CHARACTERIZATION OF ROOFING GRADE ASPHALTS

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The Midwest Roofing Contractors Association (MRCA) and the Tamko Asphalt Products Corporation joined in a research program to characterize roofing grade asphalts. ASTM Standard Specification D-312 describes the asphalts used in the study. MRCA member roofing contractors supplied samples from their working stock. The samples represented unheated and heated materials. Tamko tested all samples for compliance with applicable ASTM standards and measured their chemical and rheological properties. Following are the objectives of the study:

- To identify properties of roofing grade asphalts.
- To determine effects of heating on asphalts subjected to field heating practices.
- To evaluate the feasibility of using chemical composition as a measure of asphalt performance.

This paper interprets data collected on 14 ASTM D-312 Type III asphalts. The data included chemical composition, rheological properties and selected physical characteristics. The paper provides an analysis of these data with respect to changes that occur in performance characteristics of the asphalts. It reflects the vast variations among the properties of Type III asphalts before and after heating. Information is presented on changes that take place in chemical, rheological and physical characteristics during the field heating process. In brief, the paper places the data in perspective to address the contractor's concerns about asphalt performance.

KEYWORDS

Application, asphalt, chemical composition, data, information, heating effects, performance, properties, roofing, softening point, viscosity.

CHARACTERIZATION OF ROOFING ASPHALTS

The Midwest Roofing Contractors Association (MRCA) and the Tamko Asphalt Products Corporation (Tamko) joined in a research program to characterize roofing grade asphalts. The objectives of the study were:

- To identify chemical, physical and rheological properties of roofing grade asphalts.
- To determine heating effects on asphalts subjected to field heating practices.
- To measure selected performance characteristics of representative samples.

As part of the program, MRCA member contractors supplied 14 samples from their working stock for testing. The samples included unheated and field heated asphalts. Tamko tested the samples for compliance with ASTM Standard D-312 for "Asphalts Used in Roofing," and measured chemical, physical and rheological properties before and after heating. Mitchell and Kirk[1] prepared a comprehensive report presenting data and information from laboratory testing.

Analysis of the Tamko-generated data reflects information pertinent to the roofing contractor's interests. The data include chemical composition, rheological properties and selected physical characteristics, such as softening point. The data show several of the asphalts were not strictly in compliance with the ASTM standard specifications. However, this issue is not emphasized here.

CHEMICAL COMPOSITION

In general, chemical composition of asphalt is rather unfamiliar to the practicing roofing contractor. The black, sticky substance we know as roofing asphalt is, in reality, a very complex chemical mixture. Laboratory techniques are available to separate asphalt into various fractions. In this study asphaltenes, saturates, aromatics and polar aromatics comprise the four components. In non-technical terms, the saturates are often described as light oils, the aromatics as dark oils and the polar aromatics as the resins. The components are chemically different and each imparts distinct properties to each asphalt. For example, the resin component acts as the building block of the asphalt. The asphaltenes are the stabilizers or fillers that impart stiffness or body. The oily constituents, both light and dark oils, serve as a plasticizer to give asphalt flexibility and ability to flow. Each contributes to the asphalts specific performance properties experienced in service.

The composition, expressed in component percentages, of the 14 contractor supplied unheated asphalts are given in Table 1.

The variation in the chemical component distribution among the asphalts indicates that all Type III asphalts are not the same chemically. The question arises as to how the variations effect performance characteristics? Some general assumptions are presented. Figure 1 indicates that as the asphaltene component increases, the softening point and viscosity increase. The asphalt becomes harder. Interpreted in field performance terms, the flexibility, flow potential, self-healing properties and chemical activity decrease. In broad general terms, the durability decreases.

Conversely, when the oily constituents increase, the softening point and viscosity decrease. The asphalt becomes softer. An increase in flow potential, flexibility, self-healing properties and chemical activity results as illustrated in Figure 2. In general, asphalts having the higher oily constituent content tend, within reason, to be the superior performers.

In either case, it is difficult to make rigid and fast statements about a preference for high or low values for specific properties. Job conditions alone dictate the specific properties required. For example, in hot climates, a low flow potential is desirable. In cold climates, good flexibility and self-healing are the preferred characteristics.

