RAP In HMA In California

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A Short History

Caltrans evaluated RAP use in several forms in 1970's and 1980's:

- Cold In-Place Recycling
- Hot In-Place Recycling
- RAP use in Hot Mix Asphalt

But, low binder costs, etc. made the effort involved unattractive in late 1980's & 1990's

Caltrans

More Recent History

Caltrans and Industry have developed specifications for:

- Cold In-Place Recycling
- Cold Foam – Full Depth Recycling
- Hot In-Place Recycling
- RAP use in Hot Mix Asphalt

Moderate interest in CIPR, Cold Foam, and HIPR

Caltrans

RAP in HMA History

1996 –

- Dedicated/Blended Piles of RAP
- Binder blending and Final Binder Testing
- Performance Testing of Mix and Binder

2000 –

- Dedicated/Blended Piles of RAP
- Binder blending and Final Binder Testing

Etc., Etc.

Less than moderate interest by Caltrans or Industry

Caltrans

RAP in HMA Since 2003

Specifications:

- Contractor's Option – DGAC and QC/QA projects
- Maximum 15% RAP
- Live Piles of RAP
- No final binder blend testing
- HMA meets all requirements

As a CCO during Construction

- Misunderstandings – Producers/Engineers/Contractors

As an SSP in projects

- Misunderstandings/Mistrust – Caltrans

Caltrans

RAP Site Evaluations 2007

Stantech and Caltrans Evaluated 4 Sites for conditions and structural adequacy

Information available from
T_Joe_Holland@dot.ca.gov

RAP in HMA Since 2003

***Use Statewide** (from District poll)*

Year	*10%*	*15%*
2004	*1*	*1*
2005	*3*	*10*
2006	*5*	*7*
2007	*6*	*9*

RAP in HMA
Standard Specifications
(November 2007)

Specifications:

- Contractor's Option – All DGAC
- Maximum 15% RAP – No more than +/-%5 change
- Live Piles of RAP
- No binder/blend testing – no adjusting binder grades
- HMA meets all requirements

In "Amended to Read" Section 39

- Included in all projects

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RAP in HMA Standard Specifications

(November 2007)

Annual Mix Design Verification:

- Contractor prepared mix design – JMF submittal
- Verification on plant produced HMA
  - ✓ *No more than +/-5% adjustment in RAP*

Production Start-up for all projects

- Re-verification of all aggregate and mix qualities
  - ✓ *RAP aggregate not tested*

Requests for use – So Far 2008

- 10% RAP - 2 submittals
- 15% RAP - 8 submittals
  - ✓ *Some may be under old specifications and prepared by District*

Caltrans

RAP in HMA
Lab Procedure #9

(HMA Using up to 15% RAP)

Procedure Summary

- Obtain representative samples of RAP
- Evaluate RAP
  - ✓ *Binder content*
  - ✓ *Aggregate gradation & specific gravity*
  - ✓ *Rice specific gravity*
- Prepare Mix Design
  - ✓ *Determine combined gradation - Virgin aggregate + RAP*
  - ✓ *Determine approximate bitumen ratio*
  - ✓ *Calculate quantity of new binder*
  - ✓ *Determine batch weights*
  - ✓ *Prepare test specimens using Hveem Compactor*
  - ✓ *Determine OBC*
- Conduct QC testing during production

Caltrans

RAP in HMA
Lab Procedure #9

(HMA Using up to 15% RAP)

Procedure Summary

- Obtain representative samples of RAP
  - ✓ *From piles in Mix Design*
  - ✓ *From feed system during production*
- Obtain representative samples of Aggregate/RAP blend
  - ✓ *Virgin aggregate from feed system*
  - ✓ *Blend determined as a mathematical equation*
    - % Virgin + % RAP from daily sampling
- Obtain representative samples of HMA
  - ✓ *Behind the paver*

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RAP in HMA
Lab Procedure #9

- Extract Binder
  Specific Gravity of RAP
- Extraction Gradation
  Ignition Oven Gradation
- Determine Correlation Factor
  Extraction vs. Ignition Oven

