LTPP Manual for Falling Weight Deflectometer Measurements
Operational Field Guidelines

Version 3.1

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Prepared by:

FHWA-LTPP Technical Support Services Contractor
LAW PCS
A Division of Law Engineering and Environmental Services, Inc.
12104 Indian Creek Court, Suite A
Beltsville, Maryland 20705-1242

Prepared for:

Office of Infrastructure R&D
Long-Term Pavement Performance Team, HRDI-13
Federal Highway Administration
6300 Georgetown Pike
McLean, Virginia 22101
(202) 493-3079

U.S. Department of Transportation
Federal Highway Administration

Long-Term Pavement Performance
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FOREWORD

This manual was developed for use by personnel responsible for collecting deflection data on pavement test sections in the Long-Term Pavement Performance (LTPP) program. The manual provides field operational guidelines for data collection under the following headings:

(1) Falling Weight Deflectometer (FWD) Field Test Procedures

(2) Data Acquisition and Handling

(3) Equipment Calibration

(4) Equipment Maintenance and Repair.

The test procedures contained in this manual are a product of the LTPP program and its many participants. These test procedures are designed for pavement research purposes. The manual was originally developed by Pavement Consultancy Services, a Division of Law Engineering and Environmental Services, Incorporated (PCS/LAW), under contract to the Strategic Highway Research Program (SHRP), National Research Council. The second version of the manual was developed by PCS/LAW and Braun Intertec Pavement, Inc. under contract to the Federal Highway Administration (FHWA). The third version of the manual (3.0) was prepared by LAW PCS under contract to the FHWA. Inputs to the manual were received from a wide variety of individuals including SHRP staff, FHWA LTPP team staff, SHRP and FHWA Regional Coordination Office Contractors (RCOC), and state highway agency officials and academicians who participated on the SHRP Deflection Testing and Backcalculation Expert Task Group.

This updated version of the manual (3.1) was prepared by LAW PCS under contract to the FHWA and includes modifications made for purposes of implementing the FHWA-LTPP FWD customized software Dyna25 Aug 2000 version.

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APPENDICES

I. INTRODUCTION

The Long-Term Pavement Performance (LTPP) program was one of four major technical research areas established under the five-year, $150 million Strategic Highway Research Program (SHRP) initiated in 1987. After SHRP came to a close in 1992, the management of the LTPP program shifted to the Federal Highway Administration (FHWA).

Two of the primary objectives of the LTPP program are to improve pavement prediction and design models. One key variable needed to accomplish these objectives is the change in the long term response of pavements to load. The LTPP program uses a Falling Weight Deflectometer (FWD) to measure the deflection response of a pavement to a load of known magnitude. The deflection response of a pavement to an applied load is an important indicator of structural capacity, material properties, and subsequent pavement performance.

LTPP established four Regional Coordination Offices for data collection and coordination with United States and Canadian highway agencies participating in LTPP program. The assignment of the Regional Coordination Offices boundaries is shown in Figure I-1.

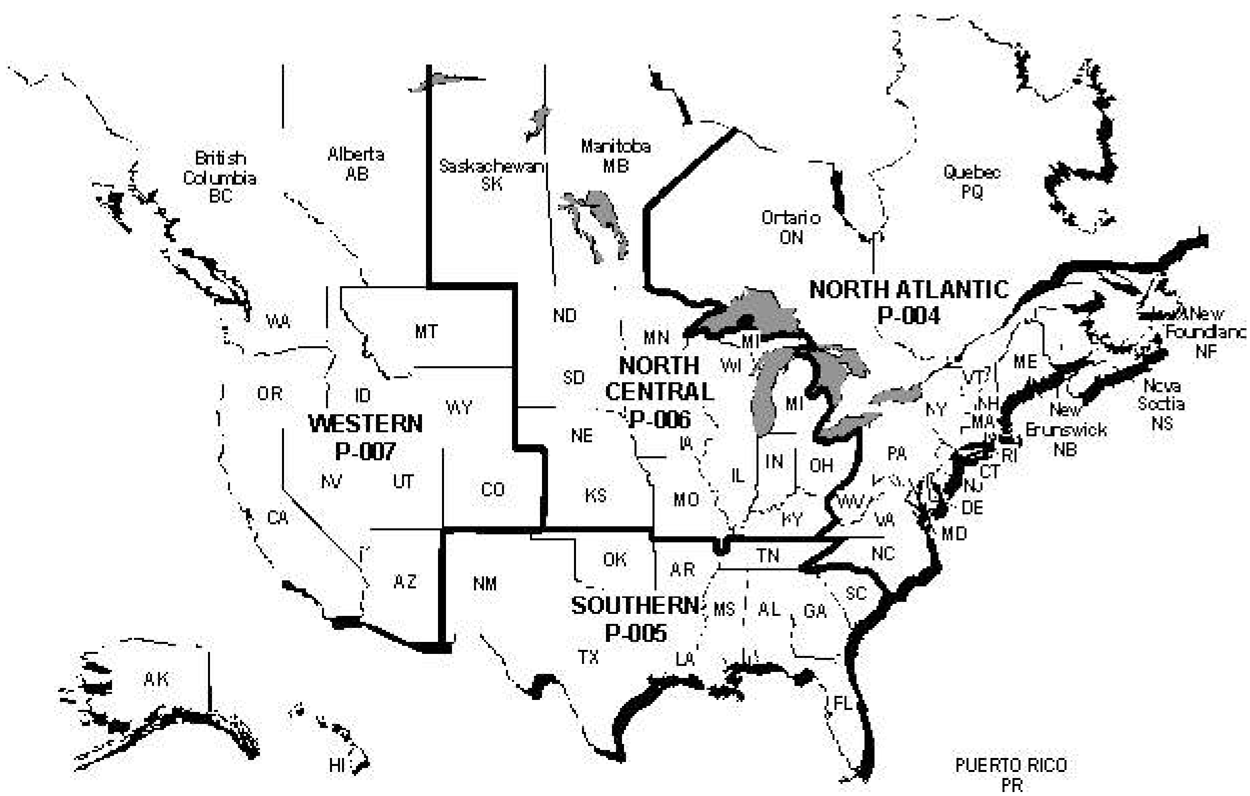


Figure I-1. Regional coordination office boundaries.

The LTPP program has approximately 800 in-service pavement sections in the General Pavement Studies (GPS) and approximately 1,700 in-service pavement sections in the Specific Pavement Studies (SPS). The FWD test procedures and plans are specifically tailored for pavement research purposes. The LTPP FWD test plans vary by experiment type and pavement type, though some features and practices are common to all FWD testing. Additional test plans may be employed for special pavement monitoring studies such as the LTPP Seasonal Monitoring Program (SMP). Specifics of FWD test plans presented are in the appendices of this manual.

II. FWD FIELD TESTING

Background

Accurate measurement of deflection data with the FWD is an important element of LTPP pavement performance monitoring. Factors other than variations in the pavement cross-section (layer thickness, layer material type, material quality, and subgrade support) influence the deflection response of a pavement. FWD operators need a general understanding of these factors so that correct and meaningful deflection data are collected. In addition to pavement cross-section factors, the three other sets of factors that can significantly affect pavement deflection include:

- Environmental Factors
- Pavement Discontinuities
- Variability in the Pavement Structure.

Environmental Factors

Temperature and moisture affect the deflection response of both flexible pavements (asphaltic concrete) and rigid pavements (Portland Cement Concrete). The stiffness (rigidity) of asphalt concrete (AC) is very sensitive to temperature changes occurring over both long-term (seasonal) and short-term (hourly) periods. As the temperature of the pavement increases, the magnitude of deflection from a given load impulse will increase if all other factors remain the same. Therefore, deflections measured on a hot summer day will be larger than the deflections measured during a cooler period. Also, changes in temperature with depth (vertical temperature gradients) influence stresses in the AC layer. The influence of vertical temperature gradients becomes more pronounced as the thickness of the AC increases.

Portland cement concrete (PCC) pavement behavior is affected by temperature in two ways. First, variations in temperature cause panels to contract during cooling and expand when heated. The expansion and contraction of panels influence the width of joints and cracks in the pavement and the degree of mechanical interlock between the panels. The degree of mechanical interlock between panels affects the deflection response of the joint. Load transfer tests at joints and cracks in PCC pavements are used to calculate the degree of interlock and transfer of load.

Variations in temperature also cause vertical temperature gradients through the PCC that in turn cause differential expansion of materials with depth. Differential expansion with depth causes the panels to "curl" in either a concave or convex shape. This curling action influences the deflection response of the PCC panels. For negative temperature gradients (surface cooler than the bottom of the PCC), the panels are concave with the panel edges lifted and the mid-panel resting on the base material. This condition normally occurs during early morning hours and normally results in higher deflections near the panel edges. For positive temperature gradients (surface warmer than the bottom of the slab), the panels are convex with the panel edges resting on the base material and the mid-panel lifted. This condition normally exists later in the day after the PCC has been exposed to the sun and can produce higher deflection at the mid-panel locations.

In general, excess moisture in a pavement structure weakens the structure and causes deflections to increase. Moisture changes are normally long-term, occurring over an annual cycle. However, pavement sections in areas with significant frost penetration can have extreme changes in deflection if significant moisture exists with fine-grained soil. With the structure frozen, the deflections are small. In the spring, as the structure thaws, moisture trapped between the surface and subgrade can saturate the soil making it weak and can increase deflections.

FWD operators should recognize that pavement deflections vary on the same pavement section throughout the day and throughout the year from temperature and moisture changes. Thus, deflection readings taken at different times on a specific pavement section may not be the same. Differences in deflection response on a test section are considered normal and do not necessarily indicate equipment problems. One of the objectives of the Seasonal Monitoring Program is to define the expected changes in deflection for temperature and moisture changes.

With the above background on environmental influences, FWD operators must insure the successful collection of FWD data for the LTPP program by:

- Recording the correct local time on all forms and data sheets for a section (especially true for operators in regions spanning more than one time zone).
- Verifying that air and pavement temperatures automatically recorded by the FWD are reasonable and the equipment is performing properly.
- Locating vertical pavement temperature gradient measurement holes in representative areas, measuring and recording the depths of the holes, and properly recoding measured temperatures at the defined time intervals.

Pavement Discontinuities

A pavement section with surface discontinuities such as cracks and/or joints, or subsurface discontinuities such as voids, will generally exhibit higher deflections than a pavement section without such discontinuities. The FWD testing plan in this manual provides specifics on deflection testing at joints and transverse cracks for PCC pavements. The testing plan also provides guidelines for recording any pavement distress near deflection test points.
It is important that FWD operators obtain typical deflection response data on each pavement section. FWD operators should not "bias" deflection readings by testing only crack-free areas or only cracked areas. More details on test point location and distribution are discussed later in this manual.

Variability in the Pavement Structure

Pavement uniformity was a key consideration in the LTPP section selection process. Although, test sections with uniform pavement features were sought, variation in pavement deflection response between test points along a section and between drops at the same load level are expected.

Deflection variation between test points within a section may be quite large; ranging from 15 percent to more than 60 percent. This variation reflects changes in layer thickness, material properties, moisture and temperature conditions, subgrade support, and contact pressure under the load plate. These are normal conditions and FWD operators should not be overly concerned with point to point variations in deflection response.

Deflection variation at a given load level for a test point will generally be less than point to point variations and typically have a magnitude of about 3 to 5 microns (0.1 to 0.2 mils). This variation occurs from limits on precision of the deflection and load measurements and possibly from changes in the pavement material properties due to the load applications during the deflection test cycle.

Some variations also occur from equipment and operational aspects, such as reduced load from warming of the FWD buffers and changes in placement of deflection sensors relative to the edge of the pavement. FWD operators need to minimize these variations by conditioning the buffers prior to testing and by following test procedures in this manual.

No guideline on acceptable data variation at a test point can cover all potential conditions. However, variation checks in the software help screen data as it is collected so FWD operators can determine the acceptability of the measurements. These data checks are discussed in chapter three along with other quality control checks and criteria for accepting and rejecting data.

Data variation checks are not used in the software to detect changes in point to point deflection response over the length of a section, because these changes are considered normal and unknown before the data are collected. However, FWD operators should watch for large changes in deflection response in order to identify potential equipment malfunctions or other spurious causes of error in the measurement process. Explanatory comments for suspected anomalous measurements or other factors that might affect the measured deflection response shall be entered by the operator into the FWD data file using either the **C**omment selection in the measurement window or the comment line at the end of the test, as appropriate.

Pavement Types

The pavement test sections in the LTPP program are assigned to two broad categories of experiment, the General Pavement Studies (GPS) and the Specific Pavement Studies (SPS). GPS sites tend to have a single test section. SPS sites have multiple test sections with varying features. There are some sites with both GPS and SPS test sections.

GPS Test Sections

The GPS has the following eight experiments defined by the type of pavement structure.

Experiment	Pavement Structure
1	AC Pavement with Granular Base (AC/AGG)
2	AC Pavement with Bound Base (AC/BND)
3	Jointed Plain Concrete Pavement (JPCP)
4	Jointed Reinforced Concrete Pavement (JRCP)
5	Continuously Reinforced Concrete Pavement (CRCP)
6	AC Overlay of AC Pavement (AC/AC)
7	AC Overlay of PCC Pavement (AC/PCC)
9	Unbonded PCC Overlay of PCC Pavement (PCC/PCC)

The AC overlay experiments, GPS 6 and 7, have subclassifications to indicate if the overlay existed prior to LTPP monitoring and the type of overlay materials and pre-overlay treatments. The FWD test plan and pattern is the same for all of these subclassifications.

SPS Test Sections

The SPS portion of the LTPP program is divided into 9 experiments. Unlike the GPS, in which experiments are divided by pavement type, SPS experiments are grouped by study parameter. A single experiment can contain more than one pavement type, for example, SPS-8 contains both flexible and rigid type pavement structures. Most SPS sites contain a single type of pavement structure, either AC or PCC, however there are some sites which contain both AC and PCC pavements. Below is a list of the SPS experiments.

Experiment	Name
1	Strategic Study of Structural Factors for Flexible Pavements
2	Strategic Study of Structural Factors for Rigid Pavements
3	Preventive Maintenance Effectiveness of Flexible Pavements
4	Preventive Maintenance Effectiveness of Rigid Pavements
5	Rehabilitation of Asphalt Concrete Pavements
6	Rehabilitation of Jointed Portland Cement Concrete Pavements
7	Bonded Portland Cement Concrete Overlays
8	Study of Environmental Effects in the Absence of Heavy Loads
9	SUPERPAVE™ Asphalt Binder Study

Deflection Testing Frequency

Deflection testing frequency is based on the LTPP assigned pavement monitoring category. Pavement monitoring categories are initially based on the LTPP experiment and are modified depending on assessment of data completeness for a site and the data collection support provided by the highway agency. The FHWA LTPP staff will provide RCOCs with instructions on the monitoring category and test frequencies for each LTPP test section. The generic FWD testing frequencies by LTPP test section classification are:

1. Deflection testing every 2 years (SPS 1, 2, 5, 6 and 8 test sections)
2. Deflection testing every 5 years (GPS1, 2, 3, 4, 5, 6B/C/D/S, 7B/C/D/F/R/S, and 9, SPS 9, and SPS supplemental test sections)
3. Close-out deflection testing (GPS 6A and 7A, SPS 3, 4 and 7)
4. Responsive testing

Deflection Testing Every 2 Years

Deflection testing on test sections in this monitoring category is performed on a nominal two (2) year interval. This testing is repeated every 2 years until one of the following conditions is reached: test section goes out-of-study, application of rehabilitation construction event, or end of field monitoring portion of LTPP program. Responsive deflection testing is required within six months prior to reaching any one of these conditions. Responsive deflection testing is also required within six months after application of a rehabilitation (not maintenance) construction event if that test section will continue to be monitored. Routine deflection testing after application of a rehabilitation construction event is done in accordance with requirements for the post-rehabilitation LTPP experiment designation monitoring category.

Responsive deflection testing is also performed on test sections within this monitoring category based on changes in pavement condition as defined in the “Definitions” section of Appendix E.

Deflection Testing Every 5 Years

Deflection testing on test sections within this monitoring category is performed on a nominal five (5) year interval. These surveys are repeated every 5 years until one of the following conditions is reached: test section goes out-of-study, application of rehabilitation construction event, or end of field monitoring portion of LTPP program. Responsive deflection testing is required within six months prior to reaching any one of these conditions. Responsive deflection testing is also required within six months after application of a rehabilitation (not maintenance) construction event if that test section will continue to be monitored. Routine deflection testing after application of a rehabilitation construction event is done in accordance with requirements for the post-rehabilitation LTPP experiment designation monitoring category.

Responsive deflection testing is also performed on test sections within this monitoring category based on changes in pavement condition as defined in the "Definitions" section of Appendix E.

Close-Out Deflection Testing

For test sections within this monitoring category, one last round of deflection testing will be performed either when it is determined that the test section will be taken out-of-study (due to a construction event or at the option of the highway agency) or at the end of the field monitoring portion of the LTPP program, whichever comes first.

FWD Test Plans

There are three basic FWD test plans for LTPP test section based on the type of layer on the pavement surface. These test plans are as follows:

FLEX	AC surfaced pavements, includes test sections in GPS-1, GPS-2, GPS-3, GPS-6, GPS-7, SPS-1, SPS-5, SPS-6 (AC overlays), SPS-8 (AC surfaced), and SPS-9.
JCP	Jointed PCC pavements, includes test sections in GPS-3, GPS-4, GPS-9 (Jointed overlay), SPS-2, SPS-6 (pre and non-overlay), SPS-7, and SPS-8 (PC surfaced).
CRCP	Continuously reinforced PCC pavements, includes test sections in GPS-5 and GPS-9 (CRCP overlays)

The experiment designations in the above list are only general guides. Since project sites can have more than one type of pavement structure, which can require more than one type of test plan, FWD operators must follow the testing plan appropriate to the pavement structure.

FWD tests on SPS-3 test sections follows the general FLEX test with some variations as shown in Appendix B. FWD tests on SPS-4 test sections follow the general JCP test plan with some variations as shown in Appendix B. Details of the test plans are discussed in this chapter and presented in the appendices.

The differences in the FLEX, JCP and CRCP testing categories include:

1. Longitudinal location of test points (spacing and stationing)
2. Lateral location of test points (distance from edge reference)
3. Type of deflection test (DB or LT test)
4. Drop sequence (drop heights and number of drops)

For longitudinal reference, all test point locations are measured from station 0+000 (0+00) using the distance measuring instrument (DMI) in the FWD tow vehicle. FWD locations are tied to the existing US Customary units; the DMI should be set to read in US Customary units. ***The location data will, in the future, be converted to SI units after the data is filtered into the LTPP IMS.*** The DMI should be checked at stations 0+030.5 (1+00), 0+061.0 (2+00), 0+091.4 (3+00), 0+121.9 (4+00) and 0+152.4 (5+00), and problems with the stationing for the section or the calibration of the instrument should be recorded.

For lateral reference, all FWD testing is done in the lane containing the test section. In general this will be the outer driving lane (truck lane) versus the passing lane of the highway. Within the lane tested, lateral offsets measured from an edge reference are used to locate the test points (two offsets used on FLEX and three on JCP and CRCP).

In this guide, the edge reference is the lane-shoulder interface on a normal paving lane (usually a 3.65 m (12.0 ft) wide lane) and the outside edge of the painted shoulder stripe on a wide paving lane (usually 4.0 m (13.0 ft) wide lane or greater). If the outside edge of the painted shoulder stripe is over 150 mm (6 in) inside the lane-shoulder interface, then use the outside edge of the painted shoulder stripe as the edge reference. If the lane-shoulder interface is inside the painted shoulder stripe, the interface should be used as the edge reference.

The three lateral offsets as measured from the edge reference towards the centerline of the roadway are as follows:

1. Mid Lane (ML) = 1.8 m ± 0.15 m (6.0 ft ± 0.5 ft)

2. Pavement Edge (PE) = 0.15 m + 0.08 m (0.5 ft ± 0.25 ft)

   Note: With a 150 mm (6 in) radius load plate, the load plate will be tangent to the edge reference when the center of the load plate is 150 mm (6 in) from the edge, and the load plate will be 80 mm (3 in) from the edge reference when the center of the load plate is 150 mm + 80 mm (6 in + 3 in) from the edge reference.

   Note: The center of the load plate should never be less than 150 mm (6 in) from the edge reference because this would place part of the load plate outside of the lane being tested. Also, the load plate and load cell could be damaged if the lane-shoulder interface is not level. Attention should be given to sections with beveled edges as well as sections with thick build up of lane edge striping material. The intent is to ensure uniform support conditions beneath the load plate.

3. Outside Wheel Path (OWP) = 0.76 m ± 0.08 m (2.5 ft ± 0.25 ft) for nominal 3.7 m (12 ft) wide lanes.

> ***Note:*** On some sections, the OWP may be shifted from this location if the lane is either narrower or wider than normal. For these sections, the lateral offset for testing may have to be different than the 0.76 m (2.5 ft).

FWD tests are performed at a constant lateral offset for each pass down the test section. When a pass is complete, the FWD returns to the beginning of the section to start on another pass at a different lateral offset. The detailed testing plans presented later in the manual and in the appendices contain more information on the order of the passes and the type of data collected on each pass.

FWD test points need to be accurately located so future tests can be performed at the same locations. For the longitudinal location, FWD operators need to check that the DMI is calibrated, functioning properly, and accurately referenced to station 0+000 (0+00). The lateral location will not be measured for any test points; however, excess deviation from the offset tolerances provided should be avoided, especially for the PE offset.

As long as these guidelines are followed, the general location of any test point can be identified in the field longitudinally within 0.3 meters (1 ft) and laterally within less than 0.3 meters (1 ft). For routine FWD testing, the test points do not need to be marked on the pavement.

Information on the spacing of test points, the type of deflection tests to run, and the drop height sequence are discussed in Appendices A, B, C under the individual testing plans for FLEX, JCP and CRCP.

