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Manual for Thin Asphalt Overlays

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MANUAL FOR THIN ASPHALT OVERLAYS

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16. Abstract

This manual presents best practices on project selection, mix design, and construction to ensure a superior product when constructing thin asphalt overlays. Experience shows these treatments provide excellent performance when placed on pavements in fair to good condition using proper construction techniques. Though sometime referred to by other names, thin asphalt overlays have been widely used for pavement preservation throughout the world for over 50 years.

Limited infrastructure funding at the local, state, and federal levels has resulted in greater emphasis on the use of pavement preservation techniques to extend pavement life and reduce maintenance costs. Thin asphalt overlays are one of many preventative maintenance treatments. Thin asphalt overlays are placed directly on existing pavement and can range from $^{1}/_{2}$ inch to $1^{1}/_{2}$ inches in thickness. Thin asphalt overlays have proven to be an economical means for maintaining and improving the functional condition of an existing pavement since the 1960s.

Specifically, this manual provides guidance for engineers regarding where and when to use thin asphalt overlays including: (1) Types and variations of thin overlays; (2) Materials and the design process; (3) Construction; (4) Quality Assurance; and (5) Troubleshooting. This chapter by chapter guidance enables an Agency's engineers to design and construct a successful thin asphalt overlay project to completion.

This manual is one of four new manuals prepared by the California Pavement Preservation Center (CP^2Center) using funding from California Senate Bill 1 (SB-1), passed in April 2017. The other three manuals provide detailed design and construction information for (1) chip seals, (2) slurry surfacing, and (3) Cape seals. The creation of these manuals was a task funded entirely from SB-1 monies for the purpose of disseminating training and technical information on highway pavement preservation to local agencies throughout California.

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EXECUTIVE SUMMARY

This manual is one of several publications designed to empower local agency staff and contractors, through training, to choose the right treatment at the right time to optimize preventative maintenance funds. Most local agencies defer road maintenance over many years, and there are thousands of miles of public roads that are currently in poor condition. With new state funding available for maintenance and construction projects, proper pavement preservation for roads is an issue of paramount importance. Thin asphalt overlays are just one type of many maintenance treatments that can preserve pavements and defer the need for—and cost of—a re-construction project.

Thin asphalt overlays were first implemented in the 1960s, and they proved to be a promising technique in maintaining road surfaces. During the 1960s, with improved hot mix asphalt mixes and continuous paving machines, real interest was shown in using thin asphalt overlays across a wide range of applications. Currently, thin asphalt overlays are used for public roads, highways, airport runways, parking lots, and a multitude of other surfacing projects throughout the world. Thin asphalt overlays have been accepted and incorporated into many maintenance programs as a cost-effective maintenance treatment that slow deterioration and correct many pavement defects by providing a new surface.

The maximum size aggregate for a thin asphalt overlay is 1/2 inch. Besides the aggregate grading, there are many types of binder that may be used to create the mix for a thin asphalt overlay.

The various types of mixes used for thin asphalt overlays include:

- Dense-graded HMA
- Gap-graded HMA or RHMA-G
- Open-graded HMA or RHMA-O
- Bonded Wearing Course (BWC), also known nationally as Ultra-Thin Bonded Wearing Course (UTBWC)

This manual is one of four manuals developed by the California Pavement Preservation Center (CP2Center) for pavement preservation. The four manuals are (1) Slurry Surfacing, (2) Chip Seals, (3) Cape Seals, and (4) Thin Asphalt Overlays.

Besides project selection and types of HMA surfacing, construction issues and the design process for thin asphalt overlays are also covered in this manual. By focusing on pavement preservation treatments for extending the life of local agencies' aging roads, these manuals will ultimately offer the necessary training and references for agencies to make the best decisions regarding the placement of pavement preservation treatments.

I. INTRODUCTION

BACKGROUND

The purpose of this manual is to develop training for local agency staff so that they will have the ability to recognize their maintenance needs and to develop the most cost-effective strategies for preserving their aging hot mix asphalt pavements.

Thin hot mix asphalt overlays have been around since 1966.[1] They were first used to provide a new wearing course for smoothing rough HMA roads. They have evolved into maintenance treatments that can successfully be used on both low- and high-volume roads. The popularity of thin asphalt overlays is a direct result of their low costs in comparison with thicker hot mix overlays. Currently, with improved binders and paving equipment, considerable interest has been shown for using thin asphalt overlays in a wide range of applications such as public roads, highways, local streets, and a multitude of other surfacing applications throughout the world. Thin asphalt overlays have been accepted and incorporated into many maintenance programs as a cost-effective maintenance treatment.

A thin asphalt overlay is a Hot Mix Asphalt (HMA) treatment that consists of a thin layer of HMA that is usually $1^1/_2$ inches or less in thickness. The HMA used for this application can have $^1/_2$-inch, $^3/_8$-inch, or as fine as $^1/_4$-inch aggregates with various gradations. A thin asphalt overlay provides a new skid-resistant wearing surface, stops raveling, seals minor cracks, and retards further deterioration of the existing roadway.

Other options for preventative maintenance would include chip seals, slurry surfacing, or Cape seals. If a major rehabilitation or reconstruction project is planned in three to five years, it may be more economical to used one of the less expensive options. The manuals for these treatments can be found at the following links:

https://transweb.sjsu.edu/research/1845B-Slurry-Surfacing-Manual

https://transweb.sjsu.edu/research/1845C-Cape-Seal-Manual

https://transweb.sjsu.edu/research/1845A-Chip-Seal-Manual

PURPOSE

This manual is one of several designed to empower local agency staff, through training, to choose the “Right Treatment” at the “Right Time” to optimize their limited maintenance funds. Most local agencies have deferred road maintenance over many years, and there are thousands of miles of public roads that are currently in poor condition. With new funding being available for maintenance and rehabilitation projects, the importance of proper road maintenance is paramount. Thin asphalt overlays are just one type of many maintenance treatments that will preserve their pavements until a re-construction project can be designed and funded.

A thin asphalt overlay has many benefits for asphalt surfacing, listed in the Project Selection section of this manual.

ORGANIZATION OF THE MANUAL

This manual addresses thin asphalt overlays used as preventive maintenance treatments. Besides “Project Selection,” different types of thin asphalt overlays are covered to aid in the e best selection of treatments to address existing road surfacing problems. This manual also addresses the “Materials and Design”, “Construction Process”, “Quality Assurance”, and “Troubleshooting Guides” for thin asphalt overlays. Some state and local specification web links and bid sheet examples are included in the references and the appendices.

II. PROJECT SELECTION

A thin asphalt overlay is often selected to preserve existing surfacing or to provide a new wearing surface. These treatments are combinations of asphalt cement and aggregate applied to the pavement in thicknesses between $^1/_2$ inch and $1^1/_2$ inch. Dense-graded, open-graded, and gap-graded mixes can all be used. Thin overlays consist of placing on the roadway a single-lift overlay that is not in need of significant repair and is in fair to good condition. If the overlay is applied at the correct time, it can delay serious distresses, extend the life of the pavement, and decrease of the lifetime cost of the pavement. This section discusses when thin asphalt overlays should be used and when they should not be used, as well as providing a discussion of their benefits.

WHEN SHOULD A THIN ASPHALT OVERLAY BE USED

There are many reasons to consider a thin asphalt overlay for highway maintenance. This treatment will provide benefits to pavement distresses such as low severity cracking, raveling/ weathering, friction loss, roughness, low-severity bleeding, and low-severity block cracking. There are many instances where the thin asphalt overlays may be used after correcting minor pavement distresses. An example is that thin asphalt overlays may be used to correct rutting but will require the use of a separate rut-fill application prior to the overlay. Questions to be asked before considering a thin asphalt overlay are as follows:[2]

- Is the project a good candidate for a thin overlay?
- How much rutting is present-- depth and extent?
- Other profile problems observed?
- How severe and what type of cracking exists?
- Is crack sealing needed?
- Is the pavement surface waterproof?
- How much bleeding or flushing exists?
- Is pavement raveling or oxidized?
- What is the traffic level?
- Is the base sound and well drained?
- Is a drainage layer required?
- Is pavement strengthening required? Use a structural overlay if it is. The information required to determine this is as follows:

- As-builts compared to current traffic and structural design standards
- Coring to verify current thicknesses of pavement structure
- Deflection testing showing deflections over acceptable maximums.

Some reasons for using these treatments to correct distresses are included in Tables 1, 2, and 3. [3]

Table 1. HMA Treatment Strategy for Preventative Minor Distresses

TREATMENTS / DISTRESSES	PM OPEN GRADED OR OPEN-GRADED RHMA OVERLAY	DENSE-GRADED HMA OR GAP-GRADED RHMA OVERLAY	ULTRA-THIN BONDED WEARING COURSES	DIGOUTS: DENSE-GRADED HMA
RAVELING	G	G	G	N
OXIDATION	G	G	G	N
BLEEDING	G	F	F	N
RUTTING < 1/2”	G	G	F	N

G = Good, F = Fair, N = Not Recommended

Notes:

(1) Fog seal should not be placed on new pavement unless the mix had low binder content. Mainline fog sealing may require skid testing after application. Never place rejuvenating fog seal on new or newer pavement, as it may cause pavement to rut or become slick.

(2) Asphalt rubber overlays may last longer than polymer modified asphalt overlays and reduce traffic noise.

(3) Ultra-thin bonded wearing courses are strategies more commonly used in urban environments and have also been used on highways by Caltrans.

(4) Open-graded HMA or RHMA reduce highway splash and improve skid resistance in wet conditions. Open-graded mixes also improve the visibility of pavement markings in wet conditions.

(5) Digouts are a repair strategy used to repair more severe highway rutting or potholes prior to placing a thin asphalt overlay.

Table 2. Thin Asphalt Overlay Treatment Strategy for Cracking and Rutting

TREATMENTS / DISTRESSES	CRACK SEALING	ULTRA-THIN BONDED WEARING COURSE 1. BWC 2. BWC-RAC O/G	1. PM OPEN GRADED 2. OPEN-GRADED RHMA OVERLAY	1.DENSE-GRADED HMA 2. GAP-GRADED RHMA OVERLAY	DIGOUTS: DENSE-GRADED HMA
ALLIGATOR A, MINOR (1)	G	G	G	G	F
ALLIGATOR B, MODERATE (1)	F	F	G	G	F
LONGITUDINAL CRACKING (2)					
MINOR	G	G	G	G	N
MODERATE	G	G	G	G	N
TRANSVERSE CRACKING (3)					
MINOR	G	G	G	G	N
MODERATE	G	G	G	G	N
EDGE CRACKING (4)	N	N	N	F	G
RUTTING (5)					
< 1/2"	N	F	G	G	N
≥ 1/2"	N	N	F	F	G

G = Good, F = Fair, N = Not Recommended

Notes:

(1) Alligator "A" or "B" distress cracking may not require a crack seal if cracks are less than 1/8 inch. An asphalt rubber chip seal or a polymer modified chip seal with a rejuvenating agent should give five or more years of life to existing pavement. A scrub seal may give a longer-lasting benefit than a chip seal. Other surface treatments will yield good results and are appropriate.

(2) Longitudinal cracking (fatigue cracking) is usually remedied by crack sealing. Crack sealing should prevent reflection cracking when overlaid. Longitudinal cracking may progress to alligator cracking over time.

(3) Transverse cracking is usually remedied by crack sealing. If cracks are greater than 1/2 inch, then they may require 1/4-inch or 3/8-inch aggregate added to the crack followed by the crack sealant. Paving fabric may be placed over the filled crack prior to paving to reduce reflection cracking.

(4) Edge cracking may only require that the shoulder backing is to be pulled, if it is minor. If it is moderate or major, it may require the ragged edge to be removed by first saw cutting (or grinding) a neat line parallel to the edge strip. Then, dig out and remove the loose HMA and shoulder backing to a depth equal to the depth of the existing HMA prior to repaving. Match new shoulder pavement surface to existing pavement surface. If it is a new shoulder, the slope of new pavement may vary from the existing cross-slope (per Topic 302: Highway Shoulder Standards of the HDM). Too-narrow HMA replacement will be difficult to construct. Minimum width of replacement should be no less than 2 feet'.

(5) Rutting (less than ½ inch) may be partially remedied by a surface treatment. This may lessen the rutting for several years, so that it isn't a safety hazard. Eventually, rutting will require an overlay, surface milling, or wheel path digouts followed by a surface treatment or overlay.

Table 3. HMA Treatment Strategy for Major Distress

TREATMENTS / DISTRESSES	BONDED WEARING COURSE 1. BWC 2. BWC-RAC O/G	1. PM OPEN GRADED OR 2. OPEN-GRADED RHMA OVERLAY	1. DENSE-GRADED HMA OR 2. GAP-GRADED RHMA OVERLAY (7)	DIGOUTS: DENSE-GRADED HMA (8)
ALLIGATOR B, SEVERE (1), (2)	N	G	G	G
LONGITUDINAL CRACKING (3) SEVERE	G	G	G	N
TRANSVERSE CRACKING (4) SEVERE	G	F	G	N
EDGE CRACKING (5) RUTTING	N	N	G	G
≥ 1/2" (6)	N	F	F	G

G = Good, F = Fair, N = Not Recommended

Notes:

(1) Alligator B (severe) should have a two-step strategy of digouts followed by a thin asphalt overlay treatment.

(2) Alligator B (moderate) should have a two-step strategy of crack sealing followed by a thin asphalt overlay treatment. Surface treatment only will not yield a good result.

(3) Longitudinal cracking (severe) may require a two-step strategy to yield good results. Crack sealing should be the first step, followed by a thin asphalt overlay treatment.

(4) Transverse cracking (severe) may require 1/4-inch or 3/8-inch aggregate added to the crack followed by the crack sealant. Paving fabric may be placed over the filled crack prior to paving to reduce reflection cracking.

(5) Edge cracking may require the ragged edge to be removed by first saw cutting (or grinding) a neat line parallel to the edge strip. Then, dig out and remove the loose HMA and shoulder backing to a depth equal to the depth of the existing HMA prior to repaving. Match new pavement paving to existing pavement. If it is a new shoulder, the slope of new pavement may vary from the existing cross-slope (per Table 307.2 in Topic 307 of the HDM). Too-narrow HMA replacement will be difficult to construct. Minimum width of replacement should be no less than 2' for constructability.

(6) Rutting greater than 1/2 inch needs to be addressed as a safety issue. This degree of rutting will cause vehicles to hydro-plane at relatively low speeds. If the rutting is due to an inadequate structural section, an overlay should be done with dense-graded HMA so that the pavement structure is adequate for the traffic loading. The rutted area may need to be removed and replaced with grinder digouts prior to the overlay. Otherwise, a 1/4-inch HMA mix may be used to fill the ruts, followed by a thin HMA overlay. Another strategy may be to perform surface milling prior to the overlay.

(7) Thin asphalt overlay (0.13' or 1 1/2 inches may be done using 1/2-inch polymer modified HMA or RHMA. A 3/8-inch maximum grading may also be used.

(8) Digouts may be less cost-effective than full-depth reclamation (FDR) or partial-depth reclamation, if they exceed 20 percent of the surface area of the highway. One FDR strategy would be a cold-foam recycle, or pulverization. A partial-depth reclamation would be a cold-in-place recycle (CIR), or a hot-in-place recycle (HIR).

WHEN SHOULD THIN ASPHALT OVERLAYS NOT BE USED

Unless extensive surface preparation is performed or an interlayer is placed, thin asphalt overlays should not be used with severe distresses, such as the following:

- Wide thermal cracking,
- Potholes,
- Fresh, over-banded crack sealant, or
- Deep rutting.

Also, thin asphalt overlays should not be placed over OGAC without first removing the open-graded layer.

Most projects are suitable for thin asphalt overlays, depending on the budget and timing of planned major rehabilitation or re-construction. If major rehabilitation or re-construction is planned within the next three to five years, a less expensive alternative such as a chip seal or crack sealing treatment may be more cost-effective for a short period of time. Most thin asphalt overlay treatments have an estimated life of five to eight or more years.

BENEFITS

The reported benefits[4] of thin asphalt overlays include, but are not limited to, the following:

- Extended service life
- Protection from water damage
- Weathertight surface that protects against oxidation
- Improved aesthetics by providing color and texture in a single pass
- Correction of small underlying pavement irregularities such as rutting
- Smoother riding surface, or improved ride quality
- Improved pavement surface runoff
- Less energy than thick hot mix applications
- Quicker construction than multiple lifts required for thicker HMA overlays
- Elimination of most emulsion curing time and emulsion runoff, as can be the case with emulsion surface treatments

- Stops loss of fines from surface and removes surface distress
- Fills minor wheel path rutting without repairing before overlaying
- Better durability in higher-traffic areas (e.g., intersections) than other preventative maintenance treatments
- Open-Graded Asphalt Concrete (OGAC or OGFC) overlays can reduce excessive splash and spray
- Increases highway service life and reduces life-cycle costs
- Reduced noise levels with asphalt rubber or open-graded overlays
- Locally available experience
- Preferred by bicyclists and pedestrians over surface treatments including Cape Seals

III. TYPES OF THIN ASPHALT OVERLAY TREATMENTS

COMMON TYPES

Common types of HMA for thin overlays include:

1. Conventional performance-graded or polymer modified asphalt.

2. Asphalt rubber in either open-graded or gap-graded mixes.

3. Bonded wearing course (BWC) or ultra-thin bonded wearing course (UTBWC).

BWC and UTBWC are slightly different from the HMA overlays in that it is formed in one pass with the application of a heavy polymer-modified asphalt emulsion tack coat and a gap-graded polymer modified or asphalt rubber HMA layer. It is placed with a spray paver at a thickness of 1/2 to 3/4 inch. Figure 1 shows a spray paver and a spray paver screed, and Figure 2 shows the BWC paved surface behind the screed of a spray paver and the finished BWC surface.

a) Spray Paver b) Spray Paver Screed

Figure 1. Spray Paver Used to Place Bonded Wearing Courses

a) Behind Screed of Spray Paver b) Finished Surface

Figure 2. Close-Ups of a Bonded Wearing Course (BWC)

The mixes commonly used in California are given in Table 4. It is common practice for the asphalt lift thickness to be three times the nominal maximum aggregate size to achieve good compaction.[5] Caltrans also uses a 1/4 inch dense-graded mix for rut filling, which could be used as a thin overlay.

Table 4. Thin Asphalt Overlay Mixes Used in California

	BINDER TYPES			
	PG-GRADED	**POLYMER-MODIFIED**	**ASPHALT RUBBER (AR)**	**NOTES**
AGGREGATE TYPES				
1/2" DENSE GRADED	X	X		Not used for AR
3/8" DENSE GRADED	X	X		Not recommended for AR
OPEN GRADED	X	X	X	1/2" or 3/8" max. typical
GAP GRADED	X	X	X	1/2" or 3/8" max.
ULTRA-THIN BONDED WEARING COURSE OR BONDED WEARING COURSE	X	X		1/2" to 3/4" thick gap-graded HMA placed over a polymer-modified emulsified asphalt membrane

Caltrans has developed a climate region map to identify different binder types for different

regions within California. The climate map is shown in Figure 3 while the approved Caltrans binder grades are listed in Table 5.[6] Polymer-modified binders may be used in any climate region but are most commonly used in severe climate regions such as high desert and high mountain regions.

