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16. ABSTRACT
This research effort by the Division of New Technology, Materials and Research 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 were 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 stimulates the effect of two years' hardening of standard asphalt in hot desert climate) for field trail 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 trail in a cold climate; 4) recalibrate the CATOD procedure for modified binders if necessary.

A significant improvement in the aging characteristics was demonstrated by two of the binders in the hot climate test sections. The CATOD procedure was recalibrated for better correlation with the field results. Performance differences were also observed for rutting and cracking. The performance of modified binders in a cold climate were demonstrated for reflective cracking resistance and stability. However, uncontrolled variables diminished the ability to gather all of the desired data.

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

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EVALUATION OF MODIFIED ASPHALT BINDERS - FINAL REPORT
FHWA/CA/TL - 92-08

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NOTICE

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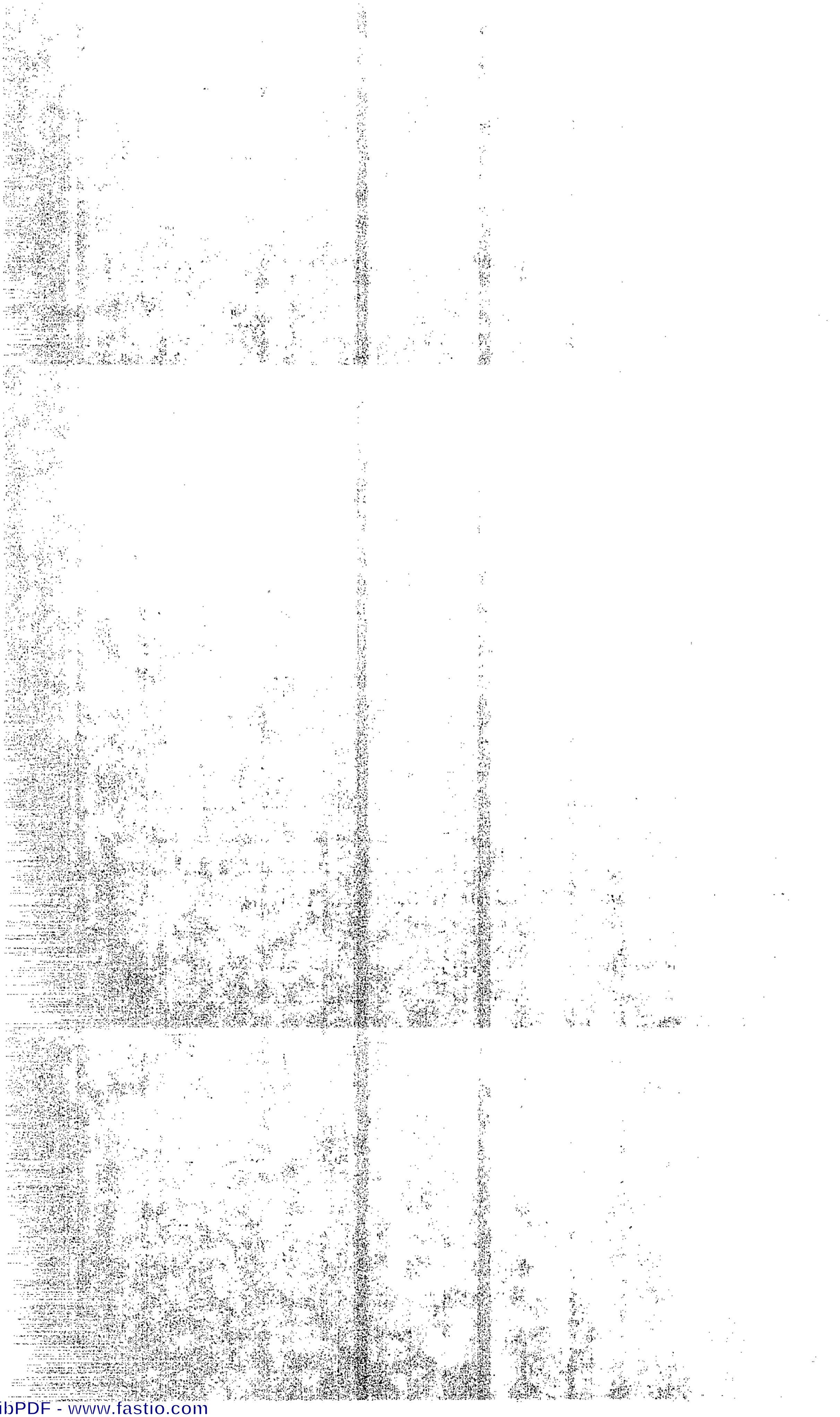

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Introduction

Approximately 25 percent of the highway network in the State of California is located in regions subject to either extreme heat or extreme cold. The effect of these extremes has been the premature distress of asphalt concrete (AC) pavements.

In an effort to address this problem, 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 (1-4) have indicated that conventional asphalt binders are unable, in all climates, to provide the properties necessary for a pavement to yield design life service without maintenance.

This research effort by the Division of New Technology, Materials and Research (NTM&R) involved the evaluation of modified asphalt binders in test sections at three test sites. Two sites are located in the desert and the third site is located in the mountains. The objectives of the study were 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 desert climate) for field trail use; 3) determine by field trials whether the modified binders are more resistant to aging in a hot climate and provide more resistance to thermal cracking in a cold climate than conventional asphalt; and 4) recalibrate the CATOD procedure for modified binders, if necessary.

This report contains the findings from this effort after four and five years of field evaluation.

Conclusions

The binder recovery procedure (California Test 380) provided material acceptable for physical property characterization in this investigation.

The accelerated aging test (California Test 374, Tilt-Oven Durability Test) properly characterizes both standard and modified asphalts for aging tendencies in the California desert climate.

The materials that met the desert specification by a wide margin aged slower in the pavement than predicted by the seven-day Tilt-Oven test.

The materials that met the desert specification by a wide margin should provide cost-effective design life performance.

The aging resistance of the materials that met the desert specification by a wide margin was demonstrated at air void contents (9-10%) that are normally discouraged for durability considerations.

The long term aging of asphalt binders should be a concern for specification purposes even in a cold climate.

Polymer modified binders with very soft base asphalts can cost effectively provide the low temperature property necessary for thermal cracking resistance and the high temperature property necessary for stability.

The polymer modified binders evaluated in this study are showing reductions of 80-90% in reflective cracking relative to standard asphalt at 3.5 years of service.

Recommendations

Dense graded AC pavements placed by Caltrans in a desert climate should contain binders that meet the following requirements for a Performance Based Asphalt - grade 7 (PBA-7) after Tilt-Oven conditioning for 7 days at 111°C:

PENETRATION @ 25C	30 dmm minimum
DUCTILITY @25C	40 cm minimum
ABSOLUTE VISCOSITY @ 60C	50,000 poise maximum

This binder should be used in all lifts of the pavement being placed.

Caltrans should establish a test method for the 3-day exposure in the Tilt-Oven.

Caltrans, in cooperation with the Pacific Coast Conference on Asphalt specifications, should develop a specification appropriate for the residue from the 3-day exposure in the Tilt-Oven.

The target air void content used in the mix design process should be re-evaluated for projects using this binder to concurrently increase the margin for long-term stability of the pavement.

Dense graded AC pavements placed by Caltrans in a cold climate where the winter minimum temperature is expected to be below -18C (0°F) should contain a modified asphalt with the following properties on the RTFO residue:

PENETRATION @ 4C	35 dmm minimum
ABSOLUTE VISCOSITY @60C	3,000 poise minimum

Develop an accelerated aging test to simulate the degree of aging that a modified binder, meeting the requirements above, experiences in 8 to 10 years of field exposure in a cold climate.

Implementation

Caltrans representatives have been active participants in a working group known as the Pacific Coast Conference on Asphalt Specifications. The group is comprised of both asphalt user agencies and asphalt producing companies. In 1989, the Paving Asphalt Committee was charged by the Conference with the task of developing performanced-based specifications for conventional and modified asphalts. Thus, through participation on the Committee, the early findings from this research were utilized for two of the grades developed. The committee developed the Performance Based Asphalt (PBA) grading system which is based on climatic considerations. The information from our cold climate test section contributed to the properties selected for the PBA-3 grade. The information from our hot climate test sections contributed to the properties of the PBA-7 grade. The PBA grading system was presented to the Conference on May 30, 1990, and was approved for evaluation or optional use.

At the time this report was written the Paving Asphalt Committee was evaluating the usefulness of the dynamic shear rheometer as a better indicator of pavement performance than traditional tests. This consideration should be applied to the requirements for the residue from the 3-day Tilt-Oven exposure. Until this has been completed and approved by the Conference, the use of the existing PBA-7 specification should yield acceptable binders for use in the desert.

The current findings from the test sections and the PBA grading system were discussed with the District Materials Engineers at their annual meeting in 1990 and a status report was provided in 1991.

In a memo to Caltrans Headquarters Office Engineers and Deputy Directors of Construction, Maintenance and Project Development dated March 27, 1991, the PBA grading system was described. This memo contained recommendations that the Office Engineers create a Standard Special Provision for the PBA grades and that the Districts with projects in either of the severe climates consider using the appropriate grade.

Approval to use polymer modified asphalt non-experimentally was requested of and granted by the Federal Highway Administration based on a request which was supported by the performance data gathered from this research project and others reported in the literature.

A memo on the research findings and the non-experimental status of the PBA grades for severe climate use will be distributed to the districts by the Division of New Technology, Materials and Research along with recommendations for use.

