POLYMER MODIFIED ASPHALT IN HOT MIX PAVEMENT

Interim Report

Executive Summary

November 1988

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16. Abstract

This report presents a summary of a literature review to determine the most appropriate testing procedures for use with polymer modified asphalts. In examining testing procedures, it was necessary to study the effects of polymer modifiers on both binder and mix properties. The four additives most closely examined are styrene-butadiene (SB), styrene-butadiene-styrene (SBS), styrene-butadiene-rubber (SBR), and ethylene-vinyl-acetate (EVA). It was found that standard binder and mixture testing procedures may be successfully used with polymer modified aphalts. In addition, numerous other tests were investigated, the most promising of which are force ductility, toughness and tenacity, rubber industry tensile tests and dynamic shear analysis. A testing program is proposed which will result in recommendations for a specification for polymer modified binders in hot mix. A definite lack of study of long-term aging effects for polymer modified asphalt mixes was noted. Available information indicates a potential problem in this area and that additional research should be conducted.

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DISCLAIMER

The opinions expressed in this report are those of the authors and not necessarily those of FHWA or ODOT. Product names have been used for clarity of presentation. No endorsement of specific products is implied.

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Appendix A. Evaluation of Polymer Modified Asphalt in Hot Mix Pavements: Proposed Work Plan - Phase II

1.0 INTRODUCTION

1.1 Problem Statement

Polymer additives to asphalt materials are being advocated as having high potential for improving long-term pavement performance through their ability to improve the properties of the asphalt binder, and of the resulting asphalt concrete mix. Claims have been made that polymer additives to asphalt can improve adhesion and cohesion, temperature susceptibility, modulus, resistance to fatigue, resistance to rutting, and durability (Terrel and Walter 1986). Improvements to these qualities in hot-mix pavements have the potential to lengthen pavement service life. Because these additives are relatively new to hot-mix pavement construction in the U.S., work is needed to determine their effect on asphalt pavements, to identify appropriate properties which relate to performance, to select testing procedures to aid in design and construction of these pavements, and to develop tests to predict the long-term behavior of the pavements.

1.2 Objectives

The objectives of this study are to:

1) conduct a literature review on the use of, test procedures for, and specifications used in the design of polymer modified asphalt hot mixes,
2) identify the important properties required for polymer modified hot mixes and determine the best method to measure them, and
3) recommend interim specifications and test methods for polymer modified asphalt and polymer modified hot mixes.

Not all polymer modifiers are currently commercially available in the State of Oregon. Investigation of those polymer modifiers which are currently available, including the specific products being supplied, should take highest priority. Therefore, a secondary objective of this research project is to conduct laboratory testing on specific products commercially available in Oregon. These products and there respective modifiers have been identified by ODOT as:

1. Styrelf, a styrene-butadiene (SB) furnished by Pacific Emulsions
2. AC20R, a styrene-butadiene rubber (SBR) furnished by Asphalt Supply and Service
3. CA(P)-1, an asphalt modified with ethyl-vinyl-acetate (EVA) furnished by Chevron USA
4. CA(P)-2, a styrene-butadiene-styrene (SBS) also known as "Kraton" furnished by Chevron USA

1.3 Research Methodology

The literature search was conducted through a search of the Transportation Research Information Service (TRIS) Database, as well as reference lists from various publications and reports dealing with polymer modified asphalts. Promising documents were obtained and reviewed.

To supplement the published literature and get the most current information possible, questionnaires were sent to 14 researchers prominent in the area of polymer modified asphalt. Responses and comments have been summarized. This information was combined with the published information to generate a synthesis on polymer types, polymer modified asphalt hot mix properties and testing procedures.

The laboratory investigation proposed in "Evaluation of Polymer Modified Asphalt in Hot Mix Pavements; Proposed Work Plan - Phase II" focuses on using tests which have been identified as highly likely to predict field performance of polymer modified asphalts. The initial testing will include all promising binder tests and the mix tests required to validate them. After the initial testing, a tentative specification for polymer modified asphalts for hot mix will be proposed. A second testing program will test the specification by correlating the selected binder tests with mix test results for other aggregates and gradations.

2.0 POLYMER ADDITIVES USED TO MODIFY ASPHALT MIXTURES

Polymers may be defined as large molecules composed of a repetition of smaller, normally organic, structural units called monomers. It should be noted that the term polymer can be applied to many chemically crosslinked structures, each of which has its own chemical and physical properties.

