Evaluation of the Baladi Indirect Tensile Apparatus

Final Report
for
Iowa DOT Project MLR-89-8

Federal Highway Administration
Project DTFH71-89-511-IA-28

January 1990

Highway Division
Iowa Department of Transportation

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January 1990

TABLE OF CONTENTS

	Page
Abstract....................................	1
Introduction................................	2
Purpose.....................................	2
Procedure...................................	4
Results.....................................	8
Conclusions/Recommendation..................	13
Acknowledgements............................	14
References..................................	15
Appendices	
Appendix A - Mix Designs..................	16
Appendix B - Indirect Tensile Test Results.	22

DISCLAIMER

ABSTRACT

Dr. Gilbert Y. Baladi of Michigan State University has developed a new device intended for reliable determination of asphalt concrete mechanical properties such as Poisson's ratio, resilient modulus, and indirect tensile strength. The device is the result of an effort to improve upon procedures and equipment currently available for evaluation of mechanical properties. A duplicate of this device was fabricated in the Iowa Department of Transportation, Materials Lab Machine Shop in 1989.

This report details the results of an evaluation of the effectiveness of the device in testing Marshall specimens for indirect tensile strength as compared to results obtained with standard equipment described in AASHTO T-283.

Conclusions of the report are:

1. Results obtained with the Baladi device average 6 to 8 percent higher than those obtained with the standard device.

2. The standard device exhibited a slightly greater degree of precision than did the Baladi device.

3. The Baladi device is easier and quicker to use than the standard apparatus.

4. It may be possible to estimate indirect tensile strength from the stability/flow ratio by dividing by factors of 1.8 and 1.5 for 50 blow and 75 blow mixes respectively.

INTRODUCTION

Recent trends in asphalt pavement design have been shifting from empirical methods towards procedures based on elastic or viscoelastic theory concepts. Current asphalt mix design procedures result in empirical properties that have little connection to the basic materials engineering properties associated with elastic design. Dr. Gilbert Baladi of Michigan State University developed a new testing apparatus intended for reliable determination of asphalt concrete mechanical properties such as Poisson's ratio, resilient modulus, and indirect tensile strength. Dr. Baladi was prompted to develop this device due to numerous deficiencies in procedures and equipment currently available for evaluation of mechanical properties. A duplicate of the Baladi device was fabricated in the Iowa Department of Transportation Materials Lab machine shop in April 1989. The Materials Lab doesn't possess a load frame appropriate for use with this device in testing resilient modulus or Poisson's ratio; however, it was designed to fit in a Marshall load frame for determination of indirect tensile strength of a core or Marshall specimen, thus presenting the need to evaluate the device for this type of application.

PURPOSE

The objective of this study is to evaluate the indirect tensile testing capability of the Baladi device using the Marshall load frame and load application rate of 2.0 inches per minute. Evaluation of the device will be based on comparisons to results obtained using 1/2" loading strips as described in AASHTO T-283, which is the type of apparatus historically used by the Materials Lab Bituminous section. For purposes of this report, the AASHTO T-283 device will be referred to as the "standard" device.

