ROUGH DRAFT----NOT FOR PUBLICATION

CLASSIFICATION OF BITUMEN-AGGREGATE COMPATIBILITY BY SCHULZE-BREUER & RUCK PROCEDURES

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CLASSIFICATION OF BITUMEN-AGGREGATE SYSTEM COMPATIBILITY BY SCHULZE-BREUER AND RUCK PROCEDURES / C. ROBERT BENEDICT 2/89

INTRODUCTION

For those who write standards and specifications for bituminous materials and aggregates, only those properties which can be measured are described such as; gradation, specific gravity, unit weight, sand equivalent, soundness, Los Angeles abrasion viscosity, ductility, percent residue, penetration, pH, particle charge, settlement, sieve and so on. Yet, the measurement of the fundamental property of a bitumen, IT'S ABILITY TO STICK 2 STONES TOGETHER, remains neglected for the lack of objective numbers to describe this property.

It is the purpose of this paper to introduce the Schulze-Breuer and Ruck (2) procedures which offer objective measures of the ability of a bitmen to "stick two stones together"; i.e., their mutual compatibility.

HISTORY

During the early development of the German "Gussasphalt"; a molten slurry, failures were due to an apparent incompatbility of the aggregate filler with the bitumen. Schulze and Breuer (1) at the Universtiy of Munich developed a method to determine the relative compatibility of a given mineral filler (0/2mm) with a given bitumen. The laboratory results were correlated with field performance and standards resulted.

During several visits to Europe in the late 70's the author observered the Schulze-Breuer test as applied to the polymer modified slurry systems such as "Ralumac" and to the French "Seal Gum". It was noted that very few aggregate-bitumen systems would meet the established criteria and that very good field performance was obtained when the Schulze-Breuer criteria was applied in the selection of Bitumen-Aggregate combinations.

In the US as early as the 60's, Corbit (?) used a similar "sheep pill" test which has seemed to vanish. Presently, there is a pre-occupation with the laboratory measurement of "moisture induced damage of bituminous mixes by the Lottman and Kennedy procedures which measures the retained strength by split tension of water soaked Marshall pills. Other researchers seek to further define the Lottman and similiar test procedures.

Early adhesion tests such as the Bitumuls/Chevron Boiling Water test and the ISSA Technical Bulletin #114 Wet Striping Test, TB #115 System Compatibility and TB 139 60C Cured Cohesion are other examples of attempts to measure the adhesive properties of bitumen emulsion residues.

SCHULZE-BREUER TEST PROCEDURE

The aggregate to be tested is sieved and reconstituted into the following gradation

Metric Sieves	US Sieves
25% 710 uM / 2.0 mm	35% #30 / #10
40% 250 uM / 710 uM	25% #50 / #30
15% 90 uM / 250 uM	22% #200 / #50
20% 0 uM / 90 uM	18% 0 / #200

200 grams of this aggregate is combined with portland cement and/or other additives, mix water and 12.5% of a 65% residue emulsion is added (8.125% added or 7.5% extracted). The materials are mixed until broken and dried to constant weight at 60C (about 18 hours). 40 grams of the crummed and dried mix is pressed in a 30 mm diameter mold at 60C for 1 minute at 1 ton constant force.

The resulting 30 mm diameter "pill", about 24-30 mm deep, is then weighed and soaked in water for 6-days at ambient, surface dried and reweighed to determine water ABSORBTION. The pill is then placed in a shuttle cylinder (60 mm diameter X 400 mm long = 1100 ml) filled with 750 ml of water, sealed and rotated end for end at 20 RPM for 3-hours (3600 cycles) so that the pill makes 7200 trips through the water and impacted upon the cylinder bottom. The recovered pill is then surface dried and re-weighed to determine the Schulze-Breuer ABRASION loss.

Finally, in the procedure according to RUCK, the abraded pill is placed in a metal basket and suspended in boiling water for 30 minutes. The remains are then examined for percent retained coating, i.e. ADHESION and the largest pill remmant is weighed to determine the percent of retained solid mass; i.e., the high temperature wet cohesion or, simply, "INTEGRITY".

The average of guadruplicate specimen results are reported as:

1. ABSORBTION in grams (or percent)
2. ABRASION loss in grams (or percent)
3. ADHESION, percent
4. INTEGRITY, percent

(Note: A variety of other measurements which may be taken are not reported here such as: swell, voids, density compressive strength before and after soak, etc.)

EXAMPLES OF USE, INTERPRETATION, CLASSIFICATION

In our early work, swell was laboriously measured but no correlation was found with absorbtion or abrasion loss and is not reported here. No broad correlations were found with absorbtion and loss. Some statistically insignificant correlations within sets were found with both swell and absorbtion. Also in the early work the aggregate was not regraded as suggested; rather, the 0/2 mm fraction was used "as received" so that slight variations in future results would be expected in each set. However, aggregate used in the examples was prepared in the same way and offers comparable results.

6 groups of tests are described here to illustrate a variety of effects. They comprise some 124 quadruplicate tests or 496 pills, each with 7 measurements or some 3472 data bits, Test values ranged as follows:

absorbtion	.28 to 2.35 g.
abrasion loss	.03 to 5.76 g.
Ruck adhesion	0 100%
Ruck integrity	0 100%

To simplify the detailed data, we have classified each test result into understandable grades and grade point totals. We have used what we understand of the German and French criteria and our own field and laboratory observations to construct the following classification system:

Abrasion Loss, g.	0 - .7 g	= A	(4 points)	Best
	.7 - 1.0 g	= B	(3 points)	Pass
	1.0 - 1.3 g	= C	(2 points)	Marginal
	1.3 - 2.0 g	= D	(1 point)	Fail
	2.0 +	0	(0 point)	Fail
Adhesion or Integrity; %:	90 - 100	= A	4	Best
	75 - 90	= B	3	Marginal
	50 - 75	= C	2	Marginal
	10 - 50	= D	1	Fail
	0 - 10	= 0	0	Fail

Examples:

Abrasion	Adhesion	Integrity	Rating	Grade Point
.60	95	95	AAA	12 Pass
.78	99	92	BAA	11 Pass
1.21	81	45	CBD	6 Fail
.92	96	80	BAB	10 Fail

The above 3-test rating system may apply only to multiple layered mixes where high temperature cohesion is of great importance. A 2-test rating system may be more appropriate for monolayered systems.

EXAMPLES

The following examples compare the test results and ratings of a number of variables and illustrate the way that our rating systems are used:

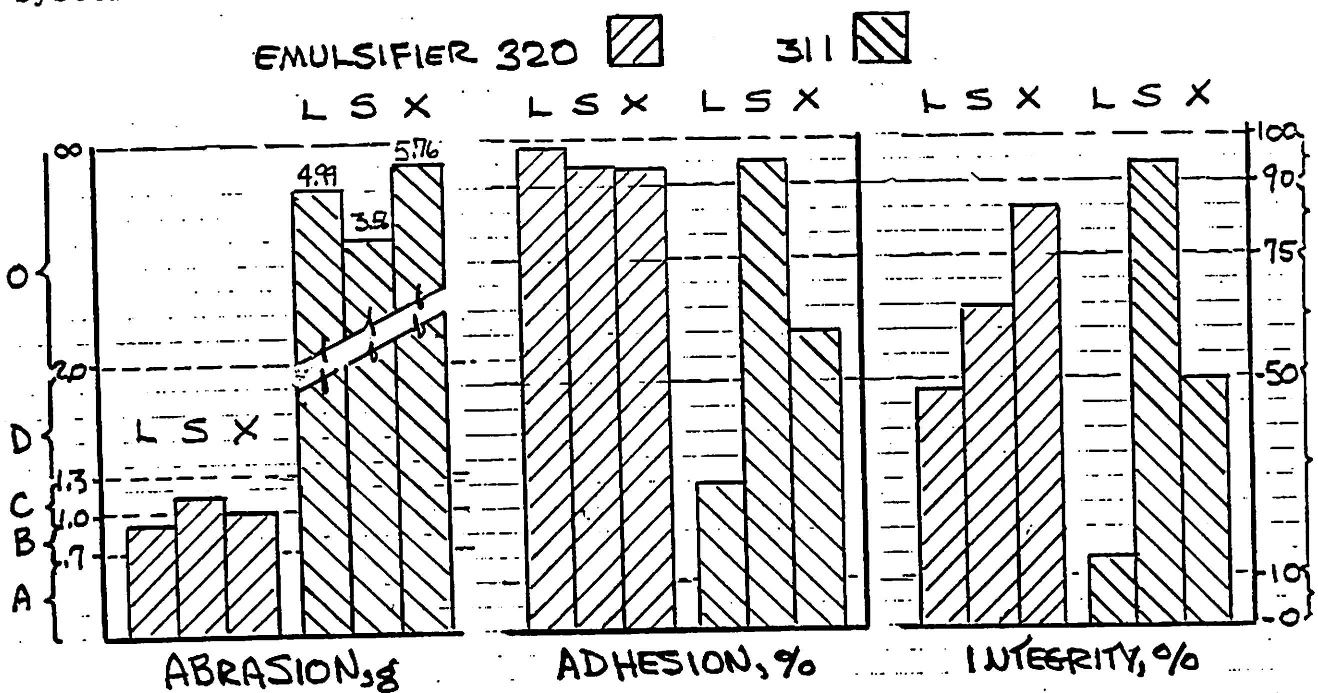

FIGURE 1 EFFECT OF TWO EMULSIFIER TYPES ON THREE CALCAREOUS AGGREGATES: L,S,X

Example 1 Effect of Emulsifier Type on 3 Calcareous Aggregate Fillers (Plain, Unmodified Emulsion)

Abrasion losses between the 320 and 311 emulsifiers are dramatically different. All 3 aggregates abrasion losses fail miserably with the 311 emulsifier but the Limestone "S" is slightly better than the "L" & "X" aggregates with 311 emulsifier.

Adhesion is excellent with emulsifier 320. The 311 emulsifier is equivalent only with the "S" aggregate.

The relevance for Ruck "Integrity" for plain unmodified systems is questionable, but in this case the 311 emulsifier with the "S" limestone outperforms all 5 of the other specimens.

The over-all ratings are:

	Emulsifier 320		Emulsifier 311		Total Points
Limestone L	BAD	7	ODD	2	9
Limestone S	CAC	8	OAA	8	16
Gravel X	BAB	10	OCD	3	13
TOTAL POINTS		25		13	

Example 1 Ratings

Based on the relative results, Limestone S performs best of the 3 aggregates while Emulsifier 320 outperforms 311 by twice. The best combinations would then be 320 emulsifier with Limestone S.

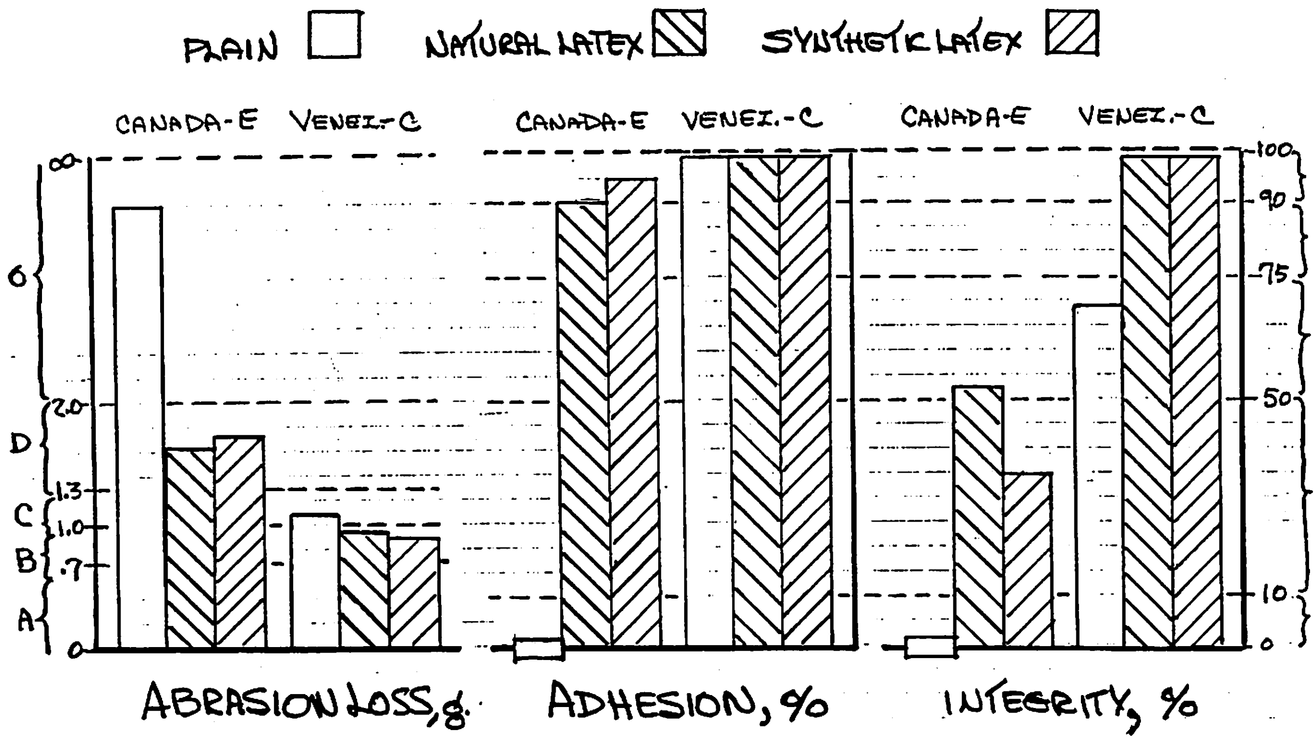

FIGURE 2 EFFECT OF BITUMEN SOURCE AND LATEX SOURCE - SAME EMULSIFIER & AGGREGATE

Example 2 Effect of Bitumen Source and Latex source with Same Emulsifier and Aggregate

Canadian E and Venezulean C bitumens were used to prepare 2 sets of emulsions each with the identical emulsifier system and Plain, Natural Latex and a Synthetic Latex. Schulze-Breuer mixes were made with Limestone "L" used in Example 1.

The Canadian "E" bitumen plain emulsion fails Abrasion, "Adhesion" and "Integrity" tests miserably. The latex modified Candadian however dramatically improves all test results.

The plain Venezulean Emulsion outperforms the Modified Canadian Emulsions.

	Canadian E	Venezulean C	Totals
Plain	000-0	CAC - 8	8
Natural Latex	DBC-7	BAA - 11	18
Synthetic Latex	DAD-6	BAA - 11	17
	--	--	
POINT TOTALS	13	30	

Example 2 Ratings

The Venzuelean bitumen is far superior in this example while the Natural latex has a slight over-all edge over the synthetic. Our criterea for a High Performance System (11 points minimum) is met only by both Modified Venezueleans.

Example 3 Three Production "PERFORMANCE" Emulsions

Three production latex modified emulsions from 3 manufacturers, each using the identical base bitumen all manufactured within 3 weeks of each other, each using nearly chemically identical emulsifiers but with 3 different latex sources were used to prepare Schulze-Breuer pills with a Trap Rock and a Granite aggregate with type 1 portland cement and hydrated lime as mix additives.

Abrasion losses are all very good. Hydrated lime outperforms cement in all cases but the 923-SL-A latex with granite. The 924 Natural Latex B performs only slightly better than the Synthetic latexes.

Adhesions were all excellent except for the Synthetic Latex B with granite which was a dismal failure with both lime and cement.

Integrity shows an interesting mixed bag. All trap rock mixes with lime showed excellent Integrity while the cement reduced integrity noticably.

However, the integrity is greatly influenced by the Granite aggregate using any of the latexes. Again the Synthetic latex B zeroed out while the Synthetic A and Natural B performed much better with cement than lime.

