DIFFERENTIATION OF SLURRY SEAL AND MICROSURFACE SYSTEMS BY LABORATORY TESTS

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In order to produce bituminous pavement mixtures, the materials combinations must be fluid enough to be mixed and placed. As the name implies, "hot mix" is fluidized for mixing and spreading by heat; i.e., melting the thermoplastic bitumen. "Set" occurs by removal of heat or cooling.

Though sometimes fluidized by solvents, most cold mixes are fluidized for mixing and spreading by the use of bitumen-in-water emulsions and additional mix water. Cold mixes must deal with the presence of water and removal of the effects of presence of water for set and cure.

Compared to thin layered cold mix, slurry seal and microsurfacing materials, hot mix is thought of as an engineering, thick layered, structural material. It is not surprising then that hot mix technologists and bituminous engineers are totally at sea when attempting to test and design thin layered cold mix systems especially when conventional hot mix technology is applied to these "wet" systems.

Compounding the problem are the many kinds or classes of Cold Mixed Slurry Seal and Microsurfaces. These mixes are much more complex than normal hot mixes because of the use of additional variables such as; water, emulsifier residues, solution pH, mineral and chemical fillers and admixtures such as retarders and accelerators and high fines contents. Each separate materials combination must be designed for the specific bitumen and aggregate to be used. "Each system is its' own thing."

To aid in the understanding of thin layered cold mix systems, it is the purpose of this paper to describe and use some 12 laboratory test procedures which are unique to slurry mixes to compare the properties or test responses of 3 very different thin layered cold mix systems: Systems "A","B" and "C".

For comparison, all specimens were made with a high quality 0/#4 (0/5mm) Dolomite with 12% 0/#200. Unless indicated, each mix used 12% emulsion content for reference.

System "A" is a polymer modified quick-traffic high performance Microsurface system.

System "B" is a high performance unmodified Slurry Seal system.

System "C" is a commodity grade, generic Slurry Seal system.

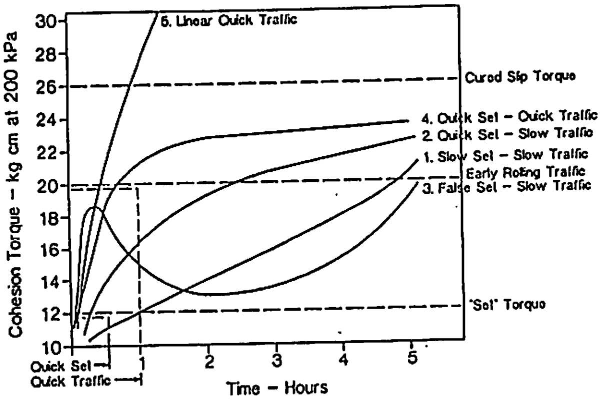
Test methods used are from the fourth edition of "Design Technical Bulletins-1990" published by the International Slurry Surfacing Association, Washington, D.C. These test methods are unique to slurry systems and attempt to simulate field conditions in the laboratory.

LABORATORY TEST RESULTS OF 3 SYSTEMS COMPARED.

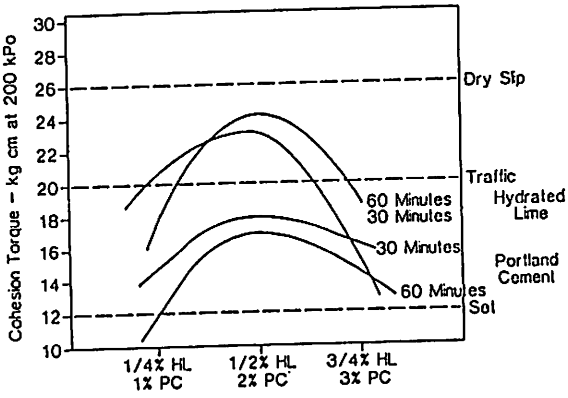
1. CHEMICAL FILLER CONTENT OPTIMIZATION BY WET COHESION TEST (ISSA TB 139)

The first testing of cold mix system is a series of trial mixes (ISSA TB113) to determine mixing characteristics, effects of water content as well as effects of chemical fillers and other admixtures. 100 or 200 gram mixes are made and cast into 6mmx60mm ø molds. Periodically (30′,60′, etc.) a single specimen is tested for wet cohesive strength by the Cohesion Tester. (figure 1a).

