PB99-100174

REPORT FHWA/NY/SR-95/120

Testing Program For the Falling-Weight Deflectometer

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SPECIAL REPORT 120

TRANSPORTATION RESEARCH AND DEVELOPMENT BUREAU
NEW YORK STATE DEPARTMENT OF TRANSPORTATION
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TESTING PROGRAM
FOR THE FALLING-WEIGHT DEFLECTOMETER

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Interim Report on Research Project 12-49
Conducted in Cooperation With
The U.S. Department of Transportation
Federal Highway Administration

Special Report 120
May 1995

TRANSPORTATION RESEARCH AND DEVELOPMENT BUREAU
New York State Department of Transportation
State Campus, Albany, New York 12232-0869

ABSTRACT

NYSDOT has purchased a non-destructive testing device (the falling-weight deflectometer or FWD) manufactured by Dynatest, Inc., to improve New York pavement design practice. Pavement deflection measured with the FWD can be used to assess pavement structural condition by evaluating parameters of in-situ materials. To serve its intended purpose, however, deflection testing must be conducted consistently, with an accurately calibrated FWD. This report documents procedures followed in 1994 deflection testing at ten selected sites -- seven in NYSDOT Region 1, two in Region 6, and one in Region 9. It describes the testing program, giving guidelines for testing at each site and for field quality assurance, data acquisition, and calibration. In addition to deflection testing, pavements were cored and sampled to provide specimens for laboratory characterization of paving materials, and to verify pavement layer thicknesses. Based on this experience in field testing and data analysis, further guidelines are being developed for future FWD testing.

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I. INTRODUCTION

A. Background

Structural evaluation is essential for preventive maintenance and restoration (including design) of rehabilitated, new, and reconstructed pavements. To enhance capabilities in such evaluations, NYSDOT has purchased a state-of-the-art nondestructive testing device -- the falling-weight deflectometer (FWD) manufactured by Dynatest, Inc., consisting of a trailer and towing vehicle. It measures pavement deflection using an array of seismic sensors resting on the surface at nine locations beneath the trailer, through dynamic impact loads estimated by the manufacturer as ranging from 26.7 to 120.2 kN. For a given impact loading, the pavement will deflect downward to form a bowl-shaped depression known as a deflection basin. From measured surface deflections and known layer thicknesses, backcalculation produces pavement layer parameters. These include subgrade resilient moduli and pavement moduli for both flexible and rigid pavements, and moduli of subgrade reaction for rigid pavements alone. These parameters are not inherent properties of each layer, but rather are influenced by the entire structure's response to load, and can be used in structural analyses of pavement using mechanistic approaches.

The Geotechnical Engineering Bureau manages, operates, and maintains the FWD. The Transportation Research and Development Bureau will prepare operational guidelines based on FWD field and laboratory test data gathered from selected sites. The 1994 and 1995 testing programs have five objectives:

1. To familiarize NYSDOT personnel with FWD operation,

2. To collect data on FWD deflection and pavement temperature and distress,

3. To collect pavement cores and soil samples for laboratory testing and determining layer thickness,

4. To analyze and interpret these data in the context of pavement overlay design procedure, and

5. To prepare FWD operational guidelines based on these data.

B. Factors Affecting Backcalculated Pavement Layer Parameters

Accurate measurement of deflections is the key element in assessing accuracy of backcalculated results. Four factors significantly affect deflections:

1. Pavement cross-section,
2. Environment,
3. Pavement discontinuities, and
4. Variability in the pavement structure.

1. Pavement Cross-Section

a. Pavement Type

Rigid and flexible pavements respond quite differently when subjected to applied load. The essential difference is the manner in which each distributes load through the pavement layers. Rigid pavement with high stiffness and bending strength will spread the load over a large area, resulting in a shallow deflection basin. Flexible pavements tend to distribute the load less broadly, resulting in a deeper basin.

b. Layer Thickness

Thickness of each pavement layer is important because pavement deflection (d) is directly proportional to the third power of thickness (t)[$d = F(t^3)$]. An error in pavement layer thickness thus will manifest itself exponentially in the backcalculated layer parameters.

c. Subgrade "Stiff" Layers

This is any layer below the subgrade that contributes little or nothing to measured surface deflection. Stiff layers may be real or only apparent. "Real" consists of bedrock or other stiff material. However, a high water table can give the appearance of a stiff layer beneath the subgrade because of the incompressibility of water under dynamic loads. Also, stress-sensitive subgrade material (whose modulus increases as deviator stress decreases) behaves as if an actual stiff layer exists, resulting in attenuation of deflections of outer radii and producing unrealistically high (and consequently inaccurate) material parameters for the subgrade. If an actual rigid layer exists, it can be handled as a known layer with high modulus. Bedrock information can be obtained from geologic maps, by performing cone-penetrometer tests, or by coring through the road's shoulder.

