Index-Based Tests for Asphalt Performance Engineered Mixture Designs (PEMDs)

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- Task C1: Asphalt Mixture Performance-Based Design Technical Refinement and Deployment Support.

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Task C1: Asphalt Mixture Performance-Based Design Technical Refinement and Deployment Support.

- Informational brief (*in publication review process*):
  - Provides practitioners with information about index-based performance tests that can be implemented within a Performance Engineered Mixture Design (PEMD) process.
  - To help improve performance & prolong service life of asphalt pavements.
  - Aimed to serve as a general overview & to provide context for PEMD process & how it fits into the big picture.

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Introduction

- Recognition & desire need by agencies & asphalt paving industry to:
  - Use performance testing for asphalt mixture design & QA.
  - Help ensure satisfactory asphalt pavement performance.
- Superpave mixture design method has been based solely on volumetric properties.
  - *AASHTO M 323 "Standard Specification for Superpave Volumetric Mix Design."*
  - *AASHTO R 35 "Standard Practice for Superpave Volumetric Design for Asphalt Mixtures."*
  - Several states have local modifications or adjustments.

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Introduction (Cont'd)
WHY?

- Volumetric-based design may not provide optimum performance for asphalt mixtures with:
  - Increased use of innovative & recycled materials.
  - Specific design applications.
    - e.g., mix location within pavement structure, reflective cracking relief interlayer mix, existing pavement condition—for asphalt overlay mixture.
  - Alternative project delivery methods.
- Performance testing:
  - Acceptable asphalt binder content boundaries.
  - Ultimate performance against primary modes of distress.
  - Avoid design & production of dry asphalt mixtures.
  - …

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What is a *Performance Engineered Mixture Design (PEMD)*?

- A process of engineering & design of asphalt mixtures by conducting laboratory testing on mixtures to ensure they should meet or exceed design & performance expectations over the pavement life.
- Seeks to achieve a combination of binder, aggregate, & mixture proportions that will meet performance criteria for a diverse number of pavement distresses for a given level of traffic, climate, & pavement.

Can be categorized as

Index PEMD or *Predictive PEMD*.

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PEMD: Index vs. Predictive

- Index PEMD
  - Use of performance tests to determine an *index parameter*
    - For primary modes of distress.
    - Appropriately conditioned specimens.
  - Considerations for:
    - Asphalt mixture aging.
    - Traffic.
    - Climate.
    - Location within pavement structure.
  - Focus:
    - Balance asphalt pavement rutting with durability/cracking performance.
    - Example: ***Balanced Mix Design (BMD)*** process.

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PEMD: Index vs. Predictive (Cont'd)

- Predictive PEMD
  - Captures the desire to improve performance & advance the state of practice beyond balancing two distresses.
  - Toward an approach to *predict pavement performance life* using mechanistic response models.
  - Uses performance tests to determine a:

Mechanistic-oriented parameter OR *Lab-developed performance model*

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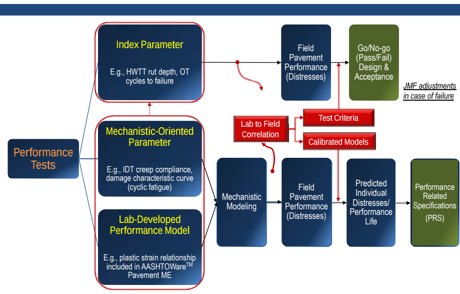
Asphalt Mixture Performance Tests
TEST RESULTS



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When to Apply Index vs. Predictive PEMD?

- Part of a decision making process with project selection criteria like:
  - Project scope, i.e., full reconstruction versus major (e.g., full depth reclamation) or minor (e.g. mill and overlay) rehabilitation.
  - Highway functional classification (principal arterial, minor arterial, etc.) & project traffic level (low, moderate, or high volume).
  - Project length and asphalt tonnage.
  - AC layer location (e.g., surface versus base course) & function (e.g., binder versus wearing surface course) in the pavement structure.
  - Outcome of a risk-based cost-benefit analysis for the project.
  - Etc.

