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Development of Design and Construction Specifications of Full-Depth Reclamation with Emulsified and Foamed Asphalt for NJDOT

Yusuf Mehta Ph.D., P.E.

Center for Research and Education in Advanced Transportation Engineering Systems (CREATES), Rowan University

creates@rowan.edu

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In This Presentation…

- Background
- Goal & objectives
- Summary of literature review
- Performance evaluation of FDR mixes
- Survey questionnaire
- Preliminary recommendations for NJDOT FDR design and construction specification

Background

- **Full-depth reclamation (FDR)** is a rehabilitation process consisting of reclaiming deteriorated asphalt pavement to a depth of up to 14 in.

- Similar benefits to CIR: economical, environmental, and construction-based.

Example of FDR Process [1]

Problem Statement

- Design and construction specifications for FDR is not available for several highway agencies and state DOTs.
- NJDOT allows only the use of cement for FDR
- Several mix design methods have been developed to improve the performance of FDR by introducing bituminous additives.
  - The outcomes of these studies can be used to update the current NJDOT specification for FDR

Goal and Objectives

- **Goal**: Review, research & enhance the existing NJDOT Full Depth Reclamation (FDR) specifications
- **Specific Objectives**
  - Conduct a thorough review pertaining to FDR
  - Evaluate the laboratory performance of FDR with and without bituminous additives
  - Distribute a survey questionnaire to FDR subject matter experts (SMEs)
  - Recommend edits to the current NJDOT FDR design and construction specification.

Selection of FDR Stabilizing Agents

To improve their long-term performance, FDR is stabilized using

1. Chemical stabilization

3. Bituminous stabilization

2. Mechanical stabilization

Selection of FDR Stabilizing Agents

Selection of the stabilization method depends on:

- ❑ Condition of the asphalt pavement to be rehabilitated using FDR
- ❑ Material availability
- ❑ Projected traffic level

Example

1. *When reclaimed aggregate base is clay and/or silty materials and Plasticity Index > 10 → chemical stabilization is recommended*
2. *When the thickness of the pulverized unbound base is high with large aggregates → bituminous stabilization is recommended*

Selection of FDR Stabilizing Agents

Criteria for selecting stabilizing agents vary between states:

- **PennDOT**: properties of RAP and soils, such as Plasticity index (PI), gradation, and percent passing sieve no. 200 sieve (P_{200}).

- **California DOT:** gradation of aggregate base, plasticity indices of both subgrade and base, and the R-value of the subgrade.

- **MnDOT:**
  - ❑ 50% RAP and 50% aggregate base (Emulsion is recommended)
  - ❑ 67% RAP and 33% aggregate base (Only cement)

Selection of Stabilizing Agents for FDR Based on the Properties of Pulverized Material

Stabilizing Agent	Properties of Pulverized Material	Pulverized Material											
		Well graded gravel	Poorly graded gravel	Silty gravel	Clayey gravel	Well graded sand	Poorly graded sand	Silty sand	Clayey sand	Silt	Lean clay	Elastic Silt	Fat Clay or with Sand
Emulsion	PI < 6 and P_{200} < 20%	Yes	Yes	Yes	Yes	Yes	Yes	Yes	-	-	-	-	-
Foamed Asphalt	PI < 10 and P_{200} < 20% and P_{200} > 5%	Yes	-	Yes	Yes	Yes	-	Yes	-	-	-	-	-
Portland Cement	PI < 20 and SO_4 < 3000 ppm	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	-	-
Lime	PI > 25 and SO_4 < 3000 ppm	-	-	-	-	-	-	-	Yes	-	Yes	Yes	Yes

General FDR Mix Design Process

Field Sampling

Characterize Reclaimed Materials

Test	Method
Moisture content	AASHTO T265
Sieve analysis	PTM 616 (AASHTO T27)
Mechanical and hydrometer particle size analysis of soils	AASHTO T88
Liquid limit, plastic limit	AASHTO T89, T90
Moisture-density relationship	PTM 106
Unconfined compressive strength	AASHTO T220
Materials finer than No. 200 sieve	PTM 100 (AASHTO T11)

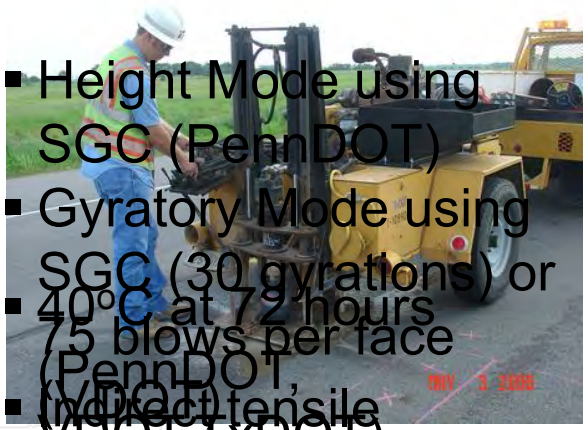
- **Portland cement or Lime** (1%, by weight) when bituminous additives are used, else (3% through 8%, by weight).
- **Water**: 3%

