SPECIFICATIONS FOR ROOFING AND INDUSTRIAL ASPHALTS

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ABSTRACT
The roofing industry needs a revised ASTM specification featuring viscosity rather than softening point as the primary distinguishing characteristic of roofing asphalts to replace the current ASTM Standard Specification D 312. Exhaustive tests reported in this paper demonstrate extremely poor correlation between an asphalt's softening point, and its viscosity, which is the prime factor determining the suitability of a given roofing asphalt for its purpose.

Viscosity is the critical determinant of satisfactory mopping asphalt quality for two requirements:

- Sufficient viscosity to provide slippage resistance on slopes at high roof-surface temperature
- The ability to achieve a uniform, void-free asphalt film of proper thickness in interply moppings at hot-mopping temperatures

The proposed change accordingly sets viscosity ranges at 71.1°C (160°F) and 135°C (275°F) as the primary characteristic differentiating four basic types of roofing asphalt.

1. ROOFING AND INDUSTRIAL ASPHALTS
Standard specifications are required for four types of roofing and related dampproofing or waterproofing asphalts.

- Mopping grade asphalts used as interply adhesives or flood coats for built-up roof membranes
- Saturants used to impregnate organic and inorganic felts utilized in both BUR roofing felts as well as in roofing shingle or roll products manufacture
- Coating grade asphalts used to coat either impregnated organic or unsaturated glass-fiber felts
- Dampproofing and waterproofing asphalts, used for canal, ditch and pond linings

All roofing and waterproofing asphalts are derived from crude petroleum, manufactured by the air-blowing of carefully selected stocks or fluxes obtained by the primary distillation of petroleum. Air-blowing may be accomplished under a variety of conditions — e.g., via use of catalysts such as ferric chloride ($FeCl_3$) or, less commonly, phosphoric acid (P_2O_5). The method of air-blowing depends on the original feed material and on the desired properties of the finished product.

2. CURRENT SPECIFICATIONS FOR ROOFING AND WATERPROOFING ASPHALTS
Standard ASTM specifications for mopping, waterproofing, dampproofing and canal, ditch and pond-lining materials [1] include D 312 for mopping grade asphalts used in the constuction of built-up roof membranes: D 449 for dampproofing and waterproofing, and D 2521 for waterproofing canal, ditch and pond linings. Comparable national specifications for saturants and coating asphalts are not available. These materials are similar to mopping asphalts, though saturants tend to be softer than Type I, the softest grade in ASTM D 312 specifications, and coating materials, often stabilized with fine mineral matter, tend to be higher in consistency than the hardest Type IV material listed in that ASTM standard.

The above specifications are similar since in all cases, asphalts are graded on the basis of their softening point temperature as measured by the Ring-and-Ball Apparatus. Ranges of softening-point temperature are varied to differentiate between asphalts of different grades and types. Besides the softening-point ranges, the specifications include two more consistency requirements: penetration at 0°C (32°F), 25°C (77°F) and 46.1°C (115°F), and ductility at 25°C (77°F). In addition to the consistency requirements, these specifications contain flash-point requirements relating to safety during heating prior to application. The requirements of solubility in trichloroethylene are also included to indicate or ensure purity of the material.

Since these standards are all patterned after ASTM D 312, Standard Specification for Asphalts in Roofing, this specification will be used primarily in this discussion.

3. PURPOSE OF SPECIFICATIONS
Specification requirements for roofing and waterproofing asphalts serve several purposes:

- To assure uniformity of the material before application, thus assuring the purchaser that important material properties will fluctuate only within an allowable range
- To assure the user that the material requires no drastic departures from standard application practices
- To assure the user that properly applied material will perform its design function throughout anticipated service life

These ideal purposes obviously cannot be attained, largely because asphalt is only one of several materials (along with felts and surfacing) that collectively constitute the composite built-up roofing or waterproofing membrane. Performance specifications for a building component comprising several materials must obviously deal with that total component, not merely with its constituent materials considered individually.

In the development of a material specification certain criteria should be kept in mind. The limits for specification requirements should be sufficiently wide to include all materials that have performed satsifactorily. Furthermore, it is necessary that specification requirements be expressed in units of measurement that are meaningful and significant with regard to the end use of the material. This may require that sufficiently accurate relatively simple test methods be available to make such measurements. A study of current roofing and waterproofing asphalt specifications reveals that they seldom satisfy, even partially, any of the above criterial. Thus, the development of specifications that satisfy the previously listed criteria would represent a substantial improvement in present material specifications.

