PUSHING THE BOUNDARIES OF RAP CONTENT IN ASPHALT MIXES IN ALBERTA

CEA TRANSPORTATION CONFERENCE 2023

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WE OPEN THE WAY

OUTLINES

1. ENGAGING TRANSPORTATION AND ECONOMIC CORRIDORS INTEREST
2. MIX DESIGN METHODOLOGY
3. PROJECTS’ INTRODUCTION & DESIGN CHANGE PROPOSALS
4. MIX DESIGN / PERFORMANCE TESTS / QA & QC
5. CONCLUSION

1

ENGAGING TRANSPORTATION AND ECONOMIC CORRIDORS INTEREST

GOALS OF HIGH RAP TRIAL PROJECTS

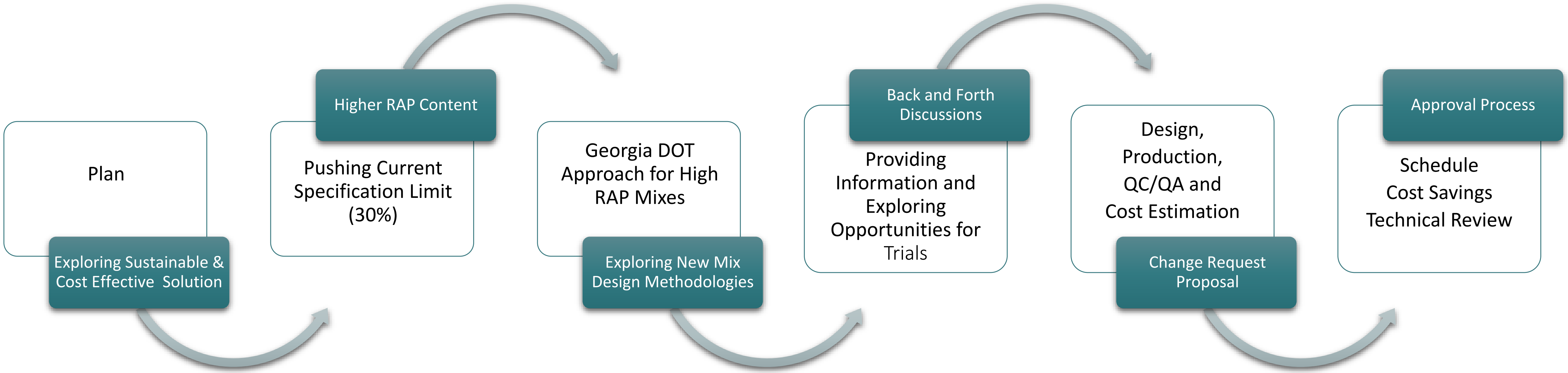
TRANSPORTATION AND ECONOMIC CORRIDORS (TEC)

"The ministry supports work with our partners to facilitate and enable the use of new and environmentally-sustainable methods for application in the construction industry, such as..."

High Recycled Asphalt Pavement (RAP) Mixes

DISCUSSIONS TO GAUGE TRANSPORTATION AND ECONOMIC CORRIDORS INTEREST

HIGH RAP MIXES



WHAT ARE THE RISKS?

- Mix Design approach
- Strategy

Durability of Mix

- Are the savings reasonable and achievable?

Cost Savings

- Early Rehabilitation
- Public Perception

Poor Performance

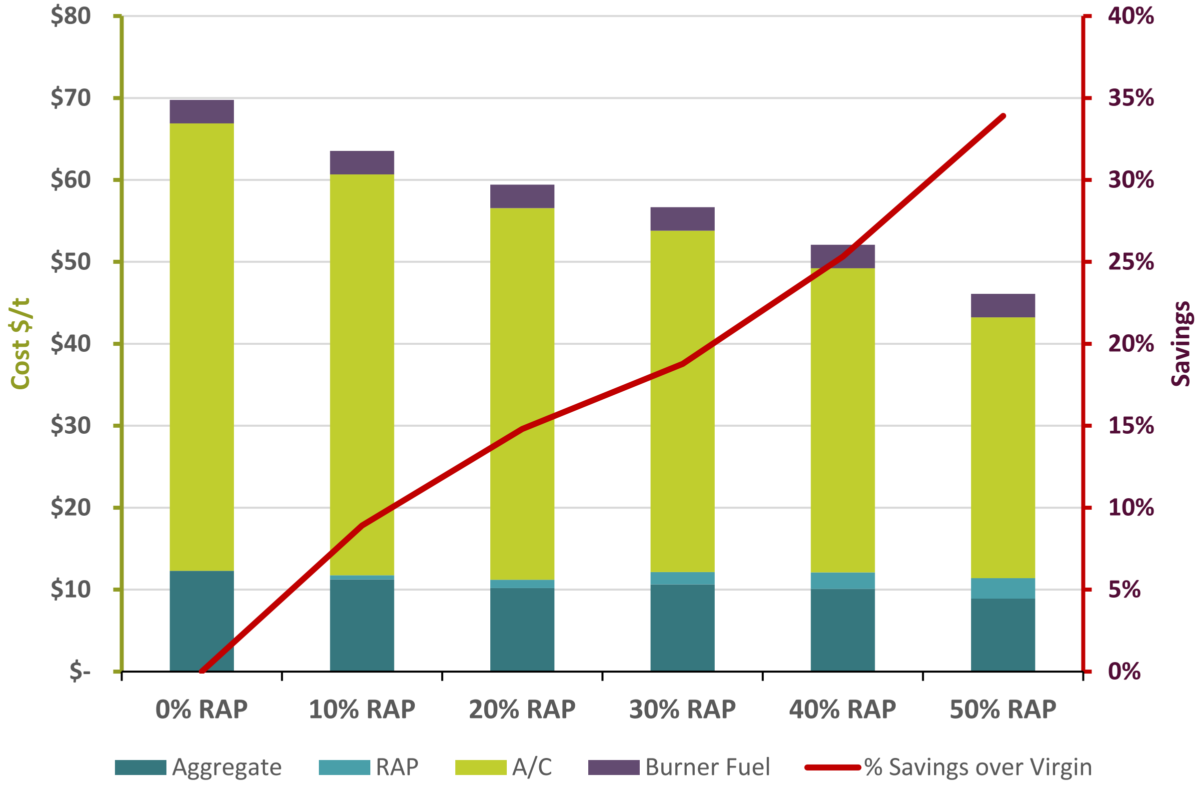
- QA/QC
- Tight timeline to review the change request
- Is this the correct project to trial this type of mix?
- Significant portion of project with new mix

