Initial Results of Pavement Texture Testing in the FHWA-LTPP Program

Chris Olmedo
chris.olmedo@stantec.com
Stantec Consulting
49 Frederick Street
Kitchener, Ontario N2H 6M7
Phone: +1 (519) 585-7493

Carlos Leal
carlos.leal@stantec.com
Stantec Consulting
49 Frederick Street
Kitchener, Ontario N2H 6M7
Phone: +1 (519) 585-7491

Gabe Cimini
gabe.cimini@stantec.com
Stantec Consulting
49 Frederick Street
Kitchener, Ontario N2H 6M7
Phone: +1 (519) 585-7470

Jack Springer, P.E.
jack.springer@dot.gov
U.S. Department of Transportation
Federal Highway Administration
Turner–Fairbank Highway Research Center
6300 Georgetown Pike, HRDI–30
McLean, VA 22101–2296
Phone: +1 (202) 493-3143

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ABSTRACT

Texture data is an important measure of a pavement's surface, which ultimately affects the safety of every commuter. The resulting statistic, Mean Profile Depth (MPD), is useful in the prediction of the high speed dependence of wet pavement friction. The Federal Highway Administration (FHWA) Long-Term Pavement Performance (LTPP) program is the largest pavement performance research program ever undertaken, gathering data from 2,400 pavement test sections for over 25 years. Since 2013, LTPP has collected macrotexture measurements from sections located on in-service highways throughout North America. Profilers, meeting LTPP's stringent acceptance criteria, use texture height sensors, rated at 62.5 kHz, to collect texture measurements at 0.5 mm intervals. Texture statistics, including MPD, RMS, Dropouts, and Cubic Skew populate the world's largest pavement performance database (PPDB).

This paper presents an investigation of texture statistics across various pavement types, materials, maintenance, rehabilitation, traffic load levels and climatic zones. This paper presents quantification of correlations between sections in the experimental matrix and provides an update on the existing texture statistic ranges. This in turn, can result in a greater understanding of the role that texture plays in ensuring the safest highways possible.

Introduction

Started in 1987, the Federal Highway Administration (FHWA) Long-Term Pavement Performance (LTPP) program is a research program that investigates in-service pavement performance. The primary goal of the LTPP program is to answer how and why pavements perform as they do. In order to accomplish this goal, LTPP collects pavement performance data using standard data collection procedures and protocols on a variety of pavement types. This information is stored in the LTPP Pavement Performance Database (PPDB) that can be used by pavement engineers and researchers worldwide to advance the science of pavement engineering. Over 2500 sections have been monitored during the life span of the project. Macrotexture data started being collected for the LTPP program in April 2013 amassing almost 1100 tests on 503 sections across North America (Figure 1). Data is collected along the wheel paths by Ames Engineering profile/texture devices.

Background

Most tire-road interactions are determined by the surface texture of a given pavement. Features of the pavement surface have different ranges (Table 1). Macrotexture is the primary component of high-speed, wet skid resistance. The Ames Engineering profilers are capable of determining macrotexture depth at highway speeds.

Various statistics for Texture data were extracted from the PPDB. Basic descriptions of each statistic are listed below (ASTM Designation E 1845-01):

- Mean Profile Depth (MPD) - The calculation of Mean Profile Depth from a profile of pavement macrotexture is calculated as follows:
    - The measured profile is divided into segments (called Mean Segment Depth or MSD) having a length of 100 mm (4”). The slope of each segment is suppressed by subtracting a linear regression of the segment. This also provides a zero mean profile, i.e., the area above the reference height is equal to the area below it. The segment is then divided in half and the height of the highest peak in each half segment is determined. The average of these two peak heights is the mean segment depth. The average value of the mean segment depths for all segments making up the measured profile is reported as the MPD.
    - Users will need to assess whether obtained MPD values are acceptable based on pavement type. Testing by the Virginia Transportation Research Council in 2003 produced some example MPD ranges for various pavement types (Table 2).
- Standard Deviation (SD) - Measurement of the amount of variation or dispersion from the average. Studies have shown that by comparing MPD and SD values together, one is able to determine the texture orientation.
- Dropout % - Invalid readings may be caused by dropouts as a result of deep surface troughs or local photometric properties of the surface. For this reason, readings are eliminated when their value is higher or lower than the range of the profile surrounding their location. Bridging takes place where one value prior to and one value after the dropout is also removed. The invalid values for these

locations are replaced with interpolated values between the previous and following location. The maximum proportion of outliers shall be 20 %. When the proportion exceeds 10 %, caution should be used in interpreting the data. Dropout percentages are based on the number of time-based texture points and not the 0.5 mm interval spatial-based values.