Compaction of Mixtures

- **Emulsion** (3% - 6%, 1% increment, by weight)
- **PG 64-22, PG 58-22, or PG 58-28 foamed asphalt** (2% - 3.5%, 0.5% increment, by weight)

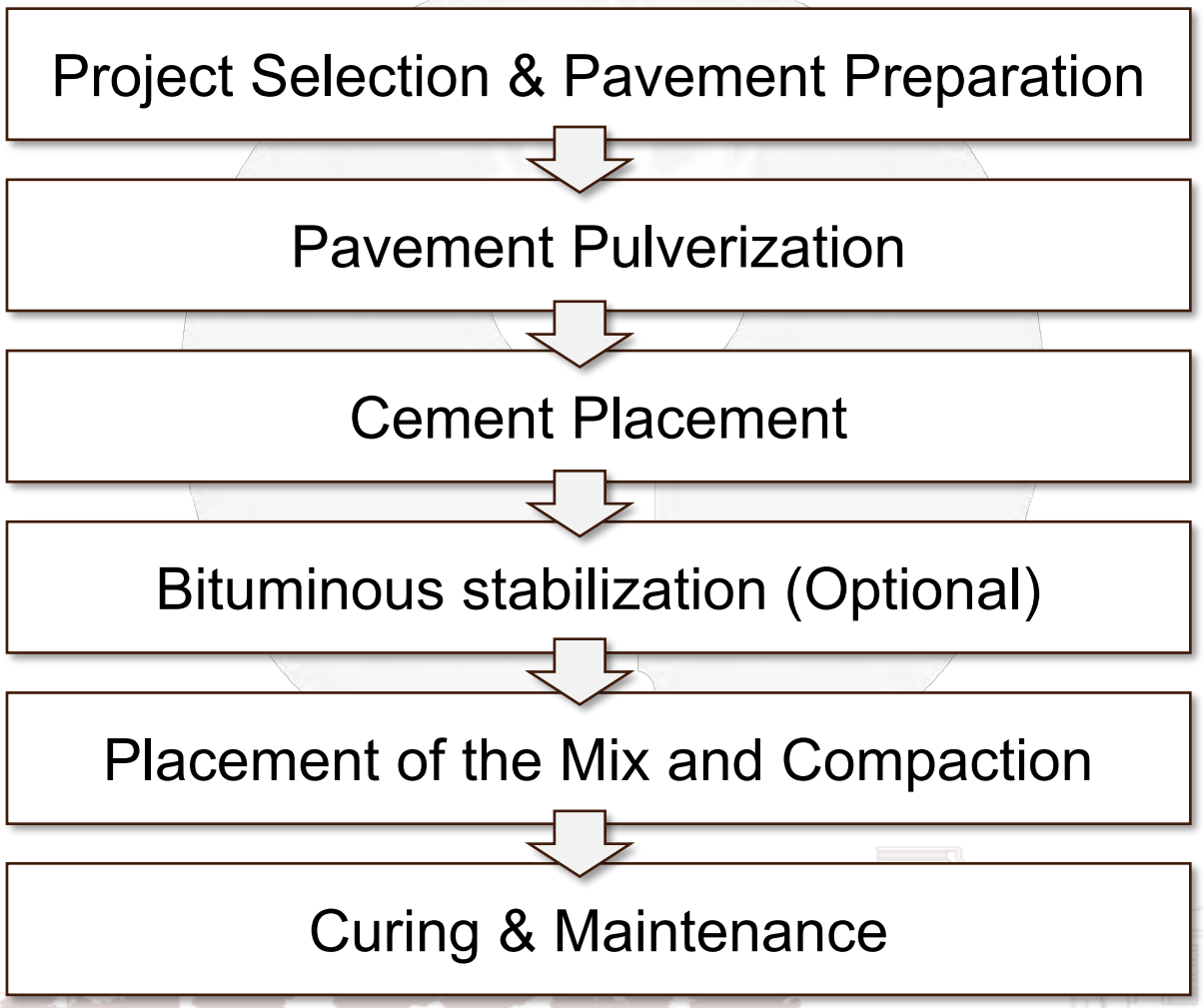
Curing

Performance Testing



- Height Mode using SGC (PennDOT)
- Gyratory Mode using SGC (30 gyrations) or 75 blows per face (PennDOT, VDOT, TxDOT)
- 40°C at 72 hours (VDOT, TxDOT)
- Indirect tensile strength
- Marshall stability

Best Practices for FDR Construction



Pulverization Depth

- Pulverization depth for FDR rehabilitation of flexible pavements: thickness of the existing asphalt layer.
- Typical pulverization depth ranges between 6 and 9 inches and rarely exceeds 12 inches.
- **ARRA:** pulverization depth - 4 to 12 inches depending on the thickness of the asphalt layer.
- **MnDOT:** most FDR projects consist of reclaiming the asphalt overlay along with 1 to 4 inches of the underlying aggregate base.