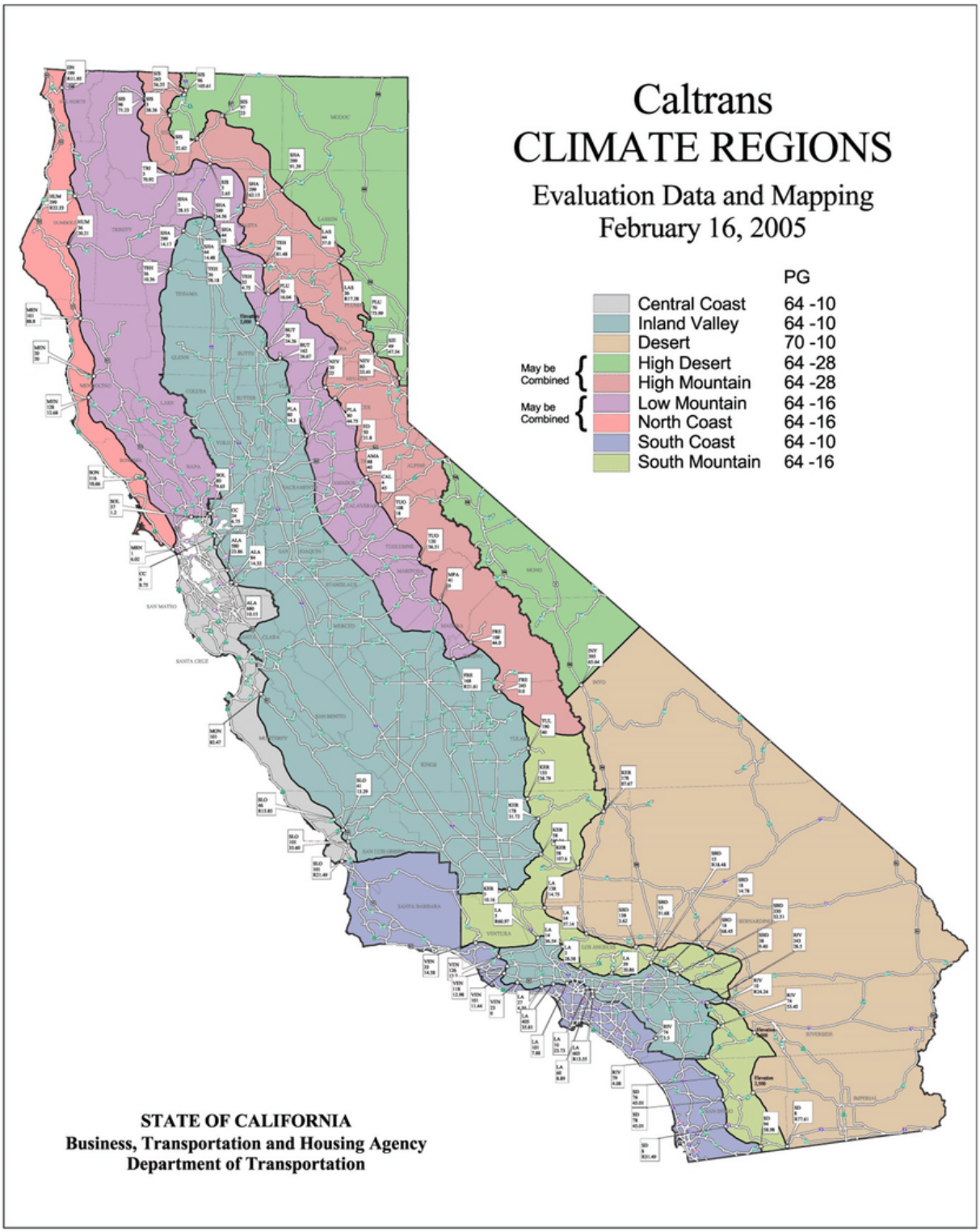


Figure 3. Caltrans Climate Regions Map

Table 5. Listed Binder Grades from Caltrans Highway Design Manual, 2020 (HDM, Table 632.1)

CLIMATE REGION (6)	BINDER GRADE FOR HOT MIXED ASPHALT (HMA) (1), (2)				
	DENSE-GRADED HMA		OPEN GRADED HMA		GAP AND OPEN GRADED RUBBERIZED HOT MIX ASPHALT (RHMA)
			PLACEMENT TEMPERATURE		
	TYPICAL	SPECIAL	> 70°F	≤ 70°F	
SOUTH COAST CENTRAL COAST INLAND VALLEY	PG 64-10	PG 70-10 or PG 64-28 M	PG 64-10	PG 58-34 M	PG 64-16
NORTH COAST	PG 64-16	PG 64-28 M	PG 64-16	PG 58-34 M	PG 64-16
LOW MOUNTAIN SOUTH MOUNTAIN	PG 64-16	PG 64-28 M	PG 64-16	PG 58-34 M	PG 64-16
HIGH MOUNTAIN HIGH DESERT	PG 64-28	PG 58-34 M	PG 64-28	PG 58-34 M	PG 58-22
DESERT	PG 70-10	PG 64-28 M	PG 70-10	PG 58-34 M or PG 64-28 M	PG 64-16

Notes:
(1) PG = Performance grade
(2) M = Modified (polymers, crumb rubber, or both)
(3) Refer to Topic 615 for determining a project's climate region.

OTHER AVAILABLE TECHNOLOGIES

Other technologies that have been developed and used in California HMA include the following:

- Warm Mix Asphalts (WMA) technologies allow for the placement of HMA or hot-applied chip seals at lower temperatures. This allows for longer haul distances, a longer opportunity for rolling, better nighttime paving, and lower mixing temperatures at the HMA hot plant. There are many different warm mix additives available for HMA and for rubberized HMA. This innovative technology can make HMA a greener product environmentally by using less energy for productions.

- Reclaimed Asphalt Pavement (RAP) is now being used in preventative maintenance projects by several state DOTs. Several of the states recently participated in an FHWA webinar describing their experience with the product. They had used the RAP as aggregate for chip seals and slurry surfacing as well as for HMA. It was reported that the RAP performed as well as virgin aggregate. RAP offers a cost-effective product that is environmentally sustainable and is an alternative to using

scarce aggregate resources.

- Fiberized bituminous membrane interlayer is applied over existing pavements prior to asphalt overlays to provide a crack relief layer and to provide a superior bonding layer so the new overlay does not delaminate from the existing pavement.

- Dry rubber mixes. These are being studied for use in California and elsewhere. These include the additional of 5–10% crumb rubber currently being studied by the University of California Pavement Research Center (UCPRC) and a proprietary product being used in the mid-west (Illinois and Missouri) and in the south (Georgia). The latter product is being manufactured under the trade name of Elastiko[R] by Asphalt Plus, LLC.

Figure 4 shows a project location map and the total quantity of construction using HMA with dry crumb rubber. Asphalt Plus, LLC cites the performance of the engineered dry crumb rubber as equal to that of polymer modified mixes and exceeds the performance of HMA using unmodified asphalt binder.[7]

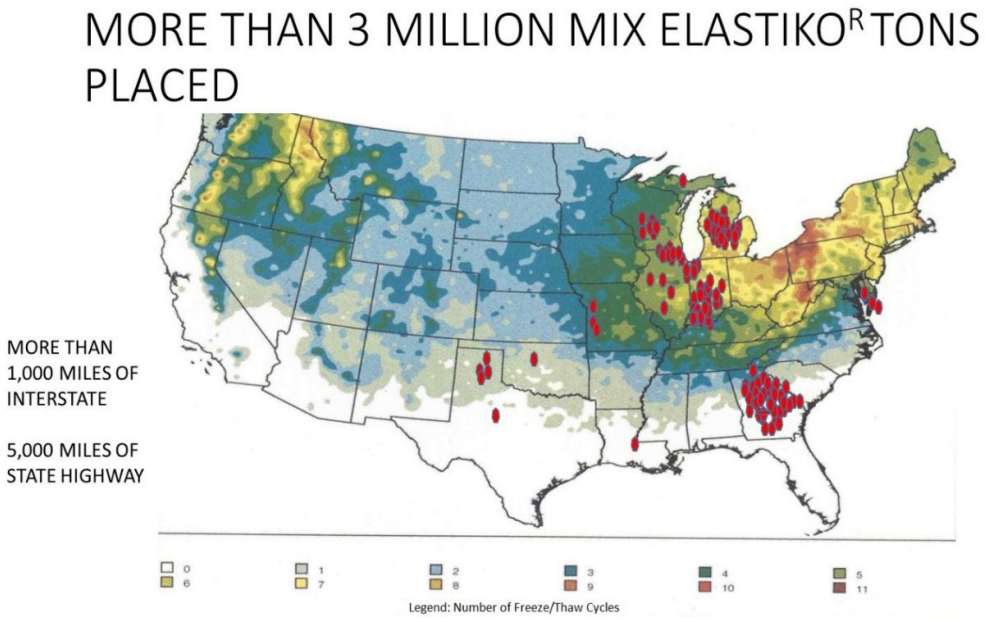


Figure 4. Project Locations on Freeze/Thaw Cycle Map of Dry Crumb Rubber (Asphalt Plus, LLC)

IV. DESIGN PROCESS FOR THIN ASPHALT OVERLAYS INCLUDING MATERIALS AND MIX DESIGN

This chapter presents topics on the development of the plans, specifications, and estimates for thin asphalt overlays specifically for local agency work. Specifications from the 2018 edition of the Standard Specifications for Public Works Construction ("the Greenbook"),[8] Caltrans 2018 Standard Specifications,[9] and the revised Standard Specifications are cited for the following mix types:

1. Dense-graded mixes
2. Gap-graded mixes
3. Open-graded mixes
4. Bonded wearing courses

PLANS

The first step in determining a design for thin asphalt overlays is to determine the distresses that must be corrected (i.e., rutting, roughness or ride deficiency, raveling, or potholes). Since a thin asphalt overlay project may be classified as pavement preservation, it is necessary to provide the reasons for choosing this maintenance strategy. For example, was this strategy triggered by a pavement management system (PMS) that is used by the Agency? Is this the best preventative maintenance strategy to meet the Agency's needs?

As discussed earlier, thin asphalt overlays may be used to correct a variety of distresses. For example, thin asphalt overlays may be used to correct minor rutting in the wheel paths. If the rutting is relatively severe (greater than 1 inch in depth), a two-lift overlay strategy may be necessary to correct the rutting. The first lift fills the ruts with a fine mix, and the second lift covers entire lane with a coarser dense-graded mix or a rubberized gap-graded (RHMA-G) mix. Another strategy for correcting rutting is to mill out the rutted areas and to fill the milled areas with new hot mix asphalt (HMA) prior to constructing the overlay. If the structural integrity is sufficient, the high areas can be milled off prior to the thin asphalt overlay.

Thin asphalt overlays may be selected to correct ride deficiencies due to pavement roughness. The International Ride Index (IRI) is a test that measures the roughness of the road, and it has a corresponding scale for rating the roughness from good to poor. A single thin overlay of HMA may not be able to bring a poor ride condition to a good ride condition. However, with milling and/or digouts, the thin asphalt overlay will achieve better smoothness. This pavement surface preparation will improve the quality of the thin asphalt overlay and should increase the service life of the pavement.

Thin asphalt overlays can provide short-term "fixes," but pavements with structural deficiencies should be programmed for a rehabilitation project. When thin asphalt overlays are 1 inch or less in thickness, added structural sufficiency is not considered

in a Caltrans pavement design. A $^{3}/_{8}$-inch mix should allow for higher compaction during construction. The more highly compacted HMA should produce a longer service life on the highway. If a $^{1}/_{2}$-inch mix is preferred, a minimum 0.15-foot overlay thickness is recommended.

Plan Procedure

This section discusses the plan development process for thin asphalt overlays, including:

- Identifying distresses
- Establishing project limits and environmental clearances
- Determining the HMA or AC type of thin asphalt overlay, and to depict the geometric details on a typical section
- Surface preparation estimates (i.e., crack sealing, milling, digouts)
- Preparing plans, specifications and estimates (PS&E)
    - Binder type
    - Liquid antistrip
    - Aggregate: NMAS, gradation, and other physical qualities (Availability? Percentage of allowable RAP?)
    - Mix temperature: Cover loads for longer-haul distances
- Number of working days in contract
- Work days, and work hours per day
- Environmental: Storm Water Pollution Prevention Plan, Lead Compliance Plan, etc.
- Project schedule: Advertise, award, and start date for contract
- Project approval and budget

Use the specifications that best meet the needs of the Agency. The standard specifications are Caltrans Standard Specifications and the Greenbook Standard Specifications. The contract special provisions include using one of these standard specifications, and then adding any special provisions that differ from the standard specifications referenced as the basis of the contract.

A tentative map needs to be prepared showing the project limits, the project's footprint, a typical cross-section, and a description of the work. The final plan sheets for a thin asphalt overlay should include the following:

- Cover sheet with project description, location map, work limits, construction limits, and surrounding streets and cities, and a block for the engineer's signature and Agency.

- Typical sections for various locations or stationing within the project

- Detailed plan sheets for intersections, and limits of work (table for all driveways and intersections)

- Multiple sheets to include total layout of project and any utility details, i.e., manholes, valve boxes, drainage inlets, and inductive loop detectors

- Construction signing plan showing sign locations and a list of required signs

- Lane closure details and detours, with required traffic control plans

- Quantity sheet with table of item quantities (must agree with item bid sheet in special provisions)

Caltrans 2018 Standard Plans and revised Standard Plans are available online.[10] These plans cover many details needed for typical projects and are often used by many agencies along with their own agency's standard plans.

SPECIFICATIONS AND MIX DESIGN

Plans and special provisions are part of the contract bid documents. Most local agencies use the 2018 edition "Greenbook" Standard Specifications for Public Works Construction,[8] or the 2018 Caltrans Standard Specifications.[9] However, there are differences between the two sets of specifications.

The term "asphalt concrete" is used in the Standard Specifications for Public Works Construction (the "Greenbook"). The term "hot mix asphalt" (HMA) is not used. HMA is the national term for Superpave mixes which are specified by Caltrans. Mixes in the Greenbook follow the Hveem method of mix design. Both the Greenbook and Caltrans specifications do incorporate the Performance Graded (PG) binder (paving asphalt) specification. In the Greenbook, paving asphalt (unmodified) is specified in Subsection 203-1. For both the Greenbook and Caltrans, the PG grade specified should conform to the climate region map previously shown in Figure 3 and the PG grading as listed in Table 5.

Selection between the Greenbook specifications or the Caltrans specifications should be determined early in the project's design phase. It is important not to mix the Greenbook and Caltrans standard specifications in the project's contract special provisions. Most private laboratories should be able to perform either Hveem or Superpave mix designs.

All thin asphalt concrete overlays should be preceded by a tack coat of emulsion or hot asphalt. Both the Greenbook and Caltrans Standard Specifications direct tack coat applications prior to overlay placement. The Greenbook specifies PG 64-10 paving asphalt,

or SS-1h emulsified asphalt. Caltrans specifies tack coats in Section 39-2.01B(10). Tack coat application rates have been changed in the Caltrans Revised 2018 Standard Specifications in Section 39-2.01C(3)(f).[11] The tack coat must comply with the revised specifications for asphaltic emulsion[11] or asphalt binder.

Appendix C includes helpful web links to Caltrans Local Assistance Procedures Manual for guidance on project development.

Balanced Mix Design Concept

Design binder content and optimum binder content are often used interchangeably; however, they mean two different things. There is only one true optimum binder content. The optimum indicates the best binder content, based on the intended application, for performance requirements and ultimately for economics. The goal is to find the optimum binder content for a mix that takes into account aging, climate conditions, traffic, and location within the pavement structural section to best meet its intended application. Figure 5 shows the balanced mix design concept which is now being evaluated in many parts of the USA.[12]

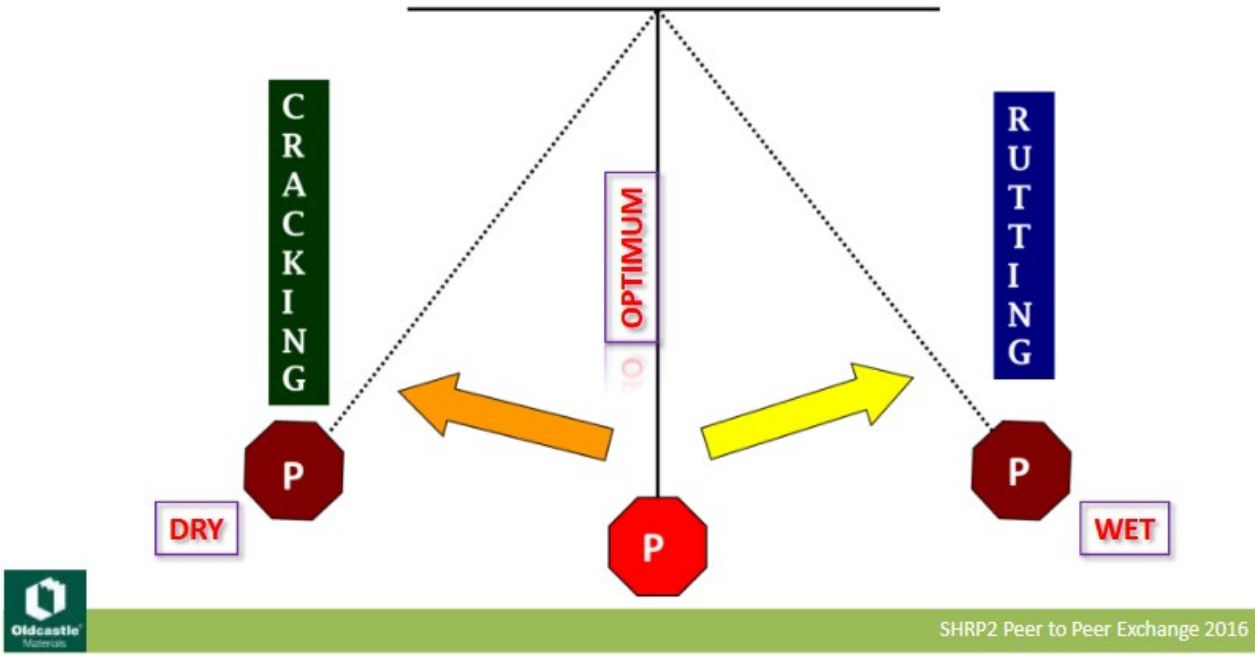


Figure 5. Balanced Asphalt Concrete Mix Design Concept

Specifications for Asphalt Concrete: Greenbook, 2018 Edition

The Greenbook is structured such that materials and material production requirements are specified in Part 2, “Construction Materials,” and Construction Methods are specified in Part 3. This section of the manual covers several different asphalt concrete (AC) mix types from the 2018 Greenbook,[8] including:

- Performance Graded (PG) asphalt binders (Subsection 203-1)
- Asphalt rubber binders and mixes (Subsection 203-11)
- Dense-graded mixes (Subsections 203-6, 203-14, and 203-16)
- Gap-graded mixes (Subsections 203-11, 203-13, and 203-14)

Porous pavements are also specified but not widely used by agencies in Southern California for roads and streets.

Subsection 203-1, Paving Asphalt

This subsection specifies paving asphalt for four performance grades (PG 64-10, PG 64-16, PG 64-28, and PG 70-10) commonly used in Southern California.

Subsection 203-6, Asphalt Concrete

The following excerpts from Subsection 203.6.1 are important:[8]

1. "Asphalt concrete shall be the product of mixing mineral aggregate and up to 20 percent reclaimed asphalt pavement (RAP) with asphalt binder at a central mixing plant. "
2. "When so specified in the Special Provisions, asphalt concrete may contain greater than 20 percent RAP and/or be produced using a warm mix asphalt (WMA) technology." If WMA technology is used, WMA appears after the class and grade "III-CE-PG 64-10-WMA." WMA technology must be specified in the special provisions for its use.
3. "Unless otherwise specified in the Special Provisions or shown on the Plans, asphalt concrete mixes shall conform to 203-6.4."