Continuity of Testing

If for any reason deflection measurements on a test section are interrupted during a measurement pass, and can not be competed on the day the pass started, the data for the incomplete pass shall be discarded and the incomplete pass, and all other passes not yet perfomed, must be performed on a subsequent day (preferably the next day). ***It is not permissible to resume an incomplete measurement pass on a different day and append data to a previously opened data file.***

The preferred practice is to complete all FWD measurement passes on a test section on the same day. If all of the required measurement passes on a test section can not be completed on the same day, then the missing passes may be performed on the next available test day, however, this should only be performed when unexpected events occur which interrupt the normal course of testing. On sites with multiple test sections, the FWD test plan shall not purposely be designed to result in completion of only a partial number of passes on any test section.

Once testing on a specific measurement pass is begun, it must be completed on the same day. ***Operators cannot append data to existing files when the data are collected different days.***

Test Pit (TP) Areas

When test pits are excavated for materials sampling purposes, FWD measurements on the test pit location should be performed prior to excavation in order to correlate the results. At each GPS section, TPs for the sampling and testing study are located approximately at station 0-015.2 (0-50) and 0+170.7 (5+60). For TPs under the FLEX testing plan, deflection basin tests should be at station 0-015.2 (0-50) and 0+170.7 (5+60) regardless of the pavement condition. For the JCP testing plan, the TP are shifted to mid-slab and the new station recorded. And for the CRCP testing plan, the station for the TP may have to be shifted slightly to keep the sampling between cracks and the new station recorded.

Typically, a 305 mm (12 in) diameter core hole is located at station 0-015.2 (0-50) in the OWP, and a 1.2 meters by 1.8 meters (4 ft by 6 ft) piece of pavement is removed at station 0+170.7 (5+60). Unless informed otherwise by a RCOC engineer, LTPP sections will have FWD measurements in the OWP at these two potential TP areas prior to coring and excavation.

When possible, FWD testing and field sampling should be performed done on the same day. However, time delays may occur between the testing programs. If the field sampling is delayed, the FWD operator should mark the FWD test locations in the TP areas. Appendix A gives the testing details for GPS sites and Appendix B give the testing details for SPS sites.

FWD Equipment Setup

Setup of the FWD equipment for testing consists of setting the sensor spacing and the drop heights to obtain the target load levels.

Deflection Sensor Spacing

The LTPP FWDs have nine deflection sensors placed at radial offsets from the center of the load plate to define the shape of the deflection basin; the Dynatest FWD Edition 25 data collection software will be used to record deflections from all nine sensors. One set of sensor spacings shall be used for all FWD measurements on LTPP test sections to simplify data collection, decrease testing time, and minimize errors in sensor spacings. Figure II-1 schematic details sensor spacing and locations for the 9 deflection sensors. Figure II-2 details the load plate on the “approach” slab of a joint and Figure II-3 details the load plate on the “leave” slab of the same joint. The sensor spacings are fixed for ALL types of deflection tests, and do not change.

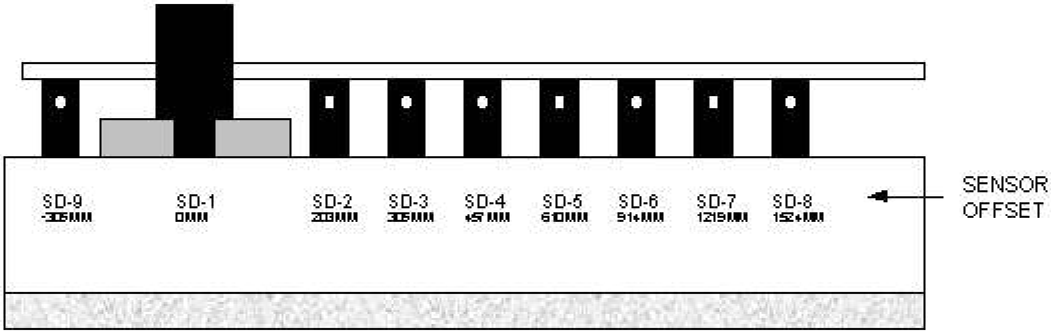


FIGURE II-1 FIXED SENSOR CONFIGURATION FOR ALL TESTING

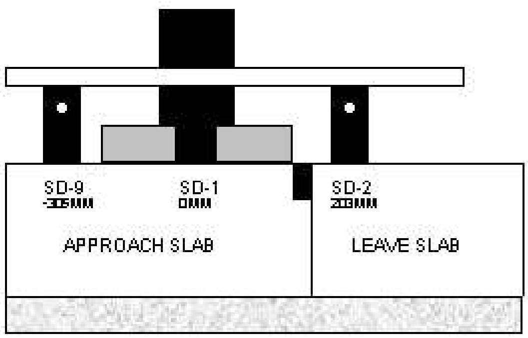


FIGURE II-2 APPROACH SLAB LOAD TRANSFER

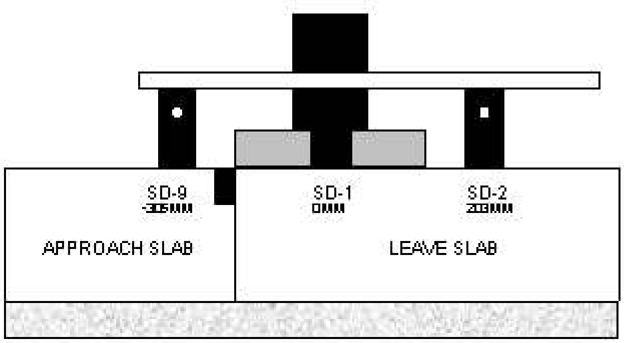


FIGURE II-3 LEAVE SLAB LOAD TRANSFER

Load Sequence (Drop Heights)

The drop sequences and target load levels for the FLEX test type differs from that used for JCP and CRCP tests. Standard test setups have been programed into the customized Dynatest version 25 software prepared for use by the LTPP RCOCs.

For the FLEX test plan, four drop heights are used with the target load and acceptable load range at each height as follows (1.0 kips = 1,000 lbs):

FLEX Testing Plan

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

For JCP and CRCP testing plans, three drop heights are used with the target load and acceptable load range at each height as follows:

JCP and CRCP Testing Plans

Hgt.	**Target Load (kN)**	**Acceptable Range (kN)**
2	40.0 (9.0 kips)	36.0 to 44.0 (8.1 to 9.9 kips)
3	53.4 (12.0 kips)	48.1 to 58.7 (10.8 to 13.2 kips)
4	71.2 (16.0 kips)	64.1 to 78.3 (14.4 to 17.6 kips)

The impulse load induced (and measured) by the FWD is influenced by the pavement stiffness. The induced load from the same drop height can vary from pavement to pavement. In addition, changes in the temperature of the rubber buffers on the FWD cause the measured load to change over the test period even though the distance the weight falls is the same. Typically, the rubber buffers increase in temperature when testing, which results in a decreased applied load, because the buffers are less stiff.

The Dynatest 8000 FWD, currently used by the LTPP program, can generate the 26.7 kN to 71.2 kN (6 kip to 16 kip) load used for testing the LTPP sections using only one combination of mass and rubber buffers. This combination uses three weights per side (total of six) and two rubber buffers per side (total of four), and is referred to as the 200 kg (440 lbs) package. The 200 kg package shall be used for all FWD measurements on the completed pavement structures of LTPP test sections unless otherwise indicated in the test protocol.

On occasion, it may be impossible to obtain the specified load for drop height one or four on certain pavements due to equipment limitations on minimum and maximum drop distance settings on the FWD. For these cases, the drop distance should be set to obtain loads as close to the target range as possible.

Prior to performing FWD measurements on a LTPP test section, the load levels from the drop height setting must be verified. The drop heights shall be adjusted as necessary to achieve the desired load response. The following procedure shall be followed:

1. After arriving at a test section and ***before*** any test data are collected, select a convenient point, (approach end of the test section) outside the monitoring portion of the test section. The test point must be located on the pavement structure to be tested, preferable in the outer wheel path. Condition the buffers using the buffer conditioning setup in the FWD software. For ambient air temperature greater than 10° C (50° F) use 64 drops and for lower air temperatures use128 repeat drops. It is not necessary to retain the data from the buffer warmup sequence since it is not loaded into the IMS.

2. Perform a trial run with the drop sequence to be used for test section measurements. Compare the measured loads against the target values. Adjust the drop heights as necessary to obtain loads on the higher side of the acceptable range since the loads will tend to decrease during testing.

3. If a target load ***cannot*** be achieved within the normal range of drop distance for a given drop height on the FWD, set the drop distance to obtain a load as close to the target range as possible. The FWD mass/buffer combination shall not be changed to achieve a target load level.

4. Extra effort should be made to obtain loads as close as possible to the 40 kN (9 kip) target load level. This is because the 40 kN drop load is most often used as the reference load for pavement design and evaluation purposes.

5. After the drop heights are set, begin data collection on the section. It is not necessary to change the drop heights after data collection has commenced on a section, even if measured loads go outside the target ranges.

Drop Sequence

The drop sequence consists of three seating drops from drop height 3 and 4 repeat measurements at each of the specified drop heights. The data from the seating drops is not stored. The complete load-deflection time histories (60 m-sec) shall be recorded for the last drop from each drop height. Thus, for the LTPP FWD test plans the following drop sequences will be used:

FLEX Testing Plan

No. Of Drops	Height	Data Stored
3	3	No[1]
4	1	Peaks
4	2	Peaks
4	3	Peaks
4	4	Peaks & History

JCP and CRCP Testing Plans

No. Of Drops	Height	Data Stored
3	3	No[1]
4	2	Peaks
4	3	Peaks
4	4	Peaks & History

1 No data stored, seating drop only. Deflection and load data are printed but not stored to a file.

Standard drop sequences are preprogrammed into the customized version of the Dynatest version 25 software prepared for the LTPP RCOCs.

Other FWD Associated Field Measurements

General

For the analysis of FWD deflection data for research purposes, LTPP FWD operators will measure pavement temperature gradients, pavement distress, and joint/crack width during the deflection testing process.

Temperature Gradient Measurements

The thermal gradient (temperature versus depth) through the bound pavement surface layer is important for the analysis of deflection data. The automatic temperature sensors on the FWD record air temperature and pavement surface temperature. To provide a direct measure of the temperature gradient through the surface, LTPP FWD operators shall measure the temperature of oil placed in holes, drilled to different depths, during deflection testing.

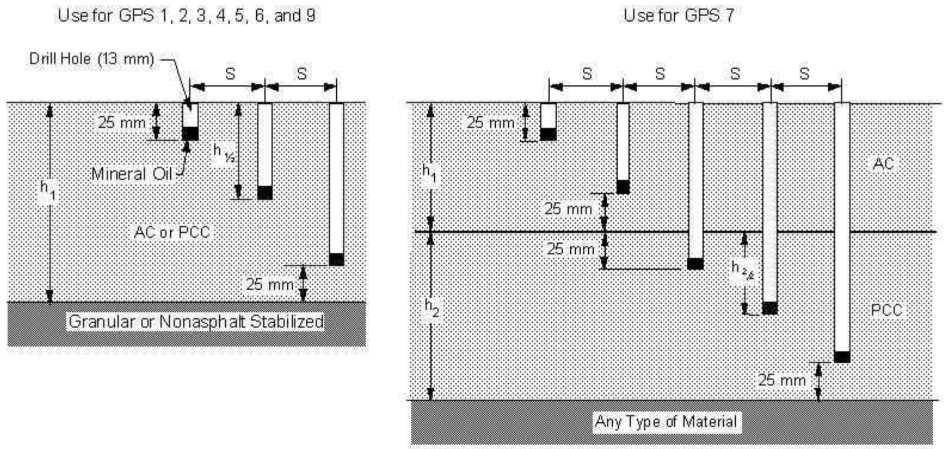
The basic procedure consists of drilling three holes into the bound surface layer, filling each hole with approximately 25-mm of oil, and using a hand held temperature probe, measure the temperature of the oil at one hour intervals during the conduct of deflection testing. Figure II-4 illustrates the layout of the pavement surface layer temperature gradient measurement holes. Exceptions to the basic procedures include:

1. On GPS 1 or 2 test sections less than 51-mm (2 inches) thick, two measurement holes at the one-third depth points in the AC surface layer are used.
2. One GPS 7 test sections, AC overlay on PCC pavement, five temperature holes are used.
3. On GPS 9 test sections, unbonded PCC overlay on /PCC pavement, three temperature holes drilled into only the PCC overlay PCC layer are used.
4. Differences for SPS test sections are detailed in Appendix B.

The steps for temperature gradient measurement are as follows:

1. Select hole locations on each end of the test section, just outside the monitoring portions, in the OWP. Typically the temperature gradient hole locations will be near station 0-001 m (0-03) and 0+153 m (5+03). The locations should be selected so that they are representative of conditions on the test section. Consideration of of sun exposure (shade from surrounding objects) and wind conditions shall be made in determining the most suitable location for the temperature gradient holes. The locations selected shall never be within the limits of the monitoring portion of the test section.

2. Determine the thickness of all AC and/or PCC layers using drilling and sampling data on the test section, previously obtained from the RCOC data files. The FWD operator shall have this information available in the FWD test vehicle for each test section being tested. This includes test sections previously tested since it may be



NOTES:

1. Drill hole spacing(s) should be 450 mm CC or greater with all holes located in the outer wheel path.
2. If AC surface layer in GPS 1 or 2 sections is less than 50 mm thick, drill two temperature holes only at the one-third points.

Figure II-4. Pavement surface layer temperature gradient meqasurement hole layout

necessary to drill new temperature measurement holes. If material sampling has not yet been performed on a test section, the depth of the bound surface layer should be estimated from information provided by the agency, or from the target thickness for sections in the SPS experiment.

3. Determine the number and depth of temperature holes as required by the experimental designation of the test section. See Figure A-4 to determine whether to drill three or five holes at each location, and to what depth each hole should be drilled.

4. Mark locations for the holes in the OWP. There should be at least 0.5 m (1.5 ft) between holes.

5. Drill 13 mm (0.6 in) diameter holes using a portable hammer drill to the depths determined in step 3.

6. Clear holes of cuttings and dust by blowing them out with a short piece of 6 mm (0.3 in) diameter plastic tubing or other suitable device.

7. Measure and record the depth of each hole to the nearest 5 mm (0.2 in) on the Temperature Measurement Form; see Form F01: Appendix F.

8. Fill the bottom of each hole with 13 mm (0.5 in) to 25 mm (1 in) of mineral oil (provides thermal conduction at the bottom of the hole to a temperature probe inserted in the hole).

9. Cover each hole with a small piece of duct tape to prevent water and debris from entering the hole. The tape also prevents the sun from warming the oil. A small incision or hole can be made in the tape for inserting the temperature probe.

10. Record temperatures to the nearest 0.05°C (0.1°F) each hour during FWD testing. The first temperature measurement should not be taken for at least 15 minutes after the oil is placed in the holes to allow heat from drilling to dissipate. After inserting the temperature probe in a hole, the reading should be allowed to stabilize for about one minute before recording the temperature. All temperatures should be recorded on the Temperature Measurement Form (Form F01). The first measurement shall be performed prior to the start of deflection measurements on the monitoring portion of the test section. The last temperature measurement should be obtained immediately following the last FWD test.

11. Seal the holes after the last set of temperature measurements have been made. A sealant, such as silicone caulk, that can be drilled out for future testing without gumming up or binding the drill bit is recommended.

The following equipment and material are needed for temperature gradient measurements:

1. A hand-held battery-powered digital temperature meter with resolution to 0.05° C (0.1° F) over the range from -18° C to 60° C (0° F to 140° F).

2. Two temperature probes, one at least 0.6 m (2 ft) long with probe diameter not greater than 6 mm (0.3 in). The probes should be stainless steel with a thermocouple sealed in the tip and calibrated against NIST traceable standards by the manufacturer.

3. A gasoline- or electric-powered, portable, rotary-hammer drill for drilling holes.

   Note: the electrical power from the DC to AC inverter in the tow vehicle only provides about 4 amps of AC power (500 watts), which will not operate most electric hammer drills.

4. The following supplies need to be available and replenished as needed:

   - A minimum of 2 , 13-mm (0.5 in) diameter carbide tipped bits for the hammer drill. Lengths from 0.3 m (1 ft) to 0.6 m (2 ft) should handle all hole depths needed.

- Several 0.9 m (3 ft) pieces of 6 mm (0.3 in) diameter plastic tube for blowing dust out of the temperature holes.

- Mineral oil and a bottle with a cap that can place a small volume of oil in the temperature holes without excessive spillage.

- Duct tape for covering the temperature holes.

- Temperature Measurement Form (Form F01).

- Several tubes of silicone caulk and a caulking gun for sealing the temperature holes after testing is complete.

For each set of temperature holes, the information contained on the Temperature Measurement Form (Form F01) must be properly and completely recorded by the FWD operator. Time entries for the temperature measurements are local time using a four-digit military time format (e.g., use1615 for 4:15 PM and 0825 for 8:25 AM). The depth of temperature holes are ***measured*** and recorded to the nearest 3 mm (0.15 in). Temperatures are measured and recorded to the nearest 0.05° C (0.1° F).

In addition to reading the temperature gradients, FWD operators should monitor the ambient air temperature and pavement surface temperatures automatically recorded to make sure the values recorded are reasonable (i.e., consistent with actual conditions or compared to hand-held meters used for temperature holes).

Pavement Distress

The type and severity of pavement distress influence the deflection response for a pavement. Therefore, FWD operators need to record any distress located from about 0.3 m in front of geophone No. 8 to about 0.9 m behind the load plate. This information should be recorded in the FWD file using the comment line in the field program immediately following the test. Abbreviations can be used for common distresses (i.e., alligator cracking = ALLIG.CR.). The severity level for a distress is not recorded. FWD operators should refer to the "LTPP Distress Identification Manual" for information on distress type.

When appropriate, the location of the distress relative to the geophone or load plate should be recorded. Abbreviations to make this easier include: OWP, ML, IWP (Inside Wheel Path), LP (load plate), and D1 to D9 for the geophones.

Examples: TRANS.CR. BETWEEN D4 AND D5
RUTTING OWP
PATCH UNDER LP

Other factors to document using the comment line after the test include: data with non-decreasing deflections, data with variations, and unusual conditions or events. Unusual conditions or events could include items such as delays in testing due to break downs or weather, pavement changes within the section, moisture seeping out of cracks, or any other conditions that may help with or explain analysis results for the FWD data.

Joint/Crack Opening

Joint openings in rigid pavement systems affect deflection response and load transfer, and cracks in AC pavements affect pavement response. The following procedures are used for measuring joint/crack openings for the three FWD testing plans.

FLEX Crack Openings: For any GPS or SPS experiment under the FLEX testing plan, ***no*** crack opening measurements are made; however, the FWD operator still needs to record any pavement distress at the test point locations using the comment line as previously discussed.

JCP and CRCP Joint/Crack Widths: The GPS experiments under the JCP and CRCP testing plans and the SPS experiments under the JCP testing plan have joint/crack opening measurements for at least 25% of the Load Transfer tests; however, operators are encouraged to measure 100% of the joint/cracks tested for load transfer if time allows.

Vernier calipers with tapered jaws for measuring inside dimensions are used for measuring the openings. The vernier caliper scale should have a resolution of 0.3 mm (0.01 in).

On transverse cracks, the goal is to measure the opening that extends through the pavement. If the cracks are spalled, the opening may have to be carefully estimated. On sawed joints, the goal is to measure the sawed opening (as opposed to the actual opening) through the pavement. It may be necessary to depress the joint sealant to measure the opening, especially if the joints are spalled.

Joint/crack openings should be measured at several points along the opening in the OWP, and the average value entered at the "post-prompts joint/crack width" prompt immediately following the LT test. The measurement is entered as an integer value between 1 and 25 (ie., 1 mm is entered as 01).

Measurements less than 1 mm are hard to make with a vernier caliper because the caliper jaws will not enter the joint/crack. When this occurs, the operator should enter a "01" on the "Crack Width" comment line after the test has been completed. Measurements in excess of 25 mm should be entered as "25."

For joints/cracks tested for load transfer where openings are not measured, FWD operators must clear the "condition request" data field, because the last entry in the field repeats until it is changed or the field is cleared.

For all testing, FWD operators must clear the "Comment" data field if no information is to be entered. The last entry in the field repeats until it is changed or the field is cleared.

Synthesis of Field Work Activity

The following list of field activities provides FWD operators with an overall perspective of a typical day at a test section, and it outlines the concepts and procedures presented in this Chapter. Further guidance is included in Chapter III and Chapter V.

Field Activities at a Typical Test Section:

Task 1: ***Arrive at Site***

Task 2: ***Coordinate Personnel***

a. Traffic control crew
b. Sampling and testing crew (as appropriate)
c. Other LTPP, highway agency and RCOC Personnel

Task 3: ***Inspect Test Section***

a. Test pit locations (only for first round of tests)
b. General pavement condition
c. Test section limits
d. Test section markings

Task 4: ***Initiate Pavement Temperature Gradient Measurement***

a. Select and mark locations for holes
b. Prepare temperature holes and record depths
c. Record initial temperature measurements after heat dissipation from drilling temperatures holes
d. Record temperature measurements every 60 minutes after the initial readings.

Task 5: ***Prepare FWD Equipment***

a. Remove covers/trays from FWD
b. Visual check of equipment
c. Unlock transport locks
d. Remove raise/lower bar locking pin
e. Computer/Printer setup
f. Initiate and setup FWD field program

Task 6: ***Check FWD Drop Heights***

a. Select location outside test section in travel lane to be tested
b. Condition buffers
c. Load test program
d. Verify loads at each drop height are within specified range
e. Adjust drop heights as necessary to achieve target loads

Task 7: ***Collect Deflection Data***

a. Run FWD tests at test pit locations, P_0 (See Chapter III)

b. FWD testing in sequence of P_1, P_2, and P_3 (See Appendices A, B, C, and E)

Task 8: ***Complete Data Collection and Data Backup***

a. Read final temperatures and seal holes
b. Create backup data disks and history report (see Chapter V)
c. Complete and check field activity form, and temperature form

Task 9: ***Prepare Equipment for Travel and Make Final Inspection***

a. Raise plate and engage transport locks
b. Insert raise/lower bar locking pin
c. Replace transport covers on FWD
d. Store computer, printer, and data forms
e. Final "walk around" inspection of tow vehicle and FWD
f. Site cleanup

Operator Field *Assistance*

Prior to testing, FWD operators need to carefully plan activities to make efficient use of time. Time is most critical for GPS experiments in the JCP and CRCP testing plans and SPS experiments in the JCP testing plan.

