WATERLESS, REDUCED TEMPERATURE MIX TECHNOLOGY

NOT WARM MIX
BUT
HOT MIX AT A COOLER TEMPERATURE

- Process is a co-development of Mathy Technology & Engineering Services and Paragon Technical Services, Inc
- A patent application has been filed on the technology

FACTORS CONSIDERED

- We developed a surfactant solution injection technology in 2004 and began field trials in 2005—as a result of that work several observations resulted
  - Amount of moisture in mix at plant discharge has typically been <1% and yet good field densities have been obtained regardless of temperature
  - Moisture in mix brought back to lab has been < 0.5% (often <0.2%) and yet days later mix can be adequately compacted at 230°F.
  - Mixes made in lab at 230°F with completely dry aggregate coated and compacted adequately.
- It was our belief that if you could coat the mix you could compact the mix given current roller technology

QUESTIONS ASKED

- JUST WHAT IS ACTUALLY HAPPENING IN THESE MIXES?
- IF THE WATER IS NOT NEEDED FOR COMPACTION, IS IT NEEDED FOR MIXING AND COATING?
- IF THE WATER ISN'T NEEDED, THEN WHAT IS THE MECHANISM?

What do we think is occurring?

- 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
- The 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
- Water in many processes is only a delivery system and not a necessary one
- 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
- Decrease in dry tensile strengths with some mixes when anti-strip is used in mix, even though overall TSR values increase

CHRONOLOGY OF FIELD TRIALS USING WATERLESS TECHNOLOGY

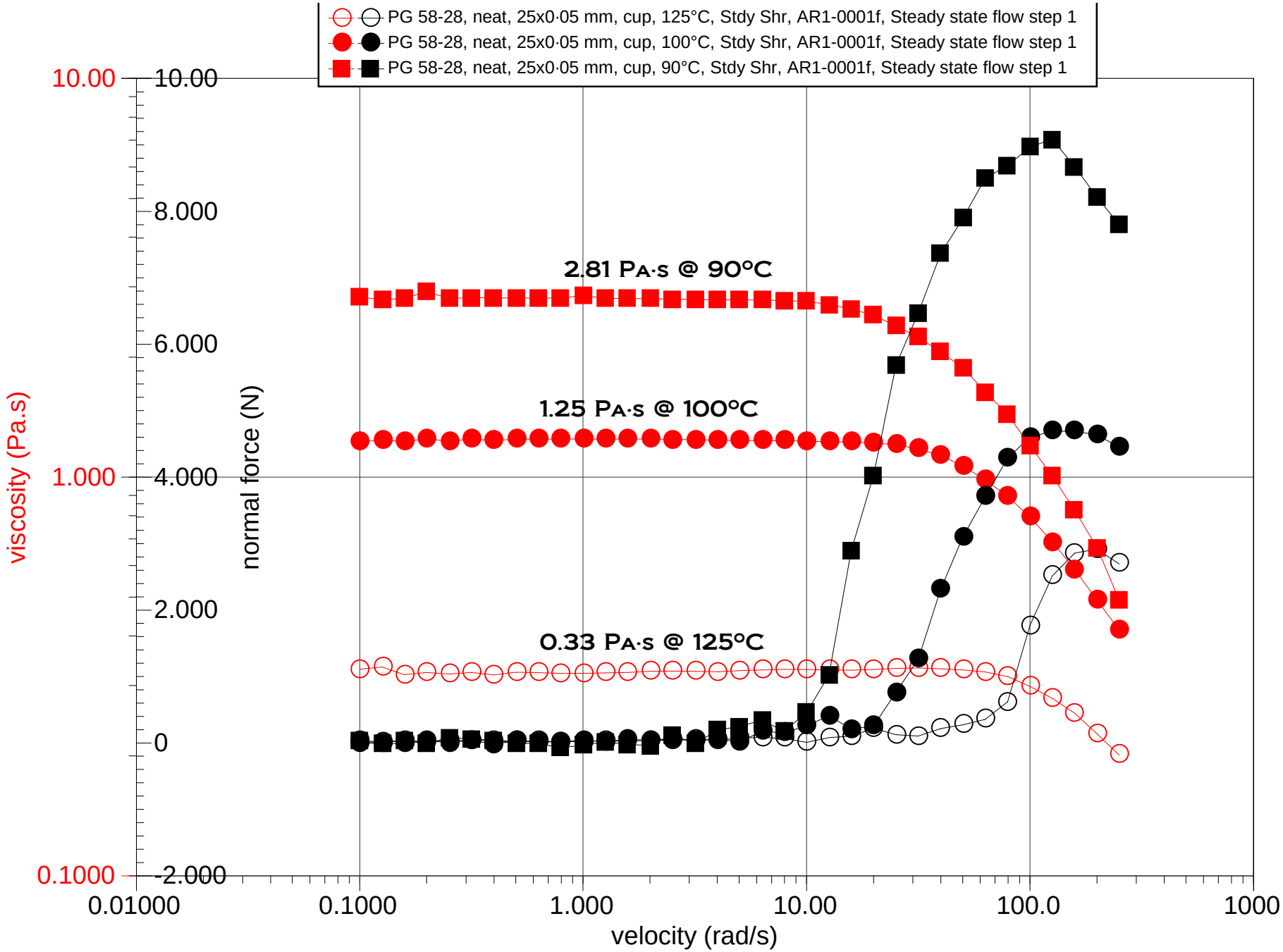
1. 300 TONS (20% RAP) OF MIX PLACED ON PRIVATE ROAD PG 58-28, 0.3% S1, 0.3% A1. Mixed at 230°F, compacted <220°F. Core densities 93.3 to 93.8% of max. Mixed in a counter flow plant.
2. 713 tons (20% RAP), Goodhue Cty, MN CTR 11,, PG 58-28, 0.3% S1, 0.3% A1. Mixed at 230°F, compacted <220°F. Same counter 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
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

