ARIZONA DEPARTMENT OF TRANSPORTATION

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LOW SOLVENT EMULSIFIED ASPHALT STUDY

FINAL REPORT

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16. ABSTRACT

The objective of this study was to develop a low solvent, stockpilable, bituminous pavement patching material. Foamed asphalt and aromatic oil with emulsified asphalt were studied as binders with virgin aggregates. Although low solvent, these were found to have unsatisfactory stockpile characteristics. Foamed asphalt and rejuvenating agents were studied to produce a pavement maintenance material from recycled asphalt pavement. Neither of these efforts were successful. Unique Paving Mixture produced by Sylvax Corporation specifications and currently in use by Arizona Department of Transportation was examined and found to meet the properties of a low solvent pavement patching material.

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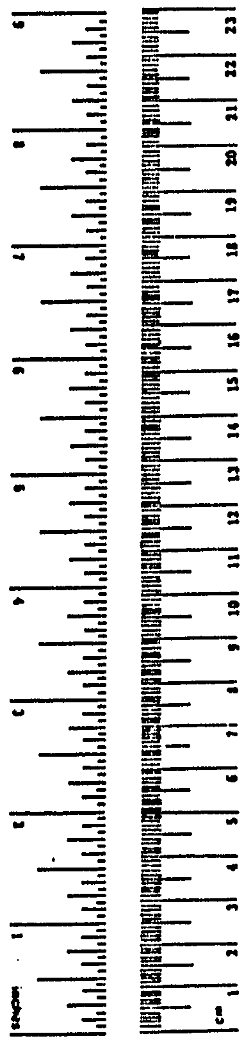
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

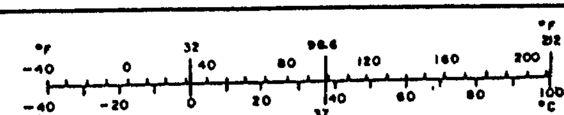
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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FINAL REPORT

1.0 INTRODUCTION

Aggregate bound by asphalt has found extensive use as a pavement material. The asphalt coats and binds the aggregate to produce a material with stability, cohesion and weathering properties greatly enhanced from that displayed by the aggregate alone. However, because asphalt is a near solid, visco-elastic material, it can not be used during mixing and placement of pavement unless its viscosity is reduced by some means to allow mixing and placing to be satisfactorily performed. Following placement and compaction of a pavement, it is necessary that the asphalt binder regain its original visco-elastic property in order to serve as a pavement binder.

The reduction in viscosity of asphalt to allow mixing and placement of an asphalt-aggregate pavement has generally been accomplished by heating the asphalt, dissolving the asphalt in a volatile petroleum solvent of low viscosity (cutbacks) or suspending asphalt particles in water (emulsions). Following placement, the pavements gain strength by cooling of the hot asphalt or by evaporation of the fluidizing medium for cutbacks and emulsions.

1.1 Problem Statement

Maintenance repair and patching of pavements has commonly been performed using asphalt-aggregate mixtures.

Maintenance repair generally involves relatively small quantities of materials and is performed at intermittent times. This manner of use makes it impractical to use a product which required placement shortly after mixing, such as a hot mixed asphalt pavement material, a rapidly curing cutback or emulsified asphalt.

For many years asphalt pavement patching has been conducted using cutback asphalt as a binder. A cutback with the proper curing properties would be selected such that little curing of the material would occur while it remained in a stockpile. Small quantities of placeable material could be acquired at any time, while uncured material could remain in the stockpile for subsequent use. If proper curing properties were selected, sufficient evaporation of the more highly volatile solvent within the cutback asphalt would occur to produce sufficient strength within the pavement upon completion of the repair operation.

The use of cutback asphalt involves the evaporation of the solvents from the mixture in order for the mixture to gain strength. This is not only a waste of non-renewable energy resources but also causes considerable air pollution during this evaporation process. The use of emulsified asphalt involves the evaporation of water rather than the hydrocarbon solvents common to cutbacks. However, stockpile stable emulsified asphalts have not been available. Because of these environmental and energy conservation concerns, it is desirable to eliminate the need for cutback asphalt and/or high solvent content binders for maintenance stockpiles of roadway patching materials. However, satisfactorily performing alternate materials must be available.

1.2 Review of Literature

Pavement maintenance patching mixtures to be stored in stockpiles for extended periods of time must be capable of placement at ambient temperatures. One of the earliest of the cold-mixed, cold-laid pavements was foamed asphalt binder. Some of the earliest reported work was by Csanyi (1). This early work used steam being combined with hot asphalt cement in a nozzle just prior to being mixed with wet aggregate. The mixed material was placed and compacted immediately after mixing.

Lee (2) reported on a process of producing foamed asphalt by the Mobil foaming process. This process introduced cold water into hot asphalt cement and discharged the foamed asphalt into cold, moist aggregate for mixing. No differences were apparent between mixtures produced by the cold water and steam processes.

McDonald (3) and Chapman (4) have reported on the use of foamed asphalt mixtures in Arizona roadway pavements. Abel (5) and Peterson (6) reported on the use of foamed asphalt construction in their respective states of Colorado and North Dakota. Indications of the intended use of foamed asphalt for maintenance stockpile mixtures were mentioned by both Abel and Peterson; however, neither author reported any experience in this application of foamed asphalt mixtures.

The Asphalt Institute (7) has recommendations for both plant-mixed and blade-mixed stockpile patching mixtures.

All of the binders recommended contain an appreciable percentage of volatile distillates. Mixtures using CMS-2 or CMS-2h emulsified asphalts are recommended, but these mixtures are recommended for use within a short time after stockpiling. In addition, CMS-2 and CMS-2h emulsified asphalts normally contain some volatile distillates.

