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Ron Reese and Nelson H. Predoehl

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16. ABSTRACT

This research effort by the Office of Transportation Materials and Research (TM&R) involves the evaluation of modified asphalt binders in test sections at three test sites. Two sites are located in hot climates and the third site is located in a cold climate. The objectives of this study are to: 1) Obtain modified asphalt binders and evaluate the aging rate and improvements in temperature susceptibility; 2) screen the modified binders using the California Tilt-Oven Durability (CATOD) Test (a procedure which simulates the effect of two years' hardening of standard asphalt in hot desert climate) for field trial use; 3) determine whether the modified binders are durable (resist property changes with aging) by trial in a hot climate and resist thermal cracking by trial in a cold climate; 4) recalibrate the CATOD procedure for modified binders if necessary.

Four different polymer modified asphalt binders were used on two hot climate (at Ocotillo and Needles) test sections and one cold climate (Crestview) test section. After two years at Ocotillo and one year at Needles, the binders have age hardened approximately as predicted by the CATOD Test in that the control binder at Ocotillo has reached a 10 penetration while the polymer modified binder has virtually no hardening. No cracking or other distress is evident at any of the sites at this time. Future annual evaluations will be performed.

17. KEYWORDS
Asphalt, asphalt concrete overlays, Polymer modified asphalt, hot climate, cold climate, temperature susceptibility, AC test sections, California Tilt-Oven Durability (CATOD) Test, age hardening

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DEPARTMENT OF TRANSPORTATION

DIVISION OF NEW TECHNOLOGY,
TRANSPORTATION MATERIALS AND RESEARCH

OFFICE OF TRANSPORTATION MATERIALS AND RESEARCH

EVALUATION OF MODIFIED ASPHALT BINDERS (INTERIM REPORT)

Performed by ..... Pavement Branch

Supervised by ..... Robert. N. Doty, P.E.

Principal Investigators. ..... Ronald E. Reese, P.E. and Bobby G. Page, P.E.

Co-investigator ..... Nelson H. Predoehl

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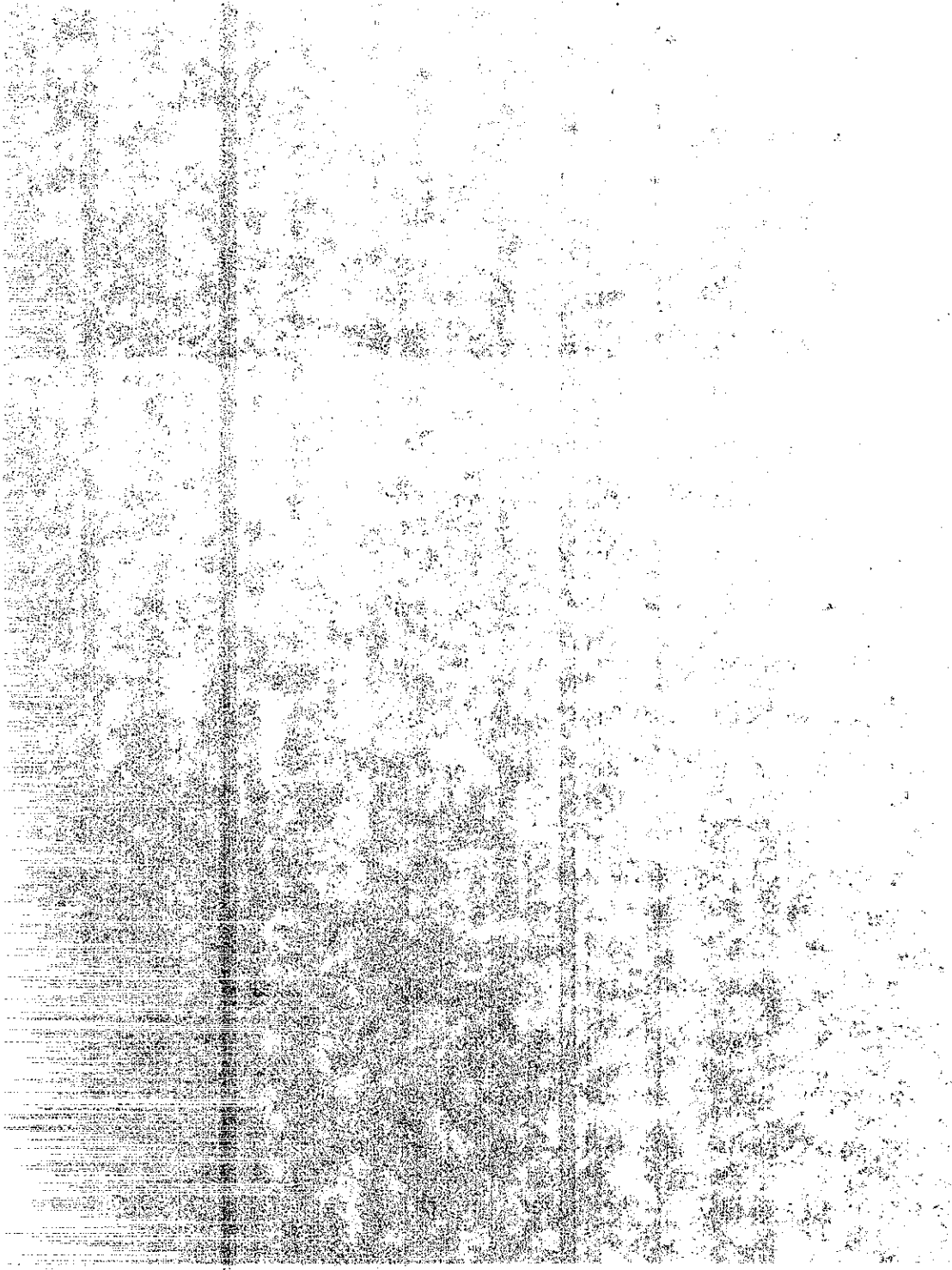
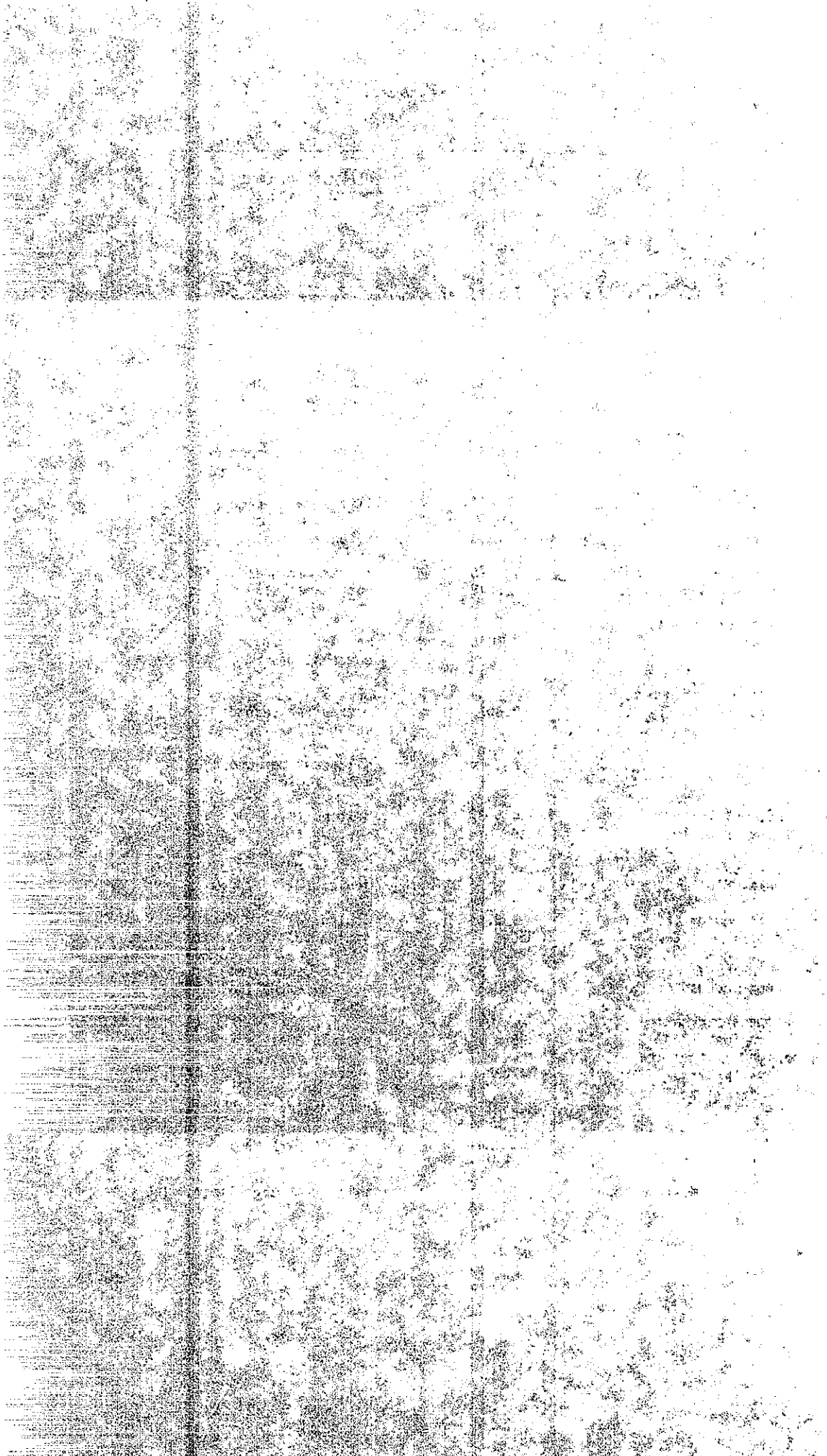


CONVERSION FACTORS

English to Metric System (SI) of Measurement

Quality	English Unit	Multiply By	To Get Metric Equivalent
Length	inches (in) or (")	25.40	millimetres (mm)
		.02540	metres (m)
	feet (ft) or (')	.3048	metres (m)
	miles (mi)	1.609	kilometres (km)
Area	square inches (in^2)	6.432×10^{-4}	square metres (m^2)
	square feet (ft^2)	.09290	square metres (m^2)
	acres	.4047	hectares (ha)
Volume	gallons (gal)	3.785	litre (l)
	cubic feet (ft^3)	.02832	cubic metres (m^3)
	cubic yards (yd^3)	.7646	cubic metres (m^3)
Volume/Time (Flow)	cubic feet per second (ft^3/s)	28.317	litres per second (l/s)
	gallons per minute (gal/min)	.06309	litres per second (l/s)
Mass	pounds (lb)	.4536	kilograms (kg)
Velocity	miles per hour (mph)	.4470	metres per second (m/s)
	feet per second (fps)	.3048	metres per second (m/s)
Acceleration	feet per second squared (ft/s^2)	.3048	metres per second squared (m/s^2)
	acceleration due to force of gravity (G)	9.807	metres per second squared (m/s^2)
Density	(lb/ft^3)	16.02	kilograms per cubic metre (kg/m^3)
Force	pounds (lb)	4.448	newtons (N)
	kips (1000 lb)	4448	newtons (N)
Thermal Energy	British thermal unit (BTU)	1055	joules (J)
Mechanical Energy	foot-pounds (ft-lb)	1.356	joules (J)
	foot-kips (ft-k)	1356	joules (J)
Bending Moment or Torque	inch-pounds (in-lb)	.1130	newton-metres (Nm)
	foot-pounds (ft-lb)	1.356	newton-metres (Nm)
Pressure	pounds per square inch (psi)	6895	pascals (Pa)
	pounds per square foot (psf)	47.88	pascals (Pa)
Plane Angle	degrees (°)	0.0175	radians (rad)
Temperature	degrees fahrenheit (°F)	$\frac{°F - 32}{1.8} = °C$	degrees celsius (°C)
Concentration	parts per million (ppm)	1	milligrams per kilogram (mg/kg)



ACKNOWLEDGEMENTS

This is to acknowledge the efforts of many individuals who assisted in the gathering of data for this report. Particular recognition is given to Glenn R. Kemp who was the principal investigator of this study prior to his retirement in April 1988. Special recognition is given to Duane Anderson, Dawn Becky, Hideyo Hashimoto, Kenneth Iwasaki, Ronald Morrison and Jayne Robinson who participated in the mix design, coring and materials testing. Appreciation is also extended to those involved with the typing and editing of this report.