I. BACKGROUND

A. Hot Climate

Previous Caltrans research (1,3) has shown the need for more durable asphalts for the regions of the state with the hottest summer temperatures.

In the Asphalt Durability Study (3), an accelerated aging test was developed that 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 @60C	AASHTO T202	100,000 poise (max.)
Penetration @25C	AASHTO T49	15 dmm (min.)
Ductility @25C	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 trail. However, this was dependent on the ability of the asphalt producers to manufacture an asphalt meeting the specification. Initially, two producters 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 @60C	AASHTO T202	75,000 poise (max.)
Penetration @25C	AASHTO T49	25 dmm (min.)
Ductility @25C	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 the specific formulation of these binders wasn't requested, it is understood that the modifiers used were selected from various styrene-butadiene polymer types.

B. Cold Climate

The project to evaluate the low temperature susceptibility of modified asphalt binders was developed in response to a the need for a solution to a thermal cracking problem in the high elevation highways in Caltrans District 9. To define the problem, Caltrans Pavement Management System performance data for original structural sections of cold climate highways constructed during the late seventies and early eighties were examined. The number of transverse cracks per 100' were plotted chronologically from the survey of eleven projects (as an example, see Figure 1).

Research efforts on thermal cracking have revealed that the minimum temperature that the pavement is exposed to is related to crack initiation (2,4-12). All of these studies have also shown a relationship between some measured or calculated property of the asphalt binder or asphalt concrete and thermal cracking. The study by Schmidt (2) revealed a correlation with a property that could be readily measured to characterize the binders that are currently specified by Caltrans. This test is the penetration at 4C on the rolling thin film (RTF) residue. Therefore, the annual winter minimums were plotted alongside the survey data as well as an estimate of this low temperature property of the asphalt for the first five years as shown in Figure 1. The asphalt test cards from the projects were used to determine the source and grade of paving asphalt for the purpose of estimating the penetration at 4C of the RTF residue from the test results at 25C for the first year. This estimate was determined from a chart (Figure 2) which is a result of penetration testing of several grades of both California Valley and California Coastal asphalts conducted in 1969. Actual data was available from one manufacturer for the projects they supplied in 1979. From this starting point on each project, an estimated penetration at 4C was plotted for the second through fifth years based on the aging rates in terms of penetration at 25C that had been determined for these asphalt sources in the Durability Study (3) at the South Lake Tahoe weathering site.

The data from eleven projects are combined in Figure 3 which shows the performance data (cracking or no cracking) in terms of the binder property and winter exposure. A correlation of these factors is apparent and is indicated by the sloped line designated as a boundary zone. A zone has been indicated because the precision of the penetration test at 4C is a concern. It can be seen that the combined factors routinely result in a condition that yields thermal cracking with the asphalt binders that are currently in use. All of these projects were constructed with AR-4000 grade paving asphalt. It appears from these data that AR-4000 should only be used where the winter minimum is above -18C (0°F).

In evaluating the polymer modified asphalts that were being submitted to Caltrans for use in the desert climate, an extremely low temperature susceptibility was observed. It was noticed that some of the binders were soft enough at 4C to provide the thermal cracking resistance that was desired for the high elevation winter temperatures along with the viscosity desired for construction and stability considerations in desert temperatures. Therefore, it was proposed to District 9 personnel that they construct a test section to evaluate the polymer modified material. In "evaluating" this material, it should be understood that the polymer is contributing to the performance properties for the highest service temperatures while the base asphalt defines the performance at the lowest service temperature. This was presented by Goodrich in the rheological analysis of several standard paving asphalts and polymer modified asphalts. (13)

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 4C (39.2°F) of 35 dmm was established from the analysis of the winter minimum temperatures in the mountain area of District 9. It is significant that both asphalts need modification to achieve this requirement even though one of them already has relatively low temperature susceptibility.

II. Hot Climate Test Sections

A. Construction

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.

1. 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 with Mexico, was severely block cracked (65-70%) with widespread alligator and longitudinal cracking. The overlay consisted of a total of 0.25' of DGAC placed in two lifts. In the Witco section the modified asphalt was used in both lifts. Details of the test section placement are contained in Appendix A.

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

The test sections at Needles were placed on December 7-9, 1987, 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 the No. 2 westbound lane (second land to the right of the median) was cold planed and replaced with 0.20 foot of Type A DGAC containing AR-4000 paving asphalt. The test section materials were placed in the 0.15 foot surface course placed in the No. 2 westbound lane while the 0.15 foot overlay placed on the No. 1 westbound lane contained AR-4000. Details of the test section placement are contained in Appendix B.

B. Postconstruction Testing

1. Testing of Binders Recovered from Cores

Figures 4, 5, and 6 contain the physical property data on the binders that have been recovered annually from these sections. The Edgington and Witco binders have experienced very little aging thus far, while the controls and the ASSCO binder have hardened significantly. The hardening of the control asphalt is consistent with the aging observed in our Asphalt Durability Study conducted on briquettes in different climates. The ASSCO binder barely met the specification on the Tilt-Oven residue while the Edgington and Witco binders met the specification by a wide margin. To put the aging resistance of the Edgington and Witco binders in perspective, they have aged less than binders in our mild coastal climates as shown in Figure 7 (viscosity data from our briquette study).

Binder was also recovered from the lower lifts of the 49 month cores taken at Needles to determine the aging experienced by a conventional asphalt when covered by a surface course of modified asphalt. The properties of the recovered AR 4000 were the same as the control AR-4000 in the surface course. Therefore, any use of an aging resistant binder in a hot climate should be in all lifts of the AC.

2. Testing of Mix from Cores

The air voids of the cores taken annually are shown in Figure 8. The difference between the Ocótillo and Needles sections is due to the difference in traffic with an ADT of 1,600 with 11% trucks and an ADT of 10,000 with 50% trucks, respectively. It should be noted that the 10% to 11% air void content after construction was the target. The theory being that with about 0.5% less asphalt in the mix there will be a sufficient margin for stability in the hot climate while the aging resistant property of the modified binder will provide the durability even at this high air void content. This is an approach worth consideration since the Ocotillo site, with very little traffic, has remained at a high air void content yet the binder is showing relatively little aging. Also, the amount of additional compaction that is imparted by heavy traffic on a pavement in a hot climate is more than the 1% to 2% that would be expected in a mild climate.

There has been some concern that the recovery of modified asphalts for physical property analysis may be inappropriate if the polymers are being separated form the asphalt in the recovery procedure. To evaluate this possibility, the torsional recovery test, California 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 9. 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.

To evaluate this concern further, an analysis of thin slices of mix from the cores was performed for comparison with the properties of recovered binders. To accomplish this, Chevron Research volunteered their dynamic mechanical analysis (DMA) equipment and expertise. They performed rheological analysis on retained mix from the windrow and retained cores that had been taken annually from the Needles test sections on I-40. In research conducted on core slices using DMA, it has been shown that at temperatures below 10C the data reflect the properties of the binder(14).

To analyze the data in the low temperature range, the temperature at which tan delta equals 0.4 was plotted for the materials at 0 months and at 37 months in Figure 10. This parameter was chosen because a correlation has been reported between this value, the penetration at 4C and the limiting stiffness temperature (13,14). Therefore, the penetrations at 4C for the recovered binders were converted to a limiting stiffness temperature, using the correlation developed by Schmidt (2), and plotted for comparison in Figure 10. This comparison shows that the binder properties from unaltered cores are ranked in the same order as the recovered binders. Therefore, the analysis of the binder properties from the mixes also verifies that the evaluation the recovered binders is appropriate.

3. Pavement Condition Survey

At both of the test sites, the control sections and the ASSCO section are showing distress. At the Ocotillo location, the control section is raveling. At the Needles location, the control sections are exhibiting reflective transverse cracking on the order of one crack per 100 feet, flushing, up to 1/2 inch deep rutting and fatigue cracking. The ASSCO section is showing reflective transverse cracking and fatigue cracking. At both locations, there is no distress in the sections that have resisted aging (the Edgington and Witco modified asphalts).

At the Needles site, the lack of distress is dramatic because there is reflective cracking in the number one lane adjacent to the test sections which are in the number two lane. The transverse cracks proceed across the entire number one lane, then disappear at the interface with the Edgington and Witco sections.

The distresses in the ASSCO and control binders at Needles were first observed at the 37 month survey. An isolated area about 100 feet long in the Edgington section showed fatigue cracking a year and a half after placement. There hasn't been any additional fatigue cracking in this section but measurement of a core at this location revealed that the 0.20' mill and replace is only 0.15' thick. Subsequent annual corings indicate that the total thickness of the Edgington section is about 0.1 foot less than the other sections. The deficiency appears to be in the 0.10 AC of original construction that was to remain after the 0.20' milling was performed. The core measurements are presented in Table 2.

4. Comparison of Laboratory and Field Aged Binders

A comparison of the properties of the residues from the Tilt-Oven with the field data shows that the accelerated aging test is more severe than the five years of field aging, especially for the Edgington and Witco binders. Therefore, it was necessary to recalibrate the Tilt-Oven parameters for better correlation with the field data. The targeted field properties for recalibration were those observed at 37 months. This time period was chosen due to the concern that the characterization be sufficiently beyond the "knee" in the penetration and ductility curves for improved precision. After varying sample size, duration, and temperature, the parameters that correlate well with the field data at 37 months (See Table 3) are:

Sample Size	:	35 grams
Temperature	:	113C
Duration	:	3 days
Air Flow	:	0

An added benefit of this recalibration is the improved productivity of a 3-day test versus the previous 7-day duration.

