



The Green Pavement





Rutting Often Occurs in Older Overlay Pavements





End of Load Segregation



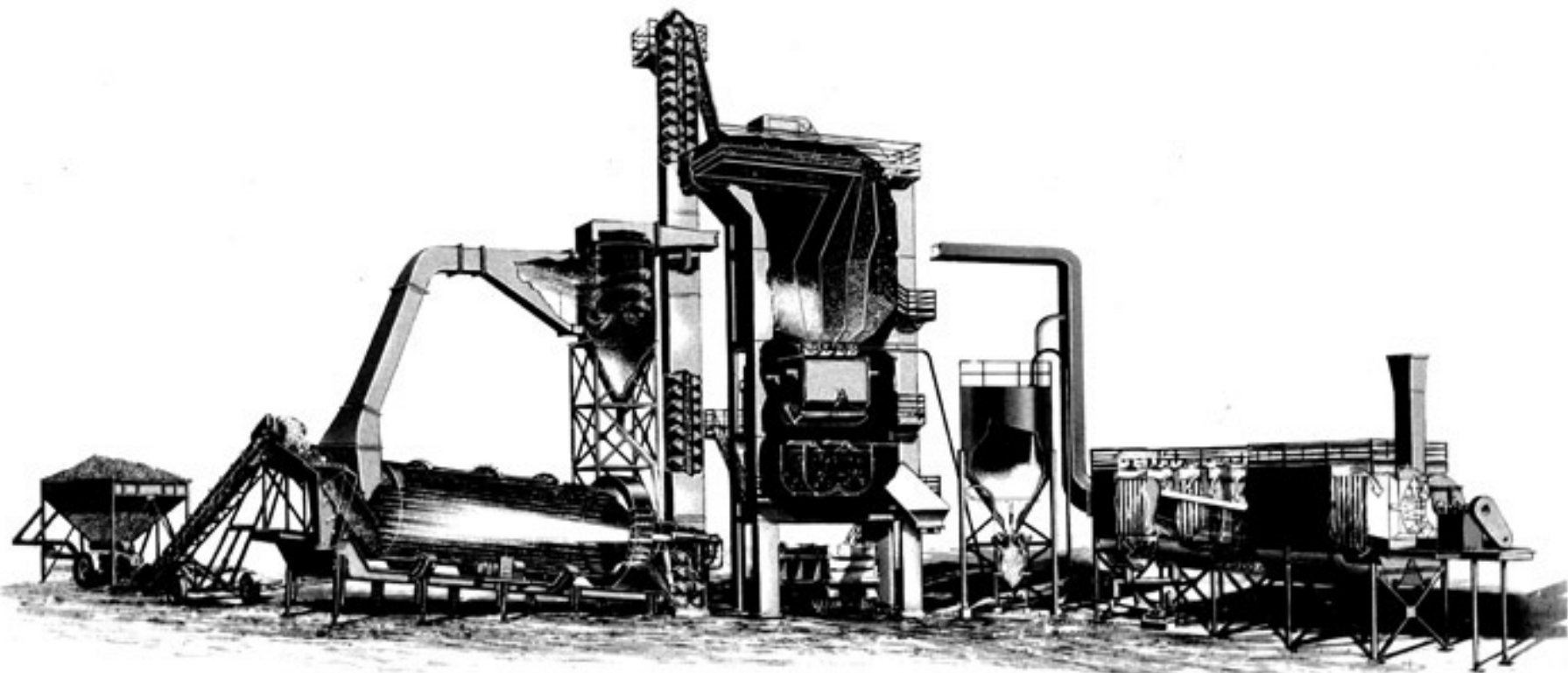
Rock Quarry

Barriers to increasing the use of more Recycle

- Meeting voids & asphalt content with Superpave Mix Design
- Meeting skid requirements
- Hardness of asphalt with high RAP - need to use softer virgin asphalt cement...fatigue cracking
- Special mixes like SMA
- Limit RAP to 15% when polymers are used

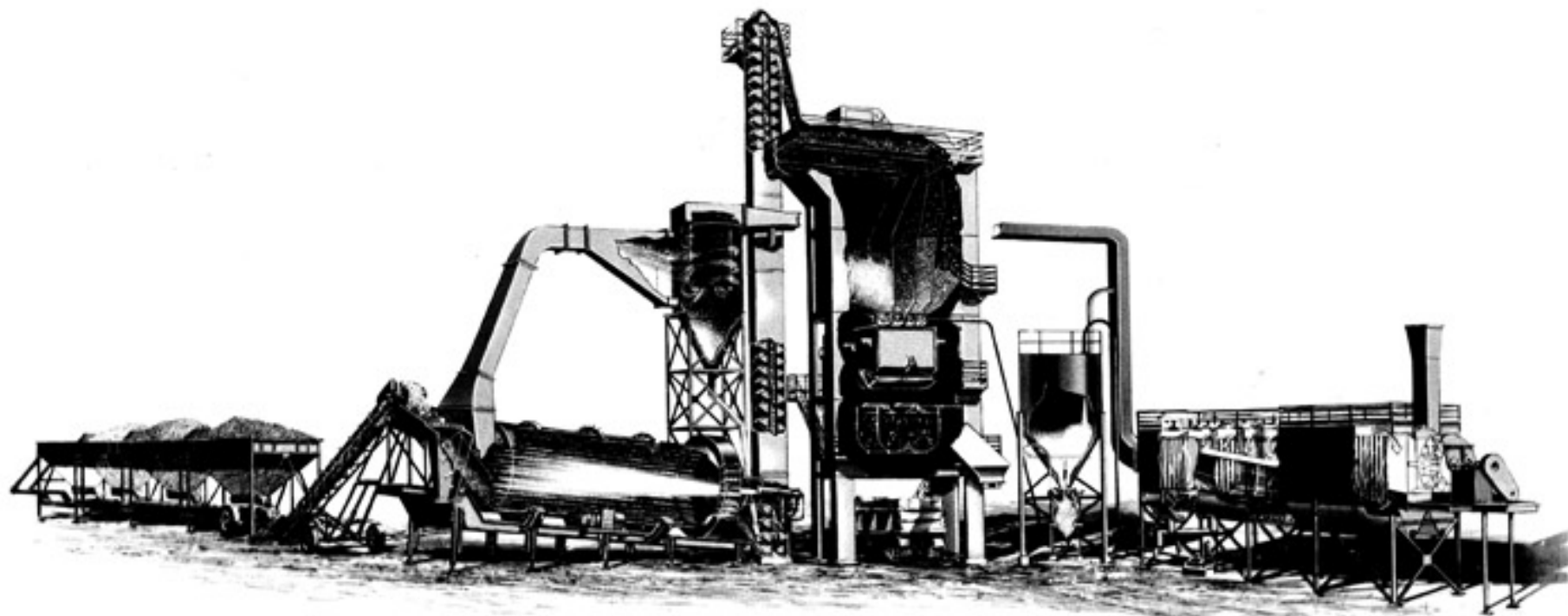
Meeting Superpave Mix Design requirements

