Guidelines for Maintenance Treatment Test Section Set-Up and Evaluation

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1.0 Introduction

Caltrans invests millions of dollars each year in pavement maintenance activities. Documented performance of the pavement maintenance treatments placed during these activities is important in order for Caltrans to determine which maintenance alternative is the best option to use. Many factors weigh in on this decision such as; existing pavement geometry, construction materials, location (District), environment and cost. One cost effective process when determining which maintenance technique to apply is the construction of test sections where performance can be monitored over time.

The purpose of this manual is to assist Caltrans personnel when selecting test section locations where specific maintenance treatments are to be evaluated. This manual offers guidelines in terms of location, field and laboratory testing, and scheduling of periodic monitoring of performance. The manual supplements the "Maintenance Technical Advisory Guide (TAG)" and the "Guide to the Investigation and Remediation of Distress in Flexible Pavements" and uses information from those documents as well as past test section project evaluations located throughout the State of California.

2.0 Defining Test Section

Implementation of the test section depends on several factors which need to be thoroughly examined before construction begins.

The purpose of a test section is to evaluate the performance of an existing or new rehabilitation alternative. Typically within the section there is a "control" section in which standard maintenance techniques are applied and therefore the different maintenance alternatives can be compared to this "control" section. An adequate location must be determined before the construction phase can begin. The following items should be considered before test section locale is made:

- Type of maintenance alternative to be investigated (i.e. seal coat, overlay).
- Traffic information on the roadway such as ADT and percentage of trucks.
- Distance from nearest town or city (i.e. within a reasonable distance (0-25 km) of a town or city). Population of the surrounding area and closeness to the nearest residential or business facility.
- Obstruction to vision and accessibility to test section that may cause safety issues.
- The pavement structure must be as uniform as possible throughout the proposed test section length, in order to effectively compare the control section and the proposed rehabilitation sections. As-built drawings and deflection testing can assist in determining pavement consistency.
- Proposed maintenance alternative should be applicable to the existing conditions.
- Determine the financing source for the budget required (i.e. Vendor or Caltrans).
- Availability of construction materials.

Finally, the test section should be selected with emphasis on state-of-the-art or state-of-the-practice rehabilitation methods. There should be a reasonable background research effort invested in the proposed maintenance alternative before funding is set aside for the project. The location of the test section or sections should be determined by the following characteristics:

- The minimum length of the test section is suggested to be 1,000 meters.

- Maintenance alternatives should be applicable to the existing environmental and material conditions of the proposed site.
- Consistent existing pavement structure.
- Safe area to construct and monitor.
- Sufficient traffic in order to assess distress/damage.
- Dedicated monitoring personnel.
- Support of Headquarters and District Maintenance Personnel.

3.0 Data Collection

The following sections summarize the most critical data to collect for monitoring performance, and typical data collection methods used. Depending on the objectives of the project some of data may be omitted or additional data may be needed.

3.1 Records Review

A records review refers to the collection of data from office files and other historical records that can provide important information about the proposed test site and is beneficial when conducting a pavement distress investigation (i.e. visual condition survey). Such data is valuable because of the insight it provides into various pavement design, construction, performance and rehabilitation/repair histories. Items included under this category are:

- Design Reports (e.g., thickness design determination report).
- Construction plans and specifications.
- Mix design records.
- Quality control/quality assurance (QC/QA) records.
- As-built drawings.
- Materials and soils properties from previous laboratory test programs and/or published reports.
- Past pavement condition surveys, nondestructive testing, and destructive sampling investigations.
- Rehabilitation/repair histories.
- Traffic measurements/forecasts.
- Environmental/climate studies.
- Pavement management system reports.

Each of these records should be examined to the extent necessary to help identify (if not quantify) the causes of the existing pavement distress.

3.2 *Visual Condition Survey*

A visual condition survey refers to a visual evaluation of the pavement to determine the type, extent, and severity of distress. Field distress surveys serve as a cornerstone in the identification of the overall pavement condition. With adequate training of personnel, these surveys can provide reliable and consistent results with which to characterize the condition of the pavement and determine the possible causes of any observed distresses. Ideally, it is desirable to conduct the condition survey over 100 percent of the pavement area. If not possible, a good mid-range value is 30 m every 150 m (i.e. 20 percent sample). However, the selection of an appropriate sampling rate for a given test section should depend upon the extent of the deterioration, traffic exposure (safety issues), and the time available for conducting the survey.

The key types of distress that should be identified and quantified in the survey depend upon the type of pavement. For flexible pavements, Appendix A and Appendix D in the "Guide to the Investigation and Remediation of Distress in Flexible Pavements" provide distress definition, photos, measurements for HMA pavements, and surfaced treated pavements, respectively. For rigid pavements, the "Distress Identification Manual for the Long-Term Pavement Performance Project" provides distress definition, photos, and measurements.

