

# Long-Term Pavement Performance Information Management System User Guide

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## FOREWORD

The Long-Term Pavement Performance (LTPP) program studies the performance of in-service pavements. It is designed to understand how and why pavements perform as they do. To accomplish this goal, the LTPP program has collected and accumulated a vast repository of pavement performance related data, extensive documentation, and related tools since 1987, which compose LTPP's comprehensive information management system (IMS). This guide helps users of the LTPP IMS understand the performance data collected at the LTPP test sections. The IMS consists of the Pavement Performance Database, LTPP Traffic Analysis Software database, and Ancillary Information Management System archives. The primary objectives of this document are to explain the types and nature of the available data and information accessible to users, and where they are stored across the various tables within the IMS.

The LTPP IMS is available on the InfoPave™ web portal, which provides a powerful and flexible tool that enables users of all levels—professionals, researchers, and students—to view, visualize, extract, and employ LTPP data. The InfoPave web portal can be accessed at <https://infopave.fhwa.dot.gov>. (InfoPave 2020c) To obtain current information and access to other technical references, LTPP data users should visit the LTPP website at <https://highways.dot.gov/research/long-term-infrastructure-performance/ltp/long-term-pavement-performance>. (Long-Term Pavement Performance 2020)

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Director, Office of Infrastructure  
Research and Development

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16. Abstract This document provides information to aid in understanding and using the Long-Term Pavement Performance (LTPP) program's Pavement Performance Database (PPDB), LTPP Traffic Analysis Software (LTAS) database, and contents of the Ancillary Information Management System (AIMS) and LTPP InfoPave™. This report describes the structure of the LTPP program, the relational structure of the LTPP PPDB, the location of various data elements, contents of data tables, tips on efficient means of manipulating data for specific types of investigations, and information on how to obtain data. This is the final updated version of this report. The LTPP InfoPave website is now the official public data dissemination mechanism for LTPP data. Over the years of updates to this report, contributing authors included Travis Thompson, Amy Simpson, Beth Visintine, and Peter Schmalzer.			
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## SI\* (MODERN METRIC) CONVERSION FACTORS

### APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
<b>LENGTH</b>				
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
<b>AREA</b>				
in <sup>2</sup>	square inches	645.2	square millimeters	mm <sup>2</sup>
ft <sup>2</sup>	square feet	0.093	square meters	m <sup>2</sup>
yd <sup>2</sup>	square yard	0.836	square meters	m <sup>2</sup>
ac	acres	0.405	hectares	ha
mi <sup>2</sup>	square miles	2.59	square kilometers	km <sup>2</sup>
<b>VOLUME</b>				
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft <sup>3</sup>	cubic feet	0.028	cubic meters	m <sup>3</sup>
yd <sup>3</sup>	cubic yards	0.765	cubic meters	m <sup>3</sup>
NOTE: volumes greater than 1,000 L shall be shown in m <sup>3</sup>				
<b>MASS</b>				
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2,000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
<b>TEMPERATURE (exact degrees)</b>				
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
<b>ILLUMINATION</b>				
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m <sup>2</sup>	cd/m <sup>2</sup>
<b>FORCE and PRESSURE or STRESS</b>				
lbf	poundforce	4.45	newtons	N
lbf/in <sup>2</sup>	poundforce per square inch	6.89	kilopascals	kPa
<b>APPROXIMATE CONVERSIONS FROM SI UNITS</b>				
Symbol	When You Know	Multiply By	To Find	Symbol
<b>LENGTH</b>				
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
<b>AREA</b>				
mm <sup>2</sup>	square millimeters	0.0016	square inches	in <sup>2</sup>
m <sup>2</sup>	square meters	10.764	square feet	ft <sup>2</sup>
m <sup>2</sup>	square meters	1.195	square yards	yd <sup>2</sup>
ha	hectares	2.47	acres	ac
km <sup>2</sup>	square kilometers	0.386	square miles	mi <sup>2</sup>
<b>VOLUME</b>				
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m <sup>3</sup>	cubic meters	35.314	cubic feet	ft <sup>3</sup>
m <sup>3</sup>	cubic meters	1.307	cubic yards	yd <sup>3</sup>
<b>MASS</b>				
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2,000 lb)	T
<b>TEMPERATURE (exact degrees)</b>				
°C	Celsius	1.8C+32	Fahrenheit	°F
<b>ILLUMINATION</b>				
lx	lux	0.0929	foot-candles	fc
cd/m <sup>2</sup>	candela/m <sup>2</sup>	0.2919	foot-Lamberts	fl
<b>FORCE and PRESSURE or STRESS</b>				
N	newtons	2.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in <sup>2</sup>

\*SI is the symbol for 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
AADTT	annual average daily truck traffic
AASHTO	American Association of State Highway and Transportation Officials
AC	asphalt concrete
AE	extracted asphalt
AIMS	Ancillary Information Management System
ANN	artificial neural network
AVC	automated vehicle classification
AWS	automated weather station
BBR	bending-beam rheometer
BSG	bulk specific gravity
CRCP	continuously reinforced concrete pavement
CSSC	Customer Support Services Center
DCV	data compilation views
DLR	dynamic load response
DOT	department of transportation
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
GESAL	generic equivalent single-axle load
GPR	ground-penetrating radar
GPS	General Pavement Studies
GVW	gross vehicle weight
HMA	hot-mix asphalt
HMAC	hot-mix asphalt concrete
HPMS	Highway Performance Monitoring System
HPMS16	2016 HPMS Field Manual
IMS	Information Management System
IRI	International Roughness Index
JPCC	jointed portland cement concrete
JPCP	jointed plain concrete pavement
JRCP	jointed reinforced concrete pavement
LTAS	LTPP Traffic Analysis Software
LTE	load transfer efficiency
LTPP	Long-Term Pavement Performance
LTQC	LTPP traffic quality control
LVDT	linear variable differential transformer
MAP-21	Moving Ahead for Progress in the 21st Century Act
MEPDG	Mechanistic–Empirical Pavement Design Guide
MERRA	Modern-Era Retrospective Analysis for Research and Applications

MSG	maximum specific gravity
NALS	normalized axle load spectra
NASA	National Aeronautics and Space Administration
NCDC	National Climatic Data Center
NCHRP	National Cooperative Highway Research Program
NPRM	Notice of Proposed Rulemaking
OWS	operating weather stations
PADIAS	Pavement Distress Analysis System
PCC	portland cement concrete
PMA	plant-mixed asphalt
PPDB	Pavement Performance Database
PVR	potential vertical rise
QC	quality control
RDBMS	relational database management system
RMSE	root mean square error
RMSVA	root mean square vertical acceleration
RPPIF	relative pavement performance impact factor
SAMI	stress-absorbing membrane interlayers
SDR	Standard Data Release
SHRP	Strategic Highway Research Program
SI	International System of Units
SMP	Seasonal Monitoring Program
SPS	Specific Pavement Studies
SQL	Structured Query Language
TDR	time-domain reflectometry
TLE	transmission line equations
TMG	Traffic Monitoring Guide
TPF	Traffic Pooled Fund
TRB	Transportation Research Board
VWS	virtual weather station
WIM	weigh-in-motion
WMA	warm-mix asphalt

## CHAPTER 1. LTPP PROGRAM OVERVIEW

### 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), conducted the Strategic Transportation Research Study, which studied 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. (Transportation Research Board 1984) The Long-Term Pavement Performance (LTPP) program research area was designated to provide research-quality data on the long-term performance of in-service pavement structures collected by contractors and stored in a National, publically available database. In 1985 and 1986, multiple contractors developed detailed research plans for all six SHRP areas. The detailed research plans were published in May 1986 as a TRB report titled *Strategic Highway Research Program—Research Plans*. (Transportation Research Board 1986)

The LTPP program was envisioned as a comprehensive program to satisfy a wide range of information needs for pavement managers, engineers, and researchers. 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 enough data become available (via various collection methods discussed later in this report), analyses are conducted to provide better performance prediction models for use in pavement design and management; a 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 traditional pavement performance research approaches. In traditional approaches, pavement performance research was divided into specific topics of limited scope and duration, with recommendations based on analysis of collected data of short-term duration. To overcome 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 shift approach, data are collected using experimental design concepts intended to enable specific data analysis objectives to be developed. 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.

## **OBJECTIVES AND SCOPE OF THE LTPP PROGRAM**

The 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 include:

- Evaluate existing design methods.
- Develop improved design methodologies and strategies for the rehabilitation of existing pavements.
- Develop improved design equations for new and reconstructed pavements.
- Determine the effects of loading, environment, material properties and variability, construction quality, and maintenance levels on pavement distress and performance.
- Determine the effects of specific design features on pavement performance.
- Establish a national long-term pavement database to support future needs.

The LTPP program is a study of the behavior of pavement test sections located on in-service roadways. These pavement test sections were constructed using highway agency specifications and are subject to real-life traffic loading. These in-service pavement test sections are classified in the LTPP program under 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 1,600 pavement test sections were constructed at SPS project sites. As the pavement test sections on SPS projects aged, they were reclassified into GPS experiments when a new rehabilitation treatment was applied.

## **PAVEMENT TEST SECTION DESIGNATIONS**

To provide a logical basis for pavement test section designations, a broad-based experimental approach was used. Pavement test sections are classified as GPS or SPS. The fundamental difference between these two classifications is that, at the start of the LTPP program, GPS pavement test sections were existing pavements and SPS pavement test sections were sites where multiple test sections of differing experimental treatment factors were constructed. When a rehabilitation treatment that is not part of a defined SPS project is applied to GPS or SPS test sections, the test section is reassigned to one of the GPS rehabilitation experiments.

While the LTPP pavement 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, SPS experiment "SPS-1" is designed to extend findings from GPS studies "GPS-1" and "GPS-2." Thus, a user may wish to use test sections from both experiment classifications in their investigation.

LTPP projects are designated by experiment designs. A factorial combination approach was used for developing the experiment design designation of each GPS and SPS experiment. This approach requires identifying pavement and environmental/loading factors considered to have an influence on the performance of a pavement. Pavement factors include variables, such 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).

A combination of factors selected from all those available forms an experimental factorial used as the sampling basis for test sections included in each study. Within GPS, these factorials are more properly considered sampling templates used in the selection of pavement structures included in the studies. Since GPS consist mostly of pavements constructed and in service prior to the start of the LTPP program, it is impossible to find pavements with all combinations defined within the factorial. SPS are more controlled experiments requiring construction of specified pavement structures (discussed in more detail later in this report). 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.

### **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 per the Transportation Research Board and have strategic future importance. (Transportation Research Board 1986) Because of the nationwide thrust of the program, studies are limited to pavement structures in common use across the United States.

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

The proposed GPS-8 study of bonded portland cement concrete (PCC) overlays on PCC pavements was not pursued because of a 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.

### **Specific Pavement Studies**

The SPS program is a study of specially constructed, maintained, or rehabilitated pavement test sections incorporating a controlled set of experiment design and construction features. The SPS program incorporates 10 studies grouped into 6 categories, as illustrated by table 2. Appendix A provides a more comprehensive definition of each experiment.

Essentially, the SPS program involves monitoring newly constructed pavement test sections or existing test sections subjected to maintenance or rehabilitation treatments. Each SPS experiment requires construction of multiple test sections at each site. The number of test sections range from 2 for SPS-8 to 12 for SPS-1 and -2. Additionally, a highway agency may construct supplemental test sections on an SPS site to investigate other factors of interest to the agency,

such as the standard pavement designed in accordance with standard agency practices at each test site. The following definitions in table 1 apply only to core test sections within each experiment. Supplemental test 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.

GPS-6, GPS-7, and SPS-9 experiments have subexperiment designations based upon when construction was performed, types of pavement structures, 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.**

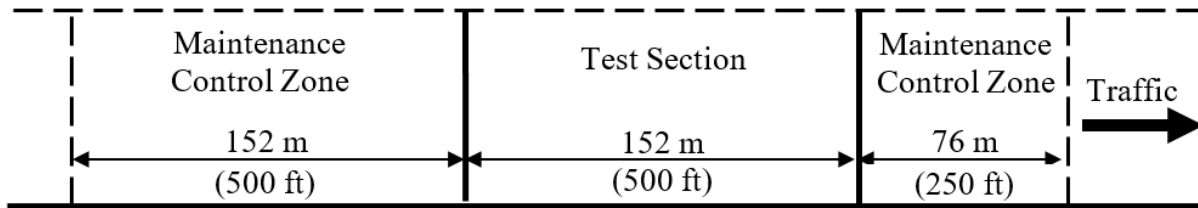
<b>Experiment</b>	<b>Experiment Title</b>
GPS-1	Asphalt Concrete (AC) Pavement on Granular Base
GPS-2	AC Pavement on Bound Base
GPS-3	Jointed Plain Concrete Pavement (JPCP)
GPS-4	Jointed Reinforced Concrete Pavement (JRCP)
GPS-5	Continuously Reinforced Concrete Pavement (CRCP)
GPS-6	AC Overlay of AC Pavement
GPS-6A	Existing AC Overlay of AC
GPS-6B	AC Overlay of AC
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 of PCC
GPS-7A	Existing AC Overlay of PCC
GPS-7B	AC Overlay Using Conventional Asphalt on PCC
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 Overlays on PCC Pavements

**Table 2. SPS experiment names by category.**

<b>Category</b>	<b>Experiment</b>	<b>Experiment Title</b>
Pavement structural factors	SPS-1	Strategic Study of Structural Factors for Flexible Pavements
Pavement structural factors	SPS-2	Strategic Study of Structural Factors for Rigid Pavements
Pavement maintenance	SPS-3	Preventive Maintenance Effectiveness of Flexible Pavements
Pavement maintenance	SPS-4	Preventive Maintenance Effectiveness of Rigid Pavements
Pavement rehabilitation	SPS-5	Rehabilitation of Asphalt Concrete Pavements
Pavement rehabilitation	SPS-6	Rehabilitation of Jointed PCC Pavements
Pavement rehabilitation	SPS-7	Bonded PCC Overlays on Concrete Pavements
Environmental effects	SPS-8	Study of Environmental Effects in the Absence of Heavy Loads
Asphalt aggregate mixture specifications	SPS-9	Validation of SHRP Asphalt Specification and Mix Design (Superpave)
Asphalt aggregate mixture specifications	SPS-9A	Superpave Asphalt Binder Study
Asphalt aggregate mixture specifications	SPS-9C	AC Overlay on CRCP
Asphalt aggregate mixture specifications	SPS-9J	AC Overlay on Jointed PCC
Asphalt aggregate mixture specifications	SPS-9N	New AC Pavement Construction
Asphalt aggregate mixture specifications	SPS-9O	AC Overlay on AC Pavement
Asphalt aggregate mixture specifications	SPS-9P	Validation and Refinements of Superpave Asphalt Specifications and Mix Design Process
Warm-mix asphalt	SPS-10	Warm Mix Asphalt Overlay of Asphalt Pavement

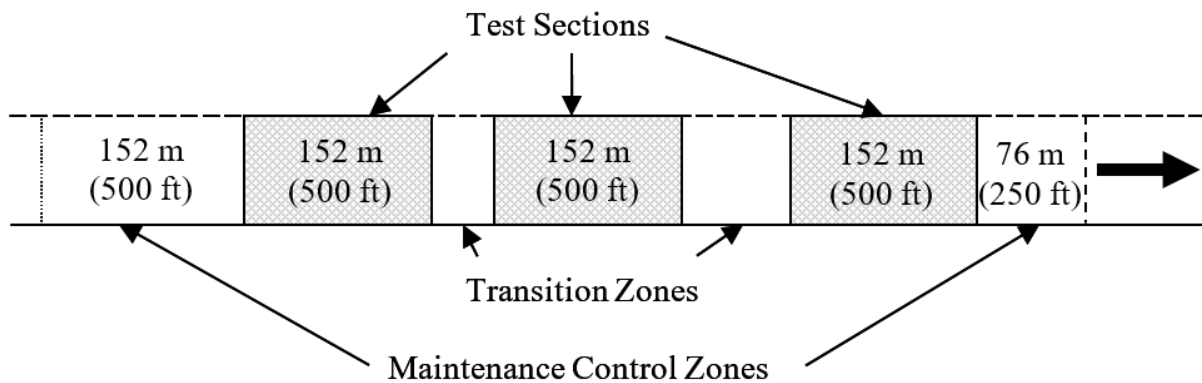
## **TEST SECTION LAYOUT**

Generally, 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. 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, was established, as illustrated in figure 1. Since SPS projects consist of multiple test sections constructed for a single project, the maintenance control zone was extended to cover groups of adjoining test sections, as illustrated in figure 2.



Source: FHWA.

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



Source: FHWA.

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

Exceptions to the 152-m (500-ft) test section include crack-and-seat test sections on SPS-6 and supplemental test sections on some SPS-4 experiment sites. Crack-and-seat test sections on SPS-6 are 305 m (1,000 ft) in length, while agency supplemental test sections have been constructed both shorter and longer than the 152-m (500-ft) standard test 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 in U.S. customary units. Units for every element are stored in the LTPPDD table. Units should be checked to ensure that calculations are performed with consistent units.

The LTPP program uses test section and project station location conventions. The test section location convention is based on the starting point of the monitoring portion of the test section being assigned a station of 0. The longitudinal locations in the direction of traffic are then 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 SI meter stations. Thus, the original 5+00 test section station painted on the pavement surface is represented as 152 m (500 ft) 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 the SPS\_PROJECTS\_STATION table, the TEST\_SECTION field contains joined STATE\_CODE+SHRP\_ID fields that can be used to identify specific test sections.

A project location convention is used where multiple test sections are located on the same SPS project site. The SECTION\_START and SECTION\_END fields in the SPS\_PROJECT\_STATIONS table 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 test section in either direction of travel.

**REFERENCE MATERIALS**

LTPP data are contained in the Library feature on InfoPave™ and on the FHWA LTPP websites. The documents listed under Program Documentation on InfoPave provide details on all the LTPP data-collection activities stored in the LTPP database. (InfoPave. 2020a)

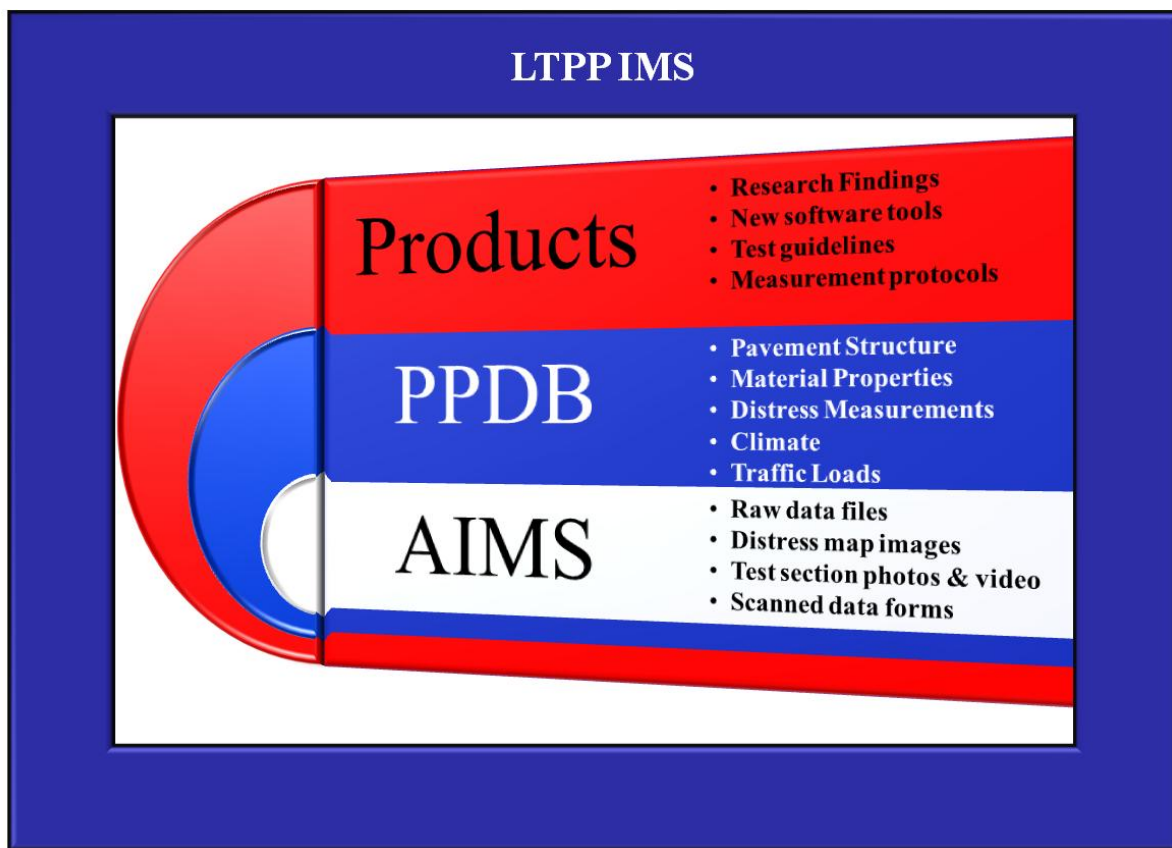
The FHWA LTPP website also contains FHWA LTPP publications on documentation of the LTPP program test methods, policies, procedures, and analysis results. (FHWA 1990–2020)



## CHAPTER 2. PAVEMENT PERFORMANCE DATABASE OVERVIEW

### LTPP INFORMATION MANAGEMENT SYSTEM

The overall system used to manage information intended for public dissemination by LTPP is called the Information Management System (IMS). Figure 3 illustrates major components of 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. PPDB is the electronic relational database that contains the majority of research data on the performance of LTPP test sections. AIMS contains the larger electronic base of raw data files used to populate PPDB and other information not contained in PPDB.



Source: FHWA.

**Figure 3. Illustration. Major categories of the LTPP IMS.**

### LTPP PPDB

PPDB was designed to store most data collected by the LTPP program for easy and convenient dissemination and use. 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 format. (See chapter 18 for data request procedures.) Datasets generated by a user through InfoPave may be delivered in Microsoft® Excel™, Access™, or Structured Query

Language (SQL) formats. Fixed collections of data are available in various versions of Microsoft Access depending on the year of publication. The latest data are available in Microsoft Access 2007, 2010, 2013, and 2016. International data users who do not have access to the English-language versions of Microsoft Access may wish to request customized extractions in other formats. LTPP has not established support for non-English-language database formats. Please contact the LTPP Customer Support Service Center (CSSC) for nonstandard data extraction requests by email at [ltppinfo@dot.gov](mailto:ltppinfo@dot.gov).

## **RELATIONAL DATABASES AND STRUCTURED QUERY LANGUAGE**

As a relational database, LTPP PPDB is composed of separate but related data tables. 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 referred to as records and columns are referred to as fields). Each row of data is uniquely identified by values in a primary key column or a combination of columns (most of the tables in the LTPP database use multicolumn key fields). 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.

The LTPP database is self-describing, meaning information about the structure of the database is represented within the database structure. The data dictionary, stored in the LTPPDD table, includes much of the database structure information. Users unfamiliar with the database should examine LTPPDD and learn how to use it.

SQL, the standard language for controlling and interacting with relational databases, is supported by modern relational database management systems (RDBMSs). 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 calculations on data stored in database format. To harness the full power and convenience of the LTPP database, users should become familiar with SQL.

## **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 the equipment measurements information consist of reviews of completeness and validity of the provided information.

Data in the database undergo several levels of QC checks. Most data tables contain a RECORD\_STATUS field, and results of these QC checks are recorded therein. Originally, five categories of checks were programmed: levels A–E. Currently, most data modules have only three categories of checks: levels C, D, and E.



The levels of QC checks are described below:

- Level A—all data records begin at level A. Originally, data were checked randomly to ensure correct data transfer from regional databases to the central database. The Level A check is performed by comparing record counts before and after a data transfer from the national LTPP Data Entry Portal to the central PPDB. The Level A check does not cause a change in record status.
- Level B—originally, level B was a set of dependency checks performed to ensure that basic essential test section information was recorded in the PPDB. These checks were incorporated into level E checks for most modules but still exist for some tables in the Test module.
- Level C—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 table design that prevent a record from being created if a value for that field is not entered.
- Level D—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) are 5 to 2,032  $\mu\text{m}$  ( $1.640^{-5}$  to 0.006 ft).
- Level E—these checks are relational checks between data stored in other fields. The Level E 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 dataset. 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 performed only to records passing level C checks, and level E checks are performed 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 found to be acceptable.

The QC checks performed on LTPP data are limited. It is impossible to inspect all data for all potential anomalies. As the LTPP 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 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 follows:

- 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 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. Record status for non-level E data can be used as a relative indicator of potential issues that might exist. As the LTPP program continues to evolve, users can expect changes to be made to LTPP data to improve their use in analyses.

## **GPS AND SPS TEST 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 test sections stems from multiple SPS test sections being co-located on a single project. Co-location allows these test sections to share climatic, traffic, and some materials data. Test 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 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 test section is a GPS or SPS section. The SHRP\_ID field for SPS test sections is “smart.” The first character in SHRP\_ID for SPS test sections is always a 0 or a letter. Over time, some SPS test sections are reassigned to GPS because of a rehabilitation activity, but they retain the original SHRP\_ID. However, all test 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 test section is an SPS test section because of its SHRP\_ID designation.

## **MODULES**

In previous versions of the LTPP public database release, database tables were classified into modules containing similar sets of tables. In this legacy table classification scheme, the first part of table names identifies module classification. While this classification scheme was used in the legacy Standard Data Releases (SDRs), InfoPave now contains an updated classification scheme that does not rely on table names and associated modules. For historical purposes, the following are the legacy database modules used in past public data releases of LTPP data:

- Administration (ADM)—contains tables that describe the structure of the database and the master test section control table. Key tables in the ADM 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)—contains data collected by the LTPP program from automated weather stations installed on some SPS projects.
- Backcalculation (Bakcal)—subset of the Monitoring module and contains the results of the backcalculation of FWD measurements.
- Climate (CLM)—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. Data in the CLM module are updated periodically.
- Data Compilation Views (DCV)—contains data from similar tables in the Inventory, Rehabilitation, 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)—contains dynamic load response instrumentation data from SPS test sections located in North Carolina and Ohio.
- Ground Penetrating Radar (GPR)—contains the results of layer thickness determinations from GPR measurements on SPS-1 and other selected SPS project sites.
- Inventory (INV)—contains inventory information for all GPS test sections and for SPS test sections originally classified in maintenance and rehabilitation experiments. Tables in the INV module contain information such as the location of the test section and structure information supplied by the owning State or Provincial agency. Because the information in the INV module 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 actual dimensions of test section pavement structure.
- Maintenance (MNT)—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)—contains pavement performance monitoring data. The MON module can be understood best as a collection of sub-modules by data type, which include the following:
  - Deflection (MON\_DEFL)—contains data from FWD tests.
  - Distress (MON\_DIS)—contains distress survey data from both manual and film-based surveys.

- Friction (MON\_FRICTION)—contains friction measurements reported by participating highway agencies.
- Profile (MON\_HSS)—contains longitudinal profile data collected by an automated profiler or by manual Dipstick measurements. Starting with the 2015 public data release, the profile module now includes pavement surface texture data.
- Rut (MON\_RUT)—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: 1.2-m (4-ft) straightedge rut measurements were not taken on all LTPP test sections.)
- Transverse Profile (MON\_T\_PROF)—contains transverse profile data and computed transverse profile distortion indices (rut depth) from manual Dipstick measurements, the optical Pavement Distress Analysis System (PADIAS), or laser-based measurement methods.
- Rehabilitation (RHB)—contains information on rehabilitation treatments. A key table in the RHB module is RHB\_IMP, which identifies various applied treatments that result in changes to CONSTRUCTION\_NO.
- Seasonal Monitoring Program (SMP)—contains SMP-specific data, such as onsite air temperature and precipitation data, subsurface temperature and moisture content data, and frost-related measurements.
- Specific Pavement Studies (SPS)—contains SPS-specific general and construction information for SPS-1 through -10 experiments.
- Traffic (TRF)—contains traffic load, classification, and volume data.
- Test (TST)—contains field and laboratory materials testing data. A key table in the TST module is TST\_L05B, which contains layer thickness and composition information based on measurements from the test section site.
- LTPP Traffic Analysis Software (LTAS)—contains data and computed quantities used to process traffic measurement data, perform QC checks, and produce various types of traffic-based computed parameters stored in PPDB. As described in chapter 16, LTAS tables use a general table naming scheme similar to the module format used in PPDB but based on temporal aggregation attributes.

## CHAPTER 3. ADMINISTRATION MODULE

### INTRODUCTION

The Administration module contains test section administration tables and metadata tables. Names and descriptions of tables in the Administration module are as follows:

- EXPERIMENT\_SECTION—master administrative control table for test sections.
- LTPPDD—data dictionary describing the format, units, and primary keys in each database table.
- LTPPTD—general descriptions of the content in each table.
- CODES—definitions of the code values used in the database.
- CODETYPES—hierarchical classification of information contained in the CODES table.
- COMMENTS\_GENERAL—general comments table concerning unique test section events.
- REGIONS—a mapping of States and Provinces to LTPP operations administrative designations.
- SECTION\_COORDINATES—test section location coordinates.
- SECTION\_LAYER\_STRUCTURE—master pavement layer table documenting changes in pavement structure over time.

### MAJOR RELATIONAL FIELDS

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

#### STATE\_CODE Field

STATE\_CODE is a field that contains a two-digit numerical value used to identify the State or Province where a test section is located. The STATE\_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 desire to participate in the LTPP program in 1987.

#### SHRP\_ID Field

SHRP\_ID is an alphanumeric character field used as an identifier for either a single test section or a group of test sections. 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 that 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, “B” for the third 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 an agency jurisdiction, and “A8” represents the

second SPS-8 experiment site. However, this general scheme changed with the introduction of the SPS-10 experiment to the LTPP database in the June 2015 public data release. Data users are advised to use entries in the EXPERIMENT\_SECTION table to determine proper assignment of test sections to experiment classification.

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 “00,” it represents a project-level record; if not, it is a specific test-section-level record. There are some minor exceptions to this structure on assignment of SHRP\_ID to SPS projects, but these are the general rules.

### **CONSTRUCTION\_NO Field**

The CONSTRUCTION\_NO field identifies changes in pavement structure caused by applying maintenance or rehabilitation treatments. When a test section first enters the LTPP program, it is assigned a CONSTRUCTION\_NO of “1.” CONSTRUCTION\_NO is incremented by one for each subsequent maintenance or rehabilitation event regardless of its impact on 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. The link between these modules provides a user information on pavement structure characteristics at the time each monitoring measurement was performed.

The type of construction event that created the change in the CONSTRUCTION\_NO field is stored in fields using the MAINT\_WORK code. These fields include CN\_CHANGE\_REASON in the EXPERIMENT\_SECTION table and IMP\_TYPE in the tables included in the Maintenance and Rehabilitation modules.

### **TABLE DESCRIPTIONS**

EXPERIMENT\_SECTION is the master control table for all test sections and project sites included in the LTPP database. Due to the EXPERIMENT\_SECTION table’s overall importance in interpreting PPDB, it is included in every database contained within LTPP database extractions. The three key fields that define a unique record in the EXPERIMENT\_SECTION table are STATE\_CODE, SHRP\_ID, and CONSTRUCTION\_NO, which form the primary backbone of relational links within the LTPP database.

Names and descriptions of other major fields in the EXPERIMENT\_SECTION table are as follows:

- CN\_ASSIGN\_DATE—identifies the date the CONSTRUCTION\_NO became active. For a CONSTRUCTION\_NO of “1,” this is the date the test 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**. The **CN\_CHANGE\_REASON** field contains codes of the type **MAINT\_WORK**, but it may contain more than one code and is therefore not directly translatable with **CODES** entries.
- **GPS\_SPS**—indicates whether a test section is classified as a GPS or SPS experiment for the corresponding **CONSTRUCTION\_NO**.
- **EXPERIMENT\_NO**—indicates to which GPS or SPS experiment the test section is assigned. The **EXPERIMENT\_NO** is a two-character code that 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**—indicates the current monitoring status of a test section. A null value indicates the test section has been approved and has an active monitoring status. A value of “O” indicates that the test section is “out of study” and no future monitoring measurements will be made.
- **ASSIGN\_DATE**—indicates the date when a test section is assigned to the LTPP experiment. When a test 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**—indicates 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**). The **DEASSIGN\_DATE** field should be null until a rehabilitation 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** should equal the **CN\_ASSIGN\_DATE** for the next **CONSTRUCTION\_NO**. If a maintenance-related event occurs that does not result in an experiment change, the **DEASSIGN\_DATE** for the previous **CONSTRUCTION\_NO** should equal the **DEASSIGN\_DATE** for the next.
- **SEAS\_ID**—indicates the agency-specific SMP identification code showing SMP measurements were made for the corresponding **CONSTRUCTION\_NO**. **SEAS\_ID** is set to “A” for the first SMP site installed in a State, “B” for the second site, and so on. The **SEAS\_ID** 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 **CONSTRUCTION\_NO** for which no SMP data are available.
- **SUPPLEMENTAL**—identifies supplemental test sections. A value of “S” identifies a test section as supplemental.

The LTPPDD table is the data dictionary for the LTPP PPDB. Starting with the January 2012 data release, the LTPPDD table also contains entries for the LTAS tables. The LTPPDD table contains metadata descriptions for each field in every table, units, references to LTPP source data form designations, and material test protocols. The LTPPDD table circulated with each new public data release is altered to match its contents.

***LTPP Database Tip!***

Users of the LTPP database SDRs 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.

Names and descriptions of major fields in the LTPPDD table are as follows:

- **FIELDNAME**—indicates the name of the specific field defined by the LTPPDD entry.
- **TABLERNAME**—indicates 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**—provides 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**—indicates the name assigned to the code field contained in the **CODES** tables. The contents of the **CODE\_TYPES** field are used to link to the **CODES** table to look up the meaning of a code.
- **DATA\_TYPE**—specifies the Oracle electronic format of the field. These fields are typically a 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 field. Typically, the **DATASHEET** field is a paper datasheet number; however, it may be a filename, file type, or general type of data file.
- **ITEM**—the item number of the form denoted within the **DATASHEET** field. The **ITEM** field is the origin of data that reside within the specified field.
- **UNITS**—indicates units used for the corresponding numeric field. Both SI and U.S. customary units are included in the database.

The LTPPTD table contains a description of the contents of tables in the database. The three fields in the table are self-describing; **TABLERNAME** contains the table name, **DESCRIPTION** is the description of the contents of the table, and **MODULENAME** is the name of the module the table is assigned.



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.

Names and descriptions of fields in the CODES table are as follows:

- CODETYPE—the code type name as shown in the CODETYPE field in the LTPPDD table.
- CODE—the code value. Although most codes are numeric, some are alphanumeric; therefore, the CODE field is coded as a character, which creates an apparent illogical sequence when the field is sorted in ascending or descending order.
- DETAIL—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 three CODETYPES that use the ADDL\_CODE field are COUNTY, in which ADDL\_CODE corresponds to the STATE\_PROVINCE code of the State or Province in which the county is located; EXPERIMENT, in which the ADDL\_CODE is “G” for GPS experiments and “S” for SPS experiments; and MAINT\_WORK that uses Unit as a code type to indicate units.
- ADDL\_CODETYPE—provides the CODETYPE of the CODE specified in the ADDL\_CODE field.

***LTPP Database Tip!***

In some tables, values for a CODE field are 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.

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

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

The REGIONS table consists of two fields—STATE\_CODE and REGION\_CODE. The REGIONS table allows a user to sort State and Provincial agencies by LTPP administrative region. The REGIONS table is used primarily for internal LTPP operations.

The SECTION\_COORDINATES table was introduced in the January 2008 SDR (data release 22). The SECTION\_COORDINATES table contains latitude and longitude coordinates of test sections and project sites previously stored in the INV\_ID and SPS\_ID tables. The SECTION\_COORDINATES table 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 high-precision receivers contain a NULL value in the MEASUREMENT\_ACCURACY field.

In the January 2009 SDR (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 the June 2015 public data release (SDR 29), project-level entries were removed and test section elevations were added. These coordinates are populated using the highest precision coordinate determinations available. The latitude and longitude coordinates of the beginning location of the test section are expressed in fractions of a degree using a negative longitude convention.

The SECTION\_LAYER\_STRUCTURE 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. The SECTION\_LAYER\_STRUCTURE table 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. The SECTION\_LAYER\_STRUCTURE table is contained in every Microsoft 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 (AWSs) were installed by the LTPP program near almost all SPS-1, -2, and -8 project sites to measure site-specific climatic information. AWS measurements include air temperature, humidity, precipitation, solar radiation, and wind speed, and wind direction. 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. AWSs were activated and retired at different dates.

### MAJOR FIELDS

AWS\_ID is a key field in AWS data tables used to link 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 test section.

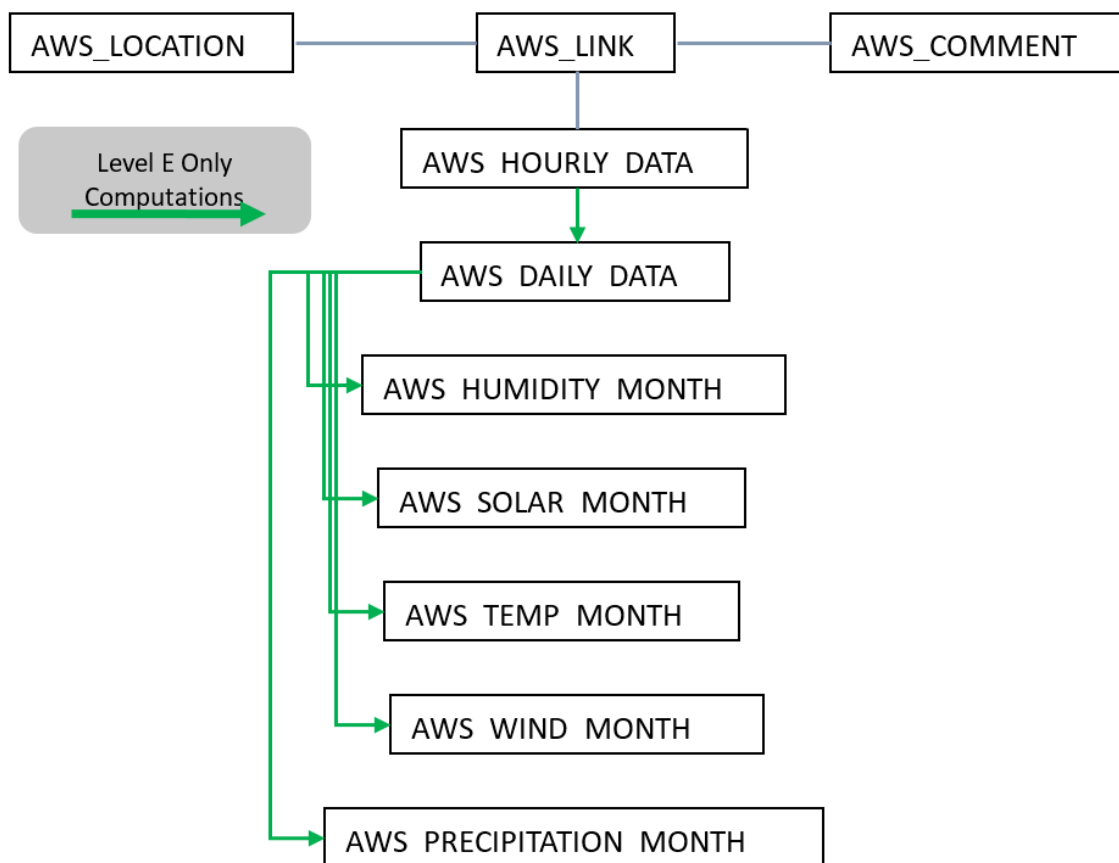
### AWS TABLES

Names and descriptions of AWS tables are as follows:

- AWS\_LINK—provides the link between the AWS identification used in AWS tables and the associated SPS project ID or GPS SHRP\_ID.
- AWS\_LOCATION—contains coordinate information for the location of each AWS. 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—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—contains daily statistics for AWS sites. When possible, 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, values in the daily table may be computed from the corresponding hourly data, if available.
- AWS\_HUMIDITY\_MONTH—contains monthly humidity statistics from LTPP AWS. These statistics are calculated from daily data for months where 24 d or more of data are available.
- AWS\_PRECIPITATION\_MONTH—contains monthly precipitation statistics from LTPP AWS. These statistics are calculated from daily data for months where 24 d or more of data are available.

- AWS\_SOLAR\_MONTH—contains monthly solar radiation statistics from LTPP AWS. These statistics are calculated from daily data for months where 24 d or more of data are available.
- AWS\_TEMP\_MONTH—contains monthly air temperature statistics from LTPP AWS. These statistics are calculated from daily data for months where 24 d or more of data are available.
- AWS\_WIND\_MONTH—contains monthly wind statistics from LTPP AWS. These statistics are calculated from daily data for months where 24 d or more of data are available.

The organization and computational relationships between AWS tables are illustrated in figure 4. The AWS\_LINK table serves as the master table for all other AWS tables. The data logger that stores the data uses measurements performed at 5-minute intervals to compute both hourly and daily statistics. If hourly data are edited, daily statistics are recomputed from hourly data. All monthly statistics are computed from daily data provided that 24 d of data exist within a month.



Source: FHWA.

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

## CHAPTER 5. CLIMATE AND MERRA MODULES

LTPP climate data are stored in the Climate (CLM) module. Data in the Climate module are based on observations from ground-based weather stations.

There is also climate data from the National Aeronautics and Space Administration (NASA) Modern-Era Retrospective Analysis for Research and Applications (MERRA) program located in the LTPP Climate Tool in InfoPave. Data in the MERRA dataset are based on an analysis of a combination of ground, satellite, ocean, and atmospheric observations.

### CLIMATE MODULE

The Climate module uses a two-tier data storage structure. 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 July 2018 SDR (data release 32). In the 2018 update, new data for the OWS through the end of 2017 were added to the database for active LTPP test sections. For the 2018 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, no wind or humidity data were available for a test site. The updated OWS selection process is expected to result in greater coverage of climate data parameters for each site.

Data stored in the Climate 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 period, which began in 1989. To summarize daily measurements, monthly and annual statistics (i.e., mean, standard deviation, minimum, maximum, count, and total) were calculated. Selected climate indices are also available as annual summaries.

