Design of High RAP Mixes for Local Roads

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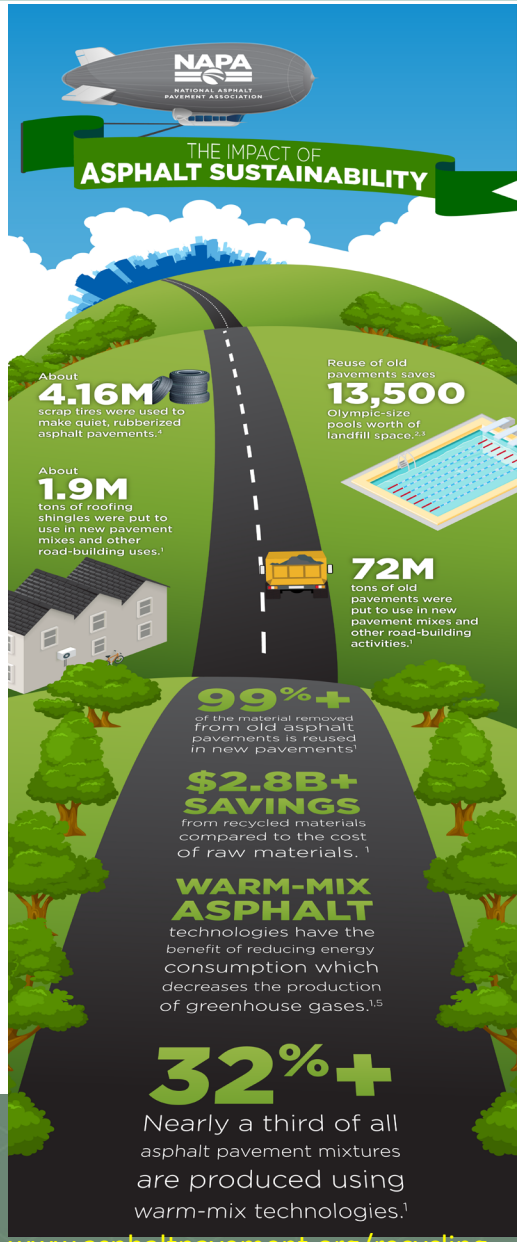
Outline

- Background
- Objectives
- Phase 1- Laboratory Testing Program
- Findings of Phase 1
- Phase 2 Field Test Sections
- Phase 2 Lab Test Results
- Phase 2 Preliminary Findings

Background

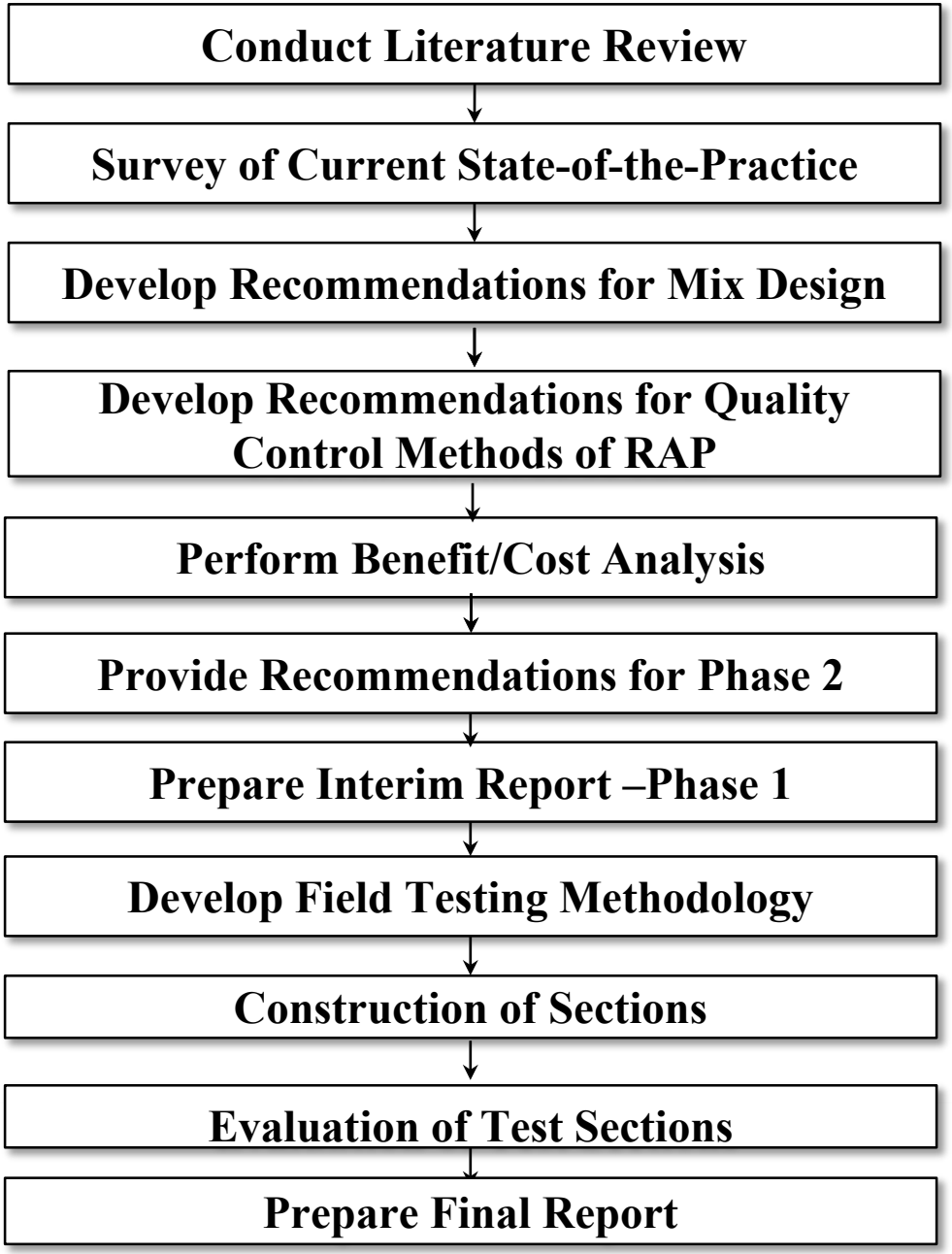
- Though the benefits of using higher amount of RAP in new mixes are high, it presents a concern that resultant mixture may be prone to more cracking.
- Over the past two decades, numerous research studies have been conducted to address issues with using higher percentages of RAP in asphalt mixtures.
- Most of these studies have focused on developing mix design procedures and specifications for mixtures used on interstates and highway systems only.



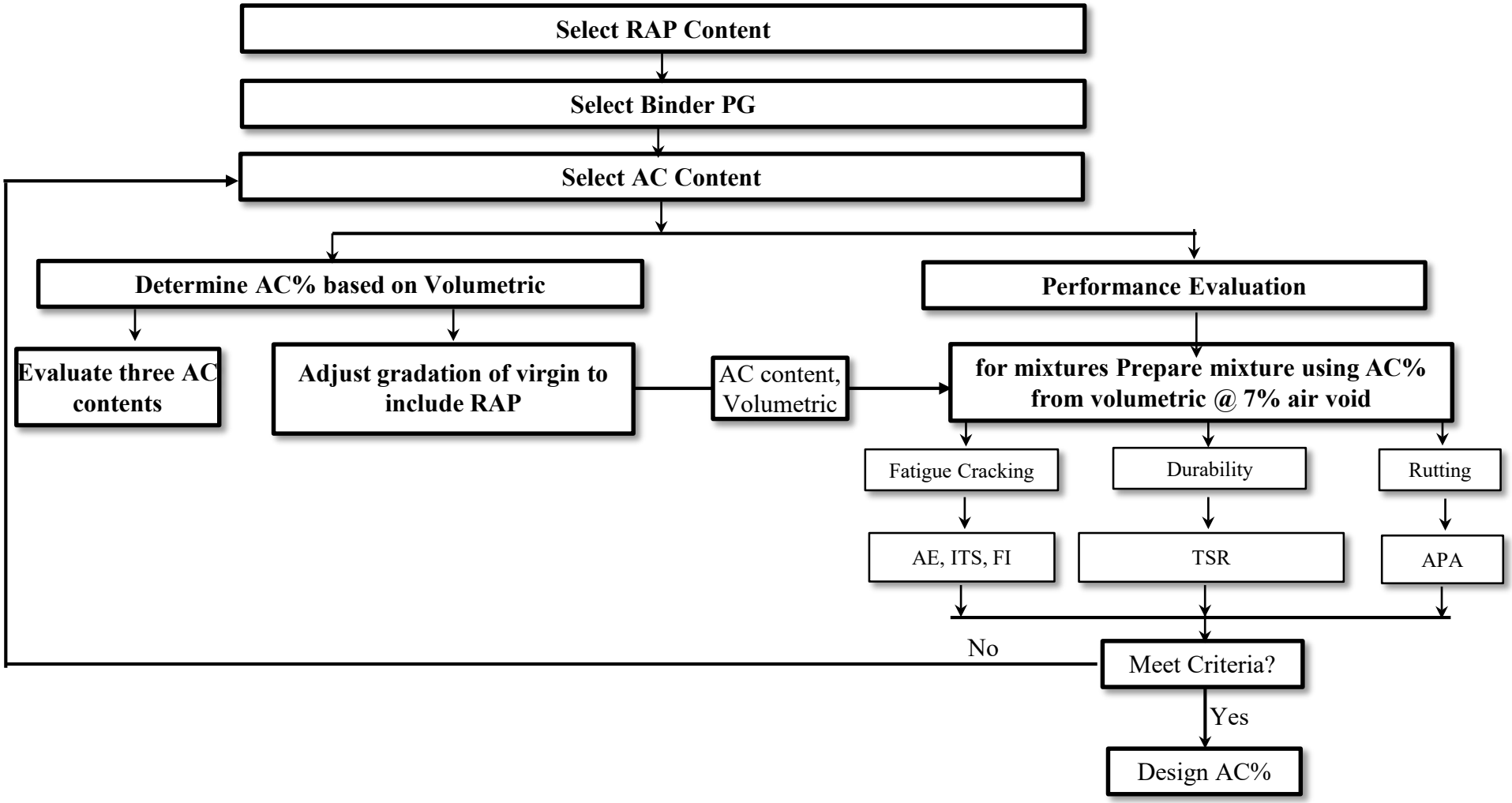
Objectives

- Assess the current practices of using RAP in surface course mixtures for local roadways.
- Develop recommendations for a cost-effective method for designing well-performing and durable surface course mixtures with different RAP contents for use on local roadways.
- Evaluate the cost benefits of using different RAP contents in the surface course layer of local roadways.
- Provide recommendations for quality control methods of RAP used in the surface mixtures of local roadways.

