LABORATORY MIXING AND COMPACTION TEMPERATURES FOR ASPHALT BINDERS

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Lab Mixing and Compaction Temperatures

- **Background**
  - MS-2
    - Recommended laboratory mixing and compaction temperature ranges for Marshall mix design based on viscosity (Saybolt Furol) as early as 1962
      - Changed to absolute and kinematic viscosity in 1974
      - 170 ± 20 centistokes for mixing
      - 280 ± 30 centistokes for compaction
- **Purpose**
  - Normalize the effect of asphalt binder stiffness on mixture volumetric properties
    - Aggregate packing and available void space
Lab Mixing and Compaction Temperatures

- **Background**
  - Modified Asphalt Binders in the Superpave Mix Design System
    - Adopted old (Marshall) standard in 1993
      - 0.17 ± 0.02 Pa-s (mixing)
      - 0.28 ± 0.02 Pa-s (compaction)
    - Manufacturer’s recommendation for modified asphalt binders
Lab Mixing and Compaction Temperatures

- **Background**
  - Modified asphalt binders in the Superpave mix design system
    - Produced lower air voids, higher density
      - Shear compaction with fixed angle, pressure
        - Not generally affected by mix stiffness (i.e., not significantly affected by temperature)
  - More heavily modified binders have a more pronounced effect
NCHRP 9-39: Mixing & Compaction Temperatures

![Diagram showing mixing and compaction ranges across temperature and viscosity.

- **Compaction Range**
- **Mixing Range**

**Temperature, °C**
100 110 120 130 140 150 160 170 180 190 200

**Viscosity, Pa·s**
0.1 0.2 0.3 0.5 1 5 10 100 110 120 130 140 150 160 170 180 190 200

Note: The diagram illustrates the mixing and compaction ranges in an asphalt mixture, with a temperature range from 100°C to 200°C and a viscosity range from 0.1 Pa·s to 10 Pa·s. The graph shows a decreasing trend in viscosity with increasing temperature, indicating the optimal temperature range for compaction and mixing.
Background

- The Asphalt Institute equiviscous concept works well for unmodified binders.
- For most modified binders, the equiviscous concept results in excessively high mixing and compaction temperatures:
  - Emission concerns
  - Binder degradation concerns
  - Cost (heating costs and plant wear)
- Most specifying agencies have relied on binder suppliers to recommend appropriate temperatures.
  - No consensus exists on how that should be done.
Research on Lab Mixing and Compaction Temperatures

- NCHRP 9-39, *Procedure for Determining Mixing and Compaction Temperatures of Asphalt Binders in Hot Mix Asphalt*
  - Purpose
    - Identify or develop a simple, rapid, and accurate laboratory procedure for determining the mixing and compaction temperatures of asphalt binder
- Steady Shear Flow (SSF) DSR method
  - Reinke
SSF Procedure: PG 64-34 (SBS-modified)

<table>
<thead>
<tr>
<th>Temperature, °C</th>
<th>Viscosity, Pa·s</th>
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<td>52</td>
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<tr>
<td>58</td>
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<td>100</td>
<td>1.8</td>
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Mixing Range

Compaction Range

RV 195°C mixing  185°C comp.
SSF 153°C mixing  143°C comp.
For unmodified\(^1\) asphalt binders...

- 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

\(^1\) 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
For modified\(^2\) asphalt binders...

- laboratory mixing and compaction temperature may be determined using:
  - (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.

\(^2\) Also identified as: (a) AASHTO M320 asphalt binders that have a useful temperature interval (UTI) of \(\geq 92\) degrees; or (b) AASHTO MP19 asphalt binders with an “H”, “V”, or “E” designation
Second phase evaluating the effect of mixing and compaction temperature on mix design is underway

CTAA Paper in November 2016
Lab Mixing and Compaction Temperatures: Caveats

- Regardless of the selected procedure, recommend that laboratory mixing temperatures do not exceed 177°C.
- Not applicable to asphalt binders that have been modified with ground tire rubber (GTR).
  - The NCHRP 9-39 research did not evaluate GTR-modified asphalt binders.
  - Unknown how the recommended procedures will work with this class of modified asphalt binder.
  - Refer to other existing practices for GTR-modified asphalt binders.
Project Mixing and Compaction Temperatures

- Laboratory mixing and compaction temperatures
  - intended for determining design volumetric properties of the asphalt mixture
  - not intended to represent actual mixing and compaction temperatures at the project level
  - Once we finish the study and suppliers modify their mixing and compaction charts, the temperature will likely be a good place to start
Project Mixing and Compaction Temperatures

Project-level mixing and compaction temperatures

- **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.

- **Compaction temperature**
  - usually in the range of 135-155°C
  - may be a bit higher for highly modified binders
  - based solely on the ability of the compaction equipment available for the project to achieve adequate in-place density
Practical Considerations

- Plant mixing temperature is dependant on achieving adequate compaction in the field
  - Time of year
  - Silo storage time
  - Haul distance (cooling in transport)
  - Spreading procedures and compaction equipment on site
- Highly modified binders may be more sensitive to pickup issues with pneumatic tyre rollers
  - More sensitive to a difference between tyre and mix temp
  - Issues with stopping – even for short intervals
  - Look for appropriate release agent – spray bars vs misting
Thanks!

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