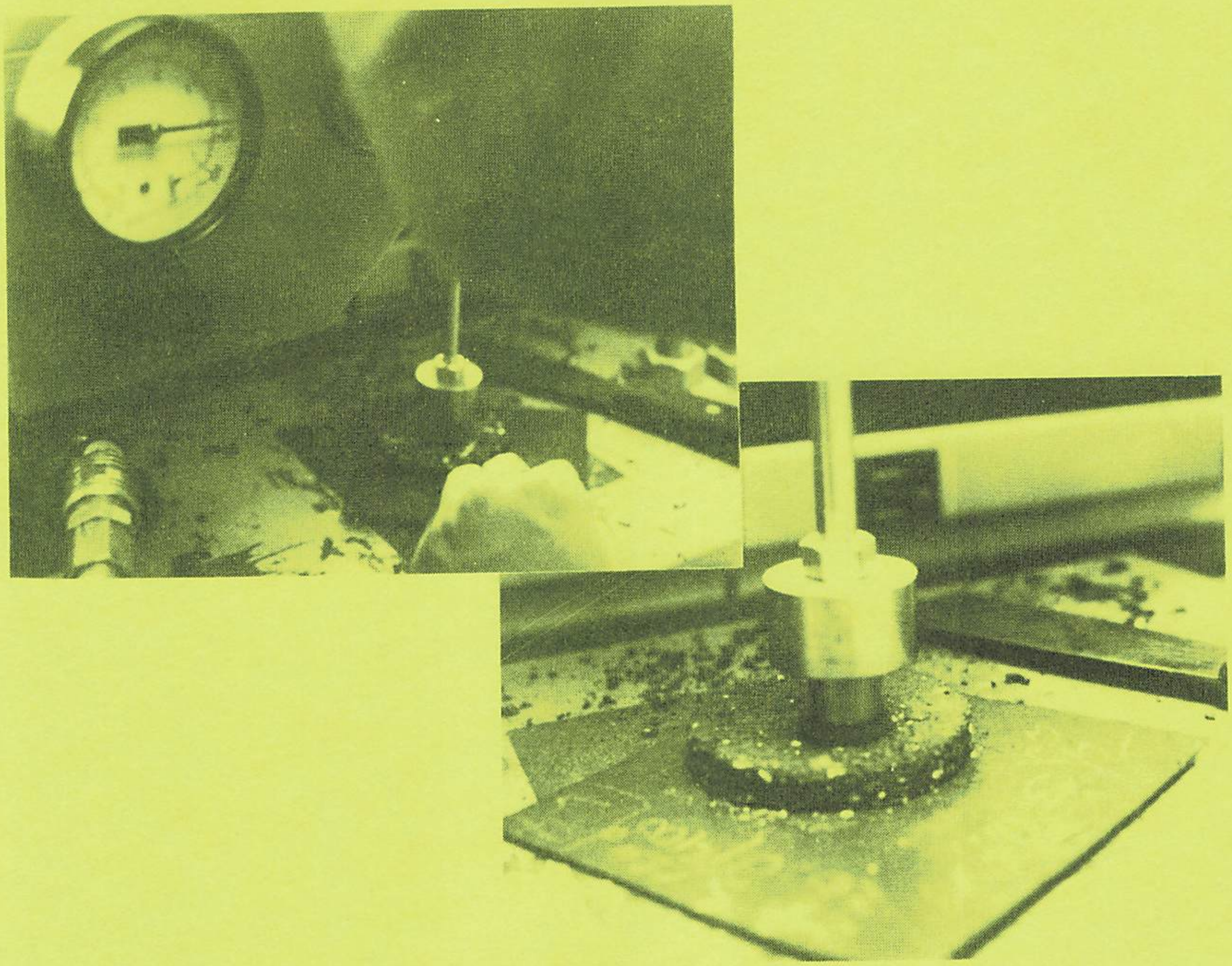
ROUGH DRAFT----NOT FOR PUBLICATION

AN APPROACH TO THE DESIGN OF FODLESS SLURRY MIXES FOR HEAVY AIRCRAFT AIRFIELDS

- EFFECTS OF FILLERS -

C. ROBERT BENEDICT, CONSULTANT
ISSA DIRECTOR OF RESEARCH
C/O POLYMAC CORP. - ALPHA LABS
P.O. BOX 74, ALPHA, OHIO 45301
PH: 513-298-6647
FX: 513-426-3368

AN INFORMAL REPORT PREPARED FOR PRESENTATION AT THE
ISSA RESEARCH COMMITTEE MEETING, 27TH
ANNUAL ISSA CONVENTION, FEBRUARY 12-16, 1989
KONA, HAWAII



AN APPROACH TO THE DESIGN OF FODLESS SLURRY MIXES FOR HEAVY AIRCRAFT AIRFIELDS----EFFECTS OF FILLERS / C. ROBERT BENEDICT 2/89

INTRODUCTION

Hundreds, if not thousands, of successful slurry seal applications have been made on light and heavy aircraft airfield pavement surfaces.

However, high temperature cohesion and mix stability problems have occurred when freshly laid, slurries are subjected to high surface temperatures (125 F+) and to the enormous shear forces encountered in turning maneuvers of heavy aircraft. These aircraft have tire contact pressures as great as 300 psi and more.

Typically, CSS-1h or SS1-h emulsions are used for airfield slurry mixes. These emulsions normally use an AC-20 bitumen whose softening points are about 120 F; lower than the surface temperatures encountered during the heat of the day! We have noted that high temperature mix stabilities decrease substantially when low fines (0/#200) and/or high bitumen contents are present.

PURPOSE

It is our purpose here to investigate the high temperature stiffening effect of (1) the quantity of 0/#200 fines/fillers (2) the quantity of portland cement or lime added and (3) latex addition.

Because of many reported difficulties with "kick-out" of large size aggregate particles when ISSA type 3 or coarse type 2 gradations are used, this preliminary study used only aggregate gradations of which 100% passed the #4 (4.75mm) screen while the 0/#200 content was varied at 4, 12 and 20%. Emulsion contents were held constant at 12% added or about 7.5% binder extracted from the dry total. The 12% range of emulsion content has been determined as at or near optimum for maximum stability of 0/#4 gradations in performance systems. Higher bitumen contents are generally required when commodity grade bitumens are used.

OBSERVATIONS

In the UK the 35, 45 & 60C (95, 115, 140 F) wheel tracking rates of compacted hot rolled asphalt concrete has been directly related to the ring and ball softening point. Figure 1 (1) shows this relationship where, if a 2 mm per hour wheel tracking rate is desired, a 64C (147.2F) R&B softening point is required.

