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Standard Guide for General Pavement Deflection Measurements¹

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1. Scope

1.1 This guide provides procedural information for measuring pavement surface deflections, directly under, or at locations radially outward (offset) from a known static, steady-state, or impulse load. Deflections are measured with sensors that monitor the vertical movement of a pavement surface due to the load. This guide describes procedures for the deflection measurement using various deflection testing devices and provides the general information that should be obtained regardless of the type of testing device used.

1.2 This guide is applicable for deflection measurements performed on flexible asphalt concrete (AC), rigid portland cement concrete (PCC), or composite (AC/PCC) pavements. Rigid pavements may be plain, jointed, jointed reinforced, or continuously reinforced concrete.

1.3 The values stated in SI units are to be regarded as standard. Inch-pound units given in parentheses are for information purposes only.

1.4 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*²

D4602 [Guide for Nondestructive Testing of Pavements Us-](#)

[ing Cyclic-Loading Dynamic Deflection Equipment](#)
D4694 [Test Method for Deflections with a Falling-Weight-Type Impulse Load Device](#)
D5858 [Guide for Calculating *In Situ* Equivalent Elastic Moduli of Pavement Materials Using Layered Elastic Theory](#)

2.2 *AASHTO Standard:*³

T 256 [Standard Method of Test for Pavement Deflection Measurements](#)
PDDX [Pavement Deflection Data Exchange—Technical Data Guide, Version 1.0, April 1998](#)

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *deflection basin, n*—the bowl shape of the deformed pavement surface due to a specified load as depicted from the peak measurements of a series of deflection sensors placed at radial offsets from the center of the load plate.

3.1.2 *deflection basin test, n*—a test with deflection sensors placed at various radial offsets from the center of the load plate. The test is used to record the shape of the deflection basin resulting from an applied load. Information from this test can be used to estimate material properties for a given pavement structure.

3.1.3 *deflection sensor, n*—electronic device(s) capable of measuring the relative vertical movement of a pavement surface and mounted in such a manner as to minimize angular rotation with respect to its measuring plane at the expected movement. Such devices may include seismometers, velocity transducers, or accelerometers.

3.1.4 *load cell, n*—capable of accurately measuring the load that is applied perpendicular to load plate and placed in a position to minimize the mass between the load cell and the pavement. The load cell shall be positioned in such a way that it does not restrict the ability to obtain deflection measurements under the center of the load plate. The load cell shall be water resistant, and shall be resistant to mechanical shocks from road impacts during testing or traveling.

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² For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

³ Available from American Association of State Highway and Transportation Officials (AASHTO), 444 N. Capitol St., NW, Suite 249, Washington, DC 20001, <http://www.transportation.org>.

3.1.5 *load plate, n*—capable of an even distribution of the load over the pavement surface. Load plates may be circular in shape (or rectangular in some cases), one piece or segmented, for measurements on conventional roads and airfields or similar stiff pavements. The plate shall be suitably constructed to allow pavement surface deflection measurements at the center of the plate.

3.1.6 *load transfer test, n*—a test, usually on PCC pavement, with deflection sensors on both sides of a break or joint in the pavement. The test is used to determine the ability of the pavement to transfer load from one side of the break to the other. Also, the load-deflection data can be used to predict the existence of voids under the pavement.

3.1.7 *test location, n*—the point at which the center of the applied load or loads are located.

4. Summary of Guide and Limitations

4.1 This guide consists of standards for measuring pavement surface deflections directly under and/or at appropriate offset locations from the load center. Each nondestructive testing (NDT) device is operated according to the standard operating procedure applicable to the device.

4.2 This guide includes general descriptions of the various types of static and semicontinuous deflection testing devices, and procedures for deflection measurement corresponding to each testing device.

4.3 The collection of general information described in this guide, such as test setup, ambient temperature, pavement temperature, equipment calibration, number of tests, and test locations, pertains to all devices.

5. Significance and Use

5.1 NDT measurement of pavement surface deflections provides information that can be used for the structural evaluation of new or in-service pavements. These deflection measurements may be used to determine the following pavement characteristics:

- 5.1.1 Modulus of each layer.
- 5.1.2 Overall stiffness of the pavement system.
- 5.1.3 Load transfer efficiency of PCC pavement joints.
- 5.1.4 Modulus of subgrade reaction.
- 5.1.5 Effective thickness, structural number, or soil support value.
- 5.1.6 Bearing capacity or load carrying capacity of a pavement.