4. PROPERTIES OF ROOFING ASPHALTS

Recently, The Asphalt Institute's laboratory conducted a comprehensive test program to measure the physical properties of nearly 150 commercially produced roofing asphalts (see The Asphalt Institute Research Report No. 82-1[2]).

In this study, empirical tests commonly described in the specifications for roofing asphalts were made. Further, fundamental viscosity measurements were determined over a wide range of temperatures. Viscosity was emphasized because it represents a true and fundamental consistency measure of the material, a measure that plays an important role throughout the temperature ranges encountered during manufacture, application and service of roofing aphalts. Viscosity is expressed in a fundamental measurement unit that is the same, or that may be readily converted to, a single system, regardless of test temperature, test apparatus or type of material.

These test data thus allow not only a ready comparison between empirical consistency properties, such as softening point, penetration and ductility, but also permit the comparison of these properties in terms of fundamental viscosity measurements at different temperatures.

5. CURRENT SPECIFICATIONS REQUIREMENTS

5.1 General Considerations

In brief ASTM D 312 and related specifications are purely empirical, since they include three empirical tests: (1) softening point, expressed in units of temperature (°C or °F); (2) penetration; and (3) ductility tests, expressed in units of length (either tenths of a millimeter (dmm) or centimeters (cm)). It is obvious that such diverse "consistency" measurements, expressed in units of length and temperature, cannot be interrelated to provide a sound and unified system describing and specifiying material properties.

Note that the measurement parameters of asphalt specified in ASTM D 312 are not uniform. For example, Type III asphalts include materials having softening points between 85°C and 96°C, a span of 11°C. For Type IV asphalts, the span is only 8°C (99°C to 107°C). The gaps between different grades also vary from 3°C to 5°C. These unexplained disparaties require correction.

5.2 Softening Point Test for Grading Roofing Asphalts

Softening point, the principal grading criterion of the ASTM D 312 specification, measures the temperature at which a small steel ball placed on top of a sample of the asphalt in a small ring, deflects and sags a distance of 25mm in a water or glycerin bath which is heated at controlled rate. If any of the test conditions, — the mass or volume of the steel ball, diameter or thicknesses of the asphalt sample, deflection distance, or the heating rate of the bath, — are changed, the results of this highly empirical test would also change. And, the magnitude of such changes would be different for asphalts of different consistency or origin.

The softening point of asphalts is often confused with the melting point of materials. There is no relationship between these two properties. Melting point is a fundamental property of crystalline, homogeneous materials, indicating the exact temperature at which the material changes from solid to liquid. Asphalts, on the other hand, are neither crystalline nor chemically homogeneous and they lack an exact melting point. The softening point of such materials indicates a consistency of material in arbitrary units at arbitrarily selected conditions. Because of such limitations, the utility and soundness of using softening point as a basis for grading materials is highly questionable.

Comparison of sofenting-point temperature with viscosity at that temperature shows another defect in current roofing asphalt specifications. In Figure 1, the scatter in the data points indicates that softening-point temperature does not correlate with the viscosity of roofing asphalts. For two asphalts of the same softening point, viscosities may vary as much as five-fold. Thus, the common assumption that softening-point grade represents materials of the same consistency or viscosity is erroneous.

Softening points and asphalt grading do not provide useful information concerning the consistency of roofing asphalts either at application or service temperatures, as illustrated in Figures 2 and 3. Figure 2 shows the relationship between softening point temperature and viscosity at 71.1°C (160°F), a temperature near the top roof surface temperature attained on a clear summer day. This figure indicates a rough correlation and a certain viscosity delineation between these two parameters for different softening point grades. However, for a given softening point grade asphalt, viscosities may vary many fold. For example, for Type III asphalts, viscosity at 71.1°C (160°F) may vary from 120,000 to 2,000,000 poise, a 17-fold variation. For Type I asphalts a similar variation is indicated. It is safe to assume that asphalts varying in viscosity to that extent will behave differently under actual service condtions. For example, Type III asphalts having the low viscosity of 120,000 poise will flow or slip more readily than asphalts of 2,000,000 poise. This type of necessary information is not provided either by sofenting point or other consistency requirements used in current specifications.