Here in Maui, Hawaii in 1984 we reported on the stiffening effect of cement and lime contents on a 114F R&B AE residue where 40% of the bitumen weight was hydrated lime. The penetration was dropped from 113 to 57 and the R&B was raised from 114F to 128F, figure 2 (2).

In Orlando in 1985, Alan Brooker (3) gave us a complete overview of the effects of aggregate filler on bitumen properties including R&B, viscosity, penetration and ductility. There appeared to be a break in the slope of the curves at a fines/bitumen weight ratio of between 1.0 and 1.5 (100-150%). (figure 3).

EFFECTS OF STONE FILLER, CEMENT AND LIME AND RUBBER CONTENTS ON R&B SOFTENING POINTS

To begin our experiments, we investigated the effects of the addition of 0/#200 stone filler, portland cement and hydrated lime to AC-20 on the Ring and Ball (4) softening point. With no 0/#200 stone filler the R&B was raised from 122 to 128F with 40% cement addition. And, when 100% 0/#200 Iofolls Granite was added with 40% cement, the R&B was raised to 146F or 24F., i.e. 8F due to cement and 16F due to the stone dust as shown in fig. 4.

When 40% cement and 100% Sandusky Dolomite 0/#200 filler is added to the bitumen instead of the granite filler, the R&B is increased from 122F to 158F or 36F. The Dolomite filler alone at 100% increases the R&B only 10F to 132F but the additional 40% cement seems to have a synergistic effect by increasing the R&B an additional 26F to 158F---8F more than when the granite filler is used under the same conditions.

Also shown, in figure 5, is the effect of 3.4% Natural and Snythetic latex solids content of the bitumen. With no fillers, the rubbers alone increased the R&B from 122 to 136 and 140F respectively or 14 to 18F. By the addition of only 20% cement and 100% 0/#200 stone filler and 3.4% Rubber, the R&B's were increased 40 to 52F to 162 and 174F respectively.

From these few experiments, it is quite apparent that the addition of 0/#200 stone filler, portland cement or hydrated lime and both natural and synthetic latex that THE R&B softening point of the bituminous binders in slurry mixes may be significantly increased to as high as 180F (82C) or more. It is also noted that low ratios of filler additions to the bitumen has only a slight effect, and that the chemical type of stone dust filler and type of chemically active fillers affect the stiffening rate as measured by the R&B softening point.

EFFECT OF FILLERS & LATEX ON 60C (140F) CURED MIX COHESION

Two emulsions were prepared using the same base asphalt and same emulsifier; one plain and the other with 3.4% snythetic latex solids based on the bitumen content.

Three aggregate gradations were prepared using Sandusky Dolomite and containing 4%, 12% and 20% 0/#200 stone filler which correspond to about 50%, 150% and 250% filler-bitumen ratios and identified as A, C and E gradations; i.e., when 12% emulsion was added to the mix (7.5 to 8% AC added), the gradations were all 100% 0/#4 (0/4.75mm).

Mixes were made and cast in 6mm and 10mm x 60mm dia. cohesion test molds (ISSA TB139) (7) combining 0.8, 1.6 and 3.2% portland cement (10, 20 and 40% filler - bitumen ratios) with the "A", "C" and "E" gradations.

The cohesion test "cookies" were force draft oven cured at 60C (140F) for 18 to 20 hours and cohesion tested using the standard manual method at 200kPa and 60C.

The 60C cured cohesion results were not very illuminating. However, when the data points are re-grouped as in figure 6, into a rising filler concentration series, an interesting pattern emerges. The rubber modified series (923-1) sharply peaks at 150% filler and 10% cement-bitumen ratios.

The plain emulsion (116-1) series was over-all more linear than the modified series. Less cement was required at high fines ratios for the best or highest cured cohesion.

It is interesting that the polymer modified emulsion cured cohesion peaked at 150% fines and 10% cement ratios and also gave the greatest resistance to the Loaded Wheel Test multilayer, vertical displacement at this point as seen in figure 7.

All 6mm uncompacted and unconfined 60C cured cohesion specimens failed or severely ravelled under the normal 200 kpa pressures. (Correcting for the 1 1/8" cylinder ID and 5/16" piston rod diameter and using the 1 1/8" dia rubber foot, the contact pressure is 26.6 psi at 200 kPag.)

EFFECT OF COMPACTION ON 60C CURED COHESION.

The 10mm specimens rings were not removed initially after curing for 18 to 20 hours at 140F. One set of specimens was immediately compacted with a flat steel disc plate while the other set was compacted by placing a 1/4", 60 durometer neoprene pad between the specimen and the steel disc, to preserve macro-texture.

Static compaction was accomplished with one ton of force for one minute at 140F which approximated 500 psi. The compacted 10mm specimens were compacted about 20% or to 8mm thickness. Compacted densities ranged from 1.8 to 2.1 and apparent voids ranged from 8 to 16%. The steel compacted surfaces were smooth and flat while the rubber compacted surfaces had rough textures.

Initially, all compacted samples were tested with ring molds in tact at 140F and 200 and 400 kPa gauge pressure using the standard 1 1/8" dia. rubber cohesion tester foot. Then the standard 1 1/8" dia. foot was replaced with a 9/16" dia. foot thus multiplying the relative force by four. All of these cohesion tests merely slipped or spun on the specimen surface with no damage whatever. The mold rings were then removed and testing proceeded at 140F, but unconfined, at pressures of 1600 and 2400 kPa guage or the actual contact pressures of 213 and 319 psi.

Figure 8 shows the "slip" torque for the steel and rubber compacted specimens. Generally, the rubber compacted surfaces were rougher in texture and required more torque to slip than the smooth surface steel compacted specimens.

Figure 9 plots the torques required to "slip" or "spin" solidly on the specimens' surface at all contact pressures used. The torques required were essentially the same at each contact pressure with the modified bitumens requiring slightly more torque to slip than the plain bitumens.

Table 1 summarizes results of these initial experiments which again were conducted at 140F. It is noted that:

(1) All monolayered (6 mm) uncompacted specimens failed by producing unacceptable FOD or loose slurry particles at normal auto tire contact pressures of 26.6 psi.

(2) All multiple layered, compacted specimens produced no FOD at contact pressures of 213 psi and less.

(3) All multi-layered modified bitumen specimens were FOD free at 319 psi contact pressures except for the highest 0/#200 filler content (20%)

(4) All multilayered plain bitumen specimens failed at 319 psi contact pressures, but were satisfactory at 213 psi.

