SLURRY SEAL DESIGNS FOR:
HIGHWAY AND RESIDENTIAL USE, USING ISSA TYPE 2
VULCAN BLAST FURNACE SLAG AND VULCAN CQS1h EMULSIFIED ASPHALT

PREPARED FOR: VULCAN MATERIALS
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DATE: JUNE 20, 1990 (FINAL)

CONTENTS:

MATERIALS

AGGREGATE 2-buckets of type 2 aggregate were received June 7 and identified as VULCAN CHATTANOOGA BLAST FURNACE SLAG (Wheland Foundry). Our Lab No. 272.

GRADATION:

Sieve#	Surface Area Factor	PERCENT PASSING Dry	Wet	SA	SPECS: ISSA	TENN DOT
3/8"	.02	100.0	100.0	2.00	100	
1/4"	-	100.0	100.0	-	-	
# 4	.02	98.2	98.4	1.97	90-100	
8	.04	82.9	83.1	3.32	65-90	
16	.08	63.3	63.6	5.09	45-70	
30	.14	44.6	45.2	6.33	30-50	
50	.30	27.9	29.0	8.70	18-30	20-38
100	.60	16.9	18.6	11.16	10-21	12-28
200	1.60	9.7	12.2	19.52	5-15	8-16
325	-	3.4	6.6	-	-	-

Simple Surface Area		58.1 SF/lb
Corrected Surface Area (2.65/2.79)		55.2
Sand Equivalent	72.5	
Methylene Blue mg/g 0/#325	3.0	
Blue Factor	19.8	
pH 10:1	8.66	
Specific Gravity (dry)	2.79	
Specific Gravity SSD	2.70(c2.77)	
Absorbtion %	2.56	
Unit Weight, loose lbs/CF	95.1	
Unit Weight, compact lbs/CF	114.1	
Voids, compacted %	34.5	
Voids, loose %	45.4	
Total Liquids Capacity,	-	
Loose, % added:	29.8	
Reaction w/HCl	sl. reaction	

MOISTURE CONTENT BULKING EFFECT, DRY BASIS:

%Moisture	DRY WEIGHT Compacted	Loose
0	114.1	95.1
2.26	109.9	79.3
3.49	105.9	69.9
5.54	104.5	70.4

ASPHALT EMULSION

Received from client June 4 - 2, 1-gallon bottles identified as CQS1h Vulcan Materials, Chattanooga, TN, 5/30/90

Our Lab No. 00608-1

Test	Found	Specs
Sieve, %	Trace	0.1%
Residue, %	63.4	57.0%
pH	2.01	-

CHEMICAL FILLERS

Type I Portland Cement, current production from Southwestern Portland Cement Co., Fairborn, Ohio.

Hydrated Lime from National Lime and Stone Co., Findlay, Ohio
(Dolomitic, 30% MgO) Current production, 4/28/90.

K-1 Proprietary mix retarder, substrate adhesion improver.
K-3 Proprietary mix retarder-cure accelerator.

WATER

Softened well water from 556 N. Valley Rd., Xenia, Ohio.

TRIAL MIXES

SPC	Mix Formula FLR	H_2O	AE	MIX"	SET'	COHESION - kg-cm 30'	60'	120'	APPEAR	ADHESION (1)	(2)	(3)
67	0	12	12	150"	10'	14.4	13.9	-	Sl Rch Tf	G	G	99+
68	.25pc	13	12	120"	5'	9.2	11.6	-	Bl Tf	G	G	99+
69	.5	14	12	180+	5'	10.0	12.2*	-	Bl Tf	G	F	100+
70	.75	14	12	180+	5'	10.0	11.2	-	Bl Tf	G	F	-
71	1.0	14	12	140	5'	8.0	10.0	-	Bl Tf	G	F	-
72	1.5	15	12	180	5'	8.6	10.2	-	Dl Tf	F	F	100+
73	2.0	15	12	165	5'	9.5	11.2	-	Dl Tf	F	G	-
74	.25hl	14	12	180	5'	10.0	12.1	-	Bl Tf	G	G	100+
75	.5	14	12	180	5'	9.0	11.9	-	Dl Tf	G	G	-
76	.75	15	12	160	5'	10.0	10.8	-	Dl Tf	G	G	-
77	.25pc	12	15	180	5'	11.9	15.0*	-	Bl Tf	G	G	-
78	.5	12	15	90	5'	13.9	14.1	-	Bl Tf	G	F	-
79	.75	14	15	180+	5'	14.0	12.9	-	Bl Tf	G	F	-
80	.25hl	13	15	180	-	11.9	14.1	-	Bl Tf	G	F	-
81	.5hl	13	15	150	-	12.6	13.0	-	Bl Tf	G	F	-
87	.25pc	11	15	-	-	-	15.2	21.1*				
88	.5	12	15	-	-	-	19.1	18.1				
90	.5/.1K1	11	15	-	-	-	18.1	16.5				
91	.5	6/4K3	15	-	-	-	21.5	26.2*				

