



Illinois Bituminous Paving Conference

HIGH RAP MIXTURES

Properties of Plant Mixes Containing High Asphalt Binder Replacement

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Heritage Research Group



Objective

- How much RAP can be used?
- Considerations
 - Quality product
 - Mixing plant
 - Placement
 - Compaction





Scope

- How much RAP can go through a plant?
 - Trials up to 70%
- Produce and Place on Low Volume Road
 - Measure quality
 - Measure properties

Asphalt Binder Replacement

$$\% \text{Asphalt binder replacement} = \frac{\% \text{recycled binder}}{\% \text{total binder}}$$

- RAP
- Coarse RAP
- Fine RAP
- Shingles

Typical Asphalt Binder Content

● RAP	4 – 5%
● Fine RAP	5 – 7%
● Coarse RAP	2 – 3%
● Manufacturer Scrap	18 – 22%
● Post Consumer	22 – 25%

Experiment

- Field Experiment
- Focus on High Binder Replacement
 - RAP
 - Post Consumer Asphalt Shingles

Phase One

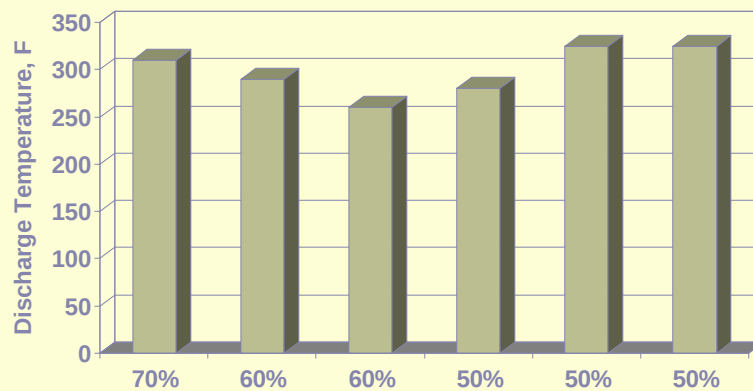
- | | |
|--|---|
| <ul style="list-style-type: none">• RAP<ul style="list-style-type: none">• 50%• 60%• 70%• Post Consumer Shingles<ul style="list-style-type: none">• 0%• 3% | <ul style="list-style-type: none">• Counter flow drum mix plant• Embedded burner<ul style="list-style-type: none">• RAP inlet capacity• Mixing chamber volume• Water injection<ul style="list-style-type: none">• Mixing aid |
|--|---|