Pulverization Depth

- Asphalt overlay is relatively thick:
  - Milling machine can be used to mill up to 4 inches of the asphalt layer to allow for the FDR reclaimer to pulverize the pavement to the desired depth.

- Asphalt overlay is thin or the aggregate base layer is relatively thick:
  - Stabilizing agents (e.g., emulsified and foamed asphalt) are applied to the top 3 to 5 inches of the reclaimed aggregate base.

Recommendations

- IOWA-DOT and NJDOT recommend the use of Portland cement with or without corrective aggregates.
- NYSDOT, Penn DOT, MnDOT and VDOT allow the use of more stabilizers along with cement (*e.g., Portland cement and hydraulic cement*) such as lime, fly ash, emulsified asphalt, or foamed asphalt.
- NYSDOT, MnDOT, and PennDOT:
  - Recommend the addition of emulsified asphalt to the reclaimed material to improve cohesion and
  - Maximize the load bearing capacity of FDR mixtures

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Performance Evaluation of FDR Mixes

Material Selection

Materials (obtained from Asphalt Paving Systems Inc.)

- Reclaimed Asphalt Pavement (3 in.) and Soil (7 in.)
- Portland Cement
- CSS-1h Emulsion
- PG 64-22 Asphalt for foaming

FDR Mix Design Procedures

Determine the Characteristics of RAP and soil

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Mix RAP and soil with stabilizing agents

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Compact using SGC at 30 gyrations

↓

Allow to cure for 72 hours at 140°F

↓

Determine air void level using Corelok

↓

Evaluate the performance of FDR specimens

FDR Mixtures

Goal: Evaluate the impact of bituminous additives on FDR mixtures typically used in New Jersey

FDR Mixtures

Mix A: Only Cement

- Cement: 4%, 4.5, & 5% by weight
- Water: 3%, by weight
- Curing: 1 Week at Room Temperature