**Controlling Air Voids and Asphalt Content
= Controlling Segregation**



BATCH PLANT
ONE BIN COLD FEED





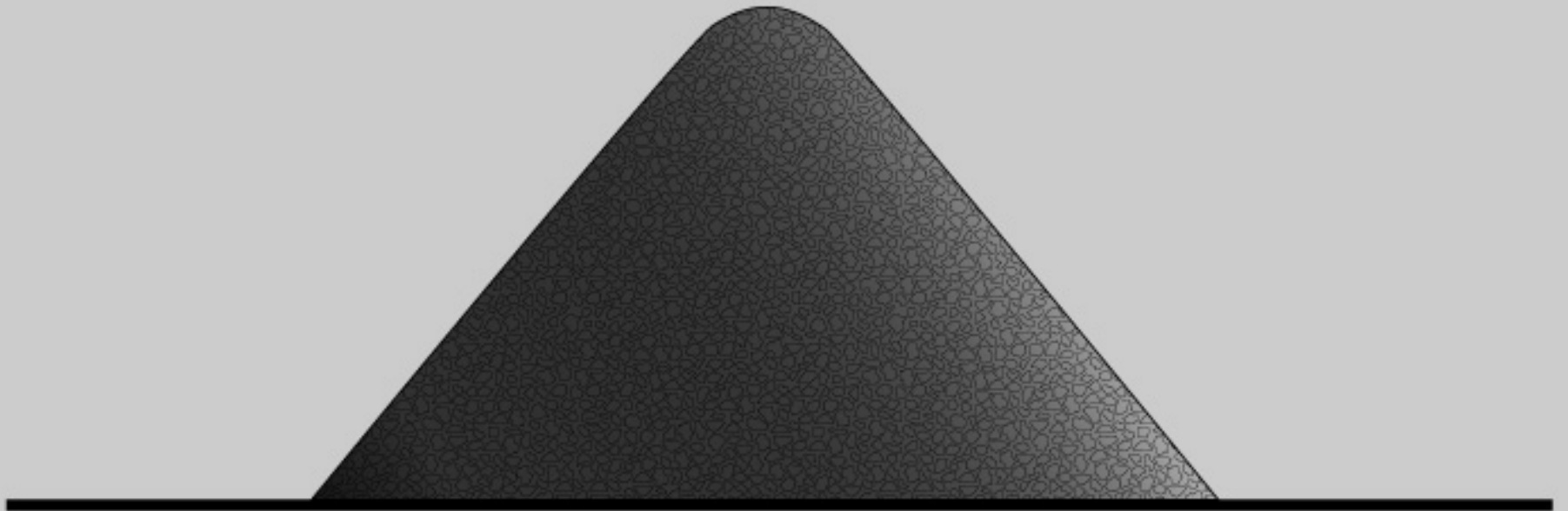
BATCH PLANT
FOUR BIN COLD FEED





Full-Lane Milling Machine

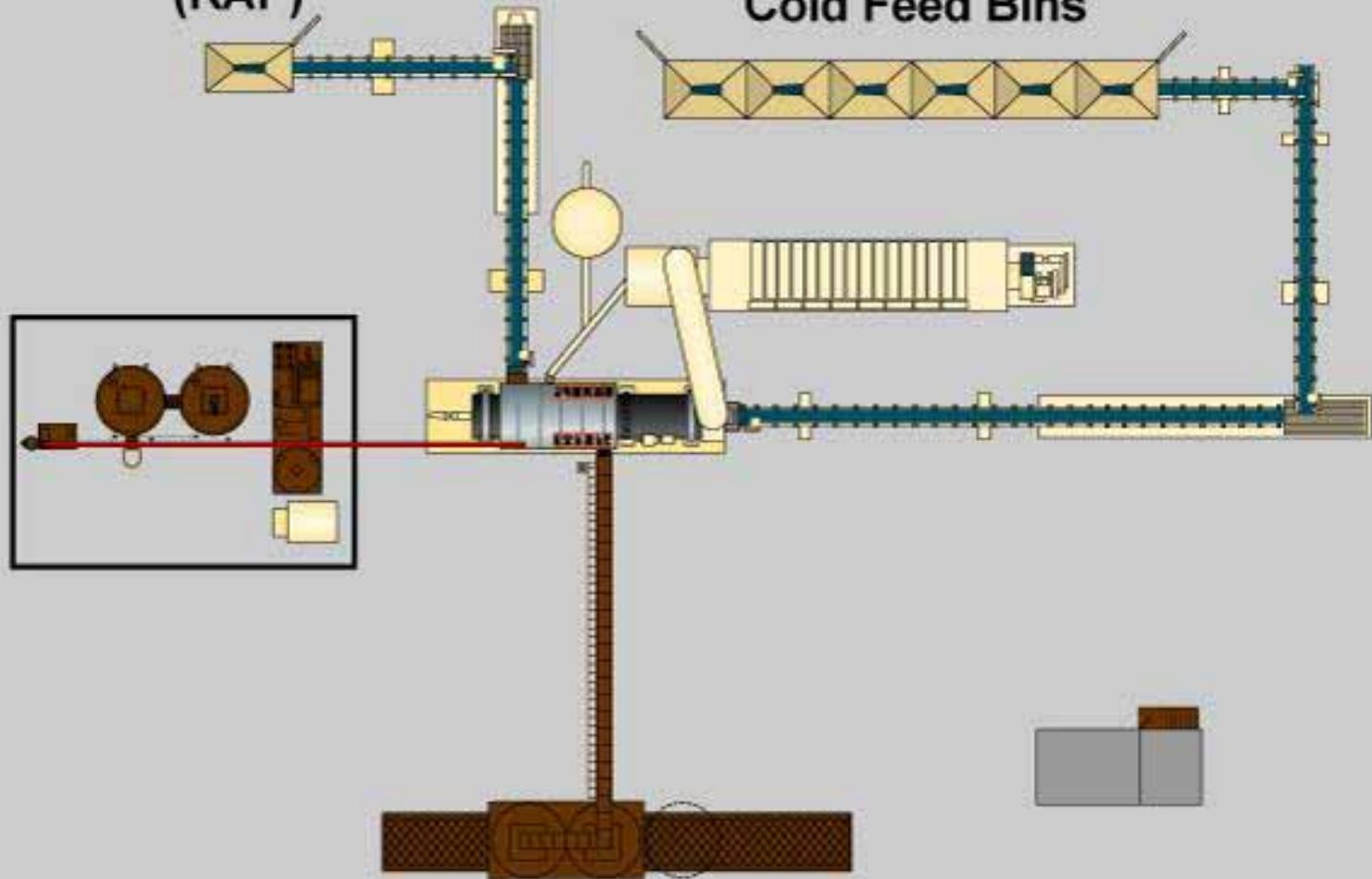
Reclaimed Asphalt Pavement
(RAP)



RAP Pile With 1/2" Minus to 3/4" Minus Aggregate

Reclaimed Asphalt Pavement Bin
(RAP)

Cold Feed Bins



1980-1990's HMA Facility with Single RAP Bin

White Rock
3/8 - 4

RAP
1/2 - 0

White Rock
4-0

White Rock
1/2 - 3/8

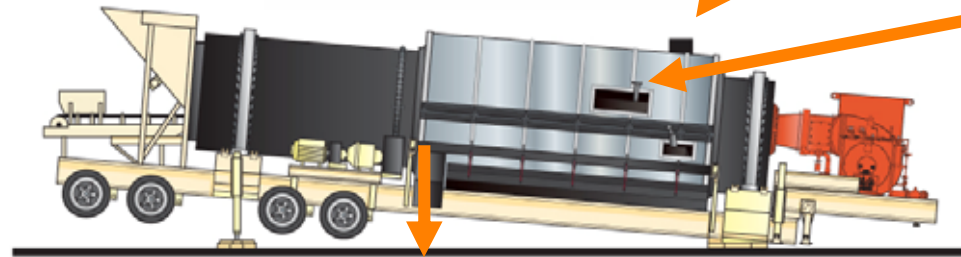
C%

A%

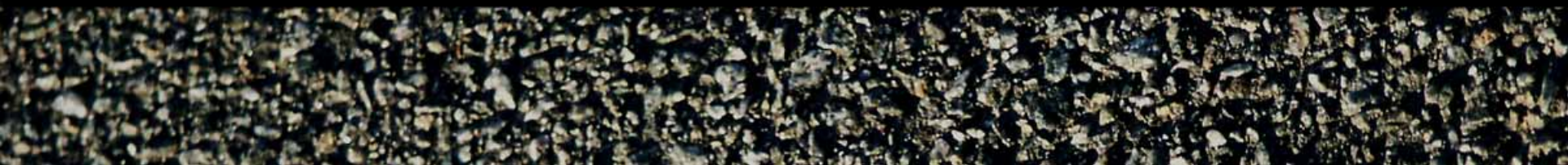
AA%

B%

X%



SUPERPAVE MIX WITH 1/2 RAP





1/2 x 0 (12mm x 0)

6% AC



1/2 x 4 (12mm x 6mm)

4% AC



4 x 0 (6mm x 0)

7% AC

Surface Area

- 1 lb. of 3/8" (9mm) Aggregate = 1 sq. ft.**
- 1 lb. of -200 mesh = 150 sq. ft.**

