


So, What do I look for ?

1


### Density

- 75% to 85% of the maximum density is obtained with the screed
- Remainder of compaction obtained with rollers

#### Steel Wheel Rollers



Small static steel wheel roller  
1.45 tons, 34 in wide drum





Large vibratory steel wheel roller  
18.7 tons, 84 in wide drum

<http://training.ce.washington.edu/wsdot/>

2

### Pneumatic Rollers

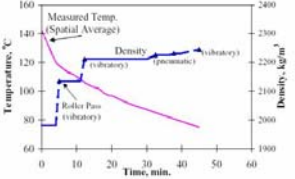



Skirt for temperature control

3

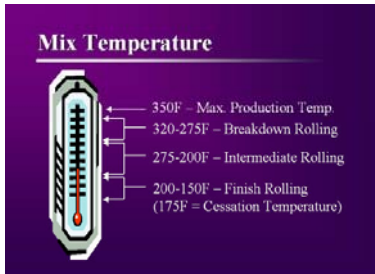
### Sequencing of Rollers

- Break down rollers
  - Steel wheel with or without vibration
- Intermediate rollers
  - Pneumatic rollers
- Finish Rollers
  - Steel wheel, static



4

## Temperature = Density



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Table 7.5: Sample *MultiCool* Calculations

Mat Thickness	Mix Temperature	Base Temperature	Approximate Time to Cool to 79 °C (175 °F)
25 mm (1 inch)	149 °C (300 °F)	16 °C (60 °F)	9 minutes
25 mm (1 inch)	149 °C (300 °F)	-4 °C (25 °F)	7 minutes
50 mm (2 inches)	121 °C (250 °F)	16 °C (60 °F)	16 minutes
50 mm (2 inches)	121 °C (250 °F)	-4 °C (25 °F)	12 minutes
105 mm (4.2 inches)	121 °C (250 °F)	16 °C (60 °F)	54 minutes
105 mm (4.2 inches)	121 °C (250 °F)	-4 °C (25 °F)	39 minutes

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## What's wrong with this picture?



7

## What HMA Properties are Linked to Pavement Performance?

- Density
  - Too little
    - Traffic ruts the surface
    - Lets water infiltrate
  - Too much
    - Traffic causes bleeding/flushing
    - Material moves under traffic loads

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### What HMA Properties are Linked to Pavement Performance?

- Segregation
  - Separation of:
    - Coarse and fine aggregate
    - Asphalt and aggregate (e.g. fat spots)
    - Cold spots (thermal segregation)

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### Definition of Segregation

- Lack of homogeneity in the hot mix asphalt constituents of the in-place mat of such a magnitude that there is a reasonable expectation of accelerated pavement distress(es)
- Covers
  - Traditional coarse/fine separation
  - Temperature
  - AC rich SMA areas
  - Fines-rich areas

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### How can I determine quality?

- Visual inspection
  - Coarse vs fine areas
  - "Bumps" from paver stops
    - Hot screed, settlement, rolling over temperature differences
- Testing of the mat
  - In place density
    - Non-destructive testing
    - Destructive testing

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### Why is segregation important?



12

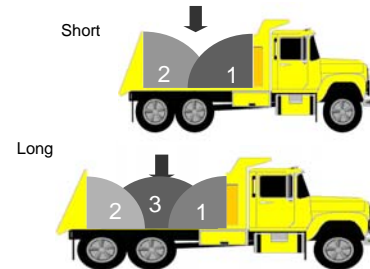
### What Causes Segregation?

