Effects of Asphalt Cement Viscosity at Mixing Temperature on Properties of Bituminous Mixtures

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ASPHALT is a versatile family of materials, not a single product. Included in the group are asphalt cement, rapid and medium curing cutback, emulsified asphalt, and slow curing liquid asphalt—each type available in several grades. These many types and grades of asphalt are used for a wide variety of construction applications. One common feature in all of these applications, however, is that the product must be brought to proper fluidity for the particular application under consideration.

Asphalt is a thermoplastic material which is made fluid by heating. It may also be made fluid by emulsification with water or by blending with petroleum solvents. In many applications, proper fluidity is achieved by a combination of these processes. Regardless of how this fluidity is achieved, however, it is a well established fact that proper fluidity is essential for the successful use of all of these materials.

Fluidity is a factor that is well understood by the physicist and the hydraulic engineer, although they normally think of this factor in terms of viscosity, the inverse of fluidity. Viscosity is a fundamental property of all liquids and may be measured in absolute units (poises) or in kinematic units (stokes). However, in the field of asphalt technology it is common practice to measure viscosity by the Saybolt Furol viscosity test. In this test, the time in seconds required for 60 ml of asphalt at a given temperature to flow through a Furol orifice of given dimensions is determined. Viscosity at this temperature is then expressed in terms of seconds, Saybolt Furol. Capillary-tube viscometers are now coming into wider use in asphalt refineries, as they offer certain advantages over the Saybolt Furol method. Regardless of how the viscosity may be measured, the fact remains that it is a fundamental property of asphalt in a fluid state. A better understanding of this fundamental property, and its appropriate use by asphalt paving engineers, will undoubtedly lead to better and more uniform asphalt pavement construction.

One popular misconception about asphalts is that the viscosity characteristics of a given type and grade are constant, regardless of the source of the asphalt. Evidence of this misconception may be found in many specifications, which require, for example, that all mixes prepared with an 85-100 penetration grade of asphalt cement be mixed within a certain temperature range. This may result in improper mixing, non-uniform mixtures, and faulty construction.

To illustrate this point, data have been taken from a report by a reputable agency operating in a specific locality of the United States. These data were not specially selected for purposes of this discussion, but represent all of the data contained in this report for 85-100 penetration grades that had been used by the agency. Temperature-viscosity data for these 85-100 penetration grade asphalts are shown in Figure 1. As will be noted, 77 F the penetration of asphalt A is 86, of asphalt B is 95, and of asphalt C is 93.

Let it be assumed that an agency requires mixes with an 85-100 penetration asphalt to be prepared within the range of 275 to 325 F. With such a specification, it is common practice to use the middle of the range, which in this case is 300 F. Figure 1 indicates that at 300 F asphalt A would have a viscosity, in terms of seconds, Saybolt Furol, of 150, the viscosity of asphalt B would be 107, and of asphalt C would be 57. Thus, the viscosity at 300 F of asphalt C would be less than one-half that of asphalt A.

Looking at these data from another viewpoint, assume for a moment that the ideal degree of fluidity for preparing an asphalt paving mix with an aggregate of given type and gradation is 100 seconds, Saybolt Furol. It may be seen that such a mix should be prepared with asphalt A at a temperature of 315 F, asphalt B at 302 F, and asphalt C at 280 F. The difference in temperature for equal viscosity of asphalts A and C is

