
Hot Mix Asphalt
Recycling
Alaska Asphalt
Pavement Summit
December 4, 2007
Anchorage, AK


Outline
Recycling Background
Hot Central Plant
Cold In-Place
Hot In-Place
Life Cycle Cost Analysis


Outline
Recycling Background
Hot Central Plant
Cold In-Place
Hot In-Place
Life Cycle Cost Analysis

Recycling Initiative

- Conservation
  - Materials (aggregate and asphalt binder)
  - Energy (burner fuel and trucking)
- Preservation
  - Environment
  - Existing materials
  - Pavement geometrics
- Economics
  - First cost (structural design and materials)
  - Life cycle cost
  - Reduced user costs (user delays)
  - Margins

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Social Responsibility

- Good Environmental Stewards
  - Landfill Diversion
  - Recycling
  - Air Quality – Green House Gases
  - Reduced consumption of virgin materials
- Increased pavement recycling 30-percent
  - 65-million barrels of oil saved

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Recycling Quantities and Rates

- Domestic Waste[1]
  - 18M tons Paper and Paperboard (25%)
  - 4.2M tons Yard Waste (12%)
  - 0.3M tons Plastic (2%)
  - 2.6M tons Glass (20%)
  - 0.4M tons Tires (17%)
  - 25.5M tons
- Steel Recycling[2]
  - 76M tons Steel (76%) – US and abroad
- Asphalt Pavement Recycling[1]
  - 80M tons Asphalt Pavement (80%)
- [1]Ref: FHWA and EPA 1993
- [2]Ref: Steel Recycling Institute

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Recycling Methods

- Asphalt Pavement Recycling
  - Hot Central Plant
  - Hot In-Place
  - Cold In-Place
  - Recycled Aggregate Base
- Portland Cement Concrete Recycling
  - Recycled Base
  - Aggregate for PCC
  - Aggregate for HMA
  - Aggregate for Chip Seals

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Why is Cement and Asphalt Binder Consumption so Important?

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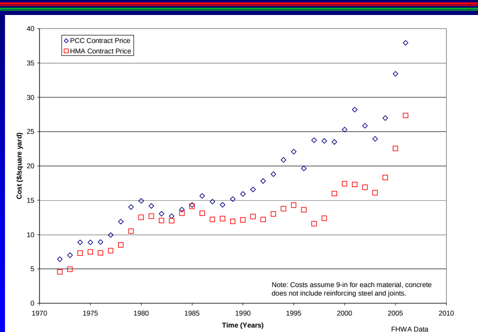
Historical Price Increases



(FHWA) 9

Why is Energy Consumption so Important?

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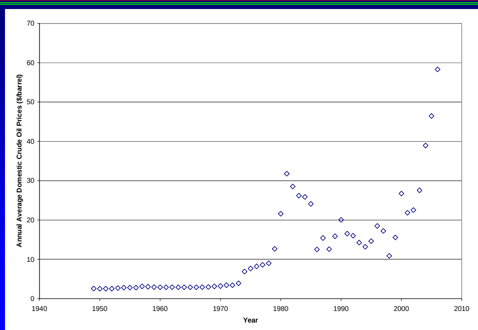
Historical Crude Oil Prices



(US Dept. of Energy) 11

Allowable %RAP by Pavement Course

State	Specification Date	Section	Pavement Course		
			Base	Leveling	Surface
Alabama	2003	410.02	20	20	20
Alaska	2002		15+	0	0
Arizona	2001	405	0	0	0
Arkansas	1996	416.03	30	30	30
California (expected)		39	15	15	15
Colorado	1999	401.02	15	15	15
Connecticut	1999	4.06	15	15	15
Delaware	2001	823.26	20	10	10
Federal Lands	1996	403.3	50	50	
Florida	2004	334-2.3	30-50	30-50	30-50
Georgia	2001	402.2	40	40	40
Hawaii	2005	312 & 401	30-40	30-40	15
Idaho	2004	405.02	0	0	0
Illinois	1997	406.1	25	25	15
Indiana	2005	401.06	25	25	25
Iowa	2002	2303.02.C.2	30	30	30
Kansas	1990	604.02	E	E	E
Kentucky	2004	409.03.02	30	30	30
Louisiana	2000	Table 502-4	20-30	20	0
Maine	2002	401.03	15	15	15
Maryland	2001	904.04.01	15	15	15
Massachusetts	1995	M3.11.03	40	40	10
Michigan	2003		25+	25+	25+
Minnesota	2000	2350.2C	40	40	30
Mississippi	2003	401.02.3.1	30	30	0
Missouri	2004	401.3.2 & 402.3.3	15	15	15
Montana			PS	PS	PS

E = Engineer – Maximum value determined by the Engineer.
PS = Project Specifications – Maximum value stated in the project specifications

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Allowable %RAP by Pavement Course

State	Specification Date	Section	Pavement Course Base	Pavement Course Leveling	Pavement Course Surface
Nebraska	2001	1028.01 3b	15-50	15-50	15-50
Nevada	1997		PS	PS	PS
New Hampshire	2002	401.2.7	50	50	15
New Jersey	2001	903.1	50	50	15
New Mexico	2000	422.27	25	25	25
New York	2002	Table 703-09A	70	70	70
North Carolina	2002	610-3	50	50	50
North Dakota	2002		0	0	0
Ohio	2005	302.02 & 401.04	30-50	30	10-20
Oklahoma	1999	708.04	25	25	0
Oregon	2002	SP745	30	30	20
Pennsylvania	2000	403.2D	15	15	15
Rhode Island	1997	407.02.1	30	30	30
South Carolina	2000	401.03F	30	25	20
South Dakota	2004	320	0	0	0
Tennessee	2006	411.03	10-25	10-25	10-25
Texas	1993	247.2	20	20	20
Utah	2005	2969 2.1F	25	25	25
Vermont	2001	704.10 b1c	15	15	15
Virginia	2002	211.03	20+	20+	20+
Washington	2002	5-04.2	20	20	20
West Virginia	2000	401.4.1	15+	15+	15+
Wisconsin	2006	460.2.5	35	35	20
Wyoming	1995	401.4.13.2	15	15	15

E = Engineer – Maximum value determined by the Engineer.
PS = Project Specifications – Maximum value stated in the project specifications.