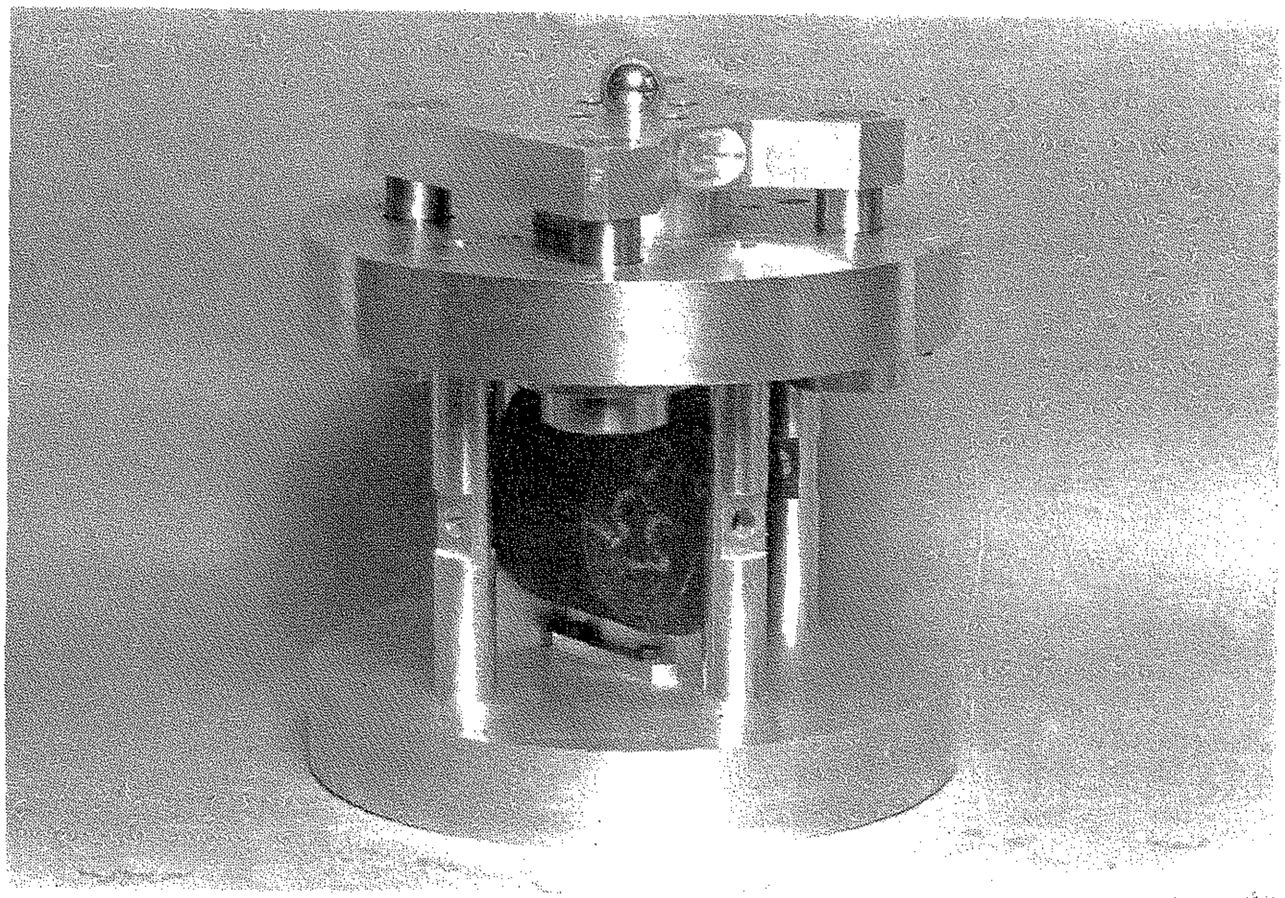

Figure 1
Baladi Indirect Tensile Test Apparatus

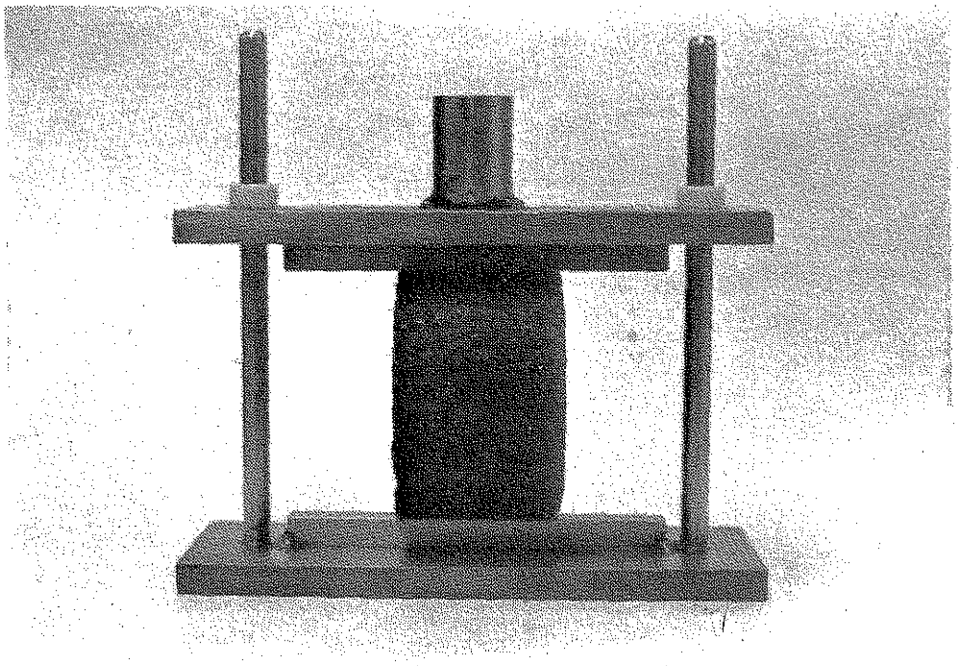

Figure 2
AASHTO T-283 "STANDARD"
Indirect Tensile Test Device With Specimen

PROCEDURE

Box samples were obtained from five active paving projects during the 1989 construction season. Two hot box samples were obtained from each of the five projects and delivered to the Central Lab for testing. The following mixes, designated as C-1 through C-5, were obtained from projects identified in Appendix A.

MIX	Lab #	MIX TYPE	MARSHALL SAMPLES PREPARED
C-1	ABD9-1012	3/4" B/I Base (50 Blow)	36
C-2	ABD9-82	3/4" B/I Base (50 Blow)	30
C-3	ABD9-122	3/4" A Surface (75 Blow)	20
C-4	ABD9-202	3/4" A Binder (50 Blow)	30
C-5	ABD9-166	3/4" A Surface (75 Blow)	27

The types of projects sampled included Type B mixes and Type A 50 and 75 blow mixes so a range of mix stiffness and composition could be used to evaluate the device. Mix design sheets for each of the five sample sources can be found in Appendix A.

The box samples were heated to 275°F, and each was divided to produce Marshall specimen samples of approximately 1200 grams each. The number of Marshall specimens produced from each project depended upon the weight of the material provided. The specimens were pounded at 275°F for the number of blows specified by the mix design sheet. After the specimens were extracted from the molds, they were numbered consecutively, height was determined for use in calculating indirect tensile strength, and density was determined to verify uniformity of compaction. Lab density and the number of specimens prepared from each mix sample can be found in Table 1. Three specimens C-1, #30; C-3, #13; and C-5, #9 produced outlying densities and, therefore, were omitted from the study.

To divide each set of specimen into two sets for indirect tensile testing, three random specimen were selected for Marshall stability testing. The remaining specimens were categorized by alternating numeric number into two groups for Baladi and standard indirect tensile testing.

Stabilities were determined after a 30 minute soak at 140°F as directed in AASHTO T-245. Specimens used for indirect tensile tests were soaked for 30 minutes in a 77°F water bath. Testing was performed using a Rainhart load frame and a load application rate of 2.0 inches per minute.