60C CURED COHESION SYSTEM CLASSIFICATION

				(1)	(2)	(3)	AVERAGE		
82	.15pc	11	15	19.2	18.1	18.8	18.7	-	
83	.25pc	12	15	19.2	16.5	18.2	18.0	Sl Rch	100+
84	.50pc	12	15	17.6	18.2	19.2	18.3	-	

SCHULZE-BREUER-RUCK COMPATIBILITY CLASSIFICATION, 0/#10 As Received

			Sp Gr.	Absorb,g.	Loss,g.	Adhesion	Integrity	Grade
A(4)	0 - 12	12.5	2.00	1.11	.21	100	99	AAA-12
B(4)	.25 14	12.5	1.97	1.23	.17	100	25	AAD-9
C(4)	1.0pc 14	12.5	1.95	1.54	1.17	90	0	CAO-7

FIELD SIMULATION TESTS

WET TRACK ABRASION TEST, ONE HOUR SOAK

Mix Formula	WEIGHTS, g. Before	After	Loss, g	Loss, g/ft^2
A1 .25pc 14 10	721.5	707.2	14.3	
A2 .25 14 10	675.7	660.2	15.5	
		AVERAGE	14.9	45.6
B1 .25pc 12 13	688.7	677.8	10.9	
B2 .25 12 13	781.2	772.1	9.1	
		AVERAGE	10.0	30.6
C1 .25pc 10 16	736.9	728.4	8.5	
C2 .25 10 16	826.3	815.5	10.8	
		AVERAGE	9.7	29.5

WET TRACK ABRASION TEST, SIX DAY SOAK

A3 .25pc 14 10	721.9	711.8	10.1	30.9
B3 .25 12 13	767.1	759.4	7.7	23.6
C3 .25 10 16	812.9	808.7	4.2	12.9

MONOLAYER LOADED WHEEL SAND ADHESION TEST, 0/#4

UNCOMPACTED

				Before	After	Sand, g	Sand,g/SF(F=6.6)
A1	.25pc	14	10	334.83	342.30	7.47	49.3
B1	.25	12	13	336.81	345.50	8.69	57.4
C1	.25	11	16	315.13	323.73	8.60	56.8
C2	.25	11	16	342.44	352.28	9.84	64.9
D2	.25	9	18	337.54	346.98	9.44	62.3

COMPACTED

A2	.25pc	14	10	330.87	336.20	5.33	35.2
B2	.25	12	13	315.84	321.40	5.56	36.7
C2	.25	11	16	327.43	333.80	6.37	42.0
D1	.25	9	18	345.91	353.17	7.26	47.9

MULTILAYER UNCONFINED LOADED WHEEL DISPLACEMENT TEST

				Density		Displacement %		
				Before	After	Vertical	Lateral	Remarks
A1	.25pc	13	10	1.62	2.10	29.9	7.82	End & sl edge splits
B1	.25	12	13	1.67	2.12	26.8	7.20	End splits
C1	.25	11	16	1.69	2.13	25.8	3.50	No splits
D1	.25	9	18	1.85	2.09	13.2	3.00	No splits, sl. rich

SAND ADHESION FROM MULTILAYER LWT DISPLACEMENT TESTS

A1	.25pc	13	10	525.08	521.43	4.15 x 7.99*	33.16
B1	.25	12	13	533.10	549.51	3.59 x 8.28*	29.73
C1	.25	11	16	525.08	518.88	6.20 x 6.6	40.92
D1	.25	9	18	521.86	515.75	6.15 x 6.6	40.57

*partial surface area

SURFACE AREA CALCULATION ISSA TECHNICAL BULLETIN #118
(U.S. ARMY, WES "INSTRUCTION REPORT S-75-1")
#272 VULCAN WHELAND BLAST FURNACE SLAG