Liquid Asphalt coats Surface Area

@ 20% RAP Coarse AC Contribution to Mix

$$= 0.20 \times 4\% = 0.8\%$$

Fine AC Contribution to Mix

$$= 0.20 \times 7\% = 1.4\%$$



0.6%

@ 40% RAP Coarse AC Contribution to Mix

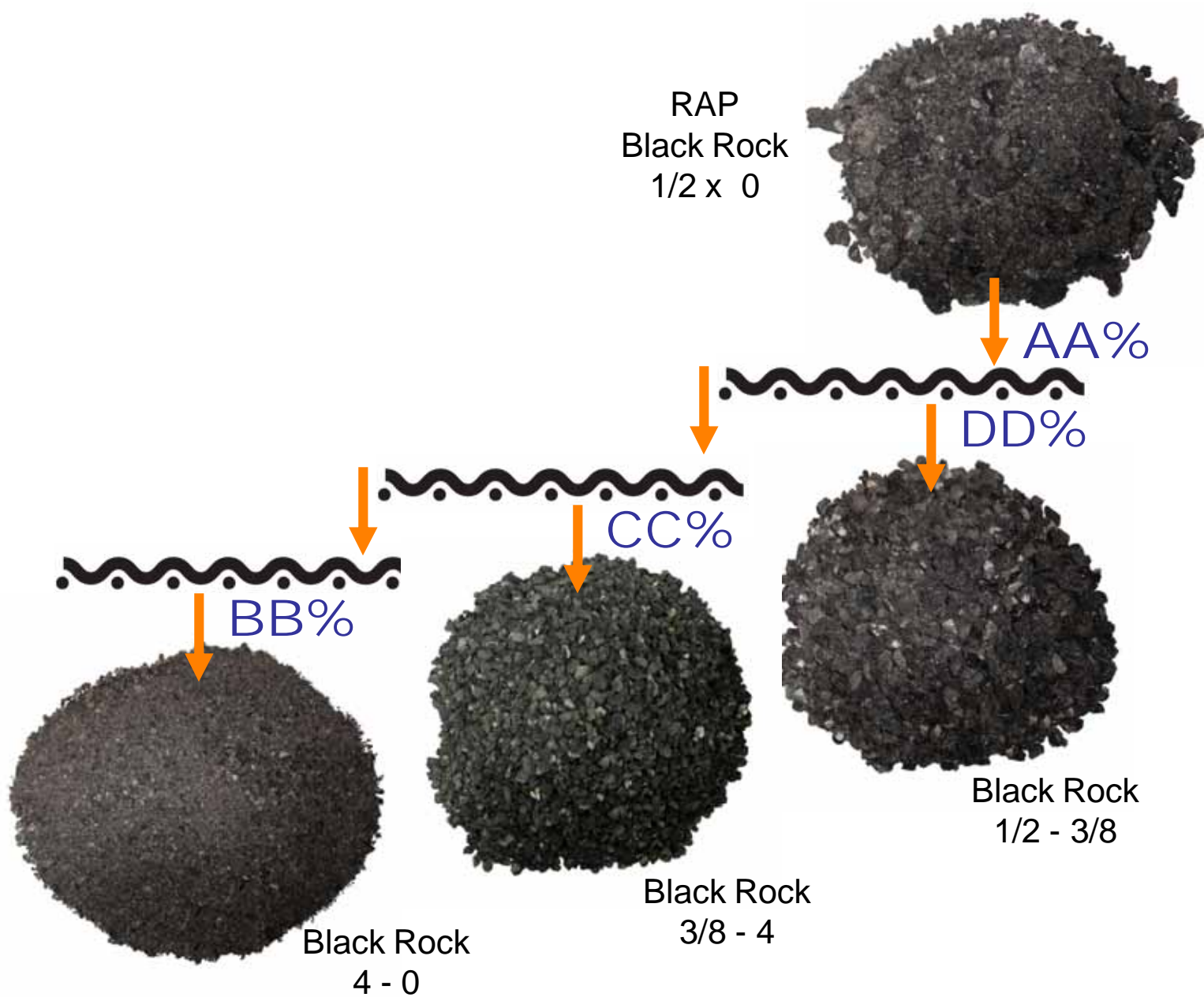
$$= 0.40 \times 4\% = 1.6\%$$

Fine AC Contribution to Mix

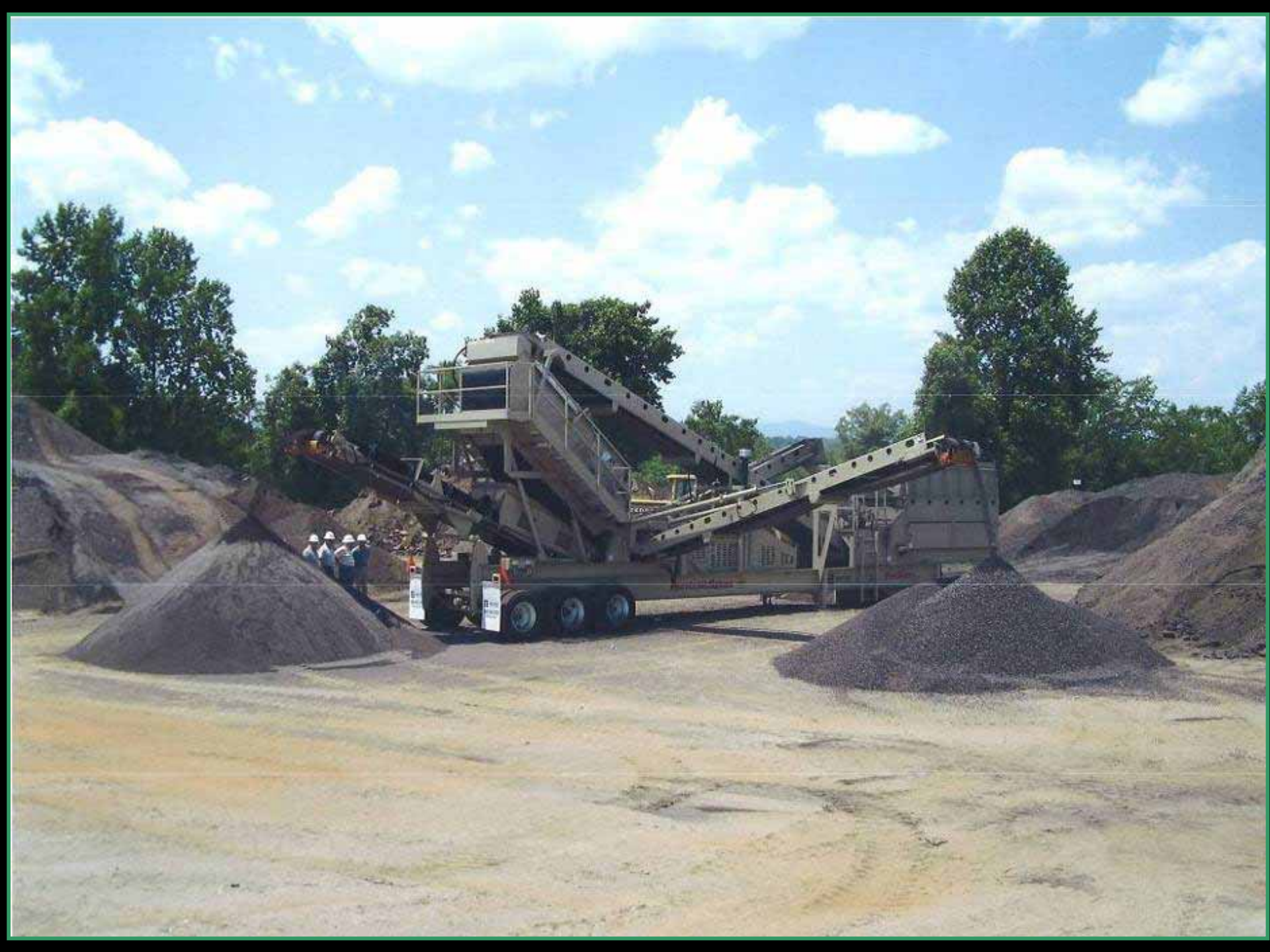
$$= 0.40 \times 7\% = 2.8\%$$



1.2%



PROCESSED RAP SCREENED TO ORIGINAL INGREDIENTS









2007 6 7

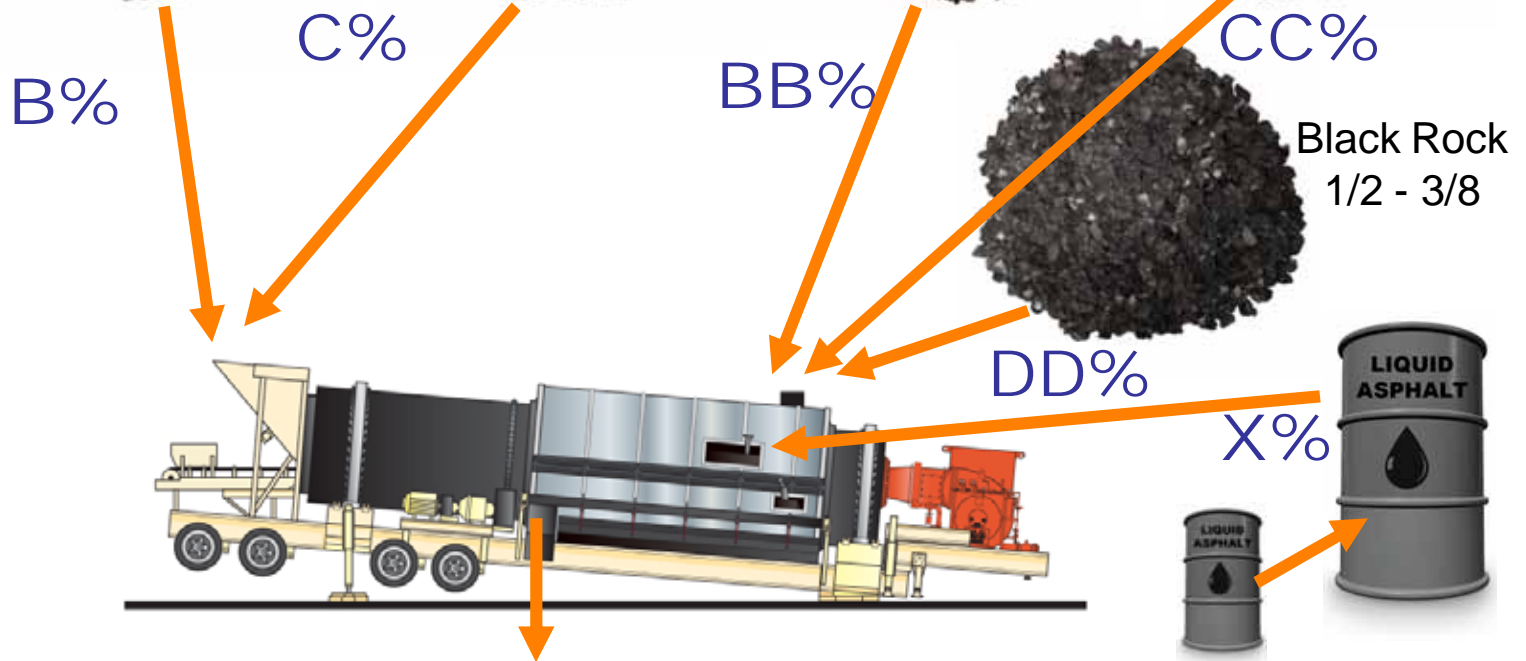
White Rock
4-0

White Rock
3/8 - 4

White Rock
1/2 - 3/8

Black Rock
4-0

Black Rock
3/8 - 4



SUPERPAVE MIX WITH PROCESSED RAP - CHOICE #2



Use of RAP for High Traffic Surface Mixes

- Is RAP made from skid resistance aggregate?
 - Yes! - No problem
 - No! - By fractionating RAP the minus $\frac{1}{4}$ " , it can be used in any mix since aggregates finer than $\frac{1}{4}$ " do not effect skid numbers