2. Environment

Temperature and moisture affect deflection response of both flexible and rigid pavements. As temperature increases within flexible pavement, magnitude of deflection from a given impulse load will increase (if all other factors remain the same). Because asphalt concrete is temperature-dependent, this results in decreased layer stiffness. Deflections measured on a hot summer day thus will be larger than those recorded during a cooler period. Also, in concrete pavements, changes in temperature with depth (vertical temperature gradients) cause curling of slabs and alter support conditions, finally affecting magnitude and location of critical stresses.

In general, moisture in a pavement weakens the subgrade and increases pavement deflection readings. Moisture changes are normally long-term, occurring over an annual cycle, but pavement sections in areas with significant frost penetration may show extreme changes in deflection if significánt moisture exists in conjunction with soils containing fines (≥3 percent of 0.02 mm particles). Deflections are small in a frozen structure, but in spring as the soil thaws from the surface it is weakened by downward-moving moisture trapped between the surface and subgrade, resulting in lower bearing capacity and higher deflections. Soils are also "loosened" by buildup of frost lenses.

The FWD operator should recognize that pavement deflections vary within the same pavement sections throughout the day and year due to temperature and moisture changes. Thus, deflection readings taken at different times on a specific pavement section may vary. The operator must perform the following tasks:

1. Verify air and pavement temperatures recorded automatically by the FWD,

2. Verify that locations along the project where flexible pavement mid-depth temperature is measured are correct and representative, and

3. Record general weather conditions before and after testing (e.g., for information affecting soil moisture).

3. <u>Pavement Discontinuities</u>

A test point on a pavement section located near such surface discontinuities as cracks and/or joints, or voids beneath rigid pavements, will generally have higher deflection readings than a section without discontinuities, if other factors remain the same. It is important that the operator obtain typical deflection-response data on each pavement section, and not bias deflection readings by testing only crack-free areas or only cracked areas. Test-point location and distribution are discussed later in greater detail.

4. <u>Variability in the Pavement Structure</u>

Pavement deflection response varies not only between weight drops at a given load level, but also between test points within a section. Deflection variation at a given load level for a test point is generally less than about 2.5 to 5 μm (0.1 to 0.2 mils) and is statistically accounted for by dropping weights four times at each load level. However, deflection variation between test points within a section may be quite large, ranging from 15 to more than 60 percent. This variation reflects changes in layer thickness, material properties, moisture and temperature conditions,

Table 1. Summary of 1994 FWD test sites.

Route	Reference Markers	Pavement Description*	Test Date	Tests Run*
ALBANY COUNTY (Region 1)				
5	1015-1024	125 mm ACC overlay on PCC pavement	11/10	DB
5	1040-1060	150 mm ACC overlay on rubbleized PCC pavement	11/10	DB
7	1153-1174	DLTD/PCC pavement	11/15	LT
32	610 m section	228 mm full-depth CRM/ACC pavement	10/4	DB
144	1052-1062 & 1080-1090	38 mm CRM/ACC overlay over 38 mm overlay over PCC pavement	10/5-6	DB
I-90	1002-1022	MILTD/PCC pavement	10/12-13	LT
DELAWARE COUNTY (Region 9)				
17	1013-1023	140 mm CRM/ACC overlay on PCC pavement	9/15-16	DB
SARATOGA COUNTY (Region 1)				
9N (before overlay)	2008-2050	242 mm ACC pavement	8/23	DB
9N (after overlay)	2008-2050	38 mm ACC overlay over 242 mm ACC pavement	9/21	DB
67 (before overlay)	1035-1098	242 mm ACC pavement	8/30	DB
67 (after overlay)	1035-1098	38 mm ACC overlay over 242 mm ACC pavement	9/22	DB
STEUBEN COUNTY (Region 6)				
17 (Southern Tier Expwy)	—	MILTD PCC pavement	10/25	DB
Corning Bypass	—	New DLTD/PCC pavement	10/26	DB, LT

*CRM = crumb-rubber modified, DLTD = dowel load-transfer devices, MILTD = malleable-iron two-component load-transfer devices, DB = deflection basin test, LT = load-transfer test.

subgrade support, and contact pressure under the load plate. These are normal conditions, and operators should not be concerned about deflection variations resulting from such changes.

C. Selection of Test Sites

The testing program involves experiments on three specific types of pavement cross-section:

1. Flexible overlay on flexible pavement (ACC/ACC),

2. Flexible overlay on rigid pavement (ACC/PCC), including cracked-and-seated and rubbleized pavements, and

3. Rigid pavement (PCC).

Testing includes collection of site-related data for each of these three pavement types. Primary data being collected include 1) thickness of pavement layers, 2) depth to any stiff layer, 3) pavement distress, and 4) environmental conditions during testing (climatic factors). Other considerations are 1) overlay material (recycled or virgin), 2) rigid pavement slab length, and 3) subgrade soil. Table 1 lists the ten sites for 1994 field testing.

