-OUTLINE DRAFT-NOT FOR PUBLICATION-

PROPERTIES OF SLURRY SEAL AND COLD MAC TO MEET DESIGN OBJECTIVES

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INTRODUCTION

1. The term "COLD MIX" describes a large variety of bituminous mixtures, each for a specific purpose. This presentation will cover many of the important properties of a variety of thin layered surface mixes including generic slurry seals and the newer "Cold Mac" or Cold Micro Asphalt Concrete.

2. Slurry Seals are generally, squeegee applied in mono-layers in the 1/8" to 3/16" thick range or 8 to 15 lbs/sy while COLD MAC, as is being defined, is screed applied in variable thicknesses, mono and multiple layers for leveling purposes and rut filling. Application rates may vary from 1 to 200 lbs/sy, more typically in the 18 to 50 lb range.

3. There are many varieties of these mixes that confusion arises. What exactly is Slurry Seal? One is reminded of the seven blind men who examined the various separate parts of an elephant and declared the elephant to be a tree, a brush, a snake, a sword, a wall, a fan and so on. None could see the whole animal. Here we want to look at the whole animal(s) by comparing a variety of objective test results of three very different cold mix systems.

DESIGN OF SLURRY SEAL

Our design approach to both SLURRY and COLD MAC is the same as the design of any pavement system which is:

1. State clearly the objectives of the treatment
2. Select materials combinations to meet these objectives
3. Prepare laboratory specimens and subject them to field related or field correlated tests.

A typical generic Slurry seal design procedure is:

1. Materials Testing
   A. AGGREGATE, SE and Gradation
   B. EMULSION % Residue, Sieve, pH
2. Trial Mixes for mixability and wet cohesion (set and cure)
3. Compatibility
4. Consistency
5. Wet Track Abrasion Test (WTAT) (Minimum AC content)
6. Loaded Wheel Test (LWT) (Maximum AC content)
7. Graphical selection of Optimum Bitumen Content

The designer is beset with many more variables than is the case with hot mix design and the chemistry of the ingredients and their chemical interaction becomes extremely complex and critical. There is no universal criteria because "Each system is its own thing."

DESIGN OF "COLD MAC"

While slurry seal is a monolayered material COLD MAC is a variably thick, multilayered material and as such requires some special testing relating to the performance of both the MONO and MULTIPLE layers. This includes the high temperature British Wheel Tracking Test to test the high temperature stability of multiple layers.

THREE SYSTEMS COMPARED

To illustrate the wide variations in types of slurry and COLD MAC we will examine the laboratory properties of three cold mix systems, A, B & C.

Figure 1. CHEMICAL FILLER CONTENT OPTIMIZATION BY WET COHESION

The cohesion test is a power steering simulating test which reports the torque required at failure of a specimen by a 30 psi (200 kPa) loaded foot. 12.0 kg-cm. is the cohesion value where the slurry sets, is water resistant and cannot be remixed. At 20.0 kg-cm. sufficient cohesion has developed to allow early rolling traffic.

At Optimum System A is Quick Set, Quick Traffic
System B is Quick Set, Slow Traffic
System C is Slow Set, Slow Traffic

Figure 2. MIX TIME AND CLEAR WATER SET TIME

System A is very fast setting with 2 minutes mix time

System B has a longer 3 minute mix time and a 10-minute clear water set time.

Both system A & B would find advantage when early traffic is anticipated or rain is a possibility.

System C on the other hand has very long mix or workability time which is excellent where much hand work is required (parking lots & play fields). However there is no early rain resistance.

Figure 3. 5-HOUR WET COHESION AT 75F AND 45F

System A Performs beautifully at either normal or low temperatures.

System B Performs well at 75F but much more time is required for initial set and traffic at 45F.

System C Is very slow setting at 75F and has virtual no traffic time. At 45F and 30 hours, it is not yet sufficiently cured to support traffic.

Figure 4. 60C CURED COHESION is a simple method to compare the overall quality of the bitmen-aggregate-emulsifier system. Here, A, B & C are worlds apart. A value of 18-20 kg-cm at 12% emulsion content is considered excellent for unmodified systems. Some systems exceed 28 kg-cm at 12% AE.