White Rock
4-0

White Rock
3/8 - 4

White Rock
1/2 - 3/8

Black Rock
4-0

Black Rock
3/8 - 4



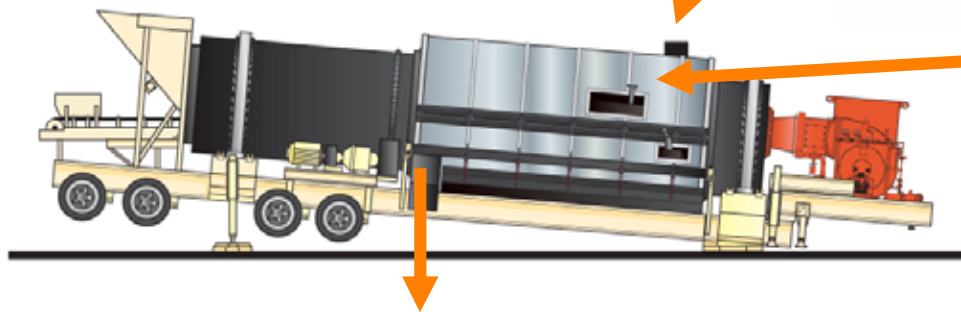
B%

C%

BB%



Black Rock
1/2 - 3/8



X%



SUPERPAVE MIX WITH PROCESSED RAP - CHOICE #1



Changing the grade of liquid when RAP increases...WHY?

- **To obtain density in mix**
- **“Is this beneficial or necessary?”**
Perception has been that it is
necessary to extend pavement life



**With Warm Mix (hot foam), we
can achieve density without
changing grades at 50% RAP**

Foam Liquid Asphalt

How much water?

1 ton mix – 2,000 lb.

20 cu ft. (25% void or 5 cu. ft.)

5.3% liquid – 106 lb.

Volume of liquid – 1.63 cu. ft.

1 lb. H₂O when converted to steam = 30 cu. ft.

$$\text{Expansion} - \frac{30}{1.63} = 18$$

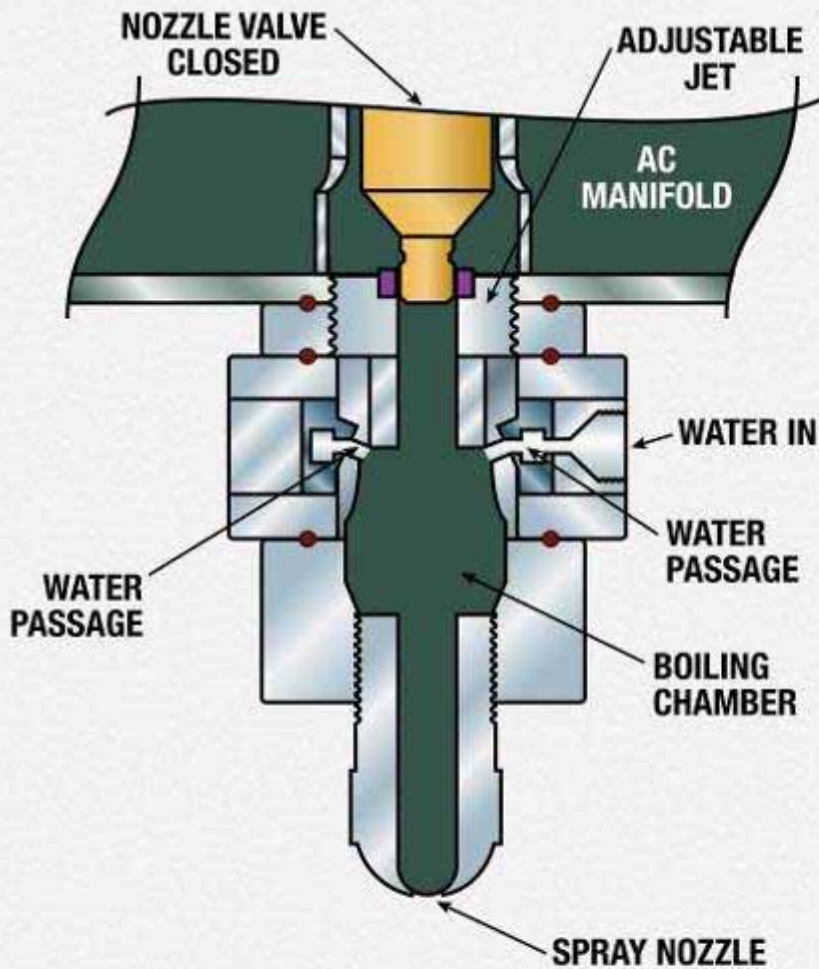
However only room for 5 cu. ft.

Therefore only 1/6 lb. of H₂O ends up in foam

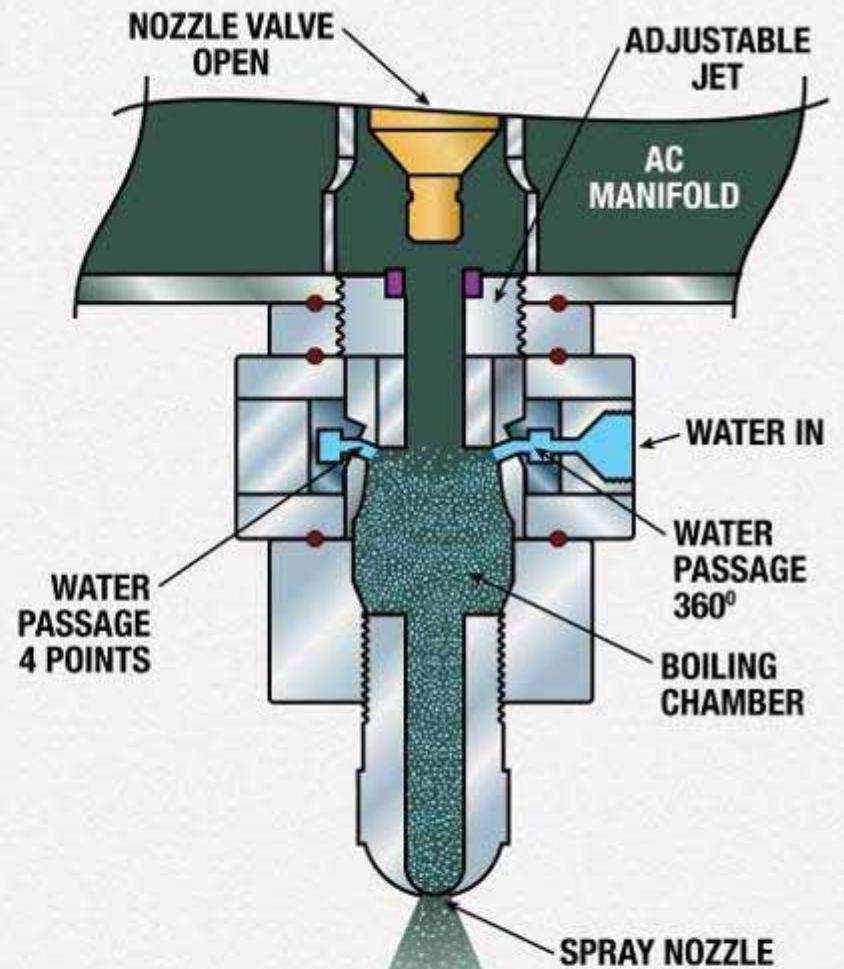
AFTER COMPACTIONS

Air voids = 5% or 1 cu. ft.

