International Workshop on
Asphalt Recycling Technologies
8th and 9th September 2025,
Aachen, Germany

Cold Recycling Technologies for Sustainable and Durable Roads. CCPR and CIR Case Studies

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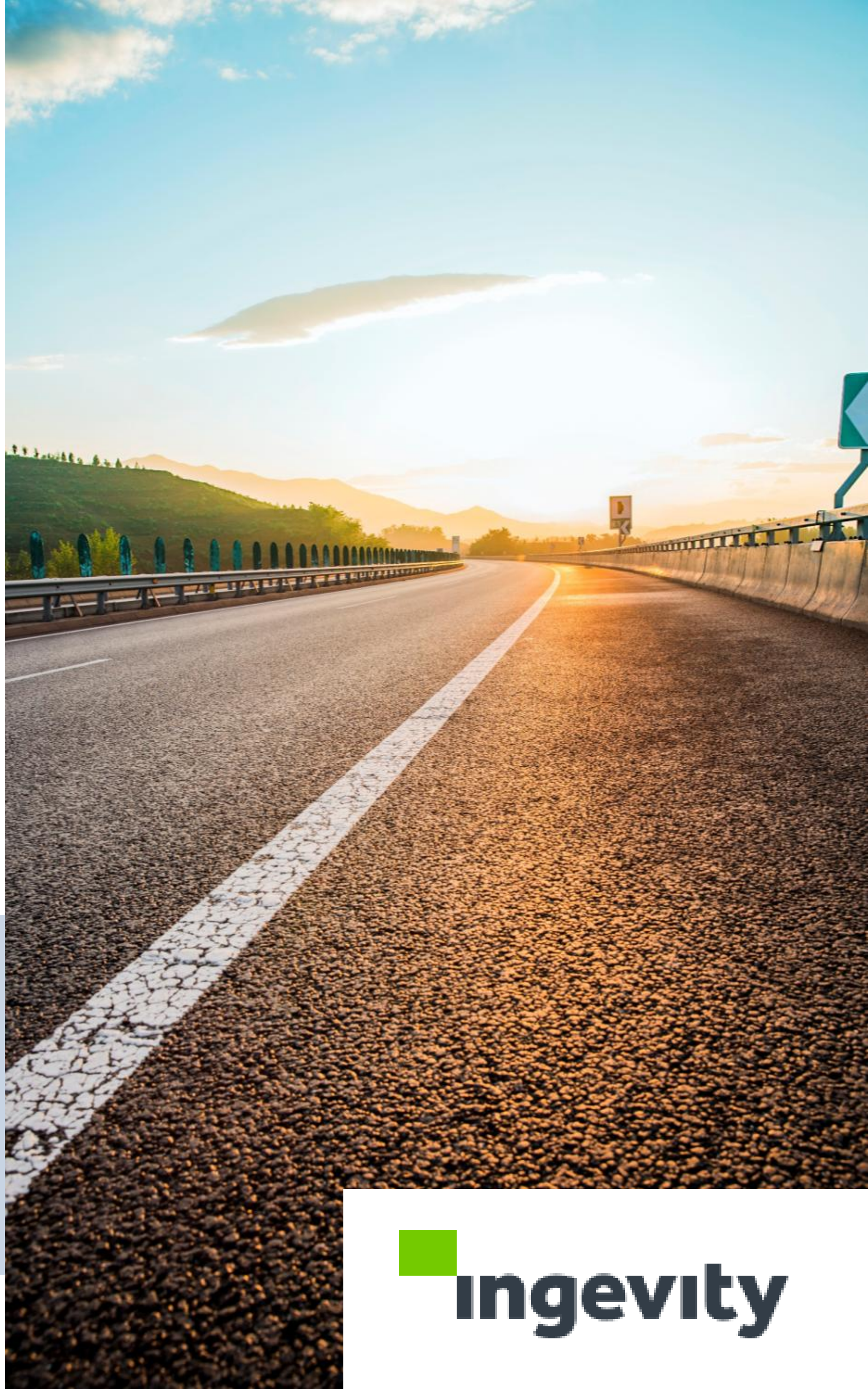
Ingevity Pavement Structural Technologies



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Outline

- Sustainability considerations
- Cold Recycling background information
  - How is cold recycling executed
  - Strength gain over time
- Case studies :
  - US-280 NCAT project (USA)
  - Expressway SMA overlay of cold recycled binder course (China)
  - MnROAD 70th Street cold climate (USA)
  - Expressway dense graded asphalt concrete overlay of cold recycled binder course (Malaysia)
  - New Mexico DOT I-25 CIR and WMA (USA)

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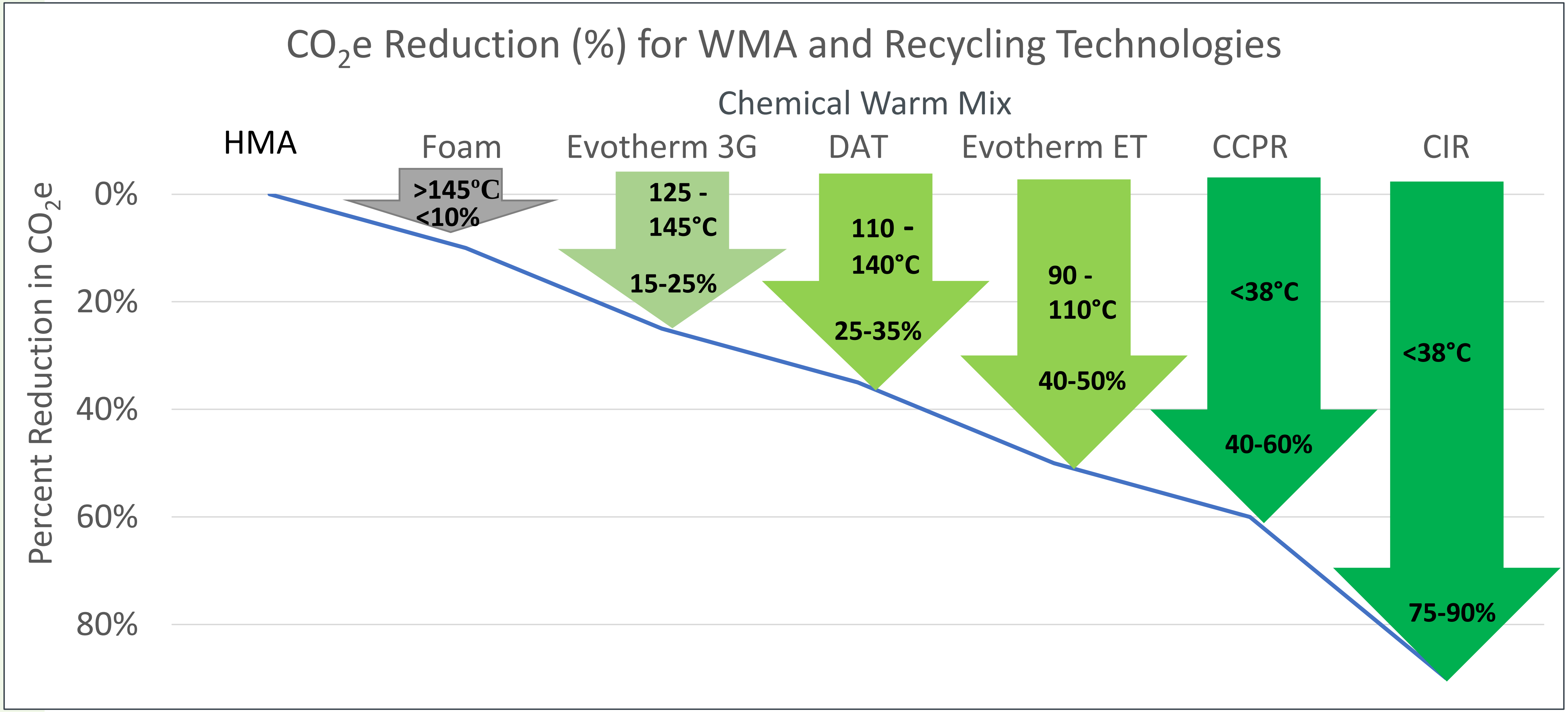
Sustainability Drivers

At the 2022 annual conference, NAPA announced the Road Forward, a plan to get to net zero carbon emissions by 2050.

