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ENGINEERING SYSTEMS

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Development of Pavement Design Procedures and Construction Specifications for Cold Central Plant Recycling (CCPR) Asphalt Mixtures

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Acknowledgement

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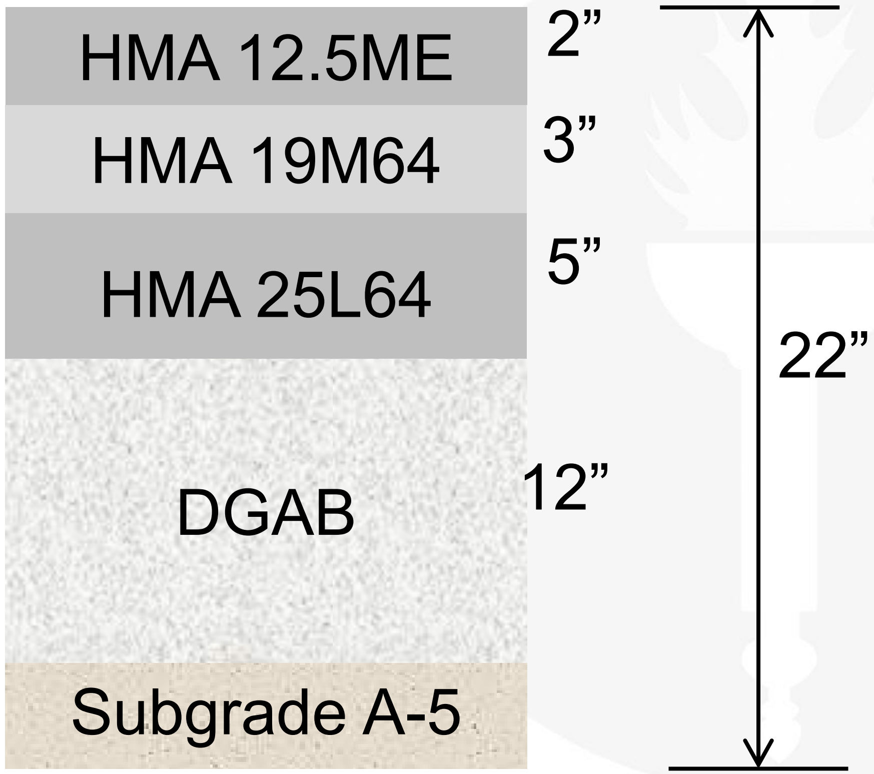
Outline of this presentation

- Background
- NJDOT recommendation for Rt.34 reconstruction
- Problem statement/objective
- Cold Central Plant Recycling (CCPR)
- CCPR pavement design procedures
- Construction specification for the CCPR pavement
- Validation of draft specifications
- Conclusions and recommendations