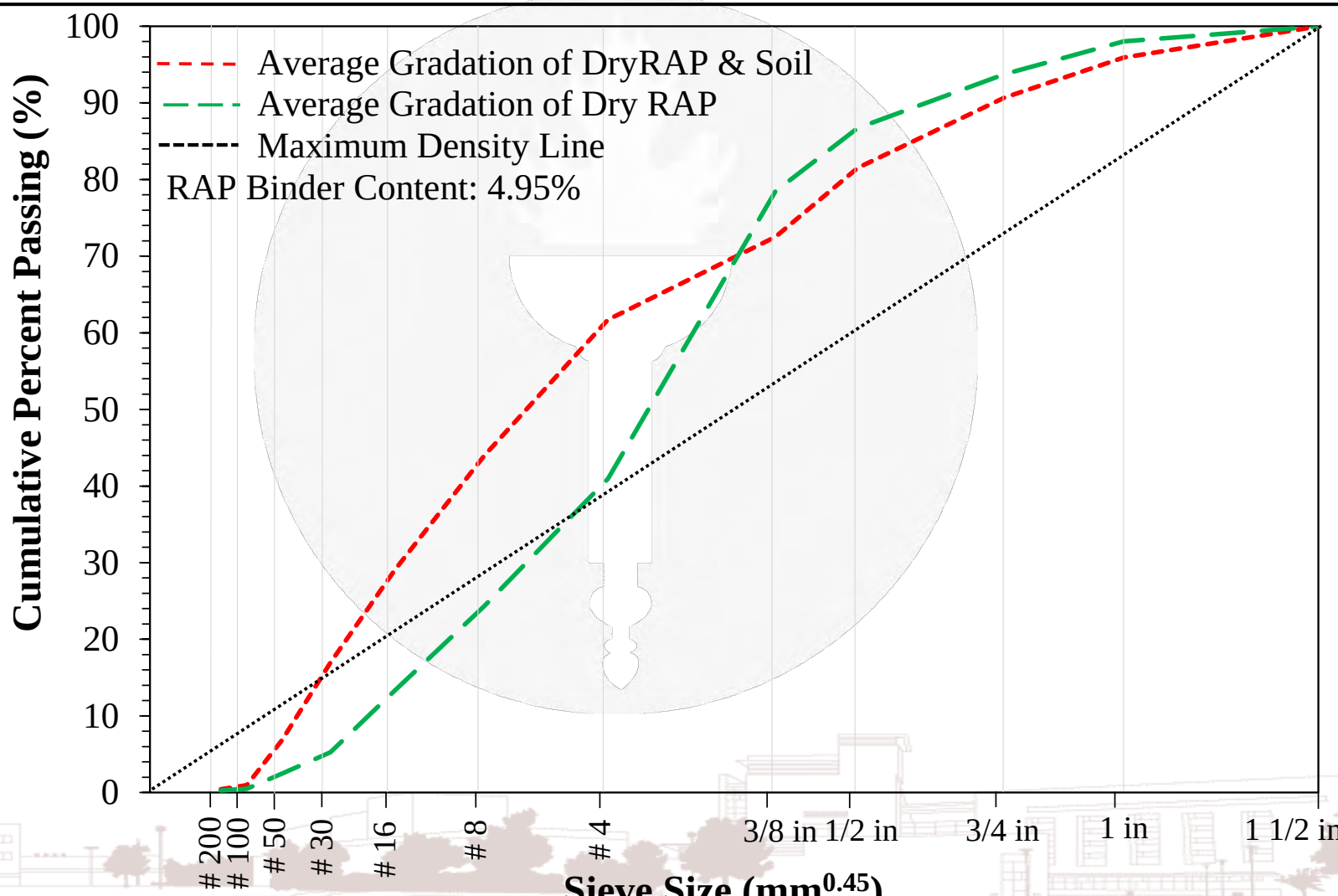
Mix B: Cement + Emulsion

- Cement: 1%, by weight
- Water: 3%, by weight
- Emulsion: 3%, 4%, and 5%, by weight
- Curing: 3 days at 140°F

Mix C: Cement + Foamed Asphalt

- Cement: 1%, by weight
- Water: 3%, by weight
- Foamed Asphalt: 3%, 4%, and 5%, by weight
- Curing: 3 days at 140°F

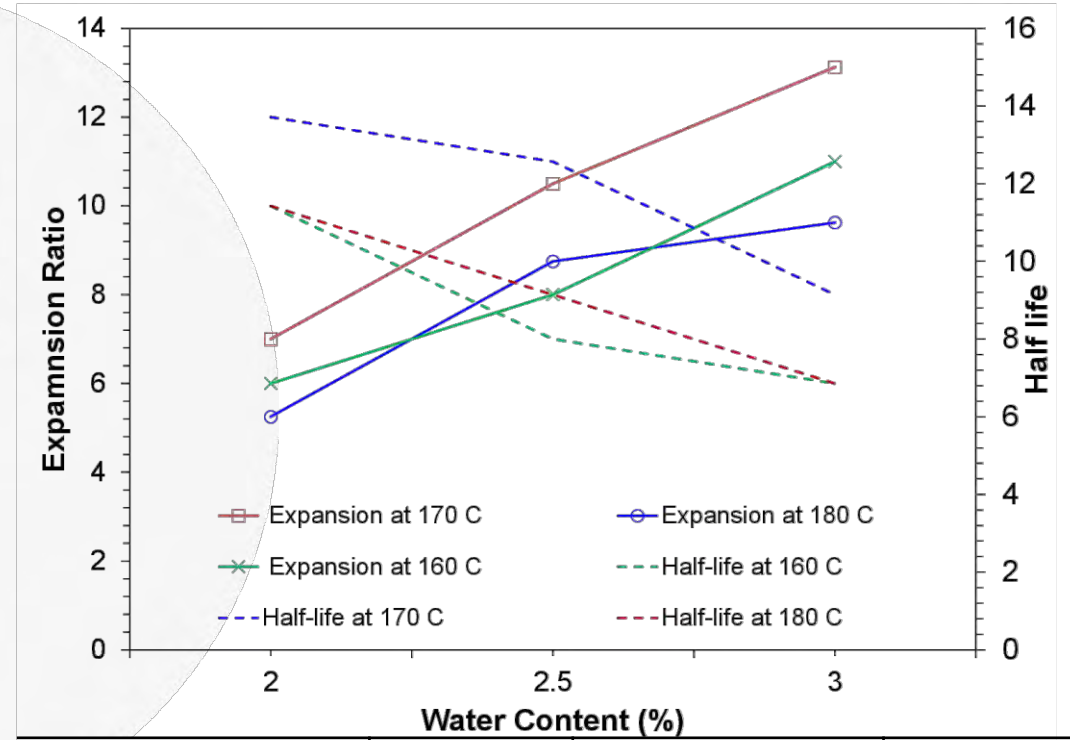
Sieve Analysis



Foaming Characteristics

Foaming Machine

Foamed Asphalt



Temperature (°C)	Half-Life (s)	Expansion Ratio	OWC (%)
160	7	8	2.5
170	11	12	2.5
180	7	10	3

