RUBBERIZED ASPHALT CONCRETE (RAC)

PILOT TRAINING COURSE NOTES

June 5, 2006 - District 4 Auditorium
111 Grand Avenue, Oakland 94623

June 12, 2006 - District 7 Conference Room
100 S. Main St., Los Angeles 90012

Prepared by

State of California Department of Transportation
Materials Engineering and Testing Services
Office of Flexible Pavement Materials
5900 Folsom Blvd
Sacramento, California 95819

June 2006
Rubberized Asphalt Concrete Training Course Outline

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Prelude
Rubberized Asphalt Concrete Pilot Training Course

Promote RAC Usage Thru Tech Transfer

Background
- Caltrans-California Integrated Waste Management Board (CIWMB) formed a partnership to expand the use of asphalt rubber in CA
- CIWMB awarded $1.7 M grant to Caltrans through interagency agreement to conduct work associated with asphalt rubber products
- Caltrans used MACTEC to assist in fulfilling the Caltrans/CIWMB agreement
- Project started in June 2004

Planned Deliverables
- Product Evaluation
  - Synthesis of the state of the technology
  - Experimental design for product evaluation
  - Feasibility of RAC recycling
  - Conduct field experiments
  - User seminar (December 1, 2005)
- Product Implementation
  - Update AR Usage Guide
  - Update structural design guidelines
  - Update RAC materials & construction specifications
- Technology Transfer
  - Class room training
  - Web-based training
Proposed Classroom Training & Schedule

- Format
  - Lecture/discussion
  - Questions/comments are encouraged
- Schedule (4 hours)
- Feedback will be used to update training materials – future workshops
- Web-based training – on hold

Housekeeping

- Mobile Phones
- Restrooms
- Refreshments
- Break
1.0 Introduction

Training Course Objectives and Content

Outline

- Course Objectives
- Course Content
- History of Asphalt Rubber (AR)
- Caltrans Experience with RAC
- Advantages of AR
- Primary References
- Summary

Course Objectives

- Basics of RAC
  - History of Asphalt Rubber
  - What is RAC and why use it?
- Design and Construction of RAC
  - Structural and material design
  - Construction
- Inspection and Basic Trouble Shooting
Course Content

- Structural Design
- Materials
- Construction
- Inspection Guide
- Summary
- Assessment of Learning (Jeopardy)
- Course Evaluation

History of Asphalt Rubber

- Used since the 1960’s
- Used in chip seals, inter-layers, and hot mix asphalt
- Used extensively in Arizona, California, Florida and Texas
- Design and construction guides now available from some agencies

History of Asphalt Rubber (Cont.)

- Applications
  - Asphalt rubber chip seals and interlayers
  - Overlays and wearing courses
- Performance
  - Variable results in early years
  - Most effective in retarding reflection cracking as a thin surface layer
  - Mixes perform satisfactorily if properly designed and constructed
Caltrans Experience with RAC
- 1970’s – Used for chip seals and hot mix
- 1983 – Ravendale project - reduced thickness
- 1995 – Over 100 RAC projects constructed
- 2001 – Over 210 RAC projects constructed
- 2003 – CIWMB/Caltrans partnership
- 2005 – AB338 mandates increased RAC use (20% AC in 2007 to 35% in 2013)

Caltrans Use of RAC
- Largest Use
  - Thin overlays (RAC-G)
  - Mitigate reflective cracking
  - Reduced thickness
- Other Uses
  - Friction course (RAC-O)
  - Durable sacrificial course (RAC-O-HB)
- Performance
  - Successful in all applications
  - Problems generally due to construction issues

Tires Used in RAC

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of Tires Used in RAC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1997</td>
<td>914,700</td>
</tr>
<tr>
<td>1998</td>
<td>913,400</td>
</tr>
<tr>
<td>1999</td>
<td>1,143,000</td>
</tr>
<tr>
<td>2000</td>
<td>3,967,900</td>
</tr>
<tr>
<td>2001</td>
<td>1,733,300</td>
</tr>
<tr>
<td>2002</td>
<td>703,900</td>
</tr>
<tr>
<td>2003</td>
<td>1,126,500</td>
</tr>
<tr>
<td>2004</td>
<td>1,788,900</td>
</tr>
<tr>
<td>Total</td>
<td>12,291,800</td>
</tr>
</tbody>
</table>
Introduction
Rubberized Asphalt Concrete Pilot Training Course

Caltrans RAC Usage (% of AC Used)

Caltrans Research with RAC Products

- 1999 – HVS confirmed “1/2 - thickness”
- 2003 – HVS on 8 field constructed overlays (6 Test Sections)
- 2004 – Fre-33 (9 Test Sections)
- 2005 – Men-20 (4 Test Sections)
- 2005 – SJ-5 and Ker-99 (rubberized bonded wearing course, RBWC)

RBWC on I-5
Caltrans Challenges with RAC

- 1997 – 00: 10 pilot projects using MB
- 2002 – 04: Five RAC (5-year warranty) projects throughout the State
- 2004 – 05: Full-scale field experiments

MB and HVS

- 10 pilot projects using RMB (1997 - 2000)
- Performance: 8 good, 1 fair*, and 1 poor*
- HVS Sites – UC Berkeley
  - 45 mm RAC-G, Field Blend
  - 45 mm Type G (MB), TB
  - 90 mm Type G (MB), TB
  - 45 mm MB 15%, TB
  - 90 mm MB 15%, Term. Blend
  - 90 mm DGAC Type A (Control)
- HVS Performance: Exceeding expectations

  * Not materials related

RAC 5-Year Warranty Projects

- 5 Projects Constructed in 2002 - 04
  - 4 - Wet Process (Fre-33, Ven-150, Mer-140, SD-75)
  - 1 - MB-D (terminal) (Las-395)
- Level Playing Field
  - 15% CRM
  - Open specifications
  - 5-Year Performance Warranty Criteria
    > Rutting > Cracking > Delamination
    > Bleeding > Potholing
- Regular Review and Evaluation
Fre-33 and Men-20 Projects

- Fre-33 (Firebaugh, 9 test sections, June 04)
  - DGAC (90 mm)
  - RAC-G (45 mm, 90 mm)
  - RUMAC (45 mm, 90 mm)
  - MB-G (45 mm, 90 mm)
  - MB-D (45 mm, 90 mm)

- Men-20 (Dist. 1, 4 test sections, August 05)
  - DGAC (105 mm)
  - RAC-G (60 mm)
  - RUMAC (60 mm)
  - MB-D (60 mm)

- Performance evaluation sections
- Laboratory performance tests
- Comparison to HVS

Advantages of AR

- Good durability – in terms of resistance to cracking and aging
- Environmental friendly – make value-added use of a waste material, reduce traffic noise
- Versatility – can be used in most maintenance and rehabilitation activities, often at reduced thickness for resistance to reflective cracking
- Longer lasting color – for better contrast with striping and marking
- Reduced maintenance – for both chip seals and hot mix

Primary References

- Asphalt Rubber Usage Guide
- Use of Scrap Tire Rubber – State of the Technology and Best Practices
- Synthesis of Caltrans Rubberized Asphalt Concrete Projects
- Feasibility of Recycling Rubber-Modified Paving Materials
- Study on Structural Design Considerations
- Flexible Pavement Rehabilitation Manual
- Asphalt Rubber Design and Construction Guidelines
- RAC-G SSP Version (12-12-05)
- RAC-O SSP Version (12-12-05)

http://www.dot.ca.gov/hq/esc/Translab/translab/CALTRANS_CIWMBPROJECTSDELIVERABLES.htm
Summary of Module 1

