Chapter 11
Bonded Wearing Course

From… Maintenance Technical Advisory Guide (MTAG)
Managers’ Overview

From… Maintenance Technical Advisory Guide (MTAG)
Bonded Wearing Course (BWC)

- What is BWC?
- Why use BWC?
- When to use BWC?
- Where to use BWC?

District 7 Rt. 66, BWC Gap
Graded, Constructed in 2005

Chapter 11 – Bonded Wearing Course
What is BWC?

- A thin, Hot Mix Asphalt Overlay placed over a polymer modified emulsion membrane which:
  - seals the existing pavement
  - bonds the two surfaces

- The roadway is open to traffic very quickly

- This process is done in a single machine

Chapter 11 – Bonded Wearing Course
What is BWC?

Emulsion membrane “wicks up” around the HMA aggregates

The emulsion cures, bonding the mix & pavement

3/4” Typical Mix Depth

3/8” Nominal Ag Size

3/16” Emulsion membrane depth

Existing Pavement
BWC Specification

- SSP 39-700
  - Modified PG binder
  - Gap Graded
- SSP 39-701
  - Asphalt binder
  - Gap Graded
- SSP 39-702
  - Modified PG or asphalt rubber
  - Open graded
- High quality aggregate
  - Restores & retains friction
- Mix designed specially for process

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BWC Specification

Single machine applies polymer modified emulsion membrane and HMA!
Why use BWC? 12+ year old surface
US 281, TX
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Performance

Before

9 years after paving

Lark Ellen LA County 12/2007
Why use BWC?

Construction Speed and Quick Return to Traffic (7-15 minutes for PM binders)

Front Street in Sacramento
May 15, 2003
When to Use?
Site Selection Guidelines

- Structurally sound pavement
- Rut depth < 1/2"
- Minor to moderate transverse & longitudinal cracking
- Bleeding minor to moderate
- Raveled

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When NOT to Use!

Poor Candidates

- High Severity Alligator Cracking
- Rutting >1/2"
- High Severity "D" Cracking
- Block Cracking
- Alligator Cracking
- Rutting
- "D" Cracking
Where/Why to Use (cont.)

- Quick return to traffic - Reduced Work Zone Time → *Workers’ Safety*
- Noise Reduction - Open/Gap Graded Mix
- Night Work → *More working days*
  - Placement temps as low as 45°F for polymer modified binders
- Reduced Backspray - Open/Gap Graded Mix
- High Volume Roadways - Faster Paving Process → *Get In- Get Out*
Where to use?

- Noise reduction
- Night Work (cooler temp)
- Reduced Backspray
- High Volume Roadways
- Quick return to traffic
Bonded Wearing Course Training Modules Available

1. Design, Materials & Specifications
2. Construction & Inspection

Chapter 11 – Bonded Wearing Course
Module 11-1
Design, Materials & Specifications

From… Maintenance Technical Advisory Guide (MTAG)
Topics to be covered

- **Project Selection**
  - Distress and Other Application Considerations
  - Performance
  - Cost

- **Design Considerations**
  - Mobilization
  - Typical Materials Items
  - Quantity Calculations
  - Production Rates
    - Roadway Widths
    - Roadway Geometry
  - Traffic Control
  - Miscellaneous Items
  - Sample Project

- **Materials and Specifications (including SSP’s)**

- **Summary**

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Project Selection

- Distress and Application Considerations
- Performance

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Rt. 103
Factors to Consider When Choosing a Maintenance Treatment

- Will the treatment address the distresses present? (i.e., Will it work?)
- Can the required preparation for the treatment be carried out?
- Is the treatment affordable and cost effective?
- Will the treatment be performed before the situation being addressed changes?
Three Basic Steps In The Selection Process

1. Assess the existing conditions.
2. Determine the feasible treatment options.
3. Analyze and compare the feasible options with each other.

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Initial Site Assessment
Distress Identification

• Types of Distresses and Definitions
• Definitions from:
  • “Guide to the Investigation and Remediation of Distress in Flexible Pavements,” Caltrans, July 2003

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Distress Types and Levels that can be addressed by BWC

- Perform Visual Site Inspection.
  - Identify types, quantity and levels of distress
  - For example on a 2 lane highway (Route xxx from PM 0.0 to PM 10.8) with <30,000 ADT:
    - 10% Alligator B Cracking
    - Minor Transverse Cracking
    - An area of isolated base failure 1000 ft x 4 ft
    - Heavy raveling and oxidation
    - Rutting < ½”

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# DISTRESS AND APPLICATION CONSIDERATIONS

<table>
<thead>
<tr>
<th>Pavement Type</th>
<th>Cracking</th>
<th>Patching/ Potholes</th>
<th>Surface Deformation</th>
<th>Surface Defects</th>
<th>Joint Deficiencies</th>
</tr>
</thead>
</table>
| AC            | 1. Longitudinal & Transverse (Medium)  
2. Block (Moderate)  
3. Edge (Moderate) | Patches: Moderate  
Potholes: Moderate | Rutting: <0.5 in  
Shoving: No | Bleeding Moderate  
Polished Agg: OK  
Raveling: Severe | N/A |
| PCC           | 1. Corner Breaks (Moderate)  
2. Materials Related Distress (Low)  
3. Longitudinal (Moderate)  
4. Transverse (Moderate) | N/A | N/A | Map cracking and scaling: < 12 yd$^2$ to 120 yd$^2$ | Spalling: Moderate |

Note: For PCC, a BWC will not treat blowups, pumping, faulting of joints, or crack widths > 3/8 in

BWC is a viable application for treating structurally sound, worn pavements.
Other Application Considerations

- Traffic control
- Safety
- Night work
- Returns/hand work (NO SETBACKS)
- Turn pockets
- Milling
- Job quantities
- Prep work required
- Quick return to traffic - reduced work zone time (Workers’ Safety)
- Noise reduction - open/gap graded Mix
- Night work - min temp 45º F (More working days)
- Reduced Backspray - open/gap graded mix
- High volume roadways - faster paving process (Get In- Get Out)
Expected Life

- Projects placed in 1993 and 1994 in Pennsylvania, Texas and Louisiana, are still performing well
- County of LA placed first project in CA in 1998
  - Exceeding the County’s expectations
  - No delamination
  - No maintenance activities have been required on the BWC section of roadway for the past 9 years.

