

DEPARTMENT OF TRANSPORTATION
DIVISION OF ENGINEERING SERVICES
Transportation Laboratory
5900 Folsom Boulevard
Sacramento, California 95819 – 4612



METHOD OF TEST FOR OBTAINING DEFLECTION MEASUREMENTS AND LAYER THICKNESS INFORMATION FOR REHABILITATION DESIGN OF HOT MIX ASPHALT SURFACED PAVEMENTS USING MECHANISTIC-EMPIRICAL DESIGN AND ANALYSIS PROCEDURES

A. SCOPE

This test method presents the basic methodology for collecting deflection data by performing Falling Weight Deflectometer (FWD) testing and pavement coring needed for rehabilitation design of Hot Mix Asphalt (HMA) surfaced pavements using the California Department of Transportation (Caltrans) Mechanistic-Empirical (ME) design procedures. The FWD and pavement layer thickness data are used for back calculation of the existing pavement layer moduli using the Caltrans software *CalBack*. The Caltrans ME based design software *CalME* uses the backcalculated layers moduli for designing rehabilitation strategies.

B. EQUIPMENT

FWD EQUIPMENT

The FWD is commercially available in both vehicle and trailer mounted models. FWD models vary amongst manufacturers, both in terms of the magnitude and duration of the load pulse as well as the manner and accuracy of the deflection measurement system. All FWD models operate on an impulse loading principle while stationary. An FWD provides an impulse load that can be varied depending on the height of fall and mass used. The kinetic energy is transferred to the pavement with a load pulse in approximately a half-sine wave form of 20 to 60 milliseconds duration through a plate that establishes a known load contact area. The deflection sensors are placed at the center of the loading plate and at radial distances from the center to measure the motion induced in the pavement. The pavement surface deflections and load are displayed on a computer screen located in the vehicle and stored in a data file. Pavement coring rigs are also commercially available in vehicle and trailer mounted units. Various manufacturers produce a variety of coring rigs with different operational characteristics. However, all require manual information gathering and recording of pavement layer thickness.

FWD SETUP

The FWD must be setup with at least eight sensors spaced as shown in Table 1. An additional sensor(s) can be placed at a 72 in. distance, or at other distances if required by the Engineer. The FWD should also be equipped with a 12 in. loading plate. Caltrans also employs sensor 9 at minus 12 in., and sensor 10 at minus 8 in. from center of the load plate.

Caltrans recommends that the FWD operating system software be capable of saving the time history for at least one drop per test point. Time histories can be valuable in the analysis of the pavement.

If feasible, equip the FWD with a Differential Global Positioning System (DGPS) to record the coordinates for every FWD test point (latitude, longitude and elevation). Caltrans requires that

the following instrumentation be incorporated in the FWD operating system software, with the instrument data included in test data files:

1. Distance Measurement Instrument (DMI) that records distances from known reference points to the test location, and distance between test locations;
2. Ambient air temperature sensor that records air temperatures for the test data set; and
3. Pavement temperature sensor (Infrared) that records pavement temperature at each test location.

Table 1.
Typical FWD sensor positions
measured from the center of the
load plate

Deflection Sensor Number	Distance from Center of the Loading Plate (inches)
1	0
2	8
3	12
4	18
5	24
6	36
7	48
8	60

FWD CALIBRATION

1. The FWD must be reference-calibrated at least once a year at one of the Strategic Highway Research Program (SHRP) approved calibration centers. Two SHRP approved calibration centers are located in the State of California (at the University of California- Davis, in Davis, CA and at Foundation Mechanics, Inc. in El Segundo, CA). Some FWD manufacturers offer on-site calibration. Consult with the FWD manufacturer for more details.
2. Perform FWD relative calibration in accordance with LTPP Publication FHWA-HRT-07-040 (Oct, 2011) titled: *Falling Weight Deflectometer Calibration Center and Operational Improvements: Redevelopment of the Calibration Protocol and Equipment*, at least once every 42 operational days. A relative calibration is a technique used to check the quality and adjust the response of each of the deflection sensors so that equivalent measurements are obtained when the sensors are subjected to the same displacement. If the FWD is in continuous and regular use, relative

calibration must be performed on a nominal monthly interval. Relative calibration is not performed during periods when the FWD is idle.