https://www.asphaltpavement.org/

CO_2 Reduction – Path to Zero



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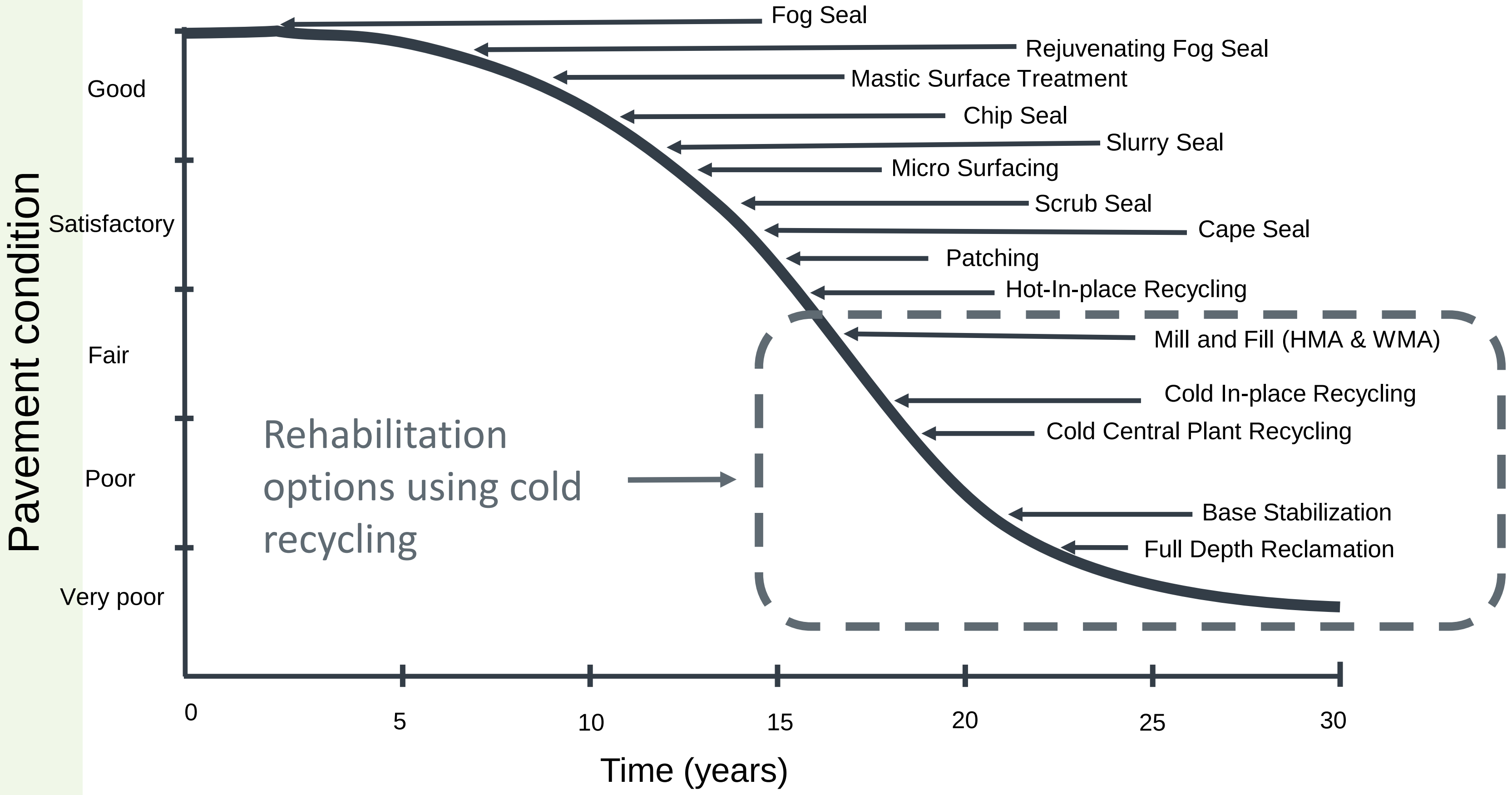
Rehabilitation Needs and Options



Cold Recycling Benefits

- Cost effectiveness (initial cost and LCCA)
- Lower energy consumption
- Lower emissions
- Re using of large amount of materials
- Reduced construction time
- Structural improvements and distress (cracking) mitigation – Deeper remediation/disrupt crack pattern
- Sustainable approach


Distressed Asphalt Concrete


Cold Recycled Mat

https://roadresource.org/

RoadResource.org™

Provided By: PPRA

The Pavement Preservation and Recycling Alliance

Better roads today.
Stronger networks tomorrow.

Road Resource provides education and support for road managers, consulting engineers, and municipal agencies working to reverse deterioration trends and break the "build-rebuild" cycle in their road networks.

Explore by Pavement Photos

Use this tool to explore potential solutions for various road conditions.

Though these tools use distress to identify potential treatment solutions, the savviest pavement managers are stretching budgets further by preventatively addressing deterioration before it starts. Link treatments together to make pavement last 40 years or more, or consider using innovative recycling methods to cost-effectively reengineering your pavement cross-section to meet increased load or traffic requirements and increase strength and longevity.

PRIMARY DISTRESS

FATIGUE CRACKING - HIGH

Full Depth Reclamation

MORE TREATMENTS...

Overview > About

OVERVIEW
- ABOUT
- PROCESS & VARIATIONS
- EXPECTATIONS
- COST
- HISTORY
- BEST PRACTICES

PRE-CONSTRUCTION
- SITE SELECTION
- MATERIAL SELECTION
- MIX DESIGN
- SPECIFICATION REVIEW

CONSTRUCTION
- PREPARATION
- WEATHER REQUIREMENTS
- EQUIPMENT
- CALIBRATION
- TRAFFIC CONTROL
- APPLICATION

QUALITY ASSURANCE

FOR PAVEMENT CONDITION C D F (PCI of 60 or less)

A cost-effective, long-lasting greener alternative to deep rehabilitation or removal and replacement techniques. Full Depth Reclamation (FDR) is an engineered rehabilitation technique in which the full thickness of the asphalt pavement and a predetermined portion of the underlying materials (base, subbase and/or subgrade) is uniformly pulverized and blended to provide an upgraded, homogeneous material. The reclaimed materials may be improved and strengthened by using Mechanical, Chemical or Bituminous stabilization. FDR isn't only for roads in poor condition, it is also a viable design process for increasing the structural capacity of a pavement in good condition.

- 40 to 80% less expensive than alternative reconstruction techniques
- Importing and exporting of materials can be reduced by 90%
- Reuses up to 100% of existing materials
- Same day return to light traffic
- Up to 25 years of life extension. The limiting factor for service life of FDR treated pavements is typically the service life of the surface course and not the FDR mixture itself.
- Structural Layer (a) Coefficients of FDR mixtures depends on the stabilizing agent used and vary from 0.14 for pulverization and mechanical stabilization to 0.15-0.25 for cementitious stabilization to 0.20-0.30 for bituminous stabilization.

Structure and Cost Comparison

yd Export

Layer Type	Depth (in)	Coefficient	Unit Cost		SN
Cold Planing	6.75	0.00	1.00	/SY/in	0.00
Thin Lift HMA	N/A	N/A	6.97	/SY	0.00
Hot Mix Asphalt	3	0.44	4.65	/SY/in	1.32
Hot Mix Asphalt	3.25	0.44	4.65	/SY/in	1.43
Existing HMA	4	0.20	0.00	/SY/in	0.80

ADD ROW

Overall Structural Number: **3.55**

7,040 SY x **$42.78** /SY = **$301,171** total

yd

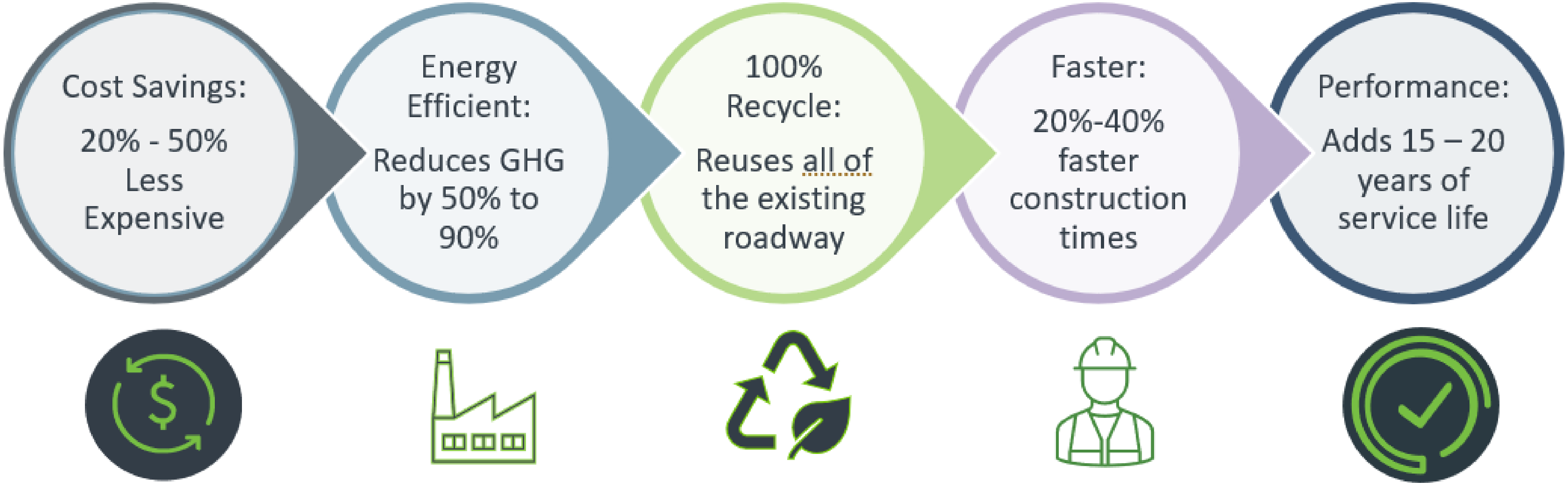
Layer Type	Depth (in)	Coefficient	Unit Cost		SN
Cold Planing	3.5	0.00	1.00	/SY/in	0.00
Thin Lift HMA	N/A	N/A	6.97	/SY	0.00
Hot Mix Asphalt	3	0.44	4.65	/SY/in	1.32
Cold In-Place Rec	4	0.36	1.90	/SY/in	1.44
Existing HMA	4	0.20	0.00	/SY/in	0.80

ADD ROW

Overall Structural Number: **3.56**

7,040 SY x **$32.02** /SY = **$225,421** total

Cold Recycling Solutions – Efficient and Sustainable



What is Partial Depth Cold Recycled and How is it Done?

