DRAFT - NOT FOR PUBLICATION

"EFFECTS OF AGGREGATE FILLER CONTENT VARIATION AND CEMENT PRESENCE ON THE LABORATORY PROPERTIES OF A SINGLE SLURRY SEAL SYSTEM."

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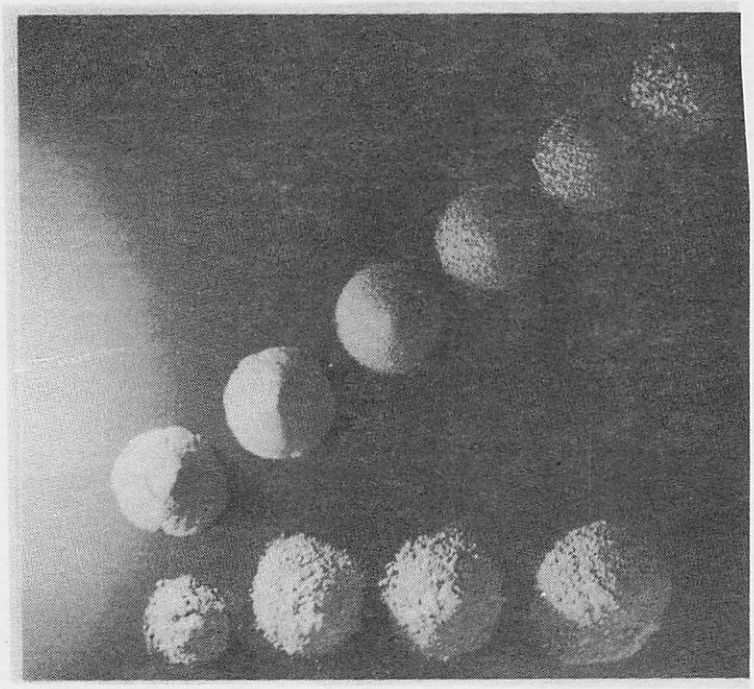


OBJECTIVES:

THIS PAPER BEGAN AS A ROUTINE TRAINING EXERCISE ON THE EFFECTS OF FILLER CONTENT ON SAND EQUIVALENT AND THEIR EFFECTS ON THE WET MIXING AND SETTING CHARACTERISTICS. THE RULE THAT MOST LABORATORY INVESTIGATIONS RAISE MORE QUESTIONS THAN ANSWERED WAS NOT THE EXCEPTION HERE WHERE THE WORK WAS EXPANDED TO INCLUDE THE EFFECTS OF FILLER CONTENTS ON MANY KINDS OF SLURRY SEAL TESTS.

UNDERLYING THIS INVESTIGATION ARE 2 GRAPHS FROM THE EARLY 60'S (FIGURES 1 & 2) WHICH APPEAR IN ISSA LITERATURE. WE HOPE TO EVENTUALLY VERIFY OR MODIFY KARI AND COYNE'S WORK.

FURTHER AROUSING OUR CURIOSITY ARE MANY COMMENTS WE HAVE RECEIVED FROM ALL CORNERS REGARDING BOTH THE GOOD AND BAD EFFECTS OF FILLER QUALITY AND CONTENT IN FIELD APPLICATIONS.

THE OBJECTIVE THEN BECOMES TO STUDY AND REPORT THE EFFECTS OF FILLER CONTENT AND CEMENT PRESENCE ON A WIDE RANGE OF SLURRY SEAL TESTS IN A SINGLE AGGREGATE-EMULSION SYSTEM. A SECONDARY OBJECTIVE IS TO ESTABLISH BENCHMARK NUMBERS FOR THE EFFECTS OF FILLER CONTENT IN THE SYSTEM TESTED FOR FUTURE COMPARISON WITH OTHER SYSTEMS.

CAUTION:

THE TESTS RESULTS PRESENTED HERE ARE RESULTS WITH A SINGLE AGGREGATE-EMULSION MIX SYSTEM AND SHOULD NOT BE CONSIDERED AS TYPICAL TO OTHER SYSTEMS. WHEN ANY ONE MATERIAL OR PROPORTION IS CHANGED, ENTIRELY DIFFERENT RESULTS WILL LIKELY BE FOUND. "EACH SYSTEM IS IT'S OWN THING" AND MUST BE TESTED INDIVIDUALLY.

PROCEDURE

THE AGGREGATE SELECTED FOR MIXING WAS SANDUSKY, OHIO DOLOMITE. THE SAMPLE WAS DRIED, SPLIT AND DRY SCREENED TO REMOVE ALL PLUS 4.75 UM (#4) AND 0/75 UM (-200) FILLERS. THE 0/75 UM FILLER WAS RETAINED FOR REBLENDING AT 0, 5, 10, 15, & 20% FILLER CONTENTS. THE PLUS 4.75, UM FRACTION WAS DISCARDED. THE AGGREGATE WAS JUDGED AS A GOOD QUALITY MID-CONTINENT DOLOMITIC LIMESTONE.

THE RECONSTITUTED OR REGRADED AGGREGATES WERE MIXED WITH AN UNMODIFIED CATIONIC CQS EMULSION JUDGED TO BE OF VERY GOOD TO EXCELLENT QUALITY. EACH MIX VARIED THE FILLER, CEMENT AND EMULSION CONTENTS. RESULTS WERE TABULATED AND GRAPHED TO SHOW THE RESULTS OF THE VARIATIONS. IN TOTAL, SOME 400 OBSERVATIONS ARE REPORTED HERE.

MATERIALS

EMULSIFIED ASPHALT (BITUMEN) WAS A SINGLE, 1-GALLON SAMPLE OF A PRODUCTION RUN OF USING HIGH QUALITY MATERIALS. 1.5% EMULSIFIER "M" WAS USED AND NEUTRALIZED TO A PH OF 3.0. THE BITUMEN RESIDUE WAS 63.0%. NO SIEVE WAS OBSERVED. STABILITY WAS GOOD. NO FURTHER TESTING OF THE EMULSION PROPERTIES IS REPORTED HERE.

PORTLAND CEMENT WAS A LOCAL TYPE 1 - PLAIN, MANUFACTURED FROM A DOLOMITIC LIMESTONE SIMILAR TO THE MIX AGGREGATE.

WATER WAS OUR SOFTENED LOCAL WELL WATER. TRACES OF IRON ARE NOTED.

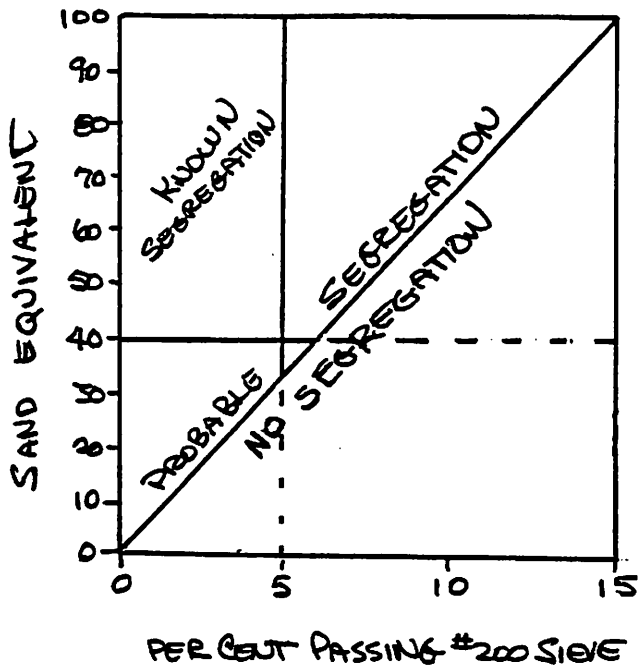


FIG. 1 RELATIONSHIP OF AGGREGATE PROPERTIES TO SLURRY SEAL SEGREGATION

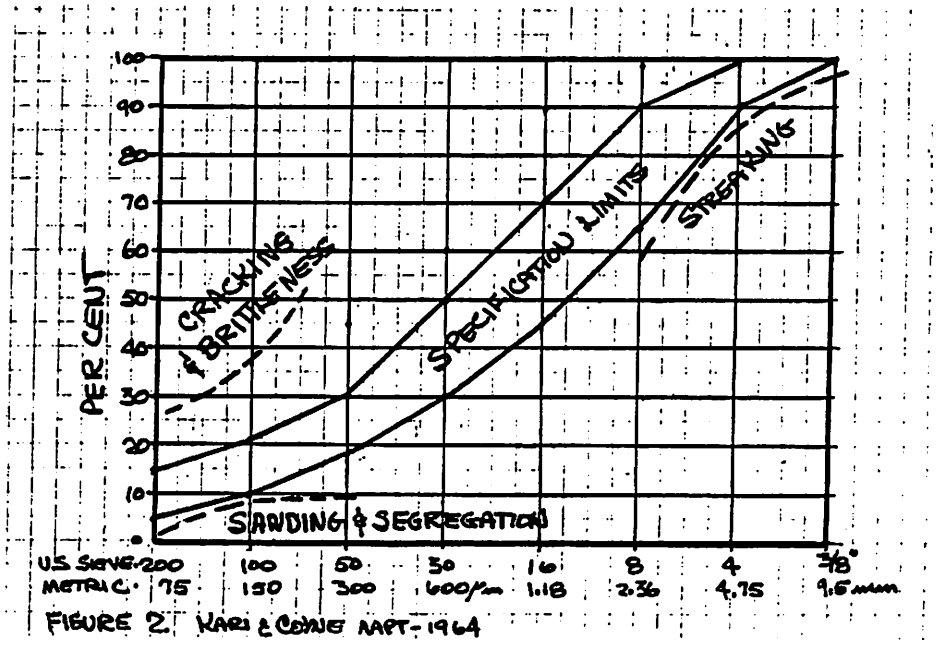


FIGURE 2 KARI & COMER AAPT-1964

FIGURE 1 SHOWS THE PROBABLE EFFECTS OF SAND EQUIVALENT AND FILLER CONTENT ON SEGREGATION. FIGURE 2 SHOWS THE CAUSE OF CRACKING AND BRITTLENESS AS HIGH FILLER CONTENT. LOW FILLER CONTENTS CAUSE SANDING AND STREAKING. OVERSIZE CAUSES STREAKING.

THESE GRAPHS REPRESENT 1964 STATE-OF-THE-ART KNOWLEDGE. 1987'S IMPROVED SYSTEMS MAY ALTER ISSA GRADATION REQUIREMENTS.

