Long-Term Pavement Performance

Information Management System User Guide

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Turner-Fairbank Highway Research Center
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FOREWORD

This document provides information to aid in understanding and using the information stored in the Long-Term Pavement Performance (LTPP) program Information Management System (IMS). The IMS consists of the Pavement Performance Database (PPDB), LTPP Traffic Analysis Software (LTAS) database, and Ancillary Information Management System (AIMS) archives. If you are interested in using LTPP data for a specific pavement research objective, this document serves as a good reference guide to LTPP data.

The InfoPave™ web site provides a modern interface to LTPP data that enables novice and experienced data users unprecedented access to LTPP data using a wide variety of tools and features. The InfoPave web site is at https://infopave.fhwa.dot.gov/ .

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**.

Dr. Cheryl Allen Richter
Director, Office of Infrastructure
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This document provides information to aid in understanding and using the Long-Term Pavement Performance (LTPP) program's Pavement Performance Database (PPDB), LTPP Traffic Analysis Software (LTAS) database and contents of the Ancillary Information Management System (AIMS) and LTPP InfoPave. This document introduces the structure of the LTPP program, the relational structure of the LTPP database, a description of the location of various data elements, contents of data tables, tips on efficient means of manipulating data for specific types of investigations, information on 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 public data release of LTPP data. The LTPP InfoPave web site is now the official public data dissemination mechanism for LTPP data that is available at: https://infopave.fhwa.dot.gov/</td></tr>
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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
ADM	Administration
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
CRCP	Continuously reinforced concrete pavement
DCV	Data compilation views
DLR	Dynamic load response
DSR	Dynamic shear rheometer
DT	Direct tension
EC	Environment Canada
ESAL	Equivalent single-axle load
FHWA	Federal Highway Administration
FIPS	Federal Information Processing Standards
FWD	Falling-weight deflectometer
GPS	General Pavement Studies**Error! Bookmark not defined.**
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
LTPP	Long-Term Pavement Performance
LTAS	LTPP Traffic Analysis Software
LVDT	Linear variable differential transformer
MAP-21	Moving Ahead for Progress in the 21^{st} Century
MEPDG	Mechanistic-Empirical Pavement Design Guide
MERRA	Modern Era Retrospective-analysis for Research and Applications
NALS	Normalized axle load spectra
NCDC	National Climatic Data Center
NCHRP	National Cooperative Highway Research Program
NPRM	Notice of Proposed Rulemaking
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
RPPIF	Relative pavement performance input factor
SAMI	Stress-absorbing membrane interlayers
SHRP	Strategic Highway Research Program
SI	International System of Units
SMP	Seasonal Monitoring Program
SPS	Specific Pavement Studies
TMG	Traffic Monitoring Guide
TPF	Traffic Pooled Fund
VWS	Virtual Weather Station
WIM	Weigh-in-motion
WMA	Warm Mix Asphalt

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 user 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 pavement test sections located on in-service roadways. 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. Approximately 1,700 test sections were constructed at SPS project sites. As the test sections on SPS projects aged, they were reclassified into GPS experiments when a new rehabilitation treatment was applied.

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 rehabilitation treatment that is not part of a defined SPS project is applied to GPS or SPS test section, the test section is reassigned to one of the GPS rehabilitation experiments.

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 was 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 performance of the pavement. 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 of each experiment 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 study of specially constructed, maintained, or rehabilitated pavement sections incorporating a controlled set of experiment design and construction features. The SPS program incorporates ten studies grouped into the six 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 experiment designations.

Experiment	Experiment Title
GPS-1	Asphalt Concrete (AC) Pavement on Granular Base
GPS-2	Asphalt Concrete 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	Asphalt Concrete Overlay on AC Pavement
GPS-6A	Existing AC Overlay of AC Pavement (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
Warm Mix Asphalt	SPS-10	Warm Mix Asphalt Overlay of Asphalt Pavement Study

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.

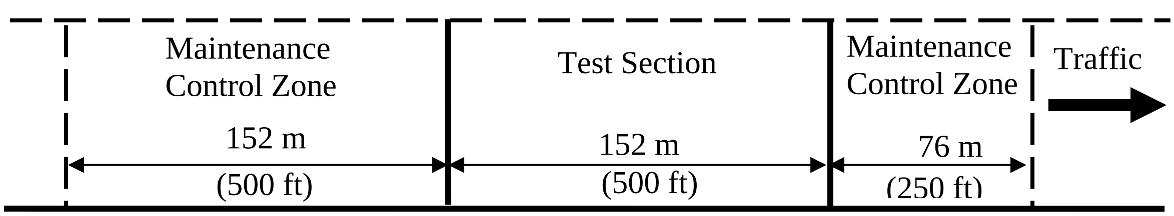

Figure 1. Illustration. Layout of a generic GPS test section.

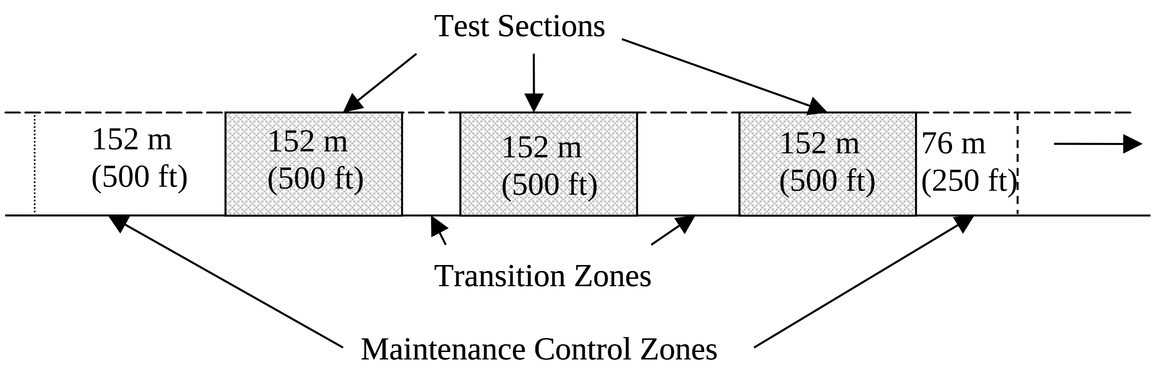

Figure 2. Illustration. Example layout of a generic SPS project.

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.

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.

A project station location convention is used where multiple test sections are located on the same SPS project site. SECTION_START and SECTION_END in SPS_PROJECT_STATIONS contain project station location information. The project station convention starts with station 0 assigned to the first test section located at the project site in the direction of travel. Some SPS test sites have test sections located on opposite sides of the road, and in these situations, station 0 is assigned to the first section in either direction of travel.

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 the LTPP data collection activities stored in the LTPP database. Reference documents are available from the InfoPave web site under the Library hub. LTPP documents are also available from the FHWA LTPP web page at:
http://www.fhwa.dot.gov/research/publications/technical/infrastructure/pavements/ltpp/ .

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 4 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.

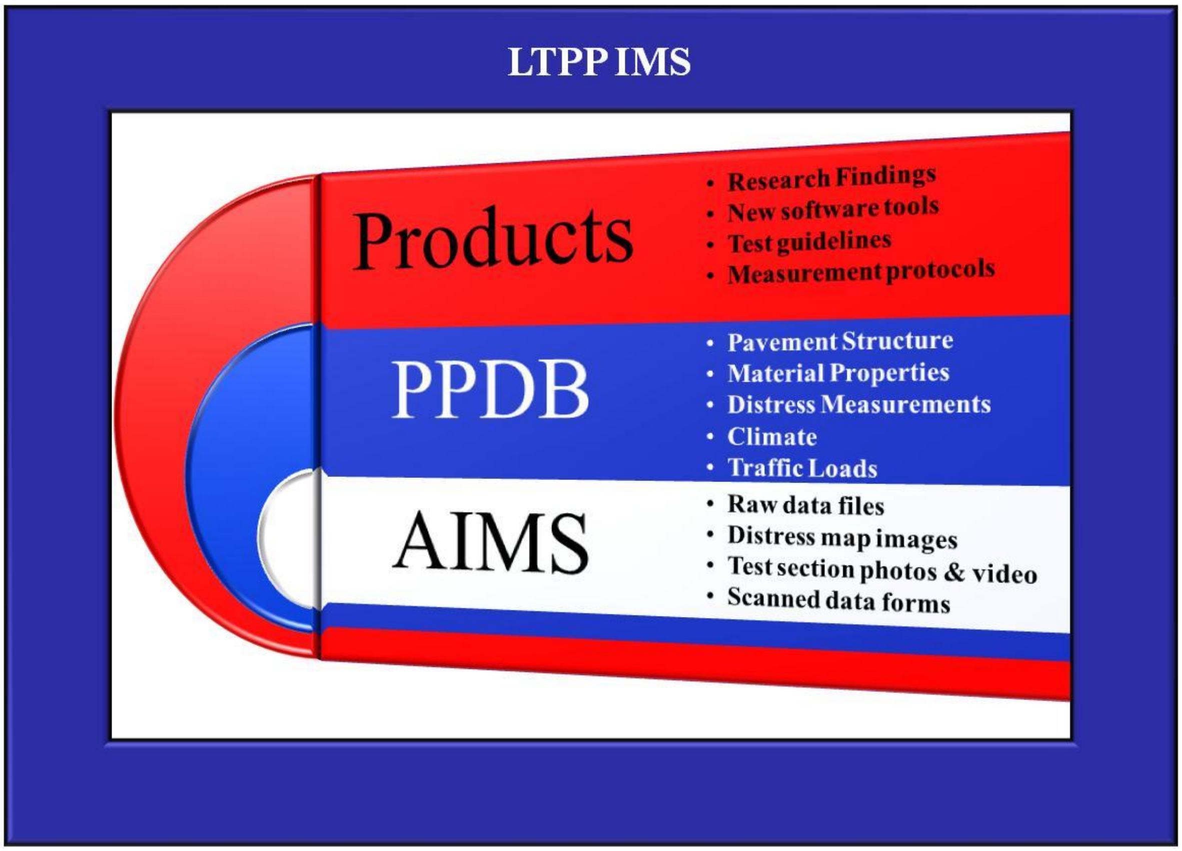

Figure 3. Illustration. The major categories of the LTPP IMS include Products, PPDB, and AIMS.

2.2. LTPP PPDB

The PPDB was designed to store the majority of the data collected by the LTPP program for easy and convenient dissemination and use. The PPDB is a relational database originally implemented in Oracle® 5 format. As of this writing, the production database is implemented in Oracle® 12. 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 18 for data request procedures.) Data sets generated by the user through InfoPave may be delivered in Microsoft® Excel, Access, or SQL. Fixed collections of data are available in Microsoft® Access 2002-2003. Microsoft Access 2002-2003 is compatible with subsequent versions of Microsoft® Access. This may change in the future. International data users, who do not have access to the English-language version of Microsoft® Access 2002-2003 or subsequent compatible versions, may wish to request customized extractions in other formats.[1]

2.3. RELATIONAL DATABASES AND STRUCTURED QUERY LANGUAGE

The LTPP PPDB 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 locate data for a specific test section in many tables.

One characteristic of the LTPP database is that it is 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 is available as a program running on Microsoft Windows® platforms or over the internet at the http://ltpp.org/ web site under the Data User's Corner tab.

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 extract, combine, count, and perform basic mathematical computations on data stored in database format. 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 commands are provided in appendix C of this document. The data extraction examples in appendix C require a basic knowledge of 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.

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. Most data tables contain a RECORD_STATUS field. Originally, five categories of checks (levels A - E) were programmed as described below. Currently, most data modules have only three categories of checks: levels C, D and E.

- Level A Checks: All data records begin at level A. Originally, random checks of data were performed to ensure correct data transfer from regional databases to the central database. This check is performed by comparing record counts before and after a data transfer from the national LTPP Data Entry Portal (LDEP) to the central PPDB. This check does not cause a change in record status.

- Level B Checks: Originally, level B were a set of dependency checks performed to ensure that basic essential section information had been recorded in the PPDB. These checks have been incorporated into the E level checks for most modules, but still exist for some tables in the TST module.

- Level-C Checks: These are checks 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.

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 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.

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.

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: GPS or 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 table also includes information about the location of these test sections relative to each other.

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. 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 LTPP databases are divided into *modules* containing similar sets of tables. In the PPDB, except for the tables in the Administration and Data Compilation Views (DCV) modules and those created for the warm mix experiment, the first part of table names identifies the module to which a table belongs. The modules in the PPDB include:

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.

Backcalculation (Bakcal): This is a subset of the Monitoring module and contains the results of the backcalculation of FWD measurements extracted from SDR 27.

Climate (CLM): This module contains data collected from offsite weather stations that are used to compute a simulated virtual weather station (VWS) for LTPP test sections or project sites. It also contains climate data estimates from Modern-Era Retrospective Analysis for Research and Applications (MERRA) developed by the National Aeronautics and Space Administration (NASA). Data in this module are updated at periodic intervals.

Data Compilation Views (DCV). This module contains data from similar tables in the INV, RHB, and SPS modules combined into a common table structure on specific test section attributes. The objective of these tables is to make data easier to find.

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 GPR 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. Because this information comes from agency project records and not necessarily from actual measurements taken at the test sections, it 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.

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. It can be understood best as a collection of sub-modules by data type:

- Deflection (MON_DEFL): This sub-module contains data from FWD tests.
- Distress (MON_DIS): This sub-module contains distress survey data from both manual and film-based surveys.
- Friction (MON_FRICTION): This sub-module contains friction measurements taken by participating highway agencies.
- Profile (MON_HSS): This sub-module contains longitudinal profile data collected by an automated profiler or by manual dipstick measurements. Starting with 2015 data release, this module now includes pavement surface texture data.
- Rut (MON_RUT): This sub-module 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 sub-module 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 for SPS-1 through SPS-9 experiments.

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.

The LTPP Traffic Analysis Software (LTAS) is a database that is used to process traffic measurement data, perform quality control checks, and produce various types of traffic based computed parameters stored in the PPDB. As described in Chapter 16, LTAS tables use a general table naming scheme that is like the module format used in the PPDB but is based on temporal aggregation attributes.

CHAPTER 3. ADMINISTRATION MODULE

3.1. INTRODUCTION

The Administration (ADM) module contains the master test section control table, metadata tables that describe the structure and content of the database, general comments table, master section pavement layer structure table, and test section location coordinates table. 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.

3.2. IMPORTANT RELATIONAL FIELDS

The following are descriptions of the overall most important relational fields in the LTPP database. Relational fields are primarily used to join, or combine, data stored in different tables.

3.2.1. STATE_CODE

STATE_CODE is a two-digit numerical value 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, expanded by LTPP to include Canadian provinces and other countries who indicated a desired to participate in the LTPP program in 1987.

3.2.2. SHRP_ID

SHRP_ID is used as an identifier for either a single test section or a group of test sections. SHRP_ID is technically a character field that is composed of alphanumeric characters.

For GPS test sections, SHRP_ID is a numerical index, that when combined with the STATE_CODE, uniquely defines an individual test section. On SPS project sites, SHRP_ID contains alphanumeric characters which are populated with either project level or test section specific entries. The first two characters in SHRP_ID on SPS projects identify the sequence and general type of SPS project constructed within an agency boundary. The first character in the sequence identifier is typically “0” for the first such project constructed in each State or Province, “A” for the second such project, and so on. The second character is generally the SPS experiment number. Thus, 08 represents the first SPS-8 experiment project site constructed within agency jurisdiction, and A8 represents the second SPS-8 experiment site. However, this general scheme is changing with the introduction of the SPS-10 experiment to the LTPP database in the July 2015 data release. Since it takes now takes more than two characters to indicate an SPS experiment type, data users are advised to use entries in the EXPERIMENT_SECTION table to determine proper assignment of test sections to experiments.

The last two characters of SHRP_ID indicate if the record applies to the project site or a specific test section. If the last two characters of SHRP_ID on SPS experimental sites are populated with a 00, then it represents a project level record, if not, it is a specific test section level record. There are some minor exceptions to this general rule structure on assignment of SHRP_ID to SPS projects, but these are the general rules.

3.2.3. CONSTRUCTION_NO

CONSTRUCTION_NO identifies changes in the pavement structure caused by application of maintenance or rehabilitation construction treatments. When a test 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.

CONSTRUCTION_NO is a key referential field needed to link records between the SECTION_LAYER_STRUCTURE and the monitoring tables. This link will provide a data user information on the pavement structure characteristics at the time each monitoring measurement was performed.

The type of construction event which created the change in CONSTRUCTION_NO is stored in fields which use the MAINT_WORK code. This includes CN_CHANGE_REASON in the EXPERIMENT_SECTION table and IMP_TYPE in the tables included in the MNT and RHB modules.

3.3. TABLE DESCRIPTIONS

EXPERIMENT_SECTION. This is the master control table for all test sections and project sites included in the LTPP database. Due to this table's overall importance of interpretation of the PPDB, it is included in every SDR database. The three key fields that define a unique record in this table are STATE_CODE, SHRP_ID, and CONSTRUCTION_NO, which form the primary backbone of relational links within the LTPP database. Other important fields in this table include:

- **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. For subsequent events, 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 field contains codes that are of the type MAINT_WORK, but it may contain more than one code, and is therefore not directly translatable with the CODES entries.

- **GPS_SPS** is a code to indicate whether a section is classified as a GPS or SPS experiment for the corresponding 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.

- **ASSIGN_DATE** is the date when a test section is assigned to the LTPP experiment. 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.

- **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 study. 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. 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.

- **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.

LTPPDD. 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) tables. LTPPDD contains metadata for each field in each table in the database. This table contains a rudimentary description of each field in every table, units, references to LTPP source data form designations, and material test protocols. The information contained in the Table Navigator program is based on the entries in this table.

The LTPPDD table circulated with each SDR is altered to match its contents. For example, in SDR 26 the DLR_*_AC table entries were removed from LTPPDD because 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.

Important fields in the LTPPDD table include:

- **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 assigned to the code field contained in the CODES tables. The contents of this field are used to link to the CODES table to lookup the meaning of a code.
- **DATA_TYPE** specifies the Oracle electronic format of the specified field. These fields are typically a VARCHAR2 (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, file type, or general type of data file.
- **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.
- **UNITS** indicate the units used for the corresponding numeric field. Both SI and U.S. customary units are included in the database.

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.

CODES. Many of the elements in the database use a code value to represent different standard entries in a field. The CODES table contains a definition of all codes used in the LTPP database.

To decipher the meaning of a code value in a data table, a user must link the corresponding CODETYPE 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 stored in a numeric formatted field whereas the CODE field in the CODES table is formatted as a character. 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 numeric format in the data table to a character, or the character format in the CODES table to a number to perform a join.

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.

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.

REGIONS. The REGIONS table 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. This table is used primarily for internal LTPP operations.

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 that 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 possible, the SPS project level ID is set to the coordinates of the first test section at the site in the direction of traffic. In data release 29, project level entries were removed and section elevations were added.

These coordinates are populated using the highest available precision coordinate determinations available.

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.

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. It contains a 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 to reduce confusion over which of the layering tables in the PPDB should be used for pavement performance analysis.

CHAPTER 4. AUTOMATED WEATHER STATION MODULE

Automated Weather Stations (AWS) were installed by the LTPP program near almost all SPS-1, -2, and -8 project sites. This equipment measured 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 were 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, AWS_ID is not always the same as the combined STATE_CODE and SHRP_ID (project ID for SPS projects), therefore, **AWS_LINK** should be used to find AWS data for a given SPS project or GPS section.

4.2. AWS TABLES

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.

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 small distance from the project site. Users should evaluate the potential impact of this displacement on their analytical objectives.

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.

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.

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.

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.

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.

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.

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 the hourly data has been edited to correct time stamp issues or bad data. The data logger that 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 the monthly statistics are computed from the daily data, provided 24 days of data exists within a month.

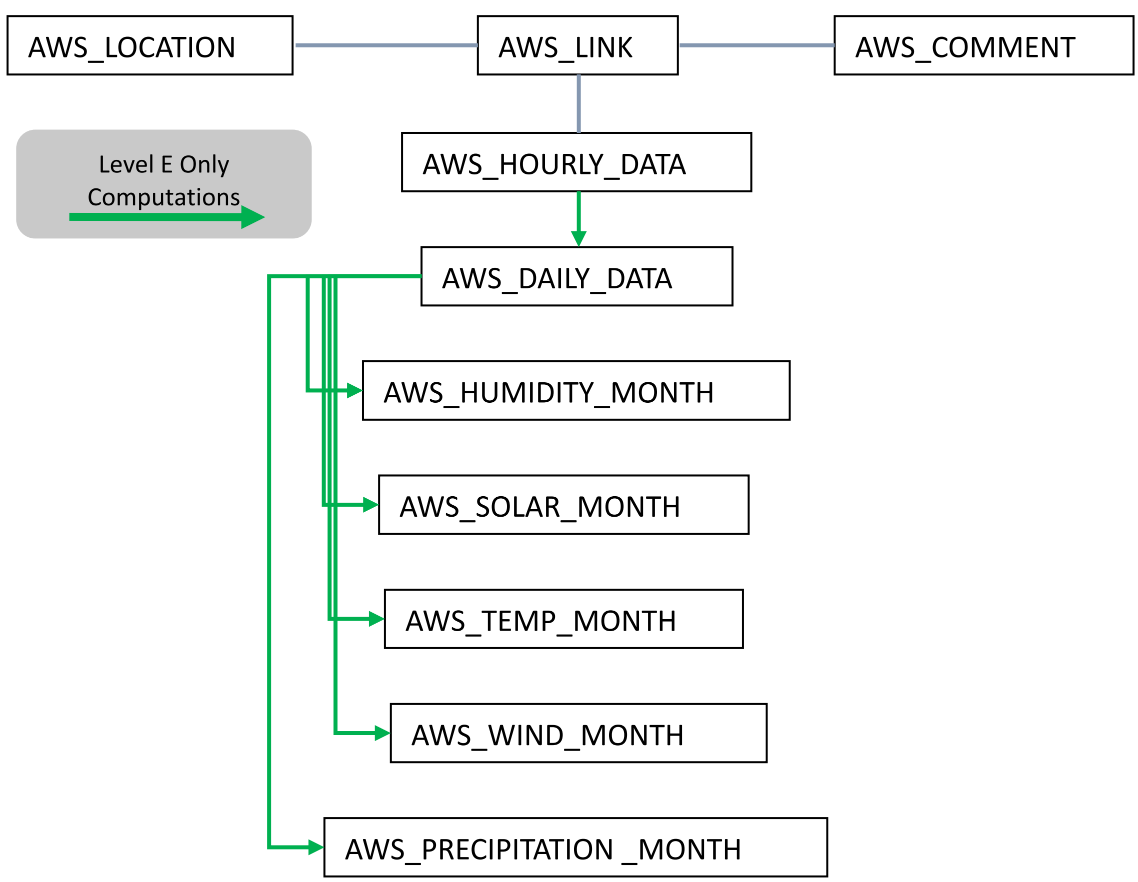

Figure 4. Schematic. Organization and computational relationships between the AWS tables.

CHAPTER 5. CLIMATE MODULE

The LTPP climate data are stored in the CLM and MERRA modules. Data in the CLM module are based on observations from ground based weather stations. Data in the MERRA module are based on an analysis of a combination of ground, satellite, ocean, and atmospheric observations. Data in the MERRA module were replaced with the LTPP Climate Tool in InfoPave with the July 2016 data release.

5.1. CLIMATE 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 proximity to LTPP test sections, period of data coverage, and type of available data. Raw climatic data from the OWS are stored in tables whose names begin with CLM_OWS. Climate statistics interpolated from nearby OWS for each test section or project location for sites where more than one test section is co-located are stored as a virtual weather station (VWS). The second tier of climate data storage is VWS statistics which represent the climate at LTPP test sections linked to the VWS. The VWS statistics are stored in tables whose names begin with CLM_VWS.

The climate database is updated periodically. The last major update was performed for the SDR 28 data release in January 2014. In this update, new data for the OWS through the end of 2012 was added to the database. For this update, a review and update of the OWS for each VWS was completed to improve data coverage. Previously, if a VWS did not have a first order weather station associated with it, then no wind or humidity data were available for a test site. It was expected that the new OWS selection process, would result in greater coverage of climate data parameters for each site. A minor update was performed for the July 2016 data release for the new test sections from the SPS-10 Warm Mix Asphalt experiment.

The data stored in the CLM module consist of daily statistics and measurements for the LTPP selected parameters. Hourly data are not stored due to lack of coverage and availability over the study time period which began in 1989. To summarize the daily measurements, monthly and annual statistics (mean, standard deviation, minimum, maximum, count, and total) have been calculated. Selected climate indexes are also available as annual summaries.

5.1.1. Important Fields

WEATHER_STATION_ID is the key field in the CLM_OWS tables. This field 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.

5.1.2. 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.

5.1.2.1. *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 and Environment Canada (EC) for Canadian locations. These data are split into daily, monthly, and annual data summaries by data type. This change was made in 2004 due to errors found in the publicly available data. Splitting the data into tables containing one type of weather measurement simplifies the computation process to allow only data that 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 the monthly and annual OWS data only contain summaries of the daily data, further QC on these tables is not necessary.

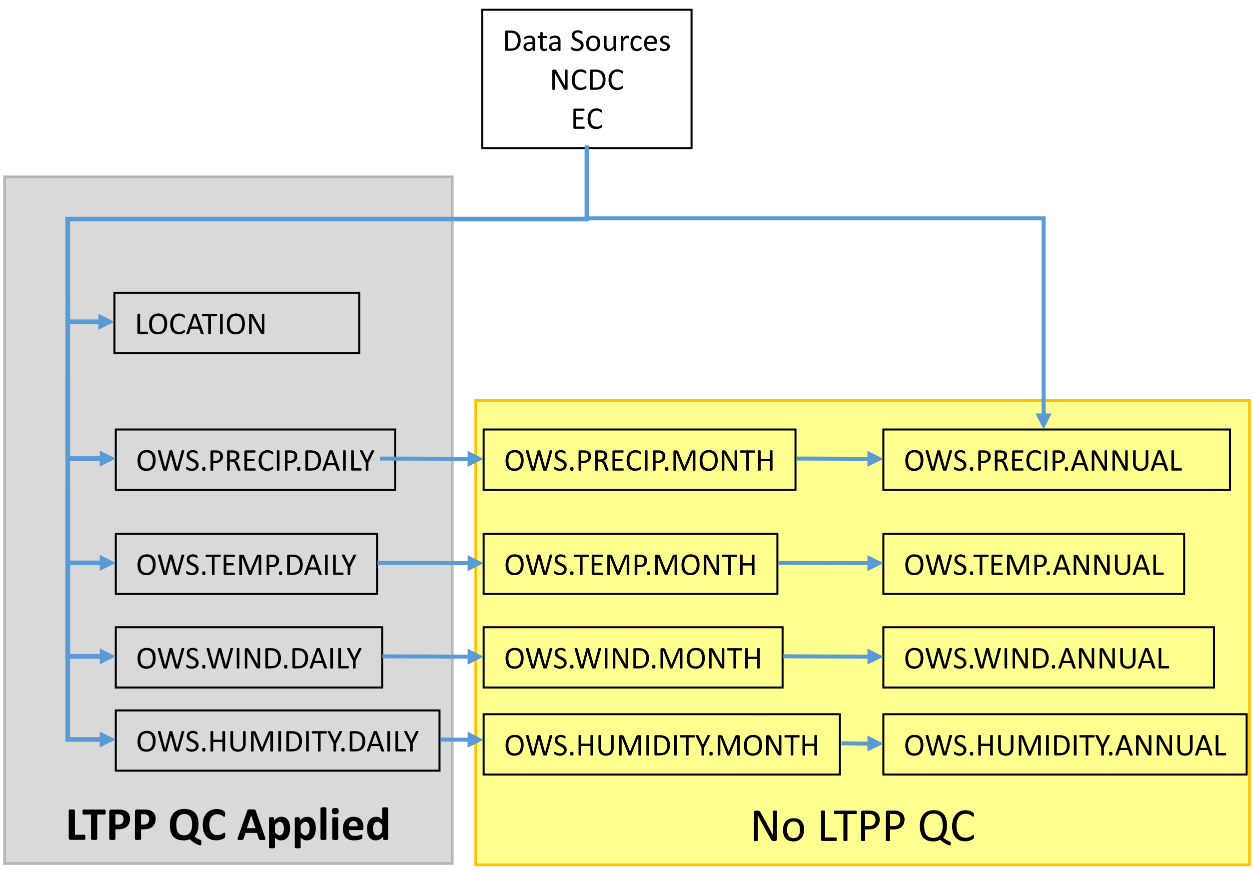

Figure 5. Schematic. Structure and relationship between the CLM_OWS_* tables.

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.

5.1.2.2. *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 that 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 monthly tables are computed using daily data that have passed all of the daily data QC checks. In addition to the checks on the daily tables, the monthly table calculations are subjected to QC checks on the number of valid days in each month's 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.

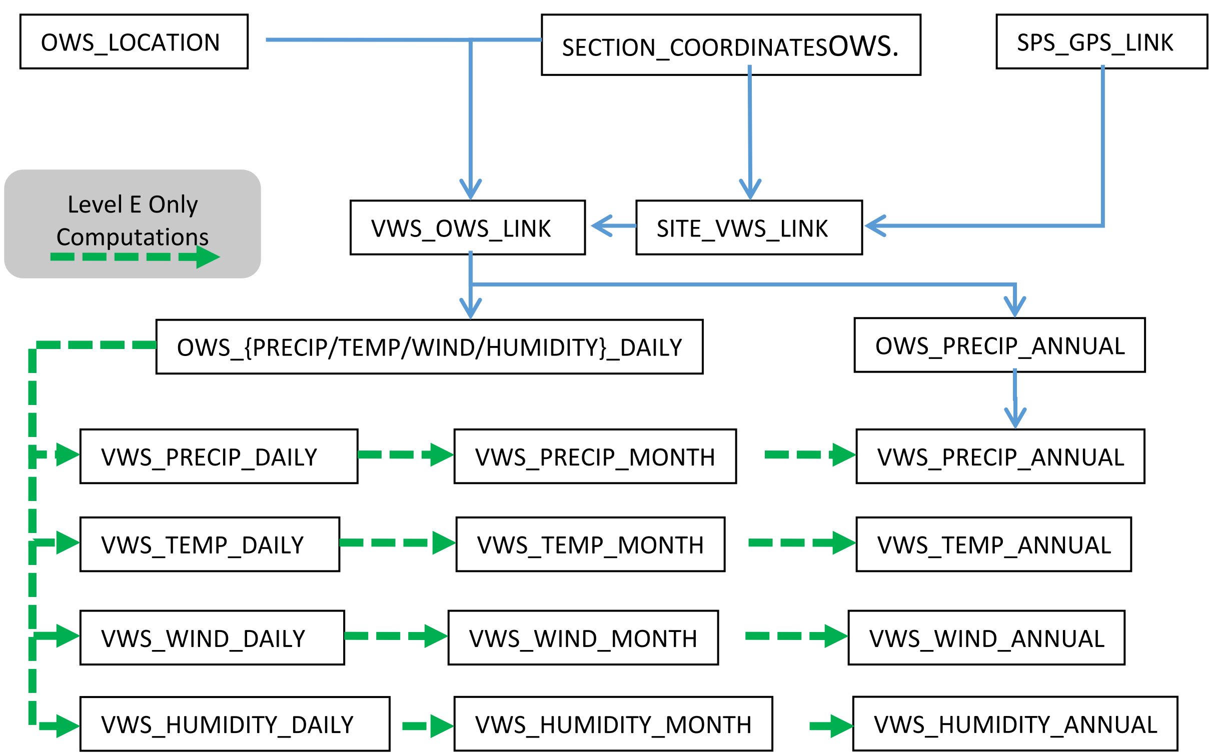

Figure 6. Schematic. Computational and relational structure of the CLM_VWS tables.

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.

5.1.3. 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 the 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 based on values contained in the CLM_VWS_*_MONTH tables.

5.1.3.1. *VWS Calculations*

Because the values stored in the VWS tables are computed using values from varying numbers of OWS locations based on a maximum distance from the section, the following equation was used to weight the influence of OWS values based on the distance from the OWS to the VWS.

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

Figure 7. Distance square interpolation model used to compute weighted virtual weather statistics from distant operating weather stations.

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 15)

5.1.3.2. *Freezing Index*

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

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

Figure 8. Equation. Freeze index calculation equation.

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.

5.2. MERRA CLIMATE DATA

The Modern-Era Retrospective Analysis for Research and Applications (MERRA) developed by the National Aeronautics and Space Administration (NASA) for its own in-house modeling needs, provides continuous hourly weather data starting in 1980 on a relatively fine-grained uniform grid. MERRA is based on a reanalysis model that combines computed model fields (e.g., atmospheric temperatures) with ground-, ocean-, atmospheric-, and satellite-based observations that are distributed irregularly in space and time.[2] The result is a uniformly gridded data set of meteorological data derived from a consistent modeling and analysis system over the entire data history. MERRA data are provided at a continuous hourly temporal resolution and a 0.5º latitude by 0.67º longitude (approximately 50 km by 60 km at mid-latitudes) spatial resolution over the entire globe. Evaluation of this data source by LTPP indicates that this unique data set provides a basis to extend, enhance, and improve infrastructure models dependent on climate inputs.

In the July 2016, public data release, MERRA climate data was incorporated into InfoPave in the LTPP Climate Tool under the data hub and MERRA Climate Data for MEPDG Inputs under the tools hub. The LTPP Climate Tool contains data for cells located on land for the entire earth. MERRA data available from LTPP can only be down loaded using these on-demand download features contained on InfoPave.

In the July 2017, public data release, MERRA-2 data was incorporated into the InfoPave Climate tool. The MERRA-2 dataset was introduced because of advances in the assimilation system that now include hyperspectral radiance and microwave observations.[3] The latitude width of the grid cell has been reduced to 0.625 degrees.