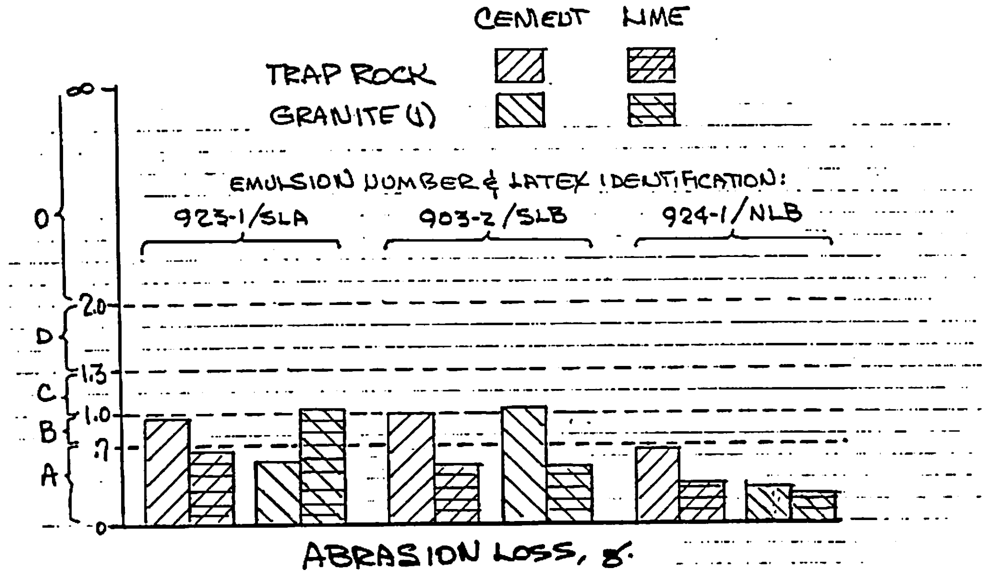

FIGURE 3a. 3 PRODUCTION EMULSIONS, 3 MANUFACTURERS
SAME SOURCE BITUMEN, 3 SIMILAR EMULSIFIERS
3 LATEX SOURCES, 2 AGGREGATES, 2 FILLERS

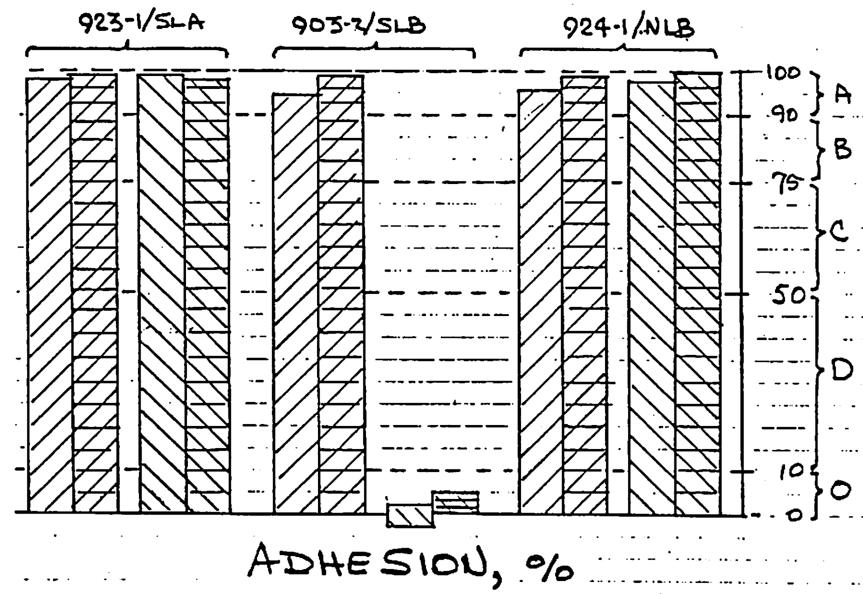

FIGURE 3b. 3 PRODUCTION EMULSIONS

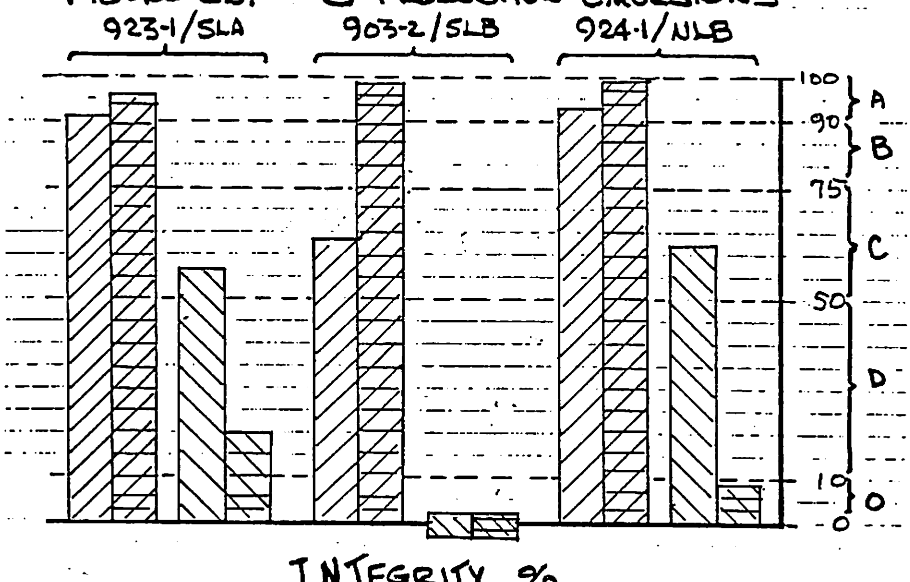

FIGURE 3c. 3 PRODUCTION EMULSIONS

			ABRASION	ADHESION	INTEGRITY	Rating	Subtotal	Overall
923-1 SLA	Trap Rock	Cement	B	A	A	11*		
	Trap Rock	Lime	A	A	A	12*		
						--		
							23	
	Granite (2)	Cement	A	A	C	10		
	Granite (2)	Lime	C	A	A	10		
						--		
							20	
							--	
			OVERALL TOTAL					43
903-3 SLB	Trap Rock	Cement	B	A	C	9		
	Trap Rock	Lime	A	A	A	12*		
						--		
							21	
	Granite (2)	Cement	C	0	0	2		
	Granite (2)	Lime	A	0	0	4		
						-		
							6	
							-	
			OVERALL TOTAL					27
924-1 NLB	Trap Rock	Cement	A	A	A	12*		
	Trap Rock	Lime	A	A	A	12*		
						--		
							24	
	Granite (2)	Cement	A	A	C	10		
	Granite (2)	Lime	A	A	0	8		
						--		
							18	
							--	
			OVERALL TOTAL					42

* Rated "High Performance"

Example 3 Ratings

With Trap Rock and hydrated lime each emulsion-filler system is rated AAA-12.

With the Granite(2) however, there is a compatibility problem which is severe enough to reject the use of the 903-3 SLB emulsion.

The 923-1 SLA and 924-1 NLB granite systems may be improved by altering the emulsion formulation and additive concentrations to improve their performances a point or two into the "high performance" category.

Note the overall rating totals of each system.