Corrected Surface area (washed) is 55.2ft^2/lb.
Assumed bitumen specific gravity (Bo Scan) is 1.03
Assumed CKE (Centrifuge Kerosene Equivalent) is 2.05(80%xABS)

FORMULA: BR = SAB+KA
SAB= CSA x T x 0.02047 x SGB
t = Bitumen film thickness, microns (micrometers)
SGB= Specific Gravity of Bitumen
KA = Centrifuge Kerosene Equivalent

THEN: For a 6.5 micron coating (heavy traffic)
BR = (CSA x t x .02047 x SGB)+KA
= (55.2 x 6.5 x.02047 x 1.03)+2.05
= 7.57+2.05
= 9.62% Bitumen added to aggregate
= 8.78% Bitumen in total dry mix
= 15.2% Emulsion added @ 63.4% AE Residue

AND: For an 8.0 micron coating (residential traffic)
BR = (55.2 x 8.0 x .02047 x 1.03)+2.05
= 9.31+2.05
= 11.36% Bitumen added to aggregate
= 10.20% Bitumen in total dry mix
= 17.9% Emulsion added @ 63.4% AE Residue

VOIDS CALCULATION

Compacted #272 .0-¼" Aggregate voids are 34.5% at a unit weight of 114.1 lbs./ft^3 and a dry specific gravity of 2.79

	Heavy Traffic 6.5 Microns	Light Traffic 8.0 Microns
Unit volume, compact	100.0%	100.0%
Less aggregate volume	65.5	65.5
Voids volume	34.5	34.5
Less bitumen volume	17.6	20.8
Voids in total mix	16.9	13.7%
Percent voids filled	49.0	60.3
Aggregate weight	114.1	114.1
Bitumen weight	11.0	13.0
Unit weight lbs/ft^3	126.1 lbs/ft^3	127.1
Density, Compact	2.01	2.04

DISCUSSION

Materials for this design met the requirements for Tennessee DOT specifications and ISSA specifications as far as tested.

Trial mixes for estimating total liquid contents, mixing characteristics, set and traffic time wet cohesion tests were performed using a series of chemical filler and additive contents.

Mix times were adequate in all cases. Clear water sets were good but 30 and 60 minute wet cohesions were relatively slow. A minimum of 15% emulsion was required to achieve a 30' wet cohesion of 12kg-cm required to qualify for a "QS" (Quick Set) system.

The optimum cement content is .25% which, with a minimum 15% emulsion will allow early rolling traffic in 2 hours. Mix time can be extended while reducing traffic time to 1 hour by the use of the K-3 additive which would qualify the system as "QT" or Quick Traffic.

Consistency tests were not run, but the total liquids content of the mixes were all less than the relatively high loose aggregate liquid capacity of 29.8%. Estimated mix consistencies were 3 to 4 cm. outflow.

Wet surface adhesion was adequate as was substrate adhesion. Both properties were hurt by increasing cement above .5%. The 3-minute boiling water adhesion tests were excellent at 99 to 100+%.

60°C Cured cohesion classification was not outstanding, but normal.

The Schulze-Breuer-Ruck aggregate bitumen compatibility tests (ISSA TB144)confirm the fact that higher cement levels harm this system and that very low cement levels are desireable if consistent with set and cure requirements.

The system is judged compatible.

Wet Track Abrasion Test, one-hour soaks were good. The losses were too low to establish a reasonable MINIMUM emulsion content. The 6-day soak WTAT's were outstanding since the losses were substantially lower than the one-hour soak, indicating excellent wet weather adhesion.

The Monolayer Loaded Wheel Test fine sand adhesion tests indicate a rather high capacity, above 16%, for emulsion content. An additional test was performed at 18% to confirm this finding.

The Unconfined Multilayer Loaded Wheel Test showed excessive shear failure between 13 and 16% emulsion contents, 16% being satisfactory. Compacted densities were relatively low, while the vertical displacements were too high to allow multilayer use as in rut filling under heavy traffic. An additional test at 18% emulsion remarkably improved stability and resistance to

displacement at low compacted density. Use for minor leveling on residential streets should be satisfactory.

The tests performed establish a relatively high maximum emulsion content of 18.75% for heavy traffic. Consequently, we looked at the surface area design method and voids analysis.

The aggregate and its gradation have relatively high void contents.

Surface area designs as practiced are frequently unreliable, but we calculate here theoretical emulsion contents of 15.1% and 17.9% for 6.5 and 8.0 micron coatings representing heavy and light traffic experience.