Kandahl and Mellott (8) published procedures for designing bituminous stockpile patching mixtures. Mixtures recommended used cutbacks, emulsified cutbacks and other types of binders containing solvents.

Standards for petroleum products were issued by the Arizona Department of Health Services in 1986 (9). These standards restricted the use of cutback asphalt or emulsified asphalt containing petroleum solvents. Although the standard made an exception for stockpiled material held longer than 1 month, the intent to prevent the use of these products was clear. Cutback asphalt was defined as any paving asphalt liquified with 5 percent or more distillate as measured by ASTM D402.

Recent interest in pavement recycling has resulted in considerable work and a great deal of literature regarding rejuvenation of reclaimed asphalt pavements. Although early efforts were with reheated mixtures, recent developments provided for cold mixes with emulsified rejuvenating agents. Canessa (10) cautioned against the use of aromatic oils to modify aged asphalts and emphasized the need to properly design the viscosity of the modified asphalt. Davidson, et.al. (11) reported on cold reconstituting of reclaimed asphalt pavement. Vallerga (12) and Canessa (13) have reported further on cold recycling of asphalt pavements.

1.3 Study Objectives

The overall objective of the project was to provide materials for roadway maintenance patching that were low in hydrocarbon emissions and could be stored, while remaining workable and compactible, for time periods up to 6 months.

Specific objectives were as follows:

1.3.1 Select two bituminous mixtures that have low solvent emissions, adequate coatings and workability and compactibility properties to serve as roadway maintenance patching materials.

1.3.2 Evaluate and test these materials in the laboratory.

1.3.3 Select two localities in Arizona with extreme climatic conditions and test the patching materials in those environments.

1.3.4 Prepare recommendations and guidelines for implementation of the use of low solvent mixtures for roadway maintenance patching.

1.4 Selection of Study sites.

It was desired that the study sites selected to test the proposed matching materials represent the extremes of the climatic conditions in Arizona. Early in the performance period of this contract, meetings were held with personnel of the Arizona Transportation Research Center and Arizona Department of Transportation. The two sites selected during these meetings were at Chino Valley and Gila Bend.

Chino Valley is at approximately 5200 ft of elevation, has a temperature range from lows of near 10F in the winter to highs of approximately 100F in summer and has 16 in. of annual precipitation.

Gila Bend is at approximately 720 ft of elevation, has a temperature range from lows of near 30F in the winter to highs of approximately 120F in the summer and has 6 in. of annual precipitation.

Laboratory work concentrated on mixtures using aggregate from the two sources utilized for production of maintenance patching materials for these maintenance operation locations.

2.0 CURRENT MAINTENANCE PATCHING MIXTURES

The material used by the Arizona Department of Transportation for roadway patching varies by the type of roadway being maintained, the locality and its environment, and the availability of materials and equipment.

2.1 Specifications

Maintenance patching materials at the two locations selected as study sites both utilized cold-mixed processes at commercial central plants using aggregates complying with ADOT requirements for mineral aggregate MA-7 and liquid asphalt binder. The Chino Valley mixture used aggregate from a pit near Prescott Valley and 5.5 percent MC-250 cutback asphalt. The Gila Bend mixture was manufactured with Agua Fria River aggregate from west of Phoenix and was mixed with an SC-800 liquid asphalt. The specified content of liquid asphalt to be added was set at 6.0 percent.

2.2 Test Results

Samples of the roadway maintenance patching material from each of the study sites were taken by ADOT materials personnel and submitted to Western Technologies Inc. for analysis.

2.2.1 Chino Valley Material

The Chino Valley material was mixed at a commercial source during March 1984. A sample of the material was taken from the stockpile at the maintenance site during June and transported to the laboratory in covered 5 gallon pails. Testing of the as-received material was completed by early July 1984. Table 2.1 contains the results of tests performed.

2.2.2 Gila Bend Material

The Gila Bend material was mixed at a commercial source during december 1983. A sample of the stockpiled material was taken by ADOT personnel, placed in covered 5 gal pails and submitted to the laboratory during the latter part of June 1984. These results, completed during early July 1984, are shown in Table 2.2.

2.3 Unique Paving Mixture (UPM)

The Arizona Department of Transportation currently uses an open-graded, cold-compacted pavement material produced with a proprietary emulsified asphalt binder. The material is currently used for patching of interstate highway pavements.

2.3.1 Samples of the liquid asphalt and the stockpiled mixture of UPM were obtained from commercial suppliers. The materials sampled were produced under the direction of the Sylvax Corporation. The liquid asphalt was tested for volalite material to 500F by the test procedure given in ASTM D402 (AASHTO T78). The test yielded no distillate.

TABLE 2.1

PHYSICAL PROPERTIES OF CHINO VALLEY ROADWAY MAINTENANCE PATCHING MATERIAL

Gradation of Extracted Aggregate (ADOT 201)		Physical Tests of Mixture
Sieve Size	Percent by Weight Passing	
3/8 in.	100	Moisture, Percent by Dry Weight of Mixture, (AASHTC T-110): 0.66
1/4 in.	85	
No. 4	74	
No. 8	60	Liquid Asphalt, Percent by Dry Weight of Mixture, (ADOT 402): 5.01
No. 10	56	
No. 16	45	
No. 30	30	
No. 40	23	Volatile Distillates in 500 g of Mixture: (AASHTO T-110): 2.9 ml
No. 50	17	
No. 100	10	
No. 200	6.2	
		Marshall Stability and Flow, 50 Blows Each Face (AASHTO T-245, compacted and tested at 77F): Stability = 690 lb Flow = 11 Unit Weight = 140.2 pcf (AASHTO T-166)