- Mixture consisting of up to 100% RAP, 2.5 to 4% emulsion (or foamed asphalt) and 0 to 1.5% active filler
- Mixed at ambient temperature in place or at a central plant, paved and compacted with traditional equipment

a) In-place with single or multi unit

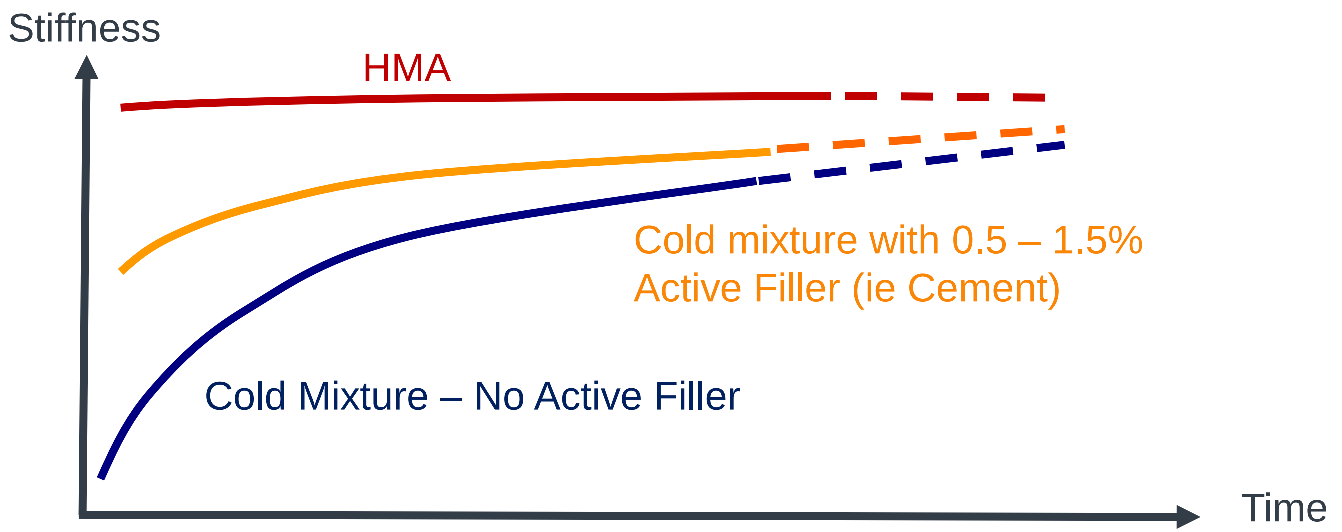
b) Central or mobile plant

c) CCPR with Cold hot mix plant

d) Paving with traditional equipment

Differences Between HMA and Cold Mixtures

	HMA	Cold Recycling
• Air voids	6-8	8-14
• Amount of RAP that can be added	0-60	up to 100
• Rut resistance	Both satisfactory	
• Strength gain over time	After cooling	Over time



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Same Day Cold Recycled Mat Opened to Interstate Traffic

Interstate 70 (Colorado, USA)

Case Study: National Center for Asphalt Technology US 280 Sections - 2015

- Test thin HMA overlay over cold recycling on heavy traffic roadway:
  - 4-Lane divided highway, 2.5 cm (1”) HMA thin lay over 10 cm (4”) Cold Recycling
  - AADT in 2015 was 18,300 vpd with truck volume of 16% (> 5 million ESALs 2024)
  - CCPR and CIR
  - Emulsion & foam

Case Study - NCAT US 280 (constructed in 2015)

- > 5 million ESALs by 2024
- FWD data was used to calculate layer coefficients

Section	Method	Recycling Agent	N	Avg	Std	Max	Min	Suggested Values
40	CCPR	Foam	84	0.31	0.092	0.539	0.153	**0.23**
41	CCPR	Emulsion	125	0.66	0.154	1.067	0.324	**0.35**
43	CIR	Emulsion	126	0.43	0.092	0.653	0.197	**0.35**
44	CIR	Foam	126	0.38	0.103	0.579	0.197	**0.31**

Recommendations took a conservative approach of 25th percentile.

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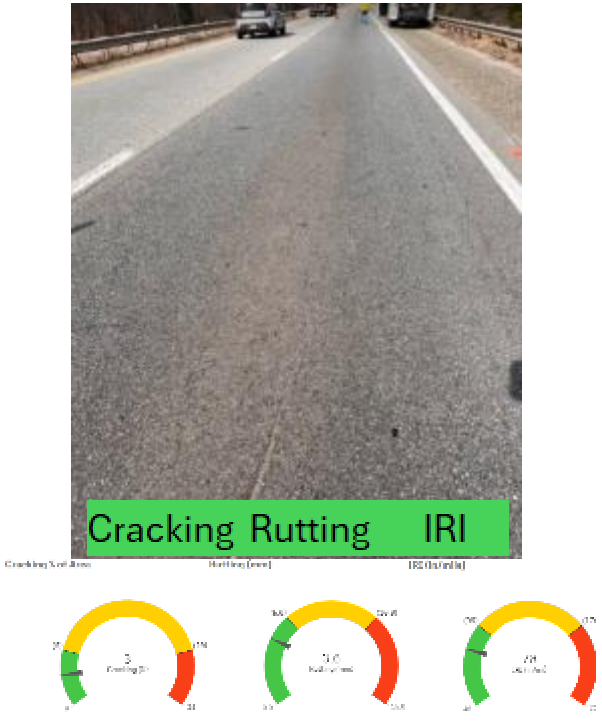
NCAT US 280 (constructed in 2015) – Performance After 9 Years And More Than 5M ESAL's

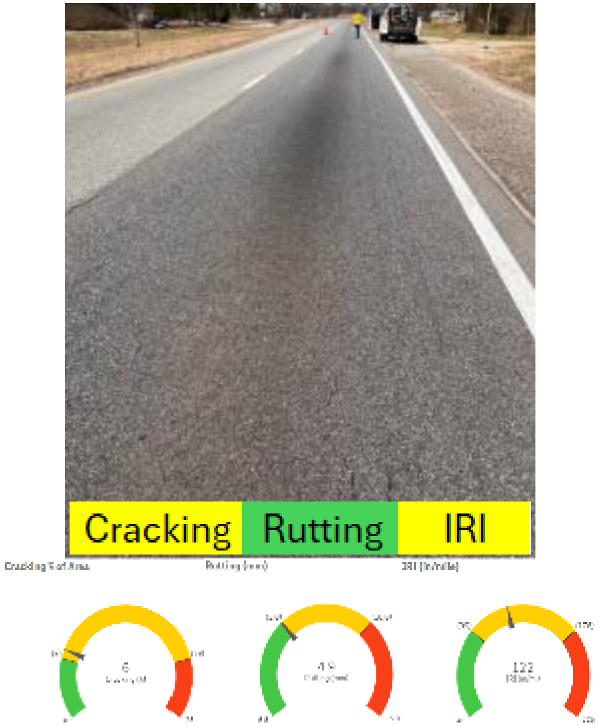
https://eng.auburn.edu/research/centers/ncat/testtrack/preservation/observed-performance.html

Foam CCPR

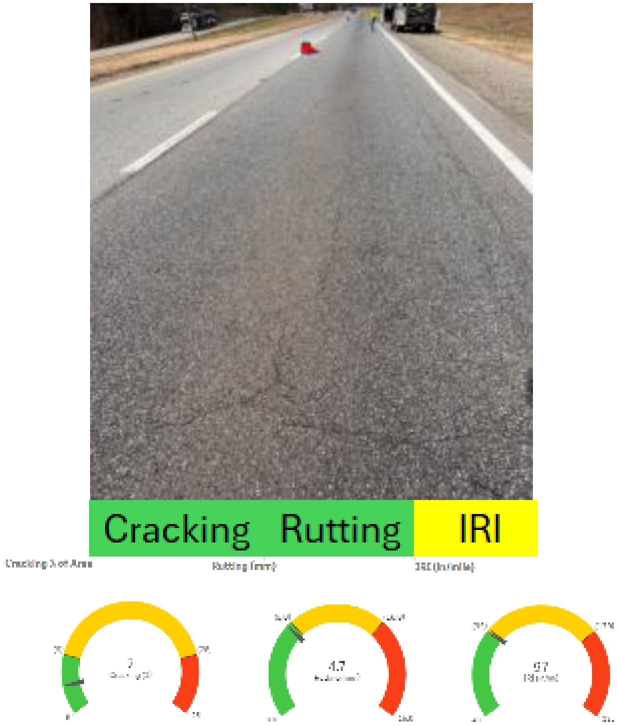
Emulsion CCPR



Foam CIR



Emulsion CIR



China 2019 Beijing-HaErbin (Jingha) G1 Expressway Same Day HMA Overlay

- Emulsion CCPR as middle layer on the expressway with thin HMA overlay
- HMA and emulsion CCPR thickness equivalency
- Same day HMA overlay

Existing Pavement
4 cm SMA (overlay)
4 cm SMA (top layer)
5 cm AC-20 (middle layer)
7 cm AC-25 (bottom layer)
54 cm lime fly ash stabilized layer

New Pavement
4 cm (1.6”) SMA new overlay
9 cm (3.5”) CCPR (new middle layer)
7 cm AC-25 (old bottom layer)
54 cm old lime fly ash stabilized layer

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2019 Beijing-HaErbin (Jingha) G1 Expressway (Cont.)