- Aggregate stockpiling practices
- HMA plant
- Truck loading practices
  - Front - back - middle
- Loading the paver
  - Truck bumping the paver
- Paver
  - Wing flipping
  - Stop - Start

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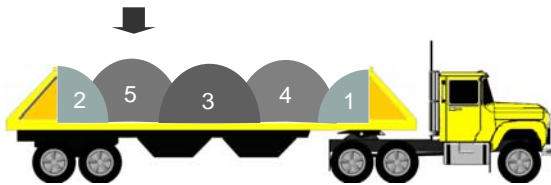
### Truck Loading Practices

Preferred practice for end dump trucks:

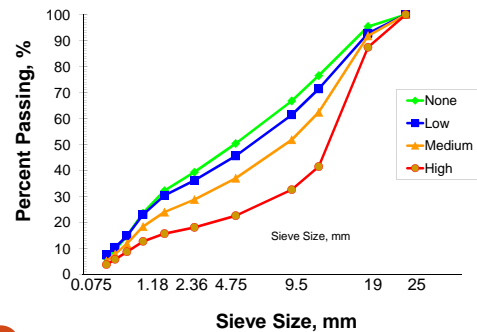


### Truck Loading Practices

Preferred practice for belly dump trucks:



Project 1-1  
0.45 Power Gradation Chart



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### Coarse vs Fines

- Increase in AC with increase in %passing or
- Decrease in AC with decrease in % passing
  - Segregation
  - Anywhere in production or construction
- Increase or decrease in AC but no change in gradation
  - Plant problems
- Out of spec gradation but AC OK
  - Plant problems
  - Aggregate stockpile issues

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### Effect of Segregation

	None	Low	Med	High
Stiffness	NA	70 - 90%	30 - 70%	<30%
TS	NA	90 - 100%	50 - 80%	30 - 50%
Grad.	JMF	1 > 5%	2 > 10%	4 > 15%
AC %	JMF	-0.3 to -0.75%	-0.75 to -1.3%	> -1.3%
Air voids %	NA	>0 - 4%	>2 to 6%	> 4%

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### So, how do I identify segregation?

- Evaluate change in properties?
  - QC/QA test results
    - Gradation
    - Asphalt content
- Behind the paver
  - Mat density?
    - Random sampling plan
      - Assumes uniform product
  - Change in texture


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### Behind the Paver Samples


- Obtain sample
  - Test for lab density, AC content, gradation

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### Troxler AC and Density Gauge



Trying a "better mousetrap" ...maybe



Pavement Quality Indicator (PQI)  
<http://www.engus.com/products/pqi.html>

Nuclear Density Gauge

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### Density the hard way


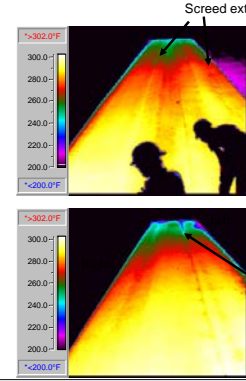


Photo courtesy of NCAI

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### Thermal Segregation



Screed extensions

Section S4 - Paved with Blaw Knox

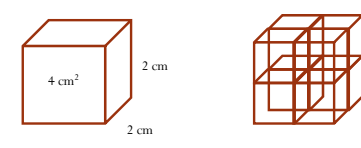
Section S5 - Paved with Road Tech Stealth Paver

