MS-59:
TT:

CENTER FOR TRANSPORTATION RESEARCH LIBRARY
L021324

TEST AND EVALUATION PROJECT NO. 21
"AUTOMATED PAVEMENT DISTRESS SURVEY EQUIPMENT"

NOVEMBER 15 - 19, 1993
AUSTIN, TEXAS
FINAL REPORT

BY

TEXAS DEPARTMENT OF TRANSPORTATION

AND

FEDERAL HIGHWAY ADMINISTRATION

TABLE OF CONTENTS

Acknowledgement i
Equipment Vendors ii
Introduction 1
Purpose 1
Scope 2
Test Dates, Sites, and Weather Conditions 3
Project Sections Description 4
Manual Rating Procedures 5
Equipment Descriptions 5
Data Reduction Speed 9
Results of Data Comparison 9
Results 10
Data Collection and Processing 10
Simulated Cracking 11
Concluding Remark 11
Future Testing 11

TABLES and CHARTS 12

APPENDIX A - LTPP and PMIS Comparison 13

APPENDIX B - Image Analysis Process 14

APPENDIX C - Equipment Description 15

ACKNOWLEDGEMENT

The work plan, field test, evaluation, and the preparation of the final report were accomplished by a team of personnel from various State highway agencies and the Federal Highway Administration. The team was composed of persons knowledgeable in the area of pavement management, pavement design and data collection equipment. This team is called the Technical Work Group and is referred to as the **TWG** in the report. The authors would like to recognize the TWG members and thank them for their support and guidance during the demonstration project.

The following are the TWG members for Test and Evaluation Project No. 21:

Robert Harris - Texas DOT (Project Coordinator)
Freddie Baker - Maryland DOT
Doug Bish - Oregon DOT
G. Norman Clark - Kansas DOT
Gaylord Cumberledge - Pennsylvania DOT
Phil Elliot - Virginia DOT
Mike Farrar - Wyoming DOT
Wouter Gulden - Georgia DOT
Dave Huft - South Dakota DOT
Luis Rodriguez - FHWA (Project Coordinator)
Bill Bellinger - FHWA
Frank Botelho - FHWA
Gary Henderson - FHWA
Rudy Hegmon - FHWA
Sonya Hill - FHWA
Evan Wisniewski - FHWA

The authors would also like to thank the Texas Department of Transportation who hosted the field test and provided coordination and logistical support during the project.

EQUIPMENT VENDORS

The following are the equipment companies that participated in the field test and evaluation:

Infrastructure Management Services (IMS)
6621 Bay Circle, Suite 120
Norcross, Georgia 30071
(404) 242-6202
(404) 242-5805 Fax
(800) 467-7110

PASCO USA, Inc.
4913 Gettysburg Road
Mechanicsburg, Pennsylvania 17055
(800) 445-4789
(717) 691-8211 Fax

Pave Tech Inc.
P.O. Box 639
Norman, Oklahoma 73070
(405) 364-5553
(405) 364-5796

ROADWARE - ARAN
P.O. Box No. 520 (R.R. No.1)
Paris, Ontario, Canada N3L3T6
(519) 442-2264
(519) 442-3680
(800) 828-2726

INTRODUCTION

Pavement Management Systems (PMS) provide information to the pavement engineer to assist not only with funding needs and allocation but also with correct types and timing for pavement related work. One goal of a PMS is to help decision makers utilize their resources as effectively and efficiently as possible. Various PMS's use information differently to meet their users needs. However, the underlying data behind the information is often the same and includes: pavement inventory, pavement structure, pavement age, work history, traffic and pavement condition. Pavement condition includes a pavement's smoothness, structural capacity, skid demand capacity and surface defects. Automated equipment is available to measure roughness, profile, skid resistance and deflection. The equipment most difficult to develop and master is that which can safely, efficiently and objectively collect pavement surface defects known as surface distress.

Surface distress includes cracking, patching, and other surface manifestations detrimental to the pavement's performance or life. These distresses have been difficult to measure using automated equipment. Appendix B provides a short description of some of the problems associated with attempting to fully automate distress rating procedures.

During June 1990, Iowa State University was host to the *"Automated Pavement Distress Seminar."* This seminar included static equipment demonstrations, equipment data collection and reporting, papers and presentations concerning equipment hardware and software testing. One result of the meeting was a consensus that, while there have been significant improvements, fully automated systems were not yet realized. Since 1990 several vendors have made improvements to the equipment displayed in Iowa. The Iowa demonstration project provided an opportunity for the vendors to display and test their equipment.

PURPOSE

In the last few years, computer and video technology has progressed so that fully automated pavement distress collection and reduction equipment were developed and implemented. This demonstration project tests the equipment to provide information to PMS end users on its ability to collect and categorize data.

The work plan written by the project coordinators and approved by the TWG described the project purpose. The PRIMARY purpose was: *"To field test and evaluate pavement distress survey equipment that can measure pavement distresses at highway speeds using 100 percent automated equipment, computers, and analysis packages without human intervention."* A SECONDARY purpose was *"To field test and evaluate manually assisted equipment."* The equipment evaluation was limited to identifying and measuring different pavement **"crack"** types and their severity levels as defined by the project level, Strategic Highway Research Program (SHRP) - Long Term Pavement Performance (LTPP) *"Distress Identification Manual."*

Additionally, there is a network level simulation using the Texas Department of Transportation's (TxDOT), *"Pavement Management Information System Rater's Manual."* This evaluation limited data analysis to crack extent. No severity levels were analyzed.

The report and appendices presents:

1) The scope of the demonstration project.
2) A description of the test sections.
3) The manual data collection and conversion from the TxDOT Pavement Management Information System (PMIS) to LTPP procedures.
4) A description of the data collection equipment and data analysis and reporting equipment.
5) An estimate of the time required to reduce the collected data.
6) Tables and charts comparing results between the manual surveys and the equipment.

SCOPE

The demonstration project limited visual distress measurements to pavement cracking; no other distress types were considered. Besides the time of day, an attempt at estimating influences of different light angles, the demonstration project sections included other variables that might influence data analysis such as changes in pavement color and texture, shadows on the pavement, and marks on the pavement.

The principal cracking distresses measured in this project were:

Flexible Pavements
Fatigue Cracking - Area & Severity
Transverse Cracking - Length & Severity
Longitudinal Cracking - Wheelpath, Non-Wheelpath, Length & Severity
Edge Cracking, Length & Severity

Rigid Pavements
Transverse Cracking - Number, Length & Severity
Longitudinal Cracking - Length & Severity

"Simulated cracks" were painted at the end of a pavement section and measured with all equipment at the test speed to estimate the equipment's camera(s) resolution. The section on page 11 describes the simulated cracking in more detail.

The test included seven sections two kilometers to fifteen kilometers long simulating network level data collection. The manual, network level cracking survey simulation used the Texas Pavement Management Information System's (PMIS), *"Visual Distress Rater's Manual."* TxDOT conducted the PMIS Visual Evaluation with a TxDOT visual evaluation trainer. The project team modified the PMIS procedure to make it more compatible with data collected by the data collection equipment and reported in LTPP format. The network level comparison is gives the reader an understanding of how well the equipment performs for pavement management system use while the LTPP procedure is more detailed and describes the equipment's use for project level or research project use.

Within the seven network simulation sections ten 150-meter segments were chosen for the LTPP distress rating procedure and randomly located throughout the network level simulations. A four member rater team supplied by the Federal Highway Administration (FHWA), including an LTPP instructor, rated the sections on a two day trip to Austin and Waco. Test site locations remained unpublished until the first day of the test.

The TWG members rotated through the vehicles during data collection. The TWG members were to note any discrepancies between reported data collection procedures and actual data collection. Data collection speed for the test was set at 80 km/h (50 mph) with the observers ensuring that the speed did not vary more than ± 8km/h (5 mph) during the test. Observers also watched the approximate wheelpath.

Vendors with fully automated equipment processed their data during their stay in Texas. TxDOT and the TWG observed the data reduction procedures to ensure that the ratings were truly automated. The observers commented on the functional steps for data reduction and estimated the data reduction speed. Problems observed during data reduction such as locating sections on video, computer lock up, incorrect crack identification, number of passes to successfully rate a section, etc. were noted.

Arrangements with TxDOT and the fully automated vendors provided for data submission to TxDOT after the test was completed. Both IMS and Roadware submitted some data after the test. The IMS data was originally processed in Austin and intentionally withheld. They were concerned about the data from two sections. After reviewing the data, they determined that it was acceptable to them and asked that it be included. This data was added a week later at their request. IMS met their obligation of two passes for each test time as requested in the original work plan, see the section on page 11 for more information. The additional data was from passes made in Waco demonstrating data collection to the TWG.

Roadware had problems processing the asphalt pavement surfaces and submitted three passes of section D by the December 19 deadline as offered to the manually rated systems below.

Vendors with manually assisted equipment were provided a list of sections to rate while in Austin. They were then provided the option to rate all sections in their home offices. One condition of this was that all data was to be in Austin one month after completion of the test.

Test Dates, Sites, and Weather Conditions

The field tests and data reduction were conducted in Austin and Waco, Texas between November 15-19, 1993.

One goal of this test was to have a balance of test sections that would have asphalt, jointed concrete, and continuously reinforced concrete. Another goal to have a balance of the type, extent, and severity of transverse, longitudinal, block, and fatigue cracking.

During the test site selection stage of this project, it was not possible to find all the pavements and crack types to fully satisfy the goals of this test. Traffic disruption and safety also limited the scope of the field test. Consequently, the test sections lacked moderate and severe cracking levels in the flexible sections. The lack of moderate and severe cracking is partially a function of the LTPP distress rating procedure. Moderate cracks are typically between six millimeters and 19 millimeters wide with severe cracks greater than 19 millimeters wide. Few pavements in the part of the state where the test was held are allowed to stay in this wide a cracked condition for long. No jointed concrete pavement sections were evaluated in the test.

Seven test sections totaled approximately 30.45 km (18.9 miles) of flexible and rigid pavements. The TxDOT marked each 150 meter segment with a letter - number combination. Thus each section was uniquely identified for more detailed analysis. The site description and locations are listed below.

PROJECT SECTION DESCRIPTION

Network Section	LTPP Section(s)	Highway	Length	Width	Surface Type	Shoulder	Traffic
A 50 segments 150 m each	A3 & A22 - dense graded hot mix	FM 1466	7.5 km	~ 3 m	alternating surface treatment and ACP	none	low
B 100 segments 150 m each	B69 - mix of approximately 30% surface treatment and 70% dense graded hot mix B96 - dense graded hot mix	FM 619	15 km	~ 3m	alternating surface treatment and dense graded hot mix	none	low
D 30 segments 150 m each	D8 & D22 - light colored surface treatment	SH 95	4.5 km	~ 3.35m	light colored surface treatment	none	low
E 7 segments 150 m each	E3	IH 35 frontage road	1.05 km	~ 3.66m	continuously reinforced concrete pavement	curb and gutter	mod.
F 7 segments 150 m each	F7	IH 35 frontage road	1.05 km	~ 3.66m	continuously reinforced concrete pavement	curb and gutter	mod.
H 7 segments 150 m each	H4	IH 35 frontage road	0.9km	~ 3.66m	continuously reinforced concrete pavement	curb and gutter	mod.
T 3 segments 150 m each	T2	Decker Lake Road	0.45 km	~ 3m	surface treatment	none	very low

Table 1: Project Site Description

There was a problem with the section lengths that was not immediately obvious before data collection began. The 150 meter segments were marked off with a vehicle that had recently been repaired. This vehicle had two distance measuring instruments (DMI's) in it; one combined with vehicle instrumentation and one stand alone. The sections were laid out with the stand alone DMI. The stand alone DMI had not been recalibrated after the vehicle repairs resulting in inaccurate measurements.

Unfortunately, all the sections were approximately eight percent short. For two vendors, PASCO and Pave Tech, this did not affect them as their distress identification procedures use a manual procedure to locate the beginning and ending of each 150 meter segment. However, the two other vendors, IMS and Roadware, rely heavily on their DMI's to accurately position data. The sections being too short would cause data reporting errors if they had used their correctly calibrated DMI's. This problem was solved by recalibrating the two vehicle DMI's to the measured section length and tricking the systems into reporting data in the correct test segment.

Field testing was originally scheduled for Monday, Tuesday and Wednesday, November 15 through 17 for all vendors except PASCO. They collected film data the week before. Data reduction was to start Tuesday and proceed through the end of the week. Data collected on Monday was not useful to either IMS or Roadware due to the section length problem described above. The TWG agreed to let IMS and Roadware recollect data Tuesday morning and then move to Waco for noon and afternoon data collection on the CRCP. Rain delayed data collection Tuesday morning. Checks with the Waco district and the weather service indicated that the rain would end during the morning. The TWG decided to move the tests to Waco for the afternoon run.

There was concern that the wet cracks in the afternoon run would be more obvious to the systems and influence the results. A review of the data does not seem to support this concern. On Wednesday the CRCP morning and noon runs were completed. The vehicles returned to the flexible sections and collected afternoon data on Wednesday and the remaining data Thursday.

Pasco began their data reduction efforts on Monday morning. Pave Tech began their data reduction on Tuesday morning. IMS and Roadware both had to wait until the data was collected using the proper DMI settings. Both vendors sent data to Austin on Wednesday morning from Waco to begin data reduction.

MANUAL RATING PROCEDURES

Appendix A describes some differences between the LTPP crack rating procedure and the standard PMIS crack rating procedure. The appendix also describes the method used to convert the LTPP data into PMIS *"equivalent"* data. For more thorough descriptions of the two rating procedures, please see the appropriate references.

One additional difference should be noted concerning the section lengths rated. The LTPP procedure rates all 150 meters. The PMIS procedure typically rates a representative 61 meter (200 foot) section in a one-half mile PMIS section. For the purposes of this study 100 percent of each section were rated using with the PMIS procedure.

EQUIPMENT DESCRIPTION

The following section describes the data collection and reduction equipment as it was configured in Austin for the test. The description includes only those subsystems mounted in the vehicles for collecting surface distress data. Workstations used for the data reduction follow the vehicle descriptions. The reader is encouraged to review other literature or contact the manufacturers for other data subsystems available for the equipment.

IMS

IMS calls their pavement distress subsystem *"PAVUE I."* The system in Austin consisted of a van equipped with:

- Four overhead electronically shuttered video cameras on the back of the van.
- Strobe lights at the back of the van to provide even illumination of the pavement and eliminate shadows.
- One overhead electronically shuttered camera mounted on the front of the van for *"right of way"* view.
- Four crack detection lasers mounted on the front bumper.
- High resolution, optical shaft, distance encoder.
- Five PAL S-VHS VCRs.
- Other equipment for collecting video and laser measurements of the pavement surface at speeds up to 90 km/h (55 mph).

The VCRs use a video data encoder to record DMI location and synchronize all four pavement view video cameras and tape recorders.

When the PAVUE system is transported long distances, such as the trip from Atlanta to Austin, the cameras are removed. IMS aligns the cameras to provide the best possible video. They also periodically calibrate with a known grey scale source placed under the camera / lighting system. This allows them to supply video system performance to the office workstation system.

PAVUE records cracking information with the front mounted lasers stored in user defined summary intervals. This is done instead of storing all laser data to reduce the amount of disk storage space required on the van. For the test in Austin, IMS picked a summary interval of 25 meters. This means that for each 150-meter segment, there were six laser summaries recorded. The summarized laser data is why the DMI offset was such a critical problem for IMS. If the section lengths were off too much, they would be recording laser video for one section that was actually in another section.

The office workstation consisted of two racks of equipment. One rack held the VCRs and monitors. The second rack held the PAVUE system computer which consisted of approximately sixty, special purpose, proprietary, video processing VME Buss cards. These sixty cards are configured as two image processing systems, one for each half lane. The image processing system performs the edge detection and feature extraction process. The data is sent through a separate program to classify the cracking and merging it together with the laser data to estimate crack severity.

After the data has been collected in the field, a packet of five video tapes and a data diskette are returned to the workstation. The PAVUE system uses a pavement surface specific initialization file to load the correct processing parameters. The section beginning points were identified and then the PAVUE system started the image analysis. Image analysis was performed at realtime video tape recording speed. In the case of the PAVUE system this is 50 fields per second, *the European PAL standard.*

A program called *"HYBRID"* combines the analyzed the video data with the laser data to generated the final pavement cracking report indicating crack type, severity and extent for each 150 meter test segment. There were a number of intermediate steps in the process demonstrated in Austin. These intermediate steps reduced the overall data reduction speed. IMS informed the TWG that these steps will be incorporated into a batch process to speed up data reduction.

PASCO

The *"Roadrecon"* system consisted of a recreation vehicle (RV) size custom built vehicle equipped with an overhead 35 mm strip film camera and halogen lights located on the front bumper. The pavement surface filming was done the night of November 7 to allow time for the film to be developed. PASCO collects at night to control the lighting conditions and the effects of shadows. The film was recorded at vehicle speeds of 80 km/h. The film was sent to Pennsylvania for developing and returned to Austin on November 15 for data reduction.

The PASCO office workstation consists of an overhead strip film projector, digitizing table and personal computer. The section header and other pertinent information are keyed into the computer and the distress ratings begin.

A section of pavement is projected onto the digitizing table. A technician digitized the cracks outlining the area or length of the cracks and not the actual cracks. With the boundaries of the pavement film image keyed into the system, and the cracks identified with the digitizer, the program calculates the length or area of cracks. This procedure was repeated for each section until all 150 meters was completed. For the test in Austin, another workstation produced crack maps and distress survey summary sheets for each test segment.

Pave Tech

The Pave Tech system consisted of a van equipped with:

- Four electronically shuttered pavement cameras; two in front and two in back that are switched by the operator depending upon lighting conditions.
- Two front cameras one that provides right of way view and one that can be aimed towards signs or other items of interest.
- An operator keyboard.
- Distance Measuring Instrument

The system can collect video and other information at speeds up to 104 km/h(65 mph).

For this test the operator entered the road description, location, survey limits and road stations in the on-board computer. This information can also be downloaded from a pavement management system. Other information collected by the computer included DMI data and time code from the S-VHS VCRs. Time code and section header / DMI data is recorded and used to control the VCRs with the computer both for recording and playback.

The recorded videos were played back at variable speeds on video monitors at the Image Processing Workstation (IPW). A trained technician viewed the videos and identified and keyed-in the type, severity, starting and ending point of the cracks using a preset pavement distress input menu in the IPW's computer. The computer automatically calculated the length or area of the cracks and generated the distress data file and pavement cracking report. Distress information can be collected for the entire section or for specific sample locations as requested in this project. When a sample is taken, the computer system keeps track of the sample location so future distress surveys can be done at the same sample location. This provides the ability to conduct historical pavement evaluations and do performance monitoring.

Roadware

The Automatic Road Analyzer (ARAN) consisted of a modified van equipped with:

- Two electronically shuttered pavement view video cameras mounted at the rear of the vehicle on self extending booms, strobes lights on the rear of the vehicle to eliminate shadows from the pavement image,

- A video multiplexer for collecting two video images on one S-VHS recorder -- the cameras collect video images simultaneously and then delay one image by a sixtieth of a second and record it on the second video field.

- One front mounted, electronically shuttered, right of way video camera.

- A computer rater keyboard for collecting event and other information.

- An optical shaft encoded DMI.

The ARAN can collect pavement images at speeds up to 80 km/h (50 mph).

As stated in the purpose section, this test was to evaluate automated equipment that did not have human intervention during data collection and reduction. A Roadware technician was observed using the rater keyboard during testing. When asked about using the keyboard, he explained that the image processing algorithm had difficulty distinguishing between block cracking and fatigue cracking. He was instructed to estimate when crack patterns changed between block and fatigue cracking and key this information into the rater keyboard. Discussions with other Roadware representatives support this explanation.

The office workstation consists of a 486 based personal computer, with two RISC image processors mounted on PC expansion cards and WISECRAX image processing software. The system uses an initialization file that provides information to the software about section length, pavement type, etc. The WISECRAX system demonstrated in Austin digitized 75 meters of pavement video at a time. The system then performed edge detection, feature extraction and classification based upon the requested rating procedures.

The office data reduction is fully automated, *i.e., the operator set up section header information and inserts the video tape and the system runs until complete.* The system uses the initialization file and relies on location from the DMI to calculate section lengths, beginnings, and endings. This section identification and length is why the section length problem was critical for data reporting. The ARAN DMI was corrected as described earlier.

Roadway chose to use off-the shelf components to build the WISECRAX system. If data reduction speed increases are needed, it is available by increasing the number of RISC processor in the PC. Each additional set of cards can add a significant cost to the system and the reader should evaluate the benefit / cost to determine whether or not it is cost effective to increase the system speed.

Additional information about each equipment, hardware, and software is included Appendix C or the vendors can be contacted from the list at the beginning of the report.

DATA REDUCTION SPEED

The following table shows the estimated speed for completing two selected sections; Section D and Section H for those systems using computers to process video data. Roadware experienced problems processing the concrete video during the speed estimating trial and thus the results are for Section D only. The data reduction rate for the manually assisted systems is based on the time needed to rate one 150-meter pavement segment. The rates for some vendors is dependent upon the number and complexity of pavement distresses present on the sections. The reader is reminded that these data reduction rates include set up times and other file manipulations. There may be some different data reduction speeds for the automated systems at the network level as full video tapes, *say two hour tapes*, would be processed with little operator intervention. These estimates provide the reader with an indication of the relative speed available from the different vendors participating in the project. The times shown below indicate the processing speed of the systems in the configuration as demonstrated in Austin for this test.

EQUIPMENT COMPANY	DATA REDUCTION RATE
IMS	14 to 28 Km/h
PASCO	0.1 Km/h
Roadware	4.5 to 5 Km/h
Pave Tech	3 to 5 Km/h

Table 2: Data Reduction Rate

RESULTS OF DATA COMPARISON

ACCURACY AND PRECISION DEFINED

There are two concerns about how well the equipment performed at the test. The first is how accurately the equipment collected the data and the second is how precisely that data was collected.

Accuracy is defined as how close or near the measurements made were to the real or actual quantity being measured. The sources of accuracy errors are typically systematic errors and are reduced by calibrating a system. For the project, accuracy is how closely the equipment measured data compared to the manual LTPP and PMIS ratings. The project does not attempt to report the validity or accuracy of the LTPP manual rating procedure or the PMIS rating procedure. For information concerning the accuracy and precision of LTPP surveys, the reader is encouraged to review the *"Evaluation of SHRP LTPP Distress Data Collection Procedures"* by Brent Rahut Engineers, the LTPP Southern regional Contractor. The TxDOT has conducted audits of its manual Pavement Evaluation System ratings, the predecessor to PMIS, and these results may be available from the TxDOT.

Precision or repeatability is defined as the closeness with which ~~the~~ measurements agree with each other. Precision errors are random or accidental errors and can be an indicator of poor instrumentation or data processing. For the project, the closer each piece of equipment agrees with itself on any given section the more precise it is. Standard deviation of the repeat runs is reported to estimate repeatability. If the standard deviation is low then the equipments agrees well with itself on any given section.

When reviewing the results, the reader should keep in mind that standard deviations for very small sample sizes, *say two passes on the same section,* statistically have little or no meaning. Additionally, the standard deviations include differences between passes made at different times of the day and may influence the results.

Results

Results for the LTPP segments are presented first. The results are shown in various ways to allow the reader to reach conclusions concerning the equipment's performance. The results are presented:

- In tabular form for each cracking type and are the averages of all runs by severity and total.
- In X-Y scatter plots by equipment showing the average, standard deviation, and high and low for all passes.
- Bar charts of total average distress showing all participants.
- Bar charts for each vendor that show total distress for repeat passes with time of day identified.
- Two sets of 3-D bar charts by severity level for the LTPP sections; **the first set** of charts show the average of each severity level between equipment and the LTPP rating and **the second set** shows individual passes for each piece of equipment by severity level compared to the LTPP survey.

The PMIS network level simulations provide similar information although the results are presented for all the 150 meters segments. To simulate network level data collection, data is summarized into 750 meter . *"pavement management data collection sections."* The section length is very similar to the PMIS section length in Texas. The PMIS results for all sections are reported:

- In tabular form for each cracking type and are the averages of all runs by total only.
- In X-Y scatter plots by equipment showing the average, standard deviation, and high and low for all passes.
- Bar charts of total average distress showing all participants.

The charts have been displayed to focus as much attention as possible on the information about the equipment. To facilitate this, some bar charts also include text boxes with numbers in them. These numbers represent the manual ratings for those sections. The X-Y scatter charts have three symbols on them. Once again, in the interest of space, no legends are displayed. On the X-Y scatter diagrams, the black squares (■) represent the average of all passes over a particular section, the plus (+) signs show the high and low averages for the pass and the hollow triangles (▵) represent the standard deviation for the passes.

Data Collection and Processing

Each vendor collected at least six passes on all the sections. The exception to this was PASCO who collected only two passes on each section. Either all the data was to be reduced or twenty of the 150-meter segments were to be reported depending upon whether or not the data reduction equipment was considered *"fully automated."* The IMS and Roadware systems were considered fully automated and results were requested by November 19. The Pave Tech and PASCO systems were considered manually assisted and they were asked to provide their results from the twenty 150-meter segments by November 19. The manually assisted vendors were provided the opportunity to complete the remaining sections and submit them to TxDOT by December 19.

IMS - provided data for all 150-meter segments, six passes of the flexible pavement sections and nine passes of the continuously reinforced concrete pavement sections for a total of approximately twelve hundred test sections. As indicated above two of the concrete sections were submitted after the end of the test although it was processed during the week of the test.

PASCO - provided data for two passes each of the twenty 150-meter sections. They supplied the remaining data to TxDOT by December 19.

Pave Tech - provided almost all the data for six passes of the twenty sections. They were unable to complete eight of the 150-meter segment repeat passes. These eight segments were scattered throughout the twenty sections. Pave Tech did provide at least four sets of data for each of the twenty sections. The remaining data for all sections was submitted to TxDOT by December 19.

ROADWARE - provided data for 19 passes of the CRCP sections and three passes of Section D. No other data was submitted for the flexible pavement sections. Roadware explained a problem they had with Wisecrax in its ability to estimate cracking on. rough textured, *surface treated,* pavement surfaces. They declined to submit data for the remaining passes from Section D and all of Sections A and B.

SIMULATED CRACKING

An aluminum template with a cut in it the shape of a crack was borrowed from the Texas Transportation Institute. This template had been used in TxDOT sponsored projects to estimate the resolution of an automated crack identification system under development at TTI.

Cracks were painted with black paint at the end of Section B to simulate both transverse and longitudinal cracks. The purpose of painting these cracks was not to evaluate the adequacy of algorithms or raters. Instead it was done to estimate the resolution of the camera / recording system. The cracks varied in width from approximately two to ten millimeters. The tapes and film were then manually reviewed to see what the minimum resolution was for each system. All video and film systems showed visible results at the two millimeter crack width. It should not be assumed that the minimum crack resolution available from the equipment is two millimeters as there are many processing steps between the video or film and final product. Rather, this provides the reader with an indication of how small a crack was visible on the recording media. Additionally, paint marks smaller than two millimeters could not be painted on the pavement as the project team did attempt thinner lines.

CONCLUDING REMARK

The purpose of this report is to present quantitative data and objective information so each individual reader can form their own opinions. This report does not contain subjective conclusions, opinions, or ratings, because pavement condition data needs are different for individual highway agencies.

FUTURE TESTING

This test is intended as a starting point to help pavement management engineers better understand this new and evolving technology. Because of the project's complexity, it is not practical or feasible to make this test all inclusive or conclusive.

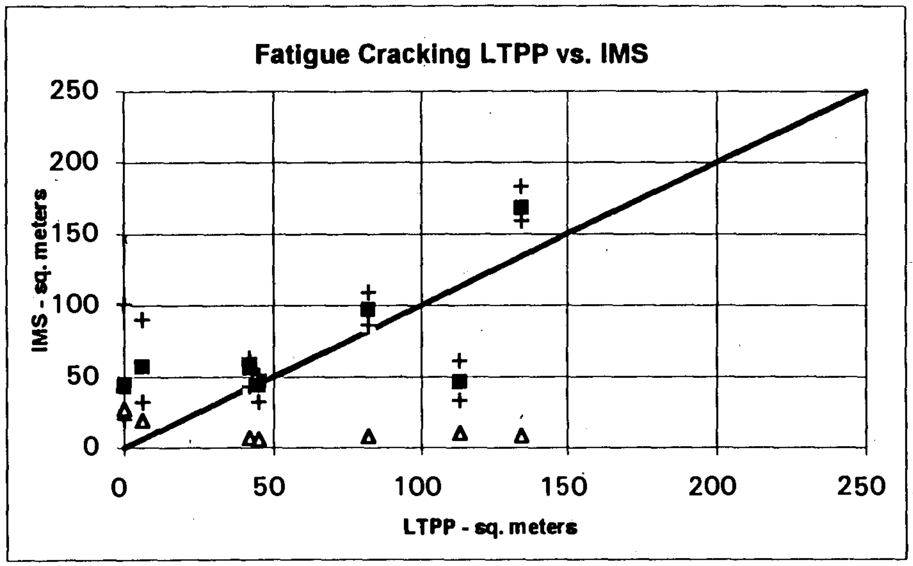
The FHWA will continue to monitor the equipment's technological advancements and conduct tests as new improvements are announced.

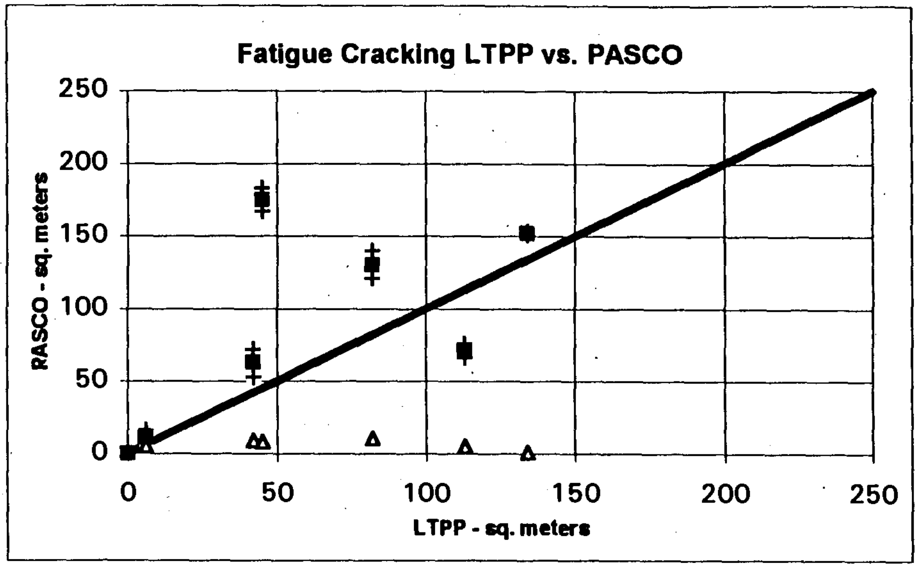
Pavement management engineers are encouraged to contact the equipment companies for additional information and to consider a personal demonstration on your particular pavement types and surfaces.

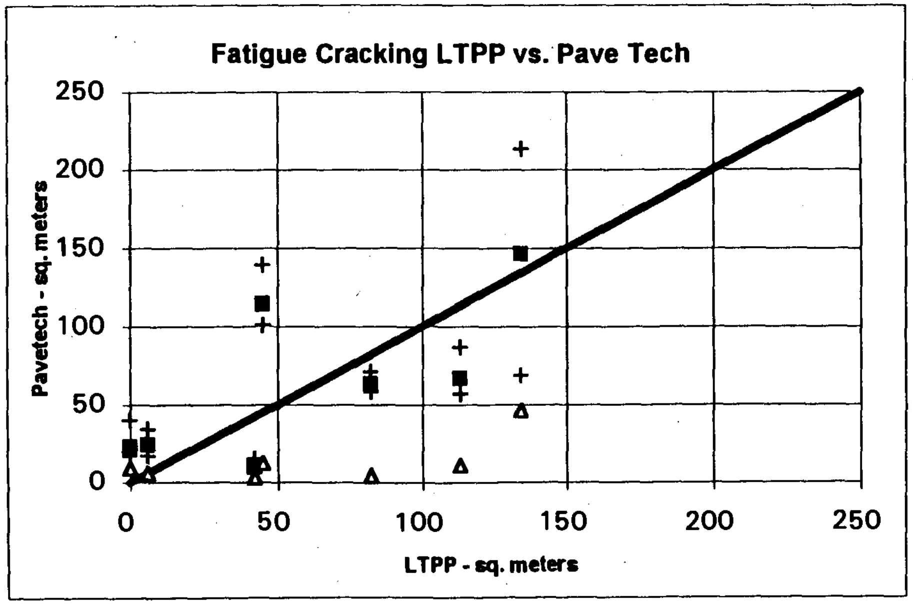
TABLES AND CHARTS

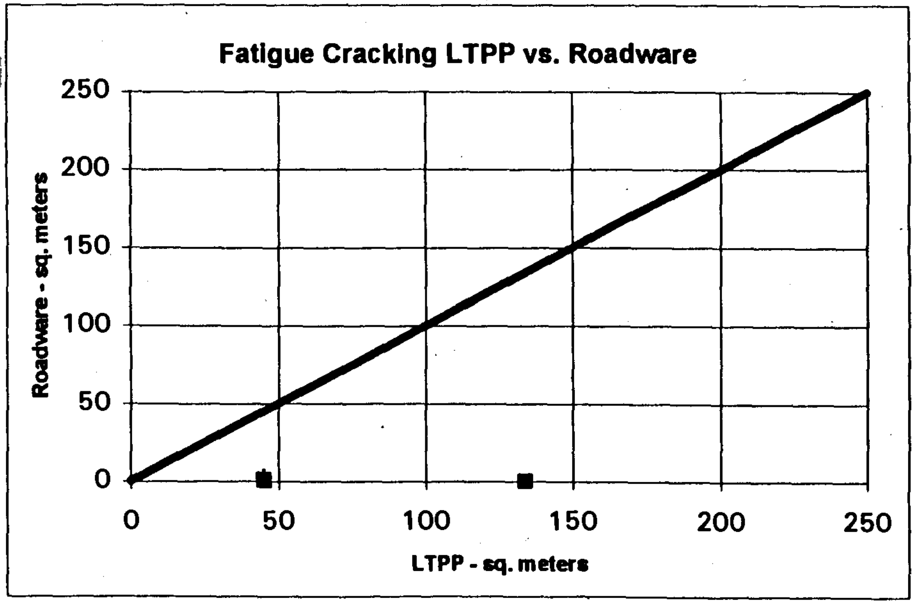
LTPP TABLES

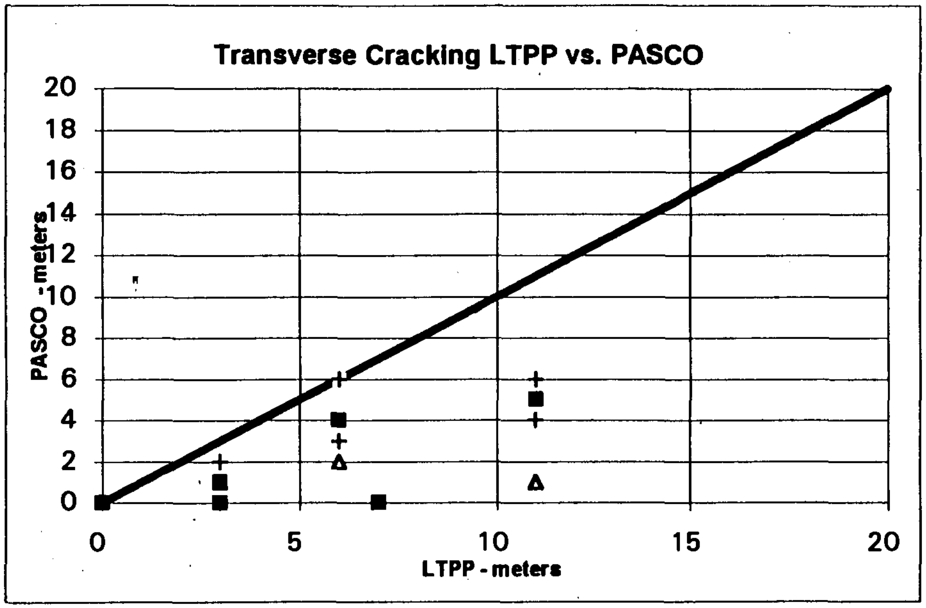
LTPP X - Y Plots

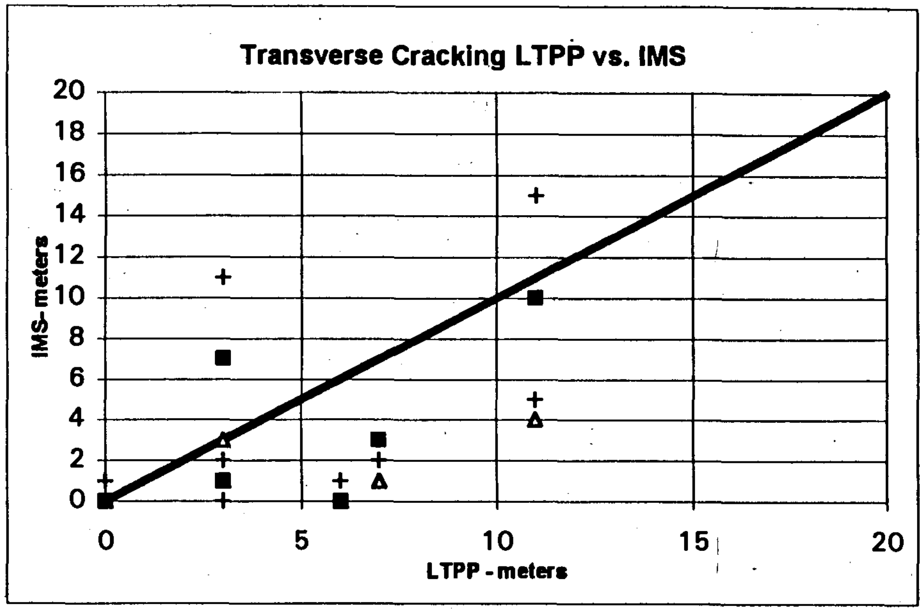

Fatigue Cracking LTPP vs. IMS
IMS - sq. meters
LTPP - sq. meters
0
50
100
150
200
250

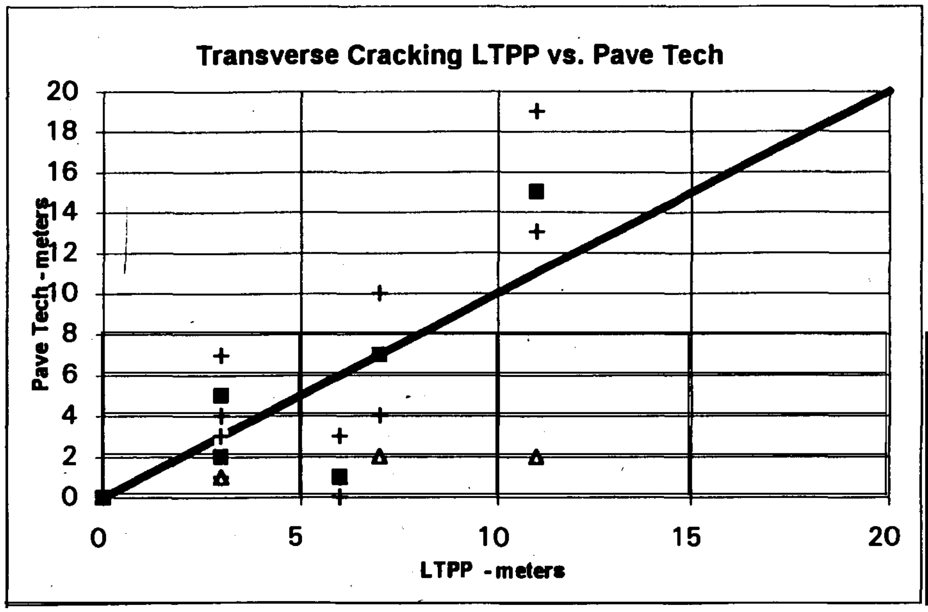

Fatigue Cracking LTPP vs. PASCO
PASCO - sq. meters
LTPP - sq. meters
0
50
100
150
200
250

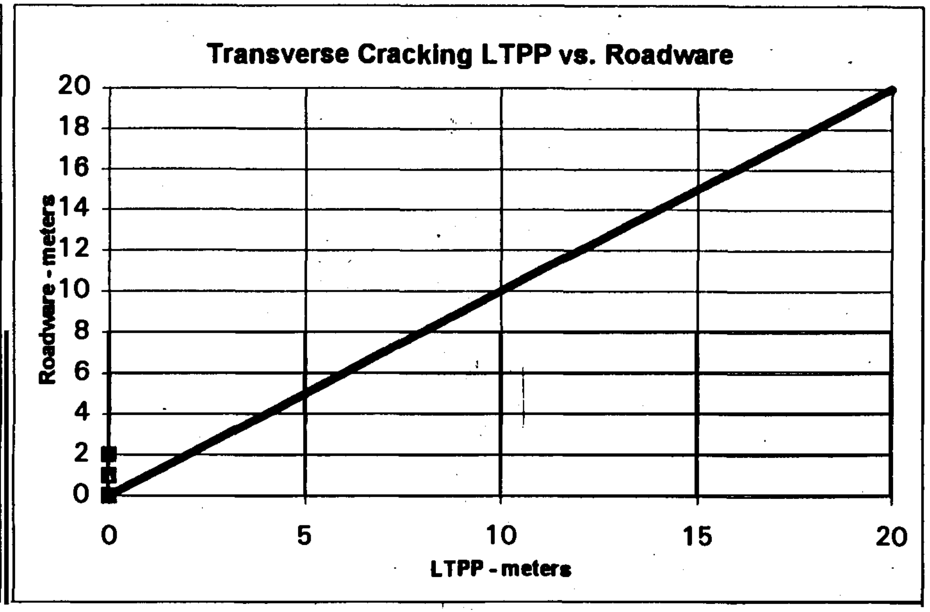

Fatigue Cracking LTPP vs. Pave Tech
Pavetech - sq. meters
LTPP - sq. meters
0
50
100
150
200
250

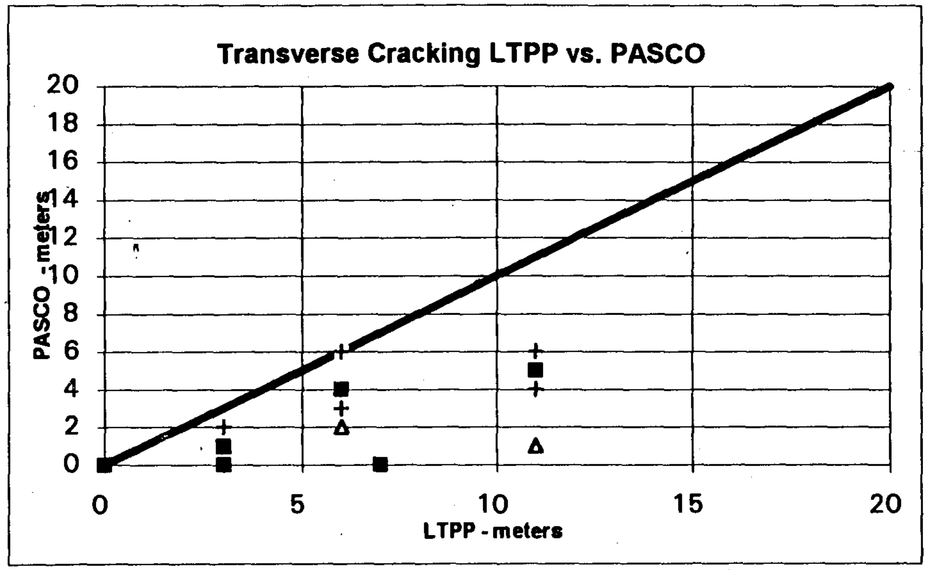

Fatigue Cracking LTPP vs. Roadware
Roadware - sq. meters
LTPP - sq. meters
0
50
100
150
200
250


Transverse Cracking LTPP vs. PASCO
PASCO - meters
LTPP - meters
0
2
4
6
8
10
12
14
16
18
20
0
5
10
15
20

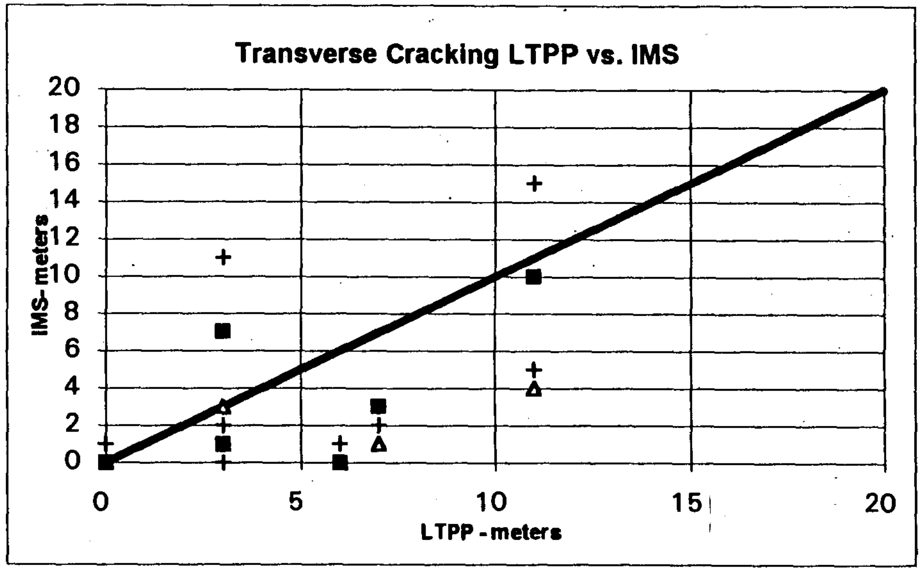

Transverse Cracking LTPP vs. IMS
IMS - meters
LTPP - meters
0
2
4
6
8
10
12
14
16
18
20
0
5
10
15
20


Transverse Cracking LTPP vs. Pave Tech
Pave Tech - meters
LTPP - meters
0
2
4
6
8
10
12
14
16
18
20
0
5
10
15
20

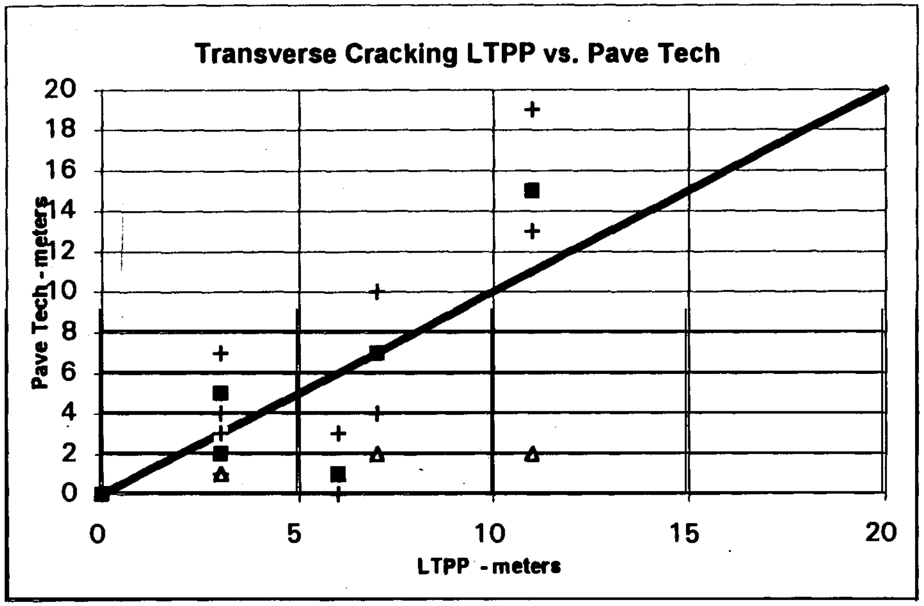

Transverse Cracking LTPP vs. Roadware
Roadware - meters
LTPP - meters
0
2
4
6
8
10
12
14
16
18
20
0
5
10
15
20



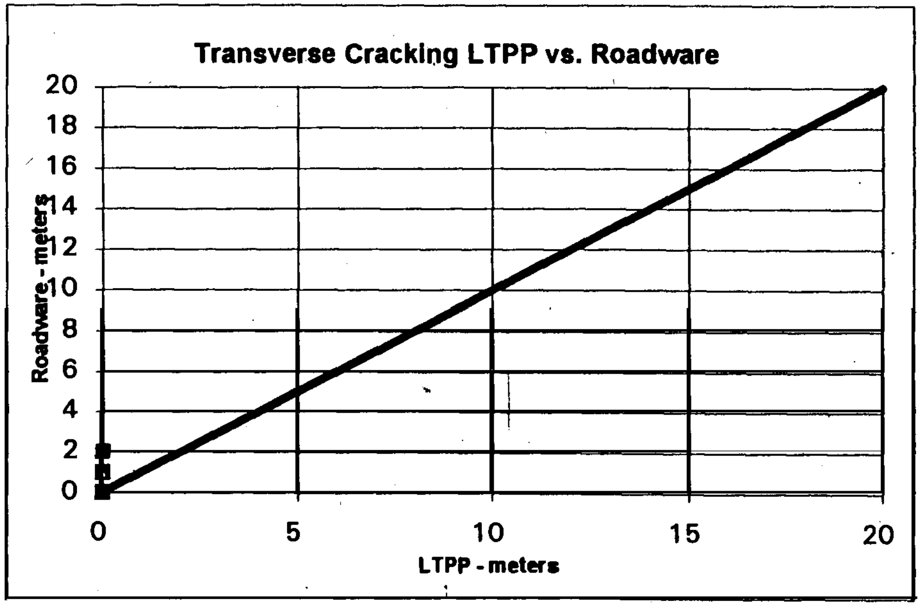
Transverse Cracking LTPP vs. PASCO
PASCO - meters
LTPP - meters



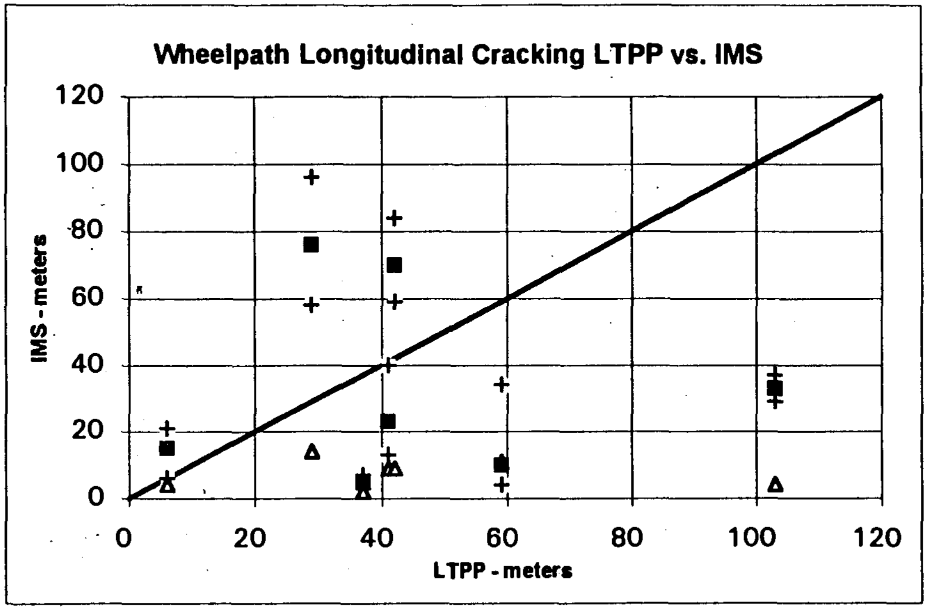
Transverse Cracking LTPP vs. IMS
IMS- meters
LTPP - meters

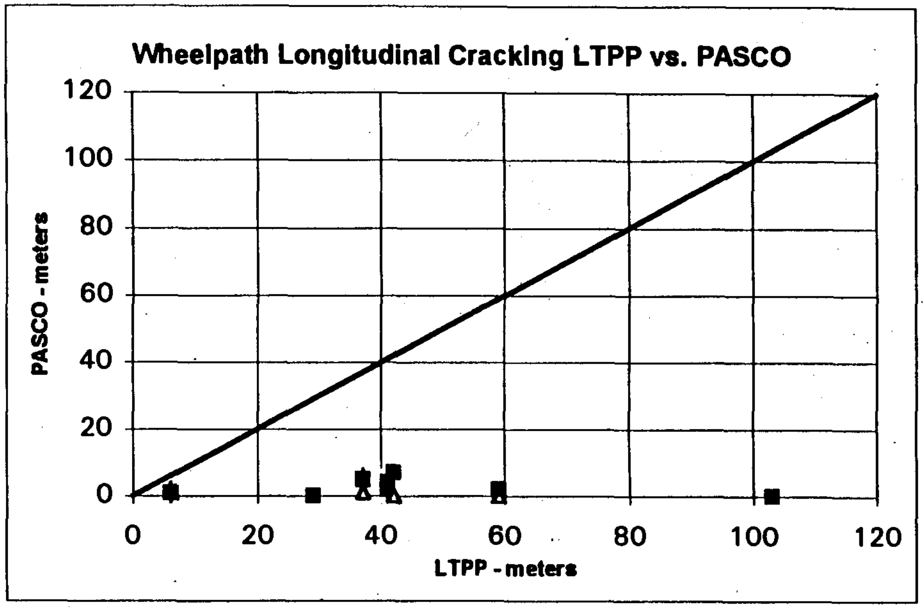


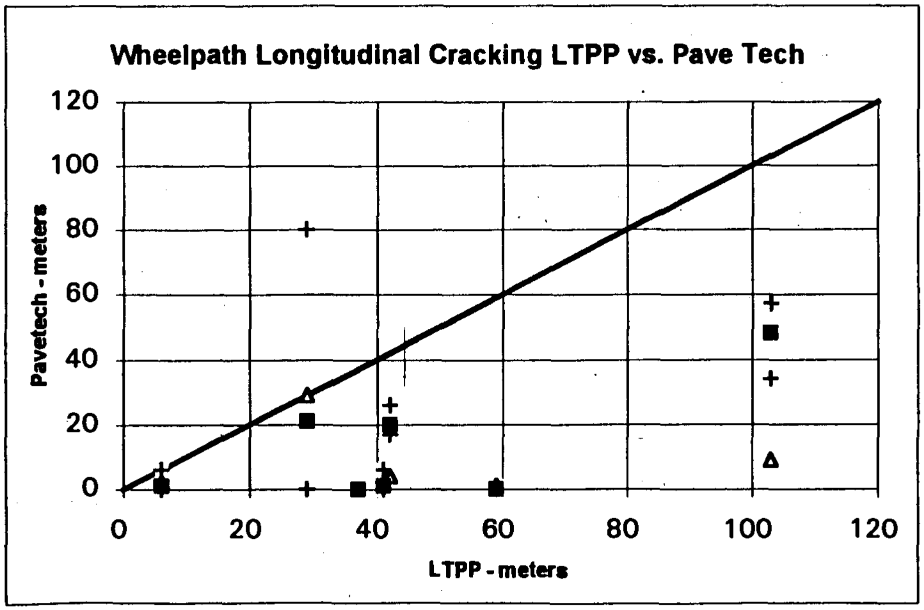
Transverse Cracking LTPP vs. Pave Tech
Pave Tech - meters
LTPP - meters

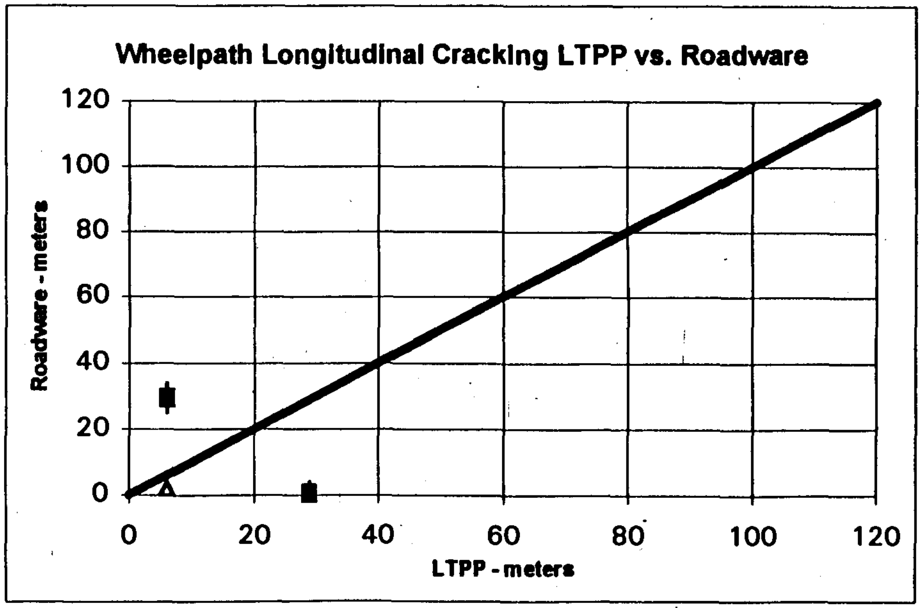


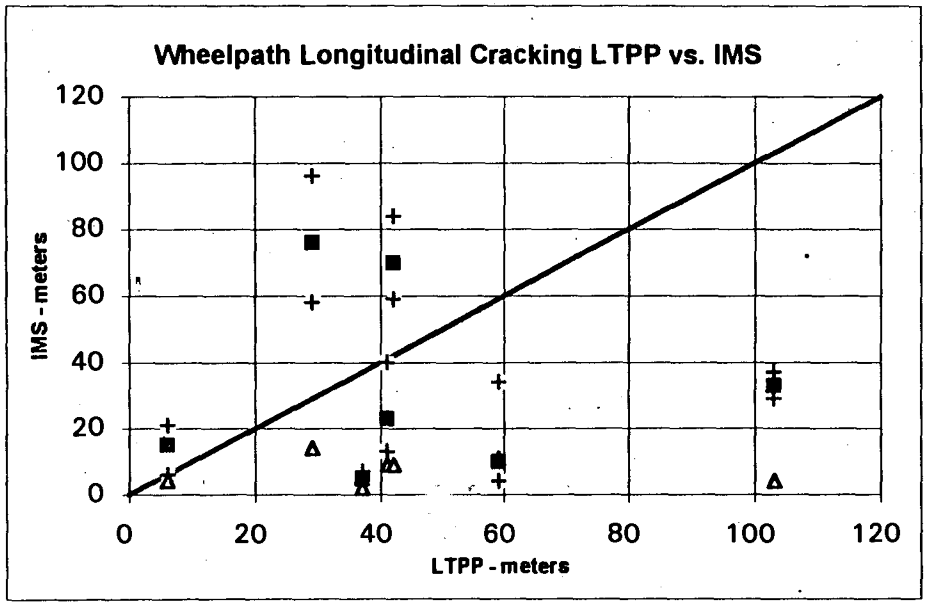
Transverse Cracking LTPP vs. Roadware
Roadware - meters
LTPP - meters

