Establishing Hot Mix Asphalt Mixing and Compaction Temperatures at the Project Level

*By Jay Hensley,
Asphalt Institute
Regional Engineer,
and Al Palmer,
Asphalt Institute
District Engineer*

Hot mix asphalt (HMA) mixing and compaction temperatures are emerging as critical issues in current asphalt pavement technology. Other factors, however, such as the total compaction process, base support, lift thickness and heat-loss prevention, must also be considered with Superpave and other new asphalt pavement technologies.

In past construction practices, plant-mixing temperatures were not a major concern for the hot mix asphalt (HMA) industry. If particle coating was a problem, the mixing time on the plant was increased. The construction practices consisted primarily of obtaining complete coating and achieving adequate field density. The adoption of the volumetric criteria to control HMA mixes in the field has increased the importance of this issue.

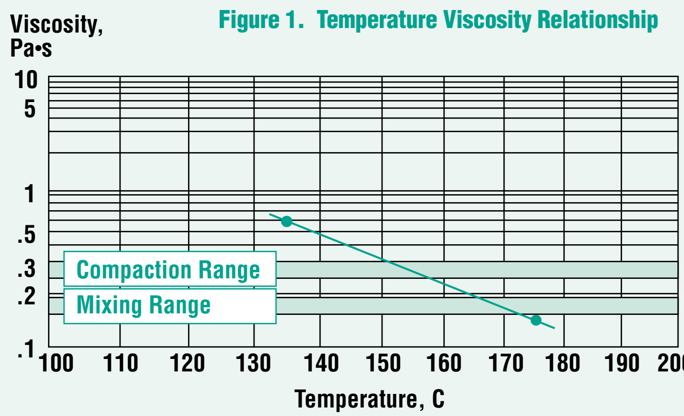
The relationship of mixing and compaction temperatures to the asphalt binder viscosity has been used as a guide for laboratory compaction for many years. *Determination of Mixing and Compaction Temperature—(ASTM 1559). The temperature to which the asphalt must be heated to produce kinematic viscosities of 170 ± 20 centistokes and 280 ± 30 centistokes shall be established as the mixing and compaction temperatures, respectively.*

The corresponding mixing and compaction temperatures are converted to Pascal-seconds (Pa•s) in the metric system using a conversion factor of 1 Pa•s ≈ 1000 centistokes. The mixing and compaction ranges are now: 0.17 ± 0.02 Pa•s and 0.28 ± 0.03 Pa•s, respectively. This has been the guide in Marshall mix design criteria for many agencies and was used for laboratory volumetrics. The relationship continues to be valid for laboratory purposes.

The Brookfield Viscometer, a rotational device, (ASTM D 4402) is now used to determine the mixing, compaction, and pumping temperatures in the Superpave system. This test can be waved under the Superpave guidelines if the supplier guarantees the binder can be adequately pumped and mixed at temperatures that meet all applicable safety standards.

The procedure for establishing mixing and compaction temperatures is valid for both neat and modified asphalt binders.

Figure 1. Temperature Viscosity Relationship



The relationship between temperature and viscosity in Figure 1 shows the idealized laboratory mixing and compaction ranges. The binder is a "super lubricant" at the mixing range temperature and a "super glue" somewhere around the compaction temperature range.

Thermal Separation

The Brookfield Viscosity data is also used to determine the pumpability of the binder. This is important data for delivery and pumping temperatures that may be signifi-

cantly higher than the mixing temperature. The maximum allowable viscosity at 135°C (275°F) is 3 Pa•s (3000 centi-stokes) at 20 rpm. This seems high given the fact that mixing temperatures are targeted at a temperature yielding 0.28 ± 0.03 Pa•s (280 centistokes). Most materials are less than 1 Pa•s (1000 centistokes) at 20 rpm. Higher temperatures exist in the manufacture, storage, and transportation of binder materials because they remain in bulk mass, are not in contact with atmosphere and will not oxidize. However, at these elevated temperatures, thermal separation of the modifiers from the base asphalt may occur. Precautions regarding thermal separation can be obtained from the binder supplier. When the material is placed on hot aggregates at elevated temperatures, oxidation and smoking could occur.

Neat Binder

Neat asphalt binder is simply one that is made with straight run crude without any modification. The PG grading system can be used to determine if the binder is a modified or neat material. If the sum of the absolute value of the high and low temperature values shown in the grade is greater than 90, the binder is probably modified. The use of the temperature/viscosity relationship is valid for the laboratory mixing and compaction procedure where neat asphalt binders are concerned. For modified binders, this may or may not be appropriate, depending on which modifying agent is used. This chart may indicate significantly higher mixing and compaction temperatures.