### Major Fields

WEATHER\_STATION\_ID is the key field in the CLM\_OWS tables. The WEATHER\_STATION\_ID field contains the unique identification code assigned to each weather station.

VWS\_ID is a key field in the CLM\_VWS\_\* data tables. The VWS\_ID field is used to link 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 climate data for a given SPS project or GPS test section.

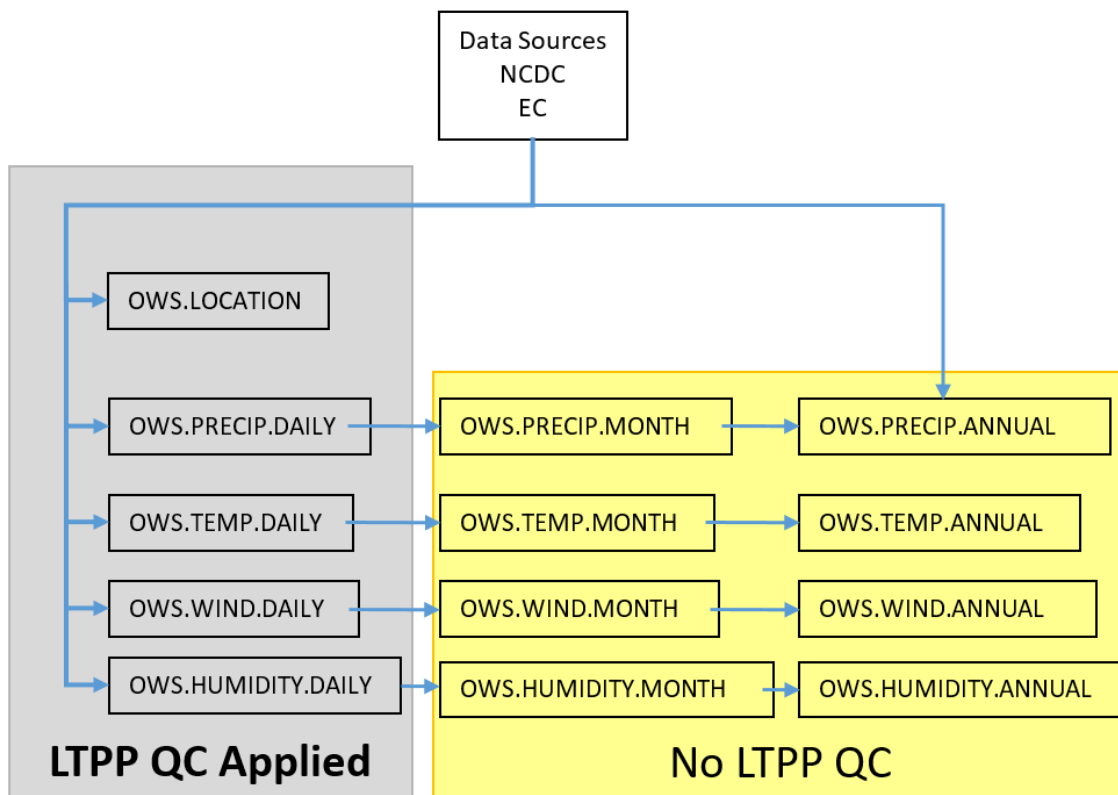
## Climate Tables

There are two major categories of Climate tables: CLM\_OWS tables, which contain weather station data from public sources, and CLM\_VWS tables, which contain linkages between OWS and VWS statistics and statistical results.

### *CLM\_OWS Tables*

The CLM\_OWS tables contain 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 publicly available data. Splitting 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 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 daily statistics are subjected to LTPP QC checks. Because monthly and annual OWS data only contain summaries of daily data, further QC on these tables is not necessary.



Source: FHWA.

**Figure 5. Schematic. Structure and relationship between CLM\_OWS\_\* tables.**

Due to the large size of the CLM\_OWS tables, only one is distributed as part of the SDR. The CLM\_OWS\_LOCATION table is distributed because it is used to determine the distance between a test section and surrounding weather stations. Extractions from the CLM\_OWS tables can be obtained by contacting the LTPP CSSC by emailing [ltpinfo@dot.gov](mailto:ltpinfo@dot.gov).

Names and descriptions of CLM\_OWS tables are as follows:

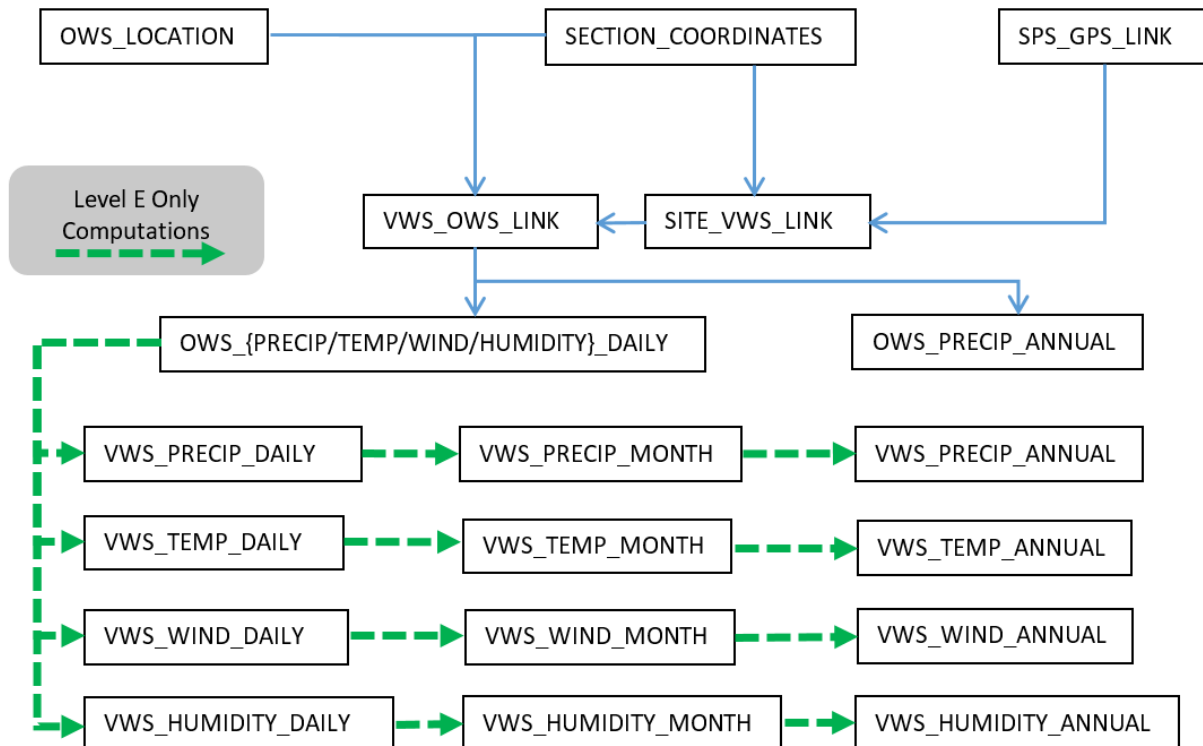
- CLM\_OWS\_LOCATION—contains location coordinates and elevation of the OWS used to estimate the climatic conditions at each test section.
- CLM\_OWS\_PRECIP\_DAILY—contains OWS daily precipitation and snowfall.
- CLM\_OWS\_PRECIP\_MONTH—contains OWS monthly precipitation statistics. The CLM\_OWS\_PRECIP\_MONTH table is populated only for months with 24 d or more of data available.
- CLM\_OWS\_PRECIP\_ANNUAL—contains OWS annual precipitation statistics. The CLM\_OWS\_PRECIP\_ANNUAL table is populated only for years with 300 d or more of data available.
- CLM\_OWS\_HUMIDITY\_DAILY—contains OWS daily maximum and minimum air humidity levels.
- CLM\_OWS\_HUMIDITY\_MONTH—contains OWS monthly humidity statistics. The CLM\_OWS\_HUMIDITY\_MONTH table is populated only for months with 24 d or more of data available.
- CLM\_OWS\_HUMIDITY\_ANNUAL—contains OWS annual humidity statistics. The CLM\_OWS\_HUMIDITY\_ANNUAL table is populated only for years with 300 d or more of data available.
- CLM\_OWS\_TEMP\_DAILY—contains OWS daily mean, maximum, and minimum temperature recorded at the weather station.
- CLM\_OWS\_TEMP\_MONTH—contains OWS monthly temperature statistics. The CLM\_OWS\_TEMP\_MONTH table is populated only for months with 24 d or more of data available.
- CLM\_OWS\_TEMP\_ANNUAL—contains OWS annual temperature statistics. The CLM\_OWS\_TEMP\_ANNUAL table is populated only for years with 300 d or more of data available.
- CLM\_OWS\_WIND\_DAY—contains OWS daily maximum and minimum measured wind speeds.

- CLM\_OWS\_WIND\_MONTH—contains OWS monthly wind statistics. The CLM\_OWS\_WIND\_MONTH table is populated only for months with 24 d or more of data available.
- CLM\_OWS\_WIND\_ANNUAL—contains OWS annual wind statistics. The CLM\_OWS\_WIND\_ANNUAL table is populated only for years with 300 d or more of data available.

**CLM\_VWS Tables**

CLM\_VWS tables contain 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 on related OWS daily data, by data type. Only OWS daily climate data that have passed all LTPP automated QC checks are used to compute associated VWS daily statistics.

After VWS daily tables are created, VWS monthly tables are computed. Monthly tables are computed using daily data that have passed all daily data QC checks. In addition to checks on daily tables, 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 on 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.



Source: FHWA.

**Figure 6. Schematic. Computational and relational structure of CLM\_VWS tables.**



Names and descriptions of CLM\_VWS tables are as follows:

- CLM\_SITE\_VWS\_LINK—provides the link between the VWS and the test section for which data are being provided. When an SPS test section is co-located with a GPS test section, the SPS section will not be in the CLM\_SITE\_VWS\_LINK table and the information will need to be accessed with the help of SPS\_GPS\_LINK.
- CLM\_VWS\_OWS\_LINK—provides the link between the VWS and associated OWS. The CLM\_VWS\_OWS\_LINK table 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—contains the results of VWS computations for daily precipitation and snowfall from associated records at level E in the CLM\_OWS\_PRECIP\_DAILY table.
- CLM\_VWS\_PRECIP\_MONTH—contains VWS monthly precipitation statistics from records at level E in the CLM\_VWS\_PRECIP\_DAILY table. The CLM\_VWS\_PRECIP\_MONTH table is populated for months with 24 d or more of available data.
- CLM\_VWS\_PRECIP\_ANNUAL—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 these data are not stored in the CLM\_VWS\_PRECIP\_DAILY table. The CLM\_VWS\_PRECIP\_ANNUAL table is populated only for years with 300 d or more of data available.
- CLM\_VWS\_HUMIDITY\_DAILY—contains the results of the VWS computations for the maximum and minimum daily air humidity based on associated records from the CLM\_OWS\_HUMIDITY\_DAILY table.
- CLM\_VWS\_HUMIDITY\_MONTH—contains VWS monthly humidity statistics computed from records at level E in the CLM\_VWS\_HUMIDITY\_DAILY table. The CLM\_VWS\_HUMIDITY\_MONTH table is populated only for months with 24 d or more of data available.
- CLM\_VWS\_HUMIDITY\_ANNUAL—contains VWS annual humidity statistics. The CLM\_VWS\_HUMIDITY\_ANNUAL table is populated only for years with 300 d or more of data available.
- CLM\_VWS\_TEMP\_DAILY—contains the VWS daily mean, maximum, and minimum temperature computed from the CLM\_OWS\_TEMP\_DAILY weather station data.
- CLM\_VWS\_TEMP\_MONTH—contains VWS monthly temperature statistics. The CLM\_VWS\_TEMP\_MONTH table is populated only for months with 24 d or more of data available.

- CLM\_VWS\_TEMP\_ANNUAL—contains VWS annual temperature statistics. The CLM\_VWS\_TEMP\_ANNUAL table is populated only for years with 300 d or more of data available.
- CLM\_VWS\_WIND\_DAILY—contains the VWS daily maximum and minimum measured wind speeds computed from the CLM\_OWS\_WIND\_DAILY table.
- CLM\_VWS\_WIND\_MONTH—contains VWS monthly wind statistics. The CLM\_VWS\_WIND\_MONTH table is populated only for months with 24 d or more of data available.
- CLM\_VWS\_WIND\_ANNUAL—contains VWS annual wind statistics. The CLM\_VWS\_WIND\_ANNUAL table is populated only for years with 300 d or more of data available.

## 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 7 and figure 8 illustrate the computational structure implemented in the February 2004 SDR (data release 17). CLM\_VWS\_\*\_DAILY tables are based on values from corresponding CLM\_OWS\_\*\_DAILY tables, where \* represents a type of weather data. CLM\_VWS\_\*\_MONTH tables are based on values contained in the corresponding CLM\_VWS\_\*\_DAILY table. Likewise, CLM\_VWS\_\*\_ANNUAL tables are based on values contained in CLM\_VWS\_\*\_MONTH tables.

### VWS Calculations

Because values stored in the VWS tables are computed using values from varying numbers of OWS locations based on a maximum distance from the test section, the equation in figure 7 was used to weight the influence of OWS values based on the distance between the OWS and VWS:

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

**Figure 7. Equation. Distance square interpolation model used to compute weighted virtual weather statistics from distant OWSs.**

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).

### ***Freezing Index***

The monthly or annual freezing index is computed as shown in figure 8:

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

**Figure 8. Equation. Freeze index calculation.**

Where:

$FI$  = freezing index, °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 the equation in figure 8, only days where the average daily temperature is below freezing are used. Therefore, the freezing index is the summation of all average daily temperatures below 0 °C (32 °F) within the given period.

### **MERRA CLIMATE DATA**

The MERRA climate data, developed by NASA for its own in-house modeling needs, has provided continuous hourly weather data since 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 distributed irregularly in space and time. (Rienecker et al. 2011) The result is a uniformly gridded dataset 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 0.5-degree-latitude by 0.67-degree-longitude (approximately 50 by 60 km (31 by 37 mi) at mid-latitudes) spatial resolution over the entire globe. Evaluation of MERRA by LTPP indicates it provides a basis to extend, enhance, and improve infrastructure models dependent on climate inputs.

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

In the July 2017 public data release, MERRA-2 data were incorporated into the InfoPave LTPP Climate Tool. The MERRA-2 dataset was introduced because of advances in the assimilation system that now include hyperspectral radiance and microwave observations. (Molod et al. 2015) The other significant change was reduction of the longitude width of the grid cells from 0.67 to 0.625 degrees.

Some MERRA data available from the InfoPave MERRA LTPP Climate Tool include the following:

- Hourly precipitation, evaporation, soil moisture profile, layer soil moisture, and water infiltration rate.
- Daily precipitation, evaporation, infiltration, runoff, snowfall, snow mass, and snow melt.
- Monthly and annual precipitation and evaporation.
- Hourly air temperature, soil temperature at six layer depths, and temperature in the unsaturated zone.
- Daily statistical summaries of hourly temperature data elements.
- Monthly and annual statistics of daily temperature data elements plus days above 32 °C (89.6 °F), days below 0 °C (32 °F), the freeze index, and computed air temperature parameters for freeze-thaw days.
- 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 LTPP Climate Tool can be obtained from the InfoPave website.

### **LTPP Climate Zones**

LTPP climate zones were originally established as a test section classification method in the test section selection process at the start of the program. The objective of the original LTPP climate zone classification was to obtain a balance in the number of test sections with each generic climate zone. In early maps, LTPP climate zones were customized to many state boundaries to simplify the test section nomination process.

Current wet/dry climate zones contained in the LTPP database are based on 508 mm (20 inches) of precipitation per year as the breakpoint for wet/dry. The current threshold between freeze/no-freeze zones contained in the LTPP database is based on an annual average freezing index of 83 °C (150 °F) days. Sites with an index over this threshold are classified in the freeze zone and those under the threshold in a no-freeze zone.

The LTPP climate zone classification for test sections based on LTPP classifications is only used within the program for equivalent single-axle load (ESAL) computations and presentations in the section summary reports on InfoPave.

Those performing analysis of LTPP data should create their own climate classification metrics related to their research objectives and not use the generic LTPP climate classifications as a standard.

## 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 SDR (data release 27), separate data storage structures were used for North Carolina and Ohio DLR measurements. Because of errors found in previous interpretations, Ohio DLR data were reinterpreted in 2012. A result of the reinterpretation was a change in data elements used to represent Ohio DLR data. These changes were significant enough that splitting the tables containing North Carolina and Ohio data resulted in an easier to understand data storage structure.

Because of the complex nature of the DLR module, users interested in analyses of these data should contact the LTPP CSSC to discuss research objectives.

### ***LTPP Database Tip!***

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

### **MAJOR FIELDS**

In addition to STATE\_CODE and SHRP\_ID, there are three other fields unique to DLR tables that can be used to link related data in associated tables to each other: 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 table 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. The link to TEST\_DATE is needed for DLR measurements on PCC test sections; TEST\_DATE is included in tables containing measurements on asphalt concrete (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 characteristics of the test truck and test speed stored in the DLR\_TEST\_MATRIX and DLR\_TRUCK\_GEOMETRY tables to measured pavement responses stored in other DLR data tables. For each TEST\_NAME event, the run number starts with “1” and is increased by one for each successive pass by the test trucks.

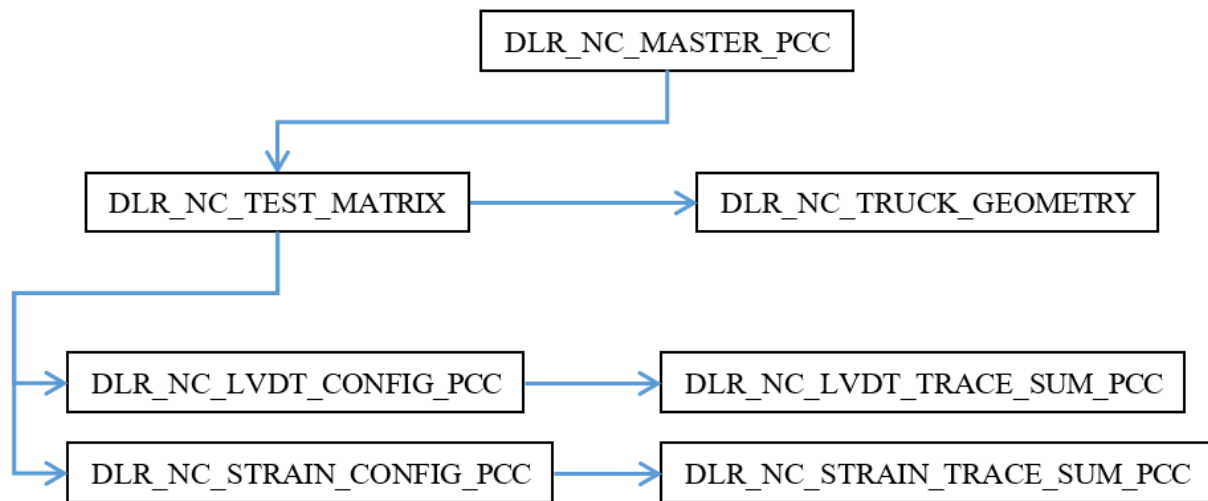
TAG\_ID is the name assigned to each sensor installed on each test section. The combination of STATE\_CODE, SHRP\_ID, and TAG\_ID uniquely identifies each response sensor. TAG\_ID

also identifies the sensor manufacturer, although the DLR data storage structure is based on measurement type.

## NORTH CAROLINA DLR DATA

Four PCC test 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 (i.e., 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 is illustrated in figure 9. Since no changes were made to interpretation of North Carolina DLR data during the 2012 update cycle, the data reported in these tables have not changed; the only change was to table names. Table fields are identical to those contained in the January 2012 SDR (data release 26).



Source: FHWA.

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

Names and descriptions of tables in the North Carolina DLR module are as follows:

- DLR\_NC\_MASTER\_PCC—contains site and instrumentation summary information for test sections with PCC surfaces. One record exists in the DLR\_NC\_MASTER\_PCC table for each DLR measurement cycle, as defined by the TEST\_NAME field.

- DLR\_NC\_TEST\_MATRIX—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—contains information on the axle spacing, tire type and pressure, and axle width of the test trucks used for DLR tests.
- DLR\_NC\_LVDT\_CONFIG\_PCC—contains linear variable differential transformer (LVDT) gauge settings and location information for instrumented PCC test sections.
- DLR\_NC\_LVDT\_TRACE\_SUM\_PCC—contains response trace summaries from LVDT measurements on PCC test sections. The time-response trace is reduced to a series of no more than 10 points to capture significant events in the measured response.
- DLR\_NC\_STRAIN\_CONFIG\_PCC—contains strain gauge information, configuration settings, and location information for measurements on PCC test sections.
- DLR\_NC\_STRAIN\_TRACE\_SUM\_PCC—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 significant events in the measured response.

## **OHIO DLR DATA**

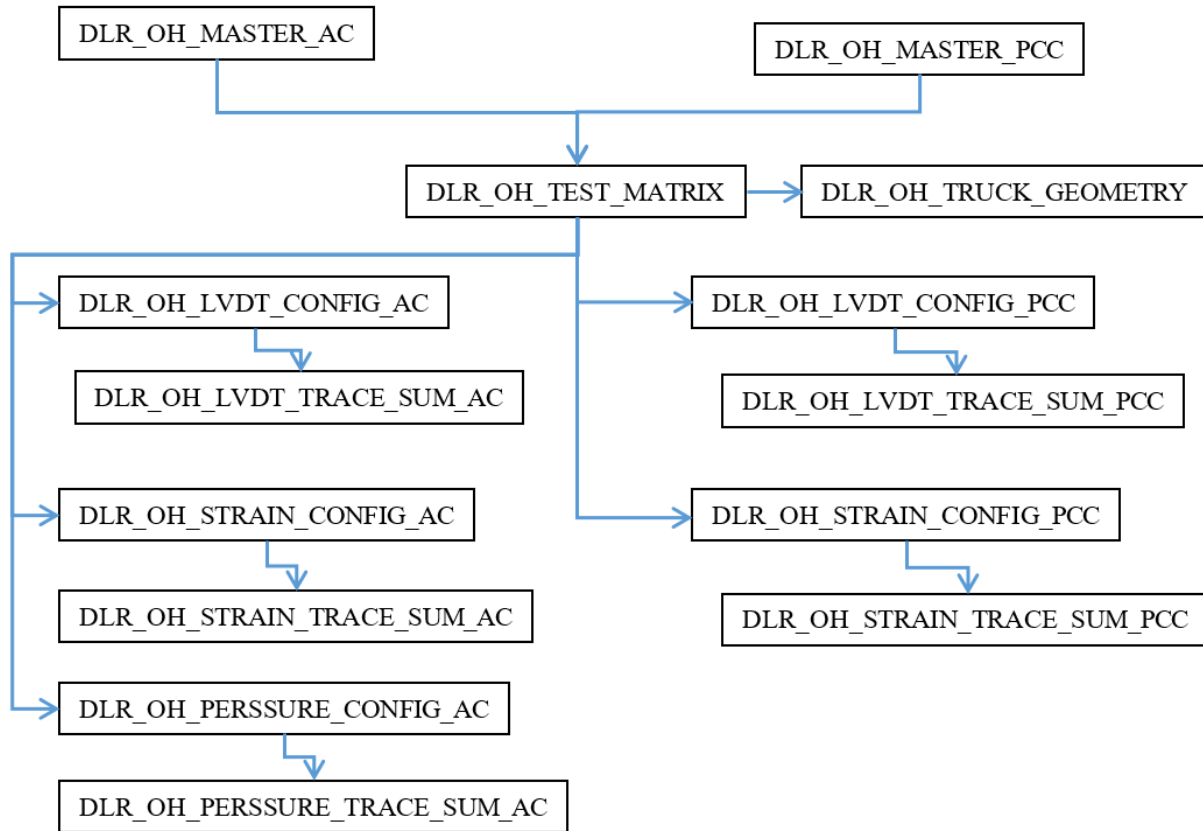
Ohio DOT and a consortium of Ohio universities performed DLR measurements on instrumented test sections in Ohio. Measurements were taken on both SPS-1 and -2 (i.e., AC and PCC) test sections. Information on the tests performed in Ohio can be found on the Ohio DOT website. (Ohio Department of Transportation 2020)

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

- Response sensor location data were modified.
- Time-history sensor responses were reinterpreted using the correct data-collection frequency rate, more peak values were identified, and sensor drift adjustment and data-collection frequency factors were 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 table names start with DLR\_OH, Ohio data include measurements on

AC surfaced test sections, and Ohio data include pressure measurements at the interface between bound and unbound pavement layers.



Source: FHWA.

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

Names and descriptions of tables in the Ohio DLR module are as follows:

- DLR\_OH\_MASTER\_PCC—contains site and instrumentation summary information for test sections with PCC surfaces in Ohio. One record exists for each DLR measurement cycle, as defined by the TEST\_NAME field.
- DLR\_OH\_MASTER\_AC—contains site and instrumentation summary information for test sections with AC surfaces in Ohio. One record exists for each DLR measurement cycle, as defined by the TEST\_NAME field.
- DLR\_OH\_TEST\_MATRIX—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—contains information on axle spacing, tire type and pressure, and axle width of the test trucks used for DLR tests.



- DLR\_OH\_LVDT\_CONFIG\_AC—contains LVDT gauge settings and location information for instrumented AC test sections.
- DLR\_OH\_LVDT\_TRACE\_SUM\_AC—contains response trace summaries from LVDT measurements on AC test sections. The time-response trace is reduced to a series of up to three points that capture 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—contains strain gauge information, configuration settings, sensor orientation, and location information for measurements on AC test sections.
- DLR\_OH\_STRAIN\_TRACE\_SUM\_AC—contains response trace summaries from strain measurements on AC test sections. Time-response trace is reduced to a series of up to eight points to capture 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—contains pressure gauge settings and location information for measurements on AC test sections.
- DLR\_OH\_PRESSURE\_TRACE\_SUM\_AC—contains response trace summaries from pressure measurements on AC test sections. Time-response trace is reduced to a series of up to three points to capture significant peaks or valleys in the measured response.
- DLR\_OH\_LVDT\_CONFIG\_PCC—contains LVDT gauge settings and location information for instrumented PCC test sections.
- DLR\_OH\_LVDT\_TRACE\_SUM\_PCC—contains response trace summaries from LVDT measurements on PCC test sections. The time-response trace is reduced to a series of up to three points that capture 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—contains strain gauge information, configuration settings, and location information for measurements on PCC test sections.
- DLR\_OH\_STRAIN\_TRACE\_SUM\_PCC—contains response trace summaries from strain measurements on PCC test sections. Time-response trace is reduced to a series of up to six points to capture 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. The Inventory module includes all 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 Inventory module represents the pavement structure prior to applying experimental treatments. Inventory data include location of the test section, pavement type, layer thicknesses and types, material properties, composition, previous construction improvements, and other background information.

Inventory 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 the reported information, it should not be assumed the data in the Inventory module represents design values.

### ***LTPP Database Tip!***

For SPS-3 and -4 projects, which include a co-located GPS test section at the project site, information for the SPS project in Inventory 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.

### **MAJOR TABLES**

Names and descriptions of Inventory tables are as follows:

- INV\_ID—contains test section location information, including route number, milepost, direction of travel, identification of if the location is part of the FHWA Highway Performance Monitoring System (HPMS), and county/parish name. Location information is provided for test sections classified in a GPS experiment or an SPS maintenance and rehabilitation experiment where CONSTRUCTION\_NO is “1” in the EXPERIMENT\_SECTION table. Location information for SPS projects based on construction of a new pavement structure is stored in the SPS\_ID table.
- INV\_AGE—contains construction completion and traffic open dates for the original pavement structure based on highway agency records.
- INV\_LAYER—contains layer information from highway agency records. The INV\_LAYER information represents the pavement structure prior to LTPP monitoring. The INV\_LAYER table acts as a layer reference table for other Inventory tables. Inventory tables that contain the LAYER\_NO field reference the layer structure described in the INV\_LAYER table. The layer structure in the INV\_LAYER 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 the INV\_LAYER table. The SECTION\_LAYER\_STRUCTURE is a copy of the TST\_L05B table and is included in each database in SDR. Further insight into how to

link the INV\_LAYER table and TST\_L05B information is included in chapter 13, Materials Testing Module.

- INV\_GENERAL—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—contains data on the gradation of coarse, fine, and combined aggregates for PCC, AC, base, and subgrade. The LAYER\_NO field is used to link to the INV\_LAYER table to indicate the type of layer. The information in the INV\_GRADATION table is based on participating highway agency records and is not consistent between highway agencies.
- INV\_MAJOR\_IMP—contains information on the type, quantity, date, and cost of major improvements to the test section prior to acceptance for LTPP monitoring. For test sections classified in the GPS-6A and -7A experiments, the INV\_MAJOR\_IMP table provides the original overlay date.
- INV\_MODIFIER—contains information on asphalt modifiers used in plant-mixed asphalt (PMA)-bound layers.
- INV\_PCC\_JOINT—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—contains PCC mix properties, including cement type, air entrainment, slump, and mix proportions.
- INV\_ADMIX—contains information on admixture type and amount for PCC layers.
- INV\_AGGR\_COMP—contains information on aggregate composition for coarse, fine, and combined aggregates used in AC and PCC mixtures.
- INV\_AGGR\_DUR—contains information on aggregate durability in AC and PCC mixtures.
- INV\_PCC\_STEEL—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—contains available strength data from highway agency records for PCC layers, including flexural strength, compressive strength, and splitting tensile strength.
- INV\_PMA—contains information on PMA-bound layer aggregate properties, including bulk specific gravity (BSG), effective specific gravity, mineral fillers, and polish value.

- INV\_PMA\_ASPHALT—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—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—contains information on field construction of PMA-bound layers, including mixing temperature and lay-down temperatures.
- INV\_PMA\_ORIG\_MIX—contains available agency information from laboratory- and field-compacted specimens on the mix properties of PMA-bound layers. Data included in the INV\_PMA\_ORIG\_MIX table are maximum specific gravity (MSG), BSG, asphalt content, air voids, voids in the mineral aggregate, mix design stability, plant type, anti-stripping agents, and moisture susceptibility.
- INV\_PMA\_ROLLER—contains details on rollers used to compact AC layers, including roller weight, tire pressure, and roller speed.
- INV\_SHOULDER—contains composition, geometric properties, structural properties, and associated details for shoulders, including surface material type, width, thickness, and base type.
- INV\_STABIL—contains data on stabilizing agents used in base and subbase layers.
- INV\_SUBGRADE—contains available information on 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—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—contains general information on snow removal and frequency of deicer use. Data stored in the INV\_DEICE\_SITE\_DATA 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 SHRP research on snow and ice control.
- INV\_DEICE\_TYPES—contains a listing of types of deicers used on test sections. Data stored in the INV\_DEICE\_TYPES 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 SHRP research on snow and ice control.

## CHAPTER 8. MAINTENANCE AND REHABILITATION MODULES

The Maintenance and Rehabilitation 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 Rehabilitation module. Tables in the Rehabilitation 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 Maintenance 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 the MNT\_IMP table. The Maintenance tables include information such as placement of seal coats, patches, joint resealing, milling, and grooving. Unlike the Rehabilitation module, there is no significant pavement structure change from a maintenance event, and therefore no maintenance layer table exists.

Although layering information for rehabilitation events is recorded in the Rehabilitation module, that layering information should only be used for the rehabilitation events themselves and not as typical test section layering. Typical pavement test section layering information should be obtained from the SECTION\_LAYER\_STRUCTURE table.

LTPP requests that participating highway agencies notify the LTPP regional office prior to performing maintenance or rehabilitation on a highway segment containing an LTPP test 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. Test sections receiving those treatments are placed out of study, are no longer studied after rehabilitation, and do not have data in the Rehabilitation module for that treatment.

### MAJOR FIELDS

The IMP\_TYPE field provides information on the type of maintenance or rehabilitation performed and is used in both MNT\_IMP and RHB\_IMP tables. The IMP\_TYPE 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 data related to the experimental maintenance treatments are stored in tables in the SPS module.

The IMP\_TYPE field should be used to determine which other Maintenance tables or Rehabilitation tables contain specifics of the activity. Table 3 shows the general relationships between IMP\_TYPE and Maintenance tables and Rehabilitation 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 Maintenance or Rehabilitation 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 Maintenance and Rehabilitation tables.

**Table 3. IMP\_TYPE code, description, and expected location of data in Maintenance and Rehabilitation tables.**

<b>IMP_TYPE</b>	<b>Type of Improvement</b>	<b>Expected Location of Data in MNT and RHB Tables</b>
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 potholes: hand spread, compacted with truck	MNT_ASPHALT_PATCH
26	Skin patching	MNT_ASPHALT_PATCH
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

<b>IMP_TYPE</b>	<b>Type of Improvement</b>	<b>Expected Location of Data in MNT and RHB Tables</b>
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 plus AC surface	RHB_CRACK_SEAT_PCC
47	Crack-and-seat PCC pavement plus PCC surface	RHB_CRACK_SEAT_PCC
48	Recycled PCC	RHB_RCYPPCC_* 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_ASPHALT_SEAL



The DATA\_AVAIL\_IMS field in the MNT\_IMP and RHB\_IMP tables indicates whether information on the maintenance or rehabilitation activity is available in other Maintenance, Rehabilitation, or SPS construction tables. The creation of a record in the MNT\_IMP or RHB\_IMP tables is an important step in the process of assigning a construction number, and the DATA\_AVAIL\_IMS field is necessary so that entries can be made in the MNT\_IMP or RHB\_IMP tables before specifics of the activity are known.

## **MAINTENANCE TABLES**

Names and descriptions of Maintenance tables are as follows:

- MNT\_IMP—contains a listing of 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—contains crack sealing information for PCC pavements, including type of sealant used, how it was applied, and how much sealing was performed.
- MNT\_PCC\_FULL\_DEPTH—contains information on full-depth PCC repair, including reasons for repair, size of the replacement slab, material used for replacement, interface of the replacement with the existing pavement, and finishing/curing methods.
- MNT\_PCC\_JOINT\_RESEAL—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—contains information on partial-depth patching for PCC pavements, including reasons for patching, type of patching performed, material used for patching, and material properties, jointing, and curing methods for PCC patches.
- MNT\_ASPHALT\_CRACK\_SEAL—contains crack sealing information for AC pavements, including type of sealant used, how it was applied, and how much sealing was performed.
- MNT\_ASPHALT\_PATCH—contains patching information for AC pavements, including reasons for patching, size of patching, and patching techniques.
- MNT\_ASPHALT\_SEAL—contains seal-coat application information for AC pavements, including reasons for sealing, type and properties of the sealant used, and application information.
- MNT\_GMG—contains information on diamond grinding, milling, and grooving of all pavement surface types, including reasons for treatment and details of the treatment type and application.

- MNT\_COST—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—contains information on test section maintenance that occurred prior to the test section’s inclusion in the LTPP program, including only basic information such as type and quantity of maintenance.

## **REHABILITATION TABLES**

### **Nonrehabilitation-Specific Tables**

Nonrehabilitation-specific tables are not specific to any one type of rehabilitation and may be filled out regardless of the rehabilitation performed. The RHB\_IMP table contains entries for every rehabilitation event. The RHB\_LAYER table is completed only for treatments that alter the material layer structure.

Names and descriptions of nonrehabilitation-specific tables are as follows:

- RHB\_IMP—contains a complete list of rehabilitation treatments placed after the test section was included in the LTPP program. The RHB\_IMP table also includes when treatments were placed.
- RHB\_LAYER—contains changes to the layer structure based on information provided by the State or Provincial highway agency. Information contained in the SECTION\_LAYER\_STRUCTURE table should be used when the actual as-placed thickness of each layer is needed.
- RHB\_CAUSE\_INFO—contains information on the cause(s) of rehabilitation for a test section and the scheduled start date for the rehabilitation.

### **Rehabilitation Tables for AC Overlays**

#### ***RHB\_PMA\_\* Tables***

These tables contain information on construction of AC overlays. They will be used regardless of whether the overlay is recycled AC or not. RHB\_PMA\_\* tables are populated only when IMP\_TYPE is 19, 43, 44, 51, 55, or 56.

Names and descriptions of RHB\_PMA\_\* tables are as follows:

- RHB\_PMA\_COMPACTION—contains compaction data for all types of AC overlays, including information on roller types and coverage.
- RHB\_PMA\_CONSTRUCTION—contains construction data for all types of AC overlays, including plant information and lay-down temperatures.

- RHB\_PMA\_ROLLER—contains roller data for rollers used on all types of AC overlays, including the type, weight, and speed of rollers used for compaction.

### ***RHB\_ACO\_\* Tables***

These tables are used for nonrecycled asphalt pavement overlays. RHB\_ACO\_\* tables are populated only if IMP\_TYPE = 19 or 51.

Names and descriptions of RHB\_ACO\_\* tables are as follows:

- RHB\_ACO\_AGGR\_PROP—contains properties of the aggregate used in AC overlays, including aggregate composition, durability, specific gravity, and gradation.
- RHB\_ACO\_LAB\_AGED\_AC—contains properties of the laboratory-aged asphalt cement used in AC overlays, including viscosity, ductility, penetration, and other asphalt cement properties.
- RHB\_ACO\_LAB\_MIX—contains 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—contains 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—contains properties of the asphalt cement used in AC overlays, including modifiers used, specific gravity, viscosity, ductility, and other asphalt cement properties.
- RHB\_ACO\_SP\_AGGR\_PROP—first introduced in the January 2006 SDR (data release 20), the RHB\_ACO\_SP\_AGGR\_PROP table contains additional aggregate properties related to the Superpave mix design method used for AC overlay layers. Some unique aggregate properties contained in the table include angularity, soundness, and toughness of fine and coarse proportions.
- RHB\_ACO\_SP\_MIX\_PROP—contains AC Superpave-related properties of the overlay layer.
- RHB\_ACO\_SP\_PROP—contains Superpave-related properties of the asphalt binder used in the AC overlay layer.

### ***RHB\_CM RAP\_\* Tables***

These tables are used for cold-mix recycled AC overlays. RHB\_CM RAP\_\* tables are populated only if IMP\_TYPE = 44 or 56. Because this is not a standard treatment option for LTPP experiments, RHB\_CM RAP\_\* tables do not have many records.

Names and descriptions of RHB\_CM RAP\_\* tables are as follows:

- RHB\_CMRAP\_COMBINED\_AGG—contains properties of the combined aggregate used in cold-mix recycled AC overlays, including aggregate composition, specific gravity, and gradation.
- RHB\_CMRAP\_COMBINE\_AC—contains properties of the asphalt cement used in cold-mix recycled AC overlays, including modifiers used, specific gravity, viscosity, ductility, and other asphalt cement properties.
- RHB\_CMRAP\_GEN\_INFO—contains properties of the reclaimed aggregate and general information for cold-mix recycled AC overlays, including 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—contains 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—contains 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—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—contains 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—contains 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—contains properties of the untreated aggregate used in cold-mix recycled AC overlays, including aggregate composition, durability, specific gravity, and gradation.

### ***RHB\_HMRAP\_\* Tables***

These tables are used for hot-mix recycled AC overlays. RHB\_HMRAP\_\* tables are populated only if IMP\_TYPE = 43 or 55.

Names and descriptions of RHB\_HMRAP\_\* tables are as follows:

- RHB\_HMRAP\_COMBINED\_AGG—contains properties of the combined aggregate used in hot-mix recycled AC overlays, including aggregate composition, specific gravity, and gradation.

- RHB\_HMRAP\_COMBINE\_AC—contains properties of the asphalt cement used in hot-mix recycled AC overlays, including modifiers used, specific gravity, viscosity, ductility, and other asphalt cement properties.
- RHB\_HMRAP\_GEN\_INFO—contains properties of the reclaimed aggregate and general information on hot-mix recycled AC overlays, including 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—contains 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—contains 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—contains 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—contains 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—contains 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—contains properties of the untreated aggregate used in hot-mix recycled AC overlays, including aggregate composition, durability, specific gravity, and gradation.

## **Rehabilitation Tables for PCC Overlays**

### ***RHB\_PCCO Tables***

These tables include information on PCC overlays. RHB\_PCCO tables are populated only when IMP\_TYPE = 20, 48, or 52.

Names and descriptions of RHB\_PCCO tables are as follows:

- RHB\_PCCO\_AGGR—contains properties of the aggregate used in PCC overlays, including aggregate composition, durability, specific gravity, and gradation.
- RHB\_PCCO\_CONSTRUCTION—contains construction data for PCC overlays, including information on curing, temperature, and existing surface preparation.

- RHB\_PCCO\_JOINT\_DATA—contains joint data for PCC overlays, including information on construction and expansion joints, sealants, and load-transfer devices.
- RHB\_PCCO\_MIXTURE—contains PCC mixture data for PCC overlays, including information on mix design, admixtures, slump, air entrainment, and other PCC mix properties.
- RHB\_PCCO\_STEEL—contains information on reinforcing steel used in PCC overlays, including the type and strength of the reinforcement and some placement information. Since no data are stored in the RHB\_PCCO\_STEEL table, it is not included in SDRs.
- RHB\_PCCO\_STRENGTH—contains PCC strength data for PCC overlays, including flexural, compressive, and tensile strength, and elastic modulus.

### ***RHB\_RCYPCC Tables***

These tables contain information on PCC overlays using recycled PCC pavement. RHB\_RCYPCC tables are used when IMP\_TYPE = 48. Since recycled PCC overlays were not an LTPP study topic, RHB\_RCYPCC tables are currently empty. Since no data are stored in these tables, they are not included in LTPP public data releases.

Names and descriptions of RHB\_RCYPCC tables are as follows:

- RHB\_RCYPCC\_COMBINED\_AGGR—contains properties of the combined aggregate used in recycled PCC overlays, including aggregate durability, specific gravity, and gradation.
- RHB\_RCYPCC\_CONSTRUCTION—contains construction data for recycled PCC overlays, including information on curing, temperature, and existing surface preparation.
- RHB\_RCYPCC\_JOINT—contains joint data for recycled PCC overlays, including information on construction and expansion joints, sealants, and load-transfer devices.
- RHB\_RCYPCC\_MIXTURE—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—contains the properties of the new (i.e., nonrecycled) aggregate used in recycled PCC overlays, including aggregate composition, durability, specific gravity, and gradation.
- RHB\_RCYPCC\_STEEL—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—contains PCC strength data for recycled PCC overlays, including flexural, compressive, and tensile strength and elastic modulus.