			STEEL COMPACTION					RUBBER COMPACTION				
		UNCOMPACTED	CONFINED			UNCONFINED		CONFINED			UNCONFINED	
psi g.		30	30	60	170	240	360	30	60	120	240	360
kPa g.		200	200	400	800	1600	2400	200	400	800	1600	2400
Contact psi		26.6	26.6	53	106	213	319	26.6	53	106	213	319
	% 0/#200	MODIFIED						MODIFIED				
A	4	F	SS	SS	SS	SS	SS	SS	SS	SS	SS	SS
C	12	F	SS	SS	SS	SS	SS	SS	SS	SS	SS	SS
E	20	F	SS	SS	SS	SS	SS	SS	SS	SS	SS	F
		PLAIN						PLAIN				
A	4	F	SS	SS	SS	SS	SS	SS	SS	SS	SS	F
C	12	F	SS	SS	SS	SS	SS	SS	SS	SS	SS	F
E	20	F	SS	SS	SS	SS	F	SS	SS	SS	SS	F

SS = Solid Spin
F = Failed

TABLE 1 QUALITATIVE ANALYSIS OF MULTILAYER TORQUE FAILURE AT 60C (140F) 12% AE, 0/#4

SUMMARY

1. The manual Modified Cohesion Tester a power steering simulator,(ISSA TB139) was further modified to produce contact pressures as high as 319 psi.

2. The effects of 0/#200 stone filler, hydrated lime and portland cement chemical fillers, and latex modification on the slip high pressure torque and cohesion as well as their effects on the ring and ball softening points of the bitumen and loaded wheel test displacement stabilities have been examined.

3. Stone filler, chemical filler and polymer modification requirements for high temperature FODless or FOD resistant slurry mixes may be determined by the methods presented.

4. When 150 psi supply air pressure is available, the ISSA TB139 manual cohesion tester may be adapted to produce 550 psi contact pressures by installing a higher pressure guage and using a 9/16" diameter rubber foot.

5. Field methods of application and compaction to achieve the necessary densities need to be developed.

6. TENTATIVE RECOMMENDATIONS FOR HEAVY ARICRAFT FODLESS SLURRY DESIGN:

A) Adequate compaction is required.

B) Two-courses or multilayers may be required to achieve adequate compaction.

C) Rubber compaction gives more macrotexture while steel compaction may require thicker lifts to avoid aggregate crushing.

D) Compaction densities of 1.80 to 2.10 (112 to 132 PCF) and voids ranging from 8.0 to 16.0% appear to be adequate.

E) Avoid very high stone filler (0/#200) contents, especially with very high (3%) cement or lime contents. (Loss of cohesion and crumminess results).

F) Effective ring and ball softening points (due to filler-polymer combinations) should be 30 to 40F (17-22C) above the maximum anticipated surface temperature.

G) Adequate effective ring and ball softening points cannot be achieved with fillers alone without a severe loss of cohesion and adhesion making the use of polymers necessary.

H) Low total liquid content aggregate-emulsion systems along with medium setting characteristics to aid in (initial void reduction and compaction are recommended.

I) All ingredients should be highly compatible as suggested in the Schulze-Breuer compatibility test (ISSA TB144) to avoid loss of fines and to insure good adhesion and high temperature cohesion.

REFERENCES

1. JACOBS, FA "Hot Rolled Asphalt: Effect of Binder Properties on Resistance to Deformation" TRRL Laboratory Report 1003, 1981, Transport and Road Research Laboratory, Crowthorne, Berkshire, U.K.

2. BENEDICT, C.R. Informal Presentation on Slurry Seal Design Problems, 22nd ISSA Convention, Maui, Hawaii; Feb. 1984.

3. BROOKER, ALAN C. "Effects of Filler Contents on Asphalt Cement Properties "Pres. 23nd ISSA convention, Orlando, Florida; Feb. 1985.

4. ASTM D36 Test Methods to Determine Softening Point, Ring and Ball. See also: ASTM D2398 and AASHTO T53.

5. ASTM D3910 "Standard Practices for Design, Testing and Construction of Slurry Seals" Annual Book of Standards, Volume 04.03, American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

6. BENEDICT, C. R. "Classification of Asphalt Emulsion/Aggregate Mixture Systems by Cohesion Tester Measurement of Set and Cure Characteristics". Proc. 21st ISSA Convention, Feb. 1983, Phoenix, AZ

7. ISSA TECH BULL. 139 AND TB 109 (Above) "Design Technical Bulletins - 1984" International Slurry Seal Assn, 1101 Connecticut Ave., NW, Washington DC 20036.

8. BENEDICT, C. R. "Uses of the Modified Cohesion Test for EmulsionFormulation and Mix Design of Performance Cold Mix Systems", pres. 12th Annual Convention of the Asphalt Emulsion Manufacturers Assn., New Orleans, March 1985.

9. BENEDICT, C. R. "Experiments with Cured Cohesion Testing of Slurry Seals and Thin Layered Cold Mixes", pres. 24th Annual ISSA Convention, San Francisco, Jan. 1986.

10. BENEDICT, C. R. "Effects of Aggregate Filler Content variation and Cement Presence on the Laboratory Properties of a Single Slurry Seal System", Pres. 25th Annual ISSA Convention and 2nd World Congress on Slurry Seal. March, 1987, Geneva, Switzerland.

11. BENEDICT, C. R. "Classification of Bitumen-Aggregate Compatibility by Schulze-Breuer & Ruck Procedures" (ISSA Tech Bull 144) pres. 27th Annual Convention, Feb 1989, Kona, Hawaii.