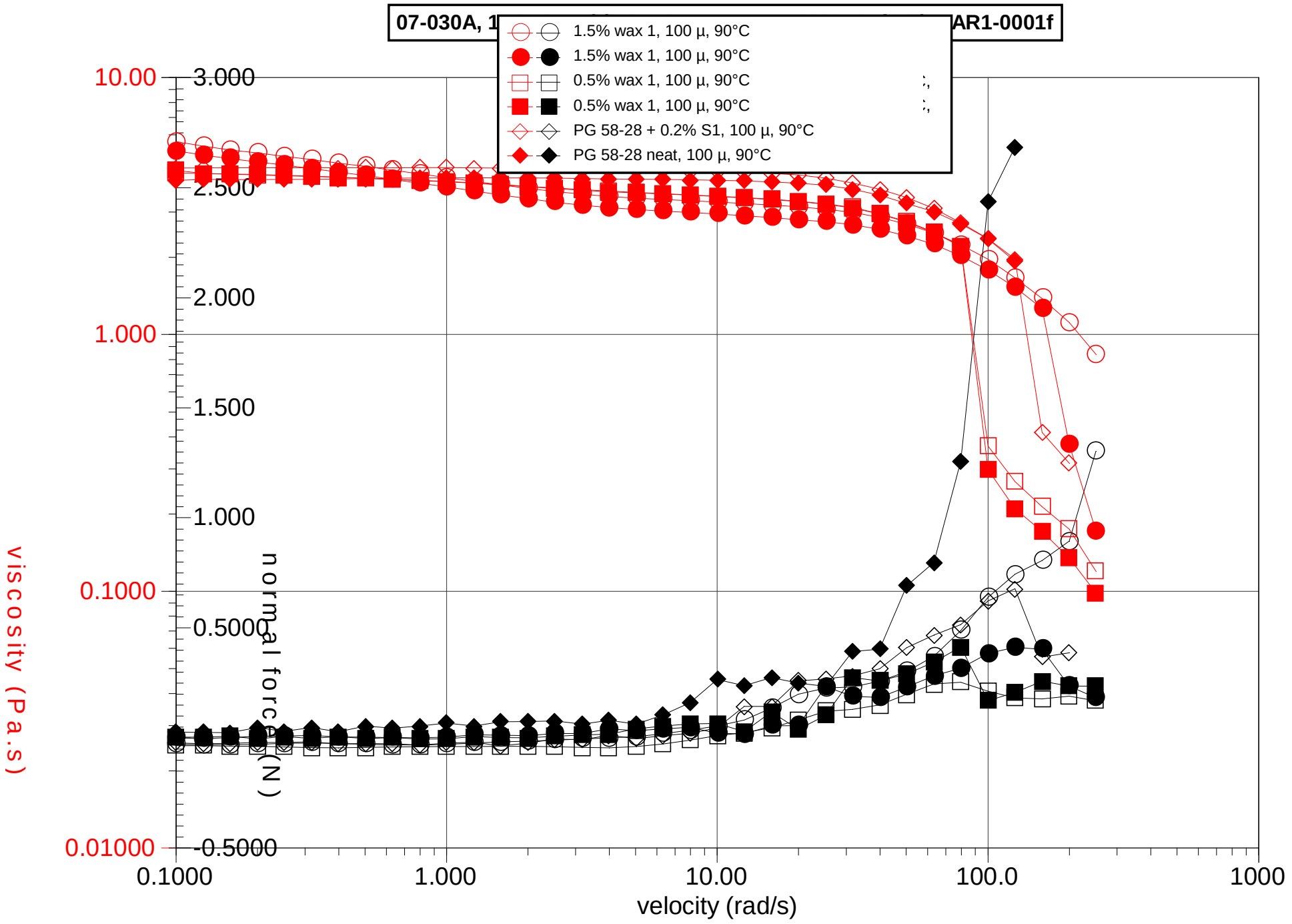
4. 700 tons (30% RAP), WI STH 33, La Crosse cty, PG 58-28, 0.3% S1, 0.3% A1, Tom Brokaw and Judy Ryan from WI DOT present on job. Double Barrel® plant. Mixed 225-235°F
5. 250 tons (30% RAP), WI STH 33, La Crosse cty, PG 58-28, 0.5% Wax 1, 0.3% A1, WI DOT present on job. Double Barrel® plant. Mix produced 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.
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.

