DRAFT - NOT FOR PUBLICATION

INTRODUCTION TO A LOADED WHEEL TEST METHOD FOR THE FOR THE MEASUREMENT OF COMPACTION, STABILITY AND RUTTING RESISTANCE OF MULTILAYERED, DENSE GRADED FINE AGGREGATE-EMULSION COLD MIXES -

OR:

IN SEARCH OF TRAFFIC SIMULATED, COLD ROLLED MARSHALL NUMBERS FOR THIN LAYERED EMULSION MIXES.

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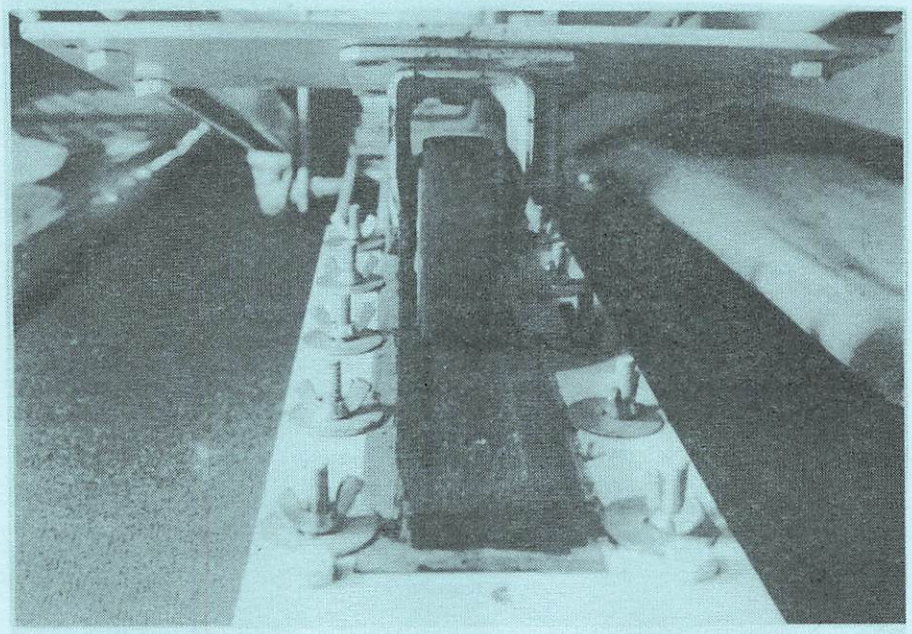

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INTRODUCTION

IN RECENT YEARS THERE IS SEEN A TREND TOWARDS THE USE OF DENSE GRADED EMULSION MIXES SUCH AS SEVERAL TYPES OF SLURRY MIX OR COLD MIXES APPLIED IN MUCH THICKER THAN NORMAL APPLICATIONS SUCH AS IN LEVELING COURSES, WEDGING AND IN RUT FILLING APPLICATIONS. THE CROSS-SECTIONALGEOMETRY REQUIRES THICKNESSES FROM "Ø" TO MULTIPLE-STONES-DEEP ACROSS SECTION DEPTHS OF AS MUCH AS 5 OR 6 CM ARE NOT UNCOMMON.

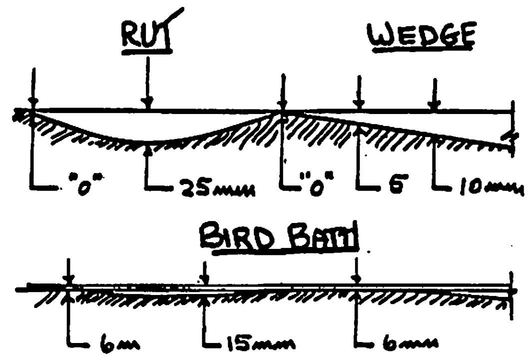


FIGURE 1. VARIABLE THICKNESS SECTIONS RUT, WEDGE, BIRD BATH

FIGURE 1 RUT AND WEDGE AND "BIRD BATH" SECTIONS

ATTEMPTS TO SOLVE THE PROBLEMS OF VARIABLE THICKNESS HOT MIXED ASPHALTIC CONCRETE APPLICATIONS ARE:

1. RATE OF COOLING VARIES FROM VERY FAST IN THIN SECTIONS AND VERY SLOW IN THICK SECTIONS. COMPACTION MUST BE DELAYED UNTIL THE THICK SECTIONS COOL SUFFICIENTLY TO SUPPORT THE ROLLERS. THIN SECTIONS HAVE THEN COOLED TOO MUCH FOR ADEQUATE COMPACTION.

   THE RESULT IS VARIABLE COMPACTION, VARIABLE DENSITY RESULTING IN REDUCED LIFE SPAN.

2. VARIABLE THICKNESS, AS IN THE CASE OF RUTS, ALLOWS ROLLERS TO SPAN OR "BRIDGE" THE RUT AND THERE IS INSUFFICIENT COMPACTION IN THE WHEEL PATH

3. TRAFFIC, IN TIME, WILL FINISH THE JOB OF COMPACTION. THE RESULT IS A RE-RUTTING OF THE PAVEMENT, USUALLY TO A GREATER DEPTH THAN BEFORE.

SPECIALLY DESIGNED MODIFIED EMULSION COLD MIXES AND EQUIPMENT TO MIX AND SPREAD THEM HAVE BEEN DEVELOPED WHICH OVERCOME THE PROBLEMS OF VARIABLE THICKNESS AND TRAFFIC COMPACTION SO THAT RE-RUTTING DOES NOT OCCUR. THIS IS ACCOMPLISHED BY DESIGNING THE MATERIAL COMBINATIONS FOR MAXIMUM STABILITY OR RESISTANCE TO RUTTING AND BY THE APPLICATION OF THESE MATERIALS IN A "LOOSE" SECTION SUFFICIENTLY CROWNED TO ALLOW FOR COMPACTION BY TRAFFIC SO THAT THE TRAFFIC COMPACTED MIX REACHES MAXIMUM COMPACTED STABILITY AT THE DESIRED GRADE AND CROSS-SLOPE.

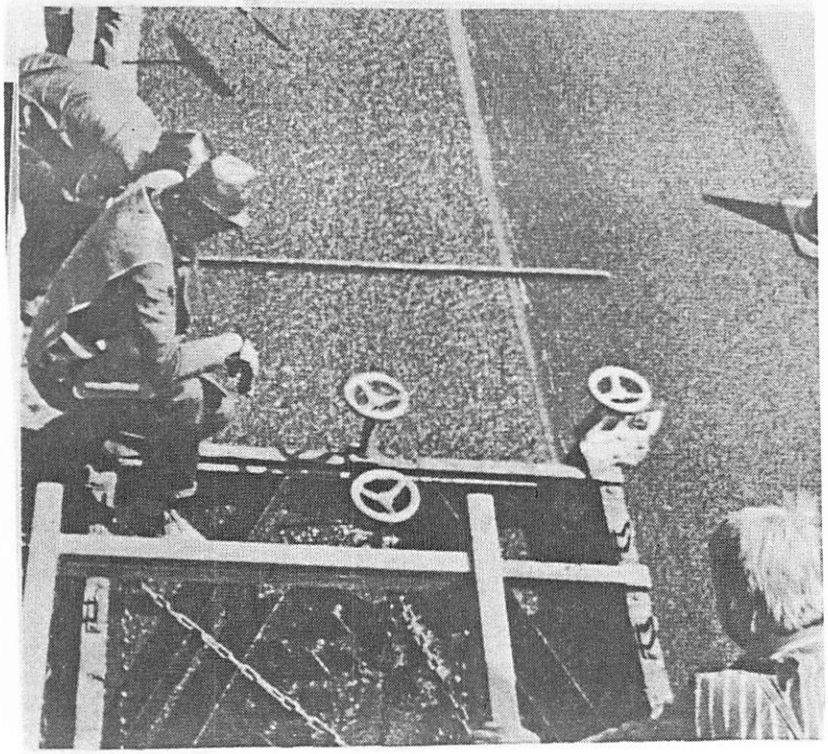


FIGURE 2 SPREADING EQUIPMENT

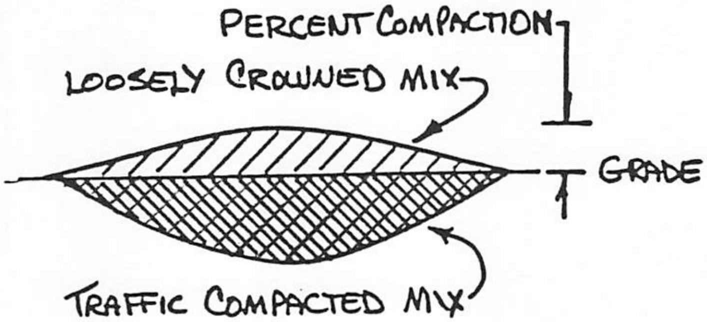


FIGURE 3. LOOSE "OVERFILL" COMPENSATION FOR TRAFFIC COMPACTION

FIGURE 3 SHOWS A HYPOTHETICAL RUT CROSS-SECTION WHICH HAS BEEN OVER-FILLED TO A "LOOSE" CROWN AND THEN TRAFFIC-COMPACTED TO A PEAK COMPACTION AND STABILITY AT THE FINAL GRADE.

THE PREDICTION OF THE AMOUNT OR PERCENTAGE OF TRAFFIC COMPACTION WHICH WILL OCCUR IS THE SUBJECT OF THE RESEARCH PRESENTED IN THIS REPORT.

HMAC (HOT MIXED ASPHALTIC (BITUMEN) CONCRETE) IS USUALLY DESIGNED FOR MAXIMUM STABILITY BY THE MARSHALL METHOD AND IS FAIRLY UNIVERSALLY UNDERSTOOD. THE HVEEM METHOD IS PREFERED IN THE WESTERN U.S. LABORATORY SPECIMENS OR "PILLS" OF ABOUT 1200 GRAMS ARE IMPACT OR GYRATORY COMPACTED AT 280-320F (138 TO 160C) INTO PILLS TYPICALLY 4" IN DIAMETER AND 2 1/2" DEEP. (101 MM DIAMETER X 64 MM). THE PILLS CONTAINING VARIOUS AGGREGATE GRADATIONS AND BITUMEN CONTENTS ARE THEN TESTED FOR STRENGTH, FLOW AND VOIDS CONTENTS AT 140F (60C), THE RESULTS PLOTTED AND THE OPTIMUM DESIGN SELECTED FROM THE PLOT.

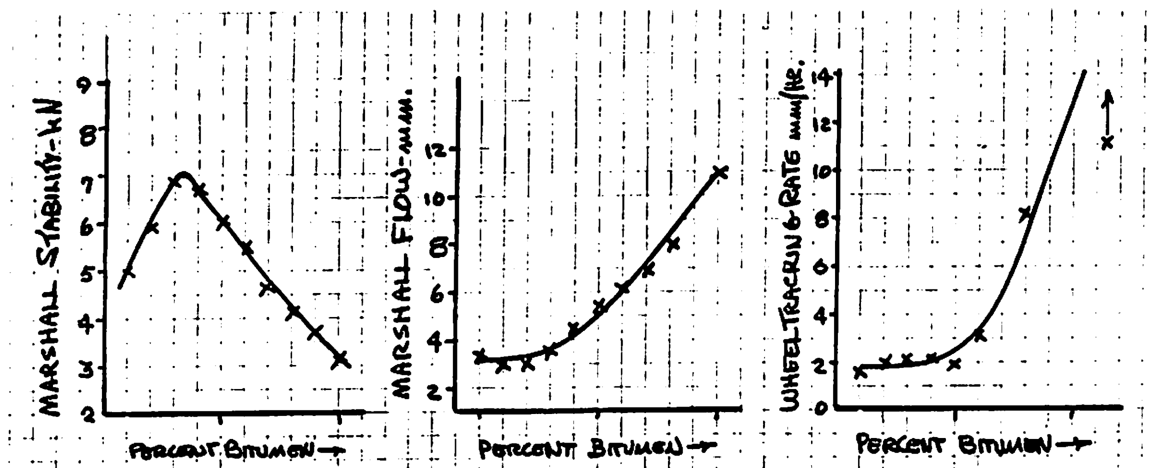


FIGURE 4. RELATION OF MARSHALL STABILITY & MARSHALL FLOW TO WHEEL TRACKING RATE.

FIGURE 4 MARSHALL STABILITY AND MARSHALL FLOW CURVES.

WHILE THESE HIGH COMPACTION TEMPERATURES, AND COMPACTION METHODS MAY SOMEWHAT SIMULATE FIELD CONDITIONS FOR HMAC, THEY SIMPLY DO NOT SIMULATE FIELD CONDITIONS FOR CMAC (COLD MIXED EMULSIFIED ASPHALTIC CONCRETE) WHERE MAXIMUM TEMPERATURES ARE LESS THAN 140F OR (60C) AND COMPACTION IS ACCOMPLISHED BY TRAFFIC UNDER AMBIENT CONDITIONS.

WE WILL PRESENT HERE THE RESULTS OF OUR INITIAL EXPERIMENTS TO DEVELOPE A TRAFFIC SIMULATING DESIGN METHOD IN ORDER TO PREDICT THE FIELD COMPACTION CHARACTERISTICS OF THIN LAYERED CMAC OR COLD OVERLAYS.