3. If a major component such as a deflection sensor, multi-signal cable, or an electronic board is replaced, the FWD should undergo reference calibration before continuing to collect data, regardless of the interval since the previous reference calibration.
4. Ensure that the Distance Measuring Instrument (DMI) is calibrated. Check that the temperature sensors are operational in accordance with the manufacturer's specifications. Perform calibrations or send the temperature sensors back to the manufacturer for repair/calibration if the temperatures are not within the specified calibration limits.

PAVEMENT CORING RIG SETUP

1. The Pavement Coring Rig must be set up for the diameter of cores that are required by the Engineer. In addition to layer thickness, material properties may be evaluated by the Engineer. If feasible, the coring rig should be equipped with Differential Global Positioning System (DGPS), a Distance Measurement Instrument (DMI), a digital camera, and a core tray to obtain pavement core information (Note that some cameras have GPS capabilities).
2. Caltrans Districts may have waste water recovery requirements in place. The coring rig must also be capable of recovering waste water, and have the necessary spill prevention supplies to contain waste water.

C. BACKGROUND DATA AND SELECTION OF TESTING LEVEL

PRELIMINARY OFFICE WORK

1. Caltrans staff should review computerized Road view Explorer videos (<http://onramp.dot.ca.gov/photolog/roadview/roadview.php>) and Pavement Condition Survey files to determine the type of alignment, nature of distress and their locations, and unusual drainage conditions. If these files are not available to the engineer, or are outdated, the project must be visually inspected by the engineer to obtain these data prior to the deflection testing.
2. Determine the existing structural section (layer materials and thicknesses) from contract records, previous deflection studies, or obtain it from investigative field work, or from Ground Penetrating Radar (GPR) data for the project location. Note that Caltrans staff may contact the Office of Pavement Management and Performance, Pavement Program, Division of Maintenance to check if GPR thickness data is available, and/or request the Office of Pavement Management and Performance to process available GPR traces for the lanes under consideration.
2. Determine, through contacting the District Materials Engineer, District Maintenance Engineer, and Project Engineer whether additional work has been performed on the pavement since the last available Pavement Condition Survey (PCS) or since the last GPR data were collected.

3. Review Traffic Accident Surveillance System [TASAS] files (post-mile log) for the project location to determine locations of structures, intersecting streets, railroad crossings, etc.
4. Based on the pavement layer thicknesses and types obtained from construction history, drawings, coring and/or GPR, and the pavement condition survey data, identify the uniform sections that have similar layer thicknesses and types as well as a relatively uniform pavement surface condition.
5. Determine the required level of testing (denoted by Levels AAA, AA, and A) based on the design criteria obtained from the District Materials Engineer or the Project Engineer, where the level indicates the testing intensity as discussed below.
6. Check maximum permissible and/or feasible length of lane closures the traffic control crew can provide, and consider the time constraints to determine the FWD testing and coring plans development. If testing cannot be performed on all lanes due to traffic control and/or time restrictions, plan testing priorities based on rehabilitation design needs. When testing cannot be performed on all lanes, plan to start testing the highest priority lanes first.
7. Caltrans staff needs to work with District Maintenance to arrange and schedule the required personnel and equipment to perform traffic control, coring, GPR, and deflection testing, as well as any other pavement/materials investigations.

PRELIMINARY FIELD WORK

The pavement design and analysis engineer should conduct a project field review to identify, photograph, and record the nature, extent, and limits of the various distresses (e.g., cracks, rutting, bleeding, raveling, patching, potholes, and localized failures). Also record the crack widths as hairline, 1/8 in. wide, ¼ in. wide, or greater than ½ in. wide for all longitudinal, transverse, alligator, and block cracking. Record the crack frequency as isolated, occasional, intermittent, nearly continuous, or continuous. Note the limits of any structural section changes that are visible (e.g., an HMA pavement change to PCC), local drainage problems, any vertical controls (e.g., curbs, gutters, structures, etc.), and any roadway intersections. During the project's field review, determine if some of the above field activities may be done in conjunction with the deflection data collection.