Lark Ellen
LA County
9 year old surface

12+ year old surface
US 281, TX
Skid Resistance

Figure 1: Change in Skid Resistance Over Time (5)

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Noise Reduction Data

Data from Acentech Route 85 Noise Mitigation Study
Report No. 184
Dated: January 1998

Note: OGAC was the designation for BWC in this study

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## Spray Reduction

### Table 8: Hydraulic Conductivity as an Indication of Spray Reduction Characteristics (4)

<table>
<thead>
<tr>
<th>Material</th>
<th>Hydraulic Conductivity (s⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>14 mm SMA</td>
<td>0.03</td>
</tr>
<tr>
<td>12.5 mm BWC Type G</td>
<td>0.06</td>
</tr>
<tr>
<td>10 mm UL-M</td>
<td>0.01</td>
</tr>
<tr>
<td>12.5 mm OGAC</td>
<td>0.12</td>
</tr>
</tbody>
</table>

- **Backspray from dense graded surface**
- **Greater visibility on BWC surface**
Improved Ride Quality - (Smoothness)

- Minor ruts and depressions can be filled with BWC to improve ride quality
Impact on Reflective Cracking

Sealed at membrane

V shaped, indicative of raveling

BWC Surface

OGFC Surface
Future Considerations

- The main method of failure is wear; the surface oxidizes and is abraded
- Future PM applications may include:
  - Fog Seal
  - Microsurfacing
  - Additional BWC Application
  - Cold in-Place Recycling
  - Mill and Replace
  - Crack Sealing
  - Patching
  - Re-Striping

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Cost

- In 2007, BWC total project prices averaged $12 per square yard with the range being between $9 and $14.

- High end of this range was seen on projects with limited work windows due to the influence on production and the thin application of the HMA.

- Other factors that influence costs for BWC projects include; materials used, night work vs. day work, quantities, lime treated aggregates, size of project, trucking, and the project location.
Design Considerations

- Mobilization
- Typical Materials Items
- Quantity Calculations
- Production Rates
  - Roadway Widths
  - Roadway Geometry
- Traffic Control
- Miscellaneous Items
- Sample Project

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Mobilization

- Similar to Typical Asphalt Paving
- On-site Staging Required –
  - Area for Tanker and Distributor exchange
- Special Permitting - None
Typical Materials Items

- **Asphalt Concrete Tons**
  - Use maximum lbs/SY for selected aggregate size
    - 3/8” max = 85 lbs/SY
    - 1/2” max = 100 lbs/SY

- **Emulsion Tons**
  - Use 0.2 gallons/SY for emulsion application
  - Varies with mix types (0.13-0.30 Gal/SY)
Quantity Calculations

- When calculating quantities for each application use highest application rate per SY for estimate purposes
  - Example:
    - Specification 37-1.06 Spreading of screenings for chip seal application. Range is 12-20 lb per SY. **Use 20 lb for estimating quantities**
Example of Actual BWC Calculation

- Typical 2 Lane Roadway 1 mile long with 3 foot shoulders = 17,600 SY
- 10 mile section of roadway = 176,000 SY
- AC Tons for Type B (3/8”):
  - $176,000 \text{ SY} \times \frac{95 \text{ lbs/SY}}{2000 \text{ lb}} = 8,360 \text{ Total AC Tons}$
- Emulsion Tons
  - $176,000 \times 0.2 \text{ GAL/SY} / 240 \text{ Gal/Ton} = 147 \text{ Tons of Emulsion}$

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Production Rates and Paving Days

- Production Rate
  - Mainline Paving - 125 tons per hour
  - Returns/Turnpockets - 20-50 tons per hour

- (# of Paving Days)
  - Minimum 5 days to make cost effective
Roadway Geometry and Widths

- **Urban**
  - **Milling**
    - 3/4 - 1” contour edge grind required to match curb and gutter and existing pavement
  - **Drainage**
    - Minimal water trapped against curb due to emulsion filling void structure and thin lift
    - Less water intrusion to pavement interface due to emulsion membrane

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Roadway Geometry and Widths

- Rural
  - Cross-slopes
  - Shoulder
    - For grade differential > 3% from mainline to shoulder, pave shoulder separately (shoulder backing machine)
    - Edge drop-off < ¾” (consider bicycle traffic, material cannot be feathered down lower than top size agg.)
    - In contrast to standard paving, pave shoulders and turn-pockets first and through lanes last. (Note to RE file)

- Varying Width
  - Typical Paving machine width 8-14 feet variable

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Traffic Control

- Typical release to traffic:
  - 10-20 minutes behind paver for polymer modified binders
  - 20 – 30 minutes for rubberized binders (require sanding)