7. EXAMPLE

7.1 RAP EVALUATION Determine the asphalt content and gradation of the RAP aggregate for the samples provided:

7.1.1 Given:

Test	CT 123, Part I	ASTM D2172, Method B	CT 382	CT 309
RAP Sample	Weight (lbs.)	Asphalt Content[1] (%)	Asphalt Content[2] (%)	Theo. Max Specific Gravity of RAP (G_{mm})
I	42	5.7	5.8	2.535
II	44	5.5	5.5	2.521
III	42	5.8	5.9	2.542
AVERAGE	42.3	5.7	5.7	2.533

[1] % by weight aggregate; [2] For information only

CT 202 RAP Gradation (aggregate recovered from ASTM D 2172 & CT 382 tests):

Sieve Size	Sample I		Sample II		Sample III	
	ASTM D2172	CT 382	ASTM D2172	CT 382	ASTM D2172	CT 382
1 1/2"	100.0	100.0	100.0	100.0	100.0	100.0
1"	100.0	100.0	100.0	100.0	100.0	100.0
3/4"	100.0	100.0	100.0	100.0	100.0	100.0
1/2"	82.3	81.6	81.1	81.9	84.3	83.8
3/8"	78.2	78.7	77.6	76.8	75.1	74.3
No. 4	62.4	63.3	65.2	63.8	59.4	61.4
No. 8	50.2	50.5	56.3	49.7	44.0	45.1
No. 16	38.5	39.0	35.9	34.7	28.7	28.2
No. 30	27.6	27.2	21.8	22.2	19.9	20.6
No. 50	17.7	17.4	13.2	13.5	12.8	10.5
No. 100	11.1	11.3	9.4	8.9	13.2	12.7
No. 200	4.8	4.2	5.1	4.7	5.3	3.9

Calculate: RAP Aggregate Gradation Correlation Factor

For each sieve:

RAP Aggregate Gradation Correlation Factor = (Average ASTM D 2172 gradation) - (Average CT 382 gradation)

Sieve Size	Average RAP Gradation		Correlation Factor
	ASTM D2172	CT 382	
1 1/2"	100.0	100.0	0.0
1"	100.0	100.0	0.0
3/4"	100.0	100.0	0.0
1/2"	82.6	82.4	0.2
3/8"	76.9	76.6	0.3
No. 4	62.3	62.8	-0.5
No. 8	49.7	48.4	0.3
No. 16	34.3	34.0	0.3
No. 30	23.1	23.3	-0.2
No. 50	14.6	13.8	0.8
No. 100	11.2	11.0	0.3
No. 200	5.1	4.3	0.8

RAP in HMA
Lab Procedure #9

7.2 MIX DESIGN Determine a mix design incorporating 10% RAP aggregate in the aggregate blend (15% maximum)

7.2.1 Given: VIRGIN AGGREGATE K FACTORS (See CT 303)

Relative particle roughness and surface capacity

K_c	K_f
1.0	1.5

COMBINED AGGREGATE GRADATION (See Table 2 of the example work sheet in Section 7.2.3)