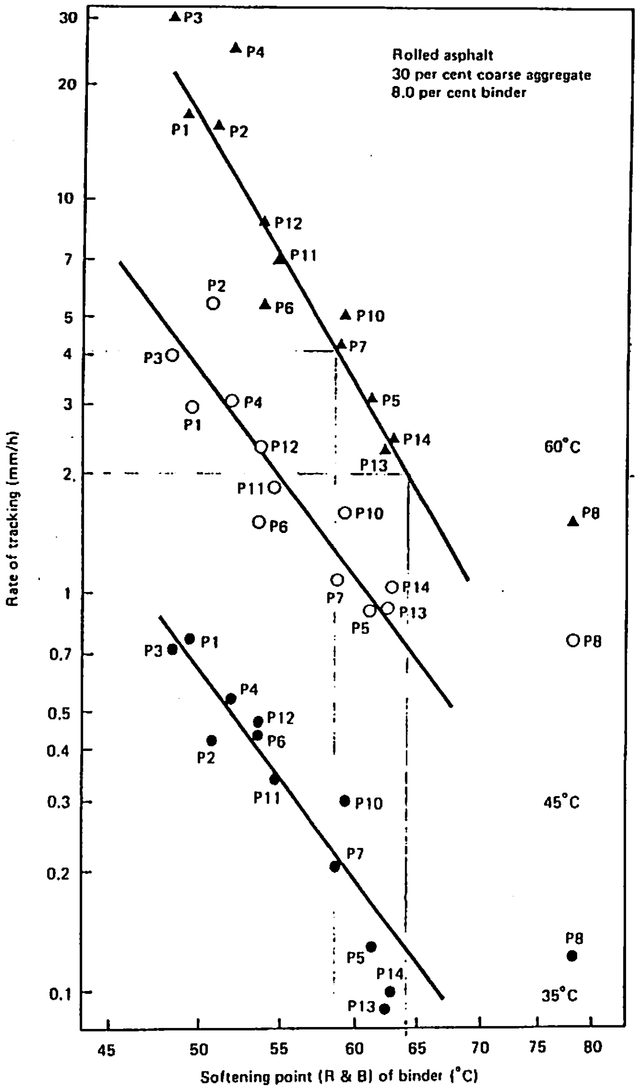


Fig. 1 Effect of softening point of binder on rate of tracking at 35, 45 and 60°C

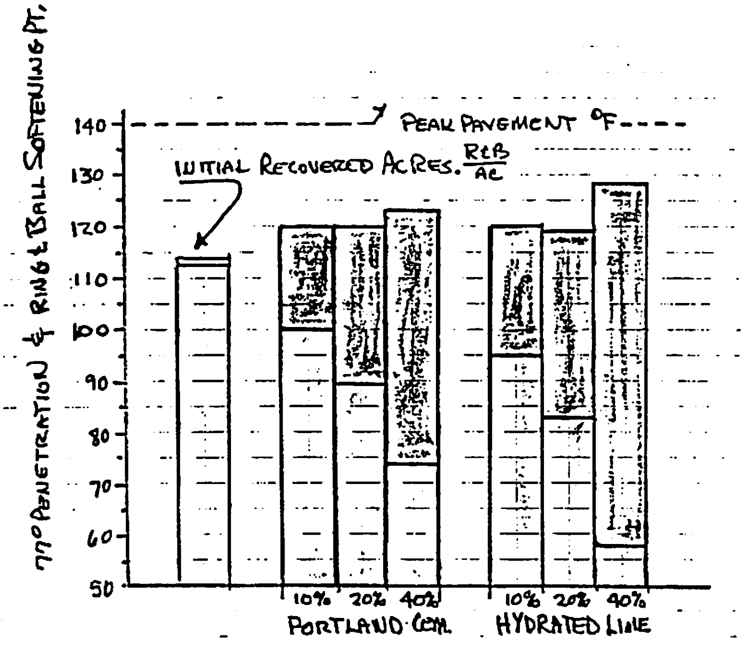


