

Laboratory Evaluation of Asphalt-Rubber in Asphalt Paving Mixtures

**Final Report
for
MLR-89-15**

April 1990

Highway Division



**Iowa Department
of Transportation**

LABORATORY EVALUATION OF ASPHALT-RUBBER
IN
ASPHALT PAVING MIXTURES

Final Report
for
Project MLR-89-15

By

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DISCLAIMER

The contents of this report reflect the views of the author and do not necessarily reflect the official views of the Iowa Department of Transportation. This report does not constitute a standard, specification or regulation.

ABSTRACT

Interest in the use of ground rubber from used tires as a hot asphalt mix binder has been increasing due to the magnitude of the disposal problem posed by the annual addition of millions of waste tires to the refuse stream.

This study evaluates, through laboratory means, the performance of asphalt-rubber as a hot mix binder as compared to conventional asphalt. The results indicate that asphalt-rubber outperforms its base asphalt in mixes of identical gradation and comparable void content on tests that are heavily dependent on binder characteristics (resilient modulus and indirect tension). An appreciable increase in rut resistance due to the use of asphalt-rubber is not indicated.

INTRODUCTION

There has recently been increasing interest in using ground rubber from discarded tires as an additive to asphalt for use in bituminous hot mix paving materials. Asphalt-rubber technology has been in existence for more than twenty years and has achieved some degree of popularity in the southwestern states. The high cost of this product is a primary factor in its failure to stimulate widespread use among most transportation agencies. Current interest in this product is being heightened by the objective of finding uses for a refuse item (used tires) which would otherwise be disposed of only at considerable environmental and/or economic cost.

Industry representatives have made claims that use of asphalt-rubber can result in pavement layers of equal structural value at one-half the thickness of conventional mixes and yielding three times the service life (up to 60 years). As with many other types of polymer additives and special products, asphalt-rubber is also purported to increase rut resistance, decrease thermal cracking, and increase general service life through increased resistance to oxidation. At a current price of \$450 per ton for asphalt-rubber binder, it appears these claims would have to be valid for the product to be economically utilized in this state. However, as landfill space continues to become scarce, special disposal fees are levied on used tires, and asphalt-rubber becomes less expensive due

to more widespread use, the economic aspects of this product could rapidly become more favorable.

OBJECTIVE

The objective of this study is to evaluate, through laboratory means, the performance of asphalt-rubber as a hot mix binder, and observe its handling characteristics throughout the asphalt mix design procedure.

SCOPE

A three-point conventional mix design was performed, and a "parallel" mix design using the same aggregate combination but substituting asphalt-rubber for the binder, was prepared using the vendor's recommended design procedure. Optimum binder content based on lab voids was determined for each mix, and additional Marshall specimens were prepared at that optimum content for testing and comparison of results.

MATERIALS

Asphalt-rubber, marketed by International Surfacing, Inc. of Chandler, Arizona, is a combination of approximately 80% asphalt and 20% ground tire rubber which is mixed and chemically reacted at 350°F to 375°F for 35-50 minutes. For hot mix applications, the entire tire, with the exception of bead and steel belt, can be ground up and reacted. The progress of the reaction can be identified by changes in viscosity of the binder. The reaction is allowed to proceed until the desired

viscosity is achieved. The rubber-modified asphalt is then allowed to cool below 350°F and further reaction ceases. Asphalt extenders are sometimes added to the binder to enhance the asphalt-rubber reaction and improve thermal crack resistance by decreasing asphalt rubber stiffness when softer asphalt grades are unavailable (1). Types of extenders used are typically naphthenic or aromatic petroleum oils.

For a typical hot mix project, the ground rubber is delivered to the plant site in plastic bags at a cost of \$65-\$70 per ton. The rubber should be free of contaminants, contain less than 0.75% moisture, and be ground to a fineness of between #10 and #30 mesh. The asphalt-rubber is reacted on site, after which it is either stored or pumped into the pugmill or drum mixer using heavy duty pumps, mixing and storage equipment.

For purposes of this study, approximately five gallons of reacted asphalt-rubber and five gallons of unreacted asphalt from the same source, were provided to us by International Surfacing, Inc. The asphalt-rubber, prepared by International Surfacing, Inc. for moderate to cold climate dense graded mix, contained 81% AR1500, 10% ground rubber, and 3% extender.