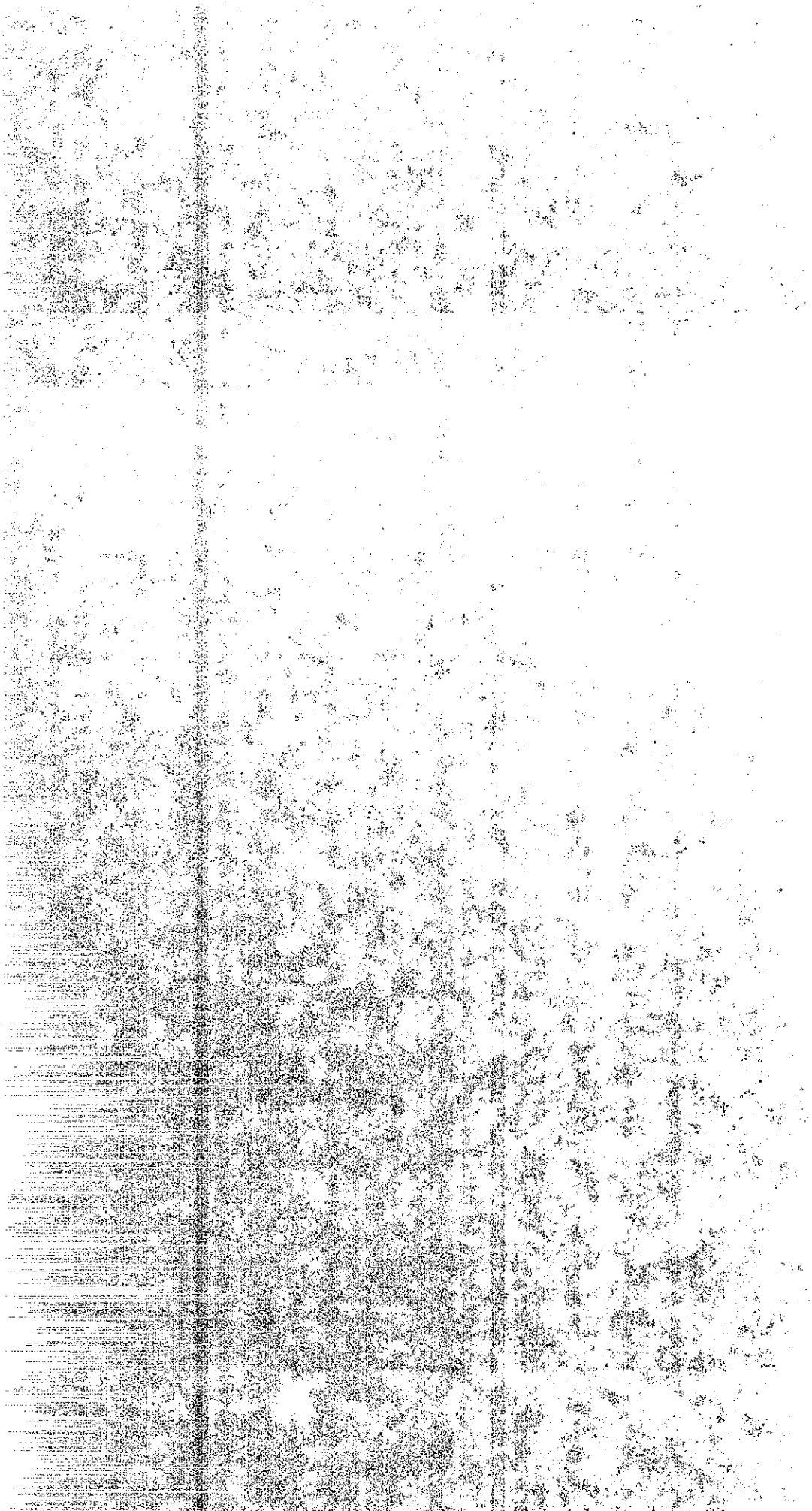
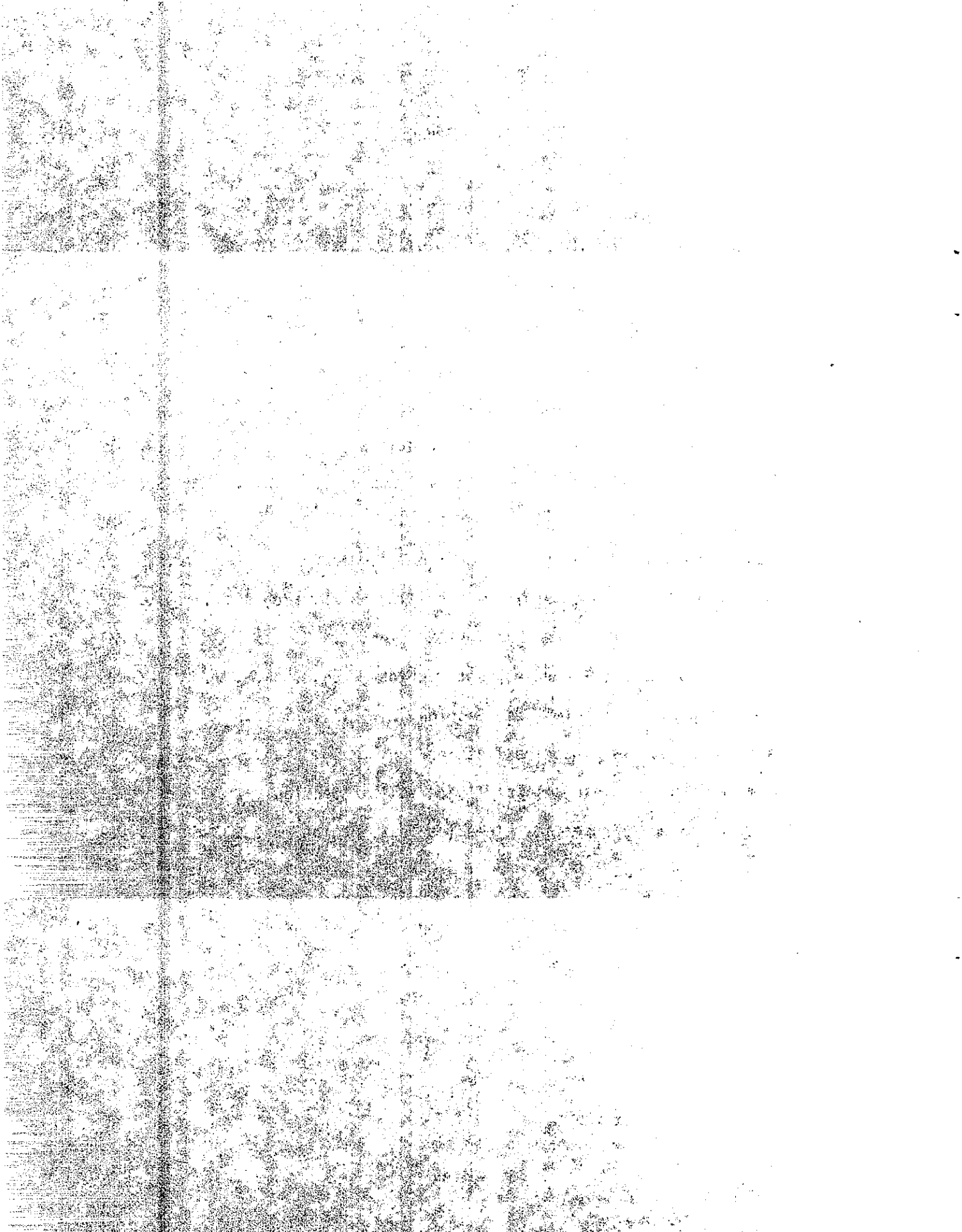
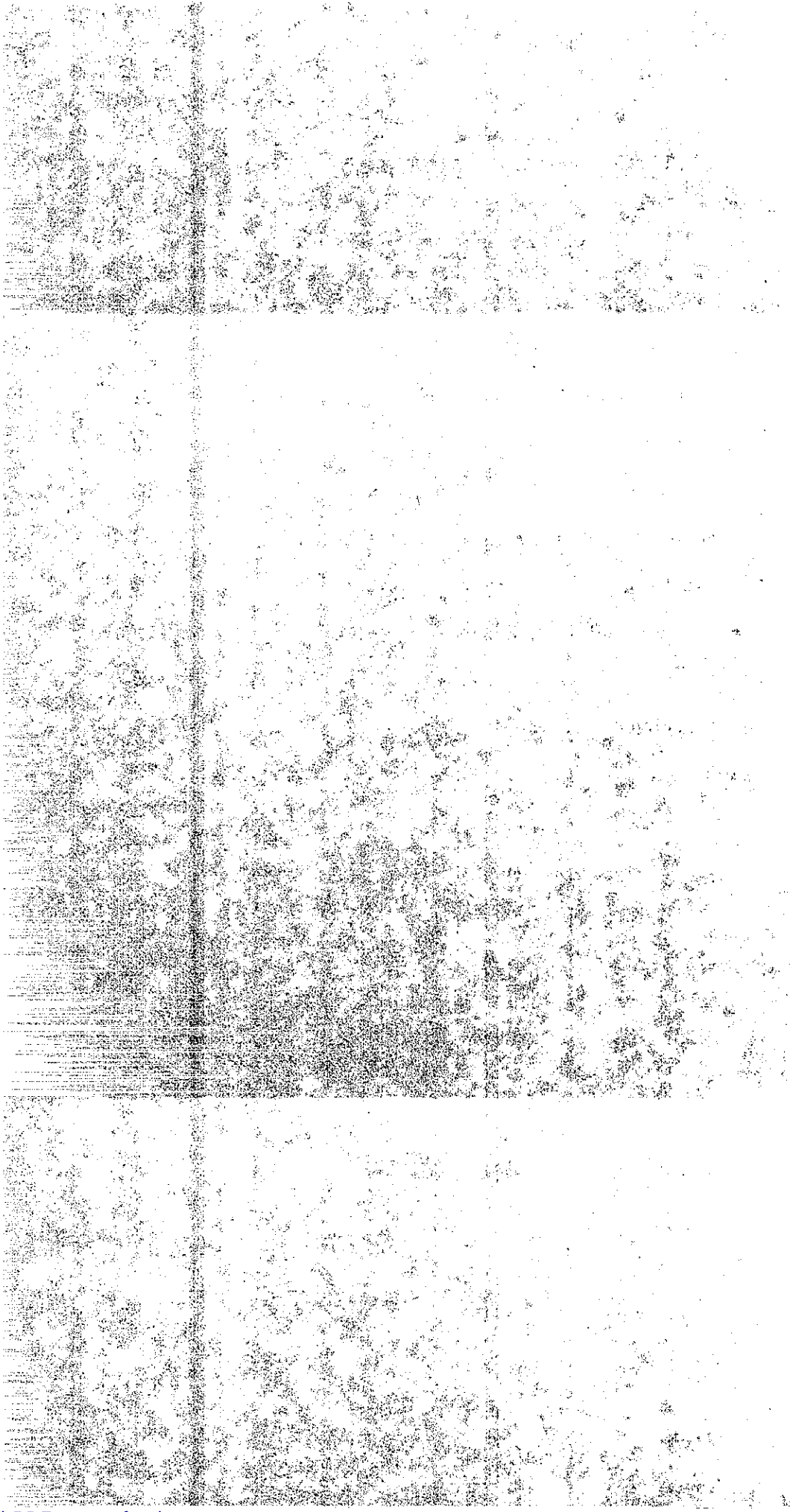


TABLE OF CONTENTS

LIST OF TABLES



LIST OF TABLES (Continued)



LIST OF FIGURES

INTRODUCTION

Approximately 25 percent of the highway network in the State of California is located in regions subject to either extreme heat (low deserts) or extreme cold (high mountain and northern interior). The effect of these extremes has been the premature distress of asphalt concrete (AC) pavements manifested by thermal cracking.