II. TESTING PROGRAM

A. FWD Deflection Testing

1. Types of Deflection Tests

Two types of test are being performed: 1) deflection basin (DB), and 2) load transfer (LT). DB tests were run in 1994 at eight flexible-pavement sites and LT tests at three rigid-pavement sites as listed in Table 1. DB test results are being analyzed to estimate in-situ characteristics of materials in the pavement structures. By contrast, LT tests at joints and cracks in rigid pavements are analyzed to evaluate load-transfer efficiency across those discontinuities, and also to detect possible presence of voids beneath the pavements.

2. Deflection Sensor Spacing

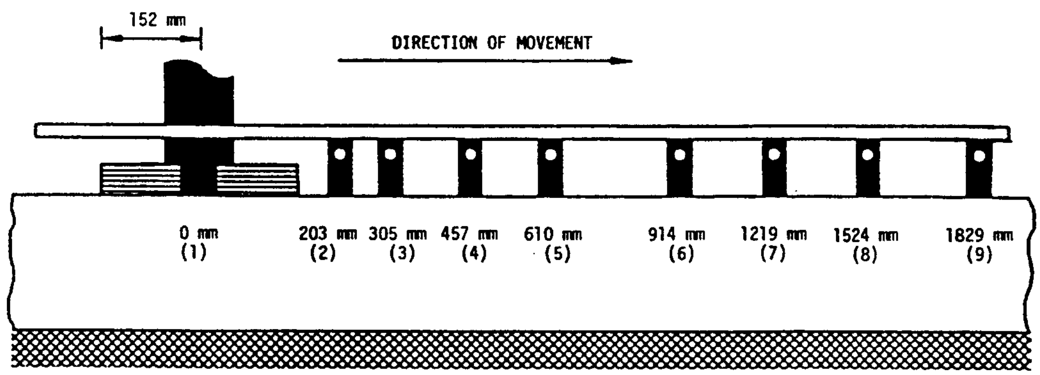
The FWD has nine geophones spaced at specific offsets from the center of the load plate to define the shape of the deflection basin. Basin shapes range from steep (for weak flexible pavements) to shallow (for stiff rigid pavements). For most pavements, basin shape varies most significantly within 0.9 m of the load plate.

For any one pavement section, an optimal set of sensor spacings exists to define basin shape, but only one set is being used for all DB and LT tests to simplify data collection, decrease testing time, and minimize errors in LT tests. Figure 1 shows sensor spacings for the DB and LT tests, and Figure 2 shows the load plate on the approach and leave sides of a joint for LT tests. Note that in Figure 2, the two load-transfer equations should be multiplied by F_b (bending factor).

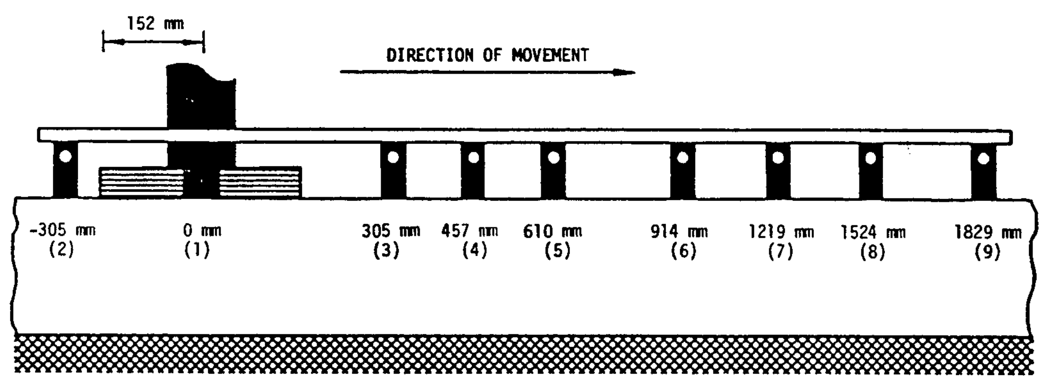
3. Load Sequence (Drop Heights)

Testing plans for flexible and rigid pavement sites have similar but not identical drop sequences, and separate test setups must be used. For flexible pavements, four drop heights are used with the target loads and acceptable load ranges at each height given in Table 2. The FWD's acceptable load range is from 24 to 78 kN, using a single combination of mass and rubber buffers (or springs). This combination uses three weights on each side (a total of six) and two rubber buffers (a total of four), referred to as a 200 kg package. The impacts on different pavements will vary even if drop distances are the same. In addition, several factors such as non-linearity damping and temperature dependency of the rubber buffers, and mass of load-transfer bracket

Figure 1. Spacing for nine deflection sensors (adapted from Figure 2 from Manual for FWD Testing in the Long-Term Pavement Performance Program, Publication SHRP-P-661, Strategic Highway Research Program, National Research Council, 1993).



