OGPA and EMOGPA Research Summary

A summary of *Comparison of Carbon Equivalent Lifecycle Emissions for Standard Open Graded Porous Asphalt and Non-standard Epoxy Modified Open Graded Porous Asphalt Surfacing* and *Epoxy Modified Open Graded Asphalt Low Noise Pavement Investigation*

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Prepared for – Waka Kotahi New Zealand Transport Agency – ABN: N/A

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Client: Waka Kotahi New Zealand Transport Agency

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Rev	Revision Date	Details	Authorised	
			Name/Position	Signature
2	18-Nov-2020	Final draft	Anthony Hume Team leader, Sustainability and Resilience	

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1.0 Introduction

Waka Kotahi New Zealand Transport Agency (Waka Kotahi), commissioned AECOM New Zealand Limited (AECOM) to compare and review open graded porous asphalt (OGPA) and epoxy modified open graded porous asphalt (EMOGPA) with respect to the following aspects over a 50-year period:

- Noise impact
- Whole of life carbon footprint
- Resource requirements
- Life cycle costs

The review of the above aspects produced two documents: a memo (*Comparison of Carbon Equivalent Lifecycle Emissions for Standard Open Graded Porous Asphalt and Non-standard Epoxy Modified Open Graded Porous Asphalt Surfacing);* and a report (*Epoxy Modified Open Graded Asphalt Low Noise Pavement Investigation*). This report summarises the findings of both documents.

OGPA is the standard pavement surfacing for high traffic flow transport networks in New Zealand (NZ). OGPA is a mix of 20% fine aggregate, 74% chips and 6% binder content. It increases skid resistance, reduces noise pollution and has more safety advantages compared to most pavement surfaces.

EMOGPA surfacing uses a two-part epoxy (epoxy) that replaces part of the 6% binder of a standard OGPA mixture. The epoxy provides extra strength in the binder to reduce the effects of oxidation while retaining all the benefits of the OGPA surface. Previous Waka Kotahi research indicated that the epoxy in EMOGPA can significantly increase expected surfacing service life compared to OGPA.

2.0 EMOGPA Whole of Life Noise Review

Tyre noise is the dominant source of noise for road traffic travelling at over 15 to 20 km/h. The main factors in pavement design which can influence road noise include:

- Aggregate size. The 7 mm aggregate is effective for low noise pavements.
- Void spaces. These should be maximised with typical sizes of 15% to 20%.
- Pavements thickness. These should be maximised, optimal depth is 40 mm.
- Pavement stiffness. This should be reduced where possible.

There are limited studies on the noise attenuation of EMOGPA. Studies that have been completed are generally inconclusive. The common finding was that OGPA and EMOGPA have similar physical characteristics. While the epoxy binder in EMOGPA allows larger voids, increasing from 20% to 30% void size makes little difference in noise attenuation. The higher stiffness of EMOGPA could potentially increase noise levels by a small amount, however this would have little impact on overall noise levels. Using 7 mm aggregate over 10 mm aggregate may reduce noise by approximately 1 dB. While the change is indiscernible, the noise reduction over the pavement lifecycle with no change in cost is a benefit.

A literature review identified that EMOGPA has a longer lifespan than OGPA. Studies have found a wide range of estimates from more than 30 years to over 100 years. However, while further research is required, the noise reduction properties are unlikely to last for more than 20 years.

2.1 Cost benefit analysis

OGPA provides significant noise reduction compared to surfaces such as Chipseal and Dense Graded Asphalt (DGA). Typically, OGPA resurfacing is required every 7 years, whereas EMOGPA resurfacing is required every 30 years. The most common OGPA coarse aggregate size in NZ is 10 mm.

A cost benefit analysis was conducted over a 50-year period between the reference pavement (OGPA with 10mm aggregate), EMOGPA with 10mm aggregate and EMOGPA with 7mm target aggregate.

