Rubberized Asphalt Concrete

Integrated Waste Management Board

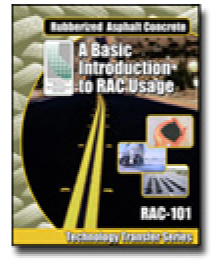
A Basic Introduction to RAC Usage

RAC-101

Technology Transfer Series

Basic Introduction to RAC Usage
Technology Transfer RAC-101

Introduction to Rubberized Asphalt Concrete Usage RAC-101



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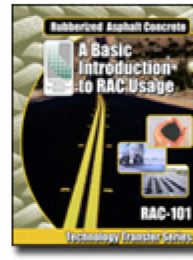


DEFINITIONS

ASTM D8 – Standard Terminology Relating to Materials for Roads and Pavements

Asphalt Rubber is defined as "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."

ASTM D 6114 - Standard Specification for Asphalt Rubber Binder

Defines asphalt rubber binders as "a blend of paving grade asphalt cements, ground recycled tire (that is, vulcanized) rubber and other additives, as needed, for use as binder in pavement construction. The rubber shall be blended and interacted in the hot asphalt cement sufficiently to cause swelling of the rubber particles prior to use."

ASPHALT RUBBER MAKEUP

Rubber modification of asphalt concrete mixes is accomplished by two methods: the wet process and the dry process. The Wet Process can produce a wide variety of CRM modified binders from high viscosity (field blend) to no agitation (terminal blend) types

Wet Process – High viscosity

Method of modifying asphalt binder with Crumb Rubber Modifier (CRM) before incorporating the binder into the asphalt paving materials. The wet process requires thorough mixing of the crumb CRM in hot asphalt cement and holding the resulting blend at elevated temperatures for a designated minimum period of time to permit an interaction between the CRM and asphalt.

- Most widely used in CA, AZ, FL & TX
- Contains 18-22 % crumb rubber
- Particle sizes # 8 to #10 top size
- Thoroughly mix CRM & other components with hot (400-425ºF) asphalt cement
- Interact at 350-375ºF for designated period (typical minimums 45-60 minutes)
- CRM particles swell, exchange oils with AC
- Rotational Viscosity is discriminator for appropriate use

High Viscosity vs. No Agitation

Wet Process – No Agitation

A form of the wet process where CRM (typically < #30) is blended with hot asphalt cement at the refinery or at an asphalt storage and distribution terminal and transported to the HMA mixing plant or job site for use. This type of rubberized asphalt (which includes Rubber Modified Binder, RMB) does not require subsequent agitation to keep the CRM particles evenly dispersed in the modified binder. Often referred to as terminal blend

- Contains from <5%-15 % crumb rubber
- Particle size ranges from 40 to 80 mesh top size
- Can also contain polymers
- Used in Arizona, Florida, Texas, and California
- Often referred to as Terminal Blend

STOP

Remember that the two families of CRM-modified binders, high viscosity and no agitation, are not interchangeable. Neither type should be directly substituted for the other in a hot mix without laboratory testing to determine appropriate adjustments in binder content and possibly aggregate gradation.

Dry Process

Method that includes scrap tire CRM as a substitute for 1 to 3 % of the aggregate in an asphalt concrete paving mixture, not as part of the asphalt binder. The CRM acts as a rubber aggregate in the paving mixture.

- Substitutes CRM for 1 to 3% of aggregate in hot mix
- Not considered to modify binder, although some interaction with CRM may occur in place over time (absorbs light fractions)
- CRM gradations have ranged form coarse (-1/4”) to fine (-#80)

ASPHALT RUBBER BINDER COMPONENTS

- Crumb Rubber - Scrap tire and High Natural Rubber
- Asphalt Cement
- Additives

ARB components are properly formulated or proportioned to comply with specifications and provide a quality product. Components shall individual comply with specifications.

CRM Used for Wet Process

Crumb Rubber Modifier (CRM) Sources

Crumb Rubber Modifier (CRM) is produced from grinding up whole scrap tires from automobiles, trucks, or buses, tread buffings, and other waste rubber products. A variety of processes and equipment are used to produce a wide range of CRM gradations for use as modifiers in asphalt paving materials.