- Multi-lane highways, consider moving lane closure

- Two-lane roadways ½ to ¾ mile closure

- Thinner lift allows faster production

- Emulsion membrane eliminates need for Tack Coat

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Miscellaneous Items

- Edge grinding
- Crack seal hot applied min one month prior
- Patching - hot mix only, cold mix continues to rut
- Utilities – Adjustments most likely necessary
- Loops may need to be replaced if doing edge grinding
- Dig outs – Prior to paving
- Signing and Striping

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Sample Design Example

- Item codes
- Item descriptions
- Unit of measure
Item code

- Caltrans uses item codes along with estimated item quantities to develop project construction costs.
- An item code is a six digit code used to describe a specific item or activity in a project.
- For example,
  - the item code 193118 is used for concrete backfill and the item code 066074 is used for traffic control.
  - Each item code has a unit of measure. Concrete backfill is measured in cubic yards and traffic control is a lump sum unit.
- The engineer must determine what work items and/or activities are expected in the project and develop estimated quantities for bidding purpose. Caltrans Standard Materials and Supplemental Work Item Codes can be found at the following web site: http://i80.dot.ca.gov/hq/esc/oe/awards/#item_code.
## Example of Item Codes

<table>
<thead>
<tr>
<th>Item Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>120090</td>
<td>Construction area signs</td>
</tr>
<tr>
<td>120100</td>
<td>Traffic control system</td>
</tr>
<tr>
<td>128650</td>
<td>Potable changeable message sign</td>
</tr>
<tr>
<td>413111</td>
<td>Repair spalled joints</td>
</tr>
<tr>
<td>413114</td>
<td>Replace joint seal (existing concrete pavements)</td>
</tr>
<tr>
<td>413115</td>
<td>Seal joint (existing concrete pavements)</td>
</tr>
<tr>
<td>414091</td>
<td>Seal longitudinal joint</td>
</tr>
<tr>
<td>414101</td>
<td>Seal transverse joint</td>
</tr>
<tr>
<td>414111</td>
<td>Rout and seal random cracks</td>
</tr>
</tbody>
</table>

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Example of Item Codes required to place **Polymer Modified Open Graded 3/8” Mix Project in District 1**

<table>
<thead>
<tr>
<th>ITEM NO.</th>
<th>ITEM CODE</th>
<th>ITEM DESCRIPTION</th>
<th>UNIT OF MEASURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>070020</td>
<td>WARRANTY</td>
<td>LS</td>
</tr>
<tr>
<td>2</td>
<td>074017</td>
<td>PREPARE WATER POLLUTION CONTROL PROGRAM</td>
<td>LS</td>
</tr>
<tr>
<td>3</td>
<td>074020</td>
<td>WATER POLLUTION CONTROL</td>
<td>LS</td>
</tr>
<tr>
<td>4</td>
<td>120090</td>
<td>CONSTRUCTION AREA SIGNS</td>
<td>LS</td>
</tr>
<tr>
<td>5</td>
<td>120100</td>
<td>TRAFFIC CONTROL SYSTEM</td>
<td>LS</td>
</tr>
<tr>
<td>6</td>
<td>128650</td>
<td>PORTABLE CHANGEABLE MESSAGE SIGN</td>
<td>EA</td>
</tr>
<tr>
<td>7</td>
<td>150715</td>
<td>REMOVE THERMOPLASTIC PAVEMENT MARKING</td>
<td>M2</td>
</tr>
<tr>
<td>8</td>
<td>153103</td>
<td>COLD PLANE ASPHALT CONCRETE PAVEMENT</td>
<td>M2</td>
</tr>
<tr>
<td>9</td>
<td>198007</td>
<td>IMPORTED MATERIAL (SHOULDER BACKING)</td>
<td>TONN</td>
</tr>
<tr>
<td>10</td>
<td>374492</td>
<td>ASPHALTIC EMULSION (POLYMER MODIFIED)</td>
<td>TONN</td>
</tr>
<tr>
<td>11</td>
<td>039925</td>
<td>ASPHALT CONCRETE (OPEN GRADED, 9.5 MM MAXIMUM GRADING)</td>
<td>TONN</td>
</tr>
<tr>
<td>12</td>
<td>840515</td>
<td>THERMOPLASTIC PAVEMENT MARKING</td>
<td>M2</td>
</tr>
<tr>
<td>13</td>
<td>840561</td>
<td>100 MM THERMOPLASTIC TRAFFIC STRIPE</td>
<td>M</td>
</tr>
<tr>
<td>14</td>
<td>840568</td>
<td>100 MM THERMOPLASTIC TRAFFIC STRIPE (BROKEN 3.66 M - 0.92 M)</td>
<td>M</td>
</tr>
<tr>
<td>15</td>
<td>840570</td>
<td>100 MM THERMOPLASTIC TRAFFIC STRIPE (BROKEN 10.98 M - 3.66 M)</td>
<td>M</td>
</tr>
<tr>
<td>16</td>
<td>850122</td>
<td>PAVEMENT MARKER (RETROREFLECTIVE-RECESSED)</td>
<td>EA</td>
</tr>
</tbody>
</table>
Material Specifications

- 3 specifications
  - SSP 39-700 – BWC Type G
  - SSP 39-701 – RBWC Type G
  - SSP 39-702 – BWC Type O and RBWC Type O

- Each differ in binder, aggregate, and mix design procedure

- Polymer modified emulsion membrane is the same for all
## PG Binders

### Binder Grades used in Pavement Climatic Regions for BWC Type G

<table>
<thead>
<tr>
<th>Climatic Region</th>
<th>PG Binder Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Desert</td>
<td>PG 76-22PM</td>
</tr>
<tr>
<td>South Coast</td>
<td></td>
</tr>
<tr>
<td>Central Coast</td>
<td></td>
</tr>
<tr>
<td>Inland Valleys</td>
<td></td>
</tr>
<tr>
<td>North Coast</td>
<td></td>
</tr>
<tr>
<td>Low Mountain</td>
<td></td>
</tr>
<tr>
<td>South Mountain</td>
<td>PG 64-28PM*</td>
</tr>
<tr>
<td>High Mountain</td>
<td></td>
</tr>
<tr>
<td>High Desert</td>
<td></td>
</tr>
</tbody>
</table>

**Note:** (*) Use PG76-22PM on routes with 20 year ESAL’s greater than 10 million (or TI of 12) and where slow moving standing traffic is expected.

