SUSTAINABILITY

- Conserving resources
- Reducing energy consumption
- Reducing Greenhouse Emissions
- Being environmentally friendly
- And building a better, longer-lasting pavement

WARM MIX IS THE FUTURE OF THE PAVING INDUSTRY.

How Does It Work?

All methods focus on lowering the viscosity (or apparent viscosity) of the liquid asphalt.

Lower viscosity enables working and compaction at temperatures 50^0F to 100^0F lower than conventional hot mix.

WARM MIX TECHNOLOGIES

Aspha-Min – Zeolite
Advera-PQ – Zeolite
WAM-Foam – Shell process using separate injections of a harder and a softer binder
Evotherm – "Chemical Package" plus Emulsion
Sasobit – FT Paraffin Wax
Asphaltan B – Natural Wax Found in Some Coal Deposits. (Not used in U.S.)
LEA (Low Energy Asphalt) – Anti-stripping agents plus technique of heating only coarse aggregate
ASTEC Double Barrel Green System – Foam Produced by water injection.

Aspha-Min

- **Product of Eurovia Services GmbH, Bottrop, Germany**
- **Synthetic Zeolite (Sodium Aluminum Silicate)**
- **Fine white powder available in bags or bulk**
- **Added at rate of 0.3% by mass of mix**
- **Open crystalline structure enables Zeolite to hold 21% water by mass.**
- **Water is release when Zeolite is exposed to temperatures of 185F to 360F.**
- **When Zeolite is added to the mixer simultaneously with the liquid AC, asphalt foam is produced.**

Advera - PQ

- Product of PQ Corporation, Malvern, PA
- Synthetic Zeolite (Sodium Aluminum Silicate)
- Same characteristics and performance as Aspha-min

WAM-Foam

- Product of joint venture between Shell and Kolo-Veidekke, Oslo, Norway.
- Two separate binder components are used.
- Soft binder is mixed with aggregate first.
- Hard binder is foamed by direct water injection added next.
- Shell says careful binder selection and complete coating with soft binder are keys to successful application.

Evotherm

- Product of MeadWestvaco Asphalt Innovations, Charleston, SC
- Chemical additive (tree sap based) and asphalt emulsion
- Chemical additive is added to the emulsion and then the resulting mixture is used in the place of the traditional asphalt binder.

Sasobit

- Product of Sasol Wax, South Africa
- A paraffin wax produced in the coal gasification process using the Fischer-Tropsch (FT) process.
- Supplied in bags as flakes or powder.
- Melting point is 210 F.
- Completely soluble in AC above 240 F.
- Added at rate of 0.8% to 3% by weight of binder by adding to liquid AC.
- Enables production temp. to be reduced by 18 F to 54 F.
- Reported to improve compactibility and rutting resistance.

Asphaltan B

- Product of Romonta GmbH, Amsdorf, Germany
- Derived from natural Montan wax found in certain lignite deposits found in Germany, Eastern Europe, and the USA.
- Available in Europe in Granular form in bags.
- Added at rate of 2 to 4% of the liquid AC.
- Performance is reported to be similar to Sasobit.

LEA (Low Energy Asphalt)

- A concept developed by a French Co., Fairco, that includes binder modifying proprietary additives.
- Only the coarse aggregate is heated. Fine aggregate is added to the mixing process in a cold and wet condition.
- A proprietary anti-stripping type additive is added to the binder.
- Mix can be produced at about 165 F.

ASTEC Double Barrel Green System

- Product of ASTEC, Inc., Chattanooga, TN
- Mechanical system that produces asphalt foam by injecting water directly into the liquid asphalt as the liquid enters the mixing process.
- Water is injected into the liquid asphalt at the rate of 2% of the asphalt.
- Water is retained in the liquid binder in the form of steam bubbles.
- Amount of water retained is approximately 0.1%.

For Detailed Reports on Some of These Technologies Go To:

http://www.eng.auburn.edu/center/ncat/reports

See reports: 05-04, 05-06, 06-02

Benefits of Warm Mix

- Requires less fuel to be burned
- Reduces emissions
  - Lower total emissions
  - Less blue smoke and odor (No capture system)
- Improves mix workability
- Improves Comfort & safety of workers
- Improves Pavements
- Extends resources via more recycle
- Increases Plant Capacity
- Allows quicker return to traffic
- Lengthens paving season
- Optimum AC content may be reduced.

