Long-Term Pavement Performance Program Manual for Falling Weight Deflectometer MEASUREMENTS



Version 4.1

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LTPP

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Foreword

This manual is intended for use in collection of Falling Weight Deflectometer (FWD) data for the Long-Term Pavement Performance (LTPP) program. As such, it contains background information on FWD equipment and the general role of FWD testing within LTPP as well as a set of field operations guidelines for the data collection process.

This is the fourth major version of the *LTPP Manual for Falling Weight Deflectometer Measurements*. The first two were developed under the auspices of the Strategic Highway Research Program; the last two were developed under contract to the Federal Highway Administration. The revisions to this manual reflect the changing data needs of LTPP as well as changes in FWD equipment.

The LTPP program is a continuing, active program. Current information and access to other technical references are available at the LTPP Web site at http://www.tfhrc.gov/pavement/ltpp/ltpp.htm. Submit LTPP data requests, technical questions, and data user feedback to LTPP customer service by e-mail at ltppinfo@fhwa.dot.gov.

Gary L. Henderson
Director, Office of Infrastructure Research
and Development

Notice

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16. Abstract

This document provides background information and field operations guidelines for the collection of Falling Weight Deflectometer (FWD) data on Long Term Pavement Performance (LTPP) test sections. It includes equipment setup, equipment calibration, test locations, and test procedures.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
^oC	Celsius	1.8C+32	Fahrenheit	^oF
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
(Revised March 2003)

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1 BACKGROUND

A falling weight deflectometer (FWD) is a device designed to simulate deflection of a pavement surface caused by a fast-moving truck. The FWD generates a load pulse by dropping a weight. This load pulse is transmitted to the pavement through a 300-millimeter (mm) diameter circular load plate.

The load pulse generated by the FWD momentarily deforms the pavement under the load plate into a dish or bowl shape. Envisioned from a side view, the shape of the deformed pavement surface is a deflection basin.

Based on the force imparted to the pavement and the shape of the deflection basin, it is possible to estimate the stiffness of the pavement by using various computational methods. If the thickness of the individual layers is also known, the stiffness of those layers can also be calculated.

In addition, an FWD can be used to determine the degree of interlock between adjacent slabs of a portland cement concrete (PCC) pavement. This degree of interlock is generally known as “load transfer efficiency” or LTE. Measurement of the LTE is obtained by placing the FWD load plate tangent to one side of the joint to be evaluated. A load pulse is then generated, and the deflections at equal distances on either side of the joint are measured. In a perfectly efficient joint, these deflections are equal. For most joints, the deflection on the unloaded slab is less than the deflection on the loaded slab.

An FWD has two types of primary measurement devices. The first is a load cell, located directly above the load plate, and it measures the force imparted to the pavement. The second is a deflection sensor, also known as a “deflector.” The FWDs operated by the Long-Term Pavement Performance (LTPP) Program use geophones as the deflection sensors, although there are other types of deflection sensors used in other FWD designs. The LTPP FWDs have nine deflection sensors placed at fixed distances from the load plate to measure the shape of the deflection basin.

In addition to the primary measurement devices, the LTPP FWDs have two additional types of measurement devices. The first is the distance measurement instrument (DMI), a high-accuracy odometer that measures the distance the FWD has traveled along a roadway. The second type is a temperature sensor. The LTPP FWDs have two categories of temperature sensors, an air temperature sensor and an infrared surface-temperature sensor. The data from these two temperature sensors, combined with data from nearby weather stations, are useful for estimating the temperature of various materials in the pavement structure.

Knowing the temperature of the materials in the pavement structure is critical. For example, asphalt is hard and brittle at very low temperatures and soft and ductile at very high temperatures; therefore, the stiffness calculated from FWD data for these materials must be corrected for these temperature effects. In addition, the LTE between two PCC slabs varies as the slabs expand and contract or warp resulting from a difference in temperature between their top and bottom surfaces.

LTPP FWD operators are also required to perform manual measurements during FWD testing. These measurements consist of subsurface temperature measurements taken with a hand-held probe and joint width measurements taken during load-transfer testing.

LTPP FWD operators also must comment on nonequipment-related conditions encountered during testing that might reasonably be expected to cause anomalous measurements. These conditions usually are cracks or other pavement surface distresses.

2 FWD-RELATED TERMINOLOGY

Use of proper terminology greatly eases troubleshooting and problem reporting. This manual uses specific terminology to refer to specific parts of the Dynatest® model 8002 FWD, which is the type operated by LTPP. Some of these terms also apply to other types of FWDs. This list is complete only for this manual. Parts not included here may be found in the owner's manual.

Buffer—A rubber block attached to the underside of the weight package to control the shape of the generated load pulse. On LTPP FWDs, the buffers are roughly cylindrical, and there are four mounted on the weight package.

Control Box—Contains connectors for the geophones, load cell, temperature sensor, and other sensors mounted on the FWD. Located on the FWD trailer, the control box sends these signals to the signal processor located in the tow vehicle through the multisignal cable. The control box also has buttons for manual control of the FWD hydraulics.

Geophone—Device used to measure deflection. It is yellow, roughly cylindrical, and about 25 mm (0.98 inch) in diameter and 50 mm (1.97 inches) high. Geophones are mounted in spring-loaded sensor support brackets suspended along the sensor bar. Each geophone has a unique serial number that is used to identify critical calibration information in the FWD data collection software. The LTPP FWDs use 2,000-micron (80-mil, or 0.8-inch) geophones.

Load Cell—Measures the force imparted to the pavement by the FWD. The load cell is located directly above the load plate and below the swivel. The load cell has a serial number, which is visible from the rear.

Load Plate—Directly contacts the pavement surface to transmit the load. The type used by LTPP is solid, and it has a 300-mm (11.81-inch) diameter. It consists of three layers: the topmost is steel, the middle is polyvinyl chloride (PVC), and the bottommost is a ribbed rubber sheet.

Multisignal Cable—Carries electrical signals from the control box to the signal processor. These signals include the outputs from the transducers on the FWD and the command signals for the FWD hydraulics.

Signal Processor—Connects the trailer control box through a multisignal cable to the data collection computer using an RS-232 serial cable. The LTPP FWDs use a Dynatest 9000 signal processor located in the tow vehicle.

Strike Plate—A flat-surfaced column above the load plate. The weight package is dropped on the strike plate during operation of the FWD. Braces and a cylinder, housing the center geophone, and to which the swivel attaches, are welded to the underside of the strike plate.

Sensor Bar—A long bar mounted above the load plate where the geophone holders are mounted. An extension of the sensor bar continues behind the load plate toward the trailer hitch to allow a geophone to be mounted behind the load plate.

Swivel—Connects the load cell to the strike plate. It allows the load cell and load plate to rotate to provide good contact with the pavement surface.

Transducer—Any measurement device that converts a physical response into an electrical signal. Transducers on an FWD include the load cell, deflection sensors, and temperature sensors.

Weight—Removable steel weights mounted to the weight package. Their mass is 20 kilograms (kg) (44.1 pounds (lb)) each.

Weight Package—The entire assembly that is raised and then dropped to generate load.

3 TEST PROCEDURE

The following list summarizes the general procedures FWD operators are to perform at each test site. The step summaries refer to sections in this manual that give the details of each step.

3.1 Before arriving at the site, an FWD operator must have a filled out copy of form F05 "FWD Operations Planning." A separate copy of this form must be filled out for each test section.

3.2 When an FWD operator arrives at the site, he or she should inspect the test section for evidence of maintenance activities. Any missing or defaced site markings should be replaced before continuing. If there is evidence of recent maintenance activities, contact the Regional Support Contractor (RSC) office. If quantitative evidence exists of the effect of the maintenance activities on the layer structure, reevaluate the temperature gradient hole section of form F05.

3.3 Prepare the temperature gradient holes as directed in manual section 6.1. List the depth of the holes on form F05 in the information blanks that are not crossed out. Previously drilled holes may be used if the operator first blows them out and remeasures the depths, which should correspond to those listed on form F05. If the operator drills new holes, the depths should be measured and filled out on form F01. The operator then fills the holes with mineral oil and waits at least 20 minutes (min) before taking the first temperature measurement.

3.4 Perform the before-operations activities listed in manual section 9.2.

3.5 Perform the standard buffer warm-up sequence or the cold weather buffer-warm-up sequence, as appropriate, outside of the test section limits. The buffer warm-up sequences and their appropriate temperature ranges are given in section 4.3.5.

After completing the buffer warm-up sequence, examine the data from the final four drops to ensure that the load levels are not all trending in the same direction (i.e., consistently increasing or consistently decreasing). If they are trending in the same direction, repeat the standard buffer warm-up sequence until the load levels stabilize.

After the last buffer warm-up sequence, examine the data from the four drops before the final four drops to ensure that the load levels for each drop height are within the limits given in section 4.2. If they are not, adjust the drop height targets accordingly and make an additional drop at each drop height to ensure that the targets are correctly set. If at any time during testing the load levels stray from the limits for their respective drop heights, stop testing, readjust the targets, and repeat the pass.

If the FWD is idle for more than 15 min, again perform a standard buffer-warm-up sequence.

3.6 Position the FWD so that the center of the load plate is on the section start limit (i.e., Station 0+000). Set the DMI to 0 centimeters (cm) (0 feet (ft)), ascending. The DMI must be set in units of "feet" for continuity with previous LTPP FWD testing.

3.7 Position the FWD at the first test location. Test locations for the appropriate test plan number (as given on form F05) are listed in manual section 5.

3.8 In the FWD data collection software, set the "Test Setup" as listed on form F05. Then open a new data file. Use the file name as listed on form F05.

3.9 Check the local time on the computer and evaluate whether the test pass can be completed before local midnight. If it is not probable that testing can be completed before midnight, do not start testing until after midnight. Any test pass that starts before midnight and ends after midnight cannot be uploaded to the LTPP database.

3.10 Perform the first temperature gradient measurement as described in manual section 6.1. Perform subsequent temperature gradient measurements every 30 min, plus or minus 10 min. For GPS sections, take temperature gradient measurements at alternate ends, with a 60-min interval between measurements at a given end.

3.11 Enter the lane specification appropriate to the test location in the field provided in the data collection software.

3.12 Start the testing sequence.

3.13 Exit the vehicle during testing and examine the pavement surface in the vicinity of the FWD for distresses and defects. Note any distresses in the area around the FWD as described in manual section 6.3.

3.14 During load transfer testing (i.e., lane specifications J4, J5, C4, C5, F4 or F5) measure the joint/crack width as described in manual section 6.2. Joint/crack widths must be measured for at least 25 percent of load transfer tests. If time permits, measure joint/crack widths for all load transfer tests.

3.15 If the data collection software generates errors during testing, follow the instructions in manual section 7. After testing, at the "Accept/Reject" prompt choose "Accept" only if no errors were generated, or after following the error resolution procedures in manual section 7.

3.16 After testing is complete and the load plate is up, proceed to the next test point.

3.17 If the next test point is at an even station (i.e., 1+00, 2+00) check that the DMI corresponds to the pavement markings. If it does not correspond, correct the DMI.

3.18 Repeat steps 3.11 through 3.17 for each test point in the test pass.

3.19 After completing each test point in the pass, close the data file. The data file must be closed and a new data file opened before beginning in a new test pass.

3.20 Return the FWD to the section start limit (i.e., station 0+000), and return the DMI to zero.

3.21 Perform steps 3.7–3.9 and 3.113.19 for the new pass. The temperature gradient measurement process does not need to be restarted, but it must be continued as long as FWD testing is being performed at the section.

3.22 Repeat steps 3.20–3.21 for each remaining pass at the test section.

3.23 After completing FWD testing at the section, perform one more temperature gradient measurement, regardless of the time since the previous measurement.

3.24 If traffic control conditions permit, perform data backup and preliminary data processing before leaving the site as described in manual section 12.1. Check that forms F01 and F02 are correctly filled out, and that form F05 is initialed and dated.

3.25 Perform after-operations activities described in manual section 9.3.

4 SETUP

4.1 PHYSICAL SETUP

The physical setup described in this manual is mandatory for all LTPP-owned FWDs. Other FWDs collecting data on behalf of LTPP may not be capable of the setup described. In those cases, the setup should be followed as closely as possible.

4.1.1 Geophone Locations

For all LTPP testing, maintain the same placement of the geophones on the FWD. Measure geophone offsets from the center of the load plate to the center of the geophone holder. Measure the location of each geophone directly from the center of the load plate to avoid accumulated error. Offsets in front of the load plate (i.e., in the direction of the hitch) are considered positive. Offsets behind the load plate (i.e., in the direction of the rear bumper) are considered negative. The required offsets are shown in Table 1.

Table 1. Deflection sensor offsets for nine sensor FWDs.

Deflection Sensor	Offset
D1	0 mm
D2	203 mm
D3	305 mm
D4	457 mm
D5	610 mm
D6	914 mm
D7	1,219 mm
D8	1,524 mm
D9	−305 mm

1mm = 0.039 inch

If testing is to be performed on behalf of LTPP by an FWD that mounts only seven deflection sensors, use the sensor spacings shown in Table 2.

Table 2. Deflection sensor offsets for seven sensor FWDs.