SENSOR CONFIGURATION FOR DEFLECITON BASIN TESTING



SENSOR CONFIGURATION FOR LOAD TRANSFER TESTING

Figure 2. Arrangement of deflection sensors for determining load transfer-efficiency at approach and leave sides of a joint or crack (Figure 5.7 from Pavement Deflection Analysis Participant Workbook, Publication FHWA-HI-94-021 for NHI Course 13127, National Highway Institute, Federal Highway Administration, U.S. Department of Transportation, February 1994). The two load-transfer equations should be multiplied by F_b (bending factor).

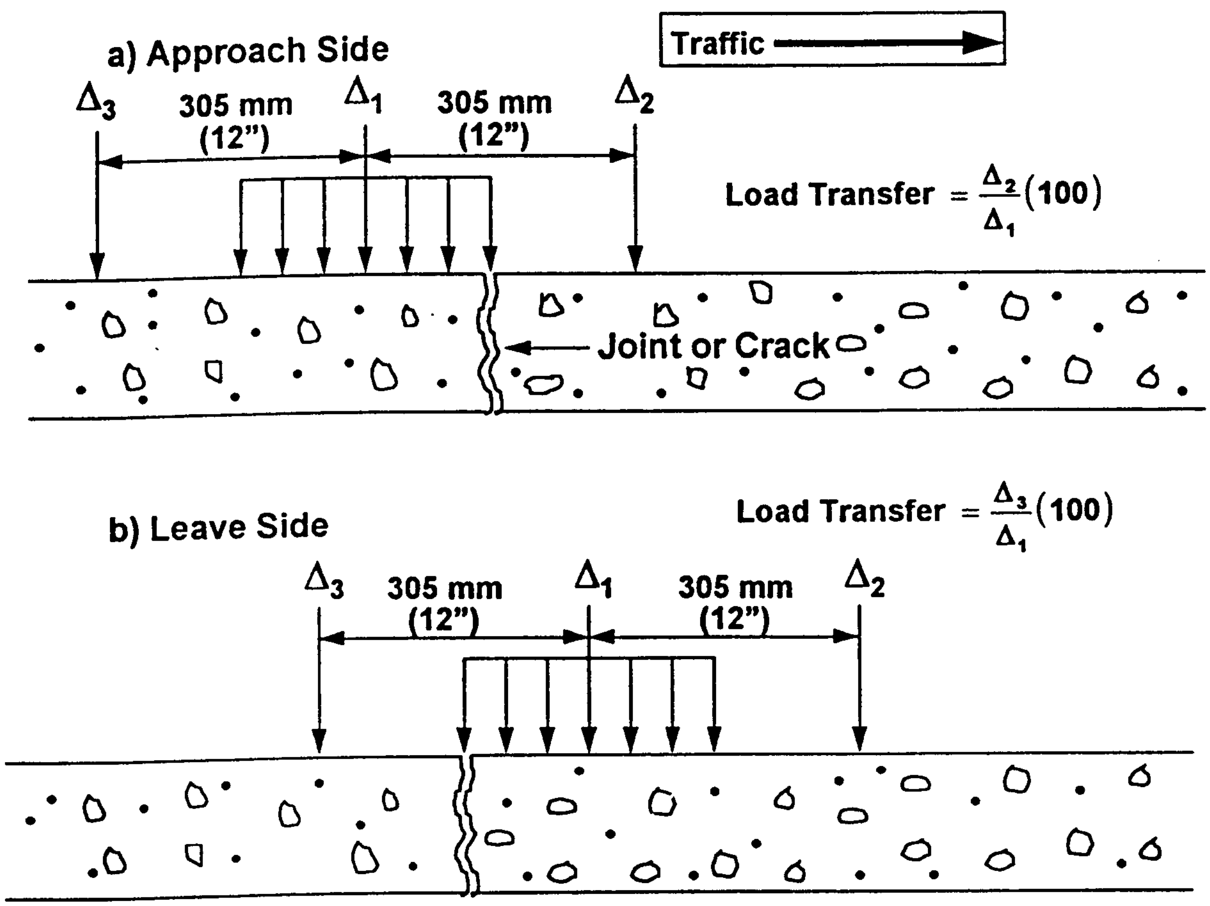


Table 2. FWD load and drop sequences.

FWD LOAD SEQUENCE

Height Setting	Target Load, kN	Acceptable Range, kN
1* 50 mm	26.7	24.0-29.4
2 100 mm	40.0	36.0-44.0
3 200 mm	53.3	48.1-58.7
4 390 mm	71.1	64.1-78.0

*Not used on rigid pavements.

FWD DROP SEQUENCE

ACC Pavement			PCC Pavement	
Height Setting	No. of Drops	Data Stored	Height Setting	No. of Drops
3	3	No*	3	3
1	4	Yes**	2	4
2	4	Yes**	3	4
3	4	Yes**	4	4
4	4	Yes**		

*Seating drop only, no data stored, deflection and load data printed but not stored to a file.

