PUMA Bitumen

Trafigura

CarbonBind®

Conversations

EPISODE 2

A Technical Deep Dive into Biogenic Bitumen

with

Erik Denneman & Mark Cannatelli

Innovation. Sustainability. Performance.

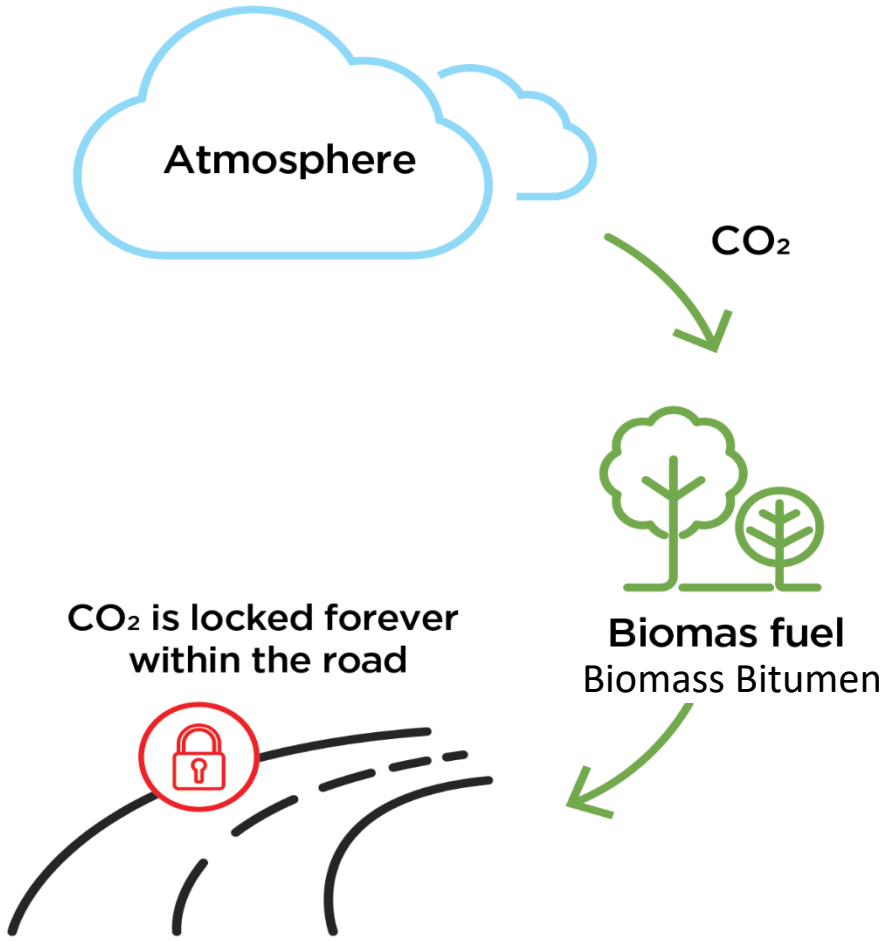

PUMA
ENERGY
Trafigura
CarbonBind®
Conversations
Meeting Australia's sustainability targets one road at a time
Going further
for better performing roads

Outline

- Puma CarbonBind technology
- Independent Technical Verification
- Humps in the road to net-zero

Recap CarbonBind® Conversation 1

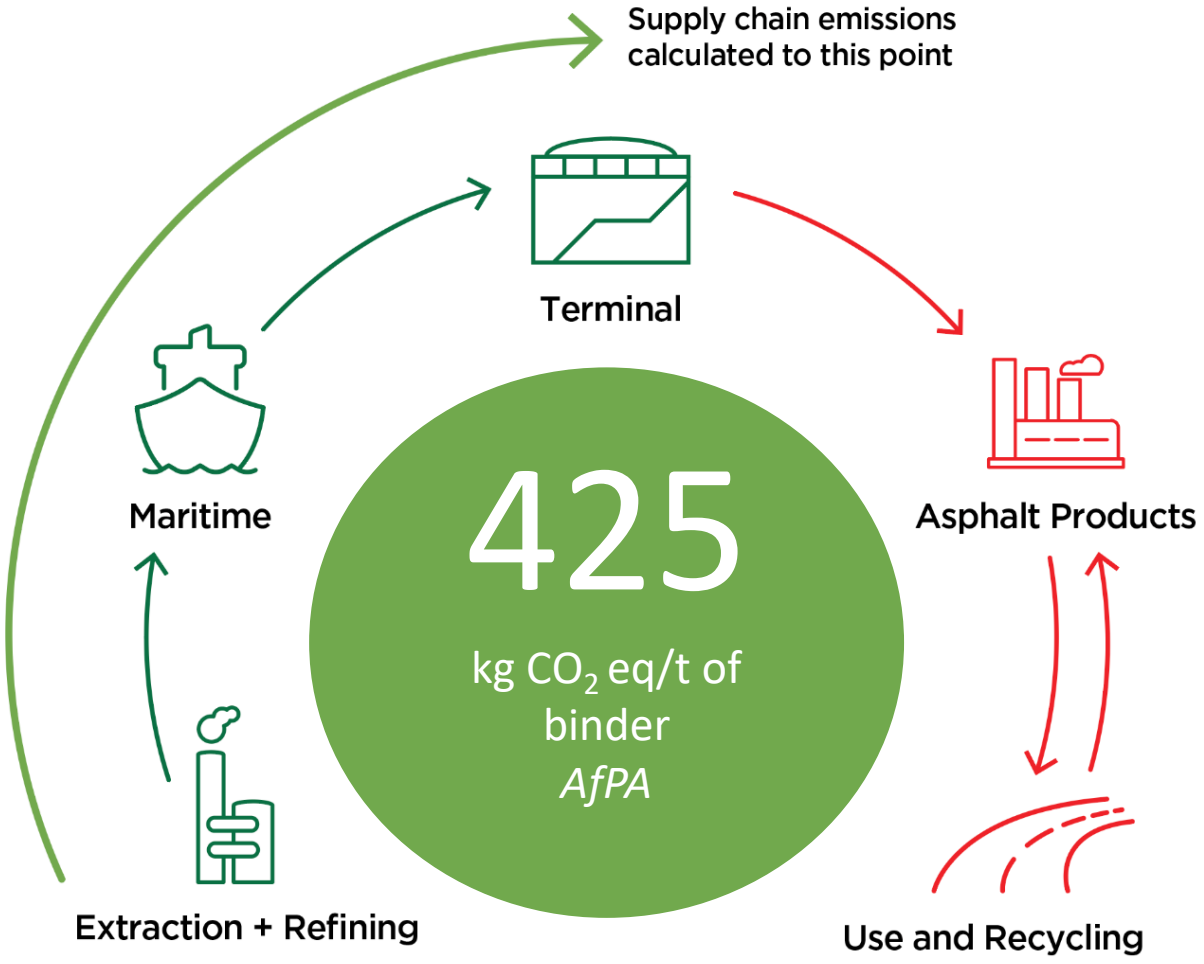
CarbonBind® Paving the Way

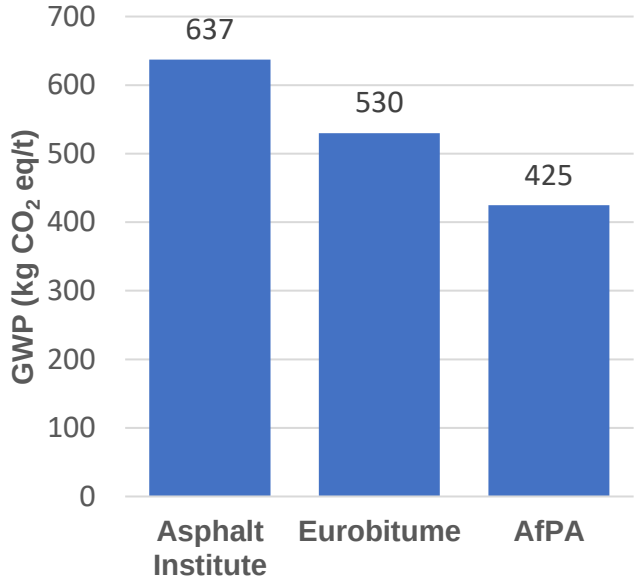


>3000

tonnes $CO_{2\text{-eq}}$ saved so far

Bitumen GWP values



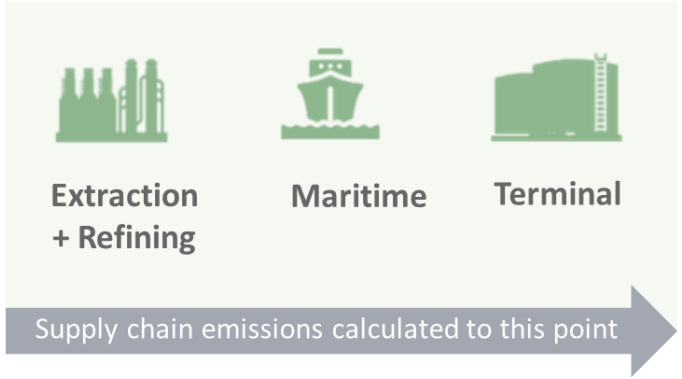


Sources:
Life Cycle Assessment of Asphalt Binder – Asphalt Institute, 2019
The Eurobitume Life Cycle Assessment 4.0 for Bitumen – Eurobitume, 2025
AfPA LCA Calculator for Asphalt

Approx. 75% attributed to extraction and refining of crude oil

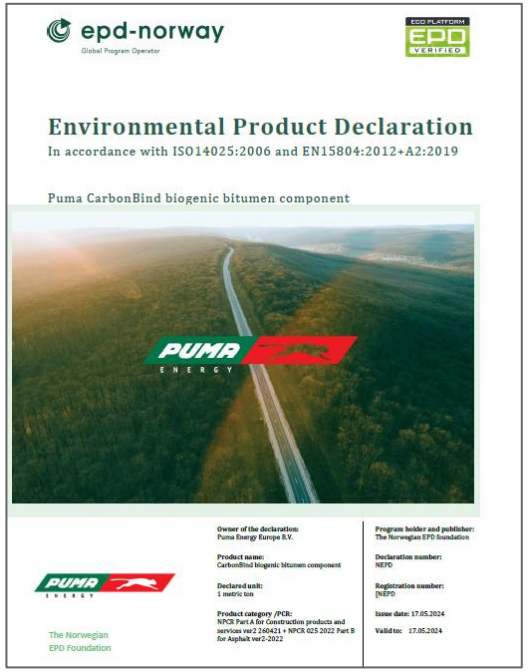
Emissions reductions with CarbonBind®

Bitumen



425 kg CO_2 eq/t of bitumen

Plant-derived component



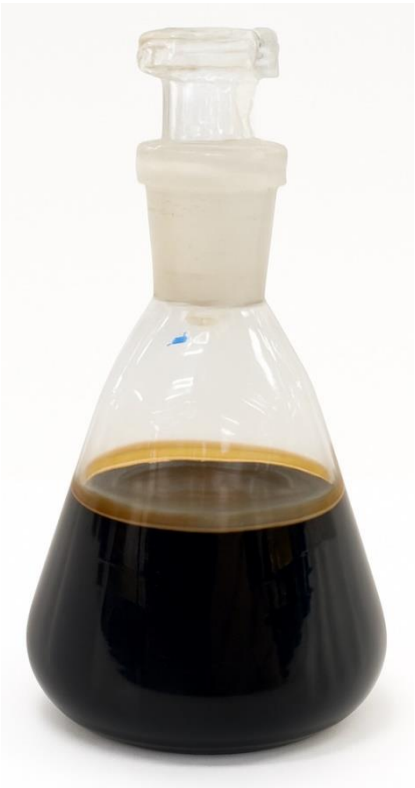
Indicator	Unit	A1-A3	A4
GWP - total	kg CO2 eq	-2.93E+03	9.96E+01

