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16. Abstract

This report summarizes the tasks conducted under TxDOT Project 0-1778 "TxDOT Rigid Pavement Database." This document presents partial results of the work performed by researchers who collaborated in this project. Various concepts presented resulted from discussions held between TxDOT staff and CTR researchers. This sixth report is the final technical document prepared for the project. Additional information is provided in previous reports. Hence, the reader should consult the available literature to better understand the evolution of this investigation.

The primary objective of this report is to inform about the activities conducted for Research Project 0-1778. Likewise, this document contains recommendations with regard to vital tasks that should be conducted in another research project in the near future to complement the information collected about rigid pavements in Texas during the last thirty years.

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Analysis and Validation of the Usefulness of the Rigid Pavement Database: Final Report

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1. Introduction

1.1 Background

This report is the sixth and last technical report prepared for this Research Project 0-1778, "The Rigid Pavement Database (RPDB)," conducted by the Center for Transportation Research (CTR) of The University of Texas at Austin and funded by the Texas Department of Transportation (TxDOT). Project 0-1778 was initiated in 1998 and focused on pursuing parallel tasks performed by previous projects. Those tasks dealt with the maintenance of the RPDB that was initiated in 1974. The efforts conducted during the development of this project are of great value to pavement engineers, not only in Texas, but nationwide. During the last six years, hundreds of pavement test sections that rationally represent the concrete pavement network in Texas have been updated or added to the RPDB. Countless condition surveys have been conducted during the last 30 years and all the data collected have contributed to a better understanding of pavement materials and their performance under different conditions. Furthermore, the RPDB has assisted other research projects that deal with design, construction, maintenance, and monitoring of pavements. Special attention was given to those studies that focused on evaluating variables such as aggregate type and placement season of concrete pavement. This report summarizes the most relevant tasks performed during the development of this project and documents activities conducted to update the RPDB.

1.2 Objectives

The primary objective of this report is to inform about the actions undertaken for Research Project 0-1778. Likewise, the report contains recommendations with regard to essential tasks that might be conducted in another research project in the future. The development of these tasks will complement the information currently available about rigid pavements in Texas collected during all these years.

1.3 Methodology

The organization of the report is analogous to previous ones. The document is divided into six chapters that describe different tasks that were pursued during the last six years. Thus, the contents of the chapters can be summarized as follows:

Chapter 1 is an introductory section that provides background information about the project and describes the objectives and the organization of the report.

Chapter 2 provides an objective assessment of the information contained in the RPDB and describes the types of data that were collected. Instead of going through the details about the information contained in the database, it points out the main characteristics of the pavement sections included in the RPDB. The last section in the chapter describes special or satellite projects that interacted with this project and its predecessors, which have been of significant value for pavement research.

Chapter 3 describes the efforts conducted to collect concrete temperature data in various locations in Texas. A description of the initial experiment is presented, followed by a narrative of consecutive field visits to recover temperature data from i-Buttons and install more of those devices where needed.

Chapter 4 contains condensed information about all the reports prepared for this project. As this is the final technical report, it was considered appropriate to include this summary information that will allow any reader to become familiar with the evolution of the project and to find information easily.

Chapter 5 outlines recommendations regarding the requirements of a future pavement database. Although the information contained in the current database is for the most part helpful, it is a fact that research requirements and standards evolve, and therefore, this section describes the type of information that will need to be collected in future efforts.

Chapter 6 contains conclusions of the findings of this project and provides recommendations for forthcoming endeavors.

2. Assessment of Current Data

2.1 Introduction

The RPDB developed and maintained at the Center for Transportation Research of The University of Texas at Austin is probably the most comprehensive source of information related to concrete pavements in Texas. Its first field data collection process was conducted in 1974, and at that time, only continuously reinforced concrete pavement (CRCP) sections were considered. Information was recorded for 246 sections spread across Texas. It was not until 1982 that jointed concrete pavement (JCP) sections were added to the RPDB and data were recorded for 135 pavement sections.

The type of information that was collected for the pavements was not steady and it evolved according to the requirements of the year in which the data were recorded. For instance, in 1974 less detailed information was gathered for lots of sections. At that time, the main objective of the database was to start collecting valuable data for as many sections as possible, so that the population of the database could be increased rapidly. In contrast, the information that was gathered during the latest collection efforts focused on obtaining more detailed data for a reduced number of sections.

2.2 Characteristics of the Information

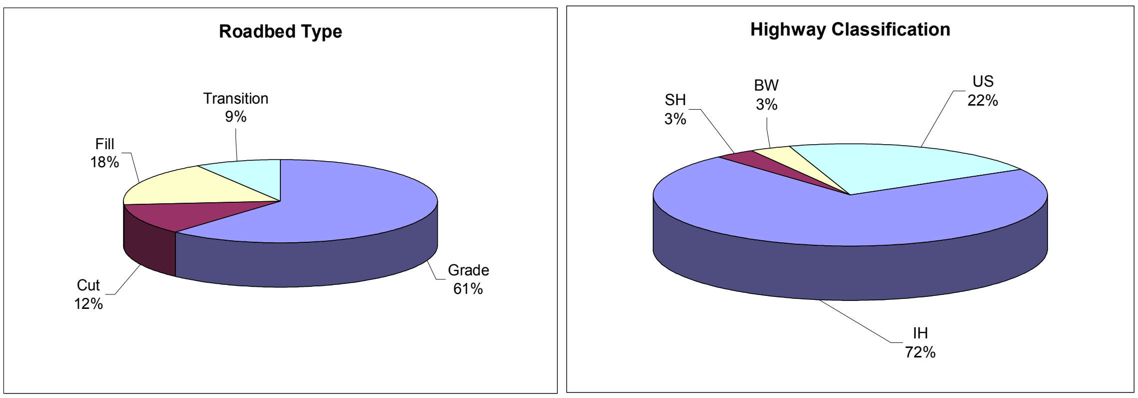
The data collected for the pavement sections are comprehensive and include almost the same variables for all of them, except for sections that are part of a special study, for which more information was usually collected. All the sections, including CRCP and JCP, are distributed in thirteen districts in Texas. Fort Worth, Yoakum, Dallas, and Houston are the districts that contain the bulk of the sections because most of the concrete pavements have been constructed in those districts.

The sections in the RPDB are all rigid pavement sections, some remain in their original condition or nonoverlaid, and some have been overlaid with asphalt. The asphalt treatments vary from thin to thick overlays and other special layers like open graded friction courses and permeable friction courses. More details about the characteristics of the information are given in the following sections.

2.3 Continuously Reinforced Concrete Pavements

The RPDB contains 424 CRCP sections and the majority is 8 in. thick. This is because lots of pavement projects that were built fifteen or more years ago were constructed using this paving technique and that thickness was a kind of standard. Thicker sections between 10 in. and 13 in. were added to the database during the collection efforts performed in the last two years. According to the latest data collected, 43 percent of the CRCP are nonoverlaid and 57 percent are overlaid (Ref 1). Almost two-thirds of the sections are located at grade, which means that they are positioned at the same vertical level as the surrounding ground. One-third of the sections is located either at cut, or fill, or transition profiles, as shown in Figure 2.1-a.

As for the location of the sections in the highway functional classification system, the interstate (IH) covers almost three-quarters of the CRCP population. The rest of the sections are located in either the United States (US), or beltway (BW), or state (SH). Figure 2.1-b shows how the sections are distributed. This classification is important because it allows identifying the influence of traffic volume and distribution on the performance of the pavement.



