# REFINED TEST METHODS AND SPECIFICATIONS TO IMPROVE COLD RECYCLING PERFORMANCE

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UC PRC
UNIVERSITY of CALIFORNIA Davis • Berkeley | PAVEMENT RESEARCH CENTER

# Outline

- Introduction
- Overview of specifications
- Specification assessment
- Conclusions & recommendations

# Introduction

- Cold recycling procedures and recycling agents have all evolved separately and tend to be siloed
- Specifications and mix design methods have also been developed separately, often based on HMA
- Nobody has really questioned origins, appropriateness, or standardization

# Introduction

- UCPRC research roadmap
  - FDR-FA pilot study in 2002
  - Phase 1
    - FDR with foamed asphalt
  - Phase 2
    - FDR with no recycling agent, emulsified and foamed asphalt, and cement
  - Phase 3
    - PDR and CCPR
  - Phase 4
    - Gaps in the knowledge/implementation
      - Standardization (cold recycling to bottom of distress / deeper)
      - Inverted pavement
      - Recycling asphalt concrete with high rubber content
      - Tack coat under in-place cold recycling
      - Rejuvenators

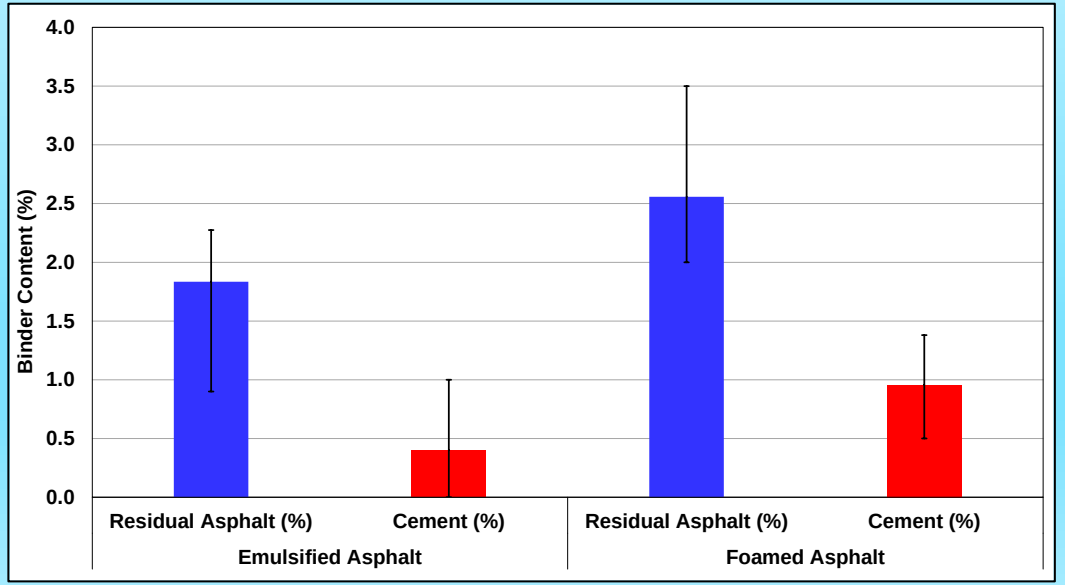
# Introduction

- Before 2022, FDR and PDR, and EA and FA had different specifications and mix design procedures
- Updated Caltrans nSSPs for PDR and CCPR were released in 2022
  - EA and FA were combined into single nSSP, but were still considered as different materials in terms of mix design, QC, and acceptance
  - nSSP required doing both testing procedures regardless of recycling agent
- Study was initiated to provide recommendations for standardizing specs and test methods for cold recycling
  - Field and laboratory



# Historical Data Review

- Statewide PDR construction projects (FA permitted after 2018)
  - 223 emulsified asphalt mix designs with Marshall stability (>5.6 kN then 6.7 kN dry)
    - Average 1.8% residual bitumen / 0.4% cement
  - 26 foamed asphalt mix designs with ITS (>240 kPa wet)
    - Average 2.6% bitumen / 1% cement



