- DRAFT - NOT FOR PUBLICATION - TO BE REVISED -

EXPERIMENTS WITH CURED COHESION TESTING OF SLURRY SEALS AND THIN LAYERED COLD MIXES

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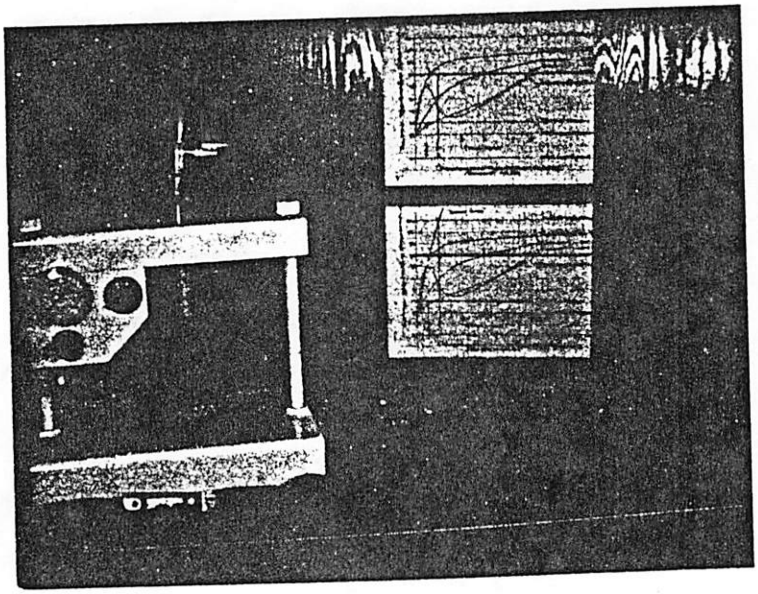
PREPARED FOR PRESENTATION TO THE 24TH ANNUAL CONVENTION OF THE INTERNATIONAL SLURRY SEAL ASSOCIATION, HYATT ON UNION SQUARE, SAN FRANCISCO, CALIFORNIA, JANUARY 28, 1986



IN OUR 1985 PAPER "USES OF THE MODIFIED COHESION TEST FOR EMULSION FORMULATION AND MIX DESIGN OF PERFORMANCE COLD MIX SYSTEMS", FIGURE 18 SHOWED OUR FIRST 60C (140F) CURED COHESION CURVES. A "NORMAL" CSS-IH CURVE WAS PRODUCED AT OUR POLYMAC ALPHA LABORATORY SHOWING THE INCREASE IN CURED COHESIVE STRENGTH WITH THE INCREASE IN EMULSION CONTENT. THIS CURVE WAS COMPARED WITH EXPERIMENTAL DATA FROM VALLEY SLURRY SEAL'S SACRAMENTO LABORATORY WHERE A LATEX MODIFIED SYSTEM WAS USED.

THE OUTSTANDING DIFFERENCES IN EXAMPLE 18 OF OUR AEMA PAPER STIMULATED THIS INVESTIGATION USING BOTH THE NORMAL AND MOTORIZED MODIFIED COHESION TESTER. IT WAS HOPED THAT "MINI-MARSHALL" STABILITY-TYPE CURVES WOULD EMERGE. THIS PAPER REPORTS ON THE RESULTS OF SEVERAL EXPERIMENTS WITH 60C CURED COHESION.

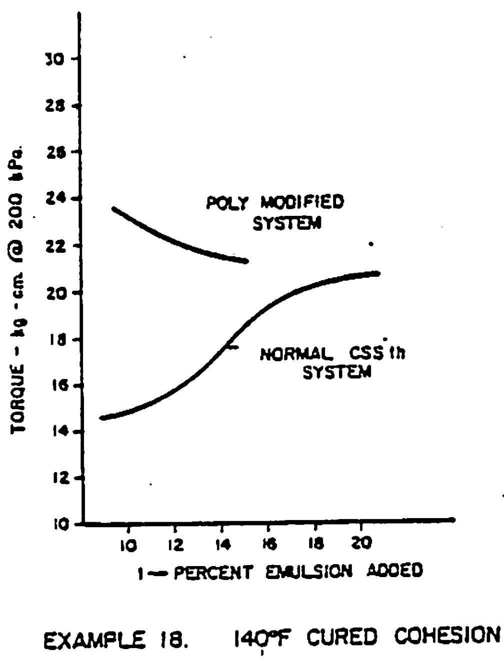


FIGURE 2. 60C CURED COHESION (SLURRY)