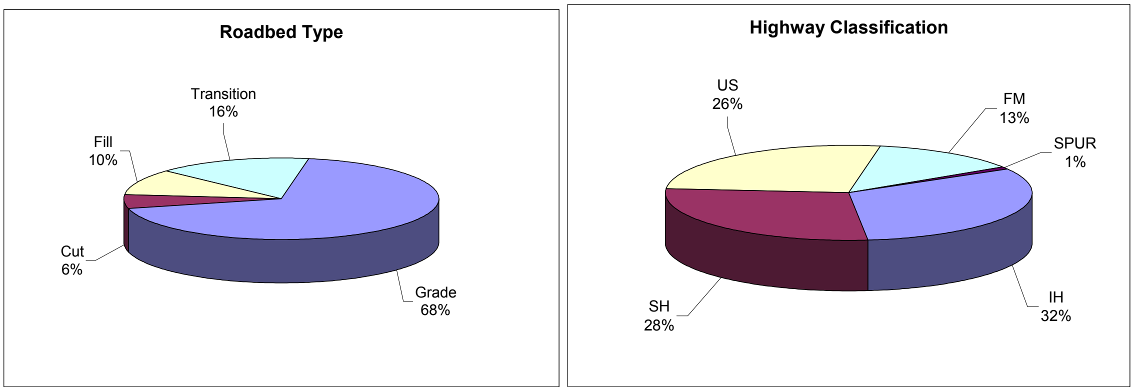
(a) (b)

Figure 2.1 Distribution of CRCP sections: (a) Roadbed Type; (b) Functional Classification

2.4 Jointed Concrete Pavements

There are 137 JCP sections in the RPDB. They are distributed within eleven districts. Houston, Dallas, and Beaumont Districts encompass the bulk of the sections. Slab thicknesses vary from 6 in. to 13 in. and the majority is 10 in. thick. According to the latest data collected, 61 percent of the JCP are nonoverlaid and 39 percent are overlaid (Ref 1). Nearly three-quarters of the sections are located at grade, and the rest are located at cut, fill, or transition. Figure 2.2-a shows the precise distribution of the sections according to their profile or roadbed.

With regard to the functional classification of the highway where the sections are located, the distribution is well balanced between IH, US, and SH. Some sections are located in farm to market (FM) roads, and two sections are located in a SPUR. Figure 2.2-b presents the exact figures.



(a) (b)

Figure 2.2 Distribution of JCP sections: (a) Roadbed Type; (b) Functional Classification

2.5 Special Projects

The RPDB project has always been in charge of collecting data for the pavement sections included in the database. Likewise, this project interacts with others where more pavement sections are monitored at greater detail. As has been stated in previous reports in this project, the RPDB contains vast information about hundreds of pavement sections in Texas. When a section was surveyed, the inventory (static) data remained the same (e.g., section identification number, location, etc.), and the performance (changing) data were updated (e.g., number of cracks along the section, patches, punchouts, etc.). For some special projects or studies, more information was collected, and that included concrete strength characteristics, monitoring of aggregates' performance, pavement deflections, etc. Frequently, those projects were referred as satellite projects and became a strong component of the RPDB.

The most recent addition of a satellite project to the RPDB included pavements for which concrete temperature data were collected. These activities were conducted in cooperation with TxDOT Project 5-1700-3 "Long-Term Performance of Portland Cement Concrete Pavement." More details about the work performed are provided later in this chapter. Table 2.1 shows the type of data that were collected since the RPDB started in 1974 and how these data collection tasks evolved to include more relevant information according to prevailing needs. Notice that the shaded cells in the table emphasize that concrete temperature data were gathered for select sections during condition surveys conducted during 2002 and 2003.

The following sections describe briefly some of the most relevant satellite projects that became part of the database project.

Table 2.1 Evolution of data collected during condition surveys

Distress	Type	Severity/ Extent	1974	1978	1980	1982	1984	1987	1994	1996	1998	1999	2000	2001	2002	2003
Cracking	Transverse [1,2,3]	Spacing						x	x	x	x	x	x	x	x	x
	Longitudinal [1,2,3]	Length	x								x	x	x	x	x	x
	Spalling [1,2]	Minor	x	x	x	x	x				x	x	x	x	x	x
		Severe	x	x	x	x	x				x	x	x	x	x	x
	Alligator [3]	Minor								x	x	x	x	x	x	x
		Severe								x	x	x	x	x	x	x
	Block [3]	Minor								x	x	x	x	x	x	x
		Severe								x	x	x	x	x	x	x
	Faulting [2]	Minor									x	x	x	x	x	x
		Severe									x	x	x	x	x	x
Corner Break [2]										x	x	x	x	x	x	x
D-Cracking [2]											x	x	x	x	x	x
Rutting [3]		Shallow								x	x	x	x	x	x	x
		Deep								x	x	x	x	x	x	x
Patching	AC [1,2,3]	0-50 ft^2	x	x	x	x	x	x	x	x	x	x	x	x	x	x
		51-150 ft^2								x	x	x	x	x	x	x
		>150 ft^2								x	x	x	x	x	x	x
	PCC [1,2]	0-50 ft^2	x	x	x	x	x	x	x	x	x	x	x	x	x	x
		51-150 ft^2								x	x	x	x	x	x	x
		>150 ft^2								x	x	x	x	x	x	x
Punchout [1]		Minor	x	x	x	x	x	x	x	x	x	x	x	x	x	x
		Severe	x	x	x	x	x	x	x	x	x	x	x	x	x	x
GPS coordinates [1,2,3]											x	x	x	x	x	x
Concrete Temperature [4]															x	x

[1] Collected for CRCPs
[2] Collected for JCPs
[3] Collected for Overlaid Pavements
[4] Collected for Special Study Sections

2.5.1 Quality Control/Quality Assurance (QC/QA) Sections

This satellite project started in 1998 and is the one for which field data collection was the most extensive. The QC/QA projects included pavement sections from different parts of the state including El Paso, Dallas, Fort Worth, and Amarillo. The main objective of the project was to develop performance-related specifications for TxDOT. The RPDB project played a key role during this study and collected data from construction projects built under varying conditions and materials. CRCP and JCP were constructed in different seasons using different types of aggregates and thicknesses. All these data served to assess the performance of pavements under the influence of a combination of those factors. The results from the QC/QA study were very satisfactory, and details about them may be found in a previous RPDB report (Ref 2).

2.5.2 Research Project 1244 Sections

This satellite project focused on the evaluation of pavement sections constructed during winter and summer seasons in Houston, Texas. Test sections were selected on SH 6, IH 35, and BW 8. During construction various concrete properties were measured including concrete strength, crack spacing, and crack width. Under the RPDB these sections were visited continuously, and data of crack spacing and spalling were updated. Likewise, a testing program that included splitting tensile and compressive strength of concrete cores was conducted. Again, the effects of aggregate type and concrete temperatures during construction were evaluated; the particulars are found elsewhere (Ref 2).

2.5.3 Research Project 3925 Sections

The studies performed under this project were a sort of continuation of the ones conducted for TxDOT Project 1244. An analysis between sawcutting time and surface crack initiation was performed. Likewise, cracking patterns were studied for CRCP constructed in Friendswood (FM 528), Cypress (US 290), and Hempstead (US 290) near Houston, Texas, using different aggregates, mix designs, reinforcement steel, and construction practices. Comprehensive information about the results can be found in the literature (Ref 3).

