CHAPTER 12 BONDED WEARING COURSE

12.1 OVERVIEW

Bonded Wearing Course (BWC) is a gap-graded, ultra-thin (0.08' or less) Hot-Mix Asphalt (HMA) mixture applied over a thick polymer modified asphalt emulsion membrane, all in one pass. A BWC can be applied and opened to traffic quickly without sanding or tracking. Bonded wearing courses are primarily used in high traffic areas as a surface treatment over HMA and Portland Cement Concrete (PCC) surfaces. BWC must be placed over structurally sound pavements as a maintenance treatment and may also be used in new construction and rehabilitation projects as the final wearing course, although the latter applications are not common. The mix is generally laid one and a half times as thick as the largest stone in the gradation; however, it may be placed thicker to correct minor surface irregularities.

The BWC polymer modified asphalt emulsion membrane seals the underlying existing pavement and bonds the gap-graded or open-graded mix to the surface. The high application rate results in a thick membrane which allows it to migrate upwards into the mix, filling voids in the aggregate and creating an interlayer of high cohesion. Due to the nature of the gap-graded or open-graded mix and the polymer in the membrane, bleeding is not normally a concern.

The types of BWC are:

- Gap-Graded (HMA, RHMA-G), referred to BWC-G and RBWC-G
- Open-Graded (HMA-O, RHMA-O), referred to BWC-O and RBWC-O

Specifications for BWC are in section 39-2.05 Bonded Wearing Courses of the Standard Specifications. BWC using RHMA-G, RHMA-O, or HMA-O must comply with the specifications for RHMA-G, RHMA-O, or HMA-O.

This document provides an overview of:

- Materials and mixtures used in construction of bonded wearing courses,
- Guidelines for project selection,
- Construction process associated with bonded wearing courses,

- Troubleshooting guide to assist the field personnel, and
- Suggested construction field considerations.

12.2 GAP-GRADED BONDED WEARING COURSES

This section provides an overview of the specifications for materials used in the production of gap-graded bonded wearing courses. Gap-graded bonded wearing courses are produced using polymer-modified or asphalt-rubber binders and gap graded aggregates.

Requirements for gap-graded BWC using polymer modified asphalt binder are specified in Section 39-2.05B Bonded Wearing Courses – Gap-Graded of the Standard Specifications. Requirements for gap-graded BWC using asphalt rubber binder are specified in section 39-2.03 Rubberized Hot Mix Asphalt – Gap-Graded of the Standard Specifications, 2024.

Binder

Section 39-2.05B(2)(c) Asphalt Binder of the 2024 Standard Specifications specifies the asphalt binder as “Reserved”. When using polymer modified asphalt binder, the grade for a specific project must be specified in the special provisions.

Asphalt-rubber is the most common asphalt binder used for BWC-GG. Asphalt rubber binder must conform to the requirements in section 39-2.03B(3) Asphalt Rubber Binder of the Standard Specifications, 2024.

Polymer modified asphalt binder (PG-M) must conform to the requirements shown in the table for PG Modified Asphalt Binders in section 92-1.02B Performance Grade Asphalt Binders of the Standard Specifications for the respective climatic zone (shown below as Table 12-1).

Table 12-1 Bonded Wearing Course – Gap-Graded HMA Binder Grades

Climatic Region	PG Binder Grade
Desert	PG 76-22PM
South Coast Central Coast Inland Valleys North Coast Low Mountain South Mountain High Mountain High Desert	PG 64-28PM

Aggregate

Aggregate quality requirements and gradations for BWC-G are specified in section 39-2.05B(2)(d) Aggregates of the Standard Specifications, 2024. The quality requirements for

BWC-G are higher than those specified for HMA in section 39-2.02B(4)(a). Aggregate quality requirements and gradations for RBWC-G are specified in section 39-2.03B(4) Aggregates of the Standard Specifications.

The purpose of using a gap-graded gradation in a BWC is to provide improved stone-to-stone contact by reducing the medium-sized aggregate content. This also produces a strong aggregate skeleton that provides space for more binder than a dense-graded mix does.

