LONG TERM PAVEMENT PERFORMANCE PROGRAM DIRECTIVE

For The Technical Direction Of The LTPP Program

Program Area: **Specific Pavement Studies** **Directive Number: S-4**

Date: **February 22, 1993** **Supersedes: P59 Drafts (various dates)**

Subject: **Deflection Testing of Subgrade and Base Layers for the SPS-1, -2, and -8 Experiments**

The attached SHRP Protocol P59, dated January 1993 provides procedures for deflection testing to be conducted on base and subgrade layers. This testing is to be conducted on SPS-1, -2, and -8 test sections as they are being constructed. However, this testing may be omitted when logistical issues related to the construction schedule, and the availability of an FWD (whether owned by the State or the Federal Highway Administration) make such testing infeasible or impractical. A special effort shall be made to accomplish this testing in lieu of, or in addition to, traditional plate bearing tests on SPS-2 projects, and on SPS-8 projects involving rigid pavements.

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LONG-TERM PAVEMENT PERFORMANCE
SPS DIRECTIVES
MASTER LIST

NUMBER	SUBJECT	DATE	STATUS	REMARKS
S-1	REVISIONS OF EXISTING SPS DOCUMENTS	11/27/92	FINAL	
S-2	POLICY ON TREATMENT OF FAILED SPS SECTIONS	11/27/92	FINAL	
S-3	REVISIONS OF CONSTRUCTION DATA SHEET 7 FOR SPS-5 AND SPS-6	2/10/93	FINAL	
S-4	DEFLECTION TESTING OF SUBGRADE AND BASE LAYERS FOR SPS-1, SPS-2, AND SPS-8 EXPERIMENTS	2/22/93	FINAL	

SHRP PROTOCOL: P59
For SHRP Test Designation: SS13
DEFLECTION TESTING OF SUBGRADE AND BASE LAYERS

This SHRP protocol covers the test method for measuring the surface deflection of subgrade and base layers. The test shall be performed during test section construction for Specific Pavement Studies experiments SPS-1, SPS-2 and SPS-8. This protocol is based on ASTM D 4694-87 (Standard Test Method for Deflections with a Falling-Weight-Type Impulse Load Device). The test shall be performed in accordance with this standard (ASTM D 4694-87), as modified herein. Those sections of the ASTM standard included in this protocol by reference and without modification shall be strictly followed. All other sections of this protocol shall be followed as written herein.

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 (FWD).

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. An impulse load more nearly represents the moving vehicle load-pulse applied to prototype pavements than does a static load.

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

1.4 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems 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 7.

2. Referenced Documents

2.1 *ASTM Standards:*
D 4695 Guide for General Pavement Deflection Measurements.

2.2. SHRP-LTPP Manual for FWD Testing, November 1992.

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

3.2 The load plate of the test apparatus is brought to a stop over the desired test location. The plate and deflection sensors are lowered to the pavement. 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 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 first force impulse is recorded in microns, millimeters, mils, or inches, as appropriate. In addition to the peak value, the deflection pulse shall be sampled at a number of intervals sufficient to completely define its shape (a minimum of 2 samples per millisecond per deflection sensor), beginning approximately 30 milliseconds (ms) before the peak deflection and ending approximately 30 ms after the peak deflection.

3.4 The peak force imparted by the falling weight is measured by a load cell and recorded, as force in kN or lbf, or mean stress (the load divided by the plate area) in kN/m^2 or psi as appropriate. In addition to the peak value, the load pulse shall be sampled at a number of intervals sufficient to completely define its shape (a minimum of 2 samples per millisecond), beginning approximately 30 milliseconds (ms) before the peak load and ending approximately 30 ms after the peak load.

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, measured at the center of the applied load, and at distances away from the load, are used to estimate the in-situ material properties and to evaluate construction uniformity.

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 50EC (10 to 120EF) and shall tolerate relatively high humidity, rain or spray, and all other adverse conditions such as dust, shock, 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 40EC (40 to 105EF).

5.2 *Force-Generating Device* (falling weight), with a guide system. The force-generating device shall be capable of being raised to four predetermined heights and dropped. The device shall generate a force pulse approximating the shape of a haversine or half-sine wave while achieving a peak force of at least 50 kN (11,000 lbf). Specific load levels and drop heights are defined in 11.4.

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 Plates*, capable of distributing an approximate uniform load to the pavement surface. The load plate shall be 11.8 inches (300 mm) in diameter for subgrade and base course testing. The plate shall be open in the center to allow a deflection measuring sensor to be installed and the plates shall be swivel suspended to tilt in any direction a minimum of 5E from the horizontal plane.