Combined Gradation Summary

AGGREGATE:	RAP		3/4"		1/2"		3/8"		Rock Dust		Natural Sand		Crushed Sand		Blend[1]	Spec Limits
% Blend w/ RAP	10.0		5.0		28.0		26.0		21.0		10.0		0.0		100.0	
% blend w/o RAP	0.0		5.6		31.1		28.9		23.3		11.1		0.0		100.0	
Sieve Size	Desired % Passing	% of Blend (w/ RAP)	Desired % Passing	% of Blend (w/ RAP)	Desired % Passing	% of Blend (w/ RAP)	Desired % Passing	% of Blend (w/ RAP)	Desired % Passing	% of Blend (w/ RAP)	Desired % Passing	% of Blend (w/ RAP)	Desired % Passing	% of Blend (w/ RAP)	Total Blend (w/ RAP)	
1 1/2"	100.0	10.0	100.0	5.0	100.0	28.0	100.0	26.0	100.0	21.0	100.0	10.0	0.0	0.0	100.0	
1"	100.0	10.0	100.0	5.0	100.0	28.0	100.0	26.0	100.0	21.0	100.0	10.0	0.0	0.0	100.0	100
3/4"	100.0	10.0	100.0	5.0	100.0	28.0	100.0	26.0	100.0	21.0	100.0	10.0	0.0	0.0	100.0	100
[illegible]	[illegible]	[illegible]	[illegible]	4.7	[illegible]	[illegible]	100.0	26.0	100.0	21.0	100.0	10.0	0.0	0.0	98.3	79-99
[illegible]	[illegible]	10.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	25.8	100.0	21.0	100.0	10.0	0.0	0.0	75.7	68-88
No. 4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	8.3	99.2	20.8	97.5	9.8	0.0	0.0	48.5	48-63
No. 8	68.0	6.8	1.0	0.1	3.0	0.8	8.0	2.1	88.7	18.6	80.6	8.1	0.0	0.0	36.3	33-53
No. 16	52.0	5.2	1.0	0.1	3.0	0.8	4.0	1.0	66.1	13.9	62.6	6.3	0.0	0.0	27.3	23-40
No. 30	39.0	3.9	1.0	0.1	3.0	0.8	3.0	0.8	48.6	10.2	43.3	4.3	0.0	0.0	20.1	14-30
No. 50	26.0	2.6	1.0	0.1	2.0	0.6	2.0	0.5	33.0	6.9	21.8	2.2	0.0	0.0	12.8	9-21
No. 100	16.0	1.6	1.0	0.1	2.0	0.6	1.0	0.3	20.5	4.3	7.2	0.7	0.0	0.0	7.4	6-16
No. 200	10.6	1.1	1.0	0.1	1.0	0.3	1.0	0.3	13.6	2.9	3.3	0.3	0.0	0.0	4.8	3-8

[1] Must = 100%

- **Calculate Combined Gradation**

Calculate: Approximate Bitumen Ratio (ABR) and the percentage of coarse, fine, and RAP aggregate in the aggregate blend

First, check the K factors of the virgin aggregate:

Per Section 39-2.02 of the Standard Specifications, K_c and K_f cannot exceed 1.7:

$K_c = 1.0 < 1.7$ => OK $K_f = 1.5 < 1.7$ => OK

Now, determine ABR of combined aggregate:

$$ABR = \frac{4R + 7S + 12F}{100}$$

Where:

R = (% retained No. 8)

S = (% passing No. 8 & retained No. 200)

F = (% passing No. 200)

R = (% retained No. 8) = 100% - (% passing No. 8)
= 100% - 36.3%
= 63.7%

S = (% passing No. 8) - (% passing No. 200)
= 36.3% - 4.8%
= 31.5%

F = (% passing No. 200)
= 4.8%

Therefore:

$$ABR = \frac{4R + 7S + 12F}{100} = \frac{(4 \times 63.7) + (7 \times 31.5) + (12 \times 4.8)}{100} = 5.3\%$$

- **Determine ABR**

Now determine the percentage of coarse, fine, and RAP aggregate in the aggregate blend:

Coarse aggregate (P_1) (retained No. 4 sieve)	= (100% - % total blend passing No. 4) - (RAP aggregate in blend - % RAP passing No. 4) = (100% - 48.5%) - (10% - 8.2%) P_1 = 49.8%
Fine aggregate (P_2) (passing No. 4 sieve)	= (% total blend passing No. 4) - (% RAP passing No. 4) = (48.5% - 8.2%) P_2 = 40.2%
RAP aggregate (P_3)	P_3 = 10.0%

Check: $P_1 + P_2 + P_3$ = 49.8% + 40.2% + 10.0% = 100%

RAP in HMA
Lab Procedure #9

7.2 MIX DESIGN (Continued):

7.2.2 Given: **BATCH WEIGHT INPUTS**
(Note: given inputs are for one sample with asphalt content equal to ASR. When using the batching worksheet shown in Section 7.4 to develop a mix design, inputs for each sample must be entered separately.)

Table 3: Input for Bin Batch Weights (from Table 1 of the example work sheet in Section 7.2.3)[3]

Total Asphalt Content, %	5.3
Desired Sample Wt., g	1200.0
Weight of RAP*, g	120.5
Weight of New Asphalt, g	63.9
Wt. of Virgin Aggregate, g	1025.6

[3] When using RAP in HMA mix designs, the aggregate gradations and total asphalt content are altered slightly from original batch percentages due to the asphalt contained in the RAP. Therefore, the input data above must be entered separately for each total desired asphalt content to properly determine batch weights at each asphalt content.