Figure 5. STRENGTH & STRETCH, 1-RPM ROTATIONAL SHEAR

The cohesion tester is modified by adding a motor, frictionless turntable, speed control and strip chart. Kg-cm at failure (=strength) and time to failure (=stretch) is measured. System A has nearly twice as much "stretch" a System B and could be expected to be more crack resistant.

Figure 6. WET TRACK ABRASION TEST 1-HOUR AND 6-DAY SOAK

The time honored WTAT is a California invention first reported at AAPT in 1964 by Lloyd Coyne and Bill Kari. The test is still valid and quite useful for determining the minimum bitumen requirement. A variation from the standard one-hour soak is a 6-day soak which really separates the men from the boys. We prefer the 6-day soak variation for complete system evaluation.

There is a correlation between the 6-day soak WTAT and the Schulze-Breuer Test.

Figure 7. SCHULZE-BREUER, RUCK ADHESION AND INTEGRITY

The Schulze-Breuer and Ruck Tests determine the 0/#10 aggregate filler-bitumen compatibility. The test has been used for many years in Germany to check aggregate-bitumen compatibility for "Gussasphalt", a molten slurry.

The 0/#10 (2 min) aggregate is mixed with 8.2% Bitumen and pressed into 40 gram pills, about 30 mm diameter X 30 mm high, then soaked for 6 days and wet tumbled in the S-B machine's shuttle cylinders for 3600 cycles at 20 RPM. The remains are the immersed in boiling water for 30 minutes.

Absorbtion, Abrasion Loss, Adhesion and high temperature integrity (% remaining) are determined.

System A & B are clear winners, while system C performs poorly. There is a correlation in the test. Not only can the aggregate-bitumen combination be evaluated, but, by the use of reference materials, the bitumen, emulsifiers, antistrips and additives may be evaluated and compared.

Figure 8. <u>4C LOW TEMPERATURE FLEXURAL TENSION TEST</u>

Test uses a compacted Loaded Wheel Test specimen chilled to 4 C and arched upwards at 20mm per minute. The mm travel is recorded at the first complete crack across the wheel path.

The values for A, B & C are relatively low but, again, A, B & C come in 1, 2 3. A having 6 times more low temperature cracking resistance than C.

Figure 9. <u>LOADED WHEEL TEST VERTICAL DISPLACEMENT</u>

0/#4 aggregate is mixed with emulsion and cast into a 1/2" LWT mold. The cured specimen is measured for thickness and width then compacted with 1000, 125-pound cycles of the LWT at room temperature and re-measured, the percent vertical and lateral displacement is recorded. Figure 9 is a plot of the vertical displacements. A and B are tied for first place at about 12% while C looses at 23% ambient vertical displacement.

This test is a measure of the resistance to compaction and thus stability.

Figure 10. <u>MARSHALL STABILITY AND FLOW</u>

These are emulsion mixes and the Marshall procedure is altered to allow 3 days air curing, 18-20 hours at 140F in forced draft oven to dry; then heated to 300F for compaction.

At 11% emulsion, B is the winner at 4100 lbs.!

Figure 11. <u>45C WHEEL TRACKING TEST (BRITISH)</u>

For many years the British have used their wheel tracking machine to test bituminous hot mixes for rutting potential and rutting rates. Successful designs are applied using WTT data.

Here we've used uncompacted 1/2", 0/#4 specimens run under a load of 59 lb/inch of width for 1 hour at 44 RPM at 45C (115 F). Here, System A is far and away the winner.

Please note that the BEST MARSHALL STABILITY (system B) HAS THE WORST WHEEL TRACKING RATE!

Figure 12. <u>LWT, WTT LATERAL DISPLACEMENT AND MARSHALL FLOW COMPARED</u>

There seems to be some correlation of these tests, but the data is insufficient since only single specimen results were recorded.

Figure 13. LWT, WTT LATERAL DISPLACEMENT

The contrast between the Loaded Wheel Test at 75F and the Wheel Tracking Test at 115F is great. Again system A has very high resistance to high temperature lateral displacement while B and C are quite poor.

