
Standard Specification for Smoothness of Pavement in Weigh-in-Motion (WIM) Systems

AASHTO Designation: M 331-17 (2021)¹

Technically Revised: 2017

Reviewed but Not Updated: 2021

Technical Subcommittee: 5a, Pavement Measurement



**American Association of State Highway and Transportation Officials
555 12th Street NW, Suite 1000
Washington, DC 20004**

Smoothness of Pavement in Weigh-in-Motion (WIM) Systems

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1. SCOPE

- 1.1. Weigh-in-motion (WIM) is the process of measuring the dynamic forces of moving vehicle tires on pavements and estimating the corresponding tire loads of the static vehicle. The dynamic forces of moving vehicles include the effects of road surface roughness and are modified by vehicle characteristics such as sprung and unsprung mass, tire inflation pressures, out-of-round or dynamically unbalanced wheels and tires, vehicle cargo, suspension damping, and the vehicles' aerodynamic characteristics. The smoothness of the pavement surface in WIM systems directly affects the scale's ability to accurately estimate static loads from measured dynamic forces. Lack of smoothness can create difficulties in calibrating WIM equipment and may cause poor results from subsequent vehicle weight data collection efforts.
- 1.2. WIM system pavement smoothness is characterized by the output of a profiler in compliance with the Operator Certification section of R 56, collecting data at 25-mm [1-in.] or less intervals. The data produced by such a profiler will approximate the actual perpendicular deviation of the pavement surface from an established horizontal reference parallel to the lane direction in the wheel tracks.
- 1.3. The specification requires field collection of pavement profile information of a WIM system or of a candidate WIM site. Computer software is then used to calculate a roughness index that has been correlated to distributions of single and tandem axle, and gross vehicle weight error levels through extensive simulations of truck dynamic loading over measured profiles. Acceptable index levels are based on ensuring to a 95 percent level of confidence that the WIM system roughness will not produce errors that exceed the tolerance level limits recommended by ASTM E1318.
- 1.4. The profiler test vehicle, as well as all attachments to it, shall comply with all applicable state and federal laws. Necessary precautions imposed by laws and regulations, as well as vehicle manufacturers, shall be taken to ensure the safety of operating personnel and other traffic.

2. REFERENCED DOCUMENTS

- 2.1. *AASHTO Standards:*
 - R 56, Certification of Inertial Profiling Systems
 - R 57, Operating Inertial Profiling Systems

- 2.2. *ASTM Standards:*
- E867, Standard Terminology Relating to Vehicle-Pavement Systems
 - E950/E950M, Standard Test Method for Measuring the Longitudinal Profile of Traveled Surfaces with an Accelerometer-Established Inertial Profiling Reference
 - E1318, Standard Specification for Highway Weigh-In-Motion (WIM) Systems with User Requirements and Test Methods

3. TERMINOLOGY

- 3.1. *Definitions:*
- 3.1.1. *dynamic axle load (kg or lb), n*—the component of the time-varying forces applied perpendicularly to the road surface by the tires of any one axle of a moving vehicle.
- 3.1.2. *index, n*—a number or formula expressing some property, form, ratio, etc. of the relation or proportion of one amount or dimension to another.
- 3.1.3. *roughness, n*—vertical deviation of a pavement surface from a horizontal reference along a wheel track with characteristics that affect vehicle dynamics, including dynamic axle loads.
- 3.1.4. *profile record, n*—a data record of the surface elevation or slope along one or both wheel tracks of the road surface.
- 3.1.5. *weigh-in-motion (WIM), n*—the process of estimating a moving vehicle's gross weight and the portion of that weight that is carried by each wheel, axle, or axle group, or combination thereof, by measurement and analysis of dynamic vehicle tire forces. (See ASTM E867.)
- 3.1.6. *WIM scale roughness index, n*—a summary index calculated from a profile trace that is correlated to the expected weighing error at a WIM scale placed within the trace.

