ISAET '21

7th International Symposium on Asphalt Emulsion Technology

Exploring the Workability of Asphalt Emulsion Stabilized Cold-in-Place Recycling

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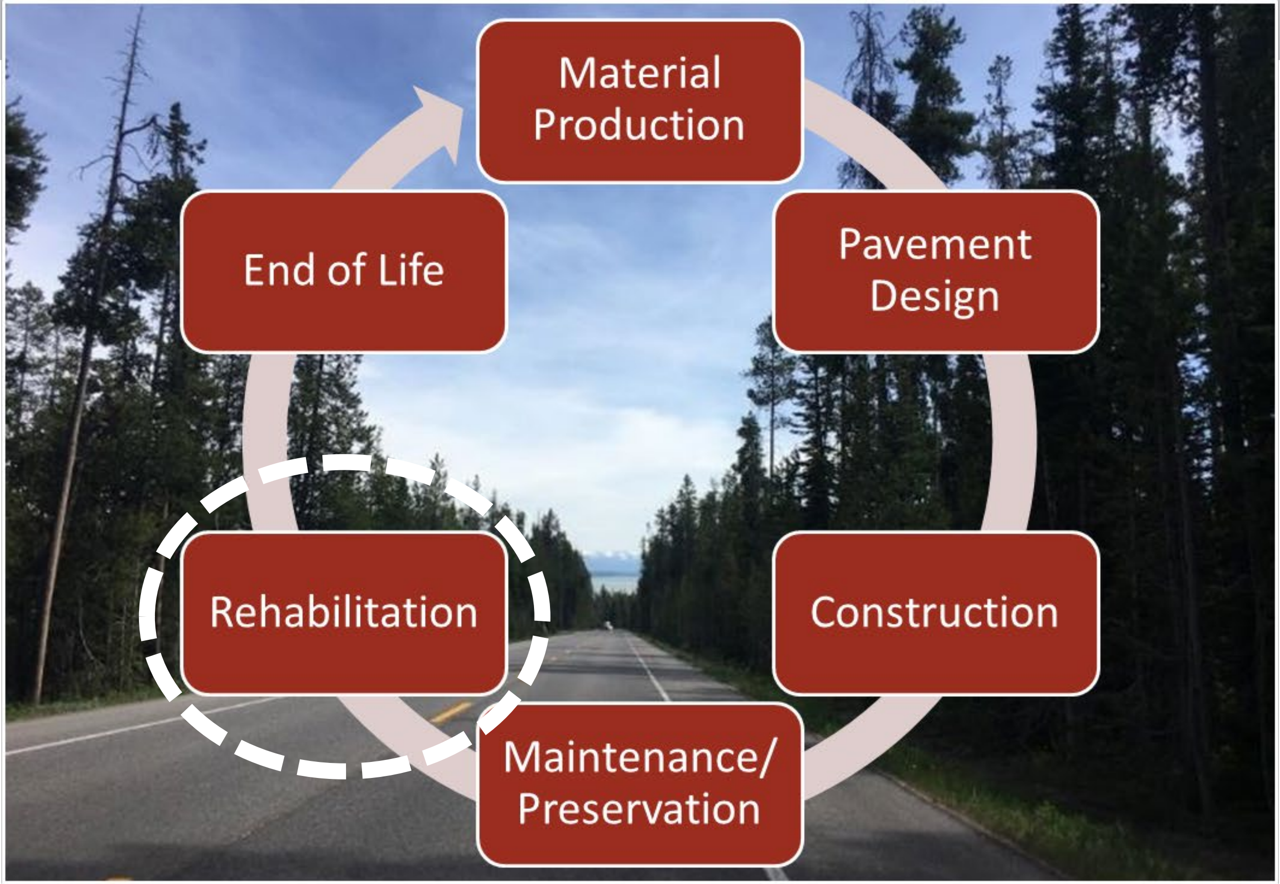
Presentation Overview

- Introduction
- Materials
- Curing Condition Evaluation
  - Casillas, S., Braham, A. Quantifying Effects of Laboratory Curing Conditions on Workability, Compactability, and Cohesion Gain of Cold In-Place Recycling, Road Materials and Pavement Design, April 2020. DOI: 10.1080/14680629.2020.1753101
- Emulsion Performance Comparison
  - Casillas, S., Braham, A. Development of a Performance-Based Approach to Asphalt Emulsion Selection for Cold In-Place Recycling Applications, under review by Transportation Research Record, October 2021.
- Conclusions

