Long-Term Pavement Performance Information Management System: Pavement Performance Database User Reference Guide

PUBLICATION NO. FHWA-RD-03-088 (Update) November 2011

U.S. Department of Transportation
Federal Highway Administration

Research, Development, and Technology
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FOREWORD

This document provides information to aid in understanding and using the Long-Term Pavement Performance (LTPP) program pavement performance database. This document provides an introduction to the structure of the LTPP program, the relational structure of the LTPP database, a description of the location of various data elements, contents of the data tables, tips on efficient means of manipulating data for specific types of investigations, and examples of Structured Query Language (SQL) scripts that can be used to build user-defined custom extractions.

The LTPP program is an ongoing and active program. To obtain current information and access to other technical references, LTPP data users should visit the LTPP Web site at **http://www.fhwa.dot.gov/research/tfhrc/programs/infrastructure/pavements/ltpp** .

LTPP data requests, technical questions, and data user feedback can be submitted to LTPP customer service via e-mail at **ltppinfo@dot.gov**.

Jorge Pagán-Ortiz
Director, Office of Infrastructure
Research and Development

NOTICE

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA-RD-03-088 (update)		

4. Title and Subtitle	5. Report Date
LONG-TERM PAVEMENT PERFORMANCE INFORMATION MANAGEMENT SYSTEM PAVEMENT PERFORMANCE DATABASE USER REFERENCE GUIDE	November 2011
	6. Performing Organization Code
7. Author(s) Gary E. Elkins, Peter Schmalzer, Travis Thompson, Amy Simpson and Barbara Ostrom	8. Performing Organization Report No.
9. Performing Organization Name and Address MACTEC Engineering and Consulting, Inc. 12104 Indian Creek Court, Suite A Beltsville, MD 20705-1242	10. Work Unit No. (TRAIS) 11. Contract or Grant No. DTFH61-10-C-00001
12. Sponsoring Agency Name and Address Office of Infrastructure Research and Development Federal Highway Administration 6300 Georgetown Pike McLean, VA 22101-2296	13. Type of Report and Period Covered Update to Final Report, August 2002– November 2011 14. Sponsoring Agency Code

15. Supplementary Notes

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16. Abstract

This document provides information to aid in understanding and using the Long-Term Pavement Performance (LTPP) program's pavement performance database. This document provides an introduction to the structure of the LTPP program, the relational structure of the LTPP database, a description of the location of various data elements, contents of the data table, tips on efficient means of manipulating data for specific types of investigations, how to obtain data, and example Structured Query Language (SQL) scripts that can be used to build user-defined custom extractions. The document is updated for each standard data release (SDR) of LTPP data. It also includes information on the database files used by the LTPP Traffic Analysis Software (LTAS) which is now included in the SDR.

17. Key Words	18. Distribution Statement
Asphalt concrete, continuously reinforced concrete pavement, database, database user guide, deflection measurements, dynamic load measurement, ESAL, general pavement studies, jointed plain concrete pavement, jointed reinforced concrete pavement, LTPP, pavement distress, pavement material properties, pavement performance, pavement profile, portland cement concrete, seasonal variations, specific pavement studies, traffic load.	No restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA 22161.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	203	

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
^oC	Celsius	1.8C+32	Fahrenheit	^oF
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380. (Revised March 2003)

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LIST OF ACRONYMS AND ABBREVIATIONS

AADT	Annual average daily traffic
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
AC	Asphalt concrete
AIMS	Ancillary Information Management System
ANN	Artificial Neural Network
ASTM	American Society for Testing and Materials
ATB	Asphalt-treated base
AVC	Automated vehicle classification
AWS	Automated weather station
BBR	Bending-beam rheometer
CCC	Canadian Climatic Center
CRCP	Continuously reinforced concrete pavement
DLR	Dynamic load response
DSR	Dynamic shear rheometer
DT	Direct tension
ESAL	Equivalent single-axle load
FHWA	Federal Highway Administration
FIPS	Federal Information Processing Standards
FWD	Falling-weight deflectometer
GPS	General Pavement Studies
GPR	Ground Penetrating Radar
HMA	Hot-mix asphalt
HMAC	Hot-mix asphalt concrete
IRI	International roughness index
JPCC	Jointed portland cement concrete
JPCP	Jointed plain concrete pavement
JRCP	Jointed reinforced concrete pavement
LEF	Load equivalency factor
LTPP	Long-Term Pavement Performance
LTAS	LTPP Traffic Analysis Software
LVDT	Linear variable differential transformer
MEPDG	Mechanistic-Empirical Pavement Design Guide
NCDC	National Climatic Data Center
NCHRP	National Cooperative Highway Research Program
NRC	National Research Council
OWS	Operating weather stations
PADIAS	Pavement Distress Analysis System
PATB	Permeable asphalt-treated base
PCC	Portland cement concrete
PMA	Plant-mixed asphalt
PPDB	Pavement Performance Database
PVR	Potential vertical rise
QC	Quality control
RDBMS	Relational database management system
RMSVA	Root mean square vertical acceleration
SAMI	Stress-absorbing membrane interlayers
SHRP	Strategic Highway Research Program
SI	International System of Units
SMP	Seasonal Monitoring Program
SPS	Specific Pavement Studies
VWS	Virtual Weather Station
WIM	Weigh-in-motion

CHAPTER 1. LTPP PROGRAM OVERVIEW

1.1 BACKGROUND

During the early 1980s, the Transportation Research Board (TRB) of the National Research Council, under the sponsorship of the Federal Highway Administration (FHWA) and with the cooperation of the American Association of State Highway and Transportation Officials (AASHTO), undertook a Strategic Transportation Research Study (STRS) of the deterioration of the Nation's highway and bridge infrastructure system. The study recommended that a Strategic Highway Research Program (SHRP) be initiated to focus research and development activities on improving highway transportation. The study report, published in 1984 as TRB Special Report 202, *America's Highways, Accelerating the Search for Innovation*, recommended six strategic research areas. The Long-Term Pavement Performance (LTPP) program was one of these areas. During 1985 and 1986, independent contractors developed detailed research plans for SHRP. The detailed research plans were published in May 1986 as a TRB report entitled *Strategic Highway Research Program–Research Plans*.

The LTPP program was envisioned as a comprehensive program to satisfy a wide range of pavement information needs. It draws on technical knowledge of pavements currently available and seeks to develop models that will better explain how pavements perform. It also seeks to gain knowledge of the specific effects on pavement performance of various design features, traffic and environment, materials, construction quality, and maintenance practices. As sufficient data become available, analyses are conducted to provide better performance prediction models for use in pavement design and management; better understanding of the effects of many variables on pavement performance; and new techniques for pavement design, construction, and rehabilitation.

The strategy behind the LTPP program represents a significant shift in the traditional research approach. Traditionally, pavement performance research was divided into specific topics of limited scope and duration, which started with data collection and ended with recommendations based on analysis of the collected data. To overcome some of the challenges posed by the study of pavement behavior in short-term efforts, the LTPP program was established as a long-term national effort. Under the LTPP paradigm, data collection is conducted in advance of the development of many specific data analysis objectives. Since individuals not involved in data collection operations conduct many of the important data analyses, the LTPP program has invested in the development of a publicly accessible database and database use tools.

1.2 OBJECTIVES AND SCOPE OF THE LTPP PROGRAM

The overall objective of the LTPP program is to assess long-term performance of pavements under various loading and environmental conditions over a pavement's life. The specific objectives for the LTPP program are:

1. Evaluate existing design methods.
2. Develop improved design methodologies and strategies for the rehabilitation of existing pavements.
3. Develop improved design equations for new and reconstructed pavements.

4. Determine the effects of: (a) loading, (b) environment, (c) material properties and variability, (d) construction quality, and (e) maintenance levels on pavement distress and performance.
5. Determine the effects of specific design features on pavement performance.
6. Establish a national long-term pavement database to support SHRP objectives and future needs.

The LTPP program is a study of the behavior of in-service pavement sections. These pavement sections have been constructed using highway agency specifications and contractors, and subjected to real-life traffic loading. These in-service pavement sections are classified in the LTPP program as General Pavement Studies (GPS) and Specific Pavement Studies (SPS). GPS consist of a series of studies on nearly 800 in-service pavement test sections throughout the United States and Canada. SPS are studies of specific variables involving new construction, maintenance treatments, and rehabilitation activities.

1.3 TEST SECTION DESIGNATIONS

To provide a logical basis for test section designations, a broad-based experimental approach has been used. Test sections are classified as GPS or SPS. The fundamental difference between these two classifications is that at the start of the LTPP program, the GPS test sections are existing pavements and the SPS projects are sites where multiple test sections of differing experimental treatment factors are constructed. When a GPS or SPS test section is rehabilitated, it can be assigned to a GPS rehabilitation designation.

While the LTPP test section classification methodology is based on experimental concepts, data users are encouraged to develop their own classification methods to meet specific analytical objectives. For example, the SPS-1 experiment is designed to extend the findings from the GPS-1 and -2 studies.

In the published literature, the LTPP projects are designated by experiment designs. A factorial combination approach has been used for the development of the experiment design designation of each GPS and SPS experiment. This approach requires the identification of pavement and environmental/loading factors considered to have an influence on pavement performance. Pavement factors include such variables as layer thickness, base type, base thickness, joint spacing, and percent steel reinforcement, which are varied as appropriate for the pavement type being studied. Environmental/loading factors include moisture (wet/dry), temperature (freeze/no-freeze), subgrade classification (fine/coarse grained), and traffic loading rate (low/high).

The combination of these selected factors form an experimental factorial that is used as the sampling basis for test sections included in each study. Within GPS, these factorials are more properly considered as sampling templates used in the selection of pavement structures included in the studies. Since GPS consists mostly of pavements that were constructed and in service prior to the start of the LTPP program, it is impossible to find pavements with all of the combinations defined within the factorial. SPS is a more controlled experiment requiring construction of the specified pavement structures. While the SPS experimental factorials are closer to a classical experiment design, between-site construction deviations should be considered in many types of statistical analyses.

1.3.1 General Pavement Studies

The GPS program is a series of studies on selected in-service pavements structured to develop a comprehensive national pavement performance database. These studies are restricted to pavements that incorporate materials and designs representing good engineering practices and that have strategic future importance. Because of the nationwide thrust of the program, the studies are limited to pavement structures in common use across the United States.

The GPS test sections are located on pavement structures constructed up to 15 years prior to the start of the LTPP program. Although detailed research-level measurements on these pavements during the early years of their lives are not available, the GPS test sections offer the potential for development of earlier results than those possible from newly constructed test sections. As the SPS test sections are rehabilitated, they are reclassified into the GPS experiment designations. Table 1 provides a list of the titles of each of the experiments. A more comprehensive definition is provided in appendix B.

It should be noted that the proposed GPS-8 study of bonded portland cement concrete (PCC) overlays on PCC pavements was not pursued because of lack of an adequate number of nominated in-service projects. An SPS study on bonded PCC overlays, SPS-7, was formulated to address this type of rehabilitation alternative.

1.3.2 Specific Pavement Studies

The SPS program is a long-term study of specially constructed, maintained, or rehabilitated pavement sections incorporating a controlled set of experiment design and construction features. The SPS program incorporates nine studies grouped into the five categories as illustrated by table 2. Appendix B provides a more complete definition of each of the experiments.

Essentially, the SPS program involves monitoring newly constructed sections or existing pavement sections subjected to maintenance or rehabilitation treatments. Each SPS experiment requires construction of multiple test sections at each site. The number of test sections may range from two for SPS-8 to twelve for SPS-1 and -2. In addition, a highway agency may construct supplemental test sections on an SPS site to investigate other factors of interest to the agency. The following definitions apply only to the core sections within each experiment. The supplemental sections that may have been constructed by a highway agency are based on the respective agency's research interests and are typically not consistent among highway agencies.

The GPS 6, GPS 7 and SPS 9 experiments have sub-experiment designations based upon when the construction was performed, type of pavement structure, construction treatments, and types of materials used. These sub-experiment designations can be used to sort test sections into general pavement family categories.

Table 1. GPS experiments designations.

Experiment	Experiment Title
GPS-1	Asphalt Concrete (AC) Pavement on Granular Base
GPS-2	AC Pavement on Bound Base
GPS-3	Jointed Plain Concrete Pavement (JPCP)
GPS-4	Jointed Reinforced Concrete Pavement (JRCP)
GPS-5	Continuously Reinforced Concrete Pavement (CRCP)
GPS-6	AC Overlay on AC Pavement
GPS-6A	Existing AC Overlay of AC Pavement (existing at the start of the program)
GPS-6B	AC Overlay Using Conventional Asphalt of AC Pavement–No Milling
GPS-6C	AC Overlay Using Modified Asphalt of AC Pavement–No Milling
GPS-6D	AC Overlay on Previously Overlaid AC Pavement Using Conventional Asphalt
GPS-6S	AC Overlay of Milled AC Pavement Using Conventional or Modified Asphalt
GPS-7	AC Overlay on PCC Pavement
GPS-7A	Existing AC Overlay on PCC Pavement
GPS-7B	AC Overlay Using Conventional Asphalt on PCC Pavement
GPS-7C	AC Overlay Using Modified Asphalt on PCC Pavement
GPS-7D	AC Overlay on Previously Overlaid PCC Pavement Using Conventional Asphalt
GPS-7F	AC Overlay Using Conventional or Modified Asphalt on Fractured PCC Pavement
GPS-7R	Concrete Pavement Restoration Treatments With No Overlay
GPS-7S	Second AC Overlay, Which Includes Milling or Geotextile Application, on PCC Pavement With Previous AC Overlay
GPS-9	Unbonded PCC Overlay on PCC Pavement

Table 2. SPS experiment names by category.

Category	Experiment	Title
Pavement Structural Factors	SPS-1	Strategic Study of Structural Factors for Flexible Pavements
	SPS-2	Strategic Study of Structural Factors for Rigid Pavements
Pavement Maintenance	SPS-3	Preventive Maintenance Effectiveness of Flexible Pavements
	SPS-4	Preventive Maintenance Effectiveness of Rigid Pavements
Pavement Rehabilitation	SPS-5	Rehabilitation of AC Pavements
	SPS-6	Rehabilitation of Jointed Portland Cement Concrete (JPCC) Pavements
	SPS-7	Bonded PCC Overlays of Concrete Pavements
Environmental Effects	SPS-8	Study of Environmental Effects in the Absence of Heavy Loads
Asphalt Aggregate Mixture Specifications	SPS-9P	Validation and Refinements of Superpave® Asphalt Specifications and Mix Design Process
	SPS-9A	Superpave Asphalt Binder Study
	SPS-9C	AC overlay on CRCP
	SPS-9J	AC overlay on JPCC
	SPS-9N	New AC Pavement Construction
	SPS-9O	AC Overlay on AC Pavement

1.4 TEST SECTION LAYOUT

Generally, each GPS and SPS test section consists of a 152-meter (m) (500-foot (ft)) monitoring portion with a 15.2-m (50-ft) materials sampling section at each end. On GPS test sections, a maintenance control zone, extending 152 m (500 ft) in front of and 76 m (250 ft) beyond the limits of the monitoring section, has been established around each test section as illustrated in figure 1. Since SPS projects consist of multiple test sections constructed for a single project, the maintenance control zone is extended to cover groups of adjoining sections as illustrated in figure 2.

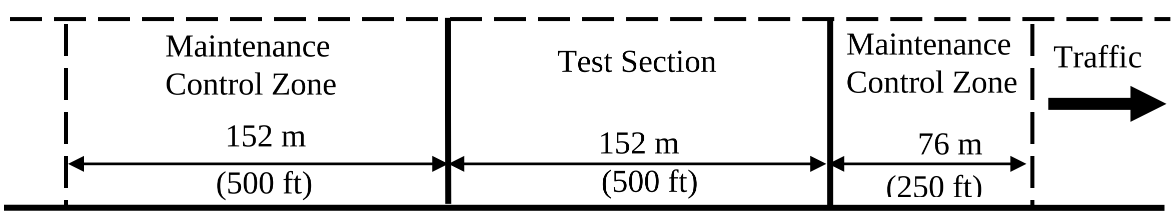

Figure 1. Layout of a generic GPS test section.

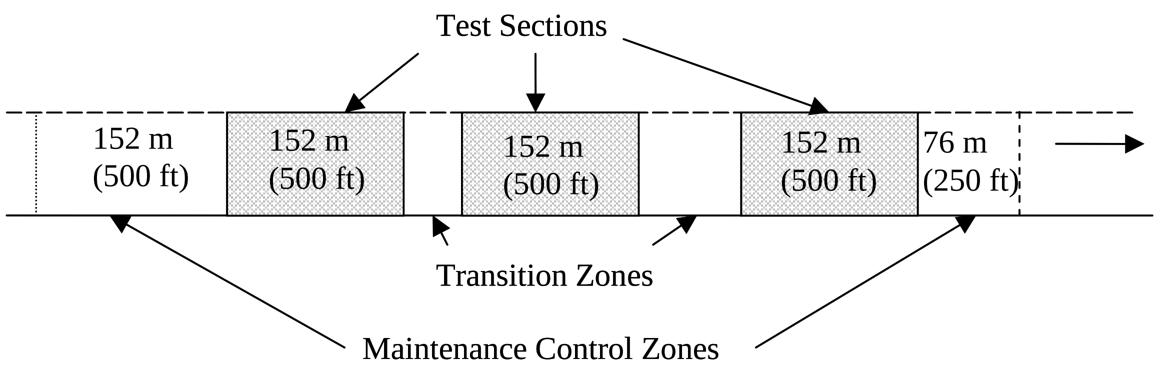

Figure 2. Example layout of a generic SPS project.

The exceptions to the 152-m (500-ft) long test section include the crack-and-seat test sections in the SPS-6 experiment and some agency supplemental sections constructed on SPS projects. The crack-and-seat sections on SPS-6 are 305-m (1,000-ft) long, while agency supplemental sections have been constructed both shorter and longer than the 152-m (500-ft) standard section.

LTPP Database Tip!	The database has not been completely converted to metric units. Some of the modules are in the International System of Units (SI) and some are still in the U.S. customary units. The units for every data element are stored in the LTPP data dictionary (LTPPDD) table. Units should be checked to ensure that calculations are performed with consistent units.

The LTPP program uses a test section and project station location convention. The test section station convention is based on the starting point of the monitoring portion of the section being assigned a station of 0. The longitudinal locations in the direction of traffic are assigned positive stations. When the LTPP program was started, longitudinal locations were designated using U.S. customary units of 100-ft (30.5-m) stations. However, in the database, longitudinal locations are converted to metric meter stations. Thus, the original 5+00 test section station painted on the pavement surface is represented as 152 m in the POINT_LOC field in the database. (Note: For data users reviewing film or video of LTPP test sections, painted white cross markings are located at 30.5-m (100-ft) intervals.) The project station location convention applies to SPS project sites where more than one test section is located.

A project station location convention is used where multiple test sections are located on the same SPS project site. The project station convention starts with station 0 assigned to the first test section located at the project site in the direction of travel. The SECTION_START and SECTION_END fields in the SPS_PROJECT_STATIONS table contain project station location information.

LTPP Database Tip!	The SPS_PROJECT_STATIONS table can be used as a link table to associate both GPS and SPS test sections co-located at an SPS project site. In this table, the TEST_SECTION field contains a joined STATE_CODE+SHRP_ID that can be used to identify specific test sections.

The overriding philosophy of sampling and monitoring measurements on LTPP test sections is to not permit destructive testing or sampling within the monitoring portion of the section.

1.5 REFERENCE MATERIALS

A list of LTPP operational documents is presented in appendix A. These documents provide details on all of the LTPP data collection activities stored in the LTPP database. Reference documents are also available from the Reference Library distributed as part of the standard data release. LTPP documents are also available from the FHWA LTPP web page at: **http://www.fhwa.dot.gov/research/tfhrc/programs/infrastructure/pavements/ltpp**

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CHAPTER 2. PAVEMENT PERFORMANCE DATABASE OVERVIEW

2.1 LTPP INFORMATION MANAGEMENT SYSTEM

The overall system used to manage information intended for public dissemination by LTPP is called the Information Management System (IMS). Figure 3 illustrates major components of the IMS which includes products, Pavement Performance Database (PPDB), and Ancillary Information Management System (AIMS). Products are program results that can be used to improve pavement performance. The PPDB is the formal database that contains the majority of research data on the performance of the LTPP test sections in an electronic relational database format. The AIMS contains the larger electronic base of raw data files used to populate the PPDB and other information not contained in the PPDB

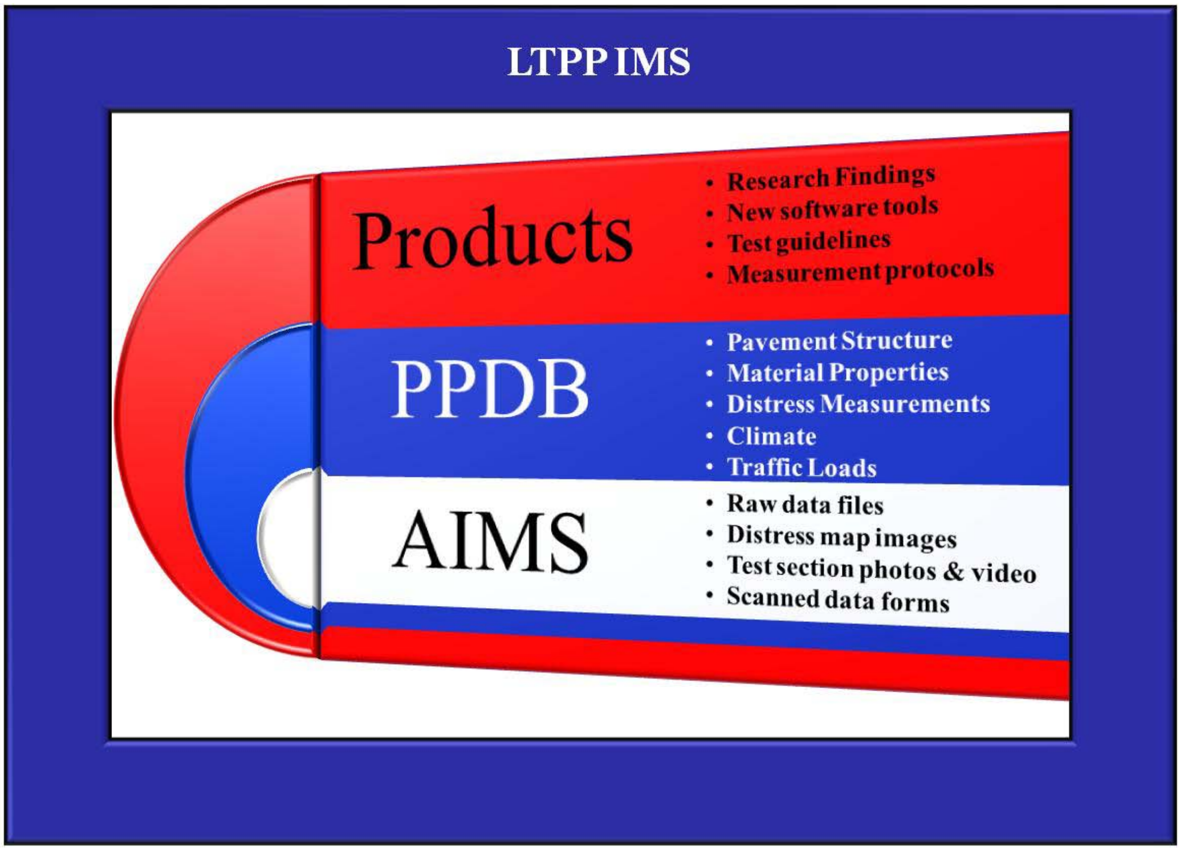

Figure 3. The major categories of the LTPP IMS include Products, PPDB, and AIMS.

2.2 LTPP PPDB

The pavement performance database (PPDB) was designed to store the majority of the data collected by the LTPP program for easy and convenient dissemination and use. The pavement performance database is a relational database originally implemented in Oracle® 5 format. As of this writing, the production database is implemented in Oracle 11. To harness the power of relational databases to manipulate large amounts of data at a reasonable cost most users prefer to obtain data from the production database in an alternate database format. (See chapter 14 for data request procedures.) Currently, the LTPP program is using Microsoft® Access 2000 as a standard format for data releases. Microsoft Access 2000 is compatible with Microsoft® Access 2003. This may change in the future. International data users, who do not have access to the English-language version of Microsoft® Access 2000, may wish to request customized extractions in other formats.[1]

The overall structure of the database is based on the LTPP data collection and processing flow. LTPP data are collected and processed by four regional contractors. Each of these contractors is responsible for loading and processing the data for test sections in their region into regional databases. Each regional database contains data for the test sections in that region (the breakdown of States and Provinces by region is located in the REGIONS table of the database). Data from the regional databases are uploaded to the national database for consolidation and release to the public.

2.3 RELATIONAL DATABASES AND STRUCTURED QUERY LANGUAGE

The LTPP pavement performance database is a *relational* database, meaning that it is composed of separate, but related, tables of data. The importance of a relational database from a user's viewpoint is that all data are stored in a simple row/column format in tables (rows are sometimes referred to as records and columns are sometimes referred to as fields). Each row of data is uniquely identified by the values in a *primary key* column or a combination of columns (most of the tables in the LTPP database use multicolumn keys). In addition, relationships exist among the tables of the database that are represented by common data values stored in more than one table. For example, many data tables contain STATE_CODE and SHRP_ID columns, which are how test sections or projects are uniquely identified. These fields can be used to located data for a specific test section in many tables.

One critical characteristic of relational databases is that they are self-describing. This means that information about the structure of the database is represented in the same row and column format as the data itself. The data dictionary, stored in the LTPPDD table, includes much of this information. Users unfamiliar with the database should examine LTPPDD and learn how to use it. Alternatively, the LTPP program developed the Table Navigator software that allows a user to browse the database structure as a three-tiered representation consisting of tables, fields, and codes. Currently, Table Navigator can be obtained as a program running on Microsoft Windows® platforms. It is planned to migrate this software to an Internet Web platform.

Structured Query Language (SQL) is the standard language for controlling and interacting with relational databases. It is supported by modern relational database management systems (RDBMS's). For data users, one of the most important features of SQL is its ability to retrieve and combine data elements stored in multiple tables based on conditions set by the user. SQL can be used to create new tables, called queries, which contain data elements of interest in a specific analytical objective. To harness the full power and convenience of the LTPP database, users should become familiar with SQL. Some example data extractions using some fundamental SQL

[1] As of this writing, LTPP had not established support for non-English language database formats. Please contact LTPP customer support for nonstandard data extraction requests.

commands are provided in appendix C of this document. The data extraction examples in appendix C require a basic knowledge of SQL.

2.4 QUALITY CONTROL

For equipment measurements, quality control (QC) procedures include routine calibrations, data checks during acquisition, and data checks prior to database loading. Large amounts of data are supplied on paper forms from many different agencies. QC checks on this information consist of reviews of completeness and validity of the provided information.

Data in the database undergo several levels of data quality checks. The results of these checks are recorded in the RECORD_STATUS field. All data tables contain a RECORD_STATUS field. There are three major types of QC checks:

Level-C Checks: These are checks on required fields to identify critical fields that contain a null value. In some cases, these checks are supplanted by non-null restrictions placed on critical fields during the table design that prevent a record from being created if a value for that field is not entered.

Level-D Checks: These are range checks on the validity and reasonableness of values entered in a field. For example, the range checks for deflection data from the center sensor on a falling-weight deflectometer (FWD) is 5 to 2032 micrometers (μm).

Level-E Checks: These checks are relational checks between data stored in other fields. This category contains a wide range of checks. The common property of these checks is that they compare the value in one field of a table to the value in another field that may or may not be in the same table. For example, a level-E check is used to see if pavement layer temperature gradient data exist for each FWD data set. In addition, level-E checks are used to enforce referential integrity between parent and child tables.

These QC checks are performed sequentially. Level-D checks are applied only to records passing level-C checks, and level-E checks are applied only to records passing level-D checks. Record statuses of A and B are used for data that either have not undergone QC check processing or have not passed the level-C checks. If a record fails a check, its record status remains at the next lower status. For example, records failing a level-D check have a status of C. Alternatively, the record status can be manually upgraded if the record has been examined and has been found to be acceptable.

A few modules contain level B checks and these are documented in the QC Manual. Most previous level B checks have been incorporated into level E checks. Any records remaining at level A where explicit level B checks are not documented in the QC Manual, most likely do not have a valid test section identification number (i.e., STATE_CODE + SHRP_ID). Records with invalid test section identification numbers will not be processed by the QC programs. The data loader programs and forms are designed to prevent entry of records in the database with an invalid test section identification number.

Records with level-E status can mean any of the following:

Records have passed all of the data checks.
Records may have failed some data checks; however, they have been manually upgraded after inspection and data editing.
Records may contain errors that have not been detected by the current data review process.

The QC checks applied to LTPP data are limited. It is not possible to inspect all of the data for all types of potential anomalies. As the program evolves and improvements are made to the data QC checks, level-E data included in previous releases may be reclassified.

Records with a status of less than E can be interpreted as:

Records have not completed the QC process.
Records have completed the QC process, but were left at a lower level of record status because they contained a flaw.
Records are not currently subjected to the QC process by policy.

LTPP data users assume the responsibility for conclusions based on interpretation of data collected by the LTPP program. Level-E data should not be considered as more reliable than non-level-E data. Likewise, non-level-E data should not be considered less reliable than level-E data. The record status for non-level-E data can be used as a relative indicator of potential issues that might exist for these data. As the LTPP program continues to evolve, users can expect changes to be made to LTPP data to improve their use in analyses.

2.5 GPS AND SPS SECTION IDENTIFICATION

LTPP test sections fall into one of two categories: General Pavement Studies (GPS) or Specific Pavement Studies (SPS). From the database viewpoint, the critical difference between GPS and SPS sections stems from the fact that multiple SPS sections are co-located on a single project. This co-location allows these sections to share climatic, traffic, and some materials data. Sections co-located on an SPS project are identified as sharing a STATE_CODE and PROJECT_ID in the SPS_PROJECT_STATIONS table. The TEST_SECTION field in this table contains the actual SHRP_ID of the test section. The SPS_PROJECT_STATIONS field also includes information about the location of these test sections relative to each other.

From a data user’s viewpoint, another important difference between GPS and SPS test sections is that similar information is stored in different tables. Construction and general information for GPS test sections are stored in the INV tables. For example, the road designation for a GPS section is stored in the INV_ID table. For SPS sections classified in maintenance or rehabilitation experiments, location information is stored in the INV_ID tables using a project-level ID in the SHRP_ID field that applies to all test sections located on the project. Additionally, data about the pavement structure prior to treatment are stored in the INV module. Construction information for SPS test sections is stored in the SPS tables. Other general information for the new construction SPS experiments is also stored in the SPS tables. Location information for these experiments is in the SPS_ID table.

LTPP Database Tip!	The GPS_SPS field in the EXPERIMENT_SECTION table identifies whether a section is a GPS or SPS section. The SHRP_ID field for SPS sections is "smart". The first character in SHRP_ID for SPS sections is always a 0 or a letter. The second character in SHRP_ID for SPS sections identifies the experiment number. Over time, some SPS test sections are reassigned to GPS because of a rehabilitation activity; however, they retain the original SHRP_ID. However, all sections with a SHRP_ID beginning with a 0 are not SPS. A GPS test section in Texas has a SHRP_ID of 0001. Always check the GPS_SPS field in EXPERIMENT_SECTION before assuming that a section is an SPS section because of its SHRP_ID.

2.6 MODULES

The database is divided into *modules* containing similar sets of tables. With the exception of the tables in the Administration module, the first part of the table name identifies the module to which a particular table belongs. The modules are as follows:

Administration (ADM): This module contains tables that describe the structure of the database and the master test section control table. Key tables in this module are LTPPDD, which describes each field in each table; CODES, which describes codes used in the database; and EXPERIMENT_SECTION, which is the master control table for the test sections. The REGIONS table contains a mapping of States to LTPP operations administrative designations.

Automated Weather Station (AWS): This module contains data collected by the LTPP program from automated weather stations installed on some SPS projects.

Climate (CLM): This module contains data collected from offsite weather stations that are used to compute a simulated virtual weather station for LTPP test sections or project sites. Data in this module are updated at 5-year intervals.

Dynamic Load Response (DLR): This module contains dynamic load response instrumentation data from SPS test sections located in North Carolina and Ohio.

Ground Penetrating Radar (GPR): This module contains the results of layer thickness determinations from ground penetrating radar measurements on SPS-1 and other selected SPS projects.

Inventory (INV): This module contains inventory information for all GPS test sections and for SPS sections originally classified in maintenance and rehabilitation experiments. Tables in this module contain information such as the location of the test section and structure information supplied by the owning State or Provincial agency. Since this structure information comes from agency project records and not necessarily from actual measurements taken at the test sections, the information is generally regarded as suspect for use in many types of pavement performance analyses requiring information on the actual dimensions of the test section pavement structure.

LTPP Traffic Analysis Software (LTAS): This module contains the tables used by LTAS software to compute the annual traffic statistics stored in the traffic module from monitoring measurements stored in the LTAS module.

Maintenance (MNT): This module contains information on maintenance-type treatments reported by a highway agency that were applied to a test section. Treatments included in these tables are thin surface treatments, crack sealing, joint sealing, and patching performed on in-service test sections.

Monitoring (MON): This module contains pavement performance monitoring data and it is the largest module in the database. It can be understood best as a collection of submodules by data type:

Deflection (MON_DEFL): This submodule contains data from FWD tests.
Distress (MON_DIS): This submodule contains distress survey data from both manual and film-based surveys.
Friction (MON_FRICTION): This submodule contains friction measurements taken by participating highway agencies.
Profile (MON_PROFILE): This submodule contains longitudinal profile data collected by an automated profiler or by manual dipstick measurements.
Rut (MON_RUT): This submodule contains rutting data measured using a 1.2-m (4-ft) straightedge. These data tables are superseded by the rutting indices located within the Transverse Profile module. (Note: Straightedge rut measurements were not taken on all test sections.)
Transverse Profile (MON_T_PROF): This submodule contains transverse profile data and computed transverse profile distortion indices (rut depth) from manual dipstick measurements or the optical Pavement Distress Analysis System (PADIAS) method.

Rehabilitation (RHB): This module contains information on rehabilitation treatments. A key table in this module is RHB_IMP, which identifies the various applied treatments that result in changes to CONSTRUCTION_NO.

Seasonal Monitoring Program (SMP): This module contains SMP-specific data, such as the onsite air temperature and precipitation data, subsurface temperature and moisture content data, and frost-related measurements.

Specific Pavement Studies (SPS): This module contains SPS-specific general and construction information.

Traffic (TRF): This module contains traffic load, classification, and volume data.

Test (TST): This module contains field and laboratory materials testing data. A key table in this module is TST_L05B, which contains layer thickness and composition information based on measurements from the test section site.

CHAPTER 3. ADMINISTRATION MODULE

The Administration (ADM) module contains the master test section control table, tables that describe the structure and content of the database, and general comments tables. Unlike tables in the other modules, the first three letters of the table name do not identify tables in the ADM module. Tables in this module are EXPERIMENT_SECTION (the master control table for test sections), LTPPDD (the data dictionary that describes each field in each table), LTPPTD (contains general descriptions for all tables), CODES (describes codes used in the database), CODETYPES, COMMENTS_GENERAL (a general comments table), REGIONS (contains a mapping of States and Provinces to LTPP operations administrative designations) , SECTION_COORDINATES (test section location coordinates), and SECTION_LAYER_STRUCTURE.

3.1 EXPERIMENT_SECTION TABLE

This can be considered the master table for the entire database. All test sections must have entries in this table. This table contains information on test section experiment assignments, assignment to SMP, dates when a test section changed experiments, dates when maintenance or rehabilitation treatments were applied, types of treatments applied and out-of-study status.

Due to its importance, this table is included in every database contained in the Standard Data Release (SDR).

This table has three key fields: STATE_CODE, SHRP_ID, and CONSTRUCTION_NO. STATE_CODE and SHRP_ID uniquely identify a test section or SPS project.

STATE_CODE is a two-digit code used to identify the State or Province where a test section is located. This code is defined in the STATE_PROVINCE code type in the CODES table. These codes are, in part, based on the Federal Information Processing Standards (FIPS) codes and include codes for agencies not participating in the LTPP program.

SHRP_ID is a four-character identifier for the test section. For GPS test sections, the number has no significance other than being unique when combined with the STATE_CODE. For SPS sections, the second character represents the experiment number; the third and fourth characters identify the sections at the project; and the first character is typically “0” for the first such project constructed in a given State or Province, “A” for the second such project, and so on. SPS SHRP_ID numbers ending in “00” are a project-level identifier and do not represent actual test sections. However, when an SPS section changes experiment type because of a rehabilitation event, it will often be transferred into a GPS rehabilitation experiment, although the SHRP_ID will stay the same. The EXPERIMENT_NO field (described below) should always be used to determine the actual experiment classification.

CONSTRUCTION_NO identifies changes in the pavement structure caused by rehabilitation treatments or application of maintenance treatments. When a section first enters the LTPP program, it is assigned a CONSTRUCTION_NO of 1. CONSTRUCTION_NO is incremented by 1 for each subsequent maintenance or rehabilitation event regardless of its impact on the pavement structure. For example, crack sealing causes a new construction event to be generated, even though it does not cause a significant change in the experiment assignment or pavement structure.

CN_ASSIGN_DATE identifies the date that the CONSTRUCTION_NO became active. For a CONSTRUCTION_NO of 1, this is the date that the section entered the LTPP program; otherwise it is the date of the maintenance or rehabilitation activity that triggered the change in CONSTRUCTION_NO.

CN_CHANGE_REASON describes the maintenance or rehabilitation activity that triggered the change in CONSTRUCTION_NO. This is a code of the type MAINT_WORK.

RECORD_STATUS is described in the Quality Control section of this document. The RECORD_STATUS field in EXPERIMENT_SECTION reflects the availability and completeness of critical data relating to that section throughout the database.

GPS_SPS is a code to indicate whether a section is classified as a GPS or SPS experiment for that CONSTRUCTION_NO.

EXPERIMENT_NO is a code indicating to which GPS or SPS experiment the pavement section is assigned. This two-character code consists of a number followed by an optional suffix letter. The suffix is used for some experiments to indicate a subcategory of test sections. EXPERIMENT_NO is a code of the type EXPERIMENT.

STATUS is a code indicating the current monitoring status of a section. A null value indicates that the test section has been approved and has an active monitoring status. A value of “O” indicates that the test section has been placed “out of study” and no future monitoring measurements will be made. This field is set to O when a test section goes out of study. At that time, the STATUS field in all records in EXPERIMENT_SECTION with a matching STATE_CODE and SHRP_ID is set to O.

ASSIGN_DATE is the date when a test section is assigned to the LTPP experiment. The experiment designation for a test section is the combination of EXPERIMENT_NO and GPS_SPS fields in the record. When a section is first accepted into the LTPP program, ASSIGN_DATE is the acceptance date. ASSIGN_DATE must precede any LTPP monitoring measurements taken on the test section for the associated experiment. When a test section changes experiments because of rehabilitation, ASSIGN_DATE is the construction start date and should equal the CN_ASSIGN_DATE (i.e., ASSIGN_DATE(CN+1) = CN_ASSIGN_DATE(CN+1), if EXPERIMENT_NO(CN) ≠ EXPERIMENT_NO(CN+1), where CN is the CONSTRUCTION_NO).

DEASSIGN_DATE is the date when a test section changed to another experiment or was placed in the out-of-study status in the LTPP program (STATUS = O). This field should be null until a rehabilitation construction event occurs that causes a change in EXPERIMENT_NO or the test section goes out of test. When a test section changes experiments because of rehabilitation, the

DEASSIGN_DATE for the previous CONSTRUCTION_NO (CN) should equal the CN_ASSIGN_DATE for the next CN (i.e., DEASSIGN_DATE(CN) = CN_ASSIGN_DATE(CN+1), if EXPERIMENT_NO(CN) ≠ EXPERIMENT_NO(CN+1)). If a maintenance-related construction event occurs that does not result in an experiment change, the DEASSIGN_DATE for the previous CN should equal the DEASSIGN_DATE for the next CN (i.e., DEASSIGN_DATE(CN) = DEASSIGN_DATE(CN+1) (even if NULL), if EXPERIMENT_NO(CN) = EXPERIMENT_NO(CN+1)).

SEAS_ID is an agency-specific SMP identification code indicating that SMP measurements were made for the corresponding construction number. SEAS_ID is set to A for the first SMP site installed in a State, B for the second site, and so on. This field is only populated for construction numbers in which SMP data have been collected. When a construction event occurs on an SMP test section that results in termination of its participation in the SMP, or if SMP monitoring is terminated prior to occurrence of a new construction event, the SEAS_ID is set to null in the EXPERIMENT_SECTION record corresponding to the new CN for which no SMP data are available.

SUPPLEMENTAL identifies supplemental test sections. A value of "S" identifies a supplemental test section.

EXP_SECT_RS is a QC summary field like RECORD_STATUS, except that it reflects the quality and completeness of data in the EXPERIMENT_SECTION table only, rather than the entire database.

BASIC_INFO_RS is a QC summary field that reflects the quality and availability of basic inventory information for the section.

PAV_STRUCT_RS is a QC summary field that reflects the quality and availability of pavement structure information in the TST_L05B table.

TRAFFIC_RS is a QC summary field that reflects the quality and availability of traffic data for the section.

CLIMATIC_RS is a QC summary field that reflects the quality and availability of climate data for the section.

3.2 LTPPDD TABLE

The LTPPDD table is the data dictionary for the LTPP PPDB. Starting with the January 2012 data release, this table also contains entries for the LTPP Traffic Analysis Software (LTAS) database. LTPPDD contains metadata for each field in each table in the database. Critical fields include FIELDNAME, TABLENAME, and DESCRIPTION. This table is a vital reference when searching for data types of understanding the contents of data contained in a field. The information contained in the Table Navigator program starts with the entries in this table.

The LTPPDD circulated with each SDR is altered to match its contents. For example, in SDR26 the DLR_*_AC tables were removed from the LTPPDD since the previously released data were removed due to discovered errors

LTPP Database Tip!	Users of the LTPP database standard data releases should use the LTPPDD and other tables in the administration module that correspond to that release, since these tables are changed to match each new data release.

FIELDNAME is the name of the specific field that is defined by the LTPPDD entry.

TABLENAME is the name of the table in which the field denoted by FIELDNAME resides. Table names generally begin with a three-letter indicator of the data module. For instance, the SMP_FROST_PENETRATION table is part of the SMP module.

DESCRIPTION is a short description of the field. For instance, the NORM_RESISTIVITY field has this entry under DESCRIPTION: “Normalized resistivity–It is the electrical resistivity of the soil at the measurement depth, relative to the extreme values at that depth.”

CODETYPE is the name of the type of code contained in the CODES tables. The contents of this field can be used to link to the CODES table to lookup the meaning of a code. If this field in LTPPDD is non-null it is also means that the corresponding field is a codes field in the corresponding table defined by the entry in TABLENAME.

DATA_TYPE specifies the Oracle electronic format of the specified field. These fields are typically a VARCHAR (variable-length character field), DATE, or NUMBER(x,y) where x is the total number of digits and y is the number of decimal places in the number.

DATASHEET specifies the source of the data stored within the specified field. Typically, this is a paper datasheet number; however, it may be a filename or individual’s name. Entries in this field may not be current or complete.

ITEM is the item number of the form denoted within the DATASHEET field. This is the origin of the data that reside within the specified field. Entries in this field may not be current or complete.

UNITS indicate the units used for the corresponding numeric field. Both SI and U.S. customary units are included in the database.

3.3 LTPPTD

This table contains a description of the contents of tables in the database. The three fields in the table are self describing; TABLENAME contains the table name, DESCRIPTION is the description of the contents of the table, and MODULENAME is the name of the module that the table is assigned.

3.4 CODES

Many of the elements in the database use a code value to represent alternate standard entries in a field. The CODES table contains a definition of the meaning codes used in the LTPP database. To decipher the meaning of a code value, a user must link the corresponding CODETPE contained in the LTPPDD table for the specific field in a table to the matching record in the CODES table with the same CODETYPE and CODE value.

CODETYPE is the code type name as shown in the CODETYPE field in the LTPPDD table.

CODE is the code value. Although most codes are numeric, some are alphanumeric; therefore, this field is coded as a character, which creates an apparent illogical sequence when the field is sorted in ascending or descending order.

DETAIL is the description of the code.

ADDL_CODE provides a second reference field for codes that require a combination of two codes to form a unique reference. The only two CODETYPES that use this field are COUNTY, in which ADDL_CODE corresponds to the STATE_PROVINCE code of the State or Province in which the county is located, and EXPERIMENT, in which the ADDL_CODE is “G” for GPS experiments and “S” for SPS experiments.

LTPP Database Tip!	In some tables the values for a CODE field is store in a numeric formatted field whereas the CODE field in the CODES table is formatted as a character. In order to provide a custom data extraction where the meaning of the code value is output next to the code, the user should use SQL functions to change the either numeric format in the data table to a character, or the character format in the code table to a number in order to perform a join.

3.5 CODETYPES

The CODETYPES table provides additional information on the codes contained in the CODES table. The TITLE field in this table provides a general description of each CODETYPE. The SOURCE field contains information on the reference document or external source for the code definitions.

3.6 COMMENTS_GENERAL

The COMMENTS_GENERAL table contains general comments related to test section anomalies, general status, and other details that are not reflected in other data tables. Comments are entered in this table at the discretion of the LTPP regional data collection contractors.

3.7 REGIONS

The REGIONS table is perhaps the simplest table in the database. It consists of two fields– STATE_CODE and REGION_CODE. This table allows a user to sort State and Provincial agencies by the LTPP administrative region. In the past, this table had not been distributed since its use is primarily for internal LTPP operations.

3.8 SECTION_COORDINATES

This table was introduced in the January 2008 data release (data release 22). This table contains the latitude and longitude coordinates of test sections and project sites previously stored in the INV_ID and SPS_ID tables. It contains coordinates for most GPS and SPS test sections measured using high precision global positioning receivers. GPS test sections and SPS project sites which have not been measured using the high precision receivers contain a NULL value in the MEASUREMENT_ACCURACY field.

In data release 23, project level entries were added for all SPS sites. When individual test section coordinate measurements were available using the new global positioning equipment, the SPS project level ID was set to the coordinates of the first test section at the site in the direction of traffic. When new measurements were not available, older measurements were used to populate these records. All SPS site now contain an entry in the SECTION_COORDINATES table. Use of the SPS_GPS_LINK table is no longer necessary to find the location of SPS site linked to a GPS section.

The latitude and longitude coordinates of the beginning location of the test section are expressed in fractions of a degree. A negative longitude convention is used.