DETERMINE METHOD AND LEVEL OF TESTING

There are two methods of collecting deflection data: (1) Continuous Method, and (2) Representative Section Method. In the Continuous Method, deflection testing is started at the beginning of the test section and continued at equal intervals to the end of the test section. In the Representative Section Method, a test section of a certain length (e.g., 1000 ft., one-quarter mile, or one-half mile) is identified in each lane-mile to represent the entire lane-mile, and testing is only done in the representative test section. The Continuous Method is the *preferred* method that should be used on any project. However, local conditions, sight distance, traffic control safety considerations, and the type of facility may not allow the use of this method. In this case, the Representative Section Method must be used. Additionally, the Representative

Section Method should be used for all road segments less than 1.0 lane-mile in length. Once field conditions improve for the next lane-mile segment, the Continuous Method should be resumed. The two testing methods are further described below.

CONTINUOUS METHOD

With the Continuous Method, there are three levels of testing varying in the testing intensity that may be used. For a given project, an appropriate testing level is selected based on design life and traffic data. Use this method for all road segments greater than 1.0 lane-mile in length (unless conditions dictate otherwise). The three testing levels are described below.

1. Level AAA

For all lanes considered for rehabilitation, measure deflections at 105 ft. intervals in the safest wheel track to obtain 50 deflection measurements per 1.0 lane-mile. If the project is shorter than 1.0 lane-mile, use the Representative Section Method discussed below. Begin testing at one Post Mile limit of the project, and proceed toward the other Post Mile limit using the 105 ft test intervals. Take 5 cores per lane mile. Longitudinally stagger the testing pattern and core locations between adjacent lanes by 50 ft. as shown in Figure 1. [Safety note: For multilane divided facility outside lanes, the right wheel track should be tested, and the left wheel track should be tested for the inside lanes. This should help keep personnel and equipment away from live traffic.] Discuss wheel track or center of lane testing with the engineer. Level AAA also requires testing with load sweeps (see Section D). For any given roadway segment where the Continuous Method cannot be done, perform the Representative Section Method described below.

2. Level AA

For all lanes considered for rehabilitation, measure deflections at 175 ft. intervals in the safest wheel track to obtain 30 deflection measurements per 1.0 lane-mile. If the project is shorter than 1.0 mile, use the Representative Section Method discussed below. Begin testing at one Post Mile limit of the project, and proceed toward the other Post Mile limit using the 175 ft. test intervals. Take 3 cores per lane mile. Longitudinally stagger the testing pattern and core locations between adjacent lanes by 85 ft as shown in Figure 2. Discuss wheel track or center of lane testing with the engineer. Level AA also requires testing with load sweeps (see Section D). For any given roadway segment where the Continuous Method cannot be done, perform the Representative Section Method described below.

3. Level A

For all lanes considered for rehabilitation, measure deflections at 250 ft. intervals in the safest wheel track to obtain 21 deflection measurements per 1.0 lane-mile. If the project is shorter than 1.0 mile, use the Representative Section Method. Begin testing at one Post Mile limit of the project, and proceed toward the other Post Mile limit using the 250 ft. test intervals. Take 2 cores per lane mile. Longitudinally stagger the testing pattern and core locations between adjacent lanes, by 125 ft. as shown in Figure 3. Discuss wheel track or center of lane testing with the engineer. For any given roadway segment where the

Continuous Method cannot be done, perform the Representative Section Method described below.

REPRESENTATIVE SECTION METHOD

1. With the Representative Section Method, the same three levels of testing intensity apply (along with their respective design life and traffic data requirements). However, this method is used only when the Continuous Method is not feasible.
2. For each lane considered for rehabilitation, select one of the possible test intervals as given in Table 2 as “representative” of every 1.0 lane-mile of roadway, or portion thereof if under 1.0 lane-mile.
3. Select test sections for each change in structural section or a change in overall surface distress condition. Obtain 2 cores in the tested wheel track within the representative section; one core at each end. Figure 4 shows a schematic of this testing method. Discuss wheel track or center of lane testing with the engineer. Note: Multiple test sections per lane-mile are possible.

**Table 2.
Typical Test Sections and Testing Intervals
for Representative Section Method**

Test Section Length		Testing Interval (ft)		
		Level AAA	Level AA	Level A
Legacy	1000 ft	20	30	50
¼ mile	1320 ft	25	45	65
½ mile	2640 ft	50	90	125
¾ mile	3960 ft	80	130	185
Others	Measure	Calculate interval for 50 tests*	Calculate interval for 30 tests*	Calculate interval for 21 tests*

*Note: Round interval to nearest 5 ft.