VISCOSITY VS. TEMPERATURE FOR ASPHALTS

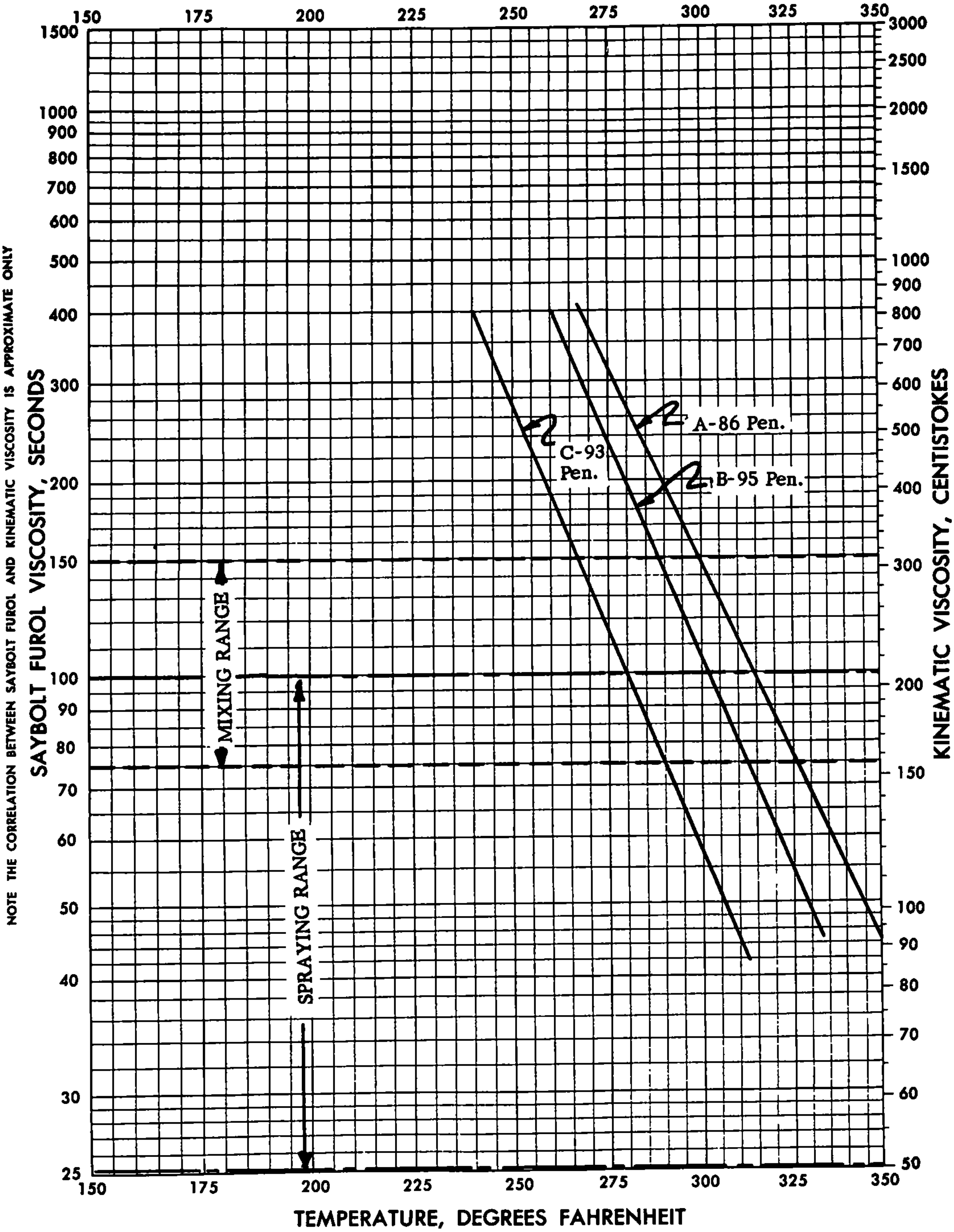

Figure 1

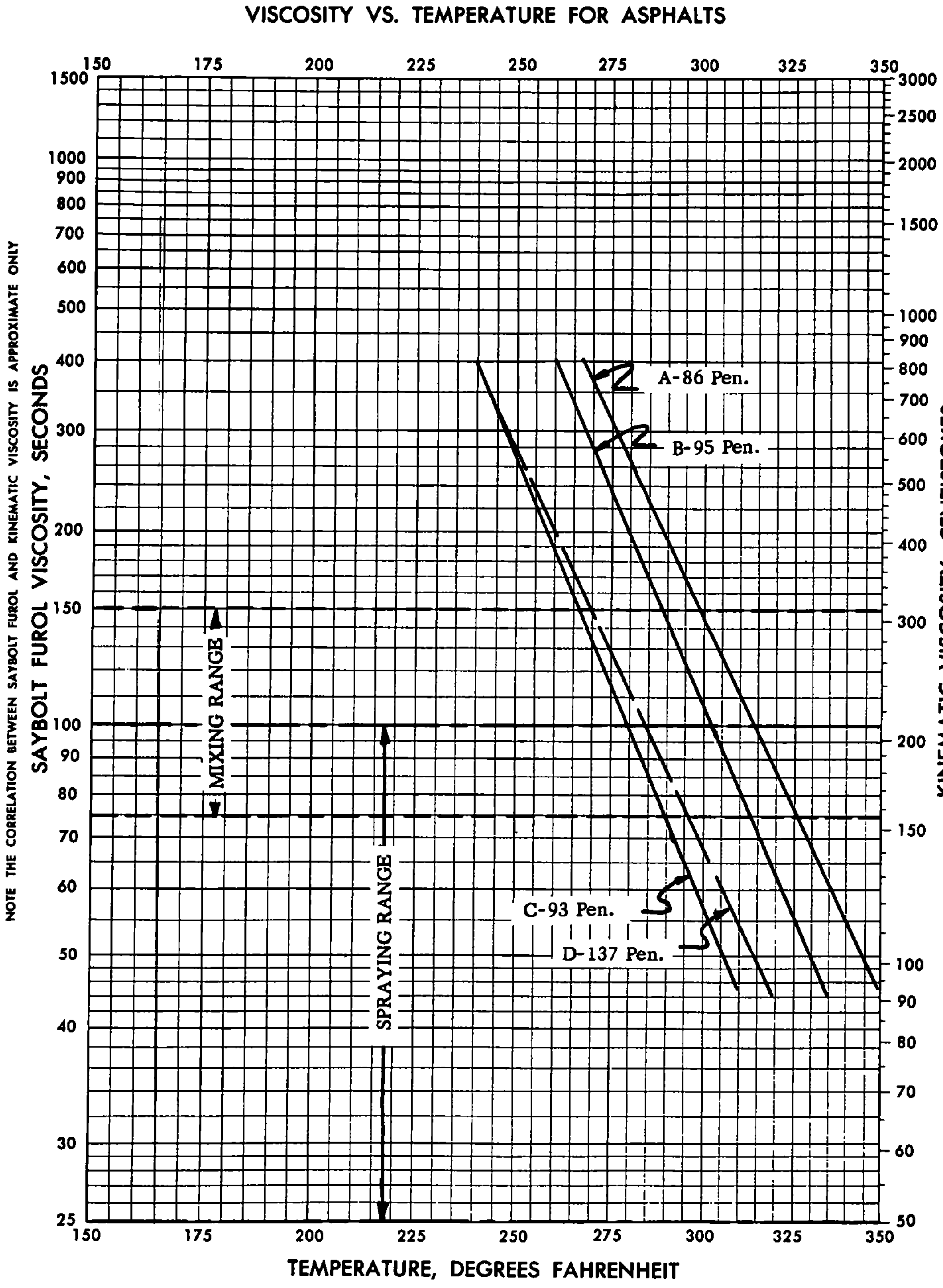
VISCOSITY VS. TEMPERATURE FOR ASPHALTS
NOTE THE CORRELATION BETWEEN SAYBOLT FUROL AND KINEMATIC VISCOSITY IS APPROXIMATE ONLY
SAYBOLT FUROL VISCOSITY, SECONDS
KINEMATIC VISCOSITY, CENTISTOKES
TEMPERATURE, DEGREES FAHRENHEIT
150
175
200
225
250
275
300
325
350
1500
1000
900
800
700
600
500
400
300
200
150
100
90
80
70
60
50
40
30
25
3000
2500
2000
1500
1000
900
800
700
600
500
400
300
200
150
100
90
80
70
60
50
MIXING RANGE
SPRAYING RANGE
A-86 Pen.
B-95 Pen.
C-93 Pen.
D-137 Pen.