2.5.4 Grade 70 Steel Reinforcement Sections

These sections were constructed in Houston during 1996 and 1997. They were built using Grade 70 reinforcement steel instead of the regularly used Grade 60. To develop these projects, contractors prepared proposals recommending the use of the Grade 70 steel to reduce construction cost per square yard of pavement. The RPDB project selected sections constructed on IH 45, SH 249, and SH 146. A total of eight sections were picked for the database. Results of the findings can be found in the literature (Ref 2).

2.5.5 Concrete Temperature Data Sections

As shown in Table 2.1, surveys conducted in 2002 and 2003 went to the next step with regard to the type of data collected. Besides gathering the conventional performance data for the existing pavement sections, new sections were added and concrete temperature data collection devices were installed. These devices, or i-Buttons, allow recording temperature history for as long as six months in a row, depending on the programming set values. Installation of i-Buttons has been done for various locations in Texas, and the RPDB contains data for three locations in North Texas: Amarillo, Wichita Falls, and Childress. A detailed narrative of the installation of the i-Buttons can be found in a previous report for this research project (Ref 1.) Information about the data collected and concrete temperature history can be found in another report (Ref 4).

3. Concrete Temperature Data

3.1 Introduction

The research conducted for the RPDB project has provided the guidelines to instrument hardened concrete pavements with i-Buttons. Other research projects have focused on developing a methodology to instrument pavements at construction time. Indeed, these two approaches are complementary. Instrumentation of a pavement during construction allows recording valuable temperature data at an early stage in the life of the pavement, when temperature differentials across the depth of the slab are most crucial for the performance of the structure. On the other hand, the instrumentation of hardened concrete pavement allows determining the after-construction conditions of the pavement. For instance, the RPDB project focused on using after-construction data to estimate the maximum temperature differential (*ΔTmaximum*) for pavements located in different geographic regions in Texas (Ref 4).

This chapter presents a narrative of the efforts conducted to collect concrete temperature data in this and other projects. Likewise, a series of charts summarizes the latest temperature data collected for the pavement sections located in North Texas, in Amarillo, Childress, and Wichita Falls. The files containing the raw data are available in Microsoft Excel format.

3.2 Summary of Collection Efforts

Because i-Buttons can save temperature data for almost six months in a row, data downloading tasks were conducted at least twice a year for the last two years. In North Texas, data were collected for winter 2002, summer 2003, and winter 2003. Data collected so far is available until April 2004. When data were downloaded in January 2004, two out of nine i-Buttons had failed. Therefore, new devices were installed in all three locations, so that backup information is available for future collections that might be conducted under another research project.

3.3 Additional Instrumented Locations

At the present time, more than 200 i-Buttons are installed in concrete pavements in other locations in Texas, including Bay Town, Van Horn, Austin, and Cleveland. The objective of installing the devices in these locations is that a good geographic coverage is accomplished and reliable information is available for almost every climatic condition in Texas. Although for this project data collection tasks were conducted in August 2004 for the last time, continuous work will be conducted under a different research project for all the locations previously mentioned. Table 3.1 shows a detailed schedule of data collection efforts for locations other than North Texas.

Table 3.1 Schedule of temperature data collection in Texas

Location	Collection Date	Collection Period
Van Horn	3/29/2003	3/26/03 - 3/29/04
	4/23/2003	3/30/03 -4/23/03
	11/17/2003	6/1/03 - 11/17/03
	4/30/2004	11/18/03 - 4/30/04
	10/10/2004	Next Data Collection Date
Baytown	7/30/2003	7/26/03 - 7/30/03
	8/7/2003	7/31/03 - 8/7/03
	8/21/2003	8/8/03 - 8/21/03
	2/12/2004	8/22/03 - 2/12/04
	10/5/2004	Next Data Collection Date
Austin	10/23/2003	9/25/03 - 10/23/03
	11/13/2003	10/24/03 -11/13/03
	3/26/2004	12/18/03 -3/26/04
	10/1/2004	Next Data Collection Date
Cleveland	7/25/2004	7/20/04 - 7/25/04
	8/24/2004	7/26/04 -8/24/04
	1/25/2005	Next Data Collection Date

3.4 Data Collection for North Texas

The latest data collection information that was processed and analyzed for North Texas was presented in a previous report (Ref 4.) That information corresponded to the winter 2002 season. This time, the data for summer 2003 and partial data for winter 2003 are shown. The field visit was scheduled on January 9, 2004. The three locations were visited on that day, and the data were downloaded successfully with no delays. All i-Buttons were reset and programmed to start collecting data right away and for 90-minute intervals.

3.4.1 Wichita Falls

The pavement section is located on US 281, southbound outside lane. It is a 12-in. thick bonded concrete overlay (BCO). Further details about the precise location of the section are found elsewhere (Ref 1). Unfortunately, the i-Button located at the top of the slab, just 1 in. under the pavement surface, ran out of power and data were lost. The other two i-Buttons provided the information without a problem. The devices were reset, and new data started to be recorded at that moment. During this visit, an i-Button was programmed to record ambient temperature and was hidden in a shaded spot in a steel structure located to the side of the road. Figure 3.1 shows a crew member pointing to the i-Button attached to the steel structure. Silicone was used to fix the wire of the device to a screw-nut joint in the structure.

Figure 3.1 I-Button placed to record ambient temperature

Figure 3.2 presents the signature of the temperature data recorded from July 27, 2003, to January 9, 2004. It can be clearly seen that the higher temperature values were recorded in July, then those values dropped progressively until the end of the recorded period of time. The maximum temperature registered at mid-depth was 113.0 °F, and the minimum temperature at this same point was 35.6 °F. The maximum temperature recorded at the bottom of the slab was 107.6 °F and the minimum was 41.0 °F. As previously mentioned, only two sets of data were recovered—mid-depth and bottom of the slab.

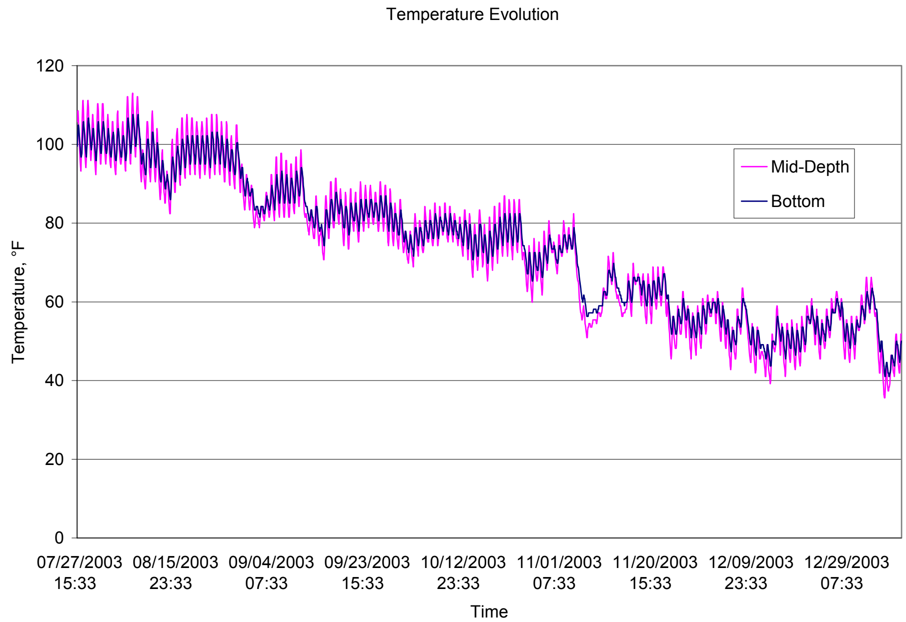


Figure 3.2 Concrete temperature data for pavement in Wichita Falls

3.4.2 Childress

The pavement is located on US 287, northbound outside lane. Originally, this section was reported as a 12-in. thick CRCP; however, after checking with the TxDOT Childress District office, the field crew found out that the section is a 13-in. thick Concrete Pavement Contraction Design (CPCD) that was constructed in 1994. The precise location and GPS coordinates of the i-Buttons can be found in another report (Ref 1). Similarly to what happened in Wichita Falls, one of the i-Buttons failed, and it was also the one located at the top of the slab. The mid-depth and bottom devices worked well and the information was downloaded easily. Figure 3.3 shows the field crew downloading the data from the outside shoulder of the pavement.