5.2 These parameters may be used for the analysis and design of reconstructed and rehabilitated flexible and rigid pavements, pavement structural adequacy assessment including joint efficiency of PCC pavement, void detection in PCC pavement, research, and/or network structural inventory purposes.

6. Apparatus

6.1 The apparatus used in this guide shall be one of the deflection measuring devices described in 6.2 and shall consist

of some type of probe or surface contact sensor(s) to measure vertical pavement movements or deformations when subjected to a given load.

6.2 Deflection Measuring Devices:

6.2.1 *Noncontinuous Static Device*,⁴ that operates on a single lever arm principle. This device shall have a minimum 2.5 m (8.2 ft) long probe, and the extension of the probe shall depress a dial gage or electronic sensor that measures maximum pavement surface deflection with a resolution of 0.025 mm (0.001 in.) or better. The vehicle used to impart the wheel load to the pavement shall be a truck capable of carrying a minimum 80 kN (18 000 lbf) test load on a single rear axle. The loading configuration, including axle loads, tire sizes, and inflation pressures, can be obtained using the manufacturer's specification; however, this information must be clearly indicated in the engineering report.

6.2.2 *Semicontinuous Static Device*,⁵ that operates on a double lever arm principle. The vehicle used to carry this device shall be a truck carrying a 130 kN (29 000 lbf) single-axle test load. The loading configuration including axle loads, tire sizes, and inflation pressures can be obtained using the manufacturer's specification; however, this information must be clearly indicated in the engineering report. The test vehicle shall be equipped with a double lever arm with probes, the geometry and size of which make it possible to measure the maximum pavement surface deflection in both wheel paths with a resolution of 0.025 mm (0.001 in.) or better. The extension of each lever arm holding the probe shall depress an electronic sensor, which may be of any type provided the sensor delivers an analog or digital signal. The digital signal shall be correlated with the movement of this extension and, therefore, with the deflection of the pavement surface under the effect of the moving test load. The truck shall be able to lift and move the probes from one measurement point to the next, lower them onto the pavement surface, and make another set of measurements in a fully automated process at a constant vehicle speed.

6.2.3 *Steady-State Dynamic Device*,⁶ that uses a dynamic force generator to produce a dynamic load. The force generator may use, for example, a counter rotating mass or a servo-controlled hydraulic actuator to produce the dynamic load. The device that uses a counter rotating mass operates at a fixed frequency to produce a dynamic load under a static weight applied through a pair of rigid steel wheels. Both loading frequency and the magnitude of the dynamic loads may be varied by the operator of the devices that use a servo-controlled hydraulic actuator. Depending on the model, normal operating frequencies range from 8 to 60 Hz and maximum dynamic forces range from 2.2 to 35.5 kN (500 to 8000 lbf) applied through a single circular or dual rectangular plate, or dual steel wheels such as those used on the standard Dynaflect device. A steady-state loading device may be mounted in a van, on the front of a vehicle, or on a trailer. Deflection measurement

⁴ An example of this instrument is the Soiltest Benkelman Beam.

⁵ An example of this instrument is the Lacroix Dec deflectograph.

⁶ Examples of this instrument are the Geolog Dynaflect and the Foundation Mechanics Road Rater.

devices should have five or more sensors to satisfactorily measure the deflection basin with a resolution of 0.002 mm (0.0001 in.) or better.

6.2.4 *Impulse Device*,⁷ that creates an impulse load on the pavement by dropping a mass from a variable height onto a rubber or spring buffer system. Generically known as a falling-weight deflectometer (FWD), the force generating device shall be capable of being raised to one or more predetermined heights and dropped. The resulting force, transmitted to the pavement through a circular load plate, shall not vary between repetitive drops by more than $\pm 3\%$. The force pulse shall approximate the shape of a haversine or half-sine wave and a peak force in the range of 7 to 105 kN (1500 to 24 000 lbf) shall be achievable. The impulse loading device shall measure pavement surface deflections using seven or more sensors with a resolution of 0.002 mm (0.0001 in.) or better.