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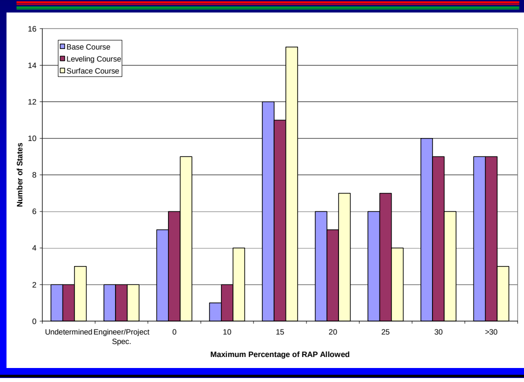
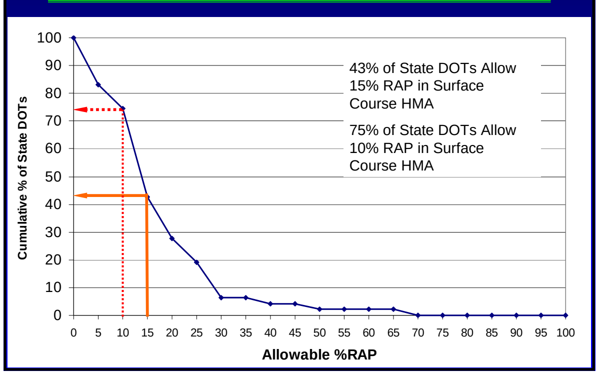
Allowable RAP by Pavement Course



Surface Course Allowable %RAP



RAP Sources

- Cold Milling
- Full Depth Reclamation
- Plant Waste/Reject

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Can We Do It?

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QC/QA Plan

- RAP Processing
- Mix Design
- HMA Production
  - Virgin asphalt binder
  - Virgin aggregate
  - RAP asphalt binder (higher RAP %)
  - RAP aggregate
- Field Construction
- Performance

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Processing RAP

- Scalp +2in material
- RAP breakers can be used
- Crusher
  - Horizonatl impact
  - Hammermill impact
  - Jaw/roll
- Fractionating (~>15% RAP)

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RAP Processing

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Stockpiling

- Separate based on sources/mix types
- Avoid consolidation
- No loaders, dozers or trucks on stockpile
- Protect from moisture intrusion
- Protect from contamination

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Stockpiling RAP

- Large, conical stockpiles preferred
- RAP does not re-compact
- Forms “crust” (200-250 mm) 8-10 inches
- Crust sheds water and easily broken
- RAP under crust easy to manage

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Disadvantage of Horizontal RAP Stockpiles

- More crust develops
  - May require re-crushing
  - Slows production
- Drainage poor
  - Increase drying costs

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Processed RAP

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Feeding RAP after Rainfall

- Remove wet part of open face and set aside to dry
- Keeps RAP percentage up and drying costs down, ensures adequate drying of RAP

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Feeding RAP

- "Trickle feed" RAP bin when charging bin with loader
  - RAP more prone to bridging than fine aggregates
  - Ensures uniform and consistent feed of RAP

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Feeding RAP

- Unload RAP bin each night and after one hour down time
  - Helps keep feed uniform, especially on hot humid days
- Do not fill RAP bin completely
  - Material may bridge
- Do not use vibrators to counteract bridging
  - Material tends to pack

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Plant Temperatures

- Virgin aggregate temperature dependent upon:
  - RAP moisture content
  - RAP content
  - Desired HMA plant discharge temperature

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	Reclaimed Material Moisture Content %	Recycled Mix Discharge Temperature 240° F/116° C	260° F/127° C	280° F/138° C	300° F/149° C
RATIO: 10% RAP 90% AGG	0	269	291	313	335
	1	274	296	318	340
	2	279	301	323	345
	3	284	306	328	350
	4	289	311	333	355
	5	294	316	338	360
RATIO: 20% RAP 80% AGG	0	292	317	342	367
	1	303	328	353	378
	2	314	339	364	389
	3	325	350	375	400
	4	336	361	386	411
	5	347	372	397	422
RATIO: 30% RAP 70% AGG	0	324	352	330	408
	1	343	371	599	427
	2	362	390	418	446
	3	381	409	437	465
	4	400	428	456	484
	5	419	447	475	503
RATIO: 40% RAP 60% AGG	0	366	397	430	463
	1	424	426	459	492
	2	453	455	488	521
	3	482	484	517	550
	4	511	513	546	579
	5	540	542	575	608
RATIO: 50% RAP 50% AGG	0	420	460	500	540
	1	464	504	544	588
	2	508	548	588	628
	3	552	592	632	672
	4	596	636	676	716
	5	640	680	720	760

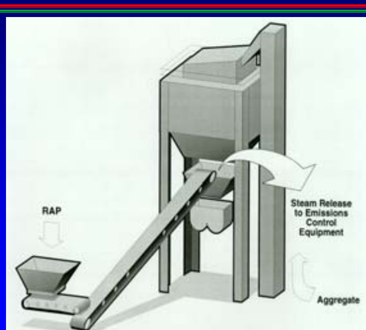
Assume 10° F loss from dryer to pugmill; 70° F outside air temperature

REQUIRED AGGREGATE TEMPERATURES

Batch Plants

- Plant Variations
  - RAP feed into weigh hopper
  - RAP feed into pugmill
  - RAP feed into elevator
  - RAP dried in separate dryer
- RAP heated conductively
- Practical RAP limit – 30%

RAP Fed into Weigh Hopper



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RAP Fed into Weigh Hopper

- RAP added to weigh hopper
- Weighed as additional material
- Mixed with virgin materials
- Conductive heat transfer
- Significant steam release

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Adding RAP into Weigh Hopper

- Cold, wet RAP into weigh hopper
- Mixed with superheated materials
- RAP heated conductively
- Significant steam release
- 25 to 30% RAP typical
- Exit gas temperature may limit % RAP

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RAP Fed into Weigh Hopper

- Balancing steam release difficult
- Tower typically ducted with butterfly damper to primary
- Over-drafting dryer helps balance air flow imbalance
- 25-30% maximum
- 10-15% practical