-2830.4 kg CO_2 eq/t of plant-derived component

e.g. 1% substitution results in an emissions reduction of 7.7%

Modified biomaterial

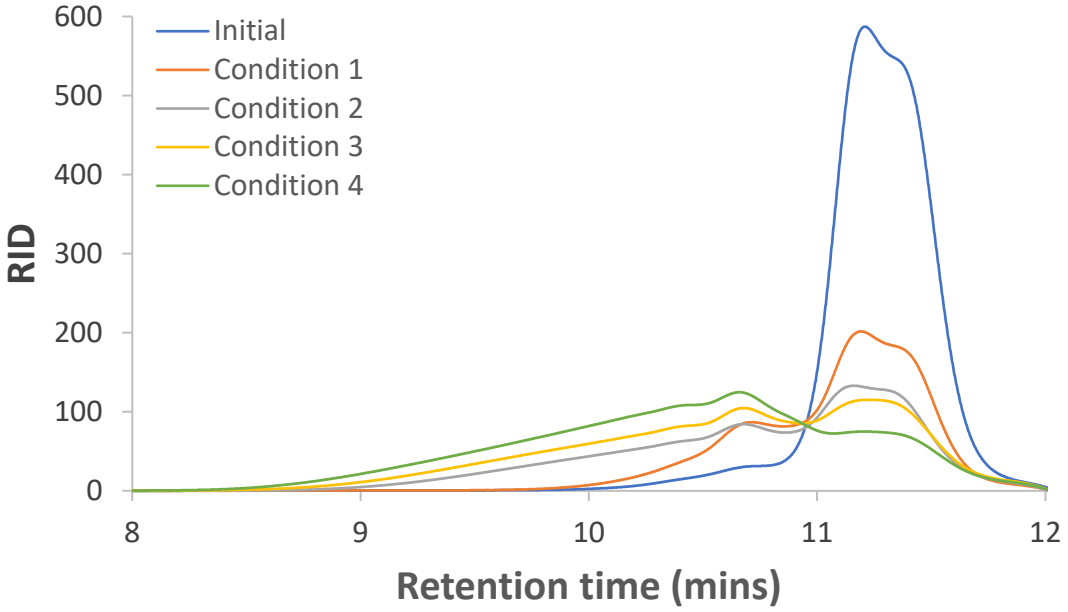
Biomaterial



Modified biomaterial

Patent pending technology

Molar mass distribution and viscosity profile

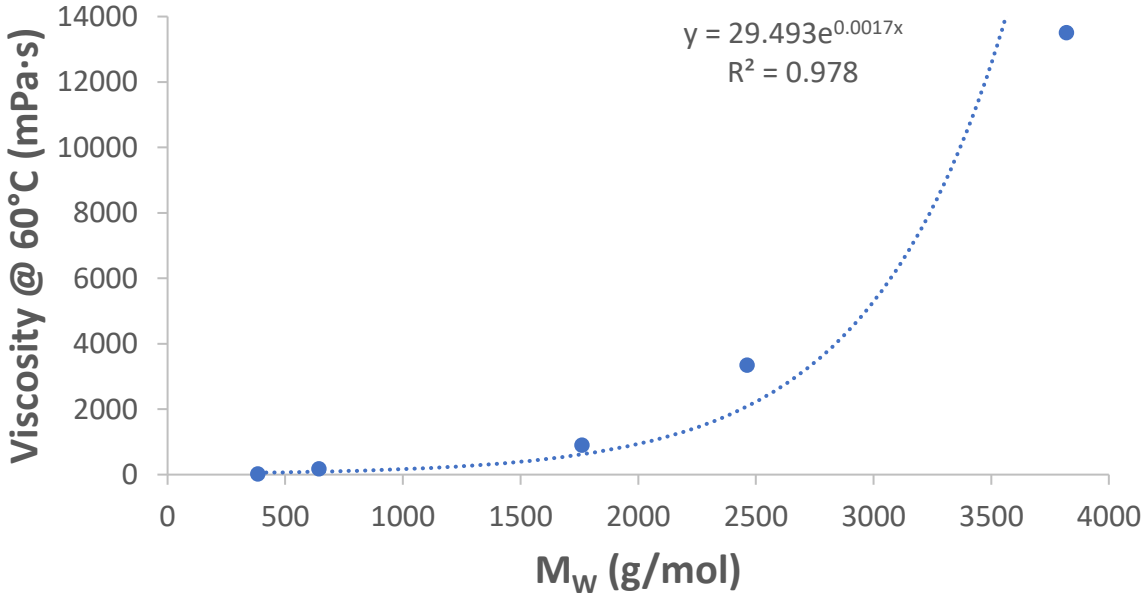


	Viscosity @ 60°C (mPa·s)	M_W (g/mol)
Initial	21	384
Condition 1	171	643
Condition 2	896	1761
Condition 3	3340	2463
Condition 4	13500	3820

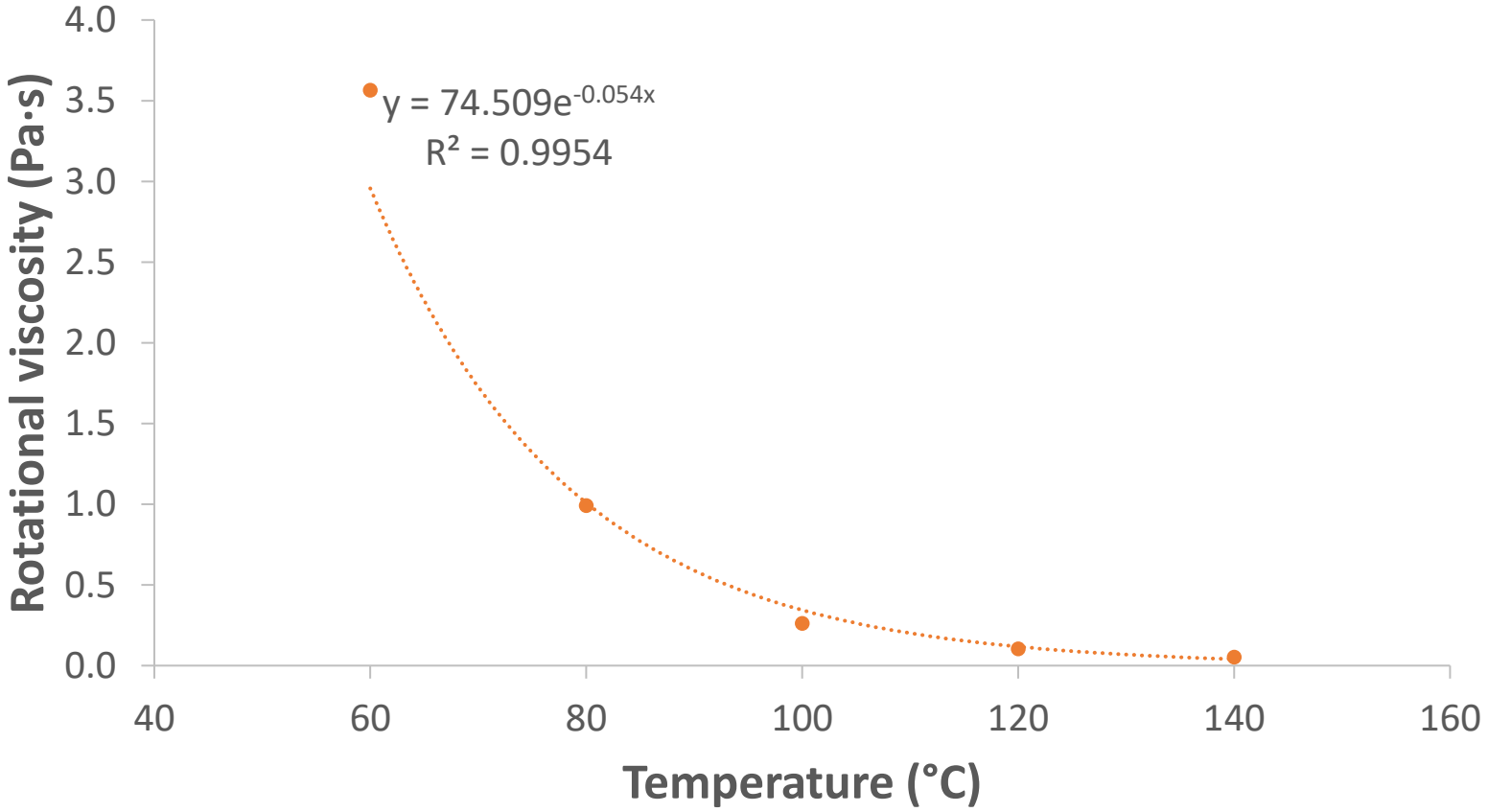
Polymerisation/crosslinking increases viscosity

→ increased incorporation

→ increased emissions reductions



Viscosity vs temperature profile of modified biomaterial



Can be pumped at approx. 90°C and above

CarbonBind® C170

Parameter	Condition	Spec. Limit	Result
GWP (kg CO_2 eq/t)			218.8
Original binder			
Viscosity (Pa·s)	60°C	140 - 200	153
Viscosity (Pa·s)	135°C	0.25 - 0.45	0.35
Penetration (dmm)	25°C	≥ 62	79
Matter insoluble (%)	Toluene	≤ 1	0.5
Flash point (°C)		≥ 250	> 300
Density (kg/m³)	15°C		1036
Post-RTFO (163°C)			
Mass change (%)			0.0
Viscosity (Pa·s)	60°C		364
Viscosity % of original	60°C	≤ 300	238

Meets AS 2008-2013 spec for C170

Approx. 49% reduction in emissions compared to standard C170

CarbonBind® 50/70

Parameter	Condition	Spec. Limit	Result
GWP (kg CO_2 eq/t)			316.4
Original binder			
Penetration (dmm)	25°C	50 - 70	65
Softening point (°C)		46 - 54	47.2
Penetration index		-1.5 - 0.7	-1.3
Solubility (%)	TCE	≥ 99	99.5
Flash point (°C)		≥ 230	284
Post-RTFO (163°C)			
Mass change (%)		≤ 0.5	-0.148
Retained penetration (%)	25°C	≥ 50	55
Increase softening point (°C)		≤ 9	6.6

Meets EN 12591 spec for 50/70

Approx. 40% reduction in emissions compared to standard 50/70

CarbonBind® PG 64-22

Parameter	Condition	Spec. Limit	Result
GWP (kg CO_2 eq/t)			415.9
Original binder			
Solubility (%)	Toluene	≥ 99	99.85
Flash point (°C)		≥ 230	308
Rotational viscosity (Pa·s)	135°C	≤ 3	0.41
G*/sinδ (kPa)	64°C, 10 rad/s	≥ 1.00	1.12
Post-RTFO (163°C)			
Mass change (%)		≤ 1	-0.133
G*/sinδ (kPa)	64°C, 10 rad/s	≥ 2.20	3.06
Post-PAV (100°C, 300 psi, 20 h)			
G*·sinδ (kPa)	25°C, 10 rad/s	≤ 6000	4005
Creep stiffness (MPa)	60s, -12°C	≤ 300	169
m-value	60s, -12°C	≥ 0.300	0.309

Meets AASHTO M 320-22 spec for PG 64-22

Approx. 35% reduction in emissions compared to standard PG 64-22

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Comparative study – AASHTO M 320-22

Original binder

$G^*/\sin\delta_{64°C,\ 10\ rad/s}$ = 1.05 kPa

240°C
150 kPa air
1 h

Oxidized binder

$G^*/\sin\delta_{64°C,\ 10\ rad/s}$ = 2.03 kPa

Modified biomaterial

Bio-modified binder

$G^*/\sin\delta_{64°C,\ 10\ rad/s}$ = 1.05 kPa

Parameter	Condition	Original binder	Bio-modified binder
GWP (kg CO_2 eq/t)		637	415.9
Original binder			
Solubility (%)	Toluene	99.9	99.1
Flash point (°C)		300	290
Rotational viscosity (Pa·s)	135°C	0.345	0.353
G*/sinδ (kPa)	64°C, 10 rad/s	1.05	1.05
Post-RTFO (163°C)			
Mass change (%)		-0.51	-0.05
G*/sinδ (kPa)	64°C, 10 rad/s	2.74	2.76
$J_{nr\ 3.2\ kPa}$ (kPa^{-1})	64°C	3.9	3.57
$J_{nr\ Diff}$ (%)	64°C	5.07	9.96
$Recovery_{3.2\ kPa}$ (%)	64°C	0	0
Post-PAV (100°C, 300 psi, 20 h)			
G*·sinδ (kPa)	25°C, 10 rad/s	4532	4496
Creep stiffness (MPa)	60s, -12°C	215	215
m-value	60s, -12°C	0.306	0.293
Creep stiffness (MPa)	60s, -18°C	437	405
m-value	60s, -18°C	0.254	0.254

