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16. Abstract

This report documents the performance of several continuously reinforced concrete pavements (CRCP) in Texas. Specifically, it involves a comparison of the performances of CRCP overlays and new CRCP construction for three projects: I35-2(45)175, located in Guadalupe County, I35-4(13)317, located in Falls and McLennan Counties (a two county project), and I35W-5(44)401, located in Johnson County. These projects were constructed by the Texas State Department of Highways and Transportation and each includes overlay and new construction built side by side.

This report documents condition surveys performed on these pavements in 1975-76. The study compares observed performances of CRCP overlays and new CRCP and reports findings and trends. While the findings are far from conclusive, they can be useful for improving future designs.

17. Key Words continuously reinforced concrete pavement (CRCP), CRCP overlay, new construction CRCP, statistical comparison, performance, present serviceability rating (PSR), crack spacing, repair patches, condition survey.

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by

James I. Daniel
W. Ronald Hudson
B. Frank McCullough

Research Report Number 177-12

Development and Implementation of the Design, Construction
and Rehabilitation of Rigid Pavements

Research Project 3-8-75-177

conducted for

Texas
State Department of Highways and Public Transportation

in cooperation with the
U.S. Department of Transportation
Federal Highway Administration

by the

CENTER FOR HIGHWAY RESEARCH
THE UNIVERSITY OF TEXAS AT AUSTIN

April 1978

PREFACE

The purpose of this report is to document and summarize experience gained in the study of several Continuously Reinforced Concrete Pavements which have been in service in Texas for the past 15 to 20 years.

This is the twelfth in a series of reports which describe work done on Project 3-8-75-177, Development and Implementation of the Design, Construction and Rehabilitation of Rigid Pavements.

The study is being conducted at the Center for Highway Research, The University of Texas at Austin, as part of the Cooperative Highway Research Program sponsored by the State Department of Highways and Public Transportation and the Federal Highway Administration.

This report would not have been possible without the help and assistance of many people. Mr. B. C. Nayak began the study and contributed much to the collection of data. The cooperation of the staff of the Center for Highway Research, in particular Rita Spohnholtz, Patty Wilson, and Patricia Henninger is greatly appreciated.

James I. Daniel
W. Ronald Hudson
B. Frank McCullough

September 1977

LIST OF REPORTS

Report No. 177-1, "Drying Shrinkage and Temperature Drop Stresses in Jointed Reinforced Concrete Pavement," by Felipe R. Vallejo, B. Frank McCullough, and W. Ronald Hudson, describes the development of a computerized system capable of analysis and design of a concrete pavement slab for drying shrinkage and temperature drop. August 1975.

Report No. 177-2, "A Sensitivity Analysis of Continuously Reinforced Concrete Pavement Model CRCP-1 for Highways," by Chypin Chiang, B. Frank McCullough, and W. Ronald Hudson, describes the overall importance of this model, the relative importance of the input variables of the model and recommendations for efficient use of the computer program. August 1975.

Report No. 177-3, "A Study of the Performance of the Mays Ride Meter," by Yi Chin Hu, Hugh J. Williamson, B. Frank McCullough, and W. Ronald Hudson, discusses the accuracy of measurements made by the Mays Ride Meter and their relationship to roughness measurements made with the Surface Dynamics Profilometer. January 1977.

Report No. 177-4, "Laboratory Study of the Effect of Non-Uniform Foundation Support on CRC Pavements," by Enrique Jiminez, W. Ronald Hudson, and B. Frank McCullough, describes the laboratory tests of CRC slab models with voids beneath them. Deflection, crack width, load transfer, spalling, and cracking are considered. Also used is the SLAB-49 computer program that models the CRC laboratory slab as a theoretical approach. The physical laboratory results and the theoretical solutions are compared and analyzed, and the accuracy is determined. August 1977.

Report No. 177-6, "Sixteenth Year Progress Report on Experimental Continuously Reinforced Concrete Pavement in Walker County," by Thomas P. Chesney and B. Frank McCullough, presents a summary of data collection and analysis over a 16-year period. During that period, numerous findings resulted in changes in specifications and design standards. These data will be valuable for shaping guidelines for future construction. April 1976.

Report No. 177-7, "Continuously Reinforced Concrete Pavement: Structural Performance and Design/Construction Variables," by Pieter J. Strauss, B. Frank McCullough, and W. Ronald Hudson, describes a detailed analysis of design, construction, and environmental variables that may have an effect on the structural performance of a CRCP. May 1977.

Report No. 177-9, "CRCP-2, An Improved Computer Program for the Analysis of Continuously Reinforced Concrete Pavements," by James Ma and B. Frank McCullough, describes the modification of a computerized system capable of analysis of a continuously reinforced concrete pavement based on drying shrinkage and temperature drop. August 1977.

Report No. 177-10, "Development of Photographic Techniques for Performance Condition Surveys," by Pieter Strauss, James Long, and B. Frank McCullough, discusses the development of a technique for surveying heavily trafficked highways without interrupting the flow of traffic. May 1977.

Report No. 177-11, "A Sensitivity Analysis of Rigid Pavement-Overlay Design Procedure," by B. C. Nayak, W. Ronald Hudson, and B. Frank McCullough, gives a sensitivity analysis of input variables of Federal Highway Administration computer-based overlay design procedure RPOD1. June 1977.

Report No. 177-12, "A Study of CRCP Performance: New Construction versus Overlay," by James I. Daniel, B. Frank McCullough, and W. Ronald Hudson, documents the performance of several continuously reinforced concrete pavements (CRCP) in Texas. April 1978.

ABSTRACT

This report documents the performance of several continuously reinforced concrete pavements (CRCP) in Texas. Specifically, it involves a comparison of the performances of CRCP overlays and new CRCP construction for three projects: I35-2(45)175, located in Guadalupe County, I35-4(13)317, located in Falls and McLennan Counties (a two county project), and I35W-5(44)401, located in Johnson County. These projects were constructed by the Texas State Department of Highways and Public Transportation and each includes overlay and new construction built side by side.

This report documents condition surveys performed on these pavements in 1975-76. The study compares observed performances of CRCP overlays and new CRCP and reports findings and trends. While the findings are far from conclusive, they can be useful for improving future designs.

KEY WORDS: continuously reinforced concrete pavement (CRCP), CRCP overlay, new construction CRCP, statistical comparison, performance, present serviceability rating (PSR), crack spacing, transverse cracking, localized cracking, spalling, pumping, punchouts, repair patches, condition survey.

SUMMARY

A statistical comparison of the performance of CRCP overlay and CRCP new construction was made for three projects in Texas. These projects include CRCP overlay and new CRCP constructed side by side. For simplicity they will be referred to by the county in which they are located: Guadalupe County, Falls-McLennan Counties (a two-county project), and Johnson County. The statistical comparison considered distress in several categories, including

(1) transverse cracking,
(2) localized cracking,
(3) spalling,
(4) pumping,
(5) punchouts,
(6) repair patches,
(7) riding quality, and
(8) crack spacing.

The comparison of a 6-inch (152-mm) CRCP overlay with an 8-inch (203-mm) CRCP new construction in Guadalupe County shows statistically that both types of pavements have very little distress and both are performing very well and relatively equally. The comparison of a 7-inch (178-mm) CRCP overlay with an 8-inch (203-mm) CRCP new construction for the Falls-McLennan project, however, shows that both have suffered extensive distress in every category and on the whole the CRCP overlay is out-performing the CRCP new construction. The comparison of a 6-inch (152-mm) CRCP overlay with an 8-inch (203-mm) CRCP new construction in Johnson County shows statistically that both pavements are performing equally in regard to observed distress; however, the CRCP overlay is shown to be slightly out-performing the CRCP new construction on the basis of ride quality criteria alone.

IMPLEMENTATION STATEMENT

This study has evaluated and compared the performances of several CRCP overlays with the performances of several new construction CRCP built side by side in Texas. Such a study is a first step in the documentation of pavement performance which is necessary to the progress of pavement design and rehabilitation. Through such field observation the pavement engineer can gain the necessary knowledge to change and improve invalid or approximate design methods, and can verify already valid methodologies.

TABLE OF CONTENTS

CHAPTER 1. INTRODUCTION

During the last two decades, Texas has built considerable mileage of continuously reinforced concrete pavements (CRCP). Some of these CRCP were placed as new construction while others were placed as overlays over existing pavements. However, since it takes many years observation before any inference can be made about the performance of these pavements, there has been little documentation of their relative performances. The aim of this study is to compare observed performance of new construction CRCP with that of existing pavements overlaid with CRCP in Texas.

This study is not comprehensive nor complete in a scientific sense because no experiment design or complete set of data exists. The study is valuable however because it documents and compares, statistically, data observed on pavements built and serving in Texas for the past 15 to 20 years. It is only through documentation of such field performance that useful information about pavement life can be gained.

The performance of a pavement is a measure of how well it serves traffic over a period of time. A pavement which had low serviceability during much of its life would not have performed its function of serving traffic as well as one which had high serviceability during most of its life, even though both ultimately reached the same state of distress at the same time. The performance of a pavement is a function of riding quality and pavement distress. The ride quality and distress manifestations are measured in the field by making a condition survey. In this study, pavement performance was evaluated using a condition survey method developed by the Center for Highway Research (CFHR) at The University of Texas at Austin (Ref 1).

In this survey the riding quality was judged on a PSR scale of zero to five, five being the smoothest ride possible as felt by the rater as he traversed a section of roadway at a speed of approximately 50 miles per hour. This ride quality rating is termed the "Present Serviceability Rating" (PSR) (Ref 1 and 2).

The pavement distress manifestations were surveyed in sections 0.2 mile in length by travelling on the shoulder at approximately 5 miles per hour. At this speed the different distress manifestations could be observed and recorded. The distress manifestations measured were

(1) transverse cracks,
(2) localized cracks,
(3) spalling,
(4) pumping,
(5) punchouts, and
(6) repair patches.

The amounts and magnitudes of these distresses are presented in the succeeding chapters for the pavements surveyed in this study.

Present Serviceability Rating values and pavement distress manifestations were measured only for sample sections, not the entire pavement length. However, a large sample was surveyed for each pavement under study to get a good representation of the entire pavement's performance.

In the summer months of '74 &'76, condition surveys were conducted on three pavement projects in Texas. For simplicity they are referred to by the county in which they are located; Guadalupe County, Falls-McLennan Counties (a two-county project), and Johnson County.

Analytical Approach

As stated previously, the intent of this study is to determine whether there is any significant difference between the performances of CRCP pavements which overlay older pavements and pavements which are of totally new construction. To make this determination a statistical comparison was made of performance data from both CRCP overlay and new construction CRCP.

The statistical comparison on the two pavements was performed for PSR values, transverse crack spacings, and each distress manifestation. Each project was analyzed individually and the results have been tabulated and are shown in the respective county chapter. The statistical tests performed are shown in Appendix 1. The completed condition survey forms for each county project are shown in Appendix 2. Example distress manifestations observed in this study are pictured in Appendix 3.

CHAPTER 2. GUADALUPE COUNTY

Limits of the Project

The project extends along IH 35 in a northeasterly direction from station 37+99.47 to station 208+16, a total distance of 3.22 miles (5.18 km), as shown in Fig 2.1.

History of Pavement Construction

The original 9-in. - 6-in. - 9-in. (229-mm - 152-mm - 229-mm) jointed concrete pavement (JCP) was built over 6 inches (152-mm) of selected base course material in 1934; to a width of 20 feet (6.1 meters). In that same year a 1-1/2 inch (38-mm) overlay of asphalt cement concrete (ACC) was constructed over the JCP and in 1954 the surface was leveled up with ACC. In 1965, a 6-inch (152-mm) overlay of CRCP was constructed in the southbound lanes from station 37+99.47 to station 123+00 and from station 150+00 to station 208+16. From station 123+00 to station 150+00 in the southbound lanes new CRCP was constructed. The pavement width was also increased to 24 feet (7.3 meters) at that time. The cross sections of the existing pavements are shown in Fig 2.2.

The Condition Survey

Both the CRCP overlay and the new construction CRCP were surveyed by the CFHR staff in June of 1976 using the performance survey of CRCP mentioned in Chapter 1 (Ref 1). A total of 14 sample sections were surveyed out of the total length of the project. Three sections were of new construction CRCP and eleven were of CRCP overlay.

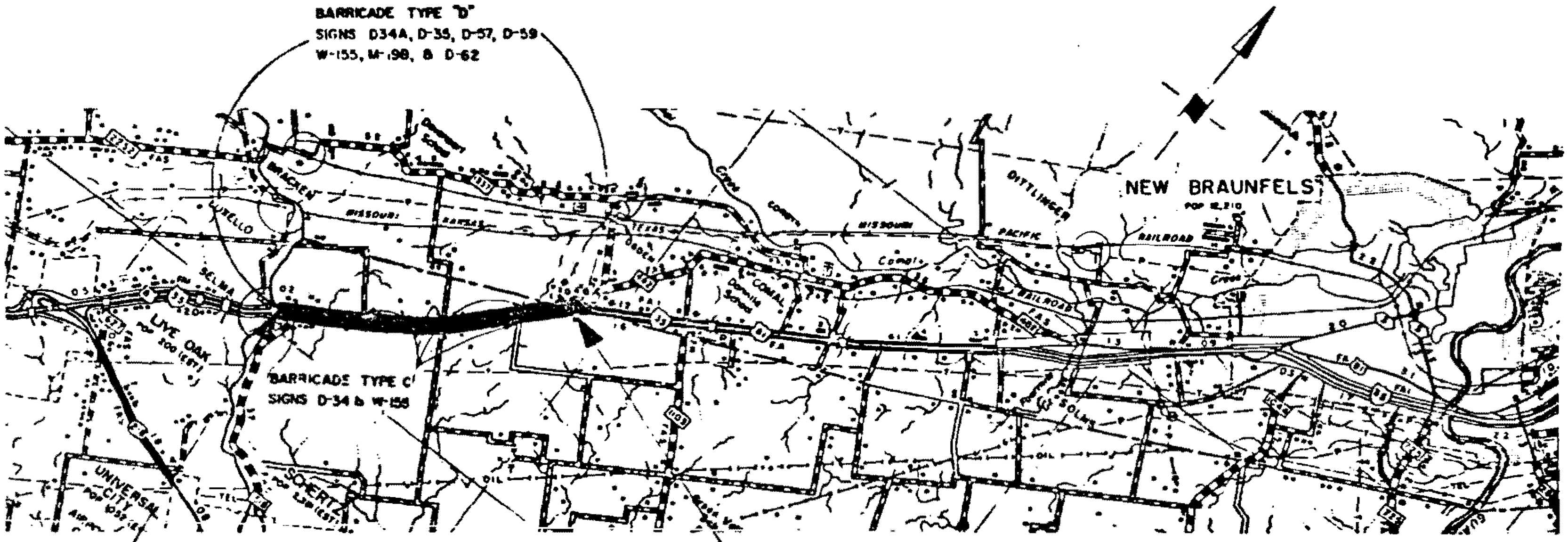
Results of Statistical Analysis

The results of the statistical analyses for both the new construction CRCP and CRCP overlay sections are shown in summary Table 2.1. The detailed statistical analysis is presented in Appendix 1.

GUADALUPE COUNTY
PROJECT NO. 135-2 (45) 175
INTERSTATE HIGHWAY NO. 35
FROM 0.03 MI. NE. OF BEXAR COUNTY LINE TO COMAL COUNTY LINE

GRADING, DRAINAGE STRUCTURES, HIGHWAY INTERCHANGE, FLEXIBLE BASE &
CONCRETE & ASPHALTIC CONCRETE PAVEMENT

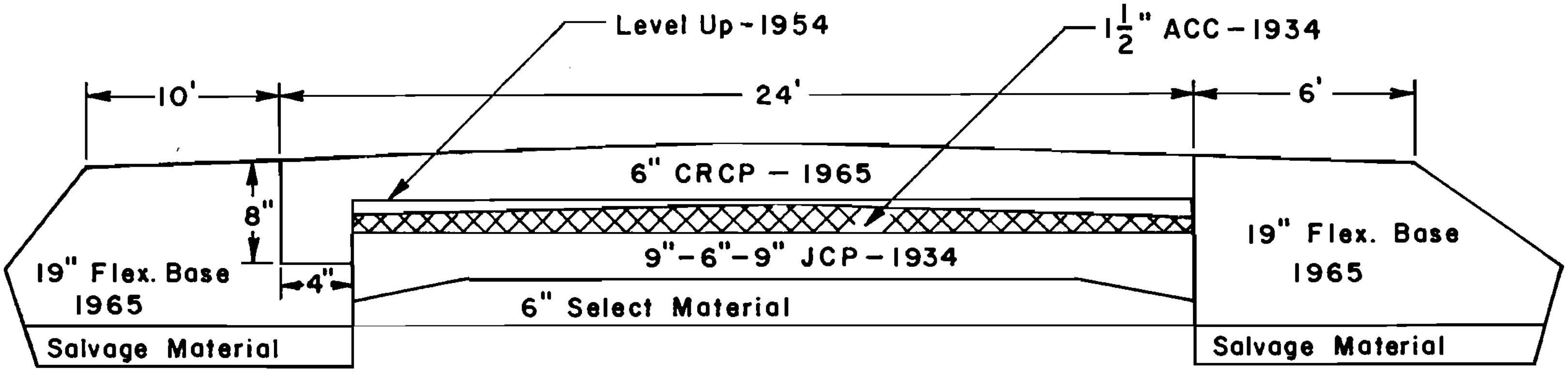
NET LENGTH OF PROJECT = 17,016.53 FT. = 3.222 MI.