Auger Connection

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### Coarse vs Fines

- Coarse aggregate has less surface area than same mass of fine aggregate



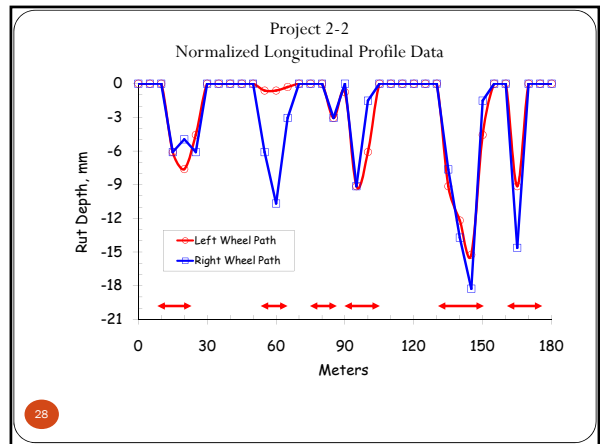
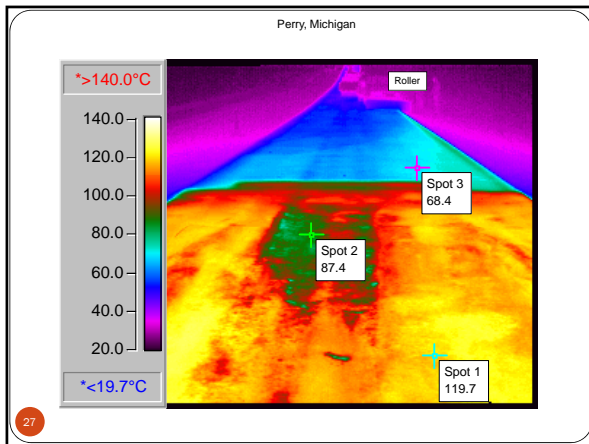
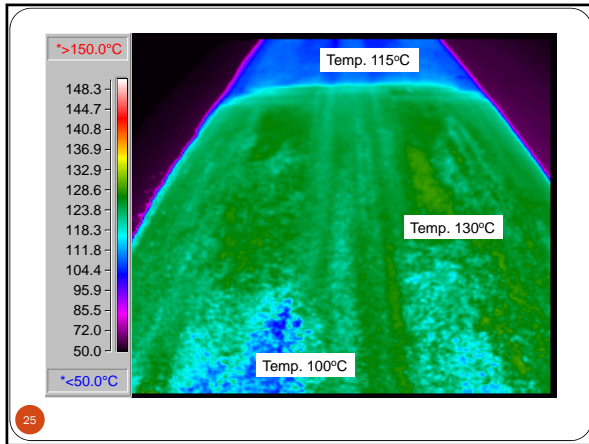
4 cm<sup>2</sup>      2 cm

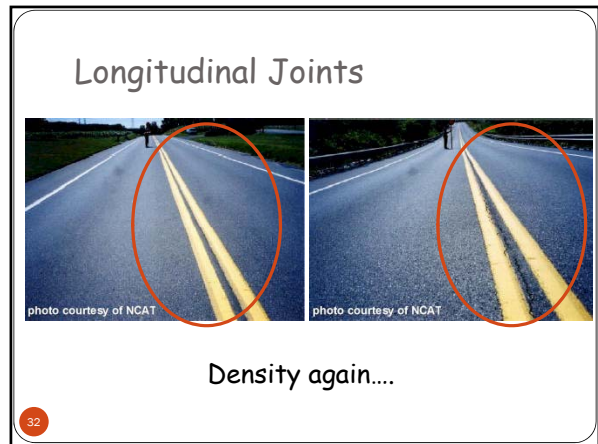
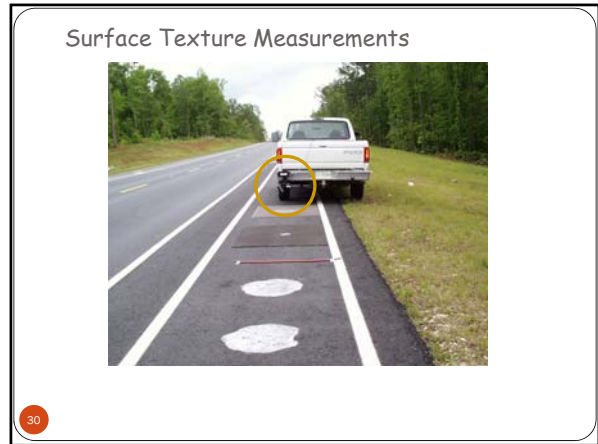
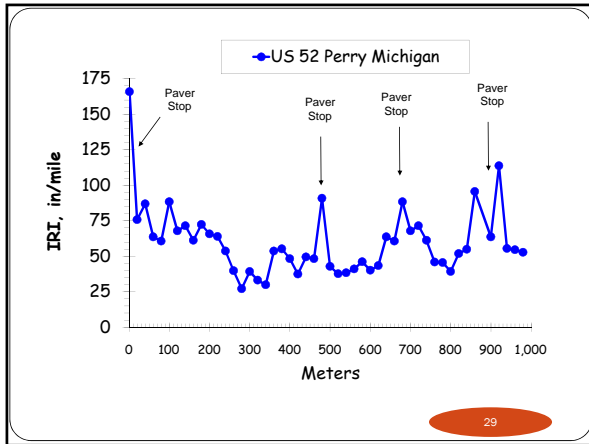
2 cm