The polymer additives being studied in this research are of two types -- plastics and elastomers. Kraton (SBS), Styrelf, and AC-20R are elastomeric additives. EVA is a plastic additive.

Although it is useful to know the generic designation of a modifier (EVA, SBS, SBR, etc.), it should be noted that variations within a classification occur. For example, Button and Little (1987) reported considerably different properties for EVA supplied by Exxon and supplied by DuPont (Elvax 150). Even knowing the specific name of an additive may not provide adequate information about performance. For example, Collins (1986) reported at least nine different blends of Kraton. Krater, Wolf, and Epps (1987) tested various blends of asphalts utilizing modifiers that were described only as "polyolefins." Thus, it is highly desireable to specify polymer modified asphalts not by chemical designation, but rather by ability to satisfy tests of binder properties that relate to mix performance.

2.1 Modifier Effects on Binder Properties

Analysis of reports of binder tests utilizing the four polymer modifers included in this study indicate that generally, the consistency of the base asphalt remains the same at low temperatures, while being increased at temperatures of 77°F and above. Results of tests for tensile, ductile, and resilient properties show large increases over the base asphalt when the binder is modified with polymers. Modified binders usually show less mix preparation aging effect than conventional binders.

2.2 Modifier Effects on Mix Properties

Reports of mixture test results show complete agreement that the four modifiers in this study increase fatigue life, reduce permanent deformation, improve tensile strength, and increase stiffness at high temperatures while retaining the stiffness of the base asphalt at low temperatures.

3.0 EVALUATION OF TEST PROCEDURES

Specifications for any asphalt binder for hot mix pavement construction should address properties that are likely to relate to good mix performance. This is true whether the binder is conventional or modified. The objective in selecting specifications is to find mixture properties that correlate well with field performance, and then find binder properties that correlate well with these mix properties so that meaningful binder tests may be selected. The literature search and questionnaire survey conducted as part of this research focused on determining which binder and mix tests are considered most appropriate when polymer-modified binders are used.

Hot mix pavement in the field must exhibit good performance with respect to

1) load resistance,
2) temperature susceptibility, and
3) durability.

Load resistance as it relates to pavement performance means the ability of the pavement to withstand repeated loading over the range of in-service temperatures. For resistance to wheel loads, fatigue strength and resistance to permanent deformation are the most important properties. However, since cracks manifesting failure are initiated by tensile failures, tensile strength at high strain rate is also of interest. In fact, tensile strength is often used to predict fatigue performance. For resistance to loads imposed by thermal forces, tensile strength at low strain rate and low temperature is generally agreed to be the best indicator of performance. Another factor basic to the load-carrying characteristics of the pavement is its stiffness, or modulus.

Temperature susceptibility refers to the vulnerability of the pavement to changes in temperature. Can the pavement remain stiff enough at high temperatures to resist rutting while still remaining pliable at low temperatures so that it may contract without cracking? An ideal pavement would exhibit high stiffness at high temperatures, and low stiffness at low temperatures.

Durability means the ability of the pavement materials to maintain desireable properties over time. During the period of construction, the paving materials must withstand the temperatures of mix preparation and laydown. During the service life of the pavement, the pavement must withstand the effects of heat, oxygen, sunlight, freeze/thaw, and traffic.

3.1 Mixture Tests

Table 3.1 presents the most significant mixture tests reported in the literature for polymer modified asphalts. They are classified as load resistance, temperature susceptibility, or durability tests. The significant mix tests of Table 3.1 are briefly discussed below:

* **Fatigue tests** -- Beam fatigue tests have the most credibility, but diametral fatigue tests give equally valid results and are faster and easier to conduct (Kennedy 1977). The diametral fatigue test is also referred to as the repeated load indirect tensile test. The overlay tester (Button and Little 1987) provides a simulation of reflective cracking in overlays over faulted pavements, but useful data is obtained more easily with the other two methods. Indirect tensile test (see below) results may also be used to predict fatigue strength.

  Recommendation: Diametral fatigue testing because it relates well to performance and is relatively fast and easy.

