

Rejuvenated High RAP Mixtures A Field Application

**Pennsylvania Asphalt Pavement Association
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PAPA

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DISCUSSION TOPICS

1 Background on the Use of Rejuvenators

2 Motivation for This Project

3 Field Application - High RAP with RA

4 Laboratory Test Results

5 Summary & Future Work



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Laboratory Test Results

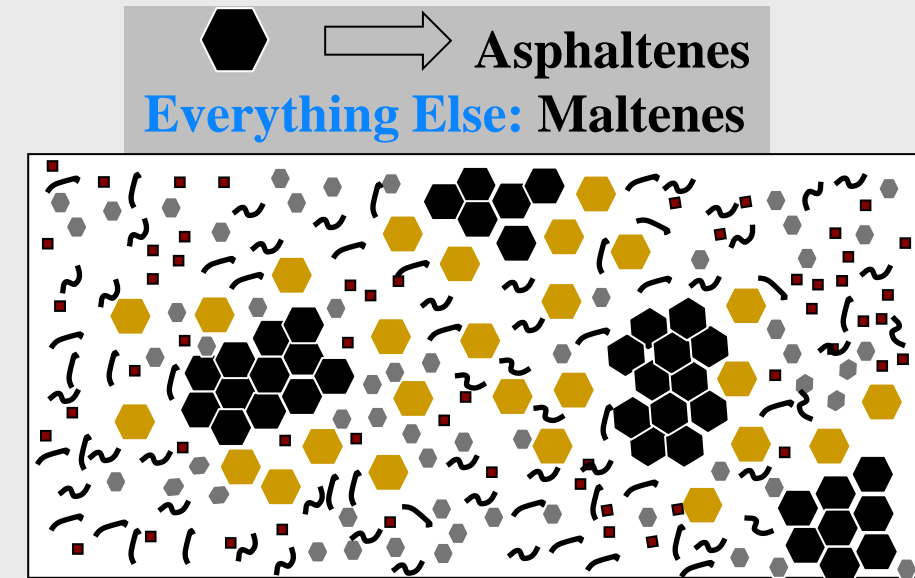
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Summary & Future Work



What Are Rejuvenators? (Recycling Agents)

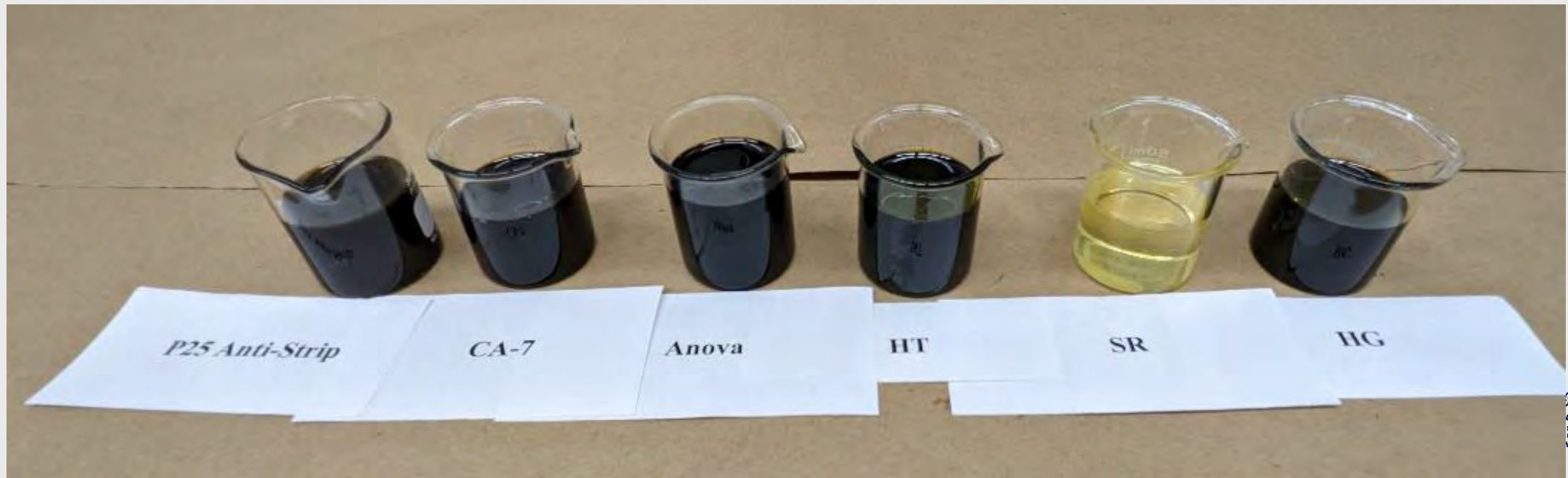
- ❖ The higher the ratio of asphaltene to maltenes, the higher brittleness and cracking potential of asphalt binder
- ❖ Asphalt Rejuvenators peptize and polarize asphaltenes
- ❖ Rebalance the ratio of Asphaltenes to Maltenes
- ❖ Reduce cracking potential
- ❖ Maintain long-term effectiveness



Peptizing: Dispersing and Deflocculating

Rejuvenator Types

- ❖ **Two Principal Categories:**
 - **Petroleum Based**
 - Paraffinic oil, aromatic extracts, engine oil
 - **Plant Based (Bio-Based)**
 - vegetable oil (virgin, modified, or waste), tall oil



Where do we need rejuvenators?

- ❖ **Most often when the RAP content or RAS content is high, or when a combination of RAP and RAS is used in the asphalt mixture.**
- ❖ **Need to consider several elements to decide if RA is needed and at what dosage rate:**
 - **RBR (reclaimed binder ratio) from RAP/RAS**
 - **Performance grade of all binders (Virgin, RAP, RAS, and Target)**
 - **Design binder content**



Dosage Rate Definition

- ❖ **Defined in four ways based on ratio of the rejuvenator mass to the material of interest (reported in percentage).**

- ❖ **Dosage Rate can be reported as a percentage of**
 - **1. Virgin Binder**
 - **2. Recycled asphalt binder (from RAP/RAS)**
 - **3. Total asphalt content (or total fluid content)**
 - **4. Total mass of the asphalt mixture**



Evaluation of Long-Term Effectiveness of Rejuvenators

❖ 1. Through Binder Testing

Parameter (measured on PAV aged binder)	Change after incorporation of the rejuvenator at the recommended dosage rate
$G^* \cdot \sin \delta$ at intermediate test temperature	Decrease of at least 25% in $G^* \cdot \sin \delta$
Stiffness (S) at low temperature	<300 MPa, and decrease of at least 25% in S
Relaxation parameter (m-value) at low temperature	Increase of at least 25% in m
ΔT_c at low temperature	>-5°C, and increase of at least 25% in ΔT_c

❖ 2. Through Mixture Testing

Parameter (measured on long term aged mixture)*	Change after incorporation of the rejuvenator at the recommended dosage rate
IDEAL-CT Index	Increase of at least 30% in the calculated index compared to the mix with no rejuvenator

* Long-term aging achieved through conditioning loose mixture through the NCAT protocol



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Reclaimed Asphalt Pavement (RAP) Usage

- ❖ Interest in PA has grown in using high-RAP mixes, even in surface mixes
- ❖ Lowering the production cost
- ❖ Leveraging the available binder and aggregates
- ❖ Environmental preservation (Think of EPD)
- ❖ Proper design needed to prevent performance issues



RAP Usage in WMA/HMA

- ❖ **#1 Recycling product in USA**
- ❖ **94.6 million tons of RAP recycled in 2021 in HMA/WMA (NAPA, 2021) – All time high**
- ❖ **21.8% of Total Asphalt Mixtures Produced (432.8 Million Tons)**
- ❖ **4.2 Million tons used as aggregate**
- ❖ **100,000 tons used in Cold-Mix Asphalt**



Field Application of High RAP Mixes

- ❖ **Laboratory-produced versus Plant-produced mixtures?**
- ❖ **Most suitable technique for incorporating RA into the asphalt binder or mixture**
- ❖ **The level of field performance improvement achieved through use of RA**