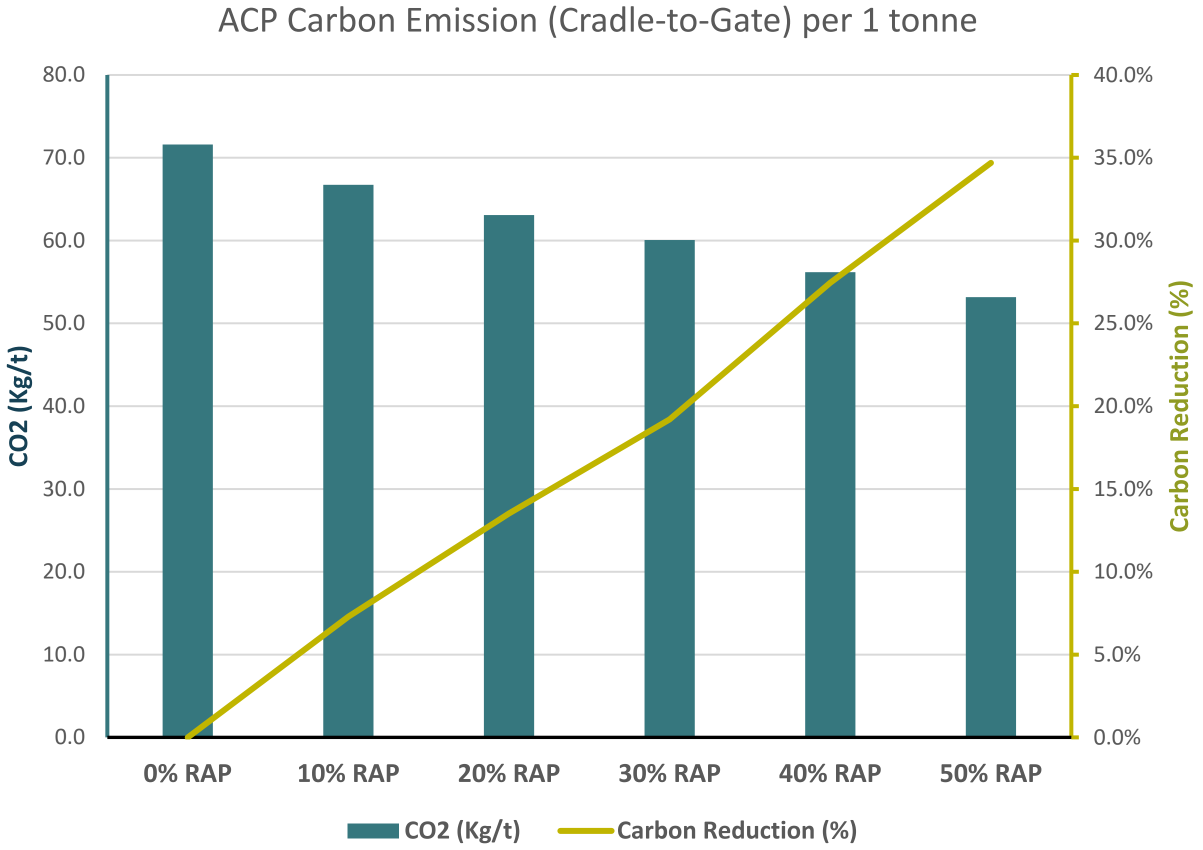
Administration challenges,

MAIN DRIVERS

HIGH RAP MIXES
DRIVERS – COST & ENVIRONMENT

90% of the avoided emissions have been achieved through using RAP

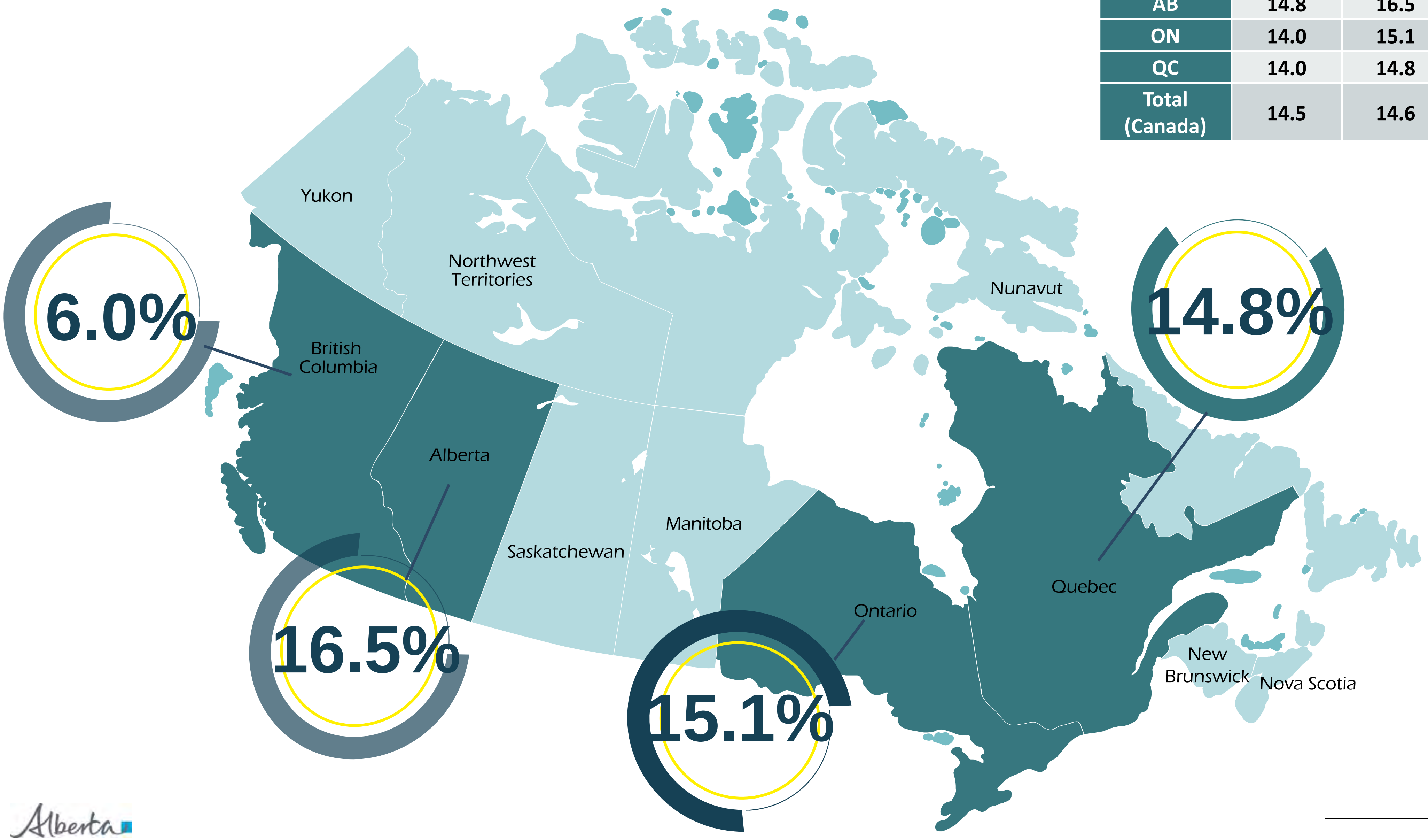




AVERAGE RECYCLING RATIOS

COLAS CANADA - 2021

	2020	2021
BC	8.6	6.0
AB	14.8	16.5
ON	14.0	15.1
QC	14.0	14.8
Total (Canada)	14.5	14.6



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MIX DESIGN METHODOLOGY

HIGH RAP MIXES
CHALLENGES

Performance

- **Aged binder of RAP (Stiffness and brittleness)**
  - Increases mix Stiffness
  - Reduces Cracking/Fatigue resistance of mixtures (intermediate and low temperature)
- **Blending/diffusion between RAP/Virgin binder**
  - Dependent on time, temperature, RAP binder stiffness, RAP binder replacement and gradation
  - Blending in high RAP mixes is more difficult.

Production

- **Variability in aggregate gradation and binder properties (grade and content)**
- **Mixing**
- **RAP sizing**
- **Stockpiling**

HIGH RAP MIXES
PERFORMANCE CHALLENGES

How to overcome performance challenges?

Choosing Proper Strategy

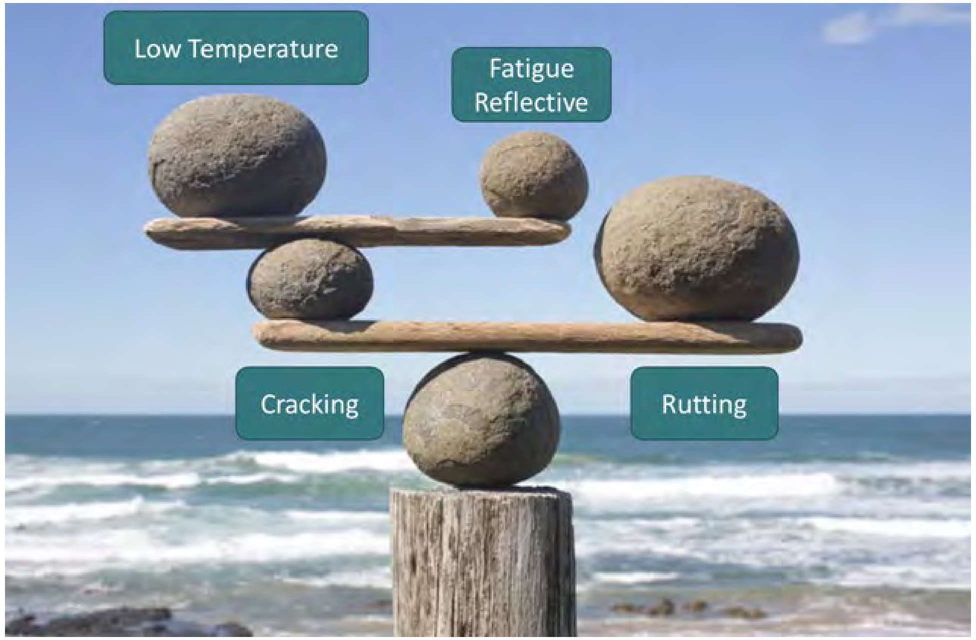
- Performance Base Specification
- Rejuvenators
- Softer Binder
- Reducing Binder Contribution

Can we use Volumetric Designs? Why?

What is the tool?

Can we incorporate these strategies into existing specifications ?