* **Permanent deformation** -- Uniaxial creep of a 4" diameter, 8" high specimen loaded perpendicular to the flat ends is the most widely accepted creep test. This test may also be done with 4" diameter, 2-1/2" high specimens, but results may be questionable if large aggregates or binders with large elastic deformations are used. Permanent deformation measured during diametral fatigue testing is

Table 3.1 Significant Mix Tests Reported for Polymer Modified Asphalt Hot Mix

I. Load Resistance

A. Fatigue
1) beam
2) diametral
3) overlay tester

B. Permanent Deformation
1) uniaxial compression creep
2) diametral
3) rutting resistance (LCPC - France method)
4) limiting stiffness temperature (LST) from low-temperature uniaxial compression creep test for thermal loads

C. Tensile Strength
1) indirect tensile test at high strain rate for wheel loads
2) indirect tensile test at low strain rate for thermal loads

D. Resilient Modulus
1) diametral

E. Stability
1) Marshall
2) Hveem

II. Temperature Susceptibility

A. Resilient modulus over wide temperature range

III. Durability

A. Moisture sensitivity
1) resilient modulus or indirect tensile strength before and after modified Lottman conditioning
2) retained Marshall
3) immersion compression

B. Aging
1) mix properties before and after pressure oxygen bomb (POB)
2) mix properties before and after Texas A&M method (14 days @ 140°F)

useful information generated as a by-product of fatigue testing (Kennedy 1977).

Goodrich (1988) used creep testing over a range of temperatures to determine limiting stiffness temperatures (LST's) as an indicator of low temperature cracking potential. It is felt that indirect tensile testing (see below) at low temperatures and low strain rate can provide as good an indication of low termperature cracking potential as low temperature creep testing, and do it faster and more easily.

Recommendation: Limited uniaxial creep testing at 104°F as a check on extensive permanent deformation data generated from diametral fatigue testing. Evaluate low temperature cracking potential through indirect tensile testing.

* **Tensile strength** -- The universally accepted method for measuring mixture tensile strength is the indirect or split tensile test. This test is also widely used to predict fatigue performance.

Recommendation: Test at 14°F and 32°F with .05in/min strain rate for resistance to low-temperature cracking, and test at 77°F and 2 in/min. strain rate to evaluate resistance to wheel loads.

* **Resilient modulus** -- Diametral resilient modulus is generally agreed to be the most efficient method for determining mixture stiffness with acceptable accuracy. Because this is a relatively fast test, and non-destructive, it serves well as a quality control measure and for testing before and after conditioning or aging. It is also a good way to test mixture temperature susceptibility over a range of in-service temperatures.

Recommendation: Test at 14°F, 32°F, and 77°F.

* **Marshall and Hveem Stabilities** -- Marshall and Hveem mix design methods are generally considered adequate for utilizing polymer modified binders, however the other tests listed above are more meaningful and more sensitive to changing binder properties, and therefore better for analysis.

Recommendation: No testing beyond ODOT's mix design tests is required.

* **Conditioning for moisture sensitivity** -- Modified Lottman, retained Marshall, and immersion/compression have all been used with polymer modified binders. All methods test load resistance before some type of thermal/moisture conditioning, then repeat the load resistance test and evaluate the decrease in load resisting ability. Modified Lottman is the most accepted type of conditioning.

Recommendation: Test diametral resilient modulus and indirect tensile strength before and after Modified Lottman conditioning.

* **Conditioning to simulate aging effects** -- Texas A&M (Button and Little 1987) has developed a simple aging procedure which shows promise. Mix specimens are aged in an oven for 14 days @ 140°F. Research at Oregon State University shows promise for a faster but more complicated procedure, the Pressure Oxygen Bomb (POB). Little research into aging with polymer modified asphalt has been done, but the research which has been done raises some serious questions about the long-term performance of some modified binders.

  Recommendation: Use both methods of conditioning. Test resilient modulus and indirect tensile strength before and after conditioning.

3.2 Binder Tests

Ideally, binder tests can be identified which predict mix performance. Table 3.2 lists significant binder tests, classified in the same manner as the mixture tests in Table 3.1. The significant binder tests of Table 3.2 are discussed below:

* **Load resistance** -- Of the tests listed, dynamic mechanical analysis is the most sophisticated and expensive -- a test not amenable to routine specification testing at this time. The other tests are relatively simple. Conventional ductility is a standard test, but has no other advantage over the others. Force ductility, toughness and tenacity, and the rubber industry tensile test similar to ASTM 412 all measure similar stress-strain data and generate similar loading curves. Force ductility is the most favored, but proponents can be found for toughness and tenacity and the rubber industry tensile test.

