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EXECUTIVE SUMMARY

Measurements of pavement surface texture were conducted on the test cells at the Mn/ROAD research facility. This report explains the organization of the texture results delivered in electronic files, provides details about the test procedure and data processing used to obtain the results, and presents some simple, overview analyses to serve as examples of how the results can be utilized.

The texture measurements were performed using a mobile, line-laser based, texture profiler that provides results with two significant attributes.

1. Texture is obtained in both the longitudinal and transverse directions. This is particularly important for portland cement concrete pavements which typically have a surface texture dependant on direction.
2. Results in the longitudinal direction include the texture spectra in third octave bands with center wavelengths from 100 to 3.15 mm.

In addition to the common texture metric, mean profile depth (MPD), a variety of other metrics are calculated and included with the reported results. This includes metrics that can distinguish between upward and downward oriented texture (for example, skew).

The texture results are useful for a variety of pavement surface characteristic studies. Texture is a key factor in many pavement surface characteristics such as friction, tire-pavement noise, splash-spray, and rolling resistance. The texture results can be used by researchers for investigating correlations between texture and surface characteristics and for developing surface characteristics models.

Chapter 1. Introduction

1.1 Purpose

Measurements of pavement surface texture were conducted on the test cells at the Mn/ROAD research facility. All the cells on both the mainline and low volume roads were evaluated in both lanes, in a single wheelpath, with a repeat run. For the few cells with multiple texture strips, each strip was evaluated instead of a wheelpath.

The purpose of this report is to explain the organization of the texture results in electronic files, provide details about the test procedure and data processing, and to present some simple, overview analyses of the results to serve as examples of how the results can be utilized.

There are two significant features of the texture profiler used to conduct the measurements that provide significant results.

1. The profiler uses a line-laser which provides the capability to evaluate texture in the longitudinal and transverse directions. This is particularly important for portland cement concrete (PCC) pavements which typically have a surface texture dependant on direction. Reported results include texture in both the longitudinal and transverse directions.
2. The profiler is a mobile device (as opposed to a stationary device) which provides the capability to measure texture versus distance and perform frequency analysis of the texture. Reported results include longitudinal texture spectra in third octave bands with center wavelengths from 100 to 3.15 mm.

In addition to the common texture metric, mean profile depth (MPD), a variety of other metrics are calculated and included in the reported results. Included are metrics that can distinguish between upward and downward oriented texture (for example, skew) and spectral based metrics.

The texture results can be used by Minnesota Department of Transportation (Mn/DOT) in a variety of ways for potential pavement surface characteristic studies.

1. Within a pavement type, for example, comparing the texture of various PCC surfaces.
2. Between pavement types, for example, comparing surface texture between dense-graded asphalt and longitudinally tined PCC pavements.

Texture is also of interest because it can be a key factor in many pavement surface characteristics such as friction, tire-pavement noise, splash-spray, and rolling resistance. The texture results and the variety of metrics can be used by Mn/DOT for investigating correlations between texture and surface characteristics and for developing surface characteristics models.

1.2 Scope

This report is limited to an explanation of the organization of the reported texture results in electronic files, details about the test procedure and data processing, and presentation of a few example plots of texture results accompanied by some general conclusions. This report is not intended to be an investigative study of the various textures on the Mn/ROAD test cells, nor documentation of texture-based models of pavement surface characteristics.

1.3 Organization

Chapter 2 of this report provides details of the test setup, instrumentation, and the measurement process. Chapter 3 describes how the texture results are organized into electronic files. Chapter 4 explains how the various texture metrics are calculated and includes equations and references to relevant standards. Finally, chapter 5 presents a few sample charts of the texture results to serve as examples uses of the data.

Chapter 2. Test Setup, Equipment, and Measurement Process

2.1 Test Project Details

2.1.1 Performing Contractor

Texture measurements were performed by:

The Transtec Group, Inc.,
6111 Balcones Drive,
Austin, Texas, 78731 (USA)

Phone: +1-512-451-6233
Fax +1-512-451-6234
www.TheTranstecGroup.com

2.1.2 Personnel

- Project Manager: Dr. Robert O. Rasmussen
- Project Engineer: Mr. Richard Sohaney
- Field Technician: Mr. R.P. Watson

2.1.3 Test Date and Location

Texture measurements were performed over three days: October 31 to November 2, 2011.

The measurements were performed at the Mn/DOT's Mn/ROAD research facility near Monticello, MN.

Mn/ROAD
9011 77th Street NE
Monticello, MN 55362

2.2 Texture Profiler

2.2.1 Description

Texture measurements were performed with a line-laser-based texture profiler. Use of a line laser (as opposed to a spot laser) provides the capability to measure texture in the transverse direction as illustrated in Figure 2-1. Texture in the longitudinal direction is measured by moving the laser longitudinally along the test section. Longitudinal motion is accomplished by mounting the laser on a mobile, robotic platform with speed and direction control. Other sensors included on the mobile platform include:

- Accelerometer – to establish an inertial reference elevation;
- Wheel encoder – to determine the precise position of the robot;
- GPS – to establish a global position of the robot for reference;
- Time – to determine speed and for global reference; and
- Digital imaging system – for a visual record of the surface.

Customized software simultaneously acquires and stores data from the laser and other sensors. The entire measurement system is shown in Figure 2-2 and is referred to as RoboTex. It is a complete texture profiler meeting the requirements of ISO 13473-3: 2002 [1].

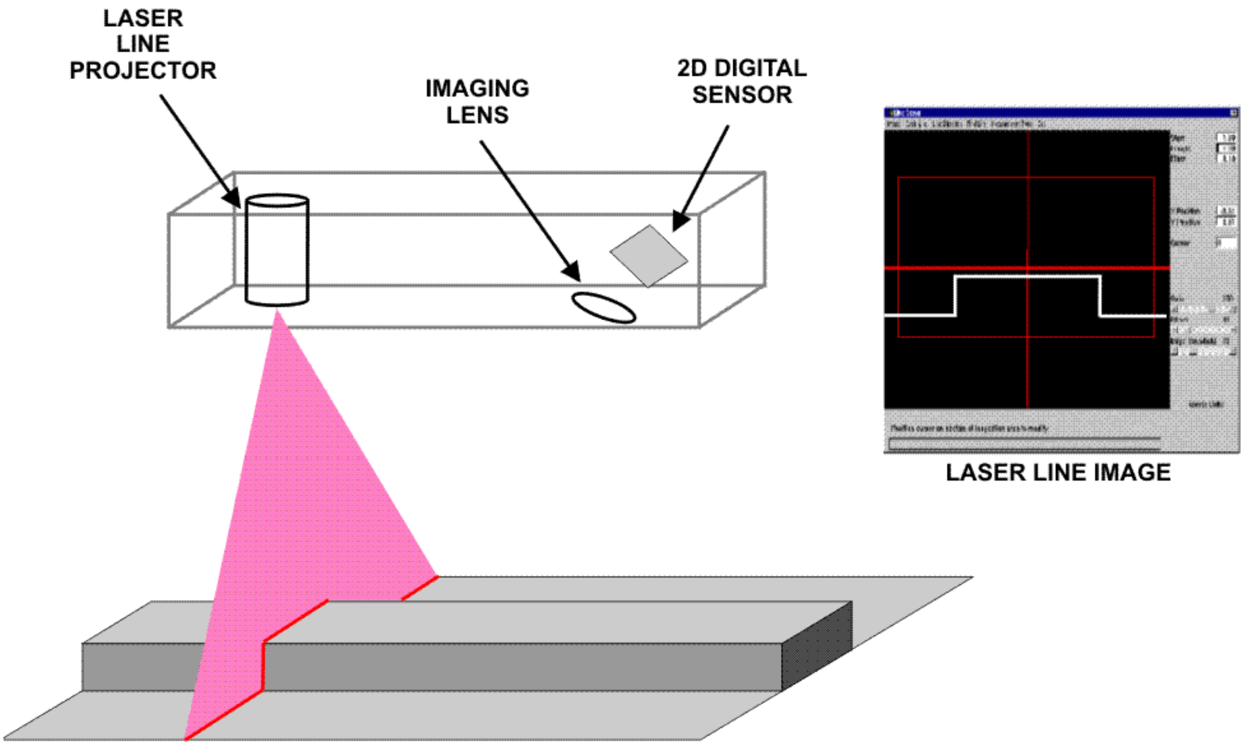

Figure 2-1. Schematic of a line-laser. (Source: LMI Technologies, Inc)

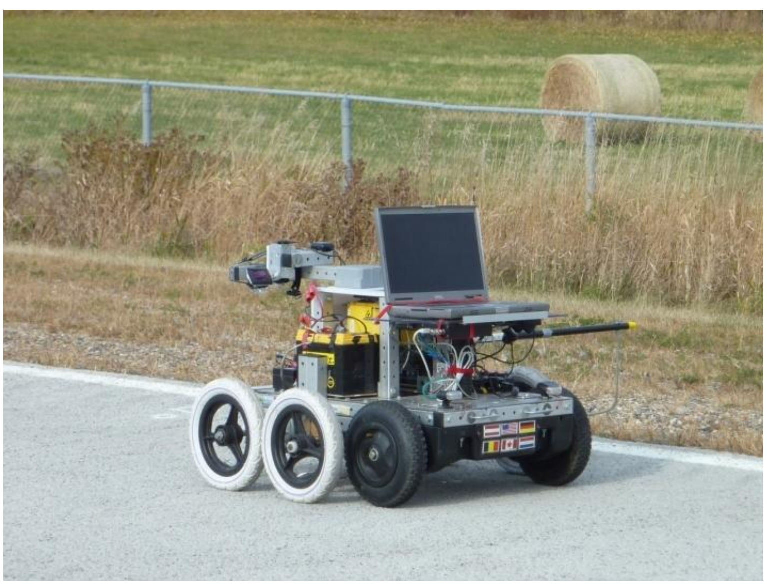

Figure 2-2. RoboTex texture profiler on the Mn/ROAD low volume road.

2.2.2 Laser

The line laser used for the texture measurements is:

- Manufacturer: LMI Technologies, Inc.
- Model number: RoLine 30427.
- Serial number: 06001.

2.3 Cells Evaluated

All the cells on the low volume road and the mainline were evaluated. With few exceptions, the texture was evaluated in the right wheelpath of both lanes and in both the eastbound and westbound directions. A few cells on the mainline were evaluated in the left wheelpath because the pavement surface in the right wheelpath was patched and not uniform along the length of the test cell. On the low volume road, cell 37 contains multiple strips of diamond ground PCC pavement. In this case, each strip was evaluated instead of the wheel path. Table 2-1, Table 2-2, and Table 2-3 list the cell numbers, subsection numbers, exceptions, and other comments for the test cells on the Mainline, Low Volume Road – South Section, and Low Volume Road – North Section.

Mn/ROAD test cell numbers are not geographically sequential. So, for convenience, the tables have a column labeled "West to East Sequence Number" containing a number assigned in geographical sequence (west to east) to aid in matching the test cell to a physical location. Also, the test cell and subsection numbers may have changed over time and variations of the numbering system may exist in other data sets. The west to east sequence number can be used to aid in aligning test cell numbering across data sets.

Table 2-1. Cell numbering and comments for the test cells on the Mainline.

