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16. Abstract

This report represents the results of a study to plan for updating and maintaining the rigid pavement condition survey database for the Texas Department of Transportation (TxDOT). These data will be used to develop performance prediction models for rigid pavements (continuously reinforced concrete, jointed reinforced concrete, and jointed plain concrete pavements) in Texas. These models will be developed for the Texas Department of Transportation for future incorporation into the Texas Pavement Management Information System (PMIS). The data collected in this project and in future projects will be combined with data collected from Project 472, which are summarized in the references, to provide improved long-term performance prediction capability.

The funds available in this small project were not adequate to actually carry out field studies, but the plans for these studies were completed and have been incorporated in Project 1342, which is ongoing, where the data will be collected.

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UPDATING AND MAINTAINING THE RIGID PAVEMENT CONDITION SURVEY DATABASE FOR TxDOT

by

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B. F. McCullough
W. R. Hudson

Research Report 187-21 Task 7

Research Project 0-187

Updating and Maintaining the Rigid Pavement Condition Survey Database

conducted for the

Texas Department of Transportation

in cooperation with the

U.S. Department of Transportation
Federal Highway Administration

by the

CENTER FOR TRANSPORTATION RESEARCH
Bureau of Engineering Research
THE UNIVERSITY OF TEXAS AT AUSTIN

July 1993

IMPLEMENTATION STATEMENT

This project would be a direct implementation of the results of previous research, which has resulted in development of an extensive overlay design procedure in Projects 3-8-79-249, "Implementation of Rigid Pavement Overlay and Design System," and 3-8-84-388, "Condition Surveys and Performance Monitoring of Existing and Overlaid Rigid Pavements." The report "Implementation of a Comprehensive Rigid Pavement Overlay Design System" (CTR Research Report 388-4) is a compilation of design techniques into a concise overlay design manual. This work will provide an excellent start for developing the integrated overlay design manual.

Other possible uses and implementations of the information contained in this database will be in analyses which are performed as part of Research Project 2/3-1-90/4-1244, "Evaluation of the Performance of Texas Pavements Made with Different Coarse Aggregates" (effects of coarse aggregate type on performance of existing concrete pavements), and Project 3-8-88/1-1169, "Concrete Pavement Design Update," where load transfer (J-factor) across joints and cracks, drainage effects, and subbase type effects are being investigated.

Another TxDOT project currently using the rigid pavement database extensively is Project 3-18-92/3-1908. In this project, the data are being used to develop utility curves and performance models for both continuous and jointed pavements. This project is sponsored by the Design Divison, Pavement Section, as part of the federally mandated effort to develop a statewide pavement management system.

Finally, representatives of the Design Division have expressed an interest in the data pursuant to the development and improvement of project level design modules. Data from jointed pavements are also needed for this task.

BENEFITS

This project will provide a number of benefits that offer a large potential savings to TxDOT. Among these are:

(1) A continuous identification of rigid pavements requiring rehabilitation. Thus, timely rehabilitation may be made that will minimize the total expenses to the taxpayers.

(2) Continuous monitoring of special test sections that permit a calibration of pavement design procedures (new and overlaid). This will ensure optimum expenditure of funds.

(3) Investigations based on long-term observations will identify the most effective construction procedures, possible changes in specifications, etc.

(4) The current database will provide quick access to information needed by engineers, planners, designers, and researchers conducting other TxDOT projects.

(5) The availability of a design manual will make it possible for District and Area personnel in TxDOT to apply improved techniques developed in recent research projects, thus producing more economical overlay design procedures.

(6) Better pavement performance will result in savings of vehicle operating and user costs.

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

DISCLAIMERS

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

NOT INTENDED FOR CONSTRUCTION,
BIDDING, OR PERMIT PURPOSES

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Research Supervisor

PREFACE

This is the final report which summarizes the basic activities of Project 0-187.7. This project is responsible for continuing the planning for data collection for long-term pavement performance evaluation of portland cement concrete pavements in Texas. The authors would like to extend their appreciation to all those who helped in this study, including Dr. Virgil L. Anderson for his expert advice on factorials, and the many persons from TxDOT who assisted us in the collection of field data and planning of future studies.