Tensile strength for both the Standard and Baladi load frames is calculated using the following equation:

$$S_t = \frac{2P}{\pi td}$$

where: S_t = tensile strength (psi)

P = maximum load (pounds)

t = specimen thickness (inches)

D = specimen diameter (inches)

TABLE 1
Marshall Specimen Lab Density

No.	C-1	C-2	C-3	C-4	C-5
1	2.362	2.410	2.402	2.362	2.434
2	2.371	2.409	2.396	2.366	2.435
3	2.370	2.412	2.379	2.366	2.436
4	2.363	2.406	2.380	2.367	2.428
5	2.368	2.411	2.408	2.370	2.433
6	2.355	2.417	2.396	2.367	2.432
7	2.361	2.412	2.399	2.360	2.425
8	2.359	2.410	2.398	2.356	2.426
9	2.363	2.417	2.404	2.366	
10	2.360	2.415	2.403	2.362	2.434
11	2.366	2.412	2.399	2.359	2.433
12	2.355	2.404	2.390	2.362	2.420
13	2.360	2.415		2.367	2.432
14	2.370	2.409	2.404	2.365	2.428
15	2.365	2.415	2.400	2.359	2.421
16	2.356	2.409	2.389	2.360	2.420
17	2.359	2.410	2.400	2.365	2.424
18	2.369	2.402	2.398	2.370	2.432
19	2.356	2.398	2.408	2.367	2.434
20	2.360	2.400	2.390	2.362	2.424
21	2.368	2.395		2.358	2.431
22	2.361	2.396		2.358	2.435
23	2.358	2.391		2.365	2.431
24	2.348	2.404		2.362	2.420
25	2.357	2.397		2.367	2.420
26	2.358	2.395		2.361	2.423
27	2.355	2.408		2.357	2.423
28	2.351	2.406		2.353	
29	2.364	2.412		2.358	
30		2.401		2.357	
31	2.356				
32	2.362				
33	2.359				
34	2.375				
35	2.356				
36	2.347				
$\bar{x}$ =	2.361	2.407	2.397	2.362	2.428
s =	0.006	0.007	0.008	0.004	0.006

RESULTS

As stated in the procedure, each set of mix specimens was further divided into two sets for indirect tensile testing plus a third set of three to be used for Marshall stability/flow testing. Average density ($\bar{\bar{x}}$) and standard deviation (s) for each set was calculated to determine the consistency of compaction and indicate if there were significant differences which might affect indirect tension results. The density results (Table 2) show close average densities for all sets with the exception of C-3 which is a coarse 75 blow mix. The standard sets have higher standard deviations on C-2 and C-5 than the Baladi sets, and essentially the same standard deviation on C-4. The Baladi sets are higher on C-1 and C-3. The greatest average density difference, 0.01, occurs in mix C-3. A difference of 0.01 in Marshall densities is generally not considered to be significant. In this case, since there are only seven specimens in C-3 Standard set, eight in C-3 Baladi set, and the difference in standard deviation is 0.0035, C-3 results might be considered suspect when compared to results from the other four mix samples which have much smaller standard deviation differences.

TABLE 2
Avg. Density and Standard Deviation
Standard vs. Baladi Apparatus

MIX	APPARATUS	$\overline{x}$ (density)	s
C-1	STD	2.360	.0057
	BALADI	2.362	.0068
C-2	STD	2.408	.0078
	BALADI	2.405	.0068
C-3	STD	2.401	.0040
	BALADI	2.393	.0075
C-4	STD	2.362	.0040
	BALADI	2.363	.0041
C-5	STD	2.428	.0061
	BALADI	2.429	.0049

Results from indirect tensile testing are summarized in Table 3. Individual results are presented in Appendix B, Tables B-1 through B-5. Table 3 shows, for each set, average indirect tension (psi), range, standard deviation, and coefficient of variance which is the ratio of s to $\overline{x}$ as a percentage. For every mix except C-3, the Baladi device produced higher indirect tensile strengths and standard deviations than the standard device. The Baladi device also yielded a higher coefficient of variance on C-1, C-2 and C-4. The ranges for all five sets were similar except for the Baladi set of mix C-1 which had a range of 56.4 psi. This was due to the unusually high result of 205.2 psi on specimen #15. If this result is omitted, the range becomes 38.4 psi, $\overline{x}$ becomes 163.0, s becomes 10.9 and the coefficient of variance becomes 6.7%, and the overall results do not differ significantly from those obtained with the Standard device.

TABLE 3
Indirect Tensile Test
Results Summary

MIX	APPARATUS	No.	AVG $\overline{X}$ IND. T. (PSI)	RANGE (PSI)	STD.DEV. s	COEFF. OF VARIANCE %
C-1	STANDARD	16	152.8	26.9	9.9	6.5
	BALADI	16	165.7	56.4	14.9	9.0
C-2	STANDARD	13	108.8	30.6	9.2	8.5
	BALADI	13	114.1	31.1	12.4	10.9
C-3	STANDARD	7	210.6	34.0	12.7	6.0
	BALADI	8	204.2	33.8	10.3	5.0
C-4	STANDARD	13	157.2	38.3	11.7	7.5
	BALADI	13	169.4	43.1	15.1	8.9
C-5	STANDARD	11	209.3	40.5	11.1	5.3
	BALADI	11	226.8	38.2	12.0	5.3

Table 4 compares the magnitude of indirect tension averages of the standard vs Baladi devices and shows that by weighted average the Baladi device yields results 6% greater than the standard device. The most likely cause of this is friction between the guideposts and bearing which causes the load on the specimen to be indicated as greater than actual. The indirect tension ratios for each mix are 1.05 to 1.08, again except for C-3 which is 0.97. This further indicates that because results are out of line with those from the other four mixes, the results of C-3 inspire the least amount of confidence, possibly from nonuniformity of compaction.

TABLE 4
Std. Ind. T. Device Vs Baladi
Ratio of Results

	N	Baladi	Standard	Ratio
C-1	16	165.7	/ 152.8	1.08
C-2	13	114.1	/ 108.8	1.05
C-3	7/8	204.2	/ 210.6	.97
C-4	13	169.4	/ 157.2	1.08
C-5	11	226.8	/ 209.3	1.08
ALL	(121)	168.2*	/ 159.5*	1.06

*Weighted average

The final aspect on which the data was evaluated was to form a comparison between stability/flow ratio and indirect tension results. For this study, a ratio of stability to flow was compared to indirect tension for both Standard and Baladi devices. From the summary of results in Table 6, it was apparent that the 50 blow mixes yielded different results from the two 75 blow mixes.