- Course Objectives and Content
- History of RAC
- Caltrans Experience with RAC
- Advantages of RAC
- References
2.0 Structural Design

New Pavements and Overlays

Outline

- Terminology
- Caltrans Practices
- 2005 Study
- Revised Caltrans Practices
- RAC Project Selection
- Cost Analysis

Terminology

- Hot-mix asphalt (HMA) replaces the term dense-graded asphalt concrete (DGAC)
- Caltrans Highway Design Manual (HDM)
- Caltrans Flexible Pavement Rehabilitation Manual (FPRM)
- Asphalt Rubber Usage Guide (AR Guide)
- Mechanistic-empirical (M-E) based analysis and design
Caltrans Practice – New Pavements
- New pavements – Caltrans does NOT have a standard practice for the use of RAC in new pavement construction

Caltrans Practice – Overlays
- Based on FPRM (2001)
- Uses deflection reduction to a tolerable level
- Design for HMA overlay thickness based on TI and existing HMA layer thickness
- Check also for reflective cracking and ride quality

Caltrans Practice – Overlays
- When RAC-G is used as overlay material
  - Design for conventional HMA thickness
  - Determine RAC-G overlay thickness according to FPRM
    - Table 3 – Based on structural equivalencies
    - Table 4 – Based on reflection crack retardation
  - RAC-G overlay thickness generally half that of the HMA overlay thickness
2005 Study

- Use of RAC in new pavements?
- Can RAC-G thickness be increased more than 60 mm?
- Does 2:1 thickness reduction for RAC-G provide adequate structural equivalency in overlays?

2005 Study

- Joint effort between Caltrans, UC-PPRC, and MACTEC
- Both new pavements and structural overlays
- Laboratory tests (Cohesiometer)
- Theoretical (M-E) analysis with lab-developed models

Primary Findings – New Pavements

- Limited cohesiometer test results indicate that $G_f$ for RAC and HMA are similar.
Primary Findings – New Pavements

- Theoretical analyses did not show structural benefit for the use of RAC-G of same thickness as HMA.
- This is due, in part, to the lower stiffness (higher strains) which offsets the improved fatigue life and which may cause concerns of rutting in the subgrade soil.

Recommendations – New Pavements

- RAC should be treated the same as HMA for new construction.
  \[(G_f)_{\text{RAC}} = (G_f)_{\text{HMA}}\]
- Caltrans thickness design provides a minimum structural capacity required for the design conditions. It should NOT be reduced when RAC mixes are used.

Primary Findings – Structural Overlays

- Based on M-E analysis, the structural benefit of the RAC-G overlay varies with the thickness placed. The greatest benefit occurs in a thin layer of 30 mm to 60 mm thick as compared to HMA of the same thickness.
- The use of reduced thickness for RAC-G overlay is valid; however, not to the extent previously employed by Caltrans.
Structural Design
Rubberized Asphalt Concrete Pilot Training Course

Simplified Overlay Thickness Design Charts

Recommendations – Structural Overlays
- Calculate GE for HMA using current methodology and determine structural overlay
- Design RAC-G overlay in a range of 30 to 60 mm to achieve most structural benefit

Revised Practice – New Pavements
- HDM and AR Guide are currently being updated to include information contained in the memo dated 4/24/06 by Caltrans
- Contact Info:
  - Terrie Bressette, METS (916-227-7303)
  - Mehdi Parvini, Division of Design (916-227-5846)
RAC Usage in New Pavements

16

- RAC
- HMA
- Base
- Subbase
- Subgrade Soil

RAC
- PCC
- Base
- Subbase
- Subgrade Soil

17

- RAC
- HMA or OGFC
- Base
- Subbase
- Subgrade Soil

RAC
- Base
- Subbase
- Subgrade Soil

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<table>
<thead>
<tr>
<th>Material Type</th>
<th>Max Thickness</th>
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<tbody>
<tr>
<td>RAC-G</td>
<td>60 mm</td>
</tr>
<tr>
<td>RAC-O</td>
<td>45 mm</td>
</tr>
<tr>
<td>RAC-O on RAC-G</td>
<td>45 mm on 60 mm</td>
</tr>
</tbody>
</table>
Revised Practice – New Pavements

- Place on top of conventional HMA or PCC. Do not place directly over aggregates bases (treated or non-treated), subbases, or native soils.
- Place gap-graded RAC (RAC-G) no thicker than 60 mm and open-graded RAC (RAC-O) no thicker than 45 mm. Up to 45 mm of RAC-O may be placed on top of 60 mm of RAC-G.

Revised Practice – New Pavements

- Do not place underneath conventional HMA or open graded friction course (open-graded HMA).
- Do not reduce the overall pavement thickness when RAC is used. Pavement thicknesses for rehabilitation can be reduced with RAC for reflective cracking only. Reflective cracking is not an issue for new construction.

Revised Practice – New Pavements

- Place RAC at the temperature specified in Standard Special Provisions. The project engineer should determine this by verifying with the District Materials Engineer and Resident Engineer that these temperatures will exist during the season and times (traffic lane closures) the Contractor will be performing this work. RAC in thin layers can be more sensitive to lower temperatures.
Revised Practice – Overlays

- Overlay design procedure is now incorporated into new HDM
- Rehabilitation strategies are divided into three categories:
  - Overlay
  - Mill and Overlay
  - Remove and Replace
- Rehabilitation designs are governed by one of the following three criteria:
  - Structural adequacy
  - Reflective cracking
  - Ride quality

Revised Practice – Overlays

- Overlay procedures for flexible over existing flexible pavement
  - Structural adequacy
    - Principle of reducing deflection to a tolerable level is still the basis
    - The required overlay thickness is determined by dividing gravel equivalency (GE) by gravel factor (Gf)
  - Reflective cracking (table for equivalencies)
  - Ride quality (evaluated based on the pavement’s smoothness)

Layer Thickness Equivalencies for Reflective Crack Retardation

<table>
<thead>
<tr>
<th>HMA</th>
<th>RAC-G</th>
<th>RAC-G on SAMI-R</th>
</tr>
</thead>
<tbody>
<tr>
<td>45 mm</td>
<td>30 mm</td>
<td></td>
</tr>
<tr>
<td>60 mm</td>
<td>30 mm</td>
<td></td>
</tr>
<tr>
<td>75 mm</td>
<td>45 mm</td>
<td></td>
</tr>
<tr>
<td>90 mm</td>
<td>45 mm</td>
<td></td>
</tr>
<tr>
<td>105 mm</td>
<td>60 mm, if CW &lt; 3 mm or if underlying material is CTB, LCB, or PCC</td>
<td>45 mm, if CW ≥ 3 mm and underlying material is untreated or if underlying material is CTB, LCB, or PCC</td>
</tr>
</tbody>
</table>

Note: CW = Crack Width
RAC Project Selection – New Pavements

- RAC may be used as final lift of the surface layer for structural purposes, but thickness must be \( \leq 60 \text{ mm} \).
- If RAC is used to replace a portion of the structural layer, M-E analysis may be used to ensure that fatigue cracking criteria and subgrade cover requirements are satisfied.
- RAC may also be used as a non-structural wearing course layer (thickness \( \leq 60 \text{ mm} \)).