Chapter 11 – Bonded Wearing Course
PG Binders

- BWC – O
  - PG 58-34PM for all project regardless of location
Asphalt Rubber Binders

- The binder for RBWC – G and RBWC – O is identical to RHMA – G of Section 39 of the Standard Specifications.
- The recommended base stock is based on DIB 86.
- RBWC only recommended in area of CA that frequently place RHMA.

<table>
<thead>
<tr>
<th>Climatic Region</th>
<th>Base Stock for Rubberized Asphalt</th>
</tr>
</thead>
<tbody>
<tr>
<td>South Coast</td>
<td>PG 64-16</td>
</tr>
<tr>
<td>Central Coast</td>
<td></td>
</tr>
<tr>
<td>Inland Valleys</td>
<td></td>
</tr>
<tr>
<td>North Coast</td>
<td></td>
</tr>
<tr>
<td>Low Mountain</td>
<td></td>
</tr>
<tr>
<td>South Mountain</td>
<td></td>
</tr>
<tr>
<td>Desert</td>
<td></td>
</tr>
<tr>
<td>High Mountain</td>
<td>PG 58-22</td>
</tr>
<tr>
<td>High Desert</td>
<td></td>
</tr>
</tbody>
</table>
## Aggregate Gradation Selection

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Gradation</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1/2”</td>
<td>3/8”</td>
<td>No. 4 (A)</td>
</tr>
<tr>
<td>Minimum Lift Thickness</td>
<td>1”</td>
<td>3/4”</td>
<td>5/8”</td>
</tr>
<tr>
<td>High Traffic</td>
<td>Excellent</td>
<td>Excellent</td>
<td>Good</td>
</tr>
<tr>
<td>City Streets</td>
<td>Excellent</td>
<td>Excellent</td>
<td>Excellent</td>
</tr>
<tr>
<td>Residential Streets</td>
<td>Good</td>
<td>Excellent</td>
<td>Excellent</td>
</tr>
<tr>
<td>Bicycle Traffic</td>
<td>Fair</td>
<td>Good</td>
<td>Excellent</td>
</tr>
<tr>
<td>Pedestrian Traffic</td>
<td>Fair</td>
<td>Good</td>
<td>Excellent</td>
</tr>
<tr>
<td>Noise Mitigation</td>
<td>Fair</td>
<td>Good</td>
<td>Excellent</td>
</tr>
<tr>
<td>Reflective Cracking Mitigation</td>
<td>Excellent</td>
<td>Good</td>
<td>Fair</td>
</tr>
<tr>
<td>Release to Traffic</td>
<td>Excellent</td>
<td>Excellent</td>
<td>Excellent</td>
</tr>
</tbody>
</table>

Note (A): No. 4 gradation only applies to BWC Type G mix
Other Considerations

- In mountainous environments with multiple daily freeze thaw cycles, use only BWC or RBWC Type G.
  - Modification to the BWC Type G gradations for this climate is in SSP

- BWC or RBWC Type O recommended for areas with frequent or heavy rainfall.
  - Open texture allows more water to be removed from road surface.
**Aggregate Gradation**  
*(Percentage Passing)*

**Bonded Wearing Course – Gap Graded**  
*3/8–inch HMA*

<table>
<thead>
<tr>
<th>Sieve Sizes</th>
<th>Target Value Limits</th>
<th>Allowable Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/2&quot;</td>
<td>100</td>
<td>-</td>
</tr>
<tr>
<td>3/8&quot;</td>
<td>80 - 100</td>
<td>TV ±6</td>
</tr>
<tr>
<td>No. 4</td>
<td>25 - 40</td>
<td>TV ±7</td>
</tr>
<tr>
<td>No. 8</td>
<td>19 - 32</td>
<td>TV ±6</td>
</tr>
<tr>
<td>No. 16</td>
<td>16 - 22</td>
<td>TV ±5</td>
</tr>
<tr>
<td>No. 30</td>
<td>10 - 18</td>
<td>TV ±5</td>
</tr>
<tr>
<td>No. 50</td>
<td>8 - 13</td>
<td>TV ±4</td>
</tr>
<tr>
<td>No. 100</td>
<td>6 - 10</td>
<td>TV ±2</td>
</tr>
<tr>
<td>No. 200</td>
<td>2 - 6</td>
<td>TV ±2</td>
</tr>
<tr>
<td>Quality Characteristic</td>
<td>Test Method</td>
<td>Requirement</td>
</tr>
<tr>
<td>------------------------</td>
<td>-------------</td>
<td>-------------</td>
</tr>
<tr>
<td>Percent of crushed particles &lt;br&gt; Coarse aggregate (% min.) &lt;br&gt; Two fractured faces &lt;br&gt; Fine aggregate (% min) &lt;br&gt; (Passing No. 4 sieve and retained on No. 8 sieve.)</td>
<td>CT 205</td>
<td>90 &lt;br&gt; 85</td>
</tr>
<tr>
<td>Los Angeles Rattler (% Max.) &lt;br&gt; Loss at 100 Rev. &lt;br&gt; Loss at 500 Rev.</td>
<td>CT 211</td>
<td>12 &lt;br&gt; 35</td>
</tr>
<tr>
<td>Sand equivalent a (min.)</td>
<td>CT 217</td>
<td>47</td>
</tr>
<tr>
<td>Cleanness value b (min.)</td>
<td>CT 227</td>
<td>57</td>
</tr>
<tr>
<td>Plasticity Index (max.)</td>
<td>CT 204</td>
<td>10</td>
</tr>
<tr>
<td>Fine aggregate angularity (% min.)</td>
<td>AASHTO T 304 Method A</td>
<td>45</td>
</tr>
<tr>
<td>Flat and elongated particles (% max. @ 3:1)</td>
<td>ASTM D 4791</td>
<td>25</td>
</tr>
<tr>
<td>$K_c$ factor (max.)</td>
<td>CT 303</td>
<td>1.7</td>
</tr>
<tr>
<td>$K_f$ factor (max.)</td>
<td>CT 303</td>
<td>1.7</td>
</tr>
</tbody>
</table>
Aggregate for RBWC Type G

- 1/2” or 3/8” gradation
- Same as requirements as RHMA-G from Section 39
Aggregate for Type O mixes

The aggregate for BWC – O or RBWC – O shall conform to the 1/2” or 3/8” maximum gradings in Section 39-1.02E, "Aggregate," of the Standard Specifications.
Include the Spec for lime treated aggregate for RAC
MACTEC Employee, 5/7/2007
Emulsion Membrane Application
(Used with both BWC and RBWC)

- High flexibility and bonding in the range of climactic conditions in which bonded wearing courses are placed.
- Application rate - 0.20 gal/sy depending on existing conditions.
- Breaks rapidly after spraying to ensure that no water is trapped. The gap-graded nature of the mix allows water to escape, thus promoting breaking of the emulsion.
# Emulsion Membrane Spec.

<table>
<thead>
<tr>
<th>Specification Designation</th>
<th>Test Method</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Min.</td>
</tr>
<tr>
<td>Saybolt-Furol Viscosity, at 25°C, s</td>
<td>AASHTO T59</td>
<td>20</td>
</tr>
<tr>
<td>Sieve Test on original emulsion (at time of delivery), %</td>
<td>AASHTO T59</td>
<td>-</td>
</tr>
<tr>
<td>24-hour Storage Stability, % (<em>Note a</em>)</td>
<td>AASHTO T59</td>
<td>-</td>
</tr>
<tr>
<td>Residue by Evaporation, %</td>
<td>California Test 331</td>
<td>63</td>
</tr>
<tr>
<td>Solubility in Organic Solvent, % (<em>Note b</em>)</td>
<td>AASHTO T44</td>
<td>97.5</td>
</tr>
<tr>
<td>Torsional Recovery, measure entire arc of recovery, at 25°C, %</td>
<td>California Test 332</td>
<td>30</td>
</tr>
<tr>
<td>Penetration (0.01 mm) at 25°C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Emulsion used with GGB1 or GGB2</td>
<td>AASHTO T49</td>
<td>70</td>
</tr>
<tr>
<td>Emulsion used with GGB3</td>
<td>AASHTO T49</td>
<td>90</td>
</tr>
<tr>
<td>Emulsion used with GGB4</td>
<td>AASHTO T49</td>
<td>100</td>
</tr>
</tbody>
</table>

**Notes:**

- *Note a*: After standing undisturbed for 24 hours, the surface shall show no white, milky colored substance, but shall be a smooth homogeneous color throughout.
- *Note b*: The organic solvent shall be from the approved list available from the Transportation Laboratory.

---

Chapter 11 – Bonded Wearing Course
BWC Type G Mix Design

Table 5: BWC Mix Requirements (1)

<table>
<thead>
<tr>
<th>Test</th>
<th>Test Method</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Film Thickness, µm</td>
<td>Gradation surface area factor method; Asphalt Institute MS-2, Table 6.1</td>
<td>10.0</td>
</tr>
<tr>
<td>Tensile Strength Ratio, %</td>
<td>California Test 371</td>
<td>70</td>
</tr>
</tbody>
</table>

Note: The optimum binder content is first established so that the film thickness requirement is met. This binder content shall conform to the drain down requirement.

Chapter 11 – Bonded Wearing Course
RBWC Type G Mix Design

- Optimum binder content (OBC) determined by California Test 367 with exception.
- The same method used for the RHMA-G mix design.
- TSR requirement may be waived with approval from DME.
Type O Mix Design

- Determined optimum binder content (OBC1) for BWC – O by California Test 368
- The RBWC – O OBC shall then be determined using the following formula:
  \[ \text{OBC2} = (\text{OBC1}) \times 1.20 \]
  where:
  - OBC1 = Optimum bitumen content using PG 64-10 paving asphalt
  - OBC2 = Optimum bitumen content using asphalt-rubber binder
- Antistrip treatment is required unless waived by DME

Chapter 11 – Bonded Wearing Course
Summary

Key components for a successful BWC project:

- Project Selection
- Design
- Materials and Specifications

District 6
Rt. 99
Topics to be covered

- Understand/Review Specifications
- Safety and Traffic Control
- SWPPP
- Surface Preparation
- Equipment Requirements
  - Calibrations
- Approved Mix design
  - Sampling and Testing
    - Binder
    - Mix
    - Emulsion
- Mix Production and Handling
- Required Application Conditions
- Application of Materials
  - Production Rates
  - Roadway Geometry and Paving Widths
- Application Problems and Solutions

Chapter 11 – Bonded Wearing Course
Understand/Review Specifications

- Review Construction Manual Chapter 4
  - Section 92 asphalt binder
  - Section 94 emulsion (emulsion membrane)
  - Section 39 Asphalt Concrete (mix and placement)

- Review RE file notes

- Project special provisions

Chapter 11 – Bonded Wearing Course
Safety and Traffic Control

- Traffic control is required both for the safety of the traveling public and the personnel performing the work.
- Traffic control includes placing construction signs, construction cones and/or barricades, flag personnel, and pilot cars required to direct traffic clear of the maintenance operation.

Chapter 11 – Bonded Wearing Course
Traffic Control

- Typical release to traffic:
  - 10-20 minutes behind paver for polymer modified binders
  - 20 – 30 minutes for rubberized binders (require sanding)

- Multi-lane highways, consider moving lane closure

- Two-lane roadways ½ to ¾ mile closure

- Thinner lift allows faster production

- Emulsion membrane serves as a tack coat

Chapter 11 – Bonded Wearing Course
OPENING TO TRAFFIC

- Traffic can be allowed onto the new surface once rolling is completed and the mix temperature has fallen below 160°F.
- Typically, no post sweeping is required except for RBWC.
Surface Preparation

- Cracks > ¼” should be filled or sealed prior to application
- Do not over-band
- Cover manhole covers, drains, grates, catch basins, and other utility services with roofing paper or equivalent
- Fill any surface irregularities deeper than 1” with dense graded hot mix before applying the BWC.
- Prior to application, sweep the pavement with a rotary broom equipped with metal or nylon broom stock.

Chapter 11 – Bonded Wearing Course
CRACK PREPARATION & MATERIAL APPLICATION PROCESS

- Kill weeds - 3 weeks prior
- Remove weeds
- Grind out weeds
- Blow out Cracks
- (If moisture exists), use hot lance to remove moisture
- Material Application
- Apply sealer in cracks

Chapter 11 – Bonded Wearing Course
CRACK PREPARATION

185 cfm @ 110 PSI
1/4” nozzle
ratios 1:1 optimum sterilants
3 weeks prior

3000 F
Velocity Heat Lance

Specialty Blades
3/8” wide
removes vegetation
Prep Work Needed

Results of not sealing joint
Minimum one month before paving
Preparation

- Milled Joints
  - Beware of Quarter Crown Issues
  - Transverse cuts should be 2 times paving depth

Chapter 11 – Bonded Wearing Course
Roadway Cleanliness
Construction Entrance Not Swept Prior to BWC Application
Miscellaneous Items

- Edge grinding
- Crack seal hot applied min one month prior
- Patching - hot mix only, cold mix continues to rut
- Utilities – Adjustments
- Loops - Move
- Dig Outs – Prior to paving
- Signing and Striping

Chapter 11 – Bonded Wearing Course
Equipment Requirements

- The binder application and hot mix spreading function are combined into a single unit.
Spray Paver
Calibration Procedure

1. Once proper nozzles sizes have been selected, make sure all nozzles are clean and working.
2. Measure pad width and length to the nearest 0.1 of an inch and record.
3. Weigh calibration pads to the nearest 0.1 g and record.
4. Place plastic container on balance. Either record the weight of the plastic container or zero out the weight of the plastic container.
5. Place calibration pads a minimum of 5 feet in front of the emulsion spray bar in the direction of travel. Use two calibration pads to get an average representative distribution. Place the second pad a minimum of 1 foot behind the first pad.
Spray Paver Calibration Procedure

6. Make sure the emulsion pump and bar pressure is set to optimal manufactures operating range.

7. Engage the paver in automatic mode and allow the paver to come up to full paving speed before passing over the calibration pads.

8. Once the spray bars has passed over the calibration pads, carefully fold the edges of the calibration pads towards the center and roll the pad up so no emulsion will be lost when picked up.
9. Bring the plastic container to the calibration pad and place the pad in the container.
10. Record weight of the calibration pads.
11. It will be necessary to clean the plastic container before the second calibration pad is weighed or the weight of the plastic container will have to be re-zeroed as emulsion from the first pad will increase the weight of the container.
Spray Bar Calculation Procedure

Pad Placement:

At least 5 feet

At least 1 meter

Use Pads
Minimum 320 square inches

Direction of Travel

Chapter 11 – Bonded Wearing Course
Spray Bar Shot Rate Calculation

\[ \text{ShotRate (gal/yd}^2\) = \frac{PW (g)}{PA (in^2)} \times 0.337 \]

- PA (in\(^2\)) = Pad Area = L (in) \times W (in)
- PW (g) = Weight of Emulsion = Pad and Emulsion (g) – Pad (g)

**Example:**
- Pad Length = 9.5 in
- Pad Width = 17.25 in
- Weight of Pad and Emulsion = 371.2 g
- Weight Pad = 300 g

\[ PW = 371.2 - 300.0 = 71.2 \, g \]
\[ PA = 9.5 \times 17.25 = 163.9 \, in^2 \]

\[ \text{ShotRate gal/yd}^2 = \frac{71.2 \, g}{163.9 \, in^2} \times 0.337 \]