Calculate: **BATCH WEIGHTS (See the example work sheet in Section 7.2.3)**

Bin Batch Weights

Fraction	RAP		3/4"		1/2"		3/8"		Rock Dust		Natural Sand		Crushed Sand	
		120.5		57.0		319.1		296.3		239.3		114.0		0.0
1" - 3/4"	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3/4" - 1/2"	0.0	0.0	6.1	3.5	6.1	19.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1/2" - 3/8"	0.0	0.0	32.2	18.3	64.0	204.2	3.7	11.0	0.0	0.0	0.0	0.0	0.0	0.0
3/8" - No. 4	17.0	20.5	23.3	13.3	25.6	81.7	64.3	190.5	0.8	1.9	2.5	2.8	0.0	0.0
No. 4 - PAN	83.0	100.0	2.0	1.1	4.3	13.7	32.0	94.8	99.2	237.4	97.5	111.1	0.0	0.0
	100.0	120.5	100.0	57.0	100.0	319.1	100.0	296.3	100.0	239.3	100.0	114.0	0.0	0.0

- **Virgin Aggregate Blending**

Cumulative Bin Batch Weights

Fraction	RAP		3/4"		1/2"		3/8"		Rock Dust		Natural Sand		Crushed Sand	
1" - 3/4"	0.0	0.0	0.0	120.5	0.0	177.4	0.0	496.5	0.0	792.8	0.0	1832.1	0.0	1146.1
3/4" - 1/2"	0.0	0.0	3.5	124.3	19.5	196.9	0.0	496.5	0.0	792.8	0.0	1832.1	0.0	1146.1
1/2" - 3/8"	0.0	0.0	18.7	143.0	204.2	401.1	11.0	507.5	0.0	792.8	0.0	1832.1	0.0	1146.1
3/8" - No. 4	20.5	20.5	13.3	176.3	81.7	482.8	190.5	698.0	1.9	794.7	2.8	1835.0	0.0	1146.1
No. 4 - PAN	100.0	120.5	1.1	177.4	13.7	496.5	94.8	792.8	237.4	1832.1	111.1	1146.1	0.0	1146.1
	120.5		57.0		319.1		296.3		239.3		114.0		0.0	

RAP in HMA
Lab Procedure #9

7.2 MIX DESIGN (Continued):

7.2.3 Given:

Component	Bulk Specific Gravity	Composition (%)	Source
Asphalt binder in RAP	1.02 (G_{ba})	P_{ba} = 5.7%	Section 7.1.1
Asphalt binder in mix	1.02 (G_b)	Use ABR=P_b= 5.3%	Section 7.2.1
Coarse aggregate (retained No. 4 sieve)	2.720 (G_1)	P_1 = 49.8%	
Fine aggregate (passing No. 4 sieve)	2.700 (G_2)	P_2 = 40.2%	
RAP	Calculate	P_3 = 10%	
Compacted Mixture	2.440 (G_{mb})	—	CT 308, Method A

Where: ABR = Approximate Bitumen Ratio for the combined aggregate gradation (from Section 7.2.1)

P_n = composition, % by dry weight of aggregate

G_{se} = effective specific gravity of RAP aggregate (assumed equal to bulk specific gravity)

Calculate: **VOIDS in MINERAL AGGREGATE (VMA) - See Lab Procedure 2**

First, calculate the effective specific gravity of the RAP aggregate:

From LP-2:

$$G_{se} = \frac{100}{\frac{100 + P_{ba}}{G_{mm}} - \frac{P_{ba}}{G_{ba}}}$$

Where:

G_{ba} = specific gravity of asphalt binder in RAP = 1.02

G_{mm} = maximum specific gravity of RAP mixture (CT 309)

P_{ba} = asphalt binder content of RAP, % by weight of aggregate

} Given in 7.1.1

Sample I: $G_{se} = \frac{100}{\frac{100 + 5.7}{2.535} - \frac{5.7}{1.02}} = 2.769$

