The Effects of Air and Base Temperature on Compaction

VERDI ADAMS, Bituminous Research Engineer, Louisiana Department of Highways

● DURING THE past few years the extent of cold weather construction of hot mix asphaltic concrete pavement has shown considerable increase in Louisiana. Hot mix operations in the past were limited only by air temperature. This was not quite adequate. Excessive rutting resulted from low densities. In order to achieve proper compaction, in cold weather, it was considered necessary to investigate the effects of base temperature and correlate it with air temperature.

This investigation was carried out during January 1958 in central Louisiana on US 84. A surface course mix with ¾-in. maximum size aggregate was used and laid in two 2-in. layers on an old concrete roadway. Compaction was accomplished with a 10-ton 3-wheel roller; followed by a 10-ton tandem roller and the number of passes were closely controlled throughout the operation. Spreading and rolling temperatures were measured by means of thermocouples and a potentiometer. Base temperatures were taken with surface thermometers. These thermometers are 2 in. in diameter and can be carried in the pocket. A light application of silicon grease is used to insure a good contact with the surface. A complete set of data was thus obtained every 600 ft.

The completed test results, accumulated over a period of one year, show a definite relationship between air-base temperature and percentage of compaction. The roadway density is not affected by incremental increases in base temperature from 43 to 65 F for which the corresponding air temperatures are 41 and 50 F, respectively.

At a base temperature of 65 F the roadway density starts improving with temperature and reaches a maximum value of 95.2 percent at 80 F. Thus there is an increase of 3.0 percent by difference in the roadway density for this 15 deg interval. Additional increases in base temperature would have had no appreciable effect on density.

The critical point of the mixture under study is 77 F base temperature with a corresponding air temperature of 55 F. This preliminary inference was confirmed when a complete study of the pavement was made six months after completion. A second curve, representing the result of that survey for the density-temperature relationship follows the same pattern as the original. Comparison of the curves shows that after 6 months of use the base with temperature up to 75 F showed an increase of 2.8 percent in the roadway density. At 80 F the densification under traffic is only 1.1 percent. In other words, six months of traffic use had only one-third as much effect on the density of the sections compacted at 80 F base temperature as on those compacted at lower temperatures.

The shape of the curve represents Marshall stability-temperature relationship at the end of the 6-month period. The shape of this curve follows the same pattern as the density-temperature curve, proving that higher density, and thus higher stability, is obtained at base temperatures above 75 F. Of course, these results represent only one type of mixture and may not be indicative for others; it is, however, reasonable to expect the same general pattern with hot mixes of this type.

Whenever pneumatic rollers are used it is possible to use lower base temperatures. Plans have been made to investigate this aspect.

In addition to the density tests the rutting was measured every 6 months. Measurements were made for each section every 20 ft in both tire tracks. The rutting after 12 months is twice as much at a base temperature of 45 F as at 80 F. Furthermore, the differential rutting from 6 months to 12 months is appreciably higher at low temperatures than at higher temperatures.

During this entire study the base temperatures were always higher than air temperatures.

To establish an approximate relationship between the air and base temperatures under different weather conditions, an additional study was conducted. This study indicated that: (a) the air temperature never exceeds the base temperature although in cold and cloudy weather the base temperature is only slightly higher than air temperature; (b) base temperature of asphaltic concrete pavement is always higher than portland cement concrete pavement; and (c) on bright and sunny days the surface temperature of portland cement concrete pavement is normally 15 to 20 deg higher than the air temperature, and asphaltic concrete is 25 to 30 deg higher.

Although this study is by no means complete, the results obtained so far have been consistent. The recommended temperature of 75 F may seem a bit high, but the air temperature necessary to allow this critical base temperature is only in the middle 50's, as pointed out earlier, and that is not a rare recording in winter months in Louisiana.

Three more studies of this nature have been planned for 1959 in an attempt to study the feasibility of reducing base temperature requirements when pneumatic rollers are used in addition to steel-wheel rollers.