After retrieving the data, the field crew reset the i-Buttons and a new recording mission was initiated right away. Figure 3.4 shows the data for the two i-Buttons that worked well. Data were recorded from July 27, 2003, to January 9, 2004. The shape of the temperature curves is similar to the shape observed for Wichita Falls. The maximum temperature registered at mid-depth was 114.8 °F, and the minimum temperature at this same point was 31.1 °F. The maximum temperature recorded at the bottom of the slab was 110.3 °F and the minimum was 37.4 °F.

Figure 3.3 Temperature data retrieval in Childress, Texas

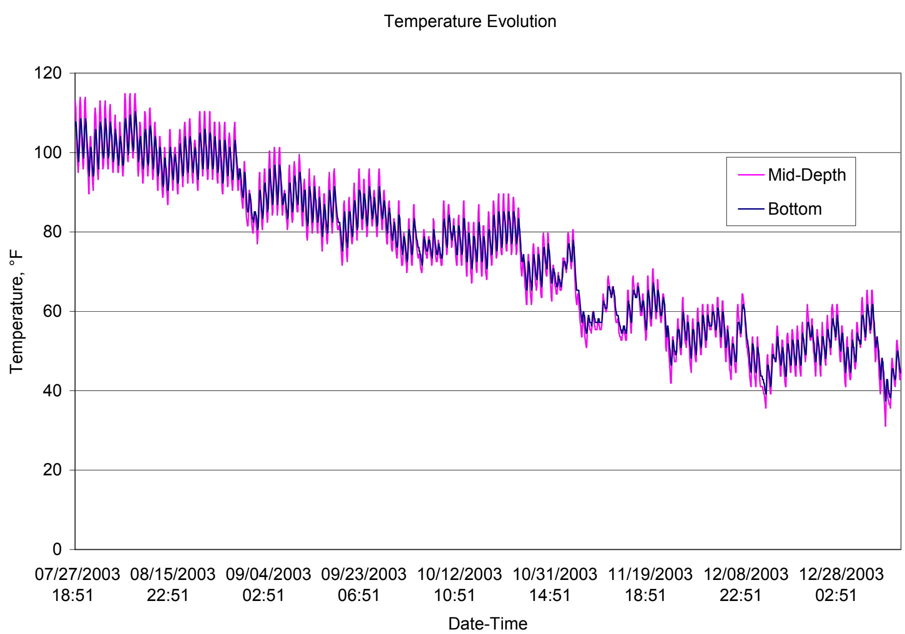


Figure 3.4 Concrete temperature data for pavement in Childress

3.4.3 Amarillo

The pavement section in Amarillo, Texas is located on Big Texan Road, just outside the TA Travel Center, a large-truck cleaning facility located on the southbound frontage road of IH 40. The exact position and GPS coordinates of the i-Buttons can be found in the literature (Ref 1). The concrete pavement section is 8 in. thick. At this location the three i-Buttons were working well and data were downloaded without trouble. Figure 3.5 shows a picture of a field crew member downloading the data from this location in Amarillo.

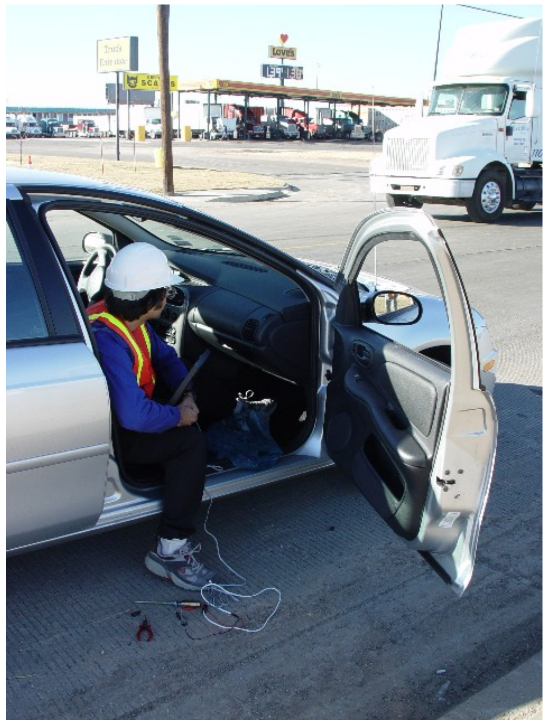


Figure 3.5 Cable downloading data from i-Buttons to computer

Temperature data are presented in Figure 3.6. As done in the other two locations, data were recorded from July 27, 2003, to January 9, 2004. The maximum temperature recorded at the top of the slab was 128.3 °F and the minimum was 11.3 °F. For the mid-depth location, the maximum temperature was 115.7 °F, and the minimum temperature was 16.7 °F. The maximum temperature recorded at the bottom of the slab was 106.7 °F and the minimum was 34.7 °F.

Notice that the minimum temperatures recorded for the top and mid-depth locations are very low. This is due to the limited capability of the i-Buttons to measure temperatures below 40 °F. When temperatures fall beyond those limits, there is a chance that the measured values are distorted. To solve this inconvenience of getting incongruent data, i-Buttons with wider temperature range should be used in future instrumentations.

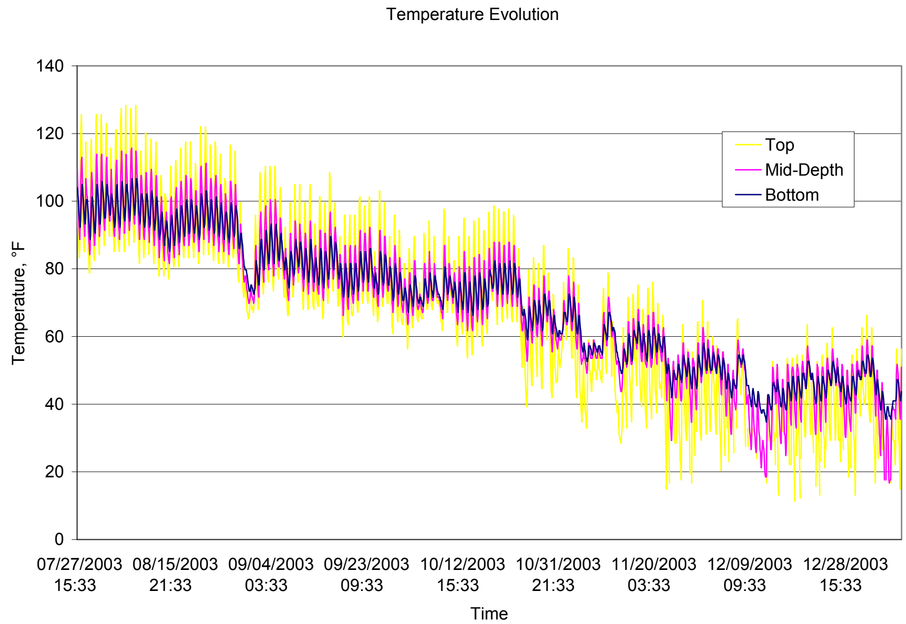


Figure 3.6 Concrete temperature data for pavement in Amarillo

3.5 Additional Temperature Data

At the time the data presented in this section were downloaded, the i-Buttons were reset to collect the supplementary information for winter 2003. Although that information was not available for reporting at press time, it is available on a CD. This information will be incorporated to the existing RPDB, but future downloading tasks will be done under another research project.