- Root Mean Square (RMS) - A statistical measure of the magnitude of a varying quantity
- Cubic Skew - To provide a directionality of the texture, elevations and RMS are correlated to provide a positive or negative value.

Pavement Data Collection

The Ames Engineering Model 8300 profile/texture device uses a Ford E150 XLT Wagon as the host vehicle (Figure 2). This device is equipped with specialized instruments to measure and record road profile data and surface macrotexture data. In addition to three laser height sensors and accelerometers, the device is also equipped with two additional laser sensors to collect surface macrotexture data.

The two texture height sensors collect macrotexture data along each wheel path. The device is equipped with two LMI-Selcom Optocator 2008-180/390 sensors that collect macrotexture data. These sensors have a measurement range of 180 mm and a stand-off height of 390 mm. The texture height sensors are rated at 62.5 kHz. This data can be post-processed to obtain macrotexture data at 0.5 mm intervals. Each sections is 152.4 m (500 feet) in length and the test speed normally used to collect profile data at LTPP sections is 80 km/h.

FHWA-LTPP software (ProQual 2014) was used to perform quality control checks in the field and office on the data collected by the Ames Device. This software is also used in the office to perform further quality control checks on the data and to select five runs whose data and computed parameters are uploaded to the PPDB. In ProQual 2014, the following computed parameters can be viewed for the left and right texture sensors for each run:

- MPD for entire run
- Standard deviation of the elevation values for the entire section.
- Dropout count.
- Dropout percentage.
- RMS value for entire run.
- Cubic skew value based on data from entire run.

After reviewing the data in the field, operators have the ability to input surface finish type comments and additional operational comments related to data collection. The run selection process was heavily weighted towards acceptable elevation profiles including:

- Elevation Cross-Correlation (Average): A value of at least 96 percent is desired
- Elevation Cross-Correlation (Standard Deviation): A value less than 1 percent is desired
- IRI Cross-Correlation (Average): A value greater than 80 percent is desired

- IRI Cross-Correlation (Standard Deviation): A value less than 10 percent is desired
- IRI (Standard Deviation): A values less than 0.04 m/km is desired
- Consistent run-to-run statistics and profiles
- Consistent visit-to-visit statistics and profiles

Texture QC's included:

- Sections with less than 20% Dropouts
- Consistent run-to-run statistics
- Consistent visit-to-visit statistics

Analysis Criteria

The PPDB database is extensive so several methods of analysis can be applied. Texture statistics were compared for the following pavement types:

- Asphalt - Course
- Asphalt - Fine
- Chip Seal
- Concrete – Broom Finish
- Concrete – Diamond Ground
- Concrete – Longitudinal Tines
- Concrete – Transverse Tines
- Open Graded/Friction Course

In turn, the following experimental factors were compared for each pavement type:

1. Climactic zones:
   - Dry, Freeze
   - Dry, Non- Freeze
   - Wet, Freeze
   - Wet, Non- Freeze
2. Surface Condition:
   - Very Good
   - Good
   - Fair
   - Poor
3. Functional Class:
   - Interstate
   - Other Principal Arterial
   - Minor Arterial
   - Local roads
4. Overlay Rehabilitation:
   - No Overlay
   - AC Overlay
   - PCC Overlay

Findings

Pavement type

The highest average MPD values were observed for the open graded/friction course sections (1.55 mm). This was followed by chip seal sections, AC (course, then fine) and finally PCC sections (transverse tines, longitudinal tines, broom finish and lastly diamond ground). Diamond ground PCC sections had an average MPD value of 0.64 mm. The greatest variation of MPD values took place with course grade asphalt sections (minimum of 1.37 mm and maximum of 7.84 mm). Detailed results are shown in Table 3 and graphically in Figure 3.

Pavement type by climactic zones

When comparing freeze to non-freeze sections (by pavement type), results indicated that non-freeze sections had higher MPD values. When comparing dry against wet, results varied.

The highest average MPD values were observed for the open graded/friction course sections in the wet, non-freeze zone (2.41 mm). The lowest values were observed for the diamond ground PCC sections in the wet, non-freeze zone (0.57 mm). The greatest variation of MPD values took place with course grade asphalt sections in the wet, non-freeze zone (minimum of 0.75 mm and maximum of 7.84 mm). Results are shown in Figure 4.

Pavement type by pavement condition

As one could expect, sections in fair or poor condition had higher MPD values (by pavement type). One exception was with chip seal sections where the opposite trend was observed.