Better Compaction +



= ***Better performance or the same as common products***

HIGH RAP MIXES

GEORGIA DOT APPROACH - HISTORY

Voids is not a requirement for a mix design in GDOT specification

1998—Implement Superpave
- **Dry mix**

1998–2005—RAP% gradually increased from 10% to 25%

2005—One level of gyration for Ndesign (65 gyrations) & fined up gradation

2005–2010—Additional performance testing (rut and permeability testing) & establish minimum film thickness

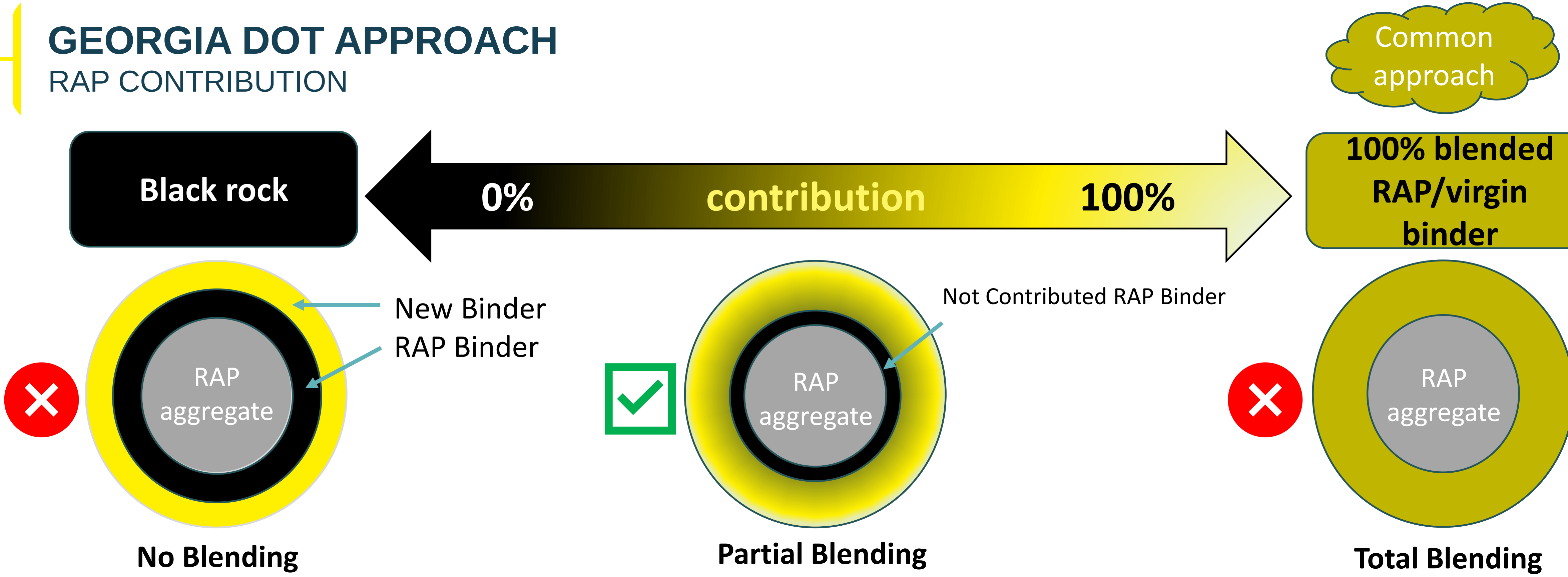
2012—RAP binder contribution reduced from 100% to 75% (Virgin binder increased)

2015—High RAP (>25% RAP) mixtures can be used in any pavement lift – 60% RAP binder contribution

They don’t call it superpave mix design anymore!

GEORGIA DOT APPROACH

RAP CONTRIBUTION



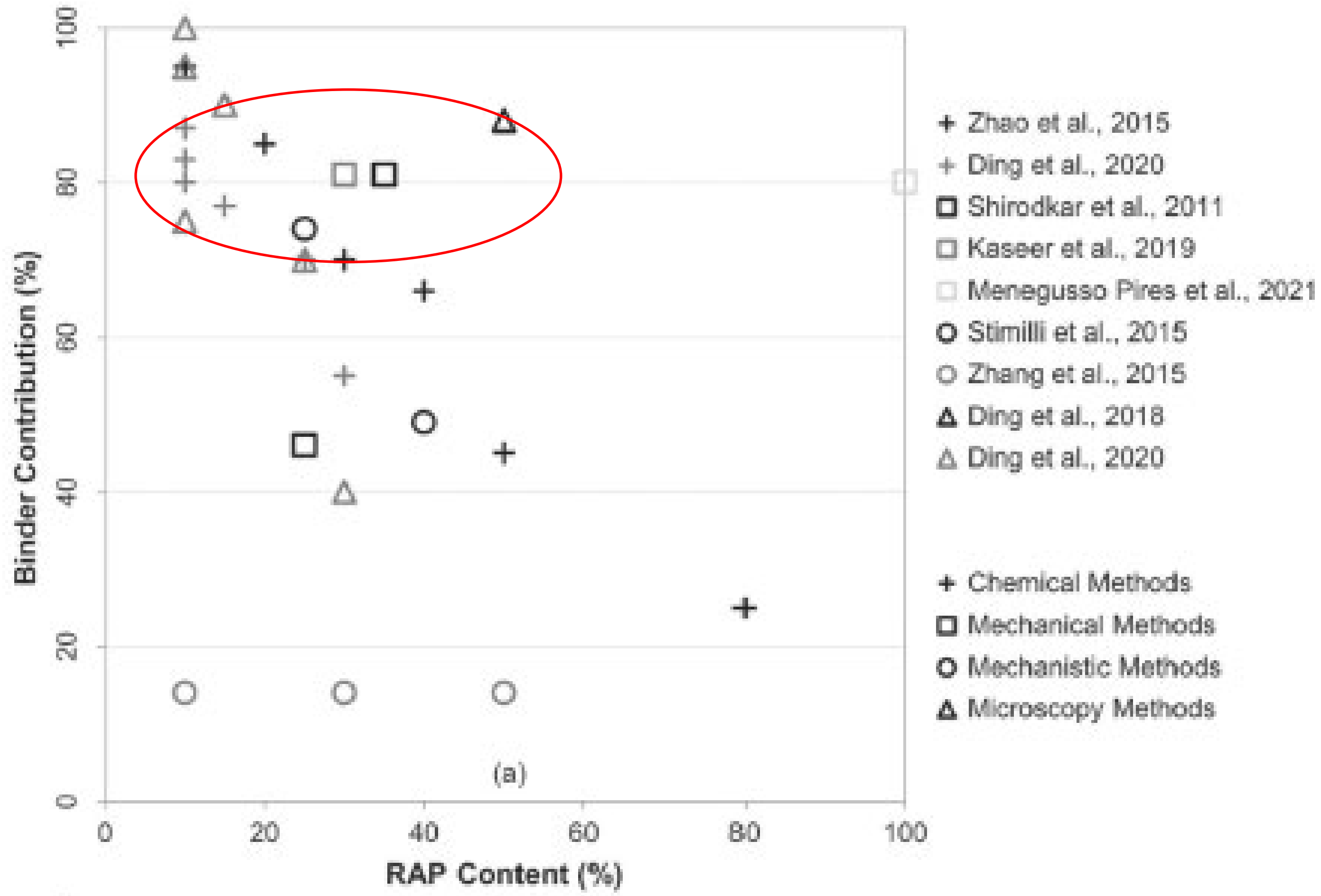
GDOT Research Objective:

How much of RAP binder does come off from RAP aggregate (diffusion)?

60% RAP binder contribution → Compensate the not contributed RAP binder (40%) with the new binder → Higher Total Binder

RAP BINDER CONTRIBUTION

LITERATURE REVIEW



RAP contribution depends on:

- **Mixing time (heat exposure)**
- **Temperature**
- **RAP binder stiffness**
- **RAP content**
- **Gradation**

