Researcher's Guide to The LTPP Layer Thickness Data

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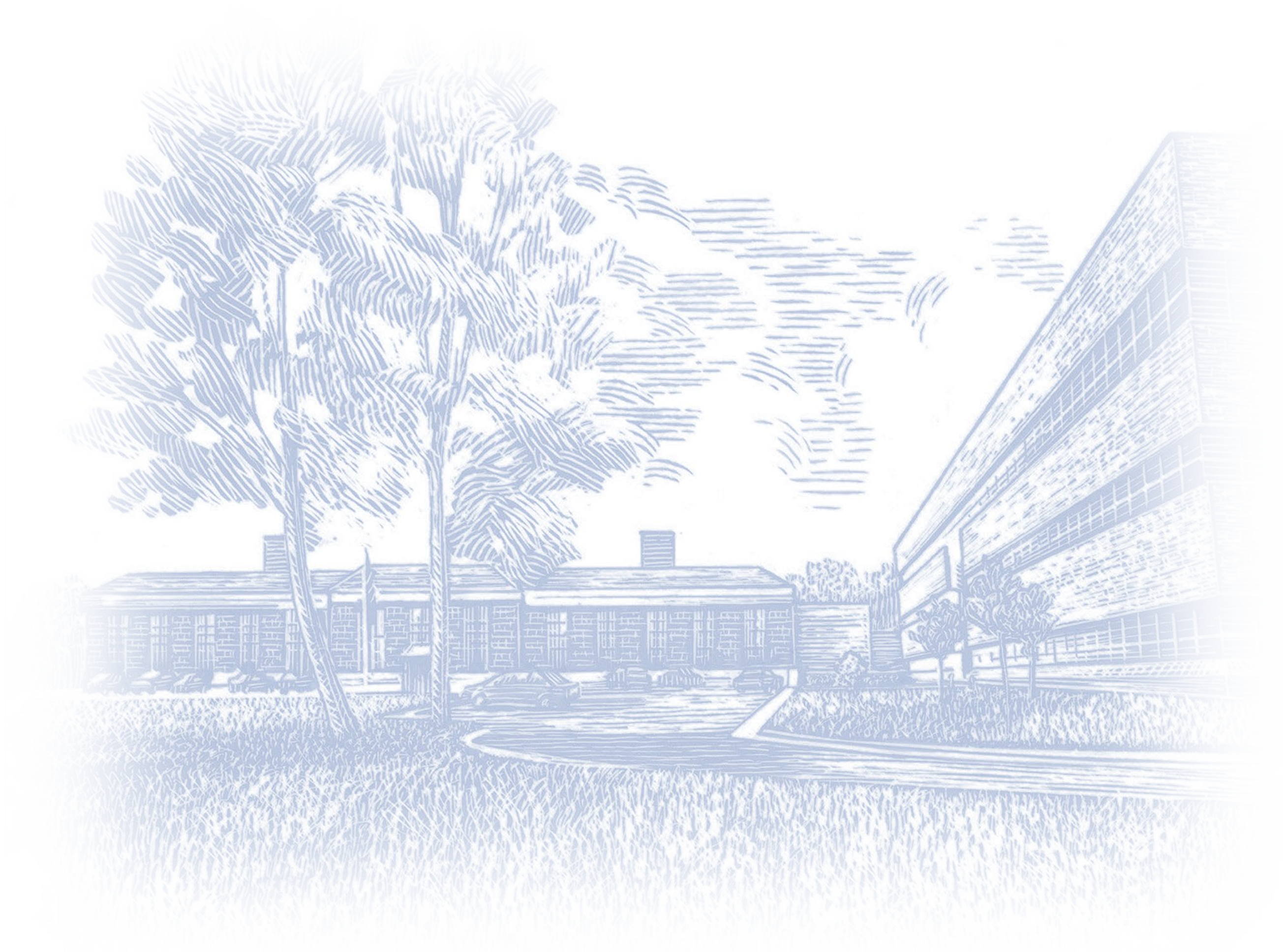

U.S. Department of Transportation
Federal Highway Administration

Federal Highway Administration
Turner-Fairbank Highway Research Center
6300 Georgetown Pike, McLean, VA 22101

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Foreword

This guide summarized the layer material type and thickness data structure in the Long-Term Pavement Performance (LTPP) database. Summaries of layer thickness within-section data variablility and constructed thickness deviations from the target thickness are also provided for LTPP sections; the guide provides several benchmark values for both of these data elements for different material types. Guidelines are also presented to search for the most appropriate thickness information for different research purposes.

This guide will be of interest to highway agency engineers and reearchers involved in pavement design, performance modeling, and construction quality assurance.

T. Paul Teng, P.E.
Director
Office of Infrastructure
Research and Development

Notice

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16. Abstract

The accuracy of layer thickness data has a great impact on the outcome of practically all analyses of pavement performance. A large amount of data related to layer material type and thickness data have been collected as part of the Long Term Pavement Performance (LTPP) Program. The main purposes of this researcher's guide for the LTPP thickness data are to:

1. Explain to the LTPP data users what and where different types of layer material type and thickness data reside in the LTPP database, as well as the limitations of the data.
2. Present LTPP thickness within-section variability.
3. Summarize as-designed versus as-constructed layer thickness comparisons.
4. Provide guidelines to search for the most appropriate thickness information for different research purposes.

Field sampling, materials testing, and other layer thickness data collection activities utilized by LTPP are discussed, along with the characterization of the within-sectin thickness variation and designed versus constructed thickness data variations for the LTPP sections. Findings from this study are applicable to pavement design reliability and construction quality assurance applications.

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SI* (Modern Metric) Conversion Factors

Approximate Conversions to SI Units				
Symbol	**When You Know**	**Multiply By**	**To Find**	**Symbol**
Length				
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
Area				
in²	square inches	645.2	square millimeters	mm^2
ft²	square feet	0.093	square meters	m^2
yd²	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi²	square miles	2.59	square kilometers	km^2
Volume				
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft³	cubic feet	0.028	cubic meters	m^3
yd³	cubic yards	0.765	cubic meters	m^3
NOTE: volumes greater than 1000 L shall be shown in m^3				
Mass				
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
Temperature (exact degrees)				
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
Illumination				
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2

Force and Pressure or Stress				
lbf	poundforce	4.45	newtons	N
lbf/in²	poundforce per square inch	6.89	kilopascals	kPa

Approximate Conversions from SI Units

Symbol	When You Know	Multiply By	To Find	Symbol
Length				
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
Area				
mm²	square millimeters	0.0016	square inches	in²
m²	square meters	10.764	square feet	ft²
m²	square meters	1.195	square yards	yd²
ha	hectares	2.47	acres	ac
km²	square kilometers	0.386	square miles	mi²
Volume				
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m³	cubic meters	35.314	cubic feet	ft³
m³	cubic meters	1.307	cubic yards	yd³
Mass				
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
Temperature (exact degrees)				

°C	Celsius	1.8C+32	Fahrenheit	°F
Illumination				
lx	lux	0.0929	foot-candles	fc
cd/m²	candela/m²	0.2919	foot-Lamberts	fl
Force and Pressure or Stress				
N	newtons	02.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in²

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

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List of Abbreviations

AC = Asphalt concrete (surface course).
AASHTO = American Association of State Highway and Transportation Officials.
ASTM = American Society for Testing and Materials.
ATB = Asphalt-treated base (dense-graded, generally similar to the AC surface course).
COV = Coefficient of variation.
CRCP = Continuously reinforced concrete pavement.
CTB = Cement-treated base.
DGAB = Dense-graded aggregate base (unbound).
DGATB = Dense-graded asphalt-treated base (bound).
FHWA = Federal Highway Administration.
FWD = Falling Weight Deflectometer.
GB = Granular base.
GPR = Ground Penetrating Radar.
GPS = General Pavement Studies.
HMAC = Hot-mix asphalt concrete.
JPCP= Jointed plain concrete pavement.
JRCP= Jointed reinforced concrete pavement.
LC= Lean concrete (base).
LTPP= Long Term Pavement Performance [program].
OD = Outside diameter.
PCC = Portland cement concrete.
PATB = Permeable asphalt-treated base.
QA = Quality assurance.
QC = Quality control.
RSC = Regional Support Contractor.
SHRP = Strategic Highway Research Program.
SB = Surface and binder [layer].
SPS = Specific Pavement Studies.

INTRODUCTION

Background

Pavement layer material type and thickness data are very important for many types of analyses, including back calculation of pavement moduli, mechanistic analysis of pavement structures, and performance modeling. The accuracy of layer thickness data has a great impact on the outcome of practically all analyses of pavement performance. As part of the Long Term Pavement Performance (LTPP) program data collection effort, a large amount of data related to layer material type and thickness has been collected from several sources, including the following:

- Inventory and design records.
- Core measurements from materials sampling and testing.
- Field logs of bore holes.
- Shoulder auger probe logs.
- Test pit logs.
- Field elevation measurements before and after layer placement for Specific Pavement Studies (SPS) sections.
- Ground Penetrating Radar (GPR) measurements (planned to be collected).

The pavement layer thickness data from these sources (except GPR) exist in many different LTPP tables. For example, tables TST_AC01, TST_AC01_LAYER, and TST_PC06 contain core measurement data. Tables SPS*_LAYER and SPS*_LAYER_THICKNESS contain field elevation data. (Note: The name SPS*_LAYER used herein refers to the SPS1_LAYER, SPS2_LAYER, SPS5_LAYER, SPS6_LAYER, SPS7_LAYER, SPS8_LAYER, and SPS9_LAYER tables. The name SPS*_LAYER_THICKNESS refers to the SPS1_LAYER_THICKNESS, SPS2_LAYER_THICKNESS, SPS5_LAYER_THICKNESS, SPS6_LAYER_THICKNESS, SPS7_LAYER_THICKNESS, and SPS8_LAYER_THICKNESS tables.) The inventory or planned layer thickness data are stored in other tables (e.g., INV_LAYER and RHB_LAYER). Field identified material type and depths to strata top and strata bottom are stored in table TST_SAMPLE_LOG. The design layer thickness data can be found in the experimental designs for newly constructed SPS sections.

Using the above information, the LTPP Regional Support Contractors (RSC's) complete tables TST_L05, TST_L05A, and TST_L05B. Table TST_L05 stores project-level material type information for SPS experiments with multiple sections constructed at the same site. Table TST_L05A contains measured layer material type and thickness data at the beginning, within, and at the end of a section, based on the core measurements and field test pit information. TST_L05B provides the representative thickness for the section. These representative layer materials and thicknesses at the section level are the best available estimates of the layer thicknesses in the LTPP database.

Purpose and Scope of the Guide

The main purposes of this guide for LTPP thickness data are:

- To explain to the LTPP data users what and where different types of layer material type and thickness data reside in the LTPP database.
- To present LTPP thickness within-section variability.
- To summarize as-designed versus as-constructed layer thickness comparisons.
- To provide guidelines to search for the most appropriate thickness information for different research purposes.

Field sampling, materials testing, and other layer thickness data collection activities utilized by LTPP are discussed briefly, along with the characterization of the within-section thickness variation and designed versus constructed thickness data variations for the LTPP sections.

Guide Organization

The guide consists of six chapters. This chapter provides background information, purpose and scope, and the organization of the guide. Chapter 2 presents LTPP layer material type and thickness data collection and storage in the LTPP database. It also provides the LTPP data users useful information as to what and where different thickness-related data reside in the database, as well as the limitations of the data. Chapter 3 discusses the variations in the layer thickness at different locations within an LTPP section. Typical variations in layer thickness for different layer and material types are discussed. Assessments were also made to whether distributions of these thickness measurements follow a normal distribution. Chapter 4 compares the as-designed layer thicknesses with the as-constructed or measured thicknesses. Statistical evaluation results are presented regarding differences between the designed thickness and the as-constructed thickness. Chapter 5 presents recommendations regarding what data to use under different scenarios. Chapter 6 provides an additional note about the LTPP data release used for this study and other information.

LTPP LAYER THICKNESS DATA

Several types of layer thickness data were collected under the LTPP program, and these data reside in different LTPP database modules and tables. This chapter provides detailed discussions about each of these data sources and data tables.

The following lists LTPP tables that contain layer material or thickness information:

- TST_AC01-Asphalt concrete (AC) core examination and thickness. Contains measured AC core thicknesses.
- TST_AC01_LAYER-AC core exam and thickness information. Contains field layer and actual layer number.
- TST_PC06-Portland cement concrete (PCC) core examination and thickness.
- SPS*_LAYER-Summarized layer descriptions and thicknesses for newly constructed SPS layers. (Sheet 4).
- SPS*_LAYER_THICKNESS-Field elevation layer thickness measurements (Sheet 12).
- TST_SAMPLE_LOG-Information about the samples taken from holes, pits, and probes.
- INV_LAYER-Layer descriptions and thickness data collected from highway agencies (Data Sheet: Inventory 3).
- RHB_LAYER-Layer descriptions and thickness data collected from highway agencies on rehabilitated layers (Data Sheet: Rehab 2).
- TST_L05-Table containing laboratory material testing data, project level for SPS experiments only.
- TST_L05A-Table containing layer descriptions for all constructions, section level - measured data.
- TST_L05B-Table containing layer descriptions for all constructions, section level - analysis section.

Additional information about the LTPP program, field sampling, materials testing, layer structure and layering information, data collection guidelines, and the LTPP database can be found in the following documents:

- Data Collection Guide for Long-Term Pavement Performance Studies, Operational Guide No. SHRP-LTPP-OG-001, Strategic Highway Research Program, Washington, DC, 1993. [1]
- SHRP-LTPP Interim Guide for Laboratory Material Handling and Testing, Operational Guide No. SHRP-LTPP-OG 004, SHRP, Washington, DC, 1991. [2]
- Field Materials Sampling, Testing, and Handling Guide No. SHRP-LTPP-OG 006, Version 2.0, Strategic Highway Research Program, Washington, DC, 1992. [3]
- LTPP SPS Pavement Layering Methodology, Federal Highway Administration, McLean, Virginia, January 1994. [4]
- Specific Pavement Studies, LTPP Material Sampling and Testing Requirements for SPS Experiments. [5-10]
- Specific Pavement Studies, LTPP Experiment Design and Research Plan for SPS Experiments. [11-16]
- SHRP-LTPP Protocol P01 for SHRP test designation AC01: Visual Examination and Thickness of Asphaltic Concrete Cores, SHRP, Washington DC, February 1991. [17]
- SHRP-LTPP Protocol P66 for SHRP test designation PC06: Visual Examination and Length Measurement of Portland Cement Concrete Cores, SHRP, Washington DC, February 1991. [18]
- LTPP Information Management System: IMS Quality Control Checks, Federal Highway Administration, McLean, Virginia, 2000. [19]
- Specific Pavement Studies, Data Collection Guidelines for SPS Experiments. [20-25]

Note that information presented in this Guide about LTPP table structures, field names and descriptions, and code lists reflect the current LTPP database structure and may be changed in the future. For the updated information, the users should refer to the most recent IMS Quality Control Checks document [19].

