2.190		2.196		1.413	1.758	1.579	1.382
750			1.120				2.445		1.958		1.357	2.557	1.824	1.393
800			1.409				2.487		2.058		1.397	2.267	1.604	1.254
850			1.449				2.496		1.875		1.364	2.073	1.541	1.385
900			1.307				2.308		1.857		1.512	1.815	1.636	1.502
950			0.784				2.481		1.885		1.466	1.934	1.605	1.491
1000							2.458		1.607		1.443	7.943	2.940	1.426

Distance	20-I10-1		24-I10-1		24-I10-2		24-I10-3		24-I10-4		25-I40-1		25-I40-2	
	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
0			2.094	1.341	1.310	1.845	2.217	2.117	1.667	1.797	1.170		1.547	
50			1.655	1.405	1.377	1.916	2.018	1.974	1.307	1.288	1.180		1.575	
100			1.733	1.279	1.235	1.557	1.886	1.833	1.300	1.415	1.400		1.473	
150			1.859	1.226	1.149	1.657	2.080	1.872	1.458	1.403	1.296		1.435	
200			1.854	1.219	1.166	1.629	1.854	1.719	1.551	1.548	1.429		1.471	
250			1.766	1.211	1.228	1.667	1.542	1.750	1.927	1.932	1.353		1.475	
300			1.610	1.315	1.230	1.674	1.966	1.782	1.784	1.671	1.291		1.519	
350			1.844	1.283	1.125	1.633	1.703	1.337	1.338	1.399	1.363		1.722	
400			1.911	1.177	1.170	1.673	1.614	1.688	1.371	1.479	1.364		1.425	
450			2.014	1.192	1.226	1.958	1.763	1.780	1.534	1.609	1.404		1.456	
500			1.756	1.173	1.289	1.767	1.704	1.229	1.528	1.343	1.384		1.684	
550			1.989	1.305	1.145	2.275	1.452	1.132	1.943	1.947	1.332		1.762	
600			2.019	1.381	1.154	1.932	1.373	2.061	1.567	1.590	1.420		1.587	
650			1.784	1.188	1.176	1.883	1.603	2.040	1.761	1.740	1.323		1.732	
700			1.956	1.351	1.220	1.753	1.698	1.817	1.291	1.436	1.398		1.515	
750			1.735	1.250	1.180	1.854	1.490	2.068	1.289	1.620	1.527		1.442	
800			1.918	1.224	1.260	2.200	1.761	1.971	1.610	1.961	1.399		1.540	
850			2.056	1.170	1.187	2.359	1.537	1.866	1.781	1.875	1.401		1.497	
900			1.882	1.321	1.272	2.310	1.579	2.050	1.974	1.838	1.303		1.432	
950			2.008	1.166	1.255	2.084	1.714	2.113	1.987	2.169	1.215		1.518	
1000				1.179	1.182	2.438	1.853	2.165	2.167	3.465	1.215		1.463	

A.2 Deflections at Transverse Cracks

- Deflections at Transverse Cracks: FY2010

SECTION I.D.	3-US287-1	WINTER TESTING				DATE		12/10/09		SUMMER TESTING				DATE			
LOCATION						TIME								TIME			
CRACKS		W1	W2	W3	W4	W5	W6	W7	LTE	W1	W2	W3	W4	W5	W6	W7	LTE
S-I-1	UPSTREAM	3.8	3.8	3.1	3.5	1.7	1.5	1.2	107								
	DOWNSTREAM	3.8	3.4	2.9	3.7	1.5	1.3	1.1									
S-I-2	UPSTREAM	4.0	3.9	3.2	3.7	1.9	1.7	1.3	106								
	DOWNSTREAM	3.8	3.7	3.2	3.9	1.9	1.6	1.2									
M-I-1	UPSTREAM	3.8	3.8	3.1	3.4	1.8	1.5	1.2	109								
	DOWNSTREAM	3.8	3.4	2.9	3.8	1.7	1.5	1.2									
M-I-2	UPSTREAM	4.2	4.1	3.4	3.8	2.0	1.7	1.3	107								
	DOWNSTREAM	4.1	3.8	3.2	4.1	1.9	1.7	1.4									
L-I-1	UPSTREAM	3.9	3.6	3.1	3.9	1.8	1.6	1.3	93								
	DOWNSTREAM	5.1	3.9	3.3	3.7	1.9	1.7	1.3									
L-I-2	UPSTREAM	3.8	3.5	3.0	3.3	1.8	1.6	1.2	107								
	DOWNSTREAM	3.7	3.3	2.8	3.5	1.7	1.5	1.2									
S-II-1	UPSTREAM	4.3	4.1	3.5	4.0	2.1	1.9	1.6	103								
	DOWNSTREAM	4.3	4.0	3.5	4.2	2.1	1.9	1.5									
S-II-2	UPSTREAM	4.1	3.8	3.2	3.8	1.8	1.6	1.3	103								
	DOWNSTREAM	3.9	3.6	3.1	3.8	1.8	1.6	1.3									
M-II-1	UPSTREAM	4.5	4.3	3.5	4.0	2.0	1.8	1.4	108								
	DOWNSTREAM	4.4	4.0	3.4	4.3	2.1	1.9	1.5									
M-II-2	UPSTREAM	4.2	4.1	3.4	3.8	1.9	1.7	1.3	107								
	DOWNSTREAM	4.2	3.8	3.2	4.1	1.9	1.7	1.3									
L-II-1	UPSTREAM	4.4	4.3	3.7	4.1	2.3	2.1	1.8	106								
	DOWNSTREAM	4.3	4.0	3.5	4.3	2.3	2.1	1.7									
L-II-2	UPSTREAM	3.6	3.5	2.9	3.4	1.8	1.6	1.3	105								
	DOWNSTREAM	3.6	3.4	2.9	3.6	1.8	1.6	1.4									

SECTION I.D.	4-I40-1	WINTER TESTING				DATE				SUMMER TESTING				DATE		06/24/10	
LOCATION						TIME								TIME			
CRACKS		W1	W2	W3	W4	W5	W6	W7	LTE	W1	W2	W3	W4	W5	W6	W7	LTE
S-I-1	UPSTREAM									2.7	2.7	2.4	2.5	1.9	1.7	1.5	103
	DOWNSTREAM									2.7	2.6	2.4	2.6	1.9	1.7	1.5	
S-I-2	UPSTREAM									2.9	2.8	2.5	2.7	1.9	1.7	1.4	101
	DOWNSTREAM									2.9	2.8	2.5	2.7	1.9	1.5	1.4	
M-I-1	UPSTREAM									3.6	3.5	3.1	3.1	2.4	2.0	1.8	108
	DOWNSTREAM									3.7	3.4	3.1	3.5	2.4	2.1	1.8	
M-I-2	UPSTREAM									2.8	2.8	2.6	2.7	2.0	1.8	1.6	101
	DOWNSTREAM									2.8	2.7	2.5	2.7	2.1	1.8	1.6	
L-I-1	UPSTREAM									2.6	2.6	2.4	2.5	1.9	1.7	1.5	102
	DOWNSTREAM									2.7	2.6	2.4	2.6	1.9	1.7	1.5	
L-I-2	UPSTREAM									2.6	2.7	2.5	2.5	1.9	1.7	1.5	102
	DOWNSTREAM									2.7	2.6	2.4	2.6	1.9	1.7	1.5	
S-II-1	UPSTREAM									2.8	2.8	2.5	2.6	1.9	1.6	1.4	102
	DOWNSTREAM									2.8	2.7	2.5	2.7	1.9	1.6	1.4	
S-II-2	UPSTREAM									2.9	2.8	2.6	2.7	2.0	1.7	1.4	101
	DOWNSTREAM									2.9	2.8	2.6	2.8	2.0	1.7	1.5	
M-II-1	UPSTREAM									3.5	3.5	3.2	3.4	2.5	2.2	1.9	102
	DOWNSTREAM									3.5	3.4	3.1	3.4	2.4	2.1	1.8	
M-II-2	UPSTREAM									2.9	3.1	2.6	2.7	1.9	1.5	1.3	108
	DOWNSTREAM									3.1	2.8	2.5	2.9	1.9	1.6	1.4	
L-II-1	UPSTREAM									3.2	3.1	2.8	3.1	2.2	1.9	1.7	101
	DOWNSTREAM									3.0	3.0	2.7	3.0	2.2	1.9	1.7	
L-II-2	UPSTREAM									2.8	2.7	2.4	2.6	1.9	1.6	1.4	102
	DOWNSTREAM									2.9	2.6	2.4	2.6	1.9	1.6	1.4	

SECTION I.D.	5-I27-1	WINTER TESTING				DATE		12/16/09		SUMMER TESTING				DATE		06/17/10	
LOCATION						TIME								TIME			
CRACKS		W1	W2	W3	W4	W5	W6	W7	LTE	W1	W2	W3	W4	W5	W6	W7	LTE
S-I-1	UPSTREAM	2.9	2.9	2.6	2.9	1.7	1.7	1.6	100	3.4	3.2	2.9	3.3	1.8	1.9	1.7	100
	DOWNSTREAM	3.0	2.9	2.6	2.9	1.7	1.7	1.5		3.2	3.1	2.8	3.2	1.8	1.9	1.7	
S-I-2	UPSTREAM	2.7	2.4	2.1	2.5	1.3	1.3	1.2	101	3.2	2.9	2.5	3.0	1.5	1.5	1.3	100
	DOWNSTREAM	2.5	2.4	2.1	2.5	1.3	1.3	1.2		2.9	2.7	2.4	2.8	1.4	1.4	1.2	
M-I-1	UPSTREAM	3.1	2.8	2.6	2.9	1.6	1.8	1.6	100	3.6	3.3	2.9	3.3	1.8	2.0	1.7	100
	DOWNSTREAM	3.0	2.8	2.6	2.9	1.6	1.7	1.5		3.4	3.3	3.0	3.3	1.9	2.0	1.7	
M-I-2	UPSTREAM	3.1	2.8	2.5	2.8	1.5	1.5	1.4	100	3.7	3.4	2.9	3.4	1.7	1.8	1.5	100
	DOWNSTREAM	3.2	2.9	2.5	2.9	1.5	1.6	1.4		3.7	3.4	2.9	3.4	1.7	1.8	1.5	
L-I-1	UPSTREAM																
	DOWNSTREAM																
L-I-2	UPSTREAM																
	DOWNSTREAM																
S-II-1	UPSTREAM	2.7	2.6	2.2	2.6	1.3	1.4	1.2	100	3.3	3.0	2.6	3.0	1.6	1.6	1.4	100
	DOWNSTREAM	2.8	2.6	2.2	2.6	1.4	1.4	1.3		3.2	3.0	2.7	3.1	1.6	1.6	1.4	
S-II-2	UPSTREAM	2.6	2.4	2.1	2.4	1.3	1.4	1.2	100	2.8	2.7	2.4	2.6	1.5	1.5	1.3	98
	DOWNSTREAM	2.7	2.4	2.1	2.4	1.3	1.4	1.2		2.8	2.8	2.5	2.7	1.5	1.6	1.3	
M-II-1	UPSTREAM	3.0	2.9	2.4	2.8	1.4	1.5	1.3	103	3.5	3.2	2.7	3.3	1.6	1.6	1.4	101
	DOWNSTREAM	3.0	2.8	2.4	2.9	1.4	1.4	1.2		3.5	3.1	2.7	3.2	1.6	1.6	1.3	
M-II-2	UPSTREAM	3.0	2.8	2.4	2.7	1.4	1.4	1.2	103	3.7	3.4	2.9	3.4	1.7	1.7	1.4	101
	DOWNSTREAM	3.0	2.8	2.4	2.8	1.4	1.4	1.2		3.7	3.3	2.9	3.4	1.7	1.7	1.4	
L-II-1	UPSTREAM																
	DOWNSTREAM																
L-II-2	UPSTREAM																
	DOWNSTREAM																

SECTION I.D.	5-LP289-1	WINTER TESTING				DATE	12/16/09			SUMMER TESTING				DATE	06/17/10		
LOCATION						TIME								TIME			
CRACKS		W1	W2	W3	W4	W5	W6	W7	LTE	W1	W2	W3	W4	W5	W6	W7	LTE
S-I-1	UPSTREAM	3.7	3.4	3.0	3.6	1.8	1.8	1.6	100	4.0	3.8	3.4	3.9	2.1	2.2	1.9	100
	DOWNSTREAM	3.5	3.2	2.9	3.4	1.8	1.8	1.6		3.9	3.7	3.2	3.7	2.2	2.2	1.8	
S-I-2	UPSTREAM	3.4	3.1	2.7	3.1	1.8	1.8	1.6	102	3.0	2.9	2.6	2.9	1.9	2.0	1.8	100
	DOWNSTREAM	3.2	3.0	2.7	3.1	1.7	1.8	1.6		3.0	2.9	2.7	2.9	1.8	2.0	1.9	
M-I-1	UPSTREAM	3.2	3.2	2.9	3.2	1.8	1.9	1.6	100	4.2	3.9	3.5	3.9	2.1	2.3	2.0	100
	DOWNSTREAM	3.3	3.2	2.9	3.2	1.8	1.8	1.6		4.0	3.8	3.5	3.9	2.2	2.2	1.9	
M-I-2	UPSTREAM	3.4	3.2	2.9	3.2	1.8	1.8	1.6	101	3.9	3.8	3.4	3.8	1.9	2.1	1.8	101
	DOWNSTREAM	3.5	3.2	2.8	3.3	1.8	1.8	1.6		3.9	3.7	3.3	3.8	2.0	2.1	1.8	
L-I-1	UPSTREAM	2.8	2.5	2.2	2.7	1.6	1.6	1.5	100	2.6	2.6	2.4	2.7	1.6	1.8	1.7	100
	DOWNSTREAM	2.6	2.4	2.2	2.6	1.5	1.6	1.5		2.8	2.6	2.4	2.7	1.7	1.8	1.7	
L-I-2	UPSTREAM	2.8	2.6	2.4	2.7	1.6	1.7	1.5	102	2.8	2.6	2.4	2.7	1.6	1.8	1.7	101
	DOWNSTREAM	3.1	2.6	2.3	2.7	1.6	1.6	1.4		2.8	2.6	2.4	2.7	1.7	1.8	1.7	
S-II-1	UPSTREAM	3.1	2.9	2.6	2.9	1.8	1.7	1.5	100	3.5	3.4	3.1	3.4	1.9	2.0	1.7	100
	DOWNSTREAM	3.1	2.9	2.6	2.9	1.7	1.6	1.4		3.7	3.4	3.1	3.4	1.9	2.0	1.6	
S-II-2	UPSTREAM	2.4	2.3	2.0	2.3	1.4	1.4	1.2	101	2.8	2.7	2.4	2.8	1.5	1.6	1.3	100
	DOWNSTREAM	2.4	2.3	2.0	2.3	1.5	1.4	1.2		2.8	2.6	2.3	2.7	1.5	1.5	1.4	
M-II-1	UPSTREAM	3.0	2.9	2.6	3.0	1.8	1.8	1.6	99	3.8	3.6	3.3	3.7	2.1	2.1	1.8	101
	DOWNSTREAM	3.0	2.8	2.6	2.9	1.8	1.8	1.6		3.8	3.6	3.3	3.7	2.1	2.1	1.9	
M-II-2	UPSTREAM	2.4	2.3	2.1	2.3	1.5	1.4	1.2	100	3.0	2.8	2.5	2.8	1.6	1.6	1.3	100
	DOWNSTREAM	2.4	2.3	2.1	2.3	1.4	1.4	1.2		2.9	2.8	2.5	2.8	1.6	1.6	1.4	
L-II-1	UPSTREAM	2.8	2.8	2.6	2.9	1.8	1.8	1.5	99	3.5	3.4	3.1	3.4	2.1	2.1	1.8	100
	DOWNSTREAM	2.9	2.8	2.6	2.9	1.9	1.8	1.6		3.8	3.6	3.2	3.6	2.1	2.2	1.9	
L-II-2	UPSTREAM	2.7	2.5	2.2	2.5	1.5	1.4	1.3	101	2.9	2.7	2.4	2.7	1.5	1.6	1.4	100
	DOWNSTREAM	2.7	2.5	2.2	2.5	1.5	1.5	1.3		2.8	2.7	2.4	2.7	1.5	1.6	1.4	

SECTION I.D.	12-US290-1	WINTER TESTING				DATE		01/17/10		SUMMER TESTING				DATE		08/19/10	
LOCATION						TIME								TIME			
CRACKS		W1	W2	W3	W4	W5	W6	W7	LTE	W1	W2	W3	W4	W5	W6	W7	LTE
J-1	UPSTREAM	3.2	3.0	2.6	2.0	1.7	1.3	1.1	109	2.4	2.2	2.0	1.6	1.3	1.1	1.0	105
	DOWNSTREAM	3.3	2.9	2.8	2.0	1.7	1.3	1.1		2.4	2.2	2.0	1.6	1.4	1.1	1.0	
C-1	UPSTREAM	3.1	2.8	2.7	2.0	1.6	1.3	1.1	106	2.4	2.2	2.1	1.6	1.4	1.1	1.0	105
	DOWNSTREAM	3.1	2.8	2.6	2.0	1.7	1.4	1.2		2.4	2.2	2.1	1.6	1.3	1.1	0.9	
J-2	UPSTREAM	3.4	3.0	2.7	2.0	1.7	1.4	1.2	109	2.5	2.3	2.1	1.7	1.4	1.2	1.0	105
	DOWNSTREAM	3.4	3.0	2.9	2.0	1.7	1.4	1.2		2.6	2.3	2.2	1.7	1.5	1.2	1.1	
C-2	UPSTREAM	3.1	2.8	2.6	2.0	1.7	1.4	1.3	107	2.6	2.3	2.2	1.7	1.5	1.3	1.1	105
	DOWNSTREAM	3.0	2.7	2.6	2.0	1.7	1.5	1.3		2.5	2.3	2.2	1.7	1.5	1.3	1.2	
J-3	UPSTREAM	2.5	2.2	2.1	1.5	1.2	0.9	0.8	108	2.1	1.9	1.8	1.3	1.1	0.9	0.8	106
	DOWNSTREAM	2.5	2.2	2.1	1.5	1.2	1.0	0.8		2.2	1.9	1.8	1.3	1.1	0.9	0.7	
C-3	UPSTREAM	2.4	2.2	2.0	1.5	1.2	1.0	0.8	107	2.1	1.9	1.7	1.3	1.1	0.9	0.8	107
	DOWNSTREAM	2.5	2.2	2.0	1.5	1.2	1.0	0.8		2.2	2.0	1.8	1.4	1.1	1.0	0.8	
J-4	UPSTREAM	2.6	2.3	2.1	1.6	1.3	1.1	0.9	108	2.3	2.1	1.9	1.5	1.3	1.0	0.9	105
	DOWNSTREAM	2.6	2.3	2.2	1.6	1.3	1.1	0.9		2.3	2.1	1.9	1.5	1.3	1.0	0.9	
C-4	UPSTREAM	2.3	2.1	2.0	1.5	1.3	1.0	0.9	106	2.1	1.9	1.7	1.3	1.1	1.0	0.8	105
	DOWNSTREAM	2.3	2.1	2.0	1.5	1.3	1.0	0.9		2.1	1.8	1.7	1.3	1.1	0.9	0.8	
J-5	UPSTREAM	2.2	1.9	1.7	1.3	1.1	0.8	0.7	109	1.8	1.6	1.6	1.2	1.0	0.8	0.7	103
	DOWNSTREAM	2.2	1.9	1.8	1.3	1.1	0.9	0.7		1.9	1.7	1.6	1.2	1.0	0.8	0.7	
C-5	UPSTREAM	2.5	2.2	2.1	1.6	1.4	1.1	1.0	106	2.5	2.2	2.1	1.7	1.5	1.2	1.0	103
	DOWNSTREAM	2.5	2.2	2.1	1.7	1.4	1.2	1.0		2.4	2.2	2.1	1.6	1.4	1.2	1.0	
	UPSTREAM																
	DOWNSTREAM																
	UPSTREAM																
	DOWNSTREAM																

SECTION I.D.	12-US290-2	WINTER TESTING				DATE		01/17/10		SUMMER TESTING				DATE		08/19/10	
LOCATION						TIME								TIME			
CRACKS		W1	W2	W3	W4	W5	W6	W7	LTE	W1	W2	W3	W4	W5	W6	W7	LTE
S-I-1	UPSTREAM	2.9	2.7	2.4	1.9	1.6	1.2	1.0	106	3.4	3.0	2.8	2.1	1.8	1.4	1.1	105
	DOWNSTREAM	2.9	2.6	2.5	1.9	1.6	1.2	1.0		3.3	3.0	2.8	2.2	1.8	1.4	1.2	
S-I-2	UPSTREAM	3.4	3.1	2.8	2.2	1.9	1.5	1.3	106	3.4	3.1	2.9	2.3	1.9	1.5	1.2	104
	DOWNSTREAM	3.5	3.1	2.9	2.2	1.9	1.5	1.2		3.4	3.2	2.9	2.3	1.9	1.5	1.2	
M-I-1	UPSTREAM	2.5	2.3	2.1	1.7	1.4	1.1	1.0	107	3.3	3.1	2.9	2.3	1.9	1.5	1.2	105
	DOWNSTREAM	2.5	2.2	2.1	1.6	1.4	1.1	1.0		3.4	3.1	2.9	2.3	1.9	1.5	1.2	
M-I-2	UPSTREAM	3.9	3.7	3.2	2.4	1.9	1.5	1.2	110	2.7	2.5	2.4	1.7	1.5	1.2	1.0	108
	DOWNSTREAM	3.9	3.3	3.4	2.2	1.8	1.4	1.1		2.7	2.5	2.3	1.7	1.5	1.1	0.9	
L-I-1	UPSTREAM	2.5	2.3	2.1	1.7	1.4	1.1	1.0	106								
	DOWNSTREAM	2.5	2.3	2.1	1.7	1.4	1.1	1.0									
L-I-2	UPSTREAM	3.1	2.8	2.6	2.0	1.7	1.4	1.2	107								
	DOWNSTREAM	3.1	2.7	2.6	2.0	1.7	1.4	1.2									
S-II-1	UPSTREAM									3.6	3.3	3.0	2.4	1.9	1.5	1.2	105
	DOWNSTREAM									3.6	3.4	3.1	2.4	2.0	1.5	1.2	
S-II-2	UPSTREAM									4.2	3.9	3.6	2.8	2.3	1.8	1.4	106
	DOWNSTREAM									4.2	3.9	3.6	2.8	2.3	1.8	1.4	
M-II-1	UPSTREAM	3.6	3.4	3.0	2.5	2.1	1.7	1.4	105	2.9	2.7	2.5	2.0	1.6	1.2	1.0	106
	DOWNSTREAM	3.8	3.5	3.2	2.6	2.1	1.7	1.4		3.0	2.7	2.5	2.0	1.6	1.2	1.0	
M-II-2	UPSTREAM									3.5	3.3	3.0	2.4	2.0	1.6	1.3	105
	DOWNSTREAM									3.6	3.3	3.1	2.4	2.0	1.6	1.3	
L-II-1	UPSTREAM	3.9	3.5	3.4	2.5	2.1	1.6	1.3	106	3.1	2.9	2.7	2.0	1.6	1.3	1.1	107
	DOWNSTREAM	3.8	3.4	3.3	2.5	2.0	1.6	1.3		3.1	2.8	2.7	2.0	1.6	1.3	1.1	
L-II-2	UPSTREAM									3.3	3.0	2.9	2.2	1.8	1.4	1.2	106
	DOWNSTREAM									3.3	3.0	2.9	2.2	1.8	1.4	1.2	

SECTION I.D.	12-US290-3	WINTER TESTING				DATE		01/17/10		SUMMER TESTING				DATE		08/19/10	
LOCATION						TIME								TIME			
CRACKS		W1	W2	W3	W4	W5	W6	W7	LTE	W1	W2	W3	W4	W5	W6	W7	LTE
S-I-1	UPSTREAM	2.9	2.7	2.4	1.9	1.6	1.2	1.0	106	2.9	2.6	2.5	1.7	1.4	1.1	0.9	109
	DOWNSTREAM	2.9	2.6	2.5	1.9	1.6	1.2	1.0		2.8	2.5	2.4	1.7	1.4	1.1	0.9	
S-I-2	UPSTREAM	3.4	3.1	2.8	2.2	1.9	1.5	1.3	106	2.5	2.2	2.1	1.5	1.2	0.9	0.8	107
	DOWNSTREAM	3.5	3.1	2.9	2.2	1.9	1.5	1.2		2.4	2.1	2.1	1.5	1.2	1.0	0.8	
M-I-1	UPSTREAM	2.5	2.3	2.1	1.7	1.4	1.1	1.0	107	3.0	2.7	2.5	1.9	1.5	1.2	1.0	107
	DOWNSTREAM	2.5	2.2	2.1	1.6	1.4	1.1	1.0		3.0	2.7	2.5	1.9	1.5	1.2	0.9	
M-I-2	UPSTREAM	3.9	3.7	3.2	2.4	1.9	1.5	1.2	110	2.6	2.3	2.1	1.6	1.3	1.0	0.9	108
	DOWNSTREAM	3.9	3.3	3.4	2.2	1.8	1.4	1.1		2.6	2.3	2.2	1.6	1.3	1.0	0.9	
L-I-1	UPSTREAM	2.5	2.3	2.1	1.7	1.4	1.1	1.0	106	2.6	2.3	2.2	1.5	1.3	1.0	0.8	108
	DOWNSTREAM	2.5	2.3	2.1	1.7	1.4	1.1	1.0		2.5	2.2	2.1	1.5	1.2	1.0	0.8	
L-I-2	UPSTREAM	3.1	2.8	2.6	2.0	1.7	1.4	1.2	107	2.6	2.4	2.2	1.7	1.4	1.1	0.9	107
	DOWNSTREAM	3.1	2.7	2.6	2.0	1.7	1.4	1.2		2.7	2.4	2.2	1.7	1.3	1.1	0.9	
S-II-1	UPSTREAM									3.1	2.8	2.6	2.0	1.6	1.2	1.0	107
	DOWNSTREAM									3.2	2.9	2.7	2.0	1.6	1.2	1.0	
S-II-2	UPSTREAM									3.4	3.1	2.9	2.1	1.7	1.3	1.0	107
	DOWNSTREAM									3.4	3.0	2.9	2.1	1.7	1.3	1.0	
M-II-1	UPSTREAM	3.6	3.4	3.0	2.5	2.1	1.7	1.4	105	2.9	2.5	2.4	1.7	1.4	1.1	0.9	109
	DOWNSTREAM	3.8	3.5	3.2	2.6	2.1	1.7	1.4		2.8	2.5	2.4	1.7	1.3	1.1	0.9	
M-II-2	UPSTREAM									2.7	2.4	2.3	1.6	1.3	1.0	0.9	108
	DOWNSTREAM									2.7	2.4	2.3	1.6	1.3	1.0	0.9	
L-II-1	UPSTREAM	3.9	3.5	3.4	2.5	2.1	1.6	1.3	106	2.5	2.3	2.1	1.6	1.3	1.0	0.9	107
	DOWNSTREAM	3.8	3.4	3.3	2.5	2.0	1.6	1.3		2.6	2.3	2.1	1.6	1.3	1.0	0.9	
L-II-2	UPSTREAM									2.6	2.4	2.2	1.7	1.4	1.1	0.9	106
	DOWNSTREAM									2.7	2.5	2.3	1.8	1.5	1.2	1.0	

SECTION I.D.	19-US59-1	WINTER TESTING				DATE		03/29/10		SUMMER TESTING				DATE		09/14/10	
LOCATION						TIME								TIME			
CRACKS		W1	W2	W3	W4	W5	W6	W7	LTE	W1	W2	W3	W4	W5	W6	W7	LTE
S-I-1	UPSTREAM	1.9	1.5	1.3	1.5	1.0	0.8	0.7	99	2.3	1.9	1.6	1.9	1.2	1.1	0.9	103
	DOWNSTREAM	1.9	1.4	1.3	1.5	1.0	0.8	0.8		2.4	1.8	1.6	2.0	1.2	1.0	0.9	
S-I-2	UPSTREAM	2.3	1.5	1.4	1.5	0.9	0.8	0.8	100	2.2	1.8	1.6	1.9	1.2	1.1	0.9	101
	DOWNSTREAM	1.9	1.5	1.3	1.5	1.0	0.8	0.7		2.4	1.8	1.6	1.9	1.2	1.1	1.0	
M-I-1	UPSTREAM	1.9	1.4	1.2	1.4	0.9	0.8	0.7	102	2.2	1.8	1.6	1.9	1.3	1.1	0.9	104
	DOWNSTREAM	1.8	1.3	1.2	1.4	0.9	0.8	0.7		2.4	1.8	1.6	2.0	1.2	1.1	0.9	
M-I-2	UPSTREAM	1.7	1.3	1.1	1.2	0.8	0.7	0.7	102	2.5	1.9	1.6	2.0	1.2	1.1	0.9	106
	DOWNSTREAM	2.4	1.2	1.1	1.2	0.9	0.7	0.7		2.9	1.9	1.6	2.1	1.2	1.1	0.9	
L-I-1	UPSTREAM	1.8	1.2	1.1	1.2	0.8	0.8	0.7	102	2.3	1.7	1.5	1.8	1.2	1.1	1.0	105
	DOWNSTREAM	2.0	1.2	1.1	1.2	0.8	0.7	0.7		2.4	1.7	1.6	1.9	1.2	1.1	1.0	
L-I-2	UPSTREAM	1.9	1.5	1.3	1.5	1.0	0.9	0.8	102	2.5	1.8	1.6	2.0	1.2	1.1	0.9	106
	DOWNSTREAM	1.8	1.5	1.3	1.5	1.0	0.8	0.8		2.5	1.7	1.6	2.1	1.3	1.1	1.0	
S-II-1	UPSTREAM	5.1	2.4	1.4	2.1	1.1	0.9	0.8	149								
	DOWNSTREAM	3.3	1.6	1.4	2.9	1.0	0.9	0.8									
S-II-2	UPSTREAM	1.9	1.4	1.2	1.4	0.9	0.8	0.7	102	2.2	1.6	1.5	1.8	1.2	1.0	0.8	100
	DOWNSTREAM	1.7	1.4	1.3	1.4	0.9	0.8	0.7		2.2	1.8	1.6	1.9	1.1	0.9	0.8	
M-II-1	UPSTREAM	1.8	1.4	1.2	1.4	0.9	0.8	0.7	101	2.6	2.0	1.8	2.2	1.4	1.2	1.0	103
	DOWNSTREAM	2.4	1.4	1.2	1.4	0.9	0.8	0.7		2.5	1.9	1.8	2.1	1.3	1.1	1.0	
M-II-2	UPSTREAM	1.9	1.4	1.3	1.4	0.9	0.8	0.7	102	2.4	1.9	1.7	2.0	1.3	1.2	0.9	102
	DOWNSTREAM	1.8	1.4	1.2	1.4	0.9	0.8	0.7		2.4	1.9	1.7	2.0	1.4	1.2	1.1	
L-II-1	UPSTREAM	2.0	1.5	1.3	1.5	1.0	0.8	0.7	104	2.2	1.6	1.4	1.7	1.1	0.9	0.8	99
	DOWNSTREAM	2.8	1.4	1.3	1.5	1.0	0.9	0.8		2.1	1.7	1.5	1.8	1.1	0.9	0.8	
L-II-2	UPSTREAM	2.1	1.4	1.3	1.4	1.0	0.8	0.8	103								
	DOWNSTREAM	2.0	1.4	1.2	1.4	1.0	0.8	0.7									

SECTION I.D.	19-US59-2	WINTER TESTING				DATE		03/29/10		SUMMER TESTING				DATE		09/14/10	
LOCATION						TIME								TIME			
CRACKS		W1	W2	W3	W4	W5	W6	W7	LTE	W1	W2	W3	W4	W5	W6	W7	LTE
S-I-1	UPSTREAM	2.0	1.3	1.2	1.4	0.9	0.8	0.7	101								
	DOWNSTREAM	3.4	1.3	1.3	1.4	1.0	0.8	0.7									
S-I-2	UPSTREAM	2.1	0.9	1.2	1.3	0.8	0.7	0.6	96								
	DOWNSTREAM	2.1	1.1	1.2	1.4	0.9	0.7	0.7									
M-I-1	UPSTREAM	3.2	1.1	1.2	1.2	0.8	0.7	0.6	101	1.9	1.4	1.3	1.6	1.0	0.9	0.8	101
	DOWNSTREAM	2.3	1.1	1.2	1.2	0.8	0.7	0.6		1.8	1.3	1.2	1.5	1.0	0.9	0.7	
M-I-2	UPSTREAM	2.2	1.2	1.3	1.4	0.9	0.8	0.6	100	2.0	1.5	1.4	1.6	1.1	1.0	0.8	101
	DOWNSTREAM	2.2	1.3	1.3	1.4	1.0	0.9	0.8		2.1	1.6	1.5	1.7	1.1	1.0	0.8	
L-I-1	UPSTREAM	2.4	1.1	1.2	1.4	0.9	0.7	0.7	97	2.0	1.6	1.4	1.6	1.0	0.9	0.6	104
	DOWNSTREAM	2.0	1.3	1.2	1.5	0.9	0.8	0.7		2.3	1.5	1.4	1.7	1.0	0.8	0.7	
L-I-2	UPSTREAM	2.0	0.9	1.2	1.2	0.8	0.6	0.5	106	1.8	1.3	1.2	1.5	1.0	0.8	0.7	101
	DOWNSTREAM	1.8	0.9	1.1	1.3	0.8	0.7	0.6		1.8	1.3	1.2	1.4	0.9	0.7	0.7	
S-II-1	UPSTREAM	2.0	1.6	1.5	1.6	1.1	0.9	0.8	99	2.3	1.7	1.5	1.9	1.2	1.0	0.8	99
	DOWNSTREAM	2.1	1.7	1.5	1.7	1.1	0.9	0.8		2.3	1.7	1.5	1.9	1.2	1.0	0.8	
S-II-2	UPSTREAM	1.6	1.2	1.1	1.2	0.8	0.7	0.6	97	1.8	1.3	1.2	1.4	0.9	0.7	0.6	102
	DOWNSTREAM	1.6	1.1	1.1	1.1	0.8	0.7	0.6		1.7	1.3	1.2	1.4	0.9	0.7	0.6	
M-II-1	UPSTREAM	2.3	1.5	1.3	1.5	1.0	0.8	0.6	100	2.1	1.6	1.4	1.7	1.1	0.9	0.8	101
	DOWNSTREAM	2.2	1.5	1.3	1.5	0.9	0.8	0.7		2.1	1.6	1.4	1.7	1.0	0.9	0.8	
M-II-2	UPSTREAM	1.9	1.2	1.1	1.3	0.8	0.7	0.6	99	1.7	1.3	1.2	1.5	0.9	0.7	0.6	100
	DOWNSTREAM	1.8	1.3	1.1	1.3	0.8	0.7	0.6		1.8	1.3	1.2	1.5	0.9	0.8	0.6	
L-II-1	UPSTREAM	2.3	1.3	1.2	1.3	0.9	0.8	0.7	100	1.9	1.4	1.3	1.5	1.0	0.8	0.7	100
	DOWNSTREAM	2.0	1.3	1.2	1.3	0.9	0.7	0.7		1.9	1.4	1.3	1.6	1.0	0.8	0.7	
L-II-2	UPSTREAM	2.1	1.3	1.2	1.3	0.9	0.7	0.7	100	1.8	1.3	1.2	1.4	0.9	0.8	0.7	95
	DOWNSTREAM	1.4	1.3	1.2	1.3	0.9	0.7	0.7		1.8	1.4	1.2	1.4	0.8	0.8	0.7	

SECTION I.D.	24-I10-1	WINTER TESTING				DATE		02/17/10		SUMMER TESTING				DATE		08/30/10	
LOCATION						TIME								TIME			
CRACKS		W1	W2	W3	W4	W5	W6	W7	LTE	W1	W2	W3	W4	W5	W6	W7	LTE
S-I-1	UPSTREAM	1.1	1.1	1.0	1.1	0.8	0.7	0.6	99	1.4	1.2	1.2	1.3	0.8	0.9	0.7	100
	DOWNSTREAM	1.2	1.1	1.0	1.1	0.8	0.7	0.6		1.5	1.3	1.2	1.3	0.9	0.9	0.8	
S-I-2	UPSTREAM	1.1	1.0	0.9	1.0	0.7	0.6	0.6	100	1.4	1.3	1.2	1.3	1.0	1.0	0.8	100
	DOWNSTREAM	1.1	1.0	0.9	1.0	0.8	0.7	0.6		1.3	1.3	1.2	1.3	0.9	0.9	0.8	
M-I-1	UPSTREAM	1.2	1.1	1.0	1.1	0.8	0.7	0.6	100	1.4	1.3	1.2	1.3	0.9	0.9	0.8	105
	DOWNSTREAM	1.2	1.1	1.0	1.1	0.8	0.7	0.6		1.4	1.1	1.2	1.2	0.9	0.8	0.7	
M-I-2	UPSTREAM	1.1	1.0	0.9	1.0	0.7	0.7	0.6	99	1.3	1.2	1.1	1.2	0.9	0.9	0.7	100
	DOWNSTREAM	1.1	1.0	0.9	1.0	0.7	0.7	0.6		1.3	1.2	1.2	1.2	0.9	0.9	0.8	
L-I-1	UPSTREAM	1.1	1.0	0.9	0.9	0.7	0.7	0.6	99	1.3	1.2	1.2	1.3	0.9	0.9	0.8	99
	DOWNSTREAM	1.1	1.0	0.9	1.0	0.8	0.7	0.5		1.4	1.2	1.1	1.2	0.9	0.9	0.7	
L-I-2	UPSTREAM	1.1	1.0	0.9	1.0	0.7	0.7	0.6	99	1.4	1.2	1.2	1.3	0.9	0.9	0.8	100
	DOWNSTREAM	1.1	1.0	0.9	1.0	0.8	0.7	0.6		1.4	1.2	1.2	1.3	0.9	0.9	0.7	
S-II-1	UPSTREAM	1.1	1.0	1.0	1.0	0.7	0.7	0.5	101	1.4	1.2	1.1	1.3	0.9	0.9	0.8	97
	DOWNSTREAM	1.1	1.0	0.9	1.0	0.7	0.6	0.6		1.3	1.2	1.1	1.3	0.9	0.9	0.8	
S-II-2	UPSTREAM	1.1	1.0	0.9	1.0	0.7	0.6	0.5	98	1.3	1.2	1.1	1.3	0.9	0.9	0.8	100
	DOWNSTREAM	1.1	1.0	0.9	1.0	0.7	0.6	0.6		1.3	1.2	1.1	1.2	0.9	0.9	0.7	
M-II-1	UPSTREAM	1.0	1.0	0.9	1.0	0.7	0.6	0.6	99	1.3	1.2	1.1	1.2	0.8	0.9	0.7	99
	DOWNSTREAM	1.1	1.0	1.0	1.0	0.8	0.7	0.7		1.3	1.2	1.1	1.3	0.9	0.9	0.8	
M-II-2	UPSTREAM	1.1	0.9	0.9	1.0	0.7	0.7	0.5	98	1.3	1.1	1.1	1.2	0.8	0.9	0.6	98
	DOWNSTREAM	1.1	1.0	0.9	1.0	0.7	0.6	0.6		1.3	1.2	1.1	1.2	0.8	0.8	0.7	
L-II-1	UPSTREAM	1.1	1.0	0.9	1.0	0.7	0.6	0.5	100	1.2	1.2	1.1	1.2	0.9	0.9	0.8	100
	DOWNSTREAM	1.1	1.0	0.9	1.0	0.7	0.7	0.6		1.3	1.2	1.1	1.2	0.9	0.9	0.7	
L-II-2	UPSTREAM	1.1	0.9	0.9	1.0	0.7	0.6	0.5	100	1.3	1.2	1.1	1.3	0.8	0.9	0.7	99
	DOWNSTREAM	1.1	1.0	0.9	1.0	0.7	0.7	0.6		1.3	1.2	1.1	1.2	0.8	0.8	0.7	