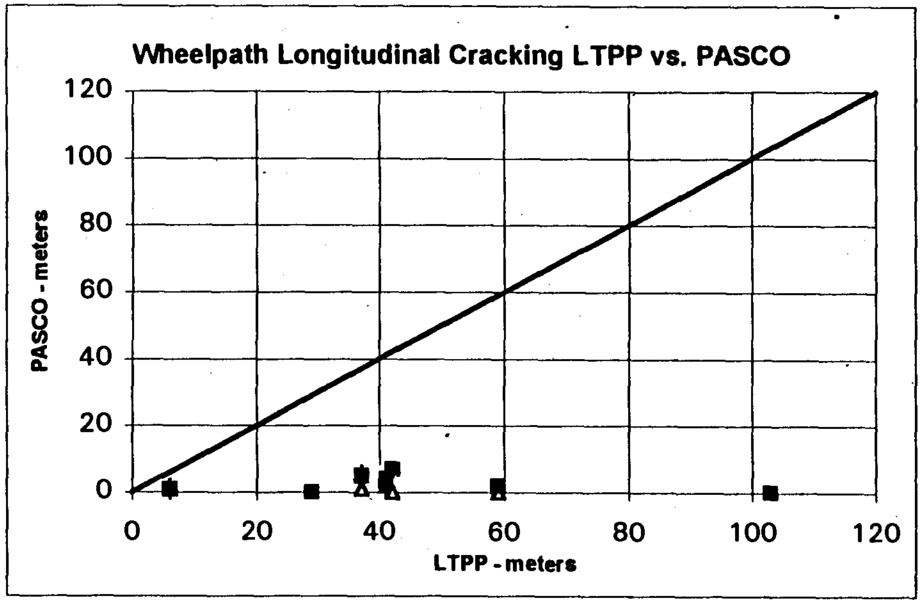

Wheelpath Longitudinal Cracking LTPP vs. IMS
IMS - meters
LTPP - meters
0
20
40
60
80
100
120

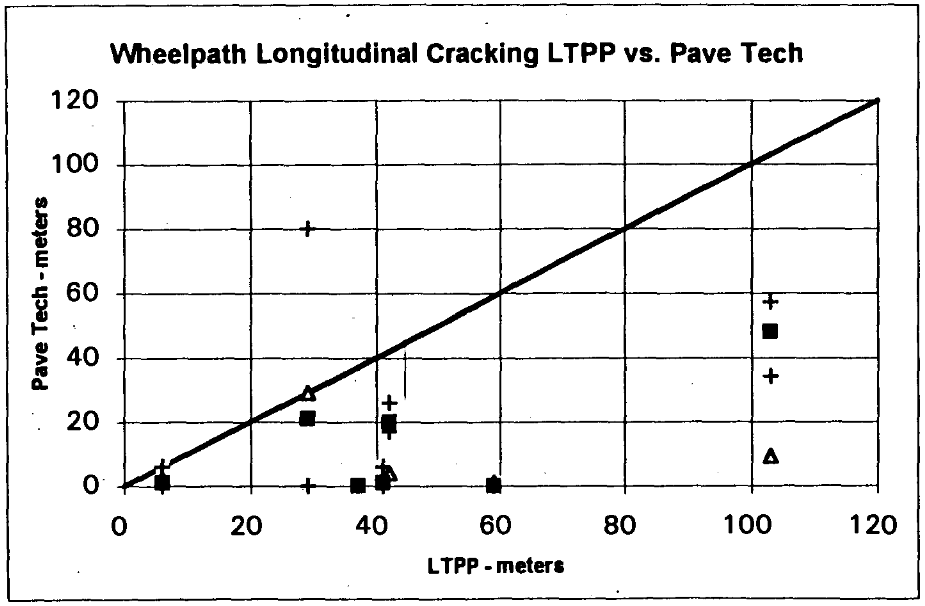

Wheelpath Longitudinal Cracking LTPP vs. PASCO
PASCO - meters
LTPP - meters
0
20
40
60
80
100
120

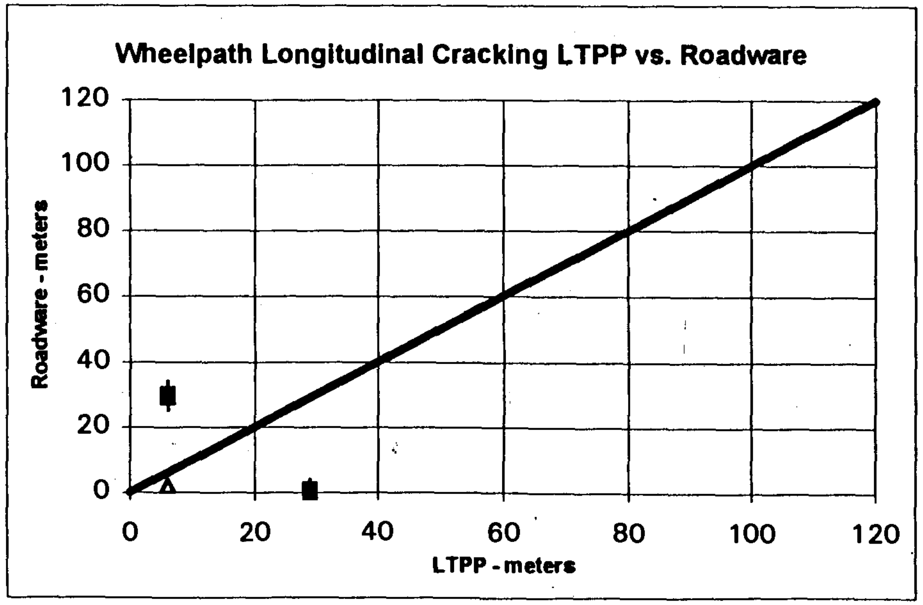

Wheelpath Longitudinal Cracking LTPP vs. Pave Tech
Pavetech - meters
LTPP - meters
0
20
40
60
80
100
120

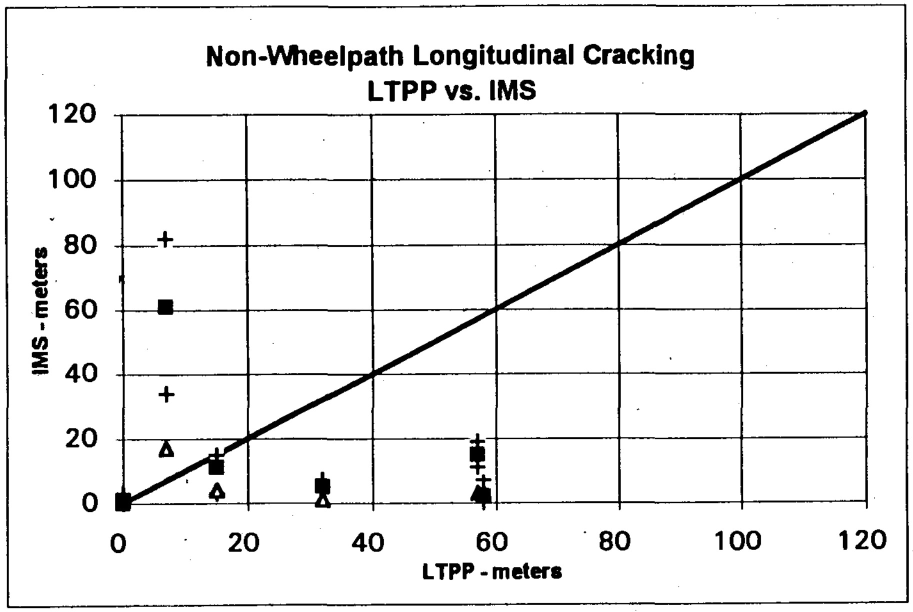

Wheelpath Longitudinal Cracking LTPP vs. Roadware
Roadware - meters
LTPP - meters
0
20
40
60
80
100
120

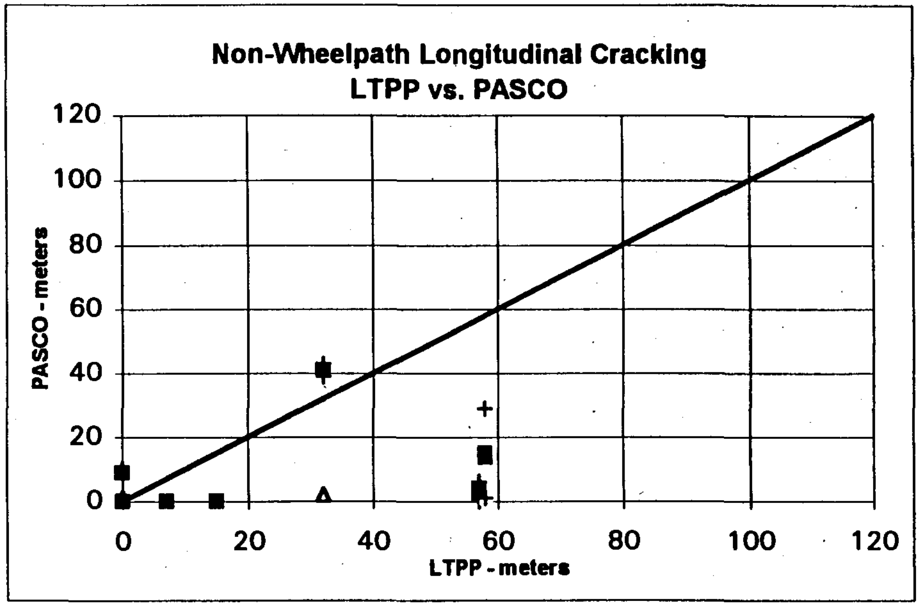

Wheelpath Longitudinal Cracking LTPP vs. IMS
IMS - meters
LTPP - meters
0
20
40
60
80
100
120

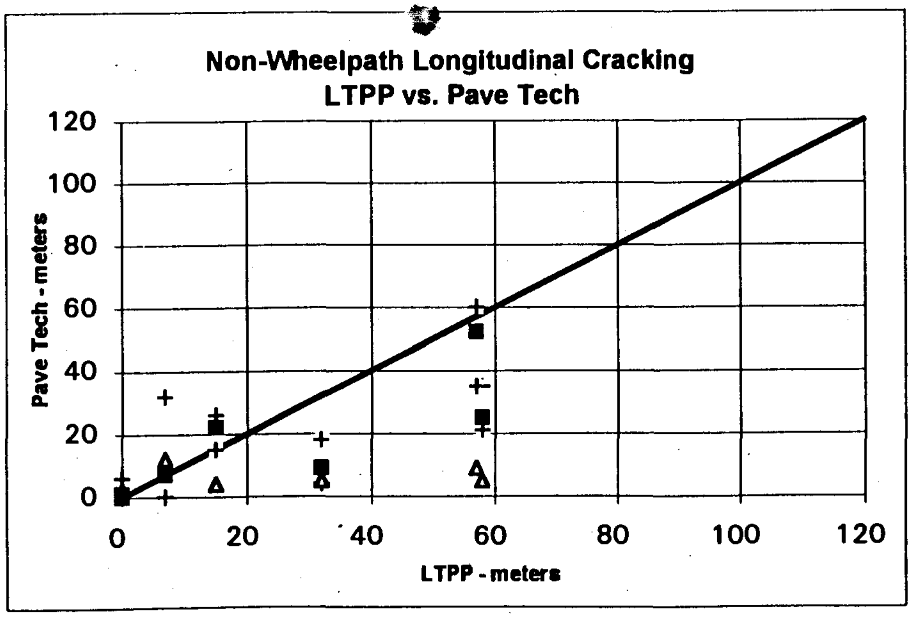

Wheelpath Longitudinal Cracking LTPP vs. PASCO
PASCO - meters
LTPP - meters
0
20
40
60
80
100
120

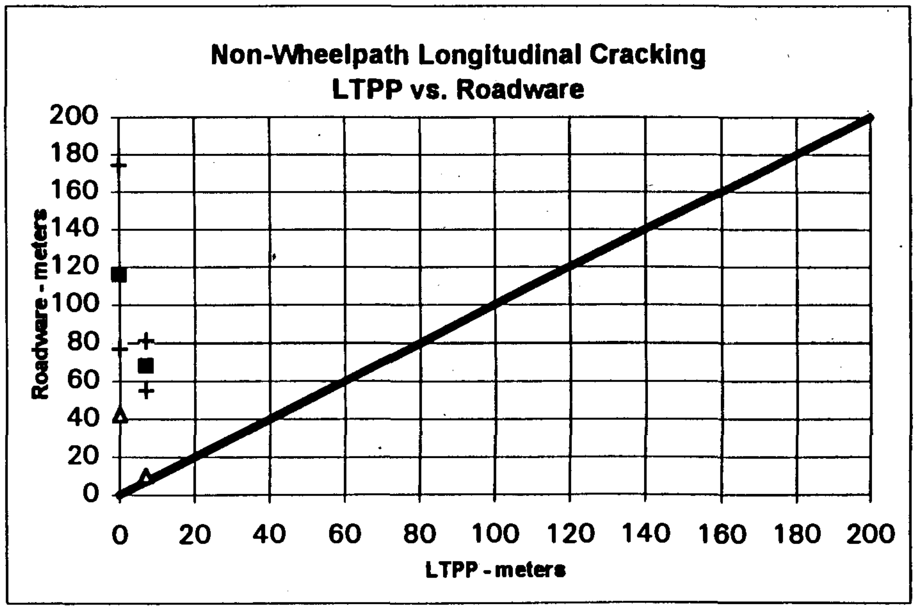

Wheelpath Longitudinal Cracking LTPP vs. Pave Tech
Pave Tech - meters
LTPP - meters
0
20
40
60
80
100
120

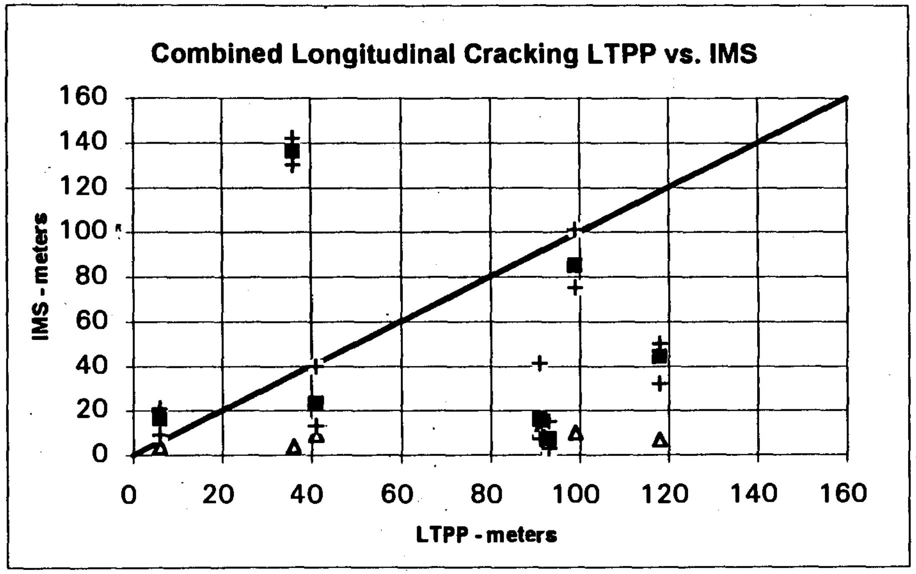

Wheelpath Longitudinal Cracking LTPP vs. Roadware
Roadware - meters
LTPP - meters
0
20
40
60
80
100
120

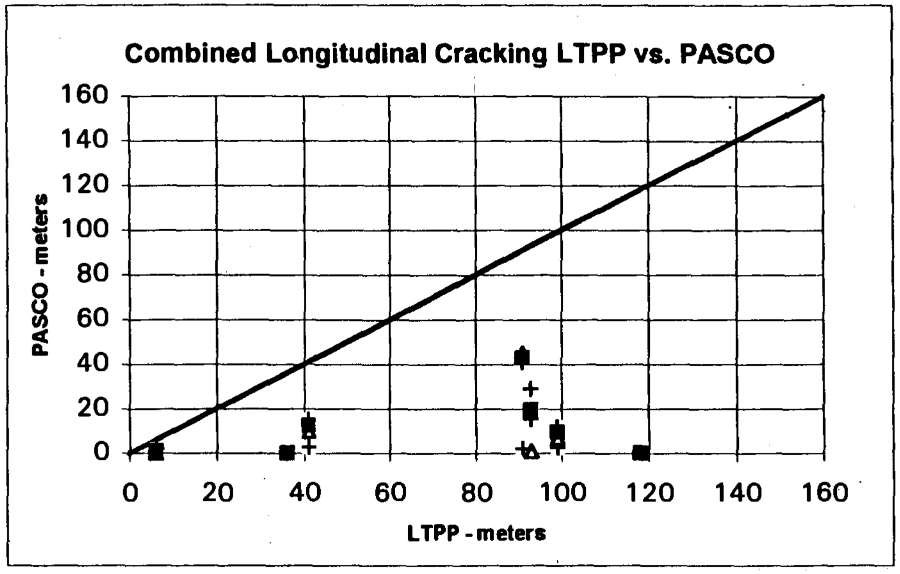

Non-Wheelpath Longitudinal Cracking
LTPP vs. IMS
IMS - meters
LTPP - meters
0
20
40
60
80
100
120

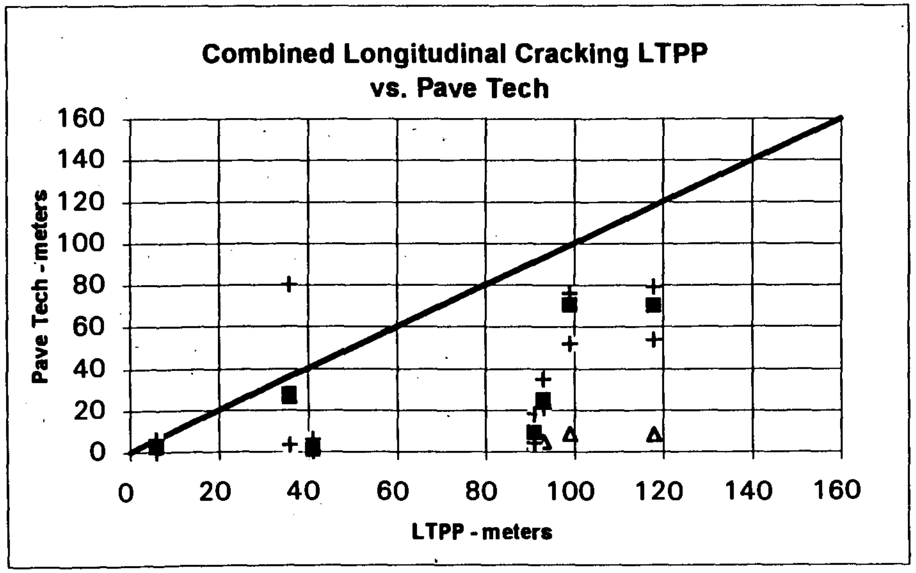

Non-Wheelpath Longitudinal Cracking
LTPP vs. PASCO
PASCO - meters
LTPP - meters
0
20
40
60
80
100
120

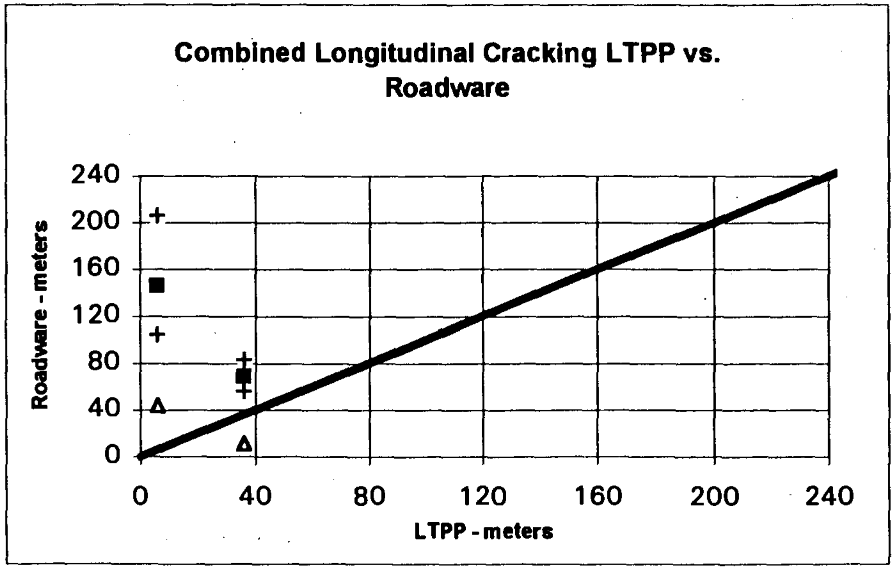

Non-Wheelpath Longitudinal Cracking
LTPP vs. Pave Tech
Pave Tech - meters
LTPP - meters
0
20
40
60
80
100
120

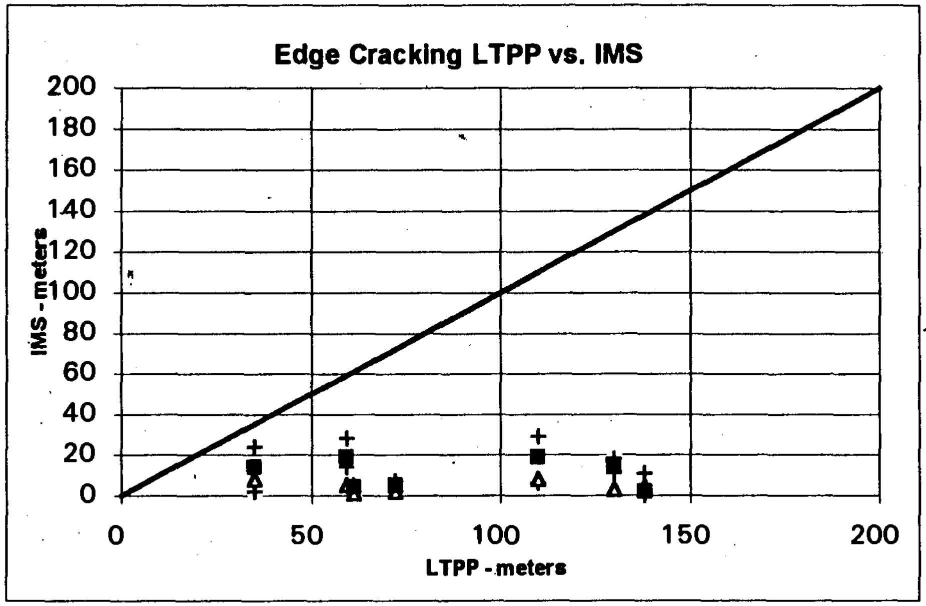

Non-Wheelpath Longitudinal Cracking
LTPP vs. Roadware
Roadware - meters
LTPP - meters
0
20
40
60
80
100
120
140
160
180
200

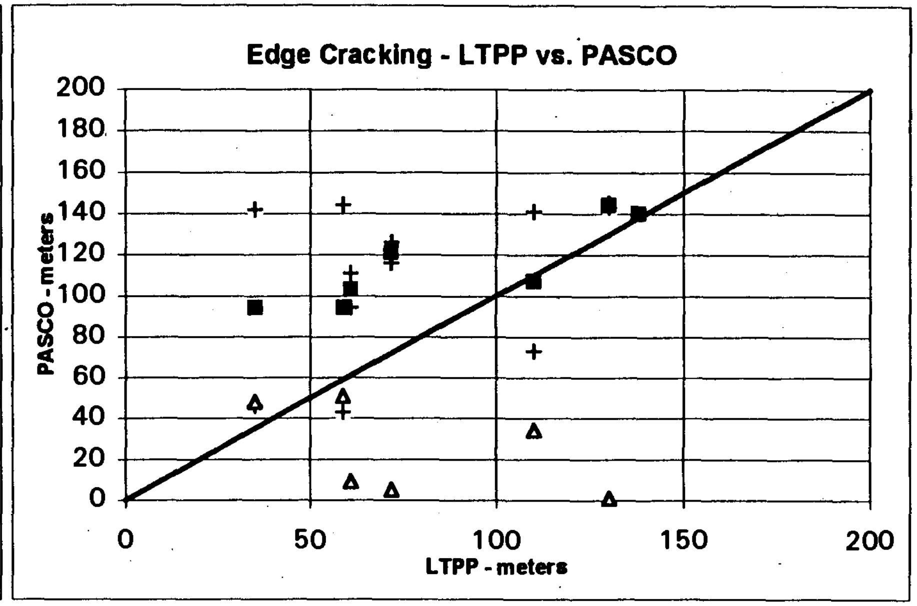

Combined Longitudinal Cracking LTPP vs. IMS
IMS - meters
LTPP - meters
0
20
40
60
80
100
120
140
160

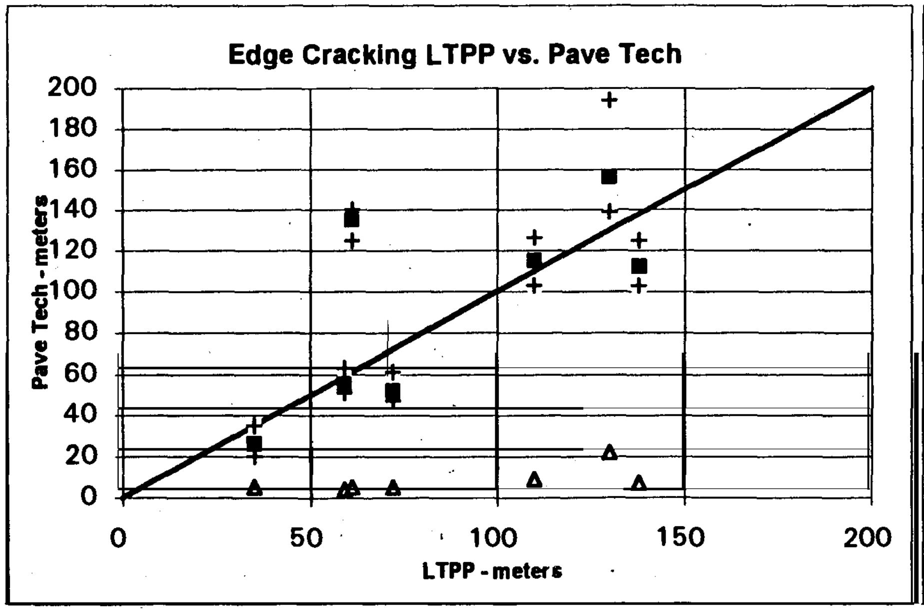

Combined Longitudinal Cracking LTPP vs. PASCO
PASCO - meters
LTPP - meters
0
20
40
60
80
100
120
140
160

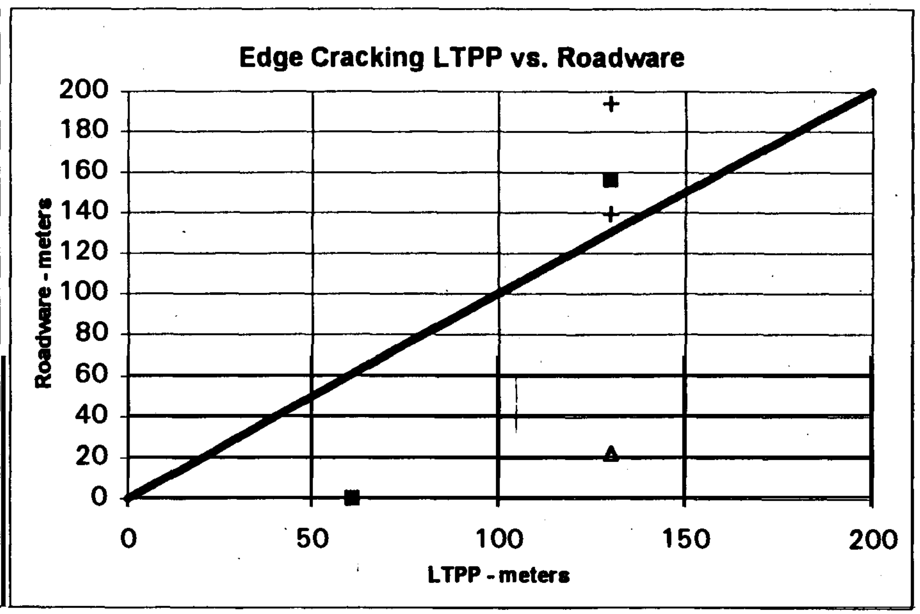

Combined Longitudinal Cracking LTPP vs. Pave Tech
Pave Tech - meters
LTPP - meters
0
20
40
60
80
100
120
140
160

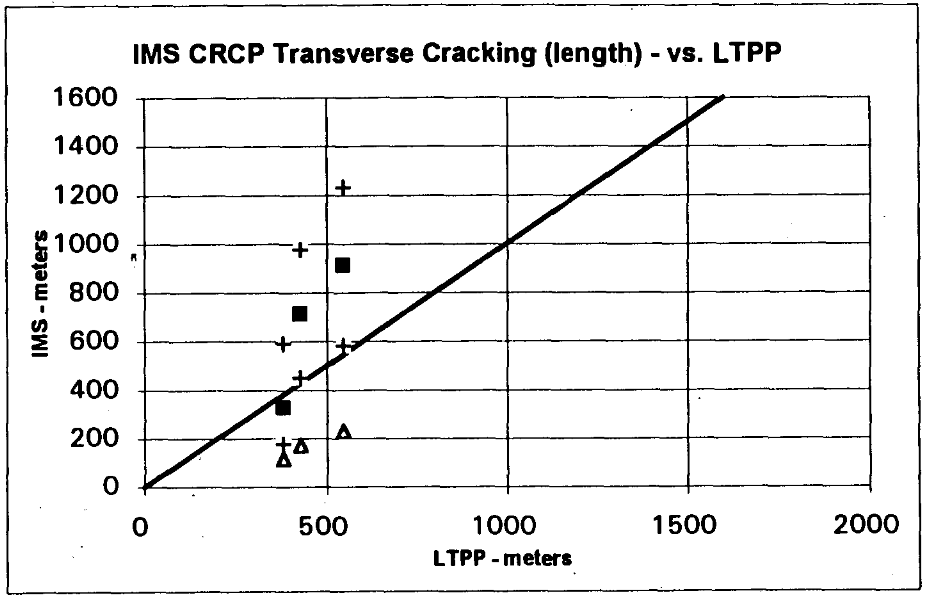

Combined Longitudinal Cracking LTPP vs. Roadware
Roadware - meters
LTPP - meters
0
40
80
120
160
200
240

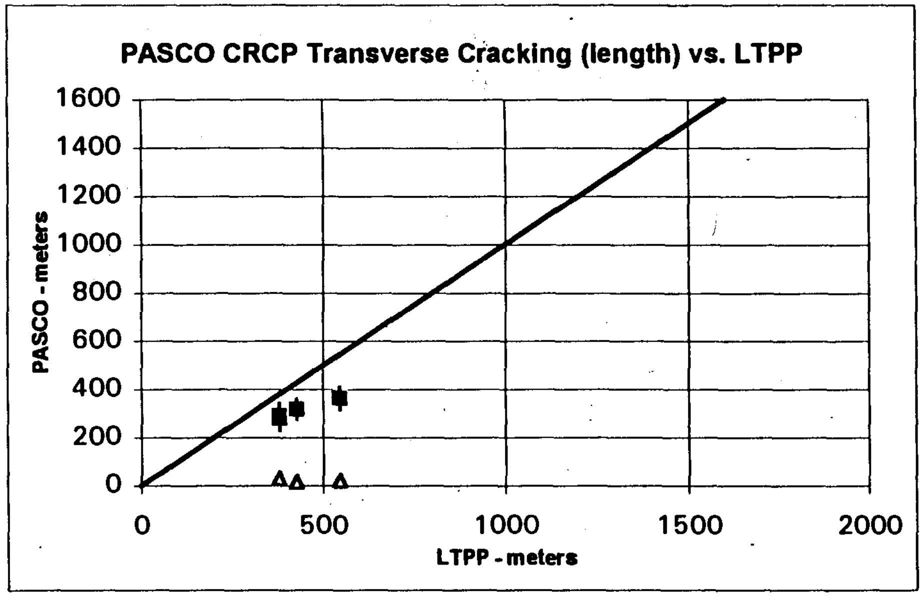

Edge Cracking LTPP vs. IMS
IMS - meters
LTPP - meters
0
20
40
60
80
100
120
140
160
180
200
50
150

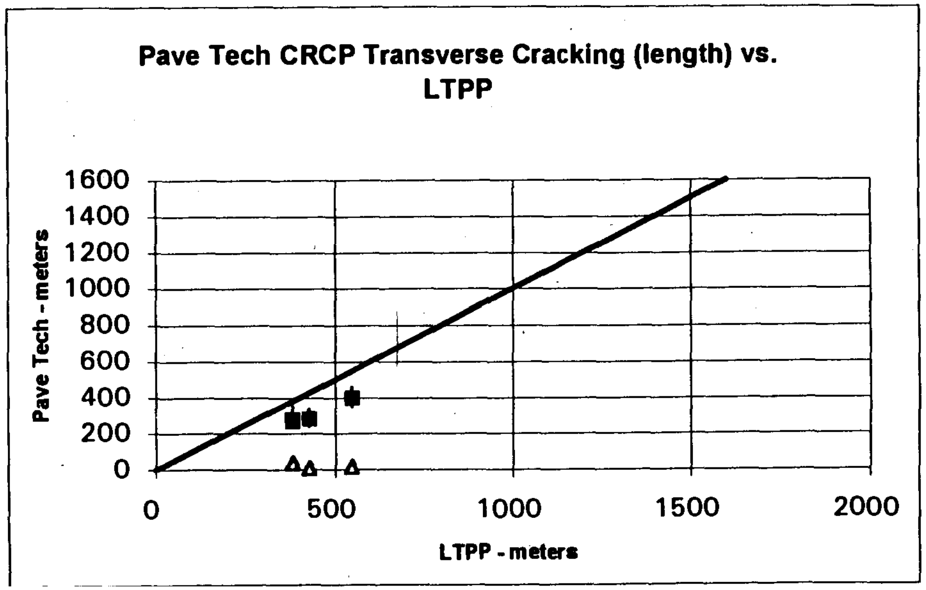

Edge Cracking - LTPP vs. PASCO
PASCO - meters
LTPP - meters
0
20
40
60
80
100
120
140
160
180
200
50
150

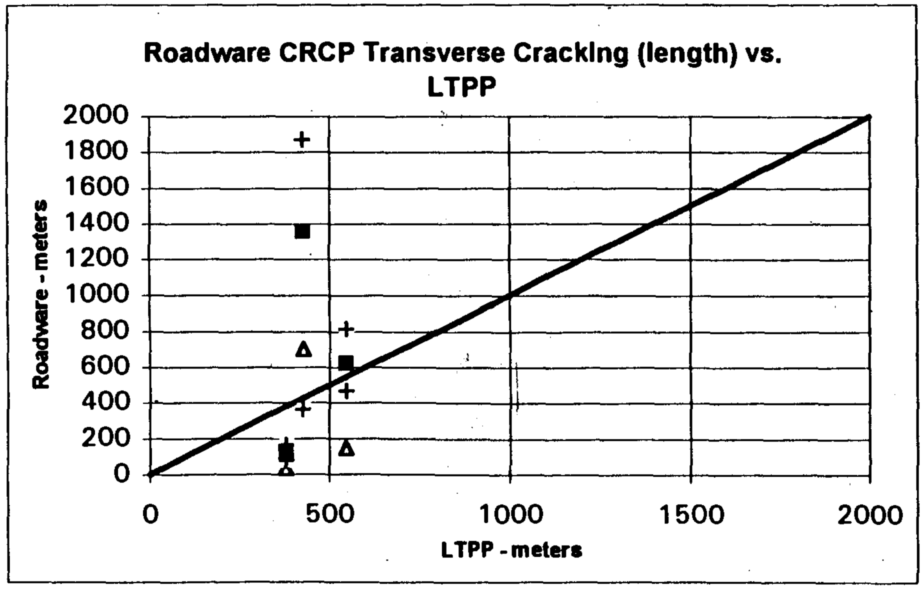

Edge Cracking LTPP vs. Pave Tech
Pave Tech - meters
LTPP - meters
0
20
40
60
80
100
120
140
160
180
200
50
150

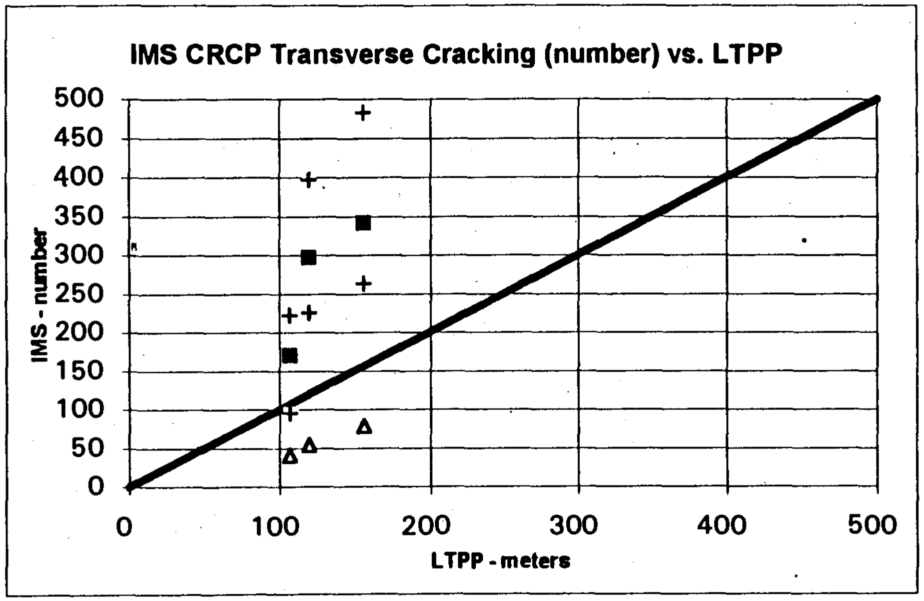

Edge Cracking LTPP vs. Roadware
Roadware - meters
LTPP - meters
0
20
40
60
80
100
120
140
160
180
200
50
150


IMS CRCP Transverse Cracking (length) - vs. LTPP
IMS - meters
LTPP - meters
0
200
400
600
800
1000
1200
1400
1600
500
1000
1500
2000

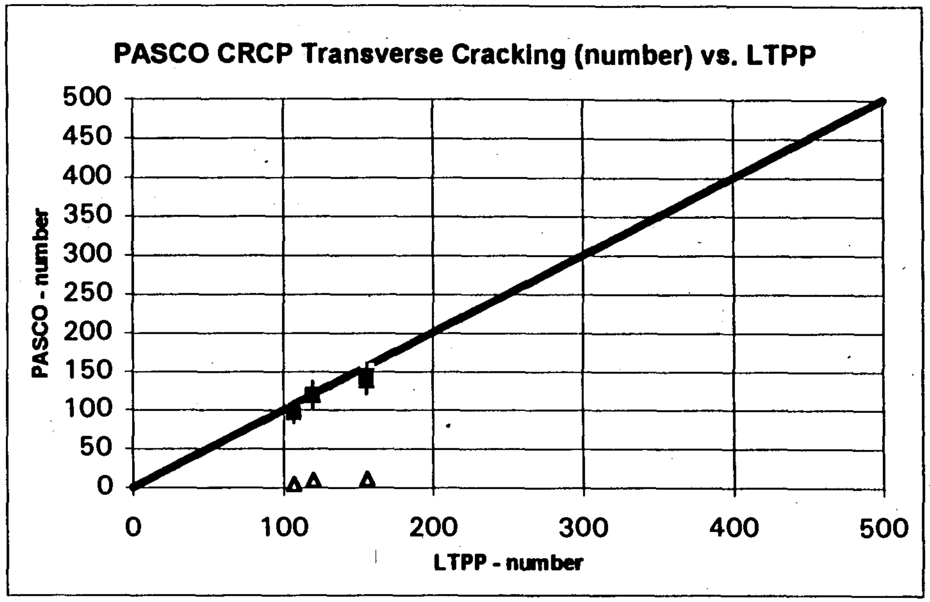

PASCO CRCP Transverse Cracking (length) vs. LTPP
PASCO - meters
LTPP - meters
0
200
400
600
800
1000
1200
1400
1600
500
1000
1500
2000


Pave Tech CRCP Transverse Cracking (length) vs. LTPP
Pave Tech - meters
LTPP - meters
0
200
400
600
800
1000
1200
1400
1600
500
1000
1500
2000

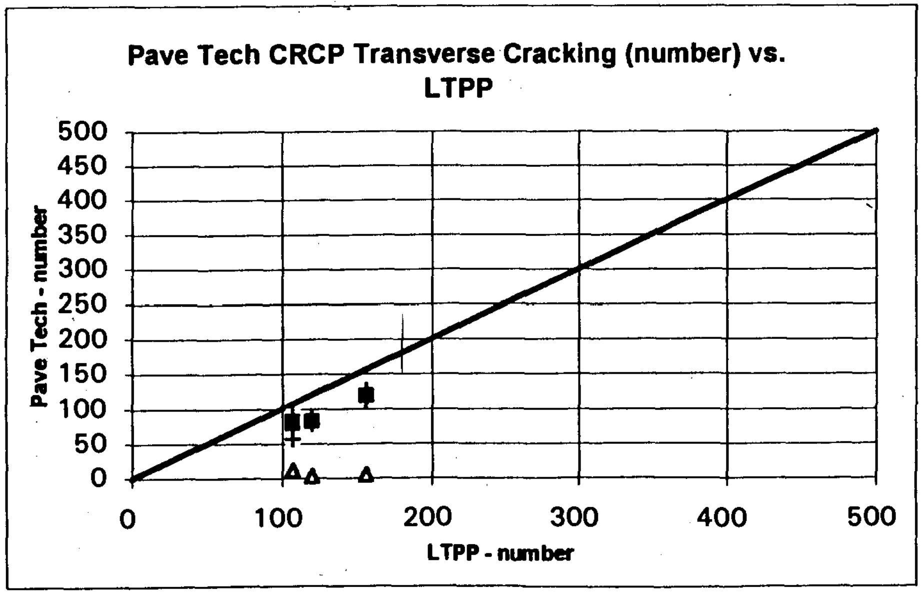

Roadware CRCP Transverse Cracking (length) vs. LTPP
Roadware - meters
LTPP - meters
0
200
400
600
800
1000
1200
1400
1600
1800
2000
500
1000
1500



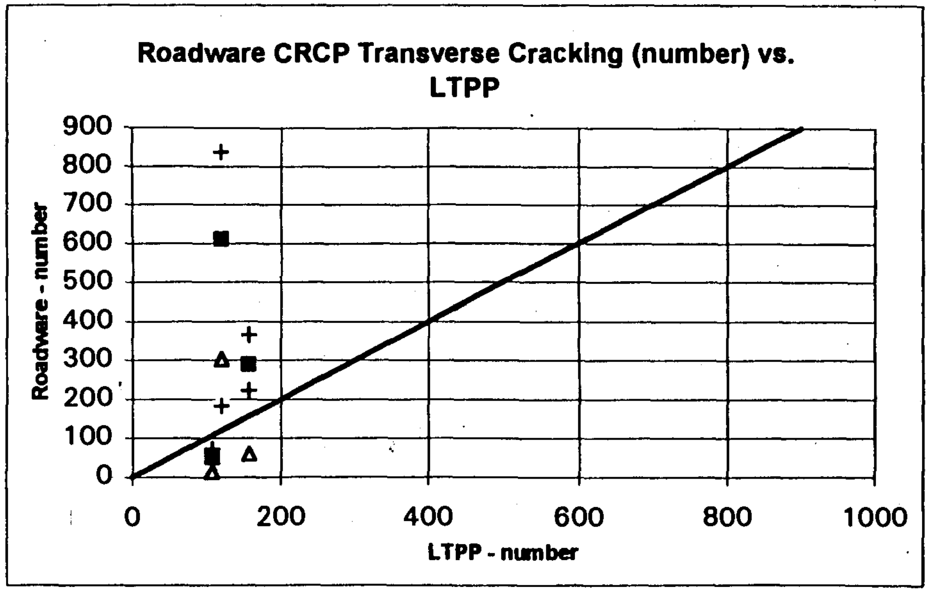
IMS CRCP Transverse Cracking (number) vs. LTPP
IMS - number
LTPP - meters
0
100
200
300
400
500
50
150
250
350
450



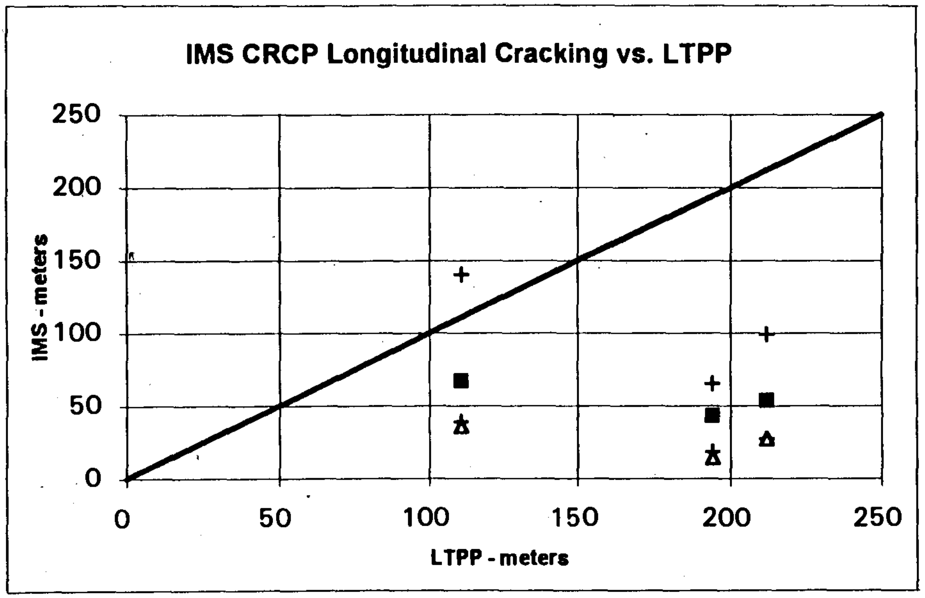
PASCO CRCP Transverse Cracking (number) vs. LTPP
PASCO - number
LTPP - number
0
100
200
300
400
500
50
150
250
350
450

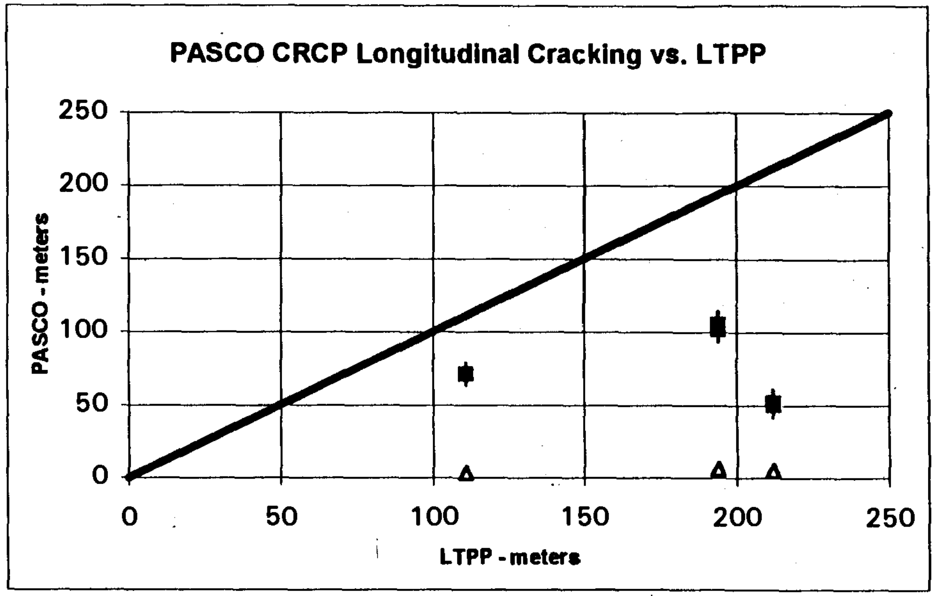


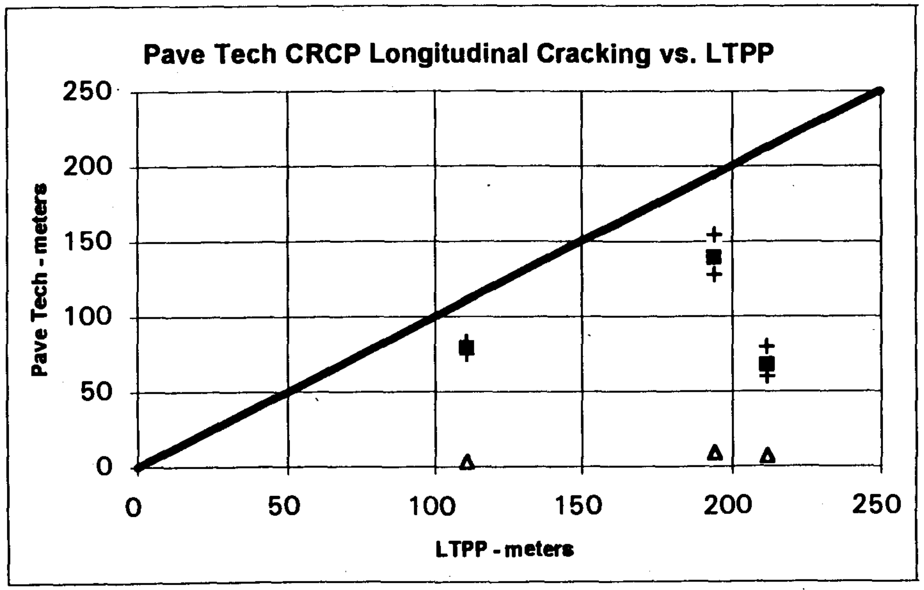
Pave Tech CRCP Transverse Cracking (number) vs. LTPP
Pave Tech - number
LTPP - number
0
100
200
300
400
500
50
150
250
350
450

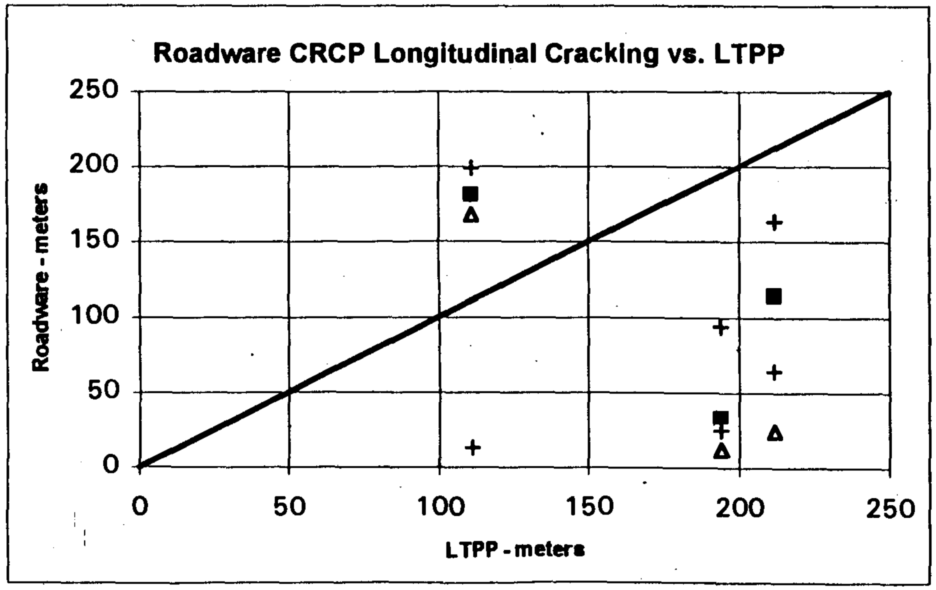


Roadware CRCP Transverse Cracking (number) vs. LTPP
Roadware - number
LTPP - number
0
100
200
300
400
500
600
700
800
900
1000

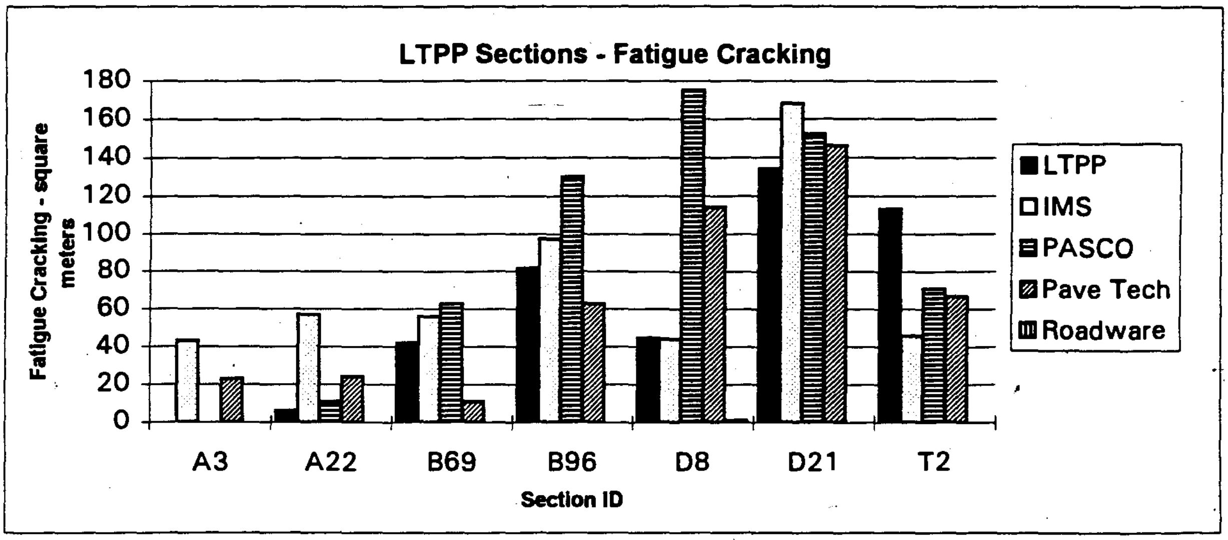

IMS CRCP Longitudinal Cracking vs. LTPP
IMS - meters
LTPP - meters
0
50
100
150
200
250


PASCO CRCP Longitudinal Cracking vs. LTPP
PASCO - meters
LTPP - meters
0
50
100
150
200
250

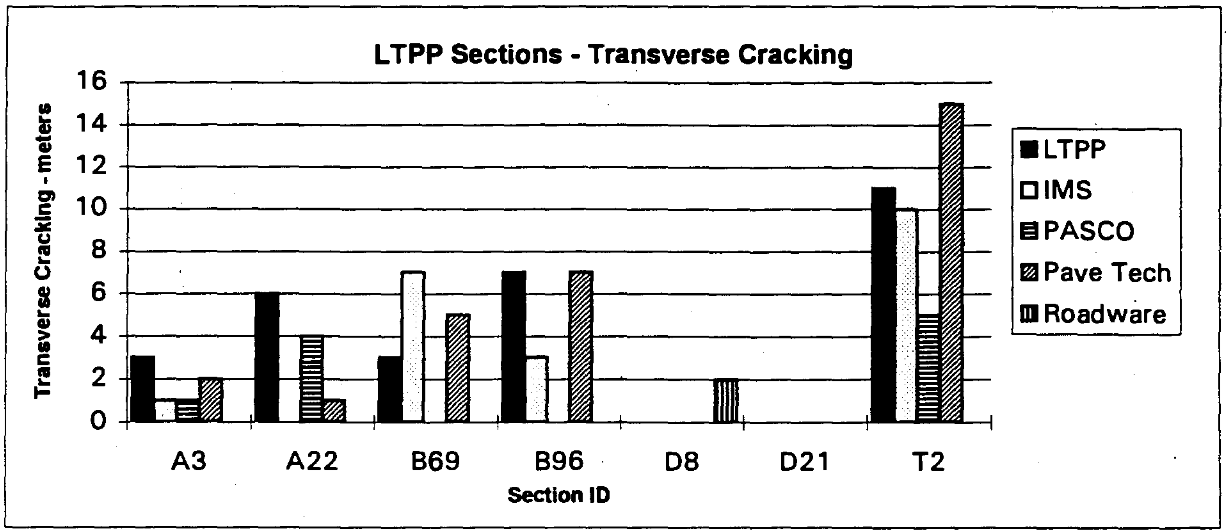

Pave Tech CRCP Longitudinal Cracking vs. LTPP
Pave Tech - meters
LTPP - meters
0
50
100
150
200
250


Roadware CRCP Longitudinal Cracking vs. LTPP
Roadware - meters
LTPP - meters
0
50
100
150
200
250

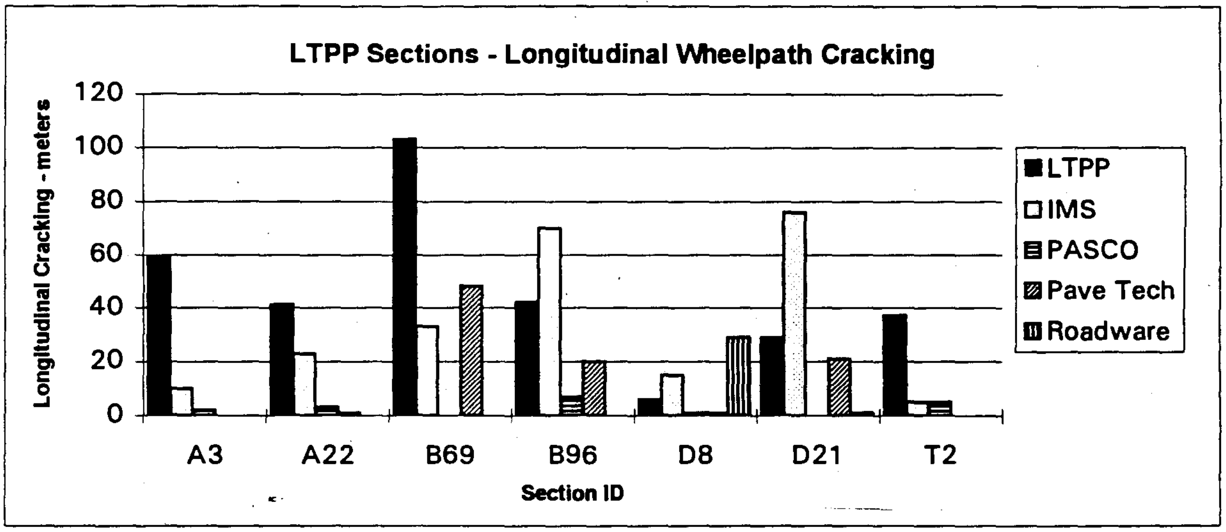
LTPP Bar Charts



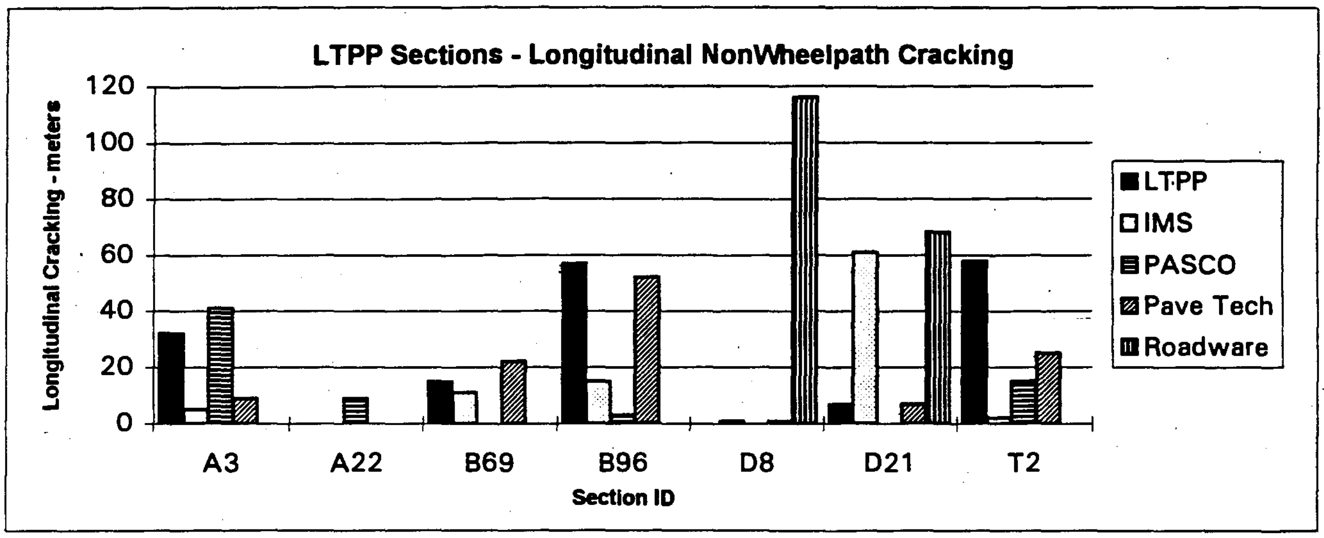
LTPP Sections - Fatigue Cracking
Fatigue Cracking - square meters
180
160
140
120
100
80
60
40
20
0
A3
A22
B69
B96
D8
D21
T2
Section ID
LTPP
IMS
PASCO
Pave Tech
Roadware