This slag aggregate and its gradation have relatively high voids contents at 34.5%; i.e., there is more space than normal for bitumen. At the 15.1% and 17.9% emulsion contents indicated by surface area calculations, 49.0 and 60.3% voids respectively would be filled with bitumen in the total compacted mix. These voids filled percentages are slightly low to in-line with satisfactory field applications.

Based on the above data, we recommend the following Job Mix Formulas:

JOB MIX FORMULA RECOMMENDATION FOR LIGHT TRAFFIC

Aggregate	100%
Type I Portland Cement	.25% +/- .15%
Water	not to exceed 29% total liquids
Emulsified Asphalt	18.0% +/- 1% @ 63.4% residue

JOB MIX FORMULA RECOMMENDATION FOR HEAVY TRAFFIC

Aggregate	100%
Type I Portland Cement	.25% +/- .1%
Water	not to exceed 29% total liquids
Emulsified Asphalt*	16% +/- 1% @ 63.4% residue

*assuming a tack cote is applied.

SPREAD RATE

The monolayer spread rate, calculated by ISSA TB 112 is 13.3 +/- 2 lbs./SY.

CAUTION

Any substantial change in aggregate properties or emulsion properties may alter the cured mix properties. The effect of changes if they occur should be re-evaluated before extensive field application.

Please call should any questions arise.

Respectfully Submitted,

C. Robert Benedict

Assuming a moderate squeegee contact pressure, a slurry consistency of 2.5 to 3 cm. and a slurry depth of 5 to 6 inches, basic spread rates applied to smooth surfaces may be selected from the 1st table. The quantity of slurry required to fill surface texture may be added to the basic rate along with an estimate of requirements due to cross sectional irregularity and for joint cracks and laps. These increments may be added to give an estimate of the spread rate.

63.6 @ 16
= 10.4 @ 16

APPROXIMATE SPREAD RATE CALCULATION*
(Under study in 1977...Subject to revision)

BASIC MONOLAYER SPREAD RATES FOR SMOOTH SURFACES
(McLeod "S" or 60cc Sand Box Spread of 16-18' - ASG=2.65)

GRADATION	TYPE I		TYPE II		TYPE III	
	%+16	lb/SY	%+16	lb/SY	%+16	lb/SY
FINE	10	5	30 (30.4)	9 (9.8)	50	14
MEDIAN	22.5	6	42.5	10.5	61	15.5
COARSE	35	7	55	12	72	17

FACTORS:	McLeod Rating	Sand Box Texture	Add lb/SY	TOTAL
BASIC RATE	S	16-18'		9.8
ADD FOR SURFACE TEXTURE	H-1	10-12'	1	2.0
	H-2	8-10'	2	
	H-3	5-7'	3	
		2-4'	4	
ADD FOR CROSS SECTIONAL IRREGULARITY	Nominal - 3/8"		1	1.0
	Moderate - 1/2-3/4"		2	
	Severe - 1-1-1/2"		3	
ADD FOR JOINT CRACKS & LAPS (Calculate)				.5
APPROXIMATE SPREAD RATE - TOTAL				13.3 ± 2 lbs

* Variables of Particle Shape, Dimensions, Matrix Volumes, Void Content, Screen Ratios, All Affect the Spread Rate. Use these tables as a GUIDE only.