West to East Sequence Number	Cell Number	Subsection	Comments and Exceptions
1	1		
2	2		
3	3		
4	4		
5	5	505	
6	5	605	
7	5	305	
8	5	405	
9	6	306	
10	6	406	
11	7		Left wheelpath evaluated in the driving lane.
12	8		Left wheelpath evaluated in the driving lane.
13	9		
14	60		Left wheelpath evaluated in the driving lane.
15	61		Left wheelpath evaluated in the driving lane.
16	62		Left wheelpath evaluated in the driving lane.
17	63		Cells 63 and 96 combined in the driving lane.
18	96		Cells 63 and 96 combined in the driving lane.
19	70		
20	71		
21	72		
22	72	A	
23	12		
24	13		
25	14		
26	15		
27	16		
28	17		
29	18		
30	19		
31	20		
32	21		
33	22		
34	23		

Table 2-2. Cell numbering and comments for the test cells on the Low Volume Road – South Section.

West to East Sequence Number	Cell Number	Subsection	Comments and Exceptions
35	24	A	Lead-in section without fog seal.
		B	Section with fog seal applied.
		C	Lead-out section without fog seal.
36	85		
37	86		
38	87		
39	88		
40	89		
41	27		
42	28		
43	77		
44	78		
45	79		
46	31		
47	32		
48	52		
49	53		
50	54		

Table 2-3. Cell numbering and comments for the test cells on the Low Volume Road – North Section.

West to East Sequence Number	Cell Number	Subsection	Comments and Exceptions
51	33		
52	34		
53	35		
54	36		
54	36		
55	37	A	Strip A is outside, next to the shoulder.
		B	Strip B – center outside.
		C	Strip C – center inside.
		D	Strip D is inside, next to the center strip.
56	38		
57	39		
58	40		

2.4 Test Cell Boundary Markers

Aluminum channel pieces are placed on the pavement to mark the start and end boundaries of the test cell. The markers are 0.5 in (12.7 mm) high and 0.875 in (22.2 mm) wide as shown in Figure 2-3.

Figure 2-3. Aluminum channel used to mark the test section boundaries.

During the measurement process, the profiler is guided over the boundary markers which produce an exaggerated texture value that allows the start and end of the test cell to be identified in the data. The profiler starts some distance before the start of the test cell to allow time for the speed and sensors to stabilize before reaching the surface to measure. Similarly, the profiler stops some distance after the end of the test cell to allow time for it to decelerate from test speed to a stop. Typically, the lead-in distance is less than 30 feet, and the lead-out distance is less than 10-feet. The setup is illustrated in Figure 2-4.

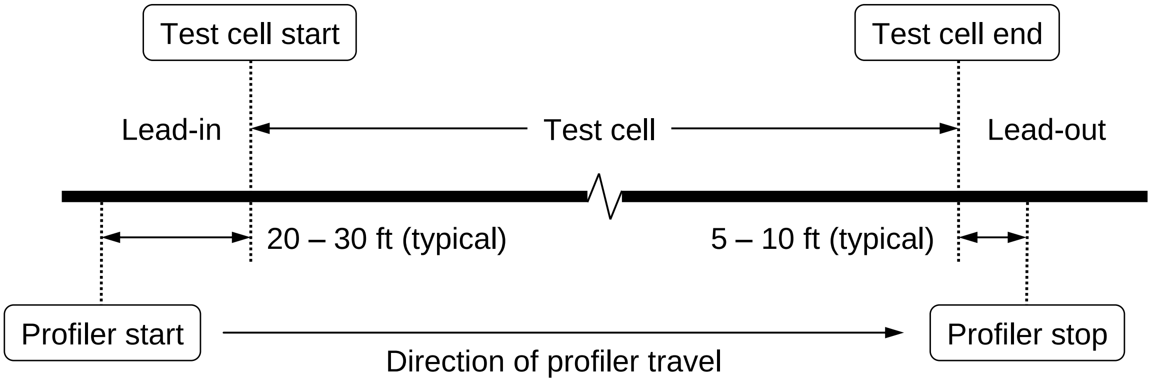

Figure 2-4. Schematic showing the relative positions of the profiler start and stop, the test cell start and end, and the lead-in and lead-out distances.

Chapter 3. Description of Files and Contents

3.1 Overview

Texture results are contained in a set of electronic files. The following files were delivered with the project test report:

1. **Test run index file** – file containing lookup information to identify the correspondence between test run number and the measured cell, lane, and direction. File format is Excel (xls).
2. **Texture results files** – files containing a table of texture metrics versus distance. One file for each test run. File format is comma separated variable (csv).
3. **Statistical summary file** – file containing the 10th, 50th, and 90th percentile values of texture metrics for each test run. File format is Excel (xls).

3.2 Test Run Index File

Name: Test_run_index.xls
Format: MS Excel

Contents:
This file contains a table defining the correspondence between texture run number, Mn/ROAD cell, lane, and direction. There is a row for each texture test run**.** Table 3-1 describes the contents of the columns in the file.

The table in the file is an Excel list and can be sorted by the various columns. Use this file to lookup the texture run number associated with a cell, or vice-versa, the cell associated with a texture run number.

Table 3-1. Description of the columns in the test run index file.

Column Label	Description
Run Number	Unique number identifying a texture test run. The run number is used in the filename containing the texture results file. Use this column to sort the table in run number order.
Cell	Mn/ROAD cell number corresponding to the texture test run. Use this column to sort the table with cells in numerical order.
Section	Subsection within a cell. The following cells have sections with separate texture test runs: Cell 6: sections 406 and 306 Cell 5: sections 305, 405, 505, and 605. Cell 72: section 72 and section 72A Cell 24: sections A, B, and C. When traveling from west to east, section A is the section of cell 24 leading up to the fog seal, section B is the section with fog seal, and section C is the section after. Cell 37: sections A, B, C, and D corresponding to the four texture strips in the outside lane.
Road	Portion of the test tracks containing the cell. Mainline = mainline road LVR-south = low volume road, south segment LVR-north = low volume road, north segment
W→E Sequence	Cell sequence number if the cells are counted in geographical order starting at 1 and in the direction of west to east. Use this column to sort the table with cells in geographical order. Mainline: cell sequence numbers 1 to 34 LVR – south: cell sequence numbers 35 to 50 LVR – north: cell sequence numbers 51 to 58
Lane	The lane on which the texture was measured. Mainline: driving and passing lanes Low volume road: outside and inside lanes
Track	The wheelpath on which the texture was measured. In general, the right wheelpath was measured, with a few exceptions. On the mainline, driving lane, cells 60, 61, 62, and sections of 5 were measured in the left wheelpath due to considerable patching and surface disruption in the right wheelpath. On the low volume road, outside lane, cell 37 was evaluated on each of its four texture strips instead of the wheelpath.

Column Label	Description
Dir	Direction of travel of the profiler during the texture measurement.
Test Section Length, ft - in	Distance in feet and inches between the profile indicators marking the boundaries of the test run. Usually, the test section length is the same as the cell length, with these exceptions: Cells 63 and 92: driving lane, are combined into one test run (0051 in the west dir and 0084 in the east direction). In this case, the test section length is a combination of two cell lengths. Cell 13: the test section length is shortened due to patches at the west end of the cell.
Comments	Miscellaneous comments about the test run.

3.3 Texture Results Files

Name: MnROAD_RoboTex####Avg2.csv
Format: ASCII, comma separated variable

Contents:
There is one texture results file for each test run. This file contains texture metrics versus distance in the form of a table. First column of the table is distance in feet along the test surface. The other columns are various texture metrics as described in Table 4-1.

Distance in the first column is measured from some reference position on the pavement to the center of a spatial calculation interval. Hence, the column label is "CenterDist". Each row is a distance increment of 2 inches (100 mm).

Note the first and last rows of the table do not correspond to the start and end of the test cell. This is because the profiler starts some distance before the boundary of the test cell and stops some distance after the end of the cell as described in Section 2.4. These lead-in and lead-out distances are included in the table in the texture results files. Typically, the lead-in distance is less than 30 feet, and the lead-out distance is less than 10-feet. The channel pieces marking the test cell boundaries produce and exaggerated texture value. These exaggerated values enable identification of the start and end boundaries of the test cell in the results file.

3.4 Statistical Summary File

Name: Texture_summary.xls
Format: MS Excel

Contents:
This file contains a table of the 10th, 50th, and 90th percentile values of the texture metrics for each test run. The following columns are included in the table to allow sorting and lookup by cell number and other attributes.

1. Road (Mainline, Low Volume Road)
2. Cell number
3. Lane
4. Track
5. Direction

There is a row for each texture test run.

Chapter 4. Description of Texture Metrics

4.1 Designating Longitudinal and Transverse

Note, throughout this report and in the data files, "Lg" and "Tr" are used as prefixes to designate longitudinal and transverse directions, respectively. In this context, "Lg" should not be confused with the logarithm operator. For example, LgMPD designates MPD (mean profile depth) in the longitudinal direction. TrMPD designates MPD in the transverse direction.

4.2 Summary of Texture Metrics

Table 4-1 summarizes the various texture metrics in the results files. Full descriptions are presented in Section 4.4.

Table 4-1. Summary description of the reported texture metrics.

Metric	Name	Brief Description
MPD	Mean profile depth	Following ISO 13473-1: 1997 [2].
MaxPeak	Maximum peak	Maximum elevation, minimum elevation, and distance from maximum to minimum elevation.
MaxValley	Maximum valley	
MaxHeight	Maximum height	
RoughAvg	Average roughness	Average absolute value (rectified) elevation.
RMS	Root mean square	Square root of the average squared elevation.
Rpk	Reduced peak height	Following ISO 13565-2:1996 [3]
Rk	Core roughness depth	
Rvk	Reduced valley depth	
RkTotal	Total roughness	
Skew	Skew	The third standardized moment.
100, 80, … 4.0, 3.15	Third octave band texture levels.	Spectral based texture. Texture level (dB) in third octave bands. The number in the metric name (100, 80, … 3.15) is the band center wavelength in mm.

4.3 General Calculation Method

This section describes the general method used for calculating longitudinal and transverse texture values from a 3-dimensional elevation profile.

4.3.1 3-D Elevation Profile

The process of calculating a texture metric begins with a sampled (digitized) 3-dimensional elevation profile generated by the texture profiler. Figure 4-1 illustrates a representation of a portion of such a profile. The X-direction is longitudinal, Y is transverse, and Z is vertical elevation. The distance between samples is 0.0394 in (1 mm) in the transverse and 0.0197 in (0.5 mm) in longitudinal directions.

The width (in the transverse direction) of the 3-dimensional profile is governed by the width of the line-laser on-board the profiler. For the RoboTex profiler, the line width is 100 samples which translates to a profile width of 3.94 in (100 mm). The length of the 3-dimensional profile depends on the length of the test section. For example, a 500 ft (152.4 m) test section will have 304800 samples. Thus, the 3-dimensional profile is really a very long and narrow strip; 100 samples wide and hundreds of thousands of samples long. In general, an individual elevation profile sample, z, is referred to by its coordinate position as z(x,y).