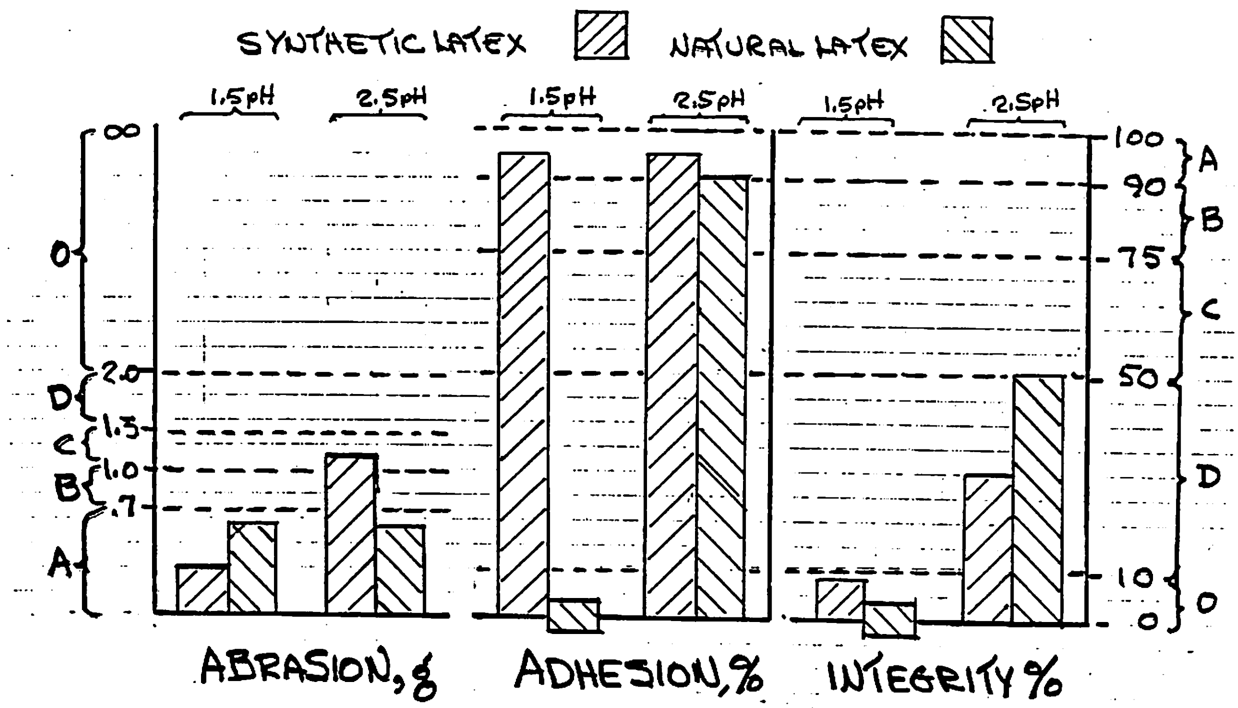

FIGURE 4. EFFECT OF pH, TWO LATEXES
#330 EMULSIFIER - GRANITE #2

Example 4 Effect of pH and Two Latexes with Granite (2).
(#330 Emulsifier)

Because of the system imcompatibility problem with Granite #2 shown in example 3, a different emulsifier was tried to improve the results. ABRASION losses increase when pH increases from 1.5 to 2.5 with
Synthetic latex while no change occurs with Natural latex.

Snythetic latex ADHESION is good at both pH levels while Natural latex adhesion is ZERO at 1.5 pH and rises to 90% at 2.5 pH!

INTEGRITY fails with both latexes at 1.5 pH but rises substantially
with an increase of pH to 2.5!

	1.5pH	2.5pH	Total
Synthetic Latex	AA0-8	CAD-7	15
Natural Latex	A00-4	AAD-9	13
TOTAL:	12	16	

Example 4 Ratings

Higher pH helps the Natural Latex in this case. Still higher pH's should be tried to improve the integrity to acceptable levels.

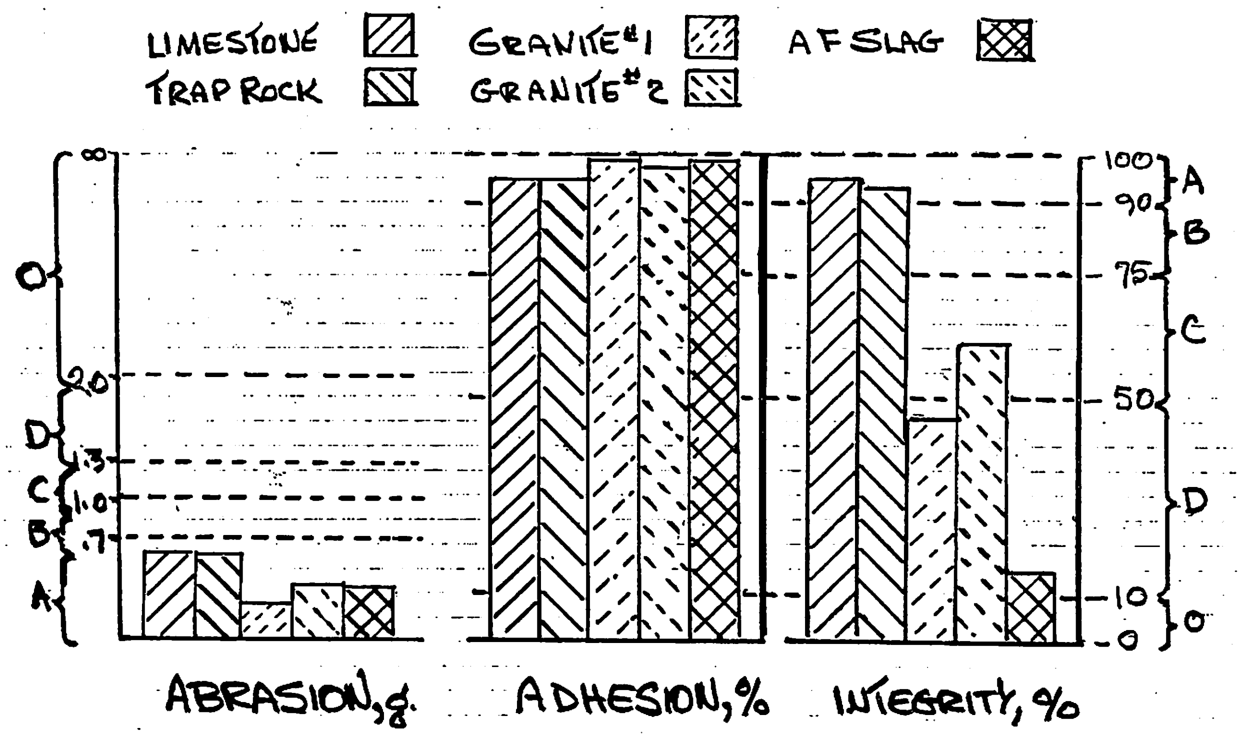

FIGURE 5, EFFECT OF A SINGLE MODIFIED EMULSION WITH FIVE AGGREGATES

Example 5 Effect of a Single Modified Emulsion on 5 Aggregates

Limestone L, Trap Rock, Granite (1), Granite (2) and an Arc Furnace Slag were used to prepare the Schulze-Breuer pills with the same Modified emulsion.

ABRASION losses and ADHESION test results all rated an "A". The INTEGRITY of Granites was about 50% but the Arc Furnace Slag results were poor.

Limestone L	A	A	A	12*
Trap Rock	A	A	A	12*
Granite (1)	A	A	D	9
Granite (2)	A	A	C	10
A.F. Slag	A	A	D	9

* High Performance

Example 5 Ratings

Excellent Abrasion and Adhesion results do not reliably indicate good high temperature cohesion or Integrity.

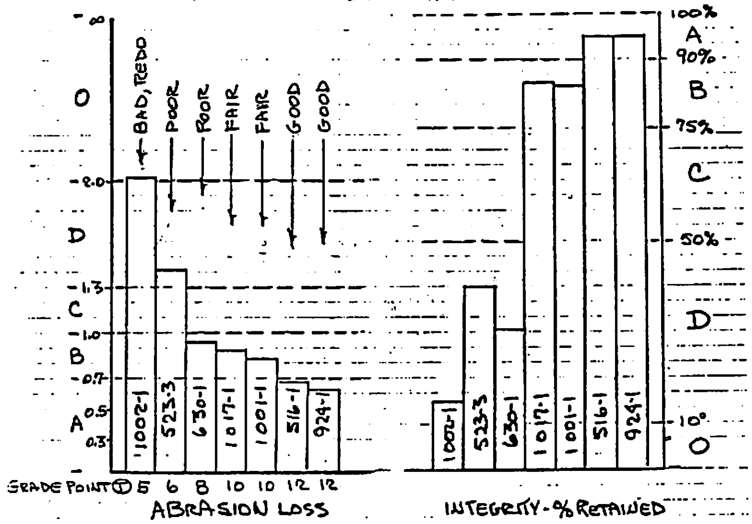

FIGURE 6 SCHULZE-BREUER-RUCK COMPATIBILITY TEST CORRELATION WITH FIELD PERFORMANCE

Example 6 Laboratory Results Correlated with Field Performance

Example 6 shows the Schulze-Breuer test results and compares them with our somewhat subjective evaluation of their field performance. The Modified emulsion was produced by the same manufacturer over two seasons. The same aggregate source was used. All applications were by the same contractor.