Figure 3 relates softening point with viscosity at 232.2°C (450°F), the typical application temperature for roofing asphalts. This graph indicates a wide band relation between these two properties. Viscosities at the application temperature for roofing asphalts vary from about 15 to 300 centistokes. Within a given grade, this variation is also very substantial. For exapmle, for Type III asphalt, viscosities at 232.2°C (450°F) vary from 30 to 200 centistokes (about seven-fold variation). For Type I material, such variation is almost four-fold.

The rate of asphalt application by a free-floating mop depends on asphalt viscosity. This is illustrated by Figure 4, which shows the relation between the viscosity of asphalt in centistokes and thickness of the applied film as well as the rate of asphalt application. To apply 20 lb/sq (approximately 1-mm thick), asphalt viscosity must be about 120 centistokes, regardless of asphalt grade. Obviously, to apply a selected rate of asphalt requires varied temperatures for different asphalts. (The temperature at which various asphalts have the same viscosity suitable for hot mopping is called Equiviscous Temperature, EVT.) Temperature below the asphalt's EVT produces an excessively thick mopping layer. Conversely, temperatures higher than the EVT will produce an excessively thin mopping layer, requiring a double mopping to obtain desired film thickness.

Unfortunately, information dealing with viscosity-temperature relationships during asphalt application and under service conditions is not provided in current specifications based on softening point. A specification grading based on viscosity at service temperatures, supplemented by a viscosity value at a higher (application) temperature, would provide valuable information. This, in turn, would produce a more durable, better performing built-up membrane.

5.3 **Penetration Requirements in Roofing Asphalt Specifications**

It is doubtful that the penetration requirements in roofing asphalt specifications provide useful information on the asphalt's response to temperature change or its general performance. For unexplained reasons, all roofing and waterproofing asphalts currently contain penetration requirements at 0°C (32°F), 25°C (77°F), and 46.1°C (115°F). These temperatures fail to cover anticipated service temperatures, either on the high or low side, and none has any special significance in assessing asphalt performance.

Penetration limits or ranges are similarly questionable, with many anomalies, non-uniformities, and irregular distributions. Why, for example, does ASTM D 312 require a minimum penetration of 3 for Type I asphalt vs. 6 for the three harder grades, Types II, III, and IV? Why is a penetration range specified for Type I asphalts at 46.1°C (115°F), but only maximum penetration for Types II, III, and IV?

If, as appears most probable, penetration requirements are designed to establish some measure of temperature susceptibility, why are penetration tests performed under arbitrarily selected test conditions? (At 0°C, the needle is loaded with 200 g for 60 sec; at 25°C, with 100 g for 5 sec; at 46.1°C, with 50 g for 5 sec). How can a generally applicable measure of the asphalt's response to temperature change be reliably correlated with such diverse loading conditions?

Other aspects of penetration testing exhibit flaws and raise questions. Penetration measurements are made with a blunt cylindrical needle having a 6.35-mm long tip shaped as a truncated cone. A great majority of penetration measurements lie within this cone section. Such rheologically unsound conditions cannot be expected to yield measurements accurately correlated with asphalt performance or roof membrane behavior at moderate or low temperatures.

There is poor correlation between viscosity at 71.1°C (160°F) and penetration at 25°C (77°F), as shown in Fig. 5. Asphalts with a penetration of 20-dmm vary in viscosity by a factor exceeding 1,000 (about 15,000 to 20,000,000 poises). Such a tremendous viscosity range embraces Type II, III, and IV asphalts, and some Type I asphalts. The response of a material to penetration by a loaded needle and to shearing forces applied during a capillary-flow viscosity test are quite different.

At all three temperatures of the penetration test, roofing asphalts exhibit a highly complex rheological flow behavior. Their viscosities are dependent on shearing rate, stress level, and loading time. To evaluate the influence of the above factors, a well defined and well controlled test is needed. The penetration test fails to satisfy this need.

