Evaluating the use of bio binders to recycle existing pavements with foam techniques

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Australian Pavement Recycling and Stabilisation Conference

Designing for Reuse and Resilience

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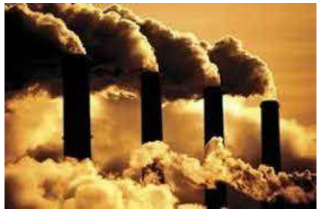
- Thickness design using Circly
- Life Cycle Assessment using SEVE Software
- Conclusion

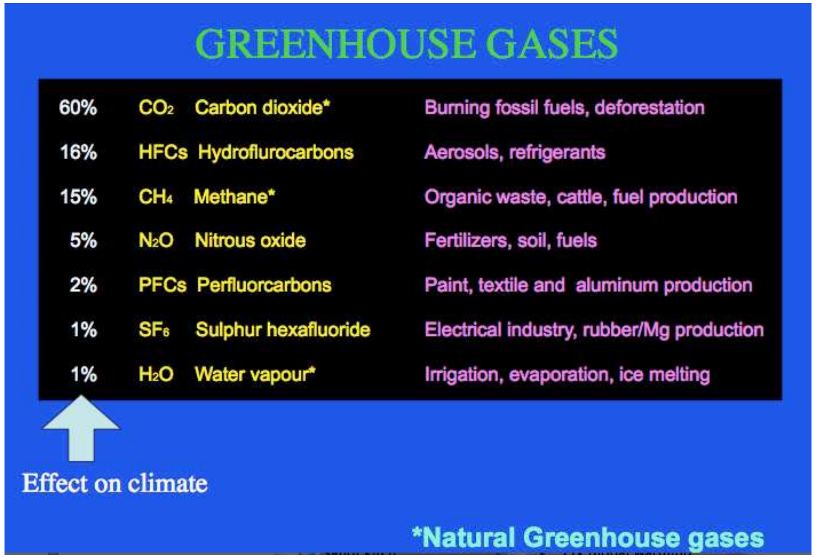
Research objectives

- Formulating a biogenic binder that is most suitable for foaming and FTB
- Evaluating the lab performance of new biogenic binder
- Comparing thickness design of bio based FTB and granular base using Circly
- Comparing environmental impact of bio based FTB and granular base using SEVE

Global warming concern



Human activities



GREENHOUSE GASES

60%	CO_2	Carbon dioxide*	Burning fossil fuels, deforestation
16%	HFCs	Hydroflurocarbons	Aerosols, refrigerants
15%	CH_4	Methane*	Organic waste, cattle, fuel production
5%	N_2O	Nitrous oxide	Fertilizers, soil, fuels
2%	PFCs	Perfluorcarbons	Paint, textile and aluminum production
1%	SF_6	Sulphur hexafluoride	Electrical industry, rubber/Mg production
1%	H_2O	Water vapour*	Irrigation, evaporation, ice melting

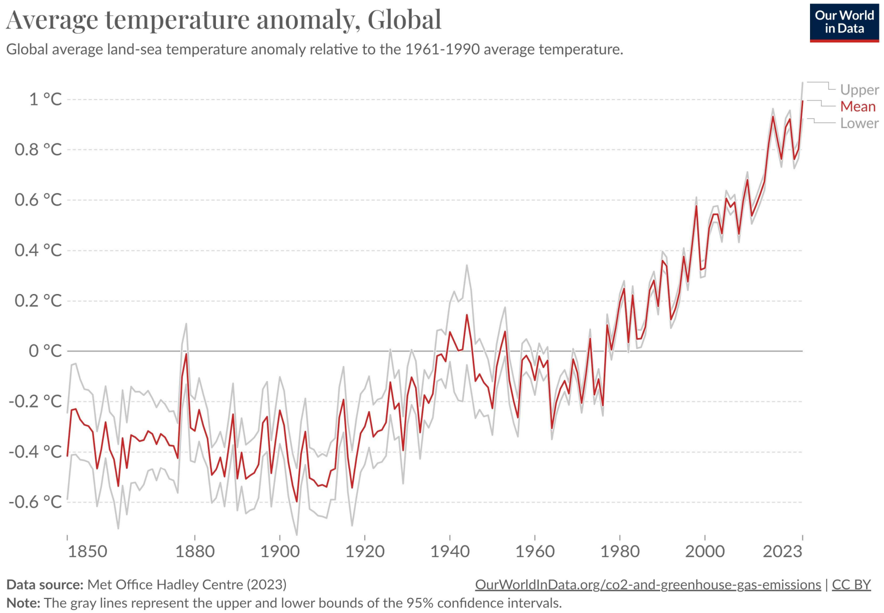
Effect on climate

*Natural Greenhouse gases

http://commons.wikimedia.org/wiki/File:Greenhouse_Gases.jpg

(Accessed: 15/10/23)