D. DEFLECTION TESTING AND CORING FIELD WORK

GENERAL

1. Reference each test section to a known Post Mile as identified on TASAS (e.g., structures, intersections, etc.)
2. For safety considerations, discuss the test sections with traffic control personnel to include sufficient sight distance in both directions. Set up traffic control limits to avoid hazardous situations, but also to maintain logical test sections.

3. Obtain representative photographs of each test section and all areas of major localized distress. Identify the project, lane, direction, Post Miles, and date the photographs. An example of a test section photograph is shown in Figure 5. Photograph and identify any other important roadway features. Record all observed pavement conditions, road intersections, locations of large cuts and fills, vertical control features, post mile markers, air temperature, and pavement surface temperatures. Also record any localized drainage and/or embankment settlement problems, and any existing structural section data. [Safety note: Should testing occur during night work, traffic control may need to be arranged for photographs during the day.]
4. Review all data for the test section's direction, lane number, and completeness before leaving the project site, and correct as necessary.

DEFLECTION DATA COLLECTION

*****WARNING: DO NOT TEST OR CORE ON STRUCTURES*****

1. Prepare the FWD equipment for deflection testing. Set up the test file with the appropriate information: project, lane, direction, Post Mile, date, etc.
2. Exercise the hydraulic system at the beginning of the shift (i.e., warm up the system).
3. Bring the FWD to a stopped position at the beginning of the test section, centered on the appropriate wheel track, and take a measurement. Apply the loads using the following sequence:
 - a. One seating drop to ensure proper contact, usually 6 kips \pm 10 %. This drop is not recorded.
 - b. Three drops with an applied load of 9 kips \pm 10 %. [Engineer's note: Drop sequence may need the loading increased to 12 kips or 15 kips] All three drops are recorded.
4. Ensure that deflections are recorded from all of the sensors.
5. Run a deflection load sweep at 9, 12, and 15 kips at three locations per lane mile when continuously testing per Level AAA or Level AA. [Deflection Testing Operator note: The load sweep tests will probably require a separate file and test run in the test section. Use a 6 kip seating drop (unrecorded), followed by the three drop load sweep (recorded).]
6. After each measurement, move the FWD forward to the next measurement point using the DMI.
7. Make sure that the deflections are being transferred electronically from all sensors. Record the surface distress type in the vicinity of the test point, the ambient air and pavement surface temperatures during testing, the test location description, the equipment identification, and the date and time of

testing. Also, record the load sweep tests marked with the words “load sweep”.

CORING

Prepare the coring rig for pavement coring. The minimum number of cores to be taken is as specified in Section C.3 and shown in Figures 1 through 4. Discuss with the Engineer if the required number of cores cannot be obtained. Discuss core hole backfilling with the District Maintenance crew. Take photographs of cores and record core data (e.g., layer depths, overall length, and base material type). An example of a core photograph is shown in Figure 6. Place the core in a core tray and log details in a data sheet. The visual inspection of the cored hole can help in determining layer thicknesses. Log the base material or uncemented material in the data sheet. A sample of a core log is shown in Figure 7. Retain cores with unidentifiable materials for the engineer’s review. [Coring Rig Operator note: Discuss core recovery and cataloging with the engineer, and plan core custody and responsibilities]. Backfill the core holes as required by the District Maintenance crew.

E. DOCUMENTATION AND CALCULATION

1. Compile all data produced by the preliminary office work, preliminary field work, deflection testing, and coring field work. Organize the collected data. Create electronic files (spreadsheets, documents, photo presentations, etc.) for the project. Submit all data files to the rehabilitation pavement design and analysis engineer.
2. Calculations to determine layer moduli using the Caltrans software *CalBack* and rehabilitation design using Caltrans M-E design software *CalME* are performed by the pavement design and analysis engineer.

F. HEALTH AND SAFETY

It is the responsibility of the user of this test method to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. Prior to handling, testing or disposing of any materials, testers must be knowledgeable about safe laboratory practices, hazards and exposure, chemical procurement and storage, and personal protective apparel and equipment.

