REVIX™ - Waterless Technology for Production of Reduced Temperature Asphalt Mixtures

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Warm Mix Asphalt Processes

- **Organic, Wax-like additives**
  - Sasobit® – Sasol International
  - Asphalan B – Romanta
  - Fatty Acid Amides – Licomont S 100

- **Foaming Processes**
  - Aspha-min zeolite – MHI/Eurovia
  - Low Energy Asphalt – Fairco/Eiffage Travaux Publics
  - WAM Foam – Kolo Veidekke/Shell/BP
  - LEAB® – BAM

- **Emulsion Based**
  - Evotherm™ – Mead Westvaco

- **Surfactant Solution Injection**
  - Mathy Technology and Engineering Services
  - Evotherm™ DAT - Mead WestVaco
  - Evotherm™ 3G – Mead WestVaco

- **Vegetable based synthetic binders**

- **Emerging Technologies**
  - REVIX™
  - Aztec Double Barrel Green
Factors Driving Development of WMA

• The environment and sustainable development concerns, “Green Construction”
  – Reduction in energy consumption
  – Reduction in CO₂ emissions

• Extension of paving season and potential for longer haul distances

• Improvement in field compaction

• Welfare of workers.
Factors Driving Development of WMA

Positive proof of global warming.

Classification of WMA by Temperature Range

- Latent Heat of Vaporization
- Heating
- Vaporization
- Drying
- Cold Mix
- Warm Mix
- Half-Warm Asphalt
- WMA
- HMA

Temperature, °F

Fuel/Ton
WMA Postulations

• Viscosity Reduction
  – Viscosity Reduction is Essential
  – Wax Additives and Water/Foam Reduce Viscosity

• Foaming
  – Asphalt Foaming is Necessary to Achieve Coating

• Water is Key to WMA Production
  – Water Provides Viscosity Reduction
  – Water Provides Foaming
“QUESTIONS?”

- WHAT IS ACTUALLY HAPPENING IN THESE MIXES?
- IS WATER THE KEY, IS IT NEEDED FOR COMPACTION, IS IT NEEDED FOR MIXING AND COATING?
- IF WATER ISN’T NEEDED, THEN WHAT IS THE MECHANISM OF WMA?
- IS VICOSITY REDUCTION THE ESSENTIAL MECHANISM?
Why We Think WMA Works

• Rheology of materials in thin films is different than bulk rheology
  – Our investigations began by looking at tribology, in particular testing conducted by the lubricating fluid and medical prosthetics industries and investigations performed by people studying rheology of plate tectonics
  – Typical DSR uses a 1000 µm film
  – Mineral fines are smaller than 50 µm
  – Aggregates have asperities that vary in size, but none are truly smooth
  – Began testing at 100 µm, are now working at 25µm and 50µm
  – Tribo-Rheology
PG 58-28, Neat, 25x0·025 mm, cup, 090°C,
PG 58-28, Neat, 25x0·025 mm, cup, 100°C,
PG 58-28, Neat, 25x0·025 mm, cup, 120°C,
PG 58-28, Neat, 25x0·025 mm, cup, 130°C,
PG 58-28, Neat, 25x0·025 mm, cup, 140°C,
07-030A, 1.5% Sasobit, 25x0.1 mm, cup, 90°C, Study Shr, AR1-0001f

1.5% wax 1, 100 µ, 90°C
0.5% wax 1, 100 µ, 90°C
PG 58-28 + 0.2% S1, 100 µ, 90°C
PG 58-28 neat, 100 µ, 90°C
MIF 64-34, 0.5% REVIX™, 25mm x 25µm, cup, 110°C, 
MIF 64-34, 0.5% REVIX™, 25mm x 25µm, cup, 115°C, 
MIF 64-34, 0.5% REVIX™, 25mm x 25µm, cup, 130°C, 
MIF 64-34, 0.5% REVIX™, 25mm x 25µm, cup, 120°C,
What we think Cont’d

- Water is not essential to the production of reduced temperature mixes

- Viscosity reduction is not essential. For example, waxes don’t really reduce the binder viscosity substantially, nor do surfactant additives at loadings typically being used in current warm mix processes.
Additive dose levels for warm mix have probably been too high from what we have seen.