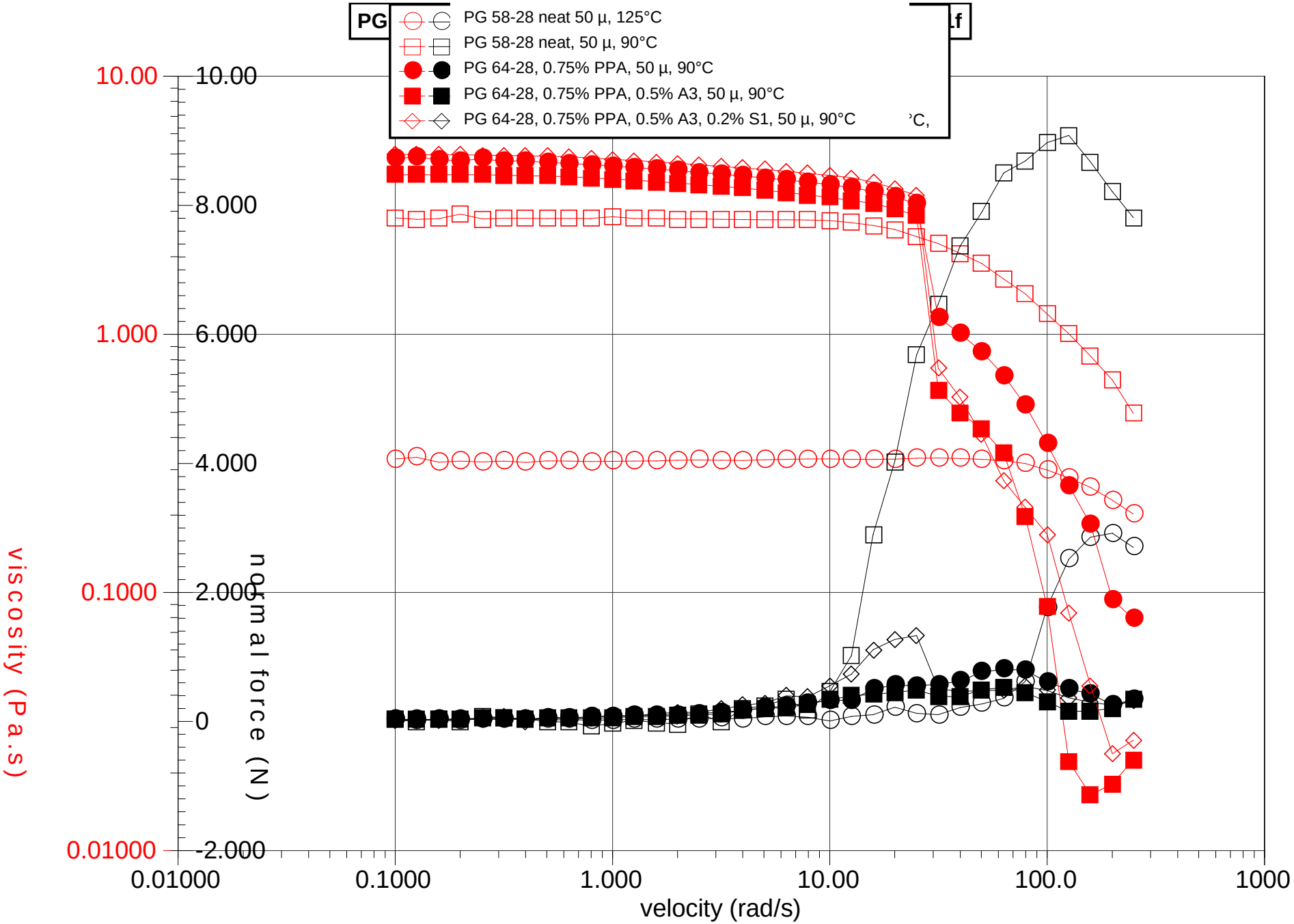
7. 250 tons, Columbia, Mississippi batch plant test. PG 64-22 + 0.3% S1 + 0.5% A2. Mixed at 240°F compacted at as low as 210°F, air temp was in the 30's°F. Because of air temp and hand work, mix temp raised to 250°F and laydown was in the 225°F range.
8. 1500 tons, 15% RAP, Near Algood,TN, Chattanooga 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°-255°F.
9. As we speak 12/11-12/07—??? 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.