Penetration numbers and softening points for the reacted and unreacted binders, as determined by the Central Materials Laboratory, were 109 and 120°F, and 164 and 103°F respectively.

The mix design for this project was a dense-graded 1/2" Type B, Class 1 base 50 blow mix with two aggregate components: 60% 1/2" crushed limestone from Cessford, LeGrand Quarry, and sand from Martin-Marietta, Marshalltown Pit. Gradations for the materials are found in Table I.

TABLE I
Mix Design Gradation
% Passing

<u>Sieve Size</u>	<u>Limestone</u>	<u>Sand</u>	<u>Combined (60-40)</u>
3/4	100	100	100
1/2	99	100	99
3/8	82	100	89
4	42	97	64
8	23	86	48
16	16	70	38
30	13	43	25
50	11	11	11
100	10	1.5	6.6
200	8	0.5	5.0

PROCEDURE

Conventional and asphalt-rubber three point mix designs were performed in accordance with Iowa Materials Lab Test Method No. 502A (App. A) with several vendor recommended changes employed for the asphalt-rubber mix (2). Prior to mixing with aggregate, the asphalt-rubber was heated to a temperature of 350°F and the aggregate to 300°F. The asphalt-rubber was stirred well prior to mixing. The mixing time was kept at two minutes after which it was divided into approximately 1200 gram portions for the Marshall specimens. The mix was placed

back into an oven until the pounding temperature of $280^{\circ} \pm 5^{\circ}\text{F}$ was attained, at which time the material was removed and 50 blow Marshall specimens were prepared. The asphalt-rubber specimens were allowed to cool to room temperature prior to extraction from the molds.

After the three point mix designs were completed, optimum binder contents to produce 4.0% Rice voids were estimated and ten and nine additional specimens, of conventional asphalt and asphalt-rubber respectively, were prepared at the optimum content. These additional specimens were tested for Marshall density, Rice specific gravity, Rice voids, Marshall stability/flow (3 specimens), and creep (3 specimens). A direct comparison was then made between the conventional and asphalt-rubber test results.

Reflux extraction, nuclear binder, and recovery content (Iowa Test Method No's. 624E, 512, and AASHTO T170) were also performed to evaluate how the material responds to our standard testing procedures.

RESULTS/OBSERVATIONS

Due to extensive experience with the aggregate combination used for this study, a two point mix design was used in lieu of a three-point design to determine conventional asphalt content necessary for a 4.0% void level. The two point mix de-

sign (5.50% and 6.50%) indicated an asphalt requirement of 5.85% to produce an approximate void level of 4.0%.

The three point asphalt-rubber mix design was prepared at contents of 6.5%, 7.5%, and 8.5%. Product literature indicated that asphalt-rubber demand can be expected to be approximately 1% greater than conventional asphalt demand when used with the same aggregates and aggregate gradation. The trial mix indicated an asphalt-rubber content of 6.0% should be used for 4.0% voids. When the asphalt-rubber mix design was performed, a nuclear asphalt content gauge calibration was also determined using a Troxler 3241-B asphalt content gauge. Detailed trial mix design information can be found in Appendix B.

Once the binder content necessary to produce 4.0% voids was determined, additional mix was produced at those binder contents in sufficient quantity to compact Marshall specimens for further testing. Ten conventional asphalt specimens were compacted, however, due to limited availability of materials, only nine additional asphalt-rubber specimens were produced.

Tests were performed on the sets of samples and average results are summarized in Table II. More detailed test result information is presented in Appendix C.

TABLE II
Conventional Rubber Vs Asphalt-Rubber
Summary of Results

<u>Test Parameter</u>	<u>5.85% Asphalt</u>	<u>6.0% Asphalt-Rubber</u>
Marshall S.G.	2.361	2.330
Maximum S.G.	2.457	2.446
% Voids	3.9	4.74
Stability	1810 lb.	2090 lb.
Flow	7	7
Indirect Tensile	105 psi	126 psi
Resilient Modulus	174 ksi	225 ksi
Creep Resistance Factor	30	32

From Table II, it can be seen that 6.0% asphalt-rubber produced a void content of 4.7%, which was .7% higher than desired for this study. Increasing the binder content by .2% to .3% should increase the maximum specific gravity and decrease voids to somewhere around the 4.0% level. Since material supplies were limited, it was not possible to produce additional specimens. Consequently, the study was continued using the 4.7% void samples.