Our field evaluations are summarized:

Emulsion #	Comments	Compatibility Rating		
1002-1	Severe ravelling, areas of complete loss. Unacceptable to customer. Application repeated.	O A D	5	BAD RE-DO
523-3	Excessive initial kick out. Excessive multilayer instability. Poor color. Macrotexture loss.	O A D	5	POOR
630-1	Excessive multilayer instability re-rutted. Black color but "dead". Loss of Macrotexture.	B A D	8	POOR
1017-1	Some instability. Black initial color but grayed out quickly.	B A B	10	FAIR
1001-1	Same	B A B	10	FAIR
516-1	No loss of aggregate. Macrotexture maintained. Only very slight densification Good color retention	A A A	12	GOOD
924-1	Same	A A A	12	GOOD

All ADHESION values were 90% or more (A) and are not shown on the graph.

It is interesting that, as the ABRASION loss decreases, the INTEGRITY increases or improves.

Conclusions

1. The effect of a number of variables and their interrelationships on the Schulze-Breuer and Ruck Compatibility Test results has been shown. Variables included: Aggregate source, Bitumen source, Emulsifier Type and Formulation, Modifier type and Additive type.

2. A relative grading or classification system of objective understandable result numbers, which was presented for clarity and communication, has been introduced. While the specific category limits may be altered with more experience, the underlying principles will likely remain valid.

