GRADING ASPHALT CEMENTS BY PENETRATION OR VISCOSITY AT 77 F

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ABRIDGMENT

•THE author would like to make it clear at the beginning that he is not opposed to grading asphalt cements by viscosity. For reasons about to be presented, he is firmly opposed to viscosity grading at 140 F. He could fully support grading by viscosity at 77 F; however, until a rapid test for viscosity at 77 F has been developed and generally accepted, it seems doubtful that any organization would be willing to substitute viscosity at 77 F for penetration at 77 F for routine asphalt consistency control.

Any attempt to modify current specifications for asphalt cements should emphasize two major objectives:

1. It should facilitate high-temperature construction operations, and 275 F is a representative temperature for the high-temperature construction tasks of mixing, spreading, and breakdown rolling; and
2. It should improve long-term pavement performance, particularly under the low winter temperatures that occur in at least half of the United States and in all of Canada, and 77 F is a reasonably average pavement service temperature in much of North America.

This abridgment, which for brevity must omit many of the details in the paper itself, will show that neither of these two objectives is achieved by the AASHO specification based on grading asphalt by viscosity at 140 F. On the other hand, grading asphalt cements by penetration or viscosity at 77 F, plus a viscosity requirement at 275 F (Fig. 1), forms the basis for a simple but highly effective improved specification for asphalt cements, one that satisfied both of these objectives. First, however, because it is essential to the discussion that follows, some general information on asphalt cements will be presented.

BASIC CHARACTERISTICS OF ASPHALT CEMENTS

Temperature Susceptibility

Figure 2 shows that two asphalt cements with the same viscosity or penetration at 77 F can have widely different viscosities at all other temperatures. This occurs because of differences in their temperature susceptibilities, which is measured by penetration index (PI). All asphalt cements currently used in Canada lie within a PI of 0.0 and -1.5. In the United States, a PI range of +0.5 to -2.0 would include practically all paving asphalts.

Penetration Index

Figure 3 shows the relation between grading asphalt cements by penetration at 77 F and grading them by viscosity at 140 F. Line A in Figure 3 represents a PI of 0.0, whereas line B represents a PI of -1.5. If an asphalt cement of, for example, 200 penetration from a given crude oil has at 140 F a viscosity that places it on the upper boundary of line A, asphalt cements of other penetrations at 77 F made from the same

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Figure 1. Grading asphalt cements by penetration at 77 F.

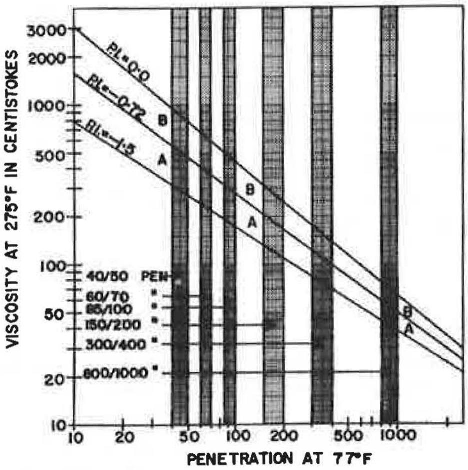


Figure 2. General relations among viscosity, temperature, and penetration indexes for asphalt cements.

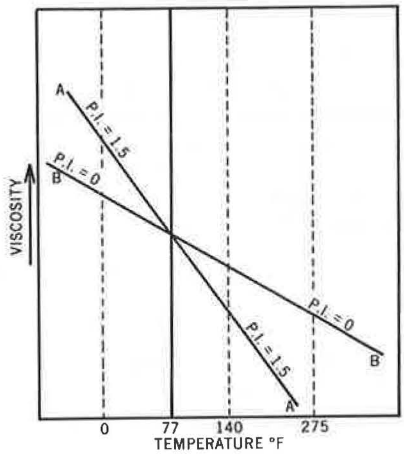
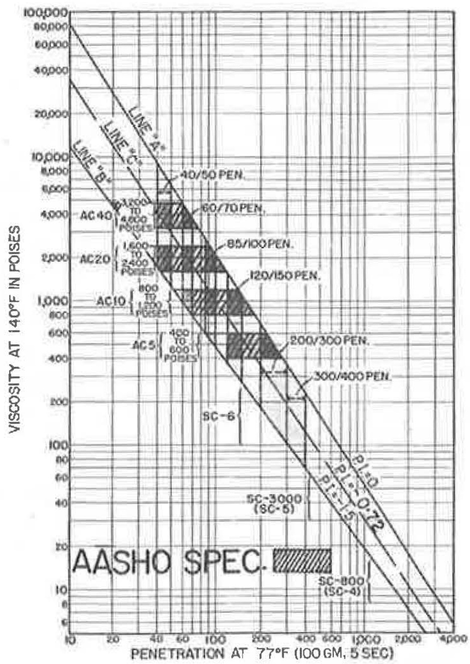