5.4 **Ductility Requirements in Asphalt Specifications**

Like softening point and penetration, ductility requirements lack any evident correlation with asphalt service performance. The probable intent of the ductility requirements is to indicate the asphalt's capacity to accommodate thermally or mechanically induced movement. Ductility, a partial tensile test, measures the extension of a standard asphalt specimen subjected to a constant-rate pull in a constant temperature bath. Minimum ductility of 10 cm is required for Type I asphalt, ranging down to 1.5 cm for Type IV asphalt at 25°C (77°F). The flaws in ductility testing are two-fold:

- The low ductility values (3.0 to 1.5cm) required for Types II, III and IV asphalts do not truly differentiate these materials
- The 5 cm/min, specimen pull test rate is too fast to differentiate the various roofing asphalts

Slowing the pull rates to 1 cm/min or slower would make ductility testing more meaningful. But test data dealing with low pull rate tests, which would more accurately simulate service conditions, are currently unavailable.

6. **SUMMARY AND CONCLUSIONS**

There is doubtful utility in softening point, penetration and ductility, the three empirical tests currently used in ASTM specifications. These tests correlate poorly with the more fundamental viscosity measurements made over a range of temperatures.

Here are the major conclusions:

- A grading system based on the softening point of roofing and other industrial asphalts has severe limitations. Softening point grades do not represent groups of asphalts of similar viscosity.
- Softening point measurements do not correlate well with viscosity measurements at selected temperatures. Thus, the theory that softening point provides an indication of asphalt viscosity is erroneous and misleading.
- The significance and contribution of penetraiton and ductility requirements to grading based on softening point is obscure. The measurement and effective control of the functional material properties by specification requirements based on these tests is questionable.

- The analyses of available data suggest that viscosity-based specifications would be a rational and fruitful approach for grading roofing and other industrial asphalts.

7. RECOMMENDATIONS

The development of viscosity graded specifications for roofing and other industrial asphalts is recommended to replace current specifications based on softening point. All segments of industry should cooperate in this undertaking. The following items should be considered for inclusion in new specifications:

1. Four grades based on viscosity at a selected grading temperature should be established. A temperature at which asphalts behave as simple (Newtonian) liquids should be selected for grading. Temperatures such as 71.1°C (160°F) or 135°C (275°F) appear to be suitable. Viscosity ranges for different grades could be either intermittent or continuous. Intermittent viscosities would provide more distinct separation for different grades.

2. Minimum or maximum viscosity requirements at considerably higher than grading temperature should be included. Such additional viscosity requirements would provide information on a viscosity-temperature relationship useful to the control of asphalt properties during application.

3. A requirement of maximum viscosity at grading temperature after exposure to standard heating conditions, such as prescribed in ASTM D 1754, should be considered. Such a requirement would indicate the heat sensitivity of the material. In place of maximum viscosity after heating, a maximum ratio of viscosities after and before heating could be used.

4. A minimum flash point requirement for the purpose of maintaining safety during application of the material should be retained in the specifications.

5. A minimum solubility in trichloroethylene requirement in the specifications would ensure purity of the materials.

A proposed specification, incorporating the above suggested specification guidelines, is tabulated in Table 1, with listed requirements and their limits provided only for study and discussion.

REFERENCES

1. ***Annual Book of ASTM Standards, Part 15,*** American Society for Testing and Materials, Philadelphia, Pennsylvania 19103, 1981.

2. V. P. Puzinauskas, ***Properties of Roofing Asphalts,*** Research Report No. 82-1, The Asphalt Institute, College Park, MD 20740, 1982.

(Proposal for Study and Discussion Purposes Only)

TEST PROPERTY	VISCOSITY GRADE			
	RA-2T	RA-20T	RA-200T	RA-2000T
Viscosity, 160°F (71.1°C), kilopoises	2-12	20-120	200-1200	2000-12000
Viscosity, 275°F (135°C), stokes, maximum	20	80	520	1280
Viscosity Ratio at 160°F (71.1°C)[1], maximum	5	5	5	5
Flash Point (COC), °F, minimum	500	500	500	500
Solubility in TCE, percent, minimum	99	99	99	99

[1]The ratio obtained by dividing asphalt viscosities at 160°F (71.1°C) after the Thin Film Oven Test (ASTM D 1754) heating, by viscosities of original asphalt at the same temperature.

TABLE I
Specification Table for Roofing Asphalts.

