

CHAPTER 630 – FLEXIBLE PAVEMENT

Topic 631 – Types of Flexible Pavements and Materials

Index 631.1 – Hot Mix Asphalt (HMA)

HMA consists of a mixture of asphalt binder and a graded aggregate ranging from coarse to very fine particles. HMA is classified by type depending on the specified aggregate gradation and mix design criteria appropriate for the project conditions. The Department uses the following types of HMA based on the aggregate gradation: (1) Dense Graded HMA, (2) Gap Graded HMA, and (3) Open Graded Friction Course. HMA types are found in the Standard Specifications and Standard Special Provisions.

631.2 Dense Graded HMA

Dense graded HMA is the most common mix used as a structural surface course. The aggregate is uniformly graded to provide for a stable and impermeable surface. The aggregate can be treated, and the asphalt binder can be modified. HMA can include recycled asphalt pavement (RAP). The Department uses one type of dense graded HMA: HMA-Type A.

631.3 Rubberized Hot Mixed Asphalt Gap Graded (RHMA-G)

Gap graded HMA is used to meet Public Resources Code section 42703 that specifies amounts of crumb rubber modifier (CRM) usage in HMA. To meet the Public Resources Code, neat asphalt binder is substituted with asphalt rubber binder containing CRM, referred to as asphalt rubber (AR) in pavement products to create rubberized HMA (RHMA). The use of gap graded aggregate creates space between the aggregate particles to accommodate larger sizes of partially digested CRM in asphalt rubber binder to make Rubberized Hot Mix Asphalt-Gap-Graded (RHMA-G). RHMA-G is used as a structural surface course. RHMA-G is commonly specified to retard reflection cracking, and resist thermal stresses created by cold temperatures and wide temperature fluctuations. RHMA-G is used as a structural surface course up to a maximum thickness of 0.20 foot. Because of maximum thickness requirements, if a thicker surface layer or overlay is called for, then an HMA layer of a predetermined thickness should be placed prior to placing the RHMA-G surface course. The minimum thickness for RHMA-G is 0.10 foot. An RHMA layer should not be placed directly on an aggregate base, except to construct a tapered edge up to a maximum of 4" wide. Do not place conventional HMA over a new RHMA-G, unless it is HMA-O. Do not place HMA or RHMA-G over an OGFC or RHMA-O.

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631.4 Open Graded Friction Courses (OGFC)

OGFC, formerly known as open graded asphalt concrete (OGAC), is a non-structural wearing course placed primarily on asphalt pavement. The aggregate is open graded to provide high permeability. The primary reasons for using OGFC are the improvement of wet weather skid resistance, reduced water splash and spray, reduced nighttime wet pavement glare, and as a stormwater treatment Best Management Practice (BMP). A secondary benefit is better visibility of pavement delineation (pavement markings and pavement markers) during wet weather conditions.

Three types of non-structural OGFC are used on asphalt pavement: Hot Mix Asphalt-Open-Graded (HMA-O), Rubberized Hot Mix Asphalt-Open-Graded (RHMA-O), and Rubberized Hot Mix Asphalt-Open-Graded-High-Binder (RHMA-O-HB). HMA-O is occasionally placed on rigid pavements. The difference between RHMA-O and RHMA-O is in the gradation of the aggregate. The difference between RHMA-O and RHMA-O-HB is in the amount of binder content. The maximum thickness of HMA-O, RHMA-O or RHMA-O-HB is 0.15 foot.

Rubberized OGFC (RHMA-O or RHMA-O-HB) is recommended unless it is documented that RHMA-O and RHMA-O-HB are not suitable due to availability, cost, constructability, or environmental factors (such as a stormwater treatment BMP for National Pollutant Discharge Elimination System [NPDES] compliance). RHMA-O and RHMA-O-HB are not expected to provide a water quality benefit. The project engineer should balance the competing requirement of recycled crumb rubber goals with those for stormwater treatment and document this in the project report. Coordinate with the district pavement engineer and NPDES coordinator to determine if both goals are on target for compliance. Open-graded mixes should not be placed in areas that will not allow surface water to drain to the shoulder or median. As an example, OGFCs should not be placed in the traveled way at an elevation lower than or level with the shoulder such as when the open-graded mix is placed in a milled area of the traveled way but the shoulder has not been milled, which forms a “bathtub” section that can trap water beneath the surface of the traveled way. To prevent this effect, HMA should be placed on the milled surface (traveled way only) and an open-graded mix should then be placed over the entire cross section of the road including the traveled way and shoulders.

For additional information and applicability of OGFC in new construction and rehabilitation projects refer to the OGFC Guideline available on the Department Pavement website. Also, see the Maintenance Technical Advisory Guide (MTAG) for additional information about use of OGFC in pavement preservation. If OGFC is proposed as a stormwater treatment BMP, see the OGFC Stormwater Treatment BMP Guidance on the Design website.

631.5 Rubberized HMA (RHMA) Use

Currently, three RHMA products are used: gap-graded (RHMA-G), open-graded (RHMA-O), and open-graded-high binder (RHMA-O-HB) mixes.

The following describes situations where RHMA should not be used:

- When HMA project quantities are 1,000 tons or less or staged construction operations require less than 1,000 tons of HMA per stage, and there are no HMA production plants with full time RHMA blending plants on site.
- Where the roadway elevation is above 3,000 feet.
- When the project has a Caltrans NPDES permit requirement for stormwater treatment BMPs (only applicable for RHMA-O or RHMA-O-HB exception).

For additional information on and applicability of RHMA in new construction and rehabilitation projects refer to the Asphalt Rubber Usage Guide available on Caltrans' Intranet Office of Asphalt Pavement Website (<https://maintenance.onramp.dot.ca.gov/paveprogram/office-asphalt-pavements>).

631.6 Other Types of Flexible Pavement Surface Courses

There are other types of materials used on flexible pavement surface for different purposes, such as cold mix used for patching, and other types of new materials that Caltrans evaluates. For pavement preservation and other maintenance treatments refer to the Caltrans Maintenance Manual (<https://dot.ca.gov/programs/maintenance/maintenance-manual>) and Maintenance Technical Advisory Guide (MTAG) (<https://dot.ca.gov/programs/maintenance/pavement/mtag>).

631.7 Bonded Wearing Course (BWC)

Placing a BWC consists of applying a polymer-modified asphaltic emulsion and placing the specified HMA in a single pass with an integrated paving machine. BWC is constructed using RHMA-G, RHMA-O, or HMA-O. BWC is intended to produce a longer lasting surface course than placing any of these surfaces using conventional techniques. The single pass paving and polymer modified emulsion is expected to produce a stronger bond than a conventional tack coat followed by mix placement.