TABLE 2.2

PHYSICAL PROPERTIES OF GILA BEND ROADWAY MAINTENANCE PATCHING MATERIAL

Gradation of Extracted Aggregate (ADOT 201)

Sieve Size	Percent by Weight Passing
3/8 in.	100
1/4 in.	90
No. 4	77
No. 8	56
No. 10	53
No. 16	43
No. 30	26
No. 40	18
No. 50	12
No. 100	6
No. 200	3.7

Physical Tests of Mixture

Moisture, Percent by Dry Weight of Mixture, (AASHTO T-110): 0.36

Liquid Asphalt, Percent by Dry Weight of Mixture, (ADOT-402): 5.64

Volatile Distillates in 500 g of Mixture: (AASHTO T-110): 1.7 ml

Marshall Stability and Flow, 50 Blows Each Face (AASHTO T-245, compacted and tested at 77F):
Stability = 300 lb
Flow = 10
Unit Weight = 130.0 pcf (AASHTO T-166)

2.3.2 A sample of the mixture of asphalt and aggregate was tested for volalites using test method ASTM D1461 (AASHTO T110). The test yielded 1.6 milliliters from 516.7 gms or 0.3 percent volalites.

2.3.3 The mixture was also tested using a 50 blow per end Marshall procedure and for binder content and gradation. These results are shown in Table 2.3.

The Marshall test specimens were made and tested at room temperatures with corrections made as required for the height of the specimens. The average bulk specific gravity of the specimens was 110.1 pounds per cubic foot. The Marshall stability was 161 lb and the average flow was 14.

2.3.4 The unit weight and stability of the material appear to be low, however, this is to be expected of a mixture with the open graded characteristics indicated by the gradation.

TABLE 2.3

TEST RESULTS FOR UNIQUE PAVING MIXTURE

Sieve Size	Percent Passing
3/8 in.	100
1/4 in.	69
No. 4	42
No. 8	16
No. 16	11
No. 40	7
No. 100	4
No. 200	2.8

Percent Asphalt Extracted: 3.7

3.0 STUDY MATERIALS

The materials studied were those commercially available within the study area. The aggregates used for laboratory experiments were those that have been used for roadway patching at the study sites selected. Recycled Asphalt Pavement (RAP) was from the Phoenix area and was similar to that available and a number of sites within the study area.

3.1 Aggregates

3.1.1 Chino Valley

Samples of coarse, intermediate and fine aggregates from the materials source used for production of Chino Valley maintenance patching material were submitted to the Western Technologies Inc. laboratory. The aggregate gradations were tested and it was found necessary to remove the minus No. 16 sieve material from the intermediate aggregate to obtain an aggregate combination complying to MA-7 specifications. The gradation of a combination of 15 percent coarse, 15 percent modified intermediate and 70 percent fine aggregates was computed and found to meet the requirements. Further work utilizing Chino Valley aggregate used these proportions.

3.1.2 Gila Bend

Samples of MA-3/8 and MA Sand were obtained at Tanner Companies United Metro Plant No. 2. These aggregates were produced from the Agua Fria River which was the source for maintenance patching material currently in use by ADOT's Gila Bend maintenance forces. A combination of 30 percent of the MA-3/8 and 70 percent of the MA sand complied with specification requirements for gradation for MA-7 and was used for all Gila Bend mixtures studied.

3.2 Recycled Asphalt Pavement Material

Asphalt pavement that had been milled or removed from previously paved areas and stockpiled for recycling was sampled from Tanner Companies United Metro Plant No. 2. The test results shown in Table 3.1 were obtained from material after the removal of material larger than 3/8 in. This material was used for all RAP mixtures.

3.3 Asphaltic Materials

3.3.1 Asphalt Cement

Asphalt cement meeting the requirements for viscosity graded AC-5 was used for the foamed asphalt mixtures studied.

3.3.2 Emulsified Asphalt

Emulsified Asphalt, Grade CSS-1, was used for coating aggregates for mixtures other than the foamed asphalt and RAP mixtures Test results for this material are shown in Table 3.2.

TABLE 3.1

PHYSICAL PROPERTIES OF RAP MATERIAL

Sieve Size	Percentage Weight Passing			
	Bituminous Aggregate	Extracted Aggregate		
3/8 in.	100	100	100	100
1/4 in.	86	89	88	89
No. 4	75	82	79	81
No. 8	54	67	62	65
No. 10	48	63	58	61
No. 16	31	53	48	53
No. 30	14	39	35	39
No. 40	9	29	28	30
No. 50	6	23	22	24
No. 100	3	15	14	14
No. 200	2.1	8.6	8.6	9.5
Asphalt Content, Percent		5.41	5.75	5.44

Absolute Viscosity of Recovered Asphalt, poises: 17,052

TABLE 3.2

TEST RESULTS FOR CSS-1 ASPHALT EMULSION

Percent Residue by Weight:	62.3
Particle Charge:	Non Ionic
Saybolt Viscosity, 77F, Sec:	22.9
Penetration on Residue, 77F, 0.1 mm:	90

3.4 Modifier Agents

3.4.1 Akzo-Chemie Emulsified Process Oil

A low solvent, cationic, emulsified, aromatic oil was supplied by Akzo-Chemie America for use as a modifier for both emulsified asphalt coated aggregates and for RAP mixtures. This material had a residue of 57.3 percent by weight and had 3.0 percent by volume oil distillate to 500F.

3.4.1 Witco chemicals Rejuvenating Agents

Three rejuvenating agents commercially supplied by Witco Chemicals were used in mixtures studied. These were identified as Reclamite, Cyclogen ME and CRF. These products had residue contents by weight of 62.8, 61.4 and 62.1 percent, respectively. None had more than 0.5 percent by volume of oil distillate to 500F.