Uses Less Fuel

- Additive providers report up to 50% fuel savings.
- We have seen fuel savings from 11% to 26%, depending upon the particular mix.
- The greatest fuel savings will be with those mixes that have been made hottest and that produced the highest baghouse temperatures. For instance, high RAP% mixes and open graded mixes.

No Smoke – No Smell…Why?

- Light oils are either put in asphalt or left in asphalt during refining
- These light oils boil above 285°F (140 C)
- By mixing at below 285°F (140 C), the boiling point is never reached… eliminating smoke (vapor) and corresponding smell

Reduced Fugitive Emissions

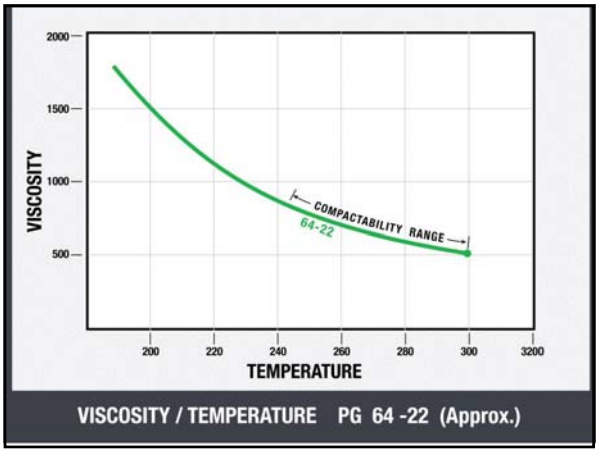
Volatile Organic Compounds (VOC)*

Mix Temperature (˚F)	Load-out Emissions (lb/yr)	Silo-filling Emissions (lb/yr)	% Reduction
325	2346	7312	
275	669	2084	71.5
260	459	1430	80.4

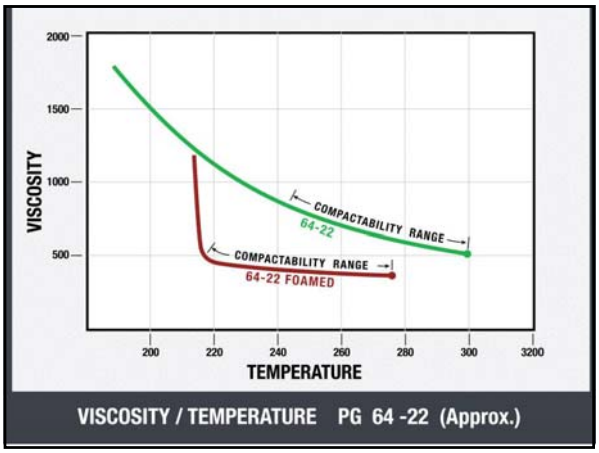
❖ Based upon a plant producing mix at 400TPH with a total yearly production of 600,000 tons

Reduces total emissions…Why?

- Producing mix at lower temperatures requires less fuel burning.
- The increased ability to use RAP decreases emissions associated with production of virgin materials.

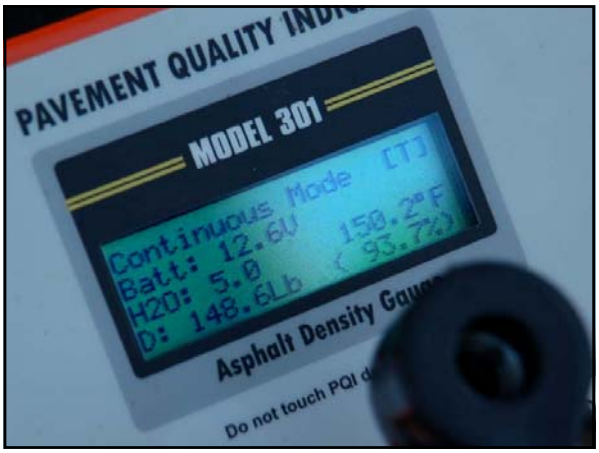


VISCOSITY / TEMPERATURE PG 64 -22 (Approx.)