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RAP Fed into Weigh Hopper

- Watch build-up in duct and duct transition areas, especially horizontal ducts
- Monitor lowering of inlet baghouse temperature and H_2O condensation on bags
- These factors can limit RAP percentages possible

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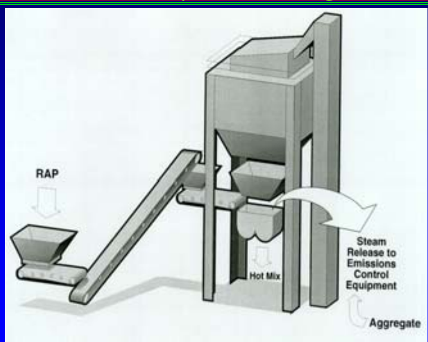
RAP Fed into a Bin which Discharges Directly into the Pugmill



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RAP Fed into Pugmill

- Separate RAP weigh hopper can be used
- Slightly shorter batch cycle time
- Chute, slinger or screw conveyor used to transport RAP from RAP hopper to pugmill

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Adding RAP into Pugmill

- Separate weigh hopper
- RAP added to pugmill
- Otherwise same as weigh bucket technique

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RAP Fed into Pugmill

- Shortens cycle times, increases production
- Ducting for steam release easier to fit to tower
- Balancing steam release easier – can draft continuous-can draft to dryer as option
- 20-25% easier to achieve (limited by heat transfer not steam management)

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RAP Fed into Pugmill

- Watch build-up in duct and duct transition areas
- DO NOT design duct too large or horizontal
- Attempt to design duct for downward flow
- DO NOT over-draft pugmill area during idle times (RAP not being produced)

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RAP Fed into Boot of Hot Elevator

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RAP Fed into Bucket Elevator

- Easier to fit to plant
- Steam management easy
- Trip up elevator short, and no agitation = low RAP %'s
- 10-20% possible
- 5-10% practical
- % impacted by whether using screens or not & size/screens

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RAP Fed into Bucket Elevator

- RAP will buildup in hot bins on side wall – requires cleanout
- Watch screen blinding
- Monitor tower for "sweating" – RAP not drying in elevator
- DO NOT push percentages too high (no agitation in drying RAP in bucket elevator)

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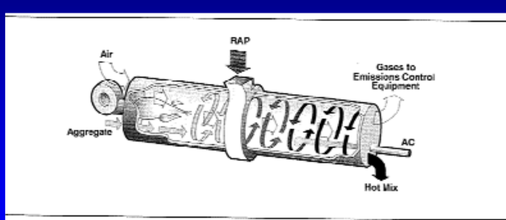
Drum Plants

- Plant Variations
  - Parallel-flow
    - Emissions limits RAP percent
  - Counter-flow
    - Can reduce gas emissions
    - RAP must be shielded from burner
- Practical RAP limit – 30 to 50%

RAP Feed to Parallel-Flow Drum Mixer



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Adding RAP Parallel Flow

- RAP collar most common
- RAP heated convectively
- Emissions limit RAP to 50 percent
- Variations
  - Isolated mixing area
  - External mixing device
- Primary dust collector usually added

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RAP Collar

- Aggregate heated convectively
- RAP heated convectively
- RAP added at mid-drum
- Emission requirements limit RAP percentage

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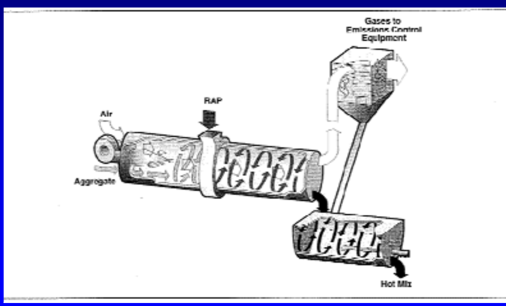
RAP Feed to Parallel-Flow Dryer and Continuous Mixer



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RAP Collar with Mixer

- RAP added at mid-drum
- Virgin binder added in mixer
  - Reduces hydrocarbons in gases
- Requires primary dust collector
  - Fines returned to mixer

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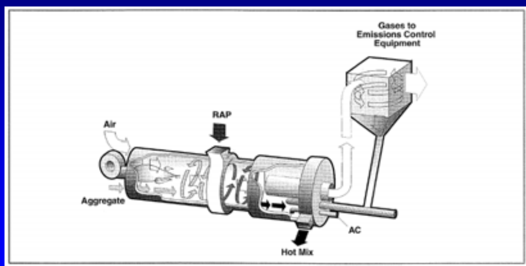
RAP Feed to Parallel-Flow Dryer with Isolated Mixing Area



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RAP Collar with Isolated Mixer

- Similar to separate mixer
- Mixer integral to dryer
- Convective RAP heating
- Requires primary dust collector
  - Fines returned to mixer

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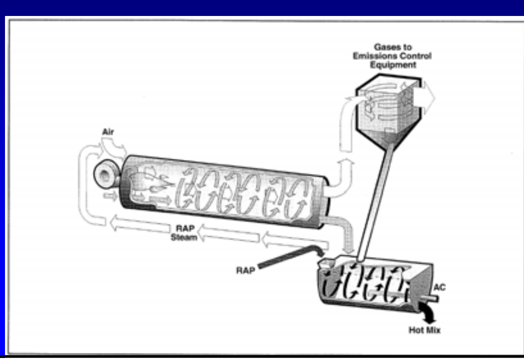
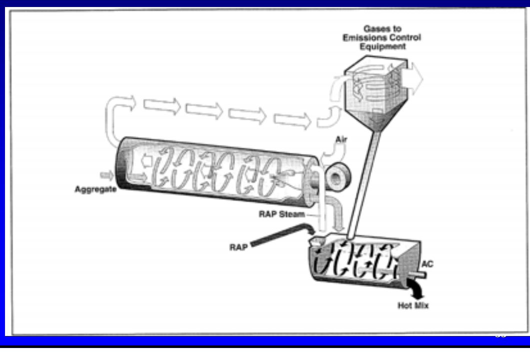
Parallel-Flow Dryer with RAP Feed to Continuous Mixer