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# Specification Overview Prior to Study

| Agency | Year | Method | Material | Gradation | Compaction Method | Test Method | Min. Strength | Condition |
|---|---|---|---|---|---|---|---|---|
| Caltrans | 2005 | LP-8 | CIR-EA | Medium/coarse | Marshall | MS | 5.6 kN | Dry |
| | | | | | Gyratory | | | |
| | 2016 | LP-8-EA | PDR-EA | Medium/coarse | Gyratory | MS | 5.6 kN | Dry |
| | 2016 | LP-8-FA | PDR-FA | Medium/coarse | Gyratory | ITS | 240 kPa | Wet |
| | 2022 | CT 315/CT 316 | PDR-EA | Medium/coarse | Marshall | MS | 6.7 kN | Dry |
| | | | CCPR-EA | | Gyratory | | | |
| | 2022 | CT 315/CT 316 | PDR-FA | Medium/coarse | Marshall | ITS | 240 kPa | Wet |
| | | | CCPR-FA | | Gyratory | | | |
| ARRA/ AASHTO | 2016/ 2023 | ARRA CR201/ AASHTO M 352 | PDR-EA | Fine/medium/coarse | Marshall | MS | 5.6 kN | Dry |
| | | | | | Gyratory | | | |
| | | | | | Gyratory | ITS | 310 kPa | |
| | 2017/ 2023 | ARRA CR202/ AASHTO MP 38 | PDR-FA | Fine/medium/coarse | Marshall | ITS | 310 kPa | Dry |
| | | | | | Gyratory | | | |
| Wirtgen/ TG2 | 2012 | Wirtgen CR Manual | PDR/FDR | Provided in spec. | Vib. hammer to Marshall or Mod. Proctor density | ITS | 225 kPa | Dry |
| | | | | | | | 100 kPa | Wet |
| | 2017 | Wirtgen CR Manual | PDR/FDR | Provided in spec. | Vib. hammer to Mod. Proctor density | ITS | 225 kPa | Dry |
| | | | | | | | 100 kPa | Wet |
| | 2020 | TG2 | PDR/FDR | Provided in spec. | Vib. hammer to Mod. Proctor density | ITS | 225 kPa | Dry |
| | | | | | | | 125 kPa | Wet |

# Overview of Current Specification Acceptance

- Assumptions in the specifications:
  1. PDR-EA and PDR-FA behave differently and require different testing methods
  2. Gyratory compaction (30 gyrations) = Marshall compaction (75 blows/face)
  3. Recycled layer performance with wet ITS of 240 kPa = dry stability of 6.7 kN

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# Binder Content

- Reviewed 7 projects under 2022 nSSP
- Compared:
  - Test method on binder content selection
  - Compaction method/density
  - Conditioning
  - ITS and stability
  - Stiffness