**Deflection peaks stored for all four drops, but deflection-time history completed for only the fourth drop.

will vary even if drop distances are the same. In addition, several factors such as non-linearity damping and temperature dependency of the rubber buffers, and mass of load-transfer bracket plus elastic properties of load-distributor pads and pavements, may cause measured load to change even if drop distances do not change.

Minimum and maximum drop distances for Drop Heights 2 and 4 are limited to 40 and 390 mm, respectively. This limitation may cause difficulty in obtaining the specified impulse loads. To minimize this effect, drop distance should be set to obtain loads as close as possible to the target range.

The following procedure is recommended in setting drop distance for the four drop heights:

1. After arriving at a test section and before any test data are collected, select a point outside the test section and run 64 drops to condition (warm up) the buffers for ambient temperatures greater than 10°C, or run 128 drops for lower temperatures.

2. Next, adjust drop heights until loads are obtained on the high side of the acceptable range. recorded loads generally decrease during a typical testing day as temperature of the rubber buffers continues to increase.

3. If a target load cannot be achieved within the normal drop-distance range for a given drop height, set the drop height to obtain a load as close as possible to the target range. Under no circumstances should the mass/buffer combination be changed to achieve a target load.

4. Obtain loads as close as possible to the 40 kN target load (40 kN represents the load on one set of dual tires for a standard 80 kN axle, historically used for pavement design purposes).

5. After drop heights are set, begin data collection. Drop heights may not be changed after data collection begins, even if measured loads go outside the target ranges.

4. <u>Drop Sequence</u>

Drop sequence (drop heights and number of drops) for the testing plans is given in Table 2.

5. <u>Determination of Load Transfer Efficiency (LTE)</u>

FWD testing may be used to evaluate load transfer capacity at rigid pavement joints. Tests are conducted by applying a load near the joint, and measuring deflections near it on the loaded and unloaded slabs. Figure 1 shows one common load and sensor configuration. Load-transfer measurements on approach and leave slabs are shown in Figure 2. In calculating LTE, the slab bending effect should be taken into consideration. In a continuous slab, a reading at its center will show that deflection under a load is higher than deflection at any distance (r) from that load. Similarly, at the joint, deflection of the loaded slab will be greater than that of the unloaded slab, even is full load transfer exists. Slab bending factor (F_b) is the ratio of deflection under the load to deflection at a distance (r) from it. Load transfer at the joint, based on deflection, is computed from the following equation:

$$LTE = (\Delta_{2,3}/\Delta_1) \times 100 \times F_b$$

where LTE = joint efficiency,

$\Delta_{2,3}$ = deflection of the unloaded slab,

Δ_1 = deflection of the loaded slab, and

F_b = bending factor.

Bending factor at the center of the slab is computed from the following equation:

$$F_b = \Delta_1/\Delta_3.$$

Theoretical joint efficiency may range from 0 to 100 percent. Joint condition can be classified according to the following deflection transfer efficiencies: "excellent" = 90 to 100 percent, "good" = 89 to 70 percent, "fair" = 69 to 50 percent, and "poor" = less than 49 percent. If joints carry heavy traffic and joint efficiency is fair to poor, faulting is likely and the joints should be considered for load-transfer restoration.

B. <u>FWD Testing Plans</u>

Flexible and rigid pavement testing plans differ as follows:

1. Longitudinal location of test points (spacing and stationing),

2. Type of deflection test (DB or LT), and

3. Drop sequence in the test (drop height and number of drops).

For longitudinal reference, all test point locations are measured from Station 0+00 using the distance-measuring instrument (DMI) in the FWD tow vehicle. The DMI should be checked at intermediate stations and problems with stationing for the section or with calibration of the instrument should be recorded. For lateral reference, all FWD testing occurs in the lane containing the test sections (generally the driving lane). Within the lane tested, two lateral offsets measured from an edge reference are used to locate the test points. The edge reference is the lane-shoulder interface for a normal paving lane (usually a 3.6 m wide lane), or the outside edge of the painted shoulder stripe for a wide paving lane (usually more than 3.6 m). The two lateral offsets measured from the edge reference toward the roadway centerline are as follows:

1. Inside wheelpath (IWP) = 2.7 ± 0.15 m

2. Outside wheelpath (OWP) = 0.76 ± 0.08 m for nominal 3.6 m wide lanes.

During actual data collection, FWD tests are run at one lateral offset for each pass down the test section, and only DB or LT tests are run in a given pass. When a pass is complete, the FWD returns to the beginning of the section to start at another lateral offset. (The detailed testing plans given later contain more information on order of passes and type of data collected during each pass.) Information on load sequence and drop height sequence are given in Table 2.