AGGREGATE PROPERTIES

EXPERIMENTAL DRY GRADATIONS - % PASSING

SIEVE SIZES METRIC	U.S.	AS REC'D	AS PREPARED (DRY) NOMINAL FILLER CONTENT: Ø	5	1Ø	15	2Ø
9.5 MM	3/8"	1ØØ	---	---	---	---	---
8.Ø	5/16"	99.Ø	---	---	---	---	---
6.3	1/4"	95.2	---	---	---	---	---
4.75	#4	87.6	1ØØ	1ØØ	1ØØ	1ØØ	1ØØ
2.36	#8	62.8	67.2	69.2	7Ø.8	72.5	74.1
1.18	#16	39.1	36.6	39.4	43.Ø	46.1	49.3
6ØØ UM	#3Ø	25.9	19.4	23.4	27.4	31.5	35.5
3ØØ UM	#5Ø	18.5	9.7	14.2	18.7	23.3	27.8
15Ø UM	#1ØØ	14.5	4.5	9.2	14.Ø	18.9	23.6
75 UM	#2ØØ	11.Ø	Ø	5.Ø	1Ø.Ø	15.Ø	2Ø.Ø
44 UM	#325	6.3					
ADD Ø/75 UM WASH LOSS			3.Ø	3.Ø	3.Ø	3.Ø	3.Ø
TOTAL Ø/75 UM (Ø/2ØØ)			3.Ø	8.Ø	13.Ø	18.Ø	23.Ø
TOTAL Ø/44 UM (Ø/325) (84.2%)			2.5	6.7	11.Ø	15.2	19.4
(MG. MB/G.Ø/44 UM (2.Ø) x TOTAL Ø/44 UM = "METHYL BLUE FACTOR"			5.Ø	13.5	21.9	3Ø.3	38.7
SAND EQUIVALENT:							
FROM WASHED SIEVE:			1ØØ.Ø	92.8	85.3	76.7	7Ø.9
FROM DRY SIEVE:			91.Ø	83.2	75.8	67.9	6Ø.2
S.E. RECIPROCAL x 1ØØ x TOTAL Ø/75 UM (Ø/2ØØ) = "SAND EQUIVALENT FACTOR"			1.1 3.3	1.2 9.6	1.3 17.2	1.5 26.5	1.7 38.2

OTHER AGGREGATE PROPERTIES

	#1	#2
ASG (APPARENT SPECIFIC GRAVITY)	2.76	----
SG-SSD (SATURATED SURFACE DRY)	2.69	2.62
BULK-SG-SSD	2.57	----
ABSORBTION #57 (3/4")	2.40%	2.36
SODIUM SULFATE SOUNDNESS (1Ø CYCLES, ON TOTALS)	2.98%	
SODIUM SULFATE SOUNDNESS (1Ø CYCLES ON #4,-3/8")	1.27%	2.Ø%
LOS ANGELES ABRASION LOSS ("B")	28.6%	
ACID SOLUBILITY	96.3%	
44/75 UM SURFACE AREA (AIR PERMEABILITY)	1548.95 CM^2 /G	
Ø/44 UM SURFACE AREA	2493.92	

ZETA POTENTIAL:

PH	MV.
2.3	1.6
6.7	-16.2
9.5	-15.9
11.2	-3Ø.9

LHORTY COEFFICIENT OF ACTIVITY Ø.5 - Ø.4

TABLE 1

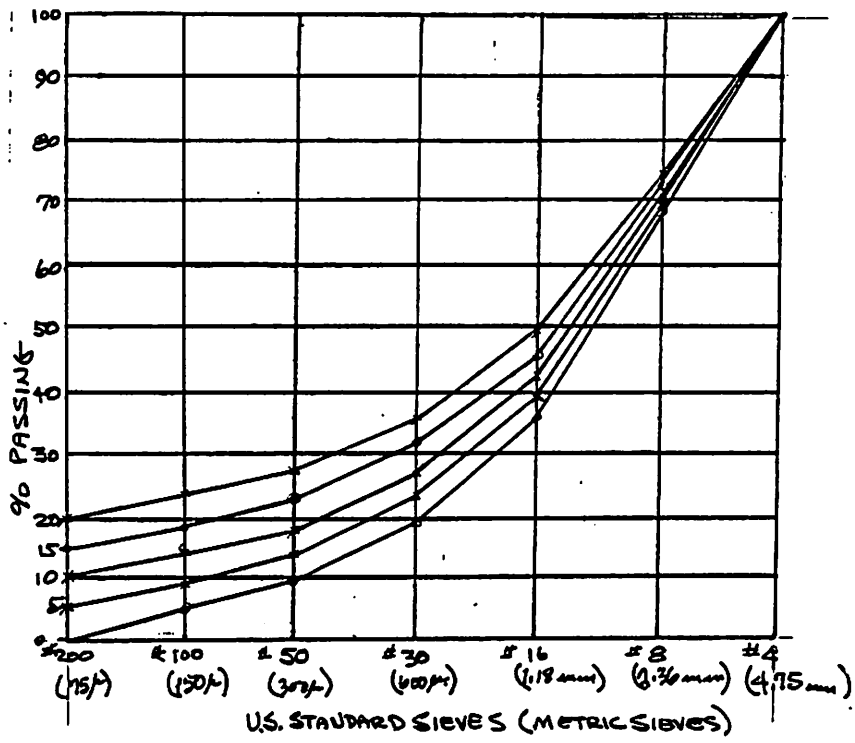


FIGURE-3 EXPERIMENTAL GRADATIONS

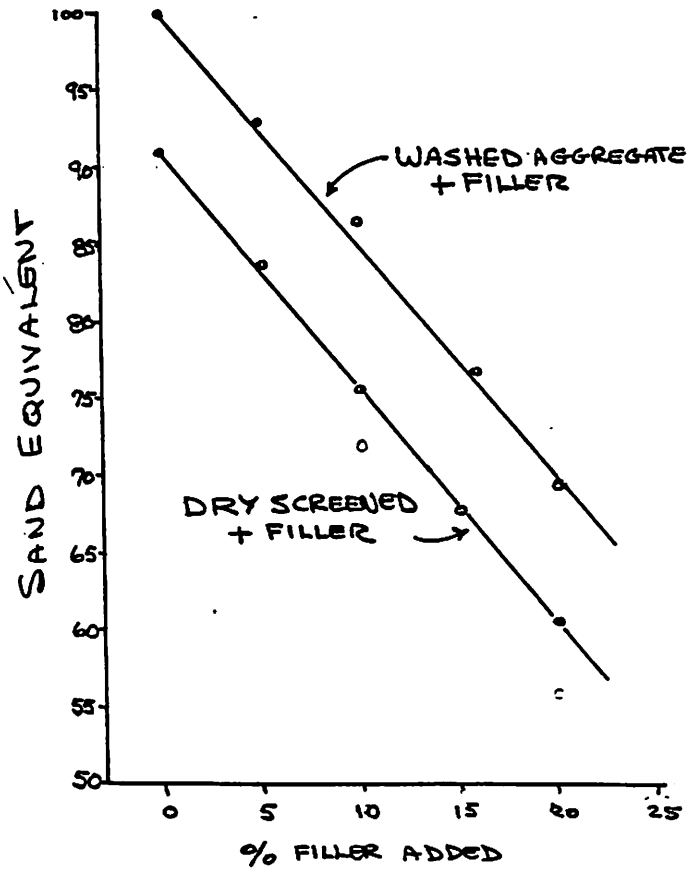


FIG. 4 EFFECT OF FILLER CONTENT ON SAND EQNAIENT

FIGURE 4 SHOWS TWO SAND EQUIVALENT CURVES. ONE USED WASHED AGGREGATE WITH FILLER ADDED WHILE THE OTHER WAS DRY SCREENED WITH FILLER ADDED. EACH ARE LINEAR, PARALLEL AND PROPORTIONAL TO THE AMOUNT OF FILLER. BY KNOWING THE PRECISE S.E. CURVES, FILLER CONTENT MAYBE ESTIMATED FROM THE S.E.

	% OF TOTAL	"BLUE" NUMBER mg MB/g AGG.
0/75 µm. (DRY SIEVED)	100	1.5
44/75 µm (WET SIEVED)	15.8	.2
0/44 µm (DRY SIEVED)	84.2	2.0

FIGURE 5. METHYL BLUE SATURATION OF FILLER FRACTIONS

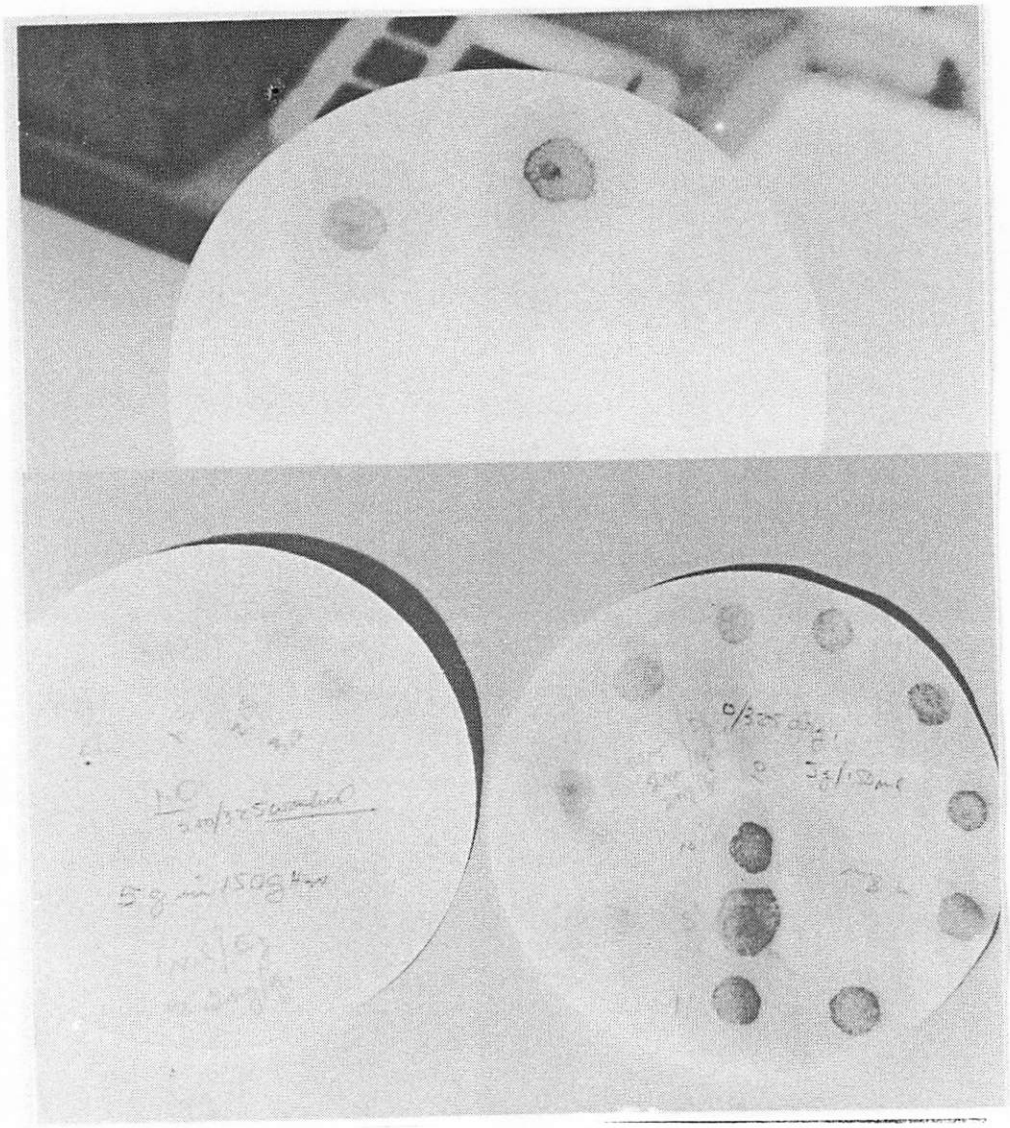


FIGURE 6 PHOTOS OF THE METHYL BLUE TESTS FOR THE 44/75 UM AND Ø/44 UM FILLER. THE METHYL BLUE "NUMBER" IS NEARLY TOTALLY DUE TO THE Ø/44 UM FRACTION.