3.9 SECTION_LAYER_STRUCTURE

This table was added as part of the administration module in the January 2009 SDR (data release 23). It is a view, or a copy, of the TST_L05B table which contains the consolidated set of pavement layer structure information for all LTPP test sections. It contains a recommended single thickness and material type for each layer from interpretation of material, sampling, material tests and FWD measurements. This table is contained in every MS Access database in the SDR in an attempt to reduce confusion over which of the 22 tables in the pavement performance database which have the word layer contained in its name should be used for pavement performance analysis. The INV_LAYER fields in the TST_L05B table were updated in SDR23, and in this table, to resolve a consistency issue with the TST_L05 table which provides a link between TST_L05 tables and the Inventory layer tables using layer project codes for SPS projects. All of the records in the TST_L05B table have entries in INV_LAYER as appropriate.

CHAPTER 4. AUTOMATED WEATHER STATION MODULE

Automated Weather Stations (AWS) have been installed by the LTPP program near almost all SPS-1, -2, and -8 project sites. This equipment measures site-specific climatic information. AWS measurements include air temperature, humidity, precipitation, solar radiation, and wind speed. The AWS tables are structured to provide users with monthly, daily, and hourly climate statistics. LTPP regional contractors are responsible for equipment maintenance, data collection, review, and processing.

LTPP AWS measurements began in August 1994 and were terminated in December 2008. The weather stations became active and were retired at different dates.

4.1 IMPORTANT FIELDS

AWS_ID is a key field in the AWS data tables used to link the data to SPS project sites and other nearby test sections. At locations where multiple SPS projects are co-located on the same site, such as in Delaware, Nevada, and Ohio, since AWS_ID is not always the same as the combined STATE_CODE and SHRP_ID (project ID for SPS projects), **AWS_LINK** should be used to find AWS data for a given SPS project or GPS section.

4.2 AWS TABLES

4.2.1 AWS_LINK: This table provides the link between the weather station identification used in the AWS tables and the associated SPS project ID or GPS SHRP_ID.

4.2.2 AWS_LOCATION: This table contains information regarding the coordinates for the location of each weather station. Because of logistical factors regarding the availability of electricity and communications, AWS may be located a relatively short distance from the project site. Users should evaluate the potential impact of this displacement on their analytical objectives.

4.2.3 AWS_HOURLY_DATA: This table contains hourly climate statistics, including air temperature, humidity, precipitation, solar radiation, wind speed, and wind direction. This is the smallest unit of time for which AWS data are available.

4.2.4 AWS_DAILY_DATA: This table contains daily statistics for the AWS sites. When possible, the information is provided by the data logger at the AWS site without the need for further computation. When data from the data logger are unavailable or otherwise problematic, the values in the daily table may be computed from the corresponding hourly data, if available.

4.2.5 AWS_HUMIDITY_MONTH: This table contains monthly humidity statistics from LTPP AWS. These statistics are calculated from daily data for months where 24 or more days of data are available.

4.2.6 AWS_PRECIPITATION_MONTH: This table contains monthly precipitation statistics from LTPP AWS. These statistics are calculated from daily data for months where 24 or more days of data are available.

4.2.7 AWS_SOLAR_MONTH: This table contains monthly solar radiation statistics from LTPP AWS. These statistics are calculated from daily data for months where 24 or more days of data are available.

4.2.8 AWS_TEMP_MONTH: This table contains monthly air temperature statistics from LTPP AWS. These statistics are calculated from daily data for months where 24 or more days of data are available.

4.2.9 AWS_WIND_MONTH: This table contains monthly wind statistics from LTPP AWS. These statistics are calculated from daily data for months where 24 or more days of data are available.

The organization and computational relationships between the AWS tables are illustrated in figure 4. The AWS_LINK table serves as the master parent table for all other AWS tables. The computational relationship between the AWS_HOURLY_DATA and AWS_DAILY_DATA tables depends on whether or not the hourly data has been edited to correct time stamp issues or bad data. The data logger which stores the data uses measurements performed at 5 minute intervals to compute both the hourly and daily statistics. If hourly data are edited, then the daily statistics are recomputed from the hourly data. All of the monthly statistics are computed from the daily data, provided 24 days of data exists within a month.

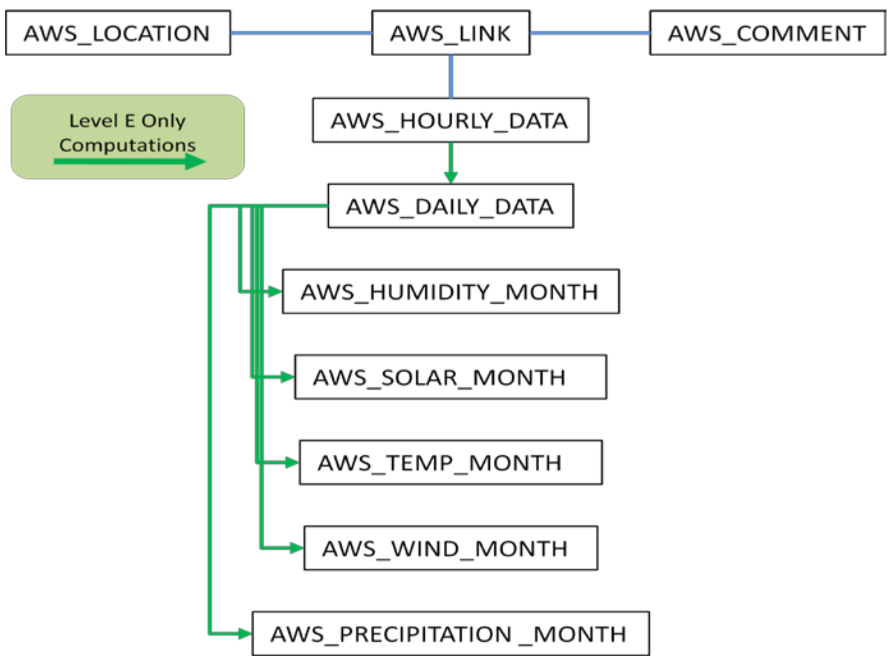

Figure 4. Organization and computational relationships between the AWS tables.

CHAPTER 5. CLIMATE MODULE

The LTPP climate data are stored in the CLM module. A two tier data storage structure is used. The first tier contains raw and processed data from operating weather stations (OWS) . These OWS were selected based on their location to LTPP test sections and period of data coverage. Raw climatic data from the operating weather stations (OWS) are stored in tables whose names begin with CLM_OWS. The second tier are virtual weather station (VWS) statistics computed from nearby OWS. The VWS statistics are stored in tables whose names begin with CLM_VWS.

The climate database was last updated for Standard Data Release 23. In this update, new data for the OWS through the end of 2006 were added to the database and a new set of VWS was also computed using new test section coordinates contained in the SECTION_COORDINATES table.

These data consist of daily measurements for the LTPP selected parameters. To summarize the daily measurements, monthly and annual statistics (mean, standard deviation, minimum, maximum, count, and total) have been calculated. Selected parameters are also available as annual summaries.

5.1 IMPORTANT FIELDS

WEATHER_STATION_ID is the key field in the CLM_OWS tables. This filed contains the unique identification code assigned to each weather station.

VWS_ID is a key field in the CLM_VWS_* data tables used to link the data from the VWS to SPS projects and GPS test sections. Because the VWS_ID is not always the same as the combined STATE_CODE and SHRP_ID (project ID for SPS projects), **CLM_SITE_VWS_LINK** (and **SPS_GPS_LINK**, if necessary) should always be used to find CLM data for a given SPS project or GPS test section.

5.2 CLM TABLES

The two major categories of CLM tables are CLM_OWS tables which contain weather station data from public sources, and the CLM_VWS tables which contain linkages between OWS and VWS statistics, and the statistical results.

5.2.1 CLM_OWS Tables

The CLM_OWS tables contain the raw data obtained from public sources such as the National Climatic Data Center (NCDC) for locations in the United States. The data obtained from external program climate data sources are split into daily, month, and annual data summaries by data type. This change was made in 2004 due to errors found in the publically available data. Splitting the data into table containing one type of weather measurement simplifies the computation process to allow only data which pass the LTPP QC checks to be used in computations.

Figure 5 illustrates the organization and relationship between the CLM_OWS tables. In the table relationships shown in figure 5, the CLM prefix from the table names has been omitted for presentation convenience. Only the tables containing the daily statistics are subjected to LTPP QC checks because they are the foundation of the climate statistics. QC checks on the monthly and annual OWS data are not performed.

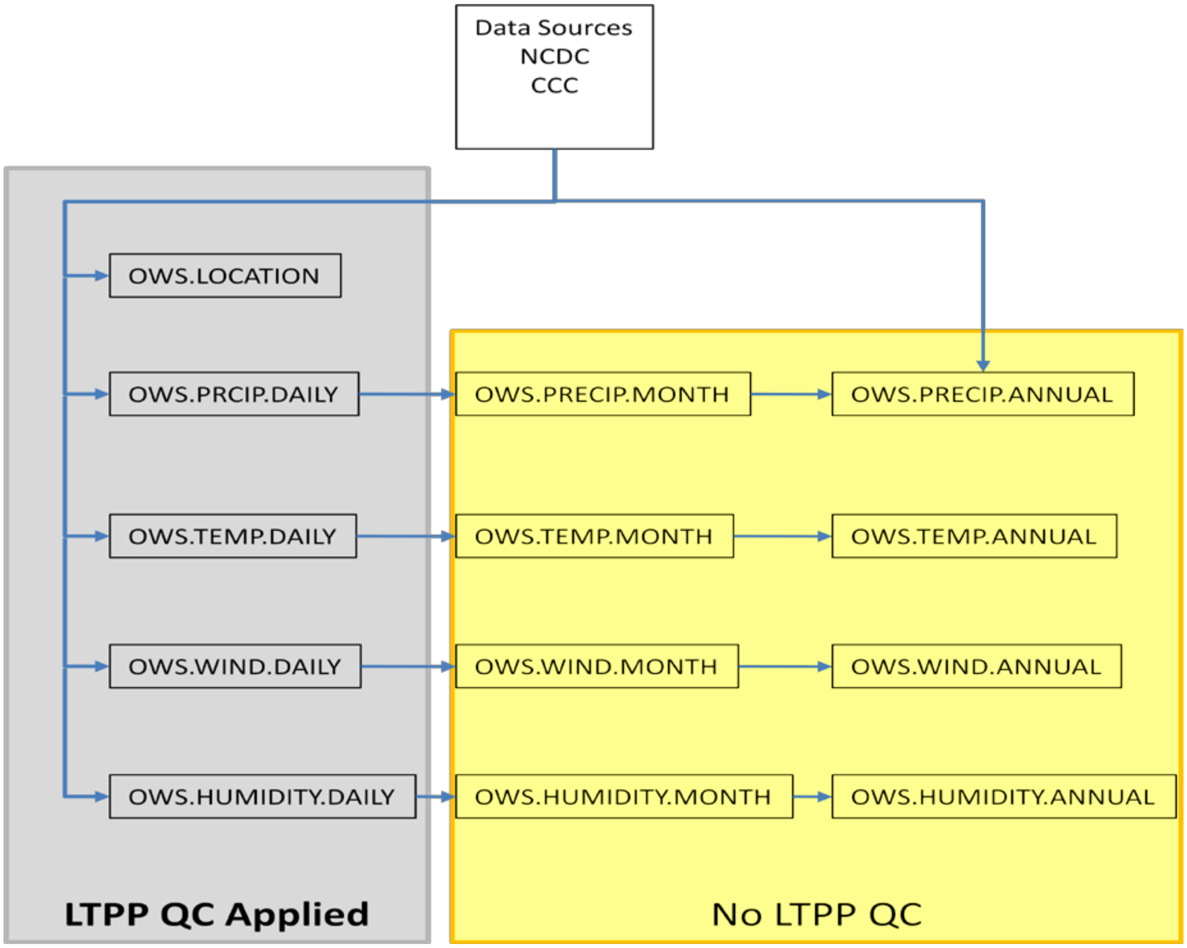

Figure 5. Structure and relationship between the CLM_OWS_* tables.

Due to large size of the CLM_OWS tables, most of them are not distributed as part of the SDR. The exception is the CLM_OWS_LOCATION table since it is used to determine the distance between a test section and surrounding weather stations. Extractions from these tables can be obtained by contacting LTPP customer service.

CLM_OWS_LOCATION: This table contains the location coordinates and elevation of the OWS used to estimate the climatic conditions at each test section.

CLM_OWS_PRECIP_DAILY: This table contains the daily precipitation and snowfall. This table is not distributed as part of the SDR.

CLM_OWS_PRECIP_MONTH: This table contains OWS monthly precipitation statistics. The table is populated only for months with 24 or more days of data available. This table is not distributed as part of the SDR.

CLM_OWS_PRECIP_ANNUAL: This table contains OWS annual precipitation statistics. The table is populated only for years with 300 or more days of data available. This table is not distributed as part of the SDR.

CLM_OWS_HUMIDITY_DAILY: This table contains the maximum and minimum air humidity levels for the day. This table is not distributed as part of the SDR.

CLM_OWS_HUMIDITY_MONTH: This table contains OWS monthly humidity statistics. The table is populated only for months with 24 or more days of data available. This table is not distributed as part of the SDR.

CLM_OWS_HUMIDITY_ANNUAL: This table contains OWS annual humidity statistics. The table is populated only for years with 300 or more days of data available. This table is not distributed as part of the SDR.

CLM_OWS_TEMP_DAILY: This table contains the daily mean, maximum, and minimum temperature recorded at the weather station. This table is not distributed as part of the SDR.

CLM_OWS_TEMP_MONTH: This table contains OWS monthly temperature statistics. The table is populated only for months with 24 or more days of data available. This table is not distributed as part of the SDR.

CLM_OWS_TEMP_ANNUAL: This table contains OWS annual temperature statistics. The table is populated only for years with 300 or more days of data available. This table is not distributed as part of the SDR.

CLM_OWS_WIND_DAY: This table contains the daily maximum and minimum measured wind speeds. This table is not distributed as part of the SDR.

CLM_OWS_WIND_MONTH: This table contains OWS monthly wind statistics. The table is populated only for months with 24 or more days of data available. This table is not distributed as part of the SDR.

CLM_OWS_WIND_ANNUAL: This table contains OWS annual wind statistics. The table is populated only for years with 300 or more days of data available. This table is not distributed as part of the SDR.

5.2.2 CLM_VWS Tables

The CLM_VWS tables contain the estimates of weather data at each test section site computed from the nearby OWS. The computational structure of the CLM_VWS tables showing the relationships to CLM_OWS tables, and other important relational links, are shown in figure 6. The CLM prefix from the table names in figure 6 has been omitted for presentation convenience. The VWS daily statistics are based upon the related OWS daily data, by data type. Only OWS daily climate data which has passed all of the LTPP automated QC checks are used to compute the associated VWS daily statistic. After the VWS daily tables are created, the VWS monthly tables are computed. The month tables are computed using daily data which have passed all of the daily data QC checks. In addition to the checks on the daily tables, the month table calculations are subjected to QC checks on the number of valid days in each month daily data. Likewise, annual statistics are based upon the monthly statistics and subjected to level E checks related to the number of valid days in the year for which data for each data type is available.

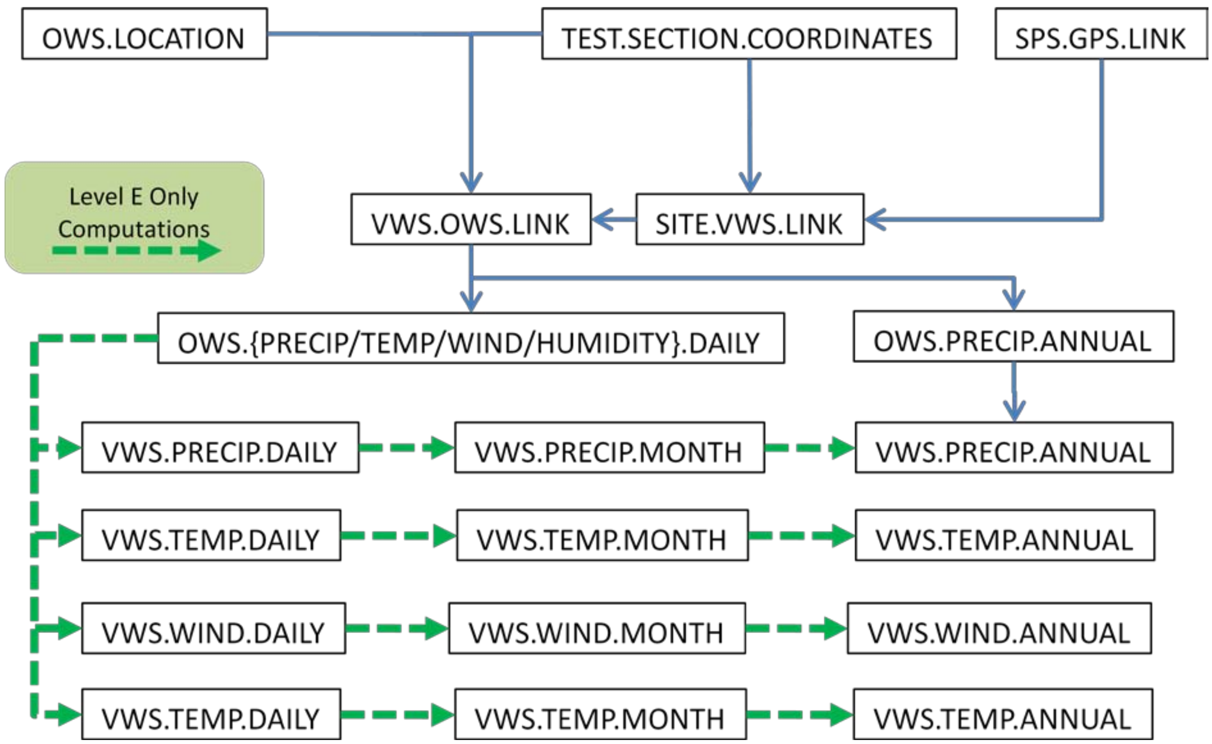

Figure 6. Computational and relational structure of the CLM_VWS tables.

CLM_SITE_VWS_LINK: This table provides the link between the VWS and the test section for which data are being provided. When an SPS section is co-located with a GPS section, the SPS section will not be in this table and the information will need to be accessed with the help of SPS_GPS_LINK.

CLM_VWS_OWS_LINK: This table provides the link between the VWS and associated OWS. It contains the distance between the VWS and the individual OWS, difference in elevation, and the directional bearing from the VWS to the OWS.

CLM_VWS_PRECIP_DAILY: This table contains the results of the VWS computations for the daily amount of precipitation and snowfall from associated records at level E in the CLM_OWS_PRECIP_DAILY table.

CLM_VWS_PRECIP_MONTH: This table contains VWS monthly precipitation statistics from records at level E in the CLM_VWS_PRECIP_DAILY table. The table is populated for months with 24 or more days of available data.

CLM_VWS_PRECIP_ANNUAL: This table contains VWS annual precipitation statistics computed from the CLM_VWS_PRECIP_MONTH table. The SNOW_COVERED_DAYS_YR field is populated from the CLM_OWS_PRECIP_ANNUAL table since this data is not stored in the daily table. The table is populated only for years with 300 or more days of data available.

CLM_VWS_HUMIDITY_DAILY: This table contains the results of the VWS computation for the maximum and minimum daily air humidity based on associated records from the CLM_OWS_HUMIDITY_DAILY table.

CLM_VWS_HUMIDITY_MONTH: This table contains VWS monthly humidity statistics computed from records at level E in the CLM_VWS_HUMIDITY_DAILY table. The table is populated only for months with 24 or more days of data available.

CLM_VWS_HUMIDITY_ANNUAL: This table contains VWS annual humidity statistics. The table is populated only for years with 300 or more days of data available.

CLM_VWS_TEMP_DAILY: This table contains the VWS daily weather statistics computed from the CLM_OWS_TEMP_DAILY weather station data.

CLM_VWS_TEMP_MONTH: This table contains VWS monthly temperature statistics. The table is populated only for months with 24 or more days of data available.

CLM_VWS_TEMP_ANNUAL: This table contains VWS annual temperature statistics. The table is populated only for years with 300 or more days of data available.

CLM_VWS_WIND_DAILY: This table contains VWS daily statistics computed from the CLM_OWS_WIND_DAILY table.

CLM_VWS_WIND_MONTH: This table contains VWS monthly wind statistics. The table is populated only for months with 24 or more days of data available.

CLM_VWS_WIND_ANNUAL: This table contains VWS annual wind statistics. The table is populated only for years with 300 or more days of data available.

5.2.3 Tables in Other Modules

SPS_GPS_LINK: This table matches co-located test sections on some SPS projects to GPS test sections for which shared climatic data are available.

5.3 CALCULATIONS

The values in the OWS daily, monthly, and annual tables are averages from the raw climatic data mentioned in the introduction. These values form the basis for the values in the VWS tables. Figure 6 illustrates the computational structure implemented in January 2004 data release. The CLM_VWS_*_DAILY tables are based on values from the corresponding CLM_OWS_*_DAILY tables, where * represents a type of weather data. The

CLM_VWS_*_MONTH tables are based on values contained in the corresponding CLM_VWS_*_DAILY table. Likewise the CLM_VWS_*_ANNUAL tables are base on values contained in the CLM_VWS_*_MONTH tables.

5.3.1 VWS Calculations

Because the values stored in the VWS tables are computed using values from up to five different OWS locations, the following equation was used to weight the influence of OWS values based on the distance from the OWS to the VWS.

$$V_m = \frac{\sum_{i=1}^{k} \frac{V_{mi}}{R_i^2}}{\sum_{i=1}^{k} \frac{1}{R_i^2}} \qquad (1)$$

where: V_m = calculated data element for day *m* for the VWS
V_{mi} = value of data element on day *m* for weather station *i*
R_i = distance between weather station *i* and pavement project site
k = number of weather stations associated with project site (up to 5)

5.3.2 Freezing Index

To compute the monthly or annual freezing index, the following equation is used:

$$FI = \sum_{i=1}^{n} (0 - T_i) \qquad (2)$$

where: FI = freezing index, degrees Celsius (°C) degree-days
T_i = average daily air temperature on day *i*, °C
n = days in the specified period when average daily temperature is below freezing
i = number of days below freezing

When using this equation, only the days where the average daily temperature is below freezing are used. Therefore, the freezing index is the negative of the sum of all average daily temperatures below 0 °C within the given period.

CHAPTER 6. DYNAMIC LOAD RESPONSE MODULE

The Dynamic Load Response (DLR) module contains instrumentation response data collected at SPS test sections in North Carolina and Ohio.

Four PCC pavement sections on the SPS-2 project in North Carolina were instrumented to measure pavement response under controlled loading conditions. Both deflections and strains at defined positions within the slab were recorded under loading by known vehicles at six locations (corner, midslab edge, and midslab outer wheel path) within two adjacent slabs. Pavement surface strains were obtained by surface-mounted strain gauges located at midslab within the wheel path and midslab along the slab edge. A total of 30 traces were obtained from each pass of the loaded vehicle with multiple repetitions at multiple speeds collected at various times of the day. The LTPP technical support services contractor and the North Carolina Department of Transportation (DOT) worked jointly during data collection operations. The LTPP technical support services contractor has summarized the raw data files to determine the characteristic peaks and valleys along the individual response traces.

Ohio DOT and a consortium of Ohio universities performed DLR measurements on instrumented sections in Ohio. Measurements were taken on both SPS-1 and -2 AC and PCC test sections. Information on the tests performed in Ohio can be found at the Ohio DOT web site: http://www.dot.state.oh.us/Divisions/Planning/SPR/Research/reportsandplans/Pages/PavementReportsDetail.aspx

The data were collected using similar techniques to the LTPP DLR data collected in North Carolina.

The Ohio DLR data previously released by the LTPP program was removed from the January 2012 data release (SDR26) because of errors found in the interpretation of the raw data. Because DLR measurements on AC test sections were performed only at the Ohio site, the entire DLR related AC tables were removed from this SDR. LTPP is working on reinterpretation of the previously released data with the objective to include it in the January 2013 data release.

Because of the complex nature of this data module, users interested in analyses of these data should contact LTPP customer service discuss research objectives and obtain the most recent technical information on the status of this data.

6.1 IMPORTANT FIELDS

Common fields unique to the DLR tables that can be used to link related data in associated tables to each other include TEST_NAME, RUN_NUMBER, and TAG_ID.

6.1.1 TEST_NAME represents data collection events on each test site. A data collection event can occur on a single day or over several consecutive test days. DLR_TEST_MATRIX provides a link between TEST_NAME in the DLR_MASTER_* tables and TEST_DATE. RUN_NUMBER in the DLR_TEST_MATRIX table can be used to differentiate between multiple test dates occurring during a single data collection event as indicated by TEST_NAME.

This link to TEST_DATE is needed for DLR measurements on PCC sections; TEST_DATE is included in the tables containing measurements on AC test sections. The last letter in TEST_NAME indicates the temporal order of testing: “a” represents the first data collection event, “b” indicates the second, and so on.

6.1.2 RUN_NUMBER represents the sequential order of runs by test trucks during the data collection event as defined by TEST_NAME. RUN_NUMBER is used to relate the characteristics of the test truck and test speed stored in the DLR_TEST_MATRIX and DLR_TRUCK_GEOMETRY tables to the measured pavement responses stored in the other DLR data tables. For each TEST_NAME event, the run number starts with 1 and is increased by 1 for each successive pass by the test trucks.

6.1.3 TAG_ID is the name assigned to the sensors installed on each test section. The combination of STATE_CODE, SHRP_ID, and TAG_ID uniquely identifies each response sensor. The TAG_ID name also identifies the type of sensor, although the DLR data tables are based on the type of measurement. TAG_ID is a mapping on the CHANNEL the sensor is wired to on the data acquisition device.

6.2 DLR TABLES

The relational structure of the tables in the DLR module is illustrated in figure 7:

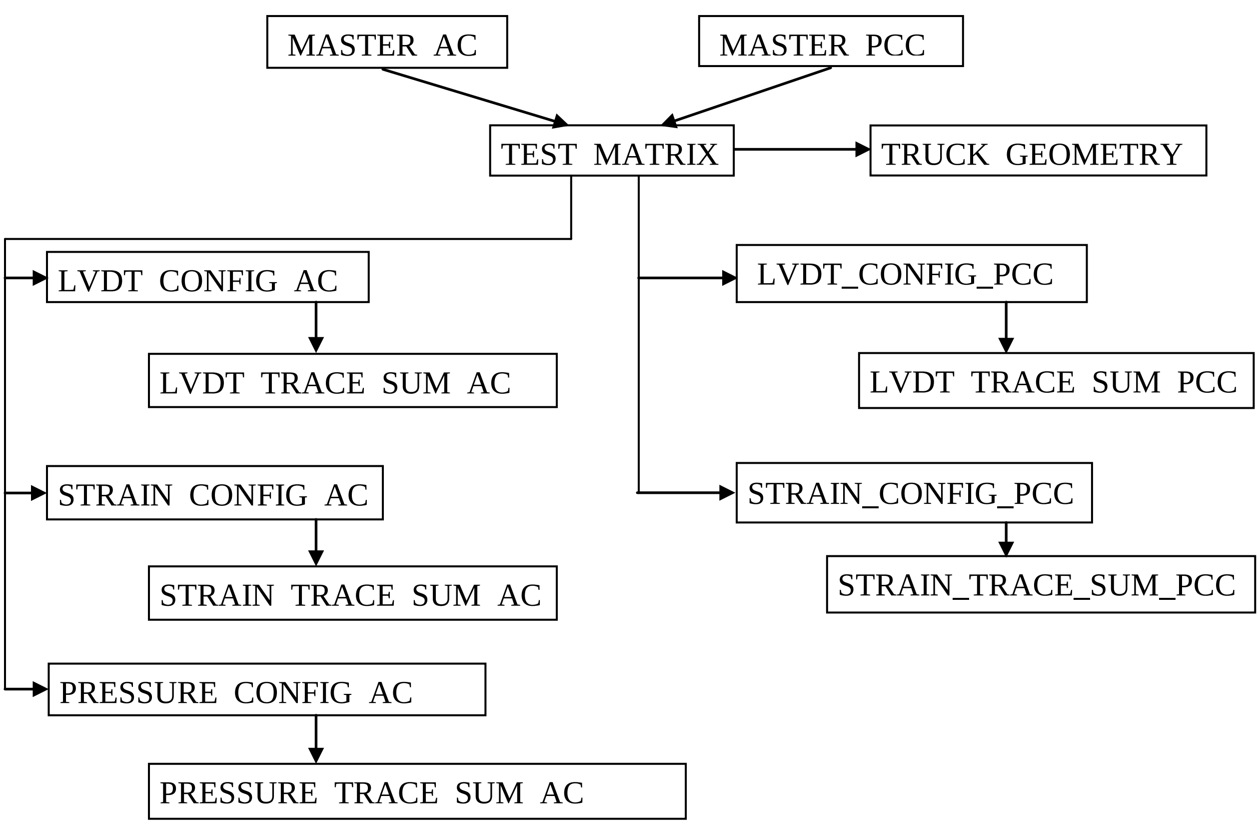

Figure 7. Relational structure of data stored in the DLR module.

The name and contents of tables in the DLR module are as follows:

6.2.1 DLR_MASTER_AC: This table contains site and instrumentation summary information for sections with AC surfaces. One record exists in this table for each DLR measurement cycle as defined by the TEST_NAME field.

6.2.2 DLR_MASTER_PCC: This table contains site and instrumentation summary information for sections with PCC surfaces. One record exists in this table for each DLR measurement cycle as defined by the TEST_NAME field.

6.2.3 DLR_TEST_MATRIX: This table contains information on each test sequence, including test date, test time, test vehicle, vehicle speed, and vehicle offset. TRUCK_ID and STATE_CODE are used to link to information on truck geometry stored in the DLR_TRUCK_GEOMETRY table.

6.2.4 DLR_LVDT_CONFIG_AC: This table contains Linear Variable Differential Transformer (LVDT) gauge settings and location information for instrumented AC test sections.

6.2.5 DLR_LVDT_TRACE_SUM_AC: This table contains response trace summaries from LVDT measurements on AC test sections. The response trace is reduced to a series of up to 10 points to capture the significant events in the response trace (most traces contain 3 to 5 points).

6.2.6 DLR_LVDT_CONFIG_PCC: This table contains LVDT gauge settings and location information for instrumented PCC test sections.

6.2.7 DLR_LVDT_TRACE_SUM_PCC: This table contains response trace summaries from LVDT measurements on PCC test sections. The response trace is reduced to a series of up to 10 points to capture the significant events in the response trace.

6.2.8 DLR_PRESSURE_CONFIG_AC: This table contains pressure gauge settings and location information for measurements on AC test sections.

6.2.9 DLR_PRESSURE_TRACE_SUM_AC: This table contains response trace summaries from pressure measurements on AC test sections. The time-response trace is reduced to a series of up to 10 points to capture the significant events in the response trace (most traces contain 3 to 5 points).

6.2.10 DLR_STRAIN_CONFIG_AC: This table contains strain gauge information, configuration settings, and location information for measurements on AC test sections.

6.2.11 DLR_STRAIN_TRACE_SUM_AC: This table contains response trace summaries from strain measurements on AC test sections. The time-response trace is reduced to a series of up to 10 points to capture the significant events in the response trace (most traces contain 3 to 5 points).

6.2.12 DLR_STRAIN_CONFIG_PCC: This table contains strain gauge information, configuration settings, and location information for measurements on PCC test sections.

6.2.13 DLR_STRAIN_TRACE_SUM_PCC: This table contains response trace summaries from strain measurements on PCC test sections. The time-response trace is reduced to a series of up to 10 points to capture the significant events in the response trace.

6.2.14 DLR_TRUCK_GEOMETRY: This table contains information on the axle spacing, tire type and pressure, and axle width of the test trucks used for the DLR tests.

CHAPTER 7. INVENTORY MODULE

The Inventory (INV) module contains information on pavement structures that were in service up to 15 years prior to selection for monitoring as an LTPP test section. This includes all of the test sections classified in a GPS experiment or SPS maintenance and rehabilitation experiment for a CONSTRUCTION_NO of 1 as defined in the EXPERIMENT_SECTION table. For SPS projects, the information stored in the INV module represents the pavement structure prior to application of the experimental treatments. INV data include location of the section, pavement type, layer thicknesses and types, material properties, composition, previous construction improvements, and other background information.

The INV information is typically based on highway agency records for the construction project. The information may not represent specific conditions found at the portion of the project selected for monitoring. The information does not necessarily represent design values.

LTPP Database Tip!	For SPS-3 and -4 projects that include a co-located GPS test section at the project site, information for the SPS project in the INV tables is coded to the GPS test section. The SPS_GPS_LINK table contains a mapping of SPS projects to data stored under the linked GPS test section.

7.1 INV_ID

This table contains section location information including route number, milepost, direction of travel, identification if the location is part of the FHWA Highway Performance Monitoring System, and county/parish name. Location information is provided in this table for sections classified in a GPS experiment or an SPS maintenance and rehabilitation experiment where CONSTRUCTION_NO = 1 in the EXPERIMENT_SECTION table. Location information for SPS projects that is based on construction of a new pavement structure is stored in the SPS_ID table.

7.2 INV_AGE

This table contains construction completion and traffic open dates for the original pavement structure based on highway agency records.

7.3 INV_LAYER

This table contains layer information from highway agency records. This information represents the pavement structure prior to LTPP monitoring. This table acts as a layer reference table for the other INV tables. INV tables that contain the LAYER_NO field reference the layer structure described in the INV_LAYER table. The layer structure in this table may differ from the actual layer structure found at the test site. The pavement structure data in this table are not recommended for use in analysis of performance monitoring measurements. The TST_L05* tables are the best representation of the actual pavement structure for each test section since they are based on field drilling and sampling measurements at the site.

7.4 INV_GENERAL

This table contains general information, including pavement type, lane width, number of lanes, subsurface drainage features, and an estimate of the depth to a rigid layer beneath the test section from agency records.

7.5 INV_GRADATION

This table contains data on the gradation of coarse, fine, and combined aggregates for PCC, AC, base, and subgrade. LAYER_NO in this table is used to link to the INV_LAYER table to indicate the type of layer. These data are based on agency project records.

7.6 INV_MAJOR_IMP

This table contains information on the type, quantity, and cost of major improvements to the test section prior to acceptance for LTPP monitoring.

7.7 INV_MODIFIER

This table contains information on asphalt modifiers used in plant-mixed asphalt (PMA)-bound layers.

7.8 INV_PCC_JOINT

This table contains information on formed joints in PCC layers, including joint type, joint spacing, load-transfer system, joint construction methods, joint sealant, and tie bars.

7.9 INV_PCC_MIXTURE

This table contains PCC mix properties, including cement type, air entrainment, slump, and mix proportions.

7.10 INV_ADMIX

This table contains information on admixture type and amount for PCC layers.

7.11 INV_AGGR_COMP

This table contains information on aggregate composition for coarse, fine, and combined aggregates used in AC and PCC mixtures.

7.12 INV_AGGR_DUR

This table contains information on aggregate durability in AC and PCC mixtures.

7.13 INV_PCC_STEEL

This table contains information on steel reinforcement in PCC layers, including reinforcing steel type, diameter, design amount of longitudinal reinforcing, depth, and installation method.

7.14 INV_PCC_STRENGTH

This table contains available strength data from highway agency records for PCC layers, including flexural strength, compressive strength, and splitting tensile strength.

7.15 INV_PMA

This table contains information on PMA-bound layer aggregate properties, including bulk specific gravity, effective specific gravity, mineral fillers, and polish value.

7.16 INV_PMA_ASPHALT

This table contains information on the asphalt cement used in PMA-bound layers, including asphalt grade, source, specific gravity, viscosity, penetration, ductility, and softening point.

7.17 INV_PMA_COMPACTION

This table contains information on field compaction of PMA-bound layers, including type of compaction equipment, coverage, air temperature, compacted thickness, and curing period.

7.18 INV_PMA_CONSTRUCTION

This table contains information on field construction of PMA-bound layers, including mixing temperature and lay-down temperatures.

7.19 INV_PMA_ORIG_MIX

This table contains available agency information from laboratory- and field-compacted specimens on the mix properties of PMA-bound layers. Data included in this table are maximum specific gravity, bulk specific gravity, asphalt content, air voids, voids in the mineral aggregate, mix design stability, plant type, anti-stripping agents, and moisture susceptibility.

7.20 INV_PMA_ROLLER

This table contains details on the rollers used to compact AC layers, including roller weight, tire pressure, and roller speed.

7.21 INV_SHOULDER

This table contains shoulder composition, geometric, and structural properties, including surface material type, width, thickness, base type, and associated details for PCC shoulders.

7.22 INV_STABIL

This table contains data on stabilizing agents used in base and subbase layers.

7.23 INV_SUBGRADE

This table contains available information on the properties of the subgrade from highway agency records, including plasticity indices, soil classification, soil strength, laboratory moisture-density relationships, in situ properties, soil suction, expansion index, frost susceptibility, and key gradation properties.

7.24 INV_UNBOUND

This table contains available information on the properties of base layers from highway agency records, including plasticity indices, classification, strength, laboratory moisture-density relationships, and in situ properties.

7.25 INV_DEICE_SITE_DATA

This table contains general information on snow removal and the frequency of deicer use. Data stored in this table are primarily for GPS test sections in the North Atlantic, North Central, and Western LTPP regions. Data were collected once at the start of the program in support of the SHRP research on snow and ice control.

7.26 INV_DEICE_TYPES

This table contains a listing of the type of deicers used on test sections. Data stored in this table are primarily for GPS test sections in the North Atlantic, North Central, and Western LTPP regions. Data were collected once at the start of the program in support of the SHRP research on snow and ice control.

CHAPTER 8. MAINTENANCE AND REHABILITATION MODULES

The Maintenance (MNT) and Rehabilitation (RHB) modules house very similar and often related data, and are therefore discussed in the same chapter. In the future, it is planned to collapse the MNT and RHB modules into a single module to avoid confusion on where these closely related data types are stored.

Major improvements to a test section after inclusion in the LTPP program are documented in the RHB module. The tables in this module contain information on activities such as overlay properties and construction, shoulder replacement, and joint repair. Rehabilitation activities include resurfacing, reconstruction, and the addition of lanes. Rehabilitation sometimes alters the pavement structure. In these cases, layer data are recorded.

The MNT module contains data reported by highway agencies on maintenance treatments applied to test sections. This module primarily records activities conducted on the test section after inclusion in the LTPP program. However, one table contains information on maintenance treatments applied prior to inclusion of the test section in the LTPP study. While the data in the MNT tables include information such as placement of seal coats, patches, joint resealing, milling, and grooving, users should also examine information stored in the RHB module since these two activities are closely related. Unlike the RHB module, there is no significant pavement structure change from a maintenance event, and therefore no maintenance layer table exists.

Regardless of whether a treatment is considered maintenance or rehabilitation, the pavement structure will always be represented in the appropriate TST tables. Chapter 14 contains more information on TST tables.

Participating highway agencies are requested to notify the LTPP regional office prior to performing maintenance or rehabilitation on a highway segment containing an LTPP section. This allows the regional office to collect any necessary monitoring data to identify the condition of the pavement prior to the activity. Data are collected on pavement condition before and after all rehabilitation and many maintenance activities. States provide information on paper forms describing the actual work done.

Some types of rehabilitation do not fit either the GPS or SPS experiments. Sections receiving those treatments are placed out of study, are no longer studied after rehabilitation, and do not have data in this module for that treatment.

8.1 IMPORTANT FIELDS

IMP_TYPE provides information on the type of maintenance or rehabilitation performed, and is used in both **MNT_IMP** and **RHB_IMP**. The field uses a code named MAINT_WORK. Some of these codes are very similar and, therefore, one type of activity may be represented by different codes in different records.

LTPP Database Tip!	For SPS maintenance and rehabilitation experiments, most of the data related to the experimental maintenance treatments are stored in tables in the SPS module.

This field should be used to determine which other MNT or RHB tables contain the specifics of the activity. Table 3 shows the general relationships between IMP_TYPE and the MNT and RHB tables. Because of the variability in the maintenance and rehabilitation improvements, and the use of SPS_* tables for some of these data, different tables may be completed for different projects, and data may not be stored in the expected MNT or RHB table for a given IMP_TYPE code. Data may not always be available for a given improvement, and when DATA_AVAIL_IMS is "N", there will be no data in other MNT and RHB tables.

Table 3. IMP_TYPE and expected location of data in MNT and RHB tables.

IMP_TYPE	Type of Improvement	Expected Location of Data in MNT and RHB Tables
1	Crack Sealing	MNT_PCC_CRACK_SEAL MNT_ASPHALT_CRACK_SEAL
2	Transverse Joint Sealing	MNT_PCC_JOINT_RESEAL
3	Lane-Shoulder Longitudinal Joint Sealing	MNT_PCC_JOINT_RESEAL
4	Full-Depth Transverse Joint Repair Patch	MNT_PCC_FULL_DEPTH
5	Full-Depth Patching of PCC Pavement Other Than at Joint	MNT_PCC_FULL_DEPTH
6	Partial-Depth Patching of PCC Pavement Other Than at Joint	MNT_PCC_PART_DEPTH
7	PCC Slab Replacement	MNT_PCC_FULL_DEPTH
8	PCC Shoulder Restoration	RHB_RESTORE_PCC_SHOULDER
9	PCC Shoulder Replacement	RHB_RESTORE_PCC_SHOULDER
10	AC Shoulder Restoration	RHB_RESTORE_AC_SHOULDER
11	AC Shoulder Replacement	RHB_RESTORE_AC_SHOULDER
12	Grinding Surface	MNT_GMC
13	Grooving Surface	MNT_GMG
14	Pressure Grout Subsealing	RHB_SUBSEALING_PCC
16	Asphalt Subsealing	RHB_SUBSEALING_PCC
19	AC Overlay	RHB_ACO_* RHB_PMA_*
20	PCC Overlay	RHB_PCCO_*
21	Mechanical Premix Patch	MNT_ASPHALT_PATCH
22	Manual Premix Spot Patch	MNT_ASPHALT_PATCH
23	Machine Premix Patch	MNT_ASPHALT_PATCH
24	Full-Depth Patch of AC Pavement	MNT_ASPHALT_PATCH
25	Patch Pot Holes: Hand Spread, Compacted With Truck	MNT_ASPHALT_PATCH
26	Skin Patching	MNT_ASPHALT_PATCH

Table 3. IMP_TYPE and expected location of data in MNT and RHB tables (continued).

IMP_TYPE	Type of Improvement	Expected Location of Data in MNT and RHB Tables
27	Strip Patching	MNT_ASPHALT_PATCH
28	Surface Treatment, Single Layer	MNT_ASPHALT_SEAL
29	Surface Treatment, Double Layer	MNT_ASPHALT_SEAL
30	Surface Treatment, Three or More Layers	MNT_ASPHALT_SEAL
31	Aggregate Seal Coat	MNT_ASPHALT_SEAL
32	Sand Seal Coat	MNT_ASPHALT_SEAL
33	Slurry Seal Coat	MNT_ASPHALT_SEAL
34	Fog Seal Coat	MNT_ASPHALT_SEAL
35	Prime Coat	MNT_ASPHALT_SEAL
36	Tack Coat	MNT_ASPHALT_SEAL
37	Dust Layering	MNT_ASPHALT_SEAL
38	Longitudinal Subdrainage	RHB_SUBDRAINAGE
39	Transverse Subdrainage	RHB_SUBDRAINAGE
40	Drainage Blankets	RHB_SUBDRAINAGE
41	Well System	RHB_SUBDRAINAGE
42	Drainage Blankets With Longitudinal Drains	RHB_SUBDRAINAGE
43	Hot-Mix Recycled AC	RHB_HMRAP_* RHB_PMA_*
44	Cold-Mix Recycled AC	RHB_CMRAP_* RHB_PMA_*
45	Heater Scarification, Surface-Recycled AC	RHB_HEATER_SCARIF
46	Crack-and-Seat PCC Pavement +AC Surface	RHB_CRACK_SEAT_PCC
47	Crack-and-Seat PCC Pavement + PCC Surface	RHB_CRACK_SEAT_PCC
48	Recycled PCC	RHB_RCYPCC_* RHB_PCCO_*
49	Pressure Relief Joints in PCC Pavements	RHB_PRESSURE_RELIEF
50	Joint Load-Transfer Restoration in PCC	RHB_LOAD_TRANSFER
51	Mill Off AC and Overlay With AC	RHB_MILL_AND_GRIND RHB_ACO_* RHB_PMA_*
52	Mill Off AC and Overlay With PCC	RHB_MILL_AND_GRIND RHB_PCCO_*
53	Other	
54	Partial-Depth Joint Patching of PCC Pavement	MNT_PCC_PART_DEPTH
55	Mill Existing Pavement and Overlay With Hot-Mix AC	RHB_MILL_AND_GRIND RHB_HMRAP_* RHB_PMA_*
56	Mill Existing Pavement and Overlay With Cold-Mix AC	RHB_MILL_AND_GRIND RHB_CMRAP_* RHB_PMA_*

DATA_AVAIL_IMS in MNT_IMP and RHB_IMP indicates whether information on the maintenance or rehabilitation activity is available in other MNT or RHB tables. The creation of a record in MNT_IMP or RHB_IMP is an important step in the process of assigning a construction number, and this field is necessary so that entries can be made in the MNT_IMP or RHB_IMP tables before the specifics of the activity are known.

8.2 MNT TABLES

MNT_IMP: This table contains a listing of the various maintenance activities conducted on each test section after its inclusion in the LTPP program and the date on which these treatments were applied.

MNT_PCC_CRACK_SEAL: This table contains crack sealing information for PCC pavements, including the type of sealant used, how it was applied, and how much sealing was performed.

MNT_PCC_FULL_DEPTH: This table contains information on full-depth PCC repair, including the reasons for the repair, the size of the replacement slab, the material used for replacement, the interface of the replacement with the existing pavement, and finishing/curing methods.

MNT_PCC_JOINT_RESEAL: This table contains joint resealing information for PCC pavements, including information on the removal of existing joint sealant, the application and type of the new sealant, and the quantity of sealing performed.

MNT_PCC_PART_DEPTH: This table contains information on partial-depth patching for PCC pavements, including the reasons for patching, the type of patching performed, the material used for patching and material properties, jointing, and curing methods for PCC patches.

MNT_ASPHALT_CRACK_SEAL: This table contains crack sealing information for AC pavements, including the type of sealant used, how it was applied, and how much sealing was performed.

MNT_ASPHALT_PATCH: This table contains patching information for AC pavements, including the reasons for patching, the size of patching, and patching techniques.

MNT_ASPHALT_SEAL: This table contains seal-coat application information for AC pavements, including the reasons for sealing, the type and properties of the sealant used, and application information.