- CCPR produced at 7:00 am on October 31, 2019
- Transportation distance was 104 km
- Paving started at 11:30 and the cold recycling paving was completed at 13:30
- SMA overlay placed at 15:30
- Overlay completed at 17:00 and opened to traffic

Emulsion CCPR Paving on Jingha Expressway (2019)

MnROAD
SAFER, SMARTER, SUSTAINABLE PAVEMENTS THROUGH INNOVATIVE RESEARCH

MnROAD – cold climate 2019

- Test sections: 1” HMA overlay over 3” Cold Recycling
- CCPR, CIR
- Emulsion (cement-free) & Foam (1% cement)
- 1” HMA overlay over 3” Mill & Fill Control
- 1” HMA overlay over distressed road (no prior milling)


2018 IRI = 365 in/mile


2019 IRI = 78 in/mile

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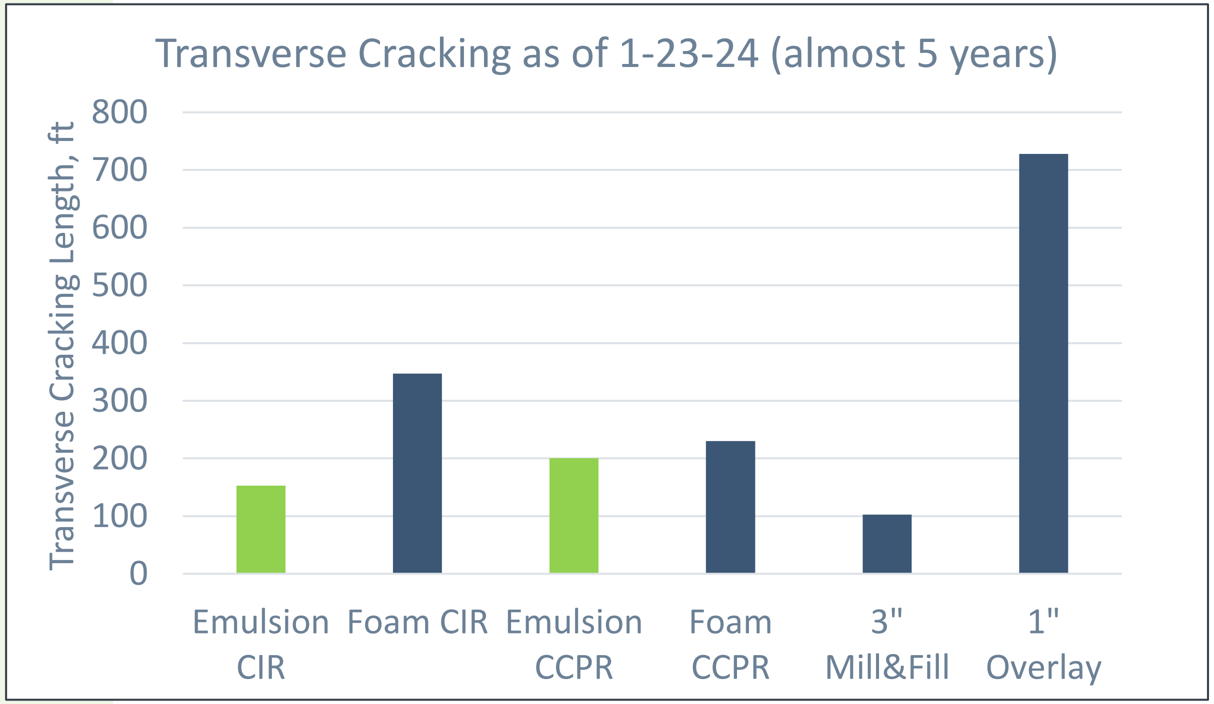
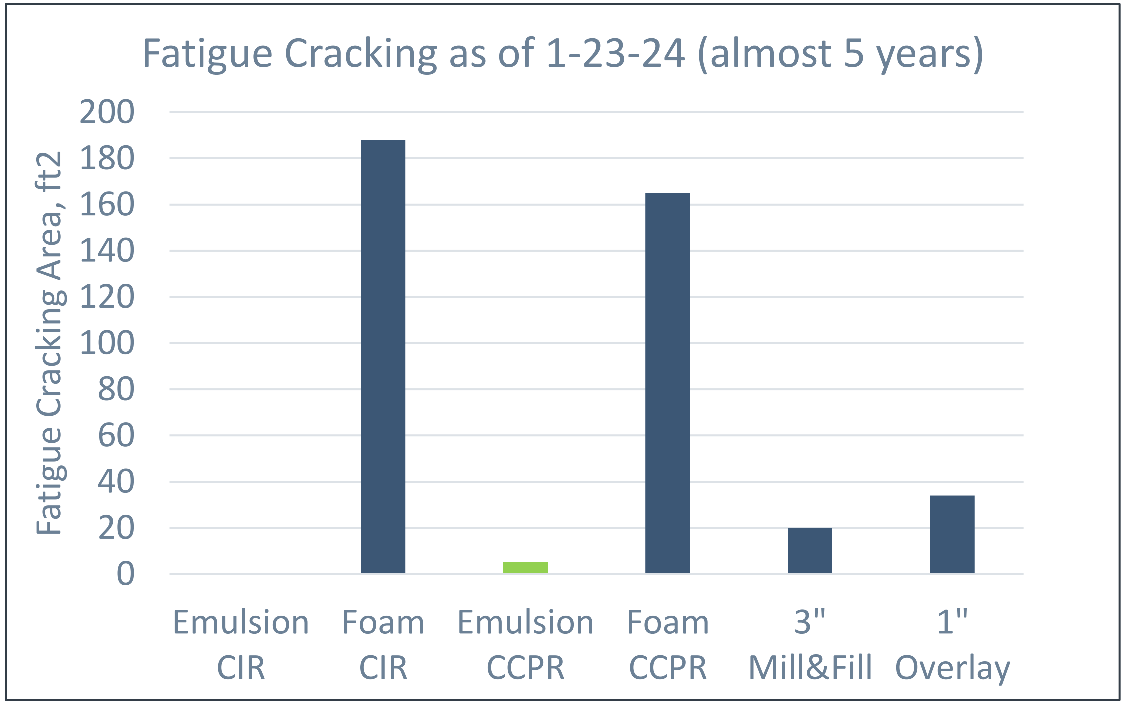
National Research on Cold Recycling

- MnROAD 70th Street



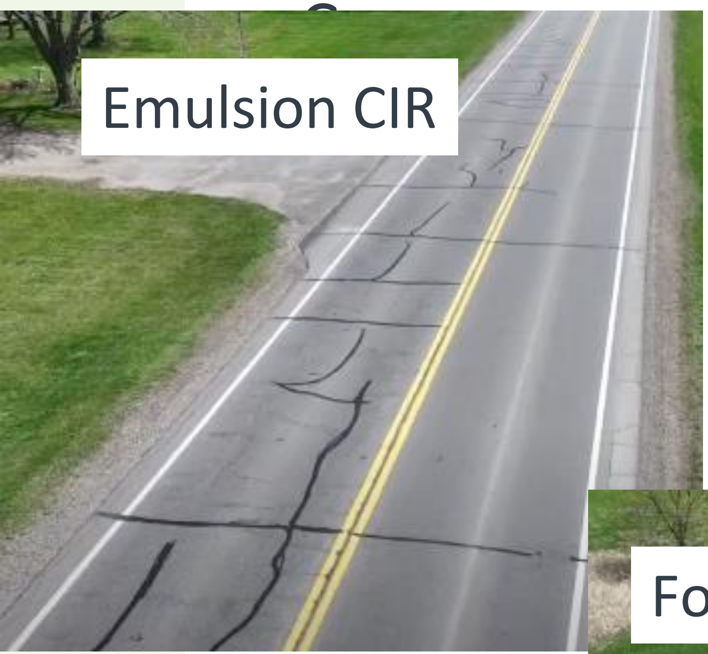


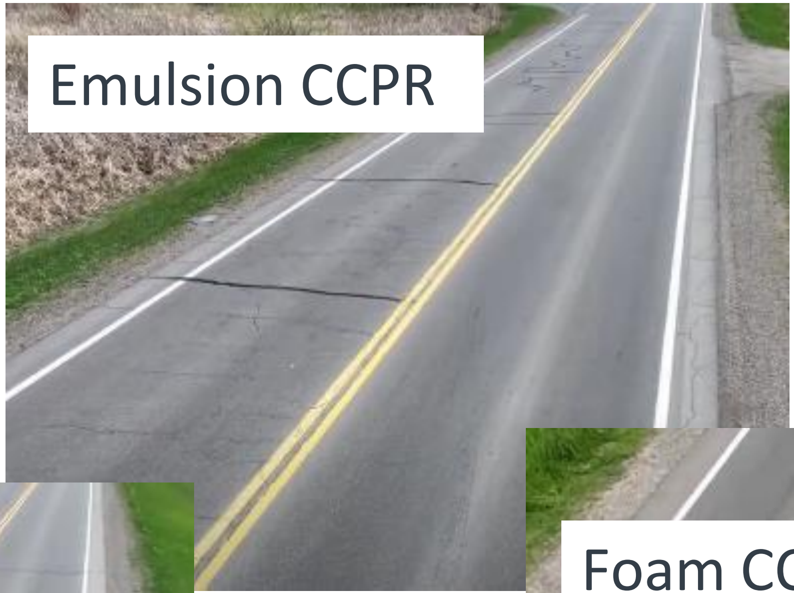
National Research on Cold Recycling

All study sections are in the right-hand east bound lane in the photos below

- MnROAD 70th Street

Drone Video:
https://www.youtube.com/watch?v=PdCBjHzhujU&list=PLdlCqh8t--qNGGXmv2MA4kDEZKz46vtHi&index=14





Performance Evaluation of Cold Recycled Binder Course with Same Day Overlay on Heavy Traffic Expressway in Malaysia