ADD Ø/75 UM WASH LOSS	3.Ø	3.Ø	3.Ø	3.Ø	3.Ø
TOTAL Ø/75 UM (Ø/2ØØ)	3.Ø	8.Ø	13.Ø	18.Ø	23.Ø
TOTAL Ø/44 UM (Ø/325) (84.2%)	2.5	6.7	11.Ø	15.2	19.4
(MG. MB/G.Ø/44 UM (2.Ø) X TOTAL Ø/44 UM = "METHYL BLUE FACTOR"	5.Ø	13.5	21.9	3Ø.3	38.7
SAND EQUIVALENT:					
FROM WASHED SIEVE:	1ØØ.Ø	92.8	85.3	76.7	7Ø.9
FROM DRY SIEVE:	91.Ø	83.2	75.8	67.9	6Ø.2
S.E. RECIPROCAL X 1ØØ X TOTAL Ø/75 UM (Ø/2ØØ) = "SAND EQUIVALENT FACTOR"	1.1	1.2	1.3	1.5	1.7
	3.3	9.6	17.2	26.5	38.2

TABLE 3. METHYL BLUE & SAND EQUIVALENT FACTORS

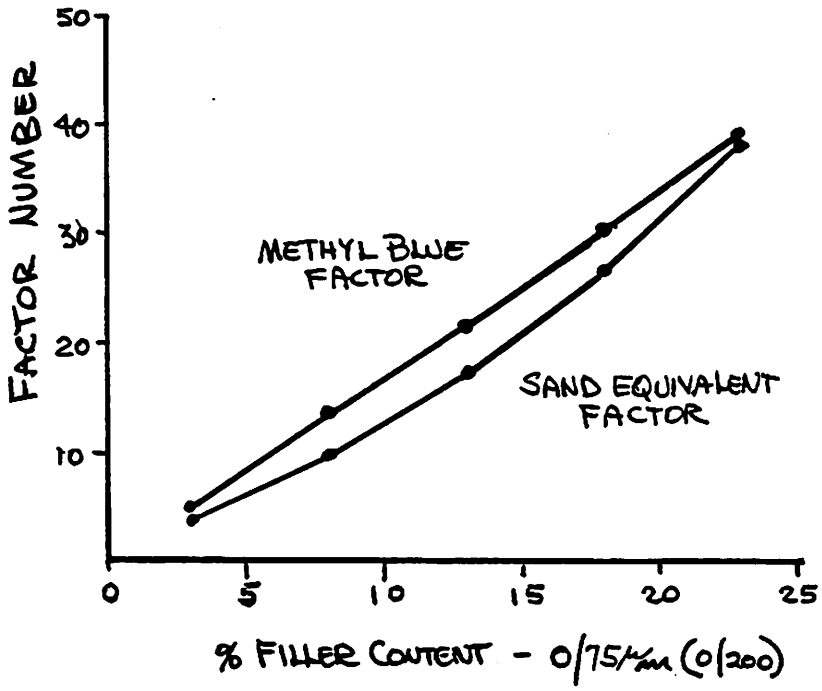


FIGURE 7. RELATION OF METHYL BLUE FACTOR AND SAND EQUIVALENT FACTOR

FIGURE 7 THE METHYL BLUE FACTOR IS THE Ø/44 UM BLUE NUMBER X THE TOTAL PERCENT OF Ø/44 UM PRESENT. THE SAND EQUIVALENT FACTOR IS THE S.E. RECIPROCAL X 1ØØ X TOTAL PERCENT OF Ø/75 UM PRESENT. THERE IS GOOD CORRELATION BETWEEN THE TWO CURVES.

PARTICLE SIZE MICROMETRES	% PASSING	PARTICLE SIZE	% PASSING
1	8.8	8.0	51.2
1.5	11.4	12.0	64.1
2.0	18.0	16.0	75.8
3.0	24.9	24.0	90.1
4.0	31.7	32.0	97.7
6.0	41.4	48.0	100.0

TABLE 4 LASER GRANULOMETER PARTICLE SIZE DISTRIBUTION OF 0/44 µM FILLER

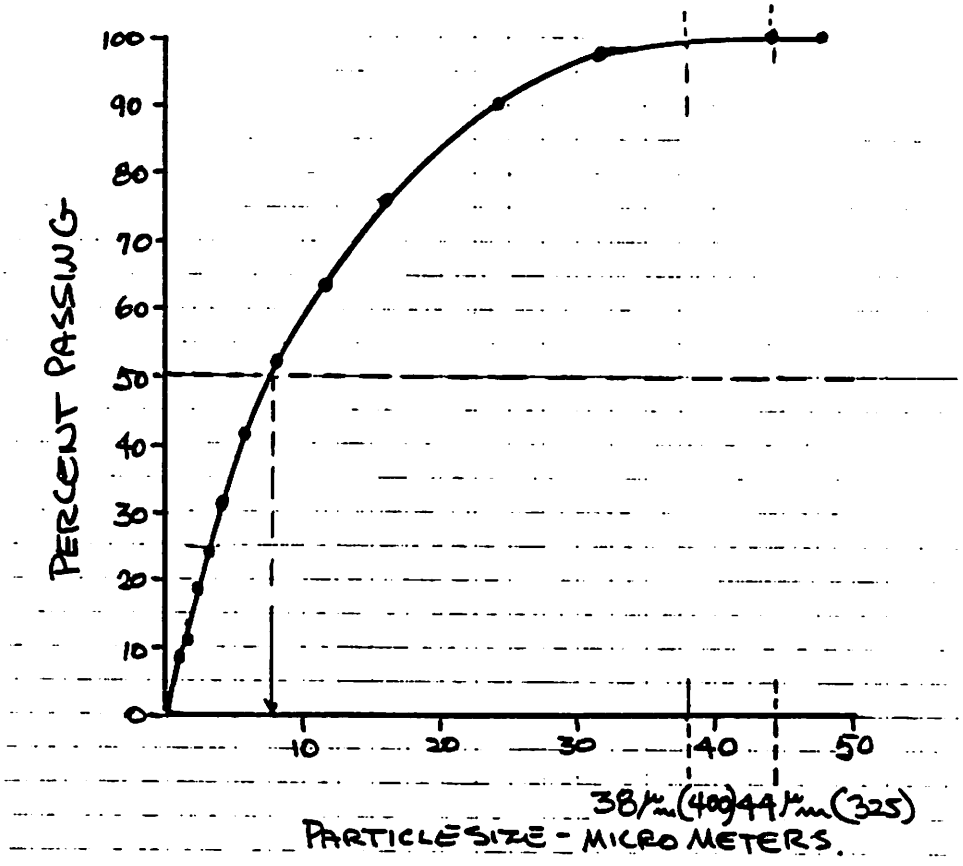


FIGURE 8. 0/44µm(0/325) PARTICLE SIZE DISTRIBUTION BY WATER & ALCOHOL LASER GRANULOMETER

FIGURE 8 SHOWS A LASER GRANULOMETER PARTICLE SIZE ANALYSIS OF THE Ø/44 UM FILLER. NOTE THAT OVER 50% OF THE FILLER IS LESS THAN 8 UM. THE PARTICLE SIZE GRADATION IS SIMILAR TO THAT FOUND IN MANY SLURRY EMULSIONS. WHEN 15% FILLER IS PRESENT AND 12% EMULSION IS USED, THERE IS ROUGHLY EQUAL WEIGHT PERCENTAGES OF BITUMEN AND FILLER PARTICLES.

OTHER AGGREGATE PROPERTIES	#1	#2
ASG (APPARENT SPECIFIC GRAVITY)	2.76	----
SG-SSD (SATURATED SURFACE DRY)	2.69	2.62
BULK-SG-SSD	2.57	----
ABSORBTION #57 (3/4")	2.40%	2.36
SODIUM SULFATE SOUNDNESS (10 CYCLES, ON TOTALS)	2.98%	
SODIUM SULFATE SOUNDNESS (10 CYCLES ON #4,-3/8")	1.27%	2.0%
LOS ANGELES ABRASION LOSS ("B")	28.6%	
ACID SOLUBILITY	96.3%	
44/75 UM SURFACE AREA (AIR PERMEABILITY)	1548.95 CM^2 /G	
Ø/44 UM SURFACE AREA	2493.92	

ZETA POTENTIAL:	pH	mV.
	2.3	1.6
	6.7	-16.2
	9.5	-15.9
	11.2	-30.9

LHORTY COEFFICIENT OF ACTIVITY Ø.5 - Ø.4

TABLE 5.

TESTS

CUP, MIX & SET TIME
STRIP CHART MIX TIME
WET COHESION
CURED COHESION
STRENGTH & STRETCH

APPEARANCE
TOUGHNESS
ADHESION
WET TRACK ABRASION;
1-HOUR SOAK
6-DAY SOAK

LOADED WHEEL:
RUT RESISTANCE
SAND ADHESION
FLEXURAL TENSION

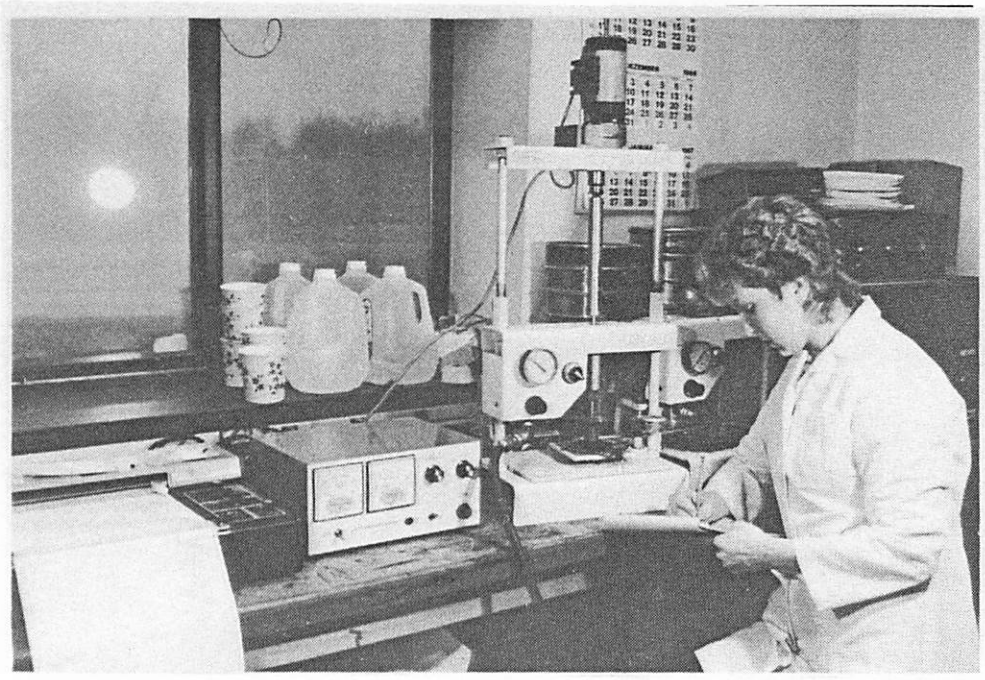


FIGURE 9 THE MOTORIZED COHESION TEST USING A STRIP CHART RECORDER FOR THE "STRENGTH & STRETCH" TEST.