The ½-inch (12.5 mm) gradation is used for roadways with high traffic volumes (which require a thicker and more durable mat) and where pedestrian or bicycle traffic are not a concern. The 3/8-inch (9.5 mm) gradation is used for urban, residential and business district roadways where pedestrian and bicycle traffic is a consideration. This can also be used on mainline travel ways if desired.

The finished mat has very high macro-texture properties, provides good skid resistance and has a void structure that improves driving visibility by reducing back-spray and tire-splash. The void structure also reduces tire noise.

12.3 OPEN-GRADED BONDED WEARING COURSES (BWC-O)

This section provides an overview of the specifications for materials used in the production of open-graded bonded wearing courses. Open-graded bonded wearing courses are produced using polymer-modified or asphalt-rubber binders and open graded aggregates.

Open-graded bonded wearing courses using RHMA-O (hereafter referred to as RBWC-O) or HMA-O (hereafter referred to as BWC-O) must comply with the specifications for RHMA-O or HMA-O, respectively.

Binder

The asphalt binder grade used in BWC-O regardless of location is PG 58-34PM. Specifications for this binder and other polymer modified asphalt binders are in section 92-1.02B Performance Grade Asphalt Binders of the Standard Specifications, 2024.

Asphalt-rubber binder used in RBWC-O must conform to the requirements in section 39-2.03B (3) Asphalt Rubber Binder of the Standard Specifications, 2024.

Aggregate

Aggregate quality requirements and gradations for BWC-O and RBWC-O are specified in section 39-2.04B(4) Aggregates of the Standard Specifications, 2024.

The purpose of using an open grading in a BWC is to provide a permeable mixture capable of removing more water from the pavement surface than a gap-graded mixture. The use of BWC-O is recommended in areas subject to frequent or heavy rainfall.

The ½-inch (12.5 mm) gradation is used.

12.4 POLYMER MODIFIED ASPHALTIC EMULSION MEMBRANE

The asphaltic emulsion applied as the membrane for a bonded wearing course is specially formulated and must conform to the specifications in section 94-1.02G Bonded Wearing Course Asphaltic Emulsion of the Standard Specifications, 2024. The polymer modified asphaltic emulsion is designed to provide high flexibility and bonding in the range of climactic conditions in which bonded wearing courses are placed). The emulsion is manufactured using conventional means.

The specifications are based on common emulsion requirements, such as stability, binder content, viscosity and torsional recovery. Application viscosity is important, as the material should be easily sprayed at the correct rate, not flow away and form a continuous membrane. The residual properties indicate polymer presence, and the base asphalt grade used. Cooler conditions call for higher residual penetration. The emulsion is designed to break rapidly after spraying to ensure that no water is trapped. The gap-graded or open-graded nature of the mix allows water to escape, thus promoting breaking of the emulsion.

12.5 PROJECT SELECTION

12.5.1 Distress and Application Considerations

While a bonded wearing course is a flexible pavement surface, it is not considered a structural layer. BWC is a viable application for treating structurally sound, worn pavements, and has shown some ability to retard reflective cracking due to its membrane and gap-graded aggregate structure. BWC's are used on both flexible and PCC pavements to correct non-structural surface defects such as skid resistance, noise dampening and splash-and-spray control. BWC is typically selected for use when speed of construction and user delays are issues.

12.5.2 Performance

Bonded wearing courses have been estimated to last 7 to 12 years (Oliver, 1999; PennDOT, 2002; Wonson, 1997). The main method of failure is wear; that is, the surface oxidizes and is abraded over time. Premature failure occurs from placement on highly deflecting and cracked surfaces, pavement with base failures. Also, delamination occurs when placed on dirty or poorly prepared surfaces.

The main performance benefits associated with using a BWC are improved skid resistance, reduced traffic noise, increased ride quality and splash and spray reduction.

12.6 CONSTRUCTION

The main components of the construction process include:

- Traffic Control
- Equipment Requirements
- Surface Preparation
- Placement Conditions
- Placement of BWC
- Opening to Traffic

Section 12.7.2, "Suggested Field Considerations", at the end of this chapter, provides a series of tables to guide project personnel through the important aspects of constructing a successful BWC.