Deflection Sensor	Offset (Flexible Pavements)	Offset (Rigid Pavements)
D1	0 mm	0 mm
D2	203 mm	−305 mm
D3	305 mm	305 mm
D4	457 mm	457 mm
D5	610 mm	610 mm
D6	914 mm	914 mm
D7	1,524 mm	1,524 mm

1mm = 0.039 inch

Non LTPP-operated FWDs and LTPP-operated FWDs that have undergone overhaul or replacement of the sensor bar or deflection sensor holders must have the deflection sensor offset measured and set accurately using the following procedure.

1. Raise the FWD load plate and engage the transport locks and hitch pin in front sensor bar guide. Make sure the "Man Key" on the control panel is switched to "ON."

2. Check the springs and foam rubber guides on all deflector holders to ensure they are in good condition. Make sure that spring tensions are properly adjusted so that a force on the end feeler can move the holder and feeler upward until the feeler is at least 5 mm (0.2 inch) inside the bottom of the holder body, and that it returns easily when released. (If this does not occur, apply a few drops of silicone oil to the top of the guide rod).

3. Use a steel tape measure with 1 mm (0.039 inch) graduations and 3 meters (m) (9.84 ft) or greater in length, and zero it on the center geophone feeler that projects through the bottom of the loading plate. Apply constant positive pressure on tape to eliminate any sag in tape throughout its length. Measure the location of every other defection sensor from this zero point to the center of the sensor's feeler. It is not adequate to measure only from center to center between individual deflector sensors; this measurement alone will result in an accumulating error. By measuring from the rear of the contact screw, a more repeatable and accurate measurement can be taken. To do this it is necessary to compensate in the measurement for the distance from the outer edge of the contact screw to the center. Check position measurements at least twice.

4. For LTPP-operated FWDs, when the location of the deflection sensor holders is properly set, lock them in place. To do this, drill through the top of the deflection sensor holder where it passes over the sensor bar and through the sensor bar itself with a 6.7-mm (17/64-inch) bit. Tap the sensor bar itself to accommodate a 6M x 1.0 mm (thread pitch) screw. The deflection sensor holder can now be secured with a 6M x 1.0 mm to 20mm stainless steel hex-head screw. Retain the screw with a flat metal washer and medium thread-locking compound.

4.1.2 Weight Package

Configure the weight package the same for all LTPP testing. For Dynatest model 8002 FWDs, use three standard weights per side. Use two buffers per side. When new buffers are installed on the FWD, fill out form F04 and submit it to the FHWA LTPP FWD task leader.

If testing is to be performed on behalf of LTPP by an FWD other than a Dynatest model 8002 FWD, select a combination of buffers and weights that achieves the load requirements described in manual section 4.2 and comes as close as possible to a 13-millisecond (ms) pulse rise time.

4.2 LOAD LEVELS

Four load levels are defined here for LTPP testing. The acceptable load range for each drop height is between 90 percent and 110 percent of the target value. Experience has shown that drop loads for a given drop height tend to decrease slightly over the course of a day of testing. Setting the drop load at 103 percent of the target load at the beginning of the day will minimize the deviation over the course of the day for most cases.

Each drop height must be within the acceptable range shown in Table 3 for all testing. Table measurements are in kilonewtons (kN) and kips (1 kip = 1 × 10^3 lb). Drop heights may not be adjusted during a test pass.

Table 3. Target loads and acceptable ranges.

Drop Height	Target Load, kN (kips)	Acceptable Range, kN (kips)
1	26.7 (6.0)	24.0 to 29.4 (5.4 to 6.6)
2	40.0 (9.0)	36.0 to 44.0 (8.1 to 9.9)
3	53.4 (12.0)	48.1 to 58.7 (10.8 to 13.2)
4	71.2 (16.0)	64.1 to 78.3 (14.4 to 17.6)

Note: Drop height 1 is not used for testing on rigid pavements.

4.3 SOFTWARE SETUP

This section includes specific software settings required for LTPP testing. Instructions on how to enter these settings into the data collection software are given in the *LTPP FWD Data Collection Software Manual.*

4.3.1 Units

All FWD data collected for LTPP should be in International System (SI) units, with the exception of station units, which should be in feet. Specifically, temperature should be recorded and displayed in Celsius (C), load in kilonewtons (kN), deflection in micrometers (µm) (microns), and deflection sensor offsets in millimeters (mm).

4.3.2 File Format

Data collected with LTPP FWDs should be in the FWDWin MDB format. Data collected with non-LTPP seven -sensor FWDs should be in the R80-20 format, where possible. For FWDs not supporting either of these formats, contact the FHWA LTPP FWD task leader for instructions with a copy to the Technical Support Services Contractor (TSSC) before testing begins.

4.3.3 Filters

Collect data with all filters and smoothing turned off.

4.3.4 Data Checks

Enable the following checks:

- Roll-off
- Nondecreasing deflections
- Overflow
- Load variation—set to +/− (0.18 kN + 0.02X)
- Deflection variation—set to +/− (2 µm + 0.01X)

Further information on what these checks are and what to do if they fail appears in manual section 6.

4.3.5 Drop Sequences

Two different drop sequences are used for LTPP testing:

- Flexible testing: C,C,C,1,1,1,1H,2,2,2,2H,3,3,3,3H,4,4,4,4H

- Rigid testing of both jointed concrete pavements (JCP) and continuously reinforced concrete pavements (CRCP): C,C,C,2,2,2,2H,3,3,3,3H,4,4,4,4H

Where *C* is a seating drop (no data saved) from drop height 3,
1 is a drop from drop height 1,
2 is a drop from drop height 2,
3 is a drop from drop height 3,
4 is a drop from drop height 4,
H indicates that the full-time history for that drop is to be saved.

In addition, one of the following drop sequences is used to warm up the buffers before testing:

- Standard buffer warm-up sequence (in ambient temperatures above 10 degrees Celsius (°C) (50 degrees Fahrenheit (°F)):
  (1,2,3,4,4,4,4) repeated 8 times.

- Cold-weather buffer warm-up sequence (in ambient temperatures below 10 °C (50 °F): drop height (1) repeated 32 times, followed by the standard buffer warm-up sequence.

Furthermore, the reference calibration and the relative calibration drop sequences from the "SHRP-LTPP FWD Calibration Protocol" should be preprogrammed into the LTPP-owned FWDs.

4.3.6 File Naming

The file name for an FWD data file should be eight characters in the following format: XXYYYYZN

Where *XX* is the state code for section location,
YYYY is the LTPP section ID for the section,
Z represents the site visit (*A* for the first visit, *B* for the second visit, and so on), and
N represents the pass number.

For example, for the first pass of the first visit to section 3807 in North Carolina, the file name should be 373807A1. Test passes are described in detail in manual section 5.2.

5 TEST PLANS

5.1 SELECTING THE APPROPRIATE TEST PLAN

Test plans specify the location of test points at an LTPP section. There are several different test plans. The appropriate test plan for an LTPP section is determined by the experiment designation of the section, and in some cases the surface type or other properties of the section. The test plan applicable to a given LTPP section should be determined according to Table 4.

Table 4. Test plans by LTPP experiment and surface type.

Experiment	Surface Type	Test Plan	Note
GPS 1	Flexible	1	
GPS 2	Flexible	1	
GPS 3	JPCP*	2	
GPS 4	JRCP**	2	
GPS 5	CRCP***	3	
GPS 6	Flexible	1	
GPS 7	Flexible	1	
GPS 9	JPCP	2	
SPS 1	Flexible	4	
SPS 2	JPCP	5	
	JPCP	7	4.3 m lane width sections
SPS 3	Flexible	8	
SPS 4	JPCP	9	
SPS 5	Flexible	4	
SPS 6	JPCP	5	
	Flexible over JPCP	10	Sections 3, 6, 7, 8
	Flexible over JPCP	11	Section 4
SPS 7	JPCP	5	
	CRCP	6	
SPS 8	Flexible	4	
SPS 8	JPCP	5	
SPS 9	Flexible	4	
	Flexible over PCC	10	

*JPCP—jointed plain concrete pavement.
**JRCP—jointed reinforced concrete pavement.
***CRCP—continuously reinforced concrete pavement.

5.2 DESCRIPTION OF TEST PLANS

Each test plan consists of one or more test passes. Data from each test pass should be stored in a separate data file. Each test pass should be performed in the direction of the flow of traffic, from the section approach limit (0+000) to the section leave limit (0+152.4 (5+00) for most test sections).

Each test pass consists of testing according to one or more lane specification. It is critical that the operator enter the lane specification appropriate to the test location in the field provided in the data collection software. The longitudinal offset between test locations vary according to the test plan and test pass. Table 5 includes detailed information for each test plan and test pass.

Table 5. Details of test plans.

Test Plan	Pass #	Lane Spec.	Lane Description	Test Type	Test Interval	Number of Tests[a]
1	1	F1	ML	Basin	7.6 m (25 ft)	21
	3	F3	OWP	Basin	7.6 m (25 ft)	21
2	1	J1	ML–MP	Basin	20 slabs	20
	2	J2	PE–CR	Basin	20 slabs	20
		J3	PE–MP	Basin	20 slabs	20
	3	J4	OWP–JA	LT	20 slabs	20
		J5	OWP–JL	LT	20 slabs	20
3	1	C1	ML–MP	Basin	20 slabs	20
	2	C2	PE–CR	Basin	20 slabs	20
		C3	PE–MP	Basin	20 slabs	20
	3	C4	OWP–JA	LT	20 slabs	20
		C5	OWP–JL	LT	20 slabs	20
4	1	F1	ML	Basin	15.2 m (50 ft)	11
	3	F3	OWP	Basin	15.2 m (50 ft)	11
5	1	J1	ML–MP	Basin	10 slabs [b]	10 [c]
	2	J2	PE–CR	Basin	10 slabs [b]	10 [c]
		J3	PE–MP	Basin	10 slabs [b]	10 [c]
	3	J4	OWP–JA	LT	10 slabs [b]	10 [c]
		J5	OWP–JL	LT	10 slabs [b]	10 [c]
6	1	C1	ML–MP	Basin	10 slabs	10
	2	C2	PE–CR	Basin	10 slabs	10
		C3	PE–MP	Basin	10 slabs	10
	3	C4	OWP–JA	LT	10 slabs	10
		C5	OWP–JL	LT	10 slabs	10

Table 5. Details of test plans—*Continued.*

Test Plan	Pass #	Lane Spec.	Lane Description	Test Type	Test Interval	Number of Tests[a]
7	1	J1	ML–MP	Basin	10 slabs	10
	2	J2	PE–CR	Basin	10 slabs	10
		J3	PE–MP	Basin	10 slabs	10
	3	J4	OWP–JA	LT	10 slabs	10
		J5	OWP–JL	LT	10 slabs	10
	4	J7	WLE–CR	Basin	10 slabs	10
		J8	WLE–MP	Basin	10 slabs	10
8	1	F1	ML	Basin	30.4 m (100 ft)	6
	3	F3	OWP	Basin	30.4 m (100 ft)	6
9	1	J4	OWP–JA	LT	Every third joint/slab starting with first joint/slab	varies
		J5	OWP–JL	LT		varies
		J6	OWP–MP	Basin		varies
10	1	F1	ML	Basin	Same as J1/J3 before overlay	6
	3	F3	OWP	Basin		6
11	1	F1	ML	Basin	Same as J1/J3 before overlay	10
	3	F3	OWP	Basin		10
		F4	OWP–JA	LT	Same as J4/J5 before overlay	10
		F5	OWP–JL	LT		10

[a] For PCC testing, if fewer effective slabs exist at a section than the number listed in the “Test interval” column, the number of slabs to be tested should equal the number of slabs that exist.
[b] Test 20 slabs for 304.8 m (1,000 ft) test sections.
[c] 20 tests for 304.8 m (1,000 ft) test sections.

Abbreviations: ML–midlane; OWP–outer wheel path; PE–pavement edge; WLE–widened lane edge; MP–mid-panel; CR–corner; LT–load transfer; JA–joint approach (load plate on approach slab); JL–joint leave (load plate on leave slab)

Appendix A contains diagrams of these test plans.

5.3 TRANSVERSE LOCATIONS

The transverse location of a test pass is given as a relative position in the lane containing the LTPP test section. These relative positions are midlane (ML), outer wheel path (OWP), pavement edge (PE) and widened lane edge (WLE). As shown in table 6, these positions are to be measured from the outside lane edge (OLE) to the center of the FWD load plate.

Table 6. Transverse locations relative to outside lane edge.

Relative Position	Offset from OLE	
	3.66 m (12 ft) Nominal Lane Width	4.27 m (14 ft) Nominal Lane Width
ML	1800 mm ± 150 mm	1800 mm ± 150 mm
OWP	760 mm ± 75 mm	760 mm ± 75 mm
PE	150 mm[a] ± 75 mm	150 mm ± 75 mm
WLE	NA	150 mm[b] ± 75 mm

[a] If proper seating of the load plate at this offset is impossible due to pavement features, the offset may be increased.
[b] Testing in the widened lane edge is referenced to the outer edge of the pavement slab, not the OLE.