Personnel at the site other than the qualified FWD operator are strictly prohibited from driving the tow vehicle or operating the FWD. These functions are the sole responsibility of the FWD operator. However, activities such as drilling temperature holes, recording temperatures, marking panels, and measuring joint/crack openings can be done by other personnel on the site (e.g., traffic control people, other RCOC staff on site, etc.).

FWD operators should never directly ask personnel at the site for assistance. Instead, they should ask crew supervisors if volunteers are available to help. FWD operators should not imply that assistance is expected from others at the site.

Safety

At any time during which FWD and onsite activities are being performed on highway pavements, ***the safety of the operating crews as well as the traveling public is of the utmost importance.*** All operations shall be conducted and conform to local and Manual for Uniform Traffic Control Devices requirements with regard to reflective vests, hard hats, safety glasses, adequate clothing, (including foot gear), and first aid equipment. RCOC onsite personnel should be prepared and field crews provided training using these procedures. Where traffic control activities are provided by the participating Highway Agency (HA), the contractor field crews shall contact the agency prior to arrival at the site to determine all safety requirements. Where traffic control is provided by the RCOC or other contractor, procedures shall be followed as required by the HA, applicable laws and local practice. Work shall be stopped and corrective actions taken if any RCOC, official Authorized Representative or agency official have any concerns about the safety of operations.

In addition, reasonable judgement and care must be exercised by all parties concerned when carrying out FWD related activities in marginal to adverse climatic conditions.

Important safety remarks for FWD operation

An FWD is a powerful, hence dangerous piece of equipment that may injure persons in case of malfunctions or mistreatment.

Things that may happen:

The weight may drop unexpectedly
Hydraulic oil may leak at high pressure
Hydraulic leakage may "DROP" the loading plate assembly onto the ground

A few simple rules for the operator:

Stay clear of the FWD if at all possible
Make sure nobody else gets close
Never place objects (e.g., tools) at or near the buffer hitplate
Do not leave weight raised to drop position
Do not leave the subassembly raised and unlocked
Support the weight or subassembly during maintenance

During demonstrations, training etc:

Announce what you are about to do before you press any control buttons.

A well supplied first aid kit shall be available in the FWD tow vehicle at all times.

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III. DATA ACQUISITION AND HANDLING

General

The FWD operator's primary responsibility is FWD operation and data collection. With data collected in the four regions by many operators, certain guidelines are needed to maintain uniform data collection. The guidelines are divided into the following three areas and described in detail:

1. Setting up the Software for Data Collection
2. Using the Software for Data Collection and Data Backup
3. Processing FWD and Related Data at the RCOC

Setting up the Software for Data Collection

This section of the manual discusses setting up the software for collecting and backing up deflection data for GPS and SPS sections. Further details on the FWD Field Program for data collection are located in manuals from the FWD manufacturer.

Setting up the FWD Field Program

When the FWD Field Program is loaded, the Log On Window for the program is displayed as shown in Figure III-1.

Figure III-1 Log-On Screen

The first time the program is run, the Operator should check Printer, Trailer, Processor, and DMI System to make sure they correspond correctly with the unit. The remaining options should be set based on the user, FWD computer, and testing to be performed. Data format should always read “25SIN. DFF” unless a calibration is being performed, then it should read “25 CAL” for Field Calibration or “R80-25F” for Reference Center Calibration. Further details for Reference Calibrations are include in Section IV. FWD Calibration.

After the options are set, hit the escape key (Esc) or Quit to save the changes and exit the menu. The new settings will be retained until they are manually changed. After quitting the Log On Window, the Page Sync Window will appear; see Figure III-2. The operator should check the Sync Window for Page Number, Current Log Destination, and Log Destination prompt are set correctly. To quit the window press either Esc or Quit.

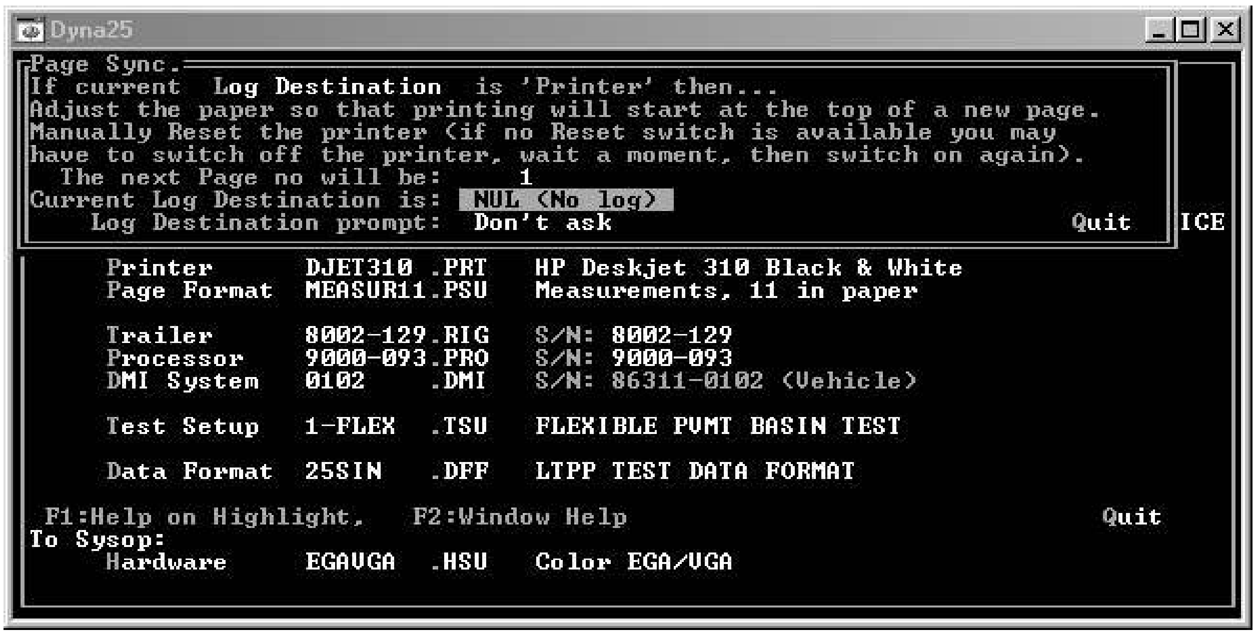

Figure III-2 Page Sync

This brings the operator to the Operator or SYSOP Main Menu Window where the operator will be doing most of the work from, as shown in Figure III-3. For all field testing operations, the Operator access option shall be used. SYSOP access shall only be used for relative and reference calibration functions. Changes made during any activity performed within the SYSOP function shall be verified by the RCOC office and recorded on the Daily Activity Report (Form 1). In addition a full system backup will be required. To continue setting up the software, the Setup option should be chosen. To observe which test setups are within the program, the operator should select “test setup” and then the “load” option. The test setups for the FWD test plans, buffer conditioning, and equipment calibration are predefined, and as such require no additional setup. Sequence Flow for each test set up can be viewed from the “Measurements “ window under Sequence Flow as shown below in Figure III-4. The choices for test setup are shown in Figure III-5.

Figure III-3 Operator Main Menu

Figure III-4 Main Menu

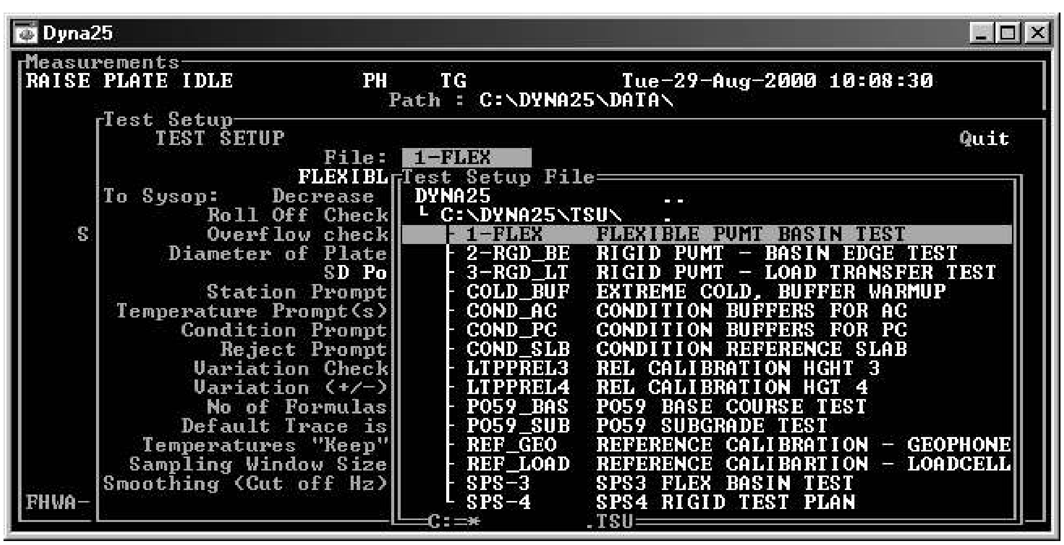

Figure III-5 Test Setup File

The program has five main FWD testing plans: 1-FLEX, 2-RGD-BE, 3-RGD-LT, SPS3,and SPS4 which include separate "Test Categories" for flexible pavements (FLEX), Jointed Concrete Pavement (JCP), and Continuously Reinforced Concrete Pavement (CRCP).

In addition, the program has base and subgrade testing plans (P059_BAS, P059_SUB). Operators should monitor the screen drop sequence data, from test point to test point for indications of changes in the pavements deflection response. In addition, the operator should visually scan the printed output at random intervals to assure the printer is functioning correctly.

In the event of a printer failure the print data can be saved to file. Under the "Setup" option you can "Log to" a named file. The default program file name is "Test.H25". ***Do not*** name the file the same as the section being testing. This normal print copy can be reproduced from the file at the RCOC office with the use of a text editor. This method is only to be used in emergency situations, and shall not be adopted for regular data collection operations.

Using the Software for Data Collection and Data Backup

Program Field Data Collection Operation

FWD operators must set several user options within the program " Measurements" window for each pavement section tested. These windows are described below.

Path - The default directory where data files are located and stored.

File - Within this window there are 3 options, **Q**uit, **C**reate NEW file, and **O**pen EXISTING file. **C**reate New File option will require the following user input. After the file name has been entered, the program will require "Pre-Open-File-Prompts".

File ID (8 Digits max) Window - The information entered on this line will be used to name the file for non-seasonal monitoring sites. File names for non-seasonal sites consist of eight characters using the following format:

373807A1

- characters one through six - SHRP six digit Section ID
- character seven - denote the number of times the section has been tested for the LTPP study (first test is 'A', second test is 'B', etc.)
- character eight - pass number of the FWD on the section

pass 0 (P_0) - OWP test pit locations
pass 1 (P_1) - ML within the 152 m section
pass 2 (P_2) - PE within the 152 m section
pass 3 (P_3) - OWP within the 152 m section

Pre-Open-File-Prompts:

Roadway Location - The Operator shall input the information describing the section within the Roadway Description dialog box. Enter information using the following format examples: Highway classification and designation, direction of lane(s), distance reference to a large city, and state abbreviation.

IH-94, EASTBOUND LANES, 1.9 KM EAST OF ALBANY, MN

US-2, EASTBOUND LANE, 8.0 KM WEST OF GRAND RAPIDS, MN

ST-15, NORTHBOUND LANE, 4.8 KM SOUTH OF LAFAYETTE, MN

SHRP ID - Input the current SHRP ID number of the section to be tested.

Test Setup - Select **L**oad from the Setup File Operation menu. The following Test setups are to be used for LTPP GPS and SPS testing: 1-FLEX, 2-RGD_BE, 3-RGD_LT, P059_BAS, P059_SUB, SPS-3 and SPS-4.

Test Category - Select the required Test category and lane spec from the following options: **O**ther, **F**LEX, **J**CP, **C**RCP. The lane spec options will vary depending on the test category chosen.

Lane Specification - The entries for this field are two-digit codes that include information on the pavement type, test type, and test point location. The codes are listed below according to the FWD testing plans, and include the pass number when the data are collected.

FLEX Testing Plan

F0 DB test at the test pits in the OWP (P_0)
F1 DB test from Sta. 0+000.0 (0+00) to 0+152.4 (5+00) in the ML (P_1)
F3 DB test from Sta. 0+000.0 (0+00) to 0+152.4 (5+00) in the OWP (P_3)
F4 LT test from Sta. 0+000.0 (0+00) to 0+152.4 (5+00) in the OWP at joints/cracks with the load plate on approach slab (P_5)
F5 LT test from Sta. 0+000.0 (0+00) to 0+152.4 (5+00) in the OWP at joints/cracks with load plate on leave slab (P_5)

F4 and F5 are only performed on SPS-6 experiments.

JCP Testing Plan

J0 DB test at the test pits in the OWP (P_0)
J1 DB test from Sta. 0+000.0 (0+00) to 0+152.4 (5+00) in the ML at the mid-panel (P_1)
J2 DB test from Sta. 0+000.0 (0+00) to 0+152.4 (5+00) in the PE at the panel corner (P_2)
J3 DB test from Sta. 0+000.0 (0+00) to 0+152.4 (5+00) in the PE at mid-panel (P_2)
J4 LT test from Sta. 0+000.0 (0+00) to 0+152.4 (5+00) in the OWP at joints/cracks with the load plate on approach slab (P_3)
J5 LT test from Sta. 0+000.0 (0+00) to 0+152.4 (5+00) in the OWP at joints/cracks with load plate on leave slab (P_3)
J6 DB test from Sta. 0+000.0 (0+00) to Sta. 0+152.4 (5+00) in the OWP at mid-panel (P_3)
J7 DB test from Sta. 0+000.0 (0+00) to 0+152.4 (5+00) in the widen lane edge pass at joints/cracks with the load plate on approach slab (P_4)
J8 DB test from Sta. 0+000.0 (0+00) to Sta. 0+152.4 (5+00) in the widen lane edge pass at mid-panel (P_4)

J7 and J8 are conducted on the shoulder, outside the edge stripe.

CRCP Testing Plan

C0 DB test at the test pit in the OWP (P_0)
C1 DB test from Sta. 0+000.0 (0+00) to 0+152.4 (5+00) in the ML at mid-panel (P_1)
C2 DB test from Sta. 0+000.0 (0+00) to 0+152.4 (5+00) in the PE at with the load plate ***centered on the crack*** defining the beginning of the panel (P_2)
C3 DB test from Sta. 0+000.0 (0+00) to 0+152.4 (5+00) in the PE at mid-panel (P_2)
C4 LT test from Sta. 0+000.0 (0+00) to 0+152.4 (5+00) in the OWP at cracks defining the beginning of the panel with the load plate on approach slab (P_3)
C5 LT test from Sta. 0+000.0 (0+00) to 0+152.4 (5+00) in the OWP at cracks defining the beginning of the panel with load plate on leave slab (P_3)

Other Testing Plans for Protocol P59

S1 DB test on Subgrade from Sta. 0+000.0 (0+00) to 0+152.4 (5+00) in the ML (P_1)
S3 DB test on Subgrade from Sta. 0+000.0 (0+00) to 0+152.4 (5+00) in the OWP (P_3)
G1 DB test on Granular Aggregate Base from Sta. 0+000.0 (0+00) to 0+152.4 (5+00) in the ML (P_1)

G3 DB test on Granular Aggregate Base from Sta. 0+000.0 (0+00) to 0+152.4 (5+00) in the OWP (P_3)
P1 DB test on Permeable Asphalt Treated Base from Sta. 0+000.0 (0+00) to 0+152.4 (5+00) in the ML (P_1)
P3 DB test on Permeable Asphalt Treated Base from Sta. 0+000.0 (0+00) to 0+152.4 (5+00) in the OWP (P_3)
L1 DB test on Lean Concrete Base from Sta. 0+000.0 (0+00) to 0+152.4 (5+00) in the ML (P_1)
L3 DB test on Lean Concrete Base from Sta. 0+000.0 (0+00) to 0+152.4 (5+00) in the OWP (P_3)

SD Position - Check the sensor spacing within this window to make sure it corresponds with the testing being conducted. This window was pre-determined; do not alter.

Rem - Any comments the operator wants to make prior to testing should be done within this window. These comments will appear in the header of the file only.

Page Sync - Verifies the data are being sent to the correct printer; if not, the operator must select the correct printer.

The new file name, as entered will appear in a small box on the screen when the Page Sync Window is **Q**uit. Assure the file name follows the LTPP file naming convention. If everything is correct, press the "Enter" key. The options selected during the "Pre-Open-File-Prompt" entry will now appear under the individual sections within the "Measurements " window. Review these selections prior to proceeding and make any necessary changes.

The extension ".F25" is hard coded and used to identify the Dyna25 file as raw deflection data.

After the file name has been input, the Operator must check several of the Measurements Window options;

MODE: The mode should read "DMI Feet"; data are stored in feet and converted to metric during the filter upload to the IMS.

DMI: Starting the DMI the operator should enter distance in feet with the ***load plate*** measured from station 0+000.0 (0+00). The FWD load plate must be positioned at the station entered before the <enter> key is hit to enter the DMI reading. The distance should be entered as follows:

- At DMI line, input station,
- Enter polarity of station only if it is negative "-"
- Enter the distance in feet from station 0+000.0 (0+00) with polarity, if it is negative.

NOTE: Excessive changes in direction can accumulate significant error in the DMI reading, and operators should always check the DMI at stations 0+030.5 (1+00), 0+061.0 (2+00), 0+091.4 (3+00), 0+121.9 (4+00), and 0+152.4 (5+00).

Operators must change the lane specifications ***immediately before*** performing a test at a given location by using the ***Lane Specifications*** field next to the ***Test Category*** window in the FWD Field Program.

After all this information has been input in the Measurements Window the operator can start FWD testing by placing the cursor on the **S**tart option and pressing return or by just pressing **S** until "Start" is highlighted and then pressing "Enter".

Data Quality Checks in the FWD Data Collection Software

Research data must be valid and accurate. For the deflection data, the FWD software uses up to five quality control checks as the data are collected. The checks in use are selected in the setups and are described below. Details on handling data failing any quality control checks are described later in this chapter in the section on "Rejecting tests".

Roll-off - electrical check that the magnitude of the deflections 60 milli-seconds after the trigger activated on FWD have decreased to less than 10% of the peak deflection readings. If this condition is not met, an error window appears explaining the problem and when exited a "What's Next" window appears and allows the operator to either **Q**uit the test sequence or continue.

This check can "fail" if the pavement is close to bedrock, if the deflections are very low (frozen subgrade), or if a sensor is not properly seated on the pavement. If a sensor is suspect, the sequence should be **Q**uit and the sensor examined. If the check "fails" from bedrock or very low deflections, a comment should be included in the file the comment line at the end of the test or the **C**omment option in the Measurements Window.

Decreasing Deflections - checks that deflections decrease with distance from the load. The check is used for DB tests only. If this condition is not met, an error window appears explaining the problem and when exited a "What's Next" window appears and allows the operator to either **Q**uit the test sequence or continue.

Most often the condition is not met when transverse cracks exist between the sensors, especially on full-depth asphalt. For this case the test should be continued, and the distress and failed check noted in the file using the "Post-Test Comment Prompt" (Comment2) line at the end of the test in the Measurements Window. This problem also occurs in JCP and CRCP tests, but no corrective action is necessary.

Out of Range - checks that deflections are less than the 2000 micron (80 mil) range of the sensors. The deflection which does not meet this criteria is highlighted. In addition, an error window appears explaining the problem and when exited a "What's Next" window appears and allows the operator to either **Q**uit the test sequence or continue.

If the condition is not met, the sensors and pavement surface should be checked for potential problems. If the deflections are large because the pavement is weak, the loads should not be changed. Comments should be included in the file using the “Post-Test Comment Prompt” comment line at the end of the test in the Measurements Window.

Load Variation - checks that the loads at a particular drop height are grouped within a specified tolerance. If the condition is not met, the load which fails is highlighted. In addition, an error window appears explaining the problem and when exited a "What's Next" window appears and allows the operator to either **Q**uit the test sequence or continue (See “Rejecting Tests” section later in this chapter).

The tolerance range for load is set at :

X ± (0.18 N + 0.02X) or X ± (40 lbs + 0.02X)

Where X = average load for all drops at that height.

For example, if the average load for four drops at drop height 1 is 26.7 kN (6,000 lbs), the allowable load range would be 26.7±(0.18+0.02*26.7) or 26.0 kN to 27.4 kN (6,000 ± (40+0.02*6,000) or 5,845 lbs to 6,160 lbs).

Deflection Variation - checks that the ***normalized*** deflections for an individual geophone at a particular drop height are grouped within a specified tolerance. If the condition is not met, the deflection which fails is highlighted. In addition, an error window appears explaining the problem and when exited a "What's Next" window appears and allows the operator to either **Q**uit the test sequence or continue (See “Rejecting Tests” section later in this chapter).

Normalized deflections are the measured deflections (raw data) adjusted to a constant load magnitude.

The tolerance range for deflections is set at:

X ± (2 microns + 0.01X) or X ± (0.08 mils + 0.01X)

Where X = average ***normalized*** deflection for a geophone for all drops at that height.

For example, if the average ***normalized*** deflection for geophone 1 for four drops at drop height 1 is 508 microns (20 mils) the allowable ***normalized*** deflection range would be 508±(2+0.01*508) or 501 microns to 515 microns (20±(0.08+0.01*20) or 19.7 mils to 20.3 mils).

Accidental Acceptance

If a "reject test" is accidentally accepted, the operator must take one of the following steps:

1. If the error is caught before the next test is started, the data set can be deleted by going back to the File window pressing "Enter" and selecting **R**everse which deletes the last block of data. The last data set is erased from the file.