Bio-modified binder 35% reduction in emissions compared to original binder

Comparative study – AS 2008-2013

Original binder
Viscosity at 60°C = 175 Pa·s

240°C
150 kPa air
1 h

Oxidized binder
Viscosity at 60°C = 333 Pa·s

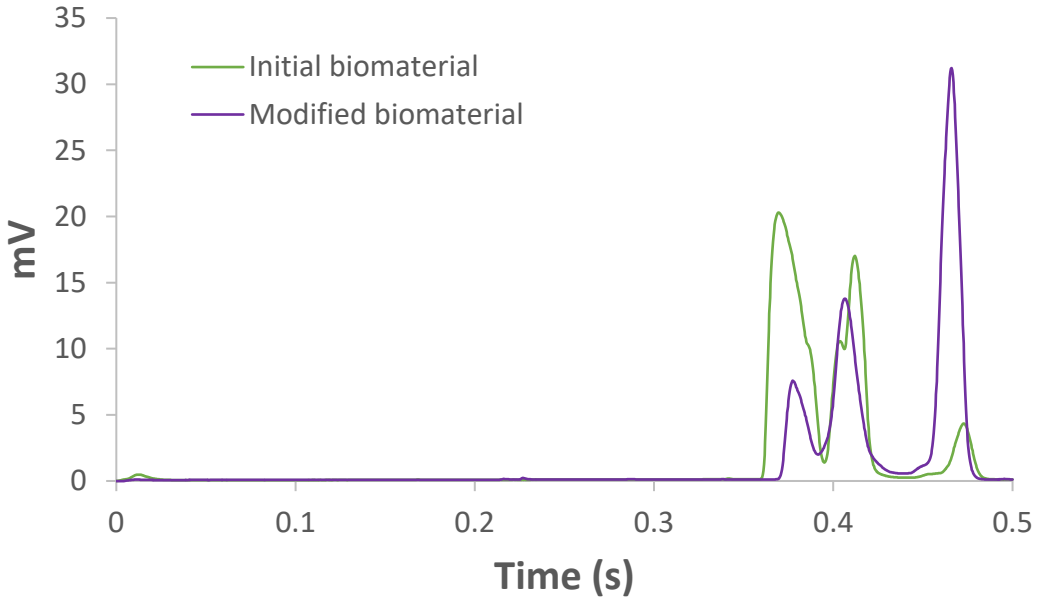
Modified
biomaterial

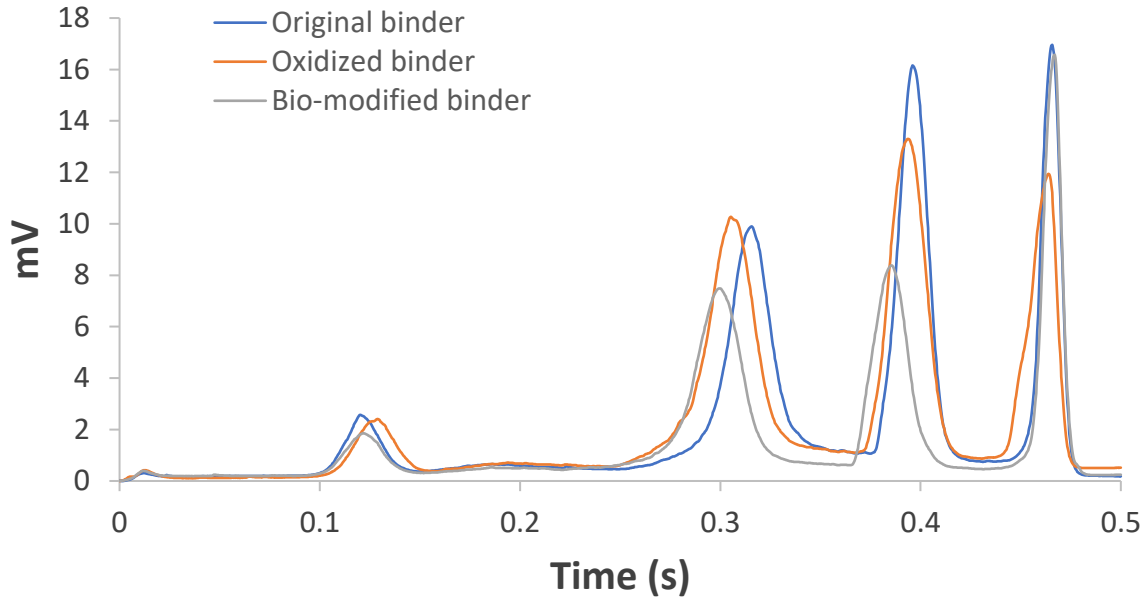
Bio-modified binder
Viscosity at 60°C = 205 Pa·s

Parameter	Condition	Original binder	Bio-modified binder
GWP (kg CO_2 eq/t)		425	248.2
Original binder			
Viscosity (Pa·s)	60°C	175	205
Viscosity (Pa·s)	135°C	0.373	0.374
Penetration (dmm)	25°C	63	71
Matter insoluble (%)	Toluene	0.1	0.9
Flash point (°C)		300	290
Post-RTFO (163°C)			
Mass change (%)		-0.51	-0.05
Viscosity (Pa·s)	60°C	462	485
Viscosity % of original	60°C	264	237

Bio-modified binder 42% reduction in emissions compared to original binder

SARA analysis





	Saturates (%)	Aromatics (%)	Resins (%)	Asphaltenes (%)
Initial biomaterial	0	0	92.7	7.3
Modified biomaterial	0	0	46.5	53.5
Original binder	8.7	31.2	35.0	25.0
Oxidized binder	9.3	34.3	33.9	22.4
Bio-modified binder	7.0	37.7	26.7	28.6

- Modification process converts resins to asphaltenes
- Modified biomaterial increases aromatics and asphaltenes content of binder → further reaction of modified biomaterial with binder??

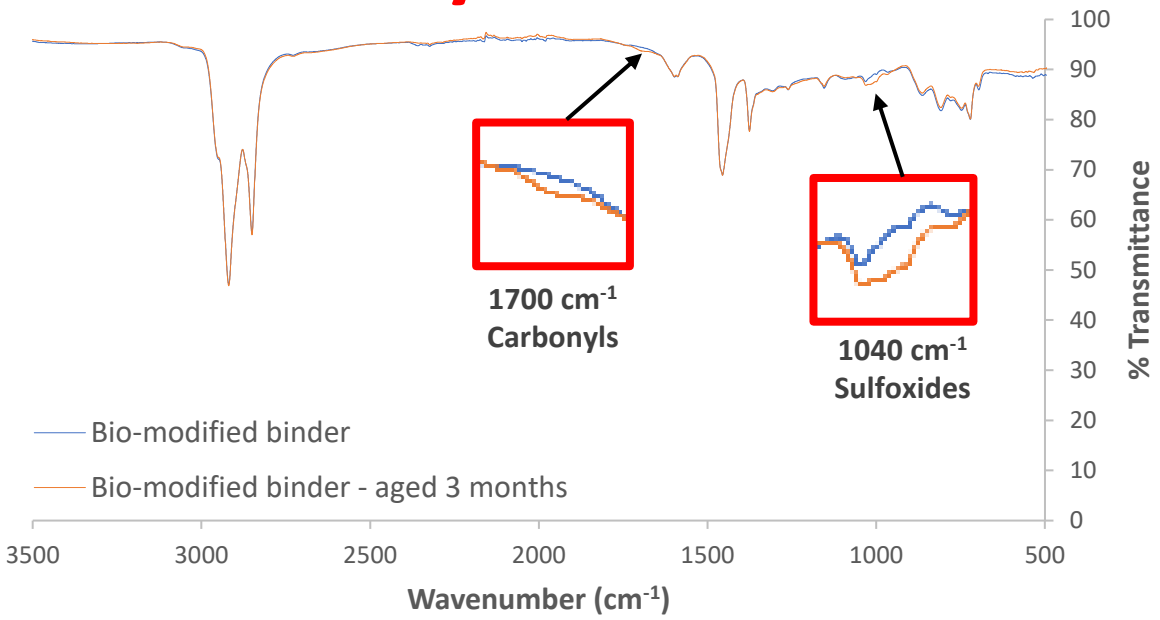
Environmental aging

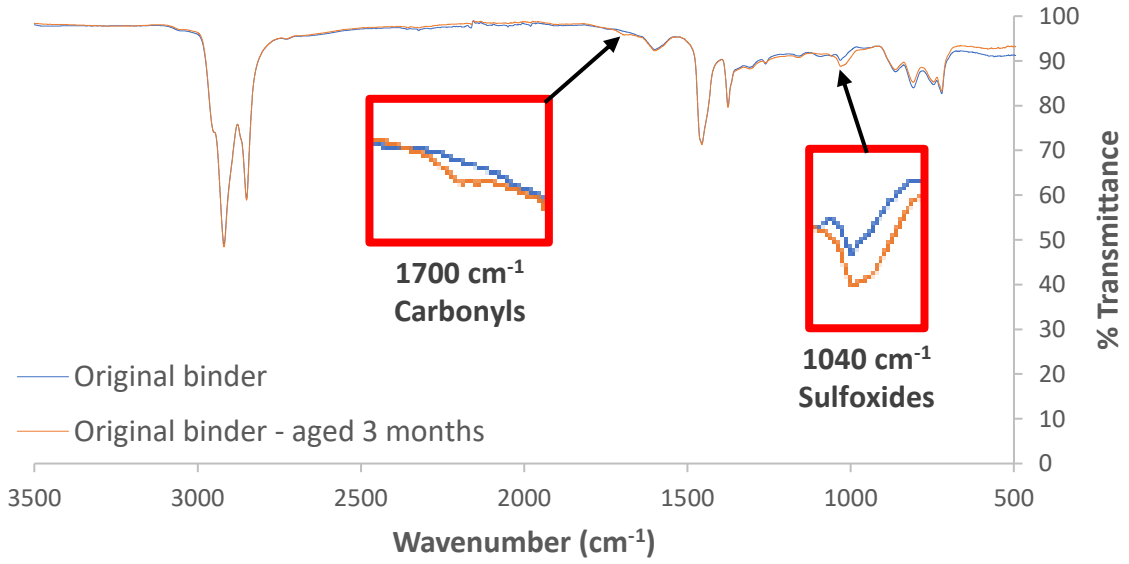
1mm film of binder aged on trays at Kwinana terminal, Western Australia

	G*·sinδ $_{25°C, 10 rad/s}$ (kPa)	
	PAV (100°C, 300 psi, 20 h)	3 months environment
Original binder	4532	3110
Bio-modified binder	4496	2629

Bio-modified binder has lower fatigue cracking parameter after 3 months aging

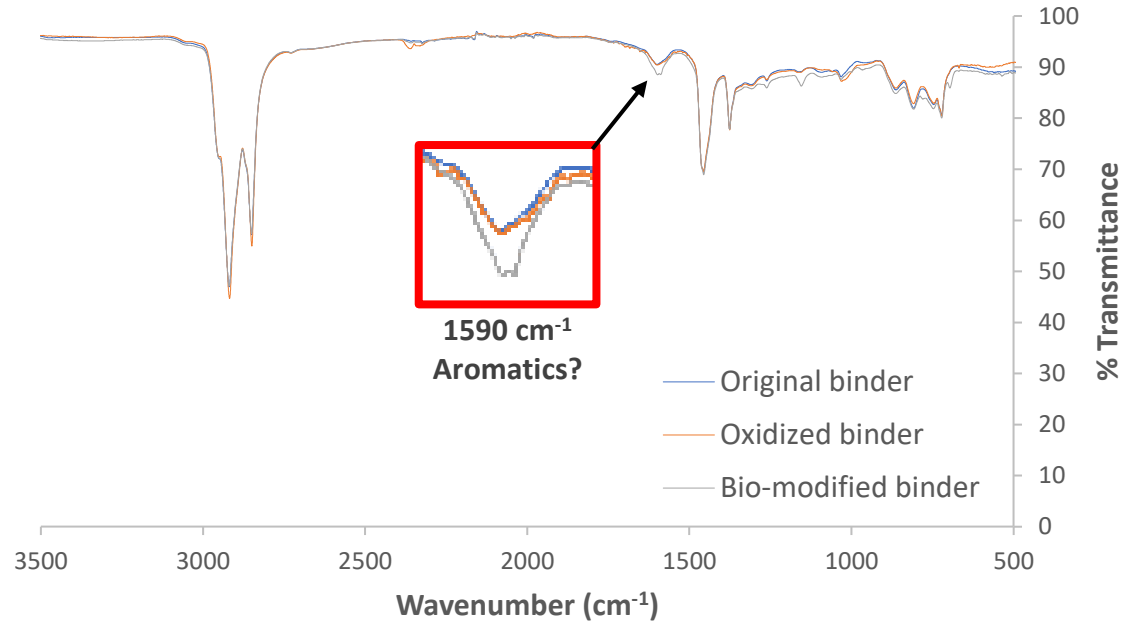
FTIR analysis





Qualitative results indicate:

- Increased aromatics for bio-modified binder
- Increased carbonyls and sulfoxides for both original and bio-modified binder after environmental aging → oxidation



Independent evaluation

Western Research Institute

- Asphalt Industry Research Consortium (AIRC)
- AIRC-I3, Focus Area 3: alternative binders

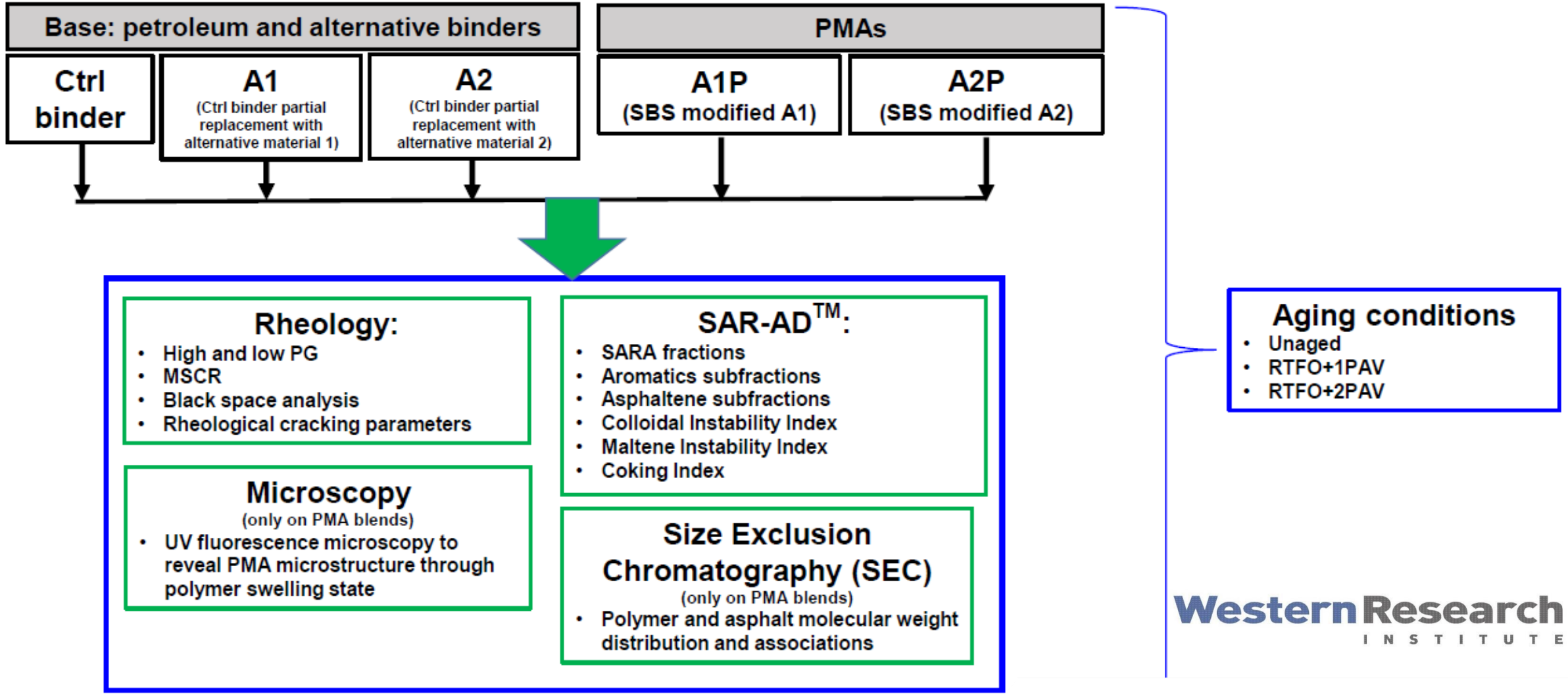
Independent evaluation

AIRC-I3, Focus Area 3: alternative binders

- Standard PG64-22 base bitumen shared by WRI
- Puma submission CarbonBind blends and process oil control
- Assess difference in chemical composition, compatibility and aging performance
- Not formulated to meet any standard specification, or optimised PMB formulation

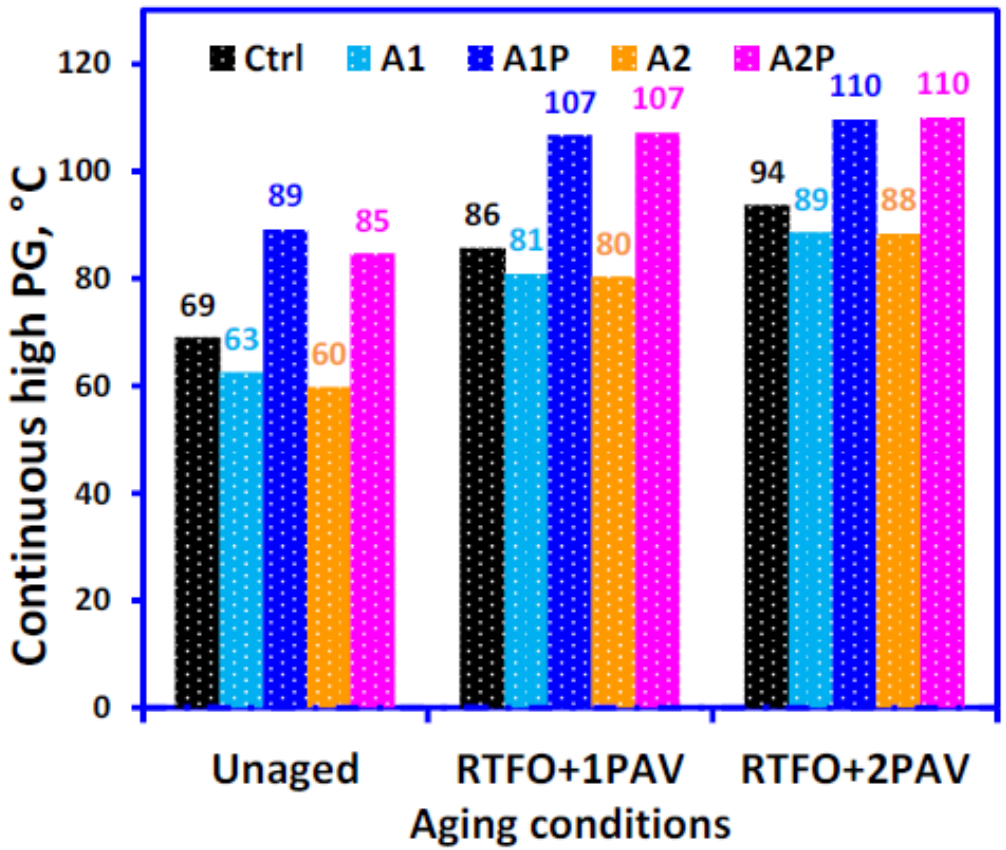
Independent evaluation

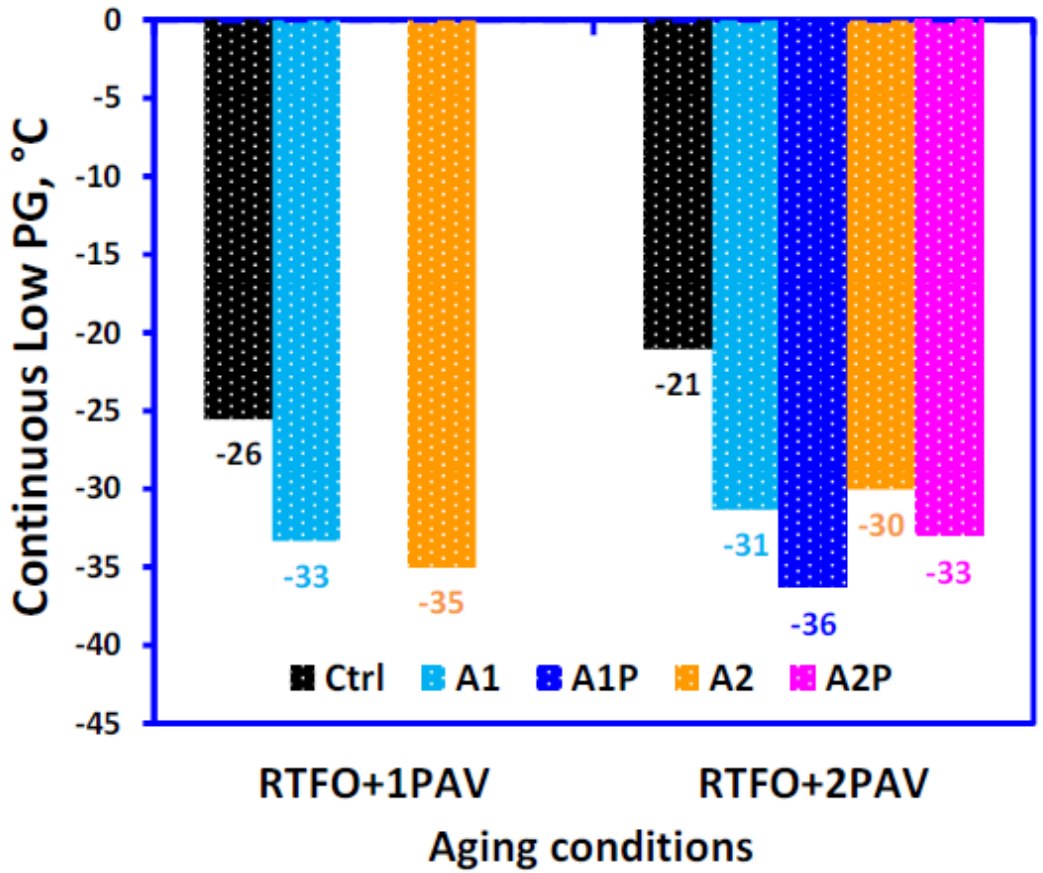
AIRC-I3, Focus Area 3: alternative binders



