
Standard Practice for Assessment of Ground Reference Data for Transverse Pavement Profiling System Assessment

AASHTO Designation: PP 110-23¹

Technically Revised: 2023

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Technical Subcommittee: 5a, Pavement Measurement



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Standard Practice for

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1. SCOPE

- 1.1. This practice describes the procedures used to assess ground reference data used in PP 109.
- 1.2. This practice describes the accuracy and precision analysis needed to ensure a ground reference equipment (GRE) system is collecting acceptable quality ground reference data. The accuracy and precision are evaluated using four surfaces: a certified straightedge, a bounding beam with gauge blocks, a road surface, and a macrotexture surface. The measures evaluated are: transverse, longitudinal, and vertical measurement error; transverse, longitudinal, and vertical measurement spacing; transverse straightness; and horizontal plane flatness.
- 1.3. It is necessary for all four surfaces to be measured and analyzed to ensure the GRE is capable of producing road surface measurements with accuracy that is acceptable for ground reference data in PP 109. To verify these accuracies are achieved for a road surface, a mix of certified smooth/flat surfaces (i.e., straightedge and gauge blocks) must be coupled with textured surfaces (e.g., macrotexture surface) with verifiable roughness and dimensions to ensure the GRE is correctly measuring road surfaces that have a nominal roughness.
- 1.4. If any part of this practice is in conflict with referenced documents, such as ASTM standards, this practice takes precedence for its purposes.
- 1.5. This test is designed to be conducted as the first steps in assessing a newly proposed ground reference data acquisition device and when acquiring ground reference data for PP 109.
- 1.6. This practice does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this practice to establish appropriate safety and health practices and determine the applicability of regulatory limitations related to and prior to its use.

2. REFERENCED STANDARDS

- 2.1. *AASHTO Standards:*
 - < PP 109, Assessment of Highway Performance of Transverse Pavement Profiling Systems
 - < PP 111, Definition of Terms Related to Transverse Pavement Profiling Systems and Ground Reference Equipment

3. TERMINOLOGY

- 3.1. See PP 111 for definition of terms used in this standard practice.
- 3.2. Table 1 provides the physical parameter definitions, symbols, and default values to be used when administering this standard.

Table 1—Physical Parameter Definitions and Default Values

Physical Parameter	Symbol	Default Value(s)
Minimum Straightedge Length and transverse width of the Road Surface	W_{gr}	4.0 m (13.1 ft)
Minimum Straightedge Width	W_{fs}	25 mm (1 in.)
Width of Transverse Bounding Beams	w_b	40.0 ± 2.0 mm (1.5 ± 0.1 in.)
Vertical Height of Gauge Blocks	$h_{g,1}$ $h_{g,2}$	75 ± 2 mm, 50 ± 1 mm, 25 ± 1 mm 25 ± 1 mm, 12 ± 1 mm, 6 ± 1 mm
Minimum Gauge Block Transverse and Longitudinal Width	w_g	19.0 mm (0.75 in.)
Transverse Distance from the Base of the Gauge Block	d_s	25.0 mm (1 in.)
Longitudinal Length of the Road Surface	L_{gr}	0.5 ± 0.05 m (19.5 ± 2 in.)
Desired Transverse Locations of Gauge Blocks from the Transverse Centerline	d_t	2.0 ± 0.05 m (78.75 ± 2 in.)
Longitudinal Length of the Macrotexture Surface	l	150.0 ± 5.0 mm (6 ± 0.2 in.)
Transverse Width of the Macrotexture Surface	w	150.0 ± 5.0 mm (6 ± 0.2 in.)
Minimum Longitudinal Length of Flat Plate	L_p	1.0 m (3.28 ft)
Minimum Transverse Width of Flat Plate	W_p	0.5 m (20 in.)
Longitudinal Offset of the Macrotexture Surface from a Reference Corner of a Flat Plate	l_o	175.0 ± 5.0 mm (6.8 ± 0.2 in.)
Transverse Offset of the Macrotexture Surface from a Reference Corner of a Flat Plate	w_o	25.0 ± 5.0 mm (1.0 ± 0.2 in.)
Measurement Error Longitudinal Grid Spacing	l_g	10.0 mm (0.4 in.)
Measurement Error Transverse Grid Spacing	t_g	10.0 mm (0.4 in.)
Number of Random Measurements to Select	N_r	100