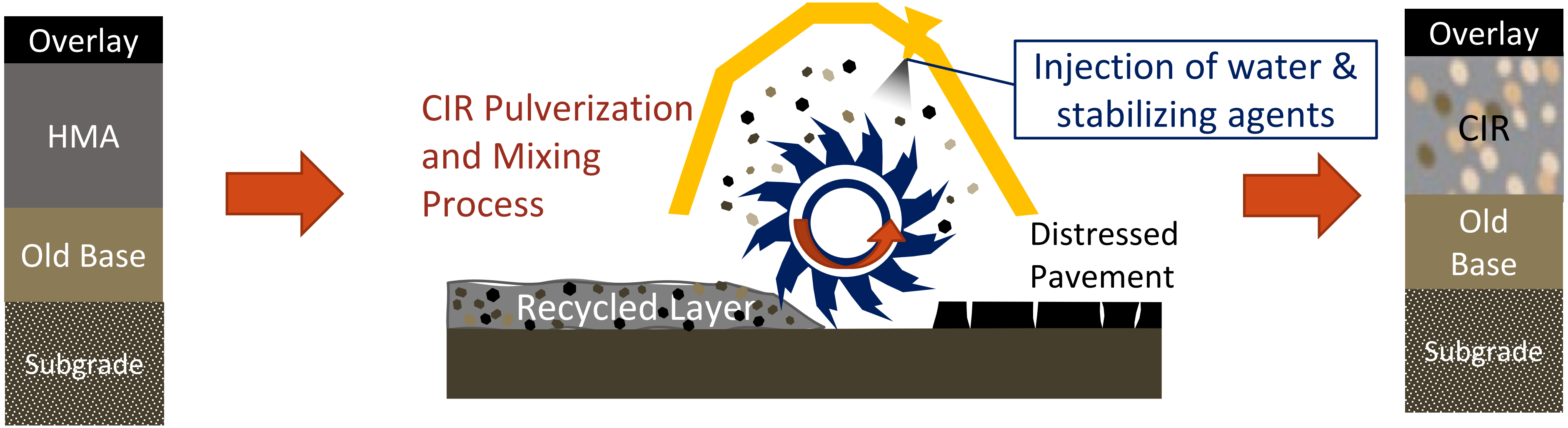
Pavement Life Cycle



Cold in-place recycling (CIR) is a rehabilitation treatment

Pavement Rehabilitation - CIR

- Maximize investment, minimizing disruption to users/environment
- In-situ recycling (CIR) vs. cold central plant recycling (CCPR)
- Focus on CIR with asphalt emulsion



What are current CIR mix design procedures?

AEMA ASPHALT EMULSION MANUFACTURERS ASSOCIATION
ibef International Bitumen Emulsion Federation
UNIVERSITY OF ARKANSAS

Existing CIR Mix Design

- AASHTO standards appear to be written through HMA lens
  - AASHTO PP 86: Emulsified Asphalt Content of Cold Recycled Mixture Designs
  - AASHTO MP 31: Materials for Cold Recycled Mixtures with Emulsified Asphalt

1. **SELECTING MIXTURE COMPONENTS**
   - Asphalt emulsion + RAP reactivity
   - Coating of RAP

2. **FINAL STRENGTH AND STABILITY**
   - Performance of fully cured mixture

Asphalt Emulsion CIR: Semi-Bound Material

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Asphalt Emulsion CIR

Unbound Granular Material (UGM)

- Stiffness influenced by stress state
- Target dry density
- Optimum moisture content

Bound HMA

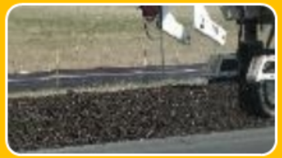
- Stiffness influenced by temperature and loading rate
- Target air voids content
- Optimum asphalt binder content