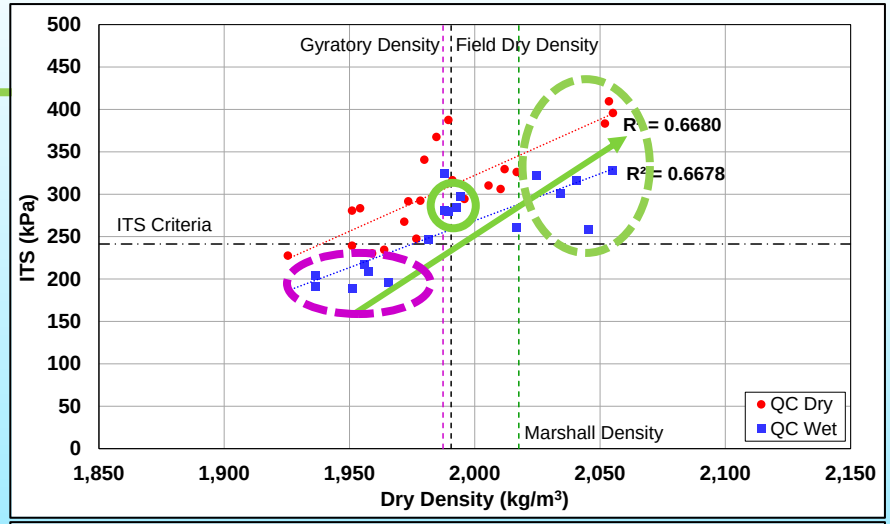
| EA Mix Design | ITS (220 kPa) | ITS (240 kPa) | Stability (6.7 kN) |
|---|---|---|---|
| Passing mix designs | 5 | 5 | 7 |
| Mean residual bitumen content (%) | 1.8 | 2.2 | 1.6 |
| Mean cement content (%) | 0.7 | 0.9 | 0.6 |

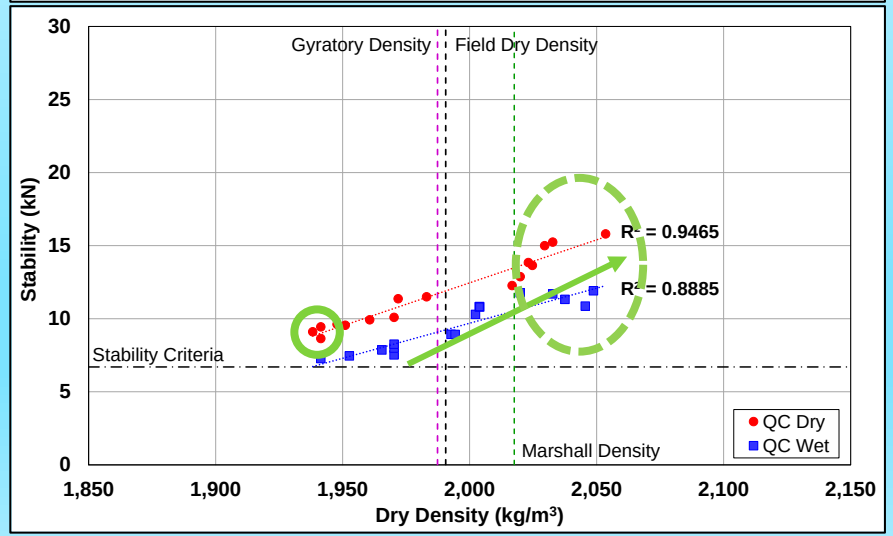
# Field Compaction Method

- Two PDR projects (2 lots per project, 360 specimens compacted)
- Compaction methods:
  - Gyratory compaction
    - 30 gyrations, = field density, = Marshall density
  - Marshall compaction
    - 75 blows per face
  - Vibratory compaction
    - = Field density, = 30 gyrations, = Marshall density
- Lowest to highest density:
  - Field (nuclear gauge) } Similar
  - Gyratory } Similar
  - Marshall — Higher

# Field Compaction Method

- Test method effect
  - ITS requires at least gyratory density to pass criteria
  - Marshall stability criteria can be passed at lower densities
- Compaction method effect
  - Strength/stability increases with increased density
  - Easier to pass test criteria when using Marshall compaction