Weighted averages were calculated separately for the 50 and 75 blow mixes. The ratio of stability/flow to indirect tension on the 50 blow mixes was 1.9 for the standard device and 1.8 for the Baladi device. For the 75 blow mixes, the ratios were 1.6 for the standard device and 1.5 for the Baladi device. These limited results indicate it may be possible to estimate indirect tensile strength from the stability/flow ratio by using a factor of 1.5 for 75 blow mixes and 1.8 to 1.9 for 50 blow mixes.

TABLE 5
Stability/Flow

MIX	SPECIMEN	STABILITY	FLOW	S/F RATIO
C-1	8	2820	9	313
	16	2940	9	326
	24	2575	9	286
		====	==	===
		$\overline{x}$ = 2778	9	308
C-2	1	2355	12	196
	7	2495	13	192
	21	2600	12	217
	28	2700	12	225
		====	====	===
		$\overline{x}$= 2538	12.3	206
C-3	5	3430	11	312
	10	3890	12	324
	15	3575	12	298
		====	====	===
		$\overline{x}$= 3632	11.7	311
C-4	6	2500	10	250
	16	2760	10	276
	26	3150	10	315
		====	==	===
		$\overline{x}$= 2803	10	280
C-5	2	3780	12	315
	12	3650	12	304
	19	3600	10	360
	27	4060	11	369
		====	====	===
		$\overline{x}$= 3773	11.3	337

TABLE 6
Ratio of Stability/Flow
to
Indirect Tensile Strength

			Std. Device		Baladi	
MIX	N	S/F RATIO	IND T.	R	IND T.	R
C-1	16	308	152.8	2.0	165.7	1.9
C-2	13	206	108.8	1.9	114.1	1.8
C-3	7/8	311	210.6	1.5	204.2	1.5
C-4	13	280	157.2	1.8	169.4	1.7
C-5	11	337	209.3	1.6	226.8	1.5

Weighted Avg. for 50 blow - Std. 267.8/140.5 = 1.9
Baladi 267.8/150.9 = 1.8

Weighted Avg. for 75 blow - Std. 326.9/209.8 = 1.6
Baladi 326.9/217.2 = 1.5

An advantage of the Baladi device, as reported by the technicians performing the tests, was that it was faster to operate than the standard device because of ease in properly setting the specimen on the 1/2 inch loading strips.

CONCLUSIONS/RECOMMENDATIONS

Based upon testing performed on five mixes and a total of 121 Marshal specimens, the following conclusions are derived:

1. The Iowa fabricated Baladi device can be expected to produce indirect tensile strength results approximately 6 to 8 percent higher than those obtained using the Standard device.

2. It may be possible to estimate indirect tensile strength of a mix type from the stability/flow ratio by using factors of 1.8 and 1.5 for 50 and 75 blow mixes respectively.

3. Generally lower standard deviations and coefficients of variance obtained with the standard device indicate it is capable of greater precision than the Baladi device.

4. The Baladi device allows greater ease of operation than the standard device.

Based primarily on the third conclusion stated above, for future testing, the Standard Indirect tensile device is recommended for use in preference to the Baladi device for Iowa DOT indirect tensile testing of asphalt concrete specimen.

ACKNOWLEDGEMENTS

Appreciation is extended to Willard Oppedal, Steve McCauley, Larry Peterson, Todd Siefken and Dan Seward of the Materials Lab Bituminous Section for their efforts expended in material preparation and testing necessary for the performance of this study. Mike Lauzon of the Materials Lab machine shop is also recognized for the time and talent put forth in the fabrication of the Baladi device.

REFERENCES

1. Baladi, Gilbert Y., Harichandran, Ronald, and De Foe, Jack H., The Indirect Tensile Test - A New Apparatus, FHWA/Michigan Department of Transportation, March 1987

Appendix A

Mix Designs

ABD9-1012
BD

IOWA DEPARTMENT OF TRANSPORTATION
OFFICE OF MATERIALS
TEST REPORT - ASPHALT MIX DESIGN
LAB LOCATION - AMES

LAB NO....:ABD9-1012

MATERIAL........:TYPE B CLASS I
INTENDED USE....:BASE
PROJECT NO......:SN-3400(2)--51-94
COUNTY..........:WEBSTER — CONTRACTOR:FORT DODGE ASPHALT
SPEC NO.........:1070.00 — SIZE......:3/4
SAMPLED BY......: — SENDER NO.:
DATE SAMPLED: — DATE RECEIVED: — DATE REPORTED:07/26/89
PROJ. LOCATION: RELOCATED SECTION ROAD P59

CR. LST- MARTIN MARIETTA, FORT DODGE MINE, WEBSTER CO.
GRAVEL- AUTOMATED SAND, CRAFT PIT, WEBSTER CO.
P.I. - NOT TESTED

JOB MIX FORMULA-COMB. GRADATION

1 1/2"	1"	3/4"	1/2"	3/8"	NO.4	NO.8	NO.16	NO.30	NO.50	NO.100	NO.20
	100.0	99.0	87.0	74.0	57.0	47.0	37.0	26.0	13.0	7.0	5.

TOLERANCE /100 :

		98	7	7	7	6		5			

MATERIAL MIX	A94002	A94522			
% AGGR. PROP.	60.00	40.00	0.00	0.00	0.00

..HALT SOURCE AND	KOCH			
..PROXIMATE VISCOSITY POISES	0510			
% ASPHALT IN MIX	4.50	5.50	6.50	0.00
NUMBER OF MARSHALL BLOWS	50	50	50	0
MARSHALL STABILITY - LBS.	2510	2602	1918	0
FLOW - 0.01 IN.	9	9	11	0
SP GR BY DISPLACEMENT (LAB DENS)	2.316	2.361	2.363	0.000
BULK SP. GR. COMB. DRY AGG.	2.616	2.616	2.616	0.000
. GR. ASPH. @ 77 F.	1.004	1.004	1.004	0.000
CALC. SOLID SP. GR.	2.473	2.436	2.400	0.000
% VOIDS - CALC.	6.36	3.08	1.53	0.00
RICE SP.GR.	2.461	2.431	2.400	0.000
% VOIDS - RICE	5.89	2.88	1.54	0.00
% WATER ABSORPTION - AGGREGATE	1.17	1.17	1.17	0.00
% VOIDS IN MINERAL AGGREGATE	15.45	14.71	15.54	0.00
% V.M.A. FILLED WITH ASPHALT	58.84	79.08	90.15	0.00
CALC. ASPH. FILM THICK. MICRONS	6.92	8.69	10.46	0.00
FILLER/BITUMEN RATIO	0.00	0.93	0.00	0.00
TEMP=	185			
WT=	7600			
SLOPE=	4.44			
INTER=	-4.87			

ORIGINALLY APPROVED FOR FM-94(13)--55-94
SWITCHED TO 50-50 TO START JOB.