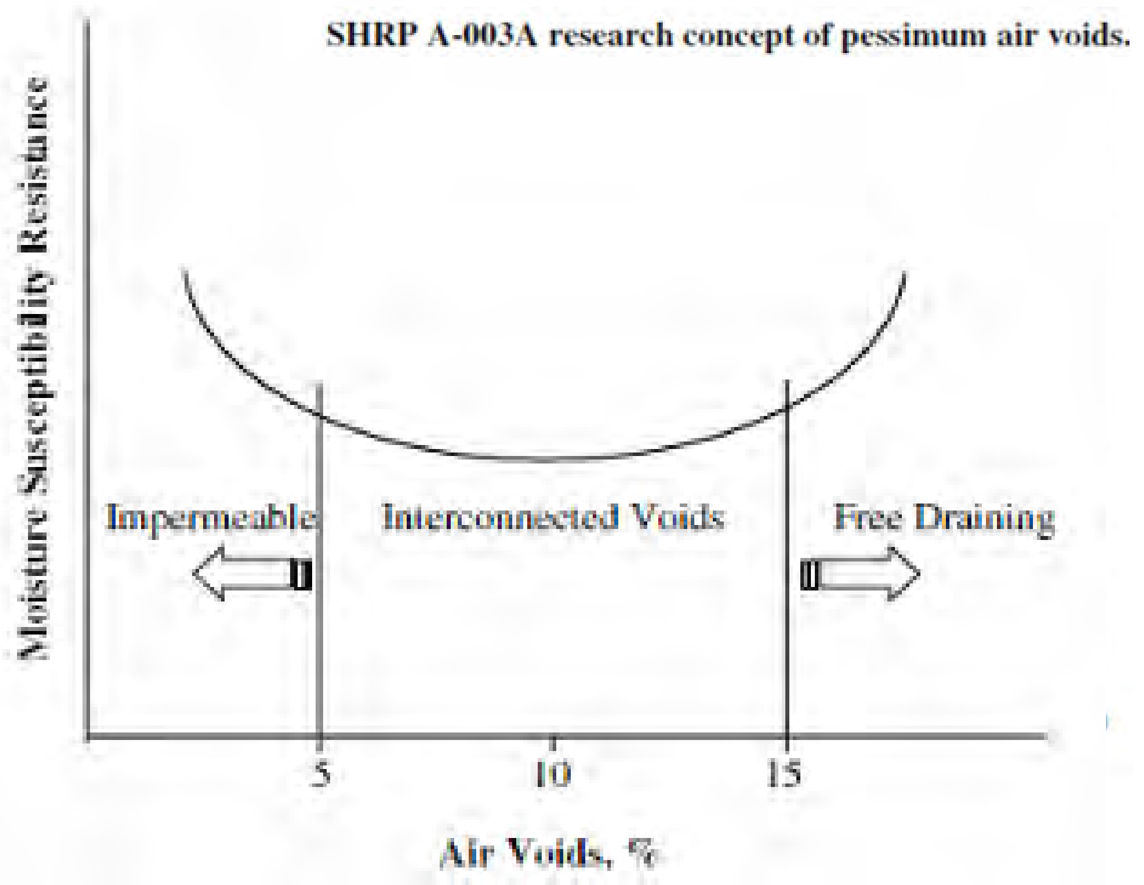
GEORGIA DOT APPROACH

COMPACTION – IN-PLACE AIR VOIDS

Goal - Better Densities

"The amount of air voids in an asphalt mixture is probably the single most important factor that affects performance throughout the life of an asphalt pavement."
- E. Ray Brown, NCAT Report 90-3

"Compaction is the most important factor in the performance of an HMA pavement."
- HMA Paving Handbook, US Army Corps of Engineers



Lower compaction effort

Higher binder content

→

Better densification

Lower In-place Air Voids

Lower permeability

More uniform surface texture

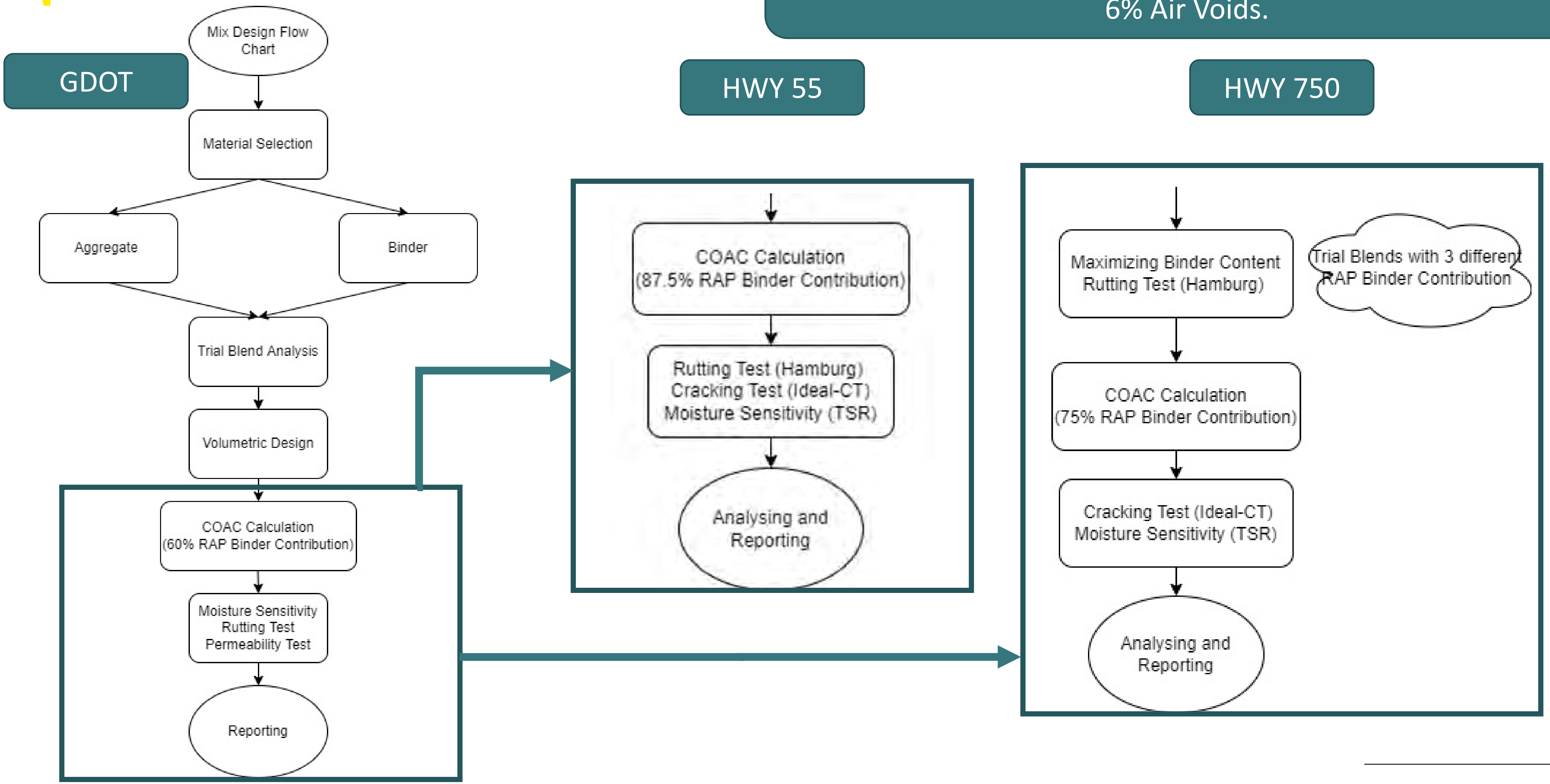
→

Lower Moisture Related Distresses

Lower Binder Aging

MIX DESIGN PROCESS

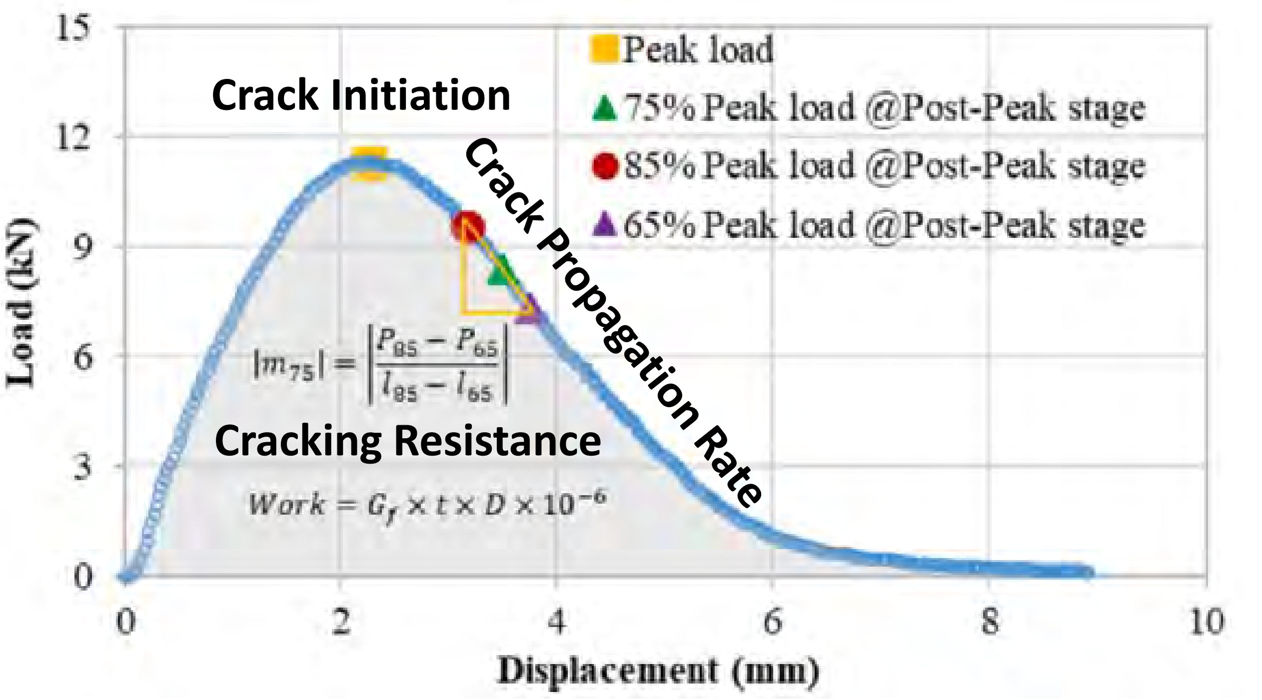
All the performance testing for mixes using GDOT approach was conducted at Corrected Optimum Asphalt Content (COAC) and 6% Air Voids.