Asphalt Cements

Defined by ASTM D8 as “a fluxed or unfluxed asphalt specially prepared as to quality and consistency for direct use in the manufacture of bituminous pavements. Asphalt cements some in a variety of grades. Typically softer binders are used for RAC than for conventional HMA

Climatic Region	PG Grading
Hot climates	PG 64-16
Moderate climates	PG 58-22
Cold climates	PG 52-28

Additives

Used in conjunction with the CRM to enhance interaction and produce desirable properties.

- Extender oils
- High natural rubber (HNR)
- Polymers – typically limited to no agitation
- Anti-strip agents, preferably mineral admixtures

Asphalt Cement and CRM interaction

The interaction between asphalt cement and CRM materials is material-specific and depends on a number of factors, including:

- Asphalt Cement Source & Grade
- Rubber Type/Source
- Amount Of Rubber
- Gradation Of Rubber
- Interaction Time
- Interaction Temperature
- High Viscosity AR Binder

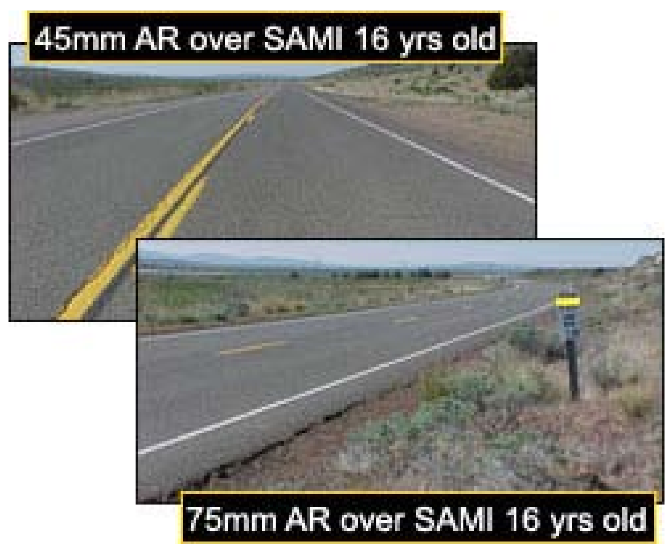
HISTORY OF ASPHALT RUBBER

Development of asphalt rubber materials for use as joint sealers, patches, and membranes began in the late 1930s. In the early 1950s, Lewis and Welborn of the Bureau of Public Roads (BPR) conducted an extensive laboratory study to evaluate "The Effect of Various Rubbers on the Properties of Petroleum Asphalts."

They used 14 types of rubber powders and three asphalts, including "a California asphalt of low-gravity, low-sulfur, low-asphaltenes type." The results were published in the October 1954 issue of Public Roads along with results of a companion "Laboratory Study of Rubber-Asphalt Paving Mixtures," conducted by Rex and Peck at BPR.

The mixtures study looked at a wide range of vulcanized and unvulcanized rubber materials including tread from scrap tires, styrene-butadiene rubber (SBR), natural rubber, polybutadiene, and reclaimed (devulcanized) rubber and at both wet and dry methods of adding them to AC mixtures. Interest and work in this area continued to grow, as did the number of patent applications. In March 1960, the Asphalt Institute held the first Symposium on Rubber in Asphalt in Chicago, IL. It consisted of five paper presentations and discussion.

Charles H. McDonald of the City of Phoenix Arizona worked extensively with asphalt and rubber materials in the 1960s and 1970s and was instrumental in development of the "wet process" (also called the McDonald process) of producing asphalt rubber. He was the first to routinely use asphalt rubber in hot mix patching and surface treatments for repair and maintenance.