Fig. 2 STIFFENING EFFECT OF FILLERS ON #33 RECOVERED AC RESIDUE

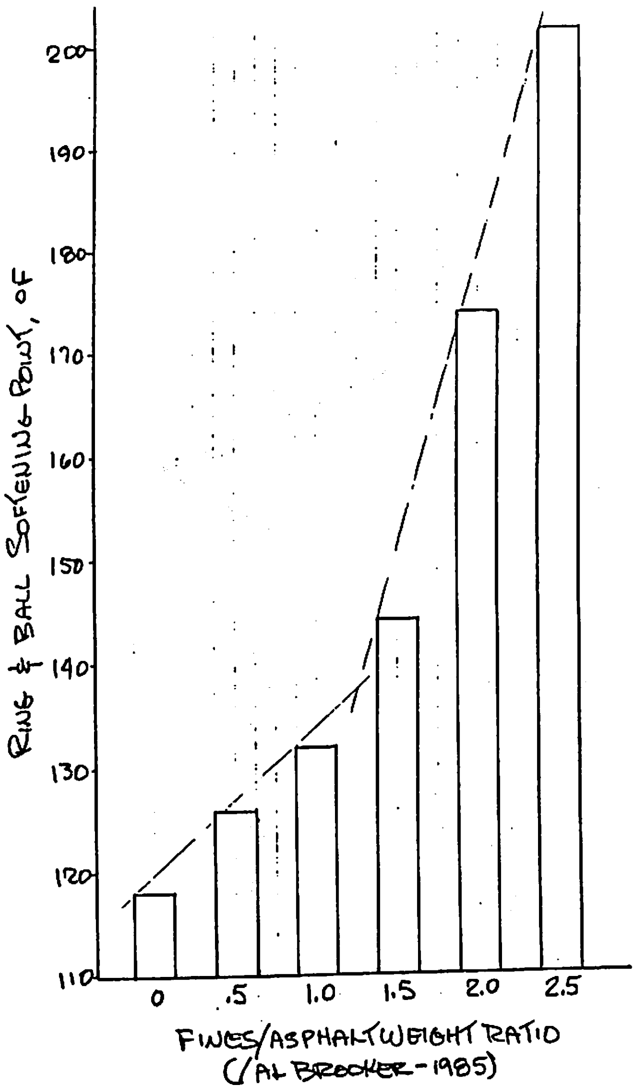
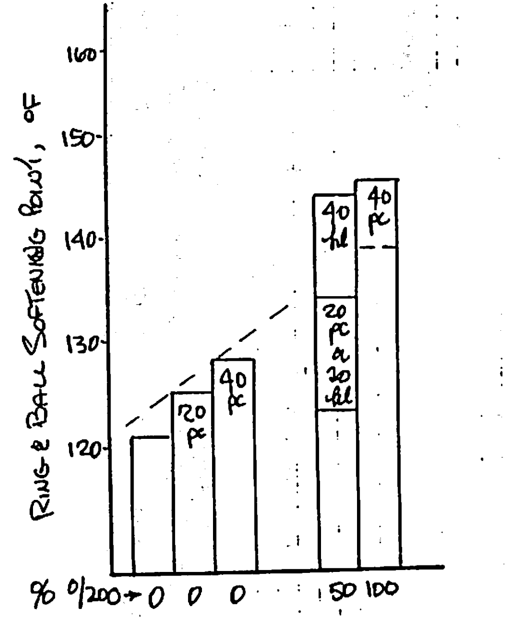
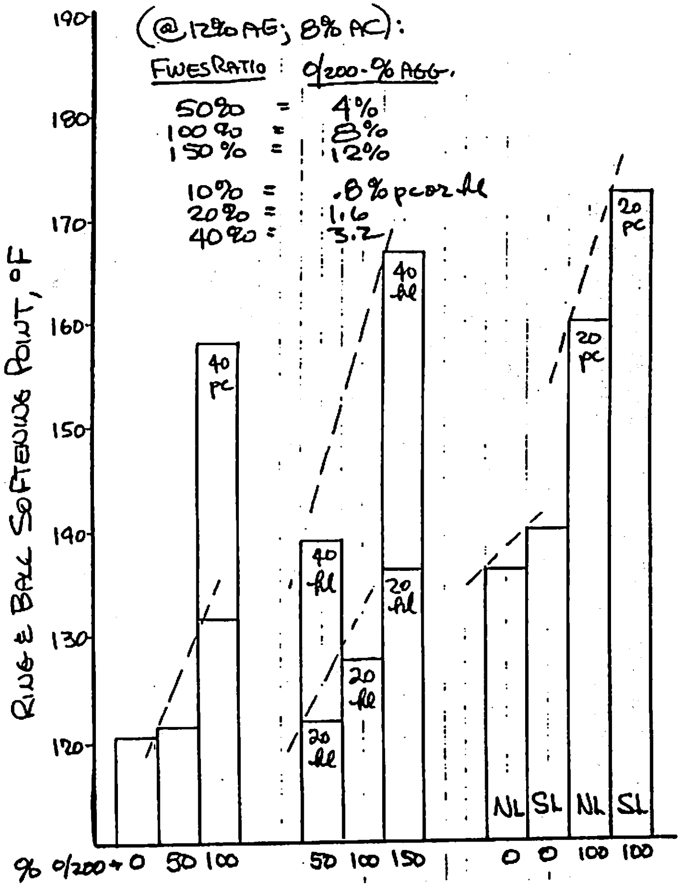