Inventory Layer Thickness Data

Inventory or design layer structure data for the existing LTPP pavement sections are collected by LTPP and stored in table INV_LAYER. The data are generally based on highway agency records. Inventory data are historical in nature and exist for all GPS sections. For SPS experiments, only the rehabilitation projects (SPS-5, SPS-6, SPS-7, and SPS-9) and the sections that are linked to a GPS section have records in the INV_LAYER table. [1, 20-25]

The essential fields other than the section and layer identification fields in table INV_LAYER are the following:

Field Name	Description
DESCRIPTION	Code indicating general type of layer.
MATERIAL_TYPE	Code for material type classification. QC applies to GPS; see QC Manual for SPS.
MEAN_THICKNESS	Mean thickness of each layer. QC applies to GPS; see QC Manual for SPS
MIN_THICKNESS	Minimum thickness of each layer. QC applies to GPS; see QC Manual for SPS.
MAX_THICKNESS	Maximum thickness of each layer. QC applies to GPS; see QC Manual for SPS.
STD_DEV_THICKNESS	Standard deviation of layer thickness. QC applies to GPS; see QC Manual for SPS.

A list of the codes and their descriptions for the field DESCRIPTION (code name "DESCRIPTION") is given in table 1. The code name for field "MATERIAL_TYPE" is "MAT_TYPE." Table 2 provides the code list and descriptions for the MATERIAL_TYPE field. Up to four numbers were provided to indicate the minimum, maximum, mean, and standard deviation of thickness for each specific layer. If only a single specified design value for thickness was available, it was entered as the mean value. When a number of boreholes were made for sampling materials, thickness measurements may also have been taken. In such cases, the mean thicknesses were then verified or revised and variability information (MIN, MAX, and STD_DEV) added as a result of these field measurements. [2,3]

Table 1. Code list and code descriptions for "DESCRIPTION"

Code Number	Code Description for Code "DESCRIPTION"
1	Overlay
2	Seal Coat
3	OriginalSurface Layer
4	AC Layer Below Surface (Binder Course)
5	Base Layer
6	Subbase Layer
7	Subgrade
8	Interlayer

9	Friction Course
10	Surface Treatment
11	Embankment Layer

Table 2. Code list and code descriptions for code "MAT_TYPE", continued.

Code Number	Code Description for Code "MAT_TYPE"
1	Hot-Mixed, Hot-Laid Asphalt Concrete, Dense-Graded
2	Hot-Mixed, Hot-Laid Asphalt Concrete, Open-Graded (Porous Friction Course)
3	Sand Asphalt
4	Portland Cement Concrete (Jointed Plain Concrete pavement [JPCP])
5	Portland Cement Concrete (Jointed reinforced Concrete pavement [JRCP])
6	Portland Cement Concrete (Continuously Reinforced Concrete Pavement [CRCP])
7	Portland Cement Concrete (Prestressed)
8	Portland Cement Concrete (Fiber-Reinforced)
9	Plant Mix (Emulsified Asphalt) Material, Cold-Laid
10	Plant Mix (Cutback Asphalt) Material, Cold-Laid
11	Single Surface Treatment
12	Double Surface Treatment
13	Recycled Asphalt Concrete Hot-Laid, Central Plant Mix
14	Recycled Asphalt Concrete Cold-Laid Central Plant Mix
15	Recycled Asphalt Concrete Cold-Laid Mixed-In-Place
16	Recycled Asphalt Concrete Heater Scarification/Recompaction
17	Recycled Portland Cement Concrete (JPCP)
18	Recycled Portland Cement Concrete (JRCP)
19	Recycled Portland Cement Concrete (CRCP)
20	Other
21	No Base(Pavement Placed Directly on Subgrade)
22	Gravel (Uncrushed)
23	Crushed Stone, Gravel or Slag
24	Sand
25	Soil-Aggregate Mixture (Predominantly Fine-Grained Soil)
26	Soil-Aggregate Mixture (Predominantly Coarse-Grained Soil)
27	Soil Cement
28	Dense-Graded, Hot-Laid, Central Plant Mix
29	Dense-Graded, Cold-Laid, Central Plant Mix
30	Dense-Graded,Cold-Laid, Mixed-In-Place
31	Open-Graded,Hot-Laid, Central Plant Mix
32	Open-Graded, Cold-Laid, Central Plant Mix
33	Open-Graded,Cold-Laid, Mixed-In-Place
34	Recycled Asphalt Concrete, Plant Mix, Hot-Laid
35	Recycled Asphalt Concrete, Plant Mix, Cold-Laid
36o	Recycled Asphalt Concrete, Mixed-In-Place
37	Cement-Aggregate Mixture
38	Lean Concrete (<3 sacks cement/cy)
39	Recycled Portland Cement Concrete
40	Sand-Shell Mixture
41	Limerock, Caliche (Soft Carbonate Rock)
42	Lime-Treated Subgrade Soil

43	Cement-Treated Subgrade Soil
44	Pozzolanic-Aggregate Mixture
45	Cracked and Seated PCC Layer
46	Sand Asphalt
49	Other
51	Clay (Liquid Limit > 50)
52	Sandy Clay
53	Silty Clay
54	Silt
55	Sandy Silt
56	Clayey Silt
57	Sand
58	Poorly Graded Sand
59	Silty Sand
60	Clayey Sand
61	Gravel
62	Poorly Graded Gravel
63	Clayey Gravel
64	Shale
65	Rock
70	Grout
71	Chip Seal Coat
72	Slurry Seal Coat
73	Fog Seal Coat
74	Woven Geotextile
75	Nonwoven Geotextile
77	Stress Absorbing Membrane Interlayer
78	Dense-Graded Asphalt Concrete Interlayer
79	Aggregate Interlayer
80	Open-Graded Asphalt Concrete Interlayer
81	Chip Seal with Modified Binder (Does Not Include Crumb Rubber)
82	Sand Seal
83	Asphalt-Rubber Seal Coat (Stress Absorbing Membrane
84	Sand Asphalt
85	Other
86	Thin Seals and Interlayers
90	Plain Portland Cement Concrete (only used for SPS-7 overlays of CRCP)

Rehabilitation Layer Thickness Data

Each highway agency is expected to notify the LTPP regional office prior to doing rehabilitation on a highway segment containing an LTPP section [1]. Rehabilitation activities include resurfacing, reconstruction, and the addition of lanes. Rehabilitation sometimes alters the pavement structure. In these cases, layer data are recorded in table RHB_LAYER from information provided by the highway agencies. Table RHB_LAYER contains layer thickness and material type information for sections that were rehabilitated during the LTPP program.

The essential fields other than the section and layer identification fields in table RHB_LAYER are the following:

Field Name	Description
DESCRIPTION	Code indicating general type of layer.
MATERIAL_TYPE	Code for type of material used in the rehabilitation.
MEAN_THICKNESS	The average thickness of each material layer.
MIN_THICKNESS	The minimum thickness of each material layer.
MAX_THICKNESS	Maximum layer thickness.
STD_DEV_THICKNESS	Standard deviation of layer thickness.

The code list and descriptions for the following fields were provided previously: DESCRIPTION (table 1) and MATERIAL_TYPE (code MAT_TYPE, table 2). Up to four numbers are provided to indicate the minimum, maximum, mean, and standard deviation of thickness for each rehabilitated layer. If only a single specified design value for thickness was available from project historic records, it was entered as the mean value. For SHRP/LTPP, when a number of boreholes were made for sampling materials, careful thickness measurements may also be made. In such cases, the mean thicknesses were then verified or revised and variability information (MIN, MAX, and STD_DEV) added as a result of these field measurements and measurements of cores in the laboratory. [2,3]

Laboratory Core Examination Data

Field and laboratory tests are conducted to establish material properties and layer characteristics. Characterization of material properties and the variations in these properties between and within the test sections is required to evaluate causes of performance differences between test sections.

Laboratory core examination data are stored in three LTPP tables: TST_AC01 and TST_AC01_LAYER for asphalt bound layers and TST_PC06 for PCC layers

AC Core Examination and Thickness

For the asphalt bound layers, SHRP protocol P01 [17], Visual Examination and Thickness of Asphaltic Concrete Cores, provides detailed procedures for identifying and determining the thickness of individual layers within the AC core. A single asphalt concrete core taken from the field may contain more than one layer. For example, a single AC core identified in the field as AC material may contain hot-mix AC (HMAC) wearing, binder, and base layers.

The test results for an entire AC core are stored in table TST_AC01, and the test results for the individual layers within the AC core are stored in table TST_AC01_LAYER

The essential fields other than the section and layer identification fields in table TST_AC01 are:

CORE_AVG-THICKNESS	Avergage thickness of core sample.
VISUAL_EXAM_1 to 6	Code "VISUAL_ACPC" for visual examination comments.
VISUAL_EXAM_OTHER	Other visual examination comments.
COMMENTS_1 to 6	Code "COMMENT" for testing comments
COMMENTS_OTHER	A note used to record additional observations regarding the test, or test results.

TEST_DATE	The date the test was performed.

Since the thickness measurements stored in table TST_AC01 is not keyed to LAYER_NO field and may not be for a single layer, it is difficult to identify which layer the measurement belongs to. The code lists for codes VISUAL_ACPC and COMMENTS are provided in tables 3 and 4 respectively.

Table 3. Code list and code descriptions for code "VISUAL_ACPC"

Code Number	Code Description for Code "VISUAL_ACPC"
66	Coarse aggregate along face of core is mix of uncrushed gravel and crushed stone.
67	The exposed aggregates along face of core are lightweight aggregate concrete.
68	More than 10% of core surface area contains soft aggregate particles/clay balls.
69	Cracks are generally across or through the coarse aggregate.
70	Cracks are generally around the periphery of the coarse aggregate.
71	Cracks are associated with embedded steel.
72	Rims are observed on aggregate.
73	Fine aggregate is natural sand.
74	Fine aggregate is manufactured sand.
75	Fine aggregate is a mixture of natural and manufactured sand.
76	Steel is present in the core.
77	Steel is corroded.
78	Core indicates D-cracking.
79	Core indicates deterioration due to freeze-thaw cycles.
80	Core indicates sulfate attack.
81	Core indicates alkali silica reactivity
82	Skewed core.
99	Other comment.

Table 4. Code list and code descriptions for code "COMMENT," continued.

Code Number	Code Description for Code "VISUAL_ACPC"
1	Intact core; excellent condition.
2	Hairline cracks on the surface; no visible vertical crack within 1/3 of length.
3	Cracks and/or voids visible along the side of the core.
4	Badly cracked or damaged core; unsuitable for testing.
5	Ridges on the sides of the cores; condition should be recorded if used.
6	Very rough and uneven bottom surface.
7	Core severely damaged from sampling, handling, etc. Unsuitable for testing.
8	Core was sawed in laboratory for removing it from the underlying bonded layer.
9	Core consisted of 2 or more AC layers. Core to be sawed and assigned layer numbers.
10	Visible separation of one or more layers. Layers to be sawed and assigned numbers.
11	Visible segregation of coarse and fine aggregates over 25% of surface area of core.

12	Voids in the matrix of the AC mixture are observed along the sides of the core.
13	Voids due to loss of coarse and fine aggregate observed along the sides of core.
14	Core missing significant portions, unsuitable for testing.
15	Coarse aggregate along face of core contains 50% or more of crushed materials.
16	Coarse aggregate along face of core is mix of uncrushed gravel and crushed stone.
17	More than 10% of core surface area contains soft aggregate particles/clay balls.
18	Slight stripping.
19	Severe stripping.
20	Slight bleeding.
21	Severe bleeding.
22	Skewed core.
51	Intact core; excellent condition.
52	Hairline cracks on the surface; suitable for testing.
53	Cracks and/or voids visible along the side of the core; suitable for testing.
54	Badly cracked or damaged core; unsuitable for testing.
55	Ridges on the sides of the cores; condition should be recorded if used for test.
56	Very rough and uneven bottom surface.
57	Core severely damaged during handling; unsuitable for testing.
58	Core was sawed in laboratory for removing it from the underlying bonded layer.
59	Core consisted of 2 or more layer. Core was assigned and assigned layer numbers.
60	Visible separation of one or more layers; layers separated and assigned numbers.
61	Segregation of coarse and fine aggregates observed over 25% of core surface area.
62	Voids in the matrix are observed along the sides of the core.
63	Voids due to loss of coarse and fine aggregates observed along sides of core.
64	Core is missing significant portions. Unsuitable for testing.
65	Coarse aggregate are generally crushed stone with predominately fractured faces.
66	Coarse aggregate along face of core is mix of uncrushed gravel and crushed stone.
67	The exposed aggregates along face of core are lightweight aggregate concrete.
68	More than 10% of core surface area contains soft aggregate particles/clay balls.
69	Cracks are generally across or through the coarse aggregate.
70	Cracks are generally around the periphery of the coarse aggregate.
71	Cracks are associated with embedded steel.
72	Rims are observed on aggregate.
73	Fine aggregate is natural sand.
74	Fine aggregate is manufactured sand.
75	Fine aggregate is a mixture of natural and manufactured sand.
76	Steel is present in the core.
77	Steel is corroded.

78	Core indicates D-cracking.
79	Core indicates deterioration due to freeze-thaw cycles.
80	Core indicates sulfate attack.
81	Core indicates alkali silica reactivity
82	Skewed core.
99	Other comment.

The essential fields other than the section and layer identification fields in table TST_AC01_LAYER are as following:

FIELD_LAYER_COMMENT	Comment on the field layer.
LAYER_DESCRIPTION	Code for the description of the pavement layer.
LAYER-THICKNESS	The measured thickness of an individual layer.

The code list and descriptions for field LAYER_DESCRIPTION (code DESCRIPTION, table 1) were provided previously.

Material Sampling Plan for AC Cores

Material sampling for AC cores was performed according to guidelines provided in several LTPP documents and reports, including the SHRP-LTPP Interim Guide for Laboratory Material Handling and Testing and the SPS Guidelines [2,3,5-16]. For GPS experiments, test samples were collected at specific locations outside the monitoring sections of the LTPP test sections. For SPS projects, cores were extracted from designated locations adjacent to the pavement test sections. Core thickness examination and thickness measurements were performed on all cores retrieved. Basically, two types of cores were extracted:

- Type A-152-mm diameter cores obtained from the approach and leave ends of a monitoring section.
- Type C-102-mm diameter cores obtained from the approach and leave ends of a monitoring section.

Sampling and testing requirements for AC core examination and thickness testing are presented in tables 5 and 6. The tables show the minimum number of core specimens required for testing for the various LTPP experiments, along with the designated sampling locations.

Table 5. Sampling requirements for visual examination and thickness of AC cores.