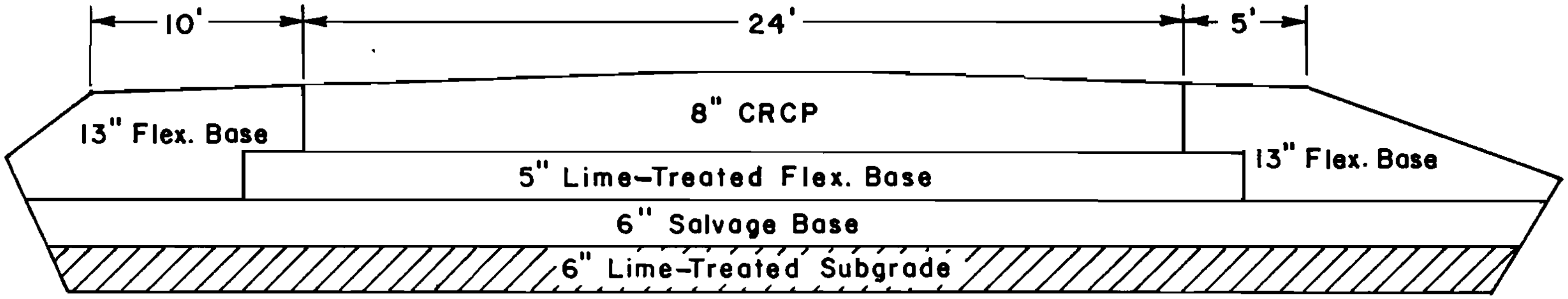
STA. 37+99.47 = BEG. PROJ. 135-2 (45) 175,
CONTROL 16-6-19
*STA 37+99.47 ON OLD PROJ.
NO. 135-2(22)173, CONTROL 16-6-17
*SECTION B-37 (AS DESIGNATED ON 104(B)5 ESTIMATE)

STA. 208+16 = END PROJ. 135-2 (45) 175,
CONTROL 16-6-19
*STA 208+16 ON OLD PROJ. FI 73(4),
CONTROL 16-6-10,
*SECTION B-35 (AS DESIGNATED ON 104(B)5 ESTIMATE)

Fig 2.1. Limits of project.



(a) Typical cross section of CRCP overlay, IH-35 SBL - Guadalupe Project.



(b) Typical cross section of CRCP new construction, IH-35 SBL - Guadalupe Project.

1 inch = 25.4 mm

1 foot = 30.48 cm

Fig 2.2. Typical cross sections of CRCP overlay and new construction CRCP for Guadalupe Project.

TABLE 2.1. STATISTICAL COMPARISON BETWEEN OBSERVED PERFORMANCE VALUES OF OVERLAY AND NEW CONSTRUCTION CRCP FOR THE GUADALUPE COUNTY PROJECT

Type of Observation		Comparison of Performance			
		CRCP Overlay Performed Better	New Construction CRCP Performed Better	No Measurable Difference in Performance	No Distress Observed in the Field
PSR value				X	
Crack spacing			X		
Transverse cracking	Minor				X
	Severe			X	
Localized cracking	Minor			X	
	Severe				X
Spalling	Minor			X	
	Severe				X
Pumping	Minor				X
	Severe				X
Punchouts	Minor				X
	Severe				X
Repair patches	ACC				X
	PCC				X

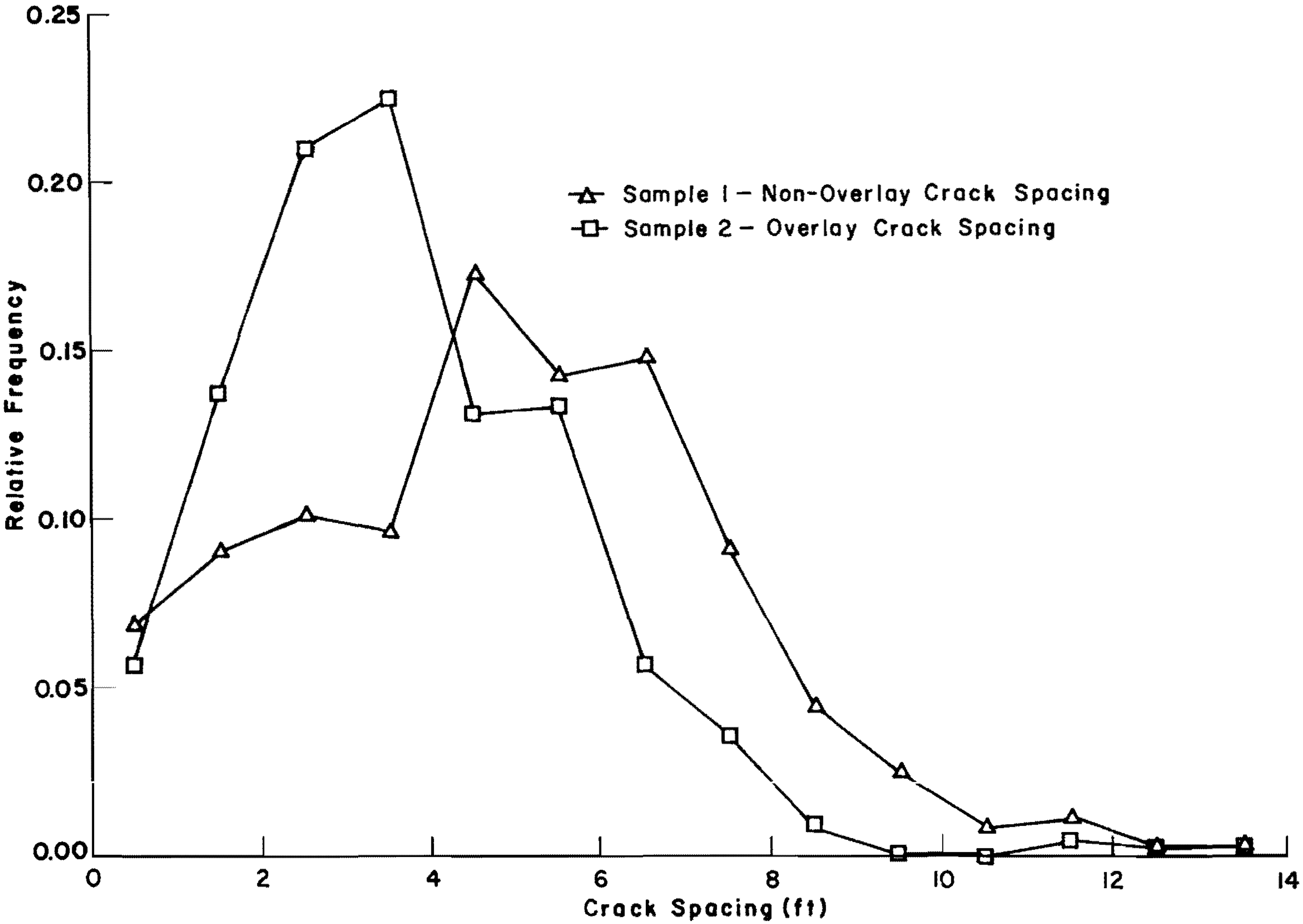
Discussion of Statistical Comparison for the Guadalupe Project

From the statistical comparison of PSR values, it is concluded that no measurable differences exist between the performances of the CRCP overlay and new construction CRCP pavements. Whatever difference there is could be attributed to a random sampling variance.

In regard to the transverse crack spacings, the statistical comparison shows a significant difference in crack spacings between the overlay and new construction CRCP sections. Figures 2.3 and 2.4 show transverse crack spacing versus relative frequency distribution and cumulative probability distribution, respectively, for the CRCP overlay and the new construction CRCP sections. In continuously reinforced concrete pavements the desirable crack spacing is from 5 to 8 feet (1.52 to 2.44 meters). In Fig 2.4, it can be seen that 13 percent of the cracks in the overlay sections and 35 percent of the cracks in the new construction sections have spacings between 5 and 8 feet (1.52 and 2.44 meters). From these results it might be said that the new construction CRCP sections are performing better with respect to crack spacings.

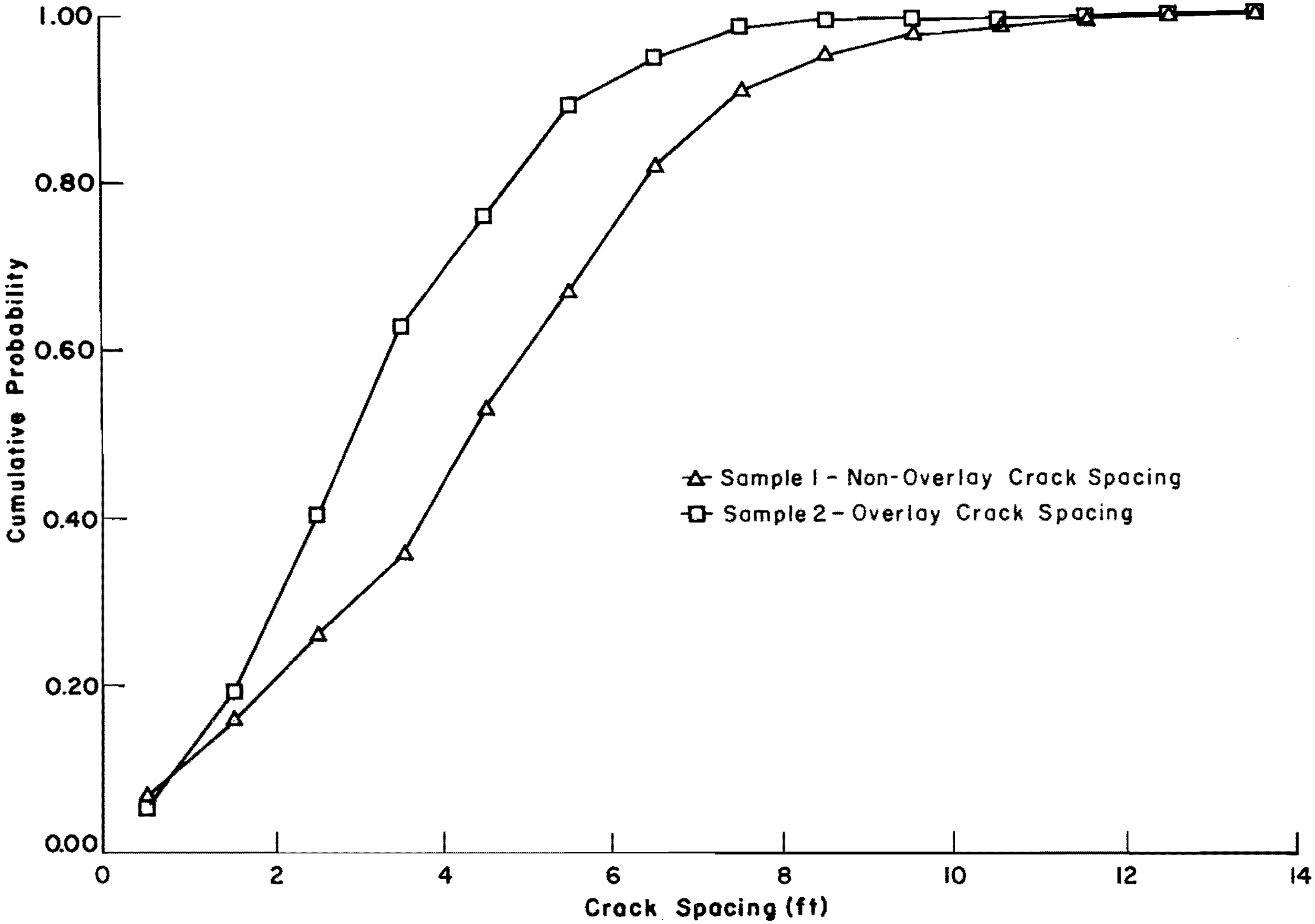
From the statistical comparison of severe transverse cracks, minor localized cracks, and minor spalling, it is concluded that no significant difference exists between the performance of the overlay and new construction pavements. Other distress phenomena (minor transverse cracks, pumping, punch-outs, etc.) were not observed in the survey of either pavement.

Since the average PSR value for both the CRCP overlay and the new construction CRCP sections is in the range of 3.8 to 3.9, it can be concluded that both pavements are performing well and are relatively equal.



1 foot = 30.48 cm

Fig 2.3. Plot of crack spacing versus relative frequency.



1 foot = 30.48 cm

Fig 2.4. Cumulative probability distribution.

CHAPTER 3. FALLS AND MCLENNAN COUNTIES

Limits of the Project

The Falls-McLennan County project extends along IH 35 in a northerly direction from station 95+00 to station 326+06. Only the first 574 feet (175 meters) lie in Falls County. The entire project covers a distance of 4.38 miles (7.05 km), as shown in Fig. 3.1.

History of Pavement Construction

The original 9-in. - 6-in. - 9-in. (229-mm - 152-mm - 229-mm) JCP was built over an 8 inch (203-mm) gravel base course in 1934; to a width of 20 feet (6.1 meters). In 1952, the original JCP was overlaid with 3-1/2 inches (89-mm) of ACC and the width of the pavement was increased to 24 feet (7.3 meters). In 1959 the northbound lanes were overlaid with 7 inches (178-mm) of CRCP from station 140+00 to station 195+00; the rest of the project was new construction CRCP. The cross-section of the existing pavement is shown in Fig 3.2.

The Condition Survey

Both the CRCP overlay and new construction CRCP pavements previously described were surveyed by the CFHR staff in July of 1974. A total of 41 sample sections were surveyed out of the total length of the project. Thirty-five sections were of new construction CRCP and six were of CRCP overlay.

Results of Statistical Analysis

The results of the statistical comparisons performed on the data obtained from the overlay and new construction CRCP section surveys were interpreted and a summary is shown in Table 3.1. Table 3.1 however, does not take into consideration the possible directional variances, e.g., the variations in traffic volumes between the northbound and southbound lanes. From the observed data it was seen that a variance between the northbound and

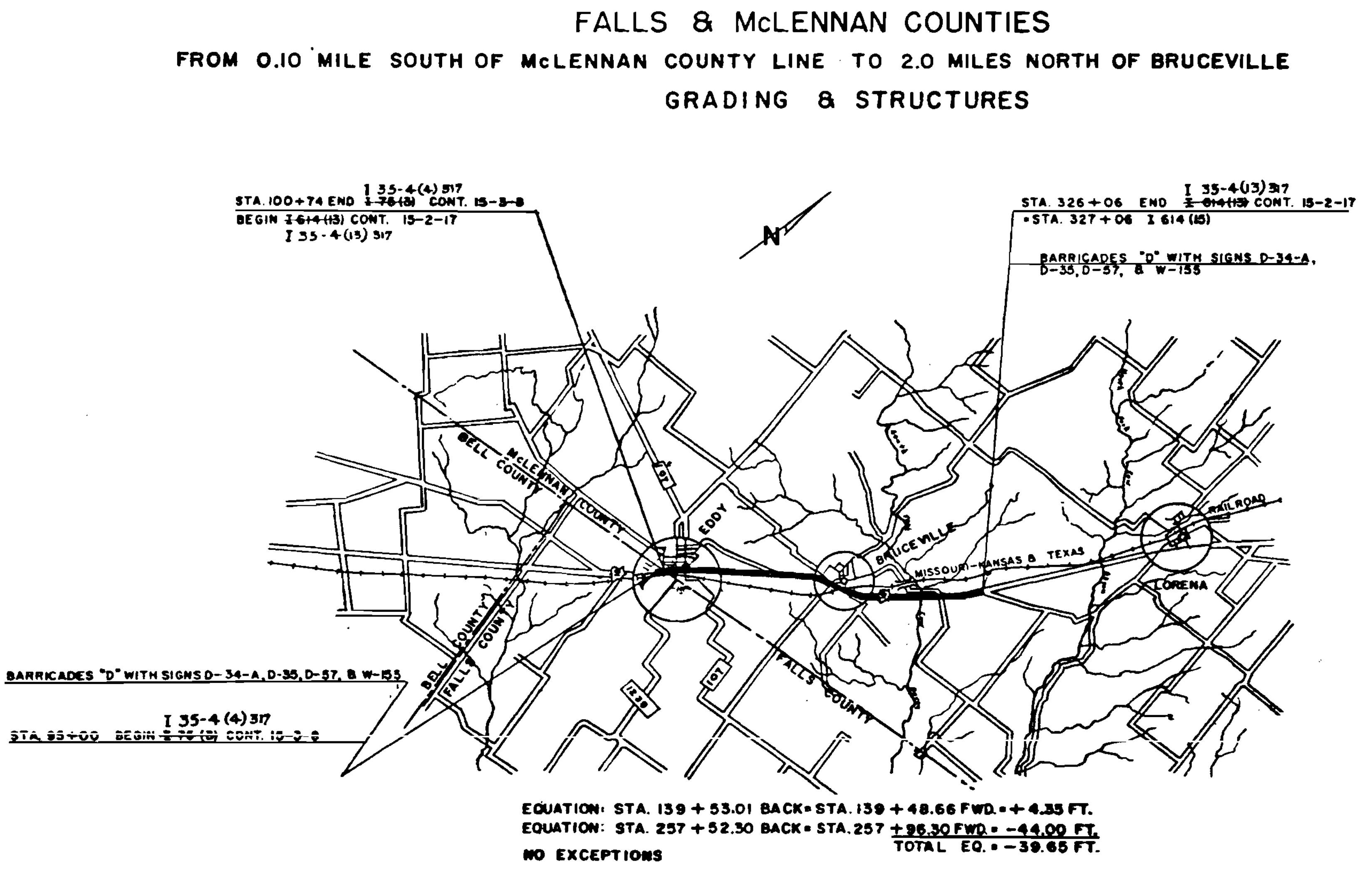
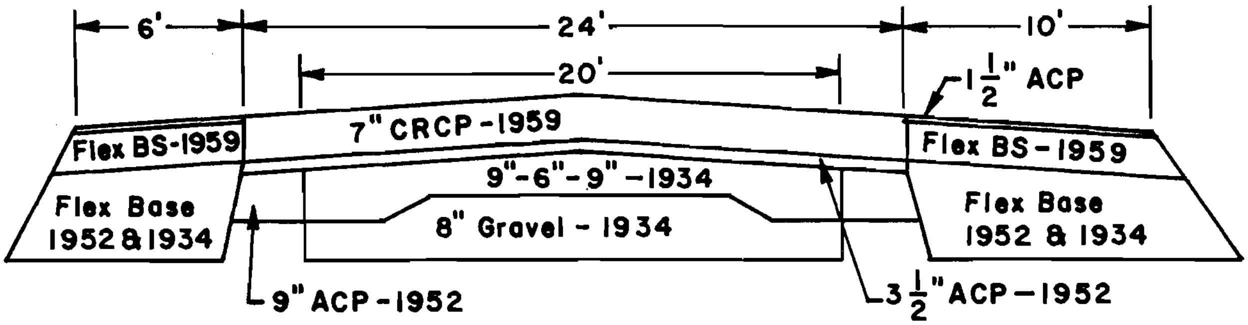
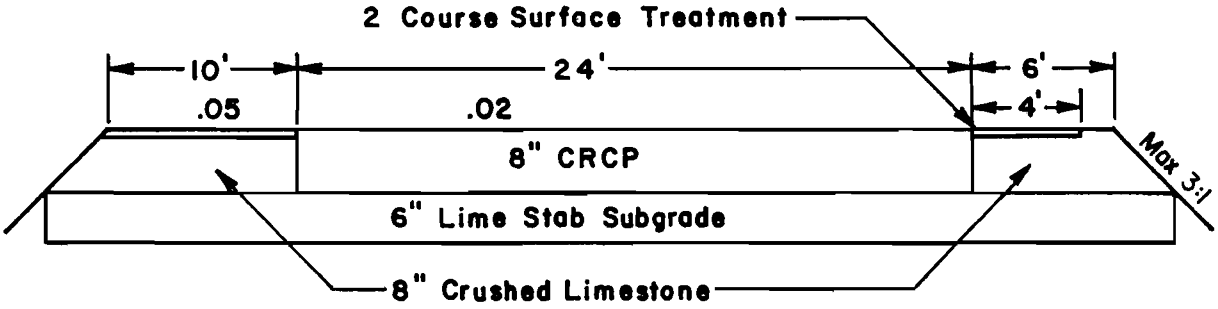


Fig 3.1. Limits of project.