MNT_GMG: This table contains information on diamond grinding, milling, and grooving of all pavement surface types, including the reasons for treatment and the details of the treatment type and application.

MNT_COST: This table contains cost information for maintenance activities. Because of differences in the way highway agencies compute costs, users should expect inconsistencies in cost information.

MNT_HIST: This table contains information on section maintenance that occurred prior to the section's inclusion in the LTPP program, including only basic information such as type and quantity of maintenance.

8.3 RHB TABLES

8.3.1 Nonrehabilitation-Specific Tables

These tables are not specific to any one type of rehabilitation, and may be filled out regardless of the rehabilitation performed. RHB_IMP contains entries for every rehabilitation event. RHB_LAYER is completed only for treatments that alter the material layer structure.

RHB_IMP: This table contains a complete list of the rehabilitation treatments placed after the test section was included in the LTPP program. This table also contains when the treatments were placed.

RHB_LAYER: This table contains changes to the layer structure based on information provided by the State or Provincial highway agency. This information should not be used when conducting analyses on long-term pavement performance; however, it is considered useful when conducting a detailed analysis of an individual section(s).

RHB_CAUSE_INFO: This table contains information on the cause(s) of rehabilitation for a test section and the scheduled start date for the rehabilitation.

8.3.2 RHB Tables for AC Overlays

8.3.2.1 RHB_PMA_* Tables

These tables contain information on the construction of AC overlays. They will be used regardless of whether the overlay is recycled AC or not. They will probably be populated when IMP_TYPE = 19, 43, 44, 51, 55, or 56.

RHB_PMA_COMPACTION: This table contains compaction data for all types of AC overlays, including information on roller types and coverage.

RHB_PMA_CONSTRUCTION: This table contains construction data for all types of AC overlays. This table includes plant information and lay-down temperatures.

RHB_PMA_ROLLER: This table contains roller data for rollers used on all types of AC overlays, including the type, weight, and speed of the rollers used for compaction.

8.3.2.2 RHB_ACO_* Tables

These tables are used for nonrecycled asphalt pavement overlays. They will probably be populated only if IMP_TYPE = 19 or 51.

RHB_ACO_AGGR_PROP: This table contains the properties of the aggregate used in AC overlays, including aggregate composition, durability, specific gravity, and gradation.

RHB_ACO_LAB_AGED_AC: This table contains the properties of the laboratory-aged asphalt cement used in AC overlays, including viscosity, ductility, penetration, and other asphalt cement properties.

RHB_ACO_LAB_MIX: This table contains the properties of the AC laboratory mix design used in AC overlays, including asphalt content, air voids, specific gravity, stability, and other AC properties.

RHB_ACO_MIX_PROP: This table contains the as-placed properties of the AC mix used in AC overlays, including asphalt content, air voids, specific gravity, stability, and other AC properties.

RHB_ACO_PROP: This table contains the properties of the asphalt cement used in AC overlays, including the modifiers used, specific gravity, viscosity, ductility, and other asphalt cement properties.

RHB_ACO_SP_AGGR_PROP: First introduced in data release 20, this table contains additional aggregate properties related to the Superpave mix design method used for AC overlay layers. Some of the unique aggregate properties contained in this table include angularity, soundness, and toughness of fine and coarse proportions. The table is sparsely populated with very few records.

RHB_ACO_SP_MIX_PROP: This table contains AC Superpave related properties of the overlay layer. This table is sparsely populated.

RHB_ACO_SP_PROP: This table contains Superpave related properties of the asphalt binder used in the AC overlay layer. In the 2011 SDR release, this table contained only one record with very limited population of the available fields.

8.3.2.3 RHB_CMRAP_* Tables

These RHB tables are used for cold-mix recycled AC overlays. They will probably be populated only if IMP_TYPE = 44 or 56. Since this is not a standard treatment option for the LTPP experiments, most of the following tables are empty. Starting with the January 2012 data release, all of the RHB_CMRAP-* tables have at least one record in them and are included in the data release.

RHB_CMRAP_COMBINED_AGG: This table contains the properties of the combined aggregate used in cold-mix recycled AC overlays, including aggregate composition, specific gravity, and gradation. Since there are no data stored in this table it is not included in the standard data release.

RHB_CMRAP_COMBINE_AC: This table contains the properties of the asphalt cement used in cold-mix recycled AC overlays, including the modifiers used, specific gravity, viscosity, ductility, and other asphalt cement properties.

RHB_CMRAP_GEN_INFO: This table contains the properties of the reclaimed aggregate and general information for cold-mix recycled AC overlays, including the gradation and specific gravity of the reclaimed aggregate, and the methods used to process and break up the existing pavement.

RHB_CMRAP_LAB_AGED_AC: This table contains the properties of the laboratory-aged asphalt cement used in cold-mix recycled AC overlays, including viscosity, ductility, penetration, and other asphalt cement properties. Since there are no data stored in this table it is not included in the standard data release.

RHB_CMRAP_LAB_MIX: This table contains the properties of the AC laboratory mix design used in cold-mix recycled AC overlays, including asphalt content, air voids, specific gravity, stability, and other AC properties.

RHB_CMRAP_MIX_PROP: This table contains the as-placed properties of the AC mix used in cold-mix recycled AC overlays, including asphalt content, air voids, specific gravity, stability, and other AC properties. This table was removed from the SDR starting with SDR 23 since all records were removed from the table in response to database module feedback report on problems with the previous data entered in the table.

RHB_CMRAP_NEW_AC_PROP: This table contains the properties of the new asphalt cement used in cold-mix recycled AC overlays, including viscosity, ductility, penetration, and other asphalt cement properties.

RHB_CMRAP_RECLAIM_AC: This table contains the properties of the reclaimed asphalt cement used in cold-mix recycled AC overlays, including viscosity, ductility, penetration, and other asphalt cement properties.

RHB_CMRAP_UNTREAT_AGGR: This table contains the properties of the untreated aggregate used in cold-mix recycled AC overlays, including aggregate composition, durability, specific gravity, and gradation.

8.3.2.4 RHB_HMRAP_* Tables

These RHB tables are used for hot-mix recycled AC overlays. They will probably be populated only if IMP_TYPE = 43 or 55.

RHB_HMRAP_COMBINED_AGG: This table contains the properties of the combined aggregate used in hot-mix recycled AC overlays, including aggregate composition, specific gravity, and gradation.

RHB_HMRAP_COMBINE_AC: This table contains the properties of the asphalt cement used in hot-mix recycled AC overlays, including the modifiers used, specific gravity, viscosity, ductility, and other asphalt cement properties.

RHB_HMRAP_GEN_INFO: This table contains the properties of the reclaimed aggregate and general information on hot-mix recycled AC overlays, including the gradation and specific gravity of the reclaimed aggregate and the methods used to process and break up the existing pavement.

RHB_HMRAP_LAB_AGED_AC: This table contains the properties of the laboratory-aged asphalt cement used in hot-mix recycled AC overlays, including viscosity, ductility, penetration, and other asphalt cement properties.

RHB_HMRAP_LAB_MIX: This table contains the properties of the AC laboratory mix design used in hot-mix recycled AC overlays, including asphalt content, air voids, specific gravity, stability, and other AC properties.

RHB_HMRAP_MIX_PROP: This table contains the as-placed properties of the AC mix used in hot-mix recycled AC overlays, including asphalt content, air voids, specific gravity, stability, and other AC properties.

RHB_HMRAP_NEW_AC_PROP: This table contains the properties of the new asphalt cement used in hot-mix recycled AC overlays, including viscosity, ductility, penetration, and other asphalt cement properties.

RHB_HMRAP_RECLAIM_AC: This table contains the properties of the reclaimed asphalt cement used in hot-mix recycled AC overlays, including viscosity, ductility, penetration, and other asphalt cement properties.

RHB_HMRAP_UNTREAT_AGGR: This table contains the properties of the untreated aggregate used in hot-mix recycled AC overlays, including aggregate composition, durability, specific gravity, and gradation.

8.3.3 RHB Tables for PCC Overlays

8.3.3.1 RHB_PCCO Tables

These tables include information on PCC overlays. These tables will probably be populated when IMP_TYPE = 20, 48, or 52.

RHB_PCCO_AGGR: This table contains the properties of the aggregate used in PCC overlays, including aggregate composition, durability, specific gravity, and gradation.

RHB_PCCO_CONSTRUCTION: This table contains construction data for PCC overlays, including information on curing, temperature, and existing surface preparation.

RHB_PCCO_JOINT_DATA: This table contains joint data for PCC overlays, including information on construction and expansion joints, sealants, and load-transfer devices.

RHB_PCCO_MIXTURE: This table contains PCC mixture data for PCC overlays, including information on mix design, admixtures, slump, air entrainment, and other PCC mix properties.

RHB_PCCO_STEEL: This table contains information on reinforcing steel used in PCC overlays, including the type and strength of the reinforcement and some placement information. Since there are no data stored in this table it is not included in the standard data release.

RHB_PCCO_STRENGTH: This table contains PCC strength data for PCC overlays, including flexural, compressive, and tensile strength, and elastic modulus.

8.3.3.2 RHB_RCYPCC Tables

These tables contain information on PCC overlays using recycled PCC pavement. These tables will probably be populated when IMP_TYPE = 48. Since recycled PCC overlays were not an LTPP study topic, the tables in this module are currently empty. Since there are no data stored in these tables they are not included in the standard data release.

RHB_RCYPCC_COMBINED_AGGR: This table contains the properties of the combined aggregate used in recycled PCC overlays, including aggregate durability, specific gravity, and gradation.

RHB_RCYPCC_CONSTRUCTION: This table contains construction data for recycled PCC overlays, including information on curing, temperature, and existing surface preparation.

RHB_RCYPCC_JOINT: This table contains joint data for recycled PCC overlays, including information on construction and expansion joints, sealants, and load-transfer devices.

RHB_RCYPCC_MIXTURE: This table contains PCC mixture data for recycled PCC overlays, including information on mix design, admixtures, slump, air entrainment, and other PCC mix properties.

RHB_RCYPCC_NEW_AGGR: This table contains the properties of the new (nonrecycled) aggregate used in recycled PCC overlays, including aggregate composition, durability, specific gravity, and gradation.

RHB_RCYPCC_STEEL: This table contains information on reinforcing steel used in recycled PCC overlays, including the type and strength of the reinforcement and some placement information.

RHB_RCYPCC_STRENGTH: This table contains PCC strength data for recycled PCC overlays, including flexural, compressive, and tensile strength, and elastic modulus.

8.3.4 Non-Overlay RHB Tables

These tables are for rehabilitation other than AC or PCC overlays, though the rehabilitation often occurs in conjunction with an overlay. They are populated for a variety of IMP_TYPE's, as shown in table 3.

RHB_CRACK_SEAT_PCC: This table contains data collected from PCC crack-and-seat operations, including information on the breaking and seating processes used. This table may also be used for rubblization. Since there are no data stored in this table it is not included in the standard data release. Data on fracture treatments applied to SPS test sections can be found in the SPS construction module.

RHB_HEATER_SCARIF: This table contains data on heater scarification surface recycling treatments on AC pavements, including information on the type of heater scarification, rejuvenating agents, and compaction.

RHB_LOAD_TRANSFER: This table contains load-transfer restoration data for PCC pavements, including information on the type of restoration and the specifics on the placement of the load-transfer devices.

RHB_MILL_AND_GRIND: This table contains milling and grinding data for all pavement types, including the type and depth of milling or grinding.

RHB_PRESSURE_RELIEF: This table contains data on the installation of pressure relief joints in PCC pavement, including information on the joint dimensions and interval, and the sealants and fillers used.

RHB_RESTORE_AC_SHOULDER: This table contains information on the restoration of AC shoulders, including the structure of the shoulder and the restoration performed.

RHB_RESTORE_PCC_SHOULDER: This table contains information on the restoration of PCC shoulders, including the structure of the shoulder and the restoration performed.

RHB_SUBDRAINAGE: This table contains data on retrofitted subdrainage installation, including information on the drainage materials used and the specifics of their placement.

RHB_SUBSEALING_PCC: This table contains data on subsealing PCC pavement, including the type, properties, and placement of the sealant.

8.4 TABLES IN OTHER MODULES

INV_MAJOR_IMP: This table contains data on major maintenance and rehabilitation treatments that were applied to the test section prior to its inclusion in the LTPP program.

CHAPTER 9. PAVEMENT MONITORING MODULE

The Pavement Monitoring (MON) module contains photographic distress, manual distress, transverse profile distortion (ruts), longitudinal profile, deflection, friction, and drainage data.

9.1 PHOTOGRAPHIC AND MANUAL DISTRESS

Data stored in the MON_DIS tables provide a measure of pavement surface condition, including the amount and severity of cracking, patching and potholes, existence of surface deformation, joint defects, and other types of surface defects. Data on the transverse profile and rut-related distresses are stored in other tables.

Initially, visual interpretation of high-resolution 35-mm (1.38-inch) photographic images of the pavement surface was the primary means used to obtain the surface distress data. A national distress data collection contractor was hired to take the field measurements and interpret the images. The images provided a photographic record that can be reviewed and reinterpreted in the future. Circa 1994, the frequency of the distress surveys conducted by manual inspection of test sections by LTPP regional contractors in the field increased. Guidelines for distress rating and interpretation are contained in the *Distress Identification Manual for the LTPP Project.*

To create a distress time history, data users are often faced with combining distresses from photographic and manual data collection methods. The limitations of each method of data collection must be recognized in interpreting combined data sets, particularly when illogical time series trends exist.

LTPP Database Tip!	The width of the pavement included in the distress interpretation can vary greatly between manual and photographic distress surveys. On average, the photographic surveys cover a width of about 4.3-m (14-feet). Since manual distress surveys typically cover a shorter pavement width, this can result in anomalies in the time series magnitudes of the total length of traverse cracking features and distress area. Since the width if the distress interpretation is not included as a data element in the database users must take this into consideration when interpreting combined data sets.

9.1.1 MON_DIS Tables

Most of the distress data tables have names beginning with MON_DIS. The one exception is the MON_DROP_SEP table that contains shoulder drop-off and separation information.

In the distress tables, a null should be interpreted that a particular distress was not rated or a measurement was not performed. A zero indicates that the distress was not present.

MON_DIS_AC_REV: This table contains distress survey information obtained by manual inspection in the field for pavements with AC surfaces. The reflection cracking fields in this table have been set to null since this type of distress is no-longer rated. Distresses previously rated as reflection cracks have been assigned to other distress categories. In the future, the reflection cracking fields will be removed from this table.

LTPP Database Tip!	Transverse cracks can include cracks caused by low temperature or reflection cracking types of mechanisms. Since the LTPP program does not classify cracks by these distress mechanisms, users must make these interpretations. Hand-drawn distress maps, 35-mm (1.38-inch) photographs, and maps of distress surveys conducted prior to overlay may be useful in identifying these types of cracking mechanisms.

MON_DIS_CRCP_REV: This table contains distress survey information obtained by manual inspection in the field for continuously reinforced PCC pavements.

MON_DIS_JPCC_REV: This table contains distress survey information obtained by manual inspection in the field for jointed PCC pavements.

MON_DIS_PADIAS_AC: This table contains distress survey information for AC-surfaced pavements interpreted from 35-mm (1.38-inch) black-and-white photographs using an early version of the PADIAS software for data collected prior to April 1992. Records for film which were reinterpreted with version 4.2 of the PADIAS software were removed from this table since they are now contained in the MON_DIS_PADIAS42_AC table.

For the January 2012 data release, the cracking fields were revised to reassign reflection cracking to the appropriate transverse and longitudinal cracking fields, and to segregate longitudinal cracking by wheel path and non-wheel path locations. The reflection cracking fields were removed from the database.

MON_DIS_PADIAS42_AC: This table contains distress survey information for AC-surfaced pavements interpreted from 35-mm (1.38-inch) black-and-white photographs using version 4.2 of the PADIAS software.

MON_DIS_ PADIAS_CRCP: This table contains distress survey information for continuously reinforced PCC pavements interpreted from 35-mm (1.38-inch) black-and-white photographs using an early version of the PADIAS software for data collected prior to May 1991. This table was removed from the database in November 2008 since all of the previous film has been reinterpreted with version 4.2 of the PADIAS software and the data is now contained in the MON_DIS_PADIAS42_CRCP table.

MON_DIS_PADIAS42_CRCP: This table contains distress survey information for continuously reinforced PCC pavements interpreted from 35-mm (1.38-inch) black-and-white photographs using version 4.2 of the PADIAS software.

MON_DIS_ PADIAS_JPCC: This table contains distress survey information for jointed PCC pavements interpreted from 35-mm (1.38-inch) black-and-white photographs using an early version of the PADIAS software for data collected prior to May 1992. Work is underway to reinterpret the film with version 4.2 of the PADIAS software and store the information in the MON_DIS_PADIAS42_JPCC table.

MON_DIS_PADIAS42_JPCC: This table contains distress survey information for jointed PCC pavements interpreted from 35-mm (1.38-inch) black-and-white photographs using version 4.2 of the PADIAS software.

MON_DIS_JPCC_FAULT: This table contains manual measurements of fault height on individual joints and cracks taken using a Georgia-style faultmeter.

LTPP Database Tip!	The MON_DIS_JPCC_FAULT table contains information on the location of joints and cracks on jointed PCC pavements. This information can be useful in interpreting FWD load-transfer measurements and profile data.

MON_DIS_JPCC_FAULT_SECT: This table contains test section summary statistics for fault measurements taken on a test section on the same monitoring day. Fault-height values that are null or are less than -1 are excluded from the section statistics calculations.

MON_DROP_SEP: This table contains lane-to-shoulder drop off measurements for AC-surfaced pavements. It also contains lane-to-shoulder drop off and lane-to-shoulder separation measurements for PCC pavements.

9.2 TRANSVERSE PROFILE DISTORTION

The bulk of the data from which users can obtain information on test section rutting is based on interpretation of transverse profile measurements. These data are stored in tables whose names begin with MON_T_PROF. Early in the program, rut-depth measurements were made using a 1.2-m (4-ft) straightedge reference. These measurements were primarily taken on SPS-3 test sections, although such measurements on other test sections varied by LTPP region. These data are stored in the MON_RUT_DEPTH_POINT table. Transverse profile measurements have been chosen by the LTPP program over 1.2-m (4-ft) straightedge measurements because research has shown that, in many instances, wheel-path depressions are wider than 1.2 m (4-ft).

Transverse profile measurements are taken using photographic and manual techniques. The photographic technique results in non-uniform spacing between profile points. The manual technique uses uniform 0.305-m (1-foot) spacing between profile points. As illustrated in figure 8, the transverse elevations are adjusted to a reference line through the endpoints so that the elevations of the endpoints are zero.

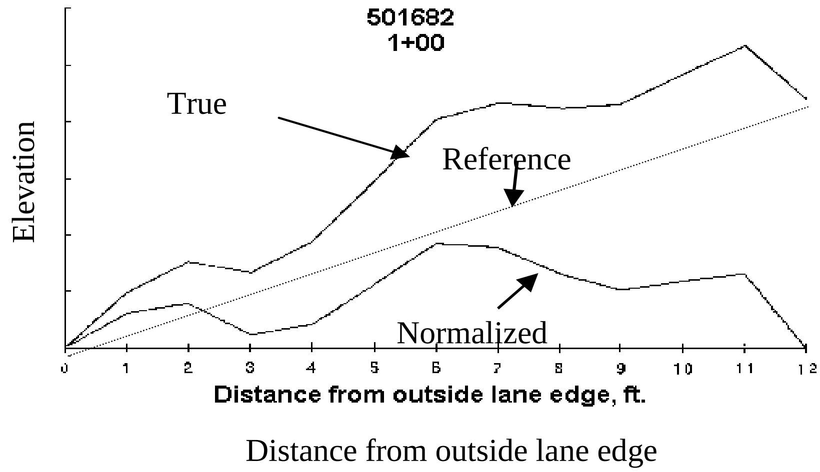

Figure 8. Illustration of how transverse profile measurements are normalized to lane edges.

In the January 2005 data release, the elevation of the last point on the cross slope measurement was added to the database for manual transverse profile measurements. These are measurements performed using a Dipstick. This allows the transverse profiles to be “un-normalized” by using an interpolation calculation procedure based on reestablishing the slope of the reference line and adjusting all elevations relative to this reference. While this cross slope elevation data can be directly used with manually collected data, with a little judgment, it can also be used to un-normalize automated collected transverse cross slope measurements. The purpose of adding these data is to allow an evaluation of transverse drainage and if the ruts hold water.

The LTPP regional offices are responsible for collecting manual transverse profile data for their region. The national data collection contractor that takes the photographic distress measurements also takes the photographic transverse profile measurements. Measurements are typically taken at 15.25-m (50-ft) intervals.

To obtain rutting information, the transverse profile shapes must be interpreted. This interpretation was performed under one of the LTPP-sponsored data analysis efforts. The results of these computations are stored in the MON_T_PROF_INDEX_POINT and MON_T_PROF_INDEX_SECTION tables. The values in the POINT table are those computed for each measurement location, while the summary statistics for all measurements on a test section are stored in the SECTION table.

A variety of transverse profile distortion indices, which can be used to characterize rutting, are stored in the MON_T_PROF_INDEX* tables. Quantification of rutting is complex; it is much more difficult than may be apparent to a casual observer. While the LTPP program has not yet developed indices that capture all aspects of rut characterization, two important measures of rut depth are based on a 1.83-m (6-ft) straightedge and lane-width wireline reference.

Straightedge rut-depth method is based on positioning the straightedge at various locations in each half of the lane until the maximum displacement from the bottom of the straightedge to the top of the pavement surface is found. As shown in figure 9, at each measurement location, three surface profile distortion indices are computed for each half of the lane. These include maximum depth, offset from lane edge to the point of maximum depth, and depression width. Distortion indices are computed for each half of the lane, including depth, offset to point of maximum depth, and depression width. Distortion indices are computed for each half of the lane, including depth, offset, and depression width.

The lane-width wireline rut indices are based on anchoring an imaginary wireline at each lane edge. The wire reference connects any peak elevation point that extends above the lane edges with straight lines. The wireline reference method is illustrated in figure 10.

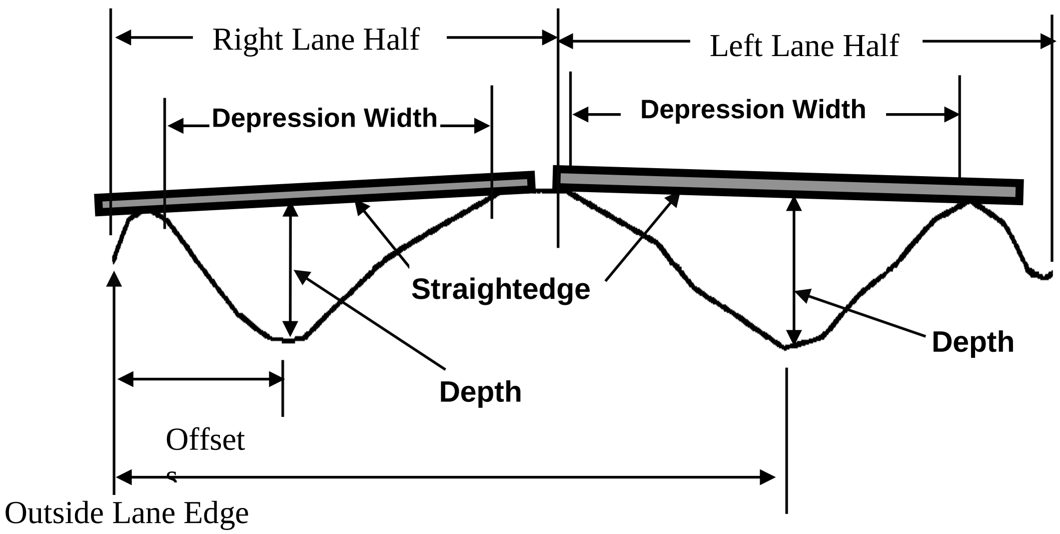

Figure 9. Illustration of LTPP transverse pavement distortion indices based on 1.8-m (6-ft) straightedge reference.

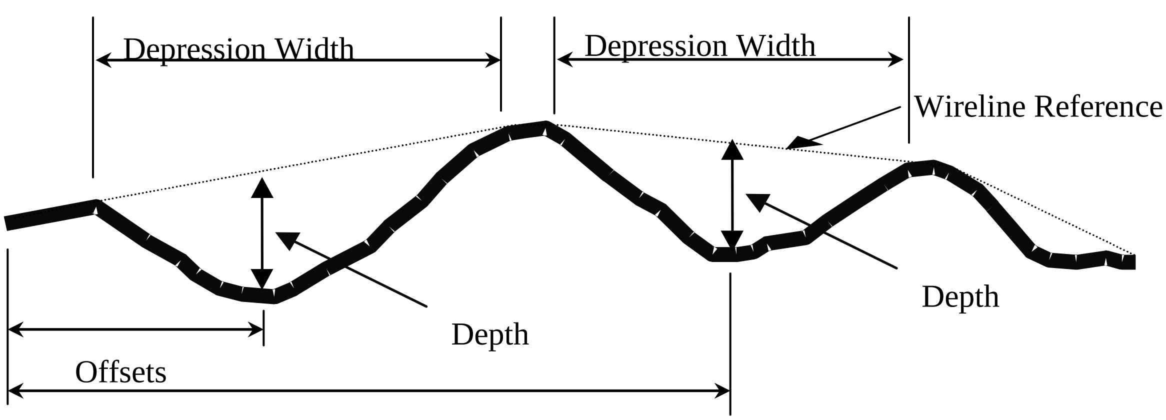

Figure 10. Illustration of LTPP transverse pavement distortion indices based on lane-width wireline reference.

The reason these indices are referred to as transverse profile distortion indices is that the location of the maximum depth is not constrained to the wheel path. The algorithm was constrained only to each half of the lane.

LTPP Database Tip!	Transverse profile statistics, based on the photographic measurement method, are available for PCC-surfaced pavements. This is an interesting data source for those interested in ruts on PCC-surfaced pavements. Manual transverse profile measurements on PCC surfaces are not taken. In 2001, the LTPP program stopped the photographic interpretation of transverse profile measurements on PCC pavements.

9.2.1 MON_T_PROF Tables

The relational structure of the MON_T_PROF tables is shown in figure 11.

MON_T_PROF_MASTER: This table contains information on the general characteristics of transverse profile measurement data, including date, measurement device, number of profiles measured, and measurement width. This is the parent table for all other tables stored in the MON_T_PROF_* submodule. One record is created in this table for each set of transverse profile measurements on a test section. The content of the DEVICE_CODE field in MON_T_PROF_MASTER indicates the type of measurement. A value of “P” indicates a photographic measurement; “D” indicates a manual dipstick measurement.

MON_T_PROF_DEV_CONFIG: This table contains information on equipment configuration settings used to capture, digitize, and interpret transverse profile measurements using the photographic and manual dipstick measurement methods. Note that transverse profile measurements based on the photographic method are obtained at the same time as the photographs for the film-based distress interpretations. Since this table provides little information to the data user, it is no longer included in the standard data release.

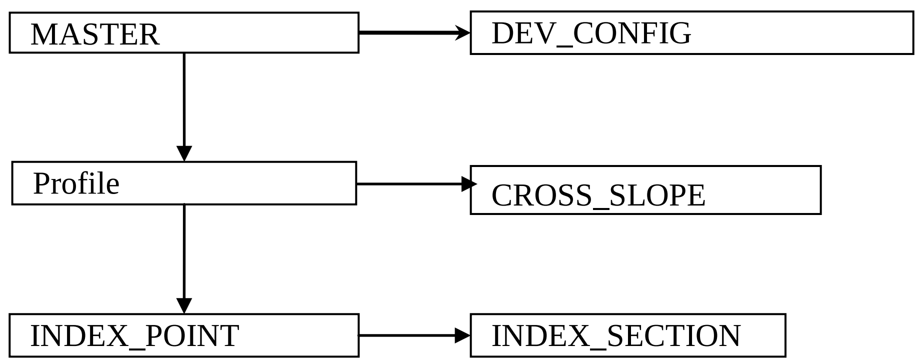

Figure 11. Relational structure among tables in the MON_T_PROF module.

MON_T_PROF_PROFILE: This table contains edge-normalized transverse profile data. Up to 30 x-y points on the transverse profile are stored in this table. Field names starting with X represent the offset from the outside lane edge; those names starting with Y are the elevation of the point relative to the outside-edge starting point.

MON_T_PROF_CROSS_SLOPE: This table contains the elevation of the last data point, relative to the begin point, of manual transverse profile measurements made using the Dipstick device. This allows the transverse profile data to be un-normalized so that the true elevation profile, relative to the outside edge of the pavement lane, to be computed. This table was first released in the January 2005. It is not expected to be fully populated until 2006.

MON_T_PROF_INDEX_POINT: This table contains transverse profile distortion indices for each longitudinal measurement location.

MON_T_PROF_INDEX_SECTION: This table contains summary statistics for the transverse profile distortion statistics stored in the MON_T_PROF_INDEX_POINT table.

9.2.2 MON_RUT_DEPTH_POINT Table

The MON_RUT_DEPTH_POINT table contains rut-depth information collected manually in the field using a 1.2-m (4-ft) straightedge. These measurements were primarily limited to SPS-3 test sections; however, these measurements were also made on other test sections. The coverage of these data varies between LTPP regions. These measurements were discontinued since it can be shown from the transverse profile measurements that on some pavements, the depression in the wheel path can be wider that 1.2 m (4 ft).

9.3 DISTRESS LINK TABLE

The MON_DIS_LINK table was added to the database starting with the January 2008 release (data release 22). This table uses the SURVEY_ID field to provide an index to link distress records in various distress tables which are considered to be part of the same survey. This is useful when one part of a distress survey was not performed on the same day as another. For example, if transverse profile measurements were performed on a different day than the distress survey, the value in the SURVEY_ID field can be used to link these two records.

The way the link works is that for a unique test section specified by STATE_CODE and SHRP_ID, the table names of tables containing data for that survey are listed with the same SURVEY_ID. If a portion of a distress survey was not performed, then there will be no link in the MON_DIS_LINK table for other parts of a survey. For example, if during a manual distress survey on a JPCC pavement, a fault measurement survey was not also performed, then there will be no link for the record in the MON_DIS_JPCP_REV table for records in the MON_DIS_JPCC_FAULT table.

The following tables can be linked together as appropriate for the pavement type and type of survey.

- Manual distress survey on AC pavement – MON_DIS_AC_REV, MON_T_PROF_MASTER, MON_RUT_DEPTH_POINT and MON_DROP_SEP
- Photographic distress survey on AC pavement – MON_DIS_PADIAS42_AC or MON_DIS_PADIS_AC and MON_T_PROF_MASTER
- Manual distress survey on JPCC pavement – MON_DIS_JPCC_REV, MON_T_PROF_MASTER, MON_JPCC_FAULT and MON_DROP_SEP.
- Manual distress survey on CRCP pavement – MON_DIS_CRCP_REV, MON_T_PROF_MASTER, and MON_DROP_SEP.
- Photographic surveys on JPCC pavements – MON_DIS_PADIAS_JPCC or MON_DIS_PADIAS42_JPCC and MON_T_PROF_MASTER.

9.4 LONGITUDINAL PROFILE

The vast majority of longitudinal profile measurements are taken on LTPP test sections using inertial profilers. To date, three models of inertial profilers have been used. The first profiler was the K.J. Law Engineering model DNC690. This profiler was used from June 1989 through April 1997. The second inertial profiler used on LTPP test sections was the K.J. Law Engineering model T6600. The transition to the model T6600 began in July 1996. Implementation dates for the new equipment varied by region. In July 2002, the transition began to implement the International Cybernetics Corporation model MDR4086L3 profiler. Each of these profilers used different types of instrumentation technology. Descriptions of these profilers can be found in the references listed in appendix A. From a data availability perspective, only 0.305-m (1-ft) moving average profile data are available for measurement with the DNC690. The raw 25-mm (1-inch) interval profile measurements are available offline for measurements taken with T6600 and MDR4086L3 devices. The raw data can be requested through ltppinfo@dot.gov.

For a small number of test sections, primarily those located in Alaska, Hawaii, and Puerto Rico, where it is not practical to obtain measurements using an LTPP inertial profiler, longitudinal profile measurements are taken using a device manufactured by FACE®, called Dipstick®, which is operated manually. This device measures the surface elevation at 0.305-m (1-ft) intervals.

9.4.1 MON_PROFILE Tables

MON_PROFILE_MASTER: This table contains information on the measurement device, measurement date, other measurement conditions, and computed profile and ride parameters. Some of the computed parameters include the International Roughness Index (IRI), the Root Mean Square Vertical Acceleration (RMSVA), and an approximation of the American Association of State Highway Officials (AASHO) Road Test slope variance parameter. These data are collected for each measurement pass on a section. For inertial profilers, data are collected for at least five repeat measurement passes on the same day.

MON_PROFILE_DATA: For inertial profilers, this table contains the 0.305- or 0.300-m (1- or 0.98-ft) moving average of the profile measurements, stored at 0.153- or 0.150-m (0.5- or 0.49-ft) intervals, depending on the measurement device. For the FACE Dipstick, the raw 0.305-m (1-ft) interval measurements are collected. This is currently the largest online table in the database. This table is typically subdivided by STATE_CODE to reduce it to a convenient size for distribution.

9.5 DEFLECTION MEASUREMENTS

LTPP regional contractors make deflection measurements using FWDs. FWD data, pavement temperature gradient data, and computed parameters based on FWD measurements are stored in tables whose names begin with MON_DEFL.

Because of the large volume of deflection testing conducted by the LTPP program, data recorded in a single FWD output file is spread across multiple tables to reduce redundancy and improve data storage efficiency. The overall structural relationship between the tables used to store FWD data is shown in figure 12. While this can be daunting to users accustomed to flat formats, with an understanding of the relationships between these tables, the data can be reassembled into any desired format. Example SQL scripts for building a data set for backcalculation are included in appendix C.

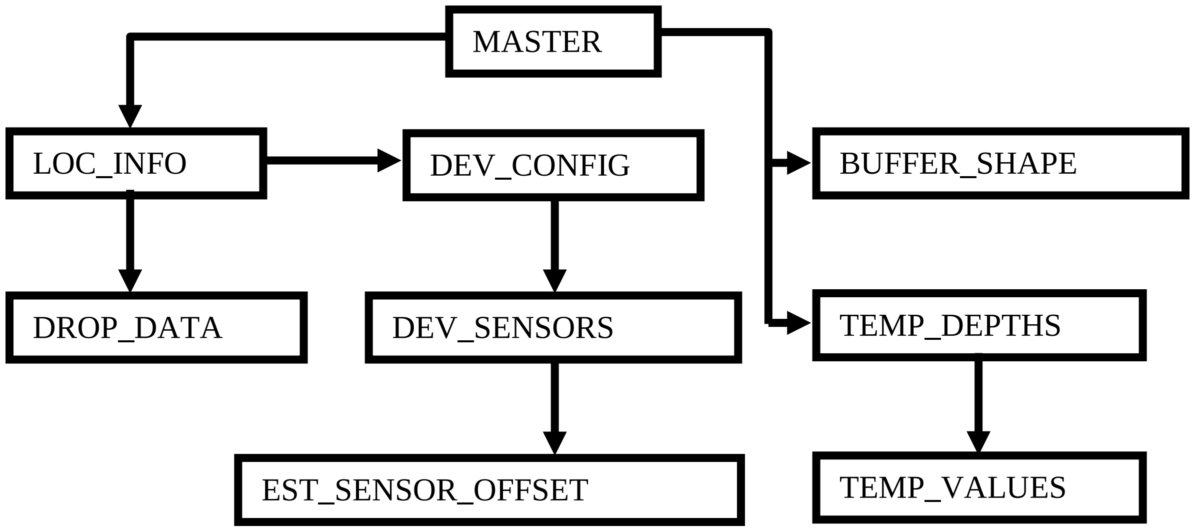

Figure 12. Structural relationship between tables used to store FWD data.

Because of the size of the deflection time-history data, they are not stored in the database. Time-history files in their native format can be requested through ltppinfo@dot.gov.

9.5.1 MON_DEFL Tables

MON_DEFL_MASTER: This table contains summary information on measurements taken during a measurement day. Data stored in this table include test date, number of deflection measurement passes, FWD serial number, operator, data collection software, and the format of the time-history files generated. This is the parent table for all other tables stored in the MON_DEFL submodule.

MON_DEFL_LOC_INFO: This table contains information specific to each point at which testing was conducted. Its contents include the time at which testing was initiated, the longitudinal and transverse location of the test point, and the air and pavement surface temperatures measured by instruments on the FWD. The LANE_NO field indicates the type of deflection test (basin or load transfer), the general location of the test (lane edge, wheel path, lane center, corner, or joint), and the type of surface material being tested. These codes are shown under LANE_SPEC in the CODES table. The CONFIGURATION_NO field is used to link to the MON_DEFL_DEV_CONFIG and MON_DEFL_DEV_SENSOR tables that contain data on sensor spacing and calibration.

MON_DEFL_DROP_DATA: This table contains peak deflection and applied load measurements for every drop conducted at each test point on a section. This is currently the second largest table in the database. Each record represents one test drop. The NON_DECREASING_DEFL field is populated with a 1 if a nondecreasing deflection pattern is detected for a basin test.

MON_DEFL_DEV_CONFIG: This table and its child, MON_DEFL_DEV_SENSORS, contain information specific to the configuration of the FWD during testing. These configurations are typically stable over many tests. Its contents include the number of deflection sensors used, load plate radius, and load cell and temperature sensor calibration factors. This table is linked to MON_DEFL_LOC_INFO through the CONFIGURATION_NO field.

MON_DEFL_DEV_SENSORS: This table contains deflection sensor offset, calibration factors, and serial numbers. This table is linked to MON_DEFL_LOC_INFO through the CONFIGURATION_NO field. The CENTER_OFFSET_FLAG field is populated when the location of a sensor is considered suspect based on analysis of the deflection basin.

MON_DEFL_EST_SENSOR_OFFSET: This table contains estimates of deflection sensor offset in those cases where analysis of the deflection basin suggests that the reported location in the MON_DEFL_DEV_SENSOR table is not correct and corroborating evidence of sensor misplacement does not exist. Values in this table are determined based on engineering analysis of the deflection data.

MON_DEFL_TEMP_DEPTHS: This table contains the depths at which temperature gradient data are collected during FWD testing. Generally, temperature measurements are taken at a minimum of three depths in the pavement structure. In some cases, it has been found that the temperature depth holes were drilled completely through the bound surface layer and into the base material. Data users should evaluate the hole depths against the information stored in the TST_L05A and TST_L05B tables to determine their position in the pavement structure.

MON_DEFL_TEMP_VALUES: This table contains temperatures measured at the depths recorded in the MON_DEFL_TEMP_DEPTHS table.

MON_DEFL_BUFFER_SHAPE: This table contains information on the four different styles of buffers used on the LTPP FWDs. Buffer use is aggregated by time period.

MON_DEFL_FWDCHECK_CMNTS: This table has been removed from the standard data release. It contained comments from the results of the analysis of section homogeneity, non-representative test pit and section data, and structural capacity from the FWDCHECK program. Use of the FWDCHECK program was discontinued by the LTPP program. The primary flaw with this table was that it did not allow a direct association with the deflection data set that the calculations were based on.

9.6 BACKCALCULATION TABLES

In 1997, data were extracted from the deflection data tables for backcalculation of material properties of layers in the pavement structure. The data used in these computations and their results were stored in tables whose names begin with either MON_DEFL_FLX or MON_DEFL_RGD. The MON_DEFL_FLX tables contained the inputs and results of the layered elastic analysis conducted on both flexible and rigid pavement structures. The MON_DEFL_RGD tables contained the inputs and results of slab analysis based on plate theory that was conducted on PCC-surfaced pavement structures. LTPP analysis contractors performed these computations. References to publications documenting these analytical procedures can be found on the LTPP Web site.

Data Release 20, September 2005, was the last release of the backcalculation results to minimize the maintenance costs to keep these tables synchronized with changes to the FWD data. These computations were performed external to the database and have not been updated. At this time, available FWD and related pavement structure data greatly exceed the volume of data available at the time of the data extraction for these data. Furthermore, over time, other problems have been found in the data set that could affect the results. Users of these data are cautioned to fully evaluate the terms of the calculation and the current status of the raw data used in the calculations. Data users interested in this data should request a copy of the Standard Data Release 20 from LTPP Customer Service.

MON_DEFL_FLX_BAKCAL_BASIN: This table contains an average of the applied load and the measurements from each deflection sensor for multiple drops, at the same point, from the same drop height.

MON_DEFL_FLX_BAKCAL_LAYER: This table contains information on the layer structure and material properties used in the backcalculation computation. BAKCAL_LAYER_NO conforms to the layer referencing system used by the computer program and the other FLX_BAKCAL tables. Links to the LTPP layer referencing method are stored in the fields whose names are similar to L05B_LAYER_NO_#.

MON_DEFL_FLX_BAKCAL_POINT: This table contains the results of the elastic layer analytical backcalculation computation for each test point on a test section by layer type, drop height, and test time. Inclusion of records in this table in the section statistics is based on the value stored in the ERROR_RMSE field. Values in this field that are greater than 2 are not included in the section statistical summaries.

MON_DEFL_FLX_BAKCAL_SECT: This table contains test section summary statistics from the elastic layer analysis. These statistics are based on records in the MON_DEFL_FLX_BAKCAL_POINT table with a value of 1 in the SECTION_STAT_INCLUDE_FLAG field. For database users interested in the evaluation of multiple deflection measurement passes on the same day on SMP test sections, only aggregate statistical summaries for the test day are included in this table.

MON_DEFL_FLX_NMODEL_POINT: This table contains the results of the nonlinear material response models for the pavement layers. Since various types of nonlinear models can be applied to the different pavement layers, this table contains codes that reference the model and the associated coefficients. Data are stored in this table for each deflection test point on a test section.

MON_DEFL_FLX_NMODEL_SECT: This table contains a statistical summary of the results of the nonlinear analysis for the complete test section. These statistics are based on records in the MON_DEFL_FLX_MODEL_POINT table that have a value of 1 in the SECTION_STAT_INCLUDE_FLAG field.

MON_DEFL_RGD_BAKCAL_LAYER: This table contains information on the pavement structure input parameters used in the backcalculation based on plate theory. Information stored in this table includes the thicknesses of the PCC and the base layer, the modulus ratio, the Poisson's ratio, and references to the layers in the TST_L05B table that may have been combined in this analysis.

MON_DEFL_RGD_BAKCAL_BASIN: This table contains the load, deflection basin, and associated parameters used in the analysis, including the average of the applied load and the measurements from each deflection sensor for multiple drops, at the same point, from the same drop height.

MON_DEFL_RGD_BAKCAL_POINT: This table contains the results of the plate theory backcalculation results for each test point on the test section. The table contains the analytical results for four models from the combination of the assumptions of dense liquid/elastic support and full base friction/no base friction. Based on the evaluation of the results by the analysts, the fields for the model results that were not considered appropriate were populated with a 999.9 type of convention.

MON_DEFL_RGD_BAKCAL_SECT: This table contains test section summary statistics from the plate theory backcalculation analysis. These statistics are based on records in the MON_DEFL_RGD_BAKCAL_POINT table with a value of 1 in the SECTION_STAT_INCLUDE_FLAG field. For database users interested in evaluation of multiple deflection measurement passes on the same day on SMP test sections, the MON_DEFL_BAKCAL_RGD-* tables contain a FWD_PASS field that is used to aggregate statistical summaries for each measurement pass on the test day.

9.7 FRICTION

The Friction submodule includes only the MON_FRICTION table. This table contains the results of friction tests on pavement sections where the State/Provincial highway agency was willing to provide the data. Because of the litigious nature of this data, submission is voluntary. The LTPP program has no control over the data collection method, measurement equipment, or calibration of the equipment used for these measurements. The database does not contain surface texture measurements and related information that are traditionally used to link pavement properties to measured friction levels.

9.8 DRAINAGE

Tables in this module contain information on the video inspection of subsurface pavement drainage outlet features and field permeability tests and calculations. The video inspections were performed under FHWA LTPP contract independent of the permeability tests. The permeability tests and calculations were performed under NCHRP Contract 1-34D project, "Effects of Subsurface Drainage on Performance of Asphalt and Concrete Pavements: Further Evaluation and Analysis of LTPP SPS-1 and SPS-2 Field Sections".

9.8.1 Drainage Outlet Video Inspections

Subsurface video inspections of drainage outlets structures were begun in September 2001 on SPS 1, 2 and 6 projects. The video inspections were performed by passing a small video camera up the drainage outlet structures and noting the condition of the subsurface passageway. Data from these inspections were first included in July 2004 data release. The following three tables contain data and information collected during the video inspections.

MON_DRAIN_MASTER: This table contains information on the permanent features of the edge drain system and the location of the lateral openings. Since the data stored in this table are from inspections on SPS project sites with multiple test sections, the primary keys are related to a project-level identifier. These data are from video inspections of the drainage system that start from an exposed lateral-side drain structure. The key field LATERAL_ID, in combination with PROJECT_STATION and NEAREST_SECTION, provides an indication of the location of the drainage structure being inspected. The SPS_PROJECT_STATIONS table can be used to understand the location of the lateral drain being inspected relative to other sections on SPS projects.

MON_DRAIN_CONDITION: This table contains information regarding the condition of the lateral openings and the area around the lateral openings at the time of inspection.

MON_DRAIN_INSPECT: This table contains information on the results of the video edge drain inspection. Significant events in the inspection are recorded as a function of the distance of insertion of the camera within the drainage outlet pipes.

9.8.2 SPS-1 & 2 Field Permeability Measurements and Calculations

Field permeability measurements and calculations contained in these two tables are from the final report from NCHRP Project 1-34D. These data are the results of field measurements by the study team based on direct injection of water into the permeable subsurface layers constructed on designated SPS-1 and 2 test sections. In addition to observations that the injected water did not drain out of the drainage structure, estimates of permeability of the sub-surface drainage system structures are based on calculations using the assumptions based on field measurements. The report also contains other significant information on soils and topography at SPS 1 and 2 sites included in the study that are not contained in the LTPP database. The final report can be obtained from this web link: http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_583.pdf .

MON_DRAIN_PERM_MEAS: This table contains the measurement data set used to estimate the hydraulic conductivity contained in the MON_DRAIN_PERM_CALC table.

MON_DRAIN_PERM_CALC: These tables contains the results of the estimated hydraulic conductivity of the subsurface permeable drainage layer and outflow structures on SPS-1 & 2 projects included in the study. Values used in the computed hydraulic conductivity estimate are contained in this table. This table is linked to the MON_DRIAN _PERM MEAS table using only three key fields of STATE_CODE, SHRP_ID, and POINT_LOC future repeat measurements are not anticipated.

