



Designation: E 950 – 98

Standard Test Method for Measuring the Longitudinal Profile of Traveled Surfaces with an Accelerometer Established Inertial Profiling Reference¹

This standard is issued under the fixed designation E 950; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers the measurement and recording of the profile of vehicular-traveled surfaces with an accelerometer established inertial reference on a profile-measuring vehicle.

1.2 The test method uses measurement of the distance between an inertial plane of reference and the traveled surface along with the acceleration of the inertial platform to detect changes in elevation of the surface along the length being traversed by the instrumented vehicle. In order to meet a particular class, the transducers must meet accuracy requirements and the calculated profile must meet the specifications of that class.

1.3 The values measured represent a filtered profile measured from a moving plane of reference using the equipment and procedures stated herein. The profile measurements obtained should agree with actual elevation measurements that are subjected to the same filtering. Selection of proper filtering allows the user to obtain suitable wavelength information for the intended data processing.

1.4 Either metric or inch-pound units may be used, but must be used consistently and not mixed.

1.5 *This standard 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 standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* Specific precautionary information is given in Section 7.

2. Referenced Documents

2.1 ASTM Standards:

E 178 Practice for Dealing with Outlying Observations²

E 867 Terminology Relating to Traveled Surface Characteristics³

¹ This test method is under the jurisdiction of ASTM Committee E-17 on Vehicle-Pavement Systems and is the direct responsibility of Subcommittee E17.31 on Methods for Measuring Profile and Roughness.

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² Annual Book of ASTM Standards, Vol 14.02.

³ Annual Book of ASTM Standards, Vol 04.03.

E 1166 Guide for Network Level Pavement Management³

E 1364 Test Method for Measuring Road Roughness by Static Level Method³

F 457 Test Method for Speed and Distance Calibration of a Fifth Wheel Equipped with Either Analog or Digital Instrumentation⁴

3. Terminology

3.1 Definitions:

3.1.1 *aliasing*—in the context of this practice,—the spectrum of a digitized data record exists over the range of frequencies from zero to one half the sampling frequency. If the spectrum of the original signal extends beyond one half the sampling frequency, then those components of the signal at frequencies higher than one half the sampling frequency will, when digitized, be folded back into the spectrum of the digitized signal. The excessively high frequency components will thus be “aliased” into low frequency components.

3.1.2 *anti-aliasing filter*—a low-pass analog filter applied to the original analog profile signal to suppress those components of the signal at frequencies higher than one half the intended digital sampling frequency.

3.1.3 *frequency domain filtering*—a filtering operation performed by first calculating the spectrum of the profile record and then multiplying the spectral components by the frequency response transfer function of the filter.

3.1.4 *profile record*—a data record of the surface elevation, slope, or acceleration, of arbitrary length.

3.1.5 *profile segment*—that part of a profile record for which the profile index will be calculated.

3.1.6 *spatial domain filtering*—a filtering operation performed directly on the profile record

4. Summary of Test Method

4.1 The test apparatus consists of a vehicle equipped with the necessary transducers, computing, and recording equipment to measure and record elevation profile of the traveled surface (1).⁵

⁴ Annual Book of ASTM Standards, Vol 09.02.

⁵ The boldface numbers in parentheses refer to the list of references at the end of this standard.

4.2 The sampling rate is selected and depends on the anticipated roadway conditions and data requirements for the intended data processing.

4.3 The test apparatus is driven in the wheel tracks or in the correct lateral location over the section of traveled surface to be profiled. Transducers measure vertical acceleration of the vehicle and the vertical distance between the accelerometer and the traveled surface and the longitudinal distance. These transducer signals are combined by a computer to produce the longitudinal profile of the traveled surface.

5. Significance and Use

5.1 The measurement of vehicular traveled surfaces using an instrumented vehicle with an inertial plane of reference provides a satisfactory method for acquiring traveled surface profile data (1).

5.2 The profile data can be processed to produce, by simulation, the outputs of other devices. This can be done on line in real time or can be computed as a post process. Some of the devices that can be simulated include road meters (2), various straightedge devices (3), profilographs, (4), as well as pavers and grinders. Comparisons of various equipment and their profile computer programs are given in reference (5, 6).