ABSTRACT

This document presents the results of a study to plan for updating and maintaining the rigid pavement condition survey database for the Texas Department of Transportation (TxDOT). These data will be used to develop performance prediction models for rigid pavements (continuously reinforced concrete, jointed reinforced concrete, and jointed plain concrete pavements) in Texas. These models will be developed for the Texas Department of Transportation for future incorporation into the Texas Pavement Management Information System (PMIS). The data collected in this project and in future projects will be combined with data collected from Project 472, which are summarized in the references, to provide long-term performance prediction capability.

The funds available in this small project were not adequate to actually carry out field studies, but the plans for these studies were completed and have been incorporated in Project 1342, which is ongoing, where the data will be collected.

Key words: rigid pavements, long-term performance, performance models, distress manifestations, performance prediction, data collection.

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SUMMARY

This research effort and the resulting data, which will be collected over the next two years, serve to provide TxDOT with an additional set of data points on its long-term performance prediction models for concrete pavements. These data will make it possible to update models currently used for rigid pavements in the Texas Pavement Management Information System (PMIS) and will ultimately save millions of dollars for the Texas Department of Transportation, by making it possible to better predict the consequences of various rehabilitation, maintenance, and design activities.

CHAPTER 1. INTRODUCTION

The Texas Department of Transportation has over 7,000 miles (112,700 kilometers) of rigid concrete pavements currently in service, and design plans call for the construction of many more miles of overlays and new pavements. The proper planning for rehabilitation and maintenance of these rigid pavements, as well as the optimum expenditure of available funds, depends to a large extent on the implementation of a statewide Pavement Management System. One of the most important components of this system is the information related to the condition of these pavements at various stages of their service life. This information is generally obtained by means of condition surveys of pavement distress.

Condition surveys constitute the data feedback system based on periodic observations that are necessary to continue improvement and implementation of the Pavement Management System. Statewide condition surveys on rigid pavements were conducted in 1974, 1976, 1978, 1980, 1982, 1984, 1987, and 1988, and they form one of the best databases in the United States on concrete pavements. However, the last full condition survey was performed in 1987, and most projects surveyed are now more than 15 years old (Figure 1.1). In order to keep the database useful, new recently placed pavements, especially those with new designs such as double-matted steel and increased thickness, must be identified and monitored. Monitoring of special-study pavement sections has provided a tremendous amount of useful information that has significantly contributed to the development of rigid pavement rehabilitation design systems, as well as criteria for prioritization and scheduling of overlays on rigid pavements at the network level.

The existing data are being used to develop performance prediction models. The effect of variables such as construction materials, subgrade type, climate, and traffic can be studied and recommendations can be developed for improvements in the design and construction specifications.

A study of the performance history of pavements, along with their rehabilitation actions, will provide important information for a pavement management system. Maintenance of a suitable rigid pavement database will create an important source of valuable information for planning, design, construction, maintenance, and rehabilitation purposes.

SIGNIFICANCE OF THE PROJECT

It is essential that the condition survey and performance monitoring of portland cement concrete pavement sections in Texas be continued in order to permit proper planning of rehabilitation and maintenance and optimum expenditure of available funds.

Additionally, actual performance of rigid pavements and overlays could be compared against the predicted performance, and recommendations could be made, if pertinent, to revise the design procedure. Likewise, improvements in the overlay design procedures could result from this feedback process.

Data from this study have already been furnished to various State and Federal projects including FHWA and SHRP and have been used to great benefit. It is anticipated that the database can be used by a number of ongoing studies and will continue to be useful for the foreseeable future in the state of Texas.

BACKGROUND

In connection with Project 3-8-75-177, "Development and Implementation of the Design, Construction, and Rehabilitation of Rigid Pavements," and Project 3-8-79-249, "Implementation of Rigid Pavement Overlay and Design System," several major works were initiated that need to be continued in the future. The first item is the condition surveys of rigid and overlaid rigid pavements that have been conducted at periodic intervals since 1974. This information has been used in connection with the development of the revised design manuals for new concrete pavements and also for overlays. In addition, a detailed computer program, PRP01, was developed that permits a prioritization of pavements in the state based on the damage associated with those pavements. The program predicts the overlay requirements on pavements that have the damage associated with those pavements. The program predicts the overlay requirements on pavements that need rehabilitation and also predicts the date of future failure and the subsequent rehabilitation needs. The program has a number of other features, such as investigating the results of fixed budgets, etc.

Sixteen projects overlaid with asphalt concrete have been monitored in connection with Projects 388 and 249. Extensive performance information including rutting has been collected over the years. For all these test sections, the distress of the existing pavement was marked and extensive follow-up measurements of the various distress types have been recorded for periods ranging from 3 to 19 years. This information has been used extensively in developing an overlay design computer program and program PRP01 that was developed for prioritizing the rehabilitation of concrete pavement and also predicting the future rehabilitation needs at later years. The observed performance has over the years permitted the study of concrete pavements behavior. Temperature models developed by Shahin and McCullough in Project 123 (CTR Research Report 123-14) permit the prediction of the temperature spectrum through a pavement structure for a range of conditions. This temperature condition information has been modeled in the CRCP4 and 5 and JRCP4 programs developed in connection with the Projects 422, 472, and

1169. A program developed by Mendoza in Project 401 also permits the inclusion of a more sophisticated version of JRCP that includes warping, horizontal movements, and load stresses.

All of these efforts point to the need for laying out a major field data collection effort which will be carried out under a future project.

CHAPTER 2. OBJECTIVES OF THE STUDY

The primary objective of the project is to outline a plan to update and maintain the existing rigid pavement database for TxDOT. This will be achieved in Project 1342 by inspecting pavement sections previously selected, by adding new pavement sections to the database (special existing sections and newly built ones), and by addressing special TxDOT requests related to the analysis of and findings from the data that have been collected thus far.

Discussions with TxDOT personnel have identified the need for adding jointed pavement sections to the database. Historical data from CTR's computer files can then be extracted for some of the selected sections to provide an "instant" history of the pavements.

Other objectives of this study are the writing of a final report summarizing the major plans and their applications, for implementation by TxDOT; the analysis of data collected in overlaid sections in the 1988 condition survey; and the calibration and improvement of prediction models for pavement performance, pavement design, traffic predictions, aggregate type effects predictions, etc.

The condition survey information collected during the past 19 years resides as SAS dataset on an IBM mainframe, and on a PC system. It is backed-up on diskettes and hard copy. The necessary computer programs to summarize and analyze the data have been developed, and presently these programs are being used to generate reports for TxDOT's use.

One use of the database is to provide input for future pavement and overlay design. Several design techniques have been developed at CTR, especially for ACP overlay to rehabilitate a concrete pavement. In the process of developing an ACP Overlay Design Manual, these design procedures have been synthesized and integrated. This process will also give directions on the development of the database in the form of variables and data of interest in the design process.

CHAPTER 3. PROJECT ACTIVITIES

This is a small project which will set the stage for a major data collection effort in the field. This chapter documents design and environmental factors which are known or expected to affect the performance of jointed concrete pavements (JCP). These factors may then be used to construct a factorial design which can be used to select JCP sections across the state for monitoring.

PERFORMANCE FACTORS FOR EXPERIMENT DESIGN

The 1986 AASHTO Design Guide lists a number of design factors which influence the performance of JCP. They are:

Traffic

Traffic exposure in the form of cumulative equivalent single axle loads (ESAL) is known to affect the performance of all pavements. Usually, ESAL must be estimated from factors such as average daily traffic (ADT), which are more widely available. A number of models have been developed for this purpose (Refs 4 and 10).