The highest average MPD values were for chip seal sections in very good condition (2.04 mm). The lowest values were observed for PCC sections with a broom finish in very good condition (0.52 mm). The greatest variation of MPD values took place again, with course grade asphalt sections in fair condition (minimum of 0.70 mm and maximum of 7.84 mm). Results are shown in Figure 5.

Pavement type by traffic load levels

Results varied when comparing sections by functional class (and by pavement type).

The highest average MPD values were observed for the chip seal sections with a local road classification (1.88 mm). The lowest values were observed for the diamond ground PCC sections classified as non-interstate principal and minor arterial (0.56 mm). The greatest variation of MPD values took place with course grade asphalt sections with a non-interstate principal arterial classification (minimum of 0.74 mm and maximum of 7.84 mm). Results are shown in Figure 6.

Experiments where sections were rehabilitated with an overlay

When comparing overlaid sections with comparable sections that did not receive a similar treatment, results indicated that overlaid sections had higher MPD values.

The highest average MPD values were observed for section overlaid with an open graded/friction course (1.55 mm). The lowest values were observed for the diamond ground PCC sections that did not receive an overlay (0.63 mm). The greatest variation of MPD values took place with course grade asphalt sections that had received an overlay treatment (minimum of 0.74 mm and maximum of 7.84 mm). Results are shown in Figure 7.

Discussion

Based on the analysis performed, various trends are evident based on the 1100 data sets available via the LTPP PPDB. Open graded/friction course and chip seal sections resulted in the highest MPD values. For AC pavements, course graded sections had higher values than fine graded. PCC sections recorded the lowest MPDS values in the following order, transverse tines, longitudinal tines, broom finish and lastly diamond ground.

Results indicated that sections in non-freeze zones had higher MPD values than sections in freeze zones. With one exception, sections in fair or poor condition had higher MPD values than ones in good or very good condition. The exception was with chip seal sections in very good condition. Functional class did not reveal any significant trends. Lastly, results showed that overlaid sections had higher MPD values than corresponding section that have not received an overlay treatment.

Recommendations for Future Analysis

The PPDB database is extensive so several methods of analysis applied here can be looked at in greater detail. In addition, other factors can be investigated such as sub-surface layer types & thicknesses and air & surface temperatures.

Diurnal testing was performed on some PCC sections in this analysis. A closer review of this experiment may yield additional findings.

Certain pavement types have a smaller sample size. These data sets should be evaluated.

For the traffic comparison, a more accurate correlation can be performed based on actual ESAL values or load spectra factors.

This analysis did not take into account the age of the pavements nor the time elapsed since overlay treatments took place.

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Tables

Table 1: Texture Classification

Texture Classification	Relative Wavelengths
Microtexture	λ < 0.5 mm
Macrotexture	0.5 mm < λ < 50 mm
Megatexture	50 mm < λ < 500 mm
Roughness/Smoothness	500 mm < λ < 50 m

Table 2: MPD ranges for various pavement types

Pavement Type	Dynamic Data		
	Mean	Low	High
PCC - Transverse tinning	2.0	0.3	9.0
PCC - Longitudinal diamond grinding		0.3	
ACC - Fine mix (9.5 mm surface mix)	0.5	0.3	1.0
ACC - Course mix (19 mm stone matrix asphalt)	1.1	1.0	2.0
AC - Open-graded friction course	2.3	1.0	6.0
AC - Surface treatment	1.5	1.0	3.0

Table 3: Texture statistics by pavement type

Surface Finish Type	No. of Tests	MPD (mm)				RMS (mm)		Skew (mm)	
		Avg.	STD	Max	Min	Avg.	SD	Avg.	SD
ASPHALT - COURSE	75	1.37	0.84	7.84	0.70	16.57	3.99	1.04	0.13
ASPHALT - FINE	207	1.03	0.29	1.95	0.56	16.90	5.93	1.04	0.17
CHIP SEAL	58	1.41	0.41	2.50	0.56	14.15	3.42	1.08	0.07
CONCRETE - BROOM FINISH	10	0.76	0.15	0.97	0.52	24.25	3.72	1.04	0.04
CONCRETE - DIAMOND GROUND	37	0.64	0.16	1.34	0.46	16.38	4.39	1.02	0.14
CONCRETE - LONGITUDINAL TINES	50	0.85	0.08	0.99	0.74	14.14	0.73	1.06	0.03
CONCRETE - TRANSVERSE TINES	657	0.92	0.21	1.74	0.51	16.73	4.84	1.06	0.12
OPEN GRADED/FRICTION COURSE	5	1.55	0.59	2.41	0.76	16.00	1.70	1.12	0.17