  Recommendation: Test force ductility and toughness and tenacity so that ODOT may verify that force ductility is the best test. Since Chevron is apparently willing to perform dynamic mechanical analysis on binder specimens, the opportunity should be taken to gain first-hand experience with this promising technique of the future.

* **Temperature susceptibility** -- Points may be plotted on a bitumen test data chart (BTDC) utilizing viscosity data at 275°F and 140°F, softening point, penetration data at 77°F and 39.2°F, and Fraass Point. Although the validity of conventional viscosities for

Table 3.2 Significant Binder Tests Reported for Polymer Modified Asphalts

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I. Load Resistance

A. Ductility
   1) conventional
   2) force ductility

B. Toughness and tenacity

C. Rubber industry tensile test similar to ASTM D412

D. Dynamic mechanical analysis (rheological mechanical spectroscopy)

II. Temperature Susceptibility

A. Tests for Bitumen Test Data Chart (BTDC) curves
   1) viscosity at 275°F
   2) viscosity at 140°F
   3) softening point
   4) penetration at 77°F
   5) penetration at 39°F
   6) Fraass Point

B. Dynamic mechanical analysis over temperature range

III. Durability

A. Moisture sensitivity -- NONE.

B. Aging
   1) during mix preparation
      a) binder properties before and after thin film oven test (TFOT)
      b) binder properties before and after rolling thin film oven test (RTFOT)
   2) in service
      a) binder properties before and after long term durability test (LTD)
      b) binder properties before and after pressure oxygen bomb (POB)

polymer modified asphalts is suspect due to their shear-thinning characteristics, these viscosities have been and will continue to be included in specifications and acceptance testing. Penetrations are well known, are easy to do, and at least one researcher (Goodrich 1988) has shown almost magical correlations with important mix properties. Softening point is an easy way to add another point to the temperature susceptibility curve. Fraass Point gives yet another data point at the very critical low-temperature end of the curve.

Recommendation: Run viscosities (275°F and 140°F), penetrations (77°F and 39.2°F) and Fraass Test.

* **Aging during mix preparation** -- TFOT and RTFOT are both commonly used and both accepted. RTFOT is the accepted process in Oregon. Aging is important, since it is aged binder that will be performing in the actual pavement.

  Recommendation: Test all binder properties before and after RTFOT.

* **Aging in-service** -- The long-term durability test (LTD), which is a 7-day, 111°C version of the RTFOT, has been used with polymer modified binders. It attempts to simulate 2 years of exposure in the California desert. The pressure oxygen bomb (POB) has shown promise for conventional binders, and should be valid for polymer modified binders.

  Recommendation: Test all binder properties before and after POB.

The above discussion has provided a rationale for selection of mixture and binder tests for further study. These selections are presented in Table 3.3.

3.3 Current and Proposed Polymer Modified Binder Specifications

The literature search uncovered several specifications which have been used or are proposed for use with polymer modified binders. Table 3.4 summarizes the binder test procedures utilized in these specifications. The ODOT specifications are the specifications used for bidding the Murphy's Road-Lava Butte project during April, 1988. These specifications were supplied by the various material suppliers. The Kentucky specification was included in a paper by Fleckenstein and Allen (1987) reporting on the use of Kraton. The proposed New Mexico specification is based on input from both Styrelf and

Table 3.3 Tests Recommended for Further Study

Binder Tests

I. Load resistance

A. Force ductility
B. Toughness and Tenacity
C. Dynamic mechanical analysis (for basic understanding and future use)

II. Temperature susceptibility

A. Conventional viscosities (275°F and 140°F)
B. Penetrations (77°F and 39.2°F)
C. Fraass Point

III. Durability

A. TFOT (or RTFOT if equipment is available) to simulate mix preparation effects.
B. Pressure Oxygen Bomb with Fraass specimens to simulate long-term effects.