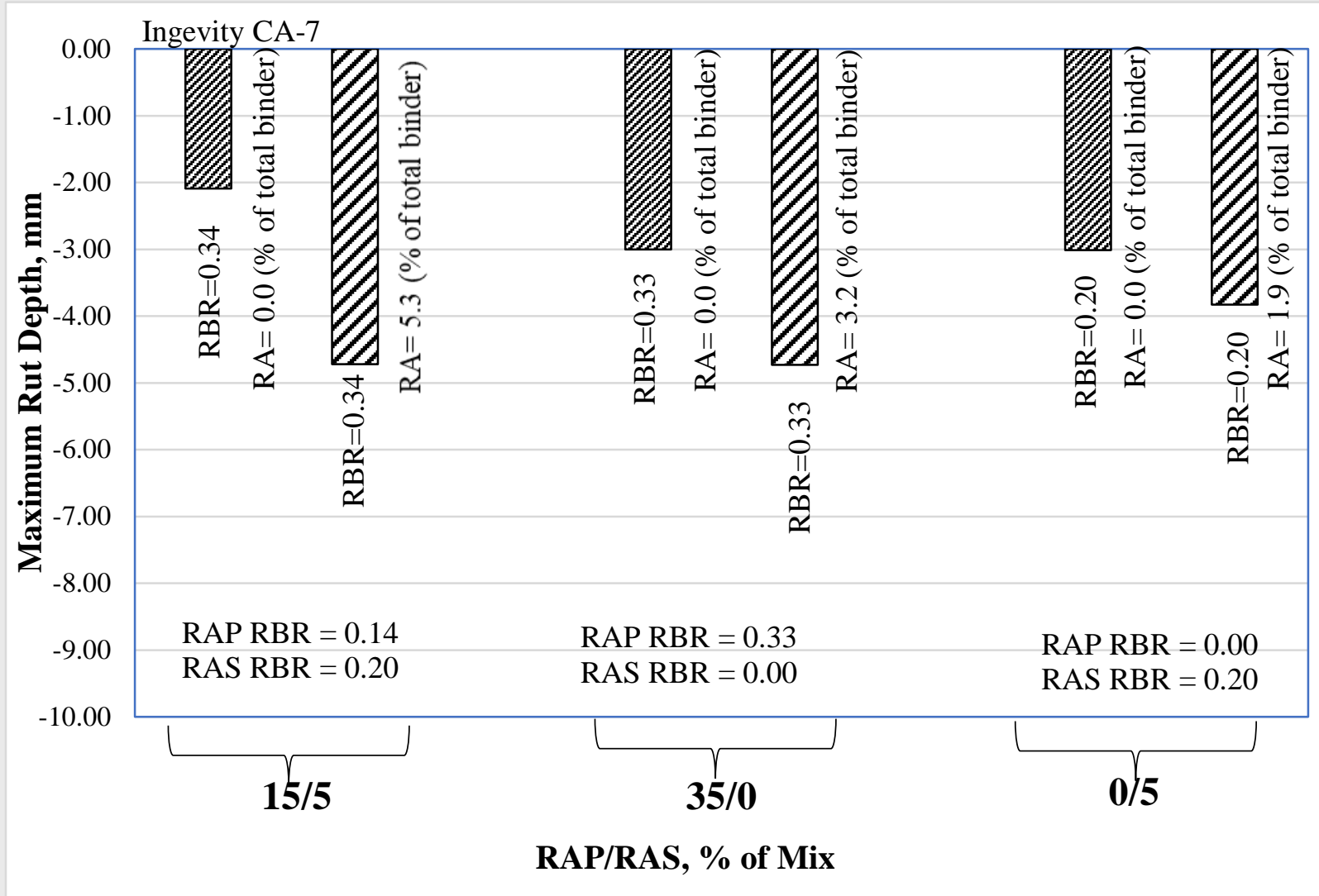
Lab Study of Recycling Agents in Asphalt Mixes

PennDOT Sponsored Research at Penn State

- ❖ **PennDOT Sponsored Research (2019-2022)**
- ❖ **Conducted by NECEPT at Penn State**
- ❖ **Recycling agents (RA) used in an extensive lab study**
- ❖ **Developed A Usage Guide**

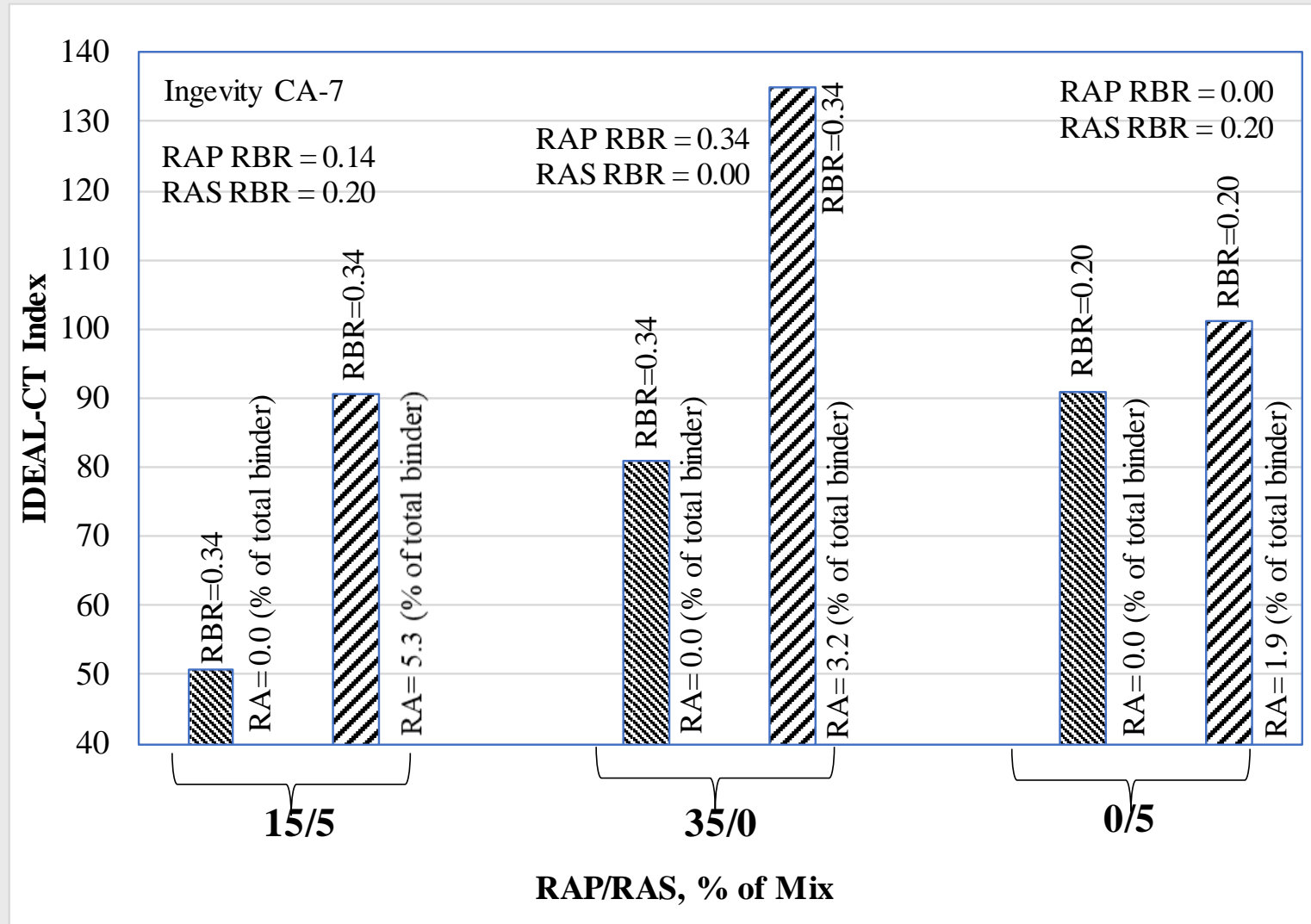


Results from HWT Test (LPLC) (Past PennDOT Research)