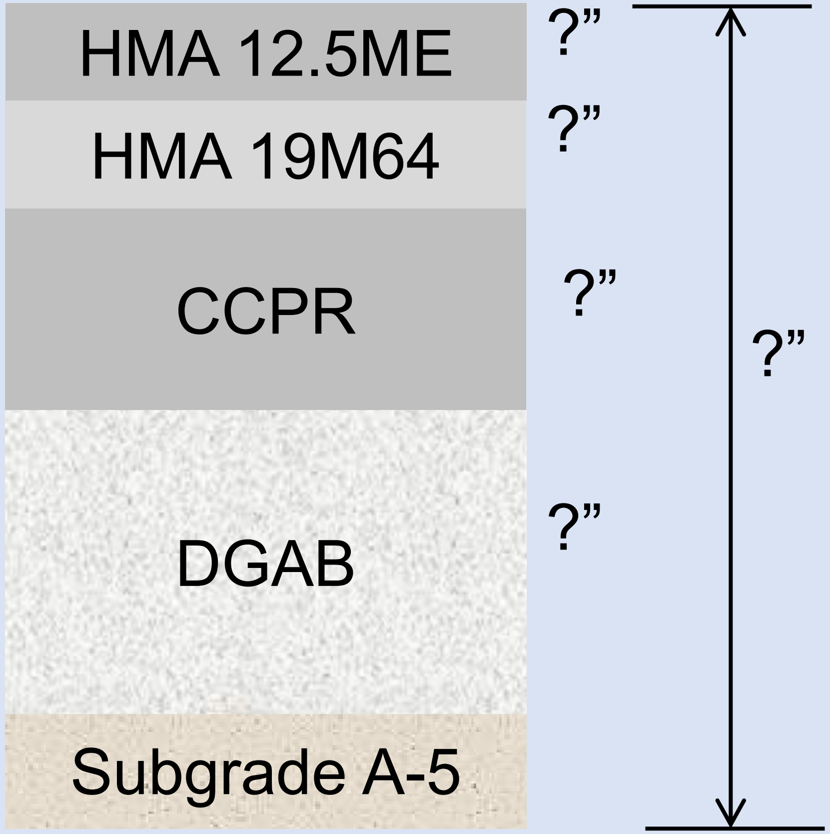
Background

- Route 34 Reconstruction
- NJDOT Rt 34 analysis:
  - Moderate to high severity reflective and fatigue cracking
  - Structural improvement is required for this project to achieve minimum 10 years design life.
  - Raising the profile is not feasible because of the impact on numerous stream crossings throughout the project.
  - Therefore, reconstruction of this section is being considered as a preferred alternative to carry future traffic

NJDOT Recommendation for Rt.34 Reconstruction



New full depth pavement



New pavement with CCPR

Focus of CREATES Study

Problem Statement / Objective

- **Problem statement:**

  Currently NJDOT doesn't have the structural layer coefficient for the CCPR layer and the design and construction specifications for pavements containing CCPR layers

- **Overall Objective:**

  Develop a pavement design procedure and construction specification to built a CCPR pavement using NJ-specific materials

Cold Central Plant Recycling (CCPR)

- RAP from highway millings or existing RAP stockpiles into new roads as bound (or stabilized) base layers
- CCPR mixture is placed using conventional paving equipment
- Advantages include reuse of huge stockpiles of RAP and preservation of natural aggregate resources
- More control over RAP gradation

Multi-unit CIR train

Central Mix Plant

Pavement Design Procedures

AASHTO 93 design procedure for CCPR

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(0.4-0.54, 4-6”)	HMA	
(0.35-0.44,3-6”)	CCPR	
(0.1-0.12, 5-12”)	Aggregate base	
	Subgrade	

Flexible pavement

↓

New construction/ Reconstruction

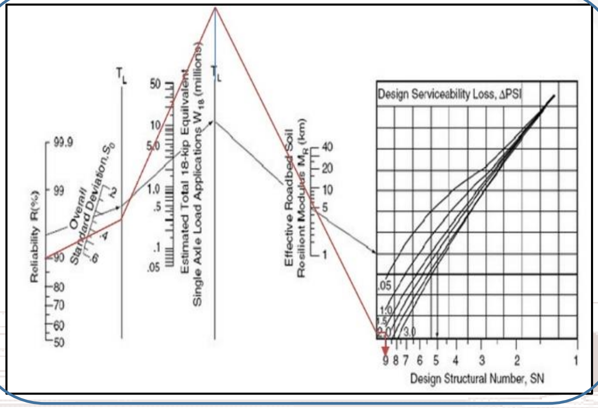
↓

Inputs:
Roadbed Resilient modulus, M_R
Overall Standard deviation, S_O
Traffic, W_{18}
Reliability, R
Serviceability loss, ΔPSI

→ Pavement analysis file for Rt.34

↓

Design Total Structural Number, SN_D



Literature review& SME interview

↓

Layer coefficient a_i and thickness D_i

0.35-0.44

Single lift max. 4 in.

↓

Calculated Total Structural Number, SN_C

$SN_C > SN_D$?