Unbroken asphalt emulsion coating unbound RAP blend

Fully cured mixture, RAP bound by asphalt emulsion residue

Proposed CIR Mix Design

1. SELECTING MIXTURE COMPONENTS
- Asphalt emulsion + RAP reactivity
- Coating of RAP



2. WORKABILITY
- Mixing
- Placement

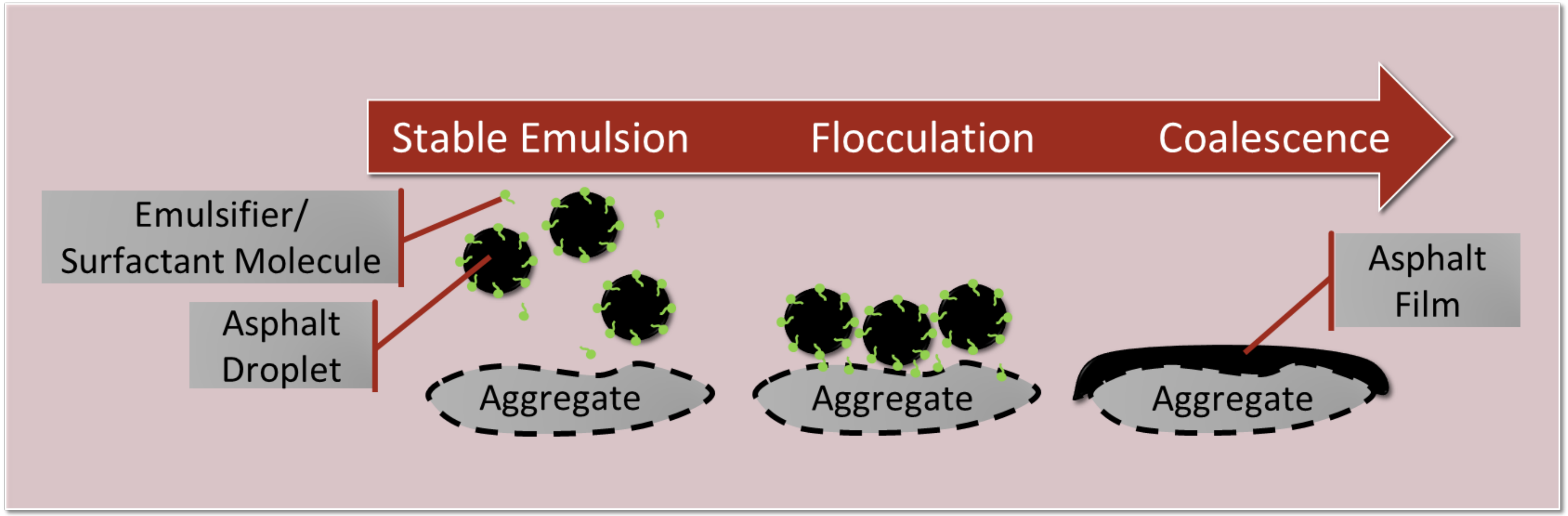
3. COMPACTABILITY
- Densification

4. COHESION GAIN
- Curing
- Increasing stiffness

5. FINAL STRENGTH AND STABILITY
- Performance of fully cured mixture

Asphalt emulsion breaks & mixture cures → transition in material behavior

How does asphalt emulsion influence workability?



For in-situ recycling, medium to slow setting emulsions – ample time for mixing, placement, and compaction

Quantifying Workability

- Effort required to manipulate an uncompacted material with minimum loss of homogeneity
- Utilize test methods commonly available in asphalt laboratories

Laboratory Tests

Loose Triaxial Test

Dongre Workability Test

CIR Modified SGC Metrics

Curing Conditions

Temperatures (°C):

- 10, 23, 40, 60

Times (minutes):

- 30, 60, 120

Materials

RAP blend from local quarry

(3) CSS-1h Asphalt Emulsions

Materials

- CIR Mix design selected using AASHTO MP31 and AASHTO PP86
  - 2.75% Asphalt Emulsion, 0.5% Cement, 2.5% Added Water

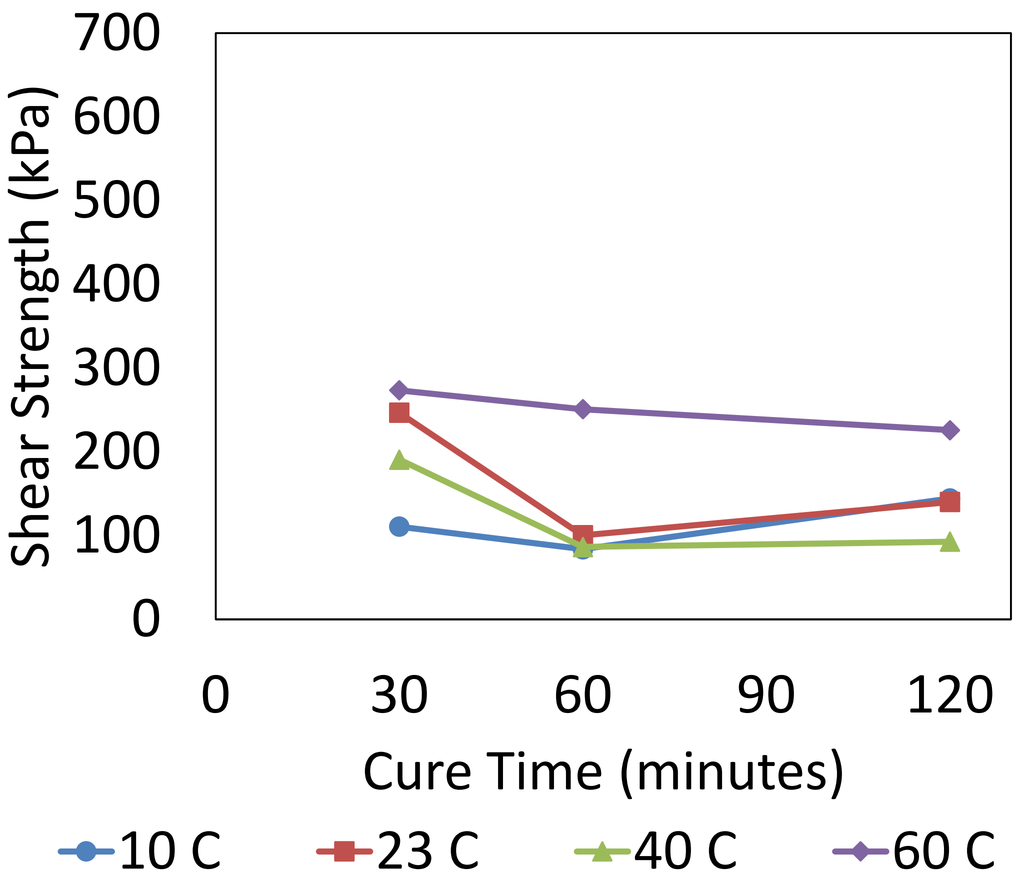
Property	AASHTO M 208 requirements	Emulsion 01	Emulsion 02	Emulsion 03
Saybolt Viscosity, 25°C (SFS)	20 – 100	55	21	37
Sieve Test (%)	< 0.10	0.00	0.04	0.01
Mean Particle Size (µm)	---	3.12	3.45	5.17
Residue (%)	> 57	64.1	62.6	62.8
Penetration (dmm)	40 – 90	68	54	61