3. Abrasion loss alone does not appear to indicate complete compatibility, nor does good abrasion loss necessarily indicate good adhesion or integrity. Good adhesion does not indicate good integrity, but good integrity always has good adhesion.

4. The test procedure used in this report is attached as proposed ISSA Technical Bulletin #144 "Test Method for Classification of Aggregate Filler-Bitumen Compatiblity by Schulze-Breuer and Ruck Procedures".

5. All raw data for each series of tests is available from the author, but is not reproduced here.

6. The Schulze-Breuer & Ruck procedures should not be taken as exclusively decisive until thoroughly proven with a wide variety of material combinations. Other tests may offer confirmation by the Schulze Breuer Ruck Compatibility Test.

Reference:

Breuer, J. U., "Prüfung der Wasserempsindlichkeit von Gesteinmehlfullerm"
Institute von der T.H. Munchen, undated
Received July, 1982.

("Analysis of the Water Sensitivity of Rock Flour Filler") - "Bitumen" - 1967

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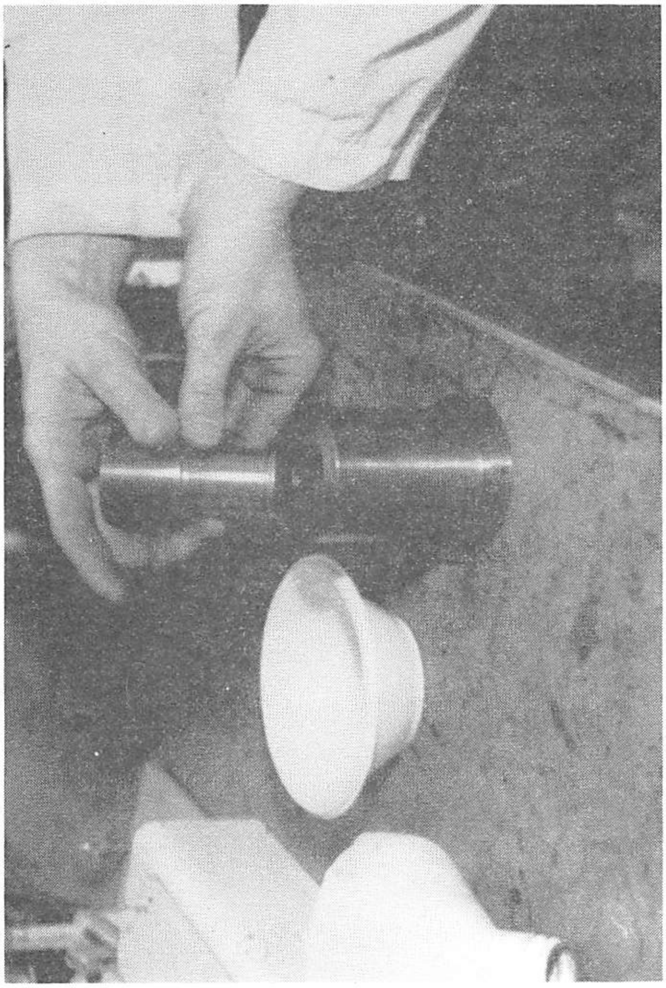
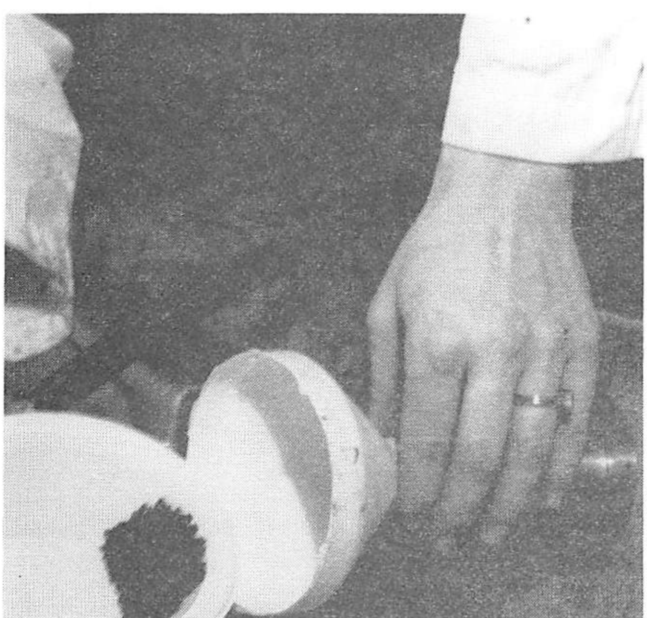
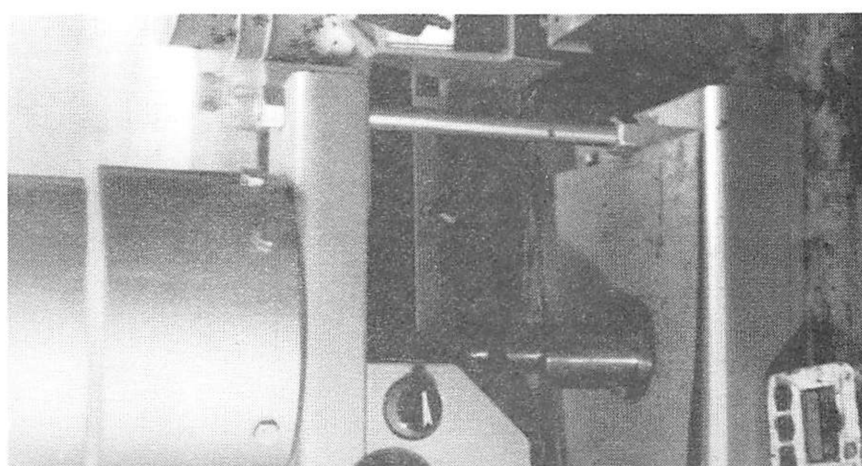
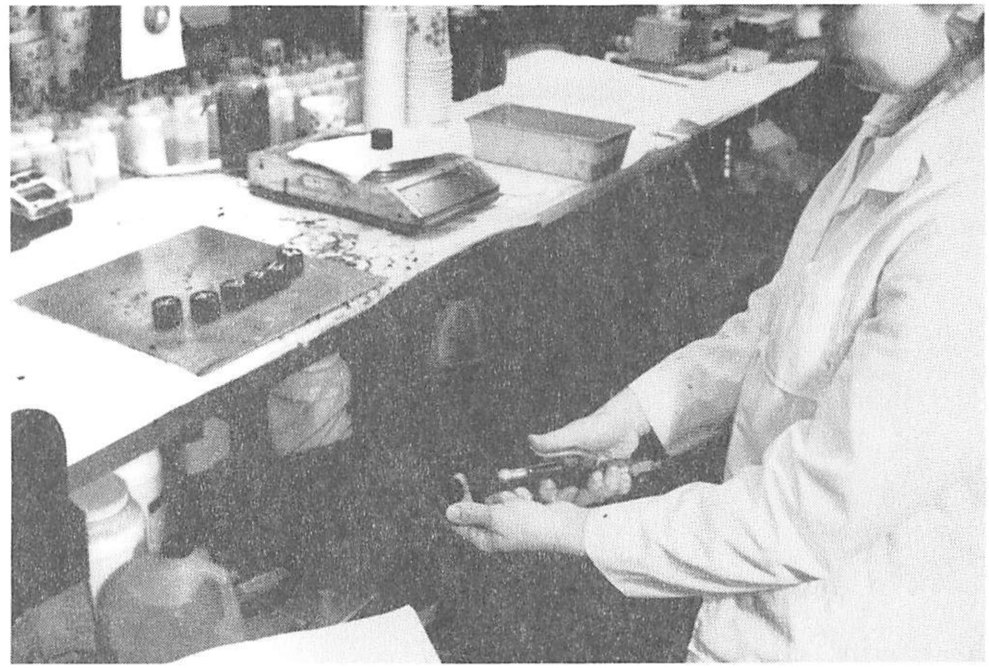
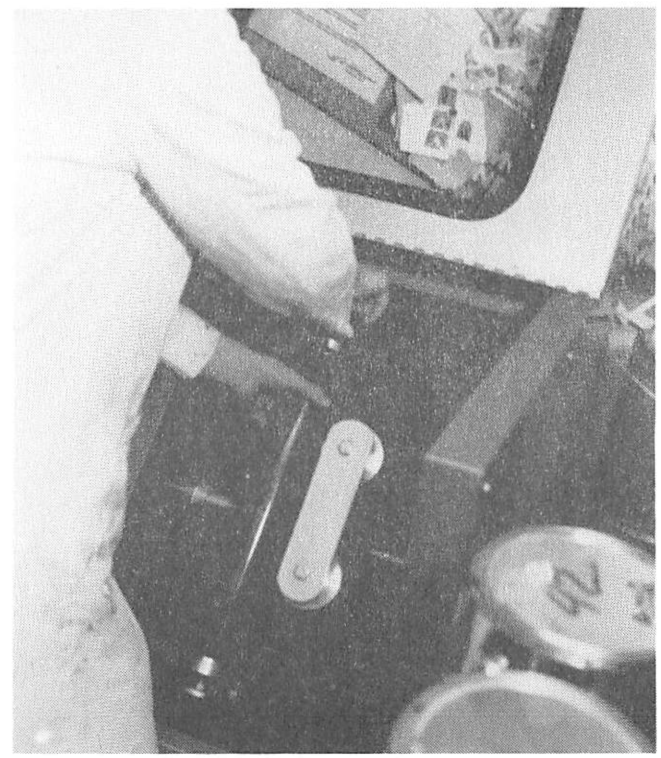
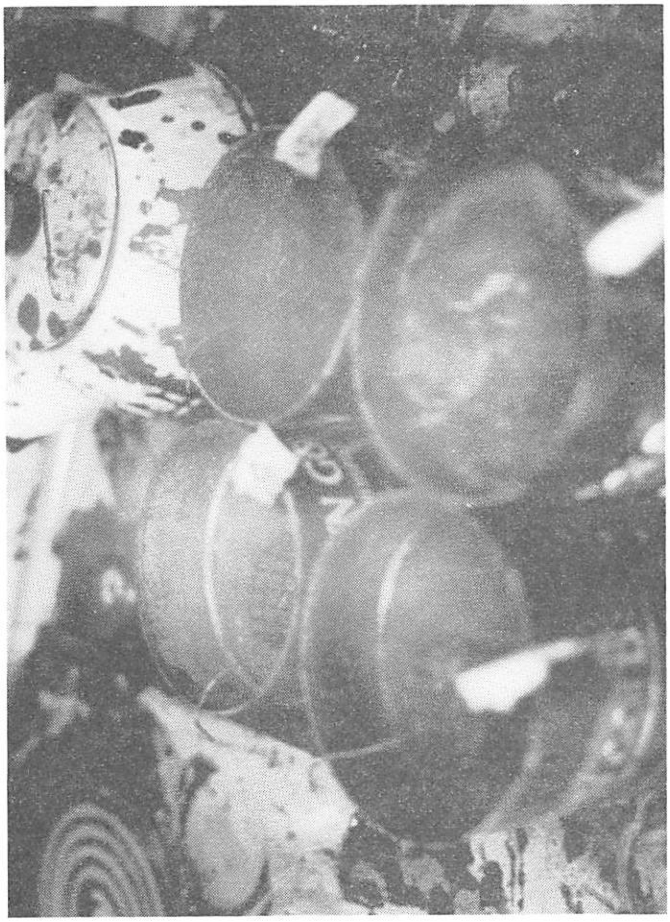