SUMMARY

We attach a summary sheet of the subjective test results of systems A, B & C. Each system, while having its own special properties, is quite adequate when used to meet the objectives sought for each special situation.

We include an appendage paper, "Laboratory Tests and Testing Trends for Slurry Seal and Cold Overlay Design and Research," which gives a more detailed description of our approach to the design and design research for these thin layered cold mixes.

SUMMARY		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 & Stretch	Strength:	Most	------	Least
	Stretch:	Most	Least	------
WTAT	One-Hour Soak	V. Good	V. Good	Bad(5)
	6-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. Hi 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 hi temp. rutting resistance.
9. LWT @ 23C may select optimum bitumen content but does not predict hi temp rutting resistance.

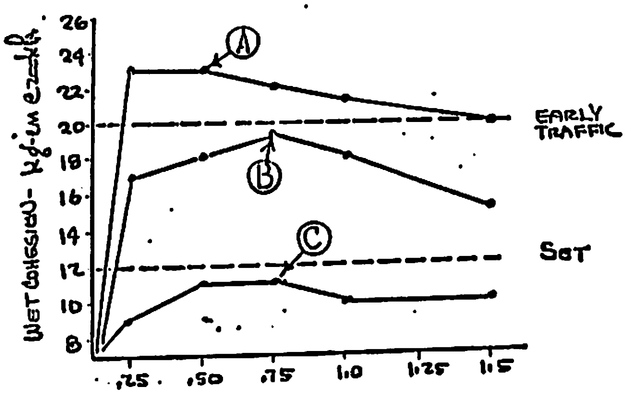


FIG. 1 TYPE I PORTLAND CEMENT OPTIMIZATION BY 60-MINUTE WET COHESION

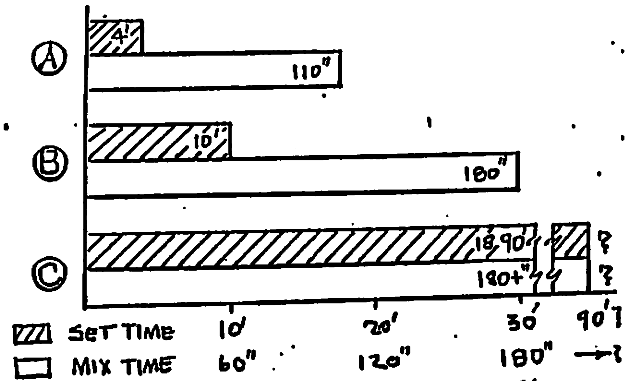


FIG 2 MIX TIME & CLEAR WATER SET TIME AT OPTIMUM CEMENT CONTENT

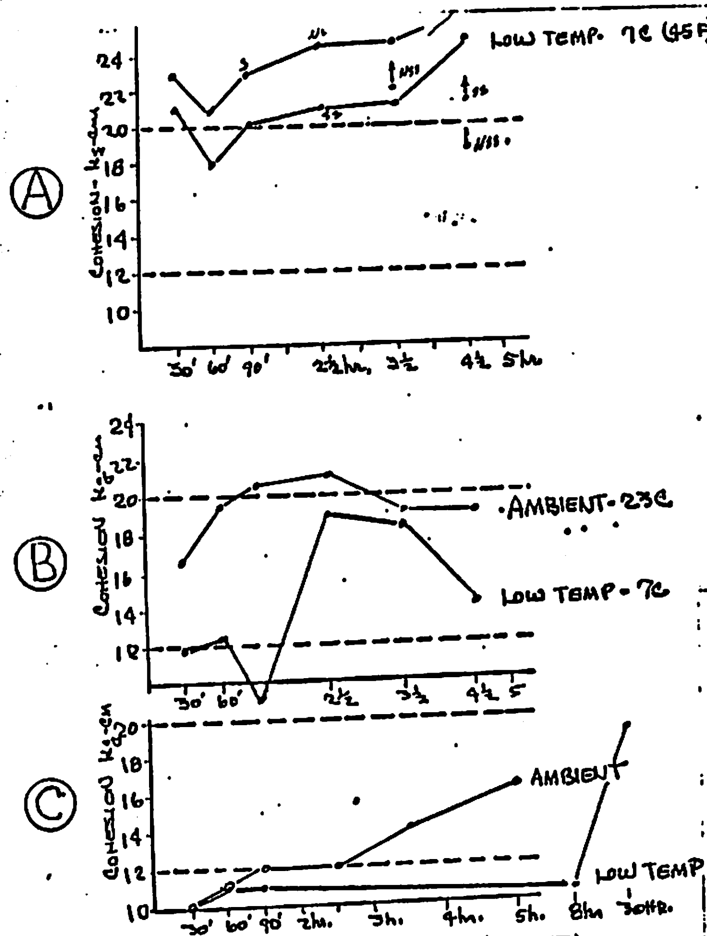
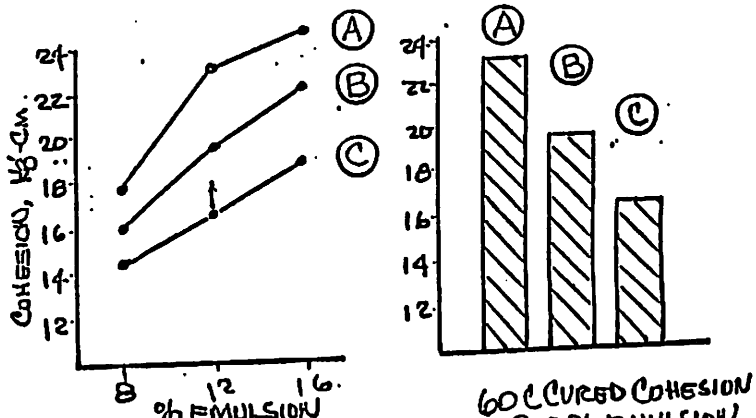