Along with this change in Tilt-Oven operation, a change is necessary in the specification limits for the residue. The new specification limits should be developed in cooperation with the Pacific Coast Conference on Asphalt Specifications. The working committee should consider both traditional binder tests and dynamic shear rheological tests for the PBA-7 grade currently recommended for desert use.

III. Cold Climate Test Section

A. Construction

The cold climate test section was placed as part of a new construction and rehabilitation project on US 395 adjacent to the Caltrans Crestview Maintenance Station. Unfortunately, scheduling precluded the placement of the test sections in the new structural section of the southbound lanes. The test sections were included in the 0.40 foot overlay placed in the northbound lanes. Modified asphalts from Conoco and Witco were placed on September 15-22, 1988 in the number two lane on a grade which ascends in elevation from approximately 7,500 to 8,000 feet.

The initial 0.14 foot leveling course, which was paved before the winter shutdown in November 1987, contained Witco AR-2000. However, when construction resumed in 1988, the job AR-2000 was supplied by Shell. The sections were placed in two 0.13 foot lifts to complete the remaining 0.26 foot AC overlay. The construction details are contained in Appendix C; however, it should be noted here that the surface course of the Witco modified asphalt was placed while it was raining.

B. Postconstruction Testing

1. Testing of Binders Recovered from Cores

Cores were taken in November 1991 from the test sections in the northbound No. 2 lane and from one location in the southbound No. 2 lane. A comparison of the low temperature penetrations of the binders recovered from these cores is made with the binders recovered from windrow samples in Table 4. The AR-2000 asphalts and the Conoco modified asphalt have experienced aging while the Witco modified asphalt remains unchanged. The condition of the Witco modified asphalt is not surprising since the Tilt-Oven residue properties indicate the same aging resistance that has been so dramatic in the much more severe desert conditions. The aging of the Conoco material raises a concern regarding the specification of binders expected to resist thermal cracking in a given climate. The low temperature specification used for obtaining binders for this project was based on the penetration of the residue form the rolling thin film oven (RTFO) test. The reduction in penetration in age, beyond that predicted by the RTFO, increases the temperature at which thermal cracking should be expected as shown in Figure 3. Therefore, the specification of a binder for a given minimum temperature exposure should be based on a residue consistent with design life age. In the absence of an accelerated aging test correlated with say ten years of aging in a cold climate, a specification based on the RTFO residue should leave a sufficient margin for some additional field aging.

It is apparent in comparison of the penetrations of the AR-2000 binders with the boundary zone in Figure 3 that their continued use is not recommended where winter minimums below -18C (0°F) are expected.

2. Pavement Condition Surveys

Surveys for pavement distress were conducted annually. In the 1989 survey there were three transverse cracks in the number one lane adjacent to the Conoco section that stopped at the lane line. The southbound lanes, however, exhibited transverse cracking of approximately two cracks per 100 feet. The previous winter minimum temperature had been -28.4C (-19°F). No additional distress was noted during the 1990 survey after a winter exposure of -24.5C (-12°F). The 90/91 winter exposure was a minimum of -27.8C (-18°F). The cracking that was observed in the 1991 survey presented confusing information. The polymer modified binder sections, both in the northbound number two lane, had some transverse cracks while the original control section in the northbound number two lane (with Shell AR-2000) had only one transverse crack in the 1,000 feet designated. The section of pavement that begins at the end of this control section had transverse cracking to the extent of six cracks per 100 feet! In addition, the inside lane (containing Shell AR-2000) adjacent to the polymer sections had 3 to 5 transverse cracks per 100 feet. The crack maps are presented in Figure 11. Cores were taken to obtain material for recoveries. These cores have provided helpful information on the overlay sections which had previously been reported as 0.40' thick. The core measurements are as follows:

BINDER	THICKNESS (ft.)
Conoco polymer modified	0.35
Witco polymer modified	0.37
Control AR-2000 (Shell) NB	0.45
Added	
Control AR-2000 (Witco) NB	0.43
Added	
Control AR-2000 (Witco) SB	0.37

Therefore, it appears that the analysis of thermal cracking resistance is overwhelmed by reflective cracking differences due to structural section variability.

Unfortunately, the pavement couldn't be mapped prior to the placement of the test section because a leveling course had already been placed when the District decided to place the test sections at this location. Therefore, the percent of reflective cracking can't be determined with any accuracy. The 1985 Pavement Management System survey shows nine transverse cracks per 100 feet for the section between postmile 32.0 to 34.2, which includes the Conoco section, and four transverse cracks per 100 feet for the section between postmile 34.2 to 35.7, which includes the Witco and Control sections. Because of this difference, a comparison longitudinally appears unadvisable.

However, photographs of the pavement condition taken at the time of the deflection study in 1985 show that the transverse cracking was consistent in both lanes. Therefore, within a section, a comparison can be made of the performance of adjacent materials.

Thus, it can be concluded that the Conoco material has currently reduced reflective cracking 80 percent and the Witco material has currently reduced reflective cracking 90 percent relative to the control AR-2000 in the adjacent lane.

The cracking history of the Witco AR-2000 in the new structural section of the southbound lane does provide consistent information on the correlation between the binder penetration at 4C and thermal cracking. The new southbound lanes were constructed in 1987, the year before the test sections were placed. A sample of the Witco AR-2000 used at this location was saved and has been characterized. A section of this pavement that has been surveyed, as shown in Figure 11, had two transverse cracks per 100 feet after the 1988/89 winter which included a minimum temperature of -28.4C (-19°F), and six cracks per 100 feet after the 90/91 winter which included a minimum of -27.8C (-18°F). These data points for thermal cracking performance are shown in Figure 12 based on the recovered binder properties presented in Table 4.

Another disturbing observation was stripping in the cores from the Witco polymer modified section. This may be due to the rain that occurred during the placement of the surface course of this section as was mentioned earlier. Currently, distress has not develop due to this occurrence, but this should be taken into consideration on future evaluations.

It appears that the test sections in the northbound lanes at Crestview are yielding useful information on binder properties necessary for reflective cracking retardation and the verification of the Caltrans overlay design procedure rather than the comparison sought on the initiation of thermal cracking. However, the test section has shown that the polymer modifier has contributed to the pavement stability during the summer (highest pavement temperatures) as intended. Combining this with the understanding that it is the base asphalt that defines the low temperature properties of the modified binder and the data showing how soft the binder needs to be for this area of California, the use of a modified asphalt binder for thermal cracking resistance is recommended instead of AR-2000.

IV. Cost Considerations

The performance improvements sought when using modified asphalts are being obtained. However, another consideration is cost-effectiveness. The average AC rehabilitation project has a thickness of 0.28' and costs $143,000/lane mile. In both climatic areas, rehabilitated AC surfaces have been receiving a maintenance surface treatment (usually crack fill and chip seal) every 3.5 years on an average due to distress. The crack filling costs $1,800/lane mile and the chip sealing $7,500/lane mile. For a 10-year life using current materials, the total cost is therefore $162,000/lane mile.

For the use of polymer modified binder, the cost analysis is based on the dense graded AC mix increasing in cost from 25% to 30%. The average over the last five years for standard AC mix has been $30/ton, or for the average overlay of 0.28', an item cost of $38,600/lane mile. Therefore, the use of a modified binder at 30% increase would be $50,200/lane mile, or a difference of $11,600/lane mile. The project costs would then be $154,600/lane mile. The only remaining question is the life of a project.

In the desert climate, the aging rate of the modified binder has been demonstrated to be less than that experienced in the coastal climate. An evaluation of pavement performance in the mild climate, where a binder experiences very little aging, shows that maintenance-free design life performance is being achieved as long as proper design and construction practices are followed. The 10-year cost of a roadway would then be the initial cost of $154,600/lane mile. Therefore, the higher initial cost of material is more than offset due to the elimination of the need for maintenance expenditures during that 10-year period.

In the cold climate, the question is whether the modified binders can maintain the low temperature properties, which have demonstrated the necessary thermal cracking resistance so far, for another seven years. This is a reasonable expectation due to the following considerations. The briquette study also defined the aging rate for asphalt in cold climates. This rate is the same low rate that has been observed in the coastal climate. For some modified binders, such as the Witco binder, the aging may be even lower. However, in the absence of an accelerated aging test for this climate, the use of a margin for aging in a specification should address this concern.

The current initial and maintenance costs are the same in the cold climate for standard asphalt and modified asphalt. Therefore, the same conclusion, that the modified asphalt is cost-effective, is reached.

V. Analysis of Objectives

Objective #1: Obtain modified asphalt binders and evaluate the aging rate and improvements in temperature susceptibility.

With the cooperation of many asphalt producers and asphalt modifier manufacturers, fifteen modified binders were obtained and evaluated.

Objective #2: Screen the modified binders using the Tilt-Oven Durability test for field trial use.

Of the fifteen binders evaluated, four were requested for field test section placement based on the properties of the Tilt-Oven residue.

Objective #3: Determine whether the modified binders are durable by trail in a hot climate and whether they will provide resistance to thermal cracking by trail in a cold climate.

Test sections were constructed which allowed the determination of both of these objectives after four to five years of exposure.

Objective #4: Recalibrate the Tilt-Oven procedure for modified binders, if necessary.

Recalibration was determined to be necessary. A new set of parameters have been determined which correlate with the properties observed after three years in the desert.