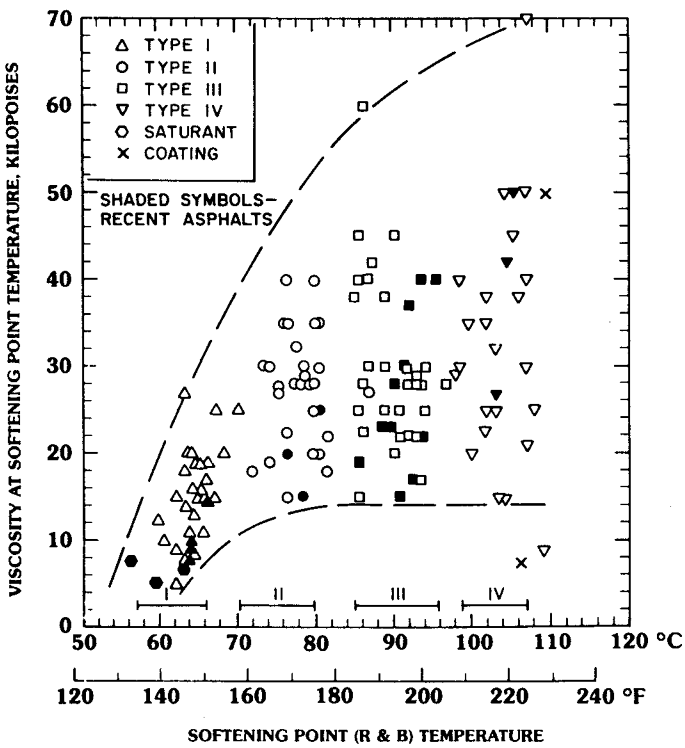

FIGURE 1
Correlation Between Viscosity and Softening Point of Roofing Asphalts.

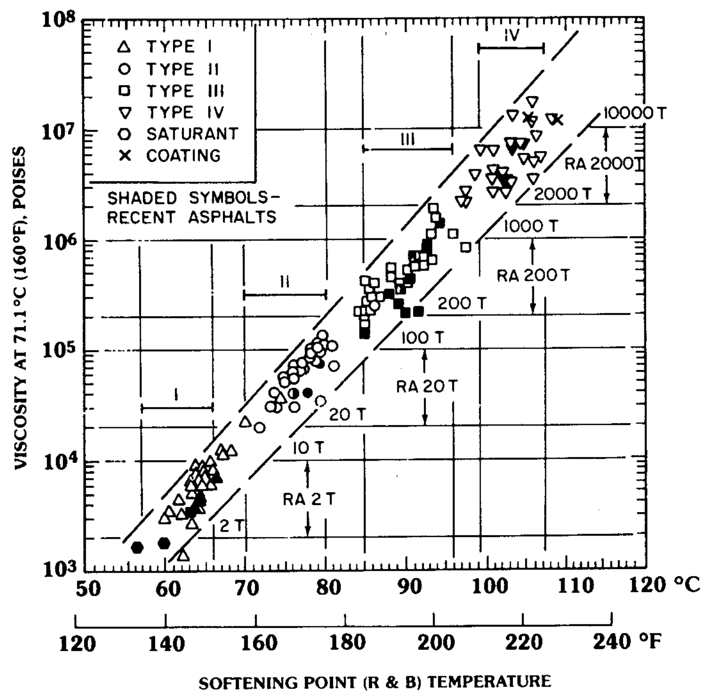

FIGURE 2
Relationship Between Viscosity at 71.1°C (160°F) and Softening Point of Roofing Asphalts.