- The process we describe potentially explains other facts such as lower mixing and compaction temperatures for PMA’s even though viscosity predicts high values.
- May explain the decrease in dry tensile strengths with some mixes when anti-strip is used in mix, even though overall TSR values increase.
- Water in many processes is only a delivery system and not a necessary one.
REVOLUTIONARY™

MIX

“HOT MIX AT A COOLER TEMPERATURE”

WATERLESS

WARM MIX ASPHALT TECHNOLOGY
Revix™
Technology Licensed to
Mead WestVaco
marketed under the tradename
Evootherm™ 3G
What is Revix™/Evootherm™ 3G

- A “process” which allows reduction of temperatures at which asphalt mixes are produced and placed.
  - Provides internal friction reduction
  - Allows the complete coating of aggregate
  - Generally if aggregate is well coated, compaction is not an issue
  - Does not rely on a specific additive
  - Additives (broadly encompassing surfactants, polymers, acids, processing aids, waxes, etc.) result in a binder with reduced resistance to coating and spreading over aggregate surfaces even at reduced temperatures
Benefits of Revix™/Evootherm™ 3G

- Seamless to the Contractor – Business as Usual
- Reduced Emissions
- Reduced Fuel Usage
- Paving Benefits
  - Pave in cool weather and still obtain density
  - Haul mix longer distances and still have workability
  - Improved compaction
  - Facilitate deep patches
  - Ability to use more RAP
- Reduced Worker Exposure
Benefits of Revix™ Evotherm™ 3G

“It’s so easy ……..!”
Benefits of Revix™ Evotherm™ 3G

No Fugitive Emissions
Reduced Emissions

- $\text{CO}_2$ reduced 30-40%
- $\text{SO}_2$ reduced 35%
- $\text{VOC}$ reduced 50%
- CO reduced 10-30%
- $\text{NO}_x$ reduced 60-70%
- Dust reduced 20-25%
- Our own monitoring showed 2/3 reduction in total organics behind the paver.
Placement and Compaction

“Business as usual”
Primarily use:
- Heavy, tamping bar, vibratory screed pavers
- Steel-wheel vibratory and static rollers
- Workability generally good
Chronology of REVIX™ Projects

1) 300 TONS (20% RAP) OF MIX PLACED ON PRIVATE ROAD PG 58-28, 0.3% S1, 0.3% A1. Mixed at 230°F, compacted <220°F. Core densities 93.3 to 93.8% of max. Mixed in a counter flow plant.

25% RAP MIX AT DRUM DISCHARGE
Chronology of REVIX™ Projects

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2) 713 tons (20% RAP), Goodhue Cty, MN CTR 11,, PG 58-28, 0.3% S1, 0.3% A1. Mixed at 230°F, compacted <220°F. Same counter flow plant as above. County Engineer and staff on project. Field monitoring of total organics at paver = 66% reduction compared to same mix produced at normal temps.
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3) **200 tons (30% RAP), WI STH 33, La Crosse cty, PG 58-28, 0.3% S1, 0.3% A1, density 95.4%, 94.7% (92.5% over aggregate shoulder),** mixed in Double Barrel® hot mix plant
Chronology of REVIX™ Projects

4) 700 tons (30% RAP), WI STH 33, La Crosse cty, PG 58-28, 0.3% S1, 0.3% A1, Tom Brokaw and Judy Ryan from WI DOT present on job. Double Barrel® plant. Mixed 225-235°F.
Chronology of REVIX™ Projects

4) 700 tons (30% RAP), WI STH 33, La Crosse cty, PG 58-28, 0.3% S1, 0.3% A1, Tom Brokaw and Judy Ryan from WI DOT present on job. Double Barrel® plant. Mixed 225-235°F.

5) 250 tons (30% RAP), WI STH 33, La Crosse cty, PG 58-28, 0.5% WA1, 0.3% A1, WI DOT present on job. Double Barrel® plant. Mix produced at 235-245°F. When mix temp behind paver dropped to around 200°F we had trouble with mix dragging on screed, at 220°F and above no difficulties.
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6) 250 tons (30% RAP), WI STH 33, La Crosse cty, PG 64-28 Elvaloy PMA + 0.5% A2. Mixed at @ 235°-240°F. Paved turning lanes and approaches, much hand work.
Chronology of REVIX™ Projects

7) 250 tons, Columbia, Mississippi batch plant test. PG 64-22 + 0.3% S1 + 0.5% A2. Mixed at 240°F compacted at as low as 210°F, air temp was in the 30’s°F. Because of air temp and hand work, mix temp raised to 250°F and laydown was in the 225°F range.

15% RAP MIX
BEHIND PAVER
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8) 1500 tons, 15% RAP, Near Algood, TN, Chattanooga Dist, PG 67-22, 0.3% S2, 0.5% A2, Mix produced in a parallel flow drum plant, 40 mile haul to job. Mix coated as low as 240°F, but because of job haul most was produced at 250°C-255°F.
Chronology of REVIX™ Projects

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9) 1500 tons, 15% RAP, Near Tupelo, MS job. PG 67-22 + 0.3% S2 + 1% hydrated lime in mix. Mix produced in Estee counter flow drum plant with an external pug mill. Typical HMA temps 330°F mix & 295°F compaction, burner at ½ to ¾ capacity. Current project 260°F average mix temp, compacting at 225° - 230°F, burner at ¼ capacity. 40 mile haul to project, mix being dropped on road and paved through pickup machine.
Chronology of REVIX™ Projects

10) 500 Tons County Road Near Vilonia – Rogers Group, Conway, AR

Typical Mix temps for PG67-22 = 320°F for mixing and 295°F for compaction as reported on the mix design. Revix™ additive was S3 at 0.5% added at the terminal, no change in asphalt grade after addition.