Counter-Flow Dryer with RAP Feed to Continuous Mixer



Counter-Flow Dryer RAP in Mixer

- Counter-flow reduces gas exit temperatures
  - Cool, wet aggregates cool gas
- RAP heated conductively in mixer
- Percent RAP affected by mixing space
- Gases from mixer back to dryer

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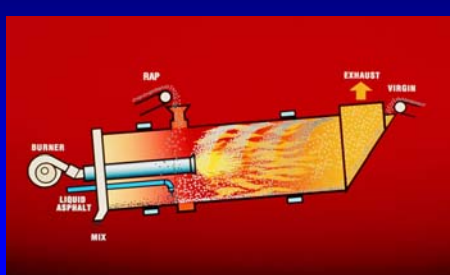
RAP Feed to Counter-Flow Drum Mixer



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Counter-Flow Mixer RAP Collar

- Burner extended into drum
- Virgin aggregate heated convectively
- RAP heated conductively
- Virgin binder added in mixing section
- Gasses in dryer

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Placement of Recycled HMA

- Potential for lower temperature production
- Less compaction time
- May be easier to compact than conventional HMA

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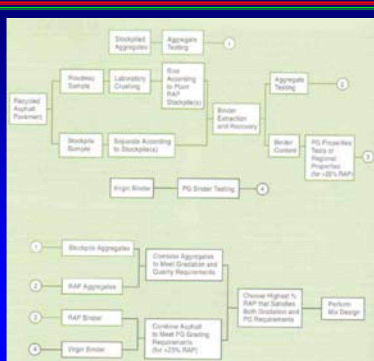
Materials Evaluation



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Mix Design

- Level 1
  - Small quantities of RAP (<10 to 15%)
- Level 2
  - Greater than approximately 15% RAP

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Virgin Asphalt Considerations (FHWA)

- 0 to 15% no change in binder grade
- 16 to 25% one temperature grade lower
- Greater than 25% use blending charts

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Level 1 Mix Design

- Gradation of RAP (asphalt free)
- Gradation of new aggregate
- Combined gradation
- Trial mix design

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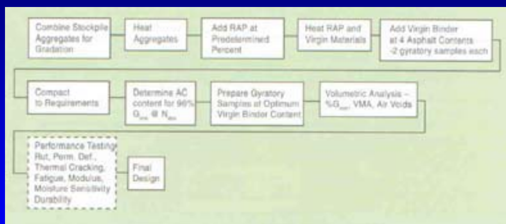
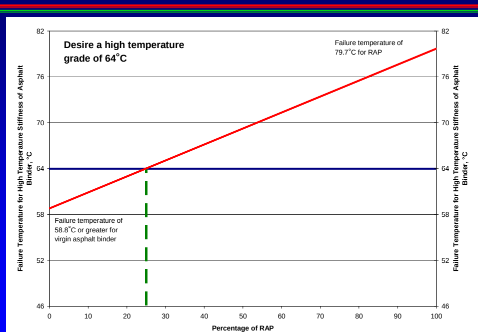
Mix Design Procedure

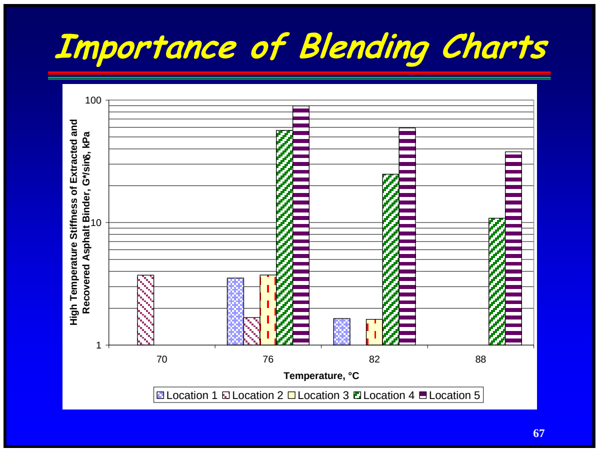


Level 2 Mix Design

- Level 1
- Plus binder grading & blending

Blending Charts





Importance of Blending Charts
100
10
1
High Temperature Stiffness of Extracted and Recovered Asphalt Binder, G*/sinδ, kPa
70
76
82
88
Temperature, °C
Location 1 Location 2 Location 3 Location 4 Location 5
67

What Happens During Mixing with RAP?
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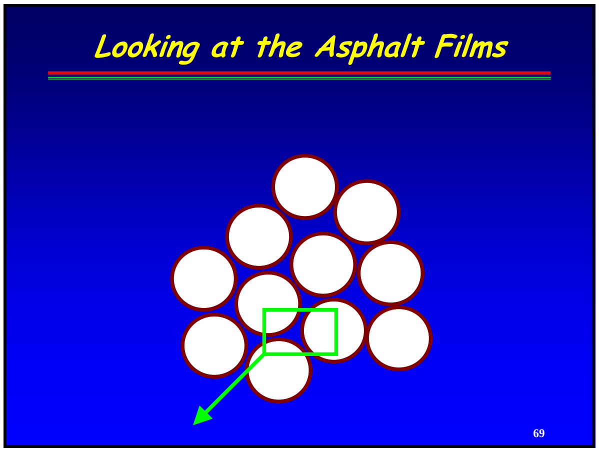