Figure 3. Correlation between viscosity at 140 F and penetration at 77 F.



crude oil will have at 140 F viscosities that also tend to lie on the upper boundary of line A. Similarly, all asphalt cements from another crude oil will have penetrations at 77 F and corresponding viscosities at 140 F, which will tend to place them along a line that is approximately parallel to the upper boundaries of lines A and C.

Influence of Temperature

Figure 4 shows that grading asphalt cements by penetration or viscosity at 77 F avoids the very wide range of viscosity at -10 F associated with grading by viscosity at 140 F, which is responsible for a corresponding wide range of low-temperature transverse cracking. It also avoids the very broad range in viscosity at 275 F, which would result from grading asphalt cements by penetration or viscosity at 32 F (which in turn would greatly increase high-temperature construction problems).

VISCOSITY GRADING AT 140 F

Low-Temperature Transverse Pavement Cracking

Figure 5 shows a typical example of low-temperature transverse pavement cracking, which occurs because asphalt pavements tend to contract in cold weather. This is currently a serious pavement performance problem in Canada, and it appears to be a severe problem in at least the colder half of the United States. Figure 6 shows that there are four basic types of transverse pavement cracks. In our experience the most significant crack is type 1, which extends across the entire width of a traffic lane.

Figure 3 shows that the AC10 grade, for example, includes all asphalt cements between 50 to 60 and 150 to 200 penetration. Figures 7, 8, and 9 show the very serious differences in transverse cracking in pavements made with 85- to 100- and 150- to 200-penetration asphalt on a 9-mile test road in southern Ontario. Figure 7 shows the very serious transverse cracking that occurred in the several miles of pavement made with 85- to 100-penetration asphalt. Figure 8 shows no transverse cracks of any kind in the several miles paved with 150- to 200-penetration asphalt. In Figure 9, the pavements made with 85- to 100- and 150- to 200-penetration asphalt were laid in adjacent lanes over a length of 1,700 ft. The transverse cracks in the 85- to 100-penetration pavement in the right lane cross the centerline about 6 in. and disappear in the 150- to 200-penetration pavement in the left lane in which no transverse cracks occurred.

Therefore, the wide range of penetration at 77 F associated with each viscosity grade AC5, AC10, AC20, and AC40 is a most damaging criticism of grading asphalt cements by viscosity at 140 F in any area where pavements are subjected to low winter temperatures. This situation is worsened by the fact that changing to a lower viscosity grade, for example from AC10 to AC5, would not necessarily reduce the number of transverse cracks. For example, an engineer in northern Minnesota, Wisconsin, or North Dakota could experience serious transverse cracking with an AC10 grade of 150 to 200 penetration and decide to change to the supposedly softer AC5 grade. However, he might obtain an AC5 of 120 to 150 penetration and would have much more severe transverse pavement cracking than before.

A major conclusion drawn from pavement cracking investigations conducted in Canada is that low-temperature transverse pavement cracking occurs when the asphalt cement (the pavement) has been chilled to a critical high viscosity value. Figure 10 shows that, for asphalt cements of the same PI from a given crude oil, transverse pavement cracking can be avoided at lower pavement temperatures by using softer asphalt cements at 77 F.