figure 3



EFFECT OF 0/200 & CHEMICAL FILLER ADDITION ON R&B (IOFOLLA GRANITE)

figure 4



EFFECT OF WEIGHT PERCENT ADDITION OF 0/200 AGG. FINES & CHEMICAL FILLERS, TO AC-20 ON R&B SOFTENING POINT (SANDUSKY DOLOMITE)

figure 5

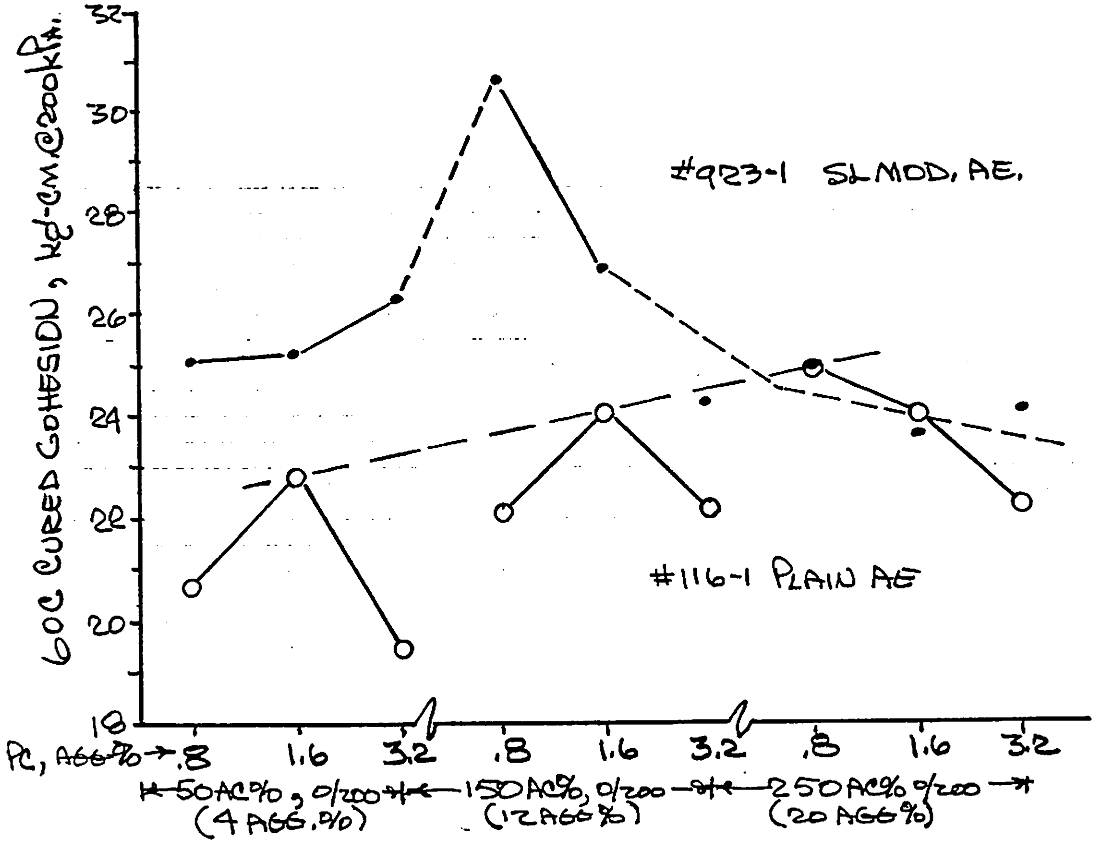


figure 6 60°C Cured Cohesion, 6mm Uncompacted

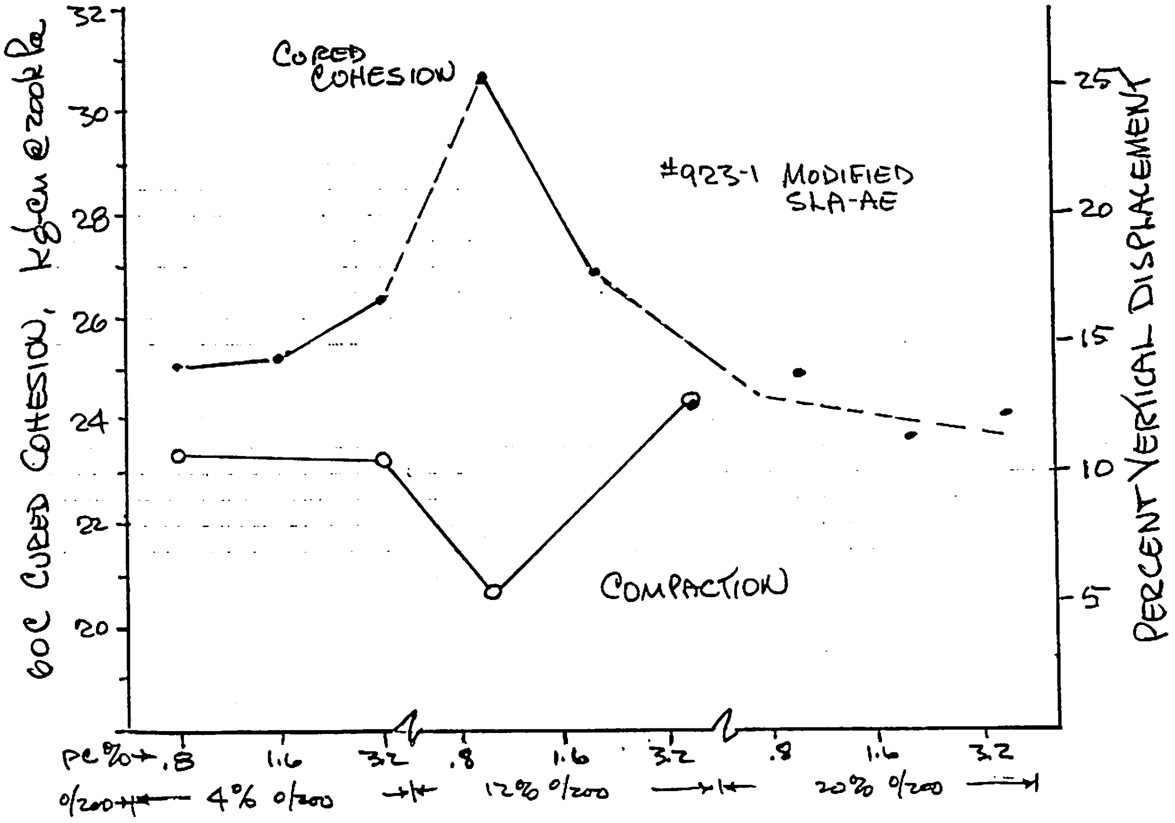


figure 7 60C CURED COHESION & LWT VERTICAL DISPLACEMENT VS. 0/200 & CEMENT %

