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Abridgment

Evaluation of Selected Recycling Modifiers

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A study was undertaken to establish guidelines for use of modifiers in recycling pavement materials for use by the field engineer. Several modifiers were subjected to physical laboratory tests both alone and in blends with aged asphalts. The results indicated that an aged asphalt could be reconstituted but would not necessarily meet all specifications for a virgin asphalt of the same grade. Indications for modifiers blended with asphalts from Woodburn, Oregon; Rye Grass, Washington; and Abilene, Texas, are that the recycled binders should perform satisfactorily.

Materials used to alter properties of asphalt cements have been called softening agents, reclaiming agents, modifiers, recycling agents, fluxing oils, extender oils, bromatic oils, etc. Suppliers of these oils market their products under such names as Cyclogen, Dutrex, Paxole, Reclaimite, and RejuvAcote (1). The term "modifier" will be used to designate this type of material in the report and originates from the American Society for Testing and Materials Subcommittee on Modifier Agents for Bitumen in Pavements and Paving Mixtures. The general definition of modifier is "a material that when added to asphalt cement will alter the physical-chemical properties of the resulting binder". A more specific definition has been developed by the Pacific Coast User-Producer Group for the term "recycling agent"; their Specification Committee defines a recycling agent as "a hydrocarbon product with physical characteristics selected to restore aged asphalt to requirements of current asphalt specifications". It should be noted that soft asphalt cements as well as specialty products can be classified as recycling modifiers or agents.

The purpose of the modifier in asphalt-pavement recycling is to (a) restore the recycled or "old" asphalt characteristics to a consistency level appropriate for construction purposes and for the end use of the mixture, (b) restore the recycled asphalt to its optimal chemical characteristics for durability, (c) provide sufficient additional binder to coat any new aggregate that is added to the recycled mixing, and (d) provide sufficient additional binder to satisfy mixture design requirements.

Methods must therefore be developed to permit the engineer to define the type and amount of modifier to use for a particular asphalt-pavement recycling operation. Findings of a study performed at the Texas Transportation Institute for the National Cooperative Highway Research Program aimed at aiding the engineer in the field are reviewed below.

MODIFIER PROPERTIES

Modifier properties of interest to the engineer are those that can be used for specification purposes to ensure that the modifier will perform the following functions:

1. Be easy to disperse in recycled mixture (2),
2. Alter viscosity of old recycled asphalt cement to the desired level (2-4),
3. Be compatible with the old recycled asphalt to ensure that syneresis (exudation of maltenes from asphalts) will not occur (3),
4. Have the ability to redisperse the asphaltenes in the old recycled asphalt (4),
5. Improve the life expectancy of the recycled asphalt mixture (2-4),
6. Be uniform in properties from batch to batch (2), and
7. Be resistant to smoking and flashing if used in hot-mix operations (2,3,5).

In an effort to classify the modifiers, four possible properties emerged that had enough information on each modifier to use as a classification test. The four tests were viscosity at 77°F (25°C) and at 140°F (60°C), the percentage loss from the thin-film oven test, (TFOT), and viscosity at 140°F on the thin-film oven residue. Since asphalts are graded by viscosity at 140°F either before or after the TFOT, these two tests were considered more significant than the thin-film oven loss and viscosity at 77°F. Also, the design procedure requires the input of viscosity at 140°F of both old asphalt and modifier. Since the old binder was to be reconstituted to an AC-10 grade asphalt, for the purposes of this program, viscosity at 140°F before the TFOT was chosen as the classifying test.

Based on these test results, the seven modifiers to be used for blending with an artifically aged asphalt were chosen. The modifiers were selected first by viscosity; one was chosen from several ranges. In addition, both commercial availability and probability of use were considered major factors. Since the mixing procedure was to simulate a hot-mix operation, emulsions were omitted. After all considerations had been taken into account, the seven modifiers were chosen.

Of the seven modifiers produced, only modifier 1 is a commercially produced additive manufactured for recycling of asphalt pavements. Modifier 2 was motor oil reclaimed from the Texas A&M University Transportation Center after being drained from university vehicles. Modifier 3 is commercially produced as a lube stock, and modifier 4 is a paving grade asphalt, AC-5. Like modifier 4, modifier 5 is also a paving grade AC-5, but it was the highest paraffinic AC-5 available from the source involved. Modifier 6 is commercially available as a slurry oil (carbon black oil), and modifier 7 is available as a roofing asphalt flux.