The cohesion tester is a power steering simulator which measures the torque required at failure to tear apart the specimen by a 32mm ø rubber foot loaded to 200 kPa (approximately auto tyre contact pressure). 12.0 kg-cm is the cohesion value where the slurry sets, is water resistant and cannot be remixed. At 20 kg-cm, sufficient cohesion has developed to allow early rolling traffic. By setting time limits on cohesion values at 30′minutes for 12 kg-cm "set" and 60′ minutes for 20 kg-cm "traffic" all slurry systems may be classified into one of 5 classes (figure 1b).



CLASSIFICATION OF MIX SYSTEMS BY COHESION TEST CURVES

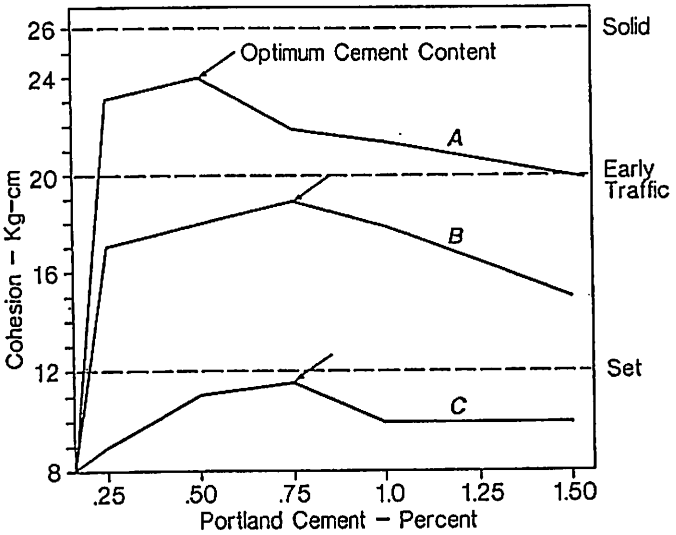


FILLER CONTENT OPTIMIZATION

The cohesion tester may also be used to optimize chemical filler selection and admixture contents by use of the "Benedict Curve" (figure 1c) where the effect on cohesion of incremental additions of admixtures is plotted (figure 1d).

At optimum cement content:

System A is Quick-set, Quick-traffic
System B is Quick-set, Slow-traffic
System C is Slow-set, Slow-traffic

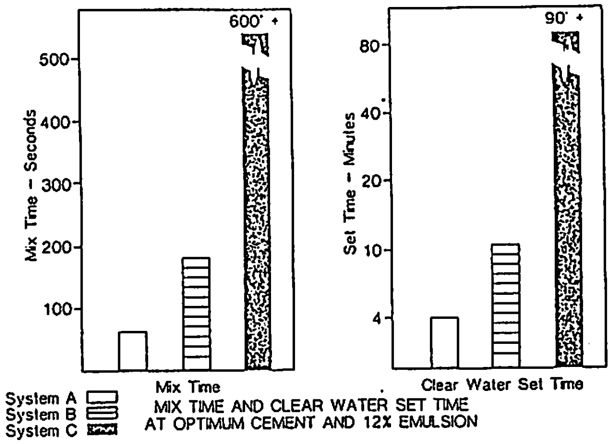


PORTLAND CEMENT OPTIMIZATION BY
60 MINUTE WET COHESION – 12% EMULSION

2. MIX TIME AND CLEAR WATER SET TIME (ISSA TB 102 & 113)

100 or 200 gram hand mixes are made. Part of the sample is cast into a cohesion test ring mold at 30 to 40 seconds. Mixing is continued until the mix breaks so that all free emulsion is exhausted onto the aggregate and/or the mix breaks (figure 2a). Time to exhaustion of the emulsion is called "mix time". Periodically, an absorbant paper towel or tissue is gently pressed onto the surface of the cast specimen. The time is noted when there is no brown stain on the towel, only clear water appears. (figure 2b). This is called the "clear water set time".