Distress data collection forms provide an effective means of recording the distress types, severities, and quantities. For flexible pavements, Appendix C and Appendix F in the "Guide to the Investigation and Remediation of Distress in Flexible Pavements" provide sample forms for distress data collection. For rigid pavements, the "Distress Identification Manual for the Long-Term Pavement Performance Project" provides sample forms for distress data collection.

Differential Global Positioning System (DGPS) can yield accurate measurements within a few meters in moving applications and even better in stationary situations. DGPS can be used to locate test sections on a map, as shown in Figure 1. Data collected on a specific test section, coupled with x and y coordinates from a DGPS, can be located accurately on a test section making it easier to manage all data.

Manual or computer entered distress data forms should be used along with digital photos for recording distress along the pavement. While the forms have the recorded data in numerical format the digital photos provide a visual reference for personnel not directly related to the pavement inspection.

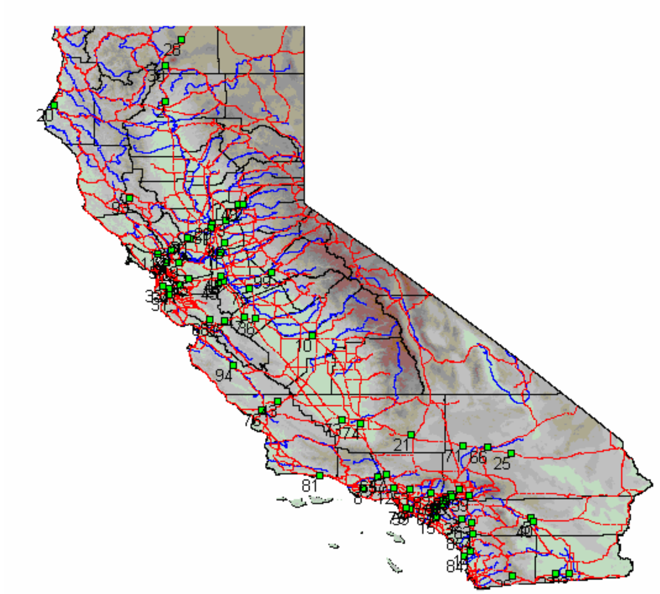

Figure 1 – Example of a California GIS Map

Equipment needed for a visual condition survey includes but not limited to:

- Hand odometer (measuring wheel) or tape measure (at least 30 m) for measuring distances.
- Stringline or straightedge between 1 and 2 m for measuring rut depth and/or edge drop-off.
- Small scale or ruler for fine measurements.
- Marking paint or lumber crayon to mark distresses or record stationing.
- Mid-to full sized vehicle with safety beacon.
- Data collection forms or sheets.
- Clipboard and pencils.
- Digital camera along with a Differential Global Positioning System (DGPS) if available.
- Hard hats and safety vests.
- Traffic control provisions, as necessary.

3.3 Pavement Thickness Evaluation

The variability along the test section (particularly as characterized by the deflection testing), recorded pavement distress, and number of samples required for laboratory testing should dictate the total number of samples required. Ground Penetrating Radar (GPR) can be used along with the coring information to determine the pavement structure changes along the test section. Also, the Dynamic Cone Penetrometer (DCP) penetration rates can be used to identify pavement layer boundaries and subgrade strata.

The best indicators of section variability are deficiencies in pavement condition and deflection testing results. Accordingly, their variability should be considered in determining an appropriate number of samples as well as sampling locations. In general, more variability means more sampling.

3.3.1 Deflection Testing

Deflection testing can be used to achieve two main objectives, determining the different subsections existing within a section and evaluating the structural capacity of each subsection. Measured deflections represent an overall system response of the pavement structure and underlying layers to the applied load. Measured deflections are not only indicative of the strength of the pavement structure but also can be used to identify changes in the overall pavement structure. The deflections measured at a radial distance of more than 1 m from the center of the load are considered a good indicator of the stiffness of the subgrade soil.

The FWD, shown in Figure 2, can be used to conduct the nondestructive deflection testing required. The FWD delivers a transient impulse load to the pavement surface. The subsequent pavement response (i.e. deflection basin) is measured by a series of sensors as shown in Figure 3.

Figure 2 – Caltrans' (Jils) Falling Weight Deflectometer

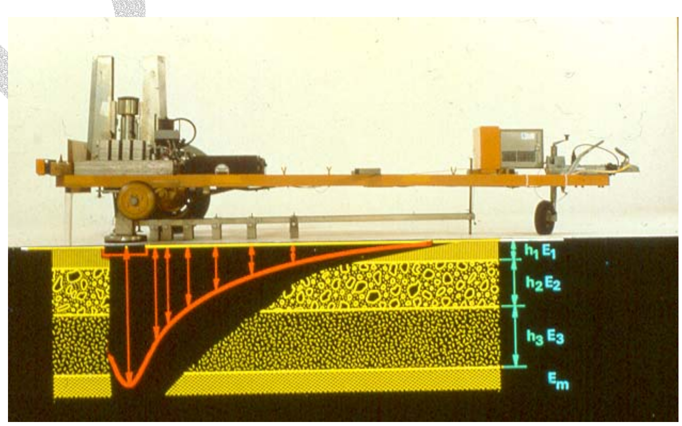

Figure 3 – Deflection Basin Generated by an FWD

The recommended test spacing is 15 to 30 m depending on the length of the test section. For flexible pavements, if the test section is located on the main roadway it is desirable to test on both wheel paths as well as between wheel paths, as shown in Figure 4. On the other hand, if the test section is constructed on the side of the main roadway it is desirable to test on three rows. For rigid pavements, testing must be conducted at the center, transverse joints, longitudinal joints and corners for each slab, as shown in Figure 5.