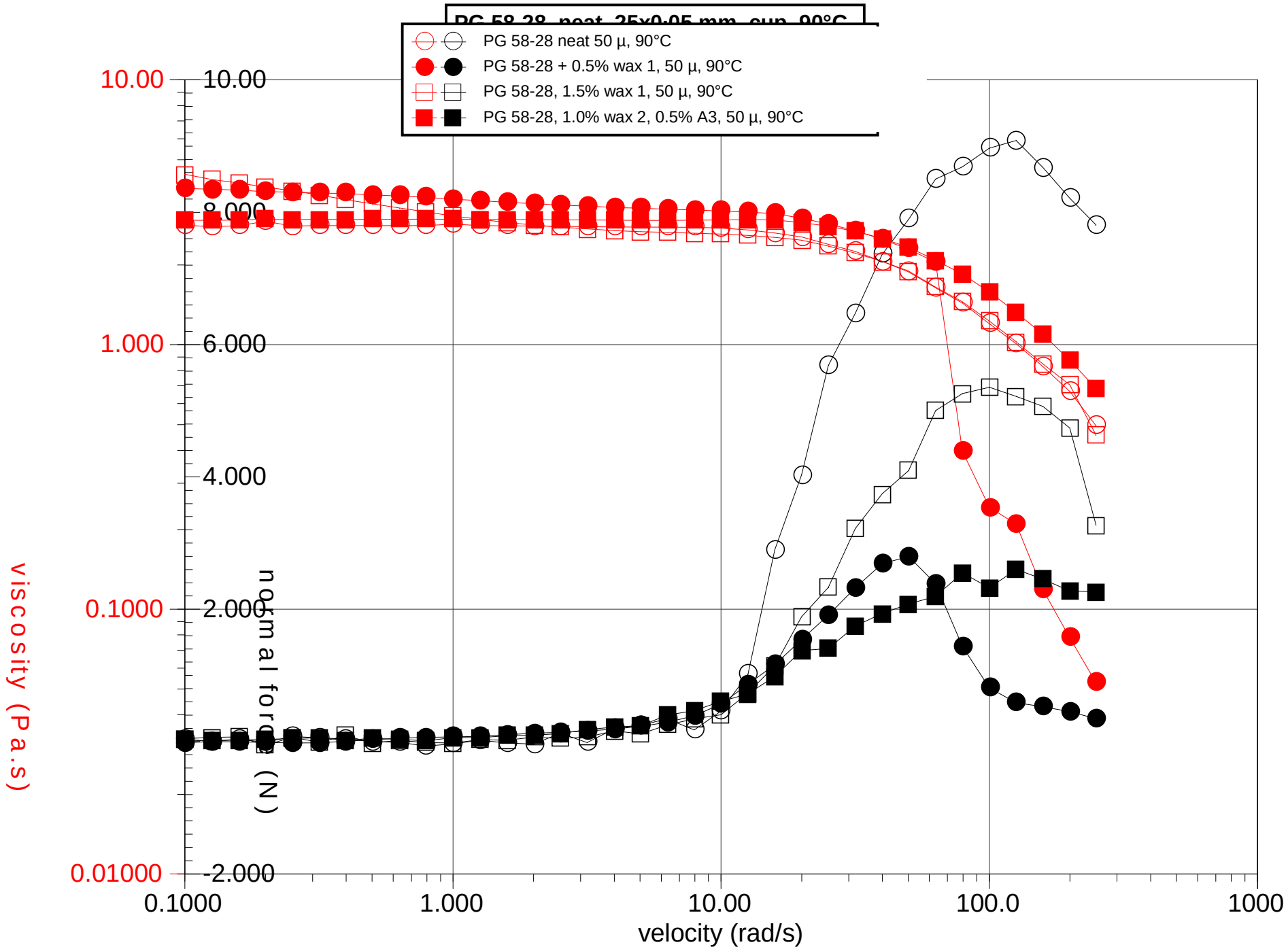
WHY DO WE THINK THIS WORKS

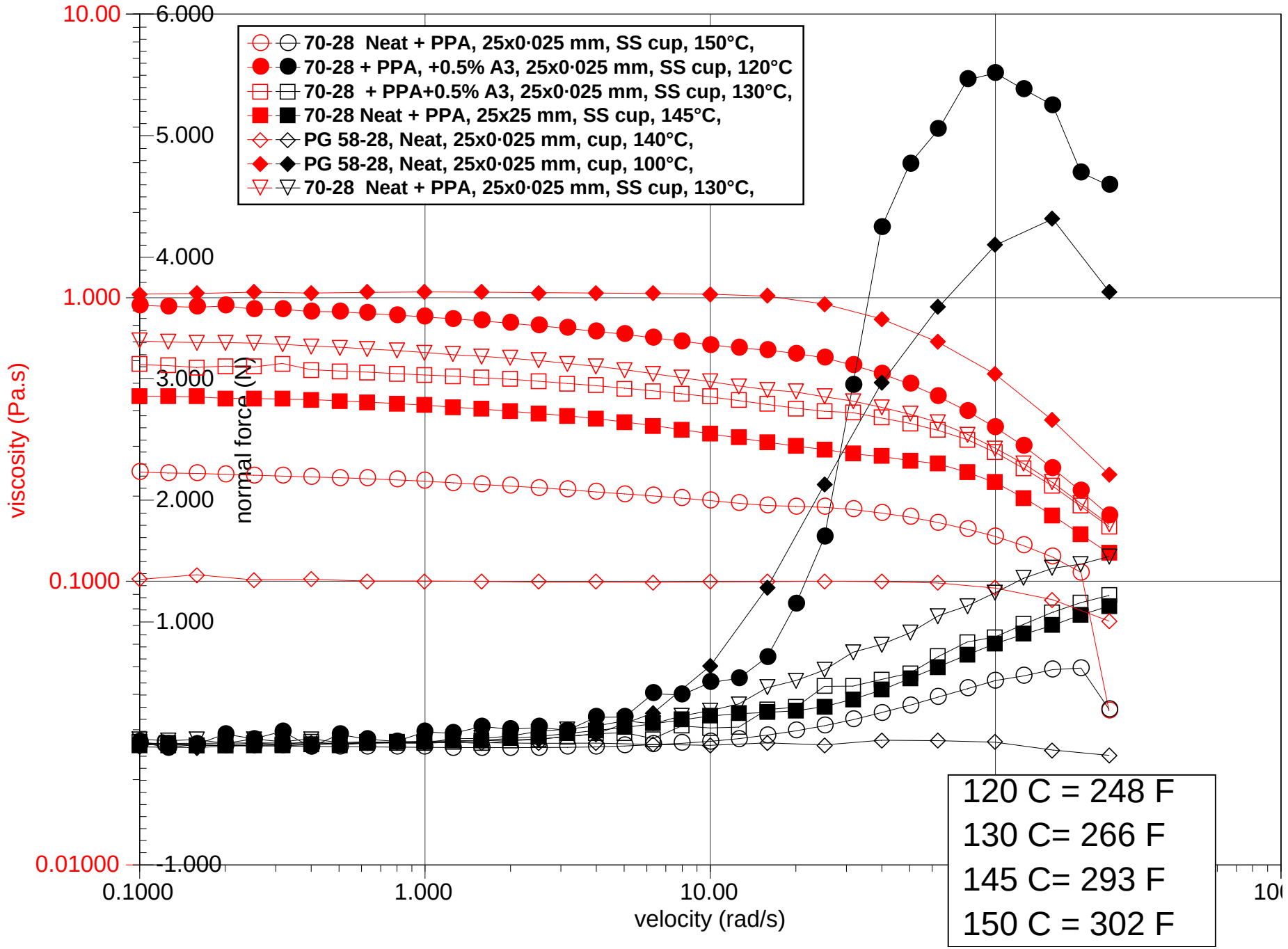
- Rheology of materials in thin films are different than bulk rheology
  - Typical DSR uses a 1000 μ film
  - Mineral fines are smaller than 50 μ
  - Aggregates have asperities that vary in sized, but none are truly smooth
  - We began our testing at 100 μ and are now working at 25μ
  - Our investigations began by looking at tribology testing conducted by the lubricating and medical prosthetics industries and investigations performed by people studying rheology of plate tectonics