System A	has very fast clear water set at 4′ with a 120" mix time.
System B	has a clear water set at 10′; mix time is 180".
System C	has very long clear water set time at 90+′ and mix time is also very long at 10+′.



MIX TIME AND CLEAR WATER SET TIME
AT OPTIMUM CEMENT AND 12% EMULSION

Systems A and B would find advantage when early traffic or rain is anticipated. System C on the other hand, has a very long mix or workability time which would be excellent where much hand work is required (parking lots and play fields). However, System C has no early rain resistance.

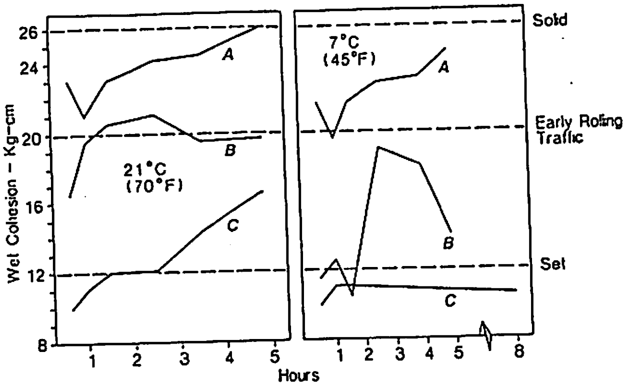
3. 5-HOUR WET COHESION AT LOW TEMPERATURE 45F (7°C) COMPARED TO AMBIENT, 72F (21°C)

This test repeats the previous test except that materials are chilled to 7C before mixing and allowed to cure at 7C in the environmental chamber. Tests are performed at one-hour intervals for 5 hours and the results plotted (figure 3).

System A performs very well at both ambient and low temperature. Note that both high and low temperature plots are nearly parallel and that the low temperature curve is 2 to 3 points lower than the ambient.

System B performs well at ambient but much more time is required for the initial set. Though the 20 kg-cm traffic torque is nearly met at 3½ hours, the cohesion values fall off in exhaustion after peaking. This could affect the long term durability of the mix.

System C is very slow setting at 21C requiring about 10 to 12 hours before use. At 7C there is no set at 8 hours. At 30 hours it is not cohesive enough for use. At 7C, this system may never develope adequate cohesive strength.

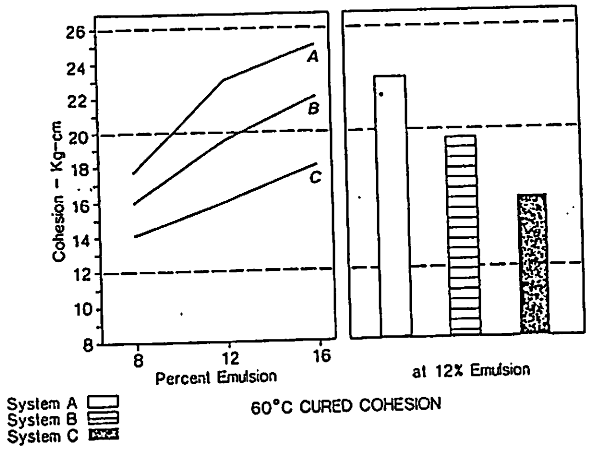


EFFECT OF TEMPERATURE ON
5 HOUR WET COHESION – 12% EMULSION

4. 60C CURED COHESION

High temp cohesion test is a simple method to compare or classify the overall quality of the bitumen-aggregate-emulsifier system. Triplicate cohesion specimens are cured in a forced draft oven at 60°C for 15 to 20 hours, individually removed from the oven and tested immediately before cooling. Though the individual curves formed at 8,12 and 16% emulsion are parallel and nearly evenly spaced, there is a substantial difference between Systems A, B and C (figure 4). A value of 18 to 20 kg-cm at 12% emulsion content is considered quite good for unmodified systems. Some systems exceed 28 kg-cm at 12% emulsion content.