4. Synopsis of the RPDB Project

4.1 Introduction

Starting in 1974, a joined effort was initiated between the former Center for Highway Research (now CTR) and the former Texas Highway Department (now TxDOT) to collect information about Texas' rigid pavement network. The idea was to create a pavement database that could be used for many purposes, especially to monitor the performance of pavements. After thirty years data are still being collected to continue the initial objective of the database: to provide a valuable research tool for monitoring the performance of different rigid pavement designs over time and under diverse traffic loadings and environmental conditions.

The RPDB contains a significant amount of information about CRCP and JCP pavement sections across Texas. Thousands of pavement sections have been surveyed during the last three decades, and due to the nature of the data collected and to evolving needs, changes to data collection procedures have been implemented at different times, though the main purpose of the database has not changed.

This chapter condenses relevant information about all the reports generated during the development of TxDOT Project 0-1778. Because this is the final technical report, it is important to dedicate this section for that purpose. The information contained here is intended to familiarize readers with the evolution of the project and to help them find information easily.

4.2 Description Reports

During the development of this project, which started in 1998, six technical reports have been prepared to inform about research findings and tasks performed at different times. The following subsections summarize the contents of the technical reports belonging to the 0-1778 Project.

4.2.1 Report 1778-1

The title of this publication is "The Texas Rigid Pavement Database Annual Report, 1999." The report analyzes and evaluates the information collected in 1998 for the JCP sections contained in the database. It presents a demographic description of the sampled test sections and shows a quantitative analysis of distresses commonly found for this type of pavement. The relevance of climatic factors that influence the early age performance of concrete pavements is highlighted and related data are incorporated into the database. Improvements to the RPDB achieved at that time, along with future challenges, are addressed.

The following is a list of tasks that were pursued and reported in this document:

- Efforts were conducted to eliminate existing data inconsistencies – JCP inventory data were fully revised, and conflicts with redundant or misleading information were corrected.
- A revised and improved condition survey form was presented – in the past few changes were made to this form and different formats were used for JCP and CRCP. The old four forms were substituted by one that is more efficient.
- Reference markers were used to locate sections in the field – for the first time, a system that was consistent with TxDOT pavement management information system (PMIS) database was used, and sections were surveyed and identified accordingly.
- GPS technology was introduced – this locating system was used with great success for the first time in this project. Differential correction allowed relocating sections in the field with minimum physical error.
- Climatic factors affecting pavement performance were incorporated – five parameters were included: average minimum annual temperature (AMAT), average annual rainfall (AARF), average monthly evaporation rate (AMER), low temperature after construction (LTAC), and high temperature during construction (HTDC). They became part of the inventory data.
- A distress analysis of JCP sections was conducted – this analysis included the evaluation of performance of JCPs in the Dallas District built with different aggregate types.

4.2.2 Report 1778-2

The title of this publication is "Updated Status of the Continuously Reinforced Concrete Pavement Database in Texas: Improvements and Trends." The report describes and evaluates the CRCPs. A demographic description of these sections is presented, and particular attention was paid to special research studies that either emerged from the RPDB or were incorporated to it as satellite projects.

The following is a list of tasks that were pursued and reported in this document:

- Demographics of the RPDB – this information revealed new requirements of the database, and an analysis performed of the demographics showed that the great majority of the CRCPs was thirty years old or more. Therefore, younger sections needed to be added.
- GPS technology was used – as done with JCPs, a reliable relocating device was used to identify CRCPs in the field with less effort that in the past.
- Access to TxDOT PMIS was accomplished – it was now possible to compare the information contained in the PMIS with that in the RPDB to trace, complement, and prevent potential incompatibilities. PMIS data could be finally browsed remotely. Reports were generated but could not be printed locally. A user guideline was prepared to access the PMIS database via Internet.
- A photo database was developed – along with the RPDB this database was created so that images could be obtained for particular pavements. For

instance, examples of pavement distresses were digitally documented and linked to performance and inventory data for the sections in the RPDB. This photo database was created in Microsoft Access to be compatible with the RPDB.

- The satellite factorial concept was outlined − satellite factorials including Projects 1244, 3925, QC/QA, and 70 ksi Steel Sections were described and their interaction with the RPDB was explained.
- A basic distress analysis was proposed − the analysis plan included nonoverlaid sections built with different aggregates. Additional to crack spacing and distribution, distresses analyzed included spalling, punchouts, and patches. Recommendations for crack width measurement were addressed.

4.2.3 Report 1778-3

The title of this publication is "Accessing the Rigid Pavement through Microsoft Access." This report describes the preparation, contents, and use of the RPDB using Microsoft Access. The report includes examples of Access reports, tables, and queries that show the capabilities of the RPDB.

The organization of the database is presented in the following order:

- Location − identifies the pavement sections and gives unchangeable location information (inventory data.) The location field provides basic information about the section such as section ID number, district number and name, county, mileposts, reference markers, and GPS location.
- Construction − this field provides the construction date, pavement thickness, aggregate type, and overlay data. Additionally, it contains the five climatic parameters introduced and explained in Report 1778-1.
- Condition − the information contained here is related to the performance of the section. Distress data are shown for different surveying years.
- Nondestructive testing (NDT) − this information is very limited and contains deflection data for a reduced number of sections.
- Traffic − the traffic data presented corresponds to annual average daily traffic (ADT) and in some cases percentage of trucks for the given section. Equivalent single axle load (ESAL) data were collected with very limited extent.

Besides presenting the organization of the RPDB in Access, the report provides instructions on how to access the database remotely. This access requires a username and password, which is provided to TxDOT personnel as requested. Likewise, the RPDB is available in CD format, and the most current version was always provided to the project director. Finally, the document describes the process that should be followed if the RPDB needs to be accessed using other platforms such as SAS or Microsoft Excel.

4.2.4 Report 1778-4

The title of this report is "Assessment of Data Collection and Supplementary Tasks Conducted for the Texas Rigid Pavement Database." This publication explains in great detail the way in which the RPDB collection factorial was organized. It presents an application of the database by showing an analysis of distresses for pavements located in the Houston District. Likewise, it shows the activities performed for the corresponding reporting cycle.