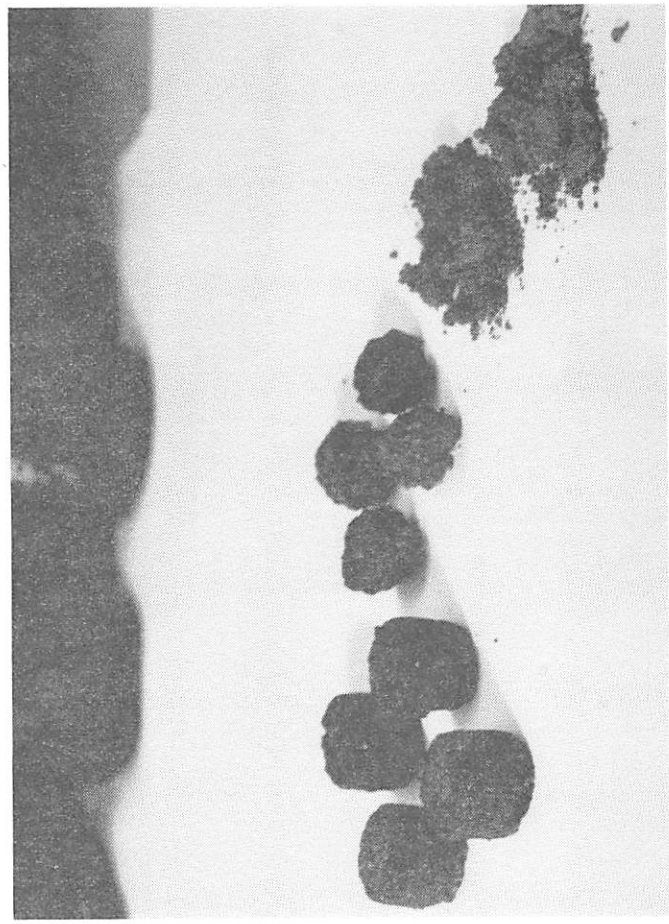



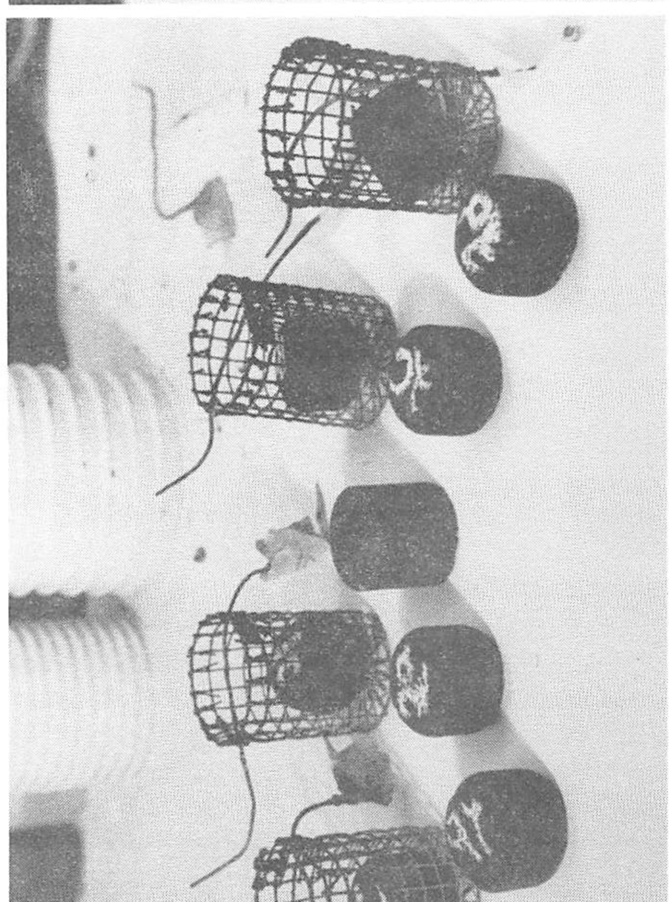

1a
1b
1d
2b
2d
3b
3c
3d

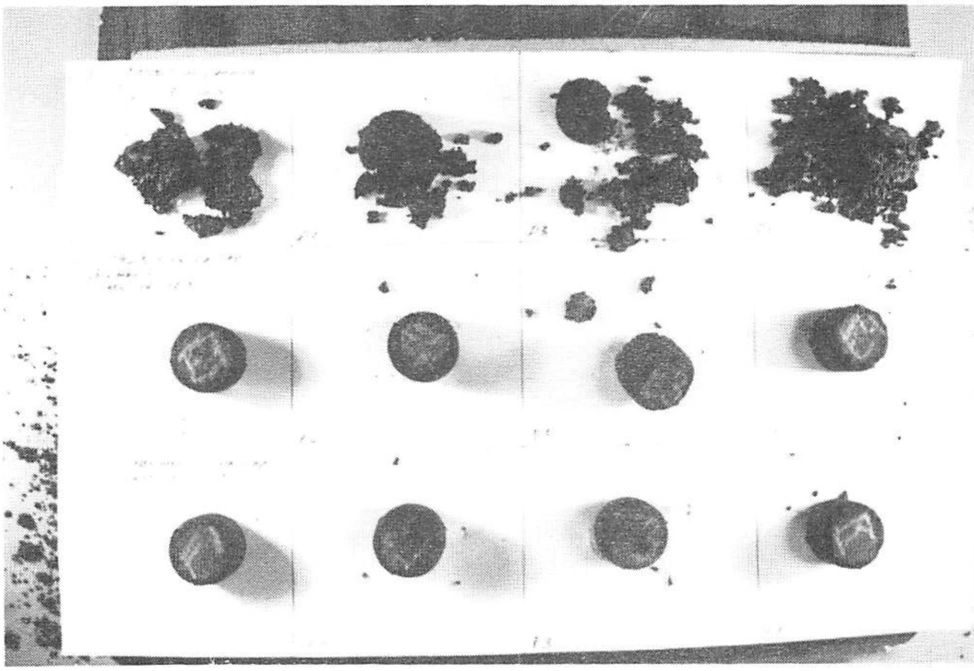


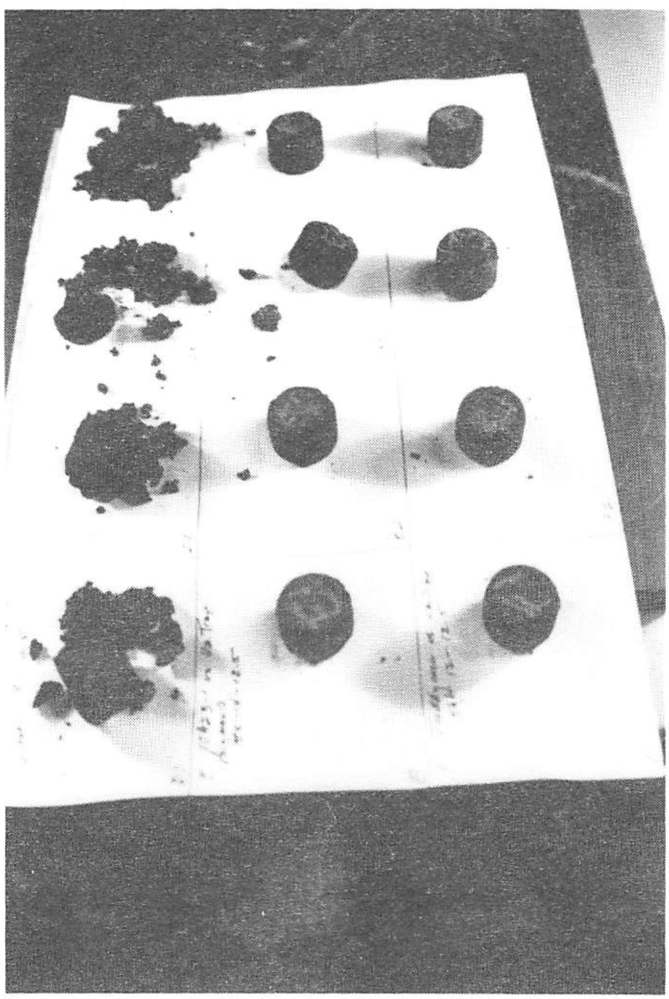


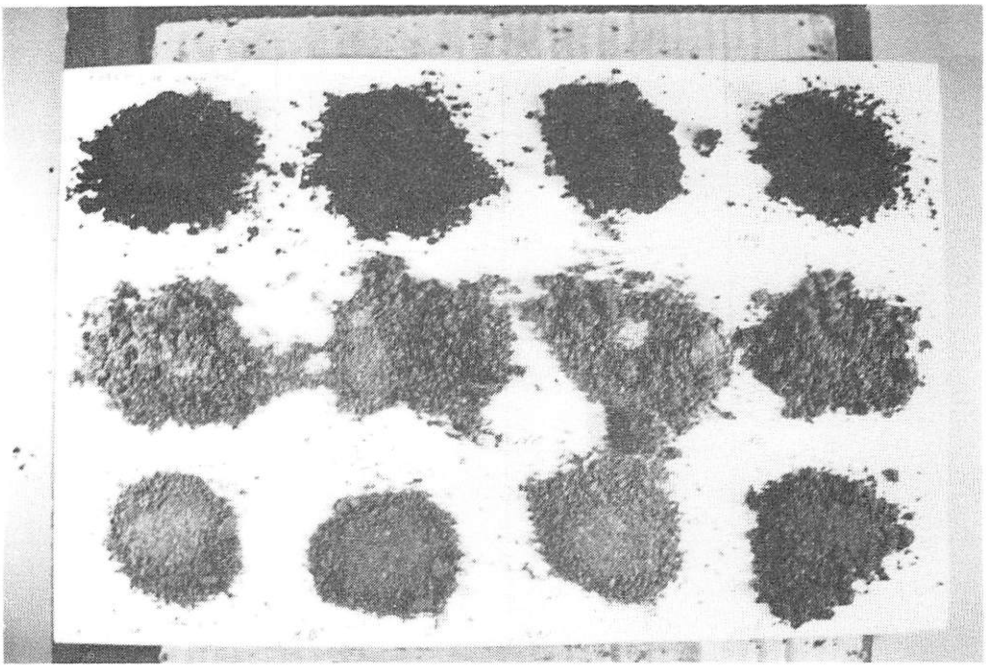


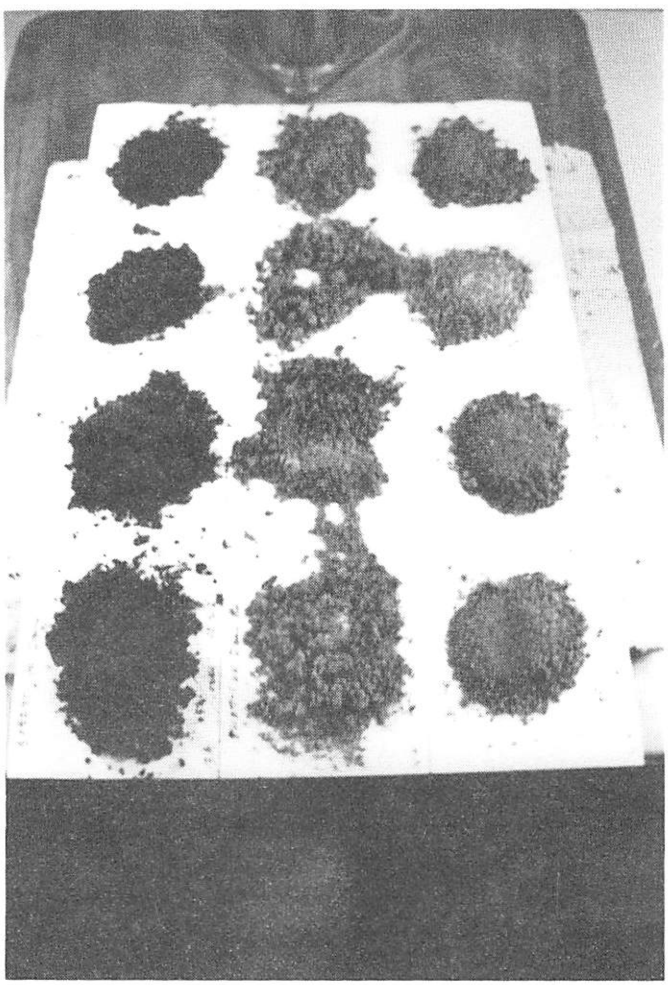












INTERNATIONAL SLURRY SEAL ASSOCIATION
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TECHNICAL BULLETIN NO. 144
PROPOSED FEBRUARY, 1989