Some of the MERRA data now available from the InfoPave MERRA Climate Tool include:

- Hourly precipitation, evaporation, soil moisture profile, layer soil moisture and water infiltration rate.

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[2] Rienecker, M., et.al. "MERRA NASA's Modern-Era Retrospective Analysis for Research and Applications", Journal of Climate, Volume 24, American Metrological Society, 2011

[3] **Molod, A., Takacs, L., Suarez, M., and Bacmeister, J.: Development of the GEOS-5 atmospheric general circulation model: evolution from MERRA to MERRA2, Geosci. Model Dev., 8, 1339-1356, doi:10.5194/gmd-8-1339-2015, 2015.**

- Daily precipitation, evaporation, infiltration, runoff, snowfall, snow mass, and snow melt.
- Monthly and annual precipitation and evaporation.
- Hourly air temperature, soil temperature at 6 layer depths, and temperature in the unsaturated zone.
- Daily statistical summaries of the hourly temperature data elements.
- Monthly and annual statistics of the daily temperature data elements plus days above 32 C, days below 0 C, freeze index, and freeze-thaw days air temperature computed parameters.
- Hourly wind velocity vectors and air density.
- Daily wind velocity statistics and average air density.
- Monthly and annual wind velocity statistics.
- Hourly specific humidity, estimated relative humidity, and air pressure.
- Daily, monthly, and annual relative humidity statistics.
- Hourly shortwave radiation at the surface, shortwave radiation at the top of the atmosphere, cloud cover, surface emissivity, and surface albedo.
- Daily, monthly and annual solar radiation and associated statistics.

Other information on MERRA data contained in the InfoPave Climate tool can be obtained from the InfoPave web site.

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.

Originally, data from both States were in one set of tables. Starting with the January 2013 data release, SDR 27, separate data storage structures are used for the North Carolina and Ohio DLR measurements. Because of errors found in the previous interpretations, the Ohio DLR data was reinterpreted in 2012. A result of this reinterpretation is a change in the data elements used to represent the Ohio DLR data. These changes were significant enough that splitting the tables containing North Carolina and Ohio data resulted in a simpler to understand data storage structure.

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

LTPP Database Tip!	Database users interested in analyzing LTPP DLR data should contact LTPP customer service before starting an analysis project to obtain advice on what data are available and other available resources to help interpret the data.

6.1. IMPORTANT FIELDS

In addition to STATE_CODE and SHRP_ID, the other 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.

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. The DLR_TEST_MATRIX tables 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.

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.

TAG_ID is the name assigned to each sensor 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 sensor manufacturer, although the DLR data storage structure is based on measurement type.

6.2. NORTH CAROLINA DLR DATA

Four PCC pavement sections on the SPS-2 project in North Carolina were instrumented to measure deflection and strain response at defined positions within the slab under loading by vehicles with known static weight and wheel geometry 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 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 conducted in August 1996.

The hierarchical relational database storage structure for North Carolina measurements are illustrated in Figure 9. Since no changes were made to interpretation of the North Carolina DLR data during the 2012 update cycle, the data reported in these tables have not been changed. Only the table names have been changed. The table fields are identical to those contained in SDR 26.

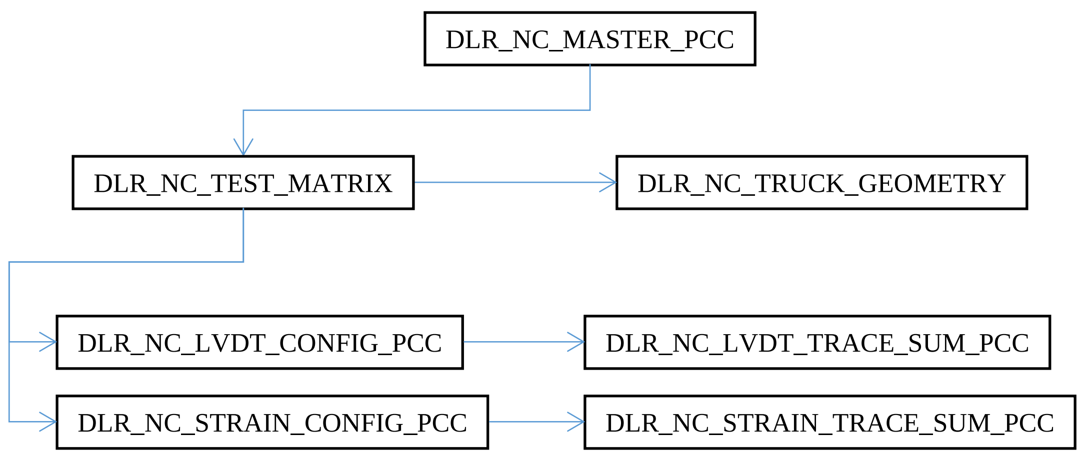


Figure 9. Schematic. Hierarchical relational database structure for North Carolina DLR measurements.

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

DLR_NC_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.

DLR_NC_TEST_MATRIX: This table contains information on each test sequence, including test date, test time, test vehicle, vehicle speed, rear axle load, and vehicle offset. TRUCK_ID and

STATE_CODE are used to link to information on truck geometry stored in the DLR_TRUCK_GEOMETRY table.

DLR_NC_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.

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

DLR_NC_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 no more than 10 points to capture the significant events in the measured response.

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

DLR_NC_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 measured response.

6.3. OHIO DLR DATA

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/PavementReports.aspx

A reanalysis of the Ohio DLR measurements was commissioned by the LTPP program in 2012 to correct problems identified in the previous analysis. Some of the changes to the Ohio DLR data structures that prompted the LTPP program to split the North Carolina and Ohio DLR measurements into different table storage structures include:

- Modification of the response sensor location data. The DLR_OH_CONFIG_* tables now contain a reference coordinate system that properly matches the relative location between DLR sensors installed at Ohio test sections. These coordinates do not contain LTPP test section specific LOC_NO, although the distance between sensors co-located on the same test section are accurate.

- The time history sensor responses were reinterpreted using the correct data collection frequency rate, more peak values were identified, sensor drift adjustment and data collection frequency factors are included in the tables.

- Strain gage orientation, which differentiates between transverse and longitudinal alignment, was added.

The hierarchical relational database storage structure for Ohio DLR measurements is illustrated in Figure 10. This relational structure is similar to the structure for the North Carolina DLR data.

The differences are that the table names start with DLR_OH; Ohio data also includes measurements on AC surfaced test sections, and pressure measurements at the interface between bound and unbound pavement layers.

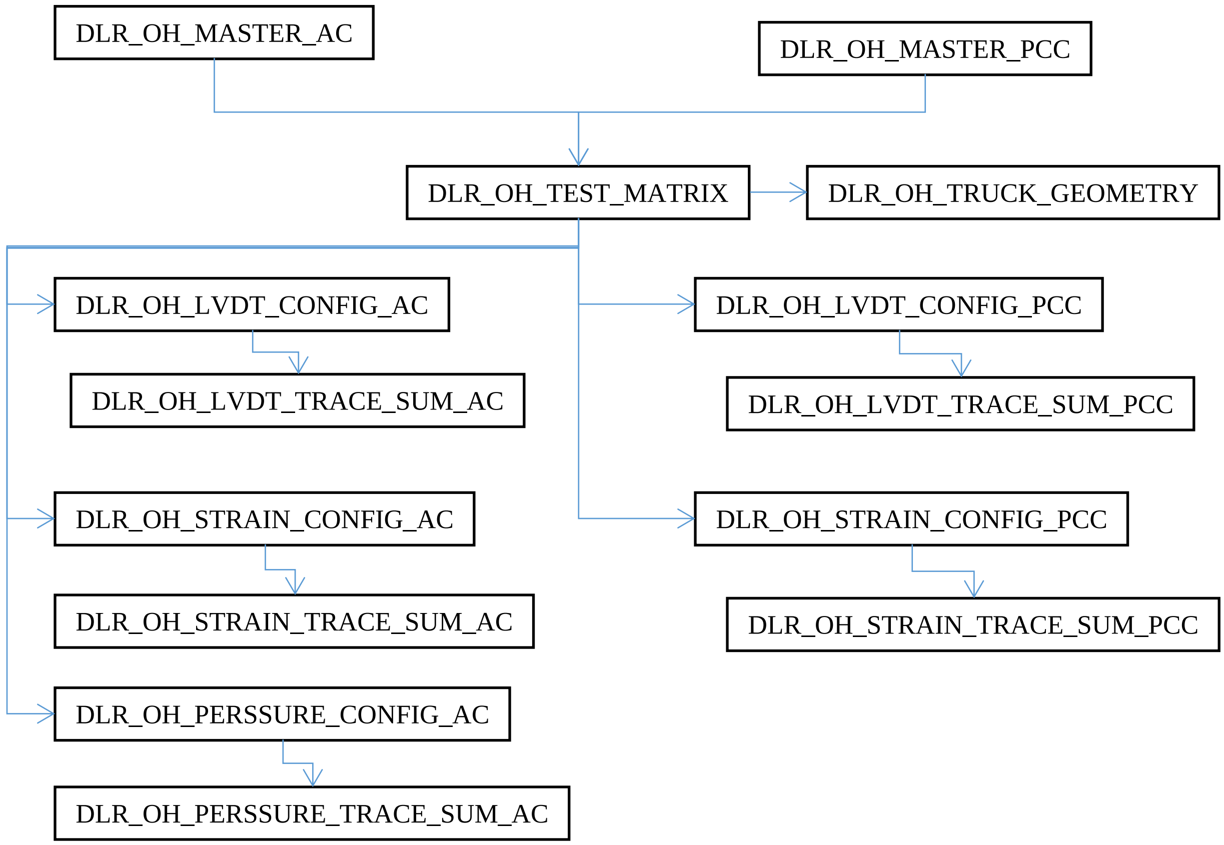


Figure 10. Schematic. Hierarchical relational database structure for Ohio DLR measurements.

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

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

DLR_OH_TEST_MATRIX: This table contains information on each test sequence, including test date, test time, test vehicle, vehicle speed, rear axle load, and vehicle offset. TRUCK_ID and STATE_CODE are used to link to information on truck geometry stored in the DLR_OH_TRUCK_GEOMETRY table.

DLR_OH_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.

DLR_OH_LVDT_CONFIG_AC: This table contains LVDT gauge settings and location information for instrumented AC surfaced test sections.

DLR_OH_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 three points that capture the significant peak points in the measured response. Both raw values which are the local maxima in the response signal and smoothed values, where the signal has been filtered to remove noise, are provided for each identified peak.

DLR_OH_STRAIN_CONFIG_AC: This table contains strain gauge information, configuration settings, sensor orientation, and location information for measurements on AC test sections.

DLR_OH_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 eight points to capture the significant peaks and valleys in the measured response. Both raw values which are the local maxima or minima in the response signal and smoothed values, where the signal has been filtered to remove noise are provided for each identified peak and valley.

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

DLR_OH_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 three points to capture the significant peaks or valleys in the measured response.

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

DLR_OH_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 three points that capture the significant peak points in the measured response. Both raw values which are the local maxima in the response signal and smoothed values, where the signal has been filtered to remove noise, are provided for each identified peak.

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

DLR_OH_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 six points to capture the significant peaks and valleys in the measured response under the moving wheel load.

CHAPTER 7. INVENTORY MODULE

The Inventory (INV) module contains information on pavement structures that were in service 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. Since a variety of sources were used to as the basis for this reported information, it should not be assumed the data in the INV module represents 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.

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.

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

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. TST_L05B is recommended for use in analysis of performance monitoring measurements as opposed to the structure data in this table. The SECTION_LAYER_STRUCTURE is a copy of the TST_L05B table and is included in each database in the SDR. Further insight into how to link the INV_LAYER and TST_L05B information is included in section 13.4.4.

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.

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. Unfortunately, there is not enough information in the table to determine with certainty whether the data is coarse, fine, or combined, but they can often be determined by evaluating the relative percent passing values.

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.

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

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.

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

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

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

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

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.

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.

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

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.

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.

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

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.

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

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

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

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

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

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.

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.

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. Layer data are recorded when the pavement structure is altered.

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, though some information on maintenance treatments applied prior to inclusion are available in MNT_IMP. The MNT tables include information such as placement of seal coats, patches, joint resealing, milling, and grooving. Unlike the RHB module, there is no significant pavement structure change from a maintenance event, and therefore no maintenance layer table exists.

Although layering information for RHB events is recorded in the RHB module, that layering information should only be used for the RHB events themselves, and not as typical section layering. Typical section layering information should be obtained from SECTION_LAYER_STRUCTURE.

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_GMG
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_*
57	Saw and seal	MNT_ASHPALT_SEAL

DATA_AVAIL_IMS in MNT_IMP and RHB_IMP indicates whether information on the maintenance or rehabilitation activity is available in other MNT, RHB, or SPS construction 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 includes 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. The information contained in the SECTION_LAYER_STRUTURE should be used when the actual as-placed thickness of each conducting analyses on long-term pavement performance; however, it may be useful when conducting a detailed analysis of individual test 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 non-recycled 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.

RHB_ACO_SP_MIX_PROP: This table contains AC SuperPave related properties of the overlay layer. In the January 2012 release, this table contains only one record with very limited population of the available fields.

RHB_ACO_SP_PROP: This table contains SuperPave related properties of the asphalt binder used in the AC overlay layer.

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. Because this is not a standard treatment option for the LTPP experiments, none of the RHB_CMRAP* tables have many records. However, in the January 2012 data release, all of the 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.

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.

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.

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 SDR.

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 likely 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 SDR.

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 (non-recycled) 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, 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 SDR. 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

All maintenance and rehabilitation events that occur on a section while it is a part of the LTPP program are documented in the RHB and MNT modules. However, information on major maintenance and rehabilitation treatments that were applied to the test section prior to its inclusion in the LTPP program will be found in **INV_MAJOR_IMP.**

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 narrower pavement width, this can result in anomalies in the time series magnitudes of the total length of traverse cracking features and distress area. The SURVEY_WIDTH field allows the user to take these width differences into account.

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.

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 that 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.

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_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. Data remaining in this table represents distress photography which was **not** reinterpreted using the PADIAS 4.2 software version.

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.

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.

In the July 2016 public data release the following tables were release which contained a reinterpretation of LTPP manually collected distress data. The distress cracking related data was reinterpreted to conform to the following guidelines:

- AASHTO MEPDG cracking distresses.
- FHWA HPMS cracking distresses defined in the 2014 HPMS Field Guide.
- Moving Ahead for progress in the 21st Century Act (MAP-21) legislation and the draft pavement Notice of Proposed Rulemaking (NPRM) cracking distresses.

To reinterpret the LTPP cracking data, the LTPP team reviewed all the manual distress crack maps that contained cracks types contained within each of the guidelines. The following tables were added which contain the newly reinterpreted cracking data:

MON_DIS_AC_CRACK_INDEX: This table contains the reinterpreted cracking data for AC surface pavements. The field names indicate the distress definition such as MEPDG, HPMS, or NPRM.

MON_DIS_CRCP_CRACK_INDEX: This table contains the reinterpreted cracking data for CRCP. The field names indicate the distress standard as MEPDG, HPMS, or NPRM.

MOIN_DIS_JPCC_CRACK_INDEX: This table contains the reinterpreted cracking data for JPCC pavements. The field names indicate the distress standard as MEPDG, HPMS, or NPRM.

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 11, the transverse elevations are adjusted to a reference line through the endpoints so that the elevations of the endpoints are zero.

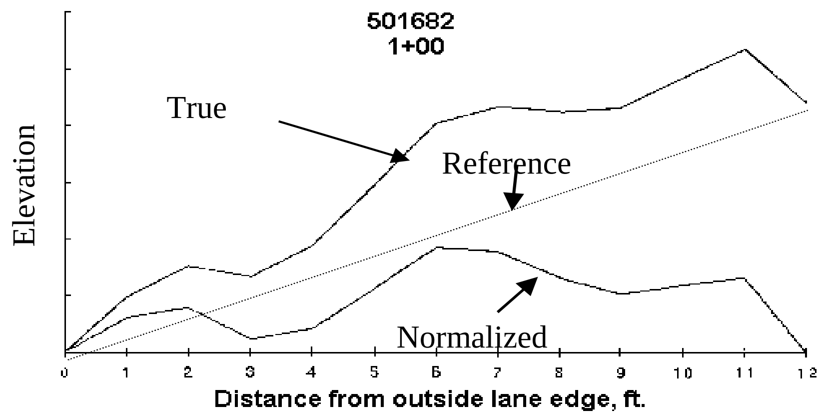


Figure 11. Illustration. Illustration of how transverse profile measurements are normalized to lane edges.

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.

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. 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 12, 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.

For the SDR-28 data release in January 2014, an updated version of the algorithm used to compute transverse pavement profile parameters was developed to replace the older program which was no longer compatible with current computer operating systems. The new program based on a 64-bit operating system resulted in some minor differences from previous results which are attributed to how significant digits in the floating point mathematical operations are represented. These minor differences are not expected to influence pavement performance models developed from previously released data.

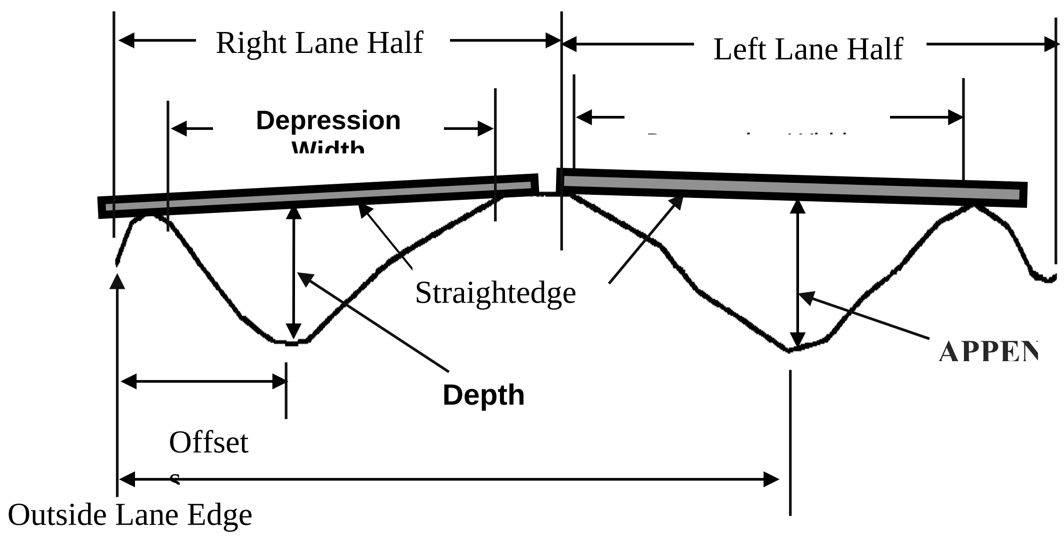


Figure 12. Illustration. Illustration of LTPP transverse pavement distortion indices based on 1.8 m (6 ft) straightedge reference.

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 13.

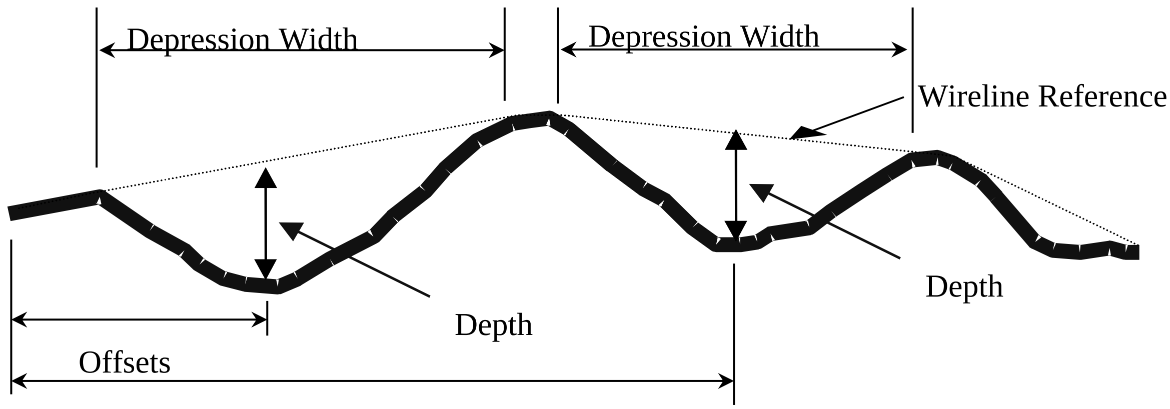


Figure 13. Illustration. Illustration of LTPP transverse pavement distortion indices based on lane-width wireline reference.

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 are available for PCC-surfaced pavements. This is an interesting data source for those interested in ruts on PCC-surfaced pavements. In 2001, the LTPP program stopped the photographic interpretation of transverse profile measurements on PCC pavements, though data is still being collected manually.

9.2.1. MON_T_PROF Tables

The relational structure of the MON_T_PROF tables is shown in Figure 14.

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.

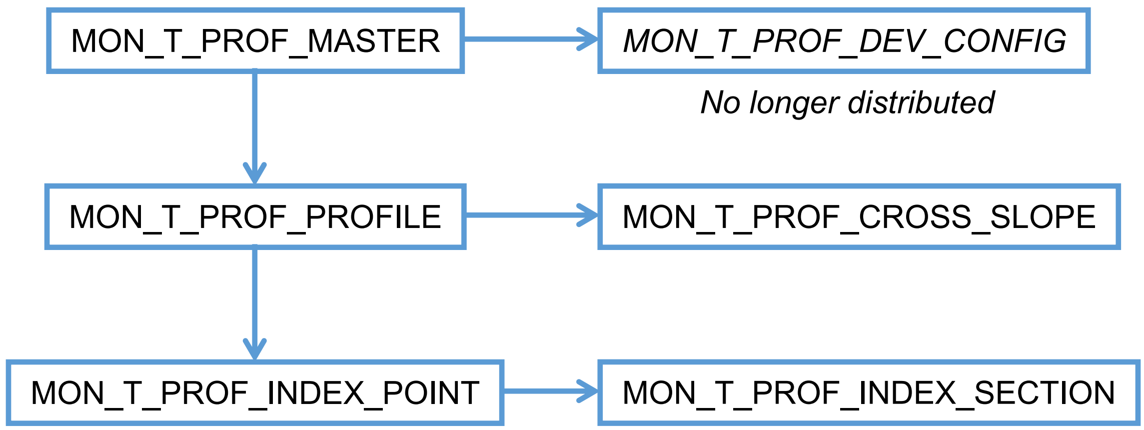


Figure 14. Schematic. Relational structure between tables in the MON_T_PROF module.

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 SDR.

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, can be computed. This table was first released in January 2005.

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

MON_RUT_DEPTH_POINT: This 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

MON_DIS_LINK: This table contains information necessary to link data in various distress tables.

MON_DIS_LINK 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 that 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_PADIAS_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 AND TEXTURE

The majority of longitudinal profile measurements are taken on LTPP test sections using inertial profilers. Throughout the history of the program, four different 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. The program transitioned to the International Cybernetics Corporation model MDR4086L3 profiler in July 2002. In 2013, the program transitioned to the AMES Engineering model 8300 Survey Pro High Speed Profiler. Each of these profilers uses 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 for most measurements taken with the other three devices. The raw data can be retrieved from InfoPave.

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.

The data from these units is stored in the MON_HSS series of tables, which completely replace the previous MON_PROFILE tables. Unlike most monitoring tables, the MON_HSS tables are primarily driven off a single key field – VISIT_NO. This value typically contains the STATE_CODE and SHRP_ID of the section, plus two characters to uniquely identify a set of runs along the section. While this naming convention allows easy identification of the section, it should be avoided for that purpose in data manipulation.

The VIST_NO key is supplemented with two other simple keys as necessary to keep uniqueness:

RUN_NUMBER represents a single pass of the survey equipment along a given section. This value is only unique to a given VISIT_NO.

STATION is used to represent the location of the individual measurements along a section. Standard section stationing is used here, with zero representing the section start.

Using these key field concepts, the MON_HSS tables are as follows:

9.4.1. MON_HSS Profile Tables

MON_HSS_VISIT_NO: This table contains information related to each high speed survey site visit. This table contains information the only MON_HSS link to STATE_CODE and SHRP_ID. It also contains the basic information that applies to the site for the entire set of runs, such as surface condition and surface finish type.

MON_HSS_RUN_NO: This table contains identification of each high speed survey run made during each visit. It includes basic identifying information such as date and time of run, as well as latitude and longitude of the section start as measured by the unit. This table also contains run specific comments and information specific to the individual pass such as surface and air temperatures.

MON_HSS_UNIT_ID: This table contains high speed survey unit identification information such as manufacturer, model number, and serial number.

MON_HSS_PROFILE_ELEVATION_25: This table contains high speed survey profile elevation data at 25mm or 25.4mm intervals. This is the highest resolution of profile data available in the LTPP database. This table is now populated with data collected prior to the introduction of the Ames profilers. This data is not available in pre-populated Microsoft® Access tables due to the number of tables required. This data is extracted on demand from InfoPave in Microsoft SQL format.

MON_HSS_PROFILE_ELEVATION_150: 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, 0.305 m (1 ft) interval measurements are collected. This data is not available in pre-populated Microsoft® Access tables due to the number of tables required. This data is extracted on demand from InfoPave in Microsoft SQL format.

MON_HSS_PROFILE_SECTION: This table contains information on the 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 calculated for each measurement pass on a section.

9.4.2. MON_HSS Texture Tables

In addition to longitudinal profile, the AMES Engineering model 8300 also collects surface texture data. This data is collected at the same time as the profile data, and therefore, the section and run identifying information is the same, and contained in MON_HSS_VISIT_NO, MON_HSS_RUN_NO, and MON_HSS_UNIT_ID.

MON_HSS_TEXTURE_SEGMENT: This table contains surface texture data such as mean segment depth and skew for both wheel paths. The units collect data at a much higher frequency (approx. 0.5 mm), and this table is an aggregation of that data to 100mm segments. This data is only collected by the Ames units, and is therefore only available starting around 2014. This data is not available in pre-populated Microsoft® Access tables due to the number of tables required. This data is extracted on demand from InfoPave in Microsoft SQL format.

MON_HSS_TEXTURE_SECTION: This table contains texture information averaged for the entire section for each wheel path.

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 15. The first three letters of the table names shown in Figure 15, which is MON, have been omitted for presentation purposes. While a distributed data storage structure can be daunting to users accustomed to flat formats, with an understanding of the relationships between these tables, the data can be reassembled into many desired formats. Example SQL scripts for building a data set for backcalculation are included in appendix C.

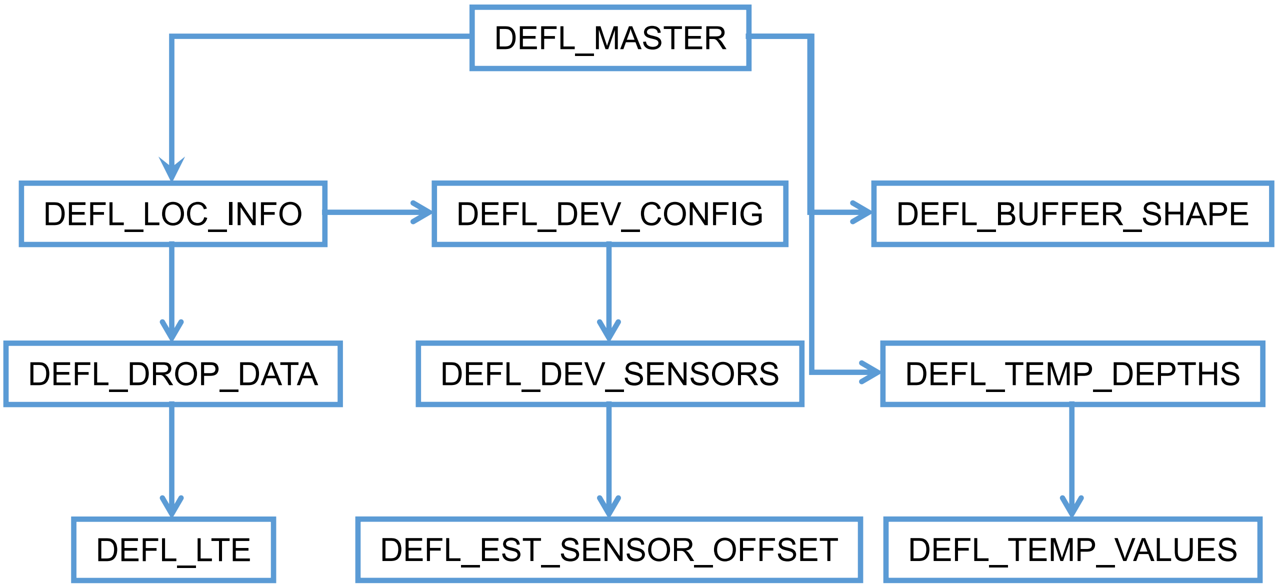


Figure 15. Schematic. Structural relationship between tables used to store FWD data.

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 the Ancillary Data Selection and Download under Data in InfoPave .

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 non-decreasing deflection pattern is detected for a basin test. This data is not available in pre-populated Microsoft® Access tables due to the number of tables required. This data is extracted on demand from InfoPave in Microsoft SQL format.

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_LTE: This table contains the Load Transfer Efficient (LTE) computed parameter. LTE is computed from FWD measurements at transverse joints and cracks on PCC pavements. The data these measurements are computed from are stored in the MON_DEFL_DROP_DATA table. LTE measurements can be identified in the MON_DEFL_DROP_DATA table using the LANE_NO field. Tests with a LANE_NO of J4 or C4 are load transfer tests where the load plate is positioned on the approach side of the joint/crack. Tests with a LANE_NO of J5 or C5 are load transfer tests with the load plate positioned on the leave side of the joint/crack.

The value of LTE is computed using the following equation:

$$LTE = \frac{d_u}{d_l} * 100\%$$

Figure 16. Equation. Load transfer efficiency.

Where,

LTE = Load transfer efficiency, %
d_u = peak measured deflection on unloaded side of joint or crack,
d_l = peak measured deflection on loaded side of joint or crack.

Restrictions on the LTE computations and reported values include:

- LANE_NO in the MON_DEFL_DROP_DATA table must be C4, C5, J4, or J5.
- Both the loaded and unloaded deflection values used in the LTE computation must be non-null and not equal to zero.
- The LTE value is less than 130%.

The MON_DEFL_LTE table does not contain a RECORD_STATUS field since the restrictions on computations provide effective quality control of the values reported in the table.

9.6. BACKCALCULATION

The BAKCAL tables contain information related to the backcalculation of material properties of layers in the pavement structure for each LTPP test section based on the deflection information available in the MON_DEFL tables. This work used the deflection data contained in the January 2013 public data release (SDR 27).

9.6.1. Backcalculation Process

The process used to perform the backcalculation is shown in Figure 17.

Three backcalculation programs were used in step 5 of the process.

- Evercalc was the primary backcalculation program used for the analyses and was used for all LTPP data and all pavement types in LTPP. The pre- and post-processing utility tools for the Evercalc analyses were fully automated. The automation process included generating the input files based on pavement simulation rules, the execution of Evercalc, and post-processing the results.
- Modcomp 6.0 was used as the auxiliary program to backcalculate results for those LTPP sections that did not yield acceptable results with Evercalc. The Modcomp analyses were semi-automated as an iterative approach and the simulated backcalculation structure was selected on a case by case basis until the results converged within the selected criteria.

- The Best Fit procedure was used to analyze LTPP sections with a PCC surface to obtain the subgrade k-value and the elastic moduli of the PCC and base layers.

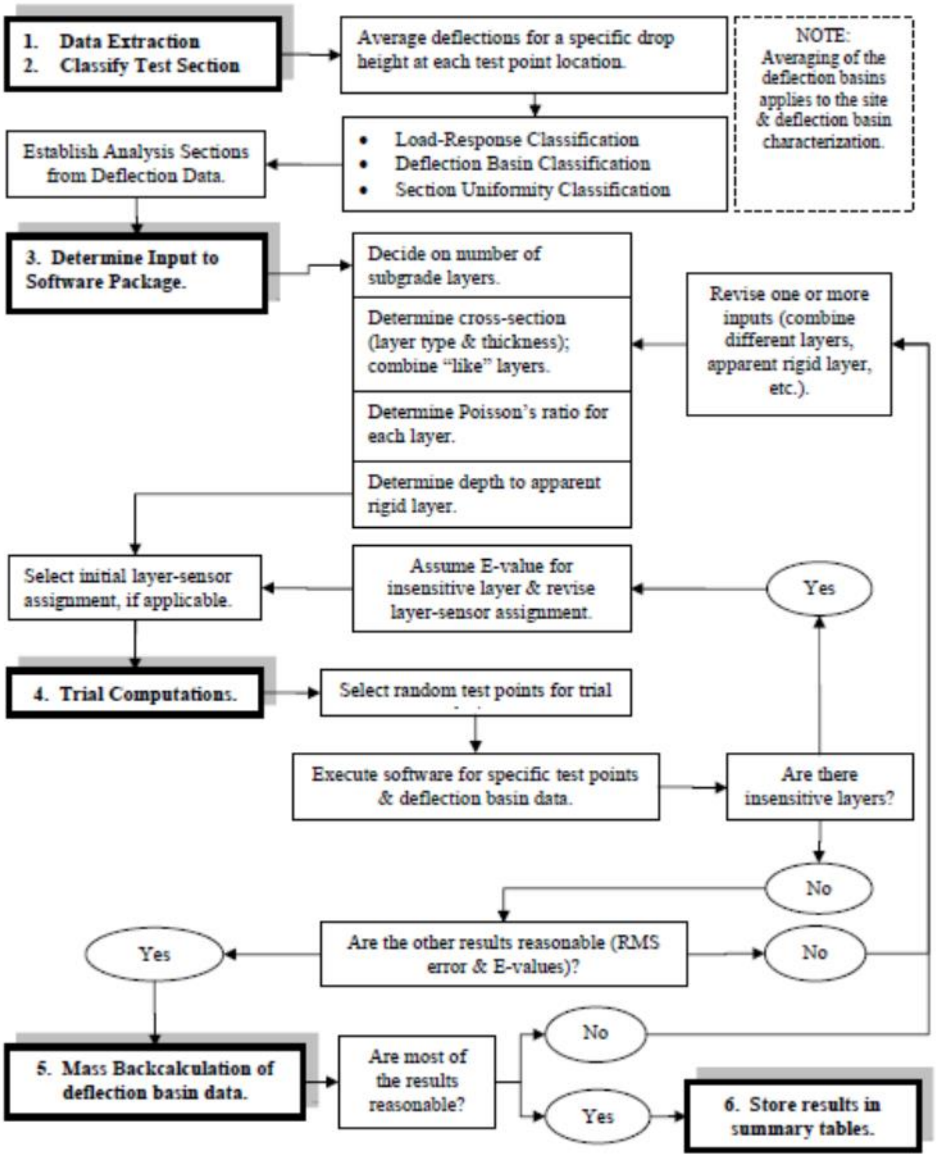


Figure 17. Schematic. Summary of backcalculation process.

