Infometrics

The Case for
Concrete Roads
Report to Concrete NZ

Prepared by
Infometrics Ltd 2024

Table of contents

Authorship

This report has been prepared by Adolf Stroombergen.

Email: adolfs@infometrics.co.nz

1

Introduction

In 2013 and 2018, as well as a brief update in 2020, Infometrics presented a high-level analysis of the case for building roads with concrete pavement (continuously reinforced concrete pavement with exposed aggregate finish) compared with asphalt-surfaced pavement (structural asphaltic pavement).

Taking into account initial construction costs and subsequent maintenance and rehabilitation costs, the discounted total cost of concrete pavement for a section of highway, evaluated over a 30-40 year period was around 25-30% cheaper than asphalt pavement, in those reports.

This 2024 report is an update of the earlier reports, again commissioned by Concrete NZ. The brief was to compare the whole-of-life costs and CO_2 emissions of the two roading technologies, as well as to compare the price volatility of concrete versus bitumen.

Executive Summary

Key points:

- Concrete roading is almost always more cost-effective to construct and maintain over a 40-year life.
- Concrete has significantly lower price volatility than bitumen, presenting a lower relative financial risk to roading procurers.
- Concrete roading has lower whole-of-life embodied CO_2 emissions than asphalt.

It is noted the earlier reports used 2009 cost data relating to State Highway 20, the southwestern motorway in Auckland. For this update, we have used more recent data, augmented with a sensitivity analysis to enhance the robustness of the results.

Section 2 samples international literature to complement a scarcity of New Zealand data. The overall conclusion is that concrete is a cheaper roading technology over whole of life than asphalt, although with significant variation between studies.

Analysis of New Zealand scenarios is presented in Section 3. We have done this by running 20,000 simulations of roading construction and maintenance costs, applying results from overseas and New Zealand data. This produces a distribution of costs, the central 90% of which delivers an 11.8 to 22.9% advantage to concrete over asphalt. The weighted mean is a 17.5% advantage to concrete.

In Section 4, we present an analysis of historical changes in the prices of petroleum products and non-metallic mineral products (as proxies for trends in asphalt prices and concrete prices, respectively). As in the previous reports, the price of petroleum products has been far more volatile than the price of non-metallic mineral products. That difference in price volatility is likely to continue, so any specific road paving project should carefully consider cost escalation scenarios. Of note is that concrete presents lower price uncertainty than asphalt, and, therefore, a lower risk related to managing that uncertainty.

Section 5 considers whole-of-life CO_2 emissions. As with the cost profiles, asphalt manufacture has lower emissions than concrete manufacture per kilometre of road, but the difference over the life cycle is negligible. That said, the equation swings decisively in favour of concrete if the CO_2 absorptive capacity of concrete pavement (carbon uptake) is included in calculations. This natural process of permanent CO_2 removal from the atmosphere is accounted for in successive updates of the Infrastructure Sustainability Council's (ISC) rating tool for infrastructure sustainability, which is becoming increasingly an input into government roading procurement.

2

International Overview

Detailed and published studies on relative concrete-asphalt costs are scarce. The following are highlights from selected international studies. Some are (seemingly) independent, while others are produced by concrete-related interests.

Naturally, one cannot infer that the relative concrete-asphalt costs in other countries apply in the same way to New Zealand. Different studies consider different types of asphalt pavement, and the asphalt type is not always clear in terms of comparability with New Zealand classifications. Nevertheless, the degree of similarity with New Zealand data is surprising. The references below are presented in likely order of relevance to New Zealand.

Arcadis (2017)

Looking close to home, an Australian life-cycle cost analysis of 72 scenarios showed that concrete pavement (with low-noise diamond grooving) had 11-18% lower construction costs and 43-55% lower maintenance costs over a 40-year lifespan, compared to ‘full depth’ asphalt roads. The whole-of-life cost advantage emerges at around 25%.