Plant Mixing Temperatures

For plant mixing, keep temperatures under 170°C (338°F) and under no conditions exceed 177°C (350°F). For most PG 70s and 76s, compaction temperatures range from 135 to 155°C (275-310°F). We recommend establishing the compaction temperature in a test section on the roadway. The mixing temperature is then increased slightly from this value. The increase should compensate for the expected loss of temperature during short-term storage at the plant, hauling and placement operations. The mixing temperature should be only slightly higher than the compaction temperature. When adequate trucks with tarps and mobile transfer vehicles (MTVs) are used, the mixes will normally lose only a few degrees of temperature on delivery to the paver.

Compaction Temperature

By knowing what type of binder is being used, and the construction variables associated with a particular project, we can estimate a start-up mixing temperature from the compaction temperature based on experience. The compaction temperature usually controls the required mixing temperature at the plant. The mixing temperature can be defined as that temperature which produces a uniform and sufficient coating of the coarse aggregate. The factors that control the mixing are time, mixing facility efficiency, aggregate type and the properties of the mix being placed.

Compaction Factors

Several factors, such as lift thickness, base support, base temperature, wind velocity, air temperature and asphalt viscosity affect compaction. All of these factors are important, but foremost are lift thickness and base support. Without these two variables being correct, the contractor will probably not achieve density, regardless of mix, air or base temperature. The Asphalt Institute recommends a minimum compacted thickness of three times the nominal maximum size aggregate for Superpave mixes. If the binder is highly modified, thicker lifts may be required to achieve density and meet smoothness requirements. Thicker lifts will hold the heat for a few minutes longer, allowing an extra pass with the breakdown or intermediate roller.

Test Strip

Rolling procedure and rolling temperature is best determined by constructing an initial test strip of adequate length to roll the mixture until break-over occurs. Break-over is defined as rolling the mixture to maximum achievable density, or until the mix begins to lose density on a subsequent pass. The mix should not break-over until it reaches at least 96 percent maximum density. When lift thickness, proper rolling procedure, proper haul trucks, and placement procedures are used and density cannot be achieved, an increase in plant temperature can then be justified.

Cessation Temperature

A higher temperature at the plant does not necessarily result in an equal increase in temperature at the paver. A review of the existing cessation temperature curves for HMA by Corlew and Dickson, *Proceedings, AAPT 1970,* indicate a much faster temperature cessation for the higher mixing temperatures. Figure 2 illustrates mixes from 225 to 300°F (107 to 149°C) with base temperatures from 10 to 60°F (-12 to 16°C). The chart shows significant increase in allowable rolling times when thicker lifts are placed. Modified asphalts are commonly mixed at 148 to 165°C (300 to 330°F) in Superpave, depending on the grade.

Compaction temperature at the paver is typically from 135 to 155°C (275 to 310°F), depending on the binder grade and lift thickness. Cessation temperature time appears to be shorter for the modified asphalts, primarily because of the higher initial temperature. Note that this is common for all asphalt binders mixed at higher temperatures, regardless of whether they are modified or not. The chart in Figure 2 illustrates the time for a cessation temperature of 200°F (93°C) for the particular material being studied, under the stated conditions. It is not known what the cessation temperatures are for all modified binders. They would also be expected to vary depending on the modifier.

Binder suppliers may furnish the equal viscosity temperature relationship as a specification requirement for the binder characteristics. The indicated compaction temperature range should be used for specimen preparation during the mix design. For the purpose of meeting the volumetric properties in the quality control test, the mixes should be compacted in the field lab at the same designated temperature. This may require that the mix be