CHAPTER 10. SEASONAL MONITORING PROGRAM MODULE

The Seasonal Monitoring Program (SMP) study is designed to measure the impact of daily and yearly temperature and moisture changes on pavement structures and the response to loads. Sixty-three test sections were selected from the GPS and SPS studies and were monitored for temperature and moisture, and at higher than normal intervals for distress, deflection, and longitudinal profile. Measurements specific to sections in the SMP were made using the following devices:

Time-Domain Reflectometry: Subsurface moisture changes.
Thermistor Probes: Subsurface temperature changes.
Electrical Resistivity: Frost/thaw depth.
Piezometer: Groundwater table determination.
Air Temperature Probes: Ambient temperature.
Tipping-Bucket Rain Gauge: Precipitation.

The data collected from these devices are stored in the tables contained in the SMP module. All other data collected at sites within the SMP, but not specific to sites in the SMP, are stored in the usual tables external to the SMP module. For example, deflection measurements on SMP test sections are stored in the MON_DEFL series of tables.

At the inception of the SMP program, subsurface time-domain reflectometry and electrical resistivity measurements were taken on a nominal monthly cycle. In the latter part of the SMP program, selected sites were instrumented to take these measurements daily and, in some cases, subdaily to capture changes caused by rainfall. The only way to identify the sites with these types of daily measurements is to inspect the contents of the tables containing these data.

In addition to the raw data as collected, several *computed parameters* are included that reduce the raw data into values in engineering units. All of the raw data used to calculate the computed parameters are included in the database.

10.1 AMBIENT TEMPERATURE AND PRECIPITATION

The ambient temperature and precipitation data collected from the onsite weather stations are stored in the SMP_ATEMP_RAIN series of tables.

10.1.1 SMP_ATEMP_RAIN_HOUR: This table contains the average hourly temperature and the total hourly precipitation. Temperature or precipitation data in this table may be null if an instrumentation error was discovered. The hour at the end of the averaging period is stored in the ATEMP_RAIN_TIME field in 24-hour military-style text format. The date of the measurement is stored in the SMP_DATE field in a native date format.

10.1.2 SMP_ATEMP_RAIN_DAY: This table contains the average, minimum, and maximum ambient air temperatures over the course of a day; the times at which the minimum and maximum temperatures occurred; and the cumulative precipitation. These values are computed directly from the SMP_ATEMP_RAIN_HOUR table when at least 20 hours of data exist for a day.

10.2 SUBSURFACE TEMPERATURE

Subsurface temperatures are stored in the SMP_MRCTEMP_* series of tables (MRC is the manufacturer of the type of thermistor used by the LTPP program).

10.2.1 SMP_MRCTEMP_AUTO_HOUR: This table contains the vast majority of subsurface temperature data. It includes average hourly temperatures at a series of depths; however, it must be linked to SMP_MRCTEMP_DEPTHS using the THERM_NO field (and the STATE_CODE and SHRP_ID for the section) to determine the depth at which the temperature was recorded.

10.2.2 SMP_MRCTEMP_MAN: This table contains the remainder of the subsurface temperature data. Its format is very similar to SMP_MRCTEMP_AUTO_HOUR; however, it contains manual temperature measurements taken when the automatic temperature monitoring equipment was out of service. Like SMP_MRCTEMP_AUTO_HOUR, it must be linked to SMP_MRCTEMP_DEPTHS to determine the depth at which the temperature was measured.

10.2.3 SMP_MRCTEMP_AUTO_DAY_STATS: This table contains the average, minimum, and maximum subsurface temperatures over the course of a day and the times at which the minimum and maximum temperatures occurred. These values are based on either the minute-by-minute readings recorded by the data logger or are computed from the averages stored in the SMP_MRCTEMP_AUTO_HOUR table when recomputation of the daily statistics is needed for adjustments, and like that table, it must be linked to SMP_MRCTEMP_DEPTHS to determine the depth at which the temperature was measured.

10.2.4 SMP_MRCTEMP_DEPTH: This table contains the depths at which each temperature probe at an SMP section was installed and the date of installation. The primary use of this table is to link to other SMP_MRCTEMP_* tables, using the STATE_CODE, SHRP_ID, and THERM_NO fields, to determine the depth corresponding to a temperature reading. In some rare cases, STATE_CODE, SHRP_ID, and THERM_NO do not resolve to a unique depth because the thermistors were reinstalled at slightly different depths at some point after the initial installation. In these cases, the link must be further refined using the INSTALL_DATE field.

10.3 SUBSURFACE MOISTURE CONTENT

The LTPP SMP uses time-domain reflectometry (TDR) to measure subsurface moisture content. A description of the process is located in chapter 2 of the *Seasonal Monitoring Program Guidelines*.

10.3.1 SMP_TDR_AUTO_MOISTURE: This table contains the volumetric and gravimetric moisture contents calculated using TDR (the dry densities used to convert volumetric to gravimetric moisture content are located in SMP_MOISTURE_SUPPORT). The depths at which these moisture contents were calculated can be determined by linking to SMP_TDR_DEPTHS_LENGTHS using STATE_CODE, SHRP_ID, and TDR_NO. Further information on the calculation of these computed parameters can be found in *An Input for*

Moisture Calculations–Dielectric Constant From Apparent Length, Publication No. FHWA-RD-99-201.

10.3.2 SMP_TDR_AUTO_MOISTURE_TLE: This table contains volumetric and gravimetric contents calculated using the transmission line equations (TLE) and micromechanics model to interpret TDR traces store in the SMP_TDR_AUTO table. In addition to moisture contents, the method also produces estimates of soil conductivity, reflectivity, and density used in the computation process. Details on the basis of these computed parameters is contained in the report *LTPP Computed Parameter: Moisture Content*, Publication Number: FHWA-HRT-08-035 LTPP

10.3.3 SMP_TDR_AUTO_CALIBRATION_TLE: This table contains the values used to calibrate the micromechanics model to each specific TDR sensor used as the basis of volumetric moisture and density computations contained in the SMP_TDR_AUTO_MOISTURE_TLE table. Details on the basis of these computed parameters is contained in the report *LTPP Computed Parameter: Moisture Content*, Publication Number: FHWA-HRT-08-035 LTPP

10.3.4 SMP_TDR_AUTO: This table contains a flat representation of the TDR waveform. The measured reflected waveform is sampled at 245 intervals and stored in the WAVP_1 through WAVP_245 fields. The distance interval between samples is recorded in the DIST_WAV_POINTS field. This table is only useful to the analyst who is interested in reinterpreting the raw TDR data.

10.3.5 SMP_TDR_MANUAL_DIELECTRIC: This table contains dielectric constants interpreted from TDR measurements recorded on paper strip charts during installation of SMP instrumentation. The protocol for interpretation of the manual TDR measurements is stored in LTPP Directive SM-28.

10.3.6 SMP_TDR_AUTO_DIELECTRIC: This table contains the dielectric constant interpreted from the waveforms stored in SMP_TDR_AUTO and several intermediate calculations.

10.3.7 SMP_TDR_DEPTHS_LENGTHS: This table contains information on the physical characteristics of the TDR probes, including the depth at which the probe is installed, the length of the probe, and its installation date. The primary use of this table is to link to other SMP_TDR_* tables, using the STATE_CODE, SHRP_ID, and TDR_NO fields, to determine the depth corresponding to a moisture reading. In some rare cases, STATE_CODE, SHRP_ID, and TDR_NO do not resolve to a unique depth because the thermistors were reinstalled at slightly different depths at some point after the initial installation. In these cases, the link must be further refined, using the INSTALL_DATE field. A secondary use of this table is to determine the length of the TDR probe, which is necessary when reinterpreting the TDR data.

10.3.8 SMP_TDR_MOISTURE_SUPPORT: This table contains the dry density of soils sampled from areas adjacent to each of the TDR probes. These data are primarily useful for converting volumetric moisture contents to gravimetric moisture contents. For some samples, gradation and plastic limit data are also available.

10.3.9 SMP_DRY_DENSITY: This table is an alternate source of soil dry density data. Data are limited to one dry density per SMP site, with the test conducted on samples obtained from approximately 1 m below the pavement surface. In practice, the utility of this table is limited because of low data availability.

10.3.10 SMP_GRAV_MOIST: This table contains the results of laboratory gravimetric moisture testing of materials sampled adjacent to each TDR probe at the time of installation.

10.4 FROST PENETRATION

The LTPP SMP uses a combination of subsurface temperature and electrical resistivity to estimate frost penetration. The soil resistivity probes used by the LTPP program are all identical; however, the data have been collected in slightly different ways, as described below.

10.4.1 SMP_ERESIST_MANUAL_CONTACT: This table contains manually collected voltage and current, and the calculated resistance between adjacent electrodes on the probe. This resistance is the contact resistance. The depths of the electrodes can be determined by linking ELECTRODE_START and ELECTRODE_END to ELECTRODE_NO in the SMP_ERESIST_DEPTHS table.

10.4.2 SMP_ERESIST_MAN_4POINT: This table contains the manually collected voltage and current, and the calculated bulk resistivity of the material around the probe using the four-point method. This process is described further in chapter 2 of *Seasonal Monitoring Program Guidelines*. The depths of the electrodes across which these measurements were made can be determined by linking EAMP_START and EAMP_END to ELECTRODE_NO in the SMP_ERESIST_DEPTHS table.

10.4.3 SMP_ERESIST_AUTO: This table contains automatically collected voltage data between adjacent electrodes on the probe using a multiplexer from the Cold Regions Research and Engineering Laboratory. This multiplexer only measures voltage between electrode pairs; contact resistance cannot be calculated. Significant changes in voltage with depth at a given time can be used to indicate changes in the freeze state of the soil. The depths of the electrodes across which these measurements were made can be determined by linking ELECTRODE_START and ELECTRODE_END to ELECTRODE_NO in the SMP_ERESIST_DEPTHS table.

10.4.4 SMP_ERESIST_AUTO_ABF: This table contains automatically collected data from an ABF data logger that uses an internal reference resistor which allows the contact resistance to be computed between electrode pairs. The contact resistance is computed using the APPLIED_VOLTAGE contained in the SMP_ERESIST_ABF_RES_VA table and the VOLTAGE contained in this table. In situations where the value of APPLIED_VOLTAGE is not available, frost zone indications can be detected by significant changes in voltage with depth at a given measurement time.

10.4.5 SMP_ERESIST_ABF_RES_VA: This table contains applied voltage from the ABF data logger used to compute the contact resistance between electrode pairs stored in the

SMP_ERESIST_AUTO_ABF table. Generally, this table is only of use to the analyst who wishes to recalculate the contact resistance data stored in SMP_ERESIST_AUTO_ABF table.

10.4.6 SMP_ERESIST_DEPTHS: This table contains the depths at which each resistivity probe at an SMP section was installed and the date of installation. The primary use of this table is to link to other SMP_ERESIST_* tables, using the STATE_CODE, SHRP_ID, and ELECTRODE_NO fields, to determine the depth corresponding to a resistance or resistivity reading. In some rare cases, STATE_CODE, SHRP_ID, and THERM_NO do not resolve to a unique depth because the probes were reinstalled at slightly different depths at some time after the initial installation. In these cases, the link must be further refined using the INSTALL_DATE field.

10.4.7 SMP_FREEZE_STATE: This table contains the computed parameters necessary to determine whether the pavement layers at a given depth are frozen or not. It includes resistivity and contact resistance extracted from SMP_ERESIST_MAN_4POINT and SMP_ERESIST_MAN_CONTACT, the daily average temperature extracted from SMP_MRC_TEMP_AUTO_DAY_STATS, and a determination of the freeze state of the soil based on these values.

For data release 22 and prior data releases, information on the calculation of these computed parameters can be found in *Freeze-Thaw Monograph for LTPP*, Publication No. FHWA-RD-98-177.

This data was updated in data release 23. Information on the calculations of these computed parameters can be found in *LTPP Computed Parameters:Frost Penetration.* This report should be available on the LTPP Reference Library disk distributed with the SDR.

10.4.8 SMP_FROST_PENETRATION: This table contains an estimation of the upper and lower boundaries of the frozen layer based on the computed parameters in the SMP_FREEZE_STATE table.

10.4.9 SMP_FROST_PRESENCE: This table was added to the data base as part of the update of the frost penetration estimates included in data release 23. This table contains the number of frozen layers on a test day from interpretation of the measurement on SMP test sections.

10.5 DEPTH TO WATER TABLE

The LTPP SMP uses an observation well (this well is sometimes called an “observation Piezometer” for reasons relating to the permitting process for drilling wells) to determine if the depth of the water table is within approximately 5 m from the pavement surface. In many cases, the observation well did not extend to the water table.

10.5.1 SMP_WATERTAB_DEPTH_MAN: This table contains manual observations of the distance from the pavement surface to the water table. A null in the WATERTAB_DEPTH indicates that no water was found in the observation Piezometer well.

10.5.2 SMP_WATERTAB_DEPTH_AUTO: This table was originally developed to contain automated readings of the water table depth; however, such readings were never obtained. Therefore, this table contains no data.

10.6 SURFACE ELEVATION DATA

Surface elevation measurements using a rod-and-level surveying method are taken at each SMP site at the time of FWD testing. Measurements are taken at the location of each FWD test and are referenced to a frost- and swell-free benchmark

10.6.1 SMP_ELEV_AC_DATA: This table contains surface elevation measurements for asphalt-surfaced SMP sections. At each longitudinal location, elevation measurements are typically taken at the pavement edge (PE), outer wheel path (OWP), midlane (ML), inner wheel path (IWP), and inner lane edge (ILE). To determine the actual transverse locations of these measurement points, this table must be linked to SMP_ELEV_AC_OFFSET using STATE_CODE, SHRP_ID, and SMP_DATE.

10.6.2 SMP_ELEV_AC_OFFSET: This table contains the transverse offset of the elevation measurement locations stored in SMP_ELEV_AC_DATA. In addition, it also contains a text description of the equipment used to conduct the elevation survey.

10.6.3 SMP_ELEV_PCC_DATA: This table contains surface elevation measurements for PCC-surfaced SMP sections. At each longitudinal location, elevation measurements are typically taken at the pavement edge (PE), midlane (ML), and inner lane edge (ILE). To determine the actual transverse locations of these measurement points, this table must be linked to SMP_ELEV_PCC_OFFSET using STATE_CODE, SHRP_ID, and SMP_DATE.

10.6.4 SMP_ELEV_PCC_OFFSET: This table contains the transverse offset of the elevation measurement locations stored in SMP_ELEV_PCC_DATA. In addition, it also contains a text description of the equipment used to conduct the elevation survey.

10.7 JOINT OPENING AND FAULTING

Joint opening and faulting measurements are typically collected concurrently with FWD testing at the same locations as where the load-transfer tests are conducted. The joint opening is measured using snap rings installed in the joint, while faulting is measured using a Georgia-style faultmeter (as done with standard LTPP distress surveys).

10.7.1 SMP_JOINT_FAULT_DATA: This table contains joint faulting measurements for PCC-surfaced SMP sections. At each longitudinal location for which FWD load-transfer testing is conducted, joint faulting is measured at the pavement edge (PE), midlane (ML), and inner lane edge (ILE). To determine the actual transverse locations of these measurement points, this table must be linked to SMP_JOINT_FAULT_OFFSET using STATE_CODE, SHRP_ID, and SMP_DATE.

10.7.2 SMP_JOINT_FAULT_OFFSET: This table contains the transverse offset of the joint fault measurement locations stored in SMP_JOINT_FAULT_DATA.

10.7.3 SMP_JOINT_GAUGE_DATA: This table contains joint opening measurements for PCC-surfaced SMP sections. At each longitudinal location for which FWD load-transfer testing is conducted, the joint opening is measured at the pavement edge (PE), midlane (ML), and inner lane edge (ILE). To determine the actual transverse locations of these measurement points, this table must be linked to SMP_JOINT_GAUGE_OFFSET using STATE_CODE, SHRP_ID, and SMP_DATE.

10.7.4 SMP_JOINT_GAUGE_OFFSET: This table contains the transverse offset of the joint opening measurement locations stored in SMP_JOINT_GAUGE_DATA.

10.8 ADDITIONAL SMP TABLES

10.8.1 SMP_LAYOUT_INFO: When using SMP data, it is critical to know the locations at which the measurements were taken. SMP_LAYOUT_INFO is the source for much of this information, including the location of the instrument hole where the TDR, thermistor, and resistance probes were installed, and the locations of the piezometer and the weather observation instrumentation. Longitudinal and transverse locations for joint opening and faulting, and surface elevation measurements are located in other tables within the SMP module, as described elsewhere in this chapter.

10.8.2 SMP_COMMENTS: This table contains a wealth of information regarding irregularities in data collection. Equipment failure, unusual weather conditions such as flooding of an adjacent river, and anything else out of the ordinary will be recorded in this table. These data are keyed to the section ID, date of occurrence, and the table in which the effected data is stored.

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CHAPTER 11. SPECIFIC PAVEMENT STUDIES MODULE

The Specific Pavement Studies (SPS) module contains construction and location information for SPS projects. The various SPS experiments are defined within table 2. New construction SPS projects include SPS-1, -2, -8, and -9 experiments, while SPS-3, -4, -6, and -7 designations identify the maintenance and rehabilitation projects. Tables with the SPS prefix contain data that are general to all SPS experiments. Data that are specific to an SPS experiment type are maintained in tables with prefixes that indicate the SPS experiment.

Materials testing and construction details within the SPS tables vary by experiment. Tables for layer materials and thicknesses are included in the SPS modules for all experiments. These tables are similar in purpose to the INV tables for GPS sections. However, since SPS sections enter the program at the time of their construction or rehabilitation, the data within the SPS module reflect initial conditions as observed at that time. Information within this module comes from construction data sheets that are filled out by highway agencies and LTPP regional contractors and from materials testing conducted by the State highway agencies on samples collected during and immediately following construction or rehabilitation. Data entry is done at the LTPP regional offices.

11.1 IMPORTANT FIELDS

Common fields unique to the SPS tables that can be used to link related data in associated tables to each other include STATION, LIFT_NO, ROLLER_CODE, and PROJECT_STATION_NO.

11.1.1 STATION is used to denote the longitudinal position within each SPS-4 test section where transient dynamic response and Benkelman beam testing were conducted. STATION is the distance in feet from the start of the test section. The usefulness of the field for relating data from different tables is limited since no transient dynamic response testing was ever done and hence the SPS4_TRANSIENT_MEASURE table is empty of data.

LTPP Database Tip!	Several fields within SPS tables can be used to relate SPS table data to monitoring data collected at specific locations on the test sections; however, the user must be careful to match converted units when necessary. STATION_NO is used within SPS#_LAYER_THICKNESS tables to denote the longitudinal position relative to the start of the test section. STATION is used for the same purpose within the SPS4_BENKELMAN_MEASURE table and POINT_DISTANCE is used within the SPS#_TRANSFER_EFFICIENCY and SPS9_LOAD_TRANS_EFFICIENCY tables. The POINT_LOC field within the monitoring data tables uses meters, while each of the SPS fields uses feet. Attention to units is required when relating data through these fields.

11.1.2 LIFT_NO can be useful in linking compaction information in the SPS#_PMA_COMPACTION tables and the lift thicknesses found in SPS#_PMA_PLACEMENT_DATA. These thicknesses are found in fields with names such as AC_SURFACE_1ST_THICK, so the data cannot be directly linked to LIFT_NO values that represent the sequential numbering of PMA lifts. To do this, a manual count of the sequential lifts recorded within the SPS#_PMA_PLACEMENT_DATA table is needed to find the number that matches the first lift of the AC surface layer, then that number must be substituted for LIFT_NO to extract the compaction data from SPS#_PMA_COMPACTION.

11.1.3 ROLLER_CODE is also part of the SPS#_PMA_COMPACTION tables. SPS#_PMA_COMPACTION contains information on the compaction of each AC lift in the construction of the section. The variables BREAKDOWN_ROLLER_CODE, INTERMED_ROLLER_CODE, and FINAL_ROLLER_CODE within this table can be related to the ROLLER_CODE variable within the SPS#_PMA_ROLLER table, which defines the characteristics of each of the rollers used during construction.

11.1.4 PROJECT_STATION_NO is found only in SPS_INTERSECTION and denotes the position of any intersections or ramps in relation to the start of the first section of an SPS project. The units are in feet. PROJECT_STATION_NO can be compared to the SECTION_START and SECTION_END fields from the SPS_PROJECT_STATIONS table to determine where the intersection is located with respect to each of the individual test sections within the project.

11.2 GENERAL SPS TABLES

Within the SPS module, a series of tables exists whose names begin with SPS, with no reference to the number of the experiment. The data stored in these tables are common to more than one SPS experiment. However, these data are not always common to all SPS experiments.

11.2.1 SPS_ID: This table contains information on the location of SPS project sites in the 1, 2, 8, and 9 experiments that started with either new pavement construction or reconstruction. Location information for SPS projects constructed on existing pavements is stored in the INV_ID table. This table contains data on roadway information, elevation, and other features of the test section location.

The latitude and longitude coordinates of SPS project sites were removed from this table starting with data release 22. The

11.2.2 SPS_GENERAL: This table contains information on road geometry, and shoulder and drainage features for new construction SPS test sections classified in the 1, 2, 8, and 9 experiments.

11.2.3 SPS_PROJECT_STATIONS: This table links test sections that are co-located on a project and provides the order in which the test sections occur in the direction of traffic flow. The stations stored in this table are in meters.

11.2.4 SPS_INTERSECTIONS: This table contains project-level intersection information and data on the location of ramps, signals, and stop signs within the project boundaries.

11.2.5 SPS_CUT_FILL_LOCATIONS: This table contains the order and location of the cuts and fills within each SPS section. Starting and ending points are recorded.

11.2.6 SPS_GPS_LINK: This table links the SPS maintenance projects and some SPS rehabilitation projects to co-located GPS test sections. SPS projects that are not included within this table do not have co-located GPS test sections.

LTPP Database Tip!	The SPS_GPS_LINK table can be used to link SPS projects to co-located GPS test sections. This table links the SHRP_ID field that identifies the project-level SPS site to the LINKED_GPS_ID field that matches the SHRP_ID field in the INV_ID table SHRP_ID in the INV_ID table identifies the co-located GPS test section. Inventory, climatic, and traffic data can be shared.

11.3 NUMBERED TABLES COMMON TO MULTIPLE EXPERIMENTS

The fourth character of the prefix of many table names in the SPS module is a number that is intended to reference a specific experiment. The following tables are common to multiple experiments and contain the same basic information; however, they have names that differ by only the fourth character. In the following list, # is used as a “wild card” character to represent all numerical values.

11.3.1 SPS#_LAYER: This table contains the pavement materials layer structure used to reference data stored in other tables whose names begin with a matching SPS#. This information is based on observations made during the construction. The layer thicknesses provided in these tables were often obtained from plans and specifications. These values should not be used in performance analyses. SPS-3 and -4 maintenance experiment sections have no LAYER tables. Information on the pavement structure layers for these sections can be found in the INV_LAYER table entries for the co-located GPS sections.

11.3.2 SPS#_LAYER_THICKNESS: These tables have thickness values for each layer computed from elevation measurements from each test section at various offsets from the pavement edge. SPS-3 and -4 maintenance experiment sections have no LAYER_THICKNESS tables.

11.3.3 SPS#_NOTES_AND_COMMENTS: This table contains miscellaneous comments and notes concerning construction operations that may have had an influence on the ultimate performance of the test section or that may have caused undesirable performance differences among test sections. SPS-3 and -4 maintenance experiment sections have no NOTES_AND_COMMENTS tables.

11.3.4 SPS#_PMA_AC_PROPERTIES: This table contains the properties of the asphalt cement that was used in the PMA-bound layers of the SPS section. These properties were typically obtained from the asphalt supplier or from tests conducted by the State highway agency. SPS-1, -2, -8, and -9 experiments have PMA#_AC_PROPERTIES tables.

11.3.5 SPS#_PMA_AGGREGATE_PROP: This table contains the properties of the aggregate that was used in the PMA-bound layers of the SPS section. These properties were typically obtained from the asphalt supplier or from tests conducted by the State highway agency. SPS-1, -2, -8, and -9 experiments have PMA_AC_PROPERTIES tables.

11.3.6 SPS#_PMA_COMPACTION: This table contains compaction data, including air temperatures, roller information, and roller coverage for each lift of each PMA-bound layer of the SPS section. SPS-1, -2, -5, -6, -8, and -9 experiments have PMA_COMPACTION tables.

11.3.7 SPS#_PMA_CONSTRUCTION: This table contains construction data for PMA-bound layers of the SPS section, including paving start and end dates, and mixing/lay-down temperatures. SPS-1, -2, -5, -6, -8, and -9 experiments have PMA_CONSTRUCTION tables.

11.3.8 SPS#_PMA_MIXTURE_PROP: This table contains mixture properties for each PMA-bound layer. SPS-1, -2, and -8 experiments have PMA_MIXTURE_PROP tables.

11.3.9 SPS#_PMA_PLACEMENT DATA: This table contains placement data for each PMA-bound layer, including asphalt-treated base (ATB), permeable asphalt-treated base (PATB), binder, surface, and friction courses. SPS-1, -2, and -8 experiments have PMA_PLACEMENT tables.

11.3.10 SPS#_PMA_ROLLER: This table contains data for each roller used on any of the PMA-bound layers, roller weights, tire pressures, vibration frequency and amplitude, and roller speed. The ROLLER_CODE field can be used to link the information within this table to that stored in SPS#_PMA_COMPACTION. SPS-1, -2, -5, -6, -8, and -9 experiments have PMA_ROLLER tables.

11.3.11 SPS#_SUBGRADE_PREP: This table contains subgrade preparation data, including information on compaction, stabilizing agents, and lift thicknesses (fill sections). SPS-1, -2, and -8 experiments have SUBGRADE_PREP tables.

11.3.12 SPS#_UNBOUND_AGG_BASE: This table contains placement information associated with unbound aggregate base layers, including compaction equipment and lift thicknesses. SPS-1, -2, -8, and -9 experiments have UNBOUND_AGG_BASE tables.

11.3.13 SPS#_QC_MEASUREMENTS: This table contains all of the construction QC procedures and the measurements that were taken during construction of SPS-5, -6, and -7 test sections.

11.3.14 SPS#_OVERLAY: This table contains placement data for the AC overlays, including equipment and plant information, surface preparation, and haul times for each AC layer. This table applies to SPS-5 and -6 rehabilitation experiments.

11.3.15 SPS#_OVERLAY_LAYERS: This table contains information specific to each lift placed during AC overlay applications on SPS-5 and -6 test sections.

11.3.16 SPS#_LOAD_TRANSFER: This table contains information on the restoration of load-transfer capacity at joints in PCC pavements within SPS-6, -7, and -9 test sections prior to the application of an overlay.

11.3.17 SPS#_PCC_CRACK_SEAL: This table contains data on crack sealing operations that occurred prior to the application of an overlay on SPS-6, -7, and -9 test sections. Since there are no data stored in the SPS7_PCC_CRACK_SEAL table it is not included in the standard data release.

11.3.18 SPS#_PCC_FULL_DEPTH: This table contains data on full-depth repair of PCC surfaces that occurred prior to the application of an overlay on SPS-6, -7, -8 and -9 test sections. Since there are no data stored in the SPS8_PCC_FULL_DEPTH table it is not included in the standard data release.

11.3.19 SPS#_PCC_JOINT_RESEAL: This table contains data on joint resealing operations that occurred prior to the application of an overlay on SPS-6, -7, and -9 test sections.

11.3.20 SPS#_PCC_PART_DEPTH: This table contains data on partial-depth patching of PCC surfaces that occurred prior to the application of an overlay on SPS-6, -7, and -9 test sections.

11.3.21 SPS#_SUBDRAINAGE: This table contains data on the process of retrofitting subgrade drainage capacity within SPS-6, -7, and -9 test sections prior to the application of a rehabilitative overlay.

11.3.22 SPS#_TRANSFER_EFFICIENCY: This table contains data on the load-transfer efficiency of transverse joints within SPS-6, -7, and -9 test sections following the load-transfer restoration process, but prior to the placement of an overlay. Since there are no data stored in the SPS6 and SPS7_TRANSFER_EFFICIENCY tables they are not included in the standard data release.

11.3.23 SPS#_UNDERSEALING: This table contains general undersealing data for work done on SPS-6 , -7 and -9 test sections prior to the application of a rehabilitative overlay. Since there are no data stored in the SPS7 and SPS9 UNDERSEALING tables they are not included in the standard data release.

11.3.24 SPS#_PCC_JOINT_DATA: This table contains construction data on joints within the test section, including skew, dowel spacing, joint forming and saw-cutting, sealant, etc. SPS-2 and -8 experiments have entries in this table.

11.3.25 SPS#_PCC_MIXTURE_DATA: This table contains construction data for the mixture for each PCC layer of the test section, including mix design, admixture information, aggregate composition and durability test results, and gradation. SPS-2 and -8 experiments have entries in this table.

11.3.26 SPS#_PCC_PLACEMENT_DATA: This table contains construction data for each PCC layer in the test section, including concrete mix plant, paver, and spreader information; and dowel placement, vibration, finishing, curing, and texturing data. SPS-2 and -8 experiments have entries in this table.

11.3.27 SPS#_PCC_PROFILE_DATA: This table contains information on the profiling and grinding of PCC surface layers of SPS-2 and -8 test sections.

11.3.28 SPS#_PMA_DENSITY_PROFILE: This table contains PMA-bound layer nuclear density measurements and profilograph data. The densities of ATB, binder, surface, and friction are courses that are included. SPS-1 and -8 experiments have entries in this table.

11.3.29 SPS#_AC_PATCHES: This table contains AC patching data collected at test sections in the SPS-5 and -9 experiments. This information is on patching that occurred in preparation for the applied AC overlay and was typically collected by the State highway agency or a representative of the regional support contractor. Since there are no data stored in the SPS9_AC_PATCHES table it is not included in the standard data release.

11.3.30 SPS#_MILLED_SECTIONS: This table contains data on milling operations that occurred at some SPS-5 and -9 test sections in preparation for AC overlays. The table contains information on the equipment, layer delamination, milled thickness measurements, and other observations of the process. Since there are no data stored in the SPS9 table it is not included in the standard data release.

11.3.31 SPS#_RUT_LEVEL_UP: This table contains data on applications of leveling treatments to correct severe rutting on SPS-5 and -9 test sections prior to the application of a PMA overlay.

11.4 TABLES SPECIFIC TO INDIVIDUAL EXPERIMENTS

The following tables are experiment-specific. The fourth character of the prefix indicates the number of the SPS experiment for which data are included in that table.

11.4.1 SPS2_PCC_FULL_DEPTH: This table contains full-depth repair data for SPS-2 (study of structural factors for rigid pavements) test sections, including information on patching, slab replacement, load-transfer devices, reinforcing steel, concrete properties, finishing and curing methods, etc.

11.4.2 SPS2_PCC_STEEL: This table contains information on the reinforcing steel used in each PCC layer of the SPS-2 test section.

11.4.3 SPS3_CHIP: This table contains chip seal aggregate and sealant properties, placement data, surface preparation, and other information for SPS-3 test sections with chip seal maintenance treatments.

11.4.4 SPS3_CHIP_EQUIP: This table contains information on all equipment used in applying chip seal maintenance treatments to SPS-3 test sections.

11.4.5 SPS3_CRACK: This table contains information on surface preparation, environmental conditions, sealant properties, equipment used, and application processes for SPS-3 test sections with crack sealing maintenance treatments.

11.4.6 SPS3_ROLLER: This table contains information on the roller equipment used in chip seal applications to SPS-3 test sections.

11.4.7 SPS3_SLURRY: This table contains asphalt and aggregate properties, application rates, surface preparation, environmental conditions, etc., for SPS-3 test sections with slurry seal maintenance treatments.

11.4.8 SPS3_SLURRY_EQUIP: This table contains information on all equipment used in slurry seal applications to SPS-3 sections.

11.4.9 SPS4_BENKELMAN_GENERAL: This table contains general information on Benkelman beam deflection tests conducted on SPS-4 test sections. Included are start and end times, dates, environmental conditions, etc.

11.4.10 SPS4_BENKELMAN_MEASURE: This table contains the results of Benkelman beam deflection tests conducted on SPS-4 test sections, including the station and joint number where each test was conducted and the corresponding deflection measurements.

11.4.11 SPS4_CONTROL_GENERAL: Each SPS maintenance test project included a control section on which no maintenance was to be performed unless required as a safety measure. This table contains general information on the characteristics of the control section for each SPS-4 project.

11.4.12 SPS4_CONTROL_LONG: This table contains the width of the longitudinal joint opening for each SPS-4 control section.

11.4.13 SPS4_CONTROL_RANDOM: This table contains the widths of the surface cracks for each SPS-4 control section.

11.4.14 SPS4_CONTROL_SHOULDER: This table contains the width of the shoulder joint for each SPS-4 control section.

11.4.15 SPS4_CONTROL_TRANS: This table contains the widths of the transverse joints for each SPS-4 control section.

11.4.16 SPS4_CRACK_SEAL_GENERAL: This table contains information on joint and crack sealing operations at SPS-4 test sections.

11.4.17 SPS4_CRACK_SEAL_PVMT: This table contains information on sealant properties, temperatures, application techniques, backer rod, removal of old sealant, cleaning, etc., associated with the sealing of transverse and longitudinal joints within SPS-4 test sections.

11.4.18 SPS4_CRACK_SEAL_PVMT_MEAS: This table contains joint seal measurements, including backer rod depths, for all sealing work on transverse and longitudinal joints within SPS-4 test sections.

11.4.19 SPS4_CRACK_SEAL_RAND: This table contains information on sealant properties, temperatures, application techniques, backer rod, removal of old sealant, cleaning, etc., associated with the sealing of cracks within SPS-4 test sections.

11.4.20 SPS4_CRACK_SEAL_RAND_MEAS: This table contains crack sealing measurements, including backer rod depths, for all sealing work on cracks within SPS-4 test sections.

11.4.21 SPS4_CRACK_SEAL_SH: This table contains information on sealant properties, temperatures, application techniques, backer rod, removal of old sealant, cleaning, etc., associated with the sealing of longitudinal joints at the shoulders of SPS-4 test sections.

11.4.22 SPS4_CRACK_SEAL_SH_MEAS: This table contains joint seal measurements, including backer rod depths, for all sealing work on longitudinal shoulder joints of SPS-4 test sections.

11.4.23 SPS4_DYNAFLECT_GENERAL: This table contains general information on Dynaflect® deflection testing that was conducted on SPS-4 test sections.

11.4.24 SPS4_DYNAFLECT_MEASURE: This table contains the point locations (stationing) and Dynaflect sensor deflections recorded at each joint or crack within the SPS-4 section that was tested.

11.4.25 SPS4_FWD_MEASUREMENTS: This table contains general information on FWD deflection testing that was conducted on SPS-4 test sections. The table name is misleading since the actual test results are stored offline.

11.4.26 SPS4_TRANSIENT_GENERAL: This table contains general information on transient dynamic response testing that was conducted on SPS-4 test sections. Since there are no data stored in this table it is not included in the standard data release.

11.4.27 SPS4_TRANSIENT_MEASURE: This table contains the point locations (stationing) and transient dynamic response test results for each joint or crack within the SPS-4 section that was tested. Since there are no data stored in this table it is not included in the standard data release.

11.4.28 SPS4_UNDERSEAL_GENERAL: This table contains general undersealing data, including information on the cement, fly ash, water source, hole installation and volume, etc.

11.4.29 SPS4_UNDERSEAL_INIT_GROUT: This table contains information on the initial grouting application process.

11.4.30 SPS4_UNDERSEAL_PRES_GROUT: This table contains information on the pressure grouting application process.

11.4.31 SPS4_UNDERSEAL_REGROUT: This table contains information on the regrouting application process.

11.4.32 SPS6_CRACK_SEAT_PCC: This table contains PCC crack-and-seat data collected at test sections in the SPS-6 experiment (rehabilitation of PCC pavements). This information is on crack-and-seat operations that occurred in preparation for overlays on PCC pavements and was typically collected by the State highway agency or a representative of the regional support contractor.

11.4.33 SPS6_SAW_AND_SEAL: This table contains data on joint sawing and sealing operations that occurred prior to the application of an overlay on SPS-6 test sections.

11.4.34 SPS7_DELAMINATION: This table contains general information on the removal/cleaning of the PCC surfaces of SPS-7 test sections in preparation for PCC overlay.

11.4.35 SPS7_MILLING: This table contains data on milling operations that occurred at some SPS-7 test sections in preparation for PCC overlay.

11.4.36 SPS7_PCCO_JOINT_DATA: This table contains construction data on joints in the PCC overlay of SPS-7 test sections, including skew, load-transfer method, joint forming and saw-cutting, sealant, etc.

11.4.37 SPS7_PCC_OVERLAY: This table contains information on the placement operations of PCC overlays on SPS-7 test sections, including air temperatures, curing, sawing, grouting, and texturing.

11.4.38 SPS7_REFLECTIVE_CRACK: This table contains the methods used for controlling reflective cracking on SPS-7 test sections after a PCC overlay.

11.4.39 SPS7_REMOVAL_CLEANING: This table contains the methods and dates for surface removal/cleaning of the PCC surfaces of SPS-7 test sections prior to a PCC overlay.

11.4.40 SPS9_DIAMOND_GRIND: This table contains information on the diamond grinding of the PCC surface of SPS-9 test sections prior to overlay. Since there are no data stored in this table it is not included in the standard data release.

11.4.41 SPS9_PMA_DENSITY: This table, which is unique to SPS-9 test sections, contains PMA layer density data used for construction control.

11.4.42 SPS9_PMA_MIX_DES_PROP: This table contains the design mixture properties for PMA layers of SPS-9 test sections.

11.4.43 SPS9_PMA_MIXTURE_PROP: This table contains the mixture properties (determined from laboratory testing) for PMA layers of SPS-9 test sections.

11.4.44 SPS9_PMA_PLACEMENT_INFO: This table contains the section wide properties of the asphalt lay-down process for each SPS-9 project, including surface preparation, asphalt plant information, equipment information, and haul time and distances for each lift.

11.4.45 SPS9_PMA_PLACEMENT_LAYER: This table contains the section wide properties of the asphalt lay-down process for SPS-9 sections, including lift thicknesses, tack coat information, and transverse joint locations.

11.4.46 SPS9_PMA_PROFILE: This table contains profilograph measurement results for the AC overlay layer of each SPS-9 test section. This information was used for construction control.

11.4.47 SPS9_SP_PMA_AC_PROPERTIES: This table, which is unique to SPS-9 test sections, contains PMA-bound layer Superpave asphalt cement properties.

11.4.48 SPS9_SP_PMA_AGGREGATE_PROP: This table, which is unique to SPS-9 test sections, contains PMA-bound layer Superpave aggregate properties.

11.4.49 SPS9_SP_PMA_MIXTURE_PROP: This table, which is unique to SPS-9 test sections, contains PMA-bound layer Superpave mixture properties.

11.4.50 SPS9_SUBGRADE_PREP: This table contains subgrade preparation data collected on construction data sheets, including information on compaction and stabilization.

CHAPTER 12. TRAFFIC MODULE

In the development of the LTPP program, provision of traffic monitoring data was assigned to participating highway agencies. The requested LTPP traffic data was based on a balance between pavement research program needs, constraints of existing traffic monitoring technology, and limited highway agency resources. The traffic data collection plan recognized the following major principles:

- Traffic loading estimates should be the result of onsite measurements wherever possible.
- Data from all LTPP locations should be treated consistently in collection, submission, review, and aggregation, without modification to reflect "expected" values.
- Data included in the database should follow the principle of "truth in data". The term "truth in data" has been defined to include the following:
    - Practices and conditions under which the data have been collected must be reported.
    - Editing of traffic data must be documented and a record of the original (unedited) data must be retained.
    - Data variance estimates should be reported when possible.

Due to the diversity of traffic data collection efforts by participating highway agencies, there is a wide range in accuracy and variability associated with traffic data estimates that is impossible to quantify. At this time it is not possible to provide reliable data variance estimates from the annual projections based on the raw monitoring data.

The LTPP PPDB contains annual estimates of traffic load characteristics in the LTPP test section lane created by the LTPP Traffic Analysis Software (LTAS). LTAS is a pre-upload data processing program that is used to perform quality control checks and compute the annual statistics stored in the PPDB. The LTAS database was first released in SDR 24, January 2010. This data was released for those interesting in other traffic engineering uses of the LTPP traffic data. The LTAS database contains daily and monthly traffic data used in the computation of annual traffic estimates stored in the PPDB, traffic monitoring equipment locations, data errors, unprocessed traffic measurements from the non-LTPP lane, and other information used in the traffic data review and analysis procedure. A separate LTAS DB user guide is distributed as a part of the SDR and is included in the LTPP Reference Library.

In order to serve the needs of data users still interested in the AASHO equivalent single axle pavement loading concept, a computer program called ESALCalc is available. This software will compute annual ESAL estimates from traffic monitoring data and pavement structure data following the most recent guidelines.

Traffic data formatted for use with the Mechanistic-Empirical Guide for the Design of New and Rehabilitated Pavement Structures (MEPDG) developed under NCHRP project 1-37A was first released in January 2008. The January 2008 MEPDG traffic data in the LTPP Pavement Performance Database was contained in a module named MEPDG. For the January 2009 data release, these tables were renamed and moved to the TRF module.

12.1 IMPORTANT FIELDS

Common fields unique to the TRF tables that can be used to link related data in associated tables to each other include VEHICLE_CLASS, AXLE_GROUP, CLASS_COUNT_BEGIN_DATE, and WIM_AVC_CALIB_DATE.

12.1.1 VEHICLE_CLASS refers to the FHWA 13-bin vehicle classification system (table 4). (Note that although the classification system is named 13-bin for historical reasons, it has 15 categories.) This field can be used to link the number of vehicles weighed within each class (from the TRF_HIST_WEIGHT_DATA table) to the distribution of axle group weights for these classes (from the TRF_HIST_WEIGHT_AXLES table). This field is also used within TRF_HIST_CLASS_DATA to indicate the number of vehicles within each category that were counted during classification surveys. The similar VEHICLE_CLASS field within TRF_MONITOR_AXLE_DISTRIB can be used to link data to the TRF_HIST tables, but only for the truck categories (classes 4 through 14) since motorcycles, automobiles, and light trucks are not generally present in weigh-in-motion (WIM) monitoring data and not summarized for loading estimates by the LTPP traffic data processing software.

Table 4. FHWA 13-bin vehicle classification system.

Vehicle Class	Description
1	Motorcycles
2	Passenger cars
3	Other 2-axle, 4-tire single-unit vehicles
4	Buses
5	2-axle, 6-tire single-unit trucks
6	3-axle single-unit trucks
7	4- or more axle single-unit trucks
8	4- or less axle single-trailer trucks
9	5-axle single-trailer trucks
10	6- or more axle single-trailer trucks
11	5- or less axle multi-trailer trucks
12	6-axle multi-trailer trucks
13	7- or more axle multi-trailer trucks
14	Unclassifiable
15	Partial vehicles, including off scale or lane-changing vehicles

12.1.2 AXLE_GROUP is a variable that defines the type of axle or axle group (single, tandem, triple, or quad). The variable is used within the TRF_HIST_WEIGHT_AXLES and TRF_MONITOR_AXLE_DISTRIB tables. Note that steering axle groups are not recorded separately from other single axles in this table. Steering axle distributions are available off-line for some site-years.

12.1.3 CLASS_COUNT_BEGIN_DATE may be used to relate information on a specific historical traffic classification count that is stored within the TRF_HIST_CLASS_MASTER table with the actual count data that is stored in TRF_HIST_CLASS_MASTER.

12.1.4 WIM_AVC_CALIB_DATE must be used when relating the specific calibration information found within TRF_CALIBRATION_AVC and TRF_CALIBRATION_WIM to the list of installed traffic monitoring equipment found within TRF_EQUIPMENT_MASTER.

12.2 TRF TABLES

All traffic volume, classification and load data contained in the traffic (TRF) module consists of annual estimates based either on agency supplied estimates or computed from reported raw traffic volume, classification and load data. This information is specific to the test section lane. Traffic volume and loading estimates for time periods prior to the start of LTPP pavement monitoring which began in 1990 are labeled as “Historical” (HIST) data. Annual estimates either provided by participating highway agencies or computed from “raw” data provided by the highway agency after 1990 are labeled as “monitoring” (MON) data. Table names in the TRF module reflect the source of the data stored within them; HIST, MON, or MONITOR are used in table names containing traffic estimates.

12.2.1 TRF_BASIC_INFO: This table contains basic information about the location of the section and the roadway on which it is located.

12.2.2 TRF_CALIBRATION_AVC: This table contains information on the calibration of automated vehicle classification (AVC) equipment installed at a test section.

12.2.3 TRF_CALIBRATION_WIM: This table contains information on the calibration of weigh-in-motion (WIM) equipment installed at a test section.

12.2.4 TRF_EQUIPMENT_MASTER: This table contains information about equipment (both AVC and WIM) in place during a calibration event.

12.2.5 TRF_HIST_CLASS_DATA: This table contains the results of vehicle classification counts that were taken by the State/Provincial agency prior to the start of LTPP traffic monitoring and were used to estimate vehicle distributions at the site. These counts were not necessarily taken at the site itself.

12.2.6 TRF_HIST_CLASS_MASTER: This table contains the specifics of the classification counts that furnished data for TRF_HIST_CLASS_DATA. The CLASS_MASTER table also contains the total volumes recorded during each count.

12.2.7 TRF_HIST_EST_ESAL: This table contains estimates of 80-kN (18-kip) equivalent single-axle loads (ESALs) at the section for each year from construction (or 1965, whichever is later) to its inclusion in the LTPP program (or 1990, whichever is earlier).

12.2.8 TRF_HIST_VOLUME_COUNT: This table contains the results of vehicle volume counts that were taken by the State/Provincial agency prior to the start of LTPP traffic monitoring and were used to estimate traffic volumes at the site. These counts were not necessarily taken at the site itself.

12.2.9 TRF_HIST_WEIGHT_AXLES: This table was designed to contain truck weighing sessions conducted by the State/Provincial agency prior to the start of LTPP traffic monitoring and were used to estimate traffic loading at the site. However since this data was not reported by participating highway agencies, this table does not contain any entries. It has been removed from the standard data release.

12.2.10 TRF_HIST_WEIGHT_DATA: This table was designed to store the number of vehicles weighed during the sessions in which TRF_HIST_WEIGHT_AXLES information was extracted. This table is also empty and is not included in the standard data release.

12.2.11 TRF_HIST_WEIGHT_MASTER: This table contains all general information on the roadway and the equipment used for historical truck weighing sessions.