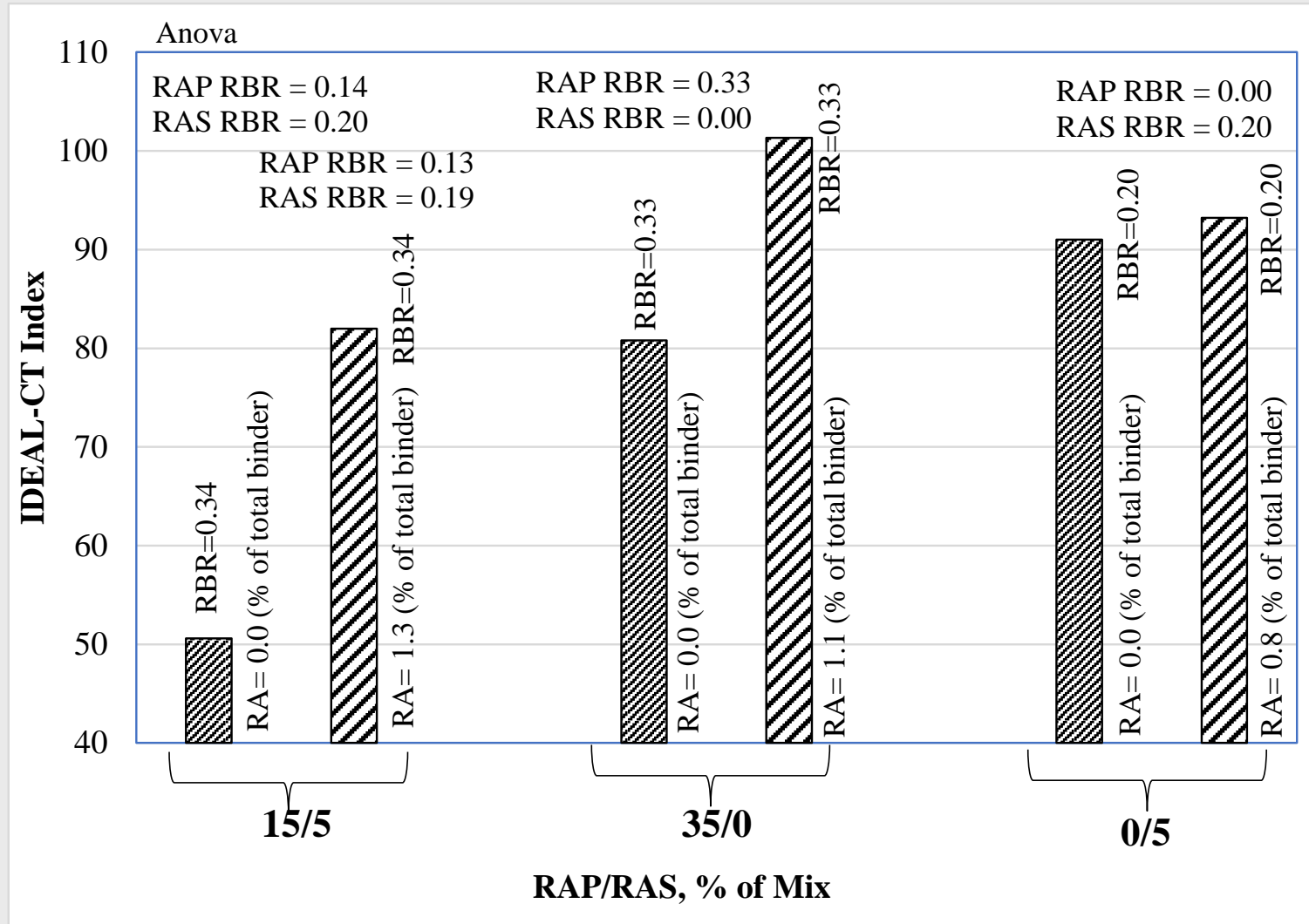
Results from IDEAL-CT Test (LPLC)

(Past PennDOT Research)

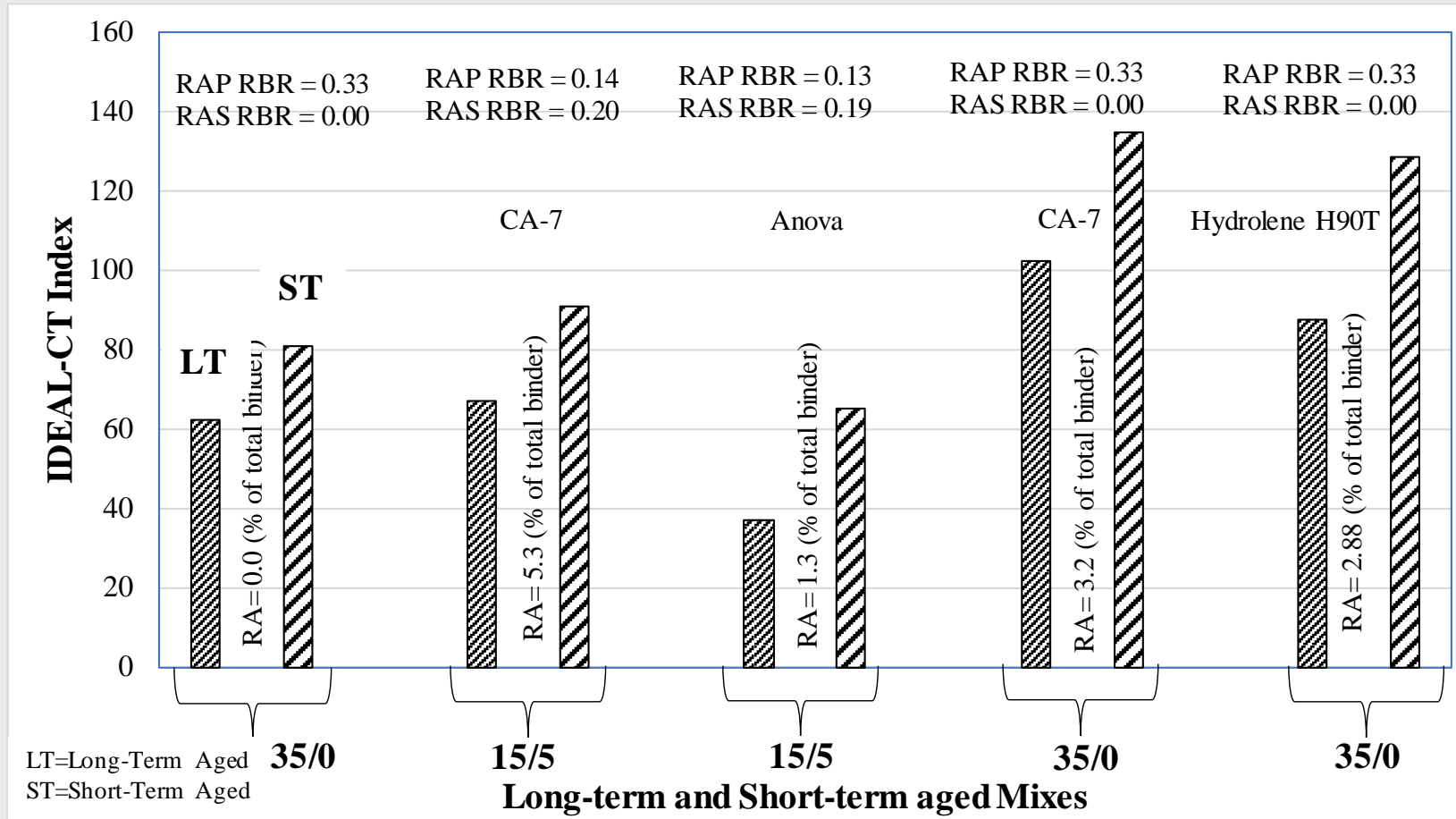


Results from IDEAL-CT Test (LPLC)

(Past PennDOT Research)

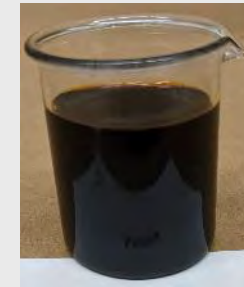


Effect of Long-Term Conditioning (LPLC) (Past PennDOT Research)



Objectives of the Field Study

- ❖ Verifying the effectiveness of the RA in the plant production conditions.
- ❖ Investigating the differences between the lab- and plant-produced mixtures modified with recycling agents (RA).
- ❖ Evaluating different RA incorporation techniques and developing guidelines in light of the asphalt plant capabilities and limitations.