Figure 11 shows that, for two asphalt cements of the same consistency at 77 F but with different PI values, a pavement containing the asphalt cement with the higher PI can be chilled to the lower temperature without transverse cracking occurring. The figure also shows that, if an asphalt cement of a given penetration or viscosity at 77 F with a high PI just avoids transverse cracking when a pavement containing it is cooled to, for example, -20 F, under the same conditions a much softer (higher penetration or lower viscosity at 77 F) asphalt cement must be slected if its PI is low.

Figure 4. Influence of temperatures selected for grading asphalt cements on viscosity ranges at -10 F and at 275 F.

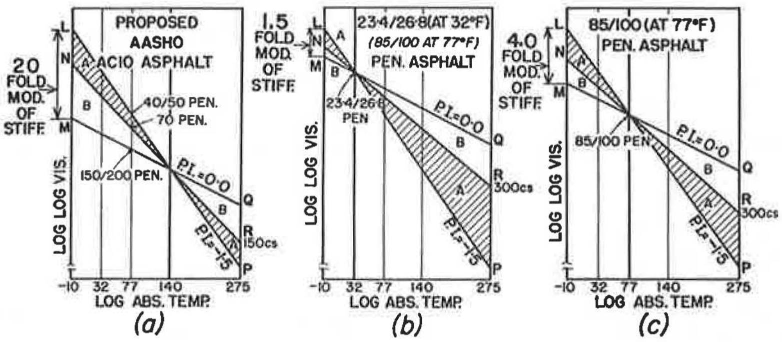


Figure 5. Typical low-temperature transverse pavement cracking (4-year old pavement made with 150- to 200-penetration asphalt).

Figure 6. Types of transverse pavement cracks.

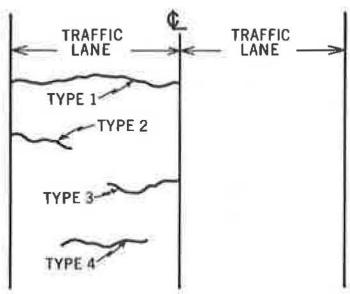


Figure 7. Transverse cracking (4-year old pavement made with 85- to 100-penetration asphalt).

Figure 8. Four-year old pavement made with 150- to 200-penetration asphalt.

Figure 9. Transverse cracking (85- to 100-penetration asphalt, right lane).

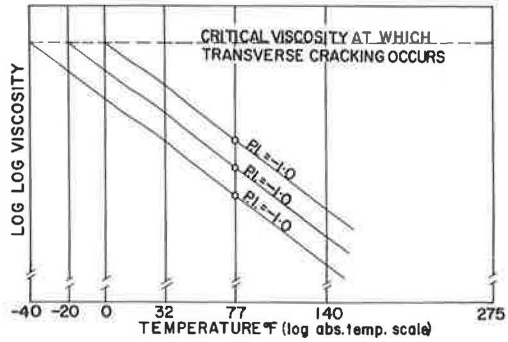


Figure 10. Relation among pavement temperature, softness of asphalt, and PI.

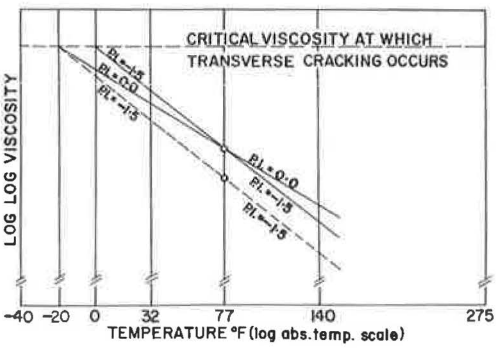


Figure 11. Relation between a low PI asphalt cement and a high PI asphalt cement at 77 F.

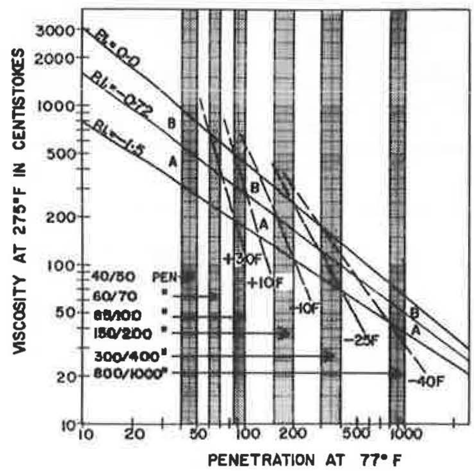


Figure 12. Guide for selecting grades of asphalt cement to avoid low-temperature transverse pavement cracking.