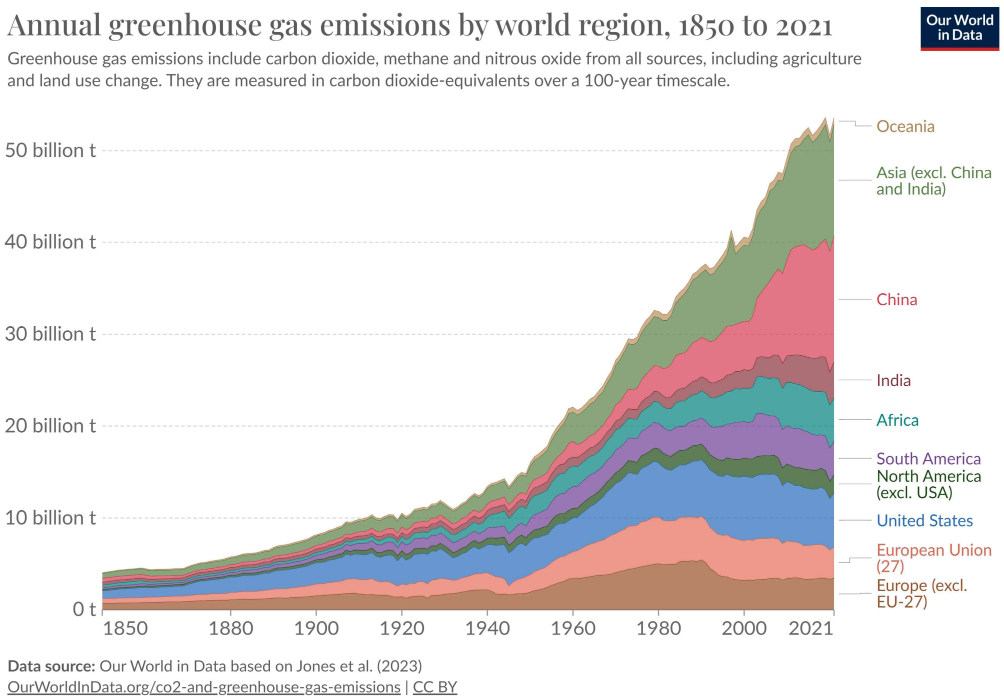
Global warming



https://ourworldindata.org/grapher/temperature-anomaly

(Accessed: 15/10/23)

Global warming concern



https://ourworldindata.org/grapher/ghg-emissions-by-world-region

(Accessed: 15/10/23)

The Paris Agreement- *legally binding international treaty on climate change*

- Signed in 2015 by 196 countries and entered into force on November 2016
- The goal- " limit global warming to well below 2 **°C** above pre-industrial levels, and to pursue efforts to limit the temperature increase to 1.5 **°C above pre-industrial levels."**
- Countries are required to regularly set and update national pledges to reduce their greenhouse gas emissions, with the aim of achieving net-zero emissions in the second half of the century.

What are our goals in road industry?

Australia action

The **Australian government** has recently committed to <u>**achieving net zero emissions by 2050**</u> and has announced a range of measures to reduce emissions.