- Busiest expressway in Malaysia with lane 10-year design ESAL's of <u>61.5 millions</u>
- Comparison of emulsion CCPR binder course with HMA mill and fill
- Same day HMA overlay over CCPR and return to traffic
- Constructed on November 22, 2021
- 12-month performance follow up

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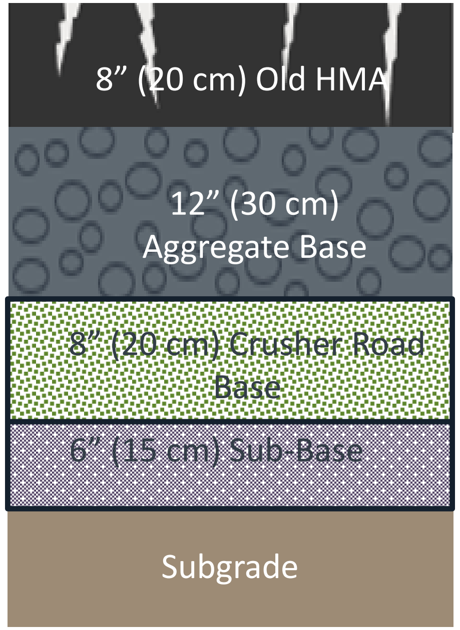
Pavement Information and Roadway Condition

Field Trial	Location	Work Order No.	Commencement Date
Northbound (NB)	KM186.30 to KM185.50, Section N4, Slow Lane	N4/011-2021/H-704/EP2/KM186.30-185.5/NB	22 November 2021

- Poor existing pavement condition with severe fatigue cracking
- 10-year design ESAL's = 61.5 Millions

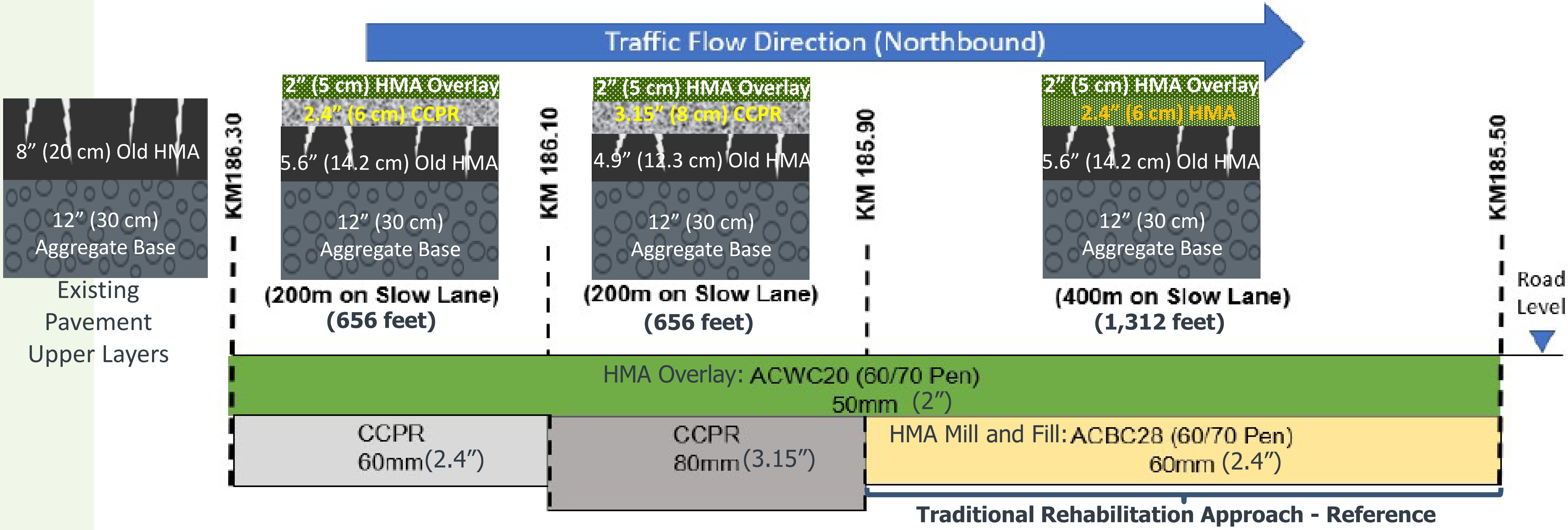


Existing Pavement

Rehabilitation Options for Comparison

Section	Chainage / Length	Treatment Options
CCPR 60mm Section	KM186.30 – KM186.10 NB / 200m	MP110 (inlay 60mm CCPR + 50mm ACWC20)
CCPR 80mm Section	KM186.10 – KM185.90 NB / 200m	MP130 (inlay 80mm CCPR + 50mm ACWC20)
ACBC28 Section	KM185.90 – KM185.50 NB/ 400m	MP110 (inlay 60mm ACBC28 + 50mm ACWC20)

Note: MP denotes Mill & Pave



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Mother RAP Pile - Fractionation

Mixture Design Process








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Cold Recycling Emulsion Properties

- Produced by the contractor at least 2 days before use for emulsion temperature < 122°F (50°C)
- Used Ingevity emulsifier package

Properties	Test Result	Requirement
Viscosity, Saybolt Furol at 25° C (sec):	22	20 – 100
Storage stability test, 24hr (%):	0.3	0 – 5
Settlement, 5 days (%):	3.8	0 – 1
Sieve test (%):	0	0 – 0.1
Cement mixing test (%):	0	0 – 2.0
Distillation for oil, by volume of bitumen emulsion (%):	0	0 – 5
Distillation for residue (%):	60.5	60 minimum
Penetration for residue (dmm):	68	60 – 200
Ductility of residue, 25° C, 5cm/min (cm):	68	40 minimum
Solubility in trichloroethylene (%):	99.5	97.5 minimum
Particle charge test:	Positive	Positive

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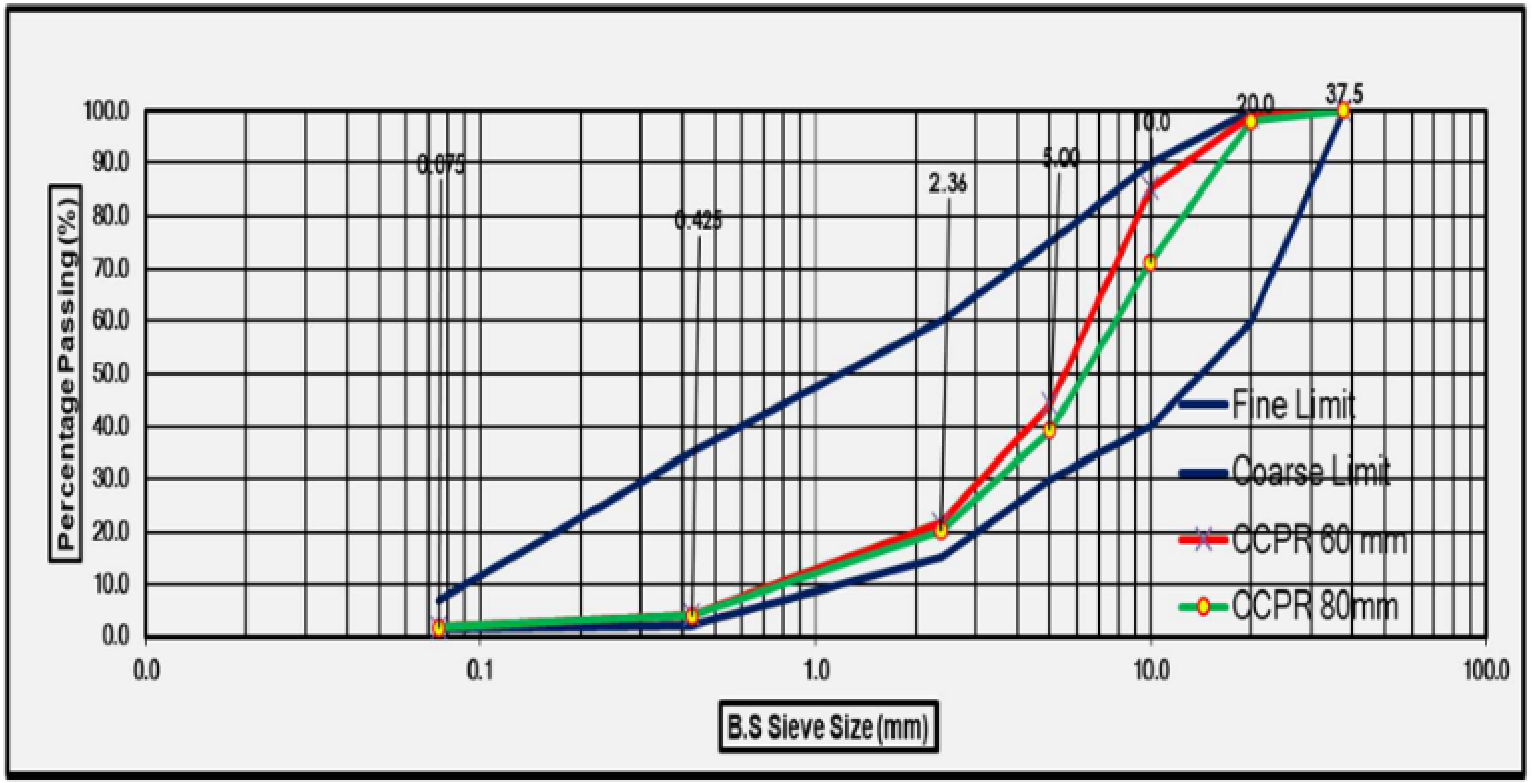
Project RAP Proportions and Gradations