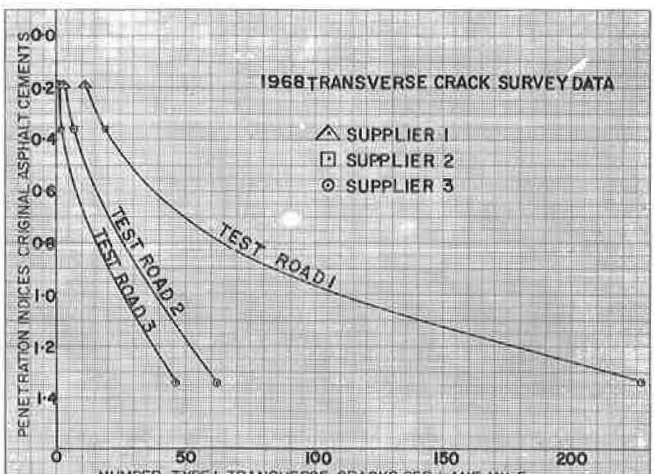


Figure 13. Relations between penetration indexes of original 85- to 100-penetration asphalt cements and number of type 1 transverse pavement cracks per lane mile after 8 years of service.

Avoidance of Low-Temperature Transverse Pavement Cracking

Based on information obtained in Canada, the author has developed Figure 12 as a guide to the selection of asphalt cements that will avoid low-temperature transverse pavement cracking throughout their service lives, provided they have been properly designed and constructed. An original asphalt cement should be selected that lies to the right of the diagonal line (Fig. 12) that represents the lowest temperature that is expected during the pavement's service life at a pavement depth of 2 in. If an engineer selects an asphalt cement that lies to the left of the oblique line (Fig. 12) that represents the critical minimum temperature, he is gambling with the probability that low-temperature transverse pavement cracking will occur sometime during the service life of the pavement.

Figure 12 shows that it is no longer acceptable to select the grade of asphalt cement for a paving job merely on the basis of its penetration at 77 F, as has been common engineering practice for at least the past 50 years. Figure 13, based on transverse crack surveys on three Ontario test roads, shows very clearly that this practice should not be continued. Figure 13, which indicates the results of a low-temperature transverse crack survey on asphalt pavements on three Ontario test roads after 8 years of service in a climate with moderate winter temperatures, shows that low-temperature transverse pavement cracking can be largely avoided when an 85- to 100-penetration asphalt with a PI of 0.0 is used. Severe transverse cracking may occur if an 85- to 100-penetration asphalt with a PI of -1.5 is employed. Consequently, if low-temperature transverse pavement cracking is to be avoided, engineers in colder climates should select the grade of asphalt cement on the basis of both its penetration at 77 F and its PI, as shown by the oblique temperature-labeled lines in Figure 12.

Grading Asphalt Cements by Viscosity at 140 F

Figure 14 shows the result obtained when the AC5, AC10, AC20, and AC40 viscosity grades shown in Figure 3 are plotted on Figure 12. Figure 14 shows very clearly that grading asphalt cements by viscosity at 140 F results in a fundamental fallacy insofar as low-temperature pavement performance is concerned.

Figure 12 shows that, if transverse pavement cracking is to be avoided, as the PI's of the asphalt cements become lower, the penetration at 77 F to be selected must become higher. On the other hand, when asphalt cements are graded by viscosity at 140 F, for any given viscosity grade, something else occurs. Figure 14 shows that, with respect to low-temperature transverse pavement cracking, as the PI's of the AC10 asphalts become lower, the penetration at 77 F to be selected must also become lower. This is contrary, as indicated by the oblique temperature-labeled lines in Figure 12, to what all practical field experience and theoretical considerations concerning the low-temperature transverse pavement cracking problem have taught us to date.