1. ORIGINAL LOADED WHEEL TEST WORK ON COMPACTION CURVES.

2. METHODS USED IN THIS INVESTIGATION.

3. RESULTS OF OUR EARLY WORK ON THE EFFECT OF LAYER THICKNESS ON COMPACITON RATES.

4. RESULTS OF OUR CURRENT WORK ON THE EFFECTS OF VARIOUS POLYMERS, EMULSIFIERS, BITUMEN QUALITY, FILLER AND ADDITIVE CONTENTS.

5. FUTURE INVESTIGATIONS TO CORRELATE THIS WORK WITH THAT OF THE TRRL'S WHEEL TRACKING TEST AND MARSHALL DESIGN.

ORIGINAL LWT WORK

1. OUR 1975 LAS VEGAS PAPER INTRODUCED THE USE OF A TRAFFIC SIMULATING LWT FOR THE TRAFFIC COUNT DESIGN OF SLURRY SEAL. COMPACTION CURVES (FIGURE 5) WERE RELATED TO THE PERCENTAGE OF BITUMEN AND LATER FIELD CORRELATED IN THE A-B ROAD TEST AND REPORTED AT THE 1ST WORLD CONGRESS IN 1977 AT MADRID.

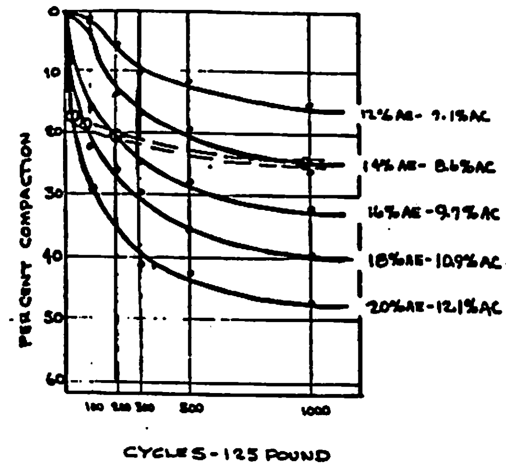


FIGURE 5A LWT COMPACTION CURVES

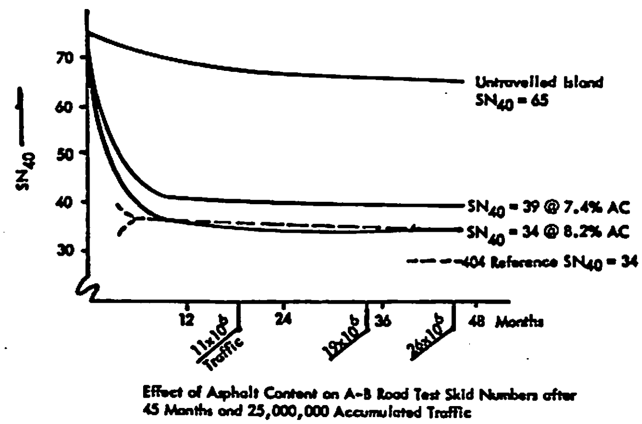


FIGURE 5B A-B ROAD FN40 CURVES RELATED TO BITUMEN CONTENT.

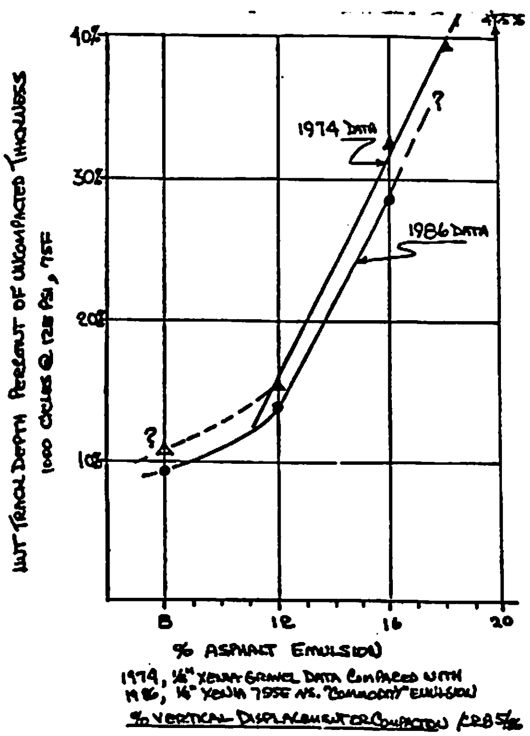


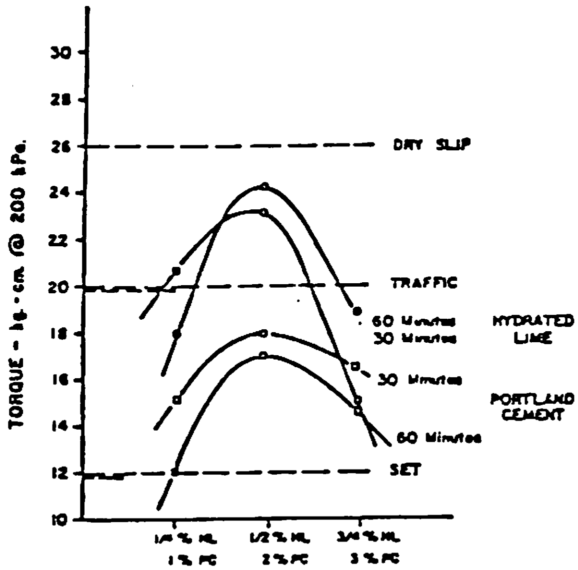
FIGURE 5C 1974 & 1986 CURVES COMPARED - SIMILAR COMMODITY GRADE MATERIALS ARE USED.

FROM THESE CURVES WE ARE ABLE TO COMPARE DATA FROM OUR CURRENT WORK. THE SAME AGGREGATE SOURCE AND SIMILAR "COMMODITY" GRADE EMULSIONS WERE USED. THE METHOD APPEARS TO BE REPRODUCIBLE, EVEN AFTER 12 YEARS.

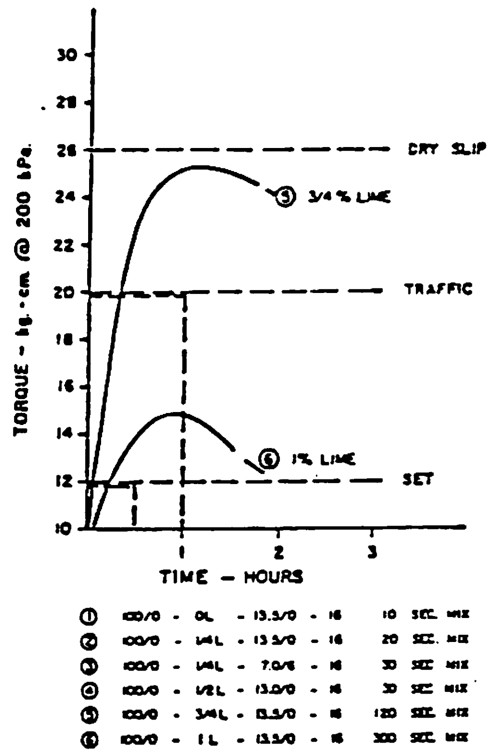
THE METHOD; SPECIMEN PREPRATION AND TESTING

ALL SPECIMENS REPORTED HERE WERE CONSTRUCTED USING A GRADATION WITHIN THE LIMITS OF ISSA TYPE 2 WITH ALL + 4.75 MM (#4) REMOVED.

THE SPECIFIC MIX DESIGNS FOR THE INGREDIENTS (E.G. CEMENT WATER, RETARDER) OF EACH MIXTURE WERE SELECTED FROM THE RESULTS OF 100-GRAM TRIAL MIXES FOR OPTIMUM MIX TIME, SET TIME AND WET COHESION TEST VALUES AT 60 MINUTES AS IN FIGURE 6.



FILLER CONTENT OPTIMIZATION



PRECISION RESULTS REQUIRES PRECISION

FIGURE 6 WET COHESION OPTIMISATION OF CEMENT CONTENT.

THE OPTIMUM MIX DESIGNS WERE MIXED IN 300, 400 AND 500 GRAM BATCHES AND CAST INTO 50 X 380 MM MOLDS WHICH WERE 6, 9.5, AND 13 MM (1/4", 3/8", 1/2") DEEP RESPECTIVELY. THE SPECIMENS WERE SUPPORTED BY A GALVANIZED SHEET METAL PLACQUE OR PLATE WHICH WAS 0.5 X 76 X 406MM (24 GA. X 3" X 16").

THE SPECIMENS WERE AIR DRIED FOR ABOUT 4-6 HOURS, THEN PLACED IN A FORCED DRAFT OVEN AT 60C (140F) FOR 20-22 HOURS.

AFTER COOLING TO ROOM TEMPERATURE THE SPECIMENS WERE COMPLETELY MEASURED, WEIGHED IN AIR AND IN WATER TO DETERMINE SPECIFIC GRAVITY, UNCOMPACTED THICKNESS AND WIDTH. AFTER SURFACE DRYING EACH WAS MOUNTED IN THE LOADED WHEEL TESTER AND SUBJECTED TO 1000 CYCLES AT 57KG (125LBS) LOADING.

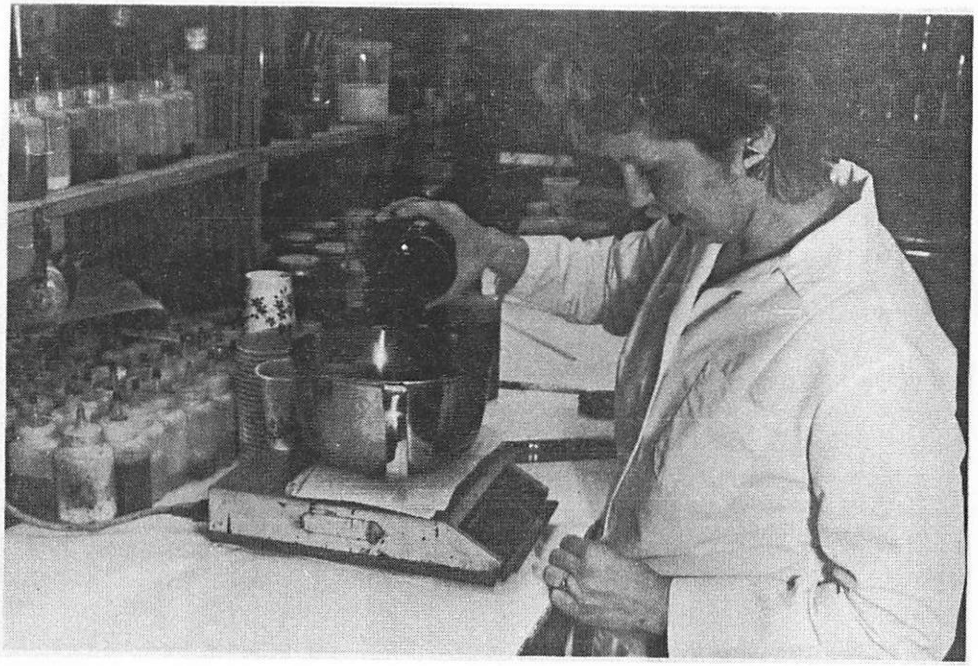


FIGURE 7 WEIGHING MIX INGREDIENTS.

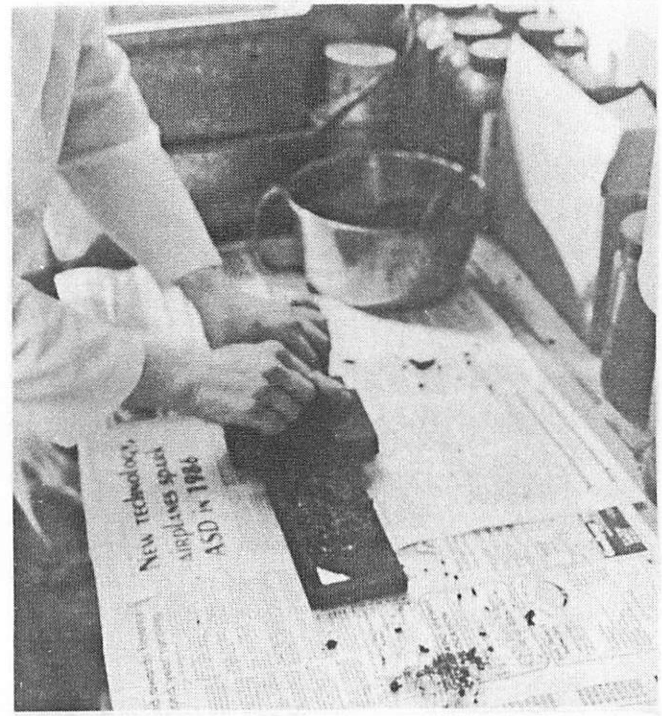
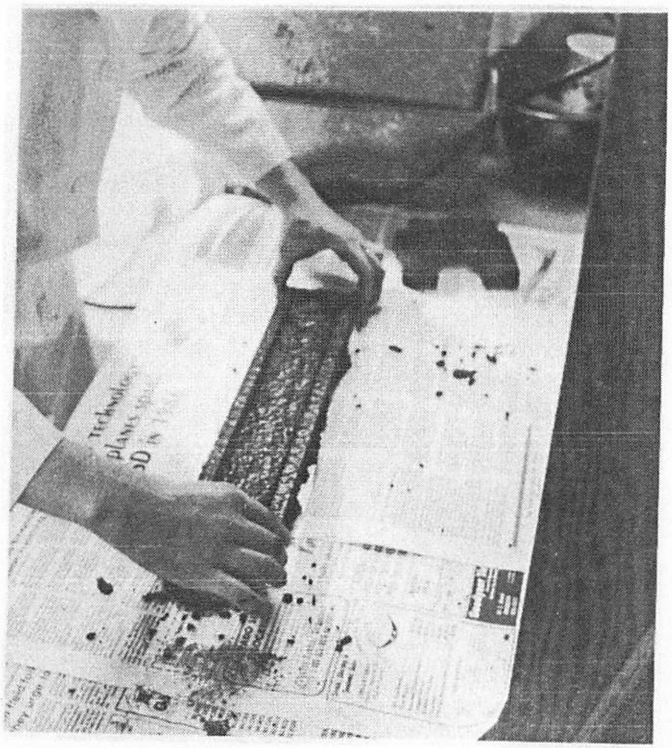


FIGURE 8 CASTING AND FINISHING THE SPECIMEN.