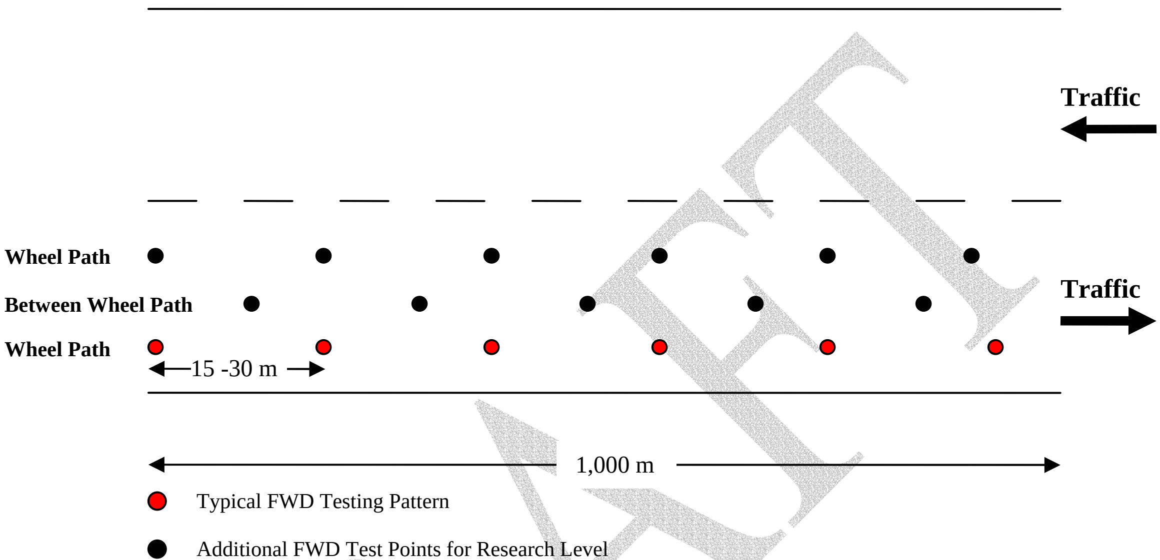

Figure 4 – Recommended Deflection Testing Pattern for Flexible Pavements

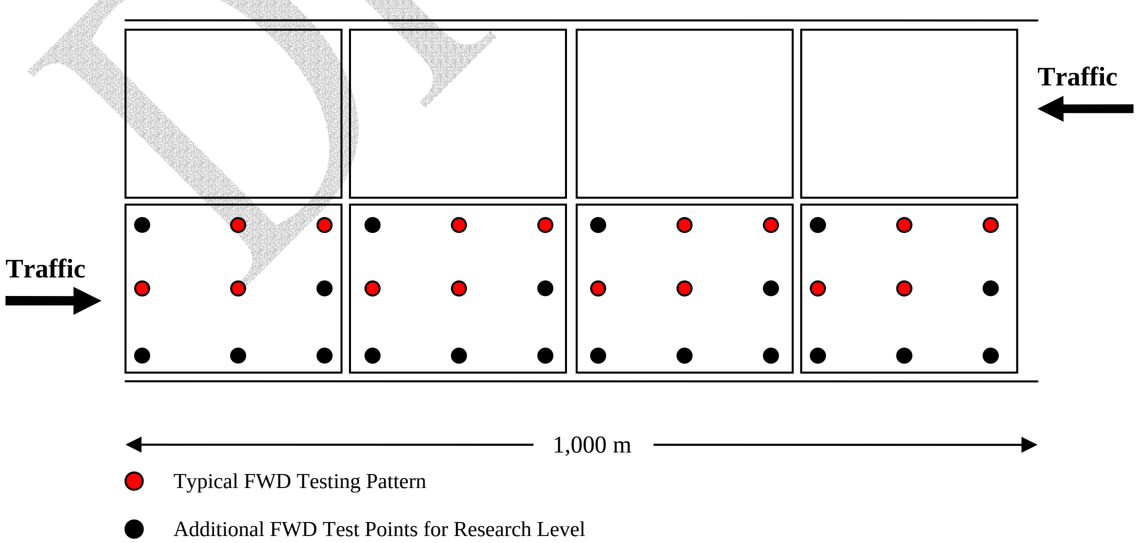

Figure 5 – Recommended Deflection Testing Pattern for Rigid Pavements

Pavement temperature can have a significant effect on measured surface deflections. For flexible pavements the temperature should be measured at 1/3 the depth of the asphalt concrete layer at least every 2 hours. Also, the temperature at the bottom of the asphalt concrete layer should be measured at least once for each test section. Based on this information and on the recorded surface temperature, an estimate of the mean asphalt temperature for each test point can be made. Another alternative to determine the asphalt concrete temperature at mid-depth is the use of BELL's equation using measured air and pavement surface temperatures, as shown in the following equation:

$$T_d = 2.9 + 0.935 \times IR + \log\left(\frac{d}{17.8mm}\right) \times \left[-0.487 \times IR + 0.626 \times (1 - day) + 3.29 \times \sin\left(\frac{(hr_{11} - 15.5) \times 2\pi}{18}\right)\right] + 0.037 \times IR \times \sin\left(\frac{(hr_9 - 13.5) \times 2\pi}{18}\right)$$

where

T_d is the temperature in ^oC at depth d,
IR is the surface temperature in ^oC, measured with the infrared sensor on the FWD,
1-day is the average air temperature the day before testing,
hr_{11} is a decimal time between 11:00 and 05:00 hrs. If the actual time is outside this time range then hr_{11} = 11. If actual time is less than 5:00 add 24. For example: time is 13:15 then decimal time is 13.25.
hr_9 is decimal time between 09:00 and 3:00 hrs. If actual time is outside range use hr_9 = 9. If time is less than 03:00 hrs add 24.

For rigid pavements, the temperature at the surface and bottom of a slab is required to determine the effect of curling and warping have on stress concentration.

3.3.2 Coring

This is the most common field sampling method. The sampling method allows the engineer to obtain a cross section of all desired pavement layers. It is most often used to determine/verify layer thicknesses, as shown in Figure 6, and to provide samples for resilient modulus or indirect tensile strength testing. A visual inspection of retrieved cores can also provide valuable information when trying to assess the causes of visual distress or poor pavement performance. Cores are commonly cut with diameters of 50, 100, or 150 mm, depending on the types of tests to which the samples will be subjected. If thickness verification is all that is needed, 50-mm cores are sufficient. The required diameter of samples taken for laboratory testing is dependent on the thickness of the bound material and the type of laboratory test being performed. Also material samples from subsurface layers can be obtained from coring.

Figure 6 – Example of a Core Sample

3.3.3 Ground Penetrating Radar (GPR)

GPR is a non-invasive electromagnetic geophysical technique for subsurface exploration, characterization and monitoring. GPR has a variety of applications, including measuring pavement layer thickness and infrastructure characterization, assessing freeze-thaw damage, evaluating deterioration, measuring overlay thickness, detecting groundwater and voids, and maintaining quality control of steel reinforcing bar placement.

In a GPR system, antennas mounted on a moving vehicle transmit short pulses of radio wave energy into the pavement (Figure 7). As this energy travels through the pavement structure, echoes are created at boundaries of dissimilar materials, such as at an asphalt-base interface. The strength of these echoes and the time it takes them to travel through the pavement can be used to calculate pavement layer thickness and other properties.

The advantages of using a GPR are:

- Pavements are surveyed quickly and with minimal traffic disruption and safety risks. The system can collect data at a rate of more than 300 kilometers per day.
- Engineers can assess subsurface conditions at a fraction of the cost of conventional methods.
- Nondestructive survey method.
- Real-time data collection.

The disadvantages of using GPR are:

- Usually must have some cores to calibrate measurements.
- Moisture within pavement layers may affect accuracy of GPR data.
- Multiple bound layers may not be easily detected.
- Reinforcing steel in concrete pavement limits penetration.

Figure 7 – Ground Penetrating Radar (GPR)

3.4 Field Material Sampling/Testing

Four basic methods have traditionally been used to obtain samples of the pavement surface and subsurface layers. The type of method depends on the type of material and the type of laboratory or field testing anticipated. Also, there are two primary methods available to test the in-situ strength of the subsurface materials: dynamic cone penetrometer (DCP) and the standard penetration test (SPT). The following are field sampling/testing methods commonly used:

3.4.1 Coring

Besides being used to verify/determine layer thicknesses, it is also used to provide samples for laboratory testing. Cores are commonly cut with diameters of 50, 100, or 150 mm, depending on the types of tests to which the samples will be subjected. The required diameter of samples taken for laboratory testing is dependent on the thickness of the bound material and the type of laboratory test being performed.

3.4.2 Augers

The simplest method of obtaining *disturbed* base, subbase, or soil samples is with the use of helical or post-hole augers. Auger samples are most commonly used to identify soil strata and for some classification tests, even though the physical state of the material is completely altered by the sampling process.

3.4.3 Shelby Tubes

Shelby tubes are commonly used when it is necessary to obtain a relatively *undisturbed* soil sample suitable for laboratory testing of structural properties or other tests that may be influenced by soil disturbance. Although this sampling method can be used on some coarse-grained materials, it is typically used to obtain samples in soft cohesive soils.