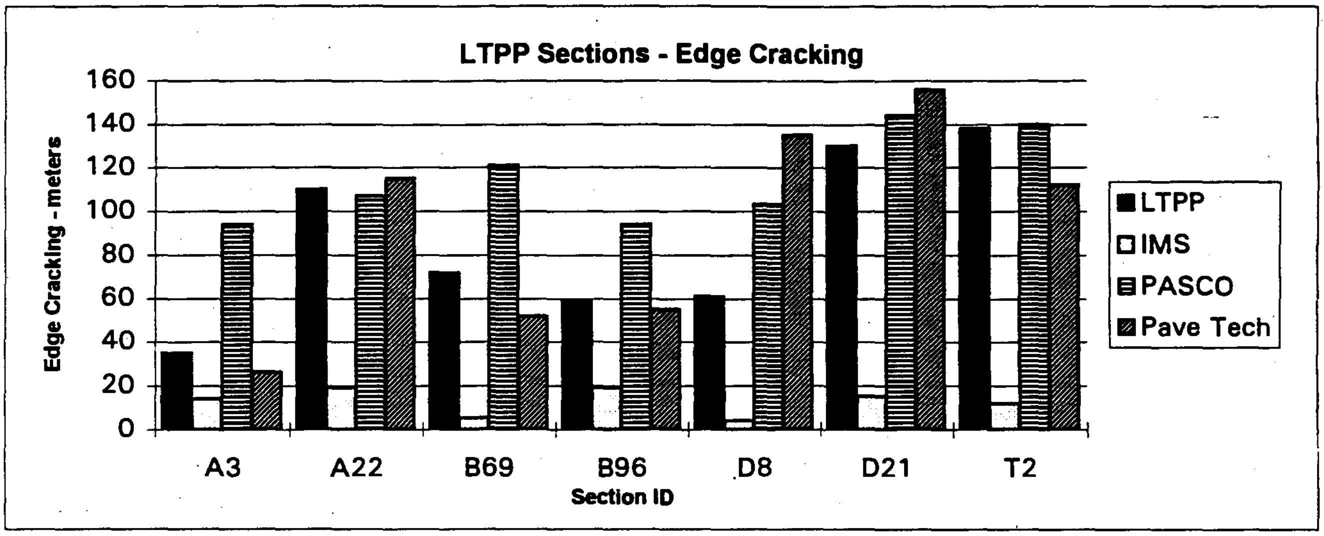


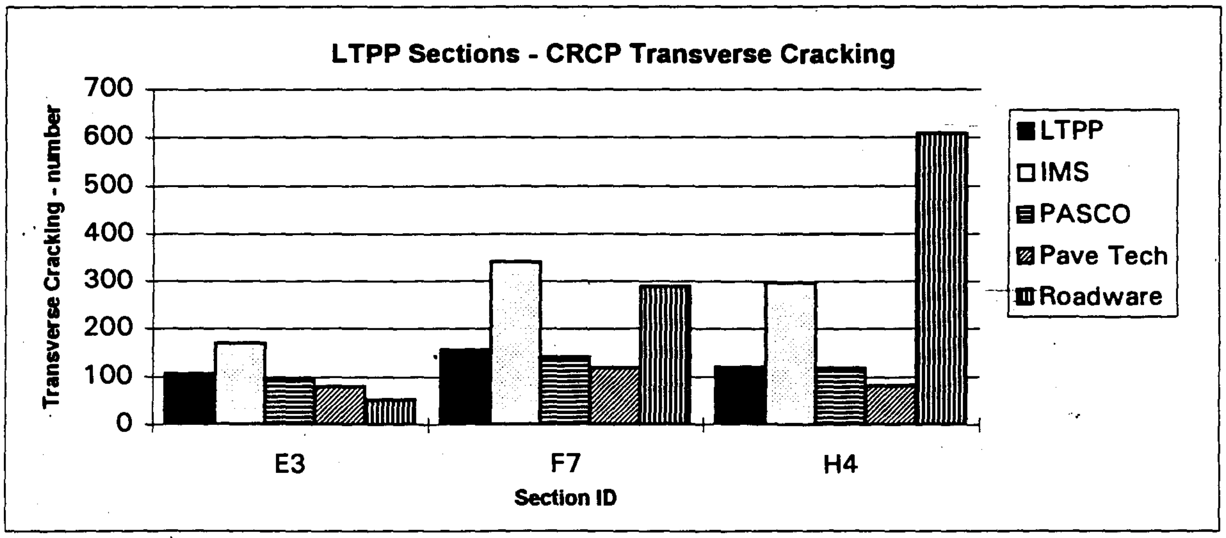
LTPP Sections - Transverse Cracking
Transverse Cracking - meters
16
14
12
10
8
6
4
2
0
A3
A22
B69
B96
D8
D21
T2
Section ID
LTPP
IMS
PASCO
Pave Tech
Roadware

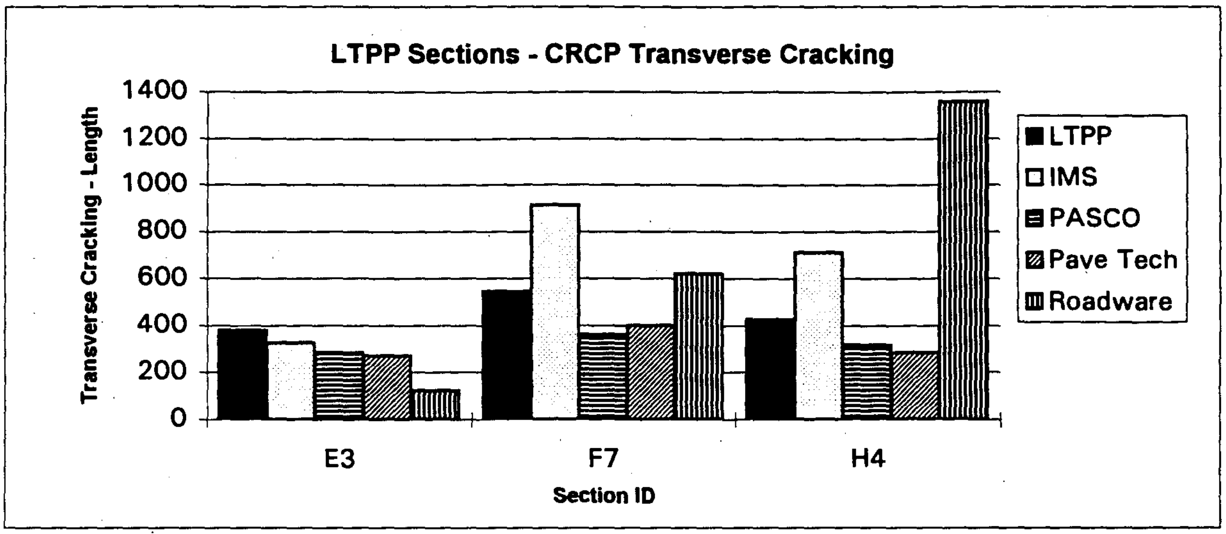


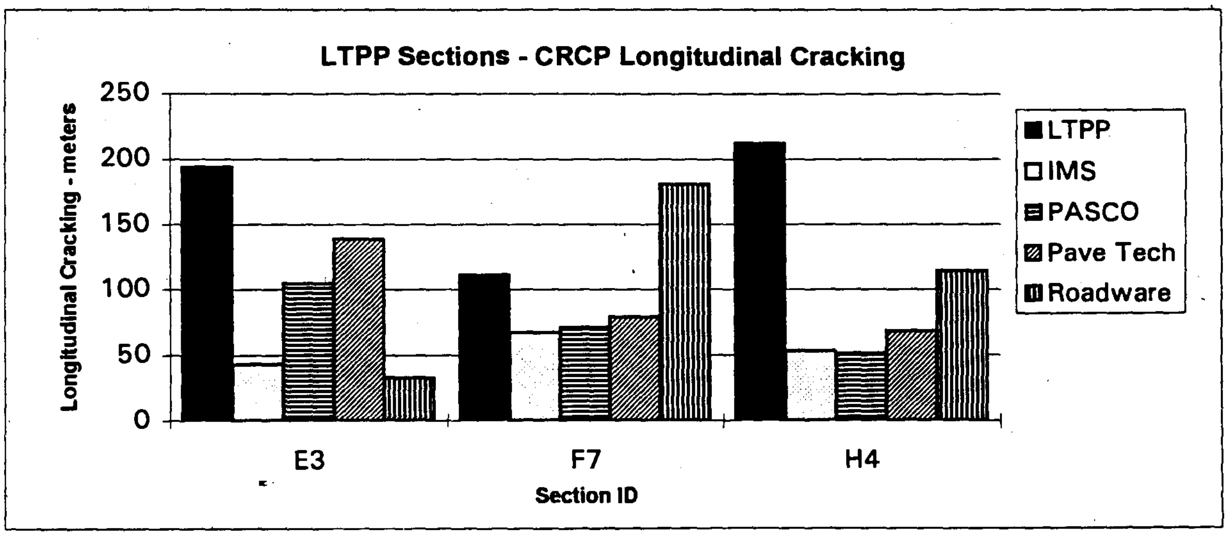
LTPP Sections - Longitudinal Wheelpath Cracking
Longitudinal Cracking - meters
120
100
80
60
40
20
0
A3
A22
B69
B96
D8
D21
T2
Section ID
LTPP
IMS
PASCO
Pave Tech
Roadware

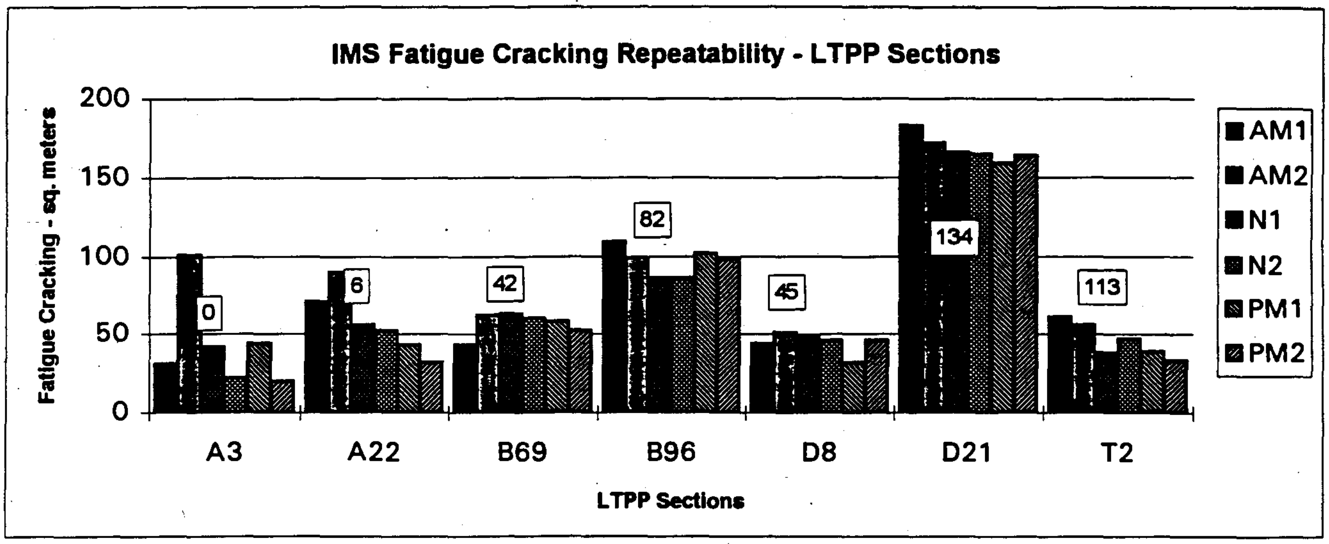

LTPP Sections - Longitudinal NonWheelpath Cracking
Longitudinal Cracking - meters
120
100
80
60
40
20
0
A3
A22
B69
B96
D8
D21
T2
Section ID
LTPP
IMS
PASCO
Pave Tech
Roadware

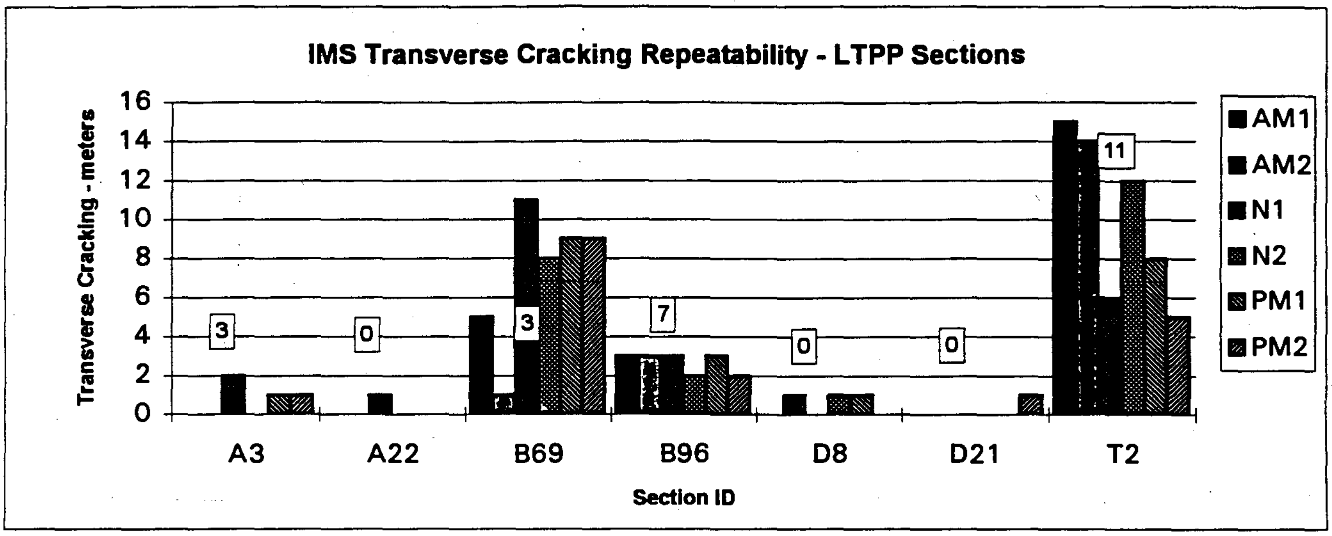

LTPP Sections - Edge Cracking
Edge Cracking - meters
160
140
120
100
80
60
40
20
0
A3
A22
B69
B96
D8
D21
T2
Section ID
LTPP
IMS
PASCO
Pave Tech

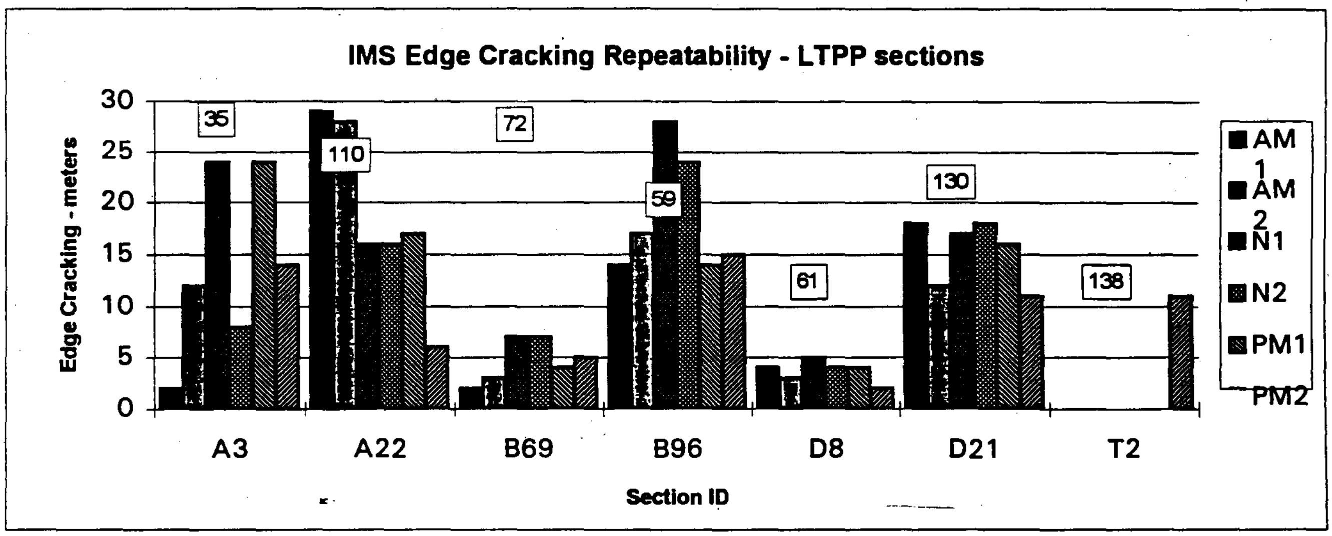

LTPP Sections - CRCP Transverse Cracking
Transverse Cracking - number
700
600
500
400
300
200
100
0
E3
F7
H4
Section ID
LTPP
IMS
PASCO
Pave Tech
Roadware

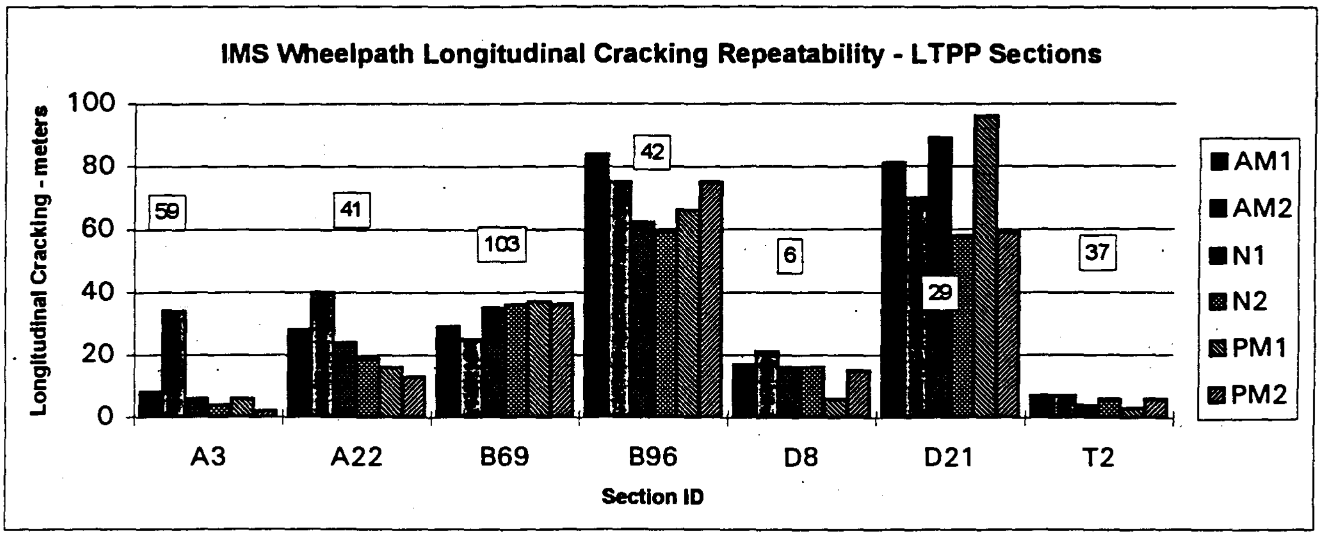

LTPP Sections - CRCP Transverse Cracking
Transverse Cracking - Length
1400
1200
1000
800
600
400
200
0
E3
F7
H4
Section ID
LTPP
IMS
PASCO
Pave Tech
Roadware


LTPP Sections - CRCP Longitudinal Cracking
Longitudinal Cracking - meters
250
200
150
100
50
0
E3
F7
H4
Section ID
LTPP
IMS
PASCO
Pave Tech
Roadware

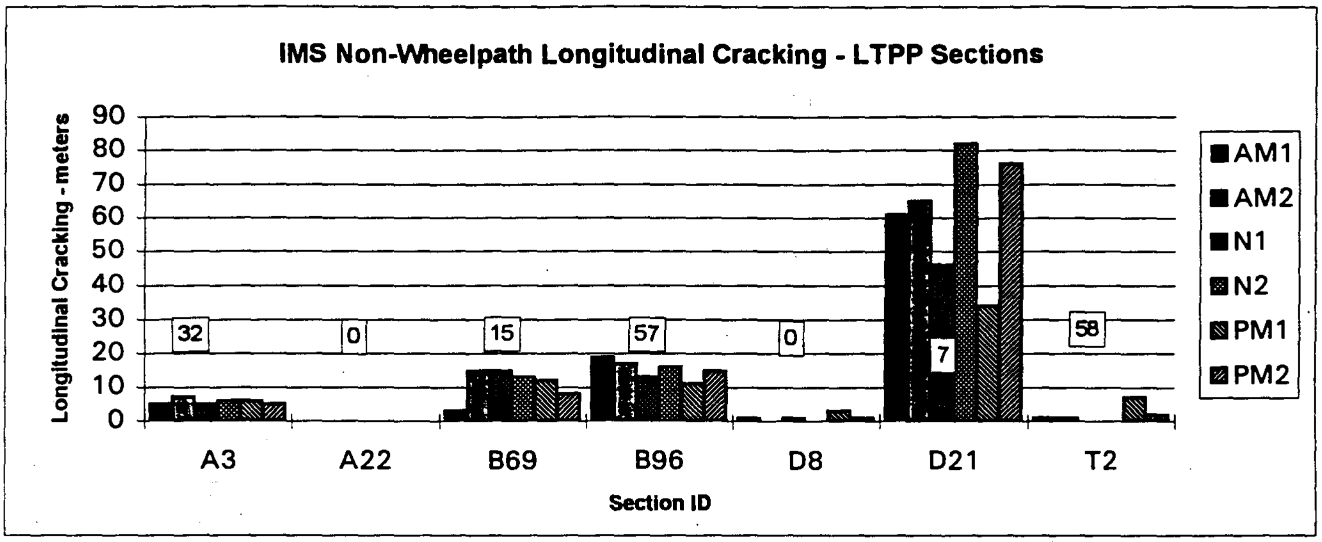

IMS Fatigue Cracking Repeatability - LTPP Sections
Fatigue Cracking - sq. meters
200
150
100
50
0
0
6
42
82
45
134
113
A3
A22
B69
B96
D8
D21
T2
LTPP Sections
AM1
AM2
N1
N2
PM1
PM2


IMS Transverse Cracking Repeatability - LTPP Sections
Transverse Cracking - meters
16
14
12
10
8
6
4
2
0
3
0
3
7
0
0
11
A3
A22
B69
B96
D8
D21
T2
Section ID
AM1
AM2
N1
N2
PM1
PM2

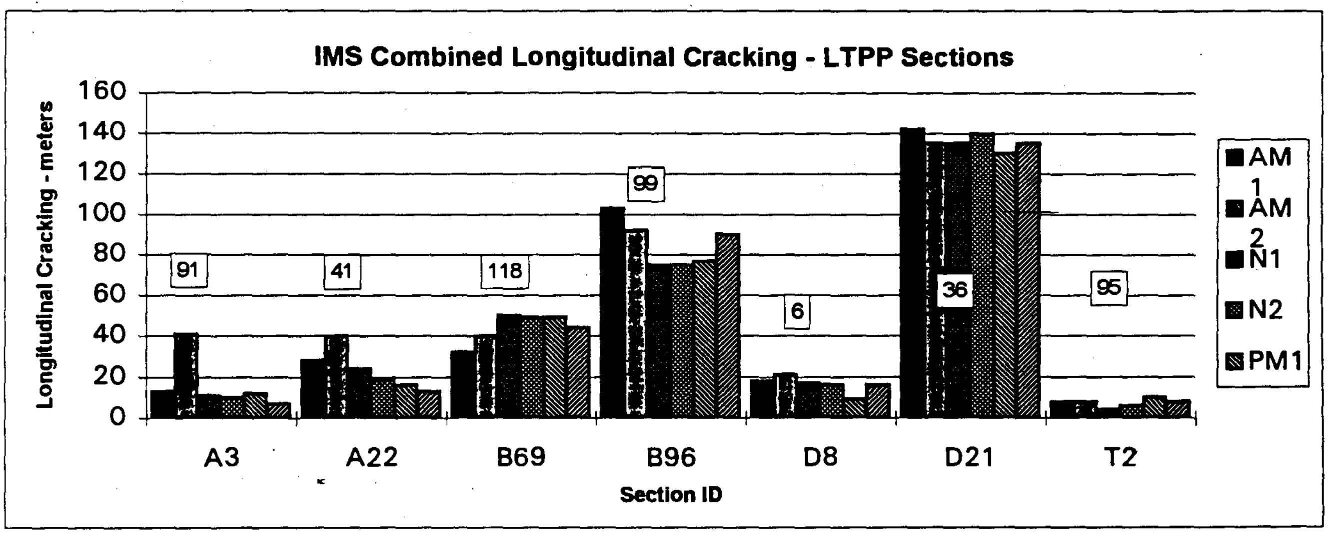

IMS Edge Cracking Repeatability - LTPP sections
Edge Cracking - meters
30
25
20
15
10
5
0
35
110
72
59
61
130
138
A3
A22
B69
B96
D8
D21
T2
Section ID
AM 1
AM 2
N1
N2
PM1
PM2



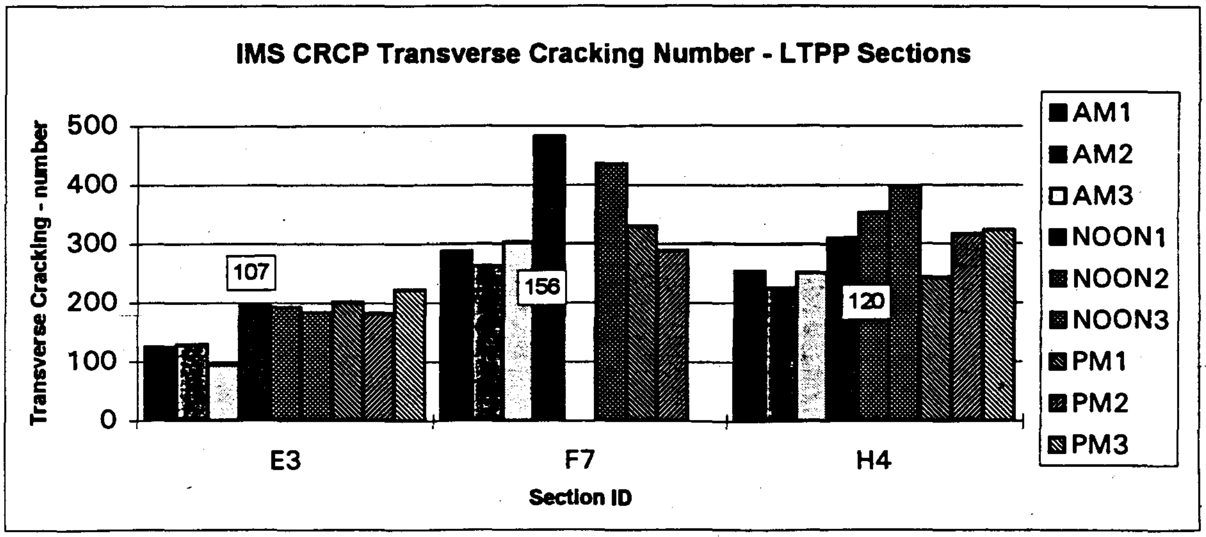
IMS Wheelpath Longitudinal Cracking Repeatability - LTPP Sections
Longitudinal Cracking - meters
100
80
60
40
20
0
59
41
103
42
6
29
37
A3
A22
B69
B96
D8
D21
T2
Section ID
AM1
AM2
N1
N2
PM1
PM2

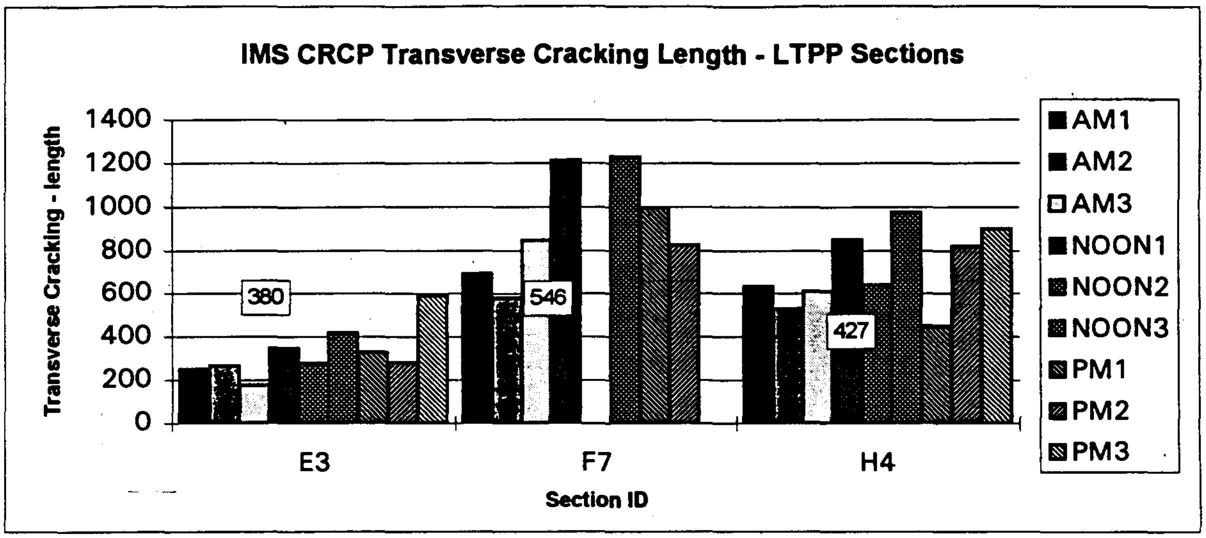


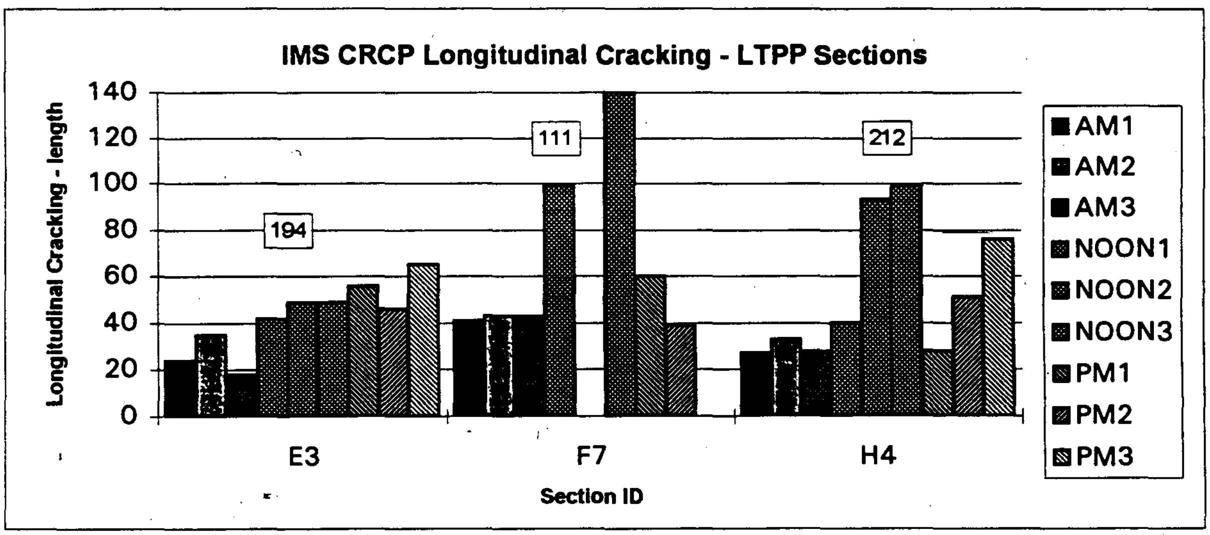
IMS Non-Wheelpath Longitudinal Cracking - LTPP Sections
Longitudinal Cracking - meters
90
80
70
60
50
40
30
20
10
0
32
0
15
57
0
7
58
A3
A22
B69
B96
D8
D21
T2
Section ID
AM1
AM2
N1
N2
PM1
PM2

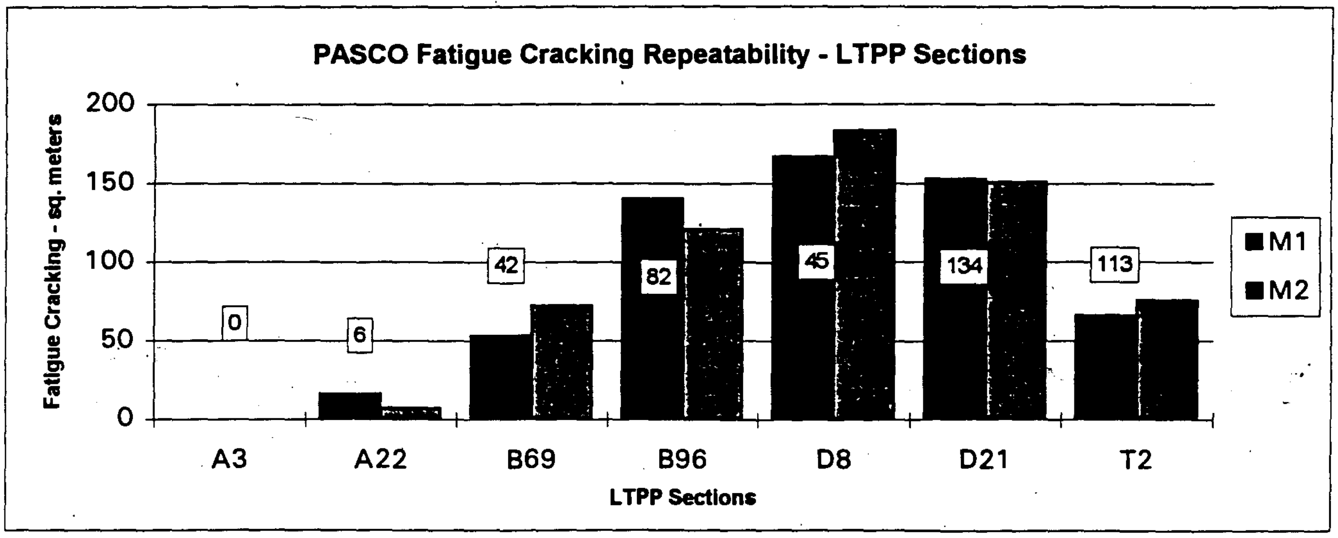


IMS Combined Longitudinal Cracking - LTPP Sections
Longitudinal Cracking - meters
160
140
120
100
80
60
40
20
0
91
41
118
99
6
36
95
A3
A22
B69
B96
D8
D21
T2
Section ID
AM 1
AM 2
N1
N2
PM1

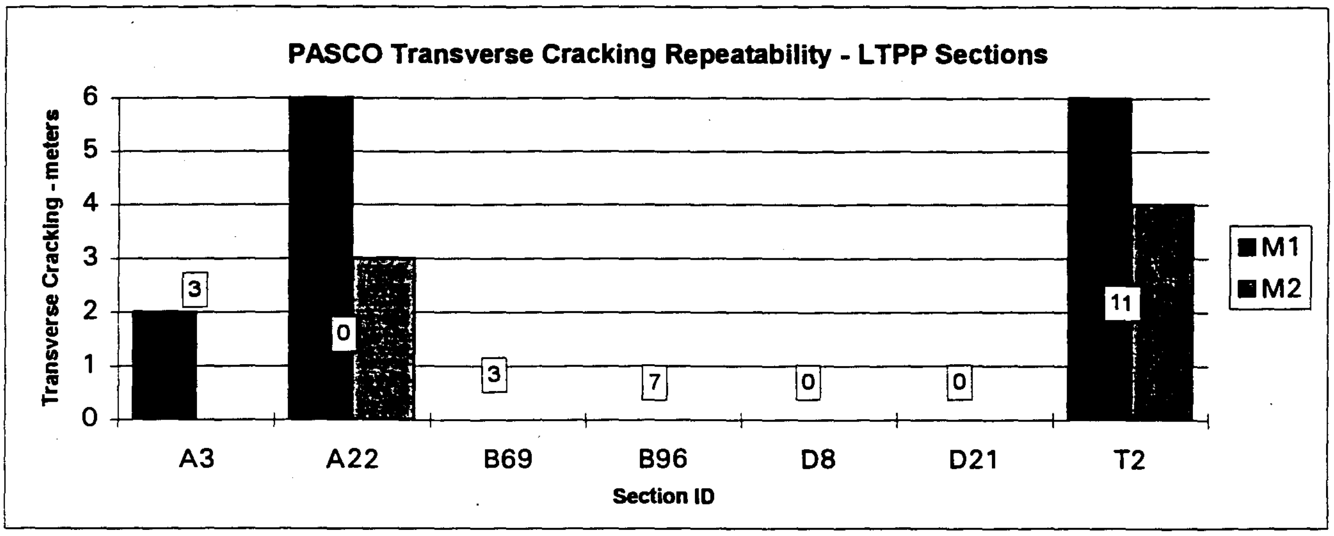

IMS CRCP Transverse Cracking Number - LTPP Sections
Transverse Cracking - number
500
400
300
200
100
0
107
156
120
E3
F7
H4
Section ID
AM1
AM2
AM3
NOON1
NOON2
NOON3
PM1
PM2
PM3


IMS CRCP Transverse Cracking Length - LTPP Sections
Transverse Cracking - length
1400
1200
1000
800
600
400
200
0
380
546
427
E3
F7
H4
Section ID
AM1
AM2
AM3
NOON1
NOON2
NOON3
PM1
PM2
PM3

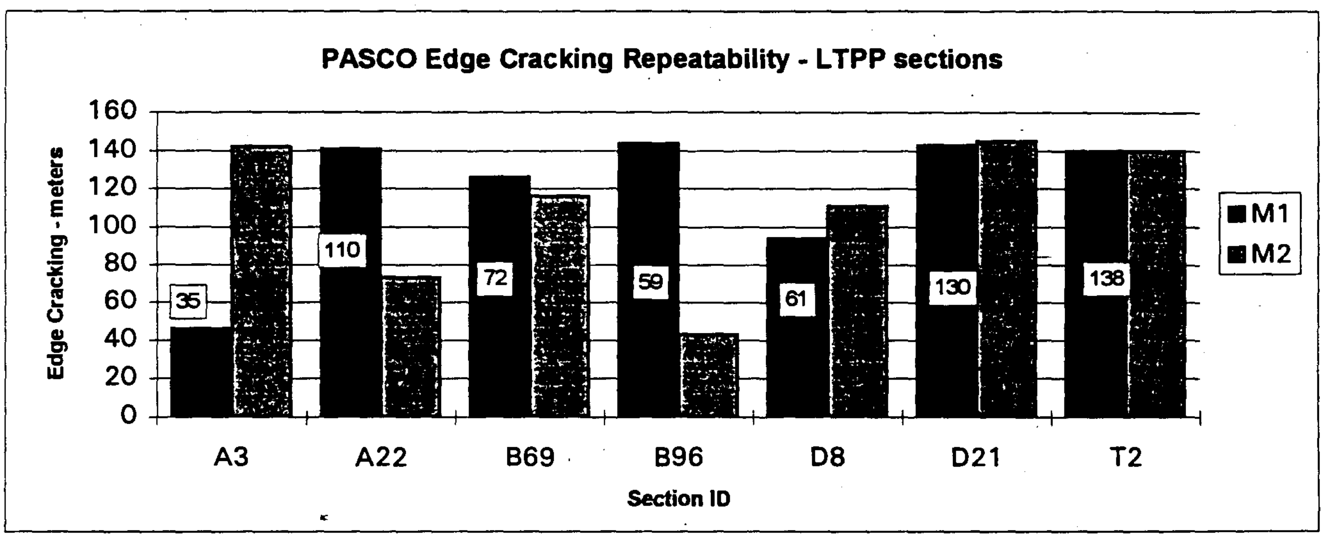

IMS CRCP Longitudinal Cracking - LTPP Sections
Longitudinal Cracking - length
140
120
100
80
60
40
20
0
194
111
212
E3
F7
H4
Section ID
AM1
AM2
AM3
NOON1
NOON2
NOON3
PM1
PM2
PM3



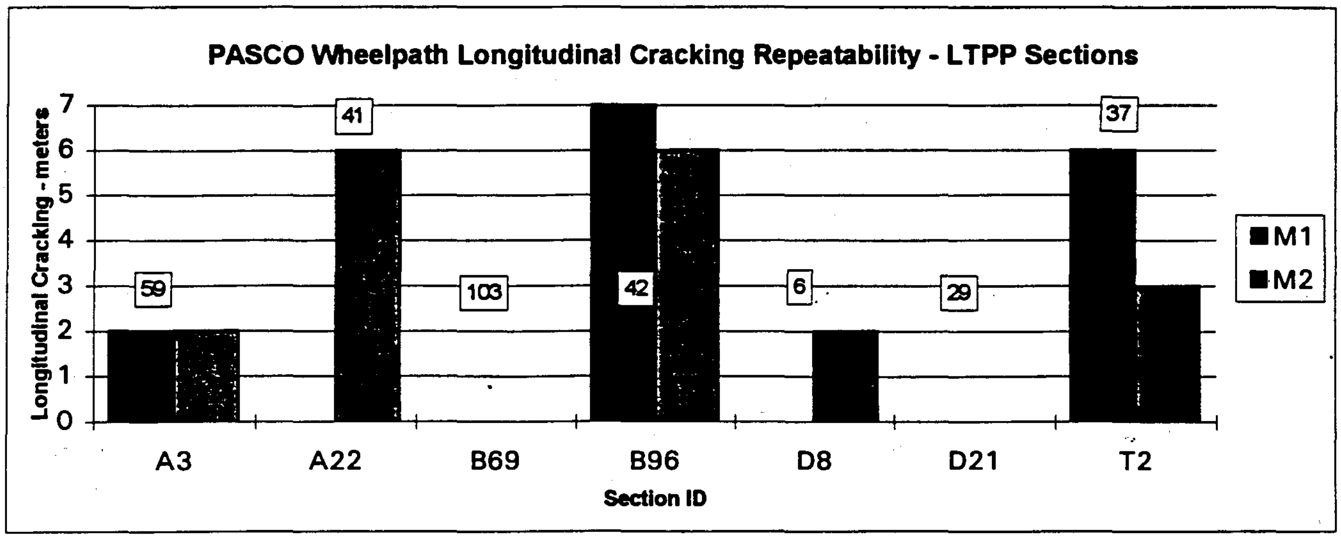
PASCO Fatigue Cracking Repeatability - LTPP Sections
Fatigue Cracking - sq. meters
200
150
100
50
0
0
6
42
82
45
134
113
M1
M2
A3
A22
B69
B96
D8
D21
T2
LTPP Sections

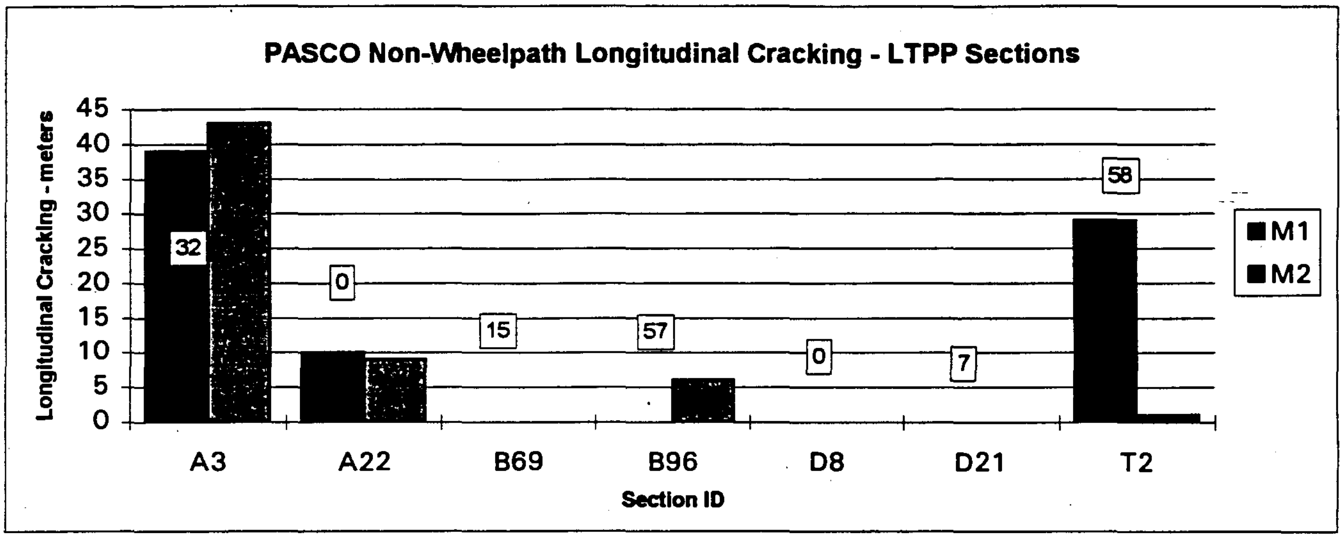


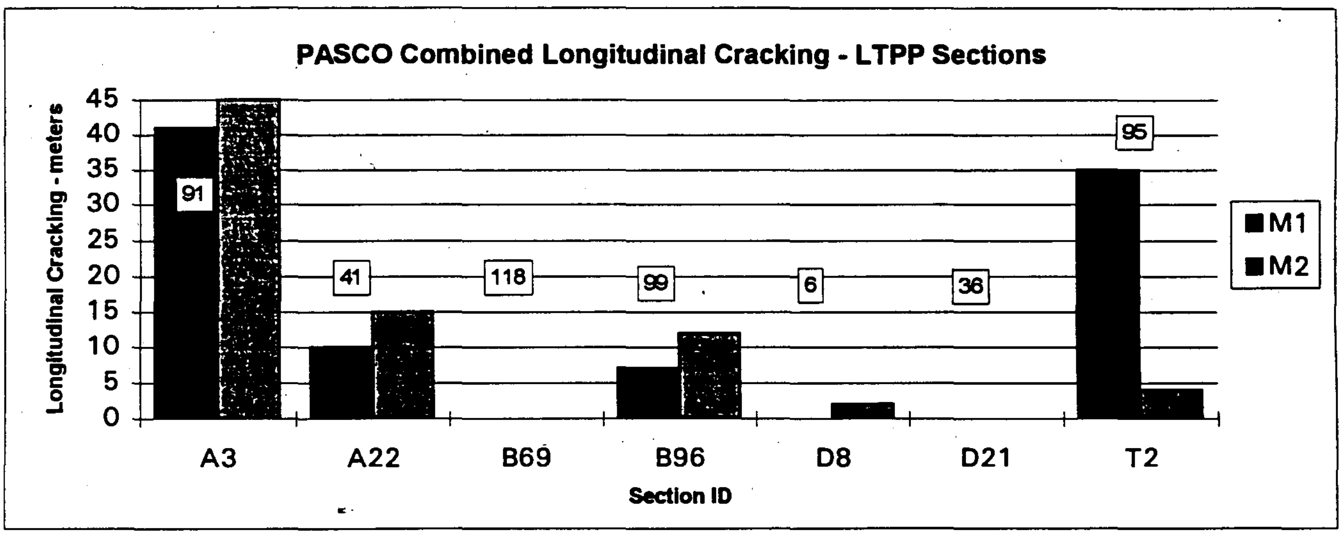
PASCO Transverse Cracking Repeatability - LTPP Sections
Transverse Cracking - meters
6
5
4
3
2
1
0
3
0
3
7
0
0
11
M1
M2
A3
A22
B69
B96
D8
D21
T2
Section ID

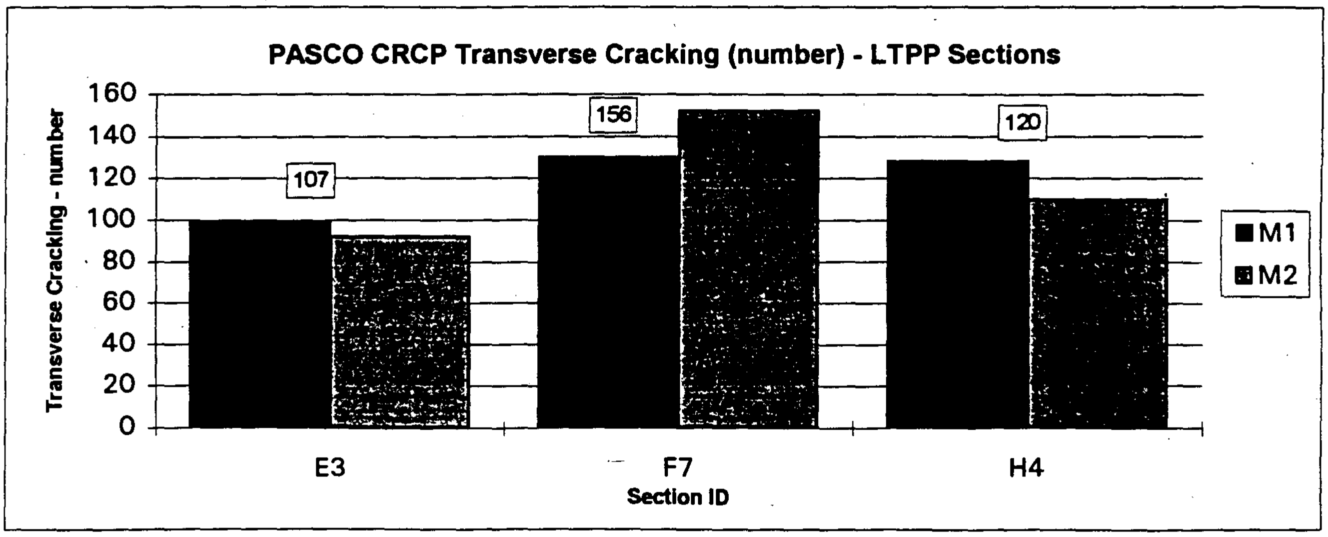


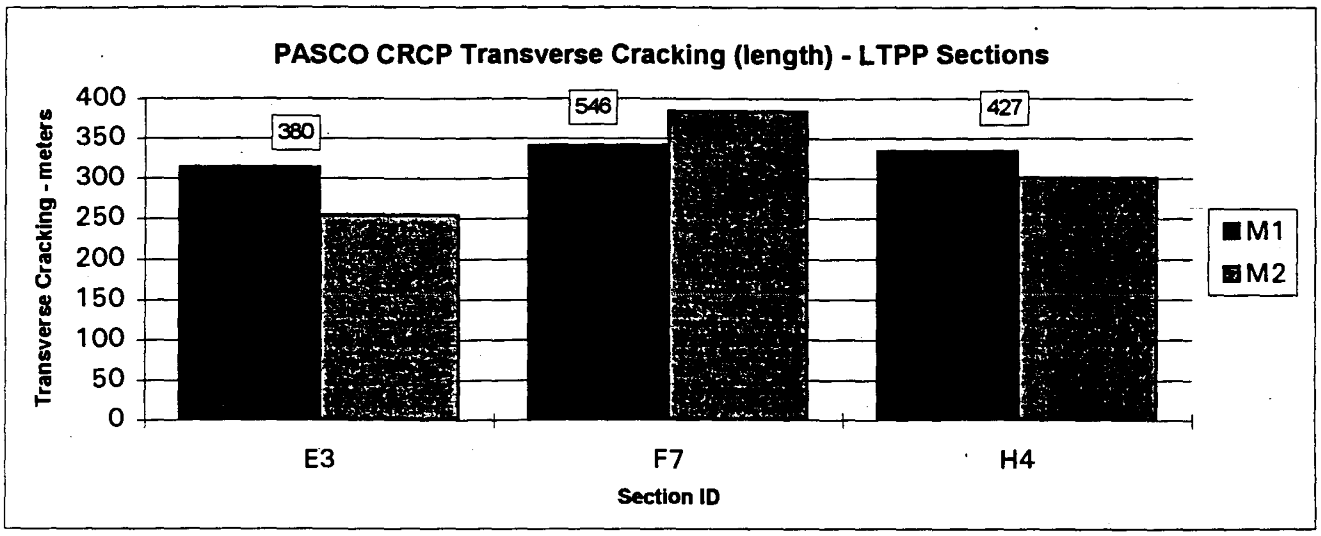
PASCO Edge Cracking Repeatability - LTPP sections
Edge Cracking - meters
160
140
120
100
80
60
40
20
0
35
110
72
59
61
130
138
M1
M2
A3
A22
B69
B96
D8
D21
T2
Section ID

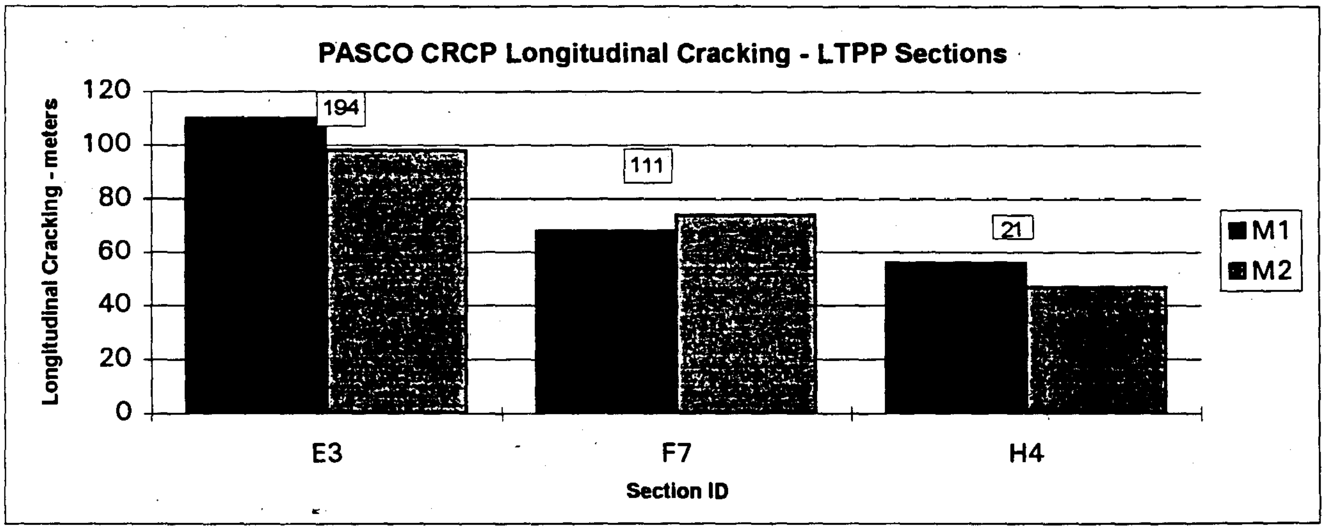

PASCO Wheelpath Longitudinal Cracking Repeatability - LTPP Sections
Longitudinal Cracking - meters
0
1
2
3
4
5
6
7
59
41
103
42
6
29
37
A3
A22
B69
B96
D8
D21
T2
Section ID
M1
M2

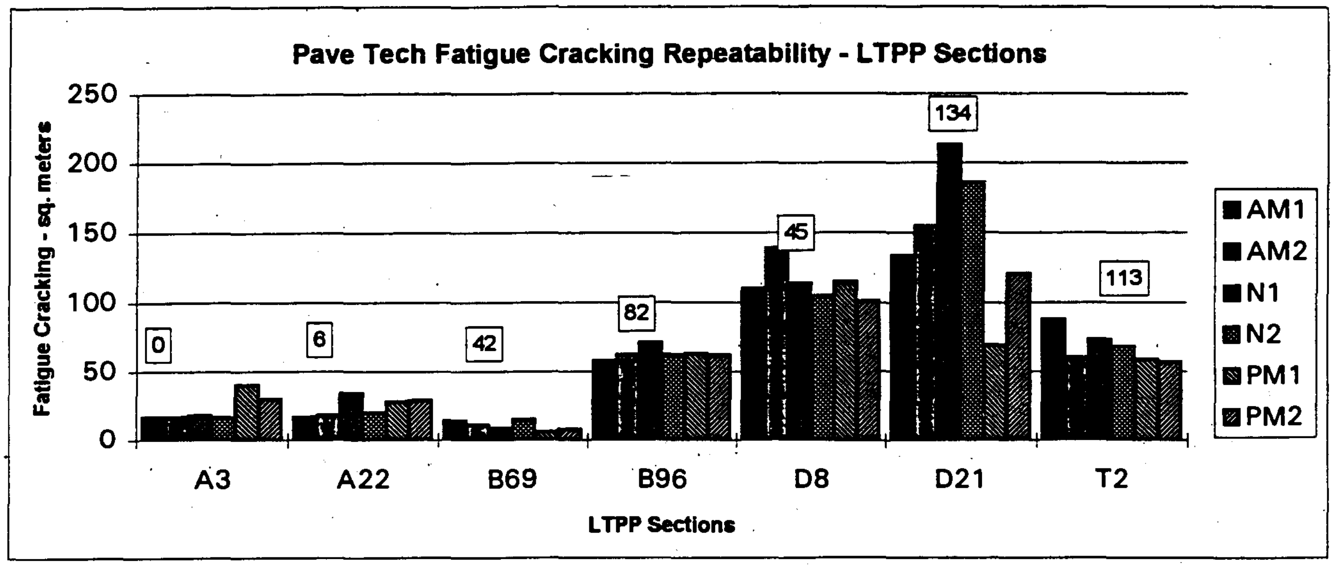

PASCO Non-Wheelpath Longitudinal Cracking - LTPP Sections
Longitudinal Cracking - meters
0
5
10
15
20
25
30
35
40
45
32
0
15
57
0
7
58
A3
A22
B69
B96
D8
D21
T2
Section ID
M1
M2