In an effort to address the cause of this type of distress, the California Department of Transportation (Caltrans) has engaged in a study sponsored by the Federal Highway Administration (FHWA) to evaluate the ability of modifiers to reduce the aging rate and improve the temperature susceptibility of asphalt binders. Studies (1,2,3,4,5) have indicated that conventional asphalt binders are unable, in all cases, to measure up to the temperature susceptibility needs of all climates.

This research effort by the Office of Transportation Materials and Research (TMR) involves the evaluation of modified asphalt binders in test sections at three test sites. Two sites are located in hot climates and the third site is located in a cold climate. The objectives of the study are to: 1) obtain modified asphalt binders and evaluate the aging rate and improvements in temperature susceptibility; 2) screen the modified binders using the California Tilt Oven Durability (CATOD) Test (a procedure which simulates the effect of two years' hardening of standard asphalt in a hot desert climate) for field trial use; 3) determine whether the modified binders are durable (resist property changes with aging) by trial in a hot climate and resist thermal cracking by trial in a cold climate; and 4) recalibrate the CATOD procedure for modified binders if necessary.

This report will detail the construction of test sections at three sites and will present preliminary evaluations.

INITIAL FINDINGS

1. The use of polymer modified asphalt binders presented no problems in the design, mixing, or placement of the AC pavement. The only noticeable difference was slightly more smoke from some of the products during paving operations.

2. Results from coring and testing reveal a significantly reduced hardening rate for two of the three modified asphalts compared to the control binders after one year at Needles and two years at Ocotillo.

3. Field evaluations after one year at Needles and Crestview and two years at Ocotillo revealed no distress in any of the sections.

4. The recovery of modified asphalt by California Test 380 yields an acceptable sample for physical property characterization of the material placed at Ocotillo.

BACKGROUND

Previous Caltrans research (1,5) has shown the need for more durable asphalts for the desert region of the state and for asphalts with lower temperature susceptibility for the cold region of the state.

In the asphalt durability study (1) an accelerated aging test was developed which correlates with two years of aging in the low desert. Based on this test (California Test 374 - California Tilt-Oven Durability Test), a specification for a "durable" asphalt was proposed. This specification requires an AR-4000 grade asphalt to meet the following requirements after aging by Test 374:

Absolute Viscosity @140°F	AASHTO T202	100,000 poise (max.)
Penetration @77°F	AASHTO T49	15 dmm (min.)
Ductility @77°F	AASHTO T51	20 cm (min.)

The use of an asphalt that complied with this specification was expected to result in extended AC pavement life in the low desert region. Therefore, one of the tasks of this project was to evaluate complying material by a field trial. However, this was dependent on the ability of the asphalt producers to manufacture an asphalt meeting the specification. Initially, two producers supplied several samples of blended asphalts, none of which met all of the requirements. Producers and additive manufacturers then began supplying samples of modified asphalts. Test results on the first set of samples submitted met the specification by such a wide margin that it was

decided to tighten the specification on the residue from Test 374 as follows:

Absolute Viscosity @140°F	AASHTO T202	75,000 poise (max.)
Penetration @77°F	AASHTO T49	25 dmm (min.)
Ductility @77°F	AASHTO T51	30 cm (min.)

Test results on the 15 modified asphalts that were submitted are listed in Table 1. Only Asphalt Supply and Service Co. (ASSCO), Chevron, Edgington and Witco were asked to supply binder for a desert test section. Plans were then made to incorporate these four binders into test sections on AC rehabilitation projects located in the desert. While we didn't ask for the specific formulation of these binders, we understand that various blends of styrene and butadiene are the key components of these four binders.

It has been recommended in previous asphalt durability studies (1,3,4) that a penetration requirement (@39.2°F) be added to the specification for paving asphalts to be used in a cold climate. It was observed while testing the modified binders submitted for desert use that some of them had extremely good low temperature properties. Therefore, plans were made to incorporate two of the binders into an existing rehabilitation contract located in a cold region. Conoco and Witco were asked to supply modified binders complying with the desert specification as a guideline plus an additional requirement on the rolling thin film residue. A minimum penetration at 39.2°F of 35 dmm was established from the previous analysis of these materials. It is significant that both asphalts need modification to achieve this requirement even though one of them already has relatively low temperature susceptibility.

TEST SECTIONS

I. Site Selection:

Selection of the test sites was dependent on finding AC construction projects in the appropriate climate with project personnel receptive to the change in project plans or contract change order necessary to incorporate an adequate test section.

Arrangements were made for a desert test section in a project on State Route 98 near Ocotillo. However, the project size limited the test section to only one of the modified asphalts. Therefore, arrangements were made for a test section in a larger project on Interstate 40 near Needles. Unfortunately, Chevron was unable to supply their material so only three modified asphalts were placed. Later a cold climate test section was incorporated into a project on U.S. Highway 395 near Crestview.

Climatological data for these sites are listed in Table 2. A map showing the location of the test sites is labeled Figure 1, and Table 3 provides traffic data and an evaluation of pavement conditions prior to the rehabilitation at these three sites.

II. Construction:

A. Ocotillo Test Section (Road 11-IMP-98-1.5/3.5)

The test section at Ocotillo was constructed between December 9 and 11, 1986 using the Witco modified asphalt. The test road, a low traffic volume road near the border of Mexico, was severely block cracked (65-70%) with widespread alligator and longitudinal cracking

(Table 3). Details of the test section are presented in Figure 2.

The asphalt concrete mixture was produced at the Val Rock plant in Seeley, California and hauled approximately 20 miles to the job site. Aggregate properties and mix design recommendations are listed in Table 4.

Paving operations were conducted under clear skies and moderate temperatures with no difficulties. Paving temperatures are recorded in Table 5. Densities were determined with the nuclear gage within one week after paving. Compaction data, showing relative compactions above 95, are recorded in Table 6. During construction, samples of the AC mix were taken from the windrow and samples of the binders were taken at the mixing plant. Results of tests performed on the mix samples are recorded in Tables 7 and 8, and tests performed on the binder samples are recorded in Table 9. The test results indicate generally acceptable paving practices and materials. The only observable difference in placing the modified asphalt was an increase in the amount of smoke from the AC in the windrow and in the paving machine hopper.

B. Needles Test Section (Road 08-SBd-40-137.2/140.0)

The test sections at Needles were placed on Interstate 40, which has exceptionally high truck traffic. Since the existing roadway had severe alligator cracking (greater than 90%) in the wheel tracks and considerable transverse, longitudinal, and block cracking, 0.20 foot of the old AC (in No. 2 lane) was cold planed and replaced with 0.20

foot of Type A dense graded AC. Traffic and preoverlay conditions are recorded in Table 3. The layout of the test section is displayed in Figure 3.

The aggregate source and the Desert Construction mixing plant were located near Essex, California; approximately 30 miles from the test section. Aggregate properties and design asphalt content recommendations are listed in Table 10.

The test section AC overlays were targeted to be 0.15 foot thick. Air temperature on the paving dates ranged from 50's in the mornings to 70's in the afternoons under clear skies. Paving temperatures and paving sequences are recorded in Table 11. The listed breakdown temperatures indicate breakdown rolling occurred above the 250°F minimum. Nuclear density tests were performed on the test section two weeks after paving. Test results contained in Table 12 indicate that while the relative compactions are greater than 95 percent, the total air voids are around 11 percent. Generally, the paving operations proceeded without any problems. The only observable difference in placement was an increase in smoke from the AC mix in the windrows. The Edgington binder produced the greatest amount of smoke with ASSCO binder only smoking when mix temperatures were above 300°F in the windrow.

During construction of the test sections, samples of the AC mix were taken from the windrow and samples of the binders taken at the mixing plant. The samples were tested at TMR for compliance with

specifications. Aggregate grading results of samples extracted from windrow samples are listed in Table 13. These results show general compliance with the grading specifications. The results of tests performed on the binder samples are recorded in Table 14. These results show a general compliance with the desert specification by all of the modified binders except for the ASSCO binders which did not meet the ductility requirement. The prequalification sample from ASSCO had met the desert specification. Test results (Figure 15) of recovered binder from windrow samples show that the Witco polymer modified binder reacted as it had previously at Ocotillo by not hardening in the mixing phase. Conversely, the Edgington and ASSCO polymer modified asphalts showed more hardening in the mixer than predicted by the rolling thin film test.

C. Crestview Test Section (Road 09-MNO-395-33.3/36.1)

The cold climate test section was placed as part of a widening and rehabilitation project on US 395 adjacent to the Caltrans Crestview Maintenance Station about 50 miles north of Bishop, California. The test sections using modified asphalt from Conoco and Witco were placed in the northbound (uphill) No. 2 lane which ascends in elevation from approximately 7500 to 8000 feet. Details of the location and length of the test areas are presented in Figure 4. Traffic and prior road condition are listed in Table 3.

The rehabilitation plans called for an overlay of 0.40 foot of Type B, 3/4 inch maximum medium AC. The initial 0.14 foot AC level

course, which was paved before the winter shutdown in November 1987, contained Witco AR-2000 asphalt binder. However, when construction resumed in 1988, the job AR-2000 was supplied by Shell. The test sections were placed in two 0.13 foot lifts to complete the remaining 0.26 foot of AC overlay.

The AC mixes were produced with aggregate mined and processed at the Hunewill pit and hot plant at Lee Vining, California, which was 15 miles from the Crestview test site. Properties of the aggregate used in the mix design and of an aggregate sample taken on the first day of paving are reported in Table 16. Also shown are the asphalt content recommendations. The target asphalt content was increased by the Resident Engineer during paving since he thought the mix looked dry and because AC (same aggregate) placed during the previous year on this project was experiencing raveling. During and after paving, the test mixes on the street looked good with no signs of richness with the higher binder content.

Construction of the test sections began on September 15, 1988. Weather conditions were clear and sunny with a maximum air temperature of about 75°F. Paving started at about 10:30 a.m. when the temperature had reached 50°F. Paving mixture and atmospheric temperature readings obtained during the placement of the test sections are recorded in Table 17. Paving of the lower 0.13 foot of each of the three test sections (each approximately 1500 feet long) was completed by approximately 3:30 p.m. Due to other paving requirements of the contract, paving of the surface course (second

lift-0.13 foot) did not resume until September 20, 1988. The weather was partly cloudy and the minimum atmospheric temperature for paving was not attained until approximately 10:30 a.m., but it appeared that paving could proceed properly.