ACPA and Cemex (2023)

The authors estimate the following relative life cycle costs in the USA (which we normalise to $100 for asphalt). As in numerous other studies, asphalt has a lower initial cost, but over the lifetime of a road, concrete emerges about 11% cheaper. The discount rate selected is not explicitly mentioned, but we infer that it is around 2-3%, real (over and above inflation).[1]

Table 1: Relative asphalt-concrete costs

	Asphalt	Concrete
Initial	$71	$78
Rehabilitation	$25	$10
Maintenance	$4	$1
Total	$100	$89
Range	±$11	±$11

---

1. Discounting is important because of the time value of money. With a 5% discount rate, a dollar next year is worth only 95c today. Similarly at a 3% discount rate, a dollar next year is worth 97c this year. Therefore, a lower discount rate increases the value today of future dollars/costs.

An error margin of 11-12% allows for different design and uncertainty, so in some cases it is possible that asphalt pavement could be cheaper. However, the authors also recommend extensive sensitivity analysis, including allowing for uncertainty in future price movements. That also advances the case for concrete over asphalt as cement prices are far more stable and, therefore, predictable than bitumen prices. We return to this point later in Section 4.

Watson et al (2020)

In a wider study of environmental impacts (incorporating harm to human health, ecosystem health and resource availability), Watson et al (2020) estimate that asphalt has the higher environmental impact, concluding that concrete is the more sustainable option.

US Federal Highway Administration (2023)

The 2023 Lifecycle Cost Analysis, *RealCost* User Manual produced by the US Federal Highway Administration contains examples of life cycle calculations. For a new rural 10km road the construction cost using HMA (hot asphalt mix) was 43% cheaper than using PCC (Portland cement concrete). Over a 40-year life cycle with a discount rate of 2%, that initial difference is still too large to be offset by the lower maintenance costs of PCC, although the difference does fall to 29%.

In another example, for an urban reconstruction project involving an 11km stretch of road the construction cost advantage of HMA over PCC is only 9%. Over a 50-year life cycle, however, HMA becomes 10% more expensive – a result more in line with other literature.

Bouteillier and Gustafson (2017)

Using a Canadian example, the authors estimate a life cycle cost difference of only 6% in favour of Portland cement concrete pavement over flexible asphalt pavement – for a time period of 50 years and a discount rate of 4%.

Jung et al (2022)

In an analysis for Korea, Jung et al estimate that concrete overlay has a 23% or more life-cycle cost advantage over 20 years in comparison with asphalt overlay. If the road shoulder is available for traffic while roadwork is undertaken, the advantage to concrete is an additional 5% over the 20-year period. The discount rate is not stated.

GCCA (2022)

In an analysis of the initial cost, maintenance and lifecycle expenses for a one km stretch of road in India, the Global Cement and Concrete Association showed that although the construction cost of concrete roads is 28% higher than bituminous roads, the life cycle and maintenance cost for cement concrete roads is 19% less. The net effect (with a 12% discount rate) is that concrete overlay is 48% cheaper. A lower discount rate would further advance the case for concrete relative to asphalt, because more weighting would be put on the higher maintenance costs for asphalt than for concrete.

It is also noted that the use of 30% fly-ash as a replacement to cement in concrete can reduce the construction cost by a further 20%.

Kumari et al (2022)

Also for India, Kumari et al look at the life cycle costs for concrete and asphalt roads, including environmental effects. The results show that the concrete roads are 20% more economical than the bitumen roads in terms of LCA (life cycle assessment) carried out for a 30-year analysis period. The discount rate used is not stated. Concrete also has a lower environmental impact.

Adow et al (2011)

A detailed Ghanaian study compares concrete (grade 35) to asphalt over a 40-year life span. Using their costs, but changing the discount rate from their 30% (which seems excessive) to 3%, yields a total discounted cost for concrete roads amounting to 48% of that for asphalt roads. At a discount rate of 6% the proportion is 54%, in both cases against a 25% higher initial construction costs.