4.0 MAINTENANCE PATCHING MIXTURES STUDIED

A series of mixtures were produced in the laboratory utilizing the aggregates for both Chino Valley and Gila Bend study sites and the RAP material from Tanner Companies United Metro Plant No. 2. A variety of combinations of the binders and modifying agents described in Chapter 3 were used in the mixtures.

4.1 Foamed Asphalt Mixtures

Foamed asphalt mixes were produced by use of a laboratory pugmill-type mixer capable of producing batches of approximately 20 lbs. The mixer was equipped with a container for holding heated asphalt. Air pressure was used to force the heated asphalt and cold water together in a line that carried the resulting foamed asphalt to the mixing chamber. The mixer operated very satisfactorily and its pugmill mixer was utilized for some other portions of the study for mixtures other than foamed asphalt.

Two foamed asphalt mixtures were prepared using a 3/8 in. maximum sized decomposed granite prewetted with 5 percent moisture. A third mixture using reclaimed asphalt pavement and foamed asphalt was prepared and studied. Foamed asphalt using a grade AC-5 asphalt cement was added in amounts of 4 and 5 percent by total dry weight of mixture to the decomposed granite aggregate. Portions of the mixtures were allowed to cure in the open air and other portions were compacted at ambient temperature by 50 blows on each specimen face with a standard Marshall compactor.

Aggregate coatings of less than 50 percent were achieved at both asphalt contents. Microscopic examination of the mixtures indicated asphalt globules up to nearly 1 mm in diameter to be distributed throughout the mixture.

The compacted specimens retained their integrity following removal from the compaction mold. One specimen that had been mixed with 4 percent foamed asphalt was placed into a pan and submerged in water to approximately one half its height for several days. Although the specimen appeared to absorb water as evidenced by the stained condition of the sample, it did not appear to loose a significant amount of its integrity and could be easily handled with little or no loss of material.

Two loose piles of foamed asphalt mixtures using the decomposed granite aggregate and 4.0 and 5.0 percent AC-5 foamed asphalt were prepared. These piles were allowed to air cure in a loose condition at ambient laboratory temperature. Two similar piles were cured outside in the open air for approximately 2 months. The curing took place during June and July of 1984 with air temperatures near 75F at nighttime and up to 115F during daytime.

Samples of minus 3/8 inch RAP material were mixed with 3 percent foamed asphalt by the same process as used for the virgin aggregate. The foamed asphalt RAP mixture had the same exposure as those using virgin aggregate except that experimentation took place during November and December, 1984 with lower outside temperatures. Outside air temperature ranged from typical highs of 85F and lows of 35F. These mixtures also exhibited poor asphalt coatings and soon dried to a non-compactible condition when air dried. Further experimentation with foamed asphalt mixtures was discountinued following these results.

4.2 Virgin Aggregate Mixtures

The preliminary studies of low solvent mixes were carried out using Chino Valley aggregate. After some success with mixtures that appeared to have desirable characteristics for stockpiling, similar mixtures were produced and examined using the Gila Bend aggregate source.

4.2.1 Chino Valley Aggregate

Early mixture testing was done using a mixture of 25 percent Witco Chemicals Reclamite emulsion and 75 percent of a slow setting, cationic emulsified asphalt. Some success was achieved when 9 percent by dry aggregate weight of this combined emulsion binder was added to aggregate with 3 percent pre-mix water. The resulting mixture was oven cured for 48 hours at 230F. Following this curing period, the cooled mixture remained workable and could be compacted. A small patch 2 to 3 in. in thickness was constructed in an asphalt pavement. Although the patch initially appeared satisfactory, it remained soft and somewhat unstable at the interior of the patch. The patch continued to compact and became depressed below the pavement surface due to traffic. Laboratory tests of a similar mixture were conducted at 77F by Marshall compaction of 50 blows per specimen face. When tested at 77F, a stability of 1617 lb and a flow of 20 were achieved. The high flow was consistent with the excessive deformation observed in the roadway patch and indicated excessive asphalt or an uncured condition.

A number of mixtures were prepared using other amounts of slow-setting, cationic, emulsified asphalt along with the Akzo-Chemie America emulsion of aromatic oil. Mixtures were made using 2 percent pre-mix water, 8 percent CSS-1 emulsified asphalt and 4 percent of the Akzo-Chemie modifier. The aromatic oil was added prior to the emulsified asphalt in one instance and after the emulsified asphalt in the other. The order of addition with emulsified asphalt followed by the aromatic oil produced the best aggregate coating. Small piles of the mixtures were allowed to air cure in the laboratory for periods of 25 to 35 days. At the end of the curing period, the mixtures were agitated in the pugmill mixer for 10 seconds. Materials compacted by 50-blow Marshall compaction in the cured state yielded stabilities of 900 and 1026 lb with flows of 13 and 11. When 2 and 3 percent water were mixed with cured materials prior to compaction, stabilities of 1100 and 1344 lb were achieved with flows of 13 and 10. In all instances, specimens were oven cured at 120F for 72 hours prior to testing.

An investigation was conducted using the Chino Valley aggregate, 8.0 percent CSS-1 emulsified asphalt and various quantities of the aromatic oil emulsion. The mixed materials were cured in waterproof plastic bags for 4 days. Following curing, specimens were compacted by 50 blow Marshall compaction and tested for unit weight, Marshall stability and flow. At the end of the curing period, the moisture contents of the mixtures were measured by oven drying and found to be less than 0.5 percent. Water was added and hand mixed with the material to bring the moisture content back to the original proportions just prior to compaction.