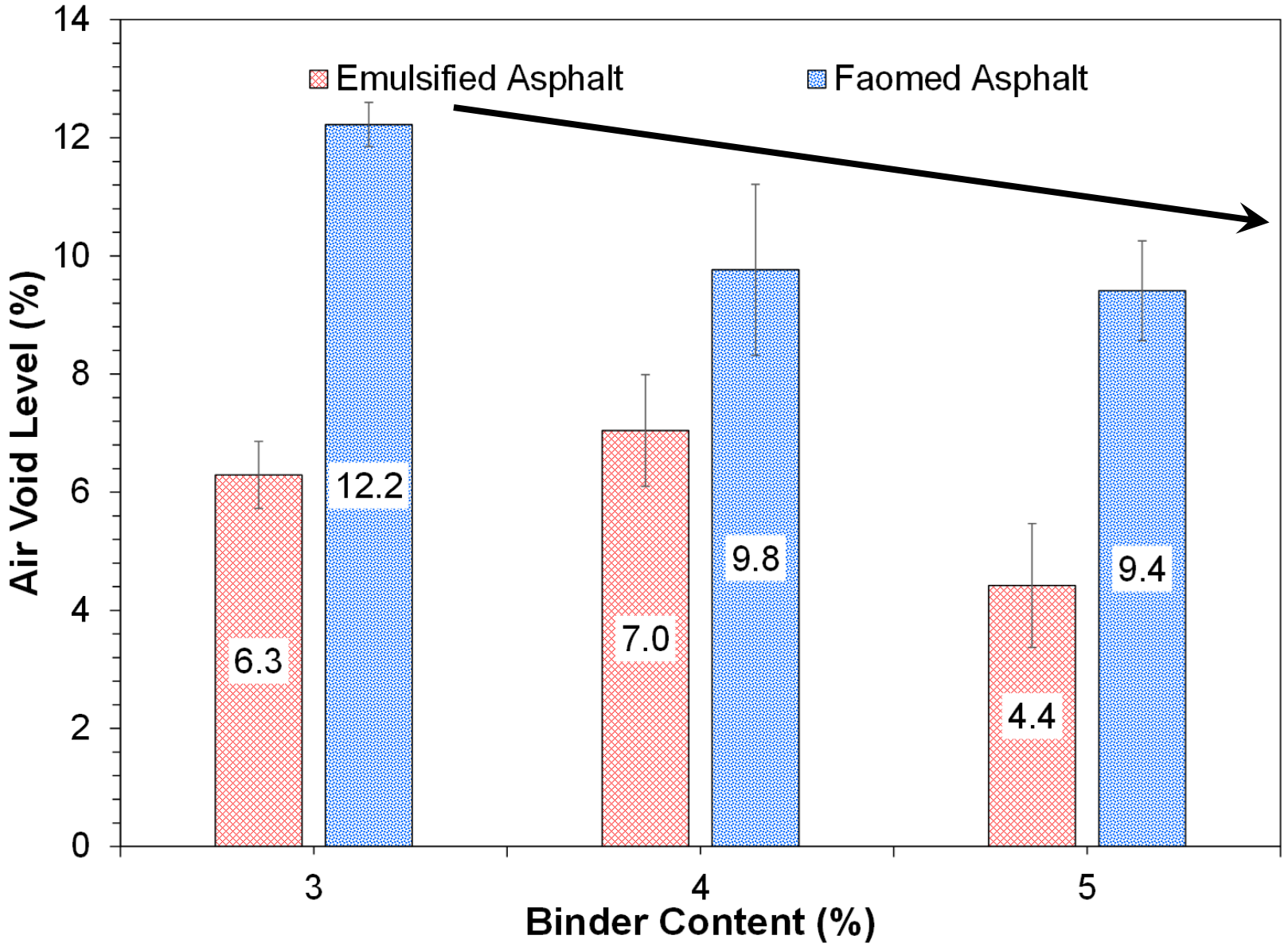
NJDOT: Half-life- 8s, Expansion ratio-10

