SIMPLE PERFORMANCE TESTS (SPTs) FOR HMA MIX DESIGN
9-19: Superpave Support and Performance Models Management,

SPTs for Rutting:

1. **Dynamic modulus, E*** – primary design procedure.
2. **Flow number, F_n** (triaxial repeated load permanent deformation) – check for tertiary flow.
3. **Flow time, F_t** (static creep)
Simple Performance Tests

**SPT Validation**: Based on material properties and field performance of IN SPS-9, NV I-80, AZ I-10, NCAT Track, MnRoad, FHWA ALF, WesTrack.

**SPT Criteria**: Developed with the HMA performance models in the 1-37A Pavement Design Guide.
E* SPT Specification Criteria

Input Data:
- $T_{\text{eff}}$
- Design traffic in 18 kESALs
- Structural cross-section
- Maximum allowable rut depth distributed by AC layer
E* SPT Specification Criteria

• Environmental Characterization
  – Mean Annual Air Temperature (MAAT)
  – Annual Cumulative Rainfall (Rain)
  – Mean Annual Wind Speed (Wind)
  – Mean Annual Sunshine (Sunshine)
  – Standard Deviation of the Mean Monthly Air Temperature ($\sigma_{\text{MMAT}}$)

• New Temperature Relationship was obtained to best-fit AC Rutting with Effective Temperature ($T_{\text{eff}}$)
E* SPT Specification Criteria

- Calculated with Microsoft Excel spreadsheet program.
- Specific criteria interpolated from solutions of the Mechanistic-Empirical Pavement Design Guide for combinations of 7 pavement structures, 4 climates, 2 mix types, and 2 binder types.
E* SPT Specification Criteria

• Three modes of operation:
  – Compare effect of mix quality v. structural design on rutting.
  – Compare lab-measured E* with E* required for allowable rutting at a project.
  – Compare as-designed and as-built E* by lot and sublot for QC/QA.
## Summary of Program Screens

### EXAMPLE OF OUTPUT

#### TEMPERATURE & FREQUENCY

In Lab, tested at given critical E* to be achieved.

#### ESTIMATED RUT DEPTH CRITERIA DIVIDED BY AC SUBLAYERS

<table>
<thead>
<tr>
<th>Layer Order</th>
<th>Layer Mix ID</th>
<th>Thick (in)</th>
<th>Cum Thick (in)</th>
<th>Depth for AC Sublayer Rut Depth (in)</th>
<th>Estimated RD by AC Sublayer (in)</th>
<th>Sublayer Critical E* (psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1ST</td>
<td>a</td>
<td>1.50</td>
<td>1.50</td>
<td>1.00</td>
<td>0.100</td>
<td>327143</td>
</tr>
<tr>
<td>2ND</td>
<td>a</td>
<td>1.00</td>
<td>2.50</td>
<td>2.00</td>
<td>0.083</td>
<td>486543</td>
</tr>
<tr>
<td>2ND</td>
<td>a</td>
<td>1.00</td>
<td>3.50</td>
<td>3.00</td>
<td>0.067</td>
<td>459431</td>
</tr>
<tr>
<td>3RD</td>
<td>b</td>
<td>1.00</td>
<td>4.50</td>
<td>4.00</td>
<td>0.082</td>
<td>146601</td>
</tr>
<tr>
<td>3RD</td>
<td>b</td>
<td>2.00</td>
<td>6.50</td>
<td>5.50</td>
<td>0.068</td>
<td>141547</td>
</tr>
</tbody>
</table>

**Layer Critical E* (psi)**

- 327143
- 486543
- 459431
- 146601
- 141547

**Effective Temperature & Frequency**

- Layer Critical E* (psi): 327143
- Effective Temperature (°F): 93.04
- Effective Frequency (Hz): 38.25
- Layer Critical E* (psi): 486543
- Effective Temperature (°F): 86.98
- Effective Frequency (Hz): 21.31
- Layer Critical E* (psi): 459431
- Effective Temperature (°F):
- Effective Frequency (Hz): 146601
- Layer Critical E* (psi): 141547
- Effective Temperature (°F): 146601
- Effective Frequency (Hz): 11.65