SECTION I.D.	24-I10-2	WINTER TESTING				DATE		02/17/10		SUMMER TESTING				DATE		08/30/10	
LOCATION						TIME								TIME			
CRACKS		W1	W2	W3	W4	W5	W6	W7	LTE	W1	W2	W3	W4	W5	W6	W7	LTE
S-I-1	UPSTREAM																
	DOWNSTREAM																
S-I-2	UPSTREAM																
	DOWNSTREAM																
M-I-1	UPSTREAM	2.8	2.7	2.4	2.6	1.8	1.6	1.3	105	2.5	2.6	2.5	2.6	2.0	1.9	1.6	101
	DOWNSTREAM	2.9	2.6	2.3	2.7	1.8	1.6	1.3		2.7	2.5	2.4	2.6	1.9	1.9	1.6	
M-I-2	UPSTREAM	2.8	2.7	2.3	2.5	1.7	1.5	1.2	106	2.4	2.2	2.2	2.3	1.7	1.7	1.4	102
	DOWNSTREAM	2.8	2.5	2.2	2.7	1.6	1.4	1.2		2.3	2.2	2.2	2.3	1.7	1.7	1.4	
L-I-1	UPSTREAM	2.3	2.2	1.9	2.1	1.4	1.2	1.0	107	2.0	1.9	1.8	1.9	1.4	1.4	1.2	98
	DOWNSTREAM	2.3	2.1	1.9	2.2	1.4	1.2	1.0		2.0	1.8	1.7	1.8	1.4	1.4	1.2	
L-I-2	UPSTREAM	2.5	2.4	2.1	2.2	1.5	1.3	1.1	107	2.0	1.9	1.8	1.9	1.3	1.3	1.1	102
	DOWNSTREAM	2.6	2.2	2.0	2.4	1.5	1.3	1.0		1.9	1.8	1.7	1.9	1.3	1.3	1.1	
S-II-1	UPSTREAM																
	DOWNSTREAM																
S-II-2	UPSTREAM																
	DOWNSTREAM																
M-II-1	UPSTREAM	2.0	1.8	1.6	1.7	1.2	1.0	0.9	104	2.1	2.0	1.9	2.0	1.5	1.5	1.2	102
	DOWNSTREAM	1.9	1.7	1.5	1.8	1.2	1.0	0.9		2.1	2.0	1.9	2.1	1.5	1.4	1.2	
M-II-2	UPSTREAM	2.4	2.3	2.1	2.2	1.6	1.4	1.2	102	2.3	2.2	2.1	2.2	1.6	1.6	1.3	101
	DOWNSTREAM	2.5	2.3	2.1	2.3	1.7	1.4	1.2		2.2	2.1	2.0	2.2	1.6	1.5	1.3	
L-II-1	UPSTREAM	2.3	2.1	1.9	2.2	1.4	1.2	1.0	94	2.0	1.8	1.8	1.9	1.4	1.4	1.1	99
	DOWNSTREAM	2.3	2.1	1.9	2.0	1.4	1.2	1.0		2.0	1.9	1.8	1.9	1.4	1.4	1.2	
L-II-2	UPSTREAM	2.3	2.1	1.8	2.0	1.4	1.2	1.0	103	2.3	2.1	2.1	2.4	1.5	1.5	1.2	97
	DOWNSTREAM	2.2	2.0	1.8	2.1	1.4	1.2	1.0		2.4	2.1	2.0	2.2	1.5	1.5	1.3	

SECTION I.D.	24-I10-3	WINTER TESTING				DATE	02/18/10			SUMMER TESTING				DATE	08/30/10		
LOCATION						TIME								TIME			
CRACKS		W1	W2	W3	W4	W5	W6	W7	LTE	W1	W2	W3	W4	W5	W6	W7	LTE
S-I-1	UPSTREAM	1.9	1.7	1.5	1.7	1.1	0.9	0.8	100	2.0	1.9	1.7	1.9	1.2	1.1	0.9	100
	DOWNSTREAM	1.8	1.7	1.5	1.7	1.1	0.9	0.7		2.0	1.8	1.7	1.9	1.2	1.1	0.9	
S-I-2	UPSTREAM	1.7	1.6	1.4	1.6	1.1	1.0	0.8	99	1.7	1.7	1.6	1.7	1.2	1.2	1.0	101
	DOWNSTREAM	1.8	1.6	1.5	1.6	1.2	1.0	0.9		1.8	1.7	1.6	1.7	1.2	1.2	1.0	
M-I-1	UPSTREAM	1.9	1.8	1.6	1.8	1.2	1.0	0.8	100	2.0	1.9	1.8	2.0	1.3	1.3	1.0	100
	DOWNSTREAM	1.9	1.8	1.6	1.8	1.2	1.0	0.8		2.1	1.9	1.8	2.0	1.3	1.2	1.0	
M-I-2	UPSTREAM	1.6	1.5	1.3	1.4	0.9	0.8	0.7	98	1.6	1.5	1.4	1.6	1.0	1.0	0.9	101
	DOWNSTREAM	1.6	1.5	1.3	1.4	1.0	0.8	0.7		1.6	1.5	1.4	1.6	1.0	1.0	0.8	
L-I-1	UPSTREAM	1.6	1.5	1.3	1.5	1.0	0.8	0.7	100	1.5	1.5	1.3	1.5	1.0	1.0	0.8	101
	DOWNSTREAM	1.7	1.5	1.3	1.5	1.0	0.9	0.7		1.6	1.4	1.3	1.5	1.0	0.9	0.8	
L-I-2	UPSTREAM	1.7	1.6	1.4	1.5	1.0	0.9	0.8	102	1.7	1.6	1.5	1.6	1.1	1.1	0.9	101
	DOWNSTREAM	1.7	1.5	1.3	1.5	1.0	0.9	0.7		1.7	1.6	1.5	1.6	1.1	1.1	0.9	
S-II-1	UPSTREAM																
	DOWNSTREAM																
S-II-2	UPSTREAM																
	DOWNSTREAM																
M-II-1	UPSTREAM	1.6	1.5	1.4	1.5	1.1	0.9	0.8	101	1.8	1.7	1.7	1.8	1.3	1.2	1.0	100
	DOWNSTREAM	1.6	1.5	1.3	1.5	1.0	0.9	0.8		1.9	1.8	1.7	1.9	1.3	1.3	1.1	
M-II-2	UPSTREAM	2.1	2.0	1.8	2.0	1.4	1.2	1.0	103	2.1	2.0	1.9	2.1	1.5	1.5	1.2	100
	DOWNSTREAM	2.1	2.0	1.8	2.0	1.4	1.2	1.0		1.9	2.0	1.9	2.1	1.5	1.5	1.2	
L-II-1	UPSTREAM	1.7	1.6	1.4	1.6	1.1	0.9	0.8	101	2.1	2.0	1.9	2.0	1.4	1.4	1.2	101
	DOWNSTREAM	1.7	1.6	1.4	1.6	1.1	0.9	0.8		1.9	2.0	1.9	2.0	1.4	1.4	1.1	
L-II-2	UPSTREAM	1.9	1.7	1.5	1.7	1.1	1.0	0.8	100	1.9	1.8	1.7	1.8	1.3	1.3	1.1	100
	DOWNSTREAM	1.9	1.7	1.5	1.7	1.2	1.0	0.8		1.9	1.8	1.7	1.9	1.3	1.3	1.1	

SECTION I.D.	24-I10-4	WINTER TESTING				DATE	02/18/10			SUMMER TESTING				DATE	08/31/10		
LOCATION						TIME								TIME			
CRACKS		W1	W2	W3	W4	W5	W6	W7	LTE	W1	W2	W3	W4	W5	W6	W7	LTE
S-I-1	UPSTREAM	1.8	1.7	1.5	1.6	1.0	0.8	0.7	101	1.5	1.3	1.2	1.3	0.8	0.8	0.6	101
	DOWNSTREAM	1.8	1.6	1.4	1.6	1.0	0.8	0.6		1.5	1.3	1.1	1.3	0.8	0.8	0.7	
S-I-2	UPSTREAM	1.5	1.4	1.2	1.4	0.9	0.7	0.6	100	1.4	1.2	1.1	1.2	0.8	0.7	0.6	100
	DOWNSTREAM	1.5	1.4	1.2	1.4	0.9	0.7	0.6		1.4	1.2	1.1	1.2	0.7	0.7	0.6	
M-I-1	UPSTREAM	1.8	1.6	1.5	1.6	1.1	0.9	0.7	99	1.4	1.3	1.1	1.3	0.8	0.8	0.7	100
	DOWNSTREAM	1.8	1.7	1.5	1.6	1.1	0.9	0.8		1.5	1.3	1.2	1.3	0.9	0.9	0.7	
M-I-2	UPSTREAM	1.8	1.6	1.4	1.5	0.9	0.8	0.6	102	1.4	1.2	1.1	1.3	0.8	0.8	0.6	97
	DOWNSTREAM	1.7	1.6	1.4	1.6	1.0	0.8	0.6		1.4	1.2	1.1	1.2	0.8	0.7	0.6	
L-I-1	UPSTREAM	1.6	1.4	1.2	1.4	0.8	0.7	0.6	101	1.3	1.2	1.0	1.2	0.8	0.7	0.6	101
	DOWNSTREAM	1.5	1.3	1.1	1.4	0.8	0.7	0.6		1.3	1.1	1.0	1.2	0.8	0.7	0.6	
L-I-2	UPSTREAM	1.6	1.5	1.3	1.4	0.9	0.8	0.6	101	1.4	1.2	1.1	1.2	0.8	0.8	0.7	100
	DOWNSTREAM	1.7	1.5	1.3	1.5	0.9	0.8	0.7		1.4	1.2	1.1	1.2	0.8	0.8	0.7	
S-II-1	UPSTREAM	2.1	1.9	1.7	1.8	1.2	1.0	0.8	101	1.8	1.6	1.5	1.7	1.1	1.1	0.9	101
	DOWNSTREAM	2.1	1.9	1.6	1.9	1.1	0.9	0.8		1.8	1.6	1.5	1.7	1.1	1.0	0.9	
S-II-2	UPSTREAM	1.7	1.6	1.4	1.6	1.0	0.9	0.7	100	1.7	1.5	1.4	1.6	1.0	1.0	0.9	99
	DOWNSTREAM	1.8	1.6	1.4	1.6	1.0	0.9	0.7		1.6	1.5	1.4	1.5	1.0	1.0	0.8	
M-II-1	UPSTREAM	1.8	1.6	1.4	1.6	1.0	0.9	0.7	101	1.7	1.5	1.4	1.5	1.0	1.0	0.9	100
	DOWNSTREAM	1.8	1.6	1.4	1.6	1.1	0.9	0.8		1.6	1.5	1.4	1.5	1.0	1.0	0.8	
M-II-2	UPSTREAM	2.1	1.9	1.8	1.8	1.4	1.2	1.0	100	2.5	2.4	2.2	2.4	1.8	1.7	1.4	101
	DOWNSTREAM	2.0	1.9	1.8	1.9	1.3	1.2	1.0		2.6	2.4	2.2	2.5	1.7	1.7	1.4	
L-II-1	UPSTREAM	2.3	2.2	1.9	2.1	1.3	1.1	0.9	102	2.0	1.9	1.7	1.9	1.3	1.2	1.0	100
	DOWNSTREAM	2.3	2.0	1.8	2.1	1.2	1.0	0.9		2.0	1.8	1.7	1.9	1.2	1.2	1.0	
L-II-2	UPSTREAM	1.8	1.7	1.5	1.7	1.1	1.0	0.8	100	1.9	1.7	1.6	1.7	1.2	1.2	1.0	100
	DOWNSTREAM	1.8	1.7	1.6	1.7	1.2	1.0	0.8		1.9	1.7	1.6	1.8	1.2	1.2	1.0	

SECTION I.D.	25-I40-1	WINTER TESTING				DATE		03/16/10		SUMMER TESTING				DATE		06/23/10	
LOCATION						TIME								TIME			
CRACKS		W1	W2	W3	W4	W5	W6	W7	LTE	W1	W2	W3	W4	W5	W6	W7	LTE
S-I-1	UPSTREAM	1.1	1.1	0.9	0.9	0.8	0.7	0.7	102	1.4	1.2	1.1	1.2	0.8	0.7	0.6	101
	DOWNSTREAM	1.2	1.1	0.9	0.9	0.8	0.7	0.7		1.4	1.2	1.1	1.2	0.8	0.7	0.6	
S-I-2	UPSTREAM	1.4	1.3	1.1	1.0	0.9	0.8	0.8	105	1.5	1.4	1.2	1.4	1.0	0.8	0.7	100
	DOWNSTREAM	1.5	1.3	1.1	1.0	0.9	0.8	0.8		1.4	1.4	1.2	1.3	0.9	0.8	0.7	
M-I-1	UPSTREAM	1.1	1.0	0.9	0.8	0.8	0.7	0.7	102	1.4	1.3	1.2	1.2	0.9	0.8	0.7	102
	DOWNSTREAM	1.2	1.0	0.9	0.9	0.8	0.7	0.7		1.4	1.3	1.2	1.3	0.9	0.8	0.7	
M-I-2	UPSTREAM	1.3	1.1	1.0	0.9	0.8	0.7	0.7	103	1.5	1.4	1.3	1.4	0.9	0.8	0.7	101
	DOWNSTREAM	1.2	1.1	1.0	0.9	0.8	0.7	0.7		1.5	1.4	1.2	1.4	0.9	0.8	0.8	
L-I-1	UPSTREAM	1.3	1.2	1.0	0.9	0.9	0.7	0.7	103	1.3	1.2	1.1	1.2	0.9	0.8	0.8	100
	DOWNSTREAM	1.4	1.2	1.1	1.0	0.9	0.7	0.7		1.3	1.2	1.2	1.2	0.9	0.8	0.8	
L-I-2	UPSTREAM	1.2	1.1	0.9	0.9	0.8	0.7	0.7	102	1.4	1.3	1.2	1.2	0.9	0.8	0.7	100
	DOWNSTREAM	1.2	1.1	0.9	0.9	0.8	0.7	0.7		1.3	1.3	1.1	1.3	0.9	0.8	0.7	
S-II-1	UPSTREAM	1.3	1.1	0.9	0.9	0.8	0.7	0.7	105	1.4	1.3	1.2	1.3	0.9	0.8	0.7	101
	DOWNSTREAM	1.2	1.1	0.9	0.9	0.8	0.7	0.7		1.4	1.3	1.2	1.3	0.9	0.8	0.7	
S-II-2	UPSTREAM	1.8	1.6	1.3	1.1	0.9	0.8	0.8	108	1.3	1.2	1.1	1.2	0.9	0.8	0.7	101
	DOWNSTREAM	1.7	1.5	1.3	1.1	1.0	0.8	0.8		1.3	1.2	1.1	1.2	0.9	0.8	0.7	
M-II-1	UPSTREAM	1.5	1.3	1.1	1.0	0.9	0.7	0.7	106	1.2	1.1	1.0	1.1	0.8	0.7	0.6	100
	DOWNSTREAM	1.4	1.3	1.1	0.9	0.8	0.7	0.7		1.2	1.1	1.0	1.1	0.8	0.7	0.6	
M-II-2	UPSTREAM	1.7	1.4	1.1	1.0	0.8	0.7	0.7	108	1.5	1.4	1.2	1.3	0.9	0.8	0.7	101
	DOWNSTREAM	1.5	1.3	1.1	0.9	0.8	0.7	0.7		1.5	1.4	1.2	1.4	0.9	0.8	0.7	
L-II-1	UPSTREAM	1.6	1.4	1.2	1.0	0.9	0.8	0.8	105	1.4	1.3	1.2	1.2	0.9	0.8	0.7	101
	DOWNSTREAM	1.6	1.4	1.1	1.0	0.9	0.8	0.8		1.4	1.3	1.2	1.3	0.9	0.8	0.7	
L-II-2	UPSTREAM	1.4	1.2	1.0	0.9	0.8	0.7	0.7	105	1.4	1.3	1.2	1.3	0.9	0.8	0.7	100
	DOWNSTREAM	1.4	1.2	1.0	0.9	0.8	0.7	0.7		1.4	1.3	1.2	1.3	0.9	0.8	0.7	

SECTION I.D.	25-I40-2	WINTER TESTING				DATE		03/16/10		SUMMER TESTING				DATE		06/23/10	
LOCATION						TIME								TIME			
CRACKS		W1	W2	W3	W4	W5	W6	W7	LTE	W1	W2	W3	W4	W5	W6	W7	LTE
S-I-1	UPSTREAM	1.2	1.1	1.0	0.9	0.9	0.8	0.8	102	1.6	1.5	1.3	1.4	1.0	0.8	0.7	101
	DOWNSTREAM	1.2	1.1	1.0	0.9	0.9	0.8	0.8		1.6	1.5	1.3	1.5	1.0	0.8	0.7	
S-I-2	UPSTREAM	1.1	1.1	1.0	0.9	0.9	0.8	0.8	102	1.7	1.5	1.4	1.5	1.0	0.9	0.8	100
	DOWNSTREAM	1.2	1.1	1.0	0.9	0.9	0.8	0.8		1.7	1.5	1.4	1.5	1.0	0.9	0.7	
M-I-1	UPSTREAM	1.1	1.0	0.9	0.9	0.8	0.7	0.8	102	1.4	1.3	1.1	1.2	0.8	0.7	0.6	100
	DOWNSTREAM	1.2	1.0	0.9	0.9	0.8	0.7	0.8		1.4	1.3	1.1	1.2	0.8	0.7	0.6	
M-I-2	UPSTREAM	1.1	1.1	0.9	0.9	0.8	0.8	0.8	101	1.5	1.4	1.2	1.3	0.9	0.8	0.7	100
	DOWNSTREAM	1.2	1.1	0.9	0.9	0.9	0.8	0.8		1.5	1.4	1.2	1.3	0.9	0.8	0.7	
L-I-1	UPSTREAM	1.2	1.1	1.0	0.9	0.9	0.8	0.8	100	1.4	1.3	1.2	1.3	0.9	0.8	0.7	101
	DOWNSTREAM	1.2	1.1	1.0	0.9	0.9	0.8	0.9		1.4	1.3	1.2	1.3	0.9	0.8	0.7	
L-I-2	UPSTREAM	1.2	1.0	0.9	0.9	0.8	0.7	0.7	102	1.5	1.4	1.2	1.3	0.9	0.8	0.7	101
	DOWNSTREAM	1.2	1.1	0.9	0.9	0.8	0.7	0.8		1.5	1.4	1.2	1.3	0.9	0.8	0.7	
S-II-1	UPSTREAM	1.2	1.1	1.0	0.9	0.9	0.8	0.8	99	1.6	1.5	1.3	1.4	0.9	0.8	0.7	101
	DOWNSTREAM	1.2	1.2	0.9	0.9	0.9	0.8	0.8		1.5	1.4	1.2	1.4	0.9	0.8	0.7	
S-II-2	UPSTREAM	1.1	1.1	1.0	0.9	0.9	0.8	0.8	101	1.8	1.7	1.5	1.6	1.1	0.9	0.8	102
	DOWNSTREAM	1.2	1.1	1.0	0.9	0.9	0.8	0.8		1.8	1.7	1.5	1.7	1.1	0.9	0.8	
M-II-1	UPSTREAM	1.1	1.0	0.9	0.9	0.9	0.8	0.8	101	1.4	1.4	1.2	1.4	0.9	0.8	0.6	101
	DOWNSTREAM	1.2	1.0	0.9	0.9	0.9	0.8	0.8		1.5	1.4	1.2	1.4	0.9	0.8	0.6	
M-II-2	UPSTREAM	1.2	1.1	1.0	0.9	0.9	0.8	0.8	102	1.6	1.5	1.3	1.4	0.9	0.8	0.7	102
	DOWNSTREAM	1.3	1.1	1.0	0.9	0.9	0.8	0.8		1.7	1.5	1.3	1.5	0.9	0.8	0.7	
L-II-1	UPSTREAM	1.1	1.1	1.0	0.9	0.9	0.8	0.8	100	1.5	1.4	1.3	1.4	1.0	0.9	0.7	100
	DOWNSTREAM	1.2	1.1	1.0	0.9	0.9	0.8	0.8		1.5	1.5	1.3	1.4	1.0	0.9	0.7	
L-II-2	UPSTREAM	1.3	1.1	1.0	1.0	0.9	0.8	0.9	101	1.6	1.4	1.2	1.4	0.9	0.7	0.6	101
	DOWNSTREAM	1.3	1.1	1.0	1.0	0.9	0.8	0.8		1.6	1.4	1.2	1.4	0.9	0.8	0.6	

- Deflections at Transverse Cracks: FY2011

SECTION I.D.	3-I35-1	WINTER TESTING				DATE		02/17/11		SUMMER TESTING				DATE		09/28/11	
LOCATION						TIME								TIME			
CRACKS		W1	W2	W3	W4	W5	W6	W7	LTE	W1	W2	W3	W4	W5	W6	W7	LTE
S-I-1	UPSTREAM	2.3	2.0	1.7	2.0	1.0	0.9	0.7	100	2.1	1.7	1.5	1.9	1.0	0.8	0.7	101
	DOWNSTREAM	2.4	1.9	1.6	1.9	1.0	0.9	0.7		2.1	1.7	1.4	1.9	1.0	0.8	0.7	
S-I-2	UPSTREAM	2.4	2.3	2.0	2.3	1.2	1.2	1.0	101	2.6	2.1	1.8	2.2	1.3	1.0	0.9	101
	DOWNSTREAM	2.4	2.2	1.9	2.3	1.2	1.2	1.0		2.5	2.1	1.8	2.3	1.3	1.0	0.9	
M-I-1	UPSTREAM	1.8	1.7	1.4	1.7	0.8	0.9	0.7	102	1.9	1.6	1.3	1.7	0.9	0.8	0.7	102
	DOWNSTREAM	2.0	1.6	1.4	1.7	0.9	0.9	0.8		2.0	1.5	1.3	1.7	0.9	0.8	0.7	
M-I-2	UPSTREAM	1.7	1.5	1.3	1.5	0.9	0.9	0.8	99	1.9	1.6	1.4	1.7	1.0	0.9	0.8	100
	DOWNSTREAM	1.6	1.4	1.3	1.5	0.9	0.9	0.8		2.0	1.6	1.4	1.7	1.0	0.9	0.8	
L-I-1	UPSTREAM	2.2	1.9	1.7	2.0	1.2	1.3	1.2	101	2.3	1.8	1.6	2.0	1.3	1.1	1.0	100
	DOWNSTREAM	2.2	1.9	1.7	1.9	1.2	1.3	1.2		2.3	1.8	1.6	2.0	1.3	1.1	1.1	
L-I-2	UPSTREAM	2.1	2.0	1.7	2.0	1.2	1.3	1.2	101	2.4	1.9	1.7	2.1	1.3	1.2	1.1	100
	DOWNSTREAM	2.1	1.9	1.6	1.9	1.2	1.2	1.2		2.4	1.9	1.7	2.0	1.4	1.3	1.2	
S-II-1	UPSTREAM	2.3	2.0	1.8	2.0	1.2	1.3	1.2	101	2.5	2.0	1.8	2.1	1.4	1.2	1.1	100
	DOWNSTREAM	2.2	2.1	1.9	2.1	1.2	1.4	1.2		2.5	2.0	1.8	2.1	1.4	1.2	1.1	
S-II-2	UPSTREAM	2.2	1.9	1.7	2.0	1.1	1.1	1.0	101	2.4	1.9	1.6	2.1	1.2	1.1	0.9	100
	DOWNSTREAM	2.1	1.9	1.6	2.0	1.1	1.2	1.1		2.3	1.8	1.6	2.1	1.3	1.1	1.0	
M-II-1	UPSTREAM	2.1	1.9	1.7	2.0	1.2	1.2	1.1	99	2.3	1.9	1.7	2.0	1.4	1.2	1.1	100
	DOWNSTREAM	2.1	1.8	1.7	1.9	1.2	1.3	1.1		2.4	1.9	1.7	2.1	1.4	1.3	1.2	
M-II-2	UPSTREAM	2.5	2.3	2.0	2.3	1.3	1.4	1.3	103	2.5	2.1	1.8	2.2	1.4	1.2	1.1	102
	DOWNSTREAM	2.4	2.2	1.9	2.2	1.2	1.3	1.2		2.5	2.0	1.7	2.2	1.3	1.1	1.0	
L-II-1	UPSTREAM	1.9	1.8	1.6	1.8	1.2	1.2	1.1	100	2.2	1.9	1.7	2.1	1.3	1.1	1.1	100
	DOWNSTREAM	2.0	1.9	1.7	1.8	1.3	1.3	1.3		2.3	1.9	1.7	2.0	1.3	1.1	1.0	
L-II-2	UPSTREAM	2.1	1.9	1.6	1.8	1.1	1.2	1.0	103	2.4	2.0	1.7	2.1	1.3	1.1	1.0	101
	DOWNSTREAM	2.1	1.9	1.7	1.9	1.1	1.2	1.1		2.5	2.0	1.7	2.1	1.3	1.1	1.0	

SECTION I.D.	3-US287-1	WINTER TESTING				DATE	02/16/11			SUMMER TESTING				DATE	08/31/11		
LOCATION						TIME								TIME			
CRACKS		W1	W2	W3	W4	W5	W6	W7	LTE	W1	W2	W3	W4	W5	W6	W7	LTE
S-I-1	UPSTREAM	4.6	4.4	3.7	4.3	2.2	1.9	1.5	103	4.6	3.9	3.2	4.1	2.1	1.6	1.2	102
	DOWNSTREAM	4.7	4.3	3.7	4.5	2.2	1.9	1.5		5.0	3.9	3.3	4.2	2.1	1.6	1.2	
S-I-2	UPSTREAM	4.7	4.4	3.7	4.2	2.2	1.9	1.5	104	5.0	4.1	3.5	4.4	2.2	1.7	1.3	101
	DOWNSTREAM	4.6	4.2	3.7	4.4	2.2	1.9	1.5		5.2	4.1	3.5	4.4	2.3	1.7	1.3	
M-I-1	UPSTREAM	5.0	4.5	3.8	4.4	2.2	1.9	1.5	105	4.7	3.8	3.2	4.0	2.1	1.6	1.2	102
	DOWNSTREAM	4.7	4.3	3.6	4.5	2.1	1.9	1.5		5.0	3.8	3.2	4.1	2.1	1.6	1.2	
M-I-2	UPSTREAM	4.9	4.6	3.8	4.3	2.3	2.0	1.6	105	5.0	4.2	3.6	4.5	2.3	1.8	1.4	101
	DOWNSTREAM	4.9	4.4	3.8	4.6	2.3	2.0	1.6		5.3	4.2	3.5	4.5	2.3	1.8	1.4	
L-I-1	UPSTREAM	4.9	4.7	3.9	4.5	2.4	2.1	1.7	105	4.5	4.0	3.4	4.2	2.3	1.8	1.4	101
	DOWNSTREAM	4.8	4.4	3.8	4.6	2.3	2.0	1.6		5.0	3.9	3.4	4.3	2.3	1.8	1.5	
L-I-2	UPSTREAM	4.4	4.2	3.5	4.0	2.1	1.8	1.5	105	4.6	3.8	3.2	4.0	2.1	1.6	1.2	101
	DOWNSTREAM	4.3	4.0	3.4	4.2	2.0	1.8	1.4		4.8	3.8	3.2	4.0	2.1	1.6	1.2	
S-II-1	UPSTREAM	4.8	4.7	4.0	4.6	2.5	2.2	1.8	103	5.6	4.6	3.9	4.8	2.6	2.1	1.7	103
	DOWNSTREAM	4.9	4.6	3.9	4.7	2.5	2.2	1.8		5.7	4.5	3.9	5.0	2.6	2.1	1.7	
S-II-2	UPSTREAM	4.6	4.2	3.5	4.3	2.1	1.8	1.4	102	5.1	4.0	3.4	4.4	2.1	1.6	1.2	101
	DOWNSTREAM	4.4	4.1	3.5	4.3	2.0	1.7	1.4		5.0	3.9	3.2	4.3	2.0	1.5	1.2	
M-II-1	UPSTREAM	5.5	5.1	4.2	4.8	2.5	2.2	1.7	107	5.3	4.5	3.8	4.8	2.5	2.0	1.6	101
	DOWNSTREAM	5.0	4.6	3.9	5.0	2.4	2.1	1.7		5.5	4.4	3.8	4.7	2.5	2.0	1.5	
M-II-2	UPSTREAM	4.7	4.4	3.7	4.2	2.2	1.9	1.5	104	5.0	4.1	3.4	4.3	2.2	1.7	1.2	101
	DOWNSTREAM	5.0	4.3	3.6	4.5	2.2	1.9	1.5		5.3	4.1	3.4	4.4	2.2	1.7	1.3	
L-II-1	UPSTREAM	5.1	4.8	4.2	4.7	2.7	2.5	2.0	103	5.5	4.6	4.1	5.0	2.8	2.3	1.8	100
	DOWNSTREAM	4.9	4.7	4.1	4.9	2.7	2.4	2.0		5.8	4.6	4.0	5.0	2.8	2.3	1.8	
L-II-2	UPSTREAM	4.1	3.9	3.3	3.8	2.0	1.8	1.5	103	4.6	3.8	3.2	3.9	2.1	1.7	1.3	102
	DOWNSTREAM	4.1	3.7	3.2	3.9	2.0	1.8	1.5		4.7	3.7	3.1	4.0	2.1	1.6	1.3	

SECTION I.D.	3-US287-2	WINTER TESTING				DATE		02/16/11		SUMMER TESTING				DATE		08/31/11	
LOCATION						TIME								TIME			
CRACKS		W1	W2	W3	W4	W5	W6	W7	LTE	W1	W2	W3	W4	W5	W6	W7	LTE
S-I-1	UPSTREAM																
	DOWNSTREAM																
S-I-2	UPSTREAM																
	DOWNSTREAM																
M-I-1	UPSTREAM	1.6	1.5	1.4	1.5	1.1	1.0	0.9	101	2.3	1.8	1.6	1.9	1.2	1.1	0.9	101
	DOWNSTREAM	1.7	1.5	1.4	1.5	1.1	1.1	1.0		2.2	1.8	1.6	1.9	1.3	1.1	0.9	
M-I-2	UPSTREAM	1.9	1.8	1.6	1.8	1.2	1.2	1.1	103	2.0	1.6	1.4	1.7	1.1	1.0	0.9	102
	DOWNSTREAM	1.8	1.7	1.6	1.8	1.2	1.1	1.0		2.0	1.6	1.4	1.7	1.2	1.0	0.9	
L-I-1	UPSTREAM	1.7	1.6	1.5	1.6	1.1	1.1	1.1	101	2.3	1.8	1.6	2.0	1.4	1.2	1.1	102
	DOWNSTREAM	1.6	1.6	1.4	1.6	1.1	1.1	1.1		2.2	1.8	1.7	2.0	1.4	1.2	1.1	
L-I-2	UPSTREAM	1.9	1.6	1.5	1.6	1.2	1.2	1.2	102	2.2	1.8	1.7	1.9	1.3	1.2	1.0	102
	DOWNSTREAM	1.8	1.6	1.5	1.6	1.2	1.2	1.1		2.2	1.8	1.6	1.9	1.3	1.2	1.1	
S-II-1	UPSTREAM	1.6	1.4	1.4	1.5	1.1	1.1	1.0	100	2.0	1.7	1.5	1.8	1.2	1.0	0.9	101
	DOWNSTREAM	1.6	1.4	1.4	1.5	1.1	1.1	1.0		2.1	1.6	1.5	1.8	1.2	1.0	0.9	
S-II-2	UPSTREAM	1.5	1.5	1.4	1.5	1.1	1.1	1.1	99	2.2	1.7	1.6	1.9	1.3	1.1	1.0	101
	DOWNSTREAM	1.6	1.5	1.4	1.5	1.1	1.1	1.0		2.2	1.7	1.6	1.9	1.3	1.1	1.0	
M-II-1	UPSTREAM	1.6	1.5	1.3	1.5	1.1	1.1	1.0	100	2.2	1.7	1.5	1.8	1.2	1.1	0.9	102
	DOWNSTREAM	1.5	1.4	1.3	1.5	1.1	1.1	1.0		2.1	1.6	1.5	1.8	1.2	1.0	0.9	
M-II-2	UPSTREAM	1.4	1.3	1.2	1.3	0.9	0.9	0.9	101	1.8	1.4	1.3	1.5	1.0	0.9	0.7	102
	DOWNSTREAM	1.4	1.3	1.2	1.4	0.9	1.0	0.9		1.9	1.5	1.3	1.6	1.0	0.8	0.7	
L-II-1	UPSTREAM	1.4	1.4	1.2	1.3	1.0	0.9	0.9	103	1.8	1.5	1.3	1.5	1.0	0.8	0.7	103
	DOWNSTREAM	1.4	1.3	1.2	1.4	0.9	0.9	0.9		1.8	1.5	1.3	1.6	1.0	0.8	0.7	
L-II-2	UPSTREAM	1.5	1.4	1.3	1.4	1.0	1.1	1.0	100	2.0	1.6	1.4	1.7	1.1	1.0	0.9	101
	DOWNSTREAM	1.4	1.4	1.3	1.4	1.0	1.1	1.0		2.0	1.6	1.5	1.7	1.2	1.0	0.9	

SECTION I.D.	3-US81-1	WINTER TESTING				DATE		12/03/10		SUMMER TESTING				DATE		09/01/11	
LOCATION						TIME								TIME			
CRACKS		W1	W2	W3	W4	W5	W6	W7	LTE	W1	W2	W3	W4	W5	W6	W7	LTE
S-1	UPSTREAM	4.2	3.9	3.3	4.0	1.9	1.7	1.4	97	4.6	3.7	3.1	4.0	1.9	1.4	1.0	100
	DOWNSTREAM	4.3	4.1	3.4	4.0	1.9	1.7	1.3		4.8	3.7	3.1	4.0	1.9	1.4	1.1	
S-2	UPSTREAM	5.2	5.0	4.1	4.6	2.3	2.0	1.6	106	8.1	6.8	5.9	6.8	4.3	3.5	2.9	103
	DOWNSTREAM	5.4	4.9	4.2	5.1	2.4	2.2	1.7		8.4	6.9	6.1	7.3	4.4	3.6	3.0	
S-3	UPSTREAM	3.4	3.1	2.5	3.0	1.4	1.3	1.0	105	3.8	3.0	2.4	3.1	1.4	1.0	0.8	103
	DOWNSTREAM	3.5	3.0	2.6	3.1	1.4	1.3	1.0		4.0	3.0	2.4	3.3	1.4	1.0	0.8	
S-4	UPSTREAM	4.5	4.0	3.3	4.0	1.9	1.7	1.4	103	7.6	6.4	5.5	7.0	3.6	2.8	2.1	103
	DOWNSTREAM	4.3	3.9	3.3	4.1	1.9	1.7	1.4		7.7	6.2	5.3	7.0	3.5	2.7	2.0	
M-1	UPSTREAM	3.9	3.7	3.0	3.5	1.6	1.4	1.0	107	4.7	3.8	3.1	4.0	1.9	1.4	1.1	102
	DOWNSTREAM	4.2	3.7	3.1	4.0	1.7	1.6	1.2		4.8	3.7	3.1	4.1	1.9	1.5	1.1	
M-2	UPSTREAM	4.4	4.0	3.4	4.0	2.0	1.7	1.3	102	5.0	4.0	3.3	4.3	2.0	1.5	1.1	101
	DOWNSTREAM	4.4	4.0	3.4	4.1	2.0	1.7	1.4		5.2	4.0	3.3	4.4	2.1	1.6	1.2	
M-3	UPSTREAM	3.6	3.3	2.8	3.5	1.6	1.5	1.2	96	4.6	4.0	3.5	3.9	2.5	2.0	1.6	100
	DOWNSTREAM	3.7	3.4	3.0	3.3	1.9	1.7	1.5		5.1	4.2	3.7	4.2	2.7	2.2	1.8	
M-4	UPSTREAM	4.0	3.8	3.1	3.7	1.8	1.6	1.3	103	4.1	3.2	2.6	3.4	1.5	1.1	0.9	102
	DOWNSTREAM	3.9	3.7	3.1	3.8	1.8	1.7	1.3		4.2	3.1	2.6	3.4	1.5	1.2	0.9	
L-1	UPSTREAM	4.0	3.8	3.0	3.5	1.7	1.5	1.1	108	4.4	3.4	2.8	3.7	1.8	1.3	1.0	101
	DOWNSTREAM	4.0	3.5	2.9	3.8	1.7	1.5	1.2		4.5	3.4	2.8	3.7	1.8	1.3	1.0	
L-2	UPSTREAM	4.4	4.3	3.5	4.0	1.9	1.6	1.3	108	4.7	3.6	3.0	3.9	1.8	1.3	1.0	101
	DOWNSTREAM	4.3	3.9	3.2	4.2	1.7	1.5	1.2		4.7	3.7	3.0	3.9	1.9	1.4	1.0	
L-3	UPSTREAM	3.3	3.1	2.5	3.0	1.4	1.3	1.0	102	3.1	2.4	1.9	2.5	1.1	0.8	0.7	101
	DOWNSTREAM	3.3	2.9	2.4	2.9	1.3	1.2	0.9		3.1	2.5	1.9	2.6	1.1	0.8	0.6	
L-4	UPSTREAM	4.0	3.7	3.1	3.7	1.7	1.5	1.2	104	5.0	4.0	3.3	4.3	2.0	1.4	1.1	103
	DOWNSTREAM	3.9	3.5	2.9	3.8	1.6	1.4	1.1		5.0	3.8	3.1	4.3	1.9	1.4	1.0	

SECTION I.D.	5-I27-1	WINTER TESTING				DATE		12/01/10		SUMMER TESTING				DATE		07/21/11	
LOCATION						TIME								TIME			
CRACKS		W1	W2	W3	W4	W5	W6	W7	LTE	W1	W2	W3	W4	W5	W6	W7	LTE
S-I-1	UPSTREAM	3.1	2.9	2.6	2.9	1.8	1.7	1.6	101	3.5	3.2	2.9	3.2	2.0	1.9	1.7	100
	DOWNSTREAM	3.0	2.9	2.6	2.9	1.8	1.8	1.5		3.7	3.2	2.9	3.2	2.0	1.9	1.7	
S-I-2	UPSTREAM	2.7	2.5	2.1	2.6	1.4	1.3	1.2	102	3.4	3.0	2.5	3.0	1.7	1.5	1.3	101
	DOWNSTREAM	2.6	2.4	2.1	2.5	1.4	1.3	1.2		3.2	2.9	2.5	3.0	1.6	1.5	1.3	
M-I-1	UPSTREAM	3.2	2.9	2.6	2.9	1.8	1.8	1.6	101	3.7	3.4	3.0	3.4	2.1	2.1	1.8	99
	DOWNSTREAM	3.1	2.9	2.6	2.9	1.8	1.7	1.5		3.6	3.5	3.1	3.4	2.2	2.1	1.8	
M-I-2	UPSTREAM	3.1	2.9	2.5	2.9	1.6	1.5	1.3	100	3.5	3.2	2.8	3.2	1.8	1.7	1.4	99
	DOWNSTREAM	3.1	2.9	2.5	2.9	1.7	1.6	1.3		3.6	3.2	2.7	3.1	1.8	1.7	1.5	
L-I-1	UPSTREAM																
	DOWNSTREAM																
L-I-2	UPSTREAM																
	DOWNSTREAM																
S-II-1	UPSTREAM	2.8	2.6	2.2	2.6	1.5	1.4	1.2	100	3.4	3.0	2.6	3.0	1.7	1.6	1.4	100
	DOWNSTREAM	2.8	2.5	2.2	2.6	1.5	1.4	1.2		3.4	3.0	2.6	3.0	1.7	1.6	1.4	
S-II-2	UPSTREAM	2.7	2.5	2.2	2.5	1.5	1.4	1.2	99	2.9	2.6	2.3	2.6	1.5	1.4	1.2	100
	DOWNSTREAM	2.7	2.5	2.2	2.5	1.5	1.4	1.2		2.9	2.6	2.2	2.7	1.5	1.5	1.3	
M-II-1	UPSTREAM	3.5	3.2	2.6	3.0	1.6	1.5	1.2	105	3.8	3.4	2.9	3.5	1.8	1.7	1.4	100
	DOWNSTREAM	3.3	3.0	2.5	3.2	1.6	1.5	1.3		3.7	3.3	2.8	3.4	1.8	1.7	1.4	
M-II-2	UPSTREAM	3.0	2.9	2.5	2.8	1.6	1.4	1.2	103	3.7	3.3	2.9	3.3	1.9	1.7	1.5	101
	DOWNSTREAM	3.2	2.9	2.5	3.0	1.6	1.5	1.2		3.2	3.2	2.8	3.3	1.8	1.7	1.4	
L-II-1	UPSTREAM																
	DOWNSTREAM																
L-II-2	UPSTREAM																
	DOWNSTREAM																

SECTION I.D.	5-LP289-1	WINTER TESTING				DATE		12/01/10		SUMMER TESTING				DATE		07/20/11	
LOCATION						TIME								TIME			
CRACKS		W1	W2	W3	W4	W5	W6	W7	LTE	W1	W2	W3	W4	W5	W6	W7	LTE
S-I-1	UPSTREAM	3.9	3.6	3.1	3.7	2.1	1.9	1.6	100	4.2	3.9	3.4	3.9	2.1	2.2	1.9	100
	DOWNSTREAM	3.7	3.5	3.1	3.6	2.1	2.0	1.7		3.8	3.8	3.4	3.9	2.1	2.3	1.9	
S-I-2	UPSTREAM	3.5	3.3	2.9	3.3	2.0	2.0	1.7	103	3.3	3.1	2.8	3.1	1.8	2.2	1.9	100
	DOWNSTREAM	3.6	3.3	3.0	3.5	2.1	2.1	1.8		3.1	3.0	2.7	3.0	1.8	2.0	1.9	
M-I-1	UPSTREAM	3.7	3.4	3.1	3.4	2.1	1.9	1.6	102	4.7	3.9	3.4	3.9	2.2	2.2	1.9	100
	DOWNSTREAM	3.7	3.5	3.1	3.6	2.1	1.9	1.7		4.0	3.9	3.5	4.0	2.1	2.2	1.9	
M-I-2	UPSTREAM	3.7	3.5	3.1	3.4	2.0	1.8	1.6	103	4.0	3.9	3.4	3.9	2.0	2.1	1.8	101
	DOWNSTREAM	4.0	3.5	3.0	3.7	1.9	1.8	1.6		4.1	3.8	3.4	3.9	2.0	2.2	1.9	
L-I-1	UPSTREAM	3.0	2.8	2.5	2.8	1.8	1.8	1.6	101	2.7	2.9	2.5	2.7	1.6	1.9	1.6	102
	DOWNSTREAM	3.1	2.8	2.5	2.8	1.8	1.8	1.6		3.1	2.8	2.5	2.8	1.7	1.9	1.8	
L-I-2	UPSTREAM	3.0	2.8	2.5	2.9	1.8	1.8	1.5	102	2.4	2.6	2.3	2.7	1.6	1.8	1.7	102
	DOWNSTREAM	3.0	2.8	2.5	2.9	1.8	1.7	1.5		2.7	2.6	2.2	2.7	1.6	1.8	1.8	
S-II-1	UPSTREAM	3.2	3.1	2.7	3.0	1.8	1.7	1.4	102	3.3	3.4	3.0	3.4	1.8	2.0	1.7	100
	DOWNSTREAM	3.5	3.1	2.7	3.2	1.8	1.7	1.5		3.6	3.4	3.0	3.4	1.8	2.0	1.7	
S-II-2	UPSTREAM	2.6	2.3	2.1	2.4	1.4	1.4	1.1	99	2.8	2.7	2.4	2.7	1.4	1.6	1.4	100
	DOWNSTREAM	2.6	2.4	2.1	2.4	1.5	1.5	1.3		2.8	2.7	2.3	2.7	1.4	1.5	1.4	
M-II-1	UPSTREAM	3.2	3.1	2.7	3.1	1.8	1.7	1.5	102	3.8	3.7	3.3	3.7	2.0	2.2	1.9	101
	DOWNSTREAM	3.2	3.1	2.7	3.1	1.8	1.7	1.5		3.5	3.6	3.3	3.7	2.0	2.2	1.9	
M-II-2	UPSTREAM	2.6	2.5	2.2	2.5	1.4	1.3	1.1	101	2.7	2.9	2.5	2.7	1.6	1.6	1.4	103
	DOWNSTREAM	2.7	2.5	2.2	2.5	1.5	1.4	1.2		2.8	2.8	2.5	2.8	1.5	1.6	1.4	
L-II-1	UPSTREAM	3.2	3.1	2.7	3.0	1.9	1.8	1.6	101	3.7	3.6	3.2	3.6	2.0	2.1	1.9	100
	DOWNSTREAM	3.3	3.1	2.8	3.1	2.0	1.9	1.6		3.9	3.7	3.3	3.6	2.0	2.2	1.9	
L-II-2	UPSTREAM	2.8	2.5	2.2	2.5	1.5	1.4	1.2	101	3.0	2.8	2.3	2.8	1.4	1.6	1.4	100
	DOWNSTREAM	2.8	2.5	2.2	2.6	1.6	1.5	1.2		2.8	2.7	2.4	2.7	1.2	1.6	1.4	