Therefore only 1/30 lb. of H₂O remains in liquid



FOAM NOZZLE CLOSED



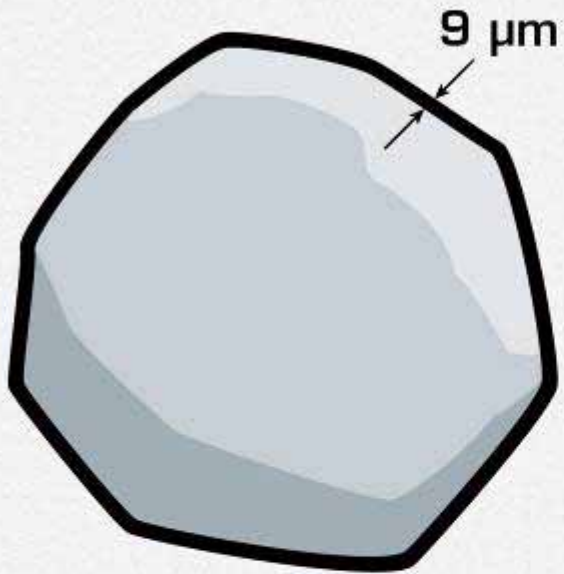
FOAM NOZZLE OPEN

FOAM NOZZLE

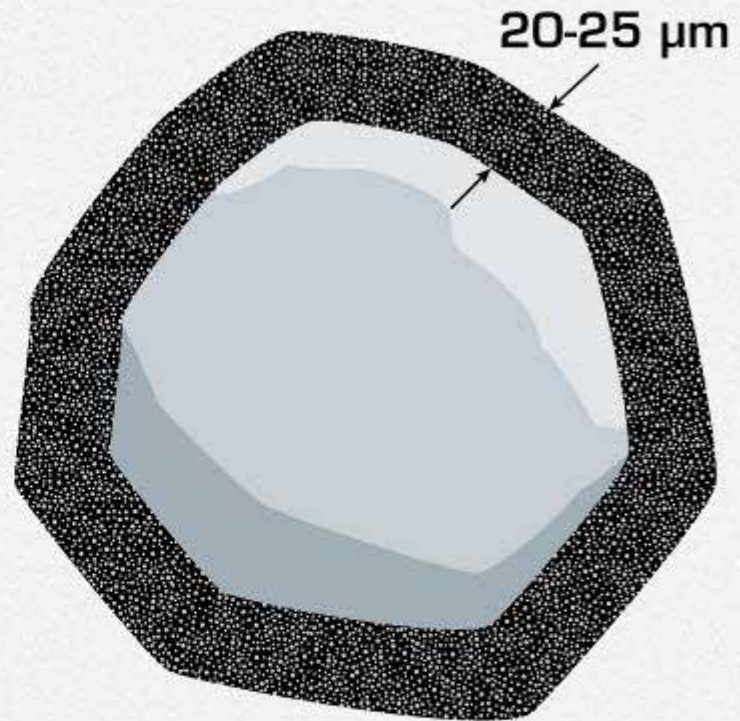




G2 GREEN SYSTEM

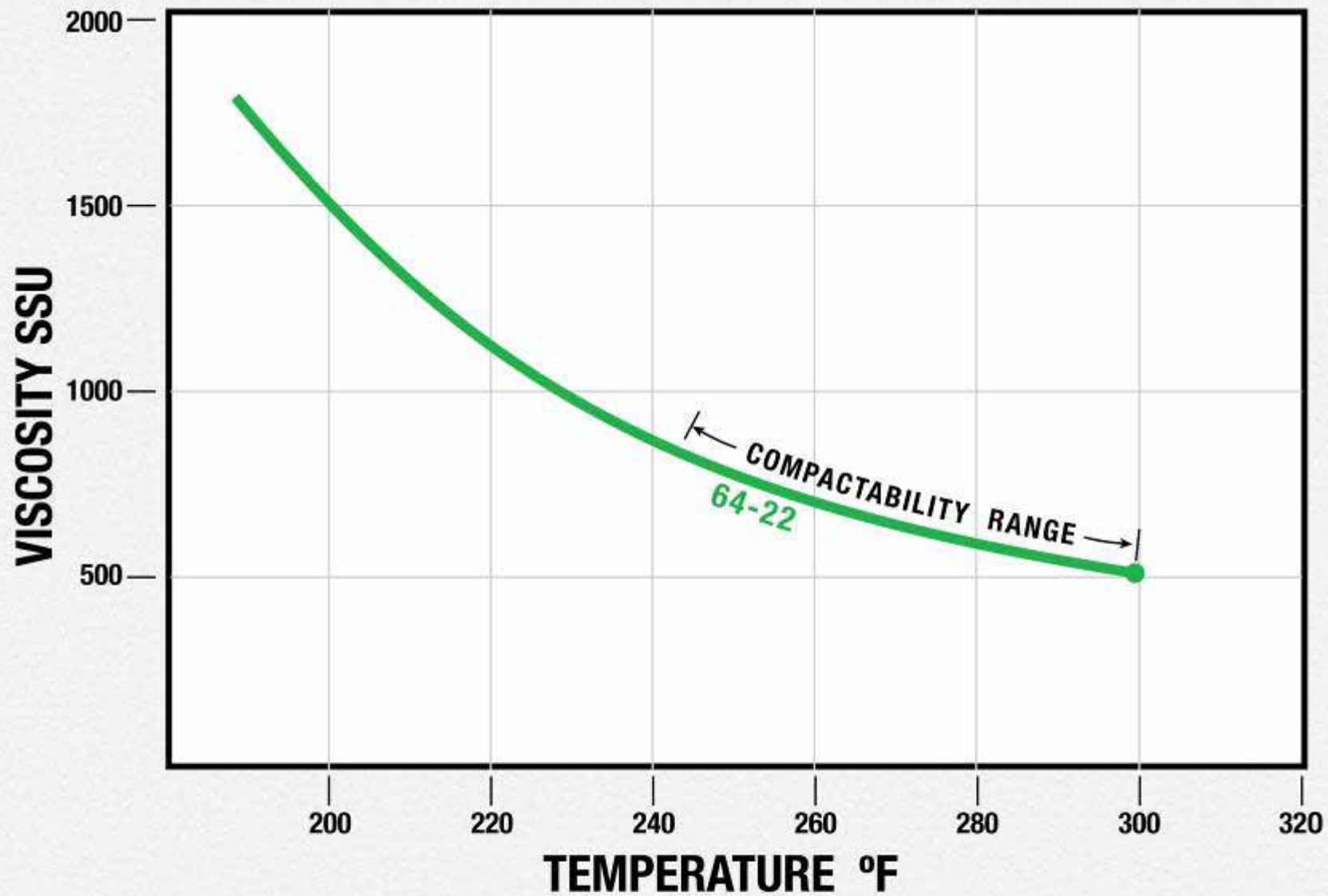


**NORMAL
COATING**

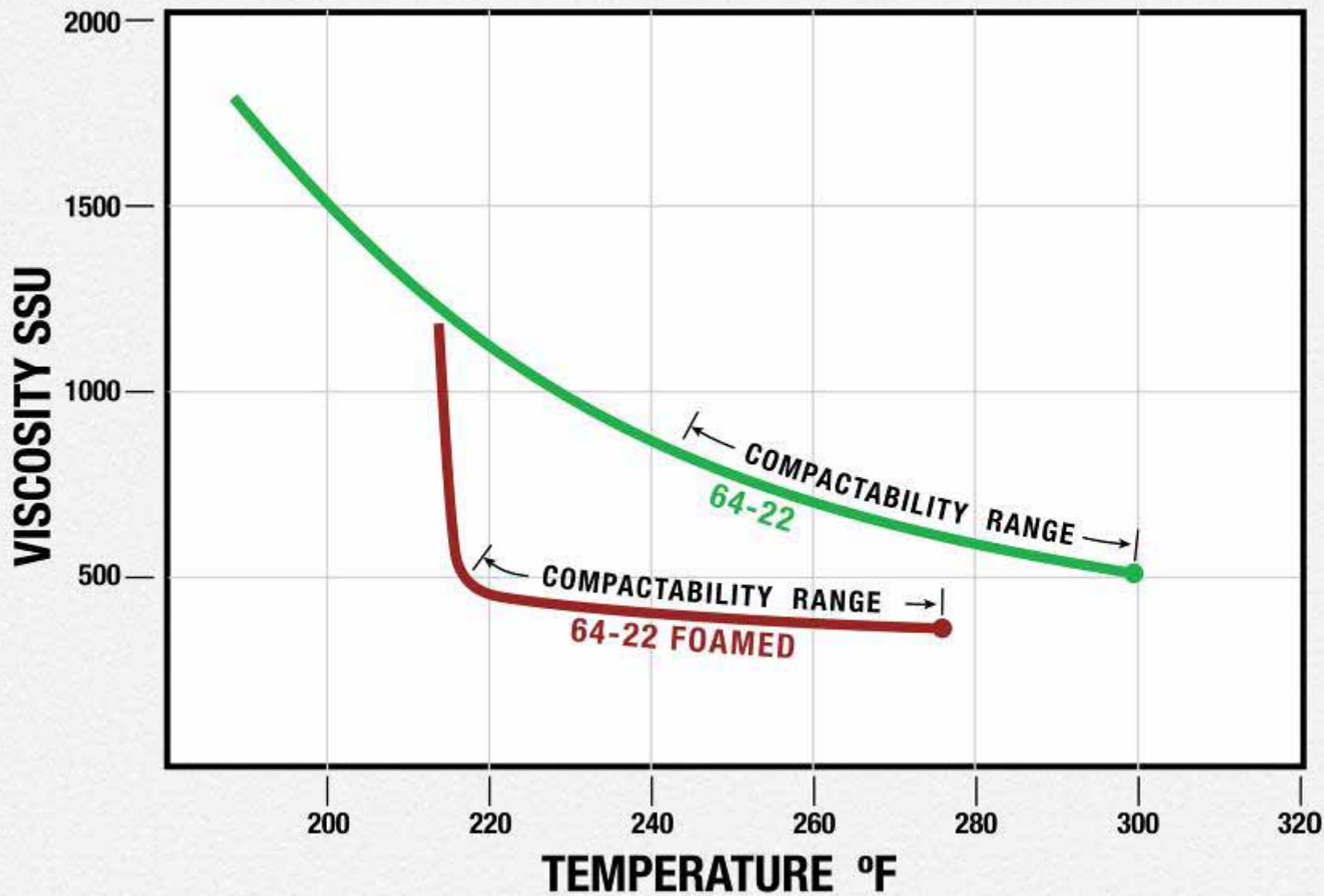


**DB GREEN FOAM
COATING**

COATING THICKNESS



VISCOSITY / TEMPERATURE PG 64 -22 (Approx.)



VISCOSITY / TEMPERATURE PG 64 -22 (Approx.)

No Smoke – No Smell...Why?