MIX DESIGN

PERFORMANCE TEST SELECTION CRITERIA - CRACKING TEST

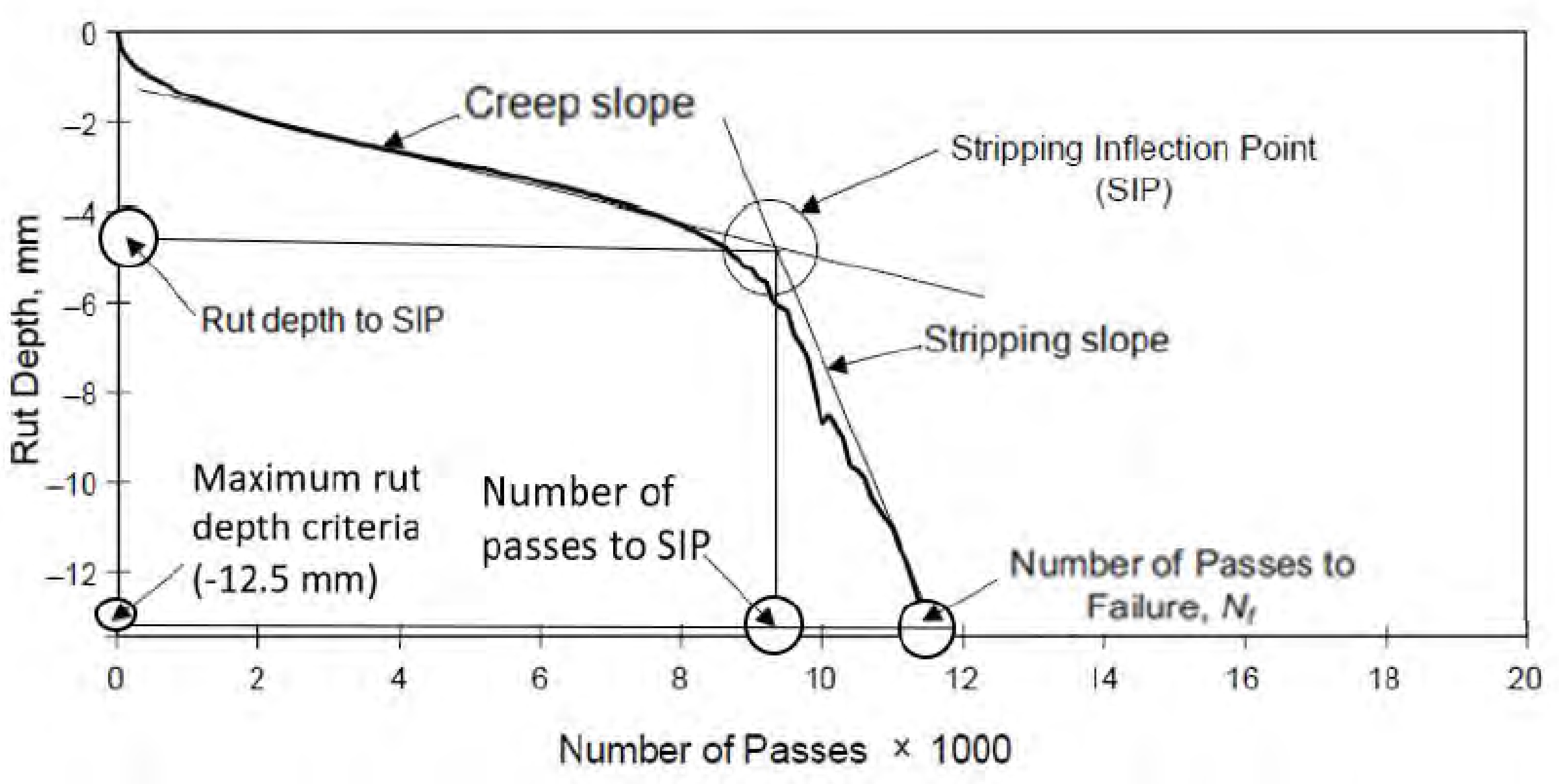
- Simplicity
- Availability
- Efficiency/Time
- Cost
- Repeatability
- Sensitivity
- Address different distress modes
- Correlation to field
- Testing Temperature
- Local data (Previous AT projects)



$$CTindex = \frac{t}{62} \times \frac{l_{75}}{D} \times \frac{G_f}{|m_{75}|} \times 10^6$$

MIX DESIGN

PERFORMANCE TEST SELECTION CRITERIA - RUTTING TEST



AASHTO T 324-17 (2018)

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PROJECTS' INTRODUCTION & DESIGN CHANGE PROPOSALS

PROJECT INFORMATION

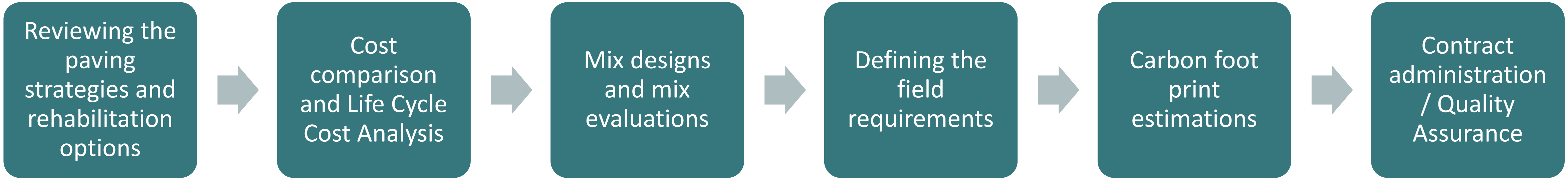
HWY 55

- **Length 31.6 Km from Hwy. 2 to Hwy. 63**
- **261,705 m2 of Cold Milling,**
- **84,000 t of ACP M1 mix**
- **10,000 t of ACP Air Void Regression Mix**

HWY 750

- **Length 18.5 Km**
- **12,100 m2 of Cold Milling,**
- **23,100 m of spray patch crack repair**
- **30,500 t of ACP L1 mix**
- **7,900 t of ACP S1 mix**

CHANGE PROPOSAL



CHANGE PROPOSAL
PAVING STRATEGIES

HWY 55

- **List of the rehabilitation options**

Treatment No.	Treatment Description	Service Life[1,2] (Years)
1	60 mm full width mill and replace	10
2	SMF t-cracks in the driving lanes (7.4 m width) plus 60 mm (two-lift) full width overlay	14
3	SMF t-cracks in the driving lanes (7.4 m width) plus 90 mm (two-lift) full width overlay	20
4	60 mm mill and inlay driving lanes (7.4 m width) plus 50 mm (single lift) full width overlay	20

Surfacing Strategy Report

- **Structural overlay was needed**
- **The mix components was changed**

HWY 750

- **List of the rehabilitation options**

Table 7.1 LCCA Analysis Results Summary

Rank	Case	Treatment Option	Service Life (yrs.)	Initial Cost ($/km)	Present Worth ($/km)	% Diff
Segment 2; Hwy 750:02 km 17.610 – km 30.963 & Hwy 750:04 km 0.000 – km 1.000						
1	3	Spray Patch Extreme Cracks + 70 mm ACP OL	19	$116,600	$151,700	
2	1	50 mm Cold Mill and Replace	13	$102,900	$160,800	6.0%
3	2	50 mm Cold Mill and 70 mm ACP Repaving	20	$136,900	$168,500	11.1%

Surfacing Strategy Report

- **Structural overlay was not needed**
- **The rehabilitation method and the mix components were changed**