SECTION I.D.	12-US290-1	WINTER TESTING				DATE	03/12/11			SUMMER TESTING				DATE			
LOCATION						TIME								TIME			
CRACKS		W1	W2	W3	W4	W5	W6	W7	LTE	W1	W2	W3	W4	W5	W6	W7	LTE
J-1	UPSTREAM	3.6	3.3	3.0	2.3	1.9	1.5	1.2	109								
	DOWNSTREAM	3.7	3.2	3.1	2.3	1.9	1.5	1.2									
C-1	UPSTREAM	3.4	3.1	3.1	2.2	1.8	1.4	1.2	107								
	DOWNSTREAM	3.4	3.0	2.9	2.2	1.8	1.4	1.2									
J-2	UPSTREAM	3.7	3.4	3.0	2.3	1.9	1.5	1.2	108								
	DOWNSTREAM	3.6	3.3	3.1	2.2	1.9	1.5	1.3									
C-2	UPSTREAM	3.2	2.8	2.8	2.0	1.7	1.4	1.2	107								
	DOWNSTREAM	3.0	2.7	2.6	2.0	1.7	1.4	1.3									
J-3	UPSTREAM	2.6	2.3	2.1	1.5	1.2	0.9	0.8	109								
	DOWNSTREAM	2.5	2.2	2.1	1.5	1.2	0.9	0.8									
C-3	UPSTREAM	2.6	2.4	2.1	1.6	1.3	1.0	0.9	109								
	DOWNSTREAM	2.6	2.3	2.2	1.6	1.3	1.1	0.9									
J-4	UPSTREAM	2.6	2.4	2.2	1.7	1.4	1.1	1.0	108								
	DOWNSTREAM	2.7	2.4	2.3	1.7	1.4	1.1	1.0									
C-4	UPSTREAM	2.3	2.1	2.0	1.5	1.3	1.0	0.9	106								
	DOWNSTREAM	2.3	2.0	1.9	1.5	1.2	1.0	0.9									
J-5	UPSTREAM	2.3	2.0	1.9	1.4	1.1	0.9	0.8	107								
	DOWNSTREAM	2.3	2.0	1.9	1.4	1.1	0.9	0.8									
C-5	UPSTREAM	2.5	2.3	2.1	1.7	1.4	1.1	1.0	106								
	DOWNSTREAM	2.5	2.3	2.2	1.7	1.4	1.2	1.0									
	UPSTREAM																
	DOWNSTREAM																
	UPSTREAM																
	DOWNSTREAM																

SECTION I.D.	12-US290-2	WINTER TESTING				DATE		03/12/11		SUMMER TESTING				DATE			
LOCATION						TIME								TIME			
CRACKS		W1	W2	W3	W4	W5	W6	W7	LTE	W1	W2	W3	W4	W5	W6	W7	LTE
S-I-1	UPSTREAM	3.4	3.2	2.9	2.3	1.9	1.4	1.2	106								
	DOWNSTREAM	3.5	3.2	3.0	2.3	1.9	1.4	1.2									
S-I-2	UPSTREAM	3.6	3.4	3.1	2.4	1.9	1.5	1.2	105								
	DOWNSTREAM	3.7	3.4	3.2	2.4	1.9	1.5	1.2									
M-I-1	UPSTREAM	3.5	3.2	3.0	2.3	1.9	1.5	1.2	106								
	DOWNSTREAM	3.5	3.2	3.0	2.3	1.9	1.5	1.2									
M-I-2	UPSTREAM	3.1	2.9	2.7	2.1	1.8	1.4	1.2	106								
	DOWNSTREAM	3.2	2.9	2.8	2.2	1.8	1.4	1.2									
L-I-1	UPSTREAM																
	DOWNSTREAM																
L-I-2	UPSTREAM																
	DOWNSTREAM																
S-II-1	UPSTREAM	4.0	3.7	3.4	2.6	2.1	1.6	1.3	107								
	DOWNSTREAM	4.0	3.6	3.4	2.5	2.1	1.6	1.3									
S-II-2	UPSTREAM	4.5	4.1	3.9	2.9	2.4	1.8	1.4	106								
	DOWNSTREAM	4.5	4.1	3.9	2.9	2.3	1.8	1.4									
M-II-1	UPSTREAM	3.5	3.3	3.0	2.3	1.9	1.5	1.2	107								
	DOWNSTREAM	3.6	3.2	3.0	2.3	1.9	1.4	1.2									
M-II-2	UPSTREAM	3.6	3.4	3.1	2.5	2.0	1.6	1.3	104								
	DOWNSTREAM	3.7	3.5	3.2	2.5	2.0	1.6	1.3									
L-II-1	UPSTREAM	3.8	3.5	3.3	2.4	2.0	1.5	1.3	106								
	DOWNSTREAM	3.7	3.4	3.2	2.4	2.0	1.5	1.3									
L-II-2	UPSTREAM	3.6	3.3	3.1	2.3	1.9	1.4	1.1	107								
	DOWNSTREAM	3.6	3.3	3.1	2.3	1.9	1.4	1.2									

SECTION I.D.	12-US290-3	WINTER TESTING				DATE		03/12/11		SUMMER TESTING				DATE			
LOCATION						TIME								TIME			
CRACKS		W1	W2	W3	W4	W5	W6	W7	LTE	W1	W2	W3	W4	W5	W6	W7	LTE
S-I-1	UPSTREAM	3.4	3.1	2.9	2.0	1.6	1.2	0.9	111								
	DOWNSTREAM	3.4	2.9	2.9	1.9	1.5	1.1	0.9									
S-I-2	UPSTREAM	2.8	2.6	2.4	1.7	1.4	1.1	0.9	107								
	DOWNSTREAM	2.9	2.5	2.4	1.7	1.4	1.1	0.9									
M-I-1	UPSTREAM	3.4	3.1	2.9	2.1	1.7	1.3	1.1	108								
	DOWNSTREAM	3.5	3.1	3.0	2.1	1.7	1.3	1.1									
M-I-2	UPSTREAM	3.2	2.9	2.7	2.0	1.6	1.2	1.0	107								
	DOWNSTREAM	3.3	2.9	2.8	2.0	1.6	1.2	1.0									
L-I-1	UPSTREAM	3.2	2.9	2.7	2.0	1.6	1.2	1.0	107								
	DOWNSTREAM	3.1	2.8	2.7	1.9	1.6	1.2	1.0									
L-I-2	UPSTREAM	2.8	2.5	2.4	1.8	1.4	1.1	0.9	106								
	DOWNSTREAM	2.9	2.5	2.4	1.8	1.5	1.1	0.9									
S-II-1	UPSTREAM	3.8	3.5	3.2	2.5	2.0	1.5	1.2	106								
	DOWNSTREAM	3.9	3.6	3.3	2.5	2.0	1.5	1.2									
S-II-2	UPSTREAM	3.3	2.9	2.7	1.9	1.5	1.2	0.9	110								
	DOWNSTREAM	3.3	2.8	2.8	1.9	1.5	1.2	0.9									
M-II-1	UPSTREAM	3.2	2.8	2.6	1.9	1.5	1.2	1.0	109								
	DOWNSTREAM	3.1	2.7	2.6	1.9	1.5	1.1	1.0									
M-II-2	UPSTREAM	3.0	2.7	2.5	1.8	1.4	1.1	0.9	108								
	DOWNSTREAM	3.0	2.6	2.5	1.8	1.4	1.1	0.9									
L-II-1	UPSTREAM	2.9	2.6	2.4	1.8	1.4	1.1	0.9	107								
	DOWNSTREAM	3.0	2.7	2.5	1.8	1.5	1.1	0.9									
L-II-2	UPSTREAM	2.9	2.7	2.4	1.8	1.5	1.2	1.0	107								
	DOWNSTREAM	2.9	2.7	2.4	1.8	1.5	1.1	1.0									

SECTION I.D.	19-US59-1	WINTER TESTING				DATE		02/23/11		SUMMER TESTING				DATE		07/19/11	
LOCATION						TIME								TIME			
CRACKS		W1	W2	W3	W4	W5	W6	W7	LTE	W1	W2	W3	W4	W5	W6	W7	LTE
S-I-1	UPSTREAM	2.3	1.8	1.5	1.9	1.2	1.0	0.9	104	2.4	1.9	1.7	2.0	1.3	1.1	0.9	100
	DOWNSTREAM	2.5	1.8	1.6	2.0	1.2	1.0	0.9		2.5	1.9	1.7	2.1	1.3	1.1	0.9	
S-I-2	UPSTREAM	2.2	1.7	1.6	1.9	1.2	1.1	0.9	94	2.4	1.9	1.7	2.0	1.3	1.1	1.0	99
	DOWNSTREAM	2.5	2.0	1.5	1.9	1.2	1.0	0.9		2.6	1.9	1.6	2.0	1.3	1.1	1.0	
M-I-1	UPSTREAM	2.3	1.8	1.6	1.9	1.2	1.0	0.9	105	2.3	1.9	1.7	2.0	1.3	1.1	1.0	102
	DOWNSTREAM	2.5	1.8	1.6	2.1	1.2	1.0	0.9		2.4	1.8	1.6	2.0	1.3	1.1	0.9	
M-I-2	UPSTREAM	2.4	1.7	1.5	1.9	1.2	1.0	0.9	97	2.8	2.1	1.8	2.2	1.3	1.1	1.0	102
	DOWNSTREAM	3.3	1.9	1.6	2.0	1.2	1.0	0.9		3.1	2.1	1.8	2.3	1.3	1.1	1.0	
L-I-1	UPSTREAM	2.6	1.8	1.5	2.0	1.2	1.1	1.0	103	2.4	1.8	1.6	1.9	1.2	1.1	1.0	104
	DOWNSTREAM	3.0	1.8	1.6	2.1	1.3	1.2	1.0		2.4	1.8	1.6	2.0	1.3	1.1	1.0	
L-I-2	UPSTREAM	2.7	1.9	1.6	2.0	1.2	1.1	0.9	106	2.7	1.9	1.7	2.0	1.3	1.1	1.0	104
	DOWNSTREAM	2.5	1.8	1.6	2.1	1.3	1.2	1.0		2.6	1.9	1.7	2.1	1.3	1.1	1.0	
S-II-1	UPSTREAM	2.3	1.9	1.7	2.0	1.4	1.2	1.0	102	2.7	2.2	2.0	2.3	1.5	1.3	1.1	102
	DOWNSTREAM	2.5	1.9	1.7	2.1	1.3	1.2	1.0		2.9	2.2	2.0	2.4	1.5	1.3	1.1	
S-II-2	UPSTREAM									2.4	1.9	1.6	2.0	1.2	1.0	0.8	99
	DOWNSTREAM									2.5	1.9	1.7	2.0	1.2	1.0	0.8	
M-II-1	UPSTREAM	2.3	1.9	1.6	2.0	1.3	1.1	0.9	103	2.7	2.2	1.9	2.3	1.4	1.2	1.0	103
	DOWNSTREAM	2.4	1.8	1.6	2.0	1.2	1.0	0.9		2.8	2.1	1.9	2.3	1.4	1.2	1.0	
M-II-2	UPSTREAM	2.1	1.7	1.6	1.9	1.3	1.1	1.0	102	2.5	1.9	1.7	2.0	1.3	1.2	1.0	101
	DOWNSTREAM	2.2	1.7	1.5	1.9	1.3	1.1	1.0		2.3	1.9	1.7	2.1	1.3	1.1	1.0	
L-II-1	UPSTREAM	2.3	1.6	1.4	1.7	1.0	0.9	0.8	106	2.4	1.7	1.4	1.8	1.1	0.9	0.8	102
	DOWNSTREAM	2.2	1.5	1.3	1.8	1.0	0.8	0.7		2.1	1.6	1.4	1.8	1.1	0.9	0.8	
L-II-2	UPSTREAM	2.9	1.8	1.5	2.1	1.1	0.9	0.8	99	2.8	1.9	1.6	2.0	1.2	1.0	0.9	104
	DOWNSTREAM	3.0	1.8	1.5	2.0	1.1	1.0	0.8		2.6	1.8	1.6	2.1	1.2	1.0	0.9	

SECTION I.D.	19-US59-2	WINTER TESTING				DATE		02/23/11		SUMMER TESTING				DATE		07/19/11	
LOCATION						TIME								TIME			
CRACKS		W1	W2	W3	W4	W5	W6	W7	LTE	W1	W2	W3	W4	W5	W6	W7	LTE
S-I-1	UPSTREAM	1.9	1.5	1.3	1.6	1.0	0.9	0.8	101	1.9	1.5	1.3	1.6	1.0	0.9	0.8	99
	DOWNSTREAM	1.8	1.4	1.3	1.6	1.0	0.9	0.7		1.7	1.4	1.2	1.4	0.9	0.8	0.7	
S-I-2	UPSTREAM	1.7	1.3	1.2	1.5	0.9	0.7	0.6	100	1.7	1.3	1.1	1.4	0.7	0.6	0.5	101
	DOWNSTREAM	1.8	1.4	1.2	1.5	0.9	0.7	0.6		1.8	1.3	1.2	1.4	0.9	0.7	0.7	
M-I-1	UPSTREAM	1.8	1.4	1.2	1.5	1.0	0.8	0.7	102	1.8	1.4	1.2	1.4	0.9	0.8	0.7	102
	DOWNSTREAM	1.8	1.4	1.2	1.6	1.0	0.8	0.7		1.9	1.5	1.3	1.6	1.1	0.9	0.8	
M-I-2	UPSTREAM	2.1	1.6	1.4	1.7	1.2	1.0	0.9	102	1.9	1.5	1.4	1.6	1.1	0.9	0.8	101
	DOWNSTREAM	2.1	1.6	1.4	1.8	1.1	1.0	0.9		2.0	1.5	1.4	1.6	1.1	0.9	0.8	
L-I-1	UPSTREAM	2.0	1.5	1.3	1.7	1.0	0.8	0.7	104	2.0	1.7	1.4	1.6	1.0	0.8	0.7	107
	DOWNSTREAM	2.1	1.4	1.3	1.7	0.9	0.8	0.7		2.0	1.5	1.3	1.7	1.0	0.9	0.7	
L-I-2	UPSTREAM	1.8	1.3	1.1	1.5	0.8	0.7	0.6	103	1.6	1.2	1.0	1.3	0.7	0.6	0.5	100
	DOWNSTREAM	1.7	1.2	1.1	1.4	0.8	0.7	0.6		1.8	1.4	1.2	1.5	0.9	0.8	0.7	
S-II-1	UPSTREAM	2.0	1.6	1.4	1.8	1.1	0.9	0.8	100	2.1	1.6	1.4	1.7	1.1	0.9	0.8	100
	DOWNSTREAM	2.0	1.6	1.5	1.8	1.1	0.9	0.8		2.0	1.6	1.4	1.7	1.1	0.9	0.8	
S-II-2	UPSTREAM	1.7	1.3	1.1	1.4	0.9	0.8	0.7	100	1.7	1.3	1.2	1.4	0.9	0.7	0.6	98
	DOWNSTREAM	1.6	1.3	1.1	1.4	0.9	0.7	0.6		1.7	1.4	1.2	1.5	0.8	0.7	0.6	
M-II-1	UPSTREAM	1.9	1.5	1.4	1.7	1.0	0.9	0.7	101	2.0	1.5	1.4	1.7	1.0	0.8	0.7	101
	DOWNSTREAM	2.0	1.5	1.4	1.7	1.0	0.9	0.7		2.0	1.5	1.3	1.7	1.0	0.8	0.7	
M-II-2	UPSTREAM	1.6	1.3	1.1	1.4	0.9	0.7	0.6	99	1.8	1.3	1.2	1.5	0.9	0.8	0.7	100
	DOWNSTREAM	1.7	1.3	1.2	1.4	0.9	0.7	0.6		1.8	1.3	1.2	1.5	0.9	0.7	0.6	
L-II-1	UPSTREAM	1.8	1.4	1.3	1.6	1.0	0.8	0.7	100	1.9	1.4	1.3	1.5	1.0	0.8	0.7	101
	DOWNSTREAM	1.8	1.4	1.3	1.6	1.0	0.8	0.7		1.9	1.4	1.2	1.5	0.9	0.8	0.7	
L-II-2	UPSTREAM	1.6	1.3	1.2	1.5	0.9	0.8	0.7	101	1.7	1.3	1.2	1.4	0.9	0.8	0.7	101
	DOWNSTREAM	1.7	1.3	1.2	1.4	0.9	0.8	0.7		1.8	1.3	1.2	1.4	0.9	0.8	0.7	

SECTION I.D.	24-I10-1	WINTER TESTING				DATE		02/23/11		SUMMER TESTING				DATE		08/03/11	
LOCATION						TIME								TIME			
CRACKS		W1	W2	W3	W4	W5	W6	W7	LTE	W1	W2	W3	W4	W5	W6	W7	LTE
S-I-1	UPSTREAM	1.5	1.3	1.3	1.4	1.0	1.0	0.8	100	1.5	1.3	1.2	1.4	0.9	0.9	0.8	99
	DOWNSTREAM	1.4	1.3	1.2	1.4	1.0	1.0	0.8		1.4	1.3	1.3	1.4	1.0	0.9	0.8	
S-I-2	UPSTREAM	1.3	1.2	1.2	1.3	0.9	1.0	0.8	101	1.4	1.2	1.2	1.3	0.9	0.9	0.7	99
	DOWNSTREAM	1.3	1.2	1.2	1.3	0.9	1.0	0.8		1.3	1.2	1.2	1.3	0.9	0.9	0.8	
M-I-1	UPSTREAM	1.5	1.3	1.3	1.4	1.0	1.0	0.8	100	1.4	1.3	1.2	1.3	0.9	0.9	0.8	100
	DOWNSTREAM	1.5	1.3	1.2	1.4	1.0	1.0	0.8		1.4	1.3	1.2	1.3	0.9	0.9	0.7	
M-I-2	UPSTREAM	1.3	1.2	1.2	1.2	0.9	0.9	0.8	99	1.3	1.2	1.1	1.2	0.8	0.8	0.7	100
	DOWNSTREAM	1.4	1.2	1.2	1.3	0.9	1.0	0.8		1.3	1.2	1.1	1.2	0.8	0.8	0.7	
L-I-1	UPSTREAM	1.3	1.2	1.1	1.2	0.9	0.9	0.8	99	1.3	1.1	1.2	1.3	0.9	1.0	0.9	95
	DOWNSTREAM	1.3	1.2	1.2	1.2	0.9	0.9	0.8		1.3	1.2	1.1	1.2	0.9	0.9	0.7	
L-I-2	UPSTREAM	1.4	1.2	1.2	1.3	1.0	1.0	0.8	99	1.3	1.2	1.2	1.2	0.9	0.9	0.7	99
	DOWNSTREAM	1.4	1.3	1.2	1.3	1.0	1.0	0.8		1.5	1.3	1.2	1.3	0.9	0.9	0.8	
S-II-1	UPSTREAM	1.3	1.2	1.2	1.3	0.9	1.0	0.8	101	1.3	1.2	1.2	1.3	0.9	0.9	0.8	100
	DOWNSTREAM	1.3	1.2	1.2	1.3	0.9	0.9	0.8		1.4	1.2	1.2	1.3	0.9	0.9	0.8	
S-II-2	UPSTREAM	1.3	1.2	1.1	1.3	0.9	0.9	0.8	97	1.3	1.2	1.1	1.3	0.9	0.9	0.7	100
	DOWNSTREAM	1.3	1.1	1.1	1.2	0.9	0.9	0.8		1.2	1.2	1.1	1.3	0.9	0.9	0.7	
M-II-1	UPSTREAM	1.4	1.3	1.2	1.3	1.0	1.0	0.9	100	1.3	1.2	1.1	1.2	0.9	0.9	0.7	100
	DOWNSTREAM	1.3	1.2	1.2	1.3	0.9	1.0	0.8		1.3	1.2	1.1	1.2	0.9	0.9	0.7	
M-II-2	UPSTREAM	1.3	1.2	1.1	1.2	0.9	0.9	0.8	99	1.3	1.2	1.1	1.2	0.8	0.8	0.7	101
	DOWNSTREAM	1.3	1.2	1.2	1.2	0.9	0.9	0.8		1.3	1.2	1.1	1.2	0.8	0.8	0.7	
L-II-1	UPSTREAM	1.3	1.2	1.2	1.3	0.9	0.9	0.8	99	1.3	1.2	1.1	1.2	0.8	0.8	0.7	100
	DOWNSTREAM	1.4	1.2	1.2	1.3	0.9	0.9	0.8		1.3	1.2	1.1	1.2	0.9	0.8	0.8	
L-II-2	UPSTREAM	1.1	1.2	1.2	1.3	0.9	0.9	0.8	99	1.3	1.2	1.1	1.2	0.9	0.8	0.7	100
	DOWNSTREAM	1.3	1.2	1.2	1.3	1.0	1.0	0.8		1.4	1.2	1.1	1.2	0.8	0.8	0.7	

SECTION I.D.	24-I10-2	WINTER TESTING				DATE		02/23/11		SUMMER TESTING				DATE		09/21/11	
LOCATION						TIME								TIME			
CRACKS		W1	W2	W3	W4	W5	W6	W7	LTE	W1	W2	W3	W4	W5	W6	W7	LTE
S-I-1	UPSTREAM																
	DOWNSTREAM																
S-I-2	UPSTREAM																
	DOWNSTREAM																
M-I-1	UPSTREAM	2.5	2.4	2.3	2.3	1.7	1.6	1.3	107	1.8	1.7	1.6	1.8	1.2	1.2	1.0	98
	DOWNSTREAM	2.5	2.3	2.2	2.5	1.7	1.6	1.3		1.7	1.7	1.6	1.7	1.2	1.2	1.0	
M-I-2	UPSTREAM	2.4	2.3	2.1	2.2	1.5	1.5	1.2	107	1.6	1.6	1.5	1.7	1.2	1.2	1.0	100
	DOWNSTREAM	2.4	2.2	2.0	2.4	1.5	1.5	1.2		1.4	1.7	1.6	1.7	1.2	1.2	1.0	
L-I-1	UPSTREAM	2.3	2.0	1.9	2.0	1.5	1.4	1.2	105	1.8	1.7	1.6	1.7	1.2	1.2	1.0	100
	DOWNSTREAM	2.2	2.0	1.9	2.2	1.4	1.4	1.2		1.8	1.7	1.6	1.8	1.2	1.2	1.0	
L-I-2	UPSTREAM	2.3	2.1	1.9	2.0	1.3	1.4	1.1	102	1.8	1.6	1.5	1.6	1.1	1.0	0.9	101
	DOWNSTREAM	2.4	2.1	1.9	2.1	1.4	1.3	1.0		1.7	1.6	1.5	1.7	1.1	1.1	0.9	
S-II-1	UPSTREAM																
	DOWNSTREAM																
S-II-2	UPSTREAM																
	DOWNSTREAM																
M-II-1	UPSTREAM	2.0	1.9	1.8	2.0	1.4	1.3	1.1	102	1.9	1.7	1.6	1.8	1.2	1.2	1.0	101
	DOWNSTREAM	2.1	1.9	1.8	2.0	1.4	1.3	1.1		1.9	1.7	1.6	1.8	1.2	1.1	1.0	
M-II-2	UPSTREAM	2.2	2.1	2.0	2.1	1.6	1.5	1.3	102	1.8	1.8	1.6	1.8	1.2	1.1	1.0	103
	DOWNSTREAM	2.4	2.2	2.1	2.3	1.6	1.6	1.3		1.9	1.7	1.6	1.8	1.2	1.1	0.9	
L-II-1	UPSTREAM	2.1	2.1	1.9	2.0	1.4	1.4	1.1	107	1.8	1.6	1.5	1.7	1.2	1.1	0.9	100
	DOWNSTREAM	2.1	1.9	1.8	2.1	1.3	1.3	1.1		1.8	1.6	1.6	1.7	1.2	1.1	0.9	
L-II-2	UPSTREAM	2.1	2.1	1.9	2.1	1.4	1.4	1.2	103	1.9	1.8	1.7	1.8	1.3	1.2	1.0	100
	DOWNSTREAM	2.2	2.0	1.9	2.2	1.5	1.4	1.2		1.9	1.8	1.7	1.9	1.3	1.3	1.0	

SECTION I.D.	24-I10-3	WINTER TESTING				DATE		02/23/11		SUMMER TESTING				DATE		09/22/11	
LOCATION						TIME								TIME			
CRACKS		W1	W2	W3	W4	W5	W6	W7	LTE	W1	W2	W3	W4	W5	W6	W7	LTE
S-I-1	UPSTREAM	2.1	2.0	1.8	2.1	1.3	1.3	1.0	101	2.1	1.9	1.8	2.0	1.2	1.2	0.9	100
	DOWNSTREAM	2.1	1.9	1.8	2.1	1.3	1.2	1.0		2.0	1.9	1.7	2.0	1.2	1.1	0.9	
S-I-2	UPSTREAM	2.0	1.9	1.8	2.0	1.5	1.4	1.2	101	1.7	1.6	1.6	1.7	1.2	1.2	1.0	100
	DOWNSTREAM	1.9	1.8	1.7	1.8	1.3	1.3	1.1		1.9	1.7	1.6	1.7	1.2	1.2	1.0	
M-I-1	UPSTREAM	2.1	2.0	1.9	2.1	1.4	1.4	1.1	100	2.0	1.9	1.8	2.0	1.3	1.3	1.1	100
	DOWNSTREAM	2.1	2.0	1.9	2.1	1.4	1.4	1.2		2.0	1.9	1.8	2.0	1.3	1.2	1.0	
M-I-2	UPSTREAM	1.8	1.7	1.6	1.7	1.1	1.1	0.9	101	1.7	1.5	1.3	1.5	0.9	0.9	0.7	100
	DOWNSTREAM	1.9	1.7	1.6	1.8	1.2	1.2	1.0		1.6	1.4	1.3	1.5	0.9	0.9	0.8	
L-I-1	UPSTREAM	1.9	1.7	1.6	1.7	1.2	1.2	1.0	101	1.7	1.5	1.4	1.5	1.0	1.0	0.8	100
	DOWNSTREAM	1.8	1.7	1.6	1.8	1.2	1.2	1.0		1.6	1.5	1.3	1.5	1.0	1.0	0.8	
L-I-2	UPSTREAM	1.9	1.8	1.7	1.8	1.2	1.2	1.0	102	1.7	1.6	1.4	1.6	1.1	1.0	0.9	101
	DOWNSTREAM	2.0	1.8	1.7	1.9	1.3	1.3	1.0		1.7	1.6	1.4	1.6	1.1	1.0	0.9	
S-II-1	UPSTREAM																
	DOWNSTREAM																
S-II-2	UPSTREAM																
	DOWNSTREAM																
M-II-1	UPSTREAM	1.8	1.8	1.7	1.8	1.3	1.3	1.1	101	1.7	1.6	1.5	1.6	1.1	1.1	0.9	100
	DOWNSTREAM	1.9	1.8	1.7	1.8	1.3	1.3	1.1		1.8	1.6	1.5	1.6	1.2	1.1	0.9	
M-II-2	UPSTREAM	2.2	2.1	2.0	2.1	1.6	1.6	1.4	101	1.9	1.8	1.7	1.9	1.3	1.3	1.1	100
	DOWNSTREAM	2.2	2.1	2.0	2.2	1.6	1.6	1.4		1.8	1.8	1.7	1.9	1.4	1.3	1.1	
L-II-1	UPSTREAM	2.0	2.0	1.9	2.0	1.5	1.4	1.2	100	1.9	1.7	1.6	1.8	1.2	1.2	1.0	101
	DOWNSTREAM	2.1	1.9	1.8	2.0	1.4	1.4	1.1		1.9	1.8	1.7	1.8	1.3	1.2	1.0	
L-II-2	UPSTREAM	2.0	1.9	1.9	2.0	1.5	1.4	1.2	101	1.8	1.7	1.6	1.7	1.2	1.2	1.0	100
	DOWNSTREAM	2.0	1.9	1.8	2.0	1.4	1.4	1.2		1.8	1.6	1.5	1.7	1.2	1.1	1.0	

SECTION I.D.	24-I10-4	WINTER TESTING				DATE		02/23/11		SUMMER TESTING				DATE		09/22/11	
LOCATION						TIME								TIME			
CRACKS		W1	W2	W3	W4	W5	W6	W7	LTE	W1	W2	W3	W4	W5	W6	W7	LTE
S-I-1	UPSTREAM	1.8	1.5	1.4	1.6	0.9	0.9	0.7	101	1.6	1.4	1.3	1.4	0.9	0.8	0.7	102
	DOWNSTREAM	1.7	1.5	1.3	1.6	1.0	0.9	0.8		1.6	1.4	1.2	1.4	0.8	0.8	0.7	
S-I-2	UPSTREAM	1.5	1.3	1.2	1.4	0.9	0.8	0.7	100	1.5	1.3	1.1	1.3	0.8	0.8	0.6	100
	DOWNSTREAM	1.5	1.3	1.2	1.3	0.9	0.9	0.7		1.4	1.3	1.1	1.3	0.8	0.8	0.6	
M-I-1	UPSTREAM	1.7	1.5	1.4	1.5	1.0	1.0	0.8	102	1.6	1.4	1.3	1.4	0.9	0.9	0.8	102
	DOWNSTREAM	1.7	1.5	1.4	1.6	1.0	1.0	0.8		1.7	1.4	1.3	1.4	0.9	0.9	0.8	
M-I-2	UPSTREAM	1.6	1.4	1.2	1.4	0.9	0.9	0.7	100	1.5	1.2	1.3	1.3	0.8	0.8	0.7	98
	DOWNSTREAM	1.5	1.3	1.2	1.4	0.9	0.8	0.7		1.5	1.3	1.1	1.3	0.8	0.8	0.6	
L-I-1	UPSTREAM	1.5	1.4	1.2	1.4	0.9	0.8	0.7	102	1.5	1.2	1.1	1.2	0.8	0.8	0.6	101
	DOWNSTREAM	1.5	1.3	1.2	1.4	0.9	0.9	0.7		1.4	1.2	1.1	1.2	0.8	0.8	0.6	
L-I-2	UPSTREAM	1.4	1.3	1.2	1.3	0.9	0.9	0.7	99	1.4	1.2	1.1	1.2	0.8	0.8	0.7	100
	DOWNSTREAM	1.5	1.3	1.2	1.4	0.9	0.9	0.8		1.4	1.2	1.1	1.2	0.8	0.8	0.7	
S-II-1	UPSTREAM	1.9	1.8	1.6	1.8	1.2	1.2	0.9	100	1.9	1.7	1.6	1.8	1.1	1.1	0.9	99
	DOWNSTREAM	2.0	1.7	1.6	1.8	1.2	1.1	0.9		1.9	1.7	1.6	1.8	1.1	1.1	0.9	
S-II-2	UPSTREAM	2.0	1.8	1.6	1.9	1.2	1.2	1.0	98	1.9	1.7	1.5	1.7	1.1	1.1	0.9	99
	DOWNSTREAM	2.0	1.8	1.6	1.8	1.2	1.2	1.0		1.8	1.7	1.5	1.7	1.1	1.1	0.9	
M-II-1	UPSTREAM	1.8	1.7	1.6	1.8	1.2	1.1	0.9	101	1.7	1.6	1.5	1.6	1.1	1.1	0.9	100
	DOWNSTREAM	1.9	1.7	1.6	1.8	1.2	1.2	1.0		1.8	1.6	1.5	1.7	1.1	1.1	0.9	
M-II-2	UPSTREAM	2.6	2.5	2.4	2.5	1.8	1.8	1.5	102	3.4	3.3	3.1	3.2	2.4	2.4	2.0	103
	DOWNSTREAM	2.7	2.5	2.4	2.6	1.8	1.8	1.5		3.5	3.3	3.2	3.4	2.5	2.4	2.0	
L-II-1	UPSTREAM	2.3	2.1	1.9	2.2	1.4	1.3	1.1	100	2.2	2.0	1.9	2.1	1.4	1.3	1.1	100
	DOWNSTREAM	2.2	2.1	1.9	2.1	1.3	1.2	1.1		2.2	2.0	1.8	2.1	1.4	1.3	1.1	
L-II-2	UPSTREAM	2.0	1.9	1.8	2.0	1.3	1.3	1.1	100	1.9	1.8	1.7	1.8	1.3	1.3	1.1	99
	DOWNSTREAM	2.1	1.9	1.8	2.0	1.3	1.3	1.1		2.0	1.8	1.8	1.9	1.4	1.4	1.2	

SECTION I.D.	25-I40-1	WINTER TESTING				DATE		02/22/11		SUMMER TESTING				DATE			
LOCATION						TIME								TIME			
CRACKS		W1	W2	W3	W4	W5	W6	W7	LTE	W1	W2	W3	W4	W5	W6	W7	LTE
S-I-1	UPSTREAM	1.1	0.9	1.0	0.8	0.7	0.7	0.6	100								
	DOWNSTREAM	1.1	0.9	1.0	0.8	0.7	0.7	0.6									
S-I-2	UPSTREAM	1.3	1.2	1.3	1.1	0.9	0.9	0.8	100								
	DOWNSTREAM	1.3	1.3	1.3	1.1	0.9	0.9	0.8									
M-I-1	UPSTREAM	1.1	1.0	1.1	0.9	0.8	0.8	0.8	100								
	DOWNSTREAM	1.1	1.0	1.1	0.9	0.8	0.8	0.8									
M-I-2	UPSTREAM	1.2	1.1	1.2	1.0	0.9	0.9	0.8	101								
	DOWNSTREAM	1.1	1.1	1.2	1.0	0.9	0.9	0.8									
L-I-1	UPSTREAM	1.2	1.1	1.2	1.0	0.9	0.9	0.8	101								
	DOWNSTREAM	1.1	1.1	1.2	1.0	0.9	0.9	0.9									
L-I-2	UPSTREAM	1.1	1.1	1.1	1.0	0.8	0.8	0.8	100								
	DOWNSTREAM	1.0	1.1	1.1	1.0	0.8	0.8	0.8									
S-II-1	UPSTREAM	1.3	1.1	1.2	1.0	0.9	0.9	0.8	100								
	DOWNSTREAM	1.3	1.2	1.2	1.1	0.9	0.9	0.8									
S-II-2	UPSTREAM	1.2	1.2	1.3	1.1	0.9	0.9	0.9	100								
	DOWNSTREAM	1.2	1.2	1.3	1.1	0.9	0.9	0.9									
M-II-1	UPSTREAM	1.1	1.0	1.1	0.9	0.8	0.8	0.7	100								
	DOWNSTREAM	1.0	1.0	1.1	0.9	0.8	0.8	0.8									
M-II-2	UPSTREAM	1.3	1.2	1.3	1.1	0.9	0.9	0.8	101								
	DOWNSTREAM	1.3	1.2	1.2	1.1	0.9	0.9	0.8									
L-II-1	UPSTREAM	1.2	1.1	1.2	1.0	0.9	0.9	0.8	100								
	DOWNSTREAM	1.1	1.1	1.2	1.1	0.9	0.9	0.9									
L-II-2	UPSTREAM	1.2	1.1	1.2	1.0	0.9	0.8	0.8	101								
	DOWNSTREAM	1.3	1.1	1.2	1.0	0.9	0.8	0.8									

SECTION I.D.	25-I40-2	WINTER TESTING				DATE	02/22/11			SUMMER TESTING				DATE			
LOCATION						TIME								TIME			
CRACKS		W1	W2	W3	W4	W5	W6	W7	LTE	W1	W2	W3	W4	W5	W6	W7	LTE
S-I-1	UPSTREAM	1.3	1.1	1.2	1.0	0.8	0.8	0.7	101								
	DOWNSTREAM	1.3	1.1	1.2	0.9	0.8	0.8	0.7									
S-I-2	UPSTREAM	1.6	1.4	1.4	1.1	0.9	0.8	0.7	104								
	DOWNSTREAM	1.5	1.4	1.3	1.1	0.9	0.8	0.7									
M-I-1	UPSTREAM	1.2	1.0	1.1	0.9	0.7	0.7	0.7	101								
	DOWNSTREAM	1.2	1.0	1.1	0.9	0.7	0.7	0.7									
M-I-2	UPSTREAM	1.3	1.2	1.2	1.0	0.8	0.8	0.7	102								
	DOWNSTREAM	1.3	1.2	1.2	1.0	0.8	0.8	0.8									
L-I-1	UPSTREAM	1.4	1.2	1.3	1.0	0.9	0.8	0.7	101								
	DOWNSTREAM	1.4	1.2	1.3	1.0	0.8	0.8	0.7									
L-I-2	UPSTREAM	1.3	1.1	1.2	1.0	0.8	0.8	0.7	102								
	DOWNSTREAM	1.3	1.1	1.2	1.0	0.8	0.8	0.7									
S-II-1	UPSTREAM	1.3	1.1	1.1	0.9	0.8	0.8	0.7	104								
	DOWNSTREAM	1.3	1.1	1.1	0.9	0.8	0.8	0.7									
S-II-2	UPSTREAM	1.7	1.5	1.5	1.1	0.9	0.8	0.7	106								
	DOWNSTREAM	1.6	1.4	1.4	1.1	0.9	0.8	0.7									
M-II-1	UPSTREAM	1.4	1.2	1.2	1.0	0.8	0.7	0.7	104								
	DOWNSTREAM	1.4	1.2	1.2	1.0	0.8	0.8	0.7									
M-II-2	UPSTREAM	1.6	1.3	1.3	1.0	0.8	0.7	0.7	104								
	DOWNSTREAM	1.5	1.3	1.3	1.0	0.8	0.7	0.7									
L-II-1	UPSTREAM	1.6	1.4	1.4	1.1	0.9	0.9	0.8	103								
	DOWNSTREAM	1.5	1.4	1.4	1.1	0.9	0.8	0.8									
L-II-2	UPSTREAM	1.4	1.2	1.2	1.0	0.8	0.7	0.7	103								
	DOWNSTREAM	1.4	1.2	1.2	1.0	0.8	0.7	0.7									

- **Deflections at Transverse Cracks: FY2012**

SECTION I.D.	3-I35-1	WINTER TESTING				DATE				SUMMER TESTING W4>W3				DATE		09/11/12	
LOCATION						TIME								TIME			
CRACKS		W1	W2	W3	W4	W5	W6	W7	LTE	W1	W2	W3	W4	W5	W6	W7	LTE
S-I-1	UPSTREAM									2.1	1.8	1.8	1.3	1.1	0.8	0.7	101
	DOWNSTREAM									2.1	1.8	1.9	1.2	1.0	0.8	0.7	
S-I-2	UPSTREAM									2.3	2.0	2.0	1.5	1.2	1.0	0.8	102
	DOWNSTREAM									2.3	2.0	2.1	1.5	1.2	1.0	0.8	
M-I-1	UPSTREAM									1.8	1.5	1.5	1.1	0.9	0.7	0.6	102
	DOWNSTREAM									1.8	1.5	1.6	1.1	0.9	0.7	0.7	
M-I-2	UPSTREAM									1.7	1.5	1.5	1.1	0.9	0.8	0.7	99
	DOWNSTREAM									1.7	1.5	1.5	1.1	1.0	0.8	0.7	
L-I-1	UPSTREAM									2.0	1.8	1.8	1.4	1.2	1.0	1.0	102
	DOWNSTREAM									2.0	1.8	1.9	1.4	1.2	1.1	1.0	
L-I-2	UPSTREAM									2.1	1.9	1.9	1.4	1.2	1.1	1.0	101
	DOWNSTREAM									2.1	1.8	1.9	1.4	1.2	1.1	1.0	
S-II-1	UPSTREAM									2.1	1.9	1.9	1.5	1.3	1.1	0.9	100
	DOWNSTREAM									2.1	1.9	1.9	1.5	1.3	1.1	0.9	
S-II-2	UPSTREAM									2.1	1.8	1.9	1.4	1.2	1.0	0.9	100
	DOWNSTREAM									2.0	1.8	1.8	1.3	1.2	1.0	0.9	
M-II-1	UPSTREAM									2.1	1.9	1.9	1.5	1.4	1.2	1.1	100
	DOWNSTREAM									2.0	1.8	1.8	1.4	1.3	1.1	0.9	
M-II-2	UPSTREAM									2.1	1.9	1.9	1.5	1.3	1.1	1.0	100
	DOWNSTREAM									2.2	1.9	1.9	1.4	1.2	1.1	1.0	
L-II-1	UPSTREAM									2.0	1.8	1.7	1.3	1.2	1.0	0.9	100
	DOWNSTREAM									2.0	1.8	1.7	1.4	1.2	1.0	0.8	
L-II-2	UPSTREAM									2.0	1.8	1.7	1.4	1.2	1.0	0.9	104
	DOWNSTREAM									2.0	1.8	1.8	1.4	1.2	1.0	0.9	