Experiment Type	Layer Type	Min. No. of Tests per Layer	Sampling Location [2,3]
GPS-1, -2, -6, and -7	AC	16	All 100-mm and 150-mm-diameter cores
SPS-1	ATB1	34	102-mm OD2 cores: C1-C10, C21-C34, C47-C56
	AC surface and binder	60	102-mm OD cores: C1-C60

SPS-3	ATB	34	102-mm OD cores: C1-C10, C21-C34, C47-C56
	AC surface and binder	60	102-mm OD cores: C1-C60
SPS-5 (Preconstruction)	AC	26	All Type-C cores
SPS-5 (Postconstruction)	AC	40	All cores
SPS-6	AC	20	All cores
SPS-8	AC	16	All cores
SPS-9 (Preconstruction)	AC	6	A01A01, A02A01, A01A02
			A02A02, A01A03, A02A03
SPS-9 (Postconstruction)	AC	8	–

Notes:
[1]Asphalt-treated base.
[2] Outside Diameter.

Table 6. Detailed SPS sampling requirements for visual examination and thickness of AC cores.

Experiment Type	Test Section	Min. No. of Cores Required (Surface and binder/ATB1)	Sampling Location [2,3]
SPS-1	0101 (0113)	Jun-00	C41-C46
SPS-1	0102 (0114)	Apr-00	C57-C60
SPS-1	0103 (0115)	4-Apr	C47-C50
SPS-1	0104 (0116)	4-Apr	C1-C4
SPS-1	0105 (0117)	6-Jun	C51-C56
SPS-1	0106 (0118)	6-Jun	C5-C9
SPS-1	0107 (0119)	Jun-00	C35-C40
SPS-1	0108 (0120)	Jun-00	C15-C20
SPS-1	0109 (0121)	Apr-00	C11-C14
SPS-1	0110 (0122)	4-Apr	C21-C24
SPS-1	0111 (0123)	4-Apr	C31-C34
SPS-1	0112 (0124)	4-Jun	C25-C30
SPS-5 (Preconstruction)	501	2	C1,C2
SPS-5 (Preconstruction)	502	4	C3-C6
SPS-5 (Preconstruction)	503	2	C7-C8
SPS-5 (Preconstruction)	504	2	C9-C10
SPS-5 (Preconstruction)	505	2	C11-C12
SPS-5 (Preconstruction)	506	5	C13-C17
SPS-5 (Preconstruction)	507	2	C18-C19
SPS-5 (Preconstruction)	508	5	C20-C24
SPS-5 (Preconstruction)	509	2	C25-C26

SPS-5 (Postconstruction)	501	0	–#
SPS-5 (Postconstruction)	502	4	C27-C30
SPS-5 (Postconstruction)	503	6	C31-C35
SPS-5 (Postconstruction)	504	6	C37-C42
SPS-5 (Postconstruction)	505	4	C43-C46
SPS-5 (Postconstruction)	506	4	C47-C50
SPS-5 (Postconstruction)	507	6	C51-C56
SPS-5 (Postconstruction)	508	6	C57-C62
SPS-5 (Postconstruction)	509	4	C63-C66
SPS-6 (Preconstruction)	601	3	C1-C3
SPS-6 (Preconstruction)	602	3	C3-C6
SPS-6 (Preconstruction)	603	2	C11-C12
SPS-6 (Preconstruction)	604	2	C13-C14
SPS-6 (Preconstruction)	605	4	C7-C10
SPS-6 (Preconstruction)	606	2	C15-C16
SPS-6 (Preconstruction)	607	2	C17-C18
SPS-6 (Preconstruction)	608	2	C19-C20
SPS-6 (Postconstruction)	603	4	C21-C24
SPS-6 (Postconstruction)	604	4	C25-C28
SPS-6 (Postconstruction)	606	4	C29-C32
SPS-6 (Postconstruction)	607	4	C33-C36
SPS-6 (Postconstruction)	608	4	C37-C40
SPS-8	0801, 0803, 0805	8	C1-C8
SPS-8	0802, 0804, 0806	8	C9-C16
SPS-9	0901, 0902, 0903	8	–#

PCC Core Examination and Thickness

Visual examination and length measurement are performed on PCC core specimens as part of the material characterization program for the LTPP study. These basic tests are conducted on all PCC cores before they are subjected to compressive strength, split tensile strength, and static modulus of elasticity testing.

Usually, cores are taken at specified periods after construction (e.g., 14, 28, and 365 days) for newly constructed pavements and several years after construction for in-service pavements adopted into the LTPP program. The number of cores taken from a given location depends on both the pavement test section properties and LTPP experiment type.

Procedures used for measuring core length (layer thickness) and examining the cores are presented in the following SHRP test protocol and AASHTO/ASTM test procedures:

- SHRP P66-Visual examination and length measurement of PCC cores. [18]
- AASHTO T148-Measuring length of drilled concrete cores. [26]
- ASTM C856-Petrographic examination of hardened concrete. [27]

The PCC core specimens are examined visually to determine their general condition, presence of distresses, presence of defects such as cracks, voids, D-cracking, alkali-silica reactivity, and problems with layer separation (for overlaid pavements). The general type and shape of aggregates (e.g., rounded gravel or angular crushed stone) were also documented. The cores were also examined to determine their suitability for length measurements and other testing. Cores with serious defects, such as uneven surfaces and segregated aggregates, were noted and not used for further testing.

The length measurement and visual examination test results are stored in the LTPP database after undergoing quality checks that ensure anomalies (e.g., negative PCC core thickness values) are identified and corrected. Data that are of acceptable quality after the quality control (QC) checks are classified as Level E and are stored in table TST_PC06. The following essential data other than the section and layer identification fields are maintained in table TST_PC06:

Field Name	Description
CORE_AVG_THICKNESS	Average thickness of core sample
VISUAL_EXAM_1 to 6	Code for visual examination comments
VISUAL_EXAM_OTHER	Other Visual examination comment.
COMMENTS_1 to 6	A note used to record additional obsservations regarding the test, or test results.
TEST_DATE	The date the test was performed.

The code list and descriptions for the following fields were provided previously: VISUAL_EXAM_1 to VISUAL_EXAM_6 (VISUAL_ACPC, table 3) and COMMENTS_1 to COMMENTS_6 (COMMENT, table 4).

Material Sampling Plan for PCC Cores

PCC core specimens are collected as directed by the SHRP P66 protocol from designated locations within the GPS and SPS experiments (GPS experiments are cored by SHRP contractors; SPS experiments are cored by highway agencies or contractors). Cores are then prepared according to procedures outlined in SHRP P66 [18], AASHTO T148 [26], and ASTM C856 [27] before being shipped to certified laboratories for testing.

For GPS pavements, cores are taken from both the approach and leave ends of the pavement test section. Both core locations are sited some distance from the monitored test section to avoid damaging the actual test section. For SPS experiments, cores are taken at designated locations from various test sections within a given site.

For SPS experiments, sampling can be complicated because these experiments consist of a diverse matrix of test sections, some of which are newly constructed with different PCC target thicknesses and strengths (e.g., SPS-2), and the others are in-service pavements that have been overlaid and, therefore, consist of both in-service and newly constructed layers (e.g., SPS-7).

Table 7 presents a summary of the minimum core specimens required by the LTPP materials testing and sampling program for core length measurements and visual examination for each LTPP experiment [2,5-10]. Although the minimum number of tests per layer indicated in the table directly translates to the required minimum tests per analysis cell for GPS projects, the same is not true for SPS projects. Therefore, a more detailed description of the testing requirements for various SPS experiments is presented in table 8.

Table 7. Summary of the sampling and testing plan for thickness measurement and visual examination of PCC cores.

Experiment Type	Layer Type	LTPP Protocol	Min. No. of Tests per Layer	Sampling Location [2,3]
GPS-3, 4, 5, 9	PCC	P66-61	2	C2, C8
GPS-7	PCC	P66-61	2	C8, C20
GPS-3, 4, 5, 9	PCC	P66-62	2	C5, C11
GPS-7	PCC	P66-62	2	C11, C23
GPS-3, 4, 5, 9	PCC	P66-64	2	C1, C7
GPS-7	PCC	P66-64	2	C7, C19
SPS-2	PCC	P66	99 per site/project	All cores
SPS-2	LCB	P66	24 per site/project	–#
SPS-6	PCC	P66	23 per site/project	C1-C20 A1 A2 A3
SPS-7	PCC-overlay (postconstruction)			C10-20 C21-64 C65-108
			99 per site/project	
	PCC-overlay (preconstruction)	P66	47 per site/project	C10-20 C21-64 C65-108
SPS-8	PCC	P66	26 per site/project	C1-C26
SPS-9A	PCC	P66	6 per site/project	–#

Table 8. Detailed SPS sampling requirements for PCC core visual examination and length measurement.

Exp. Type	Test Section	Layer Type	Min. No. of Specimens Required per Layer	Sampling Location [2,3]
SPS-2	0201 (0215)	PCC	8	C10-C17
SPS-2	02002 (0216)	PCC	8	C59-C66
SPS-2	0203 (0213)	PC	9	C34-C42
SPS-2	0204 (0214)	PCC	8	C83-C90
SPS-2	0205 (0219)	PCC	8	C21-C25, C18-C20, C22-C24
SPS-2	0206 (02020)	PCC	8	C73-C74, C67-C72
SPS-2	0207 (0217)	PCC	8	C29-C33, C26-C28, C30-C32
SPS-2	0208 (0218)	PCC	8	C78, C82, C75-C77, C79-C81
SPS-2	0209 (02023)	PCC	9	C1-C9
SPS-2	0210 (02024)	PCC	8	C51-C58
SPS-2	0211 (02021)	PCC	8	C43-C50
SPS-2	02102 (020202)	PCC	9	C91-C99
SPS-2	0205 (0219)	LCB	6	C18-C20, C22-C24
SPS-2	0206 (02020)	LCB	6	C67-C72
SPS-2	0207 (0217)	LCB	6	C26-C28, C30-C32
SPS-2	0208 (0218)	LCB	6	C75-C77, C79-C81

SPS-6	601	Original PCC	3	C1-C3
SPS-6	602	Original PCC	4	C4-C6, A1
SPS-6	603	Original PCC	3	C11-C12
SPS-6	604	Original PCC	2	C13-C14
SPS-6	605	Original PCC	4	C7-C10
SPS-6	6006	Original PCC	2	C15-C16
SPS-6	607	Original PCC	3	C17-C18, A3
SPS-6	608	Original PCC	2	C19-C20
SPS-7	701	Original (Overlay)	1 (0)	A1
SPS-7	702	Original (Overlay)	1 (8)	A2 (C21-C24, C65-C68)
SPS-7	703	Original (Overlay)	3 (9)	C1-C3 (C10, C25-C28, C69-C72)
SPS-7	704	Original (Overlay)	1 (8)	A3 (C29-C32, C73-C76)
SPS-7	705	Original (Overlay)	4 (8)	A4, BA1-BA3 (C33-C36, C77-C80)
SPS-7	706	Original (Overlay)	3 (11)	C4-C6 (C11-C13, C37-C40, C81-C84)
SPS-7	707	Original (Overlay)	1 (17)	A5 (C14-C16, C44-C50, C88-C94)
SPS-7	708	Original (Overlay)	1 (16)	A6 (C17-C18, C51-C57, C95-C101)
SPS-7	709	Original (Overlay)	3 (16)	C7-C9 (C19-C20, C58-C64, C102-C108)
SPS-8	0807, 0809, 0811	Overlay	13	C1-C13
SPS-8	0808, 0810, 0812	Overlay	13	C14-C26
SPS-9A	0901, 0902, 0903	Original	2	–

Field Elevation Measurements

For SPS newly constructed layers, elevation measurements of the final finished surface are conducted throughout the test section. The measurements normally are made at five offset points at every 500 feet along the section. Subsequently, layer thicknesses of these layers were then determined from before and after elevation measurements at each point where elevation measurements were made.

The measured layer thicknesses were recorded for each material layer type instead of for each relevant layer in the section layer structure. These layer thickness results at each measurement point are stored in the following tables:

- SPS1_LAYER_THICKNESS
- SPS2_LAYER_THICKNESS
- SPS5_LAYER_THICKNESS

- SPS6_LAYER_THICKNESS
- SPS7_LAYER_THICKNESS
- SPS8_LAYER_THICKNESS

The layer thickness measurements in the above tables are not keyed to individual layer numbers but are provided for each identified layer types. Aside from the section identification fields and coordination fields (STATION_NO and OFFSET), the following essential fields are contained in each of the above tables:

For SPS1_LAYER_THICKNESS:

Field Name	Description
DENSE_GRADE_AGG_BASE	Layer thickness measurement for dense graded aggregate base.
PERM_ASPH_TREAT_BASE	Layer thickness measurement for permeable asphalt treated aggregate base
DENSE_GRD_ASPH_TREAT_BASE	Layer thickness measurement for dense graded asphalt treated base
SURFACE_AND_BINDER	Layer thickness measurement for surface coarse and binder course.
SURFACE_FRICTION	Thickness of surface friction course layer

For SPS2_LAYER_THICKNESS:

Field Name	Description
DENSE_GRADE_AGG_BASE	Dense graded aggregate base layer.
PERM_ASPH_TREAT_BASE	Permeable asphalt treated base layer.
LEAN_CONCRETE	Lean concrete base layer.
PCC_SURFACE	PCC surface layer.

For SPS5_LAYER_THICKNESS:

Field Name	Description
RUT_LEVEL_UP	Thickness of rut level-up layer.
MILL_REPLACE	Thickness of mill replacement layer
BINDER_COURSE	Thickness of binder course layer
SURFACE_COURSE	Thickness of surface course layer.
SURFACE_FRICTION	Thickness of surface friction course layer

For SPS6_LAYER_THICKNESS:

Field Name	Description
DATE_BEGAN	Date which operations began
RUT_LEVEL_UP	Measurement of rut level-up layer after placement.
MILL_REPLACE	Measurement of mill replacement layer after placement
BINDER_COURSE	Measurement of binder course layer after placement.
SURFACE_COURSE	Thickness of surface layer
SURFACE_FRICTION	Thickness of surface friction course layer

LAYER_NO_RUT	Layer number for each layer for which a layer thickness is shown.
LAYER_NO_MILL	Layer number for each layer for which a layer thickness is shown.
LAYER_NO_BINDER	Layer number for each layer for which a layer thickness is shown.
LAYER_NO_SURFACE	Layer number for each layer for which a layer thickness is shown.
LAYER_NO_FRICTION	Layer number for each layer for which a layer thickness is shown.

For SPS7_LAYER_THICKNESS

Field Name	Description
DATE_BEGAN	Date which operations began
SURFACE_COURSE	Thickness of surface course layer.

For SPS8_LAYER_THICKNESS

Field Name	Description
DATE_BEGAN	Date which operations began
DENSE_GRADE_AGG_BASE	Surface elevation for the dense graded agrregate base.
PORT_CEMENT_CONCRETE_SURFACE	Surface elevation for the Portland Ccement Concrete surface.
ASPH_SURFACE_AND_BINDER	Surface elevation for the asphalt surface and binder.
SURFACE_COURSE	Thickness of surface friction course layer.