631.8 Warm Mix Asphalt

Warm Mix Asphalt (WMA) is a set of technologies that permit HMA to be produced, placed, and effectively compacted at lower temperatures. WMA is particularly useful when there are long haul distances, cooler temperatures, or other conditions that produce short compaction windows. HMA may be produced for use on state highways using approved WMA technologies. The Department has an approved list of WMA additives and WMA water injection technologies that contractors may choose to use,

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and the standard specifications provide information for mix design and construction when the contractor chooses to use WMA. Minimum mixing temperatures, and ambient and surface temperature requirements for both the WMA additives and WMA water injection technologies are included in the standard specifications. WMA can be used for all kinds of HMA and RHMA

WMA does not change the structural design properties of HMA or RHMA-G. Therefore, all structural design methods discussed in this chapter using HMA are also applicable to WMA.

631.9 Pavement Interlayers

Pavement interlayers are used with asphalt pavement as a means to slow propagation of cracks on the surface of the existing pavement into the new flexible layer. These interlayers are not currently considered in the *Ca/ME* mechanistic-empirical design procedure but can be used in addition to the *Ca/ME* thickness design to provide additional reflective cracking retardation. Two types of pavement interlayers are:

- Rubberized Pavement Interlayers (RPI); also known as Rubberized Stress Absorbing Membrane Interlayer (SAMI-R); which is simply a rubberized chip seal.
- Geosynthetic Pavement Interlayer (GPI). GPI consists mainly of asphalt-saturated geotextile (also called fabric), but other geosynthetic planar products such as paving grids and paving geo-composites (grid attached to geotextile) are also used. Use of a GPI and selection of the type should consider expected potential construction difficulties during future milling and in-place recycling. Refer to the Standard Specifications for the various GPI types and installation practices.

Sound engineering judgment is required when considering the use of a pavement interlayer. The following must be considered:

- Areas that may prohibit surface water from draining out to the sides of the overlay, thus forming a “bathtub” section.
- Since a pavement interlayer can act as a moisture barrier, it should be used with caution in hot environments where it could prevent underlying moisture from evaporating.
- When placed on an existing pavement, preparation is required to prevent excess stress on the membrane. This includes sealing cracks wider than $\frac{1}{4}$ inch and repairing potholes and localized failures.

A pavement interlayer may be placed between layers of new flexible pavement, such as on an asphalt leveling course, or on the surface of an existing flexible pavement. A GPI should not be placed directly on coarse surfaces such as a chip seal, OGFC, areas of numerous rough patches, or on a pavement that has been cold planed. As an example, coarse surfaces may penetrate the paving fabric and the paving asphalt binder used to saturate the fabric may collect in the voids or valleys leaving areas of

the fabric dry. For the GPI to be effective in these areas, use a leveling course of HMA prior to the placement of the GPI.

Pavement interlayers are also used on rigid pavements that are going to be overlaid with asphalt. An asphalt leveling course is required on the rigid pavement before placing the interlayer.

GPI is ineffective in the following applications:

- For providing added structural strength when placed in combination with new flexible pavement.
- In the reduction of thermal cracking in the new flexible pavement overlay.

When using a GPI, care must be taken to specify a product that can withstand temperatures of the asphalt placed above it, particularly for RHMA. Detailed information for selecting the appropriate type of pavement interlayer to use can be found in the MTAG on the Department Pavement website.

631.10 In-Place Recycled Flexible Pavement Layers

There are a number of approaches for in-place recycling of flexible pavements.

General terms for all types of in-place pavement recycling are:

- Hot in-place recycling (HIR): General term for all types of in-place recycling that involve heating the pavement before and during milling.
- Cold in-place recycling (CIR): General term for all types of in-place recycling that do not involve heating the pavement before and during milling. Different types of cold in-place recycling are:
 - Partial depth recycling (PDR): Rehabilitation/maintenance process where only the asphalt concrete layers are recycled (i.e., the recycler milling teeth remain in the asphalt concrete layers). Recycling depths are typically between 0.25 foot and 0.4 foot. Cold in-place recycling (CIR) is a commonly used term for this recycling strategy.
 - Full depth recycling (FDR): Rehabilitation process where the asphalt concrete as well as the underlying unbound and/or previously stabilized layers are recycled (i.e., recycler milling teeth go through the asphalt concrete layers into the underlying layer[s]). Recycling depths are typically between 0.65 foot and 1.0 foot. Projects that require milling and removal of all of the asphalt layers and potentially some of the original underlying layers in order to maintain grade should not be considered or designed as FDR projects. Instead, treatment of the remaining material with lime or cement should be considered and designed as subbase or subgrade stabilization.

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- Cold central plant recycling (CCPR): Rehabilitation process where materials are milled to the required depth, transported to a nearby central plant, processed, and then transported back to the road and laid with a paver. This can be for partial- or full-depth recycling. CCPR does not have thickness limits because the recycled material can be placed in multiple lifts. Stabilization of the underlying layers after milling of the existing pavement layers can be included as part of the process to increase structural capacity without increasing grade height (i.e., an inverted pavement structure).

See the Guide for Partial and Full Depth Recycling in California for further guidance on in-place recycling (<https://dot.ca.gov/programs/maintenance/pavement/local-agencies/in-place-recycling-main>).

631.11 Bonding between Asphalt Layers

A major factor in the service life of flexible pavement is the condition of the bond between the asphalt layers. All asphalt layers need a good bond between each asphalt lift regardless of their thickness. This is achieved with tack coats, which are essential to good bonding even when asphalt lifts are being placed in a short period of time. Bonding is also important between the asphalt layer and the underlying base or recycled layer. To achieve the maximum bond between asphalt lifts and between the asphalt and underlying layers, consult the District Materials Engineer or Headquarters Office of Asphalt Pavement for options on effective bonding methods.

Topic 632 – Asphalt Binder and Mix Specifications

632.1 Binder Classification

Asphalt binders are most commonly characterized by their physical properties which directly affect asphalt pavement field performance. Binder tests and specifications in use since 2006 are based on the Superpave Performance Grade (PG) System, which considers temperature extremes that pavements in the field are expected to withstand. The PG system was developed for conventional binders. These tests and specifications are particularly designed to address three specific asphalt pavement distress types: permanent deformation (rutting), fatigue cracking, and low temperature cracking.

Effective January 1, 2013, the Department has graded modified binders, excluding asphalt rubber binders, as Performance Graded Modified (PG-M) binder. Binder modification is achieved using either crumb rubber, polymers, or both. Research is underway to extend the concepts of performance grading to asphalt rubber binders.

Performance grading is based on the concept that asphalt binder properties should be related to the conditions under which the binder is used. PG asphalt binders are

selected to meet the expected project climatic conditions, traffic speed and volume, as well as desired performance reliability. Therefore, the PG system uses a common set of tests to measure physical properties of the binder that can be directly related to field performance of the pavement at its service temperatures. For example, a binder identified as PG 64-10 (64 minus 10) must meet certain performance criteria at an average seven-day maximum pavement temperature of 64°C, at a minimum pavement temperature of -10°C, and also at an intermediate temperature of 31°C.