SECTION I.D.	3-US287-1	WINTER TESTING				DATE		01/11/12		SUMMER				DATE		09/10/12	
LOCATION						TIME				TESTING W4>W3				TIME			
CRACKS		W1	W2	W3	W4	W5	W6	W7	LTE	W1	W2	W3	W4	W5	W6	W7	LTE
S-I-1	UPSTREAM	3.7	3.6	3.0	3.8	1.8	1.3	1.1	104	3.9	3.6	3.5	2.4	1.9	1.4	1.2	103
	DOWNSTREAM	4.2	3.5	2.9	4.0	1.8	1.4	1.0		4.0	3.6	3.6	2.4	1.9	1.4	1.1	
S-I-2	UPSTREAM	4.2	3.7	3.0	4.0	1.9	1.4	1.1	104	4.1	3.8	3.7	2.5	2.0	1.5	1.2	102
	DOWNSTREAM	4.2	3.6	3.1	4.1	1.9	1.4	1.1		4.0	3.7	3.7	2.5	2.0	1.5	1.2	
M-I-1	UPSTREAM	3.8	3.6	2.9	3.8	1.8	1.4	1.0	106	3.8	3.5	3.4	2.3	1.8	1.4	1.1	103
	DOWNSTREAM	4.2	3.4	2.8	4.0	1.8	1.4	1.1		3.8	3.4	3.5	2.3	1.8	1.4	1.1	
M-I-2	UPSTREAM	4.6	3.9	3.2	4.2	2.0	1.5	1.2	106	4.1	3.7	3.7	2.6	2.1	1.6	1.3	101
	DOWNSTREAM	4.6	3.8	3.2	4.4	2.0	1.6	1.3		4.1	3.7	3.7	2.6	2.1	1.6	1.3	
L-I-1	UPSTREAM	4.2	3.8	3.1	4.0	2.0	1.5	1.2	106	3.9	3.6	3.5	2.5	2.0	1.5	1.2	102
	DOWNSTREAM	4.2	3.6	3.0	4.2	2.0	1.5	1.2		3.9	3.5	3.6	2.5	2.0	1.5	1.2	
L-I-2	UPSTREAM	3.8	3.4	2.8	3.6	1.8	1.4	1.1	106	3.7	3.4	3.3	2.3	1.9	1.4	1.1	100
	DOWNSTREAM	3.7	3.2	2.7	3.8	1.7	1.3	1.0		3.7	3.3	3.3	2.3	1.9	1.4	1.1	
S-II-1	UPSTREAM	4.8	3.9	3.3	4.2	2.1	1.7	1.3	104	4.4	4.0	3.9	2.8	2.2	1.7	1.4	102
	DOWNSTREAM	4.3	3.8	3.3	4.4	2.2	1.7	1.3		4.4	4.0	4.0	2.7	2.2	1.7	1.4	
S-II-2	UPSTREAM	4.1	3.7	3.0	4.1	1.8	1.4	1.1	103	4.1	3.7	3.7	2.5	1.9	1.4	1.1	100
	DOWNSTREAM	4.2	3.5	2.9	4.1	1.8	1.4	1.0		4.0	3.6	3.7	2.4	1.9	1.4	1.1	
M-II-1	UPSTREAM	4.9	4.4	3.5	4.5	2.1	1.7	1.3	109	4.2	3.9	3.9	2.8	2.2	1.7	1.4	99
	DOWNSTREAM	4.9	4.0	3.3	4.9	2.1	1.7	1.3		4.4	4.0	3.9	2.8	2.3	1.7	1.4	
M-II-2	UPSTREAM	4.5	3.9	3.2	4.1	2.0	1.5	1.2	106	4.4	4.0	3.8	2.7	2.1	1.6	1.3	103
	DOWNSTREAM	4.1	3.7	3.1	4.4	2.0	1.5	1.2		4.4	4.0	4.0	2.7	2.1	1.6	1.3	
L-II-1	UPSTREAM	4.7	4.1	3.5	4.4	2.4	1.9	1.5	105	4.4	4.1	4.0	3.0	2.4	1.9	1.6	101
	DOWNSTREAM	4.5	3.9	3.4	4.6	2.4	1.9	1.5		4.4	4.1	4.1	3.0	2.5	1.9	1.6	
L-II-2	UPSTREAM	4.0	3.4	2.8	3.6	1.8	1.4	1.1	106	3.8	3.4	3.4	2.4	2.0	1.5	1.3	102
	DOWNSTREAM	3.7	3.3	2.8	3.9	1.8	1.5	1.1		3.8	3.4	3.4	2.4	1.9	1.5	1.2	

SECTION I.D.	3-US287-2	WINTER TESTING				DATE		01/11/12		SUMMER TESTING W4>W3				DATE		09/10/12	
LOCATION						TIME								TIME			
CRACKS		W1	W2	W3	W4	W5	W6	W7	LTE	W1	W2	W3	W4	W5	W6	W7	LTE
S-I-1	UPSTREAM																
	DOWNSTREAM																
S-I-2	UPSTREAM																
	DOWNSTREAM																
M-I-1	UPSTREAM	1.4	1.4	1.3	1.5	1.0	0.9	0.8	100	1.5	1.4	1.4	1.1	1.0	0.9	0.8	101
	DOWNSTREAM	1.7	1.4	1.2	1.5	1.0	0.9	0.8		1.5	1.4	1.4	1.1	1.0	0.9	0.8	
M-I-2	UPSTREAM	1.4	1.5	1.4	1.6	1.0	0.9	0.7	103	1.3	1.2	1.2	1.0	0.9	0.7	0.6	101
	DOWNSTREAM	1.5	1.5	1.3	1.7	1.0	0.8	0.7		1.4	1.3	1.2	1.0	0.9	0.8	0.7	
L-I-1	UPSTREAM	2.0	1.5	1.4	1.6	1.1	1.0	0.9	101	1.5	1.4	1.3	1.1	1.0	0.9	0.8	102
	DOWNSTREAM	1.4	1.5	1.3	1.6	1.1	1.0	0.9		1.5	1.4	1.4	1.1	1.0	0.9	0.9	
L-I-2	UPSTREAM	1.6	1.5	1.3	1.6	1.1	1.0	1.0	100	1.5	1.4	1.4	1.2	1.1	0.9	0.9	100
	DOWNSTREAM	1.5	1.4	1.3	1.6	1.1	1.0	0.9		1.5	1.4	1.4	1.2	1.1	0.9	0.9	
S-II-1	UPSTREAM	1.4	1.3	1.2	1.5	1.0	0.9	0.8	100	1.4	1.3	1.3	1.0	0.9	0.8	0.8	100
	DOWNSTREAM	1.5	1.3	1.2	1.5	1.0	0.9	0.8		1.4	1.3	1.2	1.0	1.0	0.8	0.8	
S-II-2	UPSTREAM	1.4	1.4	1.3	1.6	1.1	1.0	0.9	100	1.5	1.4	1.4	1.2	1.1	0.9	0.8	100
	DOWNSTREAM	1.3	1.4	1.3	1.6	1.1	1.0	0.9		1.5	1.3	1.4	1.1	1.0	0.9	0.8	
M-II-1	UPSTREAM	1.1	1.3	1.2	1.5	1.0	0.9	0.8	100	1.5	1.4	1.4	1.1	1.0	0.9	0.8	101
	DOWNSTREAM	1.2	1.3	1.2	1.4	1.0	0.9	0.8		1.5	1.4	1.4	1.1	1.0	0.8	0.8	
M-II-2	UPSTREAM	1.2	1.2	1.1	1.3	0.9	0.7	0.7	100	1.3	1.2	1.2	1.0	0.9	0.7	0.6	99
	DOWNSTREAM	1.2	1.2	1.1	1.3	0.9	0.7	0.7		1.3	1.2	1.2	1.0	0.8	0.7	0.6	
L-II-1	UPSTREAM	1.3	1.2	1.1	1.3	0.9	0.7	0.6	100	1.4	1.3	1.2	1.0	0.9	0.7	0.7	101
	DOWNSTREAM	1.2	1.2	1.1	1.3	0.9	0.7	0.6		1.4	1.2	1.2	1.0	0.9	0.7	0.7	
L-II-2	UPSTREAM	1.7	1.3	1.2	1.5	1.0	0.9	0.8	100	1.4	1.3	1.3	1.0	1.0	0.8	0.8	100
	DOWNSTREAM	1.6	1.3	1.2	1.5	1.0	0.9	0.8		1.4	1.3	1.3	1.1	1.0	0.8	0.8	

SECTION I.D.	3-US81-1	WINTER TESTING				DATE		01/12/12		SUMMER				DATE		09/11/12	
LOCATION						TIME				TESTING W4>W3				TIME			
CRACKS		W1	W2	W3	W4	W5	W6	W7	LTE	W1	W2	W3	W4	W5	W6	W7	LTE
S-1	UPSTREAM	4.2	3.6	3.0	4.3	1.8	1.4	1.0	94	4.0	3.7	3.6	2.4	1.9	1.4	1.1	99
	DOWNSTREAM	4.5	4.0	3.1	4.1	1.8	1.4	1.0		4.1	3.7	3.6	2.4	1.9	1.4	1.1	
S-2	UPSTREAM	6.1	5.0	3.6	5.5	1.8	1.3	1.0	110	3.8	3.3	3.2	2.1	1.6	1.1	0.9	103
	DOWNSTREAM	7.2	5.1	3.8	6.5	2.1	1.5	1.2		3.7	3.2	3.3	2.0	1.5	1.1	0.9	
S-3	UPSTREAM	3.4	2.8	2.1	3.0	1.2	0.9	0.7	106	3.2	2.9	2.8	1.8	1.3	1.0	0.8	104
	DOWNSTREAM	3.4	2.7	2.2	3.2	1.3	0.9	0.7		3.2	2.8	2.8	1.8	1.4	1.0	0.8	
S-4	UPSTREAM	6.0	5.1	4.1	5.2	2.7	2.1	1.7	105	5.4	5.0	4.8	3.5	2.8	2.1	1.7	103
	DOWNSTREAM	6.5	5.2	4.5	5.8	3.0	2.3	1.8		5.3	4.8	4.9	3.4	2.7	2.1	1.6	
M-1	UPSTREAM	4.5	3.8	2.9	4.0	1.7	1.2	1.0	110	4.0	3.6	3.4	2.3	1.8	1.3	1.1	104
	DOWNSTREAM	4.7	3.5	2.8	4.4	1.7	1.3	1.1		4.0	3.4	3.5	2.3	1.8	1.3	1.1	
M-2	UPSTREAM	4.5	3.7	3.0	4.1	1.8	1.3	1.0	104	4.4	4.0	4.0	2.7	2.1	1.5	1.2	101
	DOWNSTREAM	4.7	3.6	2.9	4.2	1.7	1.3	1.2		4.4	3.9	4.0	2.6	2.1	1.5	1.2	
M-3	UPSTREAM	4.0	3.5	2.8	3.6	1.7	1.2	1.0	108	3.7	3.3	3.2	2.2	1.8	1.4	1.1	100
	DOWNSTREAM	2.9	3.4	2.7	4.0	1.7	1.3	1.1		3.7	3.3	3.3	2.3	1.9	1.5	1.2	
M-4	UPSTREAM	3.7	3.0	2.4	3.4	1.4	1.1	0.9	102	3.6	3.2	3.1	2.1	1.6	1.2	1.0	102
	DOWNSTREAM	3.8	3.0	2.5	3.5	1.5	1.2	0.9		3.6	3.1	3.2	2.0	1.6	1.2	1.0	
L-1	UPSTREAM	4.1	3.5	2.8	3.7	1.6	1.2	1.0	109	3.6	3.2	3.2	2.1	1.7	1.2	1.0	101
	DOWNSTREAM	4.2	3.3	2.6	4.0	1.6	1.2	0.9		3.6	3.2	3.2	2.1	1.6	1.2	1.0	
L-2	UPSTREAM	4.4	3.9	3.0	4.0	1.7	1.3	1.0	109	4.1	3.7	3.6	2.4	1.8	1.3	1.0	102
	DOWNSTREAM	4.6	3.6	2.9	4.4	1.7	1.2	1.0		4.1	3.7	3.7	2.4	1.9	1.3	1.0	
L-3	UPSTREAM	2.8	2.3	1.9	2.6	1.2	0.9	0.7	101	2.8	2.5	2.4	1.6	1.2	0.9	0.7	101
	DOWNSTREAM	2.7	2.4	2.0	2.7	1.3	1.0	0.8		2.8	2.5	2.5	1.6	1.2	0.9	0.8	
L-4	UPSTREAM	4.8	3.7	2.9	4.2	1.6	1.1	0.9	110	3.6	3.2	3.1	2.0	1.5	1.1	0.9	102
	DOWNSTREAM	4.1	3.3	2.5	4.3	1.4	1.0	0.7		3.5	3.0	3.1	1.9	1.5	1.0	0.8	

SECTION I.D.	4-I40-1	WINTER TESTING				DATE				SUMMER TESTING				DATE		08/30/12	
LOCATION						TIME								TIME			
CRACKS		W1	W2	W3	W4	W5	W6	W7	LTE	W1	W2	W3	W4	W5	W6	W7	LTE
S-I-1	UPSTREAM									3.4	2.7	2.4	3.0	1.8	1.6	1.3	102
	DOWNSTREAM									3.4	2.8	2.4	3.1	1.8	1.6	1.3	
S-I-2	UPSTREAM									3.4	2.7	2.3	3.1	1.7	1.5	1.2	102
	DOWNSTREAM									3.4	2.7	2.3	3.2	1.7	1.5	1.3	
M-I-1	UPSTREAM									4.5	3.7	3.2	3.9	2.5	2.1	1.8	106
	DOWNSTREAM									4.5	3.6	3.2	4.2	2.5	2.1	1.8	
M-I-2	UPSTREAM									3.1	2.6	2.3	2.9	1.7	1.5	1.2	102
	DOWNSTREAM									3.2	2.6	2.3	2.9	1.7	1.5	1.3	
L-I-1	UPSTREAM									3.0	2.5	2.2	2.7	1.6	1.4	1.2	102
	DOWNSTREAM									3.1	2.5	2.2	2.8	1.6	1.4	1.2	
L-I-2	UPSTREAM									3.1	2.6	2.3	2.8	1.7	1.5	1.2	102
	DOWNSTREAM									3.0	2.5	2.2	2.8	1.6	1.4	1.2	
S-II-1	UPSTREAM									3.3	2.7	2.3	3.1	1.7	1.4	1.2	102
	DOWNSTREAM									3.2	2.6	2.2	3.0	1.6	1.3	1.1	
S-II-2	UPSTREAM									3.2	2.6	2.2	3.0	1.6	1.3	1.1	100
	DOWNSTREAM									3.3	2.7	2.2	3.0	1.6	1.3	1.1	
M-II-1	UPSTREAM									4.4	3.7	3.2	4.1	2.3	2.0	1.6	103
	DOWNSTREAM									4.4	3.6	3.1	4.2	2.3	1.9	1.6	
M-II-2	UPSTREAM									3.5	2.8	2.3	3.0	1.6	1.4	1.1	106
	DOWNSTREAM									3.5	2.6	2.2	3.2	1.6	1.3	1.1	
L-II-1	UPSTREAM									3.6	2.9	2.5	3.4	1.8	1.5	1.3	99
	DOWNSTREAM									3.5	3.0	2.4	3.3	1.8	1.5	1.2	
L-II-2	UPSTREAM									3.2	2.4	2.1	2.9	1.6	1.3	1.2	101
	DOWNSTREAM									3.4	2.4	2.1	2.9	1.6	1.4	1.1	

SECTION I.D.	5-I27-1	WINTER TESTING				DATE				SUMMER TESTING				DATE		07/23/12	
LOCATION						TIME								TIME			
CRACKS		W1	W2	W3	W4	W5	W6	W7	LTE	W1	W2	W3	W4	W5	W6	W7	LTE
S-I-1	UPSTREAM									2.7	2.5	2.8	2.5	1.6	1.4	1.2	93
	DOWNSTREAM									2.7	2.9	3.5	2.5	1.6	1.3	1.2	
S-I-2	UPSTREAM									2.2	2.5	3.0	2.2	1.3	1.1	0.9	107
	DOWNSTREAM									2.4	2.2	2.4	2.1	1.3	1.1	0.9	
M-I-1	UPSTREAM									2.7	1.7	1.6	2.5	1.6	1.4	1.2	110
	DOWNSTREAM									2.7	1.6	1.4	2.5	1.7	1.4	1.2	
M-I-2	UPSTREAM									2.7	2.9	3.6	2.4	1.4	1.2	1.0	114
	DOWNSTREAM									2.7	2.3	2.1	2.4	1.4	1.1	1.0	
L-I-1	UPSTREAM																
	DOWNSTREAM																
L-I-2	UPSTREAM																
	DOWNSTREAM																
S-II-1	UPSTREAM									2.6	2.7	2.0	2.4	1.4	1.2	1.0	114
	DOWNSTREAM									2.7	2.1	2.0	2.3	1.4	1.1	1.0	
S-II-2	UPSTREAM									2.2	2.7	3.3	2.0	1.2	1.0	0.8	127
	DOWNSTREAM									2.2	1.7	1.8	2.0	1.2	1.0	0.8	
M-II-1	UPSTREAM									2.6	2.1	2.8	2.3	1.4	1.1	0.9	94
	DOWNSTREAM									2.6	2.4	2.9	2.3	1.4	1.1	0.9	
M-II-2	UPSTREAM									2.5	3.3	3.7	2.3	1.4	1.1	0.9	123
	DOWNSTREAM									2.5	2.3	2.7	2.3	1.3	1.1	0.9	
L-II-1	UPSTREAM																
	DOWNSTREAM																
L-II-2	UPSTREAM																
	DOWNSTREAM																

SECTION I.D.	5-LP289-1	WINTER TESTING				DATE				SUMMER TESTING				DATE		07/31/12	
LOCATION						TIME								TIME			
CRACKS		W1	W2	W3	W4	W5	W6	W7	LTE	W1	W2	W3	W4	W5	W6	W7	LTE
S-I-1	UPSTREAM									3.2	3.6	2.8	3.1	2.0	1.7	1.4	116
	DOWNSTREAM									3.1	2.6	2.7	3.1	2.0	1.6	1.4	
S-I-2	UPSTREAM									2.5	2.1	2.3	2.4	1.7	1.5	1.4	94
	DOWNSTREAM									2.7	2.4	2.5	2.4	1.8	1.5	1.3	
M-I-1	UPSTREAM									3.1	3.0	2.8	3.1	2.0	1.7	1.4	93
	DOWNSTREAM									3.3	3.4	3.7	3.1	2.0	1.7	1.4	
M-I-2	UPSTREAM									3.1	2.9	3.1	3.0	1.9	1.5	1.3	115
	DOWNSTREAM									3.1	2.3	2.4	3.1	1.8	1.5	1.2	
L-I-1	UPSTREAM									2.4	2.3	2.0	2.2	1.6	1.4	1.2	83
	DOWNSTREAM									2.1	3.5	4.1	2.2	1.5	1.4	1.2	
L-I-2	UPSTREAM									2.1	1.5	1.3	2.1	1.5	1.3	1.1	199
	DOWNSTREAM									1.7	0.6	0.6	2.0	1.4	1.3	1.3	
S-II-1	UPSTREAM									2.8	2.5	2.6	2.6	1.7	1.4	1.2	94
	DOWNSTREAM									2.7	2.8	3.2	2.6	1.7	1.4	1.1	
S-II-2	UPSTREAM									2.4	2.7	3.3	2.1	1.3	1.1	0.9	110
	DOWNSTREAM									2.6	2.3	2.7	2.1	1.3	1.1	1.0	
M-II-1	UPSTREAM									3.0	3.2	3.7	2.8	1.8	1.5	1.3	102
	DOWNSTREAM									3.1	3.1	3.5	2.8	1.8	1.6	1.3	
M-II-2	UPSTREAM									2.4	2.0	1.7	2.2	1.3	1.1	0.9	90
	DOWNSTREAM									2.4	2.5	2.8	2.2	1.3	1.1	1.0	
L-II-1	UPSTREAM									3.2	3.3	3.7	2.8	1.9	1.6	1.3	118
	DOWNSTREAM									3.0	2.4	2.3	2.8	1.9	1.6	1.3	
L-II-2	UPSTREAM									2.4	2.9	3.5	2.1	1.4	1.2	1.0	108
	DOWNSTREAM									2.3	2.6	3.0	2.1	1.4	1.1	0.9	

SECTION I.D.	9-I35-2	WINTER TESTING				DATE				SUMMER TESTING				DATE		09/13/12	
LOCATION						TIME								TIME			
CRACKS		W1	W2	W3	W4	W5	W6	W7	LTE	W1	W2	W3	W4	W5	W6	W7	LTE
S-I-1	UPSTREAM									1.1	1.1	1.0	0.9	0.8	0.7	1.1	100
	DOWNSTREAM									1.1	1.0	0.9	0.9	0.8	0.7	1.1	
S-I-2	UPSTREAM									1.2	1.1	1.0	0.9	0.8	0.7	1.2	100
	DOWNSTREAM									1.2	1.1	1.0	0.9	0.7	0.7	1.1	
M-I-1	UPSTREAM																
	DOWNSTREAM																
M-I-2	UPSTREAM									1.2	1.1	1.0	0.9	0.8	0.7	1.2	101
	DOWNSTREAM									1.1	1.1	1.0	0.9	0.7	0.7	1.1	
L-I-1	UPSTREAM									1.2	1.1	1.0	0.9	0.8	0.7	1.2	100
	DOWNSTREAM									1.2	1.1	1.0	0.9	0.8	0.7	1.1	
L-I-2	UPSTREAM																
	DOWNSTREAM																
S-II-1	UPSTREAM																
	DOWNSTREAM																
S-II-2	UPSTREAM																
	DOWNSTREAM																
M-II-1	UPSTREAM																
	DOWNSTREAM																
M-II-2	UPSTREAM																
	DOWNSTREAM																
L-II-1	UPSTREAM																
	DOWNSTREAM																
L-II-2	UPSTREAM																
	DOWNSTREAM																

SECTION I.D.	12-US290-2	WINTER TESTING				DATE				SUMMER TESTING				DATE		08/18/12	
LOCATION						TIME								TIME			
CRACKS		W1	W2	W3	W4	W5	W6	W7	LTE	W1	W2	W3	W4	W5	W6	W7	LTE
S-I-1	UPSTREAM									3.5	3.3	2.9	2.5	2.1	1.7	3.3	104
	DOWNSTREAM									3.6	3.3	2.9	2.5	2.1	1.7	3.4	
S-I-2	UPSTREAM									3.3	3.1	2.7	2.3	1.9	1.6	3.1	103
	DOWNSTREAM									3.3	3.1	2.7	2.3	1.9	1.6	3.2	
M-I-1	UPSTREAM									3.6	3.3	2.9	2.5	2.1	1.7	3.4	104
	DOWNSTREAM									3.6	3.3	3.0	2.6	2.1	1.7	3.4	
M-I-2	UPSTREAM									3.0	2.8	2.5	2.1	1.8	1.5	2.8	104
	DOWNSTREAM									2.9	2.7	2.4	2.1	1.8	1.4	2.8	
L-I-1	UPSTREAM																
	DOWNSTREAM																
L-I-2	UPSTREAM																
	DOWNSTREAM																
S-II-1	UPSTREAM									3.4	3.1	2.8	2.4	2.0	1.6	3.2	104
	DOWNSTREAM									3.5	3.2	2.8	2.4	2.0	1.6	3.2	
S-II-2	UPSTREAM									4.1	3.8	3.3	2.8	2.3	1.9	3.9	104
	DOWNSTREAM									4.1	3.8	3.3	2.8	2.3	1.9	3.9	
M-II-1	UPSTREAM									2.9	2.7	2.3	2.0	1.7	1.4	2.8	104
	DOWNSTREAM									2.9	2.7	2.4	2.0	1.7	1.4	2.8	
M-II-2	UPSTREAM									3.3	3.1	2.7	2.3	1.9	1.6	3.1	104
	DOWNSTREAM									3.3	3.1	2.7	2.3	1.9	1.6	3.1	
L-II-1	UPSTREAM									3.2	2.9	2.5	2.1	1.8	1.5	3.0	105
	DOWNSTREAM									3.1	2.8	2.5	2.1	1.7	1.4	2.9	
L-II-2	UPSTREAM									3.3	3.0	2.6	2.2	1.8	1.4	3.2	105
	DOWNSTREAM									3.2	2.9	2.6	2.2	1.8	1.4	3.1	

SECTION I.D.	12-US290-3	WINTER TESTING				DATE				SUMMER TESTING				DATE		08/18/12	
LOCATION						TIME								TIME			
CRACKS		W1	W2	W3	W4	W5	W6	W7	LTE	W1	W2	W3	W4	W5	W6	W7	LTE
S-I-1	UPSTREAM									2.6	2.3	1.9	1.6	1.3	1.1	2.4	106
	DOWNSTREAM									2.5	2.2	1.9	1.6	1.3	1.1	2.4	
S-I-2	UPSTREAM									2.0	1.8	1.5	1.3	1.1	0.9	1.9	105
	DOWNSTREAM									2.0	1.8	1.5	1.3	1.1	0.9	1.9	
M-I-1	UPSTREAM									2.4	2.2	1.9	1.6	1.3	1.1	2.2	105
	DOWNSTREAM									2.4	2.2	1.9	1.6	1.3	1.1	2.2	
M-I-2	UPSTREAM									2.1	1.9	1.6	1.4	1.2	1.0	1.9	104
	DOWNSTREAM									2.1	1.9	1.7	1.4	1.2	1.0	1.9	
L-I-1	UPSTREAM									2.2	1.9	1.6	1.4	1.2	1.0	2.0	106
	DOWNSTREAM									2.1	1.9	1.6	1.4	1.2	1.0	2.0	
L-I-2	UPSTREAM									2.3	2.1	1.8	1.5	1.3	1.1	2.1	105
	DOWNSTREAM									2.3	2.1	1.8	1.6	1.3	1.1	2.2	
S-II-1	UPSTREAM									2.6	2.3	2.0	1.7	1.4	1.1	2.3	105
	DOWNSTREAM									2.6	2.3	2.0	1.7	1.4	1.1	2.4	
S-II-2	UPSTREAM									2.6	2.3	1.9	1.6	1.3	1.0	2.4	107
	DOWNSTREAM									2.5	2.2	1.8	1.5	1.2	1.0	2.3	
M-II-1	UPSTREAM									2.4	2.1	1.8	1.5	1.2	1.0	2.2	106
	DOWNSTREAM									2.4	2.1	1.8	1.5	1.2	1.0	2.2	
M-II-2	UPSTREAM									2.1	1.9	1.6	1.4	1.1	0.9	1.9	105
	DOWNSTREAM									2.1	1.9	1.6	1.4	1.1	0.9	1.9	
L-II-1	UPSTREAM									2.1	1.9	1.6	1.4	1.2	1.0	1.9	106
	DOWNSTREAM									2.1	1.9	1.6	1.4	1.2	1.0	1.9	
L-II-2	UPSTREAM									2.0	1.8	1.5	1.3	1.1	0.9	1.7	103
	DOWNSTREAM									2.0	1.8	1.6	1.3	1.1	0.9	1.8	

SECTION I.D.	19-US59-1	WINTER TESTING				DATE		01/17/12		SUMMER TESTING W4>W3				DATE		09/05/12	
LOCATION						TIME								TIME			
CRACKS		W1	W2	W3	W4	W5	W6	W7	LTE	W1	W2	W3	W4	W5	W6	W7	LTE
S-I-1	UPSTREAM	1.8	1.5	1.5	1.5	0.2	1.0	0.9	101	2.0	1.8	1.7	1.4	1.2	1.0	0.9	100
	DOWNSTREAM	1.8	1.5	1.6	1.5	0.2	1.0	0.9		2.0	1.8	1.8	1.4	1.2	1.0	0.9	
S-I-2	UPSTREAM	1.7	1.4	1.5	1.4	0.2	1.0	0.9	97	1.8	1.7	1.7	1.3	1.1	1.0	0.9	100
	DOWNSTREAM	1.8	1.6	1.6	1.5	0.2	1.0	0.9		1.9	1.8	1.7	1.3	1.1	0.9	0.8	
M-I-1	UPSTREAM	1.9	1.6	1.7	1.6	0.3	1.0	0.9	103	1.9	1.8	1.8	1.3	1.1	1.0	0.9	102
	DOWNSTREAM	1.9	1.5	1.7	1.6	0.3	1.0	0.9		1.9	1.7	1.7	1.3	1.1	0.9	0.8	
M-I-2	UPSTREAM	2.0	1.5	1.6	1.7	0.3	1.1	1.0	103	2.2	1.9	1.9	1.4	1.2	1.0	0.9	105
	DOWNSTREAM	2.3	1.6	1.6	1.8	0.2	1.0	0.9		2.4	1.9	2.0	1.4	1.1	1.0	0.9	
L-I-1	UPSTREAM	2.0	1.5	1.5	1.5	0.2	1.1	1.0	104	2.0	1.7	1.5	1.3	1.1	0.9	0.9	106
	DOWNSTREAM	2.0	1.5	1.6	1.6	0.3	1.1	1.0		2.0	1.6	1.7	1.3	1.1	0.9	0.8	
L-I-2	UPSTREAM	2.0	1.6	1.6	1.7	0.3	1.1	1.0	101	2.0	1.7	1.7	1.3	1.1	0.9	0.8	103
	DOWNSTREAM	1.9	1.5	1.7	1.6	0.3	1.1	1.0		1.9	1.7	1.7	1.3	1.1	0.9	0.8	
S-II-1	UPSTREAM	2.0	1.7	1.8	1.8	0.3	1.3	1.2	100	2.2	2.1	2.0	1.6	1.4	1.2	1.0	103
	DOWNSTREAM	2.0	1.7	1.8	1.8	0.3	1.3	1.2		2.3	2.1	2.1	1.6	1.4	1.2	1.0	
S-II-2	UPSTREAM	1.8	1.5	1.6	1.5	0.2	0.9	0.8	100								
	DOWNSTREAM	1.8	1.5	1.6	1.5	0.2	0.9	0.8									
M-II-1	UPSTREAM	1.9	1.7	1.7	1.7	0.3	1.1	1.0	103	2.3	2.1	2.0	1.5	1.4	1.1	0.9	104
	DOWNSTREAM	2.0	1.6	1.8	1.7	0.3	1.1	1.0		2.3	2.0	2.1	1.5	1.3	1.0	0.9	
M-II-2	UPSTREAM	1.8	1.5	1.6	1.5	0.2	1.1	1.0	100	2.0	1.8	1.8	1.4	1.2	1.0	0.9	103
	DOWNSTREAM	1.8	1.5	1.6	1.5	0.2	1.1	1.0		2.0	1.8	1.8	1.4	1.2	1.0	0.9	
L-II-1	UPSTREAM	1.9	1.4	1.5	1.5	0.2	0.9	0.8	101	1.9	1.7	1.7	1.3	1.0	0.9	0.7	99
	DOWNSTREAM	1.7	1.3	1.5	1.4	0.2	0.9	0.8		2.0	1.6	1.6	1.2	1.0	0.9	0.8	
L-II-2	UPSTREAM	2.2	1.6	1.7	1.7	0.3	1.0	0.9	104	2.2	1.8	1.7	1.2	1.1	0.9	0.8	104
	DOWNSTREAM	2.2	1.6	1.8	1.8	0.3	1.1	0.9		2.0	1.7	1.7	1.3	1.1	0.9	0.8	

SECTION I.D.	19-US59-2	WINTER TESTING				DATE		01/17/12		SUMMER TESTING W4>W3				DATE		09/05/12	
LOCATION						TIME								TIME			
CRACKS		W1	W2	W3	W4	W5	W6	W7	LTE	W1	W2	W3	W4	W5	W6	W7	LTE
S-I-1	UPSTREAM	1.6	1.4	1.5	1.4	0.2	0.9	0.8	100	1.6	1.4	1.4	1.1	1.0	0.8	0.7	101
	DOWNSTREAM	1.6	1.3	1.4	1.4	0.2	0.9	0.8		1.6	1.4	1.4	1.1	0.9	0.8	0.7	
S-I-2	UPSTREAM	1.6	1.3	1.4	1.3	0.2	0.8	0.7	100	1.5	1.3	1.3	1.0	0.9	0.7	0.6	99
	DOWNSTREAM	1.5	1.3	1.4	1.3	0.2	0.8	0.7		1.5	1.3	1.3	1.0	0.8	0.7	0.6	
M-I-1	UPSTREAM	1.4	1.2	1.3	1.2	0.2	0.9	0.8	100	1.5	1.3	1.3	1.0	0.9	0.7	0.7	103
	DOWNSTREAM	1.4	1.2	1.3	1.2	0.2	0.9	0.8		1.5	1.3	1.3	1.0	0.9	0.7	0.7	
M-I-2	UPSTREAM	1.6	1.4	1.5	1.4	0.2	1.0	0.9	101	1.6	1.5	1.4	1.2	1.0	0.9	0.8	101
	DOWNSTREAM	1.6	1.4	1.5	1.4	0.2	1.0	0.9		1.6	1.5	1.5	1.2	1.0	0.9	0.8	
L-I-1	UPSTREAM	1.6	1.4	1.4	1.4	0.2	0.9	0.8	102	1.7	1.5	1.5	1.1	0.9	0.8	0.7	101
	DOWNSTREAM	1.7	1.4	1.5	1.4	0.2	0.9	0.8		1.7	1.5	1.5	1.1	0.9	0.8	0.7	
L-I-2	UPSTREAM	1.5	1.2	1.3	1.3	0.2	0.8	0.7	100	1.5	1.3	1.3	1.0	0.8	0.7	0.6	100
	DOWNSTREAM	1.4	1.2	1.3	1.2	0.2	0.8	0.7		1.5	1.3	1.3	0.9	0.8	0.7	0.6	
S-II-1	UPSTREAM	2.1	1.8	1.9	1.8	0.3	1.2	1.0	100	1.9	1.7	1.7	1.3	1.2	1.0	0.8	100
	DOWNSTREAM	2.1	1.8	1.9	1.8	0.3	1.2	1.1		1.9	1.7	1.7	1.3	1.2	1.0	0.9	
S-II-2	UPSTREAM	1.5	1.3	1.3	1.3	0.2	0.8	0.7	100	1.5	1.3	1.3	1.0	0.8	0.7	0.6	101
	DOWNSTREAM	1.5	1.2	1.3	1.2	0.2	0.8	0.7		1.5	1.3	1.3	1.0	0.9	0.7	0.6	
M-II-1	UPSTREAM	1.7	1.5	1.6	1.5	0.2	1.0	0.9	101	1.8	1.6	1.6	1.2	1.0	0.9	0.7	100
	DOWNSTREAM	1.8	1.5	1.6	1.5	0.2	1.0	0.9		1.8	1.6	1.6	1.2	1.0	0.9	0.8	
M-II-2	UPSTREAM	1.4	1.1	1.2	1.1	0.2	0.8	0.7	100	1.5	1.3	1.3	1.0	0.9	0.7	0.6	99
	DOWNSTREAM	1.4	1.1	1.2	1.1	0.2	0.8	0.7		1.5	1.3	1.3	1.0	0.9	0.7	0.6	
L-II-1	UPSTREAM	1.7	1.4	1.5	1.4	0.2	1.0	0.9	101	1.6	1.5	1.5	1.1	1.0	0.8	0.7	99
	DOWNSTREAM	1.7	1.4	1.5	1.4	0.2	1.0	0.8		1.6	1.5	1.5	1.1	1.0	0.8	0.7	
L-II-2	UPSTREAM	1.5	1.2	1.3	1.3	0.2	0.9	0.8	100	1.5	1.3	1.3	1.0	0.9	0.8	0.7	100
	DOWNSTREAM	1.5	1.2	1.3	1.2	0.2	0.9	0.8		1.5	1.3	1.3	1.1	0.9	0.8	0.7	

SECTION I.D.	24-I10-1	WINTER TESTING				DATE		02/01/12		SUMMER TESTING				DATE		08/08/12	
LOCATION						TIME								TIME			
CRACKS		W1	W2	W3	W4	W5	W6	W7	LTE	W1	W2	W3	W4	W5	W6	W7	LTE
S-I-1	UPSTREAM	1.4	1.3	1.2	1.3	1.0	1.0	0.9	99	1.6	1.3	1.3	1.1	1.4	0.9	0.8	93
	DOWNSTREAM	1.4	1.3	1.3	1.4	1.0	1.0	0.9		1.5	1.5	1.8	1.0	1.4	0.9	0.8	
S-I-2	UPSTREAM	1.3	1.2	1.2	1.2	1.0	1.0	0.8	100	1.4	2.0	1.9	1.0	1.2	0.9	0.7	130
	DOWNSTREAM	1.4	1.2	1.1	1.3	1.0	1.0	0.8		1.3	1.8	1.8	1.1	1.3	0.9	0.7	
M-I-1	UPSTREAM	1.3	1.3	1.2	1.3	1.0	1.0	0.8	101	1.5	1.2	1.2	1.0	1.3	0.9	0.7	84
	DOWNSTREAM	1.5	1.3	1.3	1.4	1.0	1.0	0.9		1.4	2.0	2.9	1.1	1.4	1.0	0.8	
M-I-2	UPSTREAM	1.3	1.2	1.1	1.2	0.9	0.9	0.8	99	1.4	1.5	1.7	1.0	1.3	0.9	0.7	108
	DOWNSTREAM	1.3	1.2	1.1	1.2	0.9	0.9	0.8		1.3	1.5	1.9	1.0	1.3	0.9	0.7	
L-I-1	UPSTREAM	1.1	1.2	1.1	1.2	0.9	0.9	0.8	100	1.3	4.5	5.2	1.0	1.2	0.8	0.7	257
	DOWNSTREAM	1.4	1.1	1.1	1.2	0.9	0.9	0.9		1.4	1.8	1.8	0.9	1.2	0.8	0.7	
L-I-2	UPSTREAM	1.3	1.2	1.2	1.2	0.9	0.9	0.8	100	1.2	1.6	1.7	1.0	1.3	0.9	0.8	113
	DOWNSTREAM	1.4	1.2	1.2	1.3	0.9	0.9	0.8		1.4	1.4	1.8	1.0	1.3	0.8	0.7	
S-II-1	UPSTREAM	1.5	1.2	1.2	1.3	1.0	1.0	0.9	100	1.4	1.1	1.0	1.0	1.2	0.9	0.7	104
	DOWNSTREAM	1.4	1.2	1.2	1.3	0.9	0.9	0.8		1.3	1.0	1.1	1.0	1.3	0.9	0.7	
S-II-2	UPSTREAM	1.2	1.2	1.1	1.2	0.9	0.9	0.8	99	1.4	1.5	1.6	1.0	1.3	0.8	0.7	98
	DOWNSTREAM	1.2	1.2	1.1	1.2	0.9	0.9	0.8		1.4	2.0	2.4	1.0	1.3	0.9	0.7	
M-II-1	UPSTREAM	1.4	1.1	1.1	1.3	0.9	0.9	0.8	96	1.3	1.3	1.3	1.0	1.3	0.9	0.8	94
	DOWNSTREAM	1.3	1.3	1.2	1.3	1.0	1.0	0.8		1.3	1.7	1.9	1.0	1.2	0.9	0.7	
M-II-2	UPSTREAM	1.3	1.2	1.1	1.2	0.9	0.9	0.8	99	1.4	1.4	1.6	0.9	1.2	0.8	0.7	108
	DOWNSTREAM	1.2	1.2	1.1	1.2	0.9	0.9	0.8		1.3	1.3	1.3	0.9	1.1	0.8	0.7	
L-II-1	UPSTREAM	1.2	1.1	1.1	1.2	0.9	0.9	0.8	99	1.3	1.1	1.1	1.0	1.2	0.8	0.7	86
	DOWNSTREAM	1.3	1.2	1.2	1.2	0.9	0.9	0.8		1.4	1.8	1.9	1.0	1.2	0.9	0.7	
L-II-2	UPSTREAM	1.3	1.2	1.2	1.2	0.9	0.9	0.8	99	1.3	1.8	2.1	0.9	1.2	0.8	0.7	139
	DOWNSTREAM	1.2	1.2	1.2	1.2	1.0	1.0	0.9		1.3	1.1	1.3	0.9	1.2	0.8	0.7	