The results of tests for both curing conditions are shown in Table 4.1. The values tabulated are means of the test results of three specimens.

Observation of the data indicated stability to be reduced with increased aromatic oil and increased aging; however, stabilities were well in excess of that obtained from maintenance mixture currently being used. Flows were low and indicated that none of the mixtures would be expected to have serious deformations during use. Unit weights were lower after the 3-week cure than at 4 days and all unit weights, with the exception of the mixture with 4.0 percent aromatic oil, were below the unit weight of 140.2 pcf measured for compacted specimens of the currently used maintenance mixture.

Tests performed with the mixture cured for 4 days were intended to simulate stockpile material used for patching at the time of delivery of newly mixed material or uncured material uncovered within the center of a stockpile. The 3-week cure, which produced material with little or no moisture present at the time of use, would simulate material on the exterior of a stockpile following aging and loss of moisture.

4.2.2 Gila Bend Aggregate

Gila Bend aggregate was mixed with 8.0 percent CSS-1 emulsified asphalt and various quantities of aromatic oil and then subjected to the same curing and testing program as discussed for the Chino Valley aggregate. A summary of the test results achieved are shown in Table 4.2.

As with the Chino Valley aggregate mixture test results, the stabilities decreased as the amount of aromatic oil increased and as aging increased. All stabilities were well in excess of those obtained from tests of field use material submitted. Flows were low, as desired. Unit weights were lower for the material with increased aging. The unit weight of specimens compacted from the currently used maintenance material was between that obtained for 4-day and 3-week cured materials from this study.

4.2.3 Chino Valley Aggregate and Gila Bend Aggregate Mixtures Compacted at 275F

Aggregates from both sources studied were mixed with 8.0 percent CSS-1 emulsified asphalt and 1.0 percent of the aromatic oil. Proportioning, mixing and curing were the same as those described in 4.2.1 and 4.2.2 except that, following curing, the loose mixture was brought to 275F in a drying oven and was compacted as soon as this elevated temperature was reached. Testing for Marshall stability and flow was conducted with specimens brought to 140F in a temperature controlled water bath immediately prior to testing.

TABLE 4.1

TEST RESULTS FOR MIXTURES
USING CHINO VALLEY AGGREGATE

Curing Period	4 Days			3 Weeks	
Aromatic Oil, %	0.5	1.5	4.0	0.5	1.5
Unit Weight, pcf	134.8	135.1	141.2	125.0	128.2
Stability, lb	4014	2241	940	2242	1730
Flow, 0.01 in.	15	14	12	15	13

TABLE 4.2

TEST RESULTS FOR MIXTURES
USING GILA BEND AGGREGATE

Curing Period	4 Days			3 Weeks	
Aromatic Oil, %	0.5	1.5	4.0	0.5	1.5
Unit Weight, pcf	133.9	132.2	129.9	122.4	120.7
Stability, lb	3372	2001	758	1686	1023
Flow, 0.01 in.	10	12	15	13	15

The compaction and testing at these elevated temperatures were performed to obtain information about the mixtures' performance at elevated temperatures. There was particular concern about bleeding and mixture instability under these conditions. The potential of the mixture, when compacted under these well established conditions, could also be examined. Table 4.3 is a summary of the test results obtained.

The limited data obtained indicate unit weight and stability to increase and flow to decrease as the mixtures aged. Although the compacted mixture specimens took on a deeper black color and a more compact appearance than the unheated mixtures, there was no indication of bleeding or instability. The low flows obtained at 140F tend to confirm these conclusions.

When compacted at 275F, unit weights differed slightly from those obtained when compacted at 77F at the end of 4 days curing. This same comparison for material cured for 3 weeks indicates a significant increase for the unit weights for 275F compacted material and an even more significant decrease in unit weights for 77F compacted mixture. The results show that those specimens cured for 3 weeks and compacted at 275F have unit weights 10 percent greater than those similarly cured but compacted at 77F. This condition is of some concern regarding the compactibility of the more fully cured material.

TABLE 4.3

TEST RESULTS FOR MIXTURES USING CHINO VALLEY AND GILA BEND AGGREGATES compacted at 275F

Study Site Aggregate	Chino Valley		Gila Bend	
Curing Period	4 Days	3 Weeks	4 Days	3 Weeks
Aromatic Oil, %	0.5	1.5	0.5	1.5
Unit Weight, pcf	134.8	135.1	125.0	128.2
Stability, lb	4014	2241	2242	1730
Flow, 0.01 in.	15	14	15	13

4.3 Recycled Asphalt Pavement Material

The application of modifiers to recycled asphalt pavement (RAP) material was studied for production of a cold-mixed, cold-laid asphalt patching material. Curing periods of 4 days and 3 weeks, the same as studied for the virgin aggregate mixtures, were used. Three different emulsified rejuvenating agents supplied by Witco Chemicals and the aromatic oil emulsion supplied by Akzo-Chemie America were incorporated into the study. Figure 4.1 is a nomograph used to estimate the amount of rejuvenating agent necessary to adjust the absolute viscosity of the aged asphalt to a desired value of approximately 3000 poises. Various percentages of the modifiers were examined and compaction of mixtures at 77F and 275F was performed. Mixtures compacted at 275F were tested for stability and flow using a 140F water bath to condition the specimens immediately before testing. The 77F compacted specimens were tested at 77F. The mean values of test results are tabulated in Tables 4.4, 4.5 and 4.6.