Road industry (leaded by AfPA) targets and roles

- Reduce 30% of road construction carbon footprint by 2030
- Reduce 100% of road construction carbon footprint by 2050 (carbon neutral)

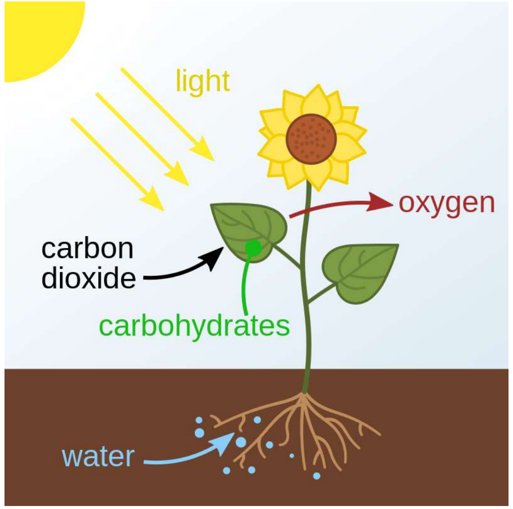
HOW?

- Increase of using waste materials in asphalt production (RAP, glass, waste plastic, crumb rubber, toner, etc)
- Decrease of production and compaction temperatures (WMA technologies)
- Reduce energy of drying aggregate (covering stockpile, insulation, using greener fuel, solar, etc)
- Omit using of high carbon footprints products such as cement and hydrated lime
- Using low-carbon materials such as Green Binders or Bio Binders
- Using recycling and reclaiming solutions such as base treatments and stabilisations

Bio based binders

CO2 gets moved from plants to roads by using green binders

Photosynthesis



Plants

Processed

Example of possible plant based materials that can be used in Green Binders

Blended

with bitumen

Green Binders/Bio Binder

Low carbon roads

Using stabilisation methods

Treated base / Stabilised base

- Definition: An intimate mixture of natural and/or crushed aggregates with lab-designed amount of different binders (cement, lime, bitumen, emulsion, chemicals, etc) and water that hardens after compaction and cures, to form a strong durable paving material

Two different main categories

- In-place
- In-plant

SAMIGreen PmB range

Properties	ATS 3110 (A15E)	ATS 3110 (A10E)	A10E	A15E	SAMIGreen A10E	SAMIGreen A15E
Torsional Recovery at 25°C, %	55-80	60 - 86	72	67	66	62
Viscosity at 165°C, Pas	0.9 mx	1.1 max	0.74	0.71	0.8	0.78
Softening Point, °C	82-105	88 - 110	102	103	105	102.5
Consistency at 60°C, Pas	Report	Report	19,041	13,260	16,816	12,102
Consistency 6% at 60°C, Pas	900 min	1000 min	1,875	1,236	1,683	1366
Stiffness at 25°C, kPa	30 max	30 max	22.3	14	23.8	25.6
Flash Point, °C	250 min	250 min	>300	2.16	>300	>300
Stress Ratio by DSR at 10°C	Report	Report	1.83	2.16	1.84	2.00
Loss on heating, % mass	0.6 max	0.6 max	<0.1	<1.0	<0.1	<0.1
Segregation Value, %	8 max	8 max	1.0	0.5	1.5	0.9

SAMIGreen C170 – Environmental impact

Products	Carbon footprint (kg CO_2e per ton of product)	Carbon footprint reduction (kg CO_2e per ton of product)	Carbon footprint reduction (%)
Polymer modified binder			
SAMIfalt A10E	724	-470	53%
SAMIGreen A10E	338		
Pure bitumen			
C170	425	-441	34%
SAMIGreen C170	279		
Polymer modified emulsion			
SAMIflex E50HR (S20E equivalent residue)	511	-367	57%
SAMIGreen E50HR (S20E equivalent residue)	218		

AfPA asphalt calculator LCA

53%

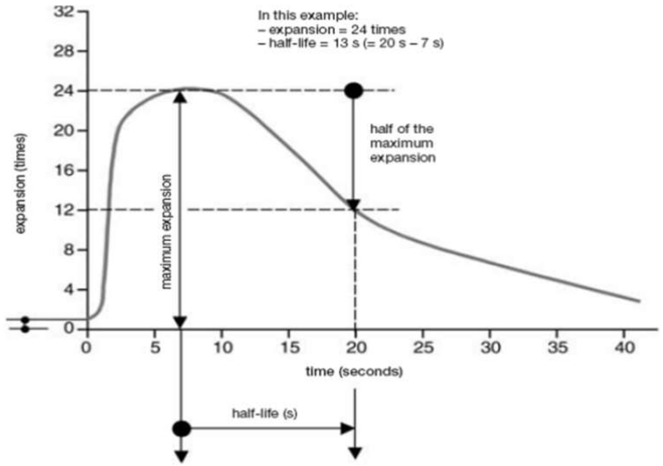
34%

57%

SAMIGreen C170 – Foaming character

Bitumen Source	Bitumen Temperature DegC	1.5% Water		2.5% Water		3.5% Water	
		Expansion Ratio	Half Life (s)	Expansion Ratio	Half Life (s)	Expansion Ratio	Half Life (s)
SAMIGreen C170	180	5	17	6	15	5	13
C170	180	6	13	7	10	10	8