Asphalt Concrete Mixes

Subsection 203-6.4 specifies dense-graded mixes. This is the subsection where asphalt concrete is to be produced for a specific project unless the Agency specifies in the Special Provisions Type III mixes specified in 203-6.5.[8]

Mixes are designated by "class" and "grade." "Class" is the class of combined aggregate gradation as shown in Table 203-6.4.4. "Grade" is the climatic grade of PG paving asphalt. The Greenbook nomenclature for mixture designation is specified in 203-6.4.1.[8]

This subsection specifies a limit of 20 percent reclaimed asphalt pavement (RAP). If the Agency requires a different limit, it must be specified in the Special Provisions.[8]

Table 203-6.4.4 shows the requirements for the composition and grading of the various dense-graded mixes. There are no open-graded or gap-graded mixes shown in this table. For thin lift asphalt overlay applications, "C2" and "D2" are the gradations most

commonly specified.[8]

Type III Asphalt Concrete Mixes

Subsection 203-6.5 specifies dense-graded asphalt concrete mixes which differ in gradation from those specified in 203-6.4. In general, Type III mixes will be finer in gradation and texture than mixes produced under 203-6.4.[8]

The requirements for Type III mixes were in Part 4 in earlier editions of the Greenbook. These specifications were developed and included to address production difficulties and compliance in areas of "soft" (porous) aggregate. When the Greenbook was restructured, and Subsection 203-6 revised and updated, the specifications for Type III mixes were moved into Part 2. In general, Type III mixes are most commonly specified in parts of Orange County and in San Diego County.

Type III mixes are not intended to be an "alternate" to the mixes specified in 203-6.4 in the sense of substitution. The word "alternate" should be disregarded wherever it appears when used in this context.

Here, too, mixes are designated by "class" and "grade." "Class" is the class of combined aggregate gradation as shown in Table 203-6.5.4 (A). "Grade" is the climatic grade of PG paving asphalt. The Greenbook nomenclature for mixture designation is specified in 203-6.5.1.[8]

This subsection also specifies a limit of 20 percent reclaimed asphalt pavement (RAP). If the Agency requires a different limit, it must be specified in the Special Provisions.

Table 203-6.5.4 (A) shows the requirements for the composition and grading of the various dense-graded mixes. There are no open-graded or gap-graded mixes shown in this table. For thin lift asphalt overlay applications, "C2," "C3," and "D" are the appropriate gradations.[8]

Asphalt Rubber Hot Mix (ARHM)

As stated in Subsection 203-11, ARHM is a mixture of gap-graded aggregate, crumb rubber, paving asphalt (PG 64-16), and asphalt modifier (extender oil). Reclaimed asphalt pavement (RAP) is not allowed in ARHM mixes.[8]

ARHM is one of three specifications in the 2018 Edition for mixes produced using a crumb rubber modified binder. Each of the mixes are different in specification and composition and should not be considered as "equals." There are also some differences between ARHM and the rubberized hot mix asphalt (RHMA) specified in the 2018 Caltrans Standard Specifications.

ARHM is sometimes referred to as "the wet process" or a "field blend." These terms are not reflective of the mixture, but only of how the asphalt rubber binder is produced. "Wet" refers to the crumb rubber being mixed with the paving asphalt in a blending unit, following by agitation and heating in a "reaction" tank. "Field blend" refers to where the asphalt rubber binder is produced: at a portable or stationary batch or drier-drum plant.

Crumb rubber is mixed with paving asphalt and asphalt modifier in a blending unit to produce asphalt rubber binder. Asphalt modifier, sometimes referred to as "extender oil," slightly softens the crumb rubber. The asphalt rubber binder is then heated and agitated in a reaction tank for a specified period of time and at a range of temperatures. Once this time has passed, the asphalt rubber binder is tested for compliance with the specified viscosity. If in compliance, it is conveyed to the plant where it is mixed with gap-graded aggregate.

Subsection 203-11.3 specifies ARHM by type and class. "Type" refers to the type of gradation, which is gap-graded (GG). No other type of gradation is specified for ARHM. ARHM cannot be produced using a dense or open gradation under this subsection. "Gap-graded" refers to a gap in the retention between certain sieve sizes. This "gap" results in greater voids in the aggregate structure, which is needed to accommodate the higher binder content. "Class" refers to the class of combined aggregate gradation. Table 203-11.3 shows the requirements for the various classes. For thin lift overlay applications, Class "C" or "D" is the appropriate gradation. Table 203-11.3, footnote 1, allows for a production tolerance in binder content of ± 0.5 percent.[8]

Tire Rubber Modified Asphalt Concrete (TRMAC)

Before specifying TRMAC, the Agency should confirm its availability.

TRMAC is a mixture of tire rubber modified paving asphalt, aggregate, and up to 20 percent reclaimed asphalt pavement (RAP). TRMAC is the second of the three specifications currently in the Greenbook for mixtures produced using a crumb rubber modified binder. Each of the mixtures is different in specification and composition, and they should not be considered as "equals." TRMAC is unique to the Greenbook. The Caltrans Standard Specifications do not contain a similar mixture.[8]

TRMAC is sometimes referred to as "the terminal blend." This term is not reflective of the mixture, but only of how the binder is produced. The binder is produced at a terminal or refinery by blending with paving asphalt. In the production process, crumb rubber is dissolved into the paving asphalt, thus modifying its properties. Tables 203-14.2.1 (A) and (B) show the solubility requirements.[8]

For a further discussion of crumb rubber modified binders, refer to "Rubber Roads: Waste Tires Find a Home," a University of California Pavement Research Center Pavement Technology Update.[13] For a further discussion of polymer modified binders, refer to "Tech Topic Number 7, Performance Graded Polymer Modified Asphalts in California" from the University of California, Berkeley, Institute of Transportation Studies.[10]

Crumb Rubber Modified Asphalt Concrete Gap Graded (CRUMAC-GG)

As stated in Subsection 203-13, CRUMAC-GG is a mixture of gap-graded aggregate, crumb rubber, and paving asphalt (PG 64-16). Though this product is not used at this time, it is included to show the differences between this mixture, TRMAC, and ARHM.

CRUMAC-GG is the third of three specifications currently in the Greenbook for mixtures

produced using a crumb rubber modified binder. Each of the mixtures are different in specification and composition and should not be considered as "equals."

CRUMAC-GG is sometimes referred to as "the dry process." This term is not reflective of the mixture, but only of how the crumb rubber is added to the mixture. Crumb rubber is added similarly to how the aggregate is added. The aggregate, paving asphalt, and crumb rubber are mixed together at the same time in the batch or drier-drum plant.

Polymer Modified Asphalt Concrete (PMAC)

As stated in Subsection 203-16, PMAC is a mixture of polymer modified paving asphalt, aggregate, and up to 20 percent reclaimed asphalt pavement (RAP).[8]

PMAC is specified by "class" and "grade," similar to mixes produced under Subsection 203-6. "Class" refers to the combined aggregate gradations shown in Table 203-6.4.4. "Grade" refers to the grade of polymer modified paving asphalt. The requirements for "PG-PM" (performance graded, polymer modified) paving asphalt are those shown in Table 203-14.2.1 (B) except for the recycled whole scrap tire rubber content. The specific mixture required must be specified in the Special Provisions or shown on the Plans.[8]

This subsection specifies a limit of 20 percent reclaimed asphalt pavement (RAP). If the Agency requires a different limit, it must be specified in the Special Provisions. For thin lift applications, C2 and D2 are the appropriate gradations. Performance grade, polymer modified (PG-PM) binders are more commonly specified in high and low desert climatic areas, and on roadways with a high traffic index.[8]

For a further discussion of polymer modified binders, refer to "Tech Topic Number 7, Performance Graded Polymer Modified Asphalts in California" from the University of California, Berkeley, Institute of Transportation Studies.[10]

Specifications for HMA: 2018 Caltrans Standard Specifications

There are several basic differences between the Greenbook and Caltrans specifications. As stated earlier, Caltrans specifies Superpave HMA mix design. Superpave requires laboratory testing different from Hveem mix design which is used in the Greenbook. Another difference in the specifications is that most Caltrans paving projects use quality assurance and quality control for payment purposes. Thin asphalt overlays may not require a lot of statistical quality assurance due to method compaction normally being specified.

If the contractor supplies a mix that is used in the project that doesn't meet project specifications, the work should be subject to pay deductions, or it may be removed and replaced as ordered by the engineer. Removal and replacement is not usually performed, because it may be more cost-effective for a contractor to take the deduction for the work that is out of contract compliance.

Hot Mix Asphalt (HMA), Caltrans 2018 Standard Specifications

Section 39-2 of the Caltrans 2018 Standard Specifications includes specifications for the following types of HMA:[9]

1. Type A HMA
2. Rubberized Hot Mix Asphalt Gap Graded (RHMA-G)
3. Open-Graded Friction Course (OGFC)
4. Bonded Wearing Course (BWC)
5. Minor HMA

It is also recommended that the QC plan and test results included in Sections 39-2.01A(3) (d) be implemented to include reporting within three business days of a request as shown in the Revised 2018 Caltrans Standard Specifications if the request includes required testing in the Agency's QC plan[11] and 39-2.01A(d)(d) should not apply to local agency projects.

Section 39-2.07A(4)(a) General, from Caltrans 2018 Standard Specification states the following:[8]

Before the addition of asphalt binder and lime, the aggregates must comply with the Section 39 requirements shown in Table 6.

WMA should be considered for all thin asphalt overlays due to the increased heat loss and its increased surface area for the mass of HMA being placed. Thin lifts of HMA cool much more quickly than thicker lifts and have a short amount of time to achieve compaction. Compaction is a very important component of construction for HMA longevity. Caltrans uses gap-graded or open-graded mixes for all their rubberized asphalt concrete pavements, and it is usually used as a wearing course over a thicker dense-graded non-rubberized mix. This design strategy has been working well by providing a quieter ride, with longer wearing characteristics.

Table 6. Aggregate Quality

QUALITY CHARACTERISTIC	TEST METHOD	REQUIREMENT HMA (TYPE A)	REQUIREMENT RHMA-G	REQUIREMENT OGFC
PERCENT OF CRUSHED PARTICLES: COARSE AGGREGATE (MIN, %) **ONE FRACTURED FACE** **TWO FRACTURED FACES** **FINE AGGREGATE (MIN, %) (PASSING NO. 4 SIEVE AND RETAINED ON NO. 8 SIEVE); ONE-FRACTURED FACE**	AASHTO 335	95 90 70	-- 90 70	 90 90
LOS ANGELES RATTLER (MAX, %) **LOSS AT 100 REV.** **LOSS AT 500 REV.**	AASHTO T 96	 12 40	 12 40	 12 40
SAND EQUIVALENT (MIN) (1)[a]	AASHTO T 176	47	47	--
Flat and elongated particles (max, % by weight at 5:1)	ASTM D4791	10	Report Only	Report Only
Fine aggregate angularity (min, %)[b]	AASHTO T 304, Method A	45	45	--

[a]The reported value must be the average of 3 tests from a single sample. Use of a sand reading indicator is required as shown in AASHTO T 176, Figure 1. Sections 4.7, "Manual Shaker," 7.1.2, "Alternate Method No. 2," and 8.4.3, "Hand Method," do not apply. Prepare the stock solution as specified in section 4.8.1, "Stock solution with formaldehyde," except omit the addition of formaldehyde.

[b]The Engineer waives this specification if the Type A HMA contains 10 percent or less of non-manufactured sand by weight of total aggregate, except if your JMF fails verification. Manufactured sand is fine aggregate produced by crushing rock or gravel.

Sections 39-2.02B(4)(b), 39-2.03B(4)(a), and 39-2.04 specify Aggregate Gradations from the 2018 Standard Specifications and they state that for the thin asphalt overlays the gradations should be for either the $^{3}/_{8}$-inch or the $^{1}/_{2}$-inch mixes depending on the overlay thicknesses as shown in Table 7. Table 8 shows the gradations for the $^{1}/_{2}$-inch, $^{3}/_{8}$-inch, and the No. 4 mixes.[14] The No. 4 mixes may be used for rut filling prior to placing a thin asphalt overlay.

If smoothness is a requirement for the Agency's project, then the Section 39-2.01A(4)(i)(III) Pavement Smoothness Specification should be followed. However, since many local agency projects have numerous intersections with lower traffic speeds, this specification may not be applicable. A "straight edge" specification may be more applicable for thin asphalt overlays. If the Agency considers this minor HMA with Caltrans Standard Specifications, then the inertial profiler requirement in Section 36-3 would not apply.

Table 7. Maximum Aggregate Size of Mix for Overlay Thickness

TYPE A HMA PAVEMENT THICKNESS SHOWN	MAXIMUM AGGREGATE SIZE
0.10 FOOT	3/8"
GREATER THAN 0.10 TO LESS THAN 0.20 FOOT	1/2"
RHMA-G PAVEMENT THICKNESS SHOWN	
0.10 TO LESS THAN 0.20 FOOT	1/2"
HMA-O PAVEMENT THICKNESS SHOWN	
0.10 FOOT OR GREATER TO LESS THAN 0.15 FOOT	1/2"
RHMA-O AND RHMA-O-HB PAVEMENT THICKNESS SHOWN	
0.10 FOOT OR GREATER	1/2"

Table 8. Aggregate Gradations for Type A HMA, RHMA-G, and OGFC

(PERCENTAGE PASSING) SIEVE SIZE	TARGET VALUE LIMIT 1/2" TYPE A HMA		TARGET VALUE LIMIT 1/2" RHMA-G		TARGET VALUE LIMIT 1/2" OGFC	
3/4"	100	--	100	--	100	--
1/2"	95–98	TV ± 5	90–98	TV ± 5	95–100	TV ± 6
3/8"	72–95	TV ± 5	83–87	TV ± 6	78–89	TV ± 6
No. 4	52–69	TV ± 5	28–42	TV ± 5	28–37	TV ± 7
No. 8	35–55	TV ± 5	14–22	TV ± 6	7–18	TV ± 5
No. 30	15–30	TV ± 4	--	--	0.0–10	TV ± 4
No. 200	2.0–8.0	TV ± 2	0.0–6.0	TV ± 2	0.0–3.0	TV ± 2
SIEVE SIZE	**TARGET VALUE LIMIT 3/8" TYPE A MIX**		**SIEVE SIZE**		**TARGET VALUE LIMIT — No. 4 TYPE A MIX**	
1/2"	100	--	1/2"		100	--
3/8"	95–98	TV ± 5	3/8"		100	--
No. 4	55–75	TV ± 5	No. 4		95–98	TV ± 5
No. 8	30–50	TV ± 5	No. 8		70–80	TV ± 6
No. 30	15–35	TV ± 5	No. 30		34–45	TV ± 5
No. 200	2.0–9.0	TV ± 2	No. 200		2.0–12.0	TV ± 4

RAP may be substituted for up to 25 percent of the virgin aggregate in the mix. If RAP substitution is 15 percent or less, fractionalization is not required. However, for the gradations needed for the thin asphalt overlay mixes, it would be best to use the fine portion for 98 to 100 percent passing the 3/8-inch screen.

Gap-Graded Rubberized Hot Mix Asphalt (RHMA-G), Section 39-2.03

Section 39-2.03 describes the requirements for RHMA-G both with and without WMA and specifies the requirements for the asphalt modifier. Table 6, Table 7, and Table 8 list the aggregate qualities, recommended overlay thicknesses, and gradations.

Caltrans also has an Authorized Materials List for Crumb Rubber Modifiers (CRM), and the specification also requires that the CRM is 75.0 ± 2.0 percent scrap tire crumb rubber and 25.0 ± 2.0 percent high natural scrap tire crumb rubber by total weight of CRM. It also specifies that the modifier must be a resinous, high-flash-point, aromatic hydrocarbon and must comply with the requirements in this section. The modifier must be from 2.0 to 6.0 percent by weight of the asphalt binder in the asphalt rubber binder.[9]

The CRM must comply with the requirements listed in this section with the asphalt modifier being from 2.0 to 6.0 percent by weight of the asphalt binder in the asphalt rubber binder. The required testing for crumb rubber modifier or asphalt rubber binder is given in this section. CRM for asphalt rubber binder is also shown, as well as the asphalt rubber binder reaction design profile from 45 minutes to 1440 minutes.[9]

Mixing specifications are listed for proportioning and mixing asphalt binder, asphalt modifier, and CRM simultaneously. Also specified are mixing times and temperatures. The asphalt rubber binder must comply with the requirements shown in “Mix Requirements for Asphalt Binder.” The aggregate quality and gradations are included in Table 6 and Table 8 for RHMA-G.[9]

Section 39-2.03B(5) states that for RHMA-G production of the asphalt rubber binder temperature must be from 375 to 425°F when mixed with aggregate. It is prudent to use at least a liquid antistrip with the binder for these mixes. It is allowable to use lime treatment for RHMA-G, but the liquid antistrip is more economical. In most cases, by using a liquid antistrip as a preventative measure, the AASHTO T-283 testing can be eliminated.[9]

Open-Graded Friction Courses (OGFC)

Section 39-2.04 includes specifications for producing and placing open-graded friction courses (OGFC). Open-graded friction courses include HMA-O, RHMA-O, and RHMA-O-HB. These mixes may also be produced using WMA technology. Table 6, Table 7, and Table 8 also list the aggregate qualities, recommended overlay thicknesses, and gradation.[9]

The smoothness requirements in Section 39-2.04A(4)(c)(ii) shouldn’t apply to local agencies. Most of the roads under local agency jurisdiction have lower traffic speeds and the use of the 12 feet straight edge specification may be more appropriate for agencies.[9]

As stated in Section 39-2.04B(1) the OGFC when mixed with asphalt binder, aggregate must not be more than 325°F except aggregate for OGFC with unmodified asphalt binder, HMA-O, must be not more than 275°F. Asphalt rubber binder in RHMA-O and RHMA-O-HB must comply with Section 39-2.03B(3). Aggregates must comply with the Section 39-2.04B(4) as shown in Table 6, Table 7, and Table 8.

If lime treatment is required, one can reduce the lime ratio for the combined aggregates from 1.0 to 0.5 percent for OGFC and eliminate antistrip from the binder.

Section 39-2.04B(5) also specifies that sand use for spreading over RHMA-O and RHMA-

O-HB pavement must be free of clay or organic matter. Sand, must comply with Section 90-1.02C(3) and it is used to prevent pickup of the wearing course from traffic.[9]

Bonded Wearing Courses (BWC)

Sections 39-2.05 includes specifications for producing and placing BWC. Placing a BWC consists of applying an asphaltic emulsion for bonded wearing course as specified in Section 94 of the 2018 Caltrans Revised Standard Specifications,[11] and placing the specified HMA in a single pass with an integrated paving machine. Asphaltic emulsion must be submitted with a Safety Data Sheet (SDS) for each shipment of emulsion as specified in Section 94-1.01C. BWC must comply with the specifications for RHMA-G, RHMA-O, or HMA-O.[9]

The JMF submittal should include the asphaltic emulsion target residual rate and the weight ratio of water to bituminous material in the original asphaltic emulsion. “Asphaltic Emulsion for BWC” lists the testing requirements for BWC asphaltic emulsion.[9]

Also, Section 39-2.05A(3)(c) states to only apply asphaltic emulsion on dry or damp pavement with no free water.[9]

The application temperature for emulsion is from 120 to 180°F and it is placed in a single application at the residual rate specified for the condition of the underlying surface. Asphaltic emulsion must have a target residual rate for the surfaces to receive the emulsion as shown in Asphaltic “Emulsion Target Residual Rate” in this section of the Caltrans Standard Specifications. The asphaltic emulsion application rates may be changed with approval by the Resident Engineer.[9]

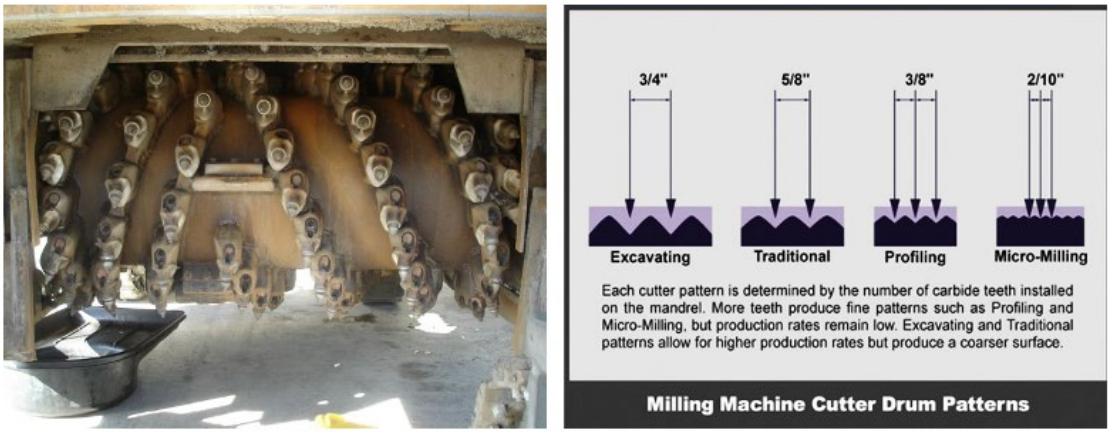
EXISTING SURFACE PREPARATION

The field condition of the roadway must be inspected for previous repairs prior to finalizing the project design. It must be determined if it was previously overlaid and if it has recent crack sealant, chip seals, slurry surfacing, or OGFC. Thermoplastic pavement markers and raised pavement markers must be removed prior to the overlay.[9]

The surfacing repairs may be handled differently by different agencies. Some agencies may choose to have their own maintenance crews perform crack sealing, patching, and digouts. Other agencies may put the surface repairs on a separate contract a year prior to the thin asphalt overlay. However, some of the surface preparation work needs to be performed by the thin asphalt overlay contractor directly prior to the overlay. Raised pavement markers and thermoplastic pavement markers need to be removed directly before the new HMA is placed. Thermoplastic must be removed because it can melt and bleed through the new overlay.