CHANGE PROPOSAL

MIX TYPES

HWY 55

Mix Name	Mix #1 (Considered in Contract)	Mix #2 (Considered in Contract)	Mix #3**	Mix #4	Mix #5*
Mix Design Method	Marshall	Marshall – Regression	Georgia approach Coarse Graded	Georgia approach Fine Graded	Superpave
Mix Type / Nmas	M1	M1	12.5	12.5	12.5
RAP (%)	25	25	40	40	40
Blow / Ndes	75	75	65	65	65
Mix-design air voids	3.5 to 4.0	3.5 to 4.0	4.0	4.0	4.0
RAP Binder Contribution (%)	100	100	87.5	87.5	100
RAP Binder Grade	PG 58-28	PG 58-28	PG 58-28	PG 58-28	PG 58-28
Vigin Binder Grade	PG 58-28	PG 58-28	PG 58-28	PG 58-28	PG 58-28
Antistrip / WMA Additives	0.05% of binder	0.05% of binder	0.1% of binder	0.1% of binder	NA
Recycling Agent /WMA	No	No	No	No	1.1% of binder

HWY 750

Mix Name	Mix #1 (Considered in Contract)	Mix #2 (Considered in Contract)	Mix #3
Mix Design Method	Marshall	Marshall	Georgia approach
Mix Type / Nmax	L1	S1	12.5
RAP (%)	0	0	40
Blow / Ndes	50	75	65
Mix-design air voids	3.5 to 4.0	3.5 to 4.0	4.0
RAP Binder Contribution (%)	100	N/A	87.5
RAP Binder Grade	PG 52-28	PG 52-28	PG 52-28
Binder Grade	PG 52-34	PG 52-34	PG 46-34
Antistrip / WMA Additives	0.3% of binder	0.3% of binder	0.5% of binder

*Gradation of Mix #5 was the as Mix #4.

**Mix #3 was not produced.

CHANGE PROPOSAL
COST ANALYSIS

HWY 55

CONSTRUCTION COST

Description	Savings (%)
Mix #1 – EPS Mix Type M1 with 25% RAP	0.0%
Mix #2 – Regression Mix	-3.8%
Mix #4 – Georgia Method Mix with 40% RAP	9.5%
Mix #5 – Rejuvenator Mix with 40% RAP	8.7%

HWY 750

LIFE CYCLE COST ANALYSIS

Rehabilitation Option	Analysis period (Years)	Design Life (Years)	Next Rehab method	Net Present Value ($)	Initial Cost Savings (%)
Spray Patch Cracks + 70 mm ACP OL (Contract)	30	19	Spray Patch +70 mm OL	-	-
50 mm Cold Milling and Replace (Proposal)	30	13	Spray Patch +70 mm OL	5.1%	32.7%

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MIX DESIGN / PERFORMANCE TESTS / QA/QC

MIX DESIGN

RAP BINDER CONTRIBUTION

HWY 55

Based on the engineering judgement RAP contribution was considered 87.5%

HWY 750

RAP Contribution %	100	87.5	80	72.5
Corrected Optimum AC (COAC)	5.00%	5.3%	5.5%	5.7%
AIR VOIDS (%)	4.0	3.2	2.7	2.2
VMA (%)	13.6	13.4	13.3	13.3
Vbe (Volume of Effective Binder%)	9.5	10.2	10.6	11.1
Film Thickness (µm)	6.3	6.7	7.0	7.3

Mix Type	RAP Binder Contribution (%)	AC%	Failure reason	SIP*	Number of passes at 12.5 mm rutting	Rutting @ 20000 passes
Trial 1	87.5	5.3%	Maximum passes	NA	NA	4.07
Trial 2	80	5.5%	Maximum Passes	NA	NA	4.28
Trial 3	72.5	5.7%	Maximum passes	NA	NA	3.74

MIX DESIGN

VOLUMETRICS

HWY 55

Project / Mix Type	Reference Mix (M1) & Field Control	Georgia Method Mix with 40% RAP		Rejuvenator Mix with 40% RAP
RAP Binder Contribution (%)	100	100	87.5	100
Optimum Asphalt Content (%)	5.4	5.2	NA	5.2
Corrected Optimum Asphalt Content (%)	NA	NA	5.5	NA
Air Voids (%)	3.5	4.0	3.1	4.0
VMA (%)	14.0	13.6	13.7	14
Effective Binder (%)	10.5	9.5	10.6	10.0
Film Thickness (µm)	6.5	6.3	7.1	6.7

HWY 750

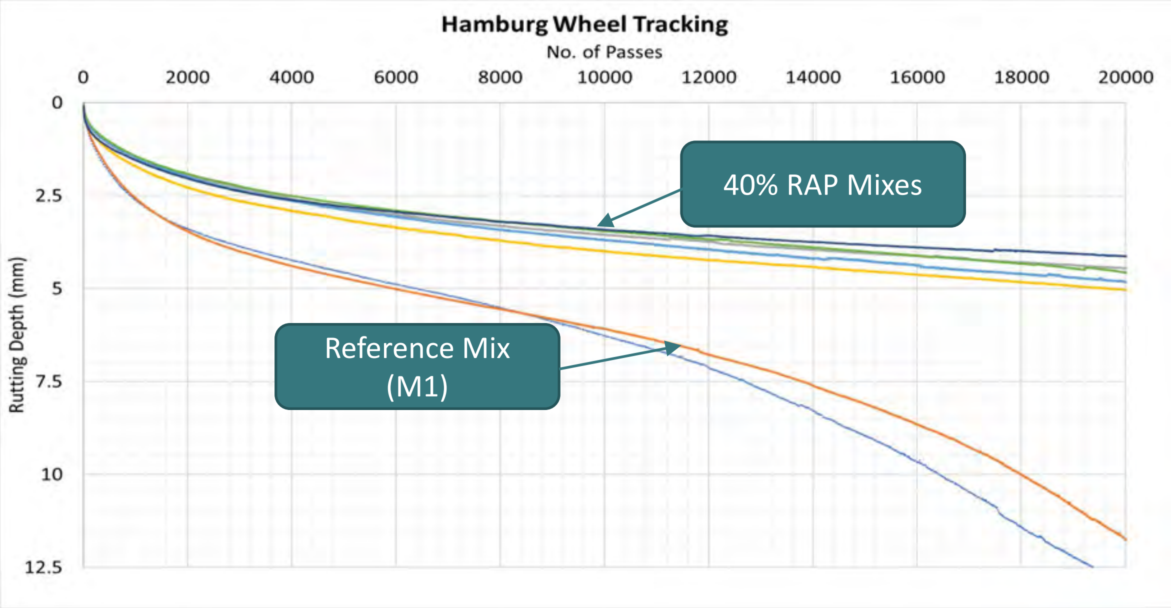
Project / Mix Type	Reference Mix (L1)	Georgia Method Mix with 40% RAP	
RAP Binder Contribution (%)	100	100	75
Optimum Asphalt Content (%)	5.4	5.0	NA
Corrected Optimum Asphalt Content (%)	NA	NA	5.6
Air Voids (%)	3.5	4.0	2.5
VMA (%)	14.0	13.6	13.3
Effective Binder (%)	10.5	9.4	10.8
Film Thickness (µm)	6.5	6.3	7.2

MIX DESIGN

PERFORMANCE TEST RESULTS – HAMBURG WHEEL TRACKING (AASHTO T 324-16)

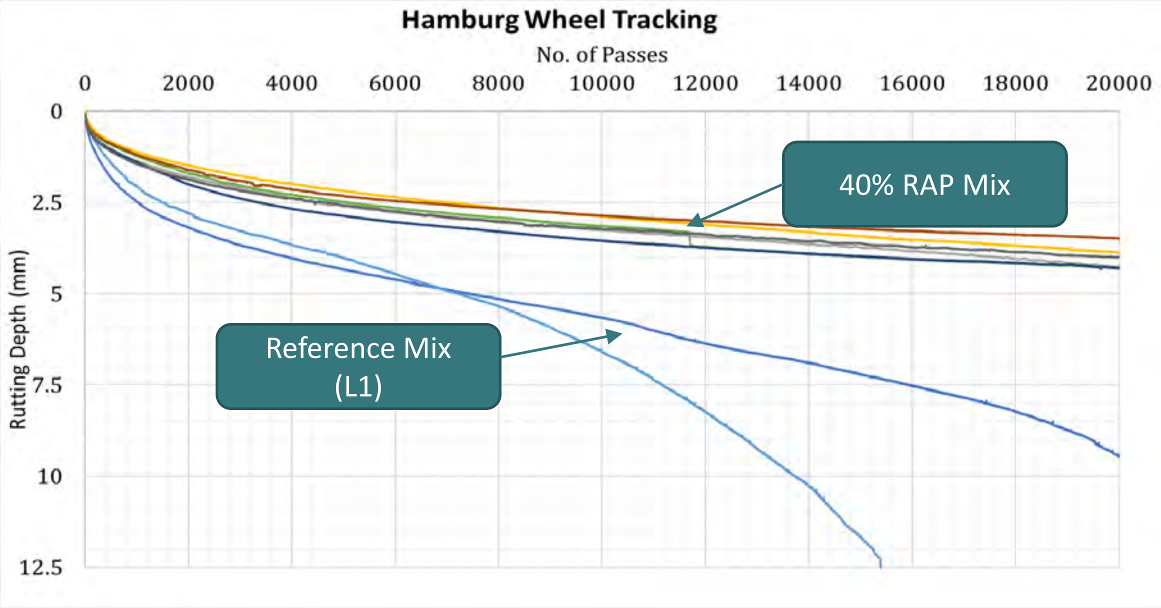
HWY 55

Mix Type	Air voids (%)	Test Temperature (°C)	Failure reason	SIP*	Number of passes at 12.5 mm rutting	Rutting @ 20000 passes
Reference Mix (M1)	7	45	Maximum rutting	NA	19362	NA
	7	45	Maximum passes	NA	NA	11.77
Georgia Method Mix with 40% RAP	6	45	Maximum passes	NA	NA	4.15
Rejuvenator Mix with 40% RAP	7	45	Maximum passes	NA	NA	4.71