Mixture Tests

I. Load resistance

A. Wheel loads
1) diametral fatigue and permanent deformation over temperature range
2) uniaxial compression creep at 104°F
3) diametral resilient modulus at different temperatures
4) indirect tensile test at 77°F and 2 in./min. strain rate
B. Thermal loading
1) indirect tensile test at 14°F and 32°F and 0.05 in./min. strain rate

II. Temperature susceptibility

A. Diametral resilient modulus over temperature range

III. Durability
A. Moisture susceptibility
1) indirect tensile strength before and after modified Lottman conditioning
B. Heat/oxygen stability
1) indirect tensile test before and after pressure oxygen bomb
2) indirect tensile test before and after maintaining specimens at 140 F for 14 days (Texas A&M method)

Table 3.4 Comparison of Tests Incorporated in Specifications for Polymer Modified Asphalt

	ODOT AC-20R (1988)	ODOT CAP-1 (1988)	ODOT CAP-2 (1988)	ODOT STYRELF (1988)	KY PAC (1987)	NM MAC (1988)	CHEVRON MAC 30/45 (1988)
Raw Binder							
Pen. (4C,200g,60s), dmm						range	range
Pen. (25C,100g,5s), dmm		min	min	min	range		
Abs. Vis. @ 60°C, poise	range	range	min	range	min	min	min
Vis. @ 135°C, cSt	min	min	min	min	min	range	range
R&B softening pt., degrees						min	
Flash pt., degrees	min	min	min	min	min		min
Sol. in trichloroethylene,%				min	min		
Ductility @ 25°C, cm	min	min	min				
Ductility @ 4°C, cm	min	min	min				
Toughness, in-lb	min	min	min				
Tenacity, in-lb	min	min	min				
RTFOT or TFOT Residues:							
Pen. (4C,200g,60s), dmm						min	min
% orig. pen.(25C,100g,5s),dmm				min			
Abs. Vis. @ 60°C, poise	max	max	max		max		
Vis. ratio @ 60°C				max		max	max
Ductility @ 4°C, cm	min	min	min		min	min	
Ductility @ 25°C, cm	min	min	min		min		
Tens. Stress @ 20°C, psi				min			
Toughness, in-lb		min	min				
Tenacity, in-lb		min	min				
Elastic recovery @ 4°C, %				min	min		
Ball pen. resilience, % (ASTM D3407)					min		
Weight Loss, %						max	max

Chevron. MAC-30 and MAC-45 specifications have just been released by Chevron, and vary considerably from the Chevron CAP-1 and CAP-2 specifications.

The specification identified as ODOT AC-20R is the most widely used polymer modified binder specification. This specification has been used by the FAA, the FHWA, and several western states. The ODOT CAP-1 and CAP-2 tests utilize the same battery of tests as the AC-20R specification, with the addition of toughness and tenacity requirements for the aged binders. The proposed New Mexico specification, the Kentucky DOH specification, and the Styrelf specification make no attempt to measure tensile, ductile and resilient properties of the unaged binder, measuring these properties only with the aged binders. The majority of specifications require testing of ductilities at 4 and 25°C even though researchers generally do not hold the test of conventional ductility in high esteem. Only Kentucky DOH and the Styrelf specifications require testing of elastic recovery or resilience. Only Styrelf requires tensile strength testing of binder. None of the specifications require testing for force ductility maximum tensile strength, even though this test is highly regarded by researchers (Button and Little 1987; Shuler 1987). The most recent specifications, New Mexico MAC and Chevron MAC-30 and MAC-45 introduce the use of penetration at 4°C, 200 grams, and 60 sec. The inclusion in the specifications of this penetration test is based on research by Goodrich (1988) indicating high correlation of this test with important mix properties. The MAC-30 and MAC-45 specifications are the only specifications which do not include some type of ductility or tensile test. It is expected that the MAC-30 and MAC-45 specifications will allow competition between AC-20R, EVA, Kraton, and Styrelf modified binders, as well as others.

Review of the literature and of the current polymer modified asphalt specifications indicates that penetrations and/or viscosities have generally been specified. Some measure of consistency is clearly needed. Various binder properties have been specified for aged and/or unaged binders. Aged properties should be of most interest, since it is aged binder that must perform in the pavement. Although elastic recovery testing and conventional ductilities have been included in specifications, there is little evidence to demonstrate their relevance. The major questions remaining to be addressed in determining a specification for modified binders are:

1) Are tests such as force ductility and toughness and tenacity required?

2) Are tests of long-term aging effects required when polymers are used?

The testing program presented in "Evaluation of Polymer Modified Asphalt in Hot Mix Pavements; Proposed Work Plan - Phase II" should help answer these questions.