1. <u>Flexible Pavement Testing Plan</u>

Table 3 summarizes the testing plan for flexible pavements. Two passes are run -- one in the IWP and the other in the OWP. In each pass, DB tests are generally run at 200 m intervals. For rubber-modified asphalt concrete (RUMAC) test sites (Rtes 17, 32, and 144), an interval of 61 m is used. At each test point, a sequence of 19 drops is used -- three seating drops at Height 3 and four drops each at Heights 1, 2, 3, and 4.

2. <u>Rigid Pavement Testing Plan</u>

Table 3 also summarizes the testing plan for jointed rigid pavements. One pass is run in the outer wheelpath (OWP). For each slab tested two LT tests are run during the OWP pass for a total of two test points per slab tested. At each test point, a sequence of 15 drops is run -- three seating drops at Height 3 and four at Heights 2, 3, and 4. The rigid pavement test plan requires great operator caution and judgment for two reasons:

Table 3. Summary of 1994 FWD testing, coring, and foundation sampling and testing.

Route	FWD Testing Location	Test Type[e]	Test Points	Pavement Cores[f] Total	RMT[g]	Foundation Sampling[f] Subbase	Subgrade	RMT[g]
ALBANY COUNTY (Region 1)								
5 (ACC over PCC)	OWP	DB	39	-	-	-	-	-
7 (DLTD/PCC)[a]	Joints	LT	34	-	-	-	-	-
32 (Full-Depth ACC)[b]	OWP/IWP[c]	DB	102	5	2	5	5	2
144 (ACC over ACC over PCC)[b]	OWP/IWP[c]	DB	82	16	3	4	4	1
I-90 (PCC)	Joints	LT	--	5	-	-	-	-
DELAWARE COUNTY (Region 9)								
17 (ACC over PCC)[b]	OWP/IWP[c]	DB	51	16	2	4	4	1
SARATOGA COUNTY (Region 1)								
9N (ACC before & after overlay)	OWP[d]	DB	68	4	1	4	4	-
67 (ACC before & after overlay)	OWP[d]	DB	108	5	2	5	5	1
STEUBEN COUNTY (Region 6)								
17 (MILTD PCC)[a]	Joint/Midslab	LT	20	-	-	-	-	-
Corning Bypass (New DLTD/PCC)	Joint/Center	LT,DB	42	-	-	-	-	-

[a] DLTD = dowel load-transfer devices, MILTD = malleable-iron two-component load-transfer devices
[b] Rtes 17 and 32 had five 610 m segments; Rte 144 had ten 305 m segments.
[c] Outer wheelpath in one direction, inner wheelpath in the other direction.
[d] Tests performed in both directions.
[e] DB = deflection-basin test, LT = load-transfer test.
[f] Holes 100 and 150 mm drilled at each site; from each hole, a core and two samples were taken (one subbase, one subgrade).
[g] RMT = resilient modulus tests.

1. In New York, slab lengths of 6.5, 18.5, and 30 m have been used. Currently, recommended lengths vary 5.0 to 5.5 m.

2. Longer slabs (18.5 and 30 m) generally have one or more transverse cracks. For example, if the original slab has one transverse crack, the operator should view it as two effective slabs. A "slab" thus can be defined as a continuous section of rigid pavement bounded by two transverse breaks in the pavement. Any effective slab tested must have two test points, no matter how long or short it is.

In summary, the operator must determine the total number of effective slabs in a rigid-pavement test section before testing begins. In addition, the effective slabs to be tested must be marked for easy identification during testing. The operator must use his best field judgment in selecting and documenting the effective slabs tested, using the following guidelines:

1. Avoid testing effective slabs that extend outside the section limits.

2. Number the effective slabs, with Slab 1 the first one entirely within the section at Station 0+00.

3. Mark the effective slabs with chalk or lumber crayon to avoid testing the wrong slabs.

4. Record the numbers of slabs tested on the Field Activity Sheet, or document the effective slabs tested by sketching the section to identify the joints and cracks tested.

C. Other FWD-Related Field Testing

The purpose of the field and laboratory testing is to collect layer-thickness data and to validate backcalculated layer moduli from the FWD deflection data. Additional field measurements include temperatures, pavement distresses, joint/crack widths, and coring locations.

1. Temperatures

Automatic sensors on the FWD record ambient air and pavement surface temperatures. However, temperature at mid-depth of the surface layer is also important for analysis of deflection data. Steps for temperature measurement are as follows:

1. Select one location at the center of each 1.5 km section (minimum of two locations), somewhere between the OWP and pavement edge. The operator must make sure these are representative of sun exposure and wind conditions for the section.

2. Estimate thickness for all flexible and/or rigid layers, using available information about the pavement structure.

3. Mark each location and drill a 13 mm diam hole, using a portable hammer drill to mid-depth of the surface layer.

4. Clear hole cuttings and dust by blowing them out through a short piece of 6 mm diam plastic tubing.

5. Measure and record depth of each hole to the nearest 2 mm and fill with 13 to 25 mm of mineral oil (providing thermal conduction at the bottom of the hole for a temperature probe inserted in the hole).