12.6.1 Traffic Control

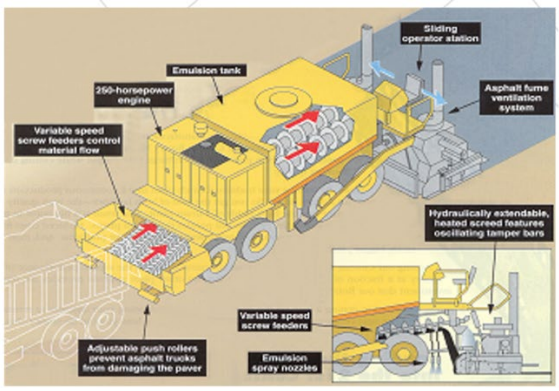
Traffic control is required both for the safety of the traveling public and the personnel performing the work. It is also used to ensure the new surface is compacted and allowed to cool to below 158°F (70°C) prior to reopening the surface to traffic.

12.6.2 Equipment Requirements

Equipment requirements for constructing a BWC are found in section 39-2.05A(3)(b) Spreading and Compacting Equipment of the Standard Specifications, 2024. The most significant requirement is that the binder application and hot mix spreading function are combined into a single unit called a "spray paver." The following section describes this specialized unit while the subsequent sections discuss other equipment requirements.

Spray Paver

The paving machine used for the construction of a BWC is a specially constructed machine referred to as a "spray paver." A diagram of a BWC paving unit is shown in Figure 12-1. Figure 12-2 and Figure 12-3 show a close look of the spray and spreading functions of a spray paver, and Figure 12-4 shows a freshly laid BWC. Spray paver manufacturers include Vogele and Roadtec.



- The paving unit pushes the truck carrying the hot mix asphalt.
- The mix drops into a hopper at the front of the paving unit.
- The mix is transported via an auger to a screed.
- The emulsion membrane is sprayed just in front of the screed and the mix is laid on top.

Figure 12-1 Paving Unit (SHRP, 1993)