Paving began with the control section which was completed by 12 noon. Paving of the Witco polymer modified (PM) binder sections continued immediately under cloudy skies, but no rain. A light misty rain started at about 1 p.m. and continued until paving stopped at about 1:30 p.m. By the end of paving, water was accumulating and running on the paving surface. The paving of the Conoco PM binder surface course was completed two days later on a sunny September 22, 1988. Using a nuclear gage, densities were obtained for each of the test sections within a week of construction. Compaction values are listed in Table 18. The results show that the total voids range between 6.5 and 8.9 percent in the test sections.

Except for somewhat cool air temperatures and some inclement weather which probably affected the compaction, the construction proceeded well. The polymer modified binders again produced more smoke during the mixing and paving operation than the control asphalt.

During construction, samples of the AC mixtures were taken by TMR personnel from the windrows and samples of the binders were taken at the mixing plant. Also samples of the mix were taken from the mat behind the paver by the District 09 street inspector. Extraction test results listed in Table 19 of windrow (TMR) and street samples

(District 09) suggest that greater than planned binder contents may have been used in the test section AC mixes. Grading values listed in Table 19 derived from these samples, indicate that the aggregate used in the modified and control AC was deficient in coarse aggregate and out of specification on 9-15-88 and 9-22-88.

In addition to using the windrow samples to fabricate briquettes, a portion of the AC mix was used to recover the binder (California Test 380). Test results on the recovered binders are recorded in Table 20. Samples of the binders were also taken on each of the paving dates. Test results from these samples are recorded in Table 21. The results show that the hardening effect of the mixing plant was similar for the control and Witco PM binders and approximately the same as the rolling thin film (RTF) procedure; however, the Conoco PM binder was less affected by the mixing plant than by the RTF procedure. The test results reveal that the modified asphalts nearly met the desired penetration value at 39.2°F. The desert specification guidelines were met by the Witco PM binder; however, the Conoco PM binder did not meet two out of three of the requirements. The failure of the Conoco PM binder to meet these guidelines suggests only that this binder would probably not be an appropriate binder for a desert climate.

POSTCONSTRUCTION EVALUATIONS

Postconstruction evaluations include coring, laboratory testing and field evaluations (crack and condition surveys). The evaluations are performed annually.

I. Coring and Testing

Annual corings have been performed at the Ocotillo (2 corings) and Needles (1 coring) sites. Abson recoveries were performed on the cores and results of tests performed on the recovered asphalts are recorded in Tables 22 and 23. The results show minimal and similar hardening by the Witco modified binders at the Ocotillo and Needles sites. The results also show considerable hardening of the control asphalt at both sites. The control asphalt after two years at the Ocotillo site appears to be reaching a point where cracking may be imminent. The viscosity increase of the binders at Ocotillo are presented graphically in Figure 5. It also shows how they relate to the CATOD prediction. All of the modified asphalts have a much-reduced hardening rate except for the ASSCO modified asphalt at the Needles site. Generally, the modified asphalts have performed as expected from the laboratory analyses, but more time will be needed to see if the trend continues. No corings are planned for the Crestview site until near the end of the research project.

There has been some concern that the recovery of modified asphalts for physical property analysis may be inappropriate if the polymers are being separated from the asphalt in the recovery procedure. To evaluate this possibility, the torsional recovery test, Califoria Test 332, was used as an indicator of polymer presence. The elastic responses of the binders recovered by California Method 380 from the windrow samples from Ocotillo and the annual corings at this site were compared with plant samples of the binder in its original state, after RTF aging, and after CATOD aging. The data are displayed graphically in Figure 6. The laboratory-aged samples, where complete polymer presence is assured, show a definite weakening of elastic tendency with age. If the polymer was being removed by the recovery procedure, it would be expected that the field-aged material would exhibit less elastic tendency than the laboratory sample of corresponding age. Notice that the windrow sample shows more "life" than the RTF sample and the second year core sample shows more "life" than the tilt-oven sample. Interestingly, this is the same trend observed for the absolute viscosity of these binders. Therefore, it seems reasonable to have some confidence that the recovery procedure is not adversely altering the polymer modified binder being studied at Ocotillo. The binders at Needles will be evaluated similarly when the two-year cores are available.

II. Field Evaluations

Crack and condition surveys have been performed at approximately yearly intervals at the Ocotillo, Needles, and Crestview sites. The surveys have revealed no distress at any of the sites.

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TABLE 1
PROPERTIES OF TILT-OVEN RESIDUE
OF MODIFIED ASPHALTS SUBMITTED
BY ASPHALT OR ADDITIVE PRODUCERS

Residue From Tilt-Oven Durability Test
California Test 374

	Lab Id Number	Absolute Viscosity @ 140°F (Kilopoise)	Penetration @ 77°F (dmm)	Ductility @ 77°F (cm)
1.	R-5116	97	15	8
2.	R-5117	85	11	8
3.	R-5118	44	11	28
4.	R-5119	33	14	10
5.	R-5130(a)	15	33	78
6.	R-5149	156	14	25
7.	R-5150	32	14	25
8.	R-5152	48	25	11
9.	R-5153	41	15	31
10.	R-5158	396	13	7
11.	R-5159(b)	38	22	31
12.	R-5164	54	23	13
13.	R-5168	112	26	9
14.	R-5169(c)	65	26	53
15.	R-5180(d)	21	34	41

a) Witco
b) Chevron
c) Asphalt Supply and Service Co.
d) Edgington

TABLE 2
CLIMATOLOGICAL DATA FOR TEST SITES*

Site (Nearest Weather Site)	Elevation (Feet)	Temperatures (°F) Yearly Average	Maximum (Avg)	Minimum (Avg)	Yearly Average Rainfall (inches)
Ocotillo (hot) (El Centro)**	(Estimated 100-200') -30	71.8	116	30	2.3
Needles (hot) (Needles FAS)	913	72.8	117	32	4.4
Crestview (cold) (Mono Lake)**	(Approximately 7500) 6450	47.7	92	5	13.0

*Data from U.S. Department of Commerce, National Oceanic and Atmospheric Administration (NOAA)

Climatological Summaries:
**El Centro is approximately 20 miles east of Ocotillo with similar climatic conditions.
Mono Lake is the nearest (approximately 25 miles north) weather station to Crestview site. Crestview is approximately 1000 feet higher in elevation and is also probably cooler with more precipitation in the form of snow.

TABLE 3
TRAFFIC AND PRIOR CONDITIONS

TRAFFIC DATA				CONDITIONS PRIOR TO OVERLAY					
TEST SITE (Lane)	T.I.(10 yr.)	ADT (year)	% Trucks	Deflections (80th Percentile) (inches (year)		Alligator Cracking (% of W.T.)	Transverse Cracking (Number/100ft)	Block Cracking (%)	Longitudinal Cracking (ft/100ft)
Ocotillo (EB & WB)	8.0	1200 (1987)	11.1	0.027 (10/84)	EB	21	4	70	200
					WB	15	3	65	200
Needles (WB)	13.5	8700 (1987)	51.7	0.009 (8/85)		92	6	16	100
Crestview (NB)	8.5	4000 (1987)	5.5	0.036 (1985)		42	6	14	100

TABLE 4

AGGREGATE PROPERTIES - OCOTILLO TEST SECTION

(Asphalt Concrete Type B, 1/2 Inch Maximum, Coarse Grading)

Aggregate Source and Plant Location: Val Rock, Seeley, California (approximately 20 miles from jobsite).

Test	California Test	California Standard Specification Section 39	Bin Sample 1-5-86
Specific Gravity	308	fine	---
		coarse	2.61
Sand Equivalent	217	42 (min)	64
K_c Factor	303	1.7 (max)	1.2
K_f Factor	303	1.7 (max)	1.2
K_m Factor	303	---	1.2
Approximate Bitumen Ratio (CKE)	303	---	5.5
Surface Area (sq ft/lb)	303	---	31.6
Design Asphalt Content Recommendation	by TMR for Polymer Modified Binder		5.5 to 6.0
	by District 11 Lab Control Binder		5.8 to 6.3

TABLE 5

PAVING TEMPERATURES - Ocotillo Test Section - 12/9/86 to 12/11/86
Road 11-IMP-98-2.5/3.5

Section	Limits (Station)	Course	Temperatures °F*					
			Mixing	Windrow	At Screed	Breakdown	Air	Date
Control	EB Lane Sta 161+67 to 186+00	Level	320-330	318	301	276	72/76	12/9/86
Polymer Modified	EB Lane Sta 189+10 to 214+39	Level	"	307	294	272	72	12/9/86
Control	WB Lane Sta 161+67 to 186+00	Level	"	310	295	260	63	12/10/86
Polymer Modified	WB Lane Sta 189+10 to 214+39	Level	"	313	292	289	66	12/10/86
Control	WB Lane Sta 161+67 to 186+00	Surface	"	311	295	275	68	12/11/86
Polymer Modified	WB Lane Sta 189+10 to 214+39	Surface	"	305	282	273	65	12/11/86

*Using infrared sensor

TABLE 6

COMPACTION DATA - Ocotillo Test Section

Section	Lift	Laboratory Specific Gravity*	Roadway Specific Gravity**	Relative Compaction(%)	Maximum Specific Gravity***	Compaction Relative to Max SG %	% Voids
Control							
EB	Surface	2.33	2.25	96.6	2.48	90.6	9.4
WB	Surface	2.32	2.27	97.8	2.48	90.8	9.2
Polymer Modified							
EB	Surface	2.32	2.24	96.6	2.48	89.6	10.4
WB	Surface	2.31	2.25	97.4	2.48	90.4	9.6

*On windrow samples, Californa Test 375

**Nuclear densities obtained 12/18/86 standard, backscatter position.

***AASHTO T-209, Rice Method

TABLE 7

Extraction Results - Ocotillo Test Section

Sieve Size (inches)	Specification Type B, 1/2 Inch Max Coarse Grading Operating Range	Gradings (percent passing)			
		Control (Paramount AR 4000)		Polymer Modified (Witco)	
		Level Course 12/9,10/86	Surface Course 12/11,12/86	Level Course 12/9,10/86	Surface Course 12/11,12/86
3/4	100	100	100	100	100
1/2	95-100	97	98	99	98
3/8	75-90	85	88	87	87
#4	55-61	59	64	61	64
#8	40-45	43	47	46	47
#16	--	31	34	33	33
#30	20-25	22	23	22	23
#50	--	16	17	16	16
#100	--	10	11	11	11
#200	3-7	5.0	7.3	6.4	7.5
Asphalt Content (percent)	Target	5.4	5.4	5.4	5.4
	Extracted	5.5	5.5	5.3	5.3

TABLE 8

Recovered Binder Properties - Ocotillo Test Section
(from Windrow Samples)