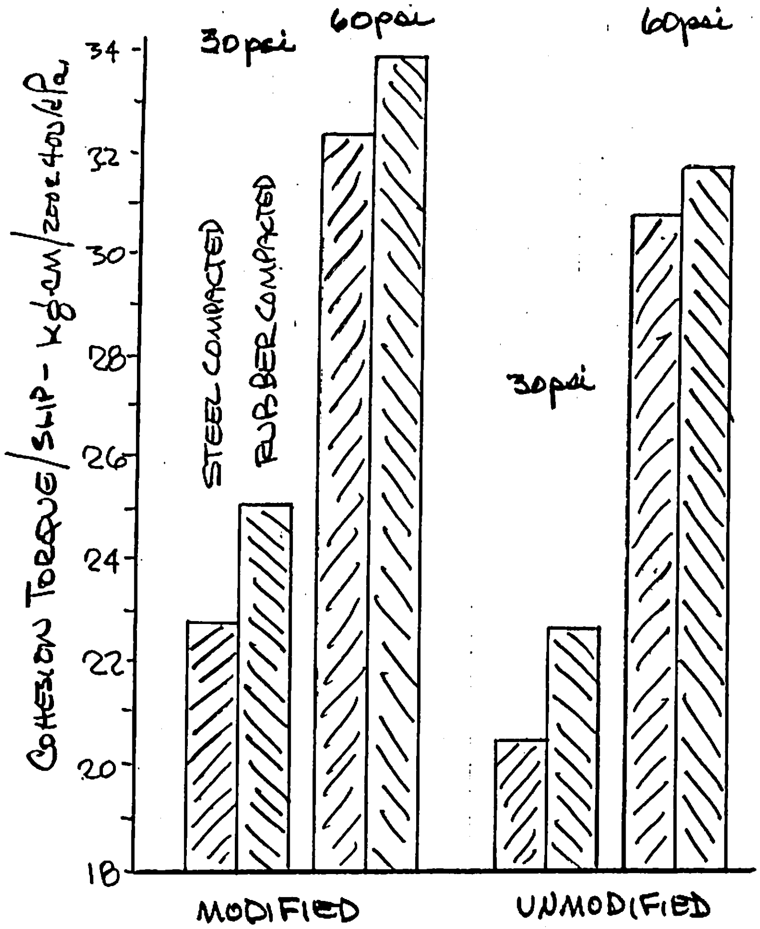


figure 8 60C HIGH TEMPERATURE FRICTION
10mm COMPACTED & CONFINED BY
COHESION TESTER - OVERALL AVERAGE

COMPACTION BY STEEL & RUBBER PLATES
1 TON FOR 1 MINUTE @ 60C

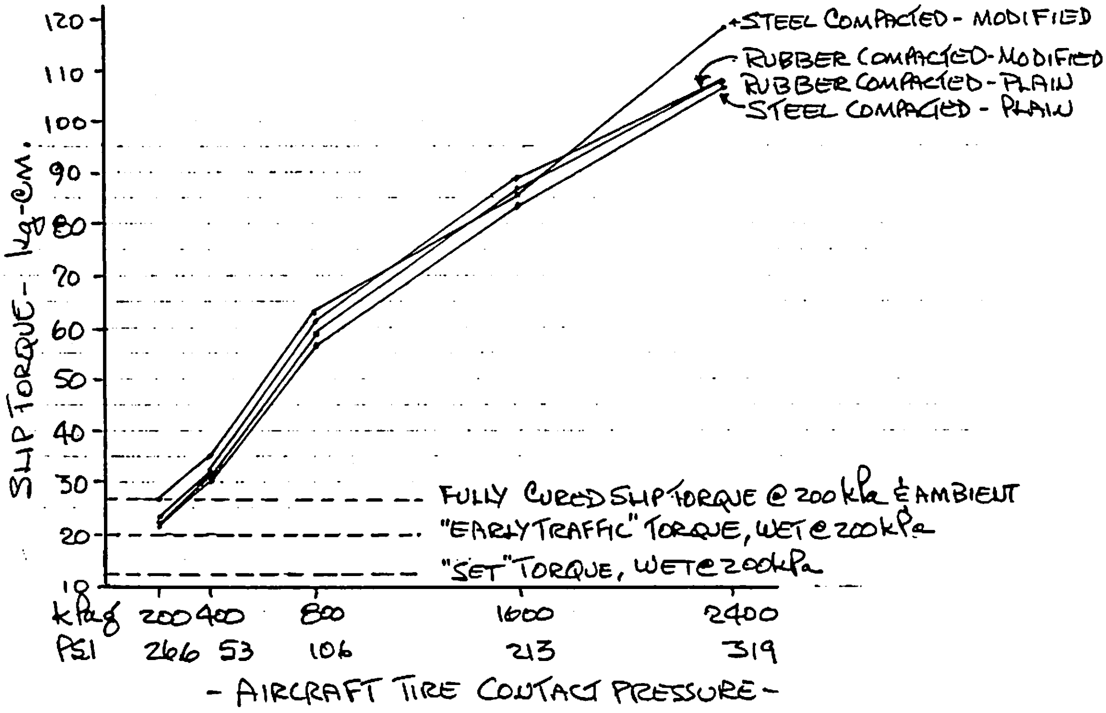
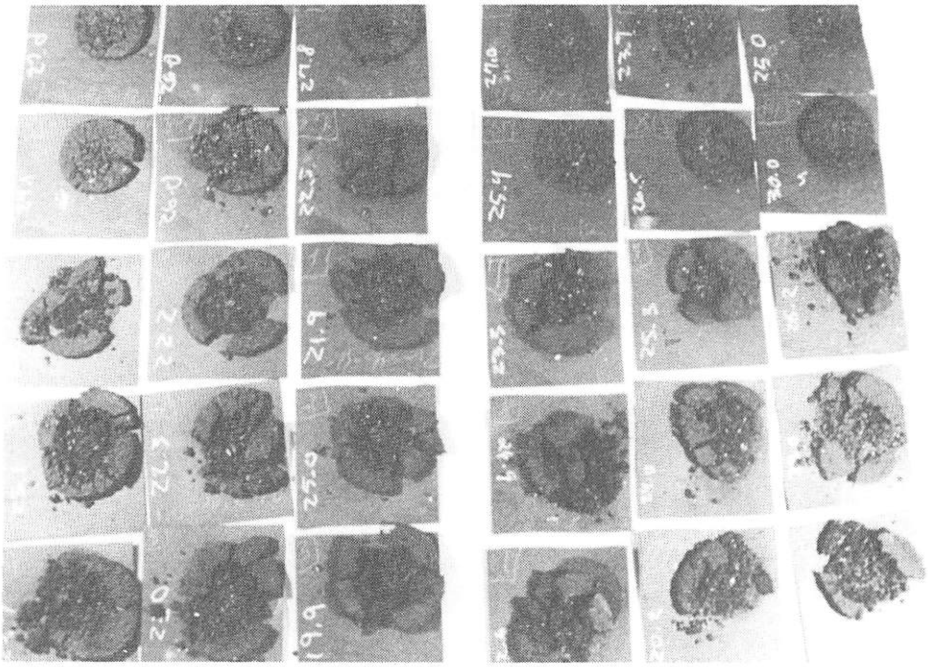
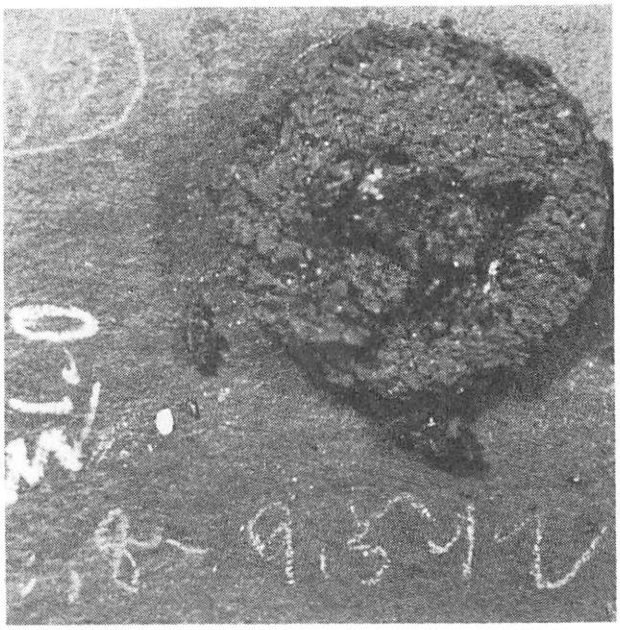


FIGURE 9 TIRE CONTACT PRESSURE VS. SLIP TORQUE
ON 8mm STEEL & RUBBER COMPACTED
PLAIN & MODIFIED SLURRY @ 60C (140F)