REFERENCES

1. E. Zube and J.B. Skog, Final Report on the Zaca-Wigmore Test Road, Proc. AAPT, Vol. . 1969

2. R.J. Schmidt, Use of ASTM Test to Predict Low-Temperature Stiffness of Asphalt Mixes, Transportation Research Record 544, 1975.

3. G.R. Kemp and N.H. Predoeh, A Comparison of Field and Laboratory Environments and Asphalt Durability, Proc, AAPT, 1981.

4. J.W. Button, et.al., Influence of Asphalt Temperature Susceptibility on Pavement Construction and Performance, NCHRP Report 268, December 1983.

5. J.F. Hills and D. Brein, The Fracture of Bitumens and Asphalt Mixes by Temperature Induced Stresses, Proc, AAPT, 1966.

6. R.A. Burgess, A. Kopbillem and F. D. Yound, Ste, Anne Test Road - Relationship Between Predicted Fracture Temperatures and Low Temperature Field Performance., Proc. AAPT, 1971.

7. N.W. Mc Leod, A 4- Year Survey of Low Temperature Transverse Pavement Cracking on Three Ontario Test Roads, Proc. AAPT 1972.

8. H.J. Fromm and W.A, PHang, A Study of Transverse Cracking of Bituminous Pavements, Proc. AAPT, 1972.

9. J.T. Christison, D.W. Murray and K.O. Anderson, Stress Prediction and Low Temperature Fracture Susceptibility of Asphalt Concrete Pavements, Proc. AAPT, 1972.

10. E.E. Readshaw, Asphalt Specifications in British Colombia for Low Temperature Performance, Proc. AAPT, 1972.

11. R.C.G. Haas, A Method for Designing Asphalt Pavements to Minimize Low-Temperature Shrinkage Cracking, Asphalt Institute Research Report 73-1, January 1973.

12. W.J. Gaw, Design Techniques to Minimize Low Temperature Pavement Transverse Cracking, Proc. Seventeeth Pacific Coast Conference on Asphalt Specifications, 1981.

13. J.L Goodrich, Asphalt and Polymer Modified Asphalt Properties Related to the Performance of Asphalt Concrete Mixes, Proc. AAPT, 1988

14.- J.L. Goodrich Asphaltic binder Rheology, Asphalt Concrete Rheology and Asphalt Concrete Mix Properties, Presented at Triaxial Institute, 1991.

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 @ 60C (Kilopoise)	Penetration @ 25C (dmm)	Ductility @ 25C (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

CORE MEASUREMENTS FROM NEEDLES TEST SECTIONS

	Surface (ft)	Replacement of Milling (ft)	Remaining Original (ft)
ASSCO	0.16	0.22	0.17
CONTROL	0.15	0.23	0.13
EDGINGTON	0.16	0.24	0
WITCO	0.15	0.20	0.16

TABLE 3

COMPARISON OF 37 MONTH FIELD-AGED SAMPLES WITH RESIDUE FROM TILT-OVEN AT 113C FOR 3 DAYS

	Penetration @ 25C (dmm)	Ductility @ 25C (cm)	Viscosity @ 60C (Poise)
ASSCO			
Field	22	10	70,000
Tilt-Oven	29	17	53,000
CONTROL			
Field	14	10	47,000
Tilt-Oven	14	9	46,000
EDGINGTON			
Field	70	100+	4,000
Tilt-Oven	75	100+	3,700
WITCO			
Field	50	100+	7,300
Tilt-Oven	51	100+	7,600

TABLE 4

PROPERTIES OF BINDERS RECOVERED
FROM CRESTVIEW TEST SECTION

Material	Penetration @ 4C (dmm) 200 g., 60 sec.	
	0 months	38 months
WITCO AR-2000 Southbound	13*	8
CONOCO Polymer Modified Northbound	43	36
WITCO Polymer Modified Northbound	32	32
SHELL AR-2000 Northbound	15	12
WITCO AR-2000 Northbound	13*	8