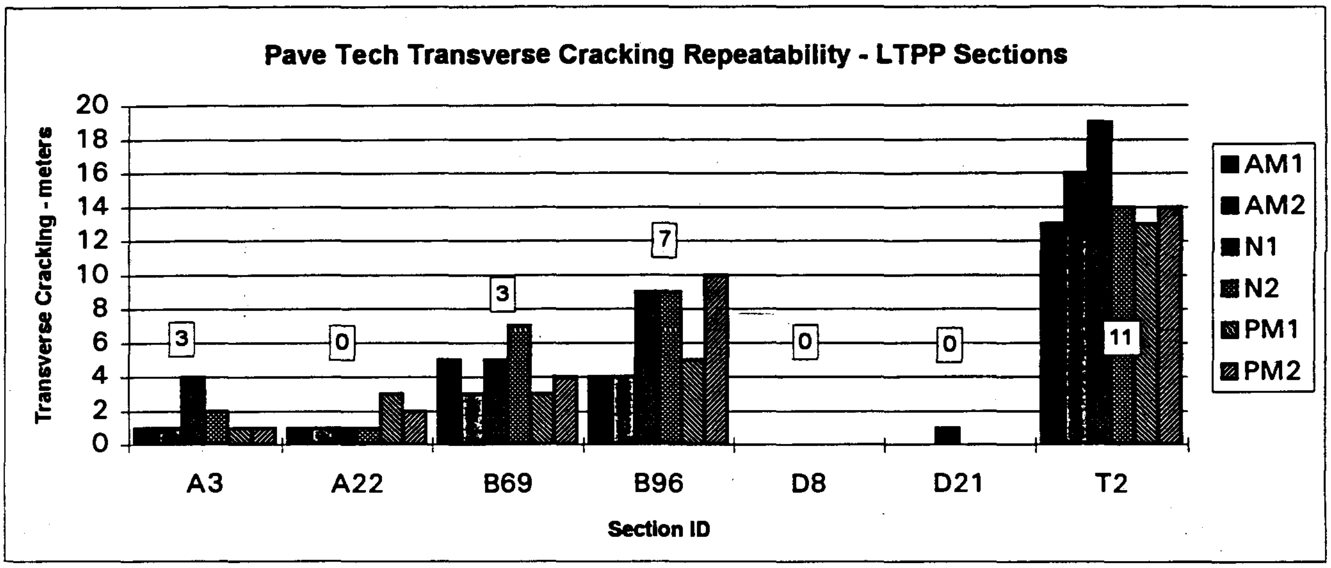

PASCO Combined Longitudinal Cracking - LTPP Sections
Longitudinal Cracking - meters
0
5
10
15
20
25
30
35
40
45
91
41
118
99
6
36
95
A3
A22
B69
B96
D8
D21
T2
Section ID
M1
M2

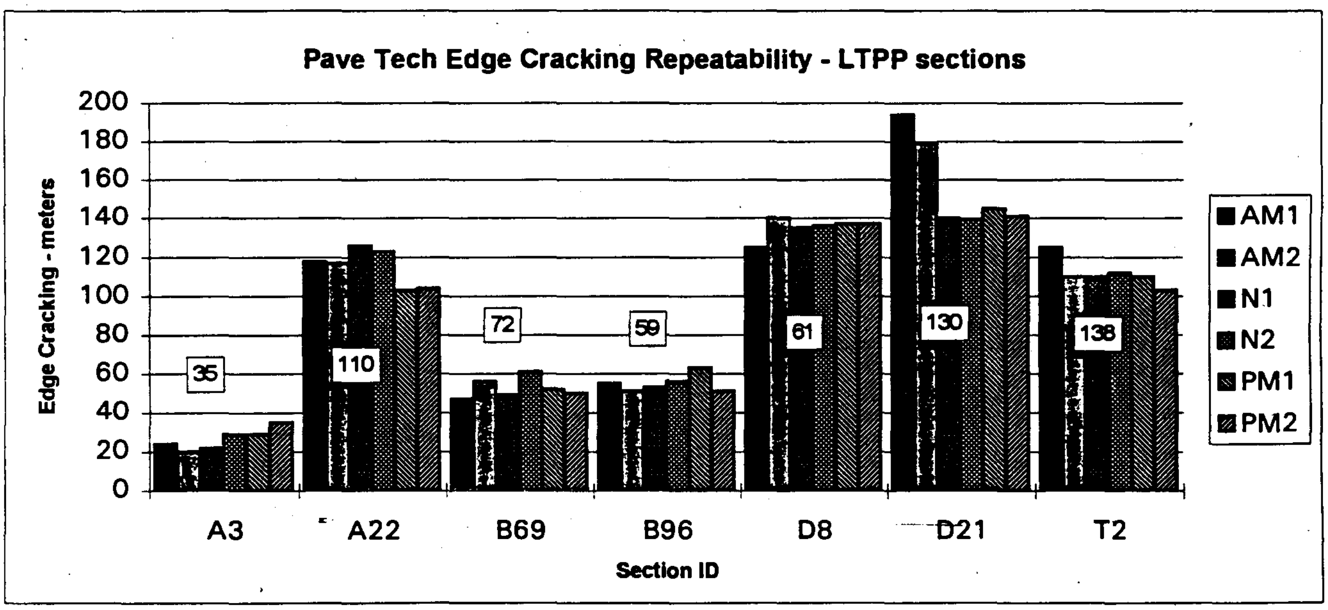

PASCO CRCP Transverse Cracking (number) - LTPP Sections
Transverse Cracking - number
160
140
120
100
80
60
40
20
0
107
156
120
E3
F7
H4
Section ID
M1
M2

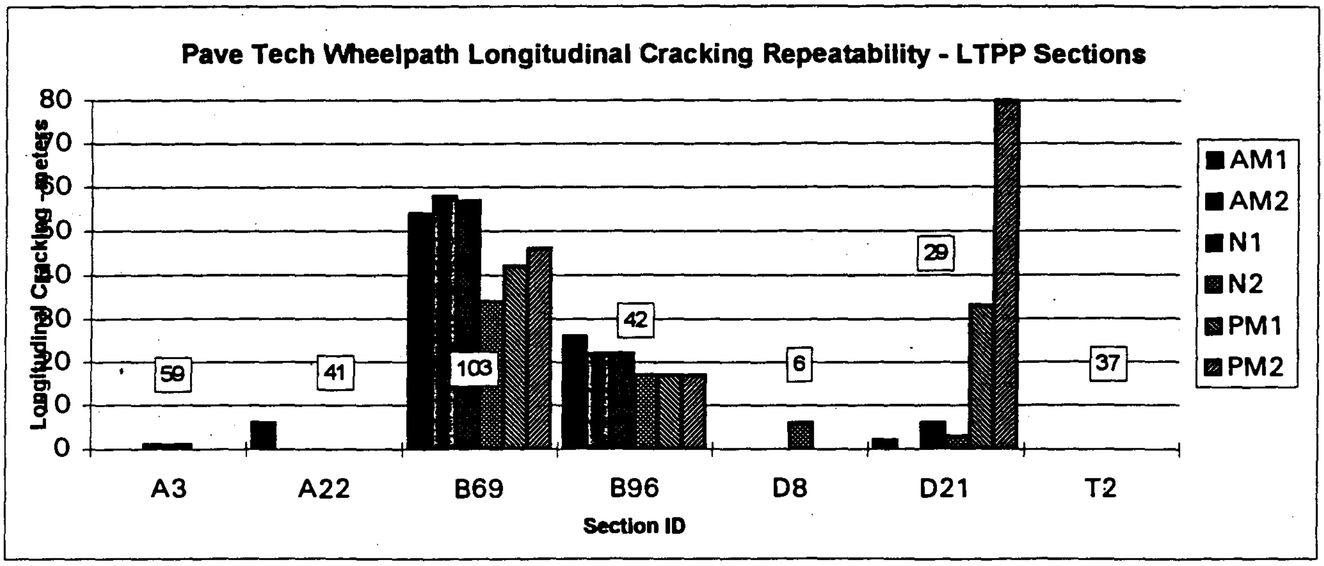

PASCO CRCP Transverse Cracking (length) - LTPP Sections
Transverse Cracking - meters
400
350
300
250
200
150
100
50
0
380
546
427
E3
F7
H4
Section ID
M1
M2


PASCO CRCP Longitudinal Cracking - LTPP Sections
Longitudinal Cracking - meters
120
100
80
60
40
20
0
194
111
21
E3
F7
H4
Section ID
M1
M2

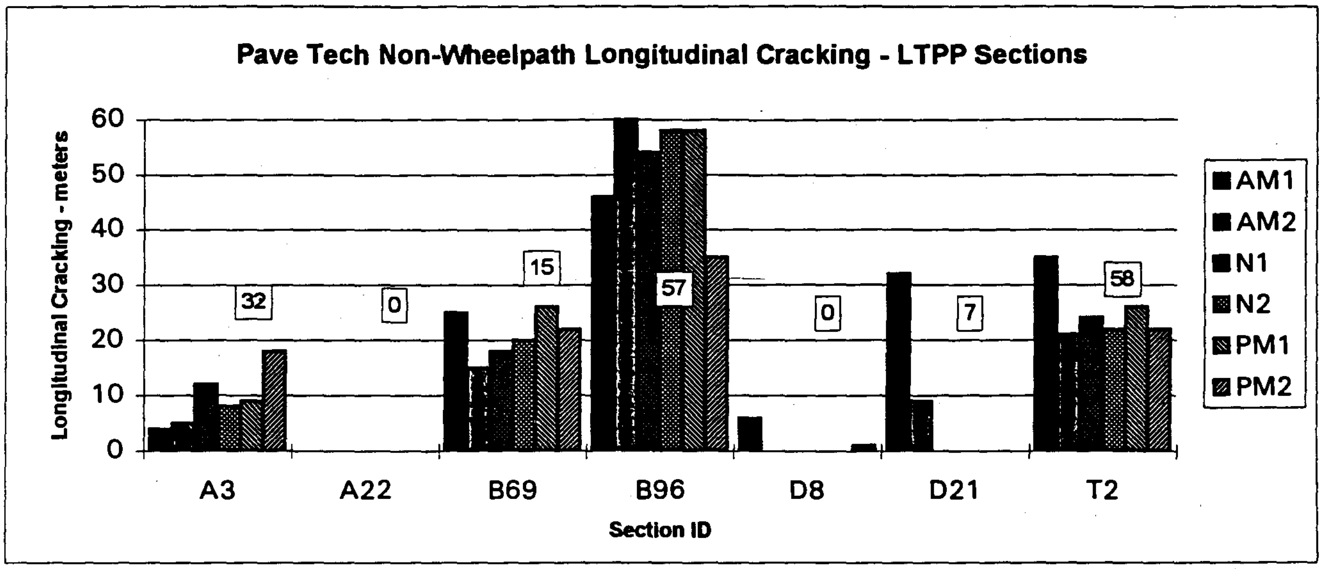

Pave Tech Fatigue Cracking Repeatability - LTPP Sections
Fatigue Cracking - sq. meters
250
200
150
100
50
0
0
6
42
82
45
134
113
A3
A22
B69
B96
D8
D21
T2
LTPP Sections
AM1
AM2
N1
N2
PM1
PM2


Pave Tech Transverse Cracking Repeatability - LTPP Sections
Transverse Cracking - meters
20
18
16
14
12
10
8
6
4
2
0
3
0
3
7
0
0
11
A3
A22
B69
B96
D8
D21
T2
Section ID
AM1
AM2
N1
N2
PM1
PM2

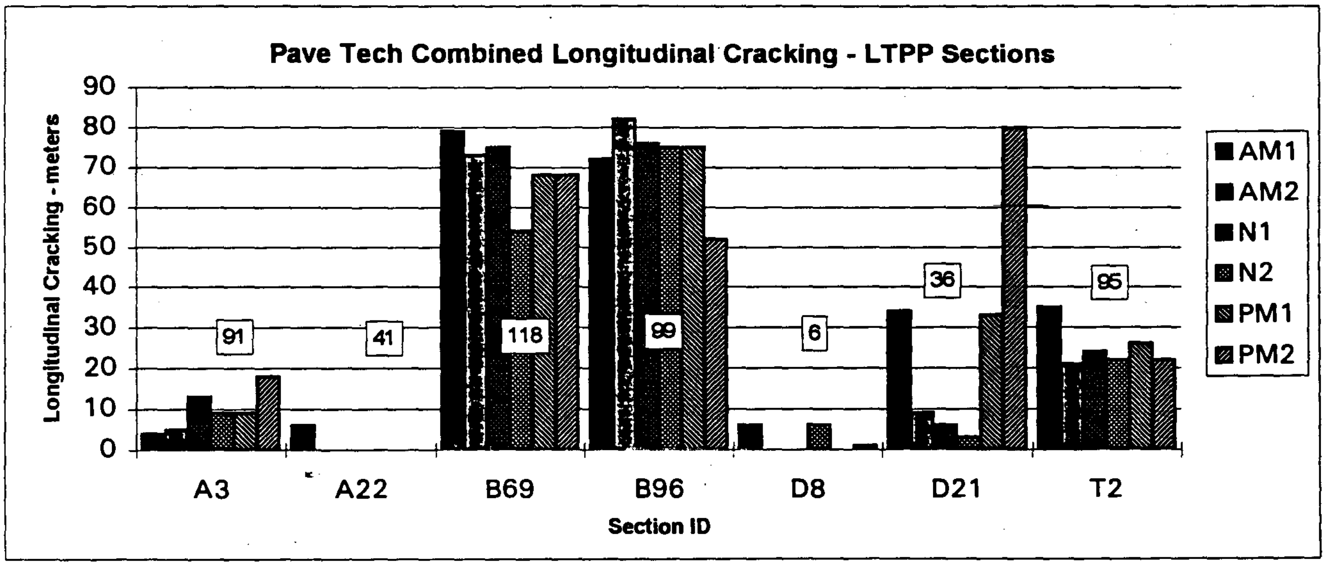

Pave Tech Edge Cracking Repeatability - LTPP sections
Edge Cracking - meters
200
180
160
140
120
100
80
60
40
20
0
35
110
72
59
61
130
138
A3
A22
B69
B96
D8
D21
T2
Section ID
AM1
AM2
N1
N2
PM1
PM2



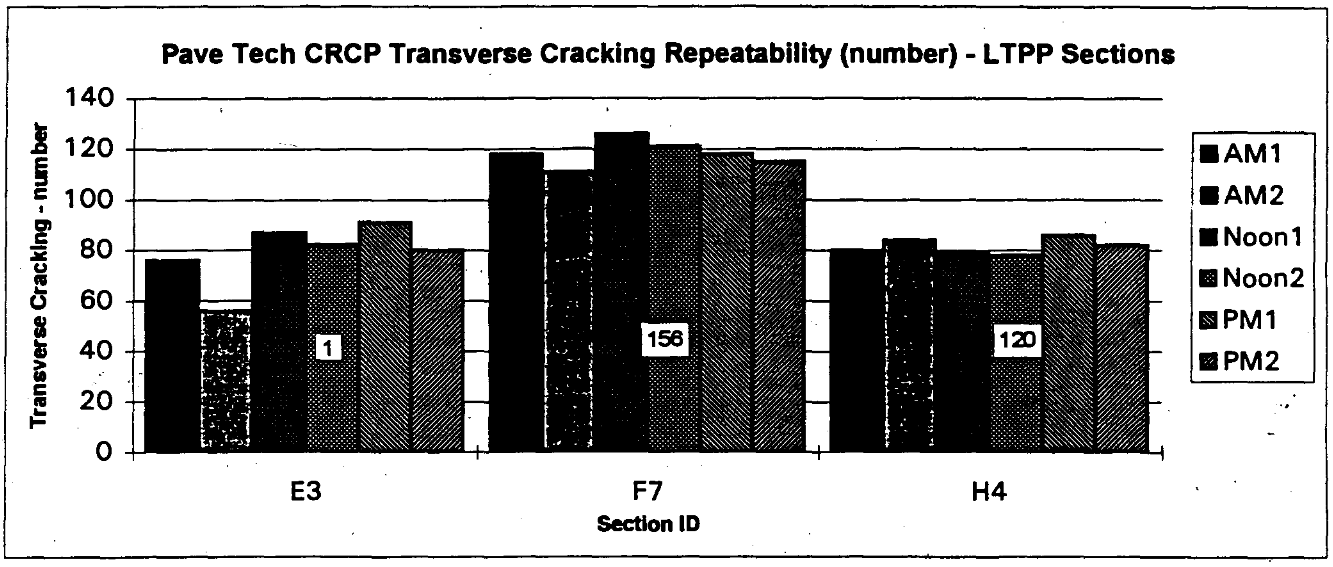
Pave Tech Wheelpath Longitudinal Cracking Repeatability - LTPP Sections
Longitudinal Cracking - meters
Section ID
A3
A22
B69
B96
D8
D21
T2
59
41
103
42
6
29
37
AM1
AM2
N1
N2
PM1
PM2



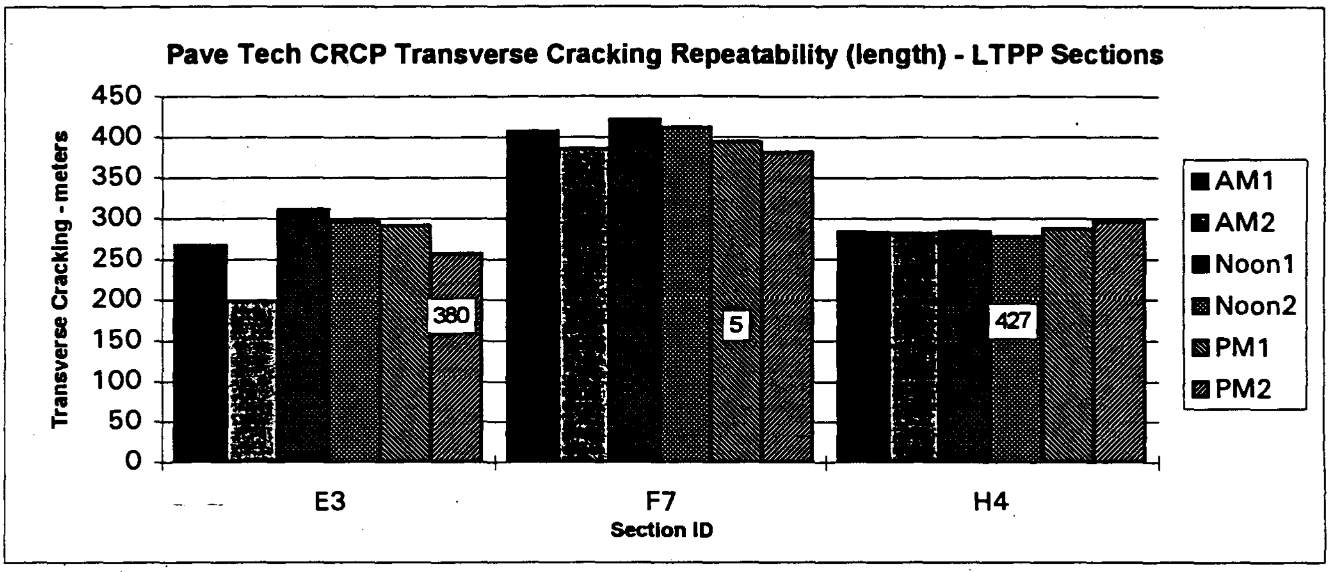
Pave Tech Non-Wheelpath Longitudinal Cracking - LTPP Sections
Longitudinal Cracking - meters
Section ID
60
50
40
30
20
10
0
A3
A22
B69
B96
D8
D21
T2
32
0
15
57
0
7
58
AM1
AM2
N1
N2
PM1
PM2



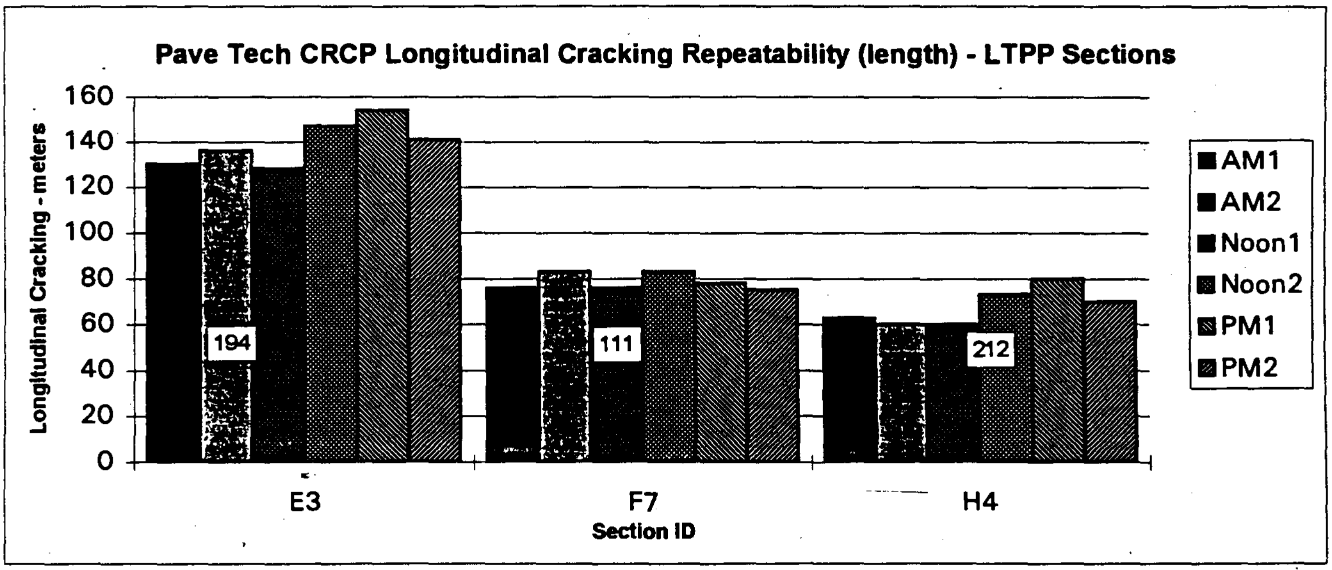
Pave Tech Combined Longitudinal Cracking - LTPP Sections
Longitudinal Cracking - meters
Section ID
90
80
70
60
50
40
30
20
10
0
A3
A22
B69
B96
D8
D21
T2
91
41
118
99
6
36
95
AM1
AM2
N1
N2
PM1
PM2



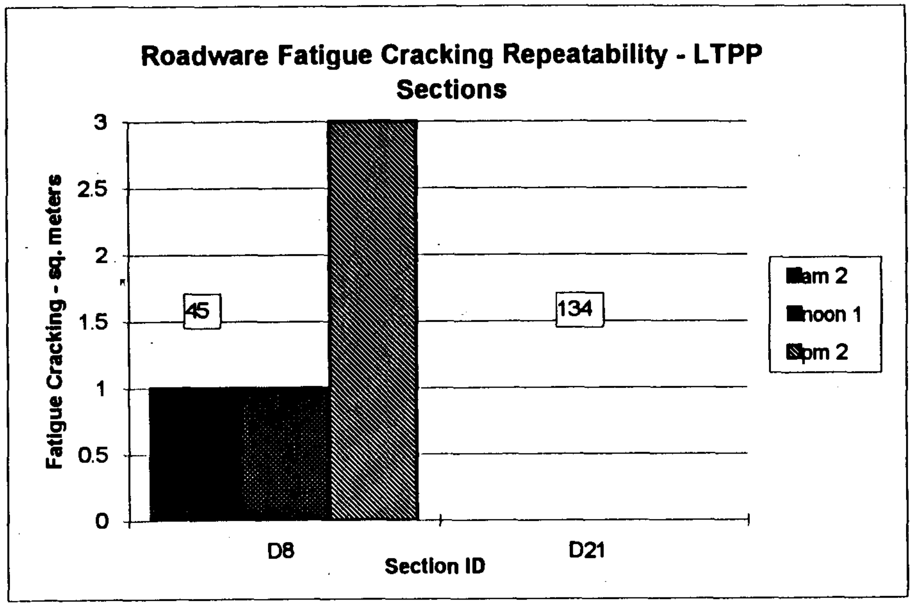
Pave Tech CRCP Transverse Cracking Repeatability (number) - LTPP Sections
Transverse Cracking - number
140
120
100
80
60
40
20
0
1
156
120
E3
F7
H4
Section ID
AM1
AM2
Noon1
Noon2
PM1
PM2



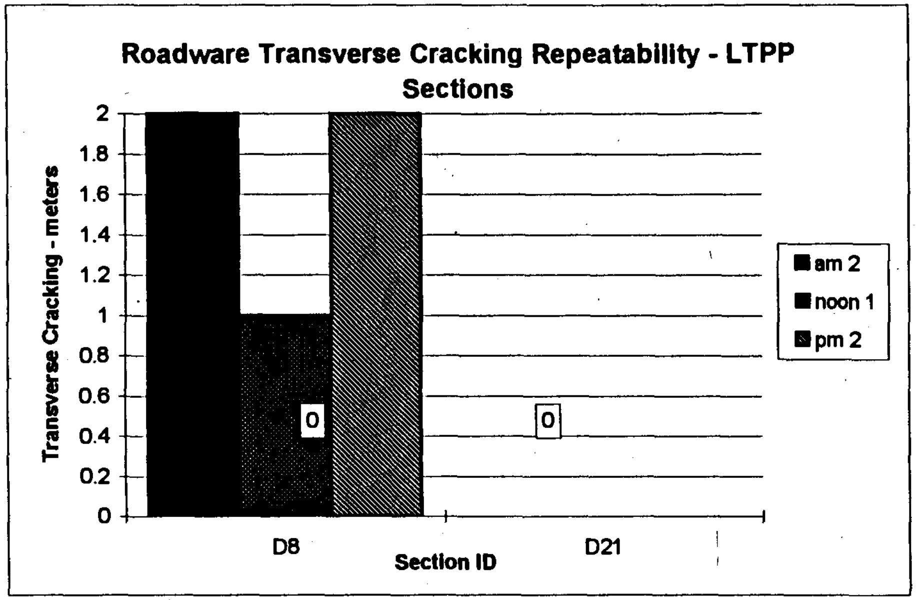
Pave Tech CRCP Transverse Cracking Repeatability (length) - LTPP Sections
Transverse Cracking - meters
450
400
350
300
250
200
150
100
50
0
380
5
427
E3
F7
H4
Section ID
AM1
AM2
Noon1
Noon2
PM1
PM2



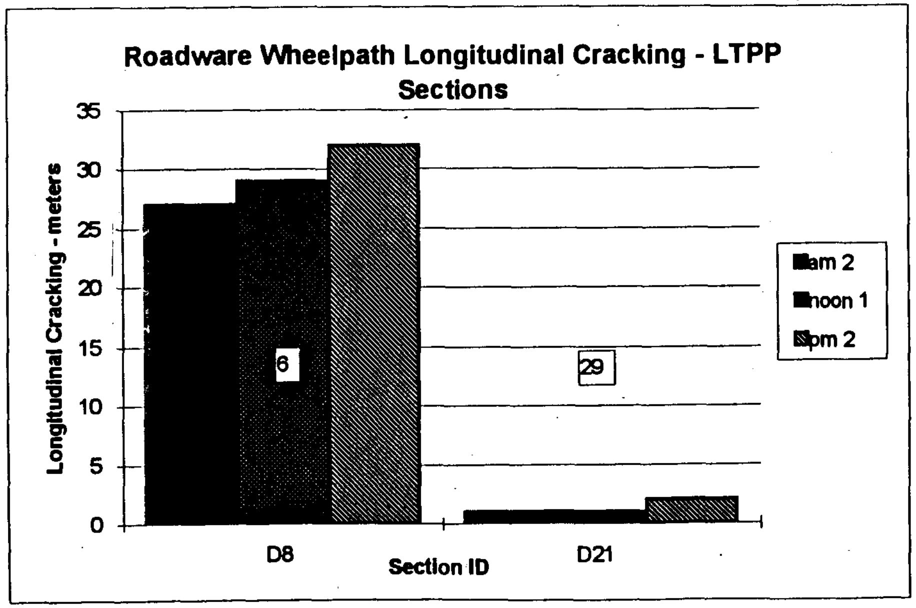
Pave Tech CRCP Longitudinal Cracking Repeatability (length) - LTPP Sections
Longitudinal Cracking - meters
160
140
120
100
80
60
40
20
0
194
111
212
E3
F7
H4
Section ID
AM1
AM2
Noon1
Noon2
PM1
PM2



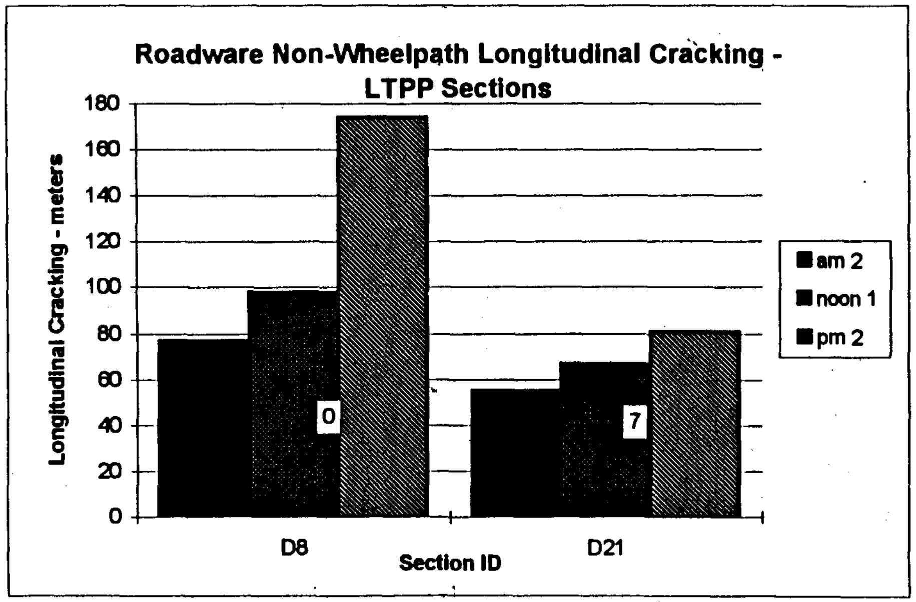
Roadware Fatigue Cracking Repeatability - LTPP Sections
Fatigue Cracking - sq. meters
3
2.5
2
1.5
1
0.5
0
45
134
D8
D21
Section ID
am 2
noon 1
pm 2



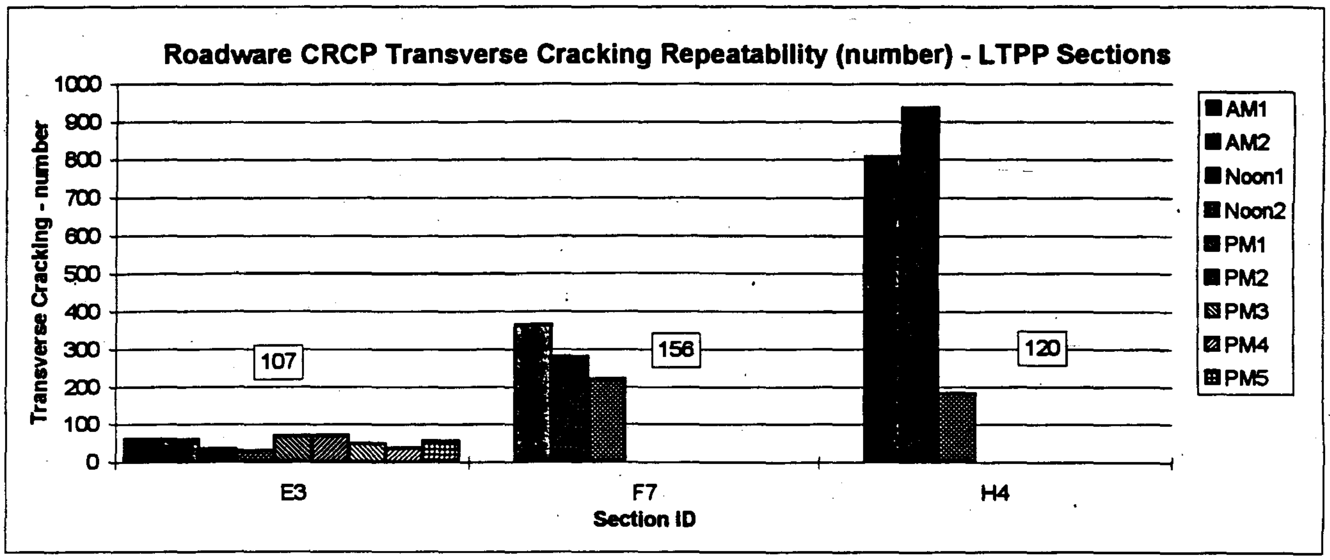
Roadware Transverse Cracking Repeatability - LTPP Sections
Transverse Cracking - meters
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
0
D8
D21
Section ID
am 2
noon 1
pm 2

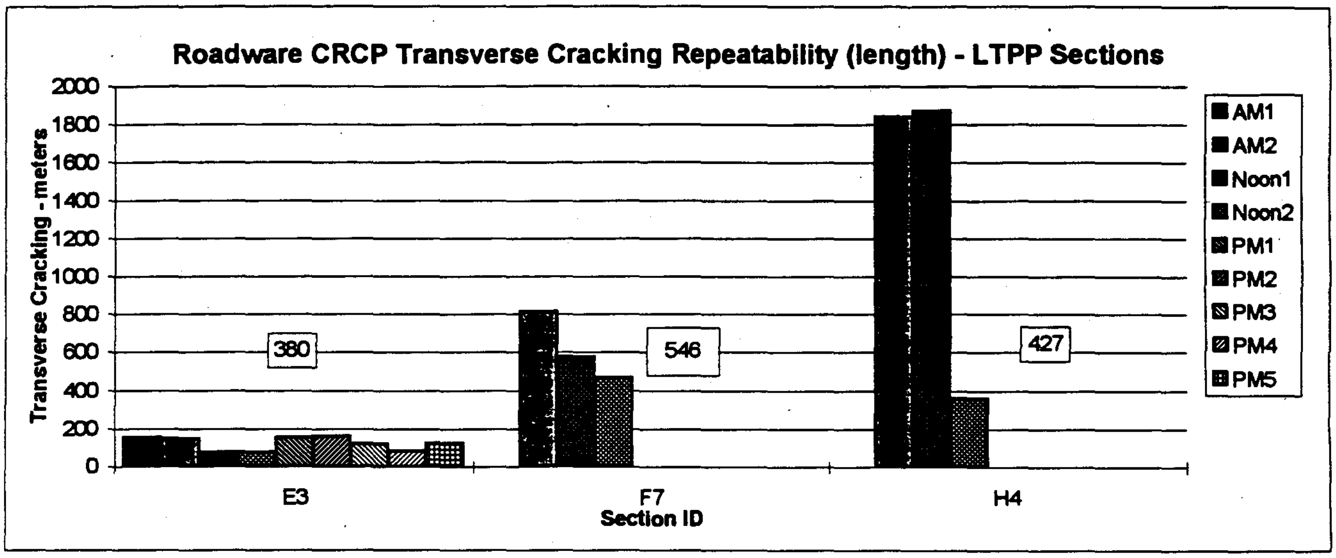


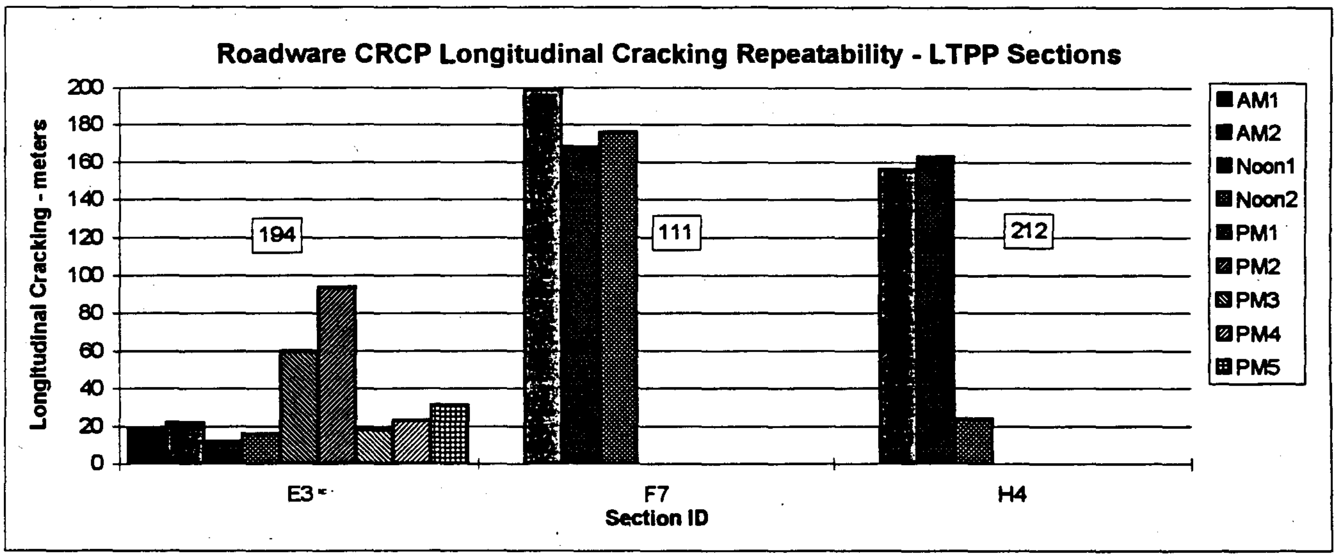
Roadware Wheelpath Longitudinal Cracking - LTPP Sections
Longitudinal Cracking - meters
35
30
25
20
15
10
5
0
6
29
D8
D21
Section ID
am 2
noon 1
pm 2



Roadware Non-Wheelpath Longitudinal Cracking - LTPP Sections
Longitudinal Cracking - meters
180
160
140
120
100
80
60
40
20
0
0
7
D8
D21
Section ID
am 2
noon 1
pm 2

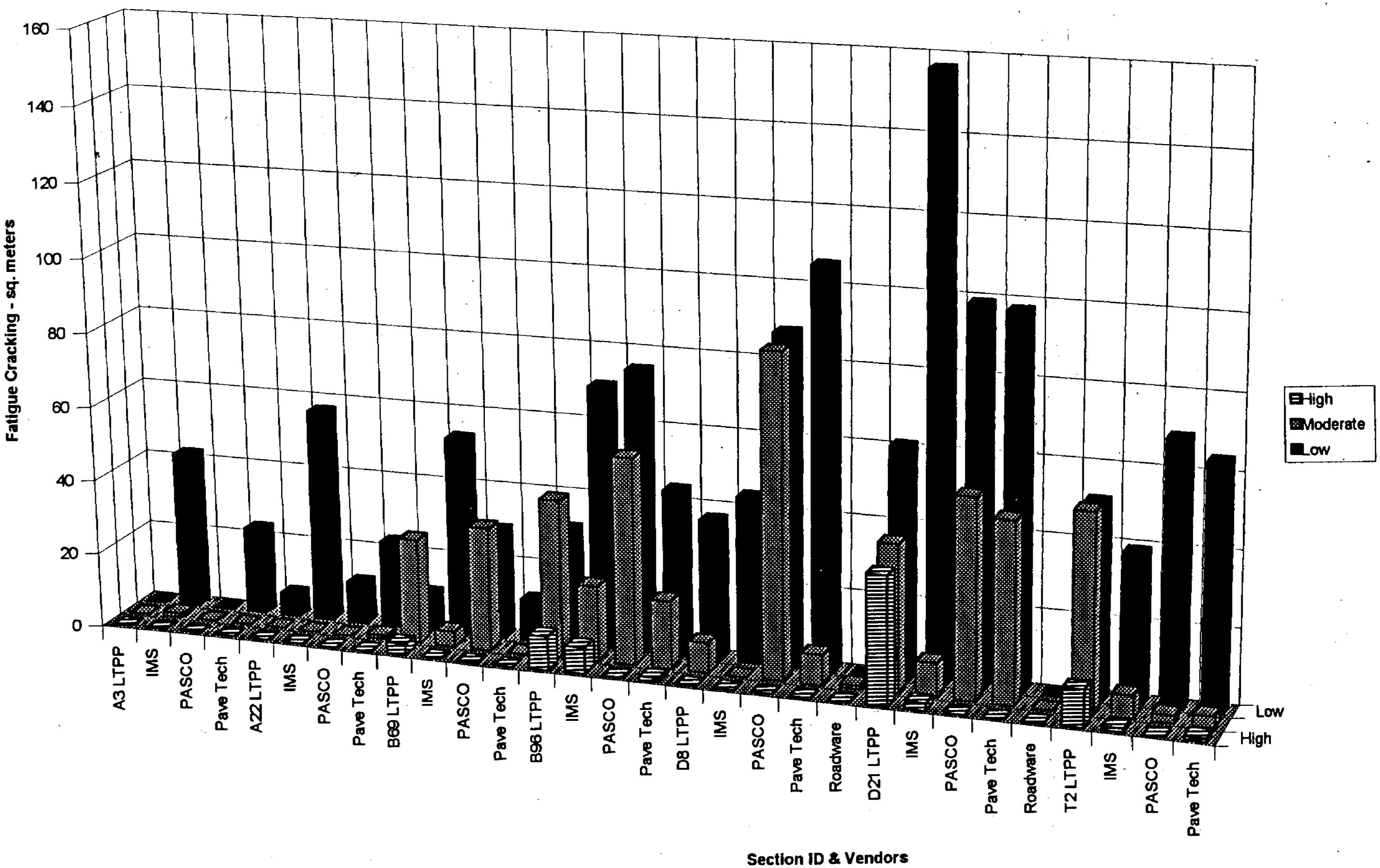

Roadware CRCP Transverse Cracking Repeatability (number) - LTPP Sections
Transverse Cracking - number
1000
900
800
700
600
500
400
300
200
100
0
107
156
120
E3
F7
H4
Section ID
AM1
AM2
Noon1
Noon2
PM1
PM2
PM3
PM4
PM5

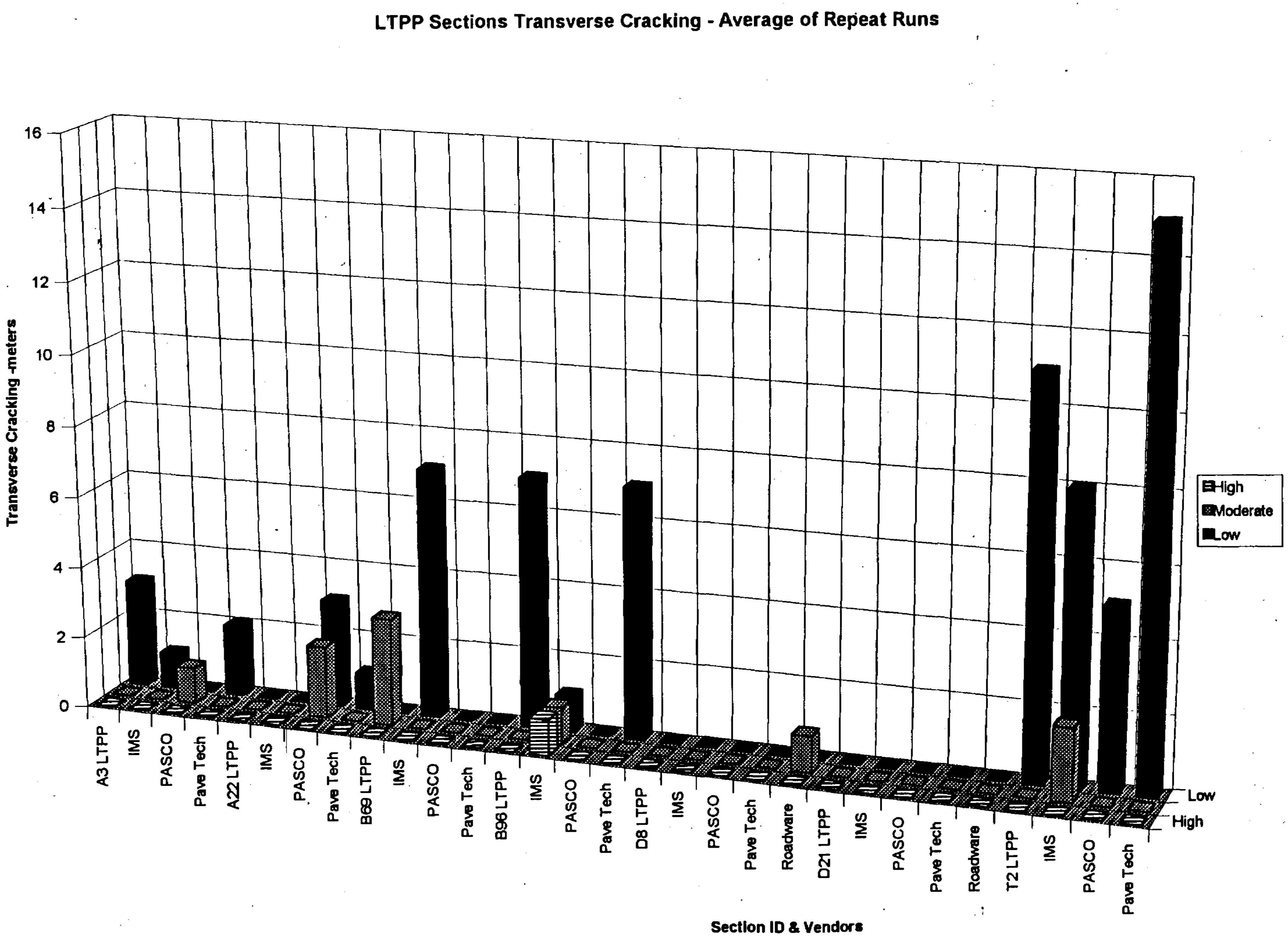

Roadware CRCP Transverse Cracking Repeatability (length) - LTPP Sections
Transverse Cracking - meters
2000
1800
1600
1400
1200
1000
800
600
400
200
0
380
546
427
E3
F7
H4
Section ID
AM1
AM2
Noon1
Noon2
PM1
PM2
PM3
PM4
PM5


Roadware CRCP Longitudinal Cracking Repeatability - LTPP Sections
Longitudinal Cracking - meters
200
180
160
140
120
100
80
60
40
20
0
194
111
212
E3
F7
H4
Section ID
AM1
AM2
Noon1
Noon2
PM1
PM2
PM3
PM4
PM5

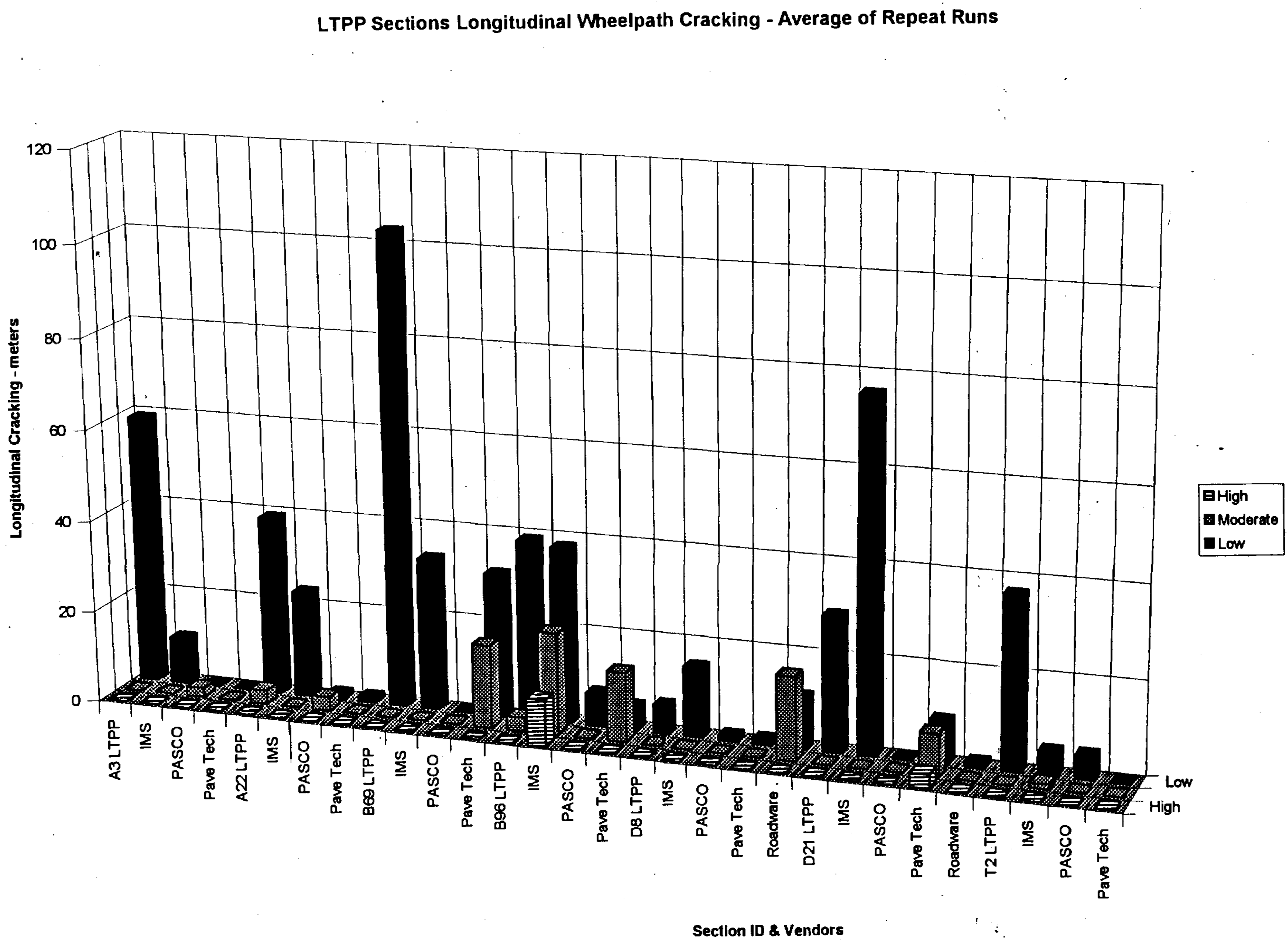
LTPP 3-D BAR CHARTS

LTPP Sections Fatigue Cracking - Average of Repeat Runs



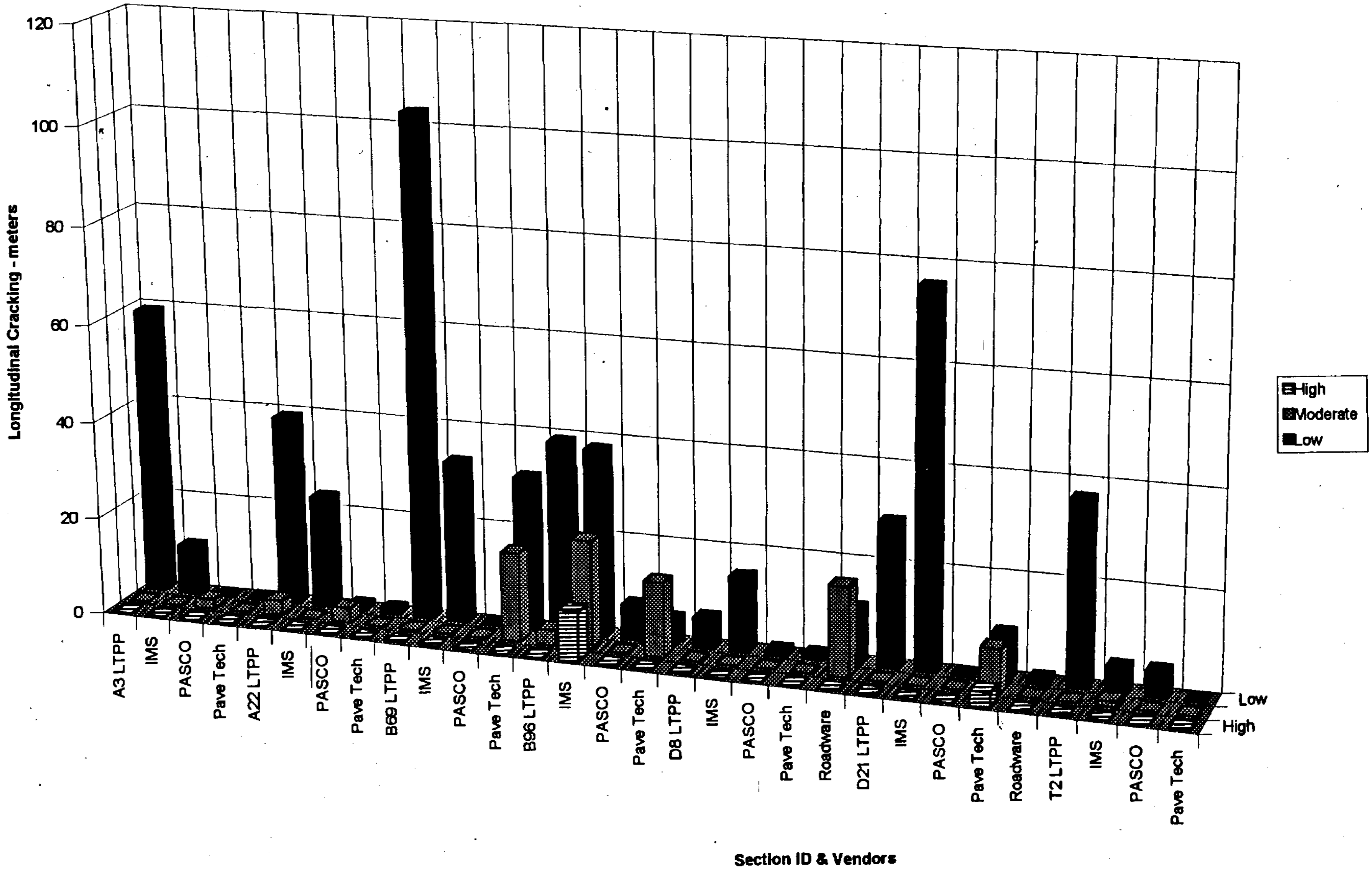


LTPP Sections Transverse Cracking - Average of Repeat Runs
Transverse Cracking -meters
0
2
4
6
8
10
12
14
16
A3 LTPP
IMS
PASCO
Pave Tech
A22 LTPP
IMS
PASCO
Pave Tech
B69 LTPP
IMS
PASCO
Pave Tech
B96 LTPP
IMS
PASCO
Pave Tech
D8 LTPP
IMS
PASCO
Pave Tech
Roadware
D21 LTPP
IMS
PASCO
Pave Tech
Roadware
T2 LTPP
IMS
PASCO
Pave Tech
Section ID & Vendors
Low
High
High
Moderate
Low

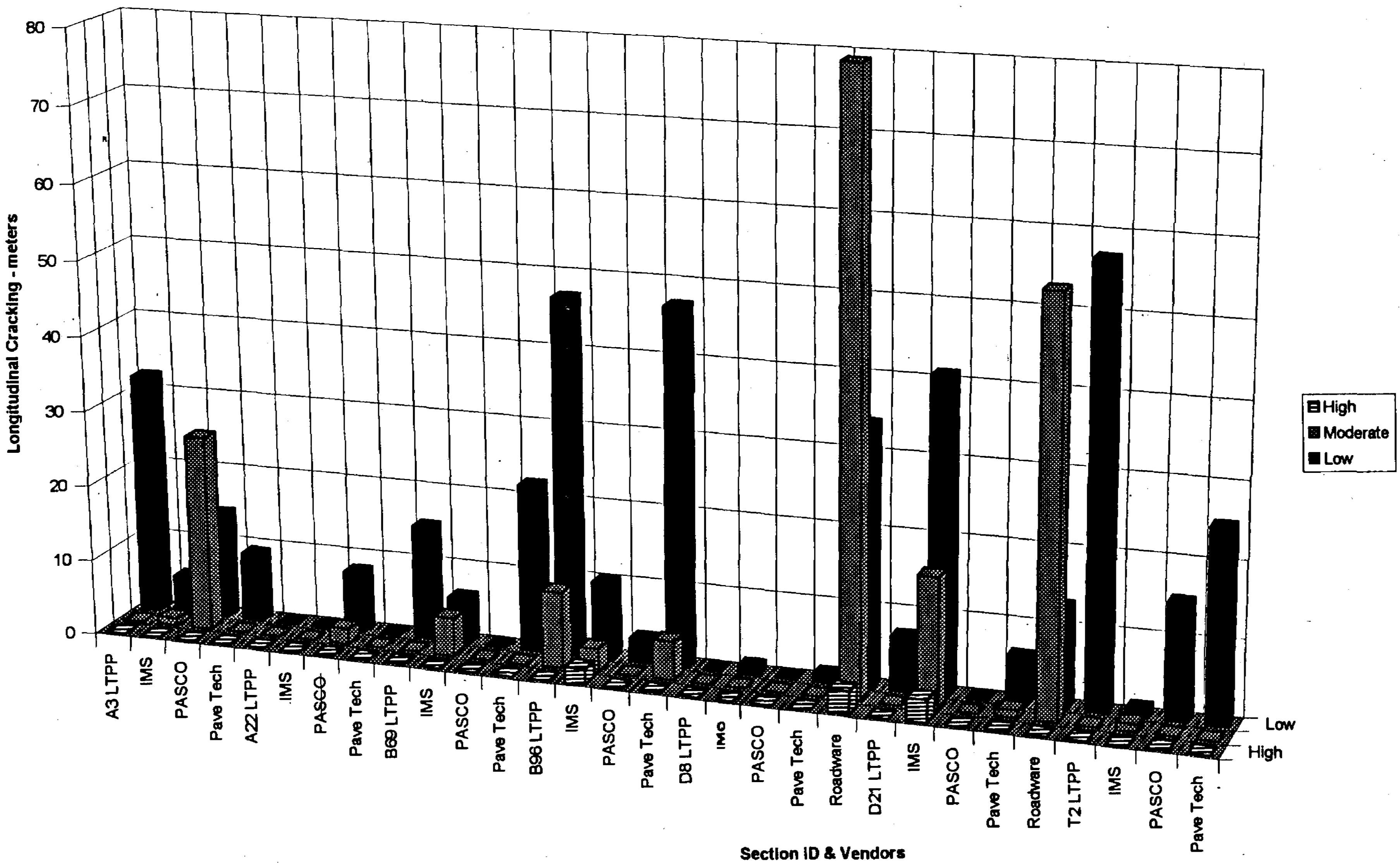


LTPP Sections Longitudinal Wheelpath Cracking - Average of Repeat Runs
Longitudinal Cracking - meters
0
20
40
60
80
100
120
A3 LTPP
IMS
PASCO
Pave Tech
A22 LTPP
IMS
PASCO
Pave Tech
B69 LTPP
IMS
PASCO
Pave Tech
B96 LTPP
IMS
PASCO
Pave Tech
D8 LTPP
IMS
PASCO
Pave Tech
Roadware
D21 LTPP
IMS
PASCO
Pave Tech
Roadware
T2 LTPP
IMS
PASCO
Pave Tech
Low
High
High
Moderate
Low
Section ID & Vendors