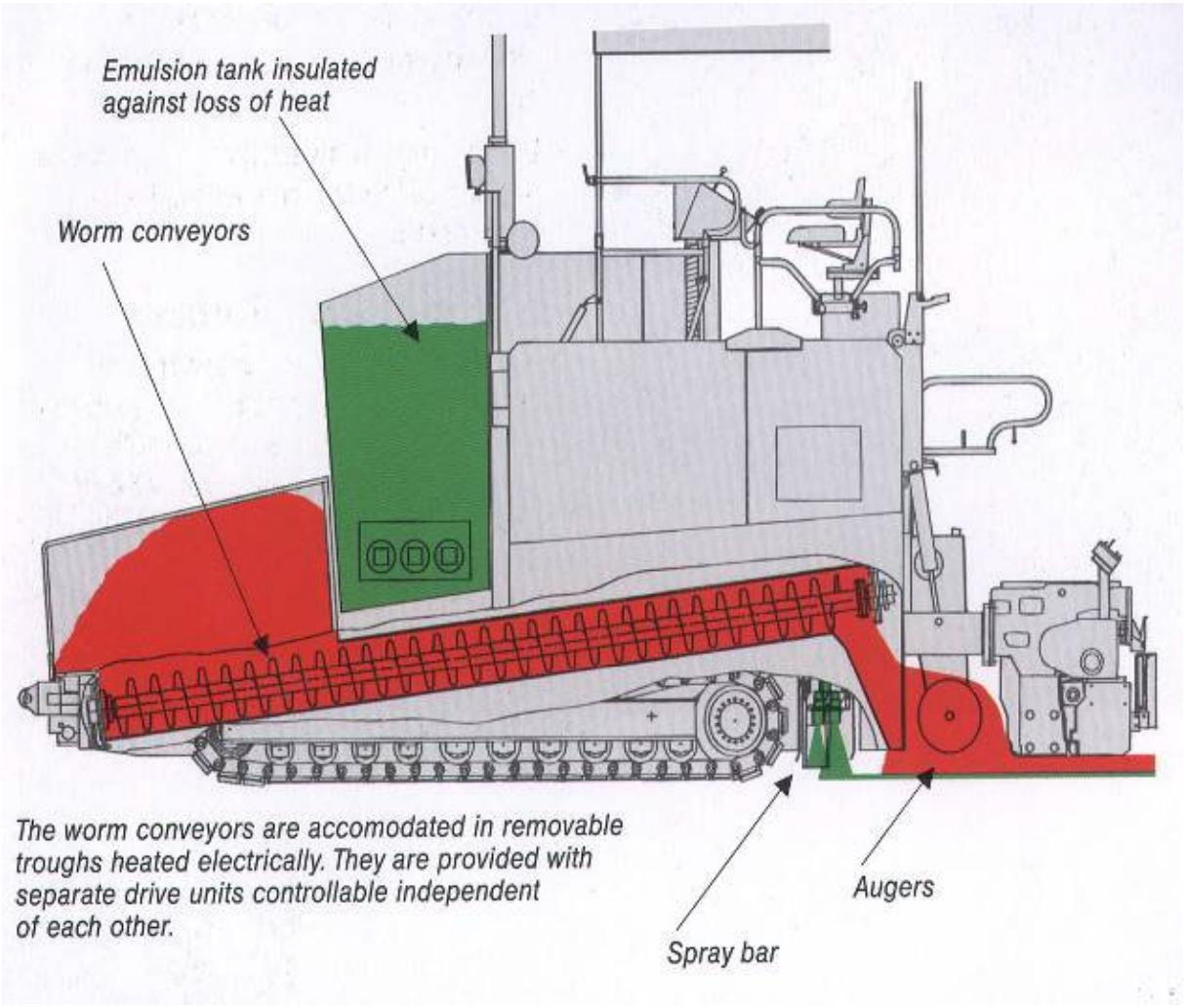


Figure 12-2 Spray Paver

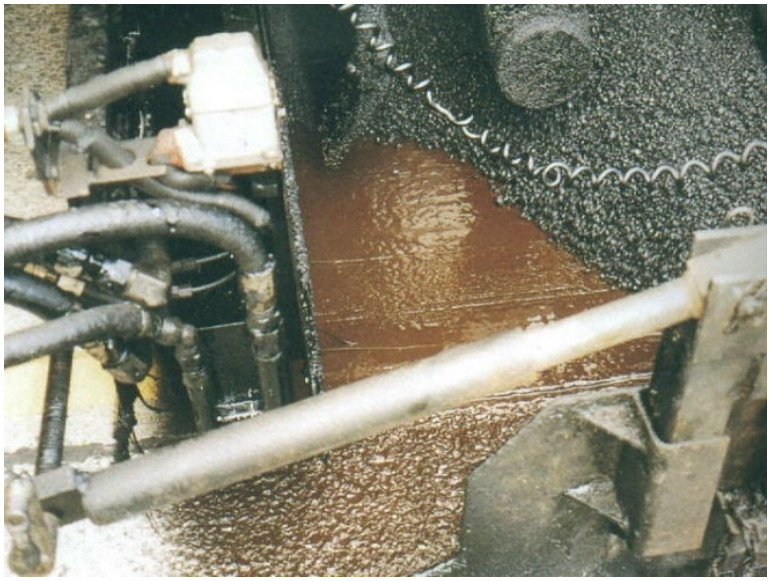


Figure 12-3 Emulsion Membrane and Mix Spreading (Alverez, 1992)

Figure 12-4 Freshly Laid BWC (Alverez, 1992)

Rollers

Rollers must conform to section 39-2.01C(2)(c) Method Compaction Equipment of the Standard Specifications, 2024.

Material Transfer Vehicle (MTV)

Section 39-2.05A(3)(b) of the 2024 Standard Specifications requires the use of an MTV when placing BWC. The thinner lift thickness of BWC results in a higher production rate. The use of an MTV allows for more consistent production and the reduction or elimination of stopping and starting from contact with delivery trucks, thus reducing the potential for bumps in the mat. In addition, an MTV remixes the material eliminating segregation and providing a more uniform mixture temperature.