2. If the error is caught after the next test has started, mark the "reject test" data on the left margin of the printout with a **RED** pen to note that the data was accidentally accepted and should be removed from the data set at the RCOC office prior to upload to the IMS.

NOTE: If data for the test point are deleted, in most cases, the test point must be retested. If the data were deleted because the wrong location was tested, then the location does not need to be retested.

Crack Measurements and Comments

Crack/joint width measurements - crack/joint openings are measured to the nearest millimeter (hundredths of an inch) and recorded in the two character Crack Width field.

19.05 mm is recorded as **19**

NOTE: if the joint/crack opening exceeds 25 mm enter **25** and if the joint/crack opening is less than 1 mm enter **01**, do not enter "00" or values greater than "25".

Proceed to the next test location, select start and press "Enter".

Rejecting Tests

For the majority of cases, the "What Next?" window appears because load or deflection data exceeds variation limits; however, non-decreasing deflections or data exceeding the range of the geophones can also activate the "What Next?" window.

Operators should examine the data on the screen to determine the cause. The deflection or load value is highlighted on the screen if the data has failed the variance criteria (see Chapter II of this manual), and messages for non-decreasing deflections or out of range data are displayed if they occur.

For all cases, the operator has to decide whether to reject or accept the data. If the data are rejected the operator must repeat the test. In many cases, one load or deflection reading will be the problem, and a single repeat test is all that is needed.

The following guidelines will help decide what to do when the "What Next?" window occurs.

1. The normal procedure is to reject the test and re-test the location without moving the equipment.

   In many cases the data will meet variation criteria on the second test if it is an isolated problem (sensor may have been on a small stone and slipped off during the test, hydraulics settled if test delayed while mass up, truck passing in adjacent lane (especially on JCP), etc.).

   If variation occurs a second time at the location, the operator should check for equipment problems.

   - Operators should compare changes in deflection at a drop height with changes in load to see if the problem is with the load or a geophone.

   - If deflections at a given drop height are very consistent, but the load varies significantly, then the load reading is suspect.

   - If the loads at a given drop height are very consistent, but a sensor has significant deflection variation, then that sensor is suspect.

   The following equipment checks should be done:

   - Check load cell and geophones electronically using the "drift" check in the “Util” option of the measurements window. Follow the directions on the computer screen. Very little, if any, noise should be present.

   - Check magnetic coupling of the geophones in the holders.

   - Check cables and connections.

   - If load variations occur, check that the four targets for the drop heights are tight.

3. If no equipment problems are found, or if minor problems are found and corrected, the location is tested a third time.

4. If the data still fails the variation criteria, and it is at a crack/joint (J2, J4, J5, C2, C4, or C5 lane specification), the FWD can not be repositioned, and the third test with data variation is saved along with a comment in the data file.

5. If the data still fails the variation criteria, and it is a DB test not adjacent to a joint/crack (F1, F3, J1, J3, and maybe C1 and C3 depending on the size of the panel), raise the load plate, move the FWD forward 0.6 meters (2 ft) and test the new location. This set of data is saved regardless of load or deflection variation. However, the Comment line should be used if the data failed the variation criteria.

6. Field judgement will be required by the operator if many variations occur, regardless of how much time is available for retests (it is more important to test all test points than to do repeat tests at all points with variations). If the operator can determine that a pavement condition is causing the variations and not a problem with the equipment, it may not be feasible to do more than a couple of repeat tests to verify that the problem or condition is inherent to the pavement structure. Some particular pavement conditions that can cause variations include:

   - New overlay, leveling course, or patch compacting under the load plate.

   - Uneven surface from rutting, patching, pavement repair, or roll-off at the pavement edge (PCC sections only) causing load variation from uneven contact pressure under the load plate.

   - Unstable layer in the pavement structure which is altered by the load applications from the FWD. Such layers could be a distressed surface, stripped base, cement stabilized subgrade, saturated granular base, or a saturated subgrade.

   For these conditions, at least one complete set of three repeat tests should be saved for analysis to determine what effect the repeat testing or "conditioning" of the pavement has on the results from analysis of the data.

Closing a Data File

The FWD data files must be closed properly at the end of each pass. This is done pressing “Enter” on the file line, which opens the File window, and selecting the **C**lose option.

If for any reason there is an incomplete pass for a section on a given date, that pass must be repeated on a subsequent (preferably next) date – i.e., cannot complete missing test points on a different date and append to original file.

Once testing on a specific pass is begun, it must be completed. Operators cannot append files when data on a test section are collected on separate dates.

FWD Data and Field Program Backup Procedures

A backup copy of the FWD field program and configuration files should always be kept up to date. The field program informs operators when changes need to be saved to the backup disk. FWD operators should take a backup copy out of the tow vehicle when they are not with the equipment.

FWD operators also have the responsibility to safeguard the FWD data files by keeping copies of the data in more than one location. Without exception, all deflection data files must be backed up before leaving the site.

FWD operators will make three complete backup copies of LTPP FWD data files using file compression software such as WinZip© (v7.0), ***and/or*** PKZIP (v2.04g). Two of the copies will be created on floppy diskette, and the third copy will be created on floppy diskette ***or*** the FWD computer hard drive. Acceptable data backup options include the following:

- Create three copies on floppy diskette using WinZip© ***or*** PKZIP©; or
- Create two of the copies on floppy diskette using WinZip© ***or*** PKZIP© and the third copy on the FWD computer hard drive using WinZip© ***or*** PKZIP©.

One backup copy on floppy diskette is to be transmitted to the RCOC along with the printed copy of the deflection data generated by the FWD during actual testing.

The remaining two copies will serve as backups should the copy sent to the RCOC be lost or damaged. One of these copies must be removed from the FWD tow vehicle whenever the FWD operator is not with the testing equipment.

Labeling Backup Diskettes for the Deflection Data Files

The format to use for the diskette labels is as follows:

Line 1:	**'xxxxxx'** where xxxxxx is the SHRP six digit section ID#
Line 2:	**'Volume x of y'** where x is the disk number within the set, and y is the total number of disks in the set
Line 3:	**'Copy x'** where x is the set number, usually 1 to 3
Line 4:	**'FWD SN xxx'** where xxx is the serial number of the FWD that tested the section
Line 5:	**'mm/dd/yyyy'** where mm/dd/yyyy is the date(s) the testing was performed
Line 6:	**'First Name/Last Name'** where name is operator who performed FWD testing

Operators should label each diskette as they are used by WinZip© and/or PKZIP.

Miscellaneous Supply Requirements

FWD operators should obtain adequate supplies before extended trips. While not complete, the following supplies are recommended.

1. Two thousand pages of 216 mm x 279 mm (8.5 in x 11 in) ink jet compatible paper. Estimate using approximately 250 pages per week.

2. Six ink cartridges.

3. Sufficient 3.5 in - 1.44 Mb diskettes. Estimate 25 plus per week.

Note: The second and third set of the FWD data backups can be reused as soon as the RCOC notifies the FWD operator that the first set of data disks has been restored, and that all the data were readable.

Processing FWD and Related Data at the RCOC

Restoring Data

FWD data received at the RCOC must be restored to its original format using the WinZip© extract function *or* PKZIP as appropriate; the same software used to create the copy on the floppy diskette(s) must be used to restore the FWD data. Once the data have been restored, and the RCOC verifies the data files are complete, and in a readable form, the FWD operators can reuse the diskettes with the extra backup copies of this data.

RCOC Deflection Data Evaluation

This field guide does not go into detail on the review and analysis of deflection data at the RCOC. However, the steps below are listed for processing the data before it is uploaded in the LTPP Information Management System (IMS) database. These steps are:

- All deflection data received at the RCOC are restored using WinZip© *or* PKZIP as described above.

- Deflection data files are to be reviewed using FWDScan, edited and stored. Editing can be done using a text editor. Edits may include correction of header information (Station, lane specification, temperatures, etc.) and deletion of erroneous drop set data, including accidentally accepted data. Edits made during this evaluation process should be recorded and used in the RCOC QC feedback process. They should also be discussed and reviewed with the FWD operator so that cause can be determined and corrected in future data collection operations when applicable.

- Convert *.H25 binary time history files to ASCII format for display and verification purposes. Conversion requires use of the “history9.exe” (for 60 msec time histories), “hist911f.exe” (for 110 msec time histories) or “hist912f.exe” (for 120 msec time histories) DOS command line executable and “egavga.bgi” Borland Graphics Interface file.

  File conversions should be run from the same subdirectory where the data resides as detailed in the following command line string example for conversion of a 60 msec time sampling window:

  C:\FWD\Data\history9 370204j1.H25 370204j1.TXT

  where:

history9	=	file conversion executable (60 msec in this example) followed by a single space.
370204j1.H25	=	*.H25 file to be converted from Binary to ASCII followed by single space
370204j1.HXT	=	ASCII text file resulting from conversion; file name shall confirm to standard FWD file naming convention and use *.HXT file extension.

With command line string appropriately typed and named, execute conversion by striking the "Enter" key. Once conversion is complete, verify that converted time history data file is in a readable form similar to the following tabular format:

Load	SD1	SD2	SD3	SD4	SD5	SD6	SD7	SD8	SD9
-25.5	0.1	-5.6	0.2	-0.1	8.5	-11.9	7.0	4.0	8.3
-51.0	6.6	-10.2	0.4	11.6	5.1	-16.8	13.9	8.0	24.6

- Using WinZip© or PKZIP, create compressed archive file that includes *.F25, *.H25 and *.HXT files. The name of the compressed file must confirm to the standard FWD file naming convention and use the *.ZIP file extension.

- The current version of the FWDScan program is used to check the *.F25 data file format and operator input data. The check results are stored in a file with an extension of *.OUT.

- The deflection data (*.F25) are loaded into the Information Management System (IMS).

- After successful loading of the data into the IMS, all *.ZIP and *.OUT files must be archived to CDROM disk.

- The FWDCheck program should not be run on Edition 25 data files (i.e., *.F25).

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IV. EQUIPMENT CALIBRATION AND CHECKS

Background

Highly accurate deflection data are required to derive meaningful estimates for the structural characteristics of a pavement structure from FWD data. For this reason, periodic calibration of any FWD collecting data for the LTPP study is required. The detailed procedures for FWD calibration are provided in Appendix F of this document. However, these procedures supplement, rather than replace, the manufacturers calibration requirements and are not intended to serve as the basic or initial calibration of the FWD.

The FWD calibration is a two-part procedure. The first part, referred to as ***reference*** (or occasionally, "absolute") calibration, involves calibration of the FWD load and deflection measurement systems against an independent reference. Within the overall calibration procedure, reference calibration ensures that the FWD load and deflection measurement systems are unbiased with respect to independently calibrated reference systems traceable to standards. The second part of the calibration procedure, referred to as ***relative*** calibration, involves calibration of all FWD deflection sensors against each other. This ensures that all sensors read the same with respect to each other. Also, relative calibration done on a monthly basis verifies the stability of the FWD deflection measurement system.

In addition to the FWD calibration, periodic checks of the DMI and temperature sensors are required. The procedures associated with those checks are presented later in this section of the manual.

LTPP FWD testing operations shall be suspended if there are any defective measuring sensors on the FWD or FWD associated measurements (deflection, load, DMI and/or temperature) or operational hardware (printer, computer).

Problems that could delay FWD testing operations more than a couple of days should be reported immediately to the FHWA LTPP Team and the LTPP Technical Support Services Contractor (TSSC), who will help the RCOC explore more expedient solutions.

FWD Calibration Requirements

As a minimum, any FWD collecting data for the LTPP study is required to undergo a ***full calibration*** (including both reference and relative calibration) at least once per year. This calibration must be done at one of the four calibration centers established by SHRP (or equivalent as determined by the Pavement Performance Division staff) following the procedures provided in Appendix D or subsequent versions. ***Full calibration*** is also required immediately after replacement of load cell, and as soon as possible after replacement of any major components of the FWD, such as deflection sensors, signal processing modules, etc.

In addition, ***relative calibration*** of the FWD deflection sensors is required monthly but not to exceed 6 weeks during the months in which the FWD unit is continually testing. During times of non-testing the FWD units are not required to have monthly calibrations but must have a relative calibration performed prior to testing after a period of inactivity. Under no circumstance should the time from the last relative calibration exceed 42 days when using an FWD for collecting data for the LTPP study.

The reference calibration requires changes in the FWD Data Format to correspond with the reference calibration center load (lbs.) and deflection (mils) input requirements. Prior to starting a reference calibration, the FWD operator needs to change the data format from 25SIN (used for all LTPP data collection) to R80-25F (SHRP compatible 9 sensor). In addition, the general setup needs to be changed from Color-SI to Color-US. From the Color-US menu, the units printed need to be changed from kN to lbs. and microns to mils. This will enable hard copy outputs in lbs. and mils, as required by the reference calibration center computer software. At the completion of the reference calibration, the FWD operator needs to change the general set up back to Color-SI and the units to metric (lbs. to kN and mils to microns). The relative calibration requires the data format 25CAL (9 sensor calibration). This is the only time you will use the R80-25F and 25CAL settings, as all LTPP FWD testing shall be conducted using the 25SIN data format.

DMI Calibration

In addition to regular daily operational checks of the DMI readout against pavement section stationing, the DMI also requires a monthly calibration. This is achieved by accessing the "Calibrations" option from the FWD Dyna25 program "Main Menu" and utilizing a pre-measured pavement section.

The FWD DMI is calibrated by driving the vehicle over a known distance to calculate the distance scale factor. This procedure requires pre-setting a driving course. The FWD operator enters actual distance traveled and FWD software calculates scale factor.

An accurately measured section exceeding 150 meters should be used to calibrate the DMI. This section should be located on a straight portion of a roadway that is reasonably level and having low volume traffic or a lane closure. The section should be measured with a tape measure (do ***not*** use a measuring wheel). Ensure that proper tension and alignment is applied during layout of the section.

The FWD operator should drive the vehicle at highway speeds prior to the calibration and ensure that the tires are set to the correct inflation pressure between 413 an 448 kPa (60 and 65 psi).

Following the screen prompts from the FWD DMI Calibration menu, this process can be effectively carried out within 3 to 4 runs. In addition, these check shall be performed when FWD operator observes "suspicious" DMI readings.

FWD Temperature Sensor Checks

The accuracy of the FWD air temperature and infra-red (IR) sensors will be checked on a monthly basis or more frequently if the FWD operator observes "suspicious" temperature readings. The equipment and materials required to perform these checks as well as the procedure are described below. The procedure is portable to allow for temperature checks at the office as well as in the field.

These checks should not be construed as a calibration of the referenced sensors. RCOCs shall not calibrate temperature sensors. If a sensor fails one or more temperature checks, it shall be sent back to manufacturer for repair or calibration, or it shall be replaced by a new sensor.

The equipment and materials needed to perform the FWD temperature sensor checks include:

- NIST Traceable Mercury Thermometer
- 3.8 Liter (1 Gallon) Bucket
- Hot Plate
- Large Wooden Spoon or Paint Stirrer
- Medium Size Cooking Pot (Approx. 125 mm diameter)
- Leather Heat Resistant Gloves
- Cooking Oil
- Ice
- Copy of LTPP Temperature Sensor Check (TSC) form

Procedures to check accuracy of air temperature sensor and of IR sensor vary slightly. Temperature checks for IR sensor shall be performed at three different temperatures - one near 0 degrees (cold temperature test), one near ambient air temperature, and one near 60 degrees Celsius (hot temperature test). Air temperature sensor checks shall only be performed at the first two temperatures - near 0 degrees Celsius and near ambient air temperature. Detailed steps for checking both of these sensors are provided next.

1. Park FWD van and trailer on smooth surface, in area with good ventilation and not exposed to direct sunlight.

2. Start Dyna25 FWD Software and proceed to Measurements Screen. Record air and surface temperatures displayed on measurement screen on LTPP Temperature Sensor Check (TSC) form.

3. Unclip air temperature sensor so that it may hang freely.

4. Conduct cold temperature sensor checks.

    - Prepare ice water bath for cold temperature check. Place ice and water in 3.8 liter bucket and begin stirring with wooden spoon. By agitating water, ice water temperature should fall to 0 to 1 degrees Celsius. Place ice water directly under IR sensor. When IR temperature reading stabilizes, record temperature of ice water with mercury thermometer and IR sensor simultaneously. Record readings on TSC form. Continue agitating ice water for one (1) minute and record temperatures again.

Next, calculate temperature difference between IR sensor and mercury thermometer for each set of readings. If difference is less than or equal to 2 degrees Celsius for both sets, IR sensor shall be considered to be working properly at cold temperatures. If difference for both sets is greater than 2 degrees, IR sensor shall be considered unacceptable. If difference is greater than 2 degrees for one of two sets, obtain a third set of IR sensor and mercury thermometer readings and if difference between those readings is within 2 degrees, consider IR sensor acceptable. Otherwise, consider IR sensor unacceptable.

- After completing IR sensor check, place air temperature sensor in ice water bath beside mercury thermometer. Once air temperature sensor reading stabilizes, record temperature of ice water with mercury thermometer and air temperature sensor simultaneously. Record readings on TSC form. Continue agitating ice water for one (1) minute and record temperatures again.

  Next, calculate temperature difference between air temperature sensor and mercury thermometer for each set of readings. If difference is less than or equal to 2 degrees Celsius for both sets, air temperature sensor shall be considered to be working properly at cold temperatures. If difference for both sets is greater than 2 degrees, air temperature sensors shall be considered unacceptable. If difference is greater than 2 degrees for one of two sets, obtain a third set of air temperature and mercury thermometer readings and if difference between those readings is within 2 degrees, consider air temperature sensor acceptable. Otherwise, consider air temperature sensor unacceptable.

5. Conduct ambient air temperature sensor checks.

- Even if IR sensor and/or air temperature sensor fails cold temperature check, proceed with ambient air temperature check. Replace ice water in bucket with luke warm tap water and allow water to sit under IR sensor for 10 minutes. Agitate water to allow excess heat to dissipate. After 10 minutes, record temperature of water with mercury thermometer and IR sensor simultaneously. Record readings on TSC form. Wait one (1) minute and record temperatures again.

  Next, calculate temperature difference between IR sensor and mercury thermometer for each set of readings. If difference is less than or equal to 2 degrees Celsius for both sets, IR sensor shall be considered to be working properly at ambient air temperature. If difference for both sets is greater than 2 degrees, IR sensor shall be considered unacceptable. If difference is greater than 2 degrees for one of two sets, obtain a third set of IR sensor and mercury thermometer readings and if difference between those readings is within 2 degrees, consider IR sensor acceptable. Otherwise, consider IR sensor unacceptable.

- After completing IR sensor check, place air temperature sensor in water bath beside mercury thermometer. Once air temperature sensor stabilizes, record temperature of water with mercury thermometer and air temperature sensor simultaneously. Record readings on TSC form. Wait one (1) minute and record temperatures again.

  Next, calculate temperature difference between air temperature sensor and mercury thermometer for each set of readings. If difference is less than or equal to 2 degrees Celsius for both sets, air temperature sensor shall be considered to be working properly at ambient air temperature. If difference for both sets is greater than 2 degrees, air temperature sensors shall be considered unacceptable. If difference is greater than 2 degrees for one of two sets, obtain a third set of air temperature and mercury thermometer readings and if difference between those readings is within 2 degrees, consider air temperature sensor acceptable. Otherwise, consider air temperature sensor unacceptable.

6. Conduct hot temperature sensor checks.

   If IR sensor has failed either cold temperature and/or ambient temperature check(s), do not perform hot temperature test. Also, do not perform hot temperature check on air temperature sensor.

   The hot temperature sensor checks are optional if those checks are being performed in the field. To perform hot temperature test, cooking oil must be heated. Pour cooking oil to a depth of approximately 50 mm in cooking pot and begin to warm on hot plate. Once cooking oil temperature has reached 60 degrees Celsius, stabilize oil temperature to 60 degrees +/- 5 degrees. Carefully stir oil to ensure consistent temperature throughout. Individual stirring oil **must** be wearing gloves. Use IR sensor to determine initial oil temperature.

   Once oil temperature stabilizes, record temperature simultaneously with IR sensor and mercury thermometer. Record the readings on TSC form. Wait five (5) minutes and repeat this step.

   Next, calculate temperature difference between IR sensor and mercury thermometer for each set of readings. If difference is less than or equal to 2 degrees Celsius for both sets, IR sensor shall be considered to be working properly at ambient air temperature. If difference for both sets is greater than 2 degrees, IR sensor shall be considered unacceptable. If difference is greater than 2 degrees for one of two sets, obtain a third set of IR sensor and mercury thermometer readings and if difference between those readings is within 2 degrees, consider IR sensor acceptable. Otherwise, consider IR sensor unacceptable.

Temperature sensor checks shall be performed monthly to ensure accurate temperature data are being collected during FWD operations. In addition, these check shall be performed when FWD operator observes “suspicious” temperature readings.

Reporting Requirements

Reference Calibrations

FWD ***reference*** calibration results shall be submitted to the respective RCOC and FHWA LTPP Team Office within seven days after calibration.

Monthly Relative Calibrations

FWD ***relative*** calibration results shall not be required for submission to the FHWA LTPP Team Office. RCOC’s shall continue to prepare the relative calibrations reports in accordance with the format specified in Appendix F. RCOC should analyze reference and relative calibration data for shifts in sensor and or load cell gain factors. The reference, relative and data records will be reviewed by FHWA LTPP Division staff or its assigned representative during the Annual Review of the LTPP FWD Regional Operations.

FWD DMI Calibration

If the DMI cannot be calibrated successfully, no further testing shall be conducted with the faulty DMI until it is fixed or replaced by a working DMI that passes the calibration checks. DMI calibration results are recorded within the FWD program; however, the FWD operator should record the time, date and any anomalies that occurred during calibration on the FWD Field Activity Report Report (Form 1), which in turn shall be submitted to the respective RCOC within seven days after calibration.