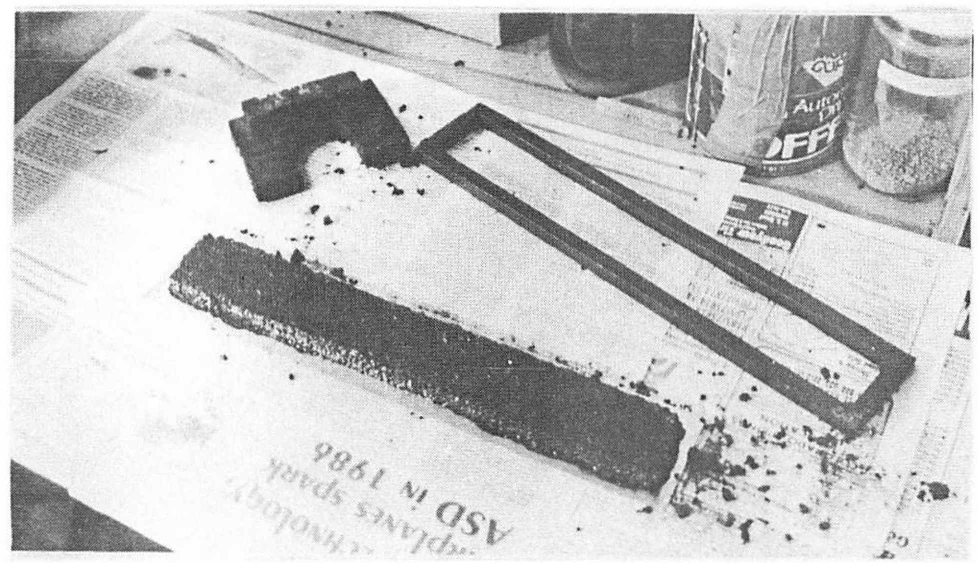


FIGURE 9 THE FINISHED SPECIMEN.

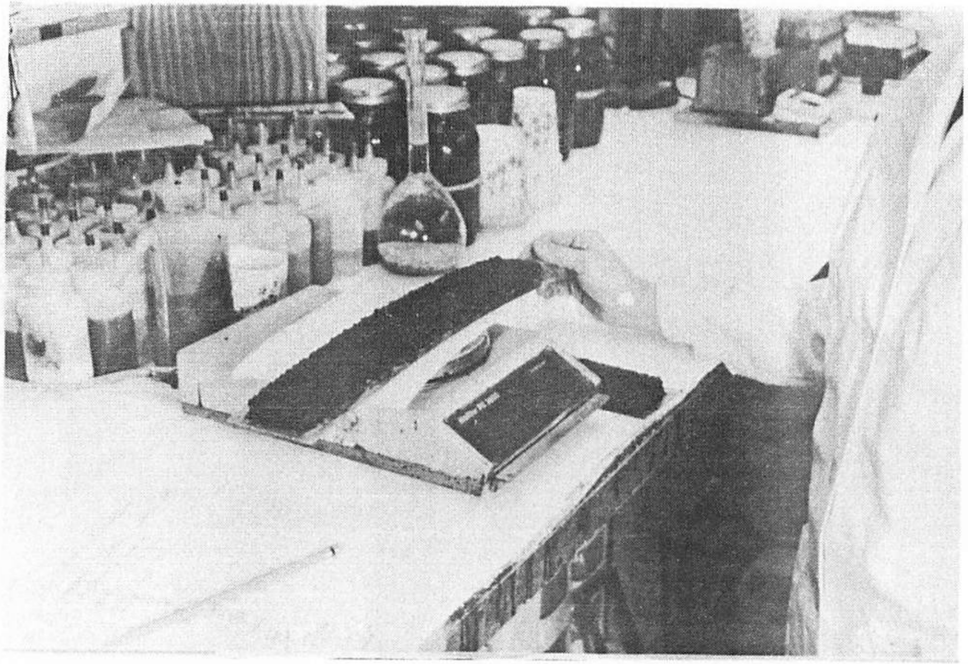


FIGURE 1Ø WEIGH IN AIR

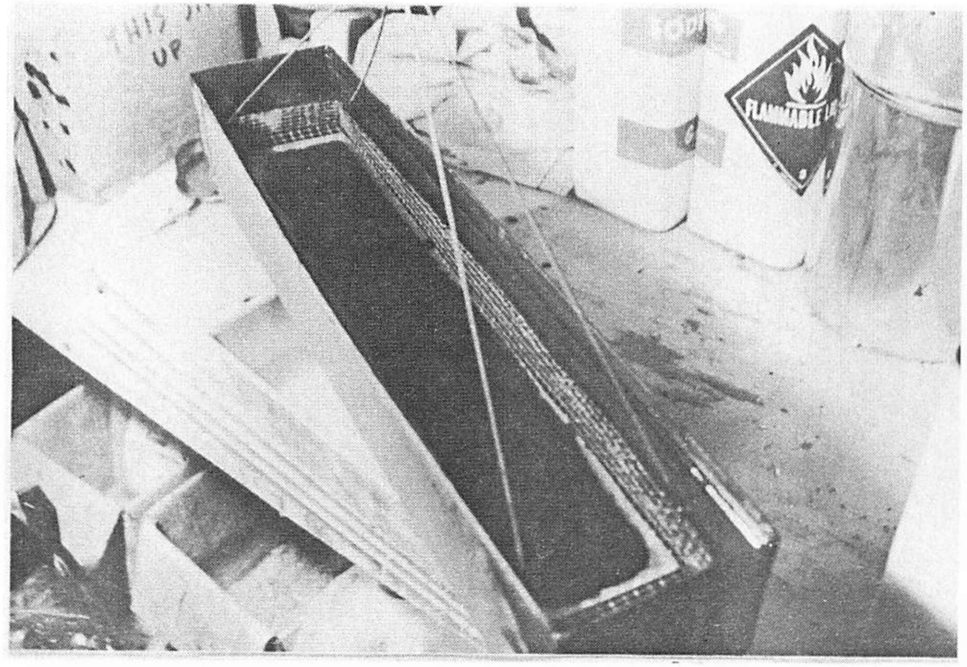


FIGURE 11 WEIGH IN WATER

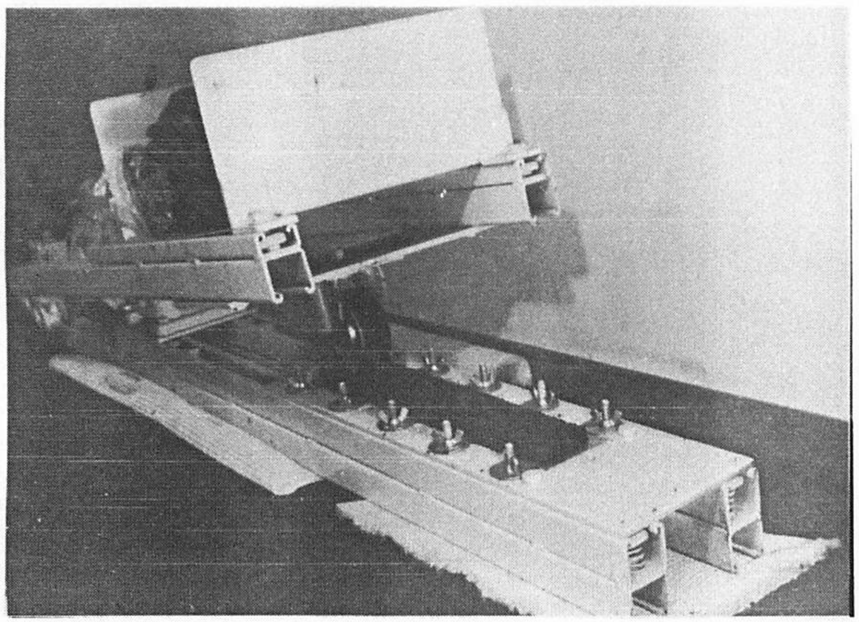


FIGURE 12 LWT COMPACTION

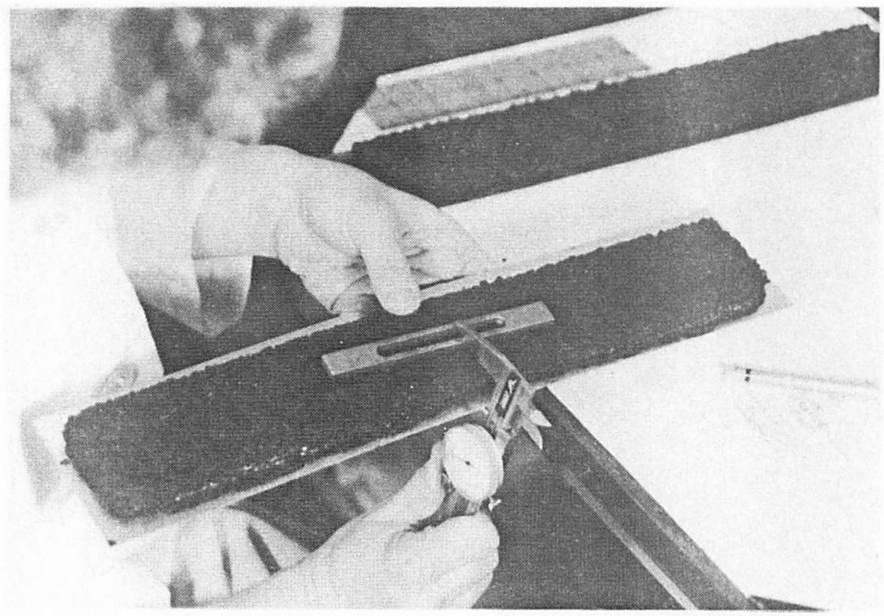


FIGURE 13 MEASURING SPECIMEN AND RECORDING DATA.

THE SPECIMEN WAS THEN REMOVED FROM THE LWT APPARATUS AND REMEASURED CENTRALLY FOR VERTICAL AND LATERAL DISPLACEMENTS. THE DATA WAS RECORDED, CALCULATED AND PLOTTED TO SHOW THE EFFECTS OF PERCENT BITUMEN AND ADDITIVES ON THE VERTICAL AND LATERAL DISPLACEMENT-MEASUREMENTS AND THE PERCENT COMPACTION.

ALL TESTS WERE CONDUCTED FOR CONVENIENCE AT ROOM TEMPERATURE OF ABOUT 22 C. THE RESULTS HERE WILL NOT SHOW THE EFFECTS OF VERY HIGH OR VERY LOW FIELD TEMPERATURES.

INITIAL WORK: RESULTS OF LAYER THICKNESS

SEVERAL TYPES OF CURVE SHAPES RELATED TO LAYER THICKNESS WERE DISCOVERED WHICH WE HAVE VERY TENTATIVELY CLASSIFIED AS:

CASE I. (FIGURE 14) NORMAL, COMMODITY GRADE SYSTEM WHERE THE TRACK DEPTH IS PROPORTIONAL TO THE LAYER THICKNESS AND A CONSTANT RATE OF COMPACTION SLOWS AT THE 12% EMULSION LEVEL. THE PERCENT COMPACTION CURVES MERGE AT A HIGH % EMULSION (16%).

CASE II. (FIGURE 15) A UNMODIFIED PERFORMANCE GRADE SYSTEM WHERE THE TRACK DEPTH IS PROPORTIONALY REDUCED AS LAYER THICKNESS INCREASES. THE CONSTANT RATES OF COMPACTION INCREASES AT 12% EMULSION. THE PERCENT COMPACTION CURVES MERGE AT A LOW % OF EMULSION (8%). PERCENT COMPACTION VARIES INVERSELY WITH LAYER THICKNESS.