In addition to being provided at individual elevation measurement points, the summary layer thickness values (mean, minimum, maximum, and standard deviation) derived from elevation measurements are also stored in the LTPP database for individual layers for each section. These summaries are maintained in the following tables:

- SPS1_LAYER
- SPS2_LAYER
- SPS5_LAYER
- SPS6_LAYER
- SPS7_LAYER
- SPS8_LAYER
- SPS9_LAYER

The following essential fields other than the section and layer identification fields are present in all the above tables:

Field Name	Description
DESCRIPTION	Code indicating general type of layer
MATERIAL_TYPE	Code identifying type of material in each layer.
MEAN_THICKNESS	The average thickness of each material layer.
MIN_THICKNESS	The minimum thickness of each material layer.
MAX_THICKNESS	Maximum thickness measurement
STD_DEV_THICKNESS	Standard deviation of the thickness measurements.

The code list and descriptions for the "DESCRIPTION" field were previously given in table 1, while the code list and descriptions for field "MATERIAL_TYPE" (code name "MAT_TYPE") were previously provided in table 2.

Field Layer Material Type and Thickness Measurements

Material types and depths to strata top and strata bottom are identified or measured in the field from holes, test pits, and probes. Table TST_SAMPLE_LOG stores information about the samples taken from holes, pits, and probes, and is a good raw data source for unbound layers. However, records in this table are not keyed to the layer numbers as stored in TST_L05B and TST_L05A tables (field LAYER_NO). The thickness measurement from this table can only be manually matched to the layers established in the TST_L05B table. Nevertheless, this table can be used as raw layer thickness related data source and be consulted for unbound layer material type and thickness on a case-by-case basis.

The following essential fields other than the section and layer identification fields are present in table TST_SAMPLE_LOG:

Field Name	Description
FIELD_SET	Sequential number indicating the field sampling event. Assigned 1 for first sample event and incremented by 1 for subsequent events.
LOC_NO	Unique code number assigned to each sampling location indicating the sample type. The single character prefix indicates the sample type. The numeric suffix is the unique project location for the sample type.
STRATA_LEVEL	The sequential number of a stratum layer.
SAMPLE_NO	Unique code number assigned to each material sample indicating the sample type and material type. The fist character indicates the sample type. The second character indicates the material type. The numeric suffix is the unique sample number for the sample type and material type.
MATERIAL_DESC	Description of the material comprising the sample.
MATERIAL_CODE	Code used to identify the material comprising the sample.
DEPTH_TOP_STRATA	Depth to top of a stratum, measured from the surface.
DEPTH_BOT_ TRATA	The depth to the bottom of a stratum, measured from the surface.
NO_BLOWS_1	Number of blows per 6 inches of penetration of the splitspoon sampler
NO_BLOWS_2	Number of blows per 6 inches of penetration of the splitspoon sampler.
NO_BLOWS_3	Number of blows per 6 inches of penetration of the splitspoon sampler.
REFUSAL	Was splitspoon refused? [REFUSAL_S].
DLR	Depth to refusal of a splitspoon sample.
IOP	Inches of penetration of the splitspoon sampler.
DIAMETER	Diameter of the sample.
MOIST_NO	Sample number assigned to a sample to be used for moisture content testing.
BULK_NO	The identification number assigned to the bulk sample.

The code list and descriptions for the field "MATERIAL_CODE" (code name "MATERIAL") are provided in table 9.

Table 9. Code list and code descriptions for code "MATERIAL".

Code Number	Code Description for Code "MATERIAL"
1	Hot Mixed, Hot Laid AC, Dense Graded
2	Hot Mixed, Hot Laid AC, Open Graded
3	Sand Asphalt
4	Portland Cement Concrete (JPCP)
5	Portland Cement Concrete (JRCP)
6	Portland Cement Concrete (CRCP)
7	Portland Cement Concrete (Prestressed)
8	Portland Cement Concrete (Fiber Reinforced)
9	Plant Mix (Emulsified Asphalt) Material, Cold Laid
10	Plant Mix (Cutback Asphalt) Material, Cold Laid
11	Single Surface Treatment
12	Double Surface Treatment
13	Recycled AC, Hot Laid, Central Plant Mix
14	Recycled AC, Cold Laid, Central Plant Mix
15	Recycled AC, Cold Laid Mixed-In-Place
16	Recycled AC, Heater Scarification/Recompaction
17	Recycled Portland Cement Concrete, JPCP
18	Recycled Portland Cement Concrete, JRCP
19	Recycled Portland Cement Concrete, CRCP
20	Other
70	Grout
71	Chip Seal
72	Slurry Seal
73	Fog Seal
74	Woven Geotextile
75	Nonwoven Geotextile
77	Stress Absorbing Membrane Interlayer
78	Dense Graded Asphalt Concrete Interlayer
79	Aggregate Interlayer
80	Open Graded Asphalt Concrete Interlayer
81	Chip Seal with Modified Binder (Does not include crumb rubber)
82	Sand Seal
83	Asphalt-rubber Seal Coat
84	Sand Asphalt
85	Other
90	Plain Portland Cement Concrete (only used for SPS-7 overlays of CRCP)
100	Fine-Grained Soils: General
101	Fine-Grained Soils: Clay
102	Fine-Grained Soils: Lean Inorganic Clay
103	Fine-Grained Soils: Fat Inorganic Clay

104	Fine-Grained Soils: Clay with Gravel
105	Fine-Grained Soils: Lean Clay with Gravel
106	Fine-Grained Soils: Fat Clay with Gravel
107	Fine-Grained Soils: Clay with Sand
108	Fine-Grained Soils: Lean Clay with Sand
109	Fine-Grained Soils: Fat Clay with Sand
110	Fine-Grained Soils: Gravelly Clay
111	Fine-Grained Soils: Gravelly Lean Clay
112	Fine-Grained Soils: Gravelly Fat Clay
113	Fine-Grained Soils: Sandy Clay
114	Fine-Grained Soils: Sandy Lean Clay
115	Fine-Grained Soils: Sandy Fat Clay
116	Fine-Grained Soils: Gravelly Clay with Sand
117	Fine-Grained Soils: Gravelly Lean Clay with Sand
118	Fine-Grained Soils: Gravelly Fat Clay with Sand
119	Fine-Grained Soils: Sandy Clay with Gravel
120	Fine-Grained Soils: Sandy Lean Clay with Gravel
121	Fine-Grained Soils: Sandy Fat Clay with Gravel
131	Fine-Grained Soils: Silty Clay
132	Fine-Grained Soils: Silty Clay with Gravel
133	Fine-Grained Soils: Silty Clay with Sand
134	Fine-Grained Soils: Gravelly Silty Clay
135	Fine-Grained Soils: Sandy Silty Clay
136	Fine-Grained Soils: Gravelly Silty Clay with Sand
137	Fine-Grained Soils: Sandy Silty Clay with Gravel
141	Fine-Grained Soils: Silt
142	Fine-Grained Soils: Silt with Gravel
143	Fine-Grained Soils: Silt with Sand
144	Fine-Grained Soils: Gravelly Silt
145	Fine-Grained Soils: Sandy Silt
146	Fine-Grained Soils: Gravelly Silt with Sand
147	Fine-Grained Soils: Sandy Silt with Gravel
148	Fine-Grained Soils: Clayey Silt
151	Fine-Grained Soils: Peat
160	Fine-Grained Soils: Organic Soil
161	Fine-Grained Soils: Organic Soil with Gravel
162	Fine-Grained Soils: Organic Soil with Sand
163	Fine-Grained Soils: Gravelly Organic Soil
164	Fine-Grained Soils: Sandy Organic Soil
165	Fine-Grained Soils: Gravelly Organic Soil with Sand
166	Fine-Grained Soils: Sandy Organic Soil with Gravel

171	Fine-Grained Soils: Organic Clay
172	Fine-Grained Soils: Organic Clay (OL)
173	Fine-Grained Soils: Organic Clay (OH)
176	Fine-Grained Soils: Organic Silt
177	Fine-Grained Soils: Organic Silt (OL)
178	Fine-Grained Soils: Organic Silt (OH)
180	Treated Subgrade Soil
181	Fine-Grained Soils: Lime-Treated Soil
182	Fine-Grained Soils: Cement-Treated Soil
183	Bituminous Treated Subgrade Soil
200	Coarse-Grained Soils: General
201	Coarse-Grained Soils: Sand
202	Coarse-Grained Soils: Poorly Graded Sand
203	Coarse-Grained Soils: Poorly Graded Sand with Gravel
204	Coarse-Grained Soils: Poorly Graded Sand with Silt
205	Coarse-Grained Soils: Poorly Graded Sand with Silt and Gravel
206	Coarse-Grained Soils: Poorly Graded Sand with Clay
207	Coarse-Grained Soils: Poorly Graded Sand with Clay and Gravel
208	Coarse-Grained Soils: Well-Graded Sand
209	Coarse-Grained Soils: Well-Graded Sand with Gravel
210	Coarse-Grained Soils: Well-Graded Sand with Silt
211	Coarse-Grained Soils: Well-Graded Sand with Silt and Gravel
212	Coarse-Grained Soils: Well-Graded Sand with Clay
213	Coarse-grained soils: well-graded sand with clay and gravel
214	Coarse-grained soil: silty sand
215	Coarse-grained soil: silty sand with gravel
216	Coarse-grained soil: clayey sand
217	Coarse-grained soil: clayey sand with gravel
251	Coarse-grained soil: gravel
252	Coarse-grained soil: poorly graded gravel
253	Coarse-grained soil: poorly graded gravel with sand
254	Coarse-grained soil: poorly graded gravel with silt
255	Coarse-grained soil: poorly graded gravel with silt and sand
256	Coarse-grained soil: poorly graded gravel with clay
257	Coarse-grained soil: poorly graded gravel with clay and sand
258	Coarse-grained soil: well-graded gravel
259	Coarse-grained soil: well-graded gravel with sand
260	Coarse-grained soil: well-graded gravel with silt
261	Coarse-grained soil: well-graded gravel with silt and sand\
262	Coarse-grained soil: well-graded gravel with clay
263	Coarse-grained soil: well-graded gravel with clay and sand

264	Coarse-grained soil: silty gravel
265	Coarse-grained soil: silty gravel with sand
266	Coarse-grained soil: clayey gravel
267	Coarse-grained soil: clayey gravel with sand
280	Rock and stone
281	Shale
282	Rock
283	Cobbles
284	Boulders
285	Claystone \ Mudstone
286	Siltstone
287	Sandstone
288	Slag
289	Shale Chunk
290	Crushed sandstone

Once layer structure information was collected from different sources, the FHWA RSC's summarize these layer structure data into the following three LTPP tables:

Layer Material Type and Thickness Summary Data

- TST_L05-Table containing laboratory material testing data (project-level) for SPS projects only.
- TST_L05A-Table containing layer descriptions for all constructions, measured data at the section level.
- TST_L05B-Table containing layer descriptions for all constructions, analysis data at the section level.

Prior to completion of the L05 tables, the FHWA RSC evaluation personnel are required to review the following information:

- Inventory data, if available.
- Field material sampling and testing data, including photographs of cores, test pits, etc. that were taken in the field.
- Materials testing data packet, including any photographs taken during core examinations, etc.
- Project-specific material sampling and testing plan
- Construction plans or typical cross-sections, when available.
- Appropriate State supplemental documents.
- Construction data sheets for the experiment, including rod and level survey data.
- For SPS sections, appropriate Specific Pavement Studies Experimental Designs [11-16]. (Used to establish the expected layer structure for new construction.)
- Any other information that the evaluation personnel deem relevant, including Falling Weight Deflectometer (FWD) information and profilometer (i.e., roughness) data.

Table TST_L05

The TST_L05 table contains layer material information for SPS projects only. Unlike the GPS studies, SPS projects consist of multiple test sections. To keep track of pavement layering and test results from various test sections, a "Project-Level Layering Structure" was developed and stored in table TST_L05.

The ultimate purpose of the Project-Level Layering is to set up an accounting system to be used to link material tests for a given pavement layer in a particular section to other similar materials throughout the project. This project layering information in table TST_L05 is important to researchers interested in the material properties at the project level. The following is a list of the essential fields other than the SPS project identification fields in table TST_L05:

Field Name	Description
PROJECT_LAYER_CODE	A sequential alphabetic code assigned to identify group project wide layers
MATL_CODE INV_LAYER_NO_1	A code corresponding to the material type classification.
INV_LAYER_NO_2	The last layer in inventory to which the testing layer corresponds.
COMMENT_NOTE	A comment providing additional information.

The code name for field "MATL_CODE" is "MATERIAL," and its code list and descriptions were previously given in table 9.

Table TST_L05A

TST_L05A includes field or laboratory determined material classification and measured thicknesses for a given pavement layer on a test section basis. TST_L05A is a final laboratory summary of pavement layering material and thickness information at each end of the pavement section, as well as within a section. The following essential information other than the section and layer identification fields is contained in this table:

Field Name	Description
PROJECT_LAYER_CODE	A sequential alphabetic code assigned to identify group project wide layers.
DESCRIPTION	Code indicating general type of layer
LAYER_THICK_STATION 0	Thickness of layer at beginning of section (station 0-).
MATL_CODE_STATION 0	Material code at the beginning of a section (station 0-).
MEASURE_TYPE_1_STATION 0	Method used to take measurements at station 0-.
MEASURE_TYPE_2_STATION 0	Method used to take measurements at station 0-.
MEASURE_TYPE_3_STATION 0	Method used to take measurements at station 0-.
LAYER_THICK_WITHIN	Thickness of layer within section.
MATL_CODE_WITHIN	Material code within the section.
MEASURE_TYPE_1_WITHIN	Method used to take measurements within the section
MEASURE_TYPE_2_WITHIN	Method used to take measurements within the section.

MEASURE_TYPE_3_WITHIN	Method used to take measurements within the section.
LAYER_THICK_STATION 5	Thickness of layer at end of section (station 5+).
MATL_CODE_STATION 5	Material code at the end of the SHRP section (station 5+).
MEASURE_TYPE_1_STATION 5	Method used to take measurements at station 5+.

Field Name	Description
PROJECT_LAYER_CODE	A sequential alphabetic code assigned to identify group project wide layers.
DESCRIPTION	Code indicating general type of layer

Field Name	Description
MEASURE_TYPE_2_STATION 5	Method used to take measurements at station 5+.
MEASURE_TYPE_3_STATION 5	Method used to take measurements at station 5+.

The code list and descriptions for the following fields were provided previously: DESCRIPTION (table 1), MATL_CODE_STATION0, MATL_CODE_ WITHIN, and MATL_CODE_STATION5 (code MATERIAL, table 9). The code list and descriptions for field LAYER_TYPE are provided in table 10. The code name for the following fields is "MEASURE_TYPE":

- MEASURE_TYPE_1_STATION0, MEASURE_TYPE_2_STATION0, MEASURE_TYPE_3_STATION 0
- MEASURE_TYPE_1_WITHIN, MEASURE_TYPE_2_WITHIN, MEASURE_TYPE_3_WITHIN
- MEASURE_TYPE_1_STATION5, MEASURE_TYPE_2_STATION5, MEASURE_TYPE_3_STATION 5

Table 10. Code list and code descriptions for code "LAYER_TYPE".