Although modified asphalt binder is more expensive than unmodified binder, it can provide improved performance and durability for sensitive climate conditions. While unmodified binder is adequate for most applications, improved resistance to rutting, thermal cracking, fatigue damage, stripping, and temperature susceptibility have led polymer modified binders to be substituted for unmodified asphalt binders in many paving and maintenance applications.

632.2 Binder Selection

Table 632.1 shows the PG binder that is to be used for each climatic region for general application. For HMA, values are given for typical and special conditions. For a few select applications such as dikes and tack coats, PG binder requirements are found in the applicable Standard Specifications or Standard Special Provisions.

For locations of each pavement climate region see Topic 615.

Binder selection based on climate region is crucial for improving the pavement resistance to temperature extremes that cause rutting and low-temperature cracking during its service life. The intermediate temperature part of the PG specification limits binder stiffness at temperatures at which most fatigue damage occurs. The intermediate specification limiting stiffness is applicable for applications of new HMA or overlays that are approximately 0.33 ft or thinner where softer binder allows the HMA to bend without excessive damage. For the same reason, polymer modified mixes which have good rutting resistance and good resistance to crack propagation, but which have low stiffness at intermediate temperatures, should not be used more than 0.25 ft below the surface of the pavement (not including open-graded mix thickness). Stiffer binder and mixes are generally preferred for thicker applications because the stiffness helps limit the amount of bending. These considerations are included in *Ca/ME* thickness design for new pavement and rehabilitation.

Special conditions in Table 632.1 are defined as those roadways or portions of roadways that need additional attention due to conditions where slow traffic and turning movements increase the risk of rutting, such as:

- Heavy truck/bus traffic (over 10 million ESALs for 20 years.)
- Truck/bus stopping areas (parking area, rest area, loading area, etc.)

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Table 632.1

Asphalt Binder Performance Grade Selection

Climate Region ⁽⁶⁾	Binder Grade for Hot Mix Asphalt (HMA) ^{(1), (2)}				
	Dense Graded HMA		Open Graded HMA		Gap and Open Graded Rubberized Hot Mix Asphalt (RHMA)
	Typical	Special ⁽³⁾	Placement Temperature		
			> 70°F	≤ 70°F	
South Coast Central Coast	PG 64-10	PG 70-10 or PG 64-28 M ^{(4) (5)}	PG 64-10	PG 64-28M	PG 64-16
Inland Valley	PG 70-10	PG 70-10 or PG 64-28 M ^{(4) (5)}	PG 70-10	PG 64-28 M	PG 64-16 or PG 70-10
North Coast	PG 64-16	PG 64-28 M ^{(4) (5)}	PG 64-16	PG 64-28 M ⁽⁵⁾	PG 64-16
Low Mountain South Mountain	PG 64-16	PG 64-28 M ^{(4) (5)}	PG 64-16	PG 58-34 M or PG 64-28 M ⁽⁵⁾	PG 64-16
High Mountain High Desert	PG 64-28 or PG 64-28 M ⁽⁴⁾	PG 58-34 M ^{(4) (5)}	PG 64-28	PG 58-34 M	PG 58-22
Desert	PG 70-10	PG 64-28 M ^{(4) (5)} or PG 76-22 M ⁽⁴⁾	PG 70-10	PG 64-28 M	PG 64-16 or PG 70-10

NOTES:

- (1) PG = Performance Grade
- (2) M = Modified (Polymers, crumb rubber, or both)
- (3) PG 76-22 M may be specified for conventional dense graded hot mix asphalt for special conditions in all climate regions when specifically requested by the District Materials Engineer.
- (4) Modified binders (M) should not be used more than 0.25 ft below the top of the structural section.
- (5) Consult with the District Materials Engineer for which binder grade to use.
- (6) Refer to Topic 615 for determining climate region for project.

- Truck/bus stop-and-go areas (intersections, metered ramps, ramps to and from Truck Scales, etc.)
- Truck/bus climbing lanes.

The final decision, whether a roadway meets the criteria for special conditions, rests with the District. It should be noted that even though special binder grades help meet the flexible pavement requirements for high truck/bus use areas, they should not be considered as the only measure needed to meet these special conditions. The District Materials Engineer should be consulted for additional recommendations for these locations.

For more detailed information on PG binder selection, refer to the Department Pavement website.

632.3 Hot Mix Asphalt Specifications and Flexible Pavement Design

Two types of specifications are typically used for the materials design and construction of HMA, either Standard Specifications or special provision specifications for the use of Quality Control/Quality Assurance (QC/QA). Beginning in 2002 a new type of specification has been used on selected projects referred to as “performance related specifications” (PRS).

When a project uses PRS there are additional requirements for laboratory performance-related testing to develop the specifications and properties of materials to be used in the structural design using *CalME*. The materials proposed by the contractor must be demonstrated to have those same performance-related properties to be used on the project. Because the performance related properties of the HMA materials to be used in a PRS project are known when the pavement structural section is being designed, the design reliability calculations in *CalME* account for the reduced variability of the properties and increased reliability of the design. This can potentially, but not always, assist in reducing cross-sectional thicknesses. The cost benefits of reduced structural thicknesses and greater certainty regarding HMA performance and the increased costs of additional laboratory testing should be considered together when deciding whether to use PRS. PRS can also be advantageous when considering new types of HMA mixes because they require that the performance-related properties used in the structural design and included in the project specifications for fatigue, rutting, and stiffness be met or exceeded when the contractor’s materials are submitted for approval. The use of PRS in a project requires approval from the Office of Asphalt Pavement.

(a) *Non-PRS HMA materials used in design.* In the *CalME* pavement design software, each type of HMA specified to meet either Standard Specifications or QC/QA specifications used in structural design (HMA with different PG grades including polymer modified HMA, RHMA-G, high RAP HMA) is labeled as a “non-PRS” HMA material. The properties of a mix with the state-wide median properties for stiffness, fatigue, and rutting are used in the design calculations for projects using non-PRS

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HMA materials. The performance related materials properties for the state-wide median HMA materials are included in the Standard Materials Library (SML) in the CalME software based on previous testing. The default reliability levels, and other default values are used for designs with non-PRS HMA materials.

- (b) *PRS HMA materials used in design.* Projects that use PRS will need to have the mixes with the specified performance related properties made available in CalME. The reliability level between projects in designed is automatically adjusted to reflect the greater certainty regarding the performance of the HMA materials by choosing “PRS” as the “Spec. Type” when running CalME.

Topic 633 - Engineering Procedures for New Construction and Reconstruction

New Construction is the building of a new facility. This includes new roadways, interchanges or grade separation crossings, new parking lots, and safety roadside rest areas.