## Nonoverlay Rehabilitation Tables

These tables are for rehabilitation other than AC or PCC overlays, though rehabilitation often occurs in conjunction with an overlay. Nonoverlay rehabilitation tables are populated for a variety of IMP\_TYPE values, as shown in table 3.

Names and descriptions of nonoverlay rehabilitation tables are as follows:

- RHB\_CRACK\_SEAT\_PCC—contains data collected from PCC crack-and-seat operations, including information on breaking and seating processes used. The RHB\_CRACK\_SEAT\_PCC table may also be used for rubblization. Since no data are stored in the RHB\_CRACK\_SEAT\_PCC table, it is not included in SDRs. Data on fracture treatments applied to SPS test sections can be found in the SPS construction module.
- RHB\_HEATER\_SCARIF—contains data on heater scarification surface recycling treatments on AC pavements, including information on type of heater scarification, rejuvenating agents, and compaction.
- RHB\_LOAD\_TRANSFER—contains load-transfer restoration data for PCC pavements, including information on the type of restoration and the specifics on placement of the load-transfer devices.
- RHB\_MILL\_AND\_GRIND—contains milling and grinding data for all pavement types, including type and depth of milling or grinding.
- RHB\_PRESSURE\_RELIEF—contains data on the installation of pressure relief joints in PCC pavement, including information on joint dimensions and interval and sealants and fillers used.
- RHB\_RESTORE\_AC\_SHOULDER—contains information on the restoration of AC shoulders, including structure of the shoulder and the restoration performed.
- RHB\_RESTORE\_PCC\_SHOULDER—contains information on the restoration of PCC shoulders, including structure of the shoulder and the restoration performed.
- RHB\_SUBDRAINAGE—contains data on retrofitted subdrainage installation, including information on drainage materials used and specifics of their placement.
- RHB\_SUBSEALING\_PCC—contains data on subsealing PCC pavement, including the type, properties, and placement of the sealant.

## TABLES IN OTHER MODULES

All maintenance and rehabilitation events that occur on a test section while it is a part of the LTPP program are documented in the Maintenance and Rehabilitation modules. However, information on major maintenance and rehabilitation treatments applied to the test section prior to its inclusion in the LTPP program will be found in the INV\_MAJOR\_IMP table.





## CHAPTER 9. PAVEMENT MONITORING MODULE

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

### PHOTOGRAPHIC AND MANUAL DISTRESS

Data stored in 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 transverse profile and rut-related distresses are discussed in the Transverse Profile Distortion section in this report.

Initially, visual interpretation of high-resolution 35-mm (1.38-inch) photographic images of the pavement surface was the primary means used to obtain surface distress data. A national distress data-collection contractor was hired to take 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 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*. (Miller and Bellinger 2014)

To create a distress time history, data users are often faced with combining distresses from photographic and manual data-collection methods. Limitations of each method of data collection must be recognized in interpreting combined datasets, 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, photographic surveys cover a width of about 4.3 m (14 ft). Since manual distress surveys typically cover a narrower pavement width, this can result in anomalies in 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.

### MON\_DIS Tables

The names of all but one distress data table begin with MON\_DIS. The exception is the MON\_DROP\_SEP table, which contains shoulder drop-off and separation information.

In the distress tables, a null value indicates that a particular distress was not rated or a measurement was not performed, while a “0” value in the field indicates that the distress was not present.

- MON\_DIS\_AC\_REV—contains distress survey information obtained by manual field inspection 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—contains distress survey information obtained by manual field inspection for continuously reinforced PCC pavements.
- MON\_DIS\_JPCC\_REV—contains distress survey information obtained by manual field inspection for jointed PCC (JPCC) pavements.
- MON\_DIS\_PADIAS\_AC—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. A good summary of the PADIAS software can be found in Rada et al. (1999). Records for film that were reinterpreted with version 4.2 of the PADIAS software were removed and are now contained in the MON\_DIS\_PADIAS42\_AC table.

For the January 2012 SDR (data release 26), 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 nonwheel path locations.

- MON\_DIS\_PADIAS42\_AC—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—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—contains distress survey information for JPCC 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 in the MON\_DIS\_PADIAS\_JPCC table represent distress photography not reinterpreted using version 4.2 of the PADIAS software.
- MON\_DIS\_PADIAS42\_JPCC—contains distress survey information for JPCC pavements interpreted from 35-mm (1.38-inch) black-and-white photographs using version 4.2 of the PADIAS software.
- MON\_DIS\_JPCC\_FAULT—contains manual measurements of fault height on individual joints and cracks taken using a faultmeter developed by the Georgia DOT.

***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—contains test section summary statistics for fault measurements taken on a test section on the same monitoring day. Fault-height values that have null values or are less than -1 are excluded from test section statistics calculations.
- MON\_DROP\_SEP—contains lane-to-shoulder drop-off measurements for AC-surfaced pavements. The MON\_DROP\_SEP table 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 released, which contained a reinterpretation of LTPP manually collected distress data. The distress-cracking-related data were reinterpreted to conform to the following guidelines:

- AASHTO MEPDG cracking distresses. (AASHTO 2020)
- FHWA HPMS cracking distresses defined in the 2016 *HPMS Field Manual (HPMS16)*. (FHWA 2016a)
- 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 LTPP cracking data, the LTPP team reviewed all manual distress crack maps containing cracks types as dictated within each of the guidelines. The following tables containing the newly reinterpreted cracking data were added:

- MON\_DIS\_AC\_CRACK\_INDEX—contains reinterpreted cracking data for AC-surfaced pavements. Field names indicate the distress definitions used, including MEPDG and HPMS16.

In the 2019 LTPP public data release, the computations of MEPDG-related cracking parameters were revised to match those used in the pavement performance prediction models used in the AASHTOWare Pavement ME Design® software. The three MEPDG cracking parameters were computed with the following equations.

Percent AC cracking index representing bottom-up fatigue cracking in MEPDG and AASHTOWare Pavement ME Design software was computed using the equation shown in figure 11:

$$AlligatorCracking_{\%LaneArea} = \left( \frac{\sum Gator\_Crack\_Area_{Low,Medium,High}}{LTPP\_section\_length \times Survey\_Width} \right) \times 100$$

**Figure 11. Equation. Computation used to populate the MEPDG\_CRACKING\_PERCENT\_AC field in the MON\_DIS\_CRACK\_INDEX\_AC table.**

Where:

*AlligatorCracking%LaneArea* = assumed bottom-up fatigue cracking in AC pavements as a percentage of the test section area.

*Gator\_Crack\_Area<sub>Low,Medium,High</sub>* = area of cracking contained in the GATOR\_CRACK\_A\_L, GATOR\_CRACK\_M, and GATOR\_CRACK\_H fields in the MON\_DIS\_AC\_REV table.

*LTPP\_section\_length* = length of the LTPP test section, which comes from multiple tables in the LTPP database.

*Survey\_Width* = width of the distress survey from the SURVEY\_WIDTH field in the MON\_DIS\_AC\_REV table.

MEPDG longitudinal cracking in the wheel path associated with top-down cracking was computed using the equation shown in figure 12:

$$LongitudinalCracksWP_{feet/mile} = \left( \frac{\sum Long\_Crack\_Length\_WP_{Low,Medium,High}}{LTPP\_section\_length} \right) \times 5,280$$

**Figure 12. Equation. Computation used to populate the MEPDG\_LONG\_CRACK\_LENGTH\_AC field in the MON\_DIS\_AC\_CRACK\_INDEX table.**

Where:

*LongitudinalCracksWP<sub>feet/mile</sub>* = assumed top-down cracking in the wheel path in units of feet per mile used to populate the MEPDG\_LONG\_CRACK\_LENGTH\_AC field in the MON\_DIS\_AC\_CRACK\_INDEX table.

*Long\_Crack\_Length\_WP<sub>Low,Medium,High</sub>* = total length of longitudinal cracking in the wheel path contained in the LONG\_CRACK\_WP\_L\_L, LONG\_CRACK\_WP\_L\_M, LONG\_CRACK\_L\_H, LONG\_CRACK\_WP\_SEAL\_L\_L, LONG\_CRACK\_WP\_SEAL\_L\_M, and LONG\_CRACK\_WP\_SEAL\_L\_H fields in the MON\_DIS\_AC\_REV table.

*LTPP\_section\_length* = length of the LTPP test section, which comes from multiple tables in the LTPP database.

MEPDG transverse cracking indices were computed using the equation shown in figure 13:

$$TransverseCracking_{feet/mile} = \left( \frac{\sum Trans\_Crack\_Length_{Low,Medium,High}}{LTPP\_section\_length} \right) \times 5,280$$

**Figure 13. Equation. Computation used to populate the MEPDG\_CRACKING\_LENGTH\_AC field in the MON\_DIS\_AC\_CRACK\_INDEX table.**

Where:

*TransverseCracking<sub>feet/mile</sub>* = total length of transverse cracking expressed in units of feet per mile used to populate the MEPDG\_CRACKING\_LENGTH\_AC field in the MON\_DIS\_AC\_CRACK\_INDEX table.

*Trans\_Crack\_Length<sub>Low,Medium,High</sub>* = total length of transverse cracking contained in the TRANS\_CRACK\_L\_L, TRANS\_CRACK\_L\_M, TRANS\_CRACK\_L\_H, TRANS\_CRACK\_SEAL\_L\_L, TRANS\_CRACK\_SEAL\_L\_M, and TRANS\_CRACK\_SEAL\_L\_H fields in the MON\_DIS\_AC\_REV table.

*LTPP\_section\_length* = length of the LTPP test section, which comes from multiple tables in the LTPP database.

HPMS16 percent cracking was computed using the equation shown in figure 14:

$$\text{PercentCracking} = \frac{\text{WheelPath\_Crack\_Area} * 100}{\text{LTPP\_Section\_Length} * \text{Survey\_Width}}$$

**Figure 14. Equation. Computation of percent AC cracking from LTPP data following HPMS16 guidelines.**

Where:

*PercentCracking* = percent cracking in the wheel paths used to populate the HPMS16\_CRACKING\_PERCENT\_AC field in the MON\_DIS+CRACK\_INDEX table.

*WheelPath\_Crack\_Area* = WP\_LENGTH\_CRACKED in units of meters from the MON\_DIS\_AC\_REV table times 1.

*LTPP\_Section\_Length* = length of the LTPP test section in units of meters, which comes from multiple tables in the LTPP database.

*Survey\_Width* = width of the distress survey from the SURVEY\_WIDTH field in the MON\_DIS\_AC\_REV table.

In the 2020 LTPP public data release, the field labeled MON\_DIS\_AC\_CRACK\_INDEX.MEPDG\_CRACKING\_PERCENT\_AC in the 2016 and 2017 public data releases was added back to the database labeled as ME\_PERCENT\_WHEEL\_PATH\_CRACK in the MON\_DIS\_AC\_CRACK\_INDEX table. Computations of these fields in the 2016 and 2017 public data releases were not calculated in accordance with the pavement performance models used in the AASHTOWare Pavement ME Design software. The ME\_PERCENT\_WHEEL\_PATH\_CRACK field was replaced in the 2019 public data release with the name MON\_DIS\_AC\_CRACK\_INDEX.MEPDG\_CRACKING\_PERCENT\_AC, where the computation is based on the total area of alligator cracking on the test section divided by test section area and is not limited to wheel path locations. This computed wheel path cracking index was added back to the database so that if an agency had used the previous mislabeled MEPDG percentage cracking index from the 2016 and 2017 public data releases, they could continue to use the index in the future. The ME\_PERCENT\_WHEEL\_PATH\_CRACK field is computed using the equation shown in figure 15:

$$MEPercentWheelPathCrack = \frac{WheelPath\_Crack\_Area * 100}{LTPP\_Section\_Length * Survey\_Width}$$

**Figure 15. Equation. Computation of percent AC wheel path cracking used in the 2016 and 2017 LTPP public data releases previously named MEPDG\_CRACKING\_PERCENT\_AC field, now named ME\_PERCENT\_WHEEL\_PATH\_CRACK field based on a 0.61-m-wide wheel path.**

Where:

*MEPercentWheelPathCrack* = percent cracking in the wheel paths used to populate the ME\_PERCENT\_WHEEL\_PATH\_CRACK AC field in the MON\_DIS\_CRACK\_INDEX table.

*WheelPath\_Crack\_Area* = WP\_LENGTH\_CRACKED in units of meters from the MON\_DIS\_AC\_REV table times 0.61.

*LTPP\_Section\_Length* = length of the LTPP test section in units of meters, which comes from multiple tables in the LTPP database.

*Survey\_Width* = width of the distress survey from the SURVEY\_WIDTH field in the MON\_DIS\_AC\_REV table.

MON\_DIS\_CRCP\_CRACK\_INDEX: This table contains the reinterpreted cracking data for CRCP. The field names indicate the distress standard as MEPDG or HPMS16.

The MEPDG\_PUNCHOUTS\_CRCP field in the the MON\_DIS\_CRCP\_CRACK\_INDEX table did not change in the 2019 public data release. The MEPDG\_PUNCHOUTS\_CRCP parameter is computed as shown in figure 16:

$$Punchouts_{1/mile} = \left( \frac{\sum Punchout\_No_{Medium/High}}{SectionLength} \right) \times 5,280$$

**Figure 16. Equation. Computation to populate the MEPDG\_PUNCHOUTS\_CRCP field in the MON\_DIS\_CRCP\_CRACK\_INDEX table.**

Where:

*Punchouts<sub>1/mile</sub>* = number of medium- and high-severity punchouts per mile.

*Punchout\_No<sub>Medium/High</sub>* = total number of punchouts from the PUNCHOUTS\_NO\_M and PUNCHOUTS\_NO\_H fields in the MON\_DIS\_CRCP\_REV table.

*SectionLength* = length of the LTPP test section, which comes from multiple tables in the LTPP database.

The HPMS16\_CRACKING\_PERCENT\_CRCP field in the in the MON\_DIS\_CRCP\_CRACK\_INDEX table is computed using the equation shown in figure 17:

$$Cracking\_Percent_{HPMS16} = \frac{(Punchout\_Area + Patching\_Area + Longitudinal\_Crack\_Area) * 100}{(LTPP\_Section\_Length * Survey\_Width)}$$

**Figure 17. Equation. Computation of the HPMS16\_CRACKING\_PERCENT\_CRCP field in the MON\_DIS\_CRCP\_CRACK\_INDEX table.**

Where:

*Cracking\_Pervcent<sub>HPMS16</sub>* = HPMS16\_CRACKING\_PERCENT\_CRCP field in the in the MON\_DIS\_CRCP\_INDEX table.

*Punchout\_Area* = summation of fields PUNCHOUTS\_A\_L, PUNCHOUTS\_A\_M, and PUNCHOUTS\_A\_H from the MON\_DIS\_CRCP\_REV table.

*Patching\_Area* = summation of the fields PATCH\_FLEX\_A\_L, PATCH\_FLEX\_A\_M, PATCH\_FLEX\_A\_H, PATCH\_RIGID\_A\_L, PATCH\_RIGID\_A\_M, and PATCH\_RIGID\_A\_H from the MON\_DIS\_CRCP\_REV table.

*Longitudinal\_Crack\_Area* = product of the summation of the LONG\_CRACK\_L\_L, LONG\_CRACK\_L\_M, and LONG\_CRACK\_L\_H fields from the MON\_DIS\_CRCP\_REV table and 0.3048.

*LTPP\_Section\_Length* = length of the LTPP test section, which comes from multiple tables in the LTPP database.

*Survey\_Width* = width of the distress survey from the SURVEY\_WIDTH field in the MON\_DIS\_CRCP\_REV table.

MON\_DIS\_JPCC\_CRACK\_INDEX—contains reinterpreted cracking data for JPCC pavements. Field names indicate the distress standard as MEPDG or HPMS16.

The MEPDG percent cracking field in the MON\_DIS\_JPCC\_CRACK\_INDEX table is computed using the equation shown in figure 18:

$$TransverseCracking_{\%SlabsCracked} = \left( \frac{\sum Transverse\_Crack\_Number_{Low,Medium,High}}{SectionLength/JointSpacing} \right) \times 100$$

**Figure 18. Equation. Computation used to populate the MEPDG\_CRACKING\_PERCENT\_JPCC field in the MON\_DIS\_JPCC\_CRACK\_INDEX table.**

Where:

*TransvereCracking<sub>%SlabsCracked</sub>* = number of cracked slabs containing transverse cracks expressed as a percentage.

*Transverse\_Crack\_Number<sub>Low,Medium,High</sub>* = total number of transverse cracks from the TRANS\_CRACK\_NO\_L, TRANS\_CRACK\_NO\_M, and TRANS\_CRACK\_NO\_H fields in the MON\_DIS\_JPCC\_REV table.

*SectionLength* = length of the LTPP test section, which comes from multiple tables in the LTPP database.

*JointSpacing* = average joint spacing on the test section, which comes from multiple tables in the LTPP database.

The HPMS16 percent cracking field in the MON\_DIS\_JPCC\_CRACK\_INDEX table is computed using the equation shown in figure 19:

$$TransverCracking_{HPMS\ 16\%} = \frac{Cracked\_Slabs\_Half * 100}{Slab\_Count}$$

**Figure 19. Equation. Computation of HPMS16\_CRACKING\_PERCENT\_JPCC field in the MON\_DIS\_JPCC\_CRACK\_INDEX table.**

Where:

*TransverseCracking<sub>HPMS 16%</sub>* = HPMS16\_CRACKING\_PERCENT\_JPCC field in the MON\_DIS\_JPCC\_CRACK\_INDEX table.

*Cracked\_Salbs\_Half* = CRACKED\_SLABS\_HALF field in the MON\_DIS\_JPCC\_REV table.

*Slab\_Count* = SLAB\_COUNT field in the MON\_DIS\_JPCC\_REV table. Note that LTPP counts full width PCC patches as new slabs for the SLAB\_COUNT computation.

In the 2020 LTPP public data release, the field labeled MON\_DIS\_JPCC\_CRACK\_INDEX.MEPDG\_CRAKING\_PERCENTAGE\_JPCC in the 2016 and 2017 public data releases was added back to the database labeled as ME\_PERCENT\_CRACKED\_SLABS. Computations of these fields in the 2016 and 2017 LTPP public data releases were not calculated in accordance with the pavement performance models used in the AASHTOWare Pavement ME Design software. The ME\_PERCENT\_CRACKED\_SLABS field was replaced in the 2019 public data release with the MON\_DIS\_JPCC\_CRACK\_INDEX.MEPDG\_CRACKING\_PERCENT\_JPCC field based on the equation shown in figure 18.

The MEPDG\_CRACKING\_PERCENT\_JPCC field computed parameter is based on actual cracked slabs in a test section and the number of slabs with transverse cracks was added so that if an agency had used the previous mislabeled MEPDG percentage cracking index from the 2016 and 2017 public data releases, they can continue to use the index in the future. The ME\_PERCENT\_CRACKED\_SLABS is computed as shown in figure 20:

$$ME\_PERCENT\_CRACKED\_SLABS = \frac{Cracked\_Slabs\_Total * 100}{Slab\_Count}$$

**Figure 20. Equation. Computation of percent slab cracking included in the 2016 and 2017 LTPP data releases as MEPDG\_CRACKING\_PERCENTAGE\_JPCC now named ME\_PERCENT\_CRACKED\_SLABS.**

Where:

ME\_PERCENT\_CRACKED\_SLABS = percentage of cracked slabs based on the actual number of slabs in the test section divided by slabs with transverse cracks that intercepted the outside lane edge and are at least 1 ft long.

CRACKED\_SLABS\_TOTAL = number of slabs in the test section with at least one transverse crack intersecting the outside lane joint contained in the MON\_DIS\_JPCC\_REV table.

SLAB\_COUNT = number of PCC slabs counted in the test section following LTPP rules on partial slabs at the beginning and end of test sections and addition of new slabs due to maintenance events.

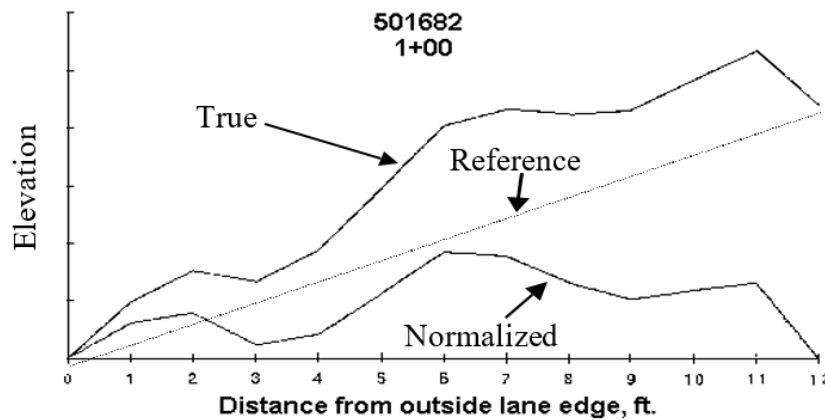
## TRANSVERSE PROFILE DISTORTION

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 LTPP 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 were 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 nonuniform spacing between profile points. The manual technique uses uniform 0.305-m (1-ft) spacing between profile points. As illustrated in figure 21, the transverse elevations are adjusted to a reference line through the endpoints so that the elevations of the endpoints are 0.



Source: FHWA.

**Figure 21. Illustration. How transverse profile measurements are normalized to lane edges.**

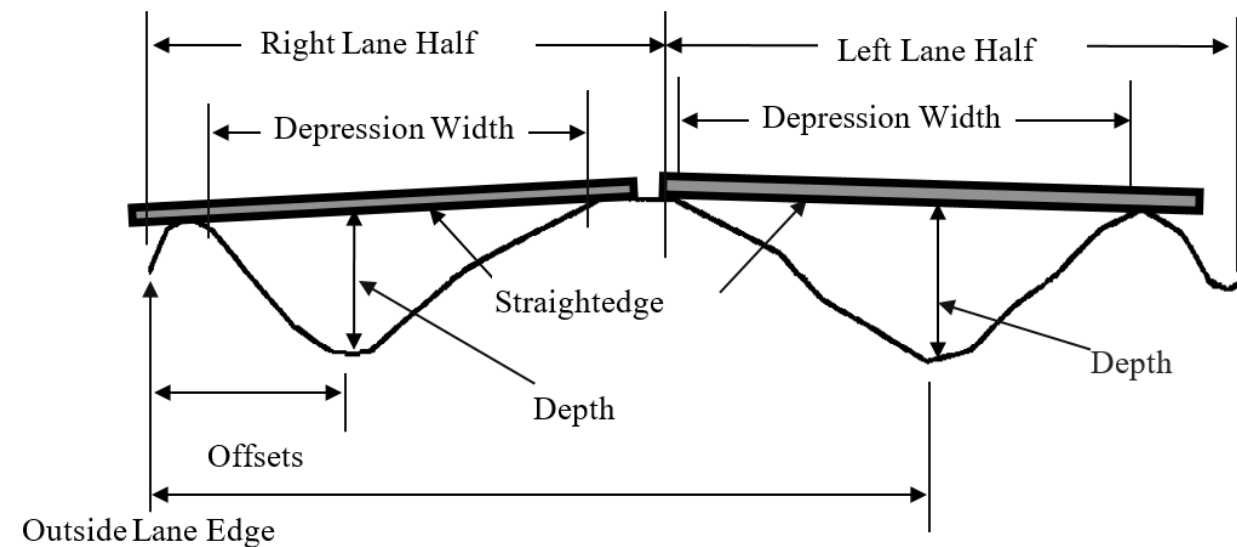
In the January 2005 SDR (data release 19), the elevation of the last point on the cross-slope measurement was added to the database for manual transverse profile measurements using Dipstick. This allows the transverse profiles to be “un-normalized” by using an interpolation calculation procedure based on reestablishing the slope of the reference line and adjusting all elevations relative to this reference. While the 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 to see 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. Results of these computations are stored in the MON\_T\_PROF\_INDEX\_POINT and MON\_T\_PROF\_INDEX\_SECTION tables. 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. Although 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.

The 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 22, 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.

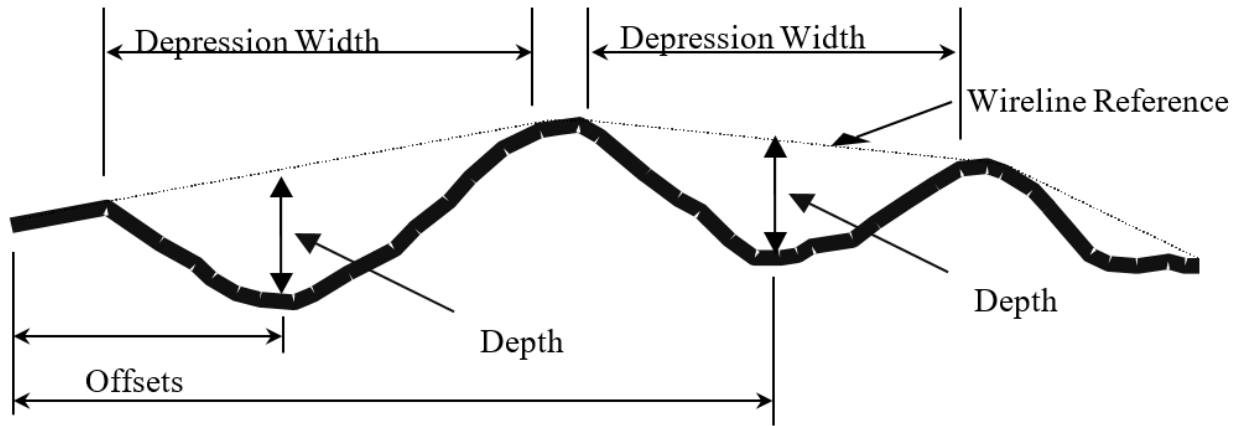
For the January 2014 SDR (data release 28), an updated version of the algorithm used to compute transverse pavement profile parameters was developed to replace the older program, which was no longer compatible with current computer operating systems. The new program, based on a 64-bit operating system, resulted in some minor differences from previous results attributable 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.



Source: FHWA.

**Figure 22. Illustration. 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 23.



Source: FHWA.

**Figure 23. Illustration. LTPP transverse pavement distortion indices based on lane-width wireline reference.**

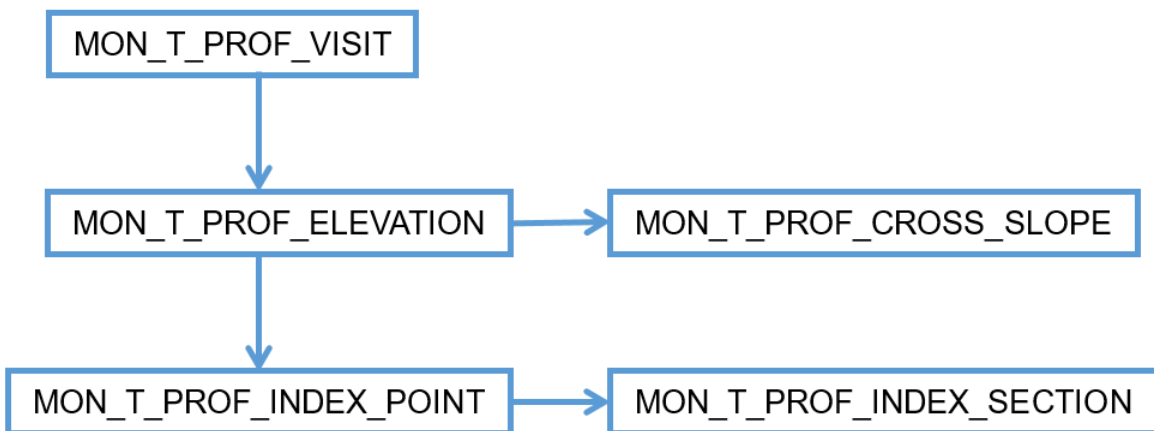
The reason these indices are referred to as transverse profile distortion indices is because the location of the maximum depth is not constrained to the wheel path. The algorithm was constrained only to each half of the lane.

***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 photographic interpretation of transverse profile measurements on PCC pavements, though data are still being collected manually.

**MON\_T\_PROF Tables**

The relational structure of MON\_T\_PROF tables is shown in figure 24.



Source: FHWA.

**Figure 24. Schematic. Relational structure between MON\_T\_PROF tables.**

Names and descriptions of MON\_T\_PROF tables are as follows:

- MON\_T\_PROF\_VISIT—contains information on general characteristics of transverse profile measurement data, including date, measurement device, number of profiles measured, and measurement width. The MON\_T\_PROF\_VISIT table is the parent table for all other tables in the MON\_T\_PROF\_\* submodule. In 2019, the MON\_T\_PROF tables were assigned new key fields VISIT\_NO and RUN\_NO, which are defined in the MON\_T\_PROF\_VISIT table. VISIT\_NO is the primary key field to all the other MON\_T\_PROF tables, since it is a unique value assigned to each measurement cycle performed on a test section. The RUN\_NO field was added in case more than one set of measurements were taken during the same visit. The content of the DEVICE\_CODE field in the MON\_T\_PROF\_VISIT table indicates the type of measurement. A value of “P” indicates photographic measurement, “D” indicates manual Dipstick measurement, and “L” indicates laser-based measurement. The MON\_T\_PROF\_VISIT table replaces the MON\_T\_PROF\_MASTER table, which is no longer distributed.
- MON\_T\_PROF\_ELEVATION—contains edge-normalized transverse elevation data. In 2019, the MON\_T\_PROF\_ELEVATION table was reformatted to contain a single elevation data point at a specific station and transverse offset as a function of the VISIT\_NO and RUN\_NO fields defined in the MON\_T\_PROF\_VISIT table. The reformatting was done to accommodate storage of the more than 2,000 possible elevation points from laser-based measurements. The MON\_T\_PROF\_ELEVATION table replaces the MON\_T\_PROF\_PROFILE table, which is no longer distributed.
- MON\_T\_PROF\_CROSS\_SLOPE—contains elevation of the last data point, relative to the begin point, of manual transverse profile measurements made using Dipstick. This allows 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. The MON\_T\_PROF\_CROSS\_SLOPE table was first released in January 2005.
- MON\_T\_PROF\_INDEX\_POINT—contains transverse profile distortion indices for each longitudinal measurement location. In 2019, the VISIT\_NO and RUN\_NO key fields were added to the MON\_T\_PROF\_INDEX\_POINT table to link it back to the data storage structure of the underlying MON\_T\_PROF data tables.
- MON\_T\_PROF\_INDEX\_SECTION—contains summary statistics for transverse profile distortion statistics stored in the MON\_T\_PROF\_INDEX\_POINT table. The MON\_T\_PROF\_INDEX\_SECTION table now contains the VISIT\_NO and RUN\_NO key fields.

### **Summary Rutting Measurements Table for Special Cases**

There is also a summary table of rut depths. The MON\_RUT\_DEPTH\_POINT table contains rut-depth information collected manually in the field using a 1.2-m (4-ft) straightedge. These measurements were primarily limited to SPS-3 test sections; however, these measurements were also made on other test sections. 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 than 1.2 m (4 ft).

## **DISTRESS LINK TABLE**

The MON\_DIS\_LINK table contains information necessary to link data in various distress tables.

MON\_DIS\_LINK was added to the database starting with the January 2008 SDR release (data release 22). The MON\_DIS\_LINK table uses the SURVEY\_ID field to provide an index to link distress records in various distress tables that are considered part of the same survey. The index 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 taken on a different day than the distress survey, the value in the SURVEY\_ID field can be used to link these two records.

For a unique test section specified by the combination of the STATE\_CODE and SHRP\_ID fields, names of tables containing data for that survey are linked by the same SURVEY\_ID. If a portion of a distress survey was not performed, there will be no link in the MON\_DIS\_LINK table to other parts of a survey. For example, if a fault measurement survey was not performed during a manual distress survey on a JPCC pavement, there will be no link to 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\_VISIT, 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\_VISIT, MON\_JPCC\_FAULT, and MON\_DROP\_SEP.
- Manual distress survey on CRCP pavement—MON\_DIS\_CRCP\_REV, MON\_T\_PROF\_VISIT, and MON\_DROP\_SEP.
- Photographic surveys on JPCC pavements—MON\_DIS\_PADIAS\_JPCC or MON\_DIS\_PADIAS42\_JPCC and MON\_T\_PROF\_VISIT.

## **LONGITUDINAL PROFILE AND TEXTURE**

The majority of longitudinal profile measurements taken on LTPP test sections use inertial profilers. Throughout the history of the program, four different inertial profilers have been used.

The first inertial profiler was used from June 1989 through April 1997. Transition to the second profiler began in July 1996, with implementation dates for the new model varying by LTPP regional contractor (LTPP had four regional data-collection contractors at the time). The LTPP

program transitioned to the third profiler in July 2002. In 2013, the program transitioned to the fourth profiler. Each of these profilers used different types of instrumentation technology.

From a data availability perspective, only 0.305-m (1-ft) moving average profile data are available for measurements taken with with the first profiler. Raw 25-mm (1-inch) interval profile data 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 manually taken using Dipstick, which measures the surface elevation at 0.305-m (1-ft) intervals.

Data from these devices are stored in the MON\_HSS series of tables, which replaces the previous MON\_PROFILE tables. Unlike most monitoring tables, MON\_HSS tables are primarily driven off a single key field—VISIT\_NO. The VISIT\_NO field typically contains the STATE\_CODE and SHRP\_ID of the test section, plus two characters to uniquely identify a set of runs along the test section. While the above naming convention allows for easy identification of the test section, it should be avoided for identification purposes in data manipulation.

The VISIT\_NO field is supplemented with the following two simple keys fields as necessary to maintain uniqueness:

- RUN\_NUMBER—represents a single pass of the survey equipment along a given test section. The RUN\_NUMBER value is only unique to a given VISIT\_NO.
- STATION—represents the location of the individual measurements along a test section. Standard test section stationing is used, with “0” representing the test section start.

Names and descriptions of MON\_HSS tables are as follows:

### **MON\_HSS Profile Tables**

- MON\_HSS\_VISIT\_NO—contains information related to each high-speed survey site visit. The MON\_HSS\_VISIT\_NO table links the other tables in the MON\_HSS group to STATE\_CODE and SHRP\_ID based on VISIT\_NO. It also contains 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—contains identification of survey runs uploaded to the database during each visit. While five repeat runs are the LTPP standard, data for some runs having greater or less than five repeat datasets are contained in the database. Only one measurement is contained in the database when the longitudinal profile was manually measured using Dipstick. The MON\_HSS\_RUN\_NO table includes basic identifying information, such as date and time of the run, as well as latitude and longitude of the test section start as measured by the high-speed profiling device. The MON\_HSS\_RUN\_NO table also contains run-specific comments and information specific to the individual pass, such as surface and air temperatures.

- **MON\_HSS\_UNIT\_ID**—contains high-speed survey unit identification information, such as manufacturer, model number, and serial number.
- **MON\_HSS\_PROFILE\_ELEVATION\_25**—contains high-speed survey profile elevation data at 25- or 25.4-mm (0.98- or 1-inch) intervals. This is the highest resolution of profile data available in the LTPP database. The **MON\_HSS\_PROFILE\_ELEVATION\_25** table is populated with data collected prior to the introduction of the fourth-generation LTPP high-speed profiler.
- **MON\_HSS\_PROFILE\_ELEVATION\_150**—for inertial profilers, the **MON\_HSS\_PROFILE\_ELEVATION\_150** table contains the 0.305- or 0.300-m (1- or 0.98-ft) moving average of profile measurements, stored at 0.153- or 0.150-m (0.5- or 0.49-ft) intervals, depending on the measurement device. Using Dipstick, 0.305-m (1-ft) interval measurements are collected. These data are not available in prepopulated Microsoft Access tables due to the number of tables required. These data are extracted on demand from InfoPave in Microsoft SQL format.
- **MON\_HSS\_PROFILE\_SECTION**—contains information on computed profile and ride parameters. Some computed parameters include the International Roughness Index (IRI), the Root Mean Square Vertical Acceleration (RMSVA), and an approximation of the AASHTO Road Test slope variance parameter. These data are calculated for each measurement pass on a test section.

### **MON\_HSS Texture Tables**

In addition to longitudinal profile, the fourth-generation high-speed profiler also collects surface texture data. These data are collected at the same time as profile data; therefore, the test section and run identifying information is the same and contained in **MON\_HSS\_VISIT\_NO**, **MON\_HSS\_RUN\_NO**, and **MON\_HSS\_UNIT\_ID** tables.

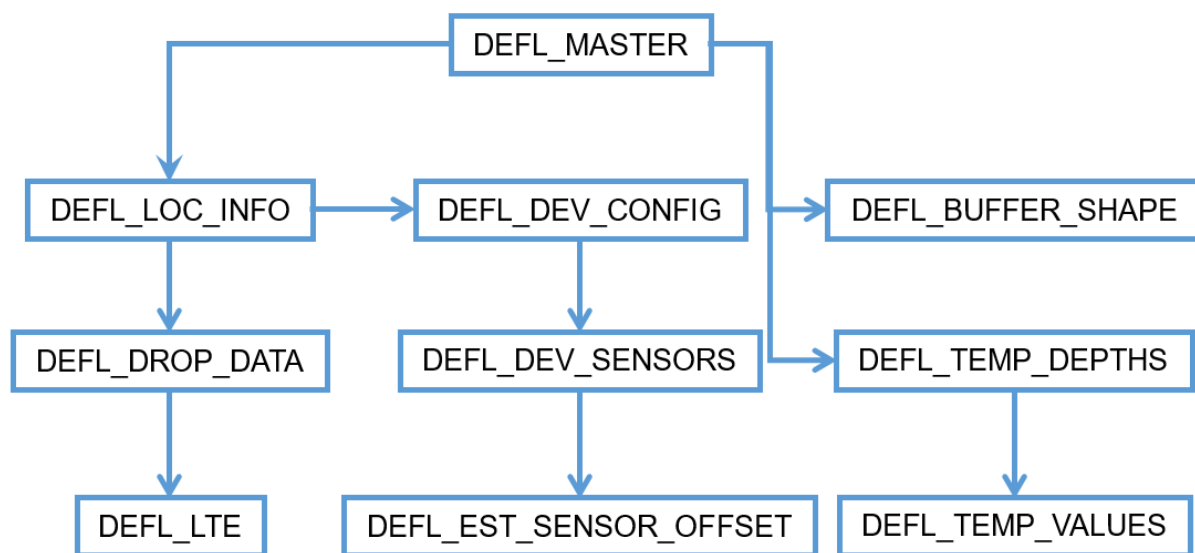
Names and descriptions of **MON\_HSS\_TEXTURE** tables are as follows:

- **MON\_HSS\_TEXTURE\_SEGMENT**—contains surface texture data, such as mean segment depth and skew, for both wheel paths. The fourth-generation high-speed profilers collect data at a much higher frequency (i.e., approximately 0.5 mm (0.02 inches)), and the **MON\_HSS\_TEXTURE\_SEGMENT** table is an aggregation of those data to 100-mm (3.94-inch) segments. These data are only collected by the fourth-generation high-speed profiler units, and is therefore only available starting in 2014. These data are not available in prepopulated Microsoft Access tables due to the number of tables required. These data are extracted on demand from InfoPave in Microsoft SQL format.
- **MON\_HSS\_TEXTURE\_SECTION**—contains texture information averaged for the entire test section for each wheel path.

## 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 are 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 25. The first three letters of the table names shown in figure 25, which are 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.



Source: FHWA.

**Figure 25. 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 option under the Data tab in InfoPave.

### MON\_DEFL Tables

Names and descriptions of MON\_DEFL tables are as follows:

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



- **MON\_DEFL\_LOC\_INFO**—contains information specific to each point at which testing was conducted. Contents of the MON\_DEFL\_LOC\_INFO table 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 (e.g., basin or load transfer), the general location of the test (i.e., lane edge, wheel path, lane center, corner, or joint), and the type of surface material being tested. The CONFIGURATION\_NO field is used to link to the MON\_DEFL\_DEV\_CONFIG and MON\_DEFL\_DEV\_SENSOR tables, which contain data on sensor spacing and calibration.
- **MON\_DEFL\_DROP\_DATA**—contains peak deflection and applied load measurements for every drop conducted at each test point on a test section. The MON\_DEFL\_DROP\_DATA table is the second largest in the database. Each record represents one test drop. The NON\_DECREASING\_DEFL field is populated with a “1” if a nondecreasing deflection pattern is detected for a basin test. These data are not available in prepopulated Microsoft Access tables due to the number of tables required. These data are 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. Contents of the MON\_DEFL\_DEV\_CONFIG table include the number of deflection sensors used, load plate radius, and load cell and temperature sensor calibration factors. The MON\_DEFL\_DEV\_CONFIG table is linked to the MON\_DEFL\_LOC\_INFO table through the CONFIGURATION\_NO field.
- **MON\_DEFL\_DEV\_SENSORS**—contains deflection sensor offset, calibration factors, and serial numbers. The MON\_DEFL\_DEV\_SENSORS table is linked to the MON\_DEFL\_LOC\_INFO table 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**—contains estimates of deflection sensor offset in cases where analysis of the deflection basin suggests that the reported location in the MON\_DEFL\_DEV\_SENSOR table is incorrect and corroborating evidence of sensor misplacement does not exist. Values in the MON\_DEFL\_EST\_SENSOR\_OFFSET table are determined based on engineering analysis of the deflection data.
- **MON\_DEFL\_TEMP\_DEPTHS**—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—contains temperatures measured at the depths recorded in the MON\_DEFL\_TEMP\_DEPTHS table.
- MON\_DEFL\_BUFFER\_SHAPE—contains information on the different styles of buffers used on the LTPP FWDs. Buffer use is aggregated by time period.
- MON\_DEFL\_LTE—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 equation shown in figure 26:

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

**Figure 26. Equation. Load transfer efficiency.**

Where:

$LTE$  = load transfer efficiency, percent.

$d_u$  = peak measured deflection on the unloaded side of the joint or crack.

$d_l$  = peak measured deflection on the loaded side of the joint or crack.