4.0 CONCLUSIONS

The results of this interim study indicate the following preliminary conclusions are warranted:

1) Important properties for polymer modified hot mixes and the best methods for measuring them are:

    a) Fatigue strength -- Flexural fatigue testing is the most accepted method for testing. Diametral fatigue is faster and easier, and equally valid (Kennedy 1977).

    b) High temperature resistance to permanent deformation -- Uniaxial compression creep is the most accepted test, but permanent deformation during diametral fatigue testing is the most efficient method to obtain this data (Kennedy 1977).

    c) Resistance to thermal cracking -- Low temperature indirect tensile testing at low strain rate is considered best.

    d) Stiffness -- Diametral resilient modulus testing is the standard.

    e) Resistance to stripping -- Indirect tensile strength before and after modified Lottman conditioning is accepted as the most useful test.

    f) Resistance to long-term heat/oxygen degradation -- Mix property testing before and after Pressure Oxygen Bomb, or Texas A&M method (14 days @ 140°F) are the most promising procedures.

2) Binder tests should be conducted and correlated with results of mix tests utilizing the various binders and the Ontario Fairwell Bend aggregates to determine which binder tests best predict mix performance. Binder tests which should be evaluated include conventional

viscosities, penetrations @ 77°F and 4°F, Fraass Point, force ductility, and toughness and tenacity. Raw binders and RTFOT or TFOT residues should be tested. Properties should also be tested before and after Pressure Oxygen Bomb conditioning. After initial selection of specification binder tests, other aggregates and gradations should be tested to verify the selection.

3) Dynamic shear analysis holds great promise for evaluation of binders because it measures basic rheological properties. However, the expense of the required testing equipment makes it impractical for use in acceptance testing specifications.

4) New binder tests have come into use which "show off" the properties of polymer modifiers, particularly elastomeric modifiers, but it has not yet been shown conclusively that these test results translate into improved pavement performance. These tests include toughness and tenacity, force ductility, binder tensile test, and elastic recovery. Since these tests involve large strains -- strains which can never be reached in asphalt pavements without failure -- it is certainly questionable how pertinent these test results are.

5) Marshall and Hveem design methods have produced acceptable results for mix design for hot mix utilizing polymer modified binders.

6) Long-term effects on polymer modified mixes of aging by heat, sunlight, and oxidation have not been thoroughly evaluated. Testing which has been done indicates that this is an area where considerable testing is required.

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APPENDIX A

Evaluation of Polymer Modified Asphalt in Hot Mix Pavements:

Proposed Work Plan - Phase II

EVALUATION OF POLYMER MODIFIED ASPHALT IN HOT MIX PAVEMENTS

PROPOSED WORK PLAN - PHASE II

Binder and mixture tests have been selected for further study based on a literature review. Binder and mixture specimens prepared with Styrelf, CAP-1 (EVA), CAP-2 (KRATON; SBS), and AC-20R (SBR), as well as a conventional AC-20 control binder will be tested. Figure 1 shows a flow chart for the binder tests for each binder during initial testing. Figure 2 shows a flow chart for the mix tests for each binder during initial testing. It is proposed that the initial mix tests be conducted with the aggregates, gradation, and design mix of the Ontario, I-84, Farewell Bend to North Fork Jacobson Gulch project. This is a dense-graded B-mix.

After evaluation of the test results from this initial testing program (Contract Task 3), a tentative specification for polymer modified asphalt will be developed and reviewed with ODOT. During the final testing program (Contract Task 4), the binder tests included in this specification will be tested further, utilizing different aggregates (Bend Murphy's Road to Lava Butte project if available) and additional binders. Mixture tests utilized to validate binder tests in the final testing program will be determined upon completion of the initial testing program, but likely will include resilient modulus, diametral fatigue and permanent deformation at 77°F, and indirect tensile strength at 32°F and 0.05 in/min. strain rate.