FDR Specimen Production

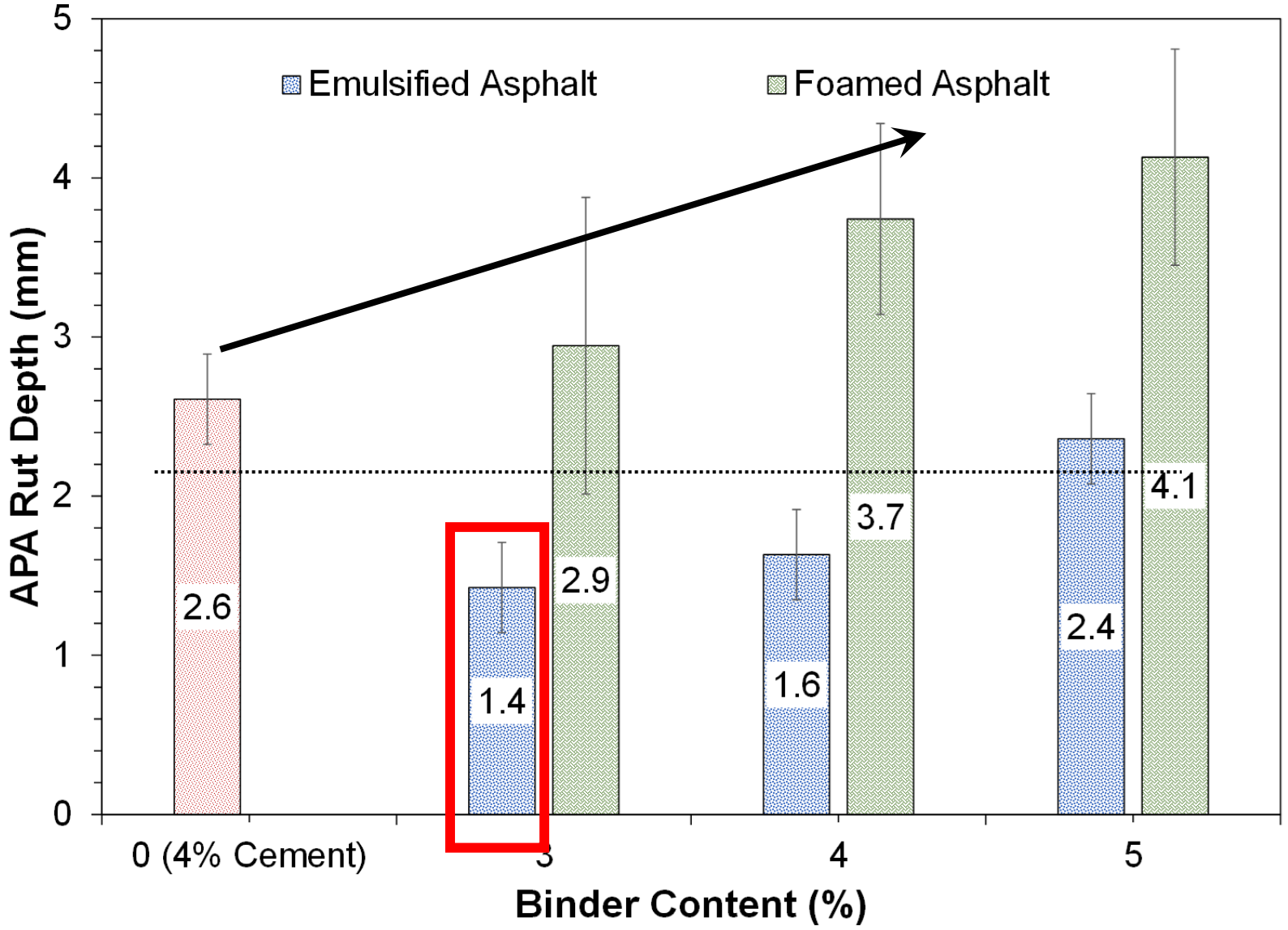
FDR at 4% cement and 3% water (Mix A)

FDR at 1% cement, 3% Emulsion and 3% water (Mix B)