HEATING AND WEATHERING EFFECTS ON CHEMICAL COMPOSITION

Laboratory and field experience indicates that roofing asphalts change in physical properties during heating operations. Research projects[2] carried out at the National Bureau of Standards (NBS) (now National Institute of Standards and Technology) show that asphalts also undergo significant physical change during exposure to weather. The question arises, what changes occur in the chemical component distribution of the asphalt during the heating and weathering procedures? The MRCA/Tamko project results provide insight about the magnitude and direction of the component shift during heating. Figure 3 illustrates an increase in the oily constituents at the expense of a decrease in asphaltene content. Consequently, viscosity values decrease as the softening point falls. Table 2 shows the changes in chemical components that occurred during exposure to on-the-job heating operations expressed as maximum, minimum and average (mean) values.

Weathering effects have the opposite influence on chemical composition than heating effects. Research described in Reference 2, conducted at the National Bureau of Standards, collaborate these findings. Weathering includes exposure to a combination of sunshine (ultraviolet radiation), heat, moisture (rain, condensation, humidity), and air (oxygen). Figure 4 indicates that, during weathering, the asphaltene content increases at the expense of the oily constituents. Consequently, softening point and viscosity increase. Flexibility, flow potential, self-healing properties, chemical activity and weather resistance decrease. These changes again may have serious implications on performance of the roof. They are either detrimental or beneficial to performance depending on the situation.

RHEOLOGICAL PROPERTIES

Viscosity, a measure of asphalts ability to flow, is a critical attribute for application and performance reasons. Asphalts must have optimum viscosity values during application to obtain proper interply amount and sufficient adhesion for the membrane to perform as intended. The MRCA/Tamko project addressed this issue by measuring viscosity values of roofing asphalts before and after heating measured over a temperature range from 350°F to 500°F. Viscosity at roof service temperatures, i.e., up to 170°F, is also an important consideration but not covered in the MRCA/Tamko study. Nonetheless, changes that occur during the heating procedures impact the rheological performance qualities at service temperatures.

Figure 5 presents theoretical temperature-viscosity curves of roofing asphalts. The curves illustrate as temperature increases, viscosity decreases. The upper curve represents a theoretical curve of unheated asphalt as received by the contractor. The lower curve represents asphalt subjected to on-the-job heating. In brief, an asphalt becomes thinner or more susceptible to flow after heating. Figure 6 presents two average (mean) viscosity curves of the asphalts tested, one for the unheated and one for heated asphalts. Data ensuing from the MRCA/Tamko study conform to the theoretical behavior pattern.

Table 3 indicates the magnitude of the viscosity value changes resulting from the contractor heating practices. Unfortunately, descriptions of the heating practices used on the asphalts were not available. The data are reported as the maximum, minimum and average (mean) values measured at three temperatures.

The data show a wide spread in viscosity values within the mopping temperature range. Further, they demonstrate that unheated asphalts vary considerably in rheological behavior in spite of the fact they are purchased to meet the identical ASTM specification. In brief, the data reflect differences in the stability of the asphalt due to the heating operations.

The effect of these variations on temperatures used for mopping or spreader applications may be significant. Tables 4 and 5 illustrate heating effects on equiviscous temperatures (EVT) at values of 125 centistokes as defined by ASTM[3] and at 75 centipoise as recommended by NRCA.[4] These data indicate that field heating operations result in lowering the EVT. Further, they show that heating lowers the EVT window for optimum application by 20°F to 50°F as reported in Table 6. The large differences in EVT values that occur during heating make the contractor's decisions about application temperatures more difficult.

PHYSICAL CHARACTERISTICS

Softening point is a major characteristic of roofing asphalts because it is used for specification purposes. ASTM Standard Specification D-312 for "Asphalts Used in Roofing" differentiates asphalt types by softening point ranges.

Unfortunately, a common misconception exists that the same asphalt type means the same performance characteristics. This is not true. For example, in the early 1970s, Cramp, Cullen and Tryon[5] of the National Bureau of Standards (NBS) demonstrated the differences in flow properties of roofing asphalts having identical softening points. Photo 1 illustrates the different flow potential of Type III asphalts with similar softening points. The data presented in the MRCA/Tamko report collaborate these NBS findings. Table 6 reports the variations in softening points among Type III asphalts and the softening point fallback due to the contractor's heating operations.

Table 6 also shows the average softening point values of unheated samples are at the top of the ASTM range. Conversely, the average values for the heated samples are at the lower end of the permitted range. This indicates that the suppliers are delivering materials at the higher softening points. They apparently anticipate the softening point fallback that occurs during the heating process. Consequently, five of the 14 unheated, Type III asphalts were out of specification on the high side. None were out of specification at the lower end. However, after heating, all 5 of the out of specification materials fell back into the acceptable range. On the other hand, 4 that were in the range originally, fell out of specification on the low end after heating. This anomaly appears to be a "catch twenty-two" situation for both contractor and asphalt supplier.