RAC Project Selection – Overlays

- Overlay projects are the best candidates for the use of RAC mixes because existing pavement helps satisfy cover requirements.
- If existing pavement is structurally sound and surface cracking is the predominant distress, RAC-G thickness may be reduced up to half of the designed HMA thickness for controlling reflective cracking.

RAC Project Selection – Mill & Overlay with RAC

- Projects in which a certain amount of the existing HMA surface is to be removed and replaced are valid candidates for RAC.
- Follow the mill and overlay procedure in HDM, check for:
  - Structural adequacy
  - Reflective cracking
  - Ride quality (sufficient)
Cost Analysis – Initial Cost

- 2005 unit costs: $65/ton for HMA vs. $80/ton for RAC. Costs will be higher in 2006.
- In general, initial costs are high; however, reduced layer thickness results in lower costs
- Experienced contractors help keep cost of RAC low

Cost Analysis – LCCA

- Available information indicates that RAC is (in general) cost-effective in the majority of cases when compared to conventional HMA rehabilitation and maintenance strategies.

Cost Analysis – LCCA

- Caltrans is currently developing a LCCA procedure based on the RealCost Model developed by FHWA
- Caltrans procedure has typical M&R schedule for California
  - By various climate region (e.g., coast, valley, desert, and mountain) and for Districts
  - By surface type (e.g., HMA, RAC)
  - By M&R design life
Cost Analysis – LCCA

- Caltrans procedure also includes overall rehabilitation construction unit cost for various strategies (e.g., RAC, CAPM 5-year)
- The Caltrans LCCA procedure will be ready for use by the end of June 2006

Summary of Module 2

- Caltrans Practices
- 2005 Study
- Revised Caltrans Practices
- RAC Project Selection
- Cost Analysis

Questions?
3.0 RAC Materials
Specifications and Binder Design

Outline
- Definitions
- Asphalt rubber binder
- Asphalt rubber binder design
- Types of mixes
- Cautions

Definitions

Asphalt Rubber Definition: ASTM D 8
A blend of asphalt cement, reclaimed tire rubber and certain additives in which the rubber component is at least 15% by weight of the total blend and has reacted in the hot asphalt cement sufficiently to cause swelling of the rubber particles.
Definitions

Related Specification: ASTM D 6114
Standard Specification for Asphalt Rubber Binder

High viscosity material (usually field-blended) that typically requires agitation to keep CRM particles dispersed.

Definitions

- The Wet Process can produce a wide variety of CRM modified binders from high viscosity (field blend) to no agitation (terminal blend) types
  - Rotational Viscosity is the discriminator for appropriate use, although rotational viscosity of terminal blends is not typically measured
  - May be blended in field or at terminal

Definitions

Wet Process
Method of modifying asphalt cement with scrap tire CRM and other components
- Most widely used approach (AZ, CA, TX, FL, others)
- Thoroughly mix CRM & other components with hot (400-425°F) asphalt cement
- Interact at 350-375°F for designated period (typical minimums 45-60 minutes)
- CRM particles swell, exchange oils with AC
Definitions

Terminal Blends and MB binders are:
- Low viscosity, no agitation
- Typically ≤ 10% CRM content, some @ 15%
- May include polymers and/or other modifiers
- Content in hot mixes is similar to neat asphalt cement
- **MB is not the subject of this presentation**

High Viscosity (Field Blend) vs. No Agitation (Terminal Blend)

Definitions

**Dry Process**
Substitutes CRM for 1 to 3% of aggregate in hot mix
- Not considered to modify binder, although some asphalt-CRM interaction may occur in place over time
- CRM gradations have ranged from coarse (-1/4") to fine (-#80)
- Mixed performance history – limited current use
  - May be related to mix design – need to account for long term absorption without starting out too rich
  - Not widely used in CA
- **Not the subject of this presentation**
Asphalt Rubber Binder

Components:
- Crumb Rubber Modifier (CRM)
  - Scrap Tire Rubber
  - High Natural Rubber Content Scrap Rubber
- Asphalt Cement
- Extender oil - Caltrans

Caltrans Specifications for High Viscosity (Field Blend) AR Binders

- Asphalt modifier: Extender oil at 1 to 6% by mass of asphalt. (For chip seal binders, CT may continue to require minimum 2.5% extender oil.)
- Asphalt + extender oil: 78-82% by total mass of AR binder
- Total CRM: 18-22% by total mass of AR binder, of which:
  - Scrap tire CRM = 73-77% of total CRM
  - High natural CRM = 23-27% of total CRM

Crumb Rubber Modifier (CRM)

- CRM is produced from grinding whole scrap tires, tread buffings, and other waste rubber products. CRM comes in a variety of grades and size designations from various suppliers and/or sources.
- CRM gradation and content affects not only AR binder properties, but also influences the voids structure of RAC-G mixes.
- Gradation limits used by Caltrans and ADOT are broad and allow considerable variation; changes are being considered.
- Check project special provisions to verify CRM gradation limits in effect for specific projects.
Crumb Rubber Modifier (CRM)

Scrap Tire (1/16" +/- in size)
High Natural Rubber (1/32" +/- in size)

Tire Processing Video Clips
Clip 1
Clip 2
Clip 3

Crumb Rubber Modifier (CRM)

- High natural rubber CRM is used to improve adhesion and flexibility, chip seal aggregate retention, and to compatibilize asphalt and CRM interactions. It has a high natural rubber content (40-48% by mass) and may be made from scrap tires or other non-tire sources.
- Caltrans also requires that "high natural" be used in binders for RAC mixes.

Asphalt Cements

- Asphalt cements come in a variety of grades and designations.
- AR-4000 was used to make asphalt rubber in the past.
- Caltrans adopted the Performance Graded (PG) system in 2006.
- Do not use modified asphalts as the base asphalt cement for CRM modification.
PG Asphalt Cements

- For high mountain and high desert areas, use PG 58-22 as the base asphalt.
- For other areas (coastal, inland valleys, low and south mountain, and desert) use PG 64-16 as base asphalt.

Additives

- Extender oils - aid in the interaction of the crumb rubber and asphalt by providing aromatics which are absorbed by the rubber, and help with dispersion by chemically suspending the rubber in the asphalt. Required by Caltrans.
- Anti-stripping agents - used to improve adhesion of binder to aggregate.

Asphalt & Rubber Interactions

Interactions Depend On:
- Asphalt Cement Source and Grade
- Rubber Type/Source
- Amount of Rubber
- Gradation of Rubber
- Interaction Time
- Interaction Temperature
Asphalt Rubber Blend Design Submittals

- Supplier and identification (or type) of scrap tire and high natural CRM.
- Typical gradation of each type of CRM material used in the asphalt rubber binder design.
- Percentage of scrap tire and high natural CRM by total mass of the asphalt-rubber blend.
- If CRM from more than one supplier is used, info will be required for each CRM supplier used.
- Laboratory test results for test parameters shown in the special provisions.

Asphalt Rubber Blend Design Submittals

- Base asphalt PG binder grade, supplier, and Certificate of Compliance.
- Percentage of the combined blend of asphalt and asphalt modifier by total mass of asphalt rubber binder.
- Asphalt modifier type, supplier, identification, and test results demonstrating conformance to specs.
- Percentage of asphalt modifier by mass of asphalt.
- Design profile.
- Minimum interaction time and temperature.
- Material Safety Data Sheets for everything.