Reconstruction is the replacement of the entire existing pavement structure by an equivalent or increased new pavement structure and rebuilding of adjacent operational and roadside features. The entire removed depth is replaced with a new or recycled base, or based and subbase layers, and a new HMA surface.

Refer to Topic 603 for more details about types of pavement projects.

633.1 Mechanistic-Empirical Method for New Flexible Pavement

- (1) *Application.* For information on Mechanistic-Empirical design application and requirements, see Index 604.2.
- (2) *Method.* The Mechanistic-Empirical (ME) method integrates the effects of traffic loading and climate on the various layers of a pavement structure at various time increments during the analyzed service life to predict pavement performances. For new construction design, a trial pavement structure comprised of layer types and thicknesses is selected and then damage and distresses are simulated with the ME method over the design life of the pavement to determine the time it takes for the pavement to reach any of the failure thresholds. The design process involves trial and error to find the optimal structure that does not fail within the service life at the designated reliability level. This requires many computations and therefore the use of a software program. To help start the design process, the CalME program provides an initial trial pavement structure estimated to approximately meet the traffic and climate needs of the project.

The ME method offers these benefits over the empirical procedure used in the past:

- Considers the performance properties of materials such as enhanced or modified HMA (e.g., PG grade specifications, RHMA, and polymer modified HMA), rather than using a generic material.
- Allows new materials to be characterized and included in the method much faster than the empirical method.
- Incorporates detailed traffic loading characteristics by using axle load spectra based on use of the Weigh-in-Motion (WIM) locations distributed across the state highway system, rather than the roughly assumed damaging effects included in calculation of ESALs and TI.
- Accounts for the effect of climate on pavement performance.
- Simulates damage and development of individual distresses that can cause the pavement to fail: fatigue cracking, reflective cracking, rutting.
- Explicitly considers design reliability using statistical consideration of the measured effects of construction quality, material properties, climate, and traffic on performance.

The ME method for designing or analyzing flexible pavement for new construction, reconstruction, requires the following:

- (a) CalME Software – Caltrans has developed CalME, the mechanistic empirical software for new flexible pavement design and rehabilitation design in California. Inputs to the CalME software include:
- Project location (district, county, route number, post mile limits), which are used by the software to determine the WIM spectrum (see Index 613) and climate region (see Topic 615).
 - Pavement design life.
 - Truck axle loadings in the first year, and linear traffic growth rate, both have default values estimated from the built-in CalME database (the same database is used in the pavement management system), or a user input Traffic Index (TI) provided by Traffic Operations for the design lane following Index 613, which CalME uses to determine the axle loadings in the first year. For verification purposes, the CalME software provides a TI calculated for the lane with maximum traffic volume at the project location based on the pavement management system traffic database. Note that these two TI values may NOT be the same unless the design lane is the truck lane.
 - Subgrade soil classification (USCS), and subgrade stiffness (resilient modulus, M_r) measured in a laboratory from field collected samples or estimated from USCS classification and dynamic cone penetrometer (DCP) testing. USCS and DCP testing results are used to determine design sub-sections when the subgrade characteristics vary significantly within the

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project. These data should be determined following the Site Investigation Guide.

Trial pavement structure to be analyzed, including surface material and other base and subbase layers, each with a design thickness and material type. The non-structural surface wearing course should be excluded when conducting a CalME analysis. All materials should be selected from the built-in Standard Materials Library (SML). CalME has typical stiffnesses for each material in the SML. In addition, CalME also has typical construction variability for each material property in the SML in terms of the standard deviation of layer thickness, layer stiffness, fatigue resistance and rutting resistance. The following inputs have default values that may only be changed with permission from the Office of Asphalt Pavement:

- HMA specification type, either using the standard specification or QC/QA specification (non-PRS), or PRS. See Index 632.3 for definition of the two specification types. The Office of Asphalt Pavement should be contacted if PRS are to be used on the project. See item (b) below for details.
- Performance criteria or thresholds such as percentage cracking and total rut depth. See item (c) below for details.
- Design reliability between projects value and within project design reliability value. The default between project reliability is 95% for all projects which is handled in CalME by selecting the appropriate project type: PRS or non-PRS. The between project reliability is the same for projects where PRS specifications are used for the HMA. Between project reliability for PRS projects is handled in CalME by changing the reliability factor in the software in consultation with the Office of Asphalt Pavement based on the PRS requirements for the project. The minimum recommended within project reliability is 95% for both non-PRS and PRS projects. See item (d) below for details.

(b) Project type regarding construction specification for HMAs – The construction specification type determines the extent of testing required and how the job mix formulas (JMF) submitted by the contractor are approved. More details on the two specification types are explained as follows:

- Non-Performance Related Specifications (Non-PRS) - In this case, the engineer will use the state-wide median non-PRS HMAs available in the SML shown in CalME. No performance related testing on HMA materials is necessary.
- Performance Related Specifications (PRS) – For PRS projects, the Office of Asphalt Pavement should be consulted to determine the approach for setting the HMA performance related test properties to be used for design and for materials acceptance, if PRS method is chosen. District has an option to choose PRS depending upon available resources and laboratory facilities. The design input and the specifications can be selected based on either of the following two approaches:

- (1) Examination of materials in the state-wide materials library to determine if they are regionally applicable to the project. If a set of regionally applicable materials are in the SML, the design properties and PRS can be set based on those materials.
 - (2) If there are no regionally applicable materials in the SML, or the project would like to consider new materials, or to develop specifications and the design based on an updated assessment of materials available in the region, the engineer develops a mix representing average local performance and submits it to the Office of Asphalt Pavement so that it is added to the SML. Note that the same mix can be used for both PRS and non-PRS project. Each HMA material (including HMA and RHMA-G) in the SML has parameters for various models needed for performance simulation. In addition, each PRS-ready HMA material has performance limits for JMF approval in the SML. Both performance model parameters and JMF limits are developed based on laboratory performance tests. See Item (f) below for more details.
- PRS is recommended to use on larger projects as determined based on total HMA quantities used on the project. PRS projects require additional costs and time for mix design and JMF approval. Cost reductions from thinner cross-sections that are greater than the increased cost of mix design and approval are more achievable on projects for higher TIs and longer design lives. Table 633.1A provides the recommended minimum criteria for use of PRS.

Table 633.1A

Selecting ME Project Type and Materials

Design Life	HMA Material	Project Specification Type
Up to 40 years	< 100,000 tons of total HMA	non-PRS
>20 years	≥ 100,000 tons of total HMA	Consider PRS ⁽¹⁾ and/or AC Long Life ⁽²⁾

NOTE:

- (1) See Index 633.2(2)(b) for the descriptions of project design and testing levels. District has an option to make this decision based on available resources and laboratory facilities for testing.
- (2) AC Long Life projects use a polymer modified HMA surface, a high stiffness HMA intermediate layer (often with greater than 15% RAP), and a high binder content very low air-void content Rich Bottom layer (may be omitted when placed over concrete).