2 cm

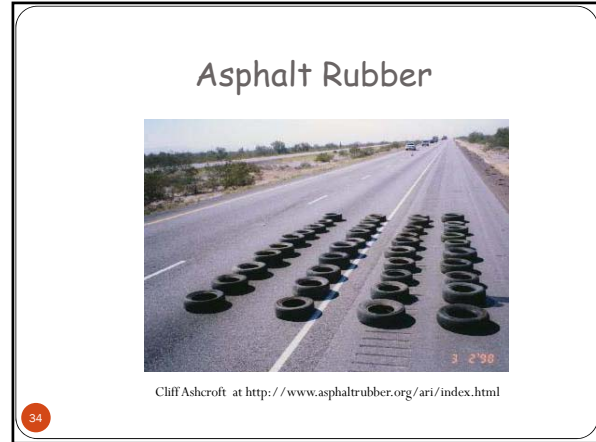
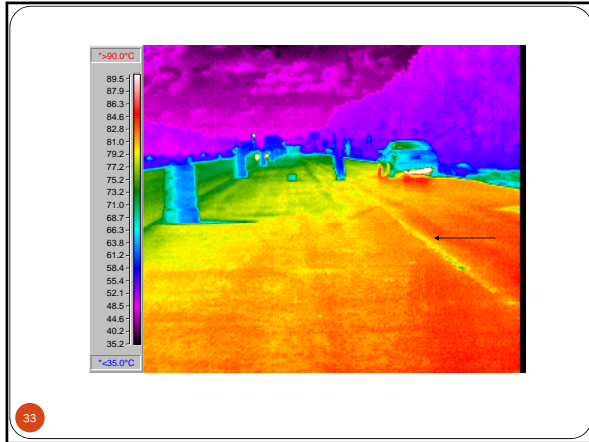
4 cm<sup>2</sup> x 6 sides = 24 cm<sup>2</sup>      1 cm<sup>2</sup> x 6 sides x 8 cubes = 48 cm<sup>2</sup>

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- ### Caltrans Experience with RAC
- 1970's - Used for chip seals and hot mix
  - 1983 - Ravendale project - reduced thickness
  - 1992 - "Design Guide for ARHM-GG"
  - 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

## 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.dst.ca.gov/hq/esc/Translab/fpmlab/CALTRANS\\_CWMBPROJECT021DELIVERABLES.htm](http://www.dst.ca.gov/hq/esc/Translab/fpmlab/CALTRANS_CWMBPROJECT021DELIVERABLES.htm)

## AR Hot Mix Asphalt Products

- Dry process
  - Aggregate replacement
- Wet process
  - Blended with asphalt
    - Polymer modified asphalt
- Field vs terminal blends

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## Definitions

Terminal Blends are:

- Low viscosity, no agitation
- Typically  $\leq 10\%$  CRM content, some @ 15%
- May include polymers and/or other modifiers
- Content in hot mixes is similar to neat asphalt cement

## 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

- Particle size
  - Surface area
    - Rate of penetration
- Selectively absorbs part of asphalt
  - Usually portion that makes asphalt soft
- Percent added

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Asphalt & Rubber Interactions

Interactions Depend On:

- Asphalt Cement Source and Grade
- Rubber Type/Source
- Amount of Rubber
- Gradation of Rubber
- Interaction Time
- Interaction Temperature