References to publications documenting these analytical procedures can be found on the LTPP Web site or in the Library section of InfoPave.fhwa.dot.gov.

9.6.2. BAKCAL Tables

There are three basic types of tables in the BAKCAL data set: Identification tables, backcalculation modulus tables, and best fit modulus tables.

The identification tables primarily provide information necessary to link the data in the BAKCAL tables back to the MON_DEFL set of tables. To make the BAKCAL tables easier to use, the key fields used in the MON_DEFL tables were generally replaced with keys specific to the BAKCAL tables. The two primary BAKCAL identification tables – BAKCAL_PASS and BAKCAL_BASIN essentially establish these keys.

The key field FWD_PASS represents the level of summarization used -for section level results. It replaces the TEST_DATE, LANE_NO, and DROP_HEIGHT information in the MON_DEFL tables. It also serves to distinguish multiple runs of the same LANE_NO on the same day – a feature not present in the current set of MON_DEFL keys. This must be combined with STATE_CODE and SHRP_ID to be unique.

The key field BASIN_NO replaces the rest of the MON_DEFL keys necessary for a unique drop set in MON_DEFL_DROP_DATA, including TEST_TIME, POINT_LOC, and DROP_NO. This must be combined with STATE_CODE, SHRP_ID, and FWD_PASS to be unique.

When these two keys are combined with STATE_CODE and SHRP_ID, an individual deflection basin can be identified with four key fields in the BAKCAL tables instead of eight key fields in the MON_DEFL tables.

The five BAKCAL tables used for identification are:

BAKCAL_PASS: This table includes information specific to the highest level of aggregation used by the backcalculation team. The table retains the STATE_CODE and SHRP_ID identifiers, and uses a single key - FWD_PASS - to replace the TEST_DATE, LANE_NO and DROP_HEIGHT fields used in MON_DEFL. Additionally, it identifies the backcalculation structure used in the process with the BC_STRUCTURE_NO field.

BAKCAL_BASIN: Using the same concepts as PASS, this table further defines items specific to each individual drop in MON_DEFL. BASIN_NO is used to replace TEST_TIME, POINT_LOC, and DROP_NO used in the MON_DEFL tables. This table also contains basin specific information such as drop load, temperature information, and a basic basin type identifier.

BAKCAL_STRUCTURE_LAYERS: This table contains information on the type and thickness of the layer structure used for backcalculation purposes. The layer types are identified by a set of codes unique to backcalculation tables, based on a classification system developed for the effort that is less specific than those used elsewhere in the database, such as TST_L05B. The layer numbering is also different that most of the rest of the database, in that layer 1 is the surface, and the layer numbers increase with depth.

BAKCAL_BEST_FIT_LAYERS: This table contains information on the type and thickness of the layer structure used for the best fit backcalculation purposes. The type codes are the same as those used for BAKCAL_STRUCTURE_LAYERS. Because the layering for the best fit process is fixed, the layers are not identified by layer number, but instead layer type, which is always either PCC or BASE.

BAKCAL_LAYER_LINK: This table provides the link between the layering system used for backcalculation, and TST_L05B – the layering system used in most of the rest of the database. In addition to providing the link, this table identifies whether the structure of the section has been significantly changed since the backcalculation effort took place. For this purpose, a difference of 0.5 inches has been chosen to represent a significant thickness change. Any change that has occurred is identified in the SIGNIFICANT_STRUCTURE_CHANGE field, which identifies the nature and extent of the difference.

The backcalculation modulus tables are presented at the basin and section level, and divided into a master and layer table for each. The section level tables are aggregated to the FWD_PASS level.

BAKCAL_MODULUS_BASIN_LAYER: This table contains backcalculated modulus values for each measured deflection basin.

BAKCAL_MODULUS_BASIN_MASTER: This table contains backcalculation fit and quality measures for each deflection basin. ERROR_STATUS is the major indicator of quality in this table, and is based on the RMSE of the fit, as well as whether the modulus is considered acceptable for the designated material type.

BAKCAL_MODULUS_SECTION_LAYER: This table contains backcalculated modulus values averaged for each FWD_PASS. Only data that has an ERROR_STATUS = 1 or 2 in the BASIN table is aggregated in the SECTION table. This means that occasionally, there is no section level entry for an FWD_PASS.

BAKCAL_MODULUS_SECTION_MASTER: This table contains information on the number of basins aggregated, the average RMSE, depth to rigid layer (if it exists), and the backcalculation program used to provide the results.

The best fit modulus tables follow the same concepts as the backcalculation modulus tables, but only apply to the PCC sections to which the best fit process was applied. Because the process has a defined layer structure, the results are not assigned to a specific layer number, but either the PCC or base layer.

BAKCAL_BEST_FIT_BASIN_LAYER: This table contains best fit backcalculation modulus values for each deflection basin.

BAKCAL_BEST_FIT_BASIN_MASTER: The table contains the primary quality indicator, ERROR_STATUS, same as the corresponding MODULUS table. It also contains a composite modulus and k-value for the section, as well as information on the beta factor assigned to the section (used to determine the modulus split for the layer structure chosen).

BAKCAL_BEST_FIT_SECTION_LAYER: This table contains best fit backcalculated modulus values for each FWD_PASS. Only data that has an ERROR_STATUS = 1 or 2 in the BASIN table is aggregated in the SECTION table. This means that occasionally, there is no section level entry for an FWD_PASS.

BAKCAL_BEST_FIT_SECTION_MASTER: This table contains section averaged values of the information provided in the corresponding BASIN table. It also contains a code identifying the subgrade layer type assigned to the section.

In addition to this current set of backcalculation data, there is was a prior backcalculation analysis performed with the data available in 1997. 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.

9.7. FRICTION

The Friction submodule includes only the MON_FRICTION table. Because of the proprietary 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.

MON_FRICTION: This table contains the results of friction tests on pavement sections where the State/Provincial highway agency was willing to provide the data.

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, “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 the 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: This table contains the results of the estimated hydraulic conductivity of the subsurface permeable drainage layer and outflow structures on SPS-1 and -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_DRAIN_PERM_MEAS table using only the 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.

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.

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).

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.

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.

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.

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*.

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 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.

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 are contained in the report *LTPP Computed Parameter: Moisture Content,* Publication Number: FHWA-HRT-08-035 LTPP.

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 are contained in the report *LTPP Computed Parameter: Moisture Content,* Publication Number: FHWA-HRT-08-035 LTPP.

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.

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.

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

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.

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.

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.

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.

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.

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.

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.

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.

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.

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.

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 Parameter: Frost Penetration* Publication No. FHWA-HRT-08-057.

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.

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 of the pavement surface. In many cases, the observation well did not extend to the water table.

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.

10.6. SURFACE ELEVATION DATA

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

SMP_ELEV_AC_DATA: This table contains surface elevation measurements for asphalt-surfaced SMP sections. At each longitudinal location, elevation measurements were 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.

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.

SMP_ELEV_PCC_DATA: This table contains surface elevation measurements for PCC-surfaced SMP sections. At each longitudinal location, elevation measurements were 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.

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

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 was conducted, joint faulting was 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.

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

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 was 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.

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

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.

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 affected data is stored.

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 some -9 experiments, while SPS-3, -4, -5, -6, -7, and some -9 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; the exception is construction data from the SPS-10 experiment in SDR-29 that are located in other data modules.

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 most 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 by 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.

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.

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.

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.

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.

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.

This table used to contain the latitude and longitude coordinates of SPS project sites, but they were removed from this table as of data release 22.

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.

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. Test sections collocated at a SPS project site have the same PROJECT_ID. The first test section in the direction of traffic flow is assigned an ORDER_NO of 1 and SECTION_START has a value of zero. All other SECTION_END and SECTION_START values represent travel distances in meters from the zero location. On SPS project sites where test sections with the same PROJECT_ID have test sections located in both directions of travel, two test sections will be assigned an ORDER_NO of 1 and SECTION_START equal to zero; in this case the DIRECTION_OF_TRAVEL field is needed to discern which side of the road the test sections are located.

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

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.

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 1 to 9. There are no SPS-10 tables.

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 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.

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.

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.

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.

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.

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.

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.

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.

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.

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.

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.

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.

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.

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.

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

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

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

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, - and -9 test sections. Since there are no data stored in the SPS8_PCC_FULL_DEPTH table it is not included in the SDR.

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.

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.

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.

SPS#_TRANSFER_EFFICIENCY: This table contains data on the load-transfer efficiency of transverse joints within SPS-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 SPS7_TRANSFER_EFFICIENCY table it is not included in the SDR.

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.

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.

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.

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

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.

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.

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.

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.

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

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.

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

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.

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

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.

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

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.

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.

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.

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

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

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

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

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

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.

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.

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.

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.

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.

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.

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

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.

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.

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

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

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

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

SPS5_AC_PATCHES: This table contains AC patching data collected at test sections in the SPS-5 experiment. 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.

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.

SPS5_RUT_LEVEL_UP: This table contains data on applications of leveling treatments to correct severe rutting on SPS-5 test sections prior to the application of a PMA overlay.

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.

SPS6_UNDERSEALING: This table contains general undersealing data for work done on SPS-6 test sections prior to the application of a rehabilitative overlay.

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.

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

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.

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.

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

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.

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

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

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

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.

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.

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.

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

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

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

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

11.5. SPS-10 CONSTRUCTION DATA

In the July 2016 public data release, data from test sections included in SPS-10 experiment were contained in the tables described in this portion of the document. Unlike data from previous SPSA experiments, data from the SPS-10 sections were consolidated into a common set of construction tables that do not contain a module identifier in the table name. Data contained in Inventory and SPS construction tables for previous SPS experiments have been consolidated into the following tables. The future vision of these tables implemented as part of the SPS-10 project, is to use them as the basis to consolidate data from all of the previous test sections into a simpler and more compact database structure. Accessing data through the InfoPave interface will provide access to similar data stored in separate tables.

PROJECT_ID: This table contains general project and layout information. It is similar to the information contained in the SPS_ID table.

PROJECT_STATIONS: This table can be used as a link between 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 first test section in the direction of traffic flow is assigned an ORDER_NO of 1 and SECTION_START has a value of zero. All other SECTION_END and SECTION_START values represent travel distances in meters from the zero location. Test sections collocated at a SPS project site have the same PROJECT_ID.

PROJECT_INTERSECTIONS: This table contains project-level intersection information and data on the location of ramps, signals, and stop signs within the project boundaries. It is similar to the SPS_PROJECT_INTERSECTIONS table.

SECTION_GENERAL: This table contains information on road geometry, lane width, speed limit, and median properties for each test section.

SECTION_DRAINAGE: This table includes information specific to drainage features of each test section.

SECTION_SHOULDER: This table contains information related to shoulder details on each test section.

SECTION_CONST_LAYER: This table contains data elements relating to the original constructed pavement structure.

PROJECT_HIST_AGE: This table contains significant event dates for activities that occurred prior to the project being accepted into the LTPP program for current construction and monitoring purposes. It is similar to the INV_AGE table.

PROJECT_MAJOR_IMP: This table is similar to the INV_MAJOR_IMP table in that it contains information on construction, rehabilitation, maintenance and preservation events from agency records that occurred prior to the project being accepted into the LTPP program for current construction and monitoring purposes.

DEICING_FREQUENCY: This table is similar to INV_DEICE_SITE_DATA in that it contains information on the frequency of snow removal and deicing chemical applications.

DEICING_TYPES: This table contains information on the types of deicing chemical used on a test section. It is similar to the INV_DEICE_TABLE.

SECTION_HPMS: This is a new table that is design to capture pavement related data elements specified in the HPMS data input guidelines.

AC_AGGR_COMP: This table contains information on the types and composition of aggregates contained in AC layers.

AC_AGGR_DUR: This table contains information on aggregate durability. It is similar to the INV_AGGR_DUR table.

AC_AGGR_PROP: This table includes physical properties of materials used as aggregate in AC mixtures. It includes properties such as bulk, effective, and maximum specific gravities, mineral fillers, recycled asphalt shingles, and absorption values.

AC_AGGR_SP_PROP: This table contains AC aggregate properties derived from SuperPave research and development activities. This table is similar to the RHB_ACO_SP_AGGR_PROP table.

AC_AGGR_GRADATION: This table contains aggregate gradation information on a weight basis passing specified sieves, classified by test section, layer number, and aggregate type.

AC_BINDER: This table contains general classification properties of AC binders including PG, penetration, viscosity, ductility, and other measures of asphalt cement used during the last 30 years.

AC_MODIFIER: This table is a copy of the INV_MODIFER table that contains data on the types and amounts of asphalt cement modifiers.

AC_AGED_BINDER: This table contains properties of the binder used in AC mixtures after aging.

AC_DSR: This table contains Dynamic Shear Rheometer, Bending Beam Rheometer, and Direct Tension tests for binders used in AC mixtures.

AC_AGGR_RECYCLED: This table contains type and storage information for recycled aggregates used in AC mixtures.

AC_LAB_MIX: This table contains laboratory mix design for AC mixtures.

AC_LAB_MIX_RECYCLE: This table contains laboratory mix design properties specific to recycled AC mixtures.

AC_LAB_MIX_WARM: This table contains laboratory mix design properties specific to warm mix AC mixtures.

AC_MIXTURE: This table contains AC mixture properties as placed.

AC_ANTISTRIPPING: This table contains AC antistripping agent information.

AC_SP_MIXTURE: This table contains AC Superpave mixture properties as placed.

AC_PLACEMENT: This table contains placement information for AC layers.

AC_CONSTRUCTION_TEMPS: This table contains construction temperature data for AC layers.

AC_COMPACTION: This table contains compaction data for AC layers.

AC_ROLLER: This table contains compaction equipment data for AC layers.

UNBOUND_STABIL: This table contains unbound layer stabilizing agent data.

UNBOUND_LAYER_PROP: This table contains unbound or stabilized base or subbase layer properties.

UNBOUND_GRADATION: This table contains unbound or stabilized base or subbase layer gradation information.

SUBGRADE_LAYER_PROP: This table contains subgrade layer properties.

AC_DENSITY_MEAS: This table contains AC layer density data used for construction quality control.

AC_PROFILE_MEAS: This table contains AC layer profile data used for construction quality control.

SECTION_FIELD_THICK_MEAS: This table contains field layer thickness measurements from time of construction at different stations.

SECTION_CONSTRUCTION_NOTES: This table contains section notes and comments.

AC_MILLING: This table contains information on AC milling operations.

CONSTRUCTION_EVENTS: This table contains improvement information - maintenance and rehabilitation events.

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-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 interested 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. Chapter 16 of this document contains descriptions of the LTAS database structure and tables included in the SDR.

To serve the needs of data users still interested in the AASHO equivalent single axle pavement loading concept, a computer program called ESALCalc was created. This software computes annual (equivalent single-axle load) ESAL estimates from traffic monitoring data and pavement structure data following the most recent guidelines for inclusion in the PPDB.

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 PPDB 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.

VEHICLE_CLASS refers to the 13-bin vehicle classification system (Table 4) described in the FHWA *Traffic Monitoring Guide* (TMG). (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 13) 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. TMG13-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

AXLE_GROUP is a variable that defines the type of axle or axle group (single, tandem, triple, or quad-plus). 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.

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.

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 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.

On SPS sites, the estimates are provided using a project level SHRP_ID for some monitored tables. In most cases it is a good assumption that the project level traffic applies to all test sections on the project. For sites that have sections located in both directions of travel, this it likely not the case. These sites can be identified by using SPS_PROJECT_STATIONS.

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

TRF_CALIBRATION_AVC: This table contains information on the calibration of automated vehicle classification (AVC) equipment.

TRF_CALIBRATION_WIM: This table contains information on the calibration of WIM equipment installed for a test section.

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

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.

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.

TRF_HIST_EST_ESAL: This table contains estimates of 80-kN (18-kip) ESALs at the section for each year from construction (or 1965, whichever is later) to its inclusion in the LTPP program (or 1989, whichever is earlier).

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.

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

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-plus). This information is obtained from 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. This distribution is for the LTPP lane only.

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.

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 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 that 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 should 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.

Other traffic monitoring data are contained within the PPDB and LTAS tables 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 monitored traffic data.

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

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. For sites that have sections located in both directions of travel, this it likely not the case. These sites can be identified by using SPS_PROJECT_STATIONS.

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 and 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 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 truck 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 truck class.

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

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.

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.

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.

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 with more than 210 days of WIM 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.

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.

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.

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. This table contains data for sites with at least 210 days of classification data in a calendar year that were validated or calibrated under LTPP contract.

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.

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.

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 the Reference Library 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.

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.

TRF_ESAL_AC_THICK: This table contains the values used to compute the structural number (SN) 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 for which these values apply.

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.

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

- The pavement type and its source.
- 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.

12.5. OTHER TRAFFIC COMPUTED PARAMETERS

The July 2017 public data release included for the first-time computed parameters and supporting information for normalized axle load spectra (NALS) and the Relative Pavement Performance Impact Factor (RPPIF).

NALS are percentile distributions of axle type count by load range[4]. Individual NALS are computed for each axle type by truck class. The axle types included in the NALS computed parameter tables include single, tandem, tridem and quad. These are computed for the vehicle classes 4 through 13 from the FHWA vehicle classification scheme. NALS are the basic traffic loading input for pavement designed based on the MEPDG and AASHTOWare Pavement-ME Design software. The computations contained in the NALS tables are not limited to the restrictions placed on similar computations contained in the TRF_MEPDG tables.

[4] Selezneva, O. I. and M. Hallenbeck, *Long-Term Pavement Performance Pavement Loading User Guide (LTPP PLUG)*, FHWA-HRT-13-089, Federal Highway Administration, https://www.fhwa.dot.gov/publications/research/infrastructure/pavements/ltpp/13089/13089.pdf, accessed June 8, 2014.

The RPPIF is a summary statistic for comparison and grouping of similar NALS[5]. This statistic converts NALS into a single value, considering both the frequency of load applications and the relative effect load magnitude on pavement performance. The intent of the RPPIF is to allow for simple summary comparisons of the damaging potential of different NALS. It is not intended as a direct input into pavement performance analysis models. The RPPIF computation is based on a W_{ij} weighting damage factor where i represents a load bin range and j represents the axle group type. Because the W_{ij} factors, which are inputs into the computations based on LTPP research, were developed based on the outcome from many distress models, these factors represent a general potential pavement damage factor that is not based on pavement structure. The RPPIF parameter is computed by multiplying the W_{ij} factor by the corresponding normalized axle load spectra bin, and then summing the products for each axle group and truck class.

The database computation process required for the creation the NALS computed parameters resulted in a series of VEHICLE_CLASS intermediate computations that are released to the public in the form of database tables. These tables contain the related vehicle classification summary statics required for the NALS computations. The tables include estimates of the average number of axles by axle group and vehicle class for both monthly and annual intervals. Other computations result in the average number of trucks by vehicle class by month or year to use in creating estimates of the relative impact of truck populations (greater or lesser) on pavement performance. In comparison to similar tables in the TRF_MEPDG set (TRF_MEPDG_AX_PER_TRUCK and TRF_MEPDG_AADT_LTPP_LN) these values are count-based without expansion to address missing days and are generated for all available weight data information in the PPDB not just the LTPP lane.

[5] Seleznava, O.H, M. Ayres, H. Hallenbeck, A. Ramachandran, H. Shirazi, and H. Von Quintus, *MEPDG Traffic Loading Defaults Derived from Traffic Pooled Fund Study*, FHWA-HRT-13-090, Federal Highway Administration, April 2016. https://www.fhwa.dot.gov/publications/research/infrastructure/pavements/ltpp/13090/13090.pdf , last accessed April 2017.

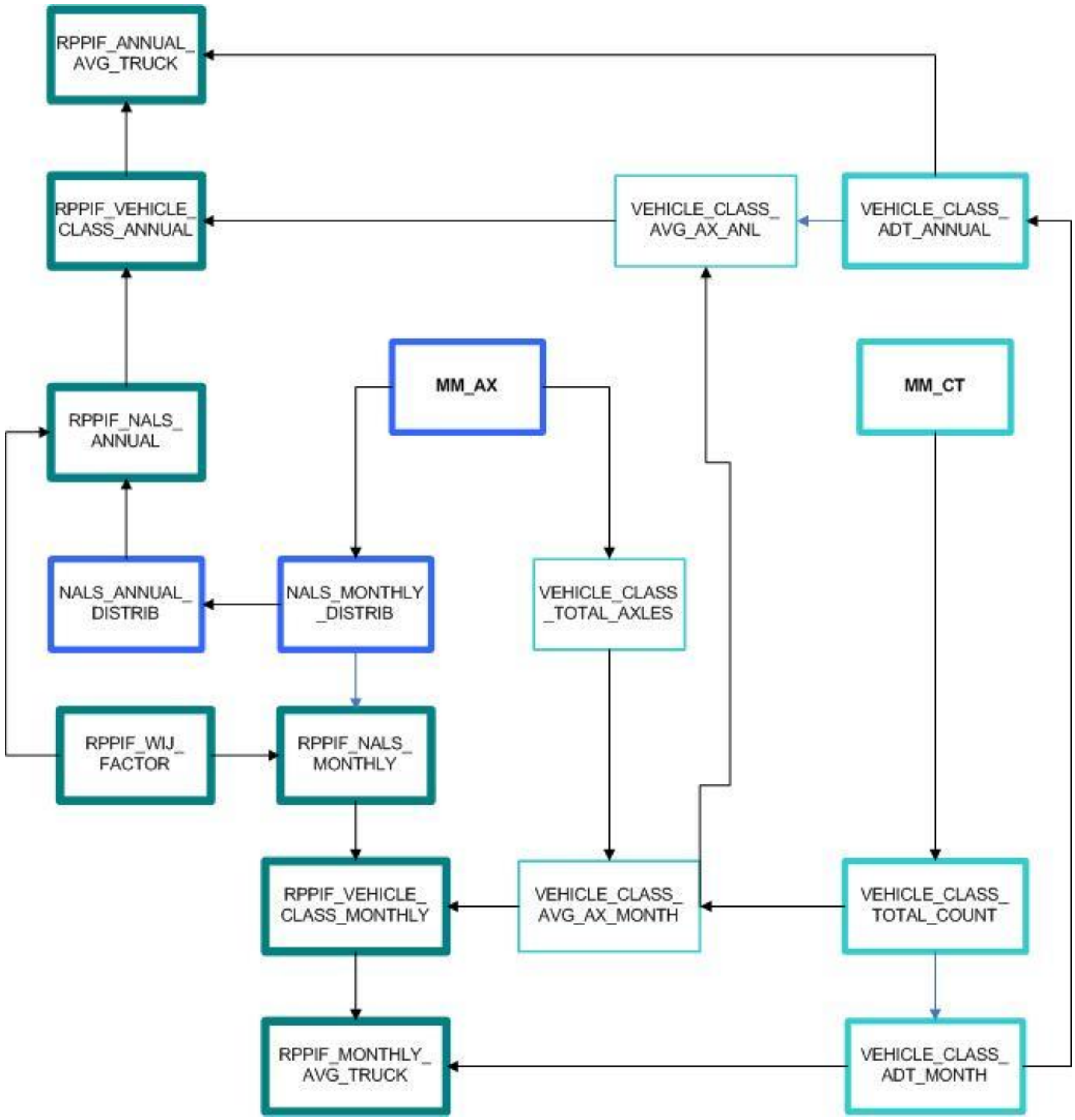


Figure 18 Schematic. Relationships between LTAS core tables and NALS and RPPIF computed parameters.

12.5.1. NALS Tables

NALS_MONTHLY_DISTRIB: This table contains the monthly normalized axle load spectra (NALS) for each axle type by truck class for each lane and direction. The distribution is derived from the information in MM_AX that is used to create the annual estimated distribution in TRF_MONITOR_AXLE_DISTRIB. The NALS for any given combination of STATE_CODE, SHRP_ID, YEAR, MONTH, LANE_TRF, DIR_TRF, VEHICLE_CLASS and AXLE_GROUP is adjusted to sum to 100. Rounding in the computation of the individual axle bin values may result in sums that are slightly different from this value.

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 for each site defined by STATE_CODE, SHRP_ID, YEAR, MONTH, LANE_TRF, DIR_TRF,VEHICLE_CLASS, and AXLE_GROUP.

NALS_ANNUAL_DISTRIB: This table contains the annual NALS for each axle type by truck class for each lane and direction. The distribution is the average of the available monthly NALS adjusted so that the sum of the distribution is 100. Rounding in the computation of the adjustment may result in a sum that is slightly different from 100.

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 for each site defined by STATE_CODE, SHRP_ID, YEAR, LANE_TRF, DIR_TRF, VEHICLE_CLASS, and AXLE_GROUP.

NALS_MONTHLY_EVAL: This table contains the results of applying a set of QC checks to the tails of Class 9 single and tandem monthly NALS. The checks are looking for larger than expected percentages of light or heavy axles. The thresholds are based on work done in development of the PLUG software and review of other calibrated weigh-in-motion sites in LTPP's PPDB. The thresholds are shown in Table 5. The checks are done in the order of light single axles, heavy single axles, light tandem axles and heavy tandem axles with the first check failed identified in the table in NALS_EVAL.

Table 5. Tail conditions for rational axle distributions (Class 9s).

Axle Group	Maximum Allowable Percentage Light Axles	Maximum Allowable Percentage Heavy Axles
Single	10 percent 4,999 lb or lighter	10 percent 21,000 lb or heavier
Tandem (US)	10 percent 7,999 lb or lighter	20 percent 34,000 lb or heavier
Tandem (Canada)	10 percent 7,999 lb or lighter	20 percent 38,000 lb or heavier

NALS_ANNUAL_EVAL: This table contains the results of applying a set of QC checks to the tails of Class 9 single and tandem annual NALS. The checks are looking for larger than expected percentages of light or heavy axles. The thresholds and check sequence are the same as for NALS_MONTHLY_EVAL. The first check failed is identified in the table in NALS_EVAL_ANL.

12.5.2. RPPIF Tables

The RPPIF tables allow comparison of loading distributions between months, years, lanes or sites at the level of axle group by vehicle class, vehicle class or truck population. The comparison indicates which distribution has a greater impact on pavement performance.

The key fields in each computed value table include STATE_CODE, SHRP_ID, YEAR, LANE_TRF, and DIR_TRF at a minimum.

RPPIF_WIJ_FACTOR: This table contains the W_{ij} factors for each axle bin by axle group. The key fields in this table are AXLE_GROUP and WEIGHT_BIN_LOW, the weight of the lightest axle included in the bin.

RPPIF_NALS_MONTHLY: This table stores the RPPIF value for a specific axle group and vehicle class by year, month, lane and direction. This is the fundamental table from which all other RPPIF_MONTHLY tables are derived. The value of RPPIF is computed using the W_{ij} factors and NALS_MONTHLY_DISTRIB and summed across all axle bins.

RPPIF_VEHICLE_CLASS_MONTHLY: This table stores the RPPIF value associated with an individual vehicle class by year, month, lane and direction. This value allows comparison of vehicles of the same class by lane, direction, month or site as having more or less impact on pavement performance as the same vehicle class at another location. The VEHICLE_CLASS_RPPIF value is computed by weighting the RPPIF value by the average number of axles per truck in VEHICLE_CLASS_AVG_AX_MONTH and summing the result.

RPPIF_MONTHLY_AVG_TRUCK: This table stores the RPPIF value associated with a truck population by year, month, lane and direction. This value allows comparison of truck populations by lane, direction, month or site as having more or less impact on pavement performance as the truck population at another location. The TRUCK_RPPIF value is computed weighting the VEHICLE_CLASS_RPPIF values using VEHICLE_CLASS_ADT_MONTH.

RPPIF_NALS_ANNUAL: This table stores the RPPIF value for a specific axle group and vehicle class by year, lane and direction. This is the fundamental table from which all other RPPIF_ANNUAL tables are derived. The value of ANNUAL_RPPIF is computed using the W_{ij} factors and NALS_ANNUAL_DISTRIB and summed across all axle bins.

RPPIF_VEHICLE_CLASS_ANNUAL: This table stores the RPPIF value associated with an individual vehicle class by year, lane and direction. This value allows comparison of vehicles of the same class by lane, direction, or site as having more or less impact on pavement performance as the same vehicle class at another location. The VEHICLE_CLASS_RPPIF_ANL value is computed by weighting the RPPIF value by the average number of axles per truck in VEHICLE_CLASS_AVG_AX_ANL and summing the result.

RPPIF_ANNUAL_AVG_TRUCK: This table stores the RPPIF value associated with a truck population by year, lane and direction. This value allows comparison of truck populations by lane, direction, or site as having more or less impact on pavement performance as the truck population at another location. The ANNUAL_TRUCK_RPPIF value is computed weighting the VEHICLE_CLASS_RPPIF_ANL values using VEHICLE_CLASS_ADT_ANNUAL.

12.5.3. VEHICLE_CLASS Tables

The VEHICLE_CLASS tables were computed primarily to speed up computation of the RPPIF tables for vehicle classes and truck populations. The provide insight into the size of the vehicle class populations and numbers of axles contributing to the NALS and RPPIF values.

VEHICLE_CLASS_TOTAL_AXLES: This table stores the total number of axles by year, month, lane, direction, vehicle class and axle group.

VEHICLE_CLASS_TOTAL_COUNT: This table stores the total number of vehicles by class by year, month, lane and direction. This table uses the counts associated with weight data in the MM_CT table as the input.

VEHICLE_CLASS_AVG_AX_MONTH: This table stores the average numbers of axles by axle group for each vehicle class by year, month, lane and direction. This table is similar to TRF_MEPDG_AX_PER_TRUCK except that it is a monthly table and does not have a minimum number of days of data requirement. It is used to compute VEHICLE_CLASS_RPPIF in the RPPIF_VEHICLE_CLASS_MONTHLY table.

VEHICLE_CLASS_ADT_MONTH: This table stores the average daily traffic by vehicle class, year, lane and direction using VEHICLE_CLASS_TOTAL_COUNT as an input. This table is similar to TRF_MEPDG_AADTT_LTPP_LN but is a monthly table and no estimation process is applied to account for missing days of data in the month. This table is used to compute RPPIF_MONTHLY_AVG_TRUCK.

VEHICLE_CLASS_AVG_AX_ANL: This table stores the average numbers of axles by axle group for each vehicle class by year, lane and direction. This table is similar to TRF_MEPDG_AX_PER_TRUCK except that it does not have a minimum number of days of data requirement. It is used to compute VEHICLE_CLASS_RPPIF_ANL in the RPPIF_VEHICLE_CLASS_ANNUAL table.

VEHICLE_CLASS_ADT_ANNUAL: This table stores the average daily traffic by vehicle class, year, lane and direction using VEHICLE_CLASS_ADT_MONTH as an input. This table is similar to TRF_MEPDG_AADTT_LTPP_LN but no estimation process is applied to account for missing days of data in the year and there is no minimum number of days of data requirement. This table is used to compute RPPIF_ANNUAL_AVG_TRUCK.

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 beginning 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 6. 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	Resilient Modulus, Tensile Strength, and Creep	P07
Asphalt Concrete	SP01	Gyratory Compaction	(4)
Asphalt Concrete	SP02	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(1)	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	(3)
SPS-3 and -4	SC02	Plastic Fines in Graded Aggregates by Use of Sand Equivalency Test	(3)
SPS-3 and -4	SC03	Testing Crushed Stone for Single Bituminous Surface Treatments	(3)
SPS-3 and -4	SC04	Determination of Flakiness Index of Aggregates	(3)
SPS-3 and -4	SC05	Testing of Slurry Seal	(3)
SPS-3 and -4	SC06	Measurement of Excess Asphalt in Bituminous Mixtures by Use of Loaded Wheel and Sand Cohesion	(3)
SPS-3 and -4	SC07	Wet Stripping Test for Cured Slurry Seal Mixes	(3)
SPS-3 and -4	SC08	Determination of Slurry System Compatibility	(3)
SPS-3 and -4	SC09	Mixing, Setting, and Water-Resistance Test to Identify Quick-Set Emulsified Asphalts	(3)
SPS-3 and -4	SC10A	Aggregate Gradation of Chip Seals	(3)
SPS-3 and -4	SC10B	Aggregate Gradation of Slurry Seals	(3)
SPS-3 and -4	SC11	Chip Seal Mix Design	(3)
SPS-3 and -4	SC12	Determination of Asphalt Content From Slurry Seal Sample	(3)
SPS-3 and -4	SC13	Polish Value of Chip Seal Aggregates	(3)
SPS-3 and -4	CS01	Properties of Hot-Poured Joint Sealants	(3)
SPS-3 and -4	CS02	Properties of Silicone Joint Sealants	(3)

Notes:

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

2 Data are limited; no more data expected.

3 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.