TEST METHOD FOR CLASSIFICATION OF AGGREGATE FILLER-BITUMEN COMPATIBILITY BY SCHULZE-BREUER AND RUCK PROCEDURES

1. Scope

1.1. This test method covers the determination of the relative compatibility between aggregate filler of specific gradation and emulsified asphalt residue or bitumen.

2. Applicable Documents:

ASTM C-136	Methods for Sieve Analysis of Fine and Coarse Aggregates
D-244	Methods of Testing Emulsified Asphalts
D-3910	Standard Practices for Design, Testing and Construction of Slurry Seal
ISSA TB 113	Trial Mix Procedure for Slurry Seal
ISSA TB 114	Wet Stripping Test for Cured Slurry Seal Mixes
ISSA TB 115	Determination of Slurry System Compatibility

3. Significance and Use

3.1 The method provides a rating system or grading values for abrasion loss, adhesion and high temperature cohesion characteristics of a specified filler-bitumen combinations for comparison with test values of reference combinations. The test values may relate to the field performance of paving mixtures (1). The method has been successfully used abroad and is currently under study in the U.S.A.

4. Apparatus

4.1 Suitable mixing spatula and bowls or pans to contain 200 grams of mixture.
4.2 Scale sensitive to .01 +/- .005 grams
4.3 Forced draft oven set at 60C to meet ASTM E145 Specification for Gravity-Convection and Forced-Ventilation ovens
4.4 Room temperature water bath (25 C +/- 3C)

4.5 Pill mold(s) consisting of a base, a case 30 mm inside diameter by 70 mm height and 29 mm diameter ram (Figure 1) (2).

4.6 Constant force press capable of exerting a constant force of 1000 kg (2204 lbs) (Figure 2) (2).

4.7 Shuttle cylinders consisting of acrylic tubes 60mm inside diameter X 400mm inside length containing 1100 ml. +/- 25 ml volume and closed with water tight metal caps at each end, one of which is readily removable (Figure 3).

4.8 Abrasion Machine capable of holding at least 2 pairs of shuttle cylinders and rotating them end for end about a central axis at 20 RPM. (Figure 4) (2).

4.9 Open top 6mm (1/4") galvanized hardware cloth baskets 50mm dia X 50mm high with suitable means for suspension in boiling water. (Figure 5).

5.0 Materials

5.1 Water shall be tap water containing no harmful dissolved solids. For reference purposes, distilled water is used.

5.2 Emulsified asphalt to be used shall be thoroughly mixed and sieved through a 20 mesh strainer to remove any sieve or agglomerates.

5.3 Additives such as portland cement, hydrated lime, aluminum or ammonium sulfate or proprietary retarders or accelerators shall be used as desired. In the absence of these additives, 1% of Type 1 Portland cement shall be used as a standard reference.

5.4 Pure bitumen or asphalt cement may be used alone or in combination with additives such as antistrip in combination with a 50% solution of a non-flamable, low boiling point, inert solvent to facilitate mixing at 60C.

5.5 Aggregate to be used is dry sieved and re-graded as follows:

Metric Sieve	%	U.S. Sieve	%
710um to 2.00mm =	25%	#30 to #10 =	35%
250um to 710um =	40%	#50 to #30 =	25%
90um to 250um =	15%	#200 to #50 =	22%
0.0 to 90um =	20%	#0 to #200 =	18%

5.5 When the aggregate is not re-graded and is screened as received to 100% passing the 2.00mm (#10) screen, the test results shall so state.

6.0 Mixture Preparation

6.1 Add to a suitable mixing bowl, 200 grams of the prepared aggregate, 2 grams (1%) type 1 portland cement or the desirable amount of cement and/or other additives and sufficient water to produce a workable slurry (about 50 g). Pre-mix thoroughly before adding the emulsion.

6.2 Add the equivalent of 8.125% +/- .1% pure bitmen (12.5% of a 65% residue emulsified asphalt) and mix until broken. Transfer the broken, crummed slurry in to a suitable drying pan and allow a minimum of 1-hour air curing, then dry to constant weight in a forced draft 60C oven (about 18 hours may be required).

6.3 Place 40 grams +/- 1 gram of the 60C dried, uniformly crummed mixture into the mold, preheated to 60C, and immediately press the mix for one minute at a pressure of 1000 kg. (2204 lbs.). Remove the resulting pill from the mold and cool to room temperature.

7.0 Testing Procedure

7.1 Remove any loose flashing from the pill, weigh to the nearest .01 gram and submerge in a 25C +/- 3C water bath for 6 days.

7.1.1 After the 6-day soaking period, surface dry the pill by blotting with a hard surface paper towel until no wet spots appear on the towel. Immediately weigh to the nearest .01g and determine the weight of water absorbed and record as "Absorbtion".

7.2 Fill the shuttle cylinder with tap water to 750 ml +/- 25ml (2/3 full), place the pill in the cylinder, replace the removable end to close the cylinder and place securely in the abrasion machine.

7.2.1 Run the abrasion machine for 3 hours +/- 3 minutes at 20 RPM (3600 cycles). At each half turn the pill will fall through the water and hit bottom.

7.2.2 After 3600 cycles of abrasion, remove the pill from the shuttle cylinder and surface dry the abraded pill as in 7.1.1 and immediately weigh to the nearest .01 gram to determine the lost weight or "Abrasion" loss.

7.3 Place the abraded pill in the hardware cloth basket and suspend in a 800 ml beaker or other suitable container full of vigorously boiling water for 30 minutes.

7.3.1 Place the remains of the boiled pill on an absorbent paper towel. When surface dry, weigh the largest remaining coherent mass and record as a percent of the original saturated pill. This percentage is the high temperature cohesion value or, simply, "Integrity".

7.3.2 After air drying for 24 hours, estimate the percent of aggregate filler particles that are completely coated with bitumen. This percentage of relative coating is recorded as "Adhesion".

8.0 Report

8.1 Each test should report the average results of quadruplicate specimens to include:

Absorbtion	in grams absorbed
Abrasion loss	in grams lost
Adhesion	in percent coated
Integrity	in percent retained mass

8.2 The following suggested Compatibility Classification system is presented to simplify and to facilitate communication:

Grade Rating, Each Test	Point Rating, Each Test	Abrasion Loss, grams	Adhesion 30' Boil, Percent Coated	Integrity 30' Boil % Retained
A	4	0 - .7	90 - 100	90 - 100
B	3	.7 - 1.0	75 - 90	75 - 90
C	2	1.0 - 1.3	50 - 75	50 - 75
D	1	1.3 - 2.0	10 - 50	10 - 50
0	0	2.0 +	0	0

Note: European standards require only "less than one gram abrasion loss". It is suggested that 11 points total be established as a minimum rating for high performance polymer modified systems. For unmodified systems, the "Integrity" values may not be applicable and is subject to current field evaluation.

Footnotes

(1) See: Benedict, C. Robert, "Classification of Bitumen-Aggregate Filler Compatibility by Schulze-Breuer and Ruck Procedures" pres. to the 27th Annual ISSA Convention Kona, Hawaii, 1989.

(2) Schulze-Breuer Apparatus is available from C. Robert Benedict, c/o Polymac Corp. - Alpha Labs, P.O. Box 74, Alpha, Ohio 45301 513-298-6647. FAX 513-426-3368