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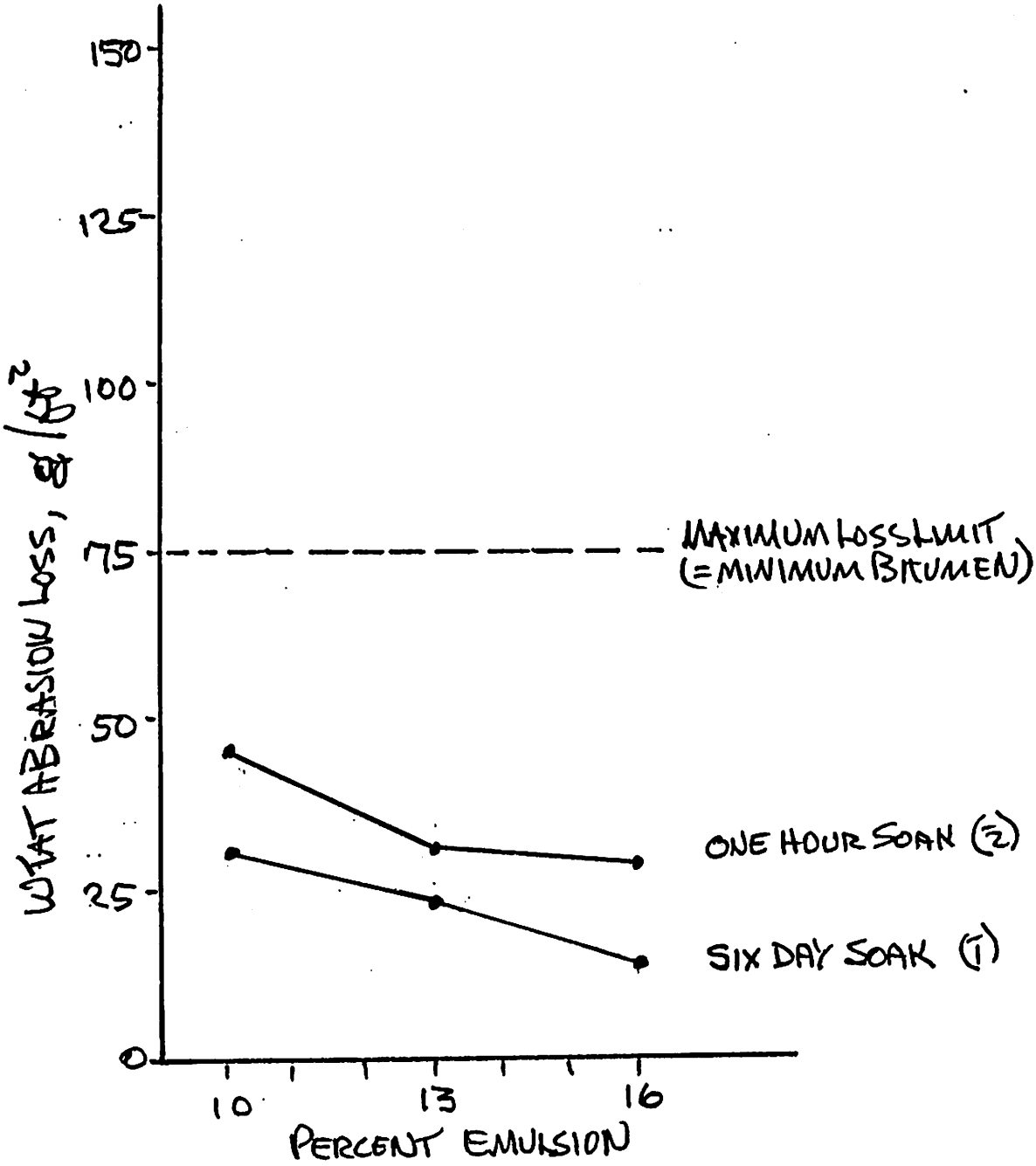
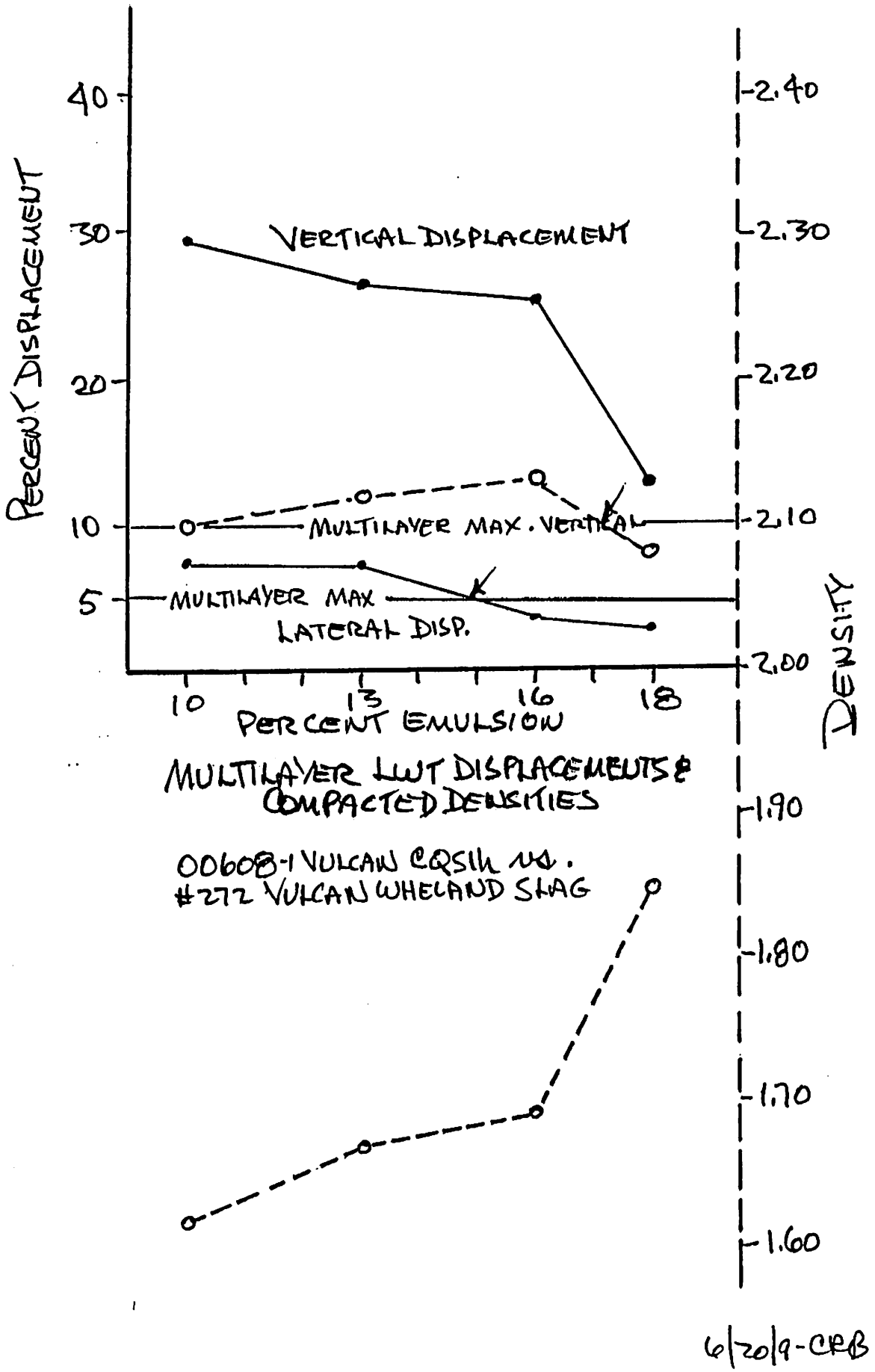