CASE III. (FIGURE 16) A PERFORMANCE GRADE SYSTEM (SAME AS CASE II BUT WITHOUT CEMENT) WHERE THE TRACK DEPTH IS PROPORTIONAL TO THE LAYER THICKNESS BUT THE CURVE IS "U"-SHAPED AND TROUGHS OR PEAKS AT 12% EMULSION. THE PERCENT COMPACTION IS EQUAL AT ALL LAYER THICKNESSES AT AN OPTIMUM EMULSION PERCENTAGE OF 12%. (AN INVERSE MARSHALL STABILITY-TYPE CURVE?)

CASE IV. (FIGURE 17) A LATEX MODIFIED SYSTEM WHERE THERE IS A "U" SHAPED CURVE WHERE THE TRACK DEPTH IS PROPORTIONAL TO LAYER THICKNESS. THE PERCENT COMPACTION AT "OPTIMUM" IS PROPORTIONAL TO LAYER THICKNESS BUT THE PERCENT CURVES MERGE AT BOTH EXTREMES.

CASE V. (FIGURE 18) A DIFFERENT LATEX MODIFIED SYSTEM WHERE THERE IS A "U" SHAPED CURVE BUT AT THE OPTIMUM OF 12%, BOTH THE TRACK DEPTHS AND PERCENTAGE COMPACTION ARE ESSENTIALLY THE SAME (PLEASE ALLOW FOR EXPERIMENTAL ERROR).

OTHER TYPES OR CLASSES OF CURVES MAY EXIST, BUT THEIR DISCOVERY MUST AWAIT REFINEMENT AND VERIFICATION OF OUR METHODS AND INTERPRETATION OF THE PARTICULAR PHEOLOGY SEEN IN EACH OF THE CLASSES OF CURVE.

LOADED WHEEL TEST (LWT) TRACK DEPTH IN mm.
1000 CYCLES @ 125 LBS, 75F

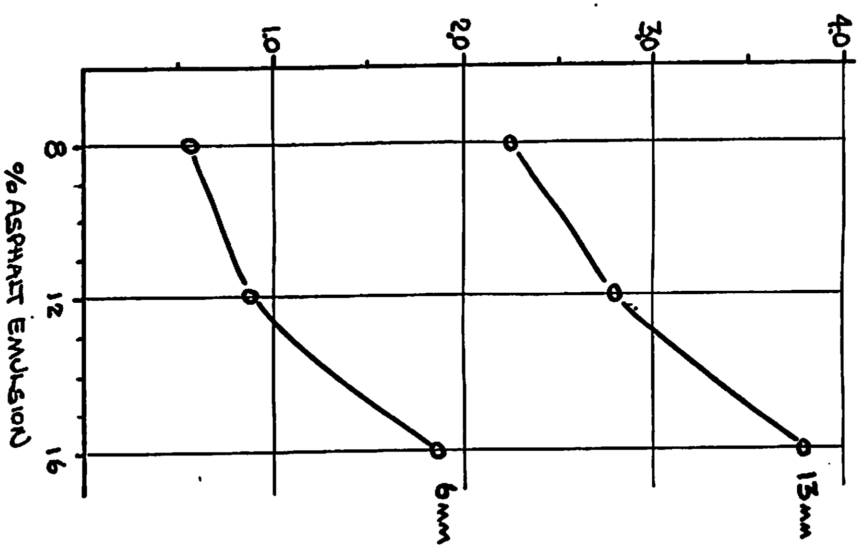


FIGURE 14a. CASE I - TRACK DEPTH PROPORTIONAL TO LAYER THICKNESS

LWT TRACK DEPTH PERCENT OF UNCOMPACTED THICKNESS
1000 CYCLES @ 125 PSI, 75F

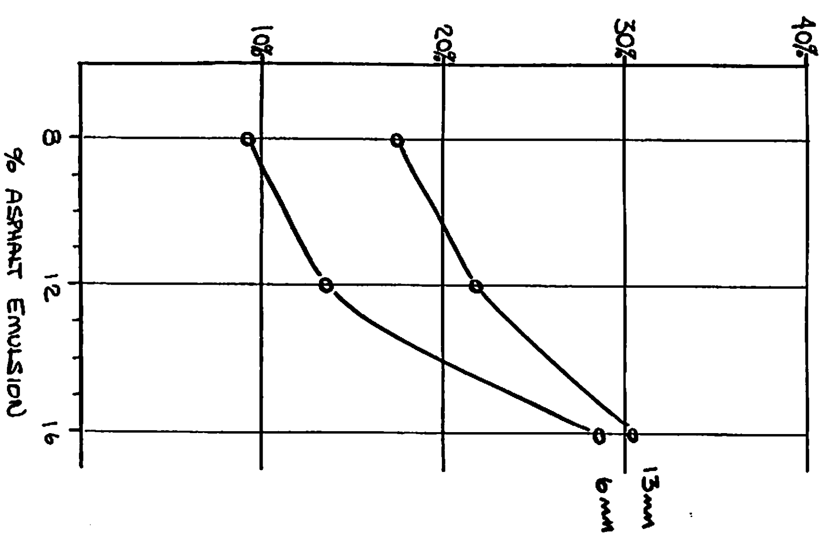


FIG. 14b. CASE I. PERCENT COMPACTION MERGES AT HIGH BITUMEN CONTENT

LOADED WHEEL TEST (LWT) TRACK DEPTH IN mm.
1000 CYCLES @ 125 LBS, 75F

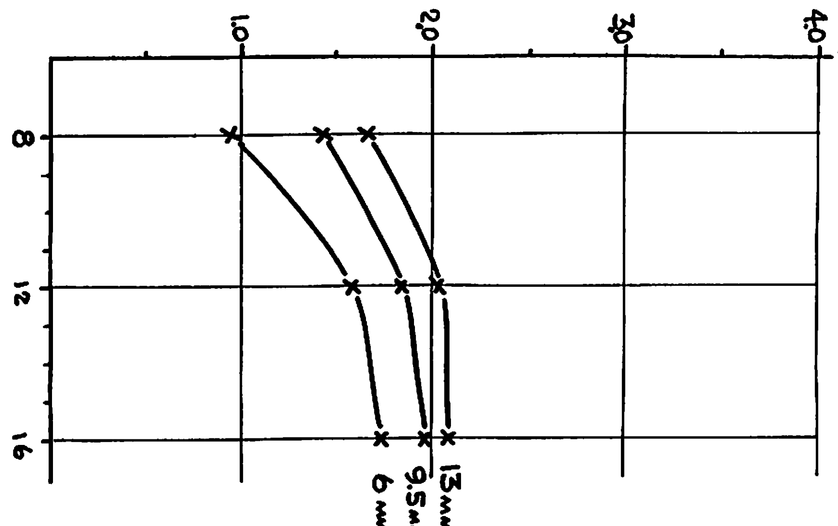


FIG. 15a CASE II - TRACK DEPTH REDUCED WITH LAYER THICKNESS

LWT TRACK DEPTH PERCENT OF UNCOMPACTED THICKNESS
1000 CYCLES @ 125 PSI, 75F

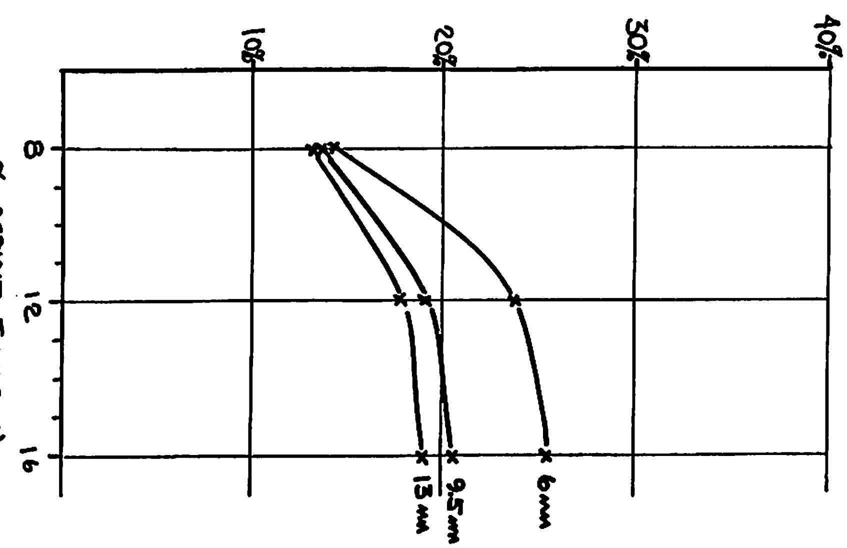


FIG. 15b CASE II - PERCENT COMPACTION MERGES AT LOW BITUMEN CONTENT. PERCENT COMPACTION VARIES INVERSELY WITH THICKNESS.

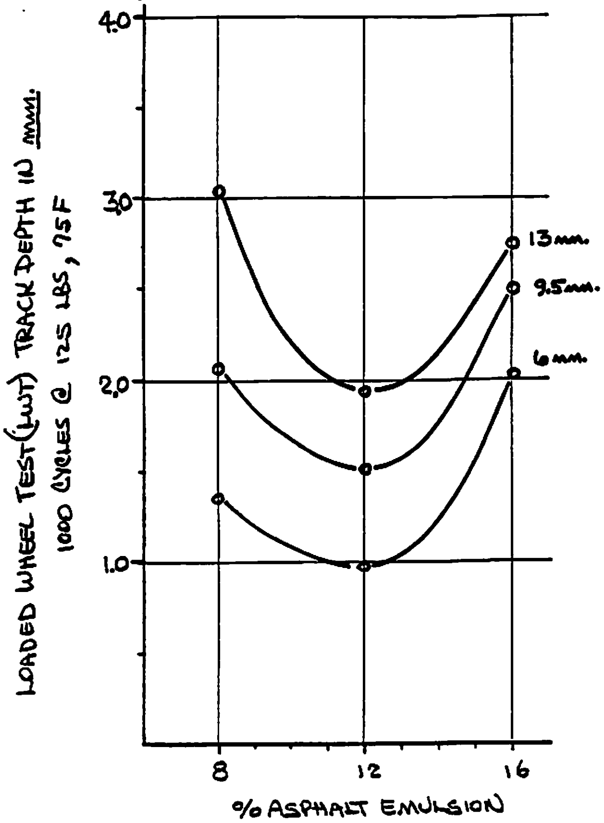


FIG. 16a CASE III - TRACK DEPTH PROPORTIONAL TO LAYER THICKNESS - OPTIMUM BITUMEN @ 12% AE

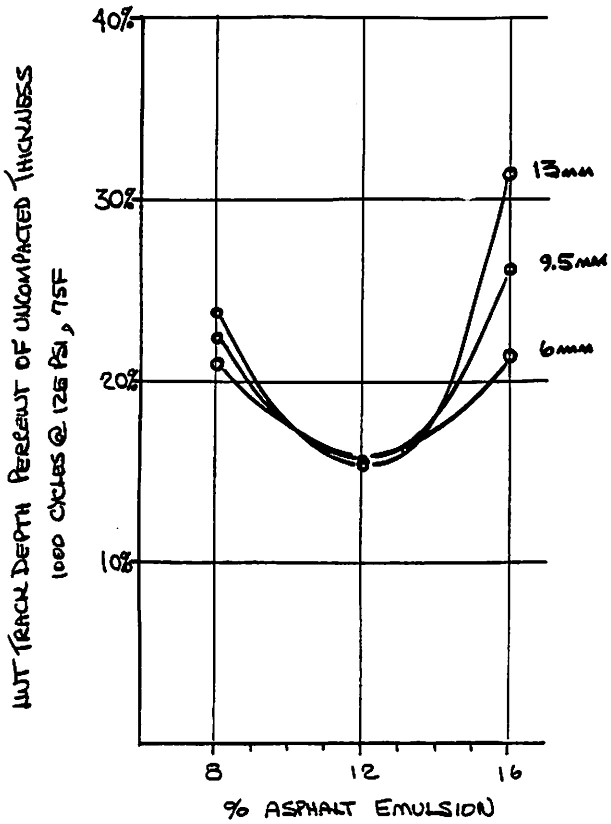


FIG. 16b CASE III PERCENT COMPACTION MERGES AT OPTIMUM

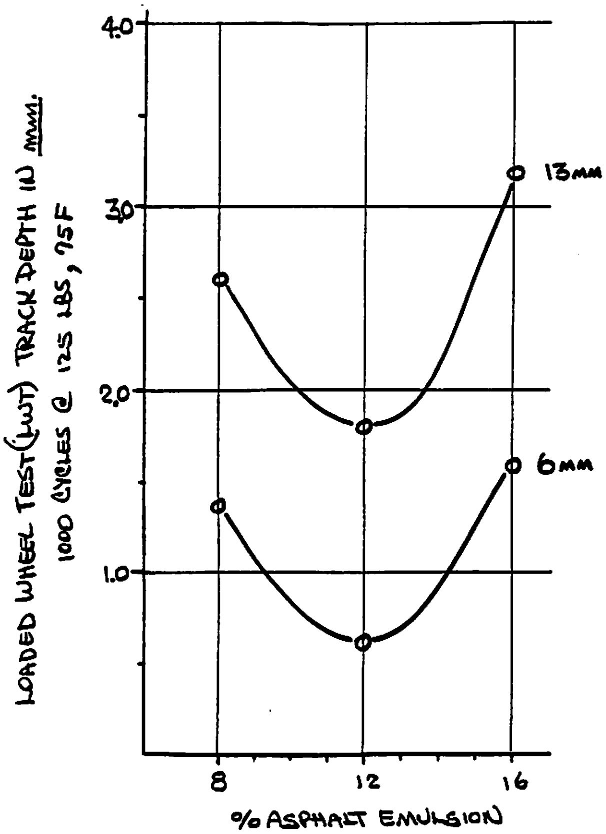


FIG. 17a. CASE IV TRACK DEPTH PROPORTIONAL TO LAYER THICKNESS. OPTIMUM BITUMEN INDICATED.