..ONTENT OF 5.0 ASPHALT IS RECOMMENDED TO START THE JOB.
..ERANCE ON #200 ALSO CONTROLLED BY FILLER/BITUMEN RATIO.

AC LOWERED FROM ORIGINAL DESIGN.

..PIES TO:

CENTRAL LAB	R. MONROE	D. HEINS
FT. DODGE ASPHALT	W. OPPEDAL	WEBSTER
DIST. 1	DIST 1 LAB	TRUEBLOOD

DISPOSITION:

ABD9-0082
BD

IOWA DEPARTMENT OF TRANSPORTATION
OFFICE OF MATERIALS
TEST REPORT - ASPHALT MIX DESIGN
LAB LOCATION - AMES

LAB NO....:ABD9-0082

MA' 'RIAL........:TYPE B CL 1
IN..NDED USE....:BINDER
PROJECT NO......:F-146-2(12)--20-79
COUNTY..........:POWESHIEK
CONTRACTOR:RIVER CITY PAVING
SPEC NO.........:1070.00
SIZE......:3/4
SAMPLED BY......:
SENDER NO.:
DATE SAMPLED: DATE RECEIVED: DATE REPORTED: 05/16/89
PROJ. LOCATION: NEW SHARON TO I-80

AGG SOURCES: CR. LST- KASER, SULLY, JASPER CO;
SAND- VAN DUSSELDORP, REASNOR

JOB MIX FORMULA-COMB. GRADATION

	1 1/2"	1"	3/4"	1/2"	3/8"	NO.4	NO.8	NO.16	NO.30	NO.50	NO.100	NO.200
			100.0	89.0	76.0	60.0	48.0	37.0	24.0	9.8	6.0	5.1
TOLERANCE /100 :			98	7	7	7	6		5			3

MATERIAL MIX	A50002	A50504			
% AGGR. PROP.	60.00	40.00	0.00	0.00	0.00

ASPHALT SOURCE AND	KOCH			
APPROXIMATE VISCOSITY POISES	0895			
PLASTICITY INDEX	NP			
% ASPHALT IN MIX	5.75	6.75	0.00	0.00
NU ER OF MARSHALL BLOWS	50	50	0	0
MARSHALL STABILITY - LBS.	1725	1635	0	0
FLOW - 0.01 IN.	7	8	0	0
SP GR BY DISPLACEMENT (LAB DENS)	2.307	2.343	0.000	0.000
BULK SP. GR. COMB. DRY AGG.	2.659	2.659	0.000	0.000
SP. GR. ASPH. @ 77 F.	1.030	1.030	0.000	0.000
CALC. SOLID SP. GR.	2.476	2.440	0.000	0.000
% VOIDS - CALC.	6.84	3.97	0.00	0.00
RICE SP.GR.	2.452	2.411	0.000	0.000
% VOIDS - RICE	5.91	2.82	0.00	0.00
% WATER ABSORPTION - AGGREGATE	1.41	1.41	0.00	0.00
% VOIDS IN MINERAL AGGREGATE	18.23	17.83	0.00	0.00
% V.M.A. FILLED WITH ASPHALT	62.49	77.72	0.00	0.00
CALC. ASPH. FILM THICK. MICRONS	9.47	11.35	0.00	0.00
FILLER/BITUMEN RATIO	0.00	0.78	0.00	0.00
TEMP=	230			
WT=	7300			
SLOPE=	4.69			
INTER=	-5.30			

A CONTENT OF 6.5% ASPHALT IS RECOMMENDED TO START THE JOB.
TOLERANCE ON #200 ALSO CONTROLLED BY FILLER/BITUMEN RATIO.
COPIES TO:

CENTRAL LAB	R. MONROE	J. SMYTHE
HEINS	RIVER CITY	W. OPPEDAL
DIST. 1	MARSHALLTOWN RES.	

DISPOSITION:
/////

SIGNED: ORRIS J. LANE, JR.

IOWA DEPARTMENT OF TRANSPORTATION
OFFICE OF MATERIALS
TEST REPORT - ASPHALT MIX DESIGN
LAB LOCATION - AMES

LAB NO....:ABD9-0122

MA .RIAL........:TYPE A
INTENDED USE....:SURFACE
PROJECT NO......:IR-35-4(58)105--12-85
COUNTY..........:STORY — CONTRACTOR:MANATTS
SPEC NO.........:1070.00 — SIZE......:3/4
SUPP SPEC NO....:0776.00
SAMPLED BY......: — SENDER NO.:
DATE SAMPLED: — DATE RECEIVED: — DATE REPORTED: 06/15/89
PROJ. LOCATION: FROM U.S. 30 SOUTH

- -

AGG SOURCES: CR. LST & CHIPS- MARTIN MARIETTA, AMES MINE,
STORY CO; QUARTZITE- EVERIST, DELL RAPIDS, SD;
SAND- HALLETTS, CHRISTENSEN PIT, STORY CO.
1/2% HYDRATED LIME ADDED

JOB MIX FORMULA-COMB. GRADATION

1 1/2"	1"	3/4"	1/2"	3/8"	NO.4	NO.8	NO.16	NO.30	NO.50	NO.100	NO.200
	100.0	99.0	78.0	55.0	38.0	27.0	19.0	13.0	6.6	4.8	3.9

TOLERANCE /100 :