Procedures

The initial testing program takes a broad look at binder and mixture testing for the designated 4 modifiers and the control asphalt. Upon completion of this testing, binder tests will be correlated with mixture test

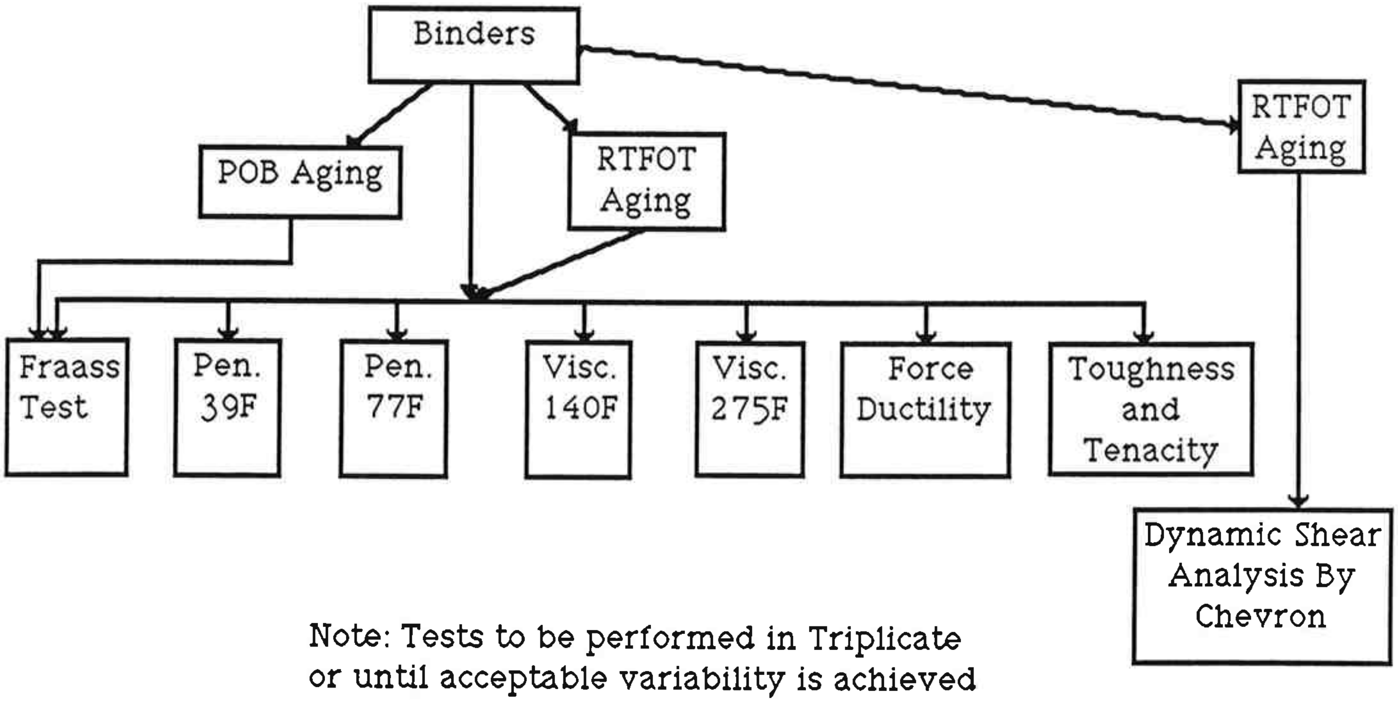

FIGURE 1 BINDER TEST FLOW CHART

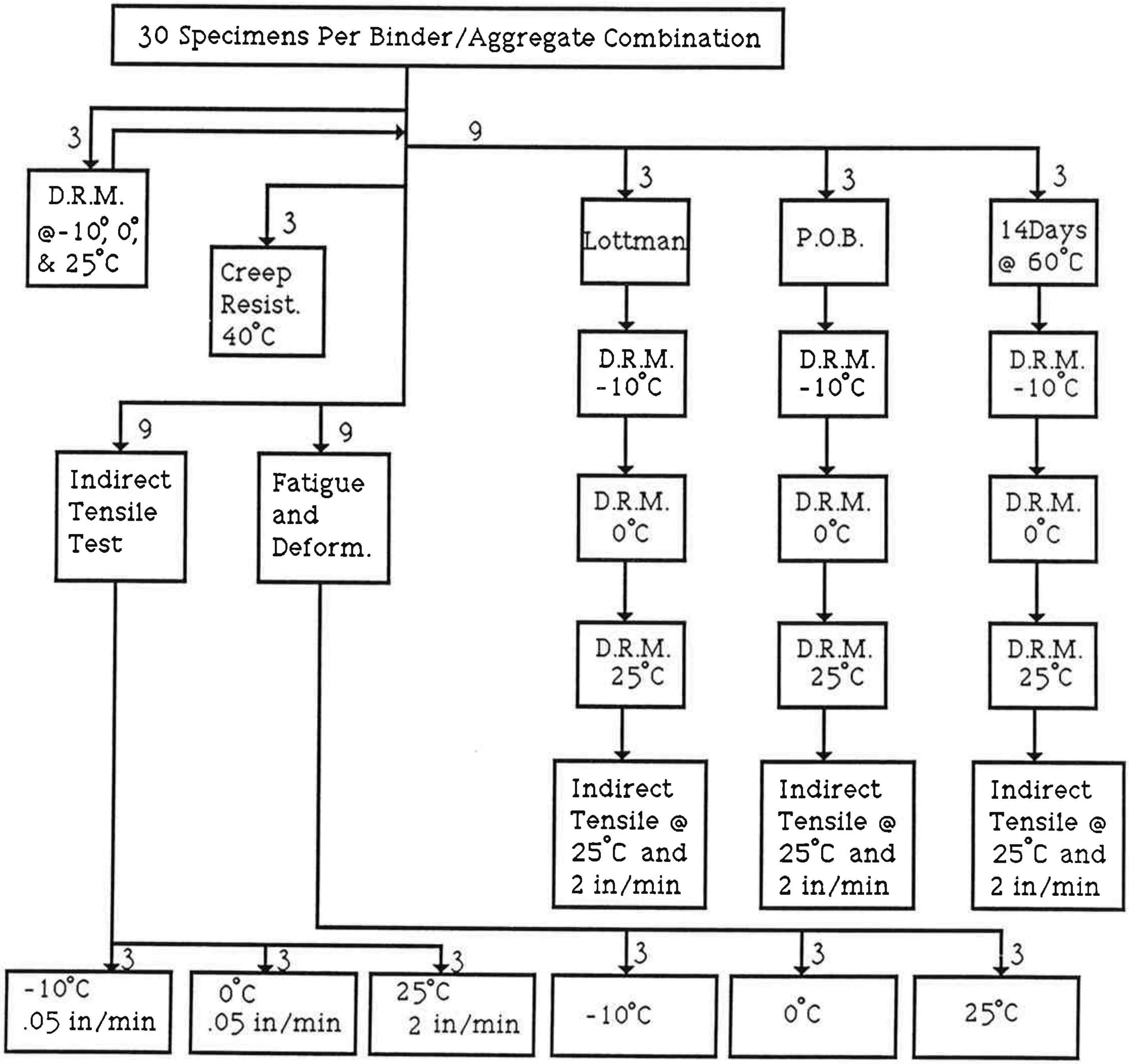

FIGURE 2 MIX TEST FLOW CHART

results to determine which binder tests show the best correlation with mixture tests. At that point, binder tests for inclusion in a specification for polymer modified asphalt for hot mix will be selected. The mixture tests to retain for validation in the final testing program will also be determined. At that point in time, a decision will be made whether long-term aging effects need to be incorporated in the proposed specification and in the final testing program. Reports by Button and Little (1987), Goodrich (1988), and Krivohlavek (1988) indicate that long-term aging effects may be significant and should therefore be considered. The initial testing program provides an opportunity to take a quick look to see if long-term aging effects appear more significant for polymer binders.

Test Repeatability

A minimum of three tests for each binder property will be made. If the three tests show excessive scatter, additional tests will be made until acceptable variability is achieved. A similar approach will be attempted with mix tests, but since all similar specimens should be prepared at one time for uniformity, additional tests can not be made without limit. Statistics of the variability of test results will be available to determine reliability and repeatability of testing procedures.

Anticipated Results

The following results would be expected from the testing program:

1) Initial Testing Program

    a) Determination of which binder tests have best correlation with various mixture tests for the modified and conventional binders.

b) Determination of whether it is necessary to address long-term aging effects in the binder specification, and if it is, whether Pressure Oxygen Bomb or another test is the correct mechanism to do it.

c) Determination of binder tests to be included in a polymer modified binder specification (and in the final testing program).

d) Determination of mixture tests to be included in the final testing program.

2) Final testing program

a) Verification of polymer modified binder specification for different aggregates and gradations, and possibly for additional modified and conventional binders.