DISCUSSION

The MRCA/Tamko report is one of the more comprehensive documents on roofing asphalts to appear in the technical literature. It reports physical, chemical and rheological properties of a wide array of roofing asphalts.

This paper uses data reported on 14 Type III asphalts submitted by MRCA roofing contractor members. It places the data in perspective to address the contractor segment's concerns. The concerns involve the performance of the asphalts available to them and with the performance of roofs they apply for their customers. Contractors feel that the quality of asphalts they purchase contribute to application and performance difficulties they experience. They seek ways and means to specify and purchase asphalts that will provide satisfactory service. Material manufacturers and asphalt suppliers share the contractor's concerns. They have similar interests in supplying good quality materials to the contractor. They too want the ultimate customer to have quality roofs. Hence, the joint sponsorship of the program by MRCA and Tamko to characterize asphalts came about. The questions now arise as to what information ensues from these data? Will the information assist in placing good quality asphalt on the roof and will the asphalt retain that quality after being heated as required for application?

First, experience shows that asphalts from many sources have performed well in built-up roofs. Asphalts vary widely in chemical composition. However, in 1986, asphalt technologists[6] reported that compositional tests based on fractional separation of asphalts have not correlated with field performance. Researchers concluded it is unlikely field performance of all asphalts can be characterized in terms of defined fractions. Consequently, it follows that standards based on the distribution of chemical fractions will be very expensive and extremely difficult to be developed.

Chemical composition is useful information for the asphalt chemist in modifying roofing asphalts with polymers and for the researcher studying its fundamental properties. For many years, asphalt technologist[7] have followed changes in the component distribution during heating and weathering. Suhaka[8] reported the development of a test, based on composition, to measure weatherability of coating grade asphalts. It involved a dispersion factor calculated by dividing the sum of the aromatics and polar aromatics by the saturates. A range of values from 1.4 to 5.3 was observed indicating weathering characteristics from worst to best. In spite of several research efforts, little has been done to apply these techniques to the real world of built-up roofing asphalt. This led Suhaka to conclude that the conversion of compositional data directly to performance information of specific asphalts may be difficult at best.

Viscosity, on the other hand, shows promise for specifying and purchasing these materials. Viscosity, a fundamental property, determines performance during application and in service. The information presented here is indicative of the large viscosity changes that occur during heating operations. The changes impact application temperatures, as indicated by equiviscous temperature (EVT) changes. They also may alter some performance characteristics, e.g., blistering and slippage of roofing membranes. Are these changes due to the quality of the asphalt or to the specific heating procedures? Perhaps the technical community should take a good look at both. After extensive research and field experience, Puzinauskas,[9] recommended that viscosity-graded specification should replace current specifications based on softening point. Cullen[10] described ASTM's recent, but unsuccessful, efforts to develop a viscosity grading standard for roofing asphalts. The author is convinced that research experience gives a hint that viscosity grading offers a viable replacement for, or a supplement to, the current ASTM practice of softening point grading.

The softening point is the primary physical property specified in the ASTM D-312 Standard. It is currently the accepted property for specifying roofing asphalts. However, it is the authors' opinion that it has little value to project performance either during application or under service conditions. The data presented in the MRCA/Tamko report seem to support this viewpoint.

In addition to research on composition, rheology and physical properties, further studies are needed to determine how alterations in heating operations, and application techniques and equipment can lessen the detrimental effect heating has on asphalts.

SUMMARY

The rheological properties correlate with application and service performance. Consequently, viscosity grading holds much promise for the grading, specifying and purchasing of roofing asphalts. Physical characteristics, such as softening point and penetration, do not necessarily relate to performance under roof service conditions and only remotely relate to application temperature factors. Nonetheless, they are and will remain important. They have industry consensus as accepted ASTM attributes used to grade, specify and purchase roofing asphalts. The chemical fractionation of asphalts is interesting from several viewpoints. However, it is unlikely that it will be extensively used in standards development or to predict the performance of roofing asphalts.

