NCAT Balanced Mix Design (BMD) Update

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1

Overview

- Quick overview of BMD
- Completed and ongoing NCAT research related to BMD
- Questions to answer

2

What is BMD?

- BMD Task Force defined BMD as "asphalt mix design using performance tests on appropriately conditioned specimens that address multiple modes of distress taking into consideration mix aging, traffic, climate and location within the pavement structure."
- Long story, short
  - A design methodology which uses a rutting test and a cracking test to balance mixture performance

3

Why is BMD Needed?

- Concerns with the volumetric mix design system
  - Dry mixes with durability/cracking issues
  - Issues with accurately determining aggregate specific gravity
  - Volumetrics not adequately sensitive to mix variables (WMA additives, polymers, recycling agents, fibers, etc.)
- Move to performance based testing
  - Design for performance instead of just to "the specifications"
  - Understand design factors that drive performance

4

Differing Approaches by State

- Experience and preference on performance tests
  - Texas overlay (OT)
  - Illinois Flexibility Index (I-FIT)
- Pavement distress considerations
  - Top-down cracking
  - Thermal cracking
  - Reflective cracking
- Intended mix applications
  - High recycled mixes
  - Thin overlay mixes

5

Expected Impacts of BMD

- Higher asphalt contents
- Increased use of additives/modifiers
- Greater investment in lab equipment
- More time to complete mix design
- **Greater freedom to innovate**
- **Improved pavement performance**
- **Extended pavement service life**

6

Ongoing NCAT Research

- NCHRP 20-07 Task 406 (Recently completed)
  - Development of a Framework for BMD
- WHRP 0092-16-06 (Recently completed)
  - Regressing Air Voids for Balanced HMA Mix Design
- 2015 NCAT Southern Cracking Group Experiment
- 2016 MnRoad Northern Cracking Group Experiment
- 2018 Test Track Research Cycle
- BMD Production Testing Study
- NCAT Performance Testing Round Robin

7

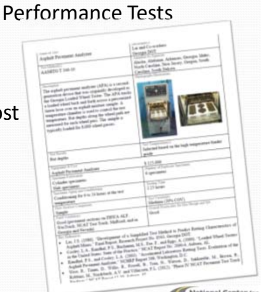
NCHRP 20-07 Task 406

- Development of a Framework for BMD
- Contains…
  - National Survey of State DOTs and Asphalt Contractors
  - Literature Review on State of the Practice for Asphalt Performance Testing
  - Preliminary Draft of AASHTO Standard Practice and Specification for BMD
  - Identifying Knowledge Gaps and Developing Research Needs

8

NCHRP 20-07 Task 406

- Overview of Asphalt Mixture Performance Tests
  - Procedure
  - Results
  - Equipment and Approx. Cost
  - Specimen Fabrication
  - Testing Time
  - Complexity of Analysis
  - Variability
  - Field Validation
  - Overall Practicality



West et al. (2018)

9

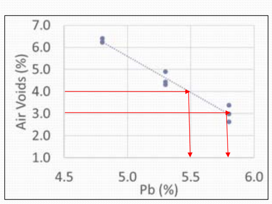
Identifying Knowledge Gaps

1. Develop draft test method and prototype equipment
2. Evaluate sensitivity to materials and relationship to other lab properties
3. Establish preliminary field performance relationship
4. Conduct ruggedness experiment
5. Develop commercial equipment specification and pooled fund purchasing
6. Conduct round-robin testing
7. Robust validation to set specification criteria
8. Training and certification
9. Implement into engineering practice

10

WHRP Regressed Air Voids Study

- Regressed Air Voids
  - Design mix to 4.0% air voids and meet volumetric requirements
  - Add virgin binder to reach design air voids of 3.5% or 3.0%



11

WHRP Regressed Air Voids Study

- Evaluate impact of air void regression on 6 WI mix designs
  - 4.0, 3.5, 3.0% air voids
  - Hamburg, I-FIT, DCT
- Air void regression from 4.0 to 3.0% design air voids resulted in 0.3% to 0.4% higher design AC contents