It is readily apparent from the data in Tables 4.4, 4.5 and 4.6 that appreciably higher unit weights were obtained with the 275F compaction temperature when compared with those achieved with a 77F compaction temperation. This was also true for the virgin aggregate mixtures; however, it was not to the extent experienced here. Whereas RAP specimens compacted at 77F had a mean unit weight of 118.4 pcf and ranged from 113.2 to 124.8 pcf, those specimens compacted at 275F had a mean unit weight of 140.1 pcf and a range from 134.9 to 144.0 pcf. The difference between the mean unit weights for the two compaction temperature was approximately 15 percent. Since stabilities and flows

TABLE 4.4

TEST RESULTS FOR RAP MIXTURES COMPACTED
AT 275F AND TESTED AT 140F

Curing Period	4 Days			3 Weeks		
Modifier Added	Cyc-Me	CRF		Cyc-ME	CRF	Reclamite
Modifier Quantity, %	1.0	1.0	2.5	1.0	1.0	1.0(1)
Unit Weight, pcf	137.1	134.9	136.4	143.2	142.0	144.0
Stability, lb	3140	1825	1745	4974	4278	4358
Flow, 0.01 in.	15	14	16	12	13	10

(1) Values are the means from two specimens. One specimen damaged during handling.

TABLE 4.5

TEST RESULTS FOR RAP MIXTURES COMPACTED AND TESTED AT 77F

Curing Period	4 Days				3 Weeks					
Modifier Added	Cyclogen ME		CRF		Cyclogen ME		CRF		Reclamite	
Modifier Quantity,%	0.5	1.5	0.5	1.5	0.5	1.5	0.5	1.5	0.5	1.5
Unit Weight, pcf	123.3	123.8	124.8	120.6	117.8	115.3	117.4	117.0	117.8	116.6
Stability, lb	4433	3786	4308	3847	3433	2512	3507	2965	3626	1995
Flow, 0.01 in.	26	20	18	24	20	25	19	26	19	17

TABLE 4.6

TEST RESULTS FOR RAP MIXTURES MODIFIED WITH AROMATIC OIL

Curing Period	3 Weeks				4 Days		
Compaction Temp/ Test Temp, F	77/77				275/140		
Aromatic Oil, %	0.5	1.5	2.5	3.5	1.0(1)	2.5	4.0
Unit Weight, pcf	119.2	115.0	113.1	114.6	142.9	136.4	144.0
Stability, lb	3306	1683	1409	1099	4914	1745	1567
Flow, 0.01 in.	18	19	25	26	13	16	23

(1) Values are from one specimen. Two specimens damaged during handling.

for the two compaction conditions were tested at different temperatures, the test results could not be directly compared. However, when the test results were compared to those with similar compaction and testing conditions for virgin aggregates, it was noted that the stabilities were nearly equivalent but flows for the RAP materials were about 50 percent higher.

Rejuvenating agents and the aromatic oil modifiers both generally indicated increased flows and decreased stabilities with increased quantities of the additives. This condition would lead to the conclusion that the lower percentages are preferable if sufficient workability is achieved to permit satisfactory placement. By use of the nomograph in Figure 4.1 values of rejuvenating emulsion of 0.7 percent Reclamite and 1.3 percent Cyclogen are recommended for the 5.5 percent asphalt RAP material studied. The Reclamite produced lower flows and is preferred for this reason. The aromatic oil does not have the rejuvenating properties that are considered desirable for use with the aged asphalt that is presented in the RAP material. All quantities of the Witco Chemical modifiers are in the concentrated form. Dilutions of these emulsions are often used in practice. In such cases, the quantities used should be adjusted according to the dilution to obtain the correct quantities of concentrate.

