Asphalt Institute Technical Advisory Committee
Guidance Document

Determination of Laboratory Mixing and Compaction Temperatures for Hot-Mix Asphalt

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Introduction

For years, asphalt mix design procedures have used equiviscous temperature ranges for selecting laboratory mixing and compaction temperatures. The Asphalt Institute's Mix Design Methods for Asphalt Concrete and Other Hot-Mix Types (MS-2) began recommending laboratory mixing and compaction temperature ranges based on viscosity as early as 1962. At that time, viscosity ranges were specified based on Saybolt-Furol viscosity, but beginning in 1974 the more fundamental kinematic viscosity test measured in centistokes was adopted At that time, the MS-2 manual recommended viscosity ranges of 170 ± 20 centistokes for mixing temperatures and 280 ± 30 centistokes for compaction temperatures when performing a Marshall mix design. Twenty years later, the same ranges were recommended for Superpave mixture design, except that the absolute viscosity test (rotational viscometer) was used and the units were converted to metric (Pascal-seconds). The Asphalt Institute's Superpave Mix Design (SP-2) manual documents this change.

The purpose of using equiviscous mixing and compaction temperatures in laboratory mix design procedures is to normalize the effect of asphalt binder stiffness on mixture volumetric properties. In this manner, a particular asphalt mixture of the same aggregate gradation will exhibit very similar volumetric properties with a soft asphalt binder, such as an AC-10 (or PG 58-28), as with a hard asphalt binder, such as an AC-40 (or PG 70-10).

When the Marshall hammer is used as the compaction procedure, mix stiffness becomes a very important factor in the laboratory compaction of mix design and quality control specimens, and ultimately the volumetric properties of the mixture. Since the Marshall compaction process is impact compaction, it imparts a certain amount of energy to the specimen based on the force impacting the face of the specimen (10-lb sliding weight falling through a free-fall distance of 18 inches for the total number of blows impacting the specimen). Thus, regardless of mix type or stiffness, a fixed amount of energy is input into the specimen. Since binder stiffness affects mix stiffness, and it is significantly affected by temperature, stiffer asphalt binders (caused by grade and/or temperature) will cause the specimen not to densify as much for the same amount of compaction energy. As a result, different asphalt binder stiffness will cause the same aggregate structure to have a different percentage of air voids, and thereby a different design asphalt binder content.

While the equiviscous compaction temperature concept works well for impact compaction, it doesn't seem to be as valid for the Superpave gyratory compaction (SGC) procedure. In the SGC, the mix is forced to densify through a combination of vertical pressure, angle of gyration, and rotation. As a result, the sensitivity of the compaction process to temperature is significantly lessened in the SGC (assuming that the compliance of the SGC is low). Research performed at the Asphalt Institute in 1995 (published in Transportation Research Record 1543) validates this lack of sensitivity to temperature.

Although the SGC-compacted mix specimens apparently do not exhibit as much sensitivity in volumetric properties to changes in compaction temperature, the same practice of determining mixing and compaction temperatures used in 1974 was continued into the Superpave mix design procedure. However, the increased use of highly-modified asphalt binders often resulted in “equiviscous” mixing and compaction temperatures that were unusually high. Mixing temperatures above 350°F (177°C) were often determined for some premium grade asphalt binders. At these excessively high mixing temperatures there are potential problems with binder degradation and increased binder stiffening (aging) during the mixing process. In addition, the corresponding high compaction temperatures lead to potential problems in obtaining density due to low mix stiffness (causing excessive lateral mix movement under the roller), excess absorption of asphalt binder into some types of aggregates (causing a lower effective asphalt binder content), and drain-down of asphalt binder in some coarse mixes. These problems can result in high in-place air voids.

As a result of some of these concerns, The Asphalt Institute developed a technical bulletin in 1997 that addressed laboratory mixing and compaction temperatures and recommended against using lab mixing temperatures in excess of 177°C (350°F). In addition, a joint AI-NAPA task group developed a document in 2000 entitled Best Management Practices to Minimize Emissions During HMA Construction. This document addresses *field* mixing and compaction temperatures, but recognizes the problems associated with excessively high temperatures.