VISCOSITY / TEMPERATURE PG 64 -22 (Approx.)


Compaction Takes Less Rolling Effort


PAVEMENT QUALITY
MODEL 301
Continuous Mode
Batt: 12.6V
H2O: 5.0
D: 148.6Lb
Asphalt Density


Improves Conditions
for Workers


NO SMOKE AT THE PAVER
COOLER WORKING CONDITIONS

Why will we have a Longer Life Pavement?

- Improves Compactibility
- Mix oxidizes less.
- Light oils remain in the mix.
- Mix shoves less during rolling.

ENHANCES RECYCLING

90 Million Tons of RAP Recovered Each Year.

High Percentage Recycle Mix

- **Two deterrents to running recycle above 20% have been:**
  - **High Stack Temperature**
  - **Need for a softer virgin liquid to ensure compaction because of the stiffer liquid in the RAP**

Make High Percentage Recycle Mix with Standard Grade of Asphalt

- **To achieve compaction (density)…run 275°F and foam virgin liquid**
- **By using a standard liquid 64-22, you produce a much softer product than with virgin mix because:**
  - **Lower temperature results in less oxidation**
  - **Light oil remains in liquid**
  - **Steam produced from drying the RAP creates an inert atmosphere**

Increases Plant Production Capacity

Lower Exhaust Gas Temperatures and Less Fuel Burned Takes Load Off of the Exhaust System.

Example:

A plant that makes 300 tph of 45% RAP HMA at 320 F will make 360 tph of WMA at 270 F.

DOUBLE BARREL GREEN

Double Barrel Green System

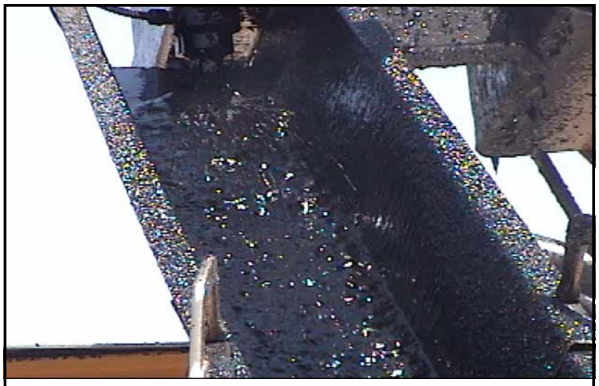
For Warm Mix, Just Add Water.

The Double Barrel Green System Injects Water Into Liquid Asphalt.

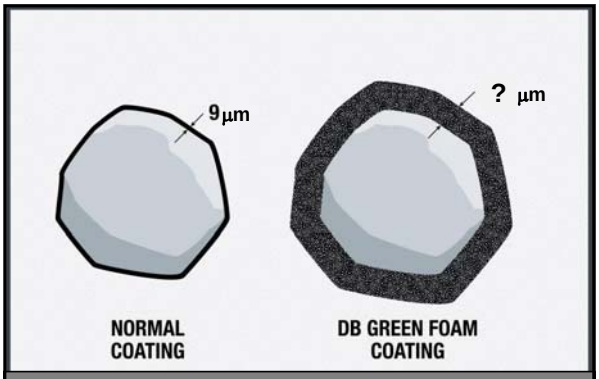
- Injected At The Rate Of 2% Of The Liquid Asphalt By Weight
  - 2 lbs. of water makes 1 ton of warm mix.
- Small Faction Of The Injected Water Becomes Trapped As Steam Bubbles In The Liquid Asphalt
- The Effect On The Mix Is To Extend The Workable Temperature Downward to about 212 F (100 C).