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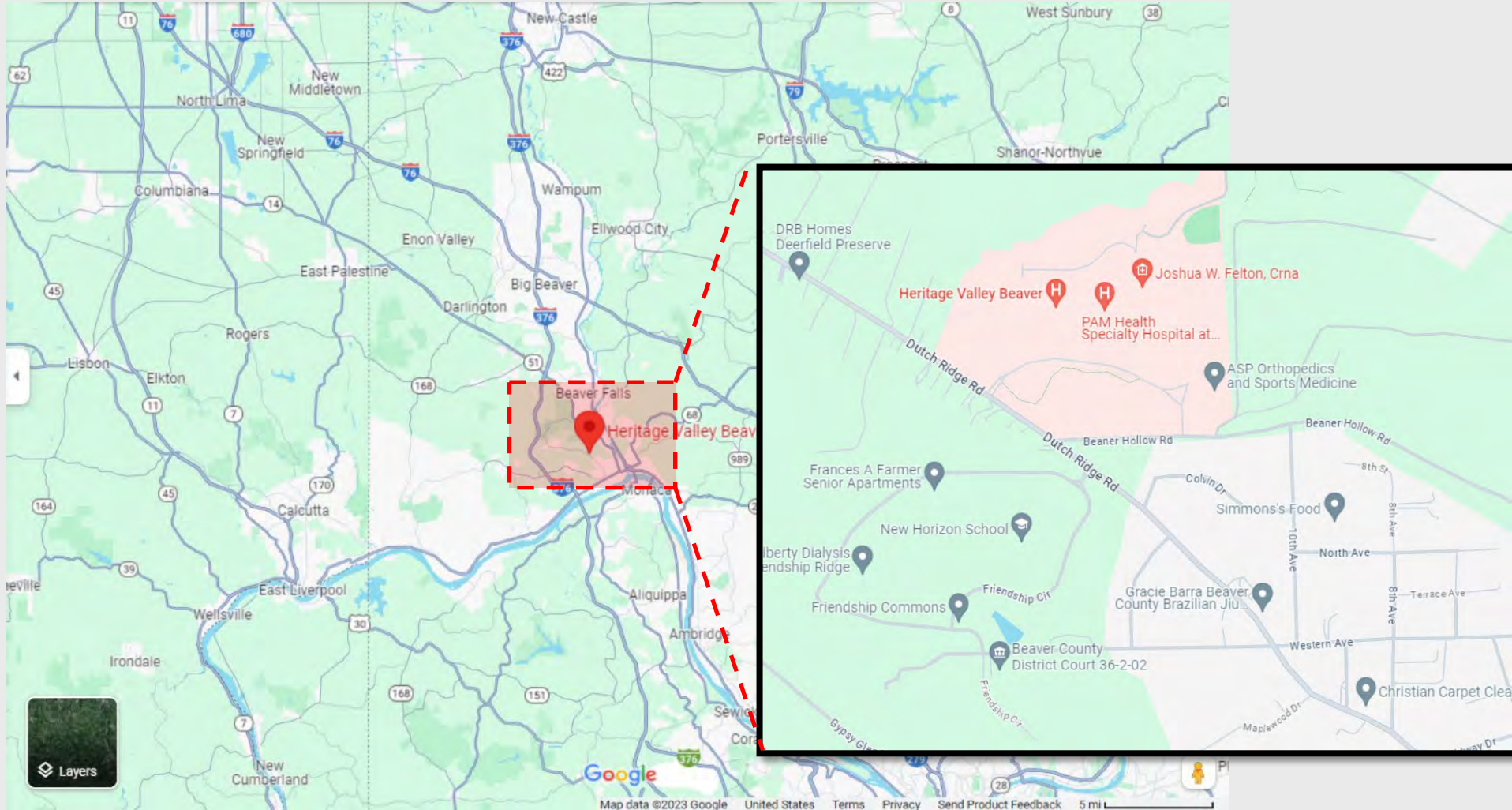
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Field Pilot and Material Sampling





Zooky's Sports Tavern

Legend

- 15% RAP-Koppel-NonRej
- 35% RAP- NI- Cargill
- 35% RAP- NI- Ingevity

Dutch Ridge Elementary School

Felicity Farms Bed & Breakfast

1.5 miles

Heritage Valley Beaver

1.4 miles

BOROUGH

Field Pilot - Mix Design

	Non-Rejuvenated (Conventional)	Rejuvenated Mix#1	Rejuvenated Mix#2
Plant	Koppel	Neville Island (NI)	Neville Island (NI)
Final Binder PG	PG64S-22	PG64S-22	PG64S-22
SRL	E	H	H
N_{Design}	50	50	50
NMAS (mm)	9.5	9.5	9.5
RA Type	NA	Cargill- Anova	Ingevity- Evoflex
RA Dosage (%)	NA	1.3	1.3
RAP (%)	15	35	35
Virgin AC (%)	4.9	3.9	3.9
Total AC (%)	5.7	5.8	5.8
P200 (%)	4.9	6.3	6.3
P#8 (%)	48	42	42
P#4 (%)	66	60	60



Field Application - High RAP with RA



Lindy Paving Rejuvenator Pilot: August 9th (Neville Island Plant)



Paving Equipment

- ❖ **CAT AP105E Paver with an Extend-A-Mat 10-20B Screed (Backup CAT AP1055E)**
- ❖ **Roadtec SB 1500D**
- ❖ **Sakai SW 800-II – Breakdown**
- ❖ **Sakai 320-1 – Rolled Shoulder Break**
- ❖ **Sakai SW 770 – Intermediate Roller**
- ❖ **Sakai SW 800-II –Roller**
- ❖ **Sakai SW 800-II –Roller (Backup)**



Non-Rejuvenated Mix

- ❖ **Conventional Mix: 8/8/23**
- ❖ **Lindy Kopple Plant**
- ❖ **15% - RAP**
- ❖ **Gencor Drum Plant 400 ton/hour Additive
Sonnegreenas at a 0.25% dosage rate**
- ❖ **12 Trucks - 1,200 tons of mix**
- ❖ **Target Temperature: 300 to 310 °F**

- ❖ **94.6% average density for the day**
- ❖ **Mat temperature behind the paver 285-300 °F**



Cargill Rejuvenated Mix

- ❖ **Date: 08/09/23**
 - ❖ **Neville Island Plant**
 - ❖ **35% RAP**
 - ❖ **1.3% Cargill Rejuvenator**
 - ❖ **Gencor Drum Plant 600 ton/hour**
 - ❖ **Additive Sonnengreenas at a 0.25% dosage rate**
 - ❖ **15 Trucks - 1,275 tons of mix**
 - ❖ **Target Temperature: 300 to 310 °F**
-
- ❖ **94.9% average density for the day**
 - ❖ **Mat temperature behind the paver 285-300 °F**



Ingevity Rejuvenated Mix

- ❖ **08/11/23**
 - ❖ **Neville Island Plant**
 - ❖ **35% RAP**
 - ❖ **1.3% Ingevity Rejuvenator**
 - ❖ **Gencor Drum Plant 600 ton/hour**
 - ❖ **Additive Sonnegrinas at a 0.25% dosage rate**
 - ❖ **15 Trucks -1,215 tons of mix**
 - ❖ **Target Temperature 300 to 310 °F**
-
- ❖ **95.9% average density for the day**
 - ❖ **Mat temperature behind the paver 285-300 °F**















Rolling Pattern

- ❖ **Breakdown - 5 vibratory passes**
- ❖ **Intermediate - 7 vibratory passes**
- ❖ **Finish Roller – All static passes**
- ❖ **1-Sakai SW 320 roller 2- vibes on shoulder break**
- ❖ **94 - 96% average density for all three days**
- ❖ **Mat Temperature behind the paver 295-300 °F**