RAP stockpile	Proportion, %	
	2.4” (60 mm) CCPR	3.15” (80 mm) CCPR
Coarse RAP (14.0 mm – 28.0 mm)	18	35
Medium RAP (4.75 mm – 14.0 mm)	58	41
Fine RAP (0.075 mm – 4.75 mm)	24	24



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Cold Recycled Mixture Job Mix Formula

- Mix design according to AASHTO M352, AASHTO R117 and JKR (local specifications)
- Laboratory compaction of 75 blows each side - JMF: Mixture Properties at 3.5% emulsion (60.5% residue) and 1.5% cement:

CRM-E 60 mm

Mix properties	Results		Requirements	
	LMLC (3)	PMLC (4)	AASHTO MP31	JKR
Air voids, % (1)	12.5	10.1	Report	NA
25℃ Un-Conditioned ITS, Mpa	0.494	0.569	0.31	0.2
25℃ Conditioned ITS, Mpa	0.426	0.524	Report	0.15
TSR (2), %	86.2	92.1	70	NA
25℃ Resilient Modulus, MPa	2764	4513	NA	NA
40℃ Resilient Modulus, MPa	935	1983	NA	NA

CRM-E 80 mm

Properties	Results		Requirements	
	LMLC (3)	PMLC (4)	AASHTO MP31	JKR
Air voids, % (1)	11.7	11.1	Report	NA
25℃ Un-Conditioned ITS, MPa	0.525	0.525	0.31	0.2
25℃ Conditioned ITS, MPa	0.454	0.475	Report	0.15
TSR (2), %	86.5	90.5	70	NA
25℃ Resilient Modulus, MPa	3421	3660	NA	NA
40℃ Resilient Modulus, MPa	1254	988	NA	NA

Notes:
(1): Typical 100% RAP CRM-E air voids between 9 and 14%
(2): ITS: Indirect Tensile Strength, TSR: Tensile Strength Ratio = (Wet ITS/Dry ITS)
(3): LMLC = Lab Mixed Lab Compacted samples
(4): PMLC = Plant Mixed Lab Compacted samples

Emulsion CCPR Plant

Emulsion CCPR Mix Production

Field Placement


Milling of the distressed slow lane


Paving of the emulsion CCPR mixture


Field target density with vibratory hammer

- Fifth level


Cold recycled mix sand cone density check


Roller pattern: 10 passes of R1-Macadam steel roller and 8 passes of the pneumatic tire roller

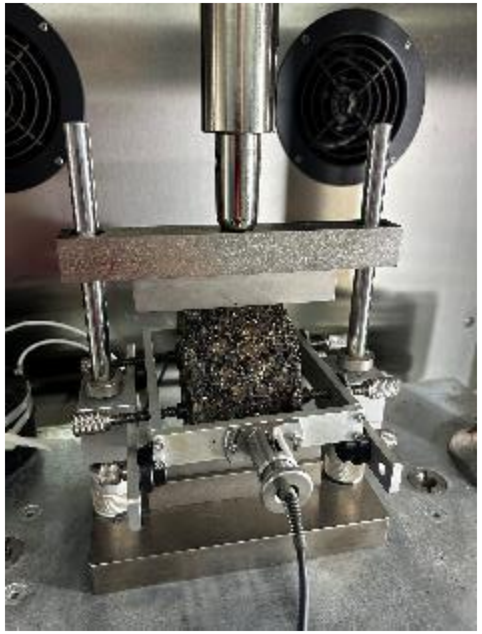

Compacted CCPR prior to tack coat and HMA overlay 4 hours later

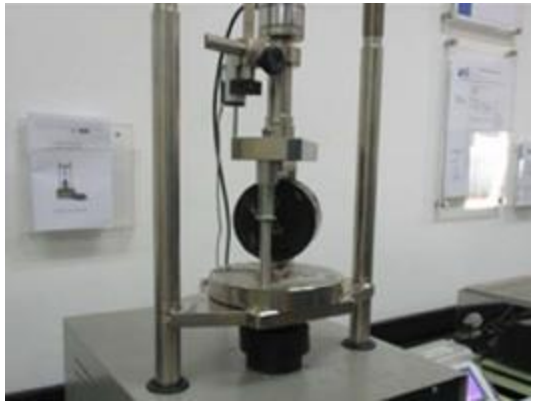
Performance Follow Up – Test Plan

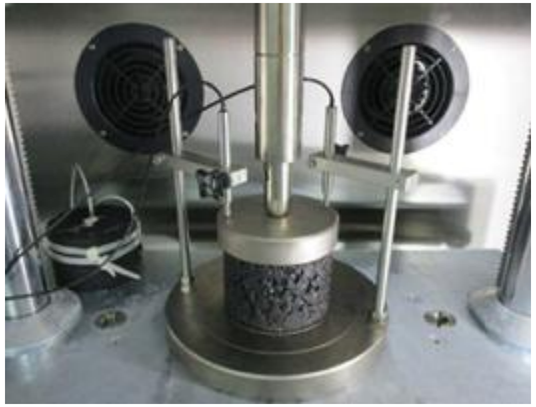
	Phase	0 (Pre-Construction)	1	2	3	4
	Time after construction	NA	14 days	6 months	9 months	12 months
	Sampling in the field or testing	11/22/21 to 11/24/21	12/8/21	6/23/22	9/14/22	12/7/22 and 1/3/23
Field cores from each section binder course	Resilient Modulus Test	✓	✓	✓	✓	✓
	Dynamic Creep Test	-	✓	✓	✓	✓
	Indirect Tensile Strength Test and Tensile Strength Ratio (TSR)	✓	✓	✓	✓	✓
Non-destructive pavement surface	Rutting laser profiler	✓	-	✓	-	✓
	Automatic crack detection	✓	-	✓	-	✓
	International Roughness Index (IRI)	✓	-	✓	-	✓

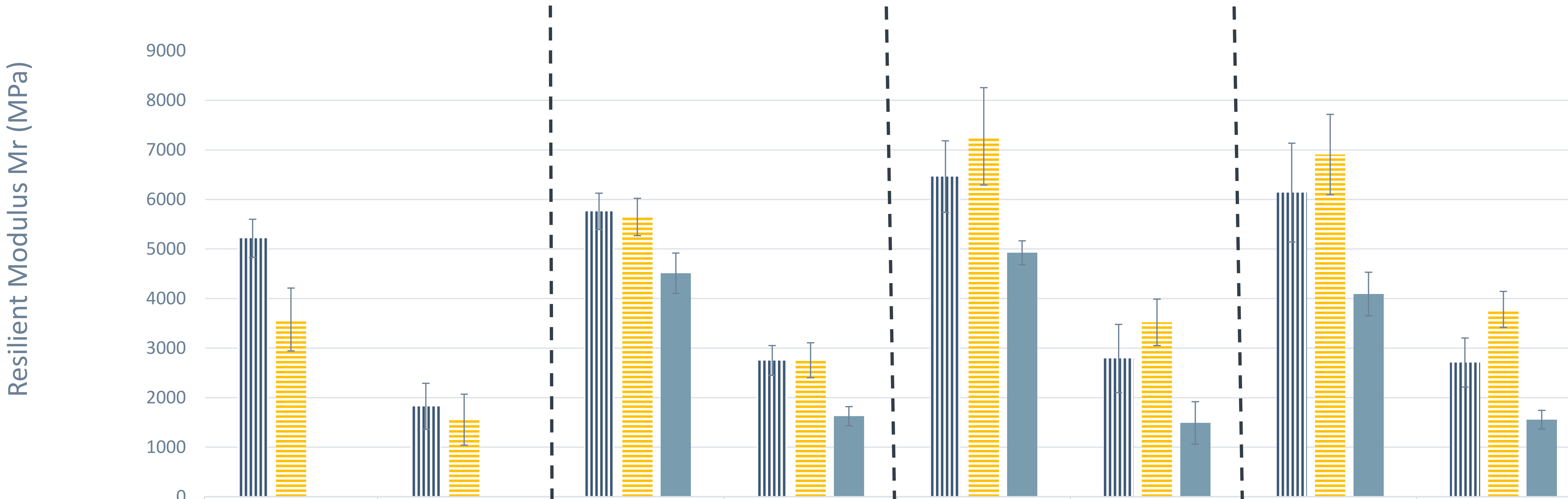
Performance Follow up and Testing of Field Cores