*Est. from RTF

FIGURE 1. THERMAL CRACKING PERFORMANCE HISTORY OF 09-MNO-395, 112.8 - 114.7

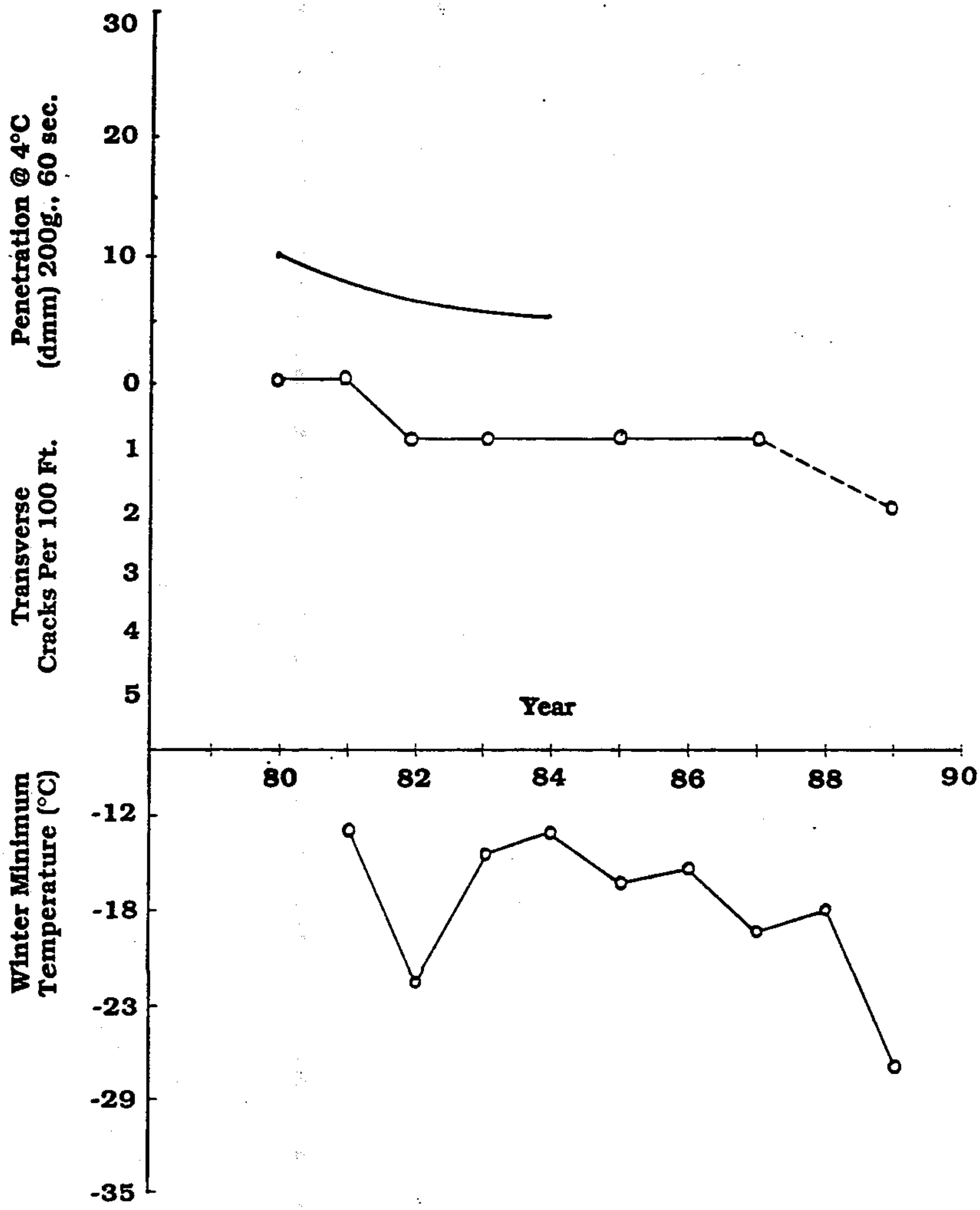

FIGURE 2. PENETRATION VERSUS TEMPERATURE OF CALIFORNIA COASTAL AND VALLEY ASPHALTS

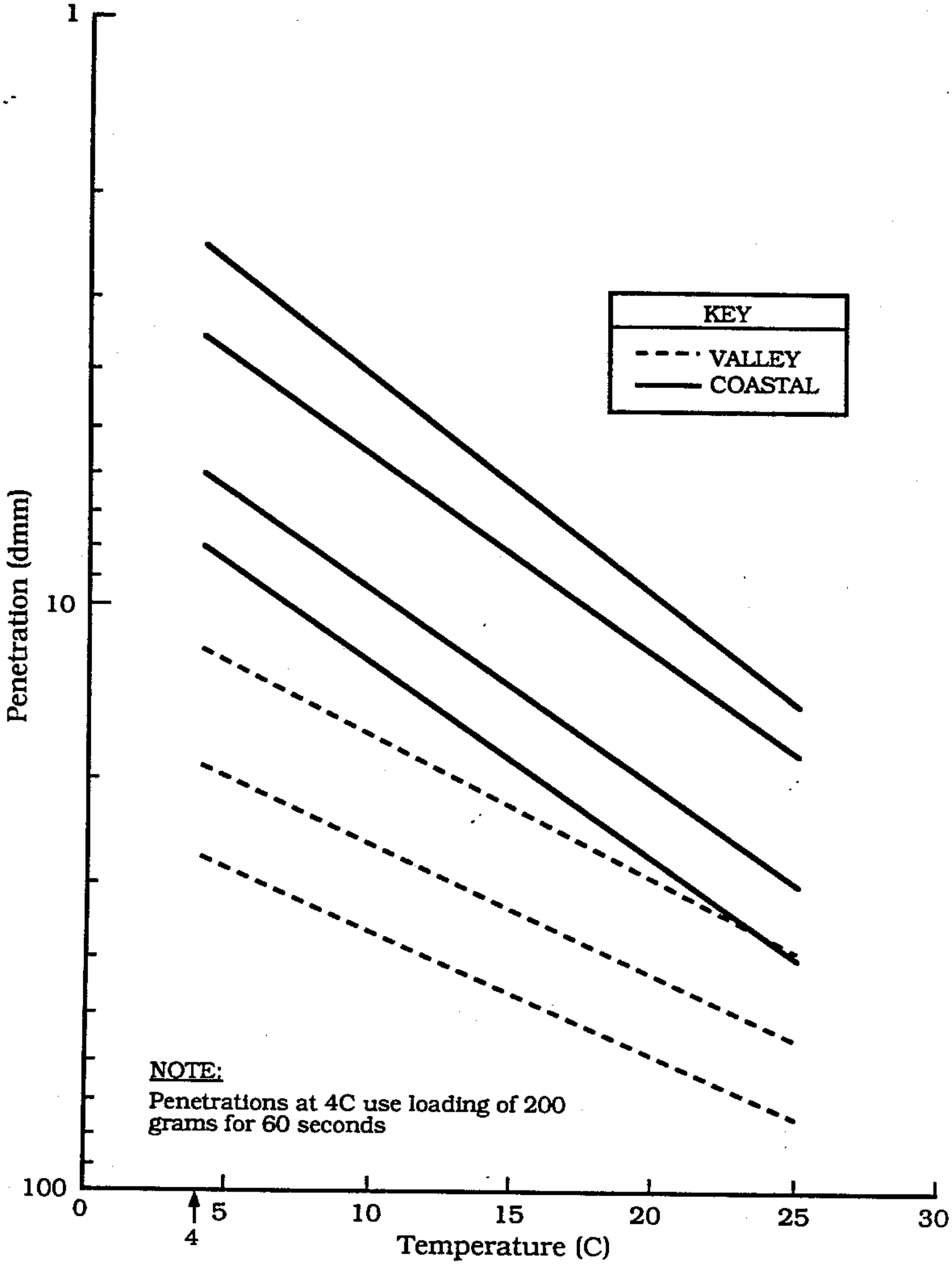