Looking at the Asphalt Films
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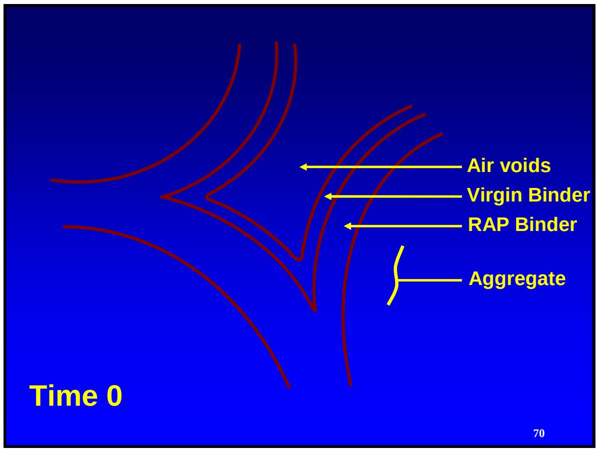
Air voids
Virgin Binder
RAP Binder
Aggregate
Time 0
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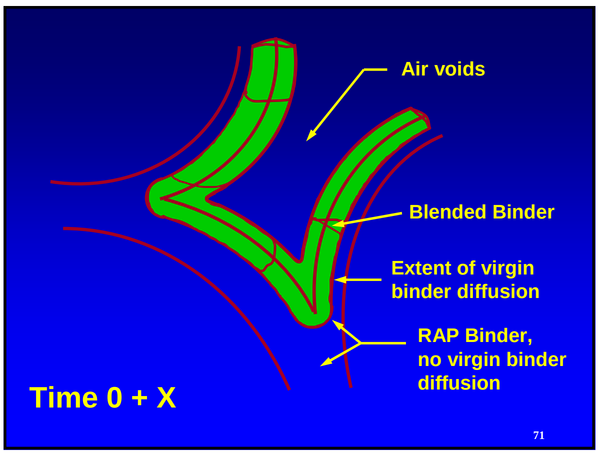
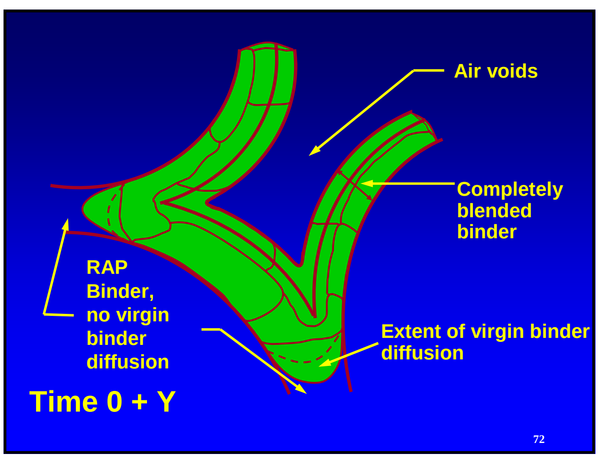
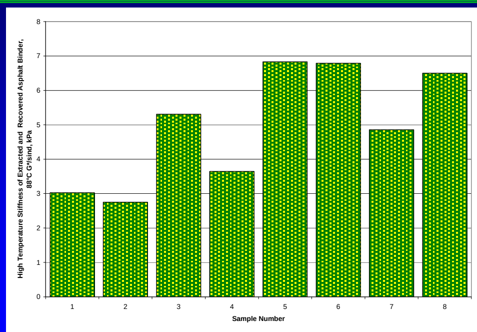

Air voids
Blended Binder
Extent of virgin binder diffusion
RAP Binder, no virgin binder diffusion
Time 0 + X
71


Air voids
Completely blended binder
RAP Binder, no virgin binder diffusion
Extent of virgin binder diffusion
Time 0 + Y
72

Importance of Material Variability



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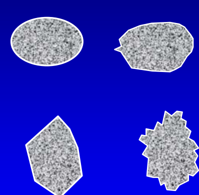
Aggregate Considerations

- Shape
- Surface texture
- Specific gravity
- Friction
- Other properties



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QC from RAP (Asphalt Free Gradations)

Test #	Reflux Asphalt Content, %DWA	3/4-in	1/2-in	3/8-in	No. 4	No. 16	No. 50	No. 200
1	3.25	100	98	89	66	48	27	12.3
2	3.52	100	99	91	70	42	23	10.9
3	3.93	100	100	96	74	46	26	11.8
4	3.83	100	98	92	74	45	22	8.6
5	3.79	100	98	92	73	45	25	11.7
6	3.05	100	98	91	66	39	22	11.4
7	3.31	100	97	90	68	41	23	11.3
8	3.47	100	98	91	72	44	24	10.4
Average	3.52	100	98	92	70	44	24	11.1
Standard Deviation	0.31	0.0	0.9	2.1	3.4	2.9	1.9	1.1

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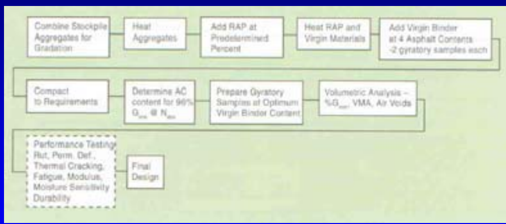
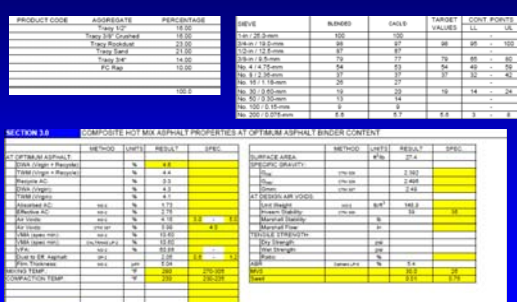
Mix Design Procedure



Mix Considerations

- Volumetrics
- Gradation
- Asphalt binder
- Engineering properties

Mix Considerations



PRODUCT CODE	AGGREGATE	PERCENTAGE
	Tracy 1/2"	16.00
	Tracy 3/8" Crushed	16.00
	Tracy Rockdust	23.00
	Tracy Sand	21.00
	Tracy 3/4"	14.00
	FC Rap	10.00
		100.0

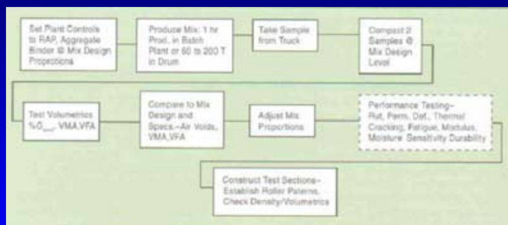
SIEVE	BLENDED	CALC'D	TARGET VALUES	CONT. POINTS LL		CONT. POINTS UL
1-in / 25.0-mm	100	100			-	
3/4-in / 19.0-mm	98	97	98	95	-	100
1/2-in / 12.5-mm	87	87			-	
3/8-in / 9.5-mm	79	77	79	65	-	80
No. 4 / 4.75-mm	54	53	54	49	-	59
No. 8 / 2.36-mm	37	37	37	32	-	42
No. 16 / 1.18-mm	26	27			-	
No. 30 / 0.60-mm	19	20	19	14	-	24
No. 50 / 0.30-mm	13	14			-	
No. 100 / 0.15-mm	9	9			-	
No. 200 / 0.075-mm	5.8	5.7	5.8	3	-	8