This test may also be used to confirm filler and admixture optimums found in the Wet Cohesion Test.

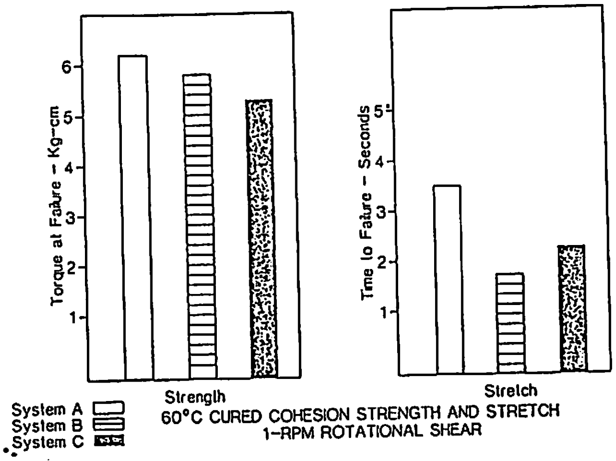


60°C CURED COHESION

5. 60C STRENGTH AND STRETCH, 1RPM ROTATIONAL SHEAR

In this test, the manual cohesion tester is modified by adding a torque motor, frictionless turn table mechanically linked to a torque meter, speed controller and strip chart. The cohesion tester foot revolutions is set at 1-RPM and lowered onto to 60C specimen at 200kPa. Kg-cm at failure is recorded as "strength" while time to failure is recorded as "stretch".

All 3 systems had about the same "strength" at 5.5 to 6.0 kg-cm but System A has nearly twice as much "stretch" as B and C; an indication of the presence of a low modulus polymer. (figure 5).



60°C CURED COHESION STRENGTH AND STRETCH
1-RPM ROTATIONAL SHEAR

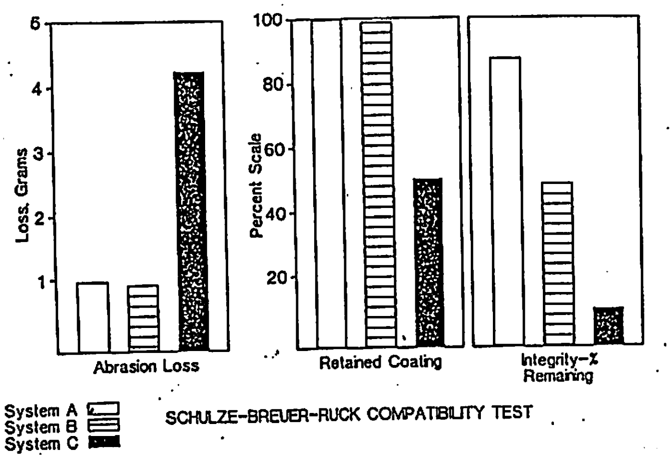
6. SCHULZE-BREUER-RUCK COMPATIBILITY (ISSA TB 144)

The Shulze-Breuer-Ruck tests determine the 0/#10 (0/2mm) aggregate filler-bitumen compatibility. The aggregate is mixed with 8.2% bitumen (12.5% emulsion)and pressed into 40 gram pills 30mmø x about 30mm long, soaked for 6 days and wet tumbled in the Schulze-Breuer machine's shuttle cylinders for 3600 cycles at 20 RPM. (figures 7a & 7b).

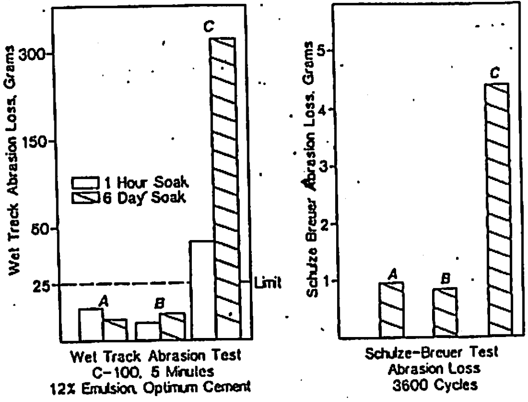
Absorbtion, abrasion loss, adhesion and high temperature integrity (% remaining) are determined and results may be grade ranked for comparative compatibility.