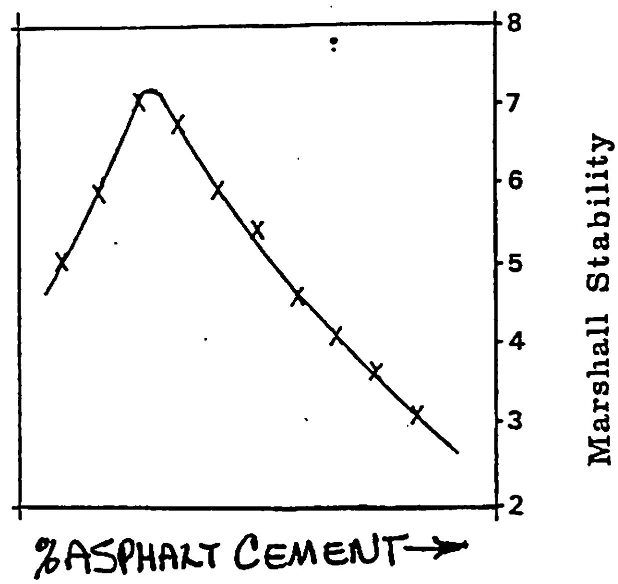
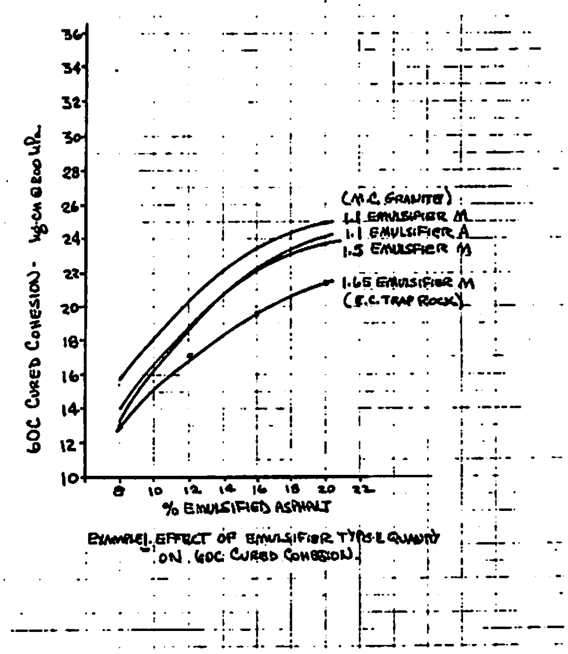


FIGURE 2. MARSHALL STABILITY CURVE (STRENGTH) (HOT MIX)

AT THE OUTSET, WE SHOULD CAUTION ONCE AGAIN THAT TO CHANGE ANY SINGLE MIX INGREDIENT, EVEN FRACTIONALLY, CAN ALTER THE RESULTS OF CURED COHESION (AND ALL OTHER SLURRY TESTS) DRAMATICALLY.

EACH SYSTEM IS ITS OWN THING!

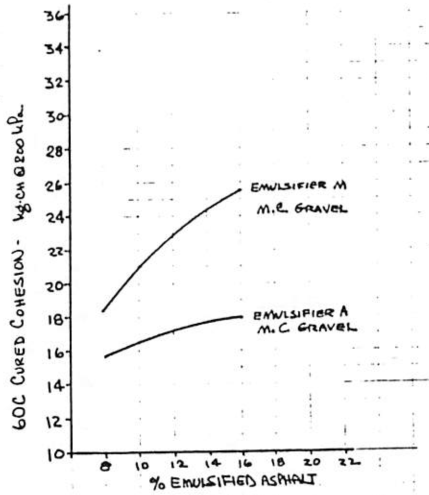
THE PROCEDURE USED WAS TO MAKE 100 GRAM CUP MIXES AT OVER A RANGE OF EMULSION AND CAST THE MIX INTO THREE, 6 MM X 50 MM MOLDS THEN PLACE THE SPECIMENS IN A FORCED DRAFT OVEN AT 60C FOR 16-18 HOURS. WATER, CEMENT AND VARIOUS ADDITIVES WERE USED SO THAT A MINIMUM MIX TIMES OF 60+ SECONDS WERE OBTAINED. IN THESE EXPERIMENTS, NO ATTEMPT WAS MADE TO OPTIMIZE ADDITIVE OR FILLER CONTENT SINCE NET RATE OF CURE WAS NOT TO BE MEASURED, ONLY THE CURED COHESIVE STRENGTH.



EXAMPLE 1

EXAMPLE 1 SHOWS TYPICAL CURED COHESION OF PLAIN CQS AND CSS EMULSIONS. TWO DIFFERENT EMULSIFIERS AND TWO AGGREGATES ARE SHOWN. THE CURED COHESION CURVE IS GENERALLY LINEAR AND PROPORTIONAL TO THE AMOUNT OF EMULSION OR BITUMEN PRESENT. AGGREGATE AND BITUMEN QUALITY, EMULSFIER CONTENT AS WELL AS EMULSIFIER TYPE AND AGGREGATE TYPE AFFECT THE MAGNITUDE OF THE TORQUE AND THE SLOPE.

IN CASE YOU HAVE ALREADY FORMED THE OPINION THAT ALL EMULSION-AGGREGATE SYSTEMS WILL RESPOND WITHIN THE RANGE SHOWN IN EXAMPLE 1, I WILL REMIND YOU THAT ALL ASPHALT EMULSIONS ARE NOT EQUAL; THAT ALL AGGREGATES ARE NOT EQUAL AND, AGAIN THAT EACH SYSTEM IS ITS OWN THING.



EXAMPLE 2. EFFECT OF EMULSIFIER TYPE WITH A MID-CONTINENT CALCAREOUS GRAVEL

EXAMPLE 2

EXAMPLE 2 SHOWS A REATHER DRAMATIC DIFFERENCE IN THE EMULSIFIERS' ROLE IN CURED COHESION. THESE ARE THE SAME EMULSIONS SHOWN IN EXAMPLE 1 BUT WITH A DIFFERENT CALCAREOUS GRAVEL AGGREGATE. EMULSFIER "M" PRODUCES A HIGHER CURED COHESION WITH GRAVEL THAN WITH GRANITE WHILE EMULSFIER "A" DOES POORLY WITH GRAVEL AND WELL WITH GRANITE.