SECTION 3.0 COMPOSITE HOT MIX ASPHALT PROPERTIES AT OPTIMUM ASPHALT BINDER CONTENT

	METHOD	UNITS	RESULT	SPEC
AT OPTIMUM ASPHALT:				
DWA (Virgin + Recycle)		%	4.6	
TWM (Virgin + Recycle)		%	4.4	
Recycle AC		%	3.3	
DWA (Virgin)		%	4.3	
TWM (Virgin)		%	4.1	
Absorbed AC	[illegible]	%	1.73	
Effective AC	[illegible]	%	2.75	
Air Voids	[illegible]	%	4.16	3.0 - 5.0
Air Voids	[illegible]	%	3.98	4.0
VMA (spec min)	[illegible]	%	10.60	
VMA (spec min)	[illegible]	%	10.60	
VFA	[illegible]	%	60.68	-
Dust to Eff. Asphalt	[illegible]		2.05	0.6 - 1.2
Film Thickness	[illegible]	μm	5.04	
MIXING TEMP.		°F	280	270-305
COMPACTION TEMP.		°F	239	230-235

	METHOD	UNITS	RESULT	SPEC
SURFACE AREA		ft²/lb	27.4	
SPECIFIC GRAVITY:				
G_{mb}	[illegible]		2.392	
G_{se}	[illegible]		2.495	
Gmm	[illegible]		2.49	
AT DESIGN AIR VOIDS:				
Unit Weight	[illegible]	lb/ft³	149.3	
Hveem Stability	[illegible]		33	35
Marshall Stability		lb		
Marshall Flow		in		
TENSILE STRENGTH:				
Dry Strength		psi		
Wet Strength		psi		
Ratio		%		
ABR	[illegible]	%	5.4	
MVS			30.2	28
Swell			0.01	0.76

Plant Verification



Plant Verification

Date Sampled	Sample Location	Test Purpose	% Passing 3/4 in.	% Passing 1/2 in.	% Passing 3/8 in.	% Passing No. 4	% Passing No. 16	% Passing No. 50	% Passing No. 200	Asphalt Content %, DWA
Min Requirement			100	95	80	54			3.00	
Max Requirement			100	100	90	64			7.00	
Mix Design Targets			100	98	87	60	32	16	6.21	
4/9/2007	Hot Sample	Process	100.0	98.7	90.8	65.1	33.6	17.4	6.8	4.82
4/9/2007	Hot Sample	Process	100.0	98.8	87.5	59.5	30.0	15.3	6.1	4.80
4/10/2007	Hot Sample	Process	100.0	97.5	86.7	61.6	31.4	15.5	5.8	5.04
4/10/2007	Hot Sample	Process	100.0	97.9	89.7	65.5	31.5	15.2	5.6	5.07
4/11/2007	Hot Sample	Process	100.0	97.9	89.7	65.5	31.5	15.2	5.6	5.07
4/11/2007	Hot Sample	Process	100.0	98.4	89.3	63.8	32.9	15.8	6.5	5.09
4/12/2007	Hot Sample	Process	100.0	97.4	82.9	55.3	28.6	15.0	5.5	5.14
4/13/2007	Hot Sample	Process	100.0	100.0	92.0	66.7	33.3	16.5	6.1	4.80
4/16/2007	Hot Sample	Process	100.0	100.0	93.0	69.0	34.8	16.3	6.4	5.31
4/16/2007	Hot Sample	Process	100.0	100.0	96.1	67.5	34.0	17.0	6.4	
4/16/2007	Hot Sample	Process	100.0	100.0	88.6	62.0	34.9	18.3	7.1	
4/16/2007	Hot Sample	Process	100.0	98.6	90.5	64.9	38.6	21.5	9.4	
4/16/2007	Hot Sample	Process	100.0	97.1	85.3	57.4	30.0	15.4	5.4	5.01
4/17/2007	Hot Sample	Process	100.0	100.0	91.4	60.0	31.1	16.1	5.2	4.96
4/17/2007	Hot Sample	Process	100.0	97.2	86.1	59.7	31.8	17.1	6.8	5.19
4/17/2007	Hot Sample	Process	100.0	97.3	86.3	64.4	36.4	18.7	7.1	5.07
4/17/2007	Hot Sample	Process	100.0	96.7	86.7	60.0	31.1	16.3	6.3	4.77
4/17/2007	Hot Sample	Process	100.0	97.3	87.8	58.1	31.2	15.9	6.1	
Number			18	18	18	18	18	18	18	14
Mean			100.0	98.4	88.9	62.6	32.6	16.6	6.35	5.01
Standard Deviation			0.0	1.2	3.1	3.8	2.5	1.6	0.94	0.16

Performance

Hot Central Plant Recycling

RAP Field Performance

- Widespread use began in mid-1970's
- High RAP contents allowed by some agencies (>40%)
- Results in higher stabilities, but prone to longitudinal, transverse and reflective cracking
- Agencies applied conventional mix design policies to RAP designs

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Published Field Performance of RAP Mixtures

- Washington DOT
  - 24 recycled HMA pavements prior to 1985
  - RAP content: 8 to 79%
  - Performance was equivalent to conventional HMA
  - Predicted service life: 9 to 16 years
- Texas SPS-5 section
  - RAP content: 30%
  - Visual condition survey: 10 years after const.
  - No significant distresses

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Published Field Performance of RAP Mixtures

- Connecticut - Route 4
  - RAP content: 30%
  - Visual condition survey: 6 years after const.
  - No permanent deformation
  - Transverse cracking similar to conventional HMA
  - Longitudinal cracking greater than conventional HMA
- Louisiana DOT
  - 10 sections
  - RAP content: 25 to 20%
  - Visual condition survey: every year for 5 years
  - Comparable performance

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Published Field Performance of RAP Mixtures