Stability results showed the asphalt-rubber averaging 280 pounds higher than the conventional mix with no increase in flow. Indirect tensile strength was higher by 21 psi for asphalt-rubber and resilient modulus at 77°F was 51 ksi greater. The creep resistance factor (CRF), which is an indicator of resistance to rutting, was 30 for the conventional asphalt mix and 32 for the asphalt-rubber (3).

Other observations and results of working with the asphalt-rubber mix were as follows:

Nuclear Asphalt Content

The three point nuclear gauge mix calibration equation based on actual asphalt content had a correlation factor of 0.9977. A correlation factor of 0.995 or better is recommended for the calibration to be considered valid. A sample of the 6.0% asphalt-rubber mix was tested in the asphalt content gauge using the above calibration, yielding a measured asphalt content of 6.03% and demonstrating that asphalt-rubber content can be effectively determined by nuclear means.

Extraction

A portion of the 6.5% trial mix was extracted to determine how well the asphalt-rubber will extract from a mix and if any unusual problems would be encountered. A reflux extraction using 1-1-1 trichloroethane was performed with the following results:

Actual Bitumen Content	6.5%
Bitumen Content by Extraction	5.31%

Sieve Analysis
(% Passing)

<u>Sieve Size</u>	<u>Job Mix Gradation</u>	<u>Extracted Gradation</u>
3/4"	100	100
0.525"	99	100
3/8"	89	88
No. 4	64	65
No. 8	48	49
No. 16	38	37
No. 30	25	26
No. 50	11	12
No. 100	6.6	5.9
No. 200	5.0	4.3

The technician performing the extraction indicated he saw what appeared to be particles of rubber floating in the solvent as it was being filtered. According to International Surfacing, Inc., the asphalt-rubber was 81% asphalt and 19% rubber and extender. If all of the asphalt were extracted, approximately 5.3% (81% of 6.5) would have been produced. This closely matches the 5.31% extraction result. However, the rubber was expected to have been chemically bound to the asphalt, and a recovery percentage closer to 6.5% was anticipated. Since rubber particles appeared to be floating freely in the solvent, the chemical reaction may not have occurred with 100% of the rubber particles. The extracted gradation was low on the #100 and #200 screens, but some of that discrepancy could have been due to splitting and sampling. The extraction solvent did not cause the filter to plug and no other unusual problems were reported. Based on these in-

itial results, a more thorough investigation of extraction characteristics is warranted.

Recovery

An Abson recovery (AASHTO T170) was performed on a portion of the 6.0% asphalt-rubber mix. Trichlorethylene is used as a solvent in this procedure, and the reflux extraction method was used to extract the binder. The actual recovery process proceeded without incident and tests on recovered asphalt resulted in a penetration of 115 and viscosity of 1693 poises. There was a problem with the refluxing of the mix in that some of the asphalt-rubber and fine aggregate seemed to coalesce and solidify on the reflux basket screen, causing the screen to plug and the refluxing action to become inefficient. An asphalt content or gradation was impossible to produce. Prolonged soaking in solvent failed to dissolve the solidified mass and the basket assembly will have to be cleaned by sandblasting or discarded. Alternate means of extracting the binder for recovery must be investigated if future work with this material becomes commonplace.

General Observations

Actual handling of the modified binder during mix design didn't present any insurmountable obstacles. There were inconveniences such as having to heat the material to

350°F for mixing and more difficulty cleaning tools and gloves. Marshall specimens prepared with asphalt-rubber must also be allowed to cool in the mold. To maintain efficient production of mix designs with this material, two or three more sets of molds would be required. When an attempt was made to remove a hot specimen from its mold, the specimen literally disintegrated as it was extruded and lost confinement from the walls of the mold. After the specimens were cooled sufficiently, they were extremely difficult to extrude from the molds, a situation apparently due to adhesion between the walls of the mold and the asphalt-rubber binder. A hydraulic extruder would be necessary for routine use of rubber modified binder in mix designs.

