-DRAFT, NOT FOR PUBLICATION-

LAB NOTES ON THE EFFECTS OF CALCAREOUS AGGREGATE QUALITY AND EMULSION FORMULATION ON SLURRY SEAL LABORATORY TESTS

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INTRODUCTION

In the summer of 1991, several field problems were brought to our lab. They were:

1. Short, high temperature mix time.
2. Low cohesion or set times and traffic times.
3. Multilayer wash-outs on the longitudinal laps.

Five Ohio calcareous aggregates which have had long term satisfactory field records, some as long as 21 years, were received for testing. They were:

1.	Plum Run	76SE	1.5mg M.Blue/g 0/#325 Agg.
2.	Latham	81	2.0
3.	Sandusky	58	2.5
4.	Xenia	54	3.0
5.	Waterville	57	4.0

The gradations used were 0/#4 Type 2 with 12-16% 0/#200.

The emulsions were all made from the same excellent high performance base asphalt with the same high quality emulsifier, but at a variety of emulsifier concentrations and pH's.

Initially, many additives were tried to solve the problems with only limited success. Wild variations in test results were noted as due to aggregate quality. Our attention was then focused on the role of emulsifier concentration and pH. Later, the study was limited to two representative aggregates: Latham and Xenia.

TESTS REPORTED ARE:

1. Wet cohesion with mix water requirements, mix times, 30 and 60 minutes wet cohesion.
2. 60C cured cohesion, dry and 14-day soak.
3. Schulze-Breuer abrasion loss.
4. Wet track abrasion loss, 1-hour and 6-day soak.

WET COHESION ISSA TB 139

Three emulsions were prepared with the same base asphalt at 1.3% emulsifier at 1.6 pH, 1.5% at 2.0 pH and 1.5% at 1.4 pH. Each was mixed in turn with the five 0/#4 aggregates at 12 and 15% added emulsion and at .5 and 1.0% type Portland cement with the following results (Table 1 and Table 2):

ALL SAME HIGH QUALITY #121 AC-20, 5/91

	AE No. 10508-1 10513-1	AE No. 10529-3	AE No. 10529-4
	1.3-320 @ 1.6pH	1.5-320 @ 2.0pH	1.5-320 @ 1.4pH

PC AE	H20	Sec	30'	60'	H20	Sec	30'	60'	H20	Sec	30'	60'	CSN	H20
Plum Run SE=76(MB=1.5 mg/g325)														
.5-12	8	180	9.0	18.9S	8	180+	18.2	20.2	10	180	18.9	18.0		
1.0-12	8	180	21.2	23.0S	8	180+	18.3	19.3S	10	180	9.8	19.7		
.5-15	7	180	24.0	21.3S	6	180+	22.0	21.2S	7	150	21.2s	22.0s		
1.0-15	7	180	19.9	24.2S	6	180+	20.2	21.2S	7	150	20.2	20.0s		
Avg.	7.5			21.8S	7.0			20.48	8.5			19.93	20.8	7.7
Latham SE=81(MB=2.0 mg/g325) #191														
.5-12	8	120	18.0	18.9	8	180+	17.0	21.0	8	180	16.2	19.2		
1.0-12	11	160	14.9	18.0	8	180+	16.2	17.6	8	180	17.2	17.9		
.5-15	7	180+	18.0	19.0S	6	180+	18.5	22.7	6	140	21.5	20.2		
1.5-15	7	180+	18.0	17.8S	6	180+	17.0	20.1	6	150	20.0	21.5		
Avg.	8.3			18.43	7			20.35	7			19.70	19.5	7.4
Sandusky SE=58(MB=2.5 mg/g325) #323														
.5-12	12	100	12.2	13.8	12	140	12.5	13.5	11	150	12.2	12.9		
1.0-12	13	140	11.2	13.9	12	180	12.0	13.6	12	170	11.3	13.2		
.5-15	7	150	17.1	16.2	11	150	14.5	17.2	10	180	14.2	15.0		
1.0-15	7	150	15.0	16.7	11	150	15.4	15.9	11	180	14.2	18.0		
Avg.	9.8			15.15	11.5			15.05	11			14.78	15.0	10.8
Xenia SE=54(MB=3.0 mg/g325) #318														
.5-12	12	100	10.0	11.5	11	175	10.5	13.9	12	120	11.6	13.5		
1.0-12	12	180+	11.3	11.0	12	170	15.0	15.5	12	165	11.5	11.6		
.5-15	11	180+	12.9	11.2	11	75	11.2	13.2	11	150	13.2	16.5		
1.0-15	11	180+	13.0	16.2	12	180	14.9	16.0	11	180	15.0	15.9		
Avg.	11.5			12.48	11.5			14.65	11.5			14.38	13.8	11.5
Waterville SE=57(MB=4.0 mg/g325) #315														
.5-12	15	120	5.9	7.0	11	180	7.5	8.2	12	120	9.2	8.0		
1.0-12	16	180	7.2	8.0	11	170	8.6	9.0	12	180+	7.2	8.0		
.5-15	10	180	9.2	11.2	9	170	10.6	13.2	15	150	7.2	7.0		
1.0-15	12	180	7.2	8.5	9	130	12.2	12.9	15	180	8.7	11.0		
Avg.	13.3			8.65	10.0			10.83	13.5			8.5	9.3	12.3