Loose Triaxial Test (LTT)

- Axial load applied while confining pressure is applied using air
  - AASHTO T296
  - (3) Confining pressures (kPa): 0, 100, 200
- Relating shear strength to resistance to mixing/placing and compaction

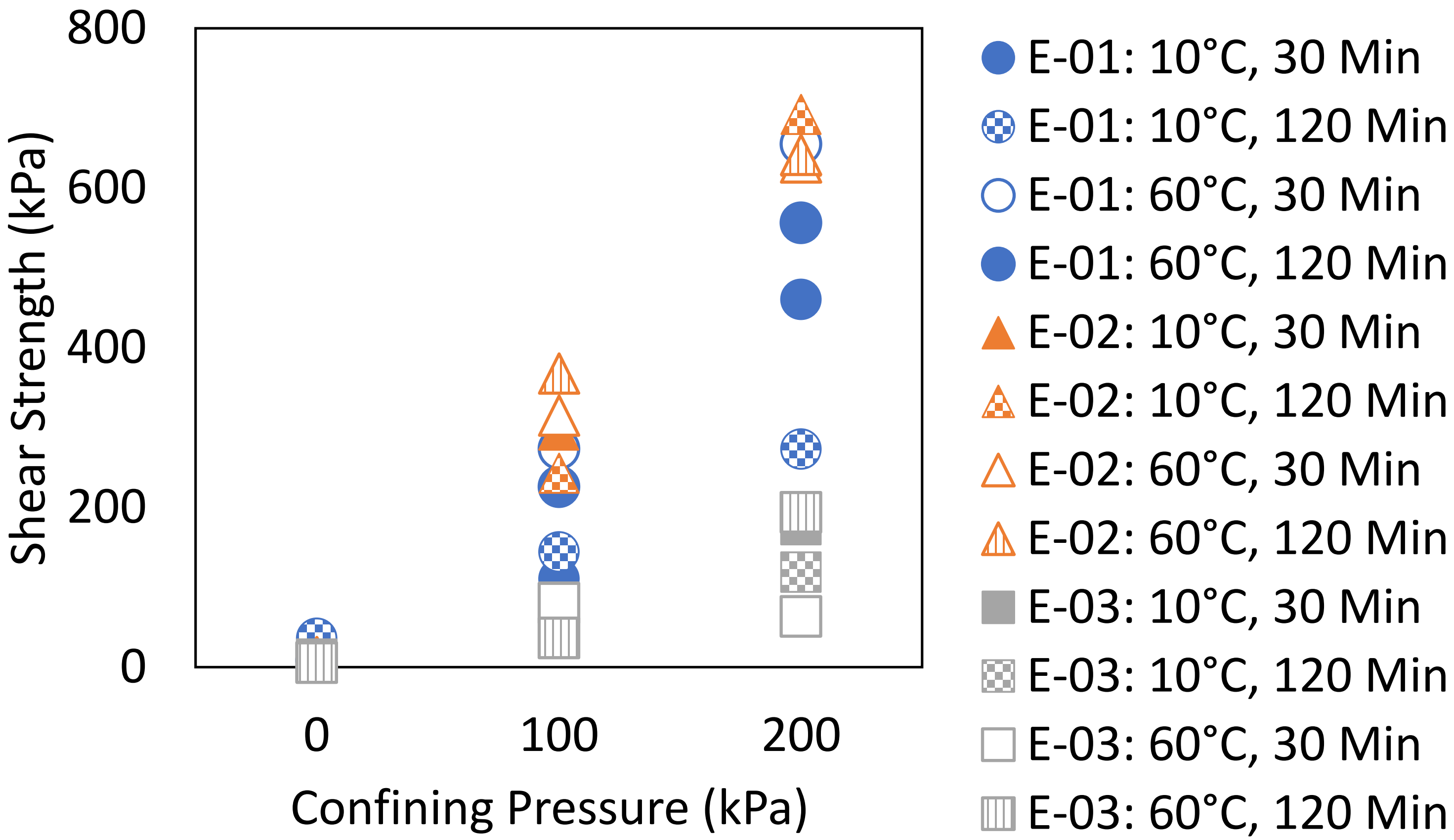
LTT: Curing Condition Evaluation

- Sensitivity of shear strength to confining pressure mimics unbound granular material
- At 0 kPa, no densification just manipulation of material
  - May quantify workability
- At 100 kPa and 200 kPa, densification occurred
  - May quantify compactability
- ↑ Curing temperature, ↓ Compactability
- Statistically significant influence of cure temperature at 100 kPa