System A and B have low abrasion loss at less than 1 gm while C is quite poor at more than 4 grams. Adhesion (coating) is also very good for A and B while system C is poor at about 50%. (figure 7c). The Ruck high temperature integrity (30-minutes in boiling water) shows system holding together rather well at about 90% while B is about half that of A and C is very poor at 10%. (figure 7d).

While not directly correlatable, the Schulze-Breuer abrasion and wet track abrasion test results all do correlate relatively. (figure 7c).



SCHULZE-BREUER-RUCK COMPATIBILITY TEST



Wet Track Abrasion Test
C-100, 5 Minutes
12% Emulsion, Optimum Cement

Schulze-Breuer Test
Abrasion Loss
3600 Cycles

7. WET TRACK ABRASION TEST 1-HOUR AND 6-DAY SOAK (ISSA TB 100)

The Wet Track Abrasion Test is a California innovation first reported at AAPT in 1964 by Lloyd Coyne and Bill Kari. The test simulates wet abrasive conditions and maneuvers such as cornering and braking. The test is useful for determining the minimum emulsion content and for classifying the system. A cured sample 6mmX280mmø is wet abraded by a rotating weighted (2.3kg) abrading rubber hose for 5 minutes. The abrasion loss is reported in grams or in grams per unit abraded area. 24.5 grams loss is the maximum permissible loss for durable slurries. (figure 6).

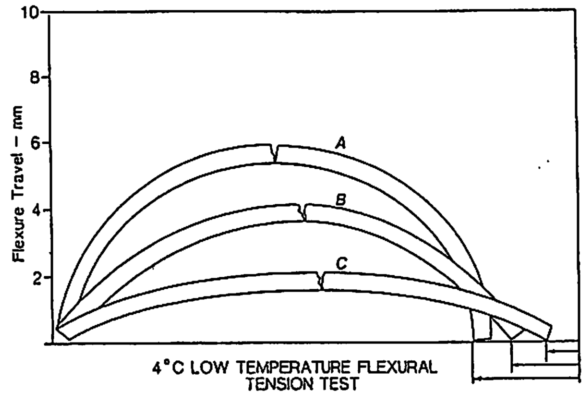
Systems A and B give quite acceptable results at 12% emulsion for both the 1-hour and 6-day soak periods. System C, however, will require perhaps 16% emulsion to give equivalent losses. We prefer to use 6-day soak WTAT test which we believe is more indicative of the system quality.

8. LOW TEMPERATURE (4C) FLEXURAL TENSION TEST (ISSA TB 146)

The low temperature flexural tension test (figure 8a) gives a relative value to the low temperature cracking properties of compacted mixes. A compacted loaded wheel test specimen is cooled to 4C and arched upwards at 20mm per minute. The horizontal distance of base travel is recorded when the first crack appears across the wheel path at the point of greatest tension.

The test values for A, B and C are low but typical of most slurry systems (figure 8b). System A has 6 times more low temperature cracking resistance than System C.

Other special composite systems, for comparison, have values of 150 to as high as 250mm.