SECTION I.D.	24-I10-2	WINTER TESTING				DATE		02/01/12		SUMMER TESTING				DATE		08/08/12	
LOCATION						TIME								TIME			
CRACKS		W1	W2	W3	W4	W5	W6	W7	LTE	W1	W2	W3	W4	W5	W6	W7	LTE
S-I-1	UPSTREAM																
	DOWNSTREAM																
S-I-2	UPSTREAM																
	DOWNSTREAM																
M-I-1	UPSTREAM	2.5	2.4	2.3	2.4	1.7	1.7	1.4	105	2.4	1.7	1.6	2.1	2.5	1.8	1.5	82
	DOWNSTREAM	2.5	2.3	2.2	2.5	1.7	1.7	1.4		2.6	2.2	2.2	1.9	2.5	1.8	1.5	
M-I-2	UPSTREAM	2.4	2.3	2.2	2.3	1.6	1.6	1.3	105	2.1	1.4	1.4	1.7	2.1	1.5	1.3	78
	DOWNSTREAM	2.3	2.2	2.1	2.4	1.6	1.6	1.3		2.1	2.3	2.6	1.7	2.2	1.5	1.3	
L-I-1	UPSTREAM	2.2	2.1	1.9	2.1	1.4	1.4	1.1	104	2.0	1.6	1.7	1.5	1.9	1.3	1.1	94
	DOWNSTREAM	2.2	2.0	1.9	2.2	1.4	1.4	1.2		1.9	1.8	2.0	1.5	1.9	1.3	1.1	
L-I-2	UPSTREAM	2.4	2.2	2.0	2.1	1.4	1.4	1.2	104	1.8	0.0	0.0	1.4	1.8	1.1	0.9	35
	DOWNSTREAM	2.3	2.1	1.9	2.2	1.4	1.4	1.1		1.8	2.0	2.3	1.4	1.8	1.2	1.0	
S-II-1	UPSTREAM																
	DOWNSTREAM																
S-II-2	UPSTREAM																
	DOWNSTREAM																
M-II-1	UPSTREAM	2.1	2.0	1.9	2.0	1.5	1.4	1.2	102	2.2	2.2	2.6	1.7	2.1	1.4	1.2	108
	DOWNSTREAM	2.1	2.0	1.9	2.1	1.4	1.4	1.2		2.2	2.0	2.2	1.7	2.1	1.4	1.1	
M-II-2	UPSTREAM	2.2	2.0	1.9	2.0	1.5	1.5	1.2	103	2.1	1.7	1.9	1.7	2.1	1.4	1.2	64
	DOWNSTREAM	2.1	2.0	1.9	2.1	1.5	1.4	1.2		2.1	6.1	6.7	1.5	2.0	1.3	1.0	
L-II-1	UPSTREAM	2.2	2.1	2.0	2.1	1.5	1.4	1.2	104	1.9	1.4	1.4	1.4	1.8	1.2	1.0	87
	DOWNSTREAM	2.1	2.0	1.8	2.1	1.4	1.4	1.1		1.9	2.0	2.3	1.5	1.9	1.2	1.0	
L-II-2	UPSTREAM	2.1	2.0	1.9	2.0	1.4	1.4	1.2	102	2.3	3.5	3.8	1.8	2.2	1.4	1.2	123
	DOWNSTREAM	2.2	2.0	1.9	2.1	1.5	1.4	1.2		2.3	3.7	3.6	1.7	2.3	1.4	1.2	

SECTION I.D.	24-I10-3	WINTER TESTING				DATE		02/01/12		SUMMER TESTING				DATE		08/08/12	
LOCATION						TIME								TIME			
CRACKS		W1	W2	W3	W4	W5	W6	W7	LTE	W1	W2	W3	W4	W5	W6	W7	LTE
S-I-1	UPSTREAM	2.0	1.9	1.8	2.0	1.3	1.2	1.0	100	2.0	1.7	2.0	1.4	1.9	1.1	0.9	93
	DOWNSTREAM	2.0	1.9	1.8	2.0	1.3	1.2	1.0		2.0	2.1	2.6	1.3	1.9	1.0	0.9	
S-I-2	UPSTREAM	1.9	1.8	1.7	1.8	1.3	1.3	1.1	99	1.8	1.8	2.2	1.4	1.7	1.1	1.0	91
	DOWNSTREAM	1.9	1.8	1.7	1.8	1.3	1.3	1.1		1.8	2.8	3.3	1.4	1.8	1.2	1.0	
M-I-1	UPSTREAM	2.1	2.0	1.9	2.0	1.4	1.4	1.1	100	2.0	2.0	2.3	1.4	2.0	1.2	1.0	120
	DOWNSTREAM	2.1	2.0	1.9	2.1	1.4	1.4	1.1		2.1	1.5	1.7	1.5	2.0	1.2	1.0	
M-I-2	UPSTREAM	1.7	1.5	1.4	1.5	1.0	1.0	0.8	101	1.5	1.5	1.6	1.0	1.4	0.9	0.7	103
	DOWNSTREAM	1.6	1.5	1.4	1.5	1.0	1.0	0.8		1.5	1.9	2.1	1.0	1.4	0.9	0.7	
L-I-1	UPSTREAM	1.7	1.6	1.5	1.6	1.1	1.1	0.9	101	1.5	1.5	1.8	1.1	1.5	0.9	0.8	103
	DOWNSTREAM	1.7	1.6	1.5	1.6	1.1	1.1	0.9		1.6	1.5	1.7	1.1	1.4	0.9	0.8	
L-I-2	UPSTREAM	1.8	1.7	1.6	1.7	1.2	1.2	1.0	102	1.7	1.7	1.9	1.3	1.7	1.1	0.9	109
	DOWNSTREAM	1.8	1.7	1.6	1.7	1.2	1.1	0.9		1.7	1.5	1.6	1.3	1.7	1.0	0.9	
S-II-1	UPSTREAM																
	DOWNSTREAM																
S-II-2	UPSTREAM																
	DOWNSTREAM																
M-II-1	UPSTREAM	1.8	1.7	1.6	1.7	1.3	1.2	1.1	100	2.0	1.8	2.2	1.6	2.0	1.3	1.1	103
	DOWNSTREAM	1.7	1.7	1.6	1.7	1.2	1.2	1.0		2.0	1.8	1.8	1.5	1.9	1.3	1.1	
M-II-2	UPSTREAM	2.1	2.0	2.0	2.1	1.5	1.5	1.3	101	2.2	2.1	2.3	1.8	2.2	1.5	1.3	99
	DOWNSTREAM	2.1	2.0	2.0	2.1	1.6	1.6	1.3		2.2	2.2	2.3	1.8	2.2	1.5	1.3	
L-II-1	UPSTREAM	2.0	1.8	1.7	1.9	1.3	1.3	1.1	100	2.2	2.2	2.4	1.7	2.2	1.5	1.3	98
	DOWNSTREAM	1.9	1.8	1.7	1.9	1.3	1.3	1.1		2.2	2.4	2.6	1.7	2.2	1.5	1.2	
L-II-2	UPSTREAM	2.0	1.8	1.8	1.9	1.4	1.3	1.1	101	2.0	1.7	1.9	1.6	2.0	1.4	1.2	95
	DOWNSTREAM	2.0	1.8	1.8	1.9	1.3	1.3	1.1		2.0	1.9	2.0	1.7	2.1	1.4	1.1	

SECTION I.D.	24-I10-4	WINTER TESTING				DATE		02/02/12		SUMMER TESTING				DATE		08/09/12	
LOCATION						TIME								TIME			
CRACKS		W1	W2	W3	W4	W5	W6	W7	LTE	W1	W2	W3	W4	W5	W6	W7	LTE
S-I-1	UPSTREAM	1.6	1.4	1.2	1.4	0.8	0.9	0.7	101	1.5	1.5	1.6	1.0	1.4	0.8	0.7	126
	DOWNSTREAM	1.6	1.4	1.2	1.4	0.9	0.9	0.7		1.6	0.9	1.1	0.9	1.4	0.8	0.6	
S-I-2	UPSTREAM	1.4	1.2	1.1	1.2	0.8	0.8	0.7	99	1.5	1.3	1.5	0.9	1.3	0.7	0.6	103
	DOWNSTREAM	1.4	1.2	1.1	1.2	0.8	0.8	0.7		1.4	1.6	1.8	0.9	1.3	0.7	0.6	
M-I-1	UPSTREAM	1.5	1.4	1.3	1.4	0.9	0.9	0.7	100	1.6	1.3	1.6	1.1	1.4	0.9	0.7	102
	DOWNSTREAM	1.5	1.4	1.3	1.4	0.9	0.9	0.7		1.6	1.3	1.5	1.1	1.4	0.9	0.7	
M-I-2	UPSTREAM	1.4	1.2	1.1	1.3	0.8	0.8	0.6	100	1.5	4.2	4.9	0.9	1.3	0.8	0.6	285
	DOWNSTREAM	1.4	1.3	1.2	1.3	0.8	0.8	0.7		1.4	1.0	1.0	0.9	1.3	0.8	0.7	
L-I-1	UPSTREAM	1.4	1.2	1.1	1.2	0.8	0.8	0.6	101	1.4	1.1	1.3	0.8	1.2	0.7	0.6	92
	DOWNSTREAM	1.3	1.2	1.1	1.2	0.8	0.8	0.6		1.3	1.5	1.9	0.8	1.2	0.7	0.6	
L-I-2	UPSTREAM	1.3	1.1	1.0	1.2	0.8	0.8	0.7	99	1.3	1.6	2.1	0.8	1.2	0.7	0.6	127
	DOWNSTREAM	1.3	1.2	1.0	1.2	0.8	0.8	0.7		1.3	1.5	1.8	0.9	1.2	0.8	0.7	
S-II-1	UPSTREAM	1.8	1.7	1.6	1.8	1.1	1.1	0.9	100	1.9	1.7	2.0	1.3	1.7	1.1	0.9	94
	DOWNSTREAM	1.9	1.7	1.6	1.8	1.1	1.1	0.9		1.9	2.4	2.7	1.3	1.8	1.1	1.0	
S-II-2	UPSTREAM	1.7	1.6	1.5	1.6	1.1	1.1	0.9	100	1.9	1.3	1.3	1.3	1.8	1.1	1.0	80
	DOWNSTREAM	1.8	1.6	1.5	1.6	1.1	1.1	0.9		1.9	2.2	2.8	1.3	1.7	1.1	0.9	
M-II-1	UPSTREAM	1.7	1.6	1.4	1.6	1.0	1.1	0.9	100	1.7	1.5	1.8	1.2	1.6	1.0	0.9	99
	DOWNSTREAM	1.7	1.5	1.4	1.5	1.1	1.1	0.9		1.7	1.7	1.9	1.2	1.6	1.1	0.9	
M-II-2	UPSTREAM	2.7	2.6	2.4	2.6	1.9	1.9	1.5	100	3.2	3.3	3.6	2.6	3.1	2.3	2.0	94
	DOWNSTREAM	2.8	2.6	2.6	2.7	2.0	1.9	1.6		3.3	4.5	4.7	2.7	3.3	2.4	2.0	
L-II-1	UPSTREAM	2.3	2.1	1.9	2.2	1.3	1.3	1.0	99	1.9	0.9	1.1	1.3	1.8	1.1	0.9	56
	DOWNSTREAM	2.3	2.1	1.8	2.1	1.3	1.3	1.0		1.9	3.3	3.3	1.4	1.7	1.1	0.9	
L-II-2	UPSTREAM	2.0	1.9	1.8	1.9	1.3	1.3	1.1	99	1.8	1.5	1.6	1.4	1.7	1.2	1.0	96
	DOWNSTREAM	2.1	1.9	1.8	1.9	1.3	1.3	1.0		1.8	1.7	2.2	1.4	1.7	1.2	1.0	

SECTION I.D.	25-I40-1	WINTER TESTING				DATE				SUMMER TESTING				DATE		08/28/12	
LOCATION						TIME								TIME			
CRACKS		W1	W2	W3	W4	W5	W6	W7	LTE	W1	W2	W3	W4	W5	W6	W7	LTE
S-I-1	UPSTREAM									1.4	1.1	0.8	1.2	0.6	0.5	0.4	104
	DOWNSTREAM									1.3	1.0	0.8	1.1	0.6	0.5	0.4	
S-I-2	UPSTREAM									1.5	1.3	1.0	1.3	0.7	0.7	0.5	105
	DOWNSTREAM									1.6	1.2	1.1	1.4	0.8	0.7	0.6	
M-I-1	UPSTREAM									1.4	1.1	0.9	1.2	0.7	0.7	0.6	101
	DOWNSTREAM									1.4	1.1	0.9	1.2	0.7	0.6	0.6	
M-I-2	UPSTREAM									1.9	1.4	1.2	1.6	0.9	0.8	0.7	100
	DOWNSTREAM									1.8	1.3	1.1	1.5	0.9	0.8	0.7	
L-I-1	UPSTREAM									1.5	1.3	1.2	1.4	0.9	0.8	0.7	100
	DOWNSTREAM									1.6	1.3	1.2	1.4	0.9	0.8	0.7	
L-I-2	UPSTREAM									1.4	1.1	0.9	1.3	0.7	0.8	0.4	100
	DOWNSTREAM									1.6	1.2	1.0	1.3	0.8	0.6	0.5	
S-II-1	UPSTREAM									1.5	1.1	1.0	1.2	0.7	0.7	0.6	102
	DOWNSTREAM									1.4	1.1	1.0	1.3	0.7	0.7	0.6	
S-II-2	UPSTREAM									1.3	1.1	1.0	1.2	0.7	0.7	0.6	101
	DOWNSTREAM									1.4	1.1	1.0	1.2	0.7	0.7	0.6	
M-II-1	UPSTREAM									1.3	1.0	0.9	1.2	0.7	0.6	0.5	101
	DOWNSTREAM									1.3	1.0	0.9	1.2	0.7	0.6	0.6	
M-II-2	UPSTREAM									1.4	1.2	1.0	1.3	0.7	0.7	0.6	103
	DOWNSTREAM									1.5	1.1	1.0	1.3	0.7	0.6	0.5	
L-II-1	UPSTREAM									1.4	1.1	0.9	1.1	0.7	0.6	0.6	101
	DOWNSTREAM									1.4	1.1	1.0	1.2	0.7	0.7	0.6	
L-II-2	UPSTREAM									1.4	1.1	0.9	1.3	0.7	0.6	0.5	105
	DOWNSTREAM									1.4	1.1	0.9	1.3	0.7	0.6	0.5	

SECTION I.D.	25-I40-2	WINTER TESTING				DATE				SUMMER TESTING				DATE		08/28/12	
LOCATION						TIME								TIME			
CRACKS		W1	W2	W3	W4	W5	W6	W7	LTE	W1	W2	W3	W4	W5	W6	W7	LTE
S-I-1	UPSTREAM									1.7	1.2	1.0	1.4	0.7	0.7	0.5	102
	DOWNSTREAM									1.5	1.2	1.0	1.4	0.8	0.7	0.5	
S-I-2	UPSTREAM									1.7	1.2	1.0	1.4	0.7	0.6	0.5	101
	DOWNSTREAM									1.7	1.3	1.1	1.5	0.8	0.6	0.5	
M-I-1	UPSTREAM									1.5	1.1	0.9	1.3	0.7	0.6	0.5	96
	DOWNSTREAM									1.5	1.1	0.9	1.2	0.7	0.6	0.5	
M-I-2	UPSTREAM									1.4	1.1	1.0	1.3	0.7	0.6	0.5	101
	DOWNSTREAM									1.4	1.1	1.0	1.3	0.7	0.6	0.5	
L-I-1	UPSTREAM									1.4	1.1	0.9	1.2	0.7	0.6	0.5	101
	DOWNSTREAM									1.4	1.1	0.9	1.3	0.7	0.6	0.5	
L-I-2	UPSTREAM									1.4	1.2	1.0	1.2	0.7	0.6	0.4	104
	DOWNSTREAM									1.5	1.2	0.9	1.2	0.7	0.6	0.5	
S-II-1	UPSTREAM									1.5	1.1	0.9	1.3	0.7	0.6	0.5	97
	DOWNSTREAM									1.4	1.1	0.9	1.2	0.7	0.6	0.5	
S-II-2	UPSTREAM									1.8	1.4	1.2	1.6	0.8	0.7	0.6	102
	DOWNSTREAM									1.7	1.4	1.2	1.6	0.8	0.7	0.6	
M-II-1	UPSTREAM									1.5	1.2	0.9	1.3	0.6	0.6	0.5	103
	DOWNSTREAM									1.4	1.1	0.9	1.3	0.7	0.6	0.5	
M-II-2	UPSTREAM									1.5	1.2	1.0	1.4	0.7	0.6	0.5	102
	DOWNSTREAM									1.7	1.2	1.0	1.4	0.7	0.6	0.5	
L-II-1	UPSTREAM									1.5	1.2	0.9	1.3	0.6	0.6	0.4	99
	DOWNSTREAM									1.5	1.2	1.0	1.2	0.8	0.6	0.5	
L-II-2	UPSTREAM									1.5	1.2	1.0	1.3	0.7	0.6	0.5	102
	DOWNSTREAM									1.5	1.1	0.9	1.3	0.7	0.6	0.5	

- **Deflections at Transverse Cracks: FY2013**

SECTION I.D.	3-I35-1	WINTER TESTING				DATE		03/20/13		SUMMER TESTING				DATE			
LOCATION						TIME								TIME			
CRACKS		W1	W2	W3	W4	W5	W6	W7	LTE	W1	W2	W3	W4	W5	W6	W7	LTE
S-I-1	UPSTREAM	1.9	1.8	1.5	2.0	0.9	0.8	0.6	102								
	DOWNSTREAM	2.1	1.8	1.5	2.0	0.9	0.7	0.6									
S-I-2	UPSTREAM	2.0	2.0	1.7	2.1	1.2	1.0	0.8	102								
	DOWNSTREAM	2.1	1.9	1.7	2.1	1.2	0.9	0.8									
M-I-1	UPSTREAM	1.5	1.4	1.2	1.5	0.8	0.6	0.5	105								
	DOWNSTREAM	1.5	1.4	1.1	1.6	0.8	0.7	0.6									
M-I-2	UPSTREAM	1.2	1.3	1.1	1.4	0.8	0.7	0.6	103								
	DOWNSTREAM	1.4	1.3	1.1	1.4	0.8	0.7	0.6									
L-I-1	UPSTREAM	1.7	1.7	1.5	1.9	1.1	0.9	0.9	100								
	DOWNSTREAM	1.7	1.7	1.4	1.9	1.1	1.0	0.9									
L-I-2	UPSTREAM	1.9	1.9	1.6	2.0	1.2	1.0	0.9	102								
	DOWNSTREAM	1.8	1.8	1.5	2.0	1.1	1.0	0.9									
S-II-1	UPSTREAM	1.8	1.7	1.5	1.8	1.2	1.0	0.9	93								
	DOWNSTREAM	1.8	1.7	1.5	1.9	1.2	1.0	0.9									
S-II-2	UPSTREAM	1.9	1.7	1.5	2.0	1.0	0.9	0.8	87								
	DOWNSTREAM	1.7	1.6	1.4	1.9	1.0	0.8	0.7									
M-II-1	UPSTREAM	1.6	1.7	1.4	1.8	1.1	1.0	0.8	90								
	DOWNSTREAM	1.4	1.6	1.4	1.8	1.1	1.0	0.9									
M-II-2	UPSTREAM	2.0	2.0	1.7	2.1	1.2	1.0	0.9	92								
	DOWNSTREAM	2.0	1.9	1.6	2.2	1.2	1.0	0.9									
L-II-1	UPSTREAM	1.6	1.7	1.4	1.8	1.1	1.0	0.9	94								
	DOWNSTREAM	1.7	1.6	1.4	1.7	1.1	1.0	0.9									
L-II-2	UPSTREAM	1.6	1.6	1.4	1.7	1.1	0.9	0.8	94								
	DOWNSTREAM	1.9	1.7	1.5	1.8	1.1	0.9	0.8									

SECTION I.D.	3-US287-1	WINTER TESTING				DATE		03/19/13		SUMMER TESTING				DATE		07/16/13	
LOCATION						TIME								TIME			
CRACKS		W1	W2	W3	W4	W5	W6	W7	LTE	W1	W2	W3	W4	W5	W6	W7	LTE
S-I-1	UPSTREAM	4.0	4.0	3.2	4.2	1.9	1.4	1.0	91								
	DOWNSTREAM	4.2	3.8	3.1	4.5	1.8	1.4	1.0									
S-I-2	UPSTREAM	4.2	4.2	3.3	4.5	2.0	1.5	1.2	89								
	DOWNSTREAM	4.4	4.0	3.4	4.7	2.1	1.5	1.1									
M-I-1	UPSTREAM	4.1	4.0	3.1	4.1	1.8	1.3	1.0	90								
	DOWNSTREAM	4.1	3.7	2.9	4.4	1.8	1.4	1.0									
M-I-2	UPSTREAM	4.6	4.3	3.5	4.6	2.1	1.6	1.2	90								
	DOWNSTREAM	4.7	4.1	3.3	4.8	2.0	1.5	1.1									
L-I-1	UPSTREAM	4.3	4.1	3.2	4.5	2.0	1.5	1.1	87								
	DOWNSTREAM	4.3	3.8	3.1	4.5	2.0	1.4	1.0									
L-I-2	UPSTREAM	3.9	3.9	3.1	4.0	2.0	1.5	1.1	90								
	DOWNSTREAM	4.1	3.7	3.1	4.4	2.0	1.5	1.0									
S-II-1	UPSTREAM	4.5	4.3	3.4	4.7	2.2	1.6	1.3	89								
	DOWNSTREAM	4.6	4.1	3.4	4.7	2.2	1.7	1.3									
S-II-2	UPSTREAM	4.0	3.7	3.0	4.2	1.7	1.3	0.8	88								
	DOWNSTREAM	4.0	3.6	3.0	4.2	1.8	1.4	1.0									
M-II-1	UPSTREAM	4.7	4.7	3.7	4.9	2.2	1.7	1.3	89								
	DOWNSTREAM	5.0	4.3	3.6	5.3	2.2	1.6	1.2									
M-II-2	UPSTREAM	4.4	4.3	3.5	4.5	2.1	1.5	1.1	92								
	DOWNSTREAM	4.5	4.1	3.3	4.8	2.0	1.5	1.1									
L-II-1	UPSTREAM	4.4	4.4	3.6	4.6	2.5	1.9	1.5	91								
	DOWNSTREAM	4.8	4.2	3.6	4.9	2.4	1.8	1.6									
L-II-2	UPSTREAM	3.7	3.6	2.8	3.9	1.8	1.3	1.1	89								
	DOWNSTREAM	3.8	3.4	2.8	4.0	1.8	1.4	1.1									

SECTION I.D.	3-US287-2	WINTER TESTING				DATE		03/19/13		SUMMER TESTING				DATE		07/16/13	
LOCATION						TIME								TIME			
CRACKS		W1	W2	W3	W4	W5	W6	W7	LTE	W1	W2	W3	W4	W5	W6	W7	LTE
S-I-1	UPSTREAM																
	DOWNSTREAM																
S-I-2	UPSTREAM																
	DOWNSTREAM																
M-I-1	UPSTREAM	1.1	1.3	1.1	1.4	1.0	0.8	0.7	100								
	DOWNSTREAM	1.2	1.3	1.1	1.4	0.9	0.8	0.8									
M-I-2	UPSTREAM	1.4	1.5	1.3	1.6	1.0	0.9	0.8	104								
	DOWNSTREAM	1.5	1.4	1.3	1.6	1.0	0.8	0.7									
L-I-1	UPSTREAM	1.4	1.4	1.3	1.6	1.1	1.0	0.8	99								
	DOWNSTREAM	1.4	1.4	1.3	1.6	1.1	1.0	0.8									
L-I-2	UPSTREAM	1.4	1.4	1.2	1.5	1.1	0.9	0.8	104								
	DOWNSTREAM	1.3	1.3	1.2	1.6	1.0	0.9	0.9									
S-II-1	UPSTREAM	1.2	1.4	1.2	1.5	1.0	0.9	0.8	100								
	DOWNSTREAM	1.2	1.3	1.2	1.5	1.0	0.9	0.8									
S-II-2	UPSTREAM	1.4	1.3	1.3	1.5	1.0	0.9	0.8	100								
	DOWNSTREAM	1.3	1.3	1.2	1.4	1.0	0.9	0.7									
M-II-1	UPSTREAM	1.2	1.3	1.1	1.4	1.0	0.9	0.8	101								
	DOWNSTREAM	1.3	1.2	1.2	1.4	0.9	0.9	0.8									
M-II-2	UPSTREAM	1.3	1.2	1.1	1.3	0.9	0.7	0.6	102								
	DOWNSTREAM	1.3	1.2	1.1	1.4	0.9	0.8	0.7									
L-II-1	UPSTREAM	1.3	1.2	1.1	1.4	0.9	0.8	0.6	97								
	DOWNSTREAM	1.2	1.2	1.1	1.3	0.9	0.7	0.6									
L-II-2	UPSTREAM	1.2	1.2	1.1	1.4	0.9	0.8	0.7	99								
	DOWNSTREAM	1.2	1.2	1.1	1.4	1.0	0.9	0.8									

SECTION I.D.	3-US81-1	WINTER TESTING				DATE		03/20/13		SUMMER TESTING				DATE			
LOCATION						TIME								TIME			
CRACKS		W1	W2	W3	W4	W5	W6	W7	LTE	W1	W2	W3	W4	W5	W6	W7	LTE
S-1	UPSTREAM	3.8	3.6	2.9	3.9	1.8	1.3	1.0	99								
	DOWNSTREAM	3.8	3.6	2.9	3.9	1.8	1.4	1.0									
S-2	UPSTREAM	7.8	7.1	5.5	7.6	3.3	2.4	1.6	107								
	DOWNSTREAM	7.9	6.6	5.4	7.9	3.2	2.2	1.6									
S-3	UPSTREAM	2.8	2.5	2.0	2.7	1.2	0.9	0.7	103								
	DOWNSTREAM	2.8	2.5	2.0	2.8	1.2	0.9	0.7									
S-4	UPSTREAM	5.3	5.1	4.2	5.5	2.7	2.2	1.7	105								
	DOWNSTREAM	5.4	4.8	4.1	5.6	2.7	2.1	1.6									
M-1	UPSTREAM	3.6	3.4	2.7	3.5	1.5	1.1	0.8	106								
	DOWNSTREAM	3.7	3.3	2.6	3.8	1.5	1.2	0.9									
M-2	UPSTREAM	4.0	3.7	3.0	4.0	1.8	1.4	1.0	103								
	DOWNSTREAM	3.9	3.6	3.0	4.1	1.8	1.3	1.0									
M-3	UPSTREAM	3.7	3.4	2.8	3.5	1.7	1.4	1.0	105								
	DOWNSTREAM	3.7	3.3	2.8	3.8	1.8	1.4	1.1									
M-4	UPSTREAM	3.2	3.0	2.4	3.3	1.5	1.1	0.9	102								
	DOWNSTREAM	3.2	2.9	2.4	3.2	1.5	1.2	0.8									
L-1	UPSTREAM	3.6	3.4	2.6	3.5	1.6	1.1	0.9	107								
	DOWNSTREAM	3.6	3.1	2.5	3.7	1.5	1.1	0.9									
L-2	UPSTREAM	4.2	3.9	3.0	4.0	1.7	1.3	0.9	108								
	DOWNSTREAM	4.3	3.6	2.8	4.3	1.7	1.2	0.8									
L-3	UPSTREAM	2.5	2.4	1.9	2.5	1.1	0.9	0.6	103								
	DOWNSTREAM	2.6	2.3	1.8	2.6	1.1	0.8	0.6									
L-4	UPSTREAM	3.5	3.3	2.6	3.4	1.4	1.1	0.7	108								
	DOWNSTREAM	3.5	2.9	2.3	3.6	1.3	0.9	0.7									

SECTION I.D.	4-I40-1	WINTER TESTING				DATE	03/06/13			SUMMER TESTING				DATE			
LOCATION						TIME								TIME			
CRACKS		W1	W2	W3	W4	W5	W6	W7	LTE	W1	W2	W3	W4	W5	W6	W7	LTE
S-I-1	UPSTREAM	4.1	3.4	3.1	3.7	2.1	1.9	1.7	109								
	DOWNSTREAM	3.9	3.1	2.9	3.9	2.1	1.9	1.8									
S-I-2	UPSTREAM	5.3	4.0	3.3	4.4	2.0	1.8	1.7	110								
	DOWNSTREAM	5.3	3.7	3.2	4.8	2.1	1.9	1.7									
M-I-1	UPSTREAM	10.3	6.2	5.7	7.8	3.6	3.1	2.8	100								
	DOWNSTREAM	8.0	6.0	5.5	7.3	3.6	3.2	2.9									
M-I-2	UPSTREAM	4.1	3.4	3.2	3.7	2.2	2.1	1.8	106								
	DOWNSTREAM	4.1	3.3	3.1	4.0	2.2	2.1	1.8									
L-I-1	UPSTREAM	3.8	3.2	3.0	3.5	2.1	1.9	1.6	105								
	DOWNSTREAM	4.0	3.1	2.9	3.7	2.0	1.8	1.6									
L-I-2	UPSTREAM	4.1	3.4	3.2	3.7	2.3	2.1	1.8	106								
	DOWNSTREAM	4.1	3.4	3.2	4.0	2.3	2.0	1.8									
S-II-1	UPSTREAM	4.1	3.4	3.1	3.7	2.2	1.9	1.7	106								
	DOWNSTREAM	4.0	3.2	3.1	3.9	2.0	1.9	1.7									
S-II-2	UPSTREAM	4.9	4.1	3.4	4.5	2.1	1.8	1.6	112								
	DOWNSTREAM	4.6	3.5	3.3	4.7	2.0	1.9	1.6									
M-II-1	UPSTREAM	6.4	5.6	5.3	6.0	3.6	3.1	2.7	110								
	DOWNSTREAM	6.5	5.2	4.9	6.6	3.4	3.0	2.6									
M-II-2	UPSTREAM	4.4	3.6	3.2	4.0	2.1	2.0	1.8	110								
	DOWNSTREAM	4.3	3.3	3.0	4.2	2.1	2.0	1.7									
L-II-1	UPSTREAM	10.2	4.4	3.8	9.1	2.2	2.2	1.9	82								
	DOWNSTREAM	7.4	5.2	4.3	6.0	2.2	2.0	1.8									
L-II-2	UPSTREAM	4.6	3.0	2.9	3.8	2.1	1.9	1.7	88								
	DOWNSTREAM	7.2	3.8	3.1	3.7	2.1	1.9	1.7									

SECTION I.D.	5-I27-1	WINTER TESTING				DATE		02/13/13		SUMMER TESTING				DATE		06/27/13	
LOCATION						TIME								TIME			
CRACKS		W1	W2	W3	W4	W5	W6	W7	LTE	W1	W2	W3	W4	W5	W6	W7	LTE
S-I-1	UPSTREAM	2.8	2.4	2.1	2.4	1.6	1.3	1.1	101	2.7	2.6	2.3	2.5	1.4	1.3	1.1	102
	DOWNSTREAM	2.6	2.4	2.1	2.4	1.6	1.3	1.1		2.7	2.5	2.2	2.5	1.6	1.4	1.2	
S-I-2	UPSTREAM	2.4	2.0	1.7	2.0	1.2	1.0	0.8	101	2.5	2.1	1.8	2.1	1.3	1.1	0.8	100
	DOWNSTREAM	2.3	2.0	1.7	2.0	1.2	1.0	0.8		2.4	2.1	1.8	2.1	1.3	1.1	0.9	
M-I-1	UPSTREAM	2.6	2.3	2.1	2.3	1.5	1.3	1.1	102	2.7	2.5	2.2	2.5	1.6	1.3	1.2	100
	DOWNSTREAM	2.6	2.3	2.1	2.3	1.5	1.3	1.1		2.8	2.5	2.2	2.5	1.6	1.4	1.2	
M-I-2	UPSTREAM	2.6	2.4	2.0	2.3	1.4	1.2	1.0	100	2.7	2.4	2.0	2.4	1.4	1.2	1.0	100
	DOWNSTREAM	2.6	2.4	2.1	2.3	1.5	1.2	1.0		2.9	2.4	2.0	2.4	1.4	1.1	1.0	
L-I-1	UPSTREAM																
	DOWNSTREAM																
L-I-2	UPSTREAM																
	DOWNSTREAM																
S-II-1	UPSTREAM	2.4	2.1	1.8	2.1	1.2	1.0	0.9	100	2.6	2.3	2.0	2.3	1.4	1.1	1.0	101
	DOWNSTREAM	2.4	2.1	1.8	2.1	1.3	1.1	0.9		2.5	2.3	2.0	2.3	1.4	1.1	0.9	
S-II-2	UPSTREAM	2.4	2.0	1.8	2.0	1.3	1.1	0.9	99	2.3	2.0	1.7	2.0	1.2	1.0	0.8	99
	DOWNSTREAM	2.4	2.1	1.8	2.0	1.3	1.1	0.9		2.3	2.1	1.8	2.0	1.2	1.0	0.9	
M-II-1	UPSTREAM	2.8	2.4	2.0	2.3	1.3	1.1	0.9	103	2.6	2.3	2.0	2.3	1.4	1.1	0.9	100
	DOWNSTREAM	2.7	2.3	2.0	2.4	1.3	1.1	0.9		2.6	2.3	2.0	2.3	1.4	1.1	0.9	
M-II-2	UPSTREAM	2.8	2.5	2.0	2.4	1.3	1.1	0.9	103	2.6	2.3	1.9	2.2	1.3	1.1	0.9	101
	DOWNSTREAM	2.7	2.4	2.1	2.5	1.4	1.1	0.9		2.5	2.3	2.0	2.3	1.3	1.1	0.9	
L-II-1	UPSTREAM																
	DOWNSTREAM																
L-II-2	UPSTREAM																
	DOWNSTREAM																

SECTION I.D.	5-LP289-1	WINTER TESTING				DATE		02/13/13		SUMMER TESTING				DATE		06/28/13	
LOCATION						TIME								TIME			
CRACKS		W1	W2	W3	W4	W5	W6	W7	LTE	W1	W2	W3	W4	W5	W6	W7	LTE
S-I-1	UPSTREAM	3.4	3.0	2.5	3.1	1.7	1.4	1.2	101	3.4	3.1	2.7	3.1	2.0	1.7	1.4	100
	DOWNSTREAM	3.3	2.9	2.5	3.0	1.7	1.4	1.1		3.7	3.1	2.7	3.1	2.0	1.7	1.4	
S-I-2	UPSTREAM	2.9	2.7	2.3	2.6	1.6	1.4	1.2	103	2.7	2.4	2.2	2.5	1.7	1.5	1.4	100
	DOWNSTREAM	2.9	2.6	2.2	2.6	1.7	1.4	1.2		2.7	2.4	2.1	2.4	1.7	1.5	1.3	
M-I-1	UPSTREAM	3.0	2.9	2.6	2.8	1.8	1.5	1.2	101	3.4	3.2	2.8	3.1	2.1	1.7	1.4	100
	DOWNSTREAM	3.3	3.0	2.6	2.9	1.8	1.5	1.2		3.5	3.2	2.8	3.1	2.0	1.7	1.4	
M-I-2	UPSTREAM	3.3	3.0	2.5	2.8	1.7	1.4	1.2	104	3.5	3.1	2.7	3.1	1.9	1.6	1.3	100
	DOWNSTREAM	3.5	2.9	2.5	3.0	1.7	1.4	1.2		3.3	3.0	2.6	3.1	1.9	1.6	1.3	
L-I-1	UPSTREAM	2.6	2.4	2.1	2.4	1.6	1.4	1.2	101	2.6	2.2	1.9	2.1	1.4	1.4	1.1	102
	DOWNSTREAM	2.7	2.4	2.1	2.4	1.6	1.4	1.2		2.4	2.1	1.9	2.1	1.5	1.4	1.2	
L-I-2	UPSTREAM	2.7	2.4	2.1	2.4	1.6	1.3	1.1	102	2.3	2.1	1.8	2.1	1.4	1.3	1.2	101
	DOWNSTREAM	2.7	2.3	2.0	2.4	1.5	1.3	1.1		2.2	2.0	1.8	2.1	1.5	1.3	1.2	
S-II-1	UPSTREAM	3.0	2.7	2.2	2.6	1.5	1.2	1.0	102	2.9	2.7	2.4	2.7	1.8	1.5	1.2	100
	DOWNSTREAM	3.0	2.7	2.2	2.7	1.5	1.3	1.0		3.0	2.7	2.4	2.7	1.8	1.5	1.2	
S-II-2	UPSTREAM	2.2	2.0	1.7	1.9	1.2	1.0	0.9	101	2.5	2.2	1.9	2.2	1.4	1.2	0.9	101
	DOWNSTREAM	2.2	1.9	1.7	2.0	1.2	1.1	0.9		2.4	2.2	1.9	2.2	1.4	1.1	0.9	
M-II-1	UPSTREAM	2.7	2.4	2.1	2.4	1.6	1.3	1.1	100	3.2	2.9	2.6	2.9	1.9	1.6	1.4	101
	DOWNSTREAM	2.6	2.4	2.1	2.4	1.6	1.4	1.1		3.2	2.9	2.6	2.9	1.9	1.6	1.4	
M-II-2	UPSTREAM	2.4	2.1	1.8	2.0	1.2	1.0	0.9	101	2.4	2.2	1.9	2.2	1.4	1.2	0.9	101
	DOWNSTREAM	2.3	2.1	1.8	2.1	1.3	1.1	0.9		2.4	2.2	2.0	2.2	1.4	1.2	1.0	
L-II-1	UPSTREAM	2.6	2.4	2.2	2.4	1.6	1.4	1.1	100	3.3	3.0	2.7	3.0	2.0	1.7	1.4	101
	DOWNSTREAM	2.7	2.4	2.2	2.4	1.6	1.4	1.1		3.3	3.0	2.7	3.0	2.0	1.7	1.4	
L-II-2	UPSTREAM	2.4	2.1	1.8	2.1	1.3	1.1	0.9	100	2.5	2.2	2.0	2.2	1.4	1.2	1.0	100
	DOWNSTREAM	2.4	2.1	1.8	2.1	1.3	1.1	0.9		2.4	2.2	1.9	2.2	1.4	1.2	1.0	

SECTION I.D.	9-I35-2	WINTER TESTING				DATE		02/21/13		SUMMER TESTING				DATE			
LOCATION						TIME								TIME			
CRACKS		W1	W2	W3	W4	W5	W6	W7	LTE	W1	W2	W3	W4	W5	W6	W7	LTE
S-I-1	UPSTREAM																
	DOWNSTREAM																
S-I-2	UPSTREAM	1.1	1.1	0.9	0.8	0.7	0.6	1.5	96								
	DOWNSTREAM	1.1	1.0	0.9	0.8	0.7	0.6	1.6									
M-I-1	UPSTREAM	1.3	1.1	1.0	0.9	0.8	0.7	1.6	107								
	DOWNSTREAM	1.1	1.1	1.0	0.8	0.8	0.6	1.5									
M-I-2	UPSTREAM	1.1	1.1	1.0	0.8	0.8	0.6	1.6	92								
	DOWNSTREAM	1.2	1.0	1.0	0.8	0.8	0.6	1.7									
L-I-1	UPSTREAM	1.2	1.1	1.0	0.9	0.8	0.7	1.5	100								
	DOWNSTREAM	1.2	1.0	1.0	0.8	0.8	0.7	1.4									
L-I-2	UPSTREAM	1.2	1.1	1.0	0.9	0.8	0.7	1.2	100								
	DOWNSTREAM	1.1	1.1	1.0	0.9	0.8	0.7	1.2									
S-II-1	UPSTREAM	1.3	1.2	1.1	1.0	0.9	0.8	1.4	100								
	DOWNSTREAM	1.2	1.1	1.1	0.9	0.8	0.7	1.7									
S-II-2	UPSTREAM	1.3	1.2	1.1	1.0	1.0	0.8	2.0	102								
	DOWNSTREAM	1.3	1.3	1.1	0.9	0.9	0.8	1.9									
M-II-1	UPSTREAM	1.4	1.3	1.1	0.9	0.9	0.8	2.0	103								
	DOWNSTREAM	1.3	1.2	1.1	1.0	0.9	0.8	1.8									
M-II-2	UPSTREAM	1.2	1.3	1.1	1.0	0.9	0.8	1.4	95								
	DOWNSTREAM	1.3	1.2	1.1	1.0	0.9	0.8	1.4									
L-II-1	UPSTREAM	1.3	1.2	1.1	1.0	0.9	0.8	1.4	101								
	DOWNSTREAM	1.3	1.3	1.1	1.0	0.9	0.8	1.6									
L-II-2	UPSTREAM	1.5	1.5	1.3	1.2	1.1	0.9	2.2	95								
	DOWNSTREAM	1.6	1.4	1.4	1.2	1.2	0.9	2.0									

