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Standard Guide for General Pavement Deflection Measurements[1]

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1. Scope

1.1 This guide provides recommendations for measuring pavement deflections resulting from the application of a known transient load, a steady-state dynamic load, or an impulse load applied by a nondestructive deflection testing (NDT) device. Deflections are measured with sensors that monitor the vertical movement of the pavement surface. This guide describes the general information that should be obtained regardless of the type of testing device used.

1.2 This guide is applicable for deflection measurements made on flexible (asphalt concrete (AC)), rigid (Portland Cement Concrete (PCC) or continuously reinforced concrete (CRCP)), or composite (AC/PCC) pavements.

1.3 This guide provides general information that is required for three suggested levels of testing effort, as follows:

1.3.1 *Level I*—a general overview of pavement condition for network analysis.

1.3.2 *Level II*—a routine analysis of the pavement for purposes such as overlay or rehabilitation design projects.

1.3.3 *Level III*—a detailed or specific analysis of the pavement, such as the evaluation of joint efficiency or foundation support for PCC slabs.

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

1.5 *This standard may involve hazardous materials, operations, and equipment. 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 *AASHTO Standard:*[2]

T256—Standard Recommended Practice for Pavement Deflection Measurements

3. Summary of Guide

3.1 This guide consists of recommendations for measuring vertical or normal pavement surface deflections, directly under or at locations radially outward (offset), or both, from the load center. Several offset deflection measurements at a specific test location describe what is called a deflection“ basin”. Each NDT device is operated according to the standard operating procedure applicable to the device.

3.2 Recommendations for collection of general information such as ambient temperature, pavement temperature, equipment calibration, number of tests, and test location pertains to all devices.

4. Significance and Use

4.1 The nondestructive measurement of pavement deflections provides information that can be used for the structural analysis of the pavement system. The series of measured deflections or deflection basins may serve as inputs for models that estimate the overall stiffness of the pavement system, the effective or apparent modulus of elasticity of individual pavement layers (also known as “backcalculation”), or an equivalent thickness of a reference material. Either the effective modulus of elasticity or equivalent thickness may be used for mechanistic pavement evaluation and overlay design.

5. Apparatus

5.1 The apparatus used in this guide shall be one of the deflection measuring devices given in 5.2 and shall consist of some type of probe or surface contact sensor to measure normal pavement movements when subjected to a given load type.

5.2 *Deflection Measuring Devices*:

5.2.1 *Noncontinuous Static Device*,[3] that operates on a single lever-arm principle. This device should have a minimum 2.5 m (8 ft) long probe and the extension of the probe should depress a dial gage or electronic sensor that measures maximum pavement deflection with a resolution of 0.025 mm (0.001 in.) or better. The vehicle used with the static deflection device should be a truck carrying an 80 kN (18 000 lb) test load on a single rear axle. The rear axle should have dual 280 by 570 mm (11.0 by 22.5 in.) 12-ply tires inflated to 480 kPa (70 psi). Other axle loads, tire sizes, and inflation pressures are permissible; however, the loading configuration must be indicated in the engineering report, for example as outlined in AASHTO Standard T256.

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[2] Available from the American Association of State Highway and Transportation Officials, 444 N. Capitol St., NW, Washington, DC 20001.

[3] An example of this instrument is the Soiltest Benkelman Beam, manufactured by Soiltest Inc., Materials Testing Div., 2205 Lee St., Evanston, IL 60202.

5.2.2 *Semicontinuous Static Device,*[4] that operates on a double lever-arm principle. The vehicle operating this device should be a truck carrying a 130 kN (29 000 lb) single-axle test load. It should have dual 280 by 570 mm (11.0 by 22.5 in.) 12-ply tires inflated to 480 kPa (70 psi). Other axle loads, tire sizes and inflation pressures are permissible, however, the loading configuration should be indicated in the engineering report. The test vehicle should be equipped with a double lever arm with probes, the geometry and size of which makes it possible to measure the maximum pavement 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 should depress an electronic sensor, which may be of any type provided it delivers an analog or digital signal 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 should 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, and at constant vehicle speed.