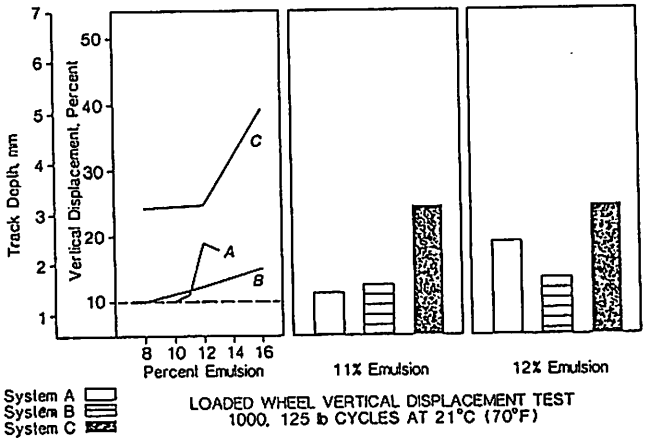


4°C LOW TEMPERATURE FLEXURAL TENSION TEST

9. MULTILAYERED LOADED WHEEL DISPLACEMENT TEST (ISSA TB 147A)

Specimens using 0/5mm or 0/8mm aggregate are cast 13 or 19mm thick x 50mm w x 380mm l are carefully measured and compacted with 1000, 57 kg LWT cycles at ambient (21C) (figure 9a). After remeasuring the percent vertical (rut depth) and lateral displacements are calculated. Figure 9b shows A and B with displacements of 12% while C is much greater at 23%.

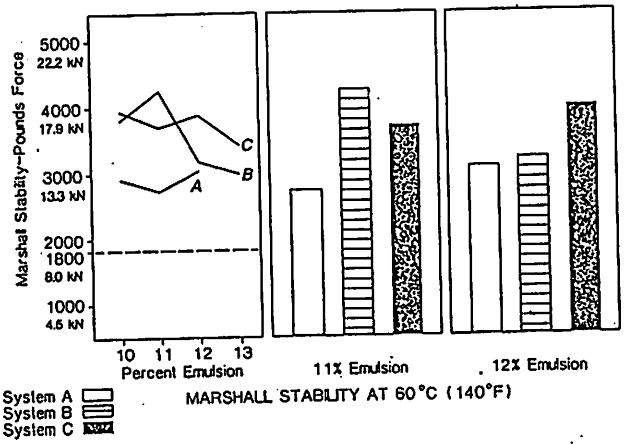
The test is useful to predict suitability for multilayer application or the amount of "crowning" required when rut filling to allow for traffic consolidation. Effectiveness of various polymers and gradations can also be determined.



LOADED WHEEL VERTICAL DISPLACEMENT TEST
1000, 125 lb CYCLES AT 21°C (70°F)

10. MARSHALL STABILITY AND FLOW (ISSA TB 148)

Since these are emulsion mixes, the normal Marshall procedure is modified to allow for air and low temperature drying before compaction at higher temperatures. In figure 10a, the unmodified Systems B and C have greater Marshall Stabilities than the polymer System A. At 11% emulsion, A is 2800 lbs while B is 4200 lbs.



MARSHALL STABILITY AT 60°C (140°F)

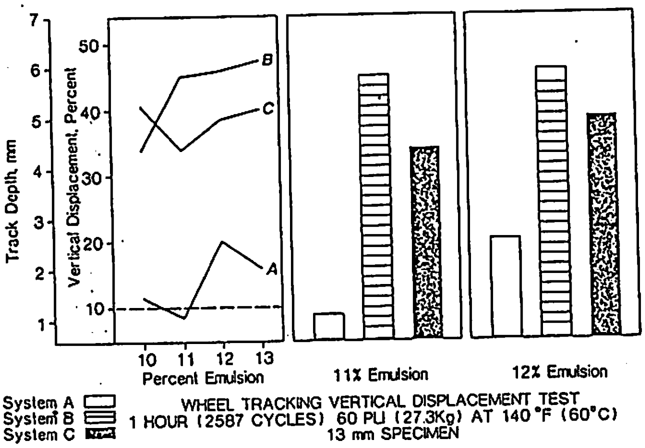
11. 45C (115F) WHEEL TRACKING TEST (ISSA TB 147B)

For many years the British have used the TRRL wheel tracking machine to test hot mix HMAC for rutting potential or rutting rates. Good correlations between lab and field have been applied to successful designs.

In contrast to the LWT, the WTT moves the work under a stationery loaded wheel at elevated temperatures. Our triple-track version of the British WTT accommodates 3 specimens (figure 11a).

Here, we've used the same uncompacted 13mm, 0/5mm specimens that were used for the ambient LWT test. They were run under an applied load of 59 lb/inch of tyre width for 1 hour at 44 RPM and 45C. System A's high temperature wheel tracking rate or vertical displacement was essentially the same as the LWT ambient displacement. Both B and C's 45C WTT displacements were dramatically increased over the LWT ambient displacements.