12.2.12 TRF_MONITOR_AXLE_DISTRIB: This table contains the number of axles measured in each weight range for each axle group (single, tandem, triple, and quad). This information is obtained from weigh-in-motion (WIM equipment installed at or near the test section. Note that steering axle weight distributions are not recorded separately from other single axles in this table. The WEIGHT_BIN_SIZE field contains the size of the weight bins used to describe the weight distribution by axle type.

12.2.13 TRF_MONITOR_LTPP_LN: This table contains information on the amount of data collected on a vehicle class basis and the estimated annual volumes of trucks and axles associated with that data for the LTPP lane only.

12.2.14 TRF_MON_EST_ESAL: This table contains an annual estimate of the number of 80-kN (18-kip) ESALs in the study lane and estimates of truck and total vehicle volumes during the period of time pavement monitoring measurements were performed. The data within this table are for the period from 1990 (or open to traffic, whichever is later) until the test section was instrumented with monitoring equipment or for any year in which the traffic monitor equipment was not operational. The estimates are supplied by participating highway agencies.

12.3 TRF_MEPDG TABLES

This series of tables contain traffic data developed for use in the MEPDG traffic module that are computed from data stored in the LTPP traffic database which have been processed using the traffic QC/QA system. Data which have passed the level D and E QC checks were used in the computations. This process restricts the traffic estimates to the LTPP study lane only and excludes directional and lane distribution factors. The computations were also limited to years in which a site had adequate traffic monitoring data to justify the computation.

Some uses, interpretations, limitations, and required extrapolations of these computed parameters for use in evaluation of the MEPDG include:

- In most instances the LTPP study lane is the pavement structural design lane.

- Users of this data can compare year specific estimates of traffic loadings based on site specific monitoring data in the design lane versus planning design values based on information available to the pavement designer prior to construction of the facility.
- All traffic data is aggregated to annual estimates as a base line; monthly variations are extrapolated to equal annual totals.
- Due to limited traffic monitoring coverage, data users will have to extrapolate this information to other years for which traffic monitoring data is not available to develop cumulative traffic loading estimates.
- The LTPP database does not include MEPDG traffic classification groups. These traffic classification groups were developed by the NCHRP MEPDG contractor independent of LTPP data.
- LTPP truck / tractor trailer classifications use FHWA standards and agency specific truck classifications are not available from the CTDB.

Other traffic monitoring data are contained within the CTDB that can be used to develop directional and lane distribution factors, as was used in the development of the factors in the MEPDG. These data are available for sites where all lanes were instrumented with a traffic measurement device. Please contact the LTPP customer service center by e-mail at ltppinfo@dot.gov to discuss acquisition of other CTDB data.

The MEPDG traffic tables contain many of the same important fields as previously discussed in this chapter.

12.3.1 TRF_MEPDG_AADTT_LTPP_LN: This table contains estimates of the annual average daily truck traffic (AADT) in the LTPP test section lane computed by three alternate computation methods based on a combination of classification or weight data, only classification, or only weight data.

- Records with a value of 0 in the TRF_DATA_TYPE field contain estimates of AADT volume in the LTPP test lane for sites for years where 210 or more days of combined classification and WIM data exists for at least one vehicle truck class.
- Records with a value of 4 in the TRF_DATA_TYPE field contain estimates of AADT volume in the LTPP test lane for sites for years where 210 or more days of classification data exists for at least one vehicle class.
- Records with a value of 7 in the TRF_DATA_TYPE field contain estimates of AADT volume in the LTPP test lane for sites for years where 210 or more days of weight data exists for at least one vehicle class.

These estimates are based on the traffic data computation guidelines contained in the current MEPDG documentation.

12.3.2 TRF_MEPDG_AX_DIST. This table contains normalized axle distributions by month, truck class and axle group. Records in this table are generated from the MM_AX table in the LTPP traffic database that contain at least 210 days of WIM data in that calendar year. The monthly distribution bin counts are based on day of the week averages. The 4,000-lb weight bins for quad axles in the LTPP traffic database are reduced to the MEPDG 3,000-lb weight bins using an assumption that the 4,000-lb bins have a uniform distribution between adjacent bins.

This table utilizes a database efficient table storage structure where a data set is stored as multiple records. To extract a complete year data set a user should use SQL to extract multiple records with different values for MONTH, VEHICLE_CLASS, AXLE_GROUP, and WEIGHT_BIN_LOW for each site defined by STATE_CODE, SHRP_ID, and YEAR.

12.3.3 TRF_MEPDG_AX_DIST_ANL. This table contains the annual normalized axle distribution by class and axle group. Records in this table are generated from the LTPP traffic database from the TRF_MONITOR_AXLE_DISTRIB table where matching records in the TRF_MONITOR_LTPP_LN have a RECORD_STATUS equal to D or E. At least two years of data must exist with more than 210 days of WIM data in the TRF_MONITOR_LTPP_LN table.

This table was created to determine the stability of the axle distribution over time. The values stored in the TRF_MEPDG_AX_DIST_ANL_VAR table can be used to determine the significance of annual variations.

This table utilizes a database efficient table storage structure where a data set is stored in multiple records. To extract a complete year data set a user should use SQL to extract multiple records with different values for VEHICLE_CLASS, AXLE_GROUP, and WEIGHT_BIN_LOW for each site defined by STATE_CODE, SHRP_ID, and YEAR.

12.3.4 TRF_MEPDG_AX_DIST_ANL_VAR. This table contains the mean and variance of the elements of the normalized axle distributions by vehicle class and axle type for all years of available site specific monitoring data. At least two years of more than 210 days of WIM data of data must exist for the table to be populated for a site.

The number of years the variances are computed over is indicated in the NUM_YEARS field.

This table utilizes a database efficient table storage structure where a data set is stored in multiple records. To extract a complete data set a user should use SQL to extract multiple records with different values for VEHICLE_CLASS, AXLE_GROUP, and WEIGHT_BIN_LOW for each site defined by STATE_CODE and SHRP_ID.

12.3.5 TRF_MEPDG_AX_PER_TRUCK. This table contains the annual average number of number of axles by vehicle class and axle type by year. This is computed from the axles actually weighed as summed in the TRF_MONITOR_LTPP_LN table.

In this beta release of data, records with averages number of axles per truck less than 0.1 or greater than 5 truck have a RECORD_STATUS=C. Users must read MEPDG documentation in order to properly interpret fractional averages contained in this table.

This table utilizes a database efficient table storage structure where a data set is stored in multiple records. To extract a complete data set a user should use SQL to extract multiple records with different values for VEHICLE_CLASS and AXLE_GROUP, for each site defined by STATE_CODE, SHRP_ID and YEAR.

12.3.6 TRF_MEPDG_HOURLY_DIST. This table contains annual average hourly distribution of trucks by hour in the LTPP lane based on classification data. The computations were performed following the algorithm contained in the Mechanistic-Empirical Guide for the Design of New and Rehabilitated Pavement Structures developed under NCHRP project 1-37A. The table contains data from only SPS_1, -2, -5 and -6 sites which have passed a validation study under the SPS WIM Pooled Fund study. Only years with at least 210 days of classification data are included.

12.3.7 TRF_MEPDG_MONTH_ADJ_FACTR. This table contains adjustment factors for ADTT for each truck class by month based on either classification or weight monitoring data as indicated by the code contained in the TRF_DATA_TYPE field. A value of 4 in the TRF_DATA_TYPE field indicates the estimate was based on only classification data and a value of 7 only weight data.

This table utilizes a database efficient table storage structure where a data set is stored in multiple records. To extract a complete data set a user should use SQL to extract multiple records with different values for MONTH and VEHICLE_CLASS for each site defined by STATE_CODE, SHRP_ID, YEAR and TRF_DATA_TYPE.

12.3.8 TRF_MEPDG_VEH_CLASS_DIST. This table contains the percentage of trucks by vehicle class within the truck population (FHWA Classes 4-13) in the LTPP lane based classification, weight or a combination of on classification and weight data as indicated by the code contained in the TRF_DATA_TYPE field. For some sections, up to three different estimates are provided. Estimates are provided by year.

On SPS sites, the estimates are provided using a project level SHRP_ID. In most cases it is a good assumption that the project level traffic applies to all test sections on the project. SPS_PROJECT_STATIONS table can be used to indentify sites where test sections are located in both directions of travel on one SPS project.

This table utilizes a database efficient table storage structure where a data set is stored in multiple records. To extract a complete data set a user should use SQL to extract multiple records with different values for VEHICLE_CLASS for each site defined by STATE_CODE, SHRP_ID, YEAR, and TRF_DATA_TYPE.

12.4 TRF_ESAL TABLES

The TRF_ESAL series of tables contain annual 18 Kip (80 kN) ESAL estimates and computation parameters for the LTPP lane based on traffic monitoring measurements computed using the 1993 AASHTO Guide for Design of Pavement Structures methodology. The data were first added to SDR 25 (January 2011) as a series of database tables contained directly in the PPDB. Previously these tables and computation program were contained on Reference Library disk as part of the ESALCalc utility software that was distributed with the SDR. The purpose of adding these tables directly into the PPDB is to make these computed parameters easier to find.

The ESALCalc program is still distributed on the Reference Library disk to allow data base users to compute ESAL by altering the input parameters. The ESALCalc documentation contains instructions on how to change ESAL computation inputs in order to produce custom estimates.

12.4.1 TRF_ESAL_COMPUTED. The results of the annual ESAL calculations in the LTPP lane are contained in this table. These ESAL estimates are provided only for sites which have an acceptable sample of axle load measurements contained in the LTPP database in the indicated year. The axle load sample is expanded to an annual estimate using a time based multiplier. The estimates are contained in the KESAL_YEAR field with units of kESAL/year or 1,000 ESAL/year. Thus a value of 1 in this field should be interpreted as 1,000 ESAL/year in the LTPP study lane.

12.4.2 TRF_ESAL_AC_THICK. This table contains the values used to compute the structural number for AC surfaced test sections. It includes the thickness, type of layer, layer coefficient, average resilient modulus, and drainage layer coefficient for base and subbase layers. This table also includes a start date and end date that these values apply.

12.4.3 TRF_ESAL_PCC_COMP_THICK. This table contains the values used to compute the value of the effective thickness of the PCC layers used in the ESAL calculation. The table includes information on the thickness of multiple PCC layers and whether or not they are bonded.

12.4.4 TRF_ESAL_INPUTS_SUMMARY. This is the master table which contains a summary if all of the input data used to in the annual ESAL estimate. Contents of this table include:

- The pavement type and its source.
- Structural number (SN) and its source used for AC pavements.
- Effective thickness and its source used for PCC pavements.
- Terminal service index value and the basis for this value.
- Functional classification of the facility which was used to establish the terminal serviceability index.
- Climate characterizations including average annual precipitation and freeze index, LTPP experimental climate region and the source for this classification.
- The start and end dates, related to the construction number that these properties apply.

12.4.5 TRF_ESAL_DRAINAGE_COEFF. This table contains the drainage coefficient for unbound base and subbase layers used in the ESAL calculation and the climate zone that the coefficient is based upon.

CHAPTER 13. MATERIALS TESTING MODULE

13.1 BACKGROUND

Extensive field tests, materials sampling, and laboratory testing are conducted on LTPP test sections to:

- Verify and document the as-constructed pavement structure of LTPP test sections.
- Provide the basic engineering material properties of the pavement structure that support a wide variety of performance analyses.
- Provide a measure of the variation in the pavement structure and material properties.

The original materials characterization scheme was based on materials testing and parameters that existed in the late 1980s. Updates to a few tests, most notably the resilient modulus of AC materials, were made in the 1990s. Overall, the intention of the LTPP program is to focus on materials tests in common use at the initiation of the project, so that upon completion, a full suite of results will be available for the entire time span.

The LTPP program developed materials sampling and testing protocols primarily based on in-place material samples from pavement structures, although for some tests on SPS sections or GPS overlay sections, materials were sampled during construction. These protocols are documented in *SHRP-LTPP Interim Guide for Laboratory Materials Handling and Testing* and *SHRP-LTPP Guide for Field Materials Sampling, Testing, and Handling*. In addition, materials sampling and testing guidelines were developed for each SPS experiment. A list of these guidelines is presented in appendix A.

The LTPP materials sampling and testing program began on GPS test sections accepted into the program before 1990. An initial round of sampling and testing was conducted in 1989. LTPP contractors conducted the field materials sampling and testing and laboratory testing for these sections. For SPS sections and GPS overlay sections, the respective highway agency is responsible for most materials testing. Resilient modulus and associated testing of hot-mix asphalt (HMA) materials and the coefficient of thermal expansion of PCC materials are conducted by LTPP-contracted laboratories.

13.2 MATERIALS TEST TYPES

A list of typical materials tests, test designations, and protocols are shown in table 5. The test designation is used for database table names. The tests actually conducted on a test section are dependent on the type of materials, the thickness of the material layers, and the type of pavement layer. Test requirements also vary according to the objectives of the experiment to which the section is assigned. In some cases, a layer may not have been thick enough to meet testing requirements for bound materials or sufficient quantities of materials could not be obtained in order to conduct a test.

LTPP Database Tip!	Perform an evaluation of data availability. Do not assume that all planned materials tests are available.

Table 5. Materials testing designations and protocols.

Material	Test Designation	Name	Protocol
Asphalt Concrete	AC01	Core Examination and Thickness	P01
Asphalt Concrete	AC02	Bulk Specific Gravity	P02
Asphalt Concrete	AC03	Maximum Specific Gravity	P03
Asphalt Concrete	AC04	Asphalt Content (Extracted)	P04
Asphalt Concrete	AC07(1)	Resilient Modulus, Tensile Strength, and Creep	P07
Asphalt Concrete	SP01(1)	Gyratory Compaction	(4)
Asphalt Concrete	SP02(1)	Volumetric and Gravimetric Properties of Superpave Mixes	(4)
Extracted Aggregate From Asphalt Concrete	AG01	Specific Gravity of Coarse Aggregate	P11
Extracted Aggregate From Asphalt Concrete	AG02	Specific Gravity of Fine Aggregate	P12
Extracted Aggregate From Asphalt Concrete	AG04	Gradation of Aggregate	P14
Extracted Aggregate From Asphalt Concrete	AG05(2)	Fine Aggregate Particle Shape	P14A
Asphalt Cement	AE01	Abson Recovery	P21
Asphalt Cement	AE02	Penetration at 77 °F and 115 °F	P22
Asphalt Cement	AE03	Specific Gravity at 60 °F	P23
Asphalt Cement	AE04	Viscosity at 77 °F	P24
Asphalt Cement	AE05	Viscosity at 140 °F and 275 °F	P25
Asphalt Cement	AE07	Dynamic Shear Rheometer (DSR) Test	(4)
Asphalt Cement	AE08	Bending-Beam Rheometer (BBR) Test	(4)
Asphalt Cement	AE09	Superpave Direct Tension (DT) Test	(4)
Bound/Treated Base and Subbase	TB01	Identification and Description of Treated Material and Type of Treatment	P31
Bound/Treated Base and Subbase	TB02	Compressive Strength of Other Than Asphalt Treated Material	P32
Unbound Granular Base and Subbase	UG01	Particle Size Analysis	P41
Unbound Granular Base and Subbase	UG02	Washed Sieve Analysis	P41
Unbound Granular Base and Subbase	UG04	Atterberg Limits	P43
Unbound Granular Base and Subbase	UG05	Moisture-Density Relations	P44
Unbound Granular Base and Subbase	UG07	Resilient Modulus	P46
Unbound Granular Base and Subbase	UG08	Classification and Description	P47
Unbound Granular Base and Subbase	UG09	Permeability of Granular Base/Subbase	P48
Unbound Granular Base and Subbase	UG10	Natural Moisture Content	P49
Unbound Granular Base and Subbase	UG13	Specific Gravity	P71
Unbound Granular Base and Subbase	UG14	Dynamic Cone Penetrometer	P72
Subgrade	SS01	Sieve Analysis	P51
Subgrade	SS02	Hydrometer Analysis	P42
Subgrade	SS03	Atterberg Limits	P43
Subgrade	SS04	Classification and Description	P52
Subgrade	SS05	Moisture-Density Relations	P55

Table 5. Materials testing designations and protocols (continued).

Material	Test Designation	Name	Protocol
Subgrade	SS06	Determination of Modulus of Subgrade Reaction by Nonrepetitive Static Plate Load Test	P58
Subgrade	SS07	Resilient Modulus	P46
Subgrade	SS09	Natural Moisture Content	P49
Subgrade	SS11(3)	Measurement of Hydraulic Conductivity of Saturated Porous Material Using a Flexible Wall Permeameter	P57
Subgrade	SS12(3)	Expansion Index	P60
Subgrade	SS13	Specific Gravity	P71
Subgrade	SS14	Dynamic Cone Penetrometer	P72
Portland Cement Concrete	PC01	Compressive Strength	P61
Portland Cement Concrete	PC02	Splitting Tensile Strength	P62
Portland Cement Concrete	PC03	Coefficient of Thermal Expansion	P63
Portland Cement Concrete	PC04	Static Modulus of Elasticity	P64
Portland Cement Concrete	PC05	Density of PCC	P66
Portland Cement Concrete	PC06	Core Examination and Thickness	P66
Portland Cement Concrete	PC07	Interface Bond Strength	P67
Portland Cement Concrete	PC08(3)	Air Content of Hardened Concrete	P68
Portland Cement Concrete	PC09	Flexural Strength	P69
SPS-3 and -4	SC01	Tests on Emulsified Asphalts	(4)
SPS-3 and -4	SC02	Plastic Fines in Graded Aggregates by Use of Sand Equivalency Test	(4)
SPS-3 and -4	SC03	Testing Crushed Stone for Single Bituminous Surface Treatments	(4)
SPS-3 and –4	SC04	Determination of Flakiness Index of Aggregates	(4)
SPS-3 and -4	SC05	Testing of Slurry Seal	(4)
SPS-3 and -4	SC06	Measurement of Excess Asphalt in Bituminous Mixtures by Use of Loaded Wheel and Sand Cohesion	(4)
SPS-3 and -4	SC07	Wet Stripping Test for Cured Slurry Seal Mixes	(4)
SPS-3 and -4	SC08	Determination of Slurry System Compatibility	(4)
SPS-3 and -4	SC09	Mixing, Setting, and Water-Resistance Test to Identify Quick-Set Emulsified Asphalts	(4)
SPS-3 and -4	SC10A	Aggregate Gradation of Chip Seals	(4)
SPS-3 and -4	SC10B	Aggregate Gradation of Slurry Seals	(4)
SPS-3 and -4	SC11	Chip Seal Mix Design	(4)
SPS-3 and -4	SC12	Determination of Asphalt Content From Slurry Seal Sample	(4)
SPS-3 and -4	SC13	Polish Value of Chip Seal Aggregates	(4)
SPS-3 and -4	CS01	Properties of Hot-Poured Joint Sealants	(4)
SPS-3 and -4	CS02	Properties of Silicone Joint Sealants	(4)

Notes:

1 Data are limited at this time; more expected in the future.

2 Test is conducted by the National Aggregates Association Joint Research Laboratory. Data are not available for all test sections.

3 Data are limited; no more data expected.

4 These tests for the SPS 3, 4 and 9 experiments were performed using non-LTPP developed material testing protocols.

13.3 IMPORTANT FIELDS

In addition to the fields described in the course of outlining the sampling and layering information tables, there are several other fields common to many tables in the Materials Testing (TST) module. While they are not critical to understanding the relational structure of the module, they do provide additional information to the analyst.

13.3.1 FIELD_SET identifies materials sampled during visits to a site as related to construction events. In theory, the FIELD_SET number should be incremented for each day that materials sampling and testing were conducted. In practice, the FIELD_SET number can span a period of time during construction events. Material samples from GPS test sections are typically obtained during the first site visit after investigations to confirm the pavement structure. If a rehabilitation event is performed on a GPS test section, such as an overlay, material samples from the overlaid pavement structure will be assigned a new FIRLD_SET number. On SPS sites, assignment of a FIELD_SET number is more complicated since construction of multiple layers within a single construction event can occur. For SPS projects starting with a new or reconstructed pavement structure (i.e., SPS-1, -2, -8, and some -9's), FIELD_SET = 1 will encompass the time until the final surface layer is completed. On SPS maintenance and rehabilitation projects, FIELD_SET = 1 typically represents materials sampling and testing prior to application of the maintenance and rehabilitation treatment. On a given test section, FIELD_SET begins at 1 and is incremented for each site visit at which material samples were obtained. As such, FIELD_SET can be used as a surrogate for the actual date of sampling in identifying samples from a single section of approximately the same age.

13.3.2 TEST_NO is a code field of the type TEST_NO that indicates where in the section the sample was obtained. As such, TEST_NO can be used as a surrogate for the actual longitudinal and transverse location of the sampling when identifying test results from adjacent material samples at a test section. In addition, some tests conducted on bulk samples had to be conducted on a combination of materials sampled at different ends of the section or, in some cases, at different sections at an SPS project to meet the minimum weight requirements of the test. Certain values of the code TEST_NO are used to identify such conditions. Material samples obtained at an LTPP test section are typically obtained from either just before the beginning of the section (the "approach end") or just after the end of the test section (the "leave end"). Sometimes samples are obtained from within the test section; however, this is kept to a minimum to avoid altering the performance characteristics of the section.

13.3.3 SAMPLE_AREA identifies the area from which the material was sampled. During the development of the SPS materials sampling guidelines, the term "sample area" was coined to uniquely identify discrete areas at an SPS project from which material samples were obtained. Generally, the sample areas at an SPS project are numbered sequentially, starting with sample area 1 being assigned to the approach end of the first test section on the project. In addition, generally, the sample area at the approach end of a section has an odd number and the sample area at the leave end of a section has an even number. However, there is no way to verify that these generalizations hold true at any given SPS project without consulting the materials sampling plan specific to that project. This information is not available in the LTPP database at this time. The format of SAMPLE_AREA varies from table to table in the TST module (and sometimes within a table as well). Generally, SAMPLE_AREA is formatted as “##”; however, sometimes it is formatted as “SA-##”, “SA##”, or even “S##”.

13.3.4 LAB_CODE is a code field of the type LAB_CODE that identifies the laboratory that conducted the test of interest. As might be expected with a project as large as the LTPP program, many different laboratories contributed to the materials testing database. The individual laboratory that conducted any given test can be identified by the LAB_CODE field. LAB_CODE is actually a “smart code” in that the first two digits of a LAB_CODE are the same as the STATE_PROVINCE code of the State or Canadian Province in which the laboratory is located.

13.4.5 COMMENTS_* are codes of the type COMMENT, so this value must be linked to the codes table for a description. Most of the test results tables share a unified set of comment codes. These comment codes document expected error conditions, such as insufficient sample size or specimen fracture during testing. These tables have multiple fields for storing these codes, taking the form of COMMENTS_* (e.g., COMMENTS_1, COMMENTS_2, etc.). For cases where no appropriate comment code is available, the COMMENT_OTHER field is used to store a text comment.

13.4 UNDERSTANDING THE MATERIALS TESTING DATA STRUCTURES

Materials testing data are stored in the TST module. Additional materials characterization data are stored in the INV, RHB, MNT, and SPS# modules; however, those are based on construction history records supplied by highway agencies and are of unknown reliability.

13.4.1 Test Results Tables

Tables containing the results for specific tests can be identified based on the test designations shown in table 5. For example, data resulting from test AC03 is stored in a table named “TST_AC03”. Some subgrade and unbound base layer tests that were conducted according to the same protocol, but which have different test designations, are stored in tables that have a name reflecting both test designations. For example, data resulting from test designations SS02 and UG03 are located in TST_SS02_UG03.

Some tests, such as the resilient modulus tests, generate more complex results that are stored in a related series of tables. The following sections include a general outline of each test results table in the TST module.

In each of the table descriptions below, the primary key is identified. The primary key is the list of fields required by the database to uniquely identify a single record in a particular table.

13.4.1.1 AC Test Results Tables

TST_AC01: This table contains the results of a visual examination of an AC core. It contains six fields (VISUAL_EXAM_1 through VISUAL_EXAM_6) for codes related to the observed properties of the core. These codes, of code type VISUAL_ACPC, encompass such items as stripping and degraded aggregate. An additional field (VISUAL_EXAM_OTHER) is reserved for text comments for which no numeric codes were reserved. In addition, the height of the core is stored in the CORE_AVG_THICKNESS field. The primary key consists of the STATE_CODE, SHRP_ID, FIELD_LAYER_NO, FIELD_SET, TEST_NO, and LOC_NO fields. Although only STATE_CODE, SHRP_ID, FIELD_LAYER_NO, and LOC_NO are required to uniquely identify a record.

The FIELD_LAYER_NO field should not be confused with LAYER_NO as used elsewhere in the TST module. Field layering, as the name suggests, is assigned during the field visit and is often modified at the regional office after inventory and materials testing data are reviewed. To obtain the "true" layer number, this table must be linked to TST_AC01_LAYER (described below) using the STATE_CODE, SHRP_ID, FIELD_SET, and FIELD_LAYER_NO fields. (FIELD_SET is required because field layering may be assigned differently on separate field visits.)

TST_AC01_LAYER: This table contains the information necessary to convert the field layer numbers recorded in TST_AC01 to "true" layer numbers as used in the rest of the module. In addition, this table contains the thickness of each "true" layer in so far as it can be determined from the core. This thickness is stored in the LAYER_THICKNESS field. The primary key consists of the STATE_CODE, SHRP_ID, FIELD_LAYER_NO, FIELD_SET, TEST_NO, LAYER_NO, and LOC_NO fields.

TST_AC02: This table contains bulk specific gravity test results from AC samples. Calculated bulk specific gravity is stored in the BSG field (no intermediate results are included). In addition, percent moisture absorption is available from the WATER_ABS field. Some specimens were paraffin-coated, and this is indicated by the value of the PARAFFIN_COAT field. The primary key consists of the STATE_CODE, SHRP_ID, FIELD_SET, LAYER_NO, TEST_NO, and LOC_NO fields, although STATE_CODE, SHRP_ID, and SAMPLE_NO should be all that is necessary to uniquely identify a record.

TST_AC03: This table contains theoretical maximum specific gravity test results from AC samples. Calculated maximum specific gravity is stored in the MAX_SPEC_GRAVITY field (no intermediate results are included). The primary key consists of the STATE_CODE, SHRP_ID, LAYER_NO, FIELD_SET, TEST_NO, and LOC_NO fields, although STATE_CODE, SHRP_ID, and SAMPLE_NO should be all that is necessary to uniquely identify a record.

TST_AC04: This table contains extracted asphalt content test results from AC samples. Calculated asphalt content is stored in the ASPHALT_CONTENT_MEAN field (no intermediate results are included). The primary key consists of the STATE_CODE, SHRP_ID, LAYER_NO, FIELD_SET, TEST_NO, and LOC_NO fields, although STATE_CODE, SHRP_ID, and SAMPLE_NO should be all that is necessary to uniquely identify a record.

TST_AC05: This table contains moisture susceptibility test results from laboratory-compacted bulk asphalt specimens. There are only data for a limited number of sections from the SPS-1, -5, -8, and -9 projects. A user should first check for data availability before attempting to use this data in analysis. The LTPP protocol for this test (P05) is primarily based on AASHTO T283, and the user should be familiar with the procedure before attempting to interpret the results.

In essence, test AC05 evaluates the changes in indirect tensile strength in a bituminous mixture caused by water saturation. Six specimens are molded from bulk samples using Marshall, Hveem, or gyratory compaction (the type of compaction used is stored in the METHOD_OF_COMPACTION field). Three of these cores are subjected to vacuum saturation followed by freezing and warm water soaking cycles, while the other three are kept dry. All six specimens are then loaded to failure in indirect tension. The ratio of the average strength of the dry specimens to the conditioned specimens, called the tensile strength ratio (TSR), is stored in the TENSILE_STRENGTH_RATIO field. In addition, the ratio of the coefficient of variation of the strength of the dry specimens to the coefficient of variation of the strength of the conditioned specimens is stored in the RELATIVE_VARIATION_IN_STRENGTH field.

TST_AC05 also contains several intermediate calculations for the six specimens. These calculations are stored in fields with names in the format {property name}_#_{C,U}, where the property name is the measured property (such as WIDTH or BSG), # is the name of the number, and {C,U} denotes whether the specimen is from the conditioned set or the unconditioned set.

TST_AC05 also has a slight complication regarding sample numbers. The SAMPLE_NO field denotes the sample number of the bulk asphalt concrete from which the specimens were molded and SAMPLE_NO_#_{C,U} denotes the sample number assigned to the compacted specimens. Since these specimens were tested to failure, their individual sample numbers should not appear in any other table.

The primary key consists of the STATE_CODE, SHRP_ID, LAYER_NO, FIELD_SET, TEST_NO, and LOC_NO fields, although STATE_CODE, SHRP_ID, and SAMPLE_NO should be all that is necessary to uniquely identify a record.

TST_AC_MOIST_DAMAGE: This table contains data resulting from a visual evaluation of moisture damage to the field cores. Data exists for only a limited number of SPS-5 and -9 sections.

TST_SP01_MASTER: This table contains sample and testing configuration information as well as summary results from the Superpave gyratory compaction test. The summary results include density values at initial, N-design, and N-max gyration compaction levels.

Since these data were primarily collected on test sections in the SPS-9 study, at a time when state agencies and industry were in the process of implementing and further refining the Superpave mixture design procedure, only a limited amount of data are available in this table. A user can expect that available data will contain missing values for some fields due to the experimental nature of these tests which were performed.

This table uses TST_ID as a primary key allowing linking of test results to test samples and material layer on more than one test section. See discussion in section 13.4.5 of this document for information on how to use TST_ID to link test results in this tables to test sections and material layers.

TST_SP01_DATA: This table contains density, air voids, voids in mineral aggregate, and voids filled with asphalt as a function of the number of compaction gyrations for the Superpave gyratory compaction test.

Since these data were primarily collected on test sections in the SPS-9 study, at a time when state agencies and industry were in the process of implementing and further refining the Superpave mixture design procedure, only a limited amount of data are available in this table. A user can expect that available data will contain missing values for some fields due to the experimental nature of these tests which were performed.

This table uses TST_ID as a primary key allowing linking of test results to test samples and material layer on more than one test section. See discussion in section 13.4.5 of this document for information on how to use TST_ID to link test results in this tables to test sections and material layers.

TST_SP02: This table contains test results and corresponding computed volumetric properties of laboratory compacted and field cores of asphalt concrete from primarily SPS-9 test sections. AC volumetric properties include effective binder content, voids in the mineral aggregate, air voids, voids filled with asphalt, and specific gravity of the mix components.

This table uses TST_ID as a primary key allowing linking of test results to test samples and material layer on more than one test section. To determine the type of material sample, a user must use TST_ID to link to the TST_LINK_SAMPLE table. See discussion in section 13.4.5 of this document for information on how to use TST_ID to link test results in this tables to test sections and material layers.

13.4.1.2 TST_AC07_V2_* AC Resilient Modulus Tables

Test results from LTPP test AC07 are stored in four related tables. These results include resilient modulus, creep compliance, and the indirect tensile strength of AC core samples. “V2” in the table names indicates that these tests were conducted according to the second version of protocol P07 used by the LTPP program. The results from the first version of protocol P07 are considered unreliable and are not available in the standard data release.

Test AC07 involves multiple tests on three specimens. The analytical procedures employ unusual data massaging, averaging, and outlier elimination methods to combine the results from these three specimens. While a full understanding of these analytical procedures is not a requirement for using the data, a basic understanding of the test procedure could prove to be useful. The test procedure is documented in *LTPP Protocol P07: Test Method for Determining the Creep Compliance, Resilient Modulus, and Strength of Asphalt Materials Using the Indirect Tensile Test Device* and is illustrated by figure 13. Protocol P07 is also similar to AASHTO TP9-96 with regards to the creep compliance and indirect tensile strength portions.

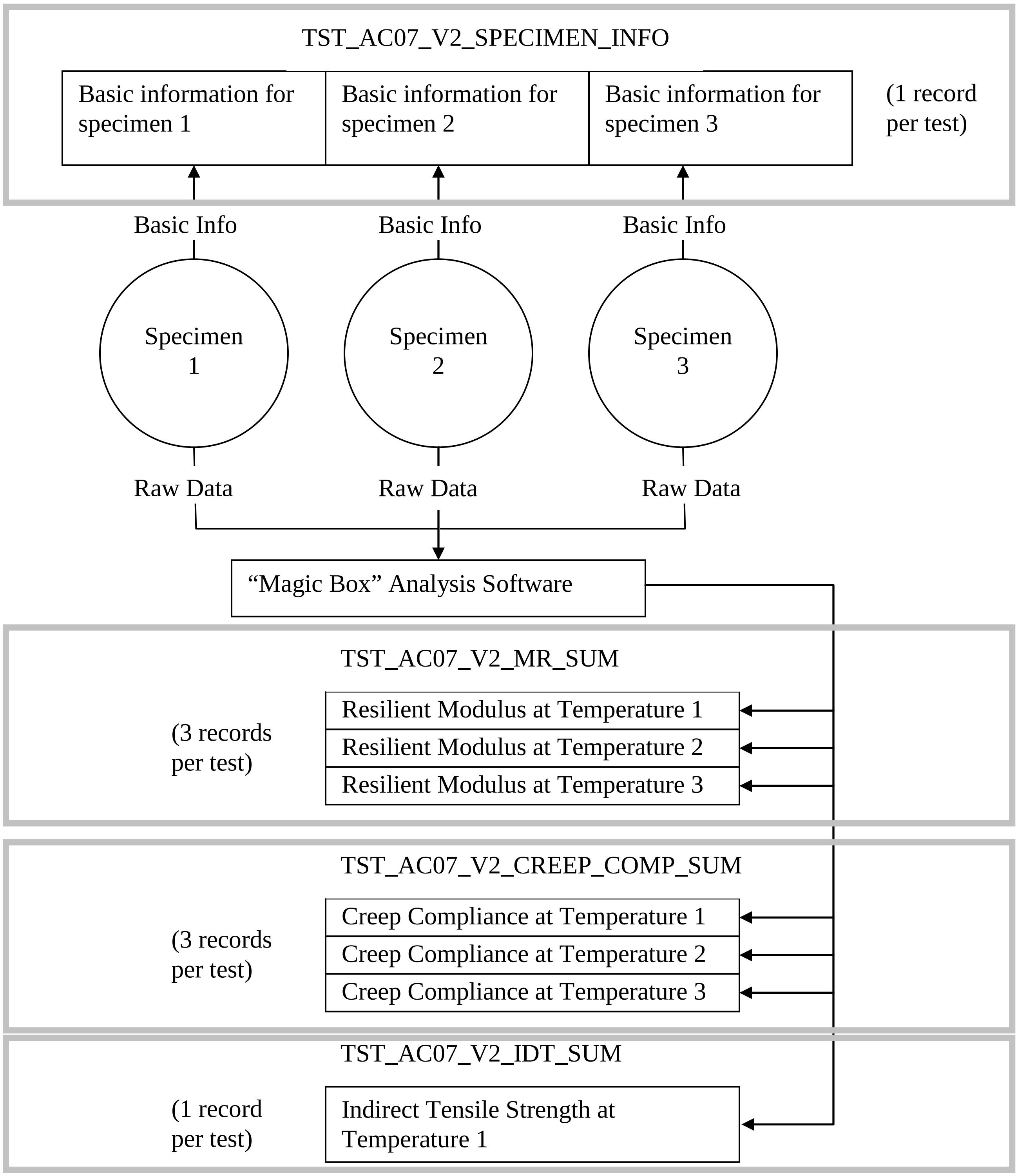


Figure 13. Illustration of relationships among TST_AC07* tables.

TST_AC07_V2_SPECIMEN_INFO: This table is considered the master table for a TST_AC07_V2 submodule. Key fields in TST_AC07_V2_SPECIMEN_INFO include STATE_CODE, SHRP_ID, LAYER_NO, TEST_NO, and FIELD_SET. This table also includes the sample numbers for the three specimens used (SAMPLE_NO_*), thickness information for the specimens (THICKNESS_SPECIMEN_*), diameter information (DIAMETER_SPECIMEN_*), and bulk specific gravity test results (BSG_SPECIMEN_*). This table also contains the unique filenames for the output files generated by the analysis software. These files are stored offline, but may contain data of interest to some analysts. These data are stored in the CREEP_DATA_ANAL_FILE, MR_DATA_ANAL_FILE, and IDT_DATA_ANAL_FILE_* fields, where MR stands for "resilient modulus" and IDT stands for "indirect tensile strength."

TST_AC07_V2_MR_SUM: This table contains summary data for the resilient modulus tests. These data include computed values for three load cycles and average values. The three computed values are instantaneous resilient modulus, total resilient modulus, and Poisson's ratio. The instantaneous resilient modulus is calculated using only the strain recovered during the unloading portion of the cycle, while the total resilient modulus includes the strain recovered during the 0.9-second "rest" portion of the cycle. In addition, there are fields containing a "used" Poisson's ratio. This is an output of the analysis software to account for the fact that the test procedure sometimes yields unreasonable Poisson's ratios. This table also contains the unique filenames for the three raw data files (one per specimen per test temperature) generated by the test data acquisition system and processed by the analysis software. They are stored offline. The primary key includes STATE_CODE, SHRP_ID, LAYER_NO, TEST_NO, FIELD_SET, and TEST_TEMPERATURE since this test is conducted at three different temperatures.

TST_AC07_V2_CREEP_COMP_SUM: This table contains summary data for the creep compliance tests. Creep compliance is stored in the CREEP_COMP_*_SEC fields, where * is the time interval from the initiation of the test in which the creep compliance was calculated. These time intervals are 1, 2, 5, 10, 20, 50, and 100 seconds. In addition, the value of the Poisson's ratio calculated using these data is stored in the CREEP_POISSON_CALC field. The CREEP_POISSON_USED field contains the value used in the computation as described in the preceding paragraph. In addition, the unique filenames for the three raw data files (one per specimen) are stored in the CREEP_COMP_DATA_FILE_SPECIMEN_* fields. The primary key includes STATE_CODE, SHRP_ID, LAYER_NO, TEST_NO, FIELD_SET, and TEST_TEMPERATURE since this test is conducted at three different temperatures.

TST_AC07_V2_IDT_SUM: This table contains the summary data for the indirect tensile strength test. Indirect tensile strengths for the three specimens are stored in the IDT_SPECIMEN_* fields, while the average is stored in the IDT_AVERAGE field. The calculated Poisson's ratio for this test is stored in the IDT_POISSON_CALC field, while the IDT_POISSON_USED field contains the value used in the computations as described in the discussion of TST_AC07_V2_MR_SUM. Several other fields for the initial tangent modulus, fracture energy, and failure strain exist; however, the data to populate them are not included in the standard release because the algorithms used by the analysis software are insufficiently documented, could not be reverse-engineered, and are suspect. The primary key includes

STATE_CODE, SHRP_ID, LAYER_NO, TEST_NO, FIELD_SET, and TEST_TEMPERATURE, although this test is only conducted at one temperature.

13.4.1.3 Asphalt Cement Test Tables

TST_AE01: This table contains the results of the extraction of asphalt cement from field cores by the Abson method. The two data fields are MASS_OF_RECOVERED_BITUMEN, which contains the mass in grams of the recovered asphalt cement, and ASH_CONTENT_OF_BITUMEN, which contains the percent ash content of the recovered asphalt cement. Generally, this test is conducted to provide material for the other AE series tests, although the sample number for the input material is the same as the sample number for the output material. The primary key consists of the STATE_CODE, SHRP_ID, LAYER_NO, FIELD_SET, TEST_NO, and LOC_NO fields, although STATE_CODE, SHRP_ID, and SAMPLE_NO should be all that is necessary to uniquely identify a record.

TST_AE01S is quite similar to TST_AE01; however, it was developed to accommodate data from SPS-3 projects that were tested according to different protocols. The only significant difference from the analyst's perspective is that the moisture content of the field core is also included in the MOISTURE_IN_MIXTURE field.

TST_AE02: This table contains the results of penetration tests conducted on extracted asphalt cements at 25 °C (77 degrees Fahrenheit (°F)) and 68 °C (155 °F) (although plant-sampled asphalt cements were tested for some SPS projects (see the discussion on sample numbers in section 13.4.2)). The three data fields are PENETRATION_77_F, PENETRATION_155_F, and PENETRATION_INDEX. The primary key consists of the STATE_CODE, SHRP_ID, LAYER_NO, FIELD_SET, TEST_NO, and LOC_NO fields, although STATE_CODE, SHRP_ID, and SAMPLE_NO should be all that is necessary to uniquely identify a record.

TST_AE02S: This table contains data for SPS-3 projects only. Penetration was performed at only one test temperature, typically 25 °C (77 °F). The test temperature is stored in the TEST_TEMPERATURE field and the penetration is stored in the AVERAGE_PENETRATION field.

TST_AE03: This table contains the results of specific gravity tests on extracted asphalt cement. Calculated specific gravity is stored in the only data field (SPECIFIC_GRAVITY). The primary key consists of the STATE_CODE, SHRP_ID, LAYER_NO, FIELD_SET, TEST_NO, and LOC_NO fields, although STATE_CODE, SHRP_ID, and SAMPLE_NO should be all that is necessary to uniquely identify a record.

TST_AE04: This table contains the viscosity of asphalt cements as measured using a cone-and-plate viscometer. This test is conducted at a nominal temperature of 25 °C (77 °F). The data fields include viscosity and the corresponding shear rate for five surcharges (100, 300, 1000, 3000, and 10,000 grams), and the fracture load and failure shear stress. Calculated specific gravity is stored in the only data field (SPECIFIC_GRAVITY). The primary key consists of the STATE_CODE, SHRP_ID, LAYER_NO, FIELD_SET, TEST_NO, and LOC_NO fields, although STATE_CODE, SHRP_ID, and SAMPLE_NO should be all that is necessary to uniquely identify a record. This test is no longer conducted.

TST_AE05: This table contains the results of kinematic viscosity testing at 135 °C (275 °F) and absolute viscosity testing at 60 °C (140 °F). The summary data fields are KINEMATIC_VISC_275_F and ABSOLUTE_VISC_140_F, although some intermediate calculations are also provided. The primary key consists of the STATE_CODE, SHRP_ID, LAYER_NO, FIELD_SET, TEST_NO, and LOC_NO fields, although STATE_CODE, SHRP_ID, and SAMPLE_NO should be all that is necessary to uniquely identify a record.

TST_AE06S: This table contains the absolute viscosity of extracted asphalt cement from SPS-3 projects. These data are similar to the absolute viscosity data stored in the TST_AE05 table. The test was conducted at a nominal temperature of 60 °C (140 ºF). Absolute viscosity data are stored in the VACUUM_CAPILARY_VISC field and the test temperature is stored in the TEST_TEMPERATURE field. The primary key consists of the STATE_CODE, SHRP_ID, LAYER_NO, FIELD_SET, TEST_NO, and LOC_NO fields, although STATE_CODE, SHRP_ID, and SAMPLE_NO should be all that is necessary to uniquely identify a record.

TST_AE07_MASTER: This table contains sample and test device configuration for Dynamic Shear Rheometer (DSR) tests on asphalt cement. The results of the DSR tests are stored in the TST_AC07_DATA table. Currently, data contained in this table are from material samples from SPS-9 test sections. In the future, it is planned to add DSR tests performed on asphalt cement samples from other test sections.

This table uses TST_ID as a primary key allowing linking of test results to test samples and material layer on more than one test section. See discussion in section 13.4.5 of this document for information on how to use TST_ID to link test results in this tables to test sections and material layers.

TST_AE07_DATA: This table contains the complex modulus and phase angle from DSR tests on asphalt cement samples at different temperatures. The sample and device configuration information for this test data is contained in the TST_AC07_MASTER table. TST_ID and AGING_TYPE fields are used to link records between these tables. Currently, data contained in this table are from material samples from SPS-9 test sections. In the future, it is planned to add DSR tests performed on asphalt cement samples from other test sections.

This table uses TST_ID as a primary key allowing linking of test results to test samples and material layer on more than one test section. See discussion in section 13.4.5 of this document for information on how to use TST_ID to link test results in this tables to test sections and material layers.

TST_AE08_MASTER: This table contains sample, test device, and regression coefficients of the creep stiffness versus load time curve from Bending Beam Rheometer (BBR) test on asphalt cement samples from SPS-9 test sections at different test temperatures. The regression coefficients contained in the REG_CO_A, REG_CO_B, and REG_CO_C fields are computed for the following equation:

$$\log S(t) = A + B(\log(t)) + C(\log(t)) \quad (3)$$

Where:

	S(t)	=	time dependent flexural creep stiffness, MPa
	t	=	loading time in seconds
	A	=	regression coefficient REG_CO_A
	B	=	regression coefficient REG_CO_B
	C	=	regression coefficient REG_CO_C

The results of the BBR tests are contained in the TST_AE08_DATA table. The key fields used to link these data together in clued TST_ID, AGING_TYPE, and TEST_TEMP.

This table uses TST_ID as a primary key allowing linking of test results to test samples and material layer on more than one test section. See discussion in section 13.4.5 of this document for information on how to use TST_ID to link test results in this tables to test sections and material layers.

TST_AE08_DATA: This table contains the results of BBR tests on asphalt cement samples from SPS-9 test sections as a function of temperature and loading time. Test results reported include the applied force, deflection, measured stiffness, stiffness estimated from equation 3, difference between the measured and estimated stiffness, and absolute value of the slope of the logarithmic stiffness-time curve computed from the first derivative of equation 3.

The related records in TST_AE08_MASTER table are linked to records in this table using the TST_ID, AGING_TYPE, and TEST_TEMP fields.

This table uses TST_ID as a primary key allowing linking of test results to test samples and material layer on more than one test section. See discussion in section 13.4.5 of this document for information on how to use TST_ID to link test results in this tables to test sections and material layers.

TST_AE09_MASTER: This table contains sample, test configuration and summary statistics of the results of the Direct Tension (DT) test on asphalt cement samples from SPS-9 test sections. For each test temperature and type of aging, test results include the average and standard deviation of the peak load, failure stress, and failure elongation.

Results of the DT test are stored in the TST_AE08_DATA table. The related records in this table are linked using TST_ID, AGING_TYPE, and TEST_TEMP.

This table uses TST_ID as a primary key allowing linking of test results to test samples and material layer on more than one test section. See discussion in section 13.4.5 of this document for information on how to use TST_ID to link test results in this tables to test sections and material layers.

TST_AE09_DATA: The table contains the results of the DT test on asphalt cement samples from SPS-9 test sections. For each aging type and test temperature, the results of up to 4 repeat tests are provided. Test results include peak load, peak stress, failure elongation, and failure strain.

These data are related to the summary information contained in the TST_AE09_MASTER table using the TST_ID, AGING_TYPE and TEST_TEMP fields.

This table uses TST_ID as a primary key allowing linking of test results to test samples and material layer on more than one test section. See discussion in section 13.4.5 of this document for information on how to use TST_ID to link test results in this tables to test sections and material layers.