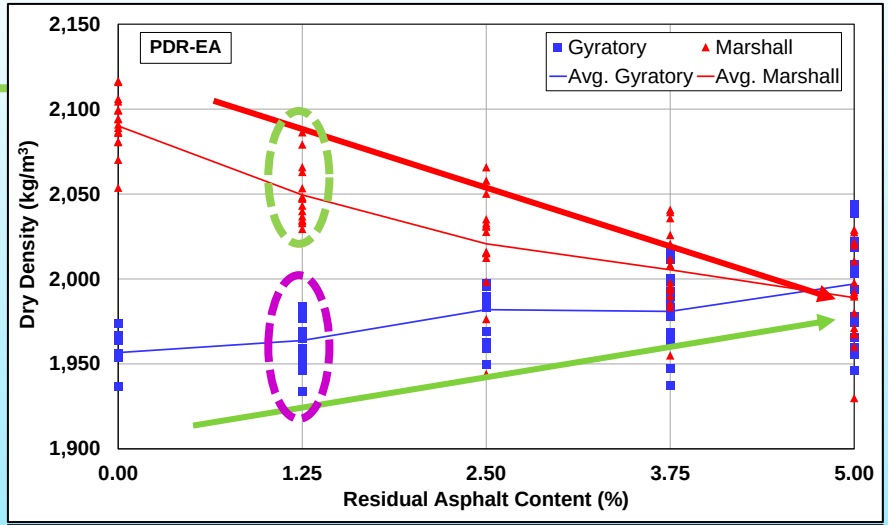
# Laboratory Testing Study

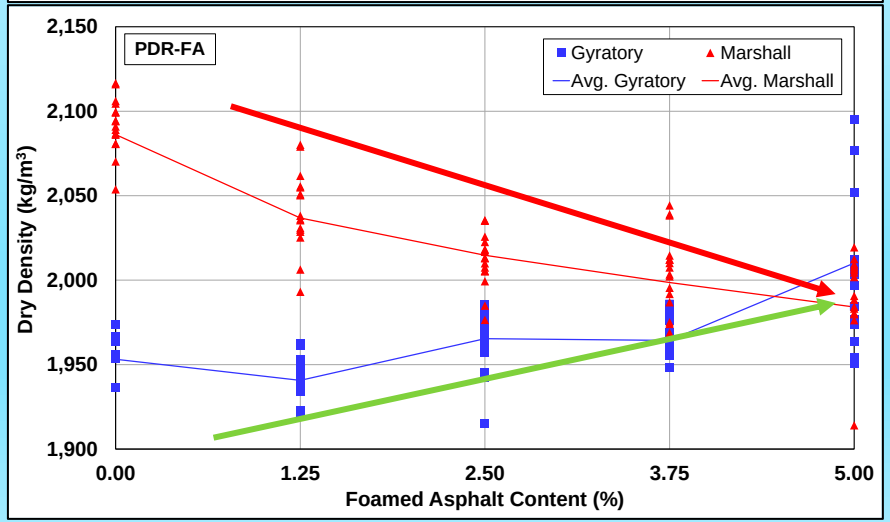
- Laboratory test factorial for EA and FA mixes
  - Two RAP sources
    - PDR and CCPR (crushed)
  - Two compaction methods
    - Gyratory and Marshall
  - Target strength/stability
    - ITS 240 kPa wet
    - Stability 6.7 kN dry
  - Fixed ratio of residual binder to cement of 2.5:1
    - 0% binder @ 0% cement*
    - 1.25% binder @ 0.5% cement
    - 2.50% binder @ 1.0% cement
    - 3.75% binder @ 1.5% cement
    - 5.00% binder @ 2.0% cement*

      *Designs to bound experiment – not recommended
  - 610 specimens / 3,200 kg of material