Code Item	Code Description for Code "LAYER_TYPE"
AC	Asphalt concrete layer
PC	Portland cement concrete layer
TB	Bound (treated) base
TS	Bound (treated) subbase
GB	Unbound (granular) base
GS	Unbound (granular) subbase
SS	Subgrade (untreated)
RB	Rigid Layer used for backcalculation

The code list and descriptions for code "MEASURE_TYPE" are provided in table 11.

Table 11. Code list and code descriptions for code "MEASURE_TYPE"

Code Item	Code Description for Code "MEASURE_TYPE"
1	Pavement Core (laboratory measurement)
2	Pavement Core (field core logs)
3	Core of Bound Base/Subbase
4	Borehole logs for BA1, BA2, BA3, and A1, A2, type boreholes
5	Shoulder Auger Probe Log
6	Shoulder Auger Probe Log
7	Other
8	No measurements conducted on this layer
9	Ground Penetrating Radar

Table TST_L05B

TST_L05B establishes the final pavement layer structure for each test section. All information available for the test section is used to derive this layer structure. Therefore, this table can potentially use data actually derived from the section itself, or if information is not available, data from other test sections in close proximity to the section. Table TST_L05B contains the following essential fields other than the section and layer identification fields:

Field Name	Description
PROJECT_LAYER_CODE	A sequential alphabetic code assigned to identify group project wide layers.
DESCRIPTION	Code indicating general type of layer.
LAYER_TYPE	A character code indicating the type of layer
REPR_THICKNESS	The representative thickness for a layer in a section.
MATL_CODE	Material code for the layer.
LAYER_COMMENT 1	Codes to describe any additional information concerning layer.
LAYER_COMMENT 2	Codes to describe any additional information concerning layer.
LAYER_COMMENT 3	Codes to describe any additional information concerning layer.
INV_LAYER_NO	The first corresponding layer in INV_LAYER.
INV_LAYER_NO_2	The last layer in inventory to which the testing layer corresponds.

The code list and descriptions for the following fields were provided previously: DESCRIPTION (table 1), LAYER_TYPE (table 10) and MATL_CODE (code MATERIAL, table 9). The code name for field LAYER_COMENT 1, LAYER_COMENT 2, and LAYER_COMENT 3 is "L05B_COMMENT_CODES," and its code list and descriptions are provided in table 12.

Table 12. Code list and code descriptions for code "L05B_COMMENT_CODES".

Code Item	Code description for Code "L05B_COMMENT_CODES"
A	FWD data on section agree best with approach end sample location.
B	FWD data agree best with leave end sample location.
C	Profile and condition data agree best with approach end sample location.

D	Profile and condition data agree best with leave end sample location.
E	Gradations similar at section ends and averaged to determine material code.
F	Gradations different at section ends, material code from approach end used.
G	Gradations different at section ends, material code from leave end used.
H	Atterberg limits similar at both section ends and average to determine material code.
I	Atterberg limits different at both section ends. Material code from approach used.
J	Atterberg limits different at both section ends. Material code from leave used.
K	This layer absent at approach end.
L	This layer absent at leave end.
M	Layer inadvertently not stamped during drill and sample, but layer does exist.
N	Information from the state DOT indicates that beginning end is more representative.
O	Information from the state DOT indicates that leave end is more representative.
P	Material code for layer derived from lab. Testing of adjacent test section
Q	Layer thickness derived by measuring same material fro adjacent test section.
R	Layer was partially removed by milling.
S	Layer was completely removed by milling.
T	Sampling only occurred at approach end.
U	Sampling only occurred at leave end.
V	No sampling at either end
Z	Other (use column 8 to describe the action taken.)

LTPP THICKNESS DATA WITHIN-SECTION VARIABILITY

This chapter contains a discussion about LTPP database sources for layer thickness variability data. In addition, typical layer thickness summary statistics used to characterize layer thickness variability are provided. These summary statistics were derived from the LTPP layer thickness data. The chapter also contains information on the extent that layer thickness variation within a section follows typical statistical distributions. Guidelines are provided for the selection of the appropriate sources for the LTPP layer thickness variability data based on layer, material, and experiment type.

Data Sources

Layer thickness summary statistics such as average, minimum, maximum, standard deviation, and coefficient of variation are used to determine layer thickness variability along the LTPP section. Most of these values are found in the following LTPP tables

- For GPS sections, indicators such as average, minimum, maximum, and standard deviation can be found in the IMS tables INV_LAYER and RHB_LAYER. These summary statistics were provided by the highway agencies and could be either estimated or computed. No additional information is available regarding how summary statistics were derived for these tables.
- For the SPS sections, layer thickness summary statistics can be obtained from the SPS*_LAYER tables. These values were computed for the SPS sections from the elevation shots measurements. The SPS*_LAYER tables do not contain summary information on the number of data points used to derive the statistics. No information is available in the database regarding whether all of these data points were used to compute summary statistics or whether some "outlier" points were excluded.

Alternatively, layer thickness summary statistics could be computed using LTPP layer thickness data obtained from individual core measurements or from elevation measurements. The following data sources are available in the LTPP database

- Tables TST_AC01_LAYER and TST_PC06 contain individual core thickness measurements for AC and PCC layers, respectively. These measurements are available for GPS and SPS sections. The methodology for preparing an analysis data set (including identification of outliers) and methodology for statistical analysis can be found in the Assessment of Selected LTPP Material Data Tables and Development of Representative Test Tables report. [28]
- The SPS*_LAYER_THICKNESS tables contain individual thickness measurements from elevation shots taken along the section and reported for different layer and material type combinations. These measurements are available for SPS sections only. The methodology for preparing an analysis data set (including identification of outliers) and methodology for statistical analysis can be found in chapter 4 of the Evaluation and Analysis of LTPP Layer Thickness Data report. [29]

Typical Values for Variability Indicators from LTPP

To estimate typical values for layer thickness variability indicators, layer thickness data for SPS experimental sections with newly constructed layers were obtained from TST_AC01_LAYER and TST_PC06 tables (core thickness), and from SPS*_LAYER_THICKNESS tables (elevation thickness). These newly constructed SPS layers were selected for estimation of the typical variability indicators because they have documented target thickness values. The target thickness values were found to affect some of the layer variability indicators significantly. Data obtained using different measurement methods were analyzed separately. The analysis was done for the sets of data grouped by target design thickness, material, and layer type. The following statistical indicators were computed:

- Total Number of Measurements.
- Mean Thickness.
- Min. Thickness.
- Max. Thickness.
- Standard Deviation.
- Coefficient of Variation (COV).

The analyses were done separately for the thickness data obtained from core measurements and for the thickness data from elevation measurements. Data from the GPS experiments were analyzed separately from the SPS experimental data because the construction quality control used during the construction of new SPS sections was different from the quality control for the GPS sections constructed prior to inception of the LTPP program.

Table 13 summarizes layer thickness COV and standard deviations by different layer and material types. These summaries are based on the analysis of core thickness data for PCC and AC layers. Table 14 summarizes layer thickness COV and standard deviations by different layer and material types obtained for the SPS sections based on the analysis of elevation measurements.

The COV values from tables 13 and 14 could be used as approximate estimates of the expected layer thickness variability along the project for a given design layer thickness, material, and layer type.

Table 13. Summary of layer thickness COV and standard deviations based on core measurements.

Experiment type	Description	Number of analysis layers	Mean COV, %	Min COV, %	Max COV, %	Mean St. dev., mm	Min St. dev., mm	Max St. dev., mm
GPS	AC Binder Course	396	10.1	0.78	83.19	7.46	0.87	110.28
	ATB Layer	88	6.83	1.02	46.92	8.34	1.3	61.38
	AC Surface Layer	506	9.76	0.7	93.24	5.44	0.52	107.46
	AC Overlay	259	10.68	1.48	59.92	5.44	0.87	44.9
SPS	AC Binder Course	382	10.41	0.62	71.38	7.89	1.27	95.19
	ATB Layer	139	12.66	0.85	184.88	14.79	1.47	135.97
	AC Surface Layer	488	10.21	0.69	64.28	5.34	1.14	45.58
	AC Overlay	160	10.7	0.72	70.71	4.9	1.14	25.85
GPS	PCC Surface Layer	336	2.36	0.4	10.92	5.44	1.04	31.14
	PCC Overlay	24	2.92	0.55	13.1	6.22	1.04	20.74
SPS	Lean Concrete Base	34	4.62	1.12	23.38	7.37	1.8	38.8
	PCC Surface Layer	233	2.66	0.51	27.97	6.31	1.14	65.21
	PCC Overlay	29	5.19	1.61	12.59	7.22	2.19	14.63

Table 14. Summary of layer thickness COV and standard deviations based on SPS elevation measurements.

Material Type	Number of Analysis Layers	Mean COV,%	MinCOV,%	MaxCOV,%	MeanSt. Dev., mm	MinSt. Dev., mm	MaxSt. Dev., mm
DGAB	219	8.78	1.9	37.44	13	3.2	55.76
DGATB	97	5.31	1.79	15.1	9.5	3.87	24.48
LC	48	5.69	2.55	20.33	8.96	3.81	32.38
PATB	129	8.74	3.45	21.21	8.91	3.59	20.41
PCC	177	4.18	0.98	17.98	8.61	2.88	22.96
SB	319	8.32	2.01	35.8	8.41	2.47	21.1

The methodology used to create an analysis data set, identify outliers, and compute summary statistics is documented in the report titled, Evaluation and Analysis of LTPP Pavement Layer Thickness Data. [29]

Layer Thickness Distribution Type

Layer thickness data from the SPS elevation measurements were analyzed to determine the extent to which the variation of layer thickness within a section follows typical statistical distributions. The layers used in the analysis include different material types and functional classifications, such as:

- AC surface courses.
- Combined AC surface and binder courses.
- AC binder courses.
- Dense-graded aggregate bases.
- Dense-graded AC-treated bases.
- Permeable AC-treated bases.
- Lean concrete bases.
- PCC surface layers.
- PCC overlay layers.

To assess layer thickness distribution characteristics, descriptive statistics such as mean, standard deviation, skewness, and kurtosis were computed for each section. Using descriptive statistics, a likely shape of layer thickness distribution was analyzed. The results of exploratory analysis indicated that, for most of the sections, the distribution is likely to be normal. For a more rigorous analysis, a combined test for skewness and kurtosis was selected to test normality of layer thickness distribution. The summary of the testing procedure is documented in reference. [29]

The analysis results for 1,034 SPS layers indicated that thickness variation within a section follows a normal distribution for 84 percent of all layers. These results could serve as an input to pavement engineering applications involving design reliability, and also for construction quality control and quality assurance applications. Figures 1 to 2 provide examples of layer thickness frequency distributions obtained from the elevation measurements data for AC and PCC surface layers, respectively. Theoretical normal distributions are superimposed over field frequency data to provide means for comparison between field data and theoretical distributions.

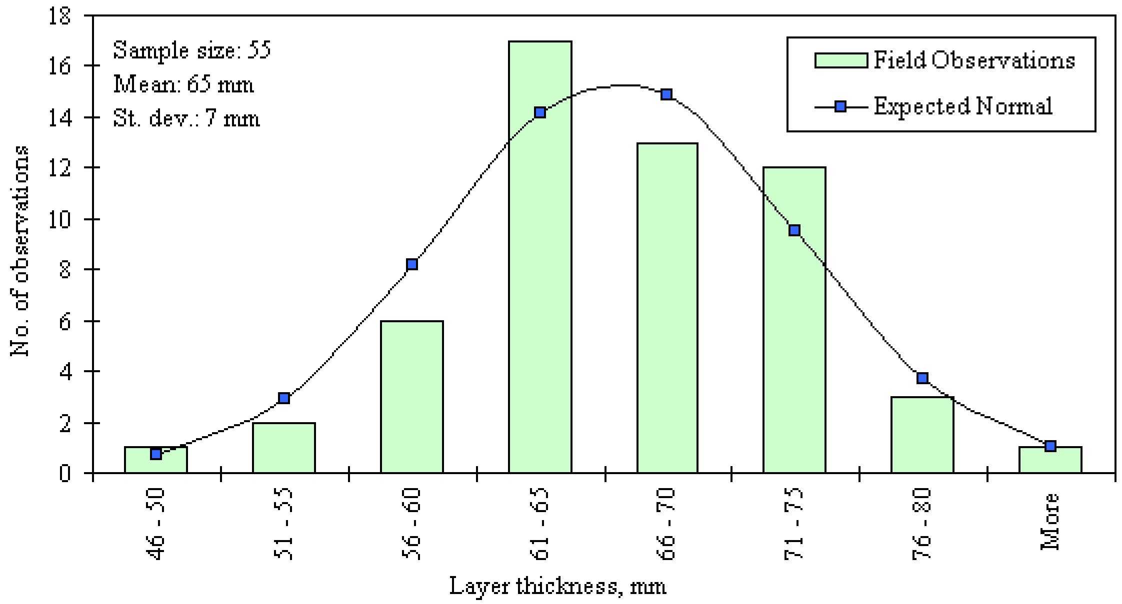

Figure 1: Chart. Example of distribution of layer thickness measurements along the section for AC surface and binder layer for the SPS-1 Section 55-0118.

Figure 1: Layer Thickness Measurements Along the Section for AC surface and Binder Layer for the SPS-1 Section 55-0118.