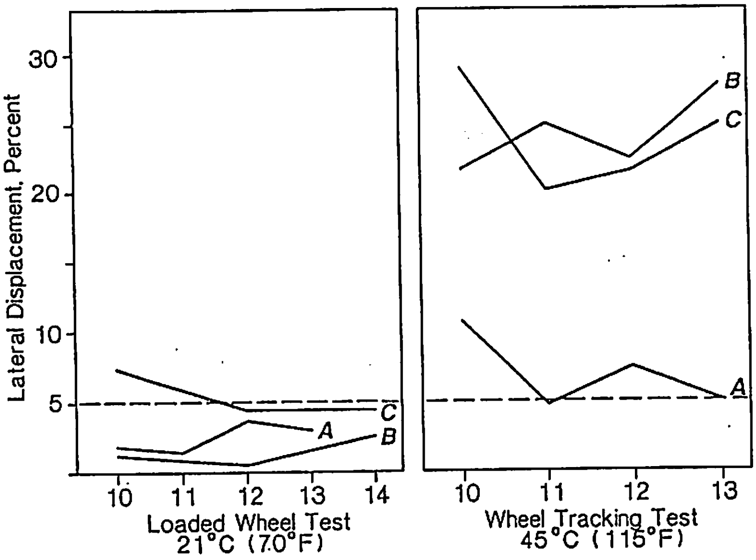
Note that the best Marshall Stability (System B) had the worst wheel tracking displacement!



WHEEL TRACKING VERTICAL DISPLACEMENT TEST
1 HOUR (2587 CYCLES) 60 PLI (27.3Kg) AT 140°F (60°C)
13 mm SPECIMEN

12. 45C WHEEL TRACKING LATERAL DISPLACEMENT

In both the LWT and WTT the specimens are unconfined. Figure 12a shows lateral displacement results quite similar to the previous vertical displacements. The ambient LWT lateral displacements are all less than 5% but system B and C high temperature WTT lateral displacements are radically higher at about 25% while A increases only slightly.



LWT AND WTT LATERAL DISPLACEMENTS COMPARED

SUMMARY

The following summary offers a subjective evaluation of the laboratory test performance of Systems A, B and C. Each system, while having its own special properties, is quite adequate when used to meet the objectives sought for each special material.

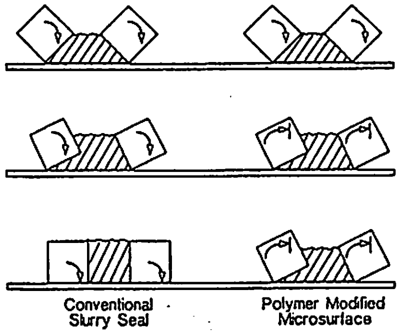
		SYSTEM A	SYSTEM B	SYSTEM C
Mix Time		Short(1)	Normal	V. Long
Set Time		V. Short	Short	V. Long
5-Hour Ambient Cohesion		V. Good	Fair	Poor
5-Hour Cold Cohesion		V. Good	Fair(4)	V. Poor(3)
60C Cured Cohesion		*V. Good	Good	Fair
Strength	Strength:	Most	----	Least
	Stretch:	Most	Least	-----
WTAT	One-Hour Soak:	V. Good	V. Good	Bad(5)
	Six-Day Soak:	V. Good	V. Good	V. Bad
Schulze-Breuer	Loss:	V. Good	V. Good	Poor(5)
	Ruck Adhesion:	V. Good	V. Good	Poor(5)
	Ruck Integrity:	*Excellent	Fair	V. Poor(5)
Low Temp Flexural Tension		Poor(6)	Poor(6)	V. Poor(6)
23C Loaded Wheel	Vertical Displacement:	V. Good(9)	V. Good(9)	Poor(9)
	Lateral Displacement:	Good	Good	Fair
60C Marshall	Stability:	Good	Excell(8)	Excell(8)
	Flow:	Normal	Normal	Normal
45C Wheel Tracking	Vertical Displacement:	*Excellent	Bad(7)	Bad(7)
	Lateral Displacement:	*Excellent	Bad(7)	Bad(7)