The following is a list of tasks documented in this report:

- Demographics of the RPDB − it contains updated demographics of both JCP and CRCP sections. The previous demographics for JCPs were presented in Report 1778-1; for CRCPs they were presented in Report 1778-2.
- Collection of data by climatic regions − this section shows how data were collected by climatic region in accordance to the Thornwaite Moisture Index (TMI) (Ref 1.) Texas is divided into four regions: Region 1 is Wet−Freeze (northeast quadrant of the state), Region 2 is Wet−No Freeze (southeast quadrant of the state), Region 3 is Dry−No Freeze (southwest quadrant of the state), and Region 4 is Dry−Freeze (northwest quadrant of the state).
- Case study of satellite project − this presents an application of the database whereby an extensive distress analysis is performed. The example analyzes and compares the performance of a pair of sections located in Houston. This quantitative analysis of distresses considers aggregate type, reinforcement steel content, and other variables. The results present a comprehensive statistical analysis of the distresses, additional to crack spacing and distribution. Finally, the example shows how a distress index (DI) could be used to objectively rate the condition of a pavement, and based on that number, decisions could be made to either rehabilitate the pavement or leave as is.
- Developments for concrete temperature data collection − this section of the report documents the initial tasks performed to instrument the pavements in North Texas using i-Buttons. Field tasks are explained in detail with pictures showing the instrumentation process. Precise locations of the i-Buttons in Wichita Falls, Childress, and Amarillo, as well as description of the pavements characteristics are given.
- Addition of new overlaid sections − the data presented here correspond to asphalt sections from the Yoakum, Bryan, and Atlanta Districts. These sections were studied jointly with TxDOT Research Project 0-4398.
- Addition of new thick CRCPs − a brief description of these sections is provided. Those recently added sections are either 10 in. thick or 12 in. thick and are located in Yoakum and Atlanta Districts.

4.2.5 Report 1778-5

The title of this publication is "Analyses Performed Using the Rigid Pavement Database in Texas." It presents examples of analyses that can be conducted using the information contained in the RPDB. It also describes the tasks that were carried out for the corresponding reporting period. The report emphasizes the need for conducting more research on pavements in Texas and in the United States. Among the data analyses presented are a methodology to predict the minimum concrete pavement temperature using climatic data and a spalling criterion model for pavement overlay.

The following is a list of tasks that were pursued and reported in this document:

- Prediction of minimum concrete temperature – this task was performed to propose a methodology to determine more accurate minimum temperature values than those used in current designs. This approach recommends using available climatic data to estimate concrete temperature for four geographical regions in Texas. The work described in Chapter 3 and the data obtained from field data collections were used to develop this methodology.
- Update of spalling model – this section focused on using current spalling data from the RPDB to update the existing spalling model. An example is presented that shows the application of the new proposed model, which might be used as an overlay design criterion.
- Collection of winter 2002 concrete temperature data – this section presents the tasks conducted for the collection of the information in North Texas.
- Development of a deflection model for pavement overlay – analogous to the spalling model, this section describes the methodology that might be followed to determine if a pavement section should be overlaid based on deflection data. An example is shown for a pavement section located in the Atlanta District.

4.2.6 Report 1778-6

This is the final technical report of the RPDB project. The title of this publication is "Analysis and Validation of the Usefulness of the Rigid Pavement Database: Final Report." Describing the contents of this report would be redundant; therefore, the objectives of the report and its contents are summarized in Chapter 1.

4.3 Additional Reports and Projects

The RPDB initiated in 1974 and Project 0-1778 started in fiscal year (FY) 1998. The latter was initiated partly to continue with efforts conducted in previous TxDOT projects that dealt with the management of the RPDB. Hence, there were a number of projects that collected data in the past. Likewise, there are dozens of reports that have been prepared and that used the database. The CTR maintains an online catalog of the reports that were prepared for all research projects. This catalog can be accessed via the Internet through the following link:

http://library.ctr.utexas.edu/dbtw-wpd/textbase/websearchcat.htm

Figure 4.1 shows the webpage that is displayed when this hyperlink is followed. When the words *database* or *pavement* are typed in the Subject field, various reports related to the RPDB are displayed. Figure 4.2 shows partial results from a query obtained when the word *database* was typed and the "Submit Query" button was clicked. Some reports can be downloaded to the computer; others should be requested to CTR's library.

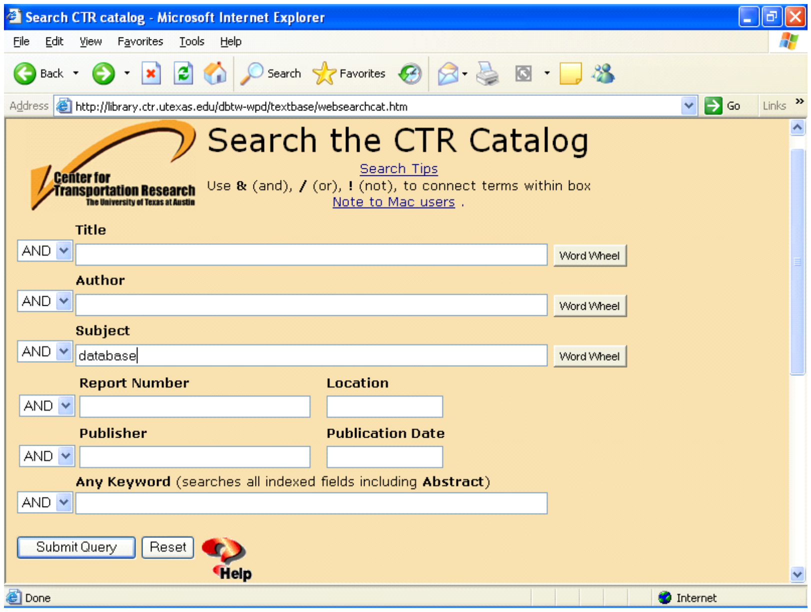


Figure 4.1   CTR's library online catalog search webpage

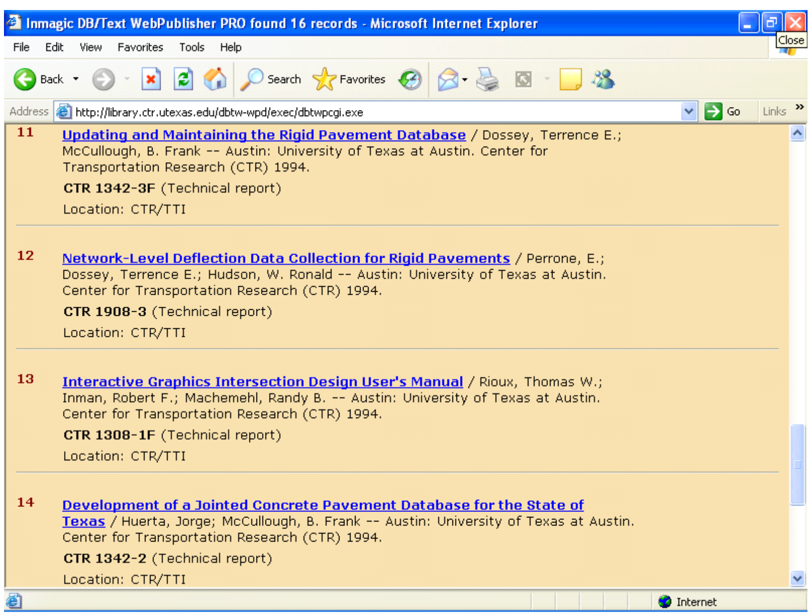


Figure 4.2   Results of search when" database" is queried

5. Database Needs

5.1 Introduction

The TxDOT 1-0-1778 project has made a great effort to maintain and improve the quality of the information stored in the database and increase its usefulness. The quantity and quality of the data collected were always the most important aspects of the RPDB that maintained its soundness. As previously mentioned, and because data have been collected for a long period of time, there were some variations in the way data were collected and in the number of sections surveyed. Early in the 1970s and 1980s, it was common practice to survey as many sections as possible; however, the data collected were not really detailed. This practice is understandable, since it was necessary to "recruit" lots of sections and start processing data. Later during the 1990s, collection efforts started to focus on more definite problems in pavements. TxDOT district pavement engineers started to express different specific concerns about pavements in different areas. For instance, the Houston District observed that crack spalling was a distress that required closer attention because it started to accelerate pavements' deterioration.