AR Test Sections

History of AR Usage

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

Caltrans Ravendale Project

- First CA project to use reduced thickness RAC when compared to the conventional AC design thickness
- Different thickness test sections of RAC, dry process, and conventional AC mixes
- Performance monitored for nearly 20 years

Caltrans Reduced Thickness Design

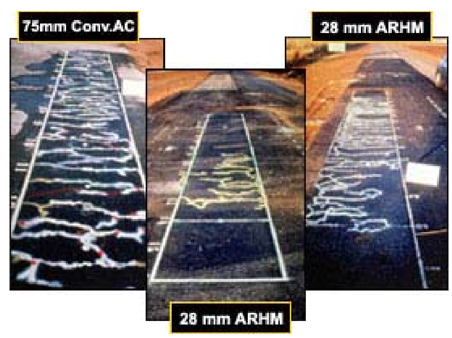
- CALTRANS developed the interim guidelines in 1992 based on laboratory and long-term field data (two decades)
- Supported by research efforts
- Uses a deflection based design method
- Up to 50 % reduction in thickness compared to conventional AC design thickness
- Over 200 reduced thickness projects

1992 Heavy Vehicle Simulator Research

- Caltrans conducted a research project with the South African Council on Scientific and Industrial Research (CSIR), University of California Berkeley, and Dynatest Consulting to verify the reduced thickness theory for Asphalt Rubber pavements
- The research used accelerated pavement testing (APT) using the heavy vehicle simulator (HVS)
- The research included laboratory testing to support the field testing

Heavy Vehicle Simulator used for the 1992 Caltrans research

1992 HVS Research
Original Condition of Pavement



1992 HVS Research – Test Results. 3” conventional HMA overlay, 1.5” AR Overlay, and 1” AR Overlay

AR APPLICATIONS

Asphalt rubber has been widely used on hot mix and spray applications, more detailed on these applications below.

AR Spray Applications

Asphalt Rubber Chip Seals

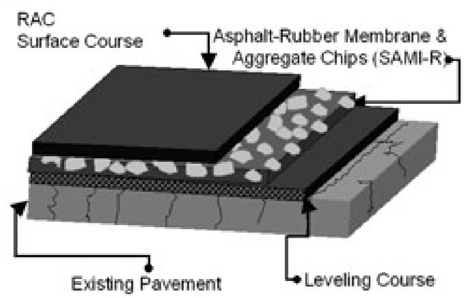
Chip Seal – Surface Treatment

- ARAM - Asphalt Rubber–Aggregate membrane
- SAM - Stress Absorbing membrane

Interlayer - chip seal sandwiched between two pavement layers

- SAMI - Stress Absorbing Membrane Interlayer
- SAMI - R when rubber modified
- ARMI - Asphalt rubber membrane interlayer

AR Chip Seals and Interlayers



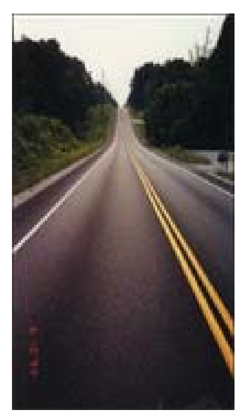
Asphalt Rubber Interlayers

- Used for maintenance or rehabilitation of existing pavements
- Same equipment and general procedures are used for both chip seals and interlayers
- Use with High Viscosity AR Binders over severely cracked but structurally sound pavements
- Significantly longer service life than conventional applications, and superior long-term performance in resisting reflective cracking

Hot Mix Asphalt (HMA) Applications

- Gap graded mixes
- Open graded mixes
- Open graded high binder mixes
- Dense graded mixes - Only with no agitation binders

Gap and Open-graded mixes made with high viscosity AR binder are most effective as surface courses



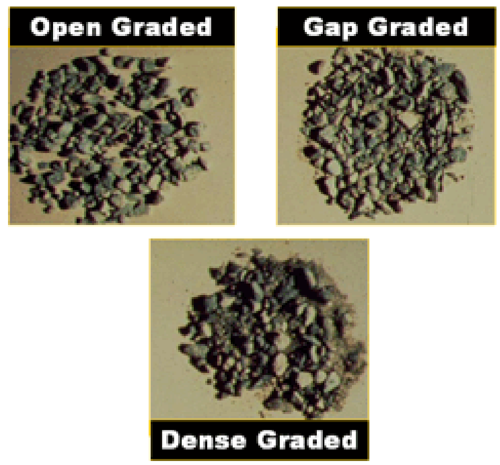
Hot mix asphalt Gap graded application

Remember that the two families of CRM-modified binders, high viscosity and no agitation, are not interchangeable. Neither type should be directly substituted for the other in a hot mix without laboratory testing to determine appropriate adjustments in binder content and possibly aggregate gradation.