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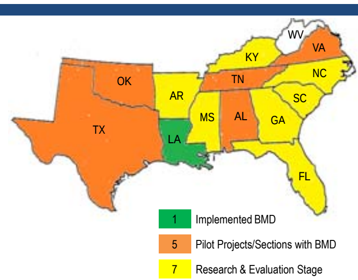
SEAUPG (2019 State Update)
Balanced Mix Design (Index PEMD)



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Asphalt Mixture Performance Tests
TEST RESULTS

- Index parameter
  - E.g., HWTT rut depth, OT cycles to failure.
  - Correlate to field pavement distresses.
  - Used in the index PEMD as go/no-go (pass/fail) design & acceptance.
  - JMF adjustments in case of failure.
- Mechanistic-oriented parameter
  - E.g., IDT creep compliance, damage characteristic curve from cyclic fatigue.
  - Combined with mechanistic models to evaluate resistance to individual distresses; providing the ability to develop PRS
  - Can be used as part of an index parameter.

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Asphalt Mixture Performance Tests
TEST RESULTS (Cont'd)

- Laboratory-developed performance model
  - E.g., plastic strain relationship included in the AASHTOWare™ Pavement ME.
  - Typically calibrated with field distresses
  - Used to predict distresses in a pavement structure under given traffic & climate conditions.

Note: a performance test can result in a combination of these outcomes.

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Examples of Performance Tests
Stability/Rutting

Test Name	Test Method	Test Outcome (I, M, P)[1]	Index Parameter	Index Definition or Performance Criteria
Asphalt Pavement Analyzer (APA)	AASHTO T 340	I	*RD*	Rut depth
Dynamic Modulus	AASHTO T 342/ AASHTO T 378/ AASHTO TP 132	I, M	E^* $G\text{-}R_m$	Dynamic modulus Mixture Glover-Rowe
Flow Number	AASHTO T 378	I, P	*FN* ε_p	Flow number Permanent axial strain
Hamburg Wheel-Tracking Test (HWTT)	AASHTO T 324	I	*RD* *NF*	Rut depth Number of passes to failure
Hveem Stability	AASHTO T 246	I	*S*	Hveem stability
Resistance to Plastic Flow	AASHTO T245	I	*Stability* *Flow*	Marshall stability Marshall flow
Stress Sweep Rutting	AASHTO TP 134	I, P	ε_{vp} *ATR (ESALs)*	Viscoplastic strain (permanent strain) Allowable traffic for rutting (equivalent single axle loads)

[1]*I=index parameter; M=mechanistic-oriented parameter, P=laboratory-developed performance model.*

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Examples of Performance Tests
Durability/Cracking

Test Name	Test Method	Test Outcome[1]	Index Parameter	Index Definition or Performance Criteria	Cracking Types
Direct Tension Cyclic Fatigue	AASHTO TP 107/ AASHTO TP 133	I, M, P	D^R S_{app}	Pseudo energy-based fatigue failure criterion Cracking index parameter	Bottom-up fatigue Top-down
Disc-Shaped Compact Tension (DCT)	ASTM D 7313	I	G_f	Fracture energy	Thermal Reflection
Dynamic Modulus	AASHTO T 342/ AASHTO T 378/ AASHTO TP 132	I, M	E^* $G\text{-}R_m$	Dynamic modulus Mixture Glover-Rowe	Bottom-up fatigue Thermal
Flexural Bending Beam Fatigue	AASHTO T 321	I, M, P	*N*	Cycles to failure	Bottom-up fatigue
Illinois Flexibility Index	AASHTO TP 124	I	*FI*	Flexibility index	Bottom-up fatigue Top down Reflection
Indirect Tensile Cracking[2]	ASTM D8225	I	CT_{Index}	Cracking tolerance index	
Overlay Test (OT)	Tex-248-F/ NJDOT B-10	I	N_{OT} G_c β	Number of cycles until failure Critical fracture energy Crack resistance index	Bottom-up fatigue Reflection
Semi-Circular Bend (SCB)	AASHTO TP 105/ ASTM D8044	I	J_c	Critical strain energy release rate	Bottom-up fatigue Thermal

[1]*I=index parameter; M=mechanistic-oriented parameter, P=laboratory-developed performance model.*
[2]formerly known as IDEAL-CT.