12

WHRP Regressed Air Voids Study

- For the mixtures evaluated, air void regression generally…
  - Did not compromise rutting resistance in the Hamburg
  - Improved intermediate temperature cracking resistance using the I-FIT
  - Did not statistically improve low temperature cracking resistance in the DCT
- Regressed air voids concept can be used as a bridge to BMD Implementation

13

MnROAD/NCAT Cracking Group Experiments

NCAT Test Track

Top-Down Cracking

MnROAD

Low-Temperature Cracking

14

Southern Cracking Group (CG)

- 7 Test Sections
- Common Structure
  - Subgrade, Aggregate Base, Base and Binder Mixture
- 7 Unique Surface Mixtures
  - Wide Range of Expected Cracking Resistance
- Top-Down, Load-Related Cracking
- Intermediate Temperatures
- Compare Field Cracking Performance to Laboratory Cracking Test Results
- Constructed in 2015

15

Southern Cracking Group (CG)

Section	Description	Rutting (mm)	Δ IRI (in/mi.)	Δ MTD (mm)	Cracking (% of lane)
N1	20% RAP (Control)	1.7	3	0.4	21.5*
N2	Control w/ High Density	2.2	7	0.5	6.2*
N5	Low AC, Low Density	1.2	5	0.4	5.0*
N8	20% RAP, 5% RAS	1.2	13	0.7	16.9
S5	35% RAP, PG 58-28	1.5	1	0.5	0
S6	Control w HiMA	1.4	10	0.6	0
S13	AZ Rubber Mix	2.8	3	0.1	0

- * = Low Severity Hairline Cracking
- Performance after 1 research cycle (~10 million ESALs)
- Trafficking to continue in 2018 Test Track Research Cycle

16

Southern Cracking Group (CG)

- Development of Critical Aging Protocol (CA)
  - Target 70,000 Cumulative Degree Days
  - 3-5 years of field aging in Alabama
  - 8 hrs. at 135°C on loose mix for Test Track Materials
- Testing Plan
  - 2 aging conditions (STOA/RH and Critically Aged)
  - X 2 production methods (LMLC and PMLC)
  - X 6 cracking tests (I-FIT,SCB-Jc,ER,OT-TX,OT-NCAT, IDEAL-CT)
  - X 7 unique surface mixes
  - = 168 sets of specimens

17

Southern Cracking Group (CG)

- Preliminary results presented at 2018 Test Track Conference
- Draft Report (18-04D) on NCAT website
- For these mixes, good correlation between 4 of the 6 cracking tests
  - I-FIT, IDEAL-CT, OT-TX, OT-NCAT
  - Generally identified first mix to crack and have the mixes with no cracking among the top performers after one cycle of traffic
  - Will use final field cracking results to develop lab to field correlations

18

Northern Cracking Group (CG)

- Constructed on MnROAD Mainline during Summer and Fall of 2016
- Establish lab to field correlations between pavement performance and laboratory cracking tests
- 8 Test Sections
  - Same Pavement Structure
  - Asphalt mixes with varying degrees of cracking potential
  - Focused on thermal cracking but will quantify other types of cracking as well

19

Northern Cracking Group (CG)

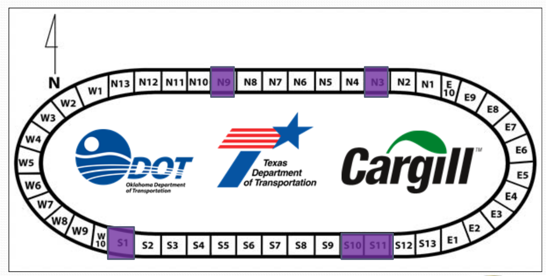
Cell #	NMAS	Design RAP (%)	Design RAS (%)	QC Total ABR %	Virgin Binder Grade	QC Total AC (%)	Ndes
C16 (20% RAP/5% RAS)	12.5	20%	5%	42%	64S-22	5.0	80
C17 (10% RAP/5% RAS)	12.5	10%	5%	28%	64S-22	5.3	80
C18 (20% RAP/PG 64S)	12.5	20%	0%	24%	64S-22	5.1	80
C19 (Cell 18 w/ +binder)	12.5	20%	0%	22%	64S-22	5.7	100
C20 (30% RAP/52S-34)	12.5	30%	0%	37%	52S-34	5.0	80
C21 (20% RAP/58H-34)	12.5	20%	0%	24%	58H-34	5.2	80
C22 (Cell 21 w/ LMS)	9.5	20%	0%	23%	58H-34	5.4	80
C23 (15% RAP/ HiMA)	12.5	15%	0%	18%	64E-34	5.2	80