Table 1 Cost benefit and noise reduction assumptions

Attribute	OGPA10	EMOGPA10	EMOGPA7
Aggregate size	10 mm	10 mm	7 mm
Cost	$25.00/m^2	$32.50/m^2	$32.50/m^2
Lifetime	8 years	40 years	40 years
Initial attenuation benefit	4dB	4dB	5dB[1]
Yearly reduction in attenuation	-0.5dB/year	-0.2dB/year	-0.2dB/year

[1]The benefits of using 7 mm aggregate over 10 mm aggregate have been assumed based on experience with other pavements such as stone-mastic asphalt. Further studies are required to confirm the assumption.

In the cost benefit analysis, it was assumed that EMOGPA would be resurfaced every 20 years despite a typical lifespan of 30-40 years. This is due to the loss of noise attenuation properties after 20 years, causing higher noise levels than DGA. EMOGPA was found to have a lower cumulative cost than OGPA after 8 years. The cost benefit ratio was found by dividing the decibels of attenuation achieved by ongoing costs. A comparison of the ratios can be found in Figure 1.

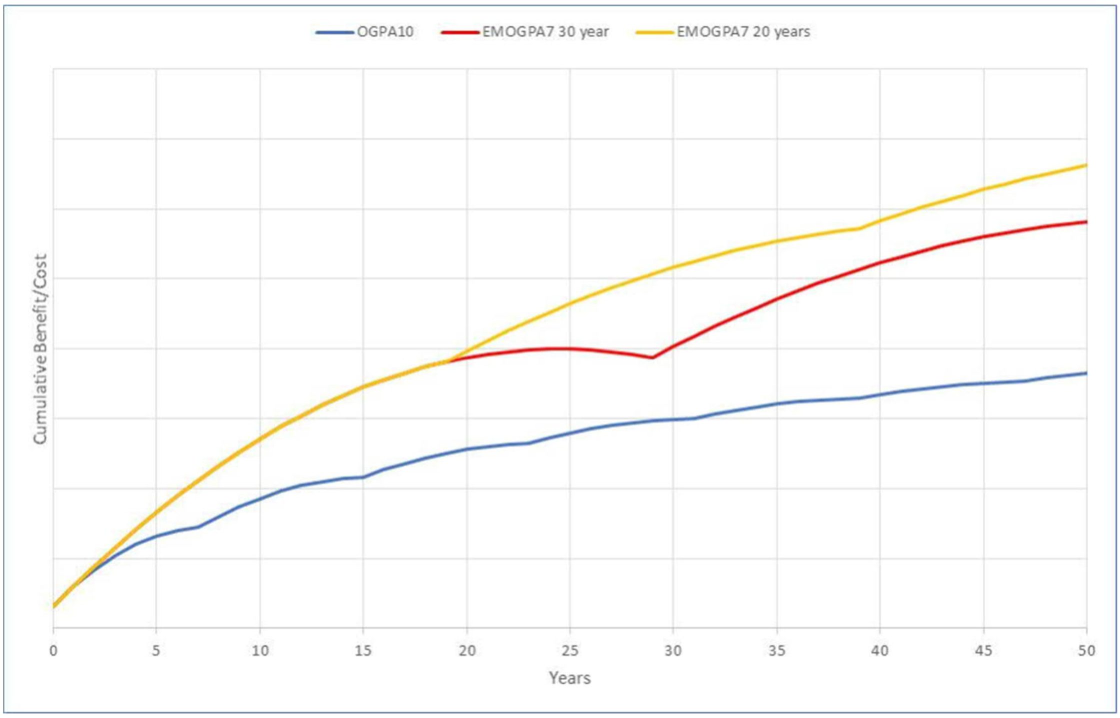

Figure 1. Cost benefit analysis - OGPA vs EMOGPA

3.0 Comparison of Carbon Equivalent Lifecycle Emissions for OGPA and EMOGPA

An assessment was undertaken to:

- Model, compare and understand the greenhouse gas emissions between OGPA and EMOGPA surfacing, with the aim of highlighting any potential benefits or disadvantages.
- Examine the high-level lifecycle financial costs of OGPA and EMOGPA.