BLENDS OF MODIFIERS AND AGED ASPHALTS

It is assumed that the field mixing process together with a reaction time (of unknown length) will allow the modifier and the aged recycled asphalt to be completely mixed. If this supposition is accepted, the problem of blending old asphalts and modifiers is greatly simplified. The basic laboratory steps consist of extraction and recovery of the old asphalt, followed by the mixing of various percentages of modifier until the desired consistency is obtained. This process is basically a trial-and-error procedure; however, methods of predicting modifier contents to produce desired viscosities have been developed by the Arizona Department of Transportation, Chevron Research Company (2), Dunning and Mendenhall (4), the Navy (6), the above-mentioned Pacific Coast User-Producer Group, and Witco Chemical Company (3). The basis for all of these methods is basically the same, in that the viscosity of a blend of asphalts of different viscosity can be characterized by equations (1-4) of the following form:

$$\log (V) = a + bp \tag{1a}$$

$$\log - \log (V) = a + bp \tag{1b}$$

$$\log - \log (V) = a + b(\log p) \tag{1c}$$

where V = viscosity of blend (normally measured at 140°F in centistokes) and p = volume by percentage of modifier in blend. If no modifier is used, the viscosity is that of the old asphalt. If 100 percent modifier is used, the viscosity is that of the modifier. Hence, the constants a and b must be determined for each old asphalt-modifier blend.

Laboratory Blends

The seven modifiers chosen for blending were blended with an air-blown Los-Angeles-basin asphalt cement (prepared by Douglas Oil Company) in small quantities in an attempt to achieve the viscosity of an AC-10, which is in the range of 800-1200 P (8000-12 000 Pa) at 140°F. Once the blend for the required viscosity was established, larger quantities were blended for further testing.

Of the seven modifiers tested, all except modifier 3 fell within the specification range of an AC-10 when blended in larger proportions (see Figure 1). It is interesting to note in Table 1 that although the viscosity at 140°F was controlled within a fairly narrow range, the penetration at 77°F (25°C) for all blends that conform to AC-10 requirements ranged from a penetration of 4.2 to a penetration of 14.2; penetrations at 60°F (15.5°C) ranged from 1.0 to 7.0; and viscosities at 210°F (98.8°C) ranged from 14.7 to 29.9 P (147-299 Pa). Note that in the case of modifier 7, an asphalt cement is produced that does not meet the AC-10 requirements (ASTM D3381) for penetrations at 77°F.

At this point, it is important to note that generally the renewed binders did not meet all specifications for a conventional AC-10. This would indicate that it is as important to evaluate the modified binders that are not within normal specifications as it is to evaluate those that do meet specifications. If the reconstituted binder performs as well as virgin binder, even though specifications are not met, then new requirements specially designed to control recycled binders will need to be derived.

Based on an extensive review of the literature, Halstead (7) has proposed a relationship between penetration and ductility that relates asphalt properties to pavement performance. In a 1978 letter, L. C. Krchma has proposed a slight modification to this relationship. Figure 2 illustrates the criteria proposed and the results of the seven modifiers tested. According to Halstead's and Krchma's criteria, blends of modifier 2 (reclaimed motor oil) and modifier 3 (lube stock) with the laboratory-aged asphalts produce asphalt cements that will have unsatisfactory field performance.

Field Blends

From the seven modifiers selected for study with the laboratory-aged asphalt, four were selected for blending with asphalts extracted and recovered from pavements located near Woodburn, Oregon; Rye Grass, Washington; and Abilene, Texas. These pavements were then used in hot-mix recycling projects; modifiers 1 and 2 were selected.

Properties were determined for the recovered asphalts from each of these projects from various locations within the projects. The three projects produced a range in viscosity and penetration typical of many in-service pavements.

The mixtures from each location were then subjected to a laboratory recycling procedure. Modifier 1 was added in an amount determined by mixing several locations and by using that recovered asphalt for blending purposes for each project.

Properties of modifier blends from several locations on the field projects were determined. Blends of materials from location 3 of the Rye Grass, Washington, project consistently gave lower viscosity and higher penetrations than did other locations. This can be explained by the relatively soft nature of the extracted and recovered field-aged asphalt from location 3. Similar behaviors were noted on results of location 5 blends, where the original asphalt had a relatively low viscosity. Blends of modifier 2 result in the largest variation in results among locations.