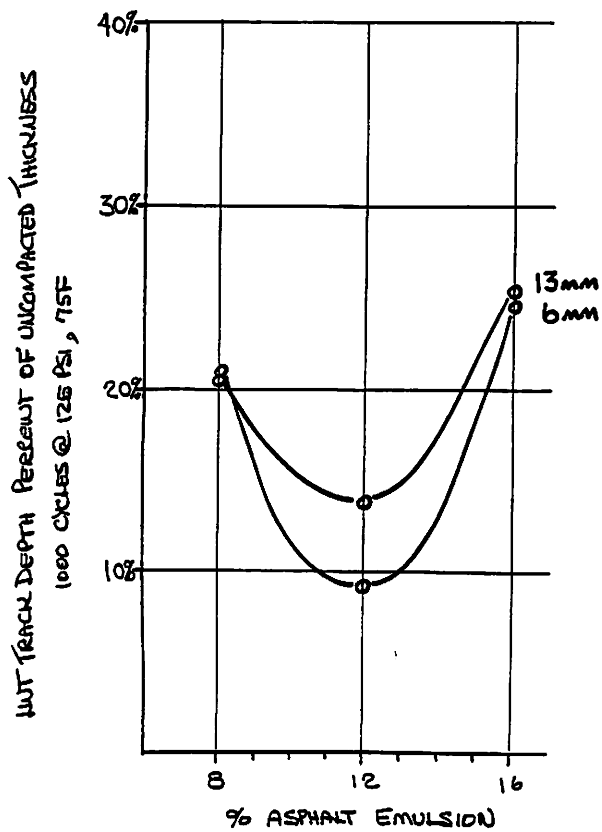


FIG 17b CASE IV - PERCENT COMPACTION MERGES AT EXTREMES. COMPACTION AT OPTIMUM, PROPORTIONAL TO THICKNESS

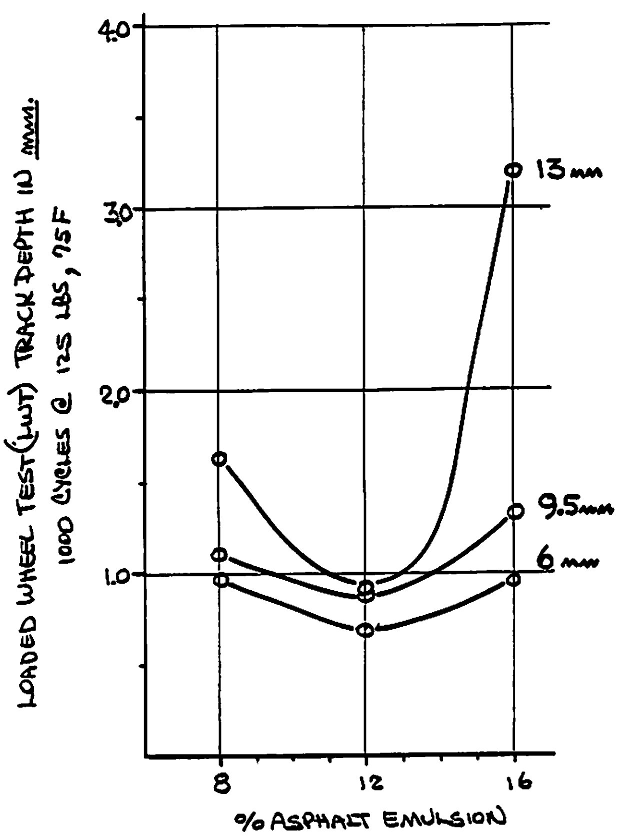


FIG. 18a CASE V - TRACK DEPTH PROPORTIONALLY LOWER AT THICKER LAYERS. MERGES AT OPTIMUM(?).

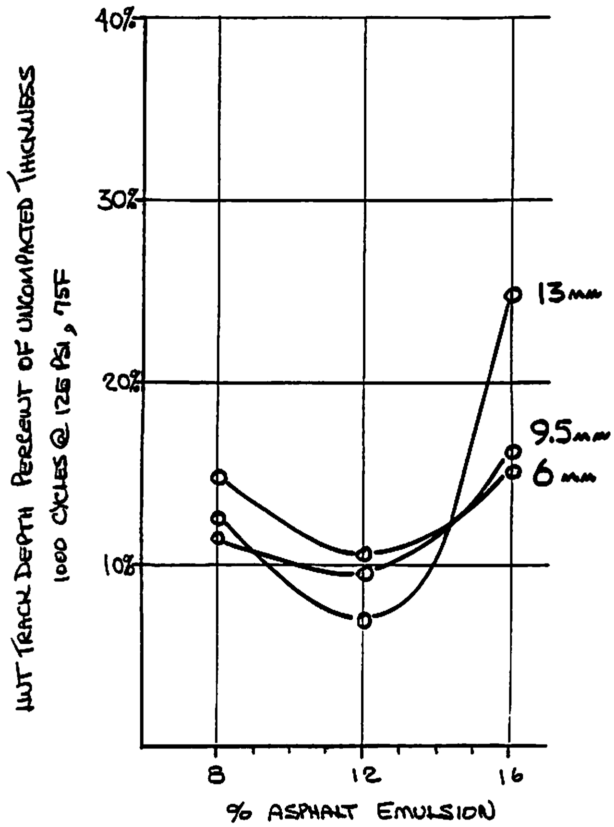


FIG. 18b. CASE V - PERCENT COMPACTION VARIES INVERSELY WITH LAYER THICKNESS AT OPTIMUM

CURRENT WORK: EFFECTS OF POLYMER TYPES, EMULSIFIERS TYPES, BITUMEN QUALITY, FILLER, AND ADDITIVE CONTENTS.

AFTER ASSIMILATING THE RESULTS OF OUR INITIAL STUDY, WE REDUCED THE NUMBER OF SPECIMENS BY USING ONLY 13 MM THICK ("3 STONES DEEP") SPECIMENS SINCE THE THICKER LAYERS WOULD MORE CLOSELY RELATE TO SOLVING THE PROBLEM OF THICK LAYER COMPACTION. WE NOTE ALSO THAT OPTIMUM EMULSION PERCENTAGES APPEAR IN THE PREVIOUS CURVES AT ABOUT THE 12% EMULSION LEVEL AND THAT THE LOWEST OR "BEST" RATES OF COMPACTION ARE AT ABOUT THE 10% OR LOWER DISPLACEMENT OR COMPACTION LEVEL AT THE OPTIMUM EMULSION CONTENT.

OUR METHODS WERE SLIGHTLY REFINED BY BETTER SAMPLE PREPARATION TO INCLUDE SLIGHTLY LONGER MIX TIMES TO ALLOW FOR MORE UNIFORM SAMPLES AND THE USE OF A "U"-SHAPED STRIKE OFF SCREED RATHER THAN THE STRAIGHT DOWEL PREVIOUSLY USED. WE ALSO IMPROVED OUR MEASURING METHODS TO INCLUDE 3-POINT AVERAGING AND BEGAN TO LOOK AT SPECIFIC GRAVITY, DENSITY AND VOID CONTENTS. ONLY PERCENT COMPACTION CURVES ARE SHOWN IN THIS SERIES.

IN OUR INITIAL EXPERIMENTS, NO MEASUREMENTS WERE MADE BEFORE COMPACTION ON THE ASSUMPTION THAT THE UNCOMPACTED EDGES WOULD NOT MOVE AND WOULD SERVE AS AN ADEQUATE REFERENCE FROM WHICH THE TRACK DEPTHS COULD BE MEASURED. THIS PROVED TO BE A FALSE ASSUMPTION IN SOME CASES SO THAT WE NOW REPORT THE DIFFERENCE BETWEEN THE BEFORE AND AFTER MEASUREMENTS OF THE UNCOMPACTED EDGE AS THE "DRAG DOWN" OR "PULL DOWN".

THE METHOD OF MEASUREMENT OF THE LATERAL, UNCONFINED DISPLACEMENT, WHILE THE TRENDS ARE CLEAR, ARE NOT YET ACCURATE ENOUGH TO REPORT ALL THE RESULTS HERE WITH CONFIDENCE.

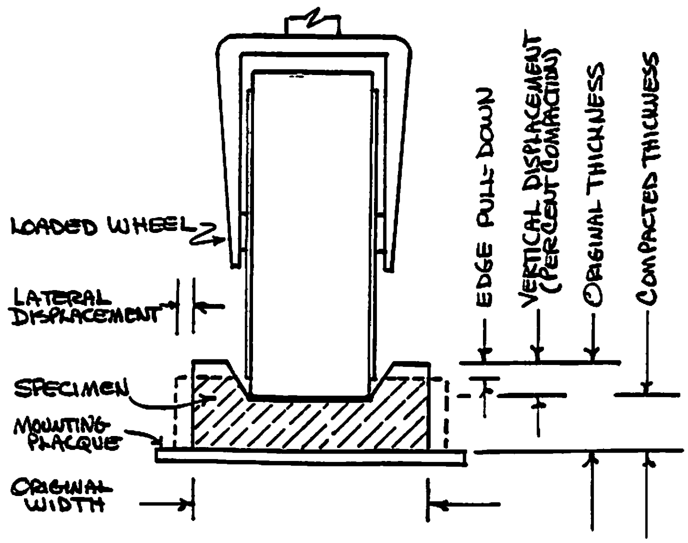
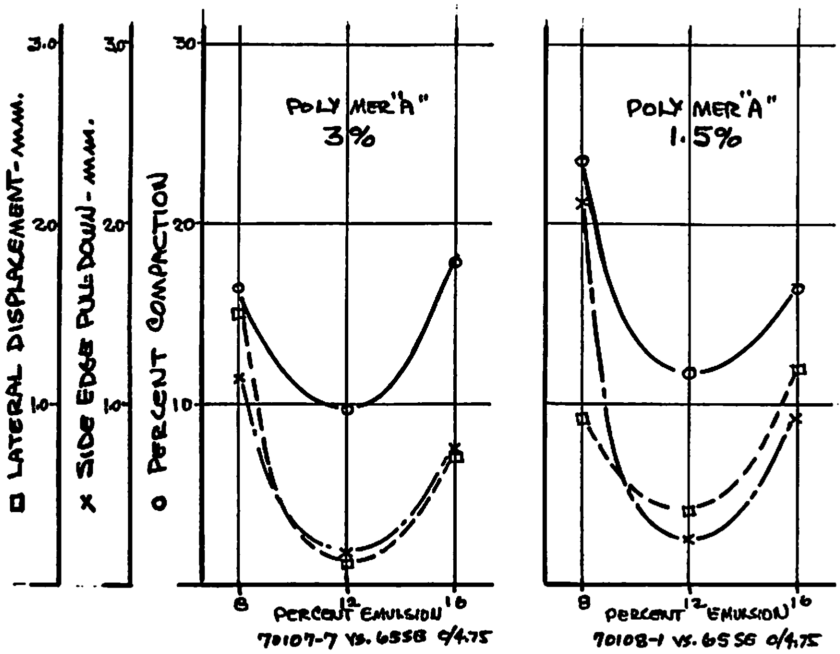


FIGURE 19. MEASURMENTS OF LOADED WHEEL SPECIMENS



FIGURES 19&20 DIMENSIONAL CHANGES AFTER 1000 CYCLES LOAD WHEEL TEST AT 57kg & 22°C

FIGURES 19 & 2Ø SHOW (1) PERCENT TRACK DEPTH OR COMPACTION FROM THE ORIGINAL THICKNESS, (2) EDGE PULL-DOWN AND (3) LATERAL DISPLACEMENT. SPECIMENS IN FIGURE 19 AND 2Ø WERE MODIFIED WITH POLYMER "A" AT 3.Ø AND 1.5 PERCENT RESPECTIVELY.

EFFECTS OF VARIOUS POLYMERS ON PERCENT COMPACTION:

VIRTUALLY ALL OUR CURVES SHOW A PEAK RESISTANCE TO COMPACTION OR MINIMUM RUTTING AT ABOUT 12% EMULSION CONTENT. THE NEAR 1Ø% COMPACTION LEVEL APPEARS TO BE A GOOD TARGET VALUE THROUGHOUT OUR EXPERIMENTS. THE EDGE PULL-DOWN AND LATERAL DISPLACEMENTS FOLLOW THE SAME PATTERN AS THE VERTICAL DISPLACEMENTS OR TRACKING PERCENTAGE.

IT IS NOTED THAT LESS POLYMER GENERALLY YIELDS LESS STABILITY AND MORE DISPLACEMENT WHILE MORE POLYMER YIELDS MORE STABILITY AND LESS DISPLACEMENT.