4. SIGNIFICANCE AND USE

- 4.1. Accurate ground reference data are needed for assessment of transverse pavement profiling (TPP) systems. Ground reference data are needed to quantify the vertical measurement error present in TPP systems when collecting measurements for cross slope, rutting, and edge/curb detection. For specifics regarding the highway performance TPP assessment process and usage of ground reference data, see PP 109.
- 4.2. In PP 109, a road surface with a transverse width of W_{gr} and a longitudinal length of L_{gr} shall be selected to test for accuracy and precision of a TPP system when measuring rutting, cross slope, and edges/curbs. For this segment of road surface, the process of collecting ground reference data using GRE is provided in detail in this standard practice.
- 4.3. This standard prescribes tests to evaluate the transverse spacing between measurements; total width of measurements; vertical resolution of the measurements; straightness of the transverse measurements; vertical, transverse, and longitudinal accuracy and precision; and error associated with measuring macrotexture. Since collected ground reference data shall be used to evaluate the accuracy and precision of TPP systems, a table of the necessary accuracy and precision

requirements for the ground reference data are provided in the form of bias and confidence intervals.

- 4.4. The testing procedure and data analysis presented in this standard verify that measurement equipment is collecting acceptable quality ground reference data. This standard practice should be performed any time ground reference data is collected for the assessment outlined in PP 109.

5. DATA COLLECTION AND REPORTING

- 5.1. A road surface segment which contains a transverse width of W_{gr} and a longitudinal length of L_{gr} shall be selected. The selected road surface shall be bounded along the longitudinal edges by a certified straightedge leveled to 0.05 percent (0.029 degree = 103 seconds) and bounding beam with gauge blocks. The transverse edges of the selected road surface shall be bounded by blocks of width w_b . Figure 1 provides a schematic of the test section with the dimensions appropriately illustrated.

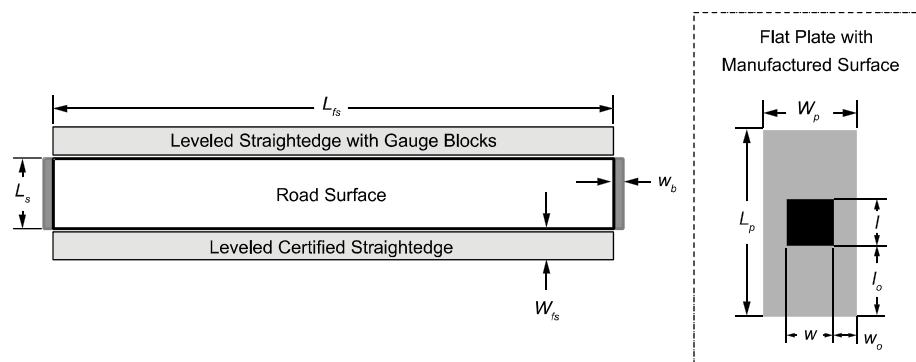


Figure 1—General Layout of the Test Section with the Bounding Straightedges and Manufactured Surface off to the Side of the Road Surface of Interest

- 5.1.1. Details regarding the tolerances and surface finish of the straightedge can be found in Annex A, Section A1 and those of the bounding beam can be found in Section A5.
- 5.2. To limit the amount of vertical distance between consecutive steps, two sets of stair-stepped gauge blocks shall be used having vertical heights of $h_{g,1}$ and $h_{g,2}$ with each step having a minimum transverse width of w_g as shown in Figure 2.