- Destructive and non-destructive testing

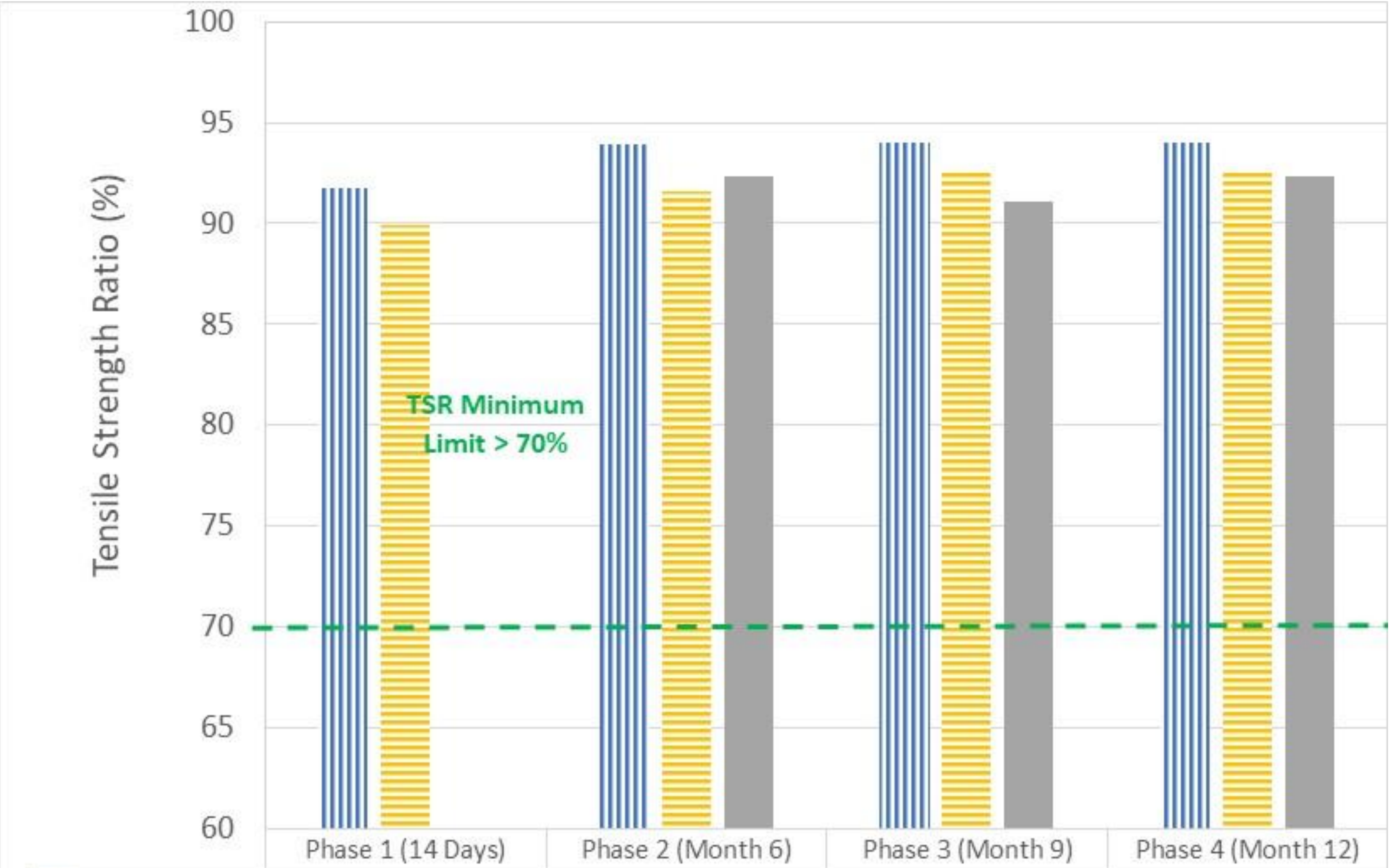




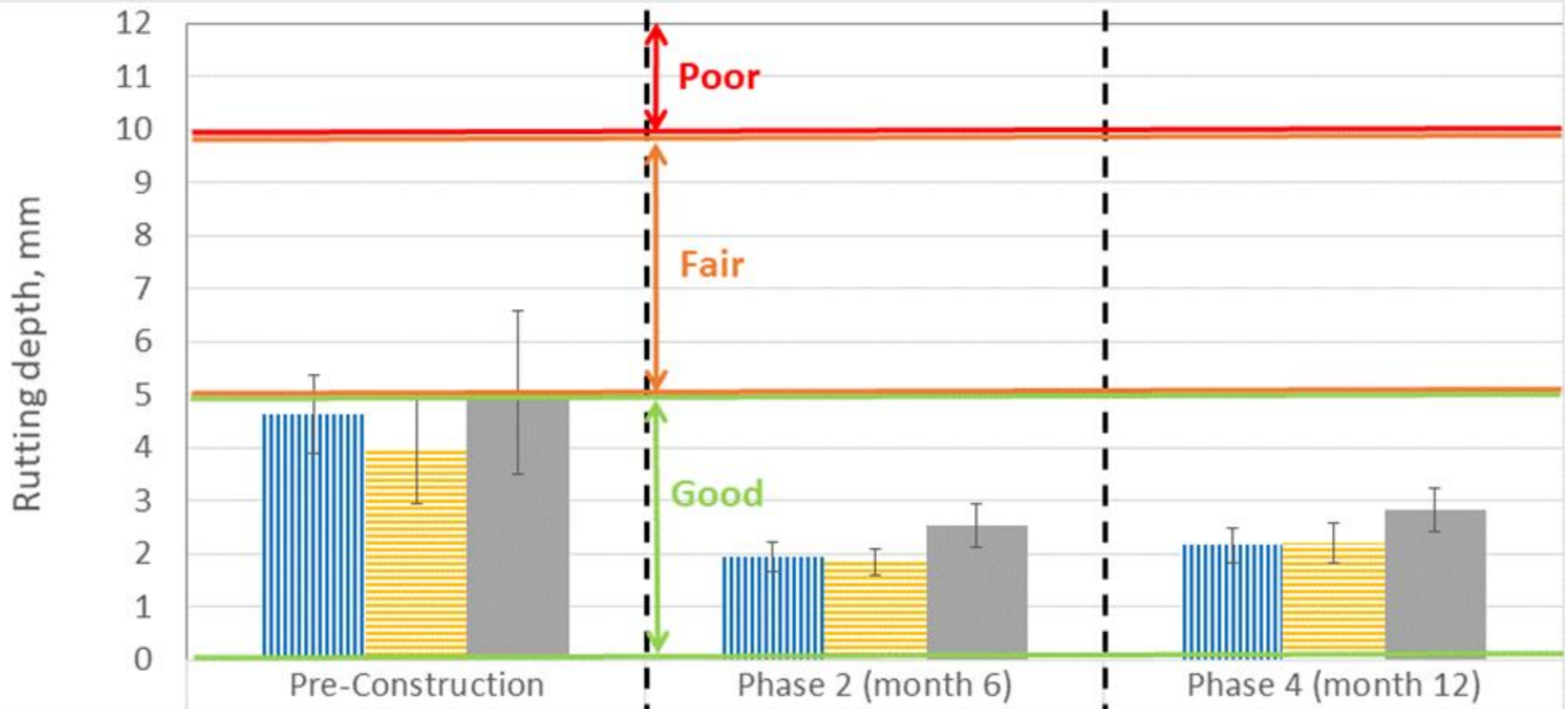




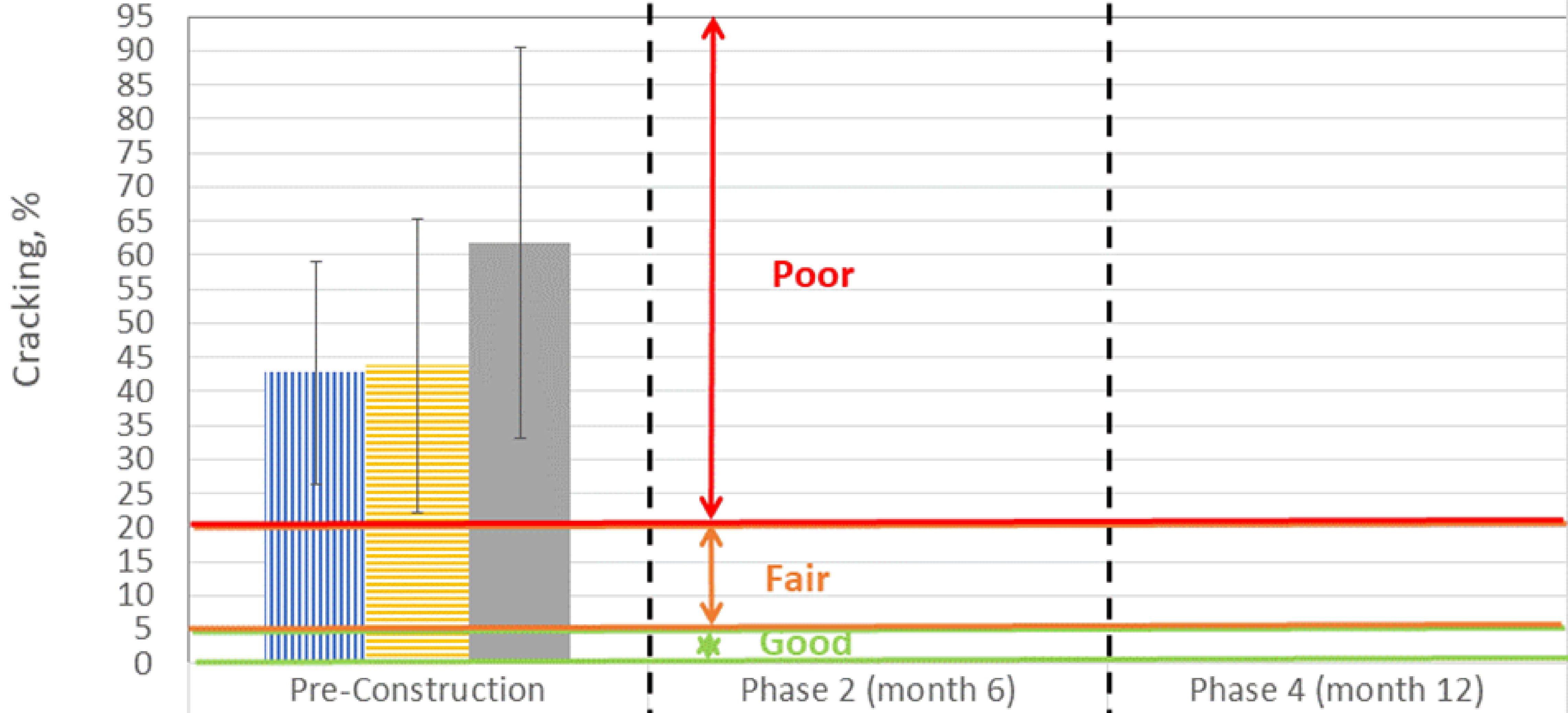
	Phase 1 (14 Days) 25°C	Phase 1 (14 Days) 40°C	Phase 2 (Month 6) 25°C	Phase 2 (Month 6) 40°C	Phase 3 (Month 9) 25°C	Phase 3 (Month 9) 40°C	Phase 4 (Month 12) 25°C	Phase 4 (Month 12) 40°C
CRM-E (60 mm)	5216	1825	5758	2750	6462	2791	6138	2709
CRM-E (80 mm)	3576	1556	5646	2754	7273	3521	6906	3780
ACBC28 (60 mm)	Not Tested	Not Tested	4511	1626	4924	1490	4092	1555