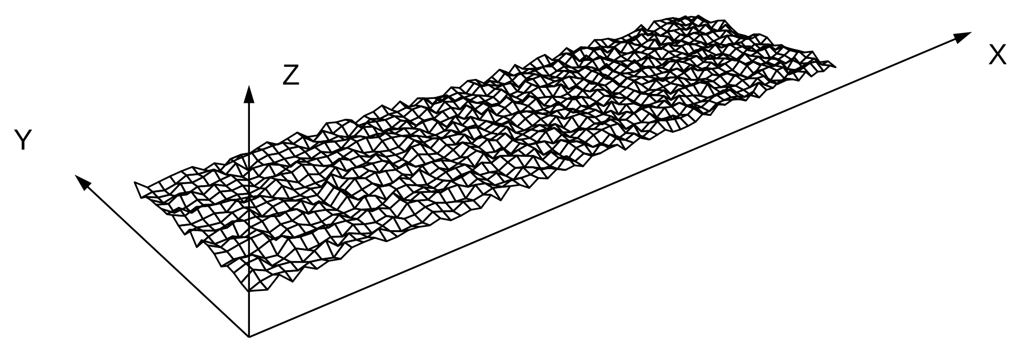

Figure 4-1. Representation of a digitized 3-dimensional elevation profile.

4.3.2 Baselength and Calculation Area

Texture metrics are calculated from a subset of the full 3-dimensional profile. The length of the subset is referred to as the “baselength” and is illustrated in Figure 4-2. In the longitudinal direction, the baselength is equal to 3.94 in (100 mm) for non-spectral texture metrics (for example, MPD). For spectral based texture metrics, the baselength is 7.0 ft (2.13 m).

In the transverse direction, the baselength is equal to the width of the 3-dimensional profile; also 3.94 in (100 mm). Spectral based texture metrics are not calculated in the transverse direction because the profile width is too short for that purpose.

The area defined by the longitudinal and transverse baselengths is referred to as the calculation area.

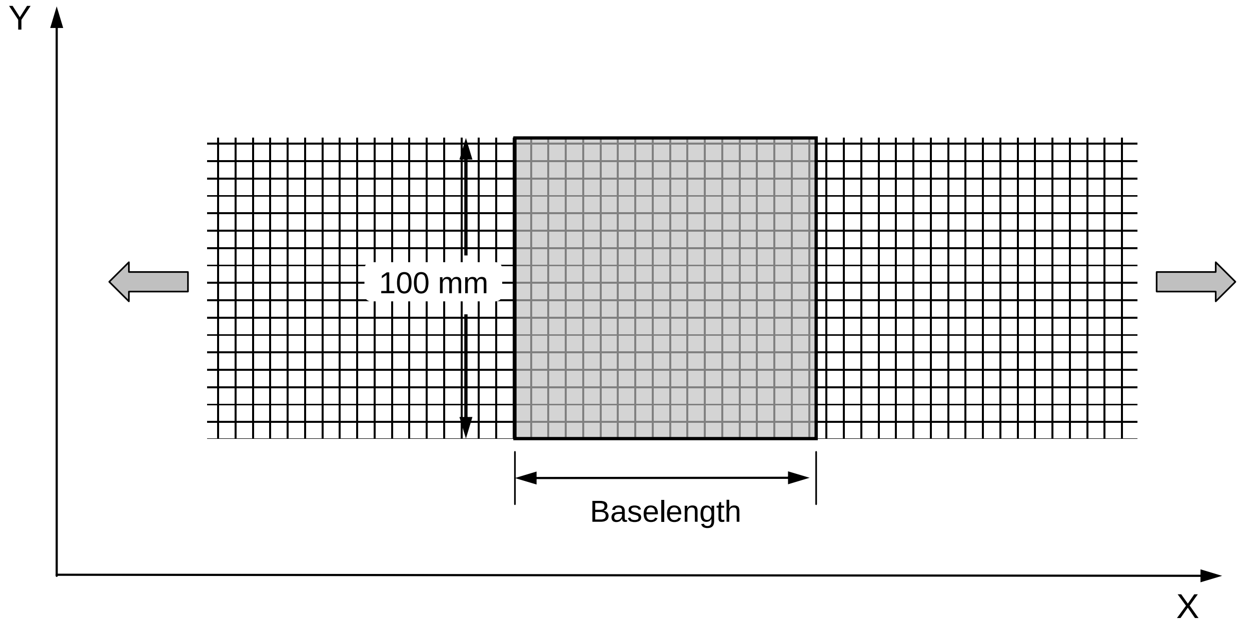

Figure 4-2. Plan view of a portion of a 3-dimensional profile with longitudinal and transverse baselengths identified. The highlighted area is referred to as the calculation area.

4.3.3 Longitudinal and Transverse Profiles

Various cross sections of the calculation area can be taken of the 3-dimensional elevation profile in Figure 4-1 and viewed as 2-dimensional profiles.

Figure 4-3 shows an example cross section in the longitudinal (X) direction. Sample points can be numbered in sequence; 1, 2, 3, and etc. Note, the letter "i" is used to designate a general sample number in the longitudinal (X) direction.

Figure 4-4 shows an example cross section in the transverse (Y) direction. Again, samples can be numbered in sequence, 1, 2, 3, and etc. Note, the letter "j" is used to designate a general sample number in the transverse (Y) direction.

The number of possible longitudinal cross sections within the calculation area is equal to 100, one at each of the transverse samples. Similarly, the number of possible transverse cross sections within the calculation area is equal to the number of samples in the baselength, which is also 100.

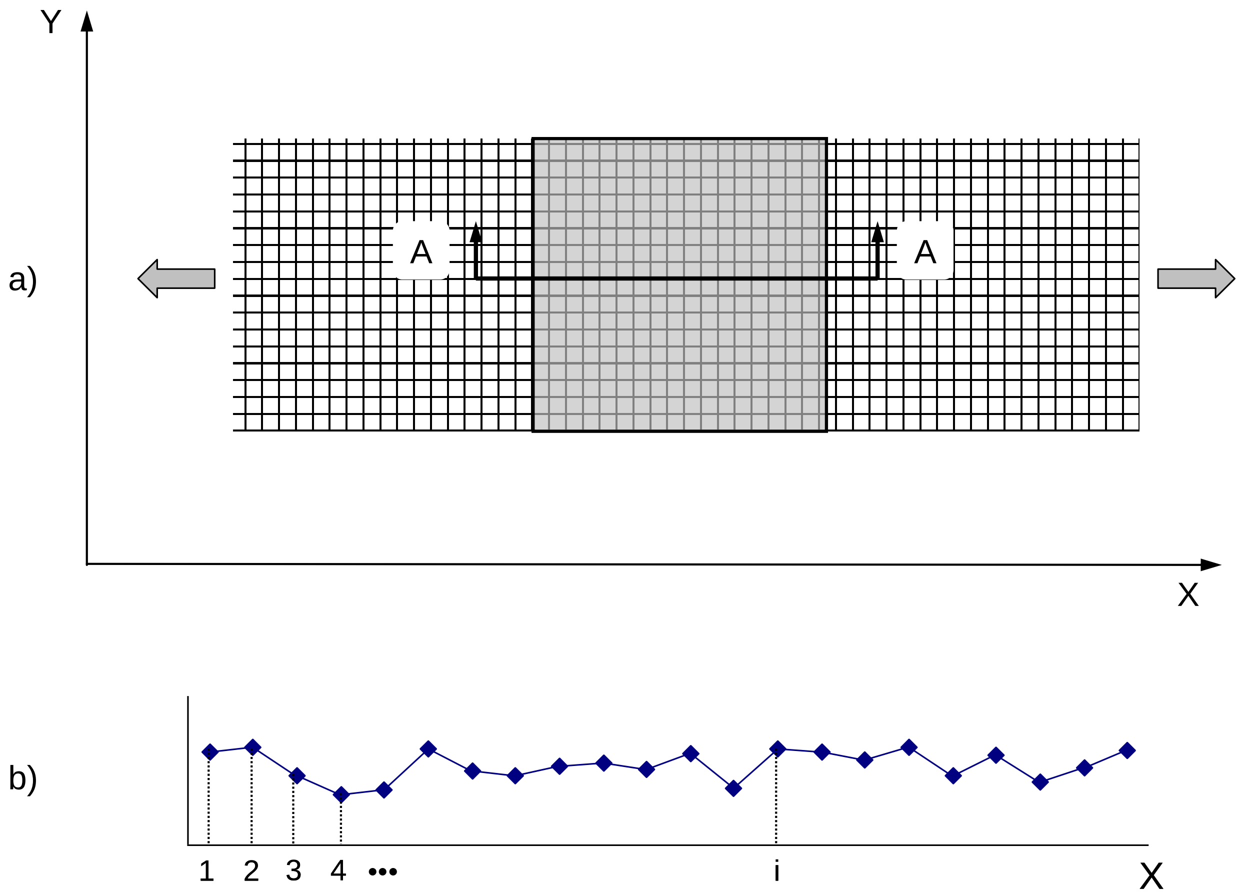

Figure 4-3. a) Plan view of a portion of the 3-dimensional profile with calculation area highlighted. b) 2-dimensional profile obtained from the full 3-dimensional profile at cross section A-A.

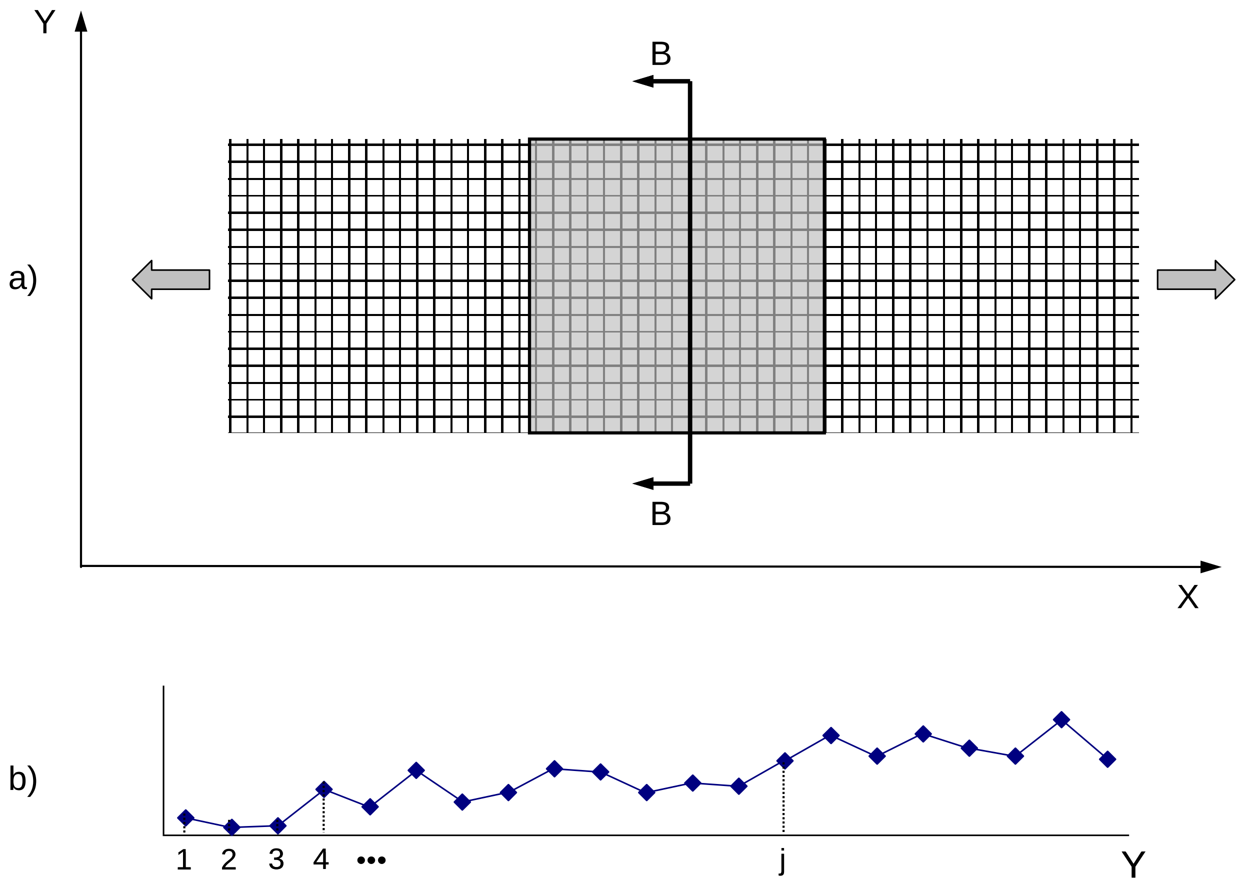

Figure 4-4. a) Plan view of a portion of the 3-dimensional profile with calculation area highlighted. b) 2-dimensional profile obtained from the full 3-dimensional profile at cross section B-B.