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 FIELD_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.

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 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.

LAB_CODE is a code field of the type LAB_CODE that identifies the laboratory that conducted the test of interest. Because of the size of 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.

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 from tests performed as part of the LTPP program are stored in the TST module. Additional materials characterization data are stored in the INV, RHB, MNT, and SPS# modules; however, applicability of this data to specific test section locations in unknown due to the general, project level, nature of this information.

13.4.1. Test Results Tables

Tables containing the results for specific tests can be identified based on the test designations shown in Table 6. 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.

Most TST tables have a primary key that consists of many fields. Typically the key is at least STATE_CODE, SHRP_ID, LAYER_NO, FIELD_SET, TEST_NO, and LOC_NO. SAMPLE_NO is also a key field in many of the tables, but should not be relied on for uniqueness.

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 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.

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.

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).

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).

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.

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 records will contain missing values for some fields due to the experimental nature of the tests that 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 13.4.6 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 records will contain missing values for some fields due to the experimental nature of the 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 13.4.6 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 13.4.6 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 SDR.

TST_AC07 involves multiple tests on three specimens. The analytical procedures employ complex 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 19. Protocol P07 is also similar to AASHTO TP9-96 with regards to the creep compliance and indirect tensile strength portions.

TST_AC07_V2_SPECIMEN_INFO: This table is considered the master table for a TST_AC07_V2 submodule. This table also includes the sample numbers for the three specimens used (SAMPLE_NO_*), thickness information (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 TEST_TEMPERATURE since this test is conducted at three different temperatures.

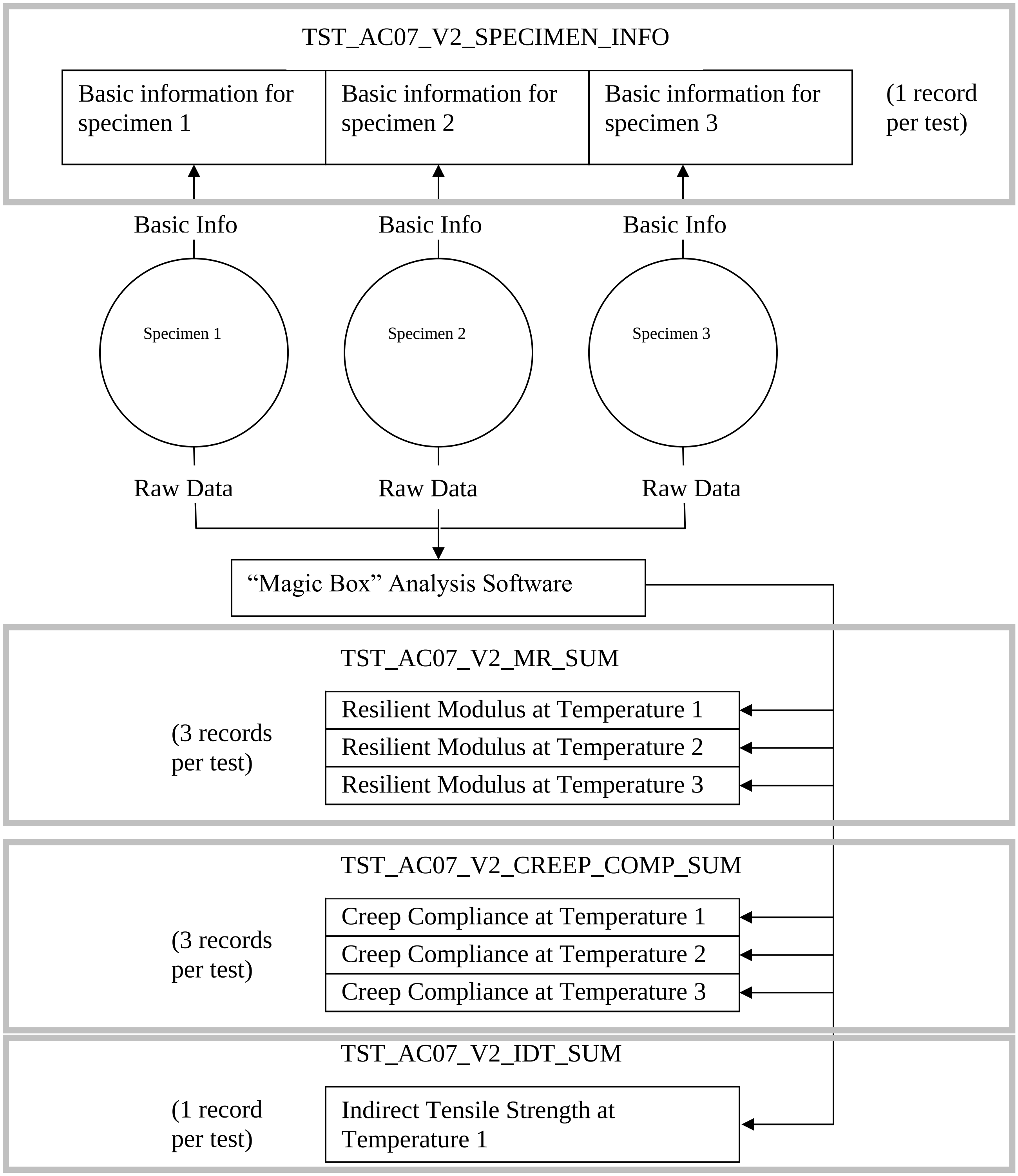


Figure 19. Illustration. Illustration of relationships among TST_AC07* tables.

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 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 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.

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.

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).

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. 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.

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.

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_AE07_DATA table.

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.

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 table 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) tests 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:

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

Figure 20. Equation. Regression equation for creep stiffness – load time curve illustrating coefficients stored in database.

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 include 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, estimated stiffness, 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 the creep stiffness load time equation from the BBR test.

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 table 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_AE09_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.

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.

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 75 µm (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.

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

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 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 starting with the SPS material action plan begun in 2005. 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 D6951-03. 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_STRENGTH_FRAC field. Several other intermediate calculations, such as the length and diameter of the specimen, are also stored.

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.

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 coded description of the character of the aggregate type is included in the PRIMARY_AGG_CLASS and SECONDARY_AGG_CLASS fields. In order to allow entry of repeat measurements on the same sample, TEST_SEQUENCE is part of the key, but it does not necessarily imply order of testing

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.

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.

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.

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.

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.

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.

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 a small number of 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 a small number of 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).

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.

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 a small number of 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.

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

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 limited data 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 limited data 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 limited data 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.

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), 1.18 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.

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.

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.

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.

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.

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.

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.

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 ASTM classification (DESC_CODE_*); and AASHTO classification (AASHTO_SOIL_CLASS).

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.

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.

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.

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.

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. This table contains limited data and no further data are expected.

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.

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.

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.

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.

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.

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 21.

TST_UG07_SS07_A: As shown in Figure 21, 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).

TST_UG07_SS07_B: As shown in Figure 21, 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).

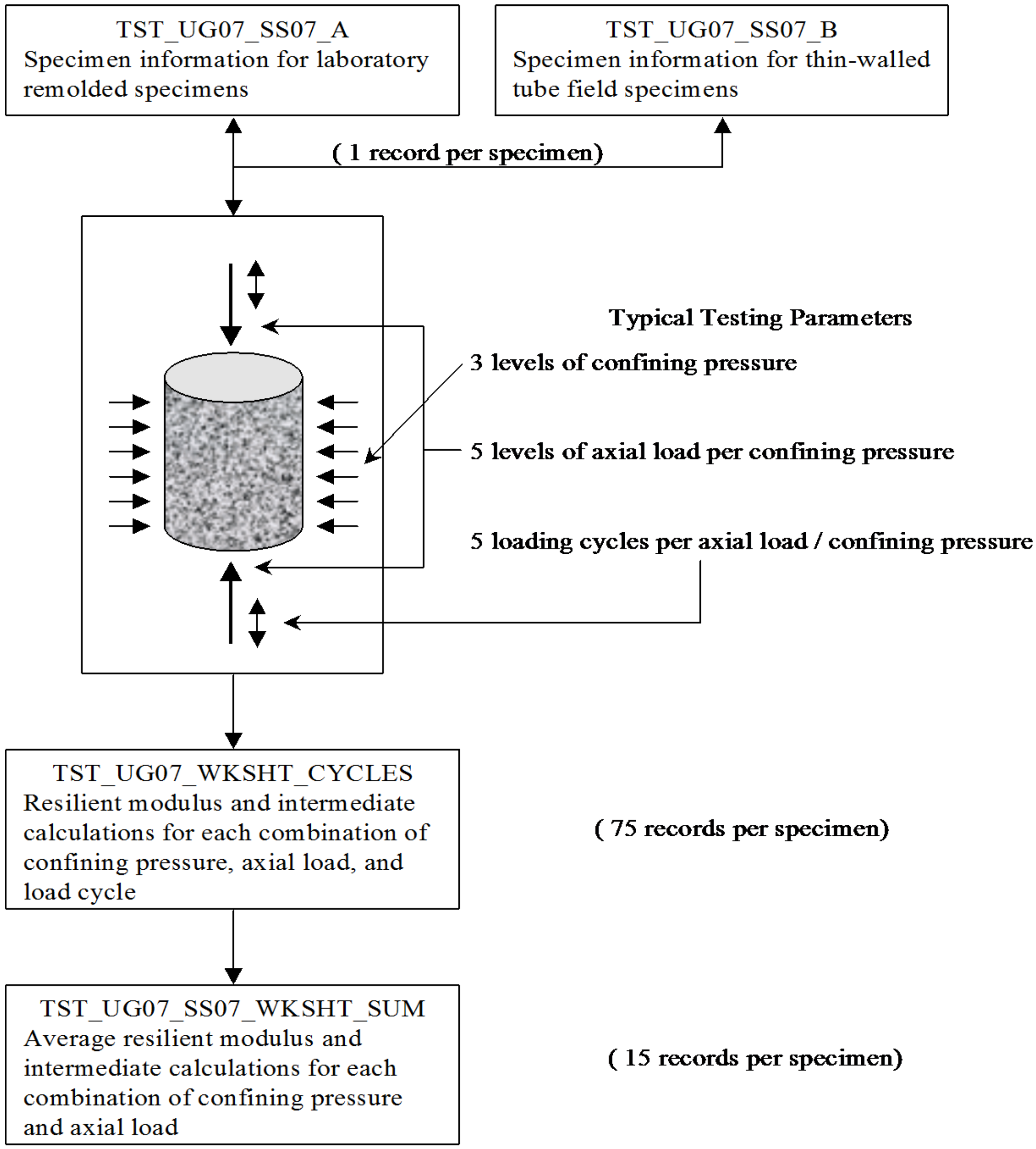


Figure 21. Illustration. Illustration of relationships among TST_UG07_SS07* tables.

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, resilient strain is stored in RES_STRAIN, and resilient modulus is stored in RES_MOD. The primary key contains the typical keys, plus CON_PRESSURE, NOM_MAX_AXIAL_STRESS, and CYCLE_NO.

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 contains the typical keys, plus CON_PRESSURE and NOM_MAX_AXIAL_STRESS.

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 04 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	SAMPLE_NO is not always a reliable way to classify materials or sample

Tip!	types. The TST_SAMPLE tables should be used 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 records will exist in this table, one for each original sample 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 check 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 GPR. 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 is the master layer 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. The SECTION_LAYER_STRUCTURE table is a copy of this table.

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. TST_L05A, TST_L05B, 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 named 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 primary 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 module refer to the same 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.

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.

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 22 shows a plan view of this project. Figure 23 shows the cross-sectional view of this hypothetical project and the layer numbering.

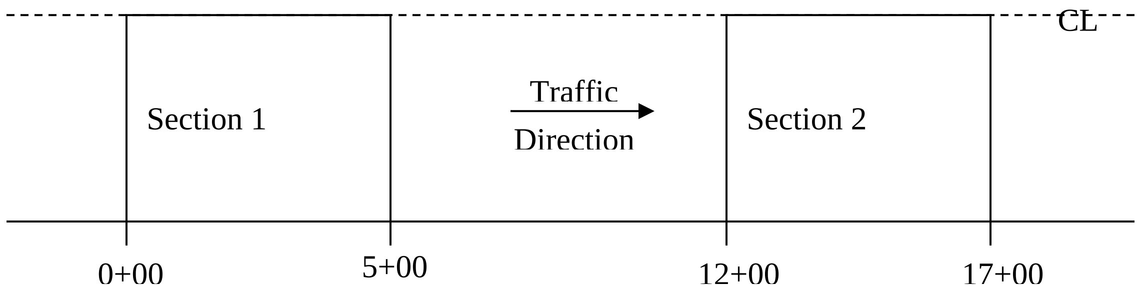


Figure 22. Figure. Plan view of hypothetical SPS project (not to scale).

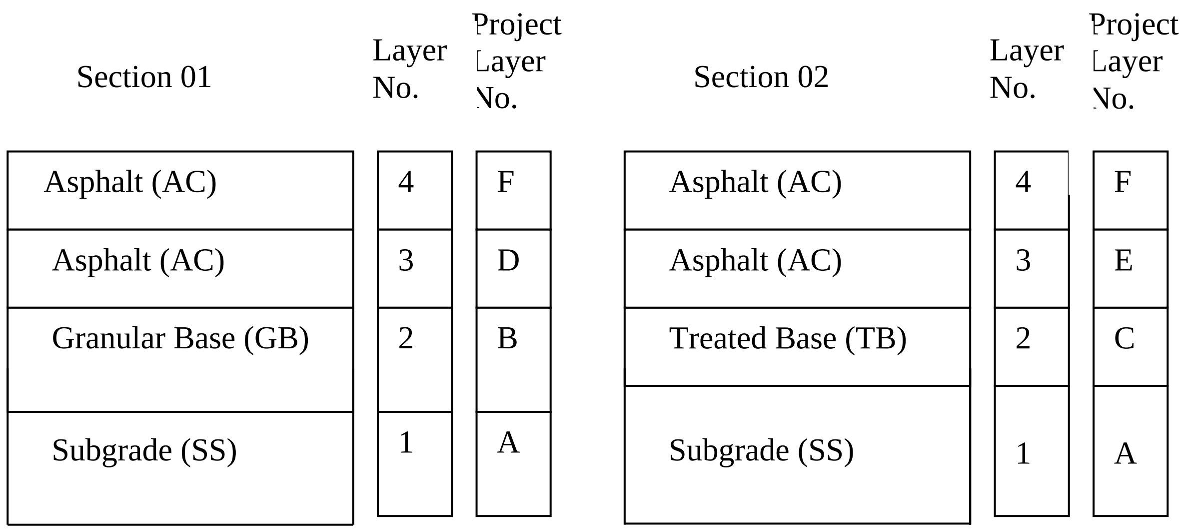


Figure 23. Figure. Cross-sectional view of hypothetical SPS project.

As described in section 13.4.3, the layering of a LTPP section can be obtained from the TST_L05B table. From Figure 22, 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.

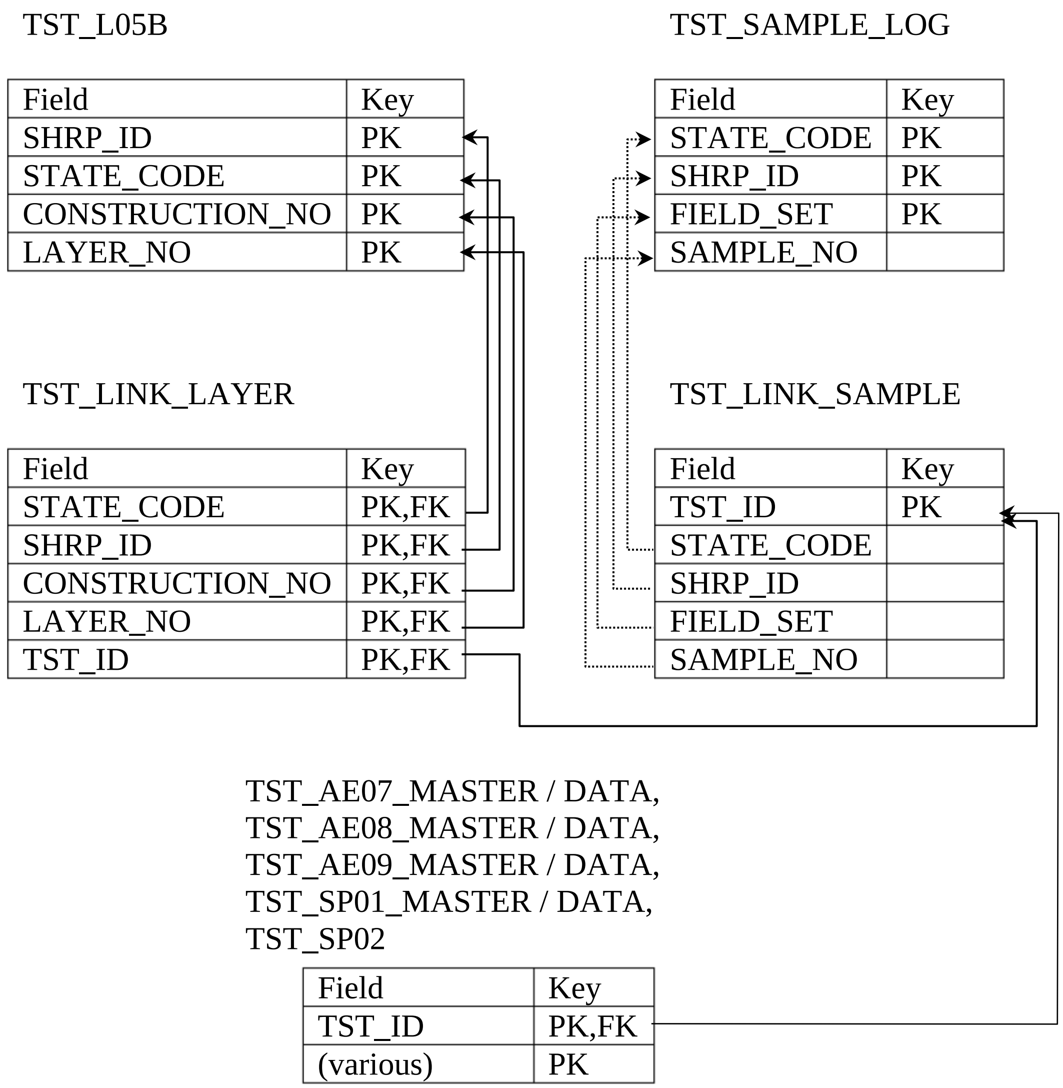
LTPP Database Tip!	When seeking materials test results for an SPS section, project layer numbers can be used to find tests of the same material on a different test section. Although the material source and placement methods may be identical, construction variability may result in differences in material 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 SDR. 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 a 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 24. 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 24, 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 24 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 to locate test results in the other tables.



Notes: Arrows indicating relationship point from the child to the master

Figure 24. Chart. Relationship between material test tables linked using TST_ID.

13.5. DYNAMIC MODULUS OF HOT MIXED ASPHALT MIXTURES

Starting with SDR 24, January 2010, estimates of the dynamic modulus, |*E**|, of HMA mixtures were added to the TST module. |*E**| is a fundamental material property that defines the HMA stiffness 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*.

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 are now contained in the LTPP database that include 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 25 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 25 are the codes for the models contained in the TST_ESTAR_MASTER table. The following is a brief description of the 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.

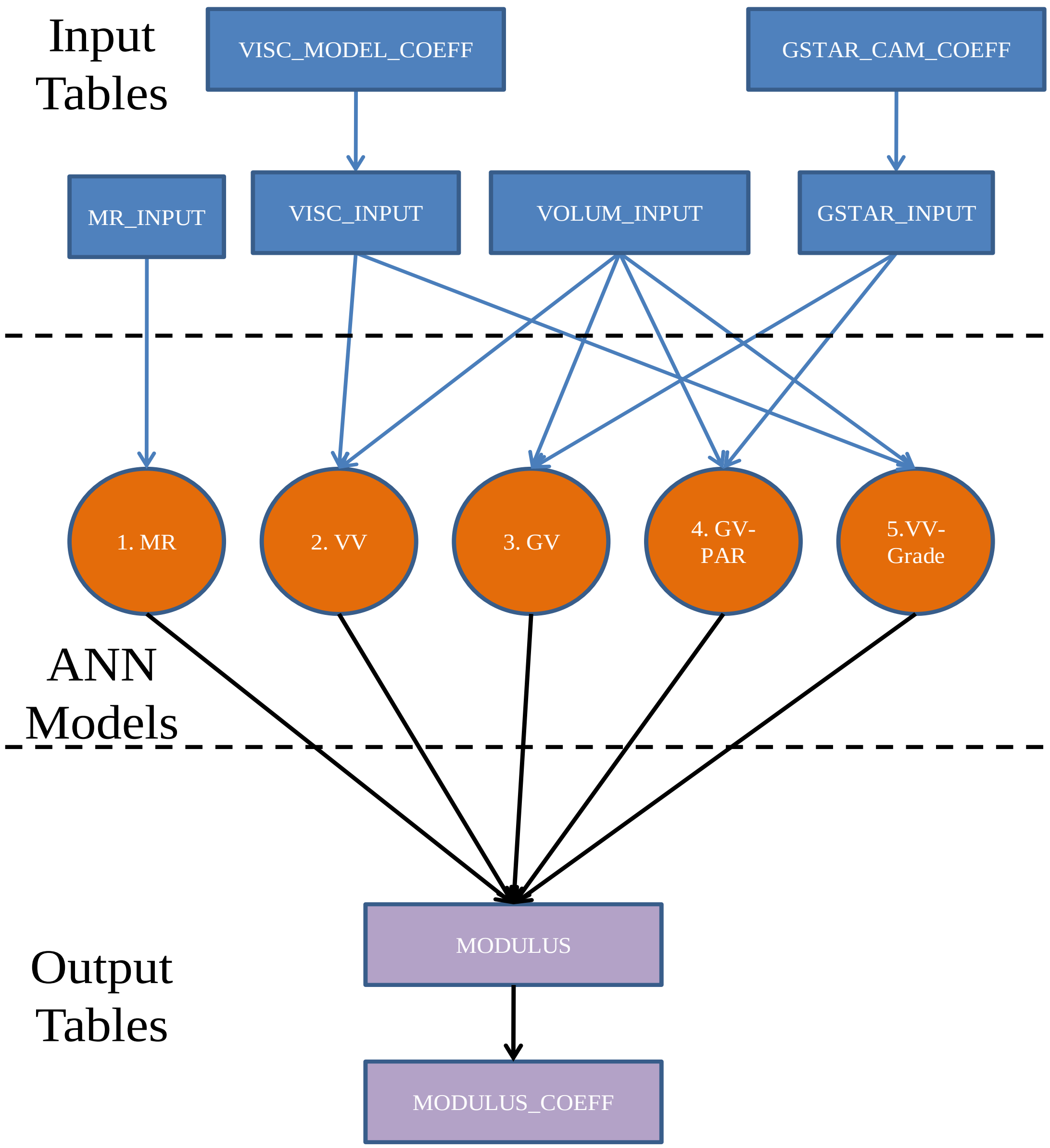


Figure 25. Schematic. Relationship between the TST_ESTAR_* input tables, Artificial Neural Network (ANN) models, and output tables containing estimated dynamic modulus for HMA layers on LTPP test sections. All tables link to TST_ESTAR_MASTER, which contains test section and layer identification information.

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.

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 degrees Fahrenheit which are the required units of this data input for the MEPDG models.

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:

$$\log|E^*| = \delta + \frac{\alpha}{1+e^{\beta+\gamma^*\log(t_R)}}$$

Figure 26. Equation. Dynamic modulus master curve showing coefficients stored in database.

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_1 field
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:

$$\log a_T = \alpha_1 T^2 + \alpha_2 T + \alpha_3$$

Figure 27. Equation. Dynamic modulus time-temperature shift factor showing coefficients stored in database.

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 the ratio of standard error to standard deviation is less than 0.05.

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:

$$|G^*| = \frac{G_g}{\left(1+\left(\dfrac{\omega_c}{\omega_R}\right)^k\right)^{m_e/k}}$$

Figure 28. Equation. CAM equation for complex shear modulus showing the coefficients stored in the database.

Where:

G^*	=	complex shear modulus
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

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.

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.

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:

$$\log\log(\eta) = \begin{cases} A + VTS\log(T_R) & T_R > T_{critical} \\ 1.0945 & T_R \leq T_{critical} \end{cases}$$

Figure 29. Equation. Asphalt binder-temperature susceptibility relationship defining coefficient values store in the database.

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 2.7×10^{12} cP

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.

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.

13.6. ASPHALT CONCRETE AIR VOIDS COMPUTED PARAMETERS

Two computed parameter tables were created in 2017 to store the result of air voids calculated from the bulk specific gravity (BSG) test results stored in TST_AC02 and the maximum specific gravity (MSG) test results stored in TST_AC03 tables, respectfully. Because of the sampling and testing practices used by LTPP, each BSG value does not necessarily have an easily matched MSG value. To keep the computed parameter tables automatable, and free from the need for external judgment, the following hierarchical approach was developed to assign MSG values to BSG values to compute air voids from LTPP laboratory test data.

GPS Sections:

- Where a BSG and MSG value for the same core exist, use the two values together to calculate air voids.
- For BSG values from cores that do not also have MSG values, use section average MSG values for air voids calculations.
- For sections that do not have test results in TST_AC02, do not calculate or assign air void values as part of this effort.
- For BSG values where no corresponding MSG value exists, do not calculate an air voids for the layer.

SPS Sections:

- Where a BSG and MSG value for the same core exist, use the two values together to calculate air voids.
- For BSG values from cores that do not also have MSG values, use the same end of the section MSG value for air voids calculations.
- If MSG does not exist for the end of the test section, use the MSG value from the other end of the test section if it exists.
- For BSG values from cores that do not also have MSG values from the same test section, use project layering to determine an average MSG value for the layer, and use that for air voids calculations.

The air void values computed from each available combination of BSG with a corresponding MSG following the computation guidelines stated above are stored in the TST_AIR_VOIDS_CALC table. The TST_AIR_VOIDS_SECT table contains test section specific estimates of air voids stratified by lane location(wheelpath/non-wheelpath), construction event, and material layer.

TST_AIR_VOIDS_CALC: This table contains the air voids calculated for each BSG value contained in TST_AC02 that could be matched with an MSG value from TST_AC03. It indicates the source of the BSG and MSG data, as well as the values used for each air voids computation. Because of the way the values are matched, the resulting computed air voids can result in a negative vale. These negative values are identified in the level D QC checks and are not used in the TST_AIR_VOIDS_SECT table calculations.

TST_AIR_VOIDS_SECT: This table contains section level average air voids values based on sample location and age. Only values that pass QC in TST_AIR_VOIDS_CALC are used to generate these section level computed parameters.

CHAPTER 14. GROUND PENETRATING RADAR MEASUREMENTS

14.1. INTRODUCTION

In 2003, 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 site. The results of the measurements are stored in the GPR data module.

Measurements were performed using an air-coupled antenna. Measurements were performed at 152 mm (6 inch) intervals using a sampling rate of 256 samples per measurement. Thickness interpretations were averaged over a .305 m (1 foot) 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.

GPR_MASTER: 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)

GPR_THICK_POINT: 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 .305 m (1 foot) 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.

GPR_THICK_SECT: 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.

GPR_LINK_LAYER: 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. DATA COMPILATION VIEWS

15.1. BACKGROUND

The tables in the DCV module contain data compiled from other existing tables with the primary intent of reducing the number of tables a user needs to examine for similar types of data elements. The LTPP database uses various types of linkages between test sections that contain data values that apply to more than one test section. To make it easier for users to find linked data or data stored in project level SPS records, these tables also expand linked and project level data to create individual test section level records. Coded values have been replaced with the code description to alleviate the need to perform the linking necessary to get the code definition. While this information is technically implemented as a "view" in database terminology, they are presented as tables in the SDR.

These tables are intended to make access to data using the traditional SDR in MS Access format easier to use. These tables are primarily intended to serve advanced data users who would rather directly access data stored in the LTPP database tables than those who use the new search and data discovery tools included in InfoPave.

15.2. DCV RELEASE

The tables in the DCV module were first released in SDR 27 as a beta or trial status in the interest of receiving data user feedback. Beginning with SDR 28 these tables are issued as part of the normal SDR. The module is released as volume 2 to indicate a separation from the other PPDB data tables. Unlike most other PPDB modules, the tables do not have a module designation in the table names. The DCV module currently contains combined data from the ADM, INV, RHB, and SPS modules.

Figure 30 provides a graphical example of the extent of consolidation by combining aggregate property data from eight primary tables into one table. In this case, aggregate property data elements are the same regardless of the type of asphalt based mixture. For example, the three RHB tables are split by type of AC mixture. The four SPS tables are split only by experiment designation. A subtle detail not represented in this example is that some of the SPS-9 projects are overlays; thus aggregate data for existing layers prior to application of the SPS-9 experimental treatment are stored in the INV_PMA table in a project level record, while aggregate properties for the experimental SPS-9 treatments are stored in test section level records in the SPS9_PMSA_AGGREGATE_PROP table. This compilation table now stores all of this data in one table using test section specific referential data.

Some of the significant details on how the tables in the DCV module were populated include:

- Only data judged to be of primary interest to the majority of data users were included in the DCV tables. For example, when an average and standard deviation were present in the source table, only the average value was reported in the DCV table.

- Each record in a DCV table contains a reference to the source table. This allows a data user the ability to link back to source information.

- No judgment was applied to the reported values. The DCV tables report values contained in the source tables. This is an important consideration for INV data when the INV layer structure does not contain a one-to-one match with the other layer tables.

- The RECORD_STATUS field was omitted from the DCV tables because they represent an extraction of a subset of data from the source tables. The data affecting the RECORD_STATUS in the source tables may not be contained in the DCV table. Users interested in the RECORD_STATUS in the source table have the ability to look it up.

- Each record in the DCV tables was assigned a multiple primary key set to identify unique records. In some cases, an extra primary key field called RECORD_NO was added for records in the INV module where two layers in the INV module were assigned to one layer in the SECTION_LAYER_STRUCTURE table (TST_L05B).

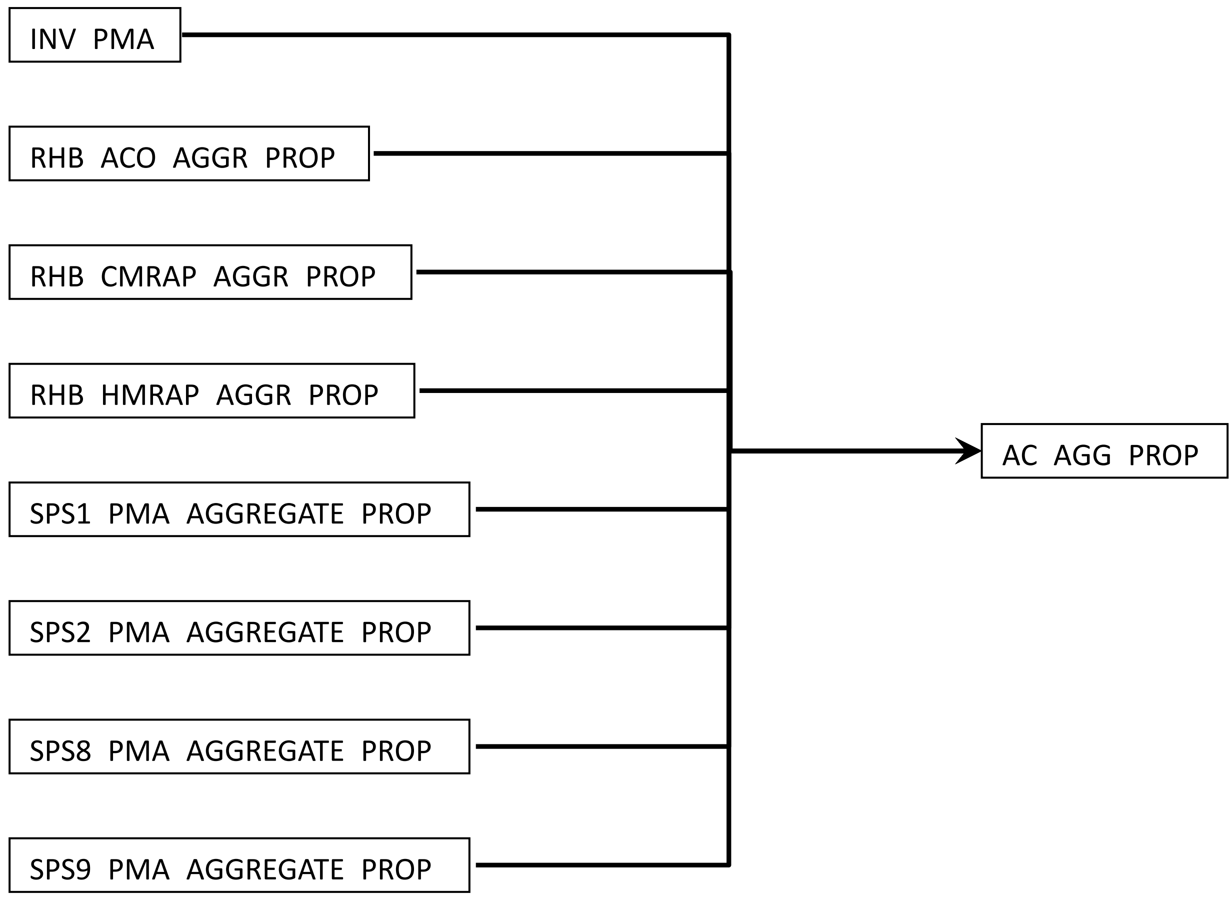


Figure 30. Schematic. Source tables for the AC_AGG_PROP table included in the DCV module.