- Kansas DOT – Reflective Cracking
  - RAP content: 50 to 70%
  - Visual condition survey: 3 years after const.
  - Comparable performance: <1% reflective cracking
- Utah DOT
  - 5 test sections
  - RAP content: 40 to 60%
  - Visual condition survey: 3 years after const.
  - Control section showed greater trans cracking than test sections

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Published Field Performance of RAP Mixtures

- Georgia
  - 5 test sections
  - RAP content: 15 to 25%
  - Visual condition survey: 2 years after const.
  - No difference in rutting, raveling and fatigue
- Kansas DOT – US 56
  - RAP content: 50%
  - Visual condition survey: 11 years after const.
  - More trans. and long. cracking than conventional HMA
  - 12 year service life

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Unpublished Field Performance of RAP Mixtures

- Arizona DOT
  - Mix designs based on conventional HMA designs
  - Considers recovered asphalt binder properties
- Florida DOT
  - Comparable performance
  - Established specs for sampling and controlling RAP
- Minnesota DOT
  - 1 test section: full depth AC
  - Comparable performance: 15 years

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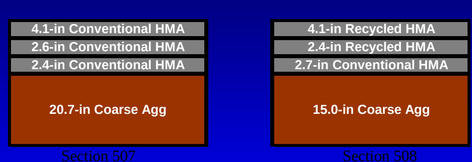
Unpublished Field Performance of RAP Mixtures

- Massachusetts DPW
  - 1 test section
  - RAP content: 35%
  - Visual condition survey: 11 years after const.
  - No trans, long, or reflective cracking
- New Jersey DOT
  - 1 test section
  - RAP content: 50%
  - Visual condition survey: 3 years after const.
  - Control section showed more significant reflective cracking

Performance – Arizona SPS-5

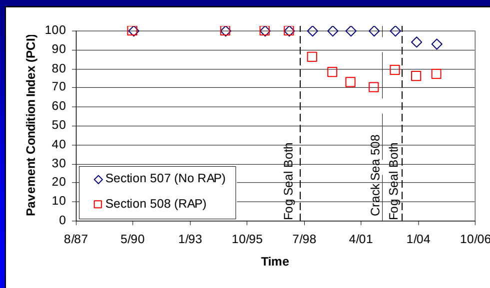
Section ID	Start of Section (m)	End of Section (m)	Section Length (m)	RAP Content (%)
04-0502	1597	1750	153	30
04-0503	469	622	153	30
04-0504	233	385	152	0
04-0505	2028	2180	152	0
04-0506	1884	1996	152	0
04-0507	0	152	152	0
04-0508	884	1036	152	30
04-0509	1165	1317	152	30

Performance – Arizona SPS-5



Performance – Arizona SPS-5

- PCI



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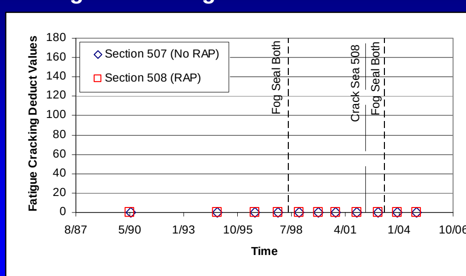
Performance – Arizona SPS-5

- Fatigue Cracking



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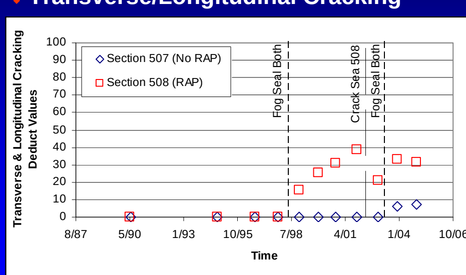
Performance – Arizona SPS-5

- Transverse/Longitudinal Cracking



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Performance – California SPS-5

Section ID	Start of Section (m)	End of Section (m)	Section Length (m)	RAP Content (%)
06-0506	1052	1204	152	0
06-0507	1281	1434	153	0
06-0508	1494	1647	153	30
06-0509	1727	1879	152	30
06-0559	7403	7708	305	0
06-0571	2652	2957	305	30

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Performance – California SPS-5

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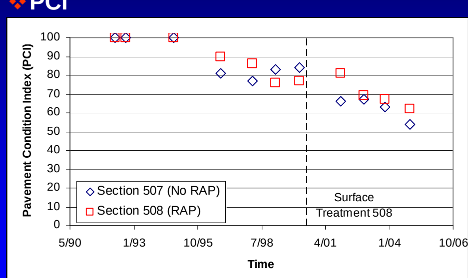
Performance – California SPS-5

- PCI



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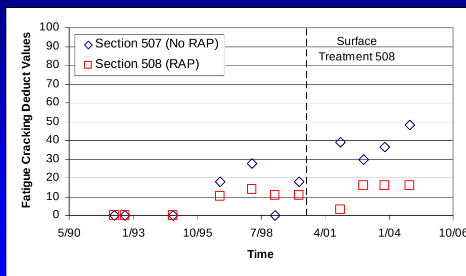
Performance – California SPS-5

- Fatigue Cracking



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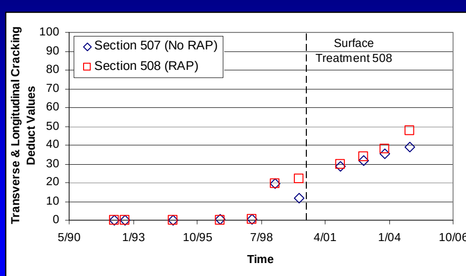
Performance – California SPS-5

- Transverse/Longitudinal Cracking



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Outline

- Recycling Background
- Hot Central Plant
- Cold In-Place
- Hot In-Place
- Life Cycle Cost Analysis

Cold in Place Recycle

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Cold In-Place Recycling: Advantages

- Significant Structural Improvements
- Most Pavement Distress Treated
- Ride Quality Improved
- Hauling Costs Minimized
- Minimal Air Quality Problems
- Pavement Widening Possible

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Partial vs. Full Depth

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Problem Areas

- Depth of removal
- Degree of pulverization
- Uniformity of mixing
- In-place density
- Curing
- Protection from traffic