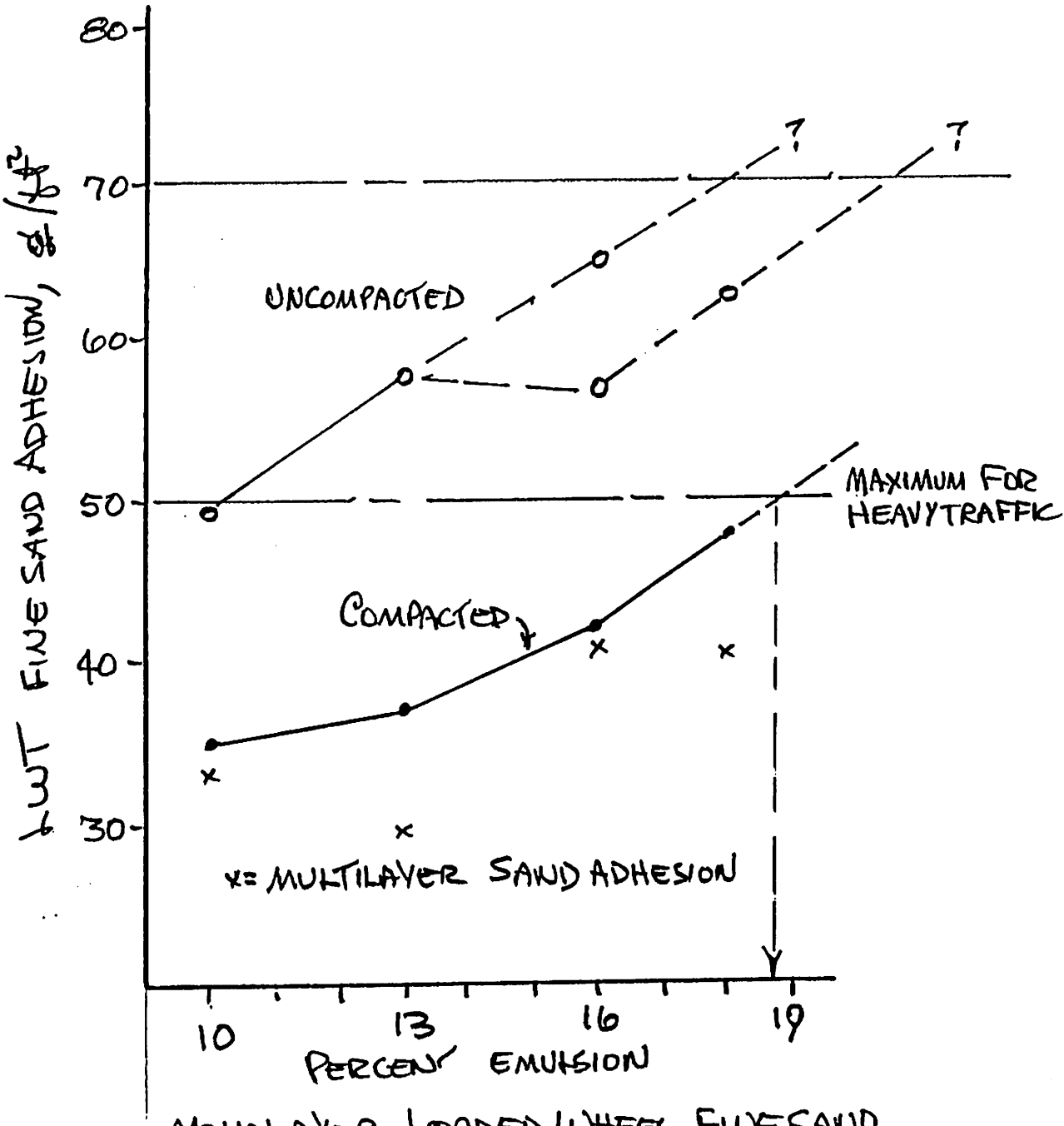