Figures

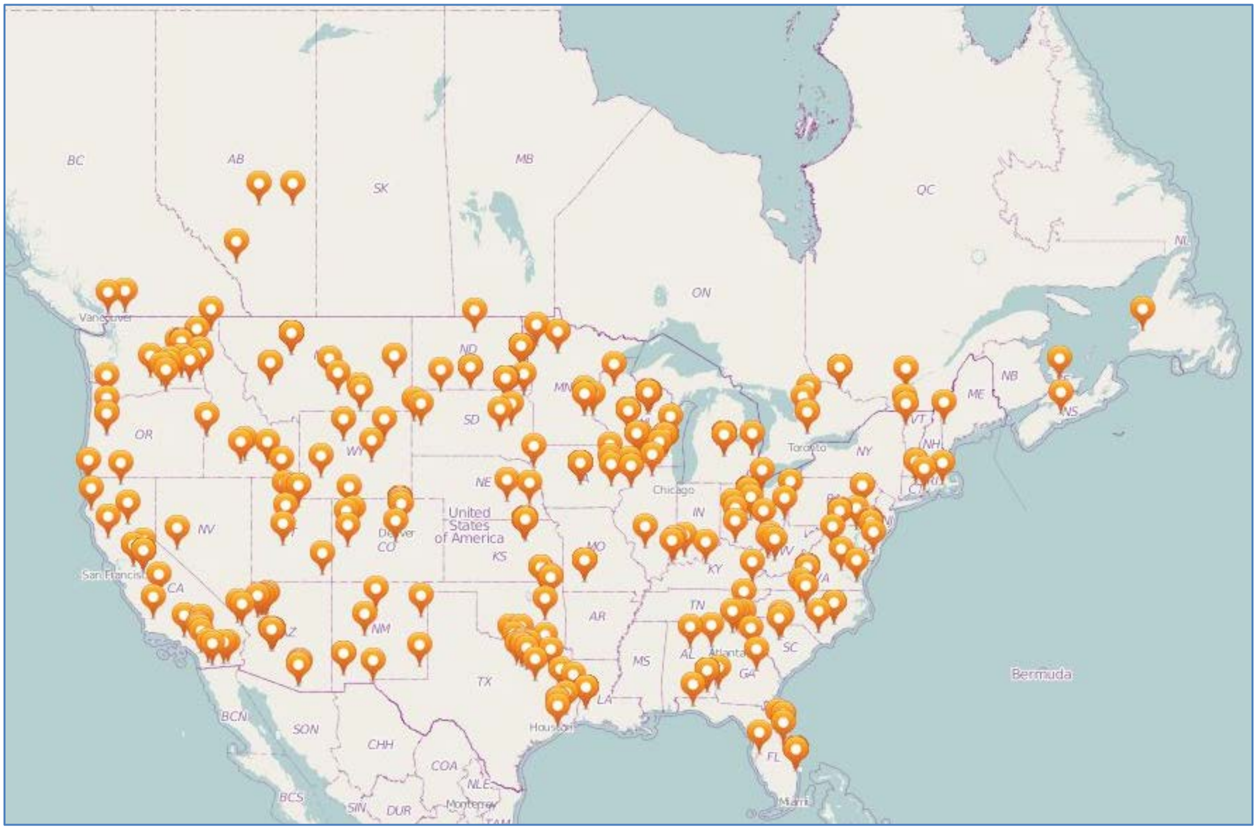

Figure 1: Map of Sections Tested for Texture

Figure 2: Ames Engineering Survey Unit