4.3.4 Detrending

Texture metrics are calculated from 2-dimensional profiles extracted from the calculation area. Prior to calculating a texture metric, the elevation profile is “detrended”. Detrending transforms the profile so that the average elevation and average slope over the baselength is zero. This process is illustrated in Figure 4-5.

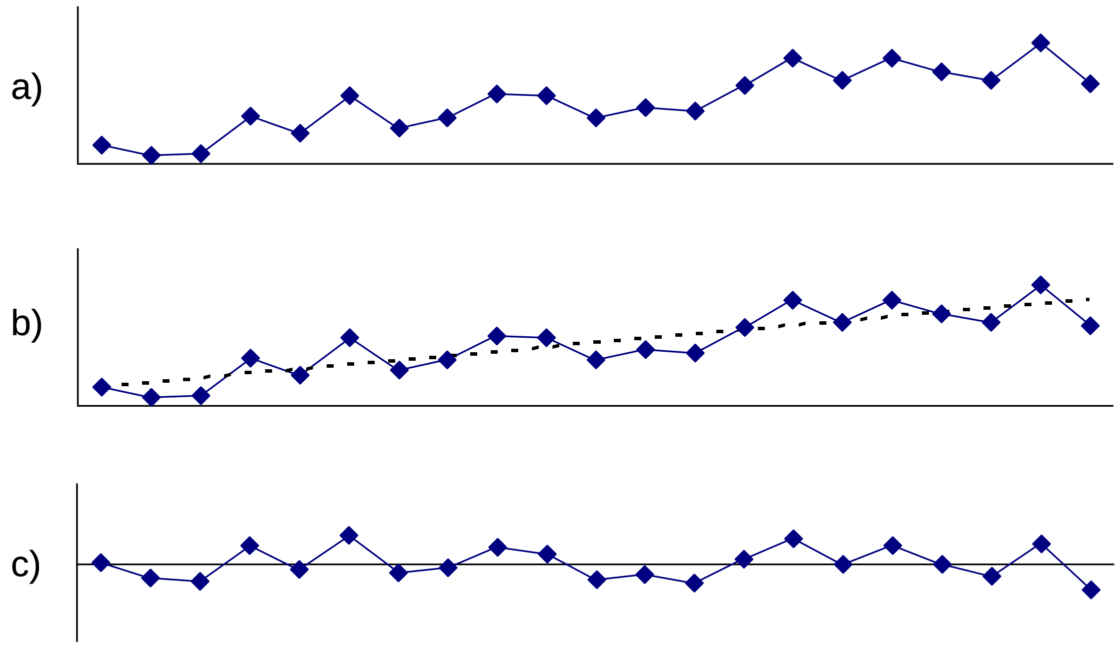

Figure 4-5. Detrending a profile. a) Original elevation profile. b) Original profile with linear trend (straight dashed line) superimposed. c) Detrended profile obtained by subtracting the linear trend from the original profile. The detrended profile has average elevation and average slope equal to zero.

4.3.5 Texture Calculations

Texture calculations are performed on the 2-dimensional profiles extracted from the calculation area and after detrending.

Let F(z) represent the general texture metric which is a function of “z”, the elevation samples of a 2-dimensional profile. Then, $LgF_j(z)$ is the longitudinal texture metric calculated from the longitudinal 2-dimensional profile from the cross section at transverse sample j. The total number of longitudinal texture values that can be calculated within one calculation area is equal to 100, one at each of the transverse samples.

Similarly, $TrF_i(z)$ is the transverse texture metric calculated from the transverse 2-dimensional profile from the cross section at longitudinal sample i. The total number of transverse texture values that can be calculated within one calculation area is equal to the number of samples in the baselength, which is 200 for a 100 mm baselength.

The functions F(z) for the various texture metrics in the data files are defined in Section 4.4. But, for example, here are equations for RMS texture in the longitudinal and transverse directions.

Longitudinal RMS texture is given by:

$$LgRMS_j = \sqrt{\frac{\sum_{i=1}^{N} z_{i,j}^2}{N}} \tag{1}$$

Where:

LgRMSj = the RMS texture in the longitudinal direction for the 2-dimensional profile at transverse sample j, and

N = the number of samples in the longitudinal baselength.

Transverse RMS texture is given by:

$$TrRMS_i = \sqrt{\frac{\sum_{j=1}^{N} z_{i,j}^2}{M}} \tag{2}$$

Where:

TrRMSi = the RMS texture in the transverse direction for the 2-dimensional profile at longitudinal sample i, and

M = the number of samples in the transverse baselength.

4.3.6 Longitudinal and Transverse Medians

The longitudinal texture value for the calculation area is the median of the longitudinal texture values over the calculation area.

$$LgF = Median\left(LgF_j\right)_{j=1}^{M} \tag{3}$$

Where:

LgF_j = the longitudinal texture value at transverse sample j, and

M = the number of samples across the transverse width of the calculation area.

Similarly, the transverse texture value for the calculation area is the average of the transverse texture values over the calculation area.

$$TrF = Median\left(TrF_i\right)_{i=1}^{N} \tag{4}$$

Where:

TrF_i = the transverse texture value at longitudinal sample i, and

N = the number of samples along the longitudinal baselength of the calculation area.

4.3.7 Texture versus Distance

Texture as a function of distance along the test section is obtained by shifting the calculation area by 2 in (50.8 mm) along the length of the 3-dimensional profile, as illustrated in Figure 4-6. (Note in the figure, a transverse offset of the calculation area is shown for illustration purposes only. A transverse offset is not used in the texture calculations.) For metrics with a baselength of 3.94 in (100 mm) this is effectively an overlap of 50 %. For spectral based texture metrics in the longitudinal direction with baselength of 7.0 ft (2.13 m), the 2-inch shift is an effective overlap of 98 %. Table 4-2 summarizes these baselengths, shifts, and percent overlaps.

The spatial position of the averaged longitudinal and transverse texture metric for the calculation area is considered to be at the center of the calculation area. The result is a longitudinal and transverse texture value at 2-inch (100 mm) intervals for the length of the test section. This 2-inch interval data is in the texture results files described in Section 3.3.

4.3.8 Statistics over the Test Section

From the texture values at 2-inch intervals as described in the preceding Section 4.3.7, statistical quantities can be calculated for the metric over the entire length of the test section. Example statistics include average, standard deviation, and cumulative distributions. The statistical summary file described in Section 3.4 contains a table of the 10^{th}, 50^{th}, and 90^{th} percentile values of the texture metrics over each test section.

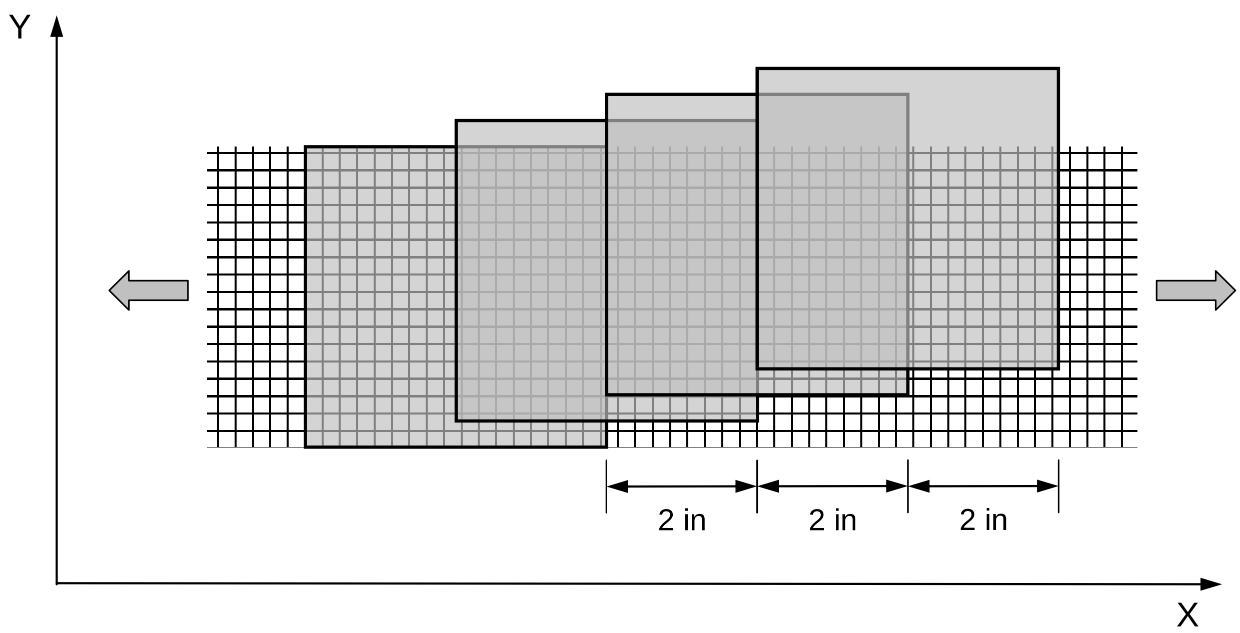

Figure 4-6. Schematic representation of sequential calculation areas, each shifted 2 inches in the longitudinal direction relative to its predecessor. For illustration purposes, the calculation areas are also offset in the transverse (Y) direction; the transverse offset is not applied in the texture calculations.

Table 4-2. Summary of baselength, calculation area shift, and effective overlap.

Direction	Metric Type	Baselength	Shift	Effective Overlap
Longitudinal	Non-spectral	3.94 in (100 mm)	2 in (50 mm)	50 %
	Spectral	84 in (2.13 m)	2 in (50 mm)	98 %
Transverse	Non-spectral	3.94 in (100 mm)	Not applicable	Not applicable
	Spectral	Not applicable	Not applicable	Not applicable

4.4 Texture Metric Definitions

4.4.1 MPD

Mean Profile Depth calculated according to standard ISO 13473-1 [2].

Equation:

$$MPD = \frac{Peak_1 - Peak_2}{2} \tag{5}$$

where:

$Peak_1$ = peak texture elevation in the first half of the baselength, and
$Peak_2$ = peak texture elevation in the second half of the baselength.

4.4.2 MaxPeak, MaxValley, and MaxHeight

MaxPeak is the maximum elevation in the baselength, z_{max}

MaxValley is the minimum elevation in the baselength, z_{min}. The minimum peak is reported as a value less than zero.