Discussion

Mr. Halstead.—The familiar suggestion has been made that mixing be done at a temperature at which there is a certain viscosity.

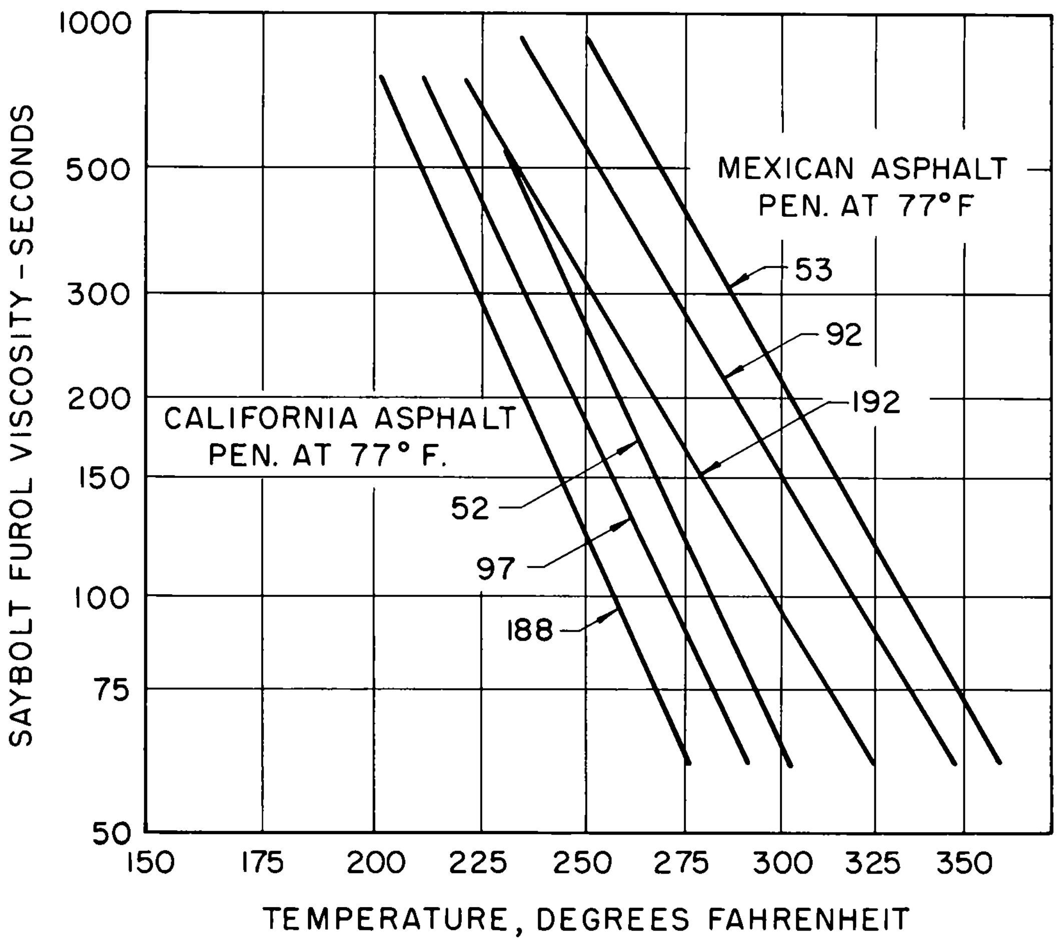

Figure 1.

So far not much has been said as to what this temperature is and how it is to be determined. One way, and perhaps the most accurate way of determining the temperature is to construct a chart showing the viscosity at various temperatures and determine from this, the temperature at the desired viscosity. Figure 1 illustrates some of the extremes that can occur in high temperature viscosities for the various grades of asphalts. Figure 2 is a chart for determining the proper mixing temperature for an asphalt from the Furol viscosity of the asphalt at 275 F.