Asphalt extracted from the various locations in the Woodburn, Oregon, project were more consistent in their properties. However, viscosity measured at 140°F varies by more than ±100 P (1000 Pa) among locations. Thus, the importance of careful laboratory techniques is apparent.

Extraction and recovery tests were performed on laboratory-recycled mixtures by using materials from the three projects. One set of tests was performed after laboratory mixing, compacting, and Marshall testing. The second set of tests was performed after

Figure 1. Viscosity of the artificially aged asphalt plus modifier at 140° F for the seven selected modifiers.

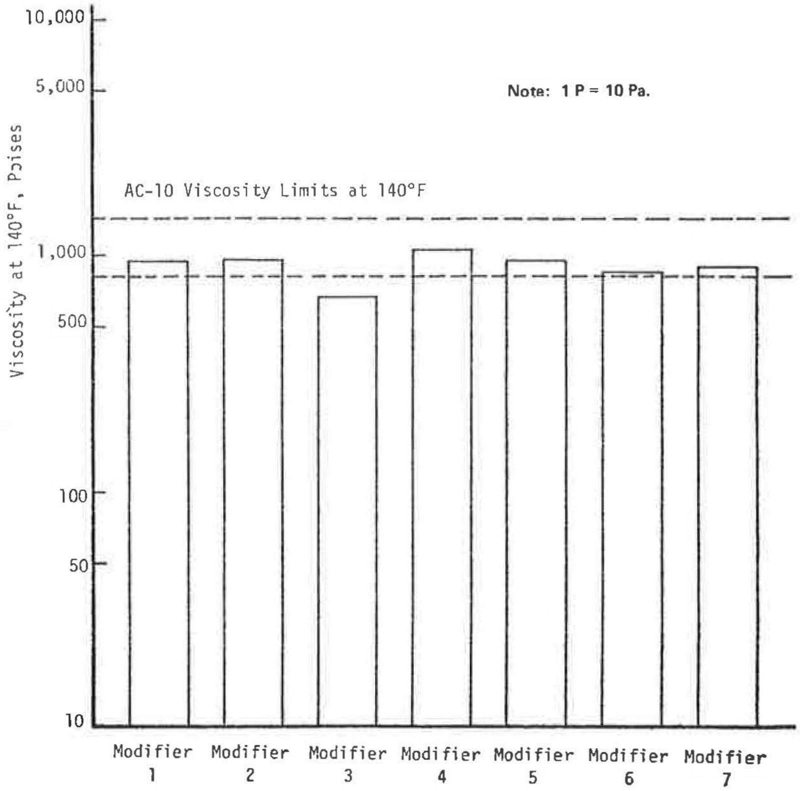


Table 1. Properties of modifier-asphalt blends.

Modifier	Modifier Content (%)	Penetration (mm) 60°F	68°F	77°F	Viscosity (P) 140°F	210°F	Ductility at 77°F (cm)	Ring-and-Ball Softening Point
1	26	3.5		11.2	940	17.1	150+	111
2	27	7.0		14.2	958	14.7	9	116
3	27	6.2		15.8	673	16.8	44	112
4	87	4.0	7.5	12.5	1052	29.9	145	118
5	84	3.1	6.0	10.7	952	24.8	188	116
6	27	3.2	6.8	11.0	853	15.4	115	115
7	47	1.0		4.2	890	21.8	115	122

Note: 1 mm = 0.04 in; $t°F = (t°C \cdot 1.8) + 32$; 1 P = 10 Pa.

Figure 2. Penetration-ductility relationship of artificially aged asphalt-modifier blend after thin-film oven exposure with Halstead's critical penetration-ductility line.