Project Overview



Phase 1: Laboratory Testing Program



Materials: RAP

- Limestone aggregates were obtained the mixes considered in the testing program.
- RAP material was obtained from two different sources.
- A typical JMF for mixes to be used in resurfacing project for the City of Columbus during next construction was obtained.
- The virgin asphalt binder that will be used in control and 20% RAP is PG 64-22.
- Softer virgin binder PG 64-28 was used.

Materials: RAP

- Two RAP materials with different rheological properties we evaluated.

RAP ID	Continuous High Temperature Grade, °C	Continuous Low Temperature Grade, °C
Shelly 2017 Pile – A RAP-1	93.1	-14.3
IR 270 (RAP 2)	79.9	-21.1

Materials: Recycling Agents (RA)

- Three types of recycling agents (RAs) were considered:
  - Aromatic Extracts: Hydrolene T90
  - Tall Oils: Sylvaroad™ RP1000
  - Triglycerides & Fatty Acids (WV Oil): Soybean Oil

Mixtures Testing

Mix	% RAP	Virgin Binder	Virgin AC%	RBR	G_{mm}
Control	0	PG 64-22	6.3	0	2.429
20% RAP-1	20	PG 64-22	5.3	16%	2.428
30% RAP-1	30	PG 64-28	4.8	25%	2.440
40% RAP-1	40	PG 64-28	4.3	33%	2.448
50% RAP-1	50	PG 64-28	3.8	41%	2.455
30% RAP-1 -Hydrolene RA	30	PG 64-22	4.8	25%	2.439
40% RAP-1 -Hydrolene RA	40	PG 64-22	4.3	33%	2.439
50% RAP-1 -Hydrolene RA	50	PG 64-22	3.8	41%	2.435
30% RAP-1 -Sylvaroad RA	30	PG 64-22	4.8	25%	2.440
40% RAP-1 -Sylvaroad RA	40	PG 64-22	4.3	33%	2.447
50% RAP-1 -Sylvaroad RA	50	PG 64-22	3.8	41%	2.444
30% RAP-1 -Soybean RA	30	PG 64-22	4.8	25%	2.437
40% RAP-1 -Soybean RA	40	PG 64-22	4.3	33%	2.441
50% RAP-1 -Soybean RA	50	PG 64-22	3.8	41%	2.439
30% RAP-2	30	PG 64-28	4.8	25%	2.434
40% RAP-2	40	PG 64-28	4.3	32%	2.433
50% RAP-2	50	PG 64-28	3.8	40%	2.438

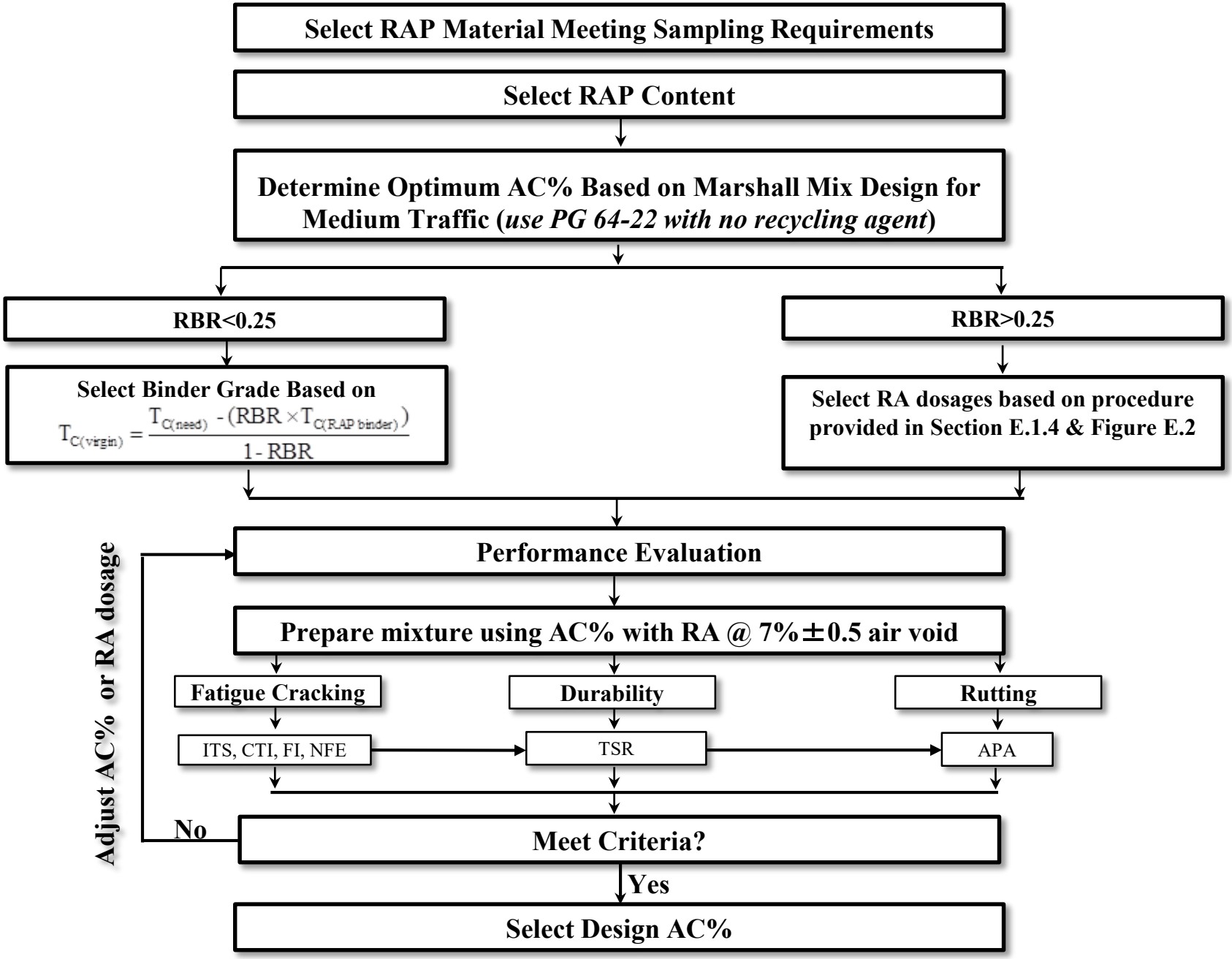
Phase 1- Findings

- Hydrolene (T90) aromatic oil RA and Sylvaroad tall oil RA had significantly improved the cracking resistance of mixes with up to 50%.
- The Hydrolene RA was more effective than the Sylvaroad RA.
- RAP mixes with Soybean RA had better performance than those with softer binder (PG 64-28). However, was 40% and 50% mixes with Soybean RA had much lower resistance to fatigue cracking as compared to those with the other RAs.

Phase 1- Findings

- Cost analyses showed that 50%RAP mix with Hydolene RA can be 26% less expensive than RAP mixes currently being used.
- Cost analyses showed that 50%RAP mix with Sylvaroad RA can be 13% less expensive than RAP mixes currently being used.
- The RAP source has a significant effect on the cracking resistance of high RAP asphalt mixes.
  - Particularly for mixes with more than 30% RAP.
- Therefore, it is very important to determine the performance grade of extracted and recovered RAP binder.