HWY 750

Mix Type	Air voids (%)	Test Temperature (°C)	Failure reason	SIP*	Number of passes at 12.5 mm rutting	Rutting @ 20000 passes
Reference Mix (L1)	7	40	Maximum rutting	10619	15390	NA
	7	40	Maximum passes	18390	NA	9.45
Georgia Method Mix with 40% RAP	6	40	Maximum passes	NA	NA	3.74



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MIX DESIGN

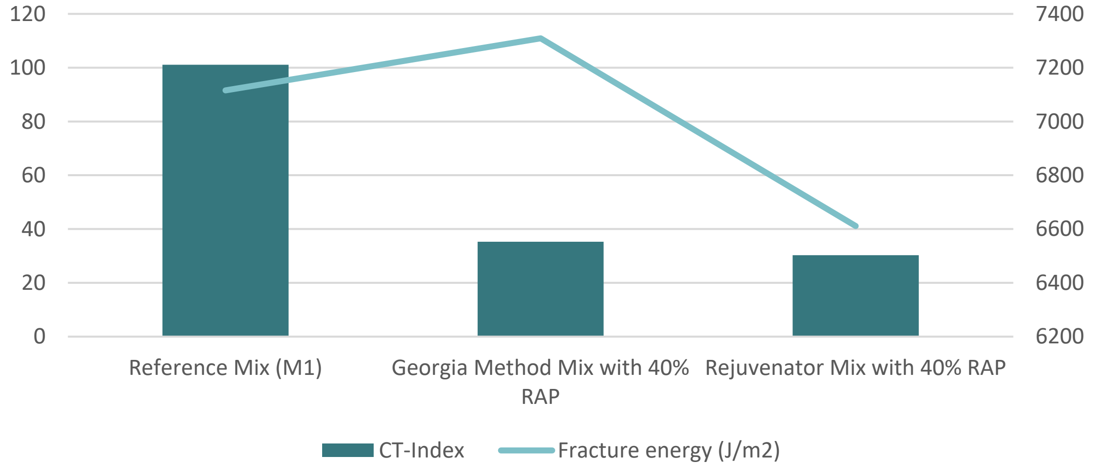
PERFORMANCE TEST RESULTS – INDIRECT TENSILE ASPHALT CRACKING TEST (IDEAL-CT, ASTM D8225-19)

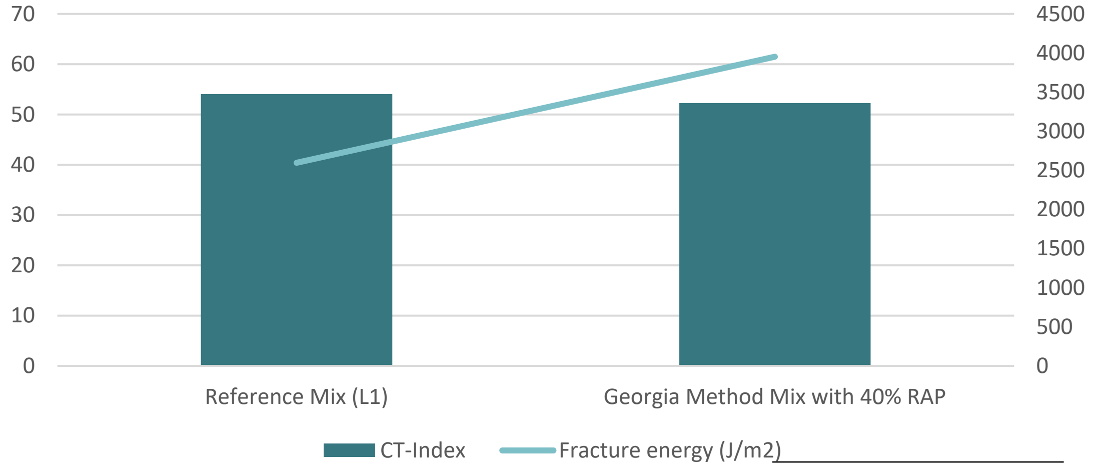
Test Temperature: 25 °c

HWY 55 Test Temperature: 25 °c **HWY 750**

Mix Type	Air voids (%)	ITS (kpa)	Fracture energy (J/m2)	CT-Index
Reference Mix (M1)	7	817.5	7115.77	101.1
Georgia Method Mix with 40% RAP	6	1230.5	7309.2	35.3
Rejuvenator Mix with 40% RAP	7	1050.3	6610.9	30.3

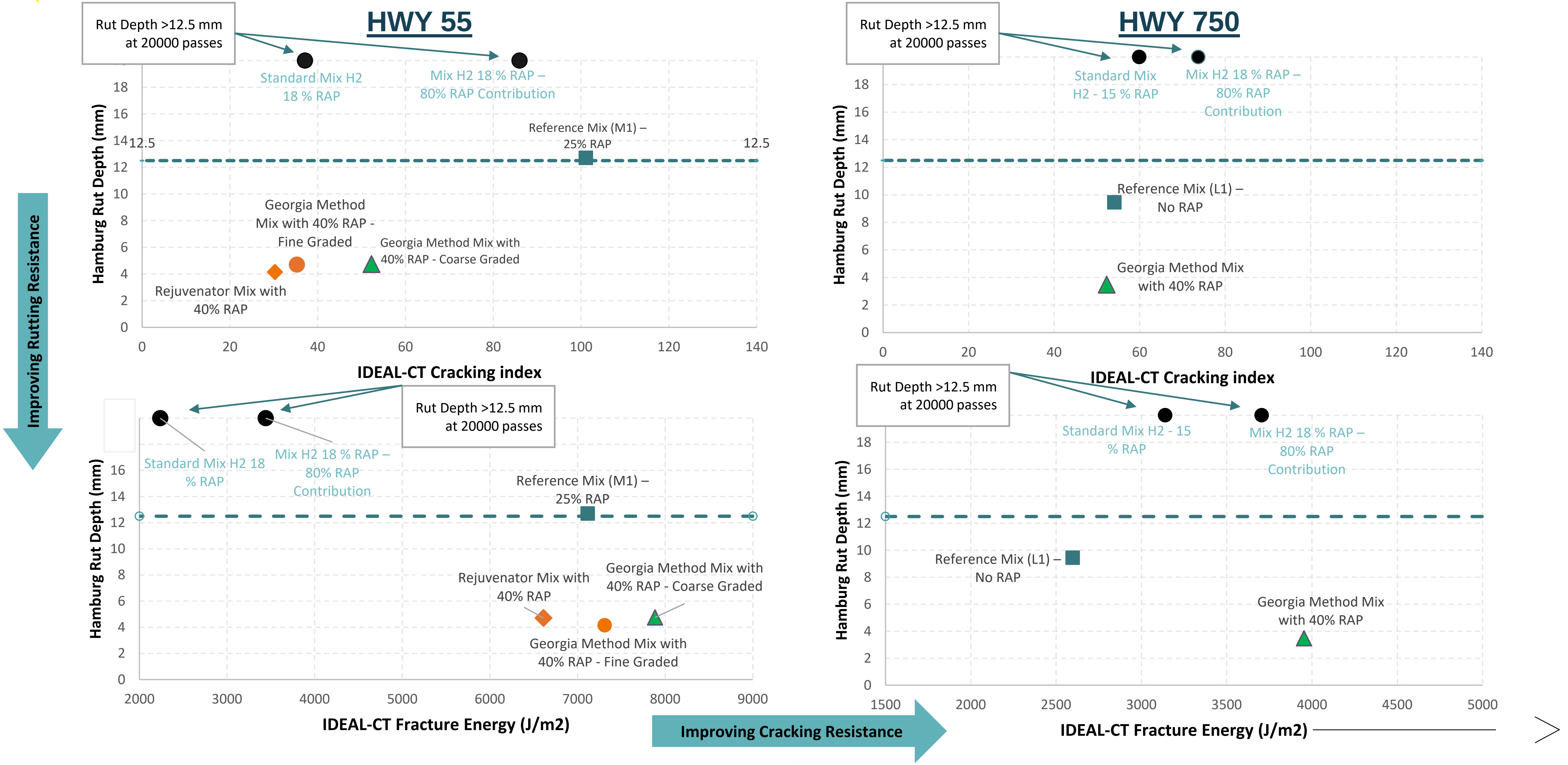
Mix Type	Air voids (%)	ITS (kpa)	Fracture energy (J/m2)	CT-Index
Reference Mix (L1)	7	377.16	2597.18	54.07
Georgia Method Mix with 40% RAP	6	551.34	3953.5	52.28