- Expansion ratio of SAMIGreen version is as good as conventional bitumen (without foaming agent)
- Half life of SAMIGreen version is higher than conventional bitumen
  - Better workability and compaction
  - Ability to coat better



<u>2.5% water for foaming was chosen</u>

FTB modulus

- Mix was made according to AGPT/T302.
- Binder was added after 1 hour curing of dry test portion + water + 1% lime.
- Water content calculated to reach 0.85*OMC (5.1%).
- Briquettes were compacted straight after making mix at 50 blows on each side of the briquettes.
- Conditioned 3 briquettes at 25C in conditioning chamber for 3 hours as stated in AGPT/T305.
- Conducted intial RM test on each conditioned briquettes at 25C & as stated in AS 2891.13.1
- Briquettes were conditioned at 40C for 72 hours.
- Briquettes were coditioned at 25C for 2 hours before tested.
- Conducted Three-day cured modulus at 25C as stated in AS 2891.13.1.
- Put them in 25C water bath for 24 hours.
- Conducted Soaked modulus test.

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FTB modulus

	SAMIGreen C170			C170		
Binder content	2%	3%	4%	2%	3%	4%
Initial modulus (Ei)	410.2	384.9	307.8	455.4	365.6	382
Three-day cured modulus (E3d)	1450.7	1400.1	1678.6	1539.4	1463.3	1799
24h soaked modulus (E3s)	1170	1174.4	1322.2	777.5	1021.2	1060.3
Ratio	0.80	0.84	0.78	0.5	0.69	0.58

Thickness design

Different design approaches

- Austroads assumes FTB as an asphaltic layer with low bitumen content.

  Fatigue – Stiffness relation is similar to that of Asphalt and is related to bitumen volume.

$$N = \left(\frac{K}{\mu\epsilon}\right)^5$$

- NZ assumes FTB as an enhanced waterproof (stop potholes) granular material with a modulus fixed at 800 MPa and no fatigue equation.

Thickness design

Using CIRCLY software (Linear Elastic Layer method)

Two different traffic scenario / Two different pavement section

Pavement sections	Traffic 1 (ESA=1E7)	Traffic 2 (ESA=1E8)
Granular base + HMA	Case study 1	Case study 3
FTB + HMA	Case study 2	Case study 4

Thickness design

Austroads AGPT02
Guide to Pavement Technology Part 2: Pavement Structural Design

☑ Design thickness of layer highlighted below ☑ Calculate Cost Total Cost: $82.44/m2

No.	ID	Title	Minimum Thickness	Maximum Thickness	Current Thickness	CDF
1	AC20-ver2	AustStab conference			60.00	7.97E-02
2	FTB-ver2	FTB AustStab conference			300.00	7.90E-01
3	Sub-ver2	AustStab conference			0.00	4.23E-04

☑ Design thickness of layer highlighted below ☑ Calculate Cost Total Cost: $143.92/m2

No.	ID	Title	Minimum Thickness	Maximum Thickness	Current Thickness	CDF
1	AC14-ver2	AustStab conference			50.00	2.04E-07
2	AC20-ver2	AustStab conference			100.00	1.00E+00
3	Gran-ver2	AustStab conference			442.79	
4	Sub-ver2	AustStab conference			0.00	1.48E-03