Figure 2.

35 F, which is indeed a substantial temperature difference.

Figure 2 illustrates one further point relating to this discussion. The three solid lines are the same data as shown on Figure 1. But, in addition, the dashed line represents temperature-viscosity data for an asphalt of 137 penetration. The temperature-viscosity characteristics of this 137 penetration asphalt are almost identical with those of asphalt C which has a penetration of 93. This difference in penetration is 44 points and, in terms of penetration measurements, is significant.

The purpose of the discussion so far has been to bring out the substantial differences in temperature-viscosity characteristics of asphalts which may be encountered. These differences are to be expected as asphalts today are refined from a wide variety of crude petroleum sources. However, these differences should not be disturbing to the informed paving engineer who recognizes them and adjusts his construction procedures accordingly.

It seems obvious that an understanding of these temperature-viscosity variations and proper utilization of this knowledge cannot help but result in more uniform and better asphalt construction. Using extreme examples for purposes of illustration, one certainly would not attempt to mix an 85-100 penetration grade of asphalt cement with an aggregate when both were at ambient temperatures. Thorough and uniform coating of the aggregate particles could not possibly be achieved under such conditions and, even if this were achieved, the mix could not be properly compacted as a pavement. At the other extreme, too high a degree of fluidity might well result in some of the asphalt draining off of the surface of the aggregate in transit, collecting in pools and causing fat and lean spots in the pavement. In addition, the excessive heat required to achieve this fluidity would be unduly harmful to the asphalt deposited in relatively thin films on the aggregate particles.

It is only logical, therefore, that for a given type and gradation of aggregate there is a corresponding "optimum" viscosity for mixing. This optimum viscosity is one at which all aggregate particles may be readily and uniformly coated with asphalt in a relatively short period of time, at which the asphalt is sufficiently viscous to remain in place on the aggregate particles and at a temperature which will have a minimum hardening effect on the asphalt cement. This viscosity may vary to some extent with variations in type and gradation of aggregate. The Asphalt Institute presently recommends that a mixing temperature be selected which will result in an asphalt viscosity of 75-100 seconds, Saybolt Furol. Later, as additional experience is gained with the viscosity approach, there may be a need for some adjustment of these limits. But, it is believed that they are sufficiently accurate to result in substantial improvements in asphalt pavement construction if used in place of current practice wherein a temperature range is specified without regard to the viscosity characteristics of the asphalt in this temperature range.

Likewise, there is no doubt that better spraying applications could be achieved by giving proper consideration to the temperature-viscosity characteristics of the particular type and grade of asphalt being used. For spraying, The Asphalt Institute recommends a viscosity of 25-100 seconds, Saybolt Furol.

In conclusion, it is emphasized that viscosity is a fundamental property of asphaltic materials which should be given thorough consideration in all of its construction applications. A proper understanding of this fundamental property, knowledge of how it varies with different asphalts, and appropriate use of this knowledge will unquestionably lead to more uniform and higher quality asphalt construction.

Discussion

Charles R. Foster, U.S. Army Corps of Engineers, Vicksburg, Mississippi. — I would like to ask him to emphasize the desirability of not getting the asphalt hot. I do not think there is any minimum point—any heating damages the asphalt, and the heat damage must be kept as low as possible.

From experiences with tar mixes, we have mixed at viscosities almost off your chart. I think your 150 is much too low a limit. We have not tried any asphalt at that, but I think you should try asphalt at a lower temperature. We can run the aggregate at 225 and not damage the asphalt.

Mr. Griffith. — It was my intent to point out that the control of mixing temperature on a viscosity basis will result in better and more uniform asphalt mixtures than the use of temperature control alone, as now commonly practiced.