Independent evaluation

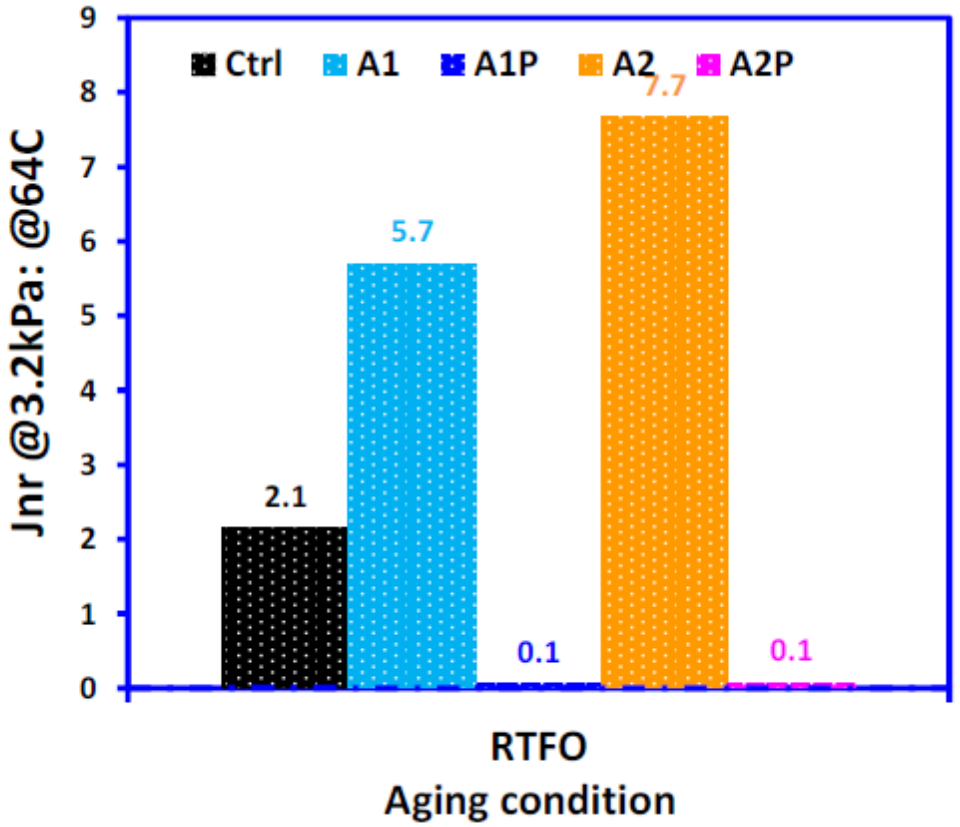
Performance Grading

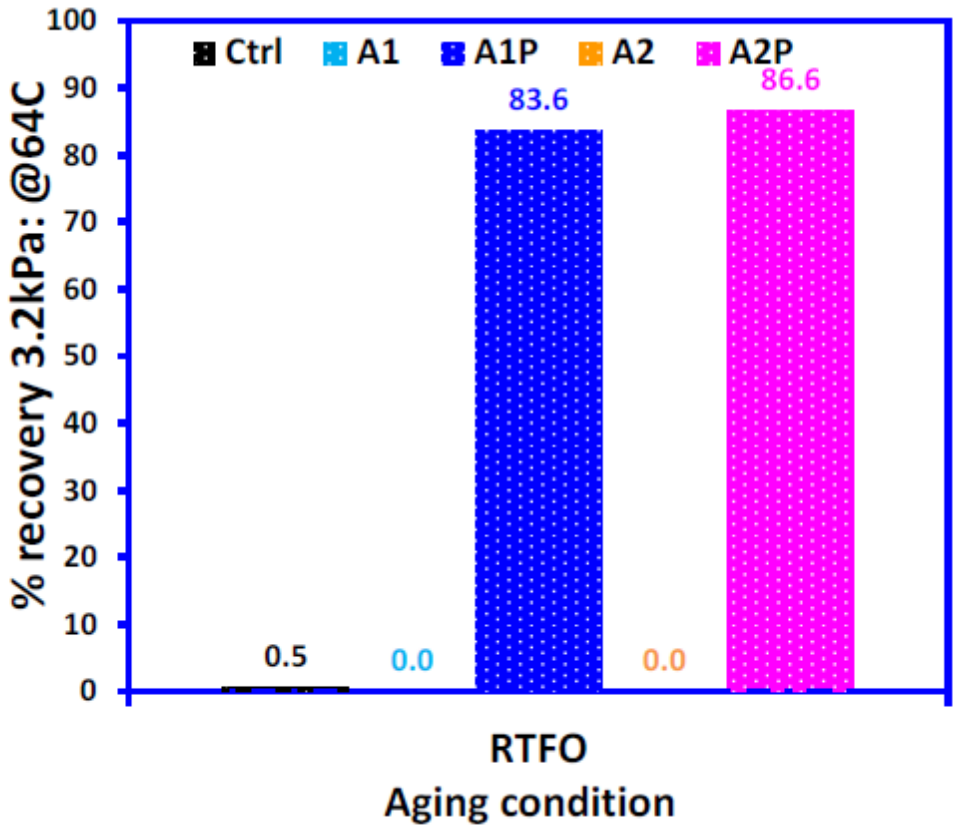




Independent evaluation

MSCR





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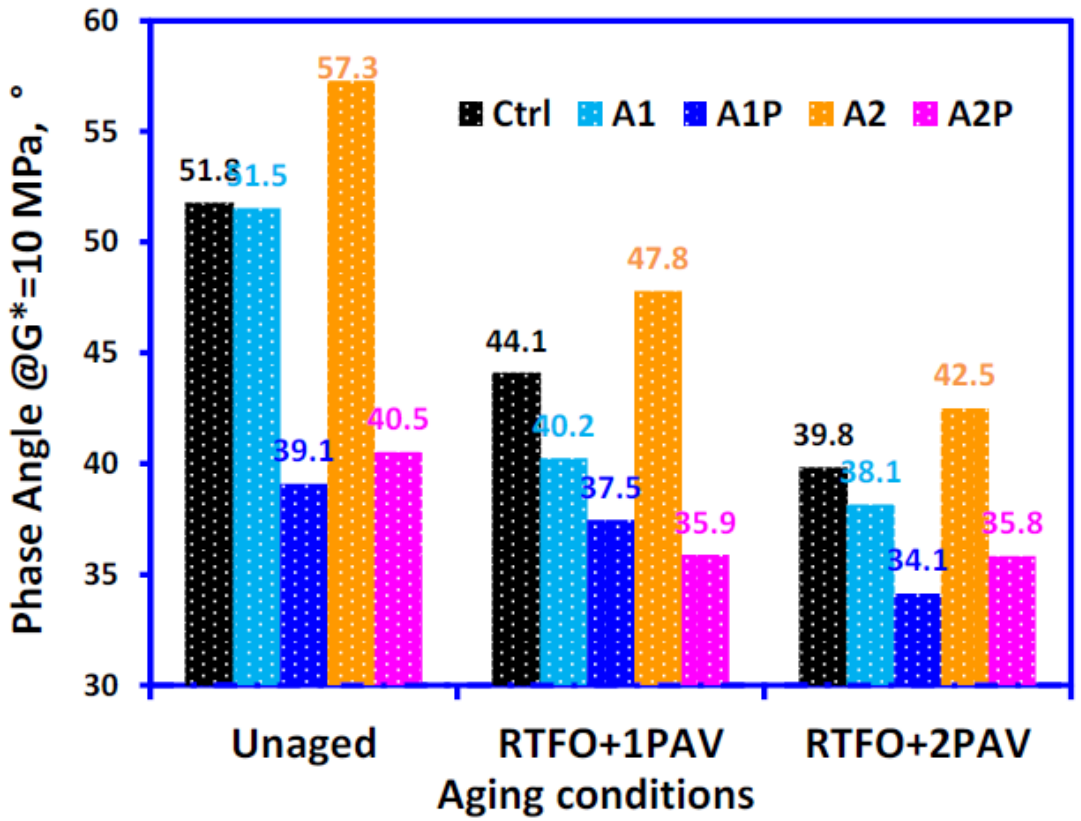
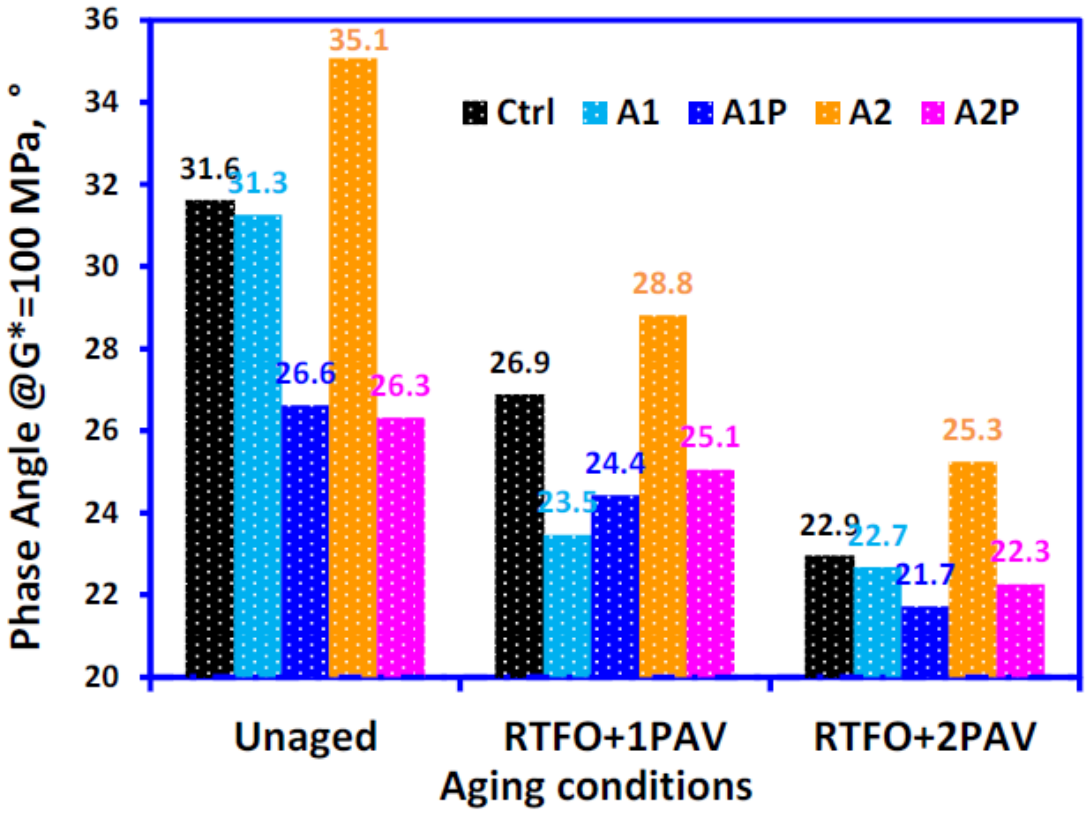
Trafigura