Double Barrel Green System

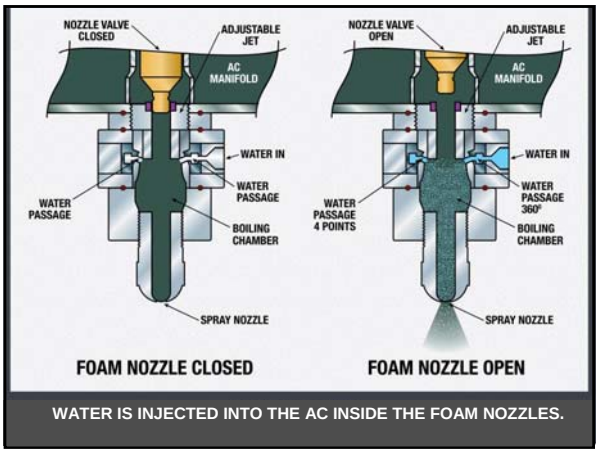
- Water Supply System
- Multi-Nozzle Foam Unit
- Control System



Steam Bubbles Produce Foamed AC.



FOAM EXPANDS THE LIQUID ASPHALT AND INCREASES FILM THICKNESS

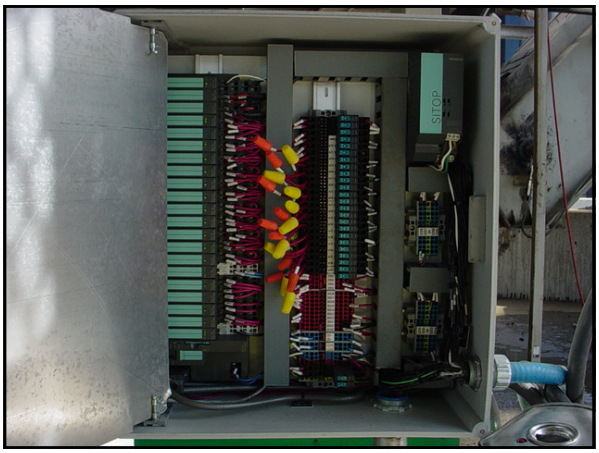


WATER IS INJECTED INTO THE AC INSIDE THE FOAM NOZZLES.

THE HEART OF THE SYSTEM IS A MULTI-NOZZLE MANIFOLD ASSEMBLY WITH ONE NOZZLE FOR EVERY 50 TPH OF PLANT CAPACITY.

THE SYSTEM CONSISTS OF:

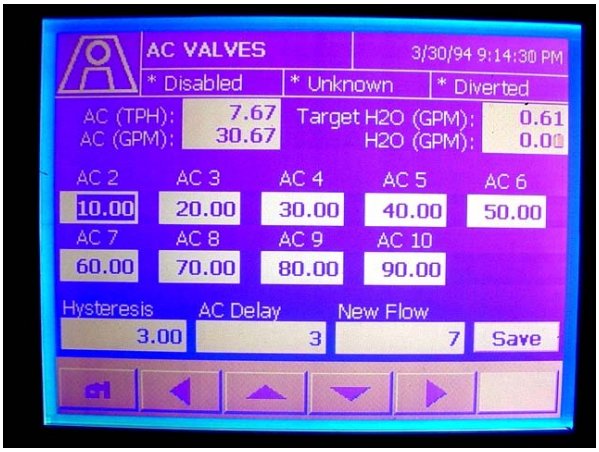
WATER TANK AND CONTROL SKID.....