Aggregate Gradation

Dense-Graded HMA

- Limited performance improvements vs. cost
- Inadequate void space to accommodate sufficient AR binder to modify behavior
- Discontinued use with high viscosity binder, but suitable for use with terminal blends



Aggregate Gradations

Gap Graded Mixes

- Proven to be a very effective use of high viscosity asphalt rubber binders
- Most widely used asphalt-rubber product in California
- Structural application
- Caltrans specifies thickness of 1.2 to 2.4 inches (30 to 60 mm)

Thickness reduction allowed by Caltrans for resistance to reflective cracking when RAC-G is used as an overlay

Remember that the two families of CRM-modified binders, high viscosity and no agitation, are not interchangeable. Neither type should be directly substituted for the other in a hot mix without laboratory testing to determine appropriate adjustments in binder content and possibly aggregate gradation.

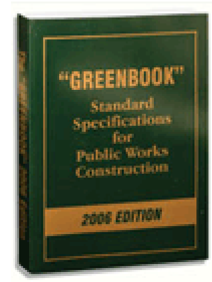
Open-Graded

- Widely used in California as surface course
- Free draining with reduced splash and spray
- Does not add any structural value
- Provides good surface friction

Open-Graded High Binder

- Widely used in Arizona as surface course
- Also used by Caltrans as surface course
- Not as free draining, but improved durability

DESIGN GUIDES



RAC Usage Guidelines

Guidelines are readily available and published for application and usage. The two most notable sources for reference and used by municipalities, cities and counties:

- Caltrans
- Greenbook

Publication Guide Resources

While the information presented in these modules is geared toward the construction of conventional asphalt concrete pavements, the same principles apply to the construction of RAC.

- "Greenbook" Standard Specifications for Public Works Construction, BN1 Building News
- Public Works Inspectors Manual, BNI Building News
- Principles of Construction of Hot-Mix Asphalt Pavements, Asphalt Institute, Manual Series No. 22
- Hot-Mix Paving Handbook 2000, AASHTO, FAA, FHWA, NAPA, U.S.A.C.E., APWA and NACE. Available through National Asphalt Pavement Association
- National Highway Institute (NHI) Hot Mix Asphalt Construction Course - FHWA

Where and Why to Use Rubberized Asphalt Concrete?

- Replaces conventional mixes where paving temperatures and haul distances are favorable
- Allows higher binder content and increased film thickness- resulting in increased durability (moisture resistance and aging resistance)
- Increases resistance to fatigue and reflection cracking
- Improves aggregate retention
- Minimizes drain-down problems
- Increases resistance to bleeding, flushing and deformation

Asphalt Rubber Blend Profile

An appropriate asphalt-rubber binder design must be developed using the designated sources and grades of asphalt, asphalt modifier if used, and CRM materials that will be used for the subject project(s). The binder design should include testing to develop and present a design profile of each specification property value measured from samples taken at intervals over a 24-hour interaction period.

Binder Blend Profile

- Best Practice
- Developed to evaluate compatibility between materials used
- Checks for stability of the blend over time
- Should be required for each project

	MINUTES OF REACTION					SPEC. LIMITS @ 45 MINUTES (CALTRANS 2006)
TEST	45	90	240	360	1,440	
VISCOSITY, CP HAAKE@ 375°F,190°C	2400	2800	2800	2800	2100	1500 - 4000
RESILIENCE@ 77°F, 25°C (% REBOUND)	27	–	33	–	23	18 Minimum
R & B SOFTENING PT (ASTM D36)	59.0	–	59.5	–	58.5	125-165°F 52 – 74°C
CONE PEN @ 77°F, 25°C (ASTM D217)	39	–	46	–	50	25 – 70

Binder Blend Profile

Asphalt Rubber Tests

Cone Penetration ASTM D 5 and AASHTO T 49

Measurement is achieved by a penetromometer and presented in tenths of a millimeter unit.
Asphalt rubber binder consistency can be evaluated at low, moderate, and high temperatures. Needle penetration is usually the standard at 39.2°F and 77.0°F. Cone penetration is typically used with asphalt rubber binder with larger particle size crumb rubber (10 mesh and up).