Micro-milling or cold milling is often used prior to the thin asphalt overlay to remove oxidized or distressed pavement: it creates a more uniform surface for the thin asphalt concrete placement and results in a smoother finished overlay as shown in Figure 6. This is becoming more popular with many local agencies, but caution should be exercised on how much of the existing pavement is to be milled off with regard to its structural sufficiency. Caltrans, Section 39-3.04, specifies cold planing asphalt concrete pavement, while the Greenbook specifies

cold milling in Section 404. Cold milling is used for removing a greater thickness, generally greater than one inch, of the existing HMA, while micro-milling is generally used for removing a thinner layer of the existing pavement, one inch or less, for smoothing a rough surface and improving the bond.



a) Cold Milling Head **b) Cutter Drum Patterns on Pavement**

Figure 6. Cold Milling Head and Cutter Drum Patterns

Micro-milling is also specified in Section 405 of the Greenbook as a treatment prior to paving. There is currently no similar specification in the Caltrans Standard Specifications, but there are many standard special provisions where it is covered. Micro-milling is similar to cold milling, except that the milling machine uses a different drum which has more teeth that are more closely spaced than those on a cold milling drum. The additional teeth create a finer spacing of the grooves with lesser depth, resulting in a surface with more closely spaced ribs. Figure 7 show a micro-milling head and a micro-milled surface. Milling the surface, whether by cold milling or micro-milling, results in a greater surface area being created. Thus, the tack coat application rate must be increased to cover the increased surface area of a rougher surface.

a) Micro-milling Head **b) Micro-milled Surface**

Figure 7. Micro-Milling Head and Micro-Milled Surface

“Mill and fill” is a common term for a project that consists of the removal by milling of the existing asphalt concrete to a certain depth, and replacement of the milled thickness with new mix. This strategy is often used for severe fatigue distress (alligator cracking) in the wheel paths. The wheel path area is milled, and it is paved to match the existing surface.

Loop detectors are lost in any mill and fill project. Loop detector replacement and the adjustment of manholes, survey monuments, and other permanent surface facilities are also often overlooked by local agencies.

Synchronized traffic signals are very common. The entire synchronization is generally lost if even one approach is taken out of operation. Signals should be turned onto fixed timing mode prior to the start of the project. Conduit stub outs should be marked and protected in place if possible.

Crack sealants should be applied prior to a thin overlay, but the thin asphalt overlay may develop bumps over the crack sealant if not used properly. If the sealant was placed using an over- banded technique, it may have to be removed prior to placing a new thin asphalt overlay. The bumps can be prevented if a low expansive type sealant is applied, and it can also be minimized by striking the sealant off at the top of pavement, and not using the banded technique.

Thin asphalt overlays may be placed directly over a chip seal, which has a rougher surface than an HMA pavement surface. A chip sealed surface may require a heavier application of tack coat due to its greater surface area than an HMA surface that has not been chip sealed.

Existing slurry surfaces can be paved over if there is no evidence of delamination or stripping of the existing HMA. If potholes are developing, the potholes must be dug out and repaired prior to an overlay. If the underlying pavement is stripping, both the existing slurry seal and the existing pavement must be entirely removed prior to placing additional pavement. Potholes can be an indicator of a stripping problem.

If the existing pavement is OGFC, it should be removed prior to placing any additional thin asphalt overlay. The OGFC is very prone to develop stripping if it is capped with a dense-graded or gap-graded mix. This can cause premature failure of the new thin asphalt overlay. The design engineer must choose a suitable asphalt mix for the thin asphalt overlay project, with consideration for mix aggregate nominal maximum grading size, gradation, and binder type. Also, there will be re-striping, pavement markers, and perhaps rumble strips with the new overlay. The guard railing will also need to be reviewed for minimum height standards. These items must be included in the engineer’s cost estimate.

COST ESTIMATES

Once the design engineer has determined the project quantities, an Engineer’s Estimate is developed, and a bid item sheet is created as part of the bid package. For a thin asphalt overlay project, an example of typical bid items is shown in Appendix A. Caltrans has listings of bid items and unit prices at their website. The reader should review the search tips to find the project’s appropriate item numbers at: https://sv08data.dot.ca.gov/contractcost/searchtips.htm. Usually, a contingency of 10 to 15 percent is added to the engineer’s estimate to cover

costs of change orders and possible quantity overruns. An example of typical bid items for the Greenbook is shown in Appendix B.

Project Approval and Budget

After the Plans, Specifications, and Estimates (PS&E) have been completed, the project must be submitted to the approving agency's board for project approval and budget. During the approval process there will be an Agency meeting. The design engineer or the director of public works makes a presentation for the project. This presentation should include a copy of the plans, specifications, and cost estimate, as well as a preliminary project schedule. Included with the presentation, there should also be a request for permission to advertise for bids from qualified contractors.

Bidding and Contract Award

Once the project is approved and with the allocation of funding, the project is advertised for bids. Usually, an Agency will require a minimum of three bids from qualified contractors. If the criteria isn't met, then it may be re-advertised for bids. The director of public works usually makes a recommendation that the contract be awarded or re-bid. If the approving agency believes that the lesser number of bids received is adequate, it may be awarded.

OTHER ITEMS TO CONSIDER

Other items may have to be considered in the area of plans by local agencies include developing information on the following:

- Number of working days, and allowable hours to perform work
- Haul distances and mix temperatures (cover loads?)
- Schedule (advertise, award, start work, end work, and accept contract)
- Availability of materials, i.e., aggregates, binders, and additives
- Environmental Clearance Plan, CEQA[15]
- Storm Water Pollution Prevention Plan[16]
- Lead Compliance Plan[17]

V. CONSTRUCTION OF THIN ASPHALT OVERLAYS

When constructing a thin asphalt overlay, the following considerations are necessary:

- The surface of the existing pavement should be made ready for the production and placement of the overlay. This step should consist of crack sealing and digouts as needed. This work should be done in advance of the construction of the new overlay.

- Weather considerations during construction can have a direct impact on performance. The weather should be warm and dry to promote proper binder setting and curing. Don't start work if rain is in the weather forecast.

- Prior to construction there should be a pre-construction meeting to discuss the following:

    - Mix design must be completed to fit pavement traffic and surface conditions. The procedures identified in the prior chapter can be considered.

    - Production of the mix should meet either the Greenbook or Caltrans specifications.

- Before placing a thin asphalt overlay, prepare and clean the existing surface. If needed, fill any potholes and seal cracks up to $^1/_4$ inch.

- Apply a tack coat to ensure good bonding.

- Place and compact the mix according to the required specifications.

- Traffic control should reduce traffic speeds until shoulder backing and striping are completed.

- Apply temporary pavement striping before opening to uncontrolled traffic.

MIX DESIGN APPROVAL PROCESS

The mix design processes for the Greenbook and for Caltrans were discussed in the previous chapter, and the approval process is briefly summarized in this section.

Greenbook

Requirements are specified in Subsection 203-6.3, Job Mix Formula (JMF) and Mix Designs.[8] The mix design procedure is based on the Asphalt Institute Publication MS-2, "Asphalt Mix Design Methods,"[18] which states, "The goal of mix design is to establish mix formulation and process control targets known as the job mix formula (JMF)." The JMF is based on the mix design requirements. The same publication, on page 2, states, "The objective of the mix design is to determine the combination of asphalt cement and aggregate that will give long-lasting performance as part of the pavement structure."

The Greenbook specifications are based on the Hveem method of mix design. Mix designs must result in mixes that conform to specific requirements for binder content, stability, and air voids. The Hveem method is discussed in detail in Chapter 8 of the Asphalt Institute publication. [18]

Important excerpts from Subsection 203-6.3 of the 2018 Greenbook are as follows:

1. "The Contractor shall submit … a JMF that summarizes each asphalt concrete mix design for each class and grade of asphalt concrete required to construct the Work."

2. "When greater than 25 percent RAP is to be included in a mixture, a mix design shall be submitted."

3. "…the asphalt binder content shall be defined as the total bituminous material present in the mix consisting of the blend of virgin paving asphalt, residual paving asphalt from RAP, and recycling agent."

Caltrans

Section 39-2.01A(3), Submittals, specifies what is included for a Job Mix Formula (JMF) for HMA. General, Section 39-2.01A(3)(b)(i), includes submittal requirements with the exception of miscellaneous areas. The following requirements are listed from the Caltrans 2018 Standard Specifications for HMA mixes, except for minor hot mix asphalt.[9] An Agency may modify these requirements to suit their project needs.

1. Mix design documentation on a Contractor Hot Mix Asphalt Design Data form dated within 12 months of the submittal for the JMF verification.

2. JMF verification on a Caltrans Hot Mix Asphalt Verification form and the Contractor Hot Mix Asphalt Design Data form that was submitted for the JMF verification, if applicable.

3. JMF renewal on a Caltrans Job Mix Formula Renewal form, if applicable.

4. Safety Data Sheet (SDS) for:

    4.1. Asphalt binder.

    4.2. Supplemental fine aggregate except fines from dust collectors.

    4.3. Antistrip additives.

The contractor's hot mix asphalt design data form must also identify the AASHTO resource accredited lab responsible for the mix design and show documentation on aggregate quality. A Superpave mix design must be performed by an AASHTO accredited laboratory.

This mix design should have current approval from with the last year. If changes are made from an approved mix design, a new JMF should be submitted by the contractor for approval by the Agency's engineer. The mix design should be submitted in time for the Agency to verify

and approve the mix as the JMF. This time requirement needs to be set by the Agency. Per Caltrans specifications, the contractor must also submit a new JMF for any of the following changes made to an approved JMF.

1. Target asphalt binder percentage greater than ±0.2 percent
2. Asphalt binder supplier
3. Combined aggregate gradation changes
4. Aggregate sources change
5. Liquid antistrip producer or dosage changes
6. Average binder content in a new processed RAP stockpile varies by more than ±2.00 percent from the original RAP
7. Average maximum specific gravity in a new processed RAP stockpile varies by more than ±0.060 from the average maximum specific gravity value in the original mix design
8. Any material in the JMF, except lime supplier and source

The Revised 2018 Caltrans Standard Specifications[11] for Section 39-2.01B(2)(b) should not apply to local Agency work unless the Agency is requiring AASHTO T 283 and California Test 389.

PRE-CONSTRUCTION MEETING

Prior to construction, it is recommended that a pre-construction meeting be held within five days before the start of project work at a mutually agreed upon time and place with the engineer and a contractor's staff including:

1. Project superintendent
2. Project foreman
3. Traffic control foreman
4. Laboratory samplers and testers
5. Agency engineer or lead inspector

For smaller jobs, it may not be possible to get all the above-mentioned people to attend. In any case, be prepared to discuss:

1. Quality control testing

2. Acceptance testing

3. Placement of asphalt overlay

4. Job mix formula including binder and aggregate sources

5. Just-in-Time-Training (JITT) on placement methods (optional)

6. Checklist of items for proper placement

7. Unique issues specific to the project, including:

   - Location of contractor's equipment and materials storage yard
   - Weather
   - Storm water pollution control plan
   - Alignment and geometrics
   - Traffic control requirements
   - Haul distances
   - Notifications to businesses and property owners as to when project will start and end
   - Contingency plan for equipment breakdowns, and traffic handling
   - Inductive loop detectors for traffic signals
   - Agenda for safety meeting

CONSTRUCTION SEQUENCE OVERVIEW

Thin asphalt overlay HMA production and paving practices are not substantially different from those of conventional asphalt paving. As in all projects, the construction area signs must be placed prior to beginning work.

Surface Preparation

In Section 4.3 of this manual, "Existing Surface Preparation," there is a discussion of the different surface preparations and how they may be handled by an Agency. The items that must be handled by the paving contractor prior to paving are removal of raised pavement markers and thermoplastic pavement markings. After these items are removed, the pavement must be swept clean of any deleterious materials prior to applying any tack coat.

After the surface is clean, apply a tack coat to existing pavement that is to receive an overlay at the residual rate as shown in Section 39-2.01C(3)(f), and to any vertical surfaces including curbs, gutters, and construction joints. Equipment for the application of the tack coat must comply with Section 37-1.03b. Tack coat area application should be limited to accommodate public and pedestrian access. Tack coat applications should not extend beyond the paving limits for the day.

Production and Placement

When producing mix with RAP, it is important to monitor aggregate and RAP moisture content, because thin asphalt overlays use finer aggregates. RAP materials retain more moisture and may require more frequent testing for moisture content. When placing a thin asphalt overlay, the paving crew should be aware the mix will lose temperature more quickly due to the thickness of the thin asphalt overlay. The rubberized mixes may lose workability more quickly. Also, because of the thickness, it is possible to operate the pavers faster than normal, which may make it hard for the rollers to keep up. RHMA-G will be difficult to compact as it cools and should be delivered to the job site at a higher temperature.

As with all asphalt pavements, proper compaction is critical. Although the same compaction principles apply to thin asphalt overlays as to thicker pavements, the thinness of the layer affects the compaction time. Thin asphalt overlays cool more quickly than thicker layers, which means there is a smaller time window for compaction, but less compaction energy is needed. Warm mix technologies can be used to extend the time window for compaction, if needed.

Contractors should operate steel-wheeled rollers close to the paver (breakdown rolling) and cover the entire surface at least twice (breakdown and intermediate rolling) before they finish rolling, except for ARHM (Greenbook) and RHMA (Caltrans) mixes. The latter mixes use a gap-graded gradation, which requires a greater compaction force. Breakdown rolling is done with the vibratory mode on, intermediate rolling, and the finish rolling is done with the vibratory mode off. Caltrans specifications in Section 39-2.03C, Construction, states to not use a pneumatic roller for intermediate rolling on RHMA-G. This conflicts with Section 39-2.01C(2)(c) of the Standard Specifications, Method Compaction Equipment, where it is stated that a pneumatic roller is to be used for intermediate rolling in method compaction. Figure 8 shows the different stages of HMA compaction, initially from the screed and followed up by three rollers with recommended temperatures for compaction. Figure 9 shows a schematic of one complete coverage for rolling.

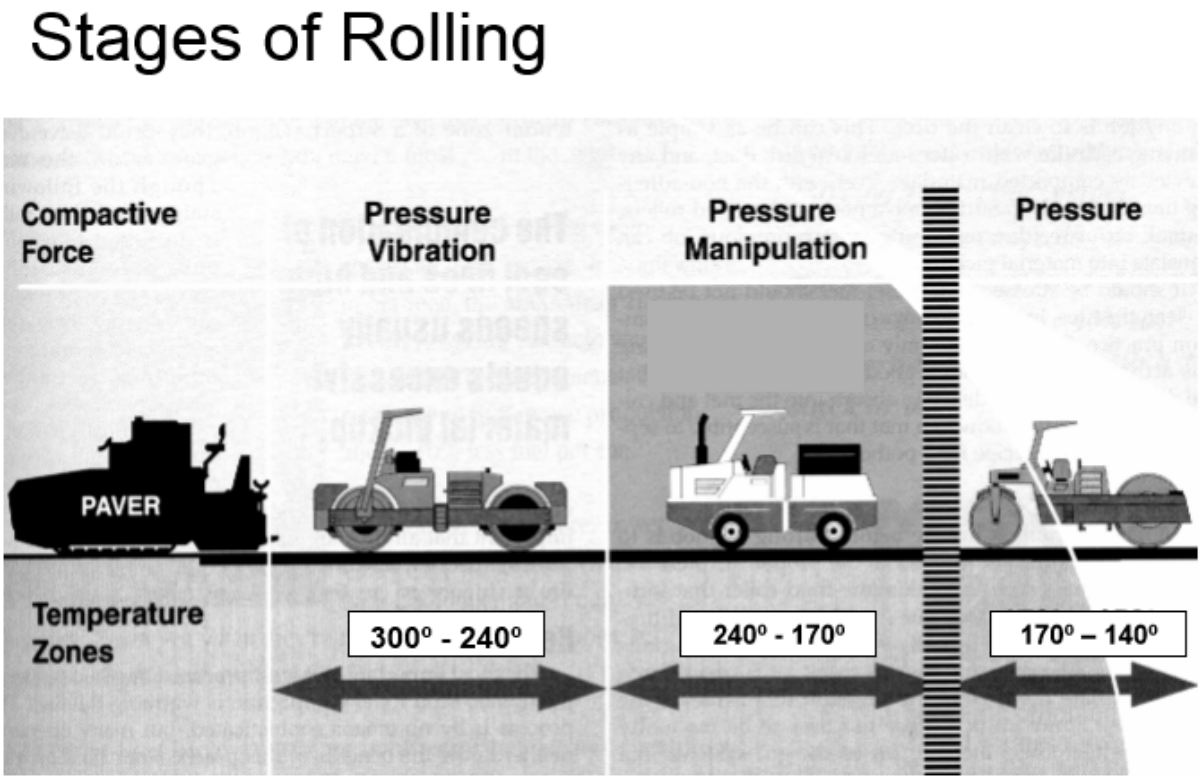


Figure 8. Stages of Rolling, Chapter 10, MTAG

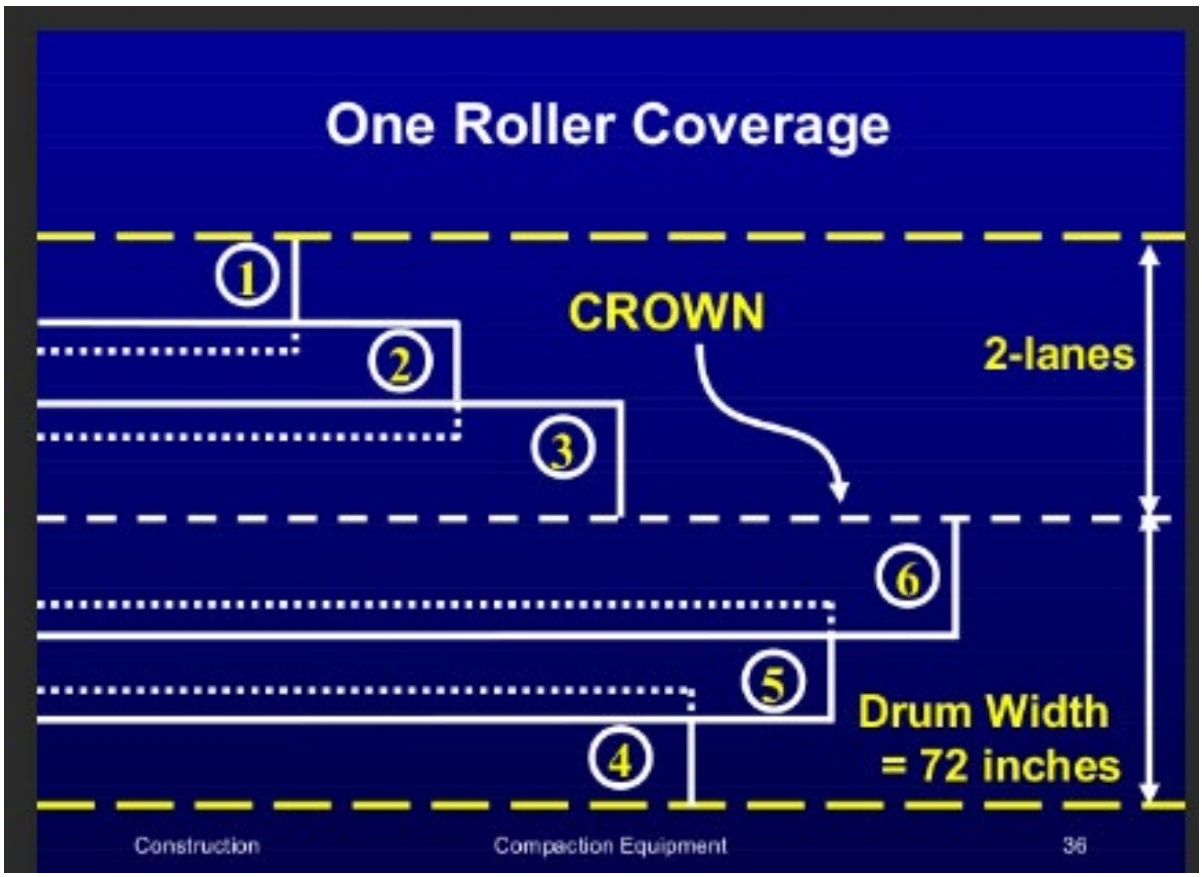


Figure 9. Schematic of Rolling Pattern for One Coverage (Bing)

Multi Cool is a free software program that helps estimate the available time for compaction: it can be downloaded from www.asphaltpavement.org/multicool.