Caltrans Laboratory Safety Manual is available at:

3. http://www.dot.ca.gov/hq/esc/ctms/pdf/lab_safety_manual.pdf

End of Text
(California Test 357 contains 12 pages)

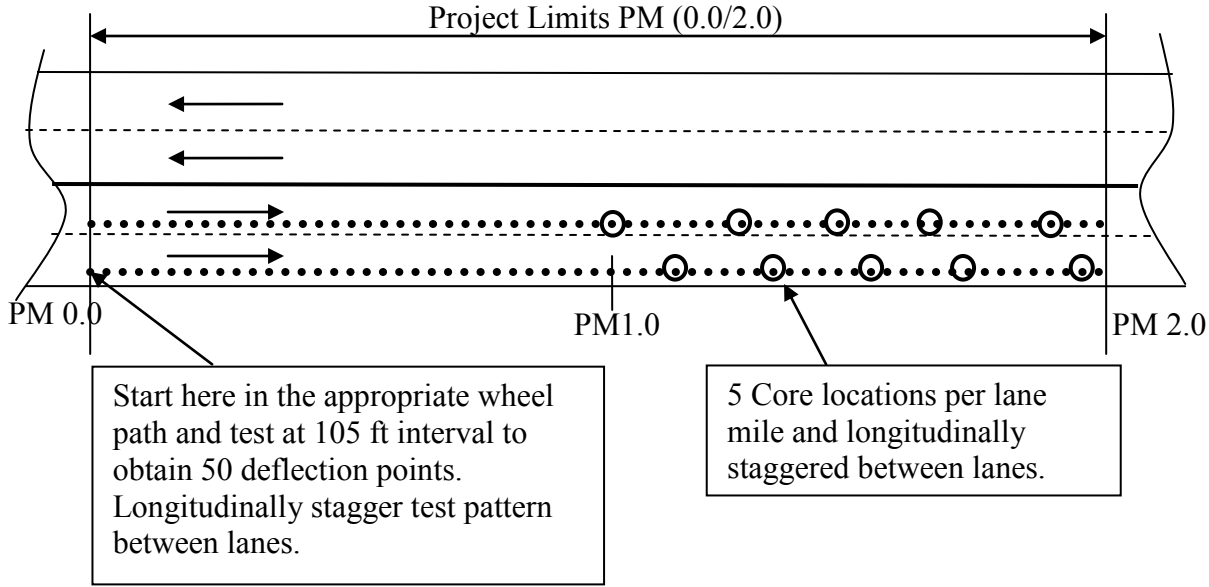


FIGURE 1. Schematic of Continuous Method for Level AAA Testing

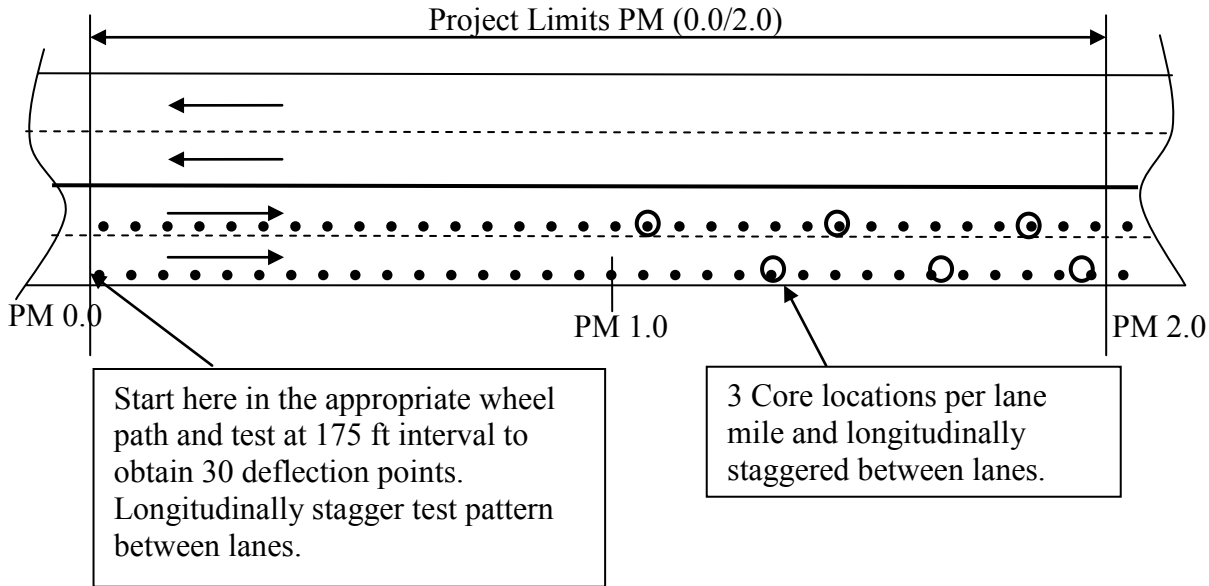


FIGURE 2. Schematic of Continuous Method for Level AA Testing

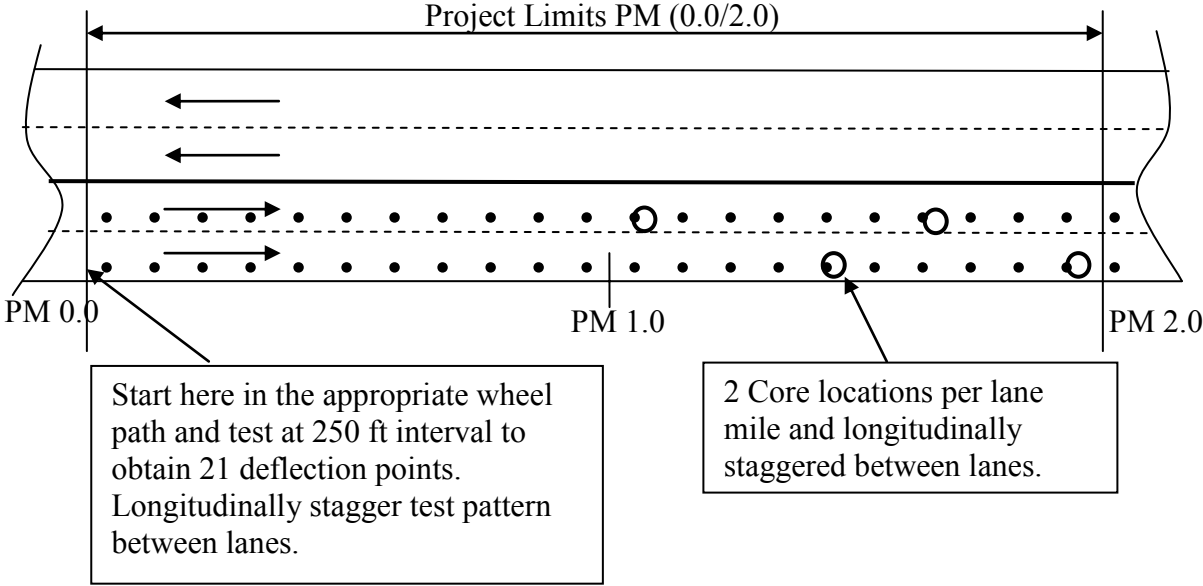


FIGURE 3. Schematic of Continuous Method for Level A Testing

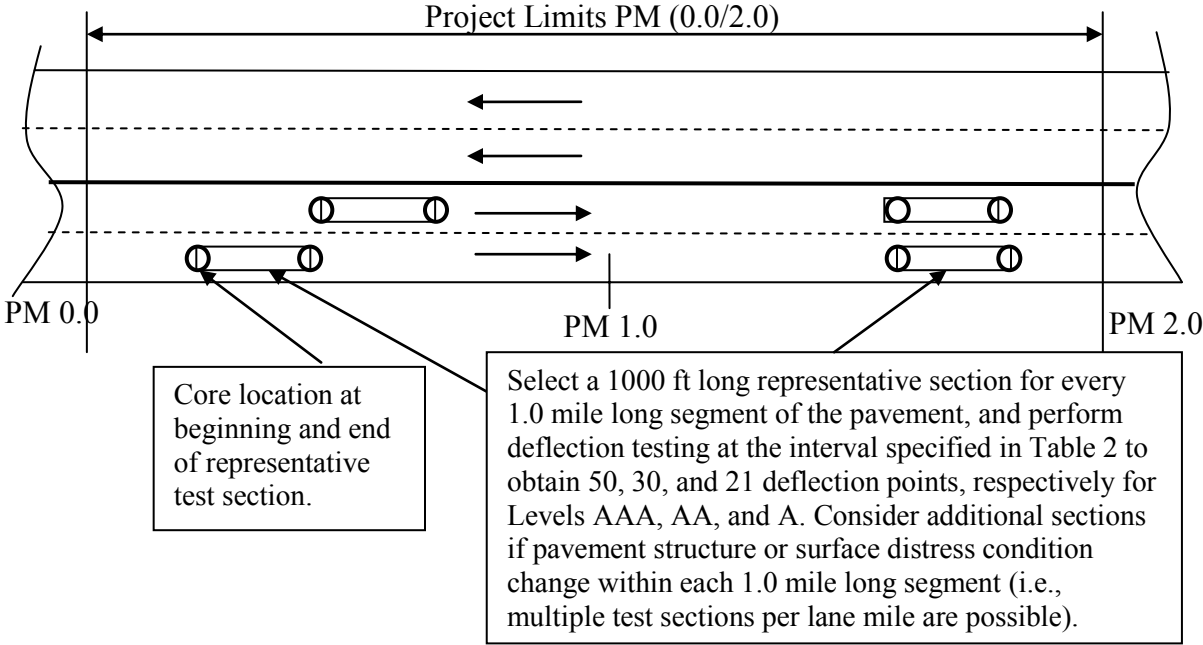


FIGURE 4. Schematic of Representative Section Method



FIGURE 5. An Example Photograph of a Test Section



FIGURE 6. An Example Photograph of Core Sample

**STATE OF CALIFORNIA, DEPARTMENT OF
TRANSPORTATION**

Division of Engineering Services