Test Section	Paving Date	Course	Tests on Abson Recovered Residue (Calif. Test 380) Absolute Viscosity at 140°F AASHTO T202 (poise)	Kinematic Viscosity at 275°F AASHTO T201 (centistokes)	Penetration at 77°F AASHTO T49 (dmm)	Softening Point AASHTO T53 (°F)	Ductility at 77°F AASHTO T51 (°F)	ASH Content (%) ASTM D-2939
Control	12/9	EB level	10138	648	24	139	100+	1.09
"	12/10	WB level	2400	364	69	127	100+	--
"	12/11	EB surface	3892	452	34	131	100+	--
"	12/12	WB surface	2190	337	66	127	100+	0.67
	Average		4655	450	48	131	100+	
Witco Polymer Modified	12/9	EB level	1480	774	173	129	75	--
"	12/10	WB level	2952	1100	119	136	94	--
"	12/11	EB surface	2540	1050	128	135	88	--
"	12/12	WB surface	1950	998	158	130	85	--
	Average		2230	980	144	132	85	

TABLE 9
SUMMARY OF BINDER TEST RESULTS - OCOTILLO TEST SECTION

Test	Test Method AASHTO	Desert Spec.	Control - Paramount AR 4000				Polymer Modified (Witco)			
			R5172 12/9/86	R5173 12/10/86	R5175 12/11/86	R5177 12/12/86	R5171 12/9/86	R5174 12/10/86	R5716 12/11/86	R5178 12/12/86
Test on Original Material										
Penetration at 77°F (dmm)	T49		51	51	51	51	134	134	138	139
Penetration at 39.2°F (dmm)	T49		15	15	15	15	54	55	57	56
Penetration Ratio $\frac{\text{Pen. 39.2} \times 100}{\text{Pen. 77}}$			29.4	29.4	29.4	29.4	41	41	41.3	40.3
Flash Point C.O.C. (°F)	T48	450 min	585	570	550	525	495	485	455	445
Softening Point (°F)	T53		128	---	---	128	135	---	---	136
Absolute Viscosity at 140°F (poise)	T202		1824	---	---	1916	2069	---	---	1953
Kinematic Viscosity at 275°F (cst)	T201		287	---	---	294	809	---	---	866
Solubility in TCE (%)	T44	99.0 min	99.9	99.9	99.9	99.9	99.9	99.9	99.9	99.9
Specific Gravity at 60°F	T228		1.023	---	---	1.022	1.020	---	---	1.020
Test on RTF Residue	T240									
Absolute Viscosity at 140°F (poise)	T202	3000-5000	4230	4295	4284	4261	4008	4062	3991	3909
Kinematic Viscosity at 275°F (cst)	T201	275 min.	409	400	411	417	941	1008	1037	1034
Penetration at 77°F (dmm)	T49	25 min.	32	32	30	31	88	87	88	87
Penetration at 39.2°F (dmm)	T49		10	---	---	12	33	---	---	33
%Original Penetration $\frac{\text{RTF Pen. 77} \times 100}{\text{Orig. Pen. 77}}$		45 min.	62.7	62.7	58.8	60.8	65.7	64.9	63.8	62.6
Ductility at 77°F (cm)	T51	75 min.	100+	100+	100+	100+	100+	100+	100+	100+
Test on CATOD Residue	(CA Test 374)									
Absolute Viscosity at 140°F (Kilopoise)	T202	75 max.	88.4	88.5	98.9	91.9	17.4	16.9	18.6	19.4
Kinematic Viscosity at 275°F (cst)	T201		1440	1350	1485	1417	1086	1086	1209	1113
Penetration at 77°F (dmm)	T49	25 min.	10	12	9	10	40	38	38	37
Softening Point (°F)	T53		159	160	157	158	145	146	145	146
Ductility at 77°F (cm)	T51	30 min.	6	6	0	6	62	53	45	48

TABLE 10

AGGREGATE PROPERTIES - Needles Test Section

(Asphalt Concrete Type A, 3/4 Inch Maximum, Medium Grading)

Aggregate Source and Plant Location - Desert Const. Co. Pit
National Trails Highway, East of Essex, CA
(approximately 30 miles from test site)

Test	California Test	California Standard Specification Section 39	Design Sample 8-11-87	Check Sample 12-10-87
Specific Gravity	308	fine coarse	2.65 2.51	2.67 2.59
Sand Equivalent	217	42 (min)	47	--
K_c Factor	303	1.7 (max)	1.1	1.3
K_f Factor	303	1.7 (max)	1.2	1.1
K_m Factor	303	--	1.2	1.2
Surface Area (sq ft/lb)	303	--	31.9	29.0
Design Asphalt Content Recommendation	With:			
	Newhall (Control) AR 4000		4.5-4.8	5.3-5.6
	Witco (R5139)		4.3-4.6	
	Edgington (R5183)		4.3-4.6	
	Asphalt Supply & Services Inc. (R5169)		4.5-4.8	

TABLE 11

PAVING TEMPERATURES - Needles Test Section

Section	Limits (Station) WB #2	Course (design thickness)	Temperatures °F*					
			Mixing	Windrow	At Screed	Breakdown	Air	Date
Polymer Modified								
Witco	Sta 425+05 To 381+50 (PM 140.0-139.2)	Surface (0.15')	300-320	275-280	260-275	275	75	12/7/87
Edgington	Sta 371+50 To 330+01 (PM 138.9-138.2)	Surface (0.15')	"	280-305	255-265	260	65	12/8/87
Asphalt Supply & Services, Co. Inc.	Sta 316+00 To 276+30 (PM 137.9-137.2)	Surface (0.15')	"	285-310	280-295	265-275	70-73	12/9/87
Control								
Newhall AR-4000	Sta 381+50 To 371+50 (PM 139.2-138.9)	Surface (0.15')	"	307	275	---	75	12/7/87
	Sta 330+01 To 316+00 (PM 138.2-137.9)	Surface (0.15')	"	280-310	275	---	70	12/8/87

*Using infrared sensor

TABLE 12

COMPACTION DATA* - Needles Test Section

Section	Lift	Laboratory Specific Gravity*	Roadway Specific Gravity**	Relative Compaction (%)	Maximum Specific Gravity***	Compaction Relative to Max SG (%)	% Voids
Polymer Modified							
Witco	Surface	2.28	2.18	95.6	2.46	88.6	11.4
Edgington	Surface	2.28	2.22	97.4	2.48	89.5	10.5
ASSCO	Surface	2.28	2.19	96.1	2.47	88.7	11.3
Control	Surface	2.30	--	--	2.44	--	--

*On Windrow samples, California Test 375
**Nuclear densities performed 12/23/87
Standard, backscatter position.
***AASHTO T-209, Rice Method

TABLE 13

Extraction Results* - Needles Test Section
(Windrow Samples)

Sieve Size (inches)	Specification Type A, 3/4 Inch Max Medium Grading Operating Range	Gradings (percent passing)			
		Witco 872366 12/7/87	Control 872367 12/8/87	Edgington 872368 12/8/87	Asphalt Supply & Services, Inc. 872369 12/9/87
3/4	95-100	100	99	98	99
1/2	---	88	85	84	82
3/8	65-80	77	72	71	69
#4	49-54x±5	58	54	51	50
#8	36-40x±5	43	40	38	37
#16	--	32	30	28	27
#30	18-21±5	23	22	20	20
#50	--	16	15	13	14
#100	--	11	10	9	9
#200	3-8	7.2	7.0	6.3	6.2
Asphalt Content (percent)	Design	4.6	5.0	4.6	4.8
	Extracted	4.6	4.8	4.6	4.4

*Extraction = Calif. Test 310
Grading = Calif. Test 202

TABLE 14
SUMMARY OF BINDER TEST RESULTS - NEEDLES Test Section

Test	Test Method AASHTO	Desert Spec.*	Control	Witco	Edgington	ASSCO**
			12-7-87 R5184	12-7-87 R5185	12-8-87 R5186	12-9-87 R5187
Test on Original Material						
Penetration at 77°F (dmm)	T49		48	126	248	100
Penetration at 39.2°F (dmm)	T49		11	45	114	33
Penetration Ratio $\frac{\text{Pen. 39.2}}{\text{Pen. 77}} \times 100$			22.9	35.7	46.0	33
Flash Point C.O.C. (°F)	T48	450 Min.	590	425*	500	580
Softening Point (°F)	T53		124	133	150	119
Absolute Viscosity at 140°F (poise)	T202		1717	1961	1844	2001
Kinematic Viscosity at 275°F (cst)	T201		260	830	269	605
Solubility in TCE (%)	T44	99 Min.	99.9	99.9	99.9	99.9
Specific Gravity at 60°F	T228		1.022	1.020	1.015	1.032
Test on RTF Residue	T240					
Absolute Viscosity at 140°F (poise)	T202	3000-5000	3876	3440	2119*	6143*
Kinematic Viscosity at 275°F (cst)	T201	275 Min.	365	815	238*	838
Penetration at 77°F (dmm)	T49	25 Min.	32	85	201	56
Penetration at 39.2°F (dmm)	T49		10	28	70	25
%Original Penetration $\frac{\text{RTF Pen. 77}}{\text{Orig. Pen. 77}} \times 100$		45 Min.	66.7	67.5	81.0	56.1
Ductility at 77°F (cm)	T51	75 Min.	100+	100+	100+	100+
at 39.2°F (cm)			1	70	100+	12
Test on CATOD Residue	Calif. Test 374					
Absolute Viscosity at 140°F (kilopoise)	T202	75 max.	98.4*	12.0	10.0	73.7
Kinematic Viscosity at 275°F (cst)	T201		1340	933	594	1971
Penetration at 77°F (dmm)	T49	25 min.	10*	36	40	26
Softening Point (°F)	T53		159	140	140	157
Ductility at 77°F (cm)	T51	30 min.	6.1*	102	61	16*

*Does not meet specification
**ASSCO - Asphalt Supply & Service Co.

TABLE 15

Recovered Binder Properties - Needles Test Section
(from Windrow Samples)

Test Section	Paving Date	Course	Tests on Absen Recovered Residue (California Test 380)				
			Absolute Viscosity at 140°F AASHTO T202 (poise)	Kinematic Viscosity at 275°F AASHTO T201 (centistokes)	Penetration at 77°F AASHTO T49 (dmm)	Softening Point AASHTO T53 (°F)	Ductility at 77°F AASHTO T51 (cm)
Witco	12/7/87	Surface	2378	705	115	129	100+
Edgington	12/8/87	Surface	3079	314	220	146	87
Asphalt Supply & Services Inc.	12/9/87	Surface	9478	1075	51	137	80
Control	12/8/87	Surface	3485	387	36	130	100+

TABLE 16

AGGREGATE PROPERTIES - Crestview Test Section

(Asphalt Concrete Type B, 3/4 Inch Maximum, Medium Grading)

Aggregate Source and Plant Location - Hunewill Pit, Lee Vining, CA
5 miles So. on S.R. 120,
(approximately 15 miles from jobsite)

Test	California Test	California Standard Specification Section 39	Design Sample 9-15-88
Percentage of Crushed Particles	205		
Coarse Aggregate (+No. 4)(%)		25 (min.)	61
Fine Aggregate (passing No. 4, retained No. 8) (%)		20 (min.)	62
Specific Gravity	308	Fine	2.68
		Coarse	2.65
Los Angeles Rattler	211		
Loss at 100 Revolutions (%)		---	4.2
Loss at 500 Revolutions (%)		50 (max.)	17.8
Sand Equivalent	217		
Contract Compliance		42 (min.)	63
Operating Range		45 (min.)	
K_c Factor	303	1.7 (max.)	1.3
K_f Factor	303	1.7 (max.)	1.2
K_m Factor			1.2
Approx. Bitumen Ratio (CKE) (%)			5.7
Surface Area (sq ft/lb)	303		33.1
Design Asphalt Content recommended for	by TMR		
	Conoco PM		4.5 to 4.8
	Witco PM		4.5 to 4.8
	by District 9 Lab		
	Job Asphalt (AR-2000)		5.2

TABLE 17

PAVING TEMPERATURES - Crestview Test Section

Section	Limits (Station) (NB #2 Lane)	Course (Thickness)	Temperatures °F* Mixing	Windrow	At Screed	Breakdown	Air	Date
CONOCO	429+50 to 33+00	1st lift (0.13')	320	298-308DT	296	277	75 (12p)	9-15-88 (10:30-12p) Clear, Sunny
	429+00 to 31+00	Surface (0.13')	310-315	287-295DT	282	272	62 (12p)	9-22-88 (12-2p)
WITCO	33+00 to 48+80	1st lift (0.13')	310-315	297-300DT	285	271	75	9-15-88 (12:15-1:45p)
	35+00 to 52+00	Surface (0.13')	320	297-300DT	278	275	55 (1p)	9-20-88 (12-1:30p) Light Rain After 1p
CONTROL	49+00 to 63+00	1st lift (0.13')	290-300	280-288DT	262	242	75 (2:45p)	9-15-88 (2-3:30p)
	52+00 to 63+00	Surface (0.13')	300-310	288-294DT	281	278	50 (11a)	9-20-88 (10:30-12a) Broken Clouds
	31+00 to 35+00	Surface (0.13')	300-310	286-288DT	---	---	---	9-22-88 (11:30-12a)

*All street temperatures obtained with infrared sensor except for those designated DT which were obtained with dial probe thermometer. Temperatures are average of 2 to 9 readings. Mixing temperatures obtained with plant thermometers.