Recommended Mix Design



Recommended Criteria for RAP Mixes

Parameter	FI (SCB)	NFE (SCB)	TSR (AAHTO T 283)	Rutting (APA)
Criteria	Minimum 2	Minimum 25 $J/m^2/kPa$	Minimum 0.8	Maximum 5 mm

NFE: Normalized fracture Energy

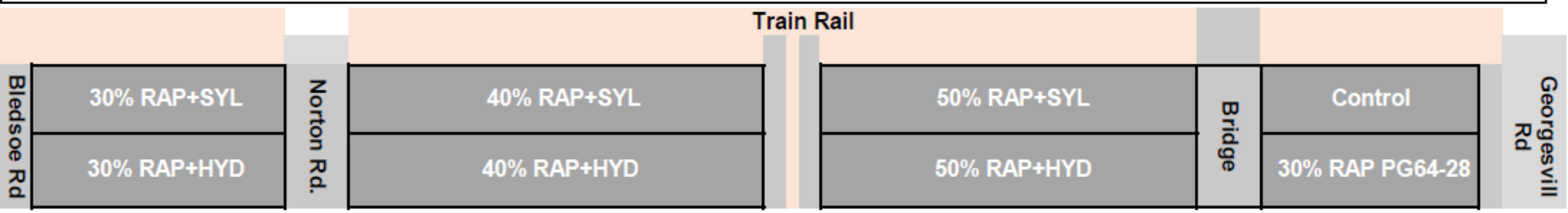
FI: Flexibility Index

TSR: Tensile Strength Ration

PHASE 2 FIELD TEST SECTIONS

Field Test Sections

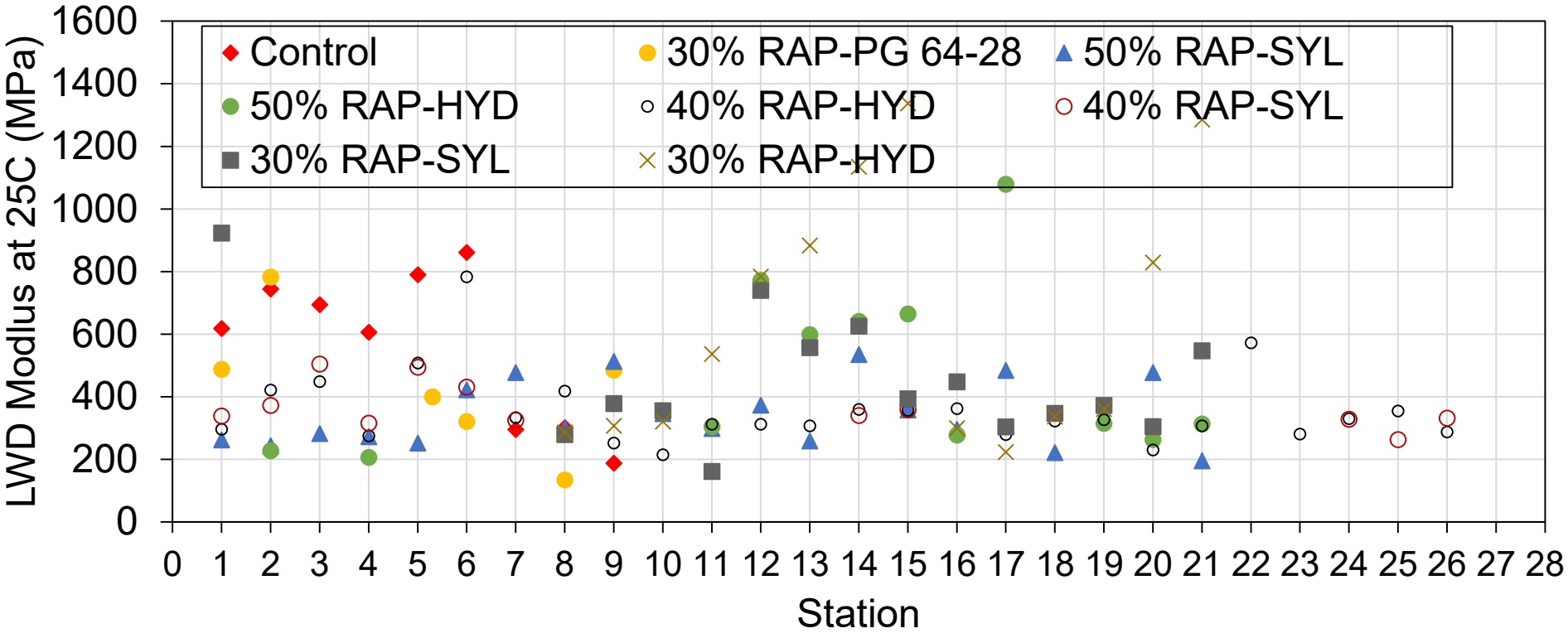
- A total of eight test sections were constructed on Hall road Hall Road in the City of Columbus:
  - A control section
  - A section with 30% RAP and softer binder PG 64-28
  - Six sections with recycling agents: Three sections with 30%,40% and 50% RAP and the following recycling agents.
    - ✓Sylvaroad™ RP1000
    - ✓Hydrolene
- Construction started on 09/11/2018 and was completed 09/21/2018.One day was allocated for each section.


Train Rail
Bledsoe Rd
30% RAP+SYL
30% RAP+HYD
Norton Rd.
40% RAP+SYL
40% RAP+HYD
50% RAP+SYL
50% RAP+HYD
Bridge
Control
30% RAP PG64-28
Georgesvill Rd

Sections Pre-Construction Evaluation

- Existing roadway was evaluated prior to milling and construction.
- Areas of distressed areas were identified.
- Core location were selected to avoid distressed areas.

Sections Pre-Construction Evaluation



Construction of Sections

- During construction, the research team monitored the placement and compaction of the control and RAP mixes .
- Pictures and videos were taken to document the construction process.

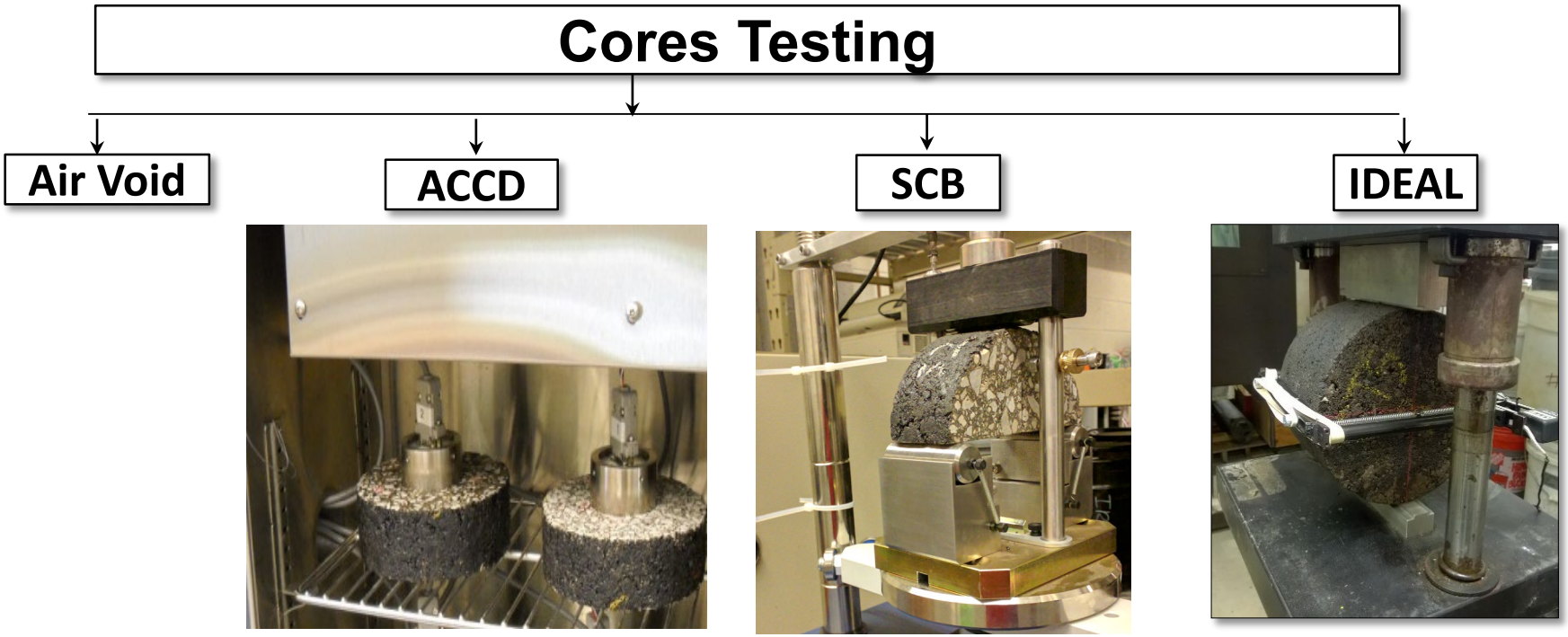
Construction of Sections

Construction of Sections

Testing of Sections

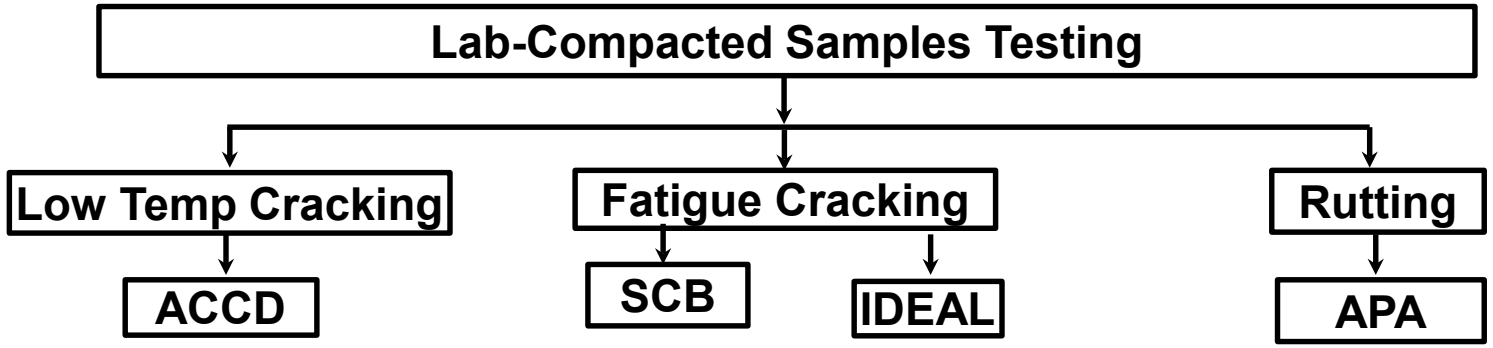
Testing Of Cores

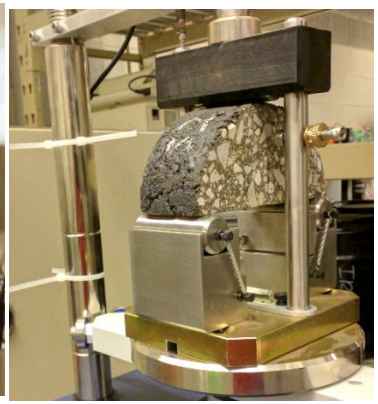
- At least 10 field Cores were obtained from each test section.