Since the end of SHRP, other research has been conducted on mixing and compaction temperatures, but the recommended procedures did not find their way into general use.

Recent research conducted by the National Center for Asphalt Technology (NCAT) on laboratory mixing and compaction temperatures suggests that modified asphalt binders should be tested following one of two procedures: the DSR Phase Angle Procedure or the DSR Steady Shear Flow Procedure. NCHRP Report 648, Mixing and Compaction Temperatures of Asphalt Binders in Hot-Mix Asphalt, describes the basis for the recommendation from the research team. The DSR Phase Angle Procedure is performed by conducting a shear frequency sweep from 0.1 to 100 rad/s at a minimum of three temperatures, developing a mastercurve at 80°C, and determining the frequency where the phase angle equals 86 degrees. This frequency is then input into an equation to calculate mixing and compaction temperatures. The DSR Steady Shear Flow Procedure uses a shear stress sweep from 50 to 1000 Pa (minimum of five data points per log decade) at a minimum of three test temperatures to determine the steady state viscosity. This viscosity is then plotted as a function of temperature and the mixing and compaction temperatures derived from that graph. According to NCHRP Report 648, either procedure is acceptable for determining mixing and compaction temperatures for asphalt binders.

Recommendations

For unmodified[1] asphalt binders, the laboratory mixing and compaction temperature may be determined using: (1) the rotational viscosity procedure (AASHTO T316) at two test temperatures; or (2) the rotational viscosity procedure at 135°C in combination with the dynamic shear rheometer procedure (AASHTO T315) at a single test temperature. Compaction temperatures are determined where the viscosity-temperature line crosses the compaction temperature range of 0.28 ± 0.03 Pa-s. Mixing temperatures are determined where the viscosity-temperature line crosses the mixing temperature range of 0.17 ± 0.02 Pa-s.

For modified[2] asphalt binders, the laboratory mixing and compaction temperature may be determined using either: (1) the DSR Phase Angle Procedure; or (2) the DSR Steady Shear Flow Procedure, as recommended by NCHRP Report 648. In addition, the recommendation of the supplier may be used, as many suppliers have determined mixing and compaction temperatures for their individual products that have proven to be appropriate.

Regardless of the selected procedure, the Asphalt Institute recommends that laboratory mixing temperatures do not exceed 177°C (350°F).

Note that the recommended procedures for determining laboratory mixing and compaction temperatures do not apply to asphalt binders that have been modified with ground tire rubber (GTR). The NCHRP 9-39 research did not evaluate GTR-modified asphalt binders and it is not known how the recommended procedures will work with this class of modified asphalt binder. Users should refer to other existing practices to determine appropriate mixing and compaction temperatures for GTR-modified asphalt binders.

Project Mixing and Compaction Temperatures

The Asphalt Institute reminds the reader that laboratory mixing and compaction temperatures are intended for determining design volumetric properties of the asphalt mixture and are not intended to represent actual mixing and compaction temperatures at the project level. In a hot-mix asphalt (HMA) facility, the mixing temperature can best be defined as the temperature at which the aggregate can be sufficiently and uniformly coated. As with the lab temperatures, the mixing temperature should not exceed 177°C (350°F). The compaction temperature for HMA is usually in the range of 135-155°C (275-310°F) and is based solely on the ability of the compaction equipment available for the project to achieve adequate in-place density.

[1] Also identified as: (a) AASHTO M320 asphalt binders that have a useful temperature interval (UTI) of < 92 degrees; or (b) AASHTO MP19 asphalt binders with an "S" designation

[2] Also identified as: (a) AASHTO M320 asphalt binders that have a useful temperature interval (UTI) of ≥ 92 degrees; or (b) AASHTO MP19 asphalt binders with an "H", "V", or "E" designation

For general guidance on storage and mixing temperatures based on different asphalt binder grades, please refer to EC-101, Best Management Practices to Minimize Emissions During HMA Construction.

References and Supplemental Information

Mix Design Methods for Asphalt Concrete and Other Hot-Mix Types, MS-2, Asphalt Institute

Superpave Mix Design, SP-2, Asphalt Institute

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