FIGURES 21, 22, 23, 24, 25, 26 SHOW THE PERCENT COMPACTION CURVES FOR THE 3% AND 1.5% LEVELS OF POLYMERS A, B, C, D, E, & F. POLYMER "F" ALSO SHOWS THE EFFECTS OF . ALL BITUMEN TYPES, EMULSIFIER TYPES, AND AGGREGATE WERE ESSENTIALLY THE SAME AND THEY ARE ALL IN THE PERFORMANCE CATEGORY. FIGURE 27 USED THE IDENTICAL MATERIALS AND PROCEDURES BUT WITH NO POLYMER PRESENT....A "PLAIN" SPECIMEN FOR COMPARISON.

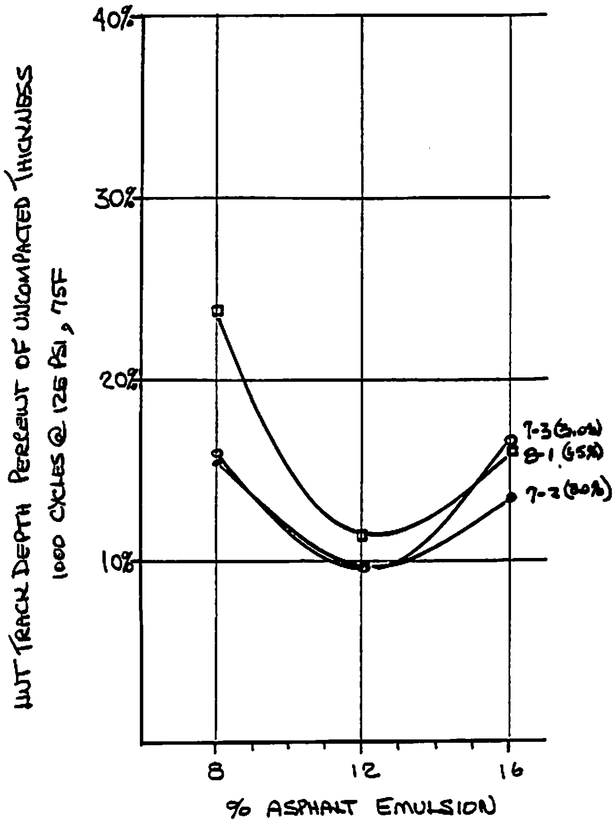


FIGURE 21. POLYMER "A"
70107-2,-3 @3%; 70108-1 @1.5%
VS. SAND TYPE 2

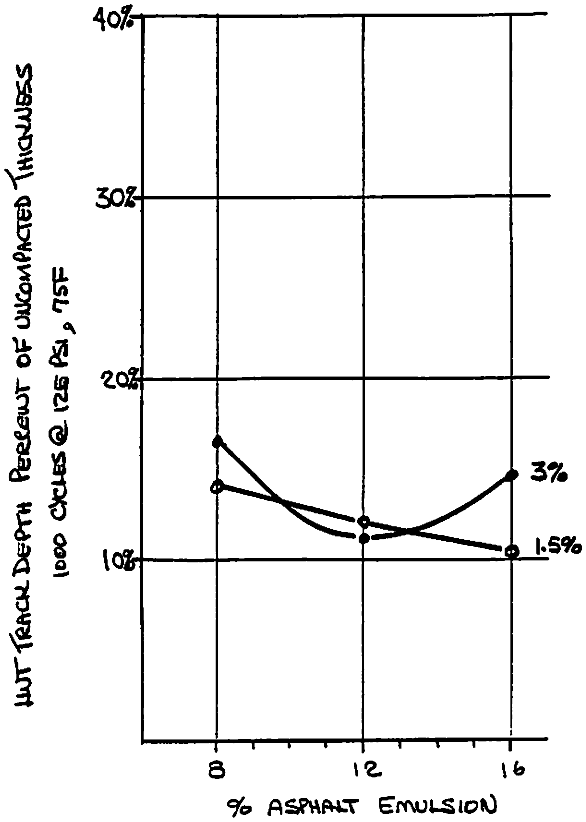


FIGURE 22. POLYMER "B"
70108-3 @3%; 70108-4 @1.5%
VS. SAND 2 AGG.

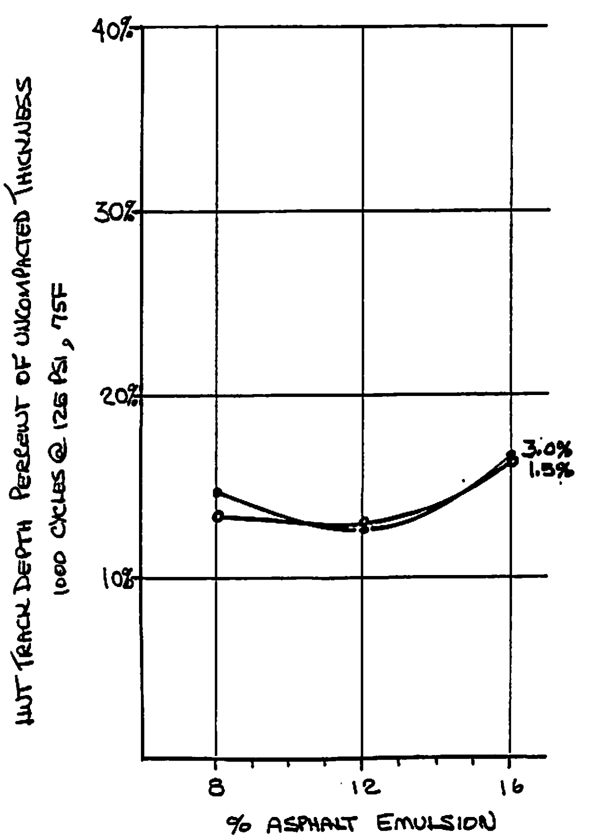


FIGURE 23. POLYMER "C"
70108-5 @3%; 70108-6 @1.5%
VS. SAND 2 AGG.

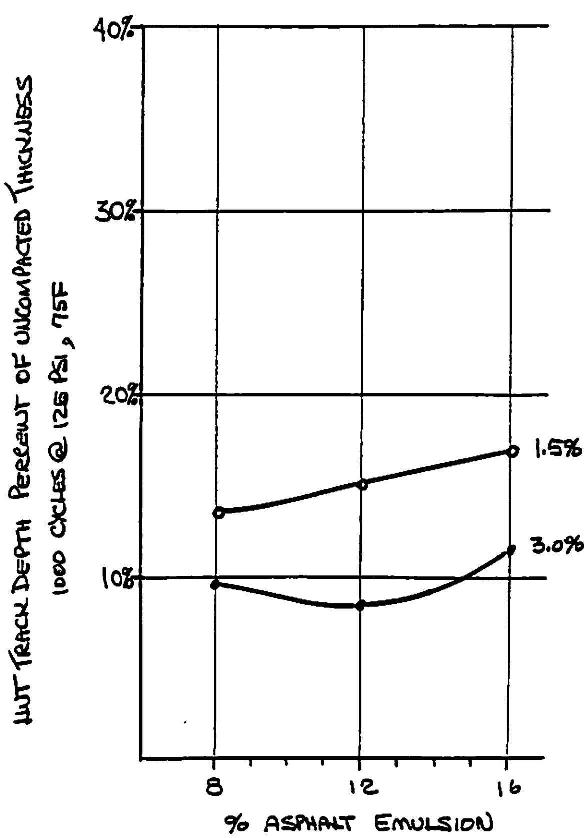


FIGURE 24. POLYMER "D"
70108-7 @ 3%; 70108-8 @ 1.5%
VS. SAND 2 AGG

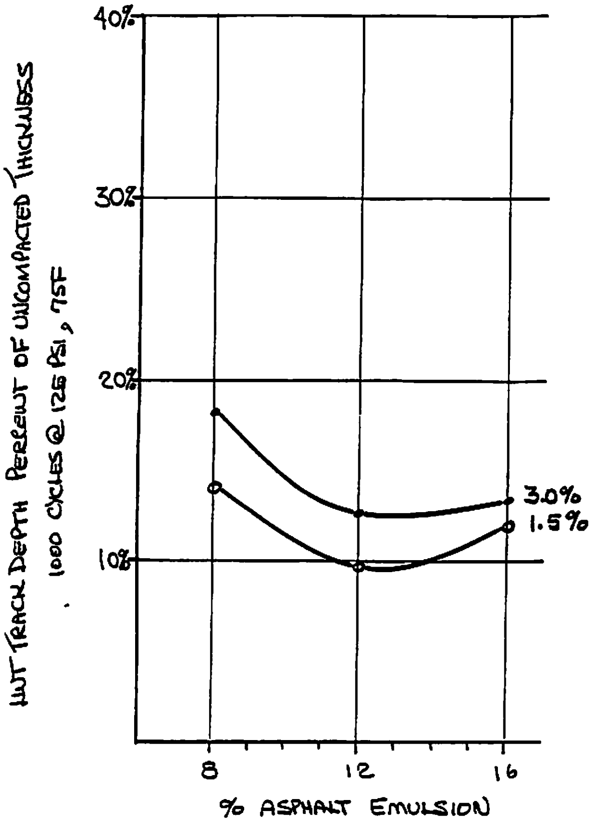


FIGURE 25. POLYMER "E"
70126-1@3%; 70126-2@1.5%
VS. SAND 2 AGG.

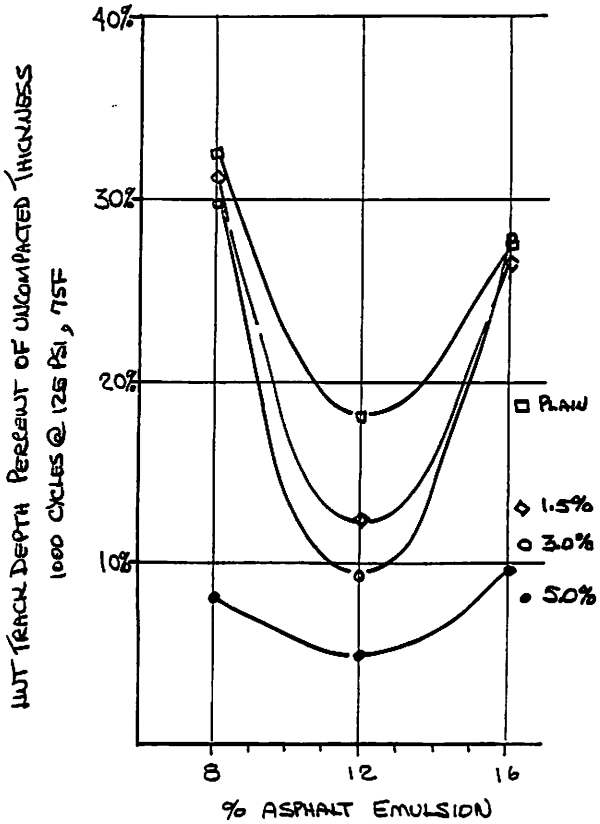


FIGURE 26. POLYMER "F"
61201-1 @5%; 61201-2 @3%
70206-3 @1.5%; 61201-3-PLAIN
VS. SAND 2 AGG.+KA ADD.

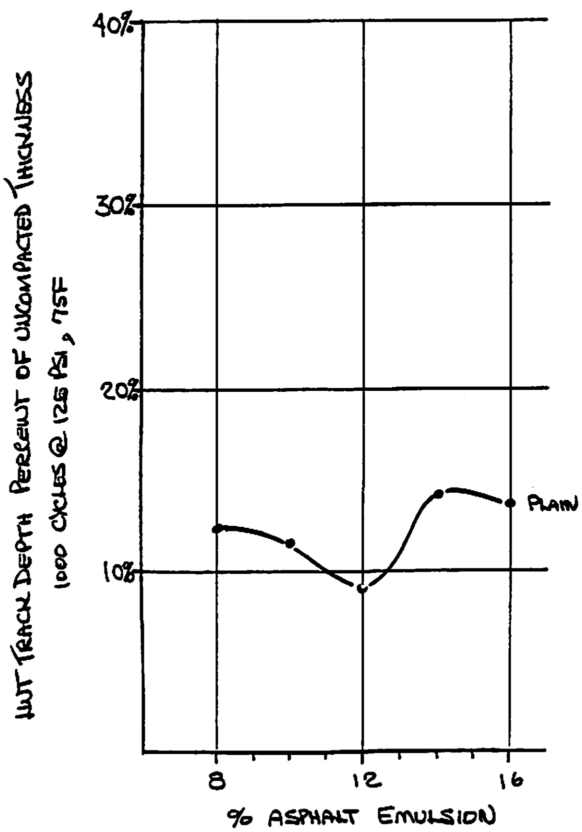


FIGURE 27. PERFORMANCE BITUMEN-PLAIN
70116-1 PLAIN (EMULSIFIER "P")
VS. SAND 2 AGG.