# Compaction Method

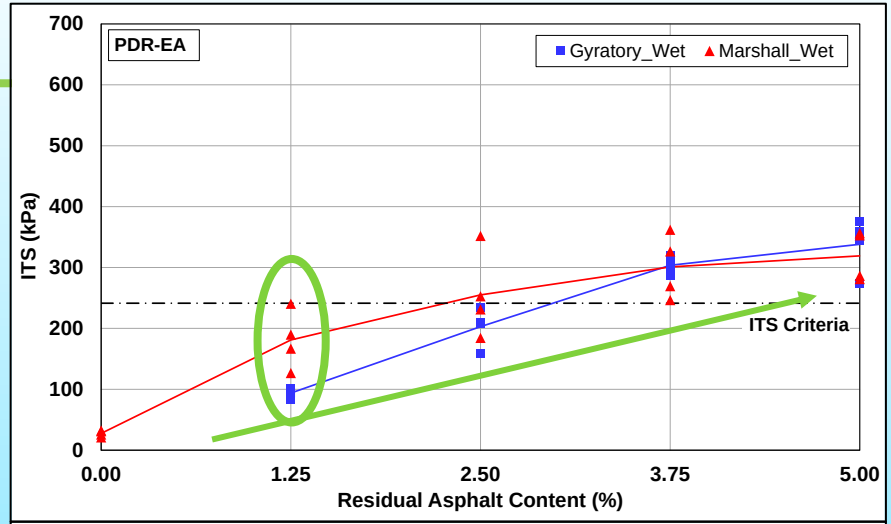
- Marshall density higher than gyratory
- Gyratory density increases with added binder content
- Marshall density decreases with added binder content
- Implications of using Marshall
  - Passing lab strengths cannot be achieved at field density
  - Field QC results can be misleading
  - Risk of lower-than-expected performance