Both the Greenbook and Caltrans include descriptions of the construction process for the various types of thin asphalt overlays. Each is described in the following sections.

CONSTRUCTION SEQUENCE

Greenbook

The Greenbook is structured such that materials and material production requirements are specified in Part 2, and construction is specified in Part 3.

Mix Production

Production requirements are more detailed in the Greenbook. The Greenbook is a "method" specification, meaning it specifies a "recipe" to follow rather than the performance requirements of the produced mixture.

Production requirements for each mixture are specified in the respective subsections. Subsections 203-6, 203-14, and 203-16 are produced under Subsection 203-6.7. Subsection 203-13 is produced under 203-6.7, except for certain specified differences.[8]

The Greenbook does not mention the Caltrans' "Material Plant Quality Program" (MPQP), but the plant must have such approval, which should be specified in the Special Provisions.

Batch Plant Method

There are basically two types of HMA or AC plants. The most common plants are batch plants and continuous drier-drum mix plants. Both plant types are capable of producing high-quality mix depending on the quality control of the producer or contractor. Figure 10 shows a schematic of a typical batch plant.

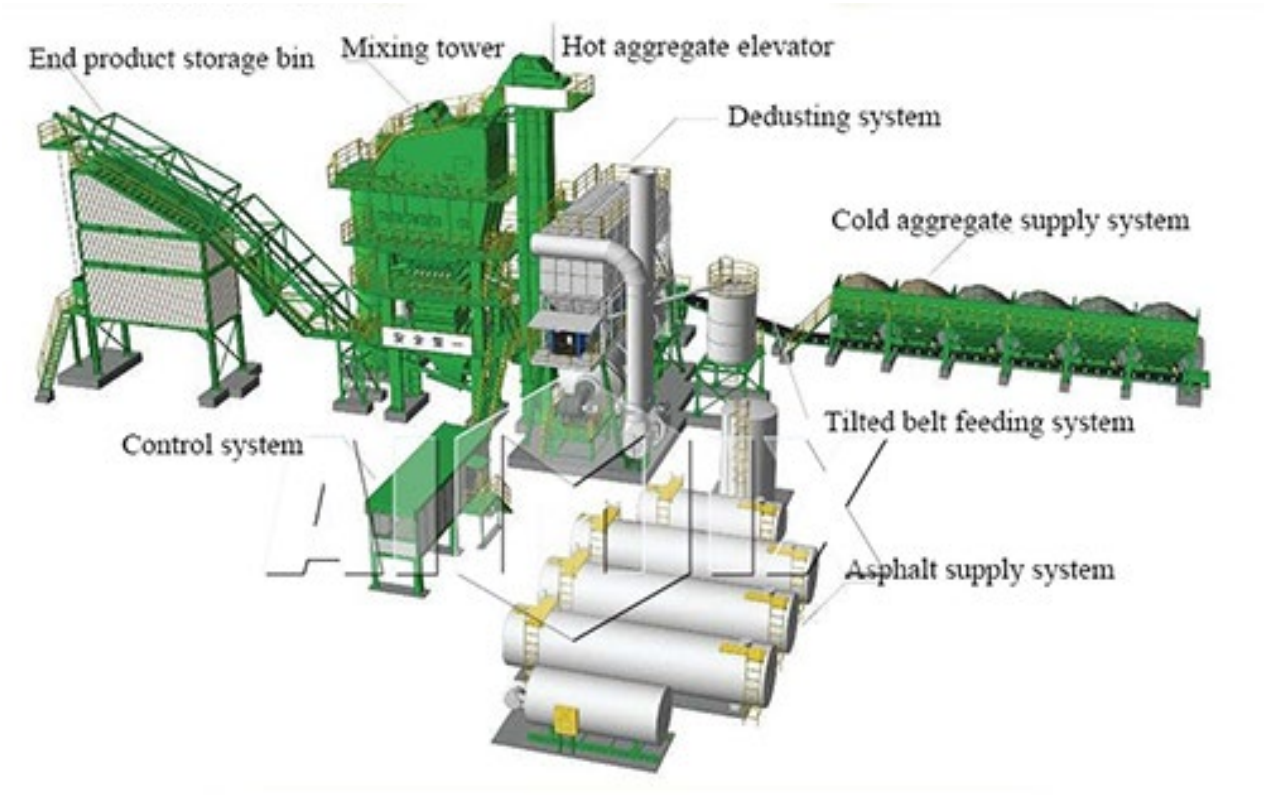


Figure 10. Basic HMA Batch Plant (Schematic from AIMIX)

Dryer-Drum Method

Another type of HMA or AC plant is a continuous mix drier-drum plant. These plants are usually capable of producing HMA at higher rates than a batch plant. Figure 11 shows a typical drier-drum HMA Plant.

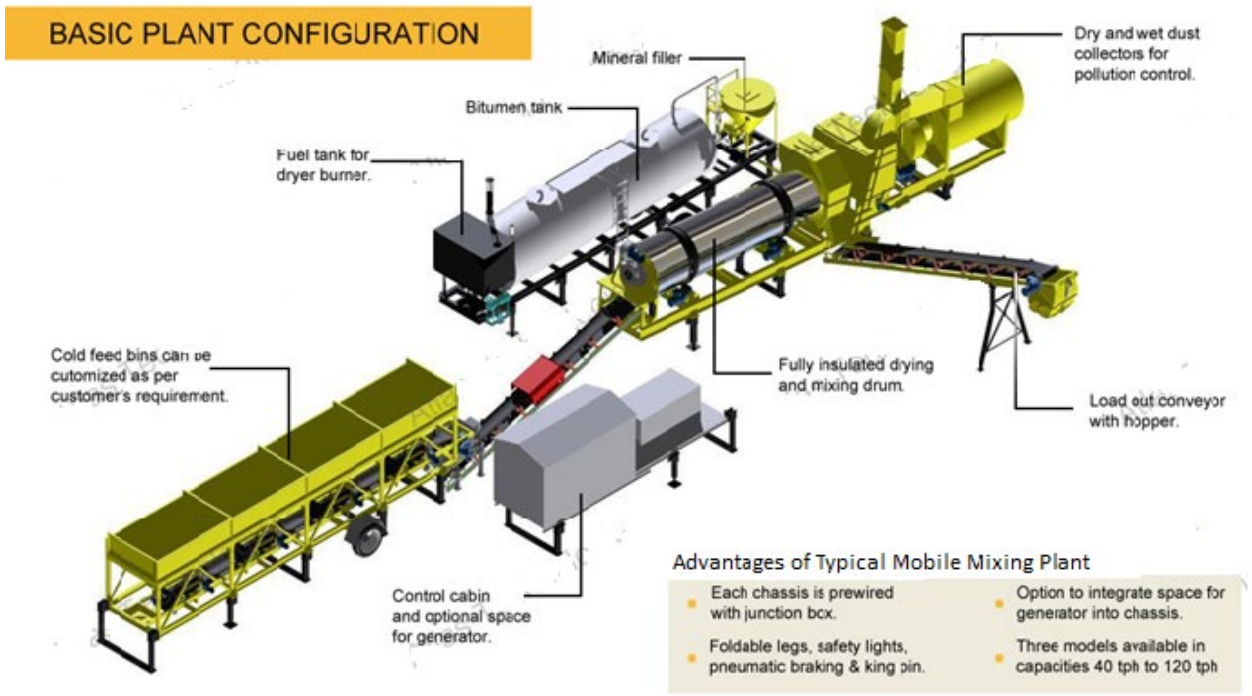


Figure 11. Basic Drier Drum HMA Plant (Schematic from Atlas Technology)

Placement

The Greenbook specifies the requirements for placement in Part 3. For each of the mixes specified in Part 2, there is a corresponding subsection in Part 3 for placement as follows:[8]

- 302-5 Asphalt Concrete Pavement
- 302-9 Asphalt Rubber Hot Mix (ARHM)
- 302-11 Crumb Rubber Modified Asphalt Concrete, Gap Graded (CRUMAC-GG)
- 302-12 Tire Rubber Modified Asphalt Concrete (TRMAC) Pavement
- 302-14 Polymer Modified Asphalt Concrete (PMAC)

Section 302-9 refers to certain subsections of 302-5; further, 302-11, 302-12, and 302-14 refer to certain subsections of both 302-5 and 302-9 but also specify the exceptions and differences from 302-5 for each material.[8]

There are very important differences between the placement requirements for asphalt concrete specified in 302-5 and those for ARHM specified in 302-9.[8]

The Greenbook does not specify the requirements for an automatic screed control system, nor does it require its operation during placement. The Agency should add those requirements in the Special Provisions.[8]

The Greenbook also does not specify the location of longitudinal joints. Longitudinal joints should be located outside of a wheel path and preferably match the traffic lane line. The Agency should add those requirements in the Special Provisions.[8]

The Greenbook does not specify the tack coat as a separate bid item. Payment is considered as included in the contract unit price for the pavement mixture. Tack coat is better controlled, and a better incentive for a proper application is provided, when the tack coat is a separate bid item, measured either by the ton or by the gallon. The Agency should consider including this modification in the special provisions.[8]

Figure 12 shows a typical thin asphalt overlay being constructed on a residential street. This paver has a hopper that allows a dump truck to directly load the hopper that is located at the front of the paver. Figure 13 is a schematic of a typical paving machine that shows the individual components.

Figure 12. Roadtec Paver Paving Residential Street with Thin Asphalt Overlay Surfacing

(Photo from https://www.roadtec.com/products/asphalt-pavers)

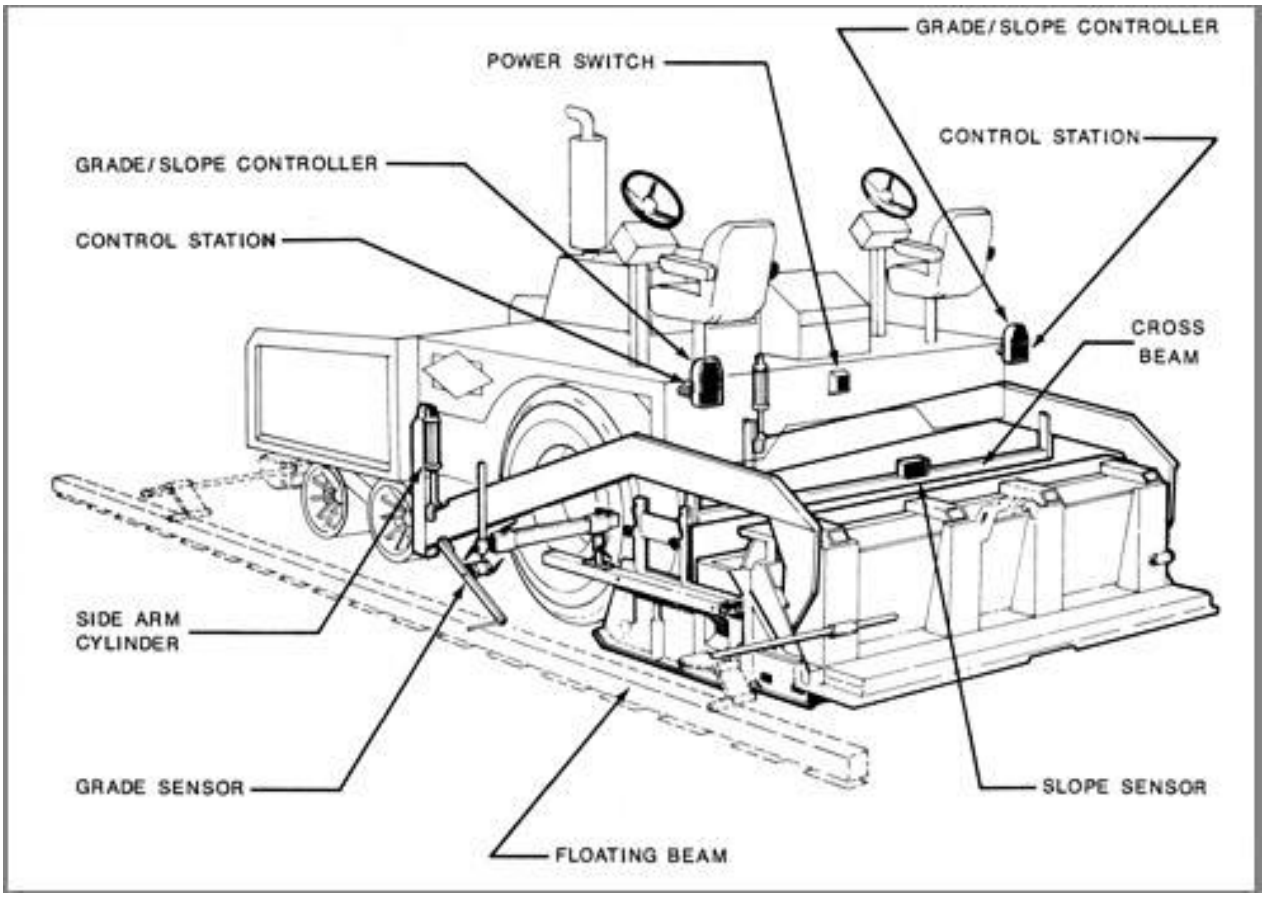


Figure 13. Schematic and Basic Components of a Typical Paving Machine

(https://www.bing.com/images/search?q=schematic+of+aphalt+paver&id=C0A2F9AE102F9ED622CF3F6241FE8DD03F285591&FORM=IQFRBA)

Most modern pavers have automatic controls which allow the paving crew to operate from a screed console, as shown in Figure 14. Some consoles even have a split screen mode that enables the screed operators to work from a single side or from both sides of the screed. The automatic controls allow for a smoother overlay with better tolerances of the thicknesses, cross-slope, and crown.

Figure 14. Example of Control Panel for Integrated Grade Control (Caterpillar)

Pick-up machines are commonly used on rural highway projects or freeways, whereas city projects often use end-dump trucks directly feeding the paving machine. Figure 15 shows an example of a pick-up machine passing HMA that was placed directly on the pavement from belly dump trailers. Some types of pick-up machines may be attached directly to the paver.

Figure 15. Paver Equipped with Pick-Up Machine

*(https://*www.bing.com/images/search?view=detailV2&ccid=UOKVROpR&id=0601C05AFB6003FF9B59C14A361CB8B82A248CD3&thid=OIP.UOKVROpROcVFNSxNjB0LRQHaE8&mediaurl=https%3A%2F%2Fcdn.forconstrutionpros.com%2Ffiles%2Fbase%2Facbm%2Ffcp%2Fimage%2F2015%2F01%2F960w%2FContin_Paving_8097.54bece5198faf.jpg&exph=640&expw=960&q=paving+with+caterpillar+paver+with+pickup+machine&simid=608026700113250775&ck=148A98471EE94D1C16079DF4845C41A8&selectedindex=142&ajaxhist=0&vt=0&eim=1&sim=11)

Caltrans

Hot Mix Asphalt Production, Section 39-2.01B(8)

In the following section, the use of "Department" is a reference to Caltrans, and in many instances, it actually means your "Agency."

Do not start HMA production before verification and authorization of the JMF. The HMA plant must have a current qualification under the Department's (Caltrans') Material Plant Quality Program. Be certain all weighing and metering devices used for the production of HMA modified with additives comply with the Department's (Caltrans') MPQP.[19]

Aggregates can be proportioned by hot- or cold-feed control. Aggregate temperature must not be more than 375°F when mixed with the asphalt binder. Asphalt binder temperature must be from 275°F to 375°F when mixed with aggregate. Mix HMA ingredients into a homogeneous mixture of coated aggregates. HMA must be produced at the temperatures shown in Section 39-2.01B(8). The "Method" compaction temperatures should be used for thin asphalt overlays. If production is stopped for longer than 30 days, a production start-up evaluation is required.[9]

Specific requirements for binders and additives are mentioned below.

- ***Asphalt Binder Requirements, Section 39-2.01B(3), Section 92.*** All asphalt binder for thin overlays must comply with Section 92[9].