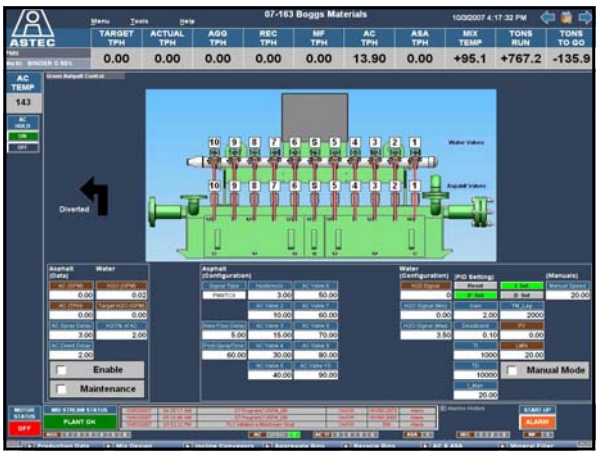


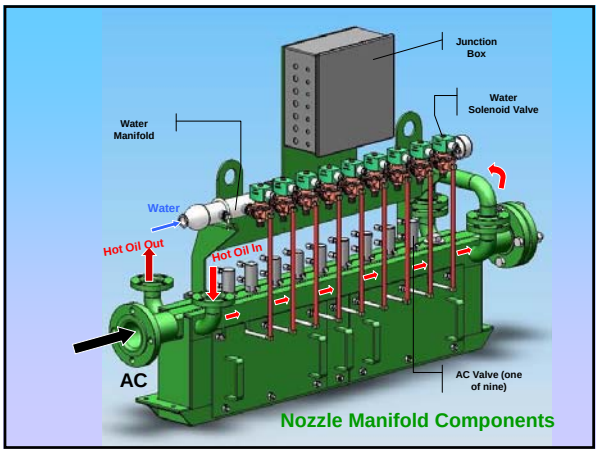

FOAM UNIT MOUNTED
ON THE DOUBLE BARREL
MIXING CHAMBER

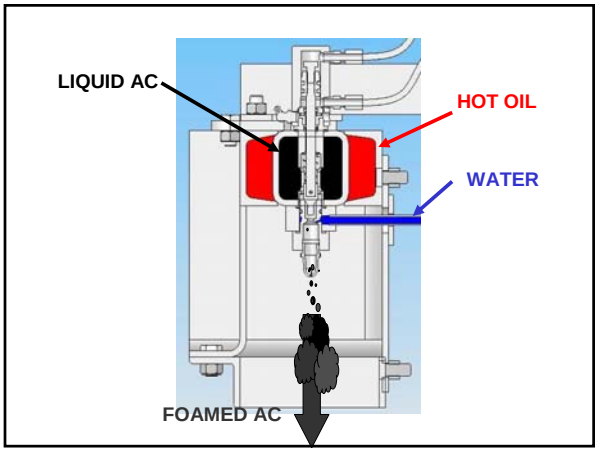

DOUBLE
BARREL
GREEN

CONTROL SYSTEM









Two Case Studies

Done by Dr. Ray Brown and Dr. Andrea Kvasnak of NCAT

Case Study 1

Completed April 18, 2007

- Three foam mixes (2% H2O to AC):
  1. Base, 30% RAP
  2. Surface Coarse, virgin aggregate
  3. Surface Coarse, 30% RAP
- Two locations at Astec HQ
- Samples taken and tested by National Center for Asphalt Technology (NCAT)

Field Observations: Case 1

- **Temperature**
  - **Virgin mix 250 F**
  - **RAP mix 270 F**
- **Coating**
- **Emissions**
- **Workability**

ASTEC PARKING LOT

RAMPS AND STREET IN FRONT OF ASTEC SHOP

Laboratory Testing Case 1

- Moisture Susceptibility
  - TSR (Tensile strength ratio)
  - Stripping via Hamburg Wheel Tracking Device
- Rutting
  - APA (Asphalt pavement analyzer)
  - Hamburg (HWTD)
- Asphalt Content
  - Ignition oven
- Gradation

Average Gradation of Foamed Asphalt Mixes (Case 1)

Sieve Size	Average Percent Passing for Virgin Surface Mix	Average Percent Passing for 30% RAP Surface Mix	Average Percent Passing for 30% RAP Base Mix
1in	100	100	100
¾ in.	100	100	98
½ in.	100	100	74
3/8 in.	99	97	60
No. 4	73	75	41
No. 8	48	47	29
No. 16	30	31	20
No. 30	21	23	15
No. 50	16	18	12
No. 100	13	15	10
No. 200	10.5	11.6	8.5

Testing Results Case 1

Asphalt Content

Mix	Sample 1	Sample 2	Average
Virgin Surface Course	5.7%	5.8%	5.7%
30% RAP Surface Course	5.7%	5.4%	5.4%
30% RAP Base Course	4.5%	4.5%	4.5%

Theoretical Maximum Specific Gravity

Virgin Surface Course	30% RAP Surface Course	30% RAP Base Course
2.562	2.555	2.586

Air Voids Contents of Field Lab Compacted with 75 Gyrations

Virgin Surface Course	30% RAP Surface Course	30% RAP Base Course
3.3	2.7	5.6
3.4	2.6	3.1
3.2	2.7	4.7
3.4	2.8	3.3
3.1	2.7	3.5
3.2	2.5	4.3