MaxHeight is the distance from the maximum peak to the maximum valley.

$$MaxHeight = MaxPeak - MaxValley \tag{6}$$

4.4.3 RoughAvg
Average roughness given by

$$RoughAvg = \frac{\sum_{n=1}^{N} \left| z_n \right|}{N} \tag{7}$$

where:

z_n = elevation of sample *n* of the detrended texture profile,
| | = the absolute value operator, and
N = number of samples in the baselength.

4.4.4 RMS
Root mean square given by

$$RMS = \sqrt{\frac{\sum_{n=1}^{N} z_n^2}{N}} \tag{8}$$

where:

z_n = elevation of sample *n* of the detrended texture profile,
N = number of samples in the baselength.

4.4.5 Rpk, Rk, Rvk, and RkTotal
These metrics are calculated using the linear material ratio curve (or Abbott curve) as defined in ISO 13565-2: 1996 [3], Geometrical Product Specifications (GPS)-Surface Texture: Profile Method; Surfaces Having Stratified Functional Properties-Part 2: Height Characterization Using the Linear Material Ratio Curve.

One property of these metrics is that they can discriminate distinguish between positive and negative oriented texture.

Rpk = Reduced peak height.
Rk = Core roughness depth.
Rvk = Reduced valley depth.

$$RkTotal = Rpk + Rk + Rvk \tag{9}$$

4.4.6 Skew

Third standardized moment given by:

$$skew = \frac{\left(\sum_{n=1}^{N} z_n^3\right) / N}{\sigma^3} \tag{10}$$

Where:

z_n = elevation of sample *n* of the detrended texture profile,
N = number of samples in the baselength, and
σ = standard deviation of the profile samples in the baselength (which is equal to the RMS).

4.4.7 Third Octave Band Texture Levels

RMS level of the elevation profile in the third octave band expressed as a decibel with reference of 10^{-6} m. The number in the metric name (100, 80, … 3.15) is the band center wavelength in mm. Spectral based band levels are calculated following ISO 13473-4: 2008 [4]. Frequency domain transformation is accomplished using an FFT operation with a baselength equal to 7 ft (2.134 m) and Hanning window. RMS amplitudes in third octave bands are synthesized from the resulting constant bandwidth spectrum. The conversion from RMS amplitude to decibel level is given by:

$$L_n = 10 \times Log_{10}\left(\frac{RMS_n}{10^{-6}}\right) \tag{11}$$

Where:

L_n = decibel level in third octave band with center wavelength *n* in mm, and
RMS_n = root mean square texture in third octave band with center wavelength *n*.

Chapter 5. Sample Texture Analyses and Trends

This section presents some charts of a portion of the texture data to serve as examples of the types of analyses that can be conducted from within the data set. Some general observations and conclusions are drawn from the data. The charts appear at the end of this chapter.

5.1 MPD

5.1.1 Overview

Figure 5-1 and Figure 5-2 show charts of average MPD for all the cells in the longitudinal and transverse directions, respectively. Some general observations and trends:

- The range of MPD in both directions is from 0.25 to 2.3 mm.
- The porous and pervious pavements have the greatest texture.
- In the longitudinal direction, the PCC pavements have lower texture than the hot-mix asphalt (HMA) pavements.

5.1.2 HMA Pavements

Figure 5-3 shows a chart of average MPD in the longitudinal and transverse directions for the cells with HMA pavements. Some general observations and trends:

- For HMA pavements, texture is independent of direction. The MPD in the longitudinal and transverse directions are nearly equal.
- Fog seal has the least texture.
- The 12.5 mm dense grade HMA surfaces have MPD ranging from 0.4 to 0.8 mm.
- The rank order of the HMA pavements from least to greatest texture is
    1. Fog seal.
    2. 12.5 mm dense-graded HMA.
    3. Bonded wearing courses.
    4. Chip seals.
    5. Porous.

5.1.3 PCC Pavements

Figure 5-4 shows a chart of average MPD in the longitudinal and transverse directions for the cells with PCC pavements. For many of the PCC pavements, the amount of texture varies with direction. This is expected because surface texture of PCC pavements is usually predominantly applied in either the longitudinal or transverse direction. Figure 5-5 shows the difference between transverse and longitudinal MPD for the PCC pavements. The following trends and conclusions are drawn from the charts.

- PCC pavement surface texture is often not isotropic, that is, it is not the same in all directions.
- Difference between transverse and longitudinal texture is greatest for the diamond grind surfaces.

5.2 Skew

Skew is a metric of interest because it can distinguish between positive and negative oriented texture.

5.2.1 Overview

Figure 5-6 and Figure 5-7 show charts of texture skew for all the test cells in the longitudinal and transverse directions. Some general observations and trends:

- The texture is predominantly negative oriented; most of the cells have texture skew less than zero.
- PCC pavements have larger negative skew than the HMA pavements.
- The largest negative skew occurs with the transverse tined PCC.

5.2.2 HMA Pavements

Figure 5-8 shows a chart of texture skew in the longitudinal and transverse directions for the cells with HMA pavement. Some general observations and trends:

- Most of the HMA surfaces have negative oriented texture (skew is less than zero).
- The bonded wearing courses have the greatest negative skew.
- The porous HMA surfaces are among those with the greatest negative skew.
- The chip seals have positive oriented texture (skew is greater than zero).

5.2.3 PCC Pavements

Figure 5-9 shows a chart of average skew in the longitudinal and transverse directions for the cells with PCC pavements. Some cells have greater skew in the longitudinal direction and some in the transverse. Figure 5-10 shows the difference between transverse and longitudinal skew for the PCC pavements. The following trends and conclusions are drawn from the charts.

- Most of the PCC pavements have negative oriented surface texture (skew less than zero).
- Transverse tine surfaces have the greatest negative oriented texture in the longitudinal direction.
- The ultimate and innovative diamond grind surfaces have the greatest negative oriented texture in the transverse direction.

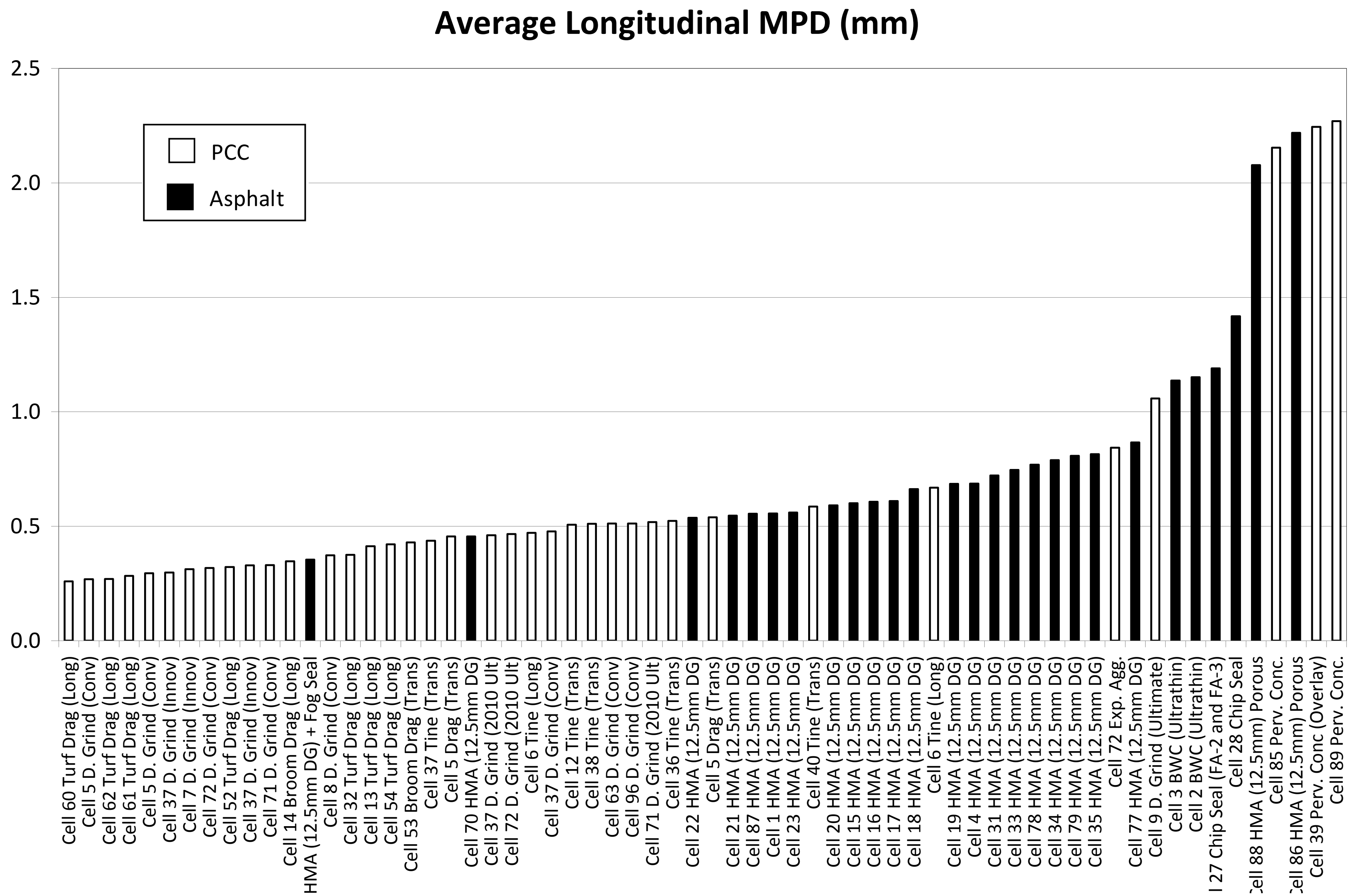

Figure 5-1. Average longitudinal MPD (mm) for all the cells.