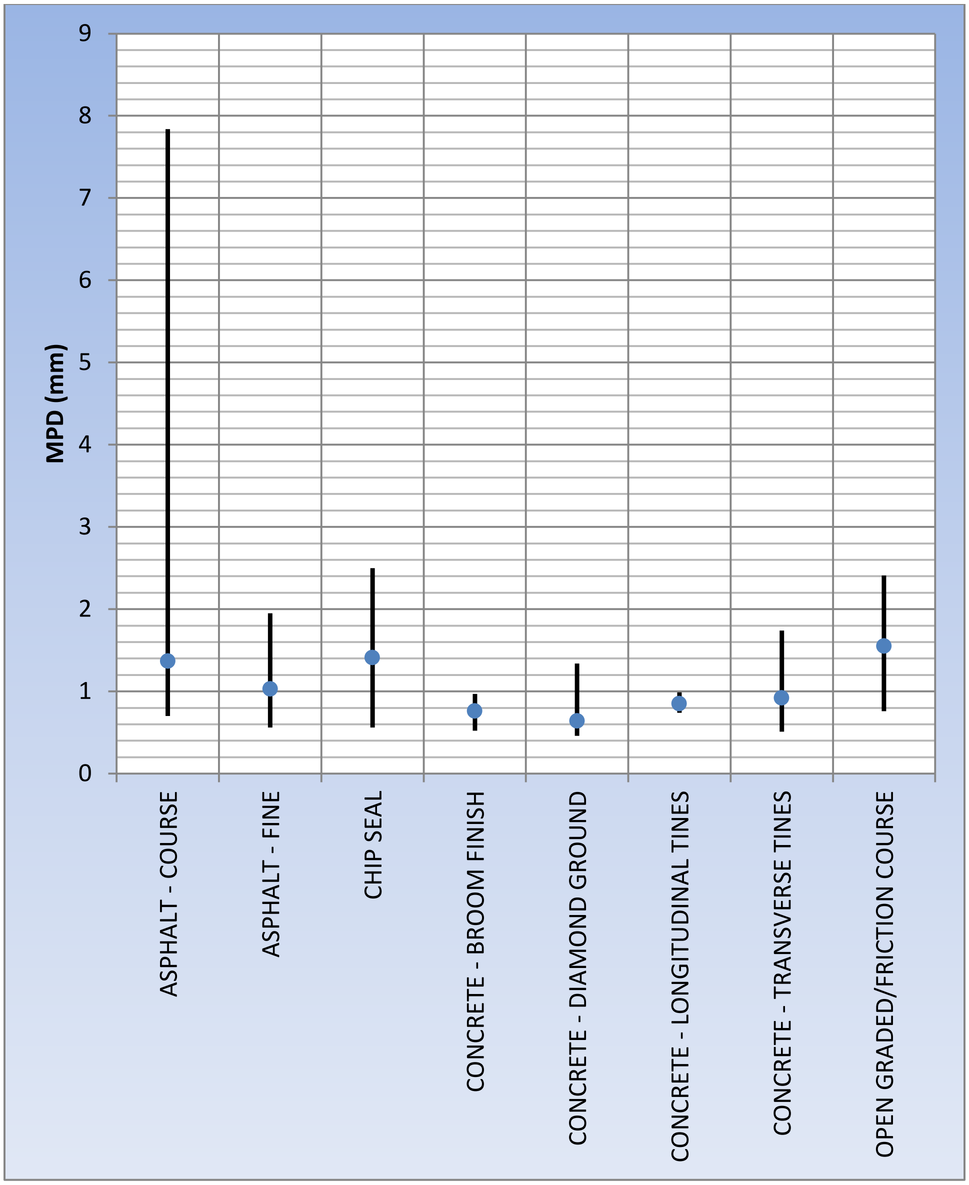

Figure 3: MPD Ranges of Surface Finish Type

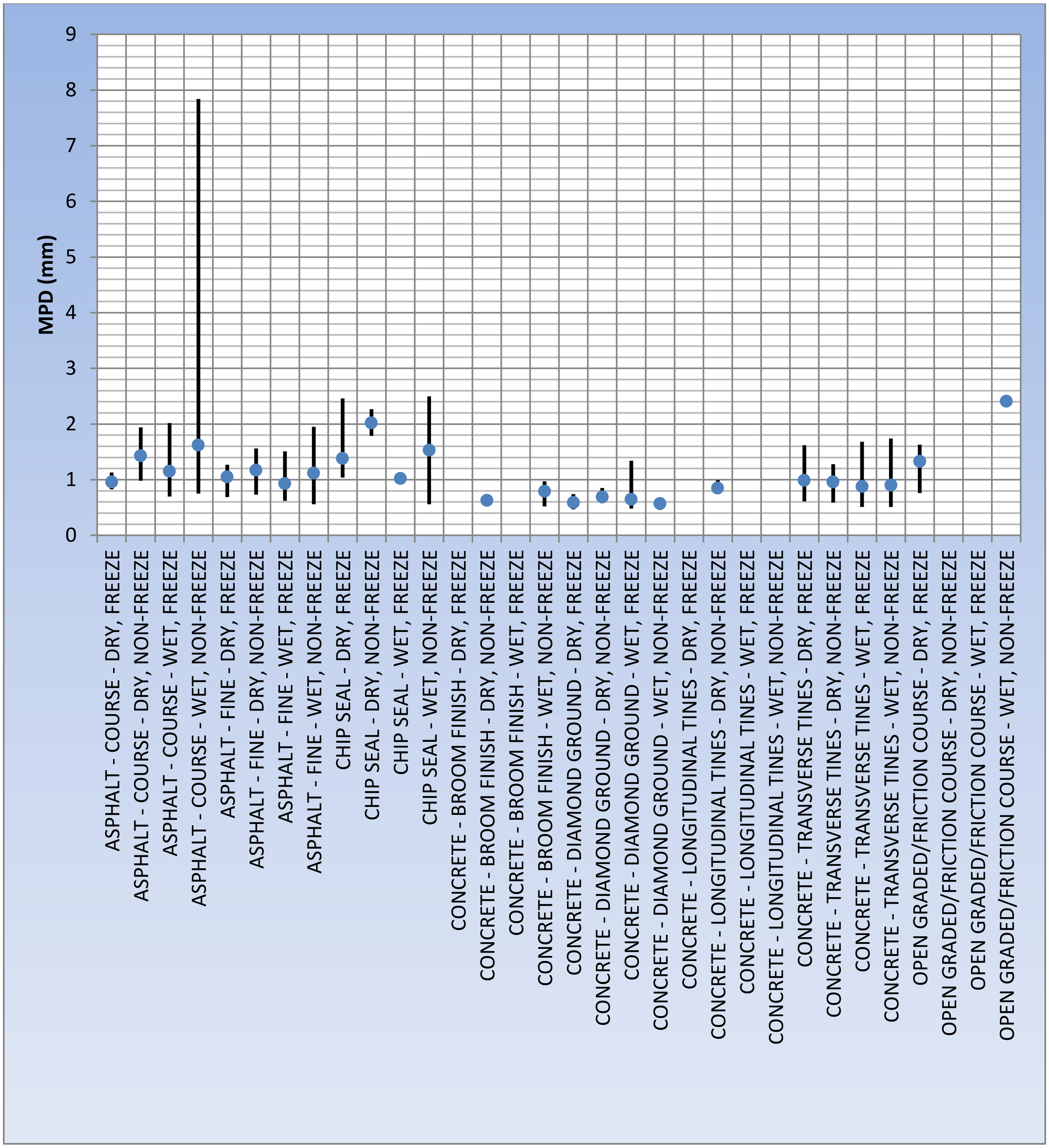