CONCLUSIONS/RECOMMENDATIONS

The objective of this study was to evaluate the performance of asphalt-rubber as a hot mix binder through laboratory comparison to a conventional mix. The results shown in Table 2 indicate that asphalt-rubber outperforms its base asphalt in mixes of identical gradation and comparable void content, on tests that are heavily dependent on binder characteristics (resilient modulus and indirect tension). The CRF was greater by only a degree of 2, which indicates the addition of rubber is of minimal contribution to increased rut resistance. The test results indicate possible improvements in fatigue life and crack resistance performance characteristics which are

more closely related to binder qualities than to aggregate characteristics.

Although the elevated mix temperature and other inconveniences make the mix design procedure more cumbersome and time consuming for the technicians to perform, the overall process proceeded reasonably well and no problems were encountered that make the general use of asphalt-rubber in mix designs impractical. However, the need for more investigation is indicated with regard to extractions and recoveries due to the procedural difficulties and data inconsistencies encountered.

An analysis of the economic impact of this material on a typical asphalt cement paving project is beyond the scope of this report. Any added value of additional life shown to occur through field trials must be assessed and weighed against the high initial cost of this product to economically justify widespread use. Possibly more difficult, but yet even more critical to the use of this material, is assigning an accurate value to the environmental benefits received from recycling tires as opposed to other means of disposal.

Another consideration is the ability of this material to be scarified and recycled as pavements begin to require rehabilitation in the future. As with tires, the ability of asphalt paving materials to be recycled is becoming more and more

critical as landfill space becomes less available and more costly.

As a final note, it should be pointed out that although this initial laboratory investigation yielded promising results, laboratory tests are not always indicative of actual pavement performance. A field trial using a dense graded asphalt-rubber mix should be initiated so pavement construction and both long and short term performance can be thoroughly evaluated.

ACKNOWLEDGEMENTS

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Appendix A

IOWA DEPARTMENT OF TRANSPORTATION
HIGHWAY DIVISION

Office of Materials

COMPACTING ASPHALTIC CONCRETE
BY THE MARSHALL METHODScope

This method of test covers the procedures to be used in compacting asphaltic concrete utilizing the Marshall apparatus.

Procedure

A. Apparatus

1. Four specimen mold assemblies each consisting of a base plate, forming mold, collar extension, and compaction plate. The forming mold shall have an inside diameter of $4.0 \pm .005$ inch, and a height of approximately 3 inches; the base plate and collar extension are designed to be interchangeable with either end of the forming mold.
2. A specimen extractor for removing the compacted specimen from the specimen mold
3. A mechanical compaction apparatus designed to drop a 10-pound hammer a distance of 18 inches and strike a 3-15/lb inch diameter compaction plate 50 times in a period of 55 ± 10 seconds or 75 times in a period of 82 ± 10 seconds.
4. A massive concrete compactor base upon which has been mounted a 1 inch thick neoprene pad capped with a 1 inch thick steel plate.
5. An oven capable of maintaining a constant temperature of 275 ± 5 F.
6. Thermometers (100 - 400 F. range).
7. Balance having a capacity of at least 1500 grams and accurate to at least 1 gram.
8. Funnel which fits inside the mold.
9. Suitable pans for heating the mixture.

10. Specimen height indicator.
11. Paper discs (4-inch diameter).
12. Spatula.
13. Hearing protection for pounding specimens, safety shoes and gloves for handling hot equipment.

B. Test Procedure

1. Sample the mixture by the procedure outlined in Test Method No. Iowa 501, "Sampling Bituminous Field or Trial Mixes for Extraction, Density and Stability Determinations.
2. Weigh into each of four separate pans the amount of asphaltic concrete required which will result in a compacted specimen 2.5 ± 0.5 inches in height. This will normally be about 1200 grams. If the first specimen height falls outside the limits, the amount of mixture used for the additional specimens may be adjusted as follows:
Adjusted weight of mixture =
$$\frac{2.5 \text{ (weight of mixture used)}}{\text{specimen height obtained}}$$
3. Heat the pans of mix in the oven to a temperature of 275 ± 5 F. as checked by a thermometer with the bulb in the center of the mix sample.
 - (a) Check the temperature of each pan of mix before placing in the mold.
 - (b) Heat the funnel and use a hot mold assembly from the oven for each specimen compacted.
4. Place a paper disc in the bottom of the mold.
5. Place one panful of the mix, that has been weighed out, into the mold at one time by quickly inverting.

