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Standard Test Method for Measuring Deflections using a Portable Impulse Plate Load Test Device[1]

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1. Scope

1.1 This test method applies to measuring plate deflections using a Portable Impulse Plate Load Test device. The method covers the measurement of deflection of the load plate rather than the deflection of the surface of the pavement or foundation layers (see Note 1).

1.2 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.3 *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.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D4695 Guide for General Pavement Deflection Measurements

D1195 Test Method for Repetitive Static Plate Load Tests of Soils and Flexible Pavement Components, for Use in Evaluation and Design of Airport and Highway Pavements

3. Summary of Test Method

3.1 This test method is a type of plate bearing test. The load is a force pulse generated by a falling mass dropped onto a spring assembly that transmits the load pulse to a plate resting on the material under test.

3.2 The mass is raised to a preset height and then dropped to deliver the desired force pulse. The device is calibrated to a preset drop height by the manufacturer. The preset drop height shall not be changed by the user.

3.3 The resulting plate deflection is measured using suitable instrumentation. Multiple drops from the same preset drop height may be performed at the same test location.

3.4 The peak plate deflection resulting from each drop at each location is recorded in micrometers or other unit of measure, as appropriate.

4. Significance and Use

4.1 This test method covers the determination of plate deflection resulting from the application of an impulse load. The deflection is measured at the center of the top of the load plate (see Note 1).

NOTE 1—If the load plate is in "perfectly uniform" contact with the unbound material under the plate, then deflection of the load plate should be equal to the deflection of the surface of the unbound material under test. However, with typical unbound materials a 100% uniform contact can seldom be achieved. Accordingly, the test surface shall be as clean and smooth as possible with loose granules and protruding material removed. For gravel surfaces it is recommended that a thin layer of fine sand be placed over the test point. For fine-grained materials, this will help in obtaining a reasonably uniform contact between the load plate and the surface. See 5.1 in Test Method .

4.2 Deflections may be either correlated directly to pavement performance or used to determine in-situ material characteristics of the pavement foundation layers. Some uses of the data include quality control and quality assurance of compacted layers, and for structural evaluation of load carrying capacity (see Note 2 and Guide).

NOTE 2—The volume of the pavement foundation materials affected by the applied load is a function of the magnitude of the load, plate size and rigidity, loading rate, buffer stiffness, and the stiffness and shear strength of the pavement foundation materials. Therefore, care must be taken when analyzing the results because the data obtained by the Portable Impulse Plate Load Test may be obtained under substantially different conditions than when a heavy moving wheel load passes over the pavement surface after construction is complete.

5. Apparatus

5.1 *Instrumentation System,* conforming to the following general requirements.

5.2 *Instruments Exposed to the Elements,* operable in the temperature range from 0°C to 50°C (32°F to 120°F) and tolerant to relatively high humidity, rain and spray, and other adverse conditions such as dust, shock, and vibrations normally encountered.

[1] This test method is under the jurisdiction of ASTM Committee E17 on Vehicle - Pavement Systems and is the direct responsibility of Subcommittee E17.41 on Pavement Testing and Evaluation.

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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.

5.3 *Force-Generating Device (falling mass),* capable of being raised, using a guide system, to a preset fixed height and dropped onto a steel-spring subassembly. Designed to operate with negligible friction or resistance.

5.4 *Force pulse,* a half-sine or haversine shaped load pulse, with a loading time between 10 and 30 msec, and reproducible within the requirements of 7.5.

5.5 *Load Plate,* shall be rigid and capable of transferring the impulse force to the surface. The stress distribution under the load plate depends on both load plate rigidity and material type, and therefore can be parabolic, inverse parabolic, or uniform (1).

5.6 *Deflection Sensor(s),* capable of measuring the maximum vertical plate movement. The deflection sensor or sensors shall be mounted so that the angular rotation is minimized with respect to its measuring plane at the maximum expected deflection. The number and spacing of the sensors is optional and will depend upon the purpose of the test and the material characteristics. Sensors may be of several types such as velocity transducers or accelerometers. The instrument shall be constructed to measure the vertical plate deflection at the center of the point of impact.

5.7 *Data Processing and Storage System,* displays and optionally records the deflection data.

5.8 *Portable Impulse Plate Load Test Device,* shall be small enough to be considered portable. Does not require a vehicle or trailer for transport.