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Examples of Performance Tests
Moisture Damage/Stripping

Test Name	Test Method	Test Outcome (I, M, P)[1]	Index Parameter	Index Definition or Performance Criteria
Hamburg Wheel-Tracking Test (HWTT)	AASHTO T 324	I	*RD* *SIF* *NF* *NSIP*	Rut depth Stripping inflection point Number of passes to failure Number of passes to stripping inflection point
Indirect Tensile Strength Ratio	AASHTO T 283	I	*TS* *TSR*	Indirect tensile strength Indirect tensile strength ratio

[1]I=index parameter; M=mechanistic-oriented parameter, P=laboratory-developed performance model.

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Index PEMD: Performance Test Selection
How to Select Test(s) for Use/Implementation?

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Index PEMD: Performance Test Selection
PROCESS

Step-By-Step Guidelines	Considerations
Step 5. Evaluate the implementation impacts of multiple performance tests on current SHA & industry practice for designing & accepting asphalt mixtures.	• Additional time & resources needed. • Operating equip, qualified personnel, testing sequence timing, etc. • …
Step 4. Assess the readiness of the selected performance tests for full implementation.	• NCHRP Project 20-07/Task 406 process • Collaborative effort between SHA & industry.
Step 3. Assess overall appropriateness of each of the candidate performance tests for routine use.	• SHA & Contractors needs, capabilities, resources, etc. • Factors: sample prep, spec conditioning & testing, training needs & applicability, equip cost, repeatability, material sensitivity, field validation.
Step 2. Identify candidate performance tests that can be or have historically been used.	• Failure mechanisms of the targeted modes of distress. • Associated performance tests.
Step 1. Identify primary asphalt pavement modes of distress.	• Intended application (new, major rehab, mill & overlay). • Road classification, traffic, and geographical location. • Commonly-observed field distresses.

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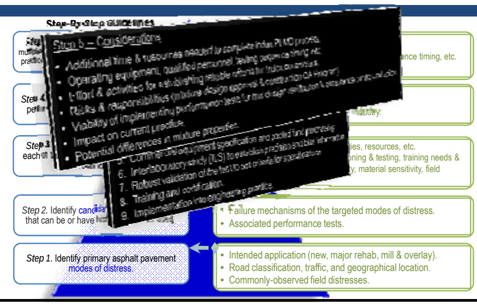
Index PEMD: Performance Test Selection
PROCESS



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Index PEMD: Performance Test Selection Considerations

- *Step 1.* Identify primary asphalt pavement modes of distress to be considered.
  - Considerations:
    - Intended application (new construction, major rehabilitation, mill & overlay).
    - Mixture design.
    - Commonly-observed field distresses.
- *Step 2.* Identify candidate performance tests that can be or have historically been used to estimate mixture resistance to the identified modes of distress (Step 1).
  - Considerations:
    - Failure mechanisms of the targeted modes of distress.
    - Associated performance tests.

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Index PEMD: Performance Test Selection Considerations (Cont'd)

- *Step 3.* Assess overall appropriateness of each of the candidate performance tests (Step 2) for routine use in an index PEMD process.
  - Considerations:
    - SHA & Contractors needs, capabilities, resources, etc.
    - Seven evaluation factors:
      - Sample preparation.
      - Specimen conditioning and testing.
      - Training needs & applicability.
      - Equipment cost.
      - Repeatability.
      - Material sensitivity.
      - Field validation.
    - Outcome: Select a performance test for each of targeted modes of distress for further evaluation in Step 4.

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Index PEMD: Performance Test Selection Considerations (Cont'd)

- *Step 4.* Assess the readiness of the selected performance tests for full implementation for available (local) materials in accordance with the process identified in NCHRP Project 20-07/Task 406.
  - Involves 9 essential steps (collaborative effort between SHA & industry):
    1. Draft test method and prototype equipment.
    2. Sensitivity to materials and relationship to other laboratory properties.
    3. Preliminary field performance relationship
    4. Ruggedness experiment
    5. Commercial equipment specification and pooled fund purchasing
    6. Interlaboratory study (ILS) to establish precision and bias information
    7. Robust validation of the test to set criteria for specifications
    8. Training and certification.
    9. Implementation into engineering practice.

