Development of a New Generation of Durable OGFC Mixtures with Binder Modification

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SEAUPG Annual Meeting
November 18 – 20, 2025
Charleston, West Virginal

Acknowledgement

- Dr. Anas Abualia
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Mohammad, L. N., Abualia, A., and Liu, J., "Development of a Standard Practice for the Design of Durable Open-Graded Friction Course (OGFC) Mixtures with Epoxy Asphalt. Report No. FHWA/LA.24/696, LTRC, Baton Rouge, LA, 2024.

Development of AI-Based Prediction Models to Evaluate Long-Term Aged Cracking Resistance in Asphalt Mixtures Using SCB Jc Parameter

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Key Topics

- Background
  - Benefits and Challenges
- Objective/Scope
- Experimental Design
- Results
- Takeaways
- Implementation
  - Specification revision

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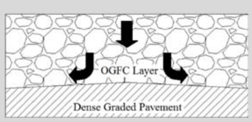
Background - Benefits

- Surface Rehabilitation Treatment
  - Thin asphalt mixture layer
    - » 0.75" to 1.5" thick
  - High air void contents
    - » 15% +
  - Porous
  - Stone-on-stone structure
- Improve safety
  - Reduce hydroplaning
  - Rapid water drainage
- Improve friction
- Reduce traffic noise
- Functional / structural

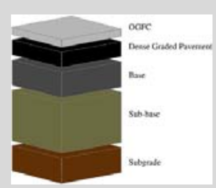


With OGFC

Without OGFC

Background - Challenges

- Durability
  - Raveling
  - Moisture damage
  - Stone-on-stone structure
- Bonding with underlying layer
  - Improper tack coat type/application/coverage
- Higher Maintenance Needs:
  - Debris clog high air void space
  - Reduce water drainage
- Higher cost
  - Quality component materials



Background
LDOTD Specification – Table 501-1

Mix Type	OGFC
Asphalt Cement Grade	PG 76-22m
Gyratory Revolutions [1]	50
Minimum AC content, %	6.5
Air Voids, % [2]	18-24[3]
Sands, Max. %	0
RAP, Max %	0
LWT rut depth, 12 mm (max) @ no. passes, AASHTO T 324[4]	5000
Draindown, % max [5]	0.30
Water Susceptibility, Boil Test, DOTD TR 317, % min	90
Min.Tack Coat Application Rate, Undiluted gal/sq.yd. (0.40 gal/sq.yd maximum) [6]	0.15

Objectives

- Develop a rational mix design methodology to improve the ***durability*** of OGFC asphalt mixtures
  - –Assess effect of various ***asphalt binder types***
    - » Asphalt Binder Experiment
    - » Asphalt Mixture Experiment
- Quantify ***structural contribution*** of OGFC asphalt mixtures
  - –Functional / Structural
  - –Performance Prediction Model

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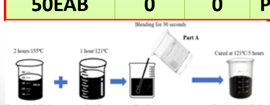
Scope

- 12.5 mm NMAS
- Materials
  - – Asphalt Binders
    - » PG 76 - 22
      - SBS - Control
      - Hybrid SBS/CR
    - » PG 88 -28
      - High SBS
    - » PG 70 - 22
      - Epoxy modification
      - 25%, 50%
- Materials
  - – Aggregates
    - » Limestone
    - » Sandstone
  - – Additives
    - » Cellulose Fibers

Scope

- **Asphalt Binder Types**

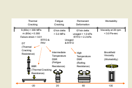
Binder/Mix ID	SBS, %	CR, %	Epoxy Modification	
			Base	Resin/Curing Agent, %
76M	3.5	0	PG 67 - 22	N/A
88HS	7.5	0	PG 67 - 22	N/A
76CS	1.5	6.5	PG 67 - 22	N/A
25EAB	0	0	PG 67-22, 75%	25
50EAB	0	0	PG 67-22, 50%	50

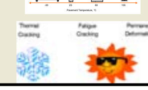


Epoxy resin

Scope:

- ***Asphalt Binder Experiment***
  - ***Microstructure analysis, Storage stability***
    - ***Epoxy Modified Asphalt***
    - ***colloidal stability/chemical compatibility b/w EA components source of base asphalt binder***
  - **Chemical characterization**
    - **Saturates, Aromatics, Resins, Asphaltenes (SARA)**
      - **Separate asphalt molecules into 4 fractions based on solubility/polarizability and polarity**
      - **Oxidative aging behavior and performance**
    - **Fourier-transform Infrared Spectroscopy (FTIR)**
      - **Aging and cracking behavior**
  - **Rheological characterization**
    - **Performance grading**
    - $\Delta T_c = T_S - T_m$
    - **Frequency sweep test at multiple temperatures**
    - **Linear amplitude sweep (LAS)**
    - **Multiple stress creep recovery (MSCR)**