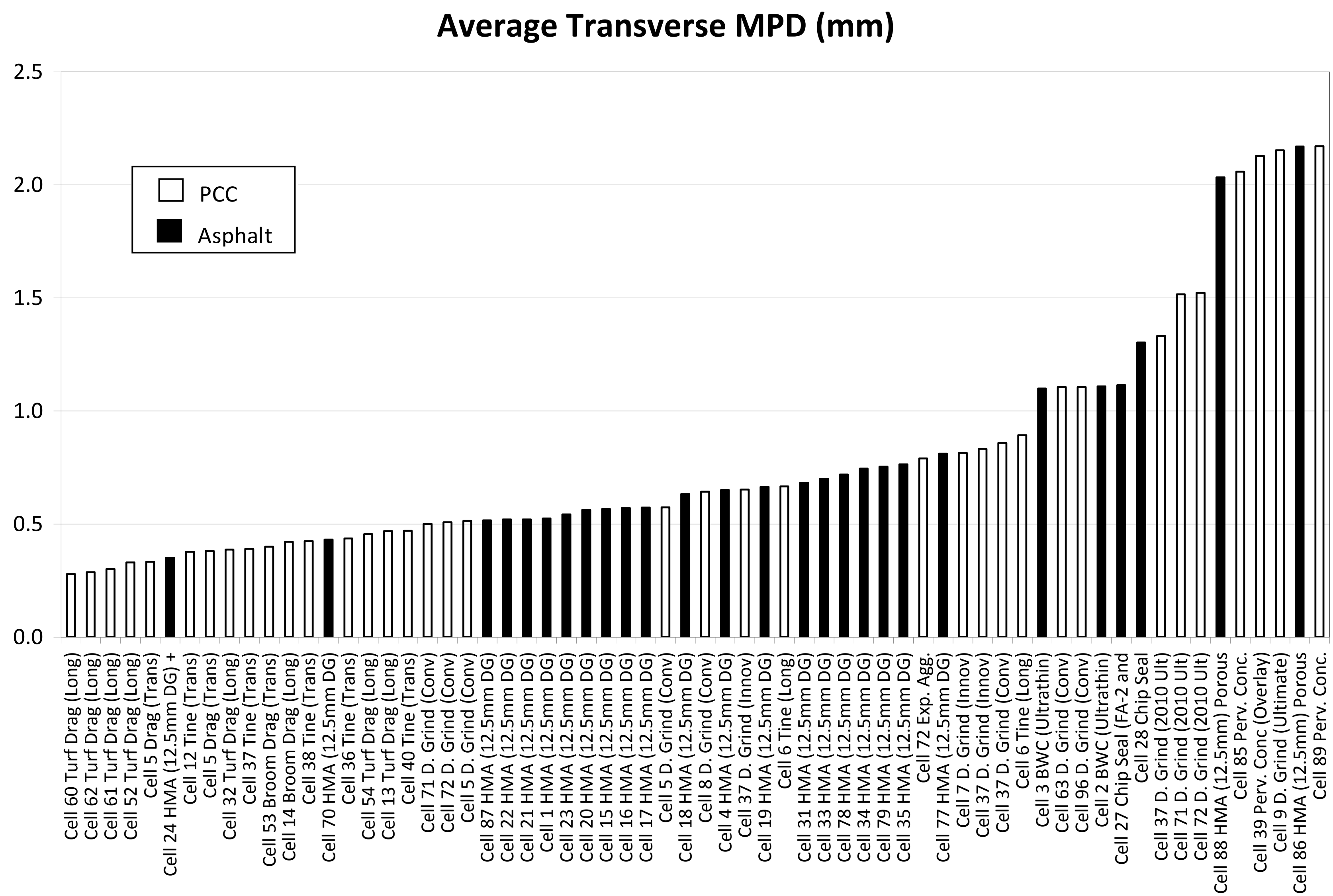

Figure 5-2. Average transverse MPD for all the cells.

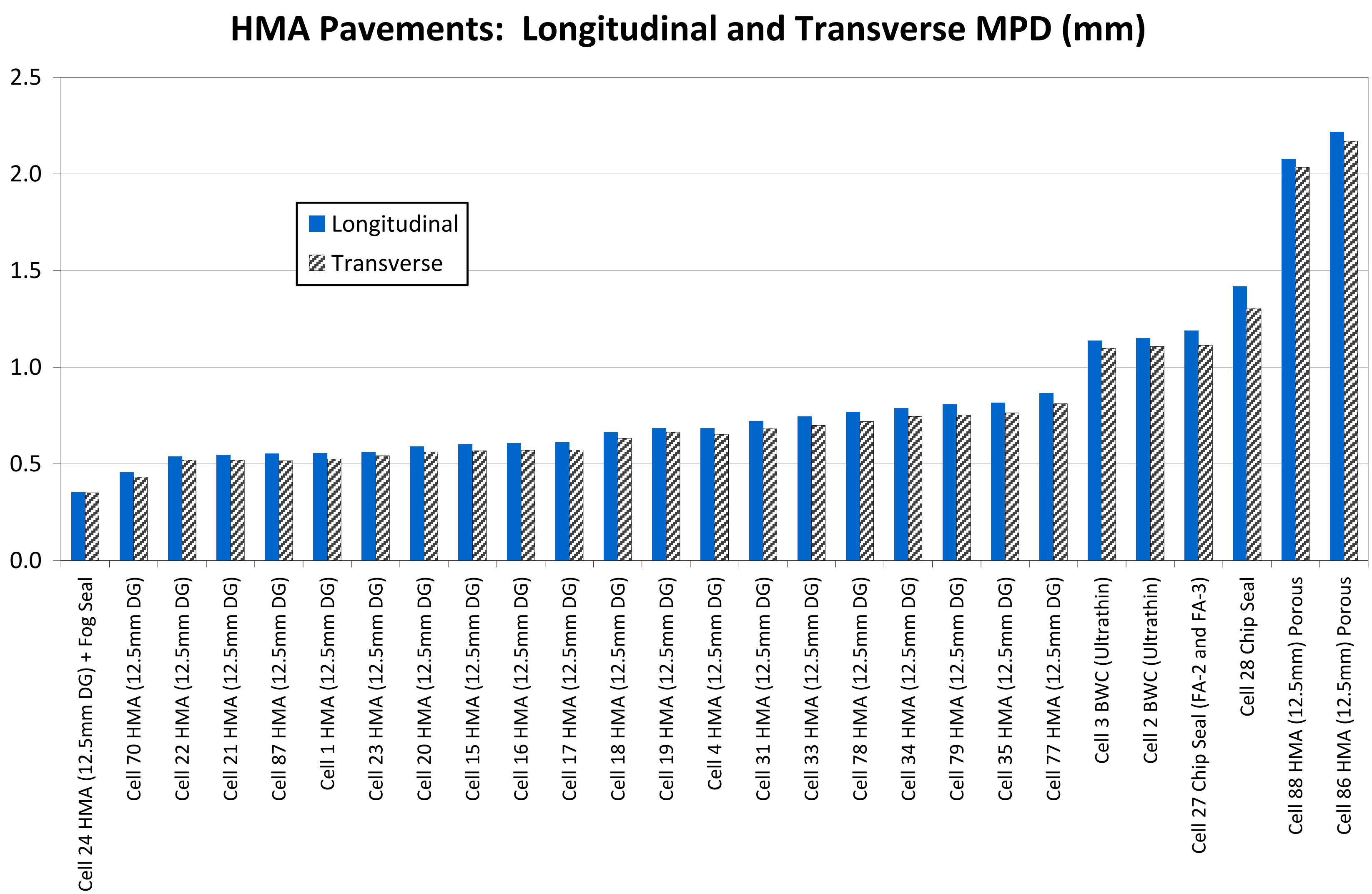

Figure 5-3. Longitudinal and transverse MPD for cells with HMA pavement.

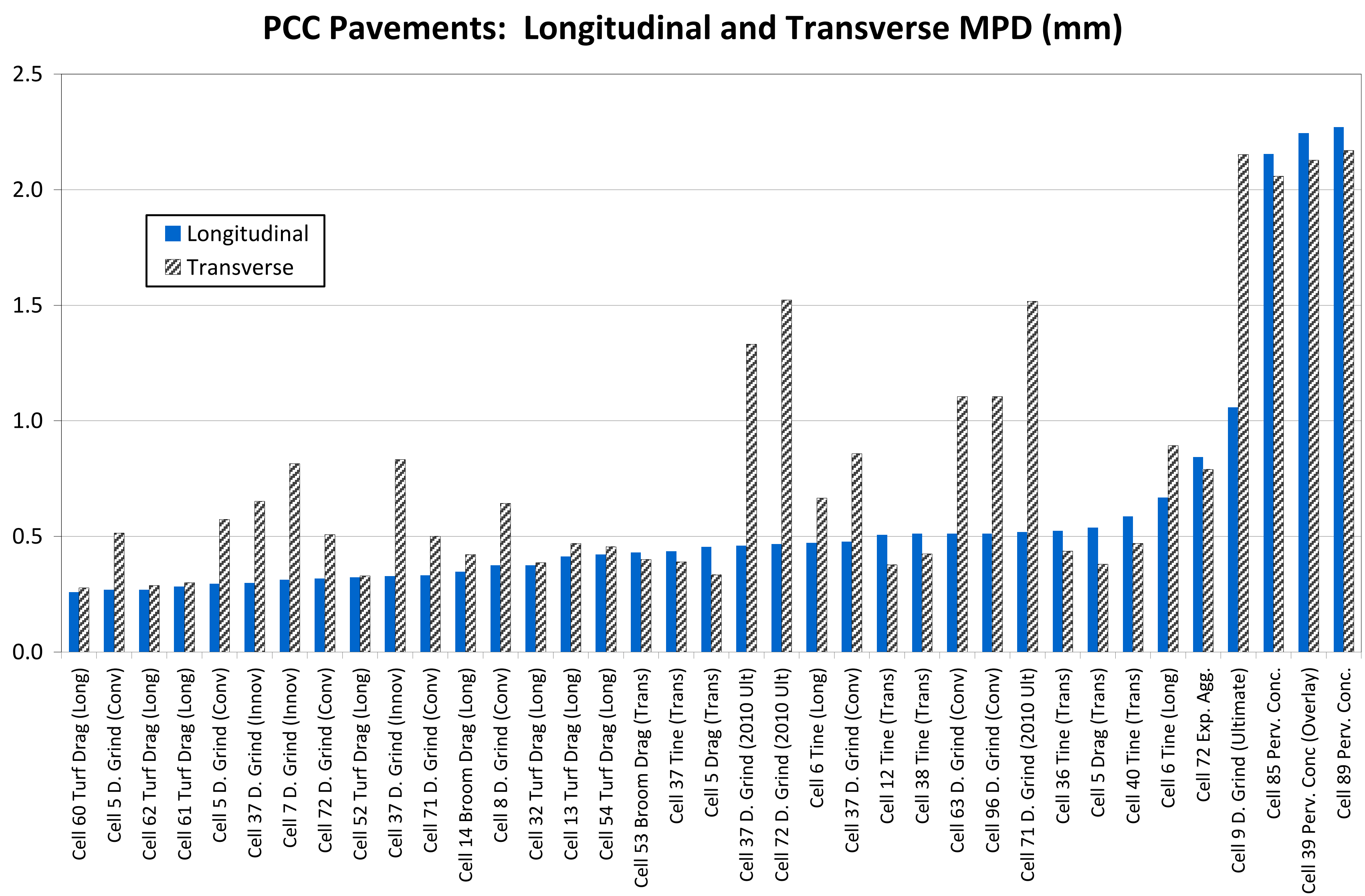

Figure 5-4. Longitudinal and transverse MPD for cells with PCC pavement.