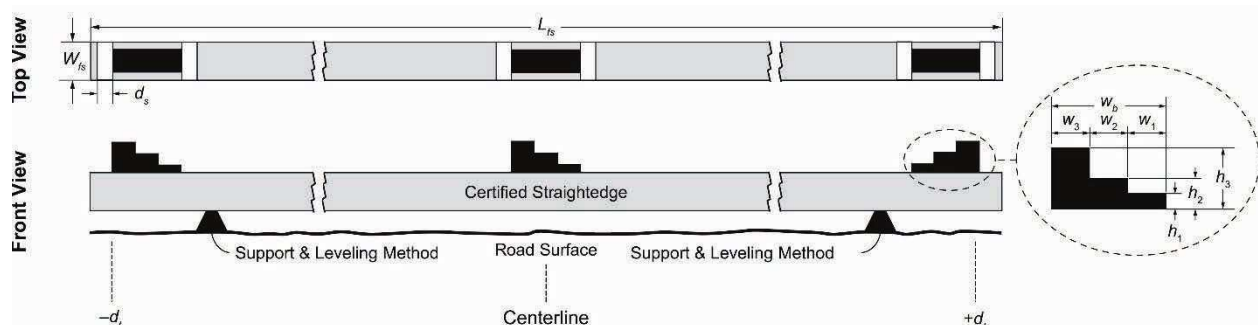


Figure 2—Detailed Schematic of the Layout of the Gauge Blocks on the Leveled Straightedge

- 5.3. Details regarding the dimensioning, tolerances, surface finish, and material properties of the straightedge and gauge blocks are given in Annex A, Sections A1 and A2.

- 5.4. Nearby to the selected road surface, a flat plate with a transverse minimum width of W_p and a minimum longitudinal length of L_p shall be placed on the ground. On top of the plate, a macrotexture surface with a transverse width of w and a longitudinal length of l shall be centered on the plate such that an offset of w_o and l_o is present from a reference corner in the transverse and longitudinal directions, respectively. Details regarding the tolerances and surface finish of the macrotexture surface are given in Annex A, Section A3.
- 5.5. One continuous scan of the selected road surface along with the leveled straightedge and leveled straightedge with gauge blocks shall be collected. In the same scan or in a separate secondary scan, the flat plate with the macrotexture surface shall be collected. If a secondary scan is used to collect measurements of the flat plate, no adjustments can be made to the equipment used.
- 5.6. All data collected shall be reported in an initial point cloud format; see Annex C for details regarding this format.

6. ROAD SURFACE ANALYSIS

- 6.1. *Transverse and Longitudinal Measurement Spacing:*
 - 6.1.1. From the measurements in the ground reference region, N_r measurements shall be randomly selected and added to the set S_s . All N_r measurements in the set S_s shall be used to estimate the transverse and longitudinal measurement spacing.
 - 6.1.2. For each measurement in the set S_s , the nearest neighboring point in each of four quadrants shall be identified (one neighboring point per quadrant). The nearest neighboring measurement per quadrant shall be identified as the measurement point that is located in the quadrant of interest and has the shortest three-dimensional Euclidian distance. The quadrants shall be defined by a set of two-dimensional orthogonal axes oriented at a 45-degree angle with respect to the transverse–longitudinal axes of the path coordinate system. Figure 3 illustrates the orientation and numbering scheme for the four quadrants.

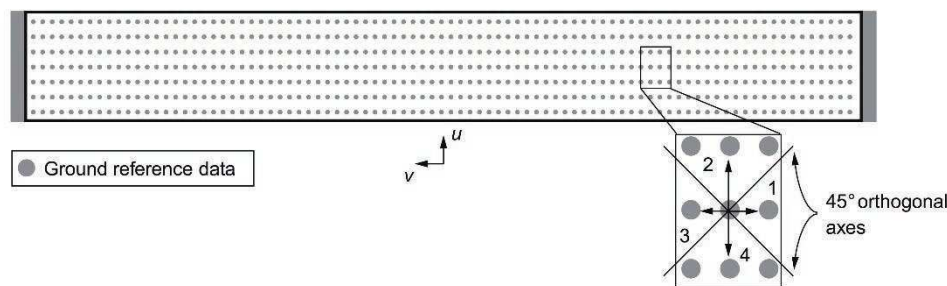


Figure 3—Illustration of Four Quadrants Oriented with Respect to the Path Coordinate System and Identification of the Nearest Neighboring Point in Each Respective Quadrant

- 6.1.3. The nearest neighboring point in quadrants 1 and 3 shall each provide an estimate of the transverse spacing. The transverse point-to-point distance between the respective measurement in the set S_s and the identified nearest neighboring point in quadrant 1 and quadrant 3 shall be calculated and added to the set r_t . The set r_t shall serve as a sample from the population of true transverse measurement spacing.
- 6.1.4. The nearest neighboring point in quadrants 2 and 4 shall each provide an estimate of the longitudinal spacing. The longitudinal point-to-point distance between the respective measurement in the set S_s and the identified nearest neighboring point in quadrant 2 and quadrant 4 shall be

calculated and added to the set r_l . The set r_l shall serve as a sample from the population of true longitudinal measurement spacing.