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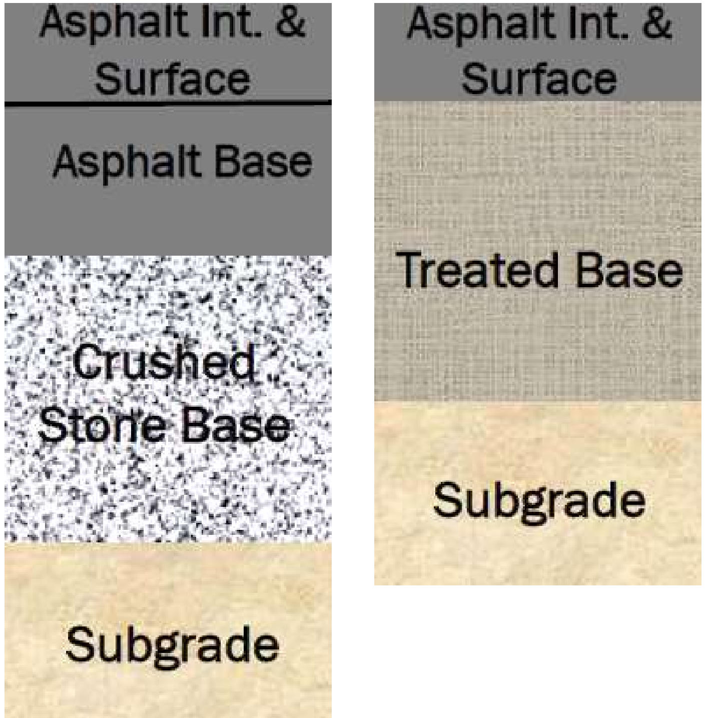
Thickness design – Material assumptions

- Performance exponent (k) for subgrade = 0.00915

	Vertical modulus (MPa)	$\frac{E_v}{E_h}$	Poisson's ratio	Bitumen content (%)	Bitumen volume (%)	Performance exponent (b)	Shift factor
AC14	4000	1	0.4	5.3	12.7	5	6
AC20	4500	1	0.4	4.7	11.3	5	6
FTB	1200	1	0.4	3	6.9	5	6
Granular base	800	2	0.35	-	-	-	
Subgrade	50	2	0.45	-	-	7	

Thickness design

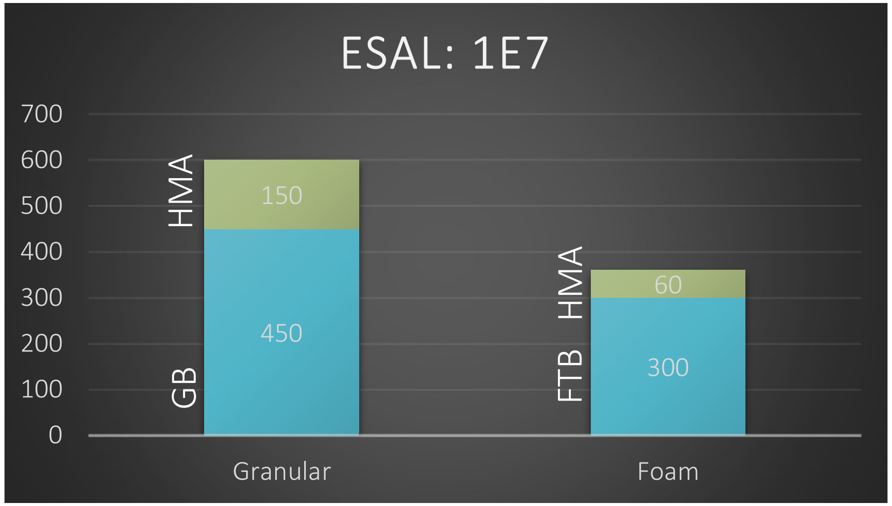
- Project reliability factor: 97.5
  - Asphalt fatigue RF: 9
- TLD: 110 – M7 Motorway
  - ESA/HVAG: 0.907
- N_{DT}: 1.1e7 and 1.1e8
- Thicknesses were calculated for all 4 case studies.