12.6.3 Surface Preparation

Cracks wider than wide ¼-inch (6 mm) should be filled or sealed prior to placing the BWC (see Chapter 4 “Crack Sealing and Filling” of this document). The use of over-banding methods of crack sealing is not recommended for this treatment as that method can leave strips that reflect through the finished pavement. All necessary repairs must also be performed prior to the application of the BWC.

Ruts must be removed by cold milling the surface or filling the ruts with Type A HMA before placing the BWC.

12.6.4 Placement

Details specific to placing bonded wearing courses are discussed in the following paragraphs.

Polymer Modified Asphaltic Emulsion Membrane

Application of the polymer modified asphaltic membrane must conform to the requirements in section 39-2.05A(3)(c) Applying Asphaltic Emulsion of the Standard Specifications, 2024.

If the screed extension is outside the spray bar width, the tack coat will need to be applied manually to coat the pavement between the end of the spray bar and the end of the screed. Care should be taken to ensure the correct application rate in such circumstances. The spray bar should be calibrated and able to be adjusted to within ± 10% of the design application rate. Coverage of the pavement must be even and uniform and, as such, it is important that there are no plugged nozzles on the spray bar.

Paving

Placement must conform to the requirements in section 39-2.05A(3)(d) Placing and Compacting Hot Mix Asphalt of the Standard Specifications, 2024. Use of an MTV is required.

Compaction

Compaction must conform to section 39-2.01C(15)(b) Method Compaction of the Standard Specifications, 2024. Figure 12-5 shows a typical positioning of the roller behind the paver.

Figure 12-5 Roller Position During Application (Alverez, 1992)

12.7 TROUBLESHOOTING AND FIELD CONSIDERATIONS

12.7.1 Troubleshooting Guide

This section provides information to assist the maintenance personnel with troubleshooting problems that may arise when applying a BWC. Table 12-2 lists some commonly encountered problems and their recommended solutions.

Table 12-2 Common Problems and Related Solutions

Problem	Solutions
Surface Waves	• Ensure the head of material in front of the paver screed is at the correct height and does not fluctuate (i.e., rise and fall). • Ensure the screed is not worn or set incorrectly. • Ensure the mix is not too stiff or has not fallen below 275°F (135°C). • Ensure the dump trucks do not bump the paving unit as this can cause long frequency waves resulting in increased pavement roughness. • Ensure grade control equipment (if in use) is functioning properly
Wash Boarding	• Slow roller down.
Tearing	• Ensure the paving unit is being operated correctly. • Ensure the mix is not too cold (i.e., below 275°F (135°C)) or too stiff. • May be fixed by adjusting the degree of crown and ensuring mix temperature is correct. • Ensure application is not too thin
Non-uniform Texture Segregation	• Ensure the mixture is not separating in the hopper or during transportation. • Ensure the paving unit is set up properly. • Ensure the mix temperature is at least 275°F (135°C). • Check the mix design for poor grading. Adjust if necessary.
Screed Marks	• Ensure the paving unit is set up correctly and that the screed in not worn or dirty. • Ensure the mix temperature is at least 275°F (135°C). • Check the mix design for poor grading. Adjust if necessary. • Ensure mix is in specification.
Roller Checking & Marks	• Ensure the roller does not cause a wave in the mat in front of the roller (i.e., mix too hot). Wait until the mix cools further. • Check the mix design for too much asphalt in the mix, or too much middle size sand in the gradation. Adjust design if necessary.

Table 12-2 Common Problems and Related Solutions (Continued)