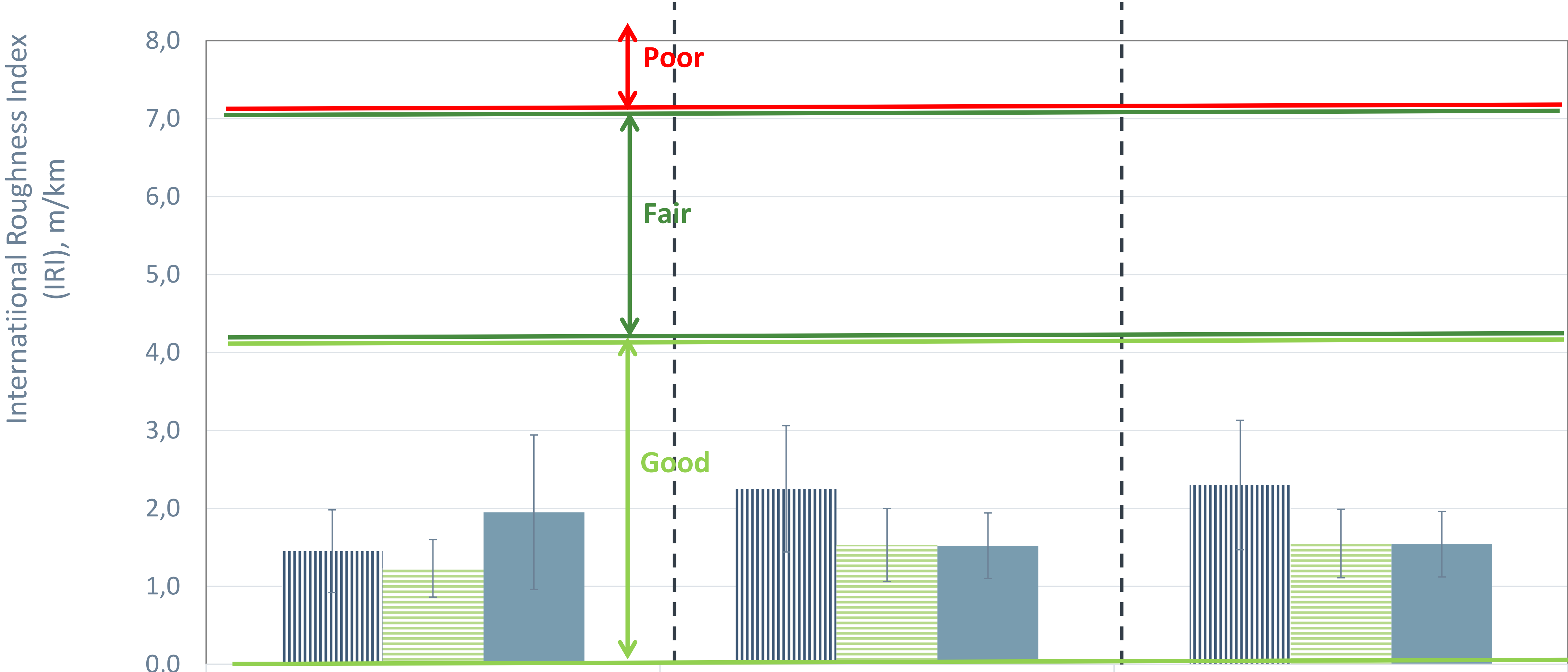
	Phase 1 (14 Days)	Phase 2 (Month 6)	Phase 3 (Month 9)	Phase 4 (Month 12)
CRM-E (60 mm)	91.8	93.9	94.0	94.0
CRM-E (80 mm)	89.9	91.6	92.6	92.5
ACBC28 (60 mm)	Not Tested	92.3	91.1	92.4



	Pre-Construction	Phase 2 (month 6)	Phase 4 (month 12)
CRM-E (60 mm)	4.63	1.94	2.16
CRM-E (80 mm)	4.00	1.85	2.21
ACBC28 (60 mm)	5.03	2.53	2.83



	Pre-Construction	Phase 2 (month 6)	Phase 4 (month 12)
CRM-E (60 mm)	42.8	0	0
CRM-E (80 mm)	43.8	0	0
ACBC28 (60 mm)	61.8	0	0



	Pre-Construction	Phase 2 (month 6)	Phase 4 (month 12)
CRM-E (60 mm)	1,45	2,25	2,30
CRM-E (80 mm)	1,23	1,53	1,55
ACBC28 (60 mm)	1,95	1,52	1,54

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Roadway Visual Condition

- Before rehabilitation condition

- Photos of the slow lane after 12 month of heavy traffic

Cold recycled 60mm section between KM186+300 and KM186+100

Cold recycled 80mm section between KM186+100 and KM185+900

ACBC28 section between KM185+900 and KM185+500

Roadway Visual Condition (Cont.)

- Before rehabilitation condition

- Photos of the slow lane after 21 month of heavy traffic

Cold recycled 60mm section between KM186+300 and KM186+100

Cold recycled 80mm section between KM186+100 and KM185+900

ACBC28 section between KM185+900 and KM185+500

Next Milestone

- Expressway emulsion CCPR binder course with same day HMA overlay at night

October 18, 2024 paving of the emulsion CCPR at night

Synergy of using WMA and Cold Recycling Combinations
A Case Study: NMDOT I-25

New Mexico I-25 – WMA over CIR (Partial Depth)

Project Details: Aug- Nov 2023

- 6.4 km center lane section of Interstate I-25 in San Miguel County near Santa Fe (MP 305 to MP 309) NB and SB
- Traffic Volume: 9,699 AADT and 19% truck traffic (829,000 ESALs per year)
- Contractor: Fisher Sand & Gravel / Coughlin Company

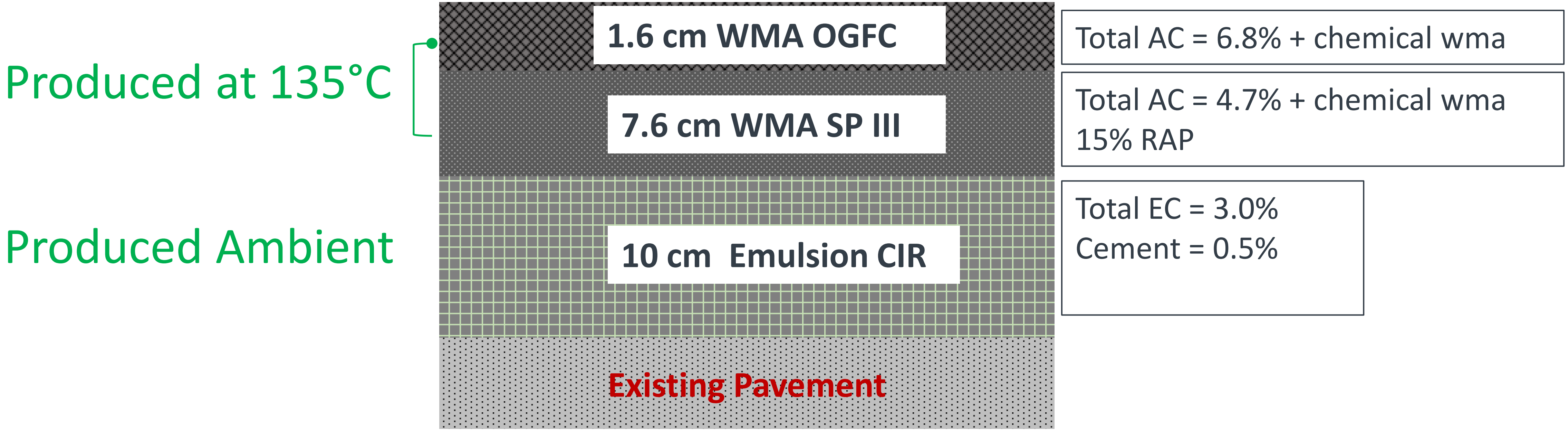
Challenges:

- Higher elevation, cooler climate, rain and snow delays
- Petromat in the existing layers
- Some areas requiring micro-milling for smoothness.
- Traffic was on just the CIR surface for 30 days before overlaying with no damage

New Mexico I-25 WMA over CIR

Construction:

- 9 cm (3.5”) Cold mill → 10 cm (4”) Cold in-Place Recycling → 7.6 cm (3”) WMA SP III Inlay → 1.6 cm (5/8”) WMA OGFC



New Mexico I-25 WMA over CIR

New Mexico I-25 WMA over CIR

I-25 in San Miguel County, New Mexico

- NMDOT project stats:
  - $1.6 million in cost-savings
  - 27% reduction in GHG emissions
- NMDOT received the 2024 ARRA Award and featured in Roads & Bridges Magazine https://www.roadsbridges.com/awards/recycling-awards/article/33017337/reusing-the-road

New Mexico I-25 WMA over CIR

Thank you – Q&A

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