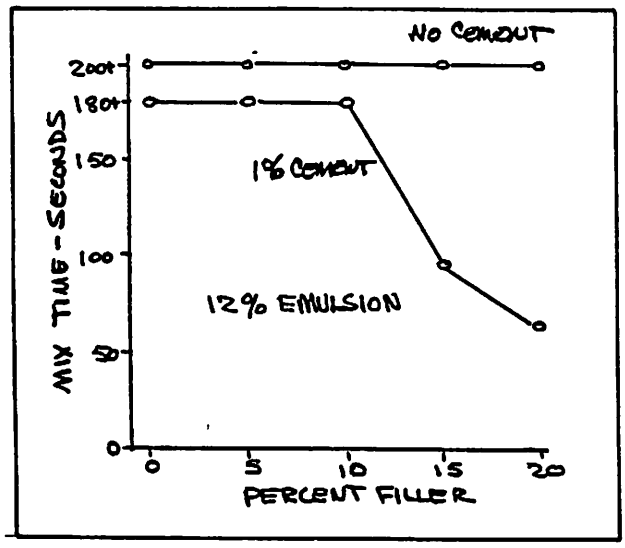


FIG 10. EFFECT OF FILLER & CEMENT CONTENT ON MIX TIME (CUP) @ 12% EMULSION

FIGURE 10 CUP MIX TIME. WITH NO CEMENT AN INCREASE IN FILLER CONTENT HAS NO EFFECT ON MIX TIME. WHEN 1% CEMENT IS ADDED MIX TIME IS GREATLY REDUCED WHEN FILLER CONTENTS ARE INCREASED TO 15% AND 20%.

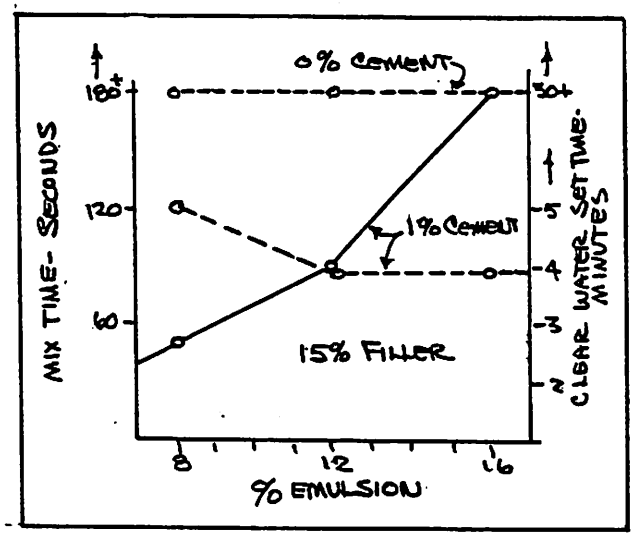


FIG. 11. EFFECT OF EMULSION CONTENT ON MIX TIME (CUP) AND CLEAR WATER SET TIME @ 15% FILLER

FIGURE 11: INCREASING THE EMULSION CONTENT HAS NO EFFECT ON MIX TIME AT 15% FILLER CONTENT. WHEN 1% CEMENT IS ADDED MIX TIME IS INCREASED WITH INCREASED EMULSION CONTENT BUT CLEAR WATER SET TIMES ARE REDUCED!

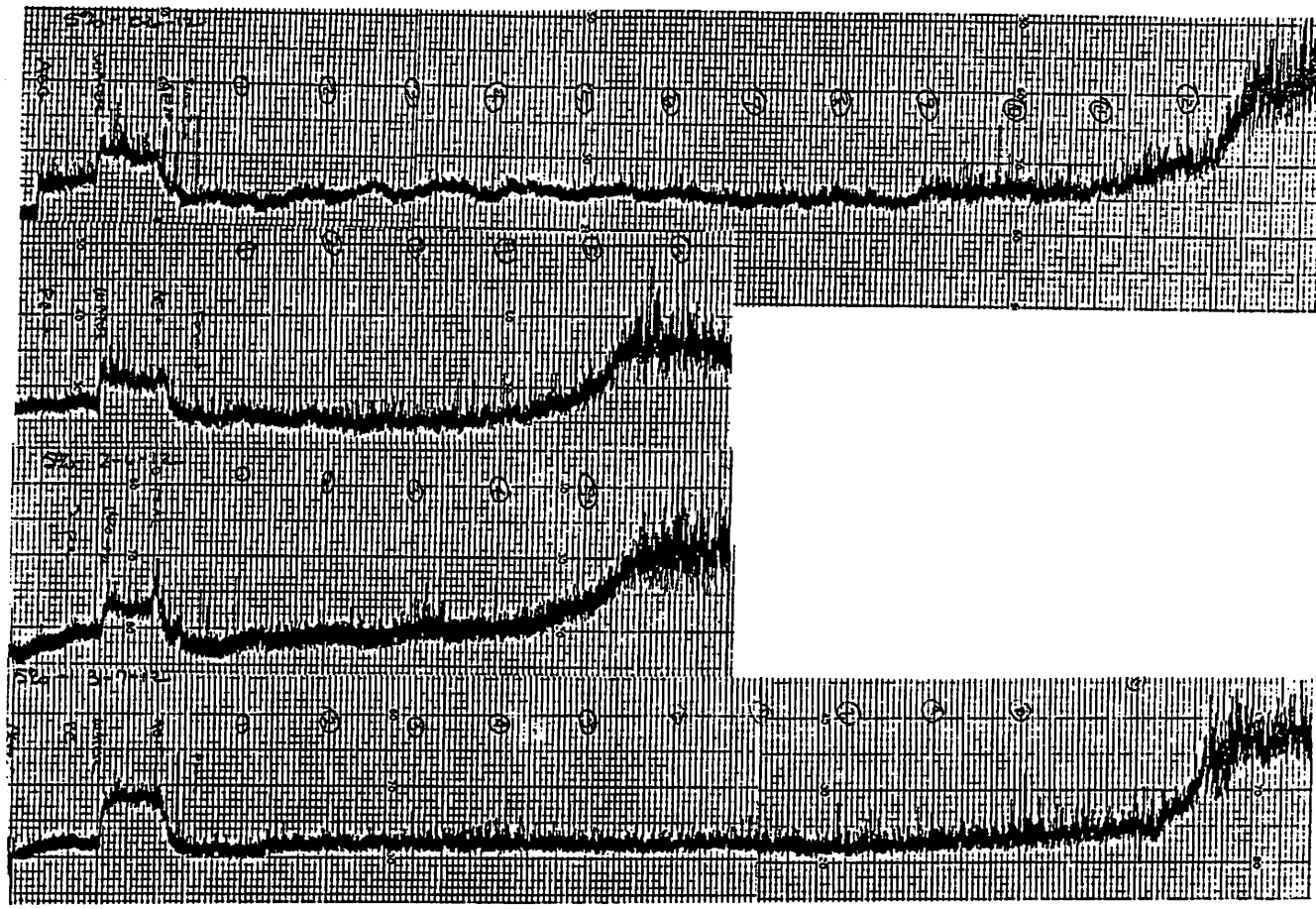


FIGURE 12A: 150 RPM MIXING CHARACTERISTICS BY STRIP CHART RECORDING: 5% FILLER WITH Ø, 1, 2, & 3% CEMENT, 12% EMULSION.

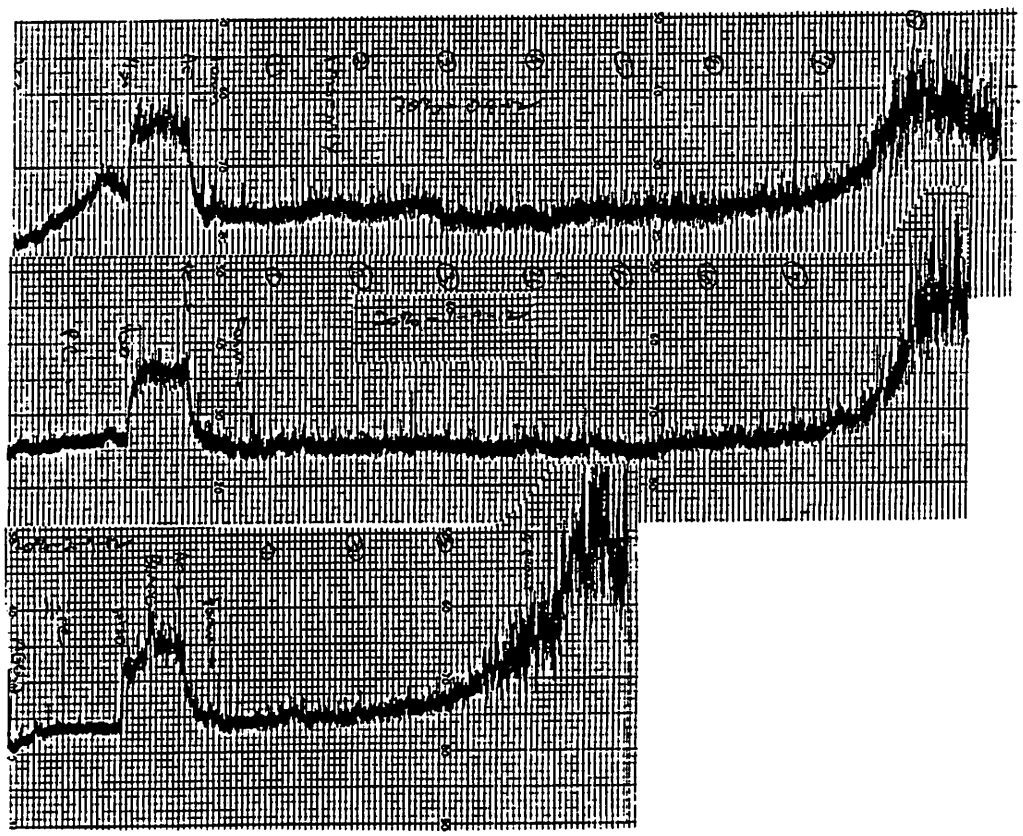


FIGURE 12B: 150 RPM MIXING CHARACTERISTICS BY STRIP CHART RECORDING: 20% FILLER WITH Ø, 1, & 2% CEMENT AT 12% EMULSION.