No

Yes ↓

$SN_D = SN_C$

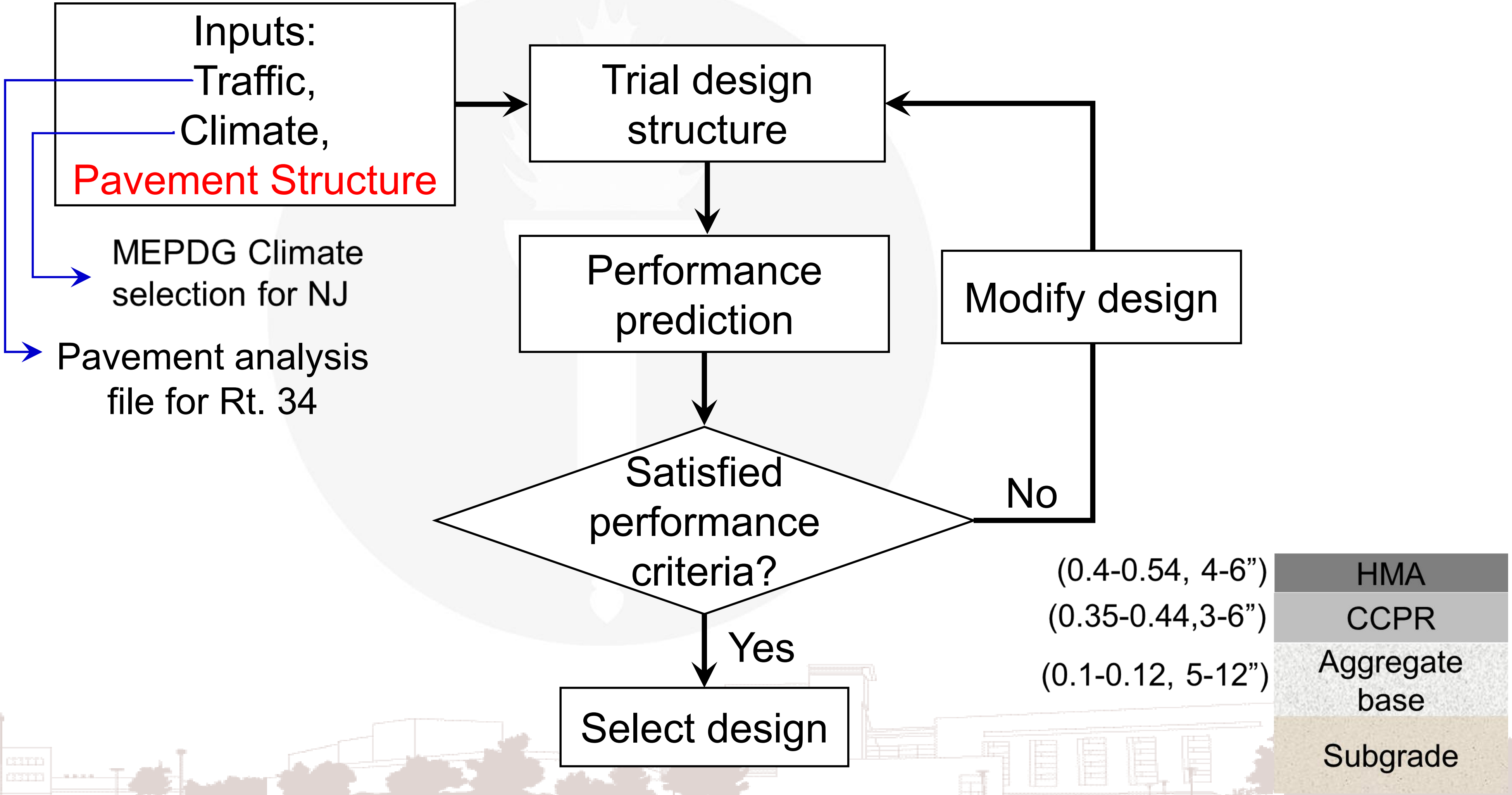
↓

a_i and D_i are acceptable

Structural layer coefficient

- NJDOT doesn't have layer coefficient for CCPR
- Layer coefficient needs to be determined either by conducting a full-scale study or by backcalculating from the dynamic modulus

AASHTOWare ME design procedure for CCPR



Limitations in analyzing CCPR layer in AASHTOWare

- Lack of provisions to characterize asphalt stabilized base course
- Input options for the properties of foamed and emulsified asphalt are not available
- Analysis does not account for cold mixes
    - Non stabilized aggregate base layer
- **Level 1 input is necessary for any special mixes like CCPR mix**