(a) Typical cross section of CRCP overlay IH 35 NBL - Falls-McLennan Project.



(b) Typical cross section of CRCP new construction IH 35 SBL and NBL - Falls-McLennan Project.

1 inch = 25.4 mm

1 foot = 30.48 cm

Fig 3.2. Typical cross sections of CRCP overlay and new construction CRCP for Falls-McLennan Ptoject.

TABLE 3.1. STATISTICAL COMPARISON BETWEEN OBSERVED VALUES OF OVERLAY AND NEW CONSTRUCTION CRCP FOR THE FALLS-MCLENNAN COUNTY PROJECT

		Comparison of Performance			
Type of Observation		CRCP Overlay Performed Better	New Construction CRCP Performed Better	No Measurable Difference in Performance	No Distress Observed in the Field
PSR value				X	
Crack spacing				X	
Transverse cracking	Minor		X		
	Severe			X	
Localized cracking	Minor			X	
	Severe			X	
Spalling	Minor			X	
	Severe		X		
Pumping	Minor	X			
	Severe	X			
Punchouts	Minor	X			
	Severe			X	
Repair patches	ACC				X
	PCC	X			

southbound lanes does exist for the new construction CRCP sections, in the cases of severe spalling, minor pumping, minor punchouts and, repair patches greater than 120 square feet (11.1 square meters) in area. Therefore, a statistical comparison was performed for these distress phenomena to see whether there is any difference in the performance between the overlay and new construction CRCP sections in the northbound lanes only. These statistical results are shown in Table 3.2. The detailed statistical tests are shown in Appendix 1.

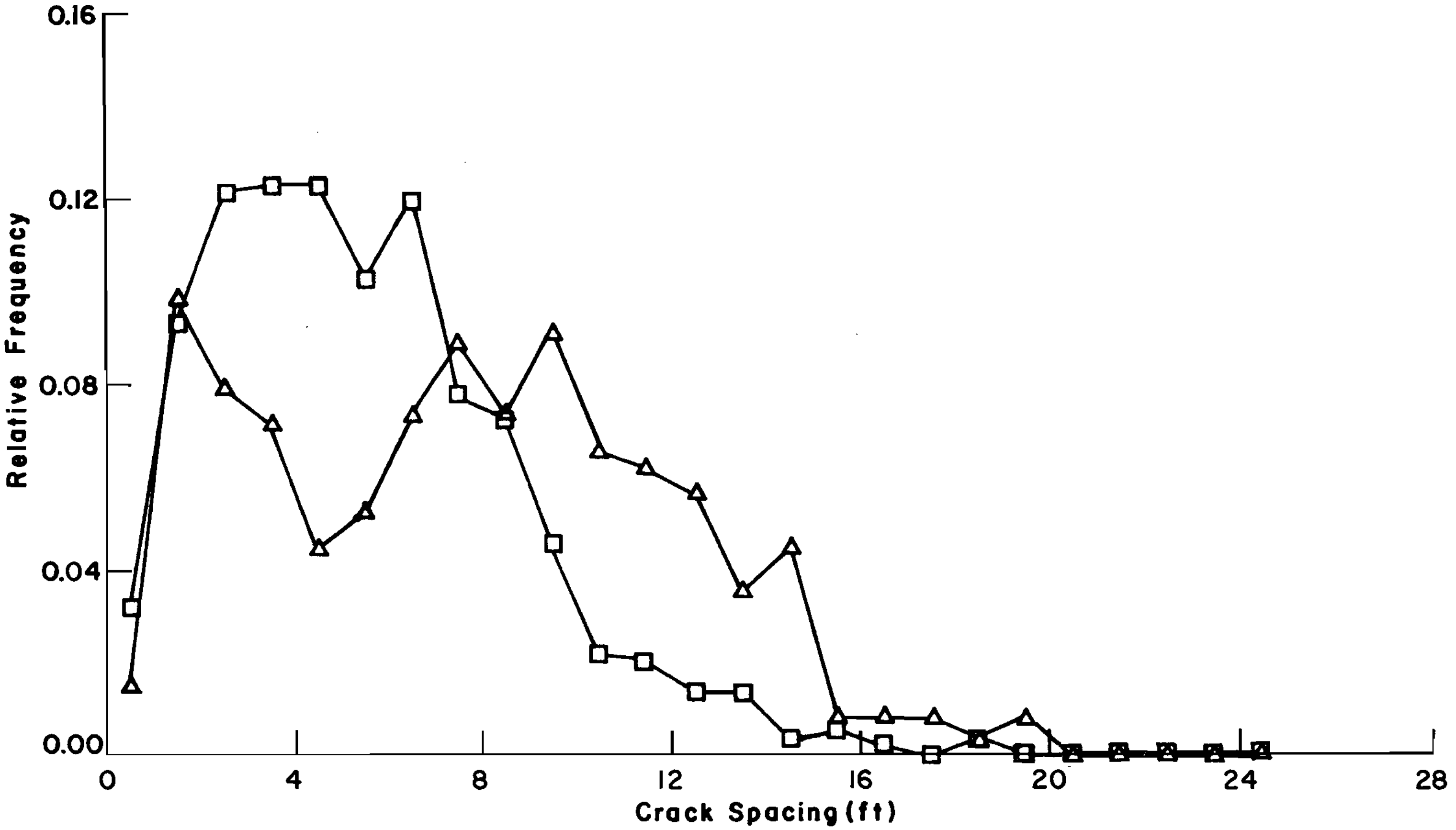
Discussion of the Statistical Comparison for the Falls-McLennan Project

From the statistical comparison of PSR values, it is concluded that there are no significant differences between the performances of the CRCP overlay and the new construction CRCP pavements. Whatever differences there are could be attributed to random sampling variance.

The statistical comparison of transverse crack spacings shows that there is a significant difference between the mean crack spacings of the CRCP overlay sections and new construction CRCP sections. The mean crack spacing for the overlay sections is 5.42 feet (1.65 meters) and for the new construction sections it is 7.93 feet (2.42 meters). As mentioned in Chapter 2, the desirable crack spacing for CRCP is in the range of 5 to 8 feet (1.52 to 2.44 meters). Figures 3.3 and 3.4 show transverse crack spacing versus relative frequency distribution and cumulative probability distribution, respectively, for both the CRCP overlay and new construction sections. As can be seen in Fig 3.4, 30 percent of the cracks in the overlay sections and 25 percent of the cracks in the new construction sections have spacings between 5 and 8 feet (1.52 and 2.44 meters). The difference in mean crack spacing can be attributed to the fact that the majority of the CRCP overlay crack spacings are less than 5 feet (1.52 meters) whereas the majority of the new construction CRCP crack spacings are greater than 8 feet (2.44 meters). From this information it is hard to determine which pavement is performing better since both large and small spacings have their disadvantages. That is to say, large crack spacings suggest large crack widths, which ultimately leads to poor rideability and possible pumping of the pavement. Small crack spacings may lead to localized cracking and punchouts.

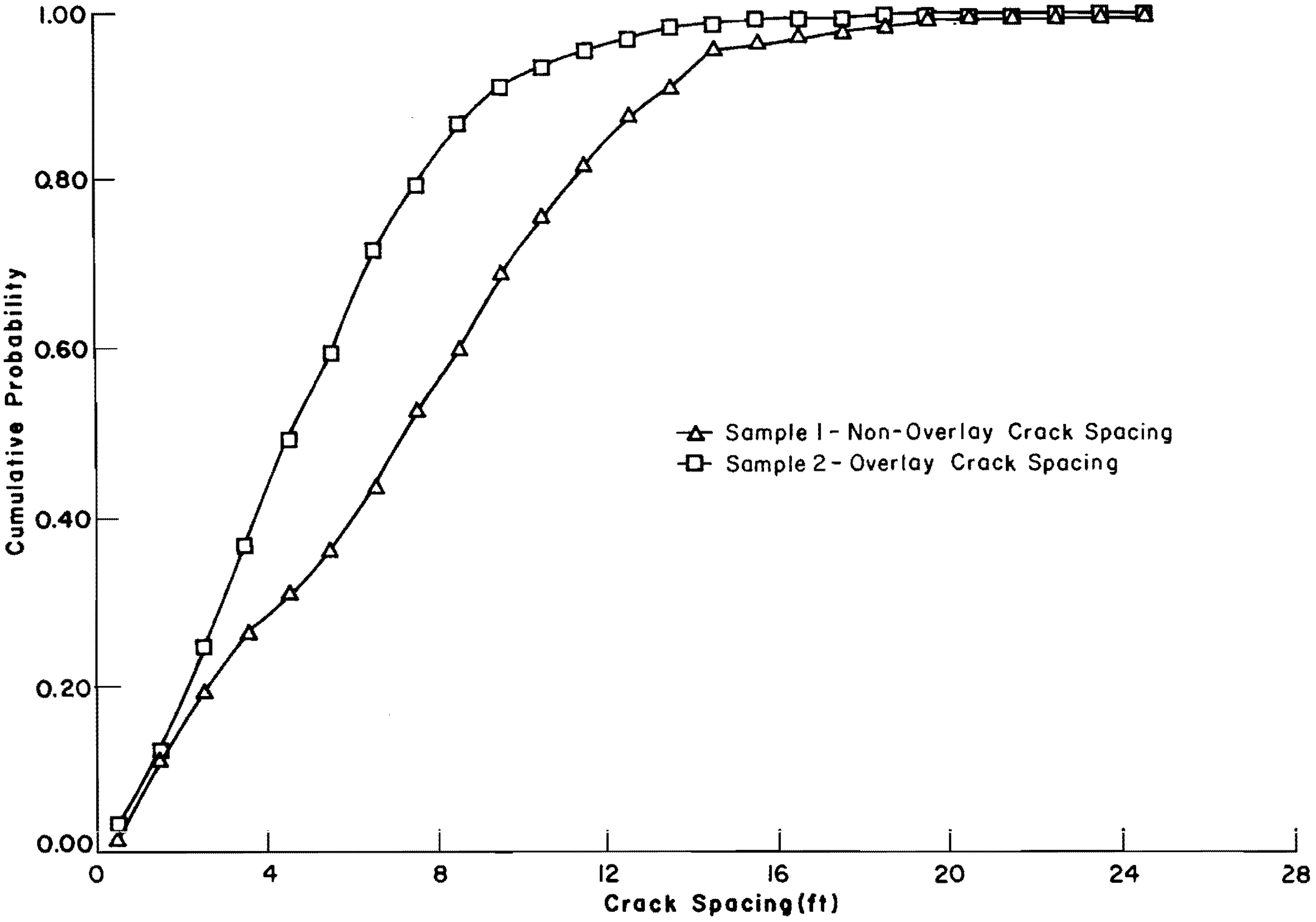
TABLE 3.2. STATISTICAL COMPARISON BETWEEN OBSERVED PERFORMANCE VALUES OF OVERLAY AND NEW CONSTRUCTION CRCP IN THE NORTHBOUND LANES ONLY FOR THE FALLS-MCLENNAN COUNTY PROJECT

Type of Observation		Comparison of Performance			
		CRCP Overlay Performed Better	New Construction CRCP Performed Better	No Measurable Difference in Performance	No Distress Observed in the Field
Spalling	Severe		X		
Pumping	Minor			X	
Punchouts	Minor			X	
Repair Patches > 120 ft^2 (11.15m^2)	PCC			X	



1 foot = 30.48 cm

Fig 3.3. Relative frequency distribution.



1 foot = 30.48 cm

Fig 3.4. Cumulative probability distribution.

Therefore, the statistical tests can only tell us of a significant difference in crack spacings; they cannot tell us which pavement is performing better.

The CRCP overlay sections are shown in the statistical comparison to have substantially more minor transverse cracks than the new construction CRCP sections. In case of severe transverse cracks, no measurable difference could be determined in their performance.

The statistical tests which were performed could not prove any measurable difference in localized cracking, either minor or severe, between the overlay sections and new construction sections.

In regard to severe spalling, the comparison shows the new construction sections to out perform the overlay sections. The minor spalling observed in both pavements is approximately the same and the statistical tests did not show any measurable difference in the two.

In the case of minor and severe pumping, it is shown that the CRCP overlay sections statistically outperformed the new construction sections.

The overlay sections are seen to have the better performance of the two with regard to minor punchouts. In regard to severe punchouts, no appreciable difference could be shown statistically.

The overlay sections are seen to have fewer portland cement concrete repair patches of area greater than 120 square feet (11.1 square meters). There is no measurable difference in the number of repair patches in the two pavements for areas of 120 square feet (11.1 square meters) or less.

In summary, it can be said that, with respect to rideability, the two pavements are about equal. However, the new construction CRCP shows evidence of many more distress manifestations than the CRCP overlay and in time may deteriorate to a much lower serviceability value. It is a conclusion of this investigation that the 7 inch (178-mm) CRCP overlay outperformed the 8 inch (203-mm) CRCP of new construction.

CHAPTER 4. JOHNSON COUNTY

Limits of the Project

The project extends along IH 35 in a southerly direction from station 13+33 to station 485+00, a total distance of 8.93 miles (14.29 km) as shown in Fig 4.1.

History of Pavement Construction

The original 9-in. - 6-in. - 9-in. (229-mm - 152-mm - 229-mm) JCP was built over select base course material in 1937 to a width of 20 feet (6.1 meters). In 1947 the southbound lanes were overlaid with 2 inches (51-mm) of ACC and in 1957 with 1-1/2 inches (38-mm) of ACC. In 1965, a new 8 inch (203-mm) CRCP was constructed over a 6 inch (152-mm) lime-treated subgrade between stations 13+29 and 20+00, stations 233+00 and 247+00, stations 264+50 and 287+00, and stations 310+00 and 322+00. All other portions of the project's southbound lanes were overlaid with 6 inches (152-mm) of CRCP. The northbound lanes were constructed of a new 8 inch (203-mm) CRCP over a 6 inch (152-mm) lime-treated subgrade throughout the entire project length. The width was also increased to 24 feet (7.3 meters) in 1965, as shown in Fig 4.2.

The Condition Survey

Both the new construction CRCP and CRCP overlay were surveyed by the CFHR staff in July 1976. A total of 94 sample sections were surveyed throughout the total length of the project. Of those, 57 were of new construction CRCP and 37 were of CRCP overlay.

Results of the Statistical Analysis

The results of the statistical analysis for both the new construction CRCP and the CRCP overlay sections are shown in summary Table 4.1. The detailed statistical analysis is shown in Appendix 1.