Cone Penetration Test

Resilience ASTM D5329

Measures the elastic properties of the asphalt rubber binder and is expressed as a percentage of rebound for the binder. Resilience is one of the most important properties in the specifications and is a more reliable measure of elasticity.

Resilience Test

R&B Softening Point ASTM D36 and AASHTO T 53

Measurement is achieved by the ring and ball method and presented in °F or °C and is an indicator of material stiffness. This shows the tendency of the material to flow at elevated temperatures.

R&B Softening Point Test

Field Viscosity

Measurement is achieved by a rotational viscometer and presented in centipoise (cP) or Pascal Seconds (Pa-s).

Monitors fluid consistency of asphalt rubber binder to ensure pumpability, to identify binder changes which might affect hot mix placement and compaction.

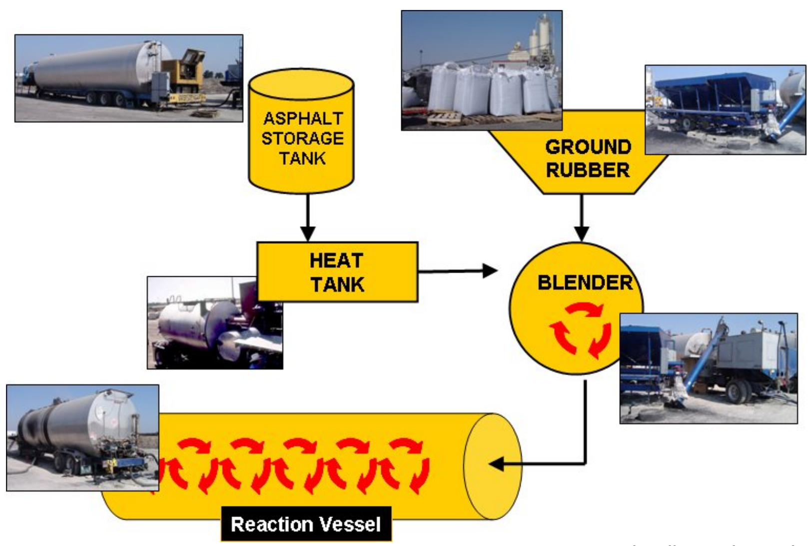
If the Brookfield is the required method for acceptance, then the Haake viscometer should be calibrated and corrected to the Brookfield measurement for field use.

Field Viscosity Test

AR Binder Production

Overview of Process

Production methods for wet process high viscosity asphalt-rubber binders are essentially the same for both hot mix and spray applications. The primary difference is the importance of coordination of asphalt-rubber and hot mix production to assure that enough asphalt-rubber binder is available to provide the desired AC production rate. Binders for spray applications are typically produced close to the job site, not necessarily at an AC plant, and their production must be coordinated with application operations.



AR Blending Schematic

Holdover and Preheating
Production Set Up

Caltrans Specs

1. Heating must be discontinued 4 hrs after 45 minute reaction period
2. Two reheat cycles are allowed
3. Asphalt rubber binder must continue to meet specification requirements
4. Restoring viscosity, up to 10 percent more CRM by binder mass can be added to restore the viscosity to specified levels

Required Documentation

- Certificate of compliance for every binder constituent as well as for the finished asphalt rubber binder
- AR binder design
- AR binder production log