IOWA DEPARTMENT OF TRANSPORTATION
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DETERMINING THE DENSITY OF COMPACTED
BITUMINOUS MIXTURESScope

This method of test describes the procedure for determining the density (bulk specific gravity) of compacted bituminous mixtures. This method is intended for use on both laboratory compacted specimens and field compacted specimens obtained by coring.

Procedure

A. Apparatus

1. Balance with a capacity of at least 2000 grams and accurate to at least 0.5 gram.
2. Suspension apparatus and basket to permit weighing the specimen while suspended from the bottom of the balance, and while completely submerged in water.
3. Water container large enough to conveniently place specimen in basket and completely submerge it without touching sides or bottom of container.
4. Damp towel.

B. Test Procedure

1. If the specimens were recently molded in the laboratory, allow them to cool for at least two hours at room temperature after molding.
2. Determine the dry weight of each laboratory specimen to the nearest 0.5 gram and record this weight.

Determine and record the dry weight of field cored specimens after completion of Step B-5 by drying in an oven for 48 hours at $140 \pm 5^\circ\text{F}$.

3. Use the same balance and carefully tare the weight of the basket or carrier suspended and completely submerged in water which is at $77 \pm 2^\circ\text{F}$.
4. Obtain the weight of each specimen while completely immersed in water and record to the nearest 0.5 gram. Make certain that neither the specimen nor basket touches the sides or bottom of the water container.
5. Remove the specimen from the water, surface dry the specimen by blotting with a damp towel, and determine and record this surface dry weight.

C. Calculations

$$\text{Bulk Specific Gravity} = \frac{A}{B - C}$$

A = weight in grams of dry specimen in air

B = weight in grams of surface dry specimen in air

C = weight in grams of specimen while immersed in water.

IOWA DEPARTMENT OF TRANSPORTATION
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Office of Materials

RESISTANCE TO PLASTIC FLOW OF BITUMINOUS MIXTURES
USING MARSHALL APPARATUSScope

This method of test provides a means of measurement of the resistance to plastic flow of compacted cylindrical specimens of bituminous mixtures, which are loaded on the lateral surface, by means of the Marshall apparatus.

Procedure

A. Apparatus

1. Breaking Head - The breaking head consists of upper and lower cylindrical segments or test heads having an inside radius of curvature of two inches, accurately machined. The lower segment is mounted on a base having two perpendicular guide rods or posts extending upward. Guide sleeves in the upper segment are in such a position as to direct the two segments together without appreciable binding or loose motion on the guide posts.
2. Loading Machine - A mechanical testing machine capable of maintaining a uniform rate of head movement of two inches per minute while the load is being applied.
3. A stress-strain recorder which records both the load and the flow on a chart.
4. Water Bath - The water bath of sufficient depth to maintain a water level of at least six inches. The temperature is thermostatically controlled so as to maintain the bath at $140 \pm 1.8^\circ\text{F}$. ($60 \pm 1^\circ\text{C}$). The tank has a perforated false bottom that supports the specimens two inches above the bottom of the tank.

B. Test Specimens

1. Prepare the test specimens by the procedure outlined in Test Method No. Iowa 502, "Compacting Asphaltic Concrete by The Marshall Method."

C. Test Procedure

1. Pre-Test

- a. Remove the dust cover from the press and the recorder.
- b. Plug all three electrical cords into wall outlets, and turn the switch on the recorder to standby position. The pilot lights on the main switch box and on the recorder will glow.
- c. Allow a 30 minute warm-up period. The Sorenson load cell, located on the back of the press crosshead, will feel warm after a few minutes.
- d. Install the recorder pen and a chart paper. Move the paper up or down to line up the zero line with the pen. The chart paper is then held in place with magnets.
- e. Lower the pen onto the chart by turning the red top switch to the "pen" position.
- f. A calibration check is necessary once a week to make sure that the equipment is functioning properly. Place a calibrated Rainhart Cat. No. 835R10 Ring Dynamometer in the press against the centering screw stops. Deflect the ring to specified amounts by hand rotation of the press drive pulley to apply known loads (obtained from the calibration

Test Method No. Iowa 510
February 1988

IOWA DEPARTMENT OF TRANSPORTATION
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Office of Materials

METHOD OF TEST FOR DETERMINING MAXIMUM SPECIFIC GRAVITY
OF BITUMINOUS PAVING MIXTURES USING A FLASK PYCNOMETER

Scope

This test method is intended to determine the maximum specific gravity of asphalt paving mixtures, commonly referred to as rice specific gravity. The apparatus and procedures are identical with those specified in AASHTO T209-82 flask determination with the following variations.