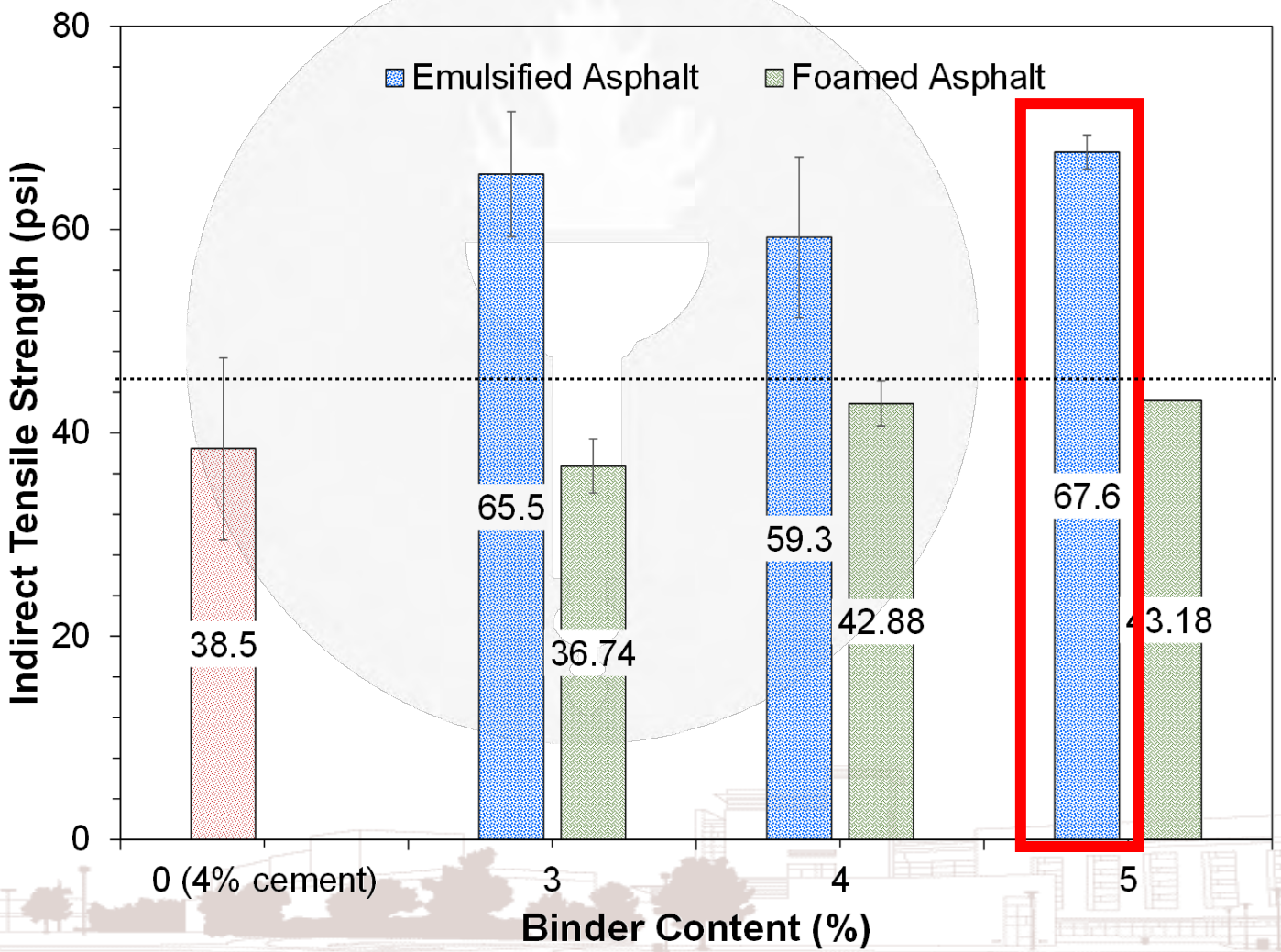
Air Voids


Emulsified Asphalt
Faomed Asphalt
Air Void Level (%)
0
2
4
6
8
10
12
14
6.3
12.2
7.0
9.8
4.4
9.4
3
4
5
Binder Content (%)

Rutting Performance (AASHTO T340)



Cracking Performance (ASTM D6931)



Summary of Findings

- Increasing the cement content from 4% to 5% improved:
  - Rutting performance by 86% (reduction of rut depth by 1.1 mm)
  - Cracking resistance by 76% (increase of ITS by 20 psi)

Summary of Findings

- The addition of bituminous additives has different impacts on FDR performance:
  - Emulsion improves the performance of FDR mixes
  - Foamed asphalt has a minor effect on FDR performance

Summary of Findings

- Rutting performance of emulsion FDR improved by 90% compared to control at the lowest content of emulsion (3%);

- Cracking resistance of emulsion FDR improved by 85% compared to control at the lowest content of emulsion (3%);

FDR with 5% cement - 3% emulsion and 1% cement is recommended.

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DEPARTMENT OF TRANSPORTATION
THE STATE OF NEW JERSEY

Survey Questionnaire

FDR Survey Questionnaire

The topics covered by this survey questionnaire include

- ❑ FDR use across the US and worldwide
- ❑ Mix design process (with/without bituminous additives)
- ❑ Selection of FDR stabilizing agents
- ❑ Construction practices including pavement investigation and selection of the depth of pulverization
- ❑ Additional details to equipment requirements
- ❑ Field monitoring and performance evaluation
- ❑ Lessons learned?

FDR Survey Questionnaire

1.1 *Use of FDR*

1. Where is your agency locat
   - Country .....
2. (*Conditional if it is in the US*

3. What are the main activities
   - Constructing rigid/fl
   - Pavement preserva
   - Pavement rehabilita
   - All the above
   - Other (Please spec
   .....
   .....
   .....

4. What is the level of knowle technique?
   - No knowledge
   - Little
   - Good
   - Excellent

5. Does your State make use
   - Yes
   - No
   - Under Consideratio

38. List the challenges, if any, encountered during the construction process of FDR (e.g., project selection, milling, paving, compaction, etc…).

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39. How do you overcome these challenges?

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40. In one or few sentences, what are the main lessons learned from the FDR projects conducted in your agency?