Mean	Standard Deviation	bin	bin	Frequency		Expected Normal	Field Observations
65.48582	6.959354666	50	50	1	46 - 50	0.716899032	1
1663.34	176.7676085	55	55	2	51 - 55	2.90984998	2
		60	60	6	56 - 60	8.213138758	6
		65	65	17	61 - 65	14.12963799	17
		70	70	13	66 - 70	14.82494145	13
		75	75	12	71 - 75	9.486755134	12
		80	80	3	76 - 80	3.70078331	3
		More	More	1	More	1.017994351	1
				55		53.98200565	55

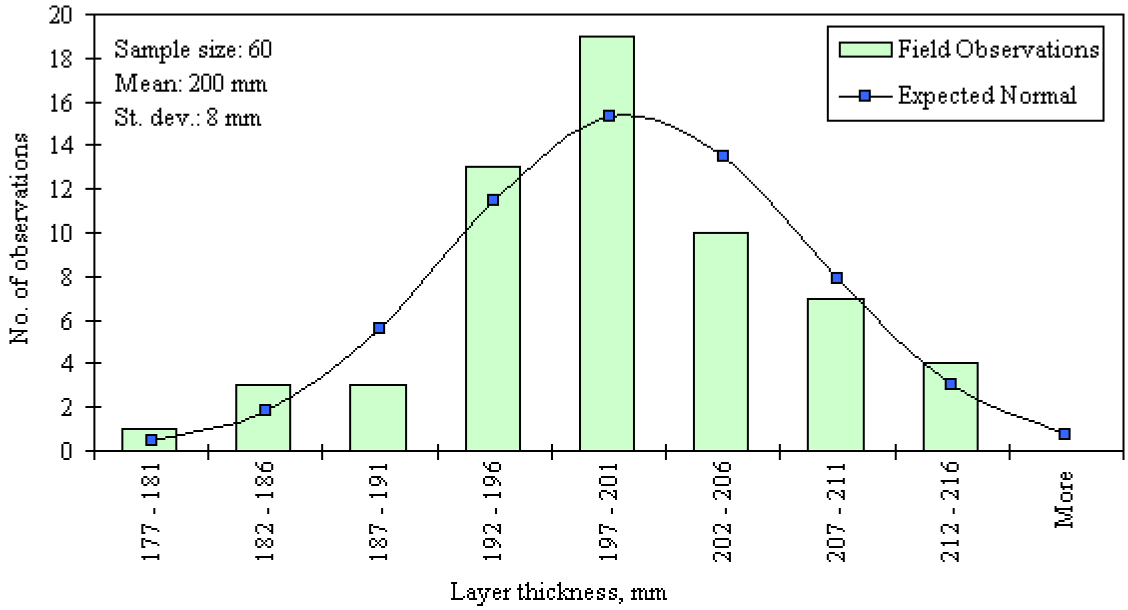

Figure 2: Chart. Example of distribution of layer thickness measurements along the section for PCC surface layer for the SPS-8 Section 39-0809.

Figure 2: Example Distribution of Layer Thickness measurements along the section for PCC surface layer for the SPS-8 Section 39-0809.

Mean	Standard Deviation	index	bin	bin	Frequency		Expected Normal	Field Observations
199.517	7.618923653	1	181	181	1	177 - 181	0.452470252	1
5067.7318	193.5206608	2	186	186	3	182 - 186	1.828750939	3
		3	191	191	3	187 - 191	5.627400247	3
		4	196	196	13	192 - 196	11.42212919	13
		5	201	201	19	197 - 201	15.29916715	19
		6	206	206	10	202 - 206	13.5254647	10
		7	211	211	7	207 - 211	7.891590078	7
		8	216	216	4	212 - 216	3.037784637	4
		8	More	More	0	More	0.771028733	0
					60		56.04697256	60

Summary of Layer Thickness Variability Assessment

Based on the assessment of the LTPP layer thickness values and analysis of layer thickness variability indicators, the following findings have been established:

- Standard deviation in layer thickness generally increases with increasing mean layer thickness.
- AC layers (surface and binder layers and permeable asphalt treated bases) and dense graded aggregate bases show the highest within section relative layer thickness variability, as estimated by COV.
- PCC layers (surface layers, overlays, and lean concrete bases) show the lowest within section relative layer thickness variability, as estimated by COV.
- Individual within-section layer thickness measurements follow a normal distribution for a majority of the LTPP layers.

VARIATION IN AS-DESIGNED AND AS-CONSTRUCTED LAYER THICKNESS DATA

This chapter summarizes analysis results concerning characterization of the differences in the as-designed and as-constructed (measured) thickness data for the newly constructed SPS layers. Only these new SPS layers have design thickness values accurately documented in the LTPP program. Typical summary statistics for as-designed versus as-constructed mean thicknesses are presented by layer types and target thickness values. Statistical test results are provided regarding whether the mean layer thickness deviations by layer type and design thickness levels are normally distributed. Finally, analysis results are presented from analyzing the percentage of the thickness measurements, as well as for the t-tests results comparing the mean layer thickness and the designed thickness values.

Data Sources

Measured Thickness Data

Two thickness data sources with multiple measurements on a given layer exist in the LTPP database:

- Elevation measurements in SPS*_LAYER_THICKNESS tables for experiments SPS-1, SPS-2, SPS-5, SPS6, SPS-7, and SPS-8.
- Pavement core measurements in testing tables TST_AC01_LAYER and TST_PC06.

According to SPS construction guidelines [30-35], rod and level survey measurements are to be taken at a minimum of five offset locations (edge, outer wheel path, mid-lane, inner wheel path, and inside edge of lane) at longitudinal intervals no greater than 15.2 m (50 ft). Typically, 55 elevation measurements are available for a section.

The number of cores taken for each section depends on experiment and layer type and is defined in the corresponding sampling and testing guides [5-10]. The number of cores per section ranges between 1 and 9.

All sections and layers with available thickness data in either one of these tables were studied to quantify design versus constructed variations in thickness.

For these section/layer combinations, an analysis cell is defined to represent a specific layer for which the target thickness was documented. The following fields in LTPP tables define a unique analysis cell:

- Experiment number.
- Layer type.
- Target thickness.

Design Thickness

For newly constructed SPS layers, the design thicknesses are defined in the corresponding SPS Experimental Designs [11-16]. The designed thicknesses are available for the following layer types:

- SB - AC surface and binder thickness (SPS-1, SPS-5, SPS-6, SPS-8).
- DGATB - Dense-graded asphalt-treated base (SPS-1).
- PATB - Permeable asphalt-treated base (SPS1, SPS-2).
- PCC - Portland cement concrete (SPS-2, SPS-7, SPS-8).
- LC - Lean concrete, (SPS-2).

- DGAB - Dense-graded aggregate base (SPS-1, SPS-2, SPS-8).

The design thicknesses for all these SPS experiments and layer types are presented in tables 15 through 20.

Table 15. Design Layer thickness for the SPS-1 experiment.

SHRP_ID	Design Layer Thickness, mm (in)			
	DGAB[1]	PATB[2]	DGATB[3]	SB[4]
101	203 (8)			178 (7)
102	305 (12)			102 (4)
103			203 (8)	102 (4)
104			305 (12)	178 (7)
105	102 (4)		102 (4)	102 (4)
106	102 (4)		203 (8)	178 (7)
107	102 (4)	102 (4)		102 (4)
108	203 (8)	102 (4)		178 (7)
109	305 (12)	102 (4)		178 (7)
110		102 (4)	102 (4)	178 (7)
111		102 (4)	203 (8)	102 (4)
112		102 (4)	305 (12)	102 (4)
113	203 (8)			102 (4)
114	305 (12)			178 (7)
115			203 (8)	178 (7)
116			305 (12)	102 (4)
117	102 (4)		102 (4)	178 (7)
118	102 (4)		203 (8)	102 (4)
119	102 (4)	102 (4)		178 (7)
120	203 (8)	102 (4)		102 (4)
121	305 (12)	102 (4)		102 (4)
122		102 (4)	102 (4)	102 (4)
123		102 (4)	203 (8)	178 (7)
124		102 (4)	305 (12)	178 (7)

Notes:
[1]Dense-graded aggregate base.
[2] Permeable asphalt-treated base.
[3] Dense-graded asphalt-treated base.
[4] Surface and binder (asphalt concrete surface courses).

Table 16. Design layer thicknesses for the SPS-2 experiment.

SHRP_ID	Design Layer Thickness, mm (in)			
	DGAB[1]	PATB[2]	LC[3]	PCC[4]
201	152 (6)			203 (8)

202	152 (6)			203 (8)
203	152 (6)			279 (11)
204	152 (6)			279 (11)
205			152 (6)	203 (8)
206			152 (6)	203 (8)
207			152 (6)	279 (11)
208			152 (6)	279 (11)
209	102 (4)	102 (4)		203 (8)
210	102 (4)	102 (4)		203 (8)
211	102 (4)	102 (4)		279 (11)
212	102 (4)	102 (4)		279 (11)
213	152 (6)			203 (8)
214	152 (6)			203 (8)
215	152 (6)			279 (11)
216	152 (6)			279 (11)
217			152 (6)	203 (8)
218			152 (6)	203 (8)
219			152 (6)	279 (11)
220			152 (6)	279 (11)
221	102 (4)	102 (4)		203 (8)
222	102 (4)	102 (4)		203 (8)
223	102 (4)	102 (4)		279 (11)
224	102 (4)	102 (4)		279 (11)

Notes:
[1]Dense-graded aggregate base.
[2] Permeable asphalt-treated base.
[3] Lead concrete base.
[4] Portland cement concrete slab.

Table 17. Design layer thickness for the SPS-5 experiment.

SHRP_ID	Design Layer Thickness, mm (in)
	SB[1]
501	0
502	51 (2)
503	127 (5)
504	127 (5)
505	51 (2)
506	51 (2)
507	127 (5)
508	127 (5)
509	51 (2)

Notes: [1]Surface and binder (asphalt concrete surface coures).

Table 18. Design Layer thickness for the SPS-6 experiment.

SHRP_ID	Design Layer Thickness, mm (in)
	SB[1]
601	0
602	0
603	102 (4)
604	102 (4)
605	0
606	102 (4)
607	102 (4)
608	203 (8)

Notes: [1]Surface and binder (asphalt concrete surface courses).

Table 19. Design Layer thickness for the SPS-7 experiment.

SHRP_ID	Design Layer Thickness, mm (in)
	PCC[1]
701	0
702	76 (3)
703	76 (3)
704	76 (3)
705	76 (3)
706	127 (5)
707	127 (5)
708	127 (5)
709	127 (5)

Notes: [1]Portland cement concrete slab

Table 20. Design layer thickness for the SPS-8 experiment.

SHRP_ID	Design Layer Thickness, mm (in)		
	DGAB[1]	PCC[2]	SB[3]
801	203 (8)		102 (4)
802	305 (12)		178 (7)
803	203 (8)		102 (4)
804	305 (12)		178 (7)
805	203 (8)		102 (4)
806	305 (12)		179 (7)
807	152 (6)	203 (8)	

808	152 (6)	279 (11)	
809	152 (6)	203 (8)	
810	152 (6)	279 (11)	
811	152 (6)	203 (8)	
812	152 (6)	279 (11)	

Notes:
[1]Dense-graded aggregate base.
[2]Portland cement concrete slab.
[3]Surface and binder (asphalt concrete surface cources).

Typical Deviations Between the Mean Measured and the Design Thicknesses

Typical mean layer thickness deviations are established by the following:

- Descriptive summary statistics of the average thicknesses deviations between as-designed and as-constructed values for the layers with the same layer material type and the same design thickness.
- Kurtosis and skewness tests of the distribution of the mean thicknesses for the layers with the same layer material type and the same design thickness.

Descriptive Summary Statistics

Mean layer thickness data for SPS experimental sections with newly constructed layers were obtained from TST_AC01_LAYER and TST_PC06 tables (core thickness), and from SPS*_LAYER_THICKNESS tables (elevation thickness), to compute measured thickness deviation from the design value. The analysis was done for the sets of data grouped by target design thickness, material, and layer type. The following statistical indicators were computed:

- Total number of sections or layers.
- Mean thickness deviation.
- Minimum thickness deviation.
- Maximum thickness deviation.
- Standard deviation of thickness deviation.
- COV of thickness deviation.

The analyses were done separately for the thickness data obtained from core measurements and for the data from elevation measurements. Table 21 summarizes layer thickness deviations by different layer and material types based on an analysis of elevation measurements. Table 22 summarizes mean core examination layer thickness deviations from their designed values by different layer and material types. The following observations are made based on these summary statistics:

- The computed descriptive statistics using elevation measurement data are different from those using core examination data. However, based on statistical analyses, the differences in the mean layer thicknesses and standard deviations are not significant for a majority of the layers. [29]
- The mean constructed layer thicknesses for PCC layers and lean concrete base layers are generally above the designed values.
- For the same layer and material type, the mean constructed layer thicknesses tend to be above the designed value for the thinner layers, and below the design value for the thicker layers.

These summary statistics characterizing the differences between as-designed and mean as-constructed layer thicknesses can be used as benchmarks for use in pavement design reliability and other research studies

Table 21. Summary of differences between mean elevation thickness measurements and target thicknesses.

Mat. Type	Target Thickness		Total Number of Sections	Mean Difference		Standard Deviation		Min. Difference		Max. Difference	
	mm	in		mm	in	mm	in	mm	in	mm	in
DGAB	102	4	84	0.4	0.01	10.3	0.4	-28.6	-1.13	33.4	1.32
	152	6	55	-1.2	-0.05	14.4	0.57	-51.5	-2.03	38.2	1.51
	203	8	40	0.9	0.04	12.7	0.5	-26.8	-1.05	45.2	1.78
	305	12	40	-6	-0.24	30	1.18	-173.3	-6.82	34.9	1.37
DGATB	102	4	27	1.8	0.07	8	0.31	-12	-0.47	21.1	0.83
	203	8	42	0.5	0.02	16.3	0.64	-62.5	-2.46	28.9	1.14
	305	12	28	-2.1	-0.08	15.9	0.63	-35.1	-1.38	38.1	1.5
LC	152	6	48	5.5	0.22	10.6	0.42	-25.8	-1.02	36.9	1.45
PATB	102	4	129	1.2	0.05	10.5	0.41	-17.1	-0.67	41.9	1.65
PCC	76	3	12	18.2	0.72	11.5	0.45	3.4	0.13	42.6	1.68
	127	5	12	16.5	0.65	11.6	0.46	5.1	0.2	39	1.53
	203	8	76	5.4	0.21	12.2	0.48	-32.6	-1.28	53.3	2.1
	279	11	77	4.7	0.18	11	0.43	-24.8	-0.98	39	1.54
SB	51	2	46	4.8	0.19	19.9	0.78	-27.8	-1.1	67.9	2.67
	102	4	125	-2.2	-0.09	18.5	0.73	-58.9	-2.32	31.7	1.25
	127	5	46	-4.4	-0.17	20.1	0.79	-70.6	-2.78	38.3	1.51
	178	7	95	-8.2	-0.32	23.9	0.94	-73.3	-2.89	59.4	2.34
	203	8	7	-2.7	-0.11	22.9	0.9	-36.9	-1.45	36.3	1.43

Table 22. Summary of differences between mean core thickness measurements and target thickness.