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(c) Performance Criteria – The performance criteria are the performance thresholds for pavement distresses considered in structural design defining the end of the pavement life. For new construction and reconstruction, CalME accounts for flexural fatigue cracking and reflective cracking when applicable in the HMA layers and total rut depth measured at the pavement surface. The corresponding thresholds must not be exceeded during the design life of the proposed pavement structure. The pavement is said to have failed as soon as one of these thresholds is reached. CalME uses the following default threshold values:

- Cracking = 5 percent of the wheelpath
- Rut depth = 0.4 inch below surface

In terms of the Mean Roughness Index (MRI), roughness, which is the mean of the International Roughness Index (IRI) in both wheelpaths, is not considered in structural design. MRI is primarily a function of the roughness achieved in construction and control of cracking and rutting through structural design. The default design rutting and cracking threshold values minimize the risk of MRI exceeding PMS criteria for keeping MRI less than 170 inches/mile due to rutting and cracking.

(d) Reliability – All final designs using CalME must use the reliability concept. In CalME, reliability includes considering of performance uncertainty from between projects variability (BPV) and within project variability (WPV). WPV is the variability of performance within a project caused by construction variabilities such as variations in layer thickness, material production, compaction, and subgrade variability. BPV is defined as all other uncertainties that affect pavement performance, which is primarily related to differences between materials delivered under the same non-PRS specification, differences between contractors, uncertainties in future traffic estimation, and variability of climate.

CalME accounts for BPV by applying calibrated built-in reliability shift factors based on state-wide variance in comparing calculated and observed performance, and accounts for WPV using Monte Carlo simulation with typical construction variability. The shift factors are lower for PRS projects compared to non-PRS projects to account for the reduced uncertainty for materials performance variability properties between projects. Reliability of a given design is calculated as the percent of projects that do not reach failure criteria within the design life in Monte Carlo simulation.

A minimum of 60 Monte Carlo simulations is required in CalME to determine the reliability of the final design within the project. When evaluating preliminary design, a lower number of simulations may be used to expedite the simulations. If the trial design is found to pass all the performance criteria, then the Engineer may gradually reduce the thickness of one or more layers and re-run the CalME analysis to find the most cost-effective structure meeting both the rutting and cracking criteria.

- (e) Materials Information – All materials used in CalME must be selected from the built-in Standard Materials Library. Contact the Office of Asphalt Pavement regarding adding new HMA or other materials to the Standard Materials Library, including new HMA materials with PRS for specific projects.

In-place recycled materials, unbound materials such as aggregate base, aggregate subbase, subgrades, and chemically stabilized bases and subbases do not require any additional testing for ME design and analysis except during construction quality control and assurance (QC/QA). The selections in CalME Standard Materials Library for these materials represent state-wide median performance. There are no PRS for these materials. The statistical distributions of resilient moduli for these pavement materials are given in Chapter 660 (Table 666.1A).

- (f) HMA Laboratory Testing – The ME procedure in CalME requires parameters for performance models for each HMA. HMA performance model parameters are determined from the following standard laboratory tests:
- AASHTO T 321 “Standard Method of Test for Determining the Fatigue Life of Compacted Asphalt Mixtures Subjected to Repeated Flexural Bending”. This test is used to determine model parameters for HMA fatigue performance and flexural stiffness master curve.
 - AASHTO T 378 “Standard Method of Test for Determining the Dynamic Modulus and Flow Number for Asphalt Mixtures Using the Asphalt Mixture Performance Tester (AMPT)” is used to determine model parameters for HMA rutting performance.

The tests used to determine performance model parameters are subject to research and review of experience to identify better performance tests. Consult with the Office of Asphalt Pavement for the current list of performance tests before starting a PRS project.

In addition, a PRS-ready HMA material requires performance limits for JMF approval and QC/QA. The tests used for determining performance related properties listed above are also required for JMF approval. The tests required for construction QC/QA are continually updated with experience from recent projects; consult with the Office of Asphalt Pavement for current requirements.

- (g) Other considerations:
- Subgrade enhancement geotextile (SEGT) on the subgrade may be considered for subgrade resilient modulus values less than 23 ksi (or equivalent R-values of 40). Refer to Chapter Topic 665 for SEGT class selection. If the subgrade is subject to chemical stabilization using an approved stabilizing agent such as lime or cement, an SEGT should not be considered.

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- A minimum thickness of Class 2 Aggregate Base (AB) is required in all flexible pavement designs to provide a construction platform depending on the subgrade USCS, see Table 633.1B.
- Consult current design requirements as identified in Index 631 and Index 602.1(4) regarding HMA surface course material types.
- Additional Guidance – Additional information on the Caltrans ME methodology and on the use of CalME can be found in the CalME Software under “Instructions” or by contacting the Office of Asphalt Pavement.

Table 633.1B**Minimum Class 2 AB Thicknesses for Different Subgrade Soils**

UCSC Soil Class	Default Stiffness		Min. Class 2 AB t (ft)
	M _R (ksi)	Equivalent R-Value	
GW	38.7	68	0
GP	29.9	52	0
GM	31	54	0
GC	19.9	34	0.35
SW	21.5	37	0.35
SP	18.3	31	0.35
SM	21.5	37	0.35
SC	13.8	23	0.35
ML	12.0	20	0.50
CL	9.9	16	0.50
MH*	5.9	9	0.75
CH*	4.4	6	1.00

* Consider subgrade improvement, such as imported materials, or utilizing mechanical (Geogrid) or chemical (Lime/Cement) stabilization.

633.2 Mechanistic-Empirical Designs for Reconstruction of Flexible Pavement

Reconstruction of Flexible Pavement strategy is most often used when:

- It is required to maintain existing profile grade and rehabilitation options such as Mill and Fill (defined as milling part of the existing HMA and replacing it with a new HMA overlay of the same thickness on top) do not satisfy design needs.
- The existing base and or subbase materials are failing and need to be completely replaced.
- The existing subgrade is failing.

- It is the most cost-effective strategy based on life-cycle cost analysis.

Reconstruction should be engineered using the same procedures used for new construction found in Topic 633.1 with the following exceptions:

- Subgrade stiffness may be determined by back calculation using results from deflection testing conducted on the existing pavement before it is removed.
- In addition, back calculated subgrade stiffness may also be used to determine design pavement subsection. See the Site Investigation Guide for more details.
- Some or all of the pavement materials removed can often be recycled at the site using cold central plant recycling (CCPR) instead of being hauled away from the site and replaced with new materials. The subgrade may be stabilized if it is necessary before reconstructing the structure. The base and subgrade materials selected should reflect any applicable recycling and stabilization guidance documents.