Consequently, any organization that adopts grading by viscosity at 140 F is including in its specification for asphalt cements the basic fallacy that is so clearly shown in Figure 14. Furthermore, Figure 14 shows that the only way in which grading asphalts by viscosity at 140 F can eliminate low-temperature transverse pavement cracking is by restricting asphalt cement production to crude oils that provide asphalt cements with high PI's. For example, if the critical minimum pavement temperature is -10 F, Figure 14 shows that only the portion of the AC5 grade with a PI above about -0.7 and the portion of the AC10 grade with a PI higher than about -0.3 lie to the left of the oblique line representing the critical minimum temperature. Consequently, grading by viscosity at 140 F carries a very heavy penalty in the form of the limited number of crude oils from which asphalt cements capable of avoiding low-temperature transverse pavement cracking can be made. Figure 15 shows that the viscosity graded specifications of Saskatchewan and Alberta are such that they are not subject to the low-temperature transverse pavement cracking that results from the use of asphalt cements of the same viscosity range at 140 F but with low penetrations at 77 F. Asphalt specifications like those of Alberta and Saskatchewan (Fig. 15) place very severe restrictions on the number of crude oils from which asphalt cements can be made.

Figure 14. Grading asphalt cements by viscosity at 140 F.

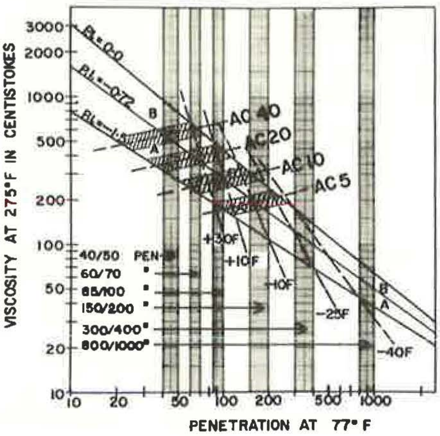


Figure 15. Correlation between viscosity at 140 F and penetration at 77 F.

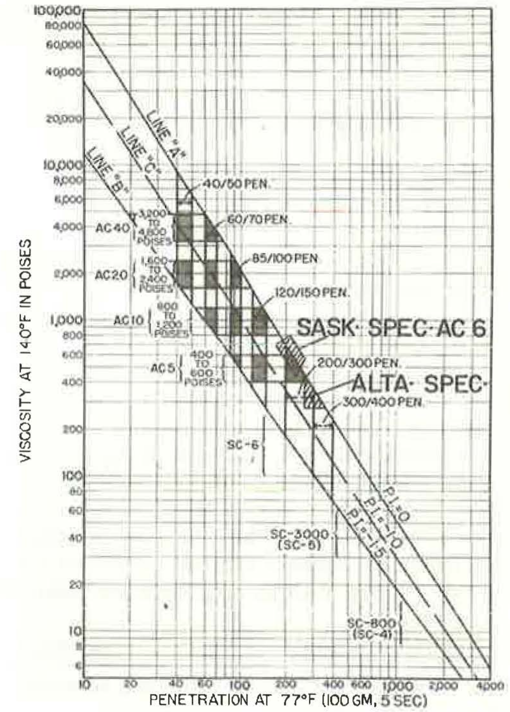
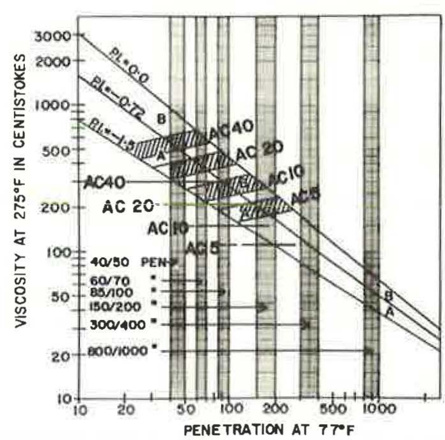


Figure 16. Comparison of actual viscosities at 275 F and AASHO requirements.



On the other hand, Figures 12 and 14 show that, when asphalt cements are graded by penetration (or viscosity) at 77 F plus a viscosity requirement at 275 F, it is a very simple matter to select an asphalt cement with the combination of PI and penetration at 77 F, which will lie to the left of the oblique line representing the critical minimum pavement service temperature. Furthermore, this selection can be made without any restriction on the crude oils from which asphalt cements are produced.