5.4 *Deflection Transducers*, capable of measuring the maximum vertical deflection of the pavement surface 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 transducers is defined in 11.3. Transducers may be of several types such as seismometers (absolute measurement transducers), velocity transducers, or accelerometers.

5.5 *Data Processing and Storage System* - A magnetic storage device shall be used to store the measured load, surface deflection data, and supporting information such as air temperature, pavement surface temperature, distance measurements, and identification data for each test point.

5.6 *Load Cell*, to measure the applied load on each impact shall be placed in a position to minimize inertial effects. The load cell shall be capable of deflection measurements at the center of the load, shall be water resistant, and shall be resistant to mechanical shocks from road impacts.

6. Signal Conditioning and Recorder System

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

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

6.1.2 Deflection measurements shall be displayed and stored with a resolution of 1 µm (0.04 mils).

6.1.3 The load and deflection measurements shall be recorded as specified under 6.1.1 and 6.1.2, respectively, within a time period or measurement window of at least 60 ms, to an absolute accuracy at the time of peak load and deflection, of ±2% and a random accuracy for deflections of ±2 µm (0.08 mils).

7. Hazards

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

8. Calibration

8.1 *Calibration* - Follow the recommendations for deflection sensor relative calibration and for deflection and load cell reference calibration specified in the SHRP-LTPP Manual for FWD Testing. Reference calibration shall be performed annually and after repairs to the sensors or the load cell. Relative calibration shall be performed monthly and immediately after reference calibration.

8.2 DELETE

8.3 DELETE

9. Procedure

9.1 Bring the device to the test location and locate the test 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 ASTM D 4695)

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

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

9.4 Perform two loading sequences at each drop height and compare the results. If the difference is greater than that specified in the SHRP-LTPP Manual for FWD Testing (for deflections, ± 2 µm (± 0.08 mils) ± 1 percent, and for load, ± 2.6 kPa (± 0.38 psi) ± 2 percent), it shall be noted in the report.

NOTE 1 - If the deflections indicate poor subgrade or base compaction, then this should be brought to the attention of the construction inspector.

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 for testing unbound materials.

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

11. Test Plan (see Table 1)

11.1 *Test Location* - Deflection tests shall be performed along the test section at the following two transverse locations in order of preference; (Note: Before performing the second pass, the influence of tow vehicle/trailer wheel rutting of the surface must be assessed. The second pass shall be omitted if rutting indicates some additional compaction or shearing of the subgrade and/or unbound materials has occurred.)

(1) Outer Wheel Path - located 0.76 m ± 0.15 m (2.5 ft ± 0.5 ft) from lane edge. (Denoted as pass "3" for consistency with SHRP procedures)

(2) Mid-Lane - located 1.8 m ± 0.15 m (6.0 ft ± 0.5 ft) from the lane edge. (Denoted as pass "1" for consistency with SHRP procedures)

11.2 *Test Interval* - A 15 m (50 ft) longitudinal test spacing shall be used for both passes. The starting station for the first pass shall be 0+00 and the second pass shall start at 0+7.5 m (0+25 ft), resulting in a staggered test pattern.

11.3 *Sensor Configuration* - A deflection sensor shall be placed directly beneath the center of the load plate and at radial offsets of 203, 305, 457, 610, 915, and 1524 mm (8, 12, 18, 24, 36, and 60 inches) from the center of the load plate.

11.4 *Load Levels/Number of Drops* - For subgrade testing, four drop heights shall be used as follows. The lowest load level shall be achieved by using the lowest possible physical drop height. The highest load level shall be achieved by determining the drop height required to obtain a maximum deflection of approximately 1524 µm (60 mils). The two intermediate load levels shall be achieved by setting the drop heights to positions that will produce evenly spaced load levels. For testing permeable asphalt treated, unbound granular base and lean concrete base courses the SHRP standard mass package and target load levels for flexible pavement testing shall be used. In all cases where excessive deflection measurements occur (greater than 1524 µm (60 mils)), only load levels that cause these high measurements shall be omitted.

11.5 *Drop Sequence* - At each test location, one seating drop at the lowest load level shall be applied prior to testing. Following the seating drop, two drops will be applied at each load level, starting with the lowest load level.