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9
$F_n/F_t$ SPT Specification Criteria

- $F_n$ is an accurate method for directly estimating rut depth at any traffic level from a single measurement.
- $F_t$ is a viable surrogate for $F_n$.
- Neither method is global.
- Both methods more variable than $E^*$. 
SIMPLE PERFORMANCE TESTERS
Simple Performance Test Equipment

**Dynamic Modulus Standard Report**

Data generated on: 01-Jan-99

Dynamic Modulus, ksi: 687.6

Data exported on: 01-Jan-99

Phase Angle, Deg.: 23.9

Sample ID: 531 Cond

Average Strain, microstrain: 35.7

Project: NCHRP 9-34

System Configuration:

- Test Frequency (Hz): 10.04
- Gauge Length (in.): 3.94
- Specimen Dia. (in.): 3.94
- Test Temperature C: 25.0
- Normalized Load and Displacements
- Normalized Load or Disp.
- Normalized Load or Disp.

**DATA TRACES**

- Load, lbs
- Disp., micro-in

**LOAD VS. DISPLACEMENT**

- Normalized Displacement
- Normalized Load

**Phase Angle:**

- Phase Angle Disp
- Phase Angle Load

**Disp 1:**

- Disp 1 Fit

**Disp 2:**

- Disp 2 Fit
Simple Performance Test System

- **Tests**
  - Flow Time
  - Flow Number
  - Dynamic Modulus

- **Modulus**
  - 10,000 psi to 2,500,000 psi

- **Temperature**
  - 4 to 60 °C

- **Confinement**
  - to 30 psi
Simple Performance Test System

• Standard Software
  – Load Control
  – Data Acquisition
  – Data Analysis
  – Reporting

• Dynamic Modulus Data Quality Statistics
  – Reliability of Results
Simple Performance Test System

• Three Production Units
  – Interlaken (also First Article)
  – Industrial Process Controls (also First Article)
  – Medical Device Testing Systems

• Production Unit Cost
  – $45,000 to $50,000
Features

- Small
- Bottom-Loading
- Servo-Hydraulic
- Automated Test Chamber
Features

• Glued Gage Point System
• Easy Installation < 3 min
Features

• Can Generate Master Curve
9-29: Simple Performance Tester for Superpave Mix Design

- Single-replicate measurement COV: dynamic modulus 13%, flow time 33%.
- Ruggedness testing underway.
- Two production units received; third expected by end of July.

Advanced Asphalt Technologies (November 2005)
Specimen Fabrication Equipment

- Sawed and Cored From Oversized Gyratory
- User Resistance
  - Time
  - Complexity
- Shedworks
  - Automate Sawing and Coring
  - $22,000 for First Article
  - $15,000 for Production Units
Specimen Fabrication Equipment

- Core Barrel
- Blades
- Chuck
9-9(1): Verification of Gyration Levels in the $N_{design}$ Table

How well does densification at the $N_{design}$ levels in AASHTO R35 match that developed in the field under traffic?

NCAT (August 2005)
Preliminary Findings:

• **Current $N_{design}$** levels slightly too high based on results from 40 field projects and 32 NCAT Track sections.

• **Modified binders** significantly reduce rate of densification.
9-27: Relationships of HMA In-Place Air Voids, Lift Thickness and Permeability

Determine in-place air voids and minimum lift thicknesses needed to achieve durable, impermeable HMA pavements.

NCAT (April 2004)
Factors Affecting In-Place Air Voids

- Recommended thickness/NMAS ratios for adequate in-place density:
  - ≥ 3 for fine-graded mixes
  - ≥ 4 for coarse-graded mixes
- Lower ratios will require more field compactive effort to achieve adequate density.
Factors Affecting HMA Permeability

• No significant difference in lab permeability between fine- and coarse-graded mixes.
• Satisfactory permeability at 7±1% AVC at t/NMAS = 2, 3, or 4.
• Permeability increases as air voids and coarse aggregate ratio increase, decreases as VMA increases.
9-25: Requirements for Voids in Mineral Aggregate for Superpave Mixtures

Which volumetric design criterion best ensures adequate durability and performance: VMA, VFA, or calculated binder film thickness?