- ***Liquid Antistrip, Section 39-2.01A(4)(h)(iv).*** If liquid antistrip is used, it must be submitted as part of the proposed JMF. Liquid ingredient additive, including a normally dry ingredient made liquid, must be proportioned with a mass flow meter at continuous mixing plants. Use a mass flow meter or a container scale to proportion liquid additives at batch mixing plants. If three consecutive sets of recorded production data show that the actual delivered liquid antistrip weight is more than ±1 percent of the authorized mix design liquid antistrip weight, stop production and take corrective action.[9]

- ***Warm Mix Asphalt (WMA) Technology, Section 39-2.01A(3)(h)***. If a WMA technology is used, it must be submitted as part of the proposed JMF. For continuous mixing or batch-plant mixing, sample asphalt binder before adding liquid antistrip. For continuous mixing, sample the combined asphalt binder and liquid antistrip after the static mixer.[9]

Proportion all ingredients by weight. The HMA plant process controller must be the sole source of ingredient proportioning control and be fully interfaced with all scales and meters used in the production process. The addition of the HMA additive must be controlled by the plant process controller.[9]

Continuous mixing plants using HMA dry ingredient additives must be proportioned with a conveyor scale or a loss-in-weight meter. Batch mixing plants using HMA metered

additives must be placed in an intermediate holding vessel before being added to the stream of asphalt binder as it enters the pugmill.[9]

Placement, Section 39-2.01A(4)(h)(v)

This section states that both the contractor and the engineer must evaluate HMA production and placement at production start-up, and also perform sampling. Caltrans specifies that within the first 750 tons produced on the first day of HMA production, in the engineer's presence, and from the same production run, take samples of:[9]

1. Aggregates
2. Asphalt binder
3. RAP
4. HMA

For local agencies, sampling should take place within one to two hours of plant production at the plant, and between 30 minutes to one hour of mix placement on the pavement, from directly behind the screed. Placement of 750 tons can be several hours of paving. If a test strip is not placed, sampling and testing of early paving is essential for quality assurance. All samples should be submitted to the Agency's testing laboratory as soon as possible for results. The results should show that the materials meet the specified JMF requirements.[9]

Section 39-2.01C specifies how the paving will be placed and at what temperatures.[9]

For method compaction, the temperature of the HMA, and the HMA produced with WMA water injection technology in the windrow, should not fall below 260°F, and for HMA produced using WMA technology, the windrow temperature does not fall below 250°F.[9]

HMA placed in a windrow on the roadway surface must not extend more than 250 feet in front of the loading equipment or material transfer vehicle. The equipment must produce uniform smoothness and texture.[9]

Further, the Caltrans specification states that the HMA must be free of:[9]

1. Segregation
2. Coarse or fine aggregate pockets
3. Hardened lumps
4. Marks
5. Tearing
6. Irregular texture

Finish rolling activities must be completed before the pavement surface temperature is:[9]

1. Below 150°F for HMA with unmodified binder

2. Below 140°F for HMA with modified binder

The above specification indicates that polymer modified HMA may be compacted at a lower temperature.[9]

Spreading and Compacting Equipment, Section 39-2.01C(2)

This section describes the paving equipment to be used on the job. Unlike the Greenbook specification, the following equipment requirements are in the Caltrans specifications regarding the paver and screed:[9]

1. Self-propelled

2. Mechanical

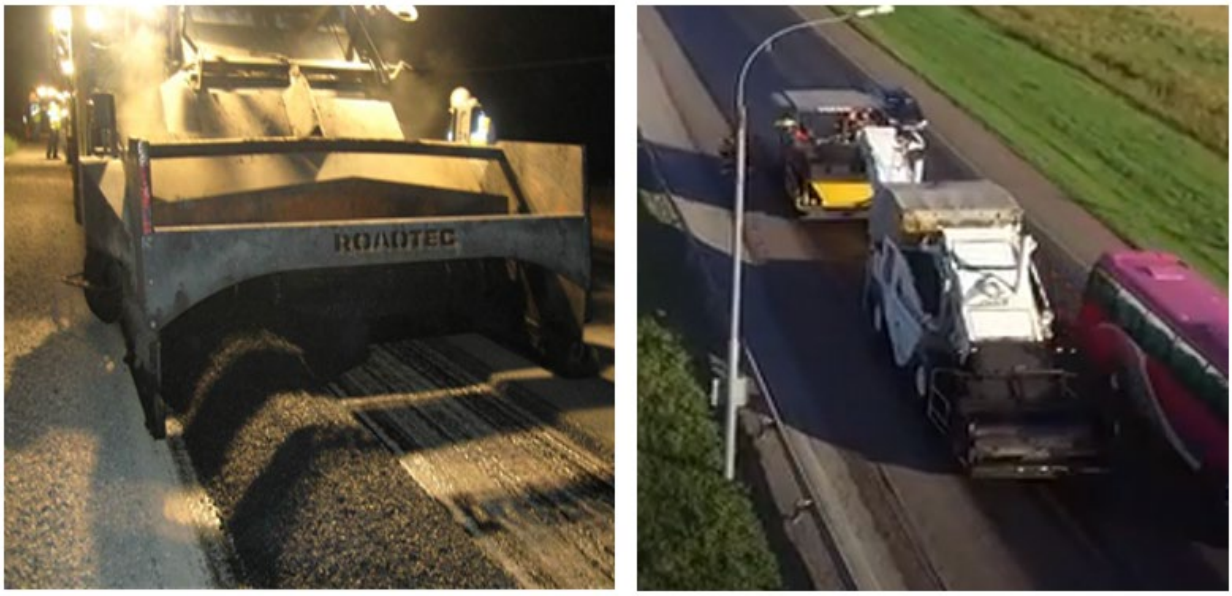
3. Equipped with a screed or strike-off assembly that can distribute HMA the full width of a traffic lane

4. Equipped with a full-width compacting device

5. Equipped with automatic screed controls and sensing devices that control the thickness, longitudinal grade, and transverse screed slope

Installing and maintaining grade and slope references may not be necessary for thin asphalt overlays used by local agencies but are specified in Caltrans 2018 Standard Specifications.

A Material Transfer Vehicle (MTV) may be specified on certain jobs. This section gives the Caltrans specifications for an MTV. MTVs are most often used on paving projects that have cooler weather conditions, long haul times, RHMA, or nighttime paving. The cooler mix on the outside surface area of the windrow is mixed with the hotter mix from the inside of the windrow, creating a mix with a more uniform temperature. The mixing helps to decrease clumping of the mix and creates a smoother finished surface behind the screed. Figure 16 shows an MTV being used in conjunction with a paver to place an asphalt overlay.



a) MTV Loading HMA from Windrow b) MTV Transferring Mix to Paver

Figure 16. MTV Picking Up Mix, and MTV Transferring Mix to Paver

Rollers must be equipped with a system that prevents HMA from sticking to the wheels. A parting agent that does not damage the HMA or impede the bonding of layers must be applied to roller wheels, or tires.

Rolling must leave the completed surface compacted and smooth without tearing, cracking, or shoving. If a vibratory roller is used as a finish roller, turn the vibratory mode off. Do not open new HMA pavement to traffic until it has cooled, to prevent damage.

Section 39-2.01C(15)(b), Method Compaction, should be used for thin asphalt overlays since the HMA thickness is 0.15 foot or less. Both vibratory and rubber-tired rollers are specified, and their usage is described in this section of the Caltrans Standard Specifications. However, a rubber-tired or pneumatic roller is not to be used for intermediate rolling on RHMA.

Types of Mixes (Caltrans)

The following types of mixes are used by Caltrans.

1. Dense-graded mixes, Type A hot mix asphalt
2. Gap-graded mixes, Rubberized Gap-Graded (RHMA-G)
3. Open-graded mixes, HMA-O, RHMA-O, and RHMA-O-HB
4. Bonded wearing courses, RHMA-G, RHMA-O, or HMA-O.

The tests and the testing frequencies shown in Table 9 and Table 10 may be used for all of

the various mix types. Several of the tests listed in the various subsections of Section 39 have been deleted from these tables. Review each pavement type specified in the 2018 Caltrans Standard Specifications and the Revised 2018 Caltrans Standard Specifications.[11] The revised sections include:

- 39-2.01A(1)
- 39-2.01A(3)(d)
- 39-2.02A(4)(b)(iii)
- 39-2.02A(4)(e)
- 39-2.01A(4)(h)(i)
- 39-2.01A(4)(i)(i)
- 39-2.01A(4)(i)(iv)
- 39-2.02A(4)(e)
- 39-2.02B(2)
- 39-2.01B(2)(b)
- 39-2.02B(11)
- 39-2.03A(4)(i)
- 39-2.04C
- 39-2.05A(1)(a)
- 39-2.05A(1)(d)(iii)
- 39-2.05A(2)(b)

For the complete list of Caltrans specified tests and testing frequencies, review both the 2018 Caltrans Standard Specifications and all revisions applying to the work. The revised specifications include revisions for RAP mixes for:[11]

1. Uncorrected RAP binder tolerances.
2. AASHTO T283 (freeze-thaw).
3. California Test 389 (modified Hamburg).

Each type of HMA mix has a separate subsection in Section 39 of the 2018 Caltrans Standard Specifications, which is subject to these revisions as well as future revisions.

Table 9. Aggregate Testing Frequencies

QUALITY CHARACTERISTIC	TEST METHOD	MINIMUM TESTING FREQUENCY
GRADATION	AASHTO T 27	1 per 750 tons and any remaining part
SAND EQUIVALENT	AASHTO T 176	
MOISTURE CONTENT	AASHTO T 255	

Reclaimed Asphalt Pavement, Section 39-2.02A(4)(b)(iii), states that during Type A HMA production, sample RAP twice daily and perform QC testing for:

1. Aggregate gradation at least once a day under California Test 384, and

2. Moisture content at least once a day.[11]

Table 10. Production Testing Frequencies

QUALITY CHARACTERISTIC	TEST METHOD	MINIMUM TESTING FREQUENCY (2)
ASPHALT BINDER CONTENT	AASHTO T 308, Method A	1 per 750 tons and any remaining part
HMA MOISTURE CONTENT	AASHTO T 329	1 per 2,500 tons but not less than 1 per paving day
NUCLEAR GAUGE DENSITY (1)	California Test 375	3 per 250 tons or 3 per paving day, whichever is greater

Note:
(1) If nuclear gauge densities are used by both the Agency and the contractor, then the gauge readings need to be calibrated between the two gauges. Method compaction in the Caltrans Standard Specifications does not have a minimum compaction specified. This specification would be an addition and included in the project's special provisions.
(2) Agency may vary testing frequency if approved by the Resident Engineer.

Dense-Graded Type A Hot Mix Asphalt, Section 39-2.02

This section includes specifications for producing and placing Type A hot mix asphalt. Type A HMA may include Reclaimed Asphalt Pavement, WMA technology, lime treatment of aggregate, and liquid antistrip.

It also includes specifications for submittals and the Job Mix Formula (JMF). The JMF must be based on the Superpave HMA mix design as described in MS-2 Asphalt Mix Design Methods by the Asphalt Institute.[20]

Section 39-2.02A(3)(c), Reclaimed Asphalt Pavement, specifies that the QC test results for RAP gradation with the combined aggregate gradation must be submitted within two business days of taking RAP samples during Type A HMA production.[9]

The required aggregate qualities, gradations with target values, and overlay thickness are included in Table 6, Table 7, and Table 8 of this manual. The test methods shown in Table 9 are modified from Section 39-2.02A(4)(b)(ii), Aggregates, and the test methods shown in Table 10 are modified from Section 39-2.02A(4)(b)(ix), Type A Hot Mix Asphalt Production.[9]

Rubberized Hot Mix Asphalt–Gap Graded, Section 39-2.03

Test the aggregate quality for the RHMA-G as shown in Table 9. Test the quality characteristics of the RHMA-G mix under the test methods and frequencies shown in Table 10. These tables are simplified from the Caltrans-specified testing. The Caltrans 2018 Standard Specification states limitations on asphalt rubber binder's time of use after mixing, as well as how many times it can have more scrap rubber added and reheated. Use a material transfer vehicle when placing RHMA-G. Do not use a pneumatic tired roller to compact RHMA-G. Spread and compact RHMA-G and RHMA-G produced with WMA water injection technology at an ambient air temperature of at least 55°F and a surface temperature of at least 60°F. Spread and compact RHMA-G produced with WMA additive technology at an ambient air temperature of at least 50°F and a surface temperature of at least 50°F. There are also specifications on tarping loads.[9]

There are also details for method compaction for the different types of WMAs. This includes water injection technology and states the allowable temperature ranges for method compaction when these technologies are used.[9]

Sand should be spread at a rate between one and two pounds per square yard on new RHMA-G pavement when the finish rolling is complete. Sand must be free of clay or organic matter. Sand must comply with Section 90-1.02C(3). Keep traffic off the pavement until spreading of the sand is complete.[9]

Open-Graded Friction Courses, Section 39-2.04

This section includes specifications for producing and placing open-graded friction courses. Open-graded friction courses include HMA-O, RHMA-O, and RHMA-O-HB. You may produce OGFC using a WMA technology.[9]

The contractor is required to submit a complete JMF for the asphalt binder content. For RHMA-O and RHMA-O-HB, the JMF submittal must comply with Section 39-2.03A(3)(c).[9]

For RHMA-O and RHMA-O-HB, the asphalt rubber binder must comply with the specifications in 39-2.03A(4)(c)(ii).[9]

Test the aggregate quality for the RHMA-G as shown in Table 9. Test the quality characteristics of RHMA-G mix under the test methods and frequencies shown in Table 10. These tables are simplified from the Caltrans testing.[9]

Bonded Wearing Courses, Section 39-2.05

This section includes specifications for producing and placing bonded wearing courses. Placing a BWC consists of applying a BWC asphaltic emulsion and placing the specified HMA in a single pass with an integrated paving machine using RHMA-G, RHMA-O, or HMA-O and must comply with the specifications for RHMA-G, RHMA-O, or HMA-O. See Revised 2018 Caltrans Standard Specifications,[11] Sections 39-2.05A(1)(a), 39-2.05A(1)(d)(iii), 39-2.05A(2)(b), and Section 94-1.02G for applicable changes.[9]

With your JMF submittal, include:

1. Asphaltic emulsion target residual rate

2. Weight ratio of water to bituminous material in the original asphaltic emulsion

Within three business days following the first job site delivery, submit test results for asphaltic emulsion properties performed on a sample taken from the asphaltic emulsion delivered. Within one business day of each job site delivery of asphaltic emulsion, submit to METS (or the Agency's laboratory) a 2-quart sample and a certificate of compliance. Ship each sample so that it is received at METS (or the Agency's laboratory) within 48 hours of sampling.[9]

Each day BWC is placed, submit the residual and application rate for the asphaltic emulsion. During production, submit certified volume or weight slips for the materials supplied. During construction, do not dilute the asphaltic emulsion. Do not place BWC if rain is forecast for the project area within 24 hours by the National Weather Service. Place BWC as directed by Section 39-2.05A(3)(b) and use method compaction for placing the BWC.[9]

Before spreading HMA, apply asphaltic emulsion on dry or damp pavement with no free water according to Section 39-2.05A(3)(c). The asphaltic emulsion application rates may be changed with the approval of the engineer. Place and compact HMA as specified in Section 39-2.05A(3)(d).[9]

For gap-graded mixes (BWC-G), include specifications for producing bonded wearing course according to Section 39-2.05B. Include film thickness and calculations and AASHTO T 305 results with your JMF submittal.[9]

For lime treated aggregate, test the aggregate before treatment and test for gradation and moisture content during BWC-G production.[9]

Take two 1-gallon samples of BWC-G in metal containers. Test the quality characteristics of BWC-G under the test methods and frequencies shown in Section 39-2.05B. The Department (Agency) accepts BWC-G based on compliance with:[9]

1. Asphalt binder content at JMF -0.40, +0.50 percent when tested under AASHTO T 308, Method A.

2. Aggregate quality requirements shown in Section 39-2.05B.

SAFETY

As with all construction projects, safety is the ***number one*** concern for pedestrians, motorists, contractors' personnel, and local agency inspectors. A personal injury accident or a fatality cannot be reversed. Thin HMA projects have some issues which are unique for this project type. As the design and construction engineer, there are many items regarding safety that you should be aware of.

Traffic Control

One factor is that lane closures are always required for thin HMA work, since traffic must be kept off of freshly laid asphalt until it has been compacted and cooled—which is a function of temperature, relative humidity, and wind speed.

If this is an urban project, the first item that should be considered is detouring traffic. In a downtown situation, it is usually easy to close a street and move traffic over a block. Also, businesses and residences should receive notification of street closures ahead of construction. Business owners will often ask that the construction be done on a weekend or at night so that their normal business is not disrupted. If that is not possible, customers may have to walk by the construction zone. It is important for pedestrian safety to cordon off the work areas from the sidewalks and for flaggers to direct pedestrians who may want to cross the street. Decisions must be made ahead of construction to leave certain intersections open to traffic, and you must determine how access to businesses and residences will be managed during construction. Construction signing for detours must be included in the contract plans.

If this is a rural two-lane road project, only one direction will be constructed at a time, with traffic control enacted using a pilot car with flaggers to alternately allow traffic to be piloted in one direction at a time. After the treatment is compacted and cooled, traffic can be switched onto the new surface, and the opposing lane will be constructed. There are traffic control standards that must be adhered to during the construction and curing process.

Safety During Construction

It is important to be familiar with the equipment traffic patterns on the project and to know what the "NO ZONES" are. Figure 17 shows where these zones are. It is recommended to drive through the project in the traffic queue if there is one-way controlled traffic. For thin HMA operations, observe the flow of construction equipment. Also, observe the haul trucks for the HMA. The haul trucks supplying the paving machine may back up at very high speeds and should have backup alarms. The Resident Engineer is usually in charge of enforcing the safety items on the project. All the equipment must be equipped with backup alarms.

The truck drivers have limited vision when backing up. Hence, be sure to make contact with the truck driver before walking behind the truck. The driver will not be able to see who or what is behind their vehicle. Many observations can be made from the vehicle,

so don't stand in the construction zone unless sampling or performing tests. Assign an observer to watch traffic when the tester is unable to**.** Be sure to perform testing or sampling in a lane closure.

Figure 17. Mirrors and the No Zone

All construction personnel must wear safety vests, hard hats, and safety glasses in active construction zones. All construction personnel must also wear long pants, as well as suitable shoes or boots. No sandals or shorts are allowed for construction personnel. If a worker is exposed to a high level of noise, earplugs may be worn by the worker. Gloves should be worn by workers performing hand labor or handling hot materials. Testers handling hot asphalt samples must wear face shields.

VI. QUALITY ASSURANCE

Quality Assurance(QA) establishes the core elements required to achieve quality materials and workmanship for construction projects, as shown in Figure 18.[22] This goal has been accomplished to a great deal in hot mix asphalt, but it is just beginning for pavement preservation treatments. This chapter discusses the various aspects of a QA program.

Figure 18. Core Elements of a Quality Assurance Program

Quality assurance of thin asphalt overlays includes planned and systematic inspections with sampling and testing to provide confidence that the asphalt mix will perform according to expectations. Quality control is part of QA and typically includes sampling and testing performed by the contractor. Acceptance sampling and testing is often, but not always, performed by the Agency to verify whether or not the thin asphalt overlay is acceptable.

QC PLAN

As stated in Section 39-2.01A(3)(c), Quality Control (QC) Plan, the following requirements in the Caltrans specifications are included:[9]

- At least five business days prior to the pre-paving meeting, submit a QC plan for

HMA. The QC plan must describe the organization and procedures for:

1. Controlling HMA quality characteristics
2. Taking samples, including sampling locations
3. Establishing, implementing, and maintaining QC
4. Determining when corrective actions are needed
5. Implementing corrective actions[8]

- The QC plan must also address the elements affecting HMA quality, including:
  1. Aggregates
  2. Asphalt binder
  3. Additives
  4. Production
  5. Paving [8]
- The QC plan must include aggregate QC sampling and testing during lime treatment. (Only if lime treatment is specified.)[9]
- Allow 5 business days for review of the QC plan."[9] This time may also be adjusted to fit an Agency's needs, but 10 days should be enough time to examine the QC.
- Liquid antistrip treatment is recommended to be used, and the Caltrans submittal requirements for the JMF and the production data are shown in Section 39-2.01A(3)(f), Liquid Antistrip Treatment. [9]

SAMPLING AND TESTING

The Statewide Independent Assurance Database (SIAD) is a web application developed by the California Department of Transportation, Materials Engineering & Testing Services (METS) to allow Independent Assurance (IA) staff the ability to easily submit tester and laboratory information into the Caltrans' database via the Internet. The SIAD serves as a central repository for statewide Independent Assurance (IA) data pertaining to IA staff, testing personnel, and laboratories. The database provides instant access to statewide IA accreditations, certifications and proficiencies. This information is at the following website: https://sia.dot.ca.gov/.[26]

More information is available about the Caltrans Independent Assurance Program (IAP): please see the Quality Assurance Program (QAP) Manual for Use by Local Agencies[19])

and associated documents on the IAP webpage at (https://dot.ca.gov/-/media/dot-media/programs/local-assistance/documents/reports/qap-manual.pdf).

Sampling

Greenbook

Subsection 203-6.10 specifies the requirements for sampling.

The Greenbook does not specify specific tests to be performed nor their frequency. The Agency should develop its own QAP for tests to be performed and should specify testing test frequency. A good practice is to follow a QAP regardless of funding source. The importance of production ("plant") inspection cannot be overemphasized. It is advantageous to both the Agency and the contractor to resolve any production problems at the plant prior to transporting mix to the job site.[8]

Caltrans

Both the contractor and the Agency need to have a sampling control plan prior to beginning work. An example of such a plan is shown in Table 11. On the Caltrans website, there are 13 tables for sampling frequency for the various HMA products in Chapter 6 of the Caltrans Construction Manual, dated 2019: The location of the website is https://dot.ca.gov/-/media/dot-media/programs/construction/documents/policies-procedures-publications/construction-manual/sec6-1.pdf.[21]

The Caltrans testing frequency may not be practical for a smaller county, or city agency; however, the following table may serve as a minimum testing plan for a small agency with limited resources. Testers must be certified for the required test methods, and all samples must be identified, i.e., by date, time, job identification, plant location, tester, resident engineer, and where the sample was taken, and what tests are to be run on the sample. Table 11 shows an example of a sampling control plan for HMA.