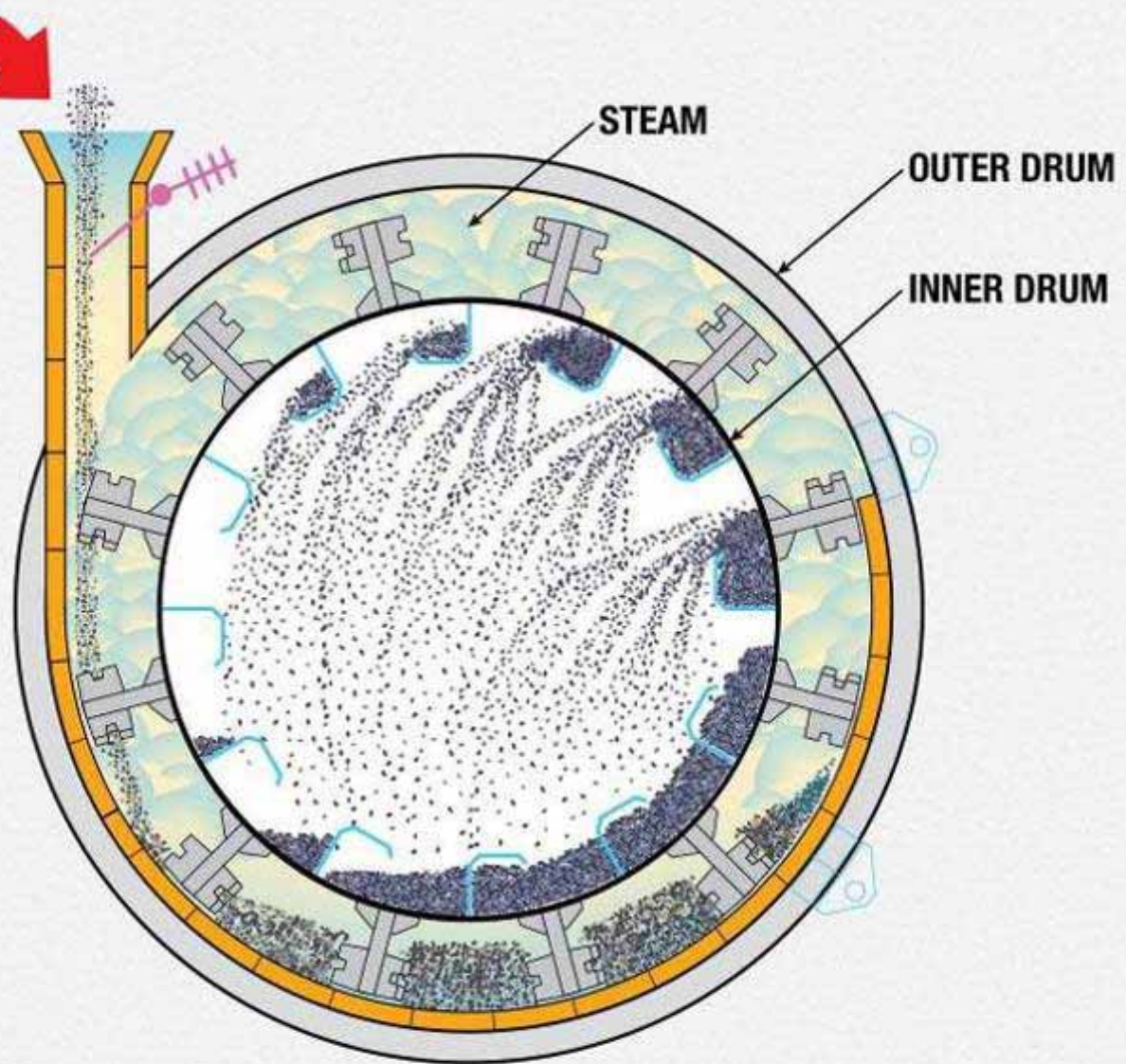
- Light oils are either put in asphalt or left in asphalt during refining**
- These light oils boil at above 285°F**
- By mixing at below 285°F, the boiling point is never reached...eliminating smoke (vapor) and corresponding smell**



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 due to:**
 - Lower temperature results in less oxidation**
 - Light oil remains in liquid**
 - Steam produced from drying the RAP creates an inert atmosphere**

RAP IN



RAP GENERATES STEAM IN OUTER DRUM

Is Changing a Grade Beneficial?

1983 Florida DOT Test on Asphalt Hardness

Batch Plant Produced Mixes

Long Range Effect on Rutting

<u>Date</u>	Section 3 (High Light Ends) Viscosity - 2000*	Section 7 (Steam Distilled) Viscosity - 4000*
	<u>Rutting (in.)</u>	<u>Rutting (in.)</u>
12/27/84	0.00	0.00
03/19/85	0.04	0.00
08/06/85	0.03	0.00
09/27/85	0.06	0.00
12/03/85	0.06	0.03
12/22/86	0.08	0.07
11/30/88	0.14	0.06
02/28/91	0.35	0.16
12/24/92	0.46	0.15
01/26/95	0.60	0.18
03/22/99	0.60	0.27

Long Range Effect on Cracking

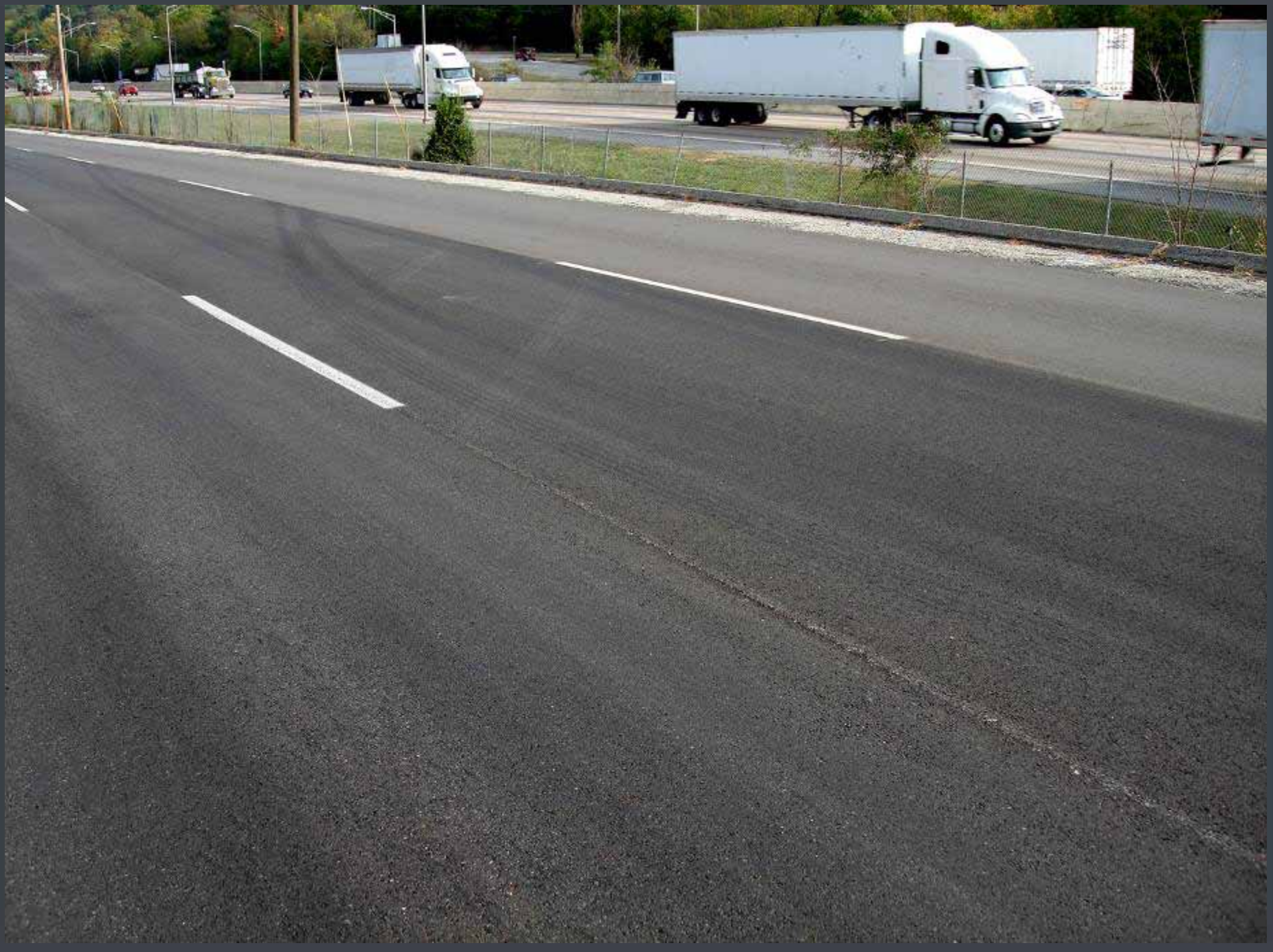
<u>Date</u>	<u>Cracking sq. ft./1,000 ft.*</u>	<u>Cracking sq. ft./1,000 ft.*</u>
12/27/84	0.0	0.0
03/19/85	0.0	0.0
08/06/85	0.0	0.0
09/27/85	0.0	0.0
12/03/85	0.0	0.0
12/22/86	3.0	2.5
11/30/88	2.0	1.6
02/28/91	61.1	2.0
12/24/92	49.0	1.1
01/26/95	175.6	38.6
03/22/99	120.2	207.5

* In each inspection period - 1,000 ft. of the 4,000 ft. test sections were analyzed. Each time the same 1,000 ft. was not analyzed; therefore, the overall average results are more meaningful.