TABLE 18

COMPACTION DATA - Crestview Test Section

Section	Lift	Laboratory Specific Gravity*	Roadway Specific Gravity**	Relative Compaction(%)	Maximum Specific Gravity***	Compaction Relative to Max. S.G. (%)	% Voids
CONTROL	1st	2.39	---	---	2.48	---	---
	2nd	2.41	2.25	93.4	2.46	91.5	8.5
WITCO	1st	2.41	---	---	2.45	---	---
	2nd	2.39	2.24	93.7	2.46	91.1	8.9
CONOCO	1st	2.38	---	---	2.45	---	---
	2nd	2.39	2.29	95.8	2.45	93.5	6.5

*On windrow samples, California Test 375.
**Standard, back scatter position, nuclear densities obtained 9-24-88.
***AASHTO T-209, Rice Method

TABLE 19

Extraction Results - Crestview Test Section

Sieve Size (inches)	Specification Type B, 3/4 Inch Max. Medium Grading	Conoco				Witco				Control	
		1st Lift 9-15		2nd Lift 9-22		1st Lift 9-15		2nd Lift 9-20		1st Lift 9-15	2nd Lift 9-20
		TMR	Dist. 9	TMR	Dist. 9	TMR	Dist. 9	TMR	Dist. 9	TMR	TMR
3/4	95-100	100	100	100	100	100	98	100	100	100	100
1/2	---	93	89	88	89	88	82	87	87	92	84
3/8	65-80	84	82	79	81	77	68	75	78	83	72
#4	50 ± 5	63	60	55	61	57	50	53	55	63	52
#8	38 ± 5	49	45	41	47	44	38	40	41	49	38
#16	---	36	34	30	35	34	29	30	31	36	29
#30	19 ±5	24	23	21	25	24	21	21	22	25	21
#50	---	14	14	13	15	15	13	13	14	15	14
#100	---	9	9	8	9	10	8	8	9	9	9
#200	3-8	5.8	5	4.9	6	6.1	5	5.2	6	5.7	5.8
Asphalt Content (%)	Design	5.0	5.0	5.2	5.2	4.8	4.8	5.2	5.2	5.2	5.2
	Extracted	5.5	5.4	5.6	6.3	5.7	5.2	5.6	5.7	5.8	5.1

Underlined valves exceed specification limits.

TABLE 20

Recovered Binder Properties* - Crestview Test Section
(from Windrow Samples)

Test Section	Paving Date	Course	Tests on Abson Recovered Residue: Absolute Viscosity at 140°F AASHTO T202 (poise)	Kinematic Viscosity at 275°F AASHTO T201 (centistokes)	Penetration at 77°F AASHTO T49 (dmm)	Penetration at 39.2°F AASHTO T49 (dmm)	Softening Point AASHTO T53 (°F)	Ductility at 77°F AASHTO T51 (cm)
Control	9-15-88	1st Lift	2296	260	56	15	123	100+
Control	9-20-88	2nd Lift (surface)	2660	292	51	15	127	100+
Conoco	9-15-88	1st Lift	3029	586	98	43	125	100+
Conoco	9-22-88	2nd Lift (surface)	3373	669	95	42	127	100+
Witco	9-15-88	1st Lift	2189	568	103	32	120	100+
Witco	9-20-88	2nd Lift (surface)	2281	567	101	30	125	100+

*Recovered by Abson Recovery Method (California Test 380)

TABLE 21
SUMMARY OF BINDER TEST RESULTS - Crestview Test Section

Test	Test Method AASHTO	Spec or Guideline	Control Shell AR-2000		Conoco Poly. Mod.		Witco Poly. Mod.	
			1st Lift R5202	2nd Lift (surf) R5205	1st Lift R5200	2nd Lift (surf) R5203	1st Lift R5201	2nd Lift (surf) R5204
Test on Original Material								
Penetration at 77°F (dmm)	T49		76	75	176	160	150	141
Penetration at 39.2°F (dmm)	T49		16	20	66	54	48	43
Penetration Ratio $\frac{\text{Pen. 39.2}}{\text{Pen. 77}} \times 100$	(2)		21.1	26.7	37.5	33.8	32.0	30.5
Flash Point C.O.C. (°F)	T48		530	540	455	445	465	470
Softening Point (°F)	T53		118	116	115	116	130	120
Absolute Viscosity at 140°F (poise)	T202		1149	1243	958	1079	1674	1425
Kinematic Viscosity at 275°F (cst)	T201		180	181	369	393	593	511
Solubility in TCE (%)	T44		99.91	99.98	98.54	99.94	99.98	99.92
Specific Gravity at 60°F	T228		1.022	1.022	1.026	1.026	1.017	1.018
Test on RTF Residue	T240							
Absolute Viscosity at 140°F (poise)	T202		2252	2263	4403	4789	2449	2229
Kinematic Viscosity at 275°F (cst)	T201		262	258	782	766	628	596
Penetration at 77°F (dmm)	T49		47	50	72	73	106	103
Penetration at 39.2°F (dmm)	T49	35 min.	11	11	32*	33*	32*	30*
% Original Penetration $\frac{\text{RTF Pen. 77}}{\text{Orig. Pen. 77}} \times 100$			61.8	66.7	40.9	45.6	70.7	73.0
Ductility at 77°F (cm)	T51		100+	100+	100+	100+	100+	100+
at 39.2°F (cm)			0.5	0	15	13	85	49
PVN (77/140 Temp. Rng.)			-1.06	-0.97	0.26	0.36	0.21	0.15
Test on CATOD Residue	Calif. Test 374	Desert Spec. guideline						
Absolute Viscosity at 140°F (kilopoise)	T202	75 max.	32.0	30.3	149.3*	114.5*	8.1	9.1
Kinematic Viscosity at 275°F (cst)	T201		785	771	3145	2930	732	790
Penetration at 77°F (dmm)	T49	25 min.	14	12	28	31	41	38
Softening Point (°F)	T53		148	150	162	160	137	138
Ductility at 77°F (cm)	T51	30 min.	10	13	14*	14*	100+	96

*Does not meet specification or guideline.

TABLE 22
PROPERTIES OF BINDER RECOVERED FROM CORES*
(Ocotillo Test Section)

Section	Test Section Age (months)	Results of Tests** Absolute Viscosity at 77°F (poise) AASHTO T202	Kinematic Viscosity at 275°F (cSt) AASHTO T201	Penetration at 77°F (dmm) AASHTO T49	Softening point (°F) AASHTO T53	Ductility at 77°F (cm) AASHTO T51
Control						
EB Lane	13	22,426	833	14	147	56
WB Lane	13	17,700	821	15	146	13
EB Lane	24	52,290	1,225	9	154	8
WB Lane	24	53,376	1,187	10	156	7
Polymer Modified (Witco)						
EB Lane	13	5,931	898	70	135	100+
WB Lane	13	5,536	933	81	134	100+
EB Lane	24	8,794	1,095	57	140	95
WB Lane	24	7,212	1,066	68	137	94

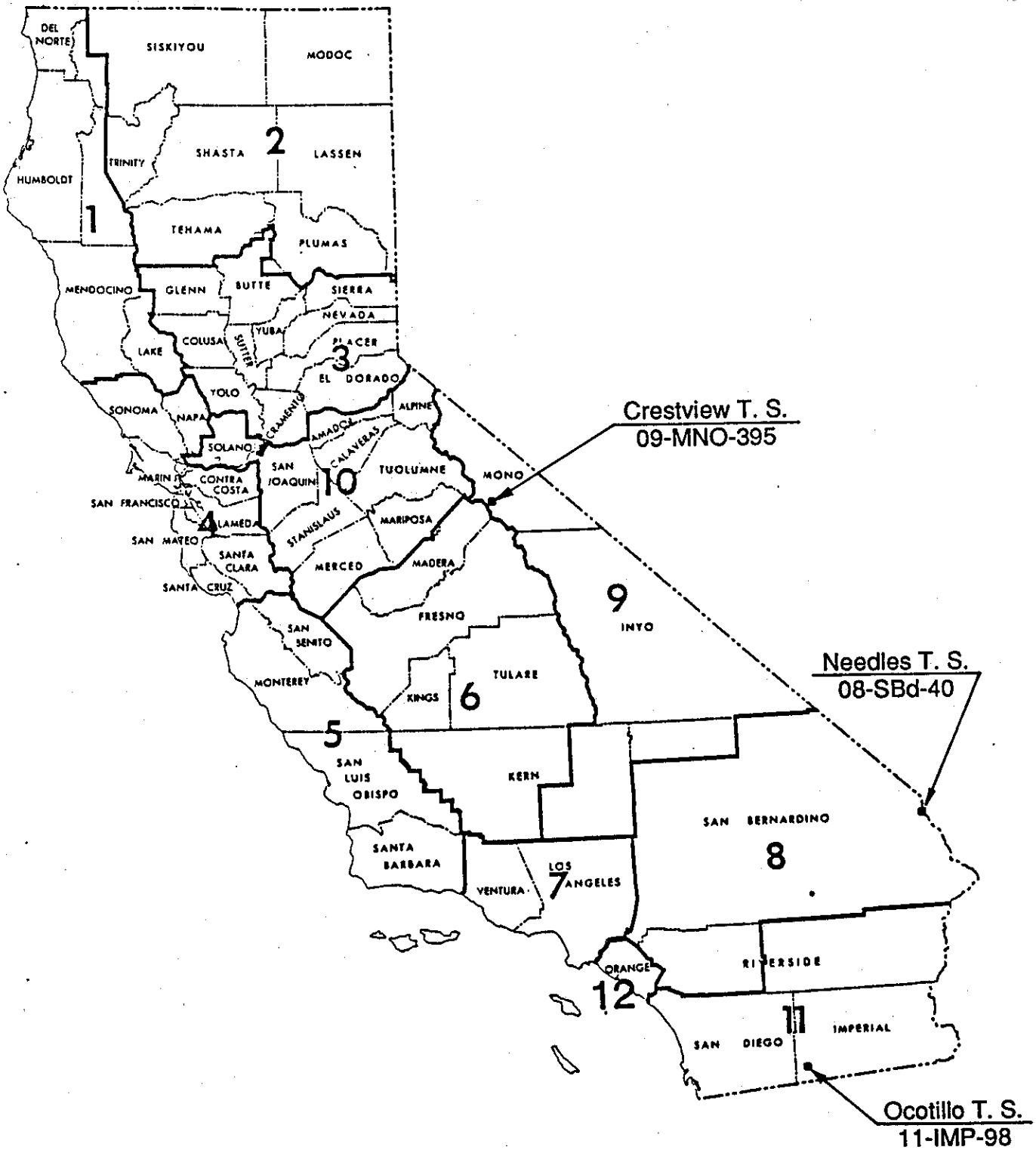
*Abson Recovery by California Test 380
**Average of 2 or more samples