TABLE 1 WET COHESION; 5 AGGREGATES, 3 EMULSIONS

TABLE 2: **WET COHESION TEST SUMMARY**

		Plum Run	Latham	Sandusky	Xenia	Waterville
10513-1	1.3@1.6pH	21.9	18.4	15.2	12.5	8.7
10529-4	1.5@1.4pH	19.9	19.7	14.8	14.4	8.5
10529-3	1.5@2.0pH	20.5	19.5	15.1	14.7	10.8
AVERAGE COHESION		20.8	19.5	15.0	13.8	9.3
AVERAGE MIX WATER		7.4	7.7	10.8	11.5	12.3
METHYLENE BLUE		1.5	2.0	2.5	3.0	4.0

We find these results astounding! Five, field tested, Calcareous-Dolomite aggregates with similar gradations, mined within a 100-mile radius, all with acceptable ISSA Sand Equivalents, ranged from average 60' cohesion values of 20.8 to 9.3; from QT to SS, traffic times from 30 minutes to perhaps 5 or 6 hours!

We note that as wet cohesion fell the mix water requirements increased and the Methylene Blue fines absorption increased. These results are plotted in Figures 1 and 1a and show very good correlations.

Sand equivalent vs. wet cohesion did not seem to correlate. Sand equivalent values, at least with calcareous aggregates, are generally highly reproducible but are rather sensitive to the % fines and whether the sample was dry or saturated, 5 to 10 points variation has been found; i.e., lower values with saturated aggregates and higher values with dry aggregates.