LTT: Emulsion Comparison

- Early curing → CIR behaves as unbound
- Poor correlation to asphalt emulsion viscosity
- Highest correlation to final density and WEI-CIR
- Friction data inconclusive



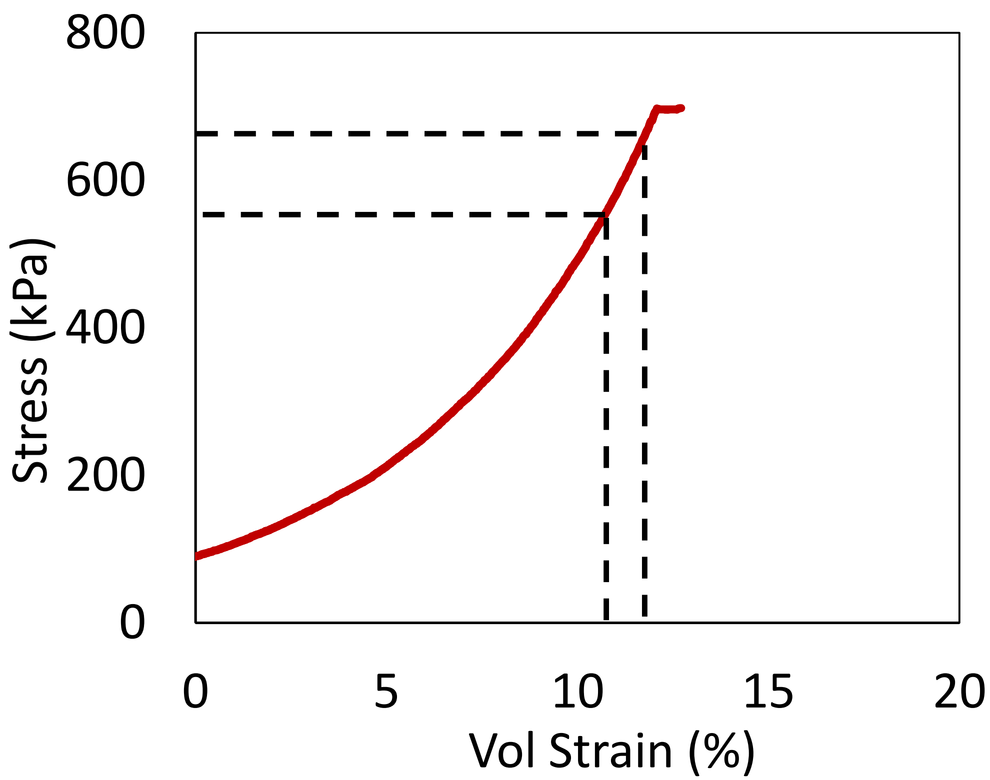
Dongre Workability Test (DWT)

Utilizes SGC to perform strain rate controlled test, records stress/strain response of material

- The DWT index value is a ratio of stress (σ) to strain (ε) between 550 kPa of pressure and 650 kPa

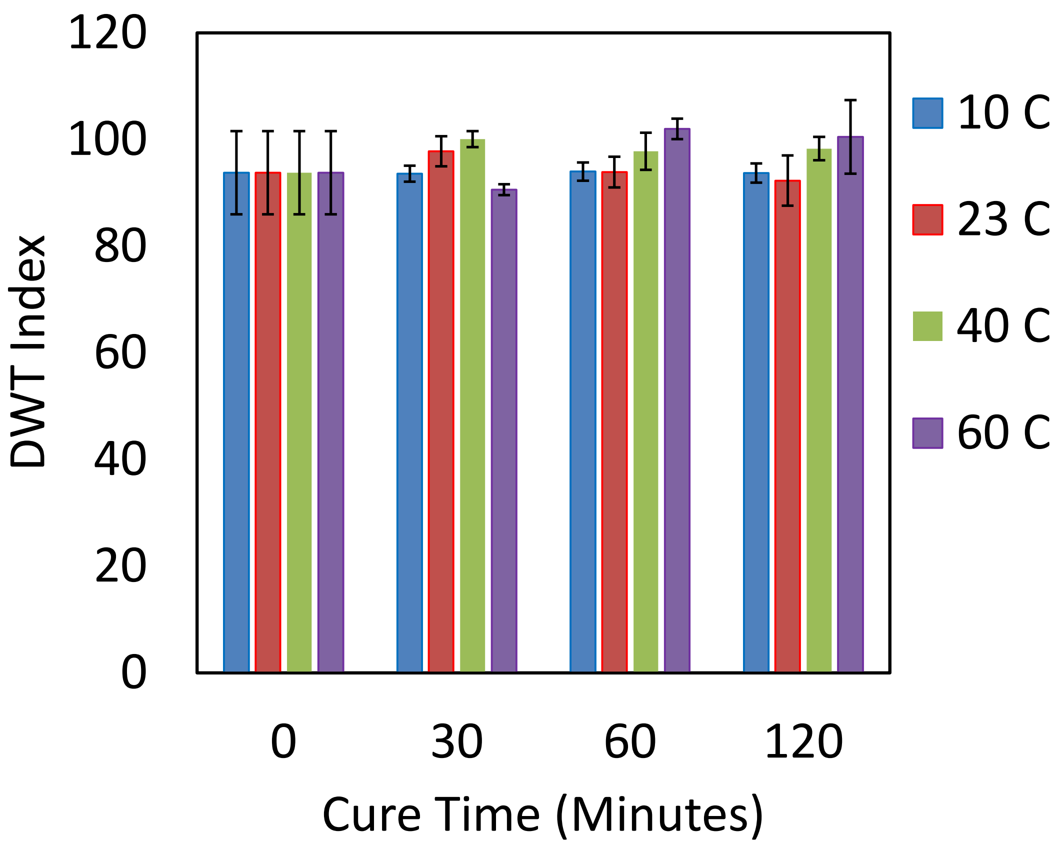
$$DWT = \frac{\sigma_{650} - \sigma_{550}}{\varepsilon_{650} - \varepsilon_{550}}$$