1. A four liter thick walled Erlenmeyer flask, with top surface of opening ground smooth and plane, and with no side discharge nozzle, shall always be used as the vacuum chamber.
2. A special weighing pan about 16"x24"x2-3/4" with one end formed in the shape of a chute, and a funnel which fits inside the mouth of the pycnometer flask, will aid in sample preparation and handling.

Note

This procedure may be used in lieu of Test Method No. Iowa 507-B which describes a version of the maximum specific gravity determination test using a Yale Pycnometer as a vacuum chamber.

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DETERMINATION OF BITUMINOUS PAVING MIXTURE
ASPHALT CONTENT BY MEANS OF NUCLEAR
ASPHALT CONTENT GAUGEScope

This method of test is for determining the asphalt content of bituminous mixtures with a gauge that utilizes a sealed source of radioactive americium-beryllium. Use of this gauge must be in accordance with the radiation regulations of the Iowa Department of Health.

Operator Qualifications

Operators must comply with I.M. 206 "Nuclear Test Equipment".

Apparatus

1. Troxler 3241-B Asphalt Content Gauge, having a 300 mCi sealed source of Am 241:Be.

Note 1: This gauge has a micro-processor that controls the operation of the gauge, calculates the slope and intercept of each calibration and leads the operator through each operational procedure.
2. 1 stainless steel nuclear gauge sample pan.
3. Thermometer (100-400 F).
4. Balance with a capacity of at least 10,000 grams and accurate to at least 1 gram.
5. Scoop and spatula.
6. Steel trowel.
7. Troxler 3241-B Instruction Manual.
8. Leather gloves.

Statistical Stability Test

1. The following situations require a statistical stability test to be performed on the gauge.

- a. After not being used for more 1 month.
- b. Occurrence of five (5) percent or more variation of the daily background count from the previous background count taken at the same location.
- c. The gauge is moved to another location.
- d. Monthly, as part of the routine check of the equipment.

2. To initiate the stability test, turn on the gauge, and allow its electronics to stabilize (about 2-3 minutes).
3. Follow the operation flow diagram in the manufacturer's manual and determine stability test results.

Note 3. The gauge will automatically take 20 one-minute counts and display a result of either pass or fail.
4. Refer to the manufacturer's manual and follow the instructions when the gauge fails the stability test.

Background Count

1. Determine a background count each day prior to calibrating or testing.
2. Turn on the gauge and allow electronic to stabilize (about 2-3 minutes).
3. Refer to manufacturer's manual, follow the appropriate operation flow diagram, and determine a 16-minute background count for calibration or testing. The gauge drawer must be empty and closed when determining a background count.

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METHOD OF TEST FOR DETERMINING THE ASPHALT CONTENT
OF BITUMINOUS PAVING MIXTURESScope

This method covers a procedure for determining the bitumen content of a paving mixture by reflux extraction, and permits the determination of the sieve analysis of the aggregate.

Apparatus

1. Extraction equipment consisting of a metal sample basket with a No. 40 mesh screen bottom, stirring apparatus, condenser, pan for retaining fine aggregate, 4000 ml. thermal shock resistant glass beaker, basket assemble holder, and hot plate (Fig. 1).
2. Filtering apparatus consisting of a No. 5 Buchner funnel, 2000 ml. filter flask, No. 497 Schleicher and Schuell filter paper, and a motor driven vacuum pump (Fig. 2).
3. Filtering apparatus consisting of a No. 3 Buchner funnel, 500 ml. filter flask, Whatman 934AH glass microfibre filter paper, and an aspirator. The vacuum pump from No. 2 (above) may be used instead of an aspirator by reducing the amount of vacuum.
4. Oven, capable of maintaining a temperature of $230 \pm 9^{\circ}\text{F}$.
5. Balance, 3000 gram capacity capable of weighing to the nearest 0.5 grams.
6. Balance, capable of weighing to the nearest 0.001 gram.
7. Erlenmeyer Flask, 2000 ml. capacity, calibrated to measure 1000 ml.
8. Pipet, 20 ml. with rubber suction bulb attached.
9. Stainless steel beaker, 2000 ml.
10. Two squeeze type wash bottles.