15.3. DCV TABLES

The tables in the DCV module contain data from the ADM, INV, RHB, and SPS modules. The combined and expanded tables are listed in the following sections.

AC_AGG_GRADATION: This table contains gradation information for aggregate used in AC mixtures. This table contains data combined from INV_GRADATION, RHB_ACO_AGGR_PROP, RHB_CMRAP_COMBINED_AGG, and RHB_HMRAP_COMBINED_AGG tables.

AC_AGG_PROP: This table contains physical properties of aggregate used in AC mixtures from the INV_PMA, RHB_ACO_AGGR_PROP, RHB_CMRAP_COMBINED_AGG, RHB_HMRAP_COMBINED_AGG, SPS1_PMA_AGGREGATE_PROP, SPS2_PMA_AGGREGATE_PROP, SPS8_PMA_AGGREGATE_PROP, and SPS9_PMA_AGGREGATE_PROP tables.

AC_ANTISTRIP: This table contains combined information on anti-stripping agents used in AC mixtures combined from the INV_PMA_ORIG_MIX, RHB_ACO_MIX_PROP, SPS1_PMA_MIXTURE_PROP, SPS2_PMA_MIXTURE_PROP, SPS8_PMA_MIXTURE_PROP, and SPS9_PMA_MIXTURE_PROP tables.

AC_BINDER_PROP: This table contains properties of the binder used in AC mixtures combined from the INV_PMA_ASPHALT, RHB_ACO_PROP, SPS1_PMA_AC_PROPERTIES, SPS8_PMA_AC_PROPERTIES, and SPS9_PMA_AC_PROPERTIES tables.

AC_MIX_PROP: This table contains combined data on AC Hveem and Marshall mix design procedures from INV_PMA_ORIG_MIX, RHB_ACO_LAB_MIX, RHB_CMRAP_LAB_MIX, RHB_HMRAP_LAB_MIX, SPS1_PMA_MIXTURE_PROP, SPS2_PMA_MIXTURE_PROP, SPS8_PMA_MIXTURE_PROP, SPS9_PMA_MIXTURE_PROP, and SPS9_PMA_MIX_DES_PROP tables.

AC_MOISTURE_SUSCEPTIBILITY: This table contains results from moisture susceptibility tests on AC samples from the INV_PMA_ORIG_MIX and RHB_ACO_MIX_PROP tables.

AC_VOLUMETRICS: This table contains volumetric properties of AC mixtures as reported by agencies combined from data contained in the INV_PMA_ORIG_MIX, RHB_ACO_LAB_MIX, RHB_ACO_MIX_PROP, RHB_CMRAP_LAB_MIX, RHB_CMRAP_MIX_PROP, RHB_HMRAP_LAB_MIX, RHB_HMRAP_MIX_PROP, SPS1_PMA_MIXTURE_PROP, SPS2_PMA_MIXTURE_PROP, SPS8_PMA_MIXTURE_PROP, SPS9_PMA_MIXTURE_PROP, SPS9_PMA_MIX_DES_PROP, and SPS9_SP_PMA_MIXTURE_PROP tables.

MNT_IMP_SOURCE: This table contains the location of the detailed information for maintenance events recorded in MNT_IMP table.

In MNT_IMP, the DATA_AVAIL_IMS field identifies whether further details for a given maintenance event are contained elsewhere in the database. Unfortunately, with so many possible data locations, it can be difficult to find those further details. For instance, a certain partial depth patching record on an SPS-6 section might indicate that further information is available, but it isn't immediately clear if it is stored in MNT_PCC_PART_DEPTH or SPS6_PCC_PART_DEPTH table. This table identifies the source of the further information directly in a field called DETAIL_LOCATION to remove the guesswork of where the available information is stored.

The source tables that contain available data from entries in the MNT_IMP table include MNT_ASPHALT_CRACK_SEAL, MNT_ASPHALT_PATCH, MNT_ASPHALT_SEAL, MNT_GMG, MNT_IMP, MNT_PCC_CRACK_SEAL, MNT_PCC_FULL_DEPTH, MNT_PCC_JOINT_RESEAL, MNT_PCC_PART_DEPTH, RHB_MILL_AND_GRIND, SPS2_PCC_FULL_DEPTH, SPS3_CHIP, SPS3_CRACK, SPS3_SLURRY, SPS4_CRACK_SEAL_GENERAL, SPS4_PCC_CRACK_SEAL, SPS5_AC_PATCHES, SPS6_DIAMOND_GRIND, SPS6_PCC_CRACK_SEAL, SPS6_PCC_FULL_DEPTH, SPS6_PCC_JOINT_RESEAL, SPS6_PCC_PART_DEPTH, and SPS7_MILLING.

PCC_ADMIXTURE: This table contains properties of admixtures used in PCC mixtures combined from data contained in the SPS2_PCC_MIXTURE_DATA, SPS8_PCC_MIXTURE_DATA, RHB_PCCO_MIXTURE, and INV_ADMIX tables.

PCC_AGG_GRADATION: This table contains gradation information for aggregate used in PCC mixtures drawn from the RHB_PCCO_AGGR, SPS2_PCC_MIXTURE_DATA, SPS8_PCC_MIXTURE_DATA, and INV_GRADATION tables.

PCC_AGG_PROP: This table contains physical properties of aggregate used in PCC mixtures combined from data contained in the RHB_PCCO_AGGR, SPS2_PCC_MIXTURE_DATA, SPS8_PCC_MIXTURE_DATA, and INV_PCC_MIXTURE tables.

PCC_JOINT_FORMING: This table contains methods used to create the joints on PCC layers. The data in this table was combined from the RHB_PCCO_JOINT_DATA, SPS8_PCC_JOINT_DATA, SPS2_PCC_JOINT_DATA, and INV_PCC_JOINT tables.

PCC_JOINT_SEALANT: This table contains properties of joint sealants used during initial placement of PCC layers. This table contains data from the RHB_PCCO_JOINT_DATA, SPS2_PCC_JOINT_DATA, SPS8_PCC_JOINT_DATA, and INV_PCC_JOINT tables.

PCC_JOINT_SPACING: This table contains joint spacing used on PCC layers compiled from the RHB_PCCO_JOINT_DATA, SPS2_PCC_JOINT_DATA, SPS7_PCCO_JOINT_DATA, SPS8_PCC_JOINT_DATA, and INV_PCC_JOINT tables.

PCC_LOAD_TRANSFER: This table contains properties of load transfer devices used on PCC layers complied from data contained in the RHB_PCCO_JOINT_DATA, SPS2_PCC_JOINT_DATA, SPS8_PCC_JOINT_DATA, and INV_PCC_JOINT tables.

PCC_MIX_DESIGN: This table contains PCC mix design properties combined from data stored in the RHB_PCCO_MIXTURE, SPS2_PCC_MIXTURE_DATA, SPS8_PCC_MIXTURE_DATA, and INV_PCC_MIXTURE tables.

PCC_REINFORCING: This table contains physical properties of reinforcement used in PCC layers extracted from data stored in the SPS2_PCC_STEEL, RHB_PCCO_STEEL, and INV_PCC_STEEL tables.

PCC_STRENGTH: This table contains strength properties of PCC layers from the RHB_PCCO_STRENGTH and INV_PCC_STRENGTH tables.

PCC_TIE_BARS: This table contains properties of tie bars placed in PCC layers extracted from entries in the RHB_PCCO_JOINT_DATA, SPS2_PCC_JOINT_DATA, SPS8_PCC_JOINT_DATA, and INV_PCC_JOINT tables.

SECTION_LAYOUT: This table contains section layout and location information. This table contains combined data from INV_ID, INV_GENERAL, SPS_ID, SPS_GENERAL, and SPS_PROJECT_STATIONS.

Basic test section layout information such as route designation, functional class, number of lanes, travel direction, lane width, and section length are stored in multiple tables depending on experiment type. This table provides a single source for this data, removing the complexity of searching multiple tables and converting project properties to test section level properties.

SECTION_STRUCTURE_HISTORY: This table contains information on dates of structural changes to each section, including original construction, milling, overlays, and crack and seat events. It contains a mixture of data extracted from the EXPERIMENT_SECTION, RHB_IMP, SPS_ID, INV_AGE, and SECTION_LAYER_STRUCTURE tables.

Because most of the tables related to pavement structure altering events are not layer specific and the main layering table has no date information, it can be difficult to determine when a given layer was placed and if or when it was later altered. This table combines date and layer information from various source tables to create a timeline for each defined material layer on a test section. For example, an overlay that was partially milled, and then fully removed by a second milling event would have an entry for the original overlay placement event, the first (partial) milling event, and the second milling event that fully removed the layer.

STABILIZATION_DETAILS: This table contains information on stabilization types and quantities for unbound layers compiled from the INV_STABIL, SPS1_SUBGRADE_PREP, SPS2_SUBGRADE_PREP, SPS8_SUBGRADE_PREP, and SPS9_SUBGRADE_PREP tables.

SUBGRADE_PROPERTIES: This table contains the physical properties of subgrade material. This table contains data from the INV_SUBGRADE table which has been expanded to test section level data for linked SPS project layers.

UNBOUND_LAYER_PROPERTIES. This table contains physical properties of unbound layers expanded to test section level from data contained in the INV_UNBOUND table. Data in this table is constrained to that reported by participating highway agencies for pavement structures whose initial construction was completed prior to inclusions into the LTPP program.

CHAPTER 16. LTPP TRAFFIC ANALYSIS SOFTWARE DATA TABLES

The LTAS is used to generate annual traffic estimates from raw traffic measurements. The LTAS data tables contain daily, and monthly traffic data used in the annual traffic estimates stored in the PPDB, 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 procedure. The LTAS data tables are included in the SDR in the form of a relational database which is grouped into data modules primarily based on level of summarization data type.

16.1. LTAS TABLES

The naming scheme for the LTAS tables indicates the general nature of the data tables contained in each database. Except for the administration database, the first part of the database name indicates the temporal coverage, the second part is the type of data, and the third part indicates the range of agencies whose data is included in each database.

Administration: This database contains tables that describe the structure of the database, the processing completed and the master test section control table. Key tables in this module are TRAFFIC_ANALYSIS_TRACKER, which indicates which data should be available in each summarization group, and SHRP_INFO, which is the master control table for traffic processing. Tables describing the various LTAS tables include TRAFFICTD which lists all of the tables provided; TRAFFICDD, which describes each field in each table; TRAFFIC_CODE_TYPES which lists the codes in the tables; and TRAFFIC_CODES, which describes codes used in the tables. The REGIONS table contains a mapping of States to LTPP operations administrative designations.

Annual: There are three types of annual databases containing aggregates of data by day of week.

- Annual_Axles – these databases contain data on the number of axles by vehicle class and axle group.
- Annual_Count – these databases contain data on counts and errors identified through rules in the data loading process or review of the data. The data comes from volume, classification and weight records.
- Annual_GVW – these databases contain data on gross vehicle weights aggregated by vehicle class.

Daily: There are three types of daily databases containing aggregates of input data by day:

- Daily_Axles – these databases contain data on the number of axles by vehicle class and axle group.

- Daily_Count_ERR – these databases contain data on counts and errors identified through rules in the data loading process or review of the data. The data comes from volume, classification and weight records.

- Daily_GVW – these databases contain data on gross vehicle weights aggregated by vehicle class.

Hourly: This database contains data on hourly classification counts.

Monthly: There are three types of monthly databases summarizing daily data by month and day of week:

- Monthly_Axles - these databases contain data on the number of axles by vehicle class and axle group

- Montly_Count - these databases contain summarized vehicle counts by month and day of week separately for classification and weight data.

- Monthly_GVW - these databases contain data on gross vehicle weights by vehicle class.

LTAS Skeleton: This skeleton database for the LTAS tables consists of empty data tables, definitions, and structures for all tables included in the 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.

16.2. IMPORTANT FIELDS

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

VEH_CLASS refers to the classification scheme in which the data is submitted. This scheme is frequently, but not always the 13-bin FHWA TMG 13-bin scheme. Count fields for data using the input classification are of the form COUNTnn.

VEHICLE_CLASS refers to the 13-bin vehicle classification system in the FHWA TMG. (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 MM_CT or YY_CT table where TRF_DATA_TYPE = 7) to the distribution of axle group weights for these classes (from the MM_AX or YY_AX tables respectively). The VEHICLE_CLASS field within TRF_MONITOR_AXLE_DISTRIB can be used to link data to the TRF_MONITOR_LTPP_LN table.

AXLE_GROUP is a variable that defines the type of axle or axle group (single, tandem, triple, or quad plus). The variable is used within all of the axle distribution tables (DD_AX, MM_AX, YY_AX, TRF_MONITOR_AXLE_DISTRIB). Note that steering axle groups (front axles) are not recorded separately from other single axles in these tables.

16.3. ADMINISTRATION TABLES

This group contains tables that describe the master test section control table, equipment and classification algorithms, the structure of the database, and the processing completed.

SHRP_INFO is the master control table for traffic processing. Records exist in SHRP_INFO for each LTPP location for which monitored traffic data is expected. This table does not list all sections in the LTPP experiments because in the case of the SPS projects the same data generally applies to all sections on the project. The companion table to SHRP_INFO is SITE_EQUIPMENT_INFO which contains the available information on data collection equipment and its location. The mapping of agency specific classification schemes to the 13-bin scheme described in FHWA's *Traffic Monitoring Guide* is contained in the TRAFFIC_CLASS_CONVERT_* tables. If the agency uses the FHWA 13-bin scheme, that is also identified in the tables.

LTAS data tables being released are listed in TRAFFICTD. The structure of those tables is described in TRAFFICDD. It is supported by TRAFFIC_CODE_TYPES, a list of all codes in the LTAS data tables and TRAFFIC_CODES, which describes the codes themselves.

The processing completed is reported in TRAFFIC_ANALYSIS_TRACKER which indicates whether data should be available by level of summarization and data type.

16.3.1. SHRP_INFO Table

This can be considered the master table for the entire database. The SHRP_INFO table describes the relationship between an LTPP section or project and the traffic data collected used as inputs to estimate pavement loading. All GPS sections and SPS projects other than SPS-3 and SPS-4 projects linked to GPS sections must have entries in this table. Projects with sections on both sides of the road have two entries in this table, one for each direction. This table contains information on the lane number and direction of the LTPP lane, the number of lanes in each direction, the site which is the data source for the section, location and nominal quantity/quality of the data from that source, and fields that control loading classification and weight records with the LTAS software.

This table has three key fields: STATE_CODE, SHRP_ID, and START_DATE.

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 TRAFFIC_CODES table. These codes are, in part, based on the 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 projects, the second character represents the experiment number; the third and fourth characters are "00" to indicate this is a project level SHRP_ID. Where the third or fourth characters are not "0" it indicates a section on the opposite side from the main SPS project sections with different traffic data. 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.

START_DATE is the first day to which the information in the record applies. A new start date may be created when the lane numbering changes, the site or equipment providing data changes or when different loading control options are in effect.

RECORD_STATUS is described in the Quality Control section of this document. The RECORD_STATUS field in SHRP_INFO reflects the completeness data in SHRP_INFO and SITE_EQUIPMENT_INFO. It is one of the factors that control the existence of an estimate for the pavement database.

END_DATE is the last day to which the information in the record applies. This date is independent of when the section may have gone out of study for pavement data collection purposes.

VOLUME_SITE, CLASS_SITE, and **WIM_SITE** contain the SHRP_IDs of the sources of data for the respective data types. When data is collected at the same location as the site it is used for, the values will match SHRP_ID. When the data is collected at another LTPP location, the SHRP_ID for that location will typically appear in these fields.

ID3, ID6 and **USEFILENAME** are controls on how data is assigned a SHRP_ID for entry in the database.

LTPP_DIR and **LTPP_LANE** identify the LTPP direction and lane for the purposes of identifying the data to be summarized for annual estimates in the pavement database.

LANES_LTPP_DIR and **LANES_NON_LTPP_DIR** control some of the QC run on the TRF_MONITOR_* tables and whether or not sufficient data exists to compute an AADT estimate.

SRO_CLASS and **SRO_WEIGHT** are qualitative indicators of the spatial relationship between the source of the associated type of data and the LTPP section or project. These may or may not reflect changes in site location since 2000.

DATA_AVAILABILITY is a qualitative description of the data available and its reliability for the period indicated. This information does not currently reflect the results of a full database review on quantity and quality of data.

FUNC_CLASS is the functional class of the route where the LTPP section is located. This value may not reflect site specific changes since 2000. The TRF_BASIC_INFO table in the pavement database may contain more current information.

COMMENTS contain notes by individuals loading and reviewing data.

CARD4INFO, CARDCINFO and **LTPP_LN_ONLY** control which data is loaded. In the case of CARD*INFO it indicates whether classification data for classes in optional columns is included.

ERR_1AM1PM, ERR_8ZERO, and **ERR_4STATIC** indicate checks to be done or omitted when loading classification data.

UPDATE_LNDIR, LOAD_LN, and **LOAD_DIR** are used to change the LTPP lane and or direction in an incoming data file.

16.3.2. SITE_EQUIPMENT_INFO

This table is used to identify the type of equipment installed and the classification schemes being used with that equipment. This table is used as a reference for SHRP_INFO to elaborate on the information pertaining to the *_SITE variable. Data in this table comes from transmittal sheets, Traffic Data Sheets 11, 12 and 13. Volume data collection equipment has no classification scheme by definition.

The table does not provide information on installation, maintenance, validation, or calibration. Validation/calibration information is entered in the pavement database in tables TRF_CALIBRATION_AVC, TRF_CALIBRATION_WIM, and TRF_EQUIPMENT_MASTER. Equipment installation and maintenance information is not included.

This information may not reflect the current installations at a site nor is information necessarily available for all years monitored traffic data was collected.

16.3.3. TRAFFIC_ANALYSIS_TRACKER

This table tracks when daily, monthly, and annual summaries and annual estimates were last updated. Data not yet received or processing that remains to be done is identified with a date of 1-JAN-1990 in this table.

The LTAS software populates this table. The first time a STATE_CODE, SHRP_ID, Year is encountered in the data loading process a record is inserted into this table. It has RECORD_STATUS = A; all non-null dates are 1-JAN-1990 and the UPLOAD_IMS_* fields are Y. Once a record exists, the dates are updated to TODAY or reset to the default 1-JAN-1990 depending on the process being executed.

The UPLOAD_IMS fields are user modified to control the inputs to an annual estimate. The options are Y, N and C. Y indicates the data has passed review and should be used in the annual estimate. N indicates the data for the entire year is not considered suitable to include in the annual estimate following review. C indicates the data has been copied over from another site, which can be identified through review of the *_SITE fields in SHRP_INFO.

The LOAD_METHOD fields indicate which version of the software was used to load the data. Data loaded using only the LTAS software is identified by A. Data loaded for review through the LTPP Traffic QC software (prior to 2001) is identified by a Q. This information is used to determine whether information on data omitted following review (purged) can be found on the ASCII data files or solely in the LTAS data tables.

16.3.4. TRAFFIC_CLASS_CONVERT_MASTER

There is no requirement for states to use the 13-bin schema from the TMG and a standard classification algorithm. LTPP has adopted the 13-bin TMG method as the standard for uniform interpretation of traffic data across all experiments. The 13-bin method is the one found in FHWA's *TMG* from the 2nd edition and later. This table indicates which classification scheme is used by an agency or a specific site.

Agencies may use any classification method that meets their needs. For the purposes of the analysis software all data loading is done using the agency system for creating daily summaries. When monthly statistics are created, all data is converted to the 13-bin method to permit comparison of equivalent truck types in pavement analyses.

There are at least two records in TRAFFIC_CLASS_CONVERT_MASTER for every State or Province in SHRP_INFO covering the entire LTPP study period. One refers to the relationships for classification data, the other to those for weight data. When initially populated, it was assumed that all agencies use the 13-bin system for both types of data. The identification of such agencies is through the value 99 in NO_SHA_CLASSES. There are no corresponding records in TRAFFIC_CLASS_CONVERT_DATA for any agencies with this field value for the period indicated.

16.3.5. TRAFFIC_CLASS_CONVERT_DATA

The table contains the specifics of matching an agency's classification method to the 13-bin TMG method.

By definition if there is an agency-specific classification method for a given data type in TRAFFIC_CLASS_CONVERT_MASTER (NO_SHA_CLASSES not equal 99), there will be at least two records in TRAFFIC_CLASS_CONVERT_DATA for that site.

There is a record in TRAFFIC_CLASS_CONVERT_DATA for every agency vehicle class used for a given data type. Cars are included for classification data and may be included for weight data. The records describe how the agency classes are divided among the 13-bin classification method being used for LTPP reporting purposes. The sum of the percentages in each bin for an agency class equals 100 percent. If the conversion method is general for the agency for a given period, it is identified by the SHRP_ID '9999'. If there is a site-specific entry in TRAFFIC_CLASS_CONVERT_MASTER there will also be site-specific entries in TRAFFIC_CLASS_CONVERT_DATA when the conversion method is not TMG 13-bin. Once a site has a specific conversion method applied to it for a given data type, specific instructions for that site exist for all years.

16.3.6. TRAFFIC_ CODE_TYPES

The TRAFFIC_CODE_TYPES table provides additional information on the codes contained in the TRAFFIC_CODES table. The CODE_USAGE field in this table provides a general description of each CODE_NAME. The CODE_SOURCE field contains information on the reference document or external source for the code definitions.

16.3.7. TRAFFIC_CODES

Many of the elements in the database use a code value to represent alternate standard entries in a field. The TRAFFIC_CODES table contains a definition of the meaning of codes used in the LTAS data tables. To decipher the meaning of a code value, a user must link the corresponding CODE_NAME contained in the TRAFFICDD table for the specific field in a table to the matching record in the TRAFFIC_CODES table with the same CODE_NAME and CODE value.

CODE_NAME is the code type name as shown in the CODE_NAME field in the TRAFFICDD 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.

16.3.8. TRAFFICDD

The TRAFFICDD table is the data dictionary for the LTAS data tables. It contains metadata for each field in each data table in the release. 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. This table is a subset of LTPPDD.

TABLENAME is the name of the table in which the field denoted by FIELDNAME resides.

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

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.

DESCRIPTION is a short description of the field. For instance, the NUM_DAY_OCCURRENCES field has this entry under DESCRIPTION: "Number of times this day of the week was included in the sum."

CODE_NAME is the name of the type of code contained in the TRAFFIC_CODES table. The contents of this field can be used to link to the TRAFFIC_CODES table to lookup the meaning of a code. If this field in TRAFFICDD is not null it is also means that the corresponding field is a codes field in the corresponding table defined by the entry in TABLENAME.

UNITS indicate the units used for the corresponding numeric field.

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.

PROTOCOL is the name of the process used to collect or validate the data.

FIELD_KEY indicates whether the field is part of the PK or index of the table. If the field is not part of the PK but is non-null, NN may be present. The NN designation in the TRAFFICDD is limited to those fields which can be null but are checked for the null condition. The majority of the fields in the LTAS data tables are non-null as part of their definition.

FIELD_ORDER indicates the sequence of fields in a record where 1 is the first field.

16.3.9. TRAFFICTD

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. This table is a subset of LTPPTD.

16.3.10. 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.

16.4. ANNUAL TABLES

Annual tables consist of summaries by day of week for counts by data source, gross vehicle weight and axles by vehicle class and axle group.

16.4.1. YY_AX

This table contains axle data by site, year, lane, direction, vehicle classification, and day of week. The number of days of data in the year for that day of the week is also included. This table is created by summing up the number of days and the axle distributions by axle group over the days in a week for a year from the MM_AX table. Only known vehicles in TMG 13-bin classes 4 through 13 (buses and trucks) are included.

The “heaviest” bin contains single axles 39,000 pounds or greater; tandem axles 78,000 pounds or greater and tridem/ quad+ axles 117,000 pounds or greater.

16.4.2. YY_CT

This table contains count data by site, year, lane, direction, day of week, and data source for each year for which classification and or weight data were accepted for estimating volumes. The number of days of data in the year for that day of the week is also included. This table is created by summing by data type the number of days and the counts over each day of the week in a month from MM_CT table for each data type. Included in the table is the number of unclassified vehicles.

16.4.3. YY_GVW

This table contains GVW data by site, year, lane, direction, vehicle classification, and day of week. The number of days of data in the year for that day of the week is also included. This table is created by summing up the number of days and the GVW distributions over the days in a week for a year from the MM_GVW table. Only known vehicles in TMG 13-bin classes 4 through 13 (buses and trucks) are included.

The “heaviest” bin contains vehicles 196,000 pounds and heavier.

16.5. DAILY TABLES

The daily data tables are created by aggregating data from classification and weight data records in one of the TMG formats from 2nd to 4th editions or the Highway Electronic License Plate (HELP) format for weight data. For classification data the day may be contiguous 24-hour groups of data or calendar days depending on the size of the data set for any given month. The tables grouped in the Daily module contain accepted counts, information on bad data, and information on changes in RECORD_STATUS values.

All data in the daily tables is retained using the agency classification method. Data in these tables is summarized from hourly or vehicle records using the agency's classification method. This may or may not correspond directly to the 13-bin TMG method. Where vehicle class is one of the record's key fields, the variable VEH_CLASS is used.

Daily data from files processed with the old (SAS-based) traffic software suite was loaded via a separate process in a one-time activity. It was already classified with the 13-bin TMG classification method. It did not populate the GVW tables. For these cases to permit the computation of monthly summaries, a dummy record has been added to the GVW table. When listing data for these sites a single GVW record will appear with the weight of one motorcycle in BIN01 of the DD_GVW table. This does not affect any monthly data entries but allows the summarization process in the software to work. This data can also be identified in TRAFFIC_ANALYSIS_TRACKER with DD_CL_DATE and DD_WT_DATE values of October 23, 2002 or earlier.

The information on bad data is contained in three tables, ERR_CL, ERR_WT and TRAFFIC_PURGES. The ERR tables are populated during data loading and reflect errors at the record level. The TRAFFIC_PURGES table records problem data based on graphical review after loading. This data is excluded from all further summarization, estimates and derived values (TRF_ESAL and TRF_MEPDG).

16.5.1. DD_AX

This table contains axle data by site, year, month, day, lane, direction, vehicle class, and axle group. This table is created by accumulating the axle distributions over all hours by vehicle class in a calendar day. All vehicle classes, including passenger vehicles may be in this table.

The data is summarized in 1,000 pound bins for single axles, 2,000 pound bins for tandem axles, and 3,000 pound bins for tridems and quad-plus axle groups. Quad-plus axles are any axle group with 4 or more axles. Data for a brief period was summarized by 4,000 pound bins for quadplus axles. Data loaded during that period has a WEIGHT_BIN_SIZE value of 4,000.

Data in S.I. units is converted to U.S. customary units for accumulating summaries. The "heaviest" bin contains single axles 39,000 pounds or greater; tandem axles 78,000 pounds or greater and tridem/quad+ axles 117,000 pounds or greater.

This data is not available in pre-populated Microsoft® Access tables due to the number of tables required. This data is extracted on demand from InfoPave in Microsoft SQL format.

16.5.2. DD_CL_CT

This table summarizes the number of vehicles by class for each day based on classification records. This table contains count data by site, year, month, day, lane, and direction for each day for which classification data was accepted for estimating volumes. This table is created by day by summing the counts over all hours in a defined day. When 7 or more days of data are present in a month, a day is defined as midnight to midnight. When fewer than 7 days exist, a day starts with the first hour of data and is defined as 24 consecutive hours of data. The process of identifying a day of data continues as long as 24 consecutive hours can be found.

16.5.3. DD_GVW

This table contains GVW data by site, year, month, day, lane, direction, and vehicle class. This table is created by accumulating the GVW distributions by vehicle class over all hours in a calendar day. All vehicle classes, including passenger vehicles may be in this table.

All data is summarized in 4,000 pound bins.

Data in S.I. units is converted to U.S. customary units for accumulating summaries. The "heaviest" bin contains vehicles 196,000 pounds and heavier.

This data is not available in pre-populated Microsoft® Access tables due to the number of tables required. This data is extracted on demand from InfoPave in Microsoft SQL format.

16.5.4. DD_WT_CT

This table summarizes the number of vehicles by class based on weight records. This table contains count data by site, year, month, day, lane, and direction for each day for which weight data exists for estimating loads. This table uses the calendar day to define a day of data but does not require that all 24 hours be present.

16.5.5. ERR_CL

This table contains a record for each lane and direction by date that was rejected in processing classification data. Each record contains total volumes by hour where hours with missing data are null valued. A code in the TRF_ORA_ERR field indicates why the data was rejected.

16.5.6. ERR_WT

This table contains a record for each error encountered for each lane and direction by date while processing weight data. Data in this table may be for record level or day level errors.

Record level errors for files loaded with the LTQC software (LOAD_METHOD_WT = Q) are identified in the files themselves. Record level errors for files loaded with the LTAS software (LOAD_METHOD_WT = A) must be filtered out by the user if the LTAS output files are to be used in another application.

Day level errors are identified only when purges were applied using the LTQC software. These errors are also identified in the files themselves.

16.5.7. TRAFFIC_PURGES

This is a table for holding information on suspect data that should not be included in daily and further summarizations. The entries in this table are created by the user and are either in pending status awaiting review by others or applied as a record of the data to be removed from summarization.

Application of a purge results in a RECORD_STATUS value of 'P' in the affected daily table. If weight data is purged, the purge applies to the DD_WT_CT, DD_AX and DD_GVW tables as well as other internal use LTAS tables. The record status value P does not appear in monthly or yearly tables. The purged data is not included in either monthly or annual summaries or values derived from them.

16.5.8. TRAFFIC_RS_CHANGES

This table indicates what modifications have been made to the RECORD_STATUS values in various data tables. The data is subjected to QC checks for reasonable values and expected between element relationships. There are occasions where higher than expected values are in fact reasonable based on site knowledge. In such cases the value of RECORD_STATUS is changed for records to permit their inclusion in further analysis and or summarization.

Copies of the TRAFFIC_RS_CHANGES table are included in all distributed databases other than Administration for easier access. The table is omitted from Administration since there is no data in it to require explanation of an unexpected RECORD_STATUS values.

16.6. HOURLY TABLES

The only hourly table is HH_CL_CT which stores the hourly volumes by vehicle class in the input method for classification data. While data for any site may be stored in this table, only data from the TPF must be included. That data is used to generate inputs to the TRF_MEPDG_HOURLY_DIST table. This table also stores data from days affected by daylight savings time that violate the 24 hour requirement to allow processing as valid days.

16.7. MONTHLY TABLES

The data in the monthly tables provides the basis for the annual estimates in the pavement database and many of the statistics computed for the TRF_MEPDG tables.

All vehicles are classified in the 13-bin method used in the *TMG.*

There is a single table with count data on the monthly basis. This contains both the counts derived from classification records and those derived from weight records.

There are two monthly weight tables, one for axle distributions and one for GVWs. Both tables contain the sum by day of week over all days by vehicle class for each month for which weight data was accepted for estimating pavement loading.

16.7.1. MM_AX

This table contains axle data by site, year, month, lane, direction, vehicle classification, axle group and day of week. The number of days of data in the month for that day of the week is also included. This table is created by summing up the number of days and the axle distributions by axle group over the days in a week for a month from the DD_AX table. Only vehicles in TMG 13-bin classes 4 through 13 (buses and trucks) are included. Once the day of week totals are found, any data in an agency specified method is converted into the TMG 13 bin method.

The "heaviest" bin contains single axles 39,000 pounds or greater; tandem axles 78,000 pounds or greater and tridem/ quad+ axles 117,000 pounds or greater.

16.7.2. MM_CT

This table contains count data by site, year, month, lane, direction, day of week and data source for each month for which classification and or weight data were accepted for estimating volumes. The number of days of data in the month for that day of the week is also included. This table is created by summing by data type the number of days and the counts over each day of the week in a month from the relevant DD_CT table. Once this is done the classes are converted from an agency specified method into the TMG 13-bin method.

Included in the table is the number of unclassified vehicles. These are vehicles that met all other record and daily QC but were not assigned to classes 1 through 13. These are not vehicles that are included in the error tables.

16.7.3. MM_GVW

This table contains GVW data by site, year, month, lane, direction, vehicle classification, and day of week. The number of days of data in the month for that day of the week is also included. This table is created by summing up the number of days and the GVW distributions over the days in a week for a month from the DD_GVW table. Only vehicles in TMG 13-bin classes 4 through 13 (buses and trucks) are included. Once the day of week totals are found, any data in an agency specified method is converted into the TMG 13 bin method.

The "heaviest" bin contains vehicles 196,000 pounds and heavier.

CHAPTER 17. ANCILLARY INFORMATION

17.1. INTRODUCTION

Ancillary information includes data, images, reference materials, resource documents, and other information that support and extend the data stored in the PPDB. This information may aid in the understanding of the performance of pavement test sections included in the LTPP program. All of the electronic ancillary information is stored at the FHWA Turner-Fairbank Highway Research Center (TFHRC) in McLean, VA, in what is called the AIMS. While the majority of the AIMS data are contained in PPDB in some form, some types of raw data that are summarized in the database are only available from AIMS. Substantially all the data not contained on paper forms is available through InfoPave. Questions about elements that cannot be located through InfoPave should be addressed to LTPP customer support (ltppinfo@dot.gov).

LTPP provides access to its ancillary information in the interest of linkage between the collected raw data and the summaries of processed data contained in the publicly disseminated database. Accessibility to the raw base line measurement data increases the potential for reinterpretation using new future data concepts. A simple example of a data concept is the International Roughness Index (IRI). Providing access to the raw longitudinal profile (LPF) data allows other types of indices to be computed, such as an index based on dynamic truck loads. Note that IRI is based on a passenger car suspension.