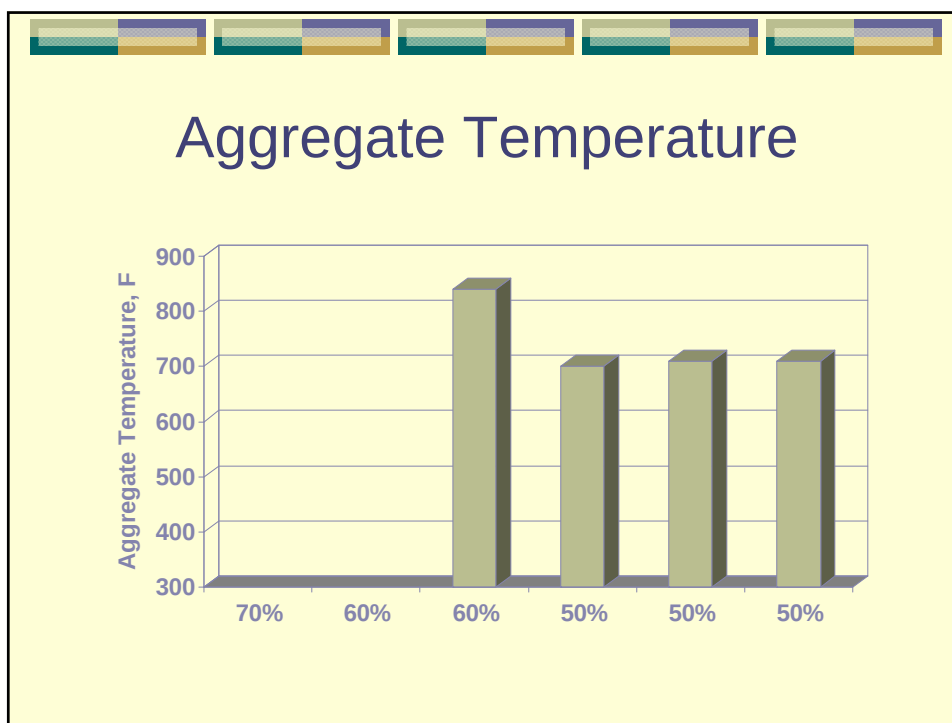


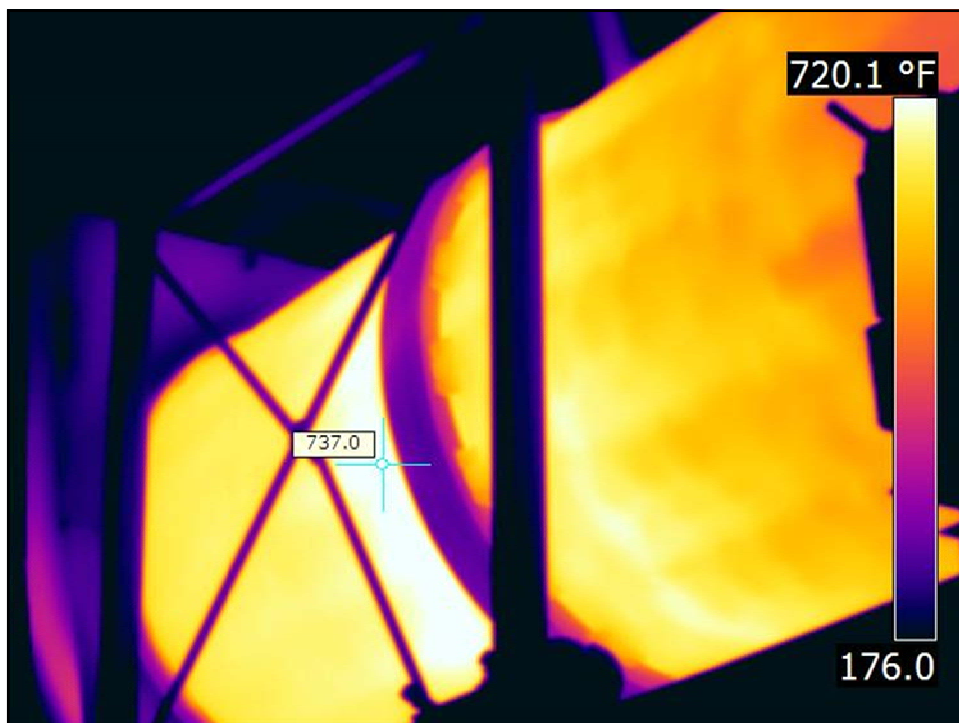
Phase One Mixes

Mix	Size	RAP	RAS	AC	BR
1	25.0	70	0	6.0	33
2	25.0	60	0	4.1	41
3	12.5	60	0		(47)
4	12.5	50	3	5.6	29
5	12.5	50	3	7.1	31
6	12.5	50	3	6.6	33