11. Spatulas, 4 inch and 8 inch.
12. Vented exhaust hood.
13. Rubber gloves.
14. Eye protection.

Reagents

1. 1-1-1 Trichlorethane, industrial grade.
2. Methanol, industrial grade.

Preparation of Sample

1. If moisture is present, follow Iowa Method No. 618 - Method of Test for Water in Petroleum Products and Other Bituminous Materials, or place the material in an oven set at $230 \pm 9^{\circ}\text{F}$. for six hours or until material reaches a constant temperature while weighing at 30 minute intervals.
2. Select a representative portion of the sample weighing 1500 to 1800 grams from materials with a maximum aggregate size of 1 inch. With mixes containing larger size aggregate, run two separate extractions with the above sample size. The sampling procedure is described in Iowa Method No. 501.

Test Procedure

A. Extraction

1. Weigh the sample to the nearest 0.5 gm. into the 2000 ml. stainless steel beaker and add approximately 400 ml. of 1-1-1 trichloroethane.
2. Stir the sample with the large spatula until the solvent has thoroughly permeated the material.
3. Let the sample soak for a minimum of 20 minutes.

Calculations

- A. Calculate the weight of fine aggregate in the extraction liquid as follows:

$$L = A \times 50$$

Where:

L = Weight of the lost aggregate, grams.
A = Weight of aggregate in the 20 ml. aliquot, grams.

$$50 = \text{Sample proportion } \frac{(1000)}{(20)}$$

- B. Calculate the asphalt content of the bituminous mixture as follows:

$$\text{Percent asphalt} = \frac{A - (B + L)}{A} \times 100$$

Where:

A = Weight of sample, grams
B = Weight of extracted aggregate from the extractions, grams.
L = Weight of fine aggregate in the extraction liquid, grams.

Sieve Analysis of Extracted Aggregate

The fine aggregate in the extraction liquid may be assumed to pass the No. 200 screen and is therefore added to this quantity as determined in the regular sieve analysis.

Precautions

Care must be exercised in handling 1-1-1 trichloroethane because of its toxicity. All steps of the procedure involving this solvent must be carried out under an exhaust hood and the oven must be provided with an outside exhaust. Rubber gloves and eye protection shall be used when handling this solvent.

Appendix B

ABDO-0003
BD

MIX DESIGN

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

LAB NO.....:ABDO-0003

MATERIAL.....:TYPE B
INTENDED USE.....:RESEARCH (CENTRAL)
PROJECT NO.....:MLR89-15

SIZE.....:1/2

SAMPLED BY.....:

SENDER NO.:

DATE SAMPLED:

DATE RECEIVED:

DATE REPORTED: 04/27/90

AGG. SOURCES: CR. LST. - CESSFORD, LEGRAND, MARSHALL CO.;
SAND - MARTIN MARIETTA, MARSHALLTOWN PIT, MARSHALL CO.
INDIRECT TENSILE P.S.I. 105

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	89.0	64.0	48.0	38.0	25.0	11.0	6.6	5.0	

TOLERANCE /100 :

98	7	7	6	5	3
----	---	---	---	---	---

MATERIAL MIX	AATO-1	AATO-3
% AGGR. PROP.	60.00	40.00

% ASPHALT IN MIX	5.50	5.85	6.50
NUMBER OF MARSHALL BLOWS	50	50	50
MARSHALL STABILITY - LBS.	1661	1807	1342
FLOW - 0.01 IN.	8	7	11
SP GR BY DISPLACEMENT (LAB DENS)	2.350	2.361	2.354
BULK SP. GR. COMB. DRY AGG.	2.632	2.632	2.632
SP. GR. ASPH. @ 77 F.	1.016	1.016	1.016
CALC. SOLID SP. GR.	2.453	2.440	2.416
% VOIDS - CALC.	4.18	3.23	2.58
RICE SP.GR.	2.463	2.457	2.427
% VOIDS - RICE	4.59	3.91	3.01
% WATER ABSORPTION - AGGREGATE	1.17	1.17	1.17
% VOIDS IN MINERAL AGGREGATE	15.63	15.54	16.38
% V.M.A. FILLED WITH ASPHALT	73.23	79.22	84.23
CALC. ASPH. FILM THICK. MICRONS	8.92	9.56	10.74