Temperature Sensor Checks

Completed Temperature Sensor Check (TSC) forms shall be kept at the RCOC offices; they shall not be submitted to the FHWA LTPP Team unless a sensor is rated as “unacceptable” after completion of sensor checks. To be considered “acceptable,” a sensor must pass **all** required check. A sensor is considered “unacceptable” if it fails **one or more** temperature checks -- cold temperature, ambient air temperature or hot temperature.

If a sensor is rated as “unacceptable,” RCOC shall submit a FWD problem report (FWDPR) with appropriate TSC form attached. In addition, no further testing shall be conducted with the faulty sensor until it is fixed or replaced by a working sensor that passes all temperature checks.

V. EQUIPMENT MAINTENANCE AND REPAIR

General Background

The extensive use of FWDs within LTPP makes good preventative maintenance practices especially important. The RCOC are responsible for preventative maintenance to keep the equipment dependable and to minimize deterioration. The maintenance procedures in the manuals provided with each piece of equipment should be followed.

Coordination of schedules for traffic control, sampling and testing, and maintenance of the deflection testing equipment are critically important. Scheduled preventive maintenance ensures proper equipment operation and helps identify potential problems. Potential problems identified can be corrected to avoid costly delays or missing data that results if the equipment malfunctions while on site.

The testing requirements at a section usually limit FWD operators from doing more than initial checks and monitoring the operation of the equipment. Typically, any maintenance must be done at the end of the day after the testing is complete, and should become part of the routine performed at the end of each test/travel day and on days when no other work is scheduled.

Equipment Maintenance and Repair

Routine Maintenance

Routine maintenance functions are performed easily with minimal disassembly and include procedures like checking the fluid levels in the tow vehicle, checking vehicle lights, etc. These basic and easily performed maintenance measures should be done each day prior to using the equipment.

The following partial list of BEFORE OPERATIONS CHECKS show the extent and detail required for preventative maintenance. These items are not to supersede manufacturer's minimum requirements for warranty compliance.

Tow Vehicle:

Under-hood : fluid levels (engine oil, brake fluid, power steering, windshield washer, engine coolant, transmission fluid); drive belt tension (water pump, alternator, a/c compressor); battery cable connections; general appearance (leaks, cracked hoses, cracked insulation).

Exterior : tires (inflation and condition); lights (headlights, signals, flashers, beacon, arrow board); glass (clean, no cracks); electrical connections (clean and corrosion free).

Interior : general appearance clean and uncluttered; equipment properly stowed; glass clean and view unobstructed; power inverter well ventilated with good electrical connections; computer in good condition; air conditioning functioning properly (operate monthly to keep compressor lubricated); temperature measuring equipment in good condition.

FWD:

Trailer connection to Van : ball tight, safety chains in place, breakaway cable for electric brakes in place; tires properly inflated and good condition; lights functioning properly (brake, turn signal); battery electrolyte level good and tight, clean connections; covers and latches in good working condition; hydraulic oil level and viscosity; load plate swivel proper lubrication; general appearance clean and paint in good condition.

FWD : catch head lubricated; weight guide rollers clean and lubricated; weight guide shaft clean and dry lubrication; raise/lower bar cable not frayed, properly adjusted and positioned; geophone holder bases undamaged, free of corrosion, and silicon lube on foam guides; pressure switches rubber boots in good condition and full of grease; transport locks undamaged and functioning properly; raise/lower bar front guide mechanism undamaged and split pin in place when in transit; trailer connection box undamaged and properly latched.

FWD operators must indicate that the BEFORE OPERATION CHECKS were performed by initialing this item on the FWD FIELD ACTIVITY REPORT (Form F02).

Scheduled Major Maintenance

Scheduled major maintenance includes much more than routine checks. These services require some disassembly of equipment and services typically beyond the skill of FWD operators or RCOC staff. Summaries for all maintenance activities are to be recorded on the MAINTENANCE AND REPAIR SUMMARY Form (Appendix H: Standard FWD Forms). Services in this category are engine tune-ups, tow vehicle brake work, drive belts, etc.

Refer to equipment owner's manuals for appropriate service intervals, unless instructed to do otherwise. The RCOC should implement a written and documented preventative maintenance program for the FWD and tow vehicle.

Equipment Problems/Repairs

LTPP FWD testing operations shall be suspended if there are any defective measuring sensors on the FWD or FWD associated measurements (deflection, load, DMI and/or temperature) or operational hardware (printer, computer).

Problems that could delay FWD testing operations more than a couple of days should be reported immediately to the FHWA LTPP Team and the LTPP Technical Support Services Contractor (TSSC), who will help the RCOC explore more expedient solutions.

Regardless of the maintenance program there will be equipment failures, and repairs must be done in a timely fashion. Repairs are easily handled when no testing is scheduled: however, if they occur during mobilization or testing, adjustments in the schedule will be needed to allow for repairs.

To minimize the impact of equipment problems, FWD operators shall notify the RCOC and other necessary agencies immediately. Sufficient spare parts should be kept in the tow vehicle to cover anticipated repairs. The length of time for repairs must be considered for rescheduling traffic control on future sites. Therefore, it is essential that maintenance be done in advance of field work, in order to minimize rescheduling of traffic control.

Serious problems which might affect the operation of other LTPP FWDs are to be brought to the attention of the FHWA LTPP Team promptly. The format for submitting problems associated with FWD testing activities are the FWD PROBLEM REPORT (FWDPR) Form (Appendix H: Standard FWD Forms).

When emergency repairs are performed by an outside agency, FWD operators report this information using the MAINTENANCE AND REPAIR SUMMARY Form (Appendix H: Standard FWD Forms). Circumstances making the work necessary should be included in the report. Any repairs by FWD operators should be noted on the FWD FIELD ACTIVITY REPORT for that day, regardless of whether the report is for a testing day, travel day or just repairs.

Procedures

Maintenance of Records

FWD operators are responsible for keeping a file for RELATIVE CALIBRATION REPORTS. Copies of FWD FIELD ACTIVITY REPORTS, MAINTENANCE AND REPAIR SUMMARY REPORTS, and RELATIVE CALIBRATION REPORTS are forwarded to the RCOC as needed to limit impacts on the testing schedule. LTPP Headquarters should be informed of major problems ***promptly***, but in general the RCOC's are responsible for FWD operations.

Equipment Repairs

The RCOC's are responsible for maintaining the FWDs. The decisions required for proper maintenance and repair should be based on the testing schedule, and expedited as necessary to prevent disruption of testing. Most services are provided by local agencies; however, annual FWD maintenance for five successive years will be performed by Dynatest as part of the maintenance contract.

Accidents

FWD operators will inform the RCOC's and LTPP Headquarters as soon as practical after any accident. Details of any accident shall be reported in writing.

Records

FWD operators perform a great deal of work during a test day, and much information needs to be manually recorded. The following forms help organize this information without significantly adding to the work load.

The responsibility for equipment maintenance and repair rests with each RCOC, and a copy of each record, form, or log need not be forwarded to LTPP Headquarters. Rather, the RCOC should keep LTPP Headquarters informed as needed of any major problems concerning deflection testing equipment. Three types of records are required. These records should be up-to-date with one complete set kept on file at the RCOC. The three forms/reports required are:

1. FWD Field Activity Report (Form F02: Appendix H)
2. Maintenance and Repair Summary Report (Form-F03: Appendix H)
3. FWD Problem Report - FWDPR (Form FWDPR: Appendix H)

A record of the calibration reports for one year should be kept in the tow vehicle. This complete set can either be paper copies and/or floppy diskette(s).

Field Activity Report

The FWD Field Activity Report (Form F02); is used by FWD operators to record daily activities for the FWD and tow vehicle. On this report, the section information data, information related to productivity, and any conditions affecting deflection data not recorded in the FWD files should be recorded. The information required includes travel time and mileage to/from a site, length of time traffic control was in place, number of FWD tests performed, any down-time, and the names and agencies of both Field Sampling & Testing and Traffic Control personnel.

The FWD Field Activity Report is filled out for all travel days, testing days, and any days the FWD operator performs maintenance on the FWD or tow vehicle. Reports for testing days must be completely filled out, while reports for travel days and maintenance days are only partially filled out including the section ID for which the traveling is done. For testing days, it is important to obtain the names of personnel on site in case of an accident.

A line is provided for FWD operators to initial indicating that routine maintenance was conducted prior to any FWD testing.

The original report is kept in the tow vehicle, and a copy is forwarded to the RCOC along with the field data diskettes and a hard copy of the data.

Equipment Maintenance Records

Equipment maintenance records include the FWD Field Activity Report (F02) and the Maintenance and Repair Summary Report. Any maintenance or repair item are reported using the maintenance and Repair Summary Report Routine maintenance, before operation checks, and minor repairs performed by FWD operators are reported on the FWD Field Activity Report (Form F02).

FWD Problem Reports (FWDPR)

The FWDPR form provides several major benefits including: a standard format for submitting problems associated with the FWD testing activities, thus making everyone's job easier; a much easier way of tracking when a problem was submitted, who is responsible for resolving it, whether or not it has been resolved, and how and when it was resolved; and reduced probability of problems being forgotten or falling through the cracks.

The FWDPR form is self explanatory except for the FWDPR number. This number consists of two parts as follows:

- A letter code representing the agency submitting the problem -- "F" for FHWA LTPP Team, "NA" for North Atlantic RCOC, "NC" for North Central RCOC, "S" for Southern RCOC, "W" for Western RCOC, "TSSC" for Technical Support Services Contractor, and "O" for others.

- A number code representing the FWDPR number for the submitting agency, in sequential fashion starting from 1.

For example,

F-07: represents the seventh problem reported by the FHWA LTPP Division; and
NA-23: represents the 23rd problem reported by the North Atlantic RCO.

Completed FWDPR forms must be submitted to the FHWA LTPP Team, with copies to the LTPP Technical Support Services Contractor (TSSC) and to the FWD coordinator at each RCOC office. A complete set of the FWDPR submittals will be maintained by the FHWA LTPP Team and LTPP TSSC. The LTPP TSSC will generate a monthly report summarizing the status of unresolved problems. A copy of this report will be submitted to RCOC FWD coordinators for their information and action, as appropriate.

Other Equipment Considerations

Special Provisions for Cold Weather FWD Testing

The FWD tow vehicle shall be warmed to achieve an interior temperature of at least 5 °C (40°F) before starting the system processor and computer, in order to conform to the ambient temperature range of the electronics.

For testing temperatures near or below -10 °C (15 °F), the lower bound of the normal operating range for the FWD components, the hydraulic fluid is to be replaced with a lighter weight fluid. Acceptable fluids include: AMZOIL synthetic, SHELL Tellus SAE10, or KENDALL SAE10. The concurrence of Dynatest is to be obtained before using fluids not specifically named herein.

The lighter weight hydraulic fluid is ***NOT*** to be used year round, as the thinner fluid will allow faster operation of the falling weight assembly, which can cause the catch to come in contact with the top flange, causing damage to the catch, and/or destruction of the catch piston flange after a short period of operation.

FWD Surface Temperature Measurements in Cold Weather

Raytec Infrared (IR) Temperature Sensor installed in the LTPP FWD units have a problem when temperatures drop below -18 ºC (0ºF). The problem is as follows:

The recommended range setting for the Raytec sensor is "1", which covers the temperature range of -17 ºC to 93 ºC (0ºF to 200ºF) (linear outputs 4 to 20 mA); all settings have -18 ºC (0ºF) as the lower limit. When the temperature drops below (0ºF), the sensor enters a "Fail Safe" mode which outputs full-scale current of 20.3 mA. For a calibrated sensor, the FWD Field Program should record temperatures greater than 93 ºC (200ºF) in the "Fail Safe" mode; however, erroneous and extremely variable temperature readings (-8 º C to 69 º C (9 to 154ºF)), have been recorded at temperatures below -18 º C (0 º F), which has not been explained.

The following procedures have been developed when testing at temperatures below -18 º C (0 º F):

1. Using the “comment” feature in the FWD Field Program, the FWD operator shall flag each FWD test cycle within a given SMP test day where pavement surface temperatures are below 0ºF. Fwd operator shall also note this occurrence on the FWD Daily Activity Report (Form 1). This shall include FWD test date, data file name, and start time of FWD test cycle(s) in question.

2. RCOC personnel shall edit the file prior to running FWDSCAN or loading the data to the IMS. Editing will be limited to pavement surface temperatures for those FWD test cycles where the pavement was below -18 º C (0 º F) at the start of testing, as indicated by the FWD operator both in the file as well as noted on the Daily Progress Report (Form 1). **PLEASE NOTE THAT EXTREME CARE SHOULD BE EXERCISED WHEN EDITING FWD DATA FILES.**

Use of FWD Trailer Accessories Requiring AC Power

Any FWD trailer accessories not installed by the FWD manufacturer, including, but not necessarily limited to block heaters used to warm hydraulic fluid, are to be disconnected (***not*** simply switched off) from their power supply while the FWD is being operated, whether for testing or for calibration. This requirement has been implemented to avoid the introduction of AC noise in the FWD data, which can significantly reduce the accuracy of the measurements.

Furthermore, such devices are not to be used at all, unless other measures to achieve satisfactory operation in cold weather (such as the use of hydraulic fluid for cold weather use) prove inadequate for the conditions encountered. This is to avoid the possibility of accidental failure to disconnect them. If absolutely necessary, the heaters may be used while traveling between test sites, and/or when the FWD is not being operated, provided that they are disconnected ***before*** testing begins.

Buffer Shape and Condition

Different FWD buffer shapes have been used to collect deflection data within the LTPP program.. Buffer shape affects deflection measurements. As such, it is a data element needed to be recorded by LTPP. Accordingly, the following data elements and consideration are required:

The buffer condition is to be inspected at least monthly for cuts, nicks and/or embedded debris such as dirt and stone chips. In addition, the buffer shape used on a given test data should be recorded on Load Plate Buffer Shape Form-F04 (Appendix H) and rated in the following four categories:

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

Buffer condition and type recorded by FWD operators are reported on the FWD Field Activity Report (Form F02) and Data Sheet FWD-D01, which in turn shall be submitted to the respective RCOC within seven days after completion.

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VI. DEFINITIONS, ABBREVIATIONS, AND CONVERSIONS

Definitions

Deflection Basin (DB) test - a test with deflection sensors placed at radial offsets from the center of the load plate. The test is used to record the shape of the deflection basin resulting from an applied load. Information from this test is used to estimate material properties for a given pavement structure.

Effective Panel - continuous section of PCC defined by two ***adjacent*** transverse breaks in the pavement. The transverse breaks can be expansion joints, cracks, or construction joints. The transverse breaks are treated as working joints for FWD testing purposes, and all tests on an effective panel are done in relation to the two transverse breaks defining the panel.

Load Transfer (LT) test - a test, usually on PCC pavement, with deflection sensors on both sides of a transverse break in the pavement. The test is used to determine the ability of the pavement to transfer load from one side of the break to the other. Also, the test data can be used to predict the existence of voids under the pavement.

List of Abbreviations

AC - Asphaltic Concrete
CRCP - Continuously Reinforced Concrete Pavement
DB - Deflection Basin
DMI - Distance Measuring Instrument
FWD - Falling Weight Deflectometer
GPS - General Pavement Study
JCP - Jointed Concrete Pavement
JPCP - Jointed Plain Concrete Pavement
JRCP - Jointed Reinforced Concrete Pavement
LT - Load Transfer
LTPP - Long-Term Pavement Performance
ML - Mid-Lane
OWP - Outside Wheel Path
PCC - Portland Cement Concrete
PE - Pavement Edge
RCOC - Regional Coordination Office Contractor
SHRP - Strategic Highway Research Program
SPS - Special Pavement Study
TP - Test Pit
TSSC - Technical Services Support Contractor

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English/Metric Conversions

Length	1.0 mil = 25.4 microns	1.0 micron = 0.039 mils
	1.0 ft. = 0.305 meters	1.0 meter = 3.281 feet
Force	1.0 lbf = 0.0044 kN	1.0 kN = 224.8 lbf
	1.0 kip = 4.45 kN	1.0 kN = 0.225 kips
Pressure	1.0 psi = 6.89 kPa	1.0 kPa = 0.145 psi

APPENDIX A

FWD TEST PLANS: GENERAL PAVEMENT STUDIES (GPS)

Introduction

This appendix provides guidelines and information specific to Falling Weight Deflectometer (FWD) testing at test sites for the Long Term Pavement Performance (LTPP) study General Pavement Studies (GPS) experiments. The intent of this document is to establish the specific testing requirements for GPS sites based on a uniform set of assumptions. It is recognized that not all sites within a GPS experiment will conform to all assumptions for that experiment. However, the objectives and approach to deflection data collection must be consistent so data obtained can be analyzed in a consistent manner. For deflection guidelines not specifically addressed in this appendix, refer to the general guidelines in this manual.

FWD Test Plans

The eight General Pavement Studies (GPS) experiments are divided by pavement characteristics into three specific FWD test plans. Experiments are divided based on pavement and surface type. Below is a list of each GPS experiment, description of the pavement structure, and the associated FWD Test Plan.

FWD Test Plan	**GPS Experiment Number and Name**
FLEX	(1) AC Pavement Over Granular Base (AC/AGG)
	(2) AC Pavement Over Bound Base (AC/BND)
	(6) AC Overlay of AC Pavement (AC/AC)
	(7) AC Overlay of PCC Pavement (AC/PCC)
JCP	(3) Jointed Plain Concrete Pavement (JPCP)
	(4) Jointed Reinforced Concrete Pavement (JRCP)
	(9) Unbonded PCC Overlay of PCC Pavement (PCC/PCC)
CRCP	(5) Continuously Reinforced Concrete Pavement (CRCP)

The details for the test plans are found in the following sections of this appendix..

Test Pit Testing Plan

The first deflection tests done at a GPS test section (excluding buffer conditioning) are in the Test Pit (TP) areas. Regardless of the pavement category, all testing in the TP areas will have the following common characteristics:

1. The first deflection tests at a section will be in the TP areas. However, TPs are only done during the first round of FWD testing and no additional testing is done in these areas during subsequent visits to the section.
2. The testing will be labeled as Pass Zero (P_o).
3. The lateral offset for the testing is the OWP.
4. Only DB tests will be run.
5. Only one test point at each TP area for a total of two for the section.

FLEX Testing Plan

Figure A-1 and Table A-1 summarize the FLEX testing plan for GPS Experiments 1, 2, 6 and 7. All pavements covered under this plan have an AC surface. Two passes (not including the TP) are done: one at ML and the other in the OWP. On each pass, DB tests are done at 7.6 m (25 ft) intervals for a total of 21 test points per pass and 42 total test points in the 152 m (500 ft) section. At each test point, a sequence of 19 drops is used; 3 seating drops at height 3 and 4 drops each at heights 1, 2, 3 and 4.

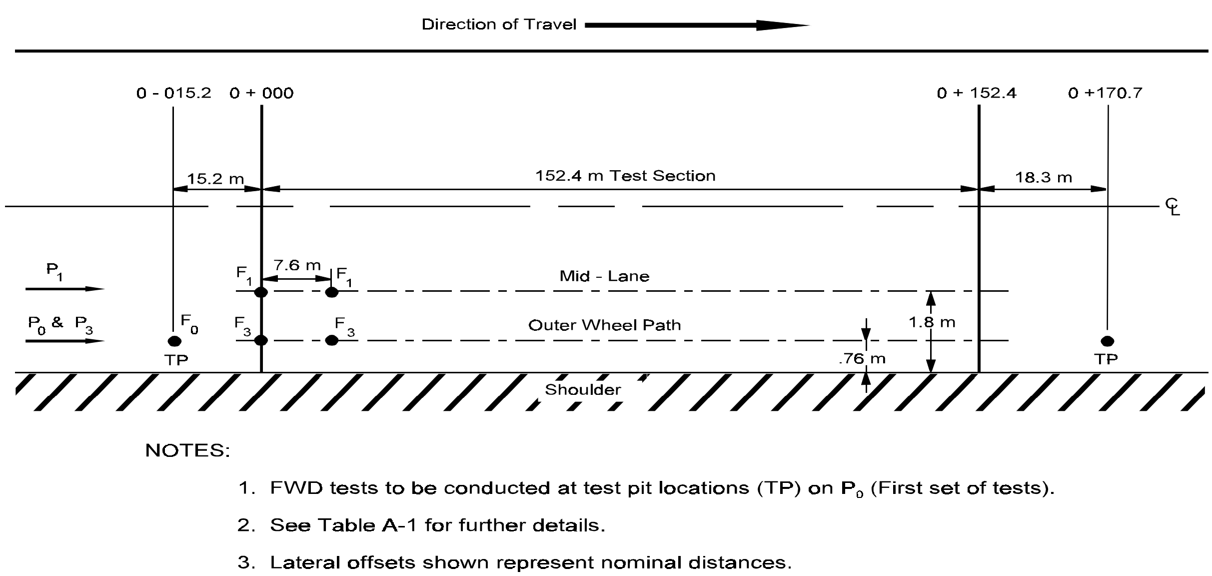


Figure A-1. FWD Test Plan (Flex Pavement Categories).