1 1/2"	1"	3/4"	1/2"	3/8"	NO.4	NO.8	NO.16	NO.30	NO.50	NO.100	NO.200
		98	7	7	7	5		4			2

MATERIAL MIX	A85006	A85006	ASD002	A85502	
% AGGR. PROP.	45.00	7.50	32.50	15.00	0.00

A: 'ALT SOURCE AND	KOCH			
APPROXIMATE VISCOSITY POISES	2030			
% ASPHALT IN MIX	3.75	4.75	5.75	0.00
NUMBER OF MARSHALL BLOWS	75	75	75	0
MARSHALL STABILITY - LBS.	3713	3387	3260	0
FLOW - 0.01 IN.	11	12	15	0
SP GR BY DISPLACEMENT (LAB DENS)	2.387	2.415	2.421	0.000
BULK SP. GR. COMB. DRY AGG.	2.664	2.664	2.664	0.000
SP. GR. ASPH. @ 77 F.	1.036	1.036	1.036	0.000
CALC. SOLID SP. GR.	2.545	2.507	2.470	0.000
% VOIDS - CALC.	6.20	3.67	1.99	0.00
RICE SP.GR.	2.512	2.480	2.443	0.000
% VOIDS - RICE	4.98	2.62	0.90	0.00
% WATER ABSORPTION - AGGREGATE	0.98	0.98	0.98	0.00
% VOIDS IN MINERAL AGGREGATE	13.76	13.65	14.35	0.00
% V.M.A. FILLED WITH ASPHALT	54.90	73.13	86.13	0.00
CALC. ASPH. FILM THICK. MICRONS	8.73	11.41	14.09	0.00
FILLER/BITUMEN RATIO	0.00	0.95	0.00	0.00
TEMP=	220			
WT=	7100			
SLOPE=	4.77			

A CONTENT OF 4.1% ASPHALT IS RECOMMENDED TO START THE JOB.
TOLERANCE ON #200 ALSO CONTROLLED BY FILLER/BITUMEN RATIO.
COPIES TO:

CENTRAL LAB	R. MONROE	D. HEINS
MANATTS	W. OPPEDAL	J. SMYTHE
DIST. 1	AMES RES.	

DISPOSITION:

SIGNED: ORRIS J. LANE, JR.

ABD9-0166
BD

IOWA DEPARTMENT OF TRANSPORTATION
OFFICE OF MATERIALS
TEST REPORT - ASPHALT MIX DESIGN
LAB LOCATION - AMES

LAB NO....:ABD9-0166

MATERIAL........:TYPE A
INTENDED USE....:SURFACE
PROJECT NO......:IR-35-4(59)92--12-77
COUNTY..........:POLK
SPEC NO.........:1070.00
SUPP SPEC NO....:0824.00
SAMPLED BY......:
CONTRACTOR:DES MOINES ASPHALT
SIZE......:3/4
SENDER NO.:
DATE SAMPLED: DATE RECEIVED: DATE REPORTED: 07/28/89
PROJ. LOCATION: SOUTHBOUND FROM ANKENY TO NORTH OF F-22

AGG SOURCES: CR. LST & CHIPS- MARTIN MARIETTA, FERGUSON, MARSHALL CO; QUARTZITE- EVERIST, DELL RAPIDS, SD; SAND- HALLETT, DENNY-JOHNSON, POLK CO.
HYDRATED LIME ADDED: 0.5%

JOB MIX FORMULA-COMB. GRADATION

1 1/2"	1"	3/4"	1/2"	3/8"	NO.4	NO.8	NO.16	NO.30	NO.50	NO.100	NO.200
		100.0	89.0	70.0	50.0	27.0	20.0	13.0	7.2	4.8	4.1

TOLERANCE /100 :

MATERIAL MIX	A64002	A64002	ASD002	A77504	
% AGGR. PROP.	45.00	10.00	30.00	15.00	0.00

ASPHALT SOURCE AND	KOCH			
APPROXIMATE VISCOSITY POISES	2106			
% ASPHALT IN MIX	3.75	4.75	5.75	0.00
NUMBER OF MARSHALL BLOWS	75	75	75	0
MARSHALL STABILITY - LBS.	3263	3205	3153	0
FLOW - 0.01 IN.	10	11	12	0
SP GR BY DISPLACEMENT (LAB DENS)	2.346	2.381	2.395	0.000
BULK SP. GR. COMB. DRY AGG.	2.673	2.673	2.673	0.000
SP. GR. ASPH. @ 77 F.	0.996	0.996	0.996	0.000
CALC. SOLID SP. GR.	2.543	2.503	2.464	0.000
% VOIDS - CALC.	7.76	4.87	2.79	0.00
RICE SP.GR.	2.525	2.485	2.444	0.000
% VOIDS - RICE	7.09	4.18	2.00	0.00
% WATER ABSORPTION - AGGREGATE	0.94	0.94	0.94	0.00
% VOIDS IN MINERAL AGGREGATE	15.52	15.16	15.55	0.00
% V.M.A. FILLED WITH ASPHALT	50.03	67.86	82.05	0.00
CALC. ASPH. FILM THICK. MICRONS	8.41	10.97	13.53	0.00
FILLER/BITUMEN RATIO	0.00	0.85	0.00	0.00
TEMP=	215			
WT=	7000			
SLOPE=	4.61			

A CONTENT OF 4.8% ASPHALT IS RECOMMENDED TO START THE JOB.
TOLERANCE ON #200 ALSO CONTROLLED BY FILLER/BITUMEN RATIO.
COPIES TO:

CENTRAL LAB
J. HEINS
DIST. 1
J. SMYTHE
DES MOINES ASPH.
DES MOINES RES.
R. MONROE
W. OPPEDAL

DISPOSITION:

SIGNED: ORRIS J. LANE, JR.