Topic 634 - Engineering Procedures for Flexible Pavement Preservation

634.1 Preventive Maintenance

For details regarding preventive maintenance strategies for flexible pavement, see the “Maintenance Technical Advisory Guide (MTAG)” on the Asphalt Pavement Office website (<https://dot.ca.gov/programs/maintenance/pavement/asphalt-pavement>). Deflection studies are not performed for preventive maintenance projects.

634.2 Capital Preventive Maintenance (CAPM)

(1) *Warrants*. A CAPM project is warranted if any of the following criteria are met per current DIB 81-02:

- $10\% \leq \text{Alligator 'B'} \leq 30\%$, and $\text{MRI} \leq 170$ inches per mile
- $\text{MRI} > 170$ inches per mile
- $> 30\%$ Alligator ‘B’ consider rehabilitation

(2) *Strategies*. CAPM strategies include the following options:

- (a) When the MRI is less than or equal to 170 inches per mile, use 0.15 foot of RHMA-G or 0.20 foot of HMA (conventional mix or polymer modified). The preferred alternative is 0.15 foot of RHMA-G. A 0.25 foot overlay is permissible if 1-inch gradation HMA is to be used on the project. (Note: A 0.2’ RHMA-G overlay or pavement interlayer may be appropriate under certain circumstances with HQ Pavement Program Advisor or Office of Asphalt Pavement concurrence). A 0.10 foot thick OGFC (HMA-O or RHMA-O) may be added on

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top of the overlay thickness but may not be substituted for an RHMA-G or HMA-A layer.

For CAPM projects with MRI greater than 170 inches per mile, the standard design is to cold plane as appropriate and place a 0.25 foot asphalt overlay in two lifts consisting of 0.10 foot followed by 0.15-foot HMA or preferably 0.15 RHMA-G overlay.

- (b) Partial Depth Recycling (PDR) (previously called cold in-place recycling (CIR)) is an acceptable CAPM strategy for pavement where the cracking is top-down (determined from coring, see the Site Investigation Guide) with little to no base failure regardless of MRI. Recycle between 0.25 foot and 0.4 foot of the existing asphalt pavement and then cap with a 0.15 foot HMA overlay or preferably 0.15 foot RHMA-G overlay.
 - (c) Existing pavement may be milled or cold planed down to the depth of the overlay prior to placing the overlay for any of the above strategies. Milling or cold planning may be beneficial or even necessary to improve ride quality, maintain profile grade, maintain vertical clearance, or taper (transition) to match an existing pavement or bridge surface.
 - (d) Non-structural wearing courses such as open graded friction courses, chip seals, or thin overlays not to exceed 0.10 foot (0.12 foot in North Coast Climate Region) in thickness may be added to the strategies listed above.
 - (e) Pavement interlayers may be used in conjunction with the strategies listed above.
 - (f) Digouts not exceeding 20 percent of the CAPM pavement costs may be included. Digouts should be designed to provide a minimum of 20 years added service life or at least to match the existing remaining service life of the pavement.
 - (g) Preventive maintenance strategies may be used in lieu of the above strategies when MRI is less than 170 inches per mile and they will extend pavement service life a minimum of 10 years until the next CAPM project is warranted.
 - (h) CAPM strategies for OGFC, HMA-O used as a stormwater treatment BMP should replace (with the same type) in kind.
- (3) *Smoothness*. For an asphalt pavement CAPM project with existing MRI less than 170 inches per mile at the time of PS&E, a 0.20 foot or less single lift overlay is used; which should improve ride quality to minimum smoothness requirements. An RHMA-G overlay is preferred over HMA overlay. For CAPM projects with existing MRI greater than 170 inches per mile the standard practice is to use a 0.25-foot overlay placed in two lifts. A 0.25-foot two-lift overlay strategy should restore the ride quality to minimum smoothness requirements. A 0.10 foot HMA followed by 0.15 foot RHMA-G is preferred. Or a PDR strategy may be used. For the minimum smoothness requirements, refer to the current relevant Standard Specifications, Standard Special Provisions, and nSSPs.

- (4) *Site Investigation and Testing.* Site investigations following the Site Investigation Guide, as applicable, should be conducted for CAPM projects. Deflection studies are not required for CAPM projects. The roadway rehabilitation requirements for overlays (see Index 635.2(1)) and preparation of existing pavement surface (Index 635.2(8)) apply to CAPM projects. Additional details and information regarding CAPM policies and strategies can be found in Design Information Bulletin 81-02 or current DIB “Capital Preventive Maintenance Guidelines.”

Topic 635 - Engineering Procedures for Flexible Pavement Rehabilitation

635.1 Rehabilitation Warrants

Locations where overall Alligator ‘B’ cracking exceeds the thresholds for CAPM are eligible for rehabilitation. When Alligator ‘B’ cracking is less than or equal to 35 percent, perform a life-cycle cost analysis (LCCA) in accordance with the requirements of Topic 619 comparing a flexible pavement rehabilitation strategy versus a CAPM strategy. Pursue a CAPM strategy when CAPM has the lowest life-cycle cost.

635.2 Mechanistic-Empirical (ME) Design Method for Rehabilitation

- (1) *General.* The methods presented in this topic are for rehabilitation projects with design life between 20 and 40 years, as per Index 612.5.

Because there are potential variations in materials and environment that could affect the performance of both the existing pavement and the rehabilitation strategy, it is difficult to develop precise and firm practices and procedures that cover all possibilities for the rehabilitation of pavements. Therefore, the pavement engineer should consult with the District Materials Engineer, Office of Asphalt Pavement, and other pertinent experts who are familiar with engineering, construction, materials, and maintenance of pavements in the geographical area of the project for requirements or limitations in addition to those listed in this manual.

- (2) *Engineering Criteria.* Inputs to the ME design procedure for flexible pavement rehabilitation are the same as those for new construction and reconstruction designs with the following additional considerations:
- Properties of the existing layers and the subgrade that will not be removed. The material type, layer thickness and its variability, and layer modulus and its variability should be determined through site investigation following the Site Investigation Guide. Additional tests such as deflection testing using falling weight deflectometer are required. To provide reliable rehabilitation strategies, deflection studies should be done no more than 18 months prior

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to the start of construction. California Test Method 357 for flexible pavement deflection measurements can be obtained from the Materials Engineering and Testing Services website. If resources permit, initial deflection studies can be done at the PID and PA&ED phases for estimating purposes. However, these initial deflection studies cannot be substituted for the final deflection study.