6. Cover each hole with a short piece of duct tape to prevent water and debris from entering. The tape also prevents the sun from warming the oil in the hole. Make a small incision or hole in the tape to insert the probe.

7. Read temperatures to the nearest 0.25°C each hour during testing. After inserting the probe, allow the reading to stabilize for about 1 minute before recording temperature. The first measurement should be taken at least 10 minutes after oil is poured into the hole, to allow heat from drilling to dissipate.

8. Seal holes after the last temperature measurement, using a sealant (such as silicon caulk) that can be drilled out for future testing.

2. Pavement Distress

Type and severity of distress influence pavement deflection response. Operators thus must record any distress located from about 300 mm in front of Geophone 9 to about 900 mm behind the load plate. This information should be recorded in the FWD file, using the F6-Comment key in the field program immediately after the test. The operator should refer to the SHRP LTPP Distress Identification Manual (Publication SHRP-P-338, 1993) and the NYSDOT Pavement Rehabilitation Manual (Vol. 1) for guidance regarding distress type and severity.

Other items to be documented using the F6-Comment key include 1) cut/fill locations and transitions, 2) increases in deflection with increasing distance, 3) variations in readings, and 4) unusual items such as testing delays due to breakdown or weather, pavement changes within the section, moisture seeping out of cracks, or anything else that might help clarify results during analysis of FWD data.

3. Joint/Crack Openings

Joint openings in rigid pavements affect deflection response and load transfer, and cracks in flexible pavements affect pavement response. Vernier calipers with tapered jaws to measure inside dimensions of joints/cracks are used to record widths. The Vernier caliper scale should have a resolution of 0.2 mm. For transverse cracks, the goal is to measure the extent of opening through the pavement. If cracks are spalled, the opening may have to be estimated. For sawed joints, the goal is to measure the sawcut width. 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 in the OWP, and average values entered at the "condition request" prompt immediately following the LT test.

4. Pavement Coring and Sampling

Table 3 gives the 1994 FWD sampling plan. Cores of 100 and 150 mm diam were removed using a coring rig fitted with a diamond bit. These cores serve two purposes -- 1) they allow determination of pavement component thicknesses for use in later analysis, and 2) they provide samples for laboratory tests to characterize material properties. Split-spoon samples of 125 mm diam were collected from the subbase and subgrade layers using a 150 mm diam sampler (about 450 mm long). These samples are used for lab resilient-modulus testing. Aside from index properties of the asphalt cement and aggregates, lab tests also include determining core tensile strength and resilient modulus.

D. Laboratory Testing

This includes determining index properties and stress-strain properties for asphalt, aggregates, and soils, according to appropriate AASHTO and ASTM standards. Table 4 lists the lab tests. Soil

Table 4. Laboratory testing plan.

Sampling Location	ASTM/AASHTO Designations
PAVEMENT (Core)	
Flexible (ACC)	
Thickness	D 3549-87
Bulk Specific Gravity and Density	D 2726-90
Theoretical Maximum Specific Gravity	D 2041-91
% Air Voids	D 3203-91
% Asphalt Content	D 4125-92
Resilient Modulus	D 4123-82
Tensile Strength	D 4867-88
Gradation	C 136-92
Rigid (PCC)	
Compressive Strength	C 39-86/T 22-92
Tensile Strength	C 496-90/T 198-93
SUBBASE (Split Spoon)	
Thickness	D 3549-87
Gradation	T 27-93
Natural Moisture Content	D 1461-85
Moisture-Density	T 180-93
In-Place Denstiy	—
Resilient Modulus	TP 46-94
SUBGRADE (Split Spoon)	
Gradation	D 422-92
Classification	D 2487-92
Atterberg Limits	D 4318-84
Moisture-Density	T 180-93
Resilient Modulus	TP 46-94
Natural Moisture Content	D 2216-92
In-Place Density	—

Note: Depth to rigid layer is determined using bedrock maps and previous soil-boring information.

boring data (including bedrock information) are obtained from the Regional Soils Engineer, and all previous geologic, design, and construction maps related to each site are collected for further evaluation, as well as field and lab data for component materials.

E. Checklist for Field Activities

The following list of daily tasks outlines an operator's typical day at a test section:

1. Arrive at site, and coordinate personnel involved in traffic control (and sampling and testing if conducted simultaneously, although it may be more convenient to core and sample at a later date rather than while FWD testing is underway).

2. Inspect the test section and record details concerning pavement condition, section limits, and coring locations.

3. Prepare FWD equipment: remove FWD covers/trays, visually inspect the equipment, check computer/printer setup, initiate FWD field program.

4. Check FWD drop weights: select a location outside the test section, condition the buffers, adjust drop heights within target ranges.