Asphalt Rubber Blend Design Profile

- A design profile is developed to evaluate the compatibility between materials used, compliance of component interaction properties, and to check for stability of the AR blend over time. A 24-hour design profile will be required for each project, for hot mix and spray applications.
- Previous AR blend designs may be validated with currently available materials and may be submitted for more than one project.
Asphalt Rubber Blend Design
Example Design Profile

<table>
<thead>
<tr>
<th>TEST</th>
<th>Minutes of Reaction</th>
<th>Spec. Limits @ 45 minutes (Caltrans 12/2005)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Viscosity @ 190°C</td>
<td>45  90  240  360  1,440</td>
<td>2800 2800 2800 2100 1500 - 4000</td>
</tr>
<tr>
<td>Resilence @ 25°C (% rebound)</td>
<td>27  --  33  --  23</td>
<td>18 Minimum</td>
</tr>
<tr>
<td>R &amp; B Softening @ 125-165°F</td>
<td>59.0 59.5 59.5 60.0 58.5</td>
<td>52 – 74 (125-165°F)</td>
</tr>
<tr>
<td>Cone Pen @ 25°C (ASTM D532)</td>
<td>39  --  46  --  50</td>
<td>25 – 70</td>
</tr>
</tbody>
</table>

Types of Rubberized Asphalt Concrete (RAC) Hot Mixes

- Dense-graded (not in use by Caltrans)
- Gap-graded
- Open-graded
- Open-graded (High Binder, HB)

Aggregate Gradation Comparison

Open Graded  Gap Graded  Dense Graded
Dense-Graded Mixes (RAC-D)

- Early use
  - Limited performance improvements vs. cost
  - Inadequate void space to accommodate sufficient AR binder to modify mix behavior
- Discontinued use with high viscosity (field blend) binders
- Suitable for use with no agitation CRM-modified binders (terminal blend) such as MB

Gap-Graded Mixes (RAC-G)

RAC-G is the most commonly used RAC mix type

- Purpose – Structural mix that provides increased resistance to rutting, fatigue and reflective cracking, and to oxidative ageing, as function of relatively high contents of modified binder.

Gap-Graded Mixes (RAC-G)

- Appropriate use - Most effective in relatively thin surface lifts (max 60 mm) as overlay of aged or distressed flexible or rigid pavements that are structurally sound. May be used as surface course for new construction. Suitable for wide range of traffic volumes and loadings.
Gap-Graded Mixes (RAC-G)

- Thickness design
  - See Module 2 for details
  - New pavements
  - Overlays
- Overlay systems – two and three layer
  - SAMI-R, not SAMI-F

---

Gap-Graded Mixes (RAC-G)

Standard Special Provisions for RAC-G with high viscosity (field blend) AR binder are currently being updated to address PG binder implementation.

Revisions include:
- Remove test methods from body of SSP, develop corresponding CT Lab Procedures for CRM sieve analysis and measuring rotational viscosity of AR binder
- Format SSP for inclusion in Section 39 of Caltrans Standard Specifications

---

Gap-Graded Mixes (RAC-G)

- Adjustments to Hveem Mix Design Method (CT 367), including:
  - Modify (coarsen) aggregate gradation requirements, particularly for 600 µm sieve, to facilitate achieving minimum VMA (18%).
  - Add maximum VMA limit of 23%.
  - Test 3 briquettes at each binder content, use average values for calculations and plots.
Gap-Graded Mixes (RAC-G)

Adjustments to Hveem Mix Design Method, cont'd
- Design air voids content may range from 3 to 5% based on traffic index and climate, and as designated by the Engineer in project special provisions.
- Still requires minimum AR binder content of 7.0% by weight of dry aggregate to provide durability. (Must have sufficient binder content to provide expected performance benefits.)

Use Caltrans Laboratory Procedures LP-1 through LP-4 for volumetric calculations.
- Report Voids Filled with Asphalt (VFA) and Dust Proportion for information only.
- Plot average unit weight, stability, % air voids, VMA, and VFA, versus asphalt rubber binder content.

Open-Graded Mixes (RAC-O, RAC-O-HB)

Standard Special Provisions for RAC-O and RAC-O-HB are also currently being updated to incorporate PG binder implementation.

Changes are similar to those for RAC-G, but with less impact on mix design method. Effects of CRM gradation and content in binder have relatively little effect on voids structure of open-graded mixes.
Open-Graded Mixes (RAC-O)

Purpose:
RAC-O is designed to provide a free-draining surface (reduced splash, spray, and hydroplaning) that maintains good frictional characteristics in wet or dry conditions. Such mixes are not considered to be structural elements and no thickness reduction applies. RAC-O is typically placed in thin lifts, nominally 24 to 30 mm thick.

Open-Graded Mixes (RAC-O)

Appropriate Use:
RAC-O may be used as an overlay or as a surface for new construction where traffic flow is essentially uninterrupted by signalization, such asfreeways, and some rural and secondary highways.

Open-Graded Mixes (RAC-O)

Do not use open-graded mixes where there is a significant amount of stop and go traffic or turning vehicles, such as city streets or in parking lots. These porous low modulus pavements are susceptible to tire scuffs from simultaneous braking and turning motions, and to damage from leaking vehicle fluids. Caltrans does not use RAC-O in snow country.
RAC-O Mix Design

- RAC-O mixture design is performed according to California Test 368, with asphalt rubber binder content set at 1.2 times the optimum bitumen content for the designated PG binder grade. A check test is used to verify that binder drain down is not excessive.

- If long hauls are anticipated, drain down should also be checked in the laboratory for the expected haul time.

Open-Graded Mixes (RAC-O-HB)

- RAC-O-HB mixes have higher binder contents (1.6 times demand for PG asphalt instead of 1.2)
- HB provides improved friction course durability and performance due to thicker AR binder films.
- Drain down check is more critical for high binder mixes.
- RAC-O-HB does not drain as freely as RAC-O due to higher binder content, but still drains more freely than DGAC.

Open-Graded Mixes

- RAC-O and RAC-O-HB provide more than safety benefits. Have also proved to:
  - Provide smooth ride
  - Significantly reduce tire noise

- Joint Caltrans/ADOT/FHWA studies are in progress to measure and document noise reduction over a ten-year period.
Caution

- The specifications and mix design methods discussed in this presentation apply to use of high viscosity asphalt rubber binders (field blend) in gap- and open-graded RAC mixes.
- No agitation binders (low viscosity, terminal blend) should never be directly substituted for high viscosity binders in any RAC mix. The two different types of CRM-modified binders have very different viscosity ranges and behave very differently from each other in asphalt concrete hot mixes.

Summary of Module 3

- A brief introduction to RAC materials and specifications. More detailed information on CRM-modified materials can be found on the Caltrans web site:
  - Previous site: http://www.dot.ca.gov/hq/esc/Translab/fpmRAC.htm
  - New web site: http://www.dot.ca.gov/hq/esc/Translab/fpmlab/CALTRANS_CIWMBPROJECTT021DELIVERABLES.htm
- Read project special provisions for RAC carefully to assure what requirements are in effect pending implementation of updated SSPs – project docs rule.

Questions?
4.0 Construction

Manufacture, Delivery, Placement, and Compaction

Outline

- Construction Overview
- Surface Preparation
- Manufacture
- Mix Delivery (Hauling)
- Placement
- Compaction
- Specifications/SSPs

Construction Overview

FOCUS: RAC surface courses

- RAC-G, RAC-O, and RAC-O-HB
- RAC placement very similar to typical dense-graded AC overlays, except:
  - Typically requires higher placement and compaction temperatures
  - For RAC-G, use vibratory mode for breakdown passes and get 95% of required compaction during breakdown
  - Not amenable to handwork
- Good practices are required for RAC production and construction, as for DGAC.
Surface Preparation
GOAL: Provide surface conditions that promote performance of the new RAC surface.