FIGURE 3. THERMAL CRACKING PEROFRMANCE HISTORY OF NEW ASPHALT CONCRETE PAVEMENTS CONSTRUCTED BETWEEN 1977 AND 1983

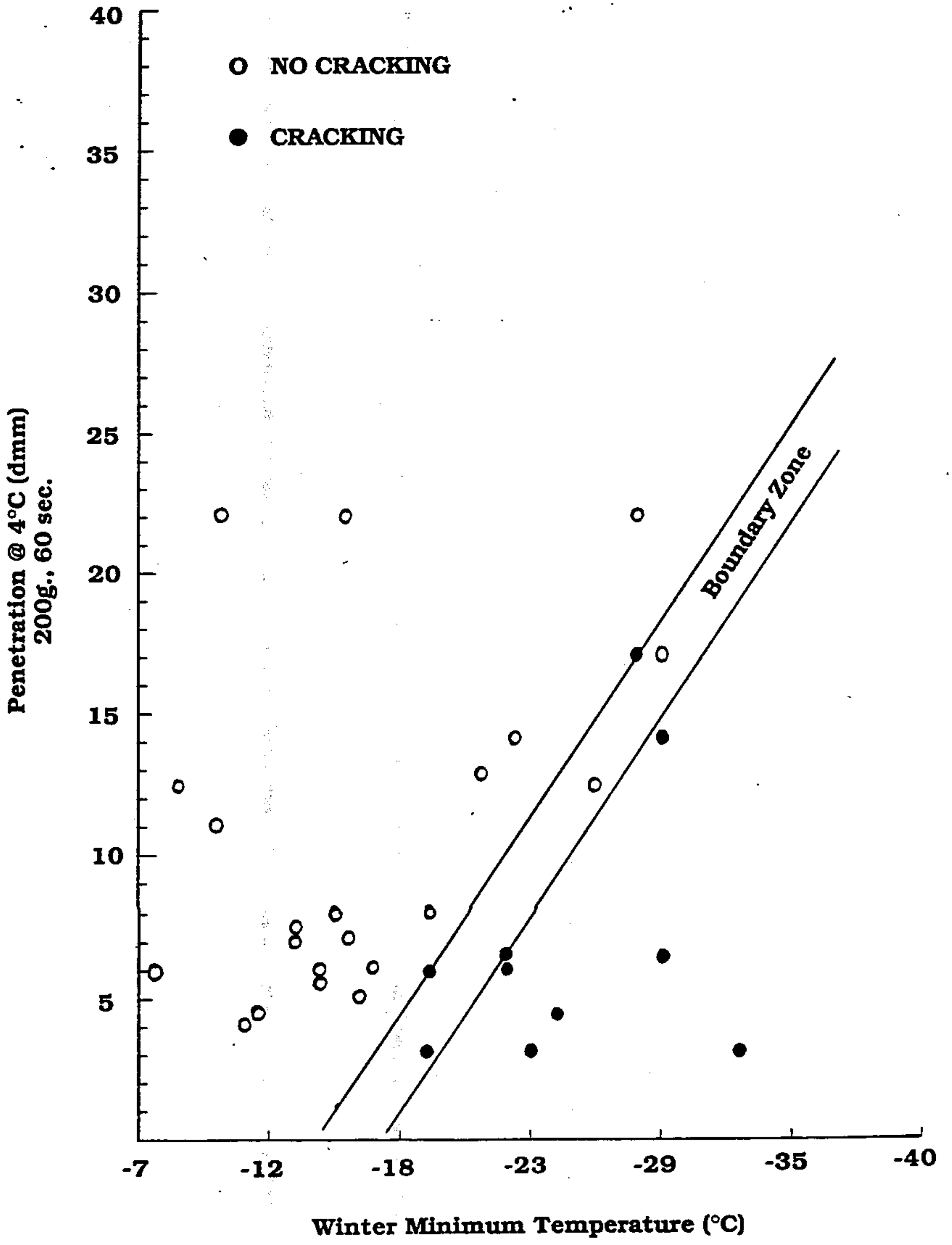

FIGURE 4. VISCOSITY OF BINDERS RECOVERED FROM DESERT TEST SECTIONS

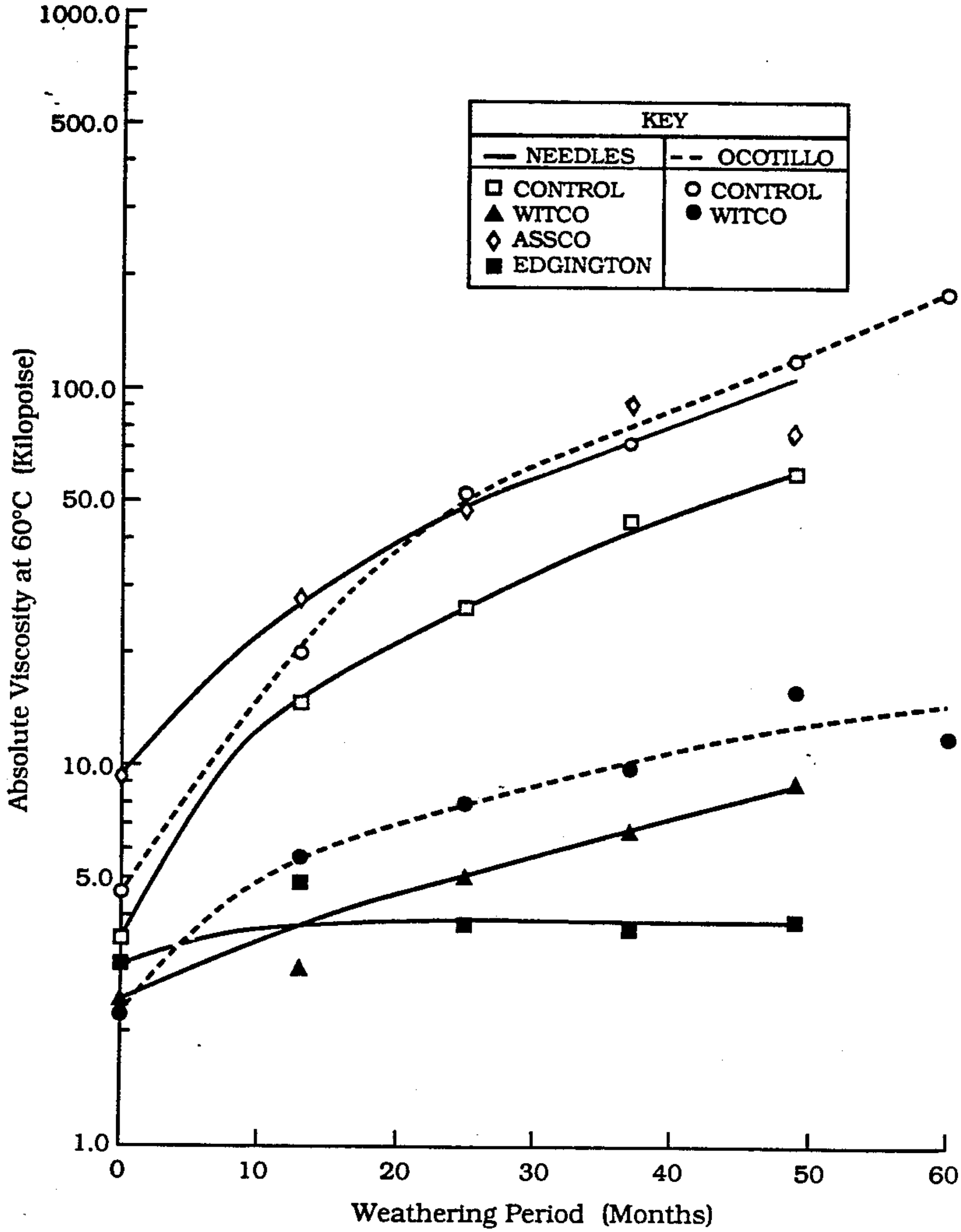

FIGURE 5. BINDER RECOVERED FROM DESERT TEST SECTIONS