3.4.4 Test Pits

Test pits are used to view the cross section of all pavement layers in their undisturbed condition as shown in Figure 8. Although not commonly used because of the cost and time required to dig and repair them, these are an excellent method of identifying problem pavement layers and assessing drainage adequacy. Another specific application of test pits includes determining the locations and amounts of permanent deformation throughout the depth of the pavement structure. They may be dug in more than one area of a project to compare areas exhibiting different performance.

Figure 8 – Cross Section of a Pavement from a Test Pit

3.4.5 Standard Penetration Test (SPT)

The SPT is one of the most common in-situ geotechnical tests used all over the world. The popularity of this test method is mainly due to the abundance of experience with it over the years, its relative simplicity, and low cost. Although the SPT can be performed in a wide variety of subgrade soils, the most consistent results are found in sandy soils where large gravel particles are absent (Newcomb and Birgisson 1999). Furthermore, in soft and sensitive clays, the SPT results should also not be relied upon, as they have not been found to be consistent with actual field conditions.

The SPT consists of driving a standard split-spoon sampler into the ground with blows from a 63.5 kg hammer. The number of blows associated with each 150 mm is recorded. Penetration through the first 150 mm of soil is considered to be a seating drive. The sum of the number of blows required for the second and third 150 mm of penetration is termed the “standard penetration resistance”, or the “N-Value”.

Although there are a number of recognized potential sources of error associated with the SPT, there are many published correlations between SPT and important mechanical soil properties, such as undrained shear strength, unconfined compressive strength, angle of internal friction, and relative density (Kulhawy and Mayne 1990).

3.4.6 Dynamic Cone Penetrometer (DCP)

The DCP is a device for measuring the in-situ strength of paving materials and subgrade soils. The principle behind the DCP is that a direct correlation exists between the "strength" of a soil and its resistance to penetration by solid objects (Newcomb and Birgisson 1999). It consists of a cone attached to a rod that is driven into the soil by the means of a drop hammer that slides along the penetrometer shaft. Figure 9 shows a schematic of the DCP apparatus. The test is performed by driving the cone into the pavement/subgrade by raising and dropping the 8 kg hammer from a fixed height of 57.5 cm, as shown in Figure 10. Earlier versions of the DCP used a 30^o cone angle with a diameter of 20 mm. More recent versions of the DCP use a 60^o cone angle and also have the option of using a 4.6 kg hammer for weaker soils (Newcomb and Birgisson 1999).

During a DCP test, the cone penetration (typically measured in mm or inches) associated with each drop is recorded. This procedure is continued until the desired depth is reached. A representative DCP penetration rate (PR = mm or inches of penetration per blow) is determined for each layer by taking the average of the penetration rates measured at three defined points within a layer: the layer midpoint, midpoint minus 50 mm, and midpoint plus 50 mm. DCP penetration rates can be used to identify pavement layer boundaries and subgrade strata. The R-value can be indirectly correlated to the DCP through an estimate of the resilient modulus. A DCP test should be conducted at every core performed on the test section.

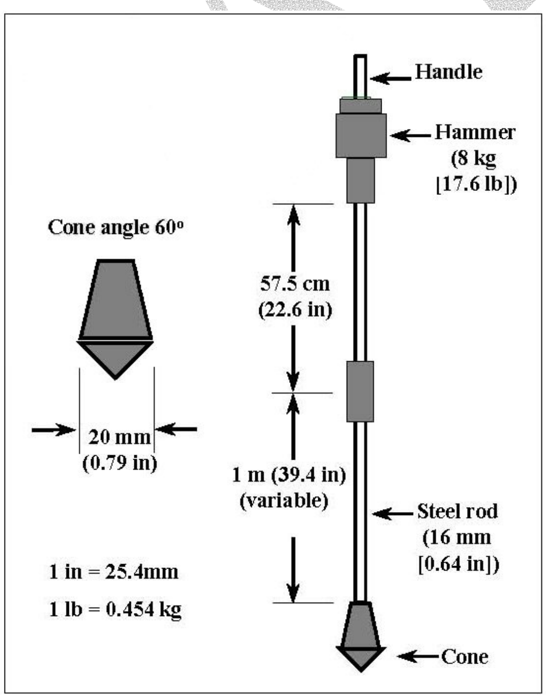

Figure 9 – Dynamic Cone Penetrometer

Figure 10 – DCP Test Performed at a Core Location

3.5 Ride Quality (IRI)

A Road Surface Profiler (RSP), as shown in Figure 11, can be used to determine the pavement surface roughness. This equipment measures the longitudinal profile elevations in both wheel paths of each lane and produces an objective roughness statistic known as the International Roughness Index (IRI), which is used worldwide. IRI is used as a standard measurement by the Federal Highway Administration. Typical IRI values range from 0.5 meters per kilometer for a new pavement to 16 meters per kilometer for an unpaved road with severe erosion. It is desirable to record the data at 15-meter intervals, three times for each test section, and report the average IRI. Also the rut depth can be collected at 15-meter intervals.