Will high RAP in surface mix effect the Life of the Pavement?

Yes...It will

- Reduce rutting and**
- Give at least as long life in
fatigue**



**Can RAP be used in SMA
mixes?**

White Rock
4-0

White Rock
3/8 - 4

White Rock
1/2 - 3/8

Black Rock
4-0

Black Rock
3/8 - 4



C%



Black Rock
-16



Black Rock
4-16

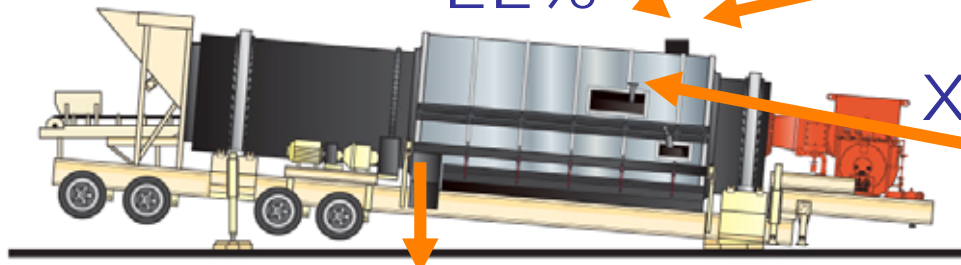


Black Rock
1/2 - 4

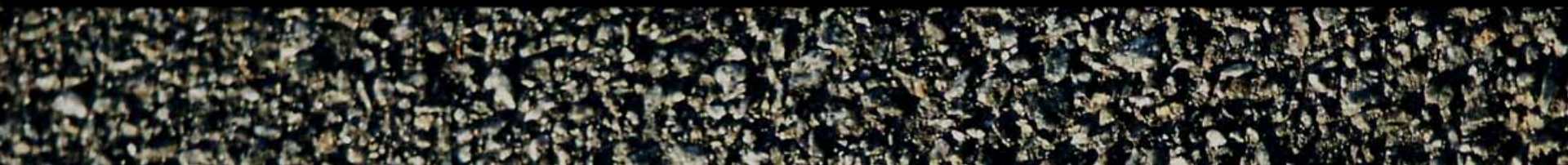
EE%

5%

X%



SUPERPAVE MIX WITH PROCESSED RAP - CHOICE #3



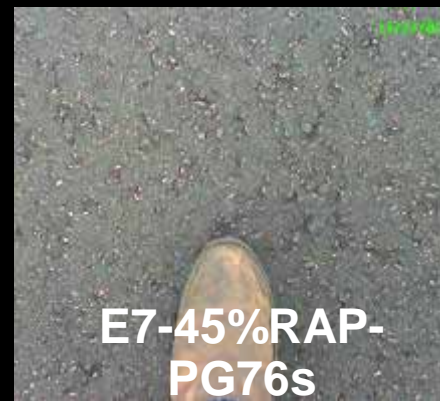
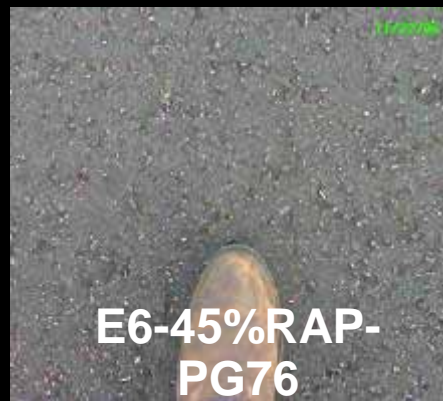
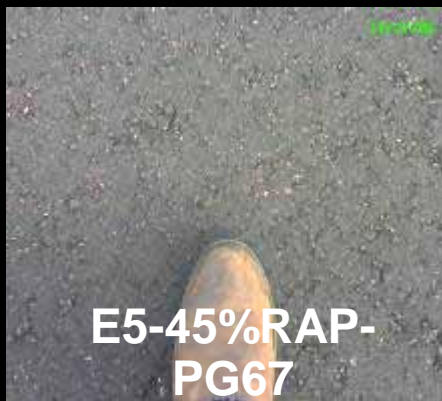
**Should the RAP be limited to
no more than 15% when
using Polymers?**

NCAT Test Track RAP Sections

- 1. virgin control mix with PG 67-22**
- 2. 20% RAP with PG 67-22 virgin binder**
- 3. 20% RAP with PG 76-22 virgin binder**
- 4. 45% RAP with PG 52-28 virgin binder**
- 5. 45% RAP with PG 67-22 virgin binder**
- 6. 45% RAP with PG 76-22 virgin binder**
- 7. 45% RAP with PG 76-22 + Sasobit**