Shot Rate = 0.15 gal/yd\(^2\)
## Approved Mix Design

<table>
<thead>
<tr>
<th>PROJECT</th>
<th>Caltrans Rte 29</th>
<th>W.O.</th>
<th>US.CA.NC.2004.0284</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONTRACTOR</td>
<td>Windsor Fuel Company</td>
<td>DATE COMPLETED:</td>
<td>9-Jun-04</td>
</tr>
<tr>
<td>BINDER</td>
<td>Valero GGBI</td>
<td>TECHNOLOGIST:</td>
<td>Michael Exline</td>
</tr>
<tr>
<td>SUPPLIER</td>
<td>Syar</td>
<td>TECHNICAL CONTACT:</td>
<td>Stéphane Charmot</td>
</tr>
<tr>
<td>TECHNICAL MARKETING REP</td>
<td>Scott Metcalf (609) 228-2189</td>
<td>PHONE:</td>
<td>(609) 673-6575</td>
</tr>
</tbody>
</table>

### Asphalt Content Percentage (BWA)

- **6.4%** (By Weight of Aggregate)
- **Recommended Starting emulsion shot rate** = 0.20 gallyd² (Range: 0.12 to 0.26 gallyd)
- **Recommended Starting emulsion shot rate** = 0.91 l/100 ft² (Range: 0.6 to 1.2 l/100 ft²)

### Aggregate Gradations - Individual and Blend

<table>
<thead>
<tr>
<th>Sample ID</th>
<th>Coarse KMC Lab No.</th>
<th>Fine KMC Lab No.</th>
<th>% in Blend</th>
<th>Blend</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2004.0194</td>
<td>2004.0196</td>
<td>100</td>
<td>100.0</td>
</tr>
</tbody>
</table>

#### SIEVE

<table>
<thead>
<tr>
<th>Size (mm)</th>
<th>1.00</th>
<th>2.00</th>
<th>3.00</th>
<th>4.00</th>
<th>5.00</th>
<th>6.00</th>
<th>8.00</th>
<th>10.0</th>
<th>12.0</th>
<th>16.0</th>
<th>20.0</th>
<th>25.0</th>
<th>30.0</th>
<th>40.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>% in Blend</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>94</td>
<td>85</td>
<td>85</td>
<td>85</td>
<td>85</td>
<td>85</td>
</tr>
</tbody>
</table>

#### Aggregate Gsb

- 2.742 mm
- 2.651 mm

**FAA (T304)**: 47.0, 46 min
- **Sand Equivalency (T176)**: 64.6, 47 min
- **Meth. Blue (TP57)**: 4.0, Report Only
- **F & E, (311) (C4791)**: 14.0, 36% max
- **Micro-Deval (TP58)**: 10.0, 36% max
- **LA Abrasion (T96)**: 16.9, 36% max

**Crushed Coarse Aggregate, % (CT 205)**: 100
- **Crushed Fine Aggregate, % (CT 206)**: 100

**Water Absorption (T846.85)**: 1.8, 2.8

**Gradation Surface Area Factor** = 3.85
**Estimated Film Thickness** = 12.9 µm

**Maximum theoretical Specific Gravity** = 2.637
- **Unconditioned Tensile Strength** = 112.2 psi, Report Only
- **Conditioned Tensile Strength (IFT)** = 112.2 psi, Report Only
- **Tensile Strength Ratio** = 87.1 psi, Report Only
- **Draindown Test (CT 368)** = 86.6 %, Report Only
- **Film Stripping (CT 302)** = 0.6 (*)
- **Film Stripping (CT 302)** = 0 (*)
Sampling and Testing Required

California Test 125    July 2002

- METHODS FOR SAMPLING HIGHWAY MATERIALS AND PRODUCTS USED IN THE ROADWAY STRUCTURAL SECTIONS

- ASPHALT CONCRETE
  - Aggregates . . . Part 1, Sections 1-2
  - Asphalt . . . . Part 6, Sections 1-3
  - Modified Asphalt Concrete . . . Part 7, Section 4

- BITUMINOUS SEAL
  - Polymer Modified Asphalt Emulsion . Part 6, Section 4

Chapter 11 – Bonded Wearing Course
Mix Production and Handling

- Mixing temperatures < 350°F
- Storage time < 12 hours.
  - A drain down test should be performed to ensure binder does not drain out of the mixture.
- All mixing plants must be calibrated to California Test Method CT 109.
- BWC mixes may be treated with an anti-stripping agent or lime if required.
Required Application Conditions

- May be applied on damp, but not wet, surfaces.
- Minimum air and pavement temperature requirements:
  - 45°F and rising for PG 76-22PM
  - 50°F for PG 64-28PM
  - 55°F for all open graded mixes and rubberized binders
  - 60°F recommended surface temperature
- No freezing conditions are allowed in the first 24 hours, the emulsion-based tack coat requires about one day to fully cure.

Chapter 11 – Bonded Wearing Course
Application of BWC - Emulsion

- Polymer modified emulsion membrane
  - 120° - 180°F placement temp
  - Average application rate of 0.20 gal/sy with adjustments depending on the surface being covered

<table>
<thead>
<tr>
<th>Surface to Receive Asphaltic Emulsion Membrane</th>
<th>Minimum Residual Rates (gallons per square yard)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCC pavement</td>
<td>0.09</td>
</tr>
<tr>
<td>Dense, compacted, new HMA surface</td>
<td>0.11</td>
</tr>
<tr>
<td>Open textured, dry, aged or oxidized HMA surface</td>
<td>0.13</td>
</tr>
</tbody>
</table>
Application of BWC - HMA

- Follow good paving practice
- No windrowing and pick up machines
- MTV recommended

Paving Depth:
- No. 4 (does contain some 3/8”) – **minimum** application thickness of 5/8”
- 3/8” - **minimum** application thickness of 3/4”
- 1/2” - **minimum** application thickness of 1”

Chapter 11 – Bonded Wearing Course
Application of BWC – HMA

- Delivery temperature
  285°F - 350°F.