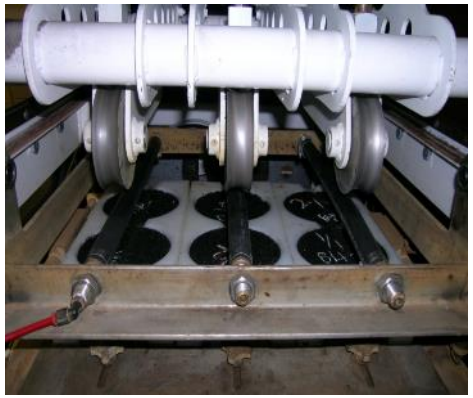


Testing of Lab-Compacted Samples

- Specimens of the loose mixtures were compacted in the laboratory to achieve target air voids of 7±0.5%.







RESULTS

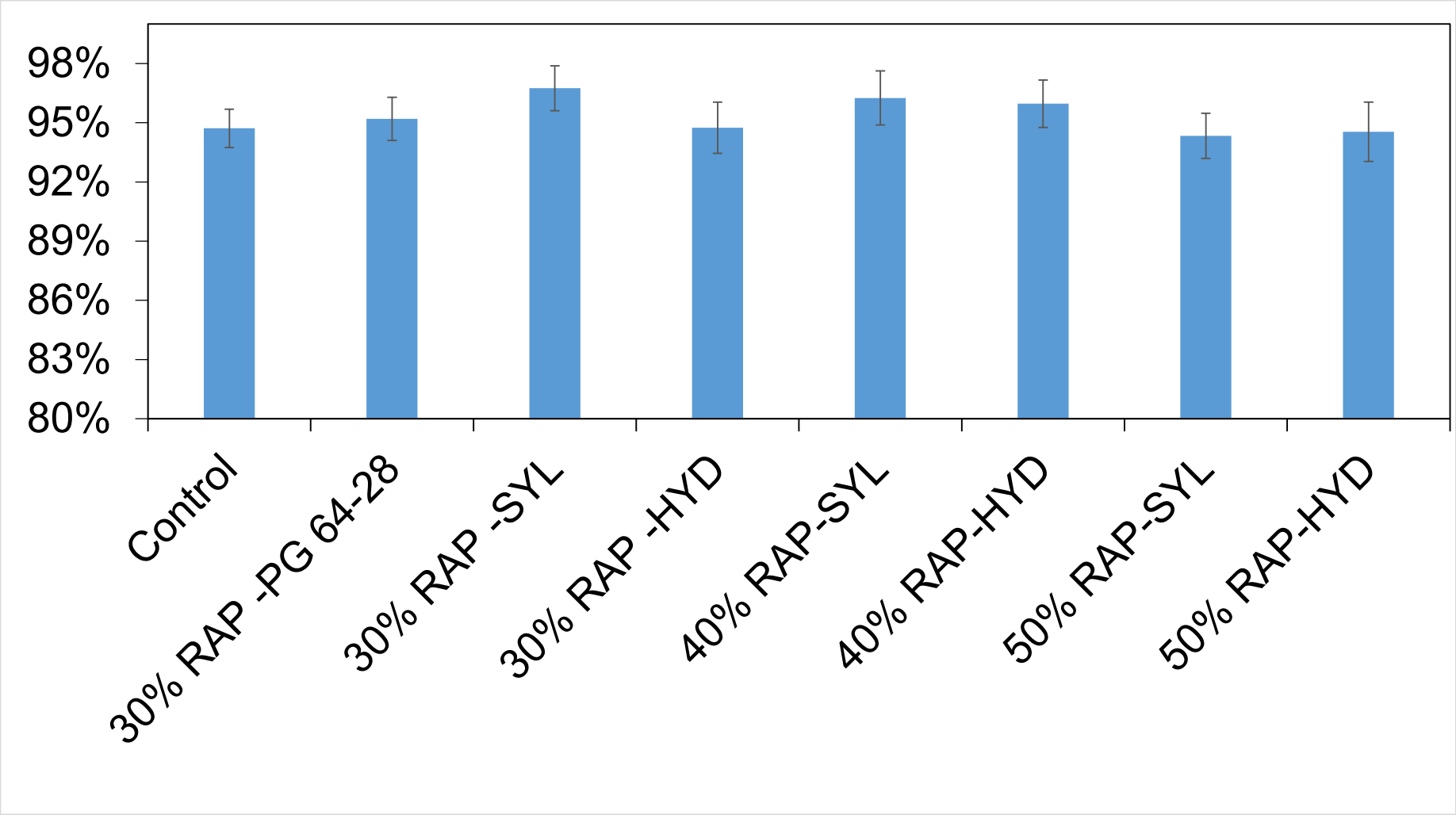
RAP Properties

RAP binder Content	High Temperature grade	Low-Temperature Grade (Stiffness)	Low-Temperature Grade (m-value)	PG
6.1%	86.8	-21.91	-16	82-16

Mixtures Properties

Mixture	Total AC (%)	Virgin AC (%)	RAP AC (%)	RBR
Control	6.3	5.1	1.2	19%
30%RAP 64-28	6.2	4.4	1.8	29%
30%RAP+SYL	6.2	4.4	1.8	29%
30%RAP+HYD	6.2	4.4	1.8	29%
40%RAP+SYL	5.8	3.4	2.4	41%
40%RAP+HYD	5.8	3.4	2.4	41%
50%RAP+SYL	5.7	2.7	3	53%
50%RAP+HYD	5.7	2.7	3	53%