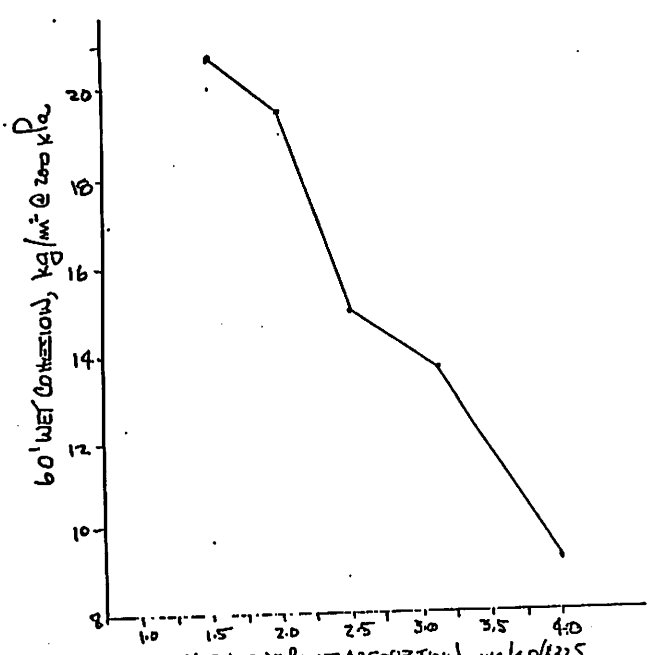


FIGURE 1. EFFECT OF METHLENE BLUE ABSORBTION ON 60' WET COHESION AVERAGE 5AGGREGATES, 5 EMULSIONS CEB 10/15/91

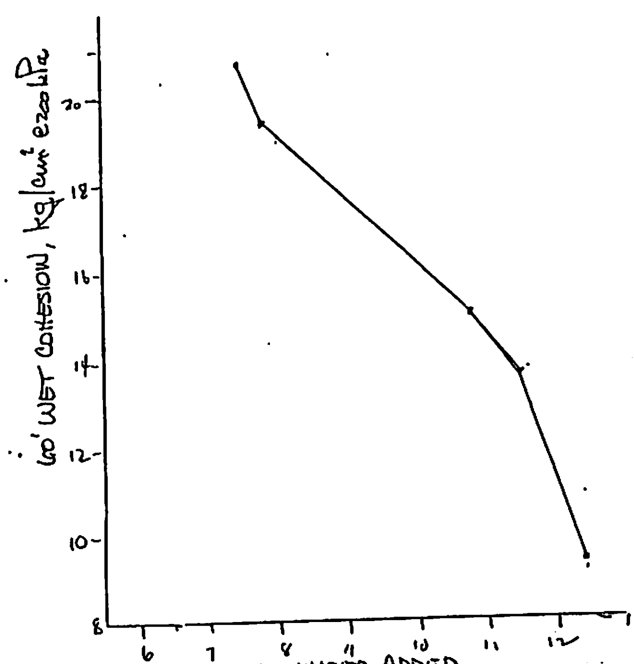
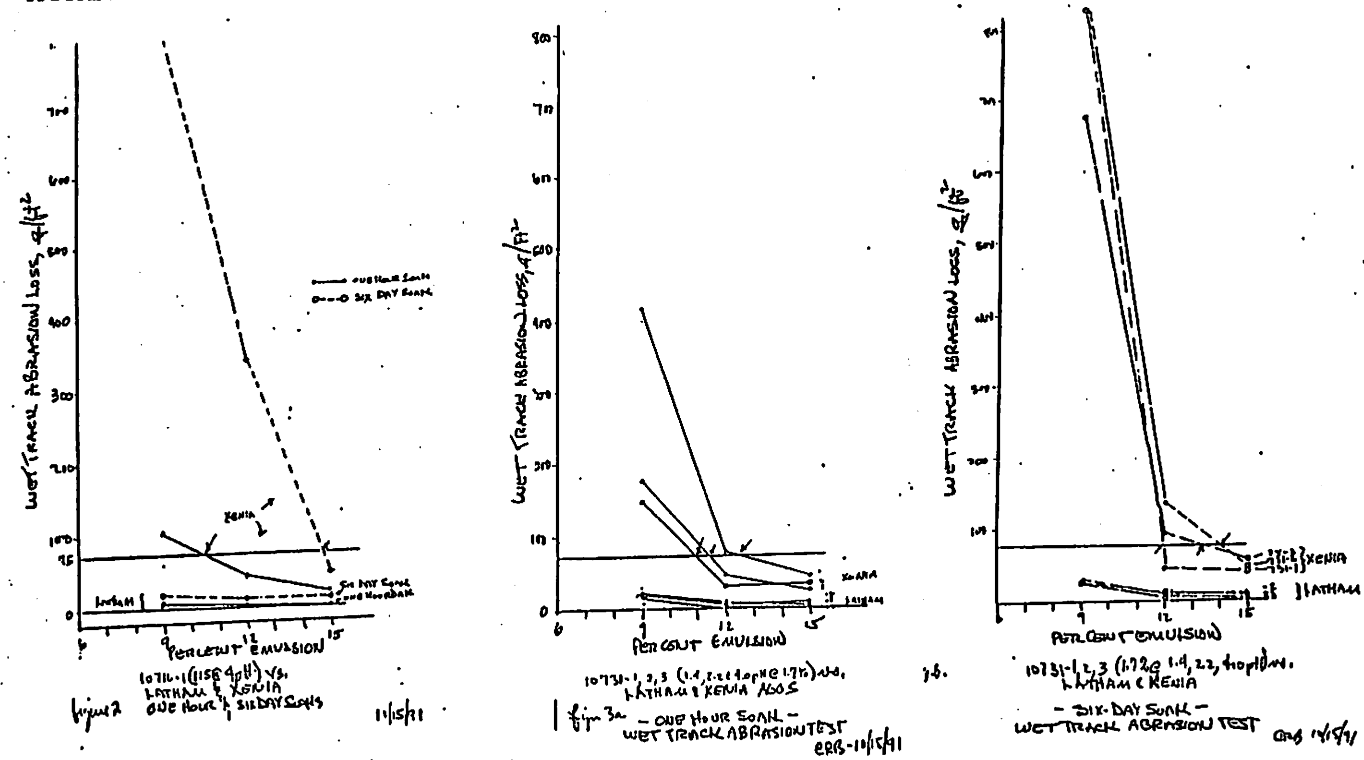