*Advanced Asphalt Technologies (March 2004)*
Should design air void content vary with traffic loading and climatic conditions?

*Advanced Asphalt Technologies (March 2004)*
9-25/9-31 Preliminary Approach to Specification Modification

- Set target VMA as a function of calculated aggregate surface area (p75+p150).
- Allowable VMA range should be target ± 1.0 %.
- Design air voids 3 to 5 %.
- Minimum $V_{be} / V_{FA}$ requirements:
  - 10% / 70% within 100 mm of surface
  - 8% / 65% otherwise
9-33: A Mix Design Manual for Hot Mix Asphalt

Update method in AI Manual SP-02:

- Simple performance test(s).
- Criteria developed with M-E design guide performance models and software.
- New volumetric criteria.
- Framework for integrated mix and structural design.

Advanced Asphalt Technologies, LLC (August 2006)
OTHER TESTS AND PROCEDURES
Asphalt Pavement Analyzer
9-17: Accelerated Laboratory Rutting Tests: Asphalt Pavement Analyzer

- APA rut depths correlated well with field performance on an individual project basis.
- APA-field performance relationships are project-specific, not global (like $F_n$ and $F_r$).

NCAT (June 2003)
9-34: Improved Conditioning Procedure for Predicting HMA Moisture Susceptibility

Improved conditioning procedure based on use of the environmental conditioning system (ECS) with a simple performance test.

*Pennsylvania Transportation Institute (December 2004)*
9-34: Improved Conditioning Procedure for Predicting HMA Moisture Susceptibility

Initial Findings:

• $F_n$ and $F_t$ tests cannot reliably identify moisture susceptible mixes.

• $E^*$ test has the potential to distinguish between good and poor performing mixes.
Improved Conditioning Procedure for Predicting HMA Moisture Susceptibility

Preliminary final results: with 8 HMA mixes of known field performance, the ECS/E* SPT provided better correlation with field performance (7/8) than the Hamburg wheel tracking or ASTM D 4867 methods.
Improved procedure for short-term laboratory aging usable in a purchase specification such as AASHTO M320.

- Apply to neat and modified binders.
- Quantify binder volatility.
- Extend to long-term aging.
- Mimic PP2 mix aging.

*Advanced Asphalt Technologies (August 2005)*
9-36: Improved Procedure for Laboratory Aging of Asphalt Binders in Pavements

Promising candidate procedures:

- Modified German Rolling Flask Method
- Stirred Air Flow Test

Key issue: Can either test be used to simulate long-term binder aging? Only the SAFT (selection study results).
9-38: *Endurance Limit of HMA Mixtures to Prevent Fatigue Cracking in Flexible Pavements*

Test the hypothesis that there is an endurance limit in the fatigue behavior of HMA mixtures and measure its value for a representative range of HMA mixtures.

*NCAT (January 2006)*
9-39: Determining the Mixing and Compaction Temperatures of Superpave Asphalt Binders in HMA

- Reliable, user-friendly method.
- Equally applicable to modified and unmodified binders.
- Simple and quick to use.
- Suitable for routine specification use.

NCAT (December 2007)
Mechanistic-Empirical Pavement Design Guide and Software

• Available online for evaluation at www.trb.org/mepdg/.

• Version 1.1 planned for spring 2005 with re-calibrated performance models, error corrections, and enhancements.
9-30A: Rutting Performance Model for HMA Mix and Structural Design

- Performance models workshop.
- Sample and test HMA materials from 30-40 field sections per M-E PDG Level 1.
- Re-calibrate M-E PDG flexible performance models with measured data.
- Support M-E Distress Prediction Models (M-E_DPM) database.

(ARA, Inc., 29 November 2008)
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www4.trb.org/trb/crp.nsf/
Thanks!

Any Questions?