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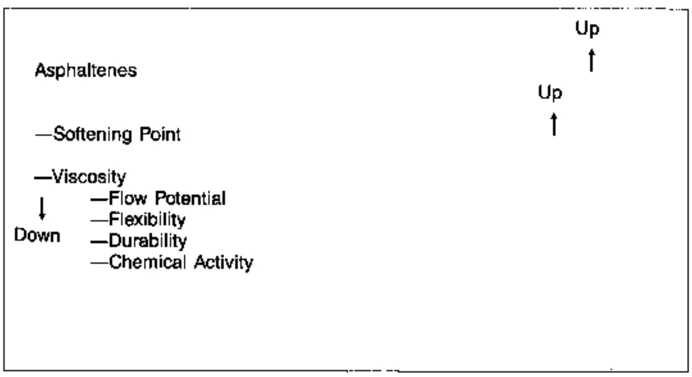

Figure 1 *Effect of increased asphaltene content.*

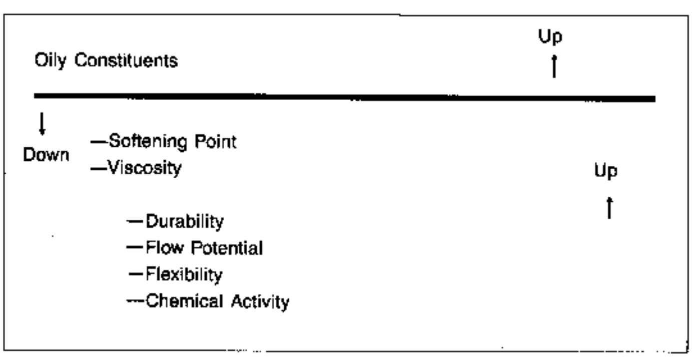

Figure 2 *Effect of increased oily constituents on performance properties.*

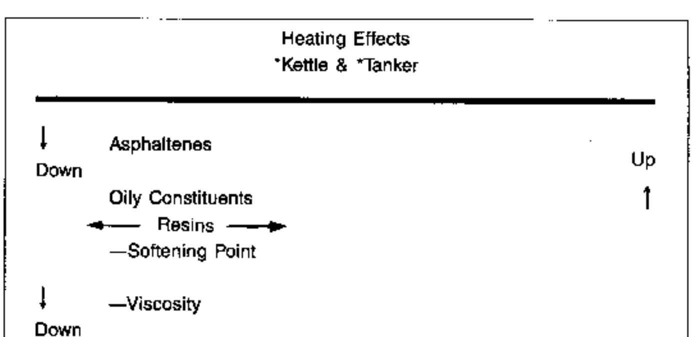

Figure 3 *Heating effects on asphalt components.*

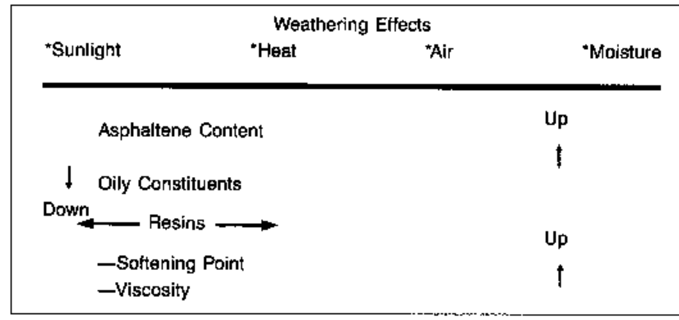

Figure 4 *Weathering effects on roofing asphalts.*

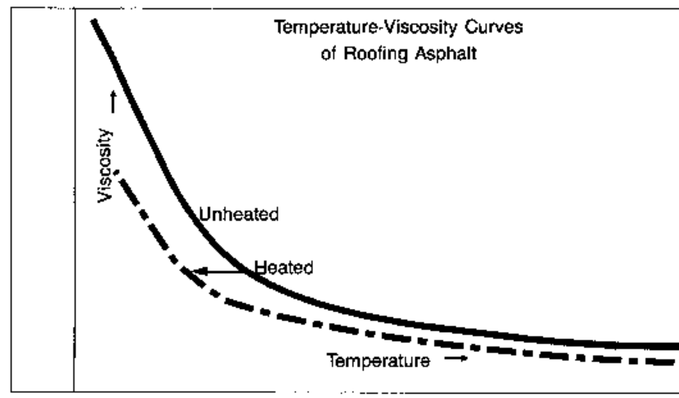

Figure 5 *Temperature/Viscosity curves of roofing asphalts.*

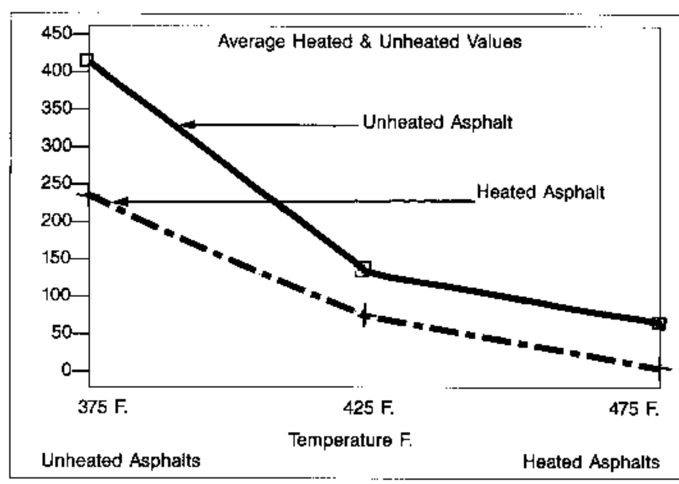

Figure 6 *Type III asphalt viscosity.*

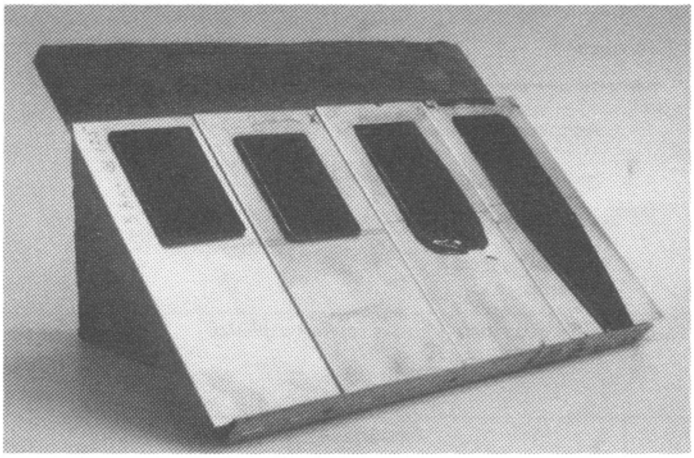

Photo 1 Difference in flow potential of four Type III asphalts with the same softening points at 125°F for five hours.

Component Distribution	Maximum	Minimum	Average (Mean)
Asphaltenes	37.7%	27.9%	32.1%
Dark Oils (Saturates)	28.3%	16.9%	23.4%
Light Oils (Aromatics)	32.1%	27.1%	28.9%
Resins (Polar Aromatics)	18.3%	12.6%	15.6%

Table 1 Component distribution of unheated contractor supplied ASTM D-312 Type III asphalts.

Asphalt Samples	Asphaltenes		Oily Constituents	
	Heated	Unheated	Heated	Unheated