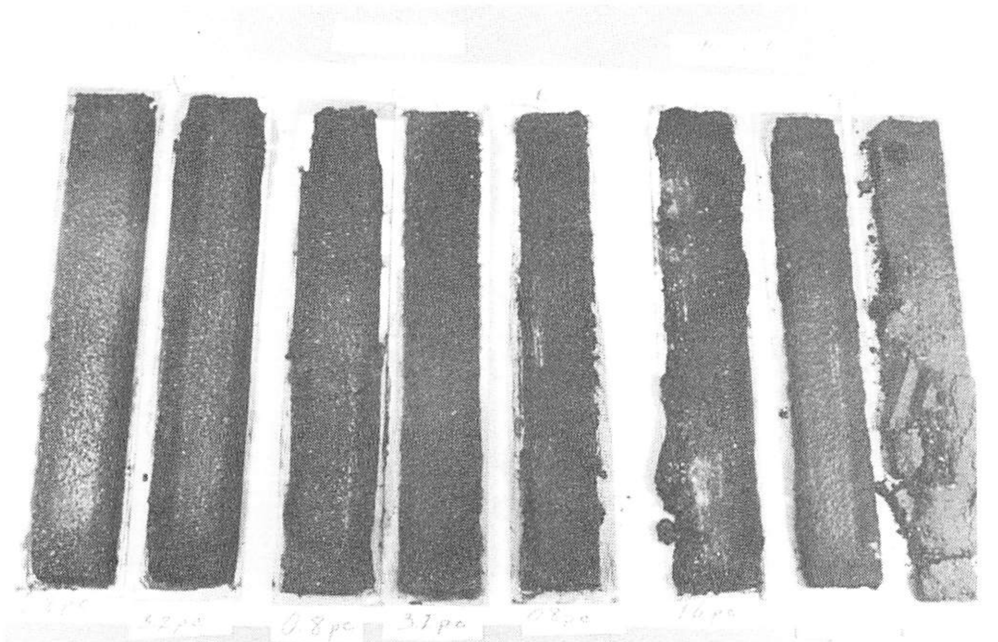
2/89



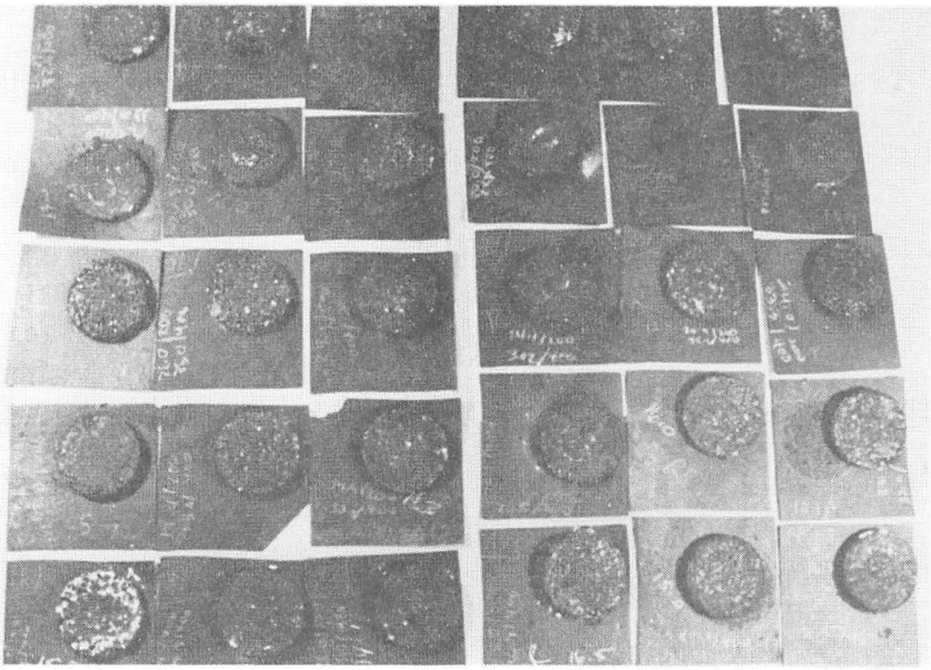
60 cured cohesion 6mm specimens
uncompacted - 26.6 psi contact pressure



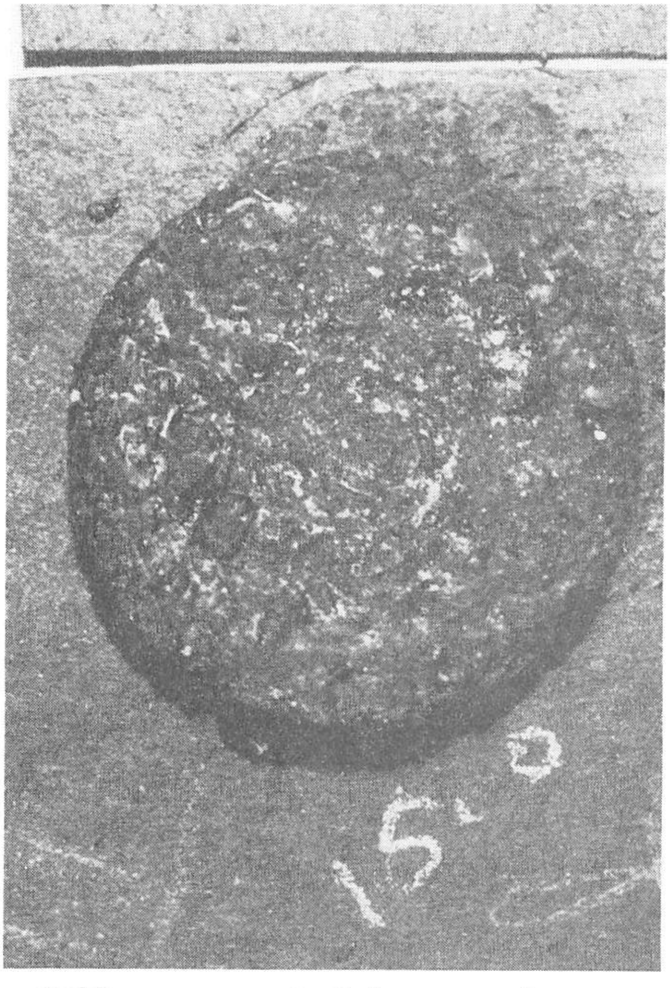
peak 60C cured cohesion
specimen-uncompacted



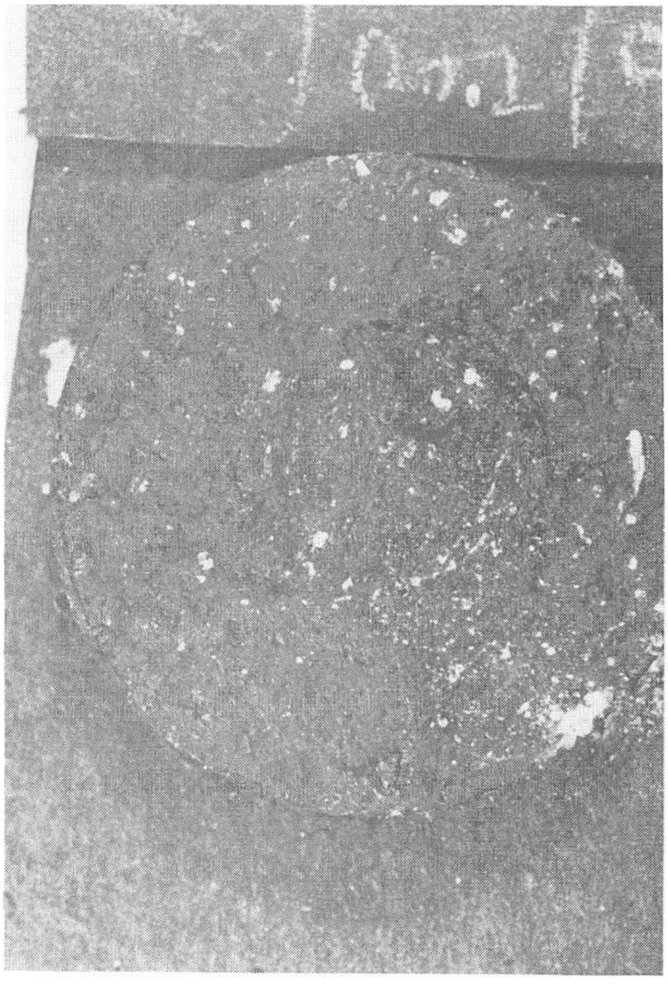
Load Wheel Test* specimens after 1000, 125 lb. cycles
*923-1AE, "C" gradation, 8% pc is optimum. Note:
Failures with 116-1AE and high filler contents



60C cured cohesion - 8mm compacted specimens
(contrast with uncompacted specimens)



Rubber compacted 8mm specimen
after 60C test @319 psi contact
pressure



Steel compacted 8mm specimen
after 60C test @319 psi contact
pressure