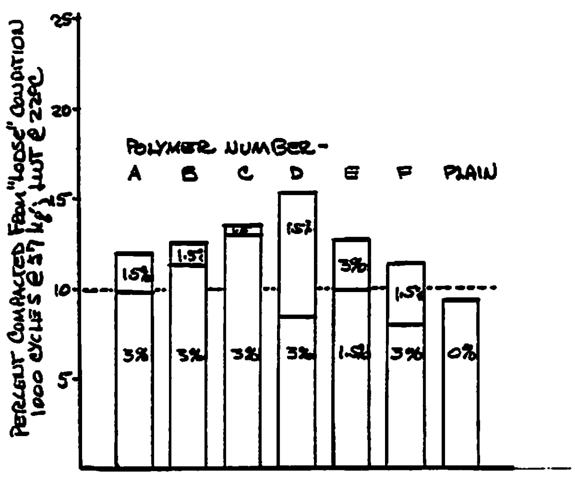


FIGURE 27a. EFFECT OF POLYMER TYPE AND PERCENT ON WWT COMPACTION @22C

FIGURE 27A SUMMARY GRAPHS FOR FIGURES 21-27

WE NOTE: IN FIGURE 25, POLYMER "E" WHERE LESS POLYMER CONTENT PRODUCES MORE STABILTIY UNDER THE TEST CONDITIONS THAN DOES MORE POLYMER.

WE ESPECIALLY NOTE THAT IN FIGURE 27, THE PLAIN, UNMODIFIED SYSTEM, USING THE SAME HIGH QUALITY MATERIALS PERFORMED AS WELL OR BETTER THAN MOST OF THE POLYMER MODIFIED MATERIALS!

OTHER FACTORS WHICH AFFECT COMPACTION RATES:

EFFECT OF FILLER CONTENT

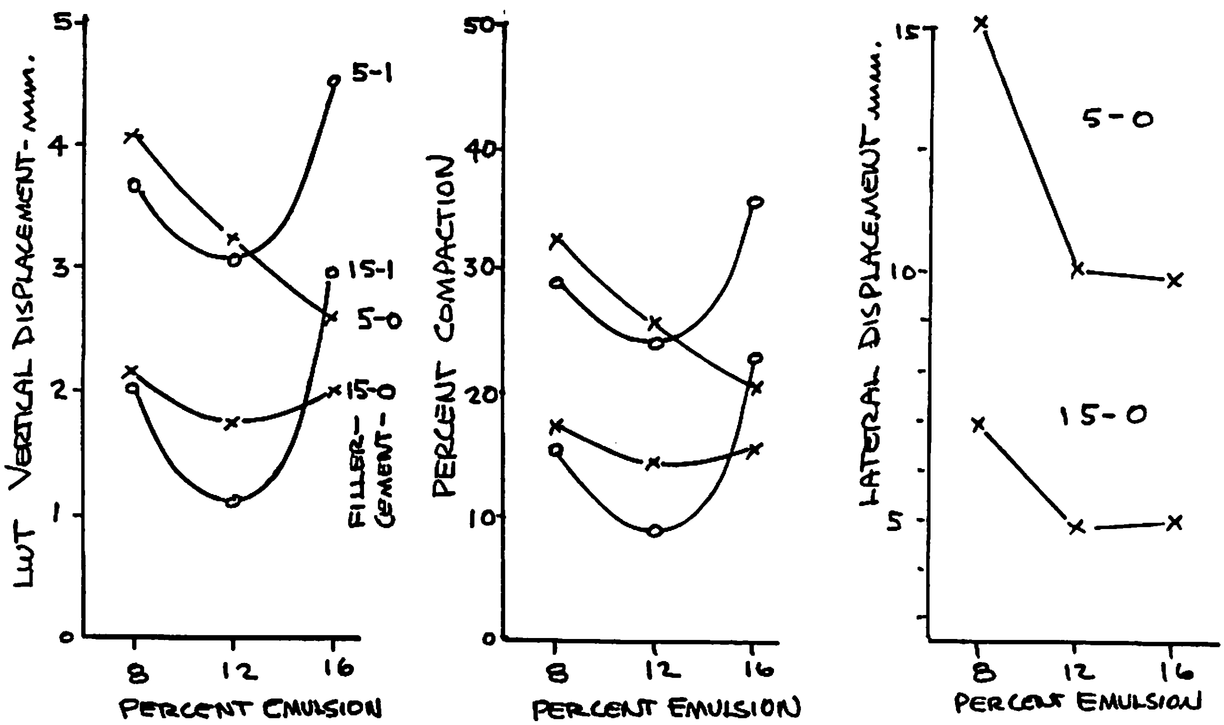


FIGURE 28. EFFECT OF FILLER, CEMENT & EMULSION CONTENT ON LOADED WHEEL COMPACTION 1000 CYCLES @ 57 KG. - 13MM SPECIMEN

FIGURE 28 SHOWS A RATHER LARGE DIFFERENCE IN THE RATE OF COMPACTION OR VERTICAL DISPLACEMENT AS WELL AS LATERAL DISPLACEMENT DEPENDING UPON THE PERCENT FILLER AND WHETHER OR NOT CEMENT IS PRESENT. IN THIS CASE, A PLAIN UNMODIFIED SYSTEM CEMENT AT THE "OPTIMUM" 12% EMULSION CONTENT STIFFENS THE MIX AT 15% FILLER. THE REVERSE MAY BE TRUE IN OTHER SYSTEMS.

<u>EFFECT OF MIX ADDITIVES</u>

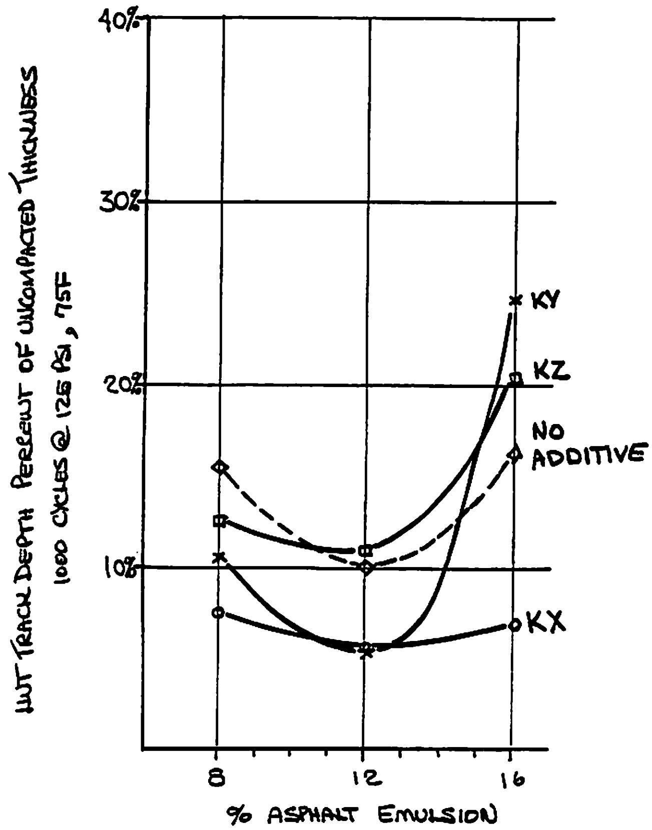


FIGURE 29. EFFECT OF MIX ADDITIVES
POLYMER "A"-3%
VS. SAND 2 AGG.

FIGURE 29 COMPARES THE EFFECT ON PERCENT COMPACTION OF 3 DIFFERENT ADDITIVES, "KX", "KY", & "KZ", USED WITH A POLYMER "A" MODIFIED MIX SYSTEM AND THE SAME SYSTEM WITH NO ADDITIVES. NOTE THAT "KZ" SLIGHTLY INCREASES THE COMPACTION ABOVE THE PLAIN CONTROL SYSTEM. KX & KY BOTH REDUCES THE COMPACTION RATE AT 12% EMULSION BY 50%!

THE SAUCER-SHAPED CURVE WHEN USING "KX" INDICATES A RATHER UNIFORM OR FLAT STABILITY CURVE OVER A WIDE RANGE OF BITUMEN CONTENTS AND WOULD PROBABLY REQUIRE LESS PRECISION IN FIELD PROPORTIONING FOR OPTIMUM RESULTS.

ADDITIVES KY AND KZ PRODUCE BOWL OR CUP-SHAPED CURVES.

EFFECT OF BITUMEN TYPE & EMULSIFIER TYPE

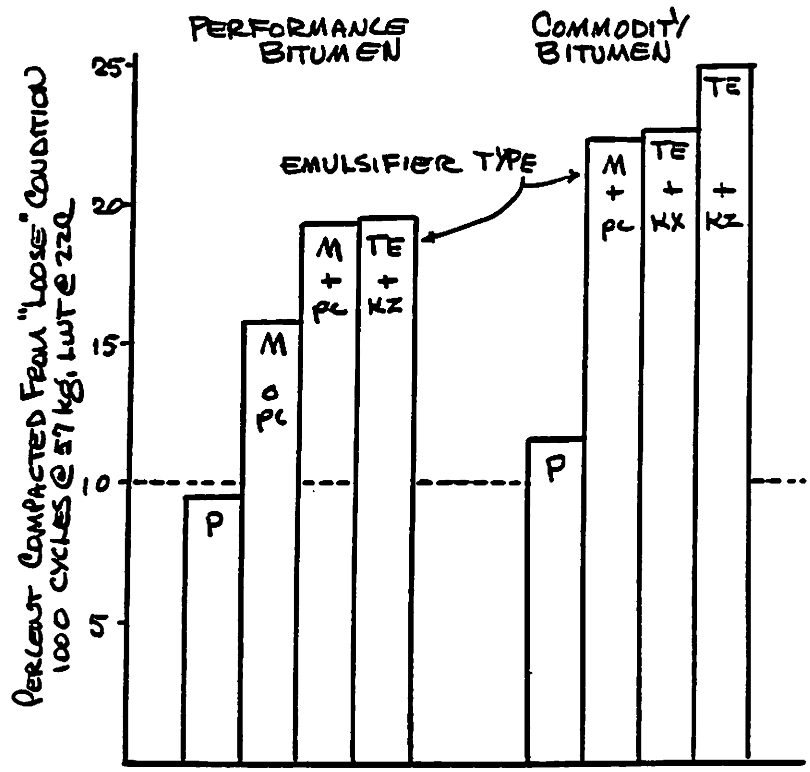


FIGURE 30. EFFECT OF BITUMEN TYPE AND EMULSIFIER TYPE ON LWT COMPACTION AT 22C 12% UNMODIFIED EMULSION

FIGURE 30 SHOWS TWO QUALITIES OF BITUMEN; "PERFORMANCE GRADE AND COMMODITY GRADE".

THERE IS ABOUT 20-25% GREATER RESISTANCE TO COMPACTION WHEN THE PERFORMANCE GRADE BITUMEN IS USED.

ALSO SHOWN IN THE GRAPH IS THE REMARKABLE DIFFERENCE THE EMULSIFIER TYPE MAKES UPON RUTTING RESISTANCE. EMULSIFIER "P" IN THESE SYSTEMS PERFORMS 50 TO 60% BETTER THAN THE "M" AND "TE" EMULSIFIERS.

RELATIONSHIP TO THE BRITISH WHEEL TRACKING TEST

CHOYCE, LAMMIMAN AND TAYLOR IN THEIR 1984 PAPER "RESISTANCE TO DEFORMATION OF HOT ROLLED ASPHALT" HAVE MADE THEIR CORRELATIONS OF MARSHALL STABILITY AND FLOW AT 60C AND THE BRITISH WHEEL TRACKING TEST AT 45C. CONSEQUENTLY, RATES OF RUTTING (AND HENCE MARSHALL NUMBER), HAVE BEEN RELATED TO MIX STABILITY, RUTTING RESISTANCE, AND TRAFFIC COUNT DESIGN.

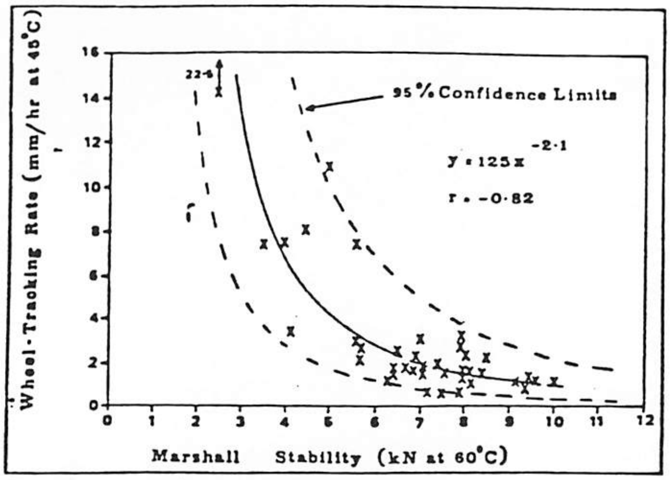


Fig 2 Marshall stability vs wheel-tracking rate.