Independent evaluation

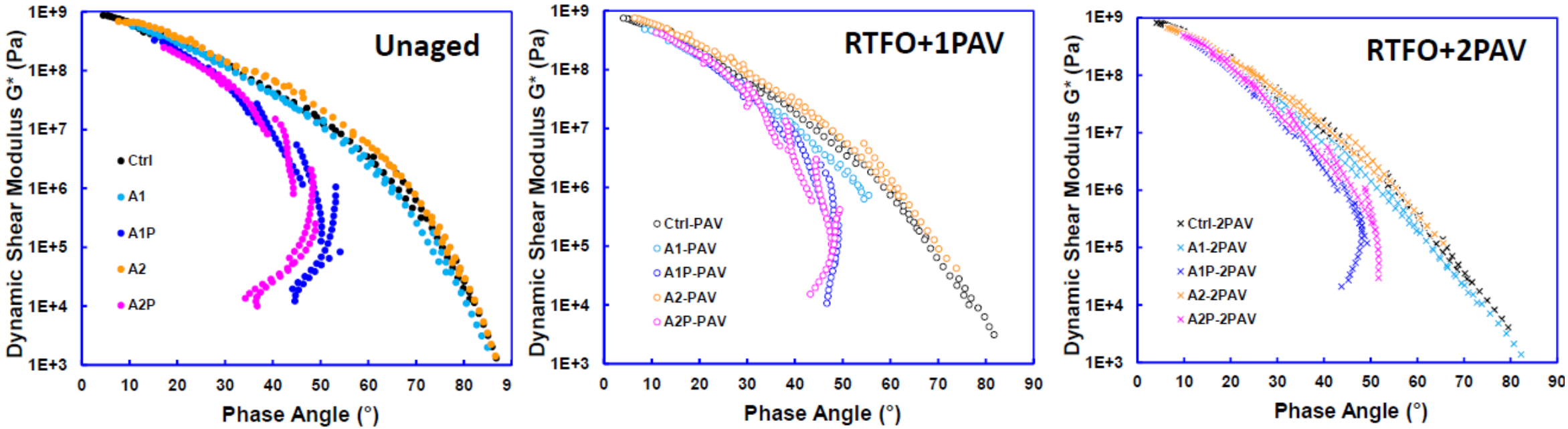
Phase Angle





Independent evaluation

Blackspace



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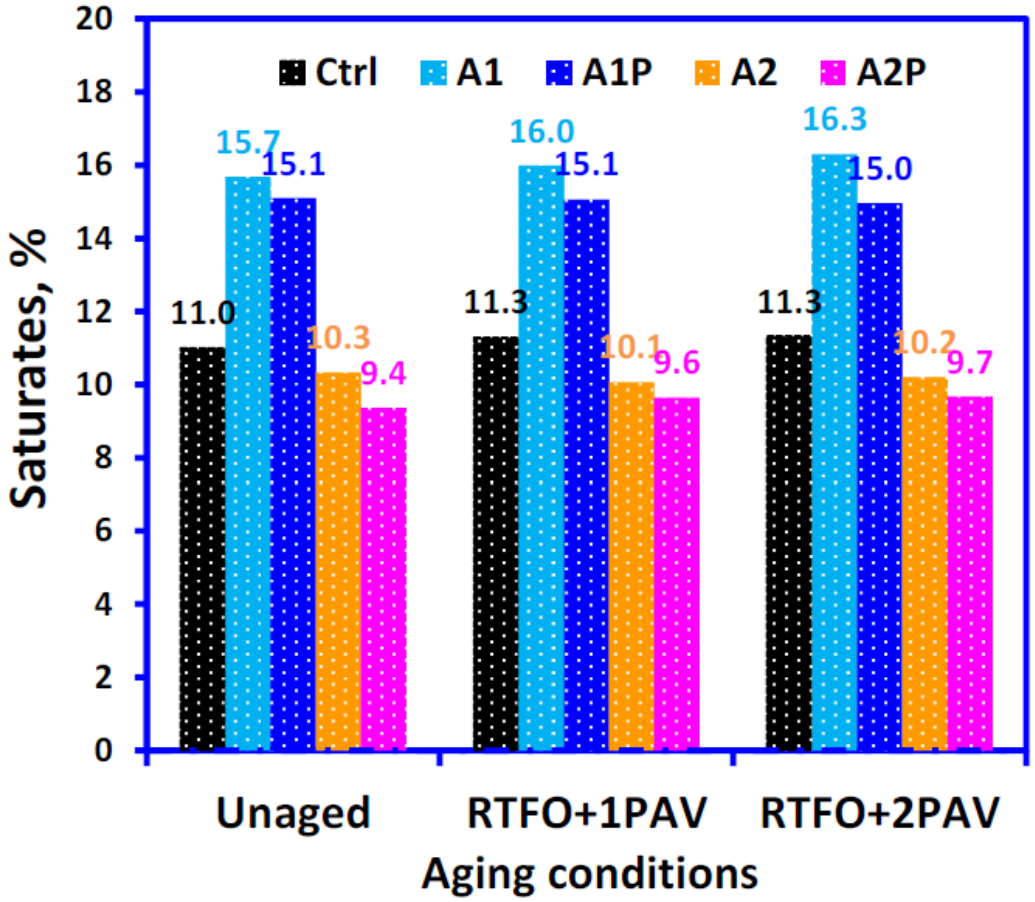
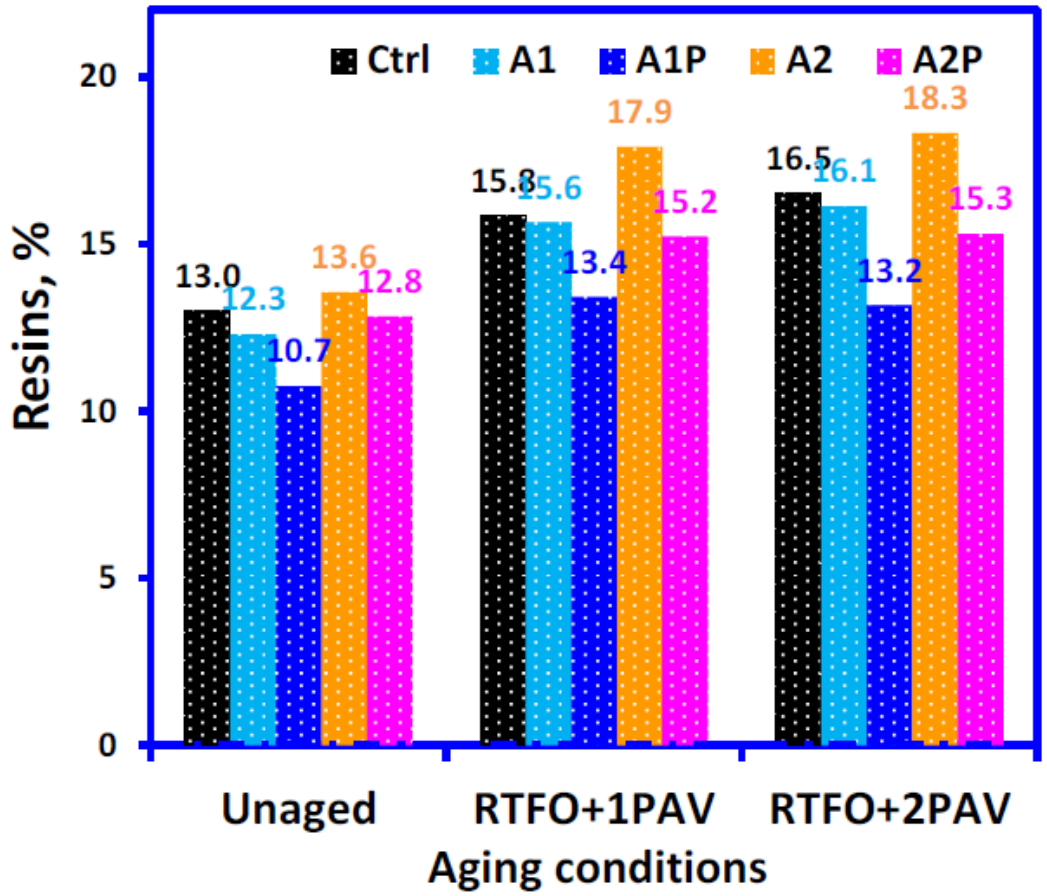
Trafigura

Independent evaluation

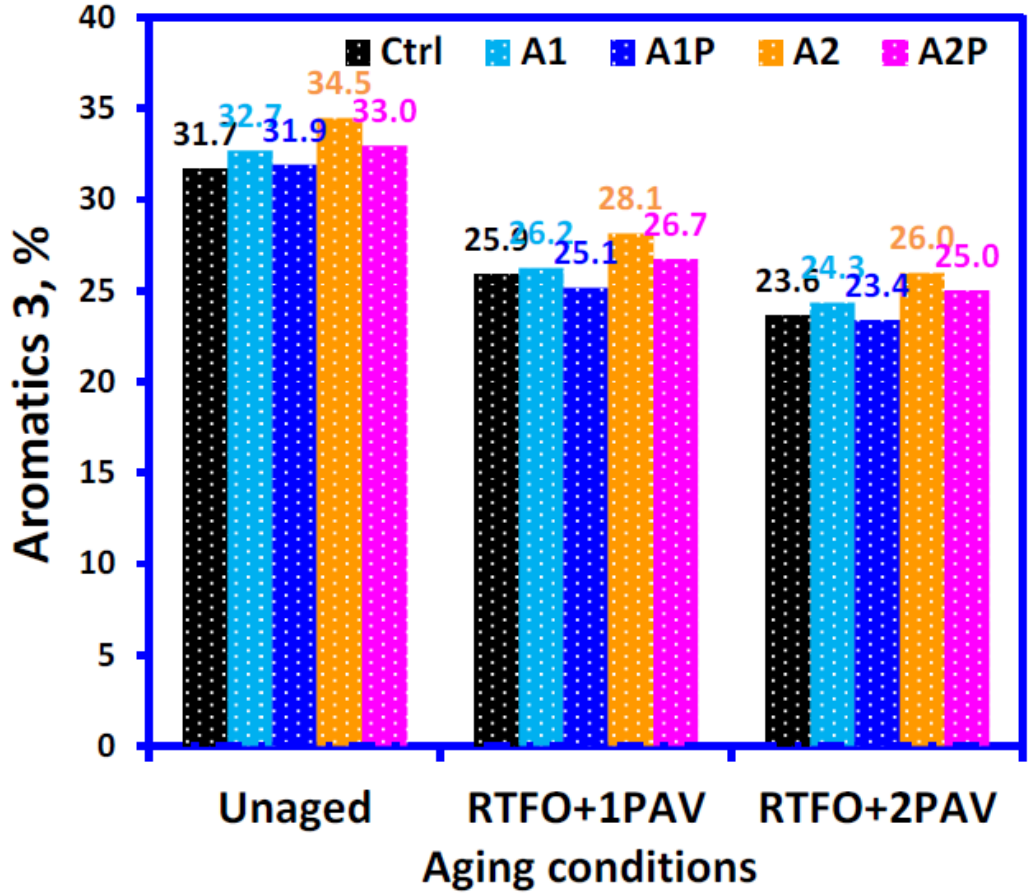
SARA-AD

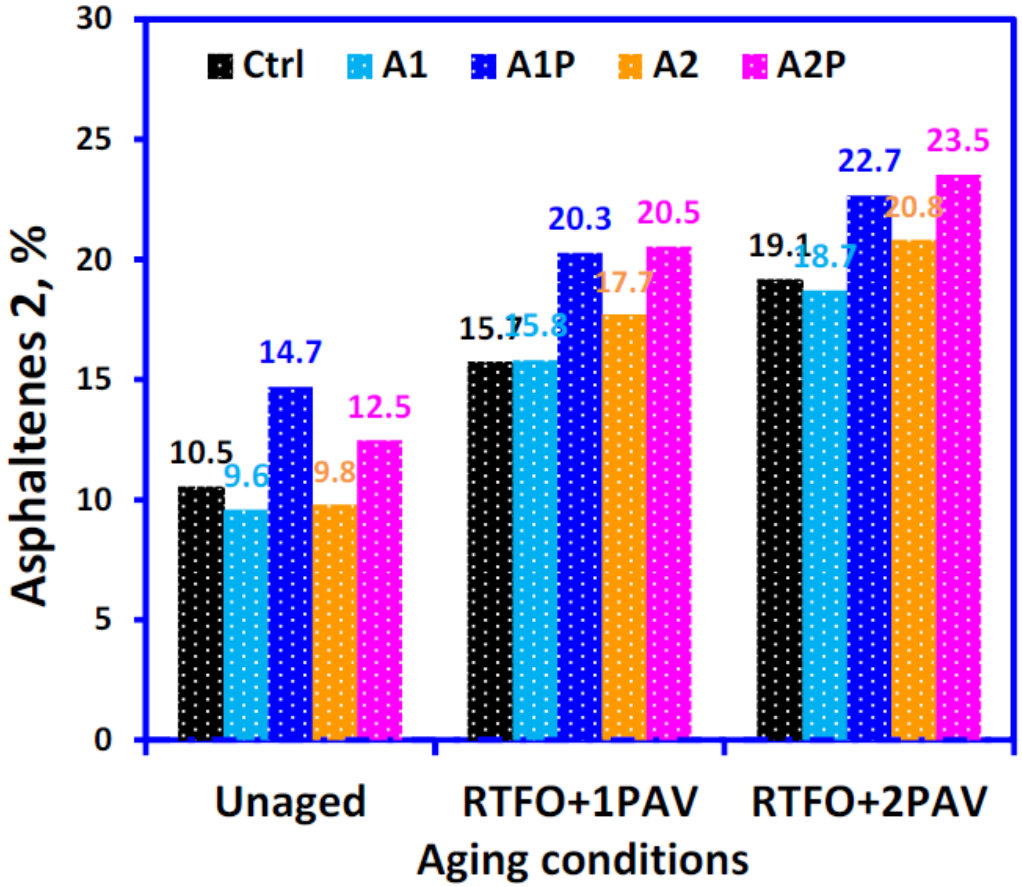




Independent evaluation

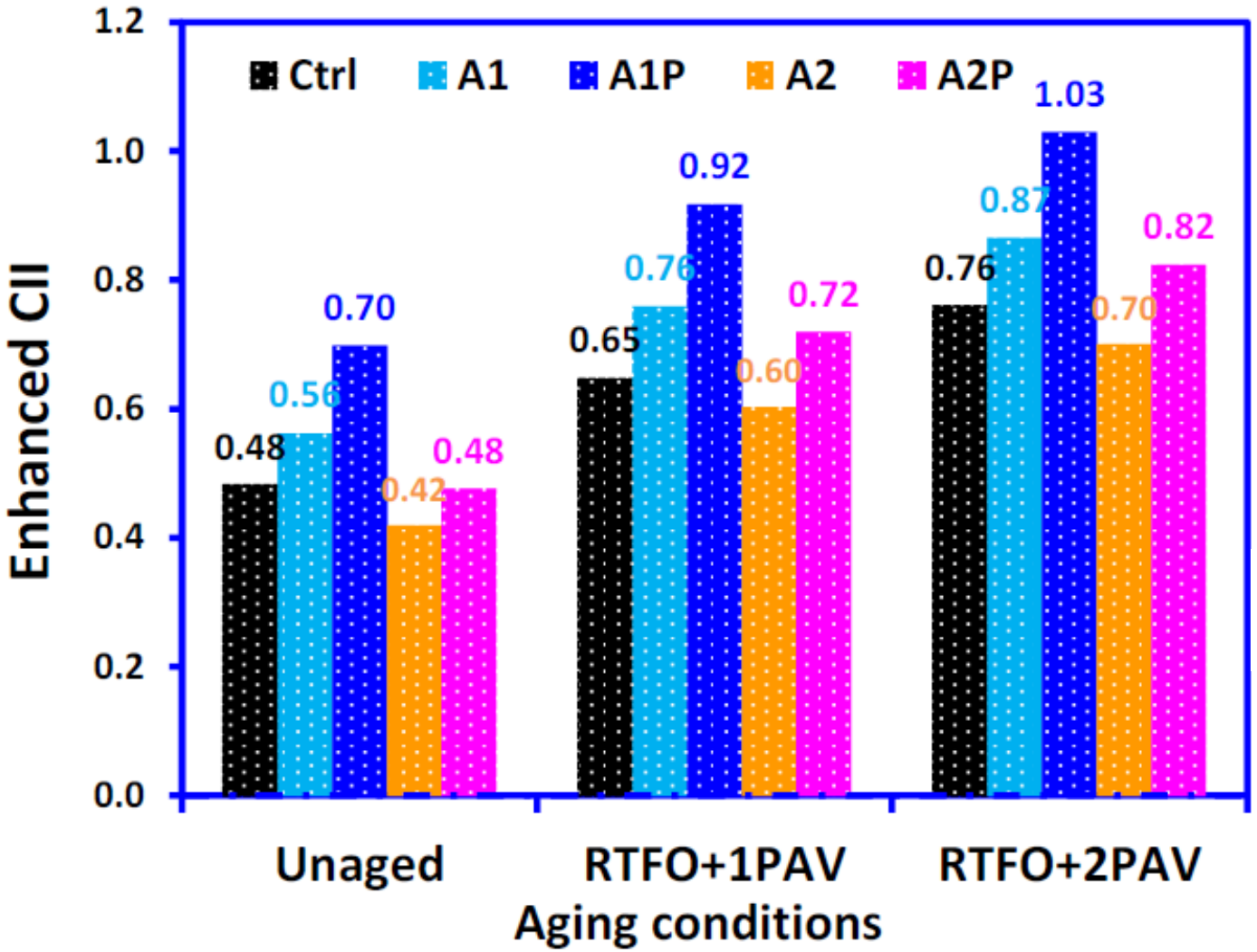
SARA-AD





Independent evaluation

Enhanced Colloidal Instability



$$Enhanced\ Colloidal\ Instability\ Index\ (CII) = \frac{Saturates + Asphaltenes\ 2}{Aromatics3 + Resins}$$