- Higher DWT index indicates a more workable mix



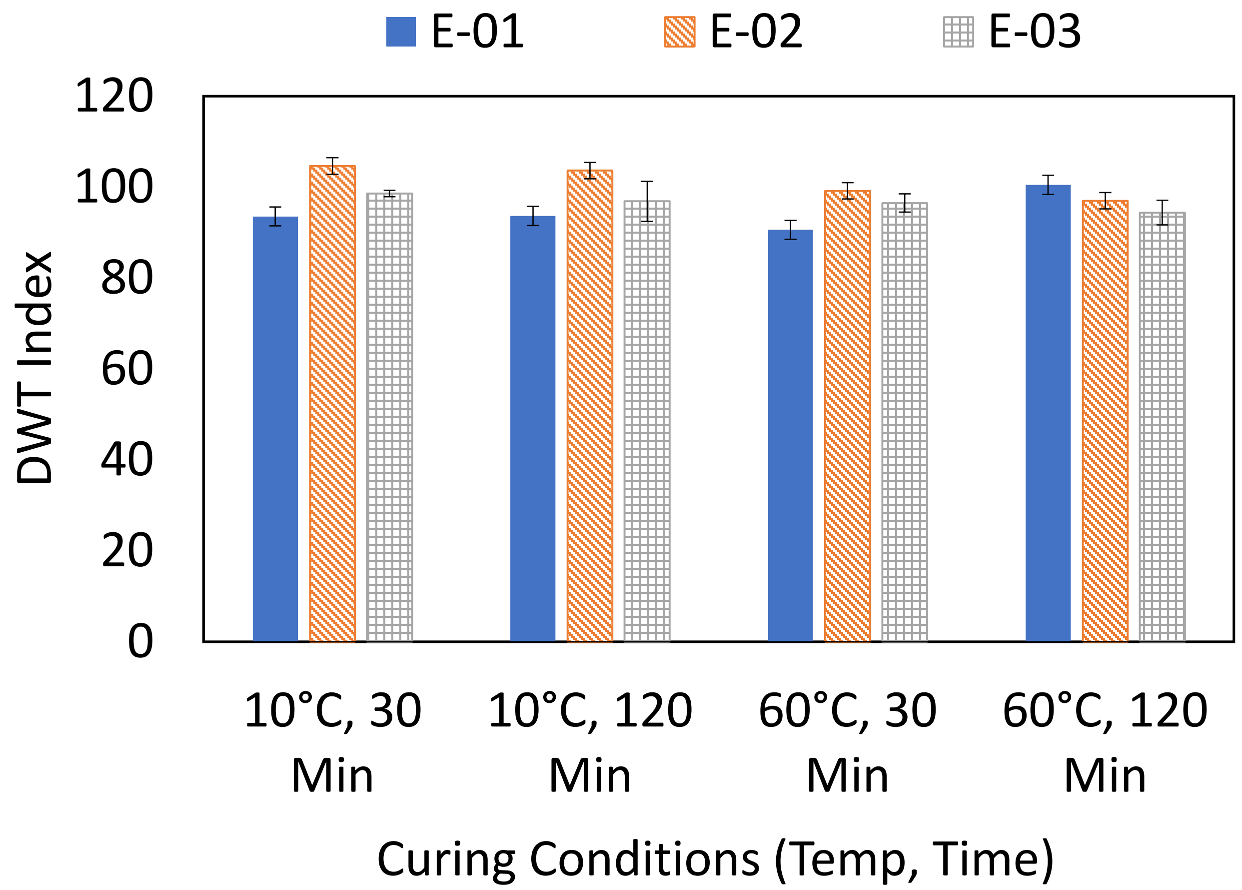
DWT: Curing Condition Evaluation

- Neither cure time nor temperature had statistically significant influence on DWT index
- DWT developed for Hot Mix Asphalt (HMA) and Warm Mix Asphalt (WMA)
    - Targets higher densities than achieved for CIR
- Constant vertical pressure different than gyratory motion used in compaction