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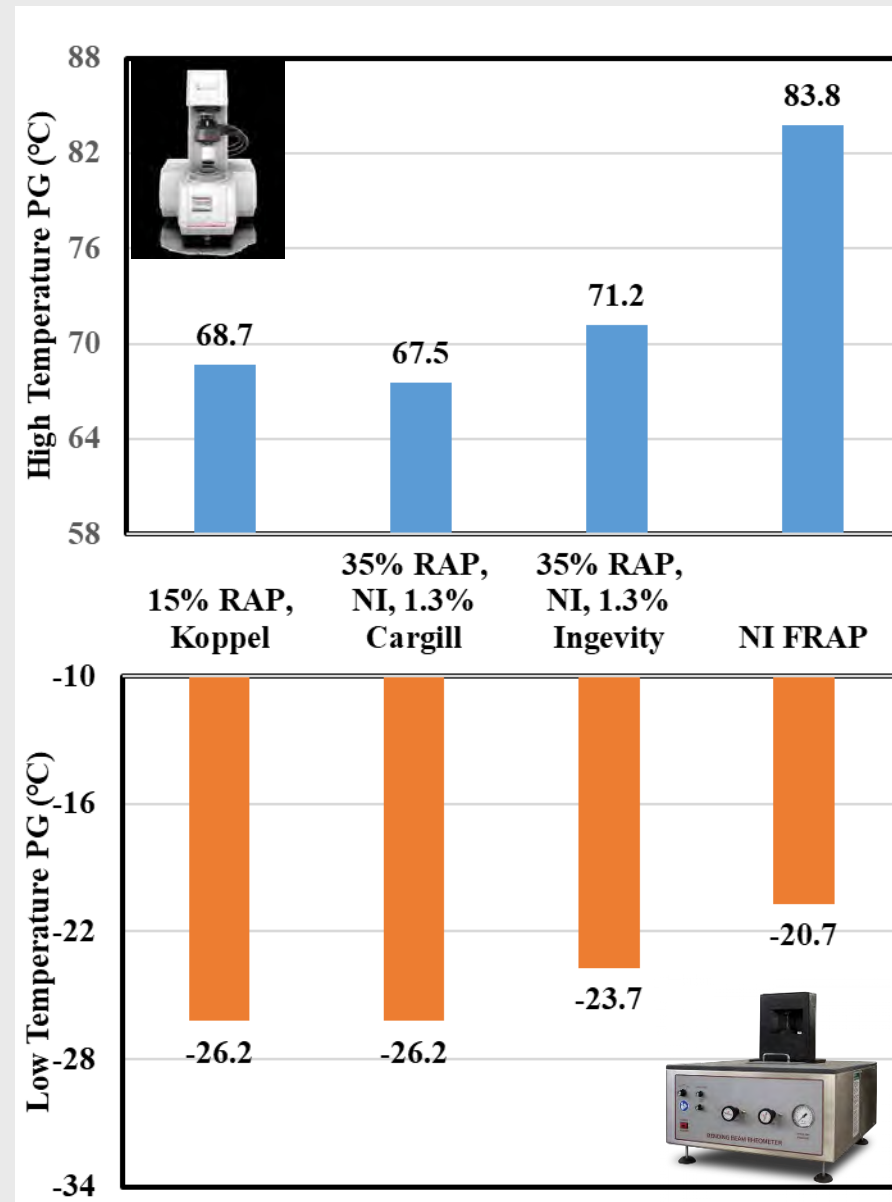
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Extracted Binder Testing Results



Hamburg Wheel Track Test (HWTT)

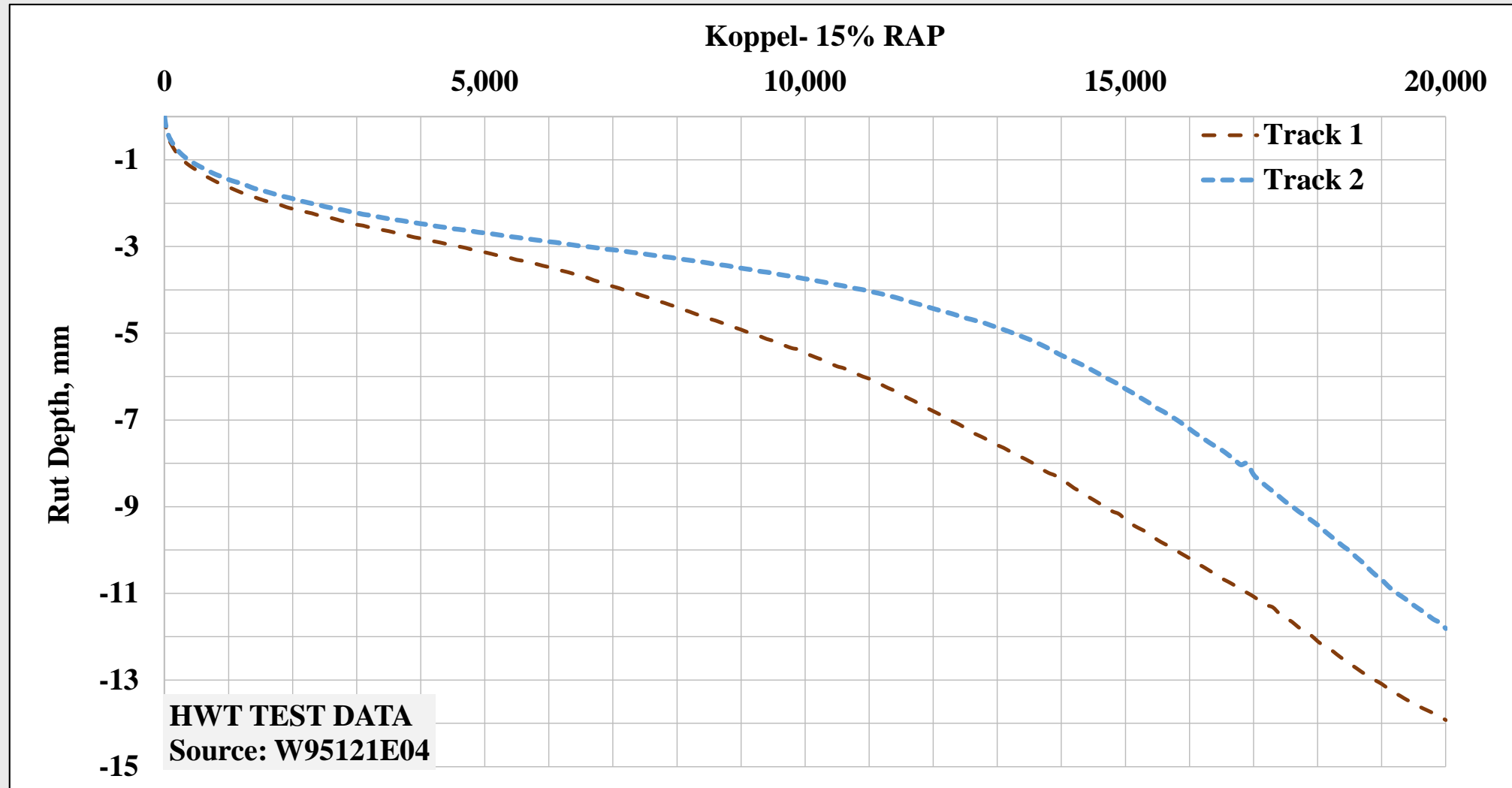
- ❖ AASHTO T 324-22
- ❖ Test Temp: 50°C (122 °F)



PARAMETERS	Koppel	NI, Cargill	NI, Ingevity
SIP (# of passes)	12,034	14,002	13,742
Ratio of the slope (strip/creep)	4.22	6.40	3.11
Max Rut Depth (mm)	-12.87	-14.11	-10.70
No. of Passes to maximum rut depth	20,000	20,000	20,000
No. of Passes to 10 mm rut depth	17,144	17,323	19,343
No. of Passes to 12.5 mm rut depth	19,536	18,947	22,436
Rut depth at 10,000 passes, mm	-4.60	-3.95	-4.562
Creep Slope (mm/1000 passes)	0.26	0.24	0.26
Stripping Slope (mm/1000 passes)	1.05	1.54	0.81