Restrictions on LTE computations and reported values include:

- The LANE\_NO field 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 0.
- The LTE value is less than 130 percent.

The MON\_DEFL\_LTE table does not contain a RECORD\_STATUS field since the restrictions on computations provide effective quality control of the values recorded.

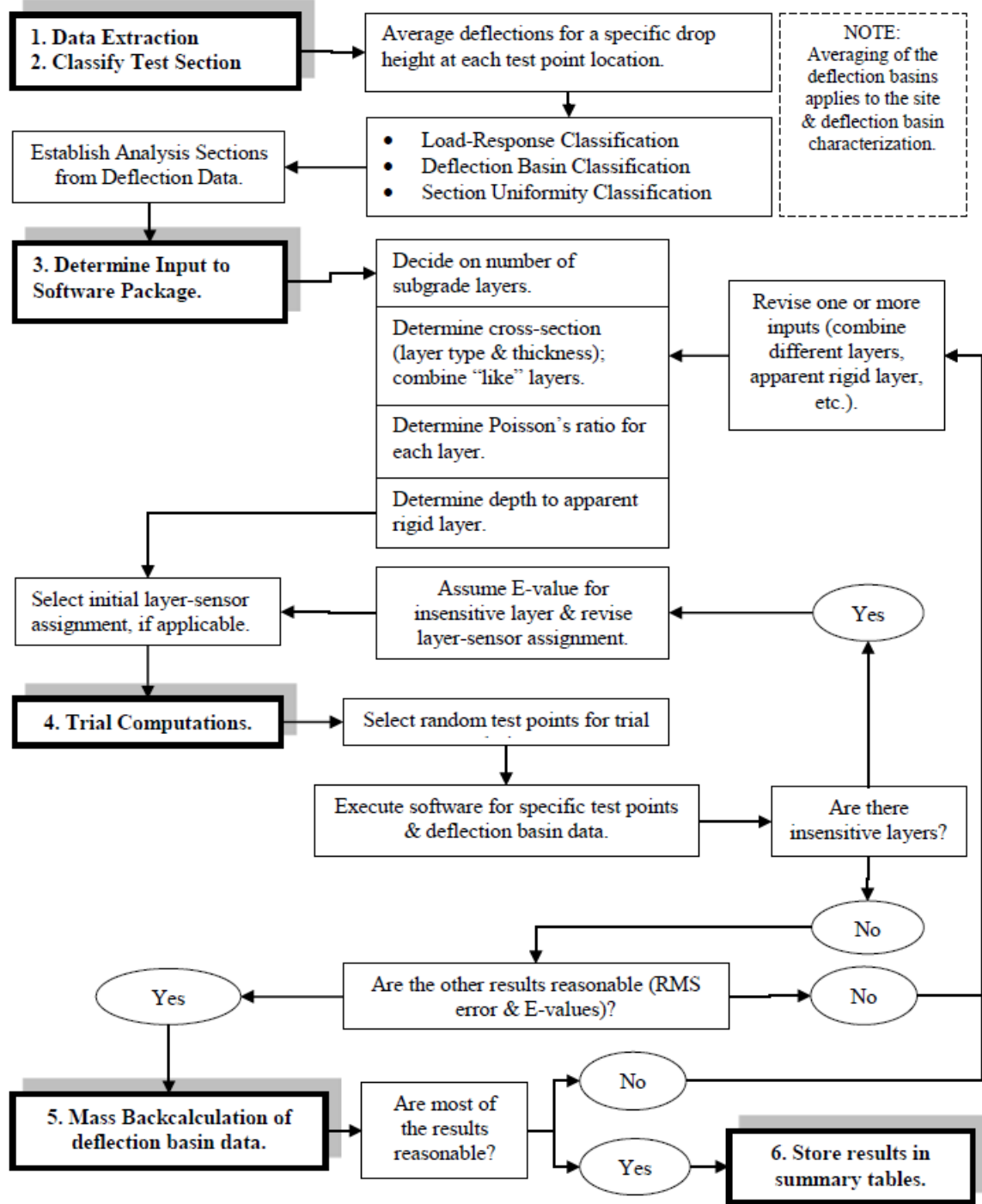
## **BACKCALCULATION**

The Backcalculation tables contain information related to the backcalculation of material properties of layers in the pavement structure for each LTPP test section based on deflection information available in the MON\_DEFL tables. These calculations used deflection data contained in the January 2013 SDR (data release 27). The processes and procedures used for the backcalculation computed parameter are documented in the LTPP report *Long-Term Pavement Performance Program Determination of In-Place Elastic Layer Modulus: Backcalculation Methodology and Procedures*. (Von Quintus, Rao, and Irwin 2015)

## Backcalculation Process

The process used to perform the backcalculation is shown in Figure 27. The three backcalculation programs that were used in step 5 of the process are as follows:

- EverCalc was the primary backcalculation program used for the analyses and was used for all LTPP data and all pavement types in LTPP. (Von Quintus, Rao, and Irwin 2015) The pre- and post-processing utility tools for the EverCalc analyses were fully automated. The automation process included generating 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 test sections that did not yield acceptable results with EverCalc. (Von Quintus, Rao, and Irwin 2015) 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 test sections with a PCC surface to obtain the modulus of subgrade reaction ( $k$ -value) and the elastic moduli of PCC and base layers.



Source: FHWA.

**Figure 27. Flowchart. Summary of backcalculation process. (Von Quintus, Rao, and Irwin 2015)**

References to publications documenting these analytical procedures can be found in the LTPP Library at <http://www.InfoPave.fhwa.dot.gov/reports/library>. (InfoPave 2020a)

## Backcalculation Tables

There are three basic types of tables in the Backcalculation dataset: identification tables, backcalculation modulus tables, and best fit modulus tables.

Identification tables primarily provide information necessary to link the data in the Backcalculation tables to the MON\_DEFL tables. To make the Backcalculation tables easier to use, the key fields used in the MON\_DEFL tables were generally replaced with keys specific to the Backcalculation tables. The two primary Backcalculation identification tables, BAKCAL\_PASS and BAKCAL\_BASIN, establish these keys.

The key field FWD\_PASS represents the level of summarization used for test section level results. It replaces the TEST\_DATE, LANE\_NO, and DROP\_HEIGHT fields in the MON\_DEFL tables. The FWD\_PASS field also distinguishes multiple runs of the same LANE\_NO on the same day, a feature not present in the current set of MON\_DEFL keys. FWD\_PASS must be combined with the STATE\_CODE and SHRP\_ID fields 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. BASIN\_NO must be combined with the STATE\_CODE, SHRP\_ID, and FWD\_PASS fields to be unique.

When the FWD\_PASS and BASIN\_NO keys are combined with STATE\_CODE and SHRP\_ID, an individual deflection basin can be identified with four fields in Backcalculation tables instead of eight key fields in the MON\_DEFL tables.

The names and descriptions of the Backcalculation tables used for identification are as follows:

- BAKCAL\_PASS—includes information specific to the highest level of aggregation used by the backcalculation team. The BAKCAL\_PASS table retains the STATE\_CODE and SHRP\_ID identifiers and uses a single key field, FWD\_PASS, to replace the TEST\_DATE, LANE\_NO, and DROP\_HEIGHT fields used in MON\_DEFL tables. Additionally, the BAKCAL\_PASS table identifies the backcalculation structure used in the process with the BC\_STRUCTURE\_NO field.
- BAKCAL\_BASIN—further defines items specific to each individual drop in MON\_DEFL using the same concepts as the BAKCAL\_PASS table. BASIN\_NO is used to replace the TEST\_TIME, POINT\_LOC, and DROP\_NO fields used in the MON\_DEFL tables. The BAKCAL\_BASIN table also contains basin-specific information, such as drop load, temperature information, and a basic basin type identifier.
- BAKCAL\_STRUCTURE\_LAYERS—contains information on the type and thickness of the layer structure used for backcalculation purposes. 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. Layer numbering is also different than 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**—contains information on the type and thickness of the layer structure used for best fit backcalculation purposes. The type codes are the same as those used for the **BAKCAL\_STRUCTURE\_LAYERS** table. 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**—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, the **BAKCAL\_LAYER\_LINK** table identifies whether the structure of the test section has been significantly changed since the backcalculation effort took place. For this purpose, a difference of 12.7 mm (0.5 inches) was chosen to represent a significant thickness change. Any change is identified in the **SIGNIFICANT\_STRUCTURE\_CHANGE** field, which identifies the nature and extent of the difference.

Backcalculation modulus tables are presented at the basin and test section level and are divided into a master and layer table for each. Test-section-level tables are aggregated to the **FWD\_PASS** level.

The names and descriptions of Backcalculation tables used for backcalculation modulus are as follows:

- **BAKCAL\_MODULUS\_BASIN\_LAYER**—contains backcalculated modulus values for each measured deflection basin.
- **BAKCAL\_MODULUS\_BASIN\_MASTER**—contains backcalculation fit and quality measures for each deflection basin. **ERROR\_STATUS** is the major indicator of quality in the **BAKCAL\_MODULUS\_BASIN\_MASTER** table, and is based on the root mean square error (RMSE) of the fit, as well as whether the modulus is considered acceptable for the designated material type.
- **BAKCAL\_MODULUS\_SECTION\_LAYER**—contains backcalculated modulus values averaged for each **FWD\_PASS**. Only data that have an **ERROR\_STATUS = 1** or **2** in the **BASIN** table are aggregated in the **SECTION** table. This means that occasionally there is no test-section-level entry for an **FWD\_PASS**.
- **BAKCAL\_MODULUS\_SECTION\_MASTER**—contains information on the number of basins aggregated, average RMSE, depth to rigid layer (if it exists), and the backcalculation program used to provide the results.

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

The names and descriptions of backcalculation tables used for best fit modulus are as follows:

- **BAKCAL\_BEST\_FIT\_BASIN\_LAYER**—contains best fit backcalculation modulus values for each deflection basin.
- **BAKCAL\_BEST\_FIT\_BASIN\_MASTER**—contains the primary quality indicator, **ERROR\_STATUS**, the same as the corresponding **BAKCAL\_MODULUS\_BASIN\_MASTER** table. The **BAKCAL\_BEST\_FIT\_BASIN\_MASTER** table also contains a composite modulus and *k*-value for the test section, as well as information on the beta factor assigned to the test section, which is used to determine the modulus split for the layer structure chosen.
- **BAKCAL\_BEST\_FIT\_SECTION\_LAYER**—contains best fit backcalculated modulus values for each **FWD\_PASS**. Only data that have an **ERROR\_STATUS** = 1 or 2 in the **BASIN** table are aggregated in the **SECTION** table. This means that occasionally there is no test-section-level entry for an **FWD\_PASS**.
- **BAKCAL\_BEST\_FIT\_SECTION\_MASTER**—contains test section averaged values of the information provided in the corresponding **BAKCAL\_BEST\_FIT\_BASIN\_MASTER** table. The **BAKCAL\_BEST\_FIT\_SECTION\_MASTER** table also contains a code identifying the subgrade layer type assigned to the test section.

In addition to this current set of backcalculation data, there was a prior backcalculation analysis performed with 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**. **MON\_DEFL\_FLX** tables contained the inputs and results of layered elastic analysis conducted on both flexible and rigid pavement structures. **MON\_DEFL\_RGD** tables contained the inputs and results of slab analysis based on plate theory that was conducted on PCC-surfaced pavement structures. These tables were last released in the January 2006 SDR (data release 20) and can be obtained from InfoPave.

## **FRICITION**

The Friction submodule includes only the **MON\_FRICITION** table. Because of the proprietary nature of these 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.

The **MON\_FRICITION** table contains results of friction tests on test sections where the State/Provincial highway agency was willing to provide the data.

## **DRAINAGE**

Tables in the Drainage module contain information on video inspection of subsurface pavement drainage outlet features and field permeability tests and calculations. The video inspections were performed under an FHWA LTPP contract independent of the permeability tests. The permeability tests and calculations were performed under National Cooperative Highway

Research Program (NCHRP) Project 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. (Hall and Corvetti 2007)

### **Drainage Outlet Video Inspections**

Subsurface video inspections of drainage outlet structures began in September 2001 on SPS-1, -2, and -6 projects. 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 SDR (data release 18). The following tables contain data and information collected during the video inspections:

- **MON\_DRAIN\_MASTER**—contains information on permanent features of the edge drain system and the location of lateral openings. Since data stored in the **MON\_DRAIN\_MASTER** 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 the **PROJECT\_STATION** and **NEAREST\_SECTION** fields, 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 test sections on SPS projects.
- **MON\_DRAIN\_CONDITION**—contains information regarding the condition of lateral openings and the area around lateral openings at the time of inspection.
- **MON\_DRAIN\_INSPECT**—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.

### **SPS-1 and -2 Field Permeability Measurements and Calculations**

Field permeability measurements and calculations contained in the **MON\_DRAIN\_PERM\_MEAS** table and the **MON\_DRAIN\_PERM\_CALC** table are from NCHRP Report 583, *Effects of Subsurface Drainage on Pavement Performance: Analysis of the SPS-1 and SPS-2 Field Sections*. (Hall and Corvetti 2007) These data are the result 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 subsurface drainage system structures are based on calculations made using the assumptions based on field measurements. NCHRP Report 583 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. (Hall and Corvetti 2007)



Names and descriptions of SPS-1 and -2 field permeability tables are as follows:

- **MON\_DRAIN\_PERM\_MEAS**—contains the measurement dataset used to estimate hydraulic conductivity in the **MON\_DRAIN\_PERM\_CALC** table.
- **MON\_DRAIN\_PERM\_CALC**—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 NCHRP Report 583. Values used in the computed hydraulic conductivity estimate are contained in the **MON\_DRAIN\_PERM\_CALC** table. The **MON\_DRAIN\_PERM\_CALC** table is linked to the **MON\_DRAIN\_PERM\_MEAS** table using the three key fields of **STATE\_CODE**, **SHRP\_ID**, and **POINT\_LOC**. Future repeat measurements are not anticipated.

## **DOWEL BAR ALIGNMENT**

The July 2018 public data release introduced dowel bar alignment measurements using an electronic dowel-scanning device. Measurements on LTPP test sections using the dowel-scanning device were primarily performed during 2016 on 121 JPCC test sections contained in the SPS-2 and GPS-3 experiments. The dowel-scanning device uses magnetic imaging techniques to measure the alignment of dowels at the transverse joints on JPCC pavements. Data contained in the dowel bar alignment tables include the interpreted primary alignment data for each dowel at each joint on a test section and computed parameters, including joint score and effective dowel diameter based on procedures presented in NCHRP Report 637, *Guidelines for Dowel Alignment in Concrete Pavements*. (Kazanovich, Hoegh, and Snyder 2009)

Names and descriptions of dowel bar alignment tables are as follows:

- **MON\_MIT\_VISIT**—serves as the master parent table in the **MON\_MIT\_\*** table data storage configuration, since it defines the general parameters of when dowel scanning measurements were taken, the joint locations where measurements were taken, and the general inputs used in analysis of dowel bar joint alignment results. A key field in the **MON\_MIT\_VISIT** table that links all the other **MON\_MIT** tables to each other is **JOINT\_NO**. The combination of the **STATE\_CODE**, **SHRP\_ID**, and **JOINT\_NO** fields uniquely defines each measurement location on a test section.
- **MON\_MIT\_DOWEL**—contains individual alignment information from the dowel scanning device for each dowel bar at a joint. While the combination of the **STATE\_CODE**, **SHRP\_ID**, and **JOINT\_NO** fields uniquely defines each measurement location on a test section, in the **MON\_MIT\_DOWEL** table the **BAR\_NO** field represents an index for each dowel bar located at the joint. The **MON\_MIT\_DOWEL** table also contains the computed **DOWEL\_SCORE** parameter, based on the dowel alignment parameters contained herein.
- **MON\_MIT\_JOINT**—contains the joint score and effective dowel diameter computed parameters based on the **DOWEL\_SCORE** and distortion statistics for each dowel bar at a transverse PCC joint.

Since the alignment of dowel bars is based on a joint-by-joint basis, no statistics based on JOINT\_SCORE are provided for a test section.

## 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. A total of 63 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 test sections in the SMP were made using the following devices:

- Time-domain reflectometry (TDR) to measure subsurface moisture changes.
- Thermistor probes to measure subsurface temperature changes.
- Electrical resistivity to measure frost/thaw depth.
- Piezometer to measure groundwater table determination.
- Air temperature probes to measure ambient temperature.
- Tipping-bucket rain gauge to measure precipitation.

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 tables.

At the inception of the SMP program, subsurface TDR 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—in some cases sub-daily—to capture changes caused by rainfall. The only way to identify 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 raw data used to calculate the computed parameters are included in the database.

### AMBIENT TEMPERATURE AND PRECIPITATION

Ambient temperature and precipitation data collected from the onsite weather stations are stored in the SMP\_ATEMP\_RAIN tables.

Names and descriptions of SMP\_ATEMP\_RAIN tables are as follows:

- SMP\_ATEMP\_RAIN\_HOUR—contains the average hourly temperature and the total hourly precipitation. Temperature or precipitation data in the SMP\_ATEMP\_RAIN\_HOUR 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.

- SMP\_ATEMP\_RAIN\_DAY—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 hr of data exist for a day.

## **SUBSURFACE TEMPERATURE**

Subsurface temperatures are stored in the SMP\_MRCTEMP\_\* tables. (MRC is the manufacturer of the type of thermistor used by the LTPP program.)

Names and descriptions of subsurface temperature tables are as follows:

- SMP\_MRCTEMP\_AUTO\_HOUR—contains the vast majority of subsurface temperature data. The SMP\_MRCTEMP\_AUTO\_HOUR table includes average hourly temperatures at a series of depths; however, it must be linked to the SMP\_MRCTEMP\_DEPTHS table using the THERM\_NO field (and the STATE\_CODE and SHRP\_ID fields for the test section) to determine the depth at which the temperature was recorded.
- SMP\_MRCTEMP\_MAN—contains the remainder of the subsurface temperature data. The format of the SMP\_MRCTEMP\_MAN table is similar to the SMP\_MRCTEMP\_AUTO\_HOUR table; however, it contains manual temperature measurements taken when the automatic temperature monitoring equipment was out of service. The SMP\_MRCTEMP\_MAN table must be linked to the SMP\_MRCTEMP\_DEPTHS table to determine the depth at which the temperature was measured.
- SMP\_MRCTEMP\_AUTO\_DAY\_STATS—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 averages stored in the SMP\_MRCTEMP\_AUTO\_HOUR table when recomputation of daily statistics is needed for adjustments. The SMP\_MRCTEMP\_AUTO\_DAY\_STATS table must be linked to the SMP\_MRCTEMP\_DEPTHS table to determine the depth at which the temperature was measured.
- SMP\_MRCTEMP\_DEPTHS—contains the depths at which each temperature probe at an SMP test section was installed and the date of installation. The primary use of the SMP\_MRCTEMP\_DEPTHS 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, the STATE\_CODE, SHRP\_ID, and THERM\_NO fields do not resolve to a unique depth because the thermistors were reinstalled at slightly different depths at some point after initial installation. In these cases, the link must be further refined using the INSTALL\_DATE field.

## SUBSURFACE MOISTURE CONTENT

The LTPP SMP uses TDR to measure subsurface moisture content. A description of the process is located in chapter 2 of the *LTPP Seasonal Monitoring Program: Instrumentation Installation and Data Collection Guidelines*. (Rada et al. 1995)

Names and descriptions of subsurface moisture tables are as follows:

- **SMP\_TDR\_AUTO\_MOISTURE**—contains the volumetric and gravimetric moisture contents calculated using TDR (the dry densities used to convert volumetric to gravimetric moisture content are in the **SMP\_TDR\_MOISTURE\_SUPPORT** table). The depths at which these moisture contents were calculated can be determined by linking to the **SMP\_TDR\_DEPTHS\_LENGTHS** table using the **STATE\_CODE**, **SHRP\_ID**, and **TDR\_NO** fields. Further information on the calculation of these computed parameters can be found in Publication No. FHWA-RD-99-201, *An Input for Moisture Calculations—Dielectric Constant From Apparent Length*. (FHWA 1999)
- **SMP\_TDR\_AUTO\_MOISTURE\_TLE**—contains volumetric and gravimetric contents calculated using the transmission line equations (TLE) and micromechanics model to interpret TDR traces stored 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 Publication No. FHWA-HRT-08-035, *LTPP Computed Parameter: Moisture Content*. (Zollinger et al. 2008)
- **SMP\_TDR\_AUTO\_CALIBRATION\_TLE**—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 Publication No. FHWA-HRT-08-035 *LTPP Computed Parameter: Moisture*. (Zollinger et al. 2008)
- **SMP\_TDR\_AUTO**—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. The **SMP\_TDR\_AUTO** table is only useful to the analyst interested in reinterpreting raw TDR data.
- **SMP\_TDR\_MANUAL\_DIELECTRIC**—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, *Interpretation Manual TDR Traces*. (InfoPave 2020b)
- **SMP\_TDR\_AUTO\_DIELECTRIC**—contains the dielectric constant interpreted from the waveforms stored in the **SMP\_TDR\_AUTO** table and several intermediate calculations.

- **SMP\_TDR\_DEPTHS\_LENGTHS**—contains information on 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 the **SMP\_TDR\_DEPTHS\_LENGTHS** 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 initial installation. In these cases, the link must be further refined using the **INSTALL\_DATE** field. A secondary use of the **SMP\_TDR\_DEPTHS\_LENGTHS** table is to determine the length of the TDR probe, which is necessary when reinterpreting TDR data.
- **SMP\_TDR\_MOISTURE\_SUPPORT**—contains the dry density of soils sampled from areas adjacent to each TDR probe. 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**—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 (3.3 ft) below the pavement surface. In practice, the utility of the **SMP\_DRY\_DENSITY** table is limited because of low data availability.
- **SMP\_GRAV\_MOIST**—contains the results of laboratory gravimetric moisture testing of materials sampled adjacent to each TDR probe at the time of installation.

## **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 were collected in slightly different ways.

Names and descriptions of frost penetration tables are as follows:

- **SMP\_ERESIST\_MANUAL\_CONTACT**—contains manually collected voltage and current and the calculated resistance between adjacent electrodes on the probe. The **SMP\_ERESIST\_MANUAL\_CONTACT** calculated resistance is the contact resistance. The depths of the electrodes can be determined by linking the **ELECTRODE\_START** and **ELECTRODE\_END** fields to the **ELECTRODE\_NO** field in the **SMP\_ERESIST\_DEPTH** table.
- **SMP\_ERESIST\_MAN\_4POINT**—contains 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 the *LTPP Seasonal Monitoring Program: Instrumentation Installation and Data Collection Guidelines*. (Rada et al. 1995) The depths of the electrodes across which these measurements were made can be determined by linking the **EAMP\_START** and **EAMP\_END** fields to the **ELECTRODE\_NO** field in the **SMP\_ERESIST\_DEPTH** table.

- SMP\_ERESIST\_AUTO—contains automatically collected voltage data between adjacent electrodes on the probe using a multiplexer from the Cold Regions Research and Engineering Laboratory. The 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 the ELECTRODE\_START and ELECTRODE\_END fields to the ELECTRODE\_NO field in the SMP\_ERESIST\_DEPTHS table.
- SMP\_ERESIST\_AUTO\_ABF—contains automatically collected data from a data logger that uses an internal reference resistor, which allows the contact resistance to be computed between electrode pairs. Contact resistance is computed using the APPLIED\_VOLTAGE field contained in the SMP\_ERESIST\_ABF\_RES\_VA table and the VOLTAGE field contained in the SMP\_ERESIST\_AUTO\_ABF 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—contains applied voltage from the data logger used to compute the contact resistance between electrode pairs stored in the SMP\_ERESIST\_AUTO\_ABF table. Generally, the SMP\_ERESIST\_ABF\_RES\_VA table is only of use to the analyst who wishes to recalculate contact resistance data stored in the SMP\_ERESIST\_AUTO\_ABF table.
- SMP\_ERESIST\_DEPTHS—contains the depths at which each resistivity probe at an SMP test section was installed and the date of installation. The primary use of the SMP\_ERESIST\_DEPTHS 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 initial installation. In these cases, the link must be further refined using the INSTALL\_DATE field.
- SMP\_FREEZE\_STATE—contains the computed parameters necessary to determine whether pavement layers at a given depth are frozen or not. The SMP\_FREEZE\_STATE table includes resistivity and contact resistance extracted from the SMP\_ERESIST\_MAN\_4POINT and SMP\_ERESIST\_MAN\_CONTACT tables, the daily average temperature extracted from the SMP\_MRC\_TEMP\_AUTO\_DAY\_STATS table, and a determination of the freeze state of the soil based on these values.

For the January 2008 SDR (data release 22) and prior data releases, information on the calculation of these computed parameters can be found in Publication No. FHWA-RD-98-177, *Freeze/Thaw Monograph for LTPP*. (FHWA 1998) These data were updated in the January 2009 SDR (data release 23). Information on the updated calculations of these computed parameters can be found in Publication No. FHWA-HRT-08-057, *Long Term Pavement Performance Computed Parameter: Frost Penetration*. (Selezneva et al. 2008)

- **SMP\_FROST\_PENETRATION**—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**—added to the database as part of the update of the frost penetration estimates included in the January 2009 SDR (data release 23). The **SMP\_FROST\_PRESENCE** table contains the number of frozen layers on a test day from interpretation of the measurement on SMP test sections.

## **DEPTH TO WATER TABLE**

The LTPP SMP uses an observation well (the well is sometimes called an observation piezometer for reasons relating to the permitting process for drilling wells) to determine if the depth to the water table is within approximately 5 m (16.4 ft) of the pavement surface. In many cases, the observation well did not extend to the water table.

The **SMP\_WATERTAB\_DEPTH\_MAN** 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.

## **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.

Names and descriptions of surface elevation tables are as follows:

- **SMP\_ELEV\_AC\_DATA**—contains surface elevation measurements for asphalt-surfaced SMP test sections. At each longitudinal location, elevation measurements were typically taken at the pavement edge, outer wheel path, midlane, inner wheel path, and inner lane edge. To determine the actual transverse locations of these measurement points, the **SMP\_ELEV\_AC\_DATA** table must be linked to the **SMP\_ELEV\_AC\_OFFSET** table using the **STATE\_CODE**, **SHRP\_ID**, and **SMP\_DATE** fields.
- **SMP\_ELEV\_AC\_OFFSET**—contains the transverse offset of the elevation measurement locations stored in the **SMP\_ELEV\_AC\_DATA** table. In addition, the **SMP\_ELEV\_AC\_OFFSET** table also contains a text description of the equipment used to conduct the elevation survey.
- **SMP\_ELEV\_PCC\_DATA**—contains surface elevation measurements for PCC-surfaced SMP test sections. At each longitudinal location, elevation measurements were typically taken at the pavement edge, midlane, and inner lane edge. To determine the actual transverse locations of these measurement points, the **SMP\_ELEV\_PCC\_DATA** table must be linked to the **SMP\_ELEV\_PCC\_OFFSET** table using the **STATE\_CODE**, **SHRP\_ID**, and **SMP\_DATE** fields.



- SMP\_ELEV\_PCC\_OFFSET—contains the transverse offset of the elevation measurement locations stored in the SMP\_ELEV\_PCC\_DATA table. In addition, the SMP\_ELEV\_PCC\_OFFSET table also contains a text description of the equipment used to conduct the elevation survey.

## **JOINT OPENING AND FAULTING**

Joint opening and faulting measurements were typically collected concurrently with FWD testing at the same locations 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 faultmeter developed by the Georgia DOT (as done with standard LTPP distress surveys).

Names and descriptions of joint opening and faulting tables are as follows:

- SMP\_JOINT\_FAULT\_DATA—contains joint faulting measurements for PCC-surfaced SMP test sections. At each longitudinal location where FWD load-transfer testing was conducted, joint faulting was measured at the pavement edge, midlane, and inner lane edge. To determine the actual transverse locations of these measurement points, the SMP\_JOINT\_FAULT\_DATA table must be linked to the SMP\_JOINT\_FAULT\_OFFSET table using the STATE\_CODE, SHRP\_ID, and SMP\_DATE fields.
- SMP\_JOINT\_FAULT\_OFFSET—contains the transverse offset of the joint fault measurement locations stored in the SMP\_JOINT\_FAULT\_DATA table.
- SMP\_JOINT\_GAUGE\_DATA—contains joint opening measurements for PCC-surfaced SMP test sections. At each longitudinal location where FWD load-transfer testing was conducted, the joint opening was measured at the pavement edge, midlane, and inner lane edge. To determine the actual transverse locations of these measurement points, the SMP\_JOINT\_GAUGE\_DATA table must be linked to the SMP\_JOINT\_GAUGE\_OFFSET table using the STATE\_CODE, SHRP\_ID, and SMP\_DATE fields.
- SMP\_JOINT\_GAUGE\_OFFSET—contains the transverse offset of the joint opening measurement locations stored in the SMP\_JOINT\_GAUGE\_DATA table.

## **ADDITIONAL SMP TABLES**

When using SMP data, it is critical to know where measurements were taken. The SMP\_LAYOUT\_INFO table is the source for much of the location 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 in the Joint Opening and Faulting and Surface Elevation Data sections of this chapter.

The SMP\_COMMENTS table contains a wealth of information regarding irregularities in data collection. Equipment failure, unusual weather conditions (e.g., flooding of an adjacent river), and anything else out of the ordinary is recorded in the SMP\_COMMENTS table. These data are keyed to the SHRP\_ID, SMP\_DATE, and the table in which the affected data are 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 maintenance and rehabilitation projects. Tables with the SPS prefix but no experiment number contain data that are general to all SPS experiments. Tables with the SPS prefix and an experiment number contain data that are specific to an SPS experiment type; the exception is construction data from the SPS-10 experiment in the June 2015 SDR (data release 29) that are 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 module for most experiments. These tables are similar in purpose to the Inventory tables for GPS test sections. However, since SPS test sections enter the program at the time of their construction or rehabilitation, data within the SPS module reflect initial conditions as observed at that time. Information within the SPS module comes from construction data sheets filled out by State or Provincial highway agencies and LTPP regional contractors and from materials testing conducted by the State or Provincial highway agencies on samples collected during and immediately following construction or rehabilitation. Data entry is performed by LTPP regional offices.

### MAJOR 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.

The STATION field is used to denote the longitudinal position within each SPS-4 test section where transient dynamic response and Benkelman beam testing were conducted. The field's value 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. As such, the SPS4\_TRANSIENT\_MEASURE table contains no 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 test sections; however, the user must be careful to match converted units when necessary. The STATION\_NO field is used within SPS#\_LAYER\_THICKNESS tables to denote the longitudinal position relative to the start of the test section. The STATION field is used for the same purpose within the SPS4\_BENKELMAN\_MEASURE table, and the POINT\_DISTANCE field 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 use feet. Attention to units is required when relating data through these fields.

The LIFT\_NO field can be useful in linking compaction information in the SPS#\_PMA\_COMPACTON tables and the lift thicknesses found in the SPS#\_PMA\_PLACEMENT\_DATA table. 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\_COMPACTON tables.

The ROLLER\_CODE field is also part of the SPS#\_PMA\_COMPACTON tables. SPS#\_PMA\_COMPACTON tables contain information on the compaction of each AC lift in the construction of the test section. The BREAKDOWN\_ROLLER\_CODE, INTERMED\_ROLLER\_CODE, and FINAL\_ROLLER\_CODE fields within the SPS#\_PMA\_COMPACTON table can be related to the ROLLER\_CODE field within the SPS#\_PMA\_ROLLER table, which defines the characteristics of each of the rollers used during construction.

The PROJECT\_STATION\_NO field is found only in the SPS\_INTERSECTION tables and denotes the position of any intersections or ramps in relation to the start of the first test section of an SPS project. The units are in feet. The PROJECT\_STATION\_NO field 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.

## **GENERAL SPS TABLES**

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

Names and descriptions of general SPS tables are as follows:

- **SPS\_ID**—contains information on the location of SPS project sites in the SPS-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, which contains data on roadway information, elevation, and other features of the test section location. The SPS\_ID table used to contain the latitude and longitude coordinates of SPS project sites, but they were removed as of the January 2008 SDR (data release 22).
- **SPS\_GENERAL**—contains information on road geometry and shoulder and drainage features for new construction SPS test sections classified in the SPS-1, -2, -8, and -9 experiments.
- **SPS\_PROJECT\_STATIONS**—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 co-located at an 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 “0.” All other SECTION\_END and

SECTION\_START values represent travel distances in meters from the “0” 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 are assigned an ORDER\_NO of “1” and SECTION\_START equal to “0.” In this case, the DIRECTION\_OF\_TRAVEL field is needed to discern which side of the road the test sections are located.

- SPS\_INTERSECTIONS—contains project-level intersection information and data on the location of ramps, signals, and stop signs within project boundaries.
- SPS\_CUT\_FILL\_LOCATIONS—contains the order and location of the cuts and fills within each SPS test section. Starting and ending points are recorded.
- SPS\_GPS\_LINK—links the SPS maintenance projects and some SPS rehabilitation projects to co-located GPS test sections. SPS projects not included 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 identifying the project-level SPS site to the LINKED\_GPS\_ID field that matches the SHRP\_ID field in the INV\_ID table identifying the co-located GPS test section. Inventory, climatic, and traffic data can be shared.

## **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 placeholder character to represent all numerical values from 1 to 9. There are no SPS-10 tables.

Names and descriptions of numbered SPS tables common to multiple experiments are as follows:

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

- **SPS#\_NOTES\_AND\_COMMENTS**—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 test sections have no SPS#\_NOTES\_AND\_COMMENTS tables.
- **SPS#\_PMA\_AC\_PROPERTIES**—contains the properties of the asphalt cement used in the PMA-bound layers of the SPS test section. These properties were typically obtained from the asphalt supplier or from tests conducted by the State or Provincial highway agency. SPS-1, -2, -8, and -9 experiments have SPS#\_PMA\_AC\_PROPERTIES tables.
- **SPS#\_PMA\_AGGREGATE\_PROP**—contains the properties of the aggregate used in the PMA-bound layers of the SPS test section. These properties were typically obtained from the asphalt supplier or from tests conducted by the State or Provincial highway agency. SPS-1, -2, -8, and -9 experiments have SPS#\_PMA\_AGGREGATE\_PROPERTIES tables.
- **SPS#\_PMA\_COMPACTION**—contains compaction data, including air temperatures, roller information, and roller coverage for each lift of each PMA-bound layer of the SPS test section. SPS-1, -2, -5, -6, -8, and -9 experiments have SPS#\_PMA\_COMPACTION tables.
- **SPS#\_PMA\_CONSTRUCTION**—contains construction data for PMA-bound layers of the SPS test section, including paving start and end dates and mixing/lay-down temperatures. SPS-1, -2, -5, -6, -8, and -9 experiments have SPS#\_PMA\_CONSTRUCTION tables.
- **SPS#\_PMA\_MIXTURE\_PROP**—contains mixture properties for each PMA-bound layer. SPS-1, -2, and -8 experiments have SPS#\_PMA\_MIXTURE\_PROP tables.
- **SPS#\_PMA\_PLACEMENT\_DATA**—contains placement data for each PMA-bound layer, including asphalt-treated base, permeable asphalt-treated base, binder, surface, and friction courses. SPS-1, -2, and -8 experiments have SPS#\_PMA\_PLACEMENT\_DATA tables.
- **SPS#\_PMA\_ROLLER**—contains data for each roller used on any PMA-bound layers, roller weights, tire pressures, vibration frequency and amplitude, and roller speed. The **ROLLER\_CODE** field can be used to link information within the SPS#\_PMA\_ROLLER table to that stored in the SPS#\_PMA\_COMPACTION table. SPS-1, -2, -5, -6, -8, and -9 experiments have SPS#\_PMA\_ROLLER tables.
- **SPS#\_SUBGRADE\_PREP**—contains subgrade preparation data, including information on compaction, stabilizing agents, and lift thicknesses (i.e., fill sections). SPS-1, -2, and -8 experiments have SPS#\_SUBGRADE\_PREP tables.

- SPS#\_UNBOUND\_AGG\_BASE—contains placement information associated with unbound aggregate base layers, including compaction equipment and lift thicknesses. SPS-1, -2, -8, and -9 experiments have SPS#\_UNBOUND\_AGG\_BASE tables.
- SPS#\_QC\_MEASUREMENTS—contains the construction QC procedures and the measurements taken during construction of SPS-5, -6, and -7 test sections.
- SPS#\_OVERLAY—contains placement data for the AC overlays, including equipment and plant information, surface preparation, and haul times for each AC layer. The SPS#\_OVERLAY table applies to SPS-5 and -6 rehabilitation experiments.
- SPS#\_OVERLAY\_LAYERS—contains information specific to each lift placed during AC overlay applications on SPS-5 and -6 test sections.
- SPS#\_LOAD\_TRANSFER—contains information on the restoration of load-transfer capacity at joints in PCC pavements on SPS-6 and -9 test sections prior to the application of an overlay.
- SPS#\_PCC\_CRACK\_SEAL—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 SDRs.
- SPS#\_PCC\_FULL\_DEPTH—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 SDRs.
- SPS#\_PCC\_JOINT\_RESEAL—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—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—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—contains data on the load-transfer efficiency of transverse joints within SPS-7 and -9 test sections following load-transfer restoration, 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 SDRs.
- SPS#\_PCC\_JOINT\_DATA—contains construction data on joints within the test section, including skew, dowel spacing, joint forming and saw-cutting, sealant, and so on. SPS-2 and -8 experiments have entries in the SPS#\_PCC\_JOINT\_DATA table.

- SPS#\_PCC\_MIXTURE\_DATA—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 the SPS#\_PCC\_MIXTURE\_DATA table.
- SPS#\_PCC\_PLACEMENT\_DATA—contains construction data for each PCC layer in the test section, including concrete mix plant, paver, and spreader information, as well as dowel placement, vibration, finishing, curing, and texturing data. SPS-2 and -8 experiments have entries in the SPS#\_PCC\_PLACEMENT\_DATA table.
- SPS#\_PCC\_PROFILE\_DATA—contains information on profiling and grinding of PCC surface layers of SPS-2 and -8 test sections.
- SPS#\_PMA\_DENSITY\_PROFILE—contains PMA-bound layer nuclear density measurements and profilograph data. Information on the densities of asphalt-treated base, binder, surface, and friction are included. SPS-1 and -8 experiments have entries in the SPS#\_PMA\_DENSITY\_PROFILE table.
- SPS#\_MILLED\_SECTIONS—contains data on milling operations that occurred at some SPS-5 and -9 test sections in preparation for AC overlays. The SPS#\_MILLED\_SECTIONS table contains information on the equipment, layer delamination, milled thickness measurements, and other observations of milling operations.

## **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.

Names and descriptions of experiment-specific SPS tables are as follows:

- SPS2\_PCC\_FULL\_DEPTH—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, and finishing and curing methods.
- SPS2\_PCC\_STEEL—contains information on the reinforcing steel used in each PCC layer of the SPS-2 test section.
- SPS3\_CHIP—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—contains information on all equipment used in applying chip seal maintenance treatments to SPS-3 test sections.



- SPS3\_CRACK—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—contains information on the roller equipment used in chip seal applications to SPS-3 test sections.
- SPS3\_SLURRY—contains asphalt and aggregate properties, application rates, surface preparation, environmental conditions, and so on for SPS-3 test sections with slurry seal maintenance treatments.
- SPS3\_SLURRY\_EQUIP—contains information on all equipment used in slurry seal applications to SPS-3 test sections.
- SPS4\_BENKELMAN\_GENERAL—contains general information on Benkelman beam deflection tests conducted on SPS-4 test sections. Included are start and end times, dates, environmental conditions, deflection measurements, and other related data.
- SPS4\_BENKELMAN\_MEASURE—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 corresponding deflection measurements.
- SPS4\_CONTROL\_GENERAL—contains general information on characteristics of the control test section for each SPS-4 project. Each SPS maintenance test project included a control test section on which no maintenance was to be performed unless required as a safety measure.
- SPS4\_CONTROL\_LONG—contains the width of the longitudinal joint opening for each SPS-4 control test section.
- SPS4\_CONTROL\_RANDOM—contains the widths of the surface cracks for each SPS-4 control test section.
- SPS4\_CONTROL\_SHOULDER—contains the width of the shoulder joint for each SPS-4 control test section.
- SPS4\_CONTROL\_TRANS—contains the widths of the transverse joints for each SPS-4 control test section.
- SPS4\_CRACK\_SEAL\_GENERAL—contains information on joint and crack sealing operations at SPS-4 test sections.
- SPS4\_CRACK\_SEAL\_PVMT—contains information on sealant properties, temperatures, application techniques, backer rod, removal of old sealant, and cleaning associated with sealing transverse and longitudinal joints within SPS-4 test sections.

- SPS4\_CRACK\_SEAL\_PVMT\_MEAS—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—contains information on sealant properties, temperatures, application techniques, backer rod, removal of old sealant, and cleaning associated with sealing cracks within SPS-4 test sections.
- SPS4\_CRACK\_SEAL\_RAND\_MEAS—contains crack sealing measurements, including backer rod depths, for all sealing work on cracks within SPS-4 test sections.
- SPS4\_CRACK\_SEAL\_SH—contains information on sealant properties, temperatures, application techniques, backer rod, removal of old sealant, and cleaning associated with sealing longitudinal joints at the shoulders of SPS-4 test sections.
- SPS4\_CRACK\_SEAL\_SH\_MEAS—contains joint seal measurements, including backer rod depths, for all sealing work on longitudinal shoulder joints of SPS-4 test sections.
- SPS4\_DYNAFLECT\_GENERAL—contains general information on deflection testing that was conducted on SPS-4 test sections.
- SPS4\_DYNAFLECT\_MEASURE—contains the point locations (i.e., stationing) and sensor deflections recorded at each joint or crack within the SPS-4 test section that was tested.
- SPS4\_FWD\_MEASUREMENTS—contains general information on FWD deflection testing that was conducted on SPS-4 test sections. The SPS4\_FWD\_MEASUREMENTS table name is misleading since the actual test results are stored offline.
- SPS4\_UNDERSEAL\_GENERAL—contains general undersealing data, including information on cement, fly ash, water source, and hole installation and volume.
- SPS4\_UNDERSEAL\_INIT\_GROUT—contains information on the initial grouting application process.
- SPS4\_UNDERSEAL\_PRES\_GROUT—contains information on the pressure grouting application process.
- SPS4\_UNDERSEAL\_REGROUT—contains information on the regrouting application process.
- SPS5\_AC\_PATCHES—contains AC patching data collected at test sections in the SPS-5 experiment. The information is on patching that occurred in preparation for the applied AC overlay and was typically collected by the State/Provincial highway agency or a representative of the regional support contractor.