For a normal paving lane (nominally 3.7 m (12 ft) wide), the OLE is defined as the lane shoulder interface unless the outside edge of the painted shoulder stripe is more than 150 mm (6 inches) inside the lane shoulder interface, in which case the OLE is defined as the outside edge of the painted shoulder stripe. For a wide paving lane (nominally 4.0 m (13 ft) or wider), the OLE is defined as the outside edge of the painted shoulder stripe.

This transverse location must be maintained within the error band listed for all test locations in the test pass.

5.4 SLAB-REFERENCED LOCATIONS

FWD testing on PCC surfaces is referenced to effective slabs, not absolute longitudinal position. When testing has been performed at a PCC-surfaced section previously, then the operator should test the same slabs again as those tested previously. The operator should use form F10 to identify slabs tested previously. On form F10, slabs are referenced by the station of the joint or crack that defines the approach end of the slab. If a previously tested slab is subdivided by a new transverse crack, then that portion of the slab which is bounded by the original approach joint or crack and the new transverse crack should be tested.

If testing has not been performed previously at a PCC-surfaced section, then the operator should determine the number of slabs to be tested according to the test plan. Then the operator should determine the number of effective slabs that are wholly within the section limits (i.e., only count slabs that begin and end in the test section). Slabs can be bounded by either joints or full-width transverse cracks that are working.

If the number of effective slabs is less than or equal to the number of slabs to be tested, then all effective slabs should be tested. If the number of effective slabs is greater than the number of slabs to be tested, then a subset of the effective slabs equal to the number of slabs to be tested should be selected. The operator should take care to evenly space the slabs to be tested along the test section. Testing in all test passes at the section should be done in reference to the same slabs.

The test plans specify test locations relative to the slab to be tested as mid-panel, joint approach, joint leave, and corner.

5.4.1 Mid-Panel

Mid-panel testing should be performed with the load plate located as close to the center of the effective slab as possible. The load plate should be within 0.3 m (1 ft) or 10 percent of the effective slab length of the center (as measured along the test pass), whichever is smaller.

5.4.2 Joint Approach

Joint approach testing should be performed with the load plate tangent to the joint or crack defining the approach end of the slab to be tested. The load plate should be located on the slab immediately before the selected slab. The edge of the load plate should be within 50 mm (2 inches) of the joint, but under no circumstances should it bridge the joint. Figure 1 shows a diagram of joint approach testing.

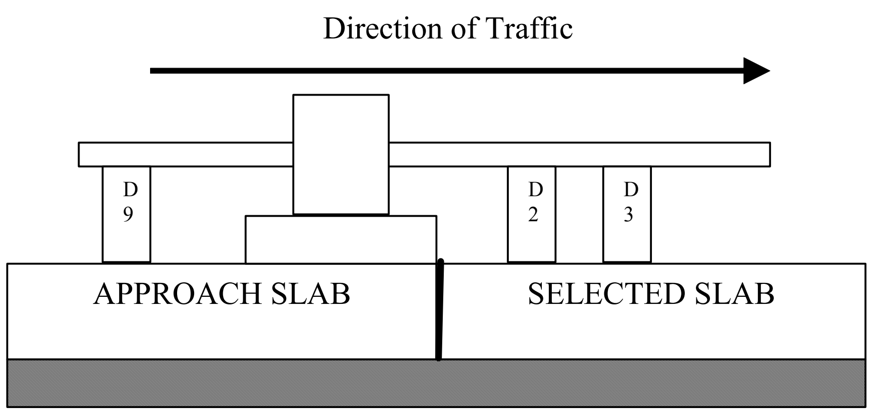


Figure 1. Diagram. Joint approach testing.

5.4.3 Joint Leave

Joint leave testing should be performed with the load plate tangent to the joint or crack defining the approach end of the slab to be tested. The load plate should be located on the selected slab and the edge of the load plate should be within 50 mm (2 inches) of the joint, but under no circumstances should it bridge the joint. A diagram of joint approach leave testing is shown in Figure 2.

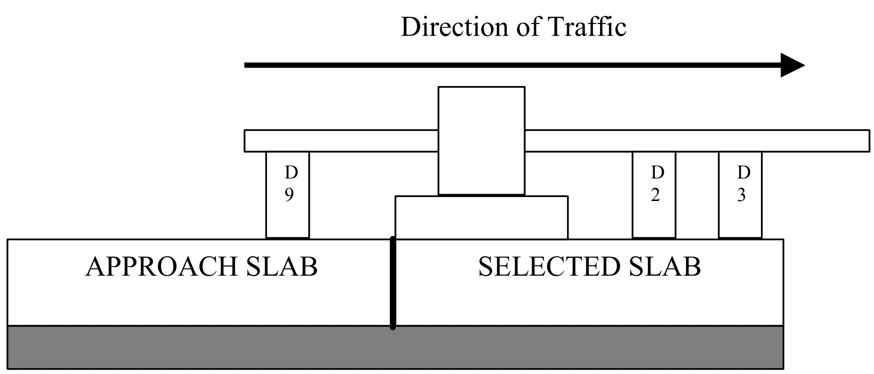


Figure 2. Diagram. Joint approach-leave testing.

5.4.4 Corner

For JCP pavements (test plans 2, 5, and 7), corner testing should be performed the same as joint leave testing except that the load plate should be tangent to both the joint or crack defining the approach end of the slab and the longitudinal joint defining the outside edge of the slab. The edge of the load plate should be no more than 75 mm (3 inches) from the joint or crack defining the approach end of the slab and no more than 75 mm (3 inches) from the longitudinal joint.

For CRCP pavements (test plans 3 and 6) the corner test should be performed with the load plate centered on the transverse crack defining the approach end of the effective slab and tangent to the longitudinal crack defining the outside edge of the slab. The edge of the load plate should be no more than 75 mm (3 inches) from the longitudinal joint.

6 OTHER MEASUREMENTS ASSOCIATED WITH FWD TESTING

6.1 TEMPERATURE GRADIENT MEASUREMENTS

Up to five holes should be drilled in the bound layers of the pavement for measuring sub-surface temperatures. Only holes that terminate in an unbound layer may be eliminated. Table 7 shows the depths to which the holes should be drilled.

Table 7. Temperature hole depths.

Hole Number	Hole Depth (mm)
1	25
2	50
3	100
4	200
5	300

1 mm = 0.039 inch

All holes should be drilled as close as possible to the depths listed in table 7. The tolerance for hole number 1 is ±5 mm (±0.2 inch). The tolerance for holes 2 through 5 is ±10 mm (±0.39 inch). The holes should be drilled in decreasing order of depth to allow extra time for the heat generated during drilling to dissipate.

If a hole is within ±25 mm (±0.98 inch) of the reported bottom of the bound layers, its depth should be decreased to 25 mm above the reported bottom of the bound layers.

The holes should be drilled in the center of the OWP, but they should be offset at least 0.5 m (1.64 ft) from each other in the longitudinal direction. For GPS sections, the holes should be located on both ends of the test section, just outside the monitoring area. Typically the holes should be located near station 0-001 (0-03) and 0+153.4 (5+03). For SPS sections, holes should be located at only one end of the section, just outside the monitoring area. The operator should choose the end of the section that is most representative of the monitoring area.

Holes should be drilled with a portable hammer drill using a 13-mm (0.51-inch) diameter bit. After the hole is drilled to the required depth, it should be cleared of debris and dust by blowing through a short piece of plastic tubing or other suitable device. The actual depth of the hole should be measured after it is cleared of debris. Then it should be filled with 15 to 25 mm (0.59 to 0.98 inch) of mineral oil to provide thermal conductivity between the pavement and the temperature probe. The hole should be covered with tape (such as duct tape) and the tape slit to allow the probe to be inserted.

In addition to subsurface temperature measurements, an infrared (IR) surface temperature measurement should be obtained at the same time that subsurface temperature readings are obtained. The location of the measurement should also be in the OWP and at least 0.5 m (1.64 ft) from the nearest hole in the longitudinal direction. The operator should take care that the area where the IR surface temperature is taken is free of oil, dirt, and other foreign debris. During temperature measurements the hand-held IR device should be held at a height consistent with the height of the FWD-mounted IR measurement device. IR temperate measurements should be taken three times in quick succession. The results should be averaged and entered on form F01.

6.2 JOINT/CRACK WIDTH MEASUREMENTS

Joint/crack width measurements should be taken only on PCC surfaced pavements. An exception is testing done in accordance with test plan 11. On flexible surfaced pavements, cracks should be noted according to the instructions in manual section 6.3.

On PCC surfaced pavements, joint/crack width measurements should be taken for at least 25 percent of the load transfer tests; however, operators are encouraged to perform such measurements for all load transfer tests if time permits.

Joint/crack width measurements should be performed using calipers with tapered jaws for measuring inside dimensions. The resolution of the calipers should be at least 0.3 mm (0.01 inch).

On transverse cracks, the goal is to measure the minimum width of the opening that extends through the pavement. If the cracks are spalled, the width of the opening may need to be estimated.

On sawed joints, the goal is the measure the sawn width (as opposed to the actual opening). It may be necessary to depress the joint sealant to measure the opening, especially if the joints are spalled.

Joint/crack width openings should be measured at several points in the OWP, and the measurements averaged and rounded to the nearest 1 mm (0.039 inch). This average should be entered into the FWD data collection software in the appropriate field.

Measurements less than 1 mm are hard to make with calipers because the jaws are too wide to enter the opening. In these situations, the measurement should be recorded as 1 mm (0.039 inch). Measurements in excess of 25 mm (0.98 inch) should be recorded as 25 mm (0.98 inch).

6.3 DISTRESS IDENTIFICATION AND COMMENTING

The type and severity of pavement distress may influence the deflection response of a pavement; therefore, FWD operators should record any distress within the lane tested from about 0.3 m (11.81 inches) in front of the forward most deflection sensor to 0.9 m (35.4 inches) behind the load plate and from 0.3 m (11.81 inches) on the left of the load plate to 0.3 m (11.81 inches) on the right of the load plate. The operator should enter this information at the “Comments” prompt immediately following the test sequence. Where possible, operators should use standard abbreviations listed in tables 8 and 9. Operators should avoid other abbreviations unless they are necessary because of space limitations.

Table 8. Standard abbreviation list—distress.

Category	Full Word or Phrase	Standard Abbreviation
Distress	Bleeding	BLD
	Block cracking	BCR
	Blowups	BLWUP
	Corner break	CBRK
	Durability cracking	DCR
	Edge crack	ECR
	Fatigue crack	FCR
	Faulting	FLT
	Joint seal damage	JTSD
	Lane shoulder dropoff	LSDROP
	Longitudinal crack	LCR
	Map cracking	MAP
	Patch	PATCH
	AC patch	ACPATCH
	PCC patch	PCPATCH
	Polished aggregate	POLAG
	Popouts	POUT
	Pothole	PTHL
	Pumping	PUMP
	Ravelling	RVL
	Rough surface	RSURF
	Rutting	RUT
	Scaling	SCL
	Shoving	SHOV
	Spalling	SPL
	Transverse crack	TCR
	Transverse construction joint damage	TCJTD
	Low severity	LSEV
	Moderate severity	MSEV
	High severity	HSEV

Table 9. Standard abbreviation list—equipment, lane geometry, miscellaneous.

Category	Full Word or Phrase	Standard Abbreviation
Equipment	Load plate	LP
	Deflection sensor	DS (or DS1, DS2 ...)
	Excess variation	EXVAR
	Nondecreasing deflections	NDD
	Roll-off	ROFF
	Rejection	RJCT
	Accept	ACPT
	Sensor bar	SBAR
	Air temperature	ATMP
	Surface temperature	STMP
	Deflection	DEFL
	Load	LD
Lane Geometry	Inner wheel path	IWP
	Outer wheel path	OWP
	Both wheel paths	BWP
	Mid-lane	ML
	Outer lane edge	OLE
	Inner lane edge	ILE
	Lane stripe	LSTR
	Shoulder stripe	SHSTR
	Joint	JT
	Longitudinal joint	LJT
	Transverse joint	TJT
Miscellaneous	Between	BTWN
	Core hole	CHOLE
	Due to time limitations	DTTL
	Due to weather conditions	DTWC
	Moved forward	MVFRD
	Test pit	TPIT
	Truck traffic	TRKTRF

6.4 OTHER COMMENTS

In addition to distress comments, other unusual conditions or events deserve comments. Operators should comment on data with nondecreasing deflections, excess variation, or other software-generated errors that could not be cleared by following the instructions in manual section 6. Operators should also comment on other events such as delays in testing because of breakdowns or weather, pavement changes within the section, moisture seeping out of cracks, or other conditions that could affect deflection measurements.

7 ERROR CONDITIONS

As described in manual section 4.3.4, several data checks should be enabled in the FWD data collection software. They are described in the following paragraphs.

7.1 ROLL-OFF

"Roll-off" is an error condition that results when the deflection of the pavement surface as recorded by a deflection sensor does not return to near zero within 60 ms of the trigger activation. Unless the pavement structure is weak enough to be permanently deformed by the load pulse, this is not a believable measurement. All LTPP test sections have sufficient strength that roll-off can only be to the result of measurement error.

Roll-off can be caused by poor contact between the deflection sensor and the pavement surface. This error can be incorrectly triggered when magnitude of the deflection approaches the resolution of the geophone. Thus, roll-off when the peak deflection is less than 25 μm (0.83 inch) is not necessarily indicative of error.