Slide 42

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**Ding1** Need to find the clips.  
DingXin Cheng, 6/5/2008

### Manufacture (Field Blend)

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

### How Rubberized Asphalt Concrete Is Made (wet process)



CRM comes in nominal 2,000 lb "Supersacks"



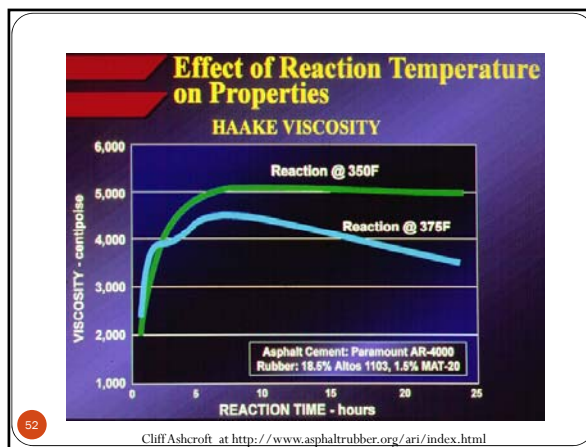
CRM is weighed in hopper



CRM is blended with hot asphalt cement



AR Blending Equipment & Interaction Tank



Asphalt Rubber Blend Design  
Example Design Profile

TEST	Minutes of Reaction					Spec. Limits @ 45 minutes (Caltrans 12/2005)
	45	90	240	360	1,440	
Viscosity, cP Haake @ 190°C	2400	2800	2800	2800	2100	1500 - 4000
Resilience @ 25°C (% Rebound) (ASTM D 5329)	27	--	33	--	23	18 Minimum
R & B Softening PL, °C (ASTM D36)	59.0	59.5	59.5	60.0	58.5	52 - 74 (125-165°F)
Cone Pen @ 25°C (ASTM D217)	39	--	46	--	50	25 - 70

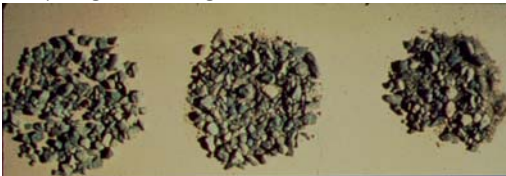
Construction Overview

FOCUS: RHMA surface courses

- RHMA-G, RHMA-O, and RHMA-O-HB
- RHMA placement very similar to typical dense-graded AC overlays, except:
  - Typically requires higher placement and compaction temperatures
  - For RHMA-G, use vibratory mode for breakdown passes and get 95% of required compaction during breakdown
  - Not amenable to handwork
- Good practices are required for RHMA production and construction, as for DGAC.

Types of Rubberized Asphalt Concrete (RHMA) Hot Mixes

- Dense-graded (limited usage by Caltrans)
- Gap-graded
- Open-graded
- Open-graded (High Binder, HB)



Open Graded

Gap Graded

Dense Graded

RHMA 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 RHMA 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

### Mix Delivery (Hauling)

- RHMA mix temperature is critical for placement and compaction
- Trucks hauling RHMA 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

### Mix Delivery

- As for DGAC, to promote quality, smoothness, and uniform compaction, must balance all aspects:
- Mix production (AC plant)
  - Mix delivery (trucking)
  - Paving operations (non stop)
  - Compaction (keep up with the paver)

### Compaction Temperature

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

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

### Compaction Temperature

- Suggest applying the higher temperature range for open-graded RHMA
- 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



### Compaction Requirements

- Caltrans will implement compaction requirements for RHMA-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 RHMA mixes, present or future

### Compaction Equipment

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

### Specifications/SSPs

- Specifications for RHMA-G, RHMA-O, and RHMA-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

- Keep it uniform!
- Pay attention to speed (time) and temperature
- Don't stop - don't flip
- AR mixes
  - Temperature critical
  - Different roller requirements
  - Different asphalt rubber products are NOT interchangeable!!

## Questions?

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