Sample II: $G_{se} = \frac{100}{\frac{100 + 5.5}{2.521} - \frac{5.5}{1.02}} = 2.743$

Sample III: $G_{se} = \frac{100}{\frac{100 + 5.8}{2.542} - \frac{5.8}{1.02}} = 2.783$

Average $G_{se} = \frac{2.769 + 2.743 + 2.783}{3} = 2.765$

- Detrmine VMA

Now, find the bulk specific gravity of the aggregate blend (G_{sb}):

$$G_{sb} = \frac{P_1 + P_2 + P_3}{\frac{P_1}{G_1} + \frac{P_2}{G_2} + \frac{P_3}{G_{se}}} = \frac{49.8 + 40.2 + 10.0}{\frac{49.8}{2.720} + \frac{40.2}{2.700} + \frac{10.0}{2.765}} = 2.716$$

Therefore:

$$VMA = 100 - \left[\frac{G_{mb}}{G_{sb}} \times \left(\frac{100}{100 + P_b}\right) \times 100\right] = 100 - \left[\frac{2.440}{2.716} \times \left(\frac{100}{100 + 5.3}\right) \times 100\right] = 14.7$$

RAP in HMA
Lab Procedure #9

7.2.3 Example Worksheet for Computing Laboratory Batch Weights for HMA Mixtures Containing RAP

Date: _____
Mix Type: _____

Prepared By: _____

_____ - yellow cell denotes a required input.

% RAP Aggregate in Aggregate Blend (15% Max)	Asphalt Content of RAP (Pba)*

* Dry Weight of Aggregate

- **Calculate Batch Weights** (ABR–5%, ABR, ABR+5%, ABR+10%)

Table 1: Batch Weights for Virgin Aggregate, RAP, and New Asphalt Binder

Parameter	Sample #1	Sample #2	Sample #3	Sample #4	Sample #5
Desired Total Asphalt Content of Mix, % (DWA)	4.3	4.8	5.3	5.8	6.3
Desired Hot Mix Sample Weight, g	1200	1200	1200	1200	1200
Desired Weight of Aggregate, g	1150.5	1146.0	1138.6	1134.2	1528.9
New Asphalt, % (DWA)	3.7	4.2	4.7	5.2	5.7
Weight of New Asphalt to be Added, g	42.9	48.4	53.9	59.3	64.7
RAP, % (DWA)	10.6	10.6	10.6	10.6	10.6
Weight of RAP to be Added, g	121.6	121.0	120.6	118.9	118.3
New Aggregate, %	90	90	90	90	90
Weight of Virgin Aggregate, g	1035.5	1030.5	1025.6	1020.8	1016.0
Check	1200.0	1200.0	1200.0	1200.0	1200.0