Same activities as for DGAC:
- Address existing distress
  - Seal cracks
  - Remove and replace failed pavement
- Improve smoothness
  - Fill ruts, level, restore or adjust profile
- Assure bond with underlying layers

Surface Leveling
- Purpose – Restore (or improve) surface profile, fill ruts, and/or maintain curb reveal
- Techniques
  - Cold milling, cold planing, grinding
  - Leveling course (DGAC)
  - Rut filler

Clean and Sweep
Remove debris from repairs, milling or grinding prior to placing overlay, to promote good bond.
- Wash if necessary
  - Make sure surface is dry before overlaying
- Sweep/broom thoroughly to remove possible bond breakers
Apply Tack
Purpose is to bond pavement layers together. Paving grade asphalt preferred for RAC.

Manufacture
- Primary difference from normal AC plant operations is on-site manufacture of high viscosity asphalt rubber binder.
  - Have already discussed binder components and design
  - Construction
  - Inspection details in next segment
  - Steps and equipment follow

AR Binder Production Process

Blending Schematic
- Asphalt Storage Tank
- Ground Rubber
- Heat Tank
- Blender
- Reaction Vessel
CRM comes in nominal 2,000 lb “Supersacks”

CRM is weighed in hopper

CRM is blended with hot asphalt cement
AR Blending Equipment & Interaction
Tank

Aerial View AR Binder Plant Set Up at AC Plant

RAC Mix Production
- Asphalt rubber binder feed is substituted for normal asphalt cement feed, interlocked and metered into the AC plant
- Little impact on AC plant operations
  - More than one AR binder plant can be used to maintain RAC production at normal tph rate
  - Primary differences from DGAC are in mixing and discharge temperatures
    - Aggregate mixing temperature range 300 - 325°F
    - AR binder added at ≈ 375°F
RAC mix temperature is critical for placement and compaction
- Trucks hauling RAC mixes must be tarped
- Spread temperature 280-325°F per Caltrans
- Minimum temperature for start of breakdown rolling is 275°F per Caltrans
- Generous compared to other specifications: Green Book requires higher temperatures

As for DGAC, to promote quality, smoothness, and uniform compaction, must balance all aspects:
- Mix production (AC plant)
- Mix delivery (truckling)
- Paving operations (non stop)
- Compaction (keep up with the paver)
Mix Segregation
- Aggregate (particle size) segregation
  - RAC-G may look segregated due to low fines content – mix texture may look coarse and somewhat open.
  - Sample, test binder content and gradation to verify
  - Segregation causes non-uniform gradation and compaction, may yield interconnected air voids
  - Sources include mix loading/unloading and paver operation

Mix Segregation
- Techniques to reduce aggregate (particle size) segregation
  - Better mix gradations – not much help for RAC-G or RAC-O
  - Improved loading and unloading practices
  - Use material transfer vehicle – not always feasible

Thermal Segregation
- Often accompanies particle size segregation
- Results in non-uniform compaction
- Sources include:
  - Processes that result in uneven cooling (hauling, windrows)
  - Managing paver wings
  - Delays in mix delivery and/or placement
Thermal Segregation

- Techniques to reduce thermal segregation
  - Minimize time between loading and placement
  - Truck insulation and tarping
  - Proper paving procedures
  - Material transfer vehicle

Issues Related to Haul Trucks

- Types and characteristics
  - End dump
  - Belly (bottom) dump – do not use windrows when site temperatures are marginally cold
  - Horizontal discharge (live bottom)
- Insulation – tarps required
- Cleaning (truck bed) – NO SOLVENTS!
  - Soap for surfactant
- Truck maintenance

Truck Loading Practices

- Primary goal – Avoid segregation!
- What makes a mix prone to segregation?
  - Range of particle sizes, limited fines
Truck Loading Practices
Preferred practice for end dump trucks:

- Short
  - 2
  - 1
- Long
  - 2
  - 3
  - 1

Truck Loading Practices
Preferred practice for belly dump trucks:

- 2 5 3 4 1

Placement (Laydown)
- Purpose – Place mix smoothly at a uniform specified thickness conforming to plan slopes and grades at temperatures above a specified minimum
- Equipment – same as for DGAC
  - Tractor unit (paver)
  - Screed unit
- Paver operation - same as for DGAC
- Joints – good practices essential
Paver Operation

Use good practices!

References:
- National Highway Institute (NHI) HMA Construction Course
- HMA Paving Handbook 2000
- Caltrans Construction Manual

Handwork

- Minimize as feasible
- Coarse gradation, stiff binder make handwork difficult
- High temperatures necessary to maintain RAC workability
- Typically yields coarse, open and rough looking appearance due to limited fines
- Minimize raking and luting
- Do not broadcast excess material

Joints

The same factors that make handwork difficult for RAC mixes also affect construction and finished appearance of joints.
- Use good practices
- Difficult to feather RAC mix due to limited fines
- Assume compaction reduces machine placement thickness by ≈ ¼-inch per inch
  - For hand placement, use 3/8-inch per inch difference
- Some raking unavoidable
  - Minimize as possible
  - Rake excess to hot side, not cold side
Joint Overlap

Typical Overlap on Longitudinal Joints

Uncompacted Mat

Compacted Mat

Compaction

Adequate compaction is required to achieve good pavement performance
- Improves resistance to rutting
- Reduces moisture/air penetration and related environmental damage
  - Oxidative ageing (embrittlement, raveling)
  - Moisture damage (stripping)
- Improves fatigue resistance
- Reduces low temperature cracking potential
- Improves durability

Compaction

Key factors influencing compaction include:
- Lift thickness
- Air temperature
- Base temperature
- Spread temperature of RAC mix
- Wind velocity, humidity, & other site factors
- Sunlight or lack thereof
- Mix properties including binder content

Temperature is the key to achieving RAC compaction!
Compaction Temperature (RAC)

- When air temperature is $\geq 55^\circ F$,
  - Minimum temperature for starting breakdown rolling is $280^\circ F$
  - Breakdown must be completed before mat temperature drops below $260^\circ F$
- When air temperature is $\geq 65^\circ F$,
  - Minimum temperature for starting breakdown rolling of RAC-G is $275^\circ F$
  - Breakdown must be completed before mat temperature drops below $250^\circ F$

Compaction Temperature

Caltrans temperature requirements for RAC mixes are more generous than those of other agencies.