ATS ad

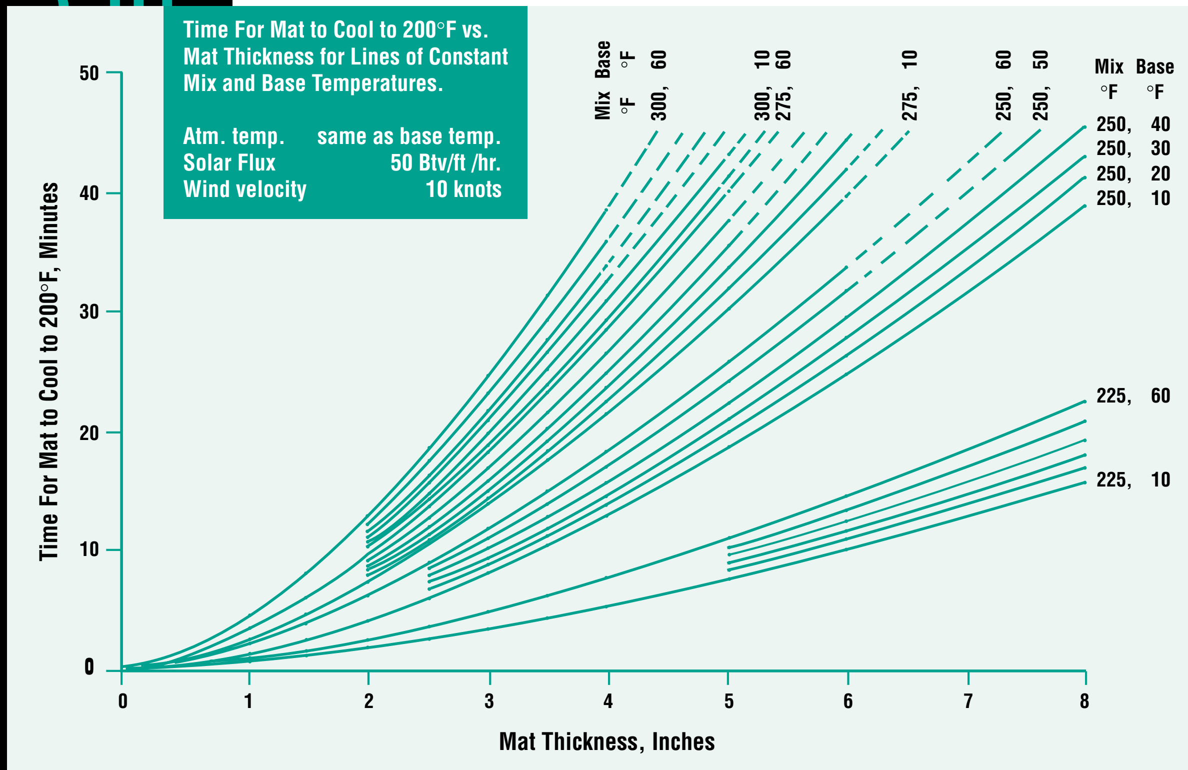


Figure 2. Temperature Cessation Curves (after Corlew & Dickson)

cooled or heated before laboratory compaction.

The temperature used for preparing laboratory specimens during mix design is the only temperature that must be carried through the production process. The laboratory compaction temperature should not be considered the same as the required compaction temperature on the roadway. The roadway compaction temperature can be significantly higher or lower than the laboratory temperature depending on the particular binder being used.

Elevated Temperatures

There are potential dangers associated with elevated mix temperatures, such as excessive fumes, worker safety, thermal separation of the modifier and binder, excessive oxidation of the binder, drain down of the binder in haul trucks, and release of internal moisture in the aggregate. It is quite normal for many binders to smoke when heated to 163 to 165°C (325 to 330°F). This does not imply that they are bad binders. Normally, if the temperature is lowered to less than 163°C (325°F), the material does not smoke. If thermal separation is experienced, the modifier may be extruded from the mix onto the surface under breakdown rolling. This will cause excessive pickup on rolling equipment and construction traffic, creating an unacceptable surface texture.

Internal moisture can be defined as moisture that is deep inside large aggregate particles that would not typically be disturbed under normal mixing temperatures. With the increased use of modified binders, and the associated higher mixing temperatures, internal moisture is being forced out of the aggregate particles.

When internal moisture is released, it normally happens in the silo or haul trucks. The moisture in the mix may cause the binder to be semi-emulsified in the vibratory rolling process, which may lead to a tender zone in the rolling pattern. If a tender zone exists, all rolling activity must stop until the mix has cooled to a much lower temperature because the binder characteristics have been modified by the emulsification.

Emphasis on Roller

The main objective in elevating the temperature is usually to provide additional assurance that specified density will be attained. Rather than increasing the mix temperature, more emphasis should be placed on the roller type, lift thickness and rolling pattern to achieve adequate density. Because Superpave mixes have a much tougher stone skeleton than the normal dense-graded mixes, the mat will support the weight of the rollers immediately behind the paver. If the mix is above the proper compaction temperature, the binder acts as a lubricant and compaction cannot be achieved at the higher temperature.

Slightly Higher Mixing Temperatures

Until more experience is gained in the use of modified binders and Superpave mixtures, it is suggested that mixing temperatures be established slightly higher than the targeted compaction temperature but not to exceed 170°C (338°F) as the maximum. The Asphalt Institute recommends a maximum of 177°C (350°F) for binder materials to prevent thermal degradation and burnout. More care in preventing heat loss during construction operations should be considered as an alternative to indiscriminately raising the mixing temperature. Breakdown rolling should commence immediately behind the paver and stop only when the desired level of density has been achieved or tenderness in the mat is noticed. At that point, all rolling operations should cease until the mix has cooled to a temperature at which the tender characteristics are no longer apparent.

The vast majority of the pavements constructed to date using the Superpave system are performing well. However, some of these pavements have exhibited unusual characteristics during construction and others have not performed as expected. The difficulties that are arising as we continue with the implementation of Superpave across the country may or may not always be easily explained or remedied. The problems are being addressed and eliminated as Superpave implementation progresses. ▲