Air Voids Contents of Cores Removed from In-Place Mixtures

Virgin Surface Course	30% RAP Surface Course	30% RAP Base Course
7.2	8.5	4.0
10.5	9.6	8.0
7.7	6.7	8.1
-----	5.3	4.0

Air Voids Contents of 95 mm Specimens Compacted at NCAT Lab

Virgin Surface Course	30% RAP Surface Course	30% RAP Base Course
7.2	7.5	6.1
7.4	7.2	7.1
7.5	7.5	6.8
7.2	7.2	6.7
6.8	7.3	6.8

Moisture Susceptibility Case 1

Mix	Condition	Air Voids	Failure Load (lbs)	Tensile Strength (psi)	Tensile Strength Ratio
Virgin Surface Course	Unconditioned	7.5	3563	102.2	93%
		7.2	3423	98.2	
	Conditioned	7.5	3476	99.7	
		7.2	3246	93.1	
		7.3	2993	85.8	
30% RAP Surface Course	Unconditioned	6.1	4470	128.2	58%
		7.1	4439	127.3	
	Conditioned	6.8	2670	76.6	
		6.7	2648	75.9	
		6.8	2480	71.1	
30% RAP Base Course	Unconditioned	7.2	3907	112	92%
		7.4	4176	119.8	
	Conditioned	7.5	3845	110.3	
		7.2	3701	106.1	
		6.8	3554	101.9	

Hamburg and APA Results Case 1

Hamburg Wheel Tracking Device

Mix	Air Voids	Rutting Rate (mm)	Total Rutting @ 10,000 Cycles (mm)	Stripping Inflection Point (cycles)	Average Rutting Rate (mm)	Average Total Rutting @ 10,000 Cycles (mm)	Average Stripping Inflection Point (cycles)
Virgin Surface	4.1	5.0	20	4200	4.1	16	4850
	3.2	3.2	13	5500			
30% RAP Surface Course	3.4	1.2	5	7750	2.0	8	7475
	2.8	2.8	11	7200			
30% RAP Base Course	5.9	1.5	6	7800	1.5	6	7800

Asphalt Pavement Analyzer

Mix	Air Voids	Rut Depth (mm)	Average Rut Depth (mm)
Virgin Surface Course	7.2	9.4	10.4
	10.5	12.1	
	7.7	9.6	
30% RAP Surface Course	8.5	7.1	8.5
	9.6	9.2	
	6.7	11.6	
	5.3	6.1	
30% RAP Base Course	4.0	3.2	4.9
	8.0	4.4	
	8.1	7.0	
	4.0	4.9	

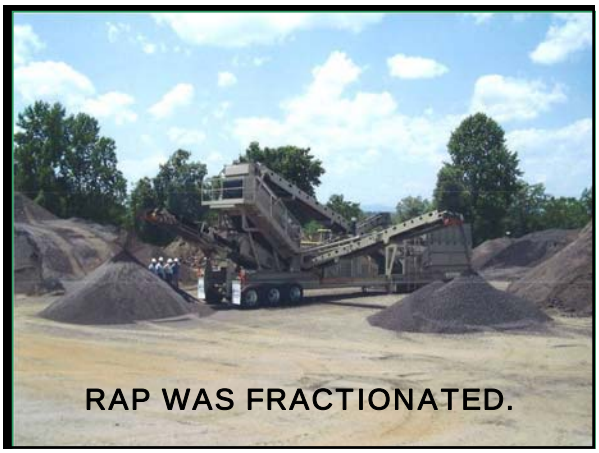
Case 1 NCAT Conclusions

- **No apparent issues with workability**
- **Mix uniformly mixed and coated**
- **Mixes reasonably resistant to rutting**
  - **Base best**
  - **Virgin worst**
- **Marginally moisture resistant**
  - **Similar results in other studies**
  - **Aged asphalt tends to be more resistant**
- **Potential for use especially with high content RAP mixes**

Case Study 2

Completed June 21, 2007

- 50% RAP and PG 64-22 binder
- 3400 ton job
- Location: North Terrace Rd, Chattanooga, Tennessee
- Samples taken and tested by National Center for Asphalt Technology (NCAT)



RAP WAS FRACTIONATED.