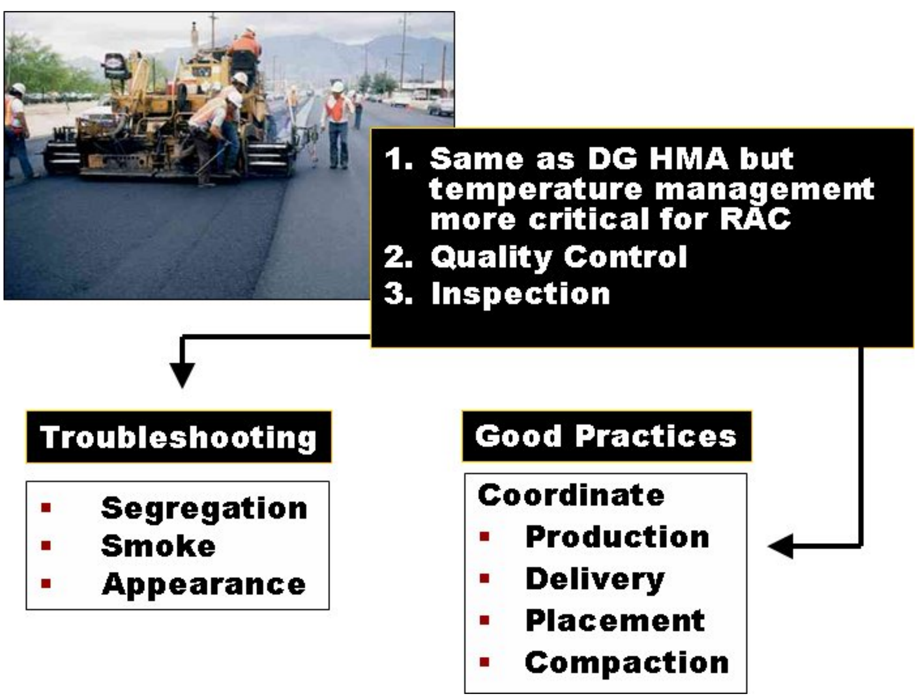
Uses for High Viscosity Binders
Increased cost so use where most effective


HMA Plant

- Most effective in gap-graded and open-graded mixes
- Most effective in relatively thin surface lifts (Caltrans max 2.4 inches [60 mm])
- Gap-graded is used as structural layer, equivalent to conventional dense-graded HMA
- Open-graded is used as surface friction course
- Increased resistance to rutting, fatigue and reflective cracking a function of binder content and modification
- Not suitable for DGAC

Rubberized Asphalt Concrete Construction

AR Good Practices



Construction Considerations

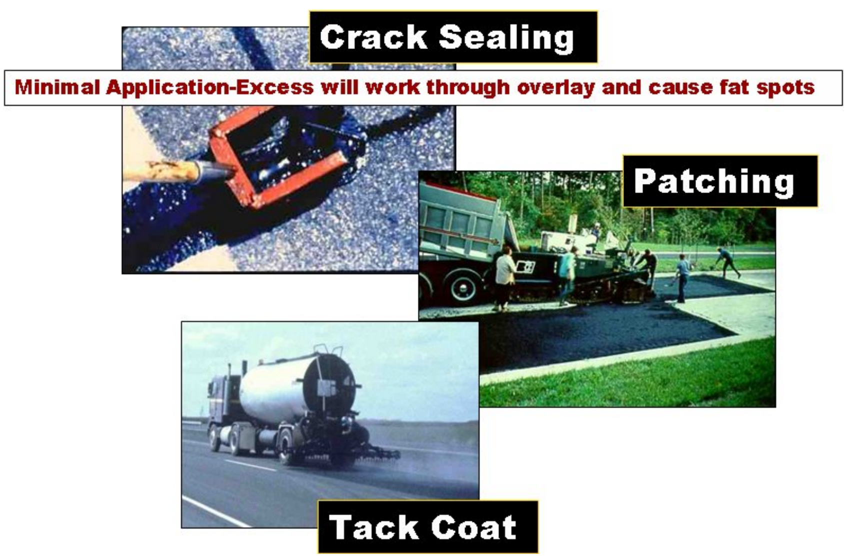
- Temperature management is critical to successful placement and compaction
- Handwork is more difficult
- Material is stickier

Construction considerations

RAC may not be the best choice for use for projects with the following conditions:

- Considerable handwork
- Long haul time and/or distance
- Site temperatures less than 60ºF

Preparation for Paving



AR Delivery Equipment

Items to Watch For:

- Good practices recommended for conventional hot mix delivery should be applied to RAC materials
- Special attention to temperature management
- Coordination and balance of binder and mix production with mix delivery, placement, and compaction operations is essential
- No solvent based release agents or diesel fuel should be used in haul truck beds


AR Delivery Equipment

- Avoid segregation by proper loading of haul trucks

AR Placement

Hot Mix Compaction

Placement of asphalt rubber materials or any AC materials requires good paving practices.