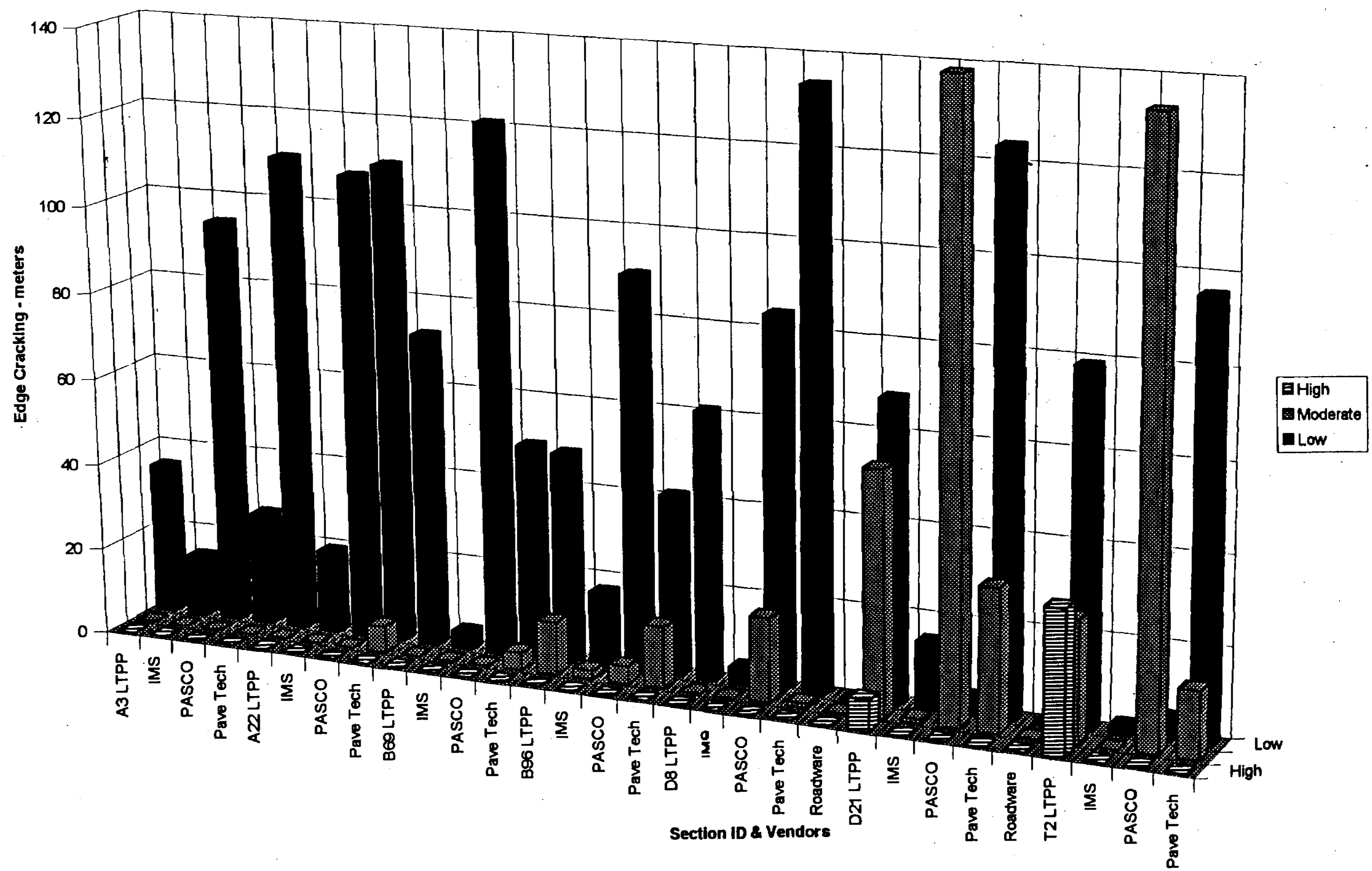
LTPP Sections Longitudinal Wheelpath Cracking - Average of Repeat Runs



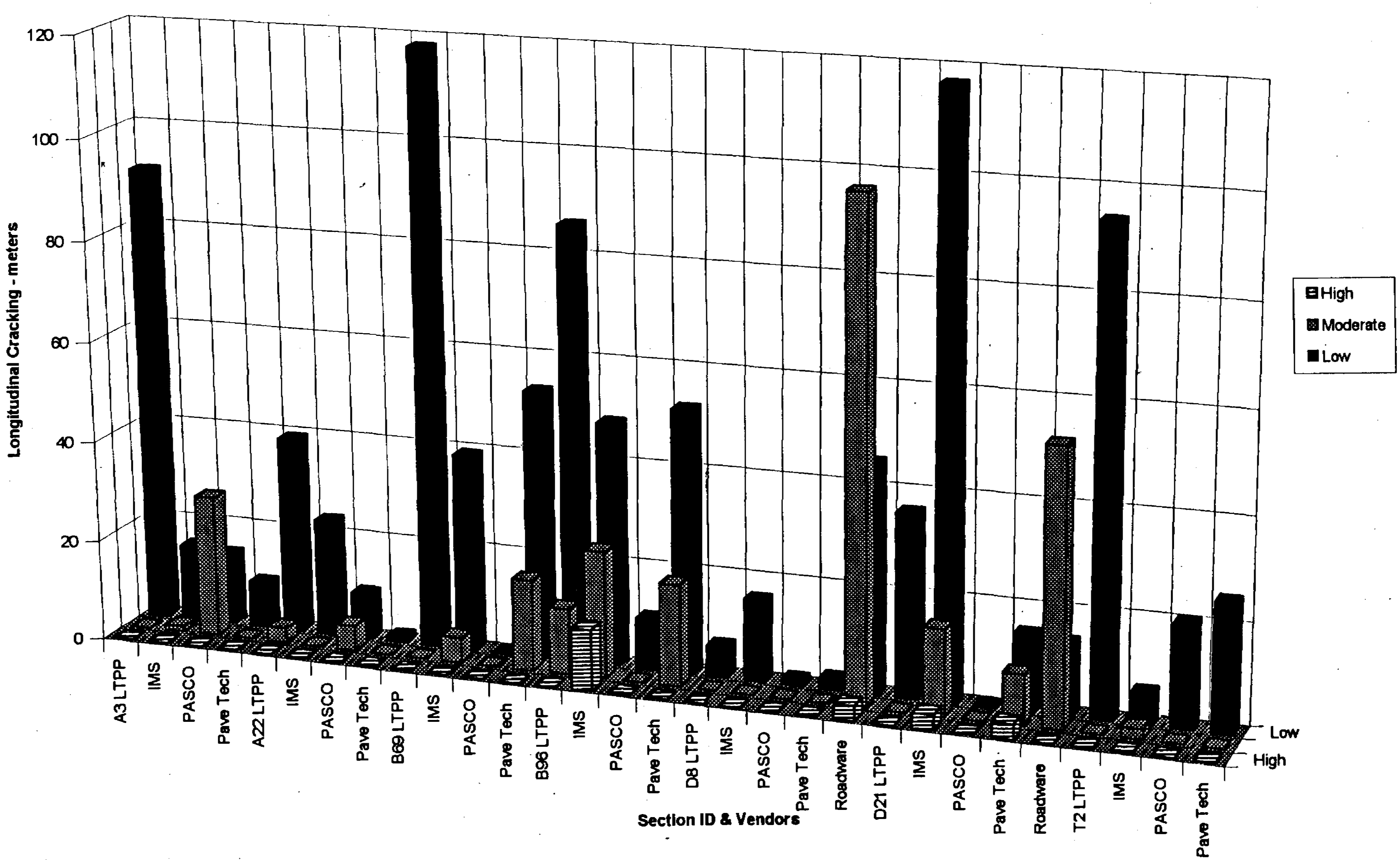
LTPP Sections Longitudinal Non-Wheelpath Cracking - Average of Repeat Runs



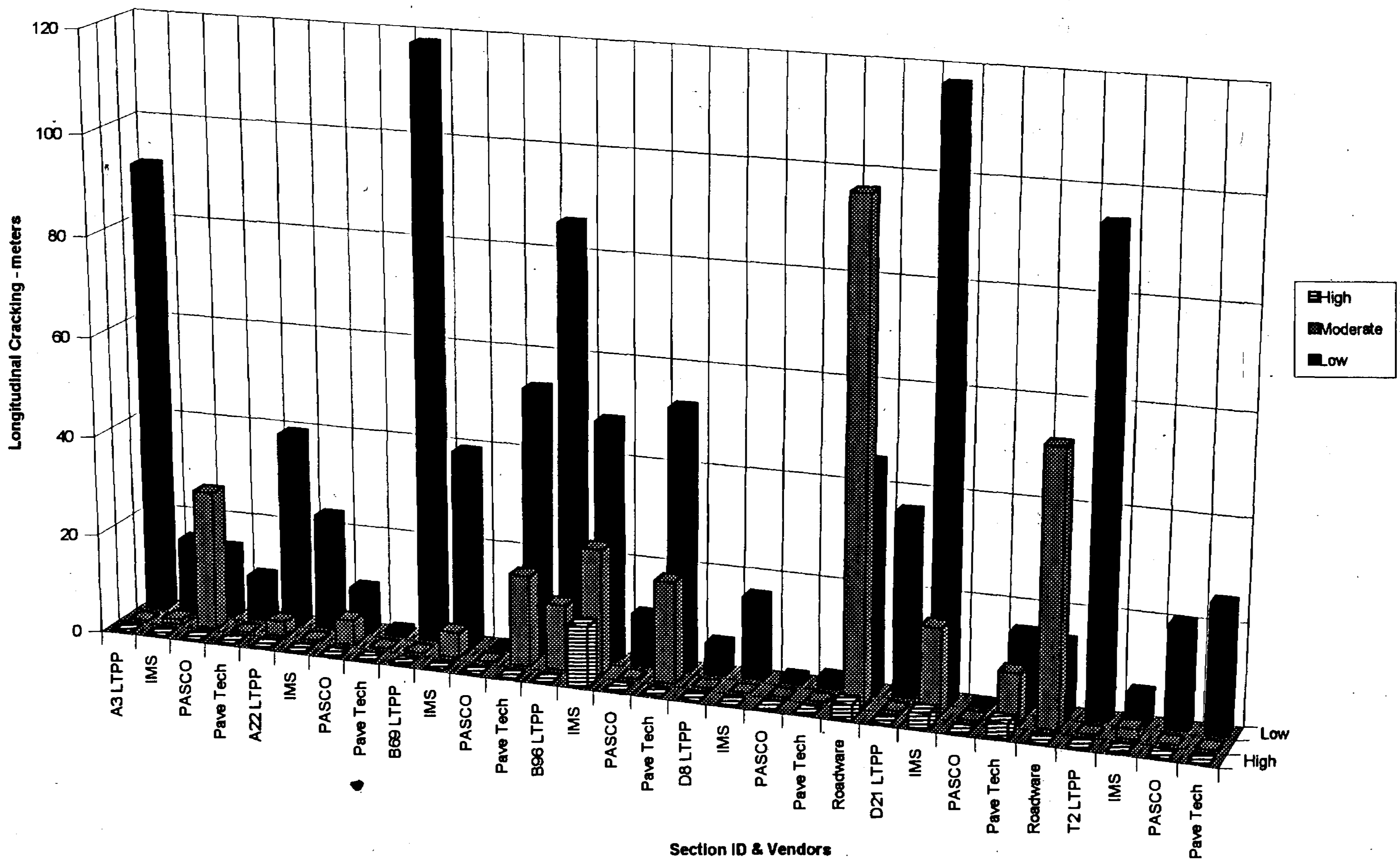
LTPP Sections Edge Cracking - Average of Repeat Runs

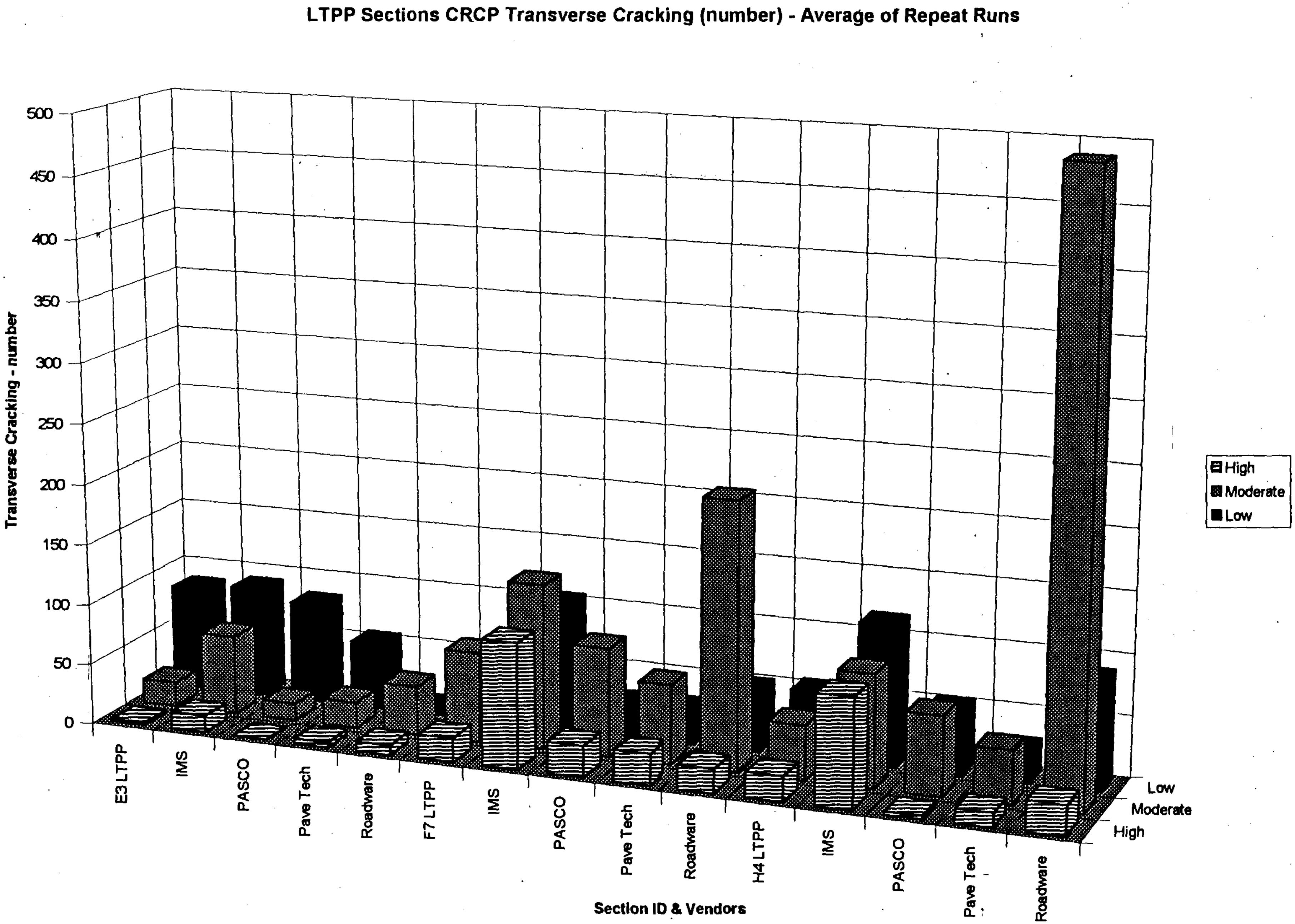


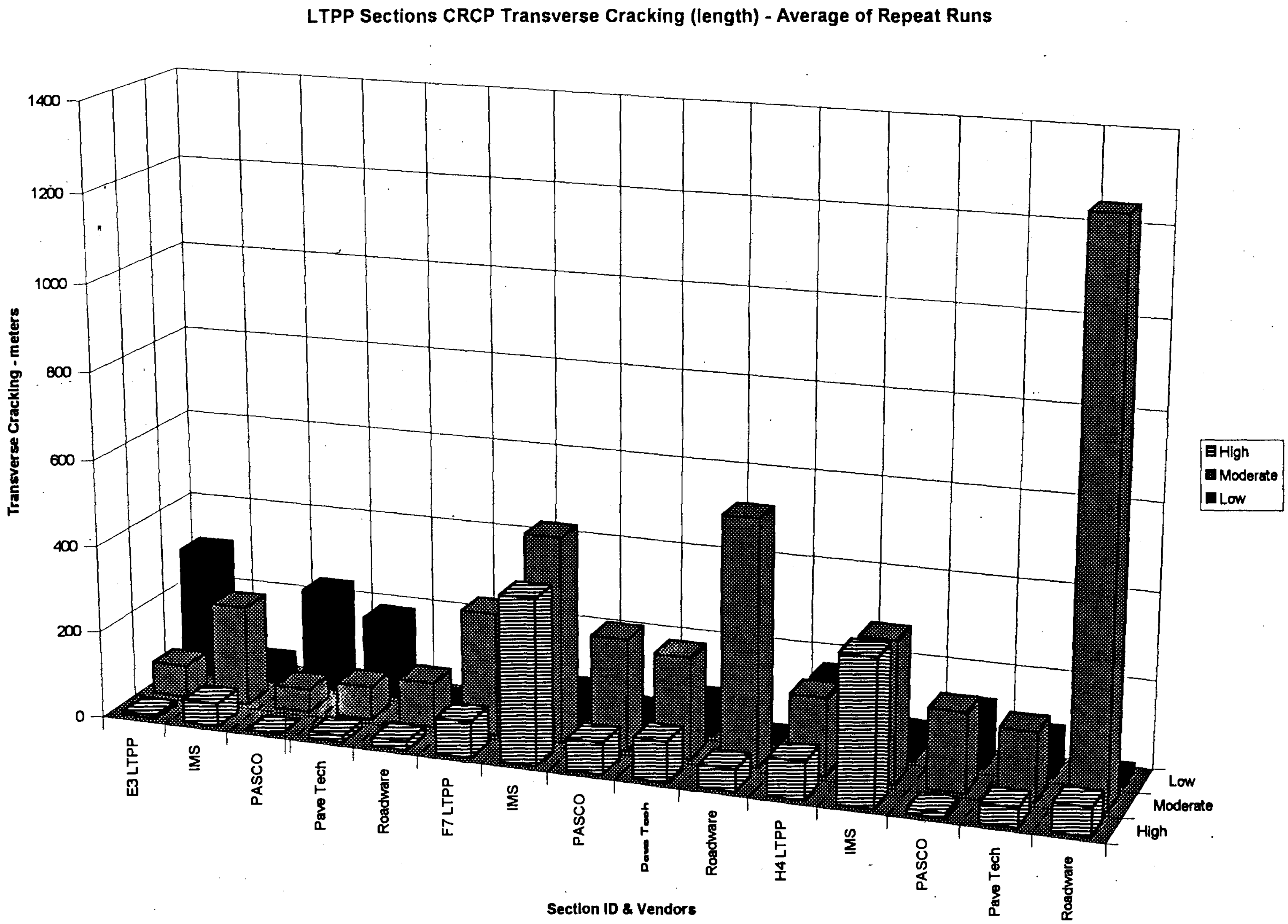
LTPP Sections Combined Longitudinal Cracking - Average of Repeat Runs



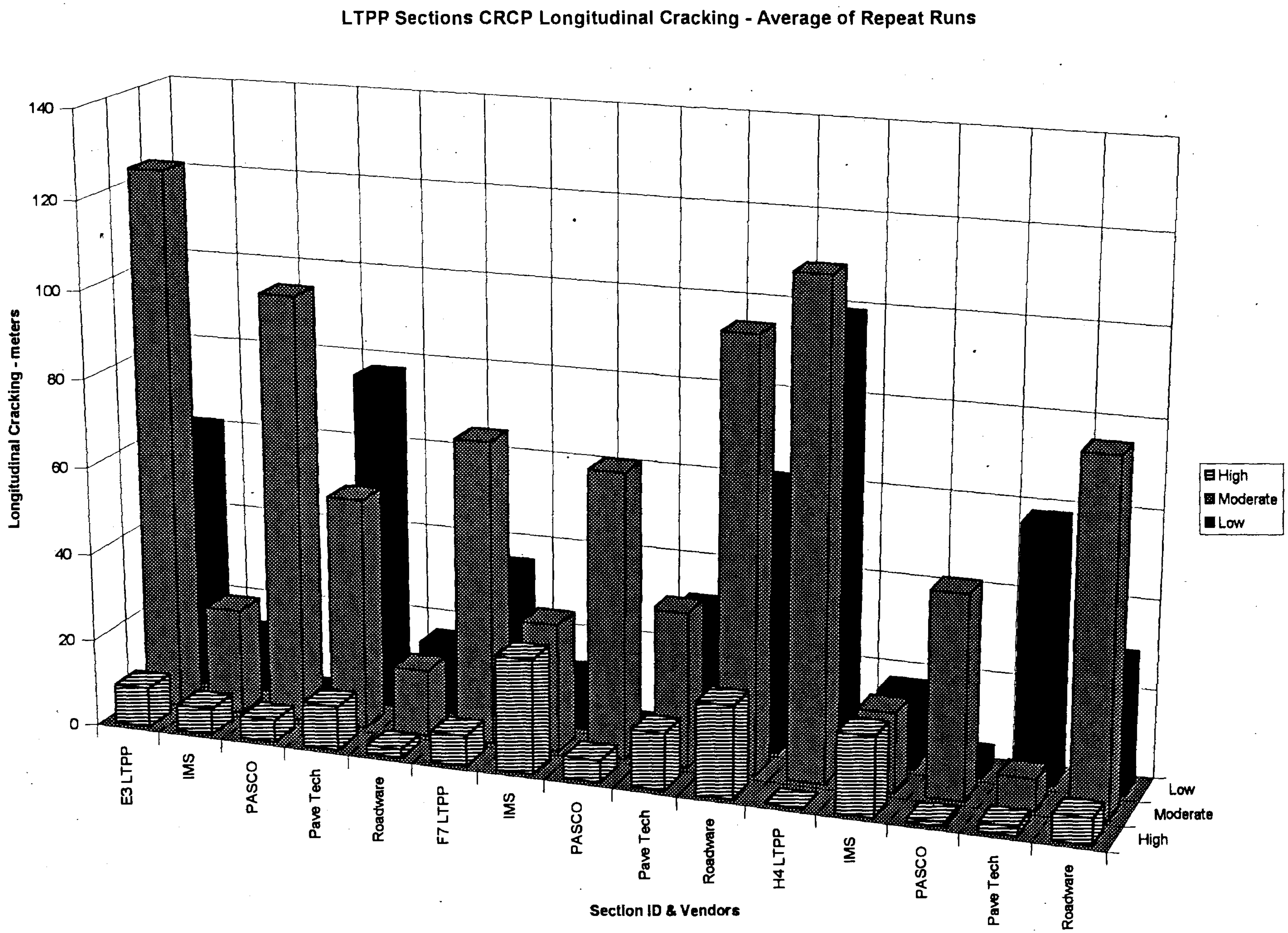
LTPP Sections Combined Longitudinal Cracking - Average of Repeat Runs




LTPP Sections CRCP Transverse Cracking (number) - Average of Repeat Runs
Transverse Cracking - number
500
450
400
350
300
250
200
150
100
50
0
E3 LTPP
IMS
PASCO
Pave Tech
Roadware
F7 LTPP
IMS
PASCO
Pave Tech
Roadware
H4 LTPP
IMS
PASCO
Pave Tech
Roadware
Section ID & Vendors
Low
Moderate
High
High
Moderate
Low



LTPP Sections CRCP Transverse Cracking (length) - Average of Repeat Runs
1400
1200
1000
800
600
400
200
0
Transverse Cracking - meters
E3 LTPP
IMS
PASCO
Pave Tech
Roadware
F7 LTPP
IMS
PASCO
Pave Tech
Roadware
H4 LTPP
IMS
PASCO
Pave Tech
Roadware
Section ID & Vendors
Low
Moderate
High
High
Moderate
Low


LTPP Sections CRCP Longitudinal Cracking - Average of Repeat Runs
Longitudinal Cracking - meters
0
20
40
60
80
100
120
140
E3 LTPP
IMS
PASCO
Pave Tech
Roadware
F7 LTPP
IMS
PASCO
Pave Tech
Roadware
H4 LTPP
IMS
PASCO
Pave Tech
Roadware
Section ID & Vendors
Low
Moderate
High
High
Moderate
Low

PMIS Tables

PMIS Rating for Project No. 21
Section A

Section ID	Alligator Cracking - Square Meters	Transverse Cracking Number per 100' Sta.	Longitudinal Cracking Feet per 100' Sta.	Edge Cracking length per 100' Sta.	Longitudinal Cracking meters	Edge Cracking meters
A1 - A5	10	0	5	11	39	84
A6 - A10	18	0	0	9	0	66
A11 - A15	31	0	2	6	18	42
A16 - A20	7	0	4	10	27	75
A21 - A25	63	0	4	17	27	127
A26 - A30	6	0	2	7	12	52
A31 - A35	39	0	0	17	0	127
A36 - A40	11	0	2	10	12	73
A41 - A45	15	0	0	2	0	12
A46 - A50	10	0	0	2	0	18

PMIS Rating for Project No. 21
Section B

Section ID	Alligator Cracking - Square Meters	Transverse Cracking Number per 100' Sta.	Longitudinal Cracking Feet per 100' Sta.	Edge Cracking length per 100' Sta.	Longitudinal Cracking - meters	Edge Cracking - meters
B1 - B5	156	0	6	9	48	64
B6 - B10	0	0	2	6	15	45
B10 - B15	160	0	7	5	55	37
B16 - B20	0	0	11	0	82	0
B21 - B25	0	0	1	0	9	0
B26 - B30	58	0	0	0	3	0
B31 - B35	57	0	3	6	25	43
B36 - B40	24	0	0	0	0	0
B41 - B45	84	0	0	1	3	7
B46 - B50	45	0	4	1	30	7
B51 - B56	0	0	0	0	0	0
B56 - B60	13	1	2	0	15	0
B61 - B65	22	0	2	3	12	24
B66 - B70	47	0	3	10	22	75
B71 - B75	70	0	5	16	40	123
B76 - B80	58	0	9	14	66	102
B81 - B85	31	0	4	39	33	295
B86 - B90	45	0	2	34	12	255
B91 - B95	265	0	10	10	75	78
B96 - B100	112	0	24	21	183	156

PMIS Rating for Project No. 21
Section D

Section ID	Alligator Cracking - Square Meters	Transverse Cracking Number per 100' Sta.	Longitudinal Cracking Feet per 100' Sta.	Edge Cracking length per 100' Sta.	Longitudinal Cracking - meters	Edge Cracking - meter
D1 - D5	214	0	0	7	0	49
D6 - D10	514	0	0	17	0	124
D11 - D15	276	0	0	3	0	24
D16 - D20	399	0	0	14	0	102
D21 - D25	560	0	0	22	0	168
D26 - D30	447	0	0	9	0	67

PMIS Rating for Project No.21
CRCP Sections

		Section E			
Section ID	Average Transverse Crack Spacing	Number of Transverse Cracks	Transverse Cracks - Number Spalled	Longitudinal Cracking - Total Number	Longitudinal Cracking - Total Length
E1	2	88	15	9	41
E2	2	88	9	4	21
E3	2	83	7	9	123
E4	2	83	1	0	0
E5	2	100	9	2	7
E6	2	79	6	5	30
E7	2	71	2	2	15
E1 - E7	2	594	49	31	237
		Section F			
Section ID	Average Transverse Crack Spacing	Number of Transverse Cracks	Transverse Cracks - Number Spalled	Longitudinal Cracking - Total Number	Longitudinal Cracking - Total Length
F1	2	79	14	6	20
F2	1	136	4	13	55
F3	1	136	0	9	42
F4	1	136	9	5	24
F5	1	136	12	14	106
F6	1	107	24	0	0
F7	1	115	19	8	75
F1 - F7	1	847	82	55	322
		Section H			
Section ID	Average Transverse Crack Spacing	Number of Transverse Cracks	Transverse Cracks - Number Spalled	Longitudinal Cracking - Total Number	Longitudinal Cracking - Total Length
H1	2	94	1	0	0
H2	2	100	2	10	52
H3	2	100	4	1	4
H4	2	88	7	11	67
H5	2	100	11	1	3
H6	1	107	10	18	132
H1 - H6	2	589	35	41	258

PMIS Rating for Project No. 21
Section T

Section ID	Alligator Cracking - Square Meters	Transverse Cracking Number per 100' Sta.	Longitudinal Cracking Feet per 100' Sta.	Edge Cracking length per 100' Sta.	Longitudinal Cracking meters	Edge Cracking - meters
T1	116	0	39	0	58	0
T2	191	0	4	0	6	0
T3	327	0	0	0	0	0
T1 - T3	635	0	43	0	64	0

IMS Section A Summary

Segment ID	Run / Pass	Fatigue	Transverse Number	Transverse Length	Longitudinal Wheelpath	Longitudinal Nonwheelpath	Edge
		Total	Total	Total	Total	Total	Total
A1 - A5	am / 1	198	8	4	58	10	15
	am / 2	425	5	2	163	17	24
	noon / 1	240	26	10	75	15	24
	noon / 2	161	15	7	43	20	27
	pm / 1	214	26	10	49	18	50
	pm / 2	149	13	4	50	12	30
Average		231	16	6	73	16	28
Std Dev P		92	8	3	42	3	11
A6 - A10	am / 1	131	8	3	38	6	37
	am / 2	188	10	3	55	3	46
	noon / 1	178	16	6	55	7	48
	noon / 2	190	9	3	52	6	51
	pm / 1	239	25	9	84	6	30
	pm / 2	241	24	10	80	6	36
Average		194	15	6	61	6	41
Std Dev P		38	7	3	16	1	7
A11 - A15	am / 1	221	19	7	51	12	31
	am / 2	227	25	8	72	12	25
	noon / 1	240	26	10	75	15	24
	noon / 2	242	29	11	75	10	30
	pm / 1	247	25	10	92	17	17
	pm / 2	254	14	9	81	26	19
Average		239	23	9	74	15	24
Std Dev P		11	5	1	12	5	5
A16 - A20	am / 1	142	14	5	30	7	38
	am / 2	169	13	5	34	11	47
	noon / 1	137	11	4	30	8	31
	noon / 2	129	8	3	33	8	28
	pm / 1	118	14	5	31	6	15
	pm / 2	131	15	5	29	7	21
Average		138	13	4	31	8	30
Std Dev P		16	2	1	2	2	11
A21 - A25	am / 1	305	6	2	141	1	81
	am / 2	336	3	1	173	3	65
	noon / 1	251	8	2	125	1	44
	noon / 2	248	14	5	116	1	39
	pm / 1	224	11	4	88	8	51
	pm / 2	199	13	5	81	2	34
Average		260	9	3	121	3	52
Std Dev P		47	4	2	31	2	16

Section A Continued

Segment ID	Run / Pass	Fatigue	Transverse Number	Transverse Length	Longitudinal Wheelpath	Longitudinal Nonwheelpath	Edge
		Total	Total	Total	Total	Total	Total
A26 - A30	am / 1	193	28	10	68	6	18
	am / 2	262	80	41	68	2	40
	noon / 1	180	17	6	62	4	26
	noon / 2	263	16	6	91	8	23
	pm / 1	244	13	5	77	11	29
	pm / 2	156	11	3	45	9	28
Average		216	28	12	68	6	27
Std Dev P		42	24	13	14	3	7
A31 - A35	am / 1	165	2	1	65	2	62
	am / 2	185	2	1	77	2	65
	noon / 1	197	16	6	62	1	49
	noon / 2	183	7	3	50	1	54
	pm / 1	89	1	1	24	2	43
	pm / 2	127	5	3	31	3	48
Average		158	6	3	51	2	53
Std Dev P		38	5	2	19	1	8
A36 - A40	am / 1	55	4	2	5	2	41
	am / 2	68	2	1	10	2	40
	noon / 1	93	39	15	11	1	10
	noon / 2	65	12	4	11	2	21
	pm / 1	41	6	2	8	2	4
	pm / 2	37	7	3	7	2	12
Average		60	12	4	9	2	21
Std Dev P		19	13	5	2	0	15
A41 - A45	am / 1	46	4	2	12	0	8
	am / 2	58	7	2	14	1	10
	noon / 1	53	12	4	13	3	4
	noon / 2	44	5	2	9	2	5
	pm / 1	43	5	2	11	1	8
	pm / 2	53	8	3	14	1	5
Average		50	7	2	12	1	7
Std Dev P		5	3	1	2	1	2
A46 - A50	am / 1	58	4	2	12	3	20
	am / 2	70	10	4	15	3	26
	noon / 1	60	4	2	10	4	16
	noon / 2	65	3	2	10	8	17
	pm / 1	66	7	3	10	3	20
	pm / 2	59	7	3	9	4	20
Average		63	6	2	11	4	20
Std Dev P		4	2	1	2	2	3

IMS Section B Summary

Segment ID	Run / Pass	Fatigue	Transverse Number	Transverse Length	Longitudinal Wheelpath	Longitudinal Nonwheelpath	Edge
		Total	Total	Total	Total	Total	Total
B1 - B6	am / 1	171	7	3	102	3	33
	am / 2	183	10	4	102	19	26
	noon / 1	153	10	5	96	3	29
	noon / 2	161	4	2	108	6	24
	pm / 1	158	6	3	101	5	28
	pm / 2	179	52	25	120	16	19
Average		167	15	7	105	9	26
Standard Deviation		11	17	8	7	6	4
B6 - B10	am / 1	63	8	3	13	1	18
	am / 2	84	3	2	25	1	10
	noon / 1	73	10	4	17	3	27
	noon / 2	87	8	4	16	1	29
	pm / 1	59	10	4	9	1	35
	pm / 2	88	16	6	20	1	23
Average		76	9	4	17	1	23
Standard Deviation		11	4	1	5	1	8
B11 - B16	am / 1	185	20	8	52	5	42
	am / 2	176	16	6	59	6	20
	noon / 1	196	18	7	51	6	32
	noon / 2	189	19	7	62	5	30
	pm / 1	143	18	8	36	5	31
	pm / 2	167	12	5	52	6	27
Average		176	17	7	52	6	30
Standard Deviation		17	3	1	8	1	6
B16 - B20	am / 1	34	7	2	5	3	5
	am / 2	30	5	2	4	2	9
	noon / 1	32	3	1	4	5	7
	noon / 2	40	4	1	6	3	11
	pm / 1	33	5	2	3	2	12
	pm / 2	43	5	3	5	2	14
Average		35	5	2	4	3	10
Standard Deviation		5	1	1	1	1	3

Section B Continued

Segment ID	Run / Pass	Fatigue	Transverse Number	Transverse Length	Longitudinal Wheelpath	Longitudinal Nonwheelpath	Edge
		Total	Total	Total	Total	Total	Total
B21 - B25	am / 1	66	21	7	13	3	2
	am / 2	50	13	5	11	3	5
	noon / 1	67	16	5	11	4	5
	noon / 2	71	14	5	12	2	10
	pm / 1	64	18	7	10	3	5
	pm / 2	70	17	6	13	1	7
Average		65	17	6	12	3	6
Standard Deviation		7	3	1	1	1	3
B26 - B30	am / 1	154	26	9	65	13	4
	am / 2	126	29	11	73	7	8
	noon / 1	160	30	12	68	5	8
	noon / 2	152	18	7	53	19	8
	pm / 1	165	27	12	75	10	7
	pm / 2	167	80	38	92	17	8
Average		154	35	15	71	12	7
Standard Deviation		13	20	10	12	5	1
B31 - B35	am / 1	134	21	9	53	5	21
	am / 2	109	27	11	42	3	25
	noon / 1	144	37	19	52	6	22
	noon / 2	143	31	14	58	5	21
	pm / 1	126	29	11	48	5	24
	pm / 2	153	35	16	45	6	26
Average		135	30	13	49	5	23
Standard Deviation		14	5	3	6	1	2
B36 - B40	am / 1	87	18	7	27	2	9
	am / 2	91	19	8	27	0	17
	noon / 1	85	15	5	24	1	10
	noon / 2	77	15	7	22	0	11
	pm / 1	128	21	8	40	4	8
	pm / 2	120	27	10	37	4	6
Average		98	19	7	29	2	10
Standard Deviation		19	4	2	7	1	3
B41 - B45	am / 1	149	18	9	56	8	52
	am / 2	124	8	4	36	1	39
	noon / 1	151	21	8	44	8	55
	noon / 2	151	31	14	46	8	72
	pm / 1	129	19	10	32	13	55
	pm / 2	138	25	10	41	9	51
Average		140	20	9	43	8	54
Standard Deviation		11	7	3	7	4	10

Section B Continued

Segment ID	Run / Pass	Fatigue	Transverse Number	Transverse Length	Longitudinal Wheelpath	Longitudinal Nonwheelpath	Edge
		Total	Total	Total	Total	Total	Total
B46 - B50	am / 1	99	2	1	42	2	9
	am / 2	137	7	3	52	4	9
	noon / 1	84	6	2	27	1	18
	noon / 2	92	8	5	32	2	8
	pm / 1	94	4	1	37	2	7
	pm / 2	81	7	4	26	2	3
Average		98	6	3	36	2	9
Standard Deviation		19	2	1	9	1	5
B51 - B55	am / 1	22	3	1	2	3	6
	am / 2	11	1	1	0	1	4
	noon / 1	29	4	2	0	1	22
	noon / 2	34	2	1	1	1	26
	pm / 1	22	3	2	3	0	15
	pm / 2	23	0	0	1	1	17
Average		23	2	1	1	1	15
Standard Deviation		7	1	1	1	1	8
B56 - B60	am / 1	52	7	3	7	1	26
	am / 2	63	9	4	8	2	25
	noon / 1	98	1	0	15	2	51
	noon / 2	68	6	3	5	1	61
	pm / 1	62	4	2	4	2	40
	pm / 2	71	1	1	10	1	38
Average		69	5	2	8	2	40
Standard Deviation		14	3	1	4	1	13
B61 - B65	am / 1	54	6	5	15	1	12
	am / 2	52	3	1	20	3	6
	noon / 1	85	4	1	13	3	64
	noon / 2	84	6	3	15	1	53
	pm / 1	51	10	5	13	2	15
	pm / 2	52	2	1	12	2	30
Average		63	5	3	15	2	30
Standard Deviation		15	3	2	3	1	21
B66 - B70	am / 1	86	21	9	49	12	5
	am / 2	86	4	2	31	18	7
	noon / 1	125	31	12	44	18	44
	noon / 2	100	23	9	41	15	30
	pm / 1	92	24	10	41	17	22
	pm / 2	84	24	10	41	10	19
Average		95	21	9	41	15	21
Standard Deviation		14	8	3	5	3	14

Section B Continued

Segment ID	Run / Pass	Fatigue	Transverse Number	Transverse Length	Longitudinal Wheelpath	Longitudinal Nonwheelpath	Edge
		Total	Total	Total	Total	Total	Total
B71 - B75	am / 1	196	10	4	52	30	66
	am / 2	149	7	3	54	29	52
	noon / 1	199	6	3	46	39	87
	noon / 2	185	5	2	56	34	77
	pm / 1	175	8	4	49	38	70
	pm / 2	198	9	5	56	34	83
Average		184	8	4	52	34	73
Standard Deviation		18	2	1	3	4	12
B76 - B80	am / 1	198	10	7	83	32	40
	am / 2	208	14	14	85	40	58
	noon / 1	226	16	10	90	36	97
	noon / 2	219	14	10	92	41	83
	pm / 1	222	13	10	93	36	61
	pm / 2	183	12	10	77	40	45
Average		209	13	10	86	37	64
Standard Deviation		15	2	2	6	3	20
B81 - B85	am / 1	299	6	5	113	1	207
	am / 2	337	3	2	157	2	194
	noon / 1	334	6	4	131	2	281
	noon / 2	321	6	5	101	4	291
	pm / 1	322	4	3	117	1	226
	pm / 2	277	4	3	100	3	203
Average		315	5	4	120	2	234
Standard Deviation		21	1	1	20	1	38
B86 - B90	am / 1	225	3	3	87	1	176
	am / 2	239	8	12	102	0	180
	noon / 1	283	2	2	121	0	211
	noon / 2	302	24	28	128	1	253
	pm / 1	185	4	3	71	1	142
	pm / 2	217	6	6	87	1	154
Average		242	8	9	99	1	186
Standard Deviation		40	7	9	20	0	37
B91 - B95	am / 1	514	21	20	281	16	181
	am / 2	532	9	9	280	27	180
	noon / 1	482	2	4	240	29	217
	noon / 2	521	16	18	313	31	191
	pm / 1	511	7	8	269	30	169
	pm / 2	529	42	39	298	42	145
Average		515	16	16	280	29	180
Standard Deviation		17	13	12	23	8	22

Section B Continued

Segment ID	Run / Pass	Fatigue	Transverse Number	Transverse Length	Longitudinal Wheelpath	Longitudinal Nonwheelpath	Edge
		Total	Total	Total	Total	Total	Total
B96 - B100	am / 1	222	6	5	127	23	63
	am / 2	264	7	6	144	21	71
	noon / 1	563	629	260	113	17	96
	noon / 2	256	44	24	121	19	63
	pm / 1	241	4	4	119	15	58
	pm / 2	230	5	4	128	18	48
Average		296	116	50	125	19	67
Standard Deviation		120	230	94	10	3	15

IMS Section D Summary

Segment ID	Run / Pass	Fatigue	Transverse Number	Transverse Length	Longitudinal Wheelpath	Longitudinal Nonwheelpath	Edge
		Total	Total	Total	Total	Total	Total
D1 - D5	am / 1	62	1	0	12	1	40
	am / 2	78	3	1	13	0	45
	noon / 1	102	4	1	17	1	49
	noon / 2	98	4	2	17	1	46
	pm / 1	71	3	1	10	1	48
	pm / 2	94	3	1	16	1	50
Average		84	3	1	14	1	46
Standard Deviation		15	1	0	3	0	3
D6 - D10	am / 1	203	8	3	61	4	37
	am / 2	216	9	3	63	1	33
	noon / 1	182	9	3	48	3	33
	noon / 2	155	6	2	43	2	33
	pm / 1	154	8	3	42	4	20
	pm / 2	161	10	3	45	3	16
Average		179	8	3	50	3	29
Standard Deviation		24	1	0	8	1	8
D11 - D15	am / 1	31	1	0	1	0	29
	am / 2	13	0	0	1	0	9
	noon / 1	42	4	1	1	0	37
	noon / 2	60	0	0	5	0	49
	pm / 1	36	1	0	4	0	25
	pm / 2	34	0	0	2	0	22
Average		36	1	0	2	0	28
Standard Deviation		14	1	1	2	0	13
D16 - D20	am / 1	76	1	1	6	1	74
	am / 2	54	1	0	5	0	59
	noon / 1	83	0	0	7	0	81
	noon / 2	84	1	1	12	0	60
	pm / 1	56	0	0	4	1	47
	pm / 2	76	2	1	6	1	63
Average		71	1	0	7	0	64
Standard Deviation		12	1	0	3	0	11
D21 - D25	am / 1	341	19	12	117	82	55
	am / 2	302	21	14	101	75	46
	noon / 1	306	17	13	133	50	47
	noon / 2	301	23	15	77	113	70
	pm / 1	296	15	10	133	46	52
	pm / 2	301	19	15	86	100	53
Average		308	19	13	108	78	54
Standard Deviation		15	3	2	22	24	8

IMS Section D Summary

Segment ID	Run / Pass	Fatigue	Transverse Number	Transverse Length	Longitudinal Wheelpath	Longitudinal Nonwheelpath	Edge
		Total	Total	Total	Total	Total	Total
D26 - D30	am / 1	204	4	2	33	2	140
	am / 2	138	2	1	19	2	80
	noon / 1	152	1	0	25	2	89
	noon / 2	148	3	1	27	1	83
	pm / 1	112	3	1	18	1	67
	pm / 2	126	2	1	22	0	70
Average		146	3	1	24	1	88
Standard Deviation		29	1	0	5	1	24

IMS Section T Summary

Segment ID	Run / Pass	Fatigue	Transverse Number	Transverse Length	Longitudinal Wheelpath	Longitudinal Nonwheelpath	Edge
		Total	Total	Total	Total	Total	Total
T Sum	am / 1	381	48	35	199	33	122
	am / 2	365	50	39	174	24	136
	pm / 1	341	37	30	160	23	90
	pm / 2	330	44	32	145	23	94
	pm / 3	322	46	31	152	22	90
	pm / 4	304	28	27	134	22	102
Average		340	42	32	161	25	106
Standard Deviation		26	8	4	21	4	17

IMS Section E

Seg ID	Run / Pass	Transverse Cracking Number Total	Transverse Cracking Number Mod & High	Transverse Cracking Length Total	Transverse Cracking Length Mod & High	Longitudinal Length Total	Longitudinal Length Mod & High
E Sum	am / 1	710	361	1445	1275	203	136
	am / 2	681	363	1449	1296	167	117
	am / 3	733	430	1657	1524	203	153
	noon / 1	1398	723	2883	2582	327	232
	noon / 2	1560	790	3178	2838	429	289
	noon / 3	1304	690	2743	2458	482	328
	pm / 1	1087	451	1958	1611	310	206
	pm / 2	1116	495	2101	1768	346	228
	pm / 3	1254	863	3289	3060	445	357
Average		**1094**	**574**	**2300**	**2046**	**324**	**227**
Std Dev.		**303**	**182**	**692**	**650**	**108**	**80**

IMS Section F

Seg ID	Run / Pass	Transverse Cracking Number Total	Transverse Cracking Number Mod & High	Transverse Cracking Length Total	Transverse Cracking Length Mod & High	Longitudinal Length Total	Longitudinal Length Mod & High
F Sum	am / 1	1519	896	3558	3212	240	0
	am / 2	1430	812	3255	2901	235	0
	am / 3	1666	1018	3970	3644	225	0
	noon / 1	2678	1482	5887	5262	546	0
	noon / 3	2692	1623	6364	5793	750	0
	pm / 1	1561	904	3593	3215	326	0
	pm / 2	1541	755	3190	2725	322	0
Average		**1870**	**1070**	**4260**	**3822**	**378**	**0**
Std Dev.		**520**	**317**	**1210**	**1120**	**183**	**0**

IMS Section H

Seg ID	Run / Pass	Transverse Cracking Number Total	Transverse Cracking Number Mod & High	Transverse Cracking Length Total	Transverse Cracking Length Mod & High	Longitudinal Length Total	Longitudinal Length Mod & High
H Sum	am / 1	1343	733	2932	2607	187	0
	am / 2	1293	617	2555	2211	230	0
	am / 3	1247	793	3081	2842	190	0
	noon / 1	1870	1065	4218	3814	441	0
	noon / 2	2033	1035	4165	3699	572	0
	noon / 3	2065	1346	5164	4811	523	0
	pm / 1	1521	623	2688	2212	218	0
	pm / 2	1588	760	3144	2705	312	0
	pm / 3	1668	1011	3994	3596	366	0
Average		**1625**	**887**	**3549**	**3166**	**338**	**0**
Std Dev.		**292**	**229**	**825**	**820**	**138**	**0**

Pasco Section A

Section ID	Fatigue Area Total	Transverse Number Total	Transverse Length Total	Longitudinal - Length Wheel Total	Longitudinal - Length NonWheel TotaL	Edge Length Total
A1 - A5	98	7	18	5	62	370
A6 - A10	229	8	10	2	12	697
A11 - A15	164	6	8	4	4	674
A16 - A20	20	3	5	4	19	674
A21 - A25	99	6	11	14	11	571
A26 - A30	12	0	0	3	0	246
A31 - A35	6	0	0	0	0	225
A36 - A40	3	0	0	5	0	239
A41 - A45	62	2	4	0	9	552
A46 - A50	44	2	2	6	6	714

Pasco Section B

Section ID	Fatigue Area Total	Transverse Number Total	Transverse Length Total	Longitudinal - Length Wheel Total	Longitudinal - Length NonWheel Total	Edge Length Total
B1 - B5	70	6	7	8	3	563
B6 - B10	17	3	4	1	2	699
B11 - B15	107	9	9	6	5	706
B16 - B20	25	0	0	1	1	493
B21 - B25	8	12	17	15	1	535
B25 - B30	60	5	7	2	2	711
B31 - B35	46	8	9	9	0	511
B36 - B40	93	1	2	1	1	739
B41 - B45	79	8	10	18	2	475
B46 - B50	42	1	2	0	1	540
B51 - B55	8	1	1	0	3	540
B56 - B60	11	3	4	0	0	241
B61 - B65	31	3	4	0	3	371
B66 - B70	148	4	8	4	14	389
B71 - B75	88	9	14	2	12	367
B76 - B80	131	3	3	1	11	208
B81 - B85	19	0	0	2	3	515
B86 - B90	20	1	1	0	0	466
B91 - B95	131	11	28	15	14	502
B96 - B100	224	1	2	42	38	465

Pasco Section D

Section ID	Fatigue Area Total	Transverse Number Total	Transverse Length Total	Longitudinal Wheel Total	Longitudinal NonWheel Total	Edge Length Total
D1 - D5	408	2	5	8	0	596
D6 - D10	510	2	4	6	19	611
D11 - D15	130	3	8	5	9	723
D16 - D20	95	1	3	2	7	554
D21 - D25	349	2	4	0	4	415
D26 - D30	167	2	6	0	33	571

Pasco Section T

Section ID	Fatigue Area Total	Transverse Number Total	Transverse Length Total	Longitudinal - Length Wheel Total	Longitudinal - Length NonWheel Total	Edge Length Total
T1	67	6	9	3	2	138
T2	66	4	6	6	29	140
T3	265	0	0	1	2	137
T Sum	398	10	15	10	33	415

Pasco Section E

Section ID	Transverse Cracking Number Total	Transverse Cracking Number M & H	Transverse Cracking Length Total	Transverse Cracking Length M & H	Longitudinal Length Total	Longitudinal Length M & H
E1	84	31	234	99	19	19
E2	91	29	304	88	33	29
E3	99	15	314	59	110	110
E4	70	5	185	15	0	0
E5	91	19	264	54	3	3
E6	92	29	265	87	29	28
E7	87	23	250	69	7	7
E Sum	614	151	1817	470	201	196

Pasco Section F

Section ID	Transverse Cracking Number Total	Transverse Cracking Number M & H	Transverse Cracking Length Total	Transverse Cracking Length M & H	Longitudinal Length Total	Longitudinal Length M & H
F1	144	70	396	211	56	43
F2	122	64	308	175	28	24
F3	113	48	209	102	171	156
F4	147	54	349	149	50	42
F5	155	113	436	337	95	92
F6	122	108	360	326	1	1
F7	130	111	341	315	68	64
F Sum	933	568	2398	1616	468	422

Pasco Section H Run 1

Section ID	Transverse Cracking Number Total	Transverse Cracking Number M & H	Transverse Cracking Length Total	Transverse Cracking Length M & H	Longitudinal Length Total	Longitudinal Length M & H
H1	97	81	318	275	0	0
H2	119	91	323	255	38	20
H3	124	67	336	171	4	3
H4	128	68	334	188	56	51
H5	119	81	346	245	11	4
H6	153	120	391	321	232	221
Hsum	740	508	2047	1455	341	300

Pasco Section H Run 2

Section ID	Transverse Cracking Number Total	Transverse Cracking Number M & H	Transverse Cracking Length Total	Transverse Cracking Length M & H	Longitudinal Length Total	Longitudinal Length M & H
H1	105	87	308	260	0	0
H2	108	72	311	213	30	26
H3	115	60	297	169	5	5
H4	110	67	301	196	47	43
H5	111	49	319	147	5	0
H6	126	57	360	169	213	213
H Sum	675	392	1896	1153	299	287

Section ID	Transverse Cracking Number Total	Transverse Cracking Number M & H	Transverse Cracking Length Total	Transverse Cracking Length M & H	Longitudinal Length Total	Longitudinal Length M & H
Run1	740	508	2047	1455	341	300
Run2	675	392	1896	1153	299	287
Average	708	450	1971	1304	320	293
Std Dev.	33	58	76	151	21	7

Pave Tech Section A

Section ID	Fatigue area Total	Transverse Number Total	Transverse Length Total	Longitudinal - Len Wheel Total	Longitudinal - Len Non-Wheel Total	Edge Length Total
A1 - A5	34	6	11	52	24	236
A6 - A10	43	7	6	22	9	328
A11 - A15	110	2	5	78	34	308
A16 - A20	33	11	17	13	0	268
A21 - A25	57	8	15	58	4	535
A26 - A30	7	1	1	46	11	195
A31 - A35	1	2	2	41	0	327
A36 - A40	6	4	4	31	5	207
A41 - A45	45	13	26	8	18	250
A46 - A50	18	9	9	8	2	223

Pave Tech Section B						
	Fatigue	Transverse		Longitudinal- Length		Edge
Section	Area	Number	Length	Wheel	Non-wheel	Length
ID	Total	Total	Total	Total	Total	Total
B1 - B5	235	65	109	10	124	441
B6 - B10	112	40	61	0	66	705
B11 - B15	398	125	187	17	125	808
B16 - B20	104	70	111	14	82	507
B21 - B25	122	74	125	37	75	414
B26 - B30	288	61	85	23	70	623
B31 - B35	95	33	45	40	86	470
B36 - B40	74	74	79	11	13	174
B41 - B45	135	32	36	13	27	353
B46 - B50	79	27	30	2	21	184
B51 - B55	54	46	55	0	35	86
B56 - B60	45	23	22	1	45	91
B61 - B65	55	41	41	3	70	52
B66 - B70	83	32	27	63	35	168
B71 - B75	135	74	75	16	83	327
B76 - B80	124	61	58	65	74	210
B81 - B85	74	47	44	25	27	565
B86 - B90	89	41	37	39	17	474
B91 - B95	167	58	77	97	153	519
B96 - B100	171	27	24	138	163	366

Pave Tech Section D

Section ID	Run / Pass	Fatigue Area	Transverse Number	Transverse Length	Longitudinal - Length Wheel	Longitudinal - Length NonWheel	Edge Area
		Total	Total	Total	Total	Total	Total
D1 - D5	am / 1	140	3	7	0	3	484
	am / 2	136	2	4	0	2	450
	noon / 1	177	4	6	18	0	368
	noon / 2	139	0	0	0	0	361
	pm / 1	168	2	5	8	0	365
	pm / 2	168	1	1	18	0	297
Average		**155**	**2**	**4**	**7**	**1**	**387**
Std. Dev.		**17**	**1**	**2**	**8**	**1**	**62**
D6 - D10	am / 1	302	0	0	0	6	620
	am / 2	375	1	1	55	0	641
	noon / 1	384	4	7	35	0	601
	noon / 2	366	0	0	42	0	588
	pm / 1	396	3	6	0	1	615
	pm / 2	357	1	2	0	1	593
Average		**363**	**2**	**3**	**22**	**1**	**610**
Std. Dev.		**30**	**2**	**3**	**23**	**2**	**18**
D11 - D15	am / 1	62	2	5	0	0	479
	am / 2	46	0	0	19	0	495
	noon / 1	84	0	0	5	0	425
	noon / 2	69	0	0	27	0	358
	pm / 1	72	1	4	0	0	402
	pm / 2	84	0	0	10	0	312
Average		**69**	**1**	**1**	**10**	**0**	**412**
Std. Dev.		**13**	**1**	**2**	**10**	**0**	**64**
D16 - D20	am / 1	127	5	11	2	0	577
	am / 2	150	4	4	12	5	591
	noon / 1	110	4	9	12	0	547
	noon / 2	119	2	5	2	0	515
	pm / 1	126	2	7	0	0	539
	pm / 2	158	1	1	2	0	554
Average		**132**	**3**	**6**	**5**	**1**	**554**
Std. Dev.		**17**	**1**	**3**	**5**	**2**	**25**

Pave Tech Section D continued

Section ID	Run / Pass	Fatigue Area	Transverse Number	Transverse Length	Longitudinal - Len Wheel	Longitudinal - Len NonWheel	Edge Area
		Total	Total	Total	Total	Total	Total
D21 - D25	am / 1	374	11	34	13	36	684
	am / 2	407	9	31	14	9	675
	noon / 1	468	13	37	21	0	558
	noon / 2	397	12	35	16	0	527
	pm / 1	311	13	38	42	0	609
	pm / 2	330	10	29	117	0	595
Average		**381**	**11**	**34**	**37**	**7**	**608**
Std. Dev.		**52**	**1**	**3**	**37**	**13**	**57**
D26 - D30	am / 1	224	3	4	1	0	622
	am / 2	235	1	1	3	0	620
	noon / 1	235	1	4	5	24	634
	noon / 2	220	5	14	0	9	613
	pm / 1	276	1	4	1	11	617
	pm / 2	252	1	1	0	11	610
Average		**241**	**2**	**5**	**2**	**9**	**619**
Std. Dev.		**19**	**2**	**4**	**2**	**8**	**8**

Pave Tech Section E

Section ID	Transverse Number		Transverse Length		Longitudinal Length	
	Total	M $ H	Total	M $ H	Total	M $ H
E1	71	41	253	147	25	0
E2	75	33	263	121	29	0
E3	76	21	267	77	130	68
E4	69	16	226	55	4	0
E5	87	29	315	106	14	0
E6	85	27	286	98	22	17
E7	75	15	272	55	18	0
Esum	538	182	1882	658	242	85

Pave Tech: Section F

Section ID	Transverse Number		Transverse Length		Longitudinal Length	
	Total	M $ H	Total	M $ H	Total	M $ H
F1	134	61	426	211	54	15
F2	122	48	389	169	107	9
F3	87	28	254	93	228	104
F4	126	34	418	120	64	26
F5	132	57	421	179	131	57
F6	109	86	376	303	7	0
F7	118	91	407	323	76	48
F sum	828	405	2690	1397	667	259

Pave Tech: Section H

Section ID	Transverse Number		Transverse Length		Longitudinal Length	
	Total	M $ H	Total	M $ H	Total	M $ H
H sum am1	458	212	1504	642	188	63
am 2	459	228	1501	694	178	58
noon 1	460	215	1524	650	169	57
noon 2	460	237	1527	727	169	60
pm 1	474	195	1554	568	198	60
pm 2	466	205	1554	611	171	64
Average	**463**	**215**	**1527**	**649**	**179**	**60**
Std Dev	**6**	**14**	**21**	**52**	**11**	**3**

Roadware Section D

Section ID	Run / Pass	Fatigue Area Total	Transverse Number Total	Transverse Length Total	Longitudinal - Length Wheel Total	Longitudinal - Length Non-Wheel Total	Edge Length Total
D1 - D5	am /2	0	26	9	15	298	0
	Noon / 1	0	21	6	33	337	0
	pm /2	4	37	11	58	584	0
Average		**1**	**28**	**9**	**35**	**406**	**0**
Std Deviation		**2**	**7**	**2**	**17**	**127**	**0**
D6 - D10	am /2	0	20	5	56	296	0
	Noon / 1	0	14	4	75	374	0
	pm /2	7	44	11	87	552	0
Average		**2**	**26**	**7**	**73**	**407**	**0**
Std Deviation		**3**	**13**	**3**	**13**	**107**	**0**
D11 - D15	am /2	0	2	1	7	5	0
	Noon / 1	0	0	0	6	9	0
	pm /2	0	0	0	23	10	0
Average		**0**	**1**	**0**	**12**	**8**	**0**
Std Deviation		**0**	**1**	**0**	**8**	**2**	**0**
D16 - D20	am /2	0	0	0	3	8	0
	Noon / 1	0	0	0	6	14	0
	pm /2	0	1	0	11	19	0
Average		**0**	**0**	**0**	**7**	**14**	**0**
Std Deviation		**0**	**0**	**0**	**3**	**4**	**0**
D21 - D25	am /2	0	23	8	19	233	0
	Noon / 1	0	16	5	32	263	0
	pm /2	2	19	5	39	330	0
Average		**1**	**19**	**6**	**30**	**275**	**0**
Std Deviation		**1**	**3**	**1**	**8**	**41**	**0**
D26 - D30	am /2	0	18	5	28	455	0
	Noon / 1	0	24	6	45	492	0
	pm /2	6	21	5	60	596	0
Average		**2**	**21**	**6**	**44**	**514**	**0**
Std Deviation		**3**	**2**	**1**	**13**	**60**	**0**