Mixing at 255°F wanted to go lower but ran out of time on the project, probably could have been mixed as low as 240°F.

Mix was compacted at 245°F with the final finish roller at 215°F. Could have been lower - probably near 225°F compaction and 200°F finish.

Nuclear Gauge densities were in the 92.5% to 93%.
SUMMARY

• Several different additives evaluated in the field, more in the lab
• Temperature reductions range from 60 to 80°F below typical hot mix temperatures for the same mix, actual values vary depending the type of binder and mix being used
• All additives necessary to produce the reduced temperature mix are typically added at the asphalt terminal. Additives can be added at the HMA plant. Binder preferably comes to contractor ready to use—all he does is run the plant as he normally does but at a lower temperature
• A mix design is necessary to adjust additive loading and check TSR properties
Five different types of hot mix plants evaluated

1. Double Barrel®—aggregate dried in inner drum prior to mixing in outer drum
2. Typical Batch plant, all aggregate pre-dried and stored in hot bins
3. Counter Flow drum mix plant
4. Parallel Flow drum mix plant
5. Remixer plant—Mix enters external pug mill after leaving drum and prior to going up slat conveyer

We felt it important to demonstrate that irrespective of plant type or possible moisture content left from aggregate and/or RAP that this approach would work

Completely dry aggregate in the lab had been evaluated with each mix type and additive package prior to field production
SUMMARY CONT’D

- PMA mixes with PPA addition (Field & Lab) and PPA only modified binder (Lab only) evaluated with limestone aggregate. Data of binder recovered from mix showed no degradation in recovered binder DSR compared to same mix produced with aqueous solution addition.
CONCLUSION

Revix™/Evotherm™ 3G is a technological approach for producing reduced temperature paving mixtures that does not rely on the principles of foaming or other methods of viscosity reduction.

A variety of surfactants, waxes, processing aids, polymers, acids and other materials may be used successfully at the reduced temperature conditions we describe.

REVIX™/Evotherm™ 3G technology is based on the realization that the aforementioned types of additives provide reduction in the internal friction between aggregate particles and the thin films of binders used to produce bituminous mixtures when subjected to high shear rates, as in mixing, and high shear stresses, as in compaction.

The data that we have shown on the reduction in normal force provided by these additives under these high shear and stress conditions is a means of explaining the technological underpinnings of our approach to producing reduced temperature mixtures.
WHAT NEEDS TO BE DONE NEXT

• Need to evaluate maximum level of RAP that can be used (as high as 40% so far)
• Need to evaluate and understand the rate at which RAP binder interacts with neat binder
• Moisture sensitivity study needed to evaluate the need for continuing addition of anti-strip given the fact that no additional water is added.
• Aging study needed to evaluate the rate at which mix stiffness modulus increases relative to initial modulus and compared to same mix produced at typical hot mix temperatures
  – We have begun this looking at wet & dry Hamburg results on mixes aged at 85°C in forced draft oven. Five days has resulted in substantial reduction in rutting at 58°C compared to mix taken directly from plant. Binder needs to be extracted and PG graded. Fewer days of aging need to be investigated.
ONGOING RESEARCH PROJECTS

- 240 day study of 85°C oven aged mix specimens from lab and field mixes. Specimens tested at 10 different cure periods.
- 180 day study of outside aged 35% RAP mix specimens from a field project
  1. Rut pills and AMPT pills compacted and curing outside. Specimens will be tested at 9 different cure periods with a goal of determining rate of warm mix strength development
  2. Binder recovery and characterization planned at each aging period
PILLS HAVE BEEN ENCASED IN PLASTIC PIPE TO PREVENT SLUMPING

AMPT TEST PILLS

RUT TEST PILLS

TORSION BAR TEST PILLS
EVERY WEEKDAY THE PILLS ARE FLIPPED
PLANT 5 FIELD WARM MIX EVALUATION  E-3 MIX
PG 58-28 + 0.65% REVIX WITH 35% RAP IN MIX
TESTED IN HAMBURG DRY AT 58° C, 158# LOAD
COMPARE FRESH MIX, 1 MONTH INSIDE & 1 MONTH + 2 WEEKS OUTSIDE

Warm Mix Time Study 1 month inside storage after compaction
Warm Mix Time Study 1 month inside and 2 weeks stored outside
Warm Mix Time Study 1 week after mix production

RUT DEPTH IN mm
RUT CYCLES AT ~ 58.4° C & 158 LBS (703 N)
Questions?