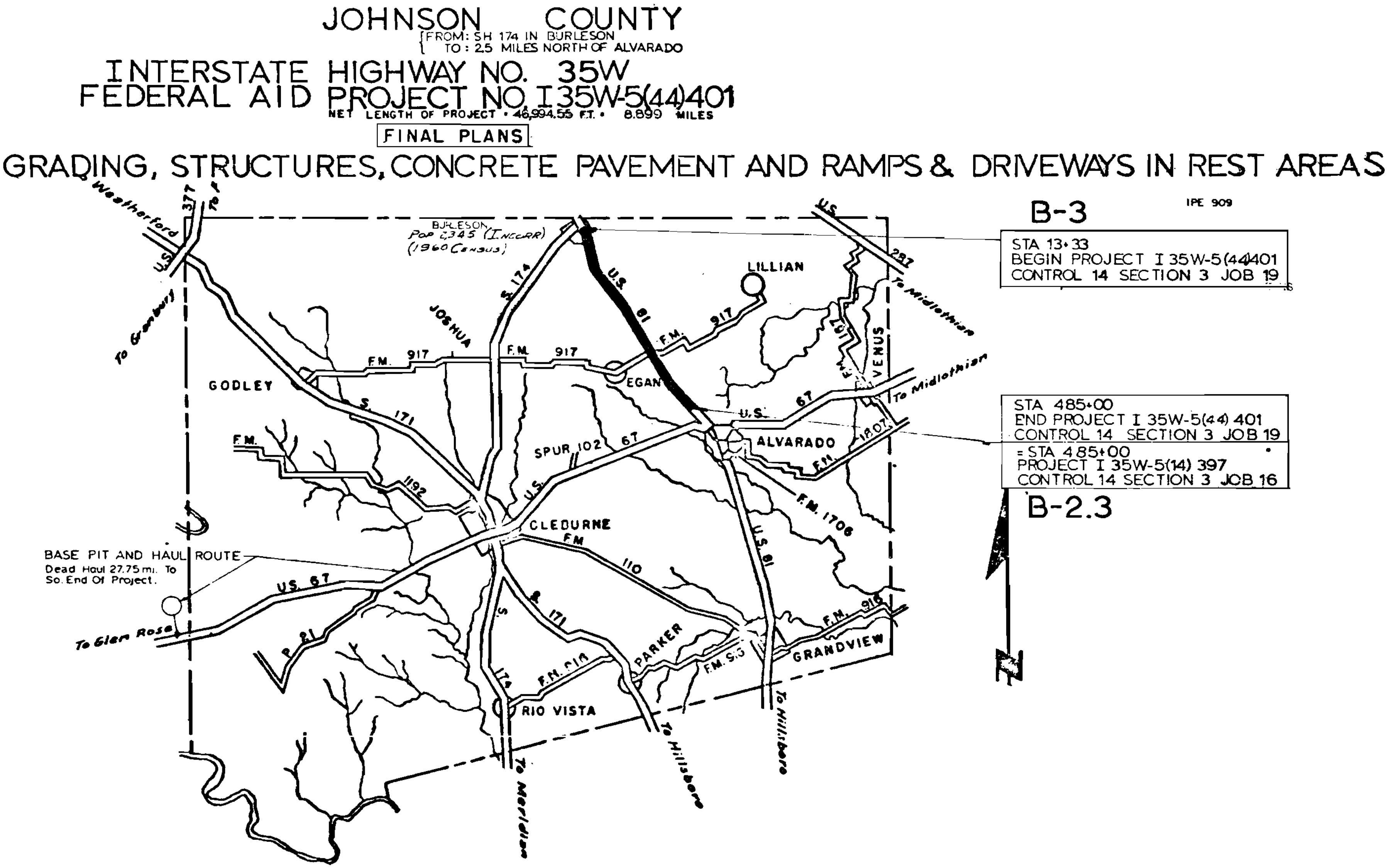
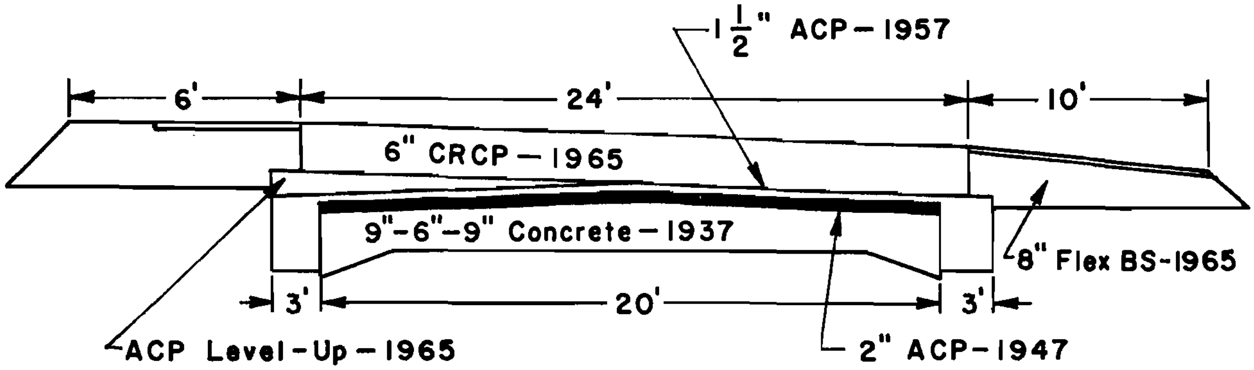
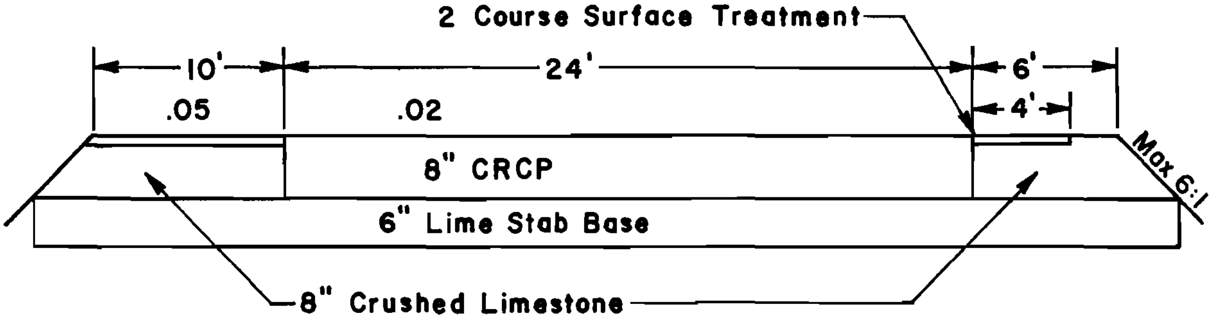


Fig 4.1. Limits of project.



(a) Typical cross section of CRCP overlay IH 35 SBL - Johnson Project.



(b) Typical cross section of CRCP new construction IH 35 - Johnson Project.

1 inch = 25.4 mm

1 foot = 30.48 cm

Fig 4.2. Typical cross-sections of CRCP overlay and new construction CRCP for Johnson Project.

TABLE 4.1. STATISTICAL COMPARISON OF RESULTS FOR THE JOHNSON PROJECT

		Comparison of Performance			
Type of Observation		CRCP Overlay Performed Better	New Construction CRCP Performed Better	No Measurable Difference in Performance	No Distress Observed in the Field
PSR value				X	
Crack spacing				X	
Transverse cracking	Minor				X
	Severe			X	
Localized cracking	Minor			X	
	Severe				X
Spalling	Minor				X
	Severe				X
Pumping	Minor			X	
	Severe			X	
Punchouts	Minor			X	
	Severe			X	
Repair patches	ACC				X
	PCC			X	

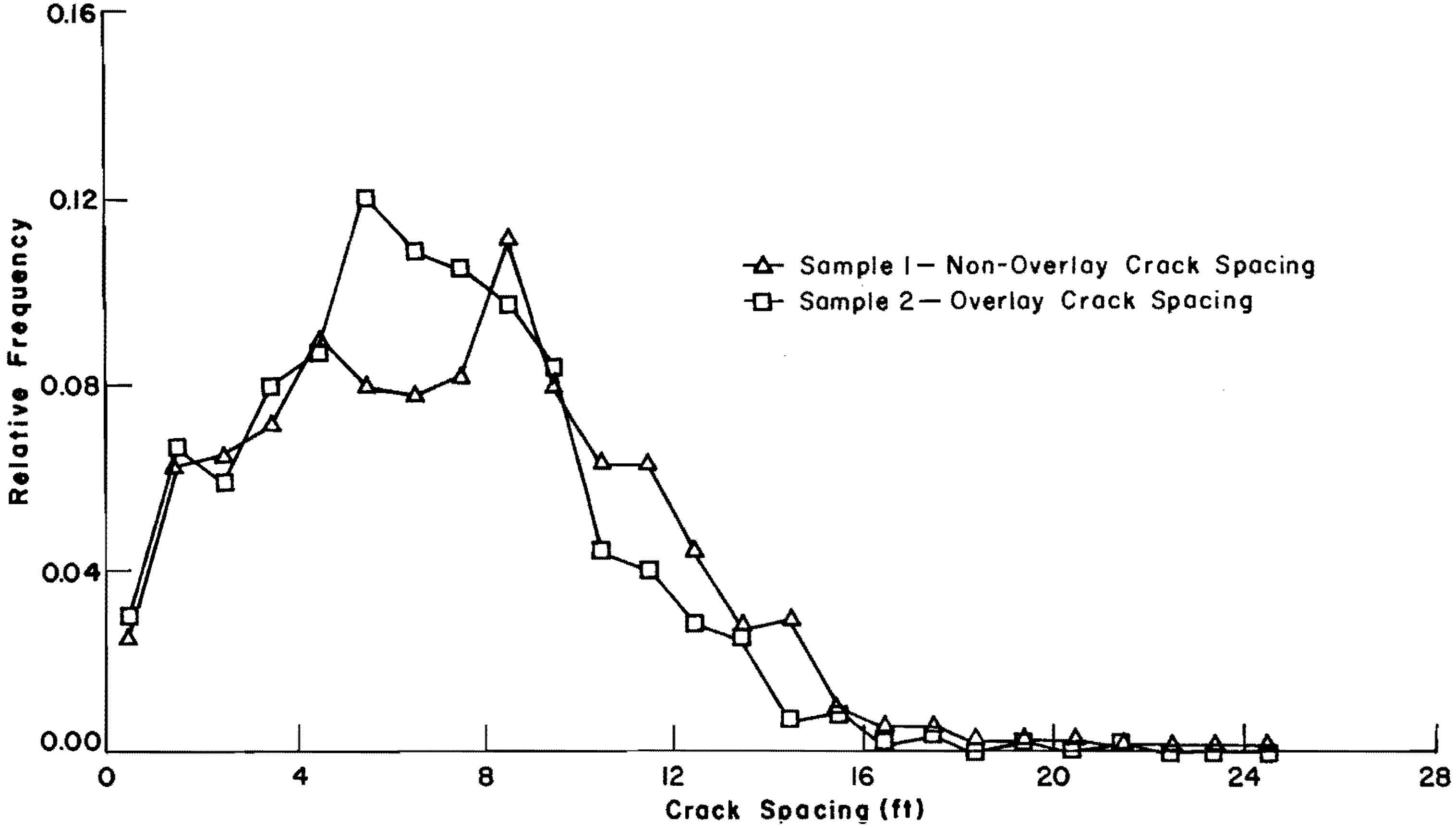
Discussion of the Statistical Comparison for the Johnson Project

The mean PSR values for the new construction CRCP sections and the CRCP overlay sections obtained by the condition survey are 3.77 and 3.89, respectively. The statistical analysis of these results shows that the overlay sections and the new construction sections are performing relatively the same.

The transverse crack spacings were statistically different for the two pavements. However, this does not imply an accompanying difference in performance or an indication as to which is performing better. Figures 4.3 and 4.4 show transverse crack spacing versus relative frequency distribution and cumulative probability distribution, respectively. In Fig 4.4, it can be seen that 32.5 percent of the transverse cracks in the overlay sections and 26 percent of the cracks in the new construction sections have spacings between 5 and 8 feet (1.52 and 2.44 meters), which is the desirable range for CRCP. The pavements have a similar number of cracks spaced within this desirable range, and, thus, it is hard to say which pavement is performing better.

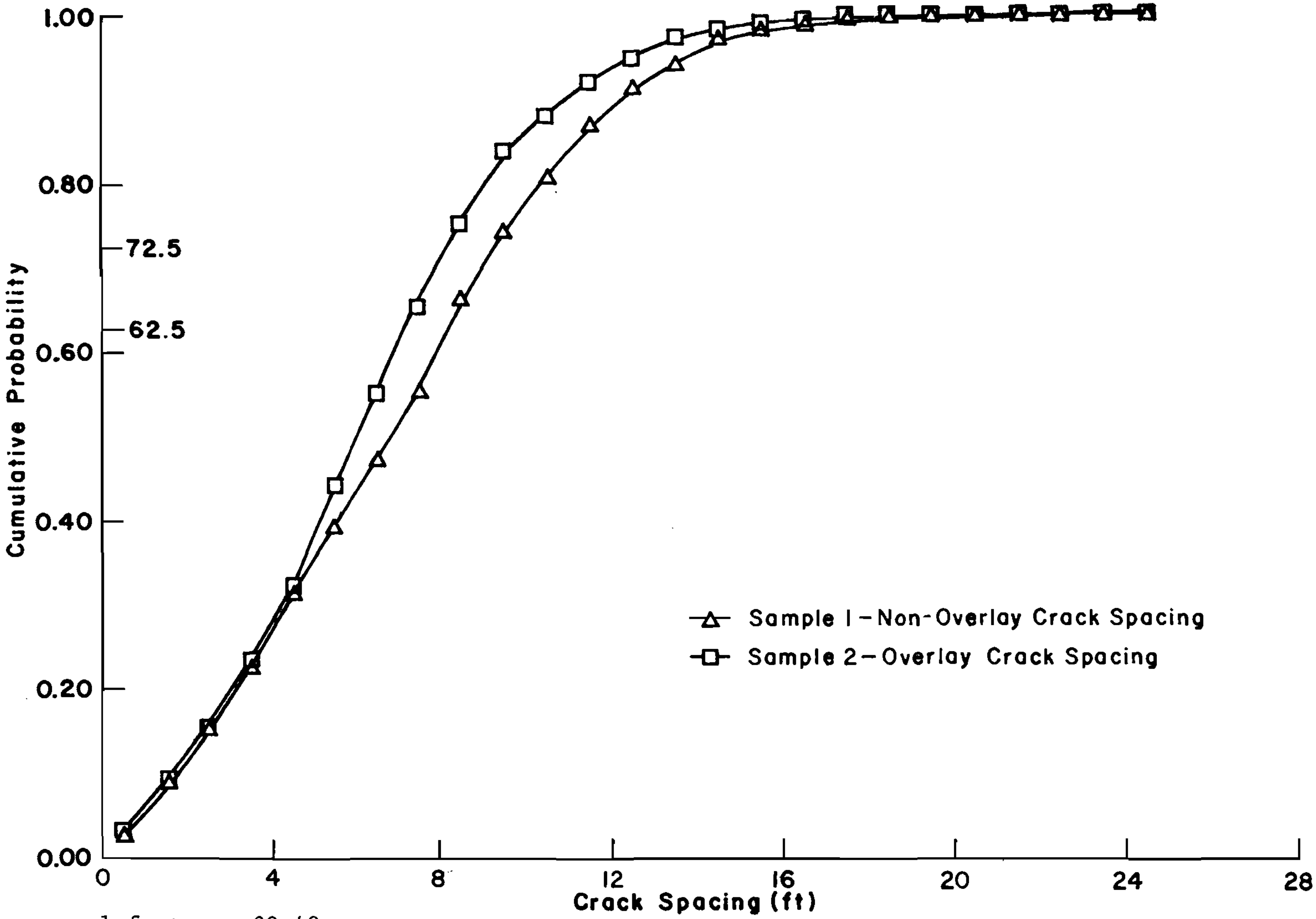
The statistical analysis shows no measurable difference between the overlay and new construction CRCP sections with respect to severe transverse cracks, minor localized cracks, pumping, punchouts, and portland cement concrete repair patches. No manifestations of minor transverse cracks, severe localized cracks, spalling, and asphalt cement concrete repair patches were observed in the condition survey.

In summary, both pavements are performing well. The CRCP overlay sections have been shown to have a better riding quality; however, as far as observable distress manifestations are concerned, the two pavements are performing equally. Assuming both pavements had equal riding quality at the time of initial construction, it can be concluded that the CRCP overlay sections are performing slightly better than the new construction sections, based on riding quality criteria alone.



1 foot = 30.48 cm

Fig 4.3. Relative frequency distribution of crack spacings.



1 foot = 30.48 cm

Fig 4.4. Cumulative probability distribution of crack spacings.

CHAPTER 5. SUMMARY OF FINDINGS

Table 5.1 shows the time history and performance comparisons between the CRCP overlay sections and the CRCP new construction sections for each of the three projects.

Several things can be observed in Table 5.1. First, the Falls-McLennan project was constructed in 1959 whereas the Guadalupe and Johnson projects were constructed in 1965. As can be seen, the Falls-McLennan project contains more distress than the projects constructed later. Over this longer period it can be seen that the performance of the CRCP overlay is better then the CRCP new construction for the Falls-McLennan project. On the other hand, the performance of the overlay sections and new construction is nearly equal for the other projects.

A second factor which has perhaps influenced the overlay sections to out-perform the new construction sections for the Falls-McLennan project, besides the time element, is the overlay thickness. In Falls and McLennan Counties the overlay thickness was 7 inches (178-mm). In the other projects, where the performance between the two sections was relatively equal, the overlay thickness was 6 inches. However, when the 6 inch (152-mm) overlays are studied at a later date after more distress has accumulated, they may out-perform the new construction sections as well.

Since uniformity is important to satisfactory pavement performance, it is helpful to achieve equal propagation of distress throughout a project composed of both overlay and new construction. This allows subsequent maintenance and overlays to be carried out more uniformly along on the entire project length. It is therefore important to establish the optimum overlay thickness which will give equal performance with new construction when used side by side. Only through future investigations like this one can such information be established.

As observed for all these sections, an existing pavement makes an excellent foundation for subsequent construction. In an existing pavement, the majority of the soil movements have already taken place and a solid base to build upon is provided.