SECTION I.D.	12-US290-2	WINTER TESTING				DATE		02/22/13		SUMMER TESTING				DATE			
LOCATION						TIME								TIME			
CRACKS		W1	W2	W3	W4	W5	W6	W7	LTE	W1	W2	W3	W4	W5	W6	W7	LTE
S-I-1	UPSTREAM	2.4	2.2	1.9	1.5	1.3	1.0	2.8	105								
	DOWNSTREAM	2.5	2.3	1.9	1.6	1.3	1.0	2.5									
S-I-2	UPSTREAM	2.4	2.2	1.8	1.5	1.2	1.0	2.3	108								
	DOWNSTREAM	2.5	2.1	1.8	1.5	1.2	1.0	2.6									
M-I-1	UPSTREAM	2.2	2.1	1.7	1.5	1.2	1.0	2.3	107								
	DOWNSTREAM	2.3	2.0	1.8	1.5	1.2	1.0	3.1									
M-I-2	UPSTREAM	2.1	1.9	1.7	1.5	1.3	1.0	2.1	104								
	DOWNSTREAM	2.2	1.9	1.7	1.5	1.3	1.0	2.1									
L-I-1	UPSTREAM																
	DOWNSTREAM																
L-I-2	UPSTREAM																
	DOWNSTREAM																
S-II-1	UPSTREAM	2.6	2.5	2.1	1.8	1.4	1.2	2.7	105								
	DOWNSTREAM	2.9	2.6	2.2	1.8	1.5	1.2	2.9									
S-II-2	UPSTREAM	2.8	2.6	2.2	1.8	1.5	1.2	2.9	106								
	DOWNSTREAM	2.1	2.0	1.7	1.5	1.2	1.0	2.3									
M-II-1	UPSTREAM	2.1	2.0	1.7	1.4	1.2	1.0	2.2	106								
	DOWNSTREAM	2.1	1.9	1.7	1.4	1.2	1.0	2.2									
M-II-2	UPSTREAM	2.4	2.3	2.0	1.7	1.3	1.1	2.4	105								
	DOWNSTREAM	2.4	2.4	2.0	1.7	1.4	1.1	2.5									
L-II-1	UPSTREAM	2.5	2.3	2.0	1.7	1.4	1.2	2.6	106								
	DOWNSTREAM	2.4	2.2	2.0	1.7	1.4	1.2	2.5									
L-II-2	UPSTREAM	2.5	2.2	1.9	1.5	1.3	1.0	2.6	108								
	DOWNSTREAM	2.3	2.1	1.8	1.5	1.3	1.0	2.4									

SECTION I.D.	12-US290-3	WINTER TESTING				DATE		02/22/13		SUMMER TESTING				DATE			
LOCATION						TIME								TIME			
CRACKS		W1	W2	W3	W4	W5	W6	W7	LTE	W1	W2	W3	W4	W5	W6	W7	LTE
S-I-1	UPSTREAM	2.4	2.1	1.7	1.3	1.2	0.9	3.4	112								
	DOWNSTREAM	2.3	2.0	1.7	1.4	1.2	0.9	2.3									
S-I-2	UPSTREAM	2.0	1.8	1.5	1.2	1.0	0.9	1.9	106								
	DOWNSTREAM	2.2	2.0	1.7	1.4	1.1	0.9	2.1									
M-I-1	UPSTREAM	2.3	2.0	1.7	1.4	1.2	0.9	2.3	107								
	DOWNSTREAM	2.1	1.9	1.7	1.4	1.1	0.9	2.2									
M-I-2	UPSTREAM	2.1	1.9	1.7	1.4	1.2	1.0	2.1	104								
	DOWNSTREAM	2.1	2.0	1.8	1.5	1.2	1.0	2.1									
L-I-1	UPSTREAM	2.3	2.0	1.7	1.4	1.1	0.9	2.2	109								
	DOWNSTREAM	2.2	1.9	1.6	1.3	1.1	0.9	2.3									
L-I-2	UPSTREAM	2.0	1.9	1.6	1.3	1.1	0.9	2.2	107								
	DOWNSTREAM	2.0	1.8	1.6	1.4	1.1	0.9	2.0									
S-II-1	UPSTREAM	2.6	2.5	2.1	1.7	1.3	1.1	2.5	105								
	DOWNSTREAM	3.6	2.0	1.6	1.3	1.1	0.9	3.0									
S-II-2	UPSTREAM	2.1	1.9	1.5	1.3	1.1	0.9	2.5	109								
	DOWNSTREAM	1.7	1.6	1.4	1.2	1.0	0.8	1.9									
M-II-1	UPSTREAM	2.1	1.9	1.6	1.3	1.1	0.9	2.2	107								
	DOWNSTREAM	2.1	1.9	1.6	1.4	1.1	0.9	2.1									
M-II-2	UPSTREAM	2.2	1.9	1.6	1.3	1.0	0.9	2.2	109								
	DOWNSTREAM	2.1	1.8	1.6	1.3	1.1	0.9	2.3									
L-II-1	UPSTREAM	2.1	1.8	1.6	1.3	1.1	0.9	2.1	105								
	DOWNSTREAM	1.9	1.8	1.6	1.3	1.1	0.9	2.0									
L-II-2	UPSTREAM	2.0	1.8	1.5	1.2	1.0	0.8	2.0	107								
	DOWNSTREAM	2.1	1.9	1.6	1.3	1.0	0.9	2.4									

SECTION I.D.	19-US59-1	WINTER TESTING				DATE		01/23/13		SUMMER TESTING				DATE			
LOCATION		W4>W3				TIME								TIME			
CRACKS		W1	W2	W3	W4	W5	W6	W7	LTE	W1	W2	W3	W4	W5	W6	W7	LTE
S-I-1	UPSTREAM	1.7	1.5	1.6	1.2	1.0	0.9	0.8	101								
	DOWNSTREAM	1.6	1.5	1.6	1.1	1.0	0.8	0.7									
S-I-2	UPSTREAM	1.6	1.5	1.6	1.1	0.9	0.8	0.6	106								
	DOWNSTREAM	1.6	1.4	1.7	1.1	0.9	0.7	0.6									
M-I-1	UPSTREAM	1.6	1.5	1.8	1.2	1.1	0.9	0.8	99								
	DOWNSTREAM	1.6	1.5	1.7	1.2	1.0	0.9	0.8									
M-I-2	UPSTREAM	1.5	1.3	1.4	1.0	0.9	0.8	0.7	107								
	DOWNSTREAM	1.4	1.3	1.6	1.1	0.9	0.8	0.7									
L-I-1	UPSTREAM	1.6	1.4	1.5	1.1	0.9	0.8	0.7	101								
	DOWNSTREAM	1.6	1.4	1.6	1.1	1.0	0.8	0.7									
L-I-2	UPSTREAM	1.5	1.3	1.5	1.0	0.8	0.7	0.6	105								
	DOWNSTREAM	1.5	1.3	1.5	1.2	0.8	0.7	0.6									
S-II-1	UPSTREAM	2.5	2.3	2.5	1.8	1.5	1.3	1.1	100								
	DOWNSTREAM	2.4	2.3	2.5	1.8	1.5	1.3	1.1									
S-II-2	UPSTREAM	1.6	1.3	1.4	1.0	0.9	0.7	0.6	100								
	DOWNSTREAM	1.4	1.3	1.4	1.0	0.9	0.7	0.6									
M-II-1	UPSTREAM	1.8	1.7	1.8	1.3	1.2	1.0	0.8	100								
	DOWNSTREAM	1.8	1.7	1.8	1.3	1.2	1.0	0.9									
M-II-2	UPSTREAM	1.4	1.2	1.4	0.9	0.8	0.7	0.6	98								
	DOWNSTREAM	1.3	1.2	1.3	1.0	0.8	0.7	0.6									
L-II-1	UPSTREAM	1.7	1.6	1.8	1.2	1.1	0.9	0.8	98								
	DOWNSTREAM	1.8	1.6	1.7	1.3	1.1	0.9	0.8									
L-II-2	UPSTREAM	1.6	1.4	1.6	1.1	0.9	0.9	0.7	97								
	DOWNSTREAM	1.5	1.4	1.5	1.1	1.0	0.8	0.7									

SECTION I.D.	19-US59-2	WINTER TESTING				DATE		01/23/13		SUMMER TESTING				DATE			
LOCATION		W4>W3				TIME								TIME			
CRACKS		W1	W2	W3	W4	W5	W6	W7	LTE	W1	W2	W3	W4	W5	W6	W7	LTE
S-I-1	UPSTREAM	1.7	1.5	1.6	1.2	1.0	0.9	0.8	102								
	DOWNSTREAM	1.8	1.5	1.7	1.2	1.0	0.9	0.8									
S-I-2	UPSTREAM	1.7	1.5	2.0	1.3	1.1	0.9	0.8	93								
	DOWNSTREAM	1.9	1.8	2.0	1.0	1.1	0.9	0.8									
M-I-1	UPSTREAM	1.8	1.6	1.8	1.2	1.1	1.0	0.8	102								
	DOWNSTREAM	1.8	1.6	1.8	1.2	1.1	1.0	0.9									
M-I-2	UPSTREAM	2.2	1.5	1.9	1.1	1.1	0.9	0.9	81								
	DOWNSTREAM	3.4	2.0	1.7	1.3	1.1	1.0	0.8									
L-I-1	UPSTREAM	2.5	1.6	2.0	1.3	1.1	1.0	0.9	93								
	DOWNSTREAM	2.3	1.7	1.8	1.3	1.1	1.0	0.9									
L-I-2	UPSTREAM	2.3	1.6	1.9	1.2	1.1	1.0	0.9	101								
	DOWNSTREAM	1.9	1.6	1.8	1.2	1.1	1.0	0.9									
S-II-1	UPSTREAM	1.9	1.7	1.8	1.4	1.2	1.0	0.9	100								
	DOWNSTREAM	2.0	1.7	1.8	1.4	1.2	1.1	0.9									
S-II-2	UPSTREAM	1.8	1.7	2.0	1.1	1.0	0.8	0.7	103								
	DOWNSTREAM	1.8	1.6	1.9	1.2	1.0	0.8	0.7									
M-II-1	UPSTREAM	1.8	1.7	1.8	1.3	1.1	1.0	0.9	101								
	DOWNSTREAM	1.9	1.7	1.9	1.3	1.1	1.0	0.9									
M-II-2	UPSTREAM	1.7	1.5	1.7	1.2	1.1	0.9	0.8	105								
	DOWNSTREAM	1.7	1.5	1.8	1.2	1.1	0.9	0.9									
L-II-1	UPSTREAM	2.2	1.6	1.8	1.2	1.0	0.9	0.7	108								
	DOWNSTREAM	1.8	1.5	1.9	1.1	1.0	0.9	0.8									
L-II-2	UPSTREAM	2.7	1.7	2.0	1.2	1.0	0.8	0.8	104								
	DOWNSTREAM	2.1	1.8	2.2	1.2	1.0	0.9	0.8									

SECTION I.D.	24-I10-1	WINTER TESTING				DATE		01/29/13		SUMMER TESTING				DATE		07/24/13	
LOCATION						TIME								TIME			
CRACKS		W1	W2	W3	W4	W5	W6	W7	LTE	W1	W2	W3	W4	W5	W6	W7	LTE
S-I-1	UPSTREAM	1.4	1.2	1.1	1.2	0.8	0.7	0.6	100	1.3	1.2	1.1	1.2	0.8	0.7	0.6	100
	DOWNSTREAM	1.3	1.1	1.0	1.2	0.8	0.7	0.6		1.4	1.2	1.1	1.2	0.8	0.8	0.6	
S-I-2	UPSTREAM	1.2	1.1	1.0	1.1	0.8	0.7	0.6	99	1.3	1.1	1.0	1.1	0.8	0.7	0.6	100
	DOWNSTREAM	1.3	1.1	1.0	1.1	0.8	0.7	0.6		1.3	1.1	1.0	1.1	0.8	0.7	0.6	
M-I-1	UPSTREAM	1.3	1.1	1.0	1.1	0.8	0.7	0.6	98	1.3	1.2	1.1	1.1	0.7	0.7	0.6	103
	DOWNSTREAM	1.3	1.2	1.0	1.1	0.8	0.7	0.6		1.3	1.2	1.1	1.2	0.8	0.7	0.6	
M-I-2	UPSTREAM	1.2	1.0	0.9	1.0	0.7	0.6	0.6	100	1.2	1.1	1.0	1.1	0.8	0.7	0.6	99
	DOWNSTREAM	1.2	1.0	0.9	1.0	0.7	0.6	0.6		1.3	1.2	1.1	1.1	0.7	0.7	0.5	
L-I-1	UPSTREAM	1.2	1.0	0.9	1.0	0.7	0.7	0.6	99	1.3	1.2	1.0	1.1	0.7	0.7	0.6	104
	DOWNSTREAM	1.2	1.0	0.9	1.0	0.7	0.7	0.6		1.3	1.1	1.0	1.1	0.8	0.7	0.6	
L-I-2	UPSTREAM	1.2	1.1	1.0	1.1	0.8	0.7	0.6	99	1.3	1.1	1.0	1.1	0.8	0.7	0.6	100
	DOWNSTREAM	1.2	1.1	1.0	1.1	0.8	0.7	0.6		1.3	1.1	1.0	1.1	0.8	0.7	0.6	
S-II-1	UPSTREAM	1.2	1.0	0.9	1.0	0.7	0.6	0.6	100	1.2	1.2	1.0	1.1	0.8	0.7	0.6	100
	DOWNSTREAM	1.2	1.1	1.0	1.1	0.8	0.7	0.6		1.2	1.2	1.0	1.1	0.7	0.7	0.6	
S-II-2	UPSTREAM	1.2	1.1	1.0	1.1	0.8	0.7	0.6	100	1.3	1.2	1.0	1.2	0.8	0.7	0.7	99
	DOWNSTREAM	1.2	1.0	0.9	1.1	0.8	0.7	0.6		1.3	1.1	1.0	1.1	0.8	0.7	0.6	
M-II-1	UPSTREAM	1.2	1.1	1.0	1.1	0.8	0.7	0.6	101	1.2	1.1	1.0	1.1	0.8	0.7	0.6	97
	DOWNSTREAM	1.2	1.0	0.9	1.0	0.7	0.7	0.6		1.2	1.1	1.0	1.0	0.7	0.7	0.6	
M-II-2	UPSTREAM	1.1	1.0	0.9	1.0	0.7	0.7	0.6	98	1.2	1.1	0.9	1.1	0.7	0.7	0.6	101
	DOWNSTREAM	1.2	1.0	0.9	1.0	0.7	0.6	0.5		1.2	1.1	1.0	1.1	0.8	0.7	0.6	
L-II-1	UPSTREAM	1.2	1.1	1.0	1.1	0.8	0.7	0.6	100	1.2	1.1	1.0	1.1	0.7	0.6	0.6	98
	DOWNSTREAM	1.3	1.1	1.0	1.1	0.8	0.7	0.6		1.2	1.1	1.0	1.0	0.7	0.6	0.5	
L-II-2	UPSTREAM	1.2	1.0	0.9	1.0	0.7	0.6	0.6	99	1.3	1.1	1.0	1.0	0.7	0.6	0.6	103
	DOWNSTREAM	1.2	1.0	1.0	1.0	0.7	0.7	0.6		1.3	1.1	1.0	1.1	0.7	0.7	0.6	

SECTION I.D.	24-I10-2	WINTER TESTING				DATE		01/29/13		SUMMER TESTING				DATE		07/24/13	
LOCATION						TIME								TIME			
CRACKS		W1	W2	W3	W4	W5	W6	W7	LTE	W1	W2	W3	W4	W5	W6	W7	LTE
S-I-1	UPSTREAM																
	DOWNSTREAM																
S-I-2	UPSTREAM																
	DOWNSTREAM																
M-I-1	UPSTREAM	2.1	1.9	1.6	1.8	1.1	1.0	0.8	104	2.5	2.3	2.1	2.2	1.6	1.4	1.0	101
	DOWNSTREAM	2.1	1.8	1.6	1.9	1.1	0.9	0.8		2.6	2.3	2.1	2.2	1.6	1.4	1.2	
M-I-2	UPSTREAM	2.1	1.9	1.6	1.8	1.1	1.0	0.8	106	2.0	1.9	1.7	1.9	1.3	1.2	0.9	100
	DOWNSTREAM	2.2	1.8	1.5	1.9	1.2	1.0	0.8		2.0	1.9	1.7	1.9	1.4	1.2	1.0	
L-I-1	UPSTREAM	2.0	1.8	1.5	1.7	1.1	1.0	0.8	105	1.7	1.6	1.4	1.6	1.1	1.0	0.7	100
	DOWNSTREAM	2.1	1.8	1.5	1.8	1.1	0.9	0.8		1.7	1.7	1.4	1.6	1.1	1.0	0.7	
L-I-2	UPSTREAM	2.2	1.9	1.6	1.8	1.1	0.9	0.8	105	1.7	1.7	1.5	1.7	1.1	1.0	0.8	102
	DOWNSTREAM	2.2	1.8	1.6	1.9	1.1	0.9	0.8		1.9	1.6	1.4	1.6	1.1	0.9	0.7	
S-II-1	UPSTREAM																
	DOWNSTREAM																
S-II-2	UPSTREAM																
	DOWNSTREAM																
M-II-1	UPSTREAM	2.0	1.8	1.6	1.7	1.1	0.9	0.8	104	2.1	1.9	1.8	1.8	1.3	1.2	0.9	103
	DOWNSTREAM	1.9	1.7	1.5	1.7	1.1	0.9	0.8		2.1	1.9	1.8	1.9	1.2	1.2	0.9	
M-II-2	UPSTREAM	1.9	1.7	1.5	1.7	1.1	0.9	0.8	103	2.1	2.0	1.8	1.9	1.3	1.2	1.0	100
	DOWNSTREAM	1.9	1.7	1.5	1.7	1.1	0.9	0.8		2.3	2.0	1.8	1.9	1.3	1.1	1.0	
L-II-1	UPSTREAM	2.0	1.8	1.6	1.7	1.1	0.9	0.8	106	1.9	1.6	1.5	1.6	1.1	1.0	0.8	100
	DOWNSTREAM	2.1	1.8	1.5	1.8	1.1	0.9	0.7		1.8	1.6	1.5	1.6	1.0	1.0	0.8	
L-II-2	UPSTREAM	1.9	1.7	1.5	1.7	1.1	1.0	0.8	102	2.4	2.1	1.9	2.1	1.3	1.3	1.0	100
	DOWNSTREAM	1.9	1.7	1.5	1.7	1.1	1.0	0.8		2.3	2.1	1.9	2.0	1.4	1.2	1.0	

SECTION I.D.	24-I10-3	WINTER TESTING				DATE		01/29/13		SUMMER TESTING				DATE		07/24/13	
LOCATION						TIME								TIME			
CRACKS		W1	W2	W3	W4	W5	W6	W7	LTE	W1	W2	W3	W4	W5	W6	W7	LTE
S-I-1	UPSTREAM	2.0	1.8	1.6	1.8	1.2	0.9	0.8	101	2.0	1.8	1.6	1.8	1.1	0.9	0.8	100
	DOWNSTREAM	2.1	1.8	1.6	1.8	1.1	0.9	0.8		2.0	1.8	1.6	1.8	1.1	0.9	0.7	
S-I-2	UPSTREAM	1.7	1.6	1.4	1.6	1.1	1.0	0.8	100	1.8	1.6	1.4	1.5	1.0	1.0	0.7	98
	DOWNSTREAM	1.8	1.6	1.5	1.6	1.1	1.0	0.9		1.8	1.7	1.4	1.5	1.0	1.0	0.8	
M-I-1	UPSTREAM	2.0	1.8	1.6	1.8	1.2	1.0	0.8	100	2.0	1.9	1.7	1.9	1.2	1.0	0.9	99
	DOWNSTREAM	2.0	1.8	1.6	1.8	1.2	1.0	0.8		2.0	1.8	1.6	1.8	1.2	1.0	0.7	
M-I-2	UPSTREAM	1.6	1.3	1.1	1.3	0.8	0.7	0.6	99	1.3	1.2	1.0	1.2	0.7	0.6	0.4	101
	DOWNSTREAM	1.5	1.3	1.2	1.3	0.8	0.7	0.6		1.3	1.1	1.0	1.1	0.7	0.6	0.5	
L-I-1	UPSTREAM	1.6	1.4	1.2	1.4	0.9	0.8	0.6	101	1.3	1.3	1.1	1.2	0.8	0.7	0.6	99
	DOWNSTREAM	1.6	1.4	1.2	1.4	0.9	0.8	0.7		1.4	1.3	1.1	1.3	0.8	0.7	0.6	
L-I-2	UPSTREAM	1.7	1.5	1.3	1.5	1.0	0.8	0.7	100	1.7	1.4	1.3	1.4	0.9	0.8	0.7	101
	DOWNSTREAM	1.7	1.5	1.3	1.5	1.0	0.8	0.7		1.6	1.4	1.3	1.4	0.8	0.8	0.6	
S-II-1	UPSTREAM																
	DOWNSTREAM																
S-II-2	UPSTREAM																
	DOWNSTREAM																
M-II-1	UPSTREAM	1.7	1.5	1.3	1.5	1.0	0.8	0.7	101	2.1	1.8	1.7	1.9	1.3	1.1	1.1	99
	DOWNSTREAM	1.7	1.5	1.3	1.5	1.0	0.9	0.8		2.0	1.9	1.7	1.9	1.3	1.1	0.9	
M-II-2	UPSTREAM	1.8	1.7	1.5	1.6	1.1	1.0	0.8	103	2.2	2.0	1.8	2.0	1.4	1.3	1.1	100
	DOWNSTREAM	1.8	1.6	1.5	1.7	1.1	1.0	0.8		2.2	2.0	1.8	2.0	1.5	1.3	1.1	
L-II-1	UPSTREAM	1.6	1.5	1.3	1.5	1.0	0.9	0.7	100	2.1	2.0	1.8	2.0	1.4	1.2	0.9	100
	DOWNSTREAM	1.6	1.5	1.3	1.5	1.0	0.9	0.7		2.1	2.0	1.8	1.9	1.4	1.2	1.0	
L-II-2	UPSTREAM	1.8	1.5	1.4	1.5	1.1	0.9	0.8	96	2.0	1.9	1.7	1.9	1.3	1.1	0.9	100
	DOWNSTREAM	1.7	1.6	1.4	1.5	1.0	0.9	0.8		2.0	1.9	1.7	1.9	1.3	1.1	1.0	

SECTION I.D.	24-I10-4	WINTER TESTING				DATE		01/30/13		SUMMER TESTING				DATE		07/16/13	
LOCATION						TIME								TIME			
CRACKS		W1	W2	W3	W4	W5	W6	W7	LTE	W1	W2	W3	W4	W5	W6	W7	LTE
S-I-1	UPSTREAM	1.4	1.1	1.0	1.2	0.7	0.6	0.5	98	1.4	1.2	1.0	1.2	0.7	0.6	0.5	104
	DOWNSTREAM	1.4	1.2	1.0	1.1	0.7	0.6	0.5		1.5	1.2	1.0	1.2	0.7	0.6	0.5	
S-I-2	UPSTREAM	1.3	1.1	0.9	1.1	0.7	0.6	0.6	100	1.4	1.2	1.0	1.1	0.7	0.6	0.5	100
	DOWNSTREAM	1.3	1.0	0.9	1.0	0.7	0.6	0.5		1.4	1.2	1.0	1.1	0.7	0.6	0.5	
M-I-1	UPSTREAM	1.4	1.2	1.0	1.2	0.8	0.6	0.5	99	1.4	1.3	1.1	1.2	0.8	0.7	0.6	104
	DOWNSTREAM	1.4	1.2	1.0	1.2	0.7	0.6	0.5		1.4	1.2	1.1	1.2	0.8	0.7	0.6	
M-I-2	UPSTREAM	1.3	1.1	1.0	1.1	0.7	0.6	0.5	99	1.4	1.3	1.0	1.1	0.8	0.7	0.5	105
	DOWNSTREAM	1.3	1.2	1.0	1.1	0.7	0.6	0.5		1.4	1.2	1.0	1.2	0.7	0.6	0.5	
L-I-1	UPSTREAM	1.1	1.0	0.8	1.0	0.6	0.5	0.4	101	1.3	1.1	0.9	1.0	0.7	0.6	0.5	103
	DOWNSTREAM	1.2	1.0	0.8	1.0	0.6	0.5	0.5		1.3	1.1	0.9	1.1	0.6	0.6	0.5	
L-I-2	UPSTREAM	1.2	1.0	0.9	1.0	0.7	0.6	0.5	98	1.3	1.1	0.9	1.0	0.7	0.6	0.5	107
	DOWNSTREAM	1.2	1.0	0.9	1.0	0.7	0.6	0.5		1.3	1.0	0.9	1.0	0.7	0.6	0.5	
S-II-1	UPSTREAM	1.8	1.6	1.4	1.5	0.9	0.8	0.7	101	1.7	1.6	1.3	1.6	0.9	0.9	0.7	100
	DOWNSTREAM	1.8	1.6	1.3	1.6	1.0	0.8	0.7		1.8	1.6	1.4	1.6	1.0	1.0	0.8	
S-II-2	UPSTREAM	1.7	1.5	1.3	1.5	1.0	0.8	0.7	99	1.8	1.6	1.4	1.5	1.0	0.9	0.7	98
	DOWNSTREAM	1.7	1.5	1.3	1.5	1.0	0.8	0.7		1.8	1.6	1.4	1.5	1.0	0.9	0.7	
M-II-1	UPSTREAM	1.6	1.4	1.2	1.4	0.9	0.8	0.7	99	1.6	1.4	1.2	1.4	0.9	0.8	0.7	100
	DOWNSTREAM	1.6	1.4	1.2	1.4	0.9	0.8	0.7		1.6	1.4	1.2	1.4	0.9	0.8	0.7	
M-II-2	UPSTREAM	3.0	2.7	2.4	2.6	1.9	1.6	1.3	101	4.5	4.3	3.9	3.7	3.3	2.8	2.5	106
	DOWNSTREAM	3.1	2.8	2.5	2.7	1.9	1.5	1.3		4.7	4.3	4.1	4.1	3.4	2.8	2.5	
L-II-1	UPSTREAM	2.0	1.7	1.5	1.7	1.0	0.9	0.7	101	1.8	1.6	1.4	1.6	1.0	0.9	0.7	94
	DOWNSTREAM	1.9	1.7	1.4	1.7	1.0	0.9	0.8		1.8	1.6	1.3	1.4	1.0	0.9	0.7	
L-II-2	UPSTREAM	1.9	1.7	1.5	1.7	1.1	1.0	0.8	100	1.9	1.6	1.5	1.6	1.2	1.0	0.9	97
	DOWNSTREAM	1.9	1.7	1.5	1.7	1.1	1.0	0.9		1.8	1.7	1.5	1.6	1.2	1.0	0.9	

SECTION I.D.	25-I40-1	WINTER TESTING				DATE		03/20/13		SUMMER TESTING				DATE			
LOCATION						TIME								TIME			
CRACKS		W1	W2	W3	W4	W5	W6	W7	LTE	W1	W2	W3	W4	W5	W6	W7	LTE
S-I-1	UPSTREAM	1.2	1.0	1.0	1.2	0.8	0.7	0.7	101								
	DOWNSTREAM	1.2	1.0	0.9	1.1	0.8	0.8	0.7									
S-I-2	UPSTREAM	1.5	1.3	1.2	1.4	1.0	1.0	0.9	100								
	DOWNSTREAM	1.6	1.3	1.2	1.4	1.0	0.9	0.9									
M-I-1	UPSTREAM	1.4	1.1	1.1	1.2	0.9	0.9	0.8	103								
	DOWNSTREAM	1.4	1.1	1.1	1.3	0.9	0.9	0.8									
M-I-2	UPSTREAM	1.5	1.2	1.2	1.4	0.9	1.0	0.9	99								
	DOWNSTREAM	1.4	1.2	1.3	1.4	1.0	1.0	1.0									
L-I-1	UPSTREAM	1.4	1.2	1.2	1.3	1.0	1.2	1.0	100								
	DOWNSTREAM	1.4	1.1	1.2	1.3	1.0	1.0	0.9									
L-I-2	UPSTREAM	1.3	1.1	1.1	1.3	0.9	0.9	0.9	101								
	DOWNSTREAM	1.4	1.1	1.1	1.3	0.9	0.9	0.9									
S-II-1	UPSTREAM	1.4	1.1	1.1	1.3	1.0	0.9	0.9	104								
	DOWNSTREAM	1.4	1.1	1.2	1.3	0.9	0.9	0.9									
S-II-2	UPSTREAM	1.4	1.2	1.2	1.3	0.9	0.9	0.8	102								
	DOWNSTREAM	1.4	1.2	1.2	1.3	1.0	1.0	0.9									
M-II-1	UPSTREAM	1.3	1.0	1.1	1.2	0.9	0.9	0.8	103								
	DOWNSTREAM	1.2	1.0	1.0	1.2	0.9	0.8	0.8									
M-II-2	UPSTREAM	1.3	1.1	1.1	1.2	0.9	0.9	0.9	99								
	DOWNSTREAM	1.4	1.1	1.1	1.2	0.9	0.9	0.8									
L-II-1	UPSTREAM	1.3	1.1	1.1	1.2	0.9	0.9	0.9	99								
	DOWNSTREAM	1.3	1.1	1.2	1.3	0.8	0.9	0.9									
L-II-2	UPSTREAM	1.4	1.1	1.1	1.2	0.9	0.8	0.8	100								
	DOWNSTREAM	1.4	1.1	1.1	1.2	0.9	0.9	0.8									

SECTION I.D.	25-I40-2	WINTER TESTING				DATE		03/20/13		SUMMER TESTING				DATE			
LOCATION						TIME								TIME			
CRACKS		W1	W2	W3	W4	W5	W6	W7	LTE	W1	W2	W3	W4	W5	W6	W7	LTE
S-I-1	UPSTREAM	1.5	1.2	1.2	1.3	0.9	0.9	0.8	98								
	DOWNSTREAM	1.5	1.2	1.2	1.3	1.0	0.9	0.8									
S-I-2	UPSTREAM	1.7	1.3	1.3	1.5	1.0	1.0	0.9	97								
	DOWNSTREAM	1.7	1.4	1.3	1.4	1.0	0.9	0.8									
M-I-1	UPSTREAM	1.4	1.1	1.1	1.3	0.9	0.9	0.8	101								
	DOWNSTREAM	1.4	1.1	1.2	1.3	1.0	0.9	0.8									
M-I-2	UPSTREAM	1.5	1.2	1.2	1.3	1.0	0.9	0.9	100								
	DOWNSTREAM	1.4	1.2	1.2	1.3	0.9	0.9	0.9									
L-I-1	UPSTREAM	1.6	1.2	1.2	1.3	1.0	0.9	0.9	104								
	DOWNSTREAM	1.5	1.2	1.2	1.4	0.9	0.9	0.9									
L-I-2	UPSTREAM	1.4	1.2	1.2	1.3	0.8	0.9	0.8	100								
	DOWNSTREAM	1.4	1.1	1.1	1.2	1.0	0.8	0.8									
S-II-1	UPSTREAM	1.5	1.2	1.2	1.4	0.9	0.8	0.8	96								
	DOWNSTREAM	1.5	1.2	1.2	1.3	0.9	0.9	0.8									
S-II-2	UPSTREAM	1.9	1.6	1.5	1.8	1.0	0.9	0.8	101								
	DOWNSTREAM	1.9	1.6	1.5	1.8	1.1	0.9	1.0									
M-II-1	UPSTREAM	1.7	1.3	1.3	1.4	0.9	0.9	0.8	104								
	DOWNSTREAM	1.7	1.3	1.3	1.5	0.9	0.9	0.8									
M-II-2	UPSTREAM	1.8	1.4	1.3	1.6	0.9	0.9	0.8	100								
	DOWNSTREAM	1.8	1.4	1.2	1.6	1.0	0.8	0.7									
L-II-1	UPSTREAM	1.7	1.4	1.4	1.6	1.0	1.0	0.9	102								
	DOWNSTREAM	1.7	1.4	1.4	1.6	1.0	1.0	0.9									
L-II-2	UPSTREAM	1.6	1.2	1.2	1.3	0.9	0.8	0.7	103								
	DOWNSTREAM	1.6	1.2	1.2	1.4	0.9	0.8	0.7									

A.3 LTE Evaluations

- LTE Evaluations in FY2010

Crack ID	3-US81-1		Crack ID	12-US290-1	
	Winter	Summer		Winter	Summer
S-1			J-1	109	105
S-2			C-1	106	105
S-3			J-2	109	105
S-4			C-2	107	105
M-1			J-3	108	106
M-2			C-3	107	107
M-3			J-4	108	105
M-4			C-4	106	105
L-1			J-5	109	103
L-2			C-5	106	103
L-3					
L-4					

Crack ID	3-I35-1		3-US287-1		3-US287-2		4-I40-1		5-I27-1	
	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
S-I-1			107					103	100	100
S-I-2			106					101	101	100
M-I-1			109					108	100	100
M-I-2			107					101	100	100
L-I-1			93					102		
L-I-2			107					102		
S-II-1			103					102	100	100
S-II-2			103					101	100	98
M-II-1			108					102	103	101
M-II-2			107					108	103	101
L-II-1			106					101		
L-II-2			105					102		

Crack ID	5-LP289-1		9-I35-1		9-I35-2		12-US290-2		12-US290-3	
	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
S-I-1	100	100					106	105	106	109
S-I-2	102	100					106	104	106	107
M-I-1	100	100					107	105	107	107
M-I-2	101	101					110	108	110	108
L-I-1	100	100					106		106	108
L-I-2	102	101					107		107	107
S-II-1	100	100						105		107
S-II-2	101	100						106		107
M-II-1	99	101					105	106	105	109
M-II-2	100	100						105		108
L-II-1	99	100					106	107	106	107
L-II-2	101	100						106		106

Crack ID	19-US59-1		19-US59-2		20-I10-1		24-I10-1		24-I10-2	
	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
S-I-1	99	103	101				99	100		
S-I-2	100	101	96				100	100		
M-I-1	102	104	101	101			100	105	105	101
M-I-2	102	106	100	101			99	100	106	102
L-I-1	102	105	97	104			99	99	107	98
L-I-2	102	106	106	101			99	100	107	102
S-II-1	149		99	99			101	97		
S-II-2	102	100	97	102			98	100		
M-II-1	101	103	100	101			99	99	104	102
M-II-2	102	102	99	100			98	98	102	101
L-II-1	104	99	100	100			100	100	94	99
L-II-2	103		100	95			100	99	103	97

Crack ID	24-I10-3		24-I10-4		25-I40-1		25-I40-2	
	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
S-I-1	100	100	101	101	102	101	102	101
S-I-2	99	101	100	100	105	100	102	100
M-I-1	100	100	99	100	102	102	102	100
M-I-2	98	101	102	97	103	101	101	100
L-I-1	100	101	101	101	103	100	100	101
L-I-2	102	101	101	100	102	100	102	101
S-II-1			101	101	105	101	99	101
S-II-2			100	99	108	101	101	102
M-II-1	101	100	101	100	106	100	101	101
M-II-2	103	100	100	101	108	101	102	102
L-II-1	101	101	102	100	105	101	100	100
L-II-2	100	100	100	100	105	100	101	101

- **LTE Evaluations in FY2011**

Crack ID	3-US81-1		Crack ID	12-US290-1	
	Winter	Summer		Winter	Summer
S-1	97	100	J-1	109	
S-2	106	103	C-1	107	
S-3	105	103	J-2	108	
S-4	103	103	C-2	107	
M-1	107	102	J-3	109	
M-2	102	101	C-3	109	
M-3	96	100	J-4	108	
M-4	103	102	C-4	106	
L-1	108	101	J-5	107	
L-2	108	101	C-5	106	
L-3	102	101			
L-4	104	103			

Crack ID	3-I35-1		3-US287-1		3-US287-2		4-I40-1		5-I27-1	
	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
S-I-1	100	101	103	102					101	100
S-I-2	101	101	104	101					102	101
M-I-1	102	102	105	102	101	101			101	99
M-I-2	99	100	105	101	103	102			100	99
L-I-1	101	100	105	101	101	102				
L-I-2	101	100	105	101	102	102				
S-II-1	101	100	103	103	100	101			100	100
S-II-2	101	100	102	101	99	101			99	100
M-II-1	99	100	107	101	100	102			105	100
M-II-2	103	102	104	101	101	102			103	101
L-II-1	100	100	103	100	103	103				
L-II-2	103	101	103	102	100	101				

Crack ID	5-LP289-1		9-I35-1		9-I35-2		12-US290-2		12-US290-3	
	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
S-I-1	100	100					106		111	
S-I-2	103	100					105		107	
M-I-1	102	100					106		108	
M-I-2	103	101					106		107	
L-I-1	101	102							107	
L-I-2	102	102							106	
S-II-1	102	100					107		106	
S-II-2	99	100					106		110	
M-II-1	102	101					107		109	
M-II-2	101	103					104		108	
L-II-1	101	100					106		107	
L-II-2	101	100					107		107	

Crack ID	19-US59-1		19-US59-2		20-I10-1		24-I10-1		24-I10-2	
	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
S-I-1	104	100	101	99			100	99		
S-I-2	94	99	100	101			101	99		
M-I-1	105	102	102	102			100	100	107	98
M-I-2	97	102	102	101			99	100	107	100
L-I-1	103	104	104	107			99	95	105	100
L-I-2	106	104	103	100			99	99	102	101
S-II-1	102	102	100	100			101	100		
S-II-2		99	100	98			97	100		
M-II-1	103	103	101	101			100	100	102	101
M-II-2	102	101	99	100			99	101	102	103
L-II-1	106	102	100	101			99	100	107	100
L-II-2	99	104	101	101			99	100	103	100

Crack ID	24-I10-3		24-I10-4		25-I40-1		25-I40-2	
	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
S-I-1	101	100	101	102	100		101	
S-I-2	101	100	100	100	100		104	
M-I-1	100	100	102	102	100		101	
M-I-2	101	100	100	98	101		102	
L-I-1	101	100	102	101	101		101	
L-I-2	102	101	99	100	100		102	
S-II-1			100	99	100		104	
S-II-2			98	99	100		106	
M-II-1	101	100	101	100	100		104	
M-II-2	101	100	102	103	101		104	
L-II-1	100	101	100	100	100		103	
L-II-2	101	100	100	99	101		103	

- **LTE Evaluations in FY2012**

Crack ID	3-US81-1	
	Winter	Summer
S-1	94	99
S-2	110	103
S-3	106	104
S-4	105	103
M-1	110	104
M-2	104	101
M-3	108	100
M-4	102	102
L-1	109	101
L-2	109	102
L-3	101	101
L-4	110	102

Crack ID	12-US290-1	
	Winter	Summer
J-1		
C-1		
J-2		
C-2		
J-3		
C-3		
J-4		
C-4		
J-5		
C-5		

Crack ID	3-I35-1		3-US287-1		3-US287-2		4-I40-1		5-I27-1	
	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
S-I-1		101	104	103				102		93
S-I-2		102	104	102				102		107
M-I-1		102	106	103	100	101		106		110
M-I-2		99	106	101	103	101		102		114
L-I-1		102	106	102	101	102		102		
L-I-2		101	106	100	100	100		102		
S-II-1		100	104	102	100	100		102		114
S-II-2		100	103	100	100	100		100		127
M-II-1		100	109	99	100	101		103		94
M-II-2		100	106	103	100	99		106		123
L-II-1		100	105	101	100	101		99		
L-II-2		104	106	102	100	100		101		

Crack ID	5-LP289-1		9-I35-1		9-I35-2		12-US290-2		12-US290-3	
	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
S-I-1		116				100		104		106
S-I-2		94				100		103		105
M-I-1		93						104		105
M-I-2		115				101		104		104
L-I-1		83				100				106
L-I-2		199								105
S-II-1		94						104		105
S-II-2		110						104		107
M-II-1		102						104		106
M-II-2		90						104		105
L-II-1		118						105		106
L-II-2		108						105		103

Crack ID	19-US59-1		19-US59-2		20-I10-1		24-I10-1		24-I10-2	
	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
S-I-1	101	100	100	101			99	93		
S-I-2	97	100	100	99			100	130		
M-I-1	103	102	100	103			101	84	105	82
M-I-2	103	105	101	101			99	108	105	78
L-I-1	104	106	102	101			100	257	104	94
L-I-2	101	103	100	100			100	113	104	35
S-II-1	100	103	100	100			100	104		
S-II-2	100		100	101			99	98		
M-II-1	103	104	101	100			96	94	102	108
M-II-2	100	103	100	99			99	108	103	64
L-II-1	101	99	101	99			99	86	104	87
L-II-2	104	104	100	100			99	139	102	123

Crack ID	24-I10-3		24-I10-4		25-I40-1		25-I40-2	
	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
S-I-1	100	93	101	126		104		102
S-I-2	99	91	99	103		105		101
M-I-1	100	120	100	102		101		96
M-I-2	101	103	100	285		100		101
L-I-1	101	103	101	92		100		101
L-I-2	102	109	99	127		100		104
S-II-1			100	94		102		97
S-II-2			100	80		101		102
M-II-1	100	103	100	99		101		103
M-II-2	101	99	100	94		103		102
L-II-1	100	98	99	56		101		99
L-II-2	101	95	99	96		105		102

- LTE Evaluations in FY2013

Crack ID	3-US81-1		Crack ID	12-US290-1	
	Winter	Summer		Winter	Summer
S-1	99		J-1		
S-2	107		C-1		
S-3	103		J-2		
S-4	105		C-2		
M-1	106		J-3		
M-2	103		C-3		
M-3	105		J-4		
M-4	102		C-4		
L-1	107		J-5		
L-2	108		C-5		
L-3	103				
L-4	108				

Crack ID	3-I35-1		3-US287-1		3-US287-2		4-I40-1		5-I27-1	
	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
S-I-1	102		91				109		101	102
S-I-2	102		89				110		101	100
M-I-1	105		90		100		100		102	100
M-I-2	103		90		104		106		100	100
L-I-1	100		87		99		105			
L-I-2	102		90		104		106			
S-II-1	93		89		100		106		100	101
S-II-2	87		88		100		112		99	99
M-II-1	90		89		101		110		103	100
M-II-2	92		92		102		110		103	101
L-II-1	94		91		97		82			
L-II-2	94		89		99		88			

Crack ID	5-LP289-1		9-I35-1		9-I35-2		12-US290-2		12-US290-3	
	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
S-I-1	101	100					105		112	
S-I-2	103	100			96		108		106	
M-I-1	101	100			107		107		107	
M-I-2	104	100			92		104		104	
L-I-1	101	102			100				109	
L-I-2	102	101			100				107	
S-II-1	102	100			100		105		105	
S-II-2	101	101			102		106		109	
M-II-1	100	101			103		106		107	
M-II-2	101	101			95		105		109	
L-II-1	100	101			101		106		105	
L-II-2	100	100			95		108		107	