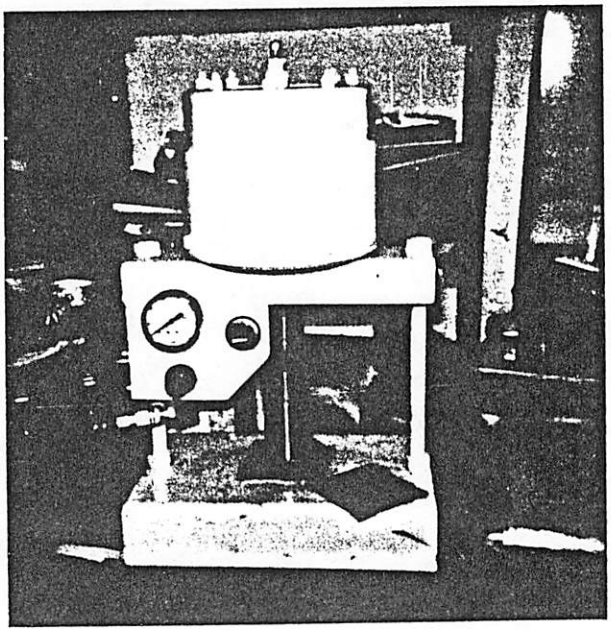
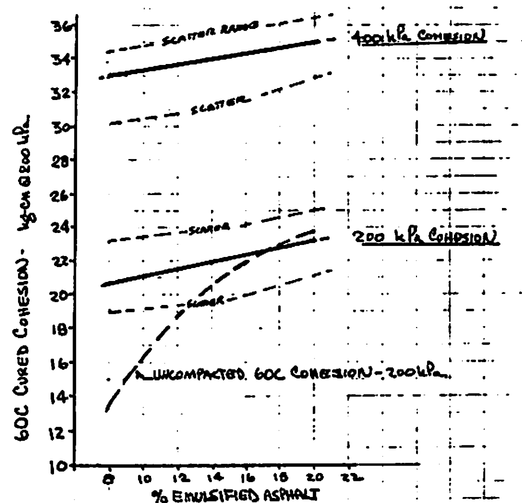


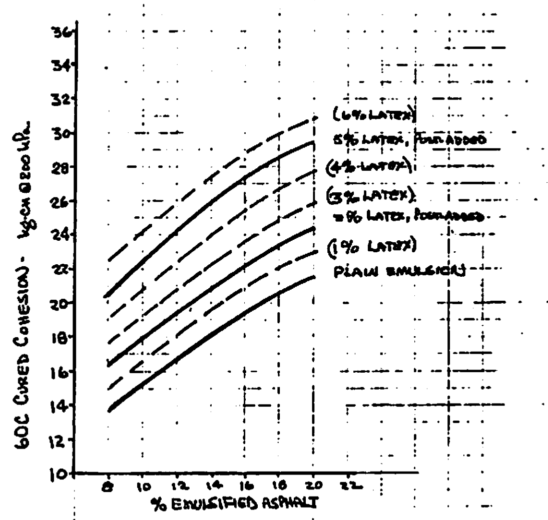
FIGURE 3. SCHULZE-BREURER COMPACTION DEVICE USED FOR COMPACTING SPECIMENS.



EXAMPLE 3. COHESION OF 100 GRAM SPECIMENS COMPACTED @ 2 TONS, 2 MINUTES @ 60C

<u>EXAMPLE 3.</u> SINCE NO MARSHALL-TYPE CURVES WERE EVIDENT, WE REHEATED AND COMPACTED THE MIXES IN EXAMPLE #1 FOR TWO MINUTES AT TWO TONS AND 60C, PLACED THE SPECIMENS IN THE OVEN FOR TWO HOURS @ 60C AND RAN THE CURED, COMPACTED COHESION ON EACH SAMPLE AT 200 KPA AND 400 KPA. DUE TO THE SPECIMEN'S TOUGHNESS FROM COMPACTION, THE COHESION TESTER TENDED TO SLIP ON THE SURFACE AND RESULTED IN A FAIR AMOUNT OF SCATTER IN THE DATA. THIS SCATTER COULD ALSO BE DUE TO DISUNIFORMITY IN THE REMIXING AND COMPACTION PROCEDURES. THE TRENDS HOWEVER ARE CLEAR. THE CURVES ARE MUCH FLATTER BUT ARE PROPORTIONAL TO THE EMULSION CONTENT AND FOOT PRESSURE.

THERE ARE STILL NO MARSHALL-TYPE STABILITY CURVES EMERGING NOR ANY INDICATION OF THE DROP-OFF IN COHESION VALUES EXPERIENCED AT VALLEY SLURRY'S LABS.



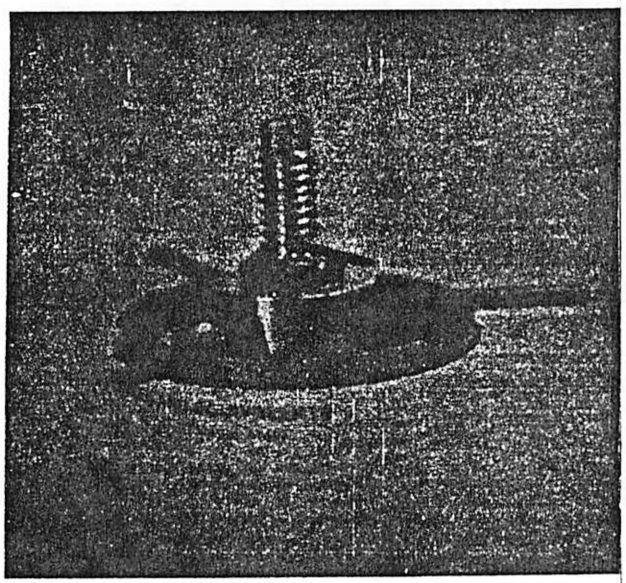
EXAMPLE 4. EFFECT OF LATEX POST ADDITION

EXAMPLE 4. EFFECT OF POST-ADDITION OF LATEX.