TABLE 5.1 CONSTRUCTION HISTORY AND PERFORMANCE SUMMARY OF GUADALUPE, FALLS-MCLENNAN, AND JOHNSON COUNTY PROJECTS

		Project					
		Guadalupe		Falls-McLennan		Johnson	
Original JCP (9"-6"-9")		1934		1934		1937	
Original Base		6" Select Material		8" Gravel		6" Select Material	
ACC Overlay		1 1/2" - 1934		3 1/2" - 1952		2" - 1947, 1 1/2" - 1957	
CRCP Overlay		6" - 1965	-	7" - 1959	-	6" - 1965	-
CRCP New Construction		-	8" - 1965	-	8" - 1959	-	8" - 1965
New Base		Original JCP	6" lime-stab.	Original JCP	6" lime-stab.	Original JCP	6" lime-stab.
Condition Survey Measurements		CRCP Overlay	New Construction CRCP	CRCP Overlay	New Construction CRCP	CRCP Overlay	New Construction CRCP
PSR value		No measurable difference		No measurable difference		No measurable difference	
Crack spacing		-	Better	No measurable difference		No measurable difference	
Transverse cracking	Minor	No distress observed		-	Better	No distress observed	
	Severe	No measurable difference		No measurable difference		No measurable difference	
Localized cracking	Minor	No measurable difference		No measurable difference		No measurable difference	
	Severe	No distress observed		No measurable difference		No distress observed	
Spalling	Minor	No measurable difference		No measurable difference		No distress observed	
	Severe	No distress observed		-	Better	No distress observed	
Pumping	Minor	No distress observed		Better	-	No measurable difference	
	Severe	No distress observed		Better	-	No measurable difference	
Punchouts	Minor	No distress observed		Better	-	No measurable difference	
	Severe	No distress observed		No measurable difference		No measurable difference	
Repair Patches	ACC	No distress observed		No distress observed		No distress observed	
	PCC	No distress observed		Better	-	No measurable difference	

Finally, this study shows that it may be beneficial economically and structurally to overlay rather than to construct entirely new pavements. As seen in this study, a 7-inch (178-mm) overlay is out-performing an 8-inch (203-mm) new construction. However, there may be certain circumstances where an overlay cannot be properly incorporated as the new pavement structure; for example, when a change in grade must be made. In these cases the original pavement must be removed and discarded or recycled.

Recommendations

To supplement this study, future condition surveys, along with additional analysis of the gathered data, should be performed on the Guadalupe and Johnson County projects. Enough time should elaspe for these pavements to accumulate additional distress in order for a comparison between the CRCP overlay and the CRCP new construction to be made most effectively.

It is further recommended that highway agencies everywhere continue to observe and document field conditions and actual performance of special pavements and to also continue comparative pavement studies. Only through such documentation can the truth be learned and better designs subsequently made and inferior ones discarded.

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2. Carey, W. N., Jr., and P. E. Irick, "The Pavement Serviceability-Performance Concept," Bulletin 250, Highway Research Board, Washington, D.C., 1960.

3. Nayak, B. C., "Distress Study of Falls and McLennan County CRCP Overlay," Inter-office Technical Memorandum No. 177-11, Research Project 3-8-75-177, Center for Highway Research, The University of Texas at Austin, August 1976.

4. Nayak, B. C., "Comparison of Distress on Overlaid and Non-Overlaid Sections of IH-35 in Johnson County, Texas," Inter-office Technical Memorandum No. 177-14, Research Project 3-8-75-177, Center for Highway Research, The University of Texas at Austin, August 1976.

5. Nayak, B. C., "Comparative Study of Performance of CRCP Overlay and Non-Overlay," Inter-office Technical Memorandum No. 177-17, Research Project 3-8-75-177, Center for Highway Research, The University of Texas at Austin, October 1976.

APPENDIX 1

STATISTICAL ANALYSIS OF CONDITION SURVEY DATA

APPENDIX 1. STATISTICAL ANALYSIS OF CONDITION SURVEY DATA

PRESENT SERVICEABILITY RATING (PSR)

To determine whether there was any significant difference between the overlay and new construction sections, in order that a conclusion could be reached as to which pavement was performing better, a statistical test was performed first to determine whether or not the variances of the PSR values are homogeneous. To determine homogeneity among the variances of PSR values, the F-test was used with the null hypothesis: $\sigma_o^2 = \sigma_n^2$, or homogeneity exists if the variances of the overlay and new construction sections are equal. The null hypothesis was tested against the alternate hypothesis: $\sigma_o^2 \neq \sigma_n^2$, or homogeneity does not exist if the PSR variances of the two pavement types are not equal.

If the variances were proven to be homogeneous, a student's t-test was performed to determine if a significant difference exists between the two means. If the variances were proven not to be homogeneous, an approximate student's t-test was performed.

GUADALUPE COUNTY PROJECT

The F-Test (To Determine Homogeneity)

New Construction Sections -

Observed PSR Values:

$$X_{n-1} = 4.0, \; X_{n-2} = 3.8, \; \text{and} \; X_{n-3} = 3.8$$

Therefore

$$\bar{X}_n = 3.87 \; \text{and} \; S_n^2 = 0.0134$$

(the subscript "n" denotes new construction).

Overlay Sections -

Observed Values:

$X_{o-1} = 3.8, \quad X_{o-2} = 3.8, \quad X_{o-3} = 3.8,$

$X_{o-4} = 4.0, \quad X_{o-5} = 3.8, \quad X_{o-6} = 3.9,$

$X_{o-7} = 3.8, \quad X_{o-8} = 3.8, \quad X_{o-9} = 3.8,$

$X_{o-10} = 3.9, \quad X_{o-11} = 3.8$

Therefore

$$\overline{X}_o = 3.84 \quad \text{and} \quad S_o^2 = 0.0045$$

(the subscript "o" denotes overlay).

$$\text{Calculated } F = \frac{S_n^2}{S_o^2} = \frac{0.0134}{0.0045} = 2.91$$

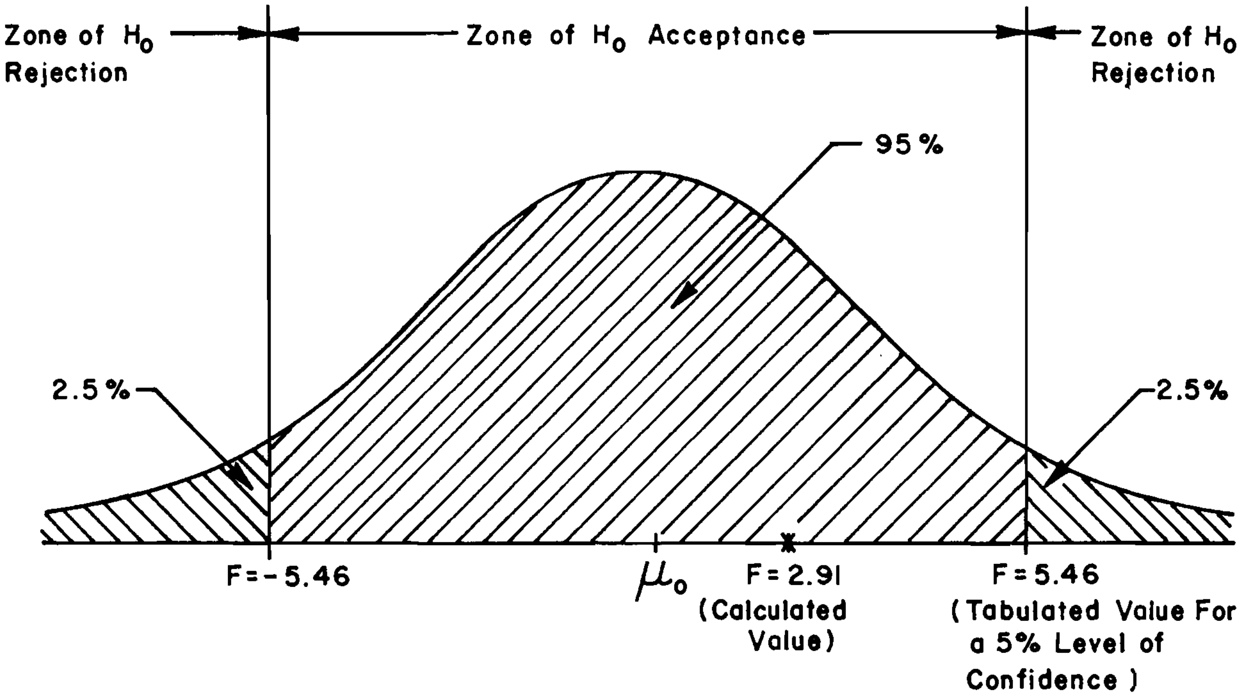
Tabulated F (with 2 and 10 degrees of freedom and a 5 percent level of significance) = 5.46

Since the calculated F-value does not exceed the tabulated F-values, it can be concluded with a 5 percent level of significance that the null hypothesis is true and the PSR values for the two types of sections, overlay and new construction are homogeneous, i.e., come from the same population. See Fig A1.1 for graphical interpretation of test results.

The Two-Mean Student's T-Test

Mean PSR of overlay $\overline{X}_o = 3.83$

Mean PSR of new construction $\overline{X}_n = 3.86$



NOTE: This example represents the F-test performed on the Guadalupe data of PSR values. The calculated value of $F\left[\frac{S_n^2}{S_o^2}\right]$ falls within the zone of H_o acceptance; therefore it is concluded that the null hypothesis is true and the mean PSR values of the overlay and new construction pavments are equal.

Fig A1.1. Graphical representation of statistical test.

Null hypothesis: $\bar{X}_o - \bar{X}_n = \delta = o$

$$t = \frac{(\bar{X}_1 - \bar{X}_n) - \delta}{S_{\bar{X}_o - \bar{X}_n}}$$

where

$$S_{\bar{X}_o - \bar{X}_n} = \sqrt{S^2_{\bar{X}_o} + S^2_{\bar{X}_n}}$$

$$S_{\bar{X}_o} = \frac{S}{\sqrt{n_1}} \quad \& \quad S_{\bar{X}_n} = \frac{S}{\sqrt{n_2}}$$

$$S = \sqrt{\frac{\Sigma\,(X_o - \bar{X}_o)^2 + \Sigma\,(X_n - \bar{X}_n)^2}{n_1 + n_2 - 2}}$$

$$n_1 = 11 \quad \& \quad n_2 = 3$$

(n_1 denotes the number of sections of overlay and n_2 denotes the number of sections of new construction).

Therefore, after all substitutions

$$t = -0.5 \text{ or } 0.5$$

The tabulated value of t is equal to 2.179 (with 12 degrees of freedom and a 5 percent level of significance).

Since the calculated t-value does not exceed the tabulated t-value, it can be concluded, with a 5 percent level of significance, that the null hypothesis, is true and that there is no significant difference between the two means.

FALLS-MCLENNAN COUNTY PROJECT

The F-Test

Overlay Sections -

Observed PSR Values

X_{o-1} 2.7, $X_{o-2} = 2.4$, $X_{o-3} = 2.1$,

$X_{o-4} = 2.6$, $X_{o-5} = 3.0$

Therefore

$\bar{X} = 2.56$ & $S_o^2 = 0.113$

(the subscript "o" denotes overlay)

New Construction Sections -

Observed PSR Values for Test Section 1:

$X_{n-1} = 3.0$, $X_{n-2} = 2.6$, $X_{n-3} = 2.9$

$X_{n-4} = 2.3$, $X_{n-5} = 2.6$

Therefore

$\bar{X}_n = 2.68$ & $S_n^2 = 0.077$

Observed PSR Values for Test Section 2:

$X_{n-1} = 2.9$, $X_{n-2} = 2.9$, $X_{n-3} = 3.1$,

$X_{n-4} = 2.9$, $X_{n-5} = 2.8$

Therefore

$\overline{X}_n = 2.92$ & $S_n^2 = 0.012$

Observed PSR Values for Test Section 3:

$X_{n-1} = 2.4$, $X_{n-2} = 2.5$, $X_{n-3} = 2.8$,

$X_{n-4} = 2.6$, $X_{n-5} = 2.8$

Therefore

$\overline{X}_n = 2.62$ & $S_n^2 = 0.032$

Observed PSR Values for Test Section 4:

$X_{n-1} = 3.0$, $X_{n-2} = 3.4$, $X_{n-3} = 2.8$,

$X_{n-4} = 3.0$, $X_{n-5} = 3.0$

Therefore

$\overline{X}_n = 2.98$ & $S_n^2 = 0.072$

Observed PSR Values for Test Section 5:

$X_{n-1} = 2.5, \; X_{n-2} = 2.8, \; X_{n-3} = 2.2,$

$X_{n-4} = 2.8, \; X_{n-5} = 2.2$

Therefore

$\overline{X}_n = 2.5$ & $S_n^2 = 0.09$

Observed PSR Values for Test Section 6:

$X_{n-1} = 2.6, \; X_{n-2} = 2.0, \; X_{n-3} = 2.1$

$X_{n-4} = 2.3, \; X_{n-5} = 2.5$

Therefore

$\overline{X}_n = 2.3$ & $S_n^2 = 0.065$

The pooled variance of the new construction sections is

$$S_n^2 = \frac{(0.077 + 0.012 + 0.032 + 0.072 + 0.09 + 0.065)}{6}$$

$$S_n^2 = 0.058$$

$$\text{Calculated F} = \frac{S_0^2}{S_n^2} = \frac{0.113}{0.058} = 1.948$$

Tabulated F (with 4 and 24 degrees of freedom and a 5 percent level of significance) = 3.38

Since the calculated F-value does not exceed the tabulated F-value, it can be concluded with a 5 percent level of significance that the mean PSR values are homogeneous.

The Two-Mean Student's T-Test

Mean PSR of overlay $\overline{X}_o = 2.56$

Mean PSR of new construction $\overline{X}_n = 2.66$

Null hypothesis: $\overline{X}_o - \overline{X}_n = \delta = 0$

$$t = \frac{(\overline{X}_o - \overline{X}_n) - \delta}{S_{\overline{X}_o - \overline{X}_n}}$$

where

$$S_{\overline{X}_o} - \overline{X}_n = \sqrt{S^2_{\overline{X}_o} + S^2_{\overline{X}_n}}$$

$$S_{\overline{X}_o} = \frac{S}{\sqrt{n_1}} \quad \& \quad S_{\overline{X}_n} = \frac{S}{\sqrt{n_2}}$$

$$S = \sqrt{\frac{\Sigma (X_o - \overline{X}_0)^2 + \Sigma (X_n - \overline{X}_n)^2}{n_1 + n_2 - 2}}$$

$n_1 = 5$ and $n_2 = 30$

(n_1 denotes the number of sections of overlay and n_2 the number of sections of new construction)

Therefore, after all substitutions

$$t = -0.4780 \text{ or } 0.4780$$

Tabulated t (with 33 degrees of freedom and a 5 percent level of significance) = 1.693

Since the calculated t-value does not exceed the tabulated t-value, it can be concluded with a 5 percent level of significance that the null hypothesis, is true, and that there is no significant difference between the two means.

JOHNSON COUNTY PROJECT

The F-Test

New Construction Sections -

Mean PSR value $\overline{X}_n$ = 3.77

Variance S_n^2 = 0.0065

(the subscript "n" denotes new construction)

Overlay Sections -

Mean PSR value $\overline{X}_o$ = 3.89

Variance S_o^2 = 0.0082

(the subscript "o" denotes overlay)

$$\text{Calculated F-value} = \frac{S_o^2}{S_n^2} = \frac{0.0082}{0.0065} = 1.2615$$

Tabulated F-value (with 36 and 56 degrees of freedom and a 5 percent level of significance) = 1.67.

Since the calculated F-value does not exceed the tabulated F-value, it can be concluded with a 5 percent level of significance that the mean PSR values are homogeneous.

The Two-Mean Student's T-Test

Mean PSR of overlay $\overline{X}_o$ = 3.89

Mean PSR of new construction $\overline{X}_n$ = 3.77

Null hypothesis: $\overline{X}_o - \overline{X}_n = \delta = 0$

$$t = \frac{(\overline{X}_o - \overline{X}_n) - \delta}{S_{\overline{X}_o - \overline{X}_n}}$$

where

$$S_{\overline{X}_o - \overline{X}_n} = \sqrt{S^2_{\overline{X}_o} + S^2_{\overline{X}_n}}$$

$$S_{\overline{X}_o} = \frac{S}{\sqrt{n_1}} \quad \& \quad S_{\overline{X}_n} = \frac{S}{\sqrt{n_2}}$$

$$S = \sqrt{\frac{\Sigma (X_o - \overline{X}_o)^2 + \Sigma (X_n - \overline{X}_n)^2}{n_1 + n_2 - 2}}$$

$$n_1 = 37 \quad \& \quad n_2 = 57$$

(n_1 denotes the number of overlay sections and n_2 denotes the number of new construction sections).

Therefore, after all substitutions

$$t = 5.35$$

Tabulated t-value (for 92 degrees of freedom and a 5 percent level of significance) = 1.989

Since the calculated t-value does not exceed the tabulated t-value, it can be concluded with a 5 percent level of significance that the null hypothesis, is true, and that there is no significant difference between the two means.

CRACK SPACINGS

To determine if the spacings between transverse cracks of the overlay and new construction CRCP sections, are significantly different, the Kolmogorov-Smirnov two-sample test was performed. The two-sample Kolmogorov-Smirnov test is based on the maximum absolute difference between the values of two observed cumulative distributions. The null hypothesis is concerned with whether or not the two independent samples come from identical continuous distributions. For this study, the Kolmogorov-Smirnov test was run on a computer. The computer program returns a plot of relative frequency distribution versus crack spacing, cumulative probability distribution versus crack spacing, and the maximum absolute difference (D) between the values of the two observed cumulative distributions, the overlay and new construction.

GUADALUPE COUNTY PROJECT

The computed maximum absolute difference between the values of the two observed cumulative distributions, obtained from the computer is $D = 0.2727$.

The tabular value of D for a 10 percent level of significance is found as follows:

$$D = 1.22 \frac{n_1 + n_2}{n_1 \text{ X } n_2}$$

where

n_1 = sample size for overlay sections

n_2 = sample size for new construction sections

For the Guadalupe County Project, $n_1 = 481$ and $n_2 = 366$. Substituting these values, $D_{.10} = 0.084$. Since the calculated value, $D_{max} = 0.2727$, exceeds the tabular value, $D_{.10} = 0.084$, it can be concluded that the null hypothesis is false and that the two samples do not come from identical continuous distributions. The overlay and new construction sections are significantly different with respect to crack spacing for a 10 percent level of confidence.

FALLS-MCLENNAN COUNTY PROJECT

The computed maximum absolute difference between the values of the two observed cumulative distributions, obtained from the computer, is $D = 0.2794$.