6. Reagents and Materials

6.1 Adhere to the precision and bias requirements of this Standard.

6.2 Display and store deflection measurements with a resolution of ± 20 µm (± 0.8 mils) or less.

6.3 Store deflection measurements for a period of 50 msec or greater to ensure that the peak deflection(s) are recorded.

7. Sampling

7.1 Calibrate the force-generating device and the deflection sensor(s) once per year.

7.2 Calibrate the force-generating device and the deflection sensor(s) using a measurement system independent of the Portable Impulse Plate Load Test device.

7.3 Execute calibration at an accredited laboratory using an approved calibration procedure (2).

7.4 Verify deflection measurements after the independent calibration is complete (See Section 8).

7.5 *Force-Generating Device*—Calibrate the force-generating device prior to the deflection sensor calibration in accordance with manufacturer's recommendations and in consideration of the following requirements:

7.5.1 Precondition new spring assemblies with at least 100 drops before the calibration procedure is started. Start the calibration procedure no earlier than 1 hour after preconditioning. (2)

7.5.2 Precondition all (both new and used) spring assemblies immediately prior to the calibration sequence with three drops of the falling mass.

7.5.3 Use a load cell rated from 20 to 50 kN (2).

7.5.4 Test amplifier with a low-pass filter of at least the fourth order (critical frequency 200 Hz at 3 dB damping) with filter characteristics as presented by Butterworth (2).

7.5.5 Measure and store the entire force record using an oscilloscope or other suitable measuring device with the appropriate resolution and storage, or a personal computer (2).

7.5.6 Ensure the force pulse meets the requirements of this Standard under Section 5.

7.5.7 Ensure that the reference load cell is uniformly supported by a rigid base (i.e. a concrete foundation not less than 0.8 m [32 in] in length, 0.8 m [32 in] in width and 0.5 m [20 in] thick). The rigid base shall not generate any interfering vibrations as a result of the impact load (2).

7.5.8 Clean the guide rod and ensure that it remains vertical to minimize friction.

7.5.9 Release the drop mass no less than ten times from the same drop height.

7.5.10 Adjust the drop height until the deviation of the mean force is within ± 1 percent of the desired force value. Additionally, ensure that the difference between the individually measured force values and the mean force does not exceed ± 2 percent (see Note 3).

7.5.11 Record each peak load level.

7.5.12 Permanently display the calibrated drop height on the device.

7.6 *Deflection Sensor*—Calibrate sensor(s) in accordance with the manufacturer's recommendations and in consideration of the following requirements

7.6.1 Measure the peak load during deflection sensor calibration.

7.6.2 Check conformity of deflection measurements within at least the following three ranges:

7.6.2.1 ≥ 0.1 mm and ≤0.7 µµ (≥ 4 mils and ≤30 mils)

7.6.2.2 > 0.7 mm and ≤ 1.3 mm (> 30 mils and ≤ 50 mils)

7.6.2.3 > 1.3 mm and ≤ 2.0 mm (> 50 mils and ≤ 80 mils)

7.6.3 For each deflection range, drop the falling mass no less than ten times from the drop height determined during calibration of the force-generating device.

7.6.4 Adjust the data processing and storage system and repeat calibration when the difference between the mean of the deflection measured by this unit and the deflection measured by the independent control unit is more than 0.02 mm (0.8 mils). Ensure that the difference between individual measured values is less than or equal to 0.04 mm (1.6 mils) (2).

NOTE 3—Replace the spring assembly when the measured impact duration deviates ± 2 msec or greater from the specified impact duration.

8. Verification Testing

8.1 Perform verification testing to establish the repeatability of deflection measurements under well defined conditions when on-site measurements are not repeatable or are questionable. (see Note 4)

8.2 Equipment requirements are as follows:

8.2.1 Rigid (that is, concrete) foundation as the testing platform

8.2.2 Pads to allow deflection measurements in the ranges specified for the calibration procedure.

8.2.3 Pad dimensions no smaller than 1.5 times the load plate diameter.

8.2.4 Fully charged batteries

8.3 Meet the following environmental requirements:

8.3.1 Complete verification testing at a temperature range from 16°C to 22°C (60°F to 72°F).

8.3.2 Allow sufficient time for the equipment to reach this specified temperature range.

8.4 Perform verification testing using the following procedure:

8.4.1 Mark test location on rigid foundation and test pad(s).

8.4.2 Place pad(s) on marked test location.

8.4.3 Place test device on marked test pad(s).

8.4.4 Perform nine mass drops using the specified procedure (See Section3).

8.4.5 Record resulting peak deflection values.

8.4.6 Record supporting information such as air temperature, surface temperature, distance measurements, and other test identification data as needed.