MIX DESIGN

PERFORMANCE TEST RESULTS – PERFORMANCE SPACE DIAGRAM (SPD)



QUALITY CONTROL RESULTS

HWY 750

PAVING
HWY 55 & 750

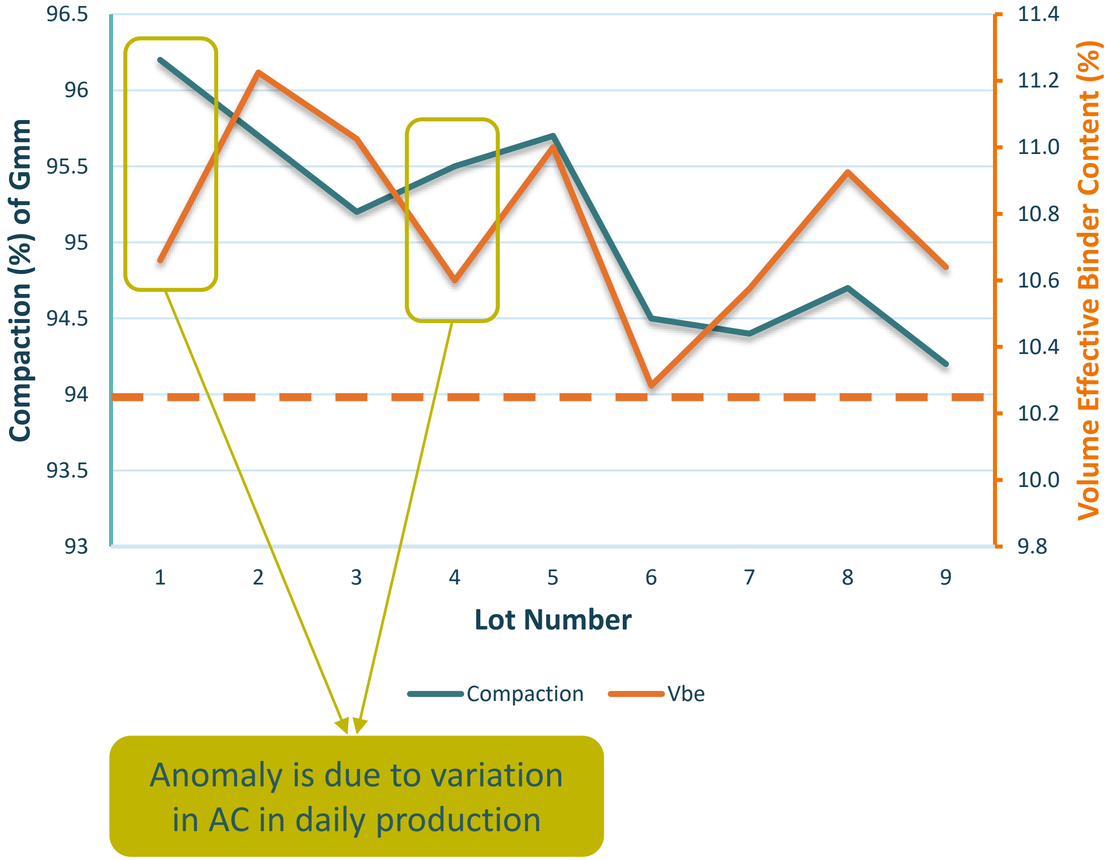
- **Paving and Rolling**
  - **Surface texture**
  - **Workability**

Georgia Method Mix with 40% RAP

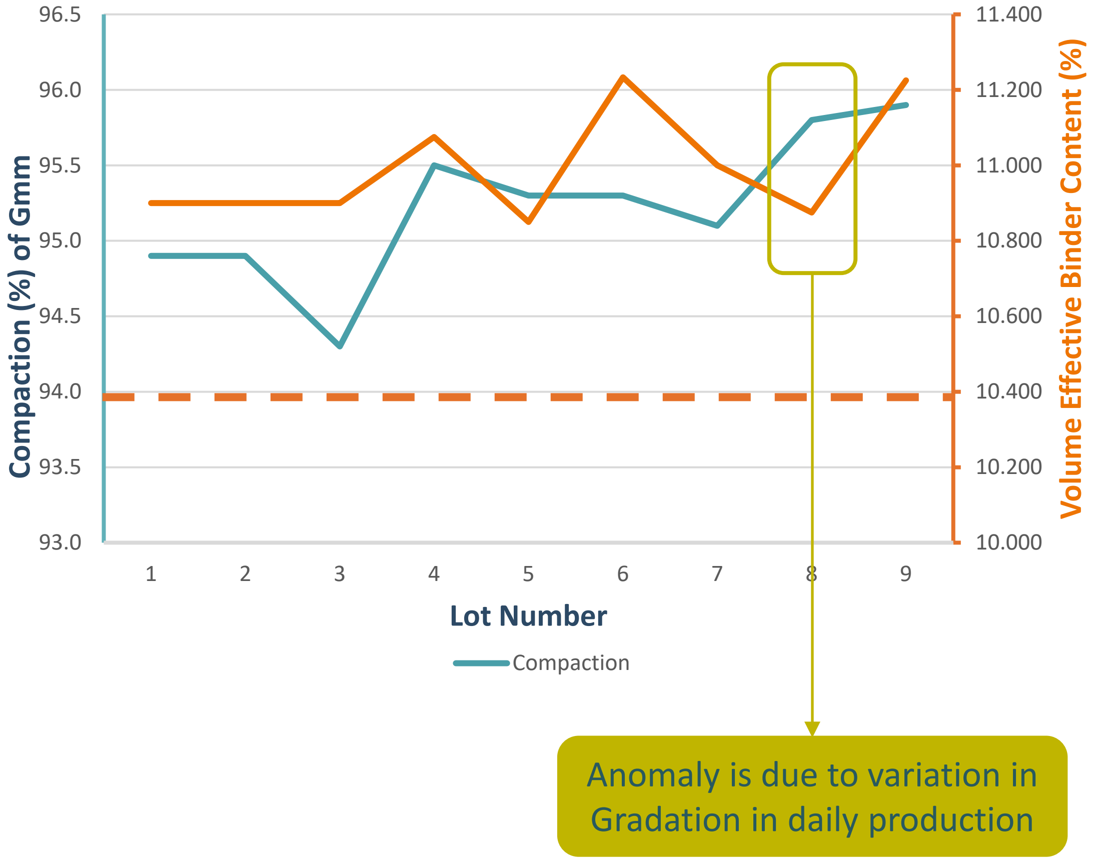
Rejuvenator Mix with 40% RAP

QUALITY CONTROL RESULTS
COMPACTION VS EFFECTIVE BINDER CONTENT

HWY 55



HWY 750



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CONCLUSIONS

PUSHING THE BOUNDARIES OF RAP CONTENT IN ASPHALT MIXES IN ALBERTA

Conclusion

- Two different strategies were implemented, using a rejuvenator and reducing the RAP binder contribution, to design the mixes with 40% RAP.

- The cost savings for the rejuvenator mix and the Georgia DOT method mix were 8.7% and 9.5% respectively in HWY 55.

- The initial cost savings from changing the rehabilitation method by using the Georgia DOT approach for mix design was 32.7%.

- The test results showed that the Georgia DOT approach provided richer binder mixes with improved rutting resistance and comparable or better cracking resistance (fracture energy)compared to the standard mixes.

- The surface texture and appearance of the mixes with 40% RAP were found to be similar to the standard mix.

PUSHING THE BOUNDARIES OF RAP CONTENT IN ASPHALT MIXES IN ALBERTA

Conclusion (cont.)

- The workability of the Georgia DOT approach mix was better than the standard mix, while the standard mix showed better workability than the rejuvenator mix.
- The production was fairly consistent with the mix design properties.
- The minimum requirement for compaction of Georgia DOT mixes was improved from 93 to 94 percent in the design change proposals and was achieved in both projects in all lots during paving.
- Further field performance monitoring is required to make any decisions during the specifications review.

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Alberta

COLAS
WE OPEN THE WAY