THERE IS PRESENTLY CONSIDERABLE INTEREST IN INCORPORATING LATEX AND POLYMERS INTO OUR MIXES. WE HOPED TO FIND A DROP-OFF IN COHESION AS THE BITUMEN CONTENT INCREASED ALONG WITH AN INCREASE IN POST-ADDED LATEX. THERE IS NO CIGAR HERE EITHER. WE FOUND THAT THE CURED COHESION, IN THIS SYSTEM AT LEAST, REMAINED LINEAR AND PARALLEL WITH THE INCREASE IN LATEX. THE DATA APPEARED GOOD ENOUGH TO PROJECT COHESION CURVES FOR 1, 3, 4 AND 6% POST-ADDED LATEX. WHAT WE SEE HERE IS THAT AS THE LATEX ADDITION INCREASES, THE CURED COHESIVE STRENGTH INCREASES. THE CURVES ARE, AGAIN LINEAR AND PROPORTIONAL TO THE INCREASE IN BITUMEN AND LATEX.

HERE, WE SPECULATE THAT IF ONE KNOWS THE MATERIALS USED, THE AMOUNT OF LATEX IN AN UNKNOWN MIX MAY BE DETERMINED.

AS AN ASIDE, CALTRANS HAS DEVELOPED A METHOD TO DETERMINE THE AMOUNT OF LATEX IN CRS AND EMULSION TITLED CALIFORNIA TEST 331, "METHOD OF TEST FOR RESIDUE BY EVAPORATION OF LATEX MODIFIED ASPHALT EMULSION," AND CALIFORNIA TEST 332, "METHOD OF TEST FOR RECOVERY FROM DEFORMATION OF LATEX MODIFIED ASPHALT EMULSION RESIDUE." THIS TEST IS SOMETIMES CALLED "TORSIONAL RECOVERY" OR "DEFORMATION RECOVERY."



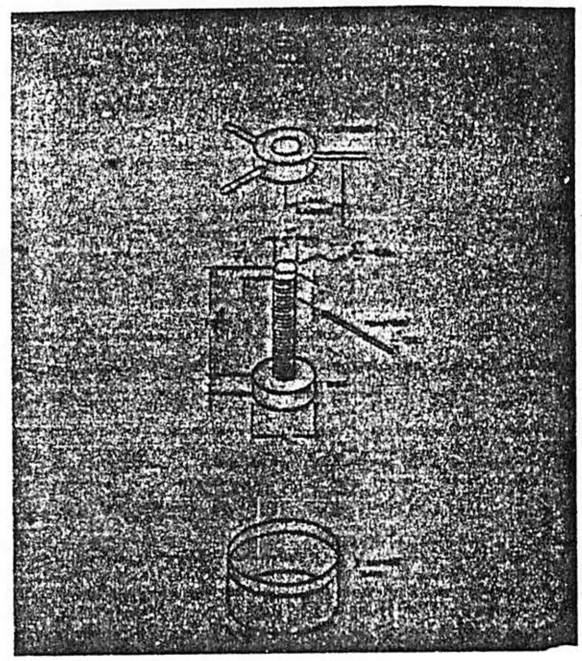
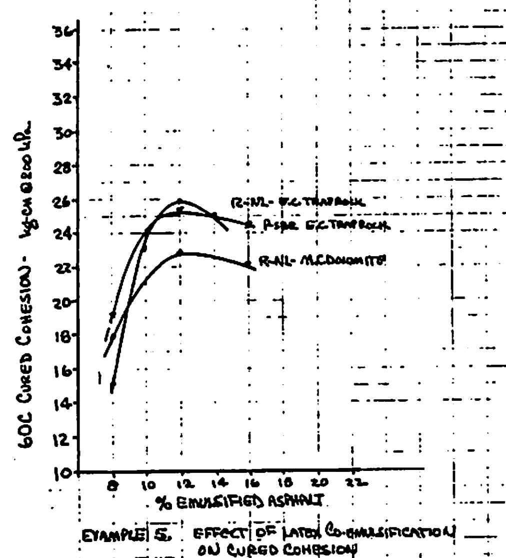


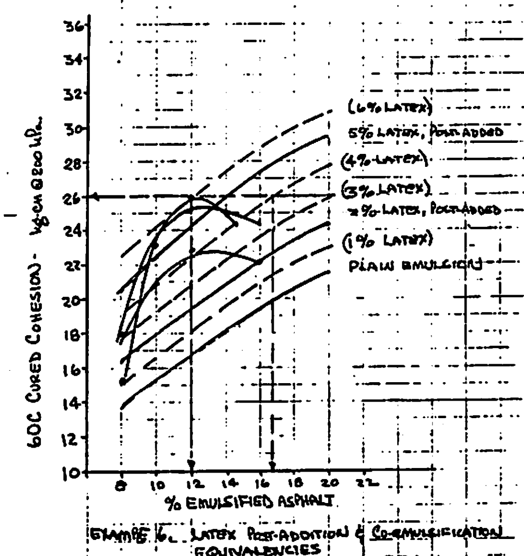
FIGURE 4. CALTRANS TORSIONAL RECOVERY APPARATUS FOR ESTIMATED RESIDUAL LATEX CONTENT OF MODIFIED BITUMEN.