Figure 4: MPD Ranges of Surface Finish Type by Climatic zone

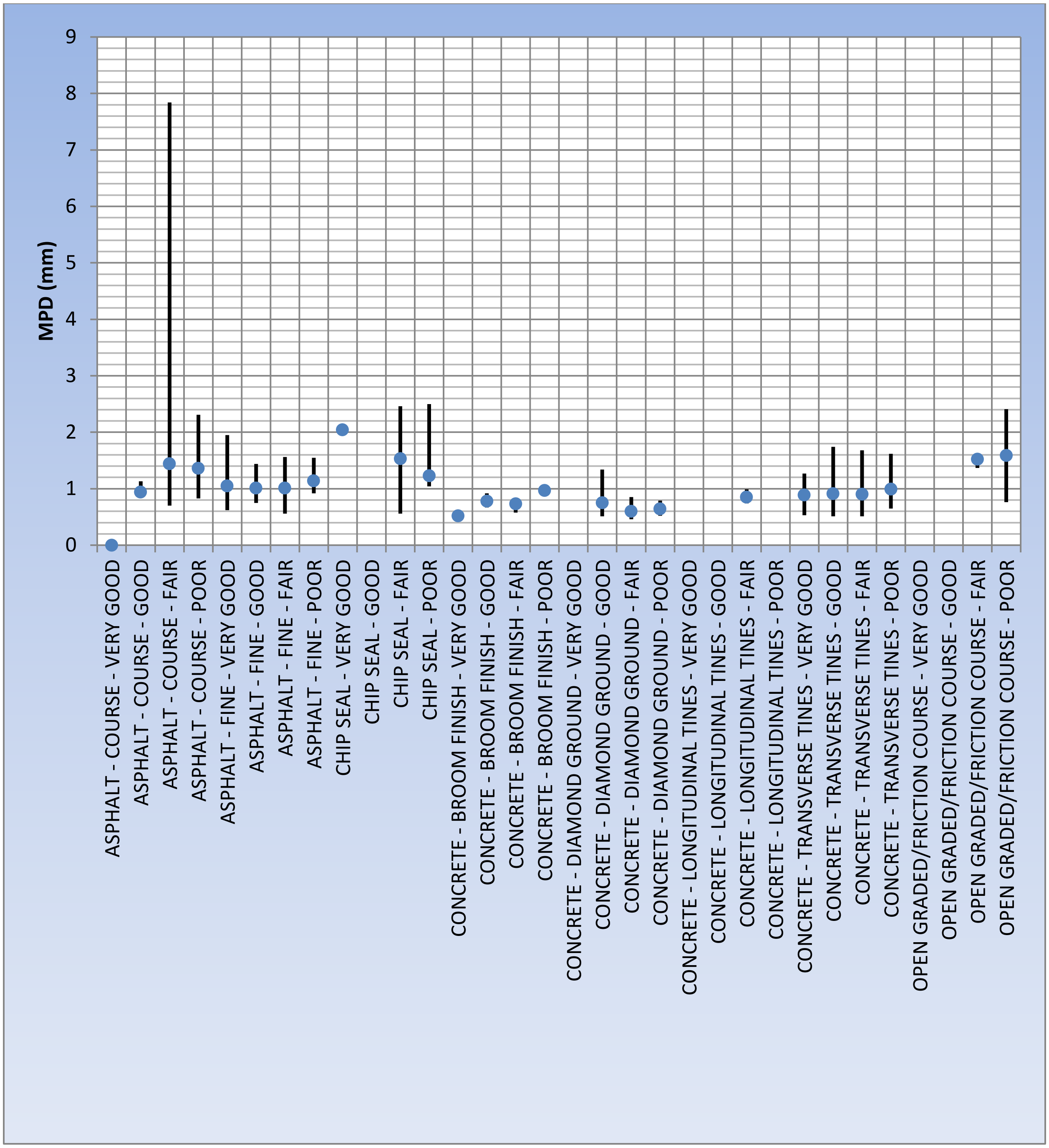