- Atmospheric and pavement surface temperature requirements
- Factors affecting compaction (listed below)
- Test strips and rolling patterns, will indicate what level of compaction effort is needed to achieve adequate in-place density
- Quality of the finishing, e.g. proper paver operations, good workmanship in constructing joints.


Compaction Equipment

Factors that Affect Compaction (AC and RAC mixes)

- Lift thickness
- Air temperature
- Pavement/base temperature
- Mix temperature
- Wind velocity
- Sunlight or lack thereof
- Mix properties including binder content

Do not use or allow rubber tire rollers on asphalt rubber HMA projects!

Sampling and Testing

Frequency of sampling and testing may vary depending on the nature of the materials, project size, and available resources. Aside from minimum requirements, additional sampling is recommended whenever changes in any material or its behavior are observed. Sampling during production and construction is relatively easy and inexpensive, and it is rarely necessary to test every sample obtained. Use Standard Practices for material sampling and testing as per conventional HMA.

Rotational viscosity is the go/no-go field test that governs use of the asphalt rubber binder. At least one viscosity test is required to establish compliance for each asphalt rubber batch and holdover load.

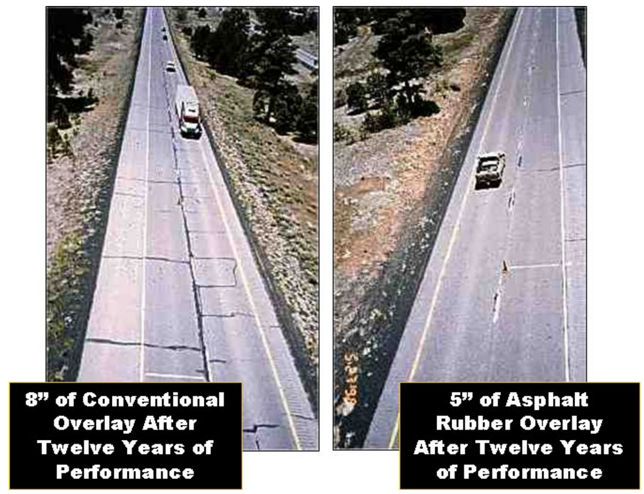
Temperature management is the key to achieving RAC compaction

Steel-wheeled rollers only - Vibratory mode essential for breakdown coverage.

Benefits and Considerations

Asphalt Rubber Benefits and Considerations

- Improved durability as surface layer
- Resistance to fatigue cracking
- Resistance to reflection cracking
- Resistance to aging
- Can be used in reduced thickness
- Reduced noise
- Lower life cycle costs
- Environmental benefits



Conventional AC and AR test sections placed on I-40 SHRP Test Section Flagstaff, AZ, 1989.

Cost Considerations

A LCCA Study developed by Gary Hicks and Jon Epps

- Establish strategies for analysis period
- Establish M&R activity timing
- Estimate agency costs
- Estimate user and non-user costs
- Develop expenditure streams
- Compute net-present value
- Analyze results

Some of the findings:

HOT MIX - Estimated $15/ton more than conventional
Offset if used in thinner layers

CHIP SEALS - 2 to 3 times more expensive than conventional
Offset by increased service life

Environmental Benefits

- Reduces landfill problems
- Tire stockpiles
- Value added products
- Recycling of wastes
- Noise abatement
- Linear tire fill

Environmental benefits of AR

ENVIRONMENTAL - AIR QUALITY

A number of stack emissions and worker exposure studies have been performed throughout the U.S. that have not indicated any increased risk due to CRM-related emissions

HEALTH & SAFETY

Numerous studies indicate no increased risk regarding the potential health effects of CRM asphalt compared to conventional asphalt. NIOSH studies showed that the various exposure measurements evaluated for both conventional AC and CRM asphalt paving were below the NIOSH recommended exposure limits

RAC Considerations

Use the Right Tool

- Increased initial costs must be offset by improved performance
- Not amenable to raking
- Higher temperatures for placement and compaction
- Knowledge of users and good HMA practices