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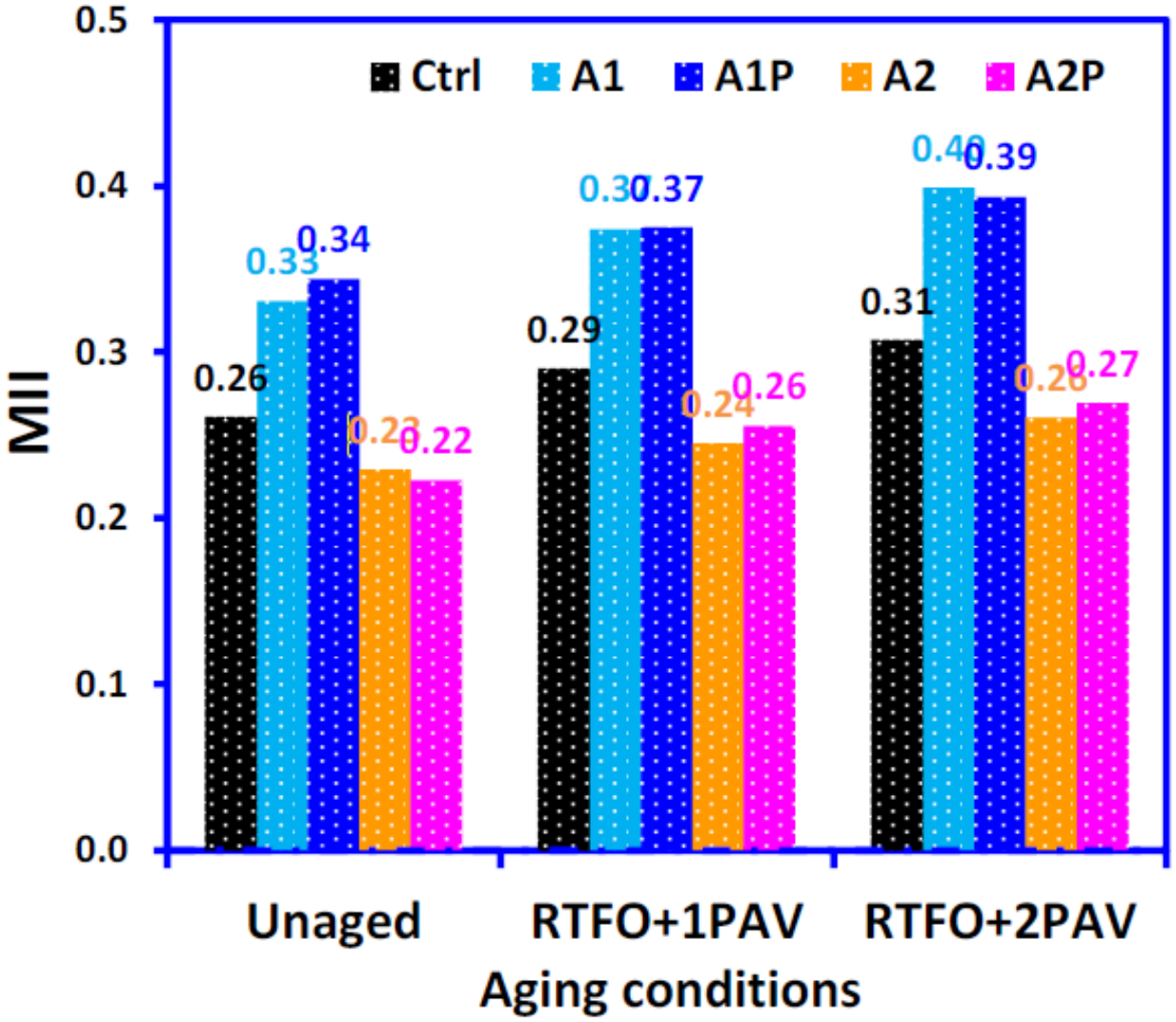
Independent evaluation

Maltene Instability Index



$$Maltene\ Instability\ Index\ (MII) = \frac{Saturates + Aromatics\ 1}{Aromatics\ 2 + Aromatics\ 3 + Resins}$$

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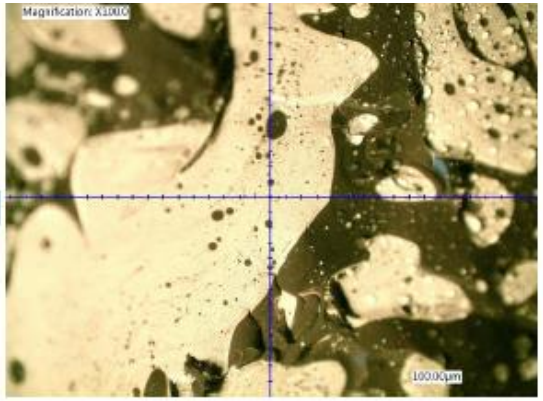
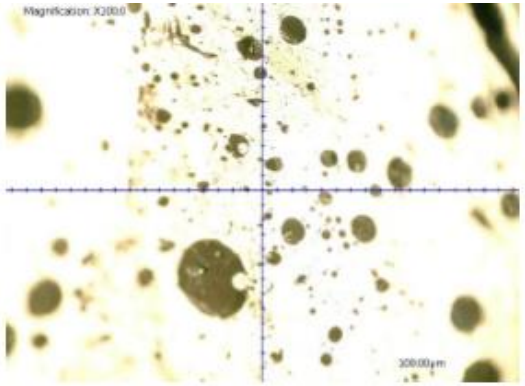
Independent evaluation

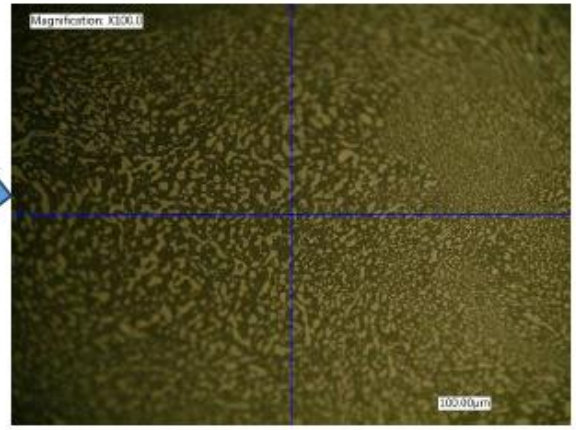
AIRC-I3, Focus Area 3: alternative binders



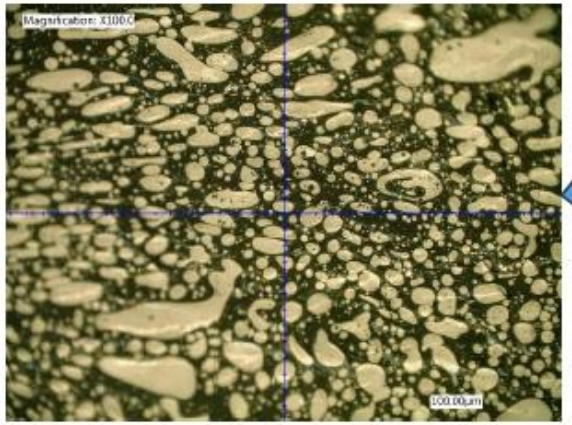
A1P unaged



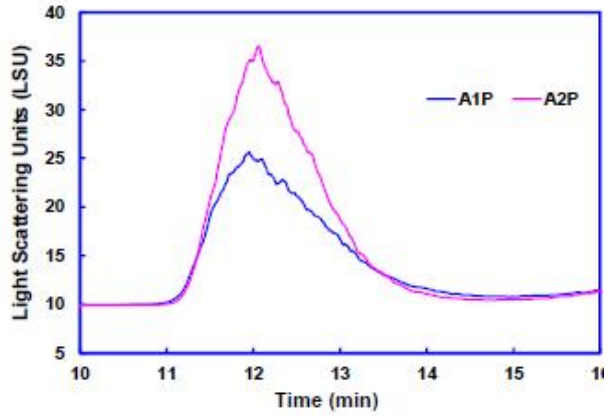
A2P unaged

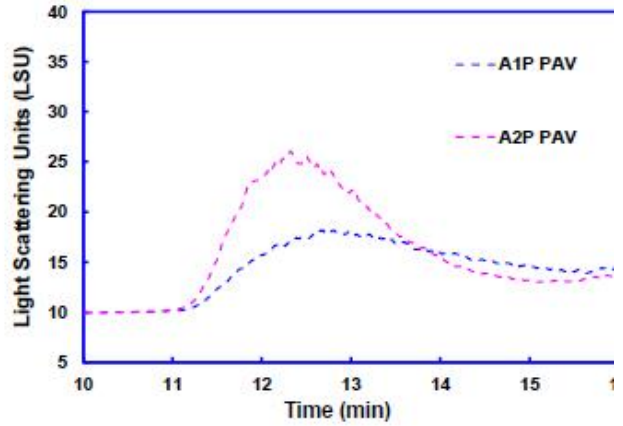


A1P RTFO+PAV



A2P RTFO+PAV





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Independent evaluation

Main Roads Western Australia

CarbonBind A15E

Test	Result	Min	Max
Softening Point (°C)	86.5	82	105
Loss on Heating (%)	0.05		0.6
Segregation (%)	0.5		8
Viscosity @165°C (Pa.s)	0.51		0.9
Consistency at 6% (Pa.s)	1234	900	
Torsional recovery (%)	69	55	80