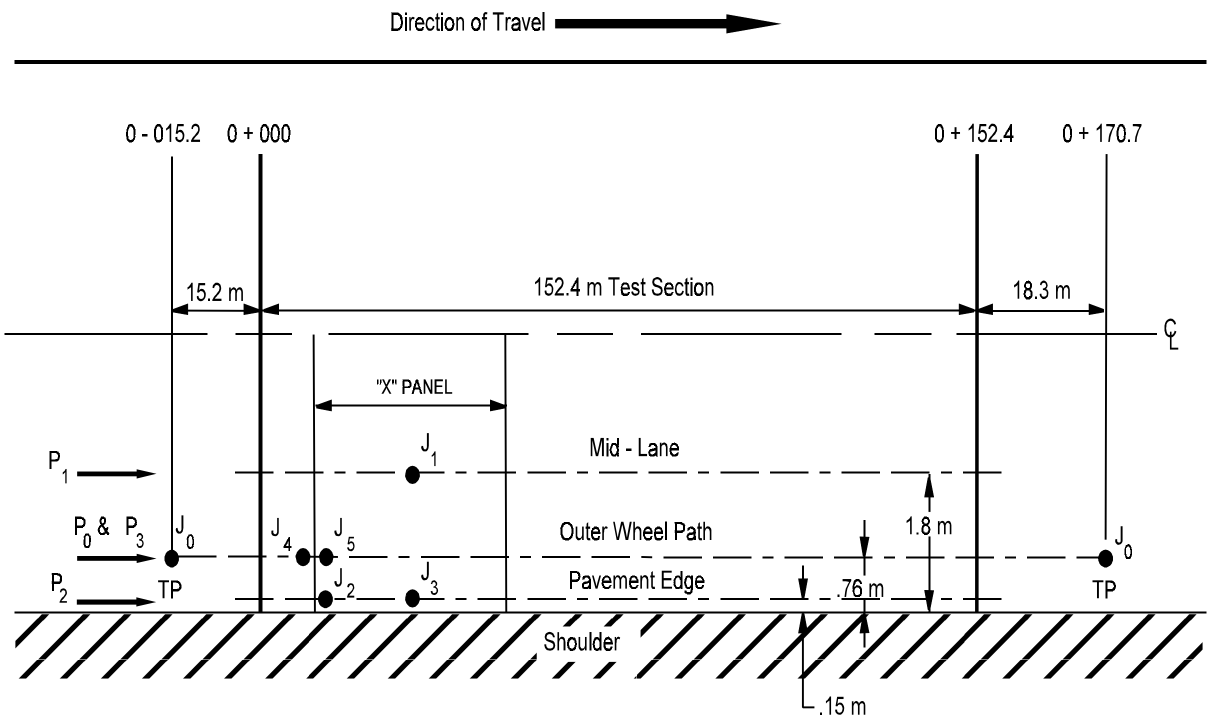
Table A-1. GPS FWD Test Plan Summary

Test Plan	Test Point ID.	Pass No.	Location: Transverse	Location: Longitudinal	Test Interval (m)	Test Type	Sensor Configuration (mm)	No. of Test Points
Flex	F0	P_0	OWP	Test Pits	N/A	DB	-305, 0, 203, 305, 457, 610, 914, 1219, 1524	2
	F1	P_1	ML	-	7.6	DB	-305, 0, 203, 305, 457, 610, 914, 1219, 1524	21
	F3	P_3	OWP	-	7.6	DB	-305, 0, 203, 305, 457, 610, 914, 1219, 1524	21
JCP	J0	P_0	OWP	Test Pits	N/A	DB	-305, 0, 203, 305, 457, 610, 914, 1219, 1524	2
	J1	P_1	ML	Mid Panel	See Text	DB	-305, 0, 203, 305, 457, 610, 914, 1219, 1524	20
	J2	P_2	PE	Corner	See Text	DB	-305, 0, 203, 305, 457, 610, 914, 1219, 1524	20
	J3	P_2	PE	Mid Panel	See Text	DB	-305, 0, 203, 305, 457, 610, 914, 1219, 1524	20
	J4	P_3	OWP	Joint Approach	See Text	LT	-305, 0, 203, 305, 457, 610, 914, 1219, 1524	20
	J5	P_3	OWP	Joint Leave	See Text	LT	-305, 0, 203, 305, 457, 610, 914, 1219, 1524	20
CRCP	C0	P_0	OWP	Test Pits	N/A	DB	-305, 0, 203, 305, 457, 610, 914, 1219, 1524	2
	C1	P_1	ML	Mid Panel	~ 7.6	DB	-305, 0, 203, 305, 457, 610, 914, 1219, 1524	20
	C2	P_2	PE	Centered on Crack	~ 7.6	DB	-305, 0, 203, 305, 457, 610, 914, 1219, 1524	20
	C3	P_2	PE	Mid Panel	~ 7.6	DB	-305, 0, 203, 305, 457, 610, 914, 1219, 1524	20
	C4	P_3	OWP	Joint Approach	~ 7.6	LT	-305, 0, 203, 305, 457, 610, 914, 1219, 1524	20
	C5	P_3	OWP	Joint Leave	~ 7.6	LT	-305, 0, 203, 305, 457, 610, 914, 1219, 1524	20

JCP Testing Plan

Figure A-2 and Table A-1 summarize the JCP testing plan for GPS Experiments 3, 4 and 9. All pavements covered under this plan have a jointed PCC pavement surface. Three passes are done: ML (P_1), PE (P_2) and OWP (P_3). For each panel tested, one DB test is done on the ML pass, two DB tests are done on the PE pass, and two LT tests are done on the OWP pass for a total of five test points per panel tested. At each test point, a sequence of 15 drops is used; 3 seating drops at height 3 and 4 drops each at heights 2, 3 and 4.

The JCP test plan requires the most caution and judgment by FWD operators in the field when determining where to test. The reason is threefold:



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.

Figure A-2. JCP Testing Plan Show Only J0, J1, J2, J3, J4 and J5

1. Panel lengths vary from less than 3.4 m (11 ft) to greater than 15.2 m (50 ft).

2. Panels with large joint spacing generally have transverse cracks present near the middle of the original panels. For example, if an original panel has one transverse crack, FWD operators should view the original panel as two effective panels. Similarly, if there are two transverse cracks, the original panel should be viewed as three effective panels.

   Note: For LTPP purposes, an effective panel is defined as a continuous section of PCC pavement bound by two transverse breaks in the pavement. The two transverse breaks can be any combination of joints, cracks, or full width patches.

3. Some JCP sections have non-uniform or random joint spacing intervals that repeat throughout the section (e.g., 3.0 m - 5.8 m -5.2 m - 4.0 m (10 ft - 19 ft - 17 ft - 13 ft) joint spacing pattern).

The number of effective panels can vary from as few as 9 or 10 to as many as 35 or more on a 152 m (500 ft) section. Regardless of the total number of effective panels present no more than 20 effective panels are tested on a section. Thus, for JCP categories, a maximum of 100 deflection tests will be made within a 152 m (500 ft) section.

Any effective panel tested must have all five test points for that panel located with reference to that same effective panel no matter how small or large the panel. On JCP sections, the five tests could be from 1.5 m (5 ft) to more than 7.6 m (25 ft) apart longitudinally.

When counting effective panels, panel No.1 should be identified as the first panel totally included within the section limits. This will prevent negative stationing for any of the 20 effective panels, and also provide consistency between operators on panel numbering. At station 0+152.4 (5+00), any panel extending past station 0+152.4 (5+00) should not be selected for testing for three reasons. First, the panel is not totally within the 152 m (500 ft) section, so it is not protected from material sampling. Second, temperature holes are located in this location. Third, conflicts with equipment collecting material samples during the first round of FWD tests will be minimized.

The following examples of typical JCP joint/crack spacings will assist FWD operators in selecting effective panels to test.

Example 1:
A pavement has a 7.6 m (25 ft) ***uniform*** joint spacing. A visual check finds no transverse cracks in the slabs. For the 152 m (500 ft) test section, a total of 20 effective panels exist. Therefore, all 20 are tested.

Example 2:
A pavement has a random joint spacing pattern of 3.0 m - 5.8 m - 5.2 m - 4 m (10 ft - 19 ft - 17 ft- 13 ft) (4.5 m (15 ft) average). No transverse cracks are present. A total of 33 effective panels exist. However, only 20 of the 33 effective panels are tested. The actual

effective panels to test must be selected by the FWD operator in the field. The FWD operator should <u>not</u> select the first 20 effective panels <u>or</u> the last 20 effective panels. Instead, approximately six slabs out of every ten should be selected.

One acceptable set of effective panel numbers to test is 1, 2, 4, 5, 7, 8, 11, 12, 15, 16, 18, 19, 21, 22, 25, 26, 29, 30, 32, and 33. However, other sets of effective panels to test will also work. In fact, it is desirable to test at least one or two groups of four adjacent panels to study the characteristics of random panel size on deflection response. For this case the following set of effective panel numbers to test may be 1, 2, 3, 4, 8, 9, 10, 11, 15, 16, 17, 18, 22, 23, 24, 25, 29, 30, 31 and 32.

Example 3:
A pavement has 12.2 m (40 ft) ***uniform*** joint spacing with no mid-panel cracks for a total of 13 effective panels. With less than the 20 effective panels, all 13 are tested.

Example 4:
A pavement has 15.2 m (50 ft) ***uniform*** joint spacing with transverse cracks near the middle of each original panel. As a result, the effective panel length is 15.2 m ¸ 2 = 7.6 m (50 ft ¸ 2 = 25 ft) and about 20 effective panels exist. Therefore, all 20 effective panels are tested. For this case, the effective panels are defined by a normal joint on one end and a transverse crack on the other end. The transverse crack is viewed as a working joint for FWD testing purposes, but comments in the field data should identify it as a transverse crack.

Example 5:
A pavement has 15.2 m (50 ft) ***uniform*** joint spacing with transverse cracks near the third points of each original panel. As a result, the effective panel length is 15.2 m ¸ 3 = 5.1 m (50 ft ¸ 3 = 16.7 ft) and about 30 effective panels exist. However, only 20 of the 30 effective panels are tested. For this case, the effective panels are defined by (1) a normal joint on one end and a transverse crack on the other end or (2) a transverse crack on both ends. The actual effective panels to test must be selected by the FWD operator in the field. The FWD operator should ***not*** select the first 20 effective panels ***or*** the last 20 effective panels. Instead, approximately seven panels out of every ten should be selected.

The above examples do not cover ***all*** JCP conditions that exist, and FWD operators must use their best field judgment for selecting and documenting the effective panels tested using the following guidelines:

1. Avoid testing effective panels that extend outside the section limits from station 0+000 and 0+152 (0+00 and 5+00).

2. Number effective panels with panel No.1 being the first panel completely in the test section limits at station 0+000 (0+00).

3. Select a maximum of 20 effective panels to test based on the examples given above and conditions in the field.

4. Mark the "effective panels" with chalk or lumber crayon to avoid testing the wrong "effective panels".

5. Record the panel numbers tested on the Field Activity Sheet (discussed in the main body of this manual), or document the "effective panels" tested using a sketch of the section showing joints and cracks and indicate the "effective panels" tested.

CRCP Testing Plan

Figure A-3 and Table A-1 summarize the CRCP FWD test plan for GPS Experiment 5. This plan is like the JCP plan ***with the major exception for the location of the load plate for Test Point ID No. C2.*** For the JCP plan, test point No. J2 is a ***corne***r load condition. However, for the CRCP plan, test point No. C2 has the load plate ***centered*** on the transverse crack defining the beginning of the effective panel being tested during the PE pass.

Effective panels for CRCP are defined by two adjacent transverse cracks typically at a spacing of 0.3 m to 2.5 m (1 ft. To 8 ft.). In general, the 20 effective panels tested should include stationing at 7.6 m (25 ft) intervals starting from station 0+000 test effective panels at station 0+000.0 (0+00), 0+007.6 (0+25), 0+015.2 (0+50), 0+022.9 (0+75), 0+030.5 (1+00), 0+038.1 (1+25), 0+045.7 (1+50), 0+053.3 (1+75), 0+061.0 (2+00), 0+068.6 (2+25), 0+076.2 (2+50), 0+083.8 (2+75), 0+091.4 (3+00), 0+099.1 (3+25), 0+106.7 (3+50), 0+114.3 (3+75), 0+121.9 (4+00), 0+129.5 (4+25), 0+137.2 (4+50), and 0+144.8 (4+75) (***no*** test at station 0+152.4 (5+00)).

Any effective panel tested must have all five test points for that panel located with reference to the same effective panel, no matter how small or large the panel. In fact, on CRCP pavements, it is possible to have all five test points no more than 0.3 m (1 ft) apart longitudinally.

FWD operators must not bias deflection data by deviating from the above stationing in order to test all large panels. However, in some cases field judgement will shift selection of effective panels from the above stations, because transverse cracks may not be fully developed or the effective panel may be wedge shaped and not extend the full width of the lane. Also, the first effective panel totally within the section at station 0+000.0 (0+00) should be tested, and the actual station for the mid-panel will typically be at station 0+000.3 (0+01) to 0+002 (0+06).

With 20 effective panels for all CRCP sections, a total of 100 tests will be run in the 152.4 m (500 ft) section; 60 DB tests and 40 LT tests. Similar to the JCP plan, the pass sequence in Figure 3 is used so the sensor spacing is only changed once on each section. At each test point, a sequence of 15 drops is used; 3 seating drops at height 3 and 4 drops each at heights 2, 3 and 4.

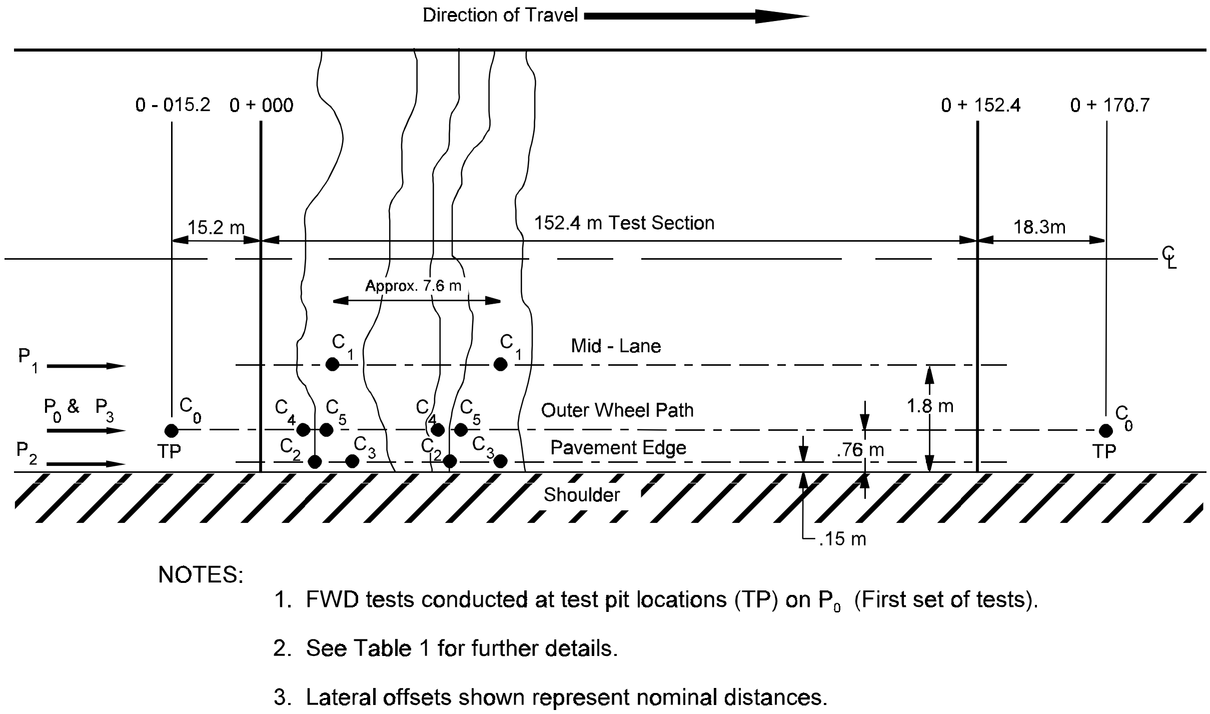


Figure A-3. CRCP Testing Plan Only C0, C1, C2, C3, C4 and C5

Other FWD Operator Field Measurements

Temperature Gradient Measurements

Temperature gradient measurements for GPS test sections are obtained using the procedure detailed in Section II. FWD Field Testing of this manual. Measurements are obtained at both ends of the test section. It is up to the FWD operator to assess variations in sun exposure and wind conditions to select the most representative location adjacent to the section limits for temperature measurements.

Temperature readings are obtained at 1 hour intervals, with the first readings prior to start of FWD testing on the section and the last readings ending after completion of the FWD testing on the section.

Joint/Crack Widths

Joint and crack opening measurements for GPS test sections under the JCP and CRCP testing plans are obtained using the procedure described in Section II. FWD Field Testing of this manual.

APPENDIX B
FWD TEST PLANS: SPECIFIC PAVEMENT STUDIES (SPS)

APPENDIX B-1
FWD TESTING GUIDELINES
FOR SPECIFIC PAVEMENT STUDIES (SPS) EXPERIMENT 1
STRATEGIC STUDY OF STRUCTURAL FACTORS
FOR FLEXIBLE PAVEMENTS

Introduction

This appendix provides guidelines and information specific to Falling Weight Deflectometer (FWD) testing at individual test sites for the Long Term Pavement Performance (LTPP) study experiment SPS-1, "Strategic Study of Structural Factors for Flexible Pavements". The intent of this document is to establish the specific testing requirements for SPS-1 sites based on a uniform set of assumptions. It is recognized that not all sites will conform to all assumptions contained herein. However, the objectives and approach to deflection data collection must be consistent so data obtained can be analyzed in a consistent manner. For deflection testing details not specifically addressed in the appendix, refer to the general guidelines in this manual.

The objective of the SPS-1 experiment is to define the relative influence of structural factors affecting performance of flexible pavements. The primary structural factors addressed include pavement subsurface drainage, base type, and pavement layer thickness. The study will help determine the influence of environmental conditions and soil type on these factors. Results of the SPS-1 experiment will improve design and construction of new and reconstructed flexible pavements. Characterization of materials and environmental conditions between test sections is required to explain performance differences and provide a basis for improved flexible pavement design.

In contrast to the LTPP General Pavement Studies (GPS), SPS has controlled construction of multiple test sections at a single site. On a SPS-1 site, there are 12 test sections. Experiment sites should conform to criteria contained in "Specific Pavement Studies Guidelines for Nomination and Evaluation of Candidate Projects for Experiment SPS-1, Strategic Study of Structural Factors for Flexible Pavements", February 1990. The site characteristic affecting FWD testing is the number of test sections.

LTPP test sections in a SPS-1 experiment are tested the same after construction regardless of cross section. Location of test sections should avoid cut/fill transitions, bridges, culverts, and side hill fills to limit the potential for variability of subgrade soils. Unlike other GPS and SPS experiments, no TPs are excavated for SPS-1 since a thorough quality control program is performed during construction.

FWD Test Plan

General

FWD testing for SPS-1 is performed during construction (labeled as "DURING"), 3 to 6 months after construction (labeled as "AFTER"), and bi-annually more than 6 months after construction (labeled as "LONG TERM"). The "AFTER" testing verifies material properties of the as-built pavement for evaluating the effectiveness and long term performance of the section. "LONG TERM" testing evaluates the effect of temperature, moisture changes and traffic loading on pavement deflections and performance.

The specific FWD test plan for SPS-1 is similar to the Flex Testing Plan for GPS. The factors inherent within this test plan are:

1. Test Point ID (F1 and F3)
2. Lane for Each FWD Pass (Transverse Location)
3. Test Interval (Longitudinal Location)
4. Test Type (Basin)
5. Deflection Sensor Spacing
6. Drop Sequence (Load Levels/Number of Drops)

All FWD testing is done in the driving lane at two lateral offsets. The two lateral offsets are the ML and OWP as defined in the GPS portion of this manual. For a given lateral offset, a single pass through the test section is made to collect a particular type of deflection data. When finished with a particular pass, the FWD returns to the beginning of the section to start another pass. All testing uses station 0+000.0 (0+00) of the test section (not the SPS project site) as the distance reference so FWD test point locations can be located for future testing.

Naming Scheme/Data Storage

A unique 6 digit code identifies the individual test sections at an SPS-1 site (similar to that for the GPS sections), with the fourth character being "1" for SPS-1.

The computer filenames are identical to those used in the GPS testing, with the 6 character test section code followed by two characters indicating the times a section has been tested and the number of the pass within the section. The "times tested" (character #7) is a single letter which corresponds to the number of times the section has been tested. Characters A and B are reserved for "BEFORE" and "DURING" construction testing on SPS experiments; all SPS testing uses letter C as the first "AFTER" construction testing; and, letter D as the first "LONG TERM" testing. The "pass" (character #8) is 1 for ML testing and 3 for OWP testing as used for GPS testing. For example, files from "AFTER" FWD testing of section 2 at an SPS-1 site in Iowa would be: 190102C1 and 190102C3.

Test Pit Areas

The SPS-1 experiment has no test pits. Therefore, pass P_0 testing is not performed in SPS-1.

Test Point Identification

FWD operators must properly record longitudinal distances with the distance measuring instrument relative to 0+00 station reference for each section, and follow the guidelines for lateral offset for the OWP and ML passes, so all FWD testing can be repeated in the same general location.

Detailed Test Plan (Test Sections)

For SPS-1 test sections, FWD testing procedures do not vary between "AFTER" and "LONG TERM" testing.

"AFTER" and "LONG TERM" Testing: All sections in SPS-1 are tested similar to the GPS FLEX Testing Plan except that the number of tests is reduced.

The test plan includes 11 FWD tests on each pass down the test section for both the ML and the OWP. Deflection Basin tests begin at station 0+000.0 (0+00) and continue to station 0+152.4 (5+00) at 15.2 m (50') intervals. Tests at ML use the lane specification F1 and tests in the OWP use the lane specification F3. Figure B-1.1 indicates the test locations for a section. Each section has 22 test points for a total of 264 test points for a project. At a rate of 20 points per hour, the FWD testing will take about 13 hours. With about 30 minutes per section for temperature gradient measurements, the total time for all tasks will be approximately 19 hours.

FWD operators must use their best judgement and carefully note any abnormal conditions or unique situations encountered in the field. However, only 22 points should be tested on a given section.

Other FWD Operator Field Measurements

Temperature Gradient Measurements

Temperature gradient measurements for SPS-1 sites are obtained similar to that for GPS sections, with the two exceptions below.

Measurements are obtained at only one location for each test section. It is up to the FWD operator to assess variations in sun exposure and wind conditions to select the most representative location adjacent to the section limits for temperature measurements.

Temperature readings at SPS-1 sites are obtained at 30 minute intervals, with the first readings prior to starting FWD testing on the section and the last readings after completion of FWD testing at the section.

Crack Widths

For any SPS-1 site, ***no*** crack opening measurements are made; however, FWD operators must record pavement distress at test point locations as described in guidelines for GPS testing using the Comment key.