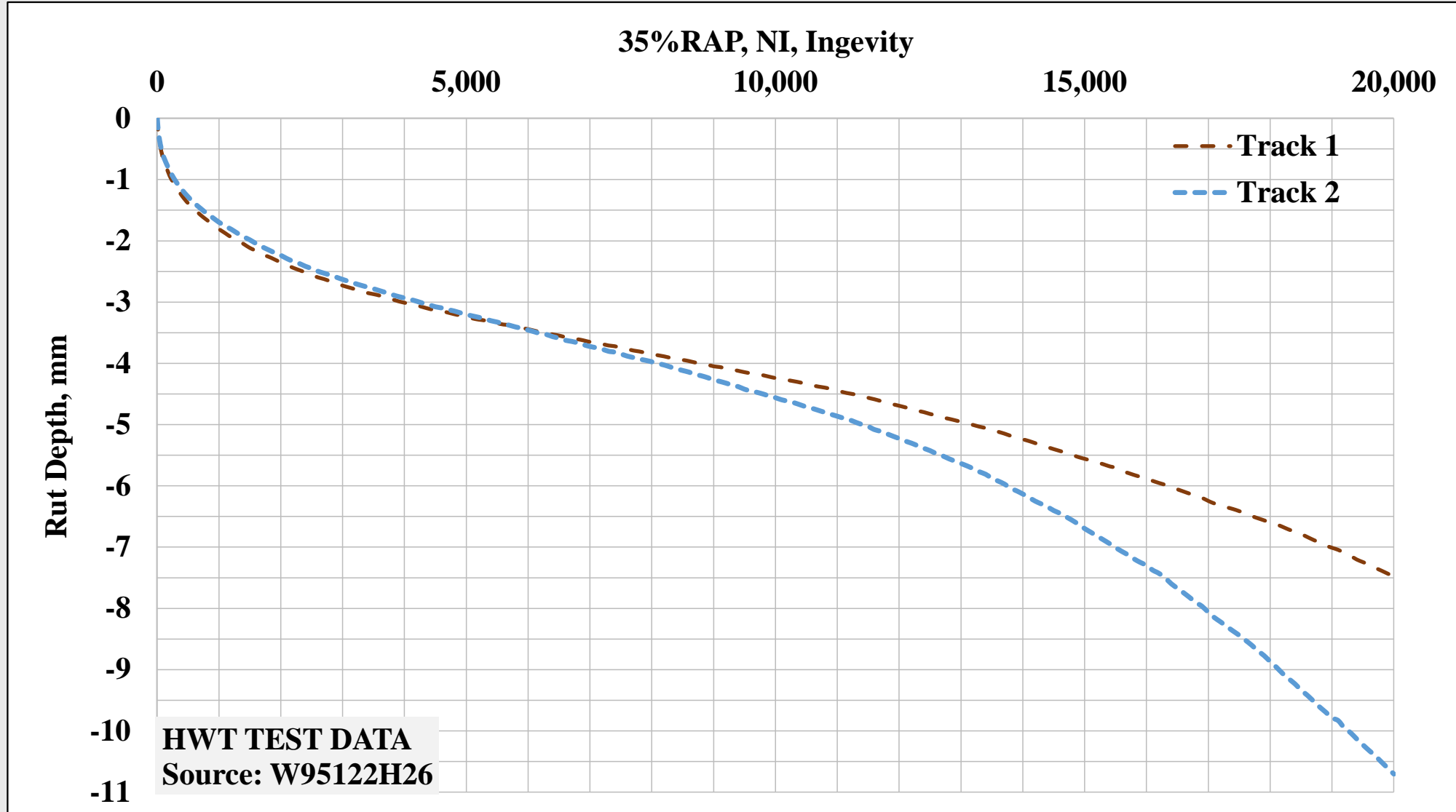
Hamburg Wheel Track Test (HWTT)

Koppel, 15% RAP, No RA



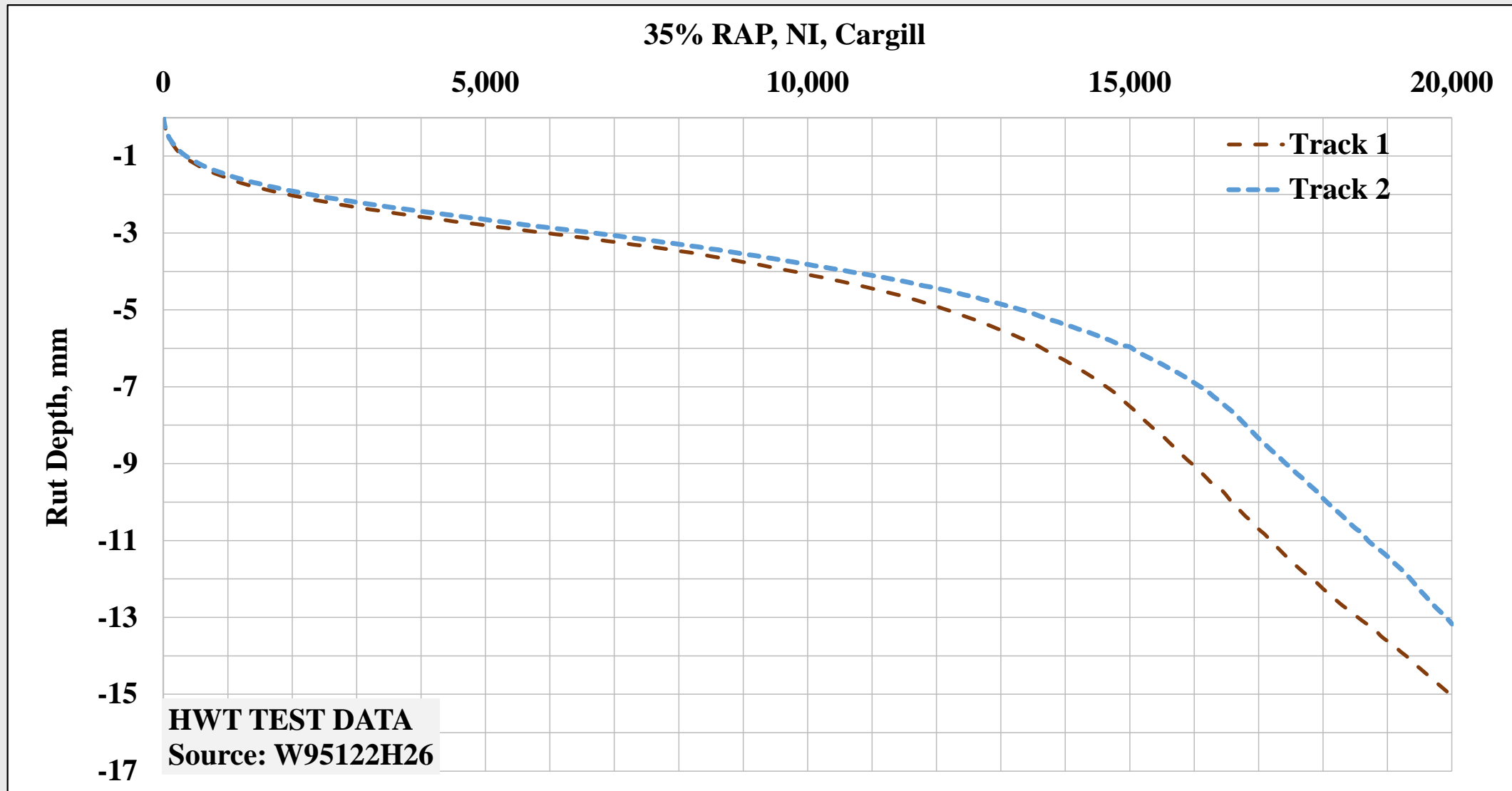
Hamburg Wheel Track Test (HWTT)