*Good Correlation -

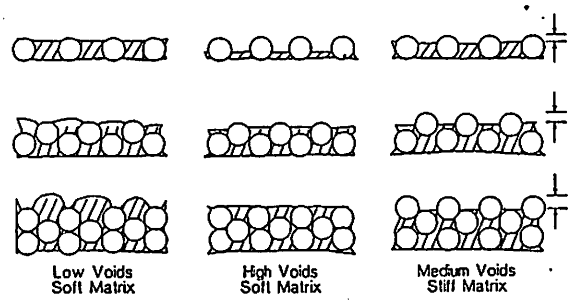
1. May have application problems in hot weather.
2. Poor rain resistance.
3. Warm weather application only.
4. Moderate weather applications only.
5. High abrasion loss in wet weather.
6. No reflection crack resistance.
7. No good for rut filling, unstable in warm weather.
8. Marshall stability does not predict high temperature rutting resistance.
9. LWT @ 23C may select optimum bitumen content but does not predict high temperature rutting resistance.

APPENDIX

As seen in the previous test results of "A","B" and "C", there is a wide spectrum of product performance. However, the primary difference between conventional slurry seal and microsurface is found in DIFFERENCES IN RESPONSE TO COMPACTION BY TRAFFIC.



MONOLAYER COMPACTION MATRIX EXTRUSION & MACROTEXTURE CHARACTERISTICS

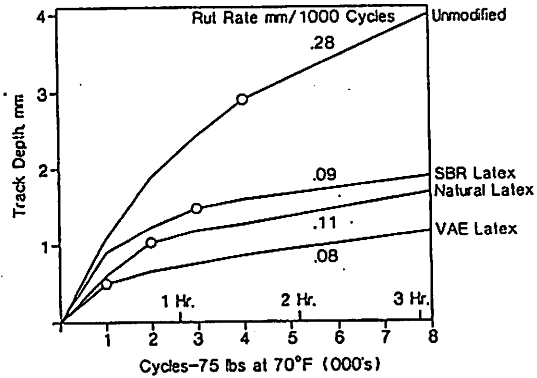


EFFECT OF LAYER THICKNESS & MATRIX PROPERTIES ON MACROTEXTURE DEPTH

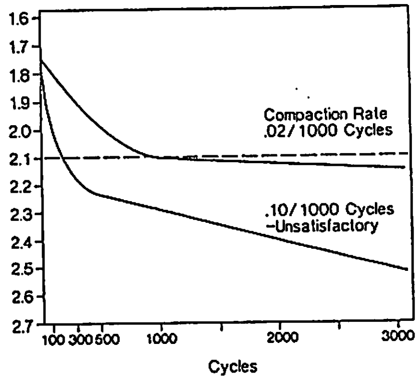
MONOLAYERED slurry systems will typically loose macrotexture due to soft matrix extrusion as traffic compacts to mix; i.e., the larger aggregates assume their "most comfortable position". On the other hand, Polymod cold MACs resist compaction because of a matrix stiff enough to prevent complete compaction; more like mix consolidation rather than compaction.

MULTILAYERED soft matrix slurries lose macrotexture as layer thickness increases, while the stiff matrix cold MAC's macrotexture actually increases with layer thickness.

Current research at Alpha Labs will hopefully more clearly define these differences. What we believe we are seeing is a high initial compaction rate which slows and becomes a steady-state rate of compaction. The number of cycles to reach the steady state as well as the rate itself, is of special interest. These tests are accelerated by wheel loadings as high as 5 times and more than loaded truck tires. In the real world, the rate of compaction in some systems eventually becomes zero where there is an equilibrium between the load and the microsurface.



EFFECT OF POLYMER TYPE ON LOADED WHEEL MULTILAYER RUTTING RATE



45°C WHEEL TRACKING TEST COMPACTION/DENSITY CURVES