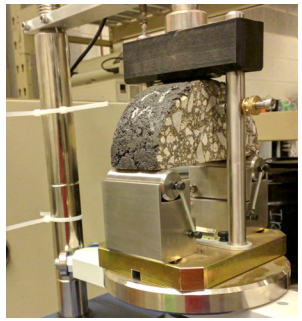
Relative Compaction



SCB Parameters

$$FI = \frac{G_F}{|m|} \times A$$

$$NFE = \frac{G_F}{\sigma_{peak}}$$

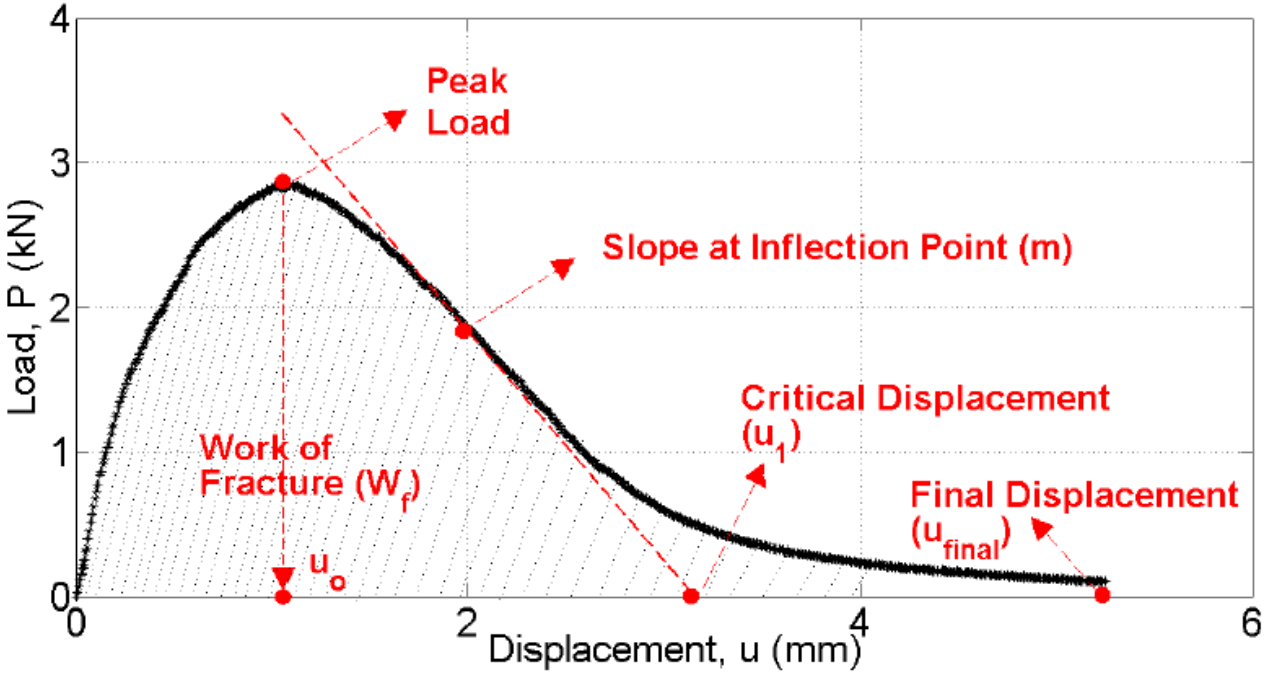


m = value of slope at inflection point

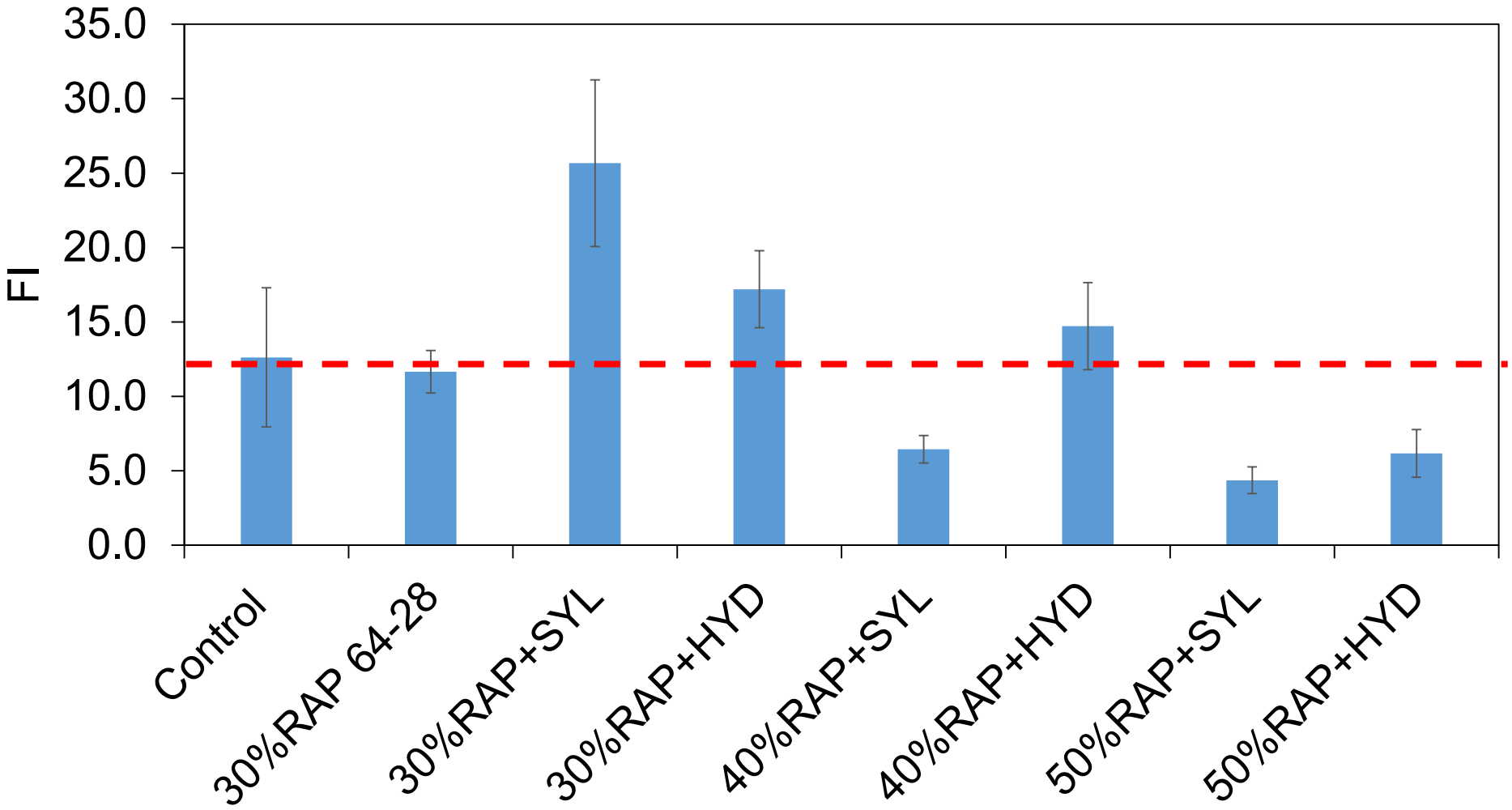
A = unit conversion (0.01)

G_F= fracture energy (Joules/m^2)

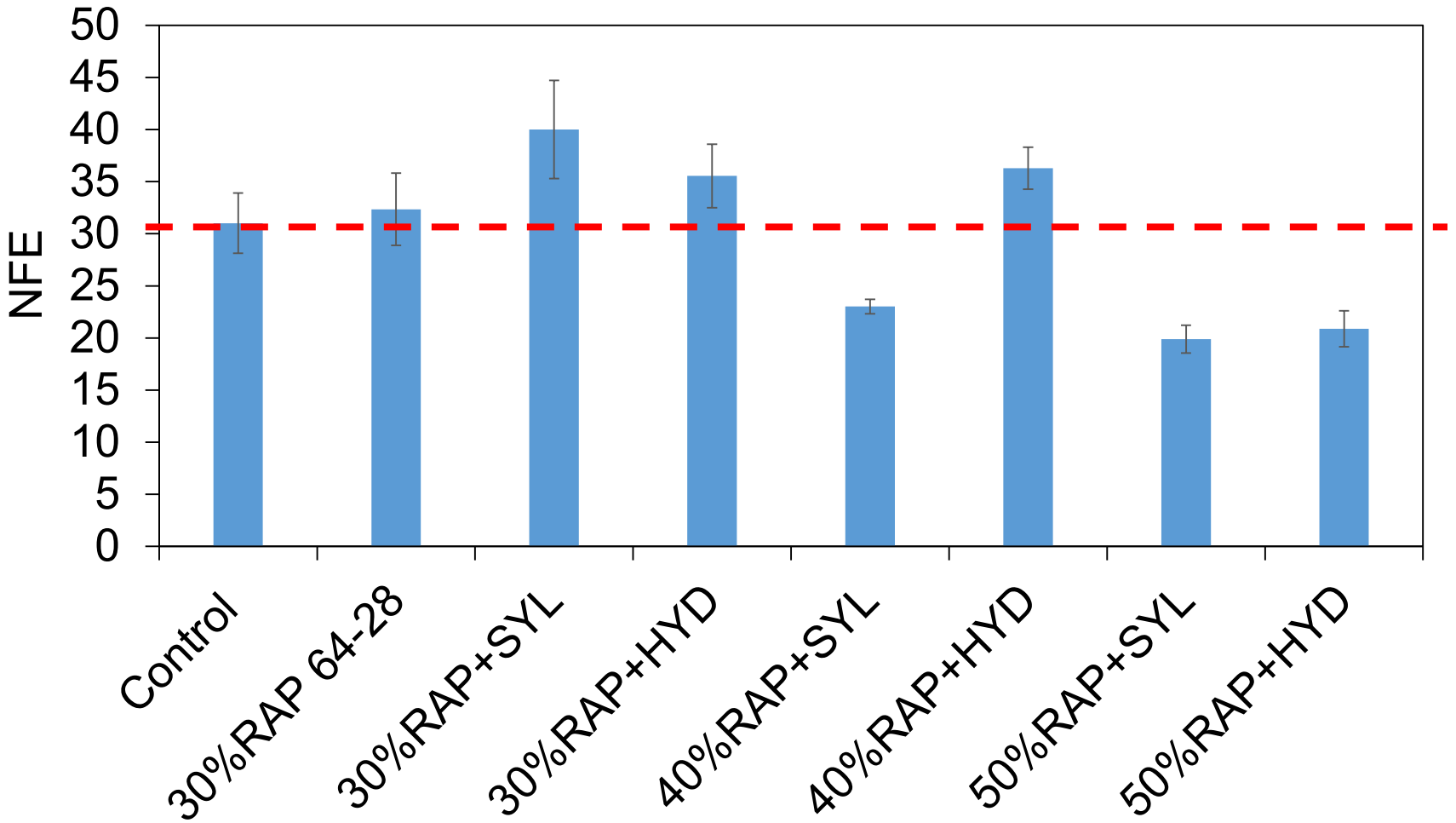
σ_{peak}=peak strength



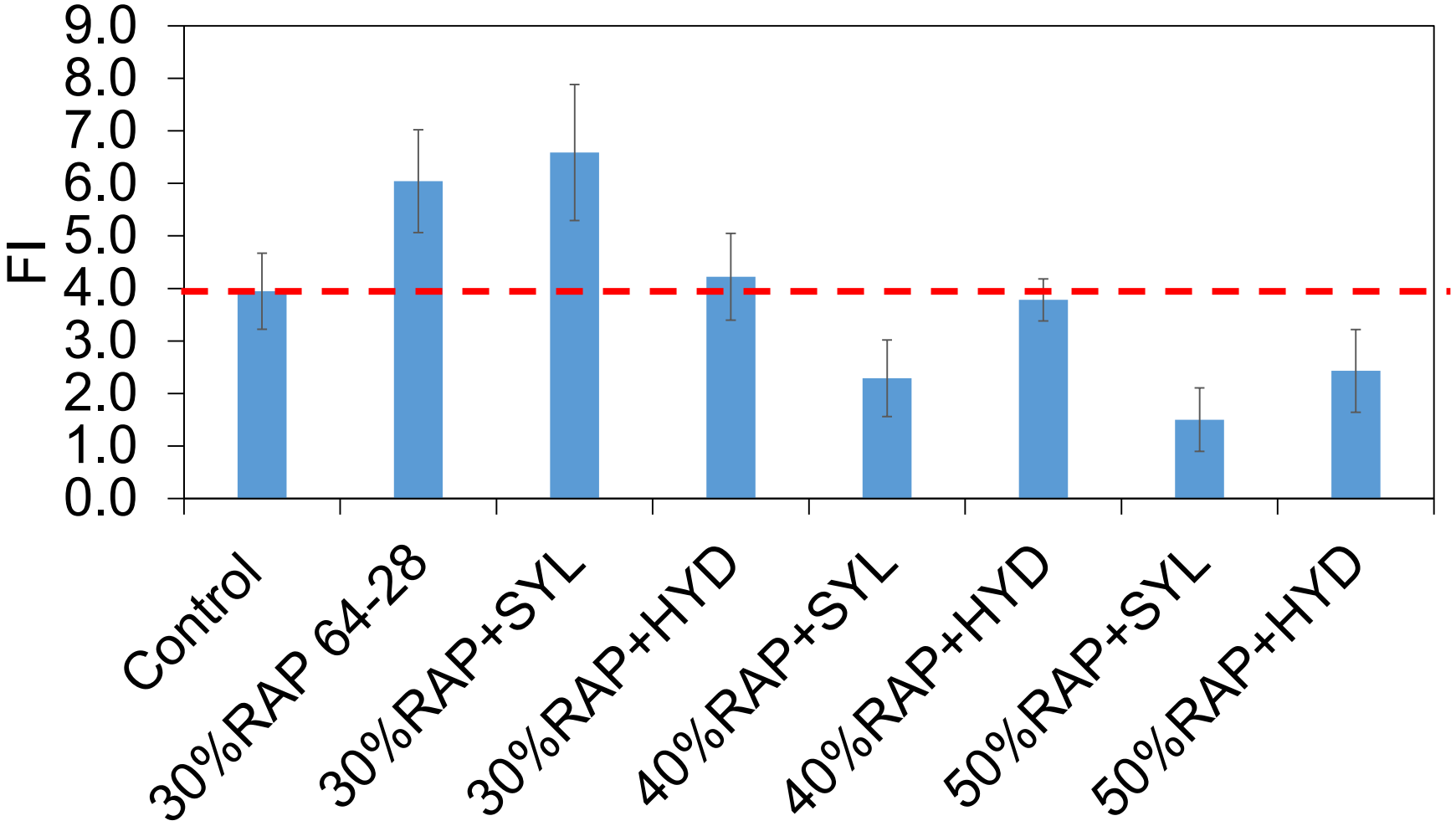
SCB- Flexibility Index (FI) (Field Cores)