FIGURE 1a MIX WATER REQUIREMENTS AND WET COHESION- AVERAGE OF 5AGGREGATES, 3 EMULSIONS

WET TRACK ABRASION TESTS: ONE HOUR AND SIX DAY SOAKS ISSA TB 100

Figure 2 and 3 compares the one-hour and six-day soak losses. All 4 emulsions yield similar results. There is very little difference between the one-hour and 6-day soaks with Latham, but Xenia shows a radical increase with the 6-day soak.



Here we use our System Evaluation Number (the minimum emulsion quantity to reach the 6-day soak WTAT 75 grams/ft^2 or 800g/m^2) for comparing the two aggregates. The theoretical implication is that the minimum emulsion content may be reduced by 55% by the use of a high performance AGGREGATE.

	LATHAM		XENIA	
Formulation	1-hour	6-day	1-hour	6-day
10731-1 1.7 @ 1.4pH	< 8.0	< 8.0	12.5	12.0
10731-2 1.7 @ 2.2	< 8.0	< 8.0	11.0	14.0
10731-3 1.7 @ 4.0	< 8.0	< 8.0	11.4	13.4
10716-1 1.5 @ 4.0	< 8.0	< 8.0	10.5	14.7
AVERAGE, % EMULSION	< 8.0	< 8.0	11.4	13.5

TABLE 4: SYSTEM EVALUATION BY WTAT (6-DAY WTAT MINIMUM EMULSION%)

SCHULZE-BREUER ABRASION LOSS - ISSA TB 144

The Schulze-Breuer test has been found to reflect or roughly correlate with the Wet Track Abrasion Test even though only the aggregate filler (0/#10) is used for the same 6-day soaking period.

Our results bear out this observation as shown in table 5.

AE No.	Formulation	LATHAM 0/#10 - 8.2% AC grams loss	XENIA 0/#10 - 8.2% AC grams loss
10731-1	1.7 @ 1.4 pH	.42	1.25
10731-2	1.7 @ 2.2 pH	.79	1.47
10731-3	1.7 @ 4.0 pH	.50	1.52
10716-1	1.5 @ 4.0 pH	.75	1.55
AVERAGE:		.62(A)	1.45(D)

TABLE 5: **SCHULZE-BREUER ABRASION LOSS**

60C CURED COHESION: DRY AND 14-DAY SOAK

This system is a system evaluator where in unmodified systems a cohesion value of 18-20 is quite good and values of 12-14 are quite poor. By comparison, good polymer modified systems have cured cohesion values of 24-26 and more. High temperature cured cohesion or high temperature "mix strength" is measured.

In Table 3, the overnight and 14-day soak 60C cured cohesion are compared for the Latham and Xenia aggregates.