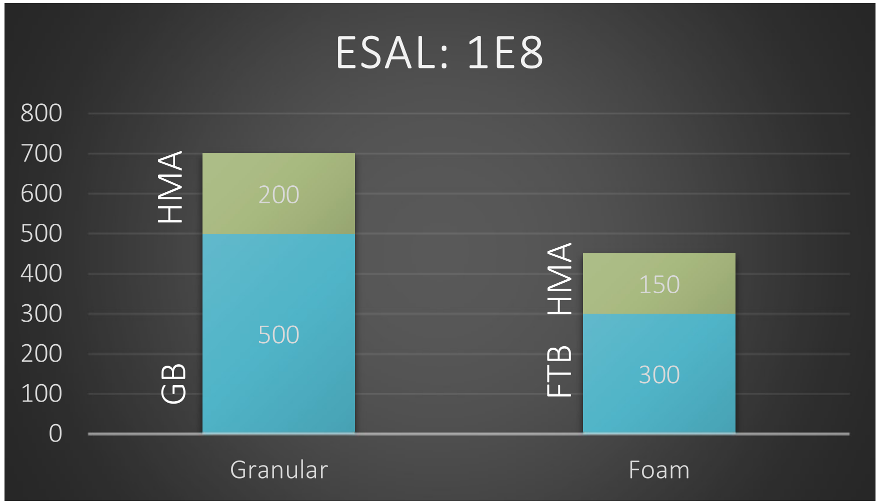


Thickness design – Results

	Case 1	Case 2		Case 3	Case 4	
	ESAL: 1E7			ESAL: 1E8		
AC14	50 mm	60 mm		50 mm	50 mm	
AC20	100 mm	-		150 mm	100 mm	
GB	450 mm	-		500 mm	-	
FTB	-	300 mm		-	300 mm	
Sum	600 mm	360 mm		700 mm	450 mm	