4. TEST METHOD TO EVALUATE THE SMOOTHNESS OF PAVEMENT IN A WIM SYSTEM

- 4.1. *Performance Requirements:*
- 4.1.1. Functional performance requirements for Types I and II WIM systems were established and tabulated within ASTM E1318. Table 1 summarizes the tolerance limits for 95 percent probability of conformity to WIM accuracy standards for axle loads, axle-group loads, and gross vehicle weights. This is accomplished using a profile-based index that estimates the potential WIM error level due to roughness of the pavement, array, and sensing technology. Annex A, Section A1 summarizes the overall calculation procedure, and Sections A2 through A5 provide details of the calculation algorithms.
- 4.1.2. Each Type I WIM scale location shall be chosen so that the WIM scale roughness index calculated from the pavement profile records of the WIM system do not exceed 1.34 m/km [84.8 in./mi] in the left and right wheel tracks. Each Type II WIM scale location shall be chosen so that the WIM scale roughness index calculated from the pavement profile records of the WIM system do not exceed 1.86 m/km [117.9 in./mi], in the left and right wheel tracks. The achievement of these values is needed to ensure that a WIM site is likely to produce load estimates that meet the requirements of ASTM E1318. When location requirements dictate scale placement in rough pavement, the existing pavement can be modified (overlaid, ground, etc.) or replaced to meet these smoothness requirements.

- 4.1.3. The very presence of a WIM scale may create localized roughness within the pavement in its vicinity. Therefore, when the WIM scale roughness index is used to select a location for WIM scale installation, the scale location must adhere to the roughness criteria in Section 4.1.2 after the scale is installed.

Table 1—Functional Performance Requirements for ASTM E1318 Type I and II WIM Systems

Function	Tolerance for 95% Probability of Conformance	
	Type I	Type II
Wheel load	±25%	—
Axle load	±20%	±30%
Axle-group load	±15%	±20%
Gross vehicle weight	±10%	±15%

- 4.1.4. In addition to the initial calculations of the WIM scale roughness index for WIM scale location acceptance, the pavement smoothness of each existing WIM scale shall be verified every two years. Profile records shall be collected and indices recalculated every two years to ensure that the scale remains likely to produce load estimates that meet the functional performance requirements of ASTM E1318.
- 4.1.5. In specifying a location for a WIM scale with more than one sensor on a single wheel track (typical with piezoelectric WIM equipment), the position of the scale shall be defined as the location of the downstream sensor. The WIM scale roughness index is to be referenced to this point.
- 4.1.6. Under certain conditions, jointed concrete pavement surfaces may exhibit significant changes in roughness due to variations in the temperatures of the pavement. Profile records of these pavements shall be taken at least twice, at times that correspond to approximate extremes of pavement (not air) temperature gradient that are likely to be experienced at the candidate location. The location for a WIM scale shall be chosen so that the WIM scale roughness index calculated from either of these profile records does not exceed the limits.
- 4.2. *Summary of Practice*—Test methods for evaluating the smoothness of pavement in an existing WIM system are presented herein. These procedures are applicable for determining a WIM scale roughness index level that would indicate that a WIM scale is likely to produce acceptable levels of weighing error as defined in Table 1. The smoothness tests require the collection of longitudinal profile data with a sampling rate of 25 mm [1 in.] or less and otherwise in accordance with R 57. Computer analysis of these profiles serves to calculate the WIM scale roughness index that will be compared to acceptable threshold values.
- 4.3. *Significance and Use*—The WIM scale roughness index was developed in a correlation of calculated roughness values to WIM scale error for a large-scale study of pitch-plane simulations of 3S2 (five-axle tractor-semitrailers) vehicles. The index was further verified in a study of simulations of WIM scale errors associated with three-axle single-unit trucks. Subsequently, the index was refined using the same set of pitch-plane simulations on several existing WIM site profiles. This correlation allows the indexes to be used to determine whether the WIM system pavement smoothness is sufficient to achieve weight measurements of 3S2 trucks and three-axle single-unit trucks that fall within ASTM error tolerance levels. The calculation of WIM scale roughness index values that fall within those that correlate to the scale measurement tolerances specified in Table 1 means that the scale is very likely to produce an acceptable level of weighing error.
- 4.4. *Procedure*: