



Greenbook Seminar

Parts 2 (Materials) & 3 (Methods)

April 23, 2024



Agenda

Parts 2 & 3

Rock Materials, Tests,
Earthwork
Subgrade Preparation, Treated Materials and Placement

Concrete, Mortar and Related Materials
Subgrade Preparation, Treated Materials and Placement

Gravity Pipe, Precast Concrete, Precast Concrete Box
Open Trench Conduit Construction
Jacking & Tunneling

Roadway Surfacing – Asphalt & Concrete

Asphalt Pavement

Parts 2 (Materials) & 3 (Methods)

Presented by Corina Wong



203 Bituminous Materials



302 Roadway Surfacing (Seals/Pavement
Fabric/Asphalt)



211 Material Tests



213 Geosynthetics



214/314 Traffic Stripping, Curb and
Pavement Markings, and Pavement
Markers

203 Bituminous Materials

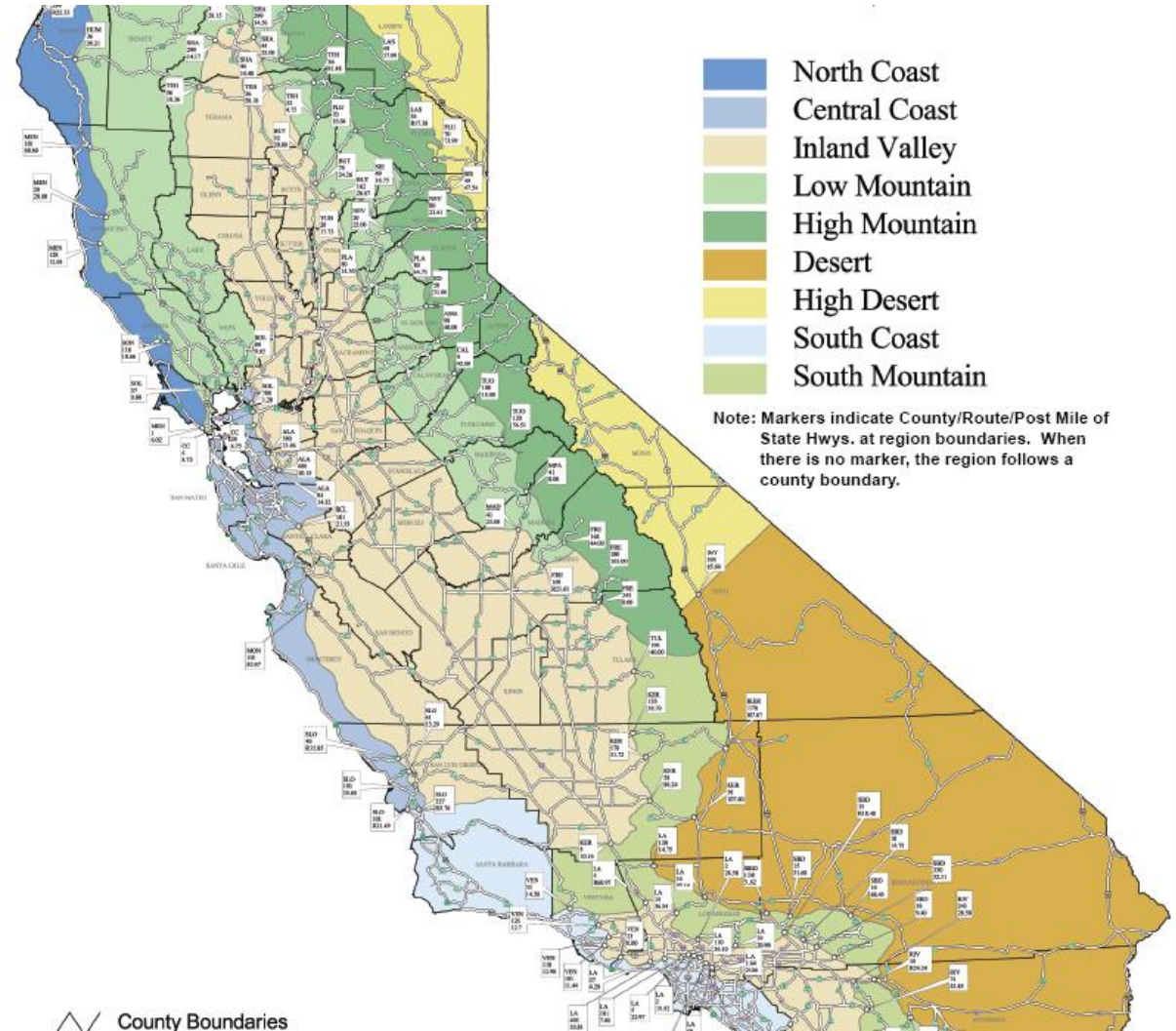
Discipline (i.e. concrete)

203-1 Paving

1) “*Paving asphalt shall be specified by performance grade ...*” (203-1.2)

Comments:

- 1) Table 203-1.2 specifies 4 out of the 5 climatic grades used in California.
- 2) Specify the climatic grade designated for the location of the Work.



203 Bituminous Materials

Discipline (i.e. concrete)

203-1 Paving (Continued)

3) “For example, PG 64-16 [paving] asphalt is intended to provide:

- ***enough stiffness at 64°C pavement temperature to help the mix resist permanent deformation or rutting.***
- ***enough elasticity at -16°C to prevent low temperature thermal cracking, and***
- ***Enough flexibility at intermediate temperatures to minimize fatigue cracking.”***

“Performance Graded (PG) Asphalts in California,” Technical Topics No. 6, Institute of Transportation Studies, U. C. Berkeley.

203 Bituminous Materials

203-2 Liquid Asphalt

Comments:

- 1) Subsection title should be, “Cutback Asphalt.”
- 2) Cutback Asphalt: *“Asphalt cement which has been liquefied by blending with a petroleum solvent ... the solvents evaporate, leaving the asphalt cement to perform the function.”* Asphalt Institute MS-22, Third Edition, page 204.
- 3) Not commonly used, except for “cold mix”
- 4) SC = Slow Curing
- 5) RC = Rapid Curing
- 6) MC = Medium Curing
- 7) “Cold Mix:” typically SC 800.

203 Bituminous Materials

203-3 Emulsified Asphalt

- 1) *“... shall be composed of a paving asphalt base uniformly emulsified with water.” (203-3.1)*
- 2) *“... shall be anionic, cationic, or rubberized polymer modified emulsion (RPME).” (203-3.4.1)*

Comments:

- | | |
|-----------------------|----------------------------|
| 1) C = Cationic | 5) h = hard (base asphalt) |
| 2) RS = Rapid Setting | 6) 1, 2 = viscosity |
| 3) SS = Slow Setting | 7) PM = Polymer Modified |
| 4) QS = Quick Setting | |

203 Bituminous Materials

Discipline (i.e. concrete)

203-5 Rubberized Emulsion-Aggregate Slurry (REAS)

- 1) "REAS shall be specified by combined aggregate gradation, e.g. Type II-REAS." (203-5.1)
- 2) "The combined aggregate gradation (Type) shall be as specified in the Special Provisions or shown on the Plans." (203-5.1)

Comment:

- ☐ REAS is produced at a central mixing plant and transported to the Work site in trucks equipped with a tank and agitator.

203 Bituminous Materials

Discipline (i.e. concrete)

203-6 Asphalt Concrete



203-6.1 General.

- 1) “... *the product of mixing mineral aggregate and up to 25 percent ... (RAP) with asphalt binder ...*”
- 2) “*When so specified in the Special Provisions, ... greater than 25 percent RAP ... (WMA) technology.*”
- 3) “*Unless otherwise specified ... mixtures shall conform to 203-6.4 [not 203-6.5].*”

203-6.3.1 General.

- 1) *For asphalt concrete with **20 to 25 percent** reclaimed asphalt pavement, the grade of the virgin binder must be the specified grade of the asphalt binder for the asphalt concrete with the upper and lower temperature classification reduced by 6 degrees C.*

203-6.4 Asphalt Concrete Mixtures.

203-6.4.1 Class and Grade.

- 1) “... *shall be designated by class of combined aggregate gradation and performance grade of paving asphalt, e.g. “C2-PG 64-10.”*
- 2) “*The class and grade shall be as shown on the Plans or specified in the Special Provisions.”*

Comment: Specify the allowable RAP content if other than 25%.

203-6.5 Type III Asphalt Concrete Mixtures.

Comment: Intended to be allowed only when so specified, not as an “alternate” to 203-6.4 mixtures.

203-6.5 Type III Asphalt Concrete Mixtures.

Comments:

- ❑ In Part 4 through the 2015 Editon.
- ❑ Intended to be allowed only when so specified, not as an “alternate” to 203-6.4 mixtures.

203-6.7 Production.

203-6.7.2 Warm Mix Asphalt (WMA) Technologies.

- 1) “... may be produced using a WMA technology if so specified in the Special Provisions.”
- 2) “*The WMA technology ... shall be as specified in the Special Provisions.*”

Comments:

- 1) 203-6.7 does not contain detailed technical requirements or alternatives.
- 2) 203-6.7 is intended to be a heading placeholder for WMA Technologies if the Agency specifies WMA in the Special Provisions.

Comments:

- 3) *“What is WMA? Very simply, WMA technologies allow the mixing and placement of asphalt mix at temperatures significantly lower than those used with conventional hot mix asphalt (HMA). These technologies reduce the viscosity of the asphalt mix and provide complete aggregate coating at temperatures 35 to 100°F (20 to 55°C) lower than HMA.”*

“Warm Mix Asphalt Hits the Road,” Pavement Technology Update, Vol. 2, No. 1, July 2010, Institute of Transportation Studies, U. C. Berkeley.

4) WMA Technologies:

- **Wax-Based.**
- **Chemical Modifiers or Surfactants.**
- **Foaming (uses water).**

Terminology

Courtesy: Don Goss, Valero

Two Major Technologies/Processes

“Field Blend” (“Wet”) Process
(203-11)

“Terminal Blend” Process
(203-14)



203-11 ASPHALT RUBBER HOT MIX (ARHM).

- 1) *“... shall consist of a mixture of paving asphalt, asphalt modifier, crumb rubber modifier (CRM), and aggregate ...” (203-11.1)*
- 2) *“The Contractor shall submit test reports and Certificates of Compliance for the paving asphalt, asphalt modifier, and CRM to be used.” (203-11.2)*
- 3) *“Paving asphalt ... shall be PG 64-16 ...” (203-11.2.1)*
- 4) *“Asphalt-rubber hot-mix gap graded (ARHM-GG) will be ~~designated by type and class~~, i.e., ARHM-GG-C, ...” (203-11.3)*



COMPOSITION OF ARHM



Gap Graded Aggregate.



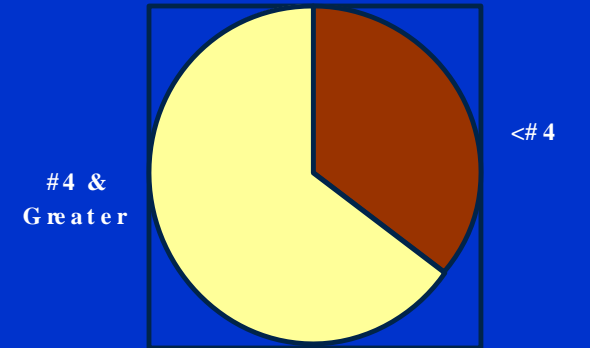
Binder

- **Paving Asphalt (PG 64-16) - 80%**
- **Crumb Rubber Modifier (CRM) - 20%**
(75% Scrap Tire, 25% High Natural Rubber)
- **Asphalt Modifier (2.5% - 6% of Paving Asphalt)**

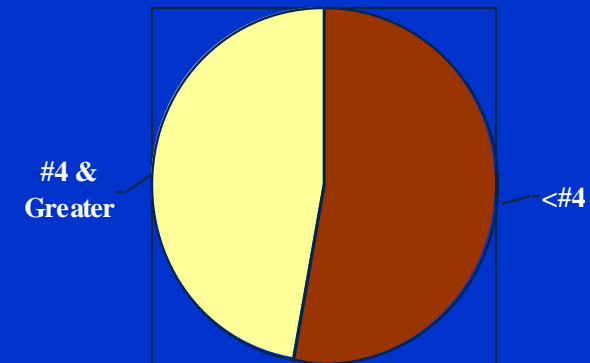


“GAP GRADED” AGGREGATE GRADATIONS

Sieve Size	C2		ARHM-GG-C	
	1/2" dense gr.		1/2" gap gr.	
	Min. - Max		Min. - Max	
(3/4 in.)	100		100	
(1/2 in.)	(2.5)	95 - 100 (97.5)	(5.0)	90 - 100 (95)
(3/8 in.)	(17.5)	72 - 88 (80)	(10.0)	78 - 92 (85)
(No. 4)	(27.0)	46 - 60 (53)	(50.0)	28 - 42 (35)
(No. 8)	(18.0)	28 - 42 (35)	(15.0)	15 - 25 (20)
(No. 30)	(14.0)	15 - 27 (21)	(10.0)	5 - 15 (10)
(No. 50)	(6.0)	10 - 20 (15)		
(No. 200)	(10.5)	2 - 7 (4.5)	(5.5)	2 - 7 (4.5)



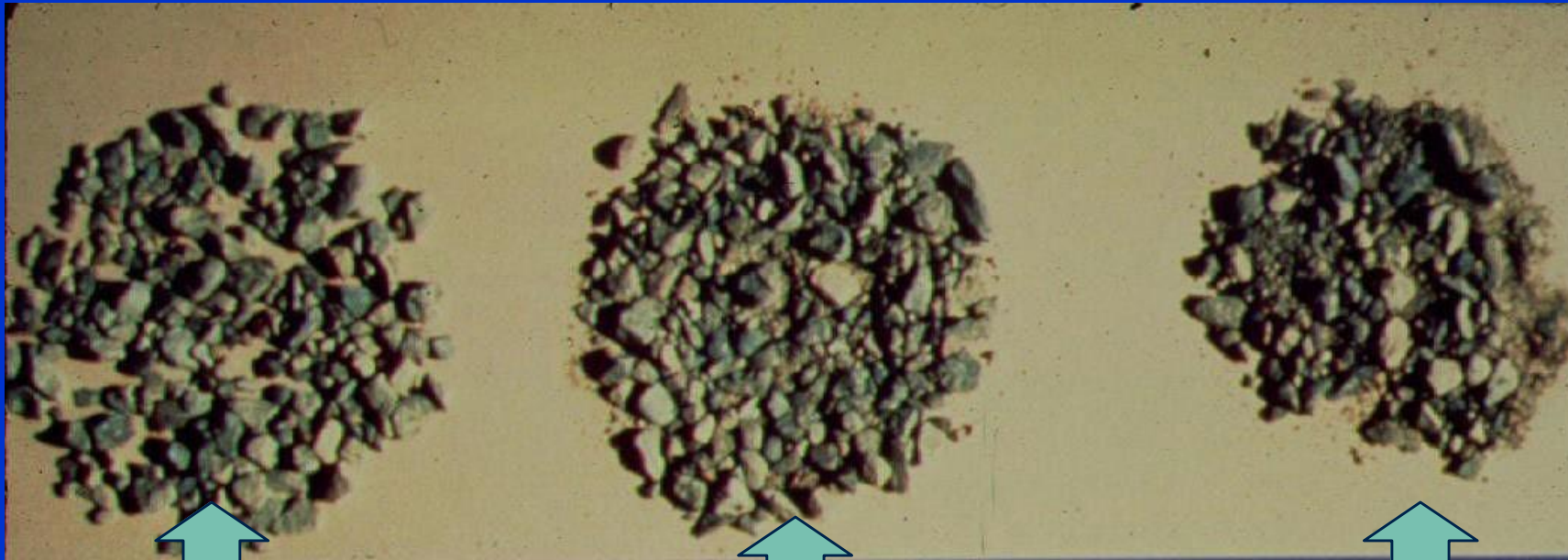
GAP GRADED



DENSE GRADED

Aggregate Ratios

AGGREGATE GRADATION COMPARISON



Open
Graded

Gap
Graded

Dense
Graded



GRADATION COMPARISON

Sieve Size	C2	ARHM-GG-C
	1/2" dense gr.	1/2" gap gr.
	Min. - Max	Min. - Max
(3/4 in.)	100	100
(1/2 in.)	95 – 100 (97.5)	90 – 100 (95)
(3/8 in.)	72 – 88 (80)	78 – 92 (85)
(No. 4)	46 – 60 (53)	28 – 42 (35)
(No. 8)	28 – 42 (35)	15 – 25 (20)
(No. 30)	15 – 27 (21)	5 – 15 (10)
(No. 50)	10 – 20 (15)	
(No. 200)	2 – 7 (4.5)	2 – 7 (4.5)



GAP GRADED



DENSE GRADED



RUBBERIZED
ASPHALT
CONCRETE
TECHNOLOGY
CENTER

CRUMB RUBBER MODIFIER



75%
SCRAP TIRE
1/16" +/- in Size

25%
HIGH NATURAL
RUBBER
1/32" +/- in Size



CRUMB RUBBER MODIFIER

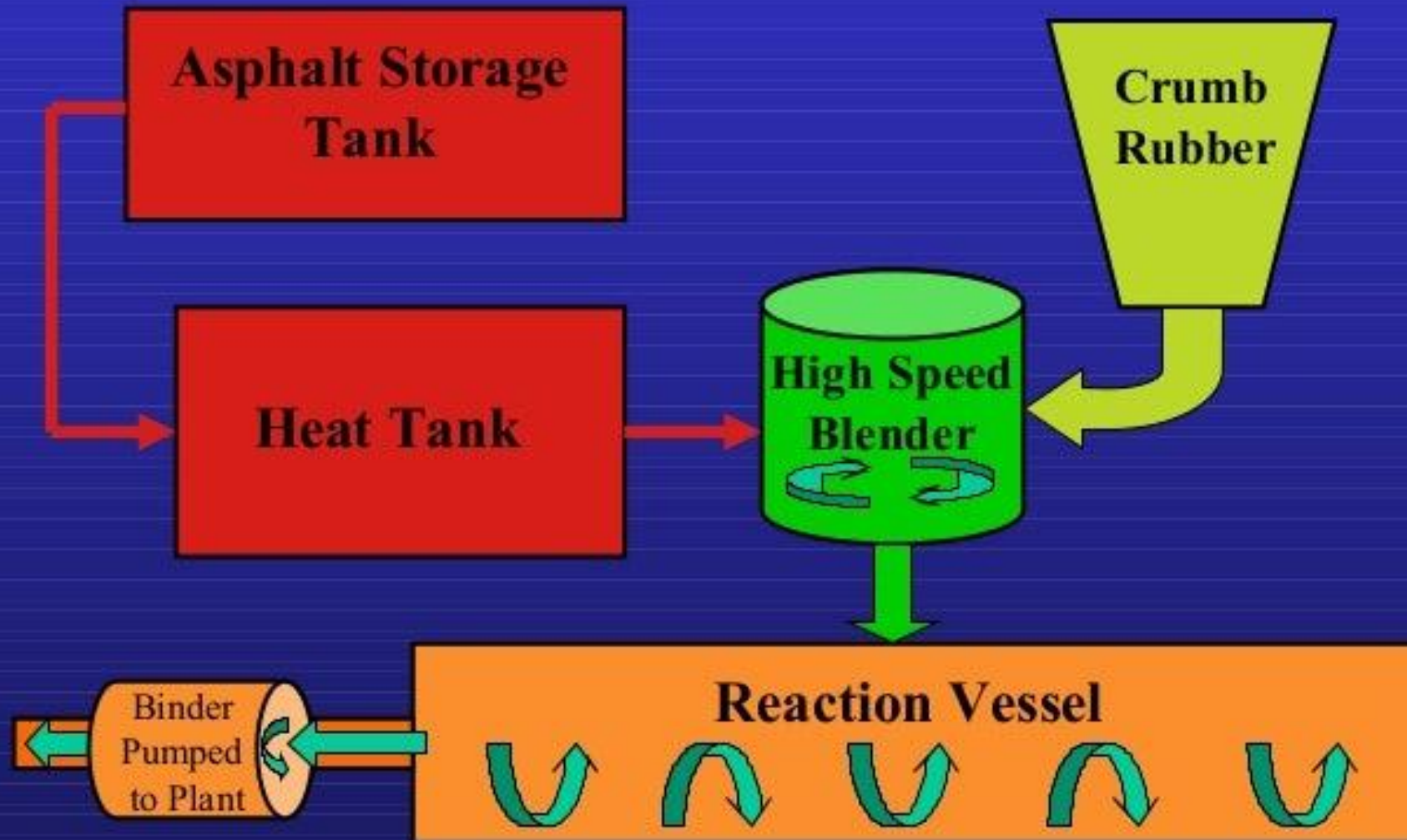
- **Scrap Tire CRM (75 +/- 2 %)**
- **High Natural CRM (25 +/- 2 %)**
- **Max. 0.01 % wire (by wt. Of CRM)**
- **Max. 0.05 % fabric (by wt. Of CRM)**
- **Max. 3 % calcium carbonate or talc may be added**
- **Specific Gravity: 1.1 - 1.2 (ASTM D297)**



ASPHALT MODIFIER

- **Aids in the reaction of the crumb rubber by providing aromatics which are absorbed by the rubber, and help with dispersion by chemically suspending the rubber in the asphalt.**

Asphalt Rubber Blending Schematic



Portable asphalt-rubber blending equipment connected to a drier-drum plant:



2,000 pound “supersacks” of crumb rubber:



Crumb rubber being loaded into the hopper of the blending unit:



Crumb rubber is weighed in the hopper:



Crumb rubber is fed from the hopper into the blender (high shear mixer):



Paving asphalt (PG 64-16) tank:

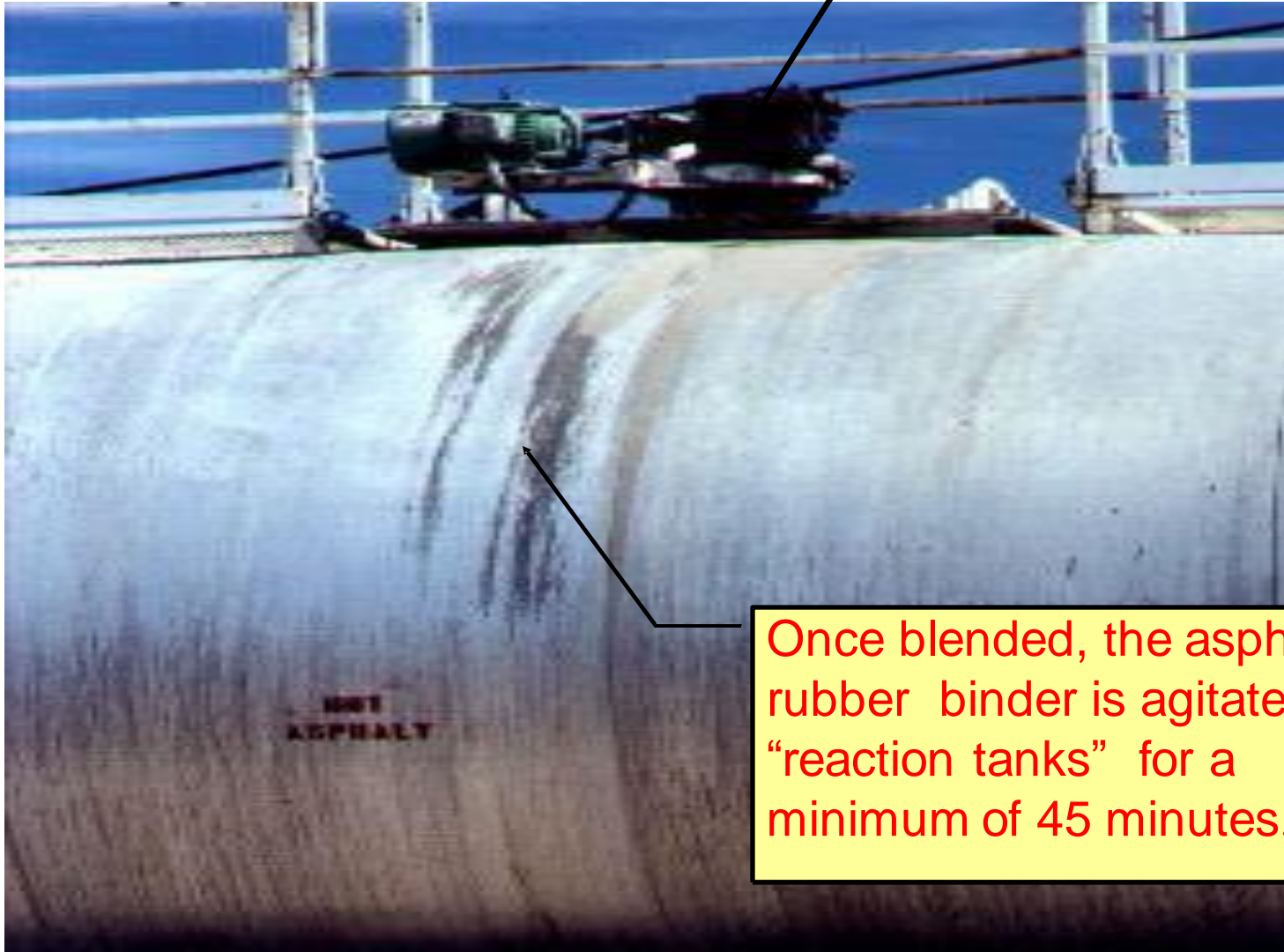


Reaction Tank:



Reaction Tank:

Internal Mixing Unit



Once blended, the asphalt-rubber binder is agitated in “reaction tanks” for a minimum of 45 minutes.

Asphalt-Rubber binder, after the “reaction,” is metered into the hot mix plant.



203-12 ASPHALT RUBBER AND AGGREGATE MEMBRANE (ARAM).



203-14 TIRE RUBBER MODIFIED ASPHALT CONCRETE (TRMAC).

Comments:

- 1) Sometimes referred to as “Terminal Blend.”
- 2) Different material than Asphalt-Rubber.
- 3) Fine mesh crumb rubber is blended with paving asphalt at a refinery or terminal.
- 4) High shear process dissolves the crumb rubber modifier into the paving asphalt.
- 5) Used in dense-graded mixes.

203-16 POLYMER MODIFIED ASPHALT CONCRETE (PMAC).

Comments:

- 1) *“The polymer addition increase the viscosity (stiffness) and flexibility of the blend at high and intermediate temperatures, thus improving the rut resistance and fatigue characteristics of the mix while the softer asphalt base and polymer presence provide improved low temperature cracking resistance.”*

*Technical Topics No. 7, Institute of Transportation Studies, U. C. Berkeley.
“Performance Graded (PG) Polymer Modified Asphalts in California,”*

- 2) Typical application: Roads with moderate to high traffic indexes
a) in areas of extreme temperature and
b) in any area on roads with fatigue cracking.

302-5 ASPHALT CONCRETE PAVEMENT.

302-5.1 General.

1) References 203-6.

2) *“The courses shall be of the type of mixture class and grade and the dimensions shown on the Plans.”*

Comment: *Significantly, revised and updated in 2024 Greenbook. Separated materials, submittals equipment, and placement considerations.*

302-5.2.2 & 302-5.7 Prime Coat.

- 1) “When specified **[Special Provisions]** ... a *prime coat shall be applied.*”



302-5.2.3 & 5.8 Tack Coat.

- 1) “... *PG 64-10 paving asphalt ... or SS-1h emulsified asphalt ... shall be uniformly applied ...*”

Tack Coat

TABLE 302-5.8 (A)

Surface Type	Minimum Application (Spray) Rate (gal/yd ²)	
	Undiluted (Original) Emulsified Asphalt (SS-1h)	Diluted (1:1) Emulsified Asphalt (SS-1h)
Asphalt Concrete	0.05	0.11
Cold milled or Micro-Milled Asphalt Concrete	0.09	0.18
New Asphalt Concrete (Between Successive Lifts)	0.04	0.08
Portland Cement Concrete	0.05	0.11

TABLE 302-5.8 (B)

Surface Type	Minimum Residual Rate (gal/yd ²) ¹	
	Emulsified Asphalt (SS-1h)	Paving Asphalt (PG 64-10)
Asphalt Concrete	0.03	0.03
Cold milled or Micro-Milled Asphalt Concrete	0.05	0.04
New Asphalt Concrete (Between Successive Lifts)	0.02	0.02
Portland Cement Concrete	0.03	0.03

1. Tack coat application rates shall be based upon the volume of asphalt remaining per square yard after application (residual rate). For SS-1h, this is the volume remaining after the emulsified asphalt has broken and no water remains. For PG 64-10, this is the volume on the roadway immediately after application.

Tack Coat Comments:

- 1) Distributor truck: Spray bar must be pressurized and set at a height that results in spray fans overlapping a minimum of 2 (preferably 3) times.
- 2) Application: Uniform and complete. ***Not streaked.***
- 3) Spray Rate (302-5.8): Rate at which material is applied.
- 4) Residual Rate: Rate of asphalt residue remaining after application (PG 64-10 & SS-1h) and evaporation (SS-1h).
- 5) Residual Rate (PG 64-10) = Spray Rate

Tack Coat Comments:

- 6) SS-1h may be diluted 1:1 or 0.5:1.
- 7) Residual Rate (SS-1h) (undiluted) = Spray Rate x % (Residue from Distillation) (Table 203-3.4.2, 57 = 0.57)
- 8) Payment is included in Contract Unit Price of AC (302-5.9)
- 9) Separate Bid item encourages quality.
- 10) For calculations and other information, see Caltrans Tack Coat Guidelines:
www.ucprc.ucdavis.edu/ccpic/pdf/Caltrans%20Tack%20Coat%20Guidelines.PDF



Spray fans overlapping twice shown above.

Reference: Asphalt Institute, MS-22, Third Edition, page 115.

302-5.4 Equipment (For Distribution and Spreading)

- 1) Provides for headers “... where shown on the Plans or specified in the Special Provisions.”
- 2) “... shall be accomplished in a single, continuous operation by means of a self-propelled mechanical spreading and finishing machine specifically designed for that purpose.”
- 3) “The machine shall be equipped with a suitable full-width compacting screed ...”



- 4) ***“The asphalt concrete as delivered shall be deposited directly into the hopper of the spreading and finishing machine.”***



- 5) ***“With the approval of the Engineer, the Contractor may deposit ... material from bottom dump trucks into a ... windrow, then pick up the material and convey it ... with loading equipment provided: ...”***



6) Doesn't require the use of automatic screed control devices.



7) Doesn't address the use of material transfer vehicles.



302-5.4 Rollers & 302-5.10 Rolling

302-5.4.6.2 General.

- 1) Table 302-5.4.6.2: Roller requirements based on production and compacted thickness.**



- 2) Provides minimum specifications for different types of rollers.**
- 3) Specifies the sequence of rolling operations.**

Comments:

1) Static vs. vibratory vs. pneumatic-tired rollers.



302-5.11 Density and 302-5.12 Smoothness.

1) Requires at 92-97 percent of TMD [AASHTO T209, CTM 375 (Modified), CT 308] relative compaction.

302-5.13 Measurement and 302-5.14 Payment.

- 1) “... will be paid for at the Contract Unit Price per square yard ..., or at the Contract Unit Price per ton ... as shown in the Bid.”**

302-9 ASPHALT RUBBER HOT MIX (ARHM).

302-9.3 Placement.

- 1) *“... shall conform to 302-5.9.1 except that at the time of delivery to the Work site, the temperature ... shall be between 300°F ... and 330°F ...”*

302-9.4 Rolling.

- 1) *“... shall conform to 302-5.10 except that vibratory rollers using the vibratory mode shall be used for initial breakdown rolling.”*

2) ***“The initial coverage ... shall commence before the ARHM temperature falls below 290°F ...”***

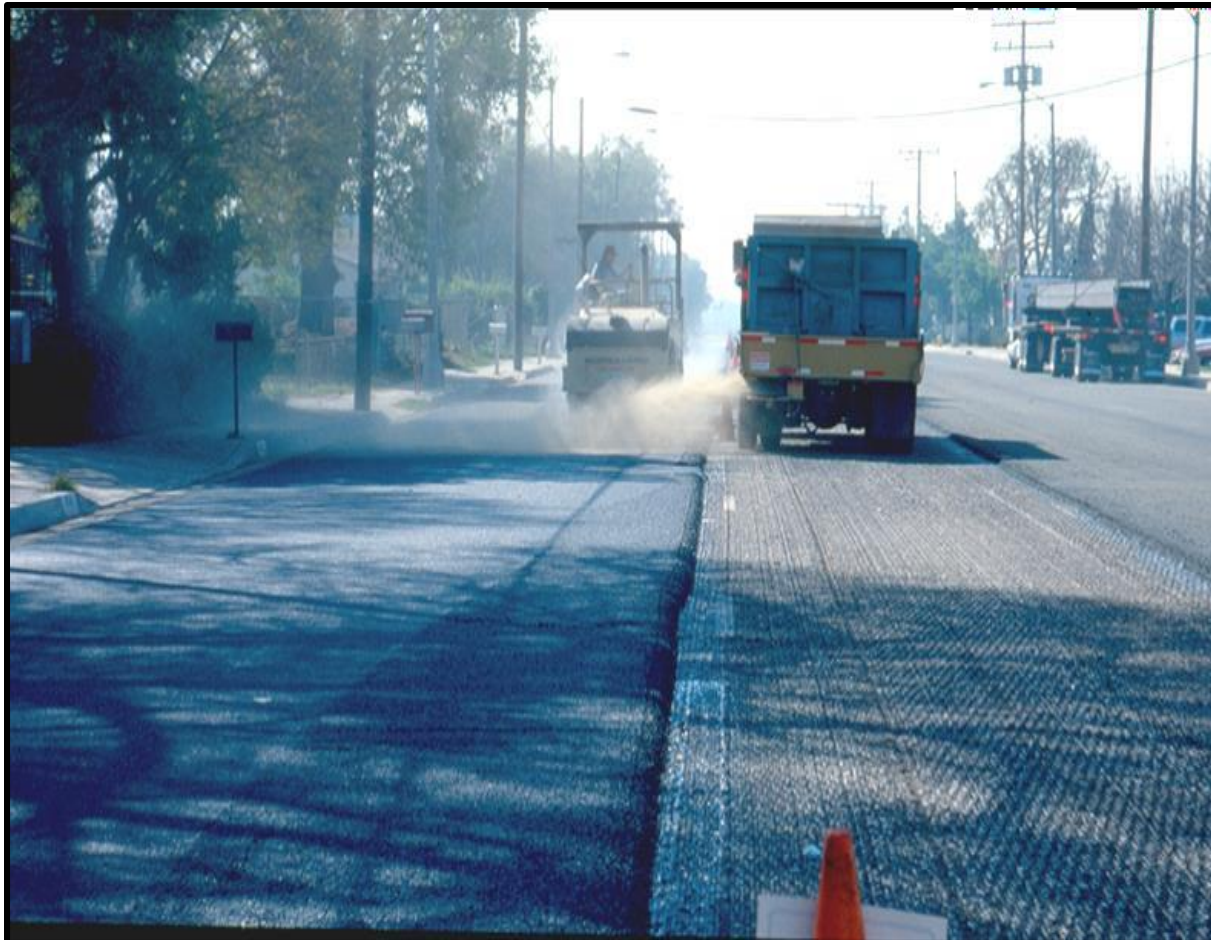


3) “*Pneumatic rollers shall not be used.*”



302-9.7 Rock Dust Blotter.

- 1) ***“At the option of the Engineer, when traffic conditions warrant, a rock dust blotter may be required to avoid tracking.”***



2) ***“When the ARHM pavement has cooled to below 150°F ..., the rock dust blotter may not be required.”***



Comment: Notice the excessive application rate and deficient traffic control.

SECTION 302 - ROADWAY SURFACING.

302-2 CHIP SEAL.

- 1) Chip seals consist of the application of polymer modified emulsified asphalt [**“cold-applied”**] or modified [**polymer or tire rubber**] paving asphalt [**“hot-applied”**] followed immediately by the application of screenings [**200-1.2.2**].
- 2) Screenings for “hot-applied” are pre-coated with paving asphalt and pre-heated.





302-3 MICROSURFACING.

- 1) *“... a mixture of microsurfacing emulsion (MSE), water, set control agents, and aggregate.” (302-3.1)*
- 2) *“The combined aggregate gradation (Type) shall be as shown on the Plans.” (302-3.1)*
- 3) Added RAP aggregate option to 2024 Greenbook

Comments:

- 1) *“Micro-surfacing is a thin surfacing, and can be laid at two to three times the thickness of the largest stone in the grading. The emulsion in the system is always polymer modified and special additives are used to create a chemical break that is largely independent of weather conditions.”*

Caltrans Maintenance Technical Advisory Guide,

<https://www.csuchico.edu/cp2c/library/caltrans-documents.html>

- 3) *“Spreader boxes shall have baffles, reversible motor driven augers, ...” (302-3.6)*
- 4) *“The basis of measurement shall be the combined weight of dry aggregate ... and MSE, in tons (tonnes), for each type [size] of aggregate used in the Work.” (302-3.12)*
- 5) *“Payment ... will be made at the Contract Unit Price per ton (tonne).” (302-3.13)*

302-4 SLURRY SEAL SURFACING.



302-4 SLURRY SEAL.

- 1) “... *mixing, spreading, and application of [polymer modified] emulsion-aggregate slurry (EAS) ... or the spreading and application of rubberized emulsion-aggregate slurry (REAS) ...*” (302-4.1)
- 2) “*The combined aggregate gradation (Type) and slurry seal mixture (EAS or REAS) shall be as specified in the Special Provisions or shown on the Plans.*” (302-4.1)

Comments:

- 1) Rubberized Polymer Modified Emulsified Asphalt: RPME (203-5.2.2)
- 2) *“The polymer enhances stone retention, especially in the early life of the treatment. The added polymer also reduces thermal susceptibility. Polymers also improve softening point and flexibility, which enhance the treatment’s crack resistance.”*

Caltrans Maintenance Technical Advisory Guide, Volume 1, Chapter 8, page 8-3.

<https://www.csuchico.edu/cp2c/assets/documents/caltrans/fpmtag-chapter-8---slurry-seals.pdf>

302-4.8 Scheduling, Public Convenience and Traffic Control.



4) ***“The Contractor shall prevent slurry seal from being deposited on other than asphalt concrete surfaces ...” (302-4.9.1)***





**5) “... and shall remove it from surfaces
not designated to be sealed.”
(302-4.9.1)**

Tables 302-4.9.2.2 [EAS], & 302-4.9.3.2 [REAS]:

- Specifies the minimum and maximum application rates.
- *Note the greater rates when applied over milled surfaces and chip seals (as part of a cape seal).*



- 6) ***“... [EAS] surfacing will be measured by the combined weight of each ton (tonne) of [polymer modified] emulsified asphalt and each ton (tonne) of each Type of aggregate used in the Work.” (302-4.11.2)***
- 7) ***“REAS will be measured by each ton (tonne), including aggregate, RPME, additives and water for each Type of aggregate used in the Work.” (302-4.11.3)***
- 8) ***“Payment ... will be made at the Contract Unit Price per ton (tonne) for each combination of EAS and aggregate Type used in the Work.” (302-4.12.2)***
- 9) ***“Payment ... will be made at the Contract Unit Price per ton (tonne) for each combination of REAS and aggregate Type used in the Work.” (302-4.12.3)***

Comment: Wet Track Abrasion Test

302-3, 302-4 Comments:

- **Aggregate Size: Type 1 vs. Type 2 vs. Type 3**



302-3, 302-4 Comments:

1) Mixer-spreader trucks vs. continuous mixer-spreader machines:



302-3, 302-4 Comments:



The photo above is of a continuous, self-loading, mixer-spreader machine.

302-3, 302-4 Comments:

**Spreader Boxes: Slurry (no auger) vs.
Micro (auger)**



302-10 ASPHALT RUBBER AND AGGREGATE MEMBRANE (ARAM).

302-10.1 Application.

- 1) *“Asphalt rubber shall be applied by distributor equipment meeting the requirements of the following: ...”*



302-10.2 Screenings.

- 1) ***“... screenings conforming to 203-12.3 shall be placed over all areas receiving asphalt rubber.”***



- 2) ***“Rolling shall be accomplished by 3 self-propelled, pneumatic-tired rollers ... A steel drum roller ... shall complete the final roller coverage.”***
- 3) ***“Sweeping shall be a multi-step operation ... all loose aggregate shall be removed prior to acceptance ...”***



302-10.5 Measurement and Payment.

- 1) *“... will be paid for at the Contract Unit Price per square yard ...”*



Comments:

- 1) ARAM is an asphalt rubber chip seal.**
- 2) Asphalt rubber binder is the same as used in ARHM.**
- 3) Application may be as a driving surface or as an interlayer (between pavement layers).**

SECTION 211 – MATERIAL TESTS

211-2 CHEMICAL RESISTANCE (PICKLE JAR) TEST.

- 1) *“This test is used to determine the physical properties and weight change of material specimens used in sewers after exposure to chemical solutions.”*

211-4 HAND HELD VISCOMETER TEST.

- 1) Test for viscosity of asphalt rubber binder.

SECTION 213 - ENGINEERING GEOSYNTHETICS

213-4 PAVEMENT FABRIC.

- 1) *“... fabric material placed within or under an asphalt concrete layer or a chip seal.”*



213-5 GEOTEXTILES AND GEOSYNTHETICS.

- 1) ***“... shall conform to Table 213-5.2 (A) or 213-5.2 (B) for the type shown on the Plans or specified in the Special Provisions.”***

Comments:

- 1) Before specifying, review manufacturer's literature.
- 2) Determine if the application requires woven, nonwoven, or geogrids.
- 3) Tables revised in the 2021 Edition.



302-7 PAVEMENT FABRIC.

302-7.1 General.

- 1) References 213-1.

302-7.2 Placement.

302-7.2.1 Pavement Preparation.

- 1) “... as shown on the Plans or specified in the Special Provisions ...”
- 2) “... shall not be placed ... where the ... overlay is less than 1-1/2 inches (38 mm) thick.”

302-7.2.2 Tack Coat.

- 1) “... shall be *PG 64-10* or *PG 70-10* paving asphalt ...”
(302-7.2.2.1.)



302-7.2.3 Laydown.

- 1) *“... shall be placed with no wrinkles that lap.”*
- 2) *“Public traffic shall not be allowed to drive over bare pavement fabric.”*



302-7.3 Measurement.

- 1) *“... will be measured by the square yard ...”*

SECTION 214 / SECTION 314 TRAFFIC STRIPING, CURB AND PAVEMENT MARKINGS, AND PAVEMENT MARKERS



See: California Manual on Uniform Traffic Control Devices (CA MUTCD)

Questions?