Roadware Section E

Section ID	Run / Pass	Transverse Cracking				Longitudinal	
		Number		Length		Length	
		Total	M & H	Total	M & H	Total	M & H
E sum	AM /1	615	549	1419	1409	510	389
E 1 - E 7	AM /2	629	561	1451	1441	519	375
	Noon / 1	426	375	968	960	285	228
	Noon / 2	360	324	837	831	482	422
	PM / 5	806	681	1766	1745	568	320
Average		567	498	1288	1277	473	347
Std Deviation		159	131	340	335	98	68
E sum	PM / 1	725	618	1604	1588	644	295
E1 - E6	PM / 2	580	489	1276	1261	588	253
	PM / 3	591	507	1315	1302	360	252
	PM /4	596	537	1386	1377	384	247
Average		623	538	1395	1382	494	262
Std Deviation		59	49	127	126	124	19

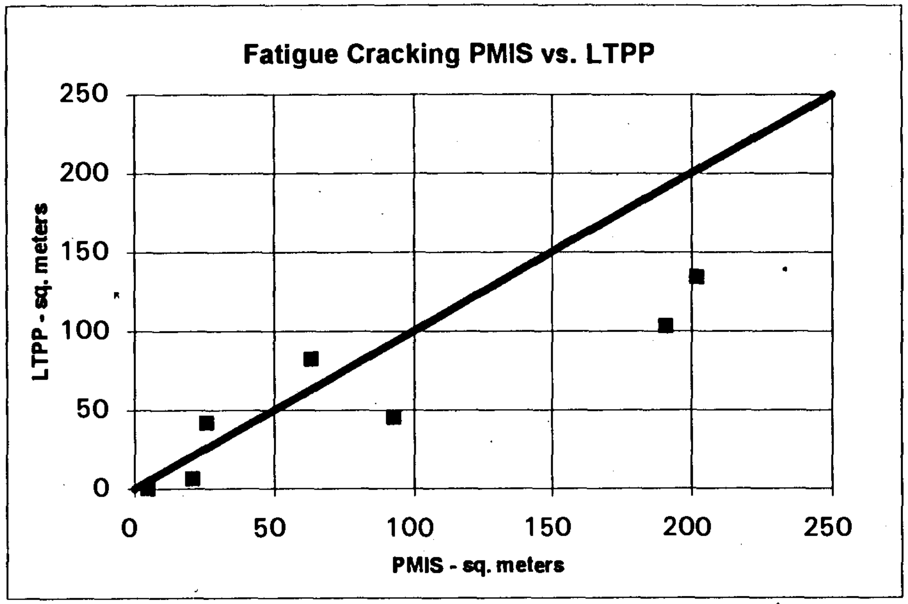
Roadware Section F

Section ID	Run / Pass	Transverse Cracking				Longitudinal	
		Number		Length		Length	
		Total	M $ H	Total	M $ H	Total	M $ H
F1 - F7	AM /2	2352	1944	5048	4973	1508	1139
	Noon /1	1382	1134	2942	2901	1055	736
	Noon /2	1198	1017	2631	2601	843	585
Average		1644	1365	3540	3492	1136	820
Std Dev.		506	412	1074	1054	277	234
F1 - F6	PM / 1	695	576	1501	1479	317	242
	PM /2	676	552	1442	1418	302	222
	PM / 3	687	567	1476	1454	481	224
		686	565	1473	1450	367	229
		8	10	24	25	81	9
F1 - F4	AM /1	597	531	1366	1352	197	168

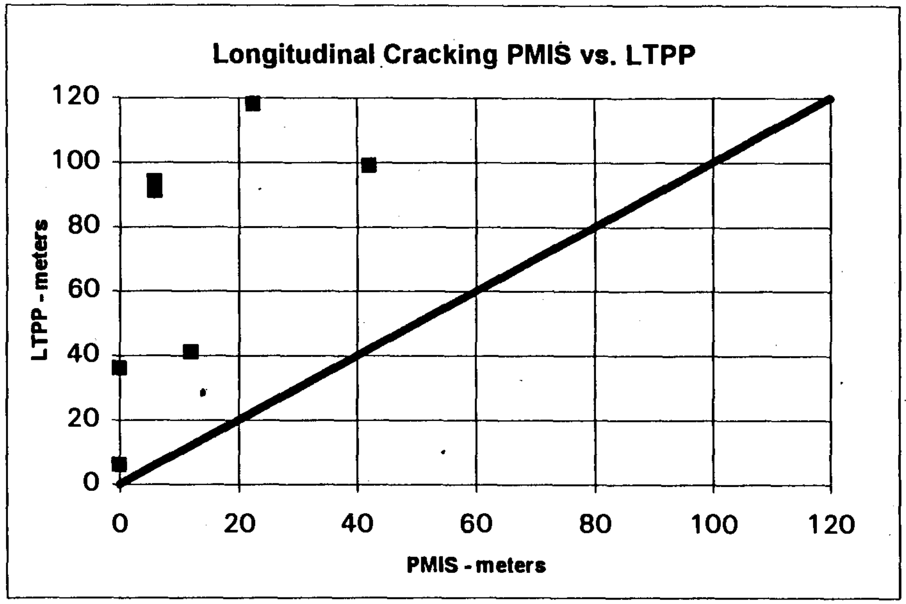
Roadware Section H

Section ID	Run / Pass	Transverse Cracking				Longitudinal	
		Number		Length		Length	
		Total	M $ H	Total	M $ H	Total	M $ H
H1 - H6	AM /1	3994	3438	8933	8827	1037	778
	AM /2	3706	3195	8293	8193	840	640
	PM /1	642	501	1314	1286	123	80
Average		2781	2378	6180	6102	667	499
Std Deviation		1517	1331	3451	3415	393	302

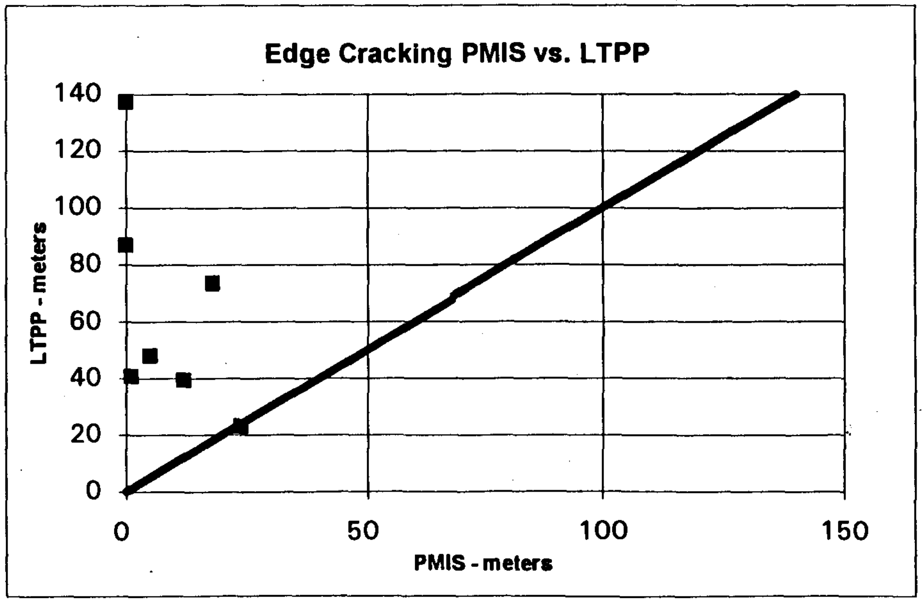
PMIS X-Y Plots



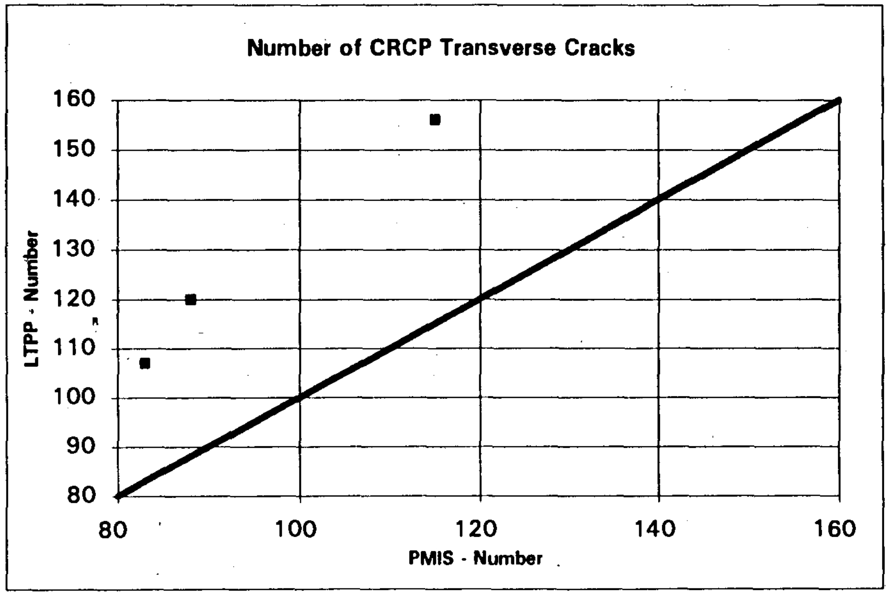
Fatigue Cracking PMIS vs. LTPP
LTPP - sq. meters
PMIS - sq. meters
0
50
100
150
200
250

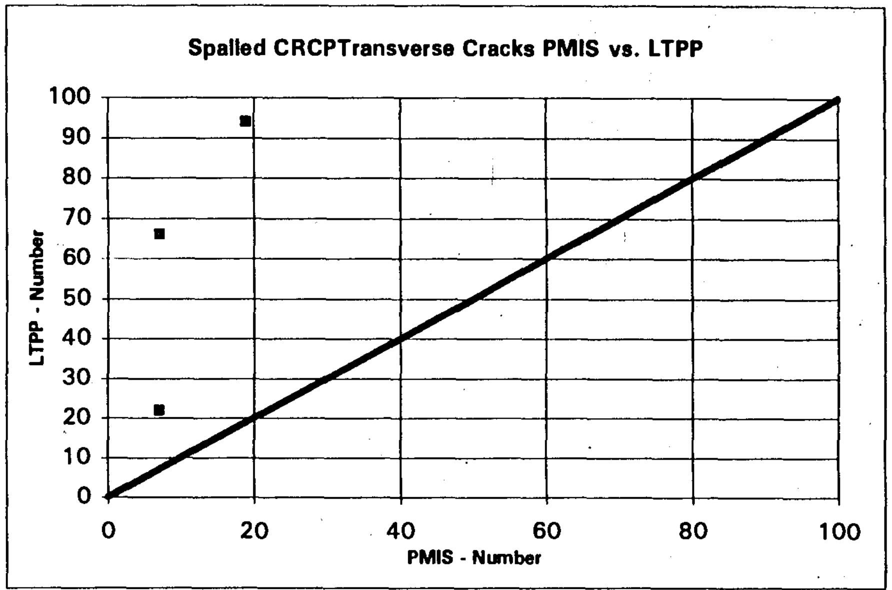


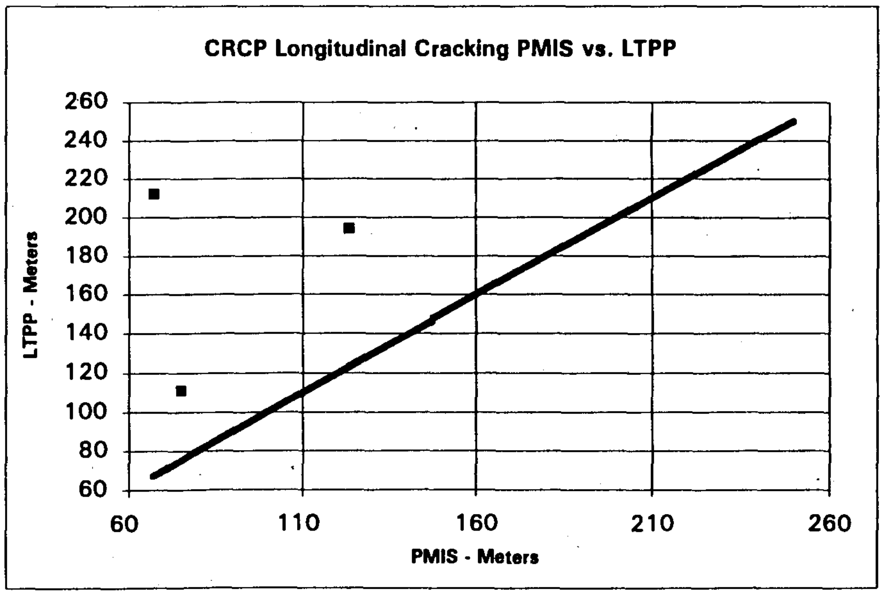
Longitudinal Cracking PMIS vs. LTPP
LTPP - meters
PMIS - meters
0
20
40
60
80
100
120

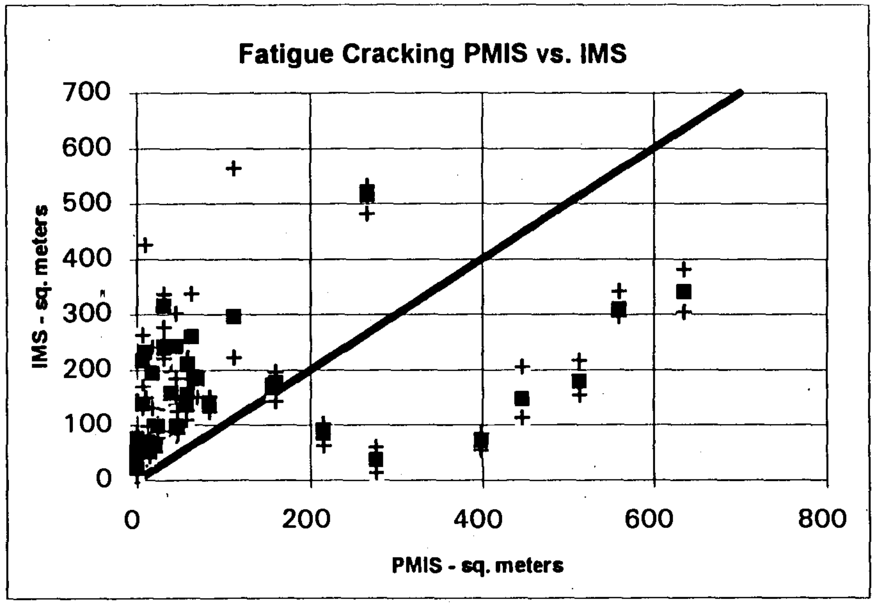


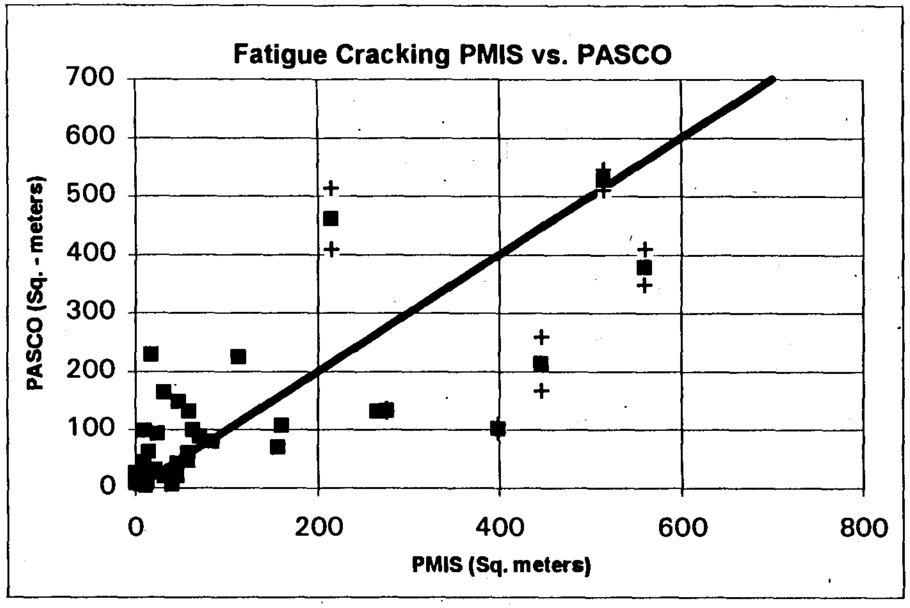
Edge Cracking PMIS vs. LTPP
LTPP - meters
PMIS - meters
0
20
40
60
80
100
120
140
50
150

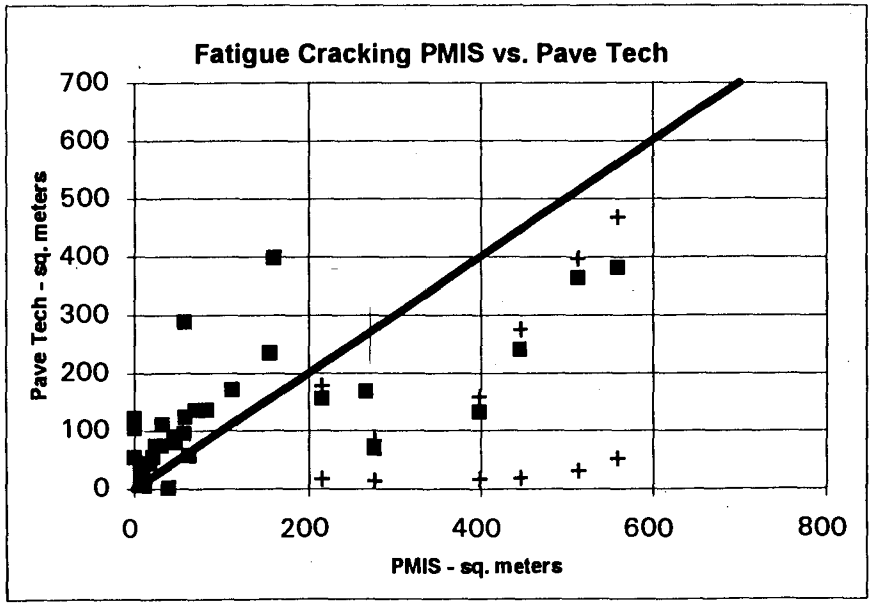

Number of CRCP Transverse Cracks
LTPP - Number
PMIS - Number
160
150
140
130
120
110
100
90
80
80
100
120
140
160

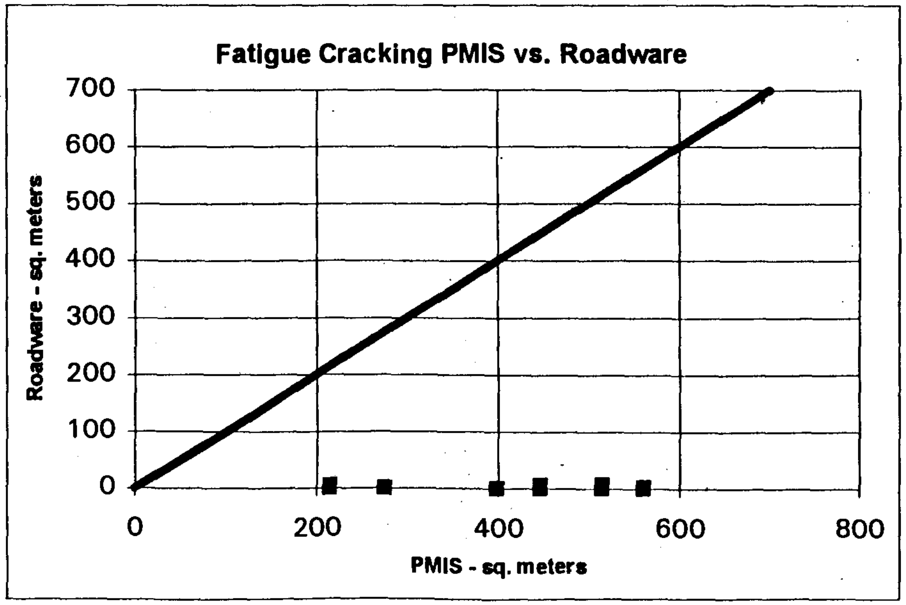

Spalled CRCPTransverse Cracks PMIS vs. LTPP
LTPP - Number
PMIS - Number
100
90
80
70
60
50
40
30
20
10
0
0
20
40
60
80
100

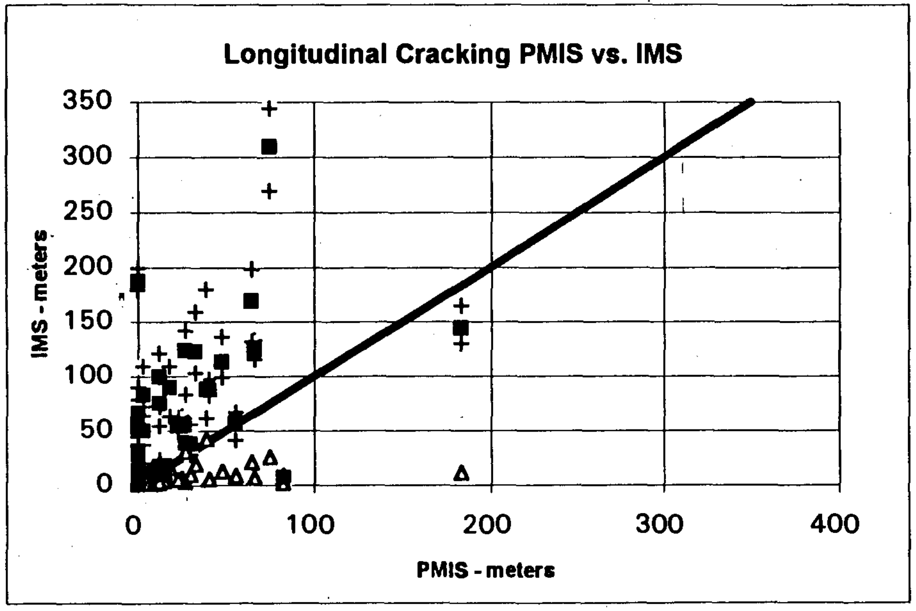

CRCP Longitudinal Cracking PMIS vs. LTPP
LTPP - Meters
PMIS - Meters
260
240
220
200
180
160
140
120
100
80
60
60
110
160
210
260

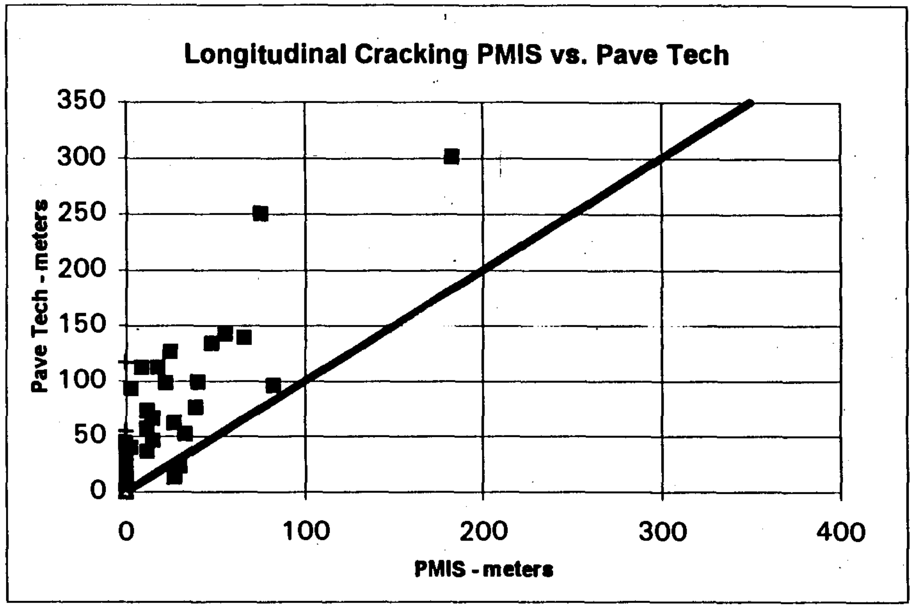

Fatigue Cracking PMIS vs. IMS
IMS - sq. meters
PMIS - sq. meters
0
100
200
300
400
500
600
700
800

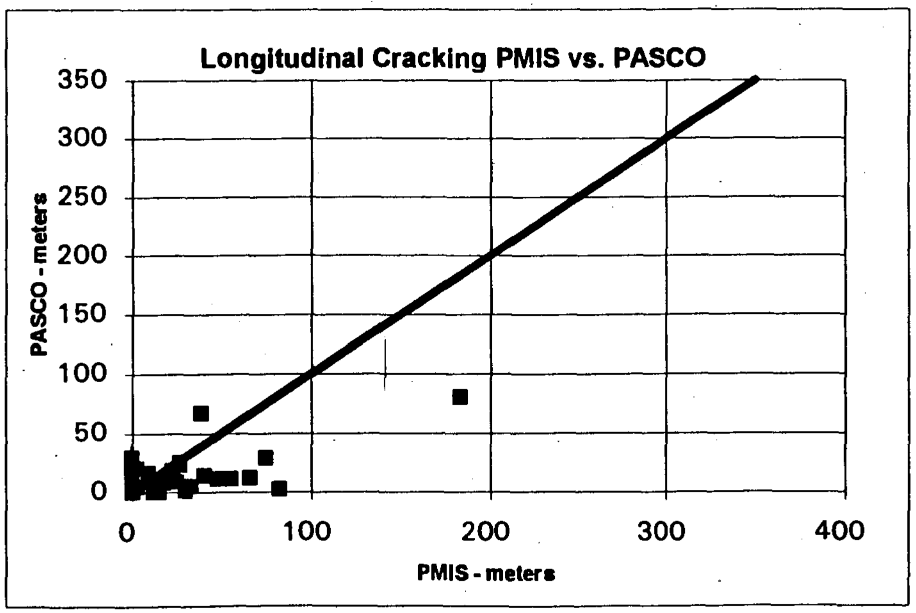

Fatigue Cracking PMIS vs. PASCO
PASCO (Sq. - meters)
PMIS (Sq. meters)
0
100
200
300
400
500
600
700
800

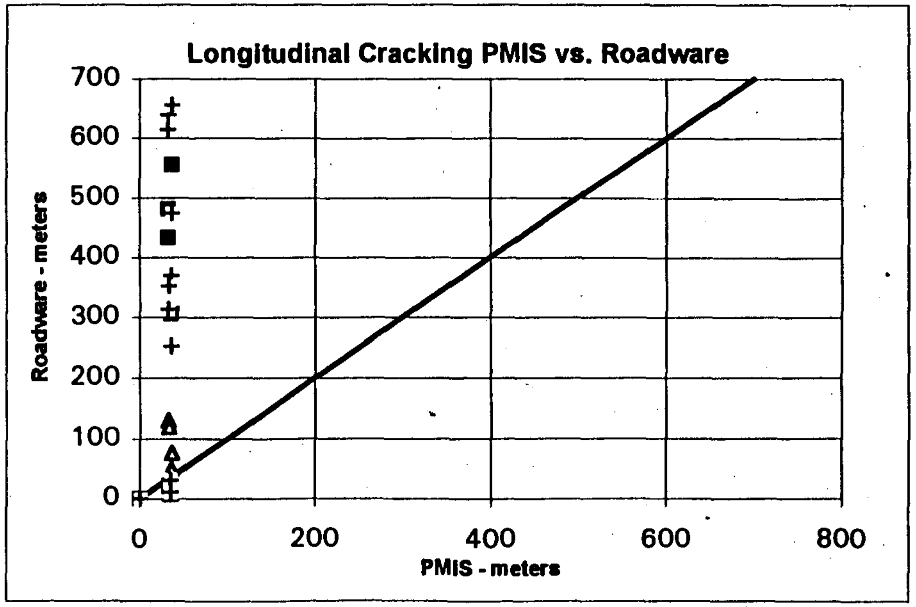

Fatigue Cracking PMIS vs. Pave Tech
Pave Tech - sq. meters
PMIS - sq. meters
0
100
200
300
400
500
600
700
800

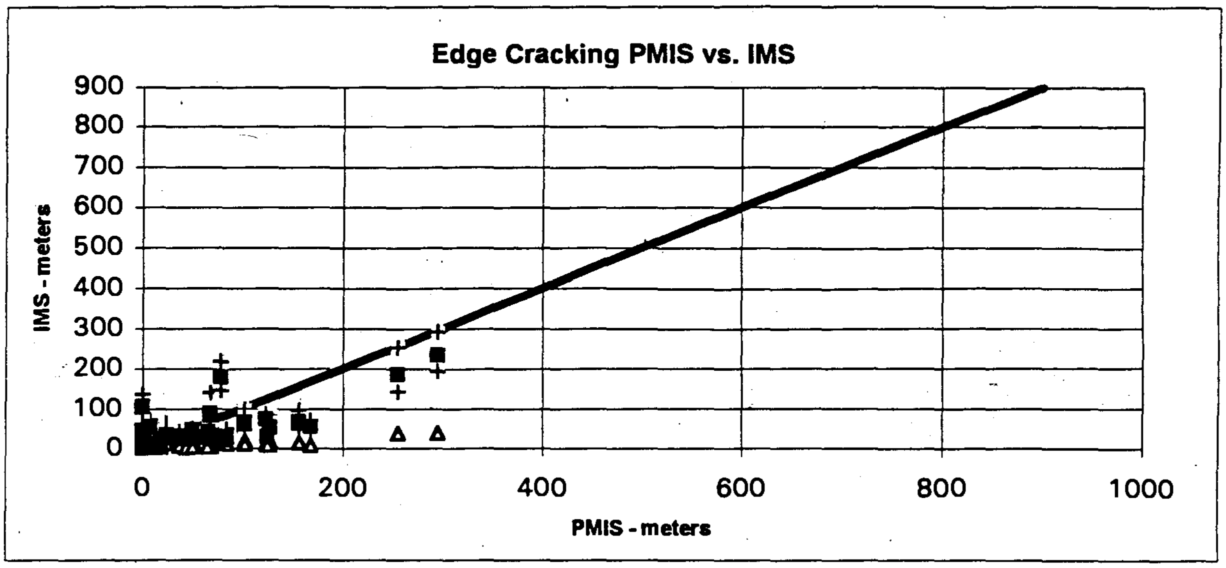

Fatigue Cracking PMIS vs. Roadware
Roadware - sq. meters
PMIS - sq. meters
0
100
200
300
400
500
600
700
800

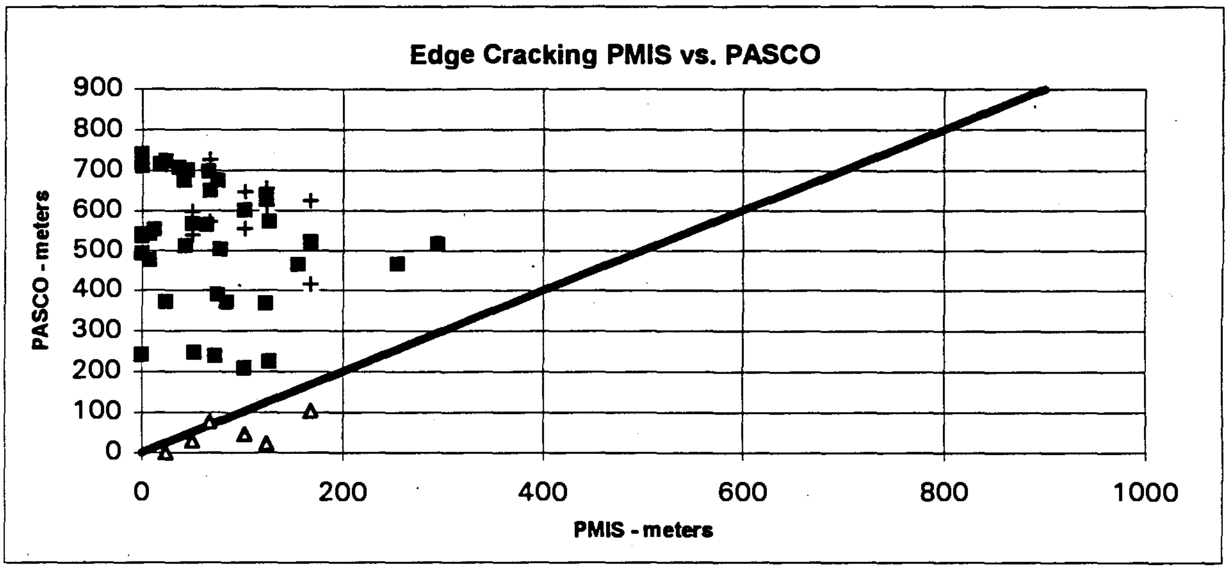

Longitudinal Cracking PMIS vs. IMS
IMS - meters
PMIS - meters
0
50
100
150
200
250
300
350
0
100
200
300
400

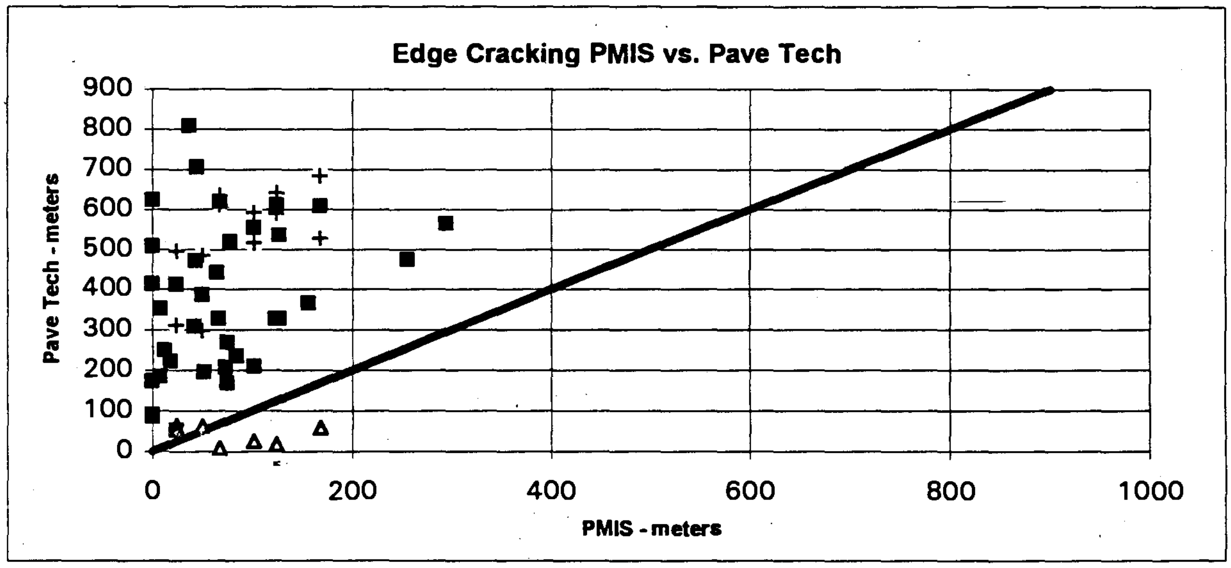

Longitudinal Cracking PMIS vs. Pave Tech
Pave Tech - meters
PMIS - meters
0
50
100
150
200
250
300
350
0
100
200
300
400

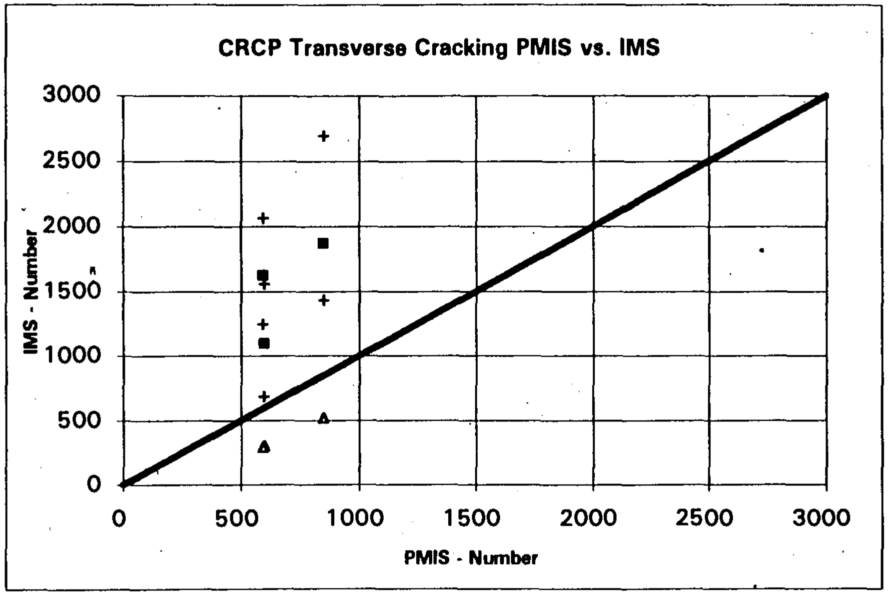

Longitudinal Cracking PMIS vs. PASCO
PASCO - meters
PMIS - meters
0
50
100
150
200
250
300
350
0
100
200
300
400

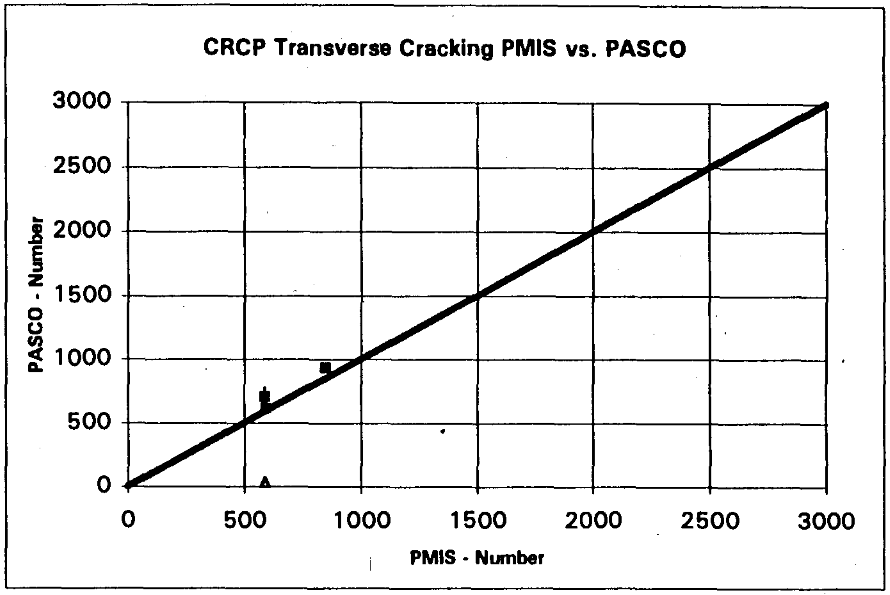

Longitudinal Cracking PMIS vs. Roadware
Roadware - meters
PMIS - meters
0
100
200
300
400
500
600
700
0
200
400
600
800

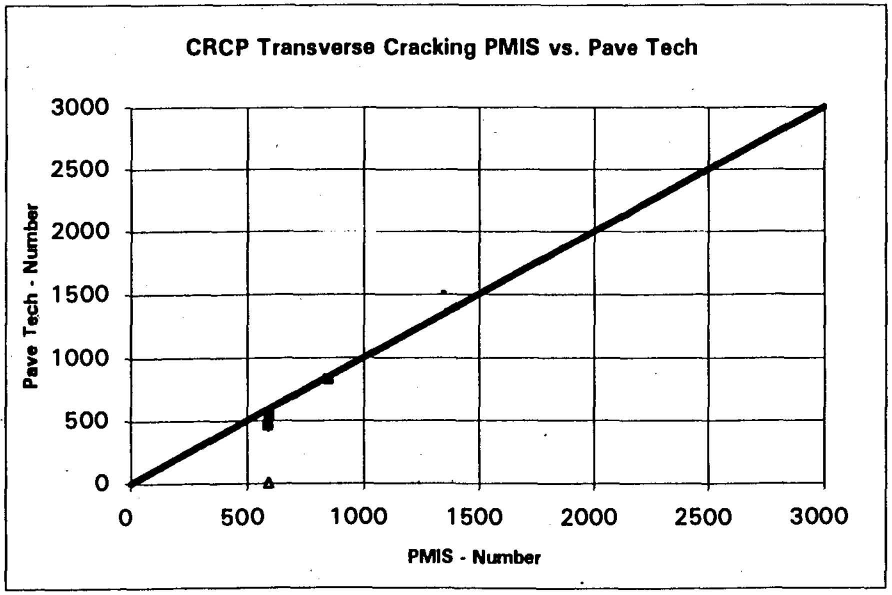

Edge Cracking PMIS vs. IMS
IMS - meters
PMIS - meters
0
100
200
300
400
500
600
700
800
900
1000

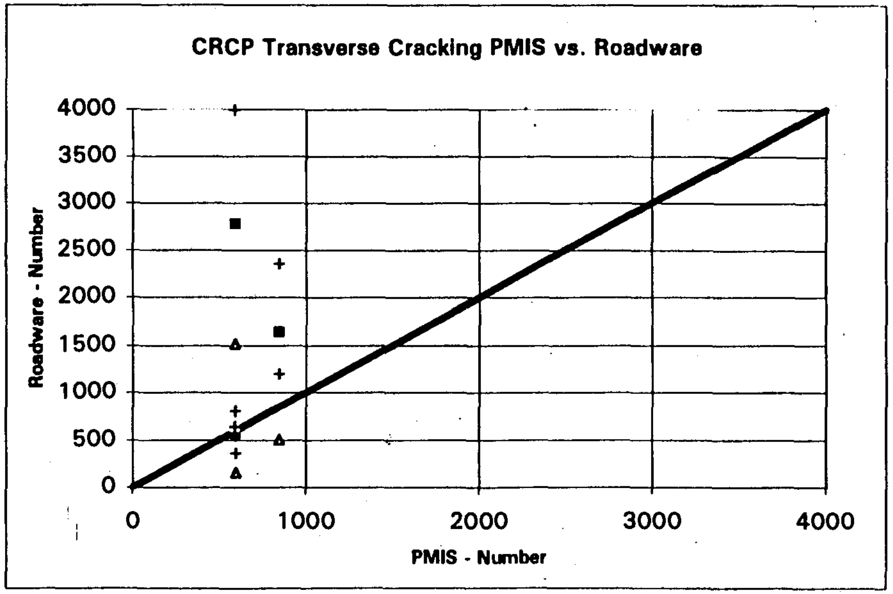

Edge Cracking PMIS vs. PASCO
PASCO - meters
PMIS - meters
0
100
200
300
400
500
600
700
800
900
1000

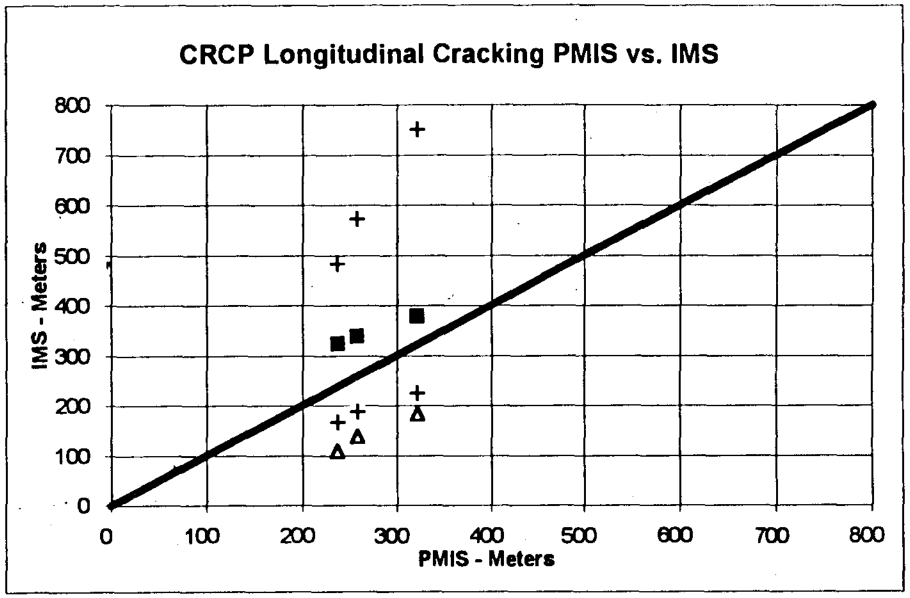

Edge Cracking PMIS vs. Pave Tech
Pave Tech - meters
PMIS - meters
0
100
200
300
400
500
600
700
800
900
1000

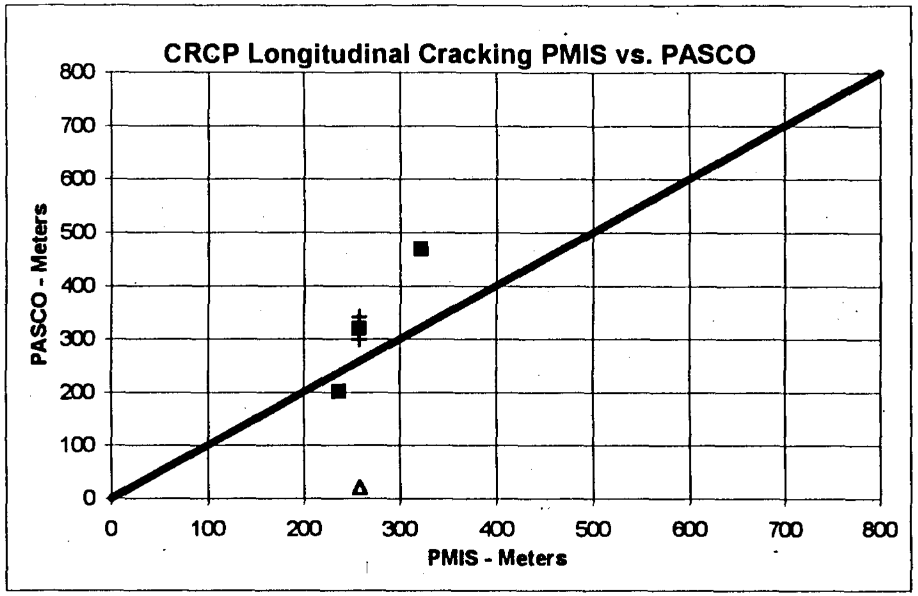

CRCP Transverse Cracking PMIS vs. IMS
IMS - Number
PMIS - Number
0
500
1000
1500
2000
2500
3000

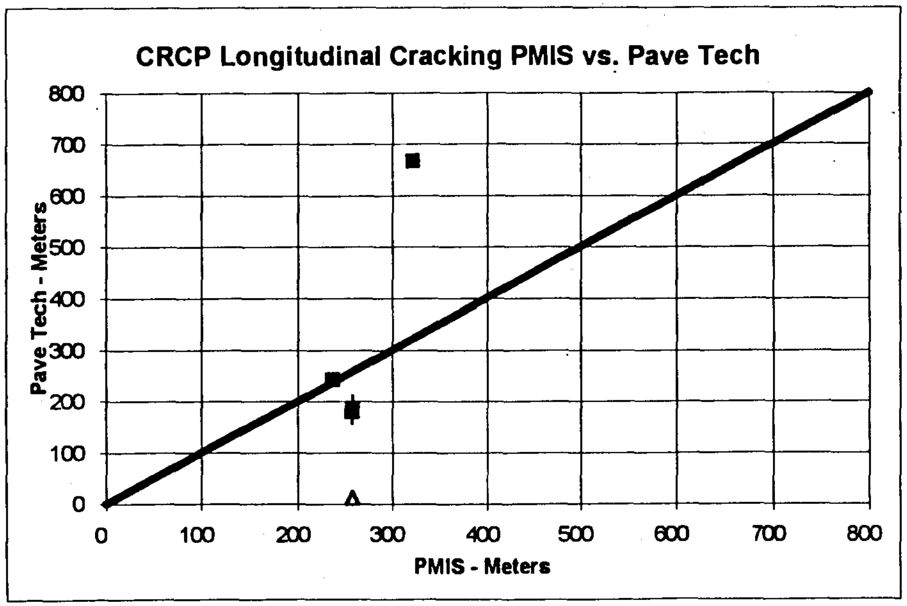

CRCP Transverse Cracking PMIS vs. PASCO
PASCO - Number
PMIS - Number
0
500
1000
1500
2000
2500
3000

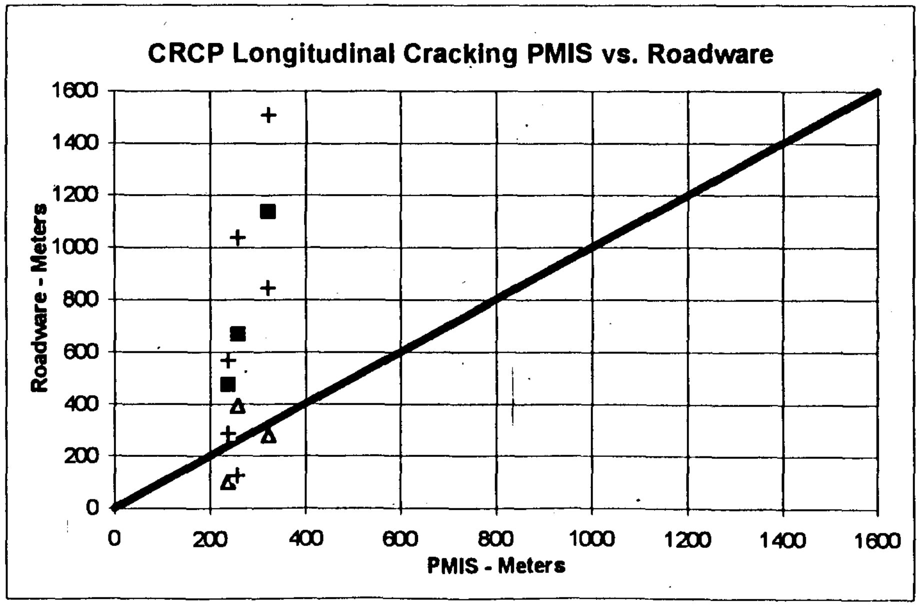

CRCP Transverse Cracking PMIS vs. Pave Tech
Pave Tech - Number
PMIS - Number
0
500
1000
1500
2000
2500
3000

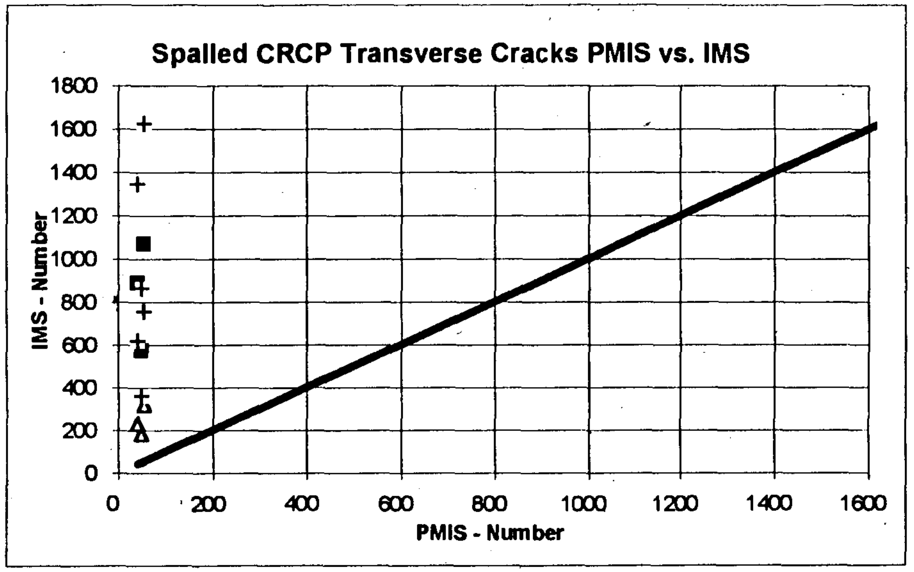

CRCP Transverse Cracking PMIS vs. Roadware
Roadware - Number
PMIS - Number
0
500
1000
1500
2000
2500
3000
3500
4000

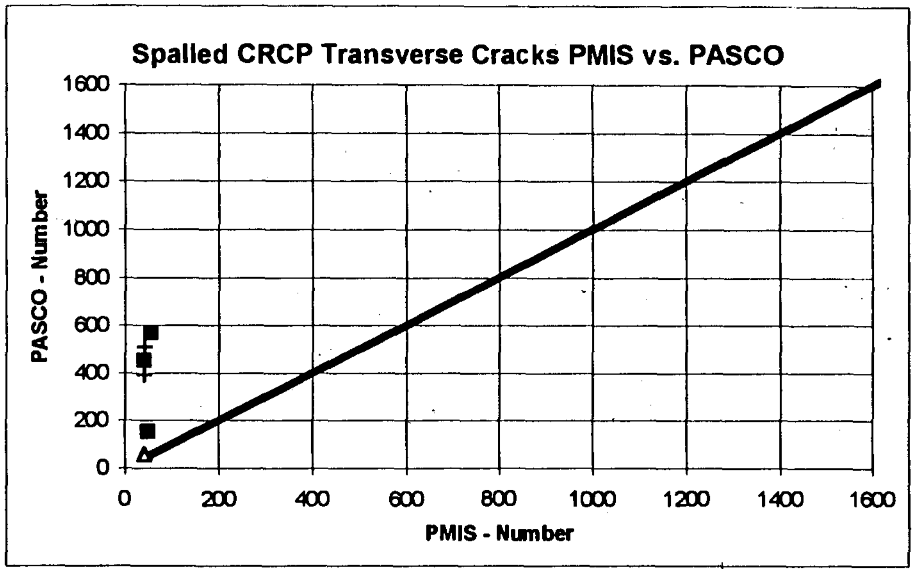

CRCP Longitudinal Cracking PMIS vs. IMS
IMS - Meters
PMIS - Meters
0
100
200
300
400
500
600
700
800

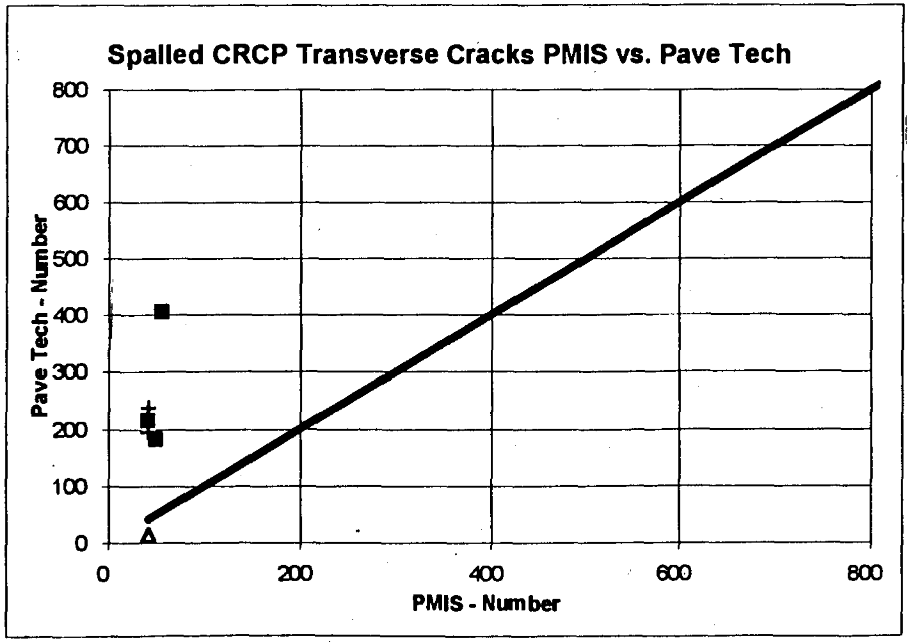

CRCP Longitudinal Cracking PMIS vs. PASCO
PASCO - Meters
PMIS - Meters
0
100
200
300
400
500
600
700
800

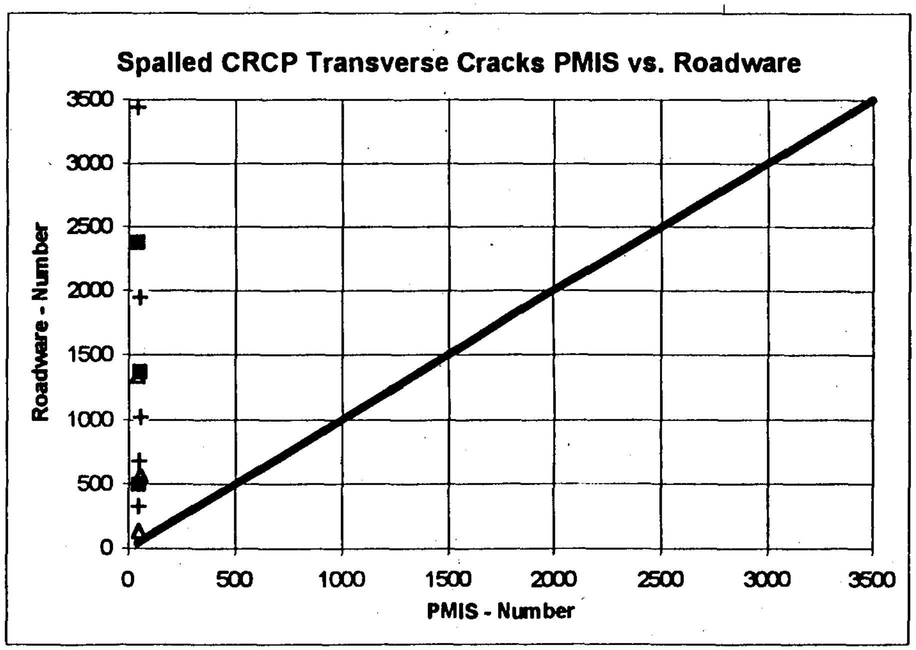

CRCP Longitudinal Cracking PMIS vs. Pave Tech
Pave Tech - Meters
PMIS - Meters
0
100
200
300
400
500
600
700
800


CRCP Longitudinal Cracking PMIS vs. Roadware
Roadware - Meters
PMIS - Meters
0
200
400
600
800
1000
1200
1400
1600

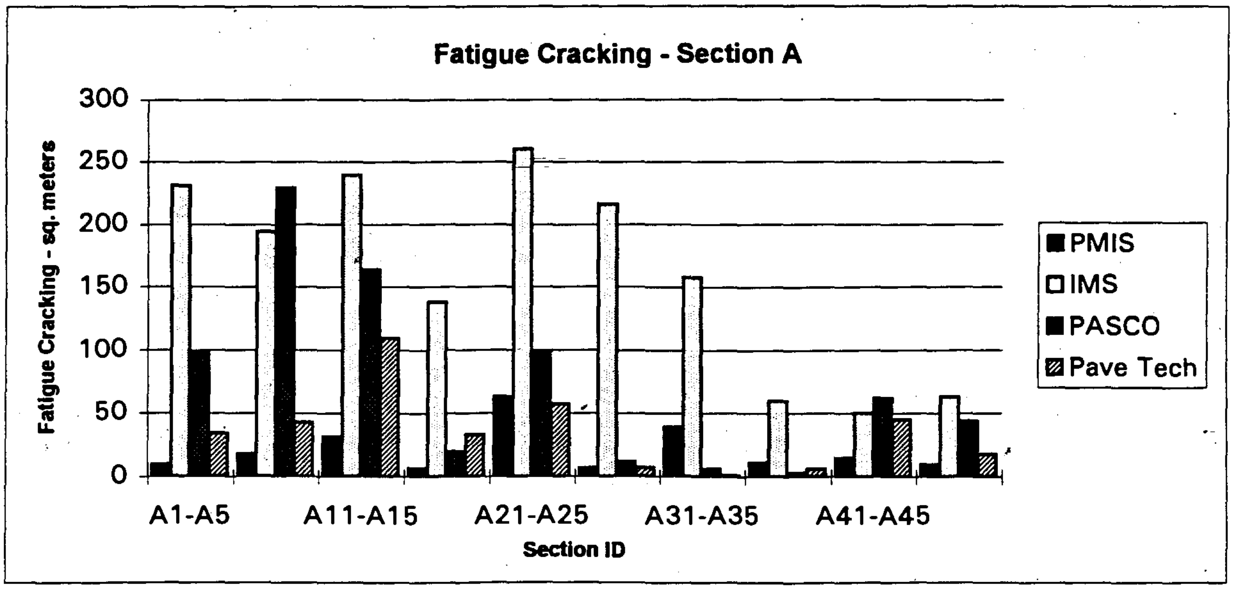

Spalled CRCP Transverse Cracks PMIS vs. IMS
IMS - Number
PMIS - Number
0
200
400
600
800
1000
1200
1400
1600
1800