13.4.1.4 Tables on Aggregate in Asphalt Concrete

TST_AG01: This table contains the bulk specific gravity and percent moisture absorption of extracted coarse aggregate from AC cores. These data are stored in the BSG_OF_COARSE_AGG and ABSORPTION_OF_COARSE_AGG fields. Some intermediate calculations are also included. The primary key consists of the STATE_CODE, SHRP_ID, LAYER_NO, FIELD_SET, TEST_NO, and LOC_NO fields, although STATE_CODE, SHRP_ID, and SAMPLE_NO should be all that is necessary to uniquely identify a record.

TST_AG02: This table contains the bulk specific gravity and percent moisture absorption of extracted fine aggregate from AC cores. These data are stored in the BSG_OF_FINE_AGG and ABSORPTION_OF_FINE_AGG fields. Some intermediate calculations are also included. The primary key consists of the STATE_CODE, SHRP_ID, LAYER_NO, FIELD_SET, TEST_NO, and LOC_NO fields, although STATE_CODE, SHRP_ID, and SAMPLE_NO should be all that is necessary to uniquely identify a record.

TST_AG04: This table contains the gradation of extracted aggregate from AC cores. Gradation is determined by sieve analysis. The sieve set used consists of 37.5-mm (1½-inch), 25.0-mm (1-inch), 19.0-mm (¾-inch), 12.5-mm (½-inch), 9.5-mm (⅜-inch), 4.75-mm (No. 4), 2.00-mm (No. 10), 425-µm (No. 40), 180 µm (No. 80), and 75µm (No. 200) sieves. The percent passing each sieve is stored in a data field such as ONE_AND_HALF_PASSING for the 37.5-mm (1½-inch) sieve or NO_80_PASSING for the 180 µm (No. 80) sieve. The primary key consists of the STATE_CODE, SHRP_ID, LAYER_NO, FIELD_SET, TEST_NO, and LOC_NO fields, although STATE_CODE, SHRP_ID, and SAMPLE_NO should be all that is necessary to uniquely identify a record.

TST_AG05: This table contains the fine aggregate shape test results for fine aggregate extracted from AC cores. Data include bulk specific gravity, percent moisture absorption, and uncompacted void content, which are stored in the BSG, ABSORPTION, and UNCOMP_VOID_AVG fields, respectively. The primary key consists of the STATE_CODE, SHRP_ID, LAYER_NO, FIELD_SET, TEST_NO, and LOC_NO fields, although STATE_CODE, SHRP_ID, and SAMPLE_NO should be all that is necessary to uniquely identify a record.

13.4.1.5 In Situ Tests

TST_ISD_MOIST: This table contains in situ density and moisture content measurements using a nuclear density gauge. Up to four measurements of dry density (ISD_DRY_*), wet density (ISD_WET_*), and moisture content (ISMC_*), along with their respective averages (ISD_DRY_AVG, ISD_WET_AVG, ISMC_AVG) are stored in this table. The primary key consists of the STATE_CODE, SHRP_ID, FIELD_SET, LOC_NO, and DEPTH_TOP_STRATA fields. The DEPTH_TOP_STRATA field contains the depth (in inches) from the measuring surface to the pavement surface.

TST_SS14_UG14_MASTER: This is the master table for Dynamic Cone Penetrometer (DCP) tests performed on unbound bases and subgrades performed as part of the SPS material action plan in the 2005 – 2006 time frame. One record is contained in this table for each test at a given location. This table contains information on the test equipment and test set up. The field ZERO_POINT_DEPTH contained in this table is needed to interpret the DCP measurements contained in the TST_SS14_UG14_DATA table.

TST_SS14_UG14_DATA: This table contains the results of the measurements from the DCP test. The measurements are stored in this table for each reading. Each reading consists of the number of blows since the last reading, the penetration since the last reading, the cumulative penetration, the DCP index, and an estimate of the California Bearing Capacity estimated using the table method contained in ASTM D 6951-03. To determine the depth below the surface of the pavement for each measurement, the ZERO_POINT_DEPTH stored in TST_SS14_UG14_MASTER table must be subtracted from the PEN_CUMULATIVE contained in this table.

TST_SS14_UG14_COMMENT: This table contains comments concerning the DCP test.

13.4.1.6 PCC Test Results

TST_PC01: This table contains the compressive strength of PCC cores (although for a few SPS projects, cylinders made from fresh PCC sampled during construction were tested (see the discussion of sample numbers in section 13.4.2 for information on how to determine the sample type)). Compressive strength is stored in the COMP_STRENGTH field and the observed fracture mechanism (a code of the type FRACTURE) is stored in the COMP_FRAC_OTHER field. Several other intermediate calculations, such as the length and diameter of the specimen, are also stored. The primary key consists of the STATE_CODE, SHRP_ID, LAYER_NO, FIELD_SET, LOC_NO, TEST_NO, and SAMPLE_NO fields, although STATE_CODE, SHRP_ID, and SAMPLE_NO should be sufficient to uniquely identify a specimen.

TST_PC02: This table contains the splitting tensile strength of PCC cores and some cylinders (see discussion for TST_PC01). Tensile strength is stored in the TENSILE_STRENGTH field and the observed failure mechanism (a code of the type FRACTURE) is stored in the TENSILE_STRENGTH_FRAC field. Several intermediate calculations, such as the length and diameter of the core, are also stored. The primary key consists of the STATE_CODE, SHRP_ID, LAYER_NO, FIELD_SET, LOC_NO, TEST_NO, and SAMPLE_NO fields, although STATE_CODE, SHRP_ID, and SAMPLE_NO should be sufficient to uniquely identify a specimen.

TST_PC03: This table contains the coefficient of thermal expansion of PCC cores. The coefficient of thermal expansion is stored in the COEFF_THERMAL_EXPANSION field. In addition, a text description of the character of the aggregate type is included in the AGGR_TYPE_PCC field. The primary key consists of the STATE_CODE, SHRP_ID, LAYER_NO, TEST_SEQUENCE, FIELD_SET, LOC_NO, TEST_NO, and SAMPLE_NO fields. The TEST_SEQUENCE field was added to allow entry of repeat measurements on the same sample.

TST_PC04: This table contains the static modulus of elasticity of PCC cores. Elastic modulus is stored in the ELASTIC_MOD field, the Poisson's ratio is stored in the POISSON_RATIO field, and unit weight is stored in the UNIT_WT field. The primary key consists of the STATE_CODE, SHRP_ID, LAYER_NO, FIELD_SET, LOC_NO, and TEST_NO fields, although STATE_CODE, SHRP_ID, and SAMPLE_NO should be sufficient to uniquely identify a specimen.

TST_PC05: This table contains the density measurements for PCC cores. Bulk specific gravity, apparent specific gravity, density, and percent voids are stored in the BULK_SPECIFIC_GRAVITY_DRY, APPARENT_SPECIFIC_GRAVITY, DENSITY_OF_PCC, and PERCENT_VOIDS_IN_PCC fields, respectively. Several other intermediate calculations are also included in this table. The primary key consists of the STATE_CODE, SHRP_ID, LAYER_NO, FIELD_SET, LOC_NO, and TEST_NO fields, although STATE_CODE, SHRP_ID, and SAMPLE_NO should be sufficient to uniquely identify a specimen.

TST_PC06: This table contains the visual examination notes for PCC cores. Six fields (VISUAL_EXAM_*) are provided for visual comments of the type VISUAL_ACPC (which means that these comments must be linked to the CODES table to retrieve their meaning). A seventh field (VISUAL_EXAM_OTHER) is reserved for comments for which no comment codes were provided. In addition, this table also provides the thickness of the core, which is stored in the CORE_AVG_THICKNESS field. The primary key consists of the STATE_CODE, SHRP_ID, LAYER_NO, FIELD_SET, LOC_NO, and TEST_NO fields, although STATE_CODE, SHRP_ID, and SAMPLE_NO should be sufficient to uniquely identify a specimen.

TST_PC07: This table contains the interface shear strength between two bonded PCC layers. This test is conducted on a core (including both layers). The maximum shear strength exhibited by the bond during testing of the core is stored in the SHEAR_BOND_STRENGTH field. Several intermediate calculations are also included in this table. The primary key consists of the STATE_CODE, SHRP_ID, LAYER_NO, FIELD_SET, LOC_NO, and TEST_NO fields, although STATE_CODE, SHRP_ID, and SAMPLE_NO should be sufficient to uniquely identify a specimen.

TST_PC08: This table contains the air content of hardened PCC as determined by visual examination of core specimens. Air content is stored in the AIR_CONTENT field. These data exist for only a handful of SPS-2 and -8 projects. The primary key consists of the STATE_CODE, SHRP_ID, LAYER_NO, FIELD_SET, LOC_NO, and TEST_NO fields, although STATE_CODE, SHRP_ID, and SAMPLE_NO should be sufficient to uniquely identify a specimen.

TST_PC09: This table contains the flexural strength of PCC beams that were poured from materials sampled at the time of construction. Because of the requirement for sampling during construction, data for this test are only available for SPS sections. The modulus of rupture is stored in the MODULUS_OF_RUPTURE field. Several other intermediate calculations are also included. The primary key consists of the STATE_CODE, SHRP_ID, LAYER_NO, FIELD_SET, LOC_NO, TEST_NO, and SAMPLE_NO fields, although STATE_CODE, SHRP_ID, and SAMPLE_NO should be sufficient to uniquely identify a specimen.

13.4.1.7 Test Results for Materials Specific to SPS-3 and -4

TST_CS01: This table contains data on hot-poured joint sealants for a few SPS-3 and -4 sections. There are 11 records in this table. For further information on these tests, see the SPS-3 and -4 data collection guide.

TST_CS02: This table contains data on silicone joint sealants for a few SPS-3 and -4 sections. There are only 12 records in this table. For further information, see the SPS-3 and -4 data collection guide.

TST_SC01: This table contains the results of various tests on asphalt emulsions used in surface treatments applied to SPS-3 sections only. Unlike most other tables in the TST module that contain the results for a single test, this table contains the results for many tests on the same material. Most of these tests are straightforward; however, some of them are fairly unusual (in these cases, consult the SPS-3 and -4 data collection guide). The primary key consists of the STATE_CODE, SHRP_ID, LAYER_NO, FIELD_SET, LOC_NO, and TEST_NO fields, although STATE_CODE, SHRP_ID, and SAMPLE_NO should be sufficient to uniquely identify a specimen.

TST_SC02: This table contains the sand equivalency of fine aggregate materials from SPS-3 sections only. The sand equivalency value, expressed as a percentage, is stored in the SAND_EQUIVALENCY field. No intermediate values are stored. The primary key consists of the STATE_CODE, SHRP_ID, LAYER_NO, FIELD_SET, LOC_NO, and TEST_NO fields, although STATE_CODE, SHRP_ID, and SAMPLE_NO should be sufficient to uniquely identify a specimen.

TST_SC03: This table contains the results of various tests on coarse aggregates used in surface treatments applied to SPS-3 sections only. There are three records in this table and no further data are expected. For further information, see the SPS-3 and -4 data collection guide.

TST_SC04: This table contains the flakiness index of aggregates used in surface treatments applied to SPS-3 sections only. The flakiness index is stored in the FLAKINESS_INDEX field. No intermediate calculations are stored. The primary key consists of the STATE_CODE, SHRP_ID, LAYER_NO, FIELD_SET, LOC_NO, and TEST_NO fields, although STATE_CODE, SHRP_ID, and SAMPLE_NO should be sufficient to uniquely identify a specimen.

TST_SC05: This table contains the results of various tests on slurry seals applied to SPS-3 sections only. This table contains a single record and no further data are expected. For further information, see the SPS-3 and -4 data collection guide.

TST_SC06: This table was intended to contain measurements of excess asphalt in bituminous mixtures obtained by using a loaded wheel and sand cohesion. Although the table structure exists, no data for this test were ever loaded into the database. Since this table is empty it is not included in the standard data release.

TST_SC07: This table contains the results of the wet stripping test of cured slurry seal mixes applied to SPS-3 sections only. This table contains a single record and no further data are expected. For further information, see the SPS-3 and -4 data collection guide.

TST_SC08: This table contains the results of the slurry system compatibility test for slurry seals applied to SPS-3 sections only. This table contains a single record and no further data are expected. For further information, see the SPS-3 and -4 data collection guide.

TST_SC09: This table contains the results of tests to identify quick-set asphalt emulsions used in surface treatments applied to SPS-3 sections only. This table contains a single record and no further data are expected. For further information, see the SPS-3 and -4 data collection guide.

TST_SC10A: This table contains the gradation of aggregates used in chip seals applied to SPS-3 sections only. Gradation analysis is conducted by sieve test using the 12.5-mm (½-inch), 9.5-mm (⅜-inch), 4.75-mm (No. 4), 2.36-mm (No.8), 2.00-mm (No. 10), and 75-µm (No. 200) sieves. The percent passing each sieve is stored in fields whose name is based on the United States (U.S.) customary designation for the sieve size. For example, NO_4_PASSING contains data passing the 4.75-mm (No. 4) sieve. The primary key consists of the STATE_CODE, SHRP_ID, LAYER_NO, FIELD_SET, LOC_NO, and TEST_NO fields, although STATE_CODE, SHRP_ID, and SAMPLE_NO should be sufficient to uniquely identify a specimen.

TST_SC10B: This table contains the gradation of aggregates used in slurry seals applied to SPS-3 sections only. Gradation analysis is conducted by sieve test using the 8.0-mm ($^{5}/_{16}$-inch), 4.75-mm (No. 4), 2.36-mm (No. 8), 1.1.8-mm (No. 16), 600-µm (No. 30), 300-µm (No. 50), 150-µm (No. 100), and 75-µm (No.200) sieves. The percent passing each sieve is stored in fields whose name is based on the U.S. customary designation for the sieve size. For example, the field named FIVE_SIXTEENTHS_PASSING contains data for percent retained on the 8.0-mm ($^{5}/_{16}$-inch) sieve. The primary key consists of the STATE_CODE, SHRP_ID, LAYER_NO, FIELD_SET, LOC_NO, and TEST_NO fields, although STATE_CODE, SHRP_ID, and SAMPLE_NO should be sufficient to uniquely identify a specimen.

TST_SC11: This table contains various data used in chip seal mix designs applied to SPS-3 sections only. Factors such as the average least dimension of the aggregate (stored in AVG_LEAST_DIMENSION) and the rate of asphalt application (stored in RESIDUAL_ASPH_SPREAD_RATE) are included. The primary key consists of the STATE_CODE, SHRP_ID, LAYER_NO, FIELD_SET, LOC_NO, and TEST_NO fields, although STATE_CODE, SHRP_ID, and SAMPLE_NO should be sufficient to uniquely identify a specimen.

TST_SC12: This table contains the asphalt content of slurry seals applied to SPS-3 sections only. The percent asphalt by weight of dry aggregate is stored in the ASPHALT_CONTENT field. No intermediate results are available. The primary key consists of the STATE_CODE, SHRP_ID, LAYER_NO, FIELD_SET, LOC_NO, and TEST_NO fields, although STATE_CODE, SHRP_ID, and SAMPLE_NO should be sufficient to uniquely identify a specimen.

TST_SC13: This table was intended to contain measurements of the polish value of aggregates used in chip seals applied to SPS-3 sections only. Although the table structure exists, no data for this test were ever loaded into the database. Since this table is empty, it is not included in the standard data release.

13.4.1.8 Treated Base Test Results

TST_TB01: This table contains various classification results for treated base materials. The overall description of the treated material is available from the DETAIL_TREAT_MATL field. The DETAIL_TREAT_TYPE field identifies the treatment agent. Both fields contain codes of the type TREAT_TYPE. There are also two fields (PRELIM_TREAT_MATL and PRELIM_TREAT_TYPE) that may have had significance at the beginning of the LTPP program; however, they no longer provide useful information except in cases where there is no data in the corresponding DETAIL* fields, in which case they may be used as a substitute. There are various soil geology-related fields and aggregate-type fields that may or may not be populated based on the nature of the treated material. The primary key consists of the STATE_CODE, SHRP_ID, LAYER_NO, FIELD_SET, LOC_NO, and TEST_NO fields, although STATE_CODE, SHRP_ID, and SAMPLE_NO should be sufficient to uniquely identify a specimen.

TST_TB02: This table contains unconfined compressive strength results for treated base materials. Compressive strength (in pounds force per square inch (lbf/inch^2)) is stored in the COMP_STRENGTH field. Fracture mode (a code of the type FRACTURE) is stored in the COMP_STRENGTH_FRAC field. The primary key consists of the STATE_CODE, SHRP_ID, LAYER_NO, FIELD_SET, LOC_NO, and TEST_NO fields, although STATE_CODE, SHRP_ID, and SAMPLE_NO should be sufficient to uniquely identify a specimen.

13.4.1.9 Unbound Materials Testing Results

TST_SS01_UG01_UG02: This table contains the gradation of unbound coarse-grained granular base, subbase, and subgrade materials. Gradation analysis is conducted by the washed sieve test, with the washed fines included with the percent passing the 75-µm (No. 200) sieve. The sieve set specified in the test protocol consists of the 75-mm (3-inch), 50-mm (2-inch), 37.5-mm (1½-inch), 25.0-mm (1-inch), 19.0-mm (¾-inch), 12.5-mm (½-inch), 9.5-mm (⅜-inch), 4.75-mm (No. 4), 2.00-mm (No. 10), 425-µm (No. 40), 180-µm (No. 80), and 75-µm (No. 200) sieves. The name of field is based on the U.S. customary sieve size name. For example, ONE_AND_HALF_PASSING contains data for amount of material passing the 37.5-mm (1½-inch) sieve. In addition, the total dry weight of the sample before washing is stored in the SAMPLE_WT field and the moisture content of the sample prior to testing is stored in the MOISTURE_CONTENT field. If data are unavailable for a given material, check TST_SS02_UG03. The primary key consists of the STATE_CODE, SHRP_ID, LAYER_NO, FIELD_SET, LOC_NO, and TEST_NO fields, although STATE_CODE, SHRP_ID, and SAMPLE_NO should be sufficient to uniquely identify a specimen.

TST_SS02_UG03: This table contains the gradation of unbound fine-grained granular base, subbase, and subgrade materials. Gradation analysis is conducted by sieve test combined with hydrometer analysis. The sieve set used is identical to that used in TST_SS01_UG01_UG02, as are the associated field names. In addition, the hydrometer results are expressed as percent size smaller (passing) 0.02 mm (780 micro inch), 0.002 mm (78 micro inch), and 0.001 mm (39 micro inch). These data are stored in fields whose name is based on the SI measurement convention. For example HYDRO_02 contains data passing, or smaller than, 0.02 mm (780 micro inch). These values are also expressed as percent gravel (GT_2MM), coarse sand, fine sand, silt, clay, and colloids in fields of the same name. If data are unavailable for a given material, check the TST_SS01_UG01_UG02 table. The primary key consists of the STATE_CODE, SHRP_ID, LAYER_NO, FIELD_SET, LOC_NO, and TEST_NO fields, although STATE_CODE, SHRP_ID, and SAMPLE_NO should be sufficient to uniquely identify a specimen.

TST_SS04_UG08: This table contains the general classification of unbound granular base, subbase, and subgrade materials. Information in this table includes maximum particle size (MAX_PART_SIZE); soil color (SOIL_COLOR); 10 fields for the description codes of the type SOIL_CRITERA, including American Society for Testing and Materials (ASTM) classification (DESC_CODE_*); and AASHTO classification (AASHTO_SOIL_CLASS). The primary key consists of the STATE_CODE, SHRP_ID, LAYER_NO, FIELD_SET, LOC_NO, TEST_NO, and SAMPLE_NO fields, although STATE_CODE, SHRP_ID, and SAMPLE_NO should be sufficient to uniquely identify a specimen.

TST_SS06: This table contains the modulus of the subgrade reaction (k-value) of unbound subgrade layers. This subgrade reaction is measured by static plate loading. Raw modulus (in lbf/inch^2/inch) is stored in SOIL_MOD_UNCORRECTED, while the modulus as corrected for plate bending is stored in SOIL_MOD_CORRECTED. The primary key consists of the STATE_CODE, SHRP_ID, LAYER_NO, FIELD_SET, and LOC_NO fields.

TST_SS08: This table contains subgrade in situ moisture and density measurements. These measurements are taken on thin-wall tube or split-spoon specimens. Moisture content is stored in the MOISTURE_CONTENT field and dry density is stored in the DRY_DENSITY field. A few intermediate calculations are also available. The primary key consists of the STATE_CODE, SHRP_ID, LAYER_NO, FIELD_SET, LOC_NO, TEST_NO, and SAMPLE_NO fields, although STATE_CODE, SHRP_ID, and SAMPLE_NO should be sufficient to uniquely identify a specimen.

TST_SS10: This table contains unconfined compressive strength measurements on subgrade materials. Test specimens are obtained by thin-wall tube sampling. Unconfined compressive strength is stored in the UNCONFINED_COMPRESSED_STRENGTH field. In addition, the moisture content and dry density of the specimen are stored in the MOISTURE_CONTENT and DRY_DENSITY fields, respectively. The primary key consists of the STATE_CODE, SHRP_ID, LAYER_NO, FIELD_SET, LOC_NO, TEST_NO, and SAMPLE_NO fields, although STATE_CODE, SHRP_ID, and SAMPLE_NO should be sufficient to uniquely identify a specimen.

TST_SS11: This table contains hydraulic conductivity measurements on subgrade materials obtained using a flexible-wall permeameter. Data are only available for a limited number of SPS-1, -2, -8, and -9 sections. Test specimens are either thin-wall tube samples or laboratory remolds. Hydraulic conductivity is stored in the AVG_HYDRAULIC_CONDUCTIVITY field. Several intermediate calculations are also available. The primary key consists of the STATE_CODE, SHRP_ID, LAYER_NO, FIELD_SET, LOC_NO, TEST_NO, and SAMPLE_NO fields, although STATE_CODE, SHRP_ID, and SAMPLE_NO should be sufficient to uniquely identify a specimen.

TST_SS12: This table contains potential vertical rise (PVR) values for subgrade materials. These data are intended for use in identifying expansive soils. This total is the summation of the PVR for the first 6.1 m (20 ft) of subgrade depth, tested at 0.61-m (2-ft) intervals. Only three records are available in the database.

TST_UG04_SS03: This table contains the Atterberg limit test results for unbound granular base, subbase, and subgrade materials. The liquid limit, plastic limit, and plasticity index are stored in the LIQUID_LIMIT, PLASTIC_LIMIT, and PLASTICITY_INDEX fields, respectively. The primary key consists of the STATE_CODE, SHRP_ID, LAYER_NO, FIELD_SET, LOC_NO, TEST_NO, and SAMPLE_NO fields, although STATE_CODE, SHRP_ID, and SAMPLE_NO should be sufficient to uniquely identify a specimen.

TST_UG05_SS05: This table contains standard Proctor test results for unbound granular base, subbase, and subgrade materials. Only the optimum dry density and moisture content are stored in the table (in the MAX_LAB_DRY_DENSITY and MAX_LAB_MOISTURE fields, respectively). The other points on the moisture-density curve are not loaded into the database. The primary key consists of the STATE_CODE, SHRP_ID, LAYER_NO, FIELD_SET, LOC_NO, TEST_NO, and SAMPLE_NO fields, although STATE_CODE, SHRP_ID, and SAMPLE_NO should be sufficient to uniquely identify a specimen.

TST_UG09: This table contains the permeability of unbound base and subbase materials as tested under constant head using a rigid-wall permeameter. Measured hydraulic conductivity is stored in the AVG_HYDRAULIC_CONDUCTIVITY field. Some intermediate calculations are also included. The primary key consists of the STATE_CODE, SHRP_ID, LAYER_NO, FIELD_SET, LOC_NO, and TEST_NO fields, although STATE_CODE, SHRP_ID, and SAMPLE_NO should be sufficient to uniquely identify a specimen.

TST_UG10_SS09: This table contains the in situ moisture content of unbound base, subbase, and subgrade materials as measured by drying samples in the laboratory. Measured moisture content is stored in the MOIST_CONTENT field. No intermediate calculations are stored. The primary key consists of the STATE_CODE, SHRP_ID, LAYER_NO, FIELD_SET, LOC_NO, TEST_NO, and SAMPLE_NO fields, although STATE_CODE, SHRP_ID, and SAMPLE_NO should be sufficient to uniquely identify a specimen.

TST_UNBOUND_SPEC_GRAV: This table contains the specific gravity of unbound base and subgrade materials. Since this test was not specified in the original material test guidelines for LTPP sections, data are only available for a subset of test sections. The current source of this data is from resilient modulus tests performed by one of the LTPP contract laboratories. Although not required that laboratory contractor included this measurement in their test results. Test data are only currently available for test section in the North Atlantic and Southern Regions. Depending on budget constraints, it is planned to obtain these measurements from SPS project sites in the future. There are no plans to obtain this data from other GPS test sections.

The field SPEC_GRAVIT contains the specific gravity value for the material sample.

13.4.1.10 Resilient Modulus of Unbound Materials TST_UG07_SS07_* Tables

The TST_UG07_SS07 family of tables contains resilient modulus data for unbound granular base, subbase, and subgrade materials. Testing is conducted according to LTPP Protocol P46. Analysts are encouraged to review the test protocol before using the data. The relational structure and some test details related to this submodule are illustrated in figure 14.

TST_UG07_SS07_A: As shown in figure 14, this table contains basic information on the tested specimen. The information on specimens molded in the laboratory from bulk material includes initial length (INITIAL_LENGTH), initial area (INITIAL_AREA), moisture content after testing (AFTER_MOIST_CONT), dry density (DRY_DENSITY), and the strength of the specimen as measured in the quick shear test (STRENGTH). This table also contains additional information used in determining the moisture-density target, including the in situ moisture and density (IN_SITU_MOIST and IN_SITU_DENSITY, respectively), and the maximum Proctor density and the associated optimum moisture content (MAX_DRY_DENSITY and OPT_MOIST_CONT, respectively). The primary key consists of the STATE_CODE, SHRP_ID, LAYER_NO, FIELD_SET, LOC_NO, TEST_NO, and SAMPLE_NO fields, although STATE_CODE, SHRP_ID, and SAMPLE_NO can be used to uniquely identify a specimen.

TST_UG07_SS07_B: As shown in figure 14, this table also contains basic information on the specimen being tested. The table contains similar information to the TST_UG07_SS07_A table;

however, it is for undisturbed thin-wall tube specimens only. As in the previous table, the information stored includes the initial length (INITIAL_LENGTH), initial area (INITIAL_AREA), moisture content after testing (AFTER_MOIST_CONT), dry density (COMP_DRY_DENSITY), and the strength of the specimen as measured in the quick shear test (STRENGTH). The primary key consists of the STATE_CODE, SHRP_ID, LAYER_NO, FIELD_SET, LOC_NO, TEST_NO, and SAMPLE_NO fields, although STATE_CODE, SHRP_ID, and SAMPLE_NO should be sufficient to uniquely identify a specimen.

TST_UG07_SS07_WKSHT_CYCLES: This table contains the resilient modulus, loading conditions, and intermediate calculations for each load sequence. Data for both remolded and thin-wall tube specimens are stored in this table. The loading condition stress states are a combination of the confining pressure (stored in the CON_PRESSURE field) and the nominal maximum applied axial stress (stored in the MON_MAX_AXIAL_STRESS field). The test protocol typically requires 3 levels of confining pressure and 5 levels of nominal maximum applied axial stress for a total of 15 unique stress states. (For type 1 materials, only 13 stress states are used; the highest two axial stress states for the highest confining pressure are not used.) For each stress state, 5 loading sequences of 100 cycles are applied to the specimen. Thus, 75 records are created in this table for the typical 15 stress states. Applied cyclic stress is stored in APPLIED_CYCLIC_STRESS, corrected resilient deformation is stored in CORR_VERT_DEF,

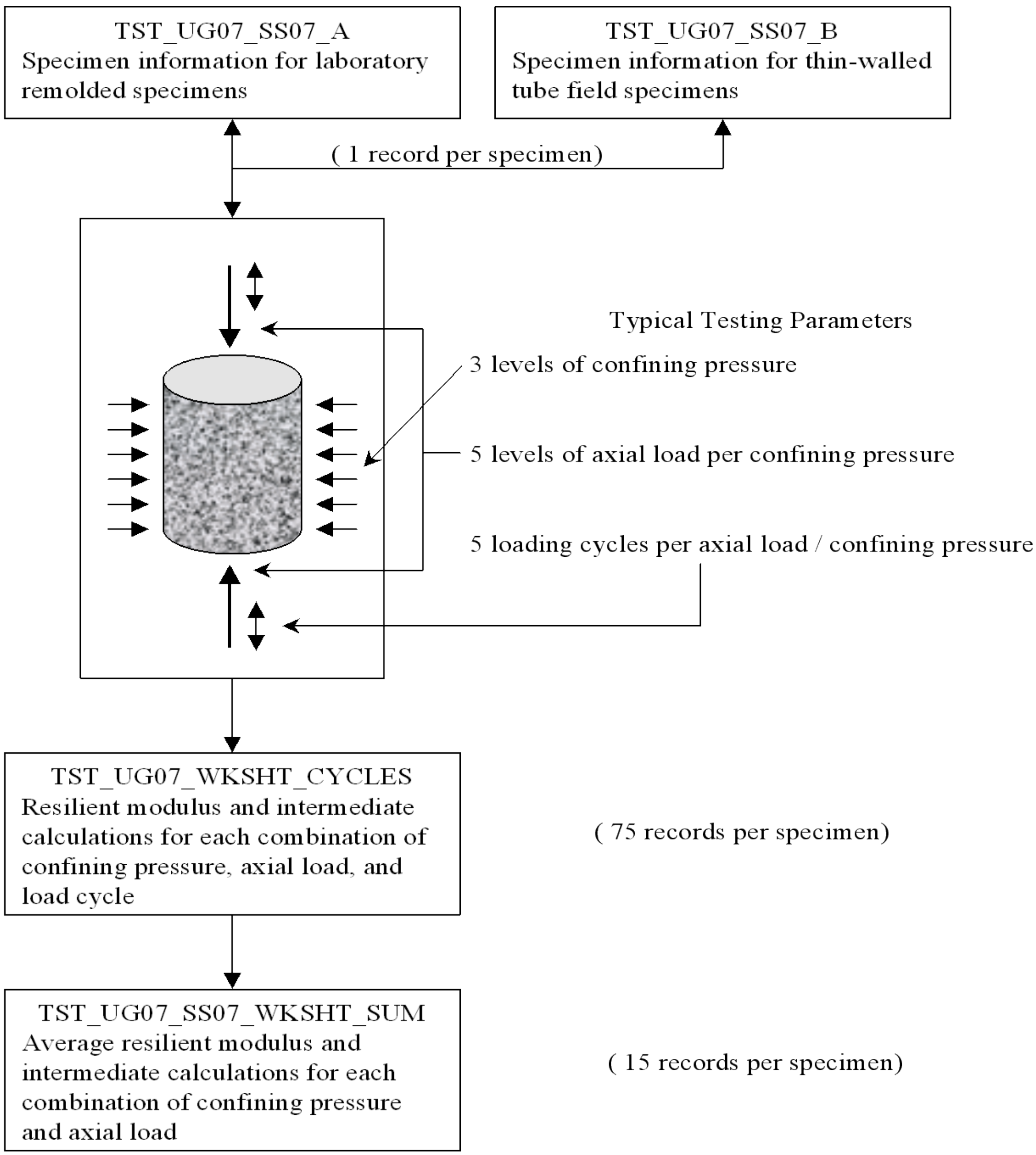


Figure 14. Illustration of relationships among TST_UG07_SS07* tables.

resilient strain is stored in RES_STRAIN, and resilient modulus is stored in RES_MOD. The primary key consists of the STATE_CODE, SHRP_ID, LAYER_NO, FIELD_SET, LOC_NO, TEST_NO, SAMPLE_NO, CON_PRESSURE, NOM_MAX_AXIAL_STRESS, and CYCLE_NO fields, although STATE_CODE, SHRP_ID, SAMPLE_NO, CON_PRESSURE, NOM_MAX_AXIAL_STRESS, and CYCLE_NO should be sufficient to uniquely identify a specimen.

TST_UG07_SS07_WKSHT_SUM: This table contains the average resilient modulus and some intermediate calculations for the five loading sequences at each stress state. Data for both remolded and thin-wall tube specimens are stored in this table. The stress state is indicated by the combination of the CON_PRESSURE and NOM_MAX_AXIAL_STRESS fields. Average cyclic stress and resilient strain are stored in the APPLIED_CYCLIC_STRESS_AVG and RES_STRAIN_AVG fields, respectively, with standard deviations stored in APPLIED_CYCLIC_STRESS_STD and RES_STRAIN_STD. The average and standard deviations of the resilient moduli values calculated for that specimen and the stress state are stored in the RES_MOD_AVG and RES_MOD_STD fields, respectively. Several intermediate calculations (including maximum axial stress, contact stress, and average deformations) are also included. The primary key consists of the STATE_CODE, SHRP_ID, LAYER_NO, FIELD_SET, LOC_NO, TEST_NO, SAMPLE_NO, CON_PRESSURE, and NOM_MAX_AXIAL_STRESS fields, although STATE_CODE, SHRP_ID, SAMPLE_NO, CON_PRESSURE, and NOM_MAX_AXIAL_STRESS should be sufficient to uniquely identify a specimen.

13.4.2 Sampling Information Tables

The majority of the field sampling information from materials sampled in-place in the field is stored in the TST_HOLE_LOG and TST_SAMPLE_LOG tables.

TST_HOLE_LOG: This table contains a record of each core hole, bore hole, or test pit cut in an LTPP section for the purpose of extracting material samples. This record includes the date the hole was dug; the location of the hole; the dimensions of the hole; and, in some cases, other information such as depth to refusal.

LTPP Database Tip!	For all samples extracted from an in-service pavement, the date of sampling is located in the TST_HOLE_LOG table. The date the sample was tested, where available, is located in the same table as the test results.

The data in the TST_HOLE_LOG table can be linked to data in the various test results tables by use of the STATE_CODE, SHRP_ID, and LOC_NO fields. The STATE_CODE and SHRP_ID fields together uniquely identify a test section, as described elsewhere in this document. Within a given test section, the LOC_NO field uniquely identifies a hole.

In addition to being useful for linking to TST_HOLE_LOG, the value of LOC_NO contains additional information about the hole. The format is as follows:

L ###t

where:

L Location type:

- A: 152-mm- (6-inch-) diameter core and/or auger locations
- AD: distributor or slurry seal applicator
- B: bulk sample location
- BA: 305-mm- (12-in-) diameter core and bulk base and subgrade sample
- C: 102-mm- (4-inch-) diameter core locations
- CS: 102-mm- (4-inch-) diameter core samples shipped to Materials Reference Library for storage
- F: Bulk AC sample obtained at construction site
- H: Sample obtained from hot-mix plant
- PB: plate-bearing test location
- S/SP: shoulder augur probe 6 m (19-ft) below the pavement surface
- SO: source of material production
- T: nuclear density/moisture test location
- T/TP: test pit (applies to material samples)
- TR: delivery truck

Location number: Up to a three-digit location number is assigned sequentially to each location type on each test section. An asterisk (*) is used to identify cases where samples from the same layer were combined to satisfy minimum testing requirements.

For core sample locations taken at specified time intervals from the start of construction on SPS-9 projects, a letter is appended to the end of the SAMPLE_NO. It is not used for other sample locations. The letter is used to designate the approximate time from paving to coring as follows:

t Time:

- A: 0 months
- B: 6 months
- C: 12 months
- D: 18 months
- E: 24 months
- F: 48 months

On some SPS-9 projects, a three-character code is appended to the LOC_NO. This code starts with an A and is followed by the last two numbers in the SHRP_ID field.

Examples of valid sample location numbers include:

B01	Bulk sample 01 from a test section
A04	Augur location 04
C04B	Core location 4 from the sampling time interval B, 6 months after paving

TST_SAMPLE_LOG: While TST_HOLE_LOG contains data for each test hole cut into an LTPP section, often multiple samples are extracted from a given test hole. Additional sampling information can be found in TST_SAMPLE_LOG. This information includes the depth from which the sample was taken and a description of the material sampled.

Records in TST_SAMPLE_LOG can be linked to records in the various test results tables using the STATE_CODE, SHRP_ID, and SAMPLE_NO fields. While STATE_CODE and SHRP_ID uniquely identify a test section, SAMPLE_NO uniquely identifies samples retrieved within that test section.

As with LOC_NO, SAMPLE_NO contains useful information and permits linking between various TST tables. SAMPLE_NO is typically a four- to six-character value with the following format:

S M ###

where:

S Sample type:

- B: bulk sample
- C: core sample
- D: gyratory-compacted AC specimen
- F: formed beams with PCC surface material
- G: formed cylinders with PCC surface material
- H: SPS-3 and -4 oddities
- J: split-spoon sample
- K: block sample
- L: formed cylinders of lean concrete base, or
- L: compacted asphalt concrete specimen from lab mixed material
- M: moisture sample
- N: uncompacted laboratory mixed material sample (asphalt concrete)
- P: broken pieces or chunks of material
- T: thin-wall tube

M Material type:

- A: asphalt concrete
- C: asphalt cement
- G: untreated, unbound granular base/subbase
- P: portland cement concrete
- S: subgrade soil or fill material
- T: treated, bound, or stabilized base/subbase

U: combined aggregate used in concrete mixes
X: PCC 14-day test specimen
Y: PCC 28-day test specimen
Z: PCC 365-day test specimen

Sample number: Up to a three-digit sample number assigned sequentially to each sample with the same sample and material type designation. An asterisk (*) or an X is used to identify cases where samples from the same layer were combined to satisfy minimum testing quantity requirements.

On some SPS-9 projects, a three-character code is appended to the SAMPLE_NO. This code starts with a time interval letter code and is followed by the last two numbers in the SHRP_ID field. The letter code used to designate the approximate time from paving to coring is as follows:

A: 0 months
B: 6 months
C: 12 months
D: 18 months
E: 24 months
F: 48 months

On SPS-3 and -4 projects, the following material type prefixes are used in the SAMPLE_NO code convention:

HA: aggregate samples
HC: joint and crack sealing material
HE: emulsified asphalt cement

The following are examples of valid sample code numbers:

BA01	Bulk samples of uncompacted HMA
BG01	Bulk samples from granular base
BS01	Bulk samples of subgrade material
CA01D	HMA core sample from an SPS-9 project taken during time interval D (18 months after construction)
CA24A	AC cores obtained from SPS-9 projects at time interval A, immediately following paving
CT24	Treated base cores
DA01	HMA specimen compacted in SHRP gyratory compactor
MS01	Subgrade moisture content sample obtained from bulk sampling location

LTPP Database Tip!	SAMPLE_NO is not always a reliable way to classify materials or sample types. The TST_SAMPLE tables should be used to as a reference. For example, the most reliable way to know if a material sample is laboratory compacted is if it has an entry in TST_SAMPLE_LOG_LAB.

13.4.2.1 Other Sampling Information Tables

The TST_HOLE_LOG and TST_SAMPLE_LOG tables contain information for all samples of in-place materials. This includes virtually all sampling conducted on GPS test sections. However, many SPS sections and GPS overlay sections also include bulk samples of materials obtained during construction prior to placement on the roadway. Sampling information for these materials is located in one of a series of additional tables (based on material type).

TST_ASPHALT_CEMENT: This table contains sampling information for bulk samples of asphalt cement obtained from the plant. Each asphalt sample has a LOC_NO and a SAMPLE_NO that are unique to the section. The table also includes additional information about the plant itself.

TST_FRESH_PCC: This table contains information about test cylinders and beams cast on site from concrete used in construction. Each batch of concrete sampled has a unique LOC_NO. Up to six cylinders and three beams were cast from each batch of sampled material. Each cylinder and beam has a unique SAMPLE_NO. In addition, this table contains information about the slump and air content of the sampled concrete.

TST_SAMPLE_LOG_LAB: This table contains information about specimens molded in the laboratory from bulk AC samples. This table is unusual in that it has an “input” sample identification (SAMPLE_NO) that identifies the bulk material used and an “output” sample number (SAMPLE_NO_LAB) that identifies the compacted specimen that will be used in further testing.

TST_SAMPLE_LOG_SPS_3_4: This table contains sampling information for chip seal, slurry seal, or joint sealant material obtained in the field for SPS-3 and -4 sections only. Treatment of LOC_NO and SAMPLE_NO are similar to TST_SAMPLE_LOG.

TST_UNCOMP_BITUMINOUS: This table contains sampling information for uncompacted AC specimens obtained during construction. LOC_NO and SAMPLE_NO are unique for a given test section. In addition to the time and location the sample was taken, this table also contains information on the plant where the asphalt concrete was mixed.

TST_SAMPLE_COMBINE: This table was added to the database in 2006 to store information on samples combined in the laboratory from multiple samples obtained in the field. In the past, the combined sample SAMPLE_NO convention using asterisk did not provide information on what samples were combined and the locations where the samples were obtained. In this table the SAMPLE_NO field contains the new combined sample number and the SAMPLE_NO_ORIG field contains the SAMPLE_NO obtained from the field. For each combined sample, multiple record will exist in this table, one for each original samples combined.

TST_SAMPLE_BASIC_INFO. This table is a view that combines basic sampling information from all the other sampling tables to make certain internal automated quality control checks operations easier, and to provide the user with a single source for sampling information.

Information contained in this table is a copy of data contained in the TST_ASPHALT_CEMENT, TST_FRESH_PCC, TST_SAMPLE_BULK_AC_AGG, TST_SAMPLE_COMBINE, TST_SAMPLE_LAB_AC_MIX, TST_SAMPLE_LOG, TST_SAMPLE_LOG_LAB, TST_SAMPLE_LOG_SPS_3_4, and TST_UNCOMP_BITUMINOUS tables.

13.4.3 Layer Tables

The TST module is the primary source for layer information in the LTPP database. The TST_L05A and TST_L05B tables contain data from field and laboratory measurements on material type and thicknesses of the pavement structure layers. In general, TST_L05A can be thought of as the worksheet that summarizes layer thickness measurements within and at the ends of a test section. TST_L05B provides a single recommended representative layer thickness for structural analysis. This representative layer thickness is based on data stored in TST_L05A in addition to the deflection testing results, inventory data, and engineering judgment. LTPP test sections are selected, in part, based on their expected homogeneity. As with any real-world pavement structure, variations in material type and thickness exist within a test section. Within-section thickness measurements on some layers exist for some SPS test sections where rod-and-level measurements were taken during the construction event or by ground-penetrating radar. Other layer thickness measurement data can be found in other test tables such as TST_AC01 and TST_SAMPLE_LOG

LTPP Database Tip!	Select the appropriate layer thickness data source based on analytical needs. For most analyses, data in TST_L05B / SECTION_LAYER_STRUCTURE is sufficient.

TST_L05A: This table contains multiple-layer thickness information. Each record in TST_L05A is uniquely identified by the STATE_CODE and SHRP_ID of the section, the CONSTRUCTION_NO that identifies the period of time for which the structural information is valid (for more information on CONSTRUCTION_NO, see the description in section 3.1), and the LAYER_NO that identifies the discrete material layers in the pavement section. Each record also includes a DESCRIPTION, which identifies the function of the layer in the pavement system, and a LAYER_TYPE indicating the general composition of the layer.

For each record in TST_L05A, there are three sets of fields containing measured thickness, the method by which the thickness was determined, and a detailed description of the material comprising the layer. These sets correspond to measurements taken at the approach end of the section (LAYER_THICK_STATION0, MATERIAL_CODE_STATION0, and MEASURE_TYPE_*_STATION0), within the section (LAYER_THICK_WITHIN, MATERIAL_CODE_WITHIN, and MEASURE_TYPE_*_WITHIN), and the leave end of the section (LAYER_THICK_STATION5, MATERIAL_CODE_STATION5, and MEASURE_TYPE_*_STATION5).

For an LTPP section, a LAYER_NO of "1" is always assigned to the *lowest* identifiable layer in the pavement section, with progressively higher LAYER_NO's assigned to the higher layers. Although this may seem counterintuitive, it allows the same layer numbering scheme to be maintained as new layers are added to the surface of a section because of maintenance or rehabilitation treatments. For example, if a section has an uppermost layer with a LAYER_NO = 5 and that section receives an overlay, the new surface layer will now have a LAYER_NO = 6; however, the lower layers will still be referenced to the same LAYER_NO's.

Sometimes a layer will be entirely removed by milling; however, it will still be referenced by the same LAYER_NO, but the thickness will now be 0. Again, while this may be counterintuitive, it maintains the referential integrity of the TST module. For the example above, if the surface layer is milled and replaced, LAYER_NO = 5 will have a thickness of 0 and a new LAYER_NO = 6 will be added to the database for the next CONSTRUCTION_NO. Therefore, materials tests keyed to a specific LAYER_NO will represent the same layer in the pavement structure regardless of the CONSTRUCTION_NO.

TST_L05B: The TST_L05B table can be considered the master table for the entire TST module. It is the best source for pavement layer thickness information. The layer thickness values stored in this table are those that the regional data collection contractors recommend as being the best representative values based on the inspection of field sampling information, deflection measurements, and laboratory measurements on cores. It is important to note that this table contains *representative* thickness information based on multiple data sources and engineering judgment, as opposed to the *measured* layer thickness data stored in TST_L05A.

Like TST_L05A, each record in TST_L05B is uniquely identified by STATE_CODE, SHRP_ID, CONSTRUCTION_NO, and LAYER_NO. The representative thickness of the layer is stored in the REPR_THICKNESS field and the overall material type is stored in the MATL_CODE field. In addition, there are three fields that contain comment codes on how the representative thickness was arrived at (LAYER_COMMENT_*) and an additional field for text comments (COMMENT_NOTE).

The CONSTRUCTION_NO field identifies changes in the pavement structure caused by rehabilitation treatments or application of maintenance treatments. When a section first enters the LTPP program, it is assigned a CONSTRUCTION_NO of 1. The CONSTRUCTION_NO is incremented by 1 for each subsequent maintenance or rehabilitation event regardless of its impact on the pavement structure. For example, crack sealing could cause a new construction event to be generated even though it does not cause a change in the experiment assignment or pavement structure. This table and EXPERIMENT_SECTION are the only tables in which CONSTRUCTION_NO is manually entered. In all other tables in the database, CONSTRUCTION_NO is computed based on the date of the event.

LAYER_NO is a unique identifier for the layers in the pavement system. A LAYER_NO of 1 is always assigned to the lowest layer in the pavement system, with each identifiable layer above it getting a progressively larger LAYER_NO.

PROJECT_LAYER_NO is an SPS project-level layer identifier. This field can allow layers in different sections on the same SPS project with the same material properties to be identified.