Crack ID	19-US59-1		19-US59-2		20-I10-1		24-I10-1		24-I10-2	
	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
S-I-1	101		102				100	100		
S-I-2	106		93				99	100		
M-I-1	99		102				98	103	104	101
M-I-2	107		81				100	99	106	100
L-I-1	101		93				99	104	105	100
L-I-2	105		101				99	100	105	102
S-II-1	100		100				100	100		
S-II-2	100		103				100	99		
M-II-1	100		101				101	97	104	103
M-II-2	98		105				98	101	103	100
L-II-1	98		108				100	98	106	100
L-II-2	97		104				99	103	102	100

Crack ID	24-I10-3		24-I10-4		25-I40-1		25-I40-2	
	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
S-I-1	101	100	98	104	101		98	
S-I-2	100	98	100	100	100		97	
M-I-1	100	99	99	104	103		101	
M-I-2	99	101	99	105	99		100	
L-I-1	101	99	101	103	100		104	
L-I-2	100	101	98	107	101		100	
S-II-1			101	100	104		96	
S-II-2			99	98	102		101	
M-II-1	101	99	99	100	103		104	
M-II-2	103	100	101	106	99		100	
L-II-1	100	100	101	94	99		102	
L-II-2	96	100	100	97	100		103	

Appendix B. Data Analysis for Transfer Function Development

Table B.1 Project Summary for Transfer Function Development

Project Information for Transfer Function [Improved]								Distresses per lanemile [Recorded in 2010 PMIS]				
NO	Dist.	County	Construction Year	Highway/ Reference Marker	Slab Thickness [in]	Project Length [lanemile]	ΣESALs [million]	PCH	ACP	PCP	Total	Damage
1	WFS	243	1972	US0287 [RM 322.0-329.0]	8	4.40	21.71	0.5	0.0	5.2	5.7	5.70
2	AMA	33	1979	IH0040 L [RM 110.0-114.5]	9	4.50	35.72	0.4	0.0	16.9	17.3	9.72
3	AMA	91	1979	IH0040 R [RM 110.0-115.5]	9	5.70	34.89	0.5	0.0	8.1	8.6	9.38
4	HOU	85	1986	FM1764 [RM 704.0-708.0]	11	5.50	5.37	0.4	0.0	0.0	0.4	0.93
5	HOU	85	1973	IH0045 L [RM 15.0-18.0]	10	3.00	23.96	0.7	0.0	1.3	2.0	5.02
6	HOU	85	2001	IH0045 L [RM 18.5-21.0]	12	2.50	7.31	1.2	0.8	9.2	11.2	1.04
7	HOU	85	1999	IH0045 L [RM 21.0-23.5]	14	2.50	9.31	1.6	0.0	4.4	6.0	1.13
8	HOU	85	1980	IH0045 R [RM 11.0-12.5]	10	1.50	16.50	6.7	0.0	5.3	12.0	3.46
9	HOU	85	1973	IH0045 R [RM 13.0-15.0]	10	2.00	18.48	1.0	0.0	4.0	5.0	3.87
10	HOU	85	1973	IH0045 R [RM 15.5-18.0]	10	2.50	23.96	0.0	0.0	0.8	0.8	5.02
11	HOU	85	2001	IH0045 R [RM 18.5-21.0]	12	2.50	7.31	3.6	0.0	8.4	12.0	1.04
12	HOU	85	1999	IH0045 R [RM 21.0-23.5]	14	2.50	9.31	9.2	0.0	2.8	12.0	1.13
13	YKM	76	1991	SH0071 [RM 636.0-640.0]	10	8.60	3.73	0.6	0.0	0.0	0.6	0.79
14	DAL	57	1975	IH0045 [RM 279.5-281.5]	8	4.00	70.02	0.5	0.0	12.0	12.5	17.97
15	DAL	57	1963	SL0012 [RM 629.0-632.0]	6	5.00	12.96	3.0	0.8	6.2	10.0	4.98
16	DAL	57	2008	SL0354 [RM 256.0-258.0]	10	4.00	1.05	0.0	0.0	0.0	0.0	0.24

(Continued)

Project Information for Transfer Function [Improved]								Distresses per lanemile [Recorded in 2010 PMIS]				
NO	Dist.	County	Construction Year	Highway/ Reference Marker	Slab Thickness [in]	Project Length [lanemile]	ΣESALs [million]	PCH	ACP	PCP	Total	Damage
17	DAL	43	1968	US0075 L [RM 249.0-252.0]	8	3.50	53.59	0.0	0.0	0.3	0.3	13.74
18	DAL	43	1968	US0075 R [RM 249.0-252.0]	8	3.00	54.90	0.0	0.0	1.3	1.3	14.08
19	DAL	19	2001	US0059 L [RM 221.6-224.0]	12	2.40	7.81	0.0	0.0	0.4	0.4	1.14
20	DAL	183	2002	US0059 L [RM 313.0-315.0]	12	2.00	5.58	0.0	0.5	1.5	2.0	0.81
21	DAL	19	2001	US0059 R [RM 221.6-224.0]	12	2.40	7.81	0.8	0.0	0.4	1.3	1.14
22	DAL	183	2002	US0059 R [RM 313.0-315.0]	12	2.00	5.58	0.0	0.0	3.0	3.0	0.81
23	BMT	181	2003	IH0010 [RM 855.2-860.8]	15	10.60	19.82	0.0	0.0	0.0	0.0	2.36
24	LBB	152	1991	IH0027 [RM 0.0-1.5]	10	1.50	14.01	0.0	0.0	4.0	4.0	3.15
25	LBB	152	1992	IH0027 L[RM 1.5-4.0]	10	2.50	14.49	2.4	0.0	9.6	12.0	3.26
26	LBB	96	1986	IH0027 L [RM 44.0-49.0]	10	5.00	9.78	0.2	0.0	1.4	1.6	2.20
27	LBB	152	1991	IH0027 R [RM 0.0-1.5]	10	1.50	14.01	0.0	0.0	0.0	0.0	3.15
28	LBB	152	1992	IH0027 R [RM 1.5-4.0]	10	2.50	14.49	2.0	0.0	4.8	6.8	3.26
29	LBB	152	1991	IH0027 R [RM 4.0-5.0]	10	1.00	12.50	2.0	1.0	4.8	7.8	2.81
30	LBB	152	1992	IH0027 R [RM 5.0-6.0]	10	1.00	9.56	2.0	0.0	0.0	2.0	2.15
31	LBB	96	1986	IH0027 R [RM 44.0-49.0]	10	5.00	9.78	0.0	0.0	2.0	2.0	2.20
32	ELP	72	2003	IH0010 L [RM 30.0-35.0]	13	2.50	18.61	0.0	0.0	0.0	0.0	2.55
33	ELP	72	2003	IH0010 R [RM 30.0-35.0]	13	2.50	18.61	0.4	0.0	0.4	0.8	2.55

(Continued)

Project Information for Transfer Function [Improved]								Distresses per lanemile [Recorded in 2010 PMIS]				
NO	Dist.	County	Construction Year	Highway/ Reference Marker	Slab Thickness [in]	Project Length [lanemile]	ΣESALs [million]	PCH	ACP	PCP	Total	Damage
34	HOU	102	1980	US0290 L [RM 732.0-734.5.5]	10	3.50	54.24	3.7	0.0	3.1	6.9	11.37
35	HOU	102	1986	US0290 R [RM 729.5-730.5]	13	1.00	47.43	2.0	0.0	0.0	2.0	6.19
36	HOU	102	1980	US0290 R [RM 732.0-734.5.5]	10	3.50	54.24	3.4	0.0	4.0	7.4	11.37
37	FTW	182	2005	IH0020 L [RM 376.5-381.5]	12	5.00	8.04	0.0	0.0	0.0	0.0	1.19
38	FTW	182	2005	IH0020 L [RM 381.5-386.5]	12	5.00	7.99	0.0	0.0	0.0	0.0	1.19
39	FTW	182	2005	IH0020 R [RM 377.0-381.5]	12	4.50	7.41	0.0	0.0	0.0	0.0	1.10
40	FTW	182	2005	IH0020 R [RM 381.5-386.5]	12	5.00	7.99	0.0	0.0	0.0	0.0	1.19

PCH; Punchout, ACP; Asphalt Concrete Patch, PCP; Portland cement Concrete Patch

Table B.2 Traffic Analysis for each Project

NO	Dist.	Construction Year	Highway / Reference Marker	Yearly ESALs																		Equation for Annual ESALs	R^2	Extrapolated ΣESALs	ΣESALs (1993-2010)	ΣESALs
				1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010					
1	WFS	1972	US0287 [RM 322.0-329.0]	0.63	0.63	0.63	0.61	0.61	0.65	0.65	0.68	0.62	0.80	0.80	0.89	1.00	1.09	1.14	1.03	1.23	0.93	8E-41e0.04603x	84%	7.10	14.61	21.71
2	AMA	1979	IH0040 L [RM 110.0-114.5]	0.94	0.94	0.94	1.24	1.24	1.36	1.32	1.41	1.27	1.55	1.55	1.55	1.42	1.68	1.63	1.71	1.69	1.37	2E-32e0.0367x	84%	10.89	24.83	35.72
3	AMA	1979	IH0040 R [RM 110.0-115.5]	0.95	0.95	0.95	1.24	1.24	1.36	1.33	1.42	1.26	1.54	1.54	1.55	1.46	1.66	1.61	1.71	1.68	1.36	4E-32e0.0363x	84%	10.08	24.81	34.89
4	HOU	1986	FM1764 [RM 704.0-708.0]	0.21	0.21	0.21	0.21	0.21	0.21	0.20	0.20	0.26	0.22	0.22	0.22	0.22	0.23	0.24	0.27	0.23	0.24	3E-10e0.0103*x	42%	1.35	4.02	5.37
5	HOU	1973	IH0045 L [RM 15.0-18.0]	0.75	0.75	0.75	0.80	0.80	0.74	0.63	0.71	0.74	0.83	0.83	0.83	0.78	0.86	0.58	0.56	0.71	0.68	3% Growth Rate		10.67	13.28	23.96
6	HOU	2001	IH0045 L [RM 18.5-21.0]										0.90	0.90	0.92	0.85	0.92	0.63	0.63	0.79	0.75	Bulit in 2001		0.00	7.31	7.31
7	HOU	1999	IH0045 L [RM 21.0-23.5]								0.85	0.83	0.94	0.94	0.96	0.89	0.95	0.66	0.67	0.83	0.79	Built in 1999		0.00	9.31	9.31
8	HOU	1980	IH0045 R [RM 11.0-12.5]	0.58	0.58	0.58	0.64	0.64	0.59	0.50	0.60	0.56	0.69	0.69	0.68	0.63	0.70	0.46	0.44	0.57	0.56	3% Growth Rate		5.78	10.71	16.50
9	HOU	1973	IH0045 R [RM 13.0-15.0]	0.56	0.56	0.56	0.63	0.63	0.57	0.49	0.58	0.54	0.66	0.66	0.67	0.61	0.68	0.45	0.43	0.57	0.54	3% Growth Rate		8.07	10.41	18.48
10	HOU	1973	IH0045 R [RM 15.5-18.0]	0.75	0.75	0.75	0.80	0.80	0.74	0.63	0.71	0.74	0.83	0.83	0.83	0.78	0.86	0.58	0.56	0.71	0.68	3% Growth Rate		10.67	13.28	23.96
11	HOU	2001	IH0045 R [RM 18.5-21.0]										0.90	0.90	0.92	0.85	0.92	0.63	0.63	0.79	0.75	Bulit in 2001		0.00	7.31	7.31
12	HOU	1999	IH0045 R [RM 21.0-23.5]								0.85	0.83	0.94	0.94	0.96	0.89	0.95	0.66	0.67	0.83	0.79	Built in 1999		0.00	9.31	9.31
13	YKM	1991	SH0071 [RM 636.0-640.0]	0.16	0.16	0.16	0.20	0.20	0.21	0.20	0.21	0.18	0.20	0.20	0.21	0.21	0.21	0.21	0.20	0.21	0.22	3% Growth Rate		0.16	3.56	3.73
14	DAL	1975	IH0045 [RM 279.5-281.5]	1.78	1.78	1.78	2.14	2.14	2.23	2.48	2.36	2.49	3.07	3.07	3.52	2.96	3.34	3.47	3.18	3.33	3.63	7E-39e0.0444x	90%	21.24	48.78	70.02
15	DAL	1963	SL0012 [RM 629.0-632.0]	0.36	0.36	0.36	0.35	0.35	0.36	0.34	0.33	0.37	0.35	0.35	0.36	0.35	0.34	0.35	0.35	0.34	0.19	3% Growth Rate		6.83	6.13	12.96
16	DAL	2008	SL0354 [RM 256.0-258.0]																	0.75	0.63	Built in 2008		0.00	1.05	1.05
17	DAL	1968	US0075 L [RM 249.0-252.0]	1.26	1.26	1.26	1.35	1.35	1.54	1.55	2.05	2.12	2.70	2.70	2.58	2.83	2.73	2.53	2.28	2.33	3.08	4E-48e0.0549x	80%	16.10	37.49	53.59
18	DAL	1968	US0075 R [RM 249.0-252.0]	1.28	1.28	1.28	1.37	1.37	1.44	1.60	1.96	2.02	2.60	2.60	2.45	2.73	2.64	2.48	2.24	2.28	3.10	3E-46e0.0528x	82%	18.18	36.72	54.90
19	DAL	2001	US0059 L [RM 221.6-224.0]										0.91	0.91	0.83	0.86	0.88	0.88	0.84	0.84	0.87	Built in 2001		0.00	7.81	7.81
20	DAL	2002	US0059 L [RM 313.0-315.0]											0.69	0.63	0.69	0.67	0.66	0.72	0.74	0.78	Built in 2002		0.00	5.58	5.58
21	DAL	2001	US0059 R [RM 221.6-224.0]										0.91	0.91	0.83	0.86	0.88	0.88	0.84	0.84	0.87	Built in 2001		0.00	7.81	7.81
22	DAL	2002	US0059 R [RM 313.0-315.0]											0.69	0.63	0.69	0.67	0.66	0.72	0.74	0.78	Built in 2002		0.00	5.58	5.58
23	BMT	2003	IH0010 [RM 855.2-860.8]												2.82	3.04	2.85	2.70	2.84	2.81	2.75	Built in 2003		0.00	19.82	19.82
24	LBB	1991	IH0027 [RM 0.0-1.5]	0.53	0.53	0.53	0.65	0.43	0.78	0.76	0.76	0.79	0.78	0.78	0.82	0.81	0.86	0.88	0.86	0.75	1.01	3% Growth Rate		0.52	13.49	14.01
25	LBB	1992	IH0027 L[RM 1.5-4.0]	0.44	0.44	0.44	0.44	0.44	1.23	0.81	0.83	0.89	0.86	0.86	0.84	0.88	0.88	0.90	0.91	0.94	1.06	3% Growth Rate		0.43	14.06	14.49
26	LBB	1986	IH0027 L [RM 44.0-49.0]	0.32	0.32	0.32	0.36	0.36	0.35	0.36	0.45	0.48	0.50	0.50	0.51	0.50	0.54	0.62	0.58	0.56	0.49	4E-34e0.038x	85%	1.65	8.13	9.78
27	LBB	1991	IH0027 R [RM 0.0-1.5]	0.53	0.53	0.53	0.65	0.43	0.78	0.76	0.76	0.79	0.78	0.78	0.82	0.81	0.86	0.88	0.86	0.75	1.01	3% Growth Rate		0.52	13.49	14.01
28	LBB	1992	IH0027 R [RM 1.5-4.0]	0.44	0.44	0.44	0.44	0.44	1.23	0.81	0.83	0.89	0.86	0.86	0.84	0.88	0.88	0.90	0.91	0.94	1.06	3% Growth Rate		0.43	14.06	14.49
29	LBB	1991	IH0027 R [RM 4.0-5.0]	0.44	0.44	0.44	0.44	0.45	0.88	0.65	0.69	0.72	0.70	0.70	0.73	0.76	0.77	0.77	0.79	0.81	0.91	3% Growth Rate		0.43	12.08	12.50
30	LBB	1992	IH0027 R [RM 5.0-6.0]	0.44	0.44	0.44	0.44	0.47	0.51	0.49	0.55	0.55	0.54	0.54	0.54	0.57	0.58	0.59	0.58	0.59	0.72	3% Growth Rate		0.00	9.56	9.56
31	LBB	1986	IH0027 R [RM 44.0-49.0]	0.32	0.32	0.32	0.36	0.36	0.35	0.36	0.45	0.48	0.50	0.50	0.51	0.50	0.54	0.62	0.58	0.56	0.49	4E-34e0.038x	85%	1.65	8.13	9.78
32	ELP	2003	IH0010 L [RM 30.0-35.0]												2.59	2.41	2.55	2.67	3.06	2.38	2.95	Built in 2003		0.00	18.61	18.61
33	ELP	2003	IH0010 R [RM 30.0-35.0]												2.59	2.41	2.55	2.67	3.06	2.38	2.95	Built in 2003		0.00	18.61	18.61
34	HOU	1980	US0290 L [RM 732.0-734.5.5]	1.46	1.46	1.46	1.70	1.70	1.79	1.98	2.50	2.45	2.72	2.72	3.13	2.83	2.93	2.79	2.79	2.81	3.05	1E-42e0.0487x	85%	11.98	42.26	54.24
35	HOU	1986	US0290 R [RM 729.5-730.5]	1.24	1.24	1.24	1.49	1.49	1.50	2.16	2.20	2.17	2.41	2.41	2.82	2.54	2.62	2.48	2.55	2.57	2.84	1E-45e0.052x	84%	9.48	37.95	47.43
36	HOU	1980	US0290 R [RM 732.0-734.5.5]	1.46	1.46	1.46	1.70	1.70	1.79	1.98	2.50	2.45	2.72	2.72	3.13	2.83	2.93	2.79	2.79	2.81	3.05	1E-42e0.0487x	85%	11.98	42.26	54.24
37	FTW	2005	IH0020 L [RM 376.5-381.5]														1.74	1.71	1.72	1.60	1.29	Built in 2005		0.00	8.04	8.04
38	FTW	2005	IH0020 L [RM 381.5-386.5]														1.74	1.69	1.69	1.57	1.30	Built in 2005		0.00	7.99	7.99
39	FTW	2005	IH0020 R [RM 377.0-381.5]														1.74	1.53	1.54	1.44	1.16	Built in 2005		0.00	7.41	7.41
40	FTW	2005	IH0020 R [RM 381.5-386.5]														1.74	1.69	1.69	1.57	1.30	Built in 2005		0.00	7.99	7.99

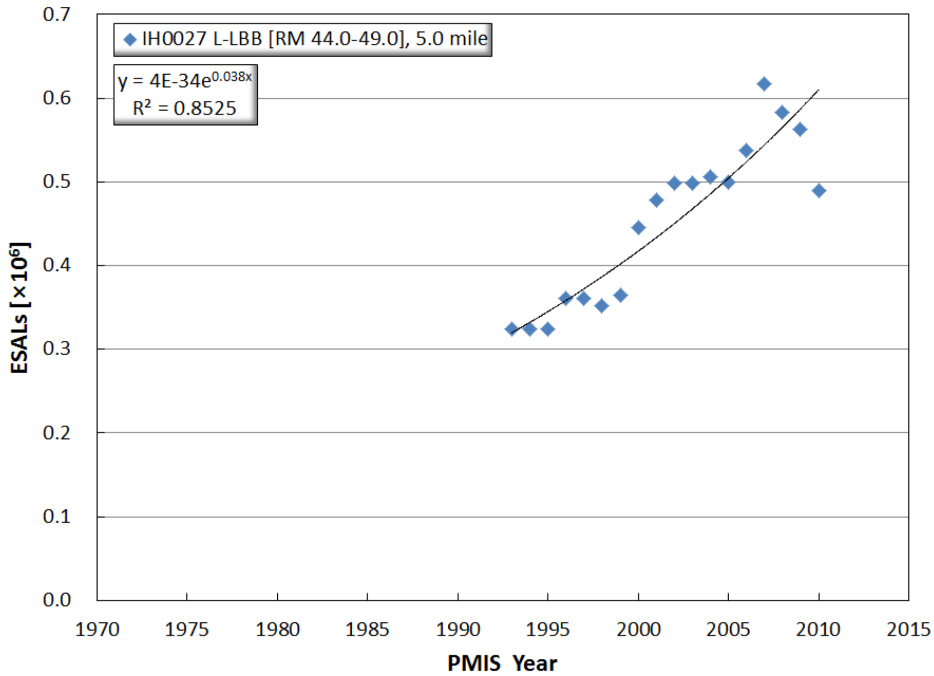


Figure B.1 Example #1 of Annual ESALs and Trend (IH 27-LBB)

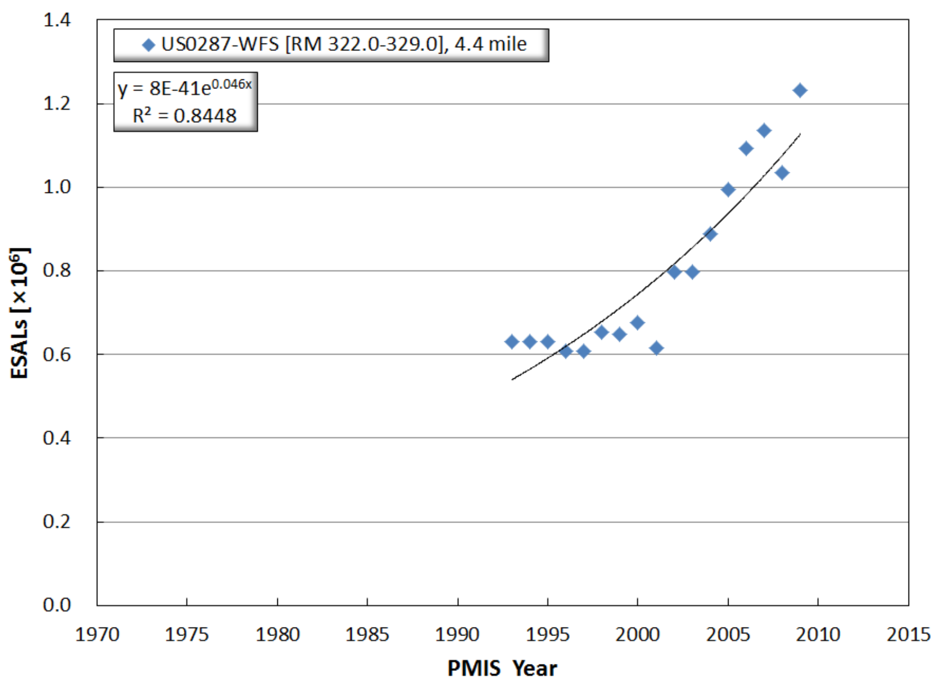


Figure B.2 Example #2 of Annual ESALs and Trend (US 287-WFS)

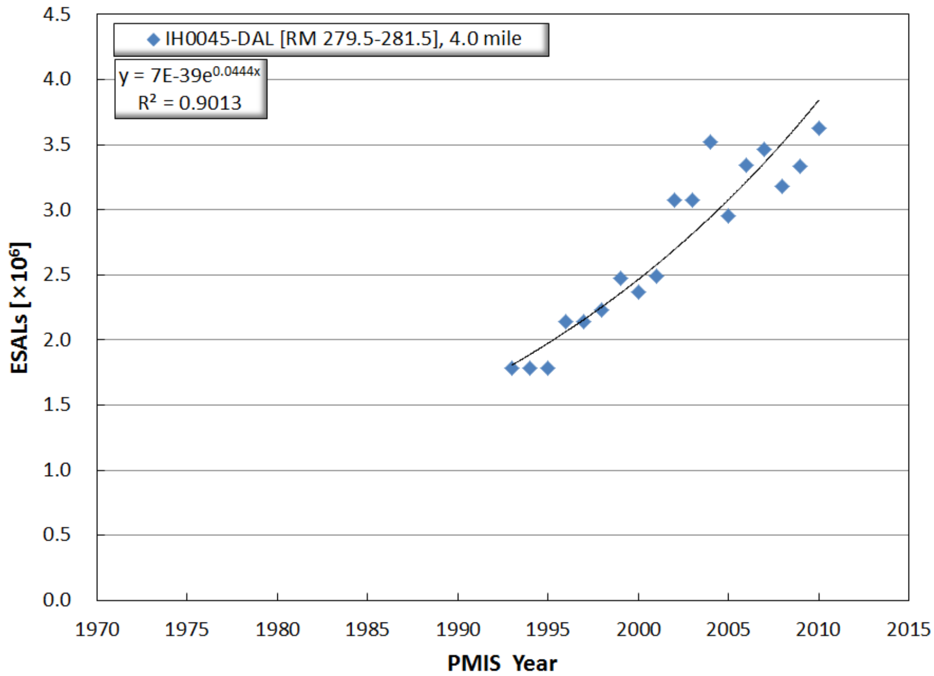


Figure B.3 Example #3 of Annual ESALs and Trend (IH 45-DAL)

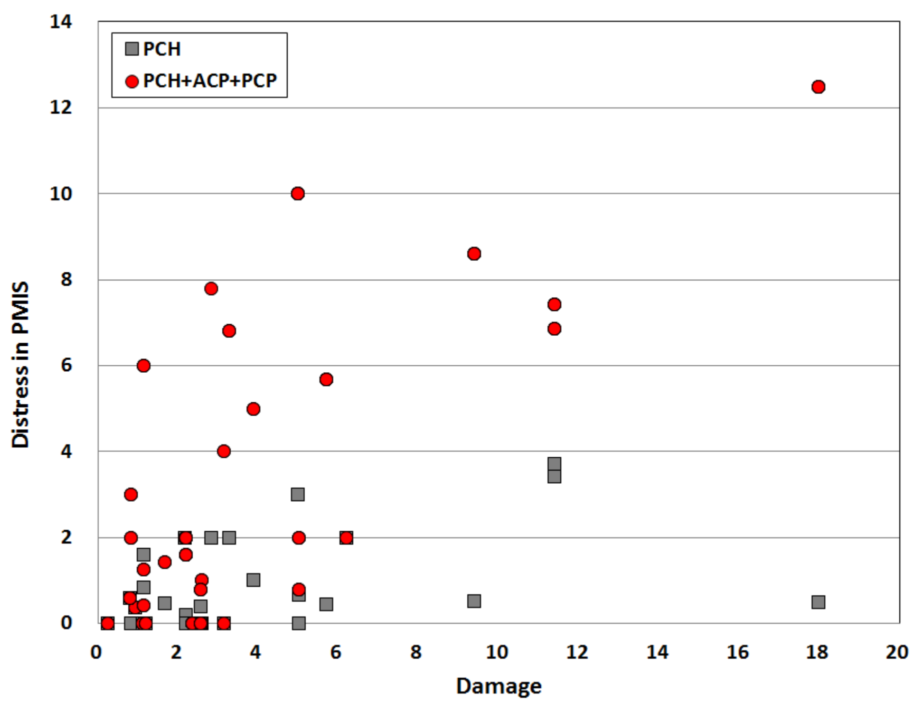


Figure B.4 Damage Comparison between PCH and Total Distresses for each Project

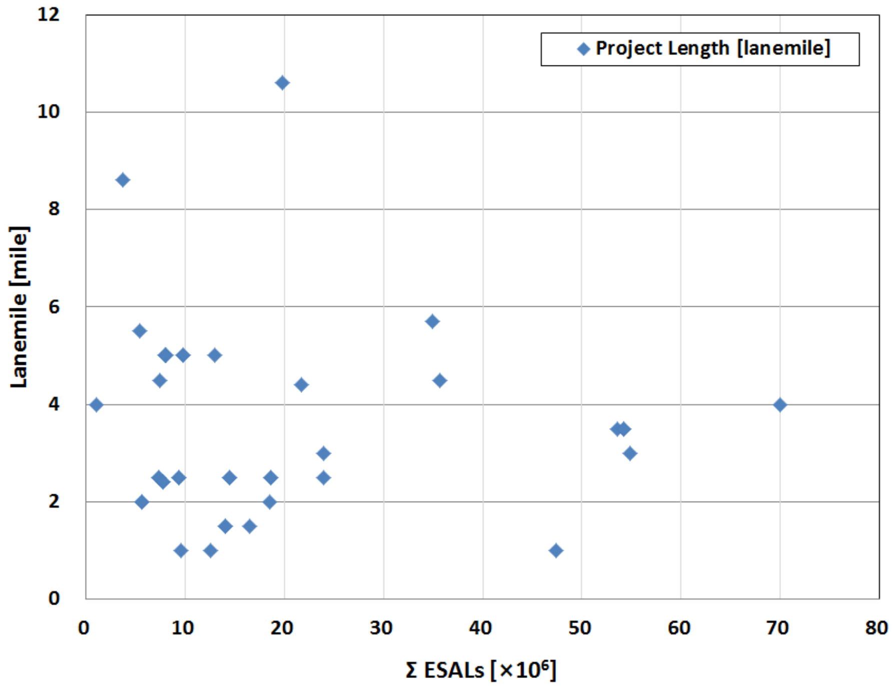


Figure B.5 Lanemile Distribution vs. ESALs

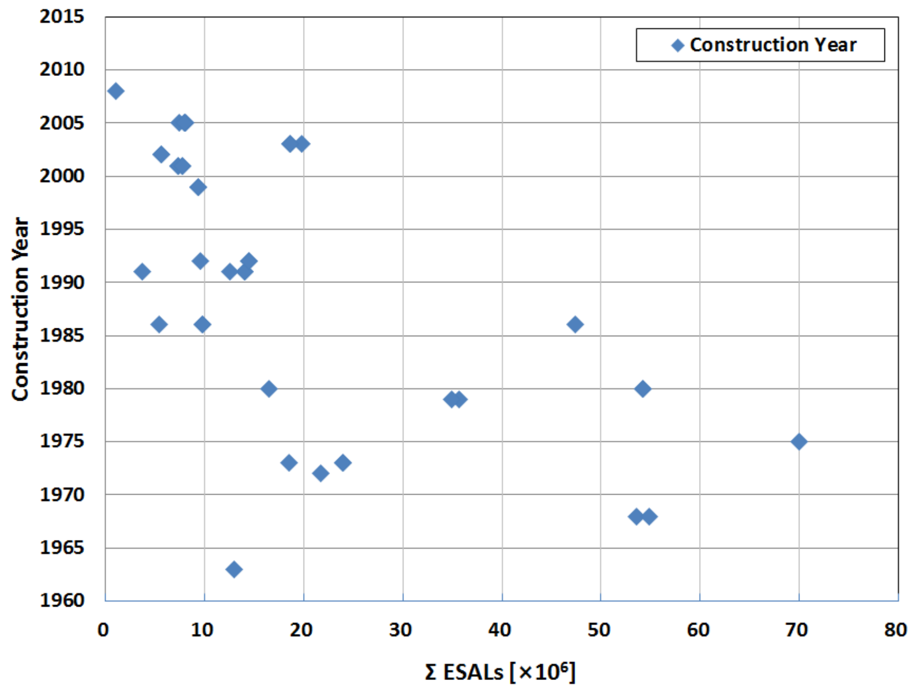


Figure B.6 Construction Year Distribution vs. ESALs

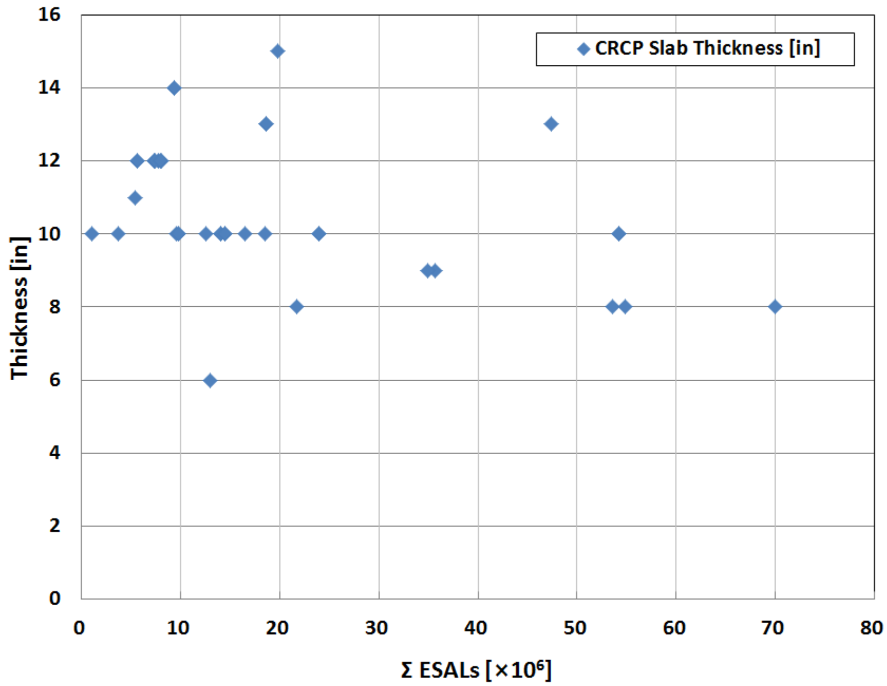


Figure B.7 Slab Thickness Distribution vs. ESALs

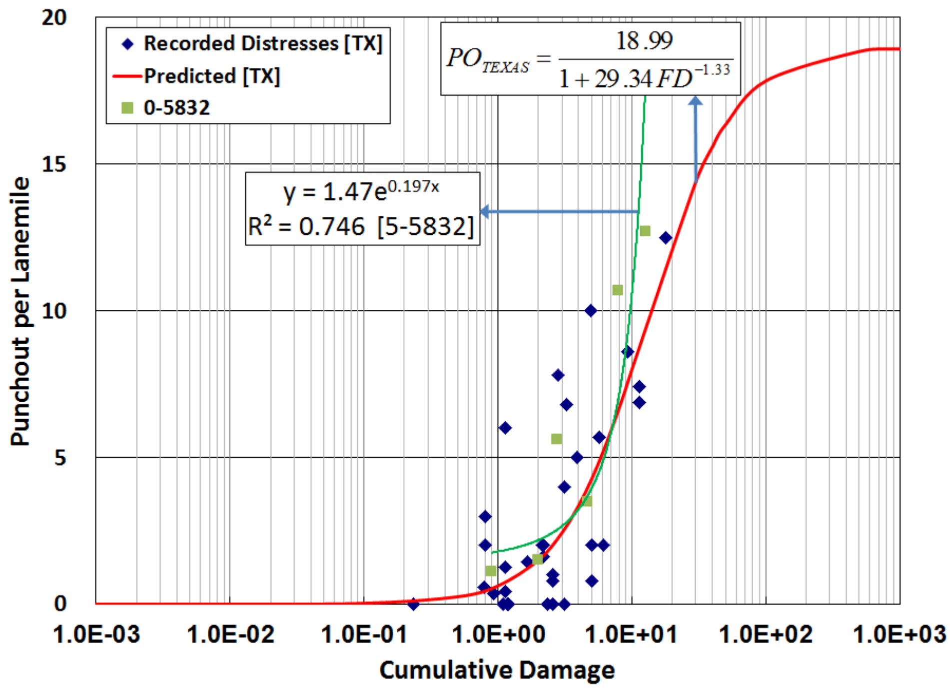
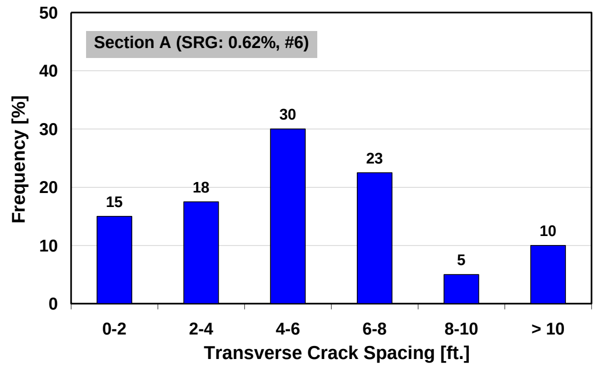
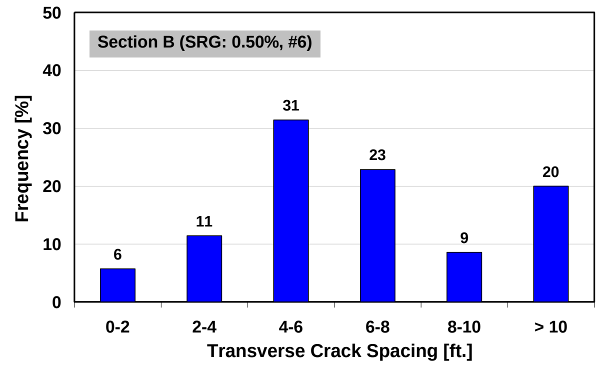


Figure B.8 Comparison of Transfer Function (0-5832 vs. 0-6274)

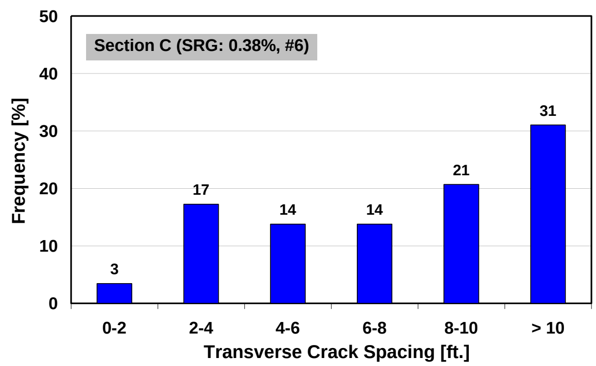
Appendix C. Performance Analysis of Experimental Sections



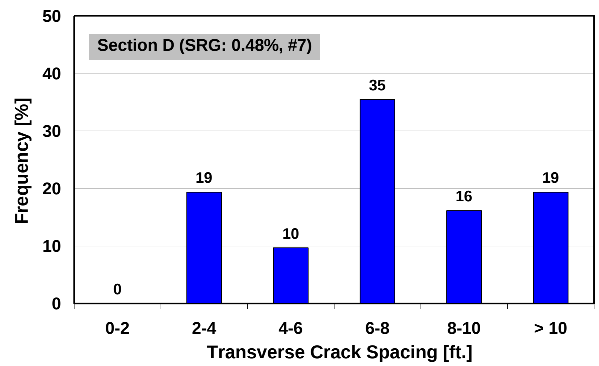
(a) Section A



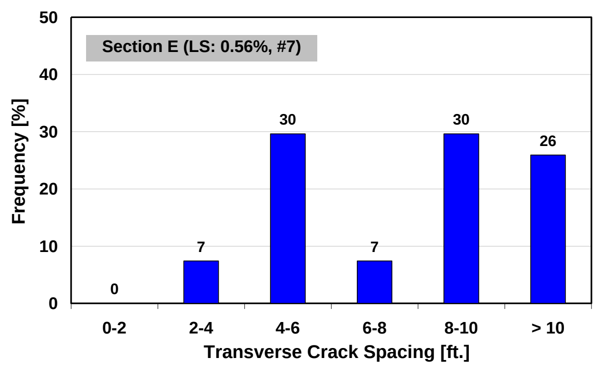
(b) Section B



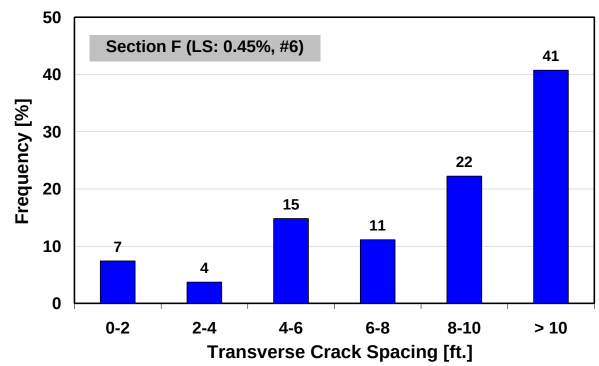
(c) Section C



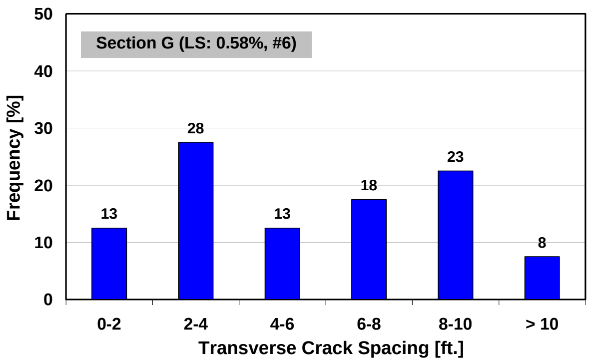
(d) Section D



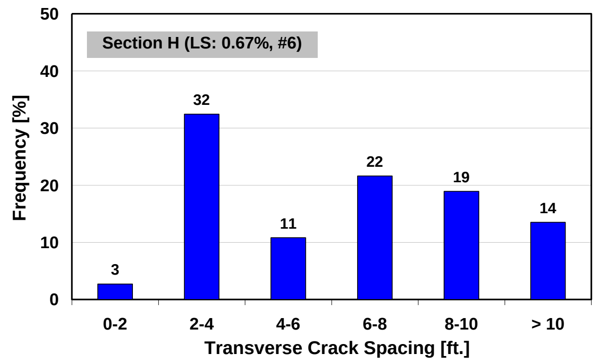
(e) Section E



(f) Section F

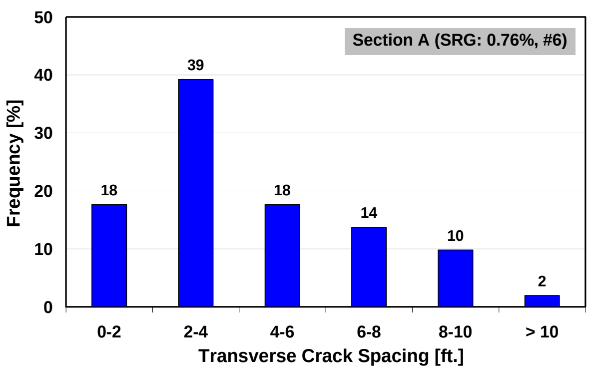


(g) Section G

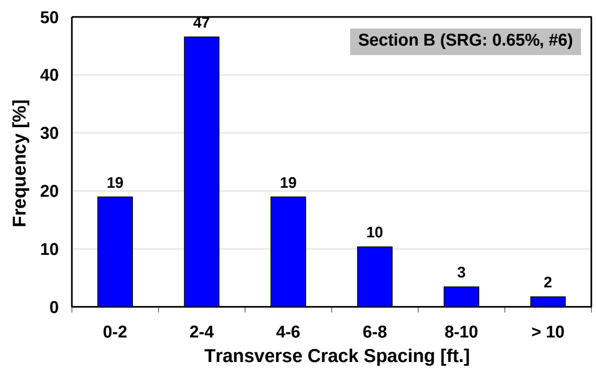


(h) Section H

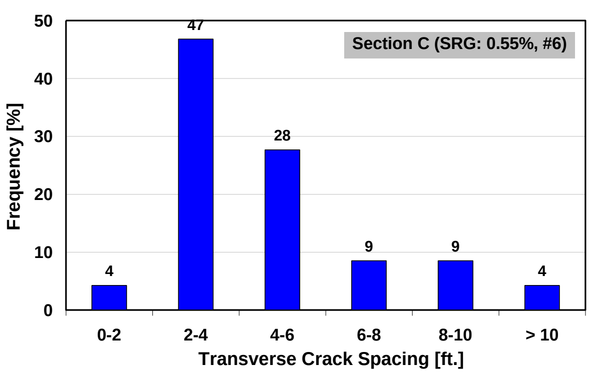
Figure C.1 Crack Spacing Distributions for Each Subsection of BW 8 Frontage Road Section