If the roll-off error is triggered on a deflection that is greater than 25 μm (0.83 inch), then the operator should follow the error resolution instructions in manual section 7.6. Otherwise the measurement should be accepted and testing should continue.

7.2 NONDECREASING DEFLECTIONS

"Nondecreasing deflections" is an error condition that results when the deflections measured by the deflection sensors do not decrease with increasing distance from the load plate. Deflections should always decrease with increasing distance from the load plate.

This condition can sometimes occur legitimately if there is a transverse crack or other discontinuity between the two sensors that exhibit the nondecreasing deflections. If the operator observes such a crack or discontinuity between the two flagged sensors, then the test should be accepted and the observation should be recorded at the "Comments" prompt.

Nondecreasing deflections can sometimes be triggered incorrectly when the magnitude of the deflections approaches the resolution of the deflection sensor. If the larger of the two deflections is less than 10 μm (0.39 inch), then the test should be accepted, and testing should continue.

Nondecreasing deflection may sometimes occur between deflection sensors 1 and 2 on extremely weak pavements because of permanent deformation of the pavement by the FWD. Nondecreasing deflections between deflection sensors 1 and 2 have also been observed on very stiff PCC pavements where the deflection basin is fairly uniform near the load plate and the difference in deflections in that area is less than the random error inherent to the deflection sensors.

If the deflections are not small and there are no cracks or discontinuities, or the nondecreasing deflections are not between sensors 1 and 2 and the pavement is not very weak or very stiff, then this error usually indicates poor seating between one or both of the flagged sensors and the pavement surface. The operator should follow the error resolution instructions in manual section 7.6.

7.3 OVERFLOW

"Overflow" is an error condition that results when a measured deflection exceeds the range of the deflection sensor. For the FWDs operated by LTPP, this range is 2,000 microns (80 mils, or 0.08 inch). Deflections of that magnitude are only expected on extremely weak pavements or when testing using extremely high load levels. For testing at an LTPP test section using the load levels specified in this document, it is not reasonable to expect that the deflections will exceed 2,000 microns (80 mils, or 0.08 inch).

If this error is encountered during testing, it is likely that the flagged sensor does not have good contact with the pavement surface. The operator should follow the error resolution instructions in manual section 7.6.

7.4 LOAD VARIATION

"Load variation" is an error condition that results when the peak load for repeat drops at the same drop height varies by more than the amount specified in manual section 4.3.4. This condition can occur legitimately on weak pavements where the structure is damaged by FWD testing, or on pavements with a saturated base or subgrade layer (such as during the spring thaw in wet-freeze zones). It may also occur if the load plate is not seated properly on the pavement surface, either because of loose debris or irregularities in the pavement surface.

If this error occurs during testing, the operator should follow the error resolution instructions in manual section 7.7.

7.5 DEFLECTION VARIATION

"Deflection variation" is an error condition that results when the load-normalized peak deflections for repeat drops vary by more than the amount specified in manual section 4.3.4. This condition can occur legitimately only if the stiffness of the pavement is changed by the FWD testing itself. This generally occurs only if the pavement is extremely weak or the unbound layers are saturated.

Deflection variations can occur as a result of uneven pavement surface conditions causing poor seating of the load plate or deflection sensors or vibrations generated by heavy equipment operating nearby, especially trucks traveling in adjacent lanes.

If this error occurs during testing, the operator should follow the error resolution instructions in manual section 7.6.

7.6 DEALING WITH DEFLECTION ERRORS

If deflection errors occur, the operator must attempt to identify the source of those errors. If the errors caused by the FWD equipment, then those problems must be fixed before testing continues. If the errors result from localized pavement conditions, the operator should reposition the FWD and comment on the condition. If the errors are the result of pavement conditions that are representative of the test section as a whole, or due to factors beyond the operator's control such as truck traffic, the operator should accept the error and comment on the condition. Manual sections 7.1, 7.2, 7.3, and 7.5 detail possible causes of the various types of deflection errors.

If the deflection errors appear to be to the result of truck traffic in an adjacent lane, the operator should attempt to pause the test sequence to allow the trucks to pass, and then continue the sequence during lulls in the traffic. If there are too many trucks for this method to be practical, the operator should provide a comment for drop sets that were potentially affected by the truck traffic.

Operators must be very careful to not to overlook the FWD equipment itself as the source of the error. The following list is a summary of the troubleshooting process that is recommended in all cases, and the operator should deviate from the process only when confident of the source of the error, and the error source is not well suited for resolution using this troubleshooting process.

7.6.1 For the first such error at a test location, it is recommended that the operator get out of the tow vehicle and check the flagged deflection sensor (or sensors). Check that the deflection sensor is seated securely in the sensor holder, that the screws retaining the sensor magnet and sensor holder are tight, that the deflection holder is not resting on a loose stone or crack, and that the holder springs and foam bushing are in good shape.

7.6.2 If several sensors are flagged, it is recommended that the operator check all analog connections: sensor to control box, control box to multisignal cable and multisignal cable to signal processor.

7.6.3 The data should be rejected and the test repeated without repositioning the FWD.

7.6.4 If the errors persist, the operator must reject the test and perform the optional activities in manual section 7.6.1 and 7.6.2. If problems with the equipment are discovered and corrected, all data collected in this test pass should be discarded, and the test pass should be restarted.

7.6.5 If errors persist and the test being performed is a load transfer test, or if the FWD cannot be moved forward because of a joint or transverse crack, then the results should be accepted whether or not they contain errors. The operator should enter a comment stating "Error could not be resolved."

7.6.6 If the errors persist and the FWD can be repositioned, the operator should reject the data and move the FWD forward .6 meters (2 ft). The operator should repeat the test a fourth time. If the errors persist the operator should accept the results and at the prompt enter a comment stating “Error could not be resolved.”

7.6.7 If the error could not be cleared, then for all subsequent errors of the same type in the same test pass the activities listed in manual sections 7.6.1 and 7.6.2 need not be repeated.

7.7 DEALING WITH LOAD ERRORS

If load errors occur, the operator must attempt to identify the source of those errors. If the errors result from problems with the FWD equipment, then those problems must be fixed before testing continues. If the errors are caused by localized pavement conditions, the operator should reposition the FWD and comment on the condition. If the errors are caused by pavement conditions that are representative of the test section as a whole, the operator should accept the error and comment on the condition. Manual section 7.4 gives details of the possible causes of load errors.

Operators must be very careful to not to overlook the FWD equipment itself as the source of the error. The following summary of the troubleshooting process is recommended in all cases, and the operator should deviate from it only if confident of the source of the error and the error source is not well suited for resolution using the troubleshooting process.

7.7.1 The data should be rejected and the test repeated without repositioning the FWD.

7.7.2 If the error persists, the operator should get out of the tow vehicle and check the equipment. All analog connections should be checked: load cell to load cell cable, load cell cable to control box, control box to multisignal cable and multisignal cable to signal processor. The weight height targets should be checked to ensure that they are tight. The load plate should be raised and the swivel checked to ensure that it moves easily. Check the rubber sheet and pavement surface under the load plate for debris, and remove any .

7.7.3 Reject the data and repeat the test without repositioning the FWD.

7.7.4 If errors persist and the test being performed is a load transfer test, or if the FWD cannot be moved forward because of a joint or transverse crack, then accept the results whether or not they contain errors. Enter a comment stating “Error could not be resolved.”

7.7.5 If the errors persist and the FWD can be repositioned, reject the data and the move the FWD moved forward .6 m (2 ft). Repeat the test a third time. If the errors persist then accept the results, and enter a comment stating “Error could not be resolved.”

7.7.6 If the error could not be cleared, then for all subsequent errors of the same type in the same test pass, the operator need not repeat the activities in step 7.7.2.

8 CALIBRATION AND VERIFICATION

Highly accurate load, deflection, and associated data are necessary to meet the requirements of the LTPP program. This section includes several calibration and verification requirements to ensure the accuracy of FWD measurements. If the FWD cannot meet the requirements of any of these procedures, it may not be used to collect data for LTPP. In such a situation the operator should fill out and submit an FWD Problem Report (FWDPR) (see appendix B) to the FHWA LTPP FWD task leader with copy to the TSSC.

8.1 REFERENCE CALIBRATION

Every FWD performing data collection on behalf of LTPP should undergo yearly reference calibration. An exception is units testing in Hawaii, Alaska, and Puerto Rico. This calibration must be performed at one of the four calibration centers established by the Strategic Highway Research Program (SHRP), or at an equivalent center as determined by the FHWA LTPP FWD task leader. The nominal yearly interval should not exceed 400 days.

If the FWD load cell or signal processor is replaced, the FWD should undergo reference calibration before performing testing on behalf of LTPP regardless of the interval since the previous reference calibration.

If a major component such as a deflection sensor, multisignal cable, or trailer printed circuit board (PCB) board is replaced, the FWD should undergo reference calibration as soon as practical, but in the meantime it can be used to collect data on behalf of LTPP.

The most recent version of the FHWA *LTPP FWD Reference and Relative Calibration Manual* should be followed during reference calibration.

8.2 RELATIVE CALIBRATION

Data should not be collected by an FWD on behalf of LTPP unless the FWD has undergone relative calibration within the previous 42 days. If the FWD is in regular use, relative calibration should be performed on a nominal monthly interval. Relative calibration should not be performed during periods when the FWD is idle.

If a major component such as a deflection sensor, multisignal cable, or trailer PCB board is replaced, the FWD should undergo relative calibration before continuing to collect data on behalf of LTPP, regardless of the interval since the previous relative calibration.

The most recent version of the FHWA *LTPP FWD Reference and Relative Calibration Manual* should be followed during relative calibration.

8.3 DMI CALIBRATION

Every FWD performing data collection on behalf of LTPP should undergo DMI calibration monthly while in service. Data should not be collected unless the FWD has undergone DMI calibration within the previous 42 days.

If the tow vehicle undergoes maintenance, including replacement of tires, the DMI should be recalibrated before continuing to collect data on behalf of LTPP, regardless of the interval since the previous DMI calibration.

The FWD DMI is calibrated by driving the vehicle over a known distance. The FWD data collection software can then calculate an appropriate calibration factor.

The section used for DMI calibration must be straight, at least 150 m (492.13 ft) in length, and reasonably level. Because the FWD must be stopped at each end of the section, it cannot be performed on an active highway without traffic control. The section must be surveyed before the DMI calibration. The section should be measured using a surveyor's tape (a measuring wheel is not acceptable). Ensure that the proper tension and alignment is applied to the tape. The operator should fill out form F07 immediately after each DMI calibration.

Immediately before DMI calibration, the tire pressure for all of the tow vehicle tires should be set to the manufacturer's specification, and then the operator should drive the vehicle at least 15 min at highway speeds. The *LTPP FWD Data Collection Software Manual* has instructions on how to operate the FWD data collection software during DMI calibration.

8.4 TEMPERATURE SENSOR VERIFICATION

Every temperature sensor collecting data associated with LTPP FWD measurements should have its accuracy verified monthly, and unless the temperature sensor has been verified during the previous 42 days, data should not be collected.

Following is a summary of a verification procedure; it should not be used as a calibration procedure. If a temperature sensor fails this procedure, it should be returned to the manufacturer for repair or recalibration, or it should be replaced with a new sensor.

8.4.1 The following equipment and supplies are required for this procedure:

- National Institute of Standards and Technology (NIST) traceable mercury thermometer (reference thermometer).
- 4-liter (L) (1-gallon (gal)) bucket.
- Hot plate.
- Large wooden spoon or paint stirrer.
- Medium-sized cooking pot, approximately 125 mm (5 inches) in diameter.
- Leather heat-resistant gloves.
- Cooking oil (about 0.5 L (1 pint)).
- Ice.

- Water.
- Copies of forms F08 and F09 (see appendix B).

8.4.2 Park the FWD and tow vehicle on a smooth surface in an area with good ventilation that is not exposed to direct sunlight.

8.4.3 Start the FWD data collection software and enter a screen from which the air and IR surface temperature measurements can be read. Further instructions are given in the *LTPP FWD Data Collection Software Manual*.

8.4.4 Unclip the FWD air temperature mounted sensor so that it hangs freely.

8.4.5 Prepare an ice water bath. Place ice and water in the 4 liter (1 gal) bucket and stir with the wooden spoon or paint stirrer. Stir until the reference temperature records a temperature that is less than or equal to 2 °C (35.6 °F).

8.4.6 Place the bucket under the FWD air temperature mounted sensor. When the reading from the IR temperature stabilizes, record the temperature from both the IR sensor and the reference thermometer on form F08. Remove the reference thermometer, then stir the ice bath for 1 min, and record the measurements from both sensors again. If the recorded temperatures vary by more than 2 °C (3.6 °F) for either data set, stir for another minute, and then record both temperatures again. If the IR temperature sensor varies by more than 2 °C (3.6 °F) from the reference thermometer for two or more data sets, then the IR temperature sensor is unacceptable.

8.4.7 Repeat the procedure in 8.4.6 for the hand-held IR temperature sensor. Hold the hand-held IR temperature sensor at a height consistent with the FWD-mounted IR temperature sensor.