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Tale of the Tape

Material	Energy, Btu/yd² in	Cost, $/yd² in	Estimated Service Life w/o Routine Maint, Yrs
HMA Asphalt Concrete	28,000	3.25	10
HMA Milling	1,500	0.45	
CIPR Cold In-Place Recycling – Full Depth	17,500	0.45	18
CIPR Cold In-Place Recycling – Partial Depth	17,500	0.90	11

GRANITE Recycling Group

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Outline

- Recycling Background
- Hot Central Plant
- Cold In-Place
- Hot In-Place
- Life Cycle Cost Analysis

Hot In-Place Recycling: Advantages

- Surface Cracks Eliminated
- Ruts, Shoves, Bumps Corrected
- Aged Asphalt is Rejuvenated
- Aggregate Gradation and Asphalt Content Can be Modified
- Reduced Traffic Interruption During Construction
- Hauling Cost Minimized

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Hot In-Place Recycling: Advantages

- Pavement Geometrics Preserved
- Corrects Surface Distresses Not Caused by Structural Inadequacy
- Can Modify Existing Surface Mix
- Can Improve Surface Frictional Resistance
- Relatively Cheap
- Needs Minimal Traffic Control

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Project Considerations

- Uniformity
- Depth of HMA
- Presence of Chip Seals
- Asphalt Content (Bleeding)
- Aggregate Gradation
- Asphalt Properties
- Traffic
- Type of Pavement Distress

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Project Considerations

- Modifiers or additives
- Mix design
- Sampling and testing

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Equipment Development and Typical Use

- Early concerns
  - In-place air voids
  - Overheating
  - Air quality
  - Safety
  - Depth
  - Production / cost
  - Vegetation

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Equipment Development and Typical Use

- Developments in the late 1980s, early 1990s
  - Greater depths
  - Uniformity and control
  - Air quality
  - Production

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HIR Processes

- Surface Recycling
- Repaving
- Remixing

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Two Stage Remixing

Tale of the Tape

Material	Energy, Btu/yd² in	Cost, $/yd² in	Estimated Service Life w/o Routine Maint, Yrs
HMA Asphalt Concrete	28,000	3.25	10
HMA Milling	1,500	0.45	
HIPR Hot In-Place Recycling – Remixing	20,000	2.10	10
HIPR Hot In-Place Recycling – Repaving	20,000	2.15	10
HIPR Hot In-Place Recycling – Surface Recycling	20,000	1.00	8

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Life Cycle Cost Analysis

- An economic analysis
- Compare design/rehabilitation alternatives
- Considers all significant costs
- Evaluates the alternatives over the same analysis period

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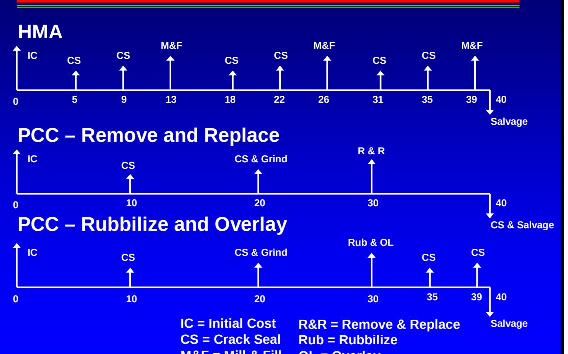
Significance of Life Cycle Cost



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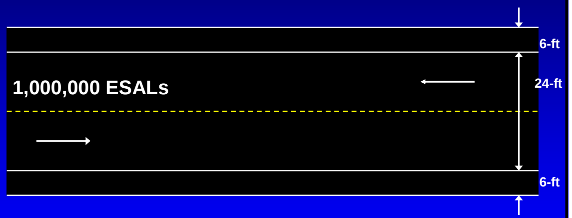
Scenario A - Hypothetical Roadway



Ex. collector roadways

Scenario A - Construction/Material Alternatives

Scenarios	Initial Rehabilitation	Rehabilitation	Year (s) of Rehab
A1	4.5-in Overlay	1.5-in Overlay	11 / 22 / 33
A2	2-in Mill/Fill 2.5-in Overlay	2-in Mill/Fill 1.5-in Overlay	14 / 28
A3	3-in CIPR – Partial Depth 4.5-in Overlay	1.5-in Overlay	14 / 28
A4	7-in CIPR – Full Depth 4-in Overlay	1.5-in Overlay	19 / 33
A5	2-in HIPR 2.75-in Overlay	1.5-in Overlay	16 / 30

Scenario A- Construction/Material Alts (per yd^{2*})

Scenarios	Energy for Initial Construction, BTU/yd^{2*}	Energy over 40 Years, BTU/yd^{2*}	Asphalt Binder Consumed, lbs/yd^{2*}	First Cost, $\$/yd^{2*}$	NPV 4.0, $\$/yd^{2*}$
A1 (Overlay)	126,000	278,200	0.017	14.63	25.11
A2 (Mill/Fill)	109,300	295,300	0.019	13.06	26.02
A3 (CIPR - Partial)	143,500	250,800	0.014	13.26	21.83
A4 (CIPR – Full)	234,500	340,600	0.017	16.15	22.71
A5 (HIPR)	103,700	209,800	0.012	11.80	19.47

Scenario A – Percent Savings (per yd²*)

Scenarios	Energy for Initial Construction % Savings, BTU/yd²*	Energy over 40 Years % Savings, BTU/yd²*	Asphalt Binder Consumed % Savings, lbs/yd²*	First Cost % Savings, $/yd²*	NPV 4.0 % Savings, $/yd²*
A1 (Overlay)	-	-	-	-	-
A2 (Mill/Fill)	13.25	(6.15)	(11.76)	10.73	(3.62)
A3 (CIPR - Partial)	(13.89)	9.85	17.65	9.36	13.06
A4 (CIPR – Full)	(86.11)	(22.43)	0.00	(10.39)	9.56
A5 (HIPR)	17.70	24.59	29.41	19.34	22.46

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Benefits Recycling Offers*

	Initial Construction**	Life Cycle of Pavement**
Cost savings	3 to 21%	4 to 19%
Asphalt Binder savings	3 to 40%	10 to 36%
Energy savings	8 to 21%	10 to 25%

*Percent reduction in comparison to conventional alternative
**Savings dependent upon recycling activity

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Questions

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