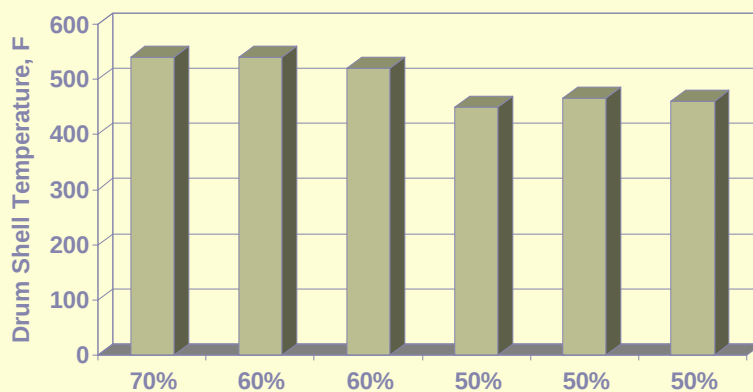
Discharge Temperature







Drum Temperature



Decisions from Phase One

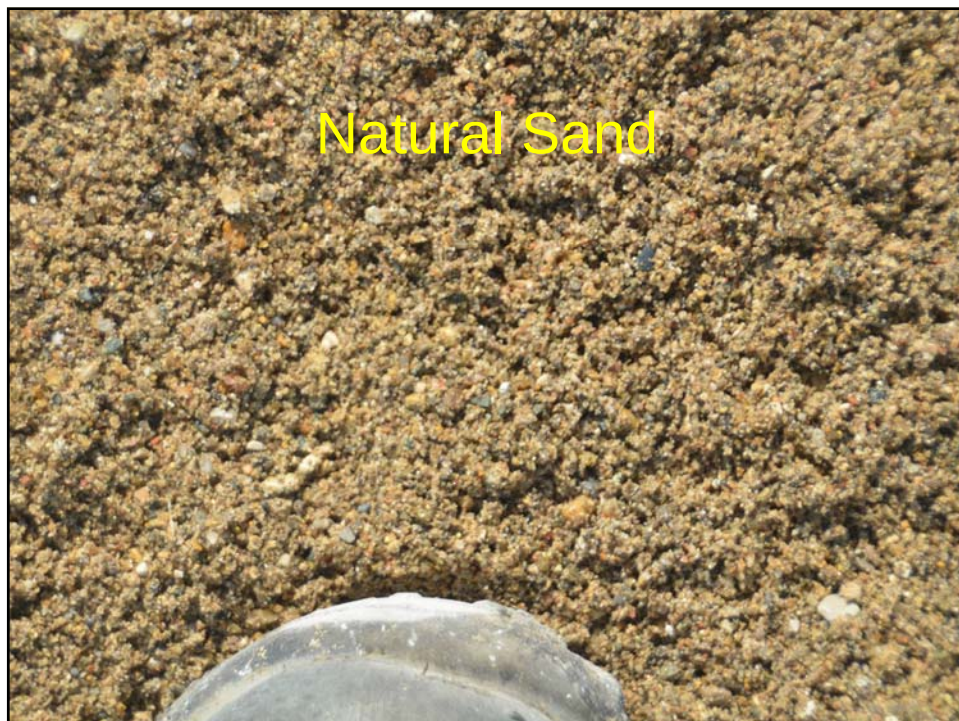
- Maximum 50% RAP
- Drum Shell Temperature
 - max 800 F
- Aggregate Temperature
 - max 700 F
- Exhaust Temperature
 - min 220 F
 - max 390 F

Phase Two Experiment

- Counterflow drum mix plant
 - With mixing drum
- 19 mm NMPS
 - 1.0 in crushed gravel
 - ½ in crushed limestone
 - ½ in pea gravel
 - Natural sand