5.2.3 *Steady State Dynamic Device,*[5] that uses a dynamic force generator to produce an oscillatory load. The force generator should either use counter-rotating masses or a servo-controlled hydraulic actuator to produce the peak-to-peak load. It should measure pavement deflections using four or more sensors with a resolution of 0.001 mm (0.00004 in.) or better, and should be capable of producing a 4.5 kN (1000 lb) peak-to-peak load or greater.

5.2.4 *Impulse Device,*[6] that creates an impulse load on the pavement by dropping a mass from different heights onto a rubber or spring buffer system. It should measure pavement deflections using five or more sensors with a resolution of 0.001 mm (0.00004 in.) or better, and should be capable of producing a 40 kN (9000 lb) load or greater.

6. Calibration of Deflection Measuring Devices

6.1 *Load*—The procedure for calibrating the load cell (if a load cell is used by the device) is dependent upon the type of apparatus used. Regardless of the apparatus used, the load cell calibration should be checked at least once per month during continuous operation. Whenever the device is used on an intermittent basis, the load cell calibration should be checked before testing begins. For impulse devices, reference load cell calibration should be carried out at least once per year, for example as outlined in Appendix A of SHRP Report SHRP-P-661.[7] Steady state dynamic devices equipped with load cells may be calibrated by measuring the load cell output under known static loading conditions, such as the load of the device itself. Load cells should be calibrated at least once per year following the manufacturer's instructions. For noncontinuous and semicontinuous static deflection equipment, immediately prior to testing weigh the axle load of the truck if the ballast consists of a material that can absorb moisture (sand, etc). Trucks with steel or concrete block loads only need to be weighed if the loads are changed.

6.2 *Deflection*—The procedure for calibrating the deflection sensors is dependent upon the type of apparatus used. Regardless of the apparatus used, the calibration of the deflection sensors should be checked at least once per month of continuous daily operation. Reference deflection sensor calibration should be carried out in accordance with the manufacturer's recommendations or any other applicable procedures. Whenever the device is used on an intermittent basis, the deflection sensor calibration should be checked before testing begins. If the device has more than one sensor, a relative calibration check may be conducted by stacking the sensors in a column that measures the deflection at a single point, for example as outlined in Appendix A of SHRP Report SHRP-P-661.[7] Also, a standard test area may be used to check the calibration of the sensors. This consists of establishing a reference test point, such as at the interior of a known slab. Static 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. Testing Procedures

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

7.1.1 *Load*—For impulse load devices, record the peak load applied to the pavement surface by the deflection device. For steady state devices, record the peak-to-peak load. For transient (static) devices, record the axle load of the test vehicle.

7.1.2 *Load Frequency*—If applicable, record the frequency of oscillatory loading for those devices such as a Road Rater. The Dynaflect frequency is set by the manufacturer, generally at 8 Hz.

7.1.3 *Geometry of Loaded Area and Deflection Sensor Locations*—For proper modeling of the pavement structure and backcalculation, etc, it is necessary that the locations of the load, deflection sensors, pavement surface cracks, and PCC joints are known and recorded. Record the location of the nearest joint or crack, in any direction from the center of the load. Record the location and orientation of all sensors as measured radially outward from the center of the load, for example "300 mm (12 in.) ahead of the applied load". In accordance with the selected method of evaluating joint efficiency (or load transfer), the load(s) and deflection sensor(s) should be properly positioned, for example with one or more sensors on each side of the joint and the load placed as close as possible to the "leave" (downstream) side of the joint in question. Failure to note the presence of joints and cracks within the zone of influence of the load could result in errors in estimating layer moduli through backcalculation, etc.

7.1.4 *Time of Test*—Record the date and time the measurements were obtained.

7.1.5 *Air and Pavement Temperatures*—At a minimum,

[4] An example of this instrument is the Lacroix Decflectograph.

[5] Examples of this instrument are the Geolog Dynaflect and the Foundation Mechanics Road Rater, manufactured by Geolog Inc., 103 Industrial Blvd., Granbury, TX and Foundation Mechanics Inc., 421 E. El Segundo Blvd., El Segundo, CA 90245.

[6] Examples of this instrument are the Dynatest Falling Weight Deflectometer (FWD), the KUAB 2m-FWD, The Phonix FWD, and the Jils FWD.