8.4.8 Stir the ice bath for another minute. Place the FWD air temperature mounted sensor and the reference thermometer in the bath. When the reading from the air temperature sensor stabilizes, record the readings of both sensors. Stir for another minute and record both temperatures again. If the recorded temperatures vary by more than 2 °C (3.6 °F) for either data set, stir for another minute, and then record both temperatures again. If the air temperature sensor varies by more than 2 °C (3.6 °F) from the reference thermometer for two or more data sets, then the air temperature sensor is unacceptable.

8.4.9 Repeat the procedure in 8.4.6 for the hand-held temperature probe.

8.4.10 Prepare the room temperature water bath. Empty the bucket and fill it with warm tap water. Allow it to sit for 10 min and then stir for 1 min.

8.4.11 Place the bucket under the FWD air temperature mounted sensor. When the reading from the IR temperature sensor stabilizes, record the temperature from both the IR sensor and the reference thermometer on form F08. Stir the water for 1 min and then record the measurements from both sensors again. If the recorded temperatures vary by more than

2 °C (3.6 °F) for either data set, stir for another minute and then record both temperatures again. If the IR temperature sensor varies by more than 2 °C (3.6 °F) from the reference thermometer for two or more data sets, then the IR temperature sensor is unacceptable.

8.4.12 Repeat the procedure in 8.4.11 for the hand-held IR temperature sensor. Hold the hand-held IR temperature sensor at a height consistent with the FWD-mounted IR temperature sensor.

8.4.13 Stir the water for another minute. Place the FWD air temperature mounted sensor and the reference thermometer in the water. When the reading from the air temperature sensor stabilizes, record the readings of both sensors. Stir for another minute and record both temperatures again. If the recorded temperatures vary by more than 2 °C (3.6 °F) for either data set, stir for another minute and then record both temperatures again. If the air temperature sensor varies by more than 2 °C (3.6 °F) from the reference thermometer for two or more data sets, then the air temperature sensor is unacceptable.

8.4.14 Repeat the procedure in 8.4.13 for the hand-held temperature probe.

8.4.15 If any IR temperature sensor was determined to be unacceptable in the low temperature or ambient temperature check, then it need not be checked at the high temperature. The high temperature check is optional if it is being performed in the field. The high temperature check is to be performed only for IR temperature sensors.

8.4.16 Prepare the high-temperature oil bath. Pour cooking oil into the cooking pot to a depth of approximately 50 mm. Place the cooking pot on the hot plate and under the FWD air temperature mounted sensor. Stir the oil while it is warming on the hot plate. The operator who is stirring the oil must wear gloves. Heat until the oil temperature stabilizes at 60 °C (140 °F) (± 5 °C) (±3.6 °F), as determined using the FWD IR temperature sensor.

8.4.17 Record the FWD IR temperature sensor and reference thermometer readings. Wait 5 min, and then record both sensors again. If the recorded temperatures vary by more than 2 °C (3.6 °F) for either data set, then wait 5 min and record both temperatures again. If the IR temperature sensor varies by more than 2 °C (3.6 °F) from the reference thermometer for two or more data sets, then the IR temperature sensor is unacceptable.

8.4.18 Repeat the procedure in 8.4.17 for the hand-held IR temperature sensor. Hold the hand-held IR temperature sensor at a height consistent with the FWD-mounted IR temperature sensor.

8.5 REPORTING REQUIREMENTS

8.5.1 Reference Calibration

For LTPP-operated FWD equipment, the operator should submit the reference calibration results to the FHWA LTPP FWD task leader within 7 days after the calibration is completed. For non LTPP-operated FWD equipment collecting data on behalf of LTPP, the reference calibration results should be submitted to the FHWA LTPP FWD task leader within 30 days of the time it first collects data for LTPP with those calibration factors.

A copy of all reference calibration results should be kept in the RSC office. A paper copy of the most recent reference calibration results should be kept in the FWD tow vehicle.

8.5.2 Relative Calibration

A copy of all relative calibration results for LTPP-operated FWD equipment should be kept at the RSC office. A paper copy of the results of the most recent relative calibration should be kept in the FWD tow vehicle. It is not necessary to submit copies to the FHWA LTPP FWD task leader.

8.5.3 DMI Calibration

The operator should fill out form F07 each time the DMI is calibrated. The RSC office should keep a copy of all completed form F07s for LTPP-operated FWD equipment. A paper copy of the most recently completed form F07 should be kept in the FWD tow vehicle. It is not necessary to submit copies to the FHWA LTPP FWD task leader.

8.5.4 Temperature Sensor Verification

A copy of all completed forms F08 and F09 for LTPP-operated FWD equipment should be kept at the RSC office. A paper copy of the most recently completed forms F08 and F09 should be kept in the FWD tow vehicle. It is not necessary to submit copies to the FHWA LTPP FWD task leader.

9 EQUIPMENT CHECKS

Because of the extensive use of FWDs in LTPP, routine equipment checks are extremely important. The FWD operator should perform the checks in this section each day that the FWD is traveling or in operation. These checks are a minimum. Operators are expected to keep an eye out for other anomalous conditions while performing these checks. These checks are not to supersede the manufacturer's minimum requirements for warranty compliance.

An operator must address any deficiencies noted while performing these checks before any further transit or testing.

9.1 BEFORE-TRANSIT CHECKS

The operator should perform the following checks on the tow vehicle before the start of travel for the day:

- Fluid levels:
  - Engine oil.
  - Brake fluid.
  - Power steering.
  - Wiper fluid.
  - Coolant.
  - Transmission fluid.
- Battery connections.
- Hose conditions.
- Tires inflated properly and in good condition.
- Lights operational:
  - Headlights.
  - Taillights.
  - Turn signals.
  - Brake lights.
  - Strobe lights.
- Interior uncluttered, equipment stowed well.

The operator should perform the following checks on the FWD trailer before the start of travel for the day:

- Ball tight.
- Safety chains in place.
- Breakaway cable connected.
- Break fluid level good (for trailers with hydraulic brakes).
- Trailer battery connections good.
- Lights operational:
  - Taillights.

- Turn signals.
- Brake lights.

- Tires inflated properly and in good condition.
- Transport locks engaged.
- Hitch pin in front sensor bar guide.
- Covers and latches secure.

9.2 BEFORE-OPERATIONS CHECKS

At a minimum, the FWD operator should perform the following checks after the FWD arrives at the test site and before testing begins:

- Trays removed.
- Transport locks unlocked.
- Hitch pin removed from front sensor bar guide.
- Hydraulic oil level good.
- Raise/lower bar cable not frayed and well adjusted.
- Geophones well-seated in geophone holders.
- Geophone holder springs and foam guides in good condition.
- Ribbed rubber sheet on load plate in good condition.
- Load plate swivel free-moving.
- Pressure switch boots in good condition.
- Trailer control box electrical connections tight.
- Buffers have no cracks or slits, and are level and tight.

In addition, the operator should observe and listen to the hydraulics during the buffer warm-up sequence to ensure that they are free of air and operating correctly.

9.3 POST-OPERATIONS CHECKS

At a minimum, the FWD operator should perform the following checks before leaving the test site:

- Transport locks engaged.
- Hitch pin replaced in front sensor bar guide.
- Pan replaced and secure.
- Trailer access doors locked.
- All supplemental testing equipment properly stowed.
- Paper forms filed out, dated, signed, and filed.

10 MAINTENANCE AND REPAIR

The RSCs are responsible for the maintenance and repair of the FWDs that they operate. This includes scheduled maintenance and reactive maintenance. FWDs should be maintained in accordance with the manufacturer's recommendations and the *LTPP FWD Maintenance Manual*, publication number FHWA-LTPP-05-153. All maintenance and repair activities performed on LTPP-operated FWDs should be documented using form F03.

11 COLD WEATHER FWD TESTING

The FWD tow vehicle should be warmed to achieve an interior temperature of at least 5 °C (40 °F) before turning on the signal processor or data collection computer.

For testing in ambient temperatures at or below −10 °C (15 °F), the standard hydraulic fluid should be replaced with a lighter-weight synthetic fluid or other oils as recommended by the manufacturer. Some oils may not be appropriate for warm-weather operations.

12 DATA HANDLING PROCEDURES

12.1 FIELD DATA HANDLING PROCEDURES

If conditions permit, the operator should process all FWD data collected at a site using FWDConvert and FWDScan before leaving the site. The operator should resolve errors generated by FWDScan and note any necessary changes to the file for correction by office personnel. A backup of the Pavement Deflection Data Exchange (PDDX) file should be made on removable media. This backup, along with the original on the FWD data collection computer, should be kept in the FWD until the office acknowledges receipt. If conditions do not allow the operator to do this work before leaving the site, the operator should do the work as soon as convenient, but no more than 24 hours after data collection.

The operator should submit completed copies of forms F01, F02, and F05 to the office along with the electronic FWD data.

12.2 OFFICE DATA HANDLING PROCEDURES

Electronic data should be received from the field along with completed copies of forms F01, F02, and F05. RSC office personnel should verify that the information on these forms corresponds to the electronic data received. Office personnel should resolve discrepancies before processing further data.

Even though the operator processed the data with FWDScan in the field, office personnel should process it through FWDScan in the office. The Office personnel should review FWDScan output and investigate warnings or errors present in the output file. If office personnel make modifications to the data file, the information should be reprocessed through FWDScan. Upload of a file in which FWDScan found errors may cause referential problems in the LTPP Pavement Performance Database, and uploading such a file should be done only with the approval of the regional database manager.

FWD data files should be uploaded to the Regional Information Management System (RIMS) using the most recent version of the upload filter provided for that purpose. Manual temperature measurements should be entered using the RIMS form provided for that purpose.

Office personnel should archive the PDDX data file and paper forms according to the latest version of the applicable LTPP General Operations (GO) directives.

13 DOCUMENTATION

The following documentation should be kept in the FWD tow vehicle when it is collecting data on behalf of LTPP:

- *LTPP Manual for Falling Weight Deflectometer Measurements.*
- *LTPP FWD Data Collection Software Manual.*
- *Distress Identification Manual for the Long-Term Pavement Performance Program.*
- *SHRP-LTPP FWD Calibration Protocol.*
- *FWDConvert Software User's Manual.*
- *FWDScan Software User's Manual.*
- *FWDCal Software User's Manual.*

Only the most recent version of each document should be kept.

In addition, all active LTPP FWD and applicable GO directives should be kept in the tow vehicle. Inactive directives should not be kept in the tow vehicle.

The operator should keep at least five blank copies of all forms in appendix B of this manual in the tow vehicle.

14 VERSION HISTORY

14.1 VERSION 1.0

The initial version of this manual , the *SHRP-LTPP Manual for FWD Testing and Operational Field Guidelines,* was released January 1989 (SHRP reference "SHRP-LTPP-OG-002"). This guide included instructions for testing with edition 10 of the Dynatest FWD data collection software only. This guide included only three test plans: flexible, JCP, and CRCP sections, and it was applicable to only GPS testing.

14.2 SPS 3 AND SPS 4 SUPPLEMENT TO VERSION 1.0

The Pavement Maintenance Effectiveness Program of SHRP published modifications to version 1.0 of the FWD guide for testing at SPS 3 and SPS 4 test sections. The following modifications were published in SHRP report SHRP-H-358 dated November 1993 (pages 134–137); however, the modifications were in effect before that date:

- SPS 3 sections, testing interval set to 30 m (100 ft) instead of 8 m (25 ft).
- For SPS 3 sections, only three drops at each drop height are to be recorded, instead of four.
- For SPS 4 sections, testing is to be performed at every third panel.
- For SPS 4 sections, all testing is to be performed in the OWP. This includes JA, JL, and MP testing. (For MP testing on SPS 4 sections, lane specification 'J6' is now used; however, this was not specified in the supplement.)
- For SPS 4 sections, only three drops at each drop height are to be recorded for loss of support testing instead of four.

14.3 VERSION 2.0

Major update released May 7, 1993.

- Appendix B includes specific test plans for all SPS experiments.
- Relative calibration procedure updated.
- Reference calibration procedure added in appendix A.

14.4 VERSION 3.0

Major update released January 21, 2000.

- Updated for use with edition 25 of the Dynatest FWD data collection software.
- Deflection sensor spacing updated for nine active sensors.
- Added verification procedure for FWD-mounted temperature sensors and Temperature Sensor Checks (TSCs) form.
- Removed relative calibration procedure from main body of document.

- Replaced reference calibration procedure with "SHRP/LTPP FWD Calibration Protocol" (March 1994) in appendix F. (This protocol includes a relative calibration procedure.)

14.5 VERSION 3.1

Minor update released October 31, 2000.

- Fixed some figures, typos, and formatting.
- Updated to reflect further changes to the Dynatest edition 25 software.

14.6 VERSION 4.0

Major update released April 1, 2005. This is the first complete rewrite of the *LTPP Manual for Falling Weight Deflectometer Measurements* since version 1.0.