Since the calculated value, $D_{max} = 0.2794$, is greater than the tabular value, $D_{.10} = .073$, it can be concluded that the null hypothesis is false and the two samples do not come from identical populations.

JOHNSON COUNTY PROJECT

The computed maximum absolute difference between the values of the two observed cumulative distributions, obtained from the computer program is $0 = 0.1036$.

The tabular value of D was found to be 0.077 for a 10 percent level of confidence for a n_1 and n_2 equal 478 and 526 , respectively.

Since the calculated value, $D_{max} = 0.1036$, is greater than the tabulated value, $D_{.10} = 0.077$, it can be concluded that the null hypothesis is false and the two samples do not come from identical populations.

TRANSVERSE CRACKS

The statistical comparisons of minor and severe transverse cracks were considered separately. The Performance Survey of CRCP has four categories for entering the amount of transverse cracks observed. They are 1-5, 6-20, 21-50, and 51-100 percent of the section's length containing cracks. If less than 1 percent of the section's length has transverse cracks, it is taken to have no transverse cracks for computational purposes. Therefore, in making the statistical analysis, the sections having one percent or more of their length affected by transverse cracks were grouped in one class and the sections having none of their length affected by transverse cracks were grouped in another class.

To determine if there was any significant difference in the number of transverse cracks for the overlay and new construction sections, the chi-square distribution test was performed with the null hypothesis that the two criteria of classification, in this case pavement type and transverse cracks, are independent of one another. The calculations for each project are shown on the following pages.

GUADALUPE COUNTY PROJECT

No minor transverse cracks were observed in either the overlay or the new construction sections.

The numbers of sections which were observed to have severe transverse cracks are shown in Table A1.1 for both the overlay and the new construction sections. Table A1.2 shows the calculations necessary to perform the chi-square statistical test.

TABLE A1.1 NUMBERS OF SECTIONS OBSERVED CONTAINING SEVERE TRANSVERSE CRACKS

Type Section	Transverse Cracks Observed	No Transverse Cracks Observed	Total
Overlay	11	0	11
New construction	3	0	3
Total	14	0	14

TABLE A1.2 CALCULATIONS FOR CHI-SQUARE TEST

	Observed Value (o)	Expected Value (e)	o-e	$(o-e)^2$	$\frac{(o-e)^2}{e}$
	11	11	0	0	0
	0	0	0	0	0
	3	3	0	0	0
	0	0	0	0	0
Total	14	14	0	0	0

The caluclated value of $\chi^2 = \Sigma \frac{(o-e)^2}{e} = 0$. The tabulated value of χ^2 (for 10 percent level of significance) is equal to 2.71. Since the calculated value is less than the tabulated value, $0 < 2.71$, it can be concluded that the null hypothesis is true and that the pavement type, whether overlaid or new construction, and transverse cracking are independent. In other words, no conclusion can be made as to whether or not the pavement type has an influence on transverse cracking.

FALLS-MCLENNAN COUNTY PROJECT

The numbers of sections which were observed to have minor transverse cracks are shown in Table A1.3 for both the overlay and new construction sections. Table A1.2 shows the calculations necessary to perform the chi-square statistical test.

TABLE A1.3 NUMBERS OF SECTIONS OBSERVED CONTAINING MINOR TRANSVERSE CRACKS

Type Section	Transverse Cracks Observed	No Transverse Cracks Observed	Total
Overlay	2	3	5
New construction	1	34	35
Total	3	37	40

TABLE A1.4 CALCULATIONS FOR CHI-SQUARE TEST

	Observed Value (o)	Expected Value (e)	o-e	$(o-e)^2$	$\frac{(o-e)^2}{e}$
	2	0.375	1.625	2.641	7.042
	3	4.625	-1.625	2.641	0.571
	1	2.625	-1.625	2.641	1.006
	34	32.375	1.625	2.641	0.082
Total	40	40.000	0	-	8.701

The calculated value of $\chi^2, \Sigma\frac{(o-e)^2}{e}$ = 8.70. The tabulated value of χ^2 (for 10 percent level of significance) is equal to 2.71. Since the calculated value exceeds the tabular value, 8.70 > 2.71, the null hypothesis is rejected and it is concluded that there is a significant difference between the performances of the overlay and the new construction sections with respect to minor transverse cracks.

The numbers of sections which were observed to have severe transverse cracks are shown in Table A1.5 for both the overlay and new construction sections. Table A1.6 shows the calculations necessary to perform the chi-square statistical test.

TABLE A1.5 NUMBERS OF SECTIONS OBSERVED CONTAINING SEVERE TRANSVERSE CRACKS

Type Section	Transverse Cracks Observed	No Transverse Cracks Observed	Total
Overlay	0	5	5
New construction	12	23	35
Total	12	28	40

TABLE A1.6 CALCULATIONS FOR CHI-SQUARE TEST

	Observed Value (o)	Expected Value (e)	o-e	$(o-e)^2$	$\frac{(o-e)^2}{e}$
	0	1.5	-1.5	2.25	1.5
	5	3.5	1.5	2.25	0.64
	12	10.5	1.5	2.25	0.21
	23	24.5	-1.5	2.25	0.09
Total	40	40.00	0	-	2.44

The calculated value of χ^2 is **2.44**. The tabulated value of χ^2 (for a 10 percent level of significance) is equal to 2.71. Since the tabular value exceeds the calculated value, the null hypothesis is accepted and it concluded that there is not a significant difference between the performances of the overlay and the new construction sections with respect to severe transverse cracks.

JOHNSON COUNTY PROJECT

No minor transverse cracks were observed in either the overlay or the new construction sections.

The numbers of sections which were observed to have severe transverse cracks are shown in Table A1.7 for both the overlay and new construction sections. Table A1.8 shows the calculations necessary to perform the chi-square statistical test.

TABLE A1.7 NUMBERS OF SECTIONS OBSERVED CONTAINING SEVERE TRANSVERSE CRACKS

Type Section	Transverse Cracks Observed	No Transverse Cracks Observed	Total
Overlay	17	40	57
New construction	16	21	37
Total	33	61	94

TABLE A1.8 CALCULATIONS FOR CHI-SQUARE TEST

	Observed Value (o)	Expected Value (e)	o–e	$(o-e)^2$	$\frac{(o-e)^2}{e}$
	17	20.00	-3.00	9.00	0.450
	40	37.00	3.00	9.00	0.243
	16	13.00	3.00	9.00	0.692
	21	24.00	-3.00	9.00	0.375
Total	94	94.00	0	-	1.760

The calculated value of χ^2 is 1.760. The tabulated value of χ^2 (for a 10 percent level of significance) is equal to 2.71. Since the calculated value does not exceed the tabular value, the null hypothesis is accepted as being true and it is concluded that the pavement type and transverse cracking are independent. In other words, no conclusion can be made about whether or not one pavement type has a greater influence than the other pavement type in the creation of transverse cracks.

LOCALIZED CRACKS

The statistical comparison of localized cracks was performed in the same manner as for transverse cracks. Minor and severe localized cracks were considered separately. The chi-square distribution test was performed with the null hypothesis that the two criteria of classification, pavement type and localized cracking, are independent of one another.

GUADALUPE COUNTY PROJECT

The numbers of sections which were observed to have minor localized cracks are shown in Table A1.9 for both the overlay and new construction sections. Table A1.10 shows the calculations necessary to perform the chi-square statistical test.

TABLE A1.9 NUMBERS OF SECTIONS OBSERVED CONTAINING MINOR LOCALIZED CRACKS

Type Section	Localized Cracks Observed	No Localized Cracks Observed	Total
Overlay	11	0	11
New construction	3	0	3
Total	14	0	14

TABLE A1.10 CALCULATIONS FOR CHI-SQUARE TEST

	Observed Value (o)	Expected Value (e)	o-e	$(o-e)^2$	$\frac{(o-e)^2}{e}$
	11	11	0	0	0
	0	0	0	0	0
	3	3	0	0	0
	0	0	0	0	0
Total	14	14	0	0	0

The calculated value of χ^2 is 0. The tabulated value of χ^2 (for a 10 percent level of confidence) is equal to 2.71. Since the calculated value does not exceed the tabular value, the null hypothesis is accepted as being true and it is concluded that the pavement type, overlay or new construction, and localized cracks are independent.

No severe localized cracks were observed in either the overlay or the new construction sections.

FALLS-MCLENNAN COUNTY PROJECT

The numbers of sections which were observed to have minor localized cracks are shown in Table A1.11 for both the overlay and new contruction sections. Table A1.12 shows the calculations necessary to perform the chi-square statistical test.

TABLE A1.11 NUMBERS OF SECTIONS OBSERVED CONTAINING MINOR LOCALIZED CRACKS

Type Section	Localized Cracks Observed	No Localized Cracks Observed	Total
Overlay	2	3	5
New construction	9	26	35
Total	11	29	40

TABLE A1.12 CALCULATIONS FOR CHI-SQUARE TEST

	Observed Value (o)	Expected Value (e)	o-e	$(o-e)^2$	$\frac{(o-e)^2}{e}$
	2	1.38	0.63	0.39	0.28
	3	3.63	-0.63	0.39	0.11
	9	9.63	-0.63	0.39	0.04
	26	25.38	0.63	0.39	0.02
Total	40	40.00	0	-	0.45

The calculated value of χ^2 is 0.45. The tabulated value of χ^2 is 2.71 (for a 10 percent level of confidence). Since the calculated value does not exceed the tabulated value, the null hypothesis is accepted as being true and it is concluded that pavement type and minor localized cracks are independent.

The numbers of sections which were observed to have severe localized cracks are shown in Table A1.13 for both the overlay and new construction sections. Table A1.14 shows the calculations necessary to perform the chi-square statistical test.

TABLE A1.13 NUMBERS OF SECTIONS OBSERVED CONTAINING SEVERE LOCALIZED CRACKS

Type Section	Localized Cracks Observed	No Localized Cracks Observed	Total
Overlay	0	5	5
New construction	2	33	35
Total	2	38	40

TABLE A1.14 CALCULATIONS FOR CHI-SQUARE TEST

	Observed Value (o)	Expected Value (e)	o-e	$(o-e)^2$	$\frac{(o-e)^2}{e}$
	0	0.25	-0.25	0.063	0.250
	5	4.75	0.25	0.063	0.013
	2	1.75	0.25	0.063	0.035
	33	33.25	-0.25	0.063	0.002
Total	40	40.00	0	-	0.30

The calculated value of χ^2 is 0.30. The tabulated value of χ^2 is 2.71 (for 10 percent level of confidence). Since the calculated value does not exceed the tabulated value, the null hypothesis is accepted as being true, and it is concluded that the pavement type and severe localized cracks are independent.

JOHNSON COUNTY PROJECT

The numbers of sections which were observed to have minor localized cracks are shown in Table A1.15 for both the overlay and new construction sections. Table A1.16 shows the calculations necessary to perform the chi-square statistical test.

TABLE A1.15 NUMBERS OF SECTIONS OBSERVED CONTAINING MINOR LOCALIZED CRACKS

Type Section	Localized Cracks Observed	No Localized Cracks Observed	Total
Overlay	11	46	57
New construction	4	33	37
Total	15	79	94

TABLE A1.16 CALCULATIONS FOR CHI-SQUARE TEST

	Observed Value (o)	Expected Value (e)	o-e	$(o-e)^2$	$\frac{(o-e)^2}{e}$
	11	9.10	1.90	3.61	0.396
	46	47.90	-1.90	3.61	0.075
	4	5.90	-1.90	3.61	0.612
	33	31.10	1.90	3.61	0.116
Total	94	94.00	0	-	1.199

The calculated value of χ^2 is 1.199. The tabulated value of χ^2 is 2.71 (for a 10 percent level of confidence). Since the calculated value does not exceed the tabular value, the null hypothesis is accepted as being true and it is concluded that pavement type and minor localized cracks are independent.

No severe localized cracks were observed in either the overlay or the new construction sections.

SPALLING

As for all the distress manifestations, to determine whether there is any significant difference between the performance of the overlay and the new construction sections with respect to spalling, the chi-square statistical test was performed. Minor spalling was considered separately from severe spalling. The chi-square statistical test was performed with the null hypothesis that the two criteria of classification, pavement type and spalling, are independent of one another.

GUADALUPE COUNTY PROJECT

The numbers of sections which were observed to have minor spalling are shown in Table A.1.17 for both the overlay and new construction sections. Table A.1.18 shows the necessary calculations to perform the chi-square statistical test.

TABLE A1.17 NUMBERS OF SECTIONS OBSERVED CONTAINING MINOR SPALLING

Type Section	Spalling Observed	No Spalling Observed	Total
Overlay	11	0	11
New construction	3	0	3
Total	14	0	14

TABLE A1.18 CALCULATIONS FOR CHI-SQUARE TEST

	Observed Value (o)	Expected Value (e)	o-e	$(o-e)^2$	$\frac{(o-e)^2}{e}$
	11	11	0	0	0
	0	0	0	0	0
	3	3	0	0	0
	0	0	0	0	0
Total	14	14	0	0	0

The calculated value of χ^2 is 0. The tabulated value of χ^2 is 2.71 (for a 10 percent level of significance). Since the calculated value does not exceed the tabular value, the null hypothesis is accepted as being true and it is concluded that pavement type and minor spalling are independent of one another.

No severe spalling was observed in either the overlay or the new construction sections.

FALLS-MCLENNAN COUNTY PROJECT

The numbers of sections which were observed to have minor spalling are shown in Table A1.19 Table A1.20 shows the calculations necessary to perform the chi-square statistical test.

TABLE A1.19 NUMBERS OF SECTIONS OBSERVED CONTAINING MINOR SPALLING

Type Section	Spalling Observed	No Spalling Observed	Total
Overlay	5	0	5
New construction	35	0	35
Total	40	0	40

TABLE A1.20 CALCULATIONS FOR CHI-SQUARE TEST

	Observed Value (o)	Expected Value (e)	o-e	$(o-e)^2$	$\frac{(o-e)^2}{e}$
	5	5	0	0	0
	0	0	0	0	0
	35	35	0	0	0
	0	0	0	0	0
Total	40	40	0	0	0

The calculated value of χ^2 is 0. The tabular value of χ^2 is 2.71 (for a 10 percent level of significance). Since the calculated value does not exceed the tabular value, the null hypothesis is accepted as being true and it is concluded that pavement type and minor spalling are independent of one another.

The numbers of sections which were observed to have severe spalling are shown in Table A1.21. Table A1.22 shows the calculations necessary to perform the chi-square statistical test.

TABLE A1.21 NUMBERS OF SECTIONS OBSERVED CONTAINING SEVERE SPALLING

Type Section	Spalling Observed	No Spalling Observed	Total
Overlay	4	1	5
New construction	2	33	35
Total	6	34	40

TABLE A1.22 CALCULATIONS FOR CHI-SQUARE TEST

	Observed Value (o)	Expected Value (e)	o-e	$(o-e)^2$	$\frac{(o-e)^2}{e}$
	4	0.75	3.25	10.56	14.08
	1	4.25	-3.25	10.56	2.49
	2	5.25	-3.25	10.56	2.01
	33	29.75	3.25	10.56	0.36
Total	40	40.00	0	-	18.94

The calculated value of χ^2 is 18.94. The tabular value of χ^2 is 2.71 (for a 10 percent level of significance). Since the calculated value exceeds the tabular value, the null hypothesis is rejected and it is concluded that pavement type, overlay and new construction, and severe spalling are not independent of one another.

JOHNSON COUNTY PROJECT

No spalling was observed either minor or severe, for the sections surveyed in Johnson County.

PUMPING

The statistical comparison of pumping was performed using the chi-square statistical test for two criteria of classification, pavement type and pumping. The comparison was performed for minor and severe pumping separately. The null hypothesis was that the two criteria of classification are independent of one another.

GUADALUPE COUNTY PROJECT

No pumping was observed, either minor or severe, for the sections surveyed in Guadalupe County.

FALLS-MCLENNAN COUNTY

The numbers of sections which were observed to have minor pumping are shown in Table A1.23. Table A1.24 shows the calculations necessary to perform the chi-square statistical test.

TABLE A1.23 NUMBERS OF SECTIONS OBSERVED CONTAINING MINOR PUMPING

Type Section	Pumping Observed	No Pumping Observed	Total
Overlay	0	5	5
New construction	16	19	35
Total	16	24	40

TABLE A1.24 CALCULATIONS FOR CHI-SQUARE TEST

	Observed Value (o)	Expected Value (e)	o-e	$(o-e)^2$	$\frac{(o-e)^2}{e}$
	0	2.00	-2.0	4.0	2.00
	5	3.00	2.0	4.0	1.33
	16	14.00	2.0	4.0	0.29
	19	21.00	-2.0	4.0	0.19
Total	40	40.00	0	-	3.81

The calculated value of χ^2 is 3.81. The tabulated value of χ^2 is 2.71 (for a 10 percent level of significance). Since the calculated value exceeds the tabular value, the null hypothesis is rejected and it is concluded that pavement type and minor pumping are not independent of one another.

The numbers of sections which were observed to have severe pumping are shown in Table A1.25. Table A1.26 shows the calculations necessary to perform the chi-square statistical test.

TABLE A1.25 NUMBERS OF SECTIONS OBSERVED CONTAINING SEVERE PUMPING

Type Section	Pumping Observed	No Pumping Observed	Total
Overlay	0	5	5
New construction	14	21	35
Total	14	26	40

TABLE A1.26 CALCULATIONS FOR CHI-SQUARE TEST

	Observed Value (o)	Expected Value (e)	o-e	$(o-e)^2$	$\frac{(o-e)^2}{e}$
	0	1.75	-1.75	3.06	1.75
	5	3.25	1.75	3.06	0.94
	14	12.25	1.75	3.06	0.25
	21	22.75	-1.75	3.06	0.13
Total	40	40.00	0	-	3.07

The calculated value of χ^2 is 3.07. The tabular value of χ^2 is 2.71. Since the calculated value exceeds the tabular value, the null hypothesis is rejected and it is concluded that pavement type and severe pumping are not independent of one another.