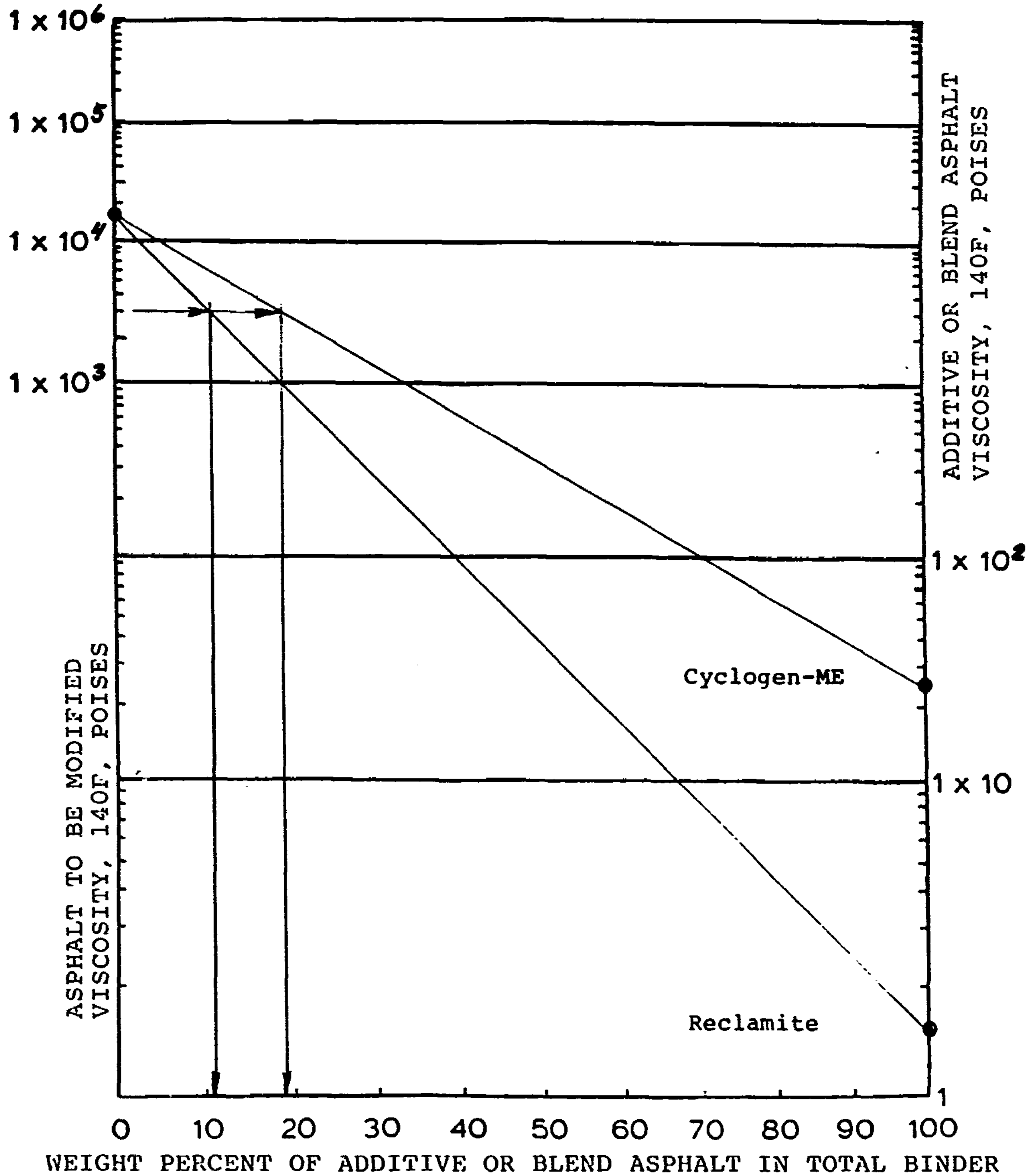

Figure 4.1. Nomograph for Adjusting Asphalt Viscosity

5.0 FIELD PATCHING MIX STUDIES

Two field mixes were prepared for use at the ADOT Gila Bend maintenance yard. One was virgin material meeting the MA-7 specifications with 8.0 percent CSS-1 emulsified asphalt and 3.0 percent aromatic oil and the other was RAP material with 1.0 percent concentrated Reclamite emulsion.

5.1 Mixtures Using Virgin Aggregate

The virgin material mix for this phase of the work was from Tanner's pit at Agua Fria. An aggregate meeting MA-7 specifications was mixed with an emulsified asphalt consisting of 73 percent CCS-1 and 27 percent aromatic oil. This binder was added to the mixture at the rate of 11 percent by dry weight of aggregate. The asphalt was metered into the plant by timing with a stop watch from a distributor with a calibrated pump. The asphalt was supplied by Sahuaro Petroleum & Asphalt Co. This mix appeared poorly coated and very wet, to the point of some run off, possibly due to excess moisture present in the aggregate. Moisture tests of the mixture indicated total water in the mix to be between 7.0 and 12.3 percent. The emulsified asphalt content was measured at 10.5 and 12.3 percent for two tests performed. The mix was transported to the Gila Bend ADOT maintenance yard where the material was placed in a stockpile. When the ADOT staff attempted to use the material, it was found to be non-uniform, ranging from inadequate asphalt to bind the mineral aggregate to lumps of mix up to 1/2 cu ft with very high asphalt contents. These lumps had hardened to such a consistency that pre-mixing with a motor grader proved ineffective.

5.1.1 Field placement of the emulsion mix proved to be troublesome due to the variability of the asphalt content. Several thin patches of less than 3/4 in. thick were placed on Interstate 8 and appeared to be stable and durable. These have since been covered by an overlay and are no longer visible. Thicker patches and filled potholes failed due to raveling on some and displacement on others. This is probably due to the variable asphalt content and poor coating characteristics of the mix.

5.1.2 Laboratory mixes of the emulsified asphalt-aromatic oil binder had given mixed results for aggregate coating. In some instances, better coating was obtained by applying the emulsified asphalt prior to the aromatic oil. In other instances, satisfactory coating was obtained when the two emulsions were simultaneously added to the aggregate. The latter method appeared to require drier aggregate than could be used for the former.

It was not practical to add the two emulsions separately when producing the field patch material and the simultaneous addition method was used. However, the aggregate did have considerable surface moisture which probably contributed to the non-uniform coating.

The surface moisture is also suspected of mixing with the emulsions and reducing the binder viscosity. The high volume of fluids and the low viscosity then caused a runoff condition with the diluted binder flowing into the lower portion of the stockpile shortly after production.

5.2 Mixture Using RAP Material

The RAP material to be used for patching material was cold screened through Tanner's hot plant at 40th Street south of the Salt River. The material was combined from the bins in portions that would provide a finished product meeting MA-7 specifications. One percent concentrated Reclamite emulsion was added and mixed in the pugmill for 1 min. The mix appeared dry and lacked cohesion after completion of the mixing cycle. The mix was stored in a stockpile at the mixing site for several days after which tests were performed on the mix. Gradation analysis indicated the material was in substantial compliance with the required MA-7 specifications, the asphalt content was 7.3 percent and the Marshall density using 75 blows per end was 120.8 lb per cu ft. This resulted in specimens with stability of 915 lb and a flow of 14. This would appear to be in the range expected for this material. However, in appearance, the material lacked the cohesion and workability desired for patching material. An Absom recovery on the asphalt was performed and indicated the residual asphalt had a viscosity of 30,900 poises. This indicated additional Reclamite should have been used for a RAP material with this high a binder viscosity. Efforts to further condition this material were discontinued.

The condition of the resulting mixture made it apparent that it would be friutless to transport the mixture to the job sites and attempt to utilize it. Consideration was given to remixing the material with more rejuvenating agent or mixing further RAP material with a higher percentage of rejuvenator. However, further work was abandoned because the control necessary to satisfactorily prepare the material could not be economically achieved for the small quantities of mixture being produced.