NI – 35% RAP, Ingevity



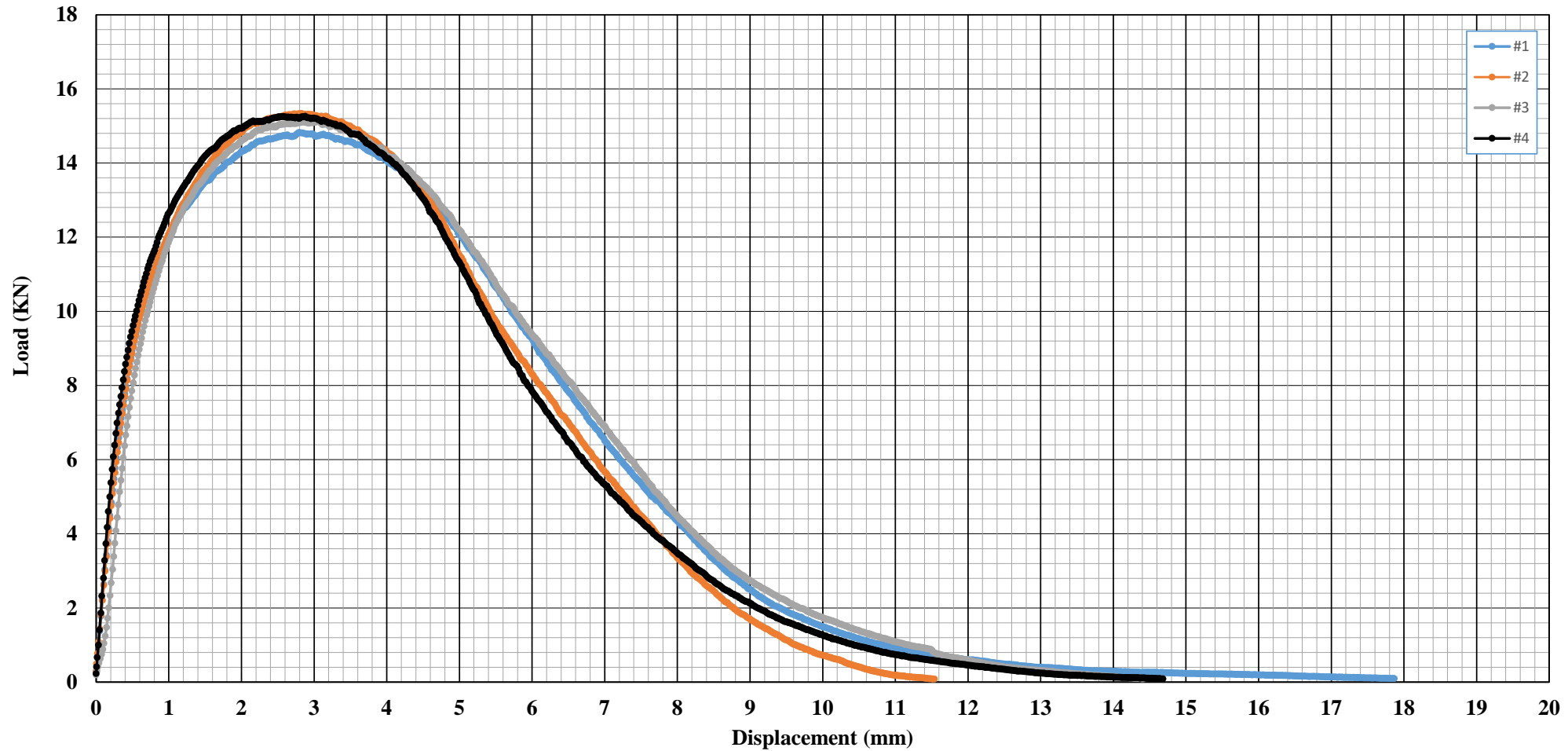
Hamburg Wheel Track Test (HWTT)