#00608-1 VULCAN CQS1h vs. #272 WHELAND SLAG

WET TRACK ABRASION TESTS

6/20/90 - CRB

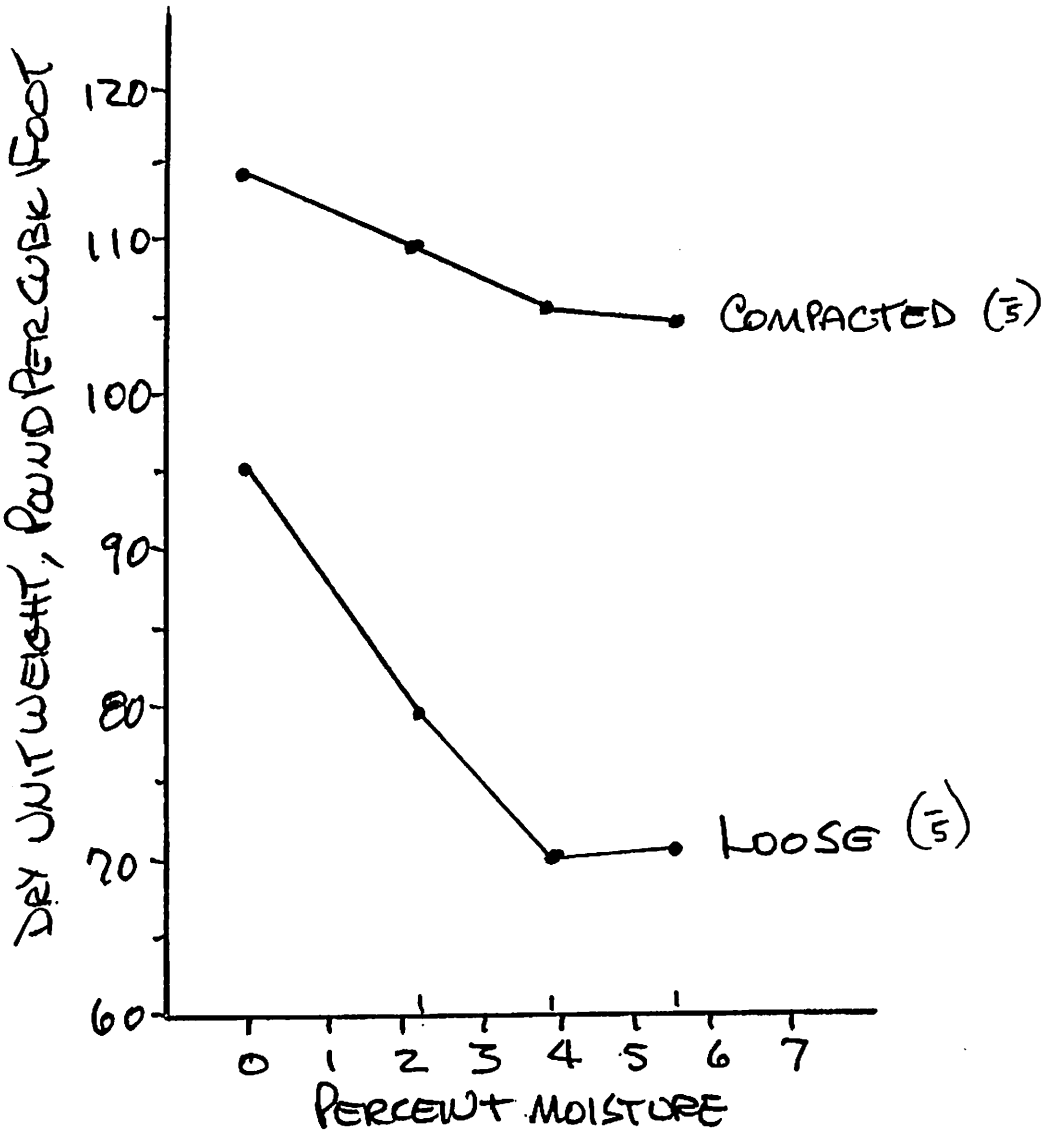

PERCENT DISPLACEMENT
40
30
20
10
5
VERTICAL DISPLACEMENT
MULTILAYER MAX. VERTICAL
MULTILAYER MAX
LATERAL DISP.
10
13
16
18
PERCENT EMULSION
2.40
2.30
2.20
2.10
2.00
1.90
1.80
1.70
1.60
DENSITY
MULTILAYER LWT DISPLACEMENTS & COMPACTED DENSITIES
00608-1 VULCAN CQSIL VS.
#272 VULCAN WHELAND SLAG
6/20/9-CRB



MONOLAYER LOADED WHEEL FINE SAND ADHESION TEST

#00608-1 VULCAN CRSI, NJ. #272 WHELAND SLAG

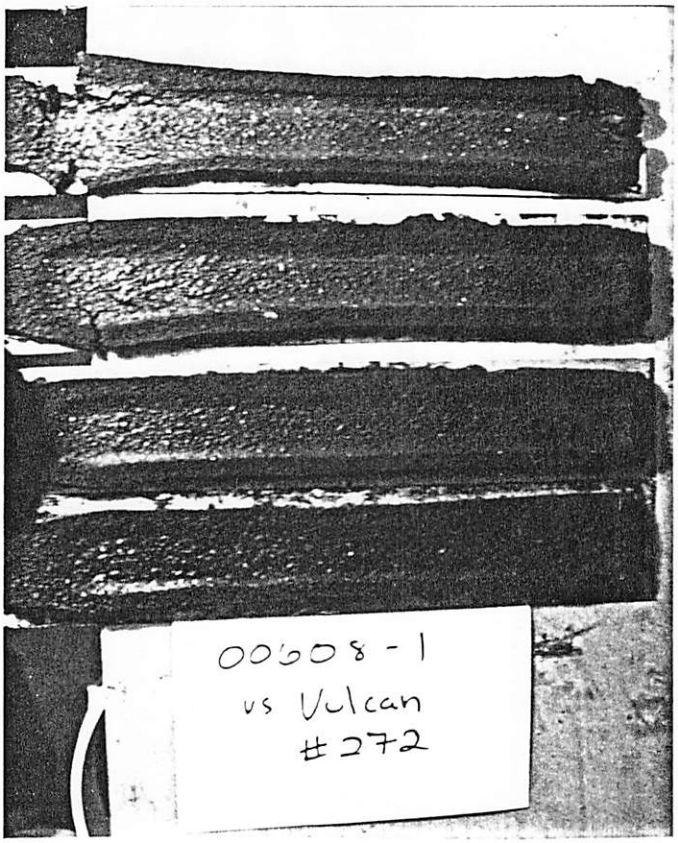
6/20/90- CRB



BULKING EFFECT OF AGGREGATE MOISTURE CONTENTS

#272 VULCAN WHECAND SLAG

6/20/90 · CRB



UNCONFINED MULTILAYER LOADED WHEEL DISPLACEMENT TESTS AT 10, 13, 16 & 18% EMULSION CONTENTS. VULCAN CQS1h #00608-1 vs. WHELAND 0/#4 SLAG.