Sample # 12 (Max.)	37.9%	31.7%	48.5%	53.4%
Sample # 13 (Min.)	31.6%	31.1%	55.5%	53.6%
All 14 Samples (Ave.)	32.1%	29.9%	52.3%	53.2%

Table 2 Effects of heating on component distribution of the 14 contractor supplied asphalts.

Viscosity cps.	375°F.		425°F.		475°F.	
	Unheated	Heated	Unheated	Heated	Unheated	Heated
Maximum	631	165	209	74	76	37
Minimum	230	119	66	56	32	27
Average	414	240	137	89	60	43

Table 3 Viscosity in centipoise of Type III asphalts before and after on-the-job heating.

	Equiviscous Temperature °F. @ 125 cps.		
	Unheated	Heated	Δ°F.
Maximum	440	395	−45
Minimum	420	380	−40
Average	425	390	−35

Table 4 Heating effect on equiviscous temperature (EVT) of Type III roofing asphalts for mopping applications.

	Equiviscous Temperature °F. @ 75 cps.		
	Unheated	Heated	Δ°F.
Maximum	475	425	−50
Minimum	445	420	−25
Average	460	440	−20

Table 5 Heating effects on equiviscous temperature of Type III roofing asphalts for spreader applications.

Asphalt Treatment	ASTM D-312, Type III Asphalt			
	ASTM Spec. Range	Maximum	Minimum	Average (Mean)
Unheated	180 to 205°F.	213°F.	190°F.	203°F.
Heated	N/A	190°F.	173°F.	186°F.

Table 6 Softening point ranges of Type III asphalts before and after heating.