- Potential causes for reflective cracking in asphalt overlays on flexible surfaced pavement. Pre-existing cracking in existing layers that will not be removed is a cause for reflective cracking, as is shrinkage cracking in chemically stabilized layers. The amount of pre-existing cracking is an additional input for CalME.
- Inputs to the ME design procedure for asphalt overlay of concrete pavements are similar to those for rehabilitation of flexible pavements except that the amount of pre-existing cracking is not an input. CalME models reflective cracking in the asphalt overlay from cracks and joints in the underlying concrete using typical crack and joint spacing. CalME does not model asphalt overlays on concrete pavement without crack and seat. Consult with the District Materials Engineer or the Office of Asphalt Pavement regarding use of crack and seat.
- CalME does not model asphalt overlays on continuously reinforced concrete pavements without crack and seat option. Once CRCP is cracked and seated, analyze the pavement similar to cracked and seat JPCP.
- Inputs to the ME design procedure for asphalt overlay of composite pavements are similar to those for rehabilitation of concrete pavements. CalME models reflective cracking in the new asphalt overlay from cracks and joints in the underlying concrete that have reflected up through the existing asphalt overlay using typical crack and joint spacing.

On overlay projects, the entire traveled way and paved shoulder shall be overlaid. Not only does this help provide a smoother finished surface, it also benefits bicyclists and pedestrians when they need to use the shoulder.

- (3) *Data Collection.* Developing a rehabilitation strategy requires collecting background data as well as field data. See the Site Investigation Guide for more information.
- (4) *In-Situ Layer Moduli Evaluation Using Back Calculation.* In-situ layer moduli are determined through a process called back calculation, using the CalBack software program. The method of back calculation uses known layer thicknesses, multilayer elastic theory, and a numerical search algorithm to determine the resilient modulus of each layer of an existing pavement structure based on deflection basin data collected from the pavement. A deflection basin describes the deflection measured on the pavement surface as a function of distance from the applied load. The results exported from CalBack can be directly imported into CalME for use in rehabilitation design. For details on

deflection data collection and back calculation, refer to the Site Investigation Guide and CalBack Manual.

For additional information on the theory of back calculation and description of CalBack procedures refer to the link “ME Designer’s Corner” located on the internal Department Pavement website

(<https://maintenance.onramp.dot.ca.gov/paveprogram/caltrans-me-designers-corner>) or by contacting the Headquarters Pavement Program Office Chief.

- (5) *Engineering Criteria Mechanistic-Empirical Analysis.* The ME method analyzes a proposed rehabilitation treatment for various performance criteria as discussed in Index 633.1(2)(c). The rehabilitation design must achieve the required reliability level for the project as discussed in Index 633.1(2)(d)
- (6) *Flexible Overlay/ Mill & Overlay on Existing Flexible Pavement or Composite Pavement and Flexible Overlay on Existing Rigid Pavement.* Reflective cracking should be included in CalME analysis when rehabilitation involves the overlay of cracked flexible pavement and is automatically assumed in CalME whenever a concrete layer is included in the structure. The minimum thicknesses recommended by the Department for reflective crack retardation on flexible pavements are 0.15 foot HMA or 0.10 ft RMHA-G on flexible pavements. Caltrans is conducting research to develop necessary models to allow CalME to explicitly consider the effects of geosynthetic pavement interlayer (GPI) on pavement performance. Before that research is complemented and implemented, the following are general guidelines for their use:
 - A GPI can be placed under HMA/RHMA-G for additional reflective crack retardation. Ensure that the melting point of the GPI to be used on the project exceeds the RHMA-G placement temperature. Refer to the Standard Specifications for selection of GPI. The GPI should be millable and recyclable for future maintenance or rehabilitation of the project. Consult with District Maintenance and Construction for input.
 - A rubberized pavement interlayer (RPI) can be placed under a rubberized or non-rubberized hot mix asphalt overlay for additional reflective crack retardation.
 - Do not reduce the HMA layer thickness for the use of GPI or RPI.

Open-graded and bonded wearing courses are not included in the thickness used to address reflective cracking.

Since existing pavement thicknesses will have slight variations throughout the project length, leave at least the bottom 0.15 foot of the existing surface course intact to ensure the milling machine does not loosen the base material or contaminate the recycled mix if used. A greater thickness of existing material must be left if the site investigation indicates that the existing asphalt layers are cracked or otherwise deteriorated, or alternatively in-place recycling or complete removal of the asphalt layers and replacement with new asphalt should be considered.

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- (7) *Overlay Thickness to Address Ride Quality.* The Department records ride quality (also called smoothness or roughness) as part of the Annual Pavement Condition Survey. According to the FHWA, the IRI value that most motorists consider uncomfortable for flexible pavement is 170 inches per mile. When average IRI across the two wheelpaths (MRI) measurements are 170 inches per mile or greater, the engineer must address ride quality. The entire project can be divided into groups of multiple segments that will be individually analyzed for ride quality.

To improve ride quality within the motorists' comfort level, place a minimum of a 0.25 foot overlay in two lifts. Because this overlay addresses ride quality, it does not matter whether HMA or RHMA-G is used, although the latter is preferred. This could be performed using either:

- The placement of 0.10 foot HMA followed by 0.15 foot HMA, or
- The placement of 0.10 foot HMA first, followed by 0.15 foot RHMA-G.

A non-structural wearing course may be included in the ride quality thickness. Pavement interlayers do not have any effect on ride quality.

- (8) *Overlay Thickness and Governing Criterion.* The overlay thickness requirements required to address structural capacity are determined using ME design. The structural adequacy requirement should be compared with the thickness required to address ride quality and the greatest thickness is selected as the overlay thickness.

- (9) *In-Place Recycling (IPR)*

IPR is the collective name of a number of different rehabilitation strategies. Refer to the In-Place Recycling Guide for more information. There are two categories of IPR depending on whether the recycling is below the bottom of the existing HMA layer.

- (a) *Partial Depth Recycling (PDR).* PDR is when only part of the HMA is recycled. The recycling can be done either in-place (0.25 to 0.4 foot) or at the construction site using cold central plant recycling (CCPR, any thickness as multiple lifts are possible).

- (b) *Full Depth Recycling (FDR).* The FDR process pulverizes the existing asphalt and a portion of the underlying material, while simultaneously mixing with stabilizer in one pass. Refer to the In-Place Recycling guide for alternative evaluation and selection based on the results of the site investigation, which also requires consideration of the type of layer below the HMA. After pulverization and mixing, the material is compacted, graded, and overlaid with HMA and/or RHMA. FDR transforms distressed existing asphalt into stabilized base to receive a new structural surface layer. FDR can treat a variety of project conditions but is most cost effective for cracked pavement surfaces requiring digouts of 20 percent or more by paving area.

Reflective cracking is assumed in CalME analysis if full depth recycling with Portland cement (FDR-C) is used that is not specified following mix design and construction recommendations in the in-place recycling guidance. No reflective cracking from drying shrinkage cracks is assumed in CalME analysis if FDR-C is specified following those recommendations,. The pavement designer needs to put a note in the Plan to specify maximum UCS of 450 psi.

The final FDR layer thickness is determined from the initial planned recycling depth plus an additional 5 to 10 percent swell that occurs due to recycling. As an example, if the initial planned recycling depth is 0.80 foot, the final FDR depth can be $0.80 \times 1.07 = 0.85$ foot.