- Removed FWD data collection software-specific information. (This information was placed in the *LTPP FWD Data Collection Software Manual.)*
- Integrated test plans in appendices A and B into main body of document to reduce redundancy (sections 5.1 and 5.2).
- Removed appendix C because Seasonal Monitoring Program (SMP) testing was no longer being performed.
- Removed appendix D because P59 (subsurface testing) was no longer being performed.
- Removed appendix E because it was a copy of LTPP Directive GO-21 that may be superseded in the future.
- Removed appendix F because it was a copy of a separate document ("SHRP-LTPP FWD Calibration Protocol") that may be updated.
- Removed appendices G and H because they were specific to the FWD data collection software.
- Integrated LTPP Directive FWD-24, "Modifications to LTPP FWD Geophone Holders," in body of document (section 4.1.1).
- Integrated LTPP Directive FWD-27, "Thermal Gradient Temperature Measurements During Deflection Testing," in body of document (section 6.1).
- Integrated LTPP Directive FWD-28, "Storage of LTPP FWD Raw (Peak and Time History) Data," in body of document (section 12.2).
- Required all testing to be performed with drop load within 10 percent of target value (section 4.2).
- Required monthly verification of hand-held temperature instruments as well as FWD-mounted temperature instruments (section 8.4).
- Added forms F05, F06, F07, F08, F09, and F10. (Forms F08 and F09 replace the TSC form.)
- Modified drop sequence for SPS 3 and SPS 4 sections to match standard LTPP drop sequence.
- Added "Unit Conversions for common FWD-Related Measurements" (appendix B).

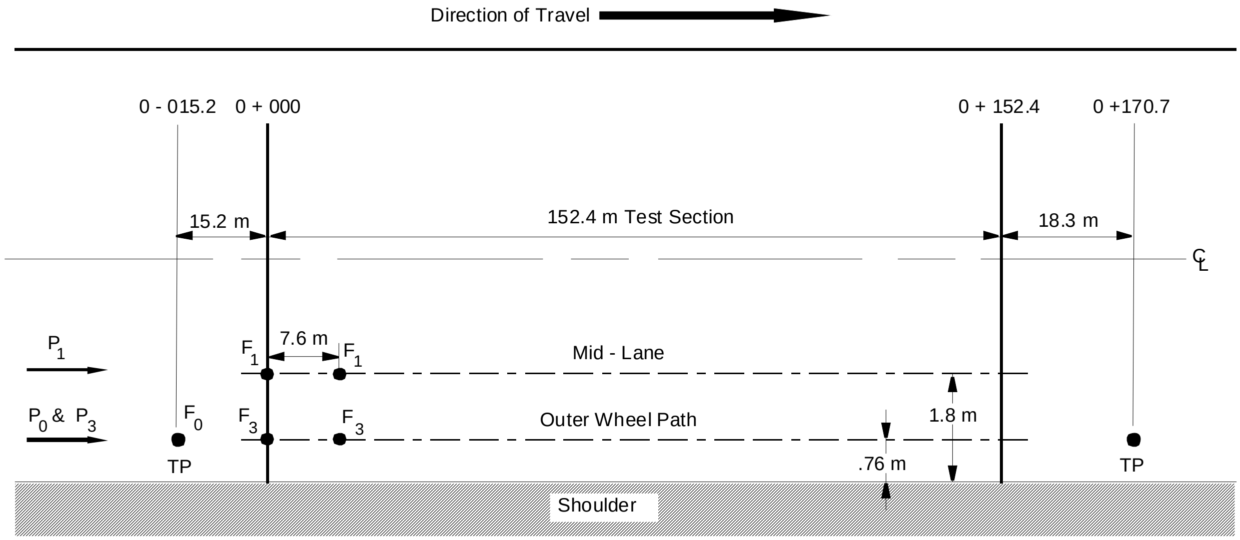
14.7 VERSION 4.1

Minor update released July 1, 2006.

- Clarified relative calibration interval in section 8.2 to indicate that the relative calibration is not required during extended periods when the FWD is not in service.
- Made various minor formatting changes required for official publication by FHWA.
- Added reference to *LTPP FWD Maintenance Manual*, FHWA-LTPP-05-153, in section 10.

Appendix A: Diagrams of FWD Test Plans

This appendix contains the 11 diagrams of the FWD test plans.

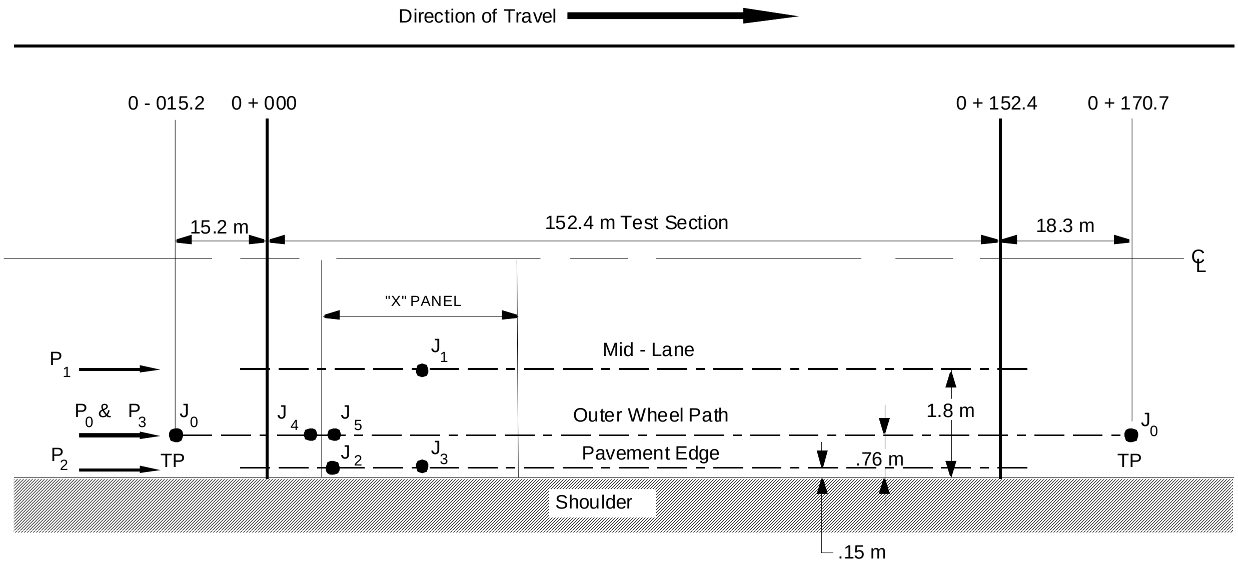


NOTES:

1. FWD tests to be conducted at test pit locations (TP) on P_0 (First set of tests).
2. See Table A-1 for further details.
3. Lateral offsets shown represent nominal distances.

1 m = 3.28 ft

Figure 3. Diagram. Test plan 1.

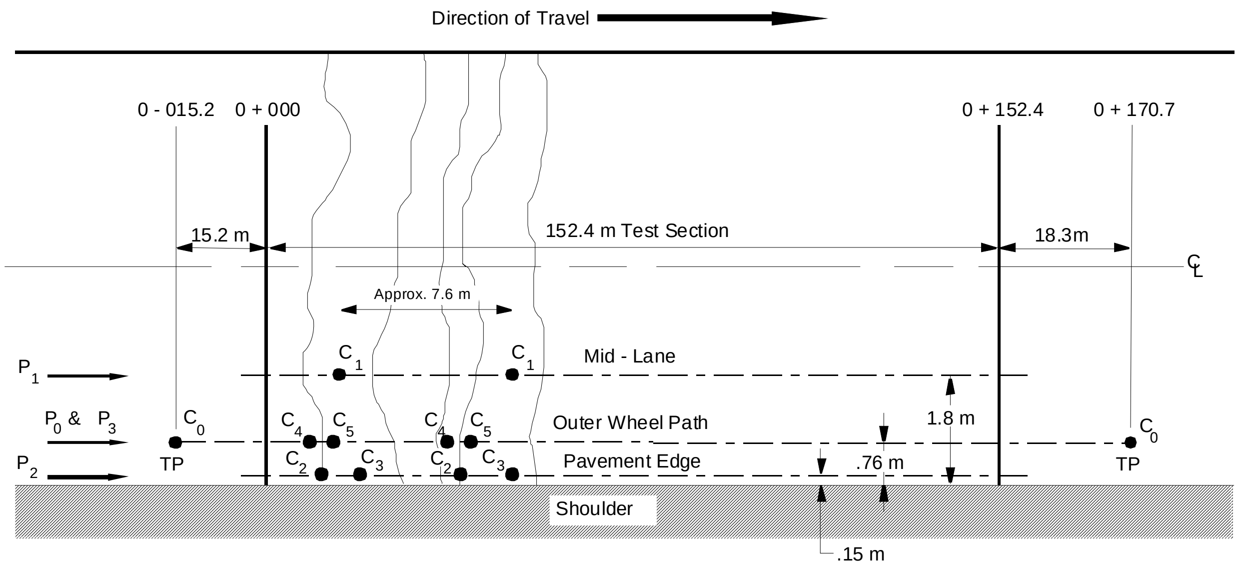


NOTES:

1. FWD tests (J_0) conducted at test pit locations (TP) on P_0 (First set of tests). Stationing will vary to locate TP at midpanel.
2. Number of panels and panel length (X) will vary depending upon specific joint spacing, transverse crack pattern and pavement type. Operator should refer to test and Table 1 for further details. A maximum of 20 effective slabs (panels) should be tested.
3. Lateral offsets shown represent nominal distances.

1 m = 3.28 ft

Figure 4. Diagram. Test plan 2.

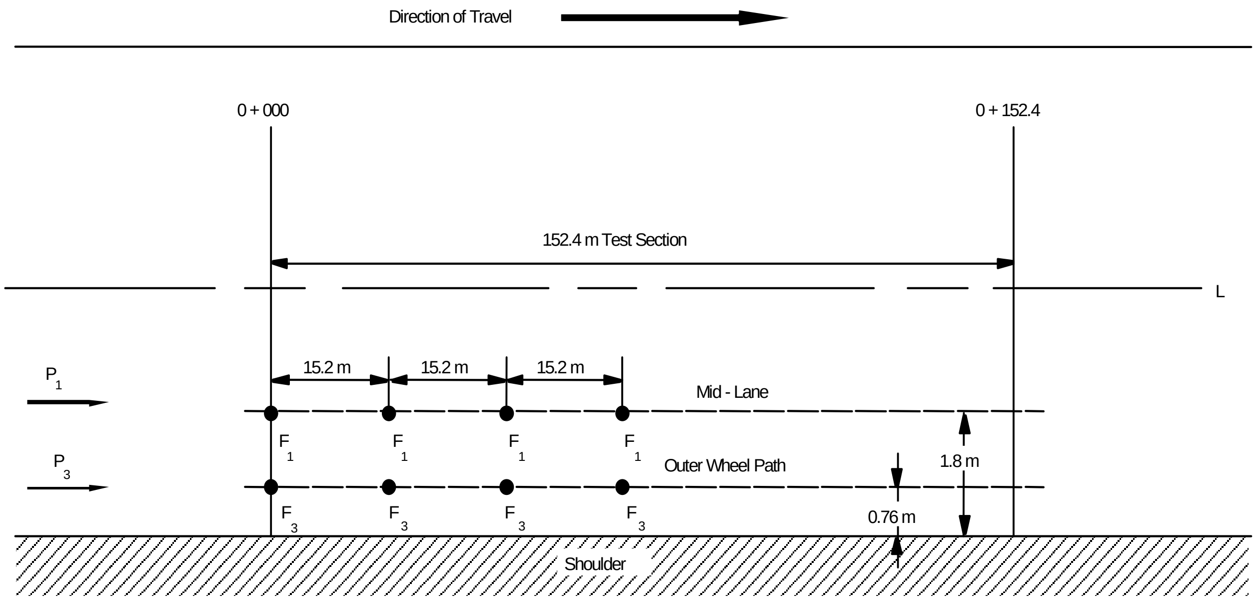


NOTES:

1. FWD tests conducted at test pit locations (TP) on P_0 (First set of tests).
2. See Table 1 for further details.
3. Lateral offsets shown represent nominal distances.

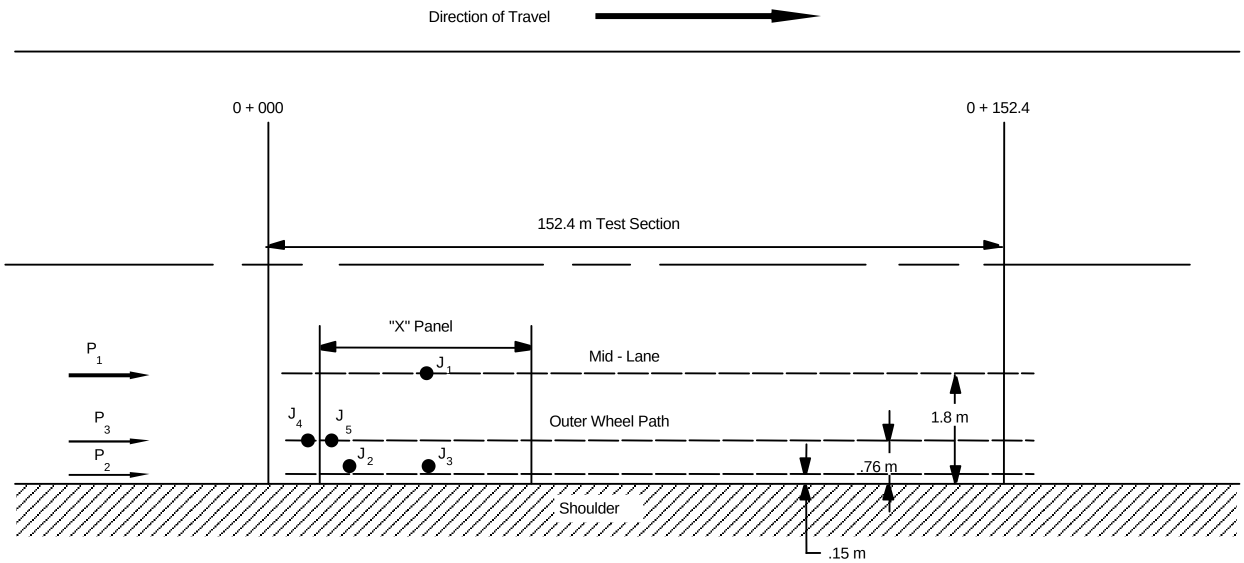
1 m = 3.28 ft

Figure 5. Diagram. Test plan 3.