THERE ARE THREE METHODS OF INCORPORATING POLYMERS INTO SLURRY EMULSIONS:

1. LATEX POST-ADDITION (LATE 60'S EARLY 70'S L165K)
2. LATEX CO-EMULSIFICATION
3. POLYMER TREATED BITUMEN.

SINCE NO MARSHALL-TYPE CURVES WERE EVIDENT WITH THE POST-ADDITION OF LATEX, WE PROCEEDED TO EXAMINE THE EFFECTS OF CO-EMULSFYING VARIOUS LATEXES OR EMULSIFIED RUBBER OR POLYMER LATEXES.





EXAMPLE 5. THE EFFECTS OF CO-EMULSIFICATION ON CURED COHESION.

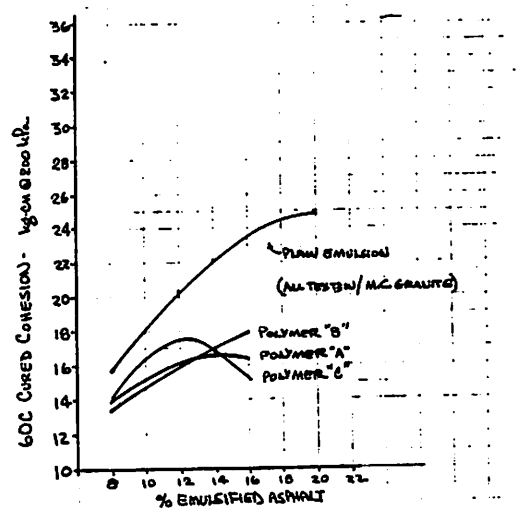
EXAMPLE 6. COMBINED POST-ADD AND CO-EMULSIFICATION CURVES.

A VERY DIFFERENT KIND OF CURVE APPEARS WHEN VARIOUS LATEXES ARE INCORPORATED BY CO-EMULSIFICATION. THEY PEAK AT ABOUT 12% EMULSION CONTENT. WHEN USING ISSA TYPE 2 (100%-4 OR 0/5 MIN.), GRADATION MAY BE SIGNIFICANT.

BY COMBINING THE POST-ADDED AND CO-EMULSIFIED LATEX CURVES, IT IS INDICATED THAT 12% CO-EMULSIFIED LATEX IS EQUAL IN CURED COHESIVE STRENGTH TO 6% POST-ADDED LATEX. ALSO, COHESIVE STRENGTH EQUIVALENCY IS FOUND BY USING 6% POST-ADDED LATEX AT 12% AE OR 4% POST-ADDED LATEX AT 16% AE CONTENTS.

ARE WE BEGINNING TO SEE A MARSHALL CURVE?

BY INCORPORATING THE POLYMER INTO THE ASPHALT CEMENT OR BITUMEN, THEN EMULSIFYING THE TREATED BITUMEN, QUITE DIFFERENT RESULTS FROM OUR EXPECTATIONS WERE OBTAINED.

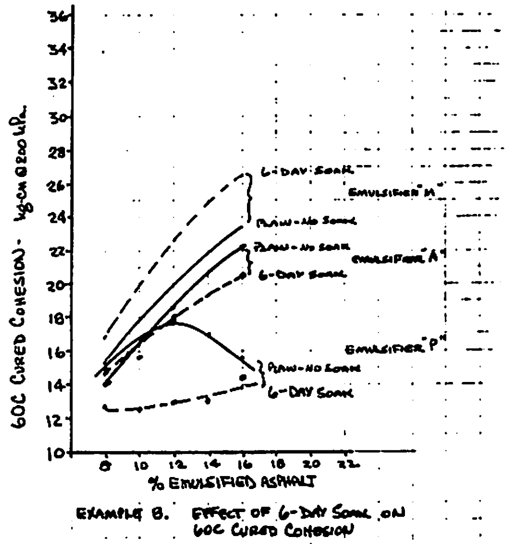


EXAMPLE 7. EFFECT OF POLYMER-TREATED BITUMEN ON CURED COHESION @ 60C.

EXAMPLE 7

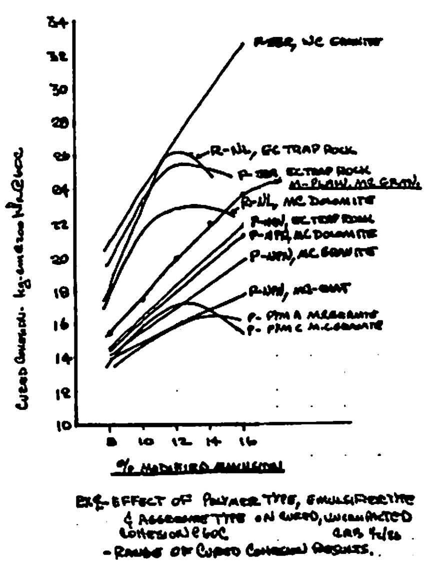
60C CURED COHESION USING POLYMER TREATED BITUMEN EMULSIONS.

THESE RESULTS REFLECT ONLY OUR INITIAL TRIALS. ADHESION BY A 10-MINUTE BOILING WATER TEST IN ALL CASES WAS EXCELLENT. THE BITUMEN SOURCES WERE VERY GOOD TO EXCELLENT. THE AGGREGATES ALL HAVE GOOD TO EXCELLENT FIELD PERFORMANCES. THERE WAS A PROBLEM IN THE 'SOLUBILITY' IN THE BITUMEN OF ONE POLYMER. THE EMULSIFIERS USED MAY NOT BE THE BEST FOR THIS PURPOSE. IT IS NOTED THAT ALL CURED SPECIMENS WERE VERY BRITTLE, ALMOST "FRIABLE."