TABLE 23

PROPERTIES OF BINDER RECOVERED FROM CORES*
(Needles Test Section)

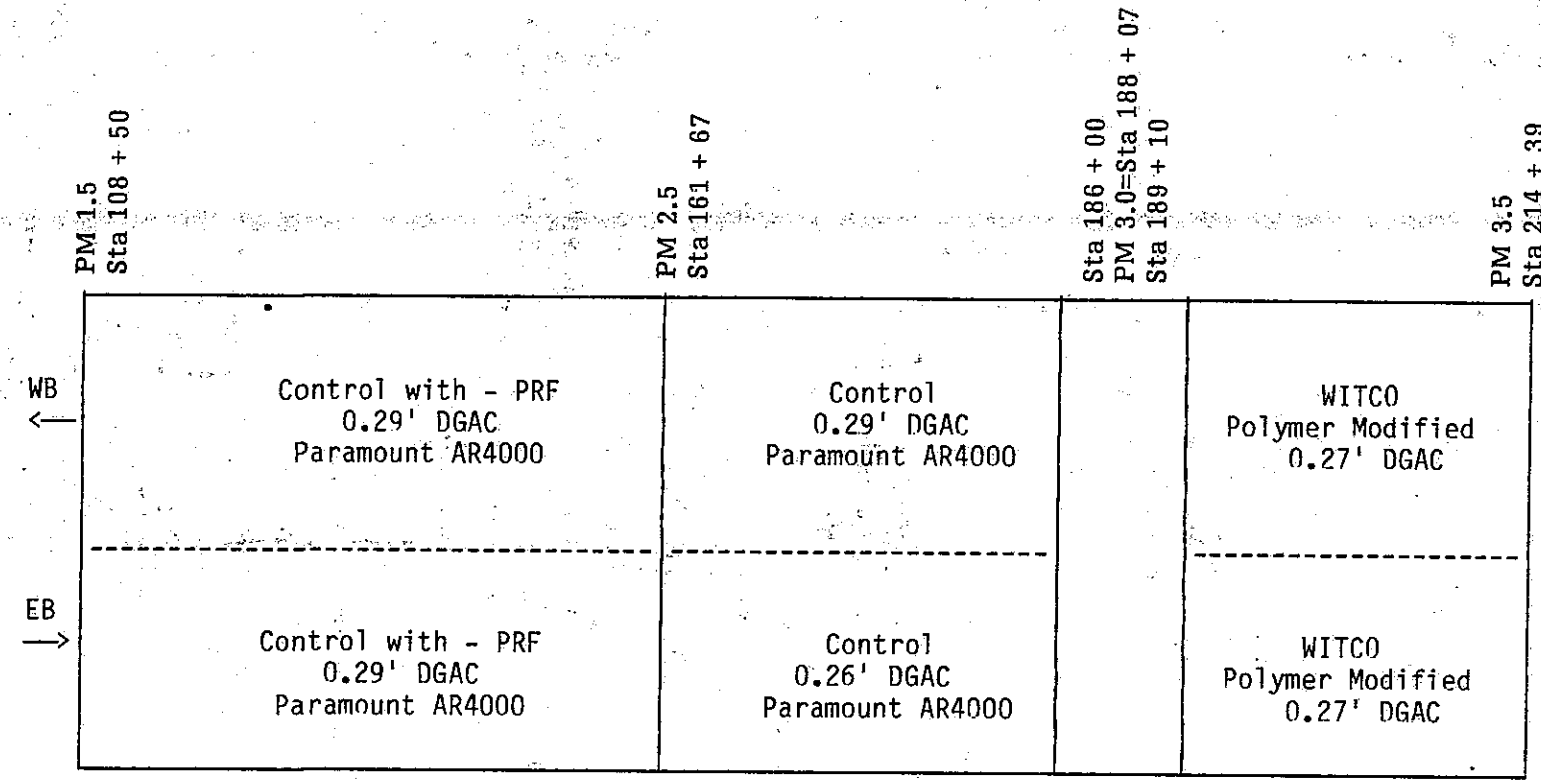
Section	TransLab Number	Results of Test (13 month cores) Absolute Viscosity at 140°F (poise) AASHTO T202	Kinematic Viscosity at 275°F (cSt) AASHTO T201	Penetration at 77°F (dmm) AASHTO T49	Softening Point (°F) AASHTO T53	Ductility at 77°F (cm) AASHTO T51
Witco	892009	3,395	652	81	132	100+
	892010	2,423	604	111	125	100+
	Average	2,909	628	96	128	100+
Edgington	892012	4,477	434	109	133	100+
	892013	5,242	363	128	138	100+
	Average	4,859	398	118	135	100+
ASSCO	892015	28,645	1,499	31	149	27
	892016	27,706	1,446	32	149	26
	Average	28,175	1,472	31	149	26
Control	892011	20,846	776	16	148	21
	892014	8,323	608	29	140	100+
	Average	14,584	692	22	144	61

*Abson Recovery by California Test 380



TEST SITE LOCATIONS

Figure 1



OCOTILLO TEST SECTION
Road 11-IMP-98-1.5/3.5 Contract 11-155164 C.E.R. No. CA 86-16
Constructed - December 1986
AC Overlay - Type B, 1/2" Max. Coarse Grading

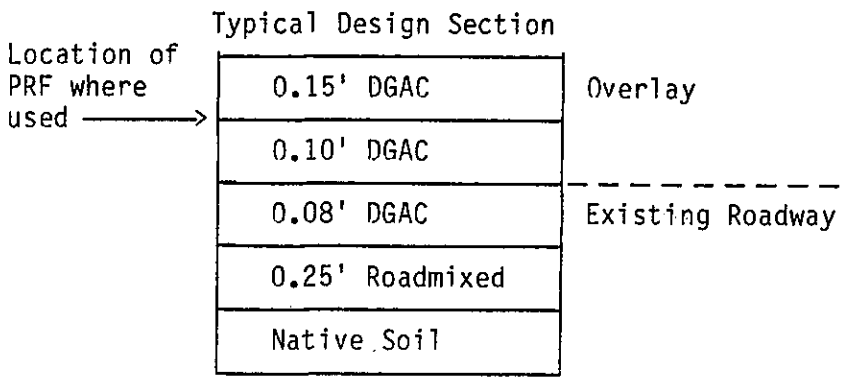


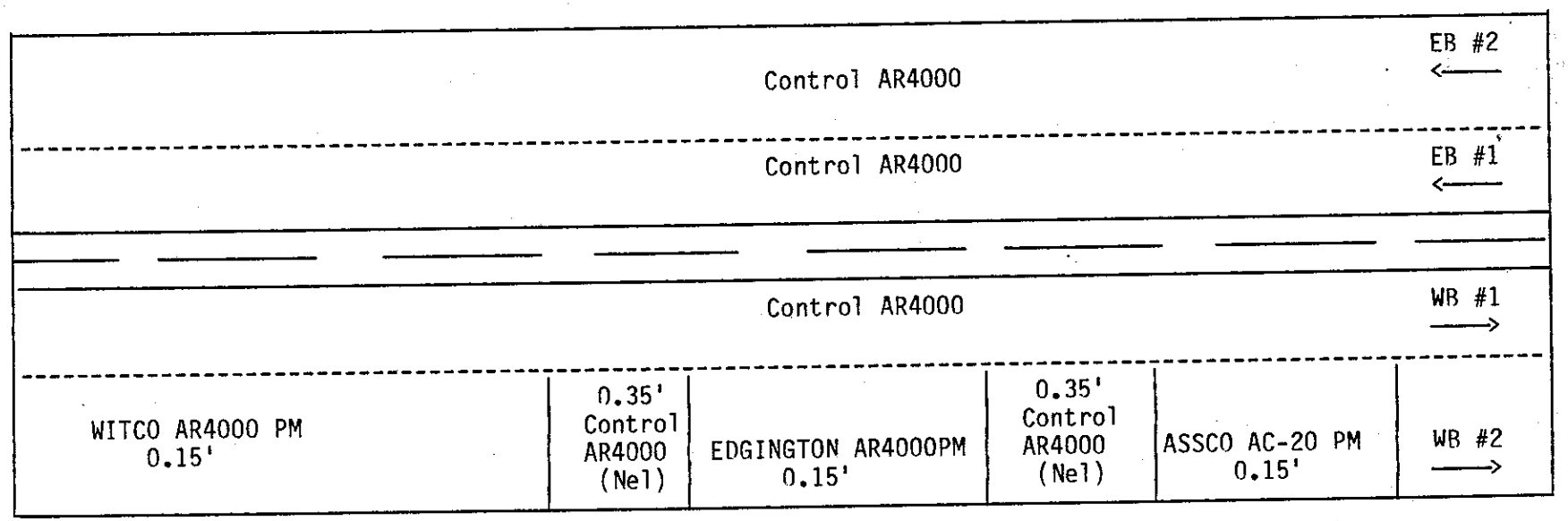
FIGURE -2-

Typical Design Section

0.15'DGAC - Poly. Mod. or Control	
Coldplaned 0.20' Replaced w/0.20'Control DGAC	Prior Roadway 0.36'AC
Existing AC 0.16'	
0.50'CTB	
0.67' Agg. Subbase	
Native Soil	

C.E.R. No. CA87-05

NEEDLES TEST SECTION
ROAD 08-SBd-40-137.0/140.0
Constructed 12-1987, Contract 08-006714



PM 140 (Sta 425+05)
(PM 138.9) Sta 381+50
(PM 138.9) Sta 371+50
(PM 138.2) Sta 330+01
(PM 137.9) Sta 316+00
(PM 137.2) Sta 276+30

FIGURE -3-

CRESTVIEW TEST SECTION
Road 09-MNO-395-33.1 1/36.1
Contract 09-204804 C.E.R. Project CA 88-02

No. 2 Lane Typical Section

Existing AC Pavement	0.13' Surface Course - See below
	0.13' 1st Lift (Surface Course) - See below
	0.14' Level Course - Witco AR2000 - placed Nov. 1987
	0.45' DGAC
	0.35' Aggregate Base
	Native Soil

Test Sections:
A=0.26' DGAC-Conoco P.M.
B=0.13' DGAC-Conoco P.M. +0.13' DGAC-Control
B=0.13' DGAC-Witco P.M.+0.13' DGAC-Control
C=0.26' DGAC-Witco P.M.
D=0.13' DGAC-Control +0.13' DGAC Witco P.M.
E=0.26' DGAC-Control Shell AR2000