All sections were placed as a 2" mill and fill on existing sections

RAP STUDY MATS



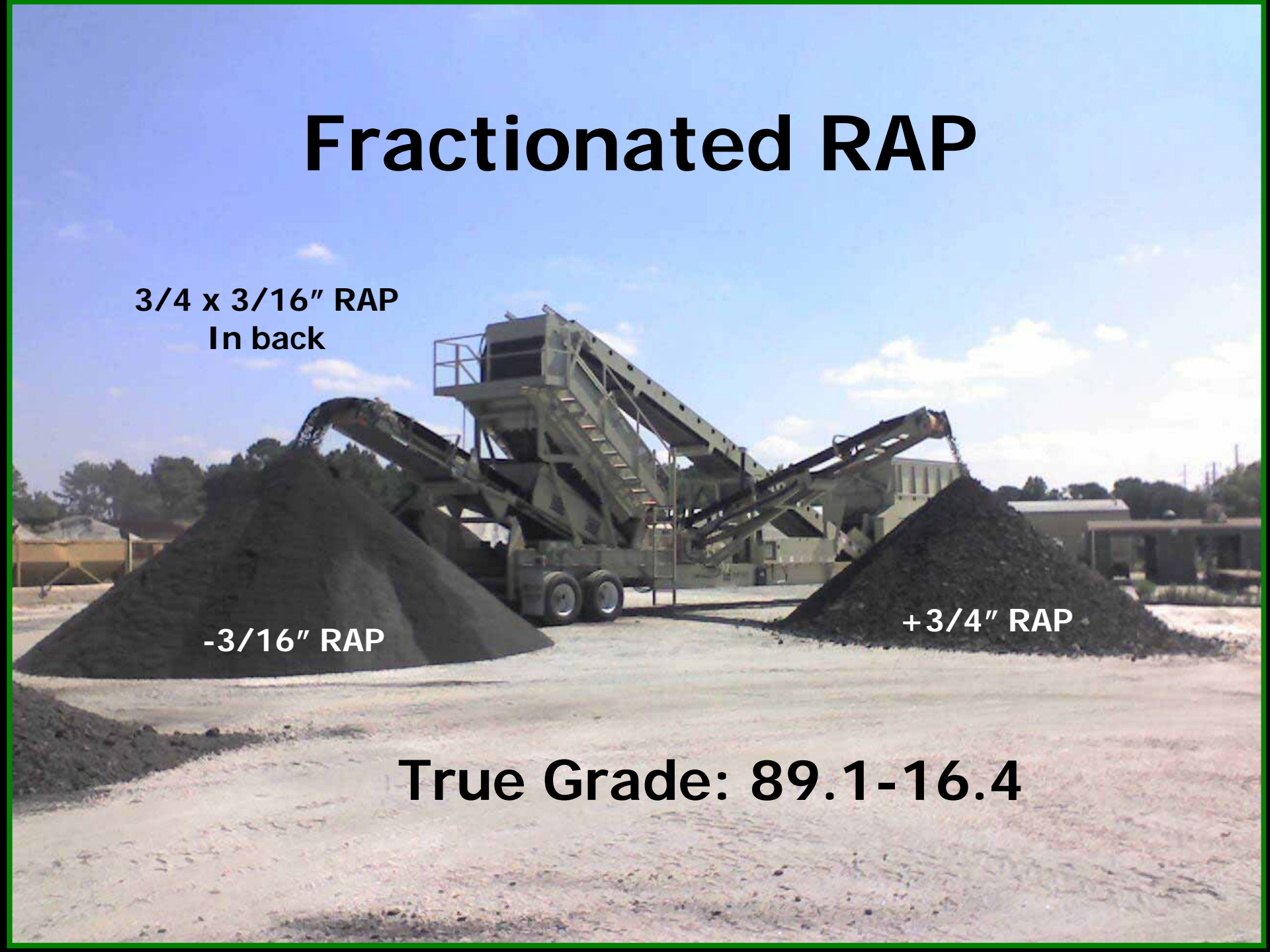
Fractionated RAP

3/4 x 3/16" RAP
In back

-3/16" RAP

+3/4" RAP

True Grade: 89.1-16.4



Production of Test Track Mixes for the RAP Study



Recycled Mix Production



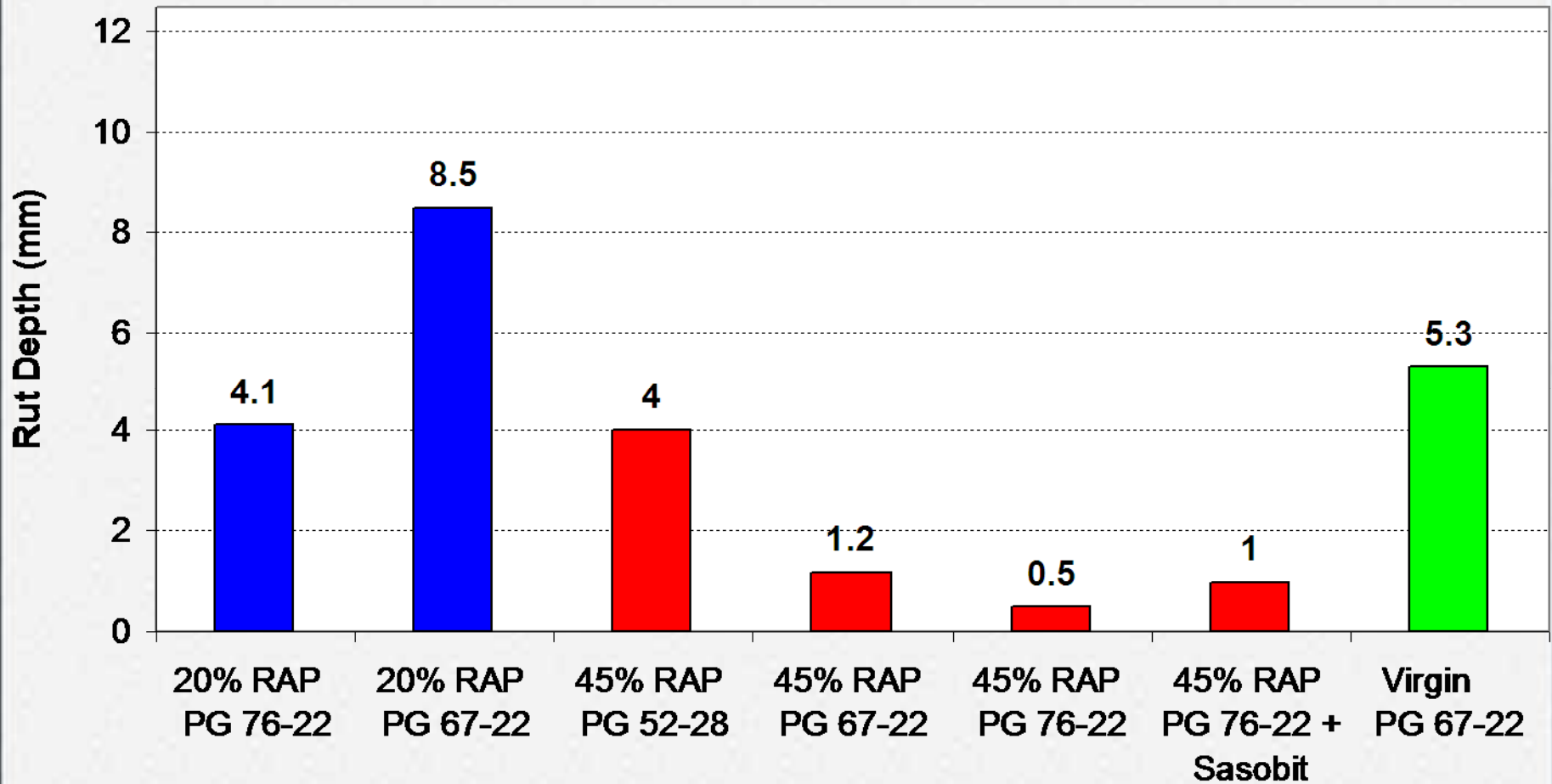
Predicted and Recovered Binder Grades

Section	%RAP ¹	%RAP Binder ²	Virgin Binder		Virgin Binder + RAP	
			PG Grade	True Grade	Predicted Grade	Recovered Grade
W3	20%	18.2%	PG 76-22	78.1 -23.8	80.1 -22.4	78.1 -30.3
W4	20%	17.6%	PG 67-22	68.4-31.2	72.0 -28.6	74.2 -29.7
W5	45%	42.7%	PG 52-28	54.7-32.8	69.4 -25.8	74.1 -30.2
E5	45%	41.0%	PG 67-22	68.4-31.2	76.9 -25.1	80.9 -26.2
E6	45%	41.9%	PG 76-22	78.1-23.8	82.7 -20.7	85.5 -25.7
E7	45%	42.7%	PG 76-22 +1.5% Sasobit	83.2 -20.6	85.7 -18.8	86.3 -24.3
N5	0%	0%	PG 67-22	68.4-31.2	68.4 -31.2	71.1 -32.4

Test Section Construction



Rutting Performance @ 10 M ESALs



E7 45% RAP PG76-22 + Sasobit



Cracking first noted in E7 in January 2008

Estimated Price Differences Compared to Virgin Mix with PG 67-22

Based on \$10 Agg., \$400 neat asphalt, \$585 polymer asphalt, \$9 RAP

- 20% RAP with PG 67-22..... -14.9%
- 20% RAP with PG 76-22..... +11.3%
- 45% RAP with PG 52-28..... -36.2%
- 45% RAP with PG 67-22..... -41.4%
- 45% RAP with PG 76-22..... -11.9%
- 45% RAP with PG 76-22 + Sasobit... -1.0%

**Substitute 50% RAP for 4%
polymers can achieve practically
the same results**

Benefits of High RAP & Warm Mix

For the Producer/Contractor



- Improved Workability
- No Smoke – No Smell
- High Percentage Recycle Mix with Standard Grade of Asphalt
- 14% Less Fuel
- 14% Higher Production
- Reduces Cost

For the Worker

- **Comfort & Safety**





For the DOT/Public

- **Comfort & Safety of workers**
- **Improve Mixes**

Why will we have a Longer Life Pavement?

- Less oxidation of mix**
- More uniformity of compaction**
- With fractionating RAP...more uniform**

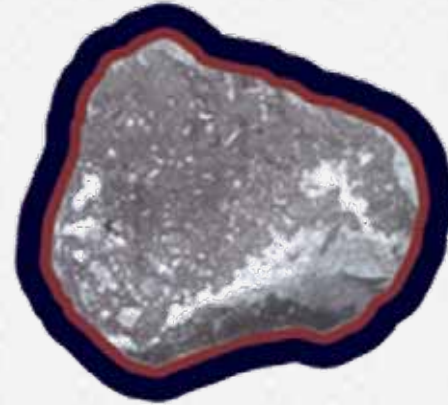
Longer Life



**VIRGIN
AGGREGATE**



**HARDER LIQUID
TRANSFERRED FROM
RAP PREVENTS
STRIPPING**



**NEW
HOT FOAM AC
HELPS DURABILITY**

Moisture Susceptibility

Mix Type	Average Air Void Content Dry (%)	Dry Indirect Tensile Strength (kPa)	Average Air Void Content Conditioned (%)	Conditioned Indirect Tensile Strength (kPa)	Tensile Strength Ratio (%)
Virgin	7.2	806.7	7.2	625.2	77.5
15% RAP	6.5	878.1	6.5	769.5	87.9
15% RAP / 5% MSM	6.8	985.1	6.5	818.6	83.1
50% RAP	7.2	1166.2	7.1	1124.7	96.4

- **ASHTO T-283**
- **Aggregate temperatures >200°C**
- **Aggregate moisture contents 0.04% - 0.1%**
- **Mix moisture contents <0.1%**



For the DOT/Public

- **Comfort & Safety of workers**
- **Improve mixes**
- **Sustainability**

Why Sustainability?

- By Milling & Recycling – 100% of the material can be re-used**
- Reduce new aggregate requirement by 245,000,000 tons/year...annually (from 15% to 50%)**
- Reduce oil consumption by 80,000,000 bbl/year...approximately 7 days of imported oil**



For the DOT/Public

- **Comfort & Safety of workers**
- **Improve mixes**
- **Sustainability**
- **Green**

It's Green!

- Use 14% less fuel due to 50°F lower temperature**
- No volatiles**
- Use more recycle**



For the DOT/Public

- **Comfort & Safety of workers**
- **Improve mixes**
- **Sustainability**
- **Green**
- **Reduce Cost**

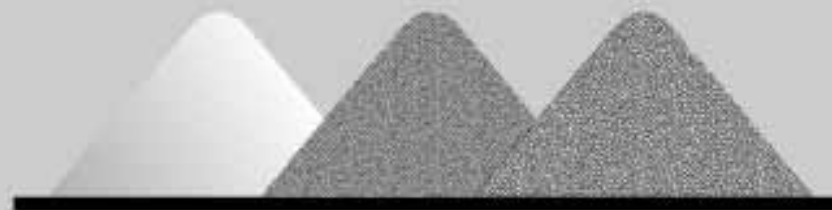


30,000 Tons of RAP

=



**70 - 6,000 Gallon Transport Trailers
and 28,200 Tons of Clean Aggregate**



RAP is Worth the Virgin Material It Replaces

What we have done to date

- Installed over 200 units to create hot foam mechanically**
- Produced between 8 and 10 million tons from 20 to 50% RAP with warm mix**
- Stored in silo for 4 days**
- Produced 76-22 (Polymers) and placed at 270°F**
- Produced rubber mix at 270°F**

Conclusions:

- 1. HMA is 100% Recyclable**
- 2. Milling corrects road profile, corrects drainage, eliminates raising shoulders and guardrails, and maintains bridge clearances...and generates RAP**
- 3. By fractionating RAP and using Warm Mix (hot foam) with 50% RAP, it will produce a rut resistant, longer life pavement. It can be produced with a standard grade of AC. Density can be achieved with one less roller and centerline joint density is substantially improved**
- 4. More miles can be paved at substantially less cost**
- 5. Greenhouse emissions and imported oil are greatly reduced**