EXAMPLE 8. EFFECT OF 6-DAY SOAKS ON 60C CURED COHESION.

BECAUSE OF THE RECENT INTEREST IN THE 6-DAY SOAK WTAT, WE TRIED TO DISCOVER ANY DIFFERENCES THAT MIGHT APPEAR AS THE RESULT OF WATER SATURATION. OUR TECHNIQUES NEED A LITTLE REFINEMENT BUT THESE RESULTS INDICATE THAT THERE IS A DIFFERENCE, CONSIDERABLE IN SOME CASES. NOTE SYSTEM "M" WHERE THE 6-DAY SOAK IMPROVED THE CURED COHESION VALUES!



EXAMPLE 9. CURED COHESION TESTS SHOWING THE RANGE OF RESULTS OBTAINED.

NOT ONLY IS EACH SYSTEM ITS OWN THING, NOT ONLY ARE ALL EMULSIONS NOT EQUAL, NOT ONLY ARE ALL AGGREGATES NOT EQUAL, BUT ALSO, ALL POLYMERS ARE NOT EQUAL!

ON TOUGHNESS & TENACITY, STRENGTH & STRETCH

AT THE 1984 NEW ORLEANS AEMA MEETING, GERRY REINKE PRESENTED A PAPER, "USE OF THE TOUGHNESS AND TENACITY TEST IN THE ANALYSIS OF POLYMER MODIFIED BINDERS" WHICH CLASSIFIED POLYMER MODIFIED BITUMENS INTO VARIOUS CATEGORIES ACCORDING TO THE SHAPE OF THEIR RESPECTIVE TOUGHNESS AND TENACITY CURVES.

AS IN THE CASE OF THE CALTRANS TORISIONAL RECOVERY TEST, THE TOUGHNESS AND TENACITY TEST, IS PERHAPS USEFUL IN COMPARING VARIOUS BITUMEN TREATED SYSTEMS, DOES NOT RELIABLY PREDICT THE PERFORMANCE OF THE TOTAL MIX SYSTEM.

EMULSION MIXES NEVER SEE THE 300F (160C) TEMPERATURES USED TO RECOVER THE BITUMEN FOR THESE TESTS. EMULSIONS ARE NOT BOILED OFF IN PRACTICE. WHAT ARE THE EFFECTS OF THE VARIOUS EMULSIFIERS, FILLERS, ACCELERATORS, RETARDERS, ADHESION AGENTS, MINERAL CHEMICALS FROM THE AGGREGATE AND AGGREGATE FINES? THESE CAN ONLY BE MEASURED BY MEASURING THE PROPERTIES OF THE CURED MIX.

YET, TOUGHNESS, TENACITY, AND TORSIONAL RECOVERY ARE IMPORTANT PROPERTIES. HOW SHOULD WE APPROACH MEASURING THEIR MIX PERFORMANCE IN A CURED SLURRY SEAL MIXTURE?

TOUGHNESS AND TENACITY MIGHT BE TERMED "STRENGTH" AND "STRETCH" WHICH IS WHAT WE'VE ATTEMPTED TO MEASURE BY USING OUR MOTORIZED COHESION TESTER CONTROLLED AT SPEEDS AS LOW AS 5 MINUTES PER REVOLUTION AT 200 KPA. PEAK TORQUE (STRENGTH) AND TIME TO PEAK TORQUE (STRETCH) IS RECORDED ON A STRIP CHART.

PEAK TORQUES OR 'STRENGTHS' ARE MEASURED BY THE PEAK-MEASURING TORQUE METER WHILE THE TIME TO PEAK OR "STRETCH" IS MEASURED DIRECTLY FROM THE CHART SCALE AND CM/MIN RATE.

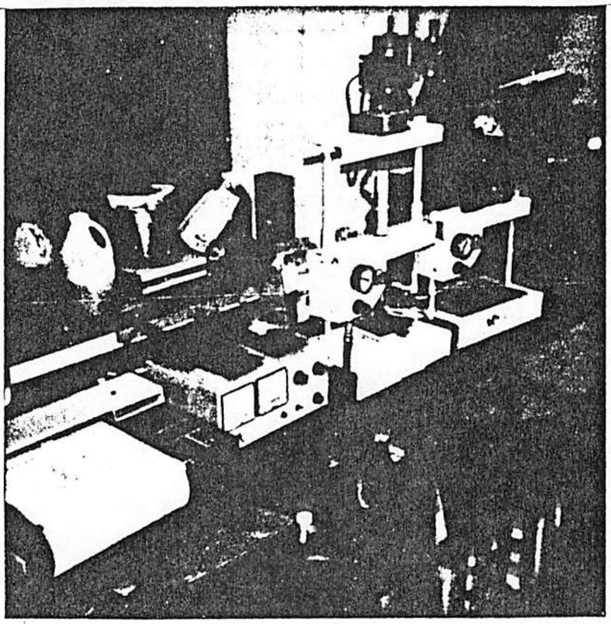


FIGURE 7. MOTORIZED COHESION TESTER SHOWING DIRECT TORQUE METER, CONTROLLER AND STRIP CHART.

