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AMERICAN SOCIETY FOR TESTING AND MATERIALS
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Standard Test Method for Deflections with a Falling-Weight-Type Impulse Load Device[1]

This standard is issued under the fixed designation D 4694; 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 of deflections of paved and unpaved surfaces with a falling-weight-type impulse load device. These devices are commonly referred to as falling-weight deflectometers or FWDs.

1.2 This test method describes the measurement of vertical deflection response of the surface to an impulse load applied to the pavement surface. Vertical deflections are measured on the load axis and at points spaced radially outward from the load axis.

NOTE 1—Subcommittee D04.39 is currently working on the development of a Precision and Bias statement. Therefore, the committee recommends that the results from this test method should not be used in a buying or selling relationship for construction materials or construction materials acceptance.

1.3 The values stated in SI units are to be regarded as the standard.

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 and health practices and determine the applicability of regulatory limitations prior to use.* A specific hazard statement is given in Section 6.

2. Referenced Documents

2.1 *ASTM Standards:*

D 4695 Guide for General Pavement Deflection Measurements[2]

2.2 *Strategic Highway Research Program:*

Manual for FWD Testing in the Long Term Pavement Performance Study, Operational Field Guidelines, Version 2.0, February 1993

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 weight dropped on a buffer system and is transmitted through a plate resting on the pavement surface. The test apparatus may be mounted in a vehicle or on a suitable trailer towed by a vehicle.

3.2 The vehicle is brought to a stop with the loading plate positioned over the desired test location. The plate and deflection sensors are lowered to the pavement surface. The weight is raised to the height that, when dropped, will impart the desired force to the pavement. The weight is dropped and the resulting vertical movement or deflection of the pavement surface is measured using suitable instrumentation. Multiple tests at the same or different heights of drop may be performed before the apparatus is then raised and moved to the next test site.

3.3 Peak pavement deflections at each measured location resulting from the force pulse are recorded in micrometres, millimetres, mils, or inches, as appropriate.

3.4 The peak force imparted by the falling weight is measured by a load cell and recorded, as the force in kN or lbf or mean stress (the load divided by the plate area) in kN/m^2 or psi as appropriate.

4. Significance and Use

4.1 This test method covers the determination of pavement surface deflections as a result of the application of an impulse load to the pavement surface. The resulting deflections are measured at the center of the applied load and at various distances away from the load. Deflections may be either correlated directly to pavement performance or used to determine the in-situ material characteristics of the pavement layers. Some uses of data include structural evaluation of load carrying capacity and determination of overlay thickness requirements for highway and airfield pavements.

5. Apparatus

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

5.1.1 *Instruments Exposed to the Elements* (outside the vehicle), shall be operable in the temperature range of − 10 to 50°C (10 to 120°F) and shall tolerate relatively high humidity, rain or spray, and all other adverse conditions such as dust, shock, or vibrations that may normally be encountered.

5.1.2 *Instruments Not Exposed to the Elements* (inside the vehicle), shall be operable in the temperature range of 5 to 40°C (40 to 105°F).

5.2 *Force-Generating Device* (falling "weight"), with a guide system. The force-generating device shall be capable of

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[2] *Annual Book of ASTM Standards*, Vol 04.03.

being raised to one or more predetermined heights and dropped. The resulting force pulse transmitted to the pavement shall be reproducible within the requirements of 7.1. The force pulse shall approximate the shape of a haversine or half-sine wave, and a peak force of approximately 50 kN (11 000 lbf) shall be achievable.

NOTE 2—It is common practice to use a force-pulse duration of 20 to 60 ms or a rise time of 10 to 30 ms.

5.2.1 *Guide System*, designed to operate with negligible friction or resistance and designed so the weight falls perpendicular to the pavement surface.

5.3 *Loading Plate*, capable of an approximate uniform distribution of the load on the pavement surface. Typical loading plates are 300 and 450 mm (12 and 18 in.) in diameter for measurements on conventional roads and airfields or similar stiff pavements. The plate shall be suitably constructed to allow pavement deflection measurements at the center of the plate.

5.4 *Deflection Sensor*, capable of measuring the maximum vertical movement of the pavement and mounted in such a manner as to minimize angular rotation with respect to its measuring plane at the maximum expected movement. The number and spacing of the sensors is optional and will depend upon the purpose of the test and the pavement layer characteristics. A sensor spacing of 300 mm (12 in.) is frequently used. Sensors may be of several types such as displacement transducers, velocity transducers, or accelerometers.

5.5 *Data Processing and Storage System*—Load and deflection data shall be recorded on either or both a magnetic storage device or paper strip recorder. Supporting information such as air temperature, pavement surface temperature, distance measurements, and identification data for each test point can be recorded either automatically or manually.

5.6 *Load Cell*, to measure the applied load on each impact shall be 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 travelling, or both.

6. Hazards

6.1 The test vehicle, as well as all attachments to it, shall comply with all applicable state and federal laws. Precautions shall be taken beyond those imposed by laws and regulations to ensure maximum safety of operating personnel and other traffic.

7. Calibration

7.1 *Force-Generating Device*—Prior to load and deflection sensor calibration, pre-condition the device by dropping the weight at least five times and checking the relative difference in each loading. Loadings shall not vary from each other more than 3 %. If the variations exceed this tolerance, the height of the drop, cleanliness of the track, as well as any springs or rubber pads that are used to condition the load shall be checked. Improperly operating parts shall be replaced or repaired prior to calibration to ensure that the horizontal forces are minimized.

7.2 *Load Calibration Platform*—Follow the manufacturer's recommendations for calibration since several types of these devices are commercially available.