TxDOT is currently planning the installation of up to 50 weigh-in-motion stations across the state which will provide axle weight data of greater quantity and quality than those which are currently available. The locations of the proposed WIM stations are already known; they are to replace currently operating portable "loop" stations which are marked "LX" on maps which have been furnished to us by the Design Division.

For the purposes of the experimental factorial, sections should be chosen which represent (in approximately equal number) both high- and low-traffic pavements (in terms of annual ESAL). This division can be determined using the data contained in the CTR CRCP database, and from the models given in Reference 4. If at all possible, survey sections should be selected which are near the proposed WIM stations. If this is done, not only will better data be available for the sections near the WIM stations, but new and improved models for the sections which are not near WIM stations can be developed, using the WIM station data.

Roadbed Swelling

As was done for CRCP pavements, a geologic map can be used to determine the presence of swelling soils (i.e., clay).

Frost Heave

The influence of frost heave can be modeled indirectly as the interaction of rainfall and temperature. These variables may be represented either by dividing the state into the four traditional climactic zones (delineated by Thornthwaite zero contour and freeze zone, Ref 2) or by obtaining temperature and rainfall data from NOAA weather records. The current variables stored for temperature and rainfall (in the CRCP database) are only slightly more specific than the four-quadrant method. NOAA records include the necessary data to calculate additional predictor variables, such as the number of freeze/thaw cycles since the pavement was constructed or the cumulative rainfall since construction, if desired.

Modulus of Subgrade Reaction (k)

K-factors are estimates of the slab support, and are dependent on a number of factors including roadbed soil resilient moduli (M_R), subbase thickness, and subbase modulus. It would probably be easier to back-calculate k from deflections. However, the k value must be adjusted for seasonal variation. It may be possible to use calculated k values to determine a class boundary for "high" and "low" slab support based on the existing CRCP database, but it would be very difficult to select the JCP sections for survey based on these criteria. One possibility would be to use either the FWD data in the TxDOT PES file, or, more generally, the average subgrade support by county file which TxDOT has supplied to us.

Layer Characteristics

Although the Guide does not list this factor for jointed pavements, the thickness (D) of the pavement should at least be obtained from construction records and included in the factorial.

PCC Modulus of Rupture (Flexural Strength)

In Reference 3, two variables were identified as representing the stiffness of the PC concrete: modulus of rupture and elastic modulus. These moduli were stated to be a function of coarse aggregate type, water-cement ratio, and cement content. In the reference it was assumed that all pavements met the TxDOT specification of approximately 720 psi (4,968 kPA) at 28 days. If indeed all pavements have identical stiffness at 28 days, it would be meaningless to include E_C as a level in the factorial. However, the Guide specifically recommends against using the specification value because of distribution considerations. For the purposes of the database contents, if possible it would be desirable to include water-cement ratio, s for the distribution, or cement content, whichever is easily available from TxDOT records. Presumably, these factors would be constant over an entire paving project, thus minimizing collection effort.

Drainage

According to the Guide, drainage is a mandatory item for JCP design. Suggested values for drainage are provided in a table, based on the "quality" of drainage versus the percentage of the time the pavement is saturated. Since mandatory drainage improvement is currently an issue, the experimental factorial should include a variable to differentiate between "improved" and unimproved drainage.

Load Transfer

Load transfer (J-factor) may be represented in the database by three variables: 1) coarse aggregate type (as a possible factor in aggregate interlock), 2) presence or absence of dowels, and 3) presence or absence of tied PCC shoulders.

Slab Length

The distance between joints has a large impact on performance in terms of concrete tensile stress. If significant differences in joint spacing exist in the Texas JCP pavement population, an effort should be made to obtain and test this factor.