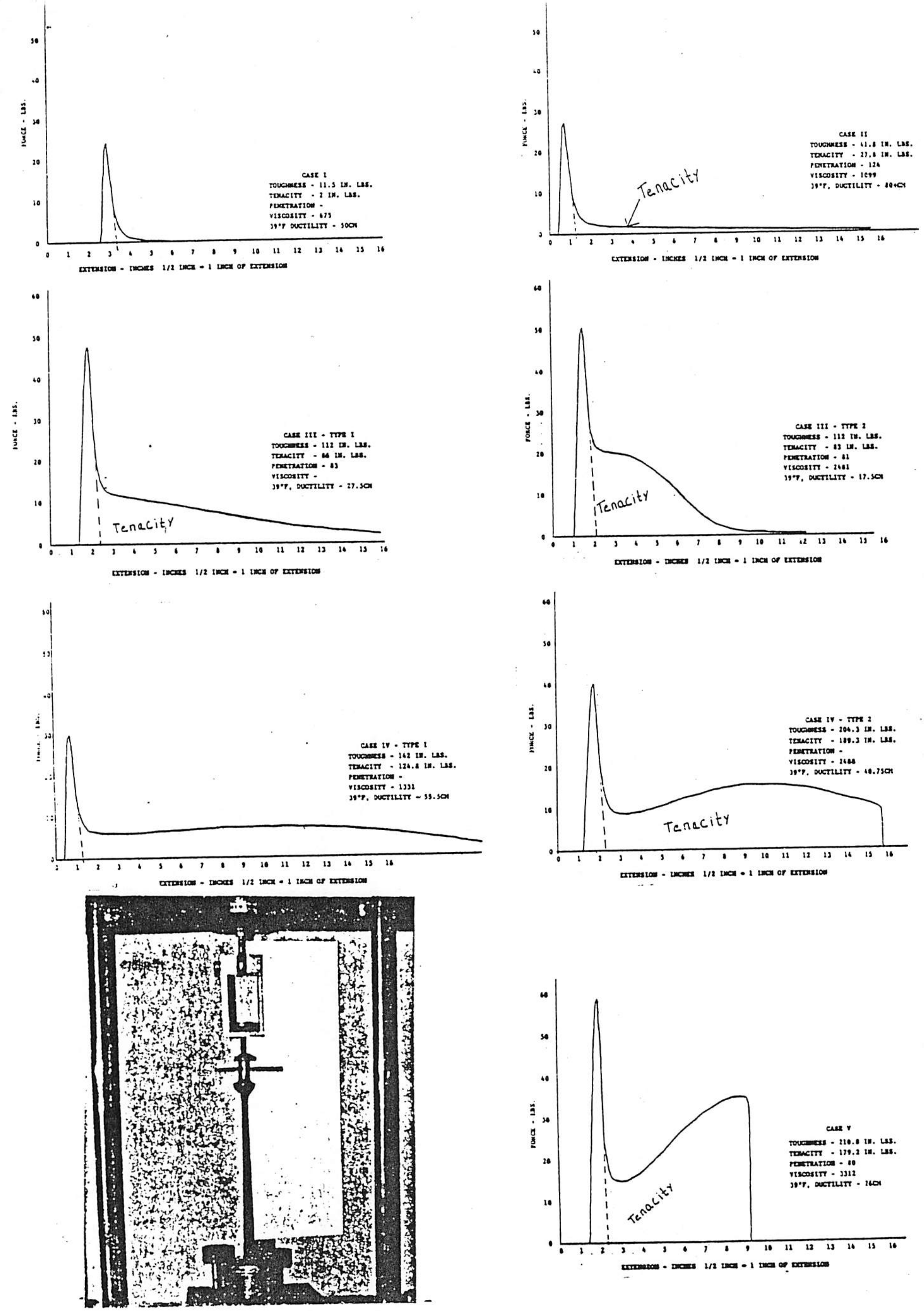
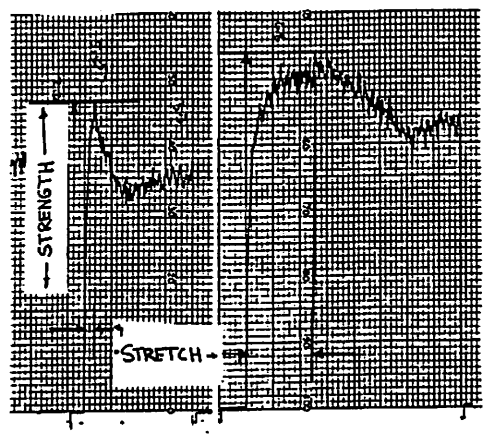
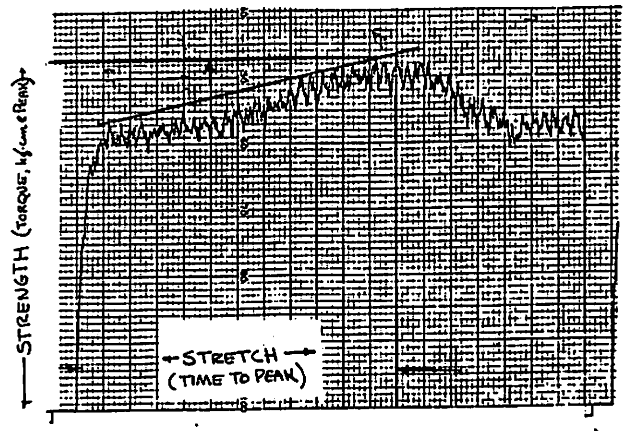


FIGURE 5. TOUGHNESS AND TENACITY CURVES FROM REINKE & O'CONNELL.



EXAMPLE 10a STRENGTH and STRETCH CURVES
60C CURED COHESION



EXAMPLE 10b STRENGTH & STRETCH (60C-CURED COHESION)

EXAMPLE 9A & B. TYPICAL CURED COHESION STRENGTH AND STRETCH STRIP CHARTS.