FIG 3 5-HOUR WET COHESION @ AMBIENT & LOW TEMPERATURE AT OPTIMUM PC & 12% AE



60C CURED COHESION @ 12% EMULSION

FIG. 4 60C CURED COHESION

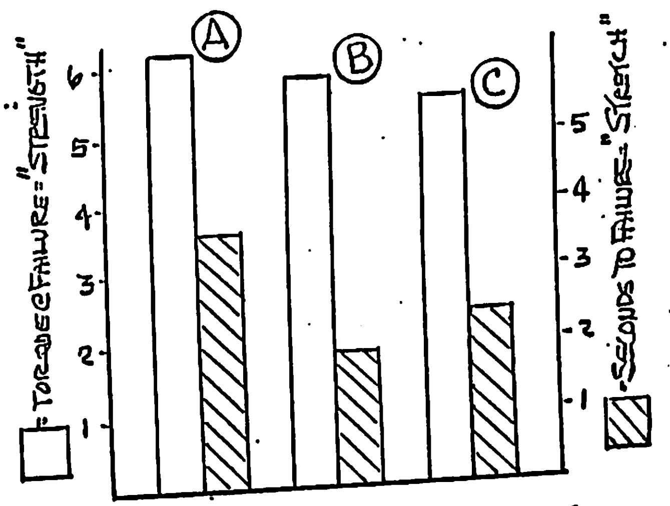


FIG. 5 60C CURED COHESION STRENGTH & STRETCH 1-RPM ROTATIONAL SHEAR

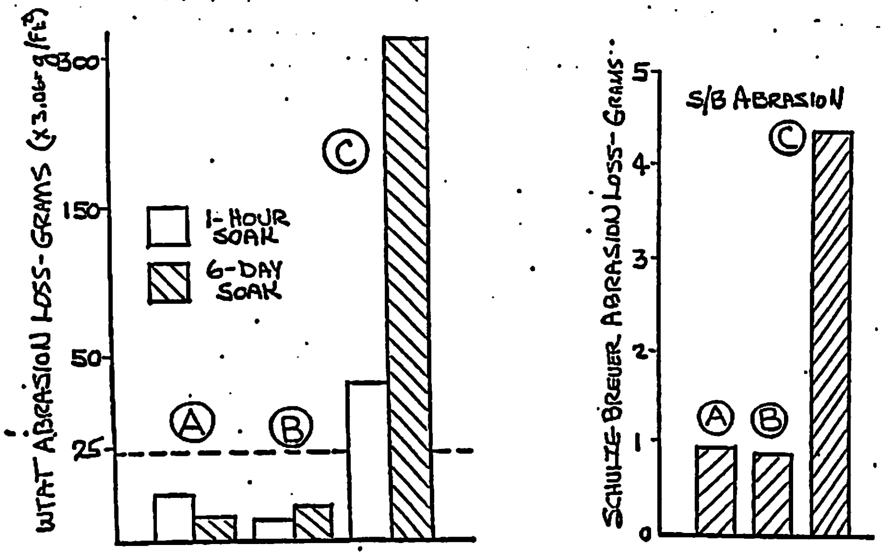


FIG. 6 WET TRACK ABRASION TEST
C-100, 5 MINUTES, GRAMS
@ 12% AE & OPTIMUM CEMENT