The DESCRIPTION field contains a code of the type DESCRIPTION that describes the generic function of a layer in the pavement structure. Common DESCRIPTION codes are 03 for the original pavement surface, 01 for an overlay, and 07 for a subgrade.

The LAYER_TYPE is a code of the type LAYER_TYPE that provides a basic description of the composition of the layer. Common LAYER_TYPES are “SS” for subgrade, “GS” for granular subbase, “GB” for granular base, “AC” for asphaltic concrete, and “PC” for portland cement concrete.

REPR_THICKNESS is the representative thickness of the pavement layer. It is a best estimate of a single representative value of layer thickness based on several data sources, including cores, analysis of deflection data, and elevation surveys.

MATL_CODE is a code of the type MATERIAL that describes the material composition of the layer. This material code is based on the results of laboratory measurements and observations. It is much more specific than the general LAYER_TYPE classification.

The LAYER_COMMENT_* fields contain comment codes contained in the CODETYPE field names L05B_COMMENT_CODES in the CODES table. These codes provide an indication of how the representative layer thickness was determined.

The INV_LAYER_NO field provides a link to the agency-supplied layer information in the INV module. This is necessary because the agency-provided data and site-specific measurements taken by the LTPP program do not always agree on the detailed layering structure at the test section location. For example, the presence of embankments at the test section site is often not included in the agency data. The INV_LAYER_NO_2 field is used in circumstances where a single layer as described in TST_L05B is described as two separate layers in the INV module.

TST_L05: This table contains information that is useful for linking project layers at SPS projects to layers in the various SPS INV tables. In practice, it does not contain any information that cannot also be obtained from TST_L05B.

13.4.4 Linking Between TST Layer Tables and INV or SPS* Layer Tables

Although the TST layer tables are the canonical source for layer thickness and description information, there may be circumstances in which the analyst will want to compare agency-supplied information located in the INV or SPS* layer tables. This comparison is complicated by the fact that site-specific information obtained from the site does not always agree with the general information on pavement structure available from agency records. For example, the agency may have combined several similar asphalt layers into a single layer, while the LTPP program treats them separately. The reverse is also possible. Therefore, the analyst cannot be certain that a specific LAYER_NO in the TST module and the same LAYER_NO in the INV or SPS modules refer to the same layer.

To link the TST layer tables and the INV layer table, the INV_LAYER_NO field and/or the INV_LAYER_NO2 field in the TST_L05B table must be used. For each record in TST_L05B, the INV_LAYER_NO field represents the LAYER_NO used in the INV_LAYER table to represent that layer. In some cases where a single layer in TST_L05B is treated as two separate layers in INV_LAYER, both INV_LAYER_NO and INV_LAYER_NO2 will contain values to reflect this. In addition, two or more layers in TST_L05B from the same LTPP section can share the same INV_LAYER_NO if they are treated as a single layer in INV_LAYER.

LTPP Database Tip!	Some basic materials characterization information is contained in the INV, SPS, and RHB and MNT modules. It may be of value in cases where such data are not available in the TST module.

13.4.5 SPS Complications

Relating materials testing data back to the layers that they represent is fairly straightforward for GPS sections. Generally, all that is needed is the STATE_CODE and SHRP_ID of the section, and the LAYER_NO of the layer within that section. Relating such data for SPS sections, however, can be more complicated.

An understanding of some of the fundamental differences between the SPS and GPS sections is necessary for understanding why SPS materials testing data are more complicated to access. GPS test sections are stand-alone in that each section was sampled as a discrete entity. SPS sections, however, are clustered with several adjacent sections comprising a project. One of the advantages of such clustering is that these sections can share data (e.g., traffic, climate, and materials testing data). However, this clustering comes at the price of a slightly more complicated data structure.

To illustrate these complexities, consider a hypothetical SPS project with two sections (1 and 2). Figure 14 shows a plan view of this project. Figure 15 shows the cross-sectional view of this hypothetical project and the layer numbering.

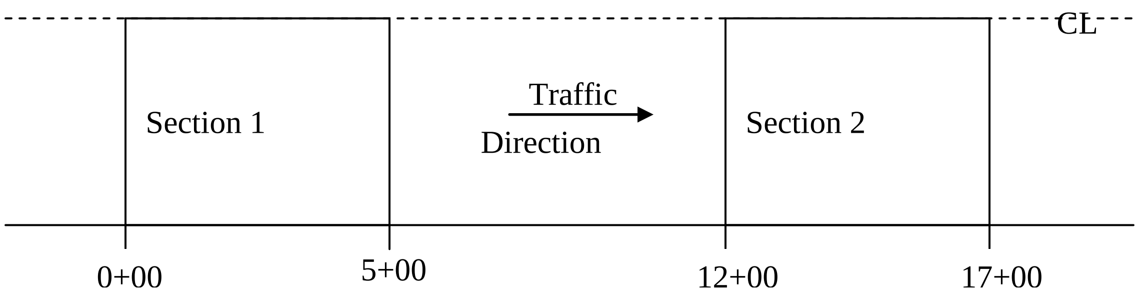


Figure 15. Plan view of hypothetical SPS project (not to scale).

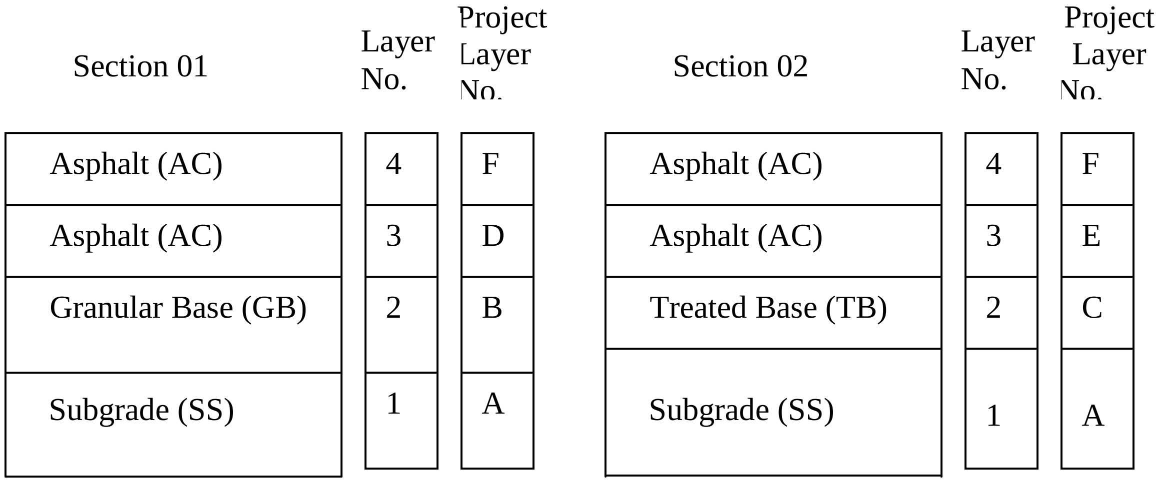


Figure 16. Cross-sectional view of hypothetical SPS project.

As described in section 13.4.3, the layering of an LTPP section can be obtained from the TST_L05B table. From figure 16, we can see that the structures of the two sections are similar, except that section 01 has a granular base, while section 02 has a treated base. In both cases, four layers have been identified. Thus, in both cases, they have been numbered 1 through 4 (despite the fact that layer 2 is different in composition for each section).

In addition to the *section* layer numbers (these are sections at an SPS project), TST_L05B also contains *project* layer numbers for these sections. Project layer numbers identify layers consisting of materials from the same source placed at the same time with the same methods. Since the project layer numbers for the surface asphalt layer and the subgrade at these two sections are identical, we now know that these layers are continuous and we expect that they should have very similar properties.

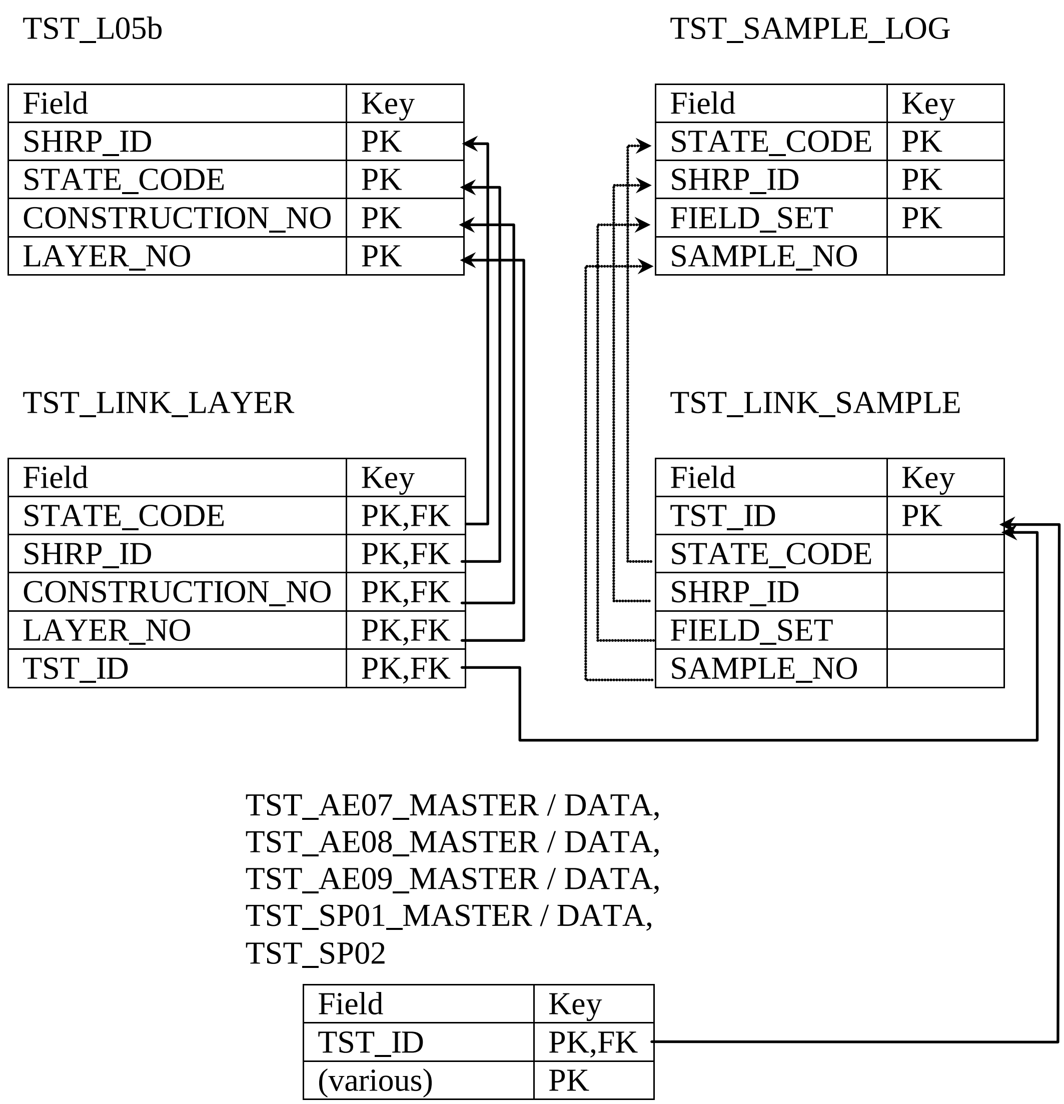
LTPP Database Tip!	When seeking materials test results for an SPS section, project layer numbers can be used to find tests of the same material on a different test section. Although the material source and placement methods may be identical, construction variability may result in differences in material properties.

Now that we know that layer F for these two sections is virtually identical (barring construction variability stemming from the fact that they are 366 m (1200 ft) apart), we can cross-reference materials testing data between these sections. For example, if an analyst wishes to calculate the air void content of layer 4 on section 02, the analyst would first have to find the bulk specific gravity and theoretical maximum specific gravity of that material in the LTPP database. However, if only bulk specific gravity results are available for that layer, the analyst could use a theoretical maximum specific gravity result for layer 4 at section 01, since there is good reason to expect that the material properties are similar.

13.4.6 Link Tables

Eleven new material test tables containing results from Superpave related asphalt binder and mixture material tests were included for the first time in the January 2004 standard data release. With the introduction of these tables, two materials database link tables were added to allow a user to link these test results to materials used in more than one layer and on multiple test sections. Within these tables the field named TST_ID is used as primary key index that is used to associate a single material result to multiple test sections and layers on test section in which the material was used. The TST_LINK_LAYER table provides a linkage between TST_ID and test sections and pavement layers in the TST_L05B layer table, using the fields STATE_CODE, SHRP_ID, CONSTRUCTION_NO, and LAYER_NO. The TST_LINK_SAMPLE table provides linkage between TST_ID and material sampling information contained in TST_SAMPLE_LOG using the fields STATE_CODE, SHRP_ID, FIELD_NO and SAMPLE_NO. The current relation structure for implementation of the TST_ID based linkage methodology is shown in figure 17. In this figure, the primary inter table field relationships are portrayed. The solid arrows indicating relationships, point from the child table to the master and indicate data integrity checks enforced by internal database functions. The dashed arrows indicate inter table relationships that are checked using quality control programs external to the database. In figure 17, the abbreviation PK indicates a primary key and FK indicates a foreign key. Primary keys in a table define a unique record. A foreign key requires that a record exist in another table with a matching field value, before a record can exist in the subject table.

Currently, only the tables listed in figure 17, which contain data from Superpave related tests are linked using the TST_ID primary key methodology. A data user wishing to locate information on a particular test section can start with either TST_LINK_LAYER or TST_LINK_SAMPLE and using the corresponding TST_ID, locate test results in the other tables.



Notes: Arrows indicating relationship point from the child to the master

PK stands for 'Primary Key', FK stands for 'Foreign Key'

Dotted lines show relationships not enforced by foreign key constraints

Figure 17. Relationship between material test tables linked using TST_ID.

13.5 ESTIMATE OF DYNAMIC MODULUS OF HOT MIXED ASPHALT MIXTURES

Starting with SDR 24, January 2010, estimates of the dynamic modulus, |*E**|, of hot mixed asphalt (HMA) mixtures were added to the TST module. |*E**| is a fundamental material property that defines the stiffness HMA as a function of temperature and load time. It is used as an input material property for HMA mixtures in the MEPDG. The |*E**| estimates provided in these tables were purposefully designed to match the level-1 input requirements of the MEPDG. Estimates of |*E**| for LTPP test sections are provided based on related data because no suitable test protocol yet exists for field samples obtained from in-service pavement structures. Details on the basis for these estimates can be found in the report ***LTPP Computed Parameter: Dynamic Modulus*** included on the LTPP Reference Library distributed with the SDR.

The following rules were used to decide on which HMA layers |E*| estimates were computed:

- Layer thickness of 1 inch or greater as reported in the TST_LO5B table.
- Virgin or recycled hot mix, hot laid, dense graded asphalt concrete (i.e., MATL_CODE 1 or 13 in the TST_L05B table).
- Placed as an original layer, overlay layer, or asphalt concreter layer below the surface. (i.e., DESCRIPTION 1, 3, or 4 in the TST_L05B table).
- Availability of data required for one of the five models.

Nine tables were added to the LTPP database that contain the inputs and outputs of the |*E**| computed parameter process. Similar to the tables containing Superpave asphalt binder data, these tables also contain a single key field that is used to link related data in all of these tables to each other. The ESTAR_LINK field is a simple numerical key with no intrinsic meaning other than to serve as a relational database link between these related tables.

Figure 18 graphically illustrates the relationships between the TST_ESTAR tables. The tables shown in the upper portion of the figure contain the inputs used in the five models used to estimate HMA dynamic modulus based on data availability. The circles in the center represent the Artificial Neural Network (ANN) models used to estimate the dynamic modulus at 14°, 40°, 70°, 100° and 130°F and 25, 10, 5, 1, 0.5, and 0.1 Hz which are the required inputs to the MEPDG. These values are contained in the TST_ESTAR_MODULUS output table.

The numbers shown beside the ANN models in figure 18 are the codes for the models contained in the TST_ESTAR_MASTER table. The following is a brief description of the models; the ***Computed Parameter: Dynamic Modulus*** report contains much more detail on the basis of these models.

1. MR - |*E**| estimates based on LTPP indirect laboratory resilient modulus tests performed at three temperatures.
2. VV – Viscosity based model
3. GV – Model based on dynamic shear modulus of asphalt binder |G*| (Gstar).
4. GC_PAR – Model based on |G*| with inconsistent aging inputs.
5. VV-GRADE – Viscosity model based on asphalt grade data.

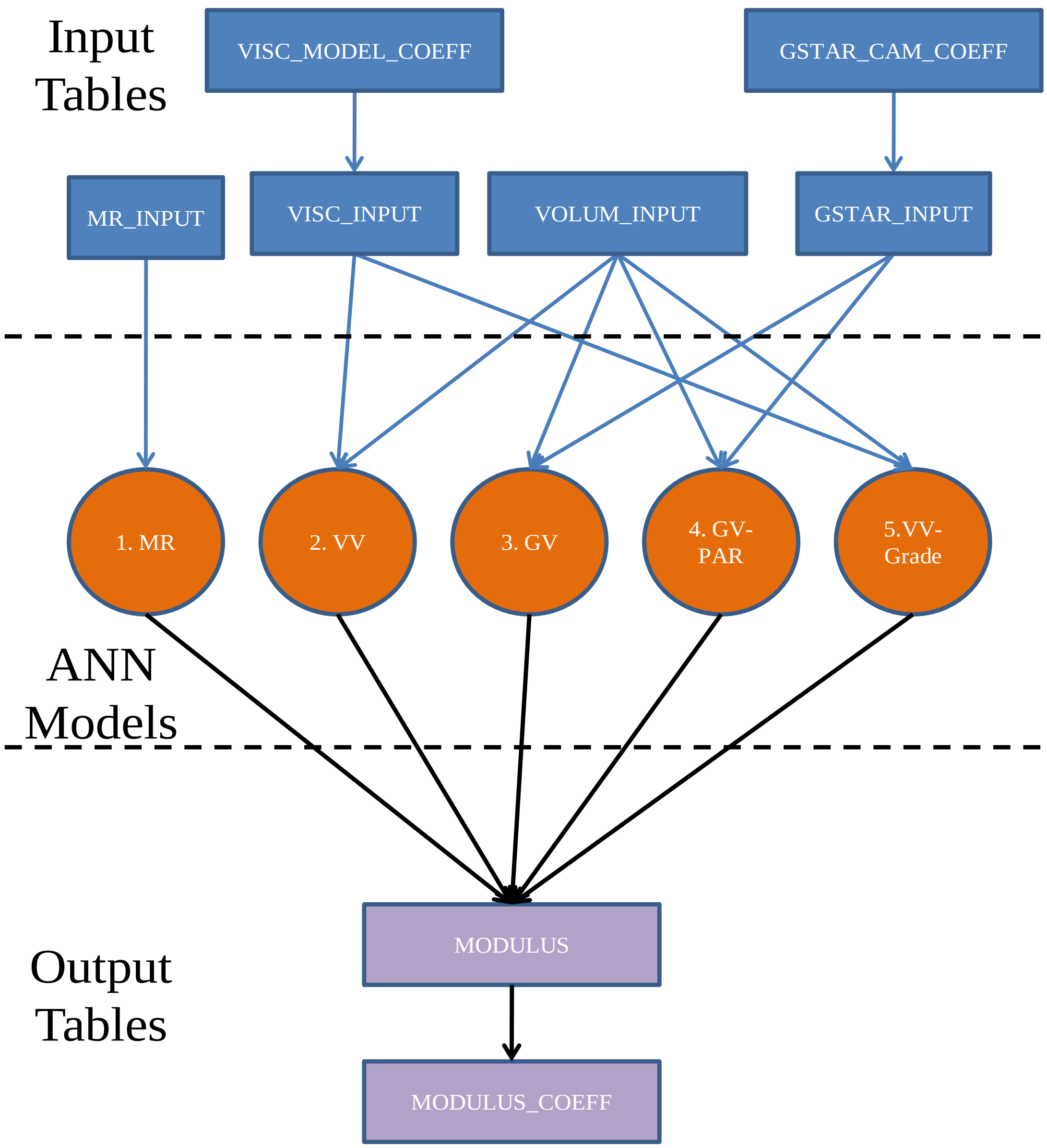


Figure 18. Relationship between the TST_ESTAR_* input tables, Artificial Neural Network (ANN) models, and output tables containing estimated dynamic modulus for HMA layers on LTPP test sections. All tables link to TST_ESTAR_MASTER which contains test section and layer identification information.

13.5.1 TST_ESTAR_MASTER

This table is the central source of identification data for |E*| estimates which define a specific test section (SHRP_ID) or SPS project, test section layer number or SPS project layer code, model used for |E*| estimates, construction date, and aging condition of inputs. It also defines the ESTAR_LINK field, which is the central key that links all of the TST_ESTAR tables to each other.

13.5.2 TST_ESTAR_MODULUS

This table contains the "raw" output of the ANN models of predicted |E*| at 14°, 40°, 70°, 100° and 130°F and 25, 10, 5, 1, 0.5, and 0.1 Hz. The |E*| estimates in this table are in units of psi, and temperature in degree Fahrenheit which are the required units of this data input for the MEPDG software.

13.5.3 TST_ESTAR_MODULUS_COEFF

This table contains the coefficients to the master curve sigmoidal function and related time-temperature shift factors.

The general master curve sigmoidal function equation and mapping of fields contained in this table are:

$$\log\left|E^*\right| = \delta + \frac{\alpha}{1+e^{\beta+\gamma*\log(t_R)}}$$

Where:

t_R	=	the inverse of reduced frequency of loading, which is defined in the same way as reduced angular frequency in hertz instead of radians per second
δ	=	SIGMOIDAL_COEFF_1field
α	=	SIGMOIDAL_COEFF_2 field
β	=	SIGMOIDAL_COEFF_3 field
γ	=	SIGMOIDAL_COEFF_4 field

This table also contains the coefficients for the time temperature shift factor function for |E*| as follows:

$$\log a_T = \alpha_1 T^2 + \alpha_2 T + \alpha_3$$

Where:

a_T	=	mixture time-temperature shift factor
T	=	temperature of interest
α_1	=	SHIFT_FACTOR_COEFF_1 field
α_2	=	SHIFT_FACTOR_COEFF_2 field
α_3	=	SHIFT_FACTOR_COEFF_3 field

This table also contains the field MASTERCURVE_QUALITY. This is a pass/fail field assigned by the data analysis team who performed the computations. It represents the goodness of fit of the |E*| estimates contained in the TST_ESTAR_MODULUS to the master curve function. A pass is assigned if the explained variance is greater than 0.99 and ratio of standard error to standard deviation is less than 0.05.

13.5.4 TST_ESTAR_GSTAR_CAM_COEFF

This table contains the coefficients to the Christensen-Anderson-Marasteanu (CAM) model to predict |G*| input values. The CAM model and mapping of the fields in this table is:

$$|G^*| = \frac{G_g}{\left(1 + \left(\frac{\omega_c}{\omega_R}\right)^k\right)^{m_e/k}}$$

Where:

ω_R	=	reduced angular frequency
G_g	=	CAM_COEFF_1 field
ω_c	=	CAM_COEFF_2 field
k	=	CAM_COEFF_3 field
m_e	=	CAM_COEFF_4 field

13.5.5 TST_ESTAR_GSTAR_INPUT

This table contains the dynamic shear modulus of the asphalt binder |G*| as a function of temperature and frequency. This table provides inputs to the GV and GV-PAR ANN models.

13.5.6 TST_ESTAR_MR_INPUT

This table contains the measured resilient modulus from test section cores measured in indirect tension from the TST_AC07_V2_MR_SUM table. This data is used as an input to the MR ANN model.

13.5.7 TST_ESTAR_VISC_MODEL_COEFF

This table contains the coefficients for the asphalt binder temperature susceptibility commonly referred relationship. The relationship used for these computations and mapping against fields in this table is:

$$\log\log(\eta) = \begin{cases} A + VTS\log(T_R) & T_R > T_{critical} \\ 2.7x10^{12} & T_R \le T_{critical} \end{cases}$$

Where:

η	=	viscosity (cP)
A	=	intercept of temperature susceptibility relationship VISC_A field
VTS	=	slope of temperature susceptibility relationship VISC_VTS field
T_R	=	temperature in Rankin
$T_{critical}$	=	temperature in Rankin at which the viscosity is equal to 2.7 x 10^{12} cP

13.5.8 TST_ESTAR_VISC_INPUT

This table contains the binder viscosity inputs as a function of temperature used in the VV and VV-Grade ANN models.

13.5.9 TST_ESTAR_VOLUM_INPUT

This table contains the values of voids in the mineral aggregate (VMA) as a percentage of total volume and voids filled with asphalt as a percentage of VMA for the HMA mixtures. These are used as inputs to the VV, GV, GV-PAR, and VV-Grade ANN models.

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CHAPTER 14. GROUND PENETRATING RADAR MEASUREMENTS

14.1 INTRODUCTION

In 2003, Ground Penetrating Radar (GPR) measurements were performed on a subset of LTPP sections to provide an estimate of layer thickness variations within the monitoring portion of the test section. The measurements were performed on all SPS-1 project sites still in-service at the time. Measurements were also performed on one selected SPS 2, 5, and 6 project sites. The results of the measurements are stored in the GPR data module.

Measurements were performed using an air-coupled antenna. Measurements were performed at 6-inch (152-mm) intervals using a sampling rate of 256 samples per measurement. Thickness interpretations were averaged over a 1-foot (.305-m) length to minimize signal irregularities. Since the surface material sampling cores were obtained outside of the test section limits, thickness interpretation before, within and after the monitoring portion of the test section are stored in the database. Measurements are performed in the outside (right) wheel path and center of the lane.

14.2 GPR TABLES

GPR data are stored in four tables in the pavement performance database. The key fields used to link together a data set in these tables include STATE_CODE, SHRP_ID, GPR_DATE and LANE_POSITION. GPR_LAYER_NO is used to identify pavement layers.

14.2.1 GPR_MASTER Table

One record is included in GPR_MASTER for each measurement pass on a test section. Typically there are two measurement passes on a test section. The field LANE_POSITION indicates if the measurement pass is the right wheel path using a code of R, or in the center of the lane using a code of C. This table also includes:

- measurement date (GPR_DATE)
- measurement time (GPR_TIME)
- antenna model and manufacturer (ANTENNA_MODEL_MAN)
- equipment control system (CONTROL_SYS_MODEL_MAN)
- version of the analysis software used for the thickness interpretation (ANALYSIS_SOFTWARE_VER)
- equipment calibration coefficients (PLATE_HIGH_CAL_SLOPE, and PLATER_HIGH_CAL_INTERCEPT)
- name of the raw data file from the GPR device (RAW_DATA_FILE)

14.2.2 GPR_THICK_POINT Table

This table contains the results of the thickness interpretations from the GPR measurements. The average thickness and dielectric constant of recognizable layers, or group of layers, are stored in 1-foot (.305-m) increments using metric stations stored in the POINT_LOC field. The zero station is the start of the monitoring portion of the test section. For combined layers, the LAYER_TYPE field contains a general description of the upper-most layer. For example, on some AC surfaced sections with asphalt treated base layers, the combined GPR layer may be represented as AC.

14.2.3 GPR_THICK_SECT Table

This table contains statistics on the thickness and dielectric constant from data contained in the GPR_THICK_POINT table whose stations fall inside the monitoring portion of the test section. The fields used to link records in this table to those in the point table include STATE_CODE, SHRP_ID, GPR_DATE, LANE_POSITION, and GPR_LAYER_NO. Statistics contained in this table include the average, minimum and maximum values of the thickness and dielectric constant values.

14.2.4 GPR_LINK_LAYER Table

It is not possible to identify layers with similar material properties with GPR measurements. Thus not all layers in the pavement structure can be identified with GPR. To analyze GPR data, layers identified in the physical pavement structure are combined into a single layer.

The layer convention for GPR measurements starts with layer 1 representing the surface of the pavement. Layer 1 in the other pavement database tables represents the subgrade. GPR measurements detect the interface between layers.

The purpose of the GPR_LINK_LAYER table is to relate the layers identified by GPR to those included in the TST_L05B table. This is a typically a many to one relationship; one GPR_LAYER_NO is linked to more than one LAYER_NO in the TST_L05B table. For example, GPR_LAYER_NO 1 may represent layers 5 and 6 in TST_L05B.

In providing this link between layers, the layer description was assigned to the upper-most layer in the GPR layer convention. Thus if an AC surface layer in the GPR tables was combined with an AC treated base layer, the layer type in the GPR tables is labeled as AC.

CHAPTER 15. OBTAINING LTPP DATA AND INFORMATION

15.1 DATA RELEASE POLICY

The following principles apply for release of LTPP data and information:

LTPP data and information are distributed under the sponsorship of the U.S. Department of Transportation in the interest of information exchange. The U.S. Government assumes no liability for its contents or use.

Understanding LTPP data collection procedures, principles, and practices is the responsibility of data users who interpret and draw conclusions based on LTPP data and information.

Some LTPP publications are available for download from the LTPP Internet Web site. Data users can contact LTPP Customer Service to inquiry about the availability of documentation not distributed with the data nor contained on the LTPP web site.

While the LTPP program strives to provide data and information at no cost to the data user, program-funding limitations may limit the level of effort spent on user requests.

Extractions from the LTPP database are provided free of charge to data users who request data in standard data release formats.

Custom extractions from the database may be requested.

Delivery of data in raw data collection formats, access to internal documents, and access to other LTPP offline information will be assessed on a case-by-case basis.

15.2 OBTAINING LTPP DATA

All requests for LTPP data and information should be made to the LTPP customer service center. LTPP customer service can be contacted via e-mail at ltppinfo@dot.gov. Other contact information is posted on the LTPP Internet Web page at: http://www.fhwa.dot.gov/research/tfhrc/programs/infrastructure/pavements/ltpp .

LTPP data can be obtained through a variety of mechanisms, including standard data release, custom data extraction, and via the DataPave Online internet site.

15.2.1 Standard Data Release

The most up-to-date data from the LTPP program are contained in the Standard Data Release (SDR) format updated periodically. These data are available free of charge to data requesters. No data restrictions are placed on the content of the data included in the release. Data at all levels of RECORD_STATUS are included in the release.

The SDR is currently formatted as a series of Microsoft Access 2000 databases based on the North American software version. The databases are divided into a series of multiple databases to meet Microsoft Access database size limitations.

Efficient use of the SDR requires knowledge of relational database concepts, the relational design of the LTPP database, and features of the Microsoft Access software. Users of the SDR have the flexibility of performing both simple and complex joins between data elements stored in related data tables to create analysis data sets for many types of pavement performance analyses. Appendix C provides examples of how to extract and create an analysis database that can be conveniently queried by exporting tables from the distribution database files.

The structure of the SDR format also allows users not familiar with relational database concepts to look at the data in separate tables from a spreadsheet viewpoint. Each table is formatted in columns and rows just like an electronic spreadsheet. This self-discovery feature facilitates progression of use of the expanded data manipulation functions offered by database software that is not available in some spreadsheet types of computational software.

LTPP Database Tip!	Because of the volume of LTPP data, LTPP database users should use modern database tools to examine, manipulate, and extract data. Some tables contain more than 1,000,000 records. LTPP customer service can provide technical assistance to database users on the use of these tools.

Starting with SDR24 released in January 2010, the SDR now includes data from the LTPP Traffic Analysis Software (LTAS) database The LTAS-DB was added as Volume 5 in the SDR.

Starting with the January 2012 data release, the SDR is packaged with a HTML based opening menu which helps to navigate the contents of the SDR. Instructions on use of this menu are contained in the SDR.

The SDR is organized by volumes on distribution DVD or Universal Serial Bus flash drive, whose roots originated from the size limitations of original CD distribution format.The SDR is currently formatted in the following series of volumes.

15.2.1.1 Volume 1 – Primary Data Set

The Primary Data Set Volume contains the following folders and MS Access databases in ZIP format.

Data_User_Documents. This folder contains documents which provide data users with current information on the changes to the database since the last release, updated database user guide, accessing LTPP data quick start tutorial, and data problem feedback report form.

Skeleton_Database. This folder contains skeleton databases for the PPDB and LTAS consisting of table definition structures for all tables included SDR in a MS-ACCESS database format. Only the tables included in the Administration module are populated; data in all other data table structures have been removed. The following are some uses for a skeleton database:

- Development of a project specific analysis database in MS Access format. The skeleton database allows a user to use the features of MS Access to pull a specific subset of data of interest from the various databases contained in the SDR into a single MS Access database. Use of the MS Access database format still limits database users to 2 GB ceiling on file size.
- Export of the LTPP database definitions into another database format. While this is not a trivial exercise and requires advanced knowledge of database software, complete provision of the entire database structure in single MS Access database file provides a more convenient export format than the native Oracle format.

Table_Navigator. This folder contains the Table Navigator program updated for each specific data release. This software automates review of data modules, table definitions, table structures and meaning of codes fields in an intuitive point and click format. Beginning with the January 2012 data release, the PPDB and LTAS metadata have been combined in the newly named LTPP Table Navigator software.

Administration. This database includes metadata tables, general comments and experiment control tables for the pavement performance database.

Auto_Weather_Station. This database contains all of the data from the Automated Weather Stations (AWS) operated by LTPP on SPS 1, 2 and 8 project sites.

Climate_Daily_Humid_Wind. This database contains the daily humidity and wind data tables used as the basis for computation of the monthly and annual statistics contained in the Climate_Summary_Data database.

Climate_Daily_Precip. This database contains the daily precipitation table used as the basis for computation of the monthly and annual statistics contained in the Climate_Summary_Data database.

Climate_Daily_Temp. This database contains the daily air temperature table used as the basis for computation of the monthly and annual statistics contained in the Climate_Summary_Data database.

Climate_Summary_Data. This database contains monthly and annual virtual climate (CLM) data statistics computed from NCDC and CCC data, information on operating weather stations used in the computations, and linkages between test sections co-located on the same project site.

Dynamic_Load_Response. This database contains dynamic load response measurements performed on the SPS-2 project in North Carolina.

Ground_Penetrating_Radar. This database contains all of the results of Ground Penetrating Radar (GPR) measurements and their interpretation on a selection of SPS project sites.

Inventory. This database contains all of the tables from the Inventory (INV) module which contains agency provided data on the characteristics of pavement test sections that were in-service prior to inclusion in the LTPP program.

Maint_Rehab. This database contains all of the tables included in the maintenance (MNT) and rehabilitation (RHB) modules in the pavement performance database.

Material_Test. This database contains all of the tables in the material Test (TST) pavement performance database module.

Monitoring. This database contains most of the tables included in the monitoring (MON) module of the pavement performance database. Because of size limitations, monitoring data from Falling Weight Deflectometer (FWD) measurements and longitudinal profile elevations measurements used to compute the pavement ride indices stored in the MON_PROFILE_MASTER table, are stored in separate volumes.

Seasonal_Monitoring. This database contains most of the included in the Seasonal Monitoring Program (SMP) module of the Pavement Performance Database. The exception is that due to size restrictions, the SMP_MRCTEMP_* tables are contained in the Seasonal_Moinitoring_MRCTemp database.

Seasonal_Moinitoring_MRCTemp. This database contains the SMP MRC thermistor probe temperature measurements and supporting installation information.

Specific_Pavement_Studies. This database contains all of the SPS_* tables, which house construction and location information for SPS projects.

15.2.1.2 Volume 2 – FWD Measurements

The following MS Access databases in ZIP file format are contained in Volume 2.

FWD_Data_Without_Drop_Data. This database module contains all of the monitoring FWD (MON_DEFL*) data other than the data stored in the MON_DEFL_DROP_DATA table. To create a complete FWD data set, a user must import a MON_DEFL_DROP_DATA table into this database from one of the FWD_Drop_Data_States_* databases included in this volume. The drop data databases were partitioned to allow a user to import one of the drop data databases into this table without exceeding MS Access database size limitations. If desired a user can create four new FWD databases by highway agency group by importing each of the FWDS_Drop_Data_States_* databases into a separate instance of the FWD_Without_Drop_Data database. The names of these combined databases should be changed to be unique.

FWD_Drop_Data_States*. These databases contain the MON_DEFL_DROP_DATA table split up according to state name, USA territory name, and Canadian Province code numbers. The STATE_CODE used by LTPP follows an alphabetical/numerical order with USA states having numbers between 0 – 56. This is followed by American Territories starting with a code of 60 and Canadian Provinces starting with a code of 81. Thus all of the FWD drop data from test sections located in Puerto Rico and Canada are contained in the database named FWD_DROP_DATA_STATES_TX_SK since the STATE_CODE for Texas is 48. The other associated data needed to interpret these measurements are contained in the FWD_Data_Without_Drop_Data database.

15.2.1.3 Volume 3 - Profile Data

The following MS Access databases in ZIP file format are contained in Volume 3.

Profile_Data_States_*. These databases contain data from the MON_PROFILE_DATA table split up in the order of STATE_CODE following the LTPP code convention due to the large size of the table. The related MON_PROFILE_MASTER table contained in the monitoring database contains ride statistics, such as IRI, computed from these profile elevation measurements.

15.2.1.4 Volume 4 – Traffic Data

The following MS Access databases in ZIP file format are contained in Volume 4.

Traffic. This database contains all of the TRF_* tables except for the MEPDG compatible axle distributions stored in the TRF_MEPDG_AX_DIST table.

TRF_MEPDG_Ax_Dist_*. These Databases contain the MEPDG compatible axle distributions stored in the TRF_MEPDG_AX_DIST table split up in the order of STATE_CODE following the LTPP convention due to the large size of the table.

15.2.1.5 Volume 5 – LTAS Tables

The LTPP Traffic Analysis Software (LTAS) database was first included in SDR 24, January 2010. The LTAS database contains daily and monthly traffic data used in the computation of annual traffic estimates stored in the pavement performance database, traffic monitoring equipment locations, statistical summaries used in the quality review of traffic data, data errors, and other information used in the traffic data review and analysis. The database is structured as a standalone series of Access databases following the same type of functional structure as the pavement performance database. Starting with SDR 26, the Table Navigator contained in SDR volume 1, includes metadata on the LTAS tables. A separate LTAS DB user guide is available from the Reference Library, since this database has many differences from the PPDB and has a different user community.

The following MS Access databases in ZIP file format are contained in Volume 5.

Annual_Traffic_*. These two databases, split by highway agencies, contains the YY_AX, YY_CT, and YY_GVW tables which contains raw data for annual time periods and the annual traffic estimates contained in the LTPP PPDB.

Daily_Axles_*. These databases contain DD_AX table for part of a state, a single state or multiple states depending on the size limitations of MS Access.

Daily_Count_ERR_*. These databases contain DD_CL_CT, DD_WT_CT, ERR_CL, DD_VOL, ERR_WT and TRAFFIC_PURGES tables.

Daily_GVW_*. These databases contain DD_GVW tables for a single state or multiple states depending on the size limitations of MS Access.

Hourly_Class_Counts. This database contains the HH_CL_CT table.

LTAS_Administration. This database contains the LTAS specific database metadata and other control tables used by the program.

LTAS Skeleton. This database contains LTAS tables consisting of table definition structures for all LTAS tables included SDR in a MS-ACCESS database format. Only the tables included in the Administration module are populated; data in all other data table structures have been removed. The following are some uses for a skeleton database:

- Development of a project specific analysis database in MS Access format. The skeleton database allows a user to use the features of MS Access to pull a specific subset of data of interest from the various databases contained in the SDR into a single MS Access database. Use of the MS Access database format still limits database users to 2 GB ceiling on file size.
- Export of the LTPP database definitions into another database format. While this is not a trivial exercise and requires advanced knowledge of database software, complete provision of the entire database structure in single MS Access database file provides a more convenient export format than the native Oracle format.

Monthly_Axle_*. These databases contain MM_AX table for part of a state, a single state or multiple states depending on the size limitations of MS Access.

Monthly_Count. This database contains MM_CT table.

Monthly_GVW_*. These databases contain MM_GVW tables.

15.2.2 Custom Extractions

Data users can request partial extractions from the database and/or extractions in a nonstandard format. The support and availability of custom data extractions will be evaluated on a case-by-case basis. While users are encouraged to use the standard data release format, database extractions can be provided in Oracle RDBMS 11, ASCII, comma-delimited ASCII, or Microsoft Excel formats. Users interested in obtaining data in other formats should contact the LTPP customer service center.

15.2.3 DataPave Online

The LTPP DataPave Online program provides access to LTPP data through a user-interactive format. It was designed as a training tool for users of LTPP data who are not acquainted with the use of modern database technology. The new version of the program runs over the internet and can be found at http://www.ltpp-products.com. The online version of DataPave limits a user to simple queries and down loads of a relative small amount of data at a time. Users desiring access to large amounts of data are encouraged to obtain a copy of the standard data release.

15.3 REFERENCE LIBRARY

Starting with data release 20, the LTPP Reference Library is distributed with the Standard Data Release. The reference library contains resource documents, data analysis reports, user software tools, and product information. For data release 26, a new interface was added to improve user navigation to specific objects.

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A.10 SITE REPORTS

A.10.1 SPS Materials Sampling, Field Testing, and Laboratory Testing Plans

The SPS materials sampling, field testing, and laboratory testing plans are very valuable sources of information for data users who want to interpret the materials data collected at SPS sites. Unlike the GPS materials sampling and testing plans, which are relatively uniform from site to site, the sampling plans for SPS sites vary substantially between sites since they are tailored to site conditions, construction sequence, test section sequence, etc. For example, to compute certain material properties, the test results from samples obtained at different test sections must be combined.

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A.10.1.2 North Central Region

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A.10.2 SPS Construction Reports

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A.10.3 SMP Installation Reports

The SMP site installation reports provide valuable information to analysts interested in the LTPP SMP data. Information contained in these reports includes: sensor installation, sensor check and calibration, site layout, problems during installation, nonstandard installation features, gravimetric moisture measurements taken during TDR installation, site photographs, and pavement layer structure in the instrumentation hole.

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LTPP Seasonal Monitoring Program: Site Installation and Initial Data Collection, Section 510113, Danville, Virginia, Publication No. FHWA-TS-96-51-03, FHWA, Pavement Performance Division, June 1996.

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LTPP Seasonal Monitoring Program: Site Installation and Initial Data Collection, Section 871622, Bracebridge, Ontario, Publication No. FHWA-TS-94-87-01, FHWA, Pavement Performance Division, December 1994.

LTPP Seasonal Monitoring Program: Site Installation and Initial Data Collection, Section 893015, Trois-Rivieres, Quebec, Publication No. FHWA-TS-94-89-01, FHWA, Pavement Performance Division, June 1996.

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A.10.3.2 North Central Region

LTPP Seasonal Monitoring Program, Site Installation Report for GPS Section 183002 (18A), Lafayette, Indiana, FHWA, Pavement Performance Division, February 1996.

LTPP Seasonal Monitoring Program, Site Installation Report for GPS Section 204054 (20A), Enterprise, Kansas, FHWA, Pavement Performance Division, February 1996.

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A.10.3.4 Western Region

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APPENDIX B. EXPERIMENT DEFINITIONS

B.1 GPS EXPERIMENTS

B.1.1 GPS-1: Asphalt Concrete on Granular Base

Pavements in the GPS-1 experiment include a dense-graded hot-mix asphalt concrete (HMAC) surface layer, with or without other HMAC layers, constructed over an untreated granular base or no base. One or more subbase layers may be present, but are not required. A treated subgrade is classified as a subbase layer. Full-depth AC pavements (defined as an HMAC surface layer combined with one or more subsurface HMAC layers beneath the surface layer, with a minimum total HMAC thickness of 152 mm (6 inches), placed directly on a treated or untreated subgrade) are also allowed in this study.

Seal coats or porous friction courses are allowed on the surface, but not in combination with each other (e.g., a porous friction course placed over a seal coat is not acceptable). Seal coats are permissible on top of granular base layers. At least one layer of dense-graded HMAC is required, regardless of the existence of seal coats or porous friction courses.

B.1.2 GPS-2: Asphalt Concrete on Bound Base

Pavements in the GPS-2 experiment consist of a dense-graded HMAC surface layer, with or without other HMAC layers, placed over a bound base layer. Bound bases are defined as those in which the cementing action of the stabilizing material is used to improve the structural characteristics of the base material. Binder types used in the base include bituminous and nonbituminous (pozzolans, PCC, lime, etc.). One or more subbase layers can be present, but are not required. Seal coats or porous friction courses are permitted on the surface, but not in combination (e.g., a porous friction course placed over a seal coat is not acceptable).

B.1.3 GPS-3: Jointed Plain Concrete Pavement (JPCP)

Pavements in the GPS-3 experiment consist of jointed plain (i.e., unreinforced) PCC slabs placed over either stabilized or unbound granular base layer. One or more subbase layers can be present, but are not required. A seal coat (prime coat) is permissible just above a granular base layer. The joints can include either no load-transfer devices or smooth dowel bars; however, jointed slabs with load-transfer devices other than dowel bars are accepted in the study on a case-by-case basis only. Slabs placed directly on a treated or untreated subgrade are not acceptable.

B.1.4 GPS-4: Jointed Reinforced Concrete Pavement (JRCP)

Pavements in the GPS-4 experiment include jointed reinforced PCC pavements with doweled joints spaced less than 13 m (40 ft) apart. The PCC slab must rest on a base layer or on unstabilized coarse-grained subgrade soils. A base layer and one or more subbase layers may exist, but are not required. JRCP placed directly on a fine-grained soil/aggregate layer or fine-grained subgrades is excluded from this study. JRCP's without load-transfer devices or with devices other than smooth dowel bars at the joints are not acceptable.

B.1.5 GPS-5: Continuously Reinforced Concrete Pavement (CRCP)

Pavements in the GPS-5 experiment include continuously reinforced PCC pavements placed directly on a base layer or on unstabilized coarse-grained subgrade. One or more subbase layers can exist, but are not required. A seal coat (prime coat) is permissible just above a granular base layer. CRCP placed directly on a fine-grained soil/aggregate layer or fine-grained subgrades is not acceptable.

B.1.6 GPS-6: Asphalt Concrete Overlay of Asphalt Concrete Pavement

Pavements in the GPS-6A, -6B, -6C, -6D, and -6S experiments include a dense-graded HMAC surface layer, with or without other HMAC layers, placed over an existing AC pavement.

The designation 6A refers to those sections that were overlaid prior to acceptance in the GPS program.

The 6B, 6C, 6D, and 6S designations refer to LTPP sections on which an overlay was placed after the section had been accepted into the LTPP program.

Seal coats or porous friction courses are allowed, but not in combination. Fabric interlayers and stress-absorbing membrane interlayers (SAMIs) are permitted between the original surface and the overlay. The total thickness of HMAC used in the overlay is required to be at least 25.4 mm (1.0 inch).