			PEAK TORQUE (KG - CM)	TIME TO PEAK (SECONDS)
3.6 RADIANS/MIN. (1.75 MIN/REV)				
A.	MOD. BITUMEN @	12% AE	5.35	2.10
	MOD. BITUMEN @	16% AE	5.33	2.53
B.	CO-EMULSIFIED LATEX @	12% AE	6.78	4.75
	CO-EMULSIFIED LATEX @	16% AE	7.38	12.50
2 RADIANS/MIN. (3 MIN/REV)				
C.	PLAIN AE @	12% AE	5.85	4.31
	PLAIN AE @	16% AE	5.30	5.75
D.	POST-ADDED LATEX @	12% AE	5.84	6.24
	POST-ADDED LATEX @	16% AE	6.55	8.33
E.	SET 2, P.A. LATEX @	16% AE	7.42	45.16
1.2 RADIANS/MIN. (5 MIN/REV)				
F.	#315 PLAIN AE @	12% AE	8.8	25.7
G.	#315 PLAIN AE @	16% AE	11.3	76.2

TABLE 1. EXPERIMENTAL "STRENGTH AND STRETCH" CURED MIX CURVE RESULTS.

THE ROTATIONAL RATE OF SHEAR AND ITS EFFECT ON RESULTS IS QUITE SIGNIFICANT. COMPARISONS AT THE THREE RATES SHOWN (3.6, 2.0 AND 1.2), RADIANS PER MINUTES CANNOT BE MADE. COMPARISONS WITHIN THE SAME RATE, HOWEVER, CAN BE MADE.

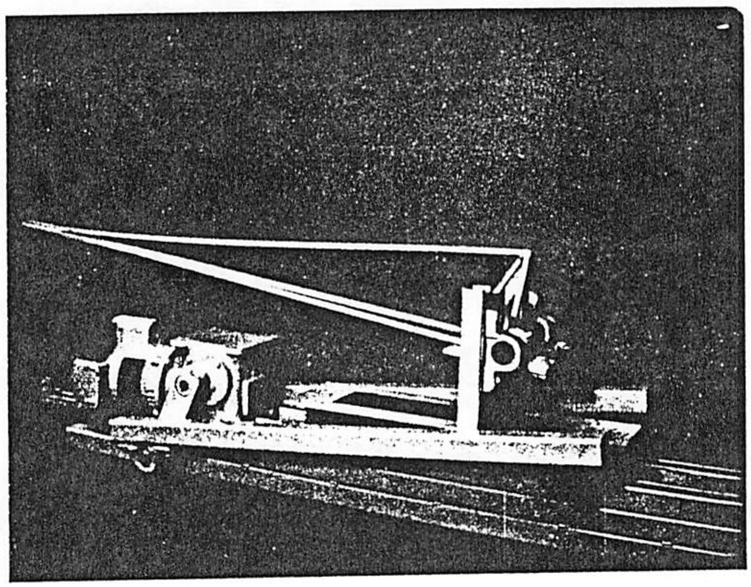
WITH THIS VERY LIMITED DATA, SEVERAL INTERESTING OBSERVATIONS CAN BE MADE BUT THERE CAN BE NO LEGITIMATE CONCLUSIONS AT THIS TIME.

SUMMARY

A RANGE OF CURED SLURRY MIXES HAVE BEEN EXAMINED USING BOTH THE MANUAL AND MOTORIZED COHESION TESTER IN ATTEMPTS TO MEASURE THE PROPERTIES OF THE MIX RATHER THAN MEASUREMENT OF THE PROPERTIES OF THE BITUMEN OR EMULSION RESIDUE SEPARATELY.

AS THE INGREDIENTS WERE CHANGED, LARGE DIFFERENCES WERE NOTED IN THE LABORATORY PERFORMANCE OF THE MIXES.

THE METHODS APPEAR VALID. FUTURE WORK IS PLANNED FOR 1986 TO CROSS-RELATE CURED COHESION VALUES WITH OUR TRAFFIC SIMULATING DEVICES, THE LOADED WHEEL TESTER AND THE WHEEL TRACKING TEST.



NOTES:

IT IS HOPED THAT INTERESTED READERS OF THIS PAPER WILL UNDERSTAND THAT THE INFORMATION CONTAINED HERE IS THE RESULT OF INITIAL EXPERIMENTS IN THE MEASUREMENT OF CURED COHESION. WE ALSO HOPE THAT OTHERS WILL USE THIS INFORMATION TO FURTHER RESEARCH INTO THE LABORATORY AND FIELD PERFORMANCE OF THIN LAYERED COLD MIXES AND SLURRY SEALS.

DURING THE COURSE OF THESE EXPERIMENTS NEARLY 1000 TESTS WERE PERFORMED USING 12 BASE ASPHALTS, 5 EMULSIFIERS, 7 AGGREGATES AND 8 POLYMERIC MATERIALS FROM ACROSS THE CONTINENTAL U.S. THE EXTREME VARIATION IN RESULTS FROM THE MANY MATERIAL COMBINATIONS DOES NOT ALLOW FOR DEFINITE CONCLUSIONS EXCEPT THAT "RESULTS WILL VARY" AND "MORE WORK NEEDS TO BE DONE."

WE WISH TO EXPRESS OUR THANKS TO THOSE WHO WILLINGLY SUPPLIED THEIR MATERIALS TO US IN ORDER TO MAKE THIS PERLIMINARY STUDY POSSIBLE. SPECIAL THANKS IS DUE BRUCE BENTLY WHO PERFORMED MANY OF THE ROUTINE COHESION TESTS AND MIXES.

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