1 m = 3.28 ft

Figure 6. Diagram. Test plan 4.



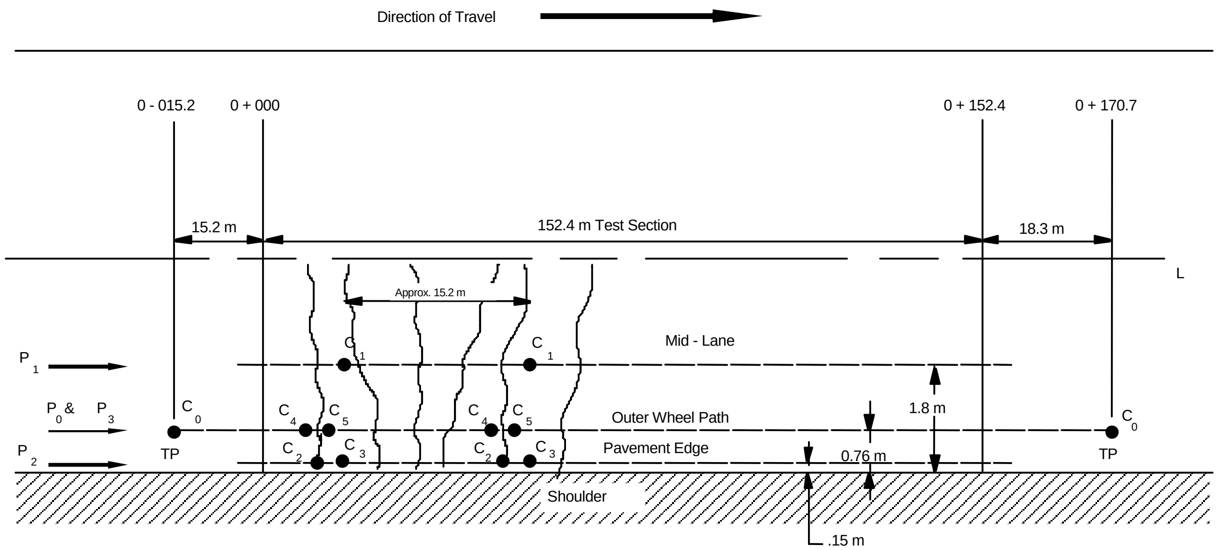
NOTES:

1. Five test points per panel done in three passes.

2. Ten panels should be tested on all sections.

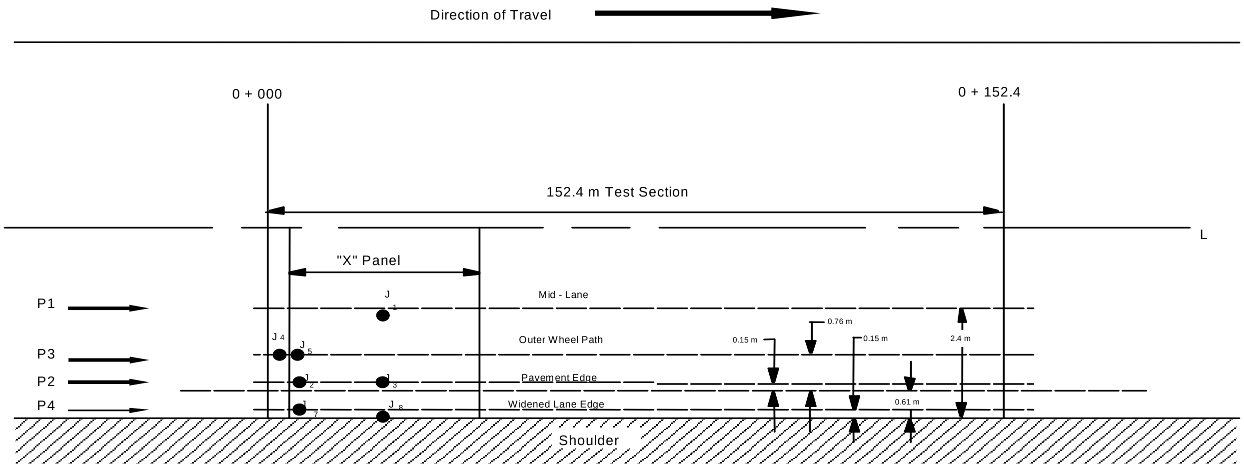
1 m = 3.28 ft

Figure 7. Diagram. Test plan 5.



1 m = 3.28 ft

Figure 8. Diagram. Test plan 6.

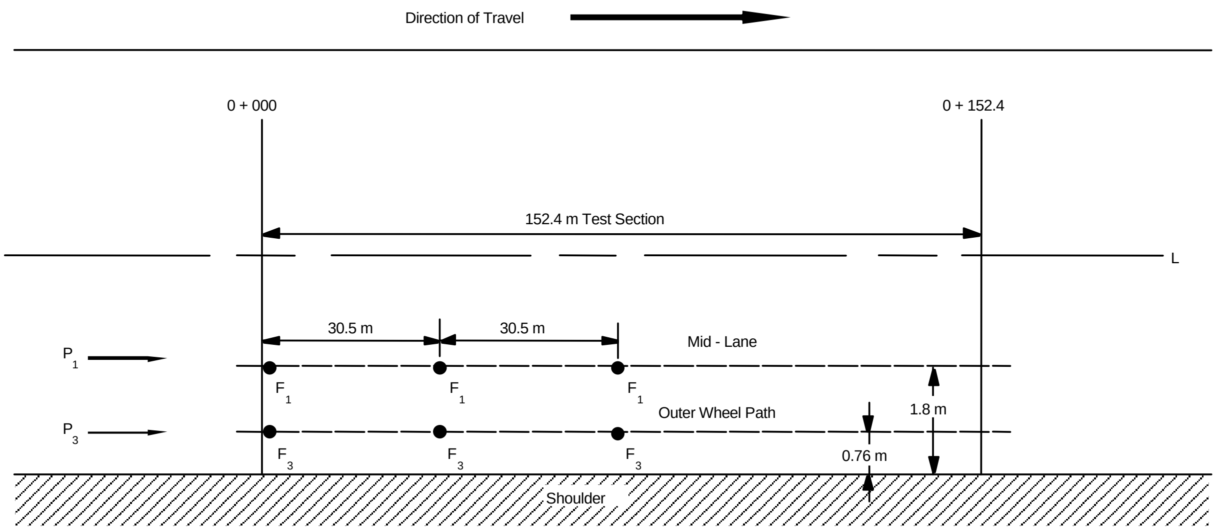


NOTES:

1. Ten panels should be tested on all sections.
2. Seven test points per panel done in four passes.
3. Lane specifications J7 and J8 are on shoulder.
4. Lateral offsets shown represent nominal distances.

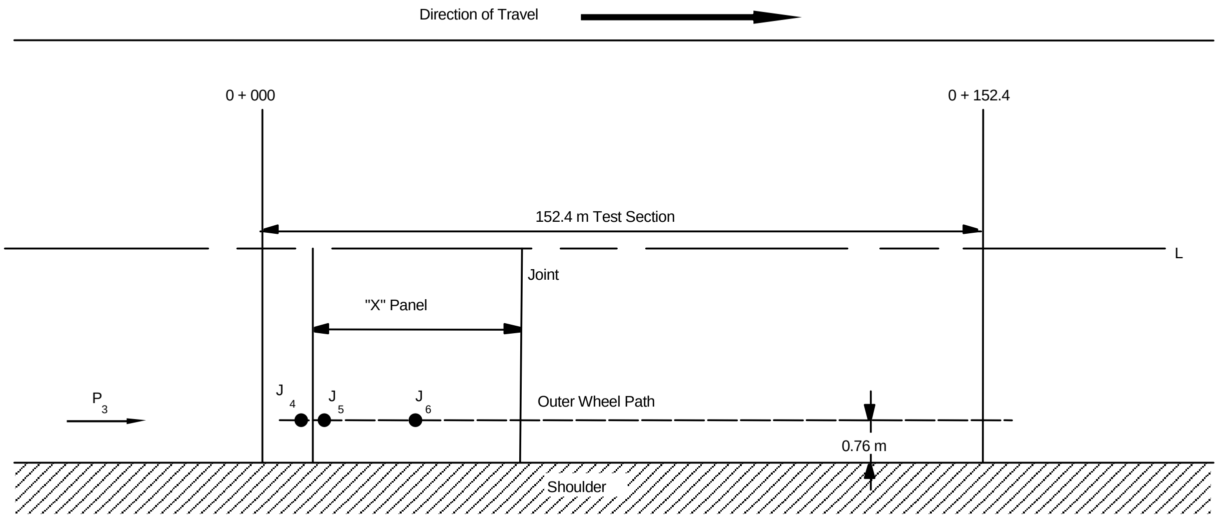
1 m = 3.28 ft

Figure 9. Diagram. Test plan 7.



1 m = 3.28 ft

Figure 10. Diagram. Test plan 8.



NOTES:

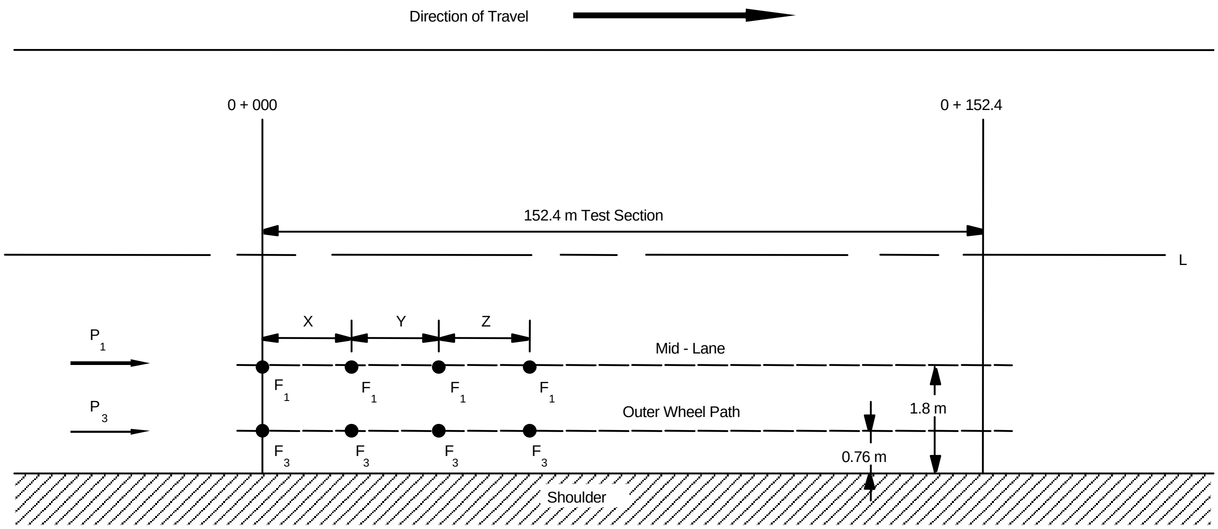
1. Panel Length "X" will be variable depending upon specific joint spacing, transverse crack pattern and pavement type.

2. Test all panels on under seal sections and every third panel on remaining sections.

3. Lateral Offsets shown represent Nominal Distances.

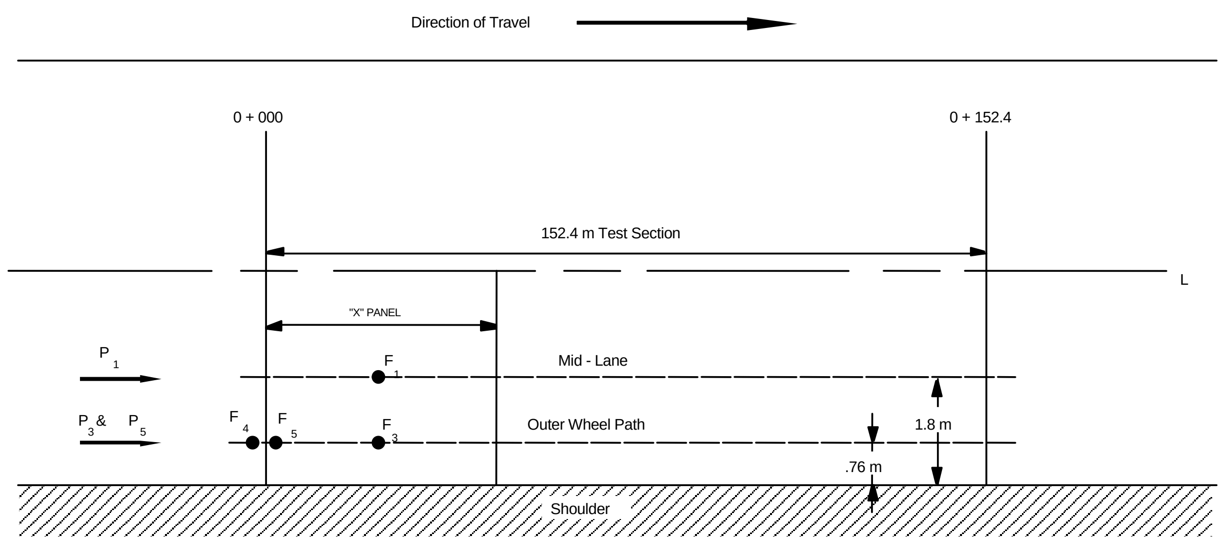
1 m = 3.28 ft

Figure 11. Diagram. Test plan 9.