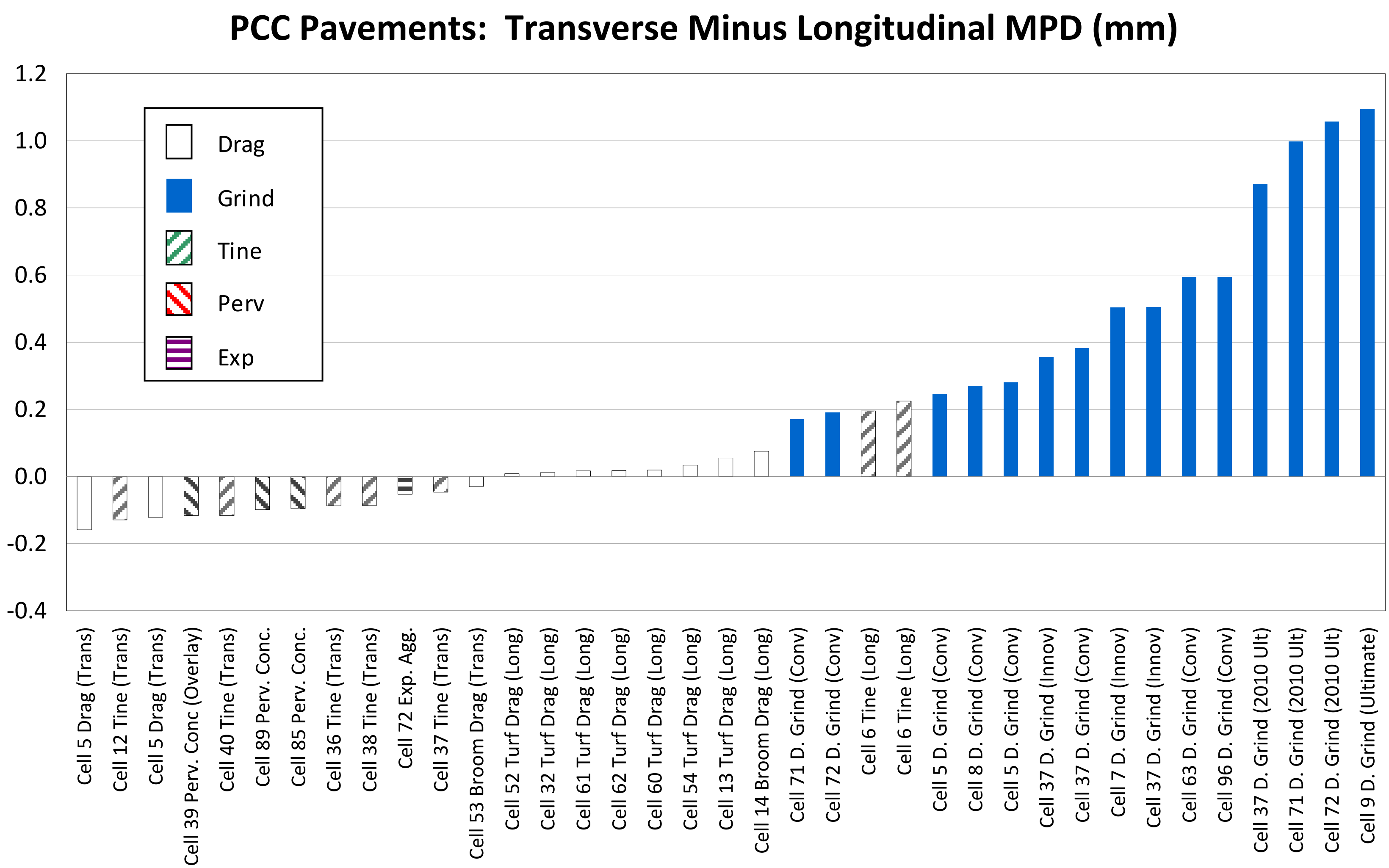

Figure 5-5. Difference in transverse and longitudinal MPD for PCC pavements.

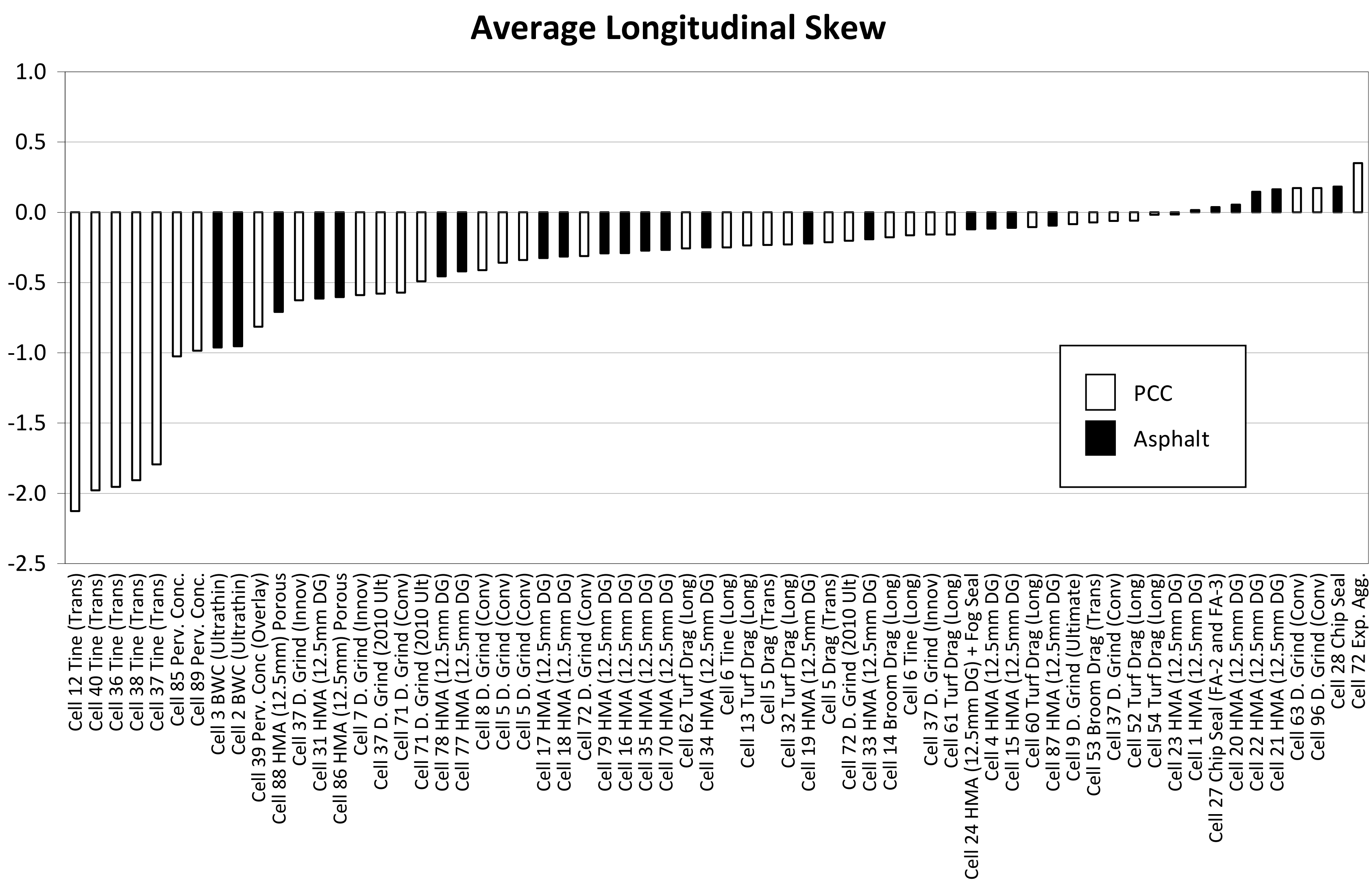

Figure 5-6. Average skew in the longitudinal direction for all cells.

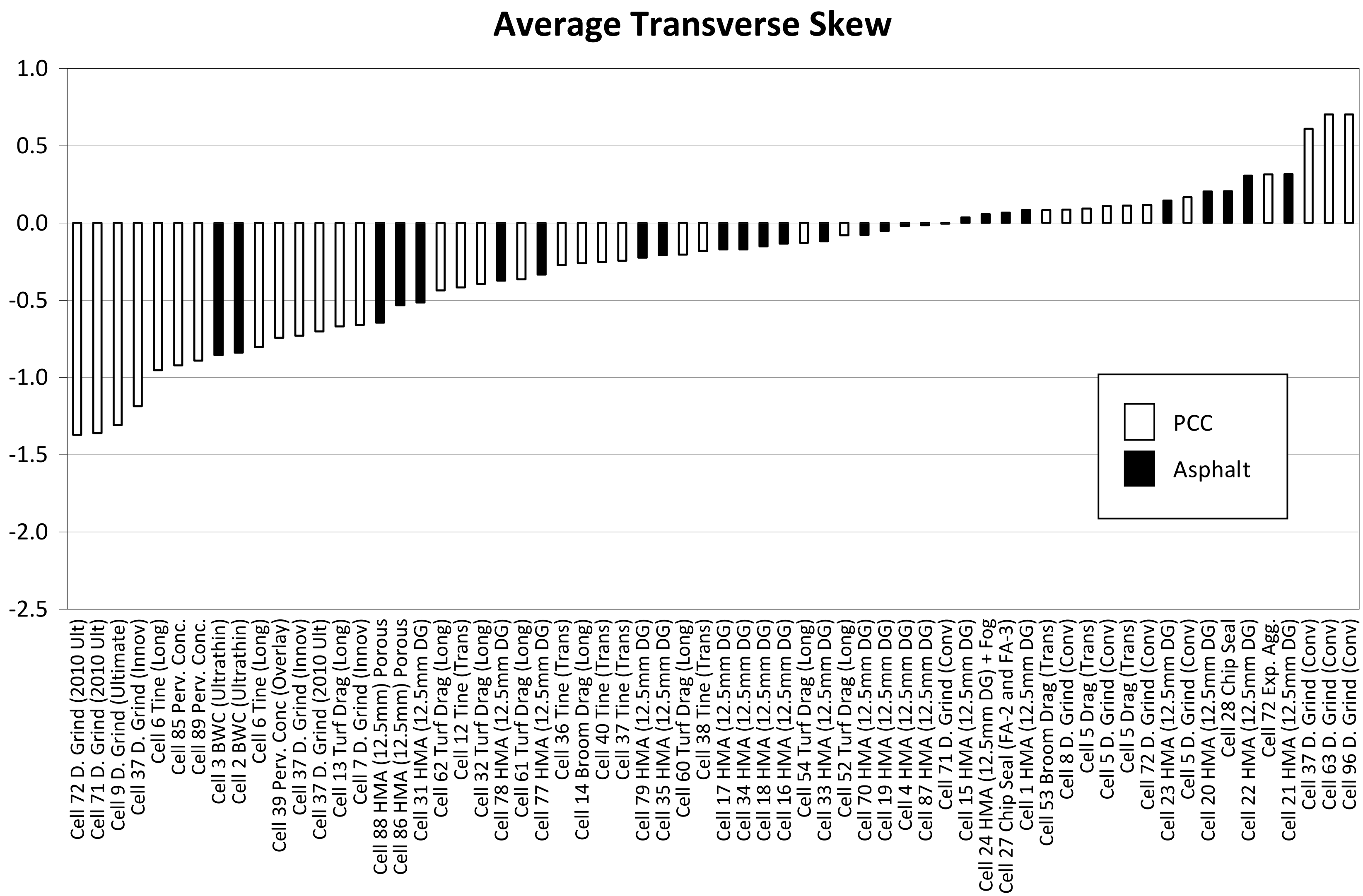

Figure 5-7. Average skew in the transverse direction for all cells.