Table 2: Combined Gradation Summary

AGGREGATE:	RAP	3/4"	1/2"	3/8"	Rock Dust	Natural Sand	Crushed Sand	Blend*	Spec Limits
% of Blend or RAP	10.0	5.0	28.0	28.0	21.0	10.0	0.0	100.0	
% of Blend w/o RAP	0.0	5.6	31.1	28.9	23.3	11.1	0.0	100.0	
Sieve Size	Desired % Passing / % of Blend (w/ RAP)	Desired % Passing / % of Blend (w/ RAP)	Desired % Passing / % of Blend (w/ RAP)	Desired % Passing / % of Blend (w/ RAP)	Desired % Passing / % of Blend (w/ RAP)	Desired % Passing / % of Blend (w/ RAP)	Desired % Passing / % of Blend (w/ RAP)	Total Blend (w/ RAP)	
1 1/2"	100.0 / 10.0	100.0 / 5.0	100.0 / 28.0	100.0 / 28.0	100.0 / 21.0	100.0 / 10.0	0.0 / 0.0	100.0	
1"	100.0 / 10.0	100.0 / 5.0	100.0 / 28.0	100.0 / 28.0	100.0 / 21.0	100.0 / 10.0	0.0 / 0.0	100.0	100
3/4"	100.0 / 10.0	100.0 / 5.0	100.0 / 28.0	100.0 / 28.0	100.0 / 21.0	100.0 / 10.0	0.0 / 0.0	100.0	100
1/2"	100.0 / 10.0	94.4 / 4.7	93.3 / 26.1	100.0 / 28.0	100.0 / 21.0	100.0 / 10.0	0.0 / 0.0	88.8	79-98
3/8"	100.0 / 10.0	82.5 / 1.3	82.9 / 8.4	96.3 / 26.9	100.0 / 21.0	100.0 / 10.0	0.0 / 0.0	75.7	69-89
No. 4	83.0 / 8.3	20.0 / 0.1	43.1 / 1.2	37.0 / 8.3	99.2 / 20.8	97.5 / 9.8	0.0 / 0.0	48.5	40-68
No. 8	69.0 / 6.9	1.0 / 0.1	30.0 / 0.8	8.0 / 2.1	85.7 / 18.0	90.0 / 9.1	0.0 / 0.0	36.3	33-53
No. 16	52.0 / 5.2	1.0 / 0.1	3.0 / 0.8	4.0 / 1.0	68.1 / 13.9	62.0 / 6.3	0.0 / 0.0	27.3	20-40
No. 30	39.0 / 3.9	1.0 / 0.1	3.0 / 0.8	3.0 / 0.8	48.6 / 10.2	43.3 / 4.3	0.0 / 0.0	20.1	14-30
No. 50	26.0 / 2.6	1.0 / 0.1	2.0 / 0.6	2.0 / 0.5	33.0 / 6.9	21.8 / 2.2	0.0 / 0.0	12.8	9-21
No. 100	16.0 / 1.6	1.0 / 0.1	2.0 / 0.6	1.0 / 0.3	22.0 / 4.5	7.2 / 0.7	0.0 / 0.0	7.4	5-15
No. 200	10.0 / 1.1	1.0 / 0.1	1.0 / 0.3	1.0 / 0.3	13.6 / 2.9	3.3 / 0.3	0.0 / 0.0	4.8	3-8

* Must = 100%

RAP in HMA
Lab Procedure #9

Table 3: Input for Bin Batch Weights (from Table 1)[1]

Total Asphalt Content, %	5.3
Desired Sample Wt., g	1200
Weight of RAP, g	120.5
Weight of New Asphalt, g	53.9
Wt. of Virgin Aggregate, g	1025.6

[1]When using RAP in HMA mix designs, the aggregate gradations and total asphalt content are altered slightly from original batch percentages due to the asphalt contained in the RAP. Therefore, the input data above must be entered separately for each total desired asphalt content to properly determine batch weights at each asphalt content.

Bin Batch Weights

Fraction	RAP		3/4"		1/2"		3/8"		Rock Dust		Natural Sand		Crushed Sand	
		120.5		57.0		315.1		296.3		230.3		114.0		0.0
1" - 3/4"	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3/4" - 1/2"	0.0	0.0	6.7	3.8	6.1	19.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1/2" - 3/8"	0.0	0.0	68.0	38.7	64.0	204.2	3.7	11.0	0.0	0.0	0.0	0.0	0.0	0.0
3/8" - No. 4	17.0	20.5	23.3	13.3	25.6	81.7	64.3	190.5	0.6	1.9	2.5	2.8	0.0	0.0
No. 4 - PAN	83.0	100.0	2.0	1.1	4.3	13.7	32.0	94.8	99.4	227.4	97.5	111.1	0.0	0.0
	100.0	120.5	100.0	57.0	100.0	319.1	100.0	296.3	100.0	230.3	100.0	114.0	0.0	0.0

- Adjust Combined Gradation

Cumulative Bin Batch Weights

Fraction	RAP		3/4"		1/2"		3/8"		Rock Dust		Natural Sand		Crushed Sand	
1" - 3/4"	0.0	0.0	0.0	120.5	0.0	177.4	0.0	496.5	0.0	792.8	0.0	1832.1	0.0	1146.1
3/4" - 1/2"	0.0	0.0	3.8	124.3	19.5	196.9	0.0	496.5	0.0	792.8	0.0	1832.1	0.0	1146.1
1/2" - 3/8"	0.0	0.0	38.7	163.8	204.2	401.1	11.0	507.5	0.0	792.8	0.0	1832.1	0.0	1146.1
3/8" - No. 4	20.5	20.5	13.3	176.3	81.7	482.8	190.5	698.0	1.9	794.7	2.8	1835.0	0.0	1146.1
No. 4 - PAN	100.0	120.5	1.1	177.4	13.7	496.5	94.8	792.8	227.4	1022.1	111.1	1146.1	0.0	1146.1
	120.5		57.0		319.1		296.3		230.3		114.0		0.0	