Steel Stress

Steel stress in the pavement may be modeled by percent reinforcement and bar size.

Friction Factor

The significance of frictional resistance between the slab and the underlying layer can be captured by including a variable for subbase treatment (e.g., asphalt-stabilized, lime-stabilized, crushed stone, cement-stabilized), as was done for CRCP pavements (Ref 3).

ADDITIONAL FACTORS FROM CRCP STUDY

Three additional factors affecting JCP performance not directly addressed in the Guide were considered in determining the factorial for CRC pavements (Ref 3).

Coarse Aggregate Type

The effect of coarse aggregate selection on pavement performance has been documented in several studies. It is likely based on the demonstrated effect of aggregate type on continuous pavements and the assumption that there will be an effect on jointed pavements as well. A code for the type of coarse aggregate used should be included as a level in the factorial design.

Roadbed Grading

A study was documented in Reference 3 showing a significant effect of grading on CRC pavement performance. Sections constructed on "filled" subgrade demonstrated poorer performance than those placed on "cuts," and pavements poured on the "transition" area between cuts and fills gave the worst performance. Since it is reasonable to expect similar effects on JCP, an effort should be made to collect cut/fill/transition/grade data from construction records.

Age

The effect of age on pavement performance is difficult to quantify, since it functions in part as a measure of the accumulation of other distress-causing factors, such as traffic, rainfall, and freezing/heating. However, for that reason it is essential to have it as a factor. Fortunately, it can be extracted fairly easily from TxDOT records in the form of construction date.

SAMPLING FACTORIAL

Based on the above analysis, the following sampling factorial is suggested for selecting plain jointed pavement sections for condition survey:

Aggregate		Limestone				Siliceous			
Thickness		< 10"		≥ 10"		< 10"		≥ 10"	
Age		L	H	L	H	L	H	L	H
Climate	Dowels?								
1	Y								
	N								
2	Y								
	N								
3	Y								
	N								
4	Y								
	N								

Figure 3.1. Sampling Plan for Plain Jointed Pavements.

Slab length was not used as a selection criteria, since meetings with TxDOT personnel indicated that all jointed plain pavements had a 15-foot (4.6-meter) slab length. This variable should still be collected as a covariate just in case a few jointed plain pavements had different joint spacings. The four climate types correspond to the traditional Texas climatic zones (wet/warm, dry/warm, wet/cold, and wet/warm). Coarse aggregate type was added to the factorial because other studies have indicated the strong effect of aggregate on pavement performance.

For jointed reinforced pavements:

Aggregate		Limestone				Siliceous			
Thickness		< 10"		≥ 10"		< 10"		≥ 10"	
Age		L	H	L	H	L	H	L	H
Climate	**Slab Length**								
1	30'								
	60'								
2	30'								
	60'								
3	30'								
	60'								
4	30'								
	60'								

Figure 3.2. Sampling Plan for Jointed Reinforced Pavements.

For jointed reinforced pavements, presence or absence of dowels is not included in the factorial because discussion with TxDOT representatives indicated that dowels are always present with this type of pavement. Although not many reinforced sections were built with 30-foot (9.2-meter) joint spacings, this variable is thought to be an important performance predictor and is included in the factorial.

For both pavement types, the age, pavement thickness, rainfall, and average annual low temperature would be recorded as continuous variables but are classified into low, high, or medium (or zone, in the case of climate) for the purposes of the sampling factorial. Although soil type (swelling or non-swelling) is known to affect pavement performance, it should be collected as a covariate rather than included in the factorial; this decision was made because dividing Texas into climate zones will automatically ensure that both soil types will be sampled, due to their locations in the state.

If the study of overlaid jointed pavements is desired, the above factorial could also be applied to those pavements.