			LATHAM			XENIA	
AE No.	EM%	pH	1-Day Dry	14-Day Soak		1-Day Dry	14-Day Soak
10805-1	1.7 @	1.4	17.8*	19.7*	rises	18.8	12.6 falls
10805-2	1.7	2.2	20.0*	20.5*	rises	17.3	15.4 falls
10805-3	1.7	4.0	18.6	19.5	rises	17.8	15.8 falls
10826-1	1.5	4.0	19.0*	19.2*	rises	17.9	13.0 falls
AVERAGE:			18.9	19.7	rises	18.0	14.2 falls
10826-2	1.3 @	4.0	18.2	13.2	falls	16.2	14.9 falls
10826-3	1.3	2.0	18.3	14.1	falls	17.4	14.0 falls

(All .5% pc; * = 1%)

TABLE 3: **DRY AND 14-DAY SOAK CURED COHESION**

WESTERN PENNSYLVANIA limestone aggregate and emulsion compared with Ohio Latham Dolomite.

This set of data compares not only the effects of aggregate quality but also the effects of a different base bitumen using the same emulsifier. The West PA limestone had a sand equivalent of 68.0, Methylene Blue of 4.0mg/g 0/#325, Schulze-Breuer loss of .92 grams and WTAT SEN of 11.8.

60′ WET COHESION @ 12% AE

	COMMERCIAL-SPRINGFIELD		LATHAM DOLOMITE	
	ASHLAND E-8	MIDWEST QS	ASHLAND E-8	MIDWEST QS
.5%pc	e 9.8	12.0	15.5	22.3
1.0%pc	12.2	12.0	16.5	19.1

12 kg-cm cohesion is required for "set". 20 kg-cm is required for "early rolling traffic". The Commercial-Springfield scarcely set in one hour with either emulsion while the Latham greatly improves the Ashland but, with Midwest CQS, Latham can be trafficked in less than 1 hour!

60C CURED COHESION @ 12% AE

	COMMERCIAL-SPRINGFIELD		LATHAM-DOLOMITE	
	ASHLAND E-8	MIDWEST QS	ASHLAND E-8	MIDWEST QS
.25%pc	-	-	17.6	19.3
.50%pc	13.0	14.1	18.4	19.9*
.75%pc	13.2	15.4*	15.8(?)	17.4
1.00%pc	14.0*	14.8	18.8	-
AVERAGE:	13.4	14.8	17.7	18.9
DIFFERENCE:		+1.4		+1.2

Cured cohesion is another measure of system quality. 12-14 is very poor, 19-20 is excellent. The difference between aggregates and emulsion base AC is quite apparent. Polymer modified systems such as Ralumac or Polymac should be 24-26. The 1.2 to 1.4 difference between emulsions is the quality probably of the bitumen base. But the 4 points difference between aggregates is due to the aggregates quality.

WET TRACK ABRASION TEST: SIX-DAY SOAK

	COMMERCIAL-SPRINGFIELD ASHLAND QS	LATHAM MIDWEST QS
6% AE	-	*
9% AE	597g/ft^2*	22.6g/ft^2
12% AE	14	4.6
15% AE	19	4.0
	*destroyed	

These 6-day soak WTAT's clearly show the high quality of the emulsifier used. Effects of both the aggregate quality and base asphalt quality show up dramatically.

CONCLUSIONS AND COMMENTS

1. With the 6 calcareous aggregates tested, there are extreme variations in laboratory performance solely due to aggregate qualities and to a lesser extent by emulsion formulation using only one emulsifier. Both excellence and disaster occur due solely to aggregate quality.

2. Methylene Blue absorbtion values correlate with results much better than sand equivalent.

3. Sand Equivalent, Fines Content and Methylene Blue Factors were not studied. A combination of Sand Equivalent and Methylene Blue values as well as the Lhorty Coefficient of Activity, Cation Exchange Capacity, Fines particle shape, absorbtion and size distribution and Zeta Potential, Differential Thermal Analysis, Surface Charge Density by streaming potentiometer and other methods may reflect a better characterization of the aggregate quality.

4. By understanding the effects of aggregate quality on Slurry Seal mix design, large economies in bitumen content and extended service life may allow importation of the highest quality aggregate.

5. This study includes only certain selected calcareous aggregates with only Portland cement. The results may not apply to siliceous-type aggregate. The study should be extended to include granites, trap rocks, quartzites, etc.

6. Only one emulsifier was used in this study. Investigation of different chemical types of emulsifiers should be made in relation to aggregate qualities; poor performance might be considerably improved. Aggregates may be emulsifier specific or exhibit emulsifier-type preference.

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