ABD9-0202
BD

MIX DESIGN

IOWA DEPARTMENT OF TRANSPORTATION
OFFICE OF MATERIALS
TEST REPORT - ASPHALT MIX DESIGN
LAB LOCATION - AMES

LAB NO....:ABD9-0202

MATERIAL........:TYPE A RECYCLED
INTENDED USE....:BINDER
PROJECT NO......:FN-30-6(48)--21-06
COUNTY..........:BENTON
CONTRACTOR:CESSFORD
SPEC NO.........:1070.00
SIZE......:3/4
SUPP SPEC NO....:0828.00
SAMPLED BY......:
SENDER NO.:
DATE SAMPLED: DATE RECEIVED: DATE REPORTED: 09/14/89
PROJ. LOCATION: TAMA CO. TO U.S. 218

AGG SOURCES: MILLED @ 4.77% - PROJECT; 3/4" CHIPS - AGGRECON, HENNESSEY QRY, LINN CO.; SAND - AGGRECON, ATKINS PIT, BENTON CO.
% ASPHALT ADDED: 2.67 3.69 4.70

JOB MIX FORMULA-COMB. GRADATION

	1 1/2"	1"	3/4"	1/2"	3/8"	NO.4	NO.8	NO.16	NO.30	NO.50	NO.100	NO.200
			100.0	92.0	78.0	53.0	41.0	32.0	22.0	10.0	6.4	5.2
TOLERANCE /100 :			98	7	7	7	5		4			2

MATERIAL MIX	ABC9-197	A57030	A065		
% AGGR. PROP.	34.00	38.00	28.00	0.00	0.00

ASPHALT SOURCE AND	KOCH			
APPROXIMATE VISCOSITY POISES	0534			
% ASPHALT IN MIX	4.25	5.25	6.25	0.00
NUMBER OF MARSHALL BLOWS	50	50	50	0
MARSHALL STABILITY - LBS.	2917	2382	1982	0
FLOW - 0.01 IN.	7	8	12	0
SP GR BY DISPLACEMENT (LAB DENS)	2.331	2.351	2.364	0.000
BULK SP. GR. COMB. DRY AGG.	2.630	2.630	2.630	0.000
SP. GR. ASPH. @ 77 F.	1.020	1.020	1.020	0.000
CALC. SOLID SP. GR.	2.511	2.473	2.436	0.000
% VOIDS - CALC.	7.15	4.93	2.96	0.00
RICE SP.GR.	2.456	2.432	2.405	0.000
% VOIDS - RICE	5.09	3.33	1.70	0.00
% WATER ABSORPTION - AGGREGATE	1.58	1.58	1.58	0.00
% VOIDS IN MINERAL AGGREGATE	15.14	15.30	15.73	0.00
% V.M.A. FILLED WITH ASPHALT	52.75	67.81	81.16	0.00
CALC. ASPH. FILM THICK. MICRONS	6.67	8.60	10.52	0.00
FILLER/BITUMEN RATIO	0.00	1.04	0.00	0.00
TEMP=	230			

COPIES TO:

CENTRAL LAB R. MONROE J. SMYTHE
D. HEINS CESSFORD W. OPPEDAL
DIST. 6 CEDAR RAPIDS RES.

DISPOSITION: A CONTENT OF 5.0% ASPHALT IS RECOMMENDED TO START THE JOB. THIS IS AN ADDITIONAL 3.43% AC5
TOLERANCE ON #200 ALSO CONTROLLED BY FILLER/BITUMEN RATIO.

SIGNED: ORRIS J. LANE, JR.

Appendix B

Indirect Tensile Test Results

Appendix B-1

MIX C-1: 3/4 Type B, Class 1 Base
(50 Blow Marshall)

STANDARD

#	SPECIMEN Id.	SPECIMEN HEIGHT	IND. TENS. LOAD (lb.)	FLOW(.01")	IND. T. (PSI)
1	1	2.54	2200	6	137.8
2	3	2.53	2295	6	144.3
3	5	2.54	2330	7	145.9
4	7	2.55	2430	7	151.6
5	10	2.33	2350	7	160.5
6	12	2.56	2250	7	139.8
7	14	2.53	2580	7	162.2
8	17	2.54	2210	7	138.4
9	19	2.54	2630	6	164.7
10	21	2.54	2600	6	162.9
11	23	2.54	2600	6	162.9
12	26	2.56	2530	7	157.2
13	28	2.56	2540	7	157.9
14	31	2.53	2600	7	163.5
15	33	2.52	2420	7	151.0
16	35	2.55	2300	7	143.5

=====

$\bar{x}$ = 152.8
r = 26.9
s = 9.88
cv% = 6.5

BALADI

#	SPECIMEN Id.	SPECIMEN HEIGHT	IND. TENS. LOAD (lb.)	FLOW(in.)	IND. T. (PSI)
1	2	2.54	2530	4	158.5
2	4	2.54	2375	4	148.8
3	6	2.54	2440	4	152.8
4	9	2.49	2500	4	159.7
5	11	2.53	2375	4	149.4
6	13	2.55	2405	4	150.1
7	15	2.54	2670	4	167.2
8	18	2.53	2640	4	166.0
9	20	2.52	2550	4	161.0
10	22	2.54	2570	4	161.0
11	25	2.54	2850	4	178.5
12	27	2.54	2675	4	167.6
13	29	2.54	2750	4	172.3
14	32	2.55	3000	4	187.2
15	34	2.52	3250	4	205.2*
16	36	2.57	2675	4	165.6

=====

$\bar{x}$ = 165.7
r = 56.4
s = 14.9
cv% = 8.99

Appendix B-2

MIX C-2: 3/4 Type B, Class 1 Base
(50 Blow Marshall)