JOHNSON COUNTY PROJECT

The numbers of sections which were observed to have minor pumping are shown in Table A1.27. Table A1.28 shows the calculations necessary to perform the chi-square statistical test.

TABLE A1.27 NUMBERS OF SECTIONS OBSERVED CONTAINING MINOR PUMPING

Type Section	Pumping Observed	No Pumping Observed	Total
Overlay	17	40	57
New construction	10	27	37
Total	27	67	94

TABLE A1.28 CALCULATIONS FOR CHI-SQUARE TEST

	Observed Value (o)	Expected Value (e)	o-e	$(o-e)^2$	$\frac{(o-e)^2}{e}$
	17	16.37	0.63	0.396	0.024
	40	40.63	-0.63	0.396	0.009
	10	10.63	-0.63	0.396	0.037
	27	26.37	0.63	0.396	0.015
Total	94	94.00	0	-	0.085

The calculated value of χ^2 is 0.085. The tabular value of χ^2 is 2.71. Since the calculated value does not exceed the tabular value, the null hypothesis is accepted as being true and it is concluded that pavement type and minor pumping are independent of one another.

The numbers of sections which were observed to have severe pumping are shown in Table A1.29. Table A1.30 shows the calculations necessary to perform the chi-square statistical test.

TABLE A1.29 NUMBERS OF SECTIONS OBSERVED CONTAINING SEVERE PUMPING

Type Section	Pumping Observed	No Pumping Observed	Total
Overlay	5	52	57
New construction	4	33	37
Total	9	85	94

TABLE A1.30 CALCULATIONS FOR CHI-SQUARE TEST

	Observed Value (e)	Expected Value (e)	o-e	$(o-e)^2$	$\frac{(o-e)^2}{e}$
	5	5.45	-0.45	0.2025	0.037
	52	51.55	0.45	0.2025	0.004
	4	3.55	0.45	0.2025	0.057
	33	33.45	-0.45	0.2025	0.006
Total	94	94.00	0	-	0.104

The calculated value of χ^2 is 0.104. The tabulated value of χ^2 is 2.71 (for a 10 percent level of significance). Since the calculated value does not exceed the tabular value, the null hypothesis is accepted as being true and it is concluded that pavement type and severe pumping are independent of one another.

PUNCHOUTS

The statistical comparison of punchouts was performed using the chi-square statistical test for two criteria of classification, pavement type and punchouts. Minor and severe punchouts were analyzed separately. The null hypothesis was that the two criteria of classification are independent of one another.

GUADALUPE COUNTY PROJECT

No punchouts were observed, either minor or severe, for the sections surveyed in Guadalupe County.

FALLS-MCLENNAN COUNTY PROJECT

The numbers of sections which were observed to have minor punchouts are shown in Table A1.31. Table A1.32 show the calculations necessary to perform the chi-square statistical test.

TABLE A1.31 NUMBERS OF SECTIONS OBSERVED CONTAINING MINOR PUNCHOUTS

Type Section	Punchouts Observed	No Punchouts Observed	Total
Overlay	1	4	5
New construction	21	14	35
Total	22	18	40

TABLE A1.32 CALCULATIONS FOR CHI-SQUARE TEST

	Observed Value (o)	Expected Value (e)	o-e	$(o-e)^2$	$\frac{(o-e)^2}{e}$
	1	2.75	-1.75	3.06	1.11
	4	2.25	1.75	3.06	1.36
	21	19.25	1.75	3.06	0.16
	14	15.75	-1.75	3.06	0.19
Total	40	40.00	0	-	2.82

The calculated value of χ^2 is 2.82. The tabular value of χ^2 is 2.71 (for a 10 percent level of significance). Since the calculated value exceeds the tabular value, the null hypothesis is rejected and it is concluded that pavement type and minor punchouts are not independent of one another.

The numbers of sections which were observed to have severe punchouts are shown in Table A1.35. Table A1.36 shows the calculations necessary to perform the chi-square statistical test.

TABLE A1.33 NUMBERS OF SECTIONS OBSERVED CONTAINING SEVERE PUNCHOUTS

Type Section	Punchouts Observed	No Punchouts Observed	Total
Overlay	0	5	5
New construction	7	28	35
Total	7	33	40

TABLE A1.34 CALCULATIONS FOR CHI-SQUARE TEST

	Observed Value (o)	Expected Value (e)	o-e	$(o-e)^2$	$\frac{(o-e)^2}{e}$
	0	0.88	-0.88	0.77	0.87
	5	4.13	0.88	0.77	0.19
	7	6.13	0.88	0.77	0.12
	28	28.88	-0.88	0.77	0.03
Total	40	40.00	0	-	1.21

The calculated value of χ^2 is 1.21. The tabular value of χ^2 is 2.71 (for a 10 percent level of significance). Since the calculated value does not exceed the tabular value, the null hypothesis is accepted as being true and it is concluded that pavement type and severe punchouts are independent of one another.

JOHNSON COUNTY PROJECT

The numbers of sections which were observed to have minor punchouts are shown in Table A1.35 Table A1.36 shows the calculations necessary to perform the chi-square statistical test.

TABLE A1.35 NUMBERS OF SECTIONS OBSERVED CONTAINING MINOR PUNCHOUTS

Type Section	Punchouts Observed	No Punchouts Observed	Total
Overlay	8	49	57
New construction	6	31	37
Total	14	80	94

TABLE A1.36 CALCULATIONS FOR CHI-SQUARE TEST

	Observed Value (o)	Expected Value (e)	o-e	$(o-e)^2$	$\frac{(o-e)^2}{e}$
	8	8.48	-0.48	0.23	0.027
	49	48.52	0.48	0.23	0.004
	6	5.52	0.48	0.23	0.041
	31	31.48	-0.48	0.23	0.007
Total	94	94.00	0	-	0.079

The calculated value of χ^2 is 0.079. The tabular value of χ^2 is 2.71 (for a 10 percent level of significance). Since the calculated value does not exceed the tabular value, the null hypothesis is accepted as being true and it is concluded that pavement type and minor punchouts are independent of one another.

The numbers of sections which were shown to have severe punchouts are shown in Table A1.37. Table A1.38 shows the calculations necessary to perform the chi-square statistical test.

TABLE A1.37 NUMBERS OF SECTIONS OBSERVED CONTAINING SEVERE PUNCHOUTS

Type Section	Punchouts Observed	No Punchouts Observed	Total
Overlay	5	52	57
New construction	3	34	37
Total	8	86	94

TABLE A1.38 CALCULATIONS FOR CHI-SQUARE TEST

	Observed Value (o)	Expected Value (e)	o-e	$(o-e)^2$	$\frac{(o-e)^2}{e}$
	5	4.85	0.15	0.0225	0.0046
	52	52.15	-0.15	0.0225	0.0004
	3	3.15	-0.15	0.0225	0.0071
	34	33.85	0.15	0.0225	0.0006
Total	94	94.00	0	-	0.0127

The calculated value of χ^2 is 0.0127. The tabular value of χ^2 is 2.71 (for a 10 percent level of significance). Since the calculated value does not exceed the tabular value, the null hypothesis is accepted as being true and it is concluded that pavement type and severe punchouts are independent of one another.

REPAIR PATCHES

The statistical comparison of repair patches was performed using the chi-square statistical test for two criteria of classification, pavement type and repair patches. The repair patches are classified as being either asphalt cement concrete (ACC) or portland cement concrete (PCC), each of which was considered separately in the analysis. The null hypothesis was that the two criteria of classification are independent of one another.

GUADALUPE COUNTY PROJECT

No repair patches were observed in the condition survey, either ACC or PCC, for both the overlay and the new construction sections.

FALLS-MCLENNAN COUNTY PROJECT

In order to fully distinguish the differences between overlay and new construction with respect to repair patches, a further breakdown in the classification of repair patches was required. This was done to account for the wide dispersion of data, from a few patches small in area to very many patches large in area.

Repair patches were considered under three separate categories: two or more patches per test section, two or more patches each 120 square feet or smaller per test section, and one or more patches each 120 square feet or larger per test section.

The numbers of sections which were observed to have two or more PCC repair patches are shown in Table A1.39. Table A1.40 shows the calculations necessary to perform the chi-square statistical test.

TABLE A1.39 NUMBERS OF SECTIONS OBSERVED CONTAINING TWO OR MORE PCC REPAIR PATCHES

Type Section	Two or More Repair Patches Observed	Less Than Two Repair Patches Observed	Total
Overlay	4	1	5
New construction	20	15	35
Total	24	16	40

TABLE A1.40 CALCULATIONS FOR CHI-SQUARE TEST

	Observed Value (o)	Expected Value (e)	o-e	$(o-e)^2$	$\frac{(o-e)^2}{e}$
	4	3	1	1	0.33
	1	2	-1	1	0.50
	20	21	-1	1	0.05
	15	14	1	1	0.07
Total	40	40	0	-	0.95

The calculated value of χ^2 is 0.95. The tabulated value of χ^2 is 2.71 (for a 10 percent level of significance). Since the calculated value does not exceed the tabular value, the null hypothesis is accepted as being true and it is concluded that pavement type and the number of PCC repair patches are independent of one another.

The numbers of sections which were observed to have two or more PCC repair patches each 120 square feet or smaller are shown in Table A1.41. Table A1.42 shows the calculations necessary to perform the Chi-square statistical test.

TABLE A1.41 NUMBERS OF SECTIONS OBSERVED CONTAINING TWO OR MORE PCC REPAIR PATCHES EACH 120 SQUARE FEET OR SMALLER

Type Section	Two or More Repair Patches 120 Square Feet or Smaller Observed	Less Than Two Repair Patches 120 Square Feet or Smaller Observed	Total
Overlay	4	1	5
New construction	12	23	35
Total	16	24	40

TABLE A1.42 CALCULATIONS FOR CHI-SQUARE TEST

	Observed Value (o)	Expected Value (e)	o-e	$(o-e)^2$	$\frac{(o-e)^2}{e}$
	4	2.0	2.0	4.0	2.0
	1	3.0	-2.0	4.0	1.33
	12	14.0	-2.0	4.0	0.29
	23	21.0	2.0	4.0	0.19
Total	40	40.00	0	-	3.81

The calculated value of χ^2 is 3.81. The tabular value of χ^2 is 2.71 (for a 10 percent level of significance). Since the tabular value does not exceed the calculated value, the null hypothesis is rejected as being true and it is concluded that pavement type and the number of PCC repair patches 120 square feet or smaller are not independent of one another.

The numbers of sections which were observed to have one or more PCC repair patches, 120 square feet or larger are shown in Table A1.43. Table A1.44 shows the calculations necessary to perform the chi-square statistical test.

TABLE A1.43 NUMBERS OF SECTIONS OBSERVED CONTAINING ONE OR MORE PCC REPAIR PATCHES 120 SQUARE FEET OR LARGER

Type Section	One or More Repair Patches 120 Square Feet or Larger Observed	Less than One Repair Patch 120 Square Feet or Larger Observed	Total
Overlay	1	4	5
New construction	16	19	35
Total	17	23	40

TABLE A1.44 CALCULATIONS FOR CHI-SQUARE TEST

	Observed Value (o)	Expected Value (e)	o-e	$(o-e)^2$	$\frac{(o-e)^2}{e}$
	1	2.13	-1.13	1.28	0.60
	4	2.88	1.13	1.28	0.44
	16	14.88	1.13	1.28	0.09
	19	20.13	-1.13	1.28	0.06
Total	40	40.00	0	-	1.19

The calculated value of χ^2 is 1.19. The tabulated value of χ^2 is 2.71 (for a 10 percent level of significance). Since the tabular value exceeds the calculated value, the null hypothesis is accepted and it is concluded that pavement type and the number of repair patches 120 square feet or larger are independent of one another.

ACC repair patches were not observed in either the overlay or the new construction sections.

JOHNSON COUNTY PROJECT

Due to the lack of sufficient dispersion in the data, the previous three categories of repair patches in which the other pavements were classified could not be practicably used here. Instead, the pavements were classified as either having or not having repair patches.

The numbers of sections which were observed to have PCC repair patches are shown in Table A1.45. Table A1.46 shows the calculations necessary to perform the chi-square statistical test.

TABLE A1.45 NUMBERS OF SECTIONS OBSERVED CONTAINING PCC REPAIR PATCHES

Type Section	Repair Patches Observed	No Repair Patches Observed	Total
Overlay	11	46	57
New construction	4	33	37
Total	15	79	94

TABLE A1.46 CALCULATIONS FOR CHI-SQUARE TEST

	Observed Value (o)	Expected Value (e)	o-e	$(o-e)^2$	$\frac{(o-e)^2}{e}$
	11	9.10	1.90	3.61	0.396
	46	47.90	-1.90	3.61	0.075
	4	5.90	-1.90	3.61	0.611
	33	31.10	1.90	3.61	0.116
Total	94	94.00	0	-	1.198

The calculated value of χ^2 is 1.198. The tabular value of χ^2 is 2.71 (for a 10 percent level of significance). Since the calculated value does not exceed the tabular value, the null hypothesis is accepted as being true and it is concluded that pavement type and PCC repair patches are independent of one another.

ACC repair patches were not observed in either overlay or new construction sections.

APPENDIX 2

CONDITION SURVEY DATA

CRCP

PERFORMANCE SURVEY

District	Control	Section	Highway	County	Leave Blank	Date Mo. Day Yr.
14	16-6-19		IH-35	Guadalupe		6-17-76

Leave Blank	Location From	To	Raters
	Start of CRCP	End of CRCP	J. Long & B.C. Nayak

	Mile Post	Mile Point	Transverse Cracks %								Localized Cracks %								Spalling %								Pumping %								Punch Outs in feet								Repair Patches Square feet								Ride
			M				S				M				S				M				S				M				S				M				S				A.C.				P.C.C.				
			1-5	5-20	20-50	50-100	1-5	5-20	20-50	50-100	1-5	5-20	20-50	50-100	1-5	5-20	20-50	50-100	1-5	5-20	20-50	50-100	1-5	5-20	20-50	50-100	1-5	5-20	20-50	50-100	1-5	5-20	20-50	50-100	1-3	4-9	10-19	> 20	1-3	4-9	10-19	> 20	1-15	16-120	121-240	>241	1-15	16-120	121-240	>241	
	177.16						1				1								1																																3.8
	176.96							1			1								1																																3.8
o.	176.76						1				1								1																																3.8
	176.56						1				1								1																																4.0
	176.36						1				1								1																																3.8
	176.16						1				1								1																																4.0
n,	175.96						1				1								1																																3.8
	175.76						1				1								1																																3.8
	175.56						1				1								1																																3.9
	175.36						1				1								1																																3.8
	175.16						1				1								1																																3.8
o.	174.96						1				1								1																																3.8
	174.76						1				1								1																																3.9
	174.56						1				1								1																																3.8

M - Minor S - Severe A.C. - Asphalt P.C.C. - Portland Cement

Condition of Shoulder ______

General Comments "o" denotes overlay & "n" denotes new construction

CRCP
PERFORMANCE SURVEY

District	Control	Section	Highway	County	Leave Blank	Date Mo. Day Yr.
9	15		IH-35 NBL	McLennan		3-07-74

Leave Blank	Location From	To	Raters
			R.Strauss, J. Long

Mile Post	Mile Point	Transverse Cracks %								Localized Cracks %								Spalling %								Pumping %								Punch Outs in feet								Repair Patches Square feet								Ride
		M				S				M				S				M				S				M				S				M				S				A.C.				P.C.C.				
		1-5	5-20	20-50	50-100	1-5	5-20	20-50	50-100	1-5	5-20	20-50	50-100	1-5	5-20	20-50	50-100	1-5	5-20	20-50	50-100	1-5	5-20	20-50	50-100	1-5	5-20	20-50	50-100	1-5	5-20	20-50	50-100	1-3	4-9	10-19	> 20	1-3	4-9	10-19	> 20	1-15	16-120	121-240	>241	1-15	16-120	121-240	>241	
316.4	1.893	1								1									1				1																								4			2.8
316.6	2.093		1							1										1		1																									2	1		2.7
316.8	2.293		1																1				1																								1			2.4
317.0	2.492																		1				1																								3			2.1
317.2	2.692																			1		1													1												3			2.6

M - Minor S - Severe A.C. - Asphalt P.C.C. - Portland Cement

Condition of Shoulder

General Comments

CRCP

PERFORMANCE SURVEY

District	Control	Section	Highway	County	Leave Blank	Date Mo. Day Yr.
9	15		IH-35 NBL	McLennan		3-07-74

Leave Blank	Location From	To	Raters
			P.Strauss, J. Long

N

Mile Post	Mile Point	Transverse Cracks %								Localized Cracks %								Spalling %								Pumping %								Punch Outs in feet								Repair Patches Square feet								Ride
		M				S				M				S				M				S				M				S				M				S				A.C.				P.C.C.				
		1–5	5–20	20–50	50–100	1–5	5–20	20–50	50–100	1–5	5–20	20–50	50–100	1–5	5–20	20–50	50–100	1–5	5–20	20–50	50–100	1–5	5–20	20–50	50–100	1–5	5–20	20–50	50–100	1–5	5–20	20–50	50–100	1–3	4–9	10–19	> 20	1–3	4–9	10–19	> 20	1–15	16–120	121–240	>241	1–15	16–120	121–240	>241	
317.6	3.092																			1																														3.0
317.8	3.292									1										1																											6			2.6
318.0	3.489																			1		1																												2.9
318.2	3.689																			1														1													1			2.3
318.4	3.889									1										1																														2.6
318.6	4.089																			1						1																								2.4
318.8	4.289																			1																		1												2.3
319.0	4.488																			1																1														2.8
319.2	4.688																			1																	1													2.6
319.4	4.888					1														1																														2.8