Thickness design – Results





Average 38% reduction in thickness

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Life Cycle Assessment

SEVE
Eco-comparateur

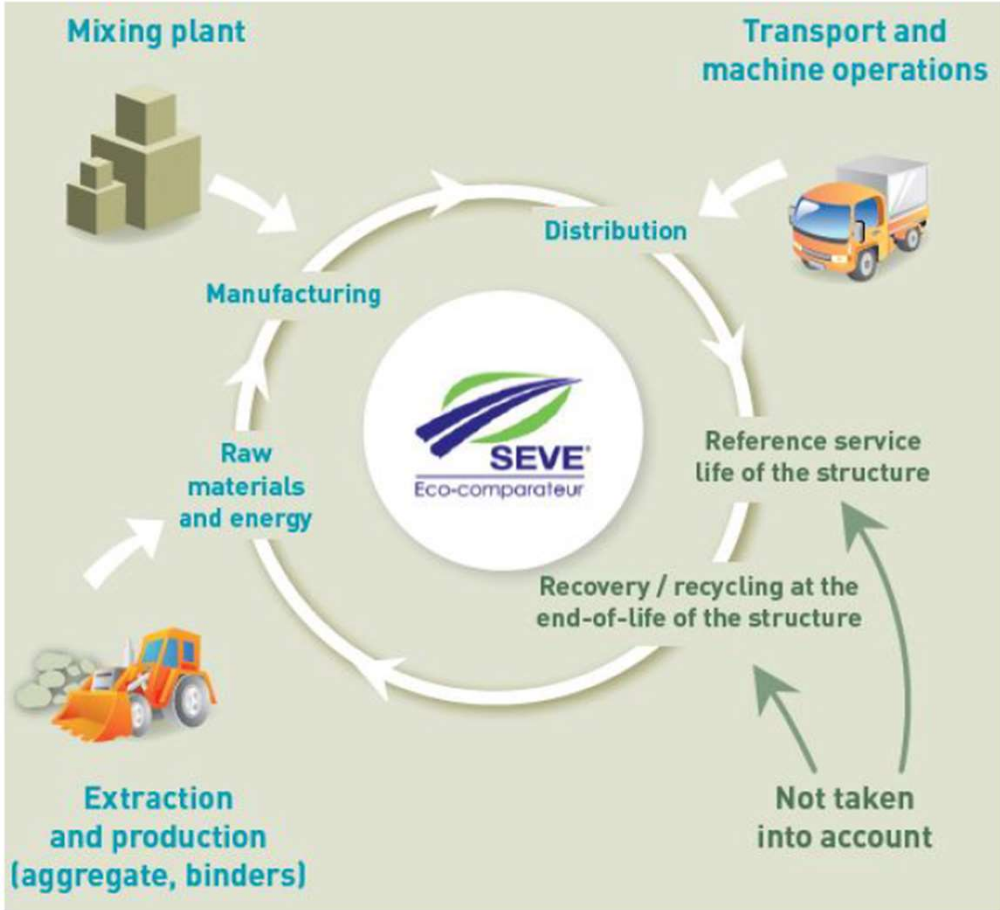
ROUTES DE FRANCE

1. In 2010, the road transport industry in France created an eco-comparator similar to AfPA.
2. A new web-based version of the eco-comparator released in 2022.
3. An English version of the eco-comparator is now accessible.
4. The eco-comparator evaluates the environmental impact of different stages in road construction, earthworks, and utility networks.
5. By conducting a partial life cycle analysis (LCA), the eco-comparator enables the comparison of two or more technical solutions.

Life Cycle Assessment

SEVE
Eco-comparateur

1. Adhere to the fundamental principles outlined in ISO 14040: 2006 - EN ISO 14044: 2006.
2. Utilize a shared database of materials, machines, and products accessible to all users.
3. Employ a database of formulas that are specific to each manufacturing plant, such as concrete or asphalt production tools.
4. Customize emission factors to match local conditions, taking into account the specific country-based parameters.

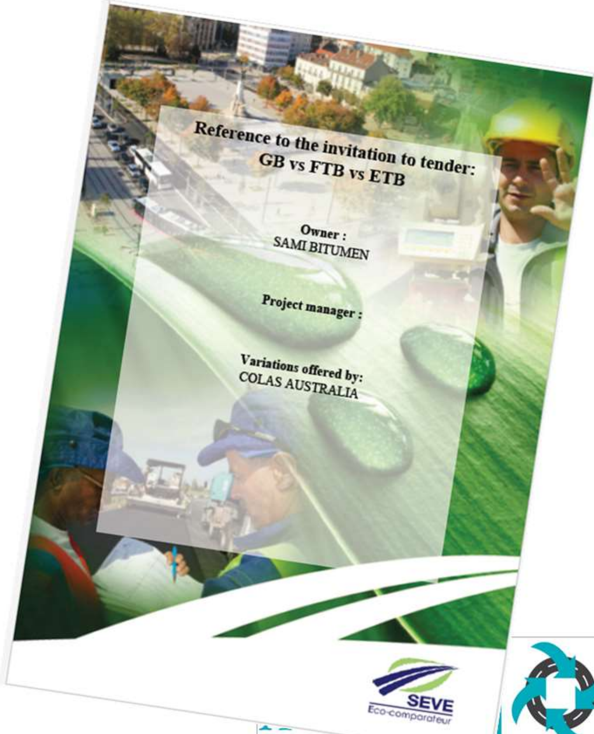


Life Cycle Assessment

SEVE
Eco-comparateur

Life cycle assessments carried out for each scenario on 4 indicators

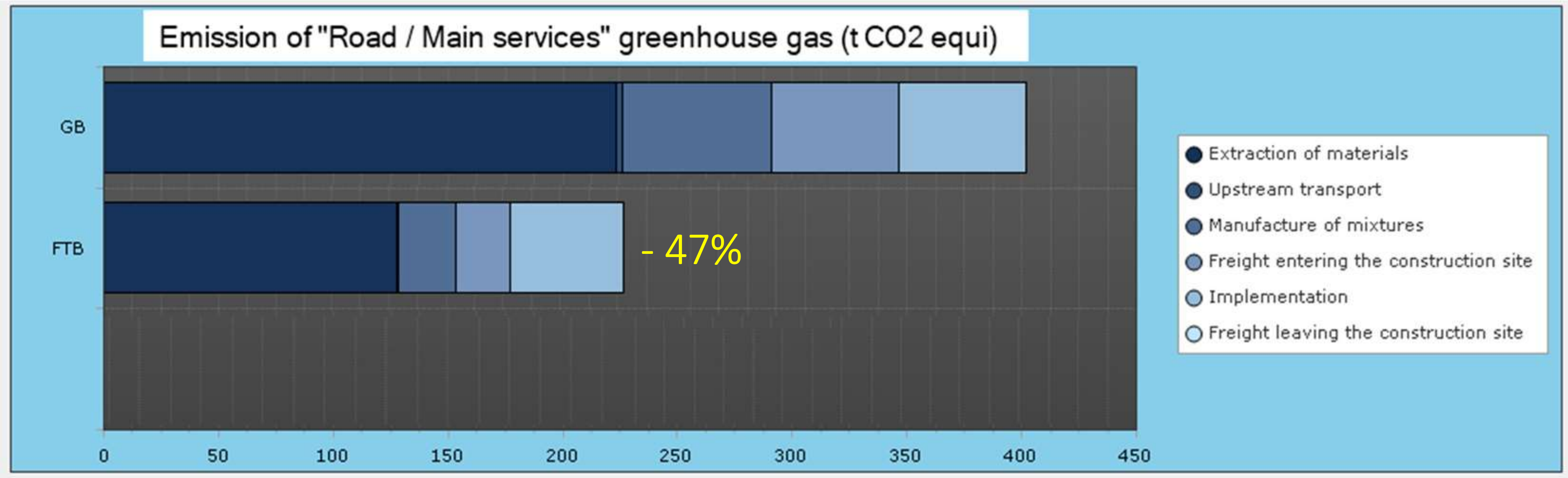
- GHG emission
- Energy consumption carried
- Resource conservation
- Ton-kilometer saved