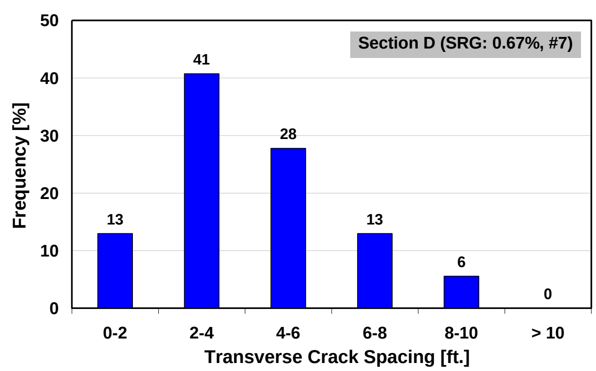
(a) Section A



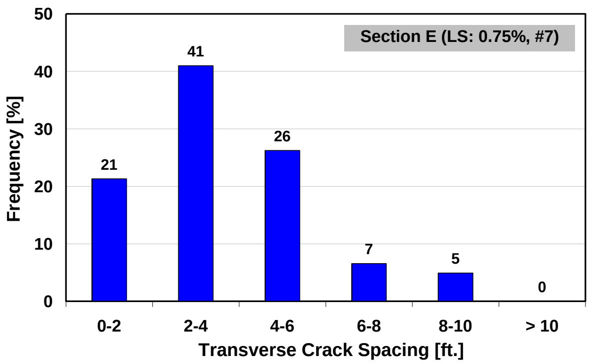
(b) Section B



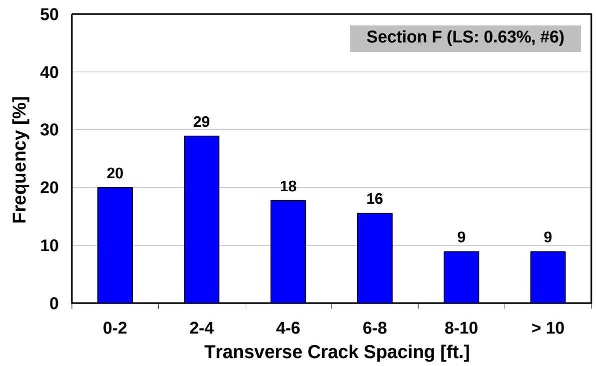
(c) Section C



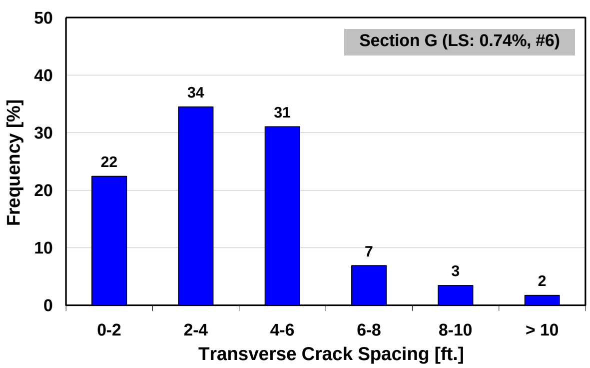
(d) Section D



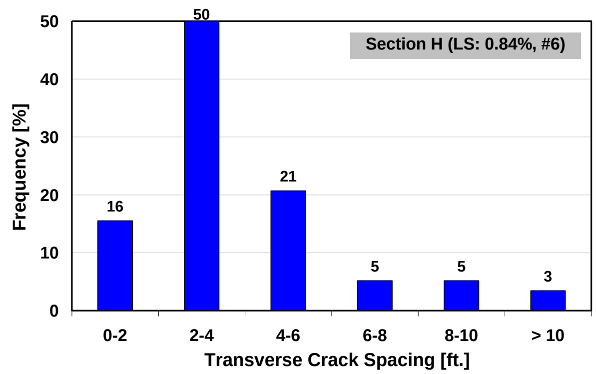
(e) Section E



(f) Section F

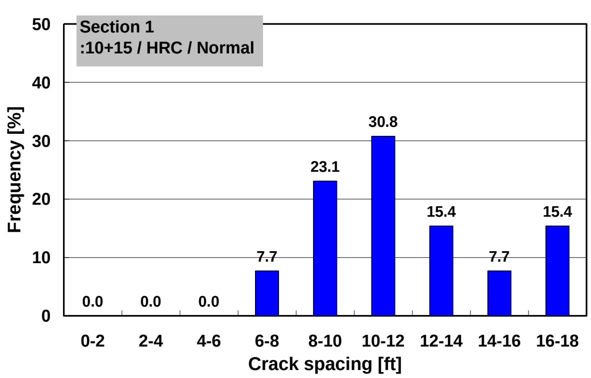


(g) Section G

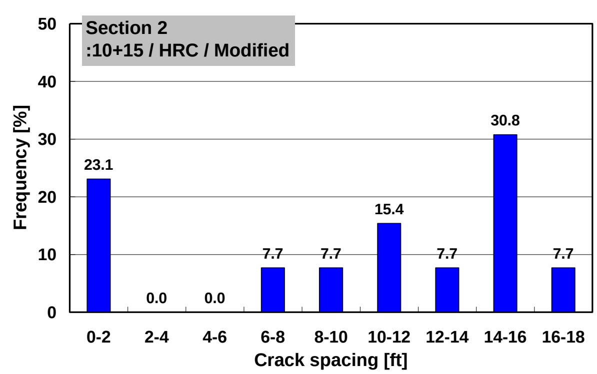


(h) Section H

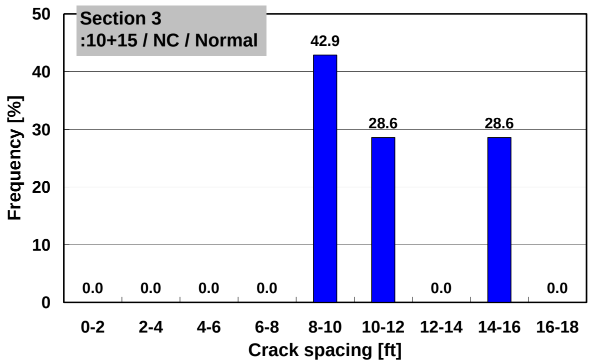
Figure C.2 Crack Spacing Distributions for Each Subsection of IH 45 Spring Creek Section



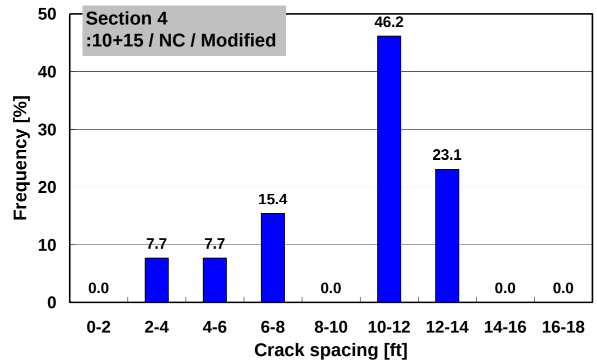
(a) Section 1



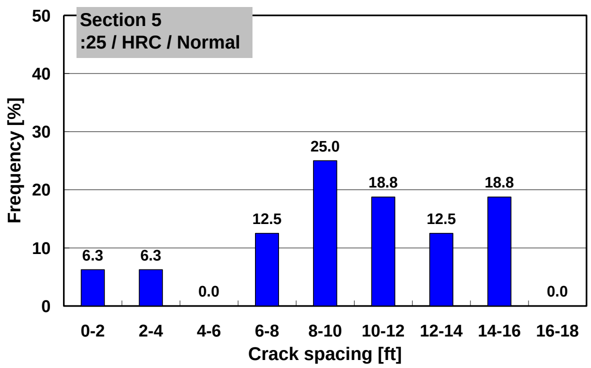
(b) Section 2



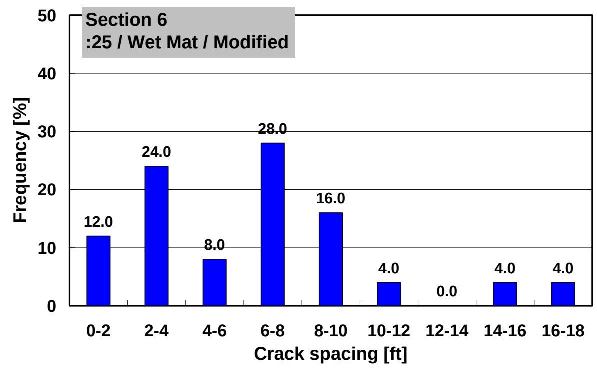
(c) Section 3



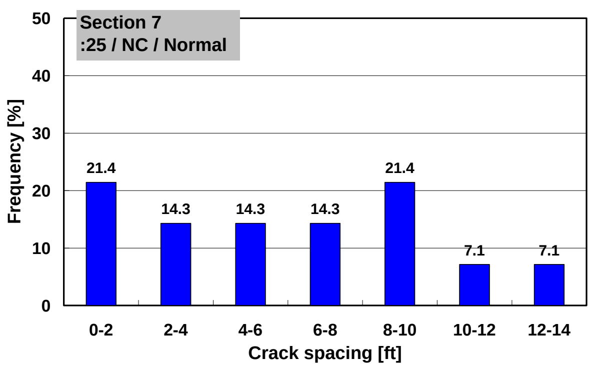
(d) Section 4



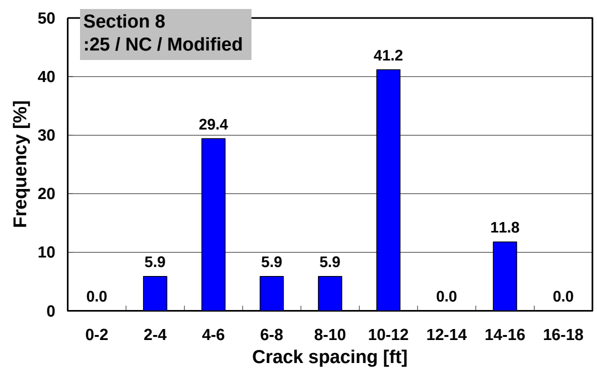
(e) Section 5



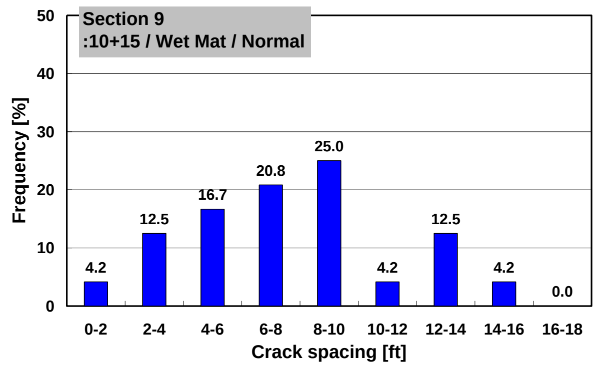
(f) Section 6



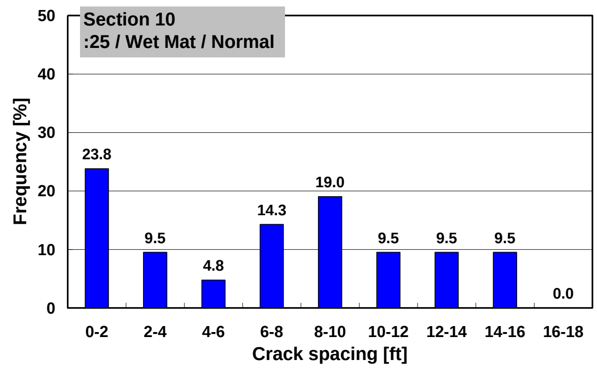
(g) Section 7



(h) Section 8

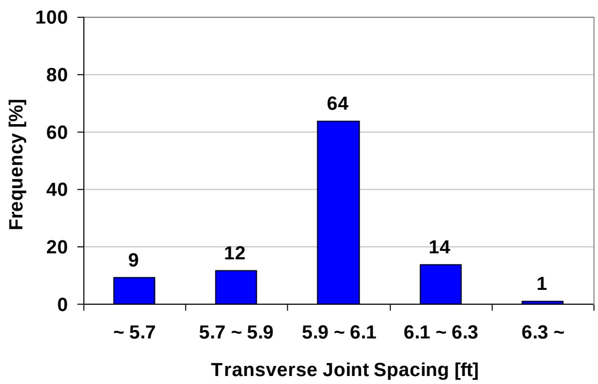


(i) Section 9

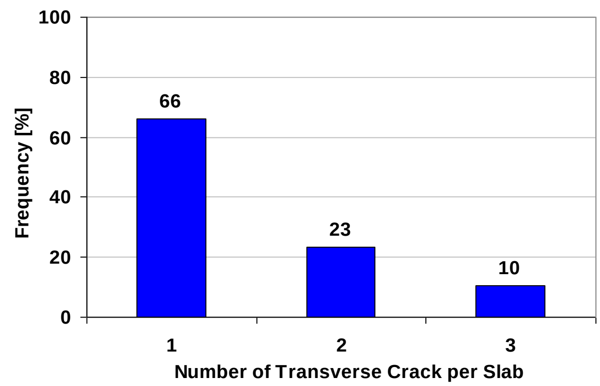


(j) Section 10

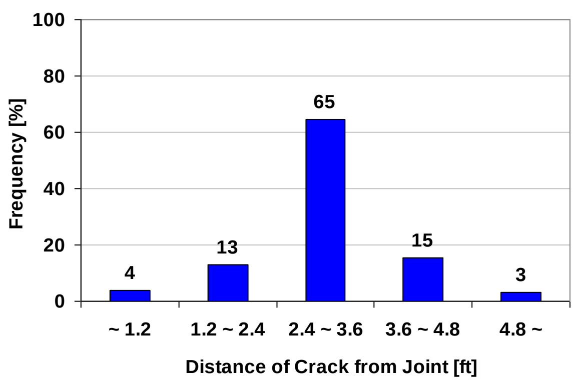
Figure C.3 Crack Spacing Distributions for Each Subsection of SH 288 Section



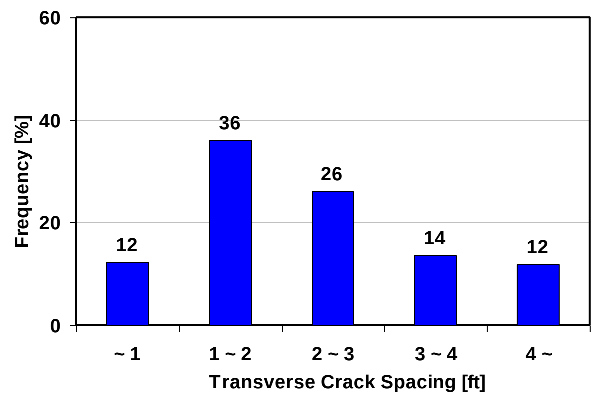
(a) Joint Spacing Distributions in Jointed Section



(b) Number of Transverse Cracks per Slab in Jointed Section



(c) Distance of Crack from Joint in Jointed Section



(d) Crack Spacing Distributions for Regular Section

Figure C.1 Detailed Crack or Joint Spacing Distributions for US 290SPS-1E Section

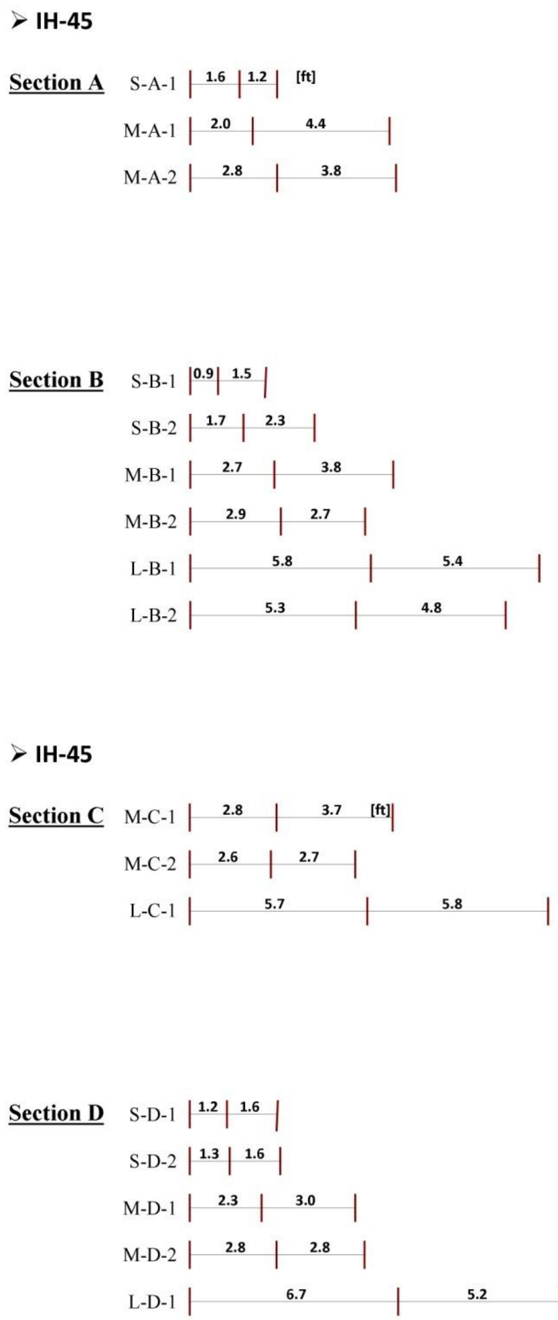
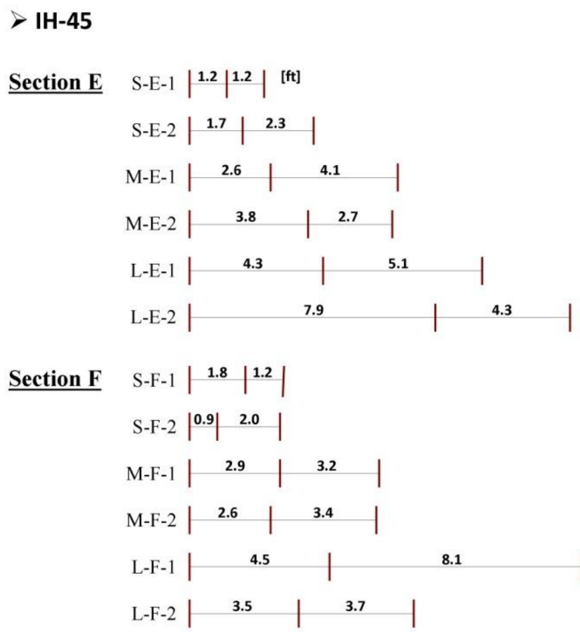


Figure C.2 Selected Cracks for FWD Testing in IH 45 Spring Creek Section



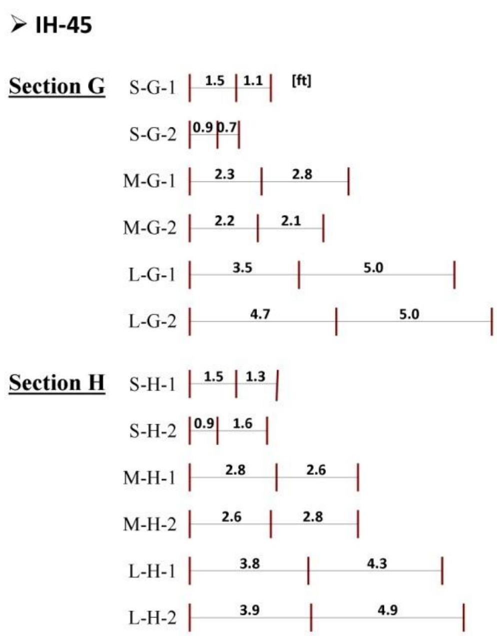


Figure C.5 Selected Cracks for FWD Testing in IH 45 Spring Creek Section (continued)

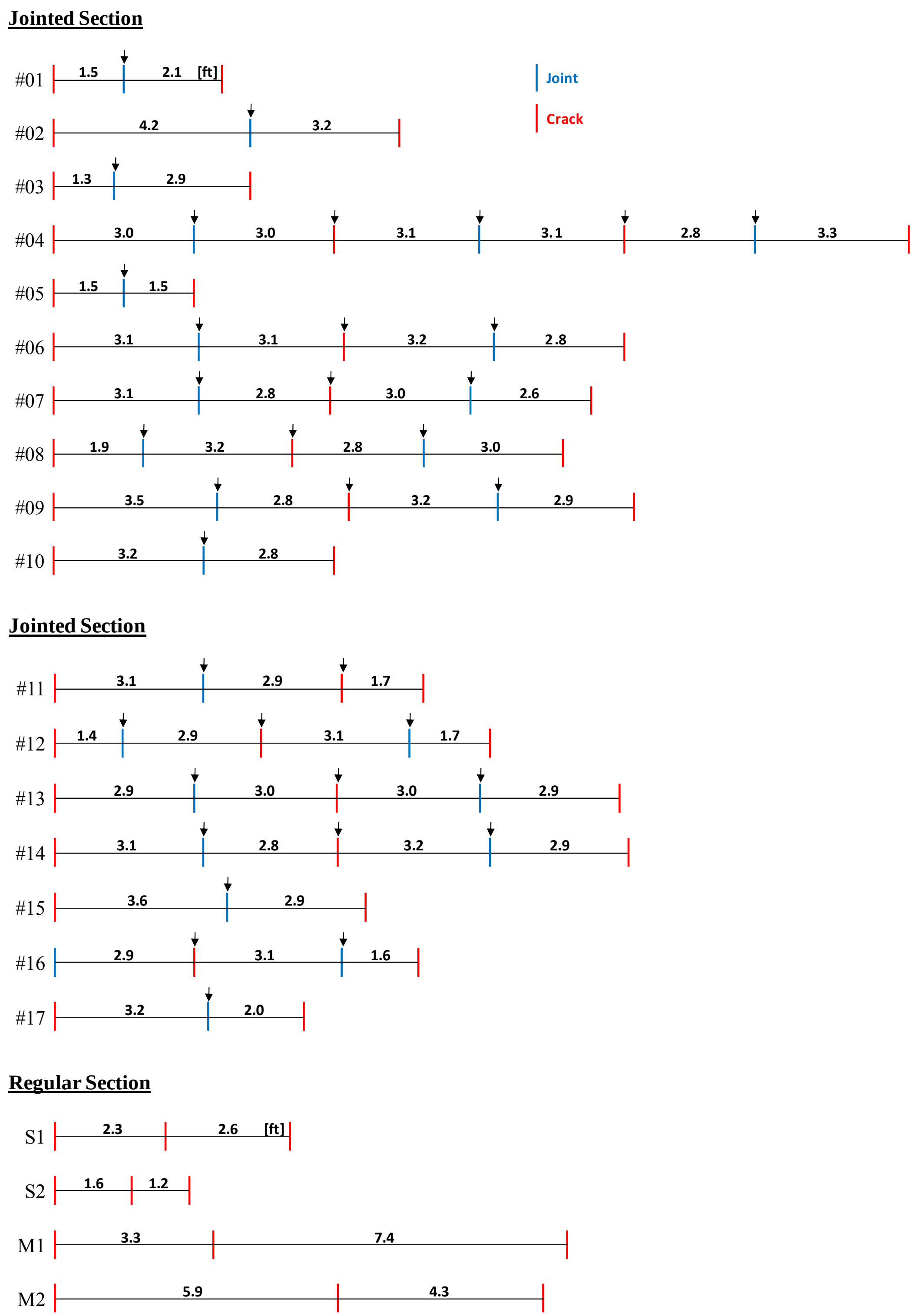


Figure C.3 Selected Cracks for FWD Testing in US290SPS-1E

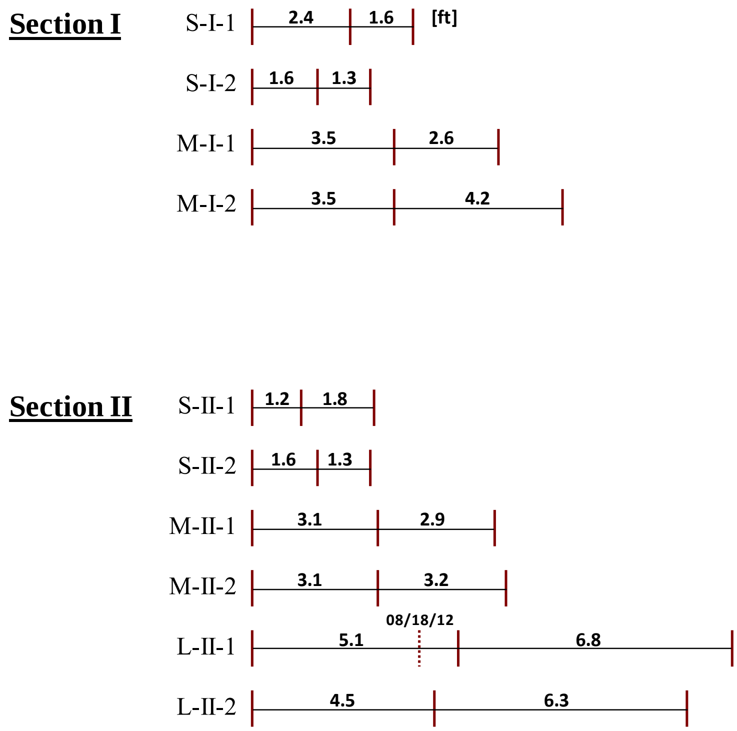


Figure C.4 Selected Cracks for FWD Testing in US290-2E

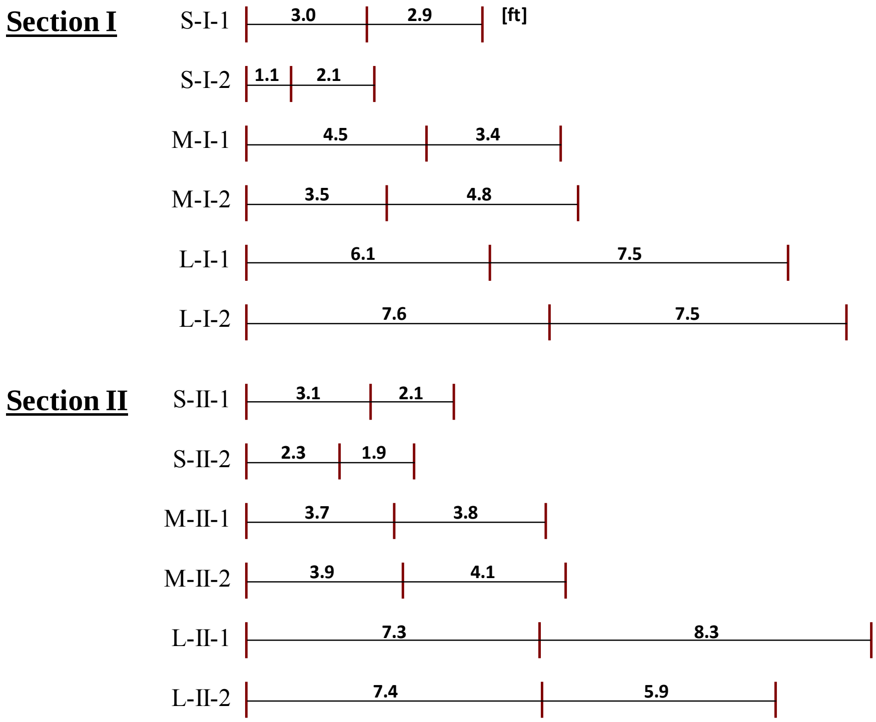
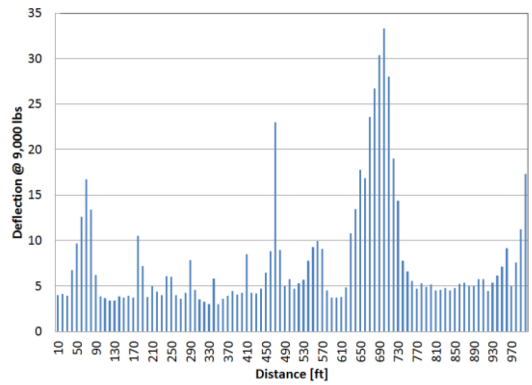


Figure C.5 Selected Cracks for FWD Testing in US290-3W

Appendix D. Performance Analysis of Special Sections

D.1 Data Analysis for US 287 in the Wichita Falls District

Figure D.1 US 287 Pavement Evaluation in the Wichita Falls District – Pavement Condition (12/03/2010)



Bowie DCP Test(US 81 - 220M - R-direction)

R-Driection(Bowie, US81) RM 220		Condition	Time	Drilling Depth (in)	Layer	mm / blow	CBR	Modulus (ksi)	Average Modulus [ksi]
DCP 2	Distance from Start ; 567'	Good Section	12/03/2010 09:48	8.5	1	0.56	554	145	67
					2	3.11	82	43	
					3	16.07	13	13	
DCP 1	Distance from Start ; 488'	Bad Section	12/03/2010 10:07	10.3	1	1.66	166	67	49
					2	5.05	48	30	
					3				
DCP 3	Distance from Start ; 137'	Good Section	12/03/2010 10:30	9.3	1	2.29	116	53	32
					2	21.35	9	11	
					3				
DCP 4	Distance from Start ; 485'	Bad Section		9.5	1	1.68	163	66	48
					2	5.15	47	30	
					3				
DCP 5	Distance from Start ; 490'	Bad Section	12/03/2010 11:08	9.25	1	1.53	181	71	49
					2	5.98	39	27	
					3				
DCP 6	Distance from Start ; 656'	Bad Section	12/03/2010 11:38	8.6	1	1.80	151	63	29
					2	8.76	26	20	
					3	72.14	2	4	

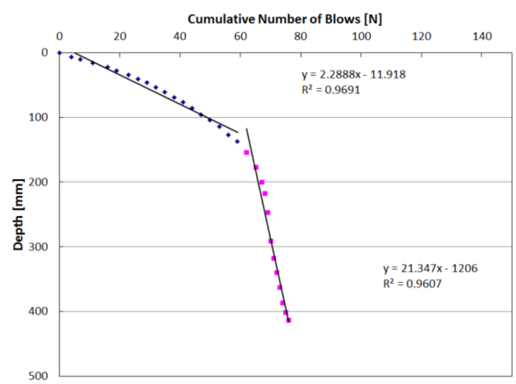
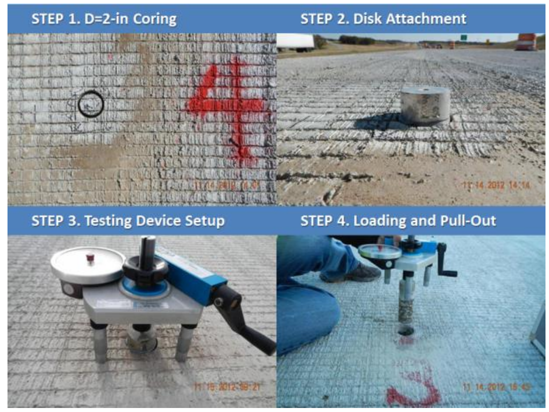
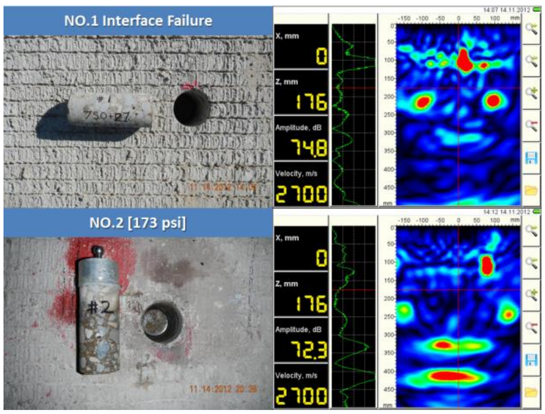
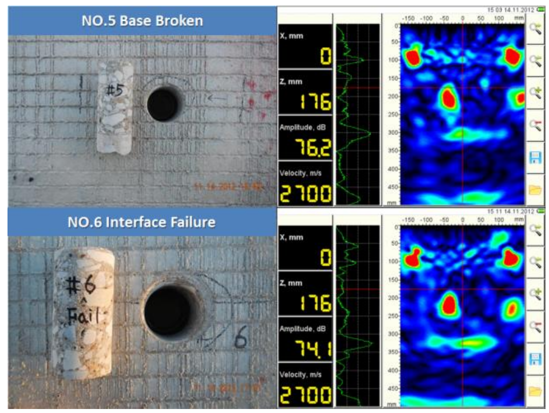


Figure D.2 US 287 Pavement Evaluation in the Wichita Falls District – Field Tests (12/03/2010)

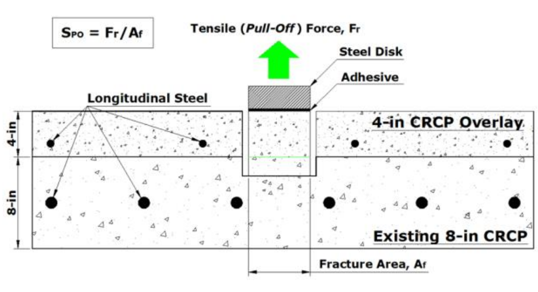
Figure D.3 US 287 Pavement Evaluation in the Wichita Falls District – Steel Placement (11/03/2012)







Schematic of Pull-Off Test



Bond Strength Test Results

Test #	Diameter of Core Specimen					AREA	Load		Bond Strength		GPS Coordinates	
	D1	D2	D3	D4	AVE. D	[in²]	[kN]	[lb]	[psi]	[Mpa]	N	W
#1	1.99	1.99	1.989	1.988	1.989	3.11			FAILURE		N 33 29 45.27	W 97 48 18.65
#2	1.977	1.977	1.967	1.97	1.973	3.06	2.35	528	173	1.2		
#3	1.976	1.985	1.971	1.971	1.976	3.07	1.60	360	117	0.8		
#4	1.957	1.969	1.983	1.966	1.969	3.04	2.60	585	192	1.3		
#5	1.989	1.98	1.983	1.98	1.983	3.09			BASE BROKEN			
#6	1.975	1.969	1.979	1.983	1.977	3.07			FAILURE			
#7	1.978	1.974	1.978	1.985	1.979	3.08	2.50	562	183	1.3		
#8	1.982	1.985	1.978	1.976	1.980	3.08	1.70	382	124	0.9		
#9	1.963	1.962	1.972	1.979	1.969	3.04	2.70	607	199	1.4		
#10	1.984	1.976	1.979	1.974	1.978	3.07	3.20	719	234	1.6		
#11	1.992	1.986	1.978	1.968	1.981	3.08	3.10	697	226	1.6		
#12	1.984	1.987	1.974	1.975	1.980	3.08	3.30	742	241	1.7		
#13	1.983	1.987	1.98	1.976	1.982	3.08	2.30	517	168	1.2		
#14	1.969	1.985	1.98	1.985	1.980	3.08	2.60	585	190	1.3	N 33 26 26.30	W 97 45 55.35
Failure [%]									14%			
Base Broken [%]									7%			
Analyzed Sample [%]									79%			
Average Bond Strength [psi]									186			
Standard Deviation, SD [psi]									40			
Coefficient of Variation, COV [%]									22%			

186 psi

Figure D.4 US 287 Pavement Evaluation in the Wichita Falls District – Bond Strength Test (11/14/2012)

Figure D.5 US 287 Pavement Evaluation in the Wichita Falls District – 9 Months after BCO (08/13/2013)

D.2 Data Analysis for IH 35 in the Laredo District

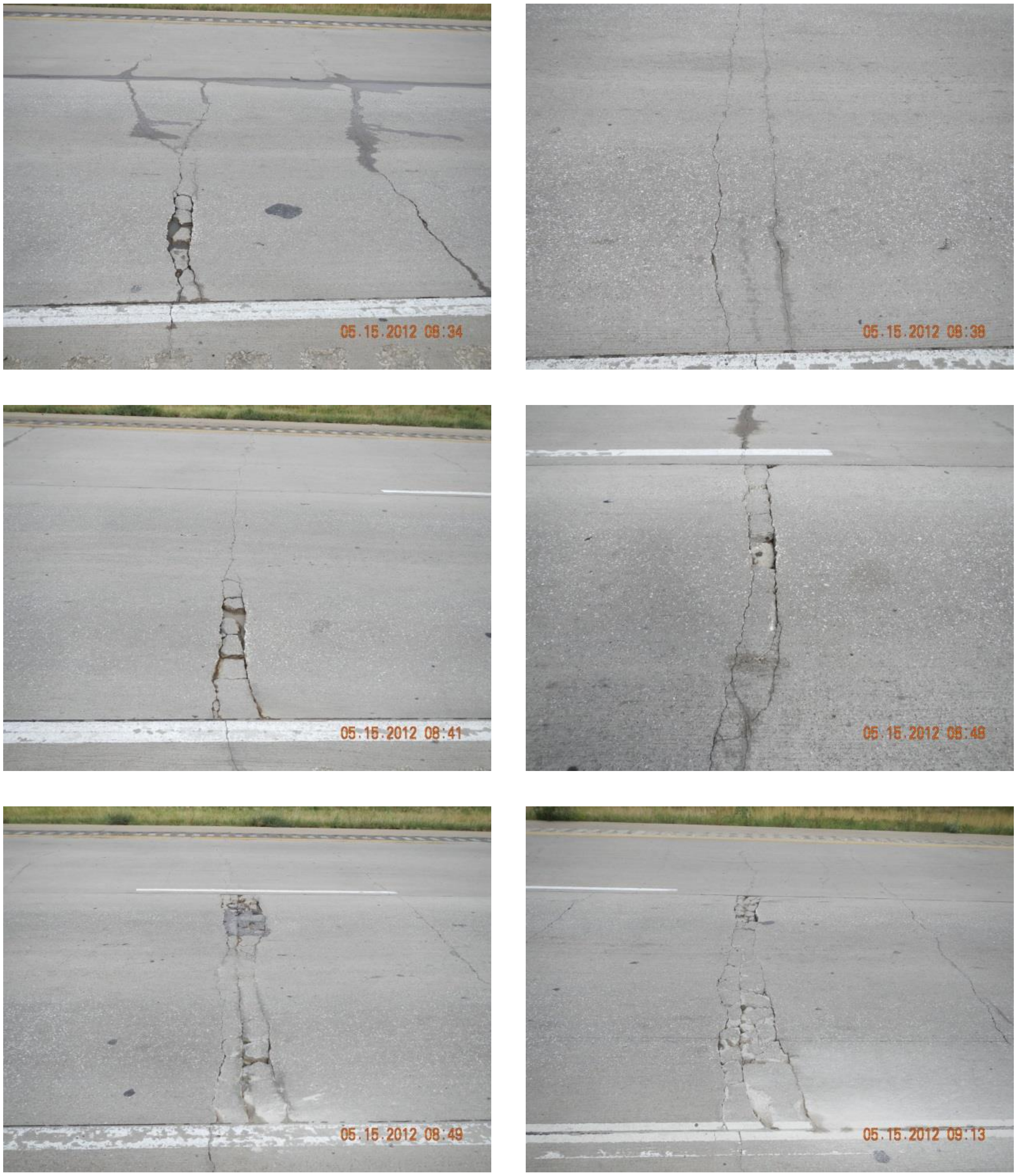


Figure D.6 IH 35 Pavement Evaluation in the Laredo District – Pavement Condition (05/15/2012)

Figure D.7 IH 35 Pavement Evaluation in the Laredo District – Mira Test (05/15/2012)

TEXAS TECH UNIVERSITY
Multidisciplinary Research in Transportation

Texas Tech University | Lubbock, Texas 79409
P 806.742.3503 | F 806.742.2644