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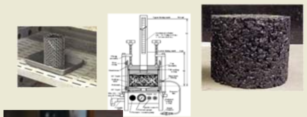
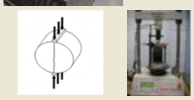
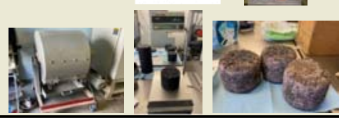
Scope

- Asphalt Mixture Experiment
  - Draindown Test
  - Falling Head Permeability Test
  - Hamburg Wheel-Track Test
    - » *Rutting*
      - Rut depth at 5K passes
  - Indirect Tensile Strength Test
    - » *Moisture damage*
      - TSR
  - Cantabro Abrasion Loss Test
    - » *Durability*
      - Abrasion loss
      - LTA, 5d, 85C



Mix Design

- Develop stable aggregate structure
  - stone-stone-contact
- Optimized based on
  - minimum required air voids
    - » permeability
  - voids in coarse aggregate, VCA_{drc}.

$VCA_{mix} \leq VCA_{drc}$
Air voids ≥ 18.0%

Develop VCA parameter

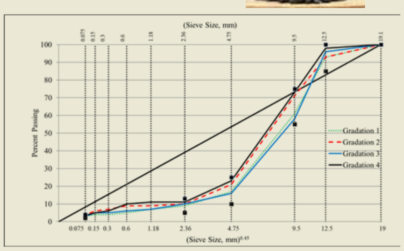
Mix Design

- Three candidate gradations
  - Louisiana practices and literature
- Compute voids in coarse aggregate, VCA_{drc}
  - ensure a coarse aggregate skeleton with stone-on-stone contact

$$VCA_{drc} = \frac{G_{sb\,CA}*\gamma_w - \gamma_s}{G_{CA}*\gamma_w}$$

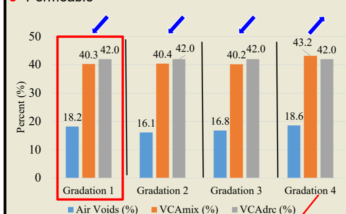
$$VCA_{mix} = 100 - \left[\frac{G_{mb}}{G_{sb\,CA}} * P_{CA}\right]$$

$VCA_{mix} \leq VCA_{drc}$
Air voids ≥ 18.0%



Mix Design

- Develop stone-stone-contact
- Permeable



Develop VCA parameter

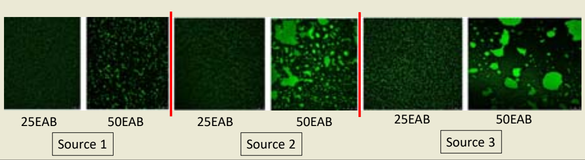
$VCA_{mix} \leq VCA_{drc}$
Air voids ≥ 18.0%

Gradation 4:
Meets Table 501-1 but does not comply with VCA requirement

Results: Compatibility Base Binder

Microstructure Analysis for Epoxy Asphalt Binder

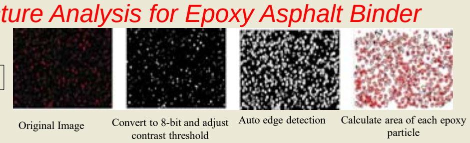
Confocal Laser-Scanning Microscopy (CLSM) Imaging

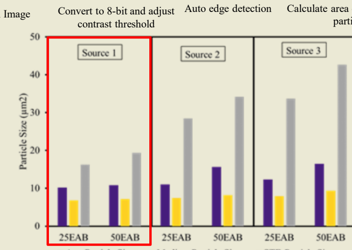


Results: Compatibility Base Binder

Microstructure Analysis for Epoxy Asphalt Binder

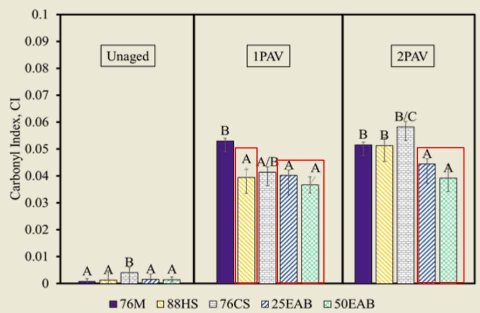
ImageJ Software





Results: Asphalt Binder Experiment – Aging Level

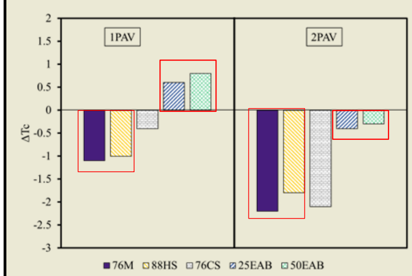
Fourier Transform Infrared Spectroscopy (FTIR)