Materials Engineering and Testing
Services

Sheet 1 of 1

District-County-
Route-PM/PM: 08-SBD. RT.138 0.0-.5 AND 10.7 TO 14.
Expense
Authorization (EA): 08-4697V1

**LOG OF CORE
HOLES**

Core Rig Operator: FRANCES CARSON
D-08 Date of Coring: 1-20 TO
23-2004

DeflecTrack Number: _____
Total Number of Cores: 14

Deflection Test Operator: G. PAYNTAR Date of Deflection Test: 1-20- TO 23-2004

Test Section	Core Hole Location (PM, Lane No., Direction)	Layer 1 (Seal Coat?)	Layer 2 (Struct. Sect.)	Layer 3 (Struct. Sect.)	Layer 4 (Struct. Sect.)	Layer 5 (Base Material)	Total Core Thickness	Remarks
1	PM. 0.80 LN. 1 WB			0.8	0.15	RM	0.95	AC + RM./ORG. GROUND
2	PM. 0.200 LN. 1 EB			0.53	0.2	RM	0.73	AC + RM./ORG. GROUND
3	PM. 1.150 LN. 1 EB			0.6		ORG. GROUND	0.6	
3	PM. 1.550 LN. 1 EB			0.6		ORG. GROUND	0.6	
4	PM. 1.800 LN. 1 WB			0.5	0.15	RM	0.65	AC + RM./ORG. GROUND
5	PM. 2.230 LN. 1 EB			0.6	0.25	RM		AC + RM./ORG. GROUND
6	PM. 2.500 LN. 1 WB			0.5	0.33	RM	0.83	AC + RM./ORG. GROUND
7	PM. 3.200 LN. 1 EB			0.6	0.25	RM	0.85	AC + RM./ORG. GROUND
8	PM. 3.850 LN. 1 WB			0.55	0.2	RM	0.75	AC + RM./ORG. GROUND
9	PM. 4.658 LN. 1 WB			0.65		ORG. GROUND	0.65	
10	PM. 4.140 LN. 1 EB			0.66		ORG. GROUND	0.66	
12	PM. 13.750 LN. 1 WB			0.2	0.25	RM	0.45	AC + RM./ORG. GROUND
13	PM. 13.440 LN. 1 WB			0.4	0.3	RM	0.7	AC + RM./ORG. GROUND SAMI AT .07
14	PM. 11.450 LN. 1 EB			0.45	0.35	RM	0.8	AC + RM. / ORG GROUND SAMI AT .15

Core Log Prepared By: GEORGE PAYNTAR 1-26-04
(Name and Date)

FIGURE 7. Example of Core Log