Problem	Solutions
Bleeding & Fat Spots	• Ensure the mix temperature is not too hot (greater than 351°F (177°C). • Check the mix design for too much asphalt or for too coarse an aggregate grading. Adjust design if necessary. • Ensure there is no moisture in the mix or on the pavement. • Ensure the tack coat application rate is not too high for the surface to which it is applied. Tight, smooth surface require less tack coat than do more open surfaces. Reduce application rate on existing surfaces that exhibit bleeding. • Ensure spray bar equipment is operating properly. • Ensure aggregates are dry before mixing with asphalt in the hot mix plant, that pavement is not bleeding, that pavement is dry, and that mix is correctly designed for traffic and aggregate.
Delamination	• Ensure adequate tack coat is applied. • Ensure the mix is above minimum application temperature (275°F (135°C)). • Ensure the mix is not below the minimum compaction temperature (194°F (90°C)). • Ensure the existing pavement surface temperature is above the minimum (i.e., 45°F (7°C)) before paving. • Ensure the surface is cleaned immediately before paving. • Ensure roller drums are not dirty and have working spray systems.
Poor Transverse Joints	• Ensure butt joints are properly constructed.
Poor Longitudinal Joints	• Ensure proper joint construction practices are followed, especially when compacting thin layers.
Excessive Ravel	• Ensure the mix design meets project specifications, particularly that the mix contains sufficient binder. • Ensure compaction is carried out above the minimum temperature (i.e., 194°F (90°C)).

12.7.2 Field Considerations

The following field considerations are a guide to the important aspects of applying a bonded wearing course. The tables list items that should be considered in order to promote a successful job outcome. The answers to these questions should be determined, as required, before, during, and after construction. The appropriate staff to do this will vary by job type and size, and some topics may need attention from several staff members. The field supervisor should be acquainted with its contents.

The intention of these tables is not to form a report, but to highlight important aspects and components of the BWC construction process. Some information is product-specific and contained in the relevant standard specifications, special standard provisions, or special provisions.

Table 12-3 Field Considerations

Preliminary Responsibilities	
Project Review	• Is the project a good candidate for a bonded wearing course? • How much rutting is present, depth and extent? • 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 base sound and well drained? • Is surface water splash-and-spray a problem? • Is pavement strengthening required? • Review project for bid/plan quantities.
Document Review	• Application specifications. • Mix design information. • Special provisions. • Construction manual. • Traffic control plan (TCP).
Materials Checks	• Have the aggregates been sampled and tested? Do they meet the requirements set forth in the Standard Special Provision? • Has the binder for the mix been sampled and tested? Does it meet the requirements set forth in the Standard Special Provision? • Is the mix produced by an approved source? • Has a full mix design has been performed for the mixture? • Has the mix been tested? Is the mix within specification? • Has the polymer modified asphalt emulsion membrane been sampled and tested? Does it meet the requirements set forth in the Standard Special Provision?

Table 12-3 Field Considerations (Continued)

Pre-seal Inspection Responsibilities	
Weather Requirements	• Have air and surface temperatures been checked at the coolest location on the project? • Do air and surface temperatures meet agency requirements? • Is rain expected before or during paving operations? • Are freezing temperatures expected within 24 hours of the completion of any paving runs?
Determining Application Rates	• Agency guidelines and requirements are followed. • Rut filling and leveling course requirements is a separate item and rates have been calculated or estimated to properly re-profile roadway. • Has a full mix design been done? • Are emulsion membrane application rates correct for the pavement surface? • More emulsion may be required on roads with porous surfaces and less for those with flush surfaces or PCC surfaces.
Surface Preparation	• Is the surface clean and dry? Has it been swept? • Have areas with oily residue been scrubbed? • Have all pavement distresses been repaired? • Has the existing surface been inspected for drainage problems? • Have all utilities been raised and masked? • Has project been laid-out to ensure the best possible results?
Equipment Inspections	
Broom	• Are the bristles the proper length? • Can the broom be adjusted vertically to avoid excess pressure?
Application Equipment	• Has the machine been calibrated to accurately spray the correct amount of membrane? • Are all spray tips clean and free of blockage? • Is there a double or triple overlap of spray fan? • Is the paving unit clean and operating correctly? • Are flow gates clear, set at the right height, and functioning properly? • Are conveyors and augers functioning properly? • Is the flow system (manual or automatic) operational? • Are material levels in the auger chamber of the paving unit set correctly? • Do the screed heaters work? • Is the screed clean and properly set? Is the angle of attack correct? • Is the automatic leveling system working and correctly set? • Is the paver speed correct for correct thickness and angle of attack? • Are the screed strike offs clean and providing a uniform mat?