Field Observations: Case 2

50% RAP mix made at 270 F:

- Good Coating
- No smoke
- No odor
- Good workability

Case 2 NCAT Conclusions

- **Good workability**
- **Rutting resistance good**
- **Marginal moisture susceptibility (add anti-strip agent)**
- **Lower than desired density – likely related to compaction process**
- **Air voids slightly high (increase AC)**

Summary Conclusions of Cases 1 and 2

1.Coating and mixing of the warm mixes were equivalent to that expected for conventional hot mixes.

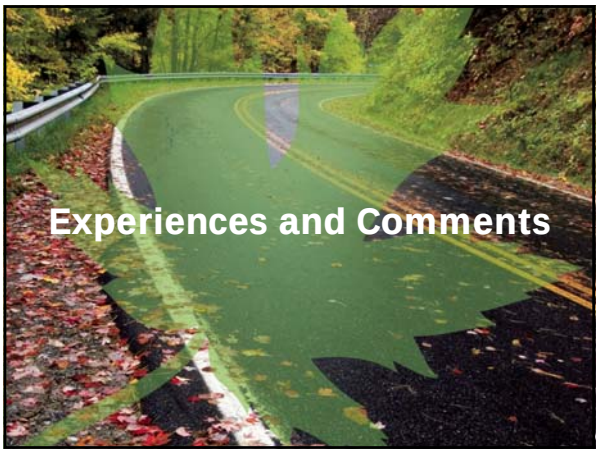
2.Workability of the warm mix at 250 F (121 C) to 270 F (132 C) was similar to that of hot mix at temperatures above 300 F (150 C).

cont'd

Summary (cont'd)

3. There was no smoke.

4. There was evidence that the warm mix was susceptible to stripping. This has been a characteristic of warm mix in general. One reason could be that the binder is not aged during mixing. Potential solutions include using a harder AC or an anti-strip agent.



Partial List of Double Barrel Green System Experience

- Southeastern Materials / City of Chattanooga, 3400 tons 50% RAP
- Columbia Bit. (Vancouver), 100tons Virgin.
- S.T. Wooten (Sims), 400tons, 20% and 40%
- S.T. Wooten (Sims), 400tons, 40%
- LoJac (Nashville), 1200tons, Virgin
- Shelly Materials (Columbus), 14,000 tons, 25%
- Boggs Materials (Rock Hill), 12,000 tons, 50%
- Columbia Bit. (Vancouver), 1,500 tons, 50%
- LoJac (Nashville), 500tons, 40%

7-26-07 to 7-28-07 Storage Test

- Approximately 50 tons of mix made at 300 tph with 20% RAP at 138 C.
- Stored for 24 hours and checked – All normal
- Few tons of mix sold to a private customer. No problems. Mix behaved normally.
- Stored for another 24 hours (48 total) and emptied– all normal.

Why mix at 270-275°F vs. 240°F?

- Culture of paving crews
- State specifications
- More time to cool

ROLLING

Achieves Density with less effort.

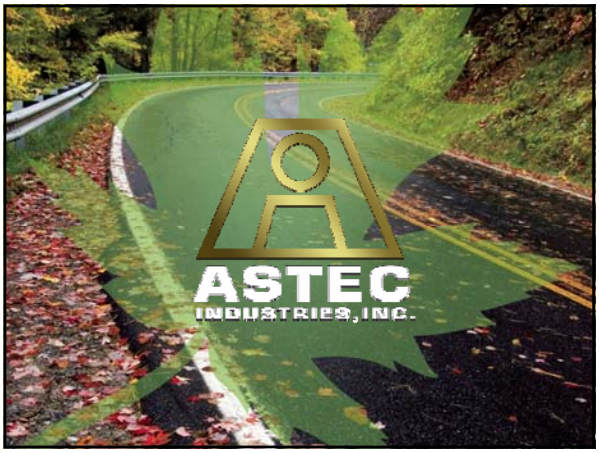
No roller marks.

Some Issues To Address

- Low Baghouse Temperature May Be a Problem with Some Virgin Mixes.
- Cost – Additives cost $2.50 to $4.00 per ton of mix, for those techniques that involve additives.