Spalled CRCP Transverse Cracks PMIS vs. PASCO
PASCO - Number
PMIS - Number
0
200
400
600
800
1000
1200
1400
1600

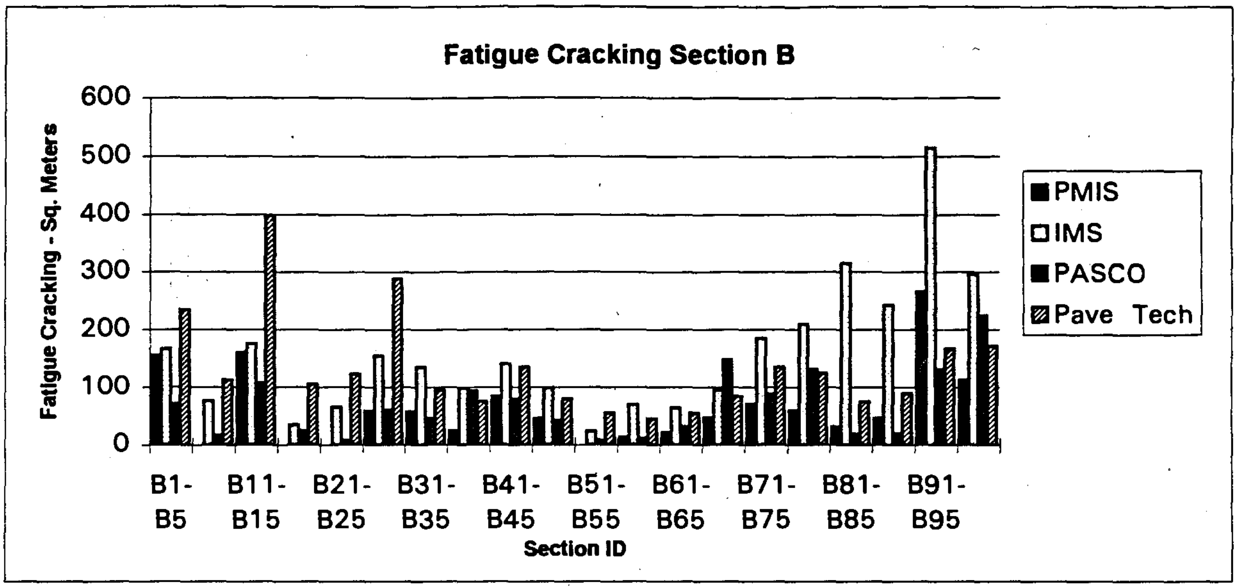

Spalled CRCP Transverse Cracks PMIS vs. Pave Tech
Pave Tech - Number
PMIS - Number
0
100
200
300
400
500
600
700
800


Spalled CRCP Transverse Cracks PMIS vs. Roadware
Roadware - Number
PMIS - Number
0
500
1000
1500
2000
2500
3000
3500

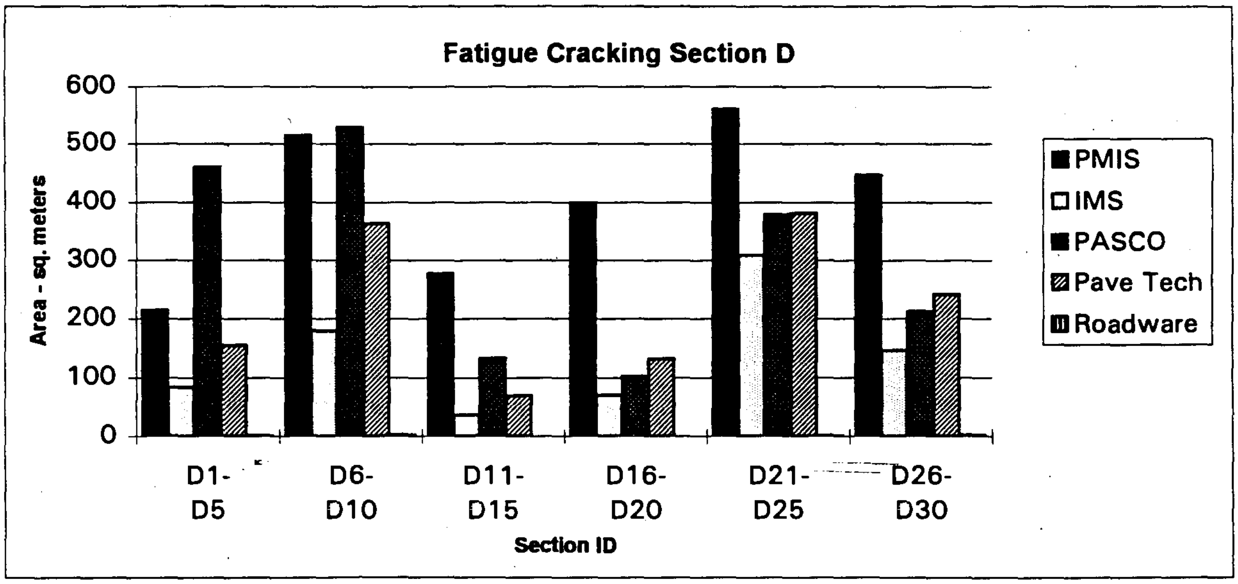
PMIS Bar Charts



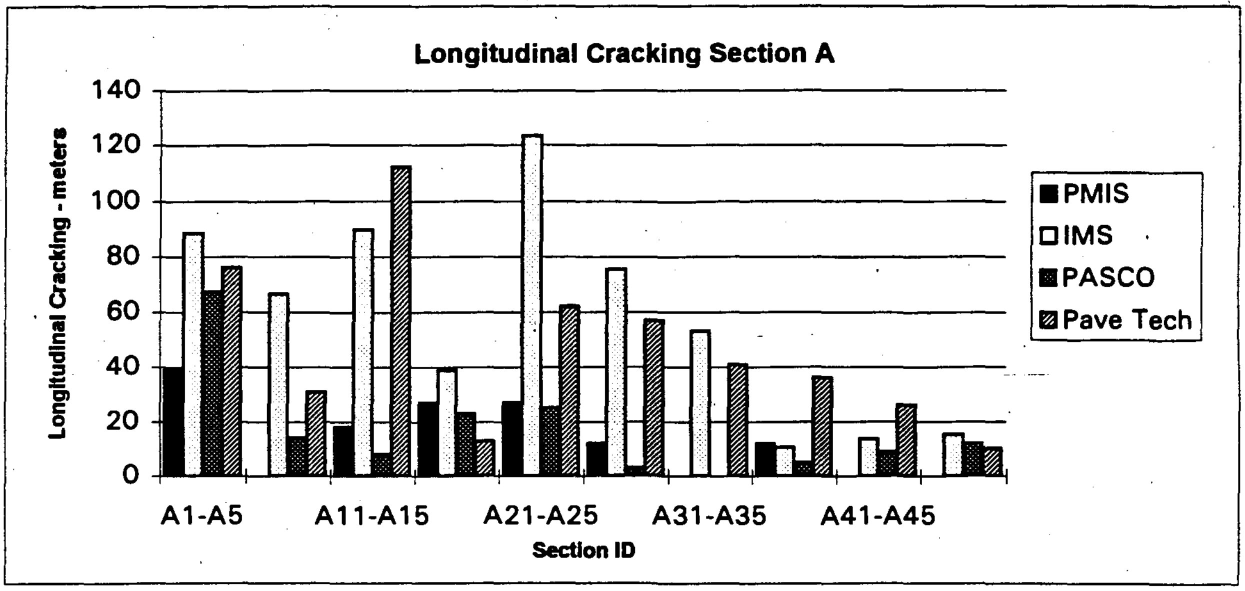
Fatigue Cracking - Section A
Fatigue Cracking - sq. meters
300
250
200
150
100
50
0
A1-A5
A11-A15
A21-A25
A31-A35
A41-A45
Section ID
PMIS
IMS
PASCO
Pave Tech



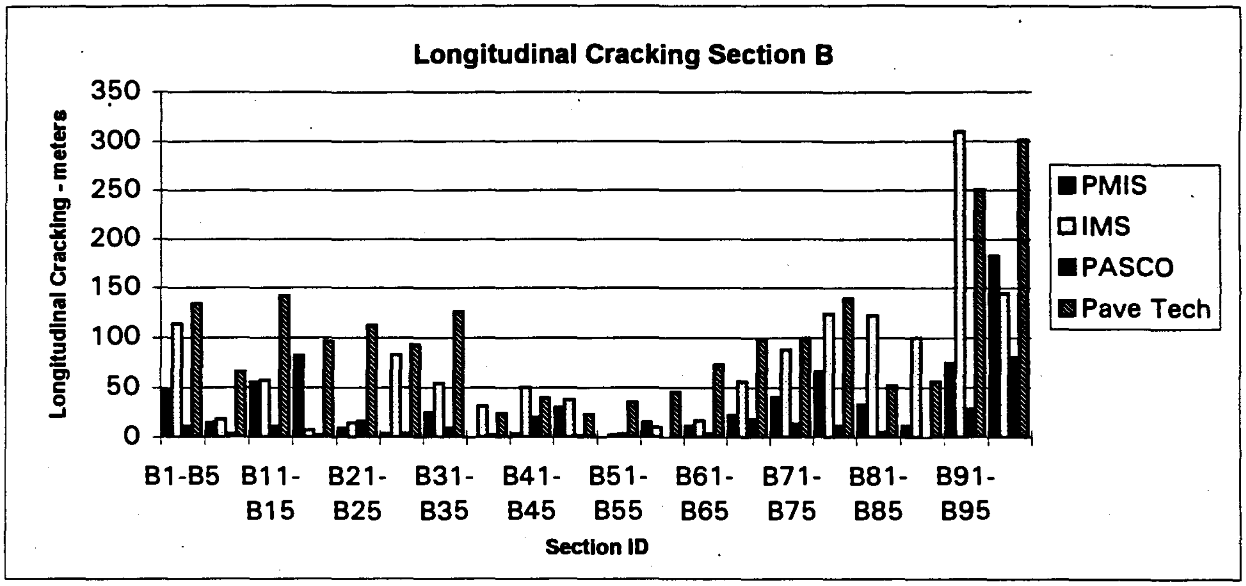
Fatigue Cracking Section B
Fatigue Cracking - Sq. Meters
600
500
400
300
200
100
0
B1-B5
B11-B15
B21-B25
B31-B35
B41-B45
B51-B55
B61-B65
B71-B75
B81-B85
B91-B95
Section ID
PMIS
IMS
PASCO
Pave Tech



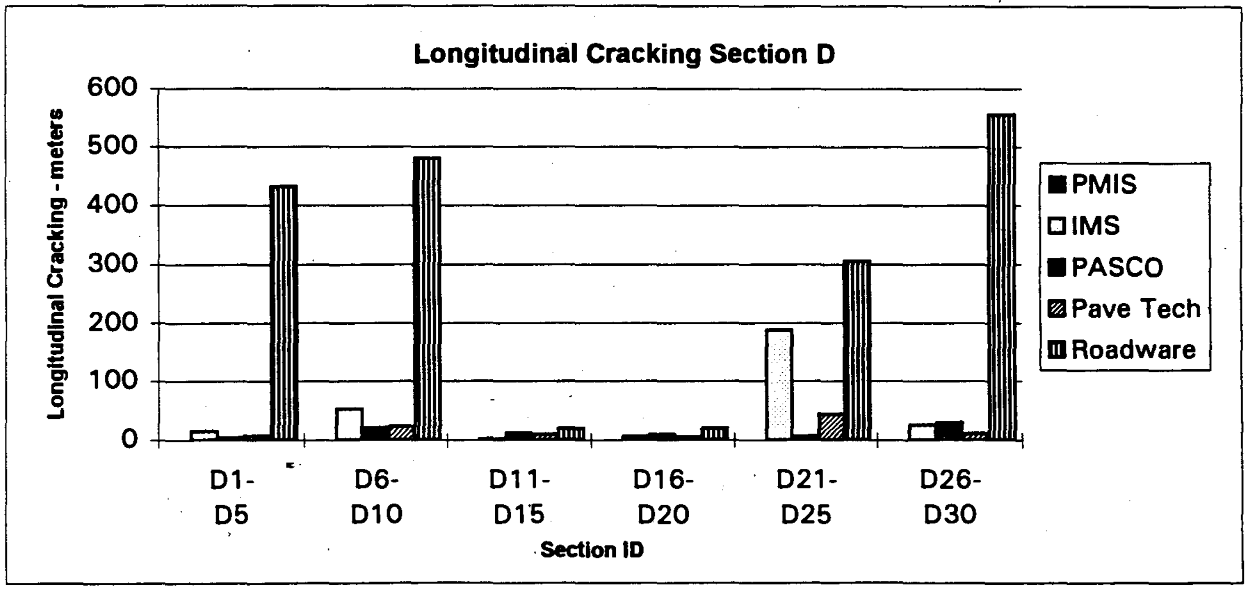
Fatigue Cracking Section D
Area - sq. meters
600
500
400
300
200
100
0
D1-D5
D6-D10
D11-D15
D16-D20
D21-D25
D26-D30
Section ID
PMIS
IMS
PASCO
Pave Tech
Roadware



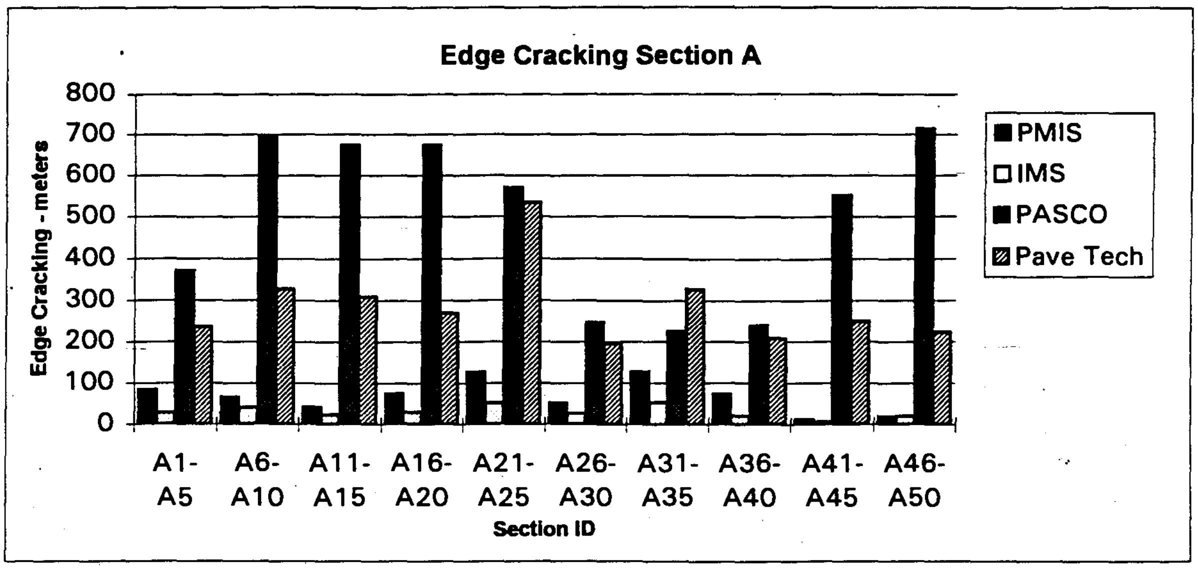
Longitudinal Cracking Section A
Longitudinal Cracking - meters
140
120
100
80
60
40
20
0
PMIS
IMS
PASCO
Pave Tech
A1-A5
A11-A15
A21-A25
A31-A35
A41-A45
Section ID

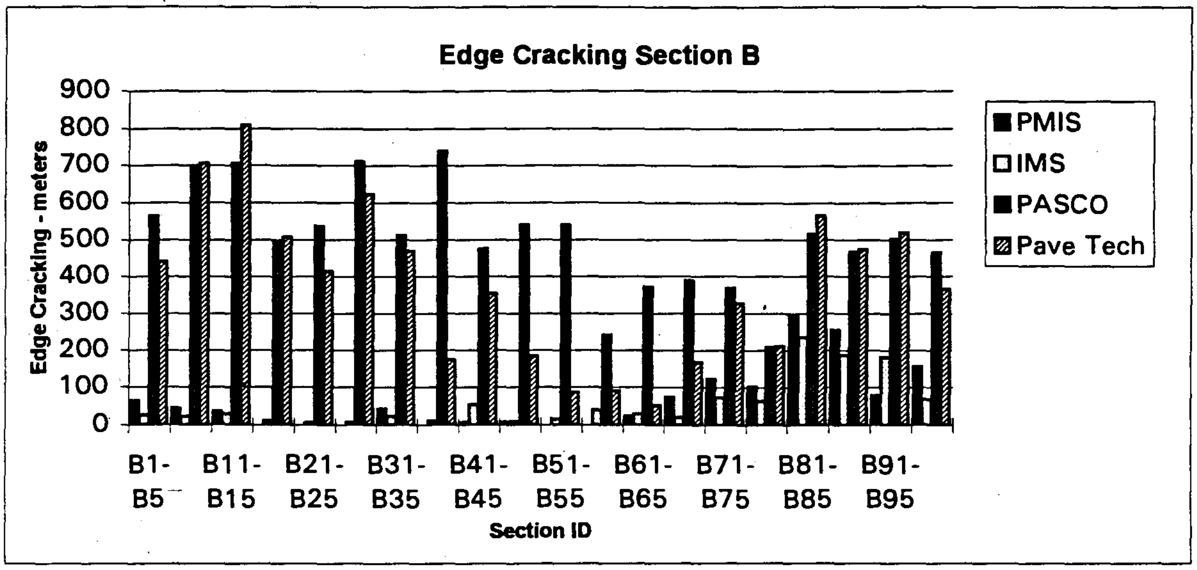


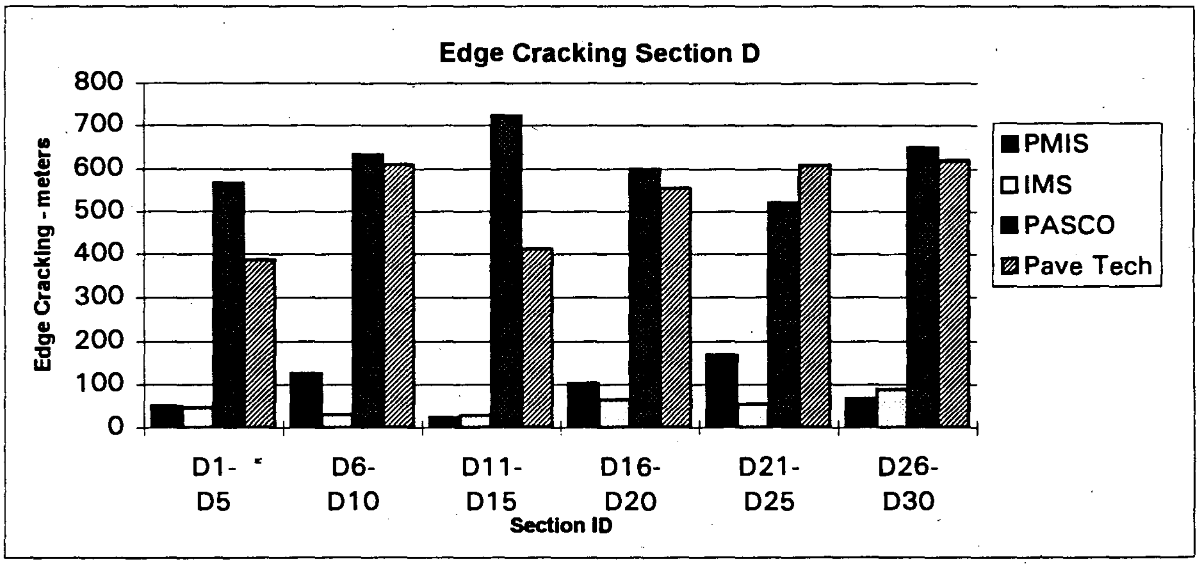
Longitudinal Cracking Section B
Longitudinal Cracking - meters
350
300
250
200
150
100
50
0
PMIS
IMS
PASCO
Pave Tech
B1-B5
B11-B15
B21-B25
B31-B35
B41-B45
B51-B55
B61-B65
B71-B75
B81-B85
B91-B95
Section ID

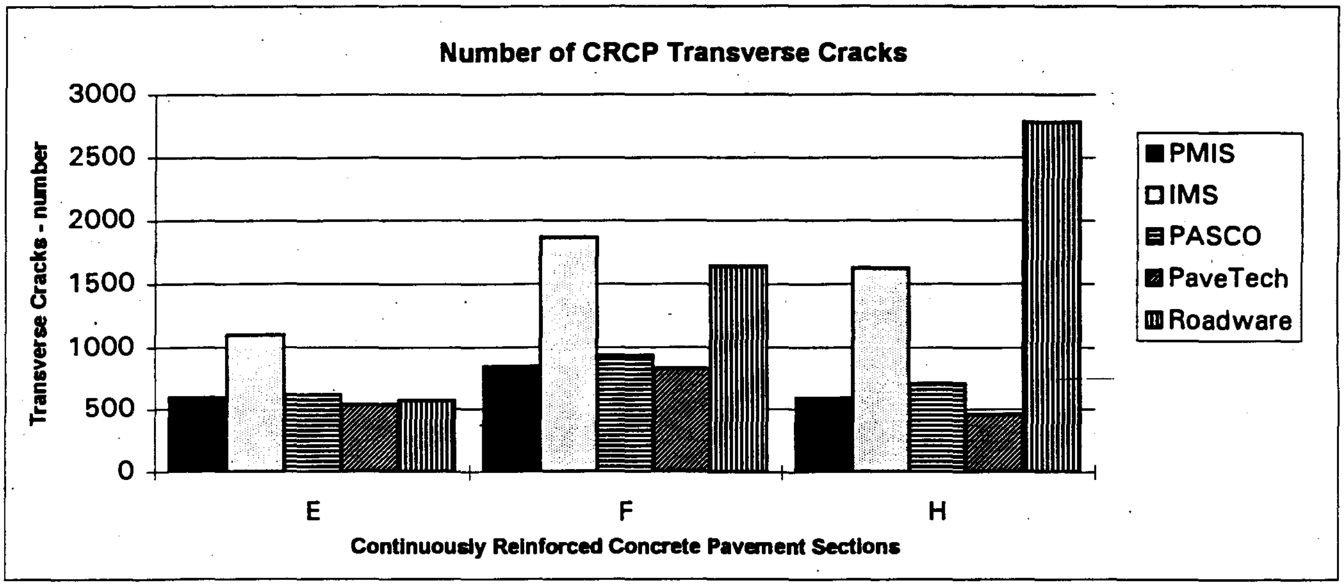


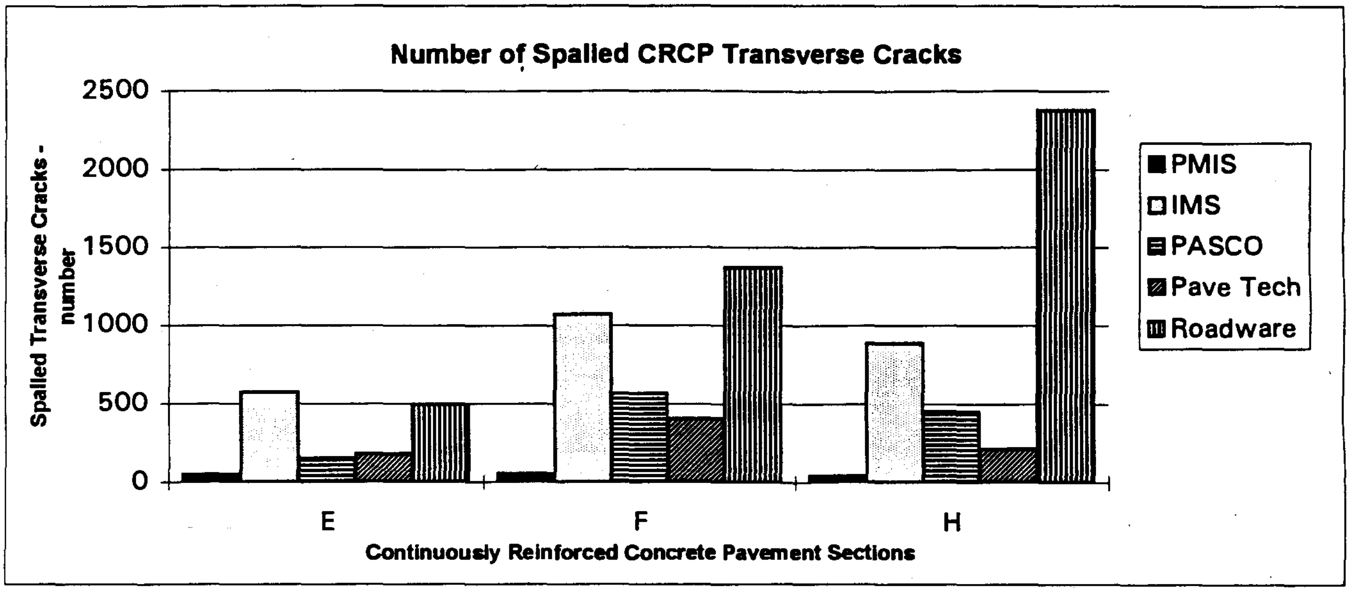
Longitudinal Cracking Section D
Longitudinal Cracking - meters
600
500
400
300
200
100
0
PMIS
IMS
PASCO
Pave Tech
Roadware
D1-D5
D6-D10
D11-D15
D16-D20
D21-D25
D26-D30
Section ID

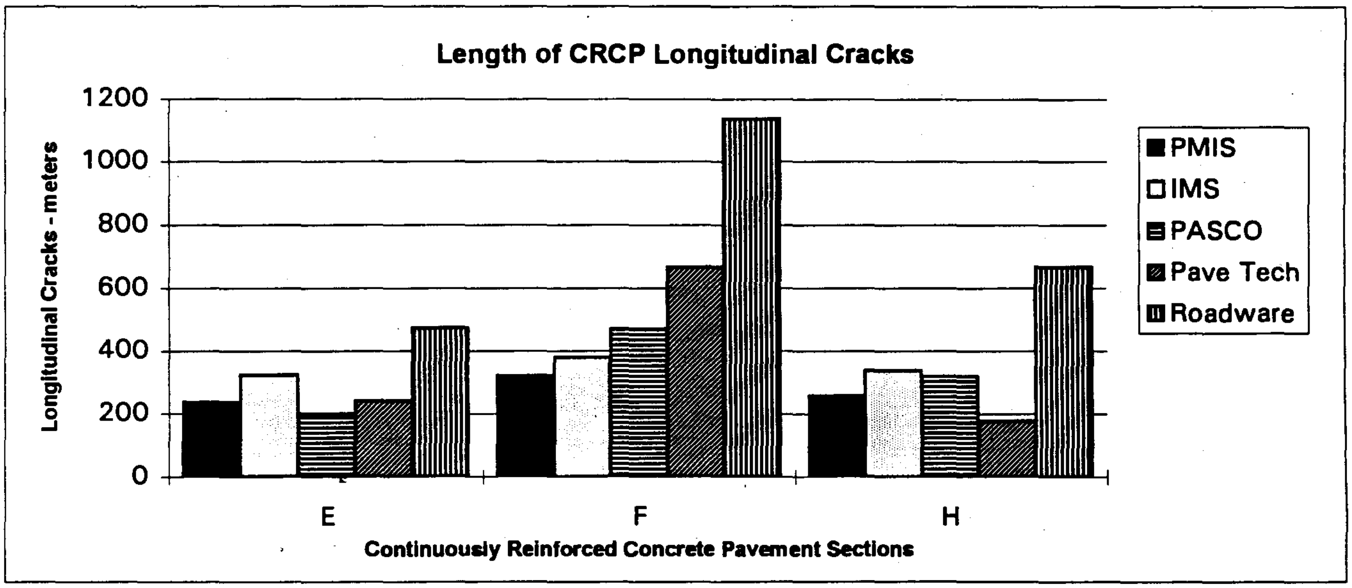

Edge Cracking Section A
800
700
600
500
400
300
200
100
0
Edge Cracking - meters
PMIS
IMS
PASCO
Pave Tech
A1-A5
A6-A10
A11-A15
A16-A20
A21-A25
A26-A30
A31-A35
A36-A40
A41-A45
A46-A50
Section ID

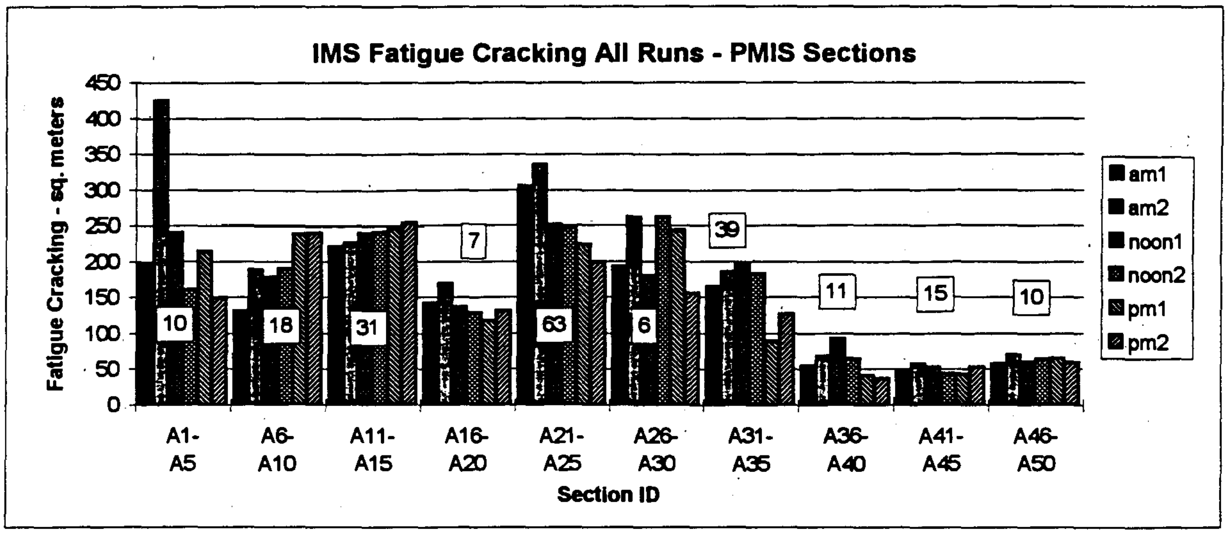

Edge Cracking Section B
900
800
700
600
500
400
300
200
100
0
Edge Cracking - meters
PMIS
IMS
PASCO
Pave Tech
B1-B5
B11-B15
B21-B25
B31-B35
B41-B45
B51-B55
B61-B65
B71-B75
B81-B85
B91-B95
Section ID


Edge Cracking Section D
800
700
600
500
400
300
200
100
0
Edge Cracking - meters
PMIS
IMS
PASCO
Pave Tech
D1-D5
D6-D10
D11-D15
D16-D20
D21-D25
D26-D30
Section ID

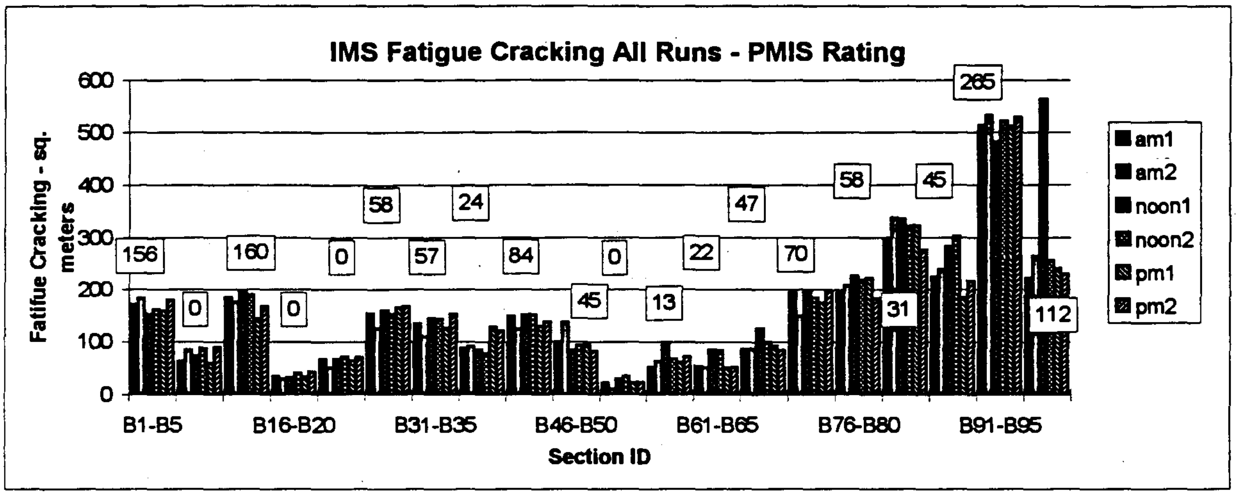

Number of CRCP Transverse Cracks
Transverse Cracks - number
3000
2500
2000
1500
1000
500
0
E
F
H
Continuously Reinforced Concrete Pavement Sections
PMIS
IMS
PASCO
PaveTech
Roadware


Number of Spalled CRCP Transverse Cracks
Spalled Transverse Cracks - number
2500
2000
1500
1000
500
0
E
F
H
Continuously Reinforced Concrete Pavement Sections
PMIS
IMS
PASCO
Pave Tech
Roadware

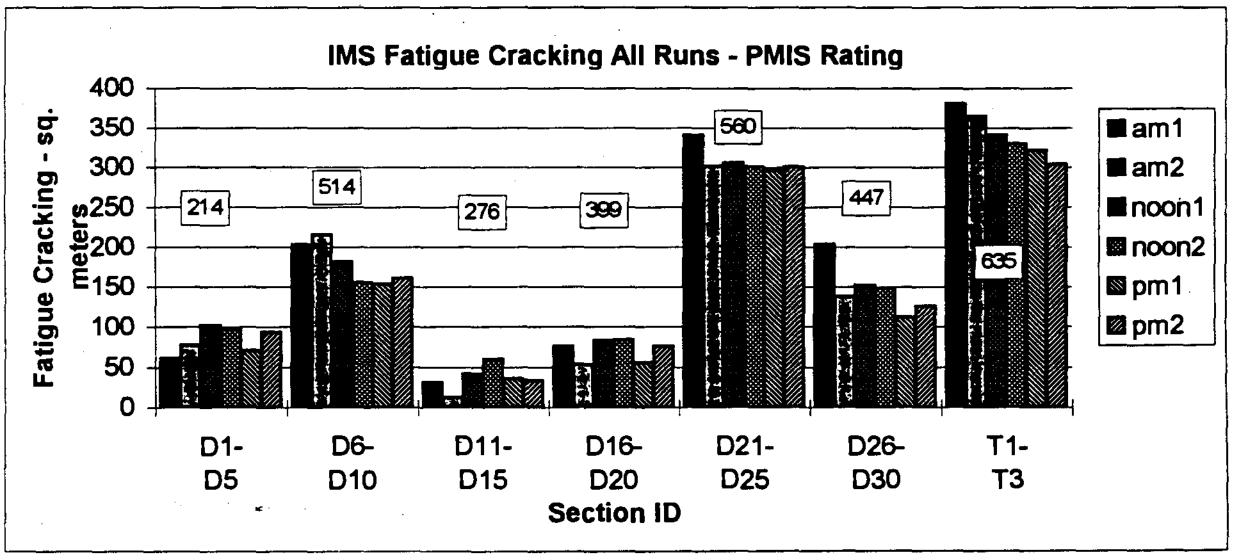

Length of CRCP Longitudinal Cracks
Longitudinal Cracks - meters
1200
1000
800
600
400
200
0
E
F
H
Continuously Reinforced Concrete Pavement Sections
PMIS
IMS
PASCO
Pave Tech
Roadware



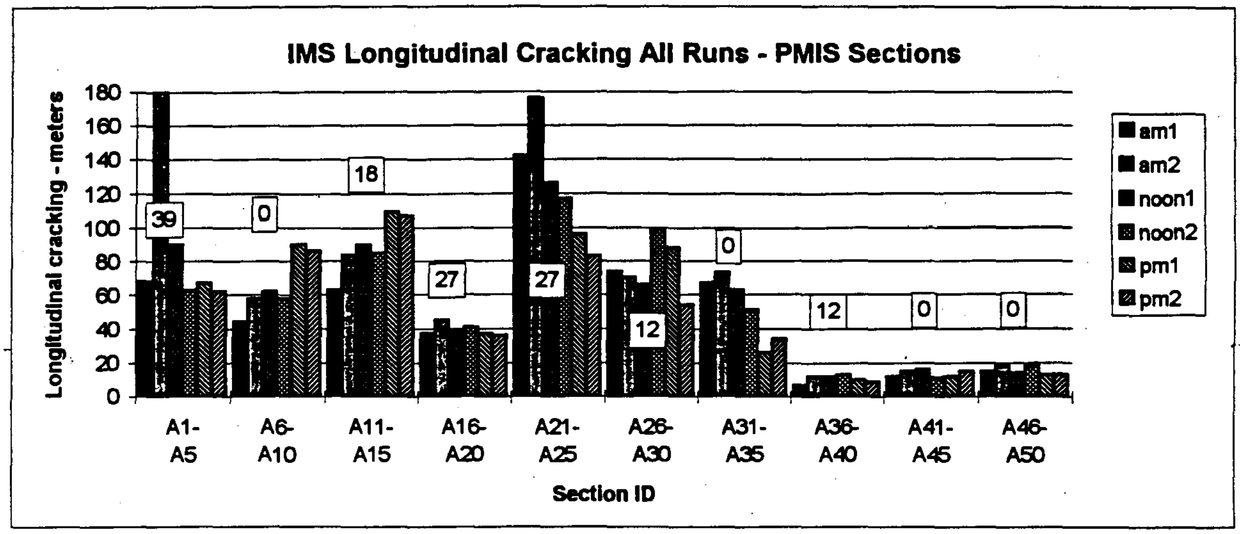
IMS Fatigue Cracking All Runs - PMIS Sections
Fatigue Cracking - sq. meters
450
400
350
300
250
200
150
100
50
0
A1-A5
A6-A10
A11-A15
A16-A20
A21-A25
A26-A30
A31-A35
A36-A40
A41-A45
A46-A50
Section ID
10
18
31
7
63
6
39
11
15
10
am1
am2
noon1
noon2
pm1
pm2



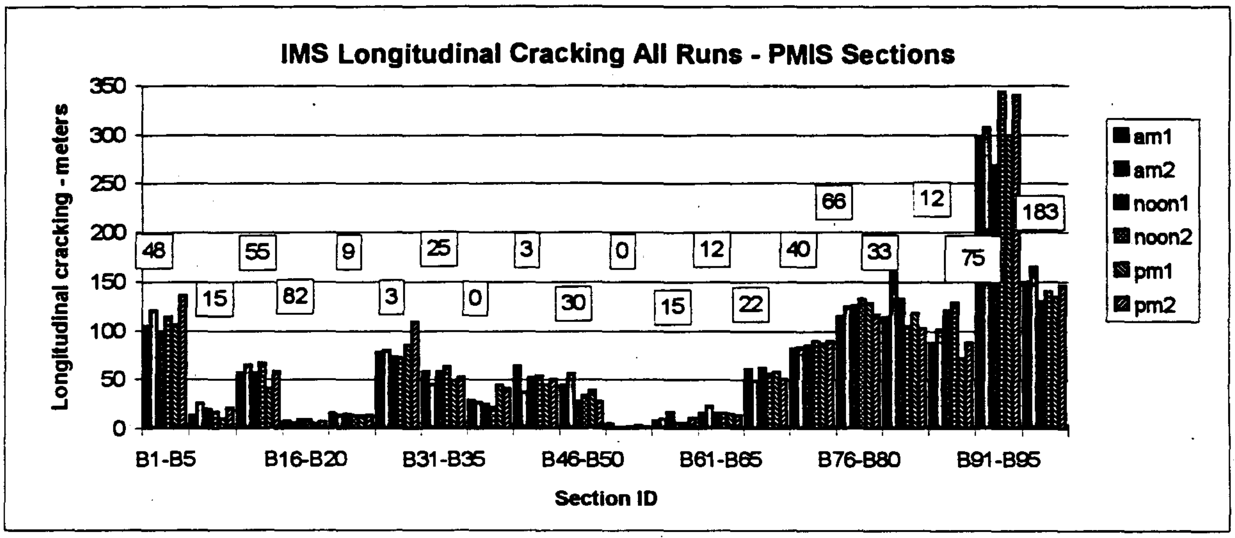
IMS Fatigue Cracking All Runs - PMIS Rating
Fatifue Cracking - sq. meters
600
500
400
300
200
100
0
B1-B5
B16-B20
B31-B35
B46-B50
B61-B65
B76-B80
B91-B95
Section ID
156
0
160
0
0
58
57
24
84
45
0
13
22
47
70
58
31
45
265
112
am1
am2
noon1
noon2
pm1
pm2



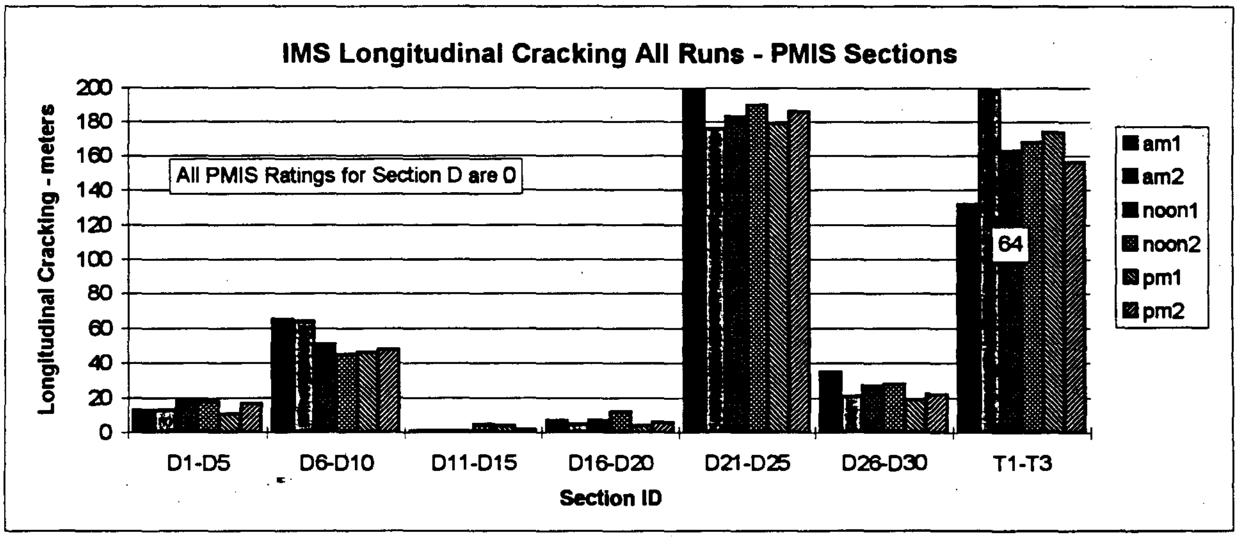
IMS Fatigue Cracking All Runs - PMIS Rating
Fatigue Cracking - sq. meters
400
350
300
250
200
150
100
50
0
D1-D5
D6-D10
D11-D15
D16-D20
D21-D25
D26-D30
T1-T3
Section ID
214
514
276
399
560
447
635
am1
am2
noon1
noon2
pm1
pm2



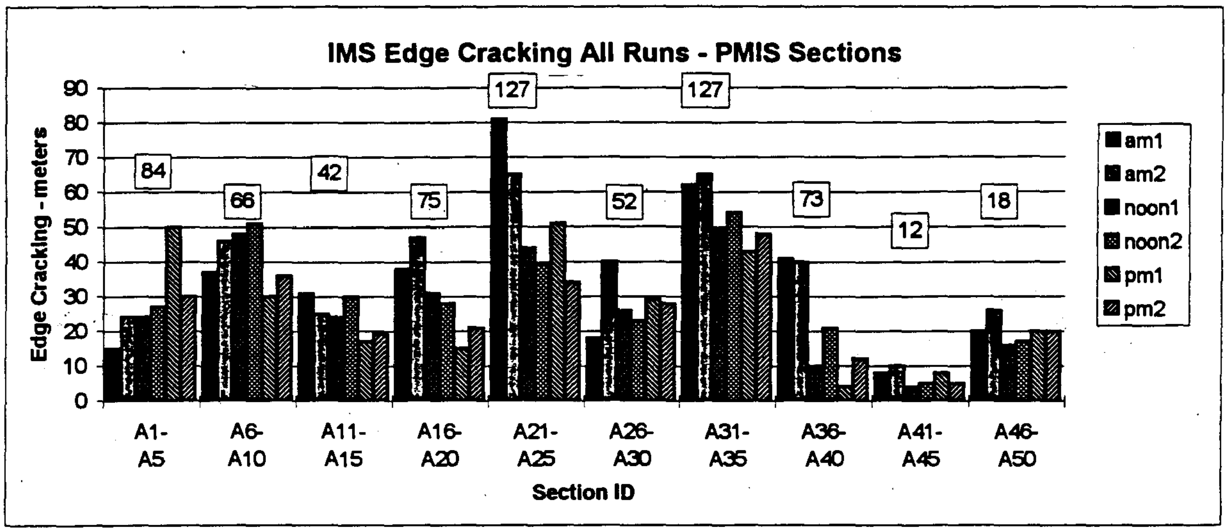
IMS Longitudinal Cracking All Runs - PMIS Sections
Longitudinal cracking - meters
180
160
140
120
100
80
60
40
20
0
39
0
18
27
27
12
0
12
0
0
A1-A5
A6-A10
A11-A15
A16-A20
A21-A25
A26-A30
A31-A35
A36-A40
A41-A45
A46-A50
Section ID
am1
am2
noon1
noon2
pm1
pm2

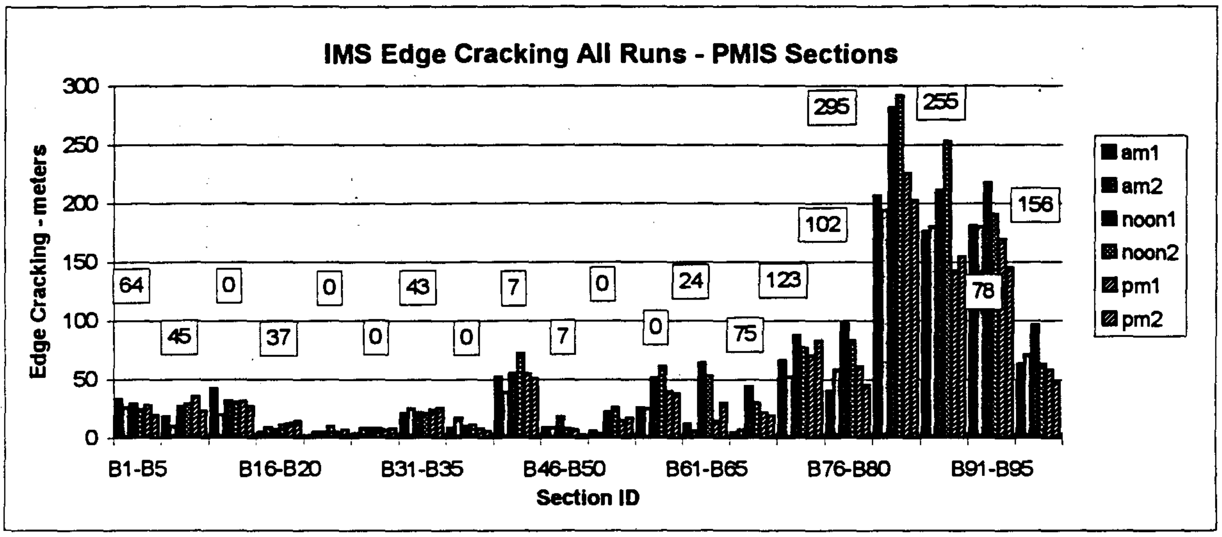


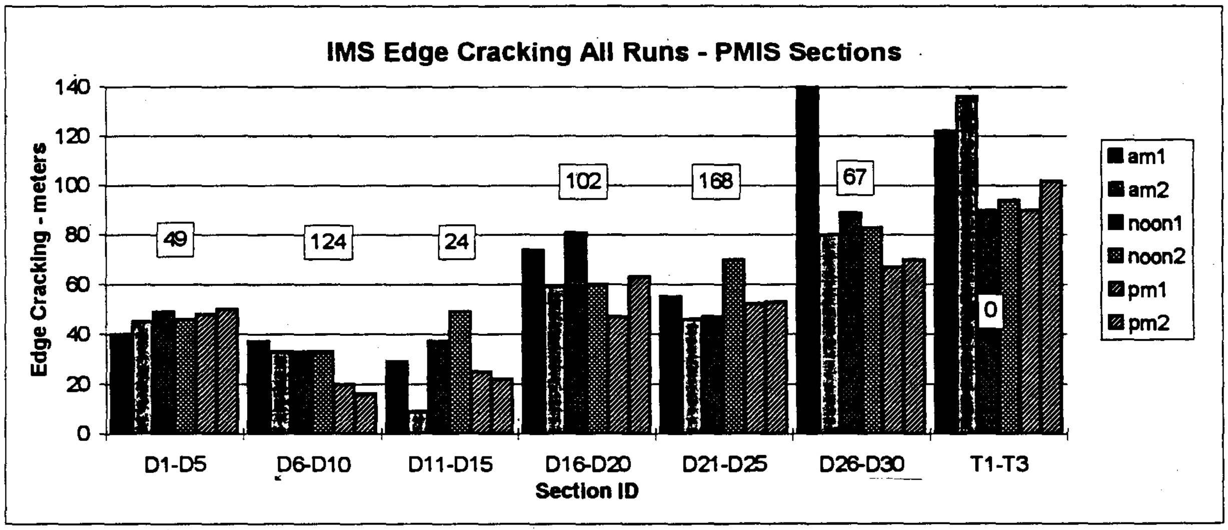
IMS Longitudinal Cracking All Runs - PMIS Sections
Longitudinal cracking - meters
350
300
250
200
150
100
50
0
48
15
55
82
9
3
25
0
3
30
0
15
12
22
40
66
33
12
75
183
B1-B5
B16-B20
B31-B35
B46-B50
B61-B65
B76-B80
B91-B95
Section ID
am1
am2
noon1
noon2
pm1
pm2

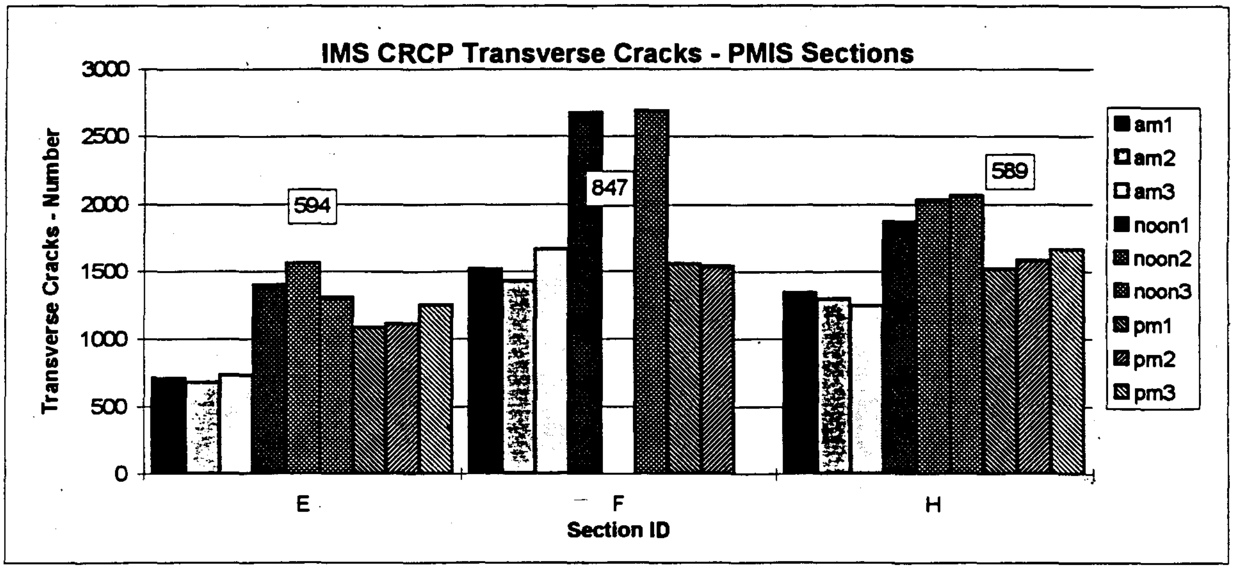


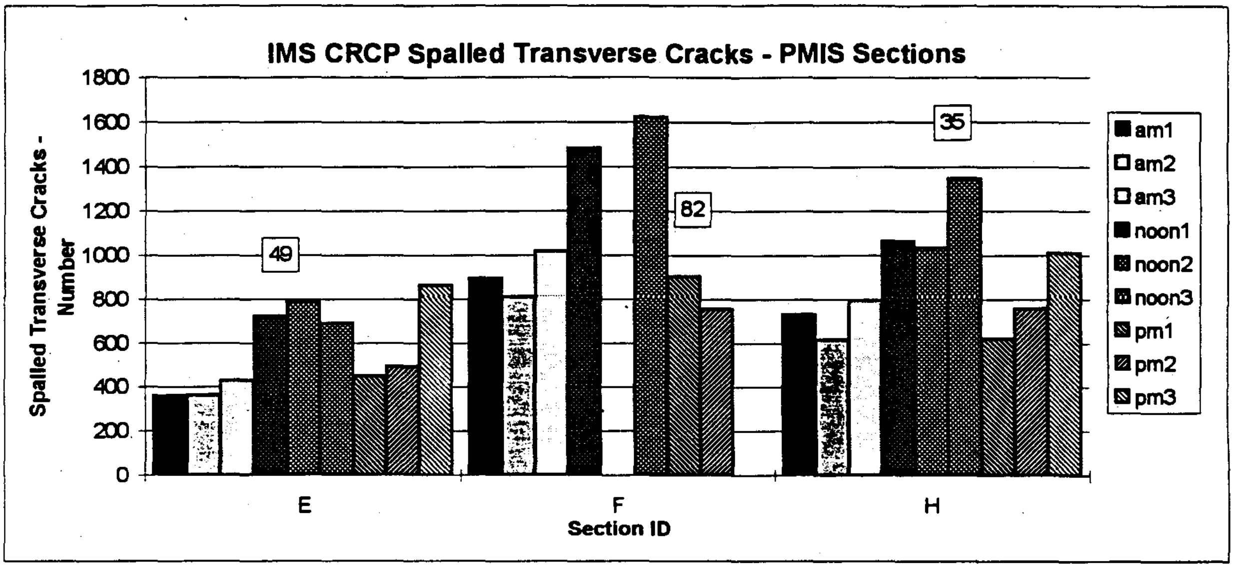
IMS Longitudinal Cracking All Runs - PMIS Sections
Longitudinal Cracking - meters
200
180
160
140
120
100
80
60
40
20
0
All PMIS Ratings for Section D are 0
64
D1-D5
D6-D10
D11-D15
D16-D20
D21-D25
D26-D30
T1-T3
Section ID
am1
am2
noon1
noon2
pm1
pm2

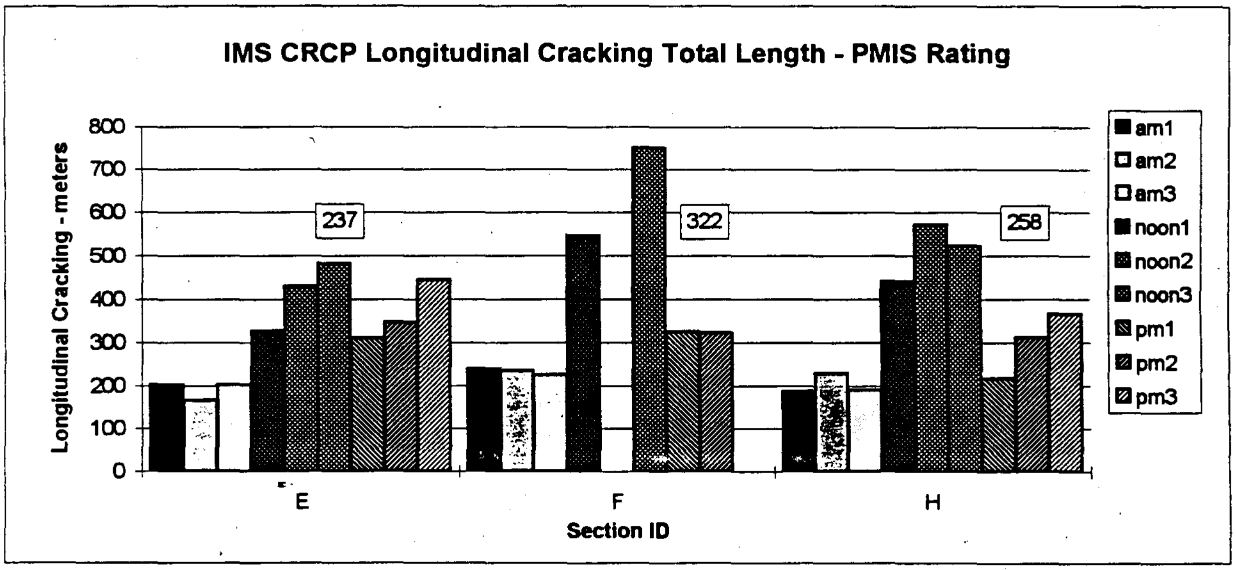

IMS Edge Cracking All Runs - PMIS Sections
Edge Cracking - meters
Section ID
A1-A5
A6-A10
A11-A15
A16-A20
A21-A25
A26-A30
A31-A35
A36-A40
A41-A45
A46-A50
84
66
42
75
127
52
127
73
12
18
am1
am2
noon1
noon2
pm1
pm2