Figure 11 – Road Surface Profiler

3.6 Skid (Friction) Testing

If required, the Pavement Friction Tester, as shown in Figure 12, can be used to evaluate the skid resistance of the pavement surface. The equipment measures the skid resistance of a wet paved surface from the force required to slide the standard ASTM E 501 or E 524 locked test tire at a predetermined speed. The measured force is divided by the effective wheel load and multiplied by 100, to provide the skid number (SN). At least five tests are recommended for each test section.

Figure 12 – Skid Tester

4.0 Laboratory Testing

This section presents some of the common testing methods used in the evaluation of pavement layer materials. Depending on the objectives of the study, more tests may be required in evaluating the existing pavement. It is important that each test be conducted on representative and sufficient material samples. A detailed laboratory testing procedure and the number of samples required for each test should be included in the evaluation procedure. It is important to note that nondestructive tests can be performed on samples prior to destructive testing. For example, an HMA core could be tested for bulk specific gravity, then resilient modulus, and then the core could be heated, broken apart, visually examined, and tested for theoretical maximum specific gravity. Appendix H in the "Guide to the Investigation and Remediation of Distress in Flexible Pavements" can be used as an example. The following table summarizes the test methods that are presented in the following sections.

Category	Property	Test Method	Sampling Locations Recommended Per Kilometer	Min. Weight or Number of Cores for each Sampling Location[1), 2)]
General Material Characteristics for Bound Materials	Density and Air Void Content	California TM 375 and California TM 308A and 309	Same as Asphalt Content Test	Same cores of the Asphalt Content Test can be used[3)]
	Aggregate Gradation	California TM 202	2 to 5	10 kg
	Asphalt Content	California TM 382	2 to 5	8 kg
	Moisture Sensitivity	California TM 307	1 to 3	Four 100-mm cores
	Slump Test	ASTM C143	1 to 3	50 kg

General Material Characteristics for Unbound Materials	Soil Classification	Caltrans Soil Classification Manual	Same as Moisture Content and Density Test	Same samples of the Moisture Content and Density Test can be used[3]
	Gradation	California TM 202 and 203	Same as Moisture Content and Density Test	Same samples of the Moisture Content and Density Test can be used[3]
	Moisture Content and Density	California TM 226 and 216	1 to 3	12.5 kg
Strength Related Testing Methods	R-Value	California TM 301	1 to 3	3 kg
	Indirect Tensile Strength and Resilient Modulus of Asphalt Mixtures	ASTM D 4123	1 to 3	Six 100-mm cores[3]
	Resilient Modulus of Unbound Materials	AASHTO T307	1 to 3	10 kg
	Dynamic Modulus of Asphalt Mixtures	ASTM D 3497	1 to 3	Three 100-mm cores
	Compressive Strength of Concrete Mixes	ASTM C39	1 to 3	Three 150-mm cores
	Flexural Strength of Concrete Mixes	ASTM C78 or ASTM C293	1 to 3	Three 150×150×550-mm beams

Notes: 1) The minimum weight or number of cores recommended per sampling location to determine the different material properties should be reviewed carefully prior to sampling.

2) The minimum weight or number of cores is per sampling location and per wheel path or between wheel paths (e.g. to determine the resilient modulus and indirect tensile strength for two sampling locations in both the wheel path and between wheel paths, the total number of samples required is 24 cores).

3) The correct sequence of testing should be conducted for testing methods sharing the same samples (e.g. the resilient modulus test should be conducted prior to the indirect tensile strength test).

4.1 Visual Inspection of Sample

While being the simplest of testing methods, a visual inspection of a sample is a very efficient way of obtaining a quick assessment of material, as well as aiding in the identification of any obvious layer material deficiencies. Soil samples provide an approximate classification based on observed texture, color, odor, particle size, plasticity, structure, moisture, and density. Inspection of cores allows the engineer to measure layer thicknesses, investigate the material integrity of all layers, and check the bonding condition between stabilized layers. This information may indicate the causes of any visual distress, and allows the engineer to choose more targeted laboratory tests to complete the required pavement evaluation.

4.2 General Material Characteristics for Bound Materials

The behavior and overall performance of the bound materials can be greatly affected by inherent properties of the cementitious material and aggregates, as well as the mix itself. For asphalt concrete mixes, the Abson recovery method (California Test 380) is used to separate the asphalt cement from the aggregate. If possible, material samples should be taken at the time of construction, especially for rigid pavements.

4.2.1 Density

Density (bulk specific gravity) is a characteristic of asphalt concrete that provides a good indication of how well the mix is compacted. Typically, it is used in pavement specifications to provide criteria to a contractor to achieve a desired level of compaction. Asphalt concrete layers that are not constructed to the specified density are more likely to have lower strength and experience increased densification after the pavement is opened to traffic. Density is usually measured in the field using nuclear density gauges. However, for purposes of a detailed pavement investigation, it is more accurately measured from cores based upon their weight and volume. The recommended test method for density is California Test Method 308. Typically, it is recommended that two to five density analyses in each the wheel path and between the wheel paths be conducted per kilometer, depending on pavement surface uniformity. Each density test requires three 100 or 150 mm diameter core. It should be noted that the density of cores obtained in the wheel paths is likely to be higher than at original placement because of increased densification due to trafficking.