The assessment was based on surfacing activity for the Auckland road network to ensure results could be compared on a large scale to fairly highlight the difference between OGPA and EMOGPA in terms of carbon emissions.

In the lifecycle of pavement surfacing, there are four main processes (refer to Figure 2).

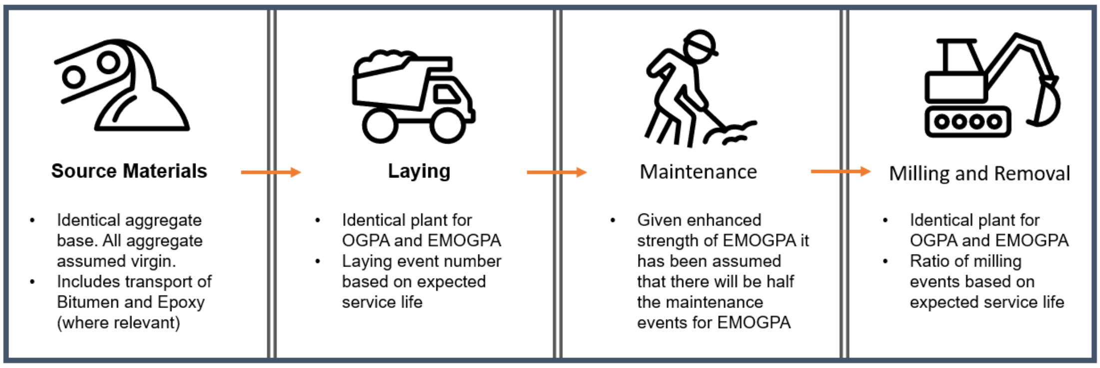

Figure 2. Four main processes of pavement surfacing

As EMOGPA is not currently used widely in NZ, it was necessary to use agreed assumptions when completing the carbon emissions assessment. These assumptions (shown in Table 2) should be considered when interpreting the results outlined below.

Table 2 Assumptions made for each lifecycle process

Life cycle Process	Assumptions
Material sourcing	- The bulk of materials for both OGPA and EMOGPA are the same except for a portion of bitumen binder for EMOGPA that is sourced from a separate location. - All aggregates for asphalt production are assumed to be quarried on the site of the asphalt plant - Average travel distance of 40km from the asphalt plant to the surface laying site - All bitumen sourced from Marsden Point refinery - An average travel distance of 110km to the asphalt plant for bitumen - The binder of OGPA is replaced using a 25% epoxy binder sourced from NZ - Tauranga Laboratory is epoxy source and a transport distance of 250km. - International epoxy is sourced from San Francisco. - Service life for nationally and internationally sourced epoxy is 40 years.
Laying surfacing materials	- The mix is assumed to be transported to the laying site by a heavy goods vehicle. - A paver, smooth drum roller and pneumatic tyre roller are assumed to be used for the overall construction of the pavement including the surface - Placement rate 40t/hour - All surface laying events after the first to use 25% recycled material.
Maintenance	- OGPA will require twice the surface maintenance compared to EMOGPA
Milling, removal and disposal (including recycling)	- 85% of waste material is sent to landfill. - Average distance of 20km for disposal - 15% of remaining material to be transported 40km back to asphalt plant for reuse.

3.1 GHG emission results

Nationally and internationally sourced EMOGPA was found to produce less than half of the kg CO_2e per lane km compared to OGPA. OGPA has a smaller carbon equivalent emission per individual laying event. However, for every five OGPA laying events there is one EMOGPA laying event due to the higher expected service life of EMOGPA. The source materials activity is the most carbon intensive process in the lifecycle. It contributes 79%, 81%, and 87% of overall emissions for OGPA, NZ sourced EMOGPA, and internationally sourced EMOGPA, respectively.