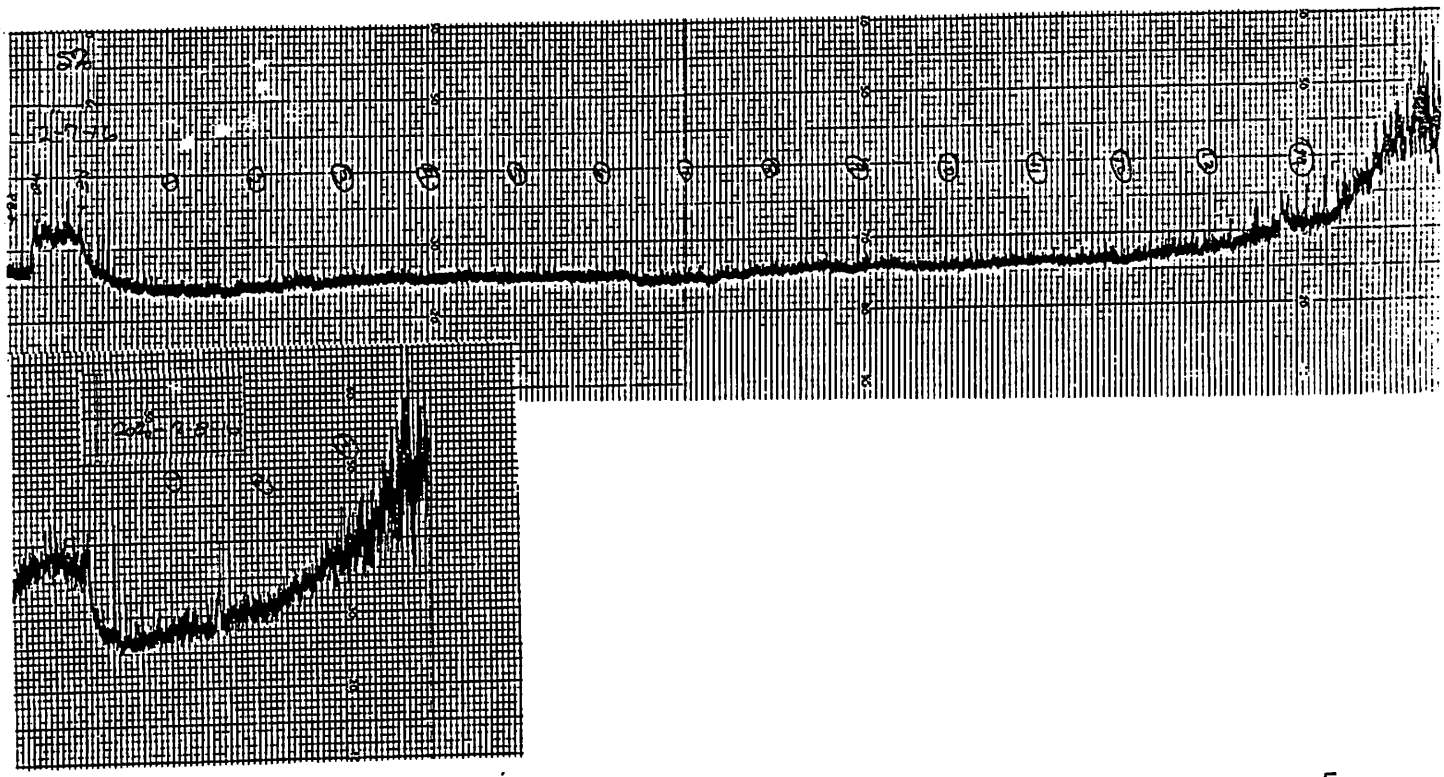


FIGURE 12c: 150 RPM MIXING CHARACTERISTICS BY STRIP CHART RECORDING: 5 & 20% FILLER AT 2% CEMENT AND 16% EMULSION. NOTE THE DRAMATIC DIFFERENCE IN TIME TO BREAK CAUSED BY THE INCREASE IN FILLER.

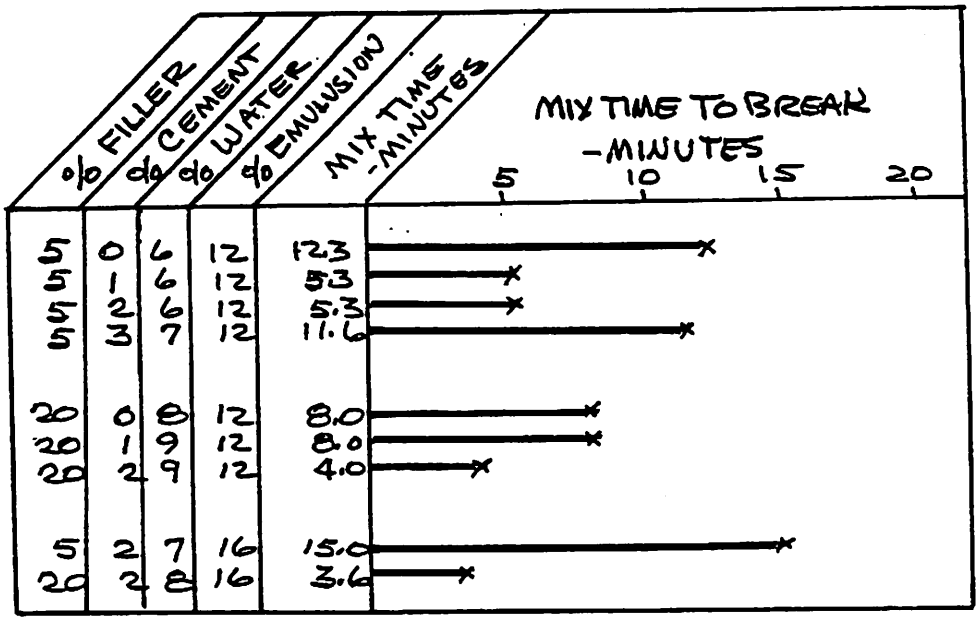


FIG. 13. EFFECT OF FILLER, CEMENT & EMULSION CONTENT ON STRIP CHART MIX TIME

FIGURE 13 SUMMARIZES RESULTS OF THE 150 RPM STRIP CHART MIXING CHARACTERISTICS TEST. AT 12% EMULSION CONTENT, AN INCREASE IN FILLER ALONE REDUCES MIX TIME TO BREAK. THE ADDITION OF CEMENT FURTHER REDUCES MIX TIME. AT 16% EMULSION AND 2% CEMENT THERE IS A LARGE REDUCTION IN MIX TIME FROM 5% TO 20% FILLER.

NOTE: THE IDIOSYNCRACIES OF EACH STRIP CHART ARE NOTED HERE. FOR THE PURPOSES OF THIS PAPER ONLY THE MIX TIME TO BREAK IS REPORTED.

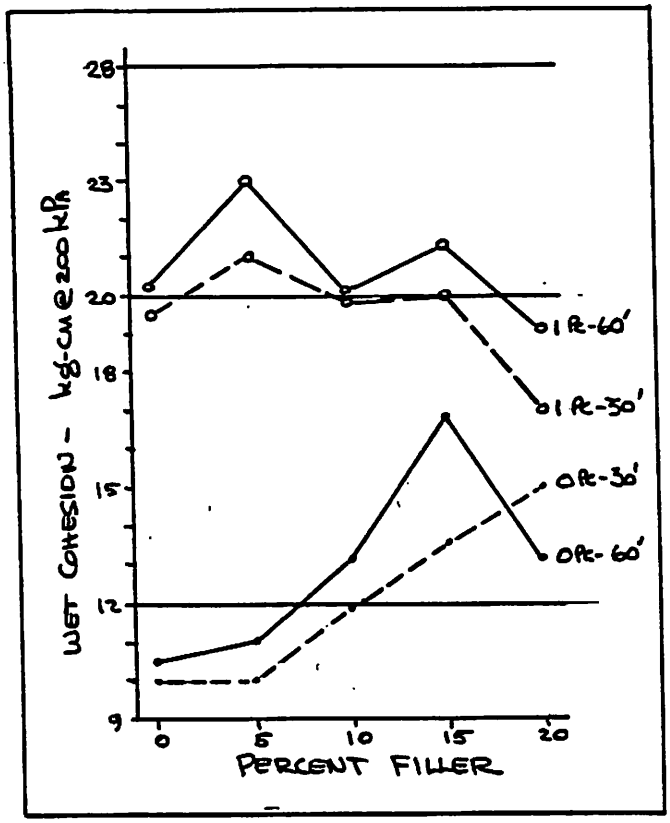


FIG. 14. EFFECT OF FILLER CONTENT AND CEMENT ON 30 & 60 MINUTE WET COHESION @ 12% EMULSION

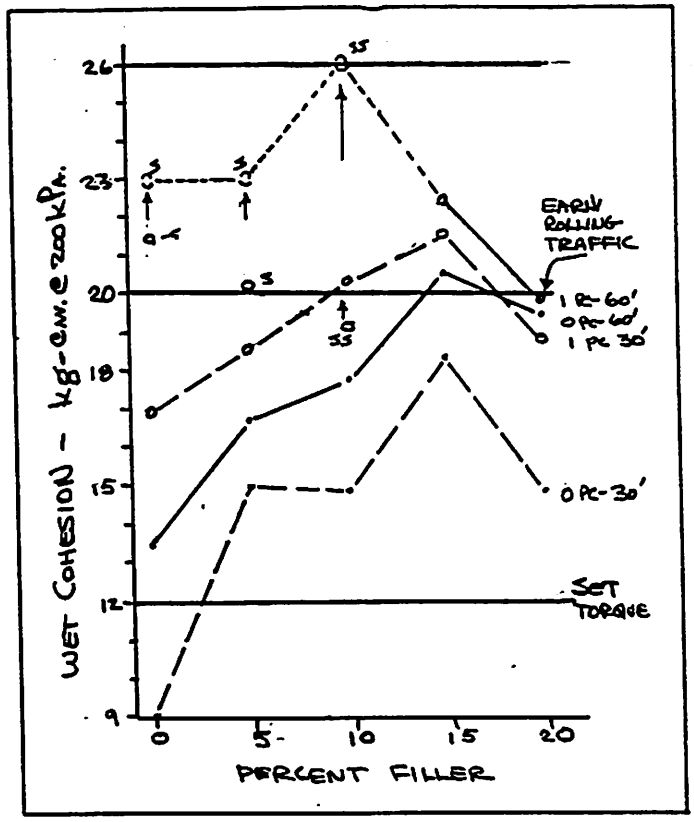


FIG. 15. EFFECT OF FILLER CONTENT AND CEMENT ON 30 & 60 MINUTE WET COHESION @ 16% EMULSION

FIGURES 14 AND 15 EACH SHOW SIMILAR TRENDS IN WET COHESION AT 30 AND 60 MINUTES USING 12% AND 16% EMULSION, WITH AND WITHOUT CEMENT.

IN ALL CASES CEMENT SHOWS HIGHER WET COHESIONS THAN PLAIN. IN ALL CASES, WET COHESION DROPS OFF AT 20% FILLER CONTENT. WHEN CEMENT IS PRESENT WET COHESION AT 12% EMULSION PEAKS AT 5% FILLER WHILE 16% EMULSION PEAKS AT 10% FILLER.

WITHOUT CEMENT WET COHESION INCREASES WITH AN INCREASE IN FILLER BUT THE REVERSE IS TRUE WHEN CEMENT IS PRESENT.