- Specify the same temperatures for RAC-O and RAC-O-HB mixes as for RAC-G
- Working at the minimum temperatures may cause problems with achieving adequate compaction of RAC-G mixes

Compaction Temperature

- Suggest applying the higher temperature range for open-graded RAC
  - Based on experience of others, may still be marginally low to provide desired performance
  - Primary problems with low temperature placement of open-graded mixes are raveling and delamination
Time Available for Compaction

<table>
<thead>
<tr>
<th>Time for Mat to Cool to 80 °C (176°F)</th>
<th>Mix Temp °C (°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Base Temp (°C)</td>
</tr>
<tr>
<td>10</td>
<td>10 (50)</td>
</tr>
<tr>
<td>0</td>
<td>0 (32)</td>
</tr>
<tr>
<td>-10</td>
<td>-10 (14)</td>
</tr>
<tr>
<td>50</td>
<td>150 (302)</td>
</tr>
<tr>
<td>40</td>
<td>120 (248)</td>
</tr>
<tr>
<td>30</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td></td>
</tr>
<tr>
<td>10</td>
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<tr>
<td>0</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

Compaction Requirements

- Caltrans will implement compaction requirements for RAC-G mixes in the future
  - Acceptance based on pavement cores
  - Proposed lower limit is 91% of maximum theoretical density (equivalent to maximum 9% in-place air voids)
  - Final requirements adopted may vary from current proposal
- No compaction requirements for open-graded RAC mixes, present or future

Compaction Equipment

- Roller types
  - Static steel wheel rollers
  - Pneumatic-tired rollers – do not use with RAC
  - Vibratory steel wheel rollers – required for breakdown
- Rolling sequence
  - Breakdown – immediately behind paver in vibratory mode
  - Intermediate
  - Finish
Roller Pattern

- Selection of compaction equipment
- Width of paving
- Width of roller(s) – for RAC need enough breakdown rollers to cover placement width
- Number of coverages needed
- Nuclear gauges for relative density
- Cores for correlation of gauges with in-place density, i.e. air voids content

Specifications/SSPs

- Specifications for RAC-G, RAC-O, and RAC-O-HB are in process of being updated and revised.
  - Will be included in pending Section 39 revisions.
- Implementation date not set
  - May phase in by piloting on selected projects
  - Might implement for projects bidding after specific date
- Follow requirements in project special provisions to assure use of appropriate version

Summary of Module 4

- Construction Overview
- Surface Preparation
- Manufacture
- Mix Delivery (Hauling)
- Placement
- Compaction
- Specifications/SSPs
Questions?
AC Plant Operations

Plant operations during RAC mix production are essentially the same as for standard AC mix production. CT 109 requirements apply.

Differences

- Production and monitoring of the asphalt rubber binder for wet process mixes.
- Plant mixing temperatures of 300-325°F may be slightly higher than usual.

AR Binder Production

**Required Documentation**

- AR Binder Design Profile, including
  - Component identification and proportions
  - CRM gradations
  - AR test results showing compliance with specifications
- Certificates of Compliance for components
  - Asphalt Cement
  - Asphalt Modifier (Extender Oil)
  - Scrap Tire CRM
  - High Natural CRM
Asphalt Rubber Blend Design
Example Design Profile

<table>
<thead>
<tr>
<th>TEST</th>
<th>Minutes of Reaction</th>
<th>Spec. Limits @ 45 minutes (Caltrans 12/2005)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Viscosity @ 190ºC Haake</td>
<td>45 90 240 360 1,440</td>
<td>2400 2800 2800 2800 2100 1500 - 4000</td>
</tr>
<tr>
<td>Cone Pen @ 25ºC (ASTM D3177)</td>
<td>39 -- 46 -- 50</td>
<td>52 – 74 (125-165ºF)</td>
</tr>
<tr>
<td>R &amp; R Softening Pt. ºC (ASTM D38)</td>
<td>59.0 59.5 59.5 60.0 58.5</td>
<td>18 Minimum</td>
</tr>
</tbody>
</table>

AR Binder Production

Inspection items

- Batch sheets or production logs for AR binder that show the amounts (typically by mass) of the components used. Check proportions of:
  - Asphalt Cement
  - Extender oil
  - Scrap tire CRM
  - High natural CRM

AR Binder Production

The AR binder production logs or viscosity testing logs should indicate when the CRM was added.

Before adding AR binder to the aggregate:

- Verify minimum AR interaction time of 45 minutes has elapsed
- Verify AR binder viscosity meets or exceeds the minimum 1500 cPs requirement at 375ºF
- Continue to monitor viscosity hourly during RAC mix production
AR Binder Production

Follow sampling and testing frequency requirements listed in the project special provisions for AR binder and individual components.

- Typically, at least one one-gallon sample should be obtained from each batch of binder produced.
- Of these, some samples would be randomly selected and tested for specification compliance.
- Take additional samples if any changes or discrepancies are observed in any of the materials.

AR Binder Production

As long as interaction time and viscosity meet or exceed minimum requirements, the AR binder may be added to the aggregate, even if viscosity differs from values shown in the design profile.

The design profile serves as a guide, not as a specification. If viscosity during production differs from design profile by 400 cPs or more for corresponding interaction interval, obtain a binder sample for compliance testing.

AR Binder Production

If viscosity falls below the minimum limit of 1500 cPs, the AR binder cannot be used to make RAC.

To restore viscosity, the AR binder producer may add up to 10% more CRM (using the design ratios of scrap tire and high natural CRM) by total binder mass.

- The amount of CRM added shall be documented.
- An additional 45 minute interaction period is required after CRM addition.
- Viscosity of the “adjusted” AR binder must comply with viscosity specifications in order to proceed with RAC mix production.
RAC Mix Production

Required Documentation
- RAC Mix Design including:
  - Individual and combined aggregate gradations
  - Results of individual and combined aggregate quality tests
  - Aggregate source(s) and blend proportions
  - Theoretical maximum specific gravity/density
  - Design AR binder content
  - Design air voids content
  - Design VMA
  - Hveem Stability

RAC Mix Production

- Verify AC plant complies with CT 109 requirements.
- Check aggregate bins.
- Sample aggregate cold feed or hot bins as appropriate and verify gradation. Test Sand Equivalent as required.
- Verify RAC mixing and discharge temperatures.
- Visually inspect the RAC mix in the haul truck before it leaves the plant.
- Sample and test RAC mix according to the project special provisions. Tests include gradation, AR binder content, maximum theoretical specific gravity, lab-compacted air voids, and Hveem stability.

RAC Mix Production

- Verify that haul trucks are tarped.
- Maintain inspector's log of pertinent information, including but not limited to:
  - List of samples obtained
  - Plant test results (aggregates and mix)
  - Quantities of AR binder and RAC mix
  - Binder production temperatures and viscosity measurements, etc.
  - Other required information
RAC Mix Production

- May use Caltrans Form CEM-3501, AC Production/Placement Checklist modified for RAC
  - See handout example

Inspection at Paving Site

Before Overlay Placement:
- Verify surface preparation is complete
  - Cracks treated or sealed?
  - Damaged areas repaired?
  - Milling properly completed (if applicable)?
  - Surface clean and swept?
  - Tack coat properly applied?
- Verify ambient and pavement temperatures are at least 55°F and rising

Inspection at Paving Site

- Equipment
  - Verify that paver and rollers meet size requirements, are in good working condition, and qualified operators are on-site
  - Verify sufficient steel-tired rollers are available for breakdown and intermediate compaction.
  - Breakdown rollers must have vibratory capability
- Delivery method: Do not use windrows if ambient temperature is marginally cold.
Inspection at Paving Site

Caltrans requirements for RAC-G, ambient temperature <65°F:
- RAC-G spread temperature 290-325°F
- Minimum temperature for breakdown rolling is 280°F
- Vibratory mode is required for RAC-G breakdown
- Complete breakdown before RAC mat temperature drops below 260°F

Inspection at Paving Site

- Less stringent for ambient temperature ≥ 65°F
- Other jurisdictions recommend minimum 290°F for breakdown rolling or completion thereof
- Compaction requirements will be implemented for RAC-G mixes in the future, with acceptance based on cores

Inspection at Paving Site

Caltrans placement temperature requirements for RAC-O and RAC-O-HB ambient temperature <65°F are the same as for RAC-G.

Other jurisdictions do not recommend placing RAC-O at temperatures <68°F.