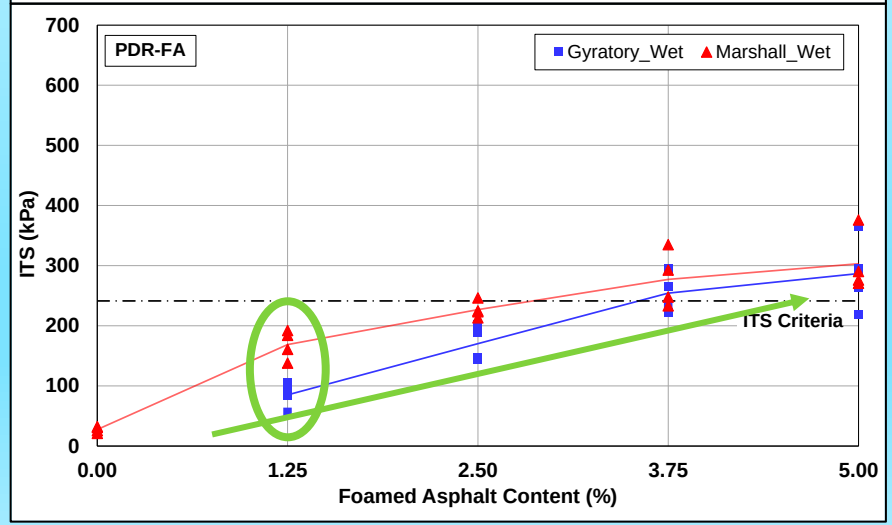


# Indirect Tensile Strength

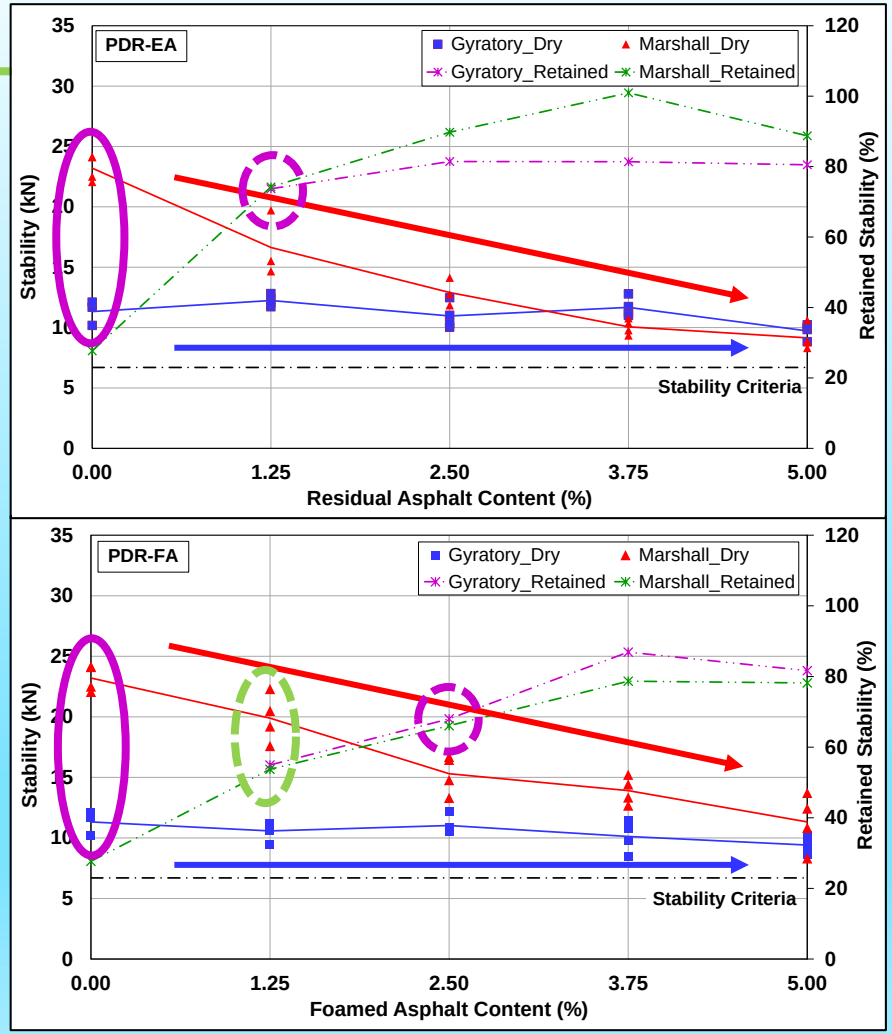
- Strength increases with added binder/cement
- Higher density from Marshall compaction produces higher strengths than gyratory for the same binder contents