ASPHALT SOURCE & APPROXIMATE VISCOSITY: INTERNATIONAL SURF
COPIES TO:

CENTRAL LAB
D. HEINS
D. HINES

R. MONROE
V. MARKS

J. ADAM
W. OPEDAL

DISPOSITION:

/////

SIGNED: ORRIS J. LANE, JR.
TESTING ENGINEER

Appendix C

TABLE C-1
Summary of Values
at
Optimum Binder Content

Rice Specific Gravity:	Asphalt Mix	2.457
	Asphalt Rubber Mix	2.446

Marshall Properties

5.85% Asphalt			6.0% Asphalt Rubber		
Ht.	S.Grav.	Voids	Ht.	S.Grav.	Voids
2.50	2.356	4.11			
2.50	2.356	4.11	2.49	2.333	4.62
2.49	2.364	3.79	2.49	2.327	4.87
2.51	2.349	4.40	2.49	2.323	5.03
2.50	2.365	3.74	2.48	2.330	4.74
2.50	2.366	3.70	2.50	2.323	5.03
2.49	2.367	3.66	2.49	2.328	4.82
2.51	2.349	4.40	2.50	2.334	4.58
2.49	2.370	3.54	2.49	2.335	4.54
2.50	2.368	3.62	2.48	2.334	4.58
	=====	=====		=====	=====
Avg.	2.361	3.95	Avg.	2.330	4.74

TABLE C-2
Indirect Tensile Strength Results

5.85% Asphalt				6.0% Asphalt Rubber			
<u>SPECIMEN</u>	<u>Ht.</u>	<u>P</u>	<u>St</u>	<u>SPECIMEN</u>	<u>Ht.</u>	<u>P</u>	<u>St.</u>
2	2.50	1490	95	3	2.50	1850	118
5	2.50	1795	114	7	2.50	2350	150
8	2.51	1675	106	9	2.48	1690	109
			===				===
		Avg.	105			Avg.	126

$$\text{Indirect Tensile Strength } (S_t) = \frac{2P}{\pi t d}$$

Where: S = tensile strength (psi)
P = maximum load (pounds)
t = specimen thickness (inches)
d = specimen diameter (inches)

TABLE C-3
Marshall Stability/Flow

5.85% Asphalt			6.0% Asphalt Rubber		
<u>SPECIMEN</u>	<u>STABILITY</u>	<u>FLOW</u>	<u>SPECIMEN</u>	<u>STABILITY</u>	<u>FLOW</u>
1	1700	7	2	2000	7
4	1600	7	5	1980	7
10	2120	7	8	2280	7
	====	=		====	=
Avg.	1810	7	Avg.	2090	7

TABLE C-4
Resilient Modulus

5.85% Asphalt		6.0% Asphalt Rubber	
<u>SPECIMEN</u>	<u>M_R (psi)</u>	<u>SPECIMEN</u>	<u>M_R (psi)</u>
3	160,000	1	240,000
7	173,000	4	213,000
9	188,000	6	223,000
	=====		=====
Avg.	174,000	Avg.	225,000

Test Parameters: 77 ± 1°F
 90° rotation @ 20 cycles ea.
 Frequency .33 hz
 Load Time 0.1 sec.
 Tested @ 50 lb. & 75 lb.

TABLE C-5
Creep Test Results

5.85% Asphalt				6.0% Asphalt Rubber			
<u>SPECIMEN</u>	<u>TIME</u>	<u>C</u>	<u>CRF</u>	<u>SPECIMEN</u>	<u>TIME</u>	<u>C</u>	<u>CRF</u>
3	210	.05	32	3	210	.05	32
7	185	.05	28	7	200	.05	31
9	200	.05	31	9	220	.05	34
			==				==
			30				32

$$\text{Creep Resistance Factor (CRF)} = \frac{t}{325} [100 - c (1000)]$$

Where: CRF is Creep Resistance Factor
 t is time in minutes until failure
 c is change in height (in.) or 0.05 inch if failure occurs