CCPR |E*| Master curve

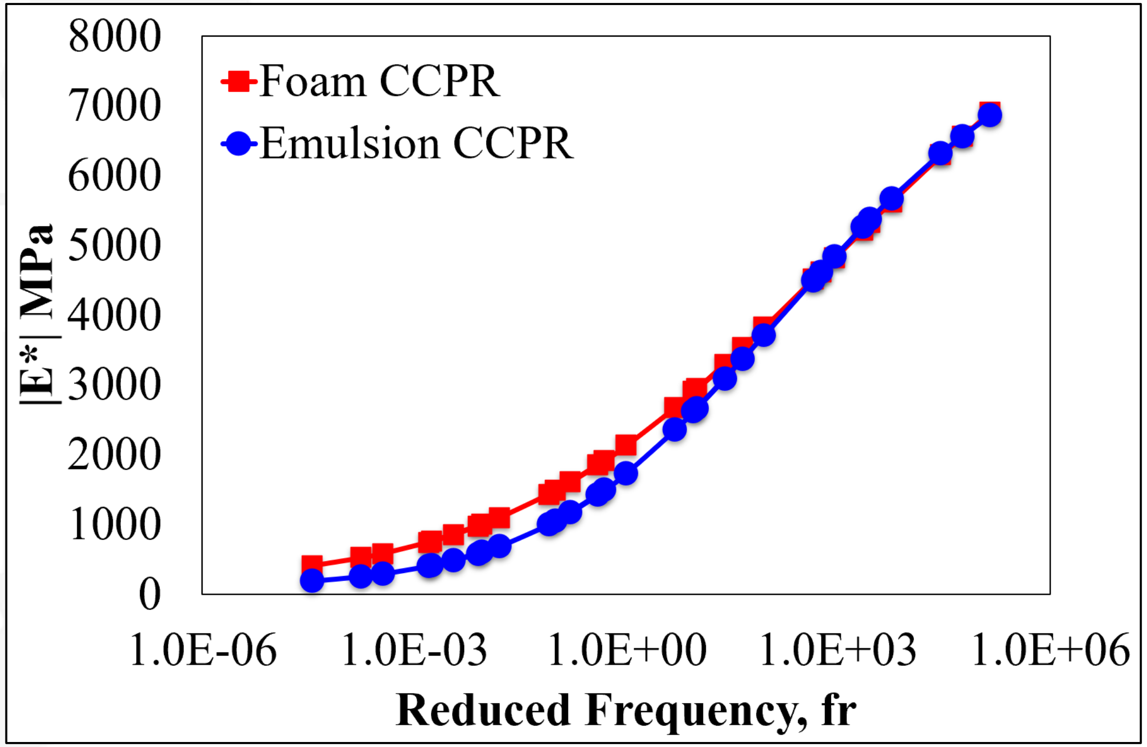
- Five temperatures:

-10, 4.4, 21.1, 37.8, and 54.4℃

- Six frequencies:

25, 10, 5, 1, 0.5 , and 0.1Hz

- Foam and emulsion CCPR mixes showed similar |E*| at lower temperature.



- At high temperature, Foam stabilized CCPR from NJ specific materials showed higher |E*| values

Inputs used for analysis

- Traffic loading- 13M ESALs (13,140,618 ESALs) 18kip loading
- Climatic conditions- Location nearest to Rt. 34
- Layer properties: Obtained from NJDOT shared data for all the layers except CCPR layer
  - HMA: 1,611,723psi
  - Aggregate layer: 40,000psi
  - Subgrade soil A-5: 8300psi
- CCPR layer properties: Laboratory test results for NJ Specific materials
  - CCPR: 366,475psi (Average value)

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AASHTOWare Pavement ME analysis

Design structures

Layer Type	Material Type	Thickness (in) Case I
Flexible	12.5ME	**2**
Flexible	19M64	**3**
Flexible	25L64	**5**
Non-Stabilized	DGAB	**12**
Subgrade	A-5	Semi-infinite

Material Type	Thickness (in) Case II
12.5ME	**2**
19M64	**3**
CCPR	**5**
DGAB	**12**
A-5	Semi-infinite

Distress prediction summary

Distress Type	Distress @ Specified Reliability			Criterion Satisfied?
	Target	Predicted		
		Case I	**Case II**	
Terminal IRI (in/mile)	172.00	**272.41**	**276.90**	Fail
Permanent deformation – total (in)	1.00	**0.81**	**0.74**	Pass
AC bottom-up fatigue cracking (%)	25.00	**2.13**	**1.45**	Pass
AC thermal cracking (ft/mile)	1000.00	**27.17**	**216.30**	Pass
AC top-down fatigue cracking (%)	25.00	**14.47**	**17.45**	Pass
Permanent deformation - AC only (in)	0.50	**0.31**	**0.10**	Pass

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Construction Specification

Draft Construction Specification

- Literature review comparing recycling methods in the United States, Canada, European countries, and Asian countries
- Subject Matter Expert (SME) Interviews with other agencies and state DOTs
- Discussion with VDOT, MnDOT, PennDOT, NYSDOT
- Referred VDOT CCPR specification and ARRA specifications
- Technology Transfer workshop in November 2022

Based on the literature review and SME interviews a draft specification was submitted at the end of 2022.