- SPS6\_CRACK\_SEAT\_PCC—contains PCC crack-and-seat data collected at test sections in the SPS-6 experiment (rehabilitation of PCC pavements). The information is on crack-and-seat operations that occurred in preparation for overlays on PCC pavements and was typically collected by the State/Provincial highway agency or a representative of the regional support contractor.
- SPS5\_RUT\_LEVEL\_UP—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—contains data on joint sawing and sealing operations that occurred prior to the application of an overlay on SPS-6 test sections.
- SPS6\_UNDERSEALING—contains general undersealing data for work done on SPS-6 test sections prior to the application of a rehabilitative overlay.
- SPS7\_DELAMINATION —contains general information on the removal/cleaning of the PCC surfaces of SPS-7 test sections in preparation for PCC overlay.
- SPS7\_MILLING—contains data on milling operations that occurred at some SPS-7 test sections in preparation for PCC overlay.
- SPS7\_PCCO\_JOINT\_DATA—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, and so on.
- SPS7\_PCC\_OVERLAY—contains information on placement operations of PCC overlays on SPS-7 test sections, including air temperatures, curing, sawing, grouting, and texturing.
- SPS7\_REFLECTIVE\_CRACK—contains the methods used for controlling reflective cracking on SPS-7 test sections after a PCC overlay.
- SPS7\_REMOVAL\_CLEANING—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—unique to SPS-9 test sections, contains PMA layer density data used for construction control.
- SPS9\_PMA\_MIX\_DES\_PROP—contains design mixture properties for PMA layers of SPS-9 test sections.
- SPS9\_PMA\_MIXTURE\_PROP—contains mixture properties (determined from laboratory testing) for PMA layers of SPS-9 test sections.
- SPS9\_PMA\_PLACEMENT\_INFO—contains test-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—contains test-section-wide properties of the asphalt lay-down process for SPS-9 test sections, including lift thicknesses, tack coat information, and transverse joint locations.
- SPS9\_PMA\_PROFILE—contains profilograph measurement results for the AC overlay layer of each SPS-9 test section. The information was used for construction control.
- SPS9\_SP\_PMA\_AC\_PROPERTIES—unique to SPS-9 test sections, contains PMA-bound layer Superpave asphalt cement properties.
- SPS9\_SP\_PMA\_AGGREGATE\_PROP—unique to SPS-9 test sections, contains PMA-bound layer Superpave aggregate properties.
- SPS9\_SP\_PMA\_MIXTURE\_PROP—unique to SPS-9 test sections, contains PMA-bound layer Superpave mixture properties.
- SPS9\_SUBGRADE\_PREP—contains subgrade preparation data collected on construction data sheets, including information on compaction and stabilization.

## **SPS-10 CONSTRUCTION DATA**

In the July 2016 public data release, data from test sections included in SPS-10 experiments were contained in the tables described in this portion of the document. Unlike data from previous SPS experiments, data from SPS-10 test 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.

Names and descriptions of inventory and construction tables for previous SPS experiments are as follows:

- PROJECT\_ID—contains general project and layout information, which is similar to the information contained in the SPS\_ID table.
- PROJECT\_STATIONS—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 “0.” All other SECTION\_END and SECTION\_START values represent travel distances in meters from the “0” location. Test sections co-located at an SPS project site have the same PROJECT\_ID.
- PROJECT\_INTERSECTIONS—contains project-level intersection information and data on the location of ramps, signals, and stop signs within the project boundaries. The PROJECT\_INTERSECTIONS table is similar to the SPS\_PROJECT\_INTERSECTIONS table.

- SECTION\_GENERAL—contains information on road geometry, lane width, speed limit, and median properties for each test section.
- SECTION\_DRAINAGE—includes information specific to drainage features of each test section.
- SECTION\_SHOULDER—contains information related to shoulder details on each test section.
- SECTION\_CONST\_LAYER—contains data elements relating to the original constructed pavement structure.
- PROJECT\_HIST\_AGE—contains significant event dates for activities that occurred prior to the project being accepted into the LTPP program for current construction and monitoring purposes. The PROJECT\_HIST\_AGE table is similar to the INV\_AGE table.
- PROJECT\_MAJOR\_IMP—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, which is similar to the INV\_MAJOR\_IMP table.
- DEICING\_FREQUENCY—contains information on the frequency of snow removal and deicing chemical applications, which is similar to INV\_DEICE\_SITE\_DATA.
- DEICING\_TYPES—contains information on types of deicing chemical used on a test section.
- SECTION\_HPMS—a new table designed to capture pavement-related data elements specified in the HPMS data input guidelines.
- AC\_AGGR\_COMP—contains information on types and composition of aggregates contained in AC layers.
- AC\_AGGR\_DUR—contains information on aggregate durability. The AC\_AGGR\_DUR table is similar to the INV\_AGGR\_DUR table.
- AC\_AGGR\_PROP—includes physical properties of materials used as aggregate in AC mixtures. The AC\_AGGR\_PROP table includes properties such as bulk, effective, and maximum-specific gravities, mineral fillers, recycled asphalt shingles, and absorption values.
- AC\_AGGR\_SP\_PROP—contains AC aggregate properties derived from Superpave research and development activities. The AC\_AGGR\_SP\_PROP table is similar to the RHB\_ACO\_SP\_AGGR\_PROP table.
- AC\_AGGR\_GRADATION—contains aggregate gradation information on a weight basis passing specified sieves, classified by test section, layer number, and aggregate type.

- AC\_BINDER—contains general classification properties of AC binders, including performance-graded binders, penetration, viscosity, ductility, and other measures of asphalt cement used during the last 30 yr.
- AC\_MODIFIER—a copy of the INV\_MODIFER table containing data on the types and amounts of asphalt cement modifiers.
- AC\_AGED\_BINDER—contains properties of the binder used in AC mixtures after aging.
- AC\_DSR—contains dynamic shear rheometer (DSR), bending-beam rheometer (BBR), and direct tension (DT) tests for binders used in AC mixtures.
- AC\_AGGR\_RECYCLED—contains type and storage information for recycled aggregates used in AC mixtures.
- AC\_LAB\_MIX—contains laboratory mix design for AC mixtures.
- AC\_LAB\_MIX\_RECYCLE—contains laboratory mix design properties specific to recycled AC mixtures.
- AC\_LAB\_MIX\_WARM—contains laboratory mix design properties specific to warm mix AC mixtures.
- AC\_MIXTURE—contains AC mixture properties as placed.
- AC\_ANTISTRIPPING—contains AC antistripping agent information.
- AC\_SP\_MIXTURE—contains AC Superpave mixture properties as placed.
- AC\_PLACEMENT—contains placement information for AC layers.
- AC\_CONSTRUCTION\_TEMPS—contains construction temperature data for AC layers.
- AC\_COMPACTION—contains compaction data for AC layers.
- AC\_ROLLER—contains compaction equipment data for AC layers.
- UNBOUND\_STABIL—contains unbound layer stabilizing agent data.
- UNBOUND\_LAYER\_PROP—contains unbound or stabilized base or subbase layer properties.
- UNBOUND\_GRADATION—contains unbound or stabilized base or subbase layer gradation information.
- SUBGRADE\_LAYER\_PROP—contains subgrade layer properties.

- AC\_DENSITY\_MEAS—contains AC layer density data used for construction quality control.
- AC\_PROFILE\_MEAS—contains AC layer profile data used for construction quality control.
- SECTION\_FIELD\_THICK\_MEAS—contains field layer thickness measurements from time of construction at different stations.
- SECTION\_CONSTRUCTION\_NOTES—contains test section notes and comments.
- AC\_MILLING—contains information on AC milling operations.
- CONSTRUCTION\_EVENTS—contains improvement information, such as maintenance and rehabilitation events.





## CHAPTER 12. TRAFFIC MODULE

Participating highway agencies provided traffic monitoring data during the development of the LTPP program. 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,” which is defined to include the following:
  - Practices and conditions under which the data were collected must be reported.
  - Edits of traffic data must be documented, and a record of the original (i.e., 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, it is impossible to quantify the wide range in accuracy and variability associated with traffic data estimates. At this time, it is not possible to provide reliable data variance estimates from annual projections based on 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 preprocessing program that is used to perform QC checks and compute the annual statistics stored in the LTPP PPDB. The LTAS database was first released in the January 2010 SDR (data release 24). These data were released for those interested in other traffic engineering uses of LTPP traffic data. The LTAS database contains daily and monthly traffic data used in the computation of annual traffic estimates stored in the LTPP 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 contains descriptions of the LTAS database structure and tables included in the SDR.

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

Traffic data formatted for use with MEPDG developed under NCHRP Project 1-37A, Development of the 2002 Guide for the Design of New and Rehabilitated Pavement Structures: Phase II, was first released in January 2008. The January 2008 MEPDG traffic data in the LTPP PPDB were contained in a module named MEPDG. For the January 2009 SDR (data release 23), these tables were renamed and moved to the Traffic module.

## MAJOR FIELDS

Common fields unique to Traffic tables that link related data in associated tables to each other include VEHICLE\_CLASS, AXLE\_GROUP, CLASS\_COUNT\_BEGIN\_DATE, and WIM\_AVC\_CALIB\_DATE.

The VEHICLE\_CLASS field refers to the FHWA 13 vehicle category classification system (table 4) described in the FHWA *Traffic Monitoring Guide* (TMG). (FHWA 2016b) (Note that although the classification system is named 13-bin for historical reasons, it has 15 classes.) The VEHICLE\_CLASS 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). The VEHICLE\_CLASS field is also used within the TRF\_HIST\_CLASS\_DATA table to indicate the number of vehicles within each category that were counted during classification surveys. The similar VEHICLE\_CLASS field within the TRF\_MONITOR\_AXLE\_DISTRIB table can be used to link data to the TRF\_HIST tables, but only for the truck classes (classes 4–13) since motorcycles, automobiles, and light trucks are not generally present in weigh-in-motion (WIM) monitoring data and not summarized for loading estimates by LTPP traffic data-processing software.

**Table 4. 13-bin TMG vehicle classification system.**

Vehicle Class	Description
1	Motorcycles
2	Passenger cars
3	Other two-axle, four-tire single-unit vehicles
4	Buses
5	Two-axle, six-tire single-unit trucks
6	Three-axle single-unit trucks
7	Four-or-more-axle single-unit trucks
8	Four-or-fewer-axle single-trailer trucks
9	Five-axle single-trailer trucks
10	Six-or-more-axle single-trailer trucks
11	Five-or-fewer-axle multi-trailer trucks
12	Six-axle multi-trailer trucks
13	Seven-or-more-axle multi-trailer trucks
14	Unclassifiable
15	Partial vehicles, including off-scale or lane-changing vehicles

The AXLE\_GROUP field is a variable defining the type of axle or axle group (e.g., single, tandem, triple, or quad-plus). The field 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 table 4. Steering axle distributions are available offline for some site-years.

The CLASS\_COUNT\_BEGIN\_DATE field may be used to relate information on a specific historical traffic classification count stored within the TRF\_HIST\_CLASS\_MASTER table with the actual count data stored in the TRF\_HIST\_CLASS\_COUNT table.

The WIM\_AVC\_CALIB\_DATE field must be used when relating the specific calibration information found within the TRF\_CALIBRATION\_AVC and TRF\_CALIBRATION\_WIM tables to the list of installed traffic-monitoring equipment found within the TRF\_EQUIPMENT\_MASTER table.

## **TRAFFIC TABLES**

All traffic volume, classification, and load data contained in the Traffic module consist of annual estimates based on agency-supplied estimates or computed from raw traffic volume, classification, and load data reported by highway agencies. The information in the Traffic module 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 Traffic 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, estimates are provided using a project-level SHRP\_ID for some monitored tables. In most cases, it is a good assumption that project-level traffic applies to all test sections on the project. For sites that have test sections located in both directions of travel, this is not a reasonable assumption. These sites can be identified by using the SPS\_PROJECT\_STATIONS table.

Names and descriptions of traffic tables are as follows:

- TRF\_BASIC\_INFO—contains basic information about the location of the test section and the roadway on which it is located.
- TRF\_CALIBRATION\_AVC—contains information on the calibration of automated vehicle classification (AVC) equipment.
- TRF\_CALIBRATION\_WIM—contains information on the calibration of WIM equipment installed for a test section.
- TRF\_EQUIPMENT\_MASTER—contains information about equipment (both AVC and WIM) in place during a calibration event.
- TRF\_HIST\_CLASS\_DATA—contains the results of vehicle classification counts 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—contains specifics of the classification counts that furnished data for the TRF\_HIST\_CLASS\_DATA table. The CLASS\_MASTER table also contains the total volumes recorded during each count.
- TRF\_HIST\_EST\_ESAL—contains estimates of 80-kN (18-kip) ESALs at the test 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—contains the results of vehicle volume counts 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—contains all general information on the roadway and the equipment used for historical truck-weighing sessions.
- TRF\_MONITOR\_AXLE\_DISTRIB—contains the number of axles measured in each weight range for each axle group (e.g., single, tandem, triple, and quad-plus). The 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 the TRF\_MONITOR\_AXLE\_DISTRIB table. The WEIGHT\_BIN\_SIZE field contains the size of the weight bins used to describe the weight distribution by axle type. The distribution is for the LTPP lane only.
- TRF\_MONITOR\_LTPP\_LN—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—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 taken. The data within the TRF\_MON\_EST\_ESAL 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. Estimates are supplied by participating highway agencies.

## **TRF\_MEPDG TABLES**

The TRF\_MEPDG series of tables contains traffic data developed for use in the MEPDG traffic module, which are computed from data stored in the LTPP traffic database that have been processed using the traffic QC/QA system. Data that have passed Level D and E QC checks were used in the computations. The process restricts 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 these 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 are aggregated to annual estimates as a baseline; 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 are 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 MEPDG. These data are available for sites where all lanes were instrumented with a traffic measurement device. Please contact the LTPP CSSC by emailing [ltppinfo@dot.gov](mailto:ltppinfo@dot.gov) to discuss acquisition of other monitored traffic data.

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

Names and descriptions of TRF\_MEPDG tables are as follows:

- TRF\_MEPDG\_AADTT\_LTPP\_LN—contains estimates of the annual average daily truck traffic (AADTT) 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 AADTT volume in the LTPP test lane for sites for years where 210 d or more of combined classification and WIM data exist for at least one truck class.
  - Records with a value of “4” in the TRF\_DATA\_TYPE field contain estimates of AADTT volume in the LTPP test lane for sites for years where 210 d or more of classification data exist for at least one truck class.
  - Records with a value of “7” in the TRF\_DATA\_TYPE field contain estimates of AADTT volume in the LTPP test lane for sites for years where 210 d or more of weight data exist for at least one truck class.

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

- TRF\_MEPDG\_AX\_DIST—contains normalized axle distributions by month, truck class, and axle group. Records in the TRF\_MEPDG\_AX\_DIST table are generated from the MM\_AX table in the LTPP traffic database and contain at least 210 d 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.

The TRF\_MEPDG\_AX\_DIST table utilizes a database-efficient table storage structure where a dataset is stored as multiple records. To extract a complete year dataset, 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—contains the annual normalized axle distribution by class and axle group. Records in the TRF\_MEPDG\_AX\_DIST\_ANL 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.

The TRF\_MEPDG\_AX\_DIST\_ANL 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.

The TRF\_MEPDG\_AX\_DIST\_ANL table utilizes a database-efficient table storage structure where a dataset is stored in multiple records. To extract a complete year dataset, 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—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 2 yr with more than 210 d of WIM data must exist for the table to be populated for a site.

The number of years variances are computed over is indicated in the NUM\_YEARS field.

The TRF\_MEPDG\_AX\_DIST\_ANL\_VAR table utilizes a database-efficient table storage structure where a dataset is stored in multiple records. To extract a complete dataset, 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—contains the annual average 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 average numbers of axles per truck less than 0.1 or greater than 5 have a RECORD\_STATUS=C. Users must read MEPDG documentation to properly interpret fractional averages contained in the TRF\_MEPDG\_AX\_PER\_TRUCK table.

The TRF\_MEPDG\_AX\_PER\_TRUCK table utilizes a database-efficient table storage structure where a dataset is stored in multiple records. To extract a complete dataset, 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—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 MEPDG. The TRF\_MEPDG\_HOURLY\_DIST table contains data for sites with at least 210 d of classification data in a calendar year that were validated or calibrated under LTPP contract.
- TRF\_MEPDG\_MONTH\_ADJ\_FACTR—contains adjustment factors for AADTT 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” indicates the estimate was based on only weight data.

The TRF\_MEPDG\_MONTH\_ADJ\_FACTR table utilizes a database-efficient table storage structure where a dataset is stored in multiple records. To extract a complete dataset, 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—contains the percentage of trucks by vehicle class within the truck population (FHWA vehicle classes 4–13) in the LTPP lane based on classification, weight, or a combination of classification and weight data, as indicated by the code contained in the TRF\_DATA\_TYPE field. (FHWA 2016b) For some test sections, up to three different estimates are provided. Estimates are provided by year.

The TRF\_MEPDG\_VEH\_CLASS\_DIST table utilizes a database-efficient table storage structure where a dataset is stored in multiple records. To extract a complete dataset, 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.

- WIM\_SITE\_INVENTORY—describes site location, geometry, and installed equipment, both type- and location-relative to the test sections to which the traffic data applies for WIM sites validated by FHWA contractors.

- WIM\_SITE\_PHOTOS—identifies all photographs of the site showing sensors, location, and electronics for WIM sites validated by FHWA contractors. The photos are not included in the PPDB. They are available through validation reports in the InfoPave library.

## TRF\_ESAL TABLES

The TRF\_ESAL tables contain annual 80-kN (18-kip) 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. (AASHTO 1993) The data were first added to the January 2011 SDR (data release 25) as a series of database tables contained directly in the PPDB. Previously, these tables and the computation program were contained on the Reference Library as part of the ESALCalc utility software distributed with SDRs. The purpose of adding these tables directly into the PPDB was to make these computed parameters easier to find.

Names and descriptions of TRF\_ESAL tables are as follows:

- TRF\_ESAL\_COMPUTED—contains the results of the annual ESAL calculations in the LTPP lane. 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/yr. Thus, a value of “1” in the KESAL\_YEAR field should be interpreted as 1,000 ESAL/yr in the LTPP study lane.
- TRF\_ESAL\_AC\_THICK—contains the values used to compute the structural number for AC-surfaced test sections. It includes the thickness, type of layer, layer coefficient, average resilient modulus, and drainage layer coefficient for base and subbase layers. The TRF\_ESAL\_AC\_THICK table also includes the start and end dates for when these values apply.
- TRF\_ESAL\_PCC\_COMP\_THICK—contains the values used to compute the value of the effective thickness of the PCC layers used in the ESAL calculation. The TRF\_ESAL\_PCC\_COMP\_THICK table includes information on the thickness of multiple PCC layers and whether they are bonded.
- TRF\_ESAL\_INPUTS\_SUMMARY—master table containing a summary of input data used in the annual ESAL estimate. Contents of the TRF\_ESAL\_INPUTS\_SUMMARY table include:
  - Pavement type and its source.
  - Structural number and its source used for AC pavements.
  - Effective thickness and its source used for PCC pavements.
  - Terminal service index value and the basis for the terminal service index value.
  - Functional classification of the facility used to establish the terminal serviceability index.



- Climate characterizations, including average annual precipitation and freeze index, LTPP experimental climate region, and the source for the climate classification.
- Start and end dates related to the construction number for which these properties apply.

## **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. (Seleznava and Hallenbeck 2013) Individual NALS are computed for each axle type by truck class. Axle types included in the NALS computed parameter tables include single, tandem, tridem, and quad. These are computed for vehicle classes 4–13 from the FHWA vehicle classification scheme. (FHWA 2016b) NALS are the basic traffic loading input for pavement design 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.

The RPPIF is a summary statistic for comparison and grouping of similar NALS. (Seleznava et al. 2016) The RPPIF 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 weighting damage factor ( $W_{ij}$ ), 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 outcomes from many distress models, they represent a general potential pavement damage factor not based on pavement structure. The RPPIF parameter is computed by multiplying the  $W_{ij}$  factor by the corresponding NALS bin, and then summing the products for each axle group and truck class.

The database computation process required for the creation of 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 and 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 (i.e., 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.

### **NALS Tables**

Names and descriptions of NALS tables are as follows:

- **NALS\_MONTHLY\_DISTRIB**—contains the monthly NALS for each axle type by truck class for each lane and direction. The distribution is derived from the information in MM\_AX 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 individual axle bin values may result in sums slightly different from 100.

The NALS\_MONTHLY\_DISTRIB table utilizes a database-efficient table storage structure where a dataset is stored in multiple records. To extract a complete dataset, 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**—contains the annual NALS for each axle type by truck class for each lane and direction. The distribution is the average of 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.

The NALS\_ANNUAL\_DISTRIB table utilizes a database-efficient table storage structure where a dataset is stored in multiple records. To extract a complete dataset, 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**—contains the results of applying a set of QC checks to the tails of Class 9 single and tandem monthly NALS. The checks look for larger-than-expected percentages of light or heavy axles. Thresholds are based on work done in development of the PLUG software and review of other calibrated WIM sites in LTPP PPDB. The thresholds are shown in table 5. (Selezneva and Hallenbeck 2013) 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.
- **NALS\_ANNUAL\_EVAL**—contains the results of applying a set of QC checks to the tails of Class 9 single and tandem annual NALS. The checks look for larger-than-expected percentages of light or heavy axles. Thresholds and check sequence are the same as for the NALS\_MONTHLY\_EVAL table. The first check failed is identified in the table in NALS\_EVAL\_ANL.

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

<b>Axle Group</b>	<b>Maximum Allowable Percentage Light Axles</b>	<b>Maximum Allowable Percentage Heavy Axles</b>
Single	10 percent 4,999 lb or lighter	10 percent 21,000 lb or heavier
Tandem (United States)	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

1 lb = 0.45 kg.

## 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 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.

Names and descriptions of RPPIF tables are as follows:

- RPPIF\_WIJ\_FACTOR—contains the  $W_{ij}$  factors for each axle bin by axle group. The key fields in the RPPIF\_WIJ\_FACTOR table are AXLE\_GROUP and WEIGHT\_BIN\_LOW, the weight of the lightest axle included in the bin.
- RPPIF\_NALS\_MONTHLY—stores the RPPIF value for a specific axle group and vehicle class by year, month, lane, and direction. RPPIF\_NALS\_MONTHLY 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 the NALS\_MONTHLY\_DISTRIB table and summed across all axle bins.
- RPPIF\_VEHICLE\_CLASS\_MONTHLY—stores the RPPIF value associated with an individual vehicle class by year, month, lane, and direction. The RPPIF\_VEHICLE\_CLASS\_MONTHLY 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 the VEHICLE\_CLASS\_AVG\_AX\_MONTH table and summing the result.
- RPPIF\_MONTHLY\_AVG\_TRUCK—stores the RPPIF value associated with a truck population by year, month, lane, and direction. The RPPIF\_MONTHLY\_AVG\_TRUCK 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 by weighting the VEHICLE\_CLASS\_RPPIF values using the VEHICLE\_CLASS\_ADT\_MONTH table.
- RPPIF\_NALS\_ANNUAL—stores the RPPIF value for a specific axle group and vehicle class by year, lane, and direction. RPPIF\_NALS\_ANNUAL 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 the NALS\_ANNUAL\_DISTRIB table and summed across all axle bins.
- RPPIF\_VEHICLE\_CLASS\_ANNUAL—stores the RPPIF value associated with an individual vehicle class by year, lane, and direction. The RPPIF\_VEHICLE\_CLASS\_ANNUAL 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 the `VEHICLE_CLASS_AVG_AX_ANL` table and summing the result.

- `RPPIF_ANNUAL_AVG_TRUCK`—stores the `RPPIF` value associated with a truck population by year, lane, and direction. The `RPPIF_ANNUAL_AVG_TRUCK` 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 by weighting the `VEHICLE_CLASS_RPPIF_ANL` values using the `VEHICLE_CLASS_ADT_ANNUAL` table.

## **VEHICLE\_CLASS Tables**

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

Names and descriptions of `VEHICLE_CLASS` tables are as follows:

- `VEHICLE_CLASS_TOTAL_AXLES`—stores total number of axles by year, month, lane, direction, vehicle class, and axle group.
- `VEHICLE_CLASS_TOTAL_COUNT`—stores total number of vehicles by class, year, month, lane, and direction. The `VEHICLE_CLASS_TOTAL_COUNT` table uses the counts associated with weight data in the `MM_CT` table as the input.
- `VEHICLE_CLASS_AVG_AX_MONTH`—stores the average numbers of axles by axle group for each vehicle class by year, month, lane, and direction. The `VEHICLE_CLASS_AVG_AX_MONTH` table is like the `TRF_MEPDG_AX_PER_TRUCK` table except that it is a monthly table and does not have a minimum number of days of data requirement. The `VEHICLE_CLASS_AVG_AX_MONTH` table is used to compute `VEHICLE_CLASS_RPPIF` in the `RPPIF_VEHICLE_CLASS_MONTHLY` table.
- `VEHICLE_CLASS_ADT_MONTH`—stores average daily traffic by vehicle class, year, lane, and direction using the `VEHICLE_CLASS_TOTAL_COUNT` table as an input. The `VEHICLE_CLASS_ADT_MONTH` table is like the `TRF_MEPDG_AADTT_LTPP_LN` table but is a monthly table and no estimation process is applied to account for missing days of data in the month. The `VEHICLE_CLASS_ADT_MONTH` table is used to compute `RPPIF_MONTHLY_AVG_TRUCK`.
- `VEHICLE_CLASS_AVG_AX_ANL`—stores the average numbers of axles by axle group for each vehicle class by year, lane, and direction. The `VEHICLE_CLASS_AVG_AX_ANL` table is like the `TRF_MEPDG_AX_PER_TRUCK` table except that it does not have a minimum number of days of data requirement. The

VEHICLE\_CLASS\_AVG\_AX\_ANL table is used to compute VEHICLE\_CLASS\_RPPIF\_ANL in the RPPIF\_VEHICLE\_CLASS\_ANNUAL table.

- VEHICLE\_CLASS\_ADT\_ANNUAL—stores average daily traffic by vehicle class, year, lane, and direction using the VEHICLE\_CLASS\_ADT\_MONTH table as an input. The VEHICLE\_CLASS\_ADT\_ANNUAL table is like the TRF\_MEPDG\_AADTT\_LTPP\_LN table, 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. The VEHICLE\_CLASS\_ADT\_ANNUAL table is used to compute RPPIF\_ANNUAL\_AVG\_TRUCK.

## **CONSOLIDATED TRAFFIC DATASET**

Five new traffic tables added in 2018 provide a consolidated set of traffic information. Three are designed for use with the AASHTOWare Pavement ME Design software. The other two use monitored and estimated data within the LTPP database to provide traffic site characteristics and complete time series values for each test section studied. Names and descriptions of tables providing a consolidated set of traffic information are as follows:

- TRF\_REP\_PARAMETERS—contents include representative truck volume, vehicle classification, and loading summary parameters by site. The TRF\_REP\_PARAMETERS table contains a set of values that can be used to describe the traffic characteristics of a site while it is in a single experiment. Test sections that are part of multiple experiments have a separate set of representative values for each experiment. The values include AADTT, percentage of trucks by vehicle class, and representative generic ESAL (GESAL) by axle type, truck, and vehicle class. The 2019 public data release contains ESALs, RPPIF, and gross vehicle weight (GVW) values by axle type, truck, and vehicle class. Representative values provide an assortment of metrics to compare site traffic characteristics.
- TRF\_TREND—contents include annual traffic statistics computed or estimated for each in-service and in-experiment year. The TRF\_TREND table contains volumes for each test section for every year they were in study. The volumes include AADTT for the entire truck population and individual vehicle classes. Loading trends are contained in the 2019 public data release for the total truck population in terms of ESALs, GESALs, and average GVW (i.e., average truck loading). The values are derived from the TRF\_REP\_PARAMETERS and MEPDG\_TRUCK\_VOL\_PARAMETERS tables.
- MEPDG\_TRUCK\_VOL\_PARAMETERS—includes parameters used in the AASHTOWare Pavement ME Design software to estimate traffic volumes for FHWA vehicle classes 4–13 over the analysis period. For each experiment, a test section was included by vehicle class, and the following information was provided: percentage of the class in the truck population, type of growth function (e.g., linear or compound), growth rate, AADTT for the first year in the experiment, and a code categorizing the underlying data.

- **MEPDG\_AXLE\_LOAD\_DIST\_FACTOR**—contents include axle load distribution factors developed based on NALS for use with AASHTOWare Pavement ME Design software. These factors represent the expected distribution of axle loads by weight for a typical day of the month for each month in the year. The data were developed under two separate analysis contracts. One required complete data (i.e., all months and days of the week being present) meeting a large set of quality checks. The other used available monitored axle distributions, ESAL estimates, and site location where necessary to select reasonable distributions from a set of typical distributions. The source and quality of the data in each distribution are identified with a code.
- **MEPDG\_AXLE\_PER\_TRUCK**—representative number of axles per truck class for use with AASHTOWare Pavement ME Design software. The data were computed from available monitored weight data where they existed. The LTPP program used the computed values to create a set of defaults based on location and highway system to assign values for sites without monitored weight data. The source and quality of the data are identified with a code in the **MEPDG\_AXLE\_PER\_TRUCK** table.

## CHAPTER 13. MATERIALS TESTING MODULE

The following are achieved through extensive field tests, materials sampling, and laboratory testing on LTPP test sections:

- 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. 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 timespan.

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 test sections or GPS overlay test 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*. (FHWA 1991, 1997) In addition, materials sampling and testing guidelines were developed for each SPS experiment.

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 field materials sampling and testing and laboratory testing for these test sections. For SPS test sections and GPS overlay test sections, the respective highway agency was 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 were conducted by LTPP-contracted and FHWA laboratories.

### MATERIALS TEST TYPES

A list of typical materials tests, test designations, and protocols are shown in table 6. The test designation is used for database table names. Tests conducted on a test section are dependent on the type of materials, thickness of the material layers, and type of pavement layer. Test requirements also vary according to the objectives of the experiment to which the test 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 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.**

<b>Material</b>	<b>Test Designation</b>	<b>Test Name</b>	<b>Protocol</b>
Asphalt Concrete (AC)	AC01	Core Examination and Thickness	P01
AC	AC02	Bulk Specific Gravity	P02
AC	AC03	Maximum Specific Gravity	P03
AC	AC04	Asphalt Content (Extracted)	P04
AC	AC07	Resilient Modulus, Tensile Strength, and Creep	P07
AC	AC08	Dynamic Modulus of Asphalt Concrete Mixtures	P74
AC	AC09	Hamburg Wheel-Track Testing of Asphalt Concrete	P75
AC	AC10	Fracture Energy of Asphalt Materials	P79
AC	SP01	Gyratory Compaction	<sup>b</sup>
AC	SP02	Volumetric and Gravimetric Properties of Superpave Mixes	<sup>b</sup>
Extracted Aggregate From AC	AG01	Specific Gravity of Coarse Aggregate	P11
Extracted Aggregate From AC	AG02	Specific Gravity of Fine Aggregate	P12
Extracted Aggregate From AC	AG04	Gradation of Aggregate	P14
Extracted Aggregate From AC	AG05 <sup>(a)</sup>	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	<sup>b</sup>
Asphalt Cement	AE08	Bending-Beam Rheometer (BBR) Test	<sup>b</sup>
Asphalt Cement	AE09	Superpave Direct Tension (DT) Test	<sup>b</sup>
Asphalt Cement	AE10	Multiple Stress Creep Recovery Test	P73
Asphalt Cement	AE11	Recycled Engine Oil Bottoms (REOB) Test	<sup>b</sup>
Asphalt Cement	AE12	Rolling Thin Film Oven Test	P77
Asphalt Cement	AE13	Pressure Aging Vessel	P78
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



<b>Material</b>	<b>Test Designation</b>	<b>Test Name</b>	<b>Protocol</b>
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
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 <sup>(c)</sup>	Measurement of Hydraulic Conductivity of Saturated Porous Material Using a Flexible Wall Permeameter	P57
Subgrade	SS12 <sup>(c)</sup>	Expansion Index	P60
Subgrade	SS13	Specific Gravity	P71
Subgrade	SS14	Dynamic Cone Penetrometer	P72
Portland Cement Concrete (PCC)	PC01	Compressive Strength	P61
PCC	PC02	Splitting Tensile Strength	P62
PCC	PC03	Coefficient of Thermal Expansion	P63
PCC	PC04	Static Modulus of Elasticity	P64
PCC	PC05	Density of PCC	P66
PCC	PC06	Core Examination and Thickness	P66
PCC	PC07	Interface Bond Strength	P67
PCC	PC08 <sup>(c)</sup>	Air Content of Hardened Concrete	P68

<b>Material</b>	<b>Test Designation</b>	<b>Test Name</b>	<b>Protocol</b>
PCC	PC09	Flexural Strength	P69
SPS-3 and -4	SC01	Tests on Emulsified Asphalts	<sup>b</sup>
SPS-3 and -4	SC02	Plastic Fines in Graded Aggregates by Use of Sand Equivalency Test	<sup>b</sup>
SPS-3 and -4	SC03	Testing Crushed Stone for Single Bituminous Surface Treatments	<sup>b</sup>
SPS-3 and -4	SC04	Determination of Flakiness Index of Aggregates	<sup>b</sup>
SPS-3 and -4	SC05	Testing of Slurry Seal	<sup>b</sup>
SPS-3 and -4	SC06	Measurement of Excess Asphalt in Bituminous Mixtures by Use of Loaded Wheel and Sand Cohesion	<sup>b</sup>
SPS-3 and -4	SC07	Wet Stripping Test for Cured Slurry Seal Mixes	<sup>b</sup>
SPS-3 and -4	SC08	Determination of Slurry System Compatibility	<sup>b</sup>
SPS-3 and -4	SC09	Mixing, Setting, and Water-Resistance Test to Identify Quick-Set Emulsified Asphalts	<sup>b</sup>
SPS-3 and -4	SC10A	Aggregate Gradation of Chip Seals	<sup>b</sup>
SPS-3 and -4	SC10B	Aggregate Gradation of Slurry Seals	<sup>b</sup>
SPS-3 and -4	SC11	Chip Seal Mix Design	<sup>b</sup>
SPS-3 and -4	SC12	Determination of Asphalt Content From Slurry Seal Sample	<sup>b</sup>
SPS-3 and -4	SC13	Polish Value of Chip Seal Aggregates	<sup>b</sup>
SPS-3 and -4	CS01	Properties of Hot-Poured Joint Sealants	<sup>b</sup>
SPS-3 and -4	CS02	Properties of Silicone Joint Sealants	<sup>b</sup>

<sup>a</sup>Test was conducted by the National Aggregates Association Joint Research Laboratory. Data are not available for all test sections.

<sup>b</sup>These tests for the SPS-3, -4, -9, and -10 experiments were performed using non-LTPP-developed material testing protocols.

## **MAJOR 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 module. While the fields 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. . 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 -9s), 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 applying 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 test section of approximately the same age.

TEST\_NO is a field that indicates where in the test 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 were conducted on a combination of materials sampled at different ends of the test section, or in some cases, at different test sections at an SPS project, to meet the minimum weight requirements of the test. Certain values of the TEST\_NO code 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 test section (i.e., the approach end) or just after the end of the test section (i.e., 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 test section.

LAB\_CODE is a code field 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 Province in which the laboratory is located.

COMMENTS\_\* codes must be linked to the codes table for a description. Most 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. The comment code fields can have multiple comments entered for a test, taking the form of COMMENTS\_\* (e.g., COMMENTS\_1, COMMENTS\_2, and so on). For cases where no appropriate comment code is available, the COMMENT\_OTHER field is used to store a text comment.

## **UNDERSTANDING THE MATERIALS TESTING DATA STRUCTURES**

Materials testing data from tests performed as part of the LTPP program are stored in the Test module. Additional materials characterization data are stored in the Inventory, Rehabilitation, Maintenance, and SPS# modules; however, applicability of these data to specific test section

locations is unknown due to the general, project-level nature of the Inventory, Rehabilitation, Maintenance, and SPS# modules information.

## **Test Results Tables**

Tables containing results for specific tests can be identified based on the test designations shown in table 6. For example, data resulting from test AC03 are 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 table 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 Test 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 tables, but should not be relied on for uniqueness.

### ***AC Test Results Tables***

Names and descriptions of AC test results tables are as follows:

- TST\_AC01—contains the results of a visual examination of an AC core. The TST\_AC01 table 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 Test module. Field layering 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, the TST\_AC01 table must be linked to the TST\_AC01\_LAYER table 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—contains the information necessary to convert the field layer numbers recorded in the TST\_AC01 table to “true” layer numbers as used in the rest of the Test module. In addition, the TST\_AC01\_LAYER table contains the thickness of each “true” layer insofar as it can be determined from the core. The thickness is stored in the LAYER\_THICKNESS field.

- TST\_AC02—contains BSG test results from AC samples. Calculated BSG is stored in the BSG field (no intermediate results are included). In addition, percent moisture absorption is available from the WATER\_ABS field. When specimens have WATER\_ABS values over 2 percent, protocol calls for additional BSG testing to be performed on a paraffin-coated specimen. If this was done, the PARAFFIN\_COATED field is set to “Y” and the BSG value is recorded in the COATED\_BSG field.
- TST\_AC03—contains theoretical MSG test results from AC samples. Calculated MSG is stored in the MAX\_SPEC\_GRAVITY field (no intermediate results are included).
- TST\_AC04—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—contains moisture susceptibility test results from laboratory-compacted bulk asphalt specimens. There are only data for a limited number of test sections from the SPS-1, -5, -8, and -9 projects. A user should first check for data availability before attempting to use these data in analysis. The LTPP protocol for this test, P05, is primarily based on AASHTO T 283, *Resistance of Compacted Asphalt Mixtures to Moisture-Induced Damage*, and the user should be familiar with the procedure before attempting to interpret the results. (AASHTO 2014)

In essence, test AC05 evaluates 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, 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.

The TST\_AC05 table 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 (e.g., 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.

The TST\_AC05 table also has a slight complication regarding sample numbers. The SAMPLE\_NO field denotes the sample number of the bulk AC 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—contains data resulting from a visual evaluation of moisture damage to the field cores. Data exist for only a limited number of SPS-5 and -9 test sections.
- TST\_SP01\_MASTER—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, number of gyrations for design, and number of gyrations maximum 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 the TST\_SP01\_MASTER table. A user can expect that available records will contain missing values for some fields due to the experimental nature of the tests performed.

The TST\_SP01\_MASTER table uses the TST\_ID field as a primary key, allowing linking of test results to test samples and material layer on more than one test section.

- TST\_SP01\_DATA—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 the TST\_SP01\_DATA table. A user can expect that available records will contain missing values for some fields due to the experimental nature of the tests performed.

The TST\_SP01\_DATA table uses the TST\_ID field as a primary key, allowing linking of test results to test samples and material layer on more than one test section.

- TST\_SP02—contains test results and corresponding computed volumetric properties of laboratory compacted and field cores of AC 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.

The TST\_SP02 table uses the TST\_ID field 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.