5. Collect deflection data in sequence.

6. Complete data collection and data backup: read final air and pavement temperatures, create backup data disks and history reports, complete and check the Field Activity Form.

7. Prepare equipment for travel and make final inspection: return FWD covers to original positions, store computer and printer, complete final walk-around inspection of tow vehicle and FWD.

III. DATA ACQUISITION AND CALIBRATION

A. Data Acquisition

The operator's primary responsibility is data collection. Guidelines are suggested here to maintain uniformity and consistency in two areas: 1) setting up the field program, and 2) using the software for data collection and backup.

1. Setting Up the Field Program

The program is described in detail in the "Quick Start Manual" section of the Dynatest Edition 25.11 Field Program. The "Setup" chapter should be consulted for this purpose.

2. Using the Software

a. Data Quality Checks

FWD data must be valid and accurate. For deflection data, FWD Software Version 25 gives four quality-control checks as data are collected, under "Test Setup":

1. Decrease Check: deflectors should exhibit decreasing peak deflections. If not, mark failure peaks.

2. Rolloff Check: check the shape of each deflector signal as follows: deflection level at the END of the sampling window must be less than 90 percent of the peak deflection. If the check fails, mark the relevant peaks.

3. Overflow Check: peak deflection must be less than 2000 µm. If they exceed that range, mark the failing peaks.

4. Variation Check: when not disabled, comparable test for consistency (same height or same target) are as follows: each peak pressure reading is compared to average pressure of the set. All peak deflections are then normalized (internally) to average peak pressure:

   D = D x average pressure/actual pressure

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For each deflector channel, normalized peak deflection is compared to average normalized deflection of the channel. If the check fails, relevant peaks are marked. For each check, any of the following four options may be selected:

1. Cancelled/disabled: no check is performed.

2. Enabled: an error massage interrupts the sequence.

3. Relaxed: marks only, sequence continues.

4. Smart: repeats failing drop.

b. Field Data Collection Program

The Dynatest Field Program (Version 25.11) consists of several interactive windows. The first appears on the screen as "Log On." This setup window again consists of several files labeled User, General, Printer, Page Format, Trailer, Processor, DMI System, GPS System, Area, Test Setup, and Data Format. The Field Program Manual describes features of each setup field in detail. For a particular type of pavement section, the same setup fields can be used without further interaction by the user for the entire test section. After completion of these files, the operator must open the "Measurement" file where several items of information must be entered: data file name, roadway ID, subsection, pavement temperature, DMI reading, lane ID, etc. Measurement begins with the START prompt, but the operator should use the following guidelines:

1. File naming convention: file names (up to eight characters) should be uniform for easy identification and convenience. Road ID, pavement type (flexible or rigid), test direction, lane number, and test number can be used to name files. The extension ".FWD" identifies a file as raw deflection data.

2. Data format: The data format setup fields determine how measurements are stored to disk. The following files are available in FWD software:

20SI	Metric "Old" Style
20US	English "Old" Style
25SI	Metric Data
25USN	English, Numeric Station
R32-20F	SHRP Compatible, Metric
R32-25F	Backwards Compatible SI
R80-20F	SHRP Compatible
R80-25F	Backwards Compatible

Selection of the appropriate data format file depends on how easily the stored data can be used by backcalculation programs, and whether data were collected using English or metric unit systems. In NYSDOT, 1994 FWD data were collected using two data formats -- 20SI and R80-20F.

3. Rejecting tests: for most cases, the Reject prompt appears when deflection data exceed variation limits, but non-decreasing deflections or data exceeding the geophone range may also activate the Reject prompt. Operators should examine data on the screen to determine the cause and decide whether to reject or accept the data. If rejected, the operator must repeat the test.

4. Closing a data file: files must be closed promptly at the end of a test set. As a general rule, after ten test points, the data file should be closed.

B. FWD Calibration

Highly accurate deflection data are required if pavement structural characteristics are to be estimated meaningfully. The FWD load cell and deflection sensors must be calibrated periodically using a two-part procedure:

1. The first is reference calibration (occasionally also referred to as "absolute" calibration) in which the load cell and sensors are calibrated at least once a year against an independent reference system, usually at the nearest SHRP Calibration Center (e.g., the PennDOT Center for the northeastern states).

2. The second is relative calibration, involving monthly calibration of sensors against one another, to ensure that all read the same.

Additional information regarding these procedures may be obtained from the Dynatest Owner's Manual: Operating Instructions (Part I), and from the SHRP Manual for FWD Testing in the LTPP Program (Publication SHRP-P-661).

IV. FWD TESTING IN 1995

FWD testing will continue in 1995. Test sites are being selected from proposed paving jobs based on pavement type, traffic, geographic region, and soil types. Data collection procedures will follow the guidelines presented in this report. Pavement cores and soil samples will be collected as considered necessary. Data analysis and interpretation will follow as soon as FWD data become available. Finally, operational guidelines will be prepared and included in a final report on this study.