Phase Two Recycled Materials

- Fine RAP
- Coarse RAP
- Post Consumer Shingles



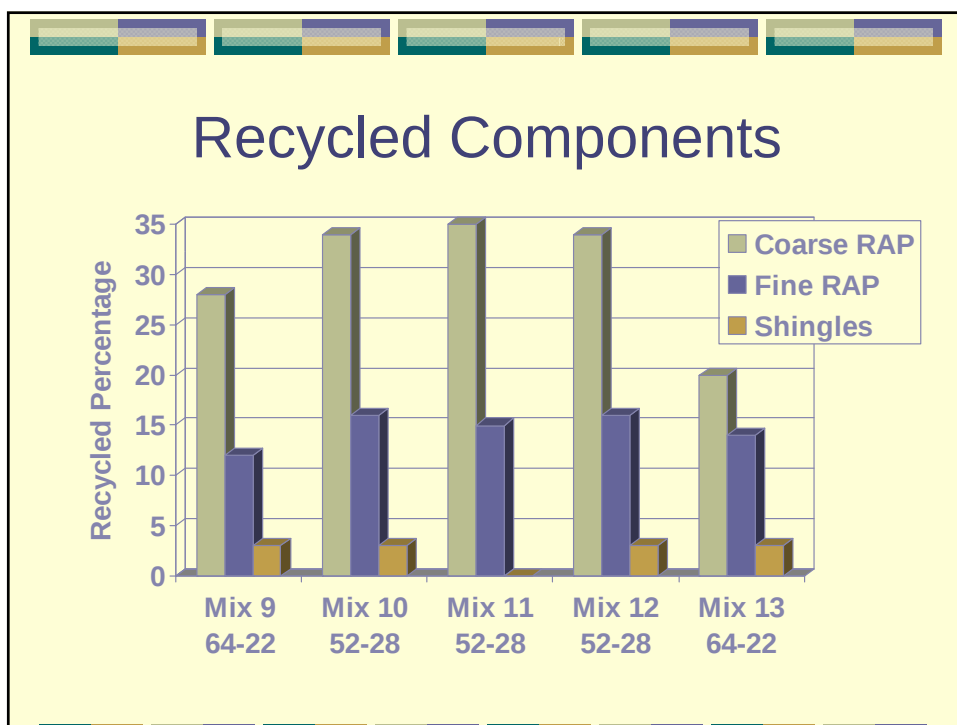
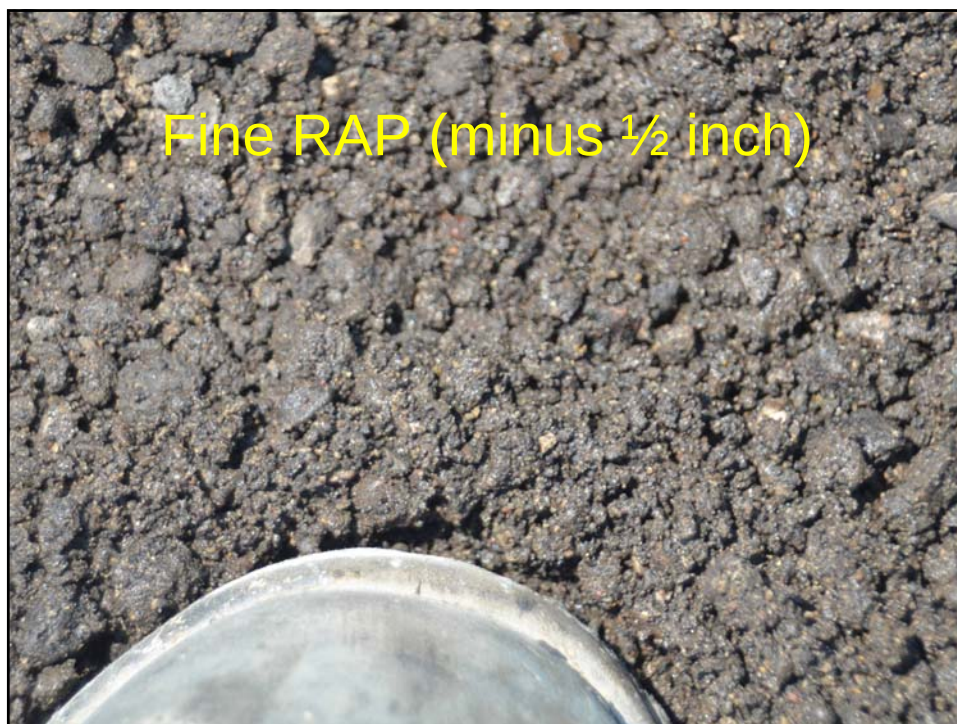