For open-graded RAC mixes, use static mode for breakdown compaction. Do not use vibratory mode. Percent compaction is not a requirement for open-graded mixes.
Inspection at Paving Site

During RAC placement:
- Collect load tickets and track tonnage placed
- Measure placement thickness and calculate yield
- Observe coordination between RAC delivery and placement – record if trucks or paver are waiting
- Note any rejected loads of RAC
- Observe delivery operations - are good practices being used?

Inspection at Paving Site

- Record if windrows are used.
- Monitor RAC temperatures at spread and during breakdown and intermediate compaction.
- Observe paver operations – note discrepancies from good practice that might impact quality of joints or ride (smoothness).
- Joints at proper locations?
- Observe raking, luting, handwork. Broadcasting of excess mix or over-raking will damage the appearance of the finished pavement.

Inspection at Paving Site

- Observe compaction operations – note discrepancies from good practice that might impact in-place density
  - Breakdown roller(s) following immediately behind paver?
  - Breakdown roller(s) using vibratory mode?
  - Sufficient breakdown rollers operating to keep up with paver?
  - Intermediate static roller(s) keeping up?
  - Finish rollers effective?
Inspection at Paving Site

Rules of Thumb for RAC-G compaction:

- Need to get 95% of minimum required density with breakdown coverages to achieve adequate compaction.
- Mix temperature is critical for adequate compaction of RAC-G materials.

After Paving

- Check the appearance of the finished surface for roller marks, scuffs, gouges, or other irregularities.
- Check smoothness as required in project special provisions.
- Visually evaluate quality of paving joints and identify any areas that may need to be sealed.
- Identify core locations for compaction acceptance.

Troubleshooting

- If any type of RAC mix problem is suspected, obtain samples immediately and test for compliance with project special provisions.
- Log full description of problem and related activities and report to the RE.
**Troubleshooting**

Possible Problems to Watch For:

- **Segregation:** Particle size segregation may be difficult to ID in coarse graded RAC-G mixtures. May appear segregated even if not, due to small percentage of fines included.
  - When in doubt, sample
  - ID affected truckloads and corresponding placement areas for info
- **Size segregation** is often accompanied by temperature segregation

---

**Troubleshooting**

- **Temperature segregation** may be identified using a heat gun or infrared camera
  - To measure actual mix temperature without surface effects, use a 6-inch long probe
- **Indicates hot and cold spots in the mix** that can cause differences in compaction
  - Can see areas in haul trucks and pavers where mix is not circulating and has cooled
  - Shows when material from paver wings is dumped into the hopper and where it comes out behind the screed

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**Troubleshooting**

- **Smoke**
  - Blue smoke means that the mix is too hot and plant operating temperature needs to be adjusted
  - White smoke is steam - too much moisture in the mix. May make mix tender and interfere with compaction. Aggregate needs to be dried longer before mixing with the AR binder.
Troubleshooting

- Stiff appearance: Too cool or possibly somewhat low AR binder content. Check temperature and get a mix sample for further testing if needed.
- Dull, flat appearance: Low AR binder content and/or excessive fines. Localized areas may indicate insufficient mixing or segregation. Get sample and test for gradation and AR binder content.

Troubleshooting

- Slumped and shiny appearance typically indicates high AR binder content.
  - RAC-O and especially RAC-O-HB may look this way and still meet specifications
  - Old descriptive term is “wormy” — mix seems to almost crawl while watched
  - Some complying RAC-G mixes may also be wormy
  - Visually check for binder drain down in the haul truck bed, sample and test for AR binder content and gradation

Summary of Module 5

- Changes in the plant inspector’s duties due to RAC production are limited to:
  - Monitoring AR binder production and viscosity results
  - Sampling AR binder and individual component materials for verification and acceptance
- Changes to field inspector’s duties are very minor, primarily related to monitoring RAC temperature and compaction operations:
  - Use modified CT production/placement report form
  - Compaction acceptance for RAC-G will be based on cores at locations designated by Caltrans
Questions?
**ASPHALT RUBBER BINDER ROTATIONAL VISCOSITY TEST REPORT FORM**

<table>
<thead>
<tr>
<th>Project Name/Number</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Asphalt Rubber (AR) Blender/Supplier</td>
<td></td>
</tr>
<tr>
<td>Location of AR Blending Plant</td>
<td></td>
</tr>
<tr>
<td>RAC Mix Supplier</td>
<td></td>
</tr>
</tbody>
</table>

### ASPHALT RUBBER BINDER FORMULATION

<table>
<thead>
<tr>
<th>Blend Proportions</th>
<th></th>
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<tbody>
<tr>
<td><strong>Asphalt Cement</strong></td>
<td></td>
</tr>
<tr>
<td>PG Grade and Supplier</td>
<td></td>
</tr>
<tr>
<td>Asphalt Modifier Type and Supplier</td>
<td>% by AC mass:</td>
</tr>
<tr>
<td>Asphalt Cement and Modifier</td>
<td>% by Asphalt Rubber Binder mass:</td>
</tr>
<tr>
<td>Scrap Tire CRM Type &amp; Supplier</td>
<td>% by Asphalt Rubber Binder mass:</td>
</tr>
<tr>
<td>High Natural CRM Source &amp; Description</td>
<td>% by Asphalt Rubber Binder mass:</td>
</tr>
</tbody>
</table>

Asphalt Rubber Binder (ARB) material must be tested to verify compliance with minimum viscosity requirement of 1,500 Pa•s (x 10⁻³) at 375±3°F before it can be used.

<table>
<thead>
<tr>
<th>*Cycle Start Date &amp; Time</th>
<th>AR Batch #</th>
<th>Temperature in ARB Tank (°F)</th>
<th>Temp. During Viscosity Test (°F) (375 ± 3°F)</th>
<th>Measured Viscosity** Pa•s(x10⁻³)</th>
<th>Date and Time Sampled</th>
<th>Date and Time Tested</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>

Viscometer Make, Model and Serial #: __________________________________________

Rotor Designation: _________________________________________________________

Test Operator: ___________________________________________________________

* The cycle begins when the asphalt rubber tank is fully loaded and temperature in the tank is 375±3°F.
** Measure viscosity at 375±3°F according to Caltrans LP-XX. Viscometer may read in units of centipoises (cPs) or dPa•s. Unit conversions are as follows:

1 Pa•s = 1,000 cPs
1 dPa•s = 0.1 Pa•s = 100 cPs
1 mPa•s = 0.001 Pa•s = 1 cPs
## Project Identification

<table>
<thead>
<tr>
<th>Completion Date (Expected)</th>
<th>Route</th>
<th>Post Kilometers</th>
<th>Completion Date (Contract)</th>
<th>Job Suspended</th>
<th>AC (Tonnes Produced to Date)</th>
<th>AC (Tonnes Remaining)</th>
</tr>
</thead>
</table>

## Problem Statement

## Mix Properties

### Type Mix

- A: Dense
- B: Gap
- Recycled: Open Graded

### Type Grading

- A: Dense
- B: Gap

### Max Grading

- A: 38
- B: 19

### Additives

- Lime
- Liquid Anti-Strip
- Cement
- Other

### Aggregate Type

- A
- B
- Absorptive
- Non-Absorptive
- Other

### Asphalt-Rubber Binder:

- Base Asphalt Grade and Source:
- Asphalt Modifier (Extended Oil) Source / % Added
- Scrap Tire CRM Source / % Added
- High Natural Source / % Added