### ***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 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 in figure 28. (FHWA 2001) LTPP Protocol P07 is also similar to the creep compliance and indirect tensile strength portions of AASHTO TP9-96, *Standard Test Method for Determining the Creep Compliance and Strength of Hot Mix Asphalt (HMA) Using the Indirect Tensile Test Device*. (AASHTO 1996)

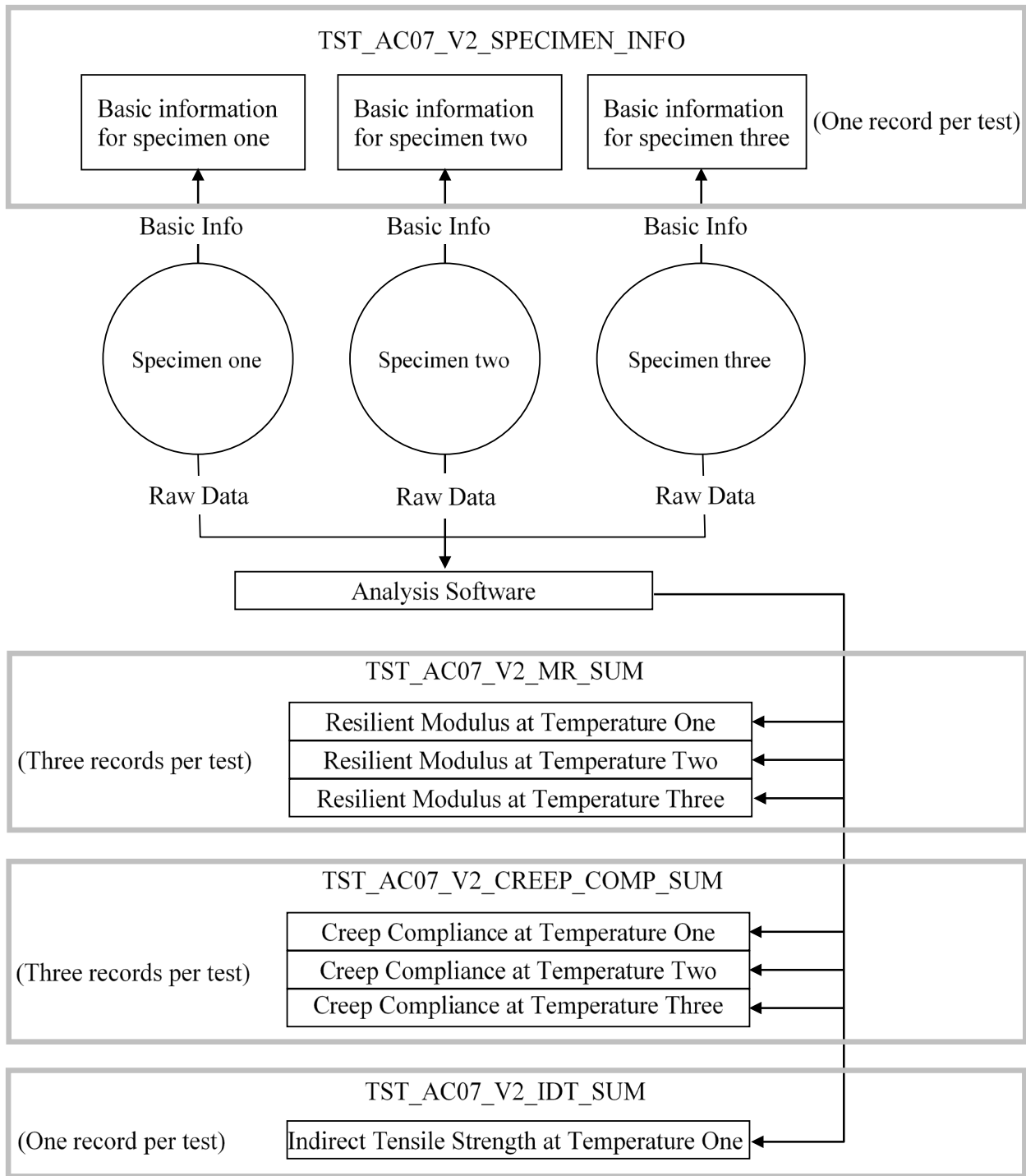
Names and descriptions of TST\_AC07\_V2 tables are as follows:

- TST\_AC07\_V2\_SPECIMEN\_INFO—considered the master table for a TST\_AC07\_V2 submodule. The TST\_AC07\_V2\_SPECIMEN\_INFO table also includes sample numbers for the three specimens used (SAMPLE\_NO\_\*), thickness information (THICKNESS\_SPECIMEN\_\*), diameter information (DIAMETER\_SPECIMEN\_\*), and BSG test results (BSG\_SPECIMEN\_\*). The TST\_AC07\_V2\_SPECIMEN\_INFO table also contains the unique filenames for the output files generated by the analysis software. These files are stored offline and can be assessed by contacting the LTPP CSSC at [ltppinfo@dot.gov](mailto:ltppinfo@dot.gov). 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—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, which is an output of the analysis software to account for the fact that the test procedure sometimes yields unreasonable Poisson’s ratios. The TST\_AC07\_V2\_MR\_SUM 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. These files are stored offline and can be assessed by contacting the LTPP CSSC at [ltppinfo@dot.gov](mailto:ltppinfo@dot.gov). The primary key includes the TEST\_TEMPERATURE field since the AC07 test is conducted at three different temperatures.
- TST\_AC07\_V2\_CREEP\_COMP\_SUM—contains summary data for the creep compliance tests. Creep compliance is stored in the CREEP\_COMP\_\*\_SEC fields, where \* is the time interval from 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 TST\_AC07\_V2\_MR\_SUM table description. 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 the TEST\_TEMPERATURE field since the AC07 test is conducted at three different temperatures.

- TST\_AC07\_V2\_IDT\_SUM—contains summary data for the indirect tensile strength tests. 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 the AC07 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 TST\_AC07\_V2\_MR\_SUM table description. Several other fields for the initial tangent modulus, fracture energy, and failure strain exist; however, the data to populate them are not included in SDRs because the algorithms used by the analysis software are insufficiently documented, could not be reverse-engineered, and are suspect. The primary key includes the TEST\_TEMPERATURE field, although the indirect tensile test is only conducted at one temperature.





Source: FHWA.

**Figure 28. Illustration. Relationships among TST\_AC07\* tables.**

## *Asphalt Cement Test Tables*

Names and descriptions of asphalt cement test tables are as follows:

- TST\_AE01—contains the results of the extraction of asphalt cement from field cores using 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, the AE01 test is conducted to provide material for the other extracted asphalt (AE) series tests, although the sample number for the input material is the same as the sample number for the output material.

The TST\_AE01S table is similar to the TST\_AE01 table except that the TST\_AE01S table was developed to accommodate data from SPS-3 projects 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—contains the results of penetration tests conducted on extracted asphalt cements at 25 °C (77 °F) and 68 °C (155 °F) (although plant-sampled asphalt cements were tested for some SPS projects). The three data fields are PENETRATION\_77\_F, PENETRATION\_155\_F, and PENETRATION\_INDEX.
- TST\_AE02S—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—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—contains the viscosity of asphalt cements as measured using a cone-and-plate viscometer. The AE04 test is conducted at a nominal temperature of 25 °C (77 °F). Data fields include viscosity and the corresponding shear rate for five surcharges (100, 300, 1,000, 3,000, and 10,000 grams (3.53, 10.58, 35.27, 105.82, and 352.74 ounces)), and the fracture load and failure shear stress. The AE04 test is no longer conducted.
- TST\_AE05—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—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 °F). 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—contains sample and test device configuration for DSR tests on asphalt cement. The results of the DSR tests are stored in the TST\_AE07\_DATA table. The TST\_AE07\_MASTER table uses the TST\_ID field as a primary key, allowing linking of test results to test samples and material layers on more than one test section.
- TST\_AE07\_DATA—contains the complex modulus and phase angle from DSR tests on asphalt cement samples at different temperatures. Sample and device configuration information for these test data is contained in the TST\_AC07\_MASTER table. The TST\_ID and AGING\_TYPE fields are used to link records between the TST\_AE07\_DATA and TST\_AC07\_MASTER tables. Currently, data contained in the TST\_AE07\_DATA table are from material samples from SPS-9 test sections. The TST\_AE07\_DATA table uses the TST\_ID field as a primary key, allowing linking of test results to test samples and material layers on more than one test section.
- TST\_AE08\_MASTER—contains sample, test device, and regression coefficients of the creep stiffness versus load time curve from BBR tests on asphalt cement samples from SPS-9 test sections at different test temperatures. The results of the BBR tests are contained in the TST\_AE08\_DATA table. Key fields used to link these data together include TST\_ID, AGING\_TYPE, and TEST\_TEMP.

The TST\_AE08\_MASTER table uses the TST\_ID field as a primary key, allowing linking of test results to test samples and material layers on more than one test section.

- TST\_AE08\_DATA—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 the TST\_AE08\_MASTER table are linked to records in the TST\_AE08\_DATA table using the TST\_ID, AGING\_TYPE, and TEST\_TEMP fields. The TST\_AE08\_DATA table uses the TST\_ID field as a primary key, allowing linking of test results to test samples and material layers on more than one test section.
- TST\_AE09\_MASTER—contains sample, test configuration, and summary statistics of the results of the 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 the TST\_AE09\_MASTER table are linked using the TST\_ID, AGING\_TYPE, and TEST\_TEMP fields. The

TST\_AE09\_MASTER table uses the TST\_ID field as a primary key, allowing linking of test results to test samples and material layers on more than one test section.

- TST\_AE09\_DATA—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 four 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. The TST\_AE09\_DATA table uses the TST\_ID field as a primary key, allowing linking of test results to test samples and material layers on more than one test section.
- TST\_AE10\_MASTER—contains sample, test configuration, and summary statistics of the results of the Multiple Stress Creep Recovery test on asphalt samples. The AE10 test is performed on samples from the SPS-10 warm mix experimental test sections. The TST\_AE10\_MASTER table is empty and is not expected to be released until the results of these tests become available. The TST\_AE10\_MASTER table uses the TST\_ID field as a primary key, allowing linking of test results to test samples and material layers on more than one test section.
- TST\_AE10\_DATA—contains the detailed results of Multiple Stress Creep Recovery tests on asphalt samples as a function of stress level and cycle number. The AE10 test is performed on samples from the SPS-10 warm mix experimental test sections. The TST\_AE10\_DATA table is empty and is not expected to be released until the results of these tests become available. The TST\_AE10\_DATA table uses the TST\_ID field as a primary key, allowing linking of test results to test samples and material layers on more than one test section.
- TST\_AE11—contains laboratory test results of asphalt cement samples from SPS-10 test sections to detect use of Recycled Engine Oil Bottoms. The TST\_AE11 table contains estimates of concentrations of calcium, copper, zinc, and molybdenum in parts per million. The REOB field contains a measure of the percentage of asphalt containing recycled engine oil bottoms. TST\_AE11 has a limited dataset. The TST\_AE11 table uses the TST\_ID field as a primary key, allowing linking of test results to test samples and material layers on more than one test section.
- TST\_AE12—contains data from the Rolling Film Oven Test, which is used to age asphalt samples for other subsequent tests. While the TST\_AE12 table tracks changes in sample numbers, it also reports on changes in the mass of the asphalt sample because of the artificial aging process applied to the material test samples. The TST\_AE12 table was added as a part of the SPS-10 warm mix experiment. The TST\_AE12 table is empty and is not expected to be released until the results of these tests become available.
- TST\_AE13—contains data from the aging of asphalt binder specimens using the Pressure Aging Vessel method. The TST\_AE13 table primarily tracks changes in sample numbers from before and after applying the pressure aging methodology. The TST\_AE13 table was created for the SPS-10 warm mix experiment. The TST\_AE13 table is empty and is not expected to be released until the results of these tests become available.

## ***Tables on Aggregate in AC***

Names and descriptions of aggregate in AC tables are as follows:

- TST\_AG01—contains the BSG 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—contains the BSG 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—contains the gradation of extracted aggregate from AC cores. Gradation is determined by sieve analysis.
- TST\_AG05—contains the fine aggregate shape test results for fine aggregate extracted from AC cores. Data include BSG, percent moisture absorption, and uncompacted void content, which are stored in the BSG, ABSORPTION, and UNCOMP\_VOID\_AVG fields, respectively.

## ***In Situ Tests***

Names and descriptions of in situ test tables are as follows:

- TST\_ISD\_MOIST—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 the TST\_ISD\_MOIST table. The DEPTH\_TOP\_STRATA field contains the depth (in inches) from the measuring surface to the pavement surface.
- TST\_SS14\_UG14\_MASTER—master table for Dynamic Cone Penetrometer tests performed on unbound bases and subgrades, starting with the SPS material action plan that began in 2005. One record is contained in the TST\_SS14\_UG14\_MASTER table for each test at a given location. The TST\_SS14\_UG14\_MASTER table contains information on the test equipment and test setup. The ZERO\_POINT\_DEPTH field contained in the TST\_SS14\_UG14\_MASTER table is needed to interpret the Dynamic Cone Penetrometer measurements contained in the TST\_SS14\_UG14\_DATA table.
- TST\_SS14\_UG14\_DATA—contains the results of the measurements from the Dynamic Cone Penetrometer test. Measurements are stored in the TST\_SS14\_UG14\_DATA 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 Dynamic Cone Penetrometer index, and an estimate of the California Bearing Capacity estimated using the table method contained in ASTM D6951-03, *Standard Test Method for Use of the*

*Dynamic Cone Penetrometer in Shallow Pavement Applications.* (ASTM 2003) To determine the depth below the surface of the pavement for each measurement, the ZERO\_POINT\_DEPTH field stored in the TST\_SS14\_UG14\_MASTER table must be subtracted from the PEN\_CUMULATIVE field contained in the TST\_SS14\_UG14\_DATA table.

- TST\_SS14\_UG14\_COMMENT—contains comments concerning the Dynamic Cone Penetrometer test.

### ***PCC Test Results***

Names and descriptions of PCC test results tables are as follows:

- TST\_PC01—contains compressive strength of PCC cores (for a few SPS projects, cylinders made from fresh PCC sampled during construction were tested). 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 length and diameter of the specimen, are also stored.
- TST\_PC02—contains splitting tensile strength of PCC cores and some cylinders (see description of the TST\_PC01 table). 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 length and diameter of the core, are also stored.
- TST\_PC03—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. To allow entry of repeat measurements on the same sample, the TEST\_SEQUENCE field is part of the key, but it does not necessarily imply order of testing.
- TST\_PC04—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—contains density measurements for PCC cores. BSG, 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 the TST\_PC05 table.
- TST\_PC06—contains visual examination notes for PCC cores. Six fields (VISUAL\_EXAM\_\*) are provided for visual comments of the type VISUAL\_ACPC (which means 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, the TST\_PC06 table also provides the thickness of the core, which is stored in the CORE\_AVG\_THICKNESS field.

- TST\_PC07—contains the interface shear strength between two bonded PCC layers. The PC07 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 the TST\_PC07 table.
- TST\_PC08—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—contains flexural strength of PCC beams poured from materials sampled at the time of construction. Because of the requirement for sampling during construction, data for the PC09 test are only available for SPS test sections. The modulus of rupture is stored in the MODULUS\_OF\_RUPTURE field. Several other intermediate calculations are also included.

#### ***Test Results for Materials Specific to SPS-3 and -4***

Names and descriptions of test results for materials specific to SPS-3 and -4 tables are as follows:

- TST\_CS01—contains data on hot-poured joint sealants for a few SPS-3 and -4 test sections. There are a small number of records in the TST\_CS01 table. For further information on these tests, see the SPS-3 and -4 data-collection guide.
- TST\_CS02—contains data on silicone joint sealants for a few SPS-3 and -4 test sections. There are a small number of records in the TST\_CS02 table. For further information, see the SPS-3 and -4 data-collection guide.
- TST\_SC01—contains the results of various tests on asphalt emulsions used in surface treatments applied to SPS-3 test sections only. Unlike most other tables in the Test module that contain the results for a single test, the TST\_SC01 table contains the results for many tests on the same material. Most of these tests are straightforward; however, some of them are unusual (in these cases, consult the SPS-3 and -4 data-collection guide).
- TST\_SC02—contains the sand equivalency of fine aggregate materials from SPS-3 test sections only. The sand equivalency value, expressed as a percentage, is stored in the SAND\_EQUIVALENCY field. No intermediate values are stored.
- TST\_SC03—contains the results of various tests on coarse aggregates used in surface treatments applied to SPS-3 test sections only. There are a small number of records in the TST\_SC03 table, and no further data are expected. For further information, see the SPS-3 and -4 data-collection guide.

- TST\_SC04—contains the flakiness index of aggregates used in surface treatments applied to SPS-3 test sections only. The flakiness index is stored in the FLAKINESS\_INDEX field. No intermediate calculations are stored.
- TST\_SC05—contains the results of various tests on slurry seals applied to SPS-3 test sections only. The TST\_SC05 table contains limited data, and no further data are expected. For further information, see the SPS-3 and -4 data-collection guide.
- TST\_SC07—contains the results of the wet stripping test of cured slurry seal mixes applied to SPS-3 test sections only. The TST\_SC07 table contains limited data, and no further data are expected. For further information, see the SPS-3 and -4 data-collection guide.
- TST\_SC08—contains the results of the slurry system compatibility test for slurry seals applied to SPS-3 test sections only. The TST\_SC08 table contains limited data, and no further data are expected. For further information, see the SPS-3 and -4 data-collection guide.
- TST\_SC09—contains the results of tests to identify quick-set asphalt emulsions used in surface treatments applied to SPS-3 test sections only. The TST\_SC09 table contains limited data, and no further data are expected. For further information, see the SPS-3 and -4 data-collection guide.
- TST\_SC10A—contains the gradation of aggregates used in chip seals applied to SPS-3 test sections only.
- TST\_SC10B—contains the gradation of aggregates used in slurry seals applied to SPS-3 test sections only.
- TST\_SC11—contains various data used in chip seal mix designs applied to SPS-3 test sections only. Factors such as the average least dimension of the aggregate (stored in the AVG\_LEAST\_DIMENSION field) and the rate of asphalt application (stored in the RESIDUAL\_ASPH\_SPREAD\_RATE field) are included.
- TST\_SC12—contains asphalt content of slurry seals applied to SPS-3 test sections only. The percent asphalt by weight of dry aggregate is stored in the ASPHALT\_CONTENT field. No intermediate results are available.

### ***Treated Base Test Results***

Names and descriptions of treated base test results tables are as follows:

- TST\_TB01—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 the DETAIL\_TREAT\_MATL and DETAIL\_TREAT\_TYPE 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 are 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—contains unconfined compressive strength results for treated base materials. Compressive strength (in lbf/inch<sup>2</sup>) is stored in the COMP\_STRENGTH field. Fracture mode (a code of the type FRACTURE) is stored in the COMP\_STRENGTH\_FRAC field.

### ***Unbound Materials Testing Results***

Names and descriptions of unbound materials testing results tables are as follows:

- TST\_SS01\_UG01\_UG02—contains the gradation of unbound coarse-grained granular base, subbase, and subgrade materials. If data are unavailable for a given material, check the TST\_SS02\_UG03 table.
- TST\_SS02\_UG03—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 the TST\_SS01\_UG01\_UG02 table, as are the associated field names. In addition, the hydrometer results are expressed as percent size smaller (i.e., passing) 0.02 mm (780 microinch), 0.002 mm (78 microinch), and 0.001 mm (39 microinch). These data are stored in fields whose names are based on the SI measurement convention. For example, HYDRO\_02 contains data passing, or smaller than, 0.02 mm (780 microinch). 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—contains the general classification of unbound granular base, subbase, and subgrade materials. Information in the TST\_SS04\_UG08 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—contains the modulus of the subgrade reaction (*k*-value) of unbound subgrade layers. The subgrade reaction is measured by static plate loading. Raw modulus (in lbf/inch<sup>2</sup>/inch) is stored in the SOIL\_MOD\_UNCORRECTED field, while the modulus as corrected for plate bending is stored in the SOIL\_MOD\_CORRECTED field.
- TST\_SS08—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—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—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 test 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—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. The TST\_SS12 table contains limited data, and no further data are expected.
- TST\_UG04\_SS03—contains 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—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 TST\_UG05\_SS05 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—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—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—contains the specific gravity of unbound base and subgrade materials. Since the unbound specific gravity test was not specified in the original material test guidelines for LTPP test sections, data are only available for a subset of test sections.

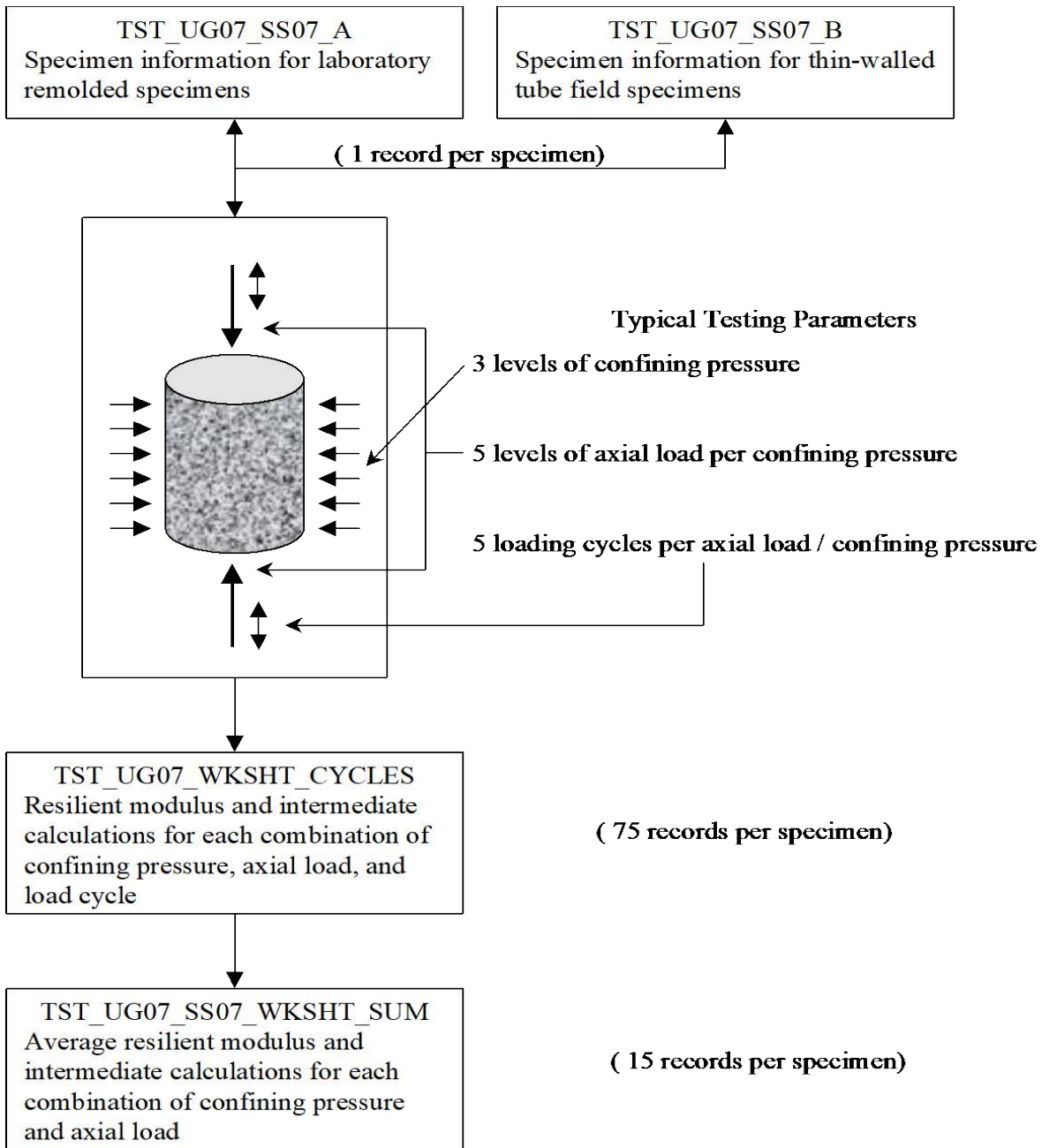
### ***Resilient Modulus of Unbound Materials TST\_UG07\_SS07\_\* Tables***

The TST\_UG07\_SS07 tables contain resilient modulus data for unbound granular base, subbase, and subgrade materials. Testing is conducted according to LTPP Protocol P46, Resilient Modulus of Unbound Granular Base/Subbase Materials and Subgrade Soils. (FHWA 1996) Analysts are encouraged to review the test protocol before using the data. The relational structure and some test details related to the TST\_UG07\_SS07 submodule are illustrated in figure 29.

Names and descriptions of TST\_UG07\_SS07\_\* tables are as follows:

- TST\_UG07\_SS07\_A—contains basic information on the tested specimen, as shown in figure 29. 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 strength of the specimen as measured in the quick shear test (STRENGTH). The TST\_UG07\_SS07\_A 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—contains basic information on the specimen being tested, as shown in figure 29. The TST\_UG07\_SS07\_B table contains similar information to the TST\_UG07\_SS07\_A table; however, it is for undisturbed thin-wall tube specimens only. As in the TST\_UG07\_SS07\_A table, information stored includes initial length (INITIAL\_LENGTH), initial area (INITIAL\_AREA), moisture content after testing (AFTER\_MOIST\_CONT), dry density (COMP\_DRY\_DENSITY), and strength of the specimen as measured in the quick shear test (STRENGTH).
- TST\_UG07\_SS07\_WKSHT\_CYCLES—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 the TST\_UG07\_SS07\_WKSHT\_CYCLES 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 2 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 the TST\_UG07\_SS07\_WKSHT\_CYCLES table for the typical 15 stress states. Applied cyclic stress is stored in the APPLIED\_CYCLIC\_STRESS field, corrected resilient deformation is stored in the CORR\_VERT\_DEF field, resilient strain is stored in the RES\_STRAIN field, and resilient modulus is stored in the RES\_MOD field. The primary key contains the typical keys, plus the CON\_PRESSURE, NOM\_MAX\_AXIAL\_STRESS, and CYCLE\_NO fields.

- TST\_UG07\_SS07\_WKSHT\_SUM—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 the TST\_UG07\_SS07\_WKSHT\_SUM 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 the APPLIED\_CYCLIC\_STRESS\_STD and RES\_STRAIN\_STD fields. 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 the CON\_PRESSURE and NOM\_MAX\_AXIAL\_STRESS fields.



Source: FHWA.

**Figure 29. Illustration. Relationships among TST\_UG07\_SS07\* tables.**

### Sampling Information Tables

The majority of field sampling information from materials sampled in-place in the field is stored in the TST\_HOLE\_LOG and TST\_SAMPLE\_LOG tables.

The TST\_HOLE\_LOG table contains a record of each core hole, bore hole, or test pit cut in an LTPP test section for the purpose of extracting material samples. The records in

TST\_HOLE\_LOG table include 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 in the TST\_HOLE\_LOG table. The date the sample was tested, where available, is in the same table as the test results.

The data in the TST\_HOLE\_LOG table can be linked to data in 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 FIELD\_SET, TEST\_NO, and LOC\_NO fields uniquely identify a hole.

In addition to being useful for linking to the TST\_HOLE\_LOG table, 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-inch) 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 mo.

- B = 6 mo.
- C = 12 mo.
- D = 18 mo.
- E = 24 mo.
- F = 48 mo.

On some SPS-9 projects, a three-character code is appended to the LOC\_NO. The LOC\_NO code starts with “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 mo after paving.

While the TST\_HOLE\_LOG table contains data for each test hole cut into an LTPP test section, often multiple samples are extracted from a given test hole. Additional sampling information can be found in the TST\_SAMPLE\_LOG table. The TST\_SAMPLE\_LOG information includes the depth from which the sample was taken and a description of the material sampled.

Records in the TST\_SAMPLE\_LOG table can be linked to records in 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 AC specimen from lab mixed material.
  - M = moisture sample.
  - N = uncompacted laboratory mixed material sample (AC).
  - P = broken pieces or chunks of material.
  - T = thin-wall tube.

M = material type:

A = AC.

C = asphalt cement.

G = untreated, unbound granular base/subbase.

P = PCC.

S = subgrade soil or fill material.

T = treated, bound, or stabilized base/subbase.

U = combined aggregate used in concrete mixes.

X = PCC 14-d test specimen.

Y = PCC 28-d test specimen.

Z = PCC 365-d 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. The SAMPLE\_NO 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:

t = time:

A = 0 mo.

B = 6 mo.

C = 12 mo.

D = 18 mo.

E = 24 mo.

F = 48 mo.

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 mo after construction).
- CA24A—AC cores obtained from SPS-9 projects at time interval A, immediately following paving.
- CT24—treated base cores.



- DA01—HMA specimen compacted in SHRP gyratory compactor.
- MS01—subgrade moisture content sample obtained from bulk sampling location.

***LTPP Database Tip!***

SAMPLE\_NO is not always a reliable way to classify materials or sample types. The TST\_SAMPLE tables should be used 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 the TST\_SAMPLE\_LOG\_LAB table.

***Other Sampling Information Tables***

The TST\_HOLE\_LOG and TST\_SAMPLE\_LOG tables contain information for all samples of in-place materials, including virtually all sampling conducted on GPS test sections. However, many SPS test sections and GPS overlay test 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).

Names and descriptions of other sampling information tables are as follows:

- TST\_ASPHALT\_CEMENT—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 test section. The TST\_ASPHALT\_CEMENT table also includes additional information about the plant itself.
- TST\_FRESH\_PCC—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, the TST\_FRESH\_PCC table contains information about the slump and air content of the sampled concrete.
- TST\_SAMPLE\_LOG\_LAB—contains information about specimens molded in the laboratory from bulk AC samples. The TST\_SAMPLE\_LOG\_LAB 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—contains sampling information for chip seal, slurry seal, or joint sealant material obtained in the field for SPS-3 and -4 test sections only. Treatment of LOC\_NO and SAMPLE\_NO is similar to the TST\_SAMPLE\_LOG table.
- TST\_UNCOMP\_BITUMINOUS—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, the TST\_UNCOMP\_BITUMINOUS table also contains information on the plant where the AC was mixed.

- TST\_SAMPLE\_COMBINE—stores information on samples combined in the laboratory from multiple samples obtained in the field. In the past, the combined sample SAMPLE\_NO convention using asterisks did not provide information on what samples were combined and the locations where the samples were obtained. In the TST\_SAMPLE\_COMBINE 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 the TST\_SAMPLE\_COMBINE table, one for each original sample combined.
- TST\_SAMPLE\_BASIC\_INFO—combines basic sampling information from all other sampling tables to make certain internal automated QC check operations easier and provide the user with a single source for sampling information. Information contained in the TST\_SAMPLE\_BASIC\_INFO 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.

## Layer Tables

The Test 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 pavement structure layers. In general, the TST\_L05A table can be thought of as the worksheet that summarizes layer thickness measurements within and at the ends of a test section. The TST\_L05B table provides a single recommended representative layer thickness for structural analysis. The representative layer thickness is based on data stored in the TST\_L05A table 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.

The TST\_L05A table contains multiple-layer thickness information. Each record in the TST\_L05A table is uniquely identified by the STATE\_CODE and SHRP\_ID of the test 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 chapter 3, Administration Module, in the Major Relational Fields section), and the LAYER\_NO that identifies the discrete material layers in the test section. Each record also includes a DESCRIPTION, which identifies the function of the layer in the pavement system, and a LAYER\_TYPE, which indicates the general composition of the layer.

For each record in the TST\_L05A table, 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 test section (LAYER\_THICK\_STATION0, MATERIAL\_CODE\_STATION0, and MEASURE\_TYPE\_\*\_STATION0), within the test section (LAYER\_THICK\_WITHIN, MATERIAL\_CODE\_WITHIN, and MEASURE\_TYPE\_\*\_WITHIN), and the leave end of the test section (LAYER\_THICK\_STATION5, MATERIAL\_CODE\_STATION5, and MEASURE\_TYPE\_\*\_STATION5).

For an LTPP test section, a LAYER\_NO of “1” is always assigned to the lowest identifiable layer in the test section, with progressively higher LAYER\_NOs assigned to 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 test section because of maintenance or rehabilitation treatments. For example, if a test section has an uppermost layer with a LAYER\_NO = 5 and that test 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 existing LAYER\_NOs.

Sometimes a layer will be entirely removed by milling; however, it will still be referenced by the existing LAYER\_NO, but the thickness will now be “0.” Again, while this may be counterintuitive, it maintains the referential integrity of the Test 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.

The TST\_L05B table is the master layer table for the entire Test module. It is the best source for pavement layer thickness information. The layer thickness values stored in the TST\_L05B 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 the TST\_L05B table contains representative thickness information based on multiple data sources and engineering judgment, as opposed to the measured layer thickness data stored in the TST\_L05A table. The SECTION\_LAYER\_STRUCTURE table is a copy of the TST\_L05B table.

Like the TST\_L05A table, each record in the TST\_L05B table 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 test 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 higher LAYER\_NO.

PROJECT\_LAYER\_NO is an SPS project-level layer identifier. The PROJECT\_LAYER\_NO field allows layers in different test sections on the same SPS project with the same material properties to be identified.

The DESCRIPTION field contains a code 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.

LAYER\_TYPE is a code 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, analyses of deflection data, and elevation surveys.

MATL\_CODE is a code that describes the material composition of the layer, based on the results of laboratory measurements and observations. MATL\_CODE is 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 agency-supplied layer information in the Inventory 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 agency data. The INV\_LAYER\_NO\_2 field is used in circumstances where a single layer as described in the TST\_L05B table is described as two separate layers in the Inventory module.

The TST\_L05 table contains information useful for linking project layers at SPS projects to layers in various SPS and INV tables. In practice, the TST\_L05 table does not contain any information that cannot also be obtained from the TST\_L05B table.

## 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 because 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 Test module and the same LAYER\_NO in the Inventory module refer to the same layer.

### ***LTPP Database Tip!***

Some basic materials characterization information is contained in the Inventory, SPS, and Rehabilitation and Maintenance modules. It may be of value in cases where such data are not available in the Test module.

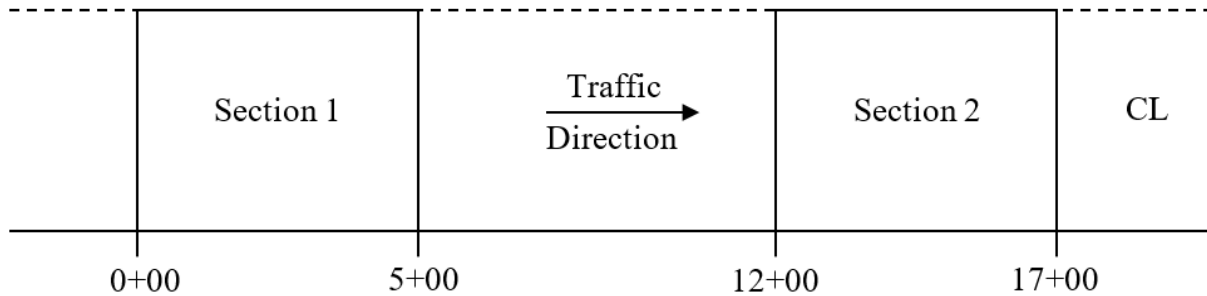
To link the TST layer tables and the INV layer table, the INV\_LAYER\_NO field and/or the INV\_LAYER\_NO2 field in the TST\_L05B table must be used. For each record in the TST\_L05B table, the INV\_LAYER\_NO field represents the LAYER\_NO used in the INV\_LAYER table to represent that layer. In some cases where a single layer in the TST\_L05B table 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 the TST\_L05B table from the same LTPP test section can share the same INV\_LAYER\_NO if they are treated as a single layer in INV\_LAYER.

### **SPS Complications**

Relating materials testing data back to the layers they represent is straightforward for GPS test sections. Generally, all that is needed is the STATE\_CODE and SHRP\_ID of the test section and the LAYER\_NO of the layer within that test section. Relating such data for SPS test sections, however, can be more complicated.

An understanding of some of the fundamental differences between the SPS and GPS test sections is necessary for understanding why SPS materials testing data are more complicated to access. GPS test sections are stand-alone in that each test section was sampled as a discrete entity. SPS test sections, however, are clustered with several adjacent test sections comprising a project. One of the advantages of such clustering is that these test 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 test sections (1 and 2). Figure 30 shows a plan view of this hypothetical project. Figure 31 shows the cross-sectional view of this hypothetical project and the layer numbering.



Source: FHWA.  
CL = centerline.

**Figure 30. Image. Plan view of hypothetical SPS project (not to scale).**

Section 01	Project Layer No.	Project Layer No.	Section 02	Project Layer No.	Project Layer No.
Asphalt (AC)	4	F	Asphalt (AC)	4	F
Asphalt (AC)	3	D	Asphalt (AC)	3	E
Granular Base (GB)	2	B	Treated Base (TB)	2	C
Subgrade (SS)	1	A	Subgrade (SS)	1	A

Source: FHWA.

**Figure 31. Image. Cross-sectional view of hypothetical SPS project.**

The layering of an LTPP test section can be obtained from the TST\_L05B table. From figure 31, we can see that the structures of the two test sections are similar, except that test section 01 has a granular base, while test section 02 has a treated base. In both cases, four layers have been identified. Thus, in both cases, they have been numbered 1–4 (despite the fact that layer 2 is different in composition for each test section).

In addition to the test section layer numbers (these are test sections at an SPS project), the TST\_L05B table also contains project layer numbers for these test 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 test sections are identical, it is understood that these layers are continuous and are expected to have similar properties.

### ***LTPP Database Tip!***

When seeking materials test results for an SPS test section, project layer numbers can be used to find tests of the same material on a different test section. Although material source and placement methods may be identical, construction variability may result in differences in material properties.

Since it is understood that layer F for these two test sections in figure 31 is virtually identical (barring construction variability stemming from the fact that they are 366 m (1,200 ft) apart), it is possible to cross-reference materials testing data between these test sections. For example, if an analyst wishes to calculate the air void content of layer 4 on test section 02, the analyst would first have to find the BSG and theoretical MSG of that material in the LTPP database. However, if only BSG results are available for that layer, the analyst could use a theoretical MSG result for layer 4 at test section 01, since there is good reason to expect the material properties are similar.

### **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 February 2004 SDR (data release 17). 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 TST\_ID field is used as the primary key index 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\_LO5B table using the STATE\_CODE, SHRP\_ID, CONSTRUCTION\_NO, and LAYER\_NO fields. The TST\_LINK\_SAMPLE table provides linkage between TST\_ID and material sampling information contained in the TST\_SAMPLE\_LOG table using the STATE\_CODE, SHRP\_ID, FIELD\_NO, and SAMPLE\_NO fields.

### **DYNAMIC MODULUS OF HMA MIXTURES**

Starting with the January 2010 SDR (data release 24), estimates of the dynamic modulus ( $|E^*|$ ) of HMA mixtures were added to the TST module.  $|E^*|$  is a fundamental material property that defines HMA stiffness as a function of temperature and load time.  $|E^*|$  is used as an input material property for HMA mixtures in MEPDG. The  $|E^*|$  estimates provided in the added tables were purposefully designed to match the level-1 input requirements of 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*. (Kim et al. 2011)

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, or dense-graded AC (i.e., MATL\_CODE “1” or “13” in the TST\_LO5B table).

- Placed as an original layer, overlay layer, or AC 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.

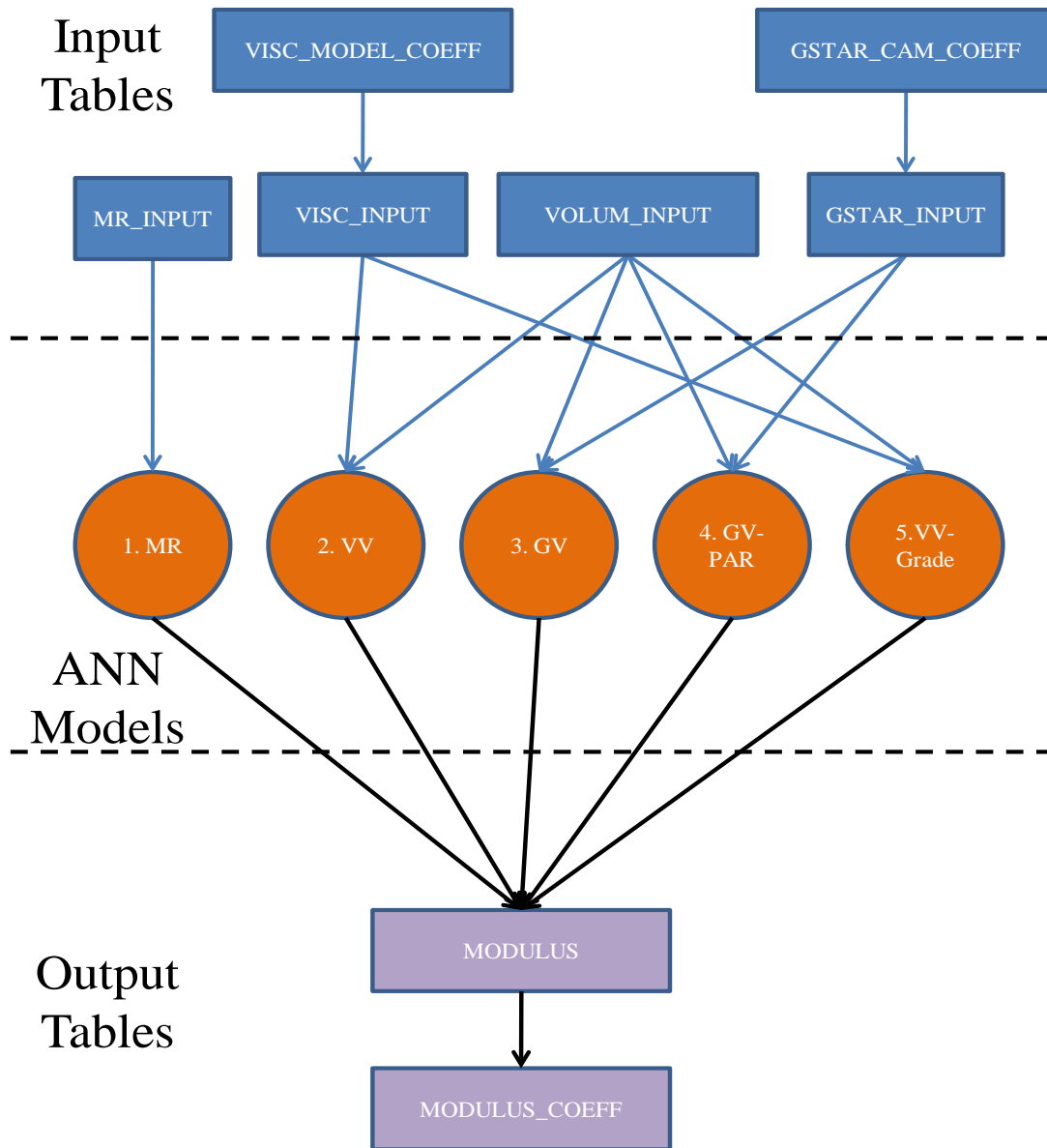
Nine tables are now contained in the LTPP database that include the inputs and outputs of the  $|E^*|$ -computed parameter process. Similar to the tables containing Superpave asphalt binder data, these tables also contain a single key field used to link related data in all of these tables to each other. 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 32 illustrates the relationships between the TST\_ESTAR tables. The tables shown in the upper portion of figure 32 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 (−10, 4.4, 21.1, 37.7, and 54.4 °C) and 25, 10, 5, 1, 0.5, and 0.1 Hz, which are the required inputs to MEPDG. These values are contained in the TST\_ESTAR\_MODULUS output table.

The numbers shown beside the ANN models in figure 32 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.





Source: FHWA.

**Figure 32. Schematic. Relationship between the TST\_ESTAR\_\* input tables, ANN models, and output tables containing estimated dynamic modulus for HMA layers on LTPP test sections. All tables link to the TST\_ESTAR\_MASTER table, which contains test section and layer identification information. (Kim et al. 2011)**

Names and descriptions of TST\_ESTAR tables are as follows:

- TST\_ESTAR\_MASTER—contains the central source of identification data for  $|E^*|$  estimates, which define a specific test section (e.g., 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. The TST\_ESTAR\_MASTER table also

defines the ESTAR\_LINK field, which is the central key that links all TST\_ESTAR tables to each other.

- TST\_ESTAR\_MODULUS—contains the raw output of the ANN models of predicted  $|E^*|$  at 14, 40, 70, 100, and 130 °F (−10, 4.4, 21.1, 37.7, and 54.4 °C) and 25, 10, 5, 1, 0.5, and 0.1 Hz. The  $|E^*|$  estimates in the TST\_ESTAR\_MODULUS table are in units of psi, and temperature in °F, which are the required units for MEPDG models.
- TST\_ESTAR\_MODULUS\_COEFF—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 the TST\_ESTAR\_MODULUS\_COEFF table are shown in figure 33:

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

**Figure 33. Equation. Dynamic modulus master curve showing coefficients stored in the database.**

Where:

$t_R$  = inverse of reduced frequency of loading, which is defined in the same way as reduced angular frequency in hertz instead of radians per second.