Mat. Type	Target Thickness		Total Number of Sections	Mean Difference		Standard Deviation		Min. Difference		Max. Difference	
	mm	in		mm	in	mm	in	mm	in	mm	in
DGATB	102	4	22	-0.9	-0.04	10.9	0.43	-22.9	-0.9	20.3	0.8
	203	8	34	1.1	0.04	21.5	0.85	-64.3	-2.53	38.1	1.5
	305	12	22	-5.4	-0.21	25.1	0.99	-88.9	-3.5	21	0.83
LC	152	6	36	8.2	0.32	12.6	0.5	-19.1	-0.75	38.9	1.53
PATB	102	4	32	-19.7	-0.78	39.4	1.55	-87.2	-3.43	113.5	4.47
PCC	76	3	10	20.3	0.8	10.7	0.42	5.9	0.23	35.9	1.41
	127	5	12	13.4	0.53	13.5	0.53	-9.9	-0.39	37.1	1.46
	203	8	71	9.8	0.39	14	0.55	-22.5	-0.89	52.3	2.06
	279	11	71	-0.7	-0.03	28.3	1.12	-94.7	-3.73	31.8	1.25
SB	51	2	45	16.2	0.64	21.4	0.84	-17.1	-0.68	59.7	2.35
	102	4	114	5.2	0.2	17	0.67	-63.5	-2.5	47	1.85
	127	5	47	9.1	0.36	23.6	0.93	-39.4	-1.55	73.2	2.88
	178	7	94	-4.3	-0.17	21.8	0.86	-96.5	-3.8	65.4	2.58
	203	8	6	-18.4	-0.73	51.6	2.03	-118.1	-4.65	16.5	0.65

Distribution Type of the Deviations between Designed and Constructed Layer Thicknesses

Table 23. Distribution of the mean thickness deviations from the design thickness based on kurtosis and skewness tests.

Mat. Type	Target Thickness		Elevation Measurement Data		Core Examination Data	
	mm	in	No. Layers	Distribution Type	No. Layers	Distribution Type
DGAB	102	4	84	Normal	No Data	
	152	6	55	Wide spread and skewed left		
	203	8	40	Wide spread and skewed right		
	305	12	40	Wide spread and skewed left		
DGATB	102	4	27	Normal	22	Normal
	203	8	42	Wide spread and skewed left	34	Normal

	305	12	28	Normal	22	Wide spread and skewed left
LC	152	6	48	Normal	36	Normal
PATB	102	4	129	Skewed right	32	Normal
PCC	76	3	12	Normal	10	Normal
	127	5	12	Normal	12	Normal
	203	8	76	Wide Spread	71	Normal
	279	11	77	Normal	71	Wide spread and skewed left
SB	51	2	46	Skewed right	45	Normal
	102	4	125	Skewed left	114	Wide spread and skewed left
	127	5	46	Normal	47	Normal
	178	7	95	Skewed left	94	Wide spread and skewed left
	203	8	7	Not enough data	6	Not enough data

As shown in table 23, for the elevation data, eight of the distributions appear to be normal while three are skewed to one side, five to the other side, and one sample tested wide spread but not skewed. The only reasonable distribution (of the differences between mean thicknesses from elevation measurements and target thicknesses) to assume for all material types and thickness is then the normal distribution. Again since the core data are of the same type as the elevation data, it is reasonable to assume normality for these data as well. Supporting the assumption for core data samples is that for the actual tests of skewness and kurtosis nine out of thirteen material types and thickness groups were determined to be normal, while the remaining five groups were skewed and wide spread.

For the cases where distributions were skewed, the reasons were further investigated, and in some cases explanations were discovered by simply examining the data points. For example, figure 4 shows an example of unreasonably large differences from the target thickness for seven PCC layers. Five layers with the largest differences belong to the same SPS project (10-0200). It appears that all core values for these layers are about 8 inch, while elevation data for the same layers show that they are 11 in or thicker. One explanation might be that the incomplete layer thicknesses were obtained during coring.

The following conclusions could be obtained from the analysis of the distribution of the differences between target and measured mean thickness values:

- It is reasonable to assume the mean thickness deviations follow the same kind of distribution;
- There is no trend being skewed to only one side for the elevation data; and
- Majority of the data tested to be normal;

As figure 4 indicates the skewness could be due to unreasonable outlier sections where it is possible that (1) incomplete layer thicknesses were obtained from the core, (2) contractor consistently deviated from the design thickness (under design or over design), or (3) erroneous data exist in the database.

The conclusions drawn from both the descriptive statistics and the kurtosis and skewness tests of their distribution types will be useful for pavement designers and researchers. They will be especially useful in reliability based mechanistic-empirical pavement performance analysis and design.

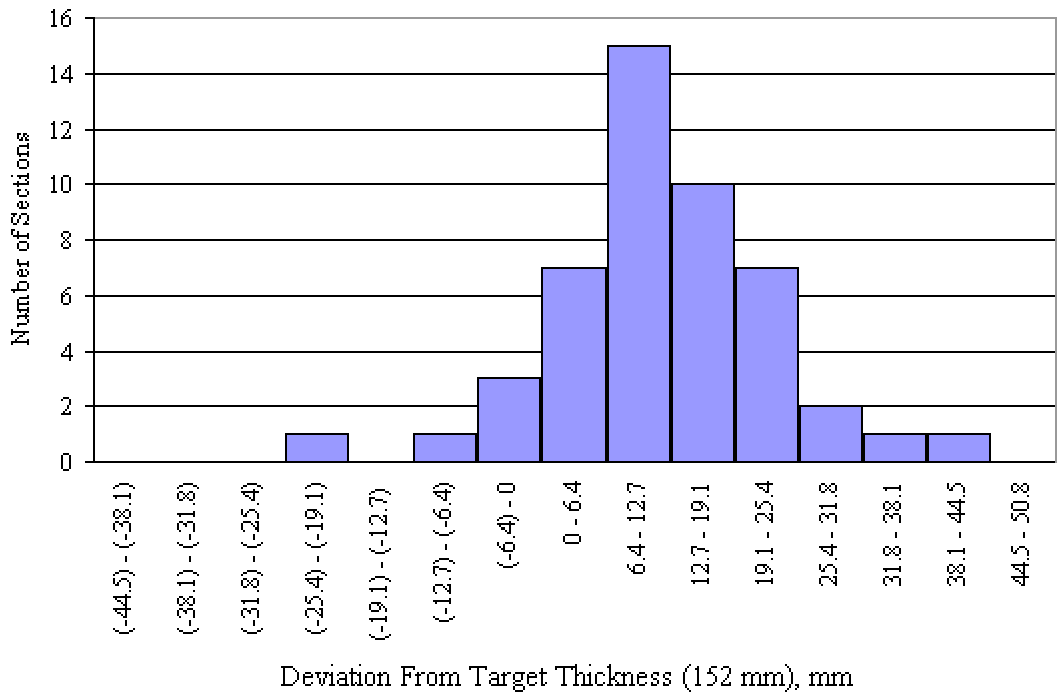

Figure 3: Chart. Example of normally distributed thickness deviations (elevation data, LC, target thickness 152 mm [6 in]).

Figure 3: Example of Normally distributed Thickness deviations.

(-44.5) - (-38.1)	0
(-38.1) - (-31.8)	0
(-31.8) - (-25.4)	0
(-25.4) - (-19.1)	1
(-19.1) - (-12.7)	0
(-12.7) - (-6.4)	1
(-6.4) - 0	3
0 - 6.4	7
6.4 - 12.7	15
12.7 - 19.1	10
19.1 - 25.4	7
25.4 - 31.8	2
31.8 - 38.1	1
38.1 - 44.5	1
44.5 - 50.8	0

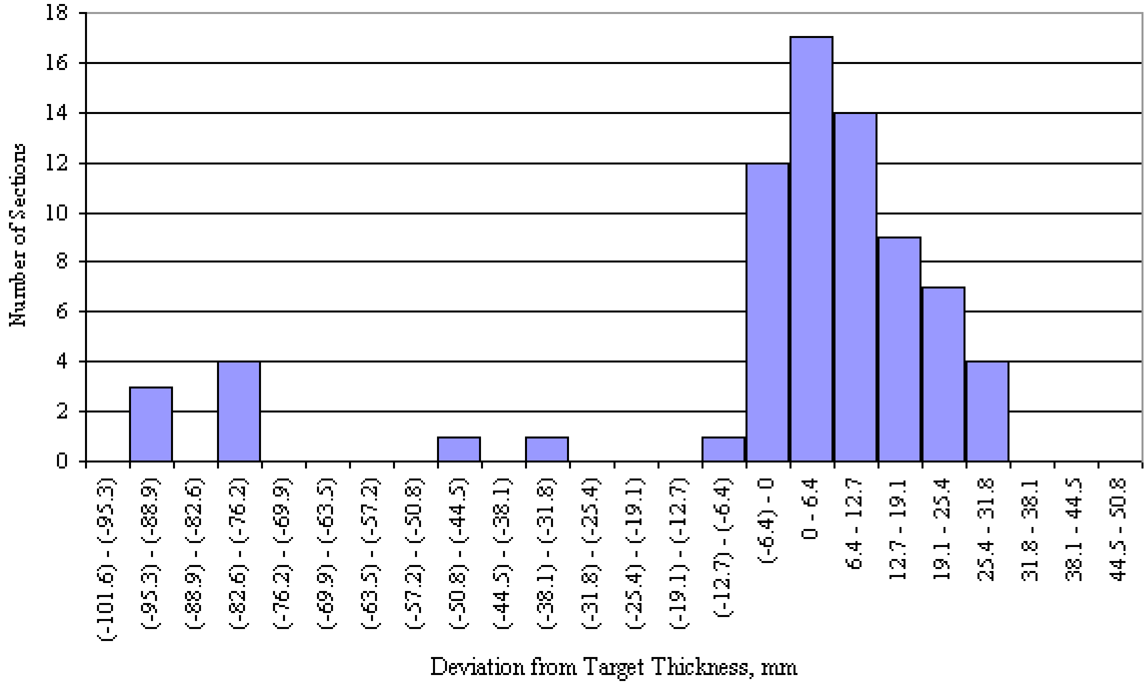

Figure 4: Chart. Example of a skewed distribution for layer thickness deviation (core data, PCC, target thickness 279 mm [11 in]).

Figure 4: Example of a Skewed Distribution for Layer thickness deviation.

	Frequency		
-3.75	0	(-101.6) - (-95.3)	0
-3.5	3	(-95.3) - (-88.9)	3
-3.25	0	(-88.9) - (-82.6)	0
-3	4	(-82.6) - (-76.2)	4
-2.75	0	(-76.2) - (-69.9)	0
-2.5	0	(-69.9) - (-63.5)	0
-2.25	0	(-63.5) - (-57.2)	0
-2	0	(-57.2) - (-50.8)	0
-1.75	1	(-50.8) - (-44.5)	1
-1.5	0	(-44.5) - (-38.1)	0
-1.25	1	(-38.1) - (-31.8)	1
-1	0	(-31.8) - (-25.4)	0
-0.75	0	(-25.4) - (-19.1)	0
-0.5	0	(-19.1) - (-12.7)	0
-0.25	1	(-12.7) - (-6.4)	1
0	12	(-6.4) - 0	12
0.25	17	0 - 6.4	17

0.5	14	6.4 - 12.7	14
0.75	9	12.7 - 19.1	9
1	7	19.1 - 25.4	7
1.25	4	25.4 - 31.8	4
1.5	0	31.8 - 38.1	0
1.75	0	38.1 - 44.5	0
2	0	44.5 - 50.8	0
More	0		

Analysis Results From Designed Versus Constructed Thicknesses Comparisons

This section presents a summary and conclusions derived from two types of statistical analyses that compared as-constructed versus as-designed thicknesses or target values. Detailed discussion of these comparisons can be found in a report titled, *Evaluation and Analysis of LTPP Pavement Layer Thickness Data. [29]*

First, both elevation data and core examination data were evaluated to establish the percentage of the individual measurements that is either within or outside the specified values from the target thickness. Three tolerance levels of 6.35 mm (0.25 in), 12.7 mm (0.5 in), and 25.4 mm (1 in) were used for this comparison.

Second, a statistical analysis of the measured mean thickness values versus the as-designed values was performed. Two types of thickness comparisons were performed for both data sources. The two-sided t-test with 95 percent reliability level was used for each section and layer to estimate whether the difference between as-designed and as-constructed thicknesses was significant. The one-sided t-test with 95 percent reliability level was used for each layer for the difference between as-designed thickness and the mean as-constructed thickness and for tolerance levels of 6.35 mm (0.25 in), 12.7 mm (0.5 in), and 25.4 mm (1 in). Analysis results from these comparisons and statistical analyses are presented in the following sections.

Analysis of the Percentage Distribution Results

Based on percentage distributions of the elevation measurements:

- Overall, about 35 percent of the measurements are within ± 6.35 mm (0.25 in) of the target value, with about 30 percent lower than the target and about 35 percent higher than the target value by more than 6.35 mm (0.25 in).
- Thickness measurements for AC surface and binder layers and thin bonded PCC layers consistently show the highest deviations from the target values.
- The percentage of the thickness measurements greater than the target value for PCC slab and lean concrete base layers is significantly higher than the percentage of measurements that are lower than the target value. Only 2 percent of thickness measurements are lower, and almost 80 percent are higher than the target value by more than 6.35 mm (0.25 in) for thin PCC bonded layers (76 mm [3 in] and 127 mm [5 in] thick).
- Thickness measurements for PATB are more evenly distributed around the target value.

Based on percentage distributions of the individual core thickness measurements:

- Overall, less than 35 percent of core measurements are within ± 6.35 mm of the design thickness value. For some material types and target thickness values, such as thin PCC layers (76 mm [3 in] or 123 mm [5 in] thick) and 203 mm (8 in) thick SB layer, this percentage is below 20.

- For LC and PCC layers, a much larger percentage of cores have thickness higher than designed. For PATB, the situation is just the opposite.

- For DGATB, SB, and PCC layers, the percentage of sections with as-constructed thickness below the target value increases with the target thickness. For PCC layers, the percentage of sections with as-constructed thickness above the target value decreases with increasing target thickness.

Statistical Analysis Results

Analysis Results from Two-sided t-tests

Based on the elevation measurements:

- Overall, only about 20 percent of the layers had mean constructed thicknesses not significantly different from their target thicknesses.

- All 24 sections with 76 mm (3 in) or 123 mm (5 in) target thicknesses for bonded PCC overlays are constructed significantly thicker.

- For only 4 to 15 percent of the sections with SB layers and target thicknesses between 51 mm (2 in) and 178 mm (7 in), the as-constructed mean thickness is not significantly different from the as-designed thickness.

- The lowest deviations from as-designed thickness are observed for DGAB layer for which more than 30 percent of the sections have as-constructed mean thickness not significantly different from the target value.

Based on the core thickness measurements:

- Overall, the mean constructed thickness for more than 45 percent of sections/layers is not significantly different from the target thickness. The percentage is highest for DGATB, and lowest for PCC and LC.

- DGATB has the highest number (overall 61 percent) of sections with mean constructed thickness not different from the target value. For almost 80 percent of the sections with DGATB layer and 102 mm (4 in) target thickness, constructed thickness is not significantly different from the designed thickness.

- PCC and LC layers have the lowest number (between 34 and 37 percent) of layers with mean constructed thickness not significantly different from the target value. For thin PCC slabs this percentage is 20 or below.

A comparison between analysis results from the elevation and core thickness measurements shows that the percentage of measurements within tolerance limits for all three tolerance levels is approximately the same. However, the percentage of measurements lower than target value is consistently higher for core measurements than for elevation measurements.