Conclusion

Drawing on the above studies we infer that:

- For most situations in most countries concrete roads are cheaper than asphalt roads when costs are considered over the typical lifetime of a road of 30-50 years.
- The effect of the oil price on the cost of bitumen and thus asphalt pavement is probably stronger than the effect of the price of Portland cement on the cost of concrete pavement.[2]
- Both types of pavements though, require other inputs such as labour and bulk raw materials; inputs that are generally not traded across countries.
- This combination of traded and non-traded inputs can and does lead to differences in the absolute costs of road construction across countries for both pavement types, but relative asphalt-concrete costs seem to exhibit much less variation across countries.

As the above examples illustrate, the specifics of any particular roading project – type of terrain, amount and composition of traffic, exposure to extreme temperatures, budget, discount rate – can affect the relative size of the cost advantage of concrete over asphalt, but in most instances does not reverse it.

---

2. For a chart of world cement prices see: https://businessanalytiq.com/procurementanalytics/index/cement-price-index/

References

ACPA and Cemex (2023) Life-Cycle Cost Analysis for Pavements.

Adow, M. A. O., Allotey, S. E., & Sasraku-Neequaye, B. K. (2011). Comparative Cost Analysis between Asphalt Pavement and Concrete Pavement in Road Construction: A Case study using Concrete grade 35. *Civil and Environmental Research*, 7(10), 94-104.

Arcadis (2017) Life Cycle Cost Analysis, Concrete v Asphalt Pavements, report for Cement and Concrete Aggregates Australia.

Bouteillier, C., & Gustafson, W. (2017). Life Cycle Cost Analysis Considerations in Pavement Type Selection in Red Deer and Construction Challenges. In *TAC 2017: Investing in Transportation: Building Canada's Economy--2017 Conference and Exhibition of the Transportation Association of Canada*.

Federal Highway Administration (2023). Lifecycle Cost Analysis, *RealCost* User Manual.

Global Cement and Concrete Association, India (2022). Benefits of Concrete Roads over Bituminous Roads.

Jung, H., Oli, T., Nam, J., Yun, K., Kim, S., & Park, C. (2022). Life-Cycle Cost Analysis on Application of Asphalt and Concrete Pavement Overlay. *Applied Sciences*, 12(10), 5098.

Kumari, M., Gupta, P., & Deshwal, S. S. (2022). Integrated Life Cycle Cost Comparison and Environment Impact Analysis of the Concrete and Asphalt Roads. *Materials Today: Proceedings*, 60, 345-350. https://www.sciencedirect.com/science/article/abs/pii/S2214785322002723

Watson, R., Abbassi, B., & Abu-Hamatteh, Z. S. (2020). Life cycle analysis of concrete and asphalt used in road pavements. *Environmental Engineering Research*, 25(1), 52-61.

3

New Zealand Scenarios

Obtaining a range of data or case studies on relative concrete-asphalt pavement costs specific to New Zealand has proved challenging given that the sector is still nascent in this country.

However, as is evident from the review of international literature, there is a high degree of consistency across countries in the relative (albeit not absolute) costs of concrete versus asphalt pavement. And the relative costs are consistent with the New Zealand data that is available.

One case study is by Opus in 2013 and relates to the Ruakura development (comprising an inland port and related logistics infrastructure) in Waikato.[3] It provides construction costs per square metre for roller-compacted concrete, traditional pumped and formed concrete pavement, and flexible asphalt – both thin and thick. The unweighted mean difference between the asphalt and concrete whole-of-life options is 20% in favour of asphalt, with a maximum of 60% and a minimum of -5% (that is, 5% in favour of concrete). This study did not analyse whole-of-life costs.

Although this range should cover many situations, we caution that relative costs (and even more so absolute costs) can vary considerably by type of terrain, traffic load, ambient temperature and so on.

In the baseline scenario of our previous report the concrete option was 29.4% cheaper than the asphalt option – this assumed a discount rate of 6% and a 40-year horizon. Concrete pavement also had 6% lower construction costs.