Figure 1 is along the same lines as one of Mr. Griffith's, except that here is a

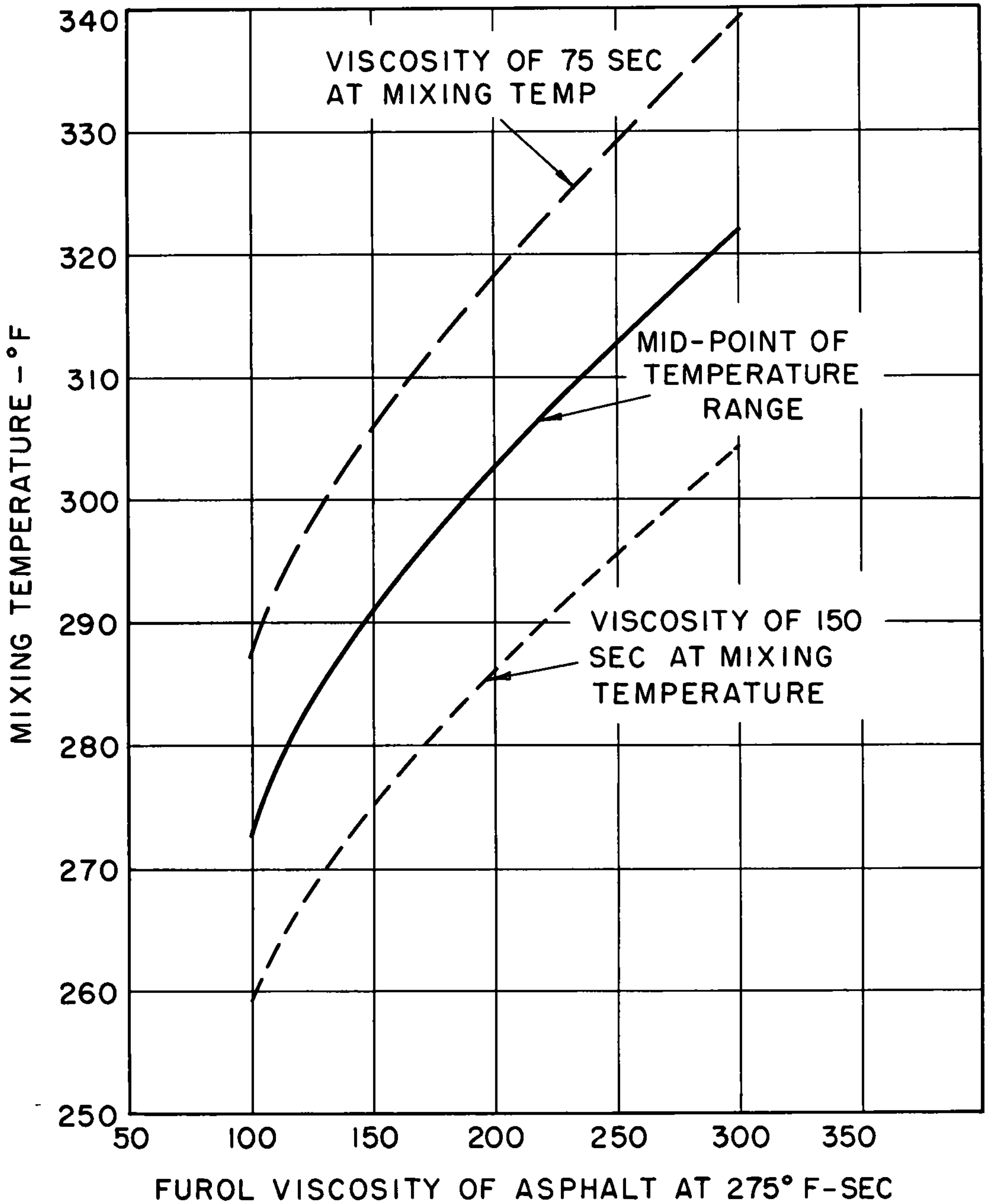

Figure 2.

selected group of asphalts whose viscosities are very susceptible to temperature change, and one group that has relatively low viscosity-temperature susceptibilities.