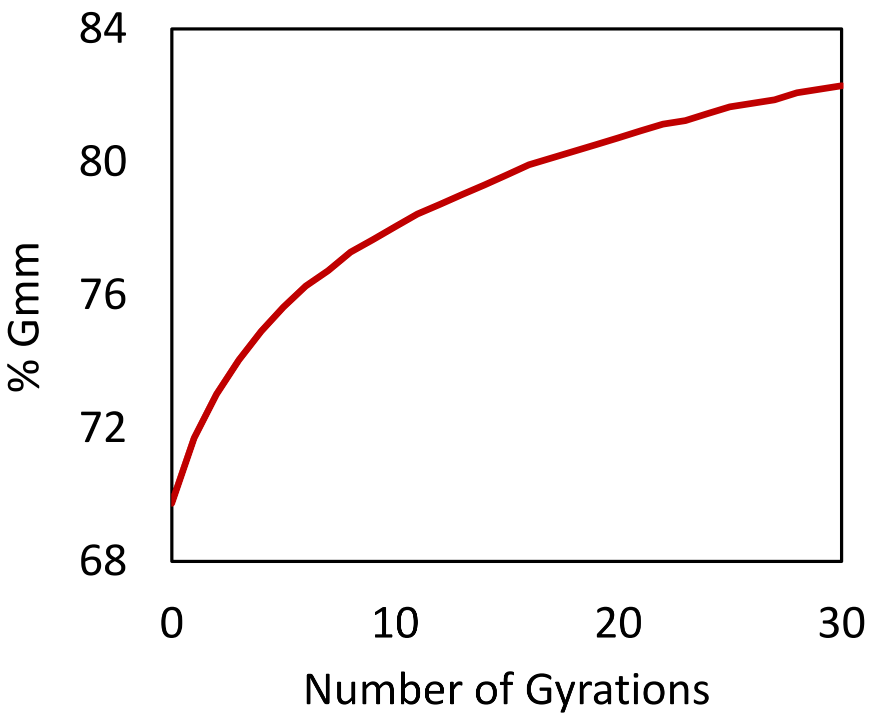
DWT: Emulsion Comparison

- Statistically significant difference between three emulsions
- E-02 most workable
- 60°C, 120 min. not appropriate
- All results below "low workability" threshold (140) defined by Dongre for HMA



CIR Modified SGC Metrics

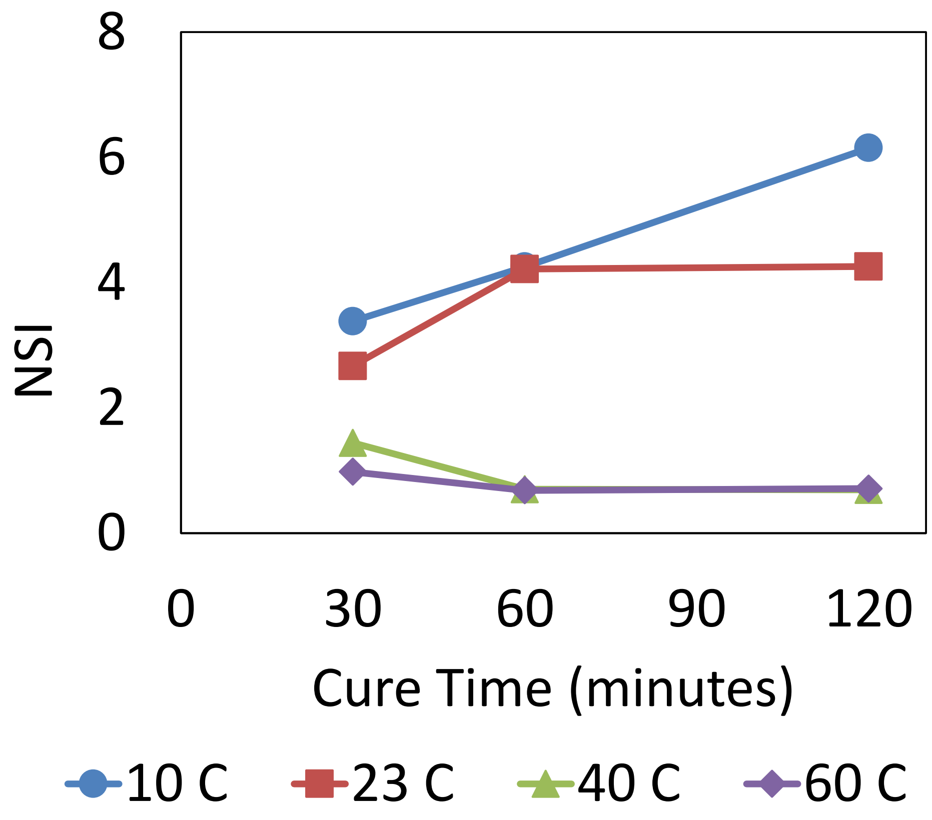
- Modified for use with CIR – lower densities, fewer gyrations
- Final height
- Final density (% Gmm)
- Construction Densification Index
- Workability Energy Index
- Normalized Shear Index