Northern Cracking Group (CG)

- Laboratory Testing Plan
  - DCT, I-FIT, IDEAL-CT, OT, Low Temperature IDT, Beam Fatigue
  - Critically Aged Testing ongoing
    - 6 hours at 135°C on loose mix
    - Simulate 4 to 5 years of aging in Minnesota
- Traffic ongoing but no thermal cracking has occurred yet

21

2018 NCAT Test Track – BMD Sections



22

Experiment Objectives

Implementation of performance testing and criteria for BMD

Performance comparison for BMD versus volumetric mixes

Implementation of BMD procedures in asphalt mixes containing rejuvenators and high RAP levels

23

2018 Test Track – Cargill BMD

- Two surface mixes on Test Track
  - Control: 30% RAP, PG 64-22
  - Experimental: 45% RAP, PG 64-22 with Anova
- Both designed as BMD mixes to meet VDOT Performance Requirements
  - APA, Cantabro, IDEAL-CT

24

2018 Test Track – ODOT BMD

- Hamburg and I-FIT used during the design process
- Section N9
  - 1.5” Mill and Inlay
  - Volumetric Design with Performance Verification
- Section S1
  - 5.5” mill and inlay (2 lifts)
  - Performance Modified Volumetric Design
    - Select 3 initial AC contents
    - Determine Opt AC based on I-FIT and Hamburg
    - Verify Volumetric Properties

25

2018 Test Track – TxDOT BMD

- HWTT for rutting and moisture resistance
  - Max. rut depth of 12.5 mm at 50°C
- Overlay Test (OT) for cracking resistance
  - Min. critical fracture energy (G_c) of 1.0 in.-lb/in.^{2}
  - Max. crack progression rate (β) of 0.45 (surface)

26

2018 Test Track – TxDOT BMD

- 2.5 in. mill and inlay
- S10 BMD, S11 volumetric control
- Designed by University of Texas at El Paso (UTEP)
  - TxDOT 12.5mm SP-C surface mix
  - PG 70-22 binder
  - 20 percent RAP binder replacement ratio
- Volumetric design with performance verification

27

BMD Production Testing Study

- 5 mixtures produced and placed on the 2018 NCAT Test Track
- Produce hot-compacted (no reheating) specimens for each of these five mixes for commonly used rutting and cracking tests
  - Hamburg, High Temp IDT, I-FIT, OT, IDEAL-CT
- When a mix is tested in different ways, how different are the results?

Design Lab-Mixed Lab-Compacted (LMLC) ↔ Production Plant-Mixed Plant-Compacted (PMLC) ↔ Re-heated Plant-Mixed Plant-Compacted (RPMLC)

28

BMD Production Testing Study

- Why is this important?
  - If tests are used for pay, how are results impacted by mix type and handling conditions?
    - If a contractor designs a mix to a FI value of 8, would he still get that value when the mix is produced in the field?
    - If a contractor and agency are comparing results for QA, will they get different values if one is using re-heated plant mix and the other is making hot compacted specimens?
  - Is it feasible to use more rapid surrogate tests during production?

29

NCAT Performance Testing Round Robin

- Sampled 200 buckets of one mixture during Test Track construction
- 50 labs have agreed to participate
- Labs selected test(s) they wanted to run
  - HB, I-FIT, APA, IDEAL-CT, OT, DCT
- Better grasp on between lab results for multiple performance tests
- Mix and instructions shipping soon

30

Questions to Answer

- Ruggedness experiments to refine performance tests
- Precision statements for performance tests
- How to address performance testing during production?
- QC/QA?
- Training materials and courses
- What cracking test(s) best predict field performance?
- How should mixture aging be addressed during mix design and production?

31

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Thanks!

32

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