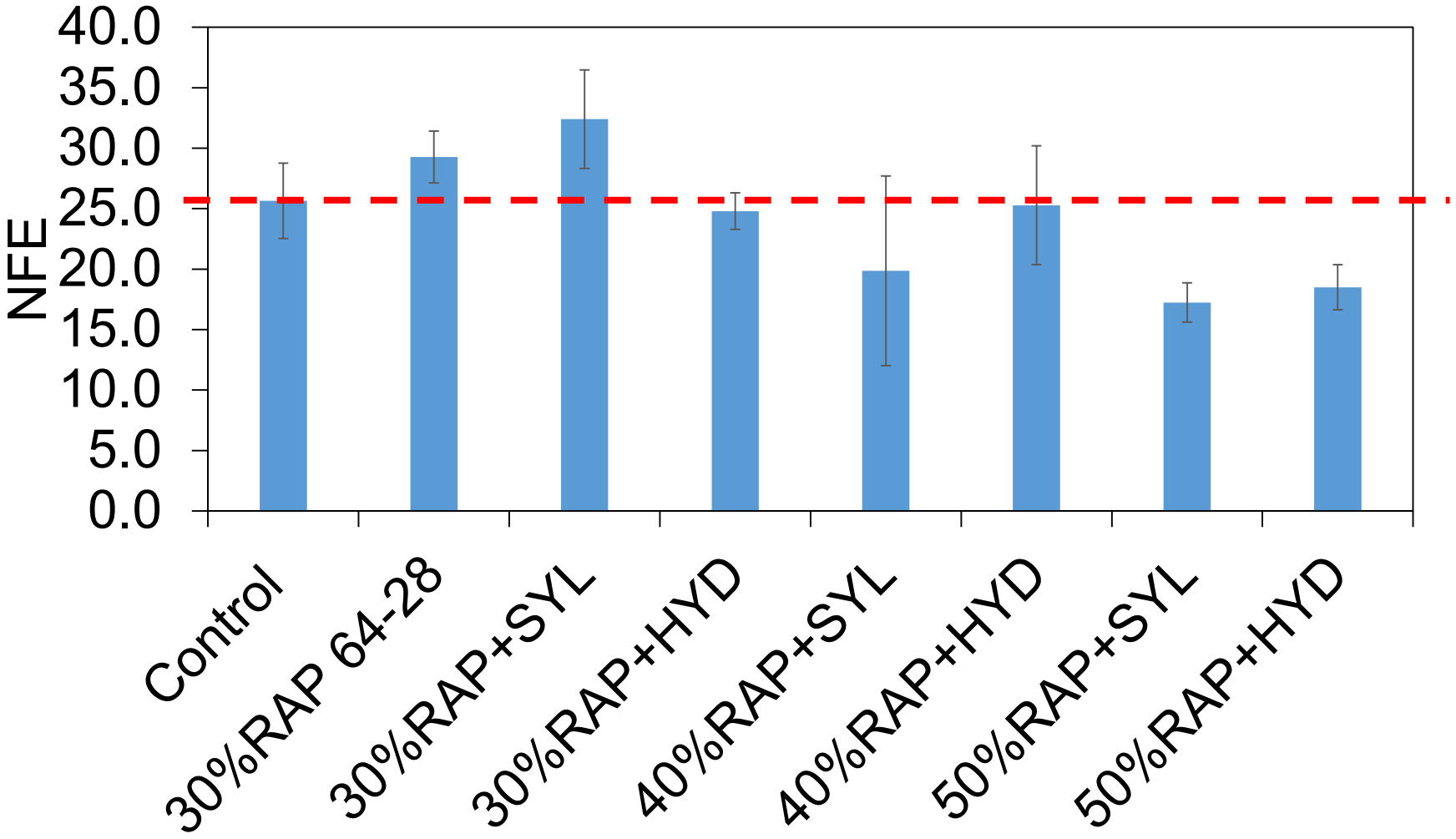
SCB-Normalized Fracture Energy (NFE) (Field Cores)



SCB- FI (Lab-Compacted Samples)



SCB-NFE (Lab-Compacted Samples)