Life Cycle Assessment

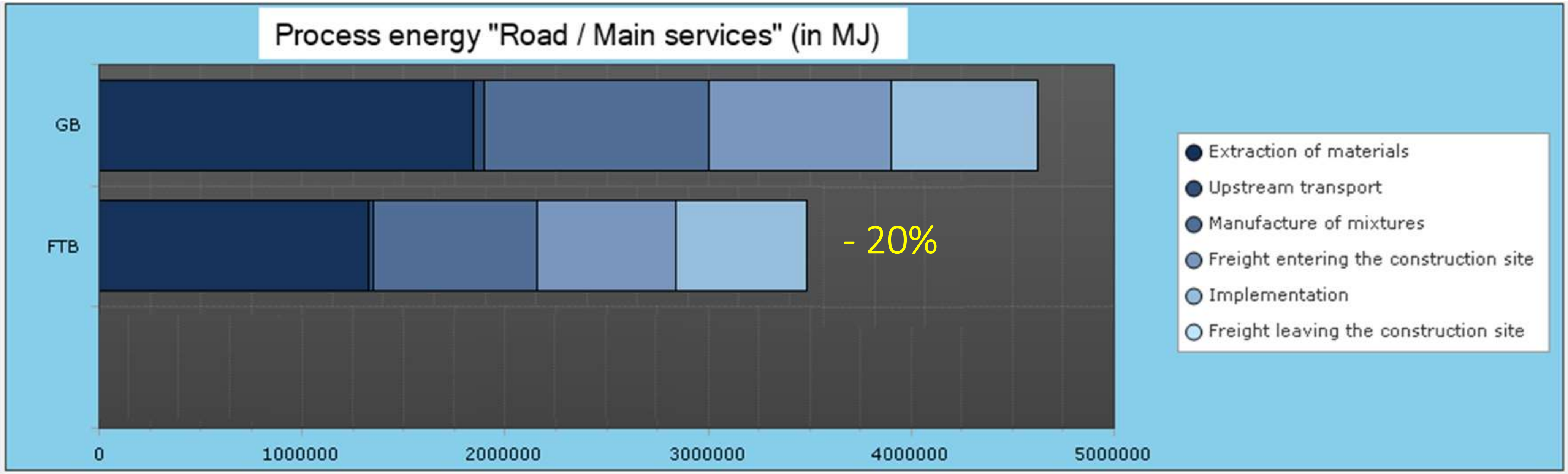
- GHG Emission comparison between Cases #1 #2

SEVE
Eco-comparateur



Life Cycle Assessment

- Energy consumption comparison between Cases #3 #4



Conclusion

The novel approach of using a bio-based binder for foam treating the base has been evaluated in this study.

- Environmental Benefits: Use of bio-based binders reduces reliance on fossil fuels, lowers greenhouse gas emissions, and promotes sustainability.
- Maintained Technical Performance: Bio-based binders offer equivalent or improved performance compared to conventional binders, ensuring durability and stability.
- Economic Opportunities: Adoption of bio-based binders aligns with growing market demand for sustainable products, creating potential economic advantages for companies.