COVARIATES

In addition to the above principal factors, a number of additional covariates should be collected, based on their demonstrated or anticipated effect on pavement performance. They are:

(1) Traffic (ADT, or ESAL if possible);
(2) Roadbed Swelling (High or Low, from soil maps);

(3) Average Annual Low Temperature (from NOAA weather records);
(4) Average Annual Rainfall (from NOAA weather records);
(5) Presence of Tied PCC Shoulders;
(6) Subbase Treatment; and
(7) Presence of Control Joints – this item added at the suggestion of TxDOT.

These items should be collected when possible as actual values rather than being assigned low or high levels. Since aggregate type has been shown to have a profound effect on pavement performance, it is included in the sampling factorial; because of anticipated difficulty in obtaining the data, it may be necessary to reduce this factor to a covariate. However, it is *very important* that the sample of the JCP pavement population contain both limestone and siliceous river gravel pavements.

SAMPLING METHODOLOGY

The above factorial has 64 cells. If both overlaid and non-overlaid projects are chosen, this would expand the factorial to 128 cells. Since the overall plan of the study calls for selecting about 50 projects, it will be necessary to employ a partial factorial technique to fill fewer cells but still provide sufficient degrees of freedom for the planned statistical analysis. The project statistician will be consulted before proceeding in this area.

STRATIFIED SAMPLE FOR ROADBED GRADING

Once pavement projects have been selected according to the factorial presented above, survey sections should be selected within the projects based on roadbed grading. Analysis of the CRCP database has shown that the location of a pavement on a cut, fill, transition, or grade has a significant effect on performance. Reference 4, pages 32-33, gives a comprehensive methodology for choosing these sections. It is recommended that this procedure be followed for choosing the JCP survey sections.

CHAPTER 4. CONCLUSIONS AND RECOMMENDATIONS

This project has been associated with the evaluation of field monitoring data collection for portland cement concrete pavements for TxDOT. This includes continuously reinforced concrete pavements, jointed reinforced concrete pavements, and jointed plain concrete pavements. Considerable effort has been expended in field condition surveys for Texas pavements over the past 19 years. However, no surveys have been carried out in the last several years, and a new complete field evaluation and condition survey of appropriate test sections is currently needed. It's also important that additional pavement sections be added to cover conditions not previously included in the study. The following conclusions and recommendations are made based upon the efforts in this project.

CONCLUSIONS

1. Additional field surveys are needed to extend the performance data available for portland cement concrete pavements in Texas. An expanded Project 1342 is being set up to carry out these additional surveys over the next two years.

2. Considerable effort is needed to coordinate the data collection effort planned for 1993-94 with prior surveys. It is essential that these surveys be compatible with previous surveys while at the same time assuring that modern adjustments be made as needed based on new equipment and new data collection techniques. It's also important that the data collection be compatible with the pavement evaluation system (PES) activities carried out as part of the regular pavement management program in TxDOT.

3. For the past 5 years, considerable effort has been put forth to collect data for the Strategic Highway Research Program (SHRP) in Texas. Approximately twenty CRCP test sections are included in the nationwide SHRP study in Texas. It is important that data collection in this long-term project for TxDOT be compatible with the data collection efforts carried out in SHRP, and, to the degree possible, continued observation should be made on the SHRP sections.

RECOMMENDATIONS

1. It is recommended that an expanded project be continued in TxDOT to provide the resources necessary to complete a full round of condition surveys including cracking, field deflection data, and roughness data to evaluate the performance of pavements and provide an extension of the database available for predicting pavement performance for Texas pavements. This database has been widely used in the past, but it needs to be updated based on new data points available at the current time.

2. Full coordination should be maintained with the Pavement Section of the /desugb Division of TxDOT to ensure that the correct number of sections, properly selected in the factorial, will be included.

3. Field testing equipment operated by TxDOT should be used to provide up-to-date nondestructive evaluations of the test sections.

4. Finally, the resulting data must be analyzed, along with previous data, to upgrade rigid pavement performance models used in the TxDOT Pavement Management System.

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