PG 58-28, neat, 25x0·05 mm, cup, 125°C, Stdy Shr, AR1-0001f, Steady state flow step 1
PG 58-28, neat, 25x0·05 mm, cup, 100°C, Stdy Shr, AR1-0001f, Steady state flow step 1
PG 58-28, neat, 25x0·05 mm, cup, 90°C, Stdy Shr, AR1-0001f, Steady state flow step 1
2.81 Pa·s @ 90°C
1.25 Pa·s @ 100°C
0.33 Pa·s @ 125°C
viscosity (Pa.s)
normal force (N)
velocity (rad/s)
10.00
1.000
0.1000
10.00
8.000
6.000
4.000
2.000
0
-2.000
0.01000
0.1000
1.000
10.00
100.0
1000


07-030A, 1
AR1-0001f
1.5% wax 1, 100 µ, 90°C
1.5% wax 1, 100 µ, 90°C
0.5% 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
10.00
1.000
0.1000
0.01000
viscosity (Pa.s)
3.000
2.500
2.000
1.500
1.000
0.5000
-0.5000
normal force (N)
0.1000
1.000
10.00
100.0
1000
velocity (rad/s)


PG 58-28 neat 50 µ, 125°C
PG 58-28 neat, 50 µ, 90°C
PG 64-28, 0.75% PPA, 50 µ, 90°C
PG 64-28, 0.75% PPA, 0.5% A3, 50 µ, 90°C
PG 64-28, 0.75% PPA, 0.5% A3, 0.2% S1, 50 µ, 90°C
10.00
1.000
0.1000
0.01000
viscosity (Pa.s)
10.00
8.000
6.000
4.000
2.000
0
-2.000
normal force (N)
0.01000
0.1000
1.000
10.00
100.0
1000
velocity (rad/s)


PG 58-28 neat 50 µ, 90°C
PG 58-28 + 0.5% wax 1, 50 µ, 90°C
PG 58-28, 1.5% wax 1, 50 µ, 90°C
PG 58-28, 1.0% wax 2, 0.5% A3, 50 µ, 90°C
10.00
1.000
0.1000
0.01000
viscosity (Pa.s)
10.00
8.000
6.000
4.000
2.000
-2.000
normal force (N)
0.1000
1.000
10.00
100.0
1000
velocity (rad/s)


70-28 Neat + PPA, 25x0·025 mm, SS cup, 150°C,
70-28 + PPA, +0.5% A3, 25x0·025 mm, SS cup, 120°C
70-28 + PPA+0.5% A3, 25x0·025 mm, SS cup, 130°C,
70-28 Neat + PPA, 25x25 mm, SS cup, 145°C,
PG 58-28, Neat, 25x0·025 mm, cup, 140°C,
PG 58-28, Neat, 25x0·025 mm, cup, 100°C,
70-28 Neat + PPA, 25x0·025 mm, SS cup, 130°C,
viscosity (Pa.s)
normal force (N)
velocity (rad/s)
10.00
1.000
0.1000
0.01000
6.000
5.000
4.000
3.000
2.000
1.000
-1.000
0.1000
1.000
10.00
120 C = 248 F
130 C= 266 F
145 C= 293 F
150 C = 302 F

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

SUMMARY CONT'D

- 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

We have presented 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. Our 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 produced 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 30% so far)
- Need to evaluate 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


QUESTIONS