1 m = 3.28 ft

Figure 12. Diagram. Test plan 10.



1 m = 3.28 ft

Figure 13. Diagram. Test plan 11.

Appendix B: Standard FWD Forms and Common Unit Conversions

This appendix is a collection of forms applicable to the operation and recordkeeping for LTPP FWDs.

Following is a list of the forms included:

- Form F01, LTPP FWD Monitoring Temperature Measurements.
- Form F02, LTPP FWD Monitoring Field Activity Report.
- Form F03, LTPP Monitoring Maintenance and Repair Summary.
- Form F04, LTPP FWD Monitoring FWD Buffer Shape.
- Form F05, LTPP FWD MonitoringFWD Operations Planning.
- Form F06, LTPP FWD Monitoring FWD Test Comments.
- Form F07, LTPP FWD MonitoringFWD DMI Calibration.
- Form F08, LTPP FWD Monitoring IR Temperature Sensor Checks.
- Form F09, LTPP FWD Monitoring Air/Manual Temperature Sensor Checks.
- Form F10, LTPP FWD Monitoring FWD Test Slab Locations.
- Long-Term Pavement Performance (LTPP) Falling Weight Deflectometer (FWD) Testing FWD Problem Report (FWDPR).

LTPP FWD Monitoring Temperature Measurements—Form F01	Region [___ ___] State Code [___ ___] LTPP Section ID [___ ___ ___ ___]

AGENCY ____________________ TESTING ________________

LTPP EXPERIMENT CODE __________ ROUTE / HIGHWAY NUMBER ____________

TESTING DATE ___________ SHEET NUMBER ________ FIELD SET NO. _________

LOCATION STATION ______________

NOMINAL DEPTH	IR Surface	25 mm	50 mm	100 mm	200 mm	300 mm	OPERATOR COMMENT
ACTUAL DEPTH							
TIME	T_0 °C	T_{25} °C	T_{50} °C	T_{100} °C	T_{200} °C	T_{300} °C	

LOCATION STATION ______________

NOMINAL DEPTH	IR Surface	25 mm	50 mm	100 mm	200 mm	300 mm	OPERATOR COMMENT
ACTUAL DEPTH							
TIME	T_0 °C	T_{25} °C	T_{50} °C	T_{100} °C	T_{200} °C	T_{300} °C	

NOTES: 1) T_i = Temperature in Depth i, °C

Operator comments should include weather related comments, and any other comments necessary to explain unusual temperature readings. Additional comments may be included on the back, and must be referenced to station and time, and a note to this effect must be added to the "Operator Comments" field.

2)

Test Completed

____________________ ____- _____ - _____ ________________________

FWD Operator DD - MMM - YYYY Affiliation

1 m = 3.28 ft; °C = (°F − 32) * 5/9

LTPP FWD Monitoring Field Activity Report—Form F02	Region [___ ___] State Code [___ ___] LTPP Section ID [___ ___ ___ ___]

AGENCY ________________ TESTING

LTPP EXPERIMENT CODE ______________ ROUTE/HIGHWAY NUMBER

TESTING DATE ____________ SHEET NUMBER _______ FIELD SET NO.

FWD AND TOW VEHICLE BEFORE OPERATION CHECKS ____________________ (initial)

	TIME	ODOMETER
START TRAVEL	________	________
END TRAVEL	________	________
READY TO TEST	________	
TRAFFIC CONTROL READY	________	
TEMP. HOLES DRILLED	________	
BEGIN TESTING	________	
END TESTING	________	
START TRAVEL	________	________
END TRAVEL	________	________

DOWN TIME ________ HOURS REASON(S)

NUMBER OF TESTS:	BASIN	JT/CRACK
TP	________	
OWP	________	________
PE	________	
ML	________	

ADDITIONAL REMARKS REGARDING TESTING

FIELD SAMPLING AND TESTING CREW		TRAFFIC CONTROL CREW	
NAMES:	________	AGENCY:	________
	________	NAMES:	________
	________		________
	________		________
	________		________

COPIES: RSC

LTPP Monitoring Maintenance and Repair Summary—Form F03	Region [___ ___] FWD Serial Number 8002- [___ ___ ___]

Date	Odometer	Problem Description [1]	Description of Maintenance	Performed By	Cost		
					Labor	Parts	Total

[1] Enter "Routine" for routine maintenance

LTPP FWD Monitoring FWD Buffer Shape—Form F04	Region	[___ ___]

Deflection Unit ID: 8002 – [___ ___ ___]

Buffer Shape:	[___] (see following code descriptions)
Assign Date:	[___ ___ - ___ ___ ___ - ___ ___ ___ ___]
De-assign Date:	[___ ___ - ___ ___ ___ - ___ ___ ___ ___]

Code	Description
1	**Flat**—100-mm (3.94-inch) diameter, flat (90º) buffers.
2	**Fully Rounded**—100-mm (3.94-inch) diameter, "knife cut" variable cone shaped (45º) buffers.
3	**Semi-Rounded**—110-mm (4.33-inch) diameter, tapered (60º) buffers.
9	**Unknown**—buffer shape is unknown.

LTPP FWD Monitoring FWD Operations Planning—Form F05	Region [___ ___] State Code [___ ___] LTPP Section ID [___ ___ ___ ___]

Experiment Designation:	__ PS __
Test Setup:	Flexible / Rigid (circle one)
Total thickness of bound layers:	___ ___ ___ ___ mm
Test Plan Number:	___

Temperature Holes (cross out holes that are not to be used)

Hole Number	Nominal Hole Depth	Adjusted Hole Depth[1]
1	25 mm (0.98 inch)	
2	50 mm (1.97 inches)	
3	100 mm (3.94 inches)	
4	200 mm (7.87 inches)	
5	300 mm (11.81 inches)	

Note 1 – Only fill out if hole is within ±25 mm (±0.98 inch) of bottom of bound layers

File Names (cross out passes that are not to be used)

Pass Number	Filename
1	___ ___ ___ ___ ___ ___ ___ ___
2	___ ___ ___ ___ ___ ___ ___ ___
3	___ ___ ___ ___ ___ ___ ___ ___
4	___ ___ ___ ___ ___ ___ ___ ___
5	___ ___ ___ ___ ___ ___ ___ ___

Prepared By: ______________________ Date Prepared: ______________________

Tested By: ______________________ Date Tested: ______________________

LTPP FWD Monitoring FWD Test Comments—Form F06	Region [___ ___] State Code [___ ___] LTPP Section ID [___ ___ ___ ___]

Date ___ ___ - ___ ___ ___ - ___ ___ ___ ___

Test Pass ____

Filename ___ ___ ___ ___ ___ ___ ___ ___

Time	**Station**	**Lane Spec**	**Comment**

Note: Time, Station, and Lane Spec should match the stored data. Necessary modifications to those values should be noted in the "Comments" column.

Tested By: ______________________________

LTPP FWD Monitoring FWD DMI Calibration—Form F07	Region	[___ ___]

Date (DD-MMM-YYYY) ___ ___ - ___ ___ ___ - ___ ___ ___ ___

Deflection Unit ID: 8002 – [___ ___ ___]

Section Length (feet) ___ ___ ___ ___

New Calibration Factor (counts per km) ___ ___ ___ , ___ ___ ___

Performed By: ______________________________________

LTPP FWD Monitoring IR Temperature Sensor Checks—Form F08	Region	[___ ___]

Date (DD-MMM-YYYY) ___ ___ - ___ ___ ___ - ___ ___ ___ ___

Deflection Unit ID: 8002 – [___ ___ ___]

Location Performed ____________________

FWD-Mounted IR Sensor Serial No. ____________________

Hand-Held IR Sensor Serial No. ____________________

Check	Reading	Reference Therm. (°C)	FWD-Mounted IR Sensor			Hand-held IR Sensor		
			Reading (°C)	Error	Pass?	Reading (°C)	Error	Pass?
Cold	1				Y / N			Y / N
	2				Y / N			Y / N
	3 (opt.)				Y / N			Y / N
Room Temp.	1				Y / N			Y / N
	2				Y / N			Y / N
	3 (opt.)				Y / N			Y / N
Hot	1				Y / N			Y / N
	2				Y / N			Y / N
	3 (opt.)				Y / N			Y / N
Acceptable?			YES / NO			YES / NO		

Performed By: ____________________

LTPP FWD Monitoring Air/Manual Temperature Sensor Checks—Form F09	Region	[___ ___]

Date (DD-MMM-YYYY) ___ ___ - ___ ___ ___ - ___ ___ ___ ___

Deflection Unit ID: 8002 – [___ ___ ___]

Location Performed ____

Serial Numbers			
FWD Air Temp	Hand-held Sensor 1	Hand-held Sensor 2	Hand-held Sensor 3

Check	Reading	Ref. Therm (°C)	FWD Air Sensor			Hand-held Sensor 1			Hand-held Sensor 2			Hand-held Sensor 3		
			Reading (°C)	Err.	Pass?	Reading (°C)	Err.	Pass?	Reading (°C)	Err.	Pass?	Reading (°C)	Err.	Pass?
Cold	1				Y / N			Y / N			Y / N			Y / N
	2				Y / N			Y / N			Y / N			Y / N
	3 (opt.)				Y / N			Y / N			Y / N			Y / N
Room Temp.	1				Y / N			Y / N			Y / N			Y / N
	2				Y / N			Y / N			Y / N			Y / N
	3 (opt.)				Y / N			Y / N			Y / N			Y / N
Acceptable?			YES/NO			YES/NO			YES/NO			YES/NO		

Performed By: ________________________________

LTPP FWD Monitoring FWD Test Slab Locations—Form F10	Region [___ ___] State Code [___ ___] LTPP Section ID [___ ___ ___ ___]

Number of Slabs to be Tested 10/20
(circle one)

Test Slab	Location of joint/crack on approach end of slab (ft)
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	
16	
17	
18	
19	
20	

Date Prepared ___ ___ - ___ ___ ___ - ___ ___ ___ ___

Prepared By ____

FWDPR #:______

LONG-TERM PAVEMENT PERFORMANCE (LTPP)
FALLING WEIGHT DEFLECTOMETER (FWD) TESTING
FWD PROBLEM REPORT (FWDPR)

Attention:	Eric Weaver	FAX:	(703) 285-2767
	Gonzalo R. Rada	FAX:	(301) 210-5032

Type of Problem: Guidelines Equipment Software Name: Version: Other:	 ___ ___ ___ _____________ _____________ _____________	Reported by: __________________________ Agency: __________________________ Date: __________________________ Urgent?(Y/N) ___ Page ____ of ____
Description:		

THIS SECTION FOR USE BY FHWA AND TSSC	
Received by: _________________	Date Received: ___________________
Referred to: _________________ Date Referred: _________________	Approved by: ___________________ Date Approved: ___________________
Resolution:	
Notes:	

Appendix C: Unit Conversions for Common FWD-Related Measurements

Deflection	
mils (inch * 10^{-3})	**microns (meter * 10^{-6})**
16	406
24	610
80	2032
microns = mils * 25.4	

Load		
kips (pound * 10^{3})	**kN (Newton * 10^{3})**	**kPa (Pascal * 10^{3}) (for 300 mm diameter plate)**
6 (5.4 to 6.6)	26.7 (24.0 to 29.4)	378 (340 to 416)
9 (8.1 to 9.9)	40.0 (36.0 to 44.0)	566 (509 to 662)
12 (10.8 to 13.2)	53.4 (48.1 to 58.7)	755 (680 to 830)
16 (14.4 to 17.6)	71.2 (64.1 to 78.3)	1007 (907 to 1108)
kN = kip * 4.448		
	kPa = kN * 14.15 (for 300 mm-diameter (11.81-inch) plate only)	

Temperature	
Fahrenheit	**Celsius**
0	-17.8
32	0
70	21.1
100	37.8
°C = (°F − 32) * 5/9	

Distance	
feet	**meters**
12	3.66
14	4.27
25	7.62
50	15.2
100	30.4
500	152.4
1000	304.8
meters = feet * 0.3048	

Recycled
Recyclable

HRDI-13/12-06(1M)E