Ancillary information is provided without any indication of data quality. While some elements may have undergone quality reviews, some of the electronic files contained in AIMS are raw files that may not have been edited to correct errors discovered during database processing. AIMS also contains data that may not have been loaded into the database for quality concerns or other reasons (e.g., the data were collected after the out-of-study date). LTPP ancillary information users assume responsibility for performing their own checks on data quality and assessing the appropriateness of the data or information for their intended purposes.

A brief summary of the ancillary data available from the LTPP program is presented in Table 7. Not all of the data indicated in Table 7 are available for all test sections, equipment evaluations, traffic measurements, etc.

Table 7. Summary of LTPP ancillary information.

Category	Ancillary Information	Comments
Automated weather station (AWS)	Raw files from data loggers	
	Edited upload files	
Drainage inspection	Inspection video	
	Scanned paper data forms	
Dynamic load response (DLR)	Raw time history sensor response files	More raw data are available than exists in PPDB
Falling weight deflectometer (FWD) measurements	Time history drop data	Not contained in PPDB
	Raw FWD measurement files	
	Scanned paper data forms	
	FWD electronic calibration files	Relative and reference calibration data
Friction	Scanned paper data forms	
Ground-penetrating radar (GPR)	Raw GPR data files	
	Interpreted measurement upload files	
	Raw data graphs	
	Images of interpretations	
Inventory	Scanned paper data forms	
Longitudinal Profile and Texture (LPF)	25 mm (1 inch) spacing raw profile data	Contained in converted Engineering Research Division (ERD) file format
	Raw profiler data files from weigh-in-motion (WIM) scale locations	
	0.50 mm (0.02 inch) raw texture measurements	
	Scanned dipstick paper data collection forms	Paper data forms contain unfiltered pavement profile
	Profile preprocessing software internal computation database files	
	Equipment comparison reports and data	
Maintenance data module (MNT) and rehabilitation data module (RHB)	Scanned paper data forms	
Material tests	Scanned paper data forms	
Pavement distress	Digitized 35 mm (1.4 inch) black and white surface images	Not all 35 mm (1.4 inch) film digitized
	35 mm (1.4 inch) black and white film surface images	Not a formal part of AIMS
	Scanned images of photographic interpreted distress location map	

Category	Ancillary Information	Comments
	Scanned images of manual survey distress location map	Shows location of surface distress features
	Scanned manual distress data (MDS?) forms	
	Digitized photographs from manual distress surveys (MDSs)	Includes photos of interesting/unusual distresses
	Manual distress photograph metadata database	Contains a description of photos
	Scanned transverse profile (TPF) dipstick measurement data sheets	TPF dipstick measurements processed by LTPP preprocessing software
	Database used by the software to perform time series review of photographic and MDS?	
Resilient modulus laboratory test	Time history load and deflection response	Data from all tests not available
Seasonal Monitoring program (SMP)	Raw files from data loggers	
	Edited upload files	
	Scanned paper data sheets	
Specific Pavement Studies	Scanned paper data forms	
Test section coordinates	Scanned paper data forms	
Test section videos	Digitized walking inspection videos	
	Through profiler windshield videos	Shows general condition of test section
Traffic	Raw traffic data in various Traffic Monitoring Guide formats	Annual estimates from the raw data are contained in PPDB
	International Road Dynamics Inc. (IRD) raw data files and outputs from its iANALYZE software	From sites in the LTPP pooled fund study project
	Vehicle images used for vehicle classification algorithm calibration	Very large data sets from limited number of sites

The 35 mm (1.4 inch) photographic images of test section surfaces used as the primary basis for distress interpretation at the start of the program have not been completely converted into electronic format. This is currently the most significant issue in digitization to complete the electronic AIMS. While not all of the available film has been converted to an electronic format, the physical photographic media is still available and contains greater resolution than the pixilated digital images.

The following sections provide more information on the general nature of the available ancillary information following the categories listed in table 6.

17.2. AUTOMATED WEATHER STATION

AWSs were installed at selected SPS-1, SPS-2, and SPS-8 experiment sites. AWS data available from AIMS include raw electronic data files downloaded from data loggers connected to the AWSs, and data files produced by the pre-upload computer program used by the LTPP regional support contractors (RSCs) to review, edit, and create database upload files from the raw data for entry into PPDB.

17.3. DRAINAGE INSPECTION

Ancillary LTPP information includes the data from inspection of the subsurface drainage structures at SPS-1 and SPS-2 project sites. The inspection data includes measurements and information recorded on paper data collection forms and video images. The video images from a remote camera inserted into the drainage system outflow exits and passed as far into the subsurface drains as possible are available in digital format.

17.4. DYNAMIC LOAD RESPONSE

DLR data were collected at the North Carolina SPS-2 site and the Ohio SPS-1, SPS-2, SPS-8, and SPS-9 sites. The available DLR ancillary information not contained in PPDB are the raw time-history data files in ACSII format produced by the strain, pressure, and linear variable differential transformer measurements under moving truck wheel loads.

AIMS contains more DLR measurement files than those uploaded into PPDB due to processing issues. Data users interested in LTPP DLR data must contact the LTPP Customer Support Service Center (CSSC) in order to obtain the most current data and information on problems discovered with past releases of DLR data.

17.5. FALLING WEIGHT DEFLECTOMETER

FWD measurements were performed on test sections to measure the deflection response of the pavement structure. In addition to the raw data produced by the automated FWD measurement device, available associated data includes manual pavement temperature gradient measurements and FWD calibration data.

The raw electronic data files from the FWD device are stored in AIMS. While the test time, test location, equipment calibration settings, equipment configuration factors, air and pavement temperature, and peak deflection basin measurements are stored in PPDB, the time-history deflection and load sensor measurements are only available from AIMS.

When FWD measurements are performed on LTPP test sections, measurement of the subsurface temperature of the bound surface pavement layers at various depths are performed using external instruments. The paper data sheets used to record these data in the field have been electronically scanned and are stored in AIMS.

LTPP FWD data undergo a variety of QC checks. Calibrations are performed using a combination of relative and reference procedures. Measurement data are also subjected to automated data checks prior to uploading into PPDB. AIMS includes the raw electronic files generated during these calibrations and pre-upload data checks.

17.6. FRICTION

Friction measurements are performed by participating highway agencies on a voluntary basis using their equipment. The measurements are recorded on paper data forms that are submitted to LTPP for entry into PPDB. The scanned images of the paper data collection forms used to report data are saved in electronic format in AIMS.

17.7. GROUND-PENETRATING RADAR

GPR measurements were performed in 2003 on all SPS-1 projects that were still in-service at the time. Measurements were also performed on selected SPS-2, SPS-5, and SPS-6 project sites.

The ancillary information from these GPR measurements includes the raw data files containing readings every 152 mm (6 inches), a graph of the data contained in the raw data file, a graph of the interpreted dielectric constant versus position, a graph of the interpreted layer thicknesses versus position in the right wheel path and center of the lane, and the upload files used to populate the table in PPDB that contains the interpreted results.

17.8. INVENTORY DATA

Inventory data include pavement age, general location, pavement type, layer thicknesses and types, material properties, composition, previous construction improvements, and other background information obtained from agency files for pavement structures in-service prior to LTPP monitoring. The data are reported to LTPP by participating highway agencies on paper data collection forms. Images of the paper data collection forms used to collect this data are saved in electronic scanned format in AIMS.

17.9. LONGITUDINAL PROFILE AND TEXTURE

LTPP LPF measurement ancillary information includes raw data files from high-speed inertial profile measurements on pavement test sites and WIM scales, and manual measurements on remote test sites using the dipstick device. While the profile data prior to 2014 used a PRF label, with the introduction of the AMES high speed survey profilers in 2014, longitudinal profile and texture data are stored using an HSS label.

The majority of LTPP longitudinal measurement data were collected using high-speed inertial profilers. The raw data files and database files generated by the LTPP pre-upload data processing software are stored in AIMS. LTPP data include measurements performed on pavement test sections and at WIM scale measurement sites.

A small subset of LPF measurement data was collected using a manually operated dipstick device. Ancillary information from dipstick measurements includes an image scan of the paper data collection forms and electronic data files generated during the pre-upload processing of these data.

Entry of the 25 mm (1 inch) interval longitudinal pavement profile data available from the more modern profilers into the PPDB started in 2015, and was completed 2016 data public data release. These data which are stored in the AIMS were previously only available by request to LTPP CSSC are now available for download from the LTPP InfoPave web site. All LPF measurements at WIM scale sites are stored in AIMS and are available from the LTPP InfoPave web site.

The raw 0.5 mm texture measurement data are stored only in the AIMS due the extremely large size if stored in database format. These files can be downloaded from the InfoPave web site.

17.10. MAINTENANCE AND REHABILITATION

Maintenance data modules (MNT) and rehabilitation data modules (RHB) include data for maintenance and rehabilitation construction events performed after LTPP monitoring of the test sections had begun. These data are reported on paper data collection forms. Images of the paper data collection forms used to collect this data are saved in electronic scanned format in AIMS.

17.11. MATERIAL TESTS

This data type contains field tests and laboratory test results on material samples obtained from the LTPP test sections. The majority of these data are reported on paper data collection forms. Images of the paper data collection forms used to collect these data are saved in electronic scanned format in AIMS.

17.12. PAVEMENT DISTRESS

The major categories of LTPP pavement distress ancillary information are manual distress, automated photographic distress, manual TPF measurements, and data from automated quality review records.

The manual distress ancillary information includes scanned images of the paper field data distress maps, paper data collection sheets, and digitized images from photographs taken during a MDS. The electronic database that documents the basic information on the location of each manual distress photographic image file is also contained in AIMS.

A significant exception to the definition of AIMS data being electronic files are the pavement images recorded on 35 mm (1.4 inch) black and white film. Two sets of film are available. One set of film was used to record the image of the pavement surface. These images were used as the basis for surface distress interpretations from raters. The other film set was used to measure the distortion in the pavement TPF using an optical image analysis process. All original raw 35 mm (1.4 inch) film media is stored in a climate-controlled facility at the Materials Reference Library. Approximately 2,000 images collected between 2002 and 2004 have been electronically digitized and stored in AIMS. Users desiring access to view raw film format must make arrangements through the LTPP CSSC.

Manual TPF measurements performed using the dipstick measurement device are recorded in the field on paper forms. The data from these paper forms are entered into a pre-upload processing software that checks the data, performs quality checks, and generates PPDB upload files. AIMS contains electronically scanned images of the field paper data collection forms and files generated by the data processing program.

Other pavement distress information stored in AIMS that are not available in PPDB includes images of the hand-drawn distress maps that indicate the location of the various distresses from the manual surveys, computer-generated maps from interpretation of 35 mm (1.4 inch) film, digitized images from photographs taken during MDSs, and digitized images from the 35 mm (1.4 inch) photography.

17.13. RESILIENT MODULUS MATERIAL TESTS

Resilient modulus tests were performed on asphalt concrete cores and unbound aggregate/subgrade material samples following the LTPP P07 and LTPP P46 test protocols. The LTPP P07 test protocol is a test procedure that includes resilient modulus, creep compliance, and tensile strength from asphalt concrete core samples tested in indirect tension. The LTPP P46 protocol is a resilient modulus test performed on unbound base and subbase materials in compression mode. The raw time history data files from the parts of these laboratory tests based on repeat cyclical load/response measurements are contained in AIMS.

Only a partial record of the raw LTPP P46 test protocol time-history data on unbound materials exists since the original laboratory contractors were not required to submit these data.

17.14. SEASONAL MONITORING PROGRAM

The data in the SMP module contain processed raw and interpreted data from instrumentation and other measurements performed on these sites. The SMP ancillary information includes the raw electronic instrumentation data files, edit files from the software program that were used to perform primary quality checks on the raw data and produce the PPDB upload files, and scanned electronic paper data collection forms.

17.15. SPECIFIC PAVEMENT STUDIES

This module includes general and construction information collected from the test sections included in the SPS experiments. These data are entered on paper data collection forms. Images of the paper data collection forms used to collect the general and construction data contained in this module are saved in electronic scanned format in AIMS.

17.16. TEST SECTION COORDINATES

Test section coordinates are measurements or estimates of test section locations using Global Positioning System (GPS) technology or other modern mapping techniques. These measurements are recorded on paper data collection forms. Images of the paper data collection forms used to collect this data are saved in electronic scanned format in AIMS.

17.17. TEST SECTION VIDEOS

The following types of test section videos have been electronically digitized and are available:

- Walking inspections of test sections: During the initial inspection of test sections at the start of the program, videos showing the test section surface and surrounding terrain were made on some sections. Walking inspection videos were also created during MDSs on some sections. The videos were taken by staff walking the length of each test section, and they contain an oral narrative of significant features.

- Through-the-windshield video from the high-speed profiler: Video cameras were mounted in some of the LTPP profilers, and videos of the test sections were recorded through the windshield during measurements. These videos were used to check on the general condition of each test section and to detect maintenance activities. These video recordings were performed by only some regional LTPP data collection contractors and are available for a subset of test sections.

17.18. TRAFFIC

LTPP traffic data ancillary information includes traffic measurement output files from LTAS and those created by legacy LTQC software and versions based on Statistical Analysis Software® (SAS®), files from the International Road Dynamics Inc. (IRD) iANALYZE® software, and scanned paper data forms. LTAS reads data files formatted in a FHWA TMG format (4^{th} edition or earlier) for classification or weight data, performs traffic data QC checks, provides data graphs for semi-automated data checks by regional staff, creates a variety of quality assurance reports, and creates the annual traffic data statistics stored in PPDB. The some of the internal database files created by LTAS are now part of the LTPP SDR. The AIMS component of LTAS-related data contains output files in a TMG format.

A contractor was selected to install WIM scales at select LTPP test section locations as part of the TPF. AIMS includes vendor proprietary binary raw data output and ASCII versions of the same data produced by the iANALYZE® software.

The traffic ancillary information includes electronic images of the paper data forms used to report basic traffic information, traffic scale calibration, historical traffic, and traffic estimates produced by the agency when no onsite measurements were performed.

Traffic ancillary information also includes images of vehicles at selected WIM sites that are tied to per vehicle classification results. These image files are of such a large size that they are prohibitive to provide in an on-demand download format from the InfoPave web site. Data users interested in access to these image files and information on how to use them in concert with raw traffic measurement data should contact LTPP CSSC.

17.19. TECHNICAL DETAILS

Some of the technical details of the electronic files containing LTPP ancillary information include the following considerations. While there are some discrepancies in file formats, the following are the general rules used to digitize the LTPP information archive.

- Electronic data formats follow U.S. National Archives and Records Administration (NARA) standards existing at the time the various versions of LTPP directives on the subject were written. In some cases, other popular formats were used if NARA did not have an existing standard at the time.

- Scanned paper data forms are saved in a black and white portable document format (PDF).

- Videos are digitized to moving pictures expert group (MPEG) and AVI formats.
- Still photographic images are digitized to joint photographic expert group (JPEG) formats.
- While some of the file name extensions conform to modern electronic file name practice (e.g., ".pdf" is a PDF file), many file extensions conform to LTPP practice for its custom electronic file structures. These file name extension practices change over time.
- Requests for schema that describes the format and content of the LTPP electronic data can be submitted to LTPP CSSC.

CHAPTER 18. OBTAINING LTPP DATA AND INFORMATION

18.1. 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 and InfoPave web sites. Data users can also contact LTPP Customer Service to inquire about the availability of documentation not distributed with the data nor contained on LTPP web sites.

Extractions from the LTPP database are provided free of charge to data users who use the InfoPave web site.

Custom extractions from the database may be requested.

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 expended on user requests.

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.

18.2. OBTAINING LTPP DATA

The LTPP InfoPave web site is now the main method to obtain LTPP data and information. The standard data release is no longer distributed on stand-alone computer media; standard data release files must now be downloaded from the InfoPave web site.

All custom requests for LTPP data and information should be made to the LTPP customer support service center (CSSC). 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/.

18.3. LTPP INFOPAVE

The LTPP InfoPave web site (https://infopave.fhwa.dot.gov/) is now the main method to obtain LTPP data and information. The InfoPave web site provides access to LTPP data and information on-demand through a web-centric interface, and provide features and tools designed to maximize user understanding of the data. Figure 31 shows the InfoPave home screen, which illustrates the modern screen layout, easy to access features, hubs, and social media links.

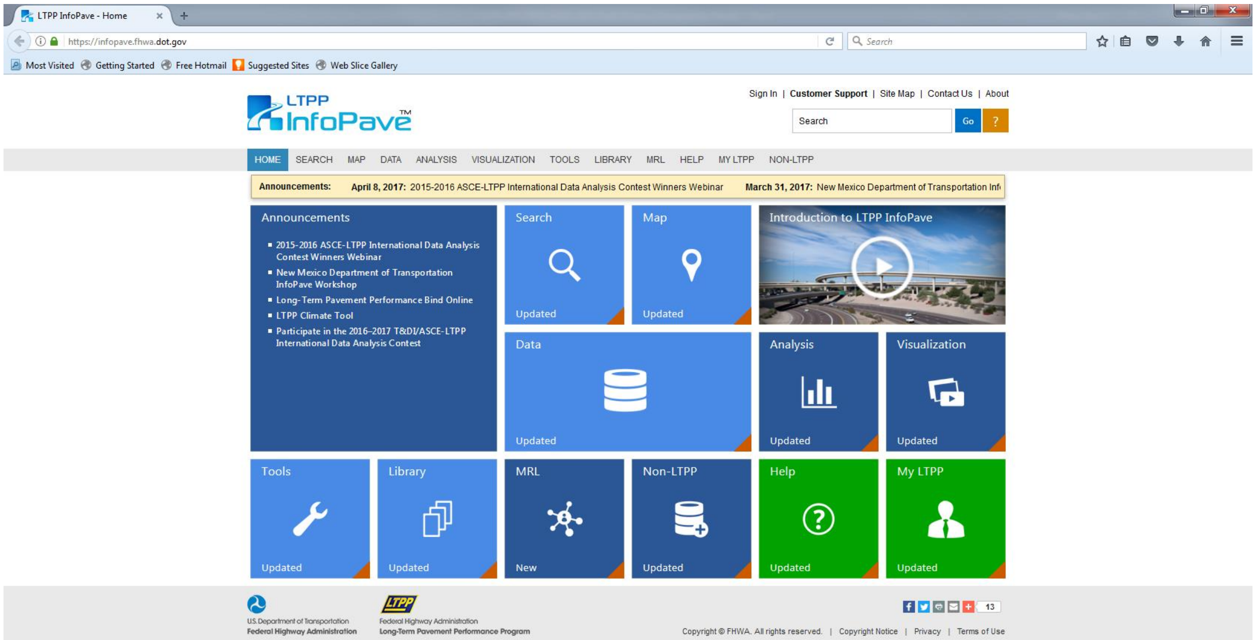


Figure 31. Image. InfoPave home screen.

Some of the features and tools designed contained in InfoPave include:

- Search. This feature is used to find information and documents by an intuitive search feature common to modern web applications
- Map. This features displays selected information on a map with the ability to zoom in and out, pan, and filter section results with a combination of criteria.
- Analysis. This feature provides access to previous research projects.
- Visualization. This feature provides access to pavement inspection videos, manual distress survey maps, summarized pavement structure visuals, test section timeline summary data, and pivot table formats.
- Advanced database query. A query tool is available for those familiar with the LTPP database that will allow users to write and execute database queries on line. The tool will also include a wizard that allows creation of queries using a graphical interface.
- Download. In addition to downloading data, a user may download documents and media selected using other InfoPave features. The following can also be downloaded:
    - Legacy SDR. This is the traditional SDR format that many LTPP data users have learned to use. The SDR is formatted as a series of Microsoft Access 2000/ 2002-2003

databases based on the North American software version. The databases are divided into multiple databases to meet Microsoft Access database size limitations. Due to size limitations, not all data is being provided in this format beginning with SDR 30 (July 2016).

  - Reference documents. The library feature contains the contents the legacy LTPP Reference Library as updated with new reports and documents.

- Tools. Tools include programs developed by LTPP. Some of the tools that can be executed on line include LTPP Rigid Pavement, WIM Cost Analysis, and Performance Forecast. Downloaded tools include LTPP* Dynamic Modulus Prediction and LTPP Bind.

The LTPP program encourages all users of LTPP data and information to explore and take advantage of the InfoPave web interface. The interface now contains help tools and other information required to access and understand LTPP data and information. Details of each data release are now posted on the InfoPave™ web site.

18.4. SDR DATA DOWNLOAD OPTIONS

The SDR prepackaged databases contained in the July 2017 LTPP public data release have evolved into a new automated format that are fully described on the InfoPave web based interface. Just like the July 2016 public data release, while most of the smaller modules are preformatted in MS Access format, the larger database modules are available in MS SQL format. The InfoPave web site contains current information on the available content, format, and download options for the preformatted standard data release options.

18.5. CUSTOM DATA EXTRACTIONS

Data users can request custom partial extractions from the database and/or extractions in a nonstandard format from LTPP Customer Service. The support and availability of custom data extractions will be evaluated on a case-by-case basis based on effort to provide the extraction. While users are encouraged to use InfoPave and its filtering capabilities, database extractions can be provided in Oracle RDBMS format, ASCII, comma-delimited ASCII, Microsoft Excel, Microsoft Access, or MS SQL formats. Users interested in obtaining data in other formats should contact the LTPP customer support service center.

APPENDIX A. LTPP OPERATIONS REFERENCE DOCUMENTS

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A.10 SITE REPORTS

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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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Materials Sampling, Field Testing, and Laboratory Testing Plan, Strategic Highway Research Program, SPS-8 Experimental Project (Flexible and Rigid), Federal Aid Project No. ACNH-P099(370)Y, Sycamore Street, Delhi, Merced County, California, FHWA, Pavement Performance Division, February 1999.

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Materials Sampling, Field Testing, and Laboratory Testing Plan, Strategic Highway Research Program, SPS-8 Experimental Project, Utah Forest Highway and Federal Lands Highway Project 5-2(3), State Highway 35 (Wolf Creek Road), Wasatch County, Utah, FHWA, Pavement Performance Division, April 1996.

Materials Sampling, Field Testing, and Laboratory Testing Plan, Strategic Highway Research Program, SPS-8 Experimental Project, Project Nos. PFH 176-1(1) and RS-A070(002), North Touchet Road, Columbia County, Washington, FHWA, Pavement Performance Division, June 1994.

Materials Sampling, Field Testing, and Laboratory Testing Plan, Strategic Highway Research Program, SPS-8 Experimental Project (Rigid), Project No. CRP 93-13, Smith Springs Road, Walla Walla County, Washington, FHWA, Pavement Performance Division, September 1999.

A.10.2 SPS Construction Reports

The SPS construction reports provide data users with site-specific information and notes on the general layout of the site, site features, construction problems, nonstandard construction features, and other information not easily captured on the data sheets.

A.10.2.1 North Atlantic Region

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Construction Report on LTPP 510100, SPS-1 Project, Danville, Virginia, FHWA, Pavement Performance Division, June 1996.

Construction Report on LTPP 100200, SPS-2 Project, Ellendale, Delaware, Publication No. FHWA-TS-96-10-04, FHWA, Pavement Performance Division, October 1996.

Report of Site Investigation on Delaware SPS-2 Problem Test Sections, FHWA, Pavement Performance Division, July 1999

Construction Report on LTPP 370200, SPS-2 Project, Lexington, North Carolina, FHWA, Pavement Performance Division, August 1994.

Construction Report on LTPP 24A300, SPS-3 Project, Ocean City, Maryland, FHWA, Pavement Performance Division, October 1990.

Construction Report on LTPP 36A300 and 36B300, SPS-3 Projects, Glen Falls and Cranberry Lake, New York, FHWA, Pavement Performance Division, October 1990.

Construction Report on LTPP 42A300 and 42B300, SPS-3 Projects, Lewisburg and Knoxville, Pennsylvania, FHWA, Pavement Performance Division, October 1990.

Construction Report on LTPP 51A300, SPS-3 Project, Petersburg, Virginia, FHWA, Pavement Performance Division, 1990.

Construction Report on LTPP 87A300 and 87B300, SPS-3 Projects, Moonstone and Bracebridge, Ontario, FHWA, Pavement Performance Division, October 1990.

Construction Report on LTPP 89A300, SPS-3 Project, Trois-Rivieres, Quebec, FHWA, Pavement Performance Division, 1990.

Construction Report on LTPP 230500, SPS-5 Project, Argyle, Maine, Publication No. FHWA-TS-95-23-02, FHWA, Pavement Performance Division, December 1995.

Construction Report on LTPP 240500, SPS-5 Project, Frederick, Maryland, FHWA, Pavement Performance Division, March 1993.

Construction Report on LTPP 340500, SPS-5 Project, Imlaystown, New Jersey, FHWA, Pavement Performance Division, December 1994.

Construction Report on LTPP 420600, SPS-6 Project, Snowshoe, Pennsylvania, FHWA, Pavement Performance Division, May 1995.

Construction Report on LTPP 340800, SPS-8 Project, NY/NJ, JFK Airport, Port Authority, Publication No. FHWA-TS-94-34-01, FHWA, Pavement Performance Division, December 1994.

Construction Report on LTPP 360800, SPS-8 Project, Lake Ontario State Parkway, Brockport, New York, Publication No. FHWA-TS-95-36-01, FHWA, Pavement Performance Division, March 1995.

Construction Report on LTPP 370800, SPS-8 Project, Jacksonville, North Carolina, Publication No. FHWA-TS-98-37-02, FHWA, Pavement Performance Division, December 1998.

Construction Report on LTPP 240900, SPS-9 Project, Frederick, Maryland, FHWA, Pavement Performance Division, December 1992.

Construction Report on LTPP 090900, SPS-9A Project, Colchester, Connecticut, Publication No. FHWA-TS-98-09-02, FHWA, Pavement Performance Division, June 1998.

Construction Report on LTPP 340900, SPS-9A Project, Allentown, New Jersey, Publication No. FHWA-TS-00-34-01, FHWA, Pavement Performance Division, December 2000.

Construction Report on LTPP 370900, SPS-9A Project, NB and SB, Sanford, North Carolina, Publication No. FHWA-TS-00-37-02, FHWA, Pavement Performance Division, June 2000.

Construction Report on LTPP 870900, SPS-9A Project, Petawawa, Ontario, Publication No. FHWA-TS-98-87-02, FHWA, Pavement Performance Division, March 1998.

Construction Report on LTPP 890900 and 89A900, SPS-9A Projects, Jonquiere, Quebec, Publication No. FHWA-TS-98-89-02, FHWA, Pavement Performance Division, April 1998.

A.10.2.2 North Central Region

SPS-1 Construction Report, US-54 Near Fort Madison, Iowa, Sections 190101 to 190112, FHWA, Pavement Performance Division, April 1994.

SPS-1 Construction Report, US-54 Near Greensburg, Kansas, Sections 200101 to 200164, FHWA, Pavement Performance Division, April 1994.

SPS-1 Construction Report, U.S. Highway 81 Southbound, 80 Miles Southwest of Lincoln, Nebraska, (4 Miles) North of the Kansas Border, Sections 310113 to 310124, FHWA, Pavement Performance Division, June 1996.

SPS-1 Construction Report, U.S. Highway 23 Southbound, Delaware County, Ohio, Sections 390101 to 390112, 390159, and 390160, FHWA, Pavement Performance Division, September 1998.

SPS-1 Construction Report, STH 29 Westbound, Marathon County, Wisconsin, Sections 550113 to 550124, FHWA, Pavement Performance Division, March 2000.

SPS-2 Construction Report, US-65 Northbound, Polk County, Iowa, Sections 190213 to 190224, FHWA, Pavement Performance Division, June 1996.

SPS-2 Construction Report, I-70 Near Abilene, Kansas, Sections 200201 to 200212, FHWA, Pavement Performance Division, March 1993.

SPS-2 Construction Report, US 23 Northbound, Monroe County, Michigan, FHWA, Pavement Performance Division, December 1995.

SPS-2 Construction Report, I-94 Eastbound, West of Fargo, North Dakota, Sections 380213 to 380224, FHWA, Pavement Performance Division, June 1996.

SPS-2 Construction Report, U.S. Highway 23 Northbound, Delaware County, Ohio, Sections 390201 to 390212 and 390259 to 390265, FHWA, Pavement Performance Division, September 1998.

SPS-2 Construction Report, STH 29 Westbound, Marathon County, Wisconsin, Sections 550213 to 550224 and 550259 to 550266, FHWA, Pavement Performance Division, December 1999.

SPS-5 Construction Report, Trunk Highway 2 Westbound, 14 Miles West of Bemidji, Minnesota, Core Sections 270501 to 270509 and Supplemental Sections 270559 to 270561, FHWA, Pavement Performance Division, June 1996.

SPS-5 Construction Report, PTH No. 1 Westbound, 35 Miles East of Winnipeg, Manitoba, Sections 830501 to 830509, FHWA, Pavement Performance Division, June 1996.

SPS-6 Construction Report, I-35 Southbound, Between Ames and Des Moines, Iowa, Test Sections 190601 to 190608, FHWA, Pavement Performance Division, June 1996.

SPS-6 Construction Report, US-10 Eastbound, Bay County, Michigan, FHWA, Pavement Performance Division, December 1995.

SPS-6 Construction Report, US Highway 12 Westbound, Approximately 15 Miles East of Aberdeen, South Dakota, Test Sections 460601 to 460608, FHWA, Pavement Performance Division, June 1996.

SPS-7 Construction Report, I-35 Near Ames, Iowa, Sections 190701 to 190710, FHWA, Pavement Performance Division, April 1994.

SPS-7 Construction Report, Interstate 94 Eastbound, Between Moorhead and Barnesville, Minnesota, Sections 270701 to 270709, FHWA, Pavement Performance Division, June 1996.

Construction Report for SPS-7, Route 67 Northbound, Jefferson County, Missouri, FHWA, Pavement Performance Division, December 1995.

Construction Report for SPS-8, Ramp A, Delaware County, Ohio, FHWA, Pavement Performance Division, December 1995.

SPS-8 South Dakota, Construction Report, State Highway 1804, Pollock, South Dakota, Sections 460803 and 460804, Supplemental Section 460859, FHWA, Pavement Performance Division, June 1996.

SPS-9 Construction Report, US-54 Near Greensburg, Kansas, Sections 200901 to 200903, FHWA, Pavement Performance Division, December 1993.

SPS-9 Construction Report, US-169, Near Belle Plaine, Minnesota, Sections 270901 to 270903, FHWA, Pavement Performance Division, April 1995.

SPS-9 Construction Report, I-94 Near Tomah, Wisconsin, Sections 550901 to 550909, FHWA, Pavement Performance Division, June 1994.

SPS-9 Construction Report, I-43 Near Milwaukee, Wisconsin, Sections 55A901 to 55A909 and Sections 55B901 to 55B909, FHWA, Pavement Performance Division, June 1994.

SPS-9A Construction Report, U.S. 65 Southbound, Sedalia, Missouri, Sections 290901 to 290903 and 290959 to 290964, FHWA, Pavement Performance Division, September 1998.

SPS-9A Construction Report, U.S. Highway 81 Southbound, 80 Miles Southwest of Lincoln, Nebraska, (4 Miles) North of the Kansas Border, Sections 310901 to 310903, FHWA, Pavement Performance Division, June 1996.

SPS-9A Construction Report, Yellow Head Highway Westbound, Radisson, Saskatchewan, Sections 900901 to 900903 and 900959 to 900962, FHWA, Pavement Performance Division, September 1998.

A.10.2.3 Southern Region

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SPS-1 Project 0101, Strategic Study of Structural Factors for Flexible Pavements, US-280 Westbound, Lee County, Alabama, Final Report, FHWA, Pavement Performance Division, February 1996.

SPS-1 Project 0501, Strategic Study of Structural Factors for Flexible Pavements, US-63 Northbound, Craighead County, Arkansas, Final Report, FHWA, Pavement Performance Division, October 1996.

SPS-1 Project 1201, Strategic Study of Structural Factors for Flexible Pavements, US-27 Southbound, Palm Beach County, Florida, Final Report, FHWA, Pavement Performance Division, December 1996.

SPS-1 Project 2201, Strategic Study of Structural Factors for Flexible Pavements, US-171 Northbound, Calcasieu Parish, Louisiana, Final Report, FHWA, Pavement Performance Division, May 1998.

SPS-1 Project 3501, Strategic Study of Structural Factors for Flexible Pavements, IH-25 Northbound, Dona Ana County, New Mexico, Final Report, FHWA, Pavement Performance Division, April 1996.

SPS-1 Project 4001, Strategic Study of Structural Factors for Flexible Pavements, US-62 Eastbound, Comanche County, Oklahoma, Final Report, FHWA, Pavement Performance Division, August 1998.

SPS-1 Project 4801, Strategic Study of Structural Factors for Flexible Pavements, US-281 Southbound, Hidalgo County, Texas, Final Report, FHWA, Pavement Performance Division, December 1997.

SPS-2 Project 0502, Strategic Study of Structural Factors for Rigid Pavements, I-30 Westbound, Hot Springs County, Arkansas, Final Report, FHWA, Pavement Performance Division, November 1997.

Report on the SPS-3 Experiment of the Long-Term Pavement Performance Project in the Southern Region, Publication No. FHWA-IF-00-026, FHWA, Pavement Performance Division, August 2000.

SPS-3 Construction Report, SHRP Southern Region Coordination Office, FHWA, Pavement Performance Division, January 1991.

SPS-4 Construction Report, SHRP Southern Region Coordination Office, FHWA, Pavement Performance Division, February 1991.

SPS-5 Project 0105, Asphalt Rehabilitation Study, US-84 Eastbound, Houston County, Alabama, Final Report, FHWA, Pavement Performance Division, March 1996.

SPS-5 Project 1205, Asphalt Rehabilitation Study, US-1 Southbound, Martin County, Florida, Final Report, FHWA, Pavement Performance Division, April 1996.