Table 11. Example of a Sampling Control Plan for Thin HMA

PLANT SAMPLING (CONTINUOUS MIX DRUM PLANT)

AGGREGATE	PG OR PM BINDER	HMA (DENSE-GRADED OR OGFC)	
Combined belt sample: gradation and moisture (Once/day)	2 gal/shipment (Hold: if from a Caltrans approved source with Cert. of Compliance) 1 gal for Agency 1 gal for contractor	Belt samples (Once/day)	Binder content: Per ignition oven or extraction Stability if specified
AGGREGATE	**RUBBER BINDER**	**RHMA-G OR RHMA-O**	
Combined belt sample: gradation and moisture (Once/day)	2 gal/day 1 gal for Agency 1 gal for contractor	Belt samples (Once/day)	Binder content: Per ignition oven or extraction
PLANT SAMPLING (BATCH PLANT)			
AGGREGATE	**PG OR PM BINDER**	**HMA (DENSE-GRADED OR OGFC)**	
Sample each bin and perform a combined gradation per contractor's bin percentages, and moisture (Once/day)	2 gal/shipment (Hold: if from a Caltrans approved source with Cert. of Compliance) 1 gal for Agency 1 gal for contractor	Truck samples (Once/day)	Binder content: Per ignition oven or extraction Stability if specified
AGGREGATE	**RUBBER BINDER**	**RHMA-G**	
Sample each bin and perform a combined gradation per contractor's bin percentages, and moisture (Once/day)	2 gal/day 1 gal for Agency 1 gal for contractor	Truck samples (Once/day)	Binder content: Per ignition oven or extraction
CONSTRUCTION SITE FIELD SAMPLES FOR ALL HMA TYPES			
Sample from placed HMA surface	2 Boxes for each 750 tons and 2 Boxes for any amount over 750 tons 1 box for Agency 1 box for contractor	Hold samples for dispute resolution should paving construction problems develop	Dispose of samples per Agency rules after prescribed time has passed

All samples should be submitted to a certified laboratory for testing as identified on the sample. The certified testing laboratory needs to submit test results to the resident engineer as quickly as possible and as specified. Any out-of-specification test results need to be highlighted and discussed with the resident engineer by the testing laboratory staff.

The consultant tester may be employed by either the contractor or the Agency. Usually, the person sampling the product will take two samples, giving one to the Agency and one to the contractor as a split sample. This is a good strategy in case there is a discrepancy on the test results. Even though there is testing of the product before construction, there needs to be assurance that the product being delivered is verified to be of the same quality as the product that was submitted to the Agency prior to construction.

Sampling Plan for Quality Control, BWC Emulsion

For each job site delivery of asphaltic emulsion, the contractor takes a 2-quart sample in the presence of the engineer. Take samples from the delivery truck at mid-load from a sampling tap or thief. If the sample is taken from the tap, draw and discard 4 quarts before sampling. Sampling shall conform to Section 94-1.01D, Quality Assurance, of the Revised 2018 Standard Specifications, and AASHTO T 40.[11]

If the asphalt binder or asphaltic emulsion is unloaded into a bulk storage tank, do not use material from the tank until the test results are submitted for a sample taken from the bulk storage tank. Testing must be performed by an AASHTO-accredited laboratory.

The Agency will take two one-gallon samples of BWC in metal containers. Test the asphaltic emulsion under ASTM D2995 at least once per paving day at the job site.

AGENCY INSPECTION, DOCUMENTATION, AND ACCEPTANCE

The Agency has a responsibility to document the quality of the products being used and the construction processes used on their project—referred to as Agency acceptance. The Agency Engineer, or Resident Engineer, is responsible for keeping daily diaries to document the construction process, and there is usually an Assistant Resident Engineer on the job. Depending on the size of the project, there may also be an Agency tester on the project responsible for the materials sampling. The Agency tester may be a consultant tester or an Agency employee. The tester should be certified in any and all of the tests that are being run, including sampling the products. Appendix C has several websites listed as resources for local agencies to help monitor independent assurance requirements. Also, the 2019 FHWA checklist for thin asphalt overlays[23] provides good information for Agency staff and contractors alike. This information can be found at the following website: https://www.fhwa.dot.gov/pavement/preservation/2019checklists/hif19030.pdf.

The materials test results are compared to the specified tests to make sure that the materials are within the specified limits of each test specified and performed. Some out-of-specification products may be accepted to be left in place on the project with a deduction, as long as the non-conformance is not excessive. This is at the contractor's discretion. If the materials are too far outside of the specified limits, the engineer should order that the material be removed and replaced at the contractor's expense.

Overall, the primary objectives of Agency acceptance are to:

- Measure the quality of all materials provided and placed by the contractor, and
- Determine the corresponding payment the contractor should receive, and any repairs or replacements necessary to bring the materials or workmanship into compliance.
- More importantly, you get what you inspect. The 2019 presentation given by Jerry Dankbar of the City of Roseville on the importance of inspection is an excellent resource. It is included as a PowerPoint presentation at the following link: https://wrapp.org/2019-wrapp-workshop-round-tables/.

Greenbook (Agency) Acceptance

The basis of acceptance of the various mixtures is specified in the following subsections:[8]

- 203-6.11 for asphalt concrete,
- 203-13.10 for CRUMAC,
- 203-14.9 for TRMAC, and
- 203-16.9 for PMAC.

Acceptance is not specified as a separate subsection under 203-11, ARHM. Acceptance of ARHM is therefore based on conformance to the contract documents.[8]

Placement acceptance is not specified as a specific subsection. As such, placement acceptance is based on conformance to the requirements in the contract documents.[8]

Subsection 3-13 includes a provision for a warranty period of one year beginning on the date of completion of the work. During the warranty period, the contractor is responsible for the correction of deficient materials and workmanship.[8]

Caltrans (Agency) Acceptance

Caltrans Section 39-2.01(4)(i) describes sampling and testing of aggregate and mix for full acceptance test procedures, which include AASHTO T 283 (Freeze-Thaw Test) and AASHTO T324 (Modified Hamburg Test). Most local agencies would not test mixes for thin asphalt overlays this rigorously. However, the sampling locations apply and include the following:[9]

1. Plant
2. Truck
3. Windrow
4. Mat behind the paver

The Agency should collect aggregate, binder, and HMA split samples per their sampling control plan and maintain the HMA samples throughout the warranty period. If the thin asphalt overlay fails to perform within the warranty period, tests should be run on HMA split samples for compliance with the JMF submittal. A suggested warranty period would be for a minimum of one year. This warranty period would be the same as the warranty period that the Greenbook requires.[9]

AASHTO T 27 (aggregate gradations) should be run daily, and California Test 382 (Determination of Asphalt Content of Bituminous Paving Mixtures by the Ignition Method) or California Test 379 (Method of Determining Asphalt Content of Bituminous Mixtures by Use of the Nuclear Gage) should be run for every 750 tons of mix produced for the job. No single aggregate or HMA test result may represent more than 750 tons or one day's production, whichever is less. If two consecutive Department (Agency) acceptance test results for one day's production do not comply with the specifications, then:

1. Stop HMA production

2. Take corrective action

3. Demonstrate compliance with the specifications before resuming production and placement.

If testing with a nuclear density gauge (California Test Method 375) is specified for HMA density, the density and the frequency of testing should be specified in the contract's special provisions.

INDEPENDENT ASSURANCE

Independent Assurance (IA) is performed by the Agency or designated Agency personnel who are not directly responsible for project acceptance. It provides independent evaluation of the QC and acceptance personnel and their equipment, but it is not used to make a determination of work quality or acceptability. See examples from the Division of Local Assistance, Office of Procedures Development and Training Quality Assurance Program (QAP) Manual for Use by Local Agencies, revised January 20, 2011.[20]

When the various ingredients are combined in proper proportions, they produce mixes that ultimately make up the new surface on the pavement. Obviously, high-quality materials, good mixing and construction practices, and good quality control/quality assurance will help maximize the smoothness, uniformity, skid resistance, and appearance of the HMA. Quality control (QC) is critical during the construction process to achieve a uniform surface finish. The contractor is responsible for QC, and the Agency is responsible for project acceptance. If there is a difference in the testing results between the contractor and the Agency, it may be necessary to go to dispute resolution. Independent assurance (IA) can mediate in the dispute resolution process, and it monitors both laboratories during their re-testing of the materials.

In case of dispute, samples that have been maintained during the project are run as split samples, similar to a round robin, between the two laboratories whose results are in dispute. The role of independent assurance is to determine why there was a difference in the test results, and to get the laboratories to produce consistent testing results on split samples. This is done so the dispute can be settled in a fair and equitable process between the contractor and the Agency.

Besides the appearance of the project, the materials need to be tested during construction. If two tests in a row fail, the work should be suspended until the contractor remedies the problem. If no problem can be identified, then re-testing needs to follow. Independent assurance processes may be used when the re-testing is being done between the two laboratories.

Caltrans 39-2.01A(4)(i)(iv) Dispute Resolution

"Contractor and Agency must work together to avoid potential conflicts and to resolve disputes regarding test result discrepancies. Contractor and Agency may only dispute

each other's test results if one party's test results pass and the other party's test results fail.[11]

If there is a dispute, submit contractor's test results and copies of paperwork including worksheets used to determine the disputed test results within 3 business day of receiving the Agency's test results. An independent third party performs referee testing. Before the third party participates in a dispute resolution, the 3rd party must be qualified under AASHTO resource program and the Agency's Independent Assurance Program. The independent third party must have no prior direct involvement with this contract. By mutual agreement, the independent third party is chosen from:[11]

1. Department laboratory in a district or region not in the district or region the project is located

2. Transportation laboratory

3. Laboratory not currently employed by you or your HMA producer

If the Department's portion of the split acceptance samples are not available, the independent third party uses any available material agreed by contractor and the Engineer as representing the disputed HMA for evaluation."[11]

Greenbook Dispute Resolution

The Greenbook does not contain a dispute resolution process.

MEASUREMENT AND PAYMENT

The 2018 Caltrans Standard Specifications does not have specific payment specifications in Section 39. The 2018 Greenbook addresses measurement and payment in section 302-5.9. The following measurement and payment recommendations include clauses for the project's contract special provisions. For the HMA, if batch weights are printed automatically, the bid item for HMA will be measured using the printed batch weights, provided the following are applicable:

1. Total HMA weight per batch is printed

2. Each truckload's zero tolerance weight is printed before weighing the first batch and after weighing the last batch

3. Time, date, mix number, load number, and truck identification are correlated with a load slip

4. A copy of the recorded batch weights is certified by a licensed weigh master and submitted to the engineer

5. Weigh tags are produced at the hot plant where the HMA is produced.

Submit tags which include the printed batch weights no later than the morning after the delivery has been made. The total HMA applied as determined by the contractor must be reported to the Resident Engineer no later than the following day. This should include a summary of the weigh tickets.

No payment will be made for quantities of HMA exceeding 105% of the bid item as defined in the Special Provisions. This quantity may be exceeded by the Resident Engineer if a contract change order (CCO) is approved.

The contract unit prices paid per ton for HMA shall be considered as full compensation for furnishing all labor, materials, tools, equipment, guarantees, warranties, and incidentals and for doing all the work involved in placing HMA surfacing, including but not limited to site preparation, cleanup, protecting utility and manhole covers, applying the treatments, corrections to application, street sweeping, and all other incidental work required to complete the work as shown and specified. Raising manholes or utilities to grade are usually a separate bid item. Signal loop detectors also need to include a separate bid item.

If required in the specifications, the contractor must warrant the materials and workmanship for a period to time, typically one to two years, following the date of completion or acceptance. The following is a warranty provision from the City of Lompoc:

> “The Contractor hereby warrants that all workmanship and all materials furnished under the contract comply fully with requirements of the HMA specifications. If at any time within two years from the date of filing of the Notice of Completion, any unfaithful or defective work should appear which in the opinion of the Agency is due to inferior materials or workmanship, the Contractor warrants doing whatever is necessary to remedy the defects immediately without cost to the Agency. The Agency will notify the Contractor in writing of the defects and the repairs to be made, and the Contractor will begin repairs within a mutually agreed time frame.”

VII. TROUBLESHOOTING GUIDES FOR FIELD PERSONNEL

TROUBLESHOOTING GUIDES

This section provides information to assist Agency personnel with troubleshooting problems associated with placing any of the thin HMA overlays. Table 12 presents a troubleshooting guide that associates common problems with their potential causes, whereas Table 13 lists some commonly encountered problems and their recommended solutions. FHWA has also developed a checklist for Agency personnel working on thin overlays. The link accessed in April 2020 to their checklist is as follows:

https://www.fhwa.dot.gov/pavement/preservation/2019checklists/hif19030.pdf. [23]

Table 12. Troubleshooting Guide (from MTAG)[24]

CAUSE	PROBLEM															
	Wavy Surface: Short Waves/ Ripples	Wavy Surface: Long Waves	Tearing of Mat: Full Width	Tearing of Mat: Center Streak	Tearing of Mat: Outside Streaks	Mat Texture: Nonuniform	Screed Marks	Screed Not Re-sponding to Cor-rec-tion	Auger Shadows	Poor Pre-Compaction	Poor Longitudinal Joint	Poor Transverse Joint	Transverse Cracking (Checking)	Mat Shoving Under Roller	Bleeding or Fat Spots in Mat	Roller Marks	Poor Mix Compaction
Fluctuating Head of Material	✔	✔				✔					✔						
Feeder Screws Overloaded	✔	✔				✔			✔								
Finisher Speed Too Fast	✔				✔												
Too Much Lead Crown in Screed					✔												
Too Little Lead Crown in Screed				✔													
Overcorrecting Thickness Control Screws	✔										✔						
Excessive Play in Screed Mechanical Connection	✔	✔					✔	✔				✔					
Screed Riding on Lift Cylinders	✔	✔				✔		✔		✔	✔	✔					
Screed Plates Worn Out or Warped			✔	✔	✔	✔											
Screed Plates Not Tight	✔					✔		✔				✔					
Cold Screed			✔	✔	✔	✔											
Moldboard on Strike off Too Low					✔												
Running Hopper Empty Between Loads		✔				✔											
Feeder Gates Set Incorrectly		✔		✔	✔												
Kicker Screws Worn Out or Mounted Incorrectly				✔													
Incorrect Nulling of Screed												✔					
Screed Starting Blocks Too Short												✔					
Screed Extensions Installed Incorrectly					✔	✔											
Vibrators Running Too Slow						✔				✔							

Table 12. Troubleshooting Guide (from MTAG)[24] (Continued)

CAUSE	PROBLEM															
	Wavy Surface: Short Waves/Ripples	Wavy Surface: Long Waves	Tearing of Mat: Full Width	Tearing of Mat: Center Streak	Tearing of Mat: Outside Streaks	Mat Texture: Nonuniform	Screed Marks	Screed Not Responding to Correction	Auger Shadows	Poor Pre-Compaction	Poor Longitudinal Joint	Poor Transverse Joint	Transverse Cracking (Checking)	Mat Shoving Under Roller	Bleeding or Fat Spots in Mat	Roller Marks	Poor Mix Compaction
Grade Control Mounted Incorrectly	✔	✔						✔			✔						
Grade Control Hunting (Sensitivity Too High)	✔										✔						
Grade Control Wand Bouncing on Reference	✔										✔						
Grade Reference Inadequate	✔	✔															
Sitting Long Period Between Loads		✔				✔											
Improper Joint Overlap											✔						
Improper Mat Thickness for Max. Agg. Size			✔			✔		✔		✔							
Trucks Bumping Paver		✔					✔										
Truck Holding Brakes		✔					✔										
Improper Base Preparation	✔	✔				✔				✔			✔	✔		✔	✔
Improper Rolling Operation	✔										✔	✔	✔	✔		✔	✔
Reversing or Turning Too Fast of Rollers		✔												✔		✔	✔
Parking Roller on Hot Mat		✔														✔	✔
Improper Mix Design (Agg.)	✔		✔			✔			✔				✔	✔	✔		✔
Improper Mix Design (Asphalt)	✔		✔			✔			✔				✔	✔	✔		✔
Mix Segregation	✔	✔	✔			✔			✔								
Moisture in Mix			✔										✔	✔	✔		✔
Variation of Mix Temperature	✔	✔	✔			✔		✔					✔	✔	✔	✔	✔
Cold Mix Temperature			✔	✔	✔	✔		✔		✔	✔	✔					✔

1. Find problem above.
2. Checks indicate causes related to paver.

✔ s indicate other problems to be investigated.

Note: Many times a problem can be caused by more than one item; therefore, it is important that each cause listed is eliminated to assure solving the problem.

Table 13. Common Problems and Related Solutions

PROBLEM	CAUSES AND SOLUTIONS
Surface Waves	**CAUSES** • A fluctuating head of material in front of the paver screed causing it to rise and fall usually causes surface waves • Worn or badly set screeds can cause surface waves • A mix that is too stiff or that has cooled too much before compaction will cause surface waves • Long waves can be caused by adjusting the screed too often and not allowing an adjustment to fully take effect before changing it again • Dump trucks bumping the paver when delivering a load of mix can cause long waves **SOLUTIONS** • The solution for avoiding surface waves is to control the material amount, temperature, and screed correctly • Pave continuously with a pick-up machine where possible
Wash Boarding	**CAUSES** • Wash boarding is caused by improper use of vibratory rollers, in either roller amplitude setting or speed **SOLUTIONS** • Use higher vibratory roller amplitudes for thicker layers and lower amplitudes for thinner layers • Slow down the roller speed
Tearing	**CAUSES** • Poor paver operation, or the mix being too cold and/or too stiff, causes tear marks **SOLUTIONS** • Tear marks can be avoided by adjusting the degree of the crown and ensuring the mix temperature is correct

Table 13. Common Problems and Related Solutions (Continued)

PROBLEM	CAUSES AND SOLUTIONS
Non-Uniform Texture: Segregation	**CAUSES** • The mixture separating in the hopper or in transportation causes segregation • Poor paver setup • Low mix temperature or poor grading or mix design • Prone to occur in thin overlays • Weak base layer • The dumping of hopper wings when paving with bottom dumps **SOLUTIONS** • Ensure thickness is at least three times that of the largest stone size, mix design is correct, and the paver is properly set up • Ensure mix temperature is correct • Do not dump the wings or, alternatively, place insert plates in the hopper eliminating the wing area
Screed Marks	**CAUSES** • Transverse screed marks occur when the paver stops and starts, and longitudinal screed marks occur when extensions are used on the screed • Poor paver setup or worn or dirty screeds • Low mix temperature or poor grading or mix design **SOLUTIONS** • Set paver and screed correctly; use windrowing to ensure paver does not stop • Ensure the mix meets specification requirements
Surface Shadows	**CAUSES** • Caused by overloading augers in the paver • May be caused by low mix temperature or poor grading or mix design **SOLUTIONS** • Adjust the distance between the screed and the tractor of the paver • Ensure that the level of mix is near the center of the auger shaft: the augers should NOT be totally covered with mix

Table 13. Common Problems and Related Solutions (Continued)

PROBLEM	CAUSES AND SOLUTIONS
Roller Checking and Roller Marks	**CAUSES** • Deflection under the roller (i.e., mix too hot) or mix design is poor • Too much asphalt in the mix, or too much middle-size sand in the gradation (No. 16–No. 30 [1.18mm–600 μm] sieve) **SOLUTIONS** • Wait until the mix cools further or adjust the mix design
Bleeding and Fat Spots	**CAUSES** • High mix temperature or poor grading or mix design • Too much asphalt in the mix or amount of fines too low in the grading • Mix design not taking the correct traffic level into account • Moisture in the mix or on the pavement • Extremely high applications of tack coat • Existing bleeding surface **SOLUTIONS** • Solve by ensuring aggregates are dry during the mixing process, that pavement is not bleeding, that pavement is dry, and that mix is correctly designed for traffic and aggregate
Shoving	**CAUSES** • Caused by excess asphalt in the mix • Improper roller operation such as sudden reversal • Rolling before the mat is stable enough • Roller going too fast **SOLUTIONS** • Ensure mix is at correct temperature • Ensure roller is not going too fast • Check and correct mix design if necessary • Consider use of modified binders

Table 13. Common Problems and Related Solutions (Continued)

PROBLEM	CAUSES AND SOLUTIONS
Delamination	**CAUSES** • Insufficient tack coat • Mix is too cold during compaction • Existing surface is too cold for paving • Dirty surface on which an overlay is being placed **SOLUTIONS** • Ensure paving temperatures are correct • Ensure the surface is free of debris
Poor Joints	**CAUSES** • Paver operating at different elevations when paving adjacent lanes • Poor joint practice, especially in compaction of thin layers **SOLUTIONS** • Make sure joints are correctly formed and compacted at the correct temperature
Raveling	**CAUSES** • Insufficient asphalt in the mix • Poor compaction **SOLUTIONS** • Ensure mix design conforms to the specification • Ensure compaction is carried out at correct temperatures

FIELD CONSIDERATIONS

The following field considerations given in Table 14 are a guide for the important aspects of performing a maintenance overlay project. The various tables list items that should be considered in order to promote best practices and a successful job outcome. As thoroughly as possible, the answers to these questions should be determined before, during, and after application. The field maintenance and construction personnel should be acquainted with its contents. The intention of the tables is not to form a report, but to bring attention to important aspects and components of the project's process. Some information is product-specific and contained in the relevant standard specifications, special standard provisions, or special provisions.