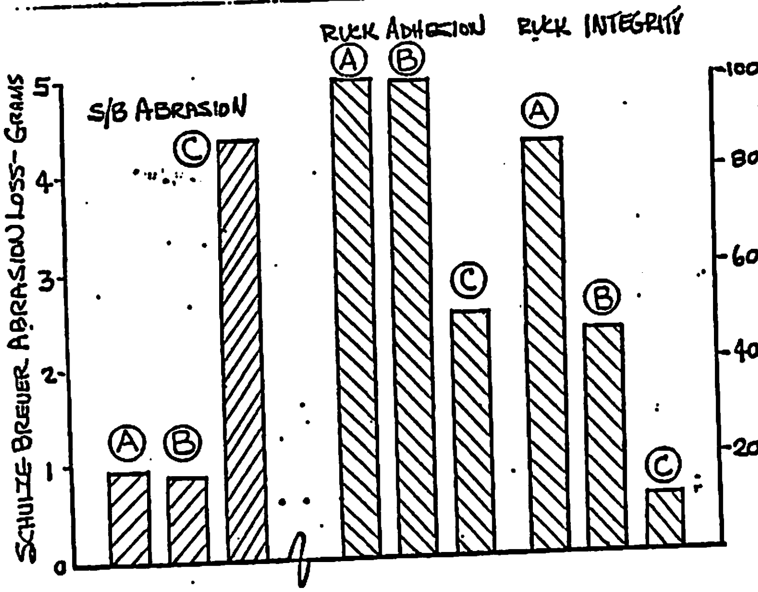


FIG. 7 SCHULZE-BREUER, RUCK ADHESION & INTEGRITY

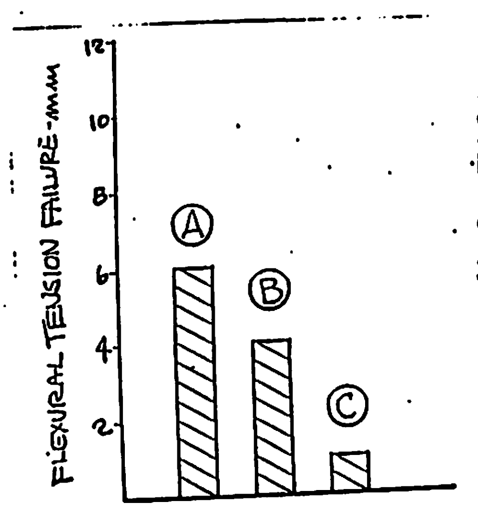


FIG. 8 4C LOW TEMPERATURE
FLEXURAL TENSION TEST

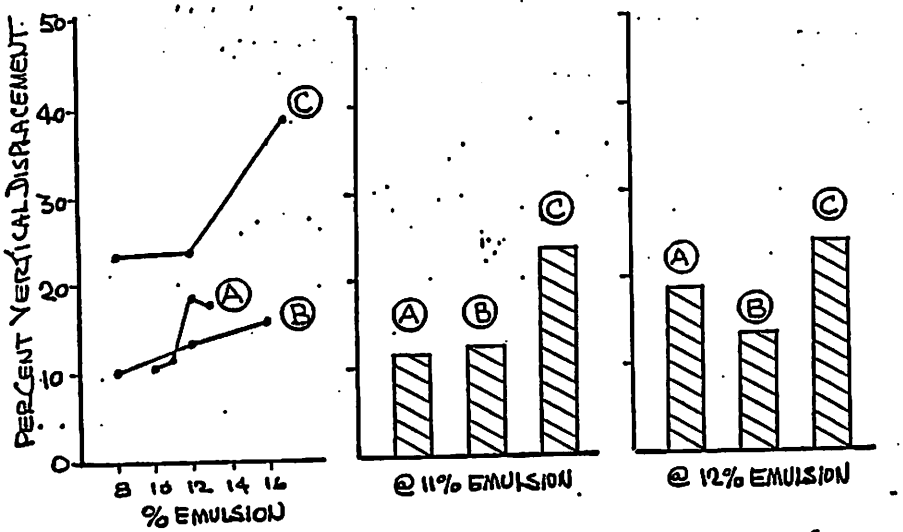


FIGURE 9 LOADED WHEEL TEST VERTICAL DISPLACEMENT
@ 23 C 1000, 125 LB. CYCLES

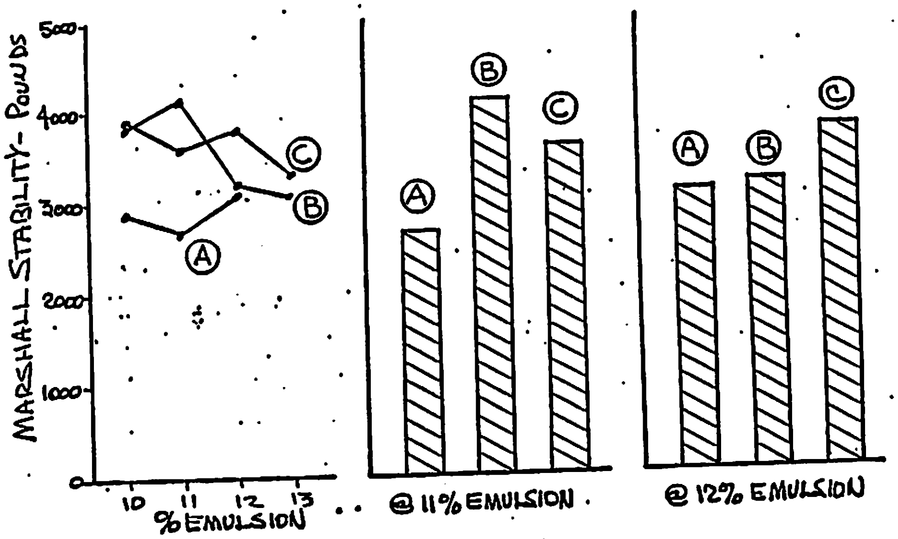


FIGURE 10 MARSHALL STABILITY @ 60C
(POUNDS FORCE AT FAILURE)