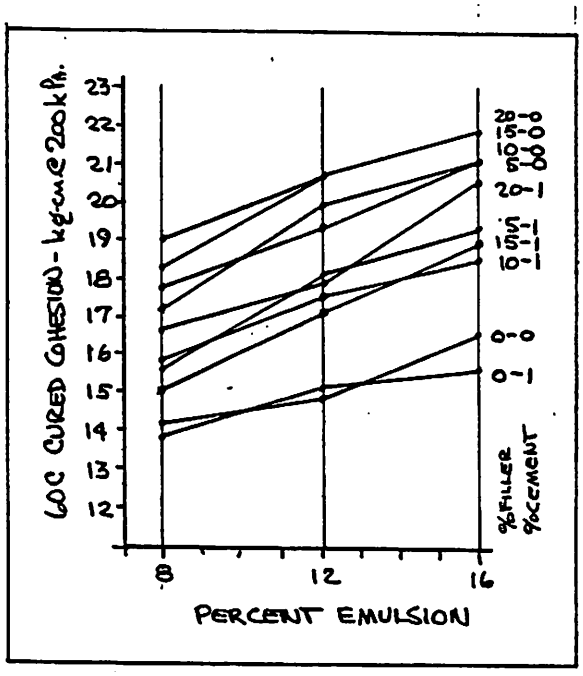


FIG. 16. EFFECT OF FILLER, EMULSION AND CEMENT CONTENT ON 60 C CURED COHESION

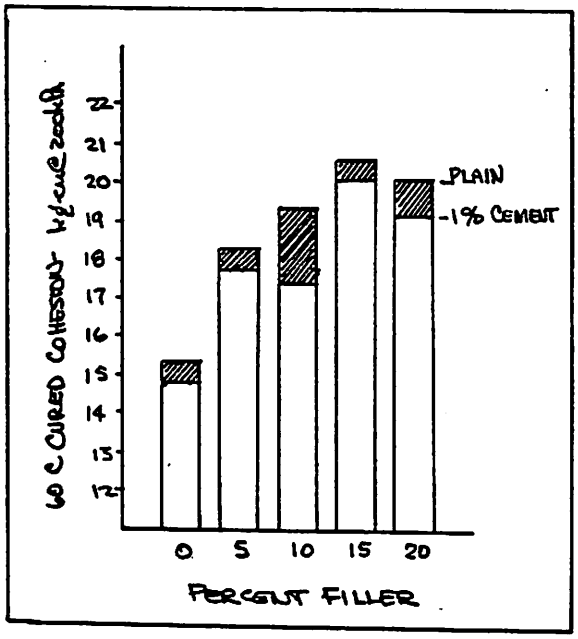
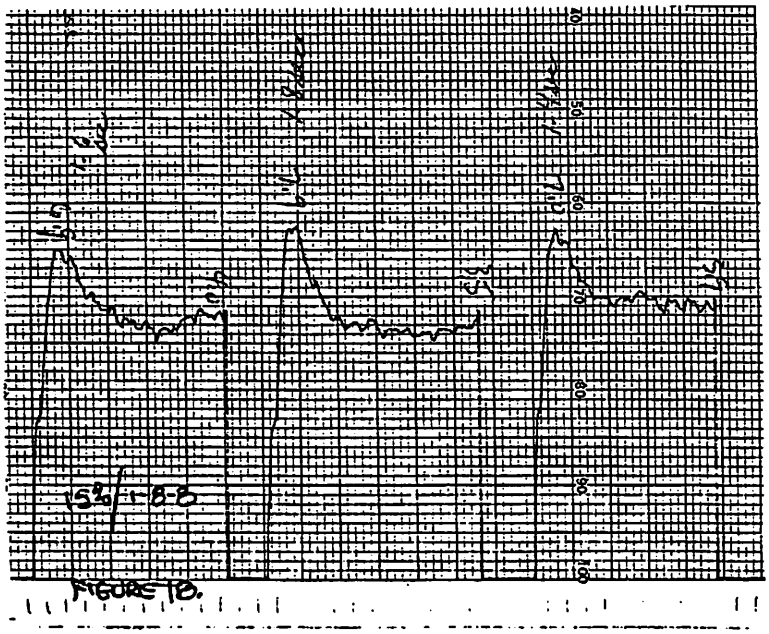


FIG. 17. EFFECT OF FILLER AND CEMENT CONTENT ON CURED COHESION— —AVERAGE OF 8, 12, 16% EMULSION

FIGURES 16 & 17 SHOW THE RESULTS OF FILLER EMULSION AND CEMENT CONTENTS ON 60C CURED COHESION (RESISTANCE TO HIGH TEMPERATURE FLOW OR COHESION). THE HIGHEST NUMBERS ARE AT HIGH FILLER CONTENTS AND NO CEMENT.



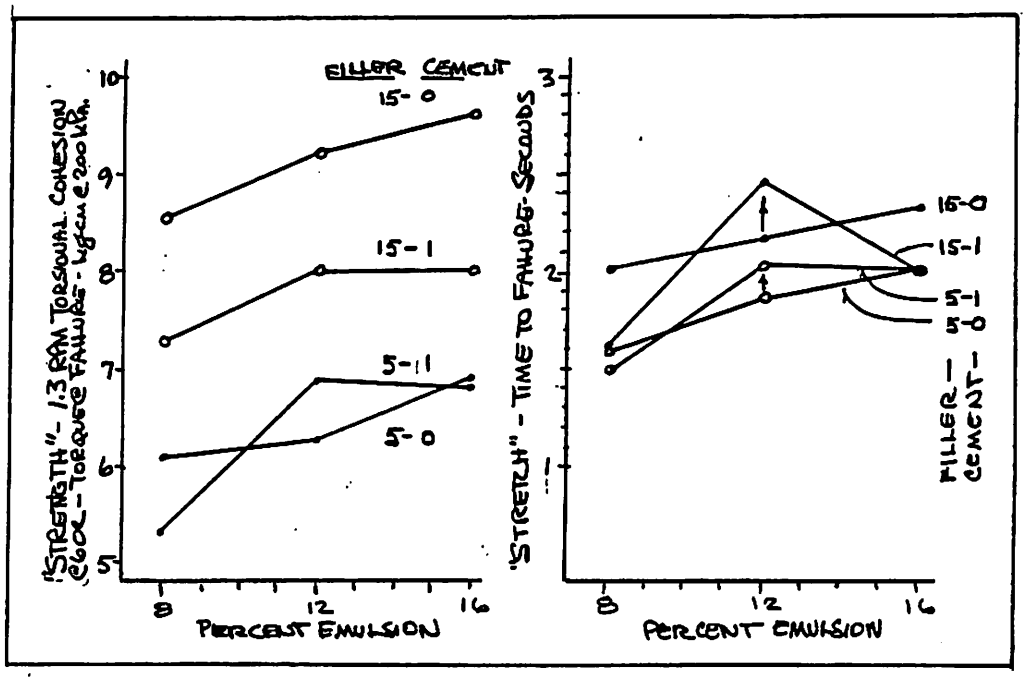


FIGURE 19. EFFECT OF FILLER, CEMENT & EMULSION CONTENT ON STRENGTH & STRETCH 60C TORSIONAL COHESION

FIGURES 18 AND 19 SHOW THE RESULTS OF 60C LOW SPEED (1.3 RPM OR 8 RADIANS) ROTATIONAL SHEAR. USING THE STRIP CHART RECORD AND A FOLLOW-UP TORQUE GAGE, THE PEAK TORQUE AT FAILURE AND THE TIME TO FAILURE IS RECORDED. THESE PROPERTIES ARE WHAT WE CALL "STRENGTH AND STRETCH."

IN OUR EXPERIENCE, THOUGH LOW, THESE VALUES ARE GOOD VALUES FOR UNMODIFIED SYSTEMS. INCREASE IN FILLER INCREASES THE "STRENGTH". MAXIMUM STRENGTH IS ACHIEVED WITHOUT CEMENT.

IT IS INTERESTING THAT "STRETCH" PEAKS AT 12% EMULSION WHEN CEMENT IS PRESENT AT BOTH 5 AND 15% FILLER CONTENTS.

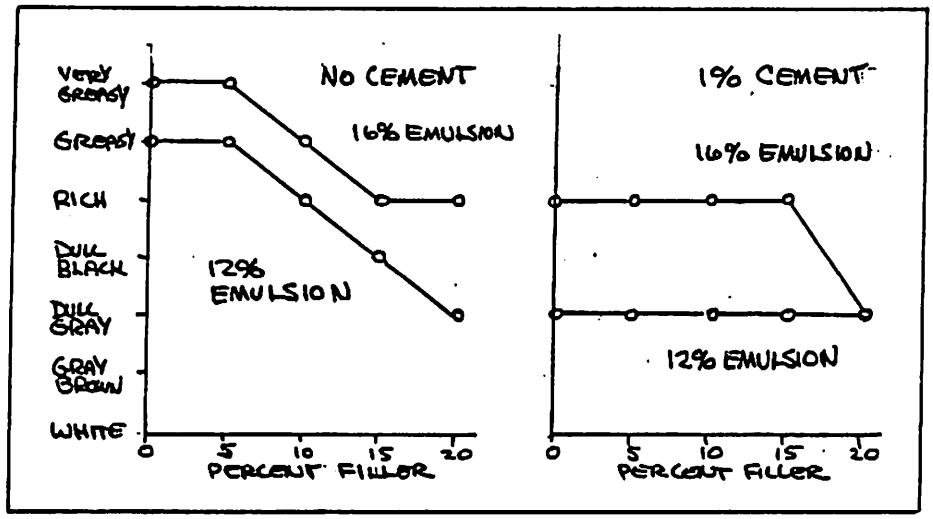


FIGURE 20. EFFECT OF FILLER, EMULSION & CEMENT CONTENT ON APPEARANCE

FIGURE 20: THE INITIAL APPEARANCE OF CURED SLURRY IS AN IMPORTANT CHARACTERISTIC. OUR RESULTS ARE SOMEWHAT SUBJECTIVE BUT THE RESULTS ARE CLEAR. BOTH THE PRESENCE OF CEMENT AND AN INCREASE IN FILLER IMPROVES THE INITIAL APPEARANCE OF THIS SYSTEM.

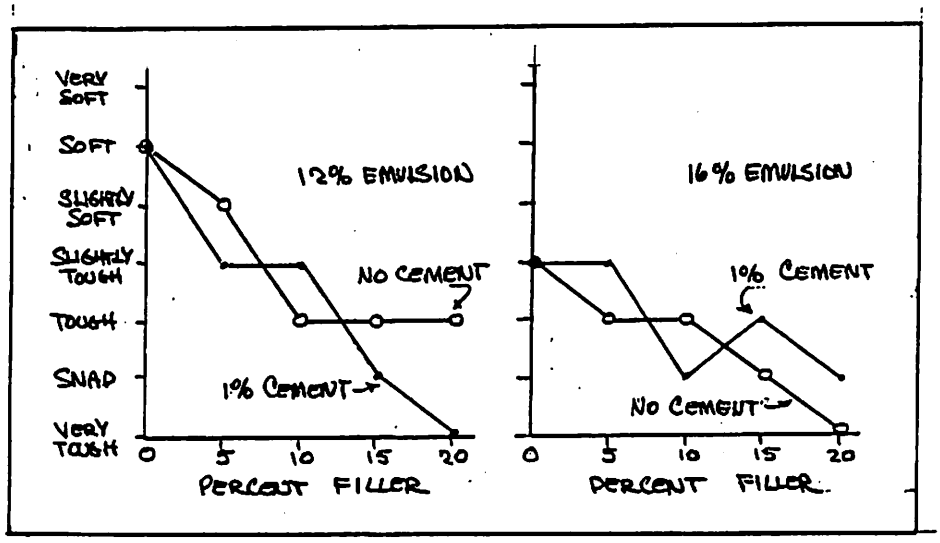


FIGURE 21. EFFECT OF FILLER, EMULSION & CEMENT CONTENT ON SUBJECTIVE TOUGHNESS

FIGURE 21: "SUBJECTIVE TOUGHNESS" OR "HOW-THE-COOKIE-CRUMBLES" TEST IN GENERAL SHOWS THAT AN INCREASE IN FILLER AT BOTH 12 AND 16% EMULSION MAKES THE CURVED SLURRY "TOUGHER". THE TOUGHEST WERE AT 15 AND 20% FILLER CONTENTS. AT 12% EMULSION, CEMENT IMPROVES TOUGHNESS WHILE AT 16% EMULSION, NO CEMENT IS BEST!