8.5 Complete the following calculations (2) or similar analyses to ensure repeatability of deflection measurements:

8.5.1

$$S_{max} - S_{min} \leq 0.04\, mm\, (1.6\, mils) \quad (1)$$

Definitions:

S_{max} = max(S_1, S_2, S_3, S_4, S_5, S_6, S_7, S_8, S_9)
S_{min} = min(S_1, S_2, S_3, S_4, S_5, S_6, S_7, S_8, $S_{9)}$
S_i = Deflection measurements for drop i (where i = 1 to 9), mm
S_{max} = maximum deflection measurement, mm
S_{min} = minimum deflection measurement, mm

8.5.2

$$|S_{mean} - S_i| \leq 0.02\, mm\, (0.8\, mils)\, for\, each\, S_i \quad (2)$$

8.5.2.1

$$S_{mean} = \frac{\sum_{i=1}^{9} S_i}{9} \quad (3)$$

S_i = Deflection measurements for drop i (where i = 1 to 9), mm
S_{mean} = Mean deflection for a set of 9 verification test drops on the given pad configuration, mm

8.5.3 $| S_i - S_{mean@calibration}| \leq 0.02$ mm (0.8 mils) (see Note 5)

8.6 Repeat above procedure on remaining pad configurations.

8.7 Submit device for calibration when the conditions outlined in 8.5 are not met for any pad configuration.

NOTE 4—It may be beneficial to perform verification testing on newly purchased or recently calibrated devices to ensure the device is working properly prior to Portable Impulse Plate Load Test device commissioning. This would also provide a baseline to which later verification testing could be compared.

NOTE 5—This calculation is carried out if deflections during calibration were measured under the same conditions as the subsequent verification tests.

9. Hazards

9.1 Keep back straight and lift with leg muscles when elevating, dropping, and catching the mass.

9.2 Make sure that hands are not positioned beneath the elevated mass.

9.3 Secure load mass into the lower locked position prior to and during transportation between test locations.

10. Maintenance and Handling

10.1 Inspect equipment for necessary repairs (see Note 6).

10.2 Store test device in a dry place when not in use.

10.3 Protect the guide rod from contact with unbound materials.

10.4 Clean the force-generating device by removing any dirt with a dry cloth. Do not grease the guide rod since it is generally made of stainless steel.

10.5 Check the drop height regularly to ensure that the release mechanism has not moved from the preset height determined during calibration.

10.6 Maintain battery charge greater than 50 percent.

NOTE 6—For some devices, ensure that the rubber bellow enclosing the spring assembly is providing a tight seal to protect the spring assembly from dust and damage.

11.

11.1 Perform unbound material test at the time of compaction and immediately after corrective actions.

11.2 Ensure pavement foundation layers are not frozen. (2).

11.3 Perform test when the deflection measurements are greater than 0.2 mm (8 mils) and less than 3.0 mm (120 mils).

12. Site Selection and Preparation

12.1 Create a relatively smooth and level spot that will allow the guide rod to remain vertical and prevent translation of the load plate during testing.

12.2 Ensure the test area slope is less than 4 percent.

12.3 Prepare a test area that is at least 1.5 times larger than the diameter of the loading plate.

12.4 Remove loose, dried, cracked, or uneven material prior to testing.

12.5 Perform tests by placing the load plate at a uniform depth. Ensure consistent plate test depths are maintained throughout the project for any given material type. The following test depths are recommended:

Material Type	Portable Impulse Plate Load Test Depth (see Note 7)
SW, SP, SW-SM, SW-SC, SP-SM, SPSC	≤ one-half lift thickness (see Note 8)
GW, GP, GW-GM, GW-GC, GP-GM, GP-GC, GM, GC, CL,	Compacted with Padfoot Roller:
	Bottom of deepest indentation of the padfoot penetration.
ML, CH, MH, OL/OH, SM, SC	Compacted with Smooth-Drum Roller:
	Compaction Surface (0 mm)

NOTE 7—The depth of influence is roughly 1 to 1.5 times the plate diameter. Consequently, deflection measurement obtained for a compacted lift with a thickness less than this influence depth will be a composite deflection measurement that is also influenced by the underlying lift.