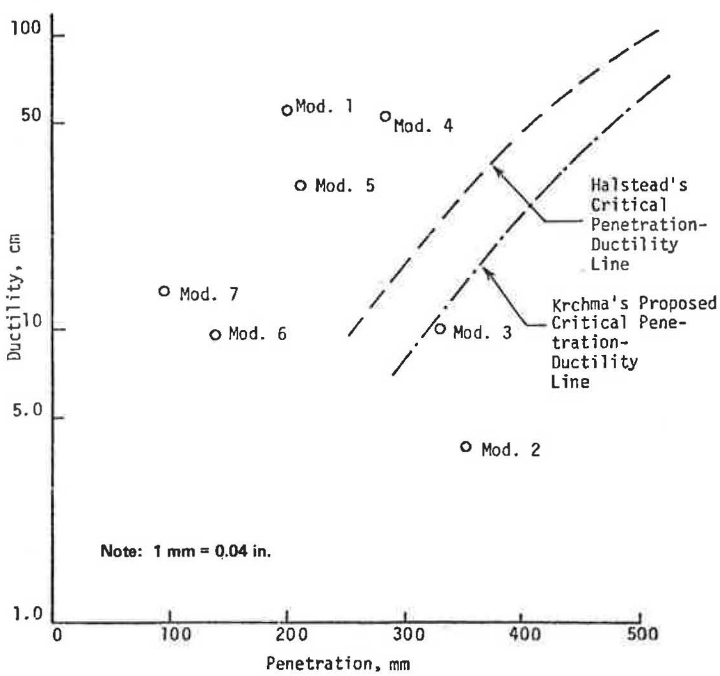
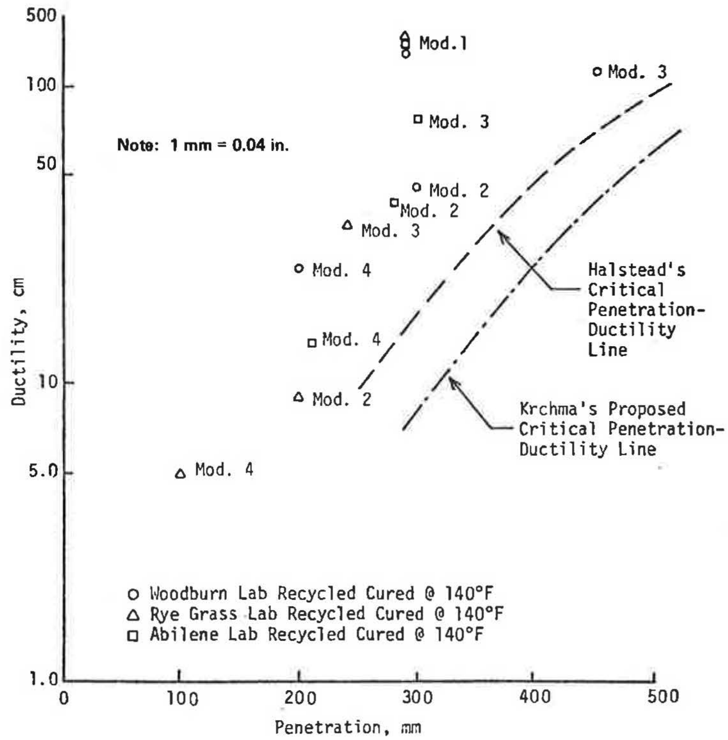


Figure 3. Penetration-ductility relationship of asphalt-modifier blend from 140° F curing samples with Halstead's critical penetration-ductility line.



laboratory curing of the compacted sample for 150 days at 140°F. The mixture that contained modifier 3 hardened excessively during the mixing and compaction operations. Mixtures that contained modifier 1 exhibited the lowest amount of hardening during mixing and compaction.

Penetration-ductility test results obtained after 150 days of curing at 140°F are shown in Figure 3. All combinations meet the established criteria; that is, the blended asphalts can be expected to produce a paving mixture that gives satisfactory performance. The result appears to be contrary to that shown in Figure 2, where results of modifier and laboratory-aged asphalt blends were reported. However, several significant differences between these two materials must be recognized.

1. The modifier and laboratory-aged asphalt blends were subjected to the TFOT.
2. The modifier and field-aged asphalt blends were subjected to laboratory mixing, compaction, and curing, which attempts to simulate field aging.
3. Halstead's criteria were based on extracted and recovered properties of field-aged asphalts and not TFOT results.
4. Laboratory-aged asphalts may produce a different type of material than a field-aged asphalt (2,5).

CONCLUSIONS

As a result of extensive literature review and limited testing at the Texas Transportation Institute, the following conclusions were drawn:

1. Testing techniques must be carefully controlled when asphalt modifying agents are evaluated.
2. Viscosity at 140°F (60°C) is an excellent physical property for classifying modifiers, since blending procedures require this information.
3. Laboratory evaluation tests must be performed on a project-by-project basis.
4. Existing methods to predict asphalt-modifier contents are sufficiently accurate to allow the engineer to estimate required modifier quantities.
5. Modified binders will not necessarily meet specifications of similar conventional binders, and special considerations must be given to each recycled binder.
6. The compatibility of asphalt modifiers and old recycled asphalts needs to be more accurately defined.
7. The best sampling procedure discovered as a result of this study is to sample at various locations and to mix in equal proportions.

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