AASHO SPECIFICATION BASED ON GRADING BY VISCOSITY AT 140 F

One of the principal reasons for promoting grading of asphalt cements by viscosity at 140 F is the construction problems caused by the wide range of high-temperature viscosity associated with each penetration grade (Figs. 1 and 3). Because 275 F is a representative temperature for the high-temperature construction operations of mixing, spreading, and breakdown rolling, it might have been expected that the AASHO specification based on viscosity grading at 140 F would include very rigid requirements for viscosity at 275 F.

Figure 16 shows quite clearly that the minimum viscosity requirements at 275 F stipulated in the AASHO specification for grading by viscosity at 140 F are much too deficient to necessarily facilitate high-temperature construction operations. Figure 16 shows that the minimum viscosity requirements at 275 F, represented by the horizontal lines, are far below the viscosities at 275 F, which are normally associated with the viscosity grades, AC5, AC10, AC20, and AC40. Furthermore, the minimum viscosity requirements are horizontal lines, whereas the viscosity grades themselves have a positive slope that places the low PI end of each viscosity grade much closer to its respective minimum viscosity limit at 275 F than the high PI end. In contrast, Figure 16 shows that the normal shape of the viscosity curve at 275 F for asphalt cements of any given PI is a straight line of negative slope.

It is apparent from Figure 16 that grading asphalt cements by penetration or viscosity at 77 F plus a viscosity requirement at 275 F would greatly improve construction operations at high temperature by dividing the viscosity range at 275 F (currently permitted for each penetration grade) into approximately two halves, categories A and B. Furthermore, for each penetration grade, a viscosity requirement at 275 F, which is normal for each grade, could be specified.

COMMENTS

By one method of analysis, asphalt cements consist of asphaltenes, asphalt resins, and oily constituents. The harder grades of asphalt are made by removing some of oily constituents present in the softer grades, usually by vacuum distillation. The oily constituent part of asphalts is highly desirable as cat-cracker feed stock at refineries, where it is converted into gasoline and other light distillates. Currently, the oily constituents are more valuable as cat-cracker feed stock than when sold in the form of asphalt. Apart from the increased hardness that results, there is no reduction or deterioration in asphalt quality by the removal of oily constituents.

In view of this, the AASHO viscosity graded specifications for AC5, AC10, etc., with their wide range of penetration at 77 F, are an invitation to petroleum refiners to produce the hardest grade permitted by the specification. The damaging effect this can have on low-temperature pavement performance has been emphasized earlier.

When we grade asphalt cements by viscosity at 140 F, we are implying for the AC10 grade, for example, that pavement performance will be the same whether it contains asphalt cement of 50 to 60 or 150 to 200 penetration. Can the petroleum refiner be blamed for assuming we know what we are doing?

On the other hand, when asphalt cements are graded by penetration or viscosity at 77 F, a petroleum refiner is restricted with regard to the amount of oily constituents that he can remove because he must provide the penetration grade that has been specified (Fig. 1).

If grading by viscosity at 140 F were adopted, there would be a complete break with all the pavement experience we have slowly and painfully accumulated over the past 50 years because all current hot-mix pavement experience with design, construction, and service performance is related to the penetration test at 77 F on asphalt cements.

Grading asphalt cements by viscosity at 140 F will promote a proliferation of specifications for asphalt cements in an attempt to avoid the variable pavement performance (Figs. 7, 8, and 9) that will inevitably result from the very wide range of penetration at 77 F, which is associated with each viscosity grade (Fig. 3). It is significant that, of the seven specifications based on viscosity grading at 140 F, which have been adopted by AASHO and various highway departments in the United States and Canada, no two of these specifications are alike.

Regional specifications for asphalt cements should not be considered whenever national specifications are possible. Regional specifications for asphalt cements, like regional languages, increase the difficulty of communication when engineers from different parts of the country try to compare their experience, and in extreme cases they make any significant comparison impossible.

It is suggested that grading by penetration or viscosity at 77 F, preferably with a viscosity requirement at 275 F (Fig. 1), could serve very adequately as a national or international specification for asphalt cements.

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