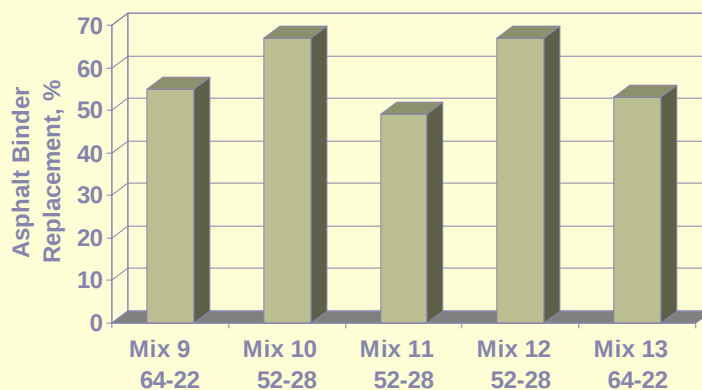
Coarse RAP ($\frac{1}{2}$ to 1 inch)



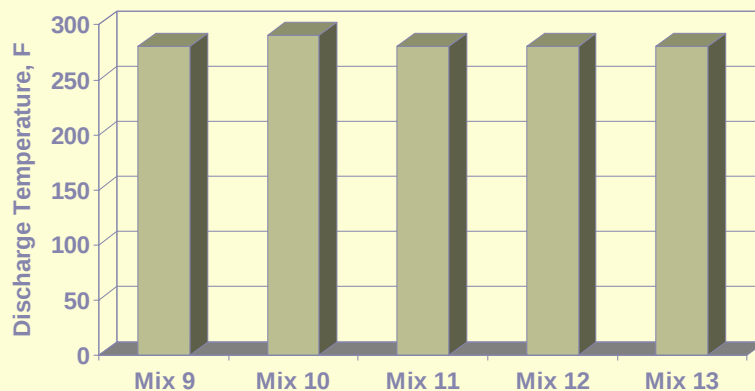
Fine RAP (minus $\frac{1}{2}$ inch)