These two asphaltic types represent the extremes in commercial asphalts that are of good grade and meet all the standard specifications.

There are three grades for each type: 52 penetration, 97 penetration, and 188 for the California asphalt and 53, 92 and 192 penetration for the Mexican asphalt.

At 275 F, all of the grades of the Mexican asphalt have considerably higher viscosities than the corresponding California asphalt, but it is somewhat surprising to see that the hardest grade of California asphalt has a lower viscosity than the softest grade of the Mexican asphalt.

Considering only the curve for the 97 penetration California material and the curve for the 92 penetration Mexican material, the difference for the viscosity at 275 F represents the extreme difference for 85-100 penetration grade asphalts. By selecting samples having viscosities at 275 F intermediate between these two values, a family of curves can be constructed between these two extremes. Such data can then be used to construct a generalized curve that will come close to fitting all of the asphalts of the same grade.

Figure 2 was constructed from the generalized family of curves just described. The solid line, is the mid-point of the temperature range between that for a viscosity of 75 seconds and that for 150 seconds. This line thus represents the most desirable mixing temperature from the standpoint of viscosity for all asphalts of the 85-100 grade depending on its viscosity at 275 F. The data are cut off at the lower limit of 100 seconds and the upper limit of 300 seconds because it has been shown that most of the materials in the United States fall within this range.

The range in temperature between a viscosity of 75 and 150 seconds may be of interest to the practical minded man. It varies from about 30 F at the lower end to 35 F at the upper end.

Although the solid line shown here is the mid-point of the temperature range, it is very close to the curve that would be drawn for a viscosity of 100 seconds at the mixing temperature.

From a practical standpoint this chart makes it possible to choose the proper mixing temperature for the asphalt without having complete viscosity-temperature data. It is necessary to know only the Furol viscosity of the material at 275 F. If there are considerations that make it desirable to raise or lower the mixing temperature, the chart also indicates what the upper and lower limits of temperature can be and still remain within the range of 75 to 150 seconds.

It has been suggested that the upper limit of mixing viscosity be extended to 300 seconds. If that were done, the 150-second line (Fig. 2) would be very close to the mid-point of the temperature range. The over-all working range would then be approximately twice the range between the 75- and 150-second lines.

This chart was constructed from interpolated data. However, some checks were made against actual viscosity data and very good agreement was found. In some cases it is within 1 or 2 deg. The maximum difference noted was 9 deg low.

Mr. Griffith.—I think one thing brought out by your two families of curves is that you could run one viscosity value on the sample.

Mr. Collier.—As a practical matter, if you get out on a job and try to control viscosity to within 5 deg you are going to find a lot of opposition from the contractor, or a lot of rejected loads.

If we find we can control within plus or minus 10 deg that is considered good.

Only six sources of asphalt are used in my state, but by using the same process the same viscosity relationship results. Therefore we require knowledge of the type of asphalt used and we specify the limits of control.

Mr. Halstead.—I think that will be true in a number of states. These data were presented to illustrate to those not familiar with the concept of mixing according to viscosity, its effect in terms of mixing temperature—in other words, what changes would be required and how much control is needed to mix in the range between 75 and 150 seconds. Figure 2 shows the over-all range of temperatures needed for such control. It also shows that the degree of temperature control necessary to stay within the 75- to 150-second range is about the same as the minimum practical tolerance for plant operating temperatures. This is a point that is likely to be overlooked if we consider changes in viscosity values only. One is apt to look at the difference between 75 and 150 seconds, mentally calculate that this is a 100 percent change in viscosity, and think that this is very large. However, in terms of temperature differences necessary to cause this change, it is not really great. As a matter of fact, for a large number of asphalts the conditions necessary to control by viscosity are the same as the conditions set in many present specifications. The change really is not revolutionary.

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