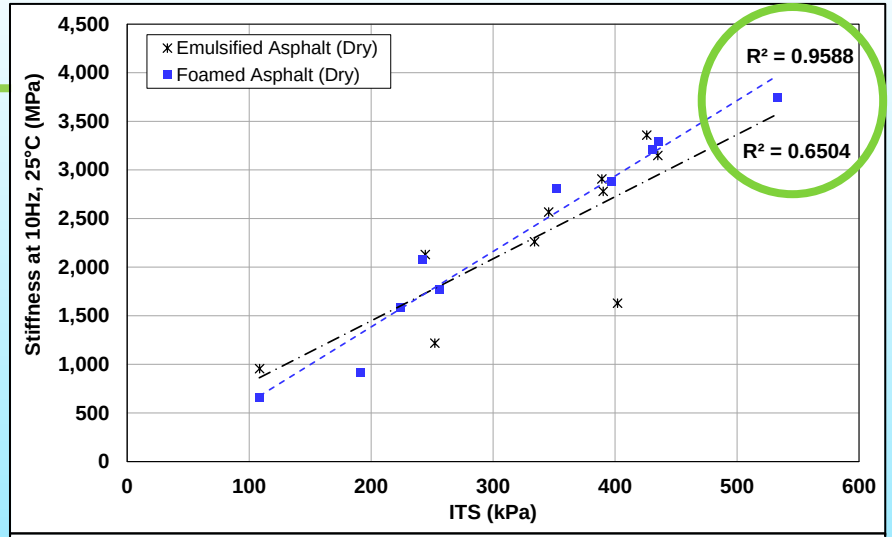
# Marshall Stability

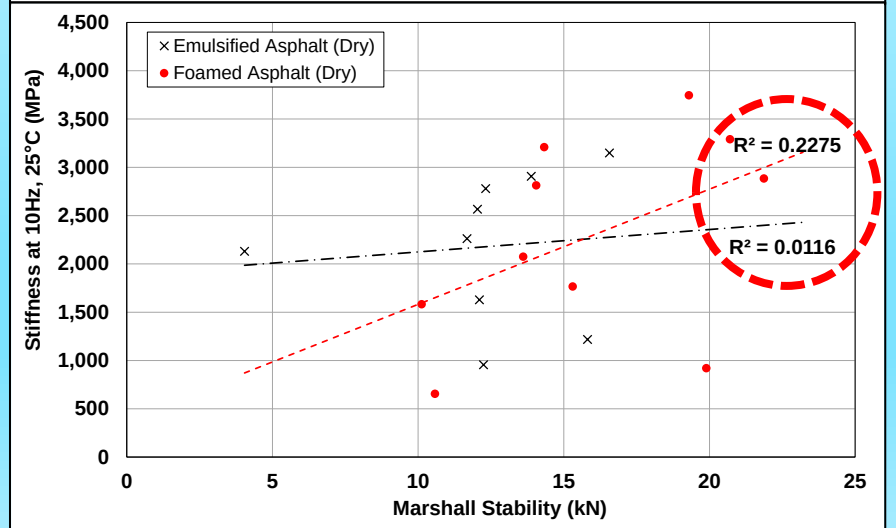
- Designs can pass with no binder
  - Retained stability requirement prevents passing designs
- Effect of compaction method
  - Gyratory: stability relatively unchanged with added binder contents
  - Marshall: stability decreases with added binder content
- Higher density from Marshall compaction produces higher stabilities



# Stiffness

- ITS has a strong positive correlation with stiffness
  - Provides a measure of the structural contribution of the recycled layer
  - EA and FA are similar
- Marshall stability has a low correlation with stiffness
  - EA and FA are different
- Stiffness and stiffness change over time of all layers are critical components for *CalME* analyses



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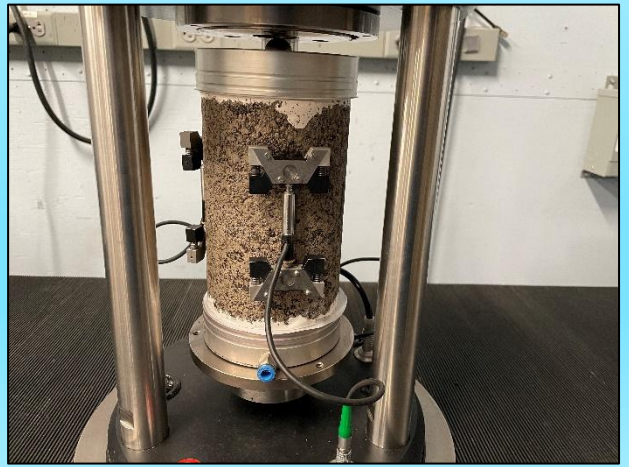
  2. Marshall comp face) tion (30 gyrations)
  3. Recycled layer per dry stability of 6.7 kN

# Conclusions

- Field density < gyratory density < Marshall density
  - Adjusting Marshall blows to match gyratory is not a solution
- Gyratory compaction requires higher binder contents than Marshall to meet minimum strength/stability
- ITS passing criteria requires higher binder content than stability to meet minimum requirements
- Stability is not an appropriate measure of likely performance given trend of decreasing stability with increasing binder content and poor correlation between stability and stiffness
- Specifications have allowed contractors to choose recycling agent and compaction method to optimize results

# Recommendations

- Focus on recycling to bottom of distress
- Recycling agent choice
  - Consider EA and FA as similar recycling agents
  - Allow contractor to choose
- Compaction method
  - Standardize to gyratory compaction for both mix design and QC, or
  - Allow vibratory compaction for QC using field density as target
- Mix design and acceptance test methods
  - Standardize test method to ITS only
- Test criteria
  - Set wet ITS criteria at ≥ 220 kPa
  - Use 2.5:1 bitumen:cement ratio



# Thank-you!

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