- Longitudinal joints
  - Straight or correctly aligned to the curvature of the roadway
  - Never in the wheel paths
Application of BWC – HMA

- Cut out the existing flexible pavement to a depth of 1.2 in and tapered back a distance of 10 ft to provide a key for the new surfacing.
- Square off end of each run where feathering begins.
Construction

Figure 4: Emulsion Membrane and Mix Spreading (11)

Figure 5: Freshly Laid BWC (11)
Trimming necessary. No overlap during construction due to emulsion membrane.

Rolling operation showing traffic control.
Paving Miscellaneous Areas

- Miscellaneous areas should be paved prior to paving the main line
- Hand work
Application

- A minimum of 2 coverages with 2 steel drum tandem roller is required for compacting a BWC.
- Rollers must be operated in static mode only.
- Rolling must be carried out before the temperature, at mid layer of the mix, falls below 200°F.

Chapter 11 – Bonded Wearing Course
Production Rates & Paving Days

- Production Rate
  - Mainline Paving - 125 tons per hour
  - Returns/Turn pockets - 40-50 tons per hour
<table>
<thead>
<tr>
<th>PROBLEM</th>
<th>SOLUTIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Surface Waves</strong></td>
<td>▪ 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).</td>
</tr>
<tr>
<td></td>
<td>▪ Ensure the screed is not worn or set incorrectly.</td>
</tr>
<tr>
<td></td>
<td>▪ Ensure the mix is not too stiff or has not fallen below 285°F.</td>
</tr>
<tr>
<td></td>
<td>▪ Ensure the dump trucks do not bump the paving unit as this can cause long frequency waves resulting in increased pavement roughness.</td>
</tr>
<tr>
<td></td>
<td>▪ Ensure grade control equipment (if in use) is functioning properly.</td>
</tr>
<tr>
<td><strong>Wash Boarding</strong></td>
<td>▪ Slow roller down.</td>
</tr>
<tr>
<td><strong>Tearing</strong></td>
<td>▪ Ensure the paving unit is being operated correctly.</td>
</tr>
<tr>
<td></td>
<td>▪ Ensure the mix is not too cold (i.e., below 285°F) or too stiff.</td>
</tr>
<tr>
<td></td>
<td>▪ May be fixed by adjusting the degree of crown and ensuring mix temperature is correct.</td>
</tr>
<tr>
<td></td>
<td>▪ Ensure application is not too thin.</td>
</tr>
<tr>
<td><strong>Nonuniform Texture-Segregation</strong></td>
<td>▪ Ensure the mixture is not separating in the hopper or during transportation.</td>
</tr>
<tr>
<td></td>
<td>▪ Ensure the paving unit is set up properly.</td>
</tr>
<tr>
<td></td>
<td>▪ Ensure the mix temperature is at least 285°F.</td>
</tr>
<tr>
<td></td>
<td>▪ Check the mix design for poor grading. Adjust if necessary.</td>
</tr>
</tbody>
</table>
# Application Problems & Solutions

| Screed Marks                      | - Ensure the paving unit is set up correctly and that the screed is not worn or dirty.  
|                                  | - Ensure the mix temperature is at least 285°F.  
|                                  | - Compare grading with the mix design data. 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 mix if necessary.  |
| Bleeding & Fat Spots             | - Ensure the mix temperature is not too hot (greater than 350°F).  
|                                  | - Compare with the mix design for binder content or aggregate grading. Adjust mix 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.  |
# Application Problems & Solutions

<table>
<thead>
<tr>
<th>PROBLEM</th>
<th>SOLUTIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delamination</td>
<td>￭ Ensure adequate tack coat is applied.</td>
</tr>
<tr>
<td></td>
<td>￭ Ensure the mix is above minimum application temperature (285°F).</td>
</tr>
<tr>
<td></td>
<td>￭ Ensure the mix is not below the minimum compaction temperature (200°F).</td>
</tr>
<tr>
<td></td>
<td>￭ Ensure the existing pavement surface temperature is above the minimum (i.e., 50°F) before paving.</td>
</tr>
<tr>
<td></td>
<td>￭ Ensure the surface is cleaned immediately before paving.</td>
</tr>
<tr>
<td></td>
<td>￭ Ensure roller drums are not dirty and have working spray systems.</td>
</tr>
<tr>
<td>Poor Transverse Joints</td>
<td>￭ Ensure butt joints are properly constructed.</td>
</tr>
<tr>
<td>Poor Longitudinal Joints</td>
<td>￭ Ensure proper joint construction practices are followed, especially when compacting thin lifts.</td>
</tr>
<tr>
<td>Excessive Ravel</td>
<td>￭ Ensure the mix design meets project specifications, particularly that the mix contains sufficient binder.</td>
</tr>
<tr>
<td></td>
<td>￭ Ensure compaction is carried out above the minimum temperature (i.e., 194°F).</td>
</tr>
</tbody>
</table>
Summary

Key components for the successful construction of a BWC project:

- Safety and Traffic Control
- Surface Preparation
- Equipment Requirements
- Approved mix design
- Mix production and handling
- Required Application Conditions
- Application of Material
- Application troubleshooting

District 6, Rt. 99
Thank You

Questions?