7. GAUGE BLOCKS ANALYSIS

- 7.1. Per measured gauge block, the set of associated measurements shall be separated into sets of measurements based on edges between surfaces. Each set of measurements shall be organized into one of three categories: transverse, longitudinal, or vertical, to define the respective direction for which the set of measurements shall provide measure errors.
- 7.2. For each category (transverse, longitudinal, and vertical), a single set of measurements in the category shall be used to establish a reference plane using a least squares error fit to the measurements. In total, per gauge block, three reference planes shall be defined to be used for point-to-plane distances.
- 7.3. *Vertical Measurement Error:*
- 7.3.1. Using the vertical measurement reference plane, the point-to-plane distance from each measurement set in the vertical category (omitting the set of points used to establish the reference plane) shall be calculated. The known certified vertical height corresponding to the point-to-plane distance shall be subtracted from the calculated point-to-plane distance to provide the vertical measurement error. See Figure 4 for an example of identification of surfaces that provide vertical measurement error and a respective point-to-plane distance for each identified surface set.

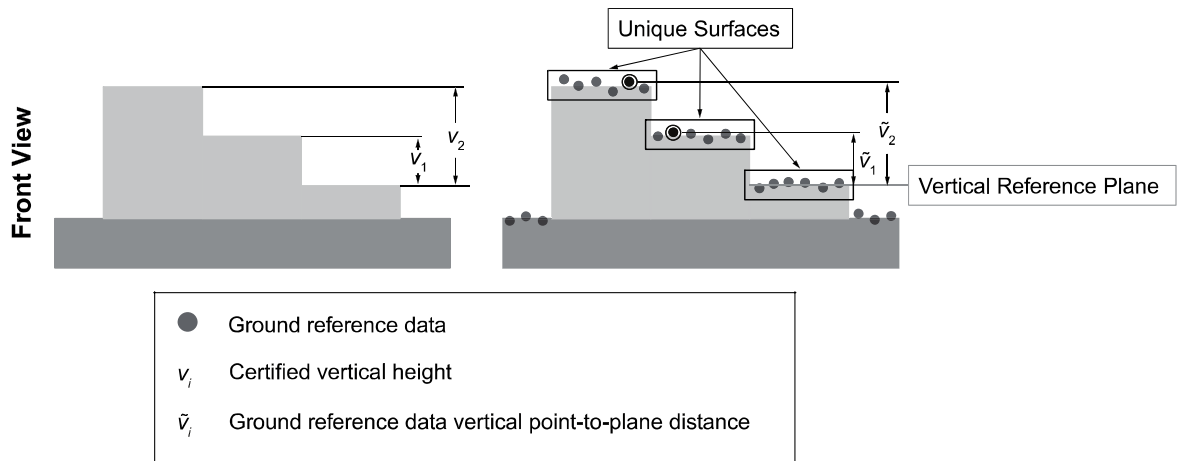


Figure 4—Identification of Unique Surfaces of a Gauge Block Corresponding to Vertical Error Measurement in the Ground Reference Data Point Cloud, and Example Vertical Point-to-Plane Distances for Each Unique Surface Set

- 7.3.2. For each point-to-plane distance, the vertical measurement error shall be added to the set e_v . The complete set of e_v values shall serve as a sample from the population of true vertical measurement accuracy and precision.
- 7.4. *Transverse Measurement Error:*
- 7.4.1. Using the transverse measurement reference plane, the point-to-plane distance from each measurement set in the transverse category (omitting the set of points used to establish the reference plane) shall be calculated. The known certified transverse width corresponding to the point-to-plane distance shall be subtracted from the calculated point-to-plane distance to provide