STANDARD

#	SPECIMEN Id.	SPECIMEN HEIGHT	IND. TENS. LOAD (lb.)	FLOW(.01")	IND. T. (PSI)
1	2	2.49	1480	10	94.6
2	4	2.48	1540	9	98.8
3	6	2.47	1640	8	105.6
4	9	2.48	1605	7	103.0
5	11	2.48	1660	7	106.5
6	13	2.50	1605	8	102.1
7	15	2.48	1610	8	103.3
8	17	2.49	1685	8	107.7
9	19	2.50	1840	7	117.1
10	22	2.51	1820	7	115.4
11	24	2.49	1755	8	112.1
12	26	2.49	1960	8	125.2
13	28	2.48	1915	7	122.9

=====

$\bar{x}$ = 108.8
r = 30.6
s = 9.21
cv% = 8.47

BALADI

#	SPECIMEN Id.	SPECIMEN HEIGHT	IND. TENS. LOAD (lb.)	FLOW(.01")	IND. T. (PSI)
1	3	2.48	1560	5	100.1
2	5	2.49	1675	5	107.0
3	8	2.49	1685	4	107.7
4	10	2.48	1605	5	102.9
5	12	2.50	1580	5	100.6
6	14	2.50	1570	5	99.9
7	16	2.49	1665	5	106.4
8	18	2.50	1930	4	122.8
9	20	2.50	1905	5	121.2
10	23	2.51	2000	4	126.8
11	25	2.49	1990	5	127.2
12	27	2.49	2050	4	131.0
13	30	2.50	2045	4	130.1

=====

$\bar{x}$ = 114.1
r = 31.1
s = 12.4
cv% = 10.9

Appendix B-3

MIX C-3: 3/4 Type A, Surface
(75 Blow Marshall)

STANDARD

#	SPECIMEN Id.	SPECIMEN HEIGHT	IND. TENS. LOAD (lb.)	FLOW(.01")	IND. T. (PSI)
1	1	2.52	3300	6	208.3
2	6	2.54	3530	6	221.1
3	8	2.54	3160	5	197.9
4	11	2.54	3100	6	194.2
5	14	2.52	3240	6	204.6
6	17	2.51	3610	5	228.2
7	19	2.50	3450	6	219.6

$\overline{x}$ = 210.6
r = 34.0
s = 12.7
cv% = 6.0

BALADI

#	SPECIMEN Id.	SPECIMEN HEIGHT	IND. TENS. LOAD (lb.)	FLOW(.01")	IND. T. (PSI)
1	2	2.52	3280	4	207.1
2	4	2.55	3300	4	205.9
3	7	2.52	3300	4	208.3
4	9	2.51	3405	4	215.8
5	12	2.53	3160	4	198.7
6	16	2.54	2905	4	182.0
7	18	2.51	3335	4	211.4
8	20	2.54	3260	4	204.2

$\overline{x}$ = 204.2
r = 33.8
s = 10.3
cv% = 5.04

Appendix B-4

MIX C-4: 3/4 Type A, Binder
(50 Blow Marshall)

STANDARD

#	SPECIMEN Id.	SPECIMEN HEIGHT	IND. TENS. LOAD (lb.)	FLOW(.01")	IND. T. (PSI)
1	2	2.48	2360	6	151.4
2	4	2.49	2315	6	147.9
3	7	2.49	2460	6	157.2
4	9	2.48	2195	10	140.8
5	11	2.49	2730	6	174.4
6	13	2.48	2350	7	150.8
7	15	2.49	2495	6	159.4
8	18	2.49	2605	7	166.4
9	20	2.49	2750	6	175.7
10	22	2.48	2600	7	166.8
11	24	2.49	2150	7	137.4
12	27	2.49	2430	7	155.3
13	30	2.50	2510	7	159.7
					=====
				$\bar{x}$ =	157.2
				r =	38.3
				s =	11.73
				cv% =	7.46

BALADI

#	SPECIMEN Id.	SPECIMEN HEIGHT	IND. TENS. LOAD (lb.)	FLOW(.01")	IND. T. (PSI)
1	1	2.47	2250	5	144.9
2	3	2.47	2450	4	157.8
3	5	2.49	2375	5	151.8
4	8	2.50	2560	4	162.9
5	10	2.48	2530	5	162.3
6	12	2.49	2835	5	181.1
7	14	2.46	2620	5	169.4
8	17	2.48	2880	4	184.8
9	19	2.49	2895	4	185.0
10	21	2.48	2790	5	179.0
11	23	2.49	2880	5	184.0
12	25	2.48	2930	4	188.0
13	29	2.50	2380	5	151.5
					=====
				$\bar{x}$ =	169.4
				r =	43.1
				s =	15.1
				cv% =	8.91

Appendix B-5

MIX C-5: 3/4 Type A, Surface
(50 Blow Marshall)

STANDARD

#	SPECIMEN Id.	SPECIMEN HEIGHT	IND. TENS. LOAD (lb.)	FLOW(.01")	IND. T. (PSI)
1	3	2.47	3280	6	211.3
2	5	2.48	3185	6	204.3
3	7	2.49	3010	6	192.3
4	10	2.48	3270	5	209.8
5	13	2.46	3255	5	210.5
6	15	2.50	3155	6	200.8
7	17	2.48	3190	6	204.6
8	20	2.48	3150	6	202.1
9	22	2.47	3260	5	210.0
10	24	2.48	3630	5	232.8
11	26	2.49	3500	6	223.6
					=====
				$\overline{x}$ =	209.3
				r =	40.5
				s =	11.06
				cv% =	5.28

BALADI

#	SPECIMEN Id.	SPECIMEN HEIGHT	IND. TENS. LOAD (lb.)	FLOW(.01")	IND. T. (PSI)
1	1	2.46	3390	4	219.2
2	4	2.48	3245	5	208.2
3	6	2.49	3400	4	217.2
4	8	2.49	3500	5	223.6
5	11	2.48	3625	4	232.6
6	14	2.49	3340	5	213.4
7	16	2.49	3520	4	224.9
8	18	2.47	3570	4	230.1
9	21	2.46	3810	4	246.4
10	23	2.47	3730	4	240.3
11	25	2.48	3720	4	238.7
					=====
				$\overline{x}$ =	226.8
				r =	38.2
				s =	12.00
				cv% =	5.29