5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80

M - Minor S - Severe A.C. - Asphalt P.C.C. - Portland Cement

Condition of Shoulder ____________________

General Comments ____________________

CRCP

PERFORMANCE SURVEY

District	Control	Section	Highway	County	Leave Blank	Date Mo. Day Yr.
9	15	2	IH-35 SBL	McLennan		3-07-74

Leave Blank	Location From	To	Raters
	Start of CRCP	Falls County Line	P.Strauss, J. Long

N

Mile Post	Mile Point	Transverse Cracks %								Localized Cracks %								Spalling %								Pumping %								Punch Outs in feet								Repair Patches Square feet								Ride
		M				S				M				S				M				S				M				S				M				S				A.C.				P.C.C.				
		1-5	5-20	20-50	50-100	1-5	5-20	20-50	50-100	1-5	5-20	20-50	50-100	1-5	5-20	20-50	50-100	1-5	5-20	20-50	50-100	1-5	5-20	20-50	50-100	1-5	5-20	20-50	50-100	1-5	5-20	20-50	50-100	1-3	4-9	10-19	> 20	1-3	4-9	10-19	> 20	1-15	16-120	121-240	>241	1-15	16-120	121-240	>241	
314.8	1.104									1										1															1			1									2			2.9
315.0	1.305																			1										1						1		1									4			2.9
315.2	1.505					1														1						1					1			1	1							1					8			2.9
315.4	1.705																									1					1			1	1	1										1	12	4		2.4
315.6	1.906																									1					1			1	2	1											3	3		2.6
315.8	1.205									1											1													1				2									2	1		3.0
316.0	1.493									1										1															1			1									1			3.4
316.2	1.693					1														1						1					1															1	3	1		2.8
316.4	1.893					1														1						1					1				1		1									2	1	1		3.0
316.6	2.093					1														1						1				1				2													2	1		2.7
316.8	2.293																			1						1								1	1	1		1									2	1		2.5
317.0	2.492					1														1						1					1						1										1	2		2.8
317.2	2.692									1										1											1																1		1	2.2
317.4	2.892													1						1						1								1	1											1			1	2.8
317.6	3.092									1										1						1								11													1	1	1	2.2
317.8	3.292						1												1															1	1		2									1	2	1		2.6

M - Minor S - Severe A.C. - Asphalt P.C.C. - Portland Cement

Condition of Shoulder ______________________________

General Comments ______________________________

____

CRCP

PERFORMANCE SURVEY

District: 9
Control: 15
Section: 2
Highway: IH-35 SBL
County: McLennan
Leave Blank:
Date Mo. Day Yr.: 3-07-74
Leave Blank:
Location From: Start of CRCP
To: Falls County Line
Raters: P. Strauss, J. Long

N

Mile Post	Mile Point	Transverse Cracks %								Localized Cracks %								Spalling %								Pumping %								Punch Outs in feet								Repair Patches Square feet								Ride
		M				S				M				S				M				S				M				S				M				S				A.C.				P.C.C.				
		1-5	5-20	20-50	50-100	1-5	5-20	20-50	50-100	1-5	5-20	20-50	50-100	1-5	5-20	20-50	50-100	1-5	5-20	20-50	50-100	1-5	5-20	20-50	50-100	1-5	5-20	20-50	50-100	1-5	5-20	20-50	50-100	1-3	4-9	10-19	> 20	1-3	4-9	10-19	> 20	1-15	16-120	121-240	>241	1-15	16-120	121-240	>241	
318.0	3.489					1					1									1														1	1															2.0
318.2	3.689					1														1						1				1					3			1	1			1				1	14	1		2.1
318.4	3.889					1								1					1							1								1			1					1					5	3	1	2.3
318.6	4.089																			1						1						1															4	1		2.5
318.8	4.289																			1						1					1															1	1			2.5
319.0	4.488	1																		1						1								1	1												1			2.3
319.2	4.688																			1											1																3	2		2.5
319.4	4.888									1										1										1																	2			2.7
319.6	5.088					1														1															1												1			3.0

M - Minor S - Severe A.C. - Asphalt P.C.C. - Portland Cement

Condition of Shoulder ____________________

General Comments ____________________

CRCP

PERFORMANCE SURVEY

District	Control	Section	Highway	County	Leave Blank	Date Mo. Day Yr.
2	14-3-19		IH-35 NBL	Johnson		7-16-76

Leave Blank	Location From	To	Raters
	Start of new const.	End of n.c.	J. Long, L. Olson, B. Nayak

N

Mile Post	Mile Point	Transverse Cracks %								Localized Cracks %								Spalling %								Pumping %								Punch Outs in feet								Repair Patches Square feet								Ride
		M				S				M				S				M				S				M				S				M				S				A.C.				P.C.C.				
		1–5	5–20	20–50	50–100	1–5	5–20	20–50	50–100	1–5	5–20	20–50	50–100	1–5	5–20	20–50	50–100	1–5	5–20	20–50	50–100	1–5	5–20	20–50	50–100	1–5	5–20	20–50	50–100	1–5	5–20	20–50	50–100	1–3	4–9	10–19	> 20	1–3	4–9	10–19	> 20	1–15	16–120	121–240	>241	1–15	16–120	121–240	>241	
28.2																																																		3.8
28.4		1								1																																								3.9
28.6			1							1																1																				1				3.7
28.8			1								1															1																						1		3.7
29.0		1								1																																								3.7
29.2		1																																																3.8
29.4		1																																													2	1		3.7
29.6		1																																																3.8
29.8																										1																				1			1	3.7
30.0																										1																								3.7
30.2		1																								1																							1	3.8
30.4																																																		3.7
30.6																										1																								3.7
30.8		1																																																3.8
31.0																														1																				3.9
31.2																														1																				3.9

M - Minor S - Severe A.C. - Asphalt P.C.C. - Portland Cement

Condition of Shoulder __________

General Comments __________

CRCP
PERFORMANCE SURVEY

District	Control	Section	Highway	County	Leave Blank	Date Mo. Day Yr.
2	14-3-19		IH-35 NBL	Johnson		7-16-76

Leave Blank	Location From	To	Raters
	Start of new constr.	End of new constr.	J. Long, L. Olson, BCN

N

Mile Post	Mile Point	Transverse Cracks %								Localized Cracks %								Spalling %								Pumping %								Punch Outs in feet								Repair Patches Square feet								Ride
		M				S				M				S				M				S				M				S				M				S				A.C.				P.C.C.				
		1-5	5-20	20-50	50-100	1-5	5-20	20-50	50-100	1-5	5-20	20-50	50-100	1-5	5-20	20-50	50-100	1-5	5-20	20-50	50-100	1-5	5-20	20-50	50-100	1-5	5-20	20-50	50-100	1-5	5-20	20-50	50-100	1-3	4-9	10-19	> 20	1-3	4-9	10-19	> 20	1-15	16-120	121-240	>241	1-15	16-120	121-240	>241	
31.4																														1																				3.8
31.6																																															1			3.8
31.8																																																		3.7
32.0																														1																				3.8
32.2																																																		3.6
32.4																																															1			3.8
32.6																										/																								3.6
32.8																										/																								3.8
33.0						/																																												3.7
33.2																																																		3.8
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33.6																																																		3.8
33.8						/				/																/																								3.8
34.0																																																		3.8
34.2																																																		3.8
34.4																																																		3.7

M - Minor S - Severe A.C. - Asphalt P.C.C. - Portland Cement

Condition of Shoulder ______________________

General Comments ______________________

CRCP
PERFORMANCE SURVEY

District	Control	Section	Highway	County	Leave Blank	Date Mo. Day Yr.
2	14-3-19		IH-35 NBL	Johnson		7-16-76

Leave Blank	Location From	To	Raters
	Start of new constr.	End of new constr.	J. Long, L. Olson, BCN.

N

Mile Post	Mile Point	Transverse Cracks %								Localized Cracks %								Spalling %								Pumping %								Punch Outs in feet								Repair Patches Square feet								Ride
		M				S				M				S				M				S				M				S				M				S				A.C.				P.C.C.				
		1-5	5-20	20-50	50-100	1-5	5-20	20-50	50-100	1-5	5-20	20-50	50-100	1-5	5-20	20-50	50-100	1-5	5-20	20-50	50-100	1-5	5-20	20-50	50-100	1-5	5-20	20-50	50-100	1-5	5-20	20-50	50-100	1-3	4-9	10-19	> 20	1-3	4-9	10-19	> 20	1-15	16-120	121-240	>241	1-15	16-120	121-240	>241	
34.6																																			1															3.7
34.8																										1																								3.6
35.0																											1							1																3.7
35.2										1																																								3.7
35.4										1																																								3.7
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36.0																																																		3.8
36.2																																																		3.7
36.4																																																		3.7
36.6																																																		3.6
36.8																										1																								3.8
37.0																										1																								3.8
37.2																																																		3.8
37.4																																																		3.8

M - Minor S - Severe A.C. - Asphalt P.C.C. - Portland Cement

Condition of Shoulder ______

General Comments ______

CRCP

PERFORMANCE SURVEY

District	Control	Section	Highway	County	Leave Blank	Date Mo. Day Yr.
2	14-3-19		IH-35 SBL	Johnson		7-16-76

Leave Blank	Location From	To	Raters
			J. Long, L. Olson, B.C.N.

O

Mile Post	Mile Point	Transverse Cracks %								Localized Cracks %								Spalling %								Pumping %								Punch Outs in feet								Repair Patches Square feet								Ride
		M				S				M				S				M				S				M				S				M				S				A.C.				P.C.C.				
		1-5	5-20	20-50	50-100	1-5	5-20	20-50	50-100	1-5	5-20	20-50	50-100	1-5	5-20	20-50	50-100	1-5	5-20	20-50	50-100	1-5	5-20	20-50	50-100	1-5	5-20	20-50	50-100	1-5	5-20	20-50	50-100	1-3	4-9	10-19	> 20	1-3	4-9	10-19	> 20	1-15	16-120	121-240	>241	1-15	16-120	121-240	>241	
37.0						/				/																/																								4.0
36.8						/				/																																								3.8
36.6						/																																												3.8
36.4						/				/																																								3.9
36.2						/				/																/				/																				3.7
36.0																																																		3.7
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35.4						/																																												4.0
35.2						/																																												4.0
35.0																																																		3.9
34.8																														/									/											3.9
34.6																																																		4.0
34.4																										/																								3.8
34.2																										/																								3.7
34.0																										/																								3.9

M - Minor S - Severe A.C. - Asphalt P.C.C. - Portland Cement

Condition of Shoulder ____________________

General Comments ____________________

CRCP

PERFORMANCE SURVEY

District	Control	Section	Highway	County	Leave Blank	Date Mo. Day Yr.
2	14-3-19		IH-35 SBL	Johnson		7-16-76

Leave Blank	Location From	To	Raters
			J. Long, L. Olson, B.C.N.

O

Mile Post	Mile Point	Transverse Cracks %								Localized Cracks %								Spalling %								Pumping %								Punch Outs in feet								Repair Patches Square feet								Ride
		M				S				M				S				M				S				M				S				M				S				A.C.				P.C.C.				
		1–5	5–20	20–50	50–100	1–5	5–20	20–50	50–100	1–5	5–20	20–50	50–100	1–5	5–20	20–50	50–100	1–5	5–20	20–50	50–100	1–5	5–20	20–50	50–100	1–5	5–20	20–50	50–100	1–5	5–20	20–50	50–100	1–3	4–9	10–19	> 20	1–3	4–9	10–19	> 20	1–15	16–120	121–240	>241	1–15	16–120	121–240	>241	
33.8						/																																												3.8
33.6																																																		3.8
33.4																										/								/																3.7
33.2						/				/																																								4.0
33.0						/																																												3.9
32.8																																																		3.8
32.6						/				/																								/																3.8
32.4																											/			/																				3.9
32.2						/																					/								/															3.8
32.0																																																		3.7
31.8						/																				/																								3.7
31.6						/																																												3.8
31.4																										/																								3.9
31.2						/																																												3.9
31.0						/																				/																								3.9
30.8						/																																												4.0

M - Minor S - Severe. A.C. - Asphalt P.C.C. - Portland Cement

Condition of Shoulder ____________________

General Comments ____________________

CRCP

PERFORMANCE SURVEY

District	Control	Section	Highway	County	Leave Blank	Date Mo. Day Yr.
2	14-3-19		IH-35 SBL	Johnson		7-16-76

Leave Blank	Location From	To	Raters
			J. Long, L. Olson, B.C.N.

Mile Post	Mile Point	Transverse Cracks %								Localized Cracks %								Spalling %								Pumping %								Punch Outs in feet								Repair Patches Square feet								Ride
		M				S				M				S				M				S				M				S				M				S				A.C.				P.C.C.				
		1-5	5-20	20-50	50-100	1-5	5-20	20-50	50-100	1-5	5-20	20-50	50-100	1-5	5-20	20-50	50-100	1-5	5-20	20-50	50-100	1-5	5-20	20-50	50-100	1-5	5-20	20-50	50-100	1-5	5-20	20-50	50-100	1-3	4-9	10-19	> 20	1-3	4-9	10-19	> 20	1-15	16-120	121-240	>241	1-15	16-120	121-240	>241	
30.6																										1																								3.9
30.4						1																												1	1															3.9
30.2						1																				1									1				1									1		4.0
30.0						1																												1													1			3.9
29.8						1				1																1																					1			3.9
29.6						1				1																																								4.0
29.4						1																								1									1								1			3.9
29.2																																																		3.9
29.0																																																		3.9
28.8																																																		3.9
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28.4																																																		3.9
28.2																																																		3.9
28.0																																																		3.9
27.8																																																		4.0

M - Minor S - Severe A.C. - Asphalt P.C.C. - Portland Cement

Condition of Shoulder __________

General Comments __________

APPENDIX 3

EXAMPLES OF TYPICAL PAVEMENT DISTRESS OBSERVED IN THIS STUDY

Fig A3.1 Typical severe transverse crack, Falls-McLennan Counties.

Fig A3.2 PCC repair patch with a transverse crack, Falls-McLennan Counties.

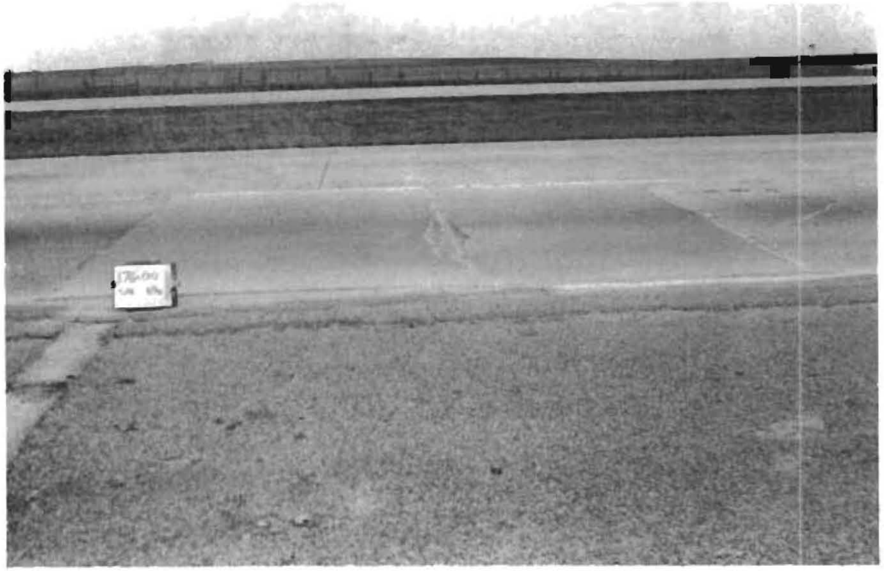

Fig A3.3 PCC repair patch with an interior transverse crack which has pumping, Falls-McLennan Counties.

Fig A3.4 PCC repair patch with a punch-out failure, Falls-McLennan Counties.

Fig A3.5 Typical minor transverse cracking, Johnson County.

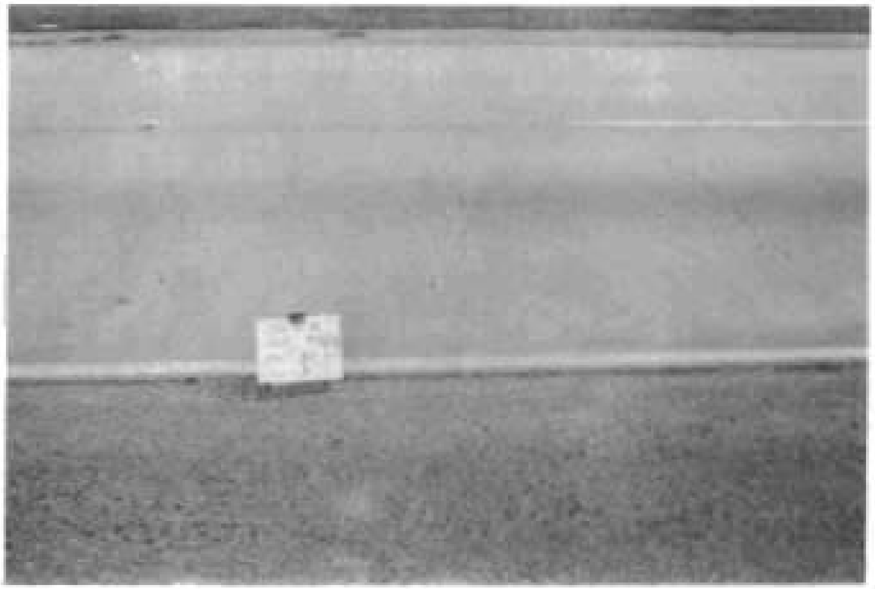

Fig A3.6 Typical minor transverse cracking, Johnson County.

Fig A3.7 Desired transverse crack spacing of from 5 to 8 feet, performance is good, Johnson County.

Fig A3.8 Desired transverse crack spacing of from 5 to 8 feet, performance is good, Johnson County.

Fig A3.9 Y-cracking (minor), Johnson County.

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