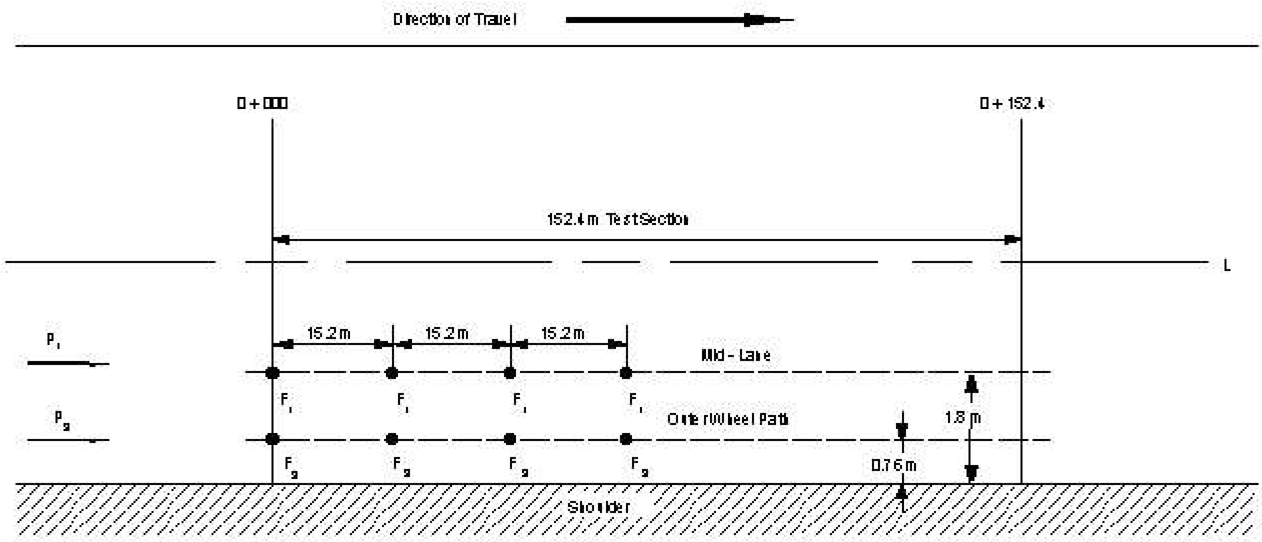


Figure B-1.1 FWD Test Plan for SPS-1 Sections

APPENDIX B-2

FWD TESTING GUIDELINES
FOR SPECIFIC PAVEMENT STUDIES (SPS) EXPERIMENT 2
STRATEGIC STUDY OF STRUCTURAL FACTORS
FOR RIGID PAVEMENTS

Introduction

This appendix provides guidelines and information specific to Falling Weight Deflectometer testing at individual test sites for the Long Term Pavement Performance (LTPP) study experiment SPS-2, "Strategic Study of Structural Factors for Rigid Pavements." The intent of this document is to establish the specific testing requirements for SPS-2 sites based on a uniform set of assumptions. It is recognized that not all sites will conform to all assumptions contained herein. However, the objectives and approach to deflection data collection must be consistent so data obtained can be analyzed in a consistent manner. For deflection testing details not specifically addressed in the appendix, refer to the general guidelines in this manual.

The objective of the SPS-2 experiment is to define the relative influence of structural factors affecting performance of rigid pavements. The primary structural factors addressed include pavement subsurface drainage, base type, concrete strength and thickness, and lane width. Secondary factors addressed in the study include load transfer, joint orientation, and steel reinforcement. The study will determine the influence of environmental conditions and soil type on these factors. Results of the study will improve design and construction of new and reconstructed rigid pavements. Characterization of materials and environmental conditions between test sections is required to explain performance differences between test sections and provide a basis for improved rigid pavement design.

In contrast to the LTPP General Pavement Studies (GPS), SPS has controlled construction of multiple test sections at a single site. The main SPS-2 experiment has jointed plain concrete with 15 foot joint spacings, supplemental experiment SPS-2A has jointed plain concrete using undoweled skewed joints at variable spacings, and supplemental experiment SPS-2B has jointed reinforced concrete with 30 foot joint spacings. The main SPS-2 experiment has 12 test sections, SPS-2A has 6 sections, and SPS-2B has 8 sections. The supplemental experiments are built in conjunction with the main experiment site, and are never constructed as individual projects. Therefore, SPS-2 projects have a minimum of 12 sections and up to 18 or 26 sections if one or both of the supplemental experiments are constructed.

Experiment sites should conform to criteria contained in "Specific Pavement Studies Guidelines for Nomination and Evaluation of Candidate Projects for Experiment SPS-2, Strategic Study of Structural Factors for Rigid Pavements", April 1990. The project characteristic affecting FWD testing is the number of test sections.

LTPP test sections in a SPS-2 experiment are tested the same regardless of cross section. Location of test sections should avoid cut/fill transitions, bridges, culverts, and side hill fills to limit the potential for variability of subgrade soils. Unlike other GPS and SPS experiments, no Test Pits are excavated for SPS-2 since a thorough quality control program is performed during construction.

FWD Test Plan

General

FWD testing for SPS-2 is performed during construction (labelled as "DURING"), 3 to 6 months after construction (labeled as "AFTER"), and bi-annually more than 6 months after construction (labeled as "LONG TERM"). The "AFTER" testing verifies material properties of the as-built pavement for evaluating the effectiveness and long term performance of the section. "LONG TERM" testing evaluates the effect of temperature, moisture changes and traffic loading on pavement deflections and performance.

Deflection Basin tests as well as Load Transfer tests will be used in the SPS-2 testing. The specific FWD test plan for SPS-2 is similar to the JCP Testing Plan for GPS. The factors inherent within this test plan are:

1. Test Point ID Number (J1, J2, J3, J4, J5, J7, and J8)
2. Lane for Each FWD Pass (Transverse location)
3. Test Interval (Longitudinal location)
4. Test Type (Basin or Load transfer)
5. Deflection Sensor Spacing
6. Drop Sequence (Load Levels/Number of Drops)

All FWD testing is done in the driving lane at three lateral offsets. For each lateral offset, a single pass through the test section is made to collect a particular type of deflection data. When finished with a particular pass, the FWD returns to the beginning of the section to start another pass. ***All*** testing uses station 0+00 of the test section (not the SPS site) as the distance reference so all FWD test point locations can be located for future testing.

Three lateral (transverse) testing passes will be employed for 3.6 meter (12 ft) lanes, with one additional pass for sections having a 4.3 meter (14 ft) lane. For SPS-2 a "Pavement Edge" is the shoulder-pavement interface for 3.6 meter lanes and the outer edge of the painted shoulder stripe on 4.3 meter lanes (widened pavement lanes). For widened lane construction a "Widened Lane Edge" is defined as the outer edge of the pavement slab. The four passes are:

1.1.1 ML (Mid Lane) - located 1.8 m ± 0.15 m (6.0'± 0.5') from the edge reference

1.1.2 OWP (Outer Wheel Path) - located 0.76 m ± 0.08 m (2.5'± 0.25') from the edge reference

1.1.3 PE (Pavement Edge) - Edge of load plate should be less than 76 mm (3") from the edge reference

1.1.4 WLE (Widened Lane Edge) - Edge of load plate should be less than 76 mm (3") from the outside edge of the slab.

Notes: (1) This pass applies only to sections built with 4.3 meter lane width, (2) FWD tests at the WLE are actually on the shoulder and not the driving lane.

FWD operators must insure that the tests are located within the above tolerances. The FWD operators are not expected to measure the position of each test point, but excessive deviations must be avoided, particularly for pavement edge and corner testing.

Testing widened lane construction in SPS-2 includes WLE testing, in addition to PE testing. Pass 4, P_4, has been assigned for WLE testing on sections with 4.3 meter lane width for doing one corner test and one mid-panel test on this pass. The following list of lane specifications are used to identify the type and location of tests performed.

"JPC" Category Pavements

- J0 NOT USED ON SPS-2
- J1 all tests in the mid-lane pass (P_1)
- J2 corner tests in the pavement edge pass (P_2)
- J3 mid-panel tests in the pavement edge pass (P_2)
- J4 approach slab tests in the outer wheel path pass (P_3)
- J5 leave slab tests in the outer wheel path pass (P_3)
- J7 corner tests in the widened lane edge pass (P_4)
- J8 mid-panel tests in the widened lane edge pass (P_4)

Lane specifications J7 and J8 are on the shoulder, outside the edge stripe.

Naming Scheme/Data Storage

A unique 6 digit code identifies the individual test sections at an SPS-2 site (similar to that for the GPS sections), with the fourth character being "2" for SPS-2.

The computer filenames are identical to those used in the GPS testing, with the 6 character test section code followed by two characters indicating the times a section has been tested and the number of the pass within the section. The "times tested" (character #7) is a single letter which corresponds to the number of times the section has been tested. Characters A and B are reserved for "BEFORE" and "DURING" construction testing on SPS experiments; all SPS testing uses letter C as the first "AFTER" construction testing; and, the letter D as the first "LONG TERM" testing. The "pass" (character #8) is 1 for ML testing, 2 for PE testing, 3 for OWP testing, and 4 for WLE testing as used for GPS testing. For example, files from "AFTER" FWD testing of section 3 (14 foot lane) at an SPS-2 site in Iowa would be: 190203C1, 190203C2, 190203C3 and 190203C4.

Test Pit Areas

The SPS-2 experiment has no test pits. Therefore pass P_0 testing is <u>not</u> performed in SPS-2.

Test Point Identification

FWD operators must properly record longitudinal distances with the distance measuring instrument relative to 0+00 station reference for each section, and follow the guidelines for lateral offsets for the WLE, PE, OWP and ML passes, so all FWD testing can be repeated in the same general location.

Detailed Test Plan (Test Sections)

For SPS-2 test sections, FWD testing procedures do not vary between "AFTER" and "LONG TERM" testing.

"AFTER" and "LONG TERM" Testing: All sections in SPS-2 are tested similar to the GPS JCP Test Plan except that the number of tests is reduced.

There are 5 FWD tests performed in each slab tested on 3.6 meter lanes. An additional 2 FWD tests are required in each slab for the widened lanes (a total of 7 tests). These include three Deflection Basin tests -- one in the center of the slab (J1), one at the leave slab corner (J2) and one at midslab at the edge of the pavement (J3) -- and two Load Transfer tests -- one on the approach side of the joint (J4) and one on the leave side of the joint (J5). For widened lanes two additional Deflection Basin tests are taken -- one along the approach corner (J7) and one midslab at the physical edge of the slab (J8). Figures B-2.1 and B-2.2 show the position of the test locations for the 12 and 14 foot lane widths, respectively. Each test section will have 10 slabs tested for a total of 50 FWD points for 12 foot lanes and 70 for the widened lanes. For the main SPS-2 experiment this totals 720 test points. At a rate of 20 points per hour, the FWD testing will take about 36 hours. With about 30 minutes per section for temperature gradient measurements, the total time for all tasks will be about 42 hours. FWD testing and temperature measurements for SPS-2A would add an additional 360 test points (about 21 hours), while SPS-2B would add 480 test points (about 28 hours).

FWD operators must use their best field judgement in the slab selection process and carefully note any abnormal conditions or unique situations encountered in the field. However, only 10 slabs should be tested on a given test section.

Other FWD Operator Field Measurements

Temperature Gradient Measurements

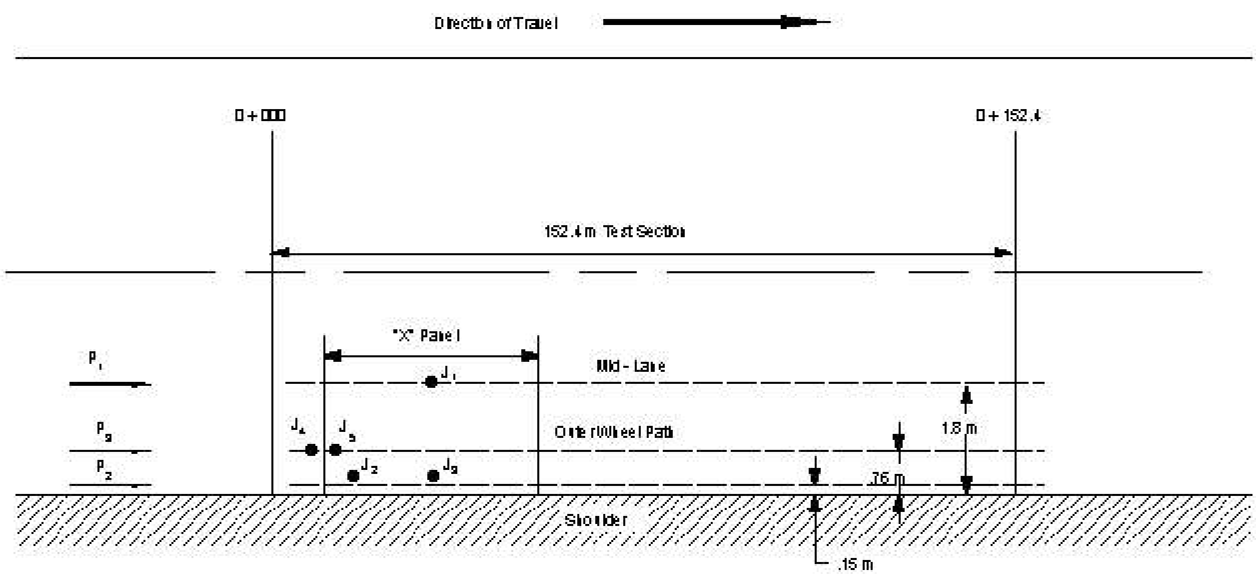
Temperature gradient measurements for SPS-2 sites are obtained similar to that for GPS sections, with the two exceptions below.

Measurements are obtained at only one location for each test section. It is up to the FWD operator to assess variations in sun exposure and wind conditions to select the most representative location adjacent to the section limits for temperature measurements.

Temperature readings at SPS-2 sites are obtained at 30 minute intervals, with the first readings prior to start of FWD testing on the section and the last readings ending after completion of the FWD testing on the section.

Joint/Crack Widths

Joint and crack opening measurements for SPS-2 sites are obtained as defined in the JCP Testing Plan for GPS.

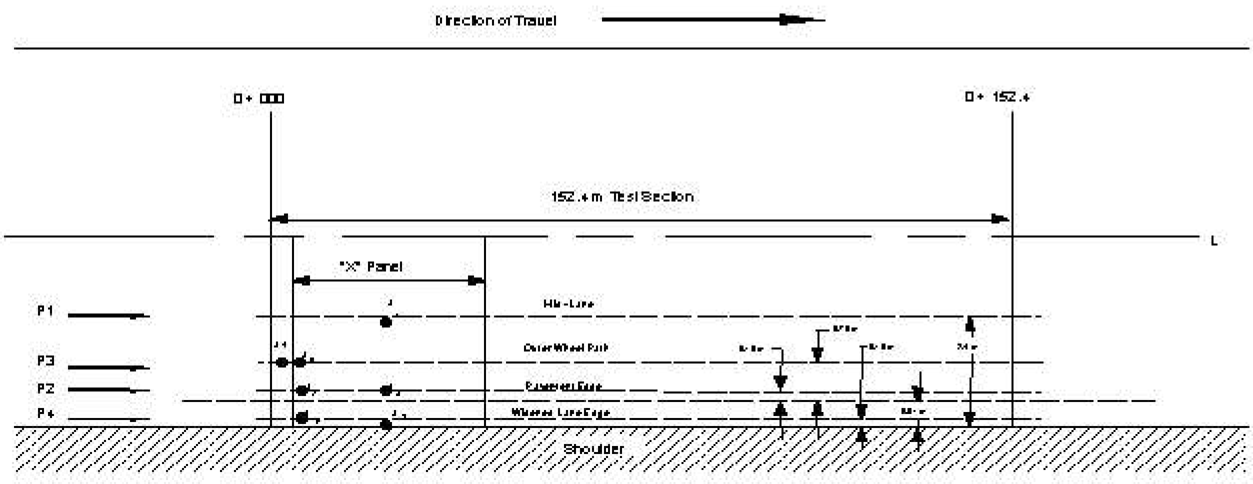


NOTES:

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

2. Ten panels should be tested on all sections.

Figure B-2.1 FWD Test Plan for SPS-2 Sections - 3.6 m Lane



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.

Figure B-2.2 FWD Test Plan for SPS-2 Sections - 4.3 m Lane

APPENDIX B-3

FWD TESTING GUIDELINES
FOR SPECIFIC PAVEMENT STUDIES (SPS) EXPERIMENT 3
PREVENTIVE MAINTENANCE EFFECTIVENESS
OF FLEXIBLE PAVEMENTS

Introduction

This appendix provides guidelines and information specific to Falling Weight Deflectometer testing at individual test sites for the Long Term Pavement Performance (LTPP) study experiment SPS-3, "Preventive Maintenance Effectiveness of Flexible Pavements." The intent of this document is to establish the specific testing requirements for SPS-3 sites based on a uniform set of assumptions. It is recognized that not all sites will conform to all assumptions contained herein. However, the objectives and approach to deflection data collection must be consistent so data obtained can be analyzed in a consistent manner. For deflection testing details not specifically addressed in the appendix, refer to the general guidelines in this manual.

The objective of the SPS-3 experiment is to compare the effectiveness and mechanisms by which selected maintenance treatments preserve or extend pavement service life, driver safety and ride quality on asphaltic concrete pavements. The impact of materials or construction process is not a part of this study. In addition, the overall goal is to compare the performance of treated sections to untreated sections. The impact of a preventive maintenance treatment is based on the process or type of treatment; e.g., a slurry seal. Process parameters for material, design, and construction specification known to work reasonably well in each individual climatic zone were selected.

The primary factors addressed in the experimental design include moisture and temperature conditions, subgrade type, and traffic loading. The secondary factors include the individual treatments: crack sealing, chip seal, slurry seal, and thin overlays. Other second level factors include pavement condition at the time the treatment is placed and the structural capacity of the pavement for the traffic loads applied to the pavement.

FWD Test Plan

General

The LTPP test sections in an SPS-3 experiment are tested the same before and after maintenance regardless of treatment. The site characteristic affecting FWD testing is the number of sections. FWD testing is performed 0 to 3 months prior to application of the maintenance treatment (labelled as "BEFORE"), 3 to 6 months after application of the maintenance treatment (labelled as "AFTER"; not required), and bi-annually more than 6 months after the application of the maintenance treatment (labelled as "LONG TERM"). In addition, sections should be tested just prior to removal of the section from the experiment.

The specific FWD test plan to be implemented will be similar to the GPS Operational Category FLEX. The factors inherent within this test plan are:

1. Test Point ID (F1, F3)
2. Lane for Each FWD Pass (Transverse Location)
3. Test Interval (Longitudinal Location)
4. Test Type (Basin)
5. Deflection Sensor Spacing

6. Drop Sequence (Load Levels/Number of Drops)

All FWD testing is done in the driving lane at two lateral offsets. The two lateral offsets are the ML and OWP as defined in the GPS portion of this manual. For a given lateral offset, a single pass through the test section is made to collect a particular type of deflection data. When finished with a particular pass, the FWD returns to the beginning of the section to start another pass. ***All*** testing uses station 0+00 of the ***test section*** (not the SPS project site) as the distance reference so FWD test point locations can be located for future testing.

Naming Scheme/Data Storage

A unique 6 digit code identifies the individual test sections of an SPS-3 site (similar to that for the GPS sections), with the fourth character being "3" for SPS-3.

The computer filenames are identical to those used in the GPS testing, with the 6 character test section code followed by two characters indicating the times a section has been tested and the number of the pass within the section. The "times tested" (character #7) is a single letter which corresponds to the number of times the section has been tested. Character "A" refers to "BEFORE" construction testing, "B" refers to "DURING" construction testing (if it were being conducted), and "C" refers to "AFTER" construction testing for a section (not required). "LONG TERM" testing is designated with letters "D" through "Z", as required. The "pass" (character #8) is 1 for ML testing and 3 for OWP testing as used for GPS testing. For example, files from "BEFORE" FWD testing of section 1 at an SPS-3 site in Iowa would be: 19A301A1 and 19A301A3. When performed, the FWD testing "AFTER" have the following filenames: 19A301C1 and 19A301C3 (test time "B" is skipped for SPS-3 as there is no testing during construction). Files representing data collected for "LONG TERM" testing will have a "D" or higher as the seventh character.

Drop Sequence

The drop sequence (load levels and number of drops) for SPS-3 testing is similar to the 1-FLEX Testing Plan for GPS, except the number of drops is reduced from four to three. Operators should use the FWD SPS-3 test plan setup.

SPS-3 Testing Plan - Drop Sequence

No. of Drops	***Drop Height***	***Data Stored***
3	3	No [1]
3	1	Yes [2]
3	2	Yes [2]
3	3	Yes [2]
3	4	Yes [2]

[1] No data stored, seating drop only. Deflection and load data is printed but not stored to a file.

[2] Store deflection peaks for all three drops and a complete deflection-time history for the third drop only.

Test Pit Areas

The SPS-3 experiment has no test pits. Therefore, pass P_0 testing is not performed in SPS-3.

Test Point Identification

FWD operators must properly record longitudinal distances with the distance measuring instrument relative to 0+000.0 (0+00) station reference for each section, and follow the guidelines for lateral offset for the OWP and ML passes, so all FWD testing can be repeated in the same general location.

Detailed Test Plan (Test Sections)

For SPS-3 test sections, FWD testing procedures do not vary between "BEFORE", "AFTER" and "LONG TERM" testing. For all test sections in SPS-3 experiments, testing is similar to the FLEX Testing Plan for GPS except that the number of tests is reduced.

The test plan includes 6 FWD tests on each pass down the test section for both the ML pass (P_1) and the OWP pass (P_3). Deflection Basin tests are at 100 foot intervals beginning at station 0+000.0 (0+00) and continuing to station 0+152.4 (5+00). Figure B-3.1 indicates the test locations for a section. Each test section has 12 deflection basin test points for a total of 36 to 72 test points for a project, depending on the number of treatments used. At a rate of 20 points per hour, the FWD testing will take about 2 to 4 hours. With about 30 minutes per section for temperature gradient measurements, the total time for all tests should be approximately 4 to 7 hours.