The layer modulus of the IPR layer is dependent on the material being recycled and the recycling agent/stabilizer used. Use the appropriate material for design in the CalME Standard Materials Library that matches the recycling strategy and stabilizing agent being designed for. Swelling does not need to be considered if the final grade elevation is not important. Use the thickness of FDR that will be used in the structure, with or without grade adjustment, for input to ME design.

(10)*Procedure for Concrete Overlay on Existing Flexible Pavement.* For concrete overlay on asphalt (COA) strategies (sometimes previously referred to as whitetopping), only structural adequacy needs to be addressed. To address structural adequacy, use the tables in Index 623.1 to determine the thickness of the concrete layer. The existing HMA layer may be considered as the base for the concrete overlay if it is at least 0.25 foot thick and the surface is in good condition or has been restored with an asphalt overlay prior to placing the concrete overlay. Refer to Index 620 for more details regarding design. Note that there are separate thickness tables for concrete overlays greater than 0.65 ft and for concrete overlays less than or equal to 0.65 ft. The design details for selecting the correct table are discussed in Index 620. Cold planing of the existing asphalt should be considered for several reasons: removal of surface distressed asphalt, providing an even surface that helps achieve a uniform overlay thickness, and matching geometric requirements such as bridge clearances. To provide a smooth and level grade for the concrete overlay surface layer a 0.10 foot to 0.15 foot HMA or RHMA-G leveling course may be placed on top of the existing flexible layer..

(11)*Preparation of Existing Pavement.* Existing pavement distresses should be repaired before overlaying the pavement. Cracks wider than $\frac{1}{4}$ inch should be sealed; loose pavement should be removed and replaced; and localized failures such as potholes should be repaired. Localized failure repairs should be designed to provide a minimum design life to match the pavement design life for the project, but no less than 20 years. Undesirable material such as bleeding seal coats or excessive crack sealant should be removed before paving. Existing thermoplastic traffic striping and raised pavement markers should also be removed. The Materials Report should include a reminder of these

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preparations. Additional discussion of repairing existing pavement can be found on the Department Pavement website.

- (12) *Choosing the Rehabilitation Strategy.* The final strategy should be chosen based on pavement life-cycle cost analysis (LCCA). The strategy should also meet other considerations such as constructability, maintenance, and other requirements in Chapter 610.

635.3 Rehabilitation of Existing RHMA-G, RHMA-O and HMA-O Surfaced Flexible Pavements

The design method is based on the ME methodology (Index 635.2.) The designer may be limited in selecting the rehabilitation strategy for the pavement. In the past, RHMA-G layers tended to be more permeable than dense graded HMA if the RHMA-G layer was not subjected to QC/QA compaction specifications. More limited research since RHMA-G was included in QC/QA compaction specifications has shown that the difference in permeability between dense-graded HMA and RHMA-G is insignificant. HMA and RHMA-G should not be placed over OGFC (HMA-O or RHMA-O) because of the potential to trap water beneath the new overlay.

Topic 636 - Other Considerations

636.1 Traveled Way

- (1) *Mainline.* No additional considerations.
- (2) *Ramps and Connectors.* Rigid pavement should be considered for freeway-to-freeway connectors and ramps near major commercial or industrial areas (TI > 14.0), truck terminals, and all truck-weighing and inspection facilities.
- (3) *Ramp Termini.* Distress is compounded on flexible pavement ramp termini by the dissolving action of oil drippings combined with the braking of trucks. Separate pavement strategies should be developed for these ramps that may include thicker pavement structures, special asphalt binders, aggregate sizes, or mix designs. Rigid pavement can also be considered for exit ramp termini where there is a potential for shoving or rutting. At a minimum, rigid pavement should be considered for exit ramp termini of flexible pavement ramps where a significant volume of trucks is anticipated (TI > 11.5). For the engineering of rigid pavement ramp termini, see Index 626.1(3).

636.2 Shoulders

The TI for shoulders is given in Index 613.4(2). See Index 1003.5(1) for surface quality guidance for bicyclists.

636.3 Intersections

Where intersections have “STOP” control or traffic signals, special attention is needed to the engineering of flexible pavements to minimize shoving and rutting of the surface caused by trucks braking, and early failure of detector loops. Separate pavement strategies should be developed for these intersections that may include thicker pavement structures, stiffer and/or polymer modified or other specially designed asphalt binders, aggregate sizes, or mix designs. Rigid pavement is another alternative for these locations. For additional information, see Index 626.3. For further assistance on this subject, consult with the District Materials Engineer or Headquarters Division of Maintenance – Pavement Program or Office of Asphalt Pavement.

636.4 Roadside Facilities

- (1) *Safety Roadside Rest Areas.* Safety roadside rest area pavements should be designed using the ME method.

For truck parking areas, where the pavement will be subjected to truck starting/stopping and oil drippings which can soften asphalt binders, separate flexible pavement structures which may include thicker structural sections, alternative asphalt binders, aggregate sizes, or mix designs should be considered. Rigid pavement should also be considered.

- (2) *Park & Ride Facilities.* Due to the unpredictability of traffic, it is not practical to design a new park and ride facility based on traffic projections. Therefore, standard structures based on typical traffic loads have been adopted. Table 636.4 provides layer thicknesses based on previous practices.

These pavement structures are minimal, but are considered adequate since additional flexible surfacing can be added later, if needed, without the exposure to traffic or traffic-handling problems typically encountered on a roadway. If project site-specific traffic information is available, it should be used with the standard engineering design procedures discussed in Topic 633 and Topic 635 to design new or rehabilitate existing pavement structures. The design life of 20 years may be selected for roadside facilities. Refer to Topic 612.

- (3) *Bus Pads.* Use rigid pavement strategies for bus pads.

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Table 636.4**Minimum Pavement Structures for Park & Ride Facilities**

Resilient Modulus (California R-value) of the Subgrade Soil	Thickness of Layers	
	HMA ⁽²⁾ (ft)	AB (ft)
Less than 23 ksi (40) ⁽¹⁾ (two options)	0.25	0
	0.15	0.35
Greater than or equal to 23 ksi (40) but less than 34 ksi (60)	0.15	0
Greater than or equal to 34 ksi (60)	Penetration Treatment ⁽³⁾	

NOTES:

- (1) Check for expansive soil and possible need for treatment per Index 614.4.
- (2) Place HMA in one lift to provide for maximum density.
- (3) Penetration Treatment is the application of a liquid asphalt or dust palliative on compacted roadbed material. See Standard Specifications.

Topic 637 - Engineering Analysis Software

Software programs for designing flexible pavements using the procedures discussed in this chapter can be found on the Department Pavement website. These programs employ the procedures and requirements for flexible pavement engineering enabling the engineer to compare numerous combinations of materials in seeking the most cost effective pavement structure.