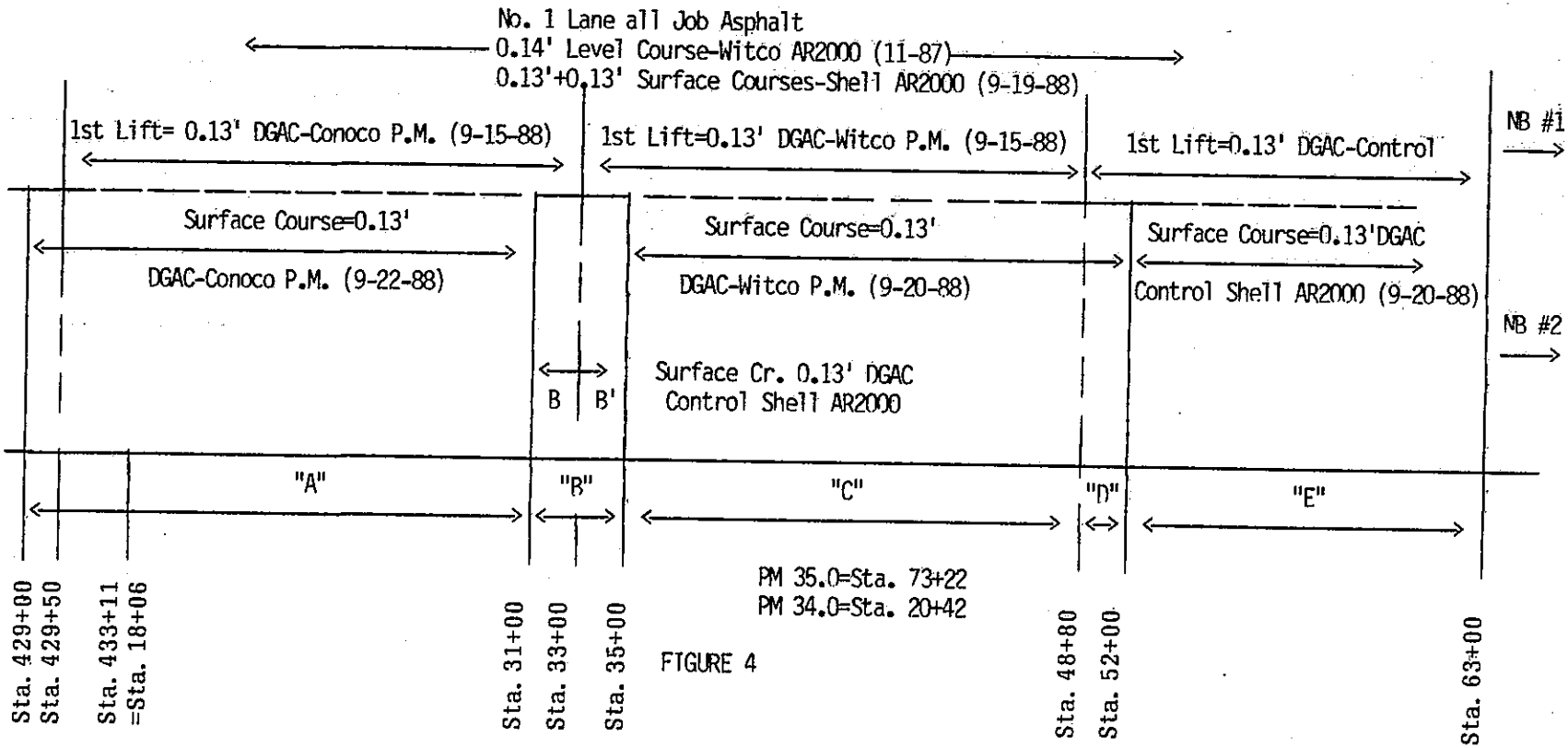


FIGURE 4

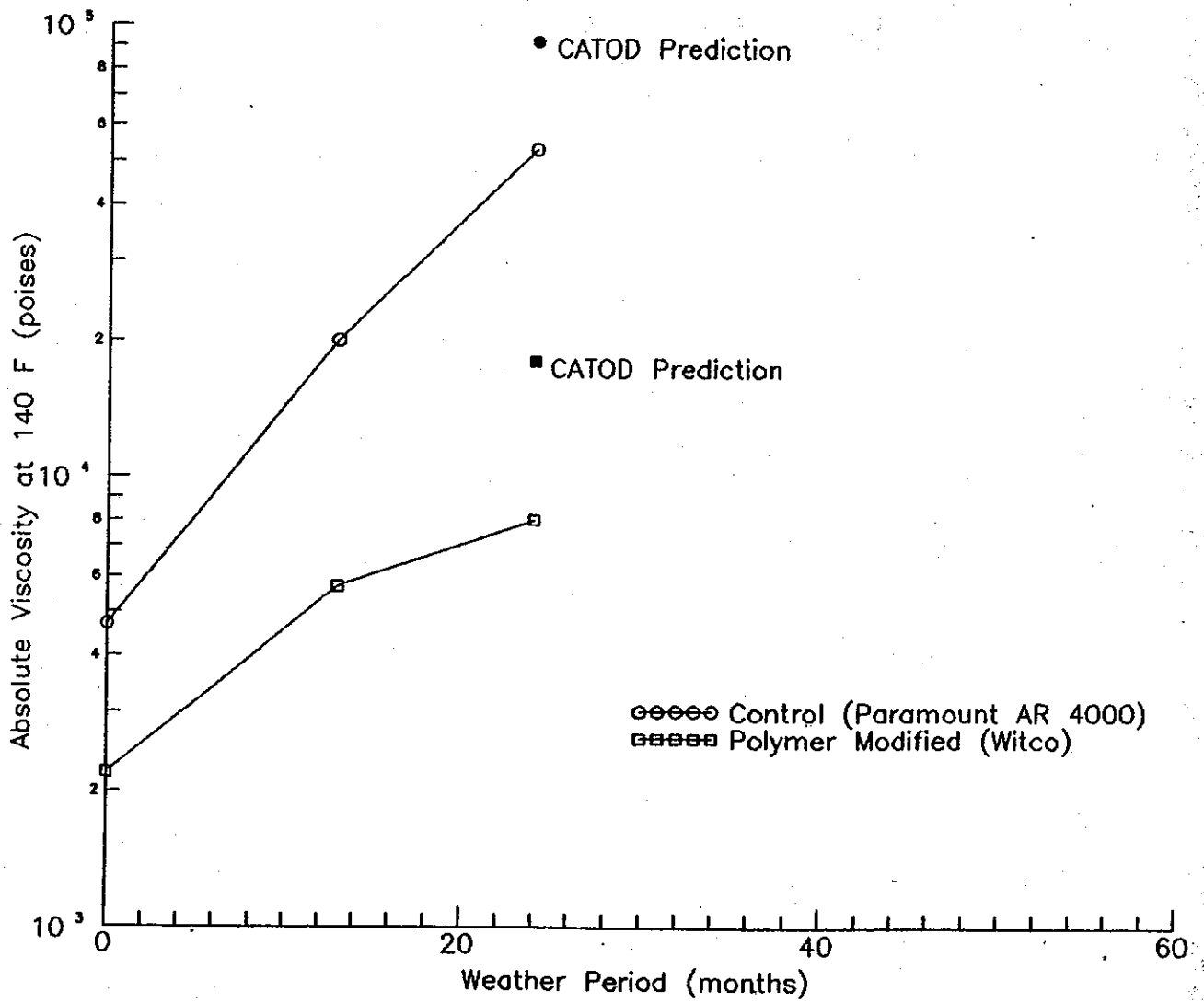


Figure 5. Viscosity Increase of Binders from Ocotillo Test Section.

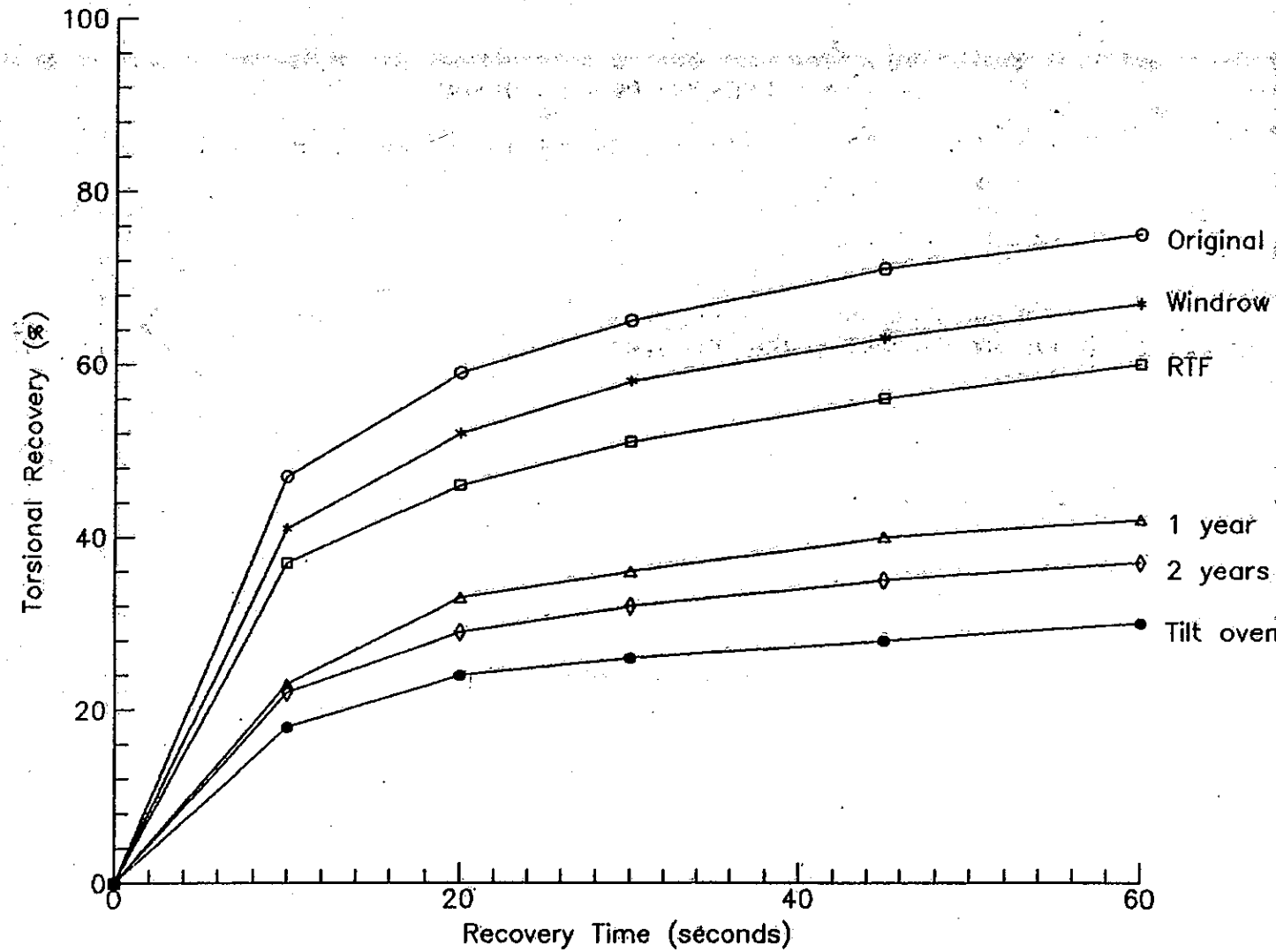


Figure 6. Torsional Recovery of Witco Modified Asphalt from Ocotillo Test Section.