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ehabilitation using FDR? In a
s about what data is collected

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tation using FDR in your

l (e.g., Medium Traffic Levels

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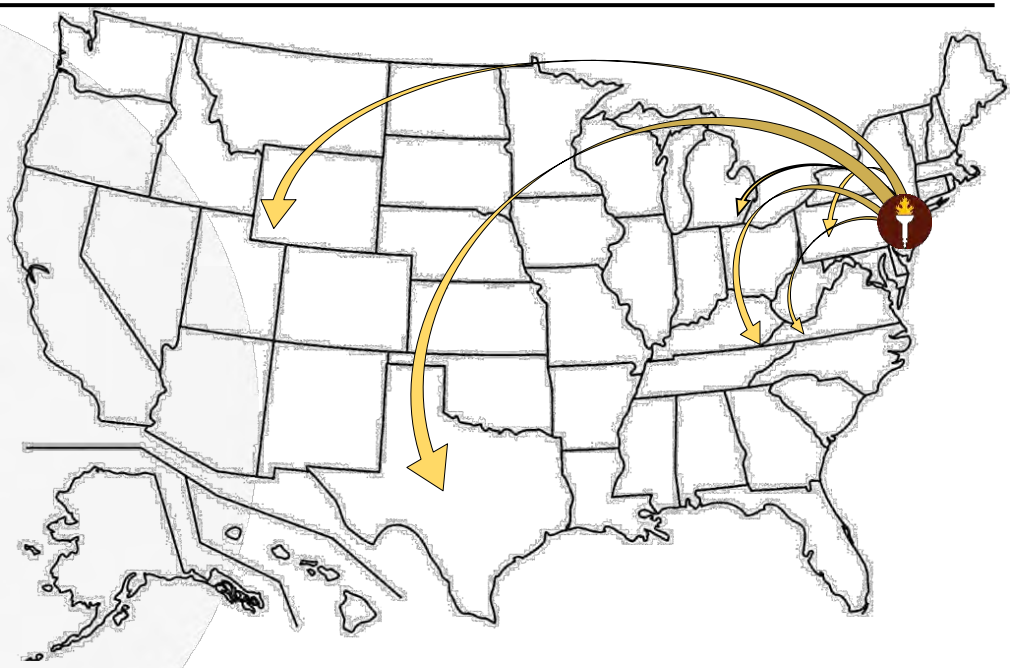
FDR Survey Questionnaire

- Prepare a list of Subject Matter Experts (SME) of highway agencies
- The list will include **all the states** (in the US) and some countries using FDR as a rehabilitation method of asphalt pavements (e.g., **Canada, Spain, Belgium and Brazil**)
- Prepare the survey in Qualtrics and distribute



Preliminary Results

Information	Responses						
State	Georgia	Pennsylvania	Virginia	Indiana	Florida	Nevada	New York
Cost savings per lane mile using FDR	-	$10,000-$30,000	Over $50,000	Over $50,0000	-	No savings	-
How is RAP and aggregate base collected	Coring, crushing	Coring, backhoe	Reclaiming/pulverization, coring, crushing	Coring, crushing	Coring	Reclaiming/pulverization, coring, crushing	Coring, asphalt pavement block samples and underlying materials (3x3 ft)
Depth of pulverization when rehabilitating	7-10 in.	10-14 in.	10-14 in.	10-12 in. for cement FDR	7-10 in.	7-10 in.	7-10 in.
What is used as chemical additives?	Cement	Cement 3-8%	Cement 4-6%	Cement 5-7%	Cement 1-1.5%	Cement 2-3%	Cement (hydraulic cement and kiln dust)
What is the typical percentage of water?	5-12%	3%	2-3% depending on conditions	Within -1%-+2% of optimum mix design moisture content	2-3%	Determined by site conditions	AASHTO T180 Method D

Preliminary Results

Information	Responses						
State	Georgia	Pennsylvania	Virginia	Indiana	Florida	Nevada	New York
Bituminous additive(s) used?	-	Emulsified asphalt, foamed asphalt	Emulsified asphalt, foamed asphalt	Emulsified asphalt	Emulsified asphalt	-	Emulsified asphalt, foamed asphalt
What are the ranges of FDR optimum contents of these stabilizing agents?	-	-	-	2.5-3%	2%	-	EA: 2-4% FA: 2-3%
Quality control requirements the contractor is mandated to perform	Layer thickness, gradation	In-place density, layer thickness, binder content	In-place density, layer thickness, gradation, binder content	In-place density, layer thickness, gradation, binder content	In-place density, layer thickness, gradation, binder content	-	In-place density, gradation, binder content
Measures followed to ensure the quality of FDR by the state/agency	In-Place Density, layer thickness, cement content, proof roll	In-place density, strength testing	In-place density, layer thickness, gradation, binder content	In-place density, binder content	Accepts based on QC data	In-place density, gradation	In-place density, gradation, binder content

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Thank You!

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Center for Research and Education in Advanced Transportation Engineering Systems (CREATES), Rowan University

856-256-5327 / mehta@rowan.edu

creates@rowan.edu