Common Questions:

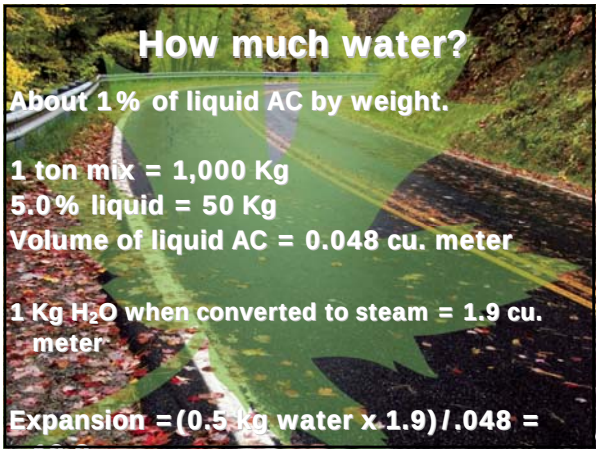
- Can the Double Barrel Green System be retrofitted to existing plants?
- Can the Double Barrel Green System be applied to other plant types?
- Does warm mix cool faster than conventional HMA?
- Is haul distance shortened?
- Does it make sense to be putting water into the mix after preaching for years to “Get it all out”?
- Does the Double Barrel Green System warm mix work with polymers?
- How will silicone affect it?
- How are mix designs affected?

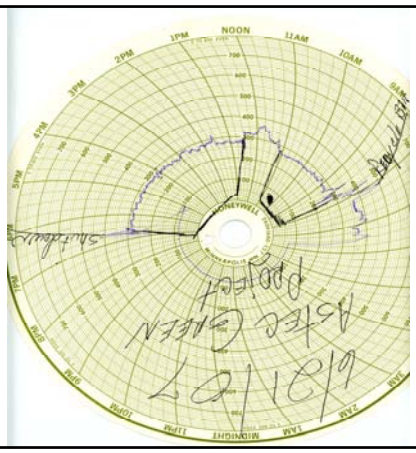


How much water ?

Astec Multi-Nozzle Foam Unit

- Mixes water and AC to create microscopic steam bubbles to foam the AC
- Water flow rate = 2% of AC flow rate
- 2.5 TPH AC per nozzle, 8 nozzles = 400 TPH mix
- PLC controlled
- Mix transported, placed and compacted using normal procedures





Reduced Emissions

Volatile Organic Compounds (VOC)*

Mix Temperature (˚C)	Load-out Emissions (kg/yr)	Silo-filling Emissions (kg/yr)	% Reduction
163	1066	3324	
135	304	947	71.5
127	209	650	80.4

* Based upon a plant producing mix at 400TPH with a total yearly production of 600,000 tons

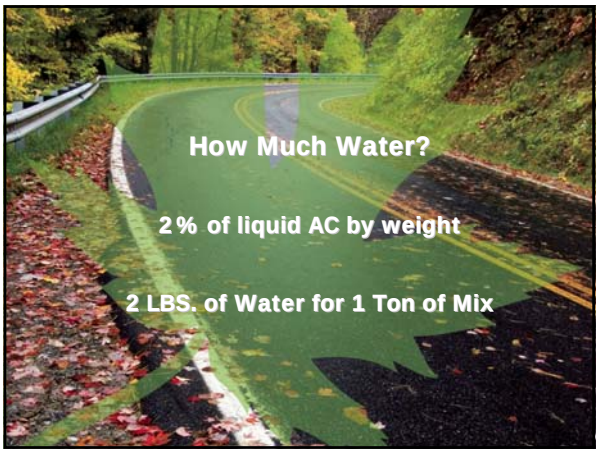
How much water?

About 1% of liquid AC by weight.

1 ton mix – 2,000 lb.
5.3% liquid – 106 lb.
Volume of liquid – 1.63 cu. ft.

1 lb. H_2O when converted to steam = 30 cu. ft.

Expansion – $\frac{30}{1.63}$ = 18


How Much Water?
2% of liquid AC by weight
2 LBS. of Water for 1 Ton of Mix


Why mix at 132 C vs. 121 C ?
• Culture of paving crews
• State specifications
• More time to cool