Two sensitivity checks to the emission calculations were completed. A sensitivity test was completed using a reduced service life of 20 years for EMOGPA, as the surface may have to be re-laid to ensure noise attenuation is kept to a maximum. NZ's energy production mix includes a higher proportion of renewable energy than countries such as the United States of America. To understand the use of NZ sourced EMOPGPA another sensitivity check was completed to estimate the impact of the typical NZ energy mix on the carbon equivalent emissions. In this sensitivity check, the emission factor taken from international literature was halved to estimate the impact of producing EMOGPA in NZ. This was halved conservatively as NZ uses more energy from renewable sources than other countries.

When reducing the service life of EMOGPA to 20 years, there is a reduction in relative emissions compared to OGPA. However, for both NZ sourced and internationally sourced EMOGPA carbon emissions are reduced when compared to the use of OGPA. For example, the emissions produced from internationally sourced EMOGPA were 91% of total OGPA emissions.

The sensitivity test on the NZ emission factor for the epoxy in EMOGPA only resulted in 4% reduction in carbon equivalent emissions. This suggests that epoxy production is a minor factor in emissions compared to the other constituents. The shorter service life of OGPA (and consequent higher resurfacing frequency) creates more carbon equivalent emissions over 50 years compared to EMOGPA.

Carbon equivalent emissions using the standard source materials are listed in Table 3.

Table 3 Overall summary of CO_2e over 40 years

	Base Line (40 yr service life)			Sensitivity Test 1 (20 yr service Life over 40 years)			Sensitivity Test 2 (0.5times Emissions Factor over 40 years)		
Surfacing type and scenario	Total kg CO_2e	Kg CO_2e/ Lane km	% of Emissions Relative to OGPA	Total kg CO_2e	Kg CO_2e/ Lane km	% of Emissions Relative to OGPA	Total kg CO_2e	Kg CO_2e/ Lane km	% of Emissions Relative to OGPA
OGPA	199,659,888	91,243	-	-	-	-	-	-	-
NZ sourced EMOGPA	58,411,372	26,693	**29%**	116,496,309	53,238	**58%**	50,342,467	23,006	**25%**
Internationally sourced EMOGPA	83,426,737	38,125	**42%**	166,516,053	76,096	**83%**	75,357,831	34,438	**38%**

3.2 Life cycle costs

A high-level cost comparison completed in this study used Christchurch Southern Motorway Stage 2 (CSM2) for project specific rates. Based on the model used, at the end of a 25-year period. The cost of the EMOGPA surface was $13,730,000, which was $29,930,000 lower than the cost of OGPA. The extended service life of EMOGPA surface allows for the capital cost to be spread over a greater period. This model assumes that there is no significant performance loss from the EMOGPA surface over the duration of its service life.

4.0 Further development

Following the issue of the two documents, EMOGPA could no longer be sourced from NZ. However, the results show the use of internationally sourced EMOGPA would reduce emissions when compared to OGPA.

5.0 Conclusion

Despite having physical similarities, OGPA and EMOGPA have different whole of life carbon equivalent emissions, noise emissions, and costs. OGPA has lower upfront costs and carbon equivalent emissions per surfacing event. In a 40-year lifecycle, the shorter OGPA service life leads to increased resurfacing. Hence, the total lifecycle carbon equivalent emissions of OGPA over 40 years becomes greater than of EMOGPA. Both reports also concluded that total lifecycle costs of EMOGPA were lower than OGPA. For optimum noise attenuation, more frequent resurfacing (20 years, compared to 30-40 years) is required. Even with an increased rate of resurfacing for optimum noise attenuation and the need for international sourcing, research has indicated that EMOGPA produces lower costs and carbon equivalent emissions compared to OGPA.

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