- O_2 Molecules
- CI
- SBS and EA Modifications
- SBS: physical, reversible reaction
- degradation SBS network during long-term aging
- EA is chemical reaction that is irreversible once fully cured

Results: Asphalt Binder Experiment

Thermal Cracking resistance / relaxation at Low Temperature:



$\Delta T_c = T_S - T_m$

EABs
good low-temp cracking resistance

Summary of Asphalt Binder Experiment

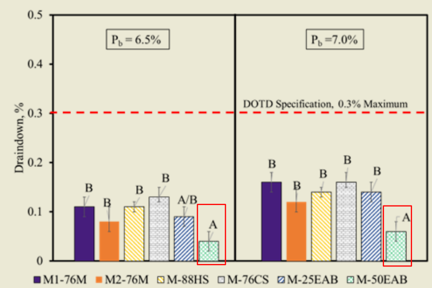
Compared to Control PG 76 – 22 Asphalt Binder

Binder Type	High Temp MSCR	Intermediate Temp	Low Temp	
PG 88 - 28	+	+	+	100
PG 76 – 22 Hybrid	=	=	=	
PG 70 – 22 25EAB	–	=	+	
PG 70 – 22 50EAB	–	+	+	67

Results: Asphalt Mixture Experiment

Asphalt Draindown

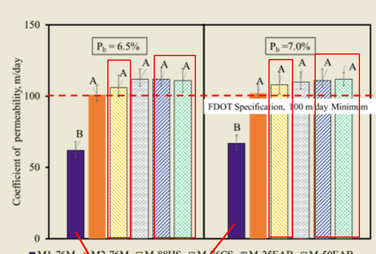
M1-76M: Mixture meeting DOTD aggregate gradation but does not meet VCA requirement
M2-76M: Mixture meeting DOTD aggregate gradation and VCA requirement



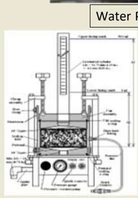
Asphalt Draindown

Results: Asphalt Mixture Experiment

Permeability



Water Permeability

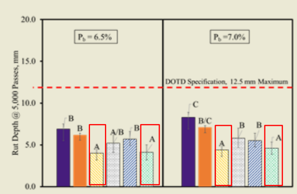


Gradation 4:
Does not comply with water drainage requirement

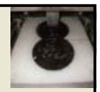
Results: Asphalt Mixture Experiment

Permanent Deformation

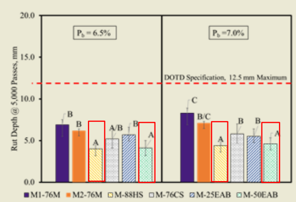
Permanent Deformation



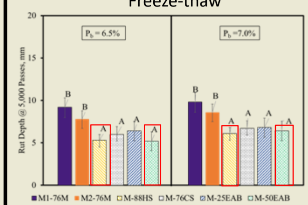
Results: Asphalt Mixture Experiment
Permanent Deformation and Moisture-damage



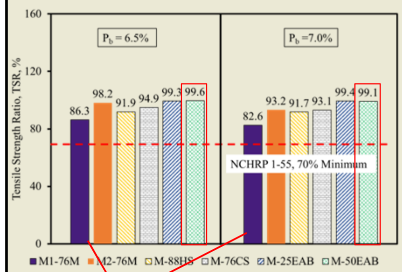
Permanent Deformation



Moisture Damage
Freeze-thaw

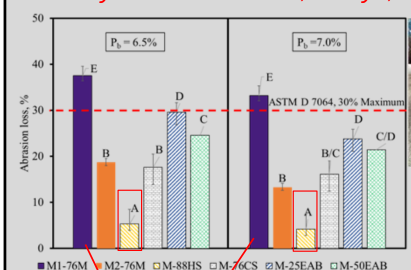


Results: Asphalt Mixture Experiment
Moisture Susceptibility

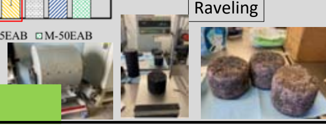


Gradation 4:
Lowest TSR

Results: Asphalt Mixture Experiment
Durability -- Abrasion Loss, 5 days, 85°C

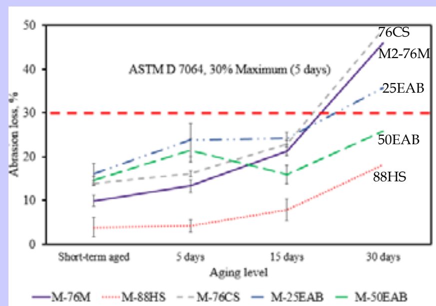


Raveling



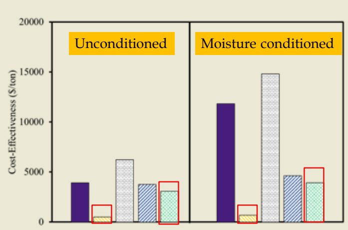
Gradation 4:
Does not comply with Abrasion Loss requirements