7. Calibration of Deflection Measuring Devices

7.1 The deflection sensor(s) and load cell (if applicable) of the deflection device should be calibrated to ensure that all readings are accurate within specified limits. For devices where the load is assumed to be constant and is not measured, the accuracy of the magnitude of load imparted should be checked periodically using the manufacturer's recommended calibration procedure.

7.2 Load Cell:

7.2.1 *General*—The procedure for calibrating the load cell (if the device uses a load cell) is dependent upon the type of device used. The calibration of load cell may be checked informally by observing the load cell readings and comparing them against expected readings based on experience or shunt calibration values in the case of Falling Weight Deflectometer or the Road Rater. Load cell reference (or absolute) calibration shall be performed at least once a year except the noncontinuous and semicontinuous loading devices (see [Table 1](#)).

7.2.2 *Noncontinuous and Semicontinuous Static Loading Devices*—Immediately prior to testing, weigh the axle load of the truck if the ballast consists of a material that can absorb moisture (sand or gravel, and so forth) or could have changed for any reason. Trucks with steel or concrete block loads only need to be weighed if the loads are changed or could have shifted.

7.2.3 *Impulse Loading Device*—Reference load cell calibration should be carried out at least once per year. Appendix A of SHRP Report SHRP-P-661 contains an example outline for such a task.

⁷ Examples of this instrument are the Dynatest falling-weight deflectometer (FWD), the KUAB 2m-FWD, the Carl Bro FWD, and the Jils FWD.

7.3 Deflection Sensors:

7.3.1 *General*—The procedure for calibrating the deflection sensors is dependent upon the type of apparatus used. Calibration of the deflection sensors should be checked at least once a month during production testing except noncontinuous and semicontinuous loading devices (see [Table 2](#)).

7.3.2 *Noncontinuous and Semicontinuous Static Loading Devices*—Static loading devices should be calibrated daily with feeler gages. When performing deflection sensor calibration, induced deflections should be similar in magnitude to the deflections encountered during normal testing.

7.3.3 *Steady-State Loading Devices*—A routine calibration check of the deflection sensors shall be conducted once a month. If significant differences are noted for a sensor, it shall be returned to the manufacturer for check or calibration under standard calibration oscillatory vibrations. Deflection sensors shall be calibrated annually.

7.3.4 *Impulse Loading Devices*—Reference deflection sensor calibration should be carried out in accordance with the SHRP Protocol (see Appendix A of SHRP Report SHRP-P-661 for impulse loading devices). A relative calibration check should be conducted once a month using the SHRP Protocol (see Appendix A of SHRP Report SHRP-P-661).

7.4 *Temperature Sensors*—Pavement temperature sensor calibration should be carried out using a calibrated reference thermometer and two reference surfaces such as a “cool” and “hot” surface. Air temperature sensor (if equipped) calibration should be carried out using two reference temperatures, for example, carefully monitored ice water (0 °C) and hot water (60 °C). Calibration of temperature sensors should be carried out at least once a year.

8. Field Data Collection and Testing Procedures

8.1 *General*—The procedure to be followed is, to some extent, dependent upon which type of device is used. The following general information is suggested as the minimum data that needs to be collected, regardless of the type of device used.

8.1.1 *Load*—For impulse loading devices, record the peak load applied to the pavement surface by the deflection device. For steady-state loading devices, record the peak-to-peak load and load configuration. For static loading devices, record the axle load, tire pressure, type and size, and the load configuration (dual spacing) of the test vehicle.

8.1.2 *Load Frequency*—If applicable, record the frequency of calculated oscillatory load for vibratory loading devices.

NOTE 1—For some devices, the manufacturer generally presets the cyclic loading frequency at a default value of 8 Hz.

8.1.3 *Geometry of Loaded Area and Deflection Sensor Locations*—For proper modeling of the pavement structure

TABLE 1 Load Cell Frequency of Calibration

Device Type	Frequency of Calibration
Noncontinuous and Semicontinuous Static Loading Types	Prior to testing
Steady-State Loading Types (see 7.2.2 for devices that do not have a load cell)	At least once a year using the manufacturer's instructions on using the procedure in Appendix A of SHRP Report SHRP-P-661
Impulse Loading Types (Falling-Weight Deflectometer)	At least once a year using the procedure in Appendix A of SHRP Report SHRP-P-661