FWD operators must use their best judgement and carefully note any abnormal conditions or unique situations encountered in the field. However, only 12 points should be tested on a given section.

Other FWD Operator Field Measurements

Temperature Gradient Measurements

Temperature gradient measurements for SPS-3 sites are obtained similar to that for GPS sections, with the one exception below.

Temperature measurements are taken as usual for the GPS section (i.e., at each end) and at two additional locations for the treatment sections, throughout the duration of FWD testing at the site. It is up to the FWD operator to assess variations in sun exposure and wind conditions to select the most representative location adjacent to the section limits for temperature measurements.

Crack Widths

For any SPS-3 site, ***no*** crack opening measurements are made; however, FWD operators must record pavement distress at test point locations as described in guidelines for GPS testing using the comment line.

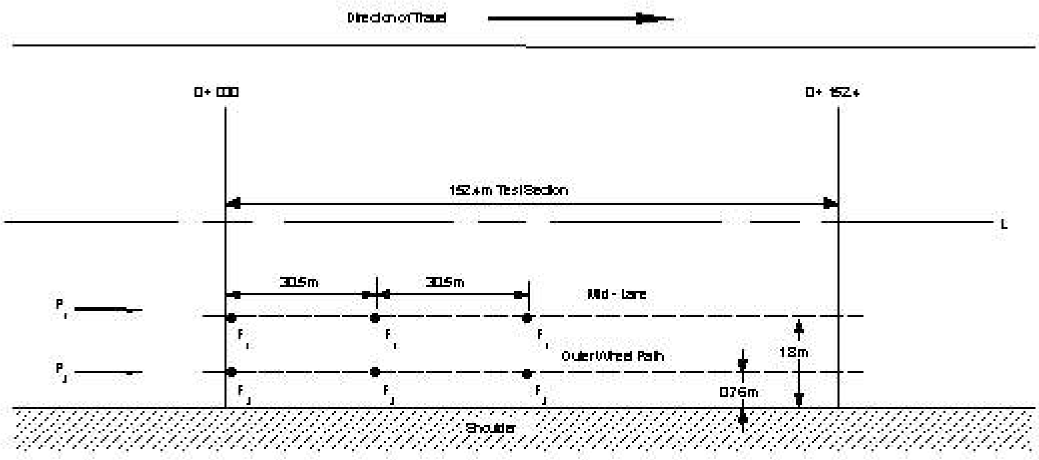


Figure B-3.1 FWD Test Plan for SPS-3 Sections

APPENDIX B-4

FWD TESTING GUIDELINES FOR SPECIFIC PAVEMENT STUDIES (SPS) EXPERIMENT 4 PREVENTIVE MAINTENANCE EFFECTIVENESS OF RIGID PAVEMENTS

Introduction

This appendix provides guidelines and information specific to Falling Weight Deflectometer (FWD) testing at individual test sites for the Long Term Pavement Performance (LTPP) study experiment SPS-4, "Preventive Maintenance Effectiveness of Rigid Pavements." The intent of this document is to establish the specific testing requirements for SPS-4 sites based on a uniform set of assumptions. It is recognized that not all sites will conform to all assumptions contained herein. However, the objectives and approach to deflection data collection must be consistent so data obtained can be analyzed in a consistent manner. For deflection testing details not specifically addressed in the appendix, refer to the general guidelines in this manual.

The objective of the SPS-4 experiment is to compare the effectiveness and mechanisms by which selected maintenance treatments preserve or extend pavement service life, driver safety and ride quality on Portland Cement Concrete (PCC) pavements. The impact of materials or construction process is not a part of this study. In addition, the overall goal is to compare the performance of treated sections to untreated sections. The impact of a preventive maintenance treatment is based on the ***process*** or ***type*** of treatment; e.g., undersealing. Process parameters for material, design, and construction specification known to work reasonably well in each individual climatic zone were selected.

The primary factors addressed in the experimental design include moisture and temperature conditions, subgrade type, and traffic loading. The secondary factors include the individual treatments: crack/joint sealing and undersealing. Other second level factors include pavement condition at the time the treatment is placed and the type of subbase.

FWD Test Plan

General

The LTPP test sections in an SPS-4 experiment are tested the same before and after maintenance regardless of treatment. The site characteristic affecting FWD testing is the number of sections. FWD testing is performed 0 to 3 months prior to application of the maintenance treatment (labelled as "BEFORE"), 3 to 6 months after application of the maintenance treatment (labelled as "AFTER"; not required), and bi-annually more than 6 months after the application of the maintenance treatment (labelled as "LONG TERM"). In addition, sections should be tested just prior to removal of the section from the experiment.

Deflection Basin tests as well as Load Transfer tests are used in the SPS-4 testing. The specific FWD test plan is similar to the JCP Testing Plan for GPS. The factors inherent within this test plan are:

1. Test Point ID (J4, J5, and J6)
2. Lane for Each FWD Pass (Transverse Location)
3. Test Interval (Longitudinal Location)
4. Test Type (Basin and Load Transfer)
5. Deflection Sensor Spacing

6. Drop Sequence (Load Levels/Number of Drops)

All FWD testing is done in the OWP of the driving lane, located 0.76 m ± 0.08 m (2.5'± 0.25') from the edge reference defined for GPS testing. ***All*** testing uses station 0+00 of the ***test section*** (not the SPS site) as the distance reference so FWD test point locations can be located for future testing.

FWD operators must insure tests are located within the above tolerances. FWD operators are not expected to measure the position of each test point, but excessive deviations must be avoided.

The GPS load transfer sensor configuration (-305 mm, 0 mm, 203 mm, 305 mm, 457 mm, 610 mm, 914 mm, 1219 mm, and 1524 mm) is used for all tests done on the single pass down the section. The following list of lane specification codes identifies the type and location of tests performed.

"JCP" Category Pavements

J4 approach slab tests in the OWP pass (P_3)
J5 leave slab tests in the OWP pass (P_3)
J6 mid-panel tests in the OWP pass (P_3)

Lane Specification J6 uses the load transfer sensor configuration so FWD operators do not have to move the D2 Sensor for each panel tested.

Naming Scheme/Data Storage

A unique 6 digit code identifies the individual test sections of an SPS-4 project (similar to that for the GPS sections), with the fourth character being "4" for SPS-4.

The computer filenames are identical to those used in the GPS testing, with the 6 character test section code followed by two characters indicating the times a section has been tested and the number of the pass within the section. The "times tested" (character #7) is a single letter which corresponds to the number of times the section has been tested. Character "A" refers to "BEFORE" construction testing, "B" refers to "DURING" construction testing (if it were being conducted), and "C" refers to "AFTER" construction testing for a section (not required). "LONG TERM" testing is designated with letters "D" through "Z", as required. The "pass" (character #8) is OWP testing as used for GPS testing. For example, computer file from "BEFORE" FWD testing of section 1 at an SPS-4 site in Iowa would be: 19A401A3. When performed, the FWD testing "AFTER" has the filename 19A401C3 (test time "B" is skipped for SPS-4 as there is no testing during construction). Files representing data collected for "LONG TERM" testing will have a "D" or higher as the seventh character.

Drop Sequence

The drop sequence (load levels and number of drops) for joint/crack sealing test sections and underseal test sections is the same as the JCP Testing Plan for GPS when FWD testing is done alone. However, for underseal test sections, the drop sequence is as follows when testing is done with other equipment for void detection (i.e. Benkelman Beam):

SPS-4 Loss of Support Testing Plan - Drop Sequence
(Used Only with Other Equipment Present)

No. of Drops	*Drop Height*	*Data Stored*
3	3	No [1]
3	1	Yes [2]
3	2	Yes [2]
3	3	Yes [2]

[1] No data stored, seating drop only. Deflection and load data is printed but not stored to a file.
[2] Store deflection peaks only.

Operators should use the FWD SPS-4 test setup in conjunction with Benkelman Beam for loss of support testing. This setup is only used on underseal sections, and only when Benkelman Beam testing is done at the same time. The reduced drop sequence lets the FWD keep up with the Benkelman Beam.

Test Pit Areas

The SPS-4 experiment has no test pits. Therefore pass P_0 testing is *not* performed in SPS-4.

Test Point Identification

FWD operators must properly record longitudinal distances with the distance measuring instrument relative to 0+000.0 (0+00) station reference for each section, and follow the guidelines for lateral offset for the OWP pass, so all FWD testing can be repeated in the same general location.

Detailed Test Plan (Test Sections)

For SPS-4 test sections, the type of FWD testing performed varies between "BEFORE", "AFTER" and "LONG TERM" testing, only if testing is done in conjunction with Benkelman Beam for loss of support testing. Deflection testing always consists of a single pass in the OWP. Tests are done on each side of the joint and/or crack and at the mid-slab, as shown in Figure B-4.1, using the GPS load transfer test sensor configuration. The standard test procedure for joint and crack sealing test sections, control sections, and state test sections is to test the first joint and the center of the first slab and every third joint and slab thereafter. Any transverse crack within the slabs is also tested. For the underseal test sections, all slabs in the sections are tested. The total number of test points and hence time requirements for SPS-4 sections will depend on the slab size, number of cracks present, number of supplemental agency sections, and whether loss of support testing is done in conjunction with Benkelman Beam.

Conditions encountered in the field may present unique and unanticipated situations. For these situations, FWD operators must use their best judgement in slab selection and carefully record any abnormal conditions using the pre and post test comment line and notation on the FWD Field Activity Report.

Other FWD Operator Field Measurements

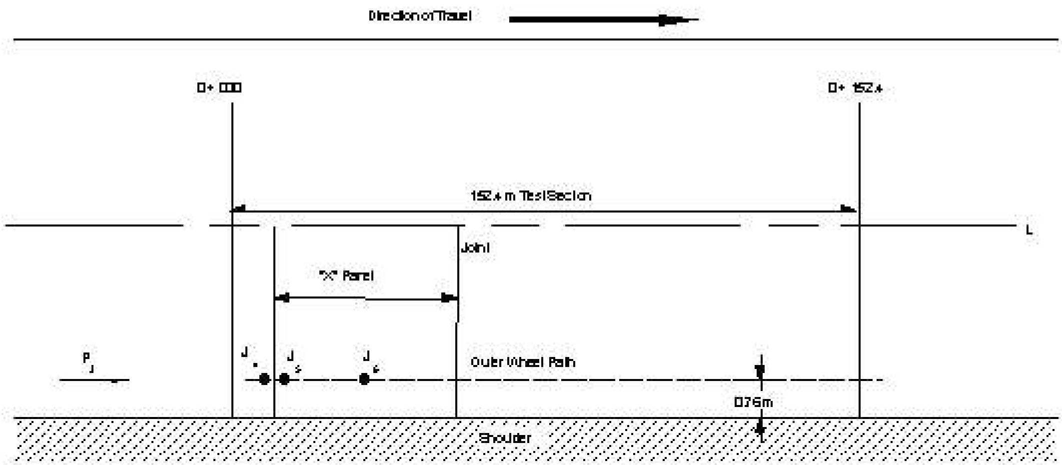
Temperature Gradient Measurements

Temperature gradient measurements for SPS-4 sites are obtained similar to that for GPS sections, with one exception as noted below.

Temperature measurements are taken as usual for the GPS section (i.e., at each end) and at two additional locations for the treatment sections, throughout the duration of FWD testing at the site. It is up to the FWD operator to assess variations in sun exposure and wind conditions to select the most representative location adjacent to the section limits for temperature measurements.

Joint/Crack Widths

Joint and crack opening measurements for SPS-4 sites are obtained as defined under the JCP Testing Plan. However, FWD operators are encouraged to measure all joints/cracks tested.



NOTES:

1. Panel Length "X" will be variable depending upon specific joint spacing, transverse crack pattern and pavement type.
2. Test all panels on underseal sections and every third panel on remaining sections.
3. Lateral Offsets shown represent Nominal Distances.

Figure B-4.1 FWD Test Plan for SPS-4 Sections

APPENDIX B-5

FWD TESTING GUIDELINES
FOR SPECIFIC PAVEMENT STUDIES (SPS) EXPERIMENT 5
REHABILITATION OF ASPHALT CONCRETE PAVEMENTS

Introduction

This appendix provides guidelines and information specific to Falling Weight Deflectometer (FWD) testing at individual test sites for the Long Term Pavement Performance (LTPP) study experiment SPS-5, "Rehabilitation of Asphalt Concrete Pavements." The intent of this document is to establish the specific testing requirements for SPS-5 sites based on a uniform set of assumptions. It is recognized that not all sites will conform to all assumptions contained herein. However, the objectives and approach to deflection data collection must be consistent so data obtained can be analyzed in a consistent manner. For deflection testing details not specifically addressed in the appendix refer to the general guidelines in this manual.

The objective of the SPS-5 experiment is to investigate the performance of selected asphalt concrete (AC) pavement rehabilitation treatments. A variety of rehabilitation techniques can be applied to AC pavements to restore condition and extend service life. The techniques included in this experiment include a combination of types and thicknesses of AC overlay using either virgin or recycled AC mixes. Another variable examined is the extent of surface preparation. Characterization of the materials and their variation between test sections is required to explain performance differences and provide a basis for improved rehabilitation design.

In contrast to the LTPP General Pavement Studies (GPS), SPS has controlled construction of multiple test sections at a single site. On a SPS-5 site, there are 8 test sections and one control section. All sections have either two or five inch AC overlays, using either virgin or recycled AC mixes and either minimum or intensive pre-overlay surface preparation.

Experiment sites should conform to criteria contained in Specific Pavement Studies Guidelines for Nomination and Evaluation of Candidate Projects for experiment SPS-5, "Rehabilitation of Asphalt Concrete Pavements", November 1989. The site characteristic affecting FWD testing is the number of sections.

Table B-5.1 lists the LTPP test sections contained in an SPS-5 experiment. Criteria for selection limit the sites to a single structural cross section, constructed of the same materials throughout, under a single contract. Location of test sections should avoid cut/fill transitions, bridges, culverts, and side hill fills to limit the potential for variability of subgrade soils. A minimum of three Test Pits are used on the total site.

Table B-5.1 - SPS-5 Test Section Numbering Scheme

SPS-5 Section No.	Surface Preparation	Overlay Material	Overlay Thickness, inches
1	Routine Maintenance		0
2	Minimum	Recycled AC	2
3	Minimum	Recycled AC	5
4	Minimum	Virgin Mix AC	5
5	Minimum	Virgin Mix AC	2
6	Intensive	Virgin Mix AC	2
7	Intensive	Virgin Mix AC	5
8	Intensive	Recycled AC	5
9	Intensive	Recycled AC	2

FWD Test Plan

General

FWD testing for SPS-5 is performed 0 to 3 months prior to overlay construction (labeled as "BEFORE"), 3 to 6 months after overlay construction is completed (labeled as "AFTER"), and bi-annually more than 6 months after the completion of overlay construction (labeled as "LONG TERM"). The preconstruction phase is used to characterize the existing pavement structure, and provide a baseline for comparison of the various rehabilitation techniques. Post construction testing is directed at verifying material properties and the as-built pavement section for use in evaluating the effectiveness and long term performance of the rehabilitations. "LONG TERM" FWD testing is performed to evaluate the effects of temperature, moisture changes and traffic loading on pavement deflection and performance.

Only deflection basin tests are used in the SPS-5 testing. The specific FWD test plan to be implemented for SPS-5 is similar to the FLEX Testing Plan for GPS. The factors inherent within each test plan are:

1. Test Point ID (F0, F1, F3)
2. Lane for Each FWD Pass (Transverse Location)
3. Test Interval (Longitudinal Location)
4. Test Type (Basin)
5. Deflection Sensor Spacing
6. Drop Sequence (Load Levels/Number of Drops)

All FWD testing is done in the driving lane at two lateral offsets. The two lateral offsets are the ML and OWP as defined in the GPS portion of this manual. For a given lateral offset, a single pass through the test section is made to collect a particular type of deflection data. When finished with a particular pass, the FWD returns to the beginning of the section to start another pass. *All* testing uses station 0+00 of the *test section* (not the SPS site) as the distance reference so FWD test point locations can be located for future testing.

Naming Scheme/Data Storage

A unique 6 digit code identifies test sections at an SPS-5 site (similar to that for the GPS sections), with the fourth character being "5" for SPS-5.

The computer filenames are identical to those used in the GPS testing, with the 6 character test section code followed by two characters indicating the times a section has been tested and the number of the pass within the section. The "times tested" (character #7) is a single letter which corresponds to the number of times the section has been tested. Characters A and B are reserved for "BEFORE" and "DURING" (if it were being conducted) construction testing on SPS experiments; all SPS testing uses the letter C as the first "AFTER" construction testing; and, letter D as the first "LONG TERM" testing. The "pass" (character #8) is 0 for TP testing, 1 for ML testing, and 3 for OWP testing, as used for the GPS testing. For example, files from "BEFORE" FWD testing of section 1 at an SPS-5 site in Iowa would be: 190501A0, 190501A1, and 190501A3. FWD testing "AFTER" results in the following files: 190501C0, 190501C1, and 190501C3 (test time "B" is skipped for SPS-5 as there is no DURING construction testing).

Test Pit Areas

As in the GPS testing, efforts are made to "link" the material sampling/testing program and FWD test results on all SPS-5 sites. At each SPS-5 experiment site, test pits (TP) are located approximately 15.2 m (50') to 18.3 m (60') from a particular test section. Due to the length of the SPS-5 sites, test pits are not located adjacent to every test section. As a rule, a minimum of three test pits are used at every SPS-5 site. *Each* potential test pit location has FWD measurements taken in the OWP pass. Subject to traffic control restrictions, this pass (P_0) is completed for the entire SPS-5 test site prior to testing of pass P_1 on any section. There may be occasions where time delays of days or weeks occur between FWD testing and sampling, and FWD operators must mark the location of the FWD tests in the TP areas. Also, pass P_0 testing is *only* performed for the "BEFORE" time period.

Test Point Identification

FWD operators must properly record all longitudinal distances with the distance measuring instrument relative to 0+000.0 (0+00) station reference for each section, and follow the guidelines for lateral offset for the OWP and ML passes, so all FWD testing can be repeated in the same general location.

Detailed Test Plan (Test Pit Areas)

TP areas are tested identical to the procedures outlined for GPS testing in the main part of this manual.

Detailed Test Plan (Test Sections)

For all SPS-5 test sections, FWD testing procedures are identical for "BEFORE", "AFTER", and "LONG TERM" testing. The procedure used is similar to the FLEX Testing Plan for GPS except the number of test points is reduced.

The test plan includes 11 FWD tests on each pass down the test section for both the ML and the OWP. Deflection Basin tests begin at station 0+000.0 (0+00) and continue to station 0+152.4 (5+00), at 50' intervals. Figure B-5.1 indicates the test locations for a section. Each section has 22 test points for a total of 198 test points (not including Test Pit locations) for a project. At a rate of 20 points per hour, the FWD testing will take approximately 10 hours. This does not include the time for testing Test Pit locations or the temperature gradient measurements. The total time for all tasks should be approximately 16 hours.

FWD operators must use their best judgement in the testing process and carefully note any abnormal conditions or unique situations encountered in the field. However, only 22 points should be tested on a given section (exclusive of test pits located adjacent to the section).

Other FWD Operator Field Measurements

Temperature Gradient Measurements

Temperature gradient measurements for SPS-5 sites are obtained similar to that for GPS sections, with the three exceptions below.

Temperature measurements are required at 2 depths (at one-third points) if the existing bituminous surface layer is less than 50mm (2 in) thick. Otherwise, three depths are always used just like normal GPS testing. Figure B-5.2 illustrates the drilling patterns to use for temperature gradient data.

Measurements are obtained at only one location for each SPS-5 section. It is up to the FWD operator to assess variations in sun exposure and wind conditions to select the most representative location adjacent to the section limits for temperature measurements.

Temperature readings are obtained at 30 minute intervals, with the first readings prior to starting FWD testing on a section and the last readings after completion of the FWD testing on the section.

Crack Widths

For any SPS-5 site, *no* crack opening measurements are made; however, FWD operators must record pavement distress at test point locations as described in guidelines for GPS testing using the comment line.

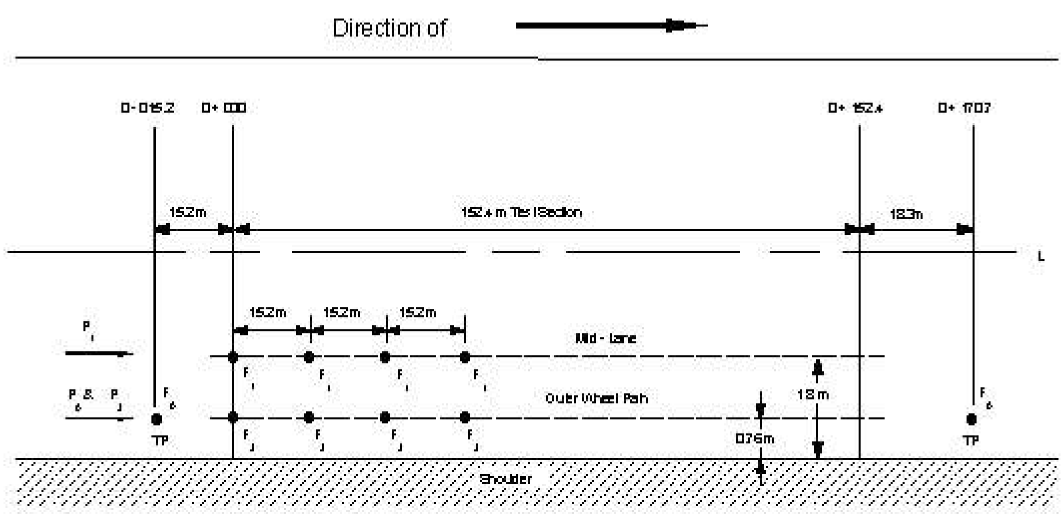


Figure B-5.1 FWD Test Plan for SPS-5 Sections