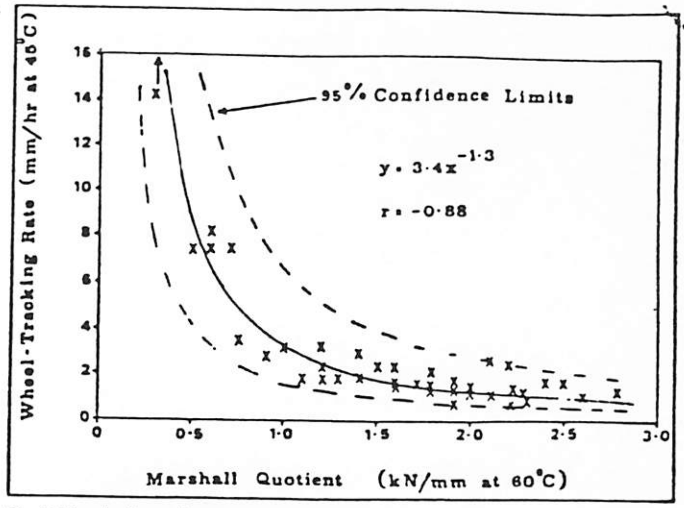
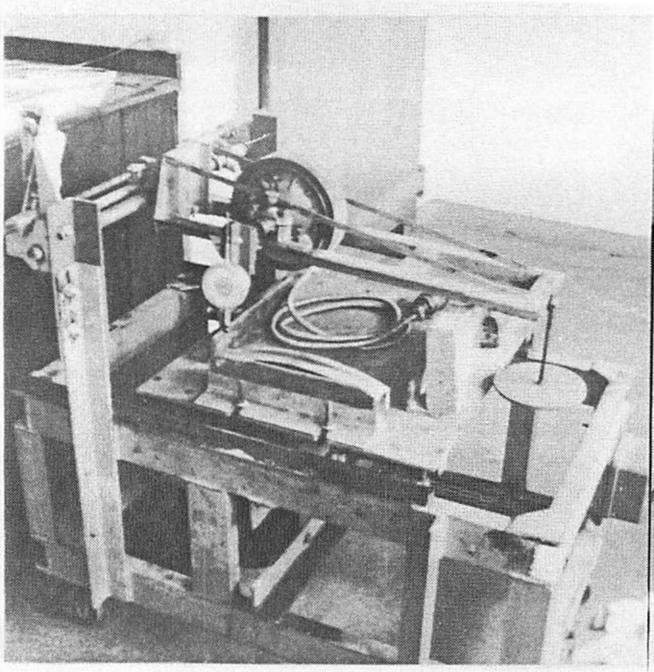
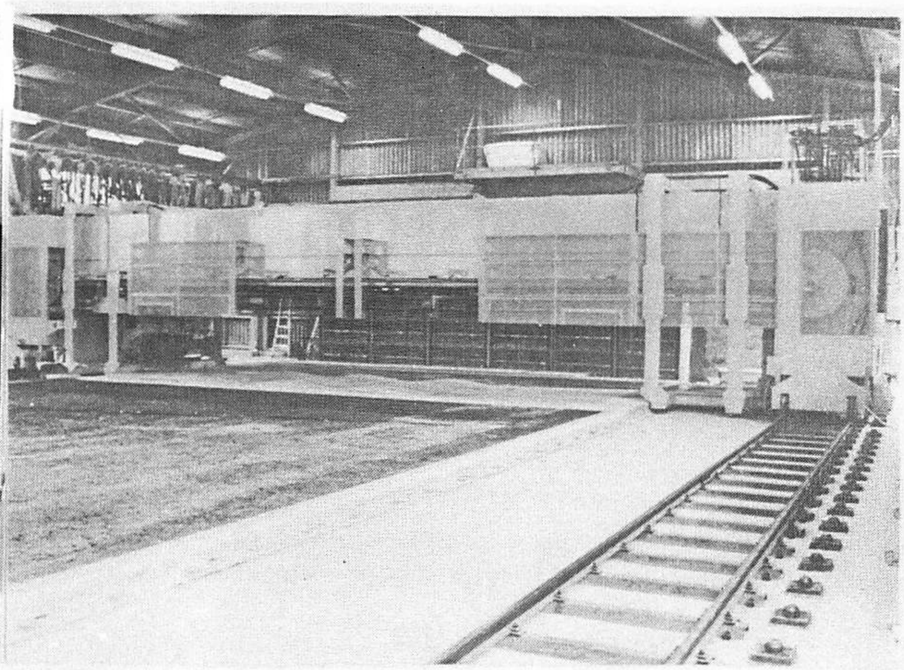


Fig 3 Marshall quotient vs wheel-tracking rate.

FIGURES 31 & 32. WHEEL TRACKING RATE VS. MARSHALL FLOW & STABILITY

BY USE OF THE BRITISH CORRELATION CURVES, WE HOPE TO RELATE OUR LWT, COMPACTIVE CURVES TO THE BRITISH AND TRRL DATA AND TO EXTRAPOLATE MARSHALL-TYPE NUMBERS OUR LWT DATA.





FIGURES 33, 34, 35, AND 36 ARE PHOTOS OF THE TRRL DEVICES. THEIR MOST RECENT TESTING MACHINING DEVELOPMENT SHOWN IN FIGURE 33 DEMONSTRATES THEIR SERIOUSNESS...14 YEARS AND £ 2,500,000!

SUMMARY

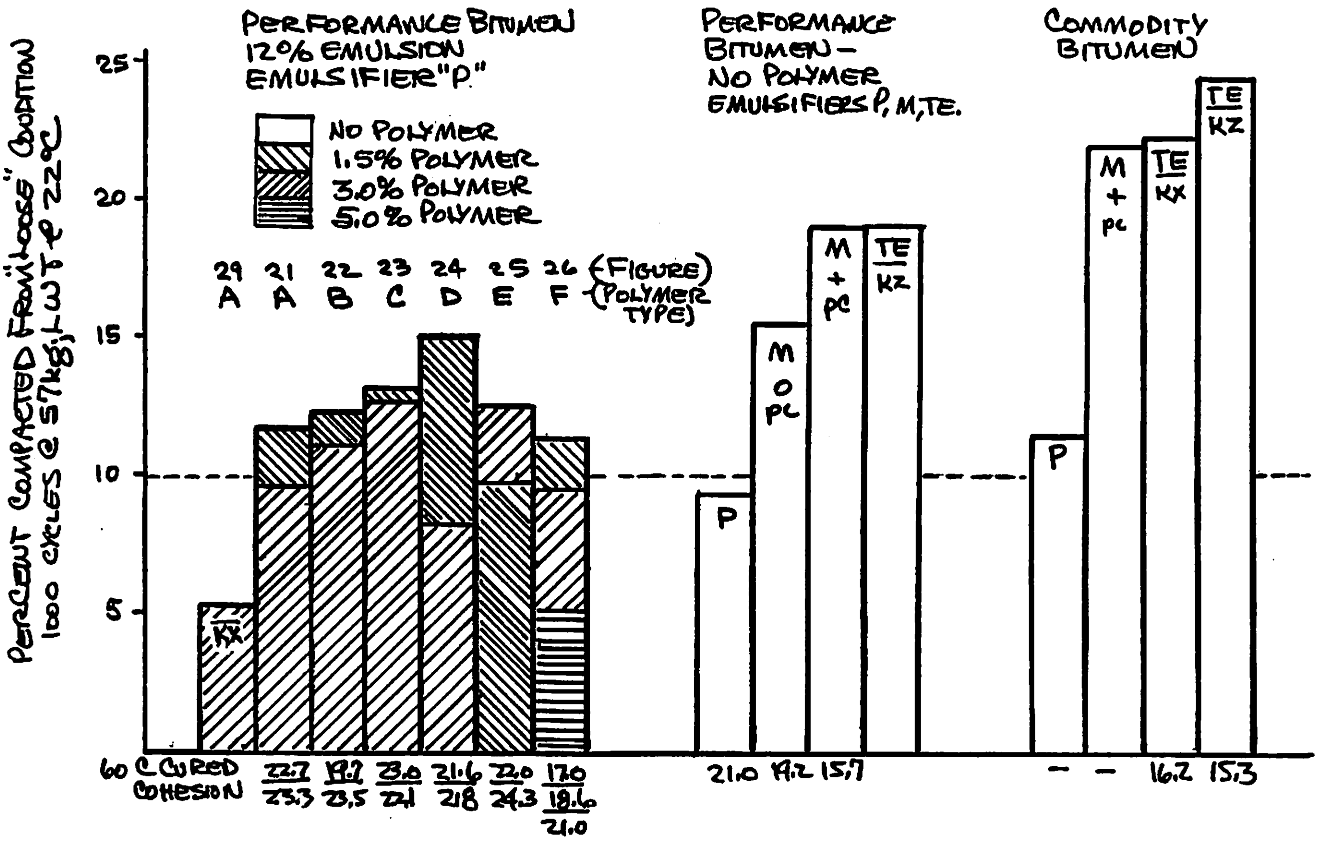


FIGURE 37. SUMMARY: EFFECT OF POLYMER TYPE, BITUMEN TYPE EMULSIFIER TYPE AND MIX ADDITIVES AT 12% EMULSION CONTENT ON 22°C LOADED WHEEL COMPACTION

FIGURE 37 SUMMARY OF FACTORS AFFECTING COMPACTION RATES.

WE HAVE PRESENTED OUR INITIAL APPROACH TO ENABLE PREDICTION FROM LABORATORY DATA OF THE AMOUNT OF COMPACTION UNDER TRAFFIC THAT WILL OCCUR IN MULTILAYERED COLD MIXES. A METHOD OF COMPACTION IS DESCRIBED WHICH CLOSELY DUPLICATES ACTUAL ROLLING COMPACTION AT REALISTIC COLD MIX TEMPERATURE CONDITIONS RATHER THAN THE HIGH TEMPERATURE IMPACT COMPACTION OF THE MARSHALL TEST. EFFECTS OF LAYER THICKNESS, BITUMEN TYPE, EMULSIFIER TYPE, POLYMER TYPE, FILLER CONTENT, CEMENT PRESENCE AND MIX ADDITIVE HAVE BEEN REPORTED. THESE EFFECTS HAVE BEEN CLASSIFIED INTO 5 CATEGORIES OR CASES OF RHEOLOGICAL RESPONSE TO THESE VARIABLES AS WELL AS COMPARISONS MADE WITH EACH MIX VARIABLE.

EFFECTS OF AGGREGATE GRADATION (COARSENESS) HIGH AND LOW TEMPERATURE, THICKER LAYERS, AGGREGATE TYPES AND THEIR EFFECTS ON MACROTEXTURE AND COMPACTION RATES REMAIN TO BE STUDIED.

EVENTUALLY, WE HOPE TO RELATE HMAC MARSHALL STABILITIES AND FLOW TO CMAC LWT DATA BY USING DATA FROM THE BRITISH WHEEL TRACKING MACHINE, MARSHALL TESTS AND ISSA LOADED WHEEL TEST. THE USE OF SOPHISTICATED DEVICES SUCH AS LASER, SONIC AND LVTD'S IN CONJUCTION WITH CONTROLLED TEMPERATURE ENVIRONMENTAL CHAMBERS IS PROPOSED. FIELD CORRELATION SHOULD FOLLOW.

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BENEDICT, C. ROBERT	"NEW TRENDS IN SLURRY SEAL DESIGN METHODS" PRES. ISSA CONVENTION ORLANDO, FEBRUARY 3-7, 1985.

ACKNOWLEDGEMENTS

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ADDENDA

THE FOLLOWING TABLE, FIGURE 38, (SEE FIG. 27 COMPACTION CURVE), SHOWS OUR FIRST ATTEMPT TO RELATE OUR LWT DATA TO A DESIGN FORMAT SIMILAR TO MARSHALL AND HVEEM WORK-UPS. THE SCATTER THE READER WILL OBSERVE IS THE REASON WE PRESENT THIS DATA WITH MANY RESERVATIONS. STILL, THE TYPICAL MARSHALL TRENDS ARE EVIDENT. VARIABLES CAUSING SOME OF THE SCATTER ARE POSSIBLY:

SPECIMEN PREPARATION AND FINISHING TECHNIQUE, TEMPERATURE VARIATIONS, VARIABLE WATER SATURATION, SEGREGATION OF DRY AGGREGATE SUPPLY, ERRORS IN MEASUREMENT.

EMULSION ADDED AC, % OF TOTAL (DRY)	8%	10%	12%	14%	16%
UNCOMPACTED HEIGHT, MM	13.9	14.2	13.3	13.3	14.0
NET SPECIMEN WEIGHT:	457.4	464.5	449.0	453.8	454.9
A. VOLUME OF AGGREGATE	68.0	70.0	66.2	72.8	70.1
C. VOLUME OF BITUMEN	8.7	11.3	12.4	16.1	17.8
B. VOIDS IN MINERAL AGG (VMA)	32.0	30.0	35.4	27.7	29.9
D. VOIDS IN TOTAL MIX (VTM)	23.4	18.8	21.4	11.3	12.1
E. VOIDS FILLED W/BITUMEN	27.1	37.5	35.1	58.1	59.5
SG SPECIFIC GRAVITY (PROJECTED)	1.89	1.97	1.84	2.08	2.04
DENSITY LB/CF	118.2	123.1	114.9	129.8	127.4
DENSITY KG/CM	1897.6	1976.3	1844.7	2083.9	2045.3
% COMPACTION FROM ORIGINAL	12.4	11.3	9.3	14.2	13.8
PULL DOWN - MM	.26	.58	.05	.46	.90
LATERAL DISPLACEMENT MM	.74	.71	.58	.23	.94

FIGURE 38. VOIDS, DENSITY, PERCENT COMPACTION.