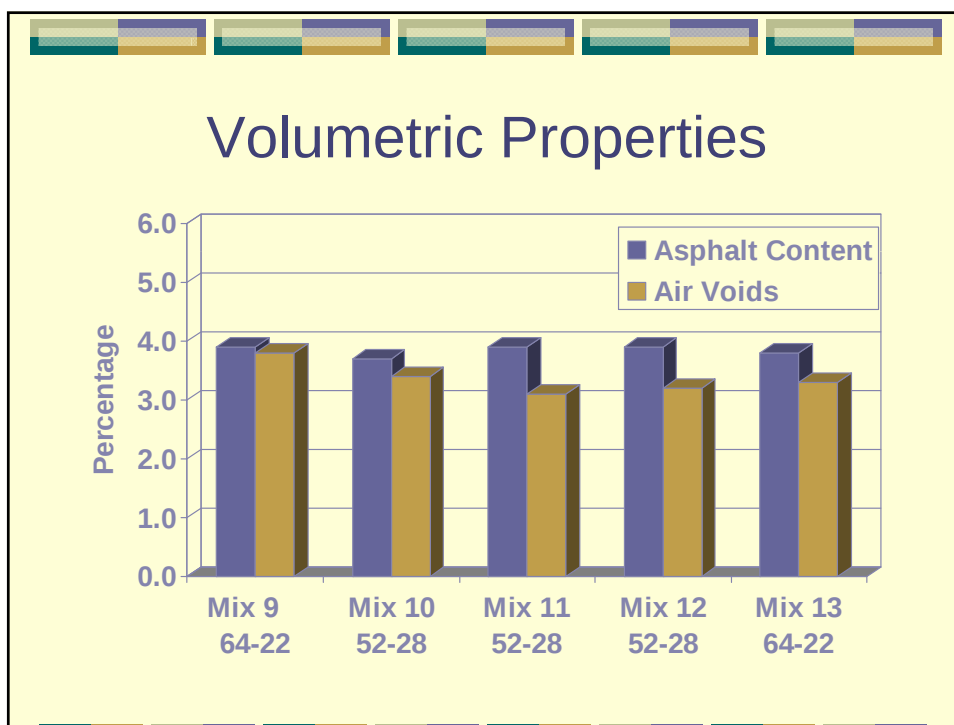
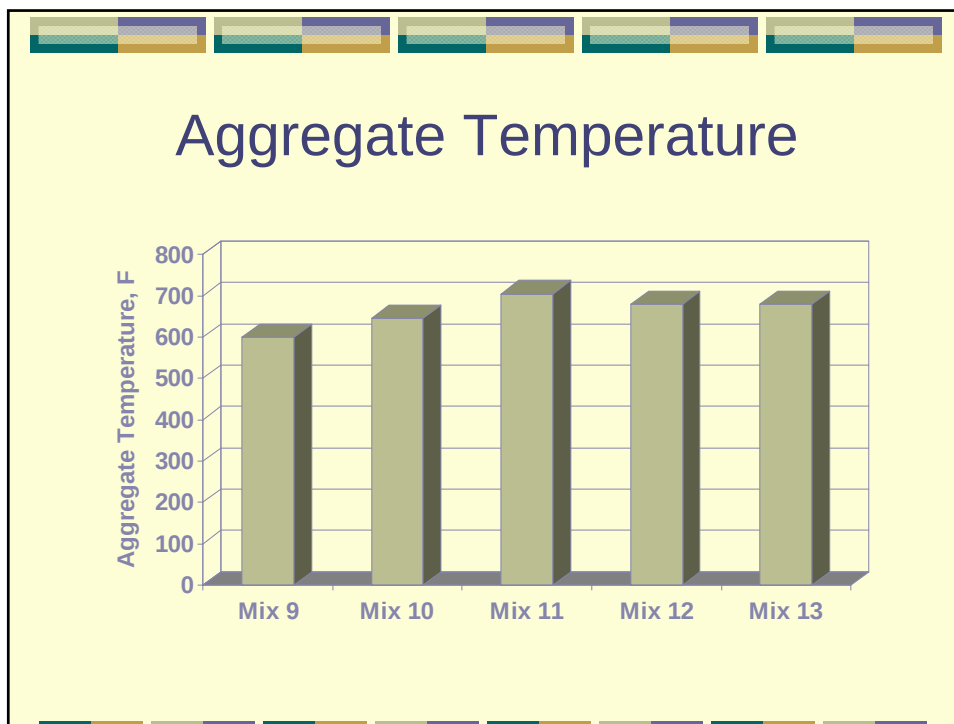