4.2.2 Asphalt Content

The amount of asphalt binder in a mix can have a significant effect on pavement performance. For a detailed pavement investigation, the asphalt content of a mix is typically determined from 100 or 150 mm diameter cores by extracting the asphalt from the mix and comparing its weight to the total weight of the core. The recommended test method for determining asphalt content from extracted cores is California Test Method 382. Typically, it is recommended that two to five asphalt content determinations in each the wheel path and between the wheel paths be conducted per kilometer, depending on pavement surface uniformity. Each asphalt content test requires approximately 8 kg of asphalt concrete material obtained from the field.

4.2.3 Air Void Content

Like asphalt content, air void content can have a significant effect on pavement performance. For a detailed pavement investigation, air void content can be calculated from laboratory testing performed on 100 or 150 mm cores. Typically, it is recommended that two to five air void determinations in each the wheel path and between the wheel paths be conducted per kilometer, depending on pavement surface uniformity. Each air void content determination requires three 100 or 150 mm cores. It should be noted that the air void content of cores obtained in the wheel paths is likely to be lower than at original placement because of increased densification due to trafficking.

4.2.4 Aggregate Gradation

The aggregate in a mix is the primary load carrying component of the material. The cement serves primarily as a glue to hold the aggregates together. Typically, it is recommended that two to five aggregate gradation determinations be conducted per kilometer for asphalt concrete pavements, depending on pavement surface uniformity. For samples with aggregates larger than 25 mm, a 2 kg sample is required. For samples with aggregates whose maximum size is 25 mm or less, a 750 g sample is needed.

4.2.5 Moisture Sensitivity

When asphalt-bound material is exposed to moisture for extended periods of time, there is a tendency for the asphalt to weaken and become separated from the aggregate in the mix. Caltrans uses the moisture vapor susceptibility test (California Test Method 307) to assess moisture susceptibility. Typically, it is recommended that one to three moisture vapor susceptibility determinations in each the wheel path and between the wheel paths be conducted per kilometer, depending on pavement surface uniformity. Each test requires four 100 mm diameter cores: two are used to determine the stabilometer value of the unconditioned mix, and two are used to determine the stabilometer value of the moisture-conditioned mix.

4.2.6 Slump Test (Rigid Pavements)

The purpose of a slump test is to determine the consistency or texture of fresh concrete and to check its uniformity. The slump test is based on ASTM C 143. It consists of a hollow metal cone that is filled with fresh concrete in three lifts and each lift is rodded 25 times. The cone is then lifted and the distance between the bottom of a straight edge and the top of the concrete pile is measured and reported.

4.3 General Material Characteristics for Unbound Materials

After the visual inspection is completed, the collected material samples are typically subjected to more detailed tests to determine specific characteristics. These material constituency tests measure intrinsic properties of the subsurface layer materials that may affect performance directly or indirectly. Included among these material characteristics are soil classification, gradation, moisture content, and density.

4.3.1 Soil Classification

The Caltrans Soil and Rock Logging Classification manual (Field Guide), which is a slightly modified version of the Unified Soil Classification System (USCS), is used for soil classification. Typically, it is recommended that one to three soil classifications be conducted per kilometer, depending on pavement and subgrade soil uniformity.

4.3.2 Gradation

Typically, it is recommended that one to three gradation analyses be conducted per kilometer, depending on base and subbase uniformity.

The recommended sample mass for conducting sieve analyses on aggregates (California Test Method 202) actually depends on the maximum nominal aggregate size and ranges from 1 to 30 kg.

California Test Method 203 requires a minimum of 215 g material passing the 4.75 mm sieve for conducting a mechanical analysis of soils. Thus, the mass of the sample obtained in the field must be of sufficient size so as to obtain at least 215 g of material passing the 4.75 mm sieve.

4.3.3 Moisture Content and Density

Standard laboratory test methods for these properties may be found in California Test Methods 226 and 216, respectively. Typically, it is recommended that one to three moisture content and density analysis be conducted per kilometer depending on subgrade soil uniformity. Moisture content tests require sample sizes of 100 g for soil, 500 g for fine aggregates and 1,000 g for coarse aggregates. Density tests require sample sizes of 9 to 11.3 kg.

4.4 Strength Related Testing Methods

The ability of a pavement structure to adequately carry repeated traffic loadings is very much dependent on the strength, stiffness, and deformation-resistance properties of each layer. There are various laboratory test methods that are used to measure strength, stiffness, or its ability to resist deformation or bending. Some of the more common tests are included in the following sections.

4.4.1 R-Value

A stabilometer may be used to assess the stability of an unbound material sample as it measures the transmitted horizontal pressure associated with the application of a vertical load. California Test Method 301 can be used to determine the R-value. The test result is empirical and does not represent a fundamental soil property. Typically, it is recommended that one to three R-values determinations be conducted per kilometer, depending on subgrade soil uniformity. It is recommended that 3,000 g of material be obtained during field sampling for each R-value test.