= yellow cell denotes a required input

RAP in HMA
Lab Procedure #9

Production Testing

7.3 PRODUCTION TESTING

7.3.1 Given: Production testing data for 1500 tons of paving:

CT 202 Actual Gradation (aggregate from CT 382):

Sieve Size	RAP (daily sample)	Virgin Aggregate (sample/ 500 ton)			Spec Limits
		Sample A	Sample B	Sample C	
1 1/2"	100.0	100.0	100.0	100.0	
1"	100.0	100.0	100.0	100.0	100
3/4"	100.0	100.0	100.0	100.0	100
1/2"	88.7	83.2	94.0	91.5	79-99
3/8"	73.1	76.3	69.2	75.7	68-88
No. 4	53.3	54.3	50.5	51.1	48-68
No. 8	42.4	44.1	48.7	43.2	33-53
No. 16	33.3	36.7	37.8	29.6	20-40
No. 30	24.6	21.1	22.9	26.3	14-30
No. 50	16.2	18.7	13.6	16.4	9-21
No. 100	10.8	14.4	12.1	15.3	6-16
No. 200	4.5	3.5	4.2	5.1	3-6

- Daily Ignition Results for RAP aggregate gradation

Calculate: **Corrected RAP Gradation (for each sieve); Combined Gradation**

Corrected RAP gradation = (Actual gradation) + (correlation factor)

Combined gradation = (% RAP in mix) x (Corrected RAP gradation) + (% Virgin Aggregate in mix) x (Sample gradation)

Sieve Size	Correlation Factor	RAP 10%		Virgin Aggregate 90%			Combined Gradation			Spec Limits
		Actual	Corrected	Sample A	Sample B	Sample C	Sample A	Sample B	Sample C	
1 1/2"	0.0	100.0	**100.0**	100.0	100.0	100.0	**100.0**	**100.0**	**100.0**	
1"	0.0	100.0	**100.0**	100.0	100.0	100.0	**100.0**	**100.0**	**100.0**	100
3/4"	0.0	100.0	**100.0**	100.0	100.0	100.0	**100.0**	**100.0**	**100.0**	100
1/2"	0.2	88.7	**88.9**	83.2	94.0	91.5	**83.8**	**93.5**	**91.2**	79-99
3/8"	0.3	73.1	**73.4**	76.3	69.2	75.7	**76.0**	**69.6**	**75.5**	68-88
No. 4	-0.5	53.3	**52.8**	50.5	54.3	51.1	**56.1**	**54.2**	**51.3**	48-68
No. 8	0.3	42.4	**42.7**	44.1	48.7	43.2	**44.0**	**48.1**	**43.1**	33-53
No. 16	0.3	33.3	**33.6**	36.7	37.8	29.6	**36.4**	**37.4**	**30.0**	20-40
No. 30	-0.2	24.6	**24.4**	21.1	22.9	26.3	**21.4**	**23.0**	**26.1**	14-30
No. 50	0.6	16.2	**17.0**	18.7	13.6	16.4	**18.5**	**13.9**	**16.5**	9-21
No. 100	0.3	10.8	**11.1**	14.4	12.1	15.3	**14.1**	**12.0**	**14.9**	6-16
No. 200	0.8	4.5	**5.3**	3.5	4.2	5.1	**3.7**	**4.3**	**5.1**	3-6

- Mathematically combined gradations

& Also

Pilot Project with RAS

- Post Product – Pre-Consumer Waste
- In Partnership with Industry
- Grant from CIWMB
- Searching for Pilot in Southern California or Bakersfield

Thank You for Your Attention

Any Questions?