Paying attention to specific pavement problems and meeting requirements for new developing projects helped tailor the RPDB project to collect data accordingly. Some satellite projects of the RPDB actually started as a result of this process, after experiencing particular problems. More detailed data started to be collected to solve those problems and analyze materials' behavior. For some sections lots of information was collected including concrete strength, crack spacing history, crack width, deflection, etc.

This chapter outlines recommendations that will hopefully meet the requirements of a future pavement database. Even though the information currently available in the database is very helpful, it is necessary to keep in mind that the database needs change as new construction materials are used, new construction procedures are applied, new equipment is developed, and new failure mechanisms are discovered.

5.2 Recommendations for Future Collections

Although this is the final technical report for TxDOT Project 0-1778 and no more activities will be performed under the current contract, recommendations are provided for future data collection efforts to be conducted under a different project. The objective of these recommendations is to enhance the quality of the data available in the current database. Some of the proposed tasks have already been pursued for the existing database; however, continuation and adaptation of these activities will ensure the reliability of the database for a long time.

5.2.1 Addition of Thick CRCPs

The current database maintains the information of nearly five hundred CRCPs of which nearly 15 percent are 10 in. thick or more. Thus, although there is a good representation of the CRCP network in the RPDB, younger sections with greater thicknesses are required to balance the current demographics. It is necessary to elaborate a plan to add those sections, and to accomplish that, it will be required that TxDOT pavement district engineers get more involved in the section selection process. It is known from experience that the results and information obtained from the continuous interaction between the state agency and researchers produces better results in terms of research products.

5.2.2 Retrieve Traffic Data from Weight-in-Motion (WIM) Stations

Traffic data are among the most important variables that need to be updated in a future database. The traffic information available in the current database is outdated. This inconvenience caused delays when analysis of information involved the inclusion of traffic. It was always necessary to either access the PMIS via the Internet or request the information from TxDOT. The first of these actions was probably the most inconvenient. Accessing the PMIS via the Internet is very limited, because only online browsing is possible. Storing data displayed on the computer screen requires extensive copying and pasting operations to a text file, consuming a lot of time. In other words, the data cannot be downloaded directly to the remote computer.

Alternatively, the information that can be obtained from WIM stations is extensive, and not all is required for the database. Usually, it is necessary to gather data of ADT by vehicle type, axle weight, and distribution. With that information, and assuming a traffic growth, ESALs can be estimated. Having updated ESALs data in the database will be of great benefit, especially to better understand the performance of newer, thicker pavements that are being constructed and were already added to the RPDB.

5.2.3 Additional Field Testing

The data collected for the existing database, except for special or satellite studies, were limited to visual distress information and crack spacing. In general, when another research project developed a field test plan, that information was also included in the RPDB. This was a convenient way to incorporate new and more detailed information to the database. It is highly recommended that if possible, more field testing be performed in addition to the visual condition survey. Among the testing and data collection procedures that could be performed are the following:

- Deflection – a falling weight deflectometer should be used to obtain deflection information of selected pavements, especially those located on main routes, where deterioration occurs more rapidly than in secondary highways.
- Coring – although this is a destructive test that requires a great effort from TxDOT and researchers, the information that can be obtained from extracted cores of pavements is invaluable. The sampling of cores would depend on a predefined plan, usually outlined by the requirements of special projects.
- Seismic testing – a Portable Seismic Pavement Analyzer (PSPA) can be used for quality assurance/quality control activities. This device is capable

of detecting voids beneath the concrete pavement slab and delamination problems. It will be appropriate to monitor pavement thicknesses at a network level, since at the project level it will be unfeasible; additionally, PSPA's estimation of the elastic modulus of concrete can be calibrated to destructive testing performed on cores.

- Temperature and moisture devices – the instrumentation of pavements using i-Buttons to measure concrete temperature has been very successful. The information that can be obtained from these devices is very useful and should be extended to other locations in the state. Likewise, it will be relevant to measure concrete, subbase, and subgrade moisture levels along time. For this purpose hygro-Buttons could be installed in various locations defined by a sampling factorial.

5.3 Recommendations for PMIS Database

The following are some recommendations of concepts that can be incorporated into PMIS. Some of these concepts correspond to the findings obtained from other research projects (Ref 5).

1. Maintain a separate research database – it is believed that keeping the PMIS and RPDB separate will produce better results for pavement management because they complement each other. The PMIS was prepared to manage data at the network level, and the RPDB deals with data at the project level. The interaction of both sources of information facilitates the identification of significant variables in pavements performance.
2. Changes in PMIS – in case changes are programmed to the PMIS database, it is recommended that they are implemented in stages and modules.
3. Expand PMIS – it will be beneficial to include and update inventory variables such as rehabilitation history, concrete tensile strength, concrete temperature at setting, concrete layer thickness, coefficient of thermal expansion (CTE) of coarse aggregate, and subbase type. Likewise, pavement performance data that could be added or updated include spalling, punchouts, AC patches, PCC patches, failures per mile, and mean crack spacing.
4. Update PMIS – the updating process will create and populate a layer database and will include rehabilitation history, layer characteristics, thicknesses, dates of construction, and maintenance history.

5.4 Specific Requirements: 2002 AASHTO Guide

The information contained in the RPDB is mostly the result of visual inspections of the pavement sections stored in the database. For special studies or projects, this information is complemented by other records like traffic data, concrete strength, subbase and foundation soil characteristics, deflection data, etc. As a result, these special studies are the ones that provide more useful information for design and prediction performance of pavements.

The objective of the RPDB project was to maintain and update the existing database, and to accomplish that, several field and office tasks were performed on a regular basis. Although the information stored in the RPDB has been very useful in coordinating additional research efforts and better understanding pavement behavior, more data collection is required in addition to the one obtained from visual inspections. The data to be collected should comply with the requirements for the implementation of the new pavement design guide published by the American Association of State Highways and Transportation Officials (AASHTO) – the AASHTO 2002 Pavement Design Guide. A partial list of data that should be collected in a future database includes the following:

- Load transfer – this information should be collected using deflection measuring equipment, like falling weight deflectometer (FWD) and rolling dynamic deflectometer (RDD). Load transfer should be measured across cracks and joints of pavements, and the load transfer capability should be estimated with one of the available algorithms, like the one specified by AASHTO (Ref 6).
- Crack width – this is a very sensitive variable that is affected mostly by concrete temperature. Thus, measuring crack width values at different times of the day will provide a range of values that requires engineering judgment. A previous report published by this research project recommends an approach for collecting this type of data (Ref 2).
- Roughness – this parameter has never been collected in this or previous projects that managed the RPDB. However, the PMIS database contains some useful information at the network level. Collecting roughness in a future database will allow estimating the international roughness index (IRI) that is widely used worldwide to estimate the serviceability of pavements.
- Subgrade/Foundation properties – the current RPDB contains basic information about this parameter. For the foundation properties, the RPDB classifies the soil as swelling and not-swelling. Although this information is very basic, at least it provides a rough idea of the characteristics of the soil. This information should be more detailed in a future database, and it should describe plasticity characteristics and strength of the materials, if possible. To accomplish the latter, a testing device such as the dynamic cone penetrometer (DCP) might be used.
- Concrete temperature – this parameter is not widely included in the RPDB , nor has it been included in other pavement databases like the long-term pavement performance (LTPP) in a comprehensive way. The information about concrete temperature that has been collected in this and other TxDOT research projects using i-Buttons will be fundamental to complete this task. At the present time, vast information has been collected for various pavements across Texas. One of the goals of collecting concrete temperature data should be estimating temperature differentials (ΔT) across the depth of the slab.
- Traffic – this information is one of the most important features of a good pavement database. Because traffic plays a crucial role in pavement performance, additional care should be given to the collection of this

information. Some of the most important characteristics of traffic data that should be collected are volume, distribution (% of trucks), tire pressure data, etc.