Analysis Results from One-sided t-tests

Based on the elevation measurements:

- The AC surface and binder layers have the highest number of sections with the mean constructed thicknesses tested to deviate more than their target values plus or minus all three tolerance levels (6.35 mm [0.25 in], 12.7 mm [0.5 in], and 25.4 mm [1 in]).
- For most sections (about 70 percent), the mean constructed thicknesses for the dense-graded aggregate base layers are within ±6.35 mm (0.25 in) of their target thicknesses.
- For portland cement concrete slabs and lean concrete bases, a much higher percent of sections had mean thicknesses greater than the target values plus tolerance levels than the ones below the target values. For thin bonded PCC overlays (76 mm [3 in] and 127 mm [5 in] thick) there are no sections with an as-constructed thickness significantly lower than the target value for all three tolerance levels.
- For all layer material types except AC surface and binder layers and thin bonded PCC slabs, more than 90 percent of sections have mean layer thicknesses tested within ±25.4 mm (1 in) of their target values.

Based on the core thickness measurements:

- The PCC layers have the highest percentage of sections with mean measured thicknesses above their target thicknesses for all three tolerance levels. This percentage decreases with the increased PCC target thickness. For thin bonded PCC layers (76 mm [3 in] or 123 mm [5 in] thick), there are no sections with a layer thickness significantly lower than the target value. For very thin bonded PCC overlays (76 mm [3 in] thick), 80 percent of sections have mean thicknesses that are significantly higher than the target value for more than 6.35 mm (0.25 in). This percentage decreases with increasing target thickness.
- For all material types except PATB and 178-mm- (7-in-) and 203-mm- (8-in-) thick SB layers, a much larger percentage of layers have mean thicknesses that are significantly higher than designed. For PATB, the situation is just the opposite, with more than 40 percent of layers having values that are significantly lower than the target value for more than 6.35 mm (0.25 in). For 203-mm- (8-in-) thick SB layers, there are no sections with mean measured thicknesses significantly higher than designed.
- For DGATB and SB layers, the number of sections with the mean thickness below the target thickness increases with the design thickness.
- All sections with DGATB and LC layers, except one, have thicknesses within ± 25.4 mm (1 in) of the target thickness.

Different conclusions were drawn between the statistical tests performed on the elevation measurements and the statistical tests conducted on the core examination measurements. For example, more core measurement data than elevation measurement data suggest that the measured mean layer thicknesses are not significantly different from their designed thicknesses.

RECOMMENDED LAYER THICKNESS DATA SOURCES IN THE LTPP DATABASE

Pavement layer thickness data are an essential input to pavement engineering analyses. The accuracy of layer thickness data has a great impact on the outcome of practically all analyses of performance. Based on the analysis type, thickness data at the "section level" or "location-specific" thickness measurements may be required. Additionally, variability information may be required for reliability-based pavement analyses. Examples of section-level analyses could be pavement performance modeling or mechanistic pavement structural analysis. For these types of analyses, the representative layer thicknesses are recommended. These thicknesses provide an overall estimate of characteristic layer thickness for the section that is being analyzed.

Example of location-specific analysis includes back calculation of pavement layer moduli. This analysis is based on interpretation of the deflection data obtained at the specific locations along the section. Layer thickness data from the specific locations where FWD tests were conducted could help to achieve more accurate results. An example of the analyses where thickness variability information is needed is reliability-based pavement performance modeling and design.

This chapter provides guidelines for searching the LTPP database for the most appropriate layer thickness data for different research purposes.

Recommended Layer Thickness Data Sources for Section-Level Analyses

Recommended layer thickness data sources for section-level analyses are summarized by the experiment type.

GPS sections:

Priority 1	The TST_L05B table is the most complete and accurate source for the representative layer thickness data.
Priority 2	If thickness data in this table are not available, data from TST_L05A could be used to determine representative thickness. TST_L05A contains laboratory- measured layer thickness data from up to three locations (beginning, within, and end of the section). Representative thickness is determined by averaging thickness values from different locations.
Priority 3	If thickness data are not available in either the TST_L05B or the TST_L05A table, representative layer thickness data from INV_LAYER (for construction event number 1) or RHB_LAYER (for construction event number 2 or above) could be used. Layer thickness data from these tables are the best estimate provided by the local highway agencies based on the existing documentation that was created prior to the LTPP experiment.

SPS sections:

Priority 1	The recommended layer thickness data source for section level analyses is the TST_L05B table. This is the most complete and accurate source for the representative layer thickness.
Priority 2	If thickness data in this table are not available, data from TST_L05A could be used to determine representative thickness. TST_L05A could include layer thickness data measured at up to three locations (beginning, middle, and end of the section).

Priority 3 Another reliable source of representative layer thickness information is the SPS* _LAYER tables. These tables contain average layer thickness measurements obtained from the elevation shots taken after construction of each layer at over 50 locations along the section.

Recommended Layer Thickness Data Sources for Location-Specific Analyses

Recommended layer thickness data sources for location-specific analyses are summarized by the experiment type.

GPS sections:

Priority 1 If the layer material type is AC or PCC, recommended layer thickness data sources for location-specific analyses are the TST_AC01_LAYER and TST_PC06 tables. Layer thicknesses obtained from these tables are based on measurements of pavement cores obtained at different locations along the section. Alternatively, the TST_L05A table could be used.

Priority 2 If the layer material type is not AC or PCC, layer thickness data from the TST_L05A table provide layer thicknesses measured at up to three locations (beginning, middle, and end of the section).

SPS sections:

Priority 1 The recommended layer thickness data sources for location-specific analyses are the SPS* _LAYER_THICKNESS tables. These tables contain layer thickness measurements obtained from the elevation shots taken after construction of each layer at over 50 locations along the section.

Priority 2 If no thickness data are available in the SPS* _LAYER_THICKNESS tables and the layer material type is AC or PCC, the recommended layer thickness data sources for location-specific analyses are the TST_AC01_LAYER and TST_PC06 tables. Layer thicknesses obtained from these tables are based

Priority 3 If no thickness data are available in the SPS* _LAYER_THICKNESS tables and the layer material type is not AC or PCC, layer thickness data from the TST_L05A table provide layer thicknesses measured at up to three locations (beginning, middle, and end of the section).

Recommended Layer Thickness Variability Data Sources

Upon review of the available layer thickness variability data, the following recommendations for the LTPP sources of the layer thickness variability information were established:

- For the GPS and SPS sections, thickness variability information for AC and PCC layers can be derived using data from TST_AC01_LAYER and TST_PC06 tables and the methodology outlined in reference [28].
- For the GPS sections, thickness variability information for layers other than AC and PCC can be obtained from the INV_LAYER and RHB_LAYER tables.

- For the SPS sections, layer thickness variability information can be obtained from the SPS*_LAYER tables or by analyzing data from SPS*_LAYER_THICKNESS tables using the methodology outlined in reference [29].

ADDITIONAL INFORMATION

This guide describes sources of layer thickness information available in the LTPP database and provides recommendations on how to search for the most appropriate layer thickness data for different research purposes. In addition, topics related to layer thickness variability, within-section layer thickness variation, and the relationship between as-design and as-constructed layer thicknesses are discussed. The recommendations provided in this guide are based on assessment of the LTPP layer thickness data available in the LTPP data release 11.5 version NT3.0, obtained on June 8, 2001. For a detailed analysis of the LTPP layer thickness data, please refer to the report titled, Evaluation and Analysis of LTPP Pavement Layer Thickness Data [29].

Also note that information presented in this Guide about LTPP table structures, field names and descriptions, and code lists reflect the current LTPP database structure and may be changed in the future. For the updated information, the users should refer to the most recent IMS Quality Control Checks document [19].

REFERENCES

1. *Data Collection Guide for Long-Term Pavement Performance Studies*, Operational Guide No. SHRP-LTPP-OG-001, SHRP, Washington, DC, 1993.
2. *SHRP-LTPP Interim Guide for Laboratory Material Handling and Testing*, Operational Guide No. SHRP-LTPP-OG 004, SHRP, Washington, DC, 1991.
3. *Field Materials Sampling, Testing, and Handling Guide*, Operational Guide No. SHRP-LTPP-OG 006, Version 2.0, SHRP, Washington, DC, 1992.
4. *LTPP SPS Pavement Layering Methodology*, Federal Highway Administration, McLean, Virginia, January 1994.
5. *Specific Pavement Studies, Materials Sampling and Testing Requirements for Experiment SPS-1, Strategic Study of Structural Factors for Flexible Pavements*, Federal Highway Administration, McLean, Virginia, January 1994.
6. *Specific Pavement Studies, Materials Sampling and Testing Requirements for Experiment SPS-2, Strategic Study of Structural Factors for Rigid Pavements*, Federal Highway Administration, McLean, Virginia, January 1994.
7. *Specific Pavement Studies, Materials Sampling and Testing Requirements for Experiment SPS-5, Rehabilitation of Asphalt Concrete Pavements*, Report Number SHRP-LTPP-OM-014, SHRP, Washington DC, October 1990.
8. *Specific Pavement Studies, Materials Sampling and Testing Requirements for Experiment SPS-6, Rehabilitation of Jointed Portland Cement Concrete Pavements*, Report Number SHRP-LTPP-OM-019, SHRP, Washington DC, January 1991.
9. *Specific Pavement Studies, Materials Sampling and Testing Requirements for Experiment SPS-7, Bonded Portland Cement Concrete Overlays*, Report Number SHRP-LTPP-OM-020, SHRP, Washington DC, January 1991.
10. *Specific Pavement Studies, Materials Sampling and Testing Requirements for Experiment SPS-8, Study of Environmental Effects in the Absence of Heavy Loads*, Report Number SHRP-LTPP-OM-030, SHRP, Washington DC, August 1992.
11. *Specific Pavement Studies, Experimental Design and Research Plan for Experiment SPS-1, Strategic Study of Structural Factors for Flexible Pavements*, Federal Highway Administration, McLean, Virginia, February 1990.
12. *Specific Pavement Studies, Experimental Design and Research Plan for Experiment SPS-2, Strategic Study of Structural Factors for Rigid Pavements*, Federal Highway Administration, McLean, Virginia, February 1990.
13. *Specific Pavement Studies, Experimental Design and Research Plan for Experiment SPS-5, Rehabilitation of Asphalt Concrete Pavements*, SHRP, Washington DC, April 1989.
14. *Specific Pavement Studies, Experimental Design and Research Plan for Experiment SPS-6, Rehabilitation of Jointed Portland Cement Concrete Pavements*, SHRP, Washington DC, April 1989.
15. *Specific Pavement Studies, Experimental Design and Research Plan for Experiment SPS-7, Bonded Portland Cement Concrete Overlays*, SHRP, Washington DC, February 1990.
16. *Specific Pavement Studies, Experimental Design and Research Plan for Experiment SPS-8, Study of Environmental Effects in the Absence of Heavy Loads*, SHRP, Washington DC, August 1991.
17. SHRP-LTPP Protocol P01 for SHRP test designation AC01: *Visual Examination and Thickness of Asphaltic Concrete Cores*, SHRP, Washington DC, February 1991.
18. SHRP-LTPP Protocol P66 for SHRP test designation PC06: *Visual Examination and Length Measurement of Portland Cement Concrete Cores*, SHRP, Washington DC, February 1991.
19. Federal Highway Administration, *LTPP Information Management System: IMS Quality Control Checks*, Washington, DC: Federal Highway Administration, 2000.
20. *Specific Pavement Studies, Data Collection Guidelines for Experiment SPS-1, Strategic Study of Structural Factors for Flexible Pavements*, Operational Memorandum No. SHRP-LTPP-OM-026, McLean, VA: Federal Highway Administration, December 1991.

21. *Specific Pavement Studies, Data Collection Guidelines for Experiment SPS-2, Strategic Study of Structural Factors for Rigid Pavements*, Operational Memorandum No. SHRP-LTPP-OM-028, McLean, VA: Federal Highway Administration, February 1992.
22. *Specific Pavement Studies, Data Collection Guidelines for Experiment SPS-5, Rehabilitation of Asphalt Concrete Pavements*, Operational Memorandum No. SHRP-LTPP-OM-015, Washington, DC: Strategic Highway Research Program, October 1990.
23. *Specific Pavement Studies, Data Collection Guidelines for Experiment SPS-6, Rehabilitation of Jointed Portland Cement Concrete Pavements*, Operational Memorandum No. SHRP-LTPP-OM-023, Washington, DC: Strategic Highway Research Program, May 1991.
24. *Specific Pavement Studies, Data Collection Guidelines for Experiment SPS-7, Bonded Portland Cement Concrete Overlays*, Operational Memorandum No. SHRP-LTPP-OM-024, Washington, DC: Strategic Highway Research Program, July 1991.
25. *Specific Pavement Studies, Data Collection Guidelines for Experiment SPS-8, Study of Environmental Effects in the Absence of Heavy Loads*, Operational Memorandum No. SHRP-LTPP-OM-031, Washington, DC: Strategic Highway Research Program, September 1992.
26. Standard Specifications for Transportation Materials and Methods of Sampling and Testing, Part II Tests, American Association of State Highway and Transportation Officials, Washington, DC, 1993.
27. American Society for Testing and Materials, Annual Book of Standards, Section 4, Volume 4.02, West Conshohocken, PA: American Society for Testing and Materials, 1997.
28. Titus-Glover L., J.Mallela, Y. J. Jiang, M. E. Ayers, and H. I. Shami, *Assessment of Selected LTPP Material Data Tables and Development of Representative Test Tables*, Report No. FHWA-RD-02-001, Washington, DC, 2001.
29. Selezneva O. I., Y. J. Jiang, and G. Mladenovic, *Evaluation and Analysis of LTPP Pavement Layer Thickness Data*, Draft Report, Federal Highway Administration, McLean, Virginia, 2002.
30. Specific Pavement Studies, Construction Guidelines for Experiment SPS-1, Strategic Study of Structural Factors for Flexible Pavements, Federal Highway Administration, McLean, Virginia, December 1993.
31. Specific Pavement Studies, *Construction Guidelines for Experiment SPS-2, Strategic Study of Structural Factors for Rigid Pavements*, Federal Highway Administration, McLean, Virginia, December 1993.
32. *Specific Pavement Studies, Construction Guidelines for Experiment SPS-5, Rehabilitation of Asphalt Concrete Pavements,* Report Number SHRP-LTPP-OM-012, SHRP, Washington DC, June 1990.
33. Specific Pavement Studies Construction Guidelines for Experiment SPS-6, *Rehabilitation of Jointed Portland Cement Concrete Pavements*, Report Number SHRP-LTTP-OM-013, SHRP, Washington DC, July 1990.
34. Specific Pavement Studies Construction Guidelines for Experiment SPS-7, Bonded Portland Cement Concrete Overlays, Report Number SHRP-LTTP-OM-016, SHRP, Washington DC, December 1990.
35. *Specific Pavement Studies, Construction Guidelines for Experiment SPS-8, Study of Environmental Effects in the Absence of Heavy Loads*, Report Number SHRP-LTPP-OM-029, SHRP, Washington DC, March 1992.