	No Cement	1% Cement
0% Filler	Thin Film Free Bitumen Non-Cohesive 99+	Very Thin Film Sl. Free Bit. Non-Cohesive 99+
10% Filler	Thin Film Sl. Free Bit. Non-Cohesive 99+	Thick Film Cohesive Mass 99+
20% Filler	Thick Film Cohesive Mass 99+	Thick Film Cohesive Mass 95+

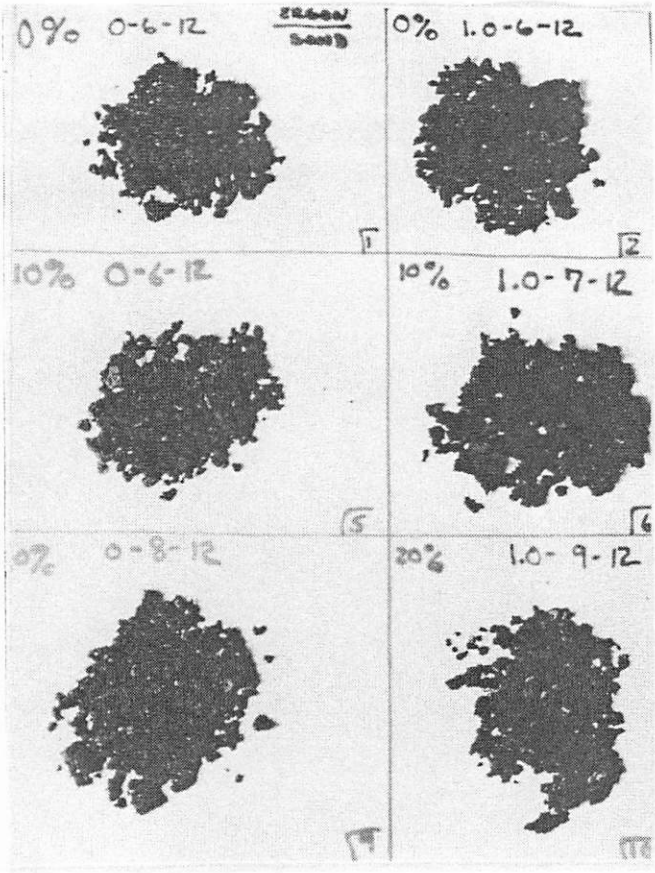


FIGURE 22. EFFECT OF FILLER AND CEMENT ON BOILING WATER ADHESION TEST

FIGURES 22 AND 23 SHOW AN EVALUATION OF ADHESION AS MEASURED BY BOILING THE CURED SPECIMENS IN WATER FOR 3 MINUTES. THE PERCENTAGE RATINGS ARE ALL VERY GOOD. HOWEVER, THIN, NON-COHESIVE FILMS ARE NOTED AT LOWER FINES CONTENT. RICH COHESIVE FILMS ARE FORMED AT HIGHER FILLER CONTENTS. COHESIVENESS IS ENHANCED BY EITHER HIGH FILLER CONTENTS, CEMENT PRESENCE OR BOTH.

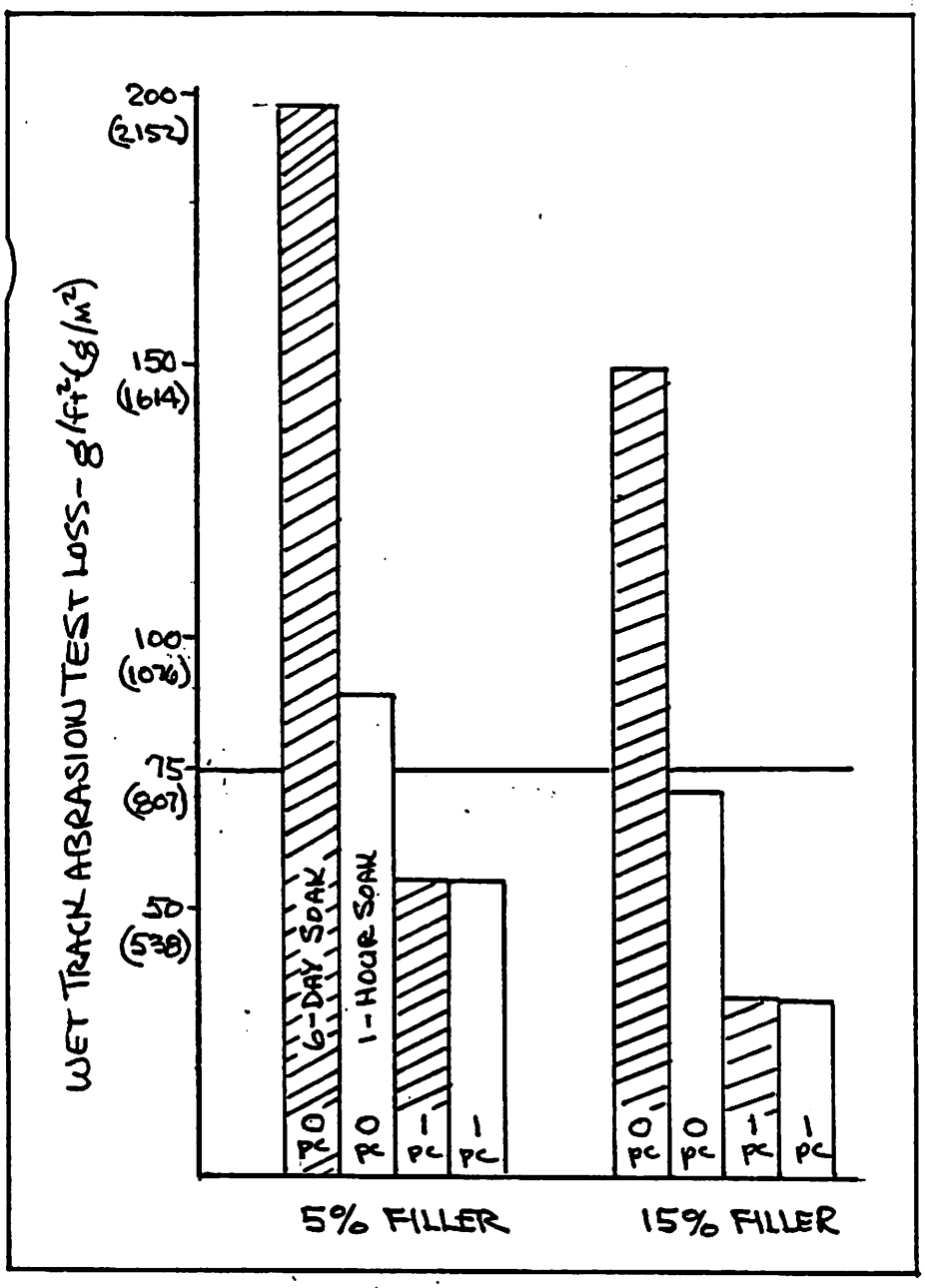


FIG. 24. EFFECT OF FILLER & CEMENT CONTENT ON 1-HOUR & 6-DAY SOAK WET TRACK ABRASION TEST LOSS – 12% EMULSION

FIGURE 24 THE PRESENCE (OR ABSENCE) OF CEMENT DRAMATICALLY AFFECTS BOTH THE ONE-HOUR AND SIX-DAY SOAK WET TRACK ABRASION TESTS.

IN ALL CASES, INCREASED FILLER IMPROVES THE WTAT. CEMENT PRESENCE AT LOW OR HIGH FILLER CONTENTS MARKEDLY IMPROVES THE TEST RESULTS.

THESE SPECIMENS WERE FIRST RUN AT THE ONE-HOUR SOAK PERIOD, OVEN DRIED FOR 18 HOURS AT 60C, COOLED AND WEIGHED TO DETERMINE THE LOSS. TO CONSERVE MATERIALS, THE SAME SPECIMENS WERE USED FOR THE SIX-DAY SOAK TEST.

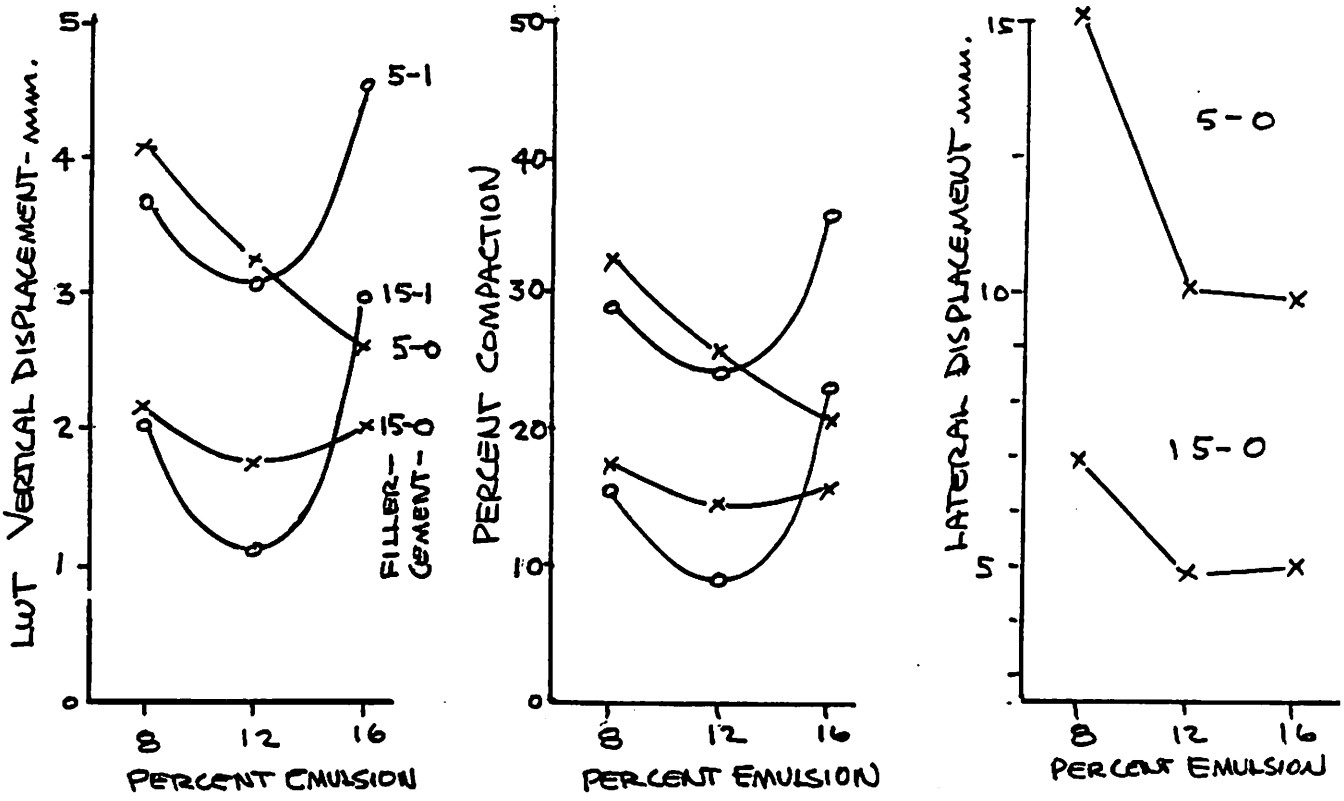


FIGURE 25 EFFECT OF FILLER, CEMENT & EMULSION CONTENT ON LOADED WHEEL COMPACTION 1000 CYCLES @ 125 POUNDS-½" SPECIMEN

FIGURE 25: RESISTANCE TO COMPACTION OR RUTTING IS PLOTTED BY MEASURING THE THICKNESS OF SPECIMENS BEFORE AND AFTER PERFORMING A LOADED WHEEL TEST OF 1000 CYCLES AT 125 POUNDS (56.8 KG.) AND 22C. THE SPECIMENS WERE CAST AT 13 MM THICK OR "THREE STONES DEEP".

AN 12% OPTIMUM EMULSION CONTENT IS SEEN FOR MAXIMUM COMPACTION RESISTANCE UNDER THE TEST CONDITIONS.

A LARGE DIFFERENCE BETWEEN THE 5 AND 15% FILLER CONTENTS IS SEEN. THE HIGHER THE BETTER. THE PRESENCE OF CEMENT FURTHER IMPROVES RESISTANCE TO COMPACTION.

THE LATERAL DISPLACEMENT OF THE UNCONFINED SPECIMEN IS MUCH LOWER AT HIGHER FILLER CONTENTS.

IT IS NOTED THAT, AT 15% FILLER, 1% CEMENT AND 12% EMULSION, THE RUTTING RESISTANCE IS ROUGHLY EQUAL TO MOST POLYMER MODIFIED MATERIALS UNDER OUR TEST CONDITIONS.