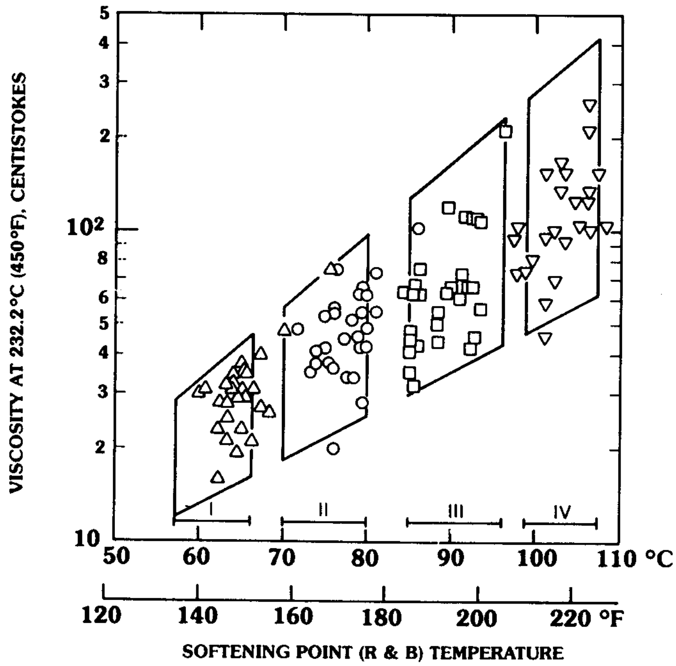

FIGURE 3
Viscosities of Roofing Asphalts at Softening Point Temperature.

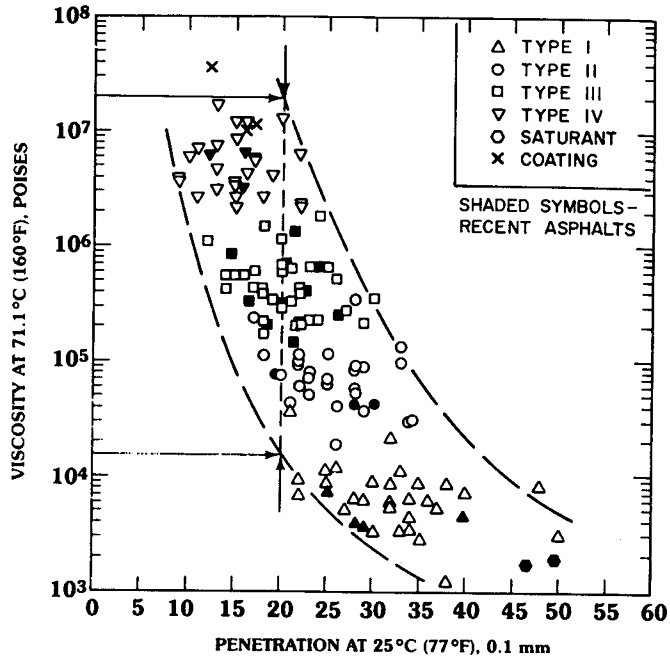

FIGURE 5
Relationship Between Viscosity and Penetration for Roofing Asphalts.

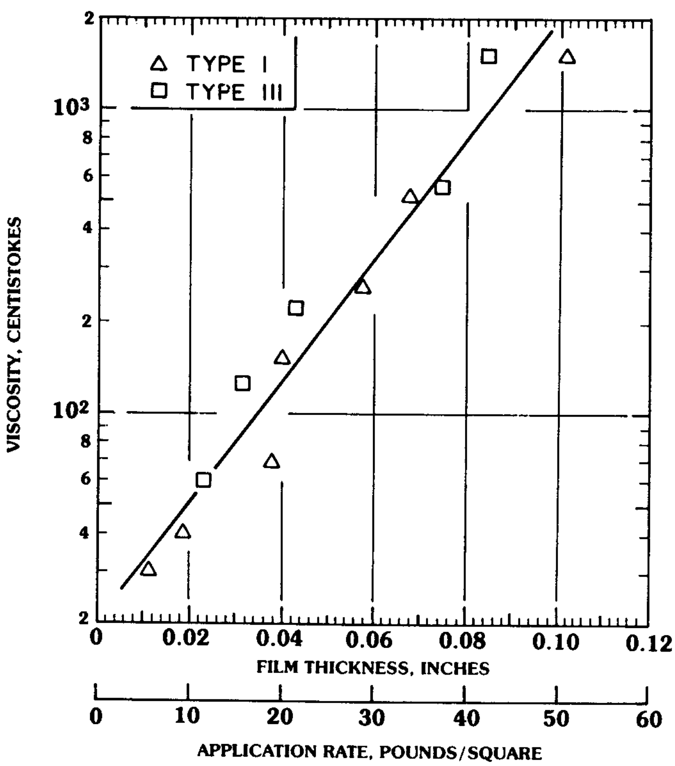

FIGURE 4
Effect of Mopping Viscosity on Application Rate of Roofing Asphalts.