Details in Draft Specification

- Suggested to add the submitted draft in the NJDOT specification as :

  Section 3XX: Cold Central Plant Recycling (CCPR) Course

Which includes:

- Section 902.XX: Foam and Emulsion CCPR Mix Design
- Section 1012.03: Cold Central Plant equipment
- Section 3XX.03: Construction

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Foam CCPR Mix Design

Mix Design Requirements verified in the Laboratory	
Test Method	Criteria
Moisture-Density Relations (AASHTO T180, Method D)	Determined by design
Dry Indirect Tensile Strength (AASHTO T283)	Min. 45 psi
Retained Indirect Tensile Strength (AASHTO T283)	Min. 70% of Dry ITS Test Result

Foamed Asphalt (Wirtgen 2012 Cold Recycling Manual)	
Expansion Ratio when Aggregate is at 50ºF-77ºF	Min. 10
Expansion Ratio when Aggregate temp. >77ºF	Min. 8
Half Life	Min.6 s

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Emulsion CCPR Mix Design

Mix Design Requirements verified in the Laboratory

Test Method	Criteria
Moisture-Density Relations (AASHTO T180, Method D)	Determined by design
Marshall Stability (ASTM 5581 for 6 in. samples/AASHTO T245 for 4 in. samples)	Min. 2500lbs for 6in. samples Min. 1250lbs for 4in. samples
Retained Stability (ASTM 5581 for 6 in. samples/AASHTO T 245 for 4 in. samples)	Min. 70% of Marshall Stability Test Result

Optimum CCPR mix designs from Laboratory study

- Foam CCPR:
  - Binder PG 64-22
  - Recycling agent (Foamed asphalt) 3%
  - Water 3%
  - Cement 1%
- Emulsion CCPR:
  - Emulsion- CSS 1h
  - Recycling agent (Emulsion) 3%
  - Water 3%
  - Cement 1%
- **Foamed and emulsified CCPR Mixtures met the requirements in the draft specification.**

Cold Central Plant

CCPR plant shall be:

- Capable of homogeneously incorporating recycling agent(s)
- Capable of delivering chemical additives and water
- Provided with facilities to print out used material quantities
- Outfitted with test/inspection nozzle at one end of spray bar
- Capable of maintaining liquid asphalt at a min. of 300°F
- Equipped with means for operator to verify process

CCPR Course Construction

Weather Limitations

- Place when ambient& CCPR mix temperature > 50°F
- Within 48 hrs, forecast must not predict freezing temperatures

Test strip

- Minimum 1000 ft. long, one-lane wide, designated thickness
- Nuclear density gauge as per AASHTO T 355/ASTM D 2950
- Rolling pattern should be finalized for the entire CCPR layer
- Field proctor density ≥ 98% of max. theoretical density

CCPR Course Construction

Placement of CCPR Mixture

- Placement thickness generally varies between 3 to 6 inches

Compaction

- Rollers should be started/stopped only on compacted material
- Nuclear gauge for target density& vibratory roller for initial compaction
- Initial compaction shall start within 30 minutes after paving
- Finish rolling shall be completed within1 hour after paving

CCPR Course Construction

Fog seal application

- After 2 hours of fog sealing, rolling traffic may be permitted

Curing

- At least 3 days of curing is needed before placing an overlay

Surface Tolerance

- Maintain the existing profile and slope of the surface

Surfacing

- Before laying surface course, prepare CCPR layer with tack coat

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Validation of draft specifications

- Accelerated Pavement Testing on full-scale pavement sections containing CCPR layers will help to:
  - Validate the draft design and construction specification
  - Determine the structural layer coefficient for CCPR layer
  - Determine the local calibration coefficients to use in AASHTOWare from the sensor data during Heavy Vehicle Simulator loading

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Conclusions and recommendations

- Mix design specifications was developed using NJ RAP sources.
- Catalog of NJ specific CCPR material characteristics can be potentially developed for a broad range of RAP properties.
- Level 1 inputs may be needed for CCPR pavement analysis
- Layer coefficient and validated construction and design specification from full-scale study will allow NJDOT to use CCPR.
- One additional tool in NJDOT's toolbox for rehabilitating deteriorated pavement structures

Thank You!

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