7.3 *Deflection Sensors*—Calibrate sensors at least once a month or in accordance with the manufacturer's recommendations.

7.3.1 *Relative Deflection Calibration*—The relative deflection calibration procedure shall be used to adjust the deflection measurements from each deflection sensor so that they will produce the same deflection measurement (within the precision limits specified in 8.2). The relative deflection calibration requires a sensor holding tower available from the manufacturer. The tower must have sufficient sensor positions to accommodate all of the sensors used during testing. The tower shall position the sensors one above the other along a vertical axis. The base of the tower shall have a single support post on the same vertical axis. The tower shall have sufficient stiffness to allow each sensor to experience the same deflection generated by the Force-Generating Device. Mount the sensors in the tower and position as near the load plate as possible. The tower position shall be fixed by making a small divot in the pavement or by cementing a washer on the pavement to provide a solid contact point for the support post. The load plate shall stay in continuous contact with the pavement surface while gathering calibration data. During calibration, rotate the sensors so that each sensor occupies every level in the tower. At each tower position, record five deflections for each sensor. The tower shall be manually held in a vertical position with a moderate downward pressure while measuring the deflections. Deflection magnitudes of about 400 µm (15 mils) are desired. The same load setting shall be maintained throughout the calibration. Determine deflection ratios for each sensor by dividing the average for all the sensors by the average of that sensor. If any of the resulting ratios are greater than 1.003 or less than 0.997, all of the sensor calibration factors shall be replaced by the existing calibration factor multiplied by the ratio. If any of the calibration factors exceed the limits established by the manufacturer, the device should be repaired and recalibrated according to the manufacturer's recommendations.

7.3.2 To ensure that small deflections (as typically encountered near the outer edge of the deflection basin) are monitored to a reasonable degree of accuracy, repeat the above procedure at a distance of 1 to 1.5 m (3 to 5 ft) from the load plate. Deflection magnitudes of between 50 µm and 100 µm (2 to 4 mils) are desired. Ensure that the average difference between any two sensor readings is 2 µm (0.08 mils) or less; the sensor calibration factors should not be altered. If any differences in average deflection greater than 2 µm (0.08 mils) are found, the device should be repaired and recalibrated according to the manufacturer's recommendations.

NOTE 3—Several methods have been developed by agencies other than the manufacturers to calibrate falling-weight-type impulse load devices using independent load cells and deflection sensors. One such method is the Reference Calibration procedure developed by the Strategic Highway Research Program (SHRP), presently under the direction of the Long Term Pavement Performance (LTPP) Office of the Federal Highway Administration (FHWA). For the purpose of using this reference method to calibrate the Falling Weight Deflectometers used in the LTPP study, four regional calibration centers have been established, one in each LTPP region. These centers are in Pennsylvania, Minnesota, Texas, and Nevada, operated by their respective State Departments of Transportation. Another method is a transportable calibration verification system developed at the University of Texas at El Paso (UTEP) for the Texas DOT. This also uses independent load cells and deflection sensors to measure the load and deflections created by a falling-weight-type device. Both SHRP and the UTEP method can use the same point on the pavement surface to calibrate the deflection readings by removing the "sensor under test" from its holder and placing it in a reference holder, while the UTEP method can also retain the use of the sensor holders provided by the manufacturer, with the verification deflection sensor(s) placed as close as possible to the sensor under test. These two calibration methods are more complementary than interchangeable, with the stationary method used to make adjustments of 2 % or less to the deflection sensor gains and the portable UTEP method used as a verification of the deflection sensor/sensor holder combination as used in the field, under actual field conditions.

8. Signal Conditioning and Recorder System

8.1 All signal conditioning and recording equipment shall allow data reading resolution to meet the following requirements:

8.1.1 Load measurements shall be displayed and stored with a resolution of 200 N (50 lbf) or less.

8.1.2 Deflection measurements shall be displayed and stored with a resolution of ±1 µm (0.04 mils) or less.

8.2 The load and deflection measurements shall be recorded as specified under 8.1.1 and 8.1.2, respectively, within a time period or measurement window of at least 60 ms, to an accuracy at the time of peak load and deflection of ± 2 %, and a precision for deflections of ± 2 µm (0.08 mils).

9. Procedure

9.1 Transport the device to the test location and position the loading plate over the desired test point. The test location shall be as clean as possible of rocks and debris to ensure that the loading plate will be properly seated. Gravel or soil surfaces shall be as smooth as possible and all loose material removed. (See Guide D 4695.)

9.2 Lower the loading plate and the sensors to ensure they are resting on a firm and stable surface.

9.3 Raise the force generator to the desired height and drop the "weight". Record the resulting peak surface deflections and peak load.

NOTE 4—If significant permanent deformation under the loading plate occurs, move the apparatus and reduce the applied force until the permanent deformation is of no significance to the first test at a test location.

9.4 Perform at least two loading sequences (9.3) and compare the results. If the difference is greater than 3 % for any sensor, note the variability in the report. Additional tests may be run at the same or different loads.

10. Precision and Bias

10.1 *Precision*—At this time, no precision from a statistically designed series of tests with different devices has been obtained. Test results from the same device or from different devices may vary due to variations in buffer stiffness or pavement stiffness. Each device, however, should be able to meet the accuracy requirements of 8.2 and the calibration requirements established by the manufacturer and SHRP.

10.2 *Bias*—No statement is being made as to the bias of this test method at the present time.

11. Keywords

11.1 deflection surveys; deflection testing; falling weight deflectometer (FWD); impulse deflection testing device; load/deflection testing; nondestructive testing (NDT); pavement deflection; pavement testing