The recommended viscosity range of 75-150 seconds was proposed some 10 or 15 years ago, and there still seems to be a general agreement that this is an appropriate viscosity range for mixing.

I would not disagree with the point raised by Mr. Foster as to the desirability of mixing at the lowest possible temperature; provided that aggregate drying efficiency and mixing efficiency are not impaired. Whether the 150 second viscosity limit can be exceeded to any appreciable extent without adversely affecting these factors is a matter which needs further study.

Perhaps some adjustments in the recommended viscosity limits may be justified on the basis of further studies and experience with this approach. If so, these adjustments should be made. Until further evidence is available, however, we believe that the 75-150 second range is appropriate and are convinced that the control of mixing temperatures on a viscosity basis will result in better and more uniform asphalt mixes.

W. Miles Warden, Miller-Warden Associates. — I agree with the others that 150 limit is questionable.

In a recent discussion with Harry Nevitt, he said he knew someone would ask why he picked the 75 to 150 range in 1943. Since then, they have mixed at a viscosity of 300 with no trouble at all, and as high as 1,000 with little difficulty in compaction, depending on the mix.

I think a great deal of this depends on the mix design, the amount of filler, the temperature, and the compaction range. The small range of 75 to 150 imposes an undue hardship on the contractor. That gives him the extreme range, ± 10 F on your chart.

We feel that he can more safely stay below the dangerous upper limit of 75 seconds by lowering the limit of 150 seconds very safely, and in a very practical manner.

Mr. Griffith. — I would agree that the proper mixing viscosity depends to some extent upon the characteristics of the aggregates in the mixture. In plant-mix macadam, for example, thick films of asphalt are desirable and higher viscosities may be needed to achieve this result. Generally speaking, however, most asphalt paving mixes are of the dense-graded type where relatively thin films of asphalt are required. For such mixes, perhaps it can be established that the 150-second limit may be increased. This remains to be determined on the basis of further experience with this approach.

The 75-150 second mixing viscosity range is not necessarily a final and unalterable recommendation on our part. We will maintain an open mind on this question and make such adjustments as may be properly established.

As to the recommended temperature tolerance of ± 10 F, it is my belief that this requirement is not unduly restrictive. Perhaps a little more rigid control of mixing temperature will do much to alleviate some problems presently encountered in asphalt construction.

C.W. Chaffin, Texas Highway Department. — There are no data on actual measurements of drops in penetration. Have you considered that overheating 15 or 20 degrees may injure some asphalts more than it will others, even though they are at the same viscosity and that you might approach this from a standpoint of drop in penetration?

Mr. Griffith. — No. The approach is primarily from the standpoint of mixing efficiency. The lower limit of viscosity should be such as to minimize hardening of the asphalt from overheating. If it is established that 75 seconds viscosity is too low and that it can be raised without impairing mixing efficiency, this should be done.

Such adjustments should be made on the basis of further study and experience with the viscosity approach. Out principal interest at this time is to encourage the viscosity approach for the control of mixing temperatures. It is felt that this approach, with properly established limits on viscosity, will help eliminate undue hardening of asphalts during mixing.

The recommended range of 75-150 seconds is a starting point. This range has been discussed for many years and there seems to be a general agreement that it is of the proper order of magnitude.

When initiating new recommendations of this nature, one does not expect unanimous agreement on all of the details. But, if the highway departments will adopt the viscosity approach and actually use it as a measure of field control, I feel sure that we will be able to verify or modify the recommended range of 75-150 seconds, as required, to minimize hardening of the asphalt and, at the same time, insure proper mixing.

Felix C. Gzemski, Atlantic Refining Company, Philadelphia, Pa. — As far as the BPR test is carried arbitrarily at 325, it unduly punishes one asphalt as compared to another. In other words, if the BPR test were carried out at viscosity temperatures rather than a 325 temperature, you would have a definite relationship and a penetration loss. Asphalt will be at a much lower viscosity, and will harden slower at 325. So there is a correlation between penetration loss and even temperature.