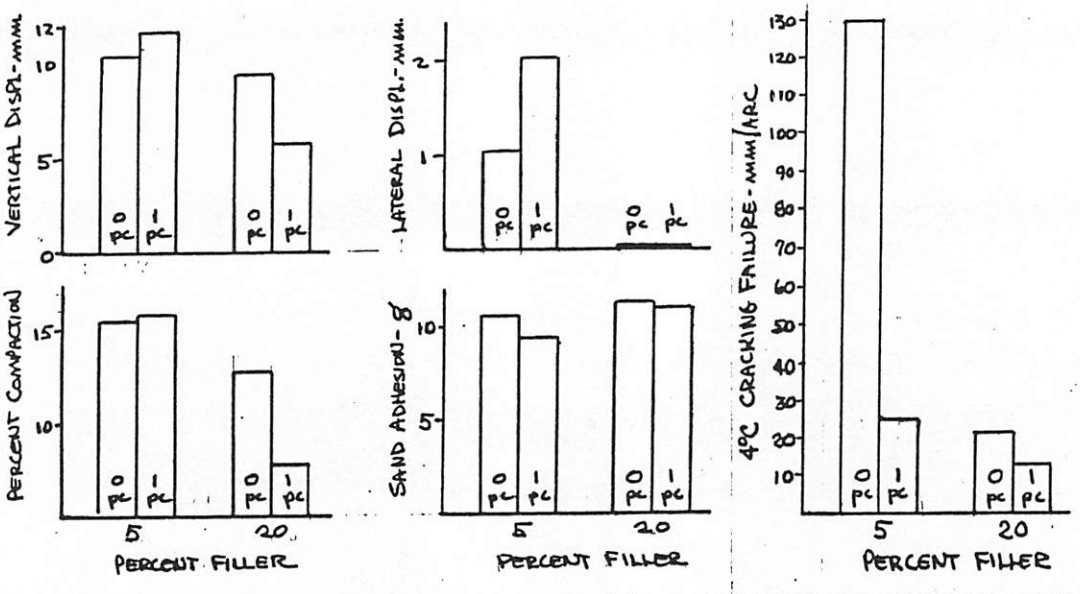


FIGURE 26. EFFECT OF FILLER AND CEMENT CONTENT ON THE LOADED WHEEL TEST - 1000 CYCLES @ 125 POUNDS 16% EMULSION - 6mm SPECIMEN

FIG. 26a. LOW TEMPERATURE - 4C FLEXURAL TENSION TEST 16% EMULSION - 6mm SPEC.

FIGURE 26: LOADED WHEEL TESTS PERFORMED ON A SERIES OF 6 MM SPECIMENS AT 16% EMULSION SHOWS MORE VERTICAL DISPLACEMENT WITH 5% FILLER AND 1% CEMENT THAN WITHOUT CEMENT. THE REVERSE IS TRUE AT 20% FILLER CONTENT.

LATERAL DISPLACEMENT IS REDUCED TO NEARLY ZERO AT HIGH FILLER CONTENT.

SAND ADHESION VALUES ARE ALL HIGH, BUT A SLIGHT REDUCTION IS NOTED WHEN CEMENT IS PRESENT. FILLER INCREASE AND CEMENT ADDITION KILLS THE LOW TEMPERATURE STRETCH.

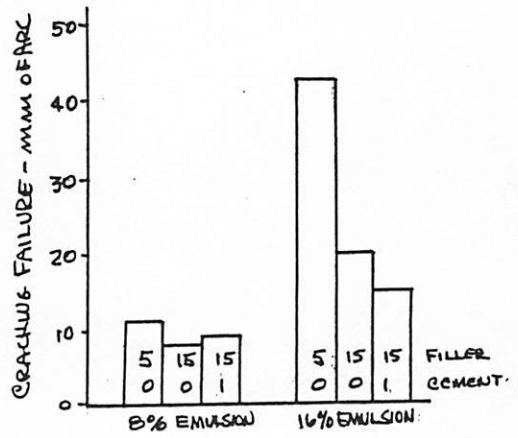


FIGURE 27 EFFECT OF FILLER, EMULSION AND CEMENT CONTENTS ON LOW TEMPERATURE (4°C) FLEXURAL TENSION TEST 13 mm SPECIMENS

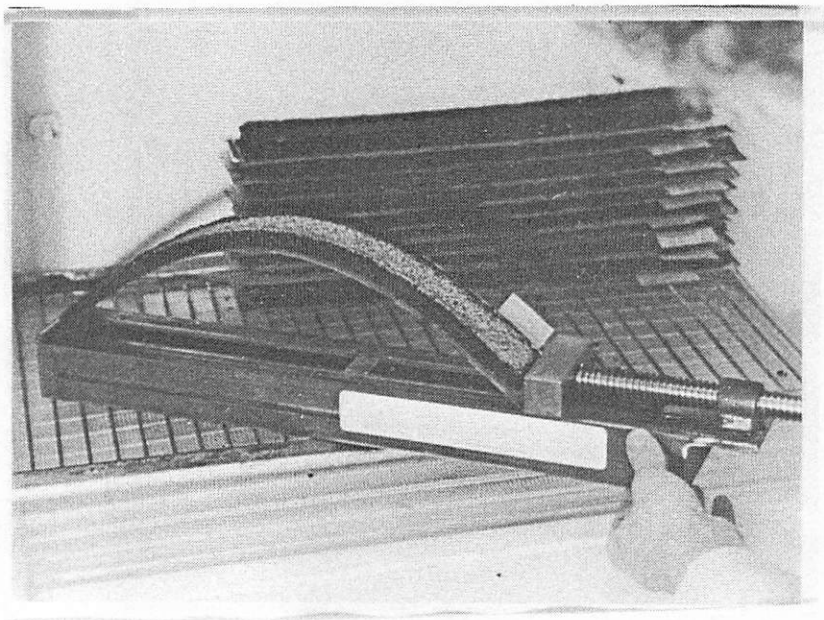


FIGURE 27: AN EXPERIMENTAL 4C LOW TEMPERATURE FLEXURAL TENSION TEST WAS TRIED ON 13 MM, COMPACTED LWT SPECIMENS. THE SPECIMEN IS BOWED UPWARD INTO AN INCREASING ARC BY A SPECIAL VICE AT A RATE OF ABOUT 1 MM PER SECOND. THE HEIGHT OF ARC AT FAILURE IS NOTED.

LOW FILLER CONTENTS AND HIGH EMULSION CONTENTS PERFORM BEST. CEMENT PRESENCE AND HIGH FILLER CONTENTS ARE MUCH MORE BRITTLE AT LOW TEMPERATURE.

SUMMARY: EFFECTS OF FILLER INCREASE AND ADDED CEMENT

FIGURE		INCREASE IN FILLER	ADDED CEMENT
10	MIX TIME @ 12%	NO EFFECT	REDUCES
11	CLEARWATER SET	NO EFFECT	REDUCES
	MIX TIME @ 8, 12, 16% AE	NO EFFECT	REDUCES
13	STRIP CHART MIX TIME TO BREAK	REDUCES	REDUCES
14	WET COHESION @ 12% AE	PEAKS @ 15%	PEAKS @ 5%
15	WET COHESION @ 16% AE	PEAKS @ 15%	PEAKS @ 10%
16	CURED COHESION	INCREASES	REDUCES (!)
17	"STRENGTH" 60C COHESION STRIP CHART	IMPROVES	REDUCES
18	"STRETCH" 60C COHESION STRIP CHART	PEAKS @ 15%	PEAKS @ 12% AE
20	APPEARANCE	IMPROVES	SL. REDUCTION
21	SUBJECTIVE TOUGHNESS	IMPROVES	IMPROVES
22	ADHESION	IMPROVES	IMPROVES
23	WET TRACK ABRASION TEST		
	ONE-HOUR SOAK	IMPROVES	IMPROVES
	SIX-DAY SOAK	IMPROVES	IMPROVES
24	RUTTING RESISTANCE	IMPROVES	IMPROVES
25	LOW TEMP. FLEXIBILITY	REDUCES	REDUCES

TABLE 6 SUMMARY OF TEST RESULTS

CONCLUSIONS

THE RESULTS OF THESE TESTS ON A SINGLE SLURRY SYSTEM INDICATE THAT FILLER CONTENTS OF 10-15% GENERALLY IMPROVE THE CHARACTERISTICS OF THIS SYSTEM. THE NOTABLE EXCEPTION IS IN LOW TEMPERATURE PROPERTIES WHERE VERY LOW FILLER CONTENTS GIVE THE BEST RESULTS.

WHEN THE COMBINATION OF BOTH STRENGTH OR TOUGHNESS AND LOW TEMPERATURE STRETCH OR FLEXIBILITY IS DESIRED THE PROPERTIES OF THIS BITUMEN-EMULSIFIER SYSTEM AND AGGREGATE GRADATION AND FILLER CONTENT MUST BE ALTERED TO GIVE THE DESIRED PROPERTIES.

REFERENCES

KARI, W.J.; COYNE, L.D. "EMULSIFIED ASPHALT SLURRY SEALCOATS". PROC. AAPT, VOL. 33, 1964 (P.502-537)

HARPER, W.J.; JIMENEZ, R.A.; GALLOWAY, BOB M. "EFFECTS OF MINERAL FILLERS IN SLURRY SEAL MIXTURES". HIGHWAY RESEARCH RECORD #104, 1965 (P. 36-59).

LANDISE, C.C., JR. "SOME MINERIAL FILLERS USED IN SLURRY SEAL". ISSA R & D COMMITTEE REPORT, AUGUST 1975 AND 14 ANNUAL CONV. 1976.

HARKNESS, L.M. "SLURRY SEALING - THE TOTAL SYSTEM". PROC. 1ST WORLD CONGRESS OF SLURRY SEAL, MADRID, FEBRUARY 12, 1977.

HARKNESS, L.M. SURFACE AREA AND ZETA POTENTIAL AND THEIR RELATION TO SLURRY MIXES. PROC. ISSA QUICK-SET, QUICK-CURE SLURRY SYSTEM SYMPOSION, FEBRUARY 13, 1978.

BENEDICT, C. ROBERT "CLASSIFICATION OF ASPHALT EMULSION/AGGREGATE MIXTURE SYSTEMS BY COHESION TESTER MEASUREMENT OF SET AND CURE CHARACTERISTICS". PRESENTED ISSA CONVENTION PHOENIX, JANUARY 24-28 1983.

BENEDICT, C. ROBERT "USES OF THE MODIFIED COHESION TEST FOR EMULSION FORMULATION AND MIX DESIGN OF PERFORMANCE COLD MIX SYSTEMS". PRESENTED AEMA CONVENTION NEW ORLEANS, MARCH 5-8 1985.

BENEDICT, C. ROBERT "EXPERIMENTS WITH CURED COHESION TESTING OF SLURRY SEALS AND THIN LAYERED COLD MIXES". PRESENTED ISSA CONVENTION SAN FRANCISCO, JANUARY 28, 1986.

WOODSIDE, ALAN PERSONAL COMMUNICATION AND METHYL BLUE TESTS. UNIVERSITY OF ULSTER AT JORDANSTOWN, NORTHERN IRELAND, ABOUT MAY 1985.

BREUER, J.U. DIPL.-ING. PRUFUNG DER WASSEREMPFINDLICHKEIT VON GESTEINSMEHLFULLERN". UNIVERSITY MUNICH, 1964-RECEIVED 1982.

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