SGC Metrics: Curing Condition Evaluation

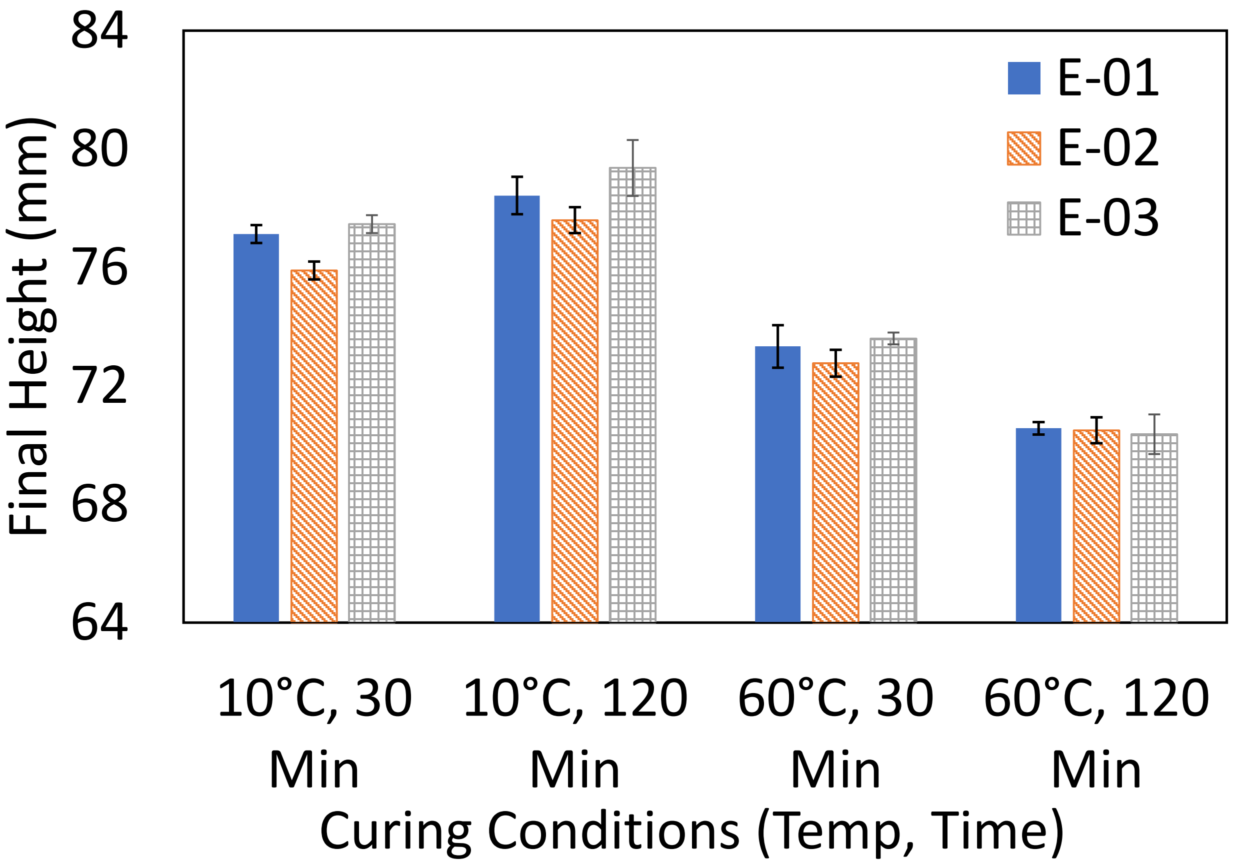
- Statistically sensitive to curing temperature only
- Trend shown in graph seen for all metrics
  - Normalized Shear Index (NSI)
  - Higher NSI indicates more energy required to compact
  - Moisture loss directly proportional to compactability
  - Different trend than seen with LTT –

↑ Curing temperature ↑ Workability



SGC Metrics: Emulsion Comparison

- Three general groupings
  1. Lowest results at 10°C, 120 min; highest results 60°C, 120 min
  2. Highest results at 10°C, 120 min; lowest results 60°C, 120 min
  3. No data or unclear trends
- Metrics not consistent across three emulsions
- Final density, WEI-CIR best differentiation between three emulsions



Conclusions

- Quantifying workability beneficial for asphalt emulsion selection and understanding time available to complete mixing and placement
- LTT and DWT useful in quantifying workability of asphalt emulsion CIR
  - More robust correlation between LTT and DWT/SGC Metrics needed
- Cure temperature more significant than cure time
  - Low or intermediate temperatures recommended for cure temperature to more clearly distinguish between asphalt emulsion performance
- Compaction method influences workability – which method mimics field placement?

Thank you! Questions?

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