Table 14. Field Considerations

PRELIMINARY RESPONSIBILITIES	
Document Review	• Application specifications and special provisions • Mix design information • Traffic control plan (TCP)
Materials Checks	• Is an approved mix design being proposed for use? • Is the mix produced by an approved source? • Has the tack coat emulsion been sampled and submitted for testing? • Aggregates meet all specifications and are not from a source known to have stripping problems? If so, what anti-stripping treatment is to be used? • Aggregate is clean and free of deleterious materials and correct grading? • Is the tack coat emulsion properly prepared (diluted) before use? • Is the mix checked at the plant for temperature compliance, and have samples been taken?

Table 14. Field Considerations (Continued)

INSPECTION RESPONSIBILITIES	
Surface Preparation	• Is the surface clean and dry? Has it been swept? • Have any areas with oily residue been scrubbed from the pavement? • Have all pertinent pavement distresses been repaired? • Has the existing surface been inspected for drainage problems? • Have all utilities within surfacing limits been raised or masked?
EQUIPMENT INSPECTION CONSIDERATIONS	
Tack Coater	• Is the machine fully functional? • Has the machine been calibrated to accurately spray the correct level of tack coat? • Are all spray tips clean and not blocked? • Are nozzles angled correctly (approximately 30°)? • Is the spray bar at the correct height to allow for an overlap of spray fan?
Paving Machine	• Is the machine fully functional? • Is the paver clean and are the wings operating correctly? • Are flow gates clear, set at the right height, and functioning properly? • Are the conveyors functioning? • Are the augers clean and functioning? • Is the flow system (manual or automatic) operational? • Are material levels in the paver auger chamber set correctly? • Do the screed heaters work? • Is the screed clean and properly set? • Is the automatic leveling system working and correctly set? • Are the screed strike offs clean and providing a uniform mat? • Is the pick-up machine working correctly for mainline paving? • Is a materials transfer device being used? Is it working correctly?

Table 14. Field Considerations (Continued)

EQUIPMENT INSPECTION CONSIDERATIONS	
Rollers	• What types of rollers will be used on the project for break down and finish rolling? • Tandem or vibratory steel rollers: are they fully functional? • Pneumatic roller: is it fully functional, and do roller tire pressures comply with the manufacturer's specification? • Do the roller tire size, rating, and pressures comply with manufacturer's recommendations? • Ensure the tire pressure is the same on all tires. • All tires should have a smooth surface. • Are the spray bars for the tires operational?
Dump Trucks	• What types of dump trucks are being used? • Are bottom dump trucks providing a clean and well-shaped windrow?
Weather Requirements	• Have air and surface temperatures been checked at the coolest location on the project? • Do air and surface temperatures meet specification requirements?
Determining Application Rates	• Have Agency guidelines and requirements been followed? • Is rut filling or a leveling course required? If so, have material quantities been calculated or estimated to properly reprofile roadway? • Is an approved mix design being furnished? • Are tack coat application rates correct for the pavement surface? A heavier spread rate may be required on roads with porous surfaces (and lighter for those with flushed surfaces).
Calibration of Equipment	• Are machines calibrated? • Who carried out the calibration, and what documentation has been provided? • Are current calibration stickers on the distributor trucks and the paving machine?

Table 14. Field Considerations (Continued)

TRAFFIC CONSIDERATIONS	
Traffic Control	• The signs and devices used match the traffic control plan. • Flaggers do not hold the traffic for extended periods of time. • Unsafe conditions, if any, are immediately reported to the Resident Engineer and corrected. • The pilot car leads traffic slowly—25 mph (40 kph) or less—over fresh overlays. • Signs are removed or covered when they no longer apply.
PROJECT INSPECTION RESPONSIBILITIES	
Tack Coat Application	• What is the emulsion temperature? • Wind, humidity, and temperature can affect set time and affect distribution. • Has tack coater application spray bar been checked for height? blocked nozzles? • Has application rate been checked? • Has the emulsion been diluted correctly? • Is the grade and ambient temperature satisfactory? • Is the application even and does it cover the entire pavement? • Is the emulsion allowed to break (to turn black) before paving? • Is the application in accordance with Caltrans guidelines? • Do the paver wheels pick up the tack coat during paving?
Laydown of Dense-Graded Mix	• Has a test strip been successfully laid and compacted? • Are the ambient and grade temperatures correct? • Is the mix temperature correct? • If continuous application is used with windrowing, is the mixture the correct temperature? • If back dump trucks are used, are changeovers smooth, causing no bumping of the paver? • Are the hopper, augers, and screed operating correctly? • Is the screed set at the correct height? • Is the mat a uniform thickness and uniform in appearance? • Are height adjustments minimal? • Are height adjustments allowed sufficient times to be effective? • Does the mat look uniform? • Are edge lines and joint overlaps neat and straight? • If problems persist, stop the paving.

Table 14. Field Considerations (Continued)

PROJECT INSPECTION RESPONSIBILITIES	
Laydown of RAC Type G Mix	• Has a test strip been successfully laid and compacted? • Is the ambient and grade temperature correct? • Is there evidence of significant drain down of the mix? • Is the mix temperature correct? • Is the paver going at a uniform speed? • Are the paver wings kept open to avoid segregated mix being laid? • If back dump trucks are used, are changeovers smooth, causing no bumping of the paver? • Are the hopper, augers, and screed operating correctly? • Is the screed set at the correct height? • Is the mat being tamped uniformly and is the mat a uniform thickness? • Are height adjustments minimal? • Are height adjustments allowed sufficient time to be effective? • Does the mat look uniform? • Are edge lines and joint overlaps neat and straight? • Is the job stopped if problems persist? • Does the material have a dull or shiny look?
Laydown of Open-Graded Mix	• Has a test strip been successfully laid and compacted? • Is the ambient and grade temperature correct? • Is the mix temperature correct? • Is there evidence of drain down? • Is the paver going at a uniform speed? • If continuous application is used with windrowing, is the mixture the correct temperature? • If back dump trucks are used, are changeovers smooth, causing no bumping of the paver? • Are the hopper, augers, and screed operating correctly? • Is the screed set at the correct height? • Is the mat being tamped uniformly, and is the mat a uniform thickness? • Are height adjustments minimal? • Are adjustments allowed time to be effective? • Does the mat look uniform? • Are edge lines and joint overlaps neat and straight? • Is the job stopped if problems persist?

Table 14. Field Considerations (Continued)

PROJECT INSPECTION RESPONSIBILTIES	
Rolling Dense-Graded Mix	• Has a roller pattern been established? [24. 25] • Have the number of passes required for breakdown rolling been established? • Is the surface temperature of the mat correct at beginning of rolling? • Is the roller being operated at the correct speed? Does the mat check under the roller? (allowing mix to get too cold with rolling) • Ensure that no aggregate is crushed under breakdown rolling. • Is water being used to cool the mat? • How many passes? • Does the mat look uniform? • Does mat meet density requirements? • Are edge lines and joint overlaps neat and straight? • Is the job stopped if problems persist?
Rolling RAC Type G Mix	• Has a roller pattern been established? [24,25] • Have the number of passes required for breakdown rolling been established? • Is the surface temperature of the mat correct at beginning of rolling? • Is the roller being operated at the correct speed? • Does the mat check under the roller? If so, wait a little longer for cooling. • Is water being used to cool the mat? • How many passes? • Does the mat look uniform? • Has density been met? • Does the mix pick up? • Are edge lines and joint overlaps neat and straight? • Is the job stopped if problems persist?

Table 14. Field Considerations (Continued)

PROJECT INSPECTION RESPONSIBILTIES	
Rolling Open-Graded Mix	• Has a roller pattern been established? [24, 25] • Have the number of passes required for breakdown rolling been established? • Is the surface temperature of the mat correct at beginning of rolling? • Is the roller being operated at the correct speed? • Does the mat check under the roller? If so, wait a little longer for cooling. • Does the mat look uniform? • Has density been met? • Does the mix pick up? • Are edge lines and joint overlaps neat and straight? • Is the job stopped if problems persist?
Truck preparation	• Trucks are staggered across the fresh tack coat to avoid driving over the same area. • Trucks travel slowly on the fresh mix. • Stops and turns are made gradually. • Truck operators avoid driving over mat. • Trucks should stagger their wheel paths when backing over a previous pass.
Longitudinal Joints	• Is echelon paving used? • Are joints overlapped or cut back? • Has a notch device been used? • Is compaction at joints satisfactory? • If left open to traffic, are edges of runs feathered to prevent fall off of traffic? • Are joints flat and smooth? • How far does the end gate of the paver overlap the previous lane? • Minimal raking of the longitudinal joint should be done. • Compaction should be from the hot side of the joint. • Are the joints straight and compact? • Ensure no gaps!

Table 14. Field Considerations (Continued)

PROJECT INSPECTION RESPONSIBILITIES	
Transverse Joints	• Transverse joints should be minimal and are used at the end of paving or when problems occur in laying. • Butt joints require a vertical face to be constructed by hand. Is this done? • Is it done quickly to avoid mix cooling? • Compaction is done upstream of the joint—are runoff boards provided for the roller? • Tapered joints are used if traffic is to be carried over a transverse joint. • Is the mat uniform up to the joint? • Is treated paper or sand used on the edge for a temporary joint to form a ramp? • Is a ramp constructed just with mix? • When paving is recommenced, is the ramp or taper removed cleanly? • Is raking used excessively to form the joint? • Is the joint compacted transversely? • If there are restrictions, is the joint compacted longitudinally? • Is the joint tight and well compacted and close to being indiscernible?
Opening the Mix to Traffic	• The traffic travels slowly—24 mph (40 kph) or less—over the fresh mat. • Remove all construction-related signs when opening to normal traffic.
Clean Up	• All loose aggregate should be removed from travel way. • Remove spills from all areas including curbs, sidewalks, and radius applications.

APPENDIX A: TYPICAL CALTRANS BID ITEMS

Shown below is a typical bid item list from a Caltrans RHMA-G project with repairs and cold planning the existing surface. The contractor's overhead clause was removed from this list. This information is available online at the Caltrans Office Engineer's website, and it can be very helpful when developing an engineer's estimate and an agency's bid item list.

Item No.	Item Code	Item Description	Unit of Measure	Estimated Quantity
1	070030	LEAD COMPLIANCE PLAN	LS	LUMP SUM
2	120090	CONSTRUCTION AREA SIGNS	LS	LUMP SUM
3	120100	TRAFFIC CONTROL SYSTEM	LS	LUMP SUM
4	120201	PORTABLE RADAR SPEED FEEDBACK SIGN SYSTEMS	LS	LUMP SUM
5	128652	PORTABLE CHANGEABLE MESSAGE SIGN (LS)	LS	LUMP SUM
6	130100	JOB SITE MANAGEMENT	LS	LUMP SUM
7	130200	PREPARE WATER POLLUTION CONTROL PROGRAM	LS	LUMP SUM
8	130620	TEMPORARY DRAINAGE INLET PROTECTION	EA	4
9	190185	SHOULDER BACKING	TON	390
10	374002	ASPHALTIC EMULSION (FOG SEAL COAT)	TON	1.2
11	039327	HOT MIX ASPHALT (TYPE A)(REPAIR FAILED AREA)	TON	840
12	390136	MINOR HOT MIX ASPHALT	TON	110
13	390137	RUBBERIZED HOT MIX ASPHALT (GAP GRADED)	TON	3,670
14	394060	DATA CORE	LS	LUMP SUM
15	394076	PLACE HOT MIX ASPHALT DIKE (TYPE E)	LF	4,170
16	397005	TACK COAT	TON	27
17	398100	REMOVE ASPHALT CONCRETE DIKE	LF	4,170
18	398200	COLD PLANE ASPHALT CONCRETE PAVEMENT	SQYD	51,500
19	039328	COLD PLANE ASPHALT CONCRETE PAVEMENT (REPAIR FAILED AREA)	SQYD	5,860
20	810120	REMOVE PAVEMENT MARKER	EA	20
21	810230	PAVEMENT MARKER (RETROREFLECTIVE)	EA	1,140
22	820510	RESET ROADSIDE SIGN (ONE POST)	EA	1
23	840505	6" THERMOPLASTIC TRAFFIC STRIPE	LF	51,600
24	840506	8" THERMOPLASTIC TRAFFIC STRIPE	LF	2,020
25	840515	THERMOPLASTIC PAVEMENT MARKING	SQFT	620
26	846030	REMOVE THERMOPLASTIC TRAFFIC STRIPE	LF	840
27	846051	12" RUMBLE STRIP (ASPHALT CONCRETE PAVEMENT)	STA	110
28	870009	MAINTAINING EXISTING TRAFFIC MANAGEMENT SYSTEM ELEMENTS DURING CONSTRUCTION	LS	LUMP SUM

APPENDIX B: TYPICAL GREENBOOK BID ITEMS

Shown below is a typical bid item list for a project which uses the Greenbook as the Standard Specifications. The items are listed in ascending order of the respective subsection which specifies the item. The scope of work is for a mill and fill and includes digouts, cold milling, ARAM interlayer, ARHM and PMAC, manhole adjustments, striping and pavement markings, and inductive loop detector replacement.

Item No.	Item Description	Unit of Measure	Estimated Quantity
1	IMPLEMENTATION OF BMPs	LS	LUMP SUM
2	MOBILIZATION	LS	LUMP SUM
3	UNCLASSIFIED EXCAVATION	CY	
4	CRUSHED MISCELLANEOUS BASE	CY	
5	AC PAVEMENT (DIGOUTS) (C2-PG 64-10)	TON	
6	ASPHALT RUBBER HOT MIX (ARHM-GG-C)	TON	
7	ASPHALT RUBBER AND AGGREGATE MEMBRANE	SY	
8	PMAC PAVEMENT (C2-PG 64-28PM)	TON	
9	STRIPING (THERMOPLASTIC)	LF	
10	PAVEMENT MARKINGS (THERMOPLASTIC)	SF	
11	ADJUST MANHOLE	EA	
12	DOUBLE ADJUST MANHOLE	EA	
13	COLD MILL AC PAVEMENT (0 - 1-1/2”)	SF	
14	TRAFFIC CONTROL	LS	LUMP SUM
15	FLASHING ARROW SIGN	EA	
16	CHANGEABLE MESSAGE SIGN	EA	
17	TEMPORARY STRIPING AND PAVEMENT MARKINGS (ONE-COAT PAINT)	LS	LUMP SUM
18	INDUCTIVE LOOP DETECTOR AND LEADS SAW CUT	LF	
19	PREFORMED INDUCTIVE LOOP DETECTOR	LF	

APPENDIX C: LOCAL AGENCY REFERENCES

Note: The special provisions for Caltrans projects are for specifying changes from the Caltrans 2018 Standard Specification. All these Caltrans special provision changes may not be necessary for a local agency project.

The Caltrans 2018 Standard Specifications and Caltrans 2018 Standard Plans can be found on the following website:

https://dot.ca.gov/programs/design/ccs-standard-plans-and-standard-specifications

All currently advertised plans are available on the Engineering Services website:

http://ppmoe.dot.ca.gov/des/oe/weekly-ads/all-adv-projects.php

The Caltrans Local Assistance Procedures Manual (see Chapter 12: Plans, Specifications & Estimate) can be viewed at the following Caltrans website:

https://dot.ca.gov/-/media/dot-media/programs/local-assistance/documents/lapm/ch12.pdf

Exhibits applicable to Chapter 12 of the Local Assistance Procedures Manual can be found at: https://dot.ca.gov/programs/local-assistance/forms/local-assistance-procedures-manual-forms

Division of Local Assistance, Office of Procedures Development and Training Quality Assurance Program (QAP) Manual for Use by Local Agencies Revised January 20, 2011. https://dot.ca.gov/-/media/dot-media/programs/local-assistance/documents/reports/qap-manual.pdf

ABBREVIATIONS AND ACRONYMS

AASHTO	American Association of State Highway and Transportation Officials
ADT	Average Daily Traffic
AI	Asphalt Institute
APWA	American Public Works Association
AR	Asphalt Rubber
ARHM	Asphalt Rubber Hot Mix
ARHM-GG	Asphalt Rubber Hot Mix: Gap Graded
ASTM	American Society for Testing and Materials
BWC	Bonded Wearing Course
Caltrana	California Department of Transportation
CalRecycle	California Department of Resources Recycling and Recovery
CCPIC	City and County Pavement Improvement Center
CP^2C	California Pavement Preservation Center
CRM	Crumb Rubber Modifier
CRUMAC-GG	Crumb Rubber Modified Asphalt Concrete Gap Graded
FHWA	Federal Highway Administration
HMA	Hot Mixed Asphalt
IA	Independent Assurance
IRI	International Roughness Index
JMF	Job Mix Formula
LCCA	Life Cycle Cost Analysis
LCC	Life Cycle Cost
MSA	Maintenance Superintendents Association
MTAG	Maintenance Technical Advisory Guide
MTC	Metropolitan Transportation Committee
MTI	Mineta Transportation Institute
NAPA	National Asphalt Paving Association
OBC	Optimum Binder Content
OGAC	Open-Graded Asphalt Concrete
OGFC	Open-Graded Friction Course
PaveM	Caltrans Pavement Management System
PCI	Pavement Condition Index
PCR	Pavement Condition Rating
PG	Performance Grade
PG-PM	Performance Grade, Polymer Modified
PS&E	Plans, Specifications, and Estimate
PMA	Polymer Modified Asphalt
PMAC	Polymer Modified Asphalt Concrete
PMS	Pavement Management System

QA	Quality Assurance
QC	Quality Control
RAP	Reclaimed Asphalt Pavement
RHMA-G	Rubber Hot Mix Asphalt: Gap Graded
RHMA-O	Rubber Hot Mix Asphalt: Open Graded
RHMA-O-HB	Rubber Hot Mix Asphalt: Open Graded, High Binder
SIAD	Statewide Independent Assurance Database
SDS	Safety Data Sheet
TCV	Total Cracking Value
TRB	Transportation Research Board
TRMAC	Tire Rubber Modified Asphalt Concrete
UTBWC	Ultra-Thin Bonded Wearing Course
WMA	Warm Mix Asphalt
WPCV	Wheel Path Cracking Value

ENDNOTES

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PEER REVIEW

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