11.6 *Other Considerations* - Provision shall be made with the construction contractor for timely site access. Testing of subgrade shall be performed after completion of fine grading and prior to placement of base course materials. Unbound granular base testing shall be

performed after completion of compaction and fine grading. Testing of permeable asphalt treated base course shall be performed after the material has been in place for a minimum of 48 hours and the prohibition of construction traffic on this material does not apply to the test vehicle and trailer. Lean concrete base material shall be tested no earlier than 7 days after placement. The prohibition of construction traffic does not apply to the test vehicle and trailer. Testing shall only be performed in the absence of standing water.

12. Report

12.1 *Test Identification Information* - Test Agency, SHRP Region, State Code, SPS Experiment Number, SPS Project Code, Test Section Number, Field Set Number, Roadway Name and Route Number, Test Designation, SHRP Protocol Number, Technician Name, and Test Date.

12.2 *Load and Deflection Data* - Load and deflection data shall be recorded in ASCII format and may be stored in compressed form on 3-1/2 inch computer diskettes. File names will consist of eight characters; characters 1-6 shall be the SHRP Section ID of the SPS section, character 7 shall be a digit between 1 and 9, signifying the number of times that this section has been tested under this protocol. The first instance of testing will be denoted with a "1", whether the first testing occurs on the subgrade, a subbase course, or a base course. Character 8 shall be a number denoting the test location (1 - mid-lane, 3 - outer wheel path). A three character extension ".FWD" shall follow the eight character file name. Example: 29B32013.FWD represents the file name for the first deflection testing of this section along the outer wheel path. A paper copy printout of the load and deflection data shall also be provided along with the computer file for each section.

12.3 *Additional Data* - In addition to the load and deflection data, the air temperature, and time of testing shall be recorded for each test location. Lane specifications shall also be recorded. All lane specification codes are two character codes where the first character indicates material information and the second character indicates test location; "1" for mid-lane testing and "3" for outer wheelpath testing.

Material codes are as follows:

S - Subgrade,
G - Granular Aggregate Base,
P - Permeable Asphalt Treated Base, and
L - Lean Concrete Base.

An example of a lane specification, "G3", denotes testing of the granular aggregate base course in the outer wheel path.

Pavement temperature profiles are not required for any of the listed materials.

Table 1. Test Plan Summary for Deflection Testing of SPS 1, 2, and 8 Subgrade and Base Layers

Test Location	Mid-Lane Outer Wheel Path
Test Interval	15 m (50 ft)
Sensor Configuration	0, 203, 305, 457, 610, 915, 1524 mm (0, 8, 12, 18, 24, 36, 60 in.)
Load Plate	300 mm (11.8 in.) Diameter
Load Levels:	
Subgrade Testing	Non-SHRP mass package to achieve target loads: Height 1 - lowest possible (1,600 lbs.) Height 4 - to achieve 5,000 lbs. (maximum 1524 µm (60 mils)) Height 2, 3 - evenly spaced between heights 1 and 4
Base Course Testing	SHRP standard mass package and drop heights for target loads: Height 1 - 6,000 lbs. Height 2 - 9,000 lbs.(maximum 1524 µm (60 mils)) Height 3 - 12,000 lbs.(maximum 1524 µm (60 mils)) Height 4 - 16,000 lbs.(maximum 1524 µm (60 mils))
Drop Sequence	1 seating drop 2 drops at each load level (record peaks for each drop and whole history for the second drop at each height)

********** SPS TESTING DATA SHEET **********

SHEET _____ OF _____

SHRP-LTPP LABORATORY MATERIAL TESTING
DEFLECTION TESTING OF SUBGRADE AND BASE LAYERS
FIELD DATA SHEET T59
SUBGRADE AND BASE LAYERS
SHRP TEST DESIGNATION: SS13/SHRP PROTOCOL P59

AGENCY PERFORMING TEST: _____

SHRP REGION: _____ STATE: _____ STATE CODE: [__ __]

SPS PROJECT CODE: [__ __]

ROADWAY: _____ TEST SECTION NO.: [__ __]

FWD Manufacturer: _____

Model: _____

S/N: _____

TESTED BY: _____

DATE TESTED: __ __ - __ __ - 19__ __

1. PAVEMENT LAYER TESTED _____

2. LAYER NUMBER [__]

3. COMPUTER FILE NAMES __ __ __ __ __ __ __ __.FWD

__ __ __ __ __ __ __ __.FWD

GENERAL REMARKS:

_____

_____

CERTIFIED BY, DATE

_____

Participating Agency
Affiliation: _____

VERIFIED AND APPROVED BY, DATE

_____

SHRP Representative
Affiliation: _____