Figure 5: MPD Ranges of Surface Finish Type by Surface Condition

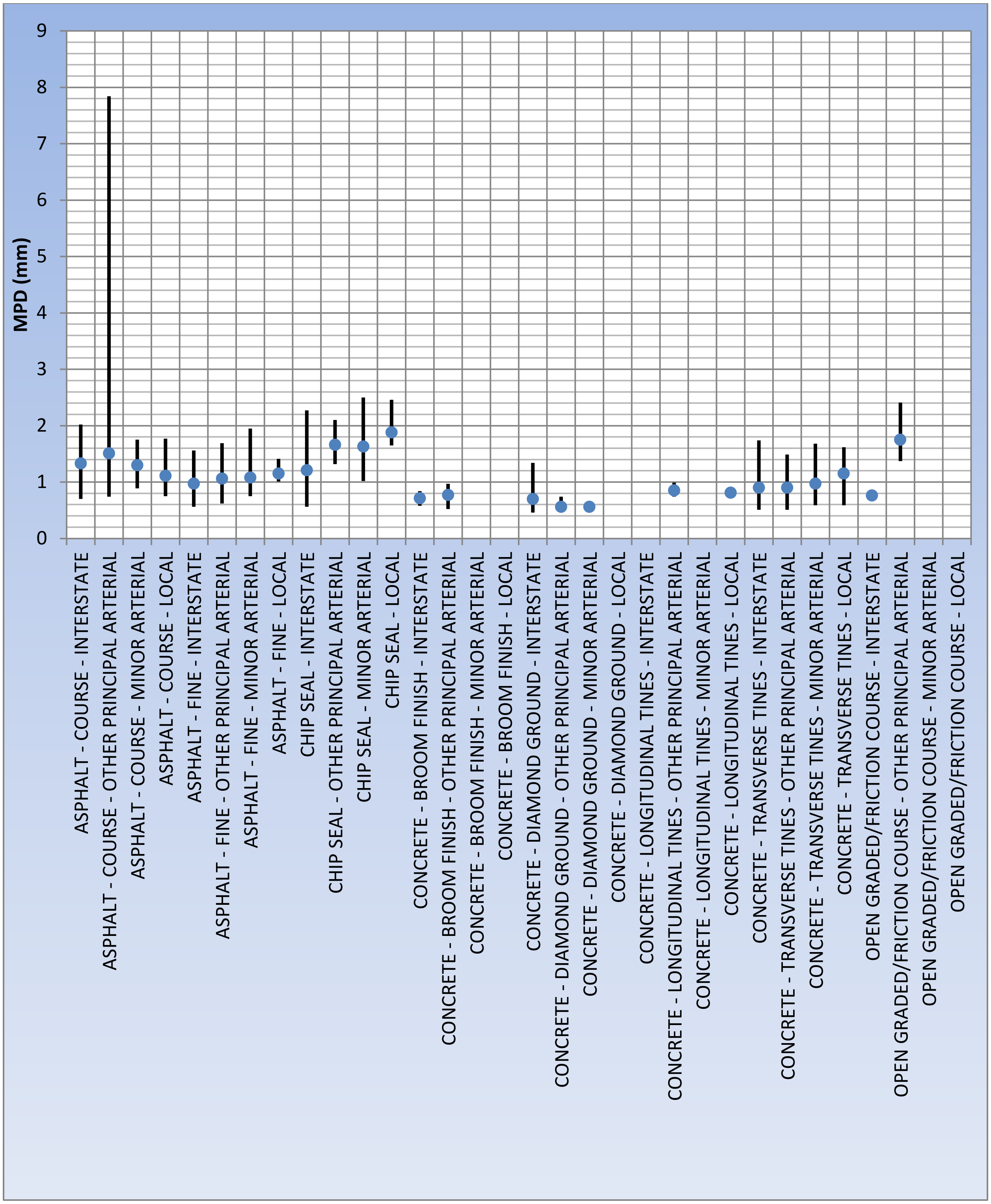

Figure 6: MPD Ranges of Surface