SPS-5 Project 1305, Asphalt Rehabilitation Study, IH-75 Southbound, Bartow County, Georgia, Final Report, FHWA, Pavement Performance Division, January 1996.

SPS-5 Project 2805, Asphalt Rehabilitation Study, IH-55 Northbound, Yazoo County, Mississippi, Final Report, FHWA, Pavement Performance Division, April 1993.

SPS-5 Project 3505, Asphalt Rehabilitation Study, IH-10 Eastbound, Grant County, New Mexico, Final Report, FHWA, Pavement Performance Division, May 1997.

SPS-5 Project 4005, Asphalt Rehabilitation Study, US-62 Westbound, Comanche County, Oklahoma, Final Report, FHWA, Pavement Performance Division, October 1998.

SPS-5 Project 4805, Asphalt Rehabilitation Study on US-175 in Kaufman County, Texas, Final Report, FHWA, Pavement Performance Division, July 1992.

SPS-6 Project 0106, Rehabilitation of Jointed Portland Cement Concrete Pavements, I-59 Southbound, Etowah County, Alabama, Final Report, FHWA, Pavement Performance Division, May 1999.

SPS-6 Project 05A6, Rehabilitation of Jointed Portland Cement Concrete Pavements, US-65 Southbound, Jefferson County, Arkansas, Final Report, FHWA, Pavement Performance Division, October 1997.

SPS-6 Project 4006, Rehabilitation of Jointed Portland Cement Concrete Pavements, IH-35 Southbound, Kay County, Oklahoma, Final Report, FHWA, Pavement Performance Division, June 1993.

SPS-6 Project 4706, Rehabilitation of Jointed Portland Cement Concrete Pavements, IH-40 Westbound, Madison County, Tennessee, Final Report, FHWA, Pavement Performance Division, March 1997.

SPS-7 Project 2207, Bonded Concrete Overlay of a Concrete Pavement, IH-10 Eastbound, Ascension Parish, Louisiana, Final Report, FHWA, Pavement Performance Division, April 1993.

SPS-8 Project 0508, Environmental Effects in the Absence of Heavy Loads, US-65 East Terminal Interchange, Right Frontage Road, Jefferson County, Arkansas, Final Report, FHWA, Pavement Performance Division, December 1998.

SPS-8 Project 2808, Environmental Effects in the Absence of Heavy Loads, SR-315 Westbound, Panola County, Mississippi, Final Report, FHWA, Pavement Performance Division, February 1998.

SPS-8 Project 3508, Environmental Effects in the Absence of Heavy Loads, IH-10 Frontage Road, Grant County, New Mexico, Final Report, FHWA, Pavement Performance Division, May 1997.

SPS-8 Project 4808, Environmental Effects in the Absence of Heavy Loads, FM-2223 Eastbound, Brazos County, Texas, Final Report, FHWA, Pavement Performance Division, October 1996.

SPS-8 Project 48A8, Environmental Effects in the Absence of Heavy Loads, FM-2670 Eastbound, Bell County, Texas, Final Report, FHWA, Pavement Performance Division, July 2000.

SPS-9A Project 0509, Superpave Asphalt Binder Study, US-65 Southbound, Pulaski County, Arkansas, Final Report, FHWA, Pavement Performance Division, September 1997.

SPS-9A Project 1209, Superpave Asphalt Binder Study, IH-10 Eastbound, Columbia County, Florida, Final Report, FHWA, Pavement Performance Division, March 1997.

SPS-9A Project 2809, Superpave Asphalt Binder Study, IH-55 Southbound, Panola County, Mississippi, Final Report, FHWA, Pavement Performance Division, November 1996.

SPS-9A Project 3509, Superpave Asphalt Binder Study, IH-10 Eastbound, Grant County, New Mexico, Final Report, FHWA, Pavement Performance Division, May 1997.

SPS-9A Project 4809, Superpave Asphalt Binder Study, FM-1604 Southbound, Bexar County, Texas, Final Report, FHWA, Pavement Performance Division, January 1996.

A.10.2.4 Western Region

Construction Report on Site 040200, Interstate Highway No. I-10, Maricopa County, Arizona, Final Report, FHWA, Pavement Performance Division, May 1994.

Construction Report on Site 040500, Interstate Highway No. I-8, Casa Grande, Arizona, Final Report, Arizona Transportation Research Center, Arizona DOT, October 1990.

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Construction Report on Site 040900/04A900, U.S. 93, Arizona Department of Transportation, Kingman, Arizona, Final Report, FHWA, Pavement Performance Division, December 1997.

Construction Report on Site 060200, SR 99, Delhi, California, Final Report, FHWA, Pavement Performance Division, December 2002.

Construction Report on Site 060500, Interstate 40, California Department of Transportation, Barstow, California, Final Report, FHWA, Pavement Performance Division, April 1996.

Construction Report on Site 060600, Interstate Highway No. I-5, Mt. Shasta City, California, Final Report, FHWA, Pavement Performance Division, April 1996.

Construction Report on Site 060800, Sycamore Street, Delhi, California, Final Report, FHWA, Pavement Performance Division, August 2002.

Construction Report on Site 06A800, Sycamore Street, Delhi, California, Final Report, FHWA, Pavement Performance Division, August 2002.

Construction Report on Site 080500, Interstate 70, Colorado Department of Transportation, Lincoln County, Colorado, Final Report, FHWA, Pavement Performance Division, October 1994.

Construction Report on Site 080800, Chestnut Street, Colorado Department of Transportation, Adams County, Colorado, Draft Report, FHWA, Pavement Performance Division, June 1998.

Construction Report on Site 300100, Interstate Highway 15, Cascade County, Montana, Final Report, FHWA, Pavement Performance Division, November 2002.

Construction Report on Site 300500, Interstate 90, Big Timber, Montana, Final Report, FHWA, Pavement Performance Division, January 1992.

Construction Report on Site 300900, Interstate Highway 15, Cascade County, Montana, Final Report, FHWA, Pavement Performance Division, August 2002.

Construction Report on Site 320100, Interstate Highway No. I-80, Humboldt and Lander Counties, Nevada, Final Report, FHWA, Pavement Performance Division, March 1998.

Construction Report on Site 320200, Interstate Highway No. I-80, Humboldt and Lander Counties, Nevada, Final Report, FHWA, Pavement Performance Division, March 1998.

Construction Report on Site 300800, SR 273, Adams County, Washington, Final Report, FHWA, Pavement Performance Division, August 1996.

Construction Report on Site 530200, SR 395, Adams County, Washington, Final Report, FHWA, Pavement Performance Division, March 1997.

Construction Report on Site 530800, North Touchet Road, Dayton, Washington, Final Report, FHWA, Pavement Performance Division, September 1997.

Construction Report on Site 53A800, Smith Springs Road, Clyde, Washington, Final Report, FHWA, Pavement Performance Division, August 2002.

Construction Report on Site 810500, Highway 16, Alberta Transportation and Utilities Department, Edson, Alberta, Final Report, FHWA, Pavement Performance Division, July 1993.

Construction Report on Site 81A900, Highway 2, Alberta Transportation and Utilities Department, Okotoks, Alberta, Draft Report, FHWA, Pavement Performance Division, March 1997.

FHWA LTPP Specific Pavement Studies, Arizona SPS-1, Construction Report on SHRP 040100, Draft Report, FHWA, Pavement Performance Division, April 1995.

Investigation of Premature Distress in Asphalt Overlays on IH-70 in Colorado, Cooperative Applied Research between the Asphalt Institute and Colorado DOT, Denver, Colorado.

SPS-2 Construction Report, SHRP 080200, Federal Aid Project No. I 076-1 (138), I-76 Eastbound, Milepost 18.43, Adams County, Colorado, FHWA, Pavement Performance Division, September 1998.

SPS-3 Construction Report, SHRP Western Region, Final Report, SHRP, National Research Council, December 1990.

SPS-8 Construction Report on Site 490800, State Route 35 (Wolf Creek Road), Utah, Draft Report, FHWA, Pavement Performance Division, September 1998.

SPS-9A I-10 Westbound Milepost 112-123, Construction Report on Site 04B900, Arizona, Draft Report, FHWA, Pavement Performance Division, August 1998.

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.

A.10.3.1 North Atlantic Region

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LTPP Seasonal Monitoring Program: Site Installation and Initial Data Collection, Section 100102, Ellendale, Delaware, Publication No. FHWA-TS-96-10-02, FHWA, Pavement Performance Division, June 1996.

LTPP Seasonal Monitoring Program: Site Installation and Initial Data Collection, Section 231026, East Dixfield, Maine, Publication No. FHWA-TS-94-23-01, FHWA, Pavement Performance Division, June 1994.

LTPP Seasonal Monitoring Program: Site Installation and Initial Data Collection, Section 241634, Ocean City, Maryland, Publication No. FHWA-TS-96-24-01, FHWA, Pavement Performance Division, June 1996.

LTPP Seasonal Monitoring Program: Site Installation and Initial Data Collection, Section 251002, Chicopee, Massachusetts, Publication No. FHWA-TS-94-25-01, FHWA, Pavement Performance Division, June 1994.

LTPP Seasonal Monitoring Program: Site Installation and Initial Data Collection, Section 331001, Concord, New Hampshire, Publication No. FHWA-TS-94-33-01, FHWA, Pavement Performance Division, June 1994.

LTPP Seasonal Monitoring Program: Site Installation and Initial Data Collection, Section 360801 Hamlin, New York, Publication No. FHWA-TS-96-36-01, FHWA, Pavement Performance Division, June 1996.

LTPP Seasonal Monitoring Program: Site Installation and Initial Data Collection, Section 364018, Oneonta, New York, Publication No. FHWA-TS-95-36-01, FHWA, Pavement Performance Division, September 1995.

LTPP Seasonal Monitoring Program: Site Installation and Initial Data Collection, Sections 370201, 370205, 370208, and 370212, Lexington, North Carolina, Publication No. FHWA-TS-97-37-01, FHWA, Pavement Performance Division, March 1997.

LTPP Seasonal Monitoring Program: Site Installation and Initial Data Collection, Section 371028, Elizabeth City, North Carolina, Publication No. FHWA-TS-96-37-01, FHWA, Pavement Performance Division, June 1996.

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LTPP Seasonal Monitoring Program: Site Installation and Initial Data Collection, Section 501002, New Haven, Vermont, Publication No. FHWA-TS-94-50-01, FHWA, Pavement Performance Division, December 1994.

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.

LTPP Seasonal Monitoring Program: Site Installation and Initial Data Collection, Section 510114, Danville, Virginia, Publication No. FHWA-TS-96-51-02, FHWA, Pavement Performance Division, June 1996.

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.

Seasonal Testing Instrumentation Pilot, GPS 361011, 1H 481 SB, E. Syracuse, New York, SHRP, National Research Council, October 1991.

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.

LTPP Seasonal Monitoring Program, Site Installation Report for GPS Section 271018 (27A), Little Falls, Minnesota, FHWA, Pavement Performance Division, January 1996.

LTPP Seasonal Monitoring Program, Site Installation Report for GPS Section 271028 (27B), Detroit Lakes, Minnesota, FHWA, Pavement Performance Division, January 1996.

LTPP Seasonal Monitoring Program, Site Installation Report for GPS Section 274040 (27D), Grand Rapids, Minnesota, FHWA, Pavement Performance Division, February 1996.

LTPP Seasonal Monitoring Program, Site Installation Report for GPS Section 276251 (27C), Bemidji, Minnesota, FHWA, Pavement Performance Division, January 1996.

LTPP Seasonal Monitoring Program, Site Installation Report for SPS Section 310114 (31A), Hebron, Nebraska, FHWA, Pavement Performance Division, February 1996.

LTPP Seasonal Monitoring Program, Site Installation Report for GPS Section 313018 (31B), Kearney, Nebraska, FHWA, Pavement Performance Division, February 1996.

LTPP Seasonal Monitoring Program, Site Installation Report for SPS Section 460804 (46A), Pollock, South Dakota, FHWA, Pavement Performance Division, February 1996.

LTPP Seasonal Monitoring Program, Site Installation Report for GPS Section 469187 (46B), Faith, South Dakota, FHWA, Pavement Performance Division, February 1996.

LTPP Seasonal Monitoring Program, Site Installation Report for GPS Section 831801 (83A), Oak Lake, Manitoba, FHWA, Pavement Performance Division, January 1996.

LTPP Seasonal Monitoring Program, Site Installation Report for GPS Section 833802 (83B), Glenea, Manitoba, FHWA, Pavement Performance Division, January 1996.

LTPP Seasonal Monitoring Program, Site Installation Report for GPS Section 906405 (90A), Plunkett, Saskatchewan, FHWA, Pavement Performance Division, January 1996.

A.10.3.3 Southern Region

LTPP Seasonal Monitoring Program: Site Installation and Initial Data Collection, Section 010102, Opelika, Alabama, FHWA, Pavement Performance Division, February 1996.

LTPP Seasonal Monitoring Program: Site Installation and Initial Data Collection, Section 131005, Warner Robins, Georgia, FHWA, Pavement Performance Division, February 1996.

LTPP Seasonal Monitoring Program: Site Installation and Initial Data Collection, Section 131031, Dawsonville, Georgia, FHWA, Pavement Performance Division, February 1996.

LTPP Seasonal Monitoring Program: Site Installation and Initial Data Collection, Section 133019, Gainesville, Georgia, FHWA, Pavement Performance Division, February 1996.

LTPP Seasonal Monitoring Program: Site Installation and Initial Data Collection, Section 281016, Kosciusko, Mississippi, FHWA, Pavement Performance Division, February 1996.

LTPP Seasonal Monitoring Program: Site Installation and Initial Data Collection, Section 281802, Laurel, Mississippi, FHWA, Pavement Performance Division, February 1996.

LTPP Seasonal Monitoring Program: Site Installation and Initial Data Collection, Section 351112, Hobbs, New Mexico, FHWA, Pavement Performance Division, March 1995.

LTPP Seasonal Monitoring Program: Site Installation and Initial Data Collection, Section 404165, Cleo Springs, Oklahoma, FHWA, Pavement Performance Division, March 1995.

LTPP Seasonal Monitoring Program: Site Installation and Initial Data Collection, Section 481060, Victoria, Texas, FHWA, Pavement Performance Division, March 1995.

LTPP Seasonal Monitoring Program: Site Installation and Initial Data Collection, Section 481068, Paris, Texas, FHWA, Pavement Performance Division, February 1995.

LTPP Seasonal Monitoring Program: Site Installation and Initial Data Collection, Section 481077, Estelline, Texas, FHWA, Pavement Performance Division, January 1995.

LTPP Seasonal Monitoring Program: Site Installation and Initial Data Collection, Section 481122, Floresville, Texas, FHWA, Pavement Performance Division, March 1995.

LTPP Seasonal Monitoring Program: Site Installation and Initial Data Collection, Section 483739, Kingsville, Texas, FHWA, Pavement Performance Division, March 1995.

LTPP Seasonal Monitoring Program: Site Installation and Initial Data Collection, Section 484142, Jasper, Texas, FHWA, Pavement Performance Division, February 1995.

LTPP Seasonal Monitoring Program: Site Installation and Initial Data Collection, Section 484143, Beaumont, **Texas**, FHWA, Pavement Performance Division, March 1995.

A.10.3.4 Western Region

LTPP Seasonal Monitoring Program: Site Installation and Initial Data Collection, Section 040113, Kingman, Arizona, Publication No. FHWA-04-0113, FHWA, Pavement Performance Division, May 1997.

LTPP Seasonal Monitoring Program: Site Installation and Initial Data Collection, Section 040114, Kingman, Arizona, Publication No. FHWA-04-0114, FHWA, Pavement Performance Division, May 1997.

LTPP Seasonal Monitoring Program: Site Installation and Initial Data Collection, Section 040215, Kingman, Arizona, Publication No. FHWA-04-0215, FHWA, Pavement Performance Division, May 1997.

LTPP Seasonal Monitoring Program: Site Installation and Initial Data Collection, Section 041024, Flagstaff, Arizona, Publication No. FHWA-04-1024, FHWA, Pavement Performance Division, May 1997.

LTPP Seasonal Monitoring Program: Site Installation and Initial Data Collection, Section 063042, Lodi, California, Publication No. FHWA-06-3042, FHWA, Pavement Performance Division, May 1997.

LTPP Seasonal Monitoring Program: Site Installation and Initial Data Collection, Section 081053, Delta, Colorado, Publication No. FHWA-08-1053, FHWA, Pavement Performance Division, January 1994.

LTPP Seasonal Monitoring Program: Site Installation and Initial Data Collection, Section 161010, Idaho Falls, Idaho, Publication No. FHWA-16-1010, FHWA, Pavement Performance Division, February 1994.

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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

B2.10 SPS-10 Warm Mix Asphalt Overlay of Asphalt Pavement Study

The objective of the SPS-10 experiment, which was implemented in 2014, is to provide a performance comparison of asphalt concrete constructed using warm mix technologies against current hot-mixed methods in an overlay application. WMA is defined by LTPP as asphalt mixtures produced at or below 275 °F, or at least 30 °F below the production temperature of the hot-mix asphalt control test section. The experiment requires three core test sections to be constructed at each site:

- a HMA control section using agency's standard mix
- WMA test section using foaming process
- WMA test section using chemical additive

The experimental layers for each test section are placed as 2-4 inch thick overlays on an existing AC pavement structure. Supplemental test sections of the participating agencies own design can also be present at each project site.

APPENDIX C. SDR DATA EXTRACTION EXAMPLES

This appendix contains data extraction examples. They illustrate productive practices for dealing with data from the LTPP database using SQL. These examples provide one method for organizing data from a relational database management system. 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 other 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

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

avg_depth	contact_resistance	bulk_resistivity
1.37	323	17
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.

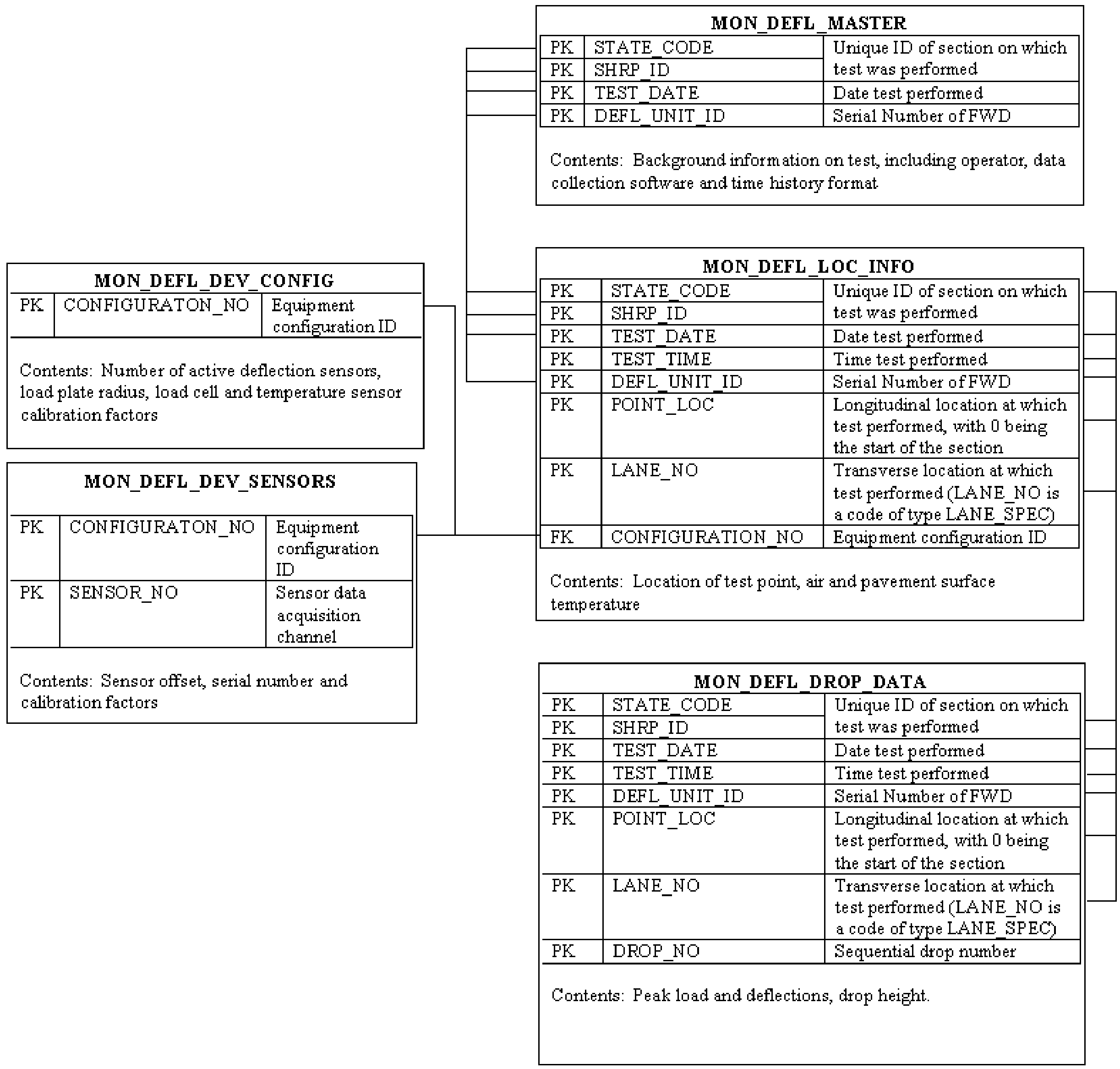
C.2.3 Deflection Tables

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

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	7	610	234
34	1003	3/11/1999	0852	8002-129	0	F1	8	607	234
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 am 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

layer_no	inv_layer_no	description	layer_type	repr_thickness	matl_code	construction_no
2	1	6	GS	24.9	308	2
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 data 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 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 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 two 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 the **SPS_GPS_LINK** table and determining 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

Note that while most of these state codes correspond to FIPS standards, codes used for Canadian provinces do not since they are not part of the United States and were developed prior to expansion of FIPS state codes to non-state entities.

APPENDIX E. PAVEMENT ENGINEERING ACRONYMS AND ABBREVIATIONS

This appendix presents a general overview of pavement engineering abbreviations and acronyms in common use in the LTPP program. This list is being provided as a general aid to data users who may not understand the meaning of all of these terms in their journey into the details of pavement engineering contained in the various LTPP related documents. Acronyms and abbreviations used in the other portions of this document are included in the list presented in the front matter of this document.

Abbreviation	Definition
AADT	annual average daily traffic
AADTT	annual average daily truck traffic
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
AC	asphalt concrete
ACF	accelerometer calibration factor
ACI	American Concrete Institute
ACP	asphalt concrete pavement
ACPA	American Concrete Paving Association
ADAPT	Automated Distress Analysis for Pavement Tool
ADEL	archive database and electronic library
ADEP	Ancillary Information Management System Data Entry Portal
ADM	administration
ADS	automated distress survey
ADT	average daily traffic
AIMS	Ancillary Information Management System
AMRL	AASHTO Materials Reference Library
ANN	artificial neural network
ANOVA	analysis of variance
APC	asphalt concrete overlay of Portland cement concrete
APEX	Oracle Application Express
APT	accelerated pavement testing
ASR	alkali-silica reactivity
ASTM	American Society for Testing and Materials
ATA	American Trucking Association
ATAF	asphalt temperature adjustment factor
ATB	asphalt treated base
ATDL	automated temperature data logger
ATR	automatic traffic recorder
AVC	automatic vehicle classifier
AWS	automated weather station
BAF	basin adjustment factor
BBR	bending-beam rheometer
BLK	block cracking
BWP	between wheel paths

Abbreviation	Definition
C	Celsius
CBR	California bearing ratio
CC	closure circle
CCC	Canadian Climatic Center
CD	Compact Disk
CGH	Cumberledge, Gramling and Hunt
CI	confidence interval
CL	centerline
CLM	climate
CN	construction number
CNCDIA	Canadian National Climate Data and Information Archive
COPES	Concrete Pavement Evaluation System
COV	coefficient of variation
CPR	concrete pavement restoration
CRC	continuously reinforced concrete
CRCP	continuously reinforced concrete pavement
C-LTPP	Canadian Long Term Pavement Performance
C-SHRP	Canadian Strategic Highway Research Program
CTB	cement-treated base
CTDB	Central Traffic Database
CTE	coefficient of thermal expansion
CSSC	Customer Support Service Center
"D" (cracking)	durability cracking
DAC	Data Analysis Contractor(s)
DAOFR	Data Analysis/Operations Feedback Report
DATS	Data Analysis Technical Support Contractor
DAWG	Data Analysis Working Group
DBM	Database Manager
DBR	dowel bar retrofit
DBI	dowel bar inserter
DCF	distance calibration factor
DCG	Data Collection Guide
DCP	Dynamic Cone Penetrometer
DCV	data compilation views
DEF	deflection
DEFCAL	deflection calibration
DEFL	deflection
DF	dry-freeze
DGAB	dense graded aggregate base
DIM	Distress Identification Manual
DIS	distress
DiVA	Distress Viewer and Analysis (tool)
DL	dense liquid
DLR	Dynamic Load Response

Abbreviation	Definition
DMI	distance measuring instrument
DNF	dry-no-freeze
DOT	Department of Transportation
DPW	Data Processing Workstation
DRAIN	drainage
DS	Dipstick
DSR	dynamic shear rheometer
DSV	digitized test section videos
DT	direct tension
DVD	digital versatile disk
EICM	Enhanced Integrated Climatic Model
ENV	environmental
ES	elastic solid
EST	estimated
ESAL	equivalent single axle load
ETG	Expert Task Group
E*	dynamic modulus
F	Fahrenheit
FAR	Federal Acquisition Regulation(s)
FHWA	Federal Highway Administration
FIPS	Federal Information Processing Standards
FRIC	friction
FT	file tracker
FWD	falling weight deflectometer
FWDPR	falling weight deflectometer problem report
GOE	General Operating Expenditures
GPS	Global Positioning System
GPR	Ground Penetrating Radar
GPS	General Pavement Studies
GPSR	Global Positioning System Recorder
GPS-1	Asphalt Concrete Pavement on Granular Base Experiment
GPS-2	Asphalt Concrete Pavement on Bound Base Experiment
GPS-3	Jointed Plain Concrete Pavement Experiment
GPS-4	Jointed Reinforced Concrete Pavement Experiment
GPS-5	Continuously Reinforced Concrete Pavement Experiment
GPS-6A	Existing Asphalt Concrete Overlay of Asphalt Concrete Pavement Experiment
GPS-6B	Planned Asphalt Concrete Overlay of Asphalt Concrete Pavement Experiment
GPS-6C	AC Overlay Using Modified Asphalt of AC Pavement-No Milling Experiment
GPS-6D	AC Overlay on Previously Overlaid AC Pavement Using Conventional Asphalt Experiment
GPS-6S	AC Overlay of Milled AC Pavement Using Conventional or Modified Asphalt Experiment
GPS-7A	Existing AC Overlay of Portland Cement Concrete Experiment
GPS-7B	Planned AC Overlay of Portland Cement Concrete Experiment
GPS-7C	AC Overlay Using Modified Asphalt on PCC Pavement Experiment

Abbreviation	Definition
GPS-7D	AC Overlay on Previously Overlaid PCC Pavement Using Conventional Asphalt Experiment
GPS-7F	AC Overlay Using Conventional or Modified Asphalt on Fractured PCC Pavement Experiment
GPS-7R	Concrete Pavement Restoration Treatments With No Overlay Experiment
GPS-7S	Second AC Overlay, Which Includes Milling or Geotextile Application, on PCC Pavement With Previous AC Overlay Experiment
GPS-9	Unbonded PCC Overlay of Portland Cement Concrete Experiment
HCA	hot compressed air
HCL	hydrochloric acid
HIST	history
HMA	hot mix asphalt
HMAC	hot mixed asphalt concrete
HPMS	Highway Performance Monitoring System
ICC	International Cybernetics Corporation
I-IMS	International Information Management System
IMS	Information Management System
INV	inventory
IR	infrared temperature
IRI	International Roughness Index
ISSA	International Slurry Surfacing Association
ISTEA	Intermodal Surface Transportation Efficiency Act
ITS	indirect tensile strength
IWP	inside wheel path
JCP	jointed concrete pavement
JPCC	jointed Portland cement concrete
JPCC	jointed plain concrete pavement
JRCP	jointed reinforced concrete pavement
JT	joint
KJL	K.J. Law
LCB	lean concrete base
LCCA	life cycle cost analysis
LCOM	TRB LTPP Committee
LDEP	LTPP Data Entry Portal
LEF	load equivalency factor
LL	liquid limit
L-NWP (cracking)	longitudinal non-wheelpath cracking
LPF	longitudinal profile
LSD	lane-to-shoulder dropoff
LSPEC	TRB LTPP Special Activities Committee
LSS	lane-to-shoulder separation
LTAS	LTPP Traffic Analysis Software
LTBP	Long Term Bridge Performance
LTE	load transfer efficiency
LTM	long-term monitoring

Abbreviation	Definition
LTPP	Long-Term Pavement Performance
LTPPDD	LTPP Data Dictionary
LTPPTD	LTPP Table Dictionary
LVDT	linear variable differential transformer
LWP	left wheelpath
L-WP (cracking)	longitudinal wheelpath cracking
MAP	Materials Action Plan
MAP-21	Moving Ahead for Progress in the 21st Century
MAT	materials
MDR	materials data resolution
MDS	manual distress surveys
MEPDG	Mechanistic-Empirical Pavement Design Guide
MERRA	Modern Era Retrospective-analysis for Research and Applications
MNT	maintenance
MON	monitoring
MOPR	Materials Operations Problem Report
M_R	resilient modulus
MRL	Materials Reference Library
MSDOS	Microsoft disk operating system
MTS	Materials Tracking System
NAPA	National Asphalt Pavement Association
NAR	North Atlantic Region
NARCOC	North Atlantic Regional Coordination Office Contractor
NARO	North Atlantic Regional Office
NARSC	North Atlantic Regional Support Contractor
NAS	National Academy of Sciences
NCDC	National Climatic Data Center
NCHRP	National Cooperative Highway Research Program
NCR	North Central Region
NCRCOC	North Central Regional Coordination Office Contractor
NCRO	North Central Regional Office
NCRSC	North Central Regional Support Contractor
NIMS	National Information Management System
NIST	National Institute of Standards and Technology
NOAA	National Oceanic and Atmospheric Administration
NPPD	National Pavement Performance Database
NRC	National Research Council
NSA	National Stone Association
ODBC	Open Database Connectivity
OG	Operations Guide
OPR	Operational Problem Report
OWP	outside wheel path
OWS	Operating Weather Station
PADIAS	Pavement Distress Analysis System

Abbreviation	Definition
PATB	permeable asphalt treated base
PAV	pressure aging vessel
PCC	Portland cement concrete
PCN	Pavement Condition Number
PDE	Public Data Extraction
PFS	Pooled Fund Study
PI	Profile Index
PG	Performance Grade
PL	plastic limit
PMA	plant-mixed asphalt
PMS	pavement management system
PP	pavement preservation
PPAC	Pavement Performance Advisory Committee
PPDB	Pavement Performance Database
PRF	profile
PROFPR	Profiler Problem Report
PSI	Present Serviceability Index
PVR	potential vertical rise
QA	quality assurance
QC	quality control
RA	recycling agent
RCO	Regional Coordination Office
RCOC	Regional Coordination Office Contractor
RDBMS	Relational Database Management System
RE	Regional Engineers
RHB	rehabilitation
RIMS	Regional Information Management System
RLSA	Regional LDEP SQL Administrator
RMSVA	root mean square vertical acceleration
RN	Ride Number
RPUG	Road Profile User Group
RSC	Regional Support Contractor
RTFO	rolling thin film oven
RWP	right wheelpath
SAFETEA	Safe, Accountable, Flexible, Efficient Transportation Equity Act
SAMI	stress-absorbing membrane interlayer
SAMP	sample
SCN	seal condition number
SCOR	Standing Committee on Research (AASHTO)
SCR	Surface Condition Rating
SD	standard deviation
SDR	Standard Data Release
SHA	State highway agency
SHRP	Strategic Highway Research Program

Abbreviation	Definition
SI	International System of Units
SLIC	Stubstad, Lukanen, Irwin, Clevenson
SMP	Seasonal Monitoring Program
SMPPR	Seasonal Monitoring Program Problem Report
SOM	Subcommittee on Materials (AASHTO)
SPR	Software Performance Report
SPS	Specific Pavement Studies
SPS-1	Strategic Study of Structural Factors for Flexible Pavements Experiment
SPS-2	Strategic Study of Structural Factors for Rigid Pavements Experiment
SPS-3	Preventative Maintenance Effectiveness of Flexible Pavements Experiment
SPS-4	Preventative Maintenance Effectiveness of Rigid Pavements Experiment
SPS-5	Rehabilitation of Asphalt Concrete Pavements Experiment
SPS-6	Rehabilitation of Jointed Portland Cement Concrete Experiment
SPS-7	Bonded Portland Cement Concrete Overlays of Concrete Pavements Experiment
SPS-8	Study of Environmental Effects in the Absence of Heavy Loads Experiment
SPS-9A	Superpave Asphalt Binder Study Experiment
SPS-9C	Superpave Asphalt Concrete Overlay on Continuously Reinforced Concrete Pavement Experiment
SPS-9J	Superpave Asphalt Concrete Overlay on Jointed Plain Concrete Pavements Experiment
SPS-9N	Superpave New Asphalt Concrete Pavement Construction Experiment
SPS-9O	Superpave Asphalt Concrete Overlay on Asphalt Concrete Pavement Experiment
SPS-9P	Validation and Refinements of Superpave Asphalt Specifications and Mix Design Process Experiment
SPS-10	Warm Mix Asphalt Overlay of Asphalt Pavement Study
SQL	Structured Query Language
SR	Southern Region
SRCOC	Southern Regional Coordination Office Contractor
SRO	Southern Regional Office
SRSC	Southern Region Support Contractor
SSD	saturated surface dry
STRS	Strategic Transportation Research Study
STURAA	Surface Transportation and Uniform Relocation Assistance Act
Superpave	SUperior PERforming Asphalt PAVEments (trademarked name)
TAC	Technical Assistance Contractor
TAC	Transportation Association of Canada
TAT	Traffic Analysis Tracker
TDP	traffic data processing
TDR	time domain reflectometry (moisture sensor)
TEA-21	The Transportation Equity Act for the 21st Century
TFHRC	Turner-Fairbanks Highway Research Center
TMG	Traffic Monitoring Guide
TN	Table Navigator
TP	test pit
TPF	transverse profile
TPF	Traffic Pooled Fund

Abbreviation	Definition
TRB	Transportation Research Board
TRF	traffic
TSSC	Technical Services Support Contractor
TST	test
UPS	uninterruptible power supply
VMA	voids in mineral aggregate
VWS	Virtual Weather Station
WF	wet-freeze
WIM	weigh-in-motion
WMA	warm mix asphalt
WNF	wet-no-freeze
WP	wheel path
WR	Western Region
WRCOC	Western Regional Coordination Office Contractor
WRO	Western Regional Office
WRSC	Western Regional Support Contractor
WSP	WIM site profile

APPENDIX F. GLOSSARY

The follow glossary primarily contains definitions of words used in the LTPP database and literature. While many of the definitions apply to LTPP terminology, some are general terms common to pavement engineering. For all definitions a source is cited.