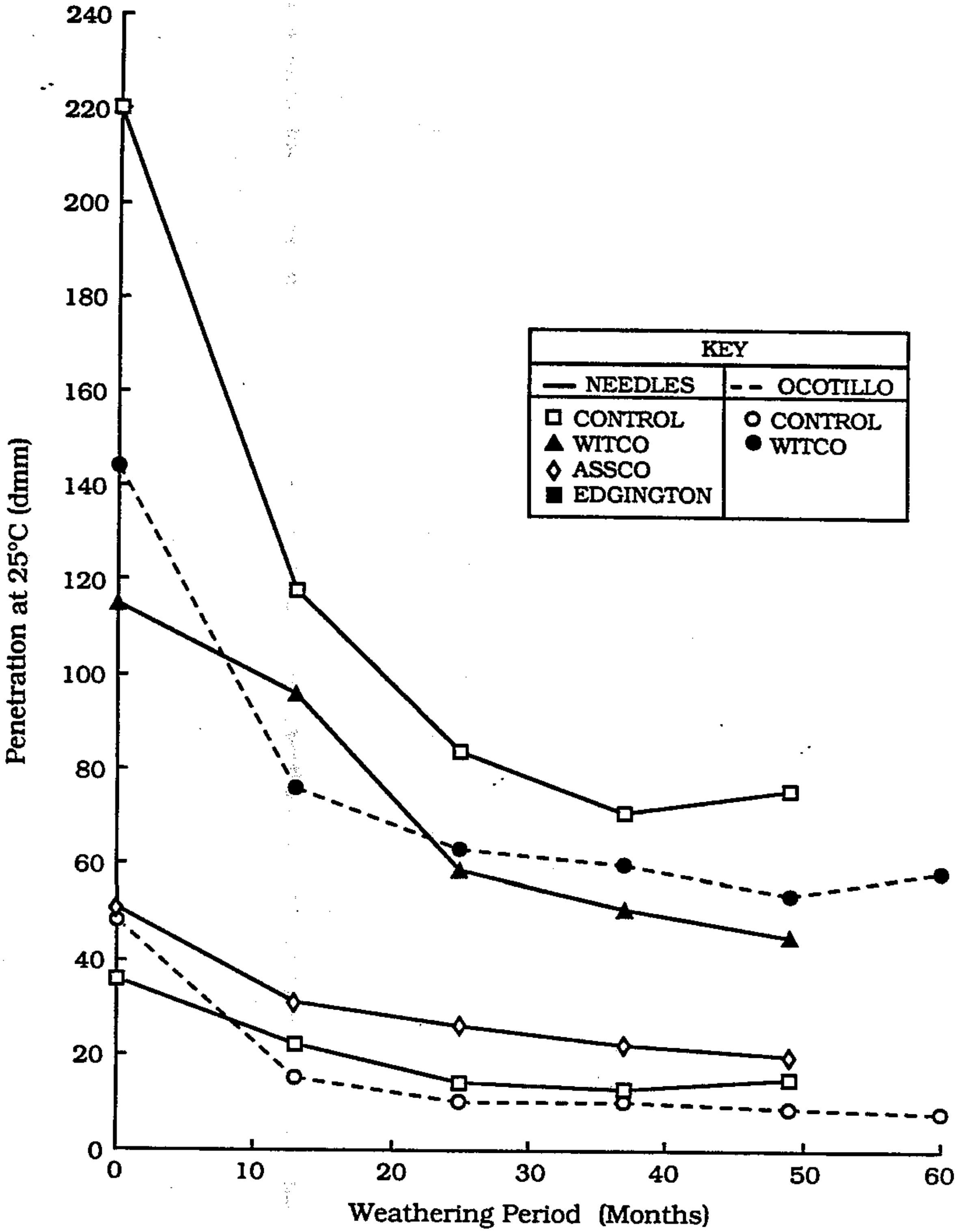

FIGURE 6. BINDER RECOVERED FROM DESERT TEST SECTIONS

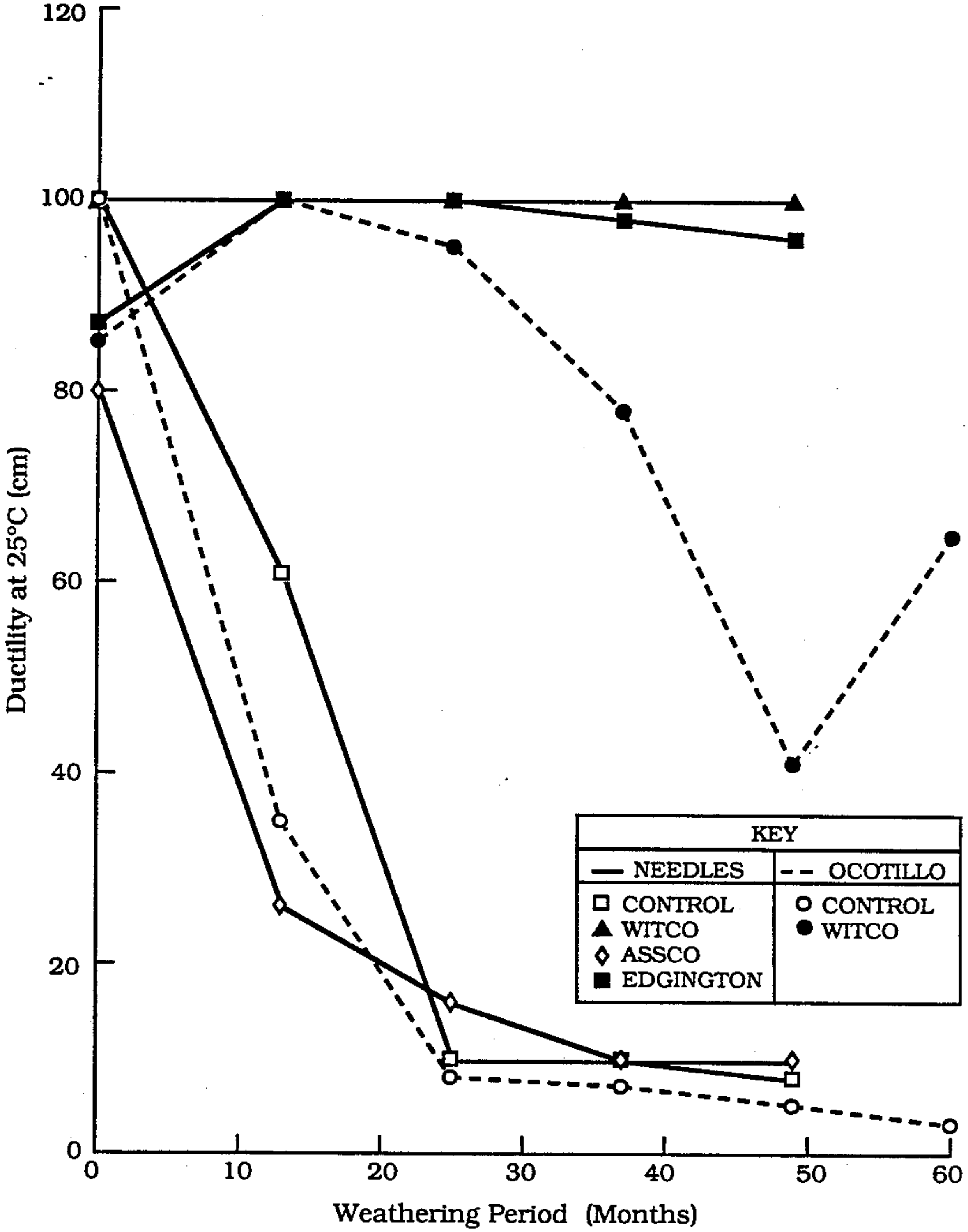

FIGURE 7. EFFECT OF CLIMATE ON HARDENING

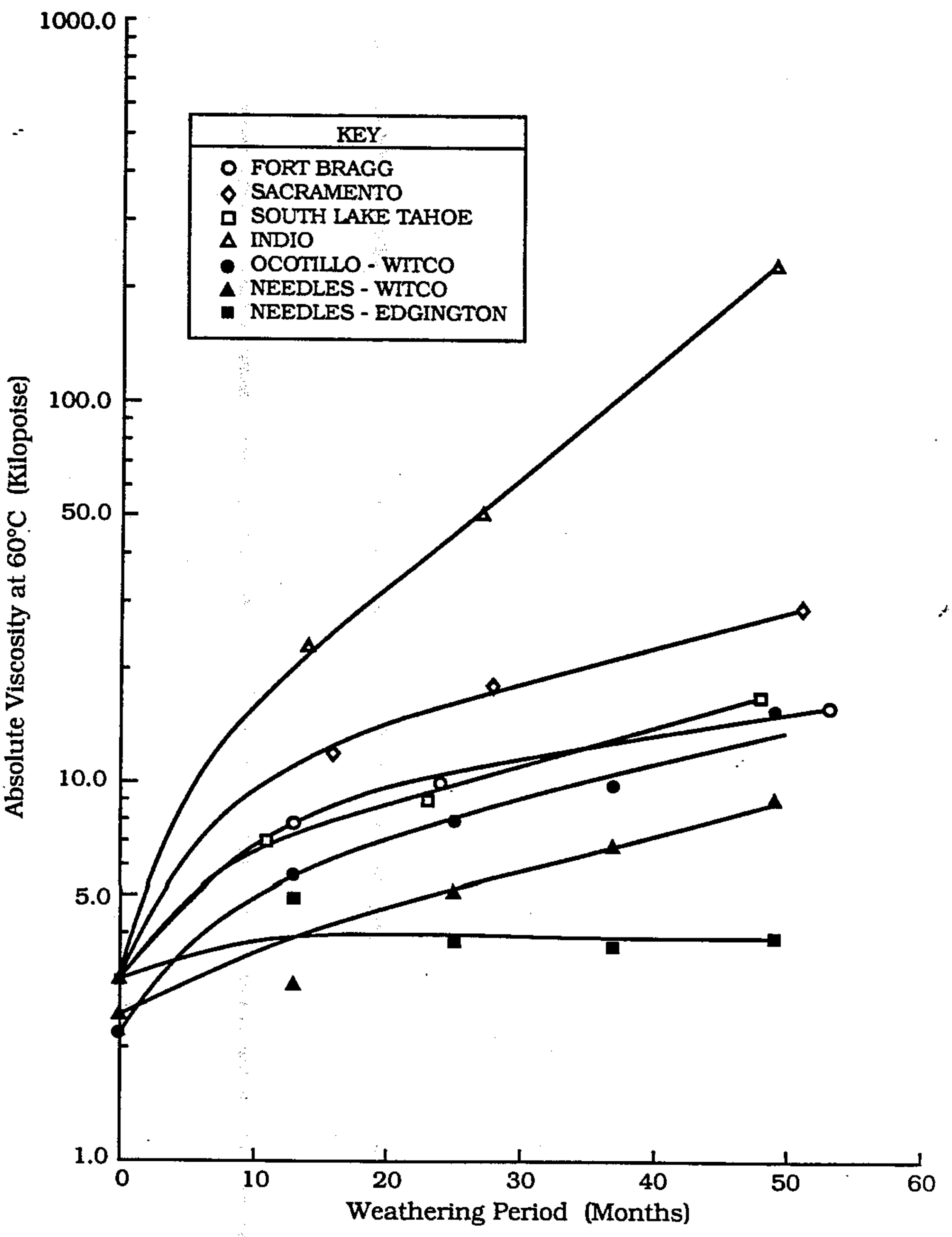

FIGURE 8. AIR VOIDS OF DESERT TEST SECTIONS
(Between the Wheel Path)