Finish Type by Functional Class

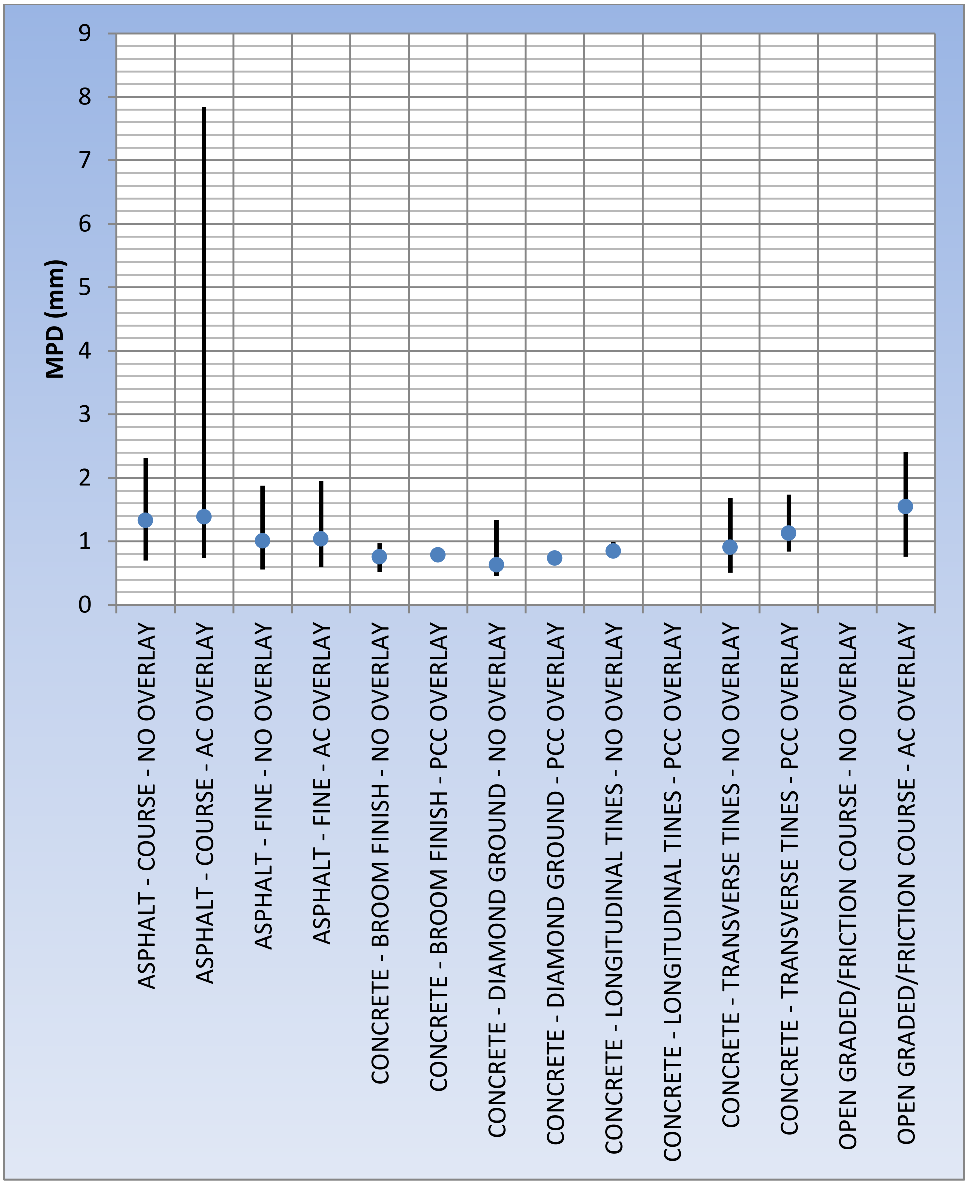

Figure 7: MPD Ranges of Surface Finish Type by Overlay