6.0 SUMMARY

This study examined two samples of cold-mix patch material currently in use in the State of Arizona. These would not qualify as a low solvent material. Another patching material, UPM, that is used in Arizona and does qualify as a low solvent material was also studied. Two further systems, one utilizing foamed asphalt binder and one utilizing low solvent emulsified asphalt and aromatic oil, were studied in an effort to develop low solvent mixtures for pavement patching.

6.1 Laboratory Mixtures

6.1.1 Foamed asphalt mixtures were laboratory mixed using a pugmill-type mixer with approximately 20 lb capacity. The aggregate used was 3/8 in. maximum sized decomposed granite, pre-wet to 5 percent moisture. AC-5 asphalt cement was added in amounts of 4 and 5 percent. Neither of these mixes appeared over 50 percent coated or retained workability after a few weeks of outside air curing. No field mixes were prepared with this mix.

6.1.2 Low solvent mixtures were prepared using CSS-1 emulsified asphalt, virgin aggregates and aromatic oils in various combinations. The mixtures, using 1 to 3 percent pre-mixing water and 8 or 9 percent emulsified asphalt with 3 percent aromatic oils, appeared to have the characteristics needed to provide the stockpile life and use features desired of the mix. A small quantity for field use was produced.

6.1.3 Unique paving mixture (UPM) was laboratory tested and both the mixture and the binder tests indicated it had the properties of a low solvent mixture. This is a proprietary product currently in limited use in Arizona as patching material on interstate highways.

6.1.4 Recycled asphalt was crushed and scalped over a 3/8 in. screen and mixed with varying amounts of recycling agents in the laboratory. Laboratory tests indicated several of these mixtures to have properties suitable for a low solvent maintenance patching material. A small quantity of material was produced for this purpose but was never delivered to the job site or placed at any locations.

6.2 Field Tests

6.2.1 The low solvent mixture using virgin aggregate and a binder of CSS-1 emulsified asphalt combined with aromatic oil was unsuccessfully produced for field patching. The non-uniformity in asphalt content was concluded to have been caused by aggregate with a high surface moisture. This resulted in a reduced viscosity and an increased quantity of fluids thereby causing rundown into the stockpile of material.

Material delivered to a stockpile at the ADOT maintenance facility at Gila Bend was found to be difficult to handle and with a highly variable asphalt content. Some material placed in the patches on Interstate 8 are still in place but have been covered by an asphalt concrete overlay. Thicker patches that were placed either ravelled or were found to be unsatisfactorily unstable.

6.2.2 The production of patching material by use of a RAP material and a rejuvenating agent may have been unsuccessful because the asphalt binder was not reduced to a low enough viscosity for handling purposes. This may have been caused by an apparent substantial difference in the aged viscosity of the RAP material laboratory tested and the RAP used for the field mixture. This points out the need for close monitoring and control of material when utilizing RAP and is of particular concern when using stockpiled material taken from a number of sources of varying properties.

The RAP and rejuvenating agent mixture was not delivered to the job site or used for patching because its apparent lack of cohesion indicated it to be unsatisfactory. Further efforts to produce a quantity of material for field use were discontinued due to the inability to satisfactorily control the proportioning and mixing for small quantittes of material and the expense involved in producing the mixture.

7.0 CONCLUSIONS

The overall objective to develop pavement patching mixtures with low solvent and a 6 month sockpile life was not achieved. Unique Paving Mixture currently in use by Arizona DOT was found to meet the requirements for a low solvent mixture. The fact that it has been successfully used by Arizona DOT maintenance for a number of years indicates its performance qualifies it as a satisfactory low solvent patching material.

Two systems of low solvent mixture were studied. Foamed asphalt was examined with both virgin aggregate and RAP material and was found to not have the necessary stockpile life to serve as a maintenance patching material. A binder of emulsified asphalt and aromatic oil was studied with a virgin aggregate. A uniform mix with necessary handling and curing properties for pavement patching was not achieved. An additional mixture utilizing RAP material and a rejuvenating agent was studied but with unsuccessful results in producing a satisfactory maintenance patching material.

Laboratory investigations eliminated foamed asphalt as a binder worthy of further studies. Laboratory studies of RAP material with a rejuvenator and virgin aggregate with an emulsified asphalt-aromatic oil binder led to field tests of these mixtures.

A RAP material and rejuvenator mixture was produced to ship to field sites; however, the material lacked satisfactory cohesion and was discarded. A quantity of mixture using emulsified asphalt and aromatic oil binder with virgin aggregate was produced and transported to a stockpile at Gila Bend. Limited success with some of the material as skin pathces was achieved. Thicker patches were found to remain unstable. No material was shipped to the Chino Valley job site selected.

Of the materials studied, only UPM was concluded to be a satisfactorily performing low solvent patching material. The material was found to meet the requirements of a low solvent mixtrue. Studies of ability to be held in a stockpile were not made; however, successful use by Arizona DOT and other agencies are an indication of its satisfactory performance.

8.0 RECOMMENDATIONS

The continued use of UPM as a patching material is recommended on the basis of its properties as a low solvent material and one with a satisfactory performance history. The manufacturer's recommended procedures should be followed.

The use of cold-recycling of RAP material with an emulsified rejuvenator may warrant further study. Such experimentation may be better conducted at local maintenance facilities with windrow type mixing and handling that would more easily allow varying the addition of rejuvenator. In any instance, a determination of the viscosity of the aged asphalt in the RAP material should be performed to set the rejuvenator quantity to be added.

The further development of low solvent pavement patching materials is desirable and further research is recommended. This study, however, did not produce a direction or areas to research other than further investigation of RAP and rejuvenating agents as previously mentioned.

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