NI – 35% RAP, Cargill



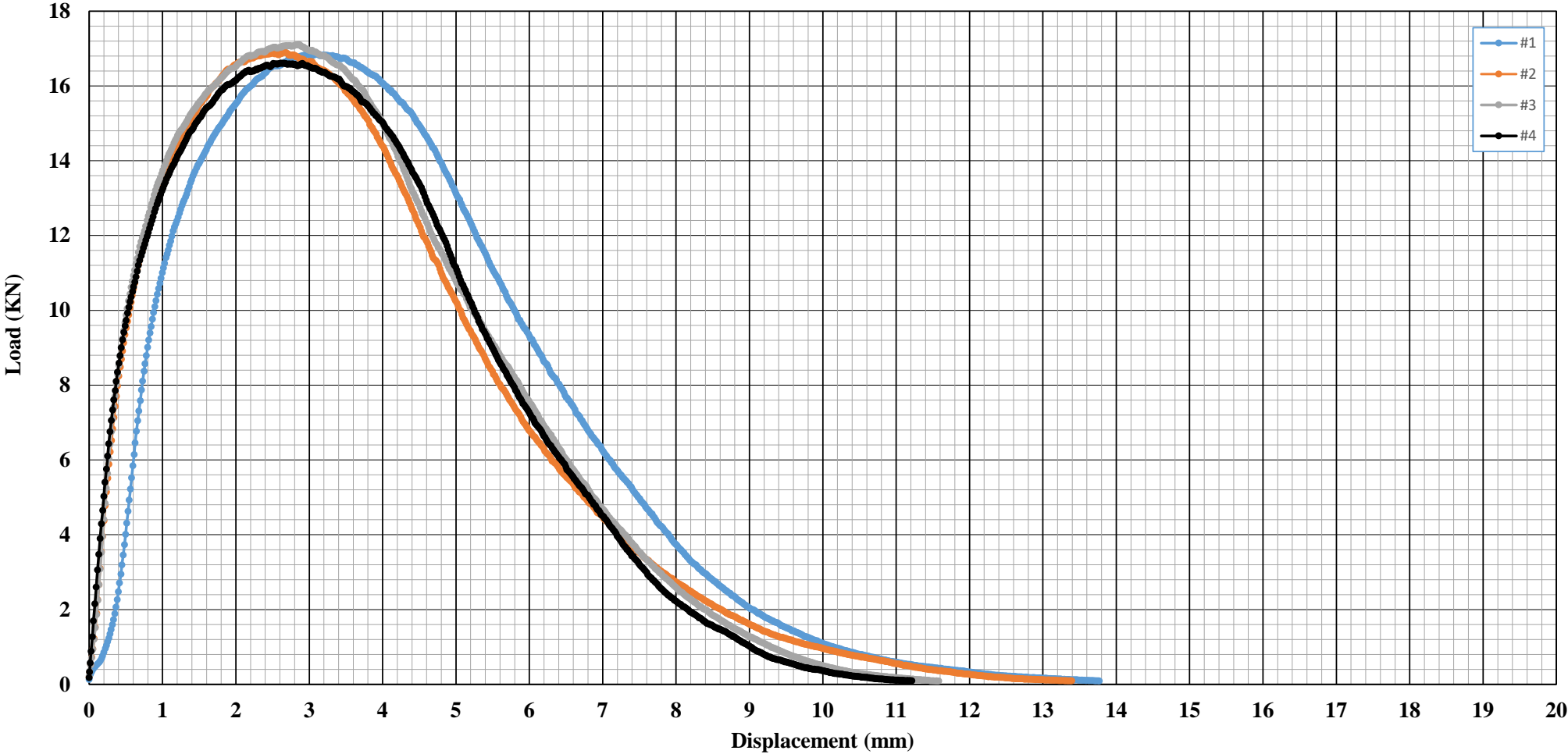
IDEAL-CT – Koppel, 15% RAP

Load vs. Displacement



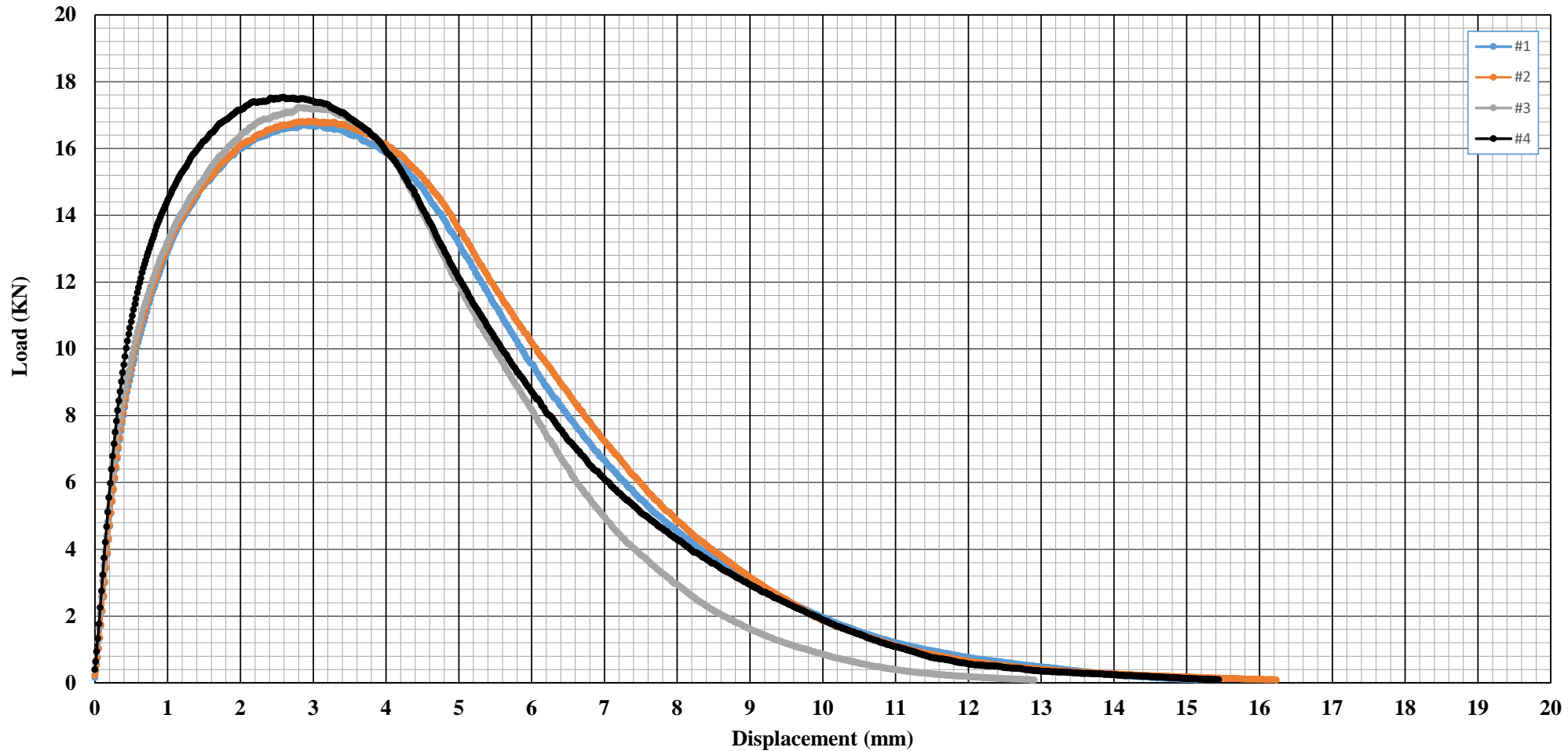
IDEAL-CT – Neville, Cargill, 35% RAP

Load vs. Displacement



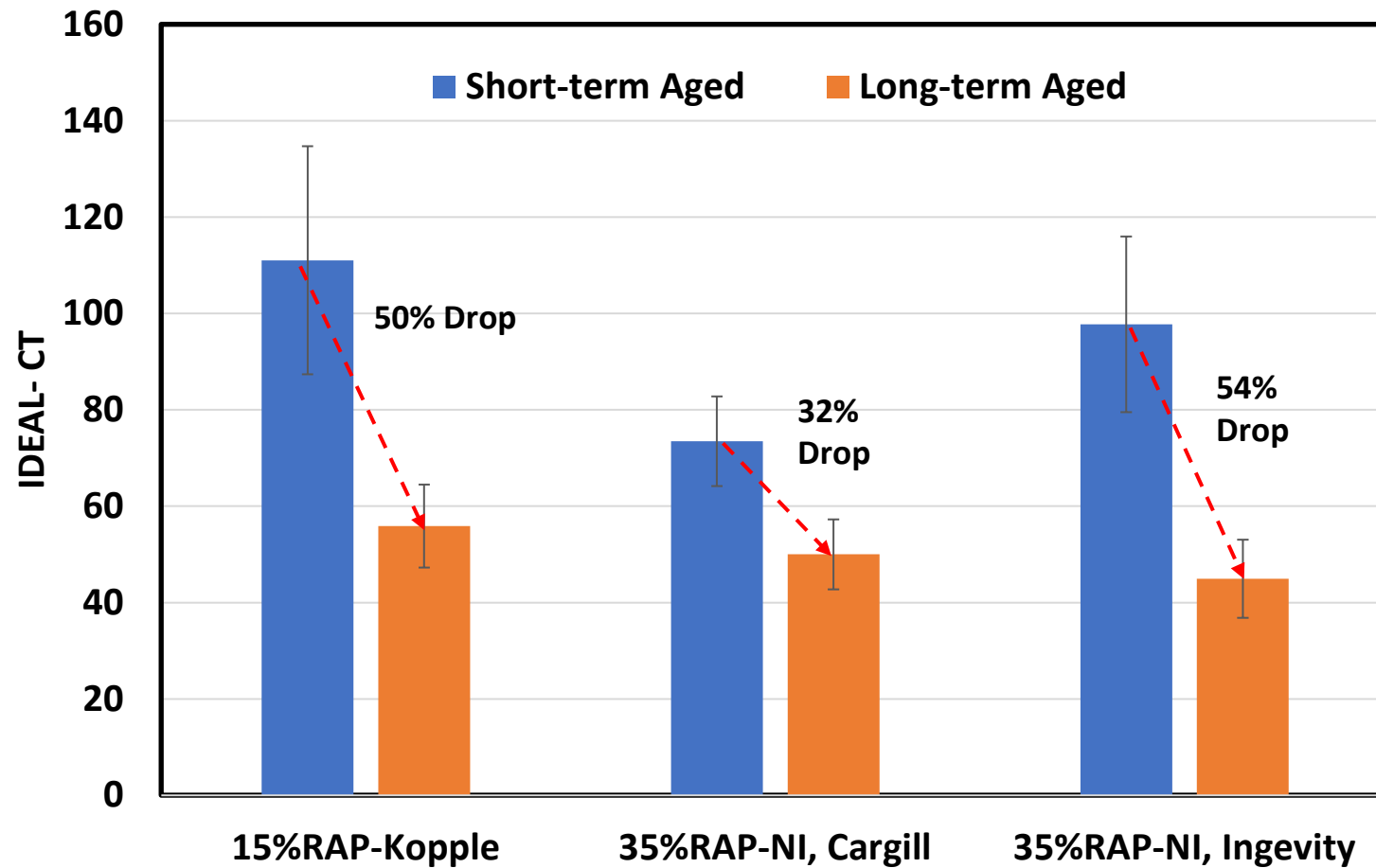
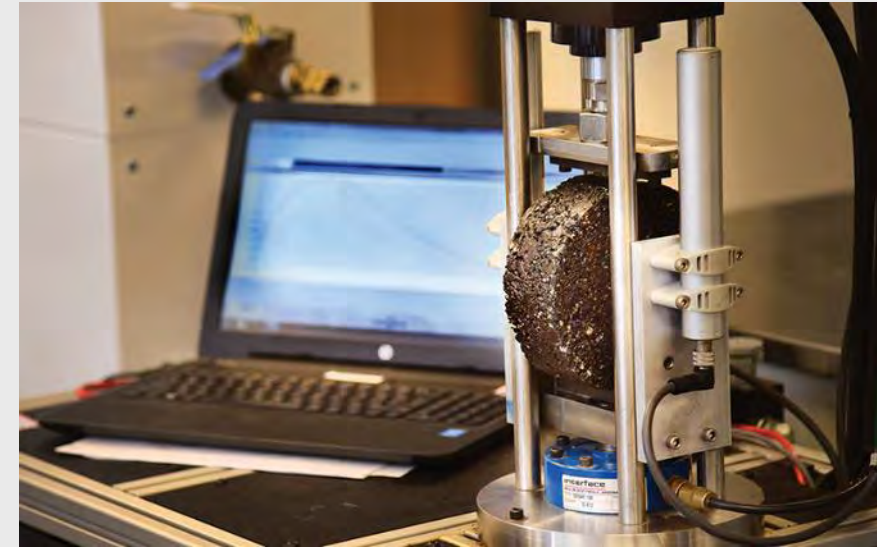
IDEAL-CT – Neville, Ingevity, 35% RAP

Load vs. Displacement



IDEAL-CT Test

- ❖ ASTM D8225
- ❖ Test Temp: 25°C (77 °F)



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Summary and Concluding Remarks

- ❖ **Feasible to place High RAP Asphalt Mixes**
- ❖ **A surface course with 35%-RAP was placed using two types of rejuvenators.**
- ❖ **The high-RAP rejuvenated mixtures compacted very well using typical rolling patterns.**
- ❖ **Laboratory results indicated that the mixes passed the current acceptance criteria on performance tests for the design traffic level**



Future Works

Investigating the effect of:

- ❖ Aggregate Type
- ❖ Rejuvenator Type
- ❖ Rejuvenator Dosage
- ❖ Mix Type (Surf., Inter., Base)
- ❖ RAP Type and Content
- ❖ Aging

Aggregate Sampling	Neville Island			2nd Ave			Zelienople		
	9.5 mm	19.0 mm	25.0 mm	9.5 mm	19.0 mm	25.0 mm	9.5 mm	19.0 mm	25.0 mm
Mix Desing									
Control mix									
Control+Rej1									
Control+Rej2									
Control+%2Rej1									
Control+%2Rej2									
Control+Rej1 (Aged)									
Control+Rej1+Methd.									
RAP source 2									
RAP source 2+ Rej1									



Thank You!