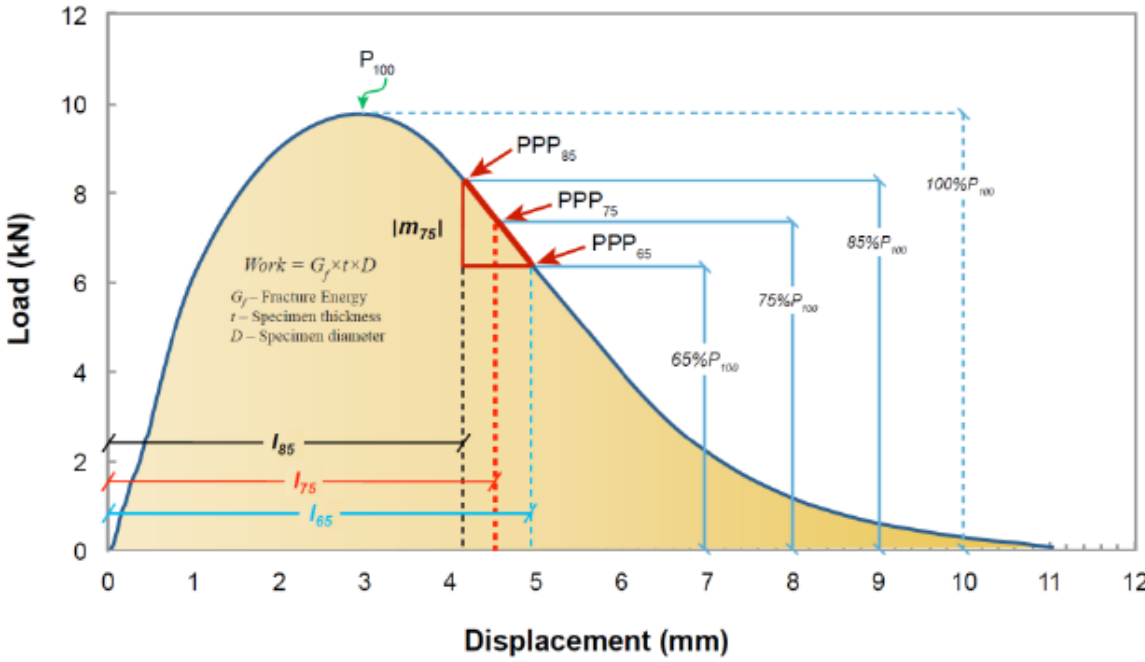


IDEAL Test Results

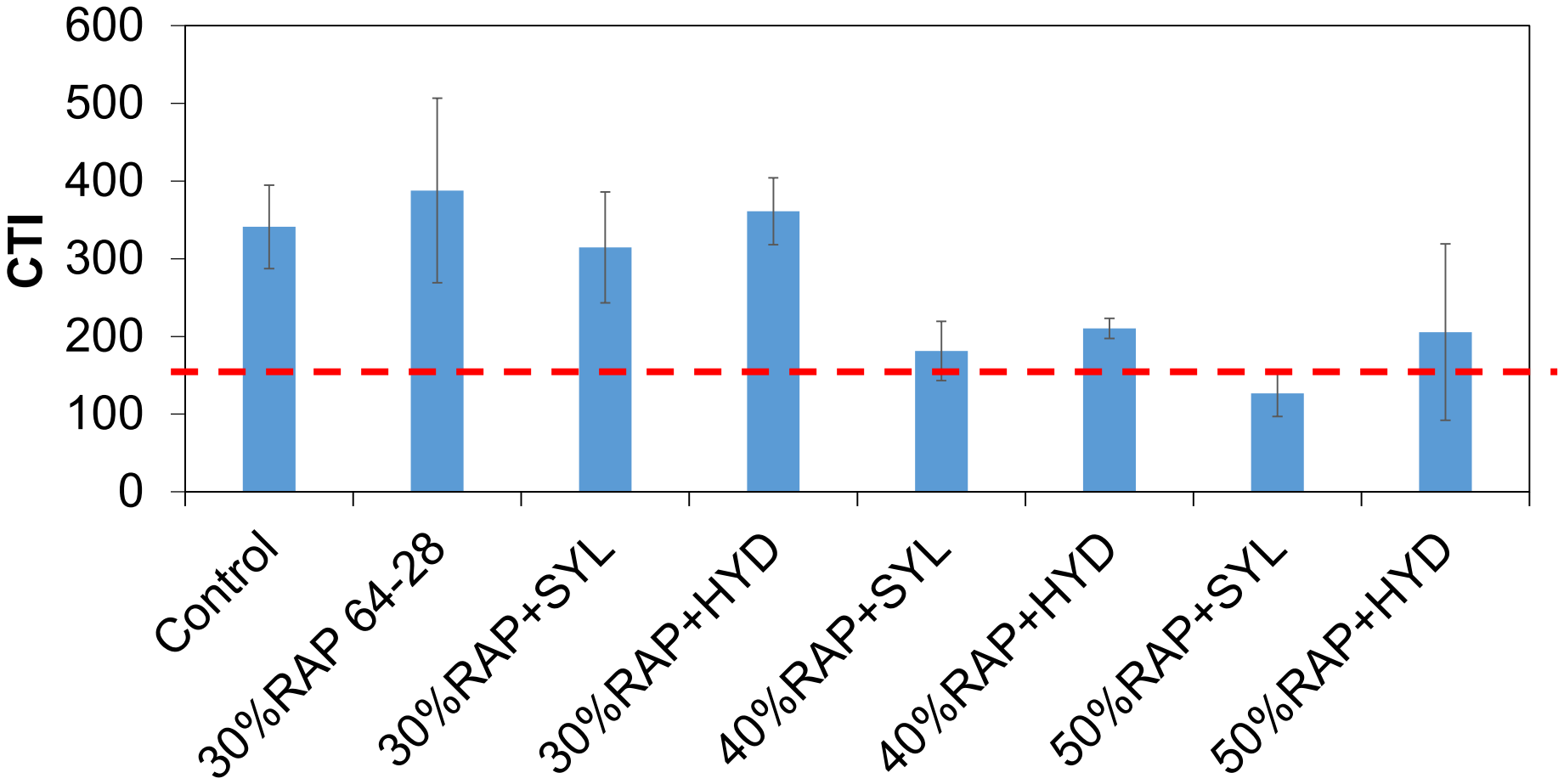
$$CTI = \frac{t}{62} \times \frac{G_f}{|m_{75}|} \times \left(\frac{l_{75}}{D}\right)$$

$$m_{75} = \frac{P_{85} - P_{65}}{l_{85} - l_{65}}$$

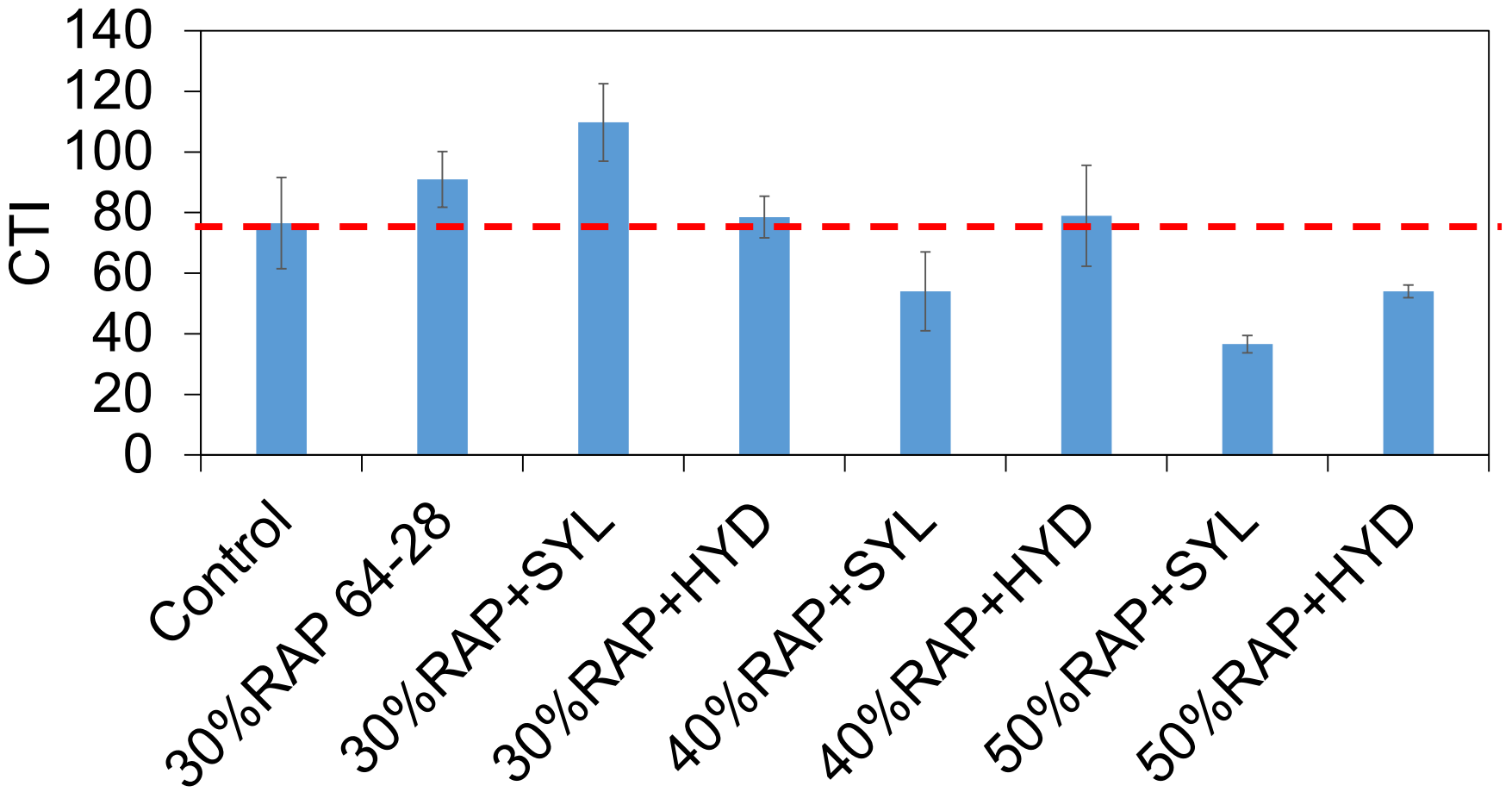
t: is thickness in mm



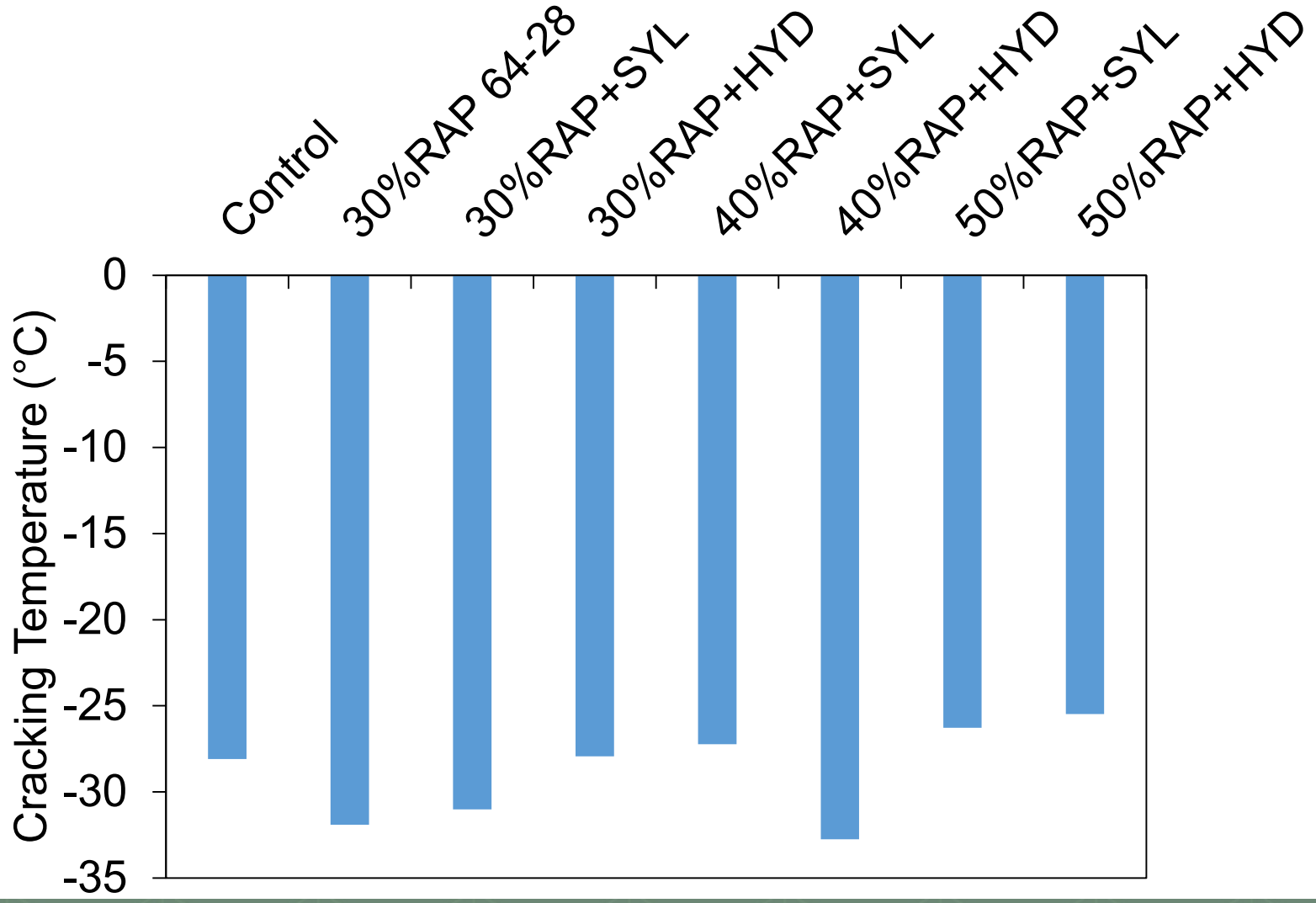
IDEAL-CTI (Field Cores)