Term	Definition	Source
absolute viscosity	Measure of how a fluid resists flow in response to an external force.	http://www.wisegeek.com/what-is-absolute-viscosity.htm
absorption	The increase in mass due to water in the pores of the material; can indicate the amount of asphalt binder the aggregate will absorb.	http://www.pavementinteractive.org/
aggregate, coarse	Material retained on the 6.3 mm [¼ inch] sieve.	LTPP Laboratory Materials Testing and Handling Guide
aggregate, fine	Material passing the 6.3 mm [¼ inch] sieve.	LTPP Laboratory Materials Testing and Handling Guide
air voids	The pockets of air between the asphalt-coated aggregate particles in a compacted asphalt mixture.	AASHTO T269-97
alligator cracking / fatigue cracking	Occurs in areas subjected to repeated traffic loadings (wheel paths). Can be a series of interconnected cracks in early stages of development. Develops into many-sided, sharp-angled pieces, usually less than 0.3 meters (m) on the longest side, characteristically with a chicken wire/alligator pattern, in later stages. Must have a quantifiable area.	LTPP Distress Identification Manual
assignment date	Date when a test section was 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.	LTPP Maintenance and Rehabilitation Data Collection Guide
Atterberg limits	Primary form of classification for cohesive soils; obtain basic index information about the soil used to estimate strength and settlement characteristics.	http://www.civil.umaine.edu/cie366/atterberg_limits/
automated vehicle classification	Description for the type of equipment used to make the automated vehicle classification count, including either a permanent Automatic Vehicle Classification (AVC) counter, portable AVC counter, permanent Weigh-In-Motion (WIM) counter, or portable WIM counter	LTPP Traffic Data Collection Guide
automated weather stations	Installed near almost all SPS-1, -2, and -8 project sites. This equipment measured site-specific climatic information. AWS measurements include air temperature, humidity, precipitation, solar radiation, and wind speed.	LTPP IMS Reference Guide
axle correction factor	Used in conjunction with the equipment manufacturer and model number of the equipment used for the automated traffic volume count to calculate the traffic volume at the site.	LTPP Traffic Data Collection Guide
axle group	The type of axle (single, tandem, triple, and quad).	LTPP Traffic Data Collection Guide
backcalculation	Method to determine the layered elastic properties (e.g. Young's modulus) from deflection basin measurements.	https://www.fhwa.dot.gov/publications/research/infrastructure/pavements/ltpp/01113/01113.pdf
bending beam rheometer	Apparatus used to determine the flexural creep stiffness of asphalt binders.	ASTM D6648
Benkelman beam	Device used to conduct deflection tests on SPS-4 test sections.	LTPP IMS Reference Guide
bleeding	Excess bituminous binder occurring on the pavement surface, usually found in the wheel paths. May range from a surface discolored relative to the remainder of the pavement, to a surface that is losing surface texture because of excess asphalt, to a condition where the aggregate may be obscured by excess asphalt possibly with a shiny, glass-like, reflective surface that may be tacky to the touch.	LTPP Distress Identification Manual
block cracking	A pattern of cracks that divides the pavement into approximately rectangular pieces. Rectangular blocks range in size from approximately 0.1 m^2 to 10 m^2.	LTPP Distress Identification Manual

Term	Definition	Source
blowup (or buckling)	Localized upward movement of the pavement surface at transverse joints or cracks, often accompanied by shattering of the concrete in that area.	LTPP Distress Identification Manual
bound layer	The upper layers of a pavement, consisting of materials such as bituminous, concrete, portland-cement concrete, roller-compacted concrete, and stabilized bases. Bound pavement layers does not include granular base and subbase materials.	ASTM D4748-06
break and seat	Fracture pretreatment to PCC pavements.	LTPP Maintenance and Rehabilitation Data Collection Guide
buffer shape	Distinguishes which of the four different styles of buffers was used on the LTPP FWDs.	LTPP Manual for Falling Weight Deflectometer Measurements
bulk samples	The part of the pavement material that is removed from an unbound base or subbase layer or from the subgrade.	LTPP Laboratory Materials Testing and Handling Guide
bulk specific gravity	The ratio of the mass of a unit volume of aggregate, including the water permeable voids, at a stated temperature to the mass of an equal volume of gas-free distilled water at the stated temperature.	http://www.pavementinteractive.org/
category	Five groupings of the nine SPS studies (pavement structural factors, pavement maintenance, pavement rehabilitation, environmental effects, asphalt aggregate mixture specifications).	LTPP IMS Reference Guide
cement treated base	A mixture of aggregate and soil binder treated with portland cement and used as base or subbase to increase the stability of the pavement structure.	LTPP Laboratory Materials Testing and Handling Guide
chip seal	A surface treatment in which the pavement is sprayed with asphalt (generally emulsified) and then immediately covered with aggregate and rolled. Chip seals are used primarily to seal the surface of a pavement with non load-associated cracks and to improve surface friction, although they also are commonly used as a wearing course on low volume roads. Use of special binders such as asphalt rubber or polymer modified binders can make an effective crack alleviation treatment and allow significantly deflecting pavements to flex without premature cracking.	Caltrans Maintenance Technical Advisory Guide
class/classification	The vehicle classification; either Agency specified or the 13-bin FHWA scheme.	LTPP Traffic Data Collection Guide
climatic region	Classified as wet freeze, wet no freeze, dry freeze, or dry no freeze.	LTPP
coarse aggregate	Material retained on the 6.3 mm [¼ inch] sieve.	LTPP Laboratory Materials Testing and Handling Guide
coarse aggregate angularity	The number of particles with fractured faces compared to the number of particles without fractured faces; test follows Penn DOT TM 621.	LTPP Laboratory Materials Testing and Handling Guide
code type	A description of the codes valid for the field. This will either be the name of a codes table, or a list of descriptions and corresponding codes.	LTPP
codes	Unique text value whose meaning is defined in CODES.DETAIL.	LTPP
coefficient of thermal expansion (CTE)	The measure of how concrete changes in volume in response to temperature change; defined as the change in unit length per degree of temperature change. The CTE of a concrete paving mixture depends on the aggregate type and degree of saturation.	http://www.fhwa.dot.gov/pavement/concrete/pubs/hif09015/hif09015.pdf
complex modulus, (G*)	Total resistance to deformation when repeatedly sheared; used as predictor of HMA rutting and fatigue cracking and used to indicate viscoelastic properties.	http://www.pavementinteractive.org/
confining pressure	The combined hydrostatic stress and lithostatic stress; i.e. the total weight of the interstitial pore water and rock above a specified depth.	http://www.encyclopedia.com/doc/1O13-confiningpressure.html
consolidation stress	Information concerning magnitude of compression and rate-of-consolidation of soil is essential in the design of earth structures and earth supported structures. The results of this test method may be used to analyze or estimate one-dimensional settlements, rates of settlement associated with the dissipation of excess pore-water pressure, and rates of fluid transport due to hydraulic gradients.	ASTM D4186

Term	Definition	Source
construction joint	The point at which work is concluded and reinitiated when building a pavement.	http://www.fhwa.dot.gov/publications/research/infrastructure/pavements/ltpp/reports/03031/glossary.htm
construction number/ event number	Event number used to relate changes in pavement structure with other time dependent data elements. This field is set to 1 when a test section is initially accepted into LTPP and is incremented with each change to the layer structure.	LTPP Maintenance and Rehabilitation Data Collection Guide
contraction joint	Joint placed in concrete pavement to relieve the tensile stresses due to temperature, moisture and friction, thereby controlling cracking. If contraction joints were not installed, random cracking would occur on the surface of the pavement.	AASHTO, 1993
control section	Each SPS maintenance test project included a control section on which no maintenance was to be performed unless required as a safety measure.	LTPP IMS Reference Guide
corner break	A portion of the slab separated by a crack, which intersects the adjacent transverse and longitudinal joints, describing approximately a 45-degree angle with the direction of traffic. The length of the sides is from 0.3 m to one-half the width of the slab on each side of the corner.	LTPP Distress Identification Manual
crack and seat	Fracture pretreatment to PCC pavements.	LTPP Maintenance and Rehabilitation Data Collection Guide
cracking, longitudinal	Cracks predominantly parallel to pavement centerline. Location within the lane (wheel path versus non-wheel path) is significant.	LTPP Distress Identification Manual
cracking, thermal /transverse cracking	Cracks that are predominantly perpendicular to pavement centerline.	LTPP Distress Identification Manual
creep	The time-dependent part of strain resulting from stress.	LTPP Laboratory Materials Testing and Handling Guide
creep compliance	The time-dependent strain divided by the applied stress.	LTPP Laboratory Materials Testing and Handling Guide
data elements	Fields in an LTPP database table that contain more than referential information.	LTPP
data release	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.	LTPP IMS Reference Guide
deleterious materials	The weight percentage of contaminants such as shale, wood, mica, and coal in the blended aggregate.	http://www.tfhrc.gov/pavement/asphalt/prodrsrch/mixturedesign/mixdsgn.pdf
design ESAL	A cumulative traffic load summary statistic representing a mixed stream of traffic of different axle loads and axle configurations predicted over the design or analysis period and then converted into an equivalent number of 18,000-lb. single axle loads summed over that period.	Construction and Material Tips, Texas DOT, 2005.
design lane	In most instances the LTPP study lane is the pavement structural design lane.	LTPP
design period	The time from original construction to a terminal condition for a pavement structure.	http://www.pavementinteractive.org/
directional distribution factor / (D factor)	The percentage of traffic traveling in the same direction as the LTPP lane.	LTPP Traffic Data Collection Guide
directive	Documents issued by the organization in control of LTPP (currently the FHWA LTPP team) which transmit directions to the various LTPP contractors. Some of them are for purely administrative purposes, such as those that deal with software upgrades. Others, such as those that deal with data collection practices, may be of great interest to analysts and others collecting similar data.	LTPP
distress	Damaged caused to pavements by certain conditions; often a result of a combination of factors, rather than just one root cause.	http://www.pavementinteractive.org/

Term	Definition	Source
drainage	Important to ensure a high quality long lived pavement; moisture accumulation in any pavement structural layer can cause problems. Moisture in the subgrade and aggregate base layer can weaken these materials by increasing pore pressure and reducing the materials' resistance to shear. Additionally, some soils expand when moist, causing differential heaving (the roadway heaves up as the underlying soil expands).	http://www.pavementinteractive.org/
dry density	The mass of the oven-dry specimen divided by the total volume of specimen.	http://passel.unl.edu/pages/informationmodule.php?idinformationmodule=1130447039&topicorder=6
ductility	The distance to which a material will elongate before breaking when two ends of a briquet specimen of the material are pulled apart at a specified speed and at a specified temperature.	ASTM D113-07
durability cracking	Closely spaced crescent-shaped hairline cracking pattern. Occurs adjacent to joints, cracks, or free edges; initiating in slab corners. Dark coloring of the cracking pattern and surrounding area.	LTPP Distress Identification Manual
effective asphalt content	The total asphalt binder content minus the amount of asphalt binder that is absorbed into the aggregate particles. It is the portion of the asphalt binder that remains as the coating of film surrounding the outside of each of the aggregate particles.	Asphalt Pavements: A Practical Guide to Design, Production and Maintenance for Engineers and Architects, CRC Press
effective specific gravity	The ratio of the mass in air of a unit volume of a permeable material (excluding voids permeable to asphalt) at a stated temperature to the mass in air (of equal density) of an equal volume of gas-free distilled water at a stated temperature.	http://www.pavementinteractive.org/
elastic modulus/ stiffness	A constant ratio of stress and strain (a stiffness).	http://www.pavementinteractive.org/
electrical resistivity	Measured property of soils during SMP to determine frost/thaw depth and indicate changes in moisture content.	LTPP Seasonal Monitoring Program Data Collection Guide
fatigue cracking	Occurs in areas subjected to repeated traffic loadings (wheel paths). Can be a series of interconnected cracks in early stages of development. Develops into many-sided, sharp-angled pieces, usually less than 0.3 meters (m) on the longest side, characteristically with a chicken wire/alligator pattern, in later stages. Must have a quantifiable area.	LTPP Distress Identification Manual
faulting	Difference in elevation across a joint or crack.	LTPP Distress Identification Manual
field	Column within a table.	LTPP
field name	Name of the specific field within a table.	LTPP
field sampling	Materials sampled in-place in the field; the majority of the field sampling information is stored in the TST_HOLE_LOG and TST_SAMPLE_LOG tables.	LTPP IMS Reference Guide
fine aggregate	Material passing the 6.3 mm [¼ inch] sieve.	LTPP Laboratory Materials Testing and Handling Guide
fine aggregate angularity	The loose uncompacted void content of a fine aggregate material; test follows ASTM C1252.	LTPP Laboratory Materials Testing and Handling Guide
flakiness index	The percentage by weight of particles whose thickness is less than three-fifths of their mean dimension.	LTPP Laboratory Materials Testing and Handling Guide
flexural strength	See modulus of rupture.	http://www.merriam-webster.com/dictionary/modulus%20of%20rupture
flushing	Excess bituminous binder occurring on the pavement surface, usually found in the wheel paths. May range from a surface discolored relative to the remainder of the pavement, to a surface that is losing surface texture because of excess asphalt, to a condition where the aggregate may be obscured by excess asphalt possibly with a shiny, glass-like, reflective surface that may be tacky to the touch.	LTPP Distress Identification Manual

Term	Definition	Source
fog seal	A maintenance activity that is a light application of a diluted slow-setting asphalt emulsion to the surface of an aged (oxidized) pavement surface.	http://www.asphaltsupply.net/surface-treatment.php
freeze index	Expressed in degree days and represents the difference between the highest and lowest points on a curve of cumulative degree days versus time for one freezing season. The degree days for any one day equals the difference between the average daily air temperature and 32ºF. Degree days are plus when the average daily temperature is below 32ºF (freezing degree days) and minus when above 32ºF (thawing degree days).	AASHTO, 1993
freeze thaw/ thaw number	Number of days in the period when the air temperature goes from less than 0 degree C to greater than zero degree C; assumes minimum daily temperature occurs before maximum daily temperature.	LTPP
frequency sweep	Test performed at selected temperature, and applies oscillatory shear load of constant amplitude over a range of loading frequencies.	AASHTO
general pavement study	Series of studies on nearly 800 in-service pavement test sections throughout the United States and Canada.	LTPP IMS Reference Guide
grinding	A process in which closely spaced diamond blades are used to remove surface imperfections such as faults, warp and curl to restore the surface to a smooth, level pavement and improve ride quality. The longitudinal texture that is created provides improved friction and low noise characteristics.	International Grooving and Grinding Association
grooving	A process in which closely spaced diamond blades are used to reduce hydroplaning and accidents by providing escape channels for surface water.	International Grooving and Grinding Association
ground penetrating radar	Systems work by sending a tiny pulse of energy into a material via an antenna. An integrated computer records the strength and time required for the return of any reflected signals. Subsurface variations will create reflections that are picked up by the system and stored on digital media.	http://www.geophysical.com/gssifaqs.htm
gyration	Revolution of the Superpave Gyratory Compactor (SGC). The SGC is used in the Superpave mixture design system to prepare asphalt concrete specimens for determining volumetric and mechanical properties. It produces specimens that are similar to pavements in aggregate orientation and mechanical properties, and it can be used for quality control at hot-mix plants.	http://www.fhwa.dot.gov/pavement/asphalt/labs/mixtures/sgc.cfm
heater scarification	Rehabilitation method of AC pavements that consisting of heating, scarifying, adding a rejuvenating agent, and compacting the existing pavement.	LTPP IMS Reference Guide
historic	Data that cover the period from the dates prior to the start of LTPP monitoring	LTPP IMS Reference Guide
hydraulic conductivity (k)	The constant that defines the proportionate relationship of flux to hydraulic gradient.	http://soils.usda.gov/technical/technotes/note6.html
hygroscopic moisture content	Difference in mass between an air dried and oven dried soil, divided by the weight of the oven dried soil	AASHTO T88-00, equation 1
inside wheel path	Approximately 2.9 m from the outside slab edge to the center with a width of 0.76m.	LTPP
International Roughness Index (IRI)	Statistic calculated from a single longitudinal profile measured with a road profiler in both the inside and outside wheelpaths of the pavement. The average of these two IRI statistics is reported as the roughness of the pavement section.	AASHTO PP37-04
joint load transfer system	The mechanism by which a portion of the moving load is transferred across the transverse contraction joint to the adjacent slab.	LTPP Inventory Data Collection Guide
joint reflection cracking	Cracks in asphalt concrete overlay surfaces that occur over joints in concrete pavements. Note: The slab dimensions beneath the AC surface must be known to identify reflection cracks at joints.	LTPP Distress Identification Manual
kinematic viscosity	Property of liquids and gases that represents how easily a given substance can flow; absolute viscosity divided by density of substance.	http://www.wisegeek.com/what-is-kinematic-viscosity.htm
K-value	Modulus of subgrade reaction; used as a primary input for rigid pavement design. It estimates the support of the layers below a rigid pavement surface course (the PCC slab).	http://www.pavementinteractive.org/
lane/shoulder drop-off	Difference in elevation between the traveled surface and the outside shoulder. Typically occurs when the outside shoulder settles as a result of pavement layer material differences.	LTPP Distress Identification Manual

Term	Definition	Source
layer	That part of the pavement produced with similar material and placed with similar equipment and techniques. The material within a particular layer is assumed to be homogeneous.	LTPP Laboratory Materials Testing and Handling Guide
lean concrete	A PCC mixture with a relatively low cement content.	LTPP Laboratory Materials Testing and Handling Guide
liquid limit	Defines the boundary between plastic and viscous fluid states of soils.	http://www.civil.umaine.edu/cie366/atterberg_limits/
load cell	One of two types of primary measurement devices carried by FWD. Located directly above the load plate, and it measures the force imparted to the pavement.	LTPP Manual for Falling Weight Deflectometer Measurements
LTPP Lane	The travel lane in which the LTPP section is located.	LTPP Data Collection Guide
milepost	The location of the site on the route using the agency's mile post location convention.	LTPP Traffic Data Collection Guide
module	Group of similar sets of tables within the database. With the exception of the tables in the Administration and Data Compilation Views (DCV) modules, the first part of the table name identifies the module to which a particular table belongs.	LTPP IMS Reference Guide
modulus of elasticity	The slope of its stress-strain plot within the elastic range.	http://www.pavementinteractive.org/
modulus of rupture	Ultimate strength pertaining to the failure of beams by flexure equal to the bending moment at rupture divided by the section modulus of the beam.	http://www.merriam-webster.com/dictionary/modulus%20of%20rupture
modulus of subgrade reaction	Used as a primary input for rigid pavement design. It estimates the support of the layers below a rigid pavement surface course (the PCC slab).	http://www.pavementinteractive.org/
modulus, dynamic	Measure of a specimen's stress-strain relationship under a continuous sinusoidal loading.	http://www.pavementinteractive.org/
modulus, tangent	The slope of the compression stress-strain curve at any specified stress or strain.	http://en.wikipedia.org/wiki/Tangent_modulus
moisture susceptibility test	Evaluation of changes in tensile strength resulting from the effects of saturation and accelerated water conditioning of compacted bituminous mixtures; primarily based on AASHTO T283.	LTPP Laboratory Materials Testing and Handling Guide
monitoring data	Module containing pavement performance data including Deflection, Distress, Friction, Profile, Rut, and Transverse Profile.	LTPP IMS Reference Guide
offset	Generally, represents the distance of a measurement from a reference point. However, there are many specific definitions within the database. For example, for rutting measurements it represents the distance from lane edge to the point of maximum depth. For deflection measurements, it represents the estimated distance from the center of the load plate to the deflection sensor when the deflection basin suggests that the reported location is not correct. Further specific definitions can be found in the Data User Reference Manual.	LTPP IMS Reference Guide
outside wheel path	Approximately 0.76 m from the outside slab edge to the center with a width of 0.76m.	LTPP
patch	Portion of pavement surface, greater than 0.1 m^2, that has been removed and replaced or additional material applied to the pavement after original construction.	LTPP Distress Identification Manual
pavement condition	Traditionally has been defined based on only the structural and functional condition of the pavement using indices such as PCI or IRI.	http://www.fhwa.dot.gov/pavement/healthtrack/pubs/technical/pht01.cfm
peak deflections	Maximum deflection at a sensor from FWD deflection testing; used to construct deflection bowl.	Pavement Management for Airports, Roads and Parking Lots. Shahin, Springer Science+Business Media, 2005
phase angle	The lag between the applied shear stress and the resulting shear strain. Phase angle of 0 degrees represents purely elastic material while a phase angle of 90 degrees represents purely viscous material.	http://www.pavementinteractive.org/

Term	Definition	Source
plastic limit	Defines the boundary between non-plastic and plastic states of soils.	http://www.civil.umaine.edu/cie366/atterberg_limits/
plasticity index (PI)	Defines the complete range of plastic state of soils.	http://www.civil.umaine.edu/cie366/atterberg_limits/
Poisson ratio	The absolute value of the ratio of transverse strain to the corresponding axial strain resulting from uniformly distributed axial stress below the proportional limit of the material.	LTPP Laboratory Materials Testing and Handling Guide
polish value	Estimate of the extent to which different coarse aggregates may polish.	ASTM D3319
polished aggregate	Surface mortar and texturing worn away to expose coarse aggregate.	LTPP Distress Identification Manual
pothole	Bowl-shaped holes of various sizes in the pavement surface. Minimum plan dimension is 150 mm.	LTPP Distress Identification Manual
profile index	Measure of pavement smoothness; often measured using profilograph.	http://www.fhwa.dot.gov/publications/research/infrastructure/pavements/ltpp/reports/02057/02057.pdf
profile, longitudinal	Collected along the wheel paths in a pavement to evaluate the roughness of the pavement by computing a roughness index such as the IRI. The change in longitudinal pavement profile over time, which is directly related to the change in roughness with time, is an important indicator of pavement performance.	LTPP Manual for Profile Measurements and Processing
profile, transverse	Used to quantify wheelpath rutting and other types of surface distortion.	http://ntl.bts.gov/lib/11000/11200/11223/01-024.pdf
pumping	Seeping or ejection of water from beneath the pavement through cracks. In some cases, detectable by deposits of fine material left on the pavement surface, which were eroded (pumped) from the support layers and have stained the surface.	LTPP Distress Identification Manual
raveling	Wearing away of the pavement surface caused by the dislodging of aggregate particles and loss of asphalt binder. Raveling ranges from loss of fines to loss of some coarse aggregate and ultimately to a very rough and pitted surface with obvious loss of aggregate.	LTPP Distress Identification Manual
record status	A code indicating the general quality of the data as outlined, based on the level of QC checks described in the Data User's Guide.	LTPP IMS Reference Guide
recycled asphalt concrete	A bituminous concrete layer containing reclaimed asphalt concrete which can either be plant mix and hot laid or cold laid or mixed-in-place.	LTPP Laboratory Materials Testing and Handling Guide
reflective cracking	Cracks in asphalt concrete overlay surfaces that occur over joints in concrete pavements. Note: The slab dimensions beneath the AC surface must be known to identify reflection cracks at joints.	LTPP Distress Identification Manual
region	One of four administrative divisions to which states and provinces are assigned in the LTPP program. These divisions are North Central, North Atlantic, Southern, and Western.	LTPP
rehabilitation	Classify how various treatments that alter a test section’s structure. Rehabilitation activities include overlays and associated pretreatments (patching, milling, joint repair, etc.), inlays (mill and fill), pressure relief joints in portland cement concrete (PCC) pavements, subsealing or undersealing, retrofitted subdrainage, joint load transfer restoration, and shoulder restoration.	LTPP Maintenance and Rehabilitation Data Collection Guide
representative thickness	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.	LTPP
resilient modulus of elasticity (M_R)	Measure of the elastic modulus of unbound base and subbase materials and subgrade soils recognizing certain nonlinear characteristics as determined by P-46.	LTPP Laboratory Materials Testing and Handling Guide
resistance value (R-value)	The R-value is a measure of the ability of a soil to resist lateral deformation under vertical load.	http://www.fhwa.dot.gov/engineering/geotech/pubs/05037/
resistivity	An intrinsic property of a material that is measured as its resistance to current per unit length for a uniform cross section.	http://www.thefreedictionary.com/resistivity

Term	Definition	Source
ring & ball test	Test method for the determination of the softening point of bitumen in the range from 30 to 157°C [86 to 315°F] using the ring-and-ball apparatus immersed in distilled water [30 to 80°C] or USP glycerin (above 80 to 157°C).	ASTM D36
root mean square vertical acceleration (RMSVA)	Roughness index computed from profile data with base lengths of 1, 2, 4, 8, 16, 32, 64, and 128 ft. (not currently used)	LTPP Manual for Profile Measurements and Processing
rubblization	Fracture pretreatment to PCC pavements.	LTPP Maintenance and Rehabilitation Data Collection Guide
rut/ rutting	A rut is a longitudinal surface depression in the wheel path. It may have associated transverse displacement.	LTPP Distress Identification Manual
sand equivalency test	Intended to be used on the aggregates used in the slurry seals as part of the SPS-3 studies. The test will be performed in accordance with AASHTO T176-86.	LTPP Laboratory Materials Testing and Handling Guide
saw and seal	marking, sawing, cleaning, and sealing joints in a HMAC overlay of PCC pavement	SPS6 Construction Guidelines
Saybolt furol viscosity	The efflux time in seconds of 60 ml of sample flowing through a calibrated Universal orifice under specified conditions.	ASTM D88
scaling	The deterioration of the upper concrete slab surface, normally 3 mm to 13 mm, and may occur anywhere over the pavement.	LTPP Distress Identification Manual
seal coat	A type of maintenance activity including fog seal, slurry seal, aggregate seal, sand seal, and cape seal.	LTPP
seasonal monitoring program	Program developed to provide data needed to attain a fundamental understanding of the magnitude and impact of temporal variations in pavement response and material properties due to the separate and combined effects of temperature, moisture and frost/thaw variations.	LTPP Seasonal Monitoring Program Data Collection Guide
section	Each GPS and SPS test section consists of a 152 m (500 ft) monitoring portion with a 15.2 m (50 ft) materials sampling section at each end. A maintenance control zone, extending 152 m (500 ft) in front of and 76 m (250 ft) beyond the limits of the monitoring section (s), has been established.	LTPP IMS Reference Guide
severity	Defined levels of the amount and characteristics of distresses.	LTPP
shoving	Shoving is a longitudinal displacement of a localized area of the pavement surface. It is generally caused by braking or accelerating vehicles, and is usually located on hills or curves, or at intersections. It also may have associated vertical displacement.	LTPP Distress Identification Manual
shrinkage cracking	Hairline cracks that usually are less than 2 m (6.5 ft) long and do not extend across the entire slab. They are formed during the setting and curing of the concrete and usually do not extend through the depth of the slab.	ASTM D6433
significant event	Any significant event occurring during construction that may influence performance.	LTPP Data Collection Guide
slurry seal	A homogenous mixture of emulsified asphalt, water, well-graded fine aggregate and mineral filler that has a creamy fluid-like appearance when applied. Slurry seals are used to fill existing pavement surface defects as either a preparatory treatment for other maintenance treatments or as a wearing course.	http://www.pavementinteractive.org/
spalling	Cracking, breaking, chipping, or fraying of slab edge face of the longitudinal joint.	LTPP Distress Identification Manual
specfic gravity	Ratio of the density of a substance to that of a standard substance. The usual standard of comparison for solids and liquids is water at 4° C (39.2° F), which has a density of 1.000 kg per liter (62.4 pounds per cubic foot).	http://www.britannica.com/EBchecked/topic/558700/specific-gravity
specific pavement study	Studies of specific variables involving new construction, maintenance treatments, and rehabilitation activities.	LTPP IMS Reference Guide
splitting tensile test	Test method to measure the splitting tensile strength of concrete by the application of a diametral compressive force on a cylindrical concrete specimen placed with its axis horizontal between the platens of a testing machine.	http://ftp.dot.state.tx.us/pub/txdot-info/cst/TMS/400-A_series/archives/421-0899.pdf
stabilized aggregate or soil	Materials are bound or treated layers containing a cementing or binding type of agent.	LTPP Laboratory Materials Testing and Handling Guide

Term	Definition	Source
Stabilometer	Apparatus used to determine the relative stability (Stabilometer Value) of asphalt concrete by measuring the horizontal pressure developed in a compacted test specimen under a given vertical pressure at 60°C.	California Test 366
standard proctor	Provide the basis for determining the percent compaction and molding water content needed to achieve the required engineering properties, and for controlling construction to assure that the required compaction and water contents are achieved.	ASTM D 698
station number	Distance in feet from the start of the test section; used to denote the longitudinal position within each test section.	LTPP IMS Reference Guide
strain, shear	A condition in or deformation of an elastic body caused by forces that tend to produce an opposite but parallel sliding motion of the body's planes.	http://www.thefreedictionary.com/shearing+strain
strain, uniaxial	Strain resulting from axial stress.	LTPP Maintenance and Rehabilitation Data Collection Guide
strain, volumetric	The relative volume change.	http://www.colorado.edu/engineering/CAS/courses.d/Structures.d/IAST.Lect04.d/IAST.Lect04.pdf
stripping	The displacement of asphalt on the aggregate particle surface by water.	http://www.pavementinteractive.org/
subbase	The layer or layers of specified or selected materials of designed thickness placed on a subgrade to support a base course. Note that the layer directly below the PCC slab is now called a base layer, not a subbase layer.	http://www.fhwa.dot.gov/engineering/geotech/pubs/05037/aa.cfm
subdrainage	Subsurface drainage is concerned with removing water that percolates through or is contained in the underlying subgrade. This water, typically the result of a high water table or exceptionally wet weather, can accumulate under the pavement structure.	http://www.pavementinteractive.org/
subgrade	The top surface of a roadbed upon which the pavement structure and shoulders are constructed.	http://www.fhwa.dot.gov/engineering/geotech/pubs/05037/aa.cfm
Superpave	SPS-9 sections created for experience implementing Superpave.	LTPP
surface course	One or more layers of a pavement structure designed to accommodate the traffic load, the top layer of which resists skidding, traffic abrasion, and the disintegrating effects of climate. The top layer of flexible pavements is sometimes called the "wearing" course.	http://www.fhwa.dot.gov/engineering/geotech/pubs/05037/aa.cfm
table name	The name of the table. Table names generally begin with a three-letter indicator of the data module.	LTPP IMS Reference Guide
tack coat	A light application of asphalt emulsion between hot mix asphalt layers designed to create a strong adhesive bond without slippage. Heavier applications may be used under porous layers or around patches where it also functions as a seal coat.	Asphalt Emulsions Manufacturers Association
tensile strength	Measures the force required to pull something such a structural beam to the point where it breaks. The tensile strength of a material is the maximum amount of tensile stress that it can be subjected to before failure.	http://www.sciencedaily.com/articles/t/tensile_strength.htm
thermistor probe	Instrument used for temperature gradient measurement.	LTPP Seasonal Monitoring Program Data Collection Guide
traffic factor	Factor used in determining binder content of a chip seal based on the role that traffic plays in achieving the target aggregate embedment.	Caltrans Maintenance Technical Advisory Guide
truck factor	The average number of ESALs per truck.	http://www.pavementinteractive.org/
two-way traffic	Vehicles traveling in both directions on a roadway.	AASHTO
unconfined compressive strength	The compressive stress at which and unconfined cylindrical specimen of soil will fail in a simple compression test	AASHTO T208
undersealing	Included as an optional factor for SPS-4 experiments and is only performed on a section in which the need for undersealing is indicated.	LTPP IMS Reference Guide

Term	Definition	Source
uniaxial strain	Strain resulting from axial stress.	LTPP Maintenance and Rehabilitation Data Collection Guide
vehicle classification	The vehicle classification; either Agency specified or the 13-bin FHWA scheme.	LTPP Traffic Data Collection Guide
viscosity grading	The grading of asphalt cements for use in in pavement construction by viscosity at 140°F	ASTM D3381-92
voids filled with asphalt	The portion of the voids in the mineral aggregate minus the air voids.	http://www.fhwa.dot.gov/infrastructure/materialsgrp/bitumin.pdf
weigh in motion (WIM)	Installed classification equipment with ability to measure the actual loads being applied to a roadway by a moving truck.	LTPP Traffic Data Collection Guide
wheelpath	See inside wheel path and outside wheel path.	LTPP

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