$\delta$  = SIGMOIDAL\_COEFF\_1 field.

$\alpha$  = SIGMOIDAL\_COEFF\_2 field.

$\beta$  = SIGMOIDAL\_COEFF\_3 field.

$\gamma$  = SIGMOIDAL\_COEFF\_4 field.

The TST\_ESTAR\_MODULUS\_COEFF table also contains coefficients for the time–temperature shift factor function for  $|E^*|$ , as show in figure 34:

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

**Figure 34. Equation. Dynamic modulus time–temperature shift factor showing coefficients stored in the database.**

Where:

$a_T$  = mixture time–temperature shift factor.

$T$  = temperature of interest.

$\alpha_1$  = SHIFT\_FACTOR\_COEFF\_1 field.

$\alpha_2$  = SHIFT\_FACTOR\_COEFF\_2 field.

$\alpha_3$  = SHIFT\_FACTOR\_COEFF\_3 field.

The TST\_ESTAR\_MODULUS\_COEFF table also contains MASTERCURVE\_QUALITY, a pass/fail field assigned by the data analysis team who performed the computations. The MASTERCURVE\_QUALITY field represents the goodness of fit of the  $|E^*|$  estimates contained in the TST\_ESTAR\_MODULUS table 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—contains the coefficients to the Christensen-Anderson-Marasteanu (CAM) model to predict  $|G^*|$  input values. The CAM model and mapping of the fields in the TST\_ESTAR\_GSTAR\_CAM\_COEFF table is shown in figure 35:

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

**Figure 35. Equation. CAM equation for complex shear modulus showing the coefficients stored in the database.**

Where:

- $G^*$  = complex shear modulus.
  - $\omega_R$  = reduced angular frequency.
  - $G_g$  = CAM\_COEFF\_1 field.
  - $\omega_c$  = CAM\_COEFF\_2 field.
  - $k$  = CAM\_COEFF\_3 field.
  - $m_e$  = CAM\_COEFF\_4 field.
- TST\_ESTAR\_GSTAR\_INPUT—contains the dynamic shear modulus of the asphalt binder  $|G^*|$  as a function of temperature and frequency. The TST\_ESTAR\_GSTAR\_INPUT table provides inputs to the GV and GV-PAR ANN models.
  - TST\_ESTAR\_MR\_INPUT—contains the measured resilient modulus from test section cores measured in indirect tension from the TST\_AC07\_V2\_MR\_SUM table. Data from the TST\_ESTAR\_MR\_INPUT table are used as an input to the MR ANN model.
  - TST\_ESTAR\_VISC\_MODEL\_COEFF—contains the coefficients for the asphalt binder temperature susceptibility relationship. The relationship used for these computations and mapping against fields in the TST\_ESTAR\_VISC\_MODEL\_COEFF table is shown in figure 36:

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

**Figure 36. Equation. Asphalt binder-temperature susceptibility relationship defining coefficient values store in the database.**

Where:

- $\eta$  = 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  $2.7 \times 10^{12}$  cP.

- TST\_ESTAR\_VISC\_INPUT—contains the binder viscosity inputs as a function of temperature used in the VV and VV-Grade ANN models.
- TST\_ESTAR\_VOLUM\_INPUT—contains the values of voids in the mineral aggregate as a percentage of total volume and voids filled with asphalt as a percentage of voids in the mineral aggregate for the HMA mixtures. Values in the TST\_ESTAR\_VOLUM\_INPUT table are used as inputs to the VV, GV, GV-PAR, and VV-Grade ANN models.

## **AC AIR VOIDS COMPUTED PARAMETERS**

Two computed parameter tables were created in 2017 to store the results of air voids calculated from BSG test results stored in TST\_AC02 and 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 Test 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 test section average MSG values for air void calculations.
- For test sections that do not have test results in the TST\_AC02 table, do not calculate or assign air void values.
- For BSG values where no corresponding MSG value exists, do not calculate air voids for the layer.

### **SPS Test 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 test section MSG value for air void 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 void calculations.

The air void values computed from each available combination of BSG with a corresponding MSG following the computation guidelines 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 (e.g., wheelpath/nonwheelpath), construction event, and material layer.

The TST\_AIR\_VOIDS\_CALC table contains the air voids calculated for each BSG value contained in the TST\_AC02 table that could be matched with an MSG value from the TST\_AC03 table. The TST\_AIR\_VOIDS\_CALC table indicates the source of the BSG and MSG data, as well as the values used for each air voids computation. Because of the way values are matched, the resulting computed air voids can result in a negative value. These negative values are identified in the level D QC checks and are not used in the TST\_AIR\_VOIDS\_SECT table calculations.

The TST\_AIR\_VOIDS\_SECT table contains test-section-level average air void values based on sample location and age. Only values that have RECORD\_STATUS = E in the TST\_AIR\_VOIDS\_CALC table are used to generate these test section-level computed parameters.



## CHAPTER 14. GROUND-PENETRATING RADAR MEASUREMENTS

### INTRODUCTION

In 2003, GPR measurements were taken on a subset of LTPP test sections to provide an estimate of layer thickness variations within the monitoring portion of the test section. Measurements were taken on all SPS-1 project sites still in service at the time. Measurements were also performed on selected SPS-2, -5, and -6 project sites. The results of the measurements are stored in the GPR data module.

Measurements were taken using an air-coupled antenna. Measurements were taken at 152-mm (6-inch) intervals using a sampling rate of 256 samples per measurement. Thickness interpretations were averaged over a 0.305-m (1-ft) 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 were taken in the outside (i.e., right) wheelpath and center of the lane.

### GPR TABLES

GPR data are stored in four tables in PPDB. The key fields used to link together a dataset in these tables include STATE\_CODE, SHRP\_ID, GPR\_DATE, and LANE\_POSITION. The GPR\_LAYER\_NO field is used to identify pavement layers.

Names and descriptions of GPR tables are as follows:

- GPR\_MASTER—one record is included in the GPR\_MASTER table for each measurement pass on a test section. Typically, there are two measurement passes on a test section. The LANE\_POSITION field indicates if the measurement pass is in the outside (i.e., right) wheelpath using a code of “R,” or in the center of the lane using a code of “C.” The GPR\_MASTER 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 thickness interpretation (ANALYSIS\_SOFTWARE\_VER).
  - Equipment calibration coefficients (PLATE\_HIGH\_CAL\_SLOPE and PLATER\_HIGH\_CAL\_INTERCEPT).
  - Name of the raw datafile from the GPR device (RAW\_DATA\_FILE).
- GPR\_THICK\_POINT—contains the results of thickness interpretations from GPR measurements. The average thickness and dielectric constant of recognizable layers, or group of layers, is stored in 0.305-m (1-ft) 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 test sections with asphalt-treated base layers, the combined GPR layer may be represented as AC.

- **GPR\_THICK\_SECT**—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 the **GPR\_THICK\_SECT** table to those in the point table include **STATE\_CODE**, **SHRP\_ID**, **GPR\_DATE**, **LANE\_POSITION**, and **GPR\_LAYER\_NO**. Statistics contained in the **GPR\_THICK\_SECT** table include the average, minimum, and maximum 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 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 layers identified by GPR to those included in the **TST\_L05B** table. This is 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 the **TST\_L05B** table.

In providing the link between layers, the layer description was assigned to the uppermost 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

### BACKGROUND

Tables in the DCV module contain data compiled from other existing tables with the 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 containing 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, the DCV tables also expand linked and project-level data to create individual test-section-level records. While the DCV module's information is technically implemented as a "view" in database terminology, they are presented as tables in the SDR.

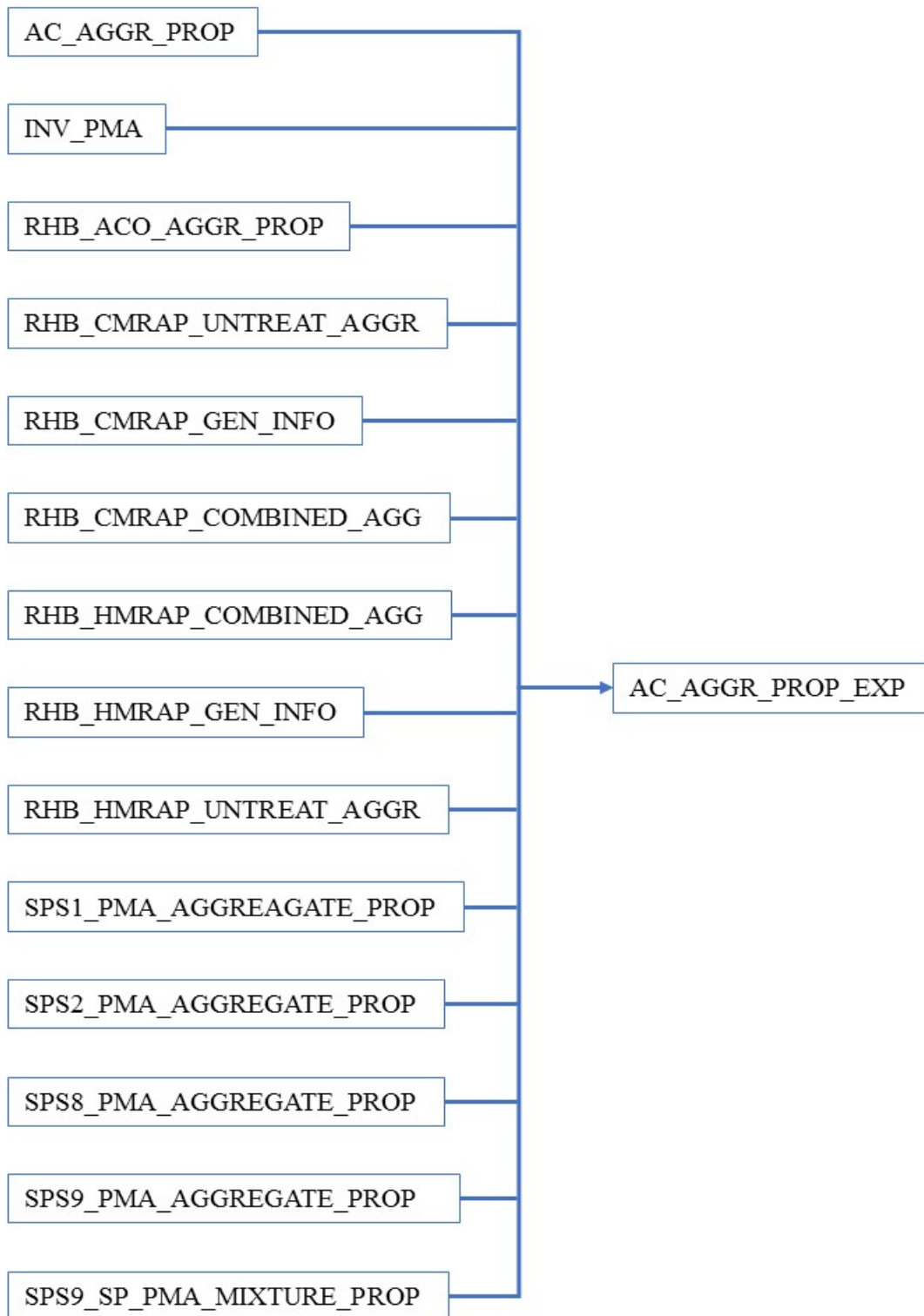
The July 2018 SDR (data release 32) contained a new set of DCV tables. In addition to a change in table names, the DCV tables now contain all of the data fields contained in the compiled source tables.

These tables are intended to make access to data using the traditional SDR in MS Access format easier to use and make the data selection and download feature in InfoPave more user-friendly.

### DCV RELEASE

The tables in the DCV module first released in the January 2013 SDR (data release 27) as a beta or trial status in the interest of receiving data user feedback are now replaced with the new tables contained in data release 32. These tables are issued as part of the normal SDR. Unlike most other PPDB modules, these tables do not have a module designation in the table name; however, they do all end in "EXP" to set them apart from similarly named tables on which they are based. The DCV module contains combined data from the Maintenance, Inventory, Rehabilitation, and SPS modules.

Figure 37 provides a graphical example of the extent of consolidation by combining aggregate property data from 14 primary source tables into one table. In this case, aggregate property data elements are the same regardless of the type of asphalt mixture. For example, the RHB tables are split by type of AC mixture. The SPS tables are split only by experiment designation. A subtle detail is that some SPS-9 projects are overlays; thus, aggregate data for existing layers prior to applying 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\_PMA\_AGGREGATE\_PROP table. AC\_AGG\_PROP\_EXP is a compilation table that stores all these data in one table using test-section-specific referential data.



Source: FHWA.

**Figure 37. Schematic. Source tables for the AC\_AGG\_PROP\_EXP table included in the DCV module.**

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

- In general, the compiled tables contain all the information stored in the source tables.
- In some cases, a new consolidated code set was developed to combine tables with similar but different code fields.
- To the extent possible, tables in the DCV module do not contain construction numbers, because they are layer-specific or independent of changes in the pavement structure over time. The most notable exceptions are the CONSTRUCTION\_EVENTS\_EXP and SECTION\_STRUCTURE tables, whose primary purpose is to document changes in pavement structure over time.
- No judgment was applied to 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.
- Because tables in the DCV module are technically “views,” they are not subject to unique QC checks. Instead, the RECORD\_STATUS values in the DCV tables are based on the values contained in the source tables. When multiple tables are used as a source for a single new record, the lowest RECORD\_STATUS value is used to represent the entire new record.

## **DCV TABLES**

Tables in the DCV module contain data from the Maintenance, Inventory, Rehabilitation, and SPS modules. Names and descriptions of the combined and expanded tables are as follows:

- AC\_AGED\_BINDER\_EXP—contains properties of the binder used in AC mixtures after aging. Uses data combined from the AC\_AGED\_BINDER, INV\_PMA ASPHALT, RHB\_ACO\_LAB\_AGED\_AC, RHB\_CM RAP\_LAB\_AGED\_AC, and RHB\_HM RAP\_LAB\_AGED\_AC tables.
- AC\_AGGR\_COMP\_EXP—contains composition information for aggregates used in AC layers. Uses data combined from the AC\_AGGR\_COMP, INV\_AGGR\_COMP, RHB\_ACO\_AGGR\_PROP, RHB\_CM RAP\_UNTREAT\_AGGR, RHB\_HM RAP\_UNTREAT\_AGGR, SPS1\_PMA\_AGGREGATE\_PROP, SPS2\_PMA\_AGGREGATE\_PROP, SPS8\_PMA\_AGGREGATE\_PROP, SPS9\_PMA\_AGGREGATE\_PROP, and SPS9\_SP\_PMA\_AGGREGATE\_PROP tables.
- AC\_AGGR\_DUR\_EXP—contains durability data for aggregates used in AC layers. Uses data combined from the AC\_AGGR\_DUR, INV\_AGGR\_DUR, RHB\_ACO\_AGGR\_PROP, RHB\_CM RAP\_UNTREAT\_AGGR, RHB\_HM RAP\_UNTREAT\_AGGR, SPS1\_PMA\_AGGREGATE\_PROP, SPS2\_PMA\_AGGREGATE\_PROP, SPS8\_PMA\_AGGREGATE\_PROP, and SPS9\_PMA\_AGGREGATE\_PROP tables.

- AC\_AGGR\_GRADATION\_EXP—contains gradation information for aggregate used in AC mixtures. Uses data combined from the AC\_AGGR\_GRADATION, INV\_GRADATION, RHB\_ACO\_AGGR\_PROP, RHB\_CMRAAP\_COMBINED\_AGG, RHB\_CMRAAP\_GEN\_INFO, RHB\_CMRAAP\_UNTREAT\_AGG, RHB\_HMRAP\_COMBINED\_AGG, RHB\_HMRAP\_GEN\_INFO, and RHB\_HMRAP\_UNTREAT\_AGG tables.
- AC\_AGGR\_PROP\_EXP—contains the physical properties of aggregate used in AC mixtures. Uses data combined from the AC\_AGGR\_PROP, INV\_PMA, RHB\_ACO\_AGGR\_PROP, RHB\_CMRAAP\_COMBINED\_AGG, RHB\_CMRAAP\_GEN\_INFO, RHB\_CMRAAP\_UNTREAT\_AGG, RHB\_HMRAP\_COMBINED\_AGG, RHB\_HMRAP\_GEN\_INFO, RHB\_HMRAP\_UNTREAT\_AGG, SPS1\_PMA\_AGGREGATE\_PROP, SPS2\_PMA\_AGGREGATE\_PROP, SPS8\_PMA\_AGGREGATE\_PROP, SPS9\_PMA\_AGGREGATE\_PROP, and SPS9\_SP\_PMA\_AGGREGATE\_PROP tables.
- AC\_AGGR\_RECYCLED\_EXP—contains type and storage information for recycled aggregates used in AC mixtures. Uses data combined from the AC\_AGGR\_RECYCLED, RHB\_CMRAAP\_GEN\_INFO, and RHB\_HMRAP\_GEN\_INFO tables.
- AC\_AGGR\_SP\_PROP\_EXP—contains Superpave-related physical properties of the aggregate used in AC mixtures. Uses data combined from the AC\_AGGR\_SP\_PROP, RHB\_ACO\_SP\_AGGR\_PROP, and SPS9\_SP\_PMA\_AGGREGATE\_PROP tables.
- AC\_ANTISTRIPPING\_EXP—contains AC antistripping agent information. Uses data combined from the AC\_ANTISTRIPPING, INV\_PMA\_ORIG\_MIX, RHB\_ACO\_MIX\_PROP, RHB\_CMRAAP\_MIX\_PROP, RHB\_HMRAP\_MIX\_PROP, SPS1\_PMA\_MIXTURE\_PROP, SPS2\_PMA\_MIXTURE\_PROP, SPS9\_PMA\_MIXTURE\_PROP, and SPS9\_SP\_PMA\_MIXTURE\_PROP tables.
- AC\_BINDER\_EXP—contains properties of the binder used in AC mixtures. Uses data combined from the AC\_BINDER, INV\_PMA ASPHALT, RHB\_ACO\_PROP, RHB\_ACO\_SP\_PROP, RHB\_CMRAAP\_COMBINE\_AC, RHB\_CMRAAP\_NEW\_AC\_PROP, RHB\_CMRAAP\_RECLAIM\_AC, RHB\_HMRAP\_COMBINE\_AC, RHB\_HMRAP\_NEW\_AC\_PROP, RHB\_HMRAP\_RECLAIM\_AC, SPS1\_PMA\_AC\_PROPERTIES, SPS2\_PMA\_AC\_PROPERTIES, SPS8\_PMA\_AC\_PROPERTIES, SPS9\_PMA\_AC\_PROPERTIES, and SPS9\_SP\_PMA\_AC\_PROPERTIES tables.
- AC\_COMPACTION\_EXP—contains compaction data for AC layers. Uses data combined from the AC\_COMPACTION, INV\_PMA\_COMPACTION, RHB\_PMA\_COMPACTION, SPS1\_PMA\_COMPACTION, SPS2\_PMA\_COMPACTION, SPS5\_PMA\_COMPACTION, SPS6\_PMA\_COMPACTION, SPS8\_PMA\_COMPACTION, and SPS9\_PMA\_COMPACTION tables.

- AC\_CONSTRUCTION\_TEMPS\_EXP—contains construction temperature data for AC layers. Uses data combined from the AC\_CONSTRUCTION\_TEMPS, INV\_PMA\_CONSTRUCTION, RHB\_PMA\_CONSTRUCTION, SPS1\_PMA\_CONSTRUCTION, SPS2\_PMA\_CONSTRUCTION, SPS5\_PMA\_CONSTRUCTION, SPS6\_PMA\_CONSTRUCTION, SPS8\_PMA\_CONSTRUCTION, and SPS9\_PMA\_CONSTRUCTION tables.
- AC\_DENSITY\_MEAS\_EXP—contains AC layers density data used for construction QC. Uses data combined from the AC\_DENSITY\_MEAS, SPS1\_PMA\_DENSITY\_PROFILE, SPS5\_QC\_MEASUREMENTS, SPS6\_QC\_MEASUREMENTS, SPS8\_PMA\_DENSITY\_PROFILE, and SPS9\_PMA\_DENSITY tables.
- AC\_DSR\_EXP—contains DSR, BBR, and DT tests for binders used in AC mixtures. Uses data combined from the AC\_DSR, RHB\_ACO\_SP\_PROP, and SPS9\_SP\_PMA\_AC\_PROPERTIES tables.
- AC\_LAB\_MIX\_EXP—contains AC laboratory mix design properties. Uses data combined from the AC\_LAB\_MIX, RHB\_ACO\_LAB\_MIX, RHB\_CM RAP\_LAB\_MIX, RHB\_HMRAP\_LAB\_MIX, and SPS9\_PMA\_MIX\_DES\_PROP tables.
- AC\_LAB\_MIX\_RECYCLE\_EXP—contains laboratory mix design properties specific to recycled AC mixtures. Uses data combined from the AC\_LAB\_MIX\_RECYCLE and RHB\_CM RAP\_COMBINE\_AC tables.
- AC\_MILLING\_EXP—contains information on AC milling operations. Uses data combined from the AC\_MILLING, SPS5\_MILLED\_SECTIONS, and SPS9\_MILLED\_SECTIONS tables.
- AC\_MIXTURE\_EXP—contains AC mixture properties as placed. Uses data combined from the AC\_MIXTURE, INV\_PMA\_ORIG\_MIX, RHB\_ACO\_MIX\_PROP, RHB\_CM RAP\_MIX\_PROP, RHB\_HMRAP\_MIX\_PROP, SPS1\_PMA\_MIXTURE\_PROP, SPS2\_PMA\_MIXTURE\_PROP, SPS8\_PMA\_MIXTURE\_PROP, SPS9\_PMA\_MIXTURE\_PROP, and SPS9\_SP\_PMA\_MIXTURE\_PROP tables.
- AC\_MODIFIER\_EXP—contains test section lane, width, and speed information. Uses data combined from the AC\_MODIFIER, INV\_MODIFIER, RHB\_ACO\_PROP, RHB\_CM RAP\_COMBINE\_AC, RHB\_HMRAP\_COMBINE\_AC, SPS1\_PMA\_AC\_PROPERTIES, SPS2\_PMA\_AC\_PROPERTIES, SPS8\_PMA\_AC\_PROPERTIES, and SPS9\_PMA\_AC\_PROPERTIES tables.
- AC\_MOIST\_SUSCEPT\_EXP—contains AC mixture moisture susceptibility test results. Uses data combined from the AC\_MOIST\_SUSCEPT, RHB\_ACO\_MIX\_PROP, RHB\_CM RAP\_MIX\_PROP, and RHB\_HMRAP\_MIX\_PROP tables.

- AC\_PLACEMENT\_EXP—contains placement information for AC layers. Uses data combined from the AC\_PLACEMENT, SPS1\_PMA\_PLACEMENT\_DATA, SPS2\_PMA\_PLACEMENT\_DATA, SPS5\_OVERLAY, SPS6\_OVERLAY, SPS8\_PMA\_PLACEMENT\_DATA, and SPS9\_PMA\_PLACEMENT\_INFO tables.
- AC\_PROFILE\_MEAS\_EXP—contains AC layers profile data used for construction QC. Uses data combined from the AC\_PROFILE\_MEAS, SPS1\_PMA\_DENSITY\_PROFILE, SPS5\_QC\_MEASUREMENTS, SPS6\_QC\_MEASUREMENTS, SPS8\_PMA\_DENSITY\_PROFILE, and SPS9\_PMA\_PROFILE tables.
- AC\_ROLLER\_EXP—contains compaction equipment data for AC layers. Uses data combined from the AC\_ROLLER, INV\_PMA\_ROLLER, RHB\_PMA\_ROLLER, SPS1\_PMA\_ROLLER, SPS2\_PMA\_ROLLER, SPS5\_PMA\_ROLLER, SPS6\_PMA\_ROLLER, SPS8\_PMA\_ROLLER, and SPS9\_PMA\_ROLLER tables.
- CONSTRUCTION\_EVENTS\_EXP—contains improvement information, including maintenance and rehabilitation events. Uses data combined from the CONSTRUCTION\_EVENTS, MNT\_IMP, and RHB\_IMP tables.
- PCC\_ADMIX\_EXP—contains PCC admixture amounts and types. Uses data combined from the INV\_ADMIX, RHB\_PCCO\_MIXTURE, SPS2\_PCC\_MIXTURE\_DATA, and SPS8\_PCC\_MIXTURE\_DATA tables.
- PCC\_AGGR\_COMP\_EXP—contains composition information for aggregates used in PCC layers. Uses data combined from the INV\_AGGR\_COMP, RHB\_PCCO\_AGGR, SPS2\_PCC\_MIXTURE\_DATA, and SPS8\_PCC\_MIXTURE\_DATA tables.
- PCC\_AGGR\_DUR\_EXP—contains durability data for aggregates used in PCC layers. Uses data combined from the INV\_AGGR\_DUR, RHB\_PCCO\_AGGR, SPS2\_PCC\_MIXTURE\_DATA, and SPS8\_PCC\_MIXTURE\_DATA tables.
- PCC\_AGGR\_GRADATION\_EXP—contains gradation information for aggregate used in PCC mixtures. Uses data combined from the INV\_GRADATION, RHB\_PCCO\_AGGR, SPS2\_PCC\_MIXTURE\_DATA, and SPS8\_PCC\_MIXTURE\_DATA tables.
- PCC\_AGGR\_PROP\_EXP—contains the physical properties of aggregate used in PCC mixtures. Uses data combined from the INV\_PCC\_MIXTURE, RHB\_PCCO\_AGGR, SPS2\_PCC\_MIXTURE\_DATA, and SPS8\_PCC\_MIXTURE\_DATA tables.
- PCC\_CONSTRUCTION\_EXP—contains PCC paver, curing, and texturing information. Uses data from the INV\_PCC\_MIXTURE table.
- PCC\_JOINT\_FORMING\_EXP—contains PCC joint-forming methods. Uses data combined from the INV\_PCC\_JOINT, RHB\_PCCO\_JOINT\_DATA,

SPS2\_PCC\_JOINT\_DATA, SPS7\_PCCO\_JOINT\_DATA, and SPS8\_PCC\_JOINT\_DATA tables.

- PCC\_JOINT\_SEALANT\_EXP—contains PCC joint sealant type, reservoir, and backer information. Uses data combined from the INV\_PCC\_JOINT, RHB\_PCCO\_JOINT\_DATA, SPS2\_PCC\_JOINT\_DATA, SPS7\_PCCO\_JOINT\_DATA, and SPS8\_PCC\_JOINT\_DATA tables.
- PCC\_JOINT\_SPACING\_EXP—contains PCC joint spacing information. Uses data combined from the INV\_PCC\_JOINT, RHB\_PCCO\_JOINT\_DATA, SPS2\_PCC\_JOINT\_DATA, SPS7\_PCCO\_JOINT\_DATA, and SPS8\_PCC\_JOINT\_DATA tables.
- PCC\_LOAD\_TRANSFER\_EXP—contains PCC joint load transfer type and placement information. Uses data combined from the INV\_PCC\_JOINT, RHB\_PCCO\_JOINT\_DATA, SPS2\_PCC\_JOINT\_DATA, and SPS8\_PCC\_JOINT\_DATA tables.
- PCC\_MIXTURE\_EXP—contains PCC mixture and mix design information. Uses data combined from the INV\_PCC\_MIXTURE, RHB\_PCCO\_MIXTURE, SPS2\_PCC\_MIXTURE\_DATA, and SPS8\_PCC\_MIXTURE\_DATA tables.
- PCC\_STEEL\_EXP—contains PCC layers reinforcing steel. Uses data combined from the INV\_PCC\_STEEL and SPS2\_PCC\_STEEL tables.
- PCC\_STRENGTH\_EXP—contains PCC layer strength information. Uses data combined from the INV\_PCC\_STRENGTH and RHB\_PCCO\_STRENGTH tables.
- PCC\_TIE\_BARS\_EXP—contains PCC joint tie bar information. Uses data combined from the INV\_PCC\_JOINT, RHB\_PCCO\_JOINT\_DATA, SPS2\_PCC\_JOINT\_DATA, and SPS8\_PCC\_JOINT\_DATA tables.
- PROJECT\_HIST\_AGE\_EXP—contains date information for the original pavement test section. Uses data combined from the INV\_AGE and PROJECT\_HIST\_AGE tables.
- PROJECT\_ID\_EXP—contains project site information. Uses data combined from the INV\_AGE, INV\_GENERAL, INV\_ID, PROJECT\_ID, and SPS\_ID tables.
- PROJECT\_INTERSECTIONS\_EXP—contains project-level intersection information. Uses data combined from the PROJECT\_INTERSECTIONS and SPS\_INTERSECTIONS tables.
- PROJECT\_MAJOR\_IMP\_EXP—contains information for major rehabilitation and construction events that took place after the pavement was constructed but before the test section became part of the LTPP program. Uses data combined from the INV\_MAJOR\_IMP and PROJECT\_MAJOR\_IMP tables.

- PROJECT\_STATIONS\_EXP—contains identification of order, length, and location of test sections within an SPS project. Uses data combined from the PROJECT\_STATIONS and SPS\_PROJECT\_STATIONS tables.
- SECTION\_CONSTRUCTION\_NOTES\_EXP—contains test section notes and comments. Uses data combined from the SECTION\_CONSTRUCTION\_NOTES, SPS1\_NOTES\_AND\_COMMENTS, SPS2\_NOTES\_AND\_COMMENTS, SPS5\_NOTES\_AND\_COMMENTS, SPS6\_NOTES\_AND\_COMMENTS, SPS7\_NOTES\_AND\_COMMENTS, SPS8\_NOTES\_AND\_COMMENTS, and SPS9\_NOTES\_AND\_COMMENTS tables.
- SECTION\_CONST\_LAYER\_EXP—describes the originally built structure of the pavement. Uses data combined from the INV\_LAYER, SECTION\_CONST\_LAYER, SPS1\_LAYER, SPS2\_LAYER, SPS5\_LAYER, SPS6\_LAYER, SPS7\_LAYER, SPS8\_LAYER, and SPS9\_LAYER tables.
- SECTION\_DRAINAGE\_EXP—contains test section subsurface drainage information. Uses data combined from the INV\_GENERAL, SECTION\_DRAINAGE, and SPS\_GENERAL tables.
- SECTION\_GENERAL\_EXP—contains test section lane, width, and speed information. Uses data combined from the INV\_GENERAL, INV\_ID, SECTION\_GENERAL, SPS\_GENERAL, and SPS\_ID tables.
- SECTION\_SHOULDER\_EXP—contains test section shoulder information. Uses data combined from the INV\_SHOULDER, SECTION\_SHOULDER, and SPS\_GENERAL tables.
- SUBDRAIN\_RETROFIT\_EXP—contains subdrainage retrofit data. Uses data combined from the RHB\_SUBDRAINAGE, SPS6\_SUBDRAINAGE, SPS7\_SUBDRAINAGE, and SPS9\_SUBDRAINAGE tables.
- SUBGRADE\_LAYER\_PROP\_EXP—contains subgrade layer properties. Uses data combined from the INV\_SUBGRADE and SUBGRADE\_LAYER\_PROP tables.
- SUBGRADE\_PREP\_EXP—contains subgrade stabilization and compaction information. Uses data combined from the SPS1\_SUBGRADE\_PREP, SPS2\_SUBGRADE\_PREP, SPS8\_SUBGRADE\_PREP, and SPS9\_SUBGRADE\_PREP tables.
- UNBOUND\_GRADATION\_EXP—contains unbound or stabilized base or subbase layer gradation information. Uses data from the INV\_GRADATION table.
- UNBOUND\_LAYER\_PROP\_EXP—contains unbound or stabilized base or subbase layer properties. Uses data combined from the INV\_UNBOUND and UNBOUND\_LAYER\_PROP tables.



- UNBOUND\_STABIL\_EXP—contains unbound layer stabilizing agent data. Uses data combined from the INV\_STABIL, SPS1\_SUBGRADE\_PREP, SPS2\_SUBGRADE\_PREP, SPS8\_SUBGRADE\_PREP, and UNBOUND\_STABIL tables.
- MNT\_IMP\_SOURCE—contains the location of the detailed information for maintenance events recorded in the MNT\_IMP table.

In the MNT\_IMP table, 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 test section might indicate that further information is available, but it is not immediately clear if it is stored in the MNT\_PCC\_PART\_DEPTH table or the SPS6\_PCC\_PART\_DEPTH table. The MNT\_IMP\_SOURCE table identifies the source of further information directly in a field called DETAIL\_LOCATION to remove the guesswork of where available information is stored.

The source tables that contain available data from entries in the MNT\_IMP table include the 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 tables.

- SECTION\_LAYOUT—contains test section layout and location information. Uses data combined from the INV\_ID, INV\_GENERAL, SPS\_ID, SPS\_GENERAL, and SPS\_PROJECT\_STATIONS tables.

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

- SECTION\_STRUCTURE\_HISTORY—contains information on dates of structural changes to each test section, including original construction, milling, overlays, and crack and seat events. The SECTION\_STRUCTURE\_HISTORY table contains a mixture of data extracted from the EXPERIMENT\_SECTION, RHB\_IMP, SPS\_ID, INV\_AGE, and SECTION\_LAYER\_STRUCTURE tables.

Because most 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. The

SECTION\_STRUCTURE\_HISTORY 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 (i.e., partial) milling event, and the second milling event that fully removed the layer.

## 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 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 grouped into data modules primarily based on level of summarization data type.

### 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 are included in each database.

**Administration:** The Administration database contains tables that describe the structure of the database, the processing completed, and the master test section control table. Key tables in the administration database 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 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—databases contain data on the number of axles by vehicle class and axle group.
- Annual\_Count—databases contain data on counts and errors identified through rules in the data loading process or review of the data. The data come from volume, classification, and weight records.
- Annual\_GVW—databases contain data on gross vehicle weights aggregated by vehicle class.

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

- Monthly\_Axles—databases contain data on the number of axles by vehicle class and axle group.
- Monthly\_Count—databases contain summarized vehicle counts by month and day of week separately for classification and weight data.
- Monthly\_GVW—databases contain data on gross vehicle weights by vehicle class.

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

- Daily\_Axles—databases contain data on the number of axles by vehicle class and axle group.
- Daily\_Count\_ERR—databases contain data on counts and errors identified through rules in the data loading process or review of the data. The data come from volume, classification, and weight records.
- Daily\_GVW—databases contain data on gross vehicle weights aggregated by vehicle class.

Hourly: This database contains data on hourly classification counts.

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 an MS Access database format. Only the tables included in the Administration database are populated; data in all other data table structures have been removed.

## **MAJOR 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 to which data are submitted. The VEH\_CLASS scheme is frequently, but not always, the 13-bin TMG vehicle classification scheme. Count fields for data using the input classification are of the form COUNTnn.

VEHICLE\_CLASS refers to the 13-bin TMG vehicle classification scheme. (Note that although the classification system is named 13-bin for historical reasons, it has 15 classes.) The VEHICLE\_CLASS 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 the TRF\_MONITOR\_AXLE\_DISTRIB table 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 (e.g., single, tandem, triple, or quad-plus). The AXLE\_GROUP variable is used within all axle distribution tables (DD\_AX, MM\_AX, YY\_AX, and TRF\_MONITOR\_AXLE\_DISTRIB). Note that steering axle groups (i.e., front axles) are not recorded separately from other single axles in these tables.

## **ADMINISTRATION TABLES**

The Administration database 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 the SHRP\_INFO table for each LTPP location for which monitored traffic data are expected. The SHRP\_INFO table does not list all test sections in the LTPP experiments, because in the case of SPS projects,

the same data generally apply to all test sections on the project. The companion to the SHRP\_INFO table is the SITE\_EQUIPMENT\_INFO table, which contains available information on data-collection equipment and its location. The mapping of agency-specific classification schemes to the FHWA 13 vehicle category classification system is contained in the TRAFFIC\_CLASS\_CONVERT\_\* tables. (FHWA 2016b) If the agency uses the FHWA 13 vehicle category classification system, that is also identified in the tables.

LTAS data tables 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 LTAS data tables, and TRAFFIC\_CODES, which describes the codes themselves.

The processing completed is reported in the TRAFFIC\_ANALYSIS\_TRACKER table, which indicates whether data should be available by level of summarization and data type.

### **SHRP\_INFO Table**

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

The SHRP\_INFO 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. The STATE\_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 test section on the opposite side from the main SPS project test 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 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 chapter 2, Pavement Performance Database Overview. The RECORD\_STATUS field in the SHRP\_INFO table

reflects the completeness of data in the SHRP\_INFO and SITE\_EQUIPMENT\_INFO tables. The RECORD\_STATUS field is one of the factors that control the existence of an estimate for the pavement database.

END\_DATE is the last day to which information in the record applies. The end date is independent of when the test section may have gone out of study for pavement data-collection purposes.

The VOLUME\_SITE, CLASS\_SITE, and WIM\_SITE fields contain the SHRP\_IDs of the sources of data for the respective data types. When data are collected at the same location as the site they are used for, the values for these fields will match SHRP\_ID. When data are collected at another LTPP location, the SHRP\_ID for that location will typically appear in these fields.

Names and descriptions of fields in the SHRP\_INFO table are as follows:

- ID3, ID6, and USEFILENAME—controls on how data are assigned a SHRP\_ID for entry in the LTAS 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 if sufficient data exist to compute an annual average daily traffic estimate.
- SRO\_CLASS and SRO\_WEIGHT—qualitative indicators of the spatial relationship between the source of the associated type of data and the LTPP test section or project. SRO\_CLASS and SRO\_WEIGHT may or may not reflect changes in site location since 2000.
- DATA\_AVAILABILITY—qualitative description of the data available and their reliability for the period indicated. The DATA\_AVAILABILITY information does not currently reflect the results of a full database review on quantity and quality of data.
- FUNC\_CLASS—the functional class of the route where the LTPP test section is located. The FUNC\_CLASS value may not reflect site-specific changes since 2000. The TRF\_BASIC\_INFO table in the pavement database may contain more current information.
- COMMENTS—contains notes by individuals loading and reviewing data.
- CARD4INFO, CARDCINFO, and LTPP\_LN\_ONLY—control which data are loaded. In the case of CARD\*INFO, it indicates whether classification data for classes in optional columns are 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—used to change the LTPP lane and/or direction in an incoming data file.

### **SITE\_EQUIPMENT\_INFO Table**

The SITE\_EQUIPMENT\_INFO table is used to identify the type of equipment installed and the classification schemes being used with that equipment. The SITE\_EQUIPMENT\_INFO table is used as a reference for the SHRP\_INFO table to elaborate on information pertaining to the \*\_SITE variable. 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 the TRF\_CALIBRATION\_AVC, TRF\_CALIBRATION\_WIM, and TRF\_EQUIPMENT\_MASTER tables. Equipment installation and maintenance information is not included.

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

### **TRAFFIC\_ANALYSIS\_TRACKER Table**

The TRAFFIC\_ANALYSIS\_TRACKER 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, are identified with a date of 1-JAN-1990 in the TRAFFIC\_ANALYSIS\_TRACKER table.

The LTAS software populates the TRAFFIC\_ANALYSIS\_TRACKER table. The first time a STATE\_CODE, SHRP\_ID, or year is encountered in the data-loading process, a record is inserted into the TRAFFIC\_ANALYSIS\_TRACKER 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 have passed review and should be used in the annual estimate. “N” indicates the data for the entire year are not considered suitable to include in the annual estimate following review. “C” indicates the data have been copied over from another site, which can be identified through review of the \*\_SITE fields in the SHRP\_INFO table.

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

## **TRAFFIC\_CLASS\_CONVERT\_MASTER Table**

There is no requirement for States to use the FHWA 13 vehicle category classification system and a standard classification algorithm. LTPP adopted the FHWA 13 vehicle category classification system as the standard for uniform interpretation of traffic data across all experiments. The 13-bin method is found in the TMG from the 2nd edition and later. The TRAFFIC\_CLASS\_CONVERT\_MASTER table indicates which classification scheme was 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 classification system for creating daily summaries. When monthly statistics are created, all data are converted to the FHWA 13 vehicle category classification system to permit comparison of equivalent truck types in pavement analyses.

There are at least two records in the TRAFFIC\_CLASS\_CONVERT\_MASTER table for every State or Province in the SHRP\_INFO table, covering the entire LTPP study period. One refers to the relationships for classification data, while the other refers to those for weight data. When initially populated, it was assumed that all agencies used the FHWA 13 vehicle category classification system for both types of data. Identification of such agencies is through the value “99” in the NO\_SHA\_CLASSES field. There are no corresponding records in the TRAFFIC\_CLASS\_CONVERT\_DATA table for any agencies with the 99 field value for the period indicated.

## **TRAFFIC\_CLASS\_CONVERT\_DATA Table**

The TRAFFIC\_CLASS\_CONVERT\_DATA table contains the specifics of matching an agency’s classification method to the FHWA 13 vehicle category classification system.

By definition, if there is an agency-specific classification method for a given data type in the TRAFFIC\_CLASS\_CONVERT\_MASTER table (NO\_SHA\_CLASSES not equal to “99”), there will be at least two records in the TRAFFIC\_CLASS\_CONVERT\_DATA table for that site.

There is a record in the TRAFFIC\_CLASS\_CONVERT\_DATA table 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 FHWA 13 vehicle category classification system 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 the TRAFFIC\_CLASS\_CONVERT\_MASTER table, there will also be site-specific entries in the TRAFFIC\_CLASS\_CONVERT\_DATA table when the agency classification system is not FHWA 13 vehicle category classification system. 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.



## **TRAFFIC\_CODE\_TYPES Table**

The TRAFFIC\_CODE\_TYPES table provides additional information on the codes contained in the TRAFFIC\_CODES table. The CODE\_USAGE field in the TRAFFIC\_CODE\_TYPES table provides a general description of each CODE\_NAME. The CODE\_SOURCE field contains information on the reference document or external source for code definitions.

## **TRAFFIC\_CODES Table**

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.