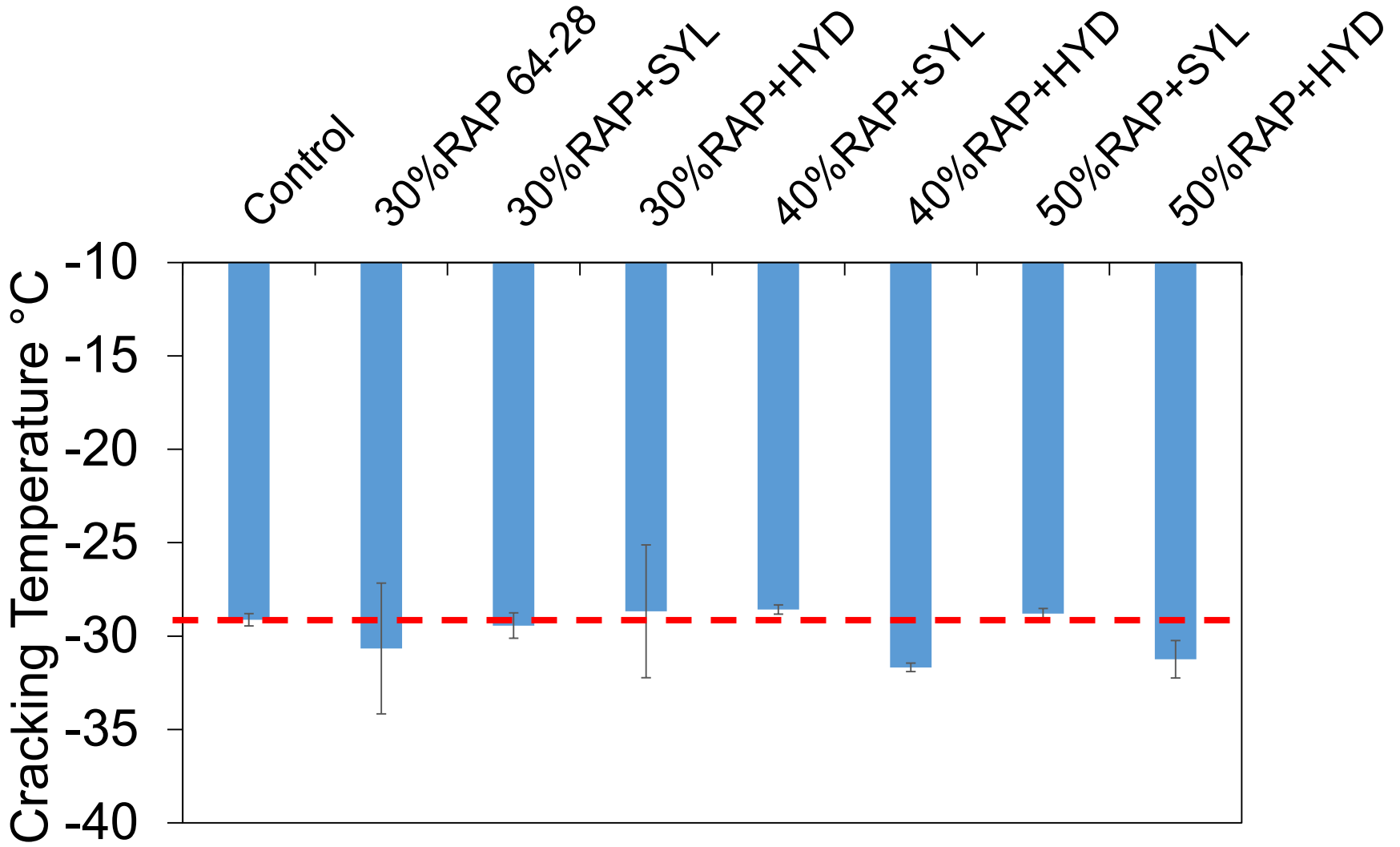
IDEAL-CTI (Lab-Compacted Samples)



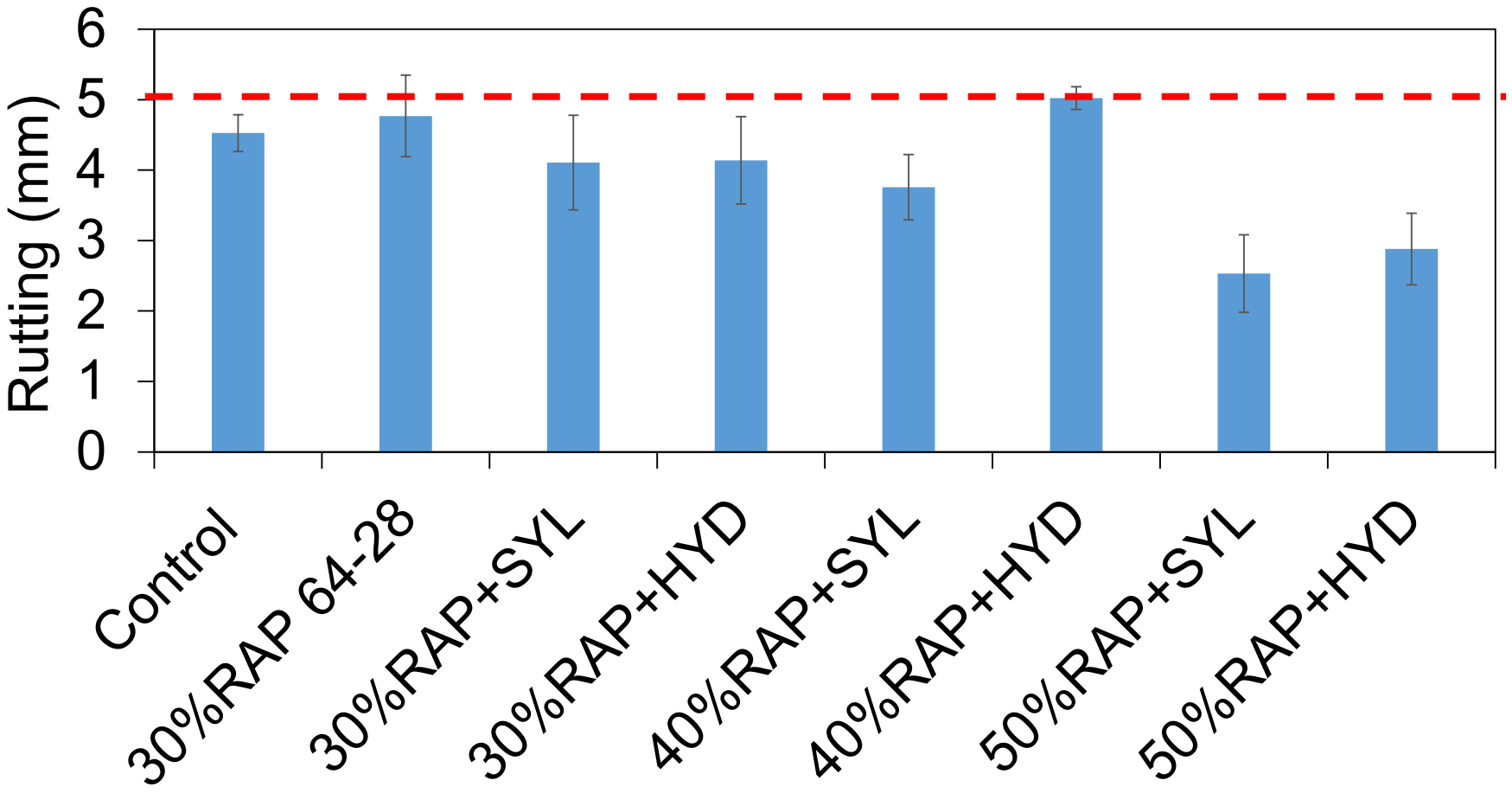
ACCD Results (Field Cores)



ACCD Results(Lab-Compacted Samples)



APA Results (Lab-Compacted Samples)



Preliminary Findings

- Hydrolene (T90) Aromatic oil RA and Sylvaroad RA had significantly improved the cracking resistance of mixes with up to RAP binder replacement (RBR) of 0.3 .
- The Hydrolene RA also improved the cracking resistance of mixes with up to 0.41 RBR and was more effective than the Sylvaroad RA for mixes with RBR higher than 0.3.
- The use of softer binder PG 64-28 and an RBR of 0.3 resulted in a mix with similar performance to that with 0.19 RBR and PG 64-22.

Preliminary Findings

- The rutting resistance was enhanced with increasing the RBR even when a recycling agent is used.
- In general, the FI, NFE, and CTI indices of the field cores had similar trends to those of samples compacted in the lab using field-produced mixes but were higher in value.

Questions??