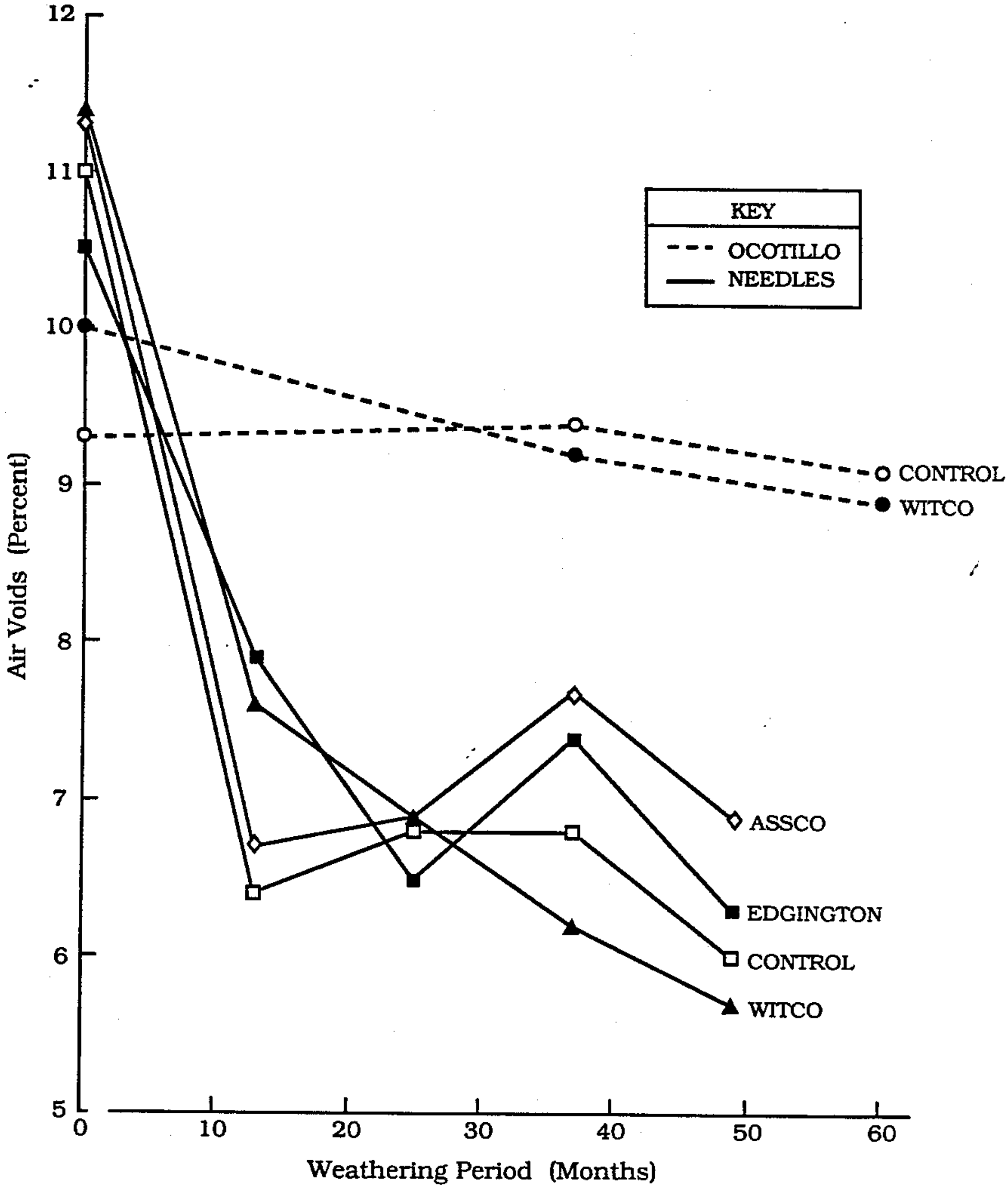

FIGURE 9. TORSIONAL RECOVERY OF WITCO MODIFIED ASPHALT FROM OCOTILLO TEST SECTION

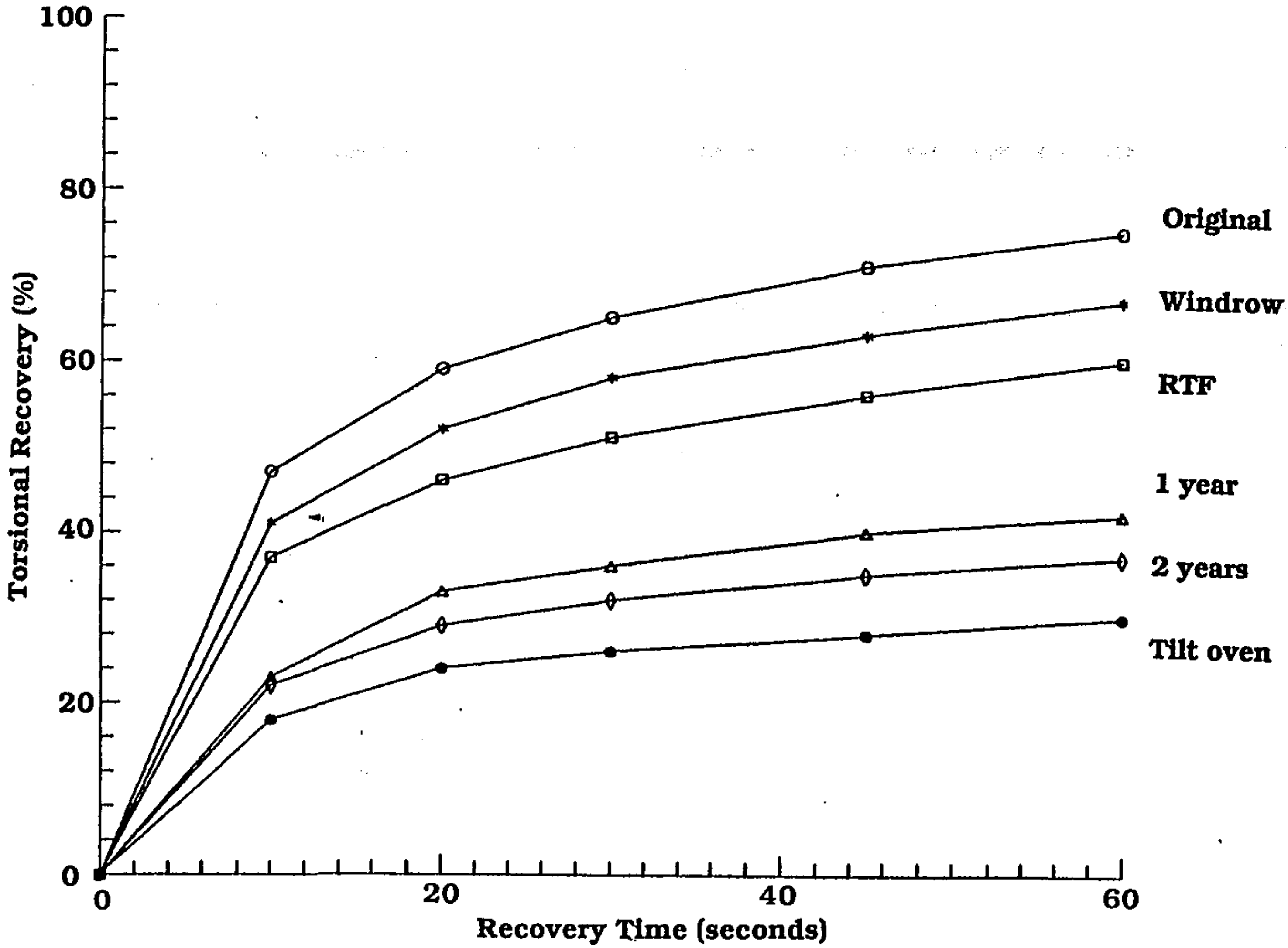

FIGURE 10. COMPARISON OF LOW TEMPERATURE PROPERTIES OF CORES AND RECOVERED BINDERS FROM NEEDLES TEST SECTIONS

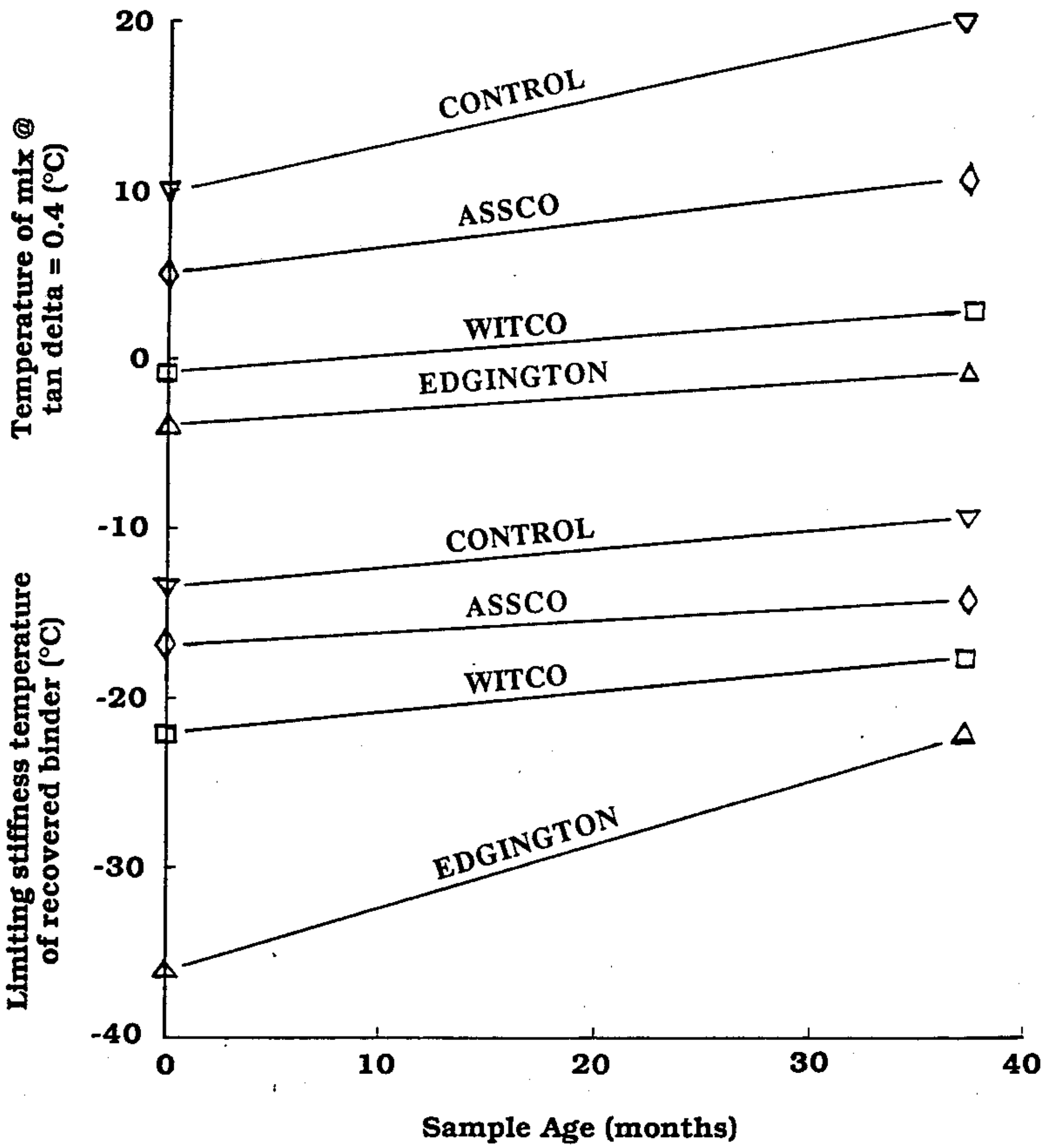

FIGURE11. PAVEMENT CRACKING MAPS FROM CRESTVIEW TEST SECTION - OCT. 1991

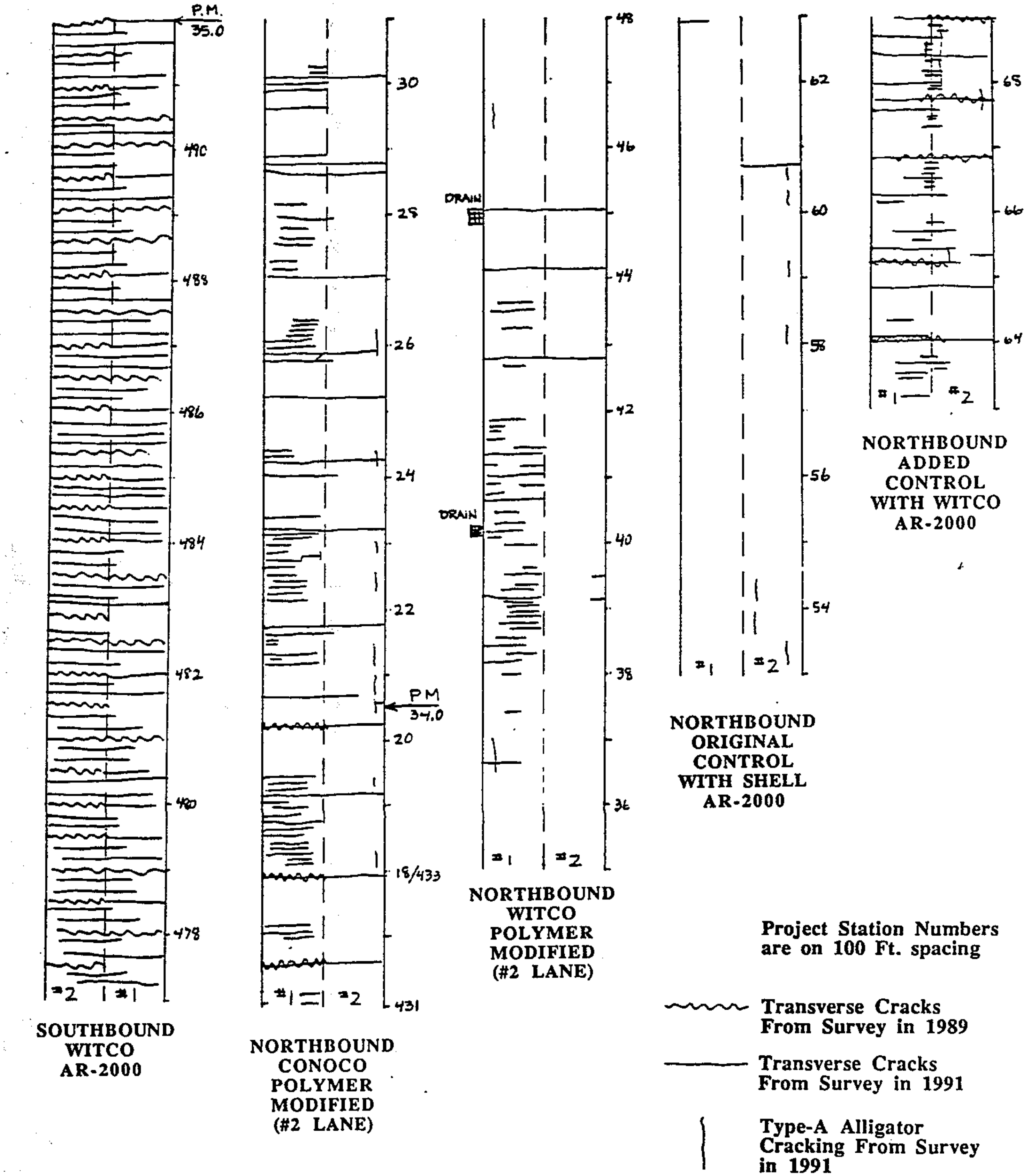

FIGURE 12. THERMAL CRACKING PERFORMANCE DATA,CRESTVIEW TEST SECTION