Names and descriptions of fields in the TRAFFIC\_CODES table are as follows:

- CODE\_NAME—the code type name as shown in the CODE\_NAME field in the TRAFFICDD table.
- CODE—the code value. Although most codes are numeric, some are alphanumeric; therefore, the CODE field is coded as a character, which creates an apparent illogical sequence when the field is sorted in ascending or descending order.
- DETAIL—the description of the code.

## **TRAFFICDD Table**

The TRAFFICDD table is the data dictionary for the LTAS data tables. It contains metadata for each field in each data table. Critical fields include FIELDNAME, TABLENAME, and DESCRIPTION. The TRAFFICDD table is a vital reference when searching for data types for understanding the contents of data contained in a field. The table is a subset of LTPPDD.

Names and descriptions of fields in the TRAFFICDD table are as follows:

- TABLENAME—the table in which the field denoted by FIELDNAME resides.
- FIELDNAME—the field defined by the TRAFFICDD entry.
- DATA\_TYPE—specifies the Oracle electronic format of the specified field. These 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 data stored within the specified field. Typically, the DATASHEET field is a paper datasheet number; however, it may be a filename or individual's name. Entries in the DATASHEET field may not be current or complete.

- DESCRIPTION—describes 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—the name of the type of code contained in the TRAFFIC\_CODES table. The contents of the CODE\_NAME field can be used to link to the TRAFFIC\_CODES table to look up the meaning of a code. If the CODE\_NAME field in the TRAFFICDD table is not null, it also means that the corresponding field is a codes field in the corresponding table defined by the entry in the TABLENAME field.
- UNITS—indicates the units used for the corresponding numeric field.
- ITEM—provides the item number of the form denoted within the DATASHEET field, which is the origin of the data that reside within the specified field. Entries in the ITEM field may not be current or complete.
- PROTOCOL—provides the name of the process used to collect or validate the data.
- FIELD\_KEY—indicates whether the field is part of the primary key field or index of the TRAFFICDD table. If the field is not part of the PK but is non-null, “NN” may be present. The “NN” designation in the TRAFFICDD table 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.

### **TRAFFICTD Table**

The TRAFFICTD table contains a description of the contents of tables in the LTAS database. The three fields in the TRAFFICTD 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. The TRAFFICTD table is a subset of LTPPTD.

### **REGIONS Table**

The REGIONS table consists of two fields—STATE\_CODE and REGION\_CODE. The REGIONS table allows a user to sort State and Provincial agencies by LTPP administrative region.

### **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.

### **YY\_AX Table**

The YY\_AX 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. The

YY\_AX 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 the FHWA 13 vehicle category classification system classes 4–13 (i.e., buses and trucks) are included.

The “heaviest” bin contains single axles 39,000 lb or greater, tandem axles 78,000 lb or greater, and tridem/quad-plus axles 117,000 lb or greater.

### **YY\_CT Table**

The YY\_CT 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. The YY\_CT 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 MM\_CT table for each data type. Included in the YY\_CT table is the number of unclassified vehicles.

### **YY\_GVW Table**

The YY\_GVW 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. The YY\_GVW 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 the MM\_GVW table. Only known vehicles in the FHWA 13 vehicle category classification system (i.e., buses and trucks) are included.

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

## **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 format for weight data. For classification data, the day may be contiguous 24-hr groups of data or calendar days depending on the size of the dataset 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 are retained using the agency classification method. Data in these tables are summarized from hourly or vehicle records using the agency’s classification method. This may or may not correspond directly to the FHWA 13 vehicle category classification system. 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 (i.e., Statistical Analysis Software®-based) traffic software suite were loaded via a separate process in a one-time activity. Data were already classified with the FHWA 13 vehicle category classification system. These data did not populate the GVW tables. For these cases to permit the computation of monthly summaries, a dummy record was added to the GVW table. When listing data for these sites, a single GVW record appears 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. These

data can also be identified in the TRAFFIC\_ANALYSIS\_TRACKER table with DD\_CL\_DATE and DD\_WT\_DATE values of October 23, 2002, or earlier.

Information on bad data is contained in three tables: ERR\_CL, ERR\_WT, and TRAFFIC\_PURGES. The error 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. These data are excluded from all further summarization, estimates, and derived values (e.g., TRF\_ESAL and TRF\_MEPDG).

### **DD\_AX Table**

The DD\_AX table contains axle data by site, year, month, day, lane, direction, vehicle class, and axle group. The DD\_AX 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 the DD\_AX table.

The data are summarized in 1,000-lb bins for single axles, 2,000-lb bins for tandem axles, and 3,000-lb bins for tridems and quad-plus axle groups. Quad-plus axles are any axle group with four or more axles. For a brief period, data were summarized by 4,000-lb bins for quad-plus axles. Data loaded during that period have a WEIGHT\_BIN\_SIZE value of 4,000.

Data in SI units are converted to U.S. customary units for accumulating summaries. The “heaviest” bin contains single axles 39,000 lb or greater, tandem axles 78,000 lb or greater, and tridem/quad-plus axles 117,000 lb or greater.

These data are not available in prepopulated Microsoft Access tables due to the number of tables required. These data are extracted on demand from InfoPave in SQL format.

### **DD\_CL\_CT Table**

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

### **DD\_GVW Table**

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

All data are summarized in 4,000-lb bins. Data in SI units are converted to U.S. customary units for accumulating summaries. The “heaviest” bin contains vehicles 196,000 lb and heavier.

These data are not available in prepopulated Microsoft Access tables due to the number of tables required. Data are extracted on demand from InfoPave in SQL format.

### **DD\_WT\_CT Table**

The DD\_WT\_CT table summarizes the number of vehicles by class based on weight records. The DD\_WT\_CT table contains count data by site, year, month, day, lane, and direction for each day weight data exist for estimating loads. The DD\_WT\_CT table uses the calendar day to define a day of data but does not require that all 24 hr be present.

### **ERR\_CL Table**

The ERR\_CL 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 were rejected.

### **ERR\_WT Table**

The ERR\_WT table contains a record for each error encountered for each lane and direction by date while processing weight data. Data in the ERR\_WT table may be for record-level or day-level errors.

Record-level errors for files loaded with the LTPP traffic quality control (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.

### **TRAFFIC\_PURGES Table**

The TRAFFIC\_PURGES table is for holding information on suspect data that should not be included in daily and further summarizations. Entries in the TRAFFIC\_PURGES table are created by the user and are either in pending status awaiting review by others or applied as a record of 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 are 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 are not included in either monthly or annual summaries or values derived from them.

### **TRAFFIC\_RS\_CHANGES Table**

The TRAFFIC\_RS\_CHANGES table indicates what modifications have been made to the RECORD\_STATUS values in various data tables. The data are 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 TRAFFIC\_RS\_CHANGES table is omitted from the Administration database since there are no data in it to require explanation of unexpected RECORD\_STATUS values.

## **HOURLY TABLES**

The only hourly table is HH\_CL\_CT, which stores hourly volumes by vehicle class in the input method for classification data. While data for any site may be stored in the HH\_CL\_CT table, only data from the Traffic Pooled Fund (TPF) must be included. These data are used to generate inputs to the TRF\_MEPDG\_HOURLY\_DIST table. The HH\_CL\_CT table also stores data from days affected by daylight saving time that violate the 24-hour requirement to allow processing as valid days.

## **MONTHLY TABLES**

Data in the monthly tables provide the basis for the annual estimates in the pavement database and many statistics computed for the TRF\_MEPDG tables.

All vehicles are classified in the FHWA 13 vehicle category classification system.

There is a single table with count data on a monthly basis, which 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 weight data were accepted for estimating pavement loading.

### **MM\_AX Table**

The MM\_AX 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. The MM\_AX 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 known vehicles in FHWA 13 vehicle category classification system 4–13 (i.e., buses and trucks) are included. Once the day of week totals are found, any data in an agency-specified method are converted into the FHWA 13 vehicle category classification system.

The “heaviest” bin contains single axles 39,000 lb or greater, tandem axles 78,000 lb or greater, and tridem/quad-plus axles 117,000 lb or greater.

## **MM\_CT Table**

The MM\_CT table contains count data by site, year, month, lane, direction, day of week, and data source for each month 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. The MM\_CT 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 FHWA 13 vehicle category classification system.

Included in the MM\_CT table is the number of unclassified vehicles, which are vehicles that met all other record and daily QC but were not assigned to FHWA vehicle classes 1–13. (FHWA 2016b) These are not vehicles included in the error tables.

## **MM\_GVW Table**

The MM\_GVW 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. The MM\_GVW 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 known vehicles in FHWA 13 vehicle category classification system classes 4–13 (i.e., buses and trucks) are included. Once the day of week totals are found, any data in an agency-specified method are converted into the FHWA 13 vehicle category classification system.

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





## CHAPTER 17. ANCILLARY INFORMATION

### INTRODUCTION

Ancillary information includes data, images, reference materials, resource documents, and other information that support and extend the data stored in PPDB. This information may aid in understanding the performance of test sections included in the LTPP program. All of the electronic ancillary information is stored at the FHWA Turner-Fairbank Highway Research Center in McLean, VA, in AIMS. While the majority of 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 data not contained on paper forms are available through InfoPave. Questions about elements that cannot be located through InfoPave should be addressed to the LTPP CSSC.

LTPP provides access to its ancillary information in the interest of linkage between collected raw data and summaries of processed data contained in the publicly disseminated database. Accessibility to raw baseline measurement data increases the potential for reinterpretation using new, future data concepts. A simple example of a data concept is the IRI. Providing access to raw longitudinal profile 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 data indicated in table 7 are available for all test sections, equipment evaluations, traffic measurements, and so on.

**Table 7. Summary of LTPP ancillary information.**

<b>Category</b>	<b>Ancillary Information</b>	<b>Comments</b>
AWS	Raw files from data loggers	—
AWS	Edited upload files	—
Curl and warp	Analysis results and input profiles for PCC pavements	Not contained in PPDB
Drainage	Inspection video	—
Drainage	Scanned paper data forms	—
DLR	Raw time–history sensor response files	More raw data are available than exists in PPDB
FWD	Time–history drop data	Not contained in PPDB
FWD	Raw FWD measurement files	—
FWD	Scanned paper data forms	—
FWD	FWD electronic calibration files	Relative and reference calibration data
Friction	Scanned paper data forms	—
GPR	Raw GPR data files	—
GPR	Interpreted measurement upload files	—
GPR	Raw data graphs	—
GPR	Images of interpretations	—
Inventory	Scanned paper data forms	—
Profile/texture	25-mm (1-inch) spacing raw profile data	Contained in converted Engineering Research Division file format
Profile/texture	Raw profiler data files from WIM scale locations	—
Profile/texture	0.50-mm (0.02-inch) raw texture measurements	—
Profile/texture	Scanned Dipstick paper data-collection forms	Paper data forms contain unfiltered pavement profile
Profile/texture	Profile preprocessing software internal computation database files	—
Profile/texture	Raw transverse profile elevation from laser measurements	—
Profile/texture	Equipment comparison reports and data	—
Maintenance module and Rehabilitation module	Scanned paper data forms	—
Material tests	Scanned paper data forms	—
Pavement distress	Digitized 35-mm (1.38 inch) black-and-white surface images	Not all 35-mm (1.38-inch) film has been digitized

<b>Category</b>	<b>Ancillary Information</b>	<b>Comments</b>
Pavement distress	35-mm (1.38-inch) black-and-white film surface images	Not a formal part of AIMS
Pavement distress	Scanned images of photographic interpreted distress location map	—
Pavement distress	Scanned images of manual survey distress location map	Shows location of surface distress features
Pavement distress	Scanned manual distress data forms	—
Pavement distress	Digitized photographs from manual distress surveys (MDSs)	Includes photos of interesting/unusual distresses
Pavement distress	Manual distress photograph metadata database	Contains a description of photos
Pavement distress	Scanned transverse profile Dipstick measurement data sheets	Transverse profile Dipstick measurements processed by LTPP preprocessing software
Pavement distress	Database used by the software to perform time series review of photographic and manual distress surveys	—
Resilient modulus laboratory test	Time history load and deflection response	Data from all tests not available
SMP	Raw files from data loggers	—
SMP	Edited upload files	—
SMP	Scanned paper data sheets	—
SPS	Scanned paper data forms	—
Test section coordinates	Scanned paper data forms	—
Videos	Digitized walking inspection videos	—
Videos	Through profiler windshield videos	Shows general condition of test section
Traffic	Raw traffic data in various TMG formats	Annual estimates from raw data are contained in PPDB
Traffic	Raw data files and outputs from its iANALYZE software	From WIM sites
Traffic	Vehicle images used for vehicle classification algorithm calibration	Very large datasets from limited number of sites

—Indicates no comment for that type of ancillary information.

The 35-mm (1.38-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 available film has been converted to an electronic format, the physical photographic media is still available and contains greater resolution than the pixelated digital images.

The following sections provide more information on the general nature of the available ancillary information following the categories listed in table 7.

## **AWS**

AWSs were installed at selected SPS-1, -2, and -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 LTPP regional support contractors to review, edit, and create database upload files from raw data for entry into PPDB.

## **DRAINAGE INSPECTION**

Ancillary LTPP information includes the data from inspection of the subsurface drainage structures at SPS-1 and -2 project sites. The inspection data include 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.

## **DLR**

DLR data were collected at the North Carolina SPS-2 site and the Ohio SPS-1, -2, -8, and -9 sites. The available DLR ancillary information not contained in PPDB is 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 CSSC to obtain current data and information on problems discovered with past releases of DLR data.

## **FWD**

FWD measurements were taken on test sections to measure the deflection response of the pavement structure. In addition to raw data produced by the automated FWD measurement device, available associated data include 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.

## **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. Scanned images of the paper data-collection forms used to report data are saved in electronic format in AIMS.

## **GPR**

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

Ancillary information from these GPR measurements includes raw data files containing readings every 152 mm (6 inches), a graph of the data contained in the raw data files, a graph of the interpreted dielectric constant versus position, a graph of the interpreted layer thicknesses versus position in the right wheelpath and center of the lane, and the upload files used to populate the GPR\_MASTER, GPR\_THICK\_POINT, and GPR\_THICK\_SECT set of tables in the PPDB.

## **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. Data are reported to LTPP by participating highway agencies 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.

## **LONGITUDINAL PROFILE, TEXTURE, AND TRANSVERSE PROFILE**

LTPP profile 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 Dipstick. While the profile data prior to 2014 used a profile (i.e., PRF) label, with the introduction of the fourth-generation high-speed survey profilers in 2014, longitudinal profile and texture data are stored using a high-speed survey (i.e., HSS) label.

Most 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 test sections and at WIM scale measurement sites.

A small subset of longitudinal profile measurement data was manually collected using Dipstick. Ancillary information from Dipstick measurements includes an image scan of the paper data-collection forms and electronic data files generated during the preupload processing of these data.

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

Raw 0.5-mm (0.02-inch) texture measurement data are stored only in AIMS due to the extremely large size if stored in database format. These files can be downloaded from the InfoPave website.

In the 2019 public data release, transverse profile data measured with a laser scanning system installed on the fourth-generation high-speed survey vehicles were added to AIMS. These data are stored with the longitudinal profile and texture measurements.

## **MAINTENANCE AND REHABILITATION**

Maintenance and Rehabilitation data modules include data for maintenance and rehabilitation construction events performed after LTPP monitoring of the test sections began. 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.

## **MATERIAL TESTS**

The material tests data type contains field tests and laboratory test results on material samples obtained from LTPP test sections. Most 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. One new addition to the material tests category is pictures of cores, in a core box, collected from SPS-10 test section samples.

## **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.

Manual distress ancillary information includes scanned images of paper field data distress maps, paper data-collection forms, and digitized images from photographs taken during a manual distress survey. The electronic database that documents 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 (1.38-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 set of film was used to measure the distortion in the pavement TPF using an optical image analysis process. All original raw 35-mm (1.38-inch) film media is stored in a climate-controlled facility at the Materials Reference Library under contract to FHWA and located in Reno, NV. 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 Dipstick 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 is 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 (1.38-inch) film, digitized images from photographs taken during manual distress surveys, and digitized images from the 35-mm (1.38-inch) photography.

## **RESILIENT MODULUS MATERIAL TESTS**

Resilient modulus tests were performed on AC 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 AC 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.

## **SMP**

Data in the SMP module contain processed raw and interpreted data from instrumentation and other measurements performed on these sites. SMP ancillary information includes 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 PPDB upload files, and scanned electronic paper data-collection forms.

## **SPS**

The SPS 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 general and construction data contained in the SPS module are saved in electronic scanned format in AIMS.

## **TEST SECTION COORDINATES**

Test section coordinates are measurements or estimates of test section locations using Global Positioning System 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 these data are saved in electronic scanned format in AIMS.

## **TEST SECTION VIDEOS**

The following types of test section videos have been electronically digitized and are available in AIMS and LTPP InfoPave:

- Walking inspections of test sections—during initial inspection of test sections at the start of the program, videos showing the test section surface and surrounding terrain were made on some test sections. Walking inspection videos were also created during manual distress surveys on some test 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 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 videos were recorded by some regional LTPP data-collection contractors and are available for a subset of test sections.

## **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, files from the iANALYZE software, and scanned paper data forms. (International Road Dynamics, Inc. 2018) LTAS reads data files formatted in a TMG format (4th edition or earlier) for classification or weight data, performs traffic data QC checks, provides data graphs for semiautomated data checks by regional staff, creates a variety of quality assurance reports, and creates the annual traffic data statistics stored in PPDB. Some 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.

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 taken.

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 website. 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 the LTPP CSSC.



## TECHNICAL DETAILS

Some 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 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 the U.S. National Archives and Records Administration did not have an existing standard at the time.
- Scanned paper data forms are saved in a black-and-white PDF.
- Videos are digitized to MPEG and AVI formats.
- Still photographic images are digitized to JPEG formats.
- While some 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 a schema that describes the format and content of LTPP electronic data can be submitted to the LTPP CSSC.



## **CHAPTER 18. OBTAINING LTPP DATA AND INFORMATION**

### **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.
- LTPP publications are available for download from the LTPP and InfoPave websites.
- Extractions from the LTPP database are provided free of charge to data users who use the InfoPave website.

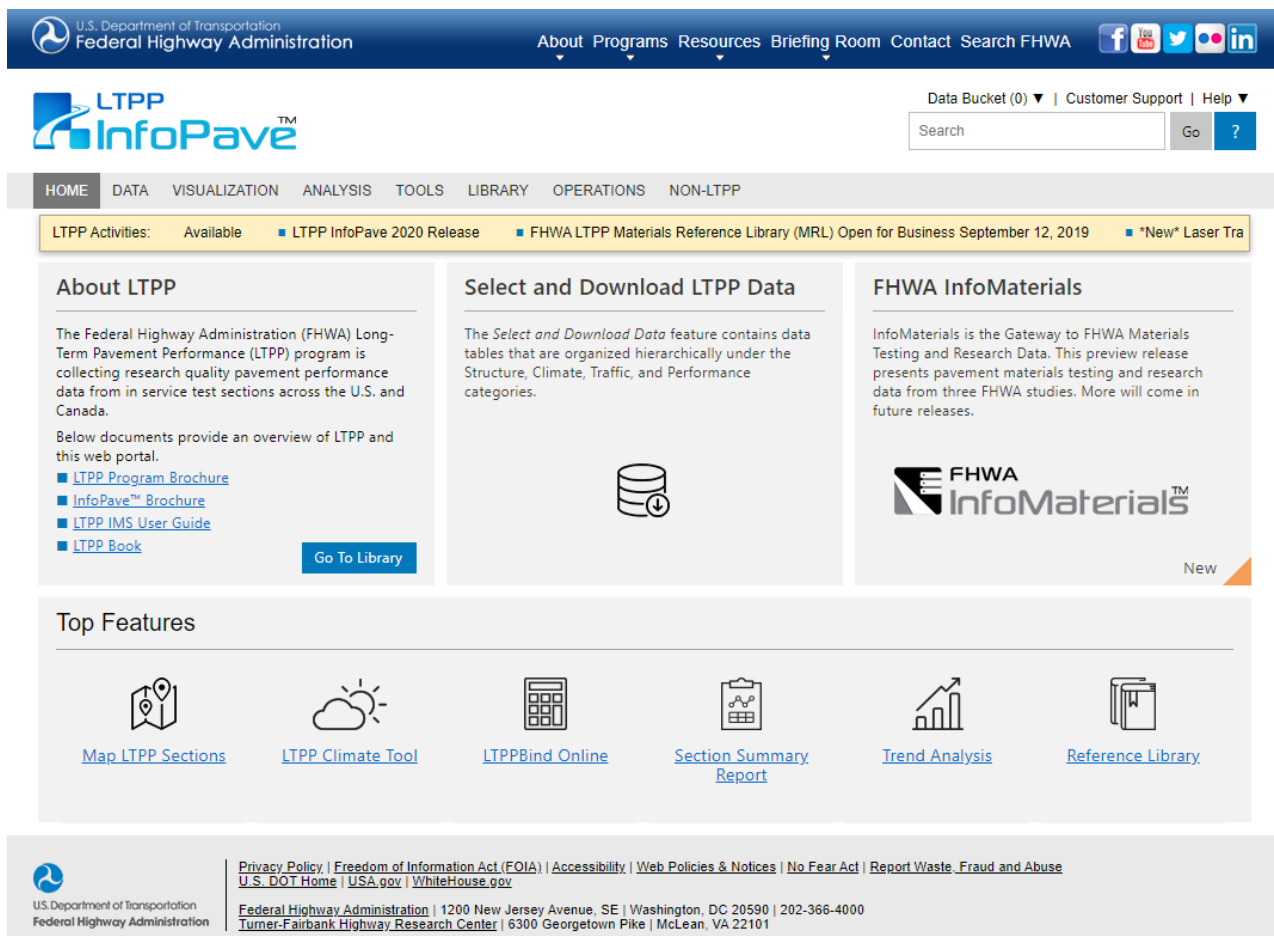
### **OBTAINING LTPP DATA**

The LTPP InfoPave website is the only method to obtain current LTPP data and information. The SDR is no longer distributed on standalone computer media. All prior SDR files can be downloaded from the InfoPave website.

Custom requests for LTPP data and information should be made to the LTPP CSSC.

### **LTPP INFOPAWE**

The InfoPave website provides access to LTPP data and information on demand through a web-centric interface and provides features and tools designed to maximize user understanding of the data. Figure 38 shows the current InfoPave homepage.



Source: FHWA.

**Figure 38. Image. InfoPave homepage.**

Features and tools contained in InfoPave include the following:

- Data Selection and Download, located under the DATA tab, is the primary feature for those interested in obtaining LTPP data for analysis and is recommended for use for self-directed data acquisition. A classification scheme has been applied to all LTPP data to make it easier to find data of interest.
- Section Summary Reports, located under the DATA tab, contains many embedded features contained as user options. The report that comes up first is a data report. The graphs tab displays time–history data for selected LTPP test section(s) in graphical format, which can be downloaded in in either a graphical or data format and are useful for many types of pavement performance analysis LTPP test sections.
- Section Timeline, located under the VISUALIZATION tab, illustrates changes in the pavement structure and access to summarized test section by date.
- Search is an intuitive search feature common to modern web applications used to find information and documents.

- LTPP Section Mapping, located under the VISUALIZATION tab, displays locations of test sections and projects on a map. The intuitive display allows a user the ability to zoom in and out, pan, and filter test section results with a combination of criteria under the Find Sections filters.
- The ANALYSIS tab provides access to the current version of the LTPP Data Analysis Plan, time trend plots of user-selected LTPP datasets, and a radar data availability plot for test sections selected under the Find Sections filters.
- The VISUALIZATION tab provides access to pavement inspection videos, manual distress survey maps, summarized pavement structure visuals, test section timeline summary data, pivot table formats, and a Multi-Feature Visualization, which allows users to select two types of information to be presented for display.
- SQL Export, located under the DATA tab, is a query tool available for those familiar with the LTPP database and allows users to write and execute database queries online. The tool also includes a wizard that allows creation of queries using a graphical interface.
- Standard Data Release, located under the DATA tab, allows users to download selected data in standard data formats in addition to downloading data from the InfoPave data selection features. SDR formats include Microsoft Access 2003 databases based on the North American software version and large datasets in Microsoft SQL server format. Refer to the InfoPave website to view datasets available in the legacy SDR format.
- The TOOLS tab includes programs developed by LTPP. Some of the tools that can be executed online include LTPP Rigid Pavement Design (which can be accessed by selecting AASHTO 1998 Rigid Pavement Design), WIM Cost Analysis, and Pavement Performance Forecast. Downloaded tools include LTPP Dynamic Modulus Prediction and LTPPBind Online.

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

## **CUSTOM DATA EXTRACTIONS**

Data users can request custom partial extractions from the database and/or extractions in a nonstandard format from the LTPP CSSC by emailing [ltppinfo@dot.gov](mailto:ltppinfo@dot.gov). The support and availability of custom data extractions is 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, and Microsoft Excel, Access, and SQL formats. Users interested in obtaining data in other formats should contact the LTPP CSSC.



## **APPENDIX A. EXPERIMENT DEFINITIONS**

### **GPS EXPERIMENTS**

#### **GPS-1: Asphalt Concrete (AC) Pavement 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 the GPS-1 study.

Seal coats or porous friction courses are allowed on the surface, but not in combination (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.

#### **GPS-2: AC Pavement 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 (e.g., pozzolans, PCC, lime). One or more subbase layers may 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).

#### **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 a stabilized or unbound granular base layer. One or more subbase layers may be present but are not required. A seal coat (i.e., prime coat) is permissible just above a granular base layer. 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.

#### **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 be present but are not required. JRCP placed directly on a fine-grained soil/aggregate layer or fine-grained subgrades is excluded from the GPS-4 study. JRCPs without load-transfer devices or with devices other than smooth dowel bars at the joints are not acceptable.

### **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 may be present but are not required. A seal coat (i.e., 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.

### **GPS-6: AC Overlay of AC 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 test sections that were overlaid prior to acceptance in the GPS program.

The -6B, -6C, -6D, and -6S designations refer to LTPP test sections on which an overlay was placed after the section was 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).

### **GPS-7: AC Overlay of PCC**

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, which was added to account for PCC test sections rehabilitated using concrete pavement restoration techniques. (To date, no test sections have been designated as -7R.)

The designation -7A refers to test 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 test section was 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 (i.e., concrete) and the overlay. Overlaid pavements involving aggregate interlayers and open-graded AC interlayers are not included in the GPS-7 study. The total thickness of HMAC used in the overlay is required to be at least 38 mm (1.5 inches).



## **GPS-9: Unbound PCC Overlays on PCC Pavements**

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.

## **SPS EXPERIMENTS**

The following definitions apply solely to the core test sections within each experiment. Any supplemental test sections constructed at each SPS project are based on the highway agency's research interests. These test sections are not consistent from one agency to the next.

### **SPS-1: Strategic Study of 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. Pavement structural factors in the SPS-1 experiment include the in-pavement drainage layer, surface thickness, base type, and base thickness. The SPS-1 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 the SPS-1 experiment results in 24 different pavement structures. The SPS-1 experiment is designed using a fractional factorial approach to enhance implementation practicality, permitting the construction of 12 test sections at one site and 12 complementary test sections to be constructed at another site within the same climatic region on a similar subgrade type.

### **SPS-2: Strategic Study of 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. Pavement structural factors included in the SPS-2 experiment are the in-pavement drainage layer, PCC surface thickness, base type, PCC flexural strength, and lane width. The SPS-2 experiment requires all test sections be constructed with perpendicular doweled joints at 4.9-m (15-ft) spacing and stipulates a traffic loading level in the lane in excess of 200,000 ESALs/yr. The experiment is designed using a fractional factorial approach to enhance implementation practicality, permitting the construction of 12 test sections at one site and 12 complementary test sections to be constructed at another site within the same climatic region on a similar subgrade type.

### **SPS-3: Preventive Maintenance Effectiveness of Flexible Pavements**

SPS-3 examines the performance of four preventive maintenance treatments (e.g., crack seal, chip seal, slurry seal, and thin overlay) on AC-surfaced test sections within the four climatic regions on the two classes of subgrade soil. The SPS-3 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.

#### **SPS-4: Preventive Maintenance Effectiveness of Rigid Pavements**

SPS-4 was designed to study the effects of crack/joint sealing and undersealing on JPCP pavement structures. Both JRCP and JPCP are included in the study. Undersealing is included as an optional factor and is only performed on a test section for which the need for undersealing is indicated. The SPS-4 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 test sections on joint-/crack-sealing test sites consist of one test section in which all joints have no sealant and one in which a watertight seal is maintained on all cracks and joints.

#### **SPS-5: Rehabilitation of Asphalt Concrete Pavements**

SPS-5 examines the performance of eight combinations of AC overlays on existing AC-surfaced pavements. The rehabilitation treatment factors included in the SPS-5 study are the intensity of surface preparation, recycled versus virgin AC overlay mixture, and overlay thickness. The SPS-5 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.

#### **SPS-6: Rehabilitation of Jointed PCC Pavements**

SPS-6 examines the performance of seven rehabilitation treatment options as a function of climatic region, type of pavement (e.g., plain or reinforced), and condition of the existing pavement. Rehabilitation methods include surface preparation (e.g., limited preparation or full concrete pavement restoration) with a 102-mm (4-inch) 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-inch) thick AC overlay with sawed and sealed joints.

#### **SPS-7: Bonded PCC Overlays on Concrete Pavements**

SPS-7 examines the performance of eight combinations of bonded PCC treatment alternatives as a function of climatic region, pavement type (e.g., jointed or continuously reinforced), and condition of the existing pavement. Rehabilitation treatment factors include combinations of surface preparation methods (e.g., cold milling plus sand-blasting and shot-blasting), bonding agents (e.g., neat cement grout or none), and overlay thicknesses (76 or 127 mm (3 or 5 inches)). The SPS-7 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.

#### **SPS-8: Study of 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 (e.g., frost-susceptible, expansive, fine, and coarse) on test sections incorporating flexible and rigid pavement designs that are subjected to limited traffic loading. The SPS-8 experiment design requires either two flexible pavements or two rigid pavement structures to be

constructed at each site. The two flexible pavement test sections consist of a 102-mm (4-inch) AC surface on a 203-mm (8-inch) thick untreated granular base and a 178-mm (7-inch) AC surface over a 305-mm (12-inch) 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-inch) thick dense-graded granular base. Pavement structures included in the SPS-8 study match pavement structures included in the SPS-1 and -2 experiments. The SPS-8 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 test sections may be constructed at the same site or at different sites.

### **SPS-9: Validation of SHRP Asphalt Specification and Mix Design (Superpave)**

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 limited set of guidelines. In some instances, specifications were based on interim Superpave specifications that were changed at a later date. Many SPS-9P 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 provides the opportunity to evaluate and improve the practical aspects of implementing the Superpave mix design by: a hands-on field trial by interested highway agencies, a comparison of the performance of the Superpave mixes against mixes designed using current highway agencies' asphalt specifications, trial asphalt-aggregate specifications and mix design procedures, and 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:

- SPS-9C—AC Overlay on CRCP.
- SPS-9J—AC Overlay on Jointed PCC.
- SPS-9N—New AC Pavement Construction.
- SPS-9O—AC Overlay on AC Pavement.

### **SPS-10 Warm Mix Asphalt Overlay of Asphalt Pavement**

The objective of the SPS-10 experiment, which was implemented in 2014, is to provide a performance comparison of AC constructed using warm mix technologies against current hot-mixed methods in an overlay application. Warm mix asphalt (WMA) is defined by LTPP as asphalt mixtures produced at or below 135 °C (275 °F), or at least -1.1 °C (30 °F) below the

production temperature of the HMA control test section. The SPS-10 experiment requires the following three core test sections to be constructed at each site:

- 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 50.8- to 101.6-mm (2- to 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 B. STATE AND PROVINCE CODES

Note that while most of the State codes in table 8 correspond to FIPS standards, codes used for 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.

**Table 8. State and Province codes.**

<b>Code</b>	<b>State/Territory/Province</b>
01	Alabama
02	Alaska
04	Arizona
05	Arkansas
06	California
08	Colorado
09	Connecticut
10	Delaware
11	District of Columbia
12	Florida
13	Georgia
15	Hawaii
16	Idaho
17	Illinois
18	Indiana
19	Iowa
20	Kansas
21	Kentucky
22	Louisiana
23	Maine
24	Maryland
25	Massachusetts
26	Michigan
27	Minnesota
28	Mississippi
29	Missouri
30	Montana
31	Nebraska
32	Nevada
33	New Hampshire
34	New Jersey
35	New Mexico
36	New York
37	North Carolina
38	North Dakota
39	Ohio

<b>Code</b>	<b>State/Territory/Province</b>
40	Oklahoma
41	Oregon
42	Pennsylvania
44	Rhode Island
45	South Carolina
46	South Dakota
47	Tennessee
48	Texas
49	Utah
50	Vermont
51	Virginia
53	Washington
54	West Virginia
55	Wisconsin
56	Wyoming
72	Puerto Rico
81	Alberta
82	British Columbia
83	Manitoba
84	New Brunswick
85	Newfoundland
86	Nova Scotia
87	Ontario
88	Prince Edward Island
89	Quebec
90	Saskatchewan

## REFERENCES

- AASHTO. 1993. *AASHTO Guide for Design of Pavement Structures*. Washington, DC: American Association of State Highway and Transportation Officials.
- AASHTO. 1996. AASHTO TP9-96, *Standard Test Method for Determining the Creep Compliance and Strength of Hot Mix Asphalt (HMA) Using the Indirect Tensile Test Device*. Washington, DC: American Association of State Highway and Transportation Officials.
- AASHTO. 2014. AASHTO T 283, *Standard Method of Test for Resistance of Compacted Asphalt Mixtures to Moisture-Induced Damage*. Washington, DC: American Association of State Highway and Transportation Officials.
- AASHTO. 2020. *Mechanistic-Empirical Pavement Design-A Manual of Practice, Third Edition*. Washington, DC: American Association of State Highway and Transportation Officials.
- ASTM. 2003. ASTM D6951-03, *Standard Test Method for Use of the Dynamic Cone Penetrometer in Shallow Pavement Applications*. West Conshohocken, PA: ASTM International.
- FHWA. 1990–2020. Federal Highway Administration (website). Accessed January 7, 2020. <https://www.fhwa.dot.gov/publications/lists/technical/infrastructure/pavements/ltp>.
- FHWA. 1991. *SHRP-LTPP Guide for Field Materials Sampling, Handling, and Testing, Operational Guide No. SHRP-LTPP-OG-006*. Washington, DC: SHRP, National Research Council.
- FHWA. 1996. *LTPP Protocol P46: Resilient Modulus of Unbound Granular Base/Subbase Materials and Subgrade Soils*. Washington, DC: Federal Highway Administration.
- FHWA. 1997. *SHRP-LTPP Interim Guide for Laboratory Materials Handling and Testing, Operational Guide No. SHRP-LTPP-OG-004*. Washington, DC: SHRP, National Research Council.
- FHWA. 1998. *Freeze/Thaw Monograph for LTPP*. Washington, DC: Federal Highway Administration. <https://www.fhwa.dot.gov/publications/research/infrastructure/pavements/ltp/98177/98177.pdf>.
- FHWA. 1999. *An Input for Moisture Calculations—Dielectric Constant From Apparent Length*. Washington, DC: Federal Highway Administration. [https://www.fhwa.dot.gov/pavement/pub\\_details.cfm?id=233](https://www.fhwa.dot.gov/pavement/pub_details.cfm?id=233).

- FHWA. 2001. *LTPP Protocol P07: Test Method for Determining the Creep Compliance, Resilient Modulus, and Strength of Asphalt Materials Using the Indirect Tensile Test Device*. Washington, DC: Federal Highway Administration.  
[https://www.fhwa.dot.gov/pavement/pub\\_details.cfm?id=264](https://www.fhwa.dot.gov/pavement/pub_details.cfm?id=264).
- FHWA. 2016a. *Highway Performance Monitoring System Field Manual*. Washington, DC: Federal Highway Administration.  
[https://www.fhwa.dot.gov/policyinformation/hpms/fieldmanual/hpms\\_field\\_manual\\_dec\\_2016.pdf](https://www.fhwa.dot.gov/policyinformation/hpms/fieldmanual/hpms_field_manual_dec_2016.pdf).
- FHWA. 2016b. *Traffic Monitoring Guide*. Washington, DC: Federal Highway Administration.  
[https://www.fhwa.dot.gov/policyinformation/tmguidetmg\\_fhwa\\_pl\\_17\\_003.pdf](https://www.fhwa.dot.gov/policyinformation/tmguidetmg_fhwa_pl_17_003.pdf).
- Hall, Kathern T., and James Corvetti. 2007. *Effects of Subsurface Drainage on Pavement Performance: Analysis of SPS-1 and SPS-2 Field Test Sections*. (NCHRP Report 583). Final, Washington, DC: The National Academies Press.  
[http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp\\_rpt\\_583.pdf](http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_583.pdf).
- InfoPave. 2020a. Federal Highway Administration (website). Accessed January 7, 2020.  
<https://infopave.fhwa.dot.gov/Reports/Library>.
- InfoPave. 2020b. Federal Highway Administration (website). Accessed December 15, 2020.  
<https://infopave.fhwa.dot.gov/Operations/LTPPDirectives>.
- InfoPave. 2020c. Federal Highway Administration (website). Accessed January 7, 2020.  
<https://infopave.fhwa.dot.gov>.
- International Road Dynamics, Inc. 2018. *iAnalyze* (version 7.7).
- Kazanovich, Lev, Kyle Hoegh, and Mark Snyder. 2009. *NCHRP Report 637: Guidelines for Dowel Alignment in Concrete Pavements*. Washington, DC: The National Academies Press. <http://www.trb.org/Publications/Blurbs/161803.aspx>.
- Kim, Y. Richard, B. Underwood, M. Sakhaei Far, N. Jackson, and J. Puccinelli. 2011. *LTPP Computed Parameter: Dynamic Modulus*. Washington, DC: Federal Highway Administration.  
<https://www.fhwa.dot.gov/publications/research/infrastructure/pavements/ltp/10035/10035.pdf>.
- Long-Term Pavement Performance. 2001. *LTPP Traffic QC Software, Volume 1: Users Guide*. (Software version 1.61). <https://infopave.fhwa.dot.gov/Reports/Library/A20>.
- Long-Term Pavement Performance. 2020. Federal Highway Administration (website). Accessed January 7, 2020. <https://highways.dot.gov/long-term-infrastructure-performance/ltp/long-term-pavement-performance>.



- Miller, J.S. and William Bellinger. 2014. *Distress Identification Manual for the Long-Term Pavement Performance Program (Fifth Revised Edition)*. Washington, DC: Federal Highway Administration.  
<https://www.fhwa.dot.gov/publications/research/infrastructure/pavements/ltp/13092/13092.pdf>.
- Molod, A., L. Takacs, M. Suarez, and J. Bacmeister. 2015. “Development of the GEOS-5 atmospheric general circulation model: evolution from MERRA to MERRA2.” *Geoscientific Model Development*. 8 (May): 1339–1356. <https://doi.org/10.5194/gmd-8-1339-2015>.
- Pavement Reports. 2020. Ohio Department of Transportation. Accessed January 7, 2020.  
<http://www.dot.state.oh.us/Divisions/Planning/SPR/Research/reportsandplans/Pages/PavementReports.aspx>.
- Rada, G.R., C. Wu, R. Bhandari, R. Shekharan, G.E. Elkins, J. Miller. 1999. *Study of Distress Variability*, Volume 1. Washington, DC: Federal Highway Administration.  
[https://www.fhwa.dot.gov/pavement/pub\\_details.cfm?id=122](https://www.fhwa.dot.gov/pavement/pub_details.cfm?id=122).
- Rada, G.R., G.E. Elkins, B. Henderson, R. Van Sambeek, and A. Lopez. 1995. *LTPP Seasonal Monitoring Program: Instrumentation Installation and Data Collection Guidelines*. Washington, DC: Federal Highway Administration.  
<https://www.fhwa.dot.gov/publications/research/infrastructure/pavements/ltp/94110/94110.pdf>.
- Rienecker, Michele M., M.J. Suarez, R. Gelaro, R. Todling, J. Bacmeister, E. Liu, M.G. Bosilovich, et al. 2011. “MERRA: NASA’s Modern-Era Retrospective Analysis for Research and Applications.” *Journal of Climate*, Volume 24: 3624–3648.  
<https://doi.org/10.1175/JCLI-D-11-00015.1>.
- Selezneva, O.I., M. Ayres, M. Hallenbeck, A. Ramachandran, H. Shirazi, and H. Von Quintus. 2016. *MEPDG Traffic Loading Defaults Derived from Traffic Pooled Fund Study*. Washington, DC: Federal Highway Administration. Accessed April 2017.  
<https://www.fhwa.dot.gov/publications/research/infrastructure/pavements/ltp/13090/13090.pdf>.
- Selezneva, O.I., and M. Hallenbeck. 2013. *Long-Term Pavement Performance Pavement Loading User Guide (LTPP PLUG)*. Report, Washington, DC: Federal Highway Administration.  
<https://www.fhwa.dot.gov/publications/research/infrastructure/pavements/ltp/13089/13089.pdf>.
- Selezneva, O.I., Y.J. Jiang, G. Larson, and T. Puzin. 2008. *LTPP Computed Parameter: Frost Penetration*. Washington, DC: Federal Highway Administration.  
<https://www.fhwa.dot.gov/publications/research/infrastructure/pavements/ltp/08057/08057.pdf>.

- Transportation Research Board. 1984. *America's Highways: Accelerating the Search for Innovation—Special Report 202*. Washington, DC: The National Academies Press.  
<https://doi.org/10.17226/11374>.
- Transportation Research Board. 1986. *Strategic Highway Research Program—Research Plans*. Washington, DC: The National Academies Press.
- Von Quintus, H.L., C. Rao, and L. Irwin. 2015. *Long-Term Pavement Performance Program Determination of In-Place Elastic Layer Modulus: Backcalculation Methodology and Procedures*. Washington, DC: Federal Highway Administration.  
<https://www.fhwa.dot.gov/publications/research/infrastructure/pavements/ltp/15036/15036.pdf>.
- Zollinger, D., S. Lee, J. Puccinelli, and N. Jackson. 2008. *LTPP Computed Parameter: Moisture Content*. Washington, DC: Federal Highway Administration.  
<https://www.fhwa.dot.gov/publications/research/infrastructure/pavements/ltp/08035/08035.pdf>.

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