Results: Asphalt Mixture Experiment
Durability -- Abrasion Loss, 5 days, 85°C



Raveling

Results: Cost Effectiveness



$\mathrm{CER} = \frac{C}{E}$

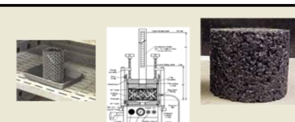
$E = \frac{50\% - \mathrm{CL\ at\ 30\ days}}{\mathrm{CL\ at\ 30\ days}}$

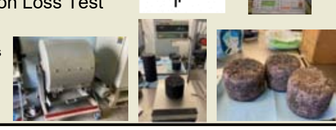
CER: cost effectiveness, $/ton
C: cost/ton of each asphalt binder, $/ton
E: normalized abrasion loss
50%: failure threshold of Cantabro abrasion loss
CL: Cantabro loss (%)

A lower CER value is desired as it indicates that a particular mixture has a higher overall effectiveness in terms of durability and cost

Scope

- Asphalt Mixture Experiment
  - Draindown Test
  - Falling Head Permeability Test
  - Hamburg Wheel-Track Test
    - » ***Rutting***
      - Rut depth at 5K passes
  - Indirect Tensile Strength Test
    - » ***Moisture damage***
      - TSR
  - Cantabro Abrasion Loss Test
    - » ***Durability***
      - Abrasion loss
      - LTA, 5d, 85C





Summary of Asphalt Mixture Experiment *as Compared to Control PG 76 – 22 Mixture (LDOTD Design)*

Test	PG 76-22	PG 88-28	PG 76-22 Hybrid	PG 70-22 25EAB	PG 70-22 50EAB
Permeability	+	+	+	+	+
Draindown	=	=	=	=	+
LWT	=	+	=	=	+
TSR	+	+	+	+	+
Cantabro	+	+	+	+	+
	3	4	3	3	5

Summary of Asphalt Mixture Experiment *as Compared to Control PG 76 – 22 Mixture (LDOTD Design)*

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Permeability	+	+	+	+	+
Draindown	=	=	=	=	+
LWT	=	+	=	=	+
TSR	+	+	+	+	+
Cantabro	+	+	+	+	+
	3	4	3	3	5

Takeaways

- **Mixture Design**:
  - Stone-on-stone contact
  - stable aggregate structure
- **Use Asphalt Binder Modification**
  - EAB: ensure compatibility
    - » Base binder
  - 88HS and 50EAB exhibited improved **permanent deformation** and **cracking**, and **aging resistance**.
- **Asphalt Mixture Experiment**:
  - Mixture containing **PG 88-28** and **PG 70-22 50EAB** exhibited improved parameters compared to conventional mixture **PG 76-22M**
    - » Drain down, LWT rut, TSR, and Cantabro

Takeaways

- **Cost Effectiveness**:
  - Mixture containing PG 88-28
  - most cost-effective followed
  - PG 70-22 -→ 50EAB
- **Function / Structural**:
  - Increased performance – 1” Layer
    - » ~ 20%

Limitation of Current Specification

- Selection of aggregate structure
- Moisture damage
- Water drainage
- Ravelling

Implementation

Recommended Specification Changes

Proposed Table 501-1
Asphalt Mix Design Requirements

Mix Type	Current OGFC	Revised OGFC
Asphalt Cement Grade	PG 76-22m	50EAB or PG 88-28
Stone-on-stone contact, ASTM D 7064	na	$VCA_{mix} \leq VCA_{drc}$
Gyratory Revolutions[1]	50	50
Minimum AC content, %	6.5	6.5
Air Voids, %[2]	18-24[3]	18-24[3]
Sands, Max. %	0	0
RAP, Max %	0	0
LWT rut depth, 12 mm (max) @ no. passes, AASHTO T 324[4]	5000	5000
Water Susceptibility, LWT rut depth, 12 mm (max) @ no. passes, Freeze-thaw conditioned samples, AASHTO T 283	na	5000
Draindown, % max[5]	0.3	0.3
Water Susceptibility, Boil Test, DOTD TR 317, % min	90	na
Durability, Cantabro Abrasion Loss, AASHTO T 401, % max	na	30[6]
Water permeability, Falling Head Permeability, m/day min	na	100

Premium binder alternatives

Rational design methodology

Moisture damage evaluation

Test removal

Cantabro test

Permeability test


THANK YOU
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