- Distress evaluation – recording the history of distresses in pavements is a good way to determine the pavement performance; however, this parameter should be related to others like traffic and climate. The current RPDB contains very good information about distresses and cracking in pavements. The next step will be to incorporate all the collected distresses into a single parameter that will provide a good idea of the condition of the pavement. For this project, previous reports (Ref 1,4) have shown how the data can be analyzed. The end results can be summarized in a single number such as the distress index (DI).

The recommendations previously listed will aid in developing a more complete pavement database. Although the recommendations have been made in such a way that the quality of the data complies with AASHTO's 2002 pavement design guide, it does not necessarily mean that they have to be pursued for that sole purpose. Alternatively, the data collected could be used for modeling pavements in the state of Texas, which means that TxDOT could have its own pavement design models that will be appropriate for in-house applications.

6. Conclusions and Recommendations

6.1 Introduction

TxDOT Project 0-1778 “The Rigid Pavement Database” started in FY 1998. This project continued the efforts of previous projects that managed and updated the database. As has been previously mentioned, the RPDB started in 1974, when Project 123 performed the initial tasks of designing an input guide for the database and implementing a rigid pavement design system. Likewise, Project 21 started the data collection for the RPDB in 1974. At that time, surveys were conducted by surveyors from inside a vehicle moving on the pavement shoulder.

Later in 1978, Project 177 continued the tasks initiated by the previous projects and condition surveys were conducted for the entire CRCP network. Next, Project 249 conducted condition surveys in 1980 and 1982 with only minor changes in procedures. Project 388 started in 1984, and brought major changes to the data collection procedure. For field collection tasks, this project introduced the use of a computer adapted to the vehicle’s battery. Although this adaptation was quite a challenge at that time, the results were fulfilling and good information was collected.

In 1987, Project 472 implemented the most profound changes to the RPDB and collection procedures. At this time, it was decided not to survey the entire pavement network. Instead, a statistical analysis was performed to develop a sampling factorial to identify a group of sections that would represent the overall population. At the same time, it was decided to stop surveys done as “windshield inspections”; instead, two surveyors performed the survey on foot. This methodology allowed the surveyors to collect more detailed data with regard to distress. Crack spacing was then collected and punchouts and patches were recorded with greater detail and size and number were included. After a seven-year gap, Project 1342 resumed collection tasks in 1994. It was in this project when collection of data for JCPs was restarted, after the collections in 1982 and 1984. Likewise, this project initiated a relationship between the PMIS and the RPDB. In 1996, Project 2952 was in charge of updating and expanding the RPDB; however, the latter task was not accomplished satisfactorily.

Finally, Project 0-1778 started in 1998 and continued the previous efforts. Since then, multiple tasks have been updated and have enriched the quality of the information contained in the database. Detailed information about the tasks performed in this project can be found in this and other reports belonging to the 1778 report series.

6.2 Conclusions

This project has performed a number of tasks focused on the enrichment of the existing pavement database. Numerous improvements have been attained in the last six years. The following is just a summary of those achievements, and the reader is referred to previous reports prepared for this project, where details about periodic evaluations are contained.

1. Initial problems and inconsistencies of the data in the RPDB from previous projects have been eliminated.
2. Inventory and performance data were updated for both CRCPs and JCPs. The information is very consistent for the last six years, when this project started. The performance data stored before this project were recorded in a simpler way, and distress data are not as specific as they are now. This means that information about distresses that was collected seven or more years ago has a different format, but is useful as well.
3. The implementation of a redundant relocating method of sections was successfully implemented in this project. All sections were relocated in the field using three methods: GPS coordinates, mile markers, and pavement marks. This approach has proved to be efficient, especially when maintenance activities were performed and paint marks on the pavements were deleted.
4. All the information collected for the sections was continuously input into electronic format, and updated versions of the database were periodically provided to the project director. Additionally, access to the RPDB was accomplished via the Internet and data can be browsed easily.
5. A photo database was created and it includes pictures of most of the sections surveyed. This database is linked to the RPDB and was found to be very useful, especially when looking for typical pavement distresses or when looking at specific highways or districts.
6. Several new CRCP sections with a thickness 10 in. or more were added to the RPDB. The demographics, although not yet well balanced, show that a good effort was made in this respect. Likewise, and in partnership with other TxDOT projects, asphalt overlay sections using different mixes were also added to the database. The demographics of the database also show that younger sections, maybe constructed during the late 1990s or after, have to be added to better represent the current CRCP network.
7. The current Microsoft Access version of the database requested for this project has limited analysis capabilities. Although it shows promise, most average users do not know how to query the information. For better analysis of the database, either Microsoft Excel or SAS have been used with great success.
8. Investigation revealed that climatic variables such as ambient temperature, wind speed, and solar radiation have a great effect on the performance of concrete pavements, in addition to material, construction, and loading conditions. Two models were proposed in this project to predict the minimum concrete design temperature. The models are reliable and can be implemented on a statewide basis (Ref 4).
9. An updated pavement distress index (DI) model was proposed in this project. This model improved the existing model developed in the 1980s, which did not considered spalling. This index can be used as a good guideline for pavement rehabilitation decisions. The study conducted under this project proposed a criterion to differentiate between two types of spalling based on dimensional characteristics.

10. Deflection data were analyzed using the information from the database. The concepts of deflection ratio and stress ratio were introduced, and their combination could be used as a decision criterion for pavement overlay and to determine the type of overlay required.

6.3 Recommendations

Most of the tasks conducted for the RPDB were periodic and repetitive due to the nature of the project. Nevertheless, the way in which data are analyzed makes a great difference and demonstrates the benefits that can be obtained from a well-maintained database. During the last six years, several research tasks were proposed and implemented and various ways to analyze the data in the RPDB were presented. In spite of this, to cope with the pace at which technology advances these days, more research has to be performed and should result from a more reliable pavement database. The analyses conducted using data from the RPDB are just examples of what can be done. Given the potential of the information in the database, it is advisable that further analysis be conducted. The activities that might be pursued in the near future in other projects will trace a path to improve the quality of the RPDB and its applications.

Chapter 5 provided a series of recommendations to enhance the current RPDB; thus, it will be redundant to list them here again. Instead, it is relevant to mention that a future database should be reorganized in such a way that users could access the information in platforms or levels. For instance, Level 1 would provide very detailed information about a pavement section including inventory and performance data plus detailed traffic, deflection data, concrete temperature history, crack spacing and width, and so forth. Likewise, Level 2 would present inventory and performance data, partial traffic data (e.g., ADT), and crack spacing. Finally, Level 3 would give limited information about a pavement section like inventory and partial performance data.

This report describes a series of tasks conducted under TxDOT Project 0-1778. The information presented here shows only partial results of the work performed by researchers. Some of the concepts presented resulted from discussions held between TxDOT staff and CTR researchers. This report is the sixth and final technical document prepared for this investigation. Supplementary information is provided in previous reports. Therefore, to better understand the evolution of this project, the reader should consult the available literature.

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