5.3 The raw data or the profile data can also be recorded for data processing at a later time and for analysis by more complex data processing procedures.

6. Apparatus

6.1 The test apparatus consists of a vehicle equipped with transducers and profile computing and recording equipment. The transducers are used to measure vertical acceleration, displacement, and the distance traveled. The computer is used to process the transducer outputs to produce the computed profile of the traveled surface. The test apparatus must have transducer capability for one or more tracks and a mass storage device for long term storage of the data. If two wheel tracks are measured, the displacement transducers shall be mounted 1.5 to 1.8 m (58 to 71 in.) apart so that they measure in the two wheel tracks of the traveled surface. A set of gage blocks must be included to calibrate and validate static transducer operation. Other supporting apparatus can include a driver speed display and a graphical display of the profile or data. Some form of data display is recommended to ensure correct data is being collected.

6.2 *Vehicle Requirements*—The vehicle is the platform for the mounting of the profile-measuring equipment. The vehicle shall be large enough to accommodate all the required equipment without major structural modifications. The engine, steering mechanisms, and suspension components shall be adequate to allow smooth maintenance of speed and direction of travel. The environment of the interior of the vehicle shall be maintained within tolerable limits of the instrumentation and operators.

6.3 Transducers:

6.3.1 *Accelerometer*—The accelerometer measures the acceleration used to establish the inertial reference. A high-quality accelerometer shall be used that meets the class requirements of the profiling device. The accelerometer shall be mounted on the measuring vehicle with the accelerometer's

sensitive axis perpendicular to the traveled surface. The accelerometer range shall be large enough to accommodate the levels of acceleration expected from the bounce motions of the measuring vehicle (typically ± 1 g). The accelerometer shall be biased to account for the 1-g acceleration of gravity. The accelerometer or external circuitry shall contain a self-calibration external voltage source which, on command, causes the output of the acceleration signal level to change a predetermined value. The accelerometer shall have a minimum resolution to allow profile calculation and accuracy and bias to meet the class requirements as given in this standard.

6.3.2 *Displacement Measurement*—A displacement transducer measures the distance between the accelerometer and the traveled surface. The transducer shall be mounted on the vehicle with its measuring axis perpendicular to the traveled surface and in line with the sensitive axis of the accelerometer. The displacement transducer shall measure the vertical distance to the traveled surface continuously, or sample at intervals not greater than that needed to allow calculated profile as given in Table 1. The vertical resolution is that necessary to meet the class given in Table 2.

6.3.3 *Distance Measurement*—The distance transducer may be of the type that produces a series of pulses, the intervals of which represent a distance along the traveled surface to a resolution needed to satisfy Table 1. The pulses are used to measure speed and can be used to convert from a function of time to a function of distance traveled. Any distance transducer that produces analog or digital signals with sufficient accuracy may be used. The accuracy of the distance measurement is established by calibration (see 9.2.3).

6.3.4 *Location Markers*—Use of a section start, intermediate feature location(s), and section end shall be identified by location marks that can be accurately detected by an automatic means, such as magnetic detection, photocells detection of reflective tape or similar means.

6.4 *Profile Computation*—A computer shall be used to process acceleration, and distance transducer outputs to produce measured traveled surface profile. There are two basic methods of computing measured traveled surface profile:

6.4.1 *Spatial Based*—In the spatial based method, the transducer outputs are acquired and profile data points are computed as a function of the distance traveled. In the spatial-based method, the computation of measured road profile is independent of the vehicle measuring speed.

6.4.2 *Time-Based*—In the time-based system, the transducer outputs are acquired and profile data points are computed as a function of a fixed-time interval. In the time-based method, the computation of measured road profile is not independent of the vehicle measuring speed.

6.4.3 Filtering that permits the computation of measured elevation profile with no attenuation or amplification of road profile wave lengths at least 60 m (200 ft) long at test speeds of 25 to 95 km/h (15 to 60 mph) shall be provided. The

TABLE 1 Longitudinal Sampling

Class 1	less than or equal to 25 mm (1 in.)
Class 2	greater than 25 mm (1 in.) to 150 mm (6 in.)
Class 3	greater than 150 mm (6 in.) to 300 mm (12 in.)
Class 4	greater than 300 mm (12 in.)