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Index PEMD: Performance Test Selection Considerations (Cont'd)

- *Step 5.* Evaluate the implementation impacts of multiple performance tests on the current SHA & industry practice for designing & accepting asphalt mixtures.
  - Considerations:
    - Additional time & resources needed to complete index PEMD process.
    - Operating equipment, qualified personnel, testing sequence timing, etc.
    - Effort & activities for establishing reliable criteria for the index parameters.
    - Risks & responsibilities (mixture design approval and construction QA Program).
    - Viability of implementing performance tests for mix design verification & acceptance during production.
    - Impact on current practice.
    - Potential differences in mixture properties designed using index PEMD process as compared to those which have historically been designed based on AQCs & specifications.

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Step 3. Assess overall appropriateness

Sample Hierarchical Levels of Evaluation Factors

Evaluation Factor	Level A	Level B	Level C
Sample preparation			
- Sample preparation and Instrumentation (Number of activities per test sample).	Low (≤ 2)	Medium (≤ 5)	High (≥ 6)
Specimen conditioning and testing			
- Specimen conditioning time.	≤ 2 hours	≤ 5 hours	> 5 hours
- Testing time.	≤ 0.5 hour	≤ 5 hours	> 5 hours
Training needs and applicability			
- Training effort.	Low	Moderate	High
- Data analysis complexity.	Simple	Fair	Complex
- Lab-molded specimens and field cores.	Yes	–	No
- Field acceptance/quality control in mobile laboratory.	Yes	–	No
Equipment cost			
- New equipment acquirement.	≤ \$40,000	≤ \$100,000	> \$100,000
- Existing equipment modification.	≤ \$15,000	≤ \$40,000	> \$40,000
Repeatability			
- Single laboratory coefficient of variation (COV).	≤ 10%	≤ 25%	> 25%
Material sensitivity			
- Status of existing national and local sensitivity analyses.	Good	Fair	Poor
- Sensitivity significance level to acceptable changes in asphalt mixture component properties/proportions, air voids, and aging.	High	Moderate	Low
Field validation (based on status of existing efforts)			
- Status of existing national and local efforts.	Good	Fair	Poor
- Mechanistic/Mechanistic-Empirical analyses.	Yes	–	No

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Sample Evaluation of Performance Test Characteristics

- Assumptions for the presented Example:
  - Sample preparation: based on a single replicate test specimen.
  - Specimen conditioning & testing: based on respective durations for a single specimen using a single test equipment.
  - Training needs & applicability: Engineers & technicians are familiar with relevant equipment but not necessarily with standard test methods & associated data analyses.
  - Equipment cost: based on the estimated purchase of new equipment only.
  - Material sensitivity: not considered.
  - Field validation: assuming existing studies using available (local) materials to relate lab results to field performance for the development of tests criteria.

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Sample Characteristics of Durability/Cracking Performance Tests (Based on Assumptions Made)

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Summary

- Efforts to develop index & predictive PEMD processes.
  - Improve mix performance using performance testing.
  - Alternative project delivery methods, different mixture types & composition, asphalt additives & modifiers, recycled materials, etc.
- Informational brief.
  - Provides examples of performance tests in an index PEMD.
- Index PEMD process:
  - Index parameters determined using performance tests.
  - Should be correlated to field pavement performance.
  - Use of available (local) materials.
  - Used as go/no-go (pass/fail) design & acceptance criteria.

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Summary (Cont'd)

- A five-step procedure guideline:
  - *Process* for selection & incorporation of performance tests in an index PEMD (SHA and Contractor can use).
  - Implementation in asphalt mixture ***design & acceptance***.
  - Test selection in collaboration between *SHA & Industry*.
  - Performance tests selection depends on *specific needs, goals, capabilities, & resources*.

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Q & A

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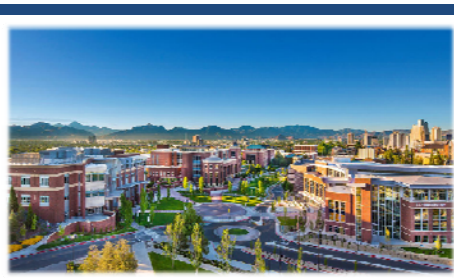

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