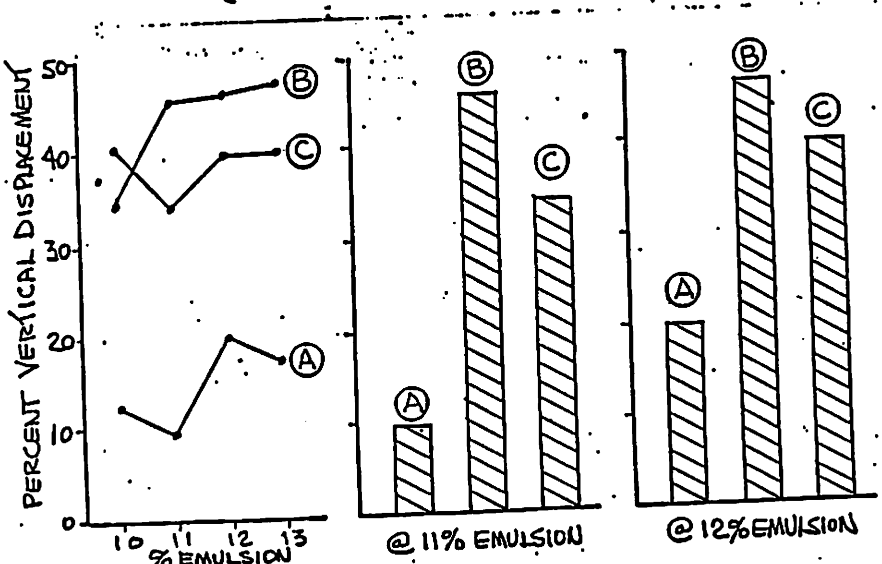


FIGURE 11 WHEEL TRACKING TEST (BRITISH STANDARD)
VERTICAL DISPLACEMENT, 1 HOUR, 60 PSI @ 45C (115F)
(FROM 12.5 mm UNCOMPACTED 0/#4 SPECIMEN)

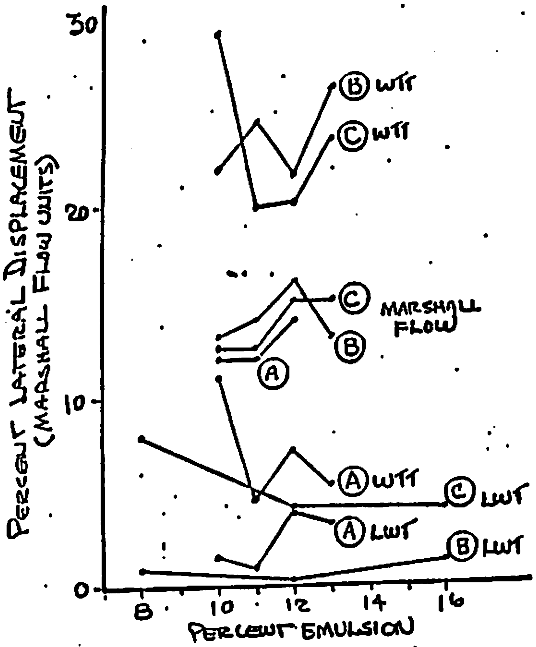


FIG. 12 LOADED WHEEL (23C), WHEEL TRACKING (45C) LATERAL DISPLACMENT COMPARED WITH MARSHALL FLOW

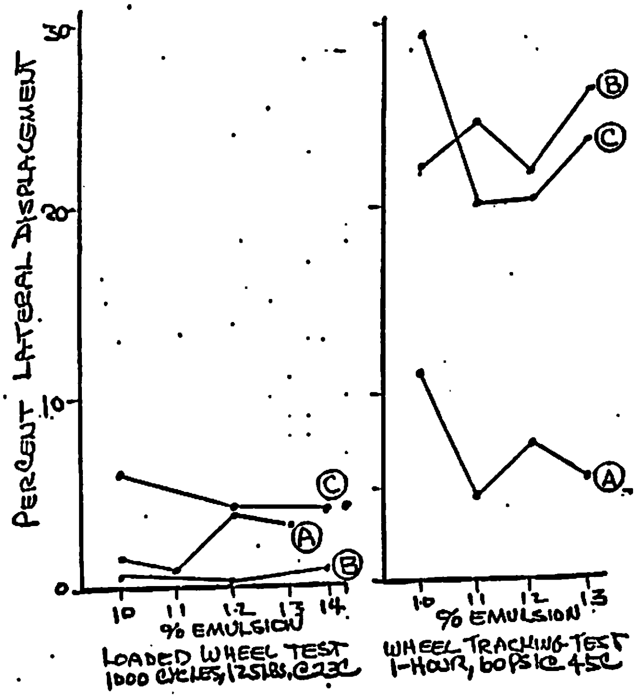


FIG 13 LWT@23C(72F) & WTT@45C(115F) LATERAL DISPLACEMENT COMPARED

PROPERTIES of SLURRY SEAL & COLD MIX TO MEET DESIGN OBJECTIVES/BENEDICT. 11/88