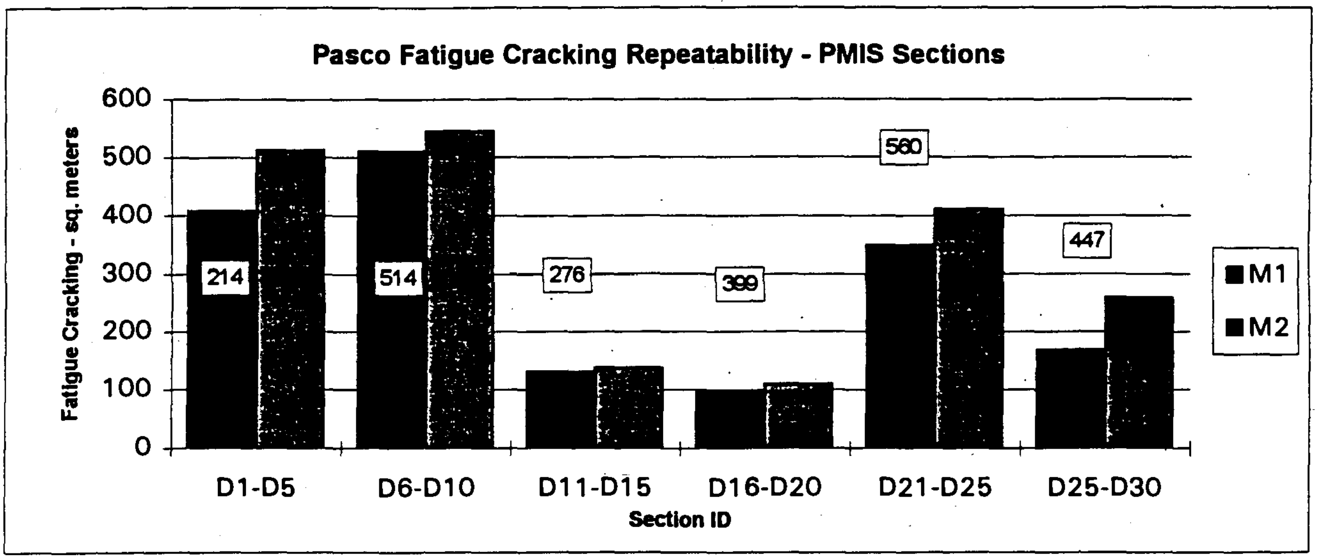

IMS Edge Cracking All Runs - PMIS Sections
Edge Cracking - meters
Section ID
B1-B5
B16-B20
B31-B35
B46-B50
B61-B65
B76-B80
B91-B95
64
45
0
37
0
0
43
0
7
7
0
0
24
75
123
102
295
255
78
156
am1
am2
noon1
noon2
pm1
pm2


IMS Edge Cracking All Runs - PMIS Sections
Edge Cracking - meters
Section ID
D1-D5
D6-D10
D11-D15
D16-D20
D21-D25
D26-D30
T1-T3
49
124
24
102
168
67
0
am1
am2
noon1
noon2
pm1
pm2

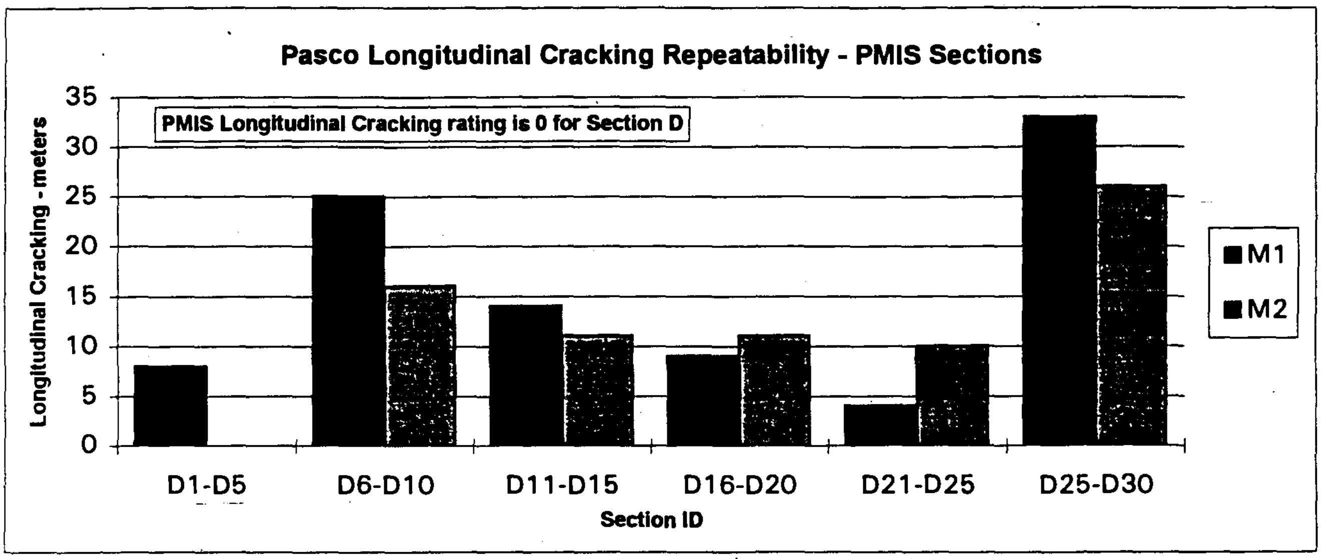

IMS CRCP Transverse Cracks - PMIS Sections
Transverse Cracks - Number
3000
2500
2000
1500
1000
500
0
594
847
589
E
F
H
Section ID
am1
am2
am3
noon1
noon2
noon3
pm1
pm2
pm3


IMS CRCP Spalled Transverse Cracks - PMIS Sections
Spalled Transverse Cracks - Number
1800
1600
1400
1200
1000
800
600
400
200
0
49
82
35
E
F
H
Section ID
am1
am2
am3
noon1
noon2
noon3
pm1
pm2
pm3

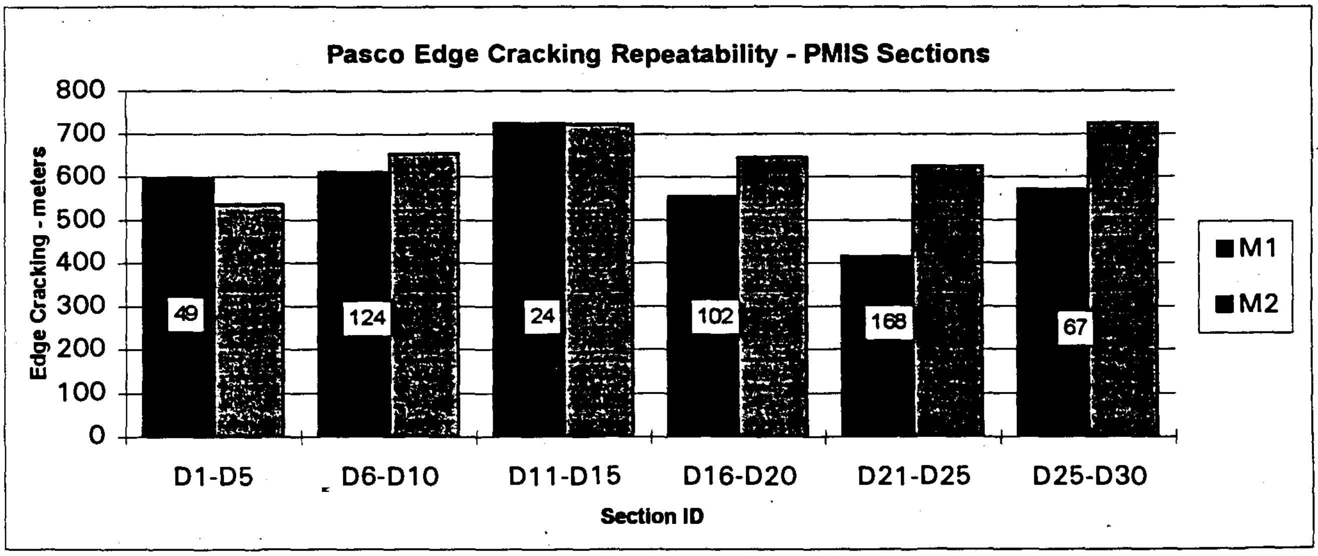

IMS CRCP Longitudinal Cracking Total Length - PMIS Rating
Longitudinal Cracking - meters
800
700
600
500
400
300
200
100
0
237
322
258
E
F
H
Section ID
am1
am2
am3
noon1
noon2
noon3
pm1
pm2
pm3



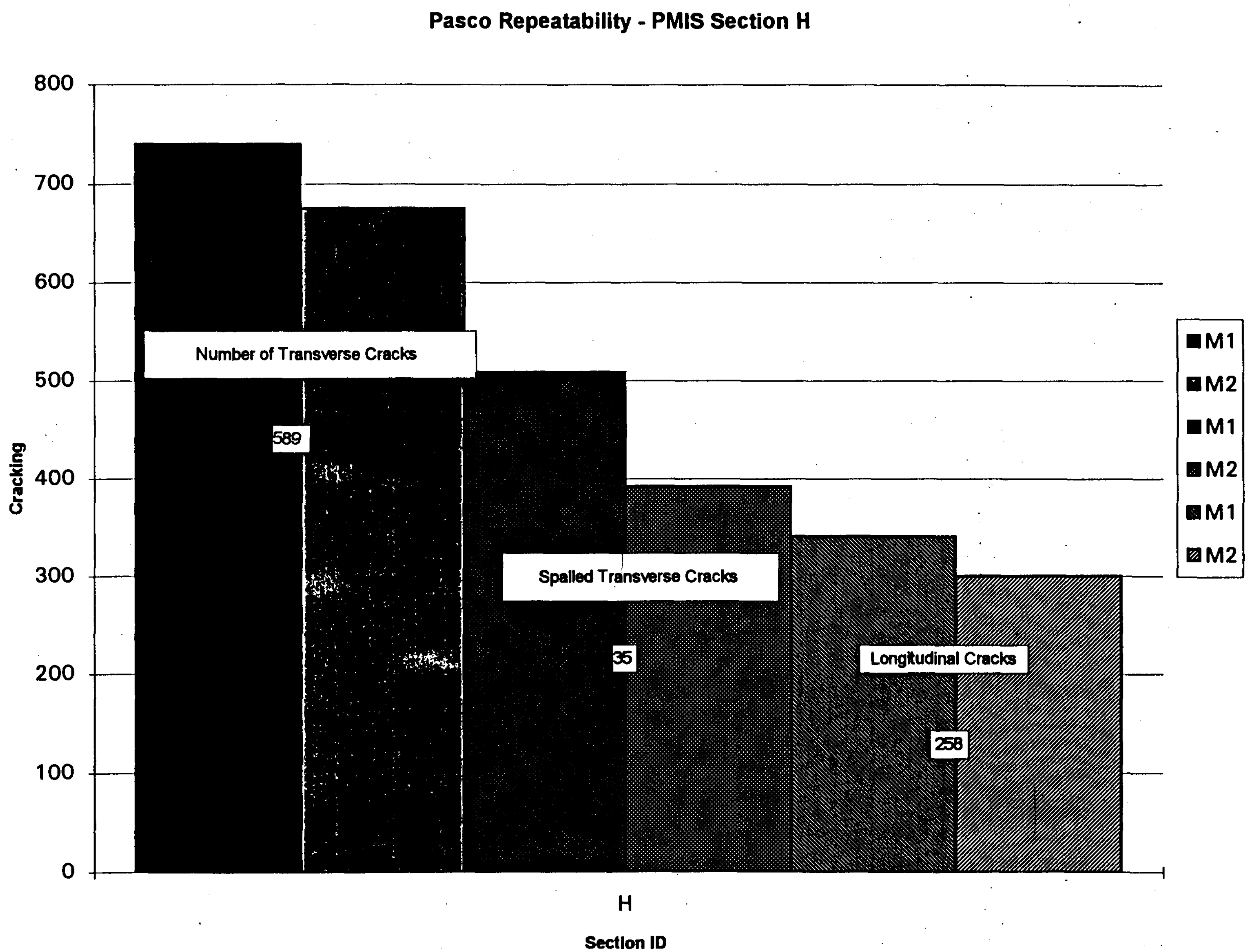
Pasco Fatigue Cracking Repeatability - PMIS Sections
Fatigue Cracking - sq. meters
600
500
400
300
200
100
0
214
514
276
399
560
447
D1-D5
D6-D10
D11-D15
D16-D20
D21-D25
D25-D30
Section ID
M1
M2



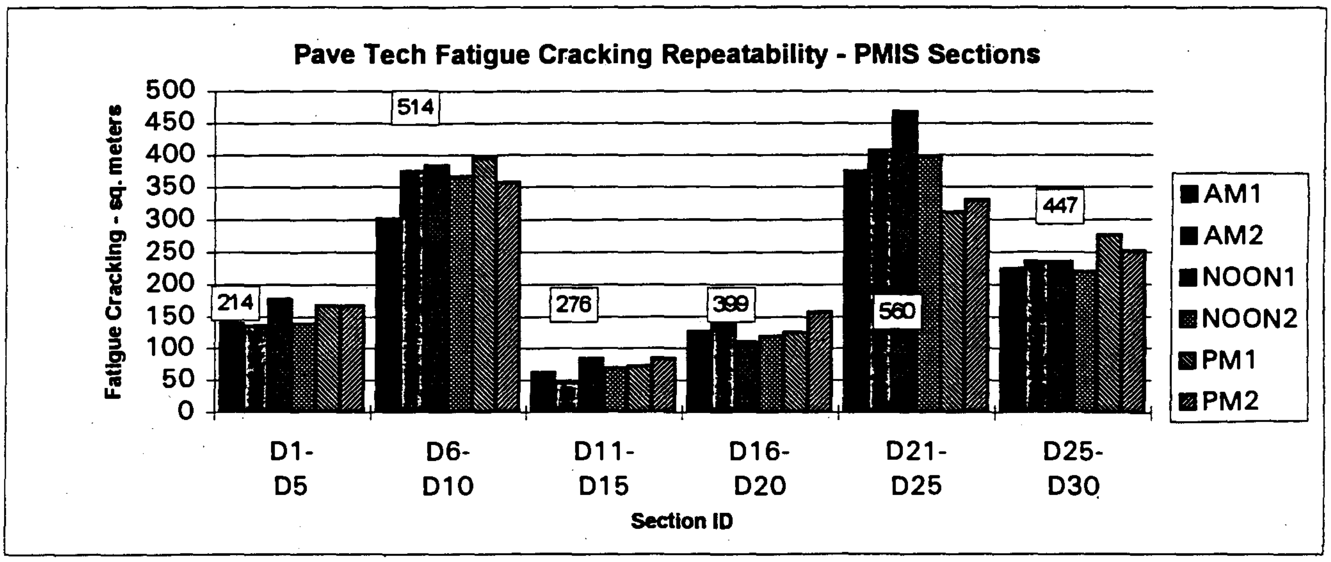
Pasco Longitudinal Cracking Repeatability - PMIS Sections
PMIS Longitudinal Cracking rating is 0 for Section D
Longitudinal Cracking - meters
35
30
25
20
15
10
5
0
D1-D5
D6-D10
D11-D15
D16-D20
D21-D25
D25-D30
Section ID
M1
M2

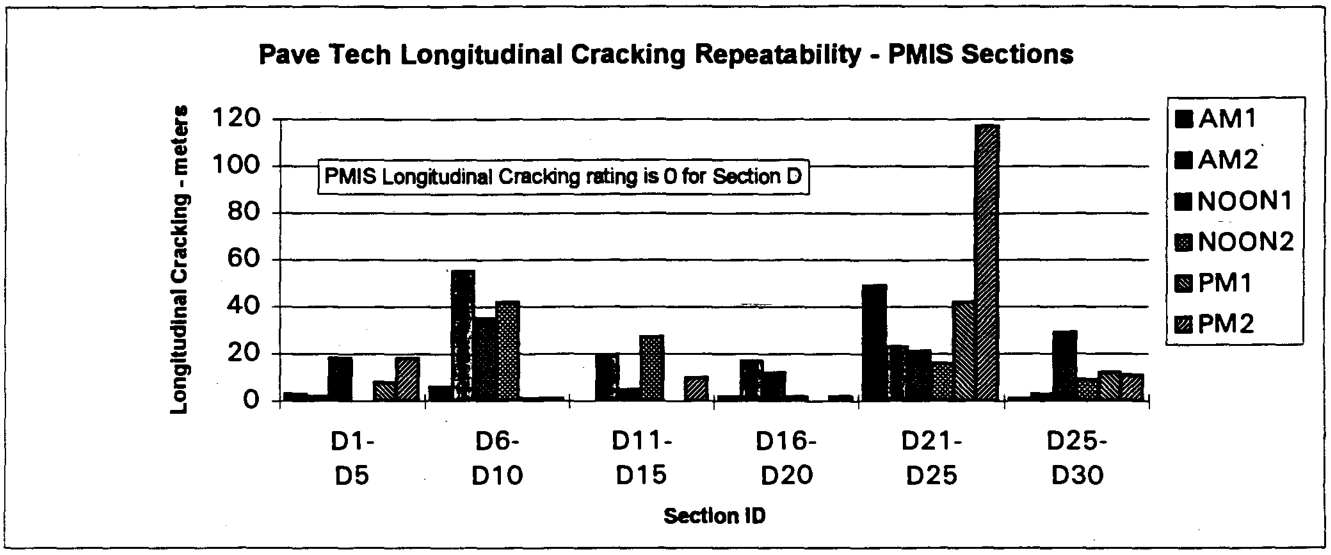


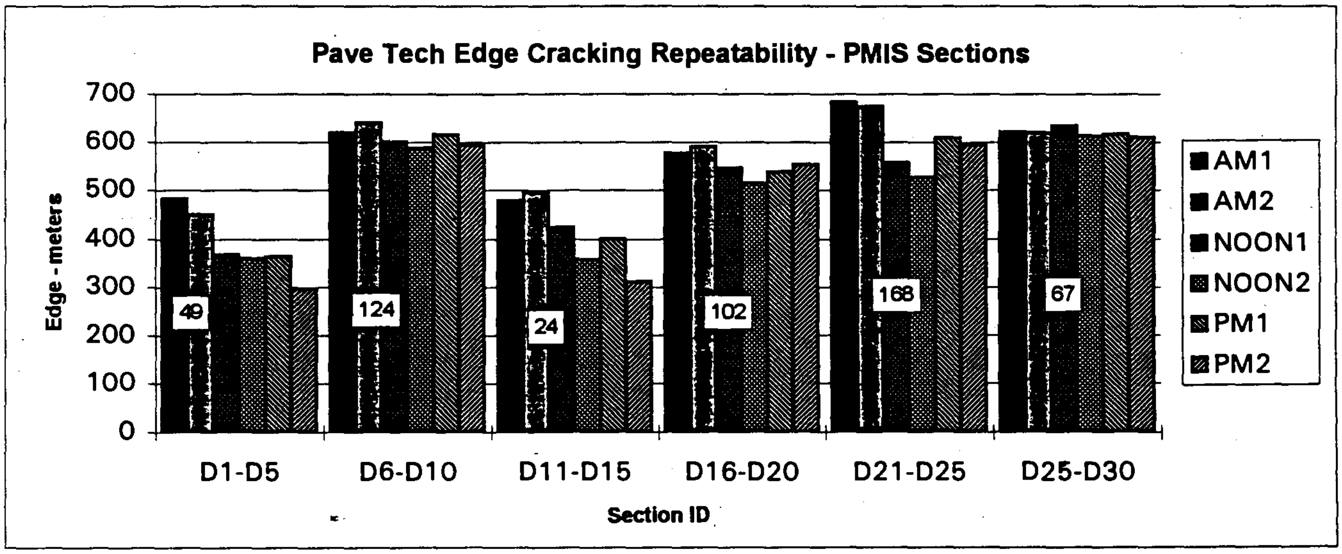
Pasco Edge Cracking Repeatability - PMIS Sections
Edge Cracking - meters
800
700
600
500
400
300
200
100
0
49
124
24
102
168
67
D1-D5
D6-D10
D11-D15
D16-D20
D21-D25
D25-D30
Section ID
M1
M2

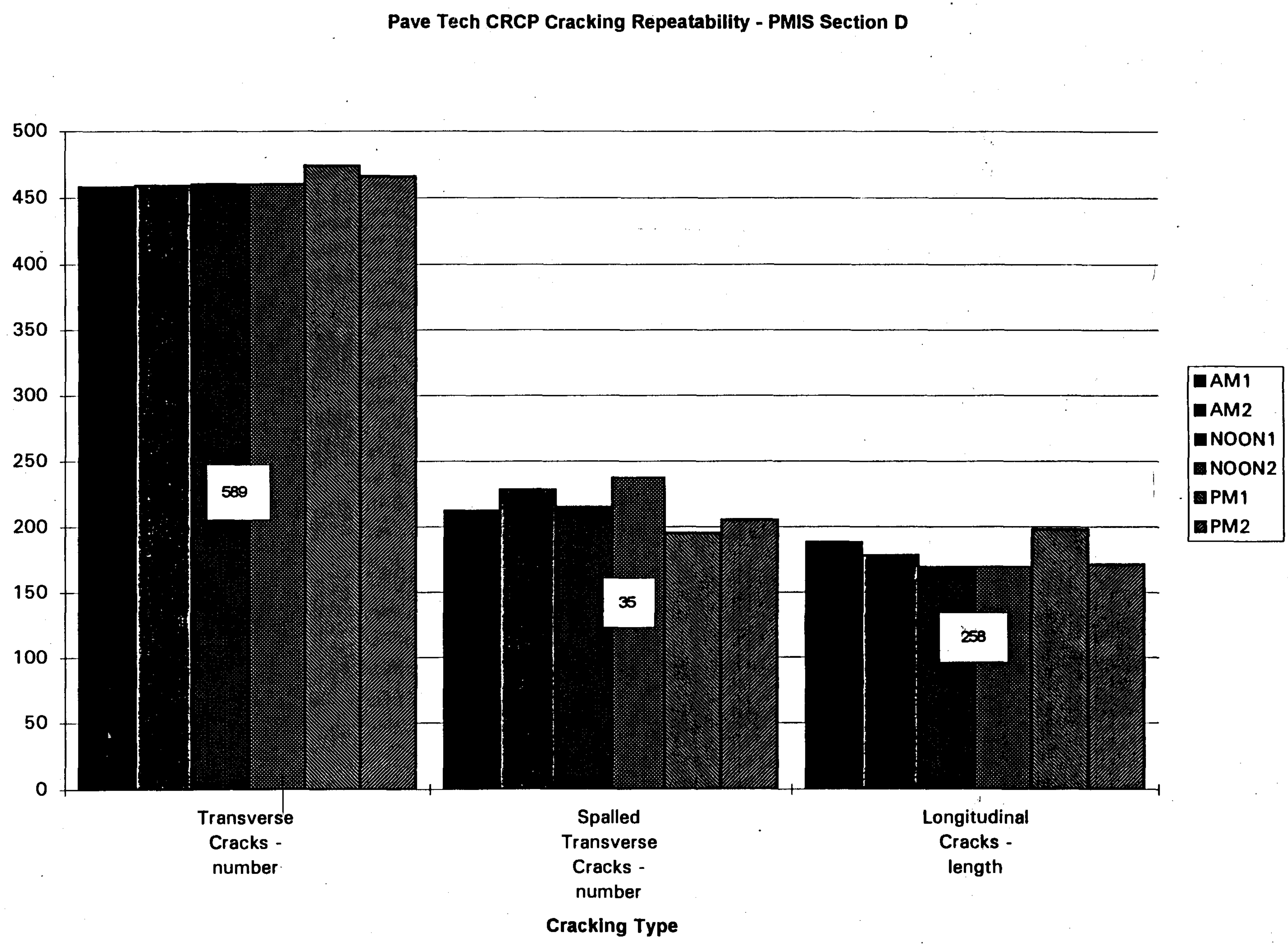


Pasco Repeatability - PMIS Section H
800
700
600
500
400
300
200
100
0
Cracking
Number of Transverse Cracks
589
Spalled Transverse Cracks
35
Longitudinal Cracks
258
M1
M2
M1
M2
M1
M2
H
Section ID

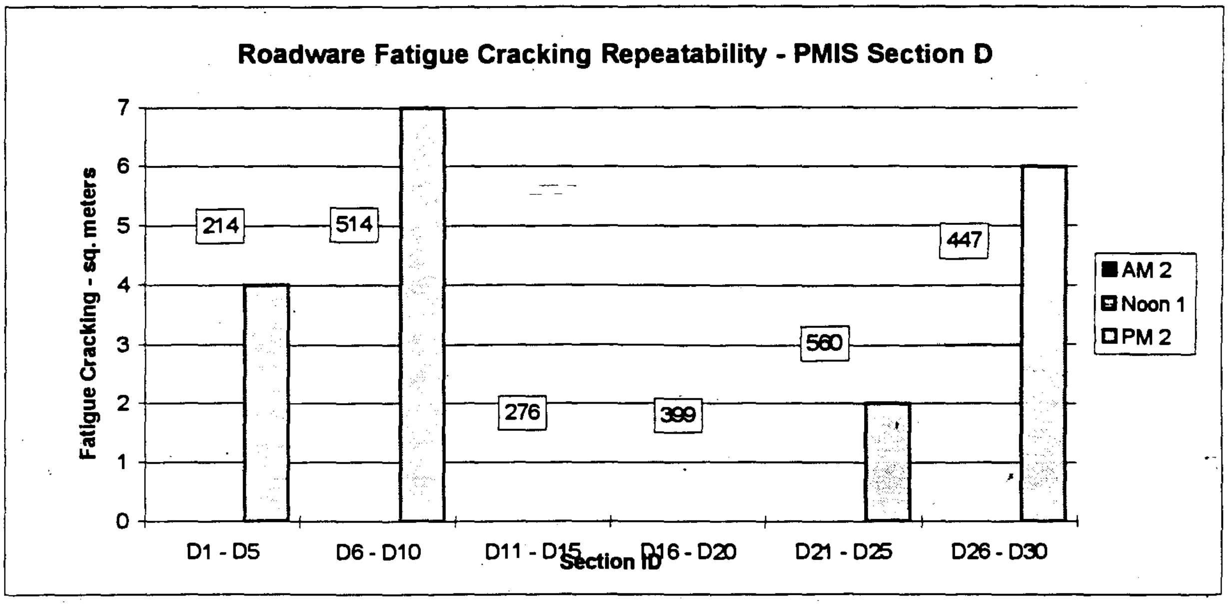

Pave Tech Fatigue Cracking Repeatability - PMIS Sections
Fatigue Cracking - sq. meters
500
450
400
350
300
250
200
150
100
50
0
214
514
276
399
560
447
D1-D5
D6-D10
D11-D15
D16-D20
D21-D25
D25-D30
Section ID
AM1
AM2
NOON1
NOON2
PM1
PM2


Pave Tech Longitudinal Cracking Repeatability - PMIS Sections
Longitudinal Cracking - meters
120
100
80
60
40
20
0
PMIS Longitudinal Cracking rating is 0 for Section D
D1-D5
D6-D10
D11-D15
D16-D20
D21-D25
D25-D30
Section ID
AM1
AM2
NOON1
NOON2
PM1
PM2

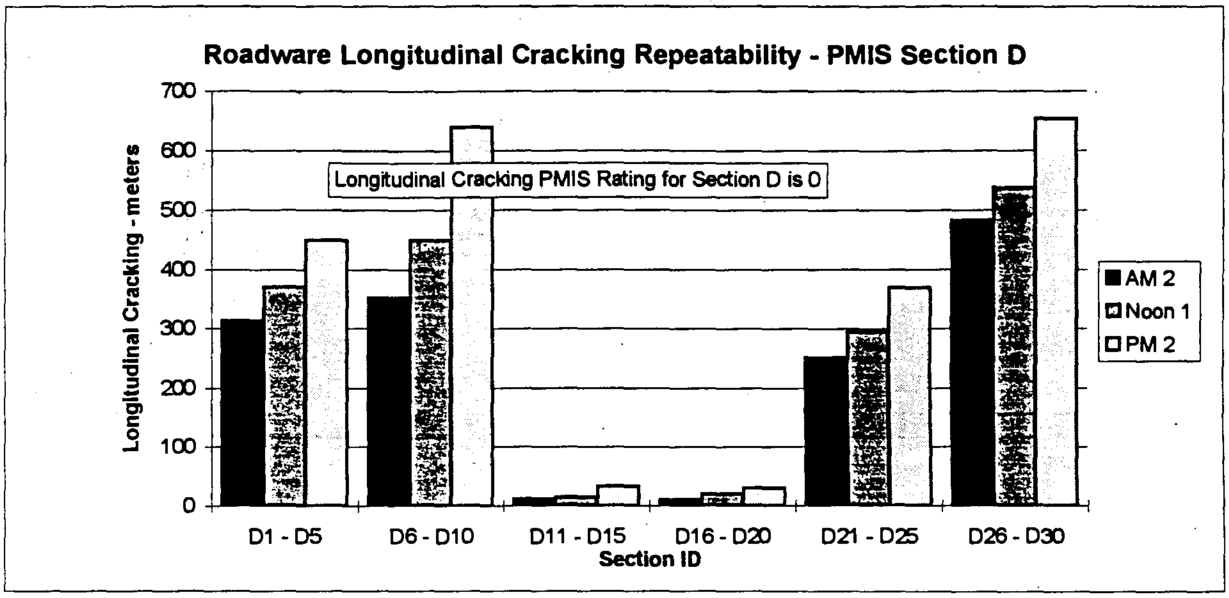

Pave Tech Edge Cracking Repeatability - PMIS Sections
Edge - meters
700
600
500
400
300
200
100
0
49
124
24
102
168
67
D1-D5
D6-D10
D11-D15
D16-D20
D21-D25
D25-D30
Section ID
AM1
AM2
NOON1
NOON2
PM1
PM2



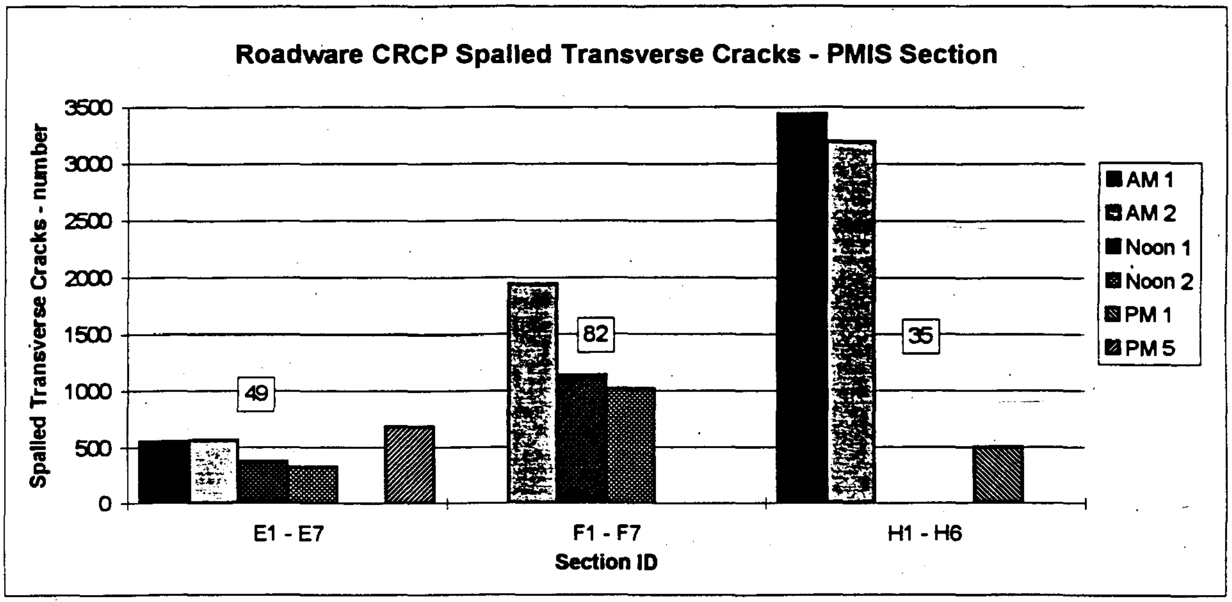
Pave Tech CRCP Cracking Repeatability - PMIS Section D
500
450
400
350
300
250
200
150
100
50
0
589
35
258
AM1
AM2
NOON1
NOON2
PM1
PM2
Transverse Cracks - number
Spalled Transverse Cracks - number
Longitudinal Cracks - length
Cracking Type



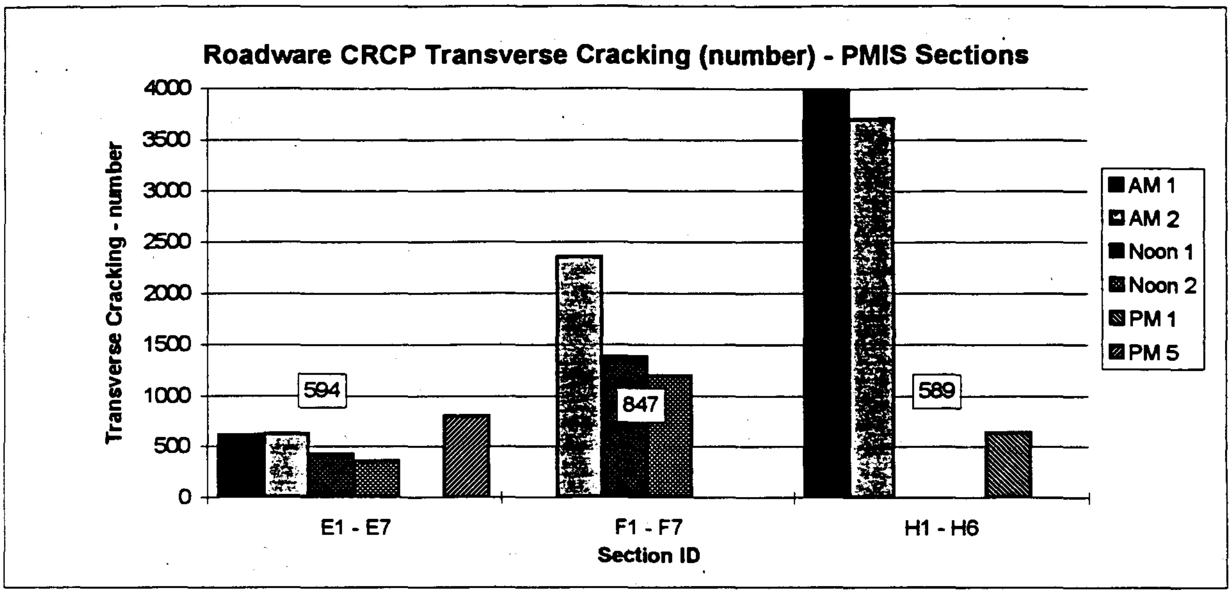
Roadware Fatigue Cracking Repeatability - PMIS Section D
Fatigue Cracking - sq. meters
0
1
2
3
4
5
6
7
214
514
276
399
560
447
AM 2
Noon 1
PM 2
D1 - D5
D6 - D10
D11 - D15
D16 - D20
D21 - D25
D26 - D30
Section ID



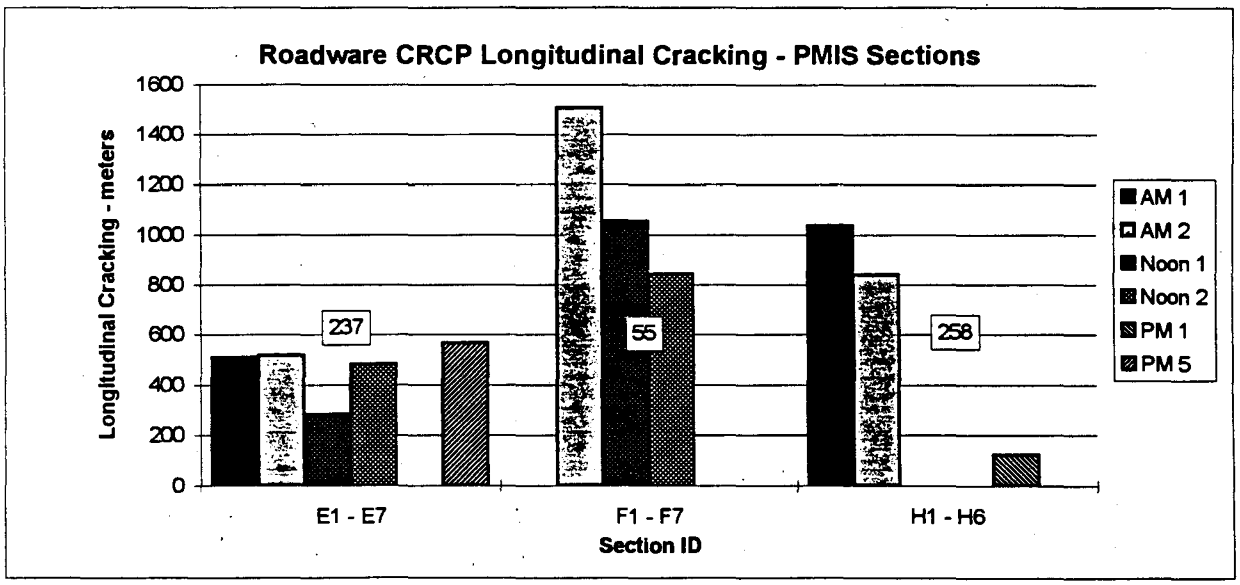
Roadware Longitudinal Cracking Repeatability - PMIS Section D
Longitudinal Cracking - meters
0
100
200
300
400
500
600
700
Longitudinal Cracking PMIS Rating for Section D is 0
AM 2
Noon 1
PM 2
D1 - D5
D6 - D10
D11 - D15
D16 - D20
D21 - D25
D26 - D30
Section ID



Roadware CRCP Spalled Transverse Cracks - PMIS Section
Spalled Transverse Cracks - number
3500
3000
2500
2000
1500
1000
500
0
49
82
35
E1 - E7
F1 - F7
H1 - H6
Section ID
AM 1
AM 2
Noon 1
Noon 2
PM 1
PM 5



Roadware CRCP Transverse Cracking (number) - PMIS Sections
Transverse Cracking - number
4000
3500
3000
2500
2000
1500
1000
500
0
594
847
589
E1 - E7
F1 - F7
H1 - H6
Section ID
AM 1
AM 2
Noon 1
Noon 2
PM 1
PM 5



Roadware CRCP Longitudinal Cracking - PMIS Sections
Longitudinal Cracking - meters
1600
1400
1200
1000
800
600
400
200
0
237
55
258
E1 - E7
F1 - F7
H1 - H6
Section ID
AM 1
AM 2
Noon 1
Noon 2
PM 1
PM 5

APPENDIX A

Asphalt Concrete Pavement Crack Rating			
LTPP		**PMIS**	
Fatigue Cracking		**Alligator Cracking**	
Location:	Predominantly Wheelpath, full lane width also rated	Location:	Wheelpath
Description:	Many-sided sharp angled pieces. Chicken wire / alligator skin appearance. Pieces are less than 1' x 1'	Description:	Irregularly shaped blocks. Resemble patterns found on alligator skin. Pieces are less than 1' x 1'
Severity :	Yes	Severity:	No - However, you see it you rate it.
Rating:	Square Meters	Rating:	Percent Area of wheelpaths
Block Cracking		**Block Cracking**	
Location:	Full Lane Width	Location:	Full Lane Width
Description:	Cracking pattern dividing the pavement into rectangular pieces ranging in size from 0.1 sq. m. to 10 sq. m.	Description:	Interconnecting cracks dividing the pavement into approximately rectangular pieces ranging in size from 1' x 1' to 10' x 10'
Severity:	Yes	Severity:	No
Rating:	Square Meters	Rating:	Percent Area
Sealed:	Yes	Sealed:	Yes - not specified fully in manual
Transverse Cracking		**Transverse Cracking**	
Location:	Full lane width	Location:	Full lane width
Description:	Predominantly perpendicular to pavement centerline. Length of individual cracks are recorded.	Description:	Cracks which travel at right angles to the pavement centerline. Estimated crack length assigned a partial lane width
Severity:	Yes	Severity:	No - must be at least ⅛ inch wide
Rating:	Number and length of cracking	Rating:	Number of full width cracks per station (100')
Sealed:	Yes	Sealed:	Yes

ASPHALT CONCRETE PAVEMENT CRACK RATING			
LTPP		**PMIS**	
Longitudinal Cracking		**Longitudinal Cracking**	
Location:	Full Lane Width - distinction made between wheelpath and non-wheelpath cracking	Location:	Full Lane Width - no distinction made between wheelpath and non-wheelpath. Longitudinal cracks at edge are rated!
Description:	Cracks predominantly parallel to pavement centerline. Record length in meters.	Description:	Cracks approximately parallel to pavement centerline. Record length in feet.
Severity:	Yes	Severity:	No - must be at least ⅛ inch wide
Rating:	Length in meters	Rating:	Feet per station (100')
Sealed:	Yes	Sealed:	Yes
Edge Cracking		**Edge Cracking**	
Location:	Within 0.6m of pavement edge - no shoulders		
Description:	Crescent-shaped cracks or fairly continuous cracks which intersect the pavement edge. Includes longitudinal cracks within 0.6m of the pavement edge.		**No Similar PMIS Rating**
Severity:	Yes		
Rating:	Length of pavement edge affected at each severity level.		
Sealed:	No		

Continuously Reinforced Concrete Pavement Crack Ratings			
LTPP		PMIS	
Longitudinal Cracking		**Longitudinal Cracking**	
Location:	Full lane width		
Description:	Crack predominately parallel to the pavement centerline		**No similar PMIS rating!**
Severity:	Yes		
Rating:	Length of sealed and unsealed cracks in meters.		
Transverse Cracking		**Transverse Cracking**	
Location:	Full Lane Width	Location:	Full Lane Width
Description:	Cracks that are predominantly perpendicular to the pavement centerline	Description:	Rated as spalled cracks. Must have spalling!
Severity:	Yes	Severity:	No
Rating:	Number and length for each severity level as well as total number in the section	Rating:	Number of spalled transverse cracks. PMIS also collects average crack spacing which is similar to total number of transverse cracks in the section.

Conversion from LTPP to PMIS

PMIS Survey

The PMIS visual distress rating procedure for this project consisted of rating each 150 meter segment. A modified PMIS rating was conducted, estimating the extent of each cracking distress. No severity levels were recorded. The conversion from LTPP to PMIS for the network simulation follows for each cracking type.

Flexible Pavement Surfaces

Fatigue to Alligator Cracking:

LTPP reports the area in square meters of fatigue cracking for the entire lane width. The PMIS rating restricts alligator cracking to the wheelpaths. The modified PMIS survey will note fatigue cracking outside the wheelpaths. For this project the wheelpath for all flexible pavements is defined as starting 0.6 meters from the pavement edge (outside) and the centerline (inside). Each wheelpath is 0.8 meters wide and is 150 meters long. . . . The PMIS rating was calculated as: **percentage of wheelpath alligator cracking * 150 * 0.8meters * 2 + area of non-wheelpath alligator cracking = fatigue cracking in square meters.**

Block Cracking:

Conditions in the part of Texas where the test was conducted typically does not produce block cracking and this was the case for the demonstration project. Thus block cracking is not reported.

Transverse Cracking:

The LTPP procedure records both the number and length of individual cracks along with their severity rating. Individually sealed cracks are included in the rating procedure. The PMIS procedure counts the number of full width cracks. As part of this procedure partial cracks are recorded, i.e. a 1.83 meter crack on a 3.66 meter lane is rated as one-half a crack. PMIS includes sealed transverse cracks in the rating procedure. The PMIS transverse cracking distress is recorded as the number of full length cracks per 30.48m (100') station. Since the PMIS rater will provide a rating in number per station, the number of transverse cracks recorded by the equipment is defined as: **the number of transverse cracks in a 150 meter segment divided by 4.92**; *there are 4.92 stations in a 150 meter segment.*

Conditions in the part of the state where the test was conducted typically does not produce transverse cracking and this was largely the case for the demonstration project. While there was some small cases of transverse cracking, only two or three 150 meter segments had enough to rate as one or more per station. Thus, there are no PMIS ratings vs. equipment vendors shown for transverse cracking.

LONGITUDINAL CRACKING:

LTPP distinguishes between wheelpath and non-wheelpath longitudinal cracking. The LTPP procedure also includes sealed cracks in the survey procedure. For the purposes of this project the longitudinal cracking reported by the equipment will be the length of the combined wheelpath and non-wheelpath longitudinal cracking. The PMIS procedure measures the length of cracking in feet per station. This rating procedure includes cracking close to the edge. For this project, edge cracking will be handled separately. Longitudinal cracking within 0.6 meters will not be included in the PMIS longitudinal edge cracking rating. For this project PMIS longitudinal cracking was converted to length in meters by the following formula: **the feet per station of longitudinal cracking*4.92 stations per segment *0.3048 meters / foot.**

EDGE CRACKING:

LTPP includes longitudinal cracking that intersect with the pavement edge and are within 0.6 meters of the pavement edge. Edge cracking applies only to those pavements without shoulders. Crescent-shaped cracks within 0.6 meter of the pavement edge are also rated. LTPP rates the severity of edge cracking. For this distress type, PMIS collected the feet of edge cracking per station. The PMIS edge cracking rating is converted to meters by the following formula: **the feet per station of edge cracking*4.92 stations per segment *0.3048 meters / foot.**

RIGID PAVEMENT SURFACES

LONGITUDINAL CRACKING:

LTPP measures longitudinal cracking by severity levels and records the length in meters. The PMIS procedure does not measure longitudinal cracking on CRCP pavements. For this study, the length of longitudinal cracking in meters was recorded ; no severity levels were used.

TRANSVERSE CRACKING:

LTPP records the number and length of all transverse cracks regardless of whether or not they are distressed. The PMIS survey only records those transverse cracks which are distressed, i.e. spalled. PMIS also collects the average crack spacing which provides an estimate of the number of transverse cracks in a section. For this study: **150 meters was divided by the PMIS average crack spacing to estimate the total number of transverse cracks**. This number is then compared to the number of transverse cracks recorded by the equipment.

To estimate the number of spalled transverse cracks, the number of cracks reported by the vendors in the moderate and severe categories were separated and compared to the number of spalled transverse cracks in the PMIS procedure. Length of transverse cracks was not recorded.

APPENDIX B

The following describes some of the challenges with image analysis for pavement surface distress ratings. This short dialog is not intent as a complete description of all the steps required to perform automated distress rating. Instead, it is intended to provide the reader understanding about this procedure that the vendors are accomplishing.

- **Recording the Pavement Image** An inexpensive, reliable, and easy to use recording device with adequate resolution has not been available until recently. Photographic film has the resolution needed to record fine pavement cracks however, light is a problem as well as exposure and shutter speed. Additionally, there is no means available to check the image quality until the film has been developed.

  Video cameras and video tape were considered the most appropriate means available for capturing images. It has been only very recently with the development of electronically shuttered video cameras and higher resolution cassette based video taping systems that video has become a viable alternative for capturing pavement images.

- **Creating a Machine Readable Version of the Image** Even if photographic film was used in the past, the images still had to be turned into something a computer program could read and process. While this is possible, it is expensive and there is a corresponding loss of resolution dependent upon the resolution of the scanning device available. Digitizing boards are now available that can directly read video, digitize the image and create a bit mapped image that a computer program can readily read and manipulate.

- **Digital Image Size** Digital image file sizes are big compared to other data types. For example, a simple 256 gray scale image 512 x 512 pixels wide is approximately 2 megabytes (Mbyte). Suppose one image can cover a full lane width, *assuming of course that the resolution necessary for crack width is available,* and that the image covers ten feet of lane length. One mile of continuous digital data from that one camera is approximately 1056 Mbyte. Obviously, even with the larger storage capacity media available at this time, storing digital images is cost prohibitive and difficult to do!

- **Manipulating the Digital Image** Once an image is available it must be manipulated to extract the features of interest from all other extraneous information; background noise, skid marks, oil stains, shadows, etc. Typically for pavements a histogram of each image is computed to establish the background intensity or average grey scale. Since most pavement cracks are darker than the average grey scale, *keep in mind that some pavements pump fines from the cracks and appear lighter,* and since they tend to look like edges, edge detection algorithms are used extract the cracks. After the edge detection phase is complete, feature extraction is used to *"connect the dots and make a crack."* Next comes the crack classification phase where type and extent of cracking and, if interested, severity of cracking are estimated.

- **The Pavement Surface** Pavement surfaces present an especially difficult challenge to machine vision systems. Pavement surfaces come in many different varieties of colors and textures from the smooth dark black of new surfaces asphalt concrete surfaces to gap graded surface treatments made with limestone aggregates. The constantly changing color and surface texture is extremely difficult to program and is time intensive because of all the calculations that are necessary. Additionally, patching, strip seals, skid marks, shadows and paint stripes create processing problems from differing background greyscale to false edges.

APPENDIX C

EQUIPMENT DESCRIPTION

IMS - PAVUE System

Vehicle

Basic vehicle is a Ford Econoline, standard except for heavy-duty towing package and an RV-type electrical generator full PAVUE and laser system installed in the van. The measurement survey speed range for collection of data is from 8 to 90 km/h (5 to 55 mph). The vehicle can collect data regarding pavement roughness, surface texture, condition survey, faulting, IRI, and right-of-way videologging. The pavement cameras horizontal Field of View (FOV) or imaged width is adjustable from 3.2 m to 4 m(10.5 ft to 13.1 ft), depending on the lane width surveyed. The PAVUE maximum vertical FOV is 0.75 m(2.5 ft).

Data Collection Equipment

4 Lasers mounted on the front bumper (32 Khz Selcom).
7 Strobe Lights (50 flashes/sec.)
4 Pavement Cameras.
2 Accelerometers (mounted in each wheel path)
1 Forward Camera.
5 S-VHS, PAL-video format, Video Tape Recorders(VTR's).
1 Personal Computer (486 processor)
1 Distance Measurement Instrument (DMI)
1 Photocell (for optical start/stop)

IMS plans to incorporate this technology onto the laser RST technology and collect roughness/longitudinal profile, rut data, transverse profile, road geometry, GPS, etc. The laser RST includes the following equipment:

8 Lasers (32 Khz Selcom)
1 GPS receiver
Road Geometry Pack (inclinometers, rate gyros)

Data Collection

The data equipment is calibrated and the equipment operation is verified. The data measuring program is downloaded to the computer system. The five VCR's are synchronize prior to start data acquisition.

General description of the pavement section is input to the data measuring program. The data acquisition is started either by manual key press or by a photocell start. The data collection is fully vehicle speed independent. Pavement videos are recorded using the five VCR's corresponding to the four pavement cameras and one forward camera. The laser data is collected in the data measuring program and checked for abnormal readings prior to be stored in a floppy disk. The video and laser data are synchronized with the DMI for proper data post-processing.

Data Processing

The data post-processing is conducted in the PAVUE Processing Workstation. This workstation consist of:

1 PC Computer
1 PAVUE Image Processor
4 S-VHS VTR's for playing pavement data
1 S-VHS VTR for playing forward video
3 Video Monitors

The data is then processed in the following steps:

The videotapes are loaded in the VCR's and the laser data is transferred to the PAVUE database.

The main program in the PAVUE Image Processor is run to access the database, synchronize the VCR's, and begin analysis of the video stream from the videotapes without any intervention from an operator. All measurements are computed and processed in real-time. Thus, the PAVUE analyzes the pavement data at the same speed at which it was collected, up to well above 90 km/h (55 mph)

The output of the PAVUE analysis is a set of two distress data files, one for each PAVUE image processor channel(two videotapes/channel). The files from each channel are combine automatically into a single presentation of the entire road width.

A distress classifier program is run to preliminary identify the type, severity and extend of the distresses.

The output of the distress classifier program and laser data are analyzed by a HYBRID program that generate the final pavement cracking report.

Data Output

Binary crack maps, available in computer disks or color printouts.
Distress data files use to generate pavement cracking reports.
Data file reports are also available and are generated from any of the specified measurement parameters.
Video tape archives

PASCO USA

Vehicle

The PASCO ROADRECON survey vehicle is equipped with two camera systems.

The vehicle operates at highway speeds, and all surveys are done at night, under controlled artificial lighting, so that the photographs are not affected by shadows and variable lighting (The lights for the survey systems are sufficiently bright that incidental light from street lights and/or passing vehicles does not significantly affect the quality of the photographs).

Data Collection Equipment

1 Distress camera system (35-mm slit camera).
1 Cross-profile camera system (35-mm pulse camera).*
1 Hairline projector.*
A series of lights mounted on the front bumper.
1 Personal Computer.
1 Distance Measurement Instrument(DMI)

* Not used in this project

The distress camera is mounted on a boom which extends out over the pavement. The cross-profile camera is mounted on the rear of the vehicle. The hairline projector is located on the rear bumper. Both camera systems are controlled by computer from the front passenger seat of the survey vehicle.

Data Collection

The vehicle operates at highway speeds, and all surveys are done at night, under controlled artificial lighting, so that the photographs are not affected by shadows and variable lighting (The lights for the survey systems are sufficiently bright that incidental light from street lights and/or passing vehicles does not significantly affect the quality of the photographs).

The distress photographs obtained with the PASCO survey vehicle are continuous 35-mm film which provide 100 percent coverage of the full lane width, and a portion of the shoulder, about 4.9 m wide (16 ft.).

Cross-profile photographs are taken at 50-foot intervals on the SHRP sections, and, like the distress photos, cover slightly more than the full lane width.

Data Processing

The 35-mm film is developed and positive copies made using the developed negative copies. PASCO'S PADIAS System is used to reduce the distress data from the film. This system consists of projection equipment with a digitizing screen linked to a personal computer, and software for the identification and quantifying of the various distresses.

To reduce the distress data, a technician first loads the film into the projector, so that the image is displayed on the digitizing screen. A digitizing cursor is used to outline the distresses, and the computer determines the corresponding length of area, based on predetermined scale factors. The technician selects the distress type and severity from menus displayed on the computer monitor. The SHRP's Distress Identification Manual provides guidance to the technician on the identification of distress type and severity level.

A number of quality assurance measures are used the collection of distress photographs on the SHRP test sections. Quality assurance measures include checks of cameras resolution, linear distortion, lateral placement in the lane, location of cross-profile photographs with respect to the target location, and film processing quality.

Data Output

SHRP's Pavement Distress Survey Data Summary Sheets. (Distresses are quantified and tabulated in terms of type and severity level)

Crack Maps showing location and extend of different types of distresses in each 150 m pavement segment.

Pave Tech, Inc.

Vehicle

Basic vehicle is a Ford Econoline Van modified to carry overhead and panoramic cameras, video units, and computer hardware. The vehicle operates at speeds up to 104 km/h (65 mph).

Data Collection Equipment

1 486/50 Mhz Compaq personal computer
1 Eight inch color VGA monitor
5 High resolution CCD color video cameras
1 Remote controlled pan/tilt color video camera (up to 12 cameras optional)
4 S-VHS commercial grade video tape recorders(VTR's)
4 High resolution, high pitch video monitors
4 Frame Id generators
1 Distance Measurement Instrument(DMI)
1 Laser printer
1 Five sensor type South Dakota Profilometer including one optical infrared sensor
2 Two sensor faulting/raveling devices, one for each wheelpath
1 Pavement grade/cross slope gyroscope
1 Heading gyroscope
1 GPS receiver

Data Collection

General description of the pavement section including road name, project number, survey limits, station at the beginning of pavement section, etc. are loaded in the inboard computer database.

Two video images of the pavement are recorded using two overhead cameras. Each of these cameras cover half of the lane surveyed up to 2.1 m (7 ft) wide. Two video images of a perspective view of the road and shoulder/curb view are recorded using two additional cameras.

Data Processing

The Image Processing Workstation (IPW) is used to perform the pavement condition data processing. The IPW consists of the following equipment:

1 486/50 Mhz Compaq personal computer
1 SVGA monitor
4 S-VHS commercial grade video tape recorders (VTR's)
4 High resolution, super fine pitch video monitors
1 256 MB external optical disk drive
1 Video printer for image hard copy
1 Laser printer
1 Video character generator

A computer pavement distress video manager program is used to perform the pavement distress survey analysis. This program features a pavement distress input menu. This menu helps the technician to control the video playback, document pavement distresses and observe the status of a distress data file. Pave Tech's distress survey analysis is perform in the following steps:

A technician proceeds to load the recorded video in the VTR's and synchronize them to the same starting point.

The video images are playback at variable speeds ranging from the equivalent of one mile per hour to ten miles per hour allowing the technician to observe the pavement condition.

When the technician observes a distress starting in the video images he/she presses the corresponding menu option in the program that commands the computer to start measuring the corresponding distress.

When the technician observes the end of the distress the video image, he/she presses corresponding options for severity, width, location in the lane, and sealed or not sealed condition. The computer automatically measures the corresponding length or area of the distress and saves it in the distress data file.

This data file is then used to summarize the distresses in a format compatible with a pavement management system.

All distresses can be extracted in a single pass because the computer can follow several distress simultaneously.

The videos can be reversed one frame at a time and replayed to review and/or revise the quality of the distress data. Edit/changes can be made in the distress files.

Data Output

Pavement Distress Condition Reports
Distress Database Summary for Quality Control
Roughness Data by User Defined Interval and Severity
Rutting Data by User Defined Interval and Severity
Faulting/Raveling Data by User Defined Interval and Severity
Road/Sign Inventory Reports
Video Tapes of Distress, Perspective and Shoulder views
Pavement Grade and Cross Slope
Heading, curvature and GPS reports
Hard copies of distress and road video images

Roadware - ARAN/WISECRAX

Vehicle:

The Roadware's ARAN (Automatic Road Analyzer) is the vehicle used to capture the pavement view video data. The ARAN captures continuous pavement video at 80 km/h (50 mph).

The ARAN vehicle can collect data regarding pavement roughness, cross sectional profile, rutting, texture, Right-ow-Way video, geometries, condition survey, and measured distances.

Data Collection Equipment:

2 Pavement Cameras
1 Right of Way View Camera
2 S-VHS Video Tape Recorders(VTR's)
2 Strobe Lights (15 flashes per second)
3 Video Monitors
1 Personal Computer
1 Distance Measuring Instrument(DMI).
2 Lasers and accelerometers
1 GPS receiver
1 37 ultra sonic rut bar
1 gyroscope geometry package
2 keyboards for entering inventory, event and other data.

Data Collection:

Continuous pavement video is collected from two overhead cameras that supply 1.5 meter images of the pavement surface. Video frames are linked to the ARAN DMI and the ARAN Rater Keyboard. The Rater Keyboard manually records events, such as different pavement types, pavement joints, sealed cracks, crack categories, or other circumstances (such as bridge locations or railroad crossings) during data collection.

Data Processing:

Data from the ARAN is included on the floppy diskette and one S-VHS video tape. This information is processed on the following computer workstation:

Computer: 486 PC with image processing boards.
Monitor: 1 TV Monitor
Playback: 1 Video Tape Player.

The data is then processed in the following steps:

Analog to Digital Conversion.
Grey Scale processed to Black & White Crack Map.
Generate Statistics from Black & White.
Optional hard copy Crack Map.
Summarize Data into Output Format from Statistics.

The Wisecrax crack image processing is a fully automated process that is performed offline. Once the image file has been created, several image processing routines are employed to correct false positive (pixels mistakenly identified as cracks during segmentation) and generation more descriptive crack statistics.

Two approaches are used to analyze the image, particle and width analysis. Particle analysis examines the image on an individual particle (blob) basis. Width analysis separates the image according to the width of the particles.

Width analysis provides details of the widths of cracking, which is analogous to the severity, and is with area statistics to determine the length of cracking. The pavement edge pavement is removed from the image using width analysis without removing edge cracking.

Wisecrax provides quantitative descriptions of the roadway cracking, including a crack map. The crack map is summarized statistically by severity (width), extent (length and area of coverage), location (edge, center, or wheel path), and by orientation (transverse or longitudinal).