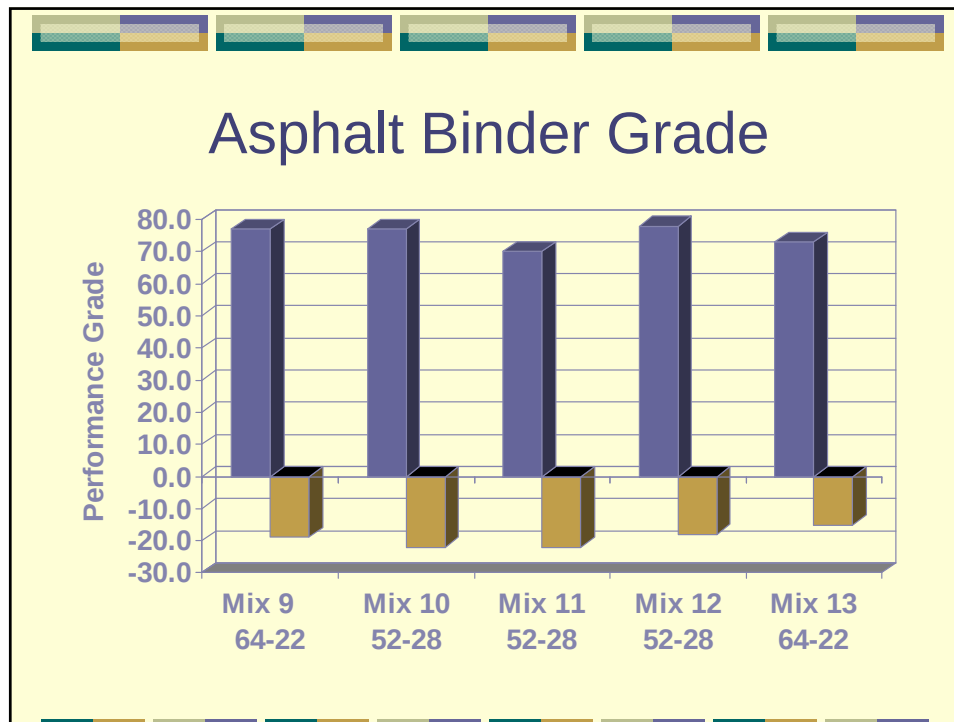
Asphalt Binder Replacement



Discharge Temperature







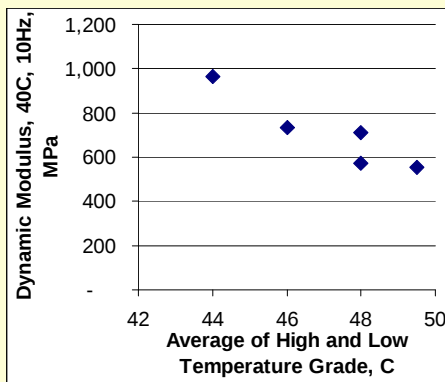
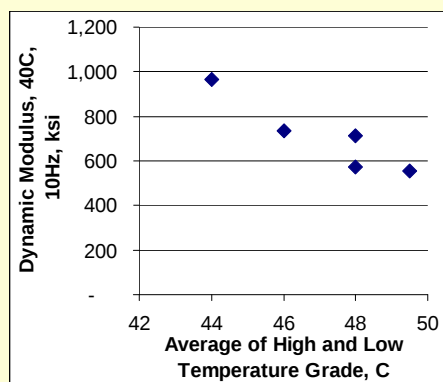
Mechanical Properties

- Stiffness
 - Low frequency
Aggregate dominates
 - High frequency
Asphalt Binder dominates

Mixture Stiffness (E^*)

0.1 Hz

10 Hz

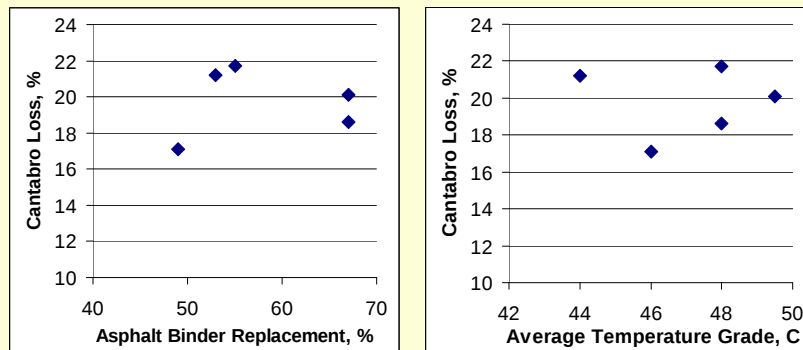


Cantabro Loss Test (Durability)

- LA Abrasion Test Machine
- Test without Steel Balls



Cantabro Test (Durability)