Table 12-3 Field Considerations (Continued)

Equipment Inspections	
Rollers	• Are appropriate rollers being used? Do they comply with the requirement set forth in the Standard Special Provisions?
Material Delivery Vehicle	• Do dump trucks or live bottom trailers properly match up with the paving unit?
Calibration of Equipment	• Are all machines properly calibrated? • Who carried out calibration? • Has documentation has been provided?
Project Inspection Responsibilities	
Traffic Control	• Do the signs and devices used match the traffic control plan? • Does the work zone comply with Caltrans requirements? • Flaggers do not hold the traffic for extended periods of time? • Unsafe conditions, if any, are reported to a supervisor? • Signs are removed or covered when they no longer apply?
Emulsion Membrane Application	• Has the emulsion temperature been checked? • Are high winds expected? Will the expected weather conditions delay the breaking of the emulsion? • Has emulsion application spray bar been checked for blocked nozzles? • Has application rate been checked? • Is the application even and does it cover the entire pavement? • Is the application in accordance with relevant CT guidelines?
Lay down of BWC gap graded mix	• Has a test strip been successfully laid and compacted? • Is the surface dry (damp is OK)? • Is the mix temperature correct? • Is the paving unit progressing at a uniform speed? • 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 times to be effective? • Is the mat uniform looking? • Are edge lines and joint overlaps neat and straight? • Is the job stopped if problems persist?

Table 12-3 Field Considerations (Continued)

Project Inspection Responsibilities	
Rolling Mix	• Is the surface temperature of the mat correct at beginning of rolling? • Is the roller being operated at the correct speed? • Is the mat uniform looking? • When making transverse joints, are they rolled from the cold side first? • Are longitudinal joints rolled from the hot side first? • Are edge lines and joint overlaps neat and straight? • Is the job stopped if problems persist?
Truck Operation	• Do truck operators avoid driving over mat? • Do truck operators allow the paving unit to push the truck? • Are changeovers of dump trucks smooth, causing no bumping of the paving unit?
Longitudinal Joints	• Are joints matched properly? • Are joints flat and smooth? • How far does the end gate of the paving unit overlap the previously placed lane (1/2-inch max (15 mm))? If not, excess material should be raked off. • Is excessive raking avoided? Minimal raking of the longitudinal joint should be done. • Are longitudinal joints rolled from the hot side of the joint first? • Are the joints straight and compacted?
Transverse Joints	• Transverse joints should be avoided and should be used only at the end of paving or when problems occur in laying. • Is the mat uniform up to the joint? • Is excessive raking avoided when forming 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 invisible?
Brooming	• Does brooming occur shortly before placement of the bonded wearing course?
Clean Up	• Is all loose mix removed from the traveled way? • Are any spills cleaned up?
Opening the Mix to Traffic	• The traffic travels slowly — 24 mph (40 kph) or less—over the fresh mat? • Are reduced speed limit signs used? • Are all construction related signs removed when opening to normal traffic?

12.8 EFERENCES

California Department of Transportation (Caltrans), Standard Specifications, Sacramento, California, 2024. https://dot.ca.gov/-/media/dot-media/programs/design/documents/2024_stdspecs-a11y.pdf

Commonwealth of Pennsylvania Department of Transportation, 2002. Novachip Final Report, October 2002.

Hanson, D., 2000. Construction and Performance of Ultra-thin Bonded HMA Wearing Course, National Center for Asphalt Technology, August 2000.

Holleran, G., 2001. Microsurfacing, Federal Highway Administration Seminar, Jackson Hole, WY, 2001.

Lobaugh, G., 1997. Performance Evaluation of NOVACHIP: Ultrathin Friction Course, Texas Transportation Institute, February 1997.

New South Wales Department of Transportation, 1995. Guide to the Use of the Novachip System of Bituminous Surfacing, NSW Dot, 1995.

Oliver, J., 1999. Thin Bituminous Surfacings and Desirable Road User Performance, Australian Road Research Board, Research Report AR 325 n, 1999.

Wonson, K., 1997. Novachip- the ultra-thin asphalt surface, Australian Asphalt Pavement Association Asphalt Review Vol 16, No1, March 1997

Note: Caltrans manuals referenced above may have later editions than those cited. Refer to the latest editions of these references for the most current information.