B.1.7 GPS-7: Rehabilitated Portland Cement Concrete Pavement

Pavements in the GPS-7A, -7B, -7C, -7D, -7F, -7R, and -7S experiments primarily consist of JPCP, JRCP, or CRCP pavements in which a dense-graded HMAC surface layer, with or without other HMAC surface layers, was constructed.

The exception is the 7R designation that was added to account for PCC pavement test sections rehabilitated using concrete pavement restoration techniques. (To date, no test sections have been designated as 7R.)

The designation 7A refers to sections that were overlaid prior to acceptance in the GPS program. The 7B, 7C, 7D, 7F, and 7S designations refer to those test sections on which an overlay was placed after the section had been accepted into the LTPP program.

The PCC slab may rest on a combination of base and/or subbase layers. The existing concrete slab can also be placed directly on lime- or cement-treated, fine- or coarse-grained subbase or on untreated coarse-grained subgrade soil. Slabs placed directly on untreated fine-grained subgrade are not acceptable.

Seal coats or porous friction courses are permissible, but are not allowed in combination. Fabric interlayers and SAMIs are acceptable when placed between the original surface (concrete) and the overlay. Overlaid pavements involving aggregate interlayers and open-graded AC interlayers are not included in this study. The total thickness of HMAC used in the overlay is required to be at least 38 mm (1.5 inches).

B.1.8 GPS-9: Unbound PCC Overlays of PCC

Pavements acceptable in the GPS-9 experiment include unbonded JPCP, JRCP, or CRCP overlays with a thickness of 129 mm (5 inches) or more placed over an existing JPCP, JRCP, or CRCP pavement. An interlayer used to prevent bonding of the existing slab and the overlay slab is required. The overlaid concrete pavement can rest on a base and/or subbase, or directly on the subgrade.

B.2 SPS EXPERIMENTS

The following definitions apply solely to the core sections within each experiment. Any supplemental sections constructed at each SPS project are based on the highway agency's research interests. These sections are not consistent from one agency to the next.

B.2.1 SPS-1: Structural Factors for Flexible Pavements

The experiment on the structural factors for flexible pavements (SPS-1) examines the performance of specific AC-surfaced pavement structural factors under different environmental conditions. Pavements within SPS-1 must start with the original construction of the entire pavement structure or removal and complete reconstruction of an existing pavement. The pavement structural factors in this experiment include the in-pavement drainage layer, surface thickness, base type, and base thickness. The experiment design stipulates a traffic loading level in the study lane in excess of 100,000 80-kN (18-kip) ESALs per year. The combination of the study factors in this experiment results in 24 different pavement structures. The experiment is designed using a fractional factorial approach to enhance implementation practicality, permitting the construction of 12 test sections at one site and a complementary 12 test sections to be constructed at another site within the same climatic region on a similar subgrade type.

B.2.2 SPS-2: Structural Factors for Rigid Pavements

The experiment on the structural factors for rigid pavements (SPS-2) examines the performance of specific JPCP structural factors under different environmental conditions. Pavements within SPS-2 must start with the original construction of the entire pavement structure or removal and complete reconstruction of an existing pavement. The pavement structural factors included in this experiment are in-pavement drainage layer, PCC surface thickness, base type, PCC flexural strength, and lane width. The experiment requires that all test sections be constructed with perpendicular doweled joints at 4.9-m (15-ft) spacing and stipulate a traffic loading level in the lane in excess of 200,000 ESALs/year. The experiment is designed using a fractional factorial approach to enhance implementation practicality, permitting the construction of 12 test sections at one site and a complementary 12 test sections to be constructed at another site within the same climatic region on a similar subgrade type.

B.2.3 SPS-3: Preventive Maintenance Effectiveness of Flexible Pavements

The experiment on the preventive maintenance effectiveness of flexible pavements (SPS-3) examines the performance of four preventive maintenance treatments (crack seal, chip seal, slurry seal, and thin overlay) on AC surface pavement sections within the four climatic regions on the two classes of subgrade soil. The experiment design stipulates that the effectiveness of each of the four treatments be evaluated independently. The effectiveness of combinations of treatments is not considered. Therefore, each test site includes four treated test sections in addition to a control section. In most cases, the control (or "do nothing") section is classified as a GPS test section.

B.2.4 SPS-4: Preventive Maintenance Effectiveness of Rigid Pavements

The experiment on the preventive maintenance effectiveness of rigid pavements (SPS-4) was designed to study the effects of crack/joint sealing and undersealing on jointed PCC pavement structures. Both JRCP and JPCP are included in the study. Undersealing is included as an optional factor and is only performed on a section in which the need for undersealing is indicated. The experiment design stipulates that the effectiveness of each of the two treatments be evaluated independently. The effectiveness of combinations of treatments is not considered. Each test site includes two treated test sections and a control section. The treatment sections on joint-/crack-sealing test sites consist of one section in which all joints have no sealant and one in which a watertight seal is maintained on all cracks and joints.

B.2.5 SPS-5: Rehabilitation of Asphalt Concrete Pavements

The experiment on the rehabilitation of AC pavements (SPS-5) examines the performance of eight combinations of AC overlays on existing AC-surfaced pavements. The rehabilitation treatment factors included in the study are the intensity of surface preparation, recycled versus virgin AC overlay mixture, and overlay thickness. The experiment design includes all four climatic regions and the condition of the existing pavement. The experiment design stipulates a traffic loading level in the study lane in excess of 100,000 80-kN (18-kip) ESALs/year.

B.2.6 SPS-6: Rehabilitation of Jointed Portland Cement Concrete (JPCC) Pavements

The experiment on the rehabilitation of JPCC pavements (SPS-6) examines the performance of seven rehabilitation treatment options as a function of the climatic region, type of pavement (plain or reinforced), and the condition of the existing pavement. The rehabilitation methods include surface preparation (limited preparation or full concrete pavement restoration) with a 102-mm- (4-in-) thick AC overlay or without an overlay, crack/break and seat with two AC overlay thicknesses (102 or 203 mm (4 or 8 inches)), and limited surface preparation with a 102-mm- (4-in-) thick AC overlay with sawed and sealed joints.

B.2.7 SPS-7: Bonded Concrete Overlays of Concrete Pavements

The experiment on the bonded concrete overlays of concrete pavements (SPS-7) examines the performance of eight combinations of bonded PCC treatment alternatives as a function of the climatic region, pavement type (jointed or continuously reinforced), and the condition of the existing pavement. The rehabilitation treatment factors include combinations of surface preparation methods (cold milling plus sand-blasting and shot-blasting), bonding agents (neat cement grout or none), and overlay thicknesses (76 or 127 mm (3 or 5 in)). The experiment design stipulates a traffic loading level in the study lane in excess of 200,000 80-kN (18-kip) ESALs/year. Only four SPS-7 projects were constructed.

B.2.8 SPS-8.: Environmental Effects in the Absence of Heavy Loads

The experiment on the environmental effects in the absence of heavy loads (SPS-8) examines the effects of climatic factors in the four environmental regions and on the subgrade types (frost-susceptible, expansive, fine, and coarse) on pavement sections incorporating flexible and rigid pavement designs that are subjected to limited traffic loading. The experiment design requires either two flexible pavement or two rigid pavement structures to be constructed at each site. The two flexible pavement sections consist of a 102-mm (4-inch) AC surface on a 203-mm- (8-in-) thick untreated granular base and a 178-mm (7-inch) AC surface over a 305-mm- (12-in-) thick granular base. Rigid pavement test sections consist of doweled JPCP with a 203-mm (8-inch) and 279-mm (11-inch) PCC surface thickness on 152-mm- (6-in-) thick dense-graded granular base. The pavement structures included in this study match pavement structures included in the SPS-1 and -2 experiments. The experiment design stipulates that traffic volume in the study lane be at least 100 vehicles per day, but not more than 10,000 80-kN (18-kip) ESALs/year. The flexible and rigid pavement sections may be constructed at the same site or at different sites.

B.2.9 SPS-9: Validation of SHRP Asphalt Specifications and Mix Design

SPS-9P was a pilot effort started at the end of the SHRP program to get some experience in implementing the Superpave specifications. Test sections classified as SPS-9P were constructed using a very limited set of guidelines. In some instances, specifications were based on interim Superpave specifications that were changed at a later date. Many of these test sections were constructed before materials sampling and testing guidelines were established.

The SPS-9A experiment, Superpave Asphalt Binder Study, requires construction of a minimum of two test sections at each project site. Construction can include new construction, reconstruction, or overlay. The minimum test sections consist of the highway agencies' standard mix, the Superpave level 1 designed standard mix, and the Superpave mix with an alternate binder grade either higher or lower than the specified Superpave binder. The minimum of two test sections at some sites results from the agency's declaration that the Superpave test section is the same as the standard agency mix. This will provide the opportunity to evaluate and improve the practical aspects of implementing the Superpave mix design by: (1) a hands-on field trial by interested highway agencies, (2) a comparison of the performance of the Superpave mixes against mixes designed using current highway agencies' asphalt specifications, (3) asphalt-aggregate specifications and mix design procedures, and (4) testing of the sensitivity of the Superpave asphalt binder specifications relative to low-temperature cracking, fatigue, or permanent deformation distress factors.

The following sub-experiment designations are provided in the EXPERIMENT_SECTION table for individual SPS-9 test sections to indicate the type of pavement structure.

9C – AC Overlay of CRCP
9J – AC Overlay of JPCC
9N – New AC Pavement Construction/Reconstruction
9O – AC Overlay on AC Pavement

APPENDIX C. DATA EXTRACTION EXAMPLES

This appendix contains data extraction examples. They illustrate productive practices for dealing with data from the LTPP database using the SQL. These examples provide one method for organizing data from an RDBMS. Some software packages provide other methods of querying data, such as the query interface in Microsoft Access 2000.

For those unfamiliar with SQL, a reference book on SQL is highly recommended. The SQL statements that follow have been written for and tested with Microsoft Access 2000. Some of them, especially the ones that make use of aliasing and subqueries, will need to be modified for use with previous versions of Microsoft Access. In addition, those that use domain aggregate functions may need slight modifications for use with RDBMS's such as Oracle.

C.1 SMP DATA

In the following example, we will extract the data necessary to track air temperature, precipitation, and subsurface temperature on an hourly basis for a single section for a period of one week. The section of choice is 360801, a test section in the SPS-8 experiment located in New York. The time period being selected is March 1-8, 1996.

C.1.1 Ambient Temperature and Precipitation

First of all, we will need the ambient air temperature and precipitation. Since we want hourly data, we need to go to SMP_ATEMP_RAIN_HOUR. The required query is straightforward:

```
SELECT smp_date, atemp_rain_time, avg_hour_air_temperature, rain_hour
FROM smp_atemp_rain_hour
WHERE state_code = 36
      AND shrp_id = '0801'
      AND smp_date BETWEEN #3/01/1996# AND #3/08/1996#;
```

The first 10 rows of the 192 rows in the result set are as follows:

smp_date	atemp_rain_time	avg_hour_air_temperature	rain_hour
3/01/1996	0100	-8.3	0
3/01/1996	0200	-7.6	0
3/01/1996	0300	-7.5	0
3/01/1996	0400	-7.3	0
3/01/1996	0500	-7.3	0
3/01/1996	0600	-7.3	0
3/01/1996	0700	-7.8	0
3/01/1996	0800	-7.8	0
3/01/1996	0900	-6.2	0
3/01/1996	1000	-4.8	0

The time is in a 24-hour military-style string format, the temperature is in degrees Celsius, and the precipitation is in millimeters.

C.1.2 Subsurface Temperatures

Next, we need to get the subsurface temperatures. This will require a join, since the temperatures themselves and the depth at which they were taken are stored in separate tables. The necessary query is:

```
SELECT smp_date, temperature_time, avg_hour_temperature, therm_depth
FROM smp_mrctemp_auto_hour a, smp_mrctemp_depths b
WHERE a.state_code = 36
      AND a.shrp_id = '0801'
      AND a.state_code = b.state_code
      AND a.shrp_id = b.shrp_id
      AND a.therm_no = b.therm_no
      AND smp_date BETWEEN #3/01/1996# AND #3/08/1996#;
```

The first 10 rows of the 960 rows in the result set are as follows:

smp_date	temperature_time	avg_hour_temperature	therm_depth
3/01/1996	2400	-4.7	0.025
3/04/1996	2200	-3.1	0.025
3/03/1996	0600	-5.4	0.025
3/08/1996	1700	-1.9	0.025
3/02/1996	0100	-4.9	0.025
3/08/1996	1800	-3.5	0.025
3/05/1996	2200	-1.7	0.025
3/08/1996	1900	-5.0	0.025
3/08/1996	1500	0.5	0.025
3/08/1996	2000	-5.6	0.025

The time is in a 24-hour military-style string format, the temperature is in degrees Celsius, and the depth is in meters from the pavement surface.

C.1.3 Subsurface Moisture

Subsurface moisture data are only available in approximately monthly intervals. A quick query of SMP_TDR_MOISTURE_AUTO will reveal that there is no subsurface moisture data available between 3/01/1996 and 3/08/1996. The following query can be conducted to determine which dates are available:

```
SELECT DISTINCT smp_date
FROM smp_tdr_auto_moisture
```

```
WHERE state_code = 36
      AND shrp_id = '0801'
      AND smp_date BETWEEN #2/01/1996# AND #4/01/1996#;
```

The result set is as follows:

smp_date
2/08/1996
3/11/1996
3/26/1996

We can then extract the moisture gradient for the day closest to our time period as follows:

```
SELECT smp_date, tdr_time, gravimetric_moisture_content, tdr_depth
FROM smp_tdr_auto_moisture a, smp_tdr_depths_length b
WHERE a.state_code = b.state_code
      AND a.shrp_id = b.shrp_id
      AND a.tdr_no = b.tdr_no
      AND a.smp_date = #3/11/1996#
```

The result set is as follows:

smp_date	tdr_time	gravimetric_moisture_content	tdr_depth
3/11/1996	1206	4.1	0.24
3/11/1996	1207	14.6	0.39
3/11/1996	1207	18.9	0.54
3/11/1996	1210	16.5	1.13
3/11/1996	1210	15.6	1.30
3/11/1996	1211	17.3	1.61

The time is in a 24-hour military-style string format, the gravimetric moisture content is in percent by weight of dry soil, and the depth is in meters from the pavement surface.

C.1.4 Electrical Resistance and Resistivity

Like subsurface moisture gradients, electrical resistance and resistivity measurements are only available in approximately monthly intervals. To determine the available dates, we can run the following query:

```
SELECT DISTINCT smp_date
FROM smp_eresist_man_contact
WHERE state_code = 36
      AND shrp_id = '0801'
      AND smp_date BETWEEN #2/01/1996# AND #5/01/1996#
```

The query returns the following result set:

smp_date
2/08/1996
4/09/1996

Since 2/08/1996 is marginally closer to our target date, we will use that date. However, you should note that these tests are commonly conducted twice during a given day, as can be shown in the following query:

```
SELECT DISTINCT smp_date, COUNT(*) as num_repetitions
FROM smp_eresist_man_contact
GROUP BY smp_date, electrode_start;
```

The result set is:

smp_date	num_repetitions
2/08/1996	2
4/09/1996	2

This query shows that the resistance was measured across all of the electrodes twice during each day. We will look at the data collected in the afternoon. Electrical resistivity measurements are taken between electrodes at different depths. We will treat the depth at which the measurement was taken as the mean depth between the two electrodes. The query is as follows:

```
SELECT g.avg_depth, contact_resistance, bulk_resistivity
FROM
      (SELECT contact_resistance, (depth_1 + depth_2)/2 as avg_depth
      FROM
            (SELECT elct_depth as depth_1, electrode_start, resistance as
            contact_resistance
            FROM smp_eresist_man_contact a, smp_eresist_depths b
            WHERE a.electrode_start = b.electrode_no
                  AND a.state_code = b.state_code
                  AND a.shrp_id = b.shrp_id
                  AND a.state_code = 36
                  AND a.shrp_id = ‘0801’
                  AND smp_date = #2/08/1996#
                  AND VAL(eresist_time) > 1200) c,
            (SELECT elct_depth as depth_2, electrode_start
            FROM smp_eresist_man_contact d, smp_eresist_depths e
            WHERE d.electrode_end = e.electrode_no
                  AND d.state_code = e.state_code
                  AND d.shrp_id = e.shrp_id
                  AND d.state_code = 36
                  AND d.shrp_id = ‘0801’
                  AND smp_date = #2/08/1996#
                  AND VAL(eresist_time) > 1200) f
      WHERE c.electrode_start = f.electrode_start) g,
      (SELECT bulk_resistivity, (depth_1 + depth_2)/2 as avg_depth
      FROM
            (SELECT elct_depth as depth_1, eamp_start, resistivity as
            bulk_resistivity
```

```
            FROM smp_eresist_man_4point h, smp_eresist_depths i
            WHERE h.eamp_start = i.electrode_no
                  AND h.state_code = i.state_code
                  AND h.shrp_id = i.shrp_id
                  AND h.state_code = 36
                  AND h.shrp_id = '0801'
                  AND smp_date = #2/08/1996#
                  AND VAL(eresist_time) > 1200) j,
            (SELECT elct_depth as depth_2, eamp_start
            FROM smp_eresist_man_4point k, smp_eresist_depths l
            WHERE k.eamp_end = l.electrode_no
                  AND k.state_code = l.state_code
                  AND k.shrp_id = l.shrp_id
                  AND k.state_code = 36
                  AND k.shrp_id = '0801'
                  AND smp_date = #2/08/1996#
                  AND VAL(eresist_time) > 1200) m
      WHERE j.eamp_start = m.eamp_start) n
WHERE g.avg_depth BETWEEN n.avg_depth - 0.01 AND n.avg_depth + 0.01;
```

The result set is as follows:

avg_depth	contact_resistance	bulk_resistivity
0.3035	396	13
0.354	243	13
0.4045	256	12
0.4555	298	10
0.5065	342	14
0.557	598	13
0.6075	954	22
0.6585	757	15
0.7095	466	23
0.76	443	14
0.8105	416	17
0.8615	384	15
0.912	414	18
0.963	475	15
1.014	525	20
1.064	506	15
1.115	479	18
1.1665	412	18
1.217	398	17
1.268	453	17
1.3195	468	19
1.37	323	17

avg_depth	contact_resistance	bulk_resistivity
1.42	218	17
1.4705	222	16
1.5205	222	16
1.572	223	14
1.6235	218	16
1.6725	227	14
1.723	252	15
1.775	262	15
1.8265	251	13
1.8765	223	14
1.9265	203	13

The depth is in meters below the pavement surface, the contact resistance is in ohms, and the bulk resistivity is in ohm-meters. The above query is quite complex since it uses four nested subqueries. When dealing with such queries, always be certain that they are working as intended before relying on the results. A good method for checking such queries is to determine ahead of time how many records should be returned and then cross-check that number against the actual number of records returned. Also, each subquery can be run and examined on its own before assembling them.

C.2 BACKCALCULATION

This example outlines a typical data extraction that involves queries of deflection and materials tables for data in support of backcalculation analysis to determine the elastic layer moduli of flexible pavements. The SQL statements required for this task illustrate a relatively complex set of instructions involving the linkage of tables from a variety of database modules. It requires careful evaluation of the tables to ensure that the correct data are used for the purpose.

The minimum requirements for data in order to support backcalculation analysis are:

Deflection measurements.
Layer thicknesses.
Supporting materials information.
Pavement temperatures.

In this example, we will perform the data extraction in the following sequence:

Extract deflection data, including pavement temperatures and the date of the tests, from MON_DEFL tables.
Use the deflection test date to tie the deflection measurements to the proper construction number (CONSTRUCTION_NO) via the EXPERIMENT_SECTION table.
Extract the applicable pavement layer data and material properties from tables in the TST and INV modules based on the STATE_CODE, SHRP_ID, and CONSTRUCTION_NO fields.

C.2.1 MON_DEFL Database Tables

Since deflection test data are distributed among a number of related tables in the MON_DEFL submodule, it is necessary to familiarize oneself with it before attempting to extract data. Prominent tables in the submodule include MON_DEFL_DROP_DATA, which contains the drop heights, load, and measured deflections for each FWD drop, and MON_DEFL_LOC_INFO, which contains the location information for the drops. The two tables are related through the STATE_CODE, SHRP_ID, TEST_DATE, and TEST_TIME fields. The offsets of each FWD geophone sensor are in MON_DEFL_DEV_SENSORS, which can be related to MON_DEFL_LOC_INFO through the CONFIGURATION_NO field.

Pavement temperatures that were measured during each FWD test can be extracted from the MON_DEFL_TEMP_VALUES and MON_DEFL_TEMP_DEPTHS tables, which are related to the previously discussed tables and to each other through the STATE_CODE, SHRP_ID, and TEST_DATE fields.

Information about the relationships among all database tables can be found within the Table Navigator software. It is recommended that the software be consulted before attempting any extraction of data from the LTPP database.

C.2.2 Temperature Tables

For sections within SMP, subsurface temperatures can be extracted from the SMP_MRCTEMP_* tables. However, temperature gradients in the pavement surface layer are also manually collected during FWD testing for both SMP and non-SMP test sections. These pavement temperature readings were taken at regular 30- to 60-minute intervals during deflection testing at each LTPP site and are stored within the MON_DEFL_TEMPS_DEPTHS and MON_DEFL_TEMPS_VALUES tables. We will have to extract the temperatures, depths, and times into a single table and the deflection values, deflection test locations, and times into another table. An interpolation process must then be used to estimate the temperature gradient present within the AC pavement layers at the time of the actual deflection test. Assuming that we want data from site 341003 for a test conducted on 3/11/99, the required SQL statement is:

SELECT d.shrp_id, d.state_code, d.test_date, layer_temp_depth_1, layer_temperature_1, time_layer_temp, d.point_loc
FROM mon_defl_temp_depths d, mon_defl_temp_values v
WHERE d.state_code = v.state_code
AND d.shrp_id = v.shrp_id
AND d.test_date = v.test_date
AND d.point_loc = v.point_loc and d.state_code = 34
AND d.shrp_id = ‘1003’
AND d.test_date = #3/11/1999#
ORDER BY v.time_layer_temp, d.point_loc;

For the purpose of brevity, only the first depth at which the temperature was measured is queried. To retrieve the other temperatures and their respective depths, simply add LAYER_TEMP_DEPTH_2, LAYER_TEMPERATURE_2, etc., to the SELECT statement. The partial result set is listed below:

state_code	shrp_id	test_date	layer_temp_depth_1	layer_temperature_1	time_layer_temp	point_loc
34	1003	3/11/1999	25	-1.4	910	-3
34	1003	3/11/1999	25	3.9	1015	-3
34	1003	3/11/1999	25	8.2	1125	-3

The depth is in millimeters, the temperature is in degrees Celsius, and the point location is in meters.

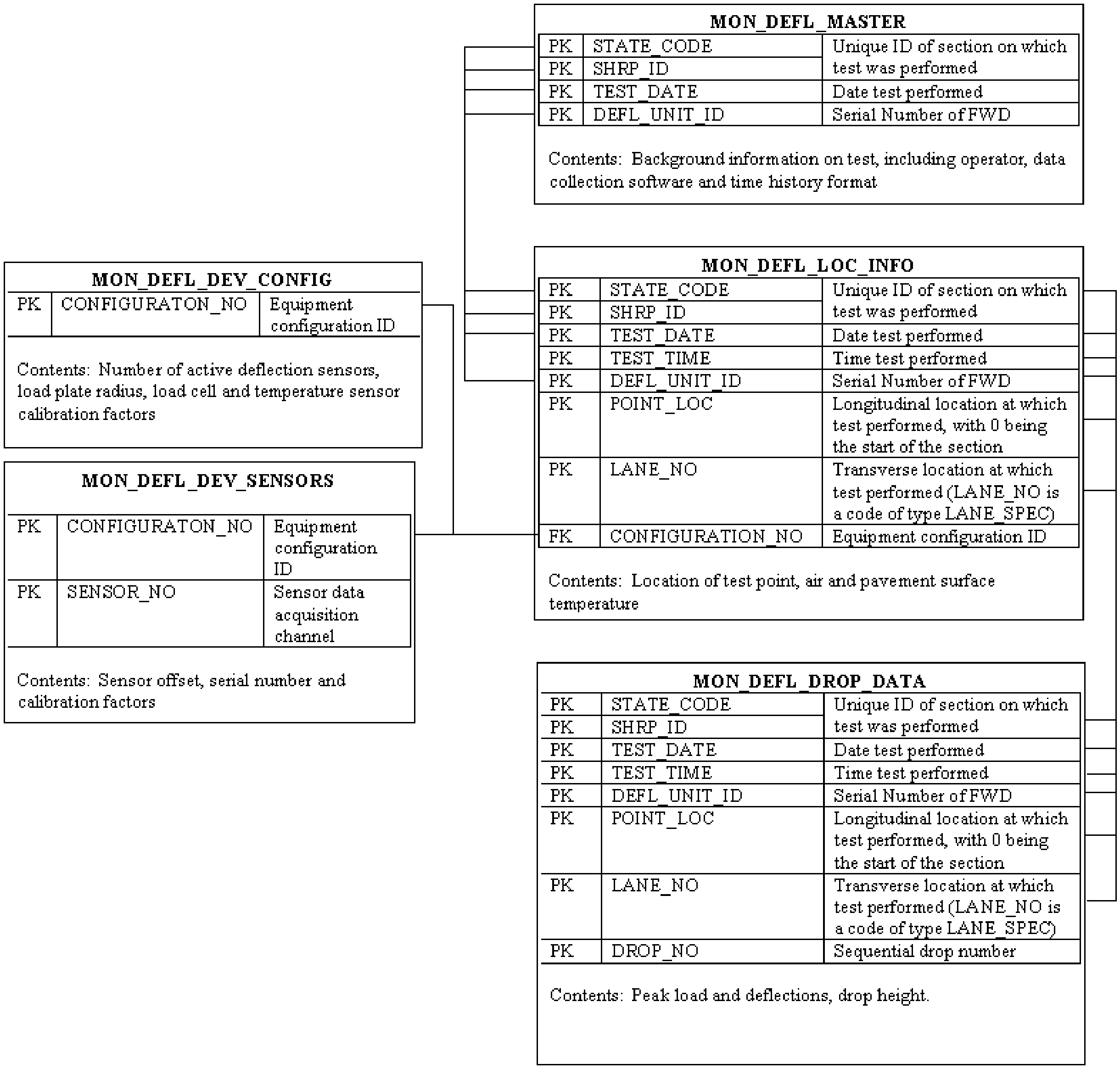
C.2.3 Deflection Tables

Having established the temperature gradient for FWD tests conducted on March 11, 1999, on LTPP test site 341003, the next step is to extract deflection values for the purpose of establishing the deflection basins. Data resulting from a single FWD test are distributed among five tables. The relationships between these tables are illustrated below.

The peak deflection values recorded by all sensors are stored within the MON_DEFL_DROP_DATA table. The sensor spacing figures can be extracted from MON_DEFL_DEV_SENSORS. A suitable SQL statement must be constructed to relate the tables so that the recorded deflection values can be matched to the appropriate sensor spacing. This can be done with the CONFIGURATION field from the MON_DEFL_LOC_INFO table. The first step is to extract the raw deflection data for the section and date in question, in this case, 341003 on March 11, 1999:

SELECT state_code, shrp_id, test_date, test_time, defl_unit_id, point_loc, lane_no, drop_no, drop_load, peak_defl_1
FROM mon_defl_drop_data
WHERE state_code = 34
AND shrp_id = ‘1003’
AND test_date = #3/11/1999#;

For the purposes of clarity and brevity, this query was written to extract deflection data from sensor 1 only. Obviously, it would need to be modified by the addition of PEAK_DEFL_2, etc., to the SELECT clause to fully characterize the deflection bowl shapes at each test location. A partial listing of the result set from that query is as follows:



state_ code	shrp_id	test_date	test_ time	defl_unit_id	point_loc	lane_no	Drop_no	drop_load	peak_ defl_1
34	1003	3/11/1999	0852	8002-129	0	F1	1	384	156
34	1003	3/11/1999	0852	8002-129	0	F1	2	381	155
34	1003	3/11/1999	0852	8002-129	0	F1	3	387	156
34	1003	3/11/1999	0852	8002-129	0	F1	4	382	154
34	1003	3/11/1999	0852	8002-129	0	F1	5	606	234
34	1003	3/11/1999	0852	8002-129	0	F1	6	608	234
34	1003	3/11/1999	0852	8002-129	0	F1	7	610	234
34	1003	3/11/1999	0852	8002-129	0	F1	8	607	234

state_ code	shrp_id	test_date	test_ time	defl_unit_id	point_loc	lane_no	Drop_no	drop_load	peak_ defl_1
34	1003	3/11/1999	0852	8002-129	0	F1	9	805	300
34	1003	3/11/1999	0852	8002-129	0	F1	10	805	300
34	1003	3/11/1999	0852	8002-129	0	F1	11	806	300
34	1003	3/11/1999	0852	8002-129	0	F1	12	805	299
34	1003	3/11/1999	0852	8002-129	0	F1	13	1067	376
34	1003	3/11/1999	0852	8002-129	0	F1	14	1068	377
34	1003	3/11/1999	0852	8002-129	0	F1	15	1068	377
34	1003	3/11/1999	0852	8002-129	0	F1	16	1067	377

The table above represents a series of 16 drops at station 0+00 in the outer wheel path of LTPP site 341003 conducted at 8:52 a.m. on March 11, 1999. For this information to be of any use in backcalculation, we must also determine the offsets of the deflection sensors. To do this, we must first determine the CONFIGURATION_NO from the MON_DEFL_LOC_INFO table and then query the MON_DEFL_DEV_SENSORS table using this value as follows:

```
SELECT DISTINCT a.configuration_no, sensor_no, center_offset
FROM mon_defl_dev_sensors a, mon_defl_loc_info b
WHERE a.configuration_no = b.configuration_no
      AND state_code = 34
      AND shrp_id = '1003'
      AND test_date = #3/11/1999#;
```

The result set from the above query is as follows:

configuration_no	sensor_no	center_offset
100642	1	0
100642	2	203
100642	3	305
100642	4	457
100642	5	610
100642	6	914
100642	7	1524

The above query does not fully specify all of the key fields in MON_DEFL_LOC_INFO; however, this is generally not necessary. In the unlikely event that two different FWDs were tested on the same section on the same day or that the unit changed configuration during the test (this would be evidenced by the query returning more than one record per sensor), the query should be further refined by specifying the DEFL_UNIT_ID and TEST_TIME.

The EXPERIMENT_SECTION table indicates that on 4/08/1994, this site was assigned a CONSTRUCTION_NO = 2. With this information, we can extract the relevant layer information.

C.2.4 Layer Information Tables

Thus far, we have deflection and temperature information for the site, but have not extracted pavement layer and material properties. The database contains two types of layer information: agency-supplied layer information and LTPP-determined layer information. The agency-supplied information is not considered to be research-grade data, and we do not recommend that it be used for backcalculation purposes. However, this alternate source of information may be of use to researchers conducting in depth investigations of a specific section. For GPS test sections, this information is located in the INV_LAYER table. For SPS test sections, similar information is located in the SPS?_LAYER tables, where "?" is the SPS experiment number. The exceptions are the SPS-3 and -4 sections, which do not have this information.

LTPP-determined layer thickness information is available from the TST_L05A and TST_L05B tables (TST_L05B is described in detail within the description of the Materials Testing module). The thicknesses recorded within these tables **DO NOT** necessarily match. The values within the TST_L05A table are the measured thicknesses of layers either from materials sampled immediately before and/or immediately after the test section location or from elevation surveys. In some cases, notably for subgrade thicknesses, there are also numbers from shoulder probe samples taken midway along the section's length. In contrast, the TST_L05B tables contain one field for a single representative thickness for each layer of the section. This value is derived from the measured values from the TST_L05A table and from analysis of the deflection data. It is a single subjective best estimate of a value that, in reality, is variable throughout the section's length. A simple SQL statement to extract layer thickness information from TST_L05B is as follows:

```
SELECT layer_no, inv_layer_no, description, layer_type, repr_thickness,
matl_code, construction_no
FROM tst_l05b
WHERE state_code = 34
      AND shrp_id = '1003';
```

The result set is as follows:

layer_no	inv_layer_no	description	layer_type	repr_thickness	matl_code	construction_no
1	1	7	SS	54.0	282	1
2	1	6	GS	24.9	308	1
3	2	5	GB	7.4	308	1
4	3	4	AC	5.9	1	1
5	4	3	AC	1.6	1	1
1	1	7	SS	54.0	282	2
2	1	6	GS	24.9	308	2

layer_no	inv_layer_no	description	layer_type	repr_thickness	matl_code	construction_no
3	2	5	GB	7.4	308	2
4	3	4	AC	5.5	1	2
5	4	3	AC	0	1	2
6		1	AC	2.2	1	2

Because we did not specify a CONSTRUCTION_NO, we received two sets of layer information. The differences are attributable to a mill and AC overlay operation that occurred in 1994. (The type of operation can be determined by querying CN_CHANGE_REASON in the EXPERIMENT_SECTION table.) The thickness of layer 5 was reduced to 0, layer 4 was reduced in thickness, and layer 6 was added to the cross section of this site at that time. This example illustrates two important aspects of TST_L05B:

The lowest layer in the pavement structure always has a LAYER_NO equal to 1.

When a layer is removed by milling or grinding, it remains in TST_L05B, but with a thickness of 0. This is necessary for maintaining the relational integrity of the TST module.

The deflection tests were conducted after the overlay date, so the layer information from CONSTRUCTION_NO = 2 should be used.

C.2.5 Laboratory Materials Testing Data

Any attribute of the materials used in the construction of these layers can be extracted from the appropriate table. For example, the following query retrieves the gradation of the unbound materials at this test section:

SELECT layer_no, loc_no, sample_no, test_no, one_half_passing, no_10_passing, no_200_passing
FROM tst_ss01_ug01_ug02
WHERE state_code = 34
AND shrp_id = ‘1003’;

The result set from this query is as follows:

layer_no	loc_no	sample_no	test_no	one_half_passing	no_10_passing	no_200_passing
2	BA*	BG**	1	73	49	9.5
2	TP1	BG56	2	83	57	6.2
3	BA*	BG**	1	76	45	8.9
3	TP1	BG55	2	75	49	11.0

Two observations can be made about this data. First, we have two different test results for the granular subbase (LAYER_NO = 2) and base layers (LAYER_NO = 3). How to resolve this is left up to the user of the data; however, the user should note that the tests with a TEST_NO of 1

(TEST_NO is a code of the type TEST) are based on samples from the approach end of the section, while those with a TEST_NO of 2 are from the leave end of the section (152- m (500-ft) apart). Also, samples with a LOC_NO like TP? are from test pits, while those with a LOC_NO like BA? are from material extracted through a core hole.

A more significant issue is that there is no information on the subgrade (LAYER_NO = 1). A fallback option is to check the agency-supplied data in INV_GRADATION with the following query:

```
SELECT layer_no, one_half_passing, no_10_passing, no_200_passing
FROM inv_gradation
WHERE state_code = 34
      AND shrp_id = '1003';
```

The result set from this query is as follows:

layer_no	one_half_passing	no_10_passing	no_200_passing
1			
2			5
3	70		
4	100		7

Note that LAYER_NO in any INV table must be mapped as INV_LAYER_NO in TST_L05B. However, in this case, the agency did not supply any useful data. Our last resort for information on the subgrade is to use MATL _CODE in TST_L05B. Checking the LTPPDD, we find that MATL_CODE is a code of the type MATERIAL. Therefore, we can conduct the following query (this can also be done with the Table Navigator software):

```
SELECT detail
FROM codes
WHERE codetype = 'MATERIAL'
      AND code = '282';
```

Our result is:

detail
Rock

This, of course, explains why we could not find any laboratory test information on this subgrade.

Likewise, information about the AC layers may be of use in setting modulus seed values in backcalculation. The following query extracts useful information from TST_AC02, TST_AC03, and TST_AC04.

SELECT a.layer_no, avg_bsg, avg_max_sg, (100 * (1 - (avg_bsg / avg_max_sg))) as air_voids, asphalt_content
FROM

```
(SELECT layer_no, AVG(bsg) as avg_bsg
FROM tst_ac02
WHERE state_code = 34
AND shrp_id = '1003'
GROUP BY state_code, shrp_id, layer_no) a,
(SELECT layer_no, AVG(max_spec_gravity) as avg_max_sg
FROM tst_ac03
WHERE state_code = 34
AND shrp_id = '1003'
GROUP BY state_code, shrp_id, layer_no) b,
(SELECT layer_no, AVG(asphalt_content_mean) as asphalt_content
FROM tst_ac04
WHERE state_code = 34
AND shrp_id = '1003'
GROUP BY state_code, shrp_id, layer_no) c
WHERE VAL(a.layer_no) = VAL(b.layer_no)
AND VAL(a.layer_no) = VAL(c.layer_no);
```

The VAL function is used here to work around an apparent bug in Microsoft Access' data type handling routine. The result set from this query is as follows:

layer_no	avg_bsg	avg_max_sg	air_voids	asphalt_content
4	2.42516666666666666666667	2.542	4.59611854183058	4.4
5	2.3805	2.4845	4.18595290802978	5.85
6	2.386	2.5115	4.99701373681067	9

The above query shows the power of SQL to easily and quickly bring together data elements spread across different tables. The researcher may want to add count(*), min(*), max(*), and even stdev(*) functions where the avg(*) function is used to identify outliers, and as a general indication of data quality. Complex queries such as the one above should certainly be examined thoroughly to ensure that they function as intended. Because SPS sections are co-located and often share maximum specific gravity specimens between them, calculating air voids sometimes requires more finesse.

C.3 FINDING MATERIAL TEST DATA ON SPS PROJECTS

Retrieving materials testing data on SPS projects often presents a challenge, given that materials' testing was generally done on a project level instead of a section level. To save cost, some material samples were obtained at only three locations on a project that can contain 12 or more test sections. In the database this material test result is associated with the test section closest to the sampling location. To find material properties for tests on a material obtained from other sections on a SPS project, a user can use the following procedures.

C.3.1 Non SPS 3 or 4 Projects

If in the previous backcalculation example we had chosen section 010105, the gradation query would have returned nothing, as no gradation for 010105 exists for this section in the table. Gradation information for the layers on that section will have to be determined by linking properties from other sections on the project using **TST_L05B**.PROJECT_LAYER_NO as described in section 13.4.4. There are many potential ways to perform this linking – one example is shown here:

```
SELECT distinct a.state_code, a.shrp_id, a.layer_no, b.project_layer_code,
b.shrp_id, b.loc_no, b.sample_no, b.test_no, b.one_half_passing,
b.no_10_passing, b.no_200_passing
FROM tst_l05b a
RIGHT JOIN
(SELECT c.*, d.project_layer_code
      FROM tst_ss01_ug01_ug02 c
      LEFT JOIN tst_l05b d
      ON c.state_code = d.state_code
      AND c.shrp_id = d.shrp_id
      AND c.layer_no = d.layer_no
      AND c.construction_no = d.construction_no
      WHERE c.state_code = 1
            AND d.project_layer_code is not null) b
ON a.state_code = b.state_code
AND left(a.shrp_id,2) = left(b.shrp_id,2)
AND a.project_layer_code = b.project_layer_code
      WHERE a.state_code = 1
            AND a.shrp_id = '0105';
```

This query returns the following information:

State code	Shrp ID	Layer no	Project layer code	Shrp ID	loc_no	Sample no	Test no	one_half passing	no_10 passing	no_200 passing
1	0105	1	C	0103	B5	BS05	2	99.7	96.6	68
1	0105	1	C	0108	B2	BS02	2	99.5	97.2	66.4
1	0105	2	E	0102	B10	BG10	1	72	34	12
1	0105	2	E	0106	B9	BG09	2	75	34	11.9
1	0105	2	E	0108	B8	BG08	2	58	23	8.2

Because gradation information from several sections is returned, the user can make a determination as to which data are more appropriate for the section of interest. If the user wants to determine which gradation data is closest spatially, **SPS_PROJECT_STATIONS** can to be consulted.

The following query returns a list of sections on the 010100 project, as well as the distance between that section and the 0105 section.

```
SELECT b.test_section, IIF(b.section_start < a.section_start, b.section_end-
a.section_start, b.section_start-a.section_end) as distance_from_section
FROM
(SELECT *
      FROM sps_project_stations
```

```
      WHERE state_code = 1
            AND project_id = '0100') a
INNER JOIN sps_project_stations b
ON a.state_code = b.state_code
AND a.project_id = b.project_id
      WHERE a.test_section <> b.test_section
            AND a.test_section = '010105';
```

The results are as follows:

test_section	distance_from_section
010107	-3414
010108	-3193
010109	-3002
010163	-2773
010110	-2438
010111	-2179
010112	-1905
010106	-792
010104	-503
010162	-274
010103	-61
010101	106
010102	1760
010161	2042

We can see that, of the sections with gradation information for layer 1, 010103 is closest, and for layer 2, 010106 is closest.

The first query in this portion of the document is easy to modify for different types of material properties on other test sections. For example, if we are interested in the maximum specific gravity of the AC mixture on test section 0113 in Arizona, the following modifications would need to be made to the query,

- The maximum specific gravity of AC mixtures is contained the TST_AC03 table. So in change the statement that currently reads "`FROM tst_ss01_ug01_ug02 c" to "FROM tst_ac03 c`"
- Since we are interested in the maximum specific gravity from the TST_AC03 table, remove "`b.one_half_passing, b.no_10_passing, b.no_200_passing`" from the first select statement and replace with "b.max_spec_gravity"
- Replace the twp statements in the query "state_code= 1" with "state_code= 4" since the state code for Arizona is 4.
- Then replace the statement "a.shrp_id= '0105'" with "a.shrp_id= '0113" since we are looking for data for this test section.

The modified query looks like the following:

```
SELECT distinct a.state_code, a.shrp_id, a.layer_no, b.project_layer_code,
b.shrp_id, b.loc_no, b.sample_no, b.test_no, b.max_spec_gravity
RIGHT JOIN
(SELECT c.*, d.project_layer_code
      FROM tst_ac03 c
      LEFT JOIN tst_l05b d
      ON c.state_code = d.state_code
      AND c.shrp_id = d.shrp_id
      AND c.layer_no = d.layer_no
      AND c.construction_no = d.construction_no
      WHERE c.state_code = 4
            AND d.project_layer_code is not null) b
ON a.state_code = b.state_code
AND left(a.shrp_id,2) = left(b.shrp_id,2)
AND a.project_layer_code = b.project_layer_code
      WHERE a.state_code = 4
            AND a.shrp_id = '0113';
```

This query returns the following results.

state_code	a.shrp_id	layer_no	project_layer_code	b.shrp_id	loc_no	sample_no	test_no	max_spec_gravity
4	0113	3	H	0115	B101	BT01	3	2.5
4	0113	3	H	0122	B112	BT12	3	2.534
4	0113	3	H	0123	B106	BT06	3	2.52
4	0113	3	H	0161	B114	BT14	3	2.525

So while there is no AC specific gravity data for section 0113, there are 4 other test sections on the project which do have test results for the same material layer.

C.3.2 SPS 3 and 4 Projects

For the SPS-3 and SPS-4 projects, most of the testing available for subsurface layers was often done on the linked GPS section only, and therefore presents yet another complication for retrieving data.

For instance, if, in the original backcalculation example, we had chosen section 04B310, the gradation query would have returned nothing, and the query modified to use PROJECT_LAYER_CODE would also have returned nothing. This is because there is no subgrade or base information for any section specifically designated as being in the 04B300 project. In order to get this information, we have to go to the linked GPS section.

Determining which GPS section is linked can be done by simply opening **SPS_GPS_LINK** table and looking at which GPS section is linked to the 04B300 project – the answer is 041021. Now we could simply use that STATE_CODE and SHRP_ID information and the original gradation query to get the available gradation for the linked GPS section.

However, depending on the situation, it may not be desirable to have to constantly look up the linked GPS section and use it for these linked sections. Fortunately, it is not overly complicated to modify the original query to look for the linked information. The following query returns information from the linked section or the original section if there is any:

```
SELECT distinct a.state_code, a.shrp_id, a.layer_no, b.shrp_id, b.loc_no,
b.sample_no, b.test_no, b.one_half_passing, b.no_10_passing, b.no_200_passing
FROM
(SELECT c.state_code, c.shrp_id, c.layer_no, d.linked_gps_id
      FROM tst_l05b c
      RIGHT JOIN (SELECT distinct e.state_code, e.shrp_id, f.linked_gps_id
                  FROM experiment_section e
                  LEFT JOIN sps_gps_link f
                  ON e.state_code = f.state_code
                  AND left(e.shrp_id,2) = left(f.shrp_id,2)) d
      ON c.state_code = d.state_code
      AND c.shrp_id = d.shrp_id)a
RIGHT JOIN tst_ss01_ug01_ug02 b
ON a.state_code = b.state_code
AND (a.linked_gps_id = b.shrp_id OR a.shrp_id = b.shrp_id)
AND a.layer_no = b.layer_no
      WHERE a.state_code = 4
            AND a.shrp_id = 'B310';
```

Since there is no information for 04B310 specifically, all the returned information is for the linked GPS section as shown below:

State code	Shrp ID	Layer no	Shrp ID	loc_no	Sample no	Test no	one_half passing	no_10 passing	no_200 passing
4	B310	1	1021	BA*	BS**	1	94	74	19.6
4	B310	1	1021	TP1	BS92	2	97	82	23.2
4	B310	2	1021	BA*	BG**	1	90	59	11.7
4	B310	2	1021	TP1	BG91	2	90	59	11.2

APPENDIX D. STATE CODES

Code	State/Territory/Province	Code	State/Territory/Province
01	Alabama	35	New Mexico
02	Alaska	36	New York
04	Arizona	37	North Carolina
05	Arkansas	38	North Dakota
06	California	39	Ohio
08	Colorado	40	Oklahoma
09	Connecticut	41	Oregon
10	Delaware	42	Pennsylvania
11	District of Columbia	44	Rhode Island
12	Florida	45	South Carolina
13	Georgia	46	South Dakota
15	Hawaii	47	Tennessee
16	Idaho	48	Texas
17	Illinois	49	Utah
18	Indiana	50	Vermont
19	Iowa	51	Virginia
20	Kansas	53	Washington
21	Kentucky	54	West Virginia
22	Louisiana	55	Wisconsin
23	Maine	56	Wyoming
24	Maryland	72	Puerto Rico
25	Massachusetts	81	Alberta
26	Michigan	82	British Columbia
27	Minnesota	83	Manitoba
28	Mississippi	84	New Brunswick
29	Missouri	85	Newfoundland
30	Montana	86	Nova Scotia
31	Nebraska	87	Ontario
32	Nevada	88	Prince Edward Island
33	New Hampshire	89	Quebec
34	New Jersey	90	Saskatchewan

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