Blending Analysis

- M323 to calculate the limiting amount $\%RAP = \frac{T_{blend} - T_{virgin}}{T_{RAP} - T_{virgin}}$

- Predicted Temperature of Blend

$$T_{blend} = T_{virgin} + \%RAP(T_{RAP} - T_{Virgin})$$

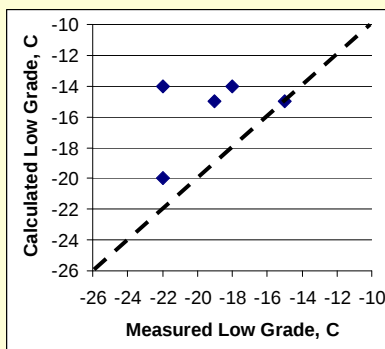
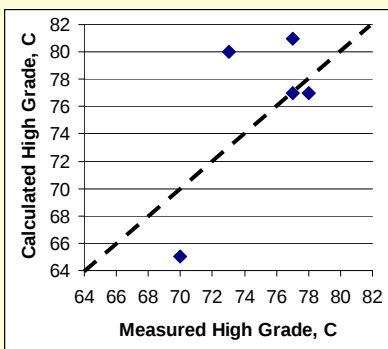
Blending Analysis

- For multiple recycled materials

$$T_{blend} =$$

$$\frac{\%RAP_F \times T_{RAP_F} + \%RAP_C \times T_{RAP_C} + \%RAS \times T_{RAS} + \%Virgin \times T_{virgin}}{\sum (\%RAP_F + \%RAP_C + \%RAS + \%Virgin)}$$

Calculated vs Measured



Placement

● County Road resurfacing

- 50 mm base
 - 19.0-mm mix
- 38 mm surface

● Placed

- May 31, 2011
- June 1, 2011

Construction Conditions

● Haul time

- 30 minutes approx

● Weather

- 85F sunny

● Paver

- Roadtec RP150
 - 50 to 60 ft/min

● Compactor

- Bomag BW266
 - 3 vibratory passes, 1 static







Quantity Placed

Mix Number	Tons
9	300
10	150
11	300
12	125
13	125

Paving Crew Observations

- Flows through paver
- Mat lays well
 - (little handwork in this application)
- Compacts well
 - No tenderness

Conclusions

Phase 1 Conclusions

- 50% RAP is reasonable maximum
 - With conventional counterflow drum
- With 60 and 70% RAP
 - Uncoated particles present
 - Aggregate temperature too high
 - Burns the asphalt binder
 - Drum temperature too high
 - Metal softens and wears

Phase 1 Conclusions (cont'd)

- Criteria selected for
 - Drum shell temperature
 - 800°F maximum
 - Virgin aggregate temperature
 - 700°F maximum
 - Bag house exhaust
 - 220°F minimum
 - 390°F maximum

Phase 2 Conclusions

- Volumetric Properties Can Be Controlled
 - With 50% RAP
 - With 67% asphalt binder replacement
- Durable Mixtures Can Be Produced
 - With 67% asphalt binder replacement
 - 18% from RAS
 - 49% from RAP

Phase 2 Conclusions (cont'd)

- Mixture Stiffness (E^*)
 - Decreased as average binder grade increased
 - Counter-intuitive
 - Not explained

Phase 2 Conclusions (cont'd)

● High Temperature Grade

- Not well predicted with blending formula
 - Some under predicted
 - Some over predicted

● Low Temperature Grade

- Consistently under predicted by blending formula



RAP in HMA

Black Rock?

- Limestone
 - 3 million – 12 million psi
- Aged Asphalt Binder
 - 150,000 psi glassy stiffness
 - 1,500 psi (50F)

500 times stiffer

Homogenous Blending?

- No

Partial Blending??

Partial Blending

Composite Material

- Virgin Binder
- Reclaimed Binder