## Appearance

- OK
- Segregated
- Rich
- Dry
- Tender
- Color
- Other

## Plant Type

- Batch
- Continuous
- Portable
- Stationary

## Background Data

- Actual Binder Content
- Actually Stability of Street Samples
- Test Maximum Density

## Mix Supplier and Location(s)

## Field Conditions (At Paving Operation)

### General Weather

- Coastal
- Valley
- Mountain
- Desert

### Air Temperature (°C)

- Under 4
- 4-9
- 10-15
- 16-20
- 21-25
- 26-32
- 33-38
- Greater than 38

### Surface Temperature (°C)

- Under 4
- 4-15
- 16-26
- 27-37
- 38-48
- 49-60
- Greater than 60

### Mix Temp at Plant (°C)

- Under 121
- 121-134
- 135-162
- 163-190
- 191-204
- Greater than 204

## Mix Temp at Window (°C)

- Under 65
- 65-89
- 90-125
- Greater than 125

## Mix Temp at Breakdown Roller (°C)

- Under 65
- 65-89
- 90-125
- Greater than 150

## Distance Paver to Breakdown Roller (Meter)

- Under 15
- 15-29
- 30-59
- Greater than 30

## Window Length (Meter)

- 0
- 0-30
- 31-61
- 62-91
- 92-122
- 123-123-152
- Greater than 152

## Average One Way Haul Time (hours)

- Under 1/2
- 1/2-1
- 1-2
- 2-3
- Greater than 3

## Notes

- Mix Supplier and Location(s)
## AC PRODUCTION/PLACEMENT CHECKLIST

### STRUCTURAL PROPERTIES

<table>
<thead>
<tr>
<th>PAINT BINDER</th>
<th>TACK SPREAD RATE (Liters per meter squared)</th>
<th>MIX THICKNESS (Compacted)</th>
<th>UNDERLYING CONDITIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASPHALT</td>
<td>0.45</td>
<td>FIRST LIFT</td>
<td>AC</td>
</tr>
<tr>
<td>EMULSION</td>
<td>0.68</td>
<td>SECOND LIFT</td>
<td>PCC</td>
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<td>OTHER</td>
<td>0.95</td>
<td>THIRD LIFT</td>
<td>OK</td>
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<tr>
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<td>1.13</td>
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<td>GRINDER PREPARED</td>
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<tr>
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<td>OTHER</td>
<td></td>
<td>CRACK &amp; SEAT</td>
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<td></td>
<td>AB</td>
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<td>PRE LEVELLED</td>
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<td>OTHER</td>
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<td>CRACKED</td>
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<td>FABRIC</td>
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<td>OTHER</td>
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</tbody>
</table>

### UNDERLYING CONDITIONS:

- ASPHALT
- EMULSION
- OTHER

### PAVER OPTIONS:

- PICKUP MACHINES
- SCREED EXT. (length)
- SKI (length)
- JOINT MATCHER
- GRADE WIRE
- OTHER

### MECHANICAL PROPERTIES

**NUCLEAR DENSITY GAGE**

- METHOD SPECIFICATION
- END RESULT COMPACTION SPECIAL PROVISION

- MAKE:
- MODEL:
- CALIBRATION (date):
- AVERAGE RELATIVE COMPACCTION

### BREAKDOWN ROLLERS

- TYPE
- WEIGHT

### INERMIEDIATE ROLLERS

- TYPE
- WEIGHT

### FINISH ROLLER (S)

- TYPE
- WEIGHT

### IF VIBRATORY ROLLERS ARE USED:

- MAKE
- MODEL

### ON CALTRANS APPROVED LIST

- YES
- NO

- SPEED
- FREQUENCY
- AMPLITUDE

- ACTUAL
- ACTUAL
- ACTUAL

- SPECIFIED
- SPECIFIED
- SPECIFIED

*A completed copy of this form should be filed in Category 35 of the Project Documents. A description of the original form is included in the Construction Manual.*

### COMMENTS:

_________________________
_________________________
_________________________
_________________________
6.0 Summary

Best Practices and Resources

Best Practices

- Wet process has proved to be most reliable approach in terms of field performance
- Gap-graded CRM mixes made with the wet process seem to perform better and more reliably than dense-graded CRM mixes

Use as a thin surface layer (≤60 mm) to

- Retard reflection/fatigue cracking
- Improve surface durability
- Improve surface friction characteristics
- Reduce tire noise (OG most effective)
- Reduce splash and spray under wet condition (OG most effective)
Best Practices

- Arizona DOT’s Experience (Wet Process)
  - Gap-graded (AR AC) for structural use, often surfaced with open-graded (AR-ACFC)
  - Open-graded (AR-ACFC)
    - ½” thick wearing course on flexible pavements
    - 1” thick wearing course on rigid pavements

Advantages of AR

- Good durability – in terms of resistance to cracking and aging
- Environmental friendly – make value-added use of a waste material, reduce traffic noise
- Versatility – can be used in most maintenance and rehabilitation activities, or in reduced thickness for resistance to reflective cracking
- Longer lasting color – for better contrast with striping and marking
- Reduced maintenance – for both chip seals and hot mix

Limitations of AR

- For small projects, mobilization costs may result in higher unit price that may not be fully offset
- AR wet process (field blend, high-viscosity) is not suited for dense graded mixes because there is not sufficient room in the aggregate voids to accommodate the coarse rubber
- Construction may be more challenging, as temperature requirements are more critical
Limitations of AR

- Potential odor problem
- Often difficult to hand work because of stiff binder and coarse mixture gradations
- If work is delayed more than 48 hours after blending the asphalt rubber, some binder may not be usable because of loss in viscosity

Implementation Challenges

- Understanding the benefits and limitations of RAC
- Identifying the best places to use RAC
- Using sound design and construction practices specific to RAC

Primary References

- Asphalt Rubber Usage Guide
- Use of Scrap Tire Rubber – State of the Technology and Best Practices
- Synthesis of Caltrans Rubberized Asphalt Concrete Projects
- Feasibility of Recycling Rubber-Modified Paving Materials
- Study on Structural Design Considerations
- Flexible Pavement Rehabilitation Manual
- Asphalt Rubber Design and Construction Guidelines
- RAC-G SSP Version (12-12-05)
- RAC-O SSP Version (12-12-05)

http://www.dot.ca.gov/hq/esc/Translab/Summary/CALTRANS_CIWMBPROJECTT021DELIVERABLES.htm
Web Resources

- American Chemical Society Rubber Division
- Asphalt Emulsion Manufacturers Association (AFMA)
- Asphalt Institute
- Asphalt Recycling & Reclaiming Association
- Asphalt Rubber Information Online (Asphalt Rubber Org)
- Asphalt Rubber Technology Services
- California Integrated Waste Management Board
- Canadian Technical Asphalt Association (CTAA)
- European Asphalt Pavement Association (EAPA)
- FNF Construction Inc.
- International Surfacing Systems: Asphalt Rubber
- National Center for Asphalt Technology (NCAT)
- Reports Prepared to Caltrans/CIWMB under Contract 59A0258
- Rubberized Asphalt Concrete Technology Center
- Scrap Tire News
- The Asphalt Contractor Online
- The Rubber Pavement Association
- ThomasNet on Asphalt Rubber

Acknowledgements

- Caltrans and California Integrated Waste Management Board (CIWMB) for sponsoring this training class
- Technical task manager – Terrie Bressette
- Contract manager – Paul Bagha
- Support from the Caltrans Districts