NOTE 8—Complete test on the compaction surface for locations where the disturbance caused by preparation would cause the deflection measurements to increase and therefore become unrepresentative of the actual compacted condition.

13. Procedure

13.1 Position load plate on properly prepared test site (see Note 9).

13.2 Rotate load plate left and right 45 degrees. (2)

13.3 Perform six falling mass drops. Use the first three drops for —seating‖ and the next three drops for analysis. Use the following procedure for each drop:

13.3.1 Raise falling mass to preset drop height and snap into the release mechanism.

13.3.2 Adjust guide rod to vertical.

13.3.3 Release falling mass and allow it to fall freely (see Note 10).

13.3.4 Catch falling mass after rebound as recommended by the manufacturer.

13.3.5 Raise and snap load mass into the release mechanism after rebound (see Note 11).

13.4 Record resulting peak deflection values.

13.5 Record supporting information such as air temperature, surface temperature, location, material type, and other identification information as needed.

13.6 Repeat deflection measurements at another location when conditions such as the following are present (see Note 12):

13.6.1 The load plate tilts more than 4 percent

13.6.2 The seating deflections differ from one another by more than ± 10 percent.

NOTE 9—Position the test device at a new test location when a faulty drop occurs. Testing cannot be repeated at the same location.

NOTE 10—Make sure the falling mass falls precisely from the calibration height (2).

NOTE 11—Ensure the following for equipment constructed using a centering ball: (1) the guide rod is not removed from the centering ball and (2) the load plate is not displaced during testing (2).

NOTE 12—Additional compaction may be necessary or the material may be too moist when these conditions are present.

14. Precision and Bias

14.1 *Equipment Precision*—The precision requirement for the deflection measurement of the load plate is ± 40 µm (1.6 mils, see also 7.6.4).

14.2 *Equipment Bias*—The bias requirement for the deflection sensor is ± 2 percent. The bias of the force introduced into the test layer is in the range of ± 2% on a concrete surface (7.5.10). The bias of the force for other surfaces is dependent on the properties of the material under test and/or the measured plate deflection.

14.3 *Between Device and Test Point Reproducibility*—The between-device and test point reproducibility of this test method for typical conditions is being determined and will be published as soon as it becomes available (see Notes 13-15).

NOTE 13—A Light Weight Deflectometer device with a load cell and where surface deflections are measured through a hole in the center of the load plate is designed such that the test results obtained may be appreciably different from a Portable Impulse Plate Load Test device without a load cell and where load plate deflections are measured.

NOTE 14—For Light Weight Deflectometer devices referred to in Note 13, the approximate —surface‖ or composite modulus that results from tests conducted on unbound materials has been estimated to lie between 1.4 and 2.0 times the composite modulus calculated using a Portable Impulse Plate Load Test device without a load cell and where plate deflections are measured. The main reason for this rather large discrepancy is that by measuring the plate deflection, a "perfect" contact between the plate and the unbound surface under test is not possible. There will always be micro-unevenness of any unbound material; therefore larger plate deflections will invariably result than the deflection of the (uneven) surface of the unbound material under test unless a material such as plaster-of-paris is placed between the load plate and the surface under test, and allowed to harden.

NOTE 15—The peak force values slowly decrease as the peak deflections of the test layer increase (e.g. by approx. 8% at 2 mm deflection re. Reference 3[see Appendix B for granular materials; Appendix C for cohesive materials]; see also Reference 4 [in German] for further details).

15. Keywords

15.1 deflection surveys; deflection test methods; deflection testing; Dynamic Plate Load Testing (DPLT), Light Drop Weight Tester (LDWT),; impulse deflection testing device; Light Weight Deflectometer (LWD); load-deflection testing; Nondestructive Testing (NDT); pavement deflection; pavement foundation layers; pavement layer modulus; pavement layer stiffness; Portable Falling Weight Deflectometer (PFWD); Portable Impulse Plate Load Test; quality assurance

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