

Bonded Wearing Course (BWC)

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

What is BWC?



- *A thin Hot Mix Asphalt Overlay placed over an 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*

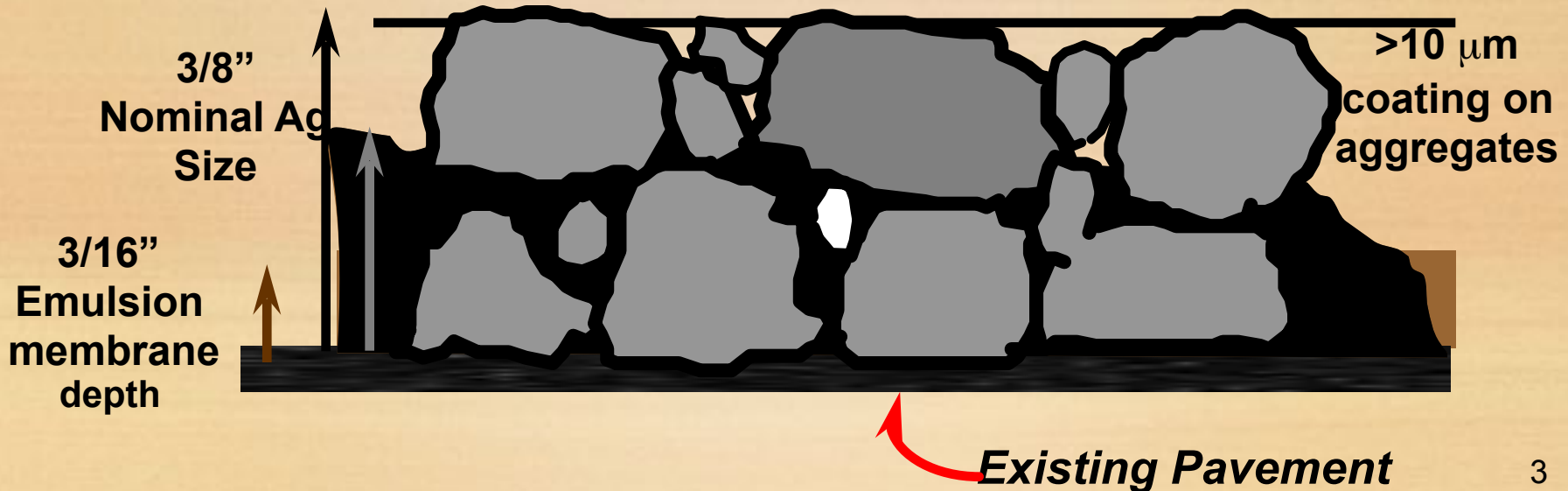


What is BWC?

*Emulsion membrane “wicks up”
around the HMA aggregates*

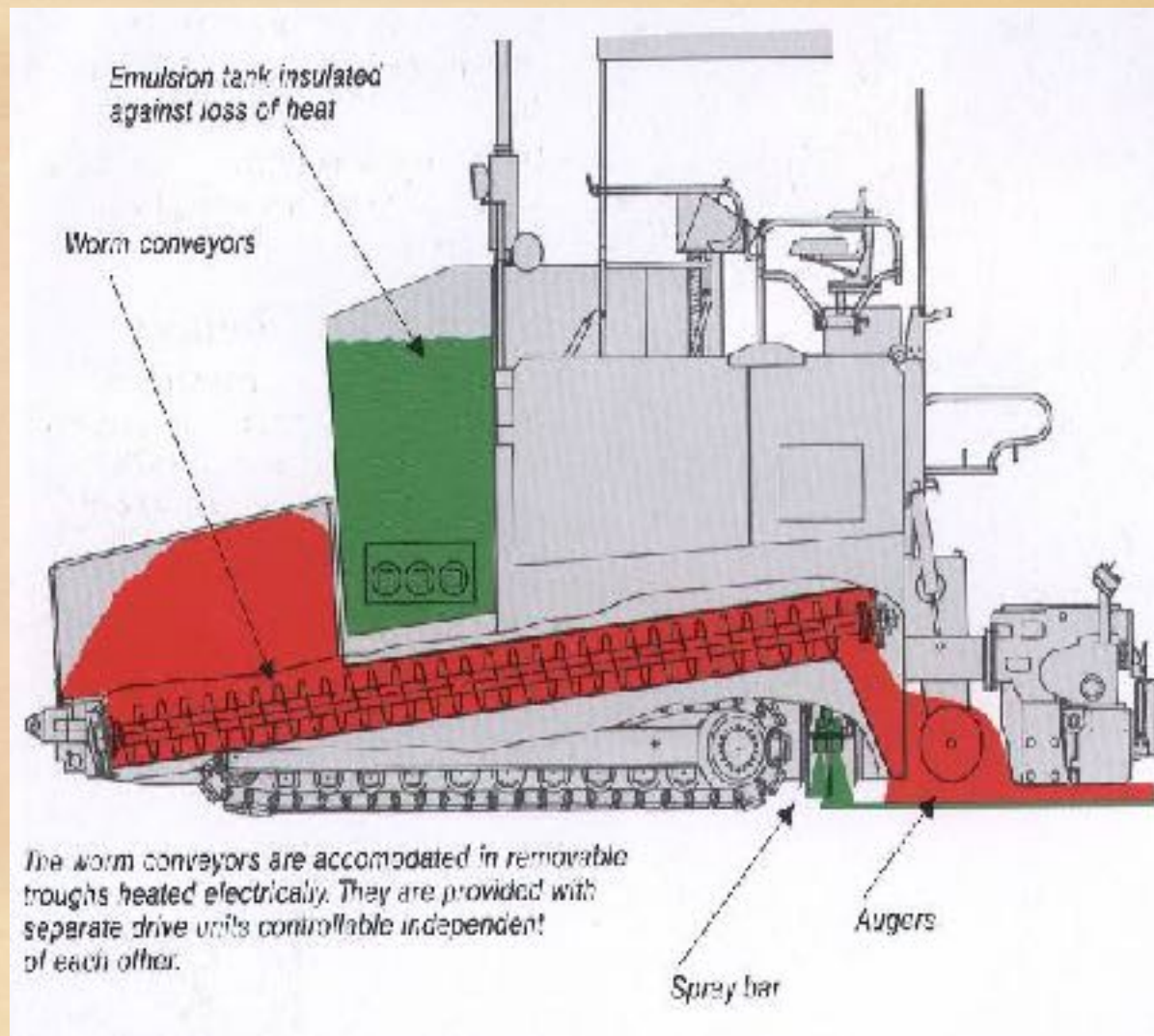
*The emulsion cures,
bonding the mix & pavement*

3/4” Typical
Mix Depth



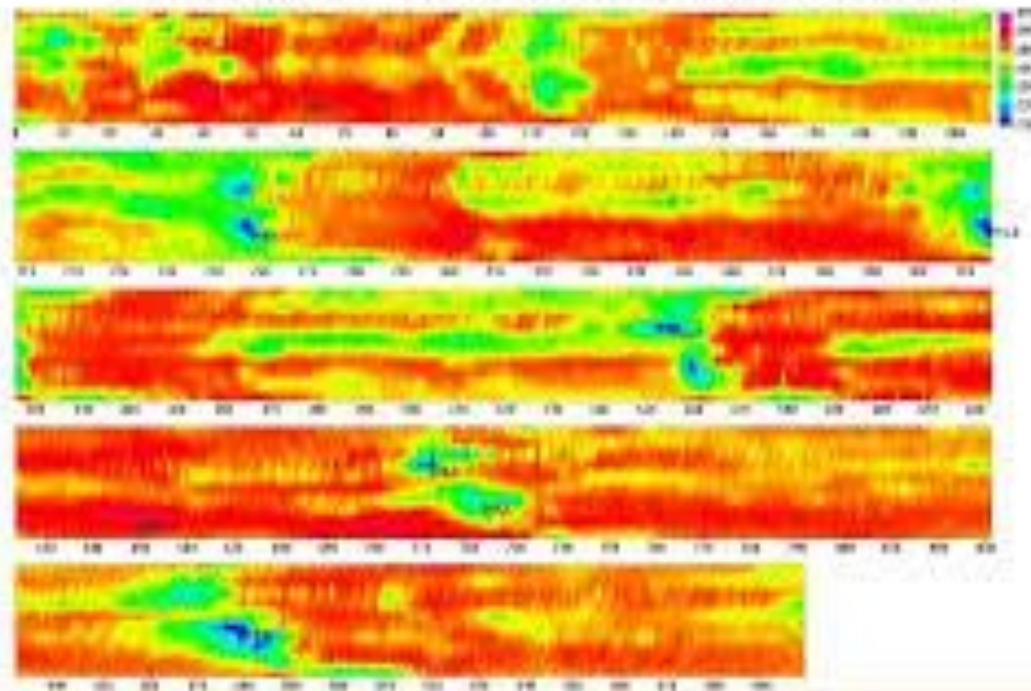
BWC Specifications

- High quality aggregate
 - Restores & retains friction
- Gap-Graded or
- Open Graded Gradation
- Modified PG Binder or
- Rubberized AC
- Mix designed specially for process





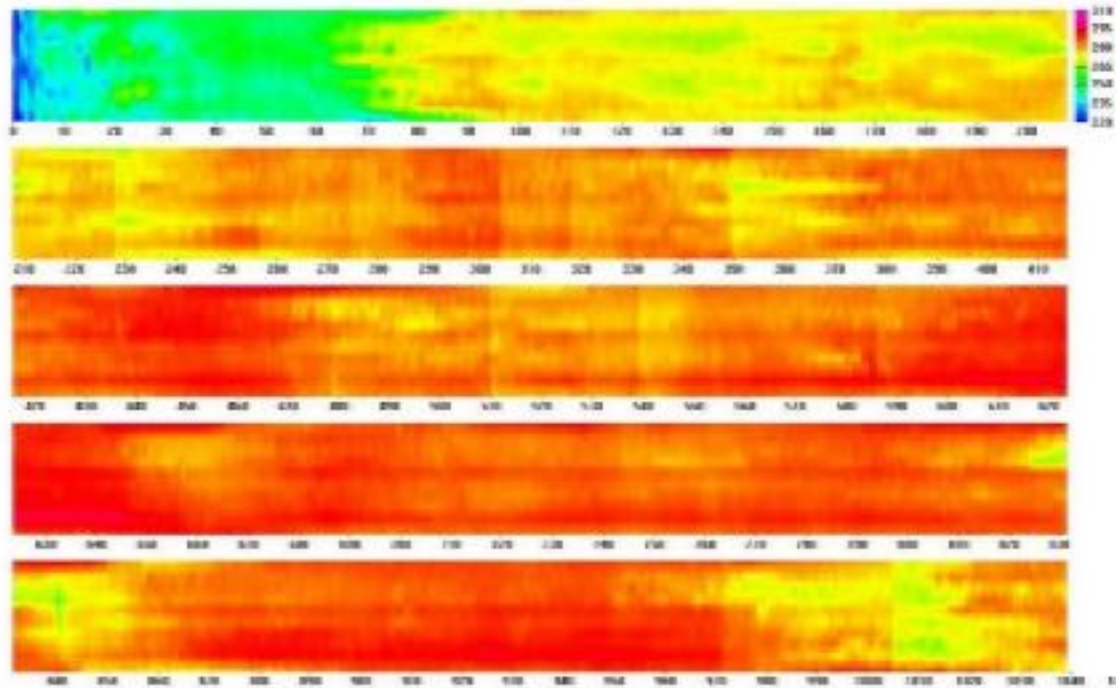
Day 1 Infrared Data – 1000 ft. by 12 ft. lane
Cold spots (blue) at 130 ft. intervals (truck ends)



ASTEC INDUSTRIES, INC.



Infrared Data – with MTV



ABTEC INDUSTRIES, INC.



When to use?

Site Selection Guidelines

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

*I-77 Columbia, SC
Dry, Oxidized,
Slightly Ruttet
Pavement,
60,000 ADT*



Why use BWC

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



Front Street in Sacramento
May 15, 2003

Hwy 99 RBWC



Hwy 73 BWC



•Where to use?

Noise reduction

Night Work

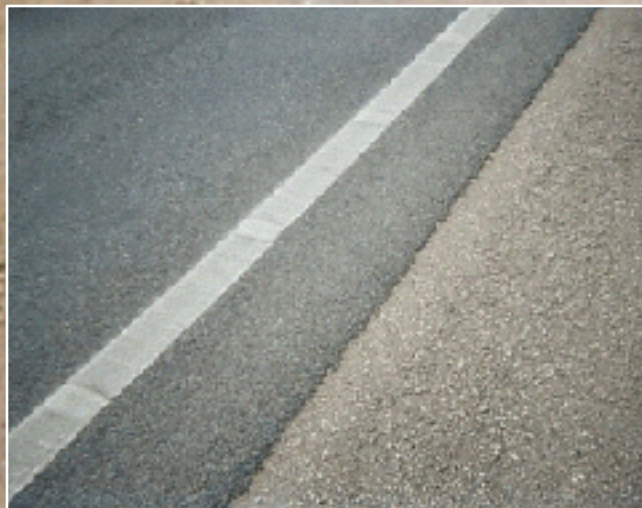
Reduced Back spray

High Volume Roadways

Quick return to traffic

Why use BWC?

12+ year old surface
US 281, TX



Lark Ellen LA County 12/10/98



Before

Performance



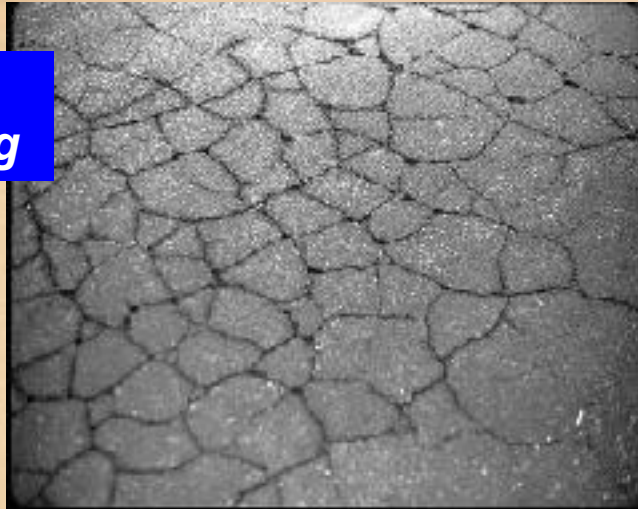
After

Lark Ellen LA County 12/10/2005

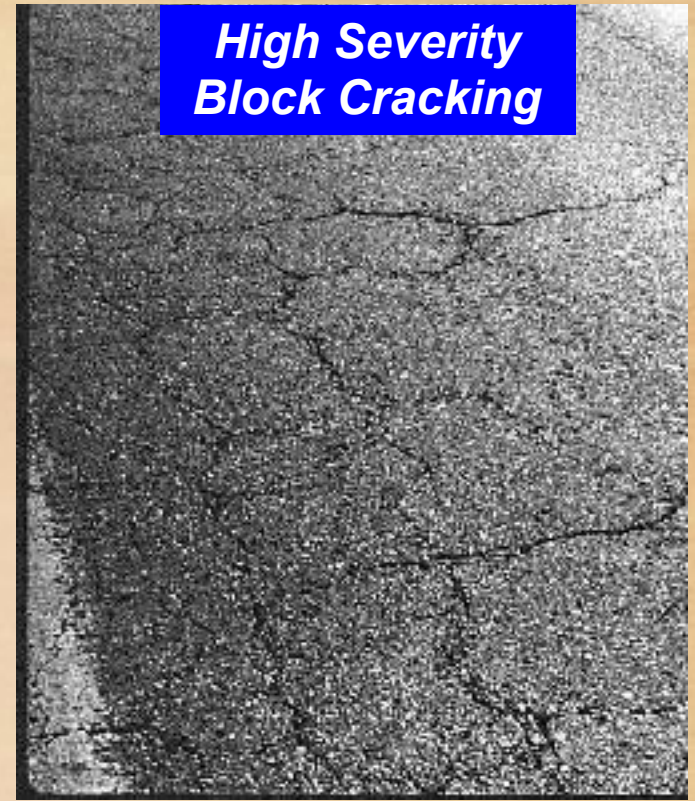
When NOT to use!

Poor Candidates

**High Severity
Alligator Cracking**



**High Severity
Block Cracking**



Rutting >1/2"



**High Severity
"D" Cracking**



Where/Why to use...continued

Quick return to traffic- Reduced Work Zone Time
(Workers' Safety)

Noise Reduction- Open/Gap Graded Mix

Night Work- Min Temp 45° F *(More working days)*

Reduced Back spray- Open/Gap Graded Mix

High Volume Roadways- Faster Paving Process *(Get In-
Get Out)*

Other Application Considerations

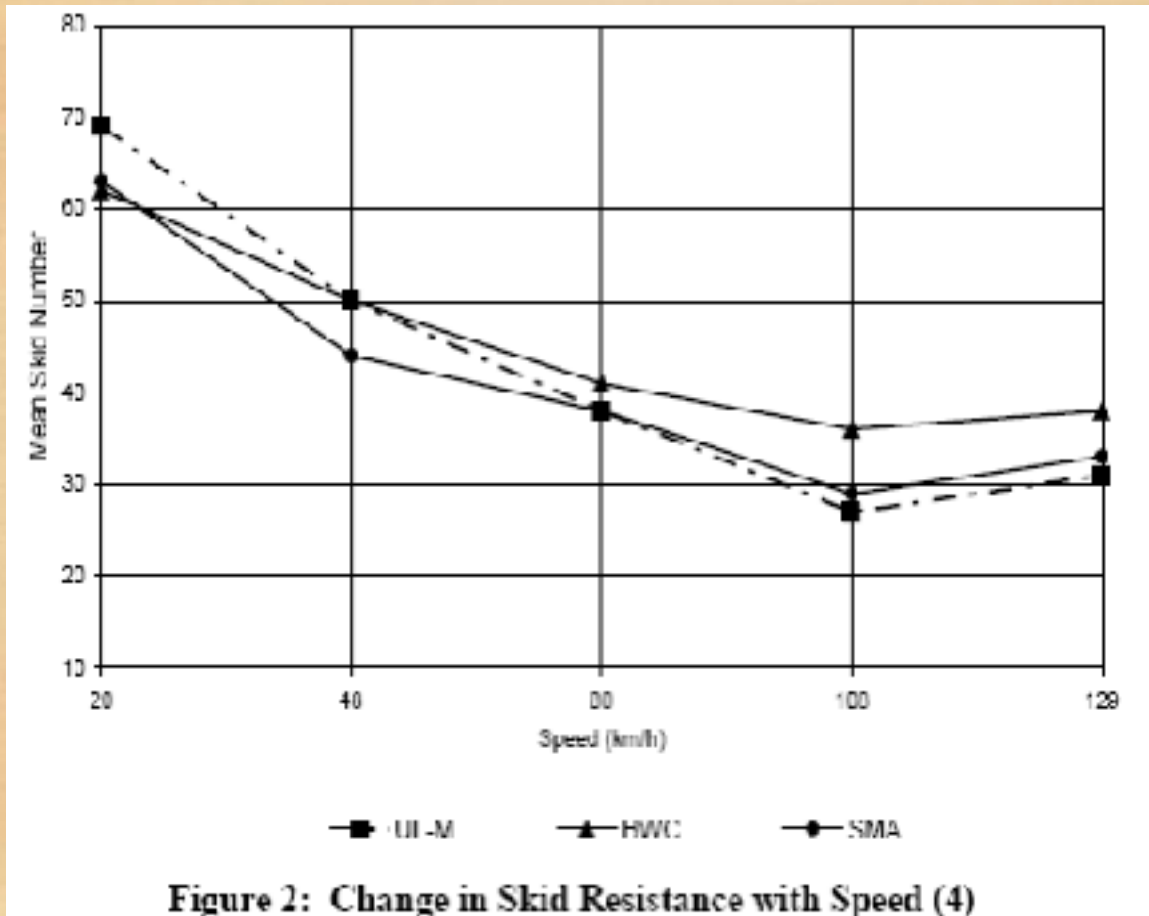
- Traffic Control
- Safety
- Night Work
- Returns/Hand Work (NO SETBACKS)
- Turn Pockets
- Milling
- Job Quantities
- Prep Work Required
- Quick return to traffic- Reduced Work Zone Time (*Workers' Safety*)
- Noise Reduction- Open/Gap Graded Mix
- Night Work- Min Temp 45° F (*More working days*)
- Reduced Back spray- Open/Gap Graded Mix
- High Volume Roadways- Faster Paving Process (Get In- Get Out)



Performance Expectations

- Life and Costing
- Improved skid resistance
- Reduced traffic noise
- Spray Reduction
- Improved ride quality (Smoothness)
- Preventive Maintenance Activities Recommended
- Future Considerations

Skid Resistance



Spray Reduction

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

Material	Hydraulic Conductivity (s⁻¹)
14 mm SMA	0.03
12.5 mm BWC	0.06
10 mm UL-M	0.01
12.5 mm OGAC	0.12

Back spray from dense graded surface



Greater visibility on BWC surface

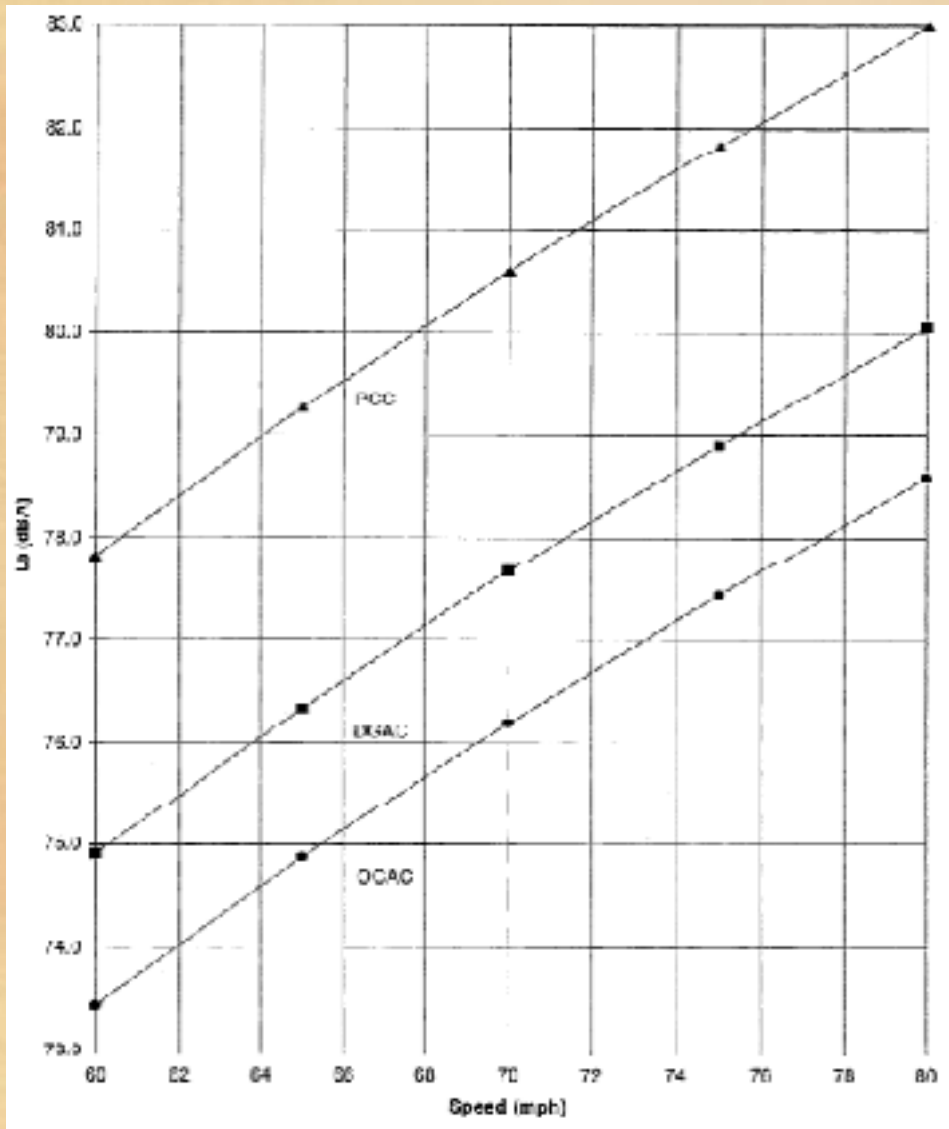


Improved Ride Quality -(Smoothness)

- Minor ruts and depressions can be filled with BWC to improve ride quality



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*

Future Considerations

- The main method of failure is wear; the surface oxidizes and is abraded
- Future PM applications may include:
 - Fog Seal
 - Micro surfacing
 - Additional BWC Application
 - Cold in-Place Recycling
 - Mill and Replace

Design Considerations

- Mobilization
- Typical Materials Items
- Quantity Calculations
- Production Rates
 - Roadway Widths
 - Roadway Geometry
- Traffic Control
- Miscellaneous Items
- Sample Projects include (City Of Hillsboro * Snohomish County, WA)

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" PMA OG or GG (9.5mm) = 85 lbs./SY
 - 1/2" PMA OG or GG (12.5mm) = 100 lbs./SY
 - 3/8" AR OG or GG (9.5mm) = 85 lbs./SY
- Emulsion Tons
 - Use 0.2 gallons/SY for emulsion application

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"):
 - $176,000 \text{ SY} \times 95 \text{ lbs./SY} / 2000 \text{ lb.} = 8,360 \text{ Total AC Tons}$
- Emulsion Tons
 - $176,000 \times 0.2 \text{ GAL/SY} / 240 \text{ Gal/Ton} = 147 \text{ Tons of Emulsion}$

Production Rates and Paving Days

- Production Rate
 - Mainline Paving - 125 tons per hour
 - Returns/Turn pockets - 40-50 tons per hour
- (# of Paving Days)
 - Minimum 5 days to make cost effective

Roadway Geometry and Widths

- Urban
 - Milling
 - $\frac{3}{4}$ - 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
- Rural
 - Cross-slopes
 - Shoulder
 - Generally best used for Travel Lane with 1 foot beyond fog line
 - For Grade differential greater than 2% from Mainline to Shoulder, the shoulder must be paved separately in order to maintain the grade
 - Edge drop-off will be less than $\frac{3}{4}$ " (consider bicycle traffic material can not be feather down lower than top size agg.)
 - With the BWC process it is recommended that shoulders and turn-pockets be paved first and through lane last.
 - Varying Width
 - Typical Paving machine width 8-14 feet variable

Traffic Control

- Typical release to traffic 10-20 minutes behind paver
- Multi-lane highways, restripe quicker
- Two-lane roadways shorter closure times
- Thinner lift allows faster production
- Emulsion Membrane eliminates need for Tack Coat
- One step operation

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

Material Specifications

- Binders
 - Polymer modified asphalt spec
 - Rubberized Asphalt spec
- Aggregates
 - Gradations
 - Physical Properties
- Mix Design
- Emulsion Membrane
 - Application
 - Specifications

Aggregate Gradations

- Aggregate Gradations available.
 - 9.5mm (3/8") Fine – **minimum** application thickness of 5/8" (typically 3/4" recommended).
 - 9.5mm (3/8") Coarse - **minimum** application thickness of 3/4" (typically 1" recommended).
 - 12.5mm (1/2") **minimum** application thickness of 7/8" (typically 1.25" recommended).

Emulsion Membrane Application

(Used with both Polymer Modified and AR Mixes)

- The emulsion membrane is designed to give high flexibility and bonding in the range of climactic conditions in which bonded wearing courses are placed.
- Application rate is typically .20 gal/SY +/- .05 depending on existing conditions.
- The emulsion is designed to break 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.

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

OPENING TO TRAFFIC

- Traffic can be allowed onto the new surface once rolling is completed and the mix temperature has fallen below 70°C (158°F).
- Typically, no post sweeping is required unless the mix begins to ravel.

Surface Preparation

- Cracks greater than 6 mm wide (1/4 in) should be filled or sealed prior to application
- The use of over-banding methods of crack sealing is not recommended for this treatment
- Manhole covers, drains, grates, catch basins, and other utility services must be covered prior to application with roofing paper or equivalent
- Any surface irregularities deeper than 25 mm (1 in) should be filled with dense graded hot mix before applying the BWC.
- Prior to application, the pavement should be swept with a rotary broom equipped with metal or nylon broom stock.
- Grinding???



Minimum one month ahead of paving

Preparation

- Milled Joints
 - Beware of Quarter Crown Issues
 - transverse cuts should be 2X paving depth
- Consider hot-mix tapers



Roadway Cleanliness

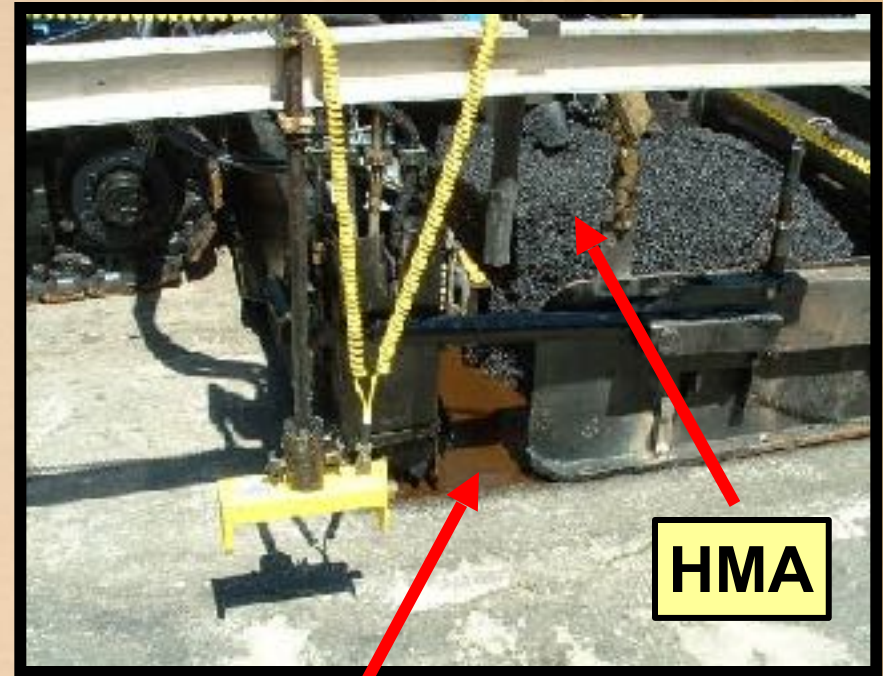
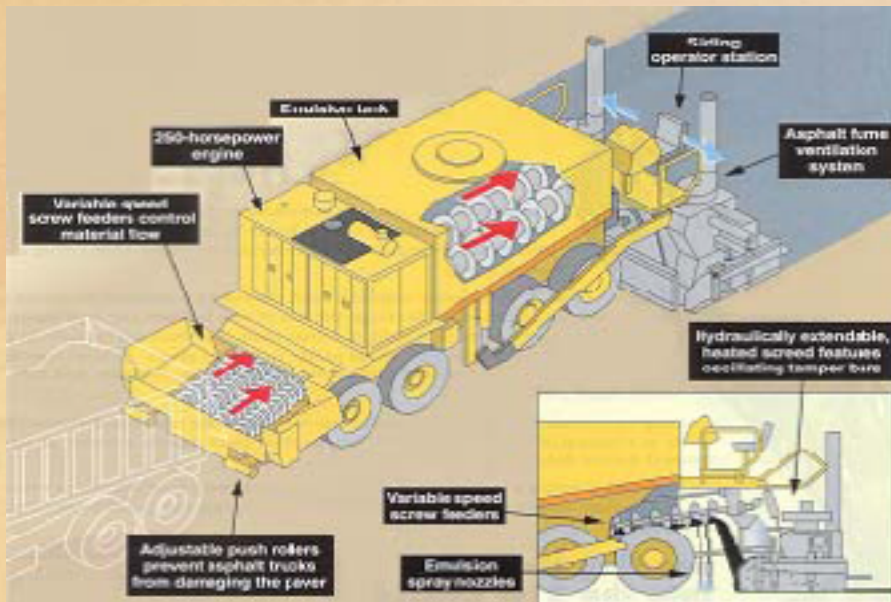


Construction Entrance Not Swept Prior to BWC Application



Equipment Requirements

- The most significant requirement is that the binder application and hot mix spreading function are combined into a single unit.



Membrane

Spray Bar Shot Rate Calculation

Shot Rate Calculation:

The following equation will be used to calculate the shot rate of the emulsion spray bar.

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

- PA (in²) = Pad Area = L (in) * 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

$$\text{PW} = 371.2 - 300.0 = 71.2 \text{ g}$$

$$\text{PA} = 9.5 * 17.25 = 163.9 \text{ in}^2$$

$$\text{ShotRate}(\text{gal} / \text{yd}^2) = \frac{71.2 \text{ g}}{163.9 \text{ in}^2} * 0.337$$

$$\text{Shot Rate} = 0.15 \text{ gal/yd}^2$$

Approved Mix Design

PROJECT	Caltrans Rte 20	W.O.	UD.OA.NO.2004.0204
CONTRACTOR	Windsor Fuel Company	DATE COMPLETED:	9-Jun-04
BINDER	Valcre 0001	TESTING LOCATION:	Michael Exline
SUPPLIER	Syar	TECHNICAL CONTACT:	Stephane Charnot
TECHNICAL MARKETING REP	Scott Metcal (909) 220 2100	PHONE:	(50) 873 6573

Asphalt Content Percentage (BWA)	6.4	%	(by Weight of Aggregate)
Recommended Starting emulsion shot rate =	0.20	gal/yd ³	(Range 0.12 to 0.26 gal/yd)
Recommended Starting emulsion shot rate =	0.81	l/m ²	(Range 0.6 to 1.2 l/m ²)

AGGREGATE GRADATIONS - INDIVIDUAL AND BLEND

Sample ID	Coarse	Fine	Blend	Limits	
KMC Lab No.	2004.0194	2004.0195	12.5-mm Max Agg		
% In Blend	70.0	30.0	100.0		
SIEVE					
1"	25.00 mm	100	100	100	100
3/4"	19.00 mm	100	100	100	100
1/2"	12.50 mm	92	84	85	100
3/8"	9.50 mm	49	84	60	80
#4	4.75 mm	4	33	39	39
#8	2.36 mm	1	30	25	32
#16	1.18 mm	1	20	16	22
#30	0.600 mm	1	12	10	18
#60	0.300 mm	1	8	8	12
#100	0.150 mm	1	6	5	11
#200	0.075 mm	0.0	0.4	0	0
Aggregate Gsb	2.742	2.651	2.714		
FAA (T304)			47.0	46 min	
Sand Equivalency (T176)		64.6		47 min	
Meth. Blue (T95T)		4.3		Report Only	
F & E, (3:1) (D4791)	14.0			26% max	
Milieu-Seval (T956)	10.0			Report Only	
LA Abrasion (T96)	15.9			36% max	
Crushed Coarse Aggregate, % (CT-205)	100			89% min	
Crushed Fine Aggregate, % (CT-203)	100			86% min	
Water Absorption (T54& 85)	1.8	2.3			

Gradation Surface Area Factor =	3.85	m ² /kg	
Estimated Film Thickness =	12.0	µm	10.0 µm min
Maximum theoretical Specific Gravity =	2.637	g/cm ³	
Unconditioned Tensile Strength =	112.2	psi	Report Only
Conditioned Tensile Strength (1FT) =	37.1	psi	Report Only
Tensile Strength Ratio =	30.0	%	Report Only
Draindown Test (CT 368) =	0.5 (*)	g	4 max
Film Stripping (CT 302) =	3 (*)	%	25 max

Mix Production and Handling

- The only special requirements are that the mixing temperatures for a BWC shall not exceed 177°C (351°F)
- Storage time shall not exceed 12 hours. A drain down test should be performed to ensure binder does not drain out of the mixture.
- All mixing plants should be calibrated.
- BWC mixes may be treated with an anti-stripping agent or lime if required.

Required Application Conditions

- Minimum air and pavement temperature requirements are 7°C (45°F) and rising, although it is recommended that the surface temperature be above 15°C (59°F).
- No freezing conditions are allowed in the first 24 hours, the emulsion-based tack coat requires about one day to fully cure.

Application of BWC - Emulsion

- The polymer modified emulsion membrane at a temperature between 40° and 85°C (104° and 185°F) at a rate of 0.6 to 1.2 liter/m² (0.13 to 0.3 gal/yd²).
- The application rate should be adjusted according to the surface being covered.

Construction

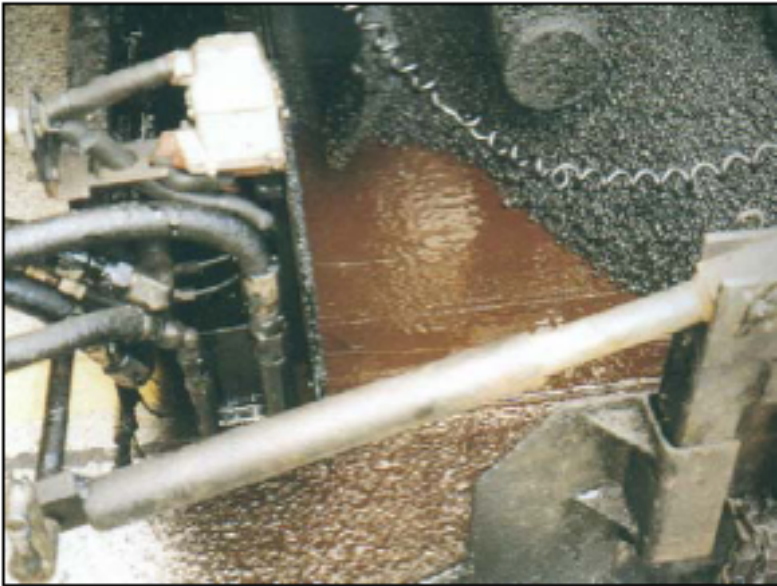


Figure 4: Emulsion Membrane and Mix Spreading (11)



Figure 5: Freshly Laid BWC (11)

Pictures from MTAG Bonded Wearing Course for Pilot Projects pg 11

Construction



Rolling operation showing traffic control.

Trimming necessary. No overlap during construction due to emulsion membrane.



- Steel Drum tandem rollers are required for compacting a BWC.
- Rollers must be operated in static mode only.
- Usually two passes using a 12 to 15 ton roller is sufficient to properly seat the aggregates.
- Rolling must be carried out before the temperature, at mid layer of the mix, falls below 90°C (194°F).

Where has BWC been used in the Northwest:

2001 26,000 SY - SR 17 Moses Lake, WA,


2015 135,381 SY – Various Locations Snohomish County
City of Mill Creek, City Of Marysville, and the City of Mukilteo, WA.

2015 12,000 SY- Bentley Road, City of Hillsboro.


2016 84,000 SY- Hwy 97 ODOT Bend, Oregon.




BWC pics from Snohomish County -
Snohomish Cascade Drive



BWC pics from Snohomish County -
Snohomish Cascade Drive



BWC pics - 148 St SE



BWC pics - 148 St SE



Snohomish Cascade Drive













← →
Grade
Entrance

09.26.2017





Joyce Barnes | *Program Planning / Pavement Management*

Snohomish County Public Works

3000 Rockefeller Ave., M/S 607 | Everett, WA 98201

425-262-2468 | joyce.barnes@snoco.org

Greg H. Hayes | *Senior Engineering Technician*

City of Hillsboro, Oregon | Public Works - Engineering

503-681-6152 | greg.hayes@hillsboro-oregon.gov



Teresa Gibson, P.E. | *Traffic Analyst*

Oregon Department of Transportation, Region 4

63055 N. Hwy 97, Bldg K, | Bend, OR 97703

541-388-6242 |