Independent evaluation

Main Roads Western Australia

CarbonBind A15E in standard AC14

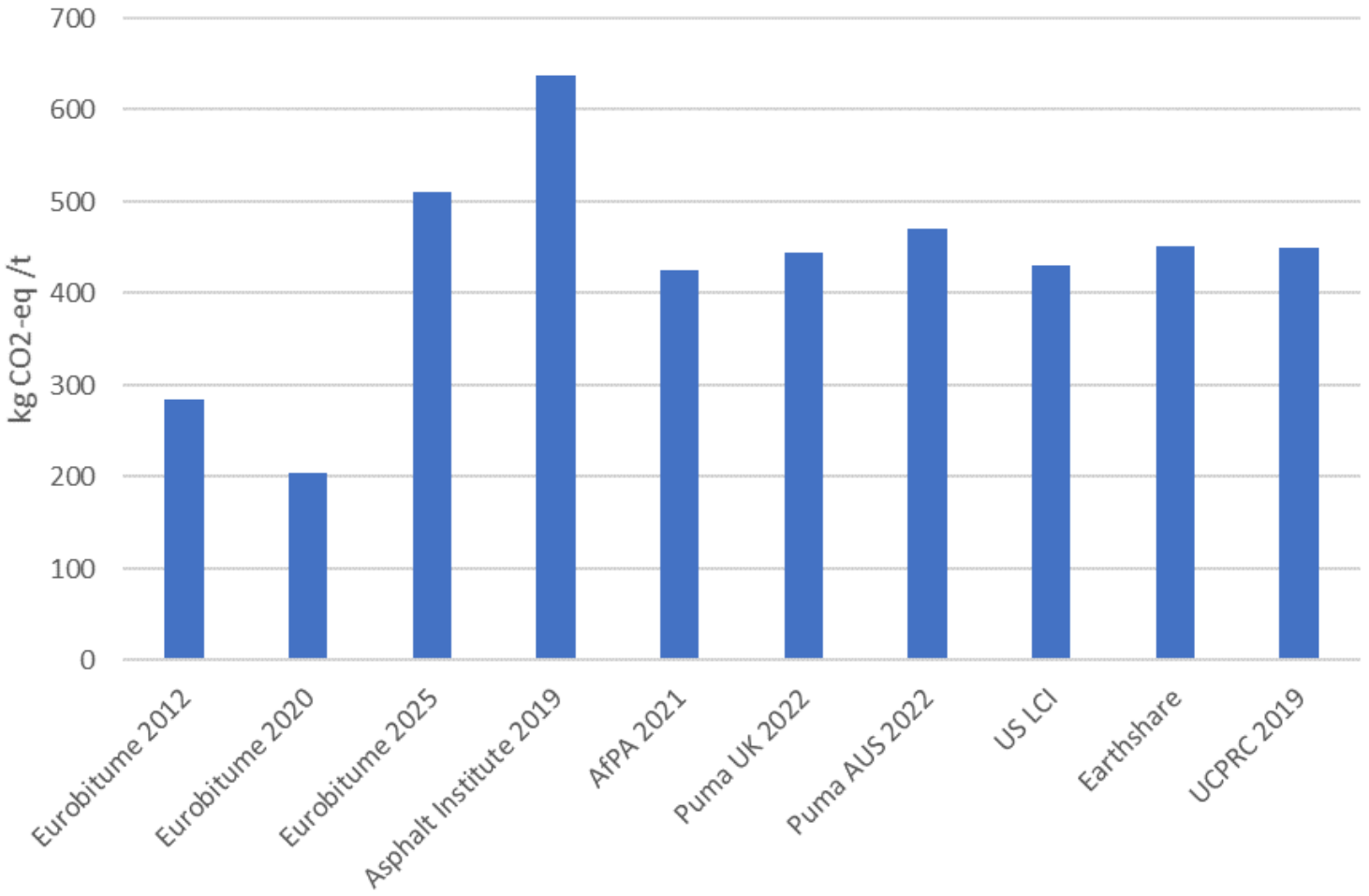
Test	Result	Unit
Wheel tracking AGPT/T220, deformation at 10,000 passes 60°C	1.6	mm
Stripping Potential of Asphalt AGPT/T323, Tensile Strength Ratio	86	%
Resilient Modulus AS 2891.13.1	4400	MPa
Hamburg Wheel Tracking AGPT/T220, 50 °C Rut Depth at 50,000 cycles	3.4	mm
Fatigue AGPT/T274 strain level to 10E6, 10Hz, 20°C*	209	με

*Determined on 9 beams

Humps in the road to net-zero

Navigating LCA rules

PUBLISHED GWP FOR BITUMEN



Navigating LCA rules

- **Example 1)**

- **Puma LCA for bitumen in UK:** **445 kg/t $CO_{2\text{-eq}}$**
- **Puma LCA for CarbonBind in UK:** **287 kg/t $CO_{2\text{-eq}}$**

- **Pre 2025 Local industry uses Eurobitume LCI: 206 kg/t $CO_{2\text{-eq}}$**
- **Post 2025 Local industry uses Eurobitume LCA: 530 kg/t $CO_{2\text{-eq}}$**

- **Difference: dataset on crude oil extraction & refining**
- **Implications: Need local LCA based on Eurobitume LCI**

Navigating LCA rules

- **Example 2)**

- **Puma LCA for bitumen in AUS:** **470 kg/t $CO_{2\text{-eq}}$**
- **AUST LCI published GWP:** **425 kg/t $CO_{2\text{-eq}}$**

- **Difference: Aust LCI based on older version of EN standard**
- **Solution?**

Humps in the road to net-zero

Overcoming LCA challenges

- Need bitumen PCR
- Harmonisation
- Independent external verification


epd-norway
Global Program Operator

ECO PLATFORM EPD VERIFIED

Environmental Product Declaration

In accordance with ISO14025:2006 and EN15804:2012+A2:2019

Puma CarbonBind biogenic bitumen component

PUMA ENERGY

PUMA ENERGY

The Norwegian EPD Foundation

Owner of the declaration: Puma Energy Europe B.V.

Product name: CarbonBind biogenic bitumen component

Declared unit: 1 metric ton

Product category /PCR: NPCR Part A for Construction products and services ver2 260421 + NPCR 025 2022 Part B for Asphalt ver2-2022

Program holder and publisher: The Norwegian EPD foundation

Declaration number: NEPD-6658-5905-EN

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Green procurement

- Urgent need for green procurement processes
- Available carbon calculators consider conventional materials only
- Label/Rating low resolution and inconsistent
- Level the playing field by:
  - Putting $ value on carbon emissions
  - Setting clear reduction targets for asphalt/sprayed seals

Specifications

- **Written around petroleum based binders**
  - **E.g. AASHTO M320:**
    - ***Must be refined from crude petroleum***
    - ***Must be 99% soluble in Toluene***
- **Empirical specifications applicability to non-standard materials?**
- **Increasingly problematic as % bio and range of bio feedstocks increase**

CarbonBind: Paving Grade

Grade	GWP [kg $CO_{2\text{-eq}}$/t]	Emissions reduction
Standard Bitumen	530	-
CarbonBind 40/60	427	20%
CarbonBind 50/70	347	35%
CarbonBind 70/100	194	63%
CarbonBind 160/220	11.4	98%

Relative to Eurobitume LCA 4.0 2025

Compliance to empirical specifications

CarbonBind® 50/70

Objective: Verify the sample in accordance with EN 12591 requirements

DATA/ RESULTS:

Property	Unit	Method	Specification EN 12591: 2009 E, Table 1	Results
ORIGINAL BINDER				
Penetration at 25°C, 100g, 5s	0.1mm	EN 1426	50-70	**65**
Softening Point	°C	EN 1427	46-54	**47.2**
Pen Index	-	Anex A	From -1,5 to + 0,7	**-1.3**
Flash Point	°C	ISO 2592	≥ 230	**284**
Solubility	%	EN 12592	≥ 99,0	**99.5**
AFTER RTFOT AT 163°C				
Change of mass	%	EN 12607-1	≤ 0,5	**-0.148**
Retained Penetration at 25°C, 100g, 5s	%	EN 1426	≥ 50	**55**
Increase in Softening Point	°C	EN 1427	≤ 9	**6.6**

Compliance to empirical specifications

CarbonBind® 70/100

Objective: Verify the sample in accordance with EN 12591 requirements

DATA/ RESULTS:

Property	Unit	Method	Specification EN 12591: 2009 E, Table 1	Results
ORIGINAL BINDER				
Penetration at 25°C, 100g, 5s	0,1mm	EN 1426	70-100	**89**
Softening Point	°C	EN 1427	43-51	**44.0**
Pen Index	-	Anex A	From -1,5 to + 0,7	**-1.5**
Flash Point	°C	ISO 2592	≥ 230	**274**
Solubility	%	EN 12592	≥ 99,0	**99.2**
AFTER RTFOT AT 163°C				
Change of mass	%	EN 12607-1	≤ 0,8	**-0.186**
Retained Penetration at 25°C, 100g, 5s	%	EN 1426	≥ 46	**54**
Increase in Softening Point	°C	EN 1427	≤ 9	**6.8**

Compliance to empirical specifications

CarbonBind® 160/220

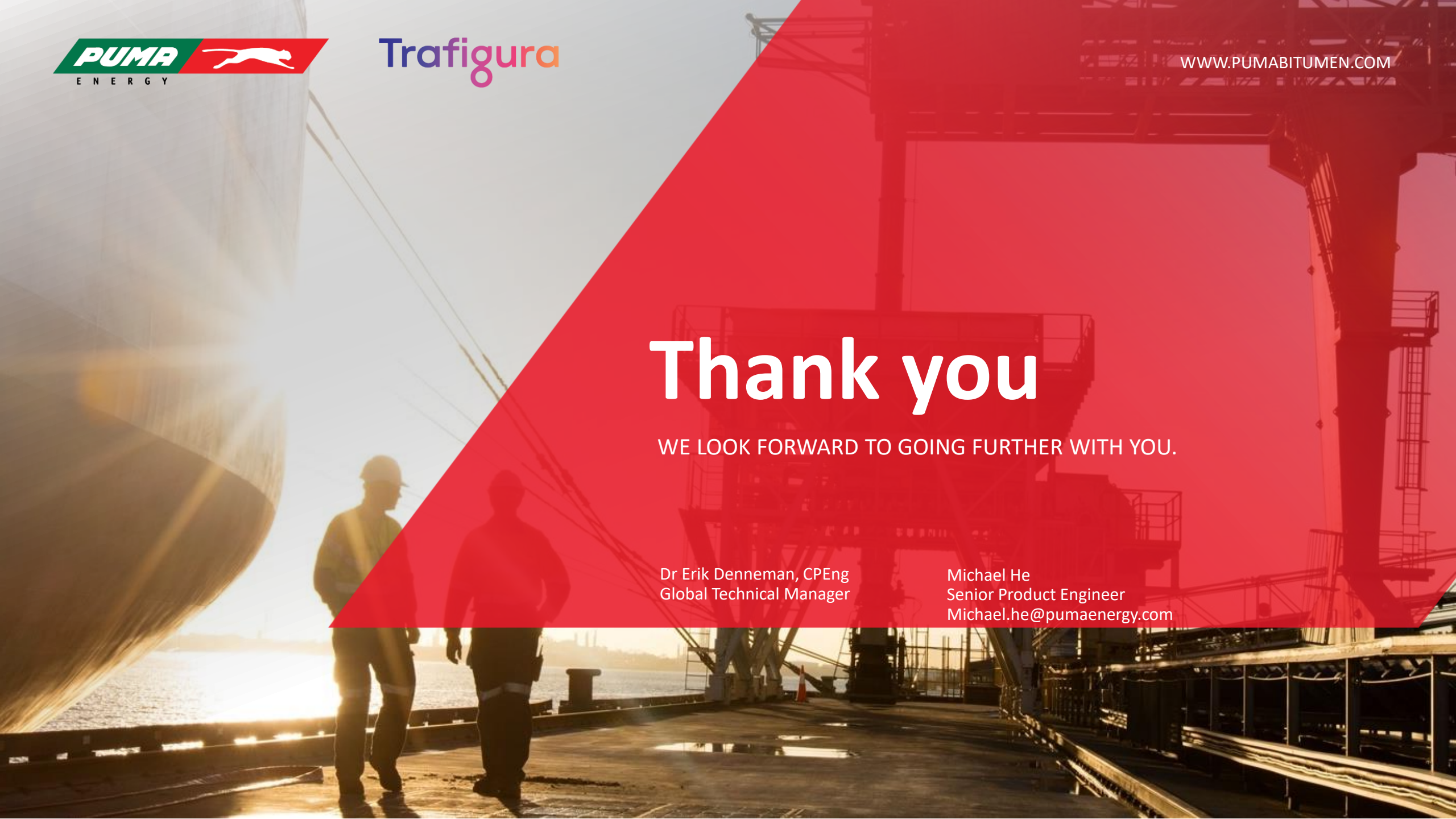
Objective: Verify the sample in accordance with EN 12591 requirements

DATA/ RESULTS:

Property	Unit	Method	Specification EN 12591: 2009 E, Table 1	Results
ORIGINAL BINDER				
Penetration at 25°C, 100g, 5s	0.1mm	EN 1426	160-220	**170**
Softening Point	°C	EN 1427	35-43	**39.6**
Pen Index	-	Anex A	From -1.5 to + 0.7	**-0.9**
Flash Point	°C	ISO 2592	≥ 220	**270**
Solubility	%	EN 12592	≥ 99.0	**98.8**
AFTER RTFOT AT 163°C				
Change of mass	%	EN 12607-1	≤ 1.0	**-0.290**
Retained Penetration at 25°C, 100g, 5s	%	EN 1426	≥ 37	**51**
Increase in Softening Point	°C	EN 1427	≤ 11	**6.2**

Conclusions

- CarbonBind® is formulated to meet current specification limits
  - Performance Based or Empirical
  - PMB and Paving grade
- Equal performance in asphalt testing
- Potential benefits of modified bio-material for durability and compatibility
- LCA and green procurement practices are still evolving and need consolidation



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Thank you

WE LOOK FORWARD TO GOING FURTHER WITH YOU.

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