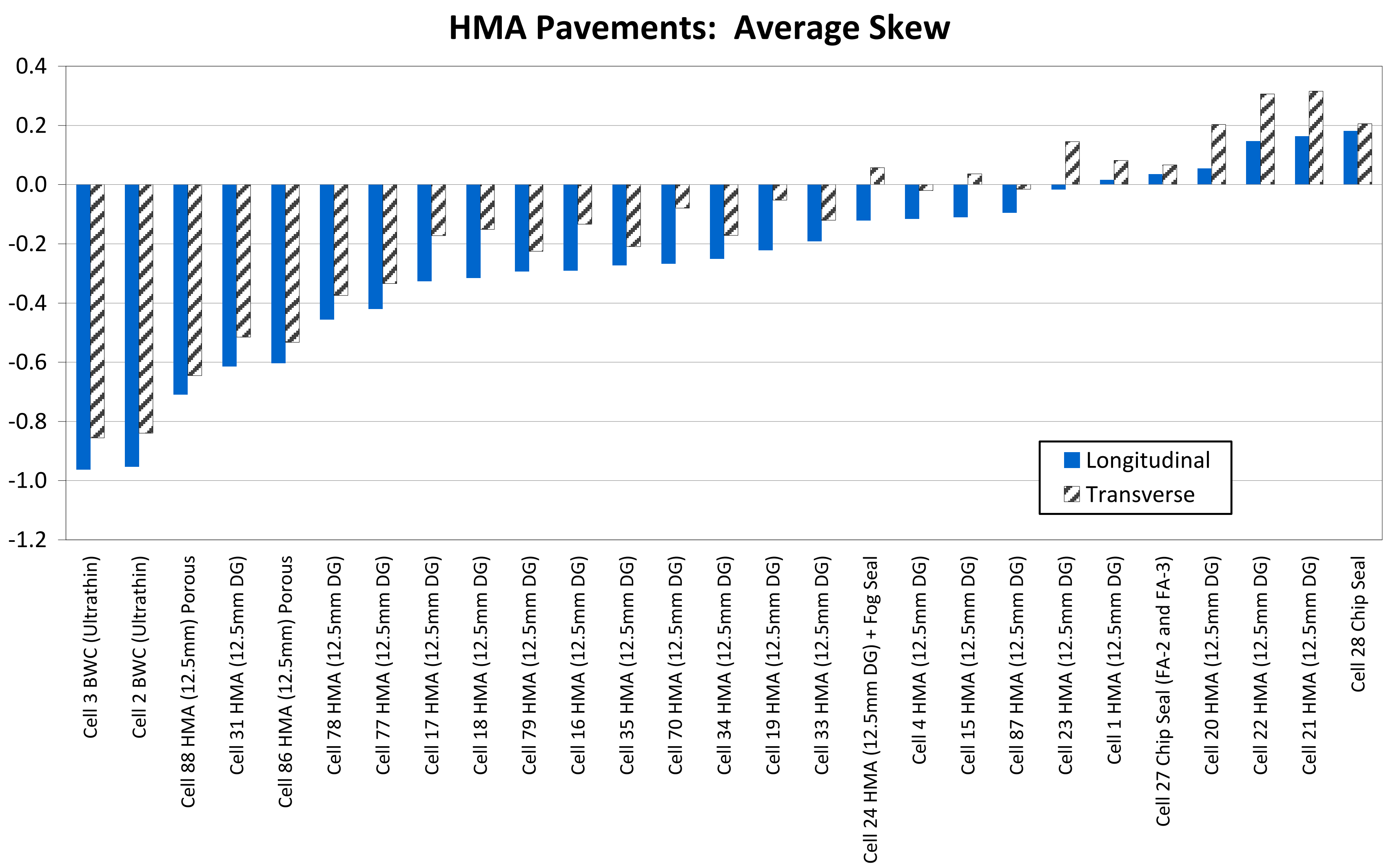

Figure 5-8. Texture skew for cells with HMA pavements.

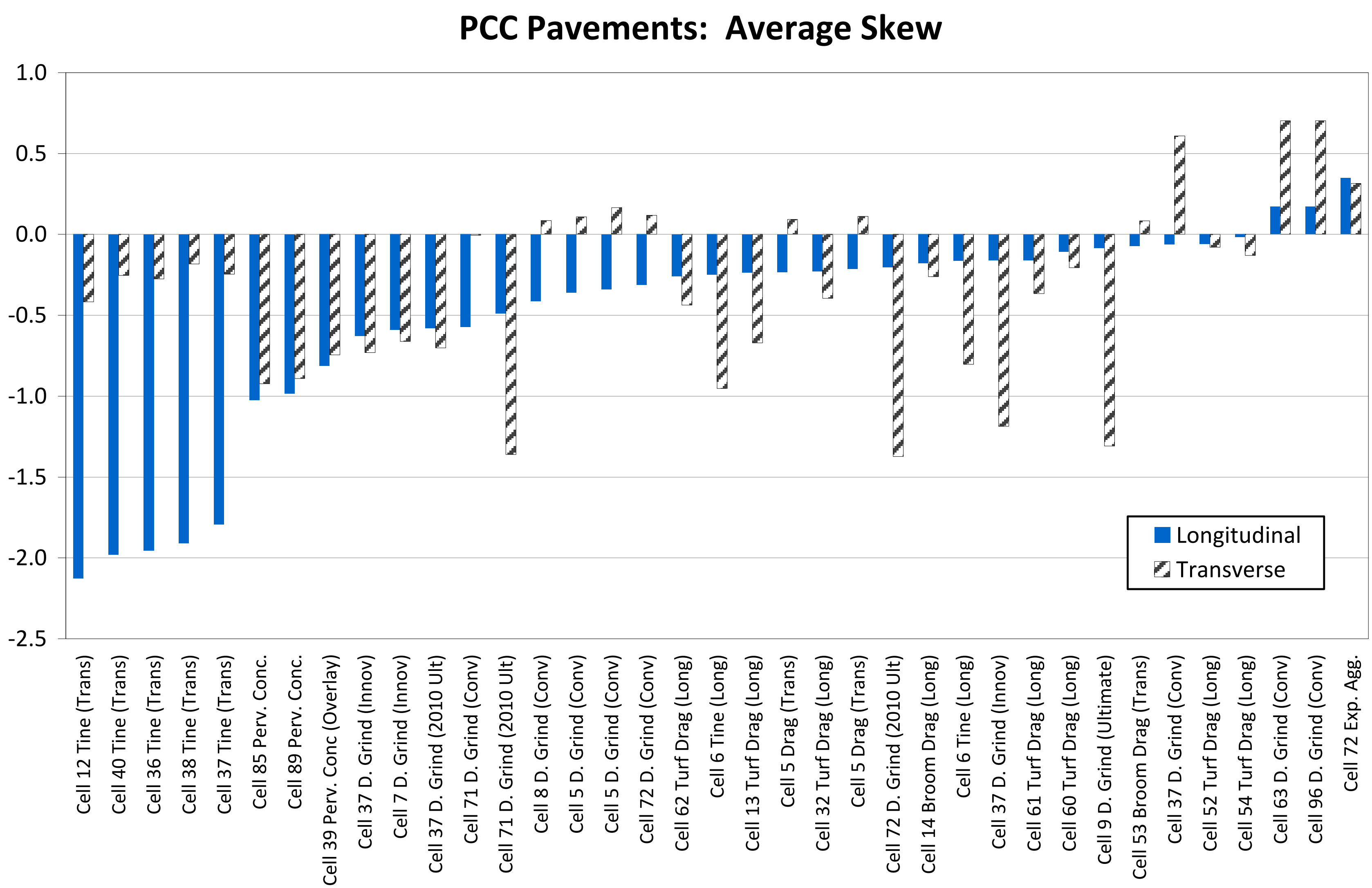

Figure 5-9. Longitudinal and transverse skew for cells with PCC pavements.

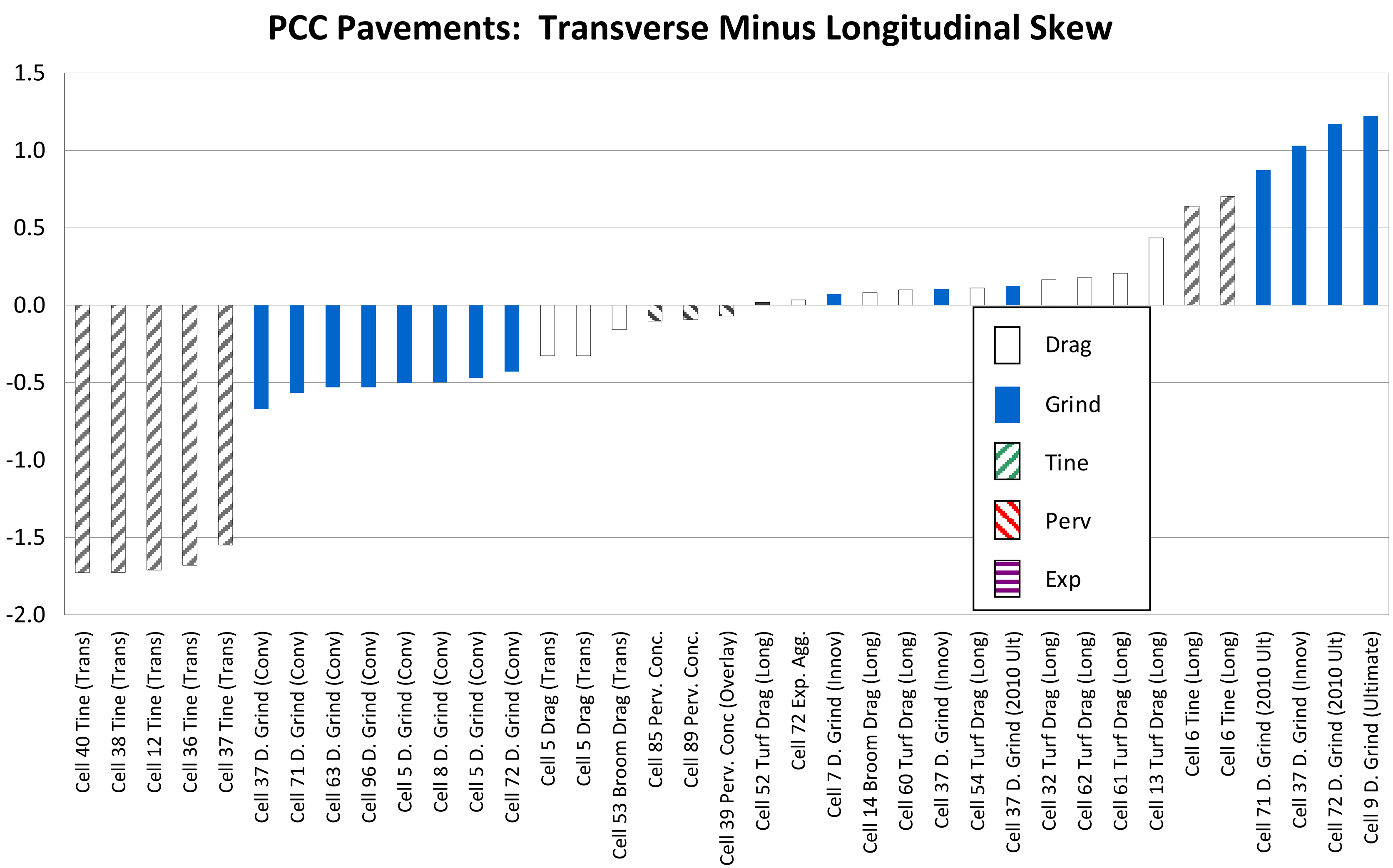

Figure 5-10. Difference between transverse and longitudinal skew for cells with PCC pavement.

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1. ISO 13473-3: 2002, *Characterization of Pavement Texture by use of Surface Profiles – Part 3: Specification and Classification of Profilometers*, International Organization for Standardization, Geneva, Switzerland (2002).

2. ISO 13473-1: 1997, *Characterization of Pavement Texture by use of Surface Profiles – Part 1: Determination of Mean Profile Depth*, International Organization for Standardization, Geneva, Switzerland (1997).

3. ISO 13565-2:1996, *Geometrical Product Specifications (GPS) - Surface texture: Profile method; Surfaces having stratified functional properties* -- *Part 2: Height Characterization Using the Linear Material Ratio Curve*, International Organization for Standardization, Geneva, Switzerland (1996).

4. ISO 13473-4: 2008, *Characterization of Pavement Texture by use of Surface Profiles – Part 4: Spectral Analysis of Surface Profiles*, International Organization for Standardization, Geneva, Switzerland (2008).