4.4.2 Indirect Tensile Strength

The indirect tension test can be used to determine the tensile strength of asphalt concrete cores or any asphalt stabilized pavement layer. The procedure is described in ASTM D-4123. The test involves applying a vertical load at a constant rate of deformation on the diameter of a cylindrical sample. The sample will fail in tension along the vertical diameter of the sample and the indirect tensile strength is calculated. Typically, it is recommended that one to three indirect tensile strength determinations in each the wheel path and between the wheel paths be conducted per kilometer, depending on pavement surface uniformity. It is recommended that six 100 mm diameter cores be obtained during field sampling for each test.

4.4.3 Resilient Modulus of Unbound Materials

The resilient modulus test provides a material parameter that more closely simulates the behavior of material under a moving wheel. Typically, it is recommended that one to three resilient modulus tests be conducted per kilometer, depending on base material or subgrade soil uniformity. Resilient modulus tests require obtaining roughly 10 kg of material for each test during field sampling.

4.4.4 Resilient Modulus of Asphalt Mixtures

The resilient modulus test for asphalt mixtures provides an estimate of the material's modulus of elasticity. The recommended test method for resilient modulus of asphalt mixtures is ASTM D-4123. The test can be run on either 100 or 150 mm diameter samples. The load is typically applied for 0.1 seconds followed by a rest period of 0.9 seconds. The lateral deformation is measured during loading using strain gauges or LVDT's. From the applied load, horizontal deformation, sample thickness and poisson's ratio the resilient modulus is calculated. The test is typically run at more than one temperature in order to determine the sensitivity of the resilient modulus to changes in temperature. Typically, it is recommended that one to three resilient modulus determinations in each the wheel path and between the wheel paths be conducted per kilometer, depending on pavement surface uniformity. It is recommended that three cores be obtained during field sampling for each location being evaluated by the resilient modulus test.

4.4.5 Dynamic Modulus of Asphalt Mixtures

This test procedure is designed to provide an estimate of the elastic modulus of an asphalt mixture under a repeated uniaxial compressive load. The measured property is sometimes referred to as the complex modulus. The procedure is described in ASTM D-3479. Cyclic sinusoidal loading is applied to the sample at a fraction of the mixture's strength. The dynamic modulus is simply a function of the maximum applied stress and the resulting vertical strain in the sample. The dynamic modulus test is distinctly different from the resilient modulus test in terms of both the state of stress (compression versus tension) as well as the loading pattern (sinusoidal versus haversine). Both of these contribute to some significant differences in the estimates of the elastic modulus. One weakness associated with the dynamic modulus test is the requirement of a 2:1 ratio between the sample length and diameter. It is recommended that one to three dynamic modulus determinations in each the wheel path and between the wheel paths be conducted per kilometer, depending on pavement surface uniformity. It is recommended that three cores be obtained during field sampling for each location being evaluated.

4.4.6 Compressive Strength Test (Rigid Pavements)

The compressive strength test results are primarily used to determine that the concrete mixture as delivered meets the requirements of the specified strength, f'_c, in the job specification. The compressive strength is measured by breaking cylindrical concrete specimens in a compression-testing machine. The compressive strength is calculated from the failure load divided by the cross-sectional area resisting the load and reported in units of megapascals (MPa). A test result is the average of three standard-cured strength specimens made from the same concrete sample and tested at the same age. In most cases strength requirements for concrete are at an age of 28 days. The procedure is described in ASTM C39.

4.4.7 Flexural Strength Test (Rigid Pavements)

Flexural strength is one measure of the tensile strength of concrete. It is a measure of an unreinforced concrete beam to resist failure in bending. It is measured by loading 150×150 mm concrete beams with a span length at least three times the depth. The flexural strength is expressed as Modulus of Rupture (MOR) in MPa and is determined by standard test method ASTM C 78 (third-point loading) or ASTM C 293 (center-point loading).

5.0 Field Performance Evaluation

Performance of the test section should be monitored regularly. The monitoring schedule depends on expected life of test section and should be determined on a site/test specific basis, and detailed in the experiment plan and resourced. The data collected on a routine basis is summarized in the following table:

Data Type	Chapter in Manual	Initial Data Collection	Follow-up Data Collection	Periodic Collection Schedule
Visual Condition Survey	3.2	Yes	Yes	At least twice a year
Coring	3.3.2	Yes	No	During initial site investigation
GPR	3.3.3	Yes	No	During initial site investigation
Deflection Testing	3.3.1	Yes	Yes	At least twice a year
DCP	3.4.6	Yes	No	During initial site investigation
Material Sampling/Testing	3.4	Yes	As necessary	During initial site investigation
Skid Testing	3.6	As necessary	As necessary	Performed with Deflection Testing
Ride Quality	3.5	As necessary	As necessary	Performed with Deflection Testing