[7] Report SHRP-P-661-Manual for FWD Testing in the Long-Term Pavement Performance Study.

record the pavement surface temperature at each test location to provide data for estimating the average temperature of the bound pavement layer(s). If needed for the analyses, the ambient air temperatures should also be recorded. In lieu of the ambient air temperature, some procedures use the five-day mean air temperature, that is, the sum of the high and low air temperatures for the five days immediately preceding testing, divided by ten to estimate the weighted average or mid-depth temperature of the bound layer(s). If feasible, pavement layer temperatures may be more accurately determined by drilling holes to various depths within the pavement layer(s), filling the bottom of these holes with glycerin or any other suitable liquid, and recording the temperature of the fluid at the desired depth. If testing is done for an extended period of time, take temperature measurements of the fluid every 1 to 2 h to establish a direct correlation between air, pavement surface, and depth temperature measurements. Often, temperature gradients may exist within PCC slabs that can cause curling or warping of the slabs, and thereby significantly affect the measured deflections. In these cases it may be necessary to monitor the temperatures within the slab (for example, with thermocouples), at the surface, mid-depth and bottom of a control slab.

7.2 *Test Method*—Depending on the type of apparatus, there are a number of test methods that can be applied. Steady state devices capable of variable loads and frequencies can be used to conduct "load sweeps" (multiple tests at various loads, at the same test location and frequency) or "frequency sweeps" (multiple tests at various frequencies, at the same test location and load). Impulse devices are typically capable of applying various loads, and some can control the shape and duration of the load pulse. Joint efficiency measurements on jointed PCC pavements can be made with devices equipped with multiple sensors by placing the load plate on one side of the joint and positioning sensors on both sides of the joint (see also 7.1.3).

7.3 *Testing Locations*—The test location and number of tests are dependent upon the testing level selected. Three suggested levels of testing are as follows:

7.3.1 *Level I*—This test level provides for a general (for example, network) overview of pavement condition with limited testing. Testing should be performed at 200 to 500 m (500 to 1500 ft) intervals, depending on specific pavement conditions, but a minimum of 5 to 10 tests per uniform pavement section are recommended to ensure a statistically significant sample. For AC and CRCP pavements, as a minimum, the load should be positioned along the outer wheel path, or alternatively along the centerline of CRCP slabs. For jointed PCC pavements, the load should first be positioned at or near the geometric center of the slab. For Level I testing, at least 5 % of the slabs covered should be tested at the joints as well, for deflection or load transfer efficiency.

7.3.2 *Level 2*—This test level provides for a more detailed analysis of the pavement, for example, for the purpose of overlay or rehabilitation design. Testing should be performed at 25 to 200 m (100 to 500 ft) intervals, depending on specific pavement conditions, with a minimum coverage of 10 to 20 tests recommended per uniform pavement section. For AC and CRCP pavements, as a minimum the load should be positioned along the outer wheel path, or alternatively along the centerline of CRCP slabs. For jointed PCC pavements, the load should first be positioned at or near the geometric center of the slab and then moved to the nearest joint and positioned along the same line, generally on the leave side of the joint. On roads, streets and highways, joint tests are often conducted along the outer wheel path. Generally, not every joint associated with each interior slab test is covered; however, a minimum joint coverage rate of 25 % is recommended. On airfield PCC pavements, joint efficiency measurements may be carried out on both transverse and longitudinal joints.

7.3.3 *Level 3*—This test level provides for a highly detailed or specific analysis of the pavement for purposes such as identifying localized areas of high deflection or detecting subsurface voids on PCC pavements. For AC or CRCP pavements, testing should be performed at 3 to 25 m (10 to 100 ft) intervals, along one or more test lines. On roads, streets and highways, testing is often carried out in both wheel paths. For jointed PCC pavements, the load should first be positioned at or near the geometric center of every slab along the length of the test section, and then moved to the nearest joint or crack on each slab, either along the outer wheel path or at the corner of the slab, or both. On airfield PCC pavements, joint efficiency measurements should be carried out on both transverse and longitudinal joints.

8. Keywords

8.1 Benkelman beam; deflection surveys; deflection testing; deflectograph; falling-weight deflectometer (FWD); heavy-weight deflectometer (HWD); impulse deflection testing device; load/deflection testing; nondestructive testing (NDT); pavement deflection; pavement testing; static deflection testing device; steady-state dynamic deflection testing device