From an analytical perspective the absolute costs of the different pavements are irrelevant. Relative costs are what count. For example, if the construction costs for asphalt pavement are normalised to 1000, we need to know the construction costs for concrete pavement relative to that 1000. Similarly, we need to know relative maintenance and rehabilitation costs, and their timing over (say) a 40-year period.

To gain a better understanding of the relative costs of roading technologies in New Zealand, we conducted 20,000 computer simulations taking in plausible variations in the following variables and parameters:

- Relative initial construction costs
- Relative maintenance and rehabilitation costs
- Discount rate
- Time period

What this analysis does is convert the Opus case study into a format where robust cost comparisons can be made between concrete and asphalt roading, over whole of life.

Table 2 below lists the initial values for the costs and their assumed ranges. In each case, a Beta

---

[3] Opus (2013) Ruakura Development Stage 1: Pavement Options Report, for Tainui Group Holdings Ltd.

distribution is assumed,[4] which is symmetric for all variables except for the initial construction costs of concrete pavement, as indicated by the previously cited studies. Every cost is expressed relative to an initial construction cost for asphalt pavement of 1000. For example, in year 21 concrete pavement incurs rehabilitation costs of 28, or 2.8% of asphalt pavement construction costs.

The standard discount rate is 6%, with values of 4% and 8% also tested. The time horizon is 40 years, with 30 years also tested. Further discussion of discount rates was provided in our previous reports.

Note that in comparison to the previous 2013-20 Infometrics reports, but recognising the international findings discussed in Section 2 and the newer data for Ruakura (from 2013), the main difference is that in the base case the construction cost for concrete pavement is assumed to be 20% higher than that for asphalt pavement, rather than 6% lower.

Table 2: Cost assumptions

	Concrete	Asphalt	Range
Construction cost	1200	1000	-250 to +400 for concrete
Average annual maintenance	20	43	±10 for each
Periodic maintenance	13 (every 5 years, beginning year 5)	15 (every 10 years beginning year 5)	±5 for each
Major periodic maintenance		82 (every 10 years)	±10 for asphalt
Rehabilitation	28 (in years 21 & 31)	196 (in year 26)	±5 for concrete ±30 for asphalt

The base case produces a total discounted cost over 40 years for concrete pavement that is 14.0% below the cost of asphalt pavement. If the initial construction cost difference is changed from 20% to -6% (as in the original case study), the difference in total discounted costs increases to 28.4% which is very close to the previous base case.

Figure 1 illustrates the distribution of the discounted cost difference (concrete cost divided by asphalt cost, minus one, as a percentage) from 20,000 simulations, with a discount rate of 6% and a 40-year time period. The associated summary statistics are presented in the top line of Table 3.

All simulations produce a cost advantage in favour of concrete pavement. The middle 90% of the distribution (from the 5th percentile to the 95th percentile) ranges from a 22.9% advantage to an 11.8% advantage. The mean is 17.5% which is higher (absolutely) than the base case value of 14.0% due mostly to the asymmetry in the range of the initial concrete construction cost difference. As shown in Table 2, construction costs for concrete pavement are 20% above those for asphalt pavement, but the range varies from -5% to +60%, so not symmetric.

As expected, the advantage of concrete declines if the time horizon is shorter, as there is less opportunity for the durability of concrete to prove its worth. A higher discount rate has the same effect, as future benefits receive less recognition. At an 8% discount rate, six out of the 20,000 simulations produce a net benefit in favour of asphalt.

---

[4] We may investigate an asymmetric distribution if future data permits.

Figure 1: Distribution of discounted total discounted cost: concrete v asphalt pavement (6% discount rate, 40-year horizon)

Table 3: Results of simulation analysis*

	Base	Mean	5th percentile	95th percentile	% of runs ≤0%
6% and 40 years	-14.0%	-17.5%	-22.9%	-11.8%	100.00%
6% and 30 years	-13.1%	-16.2%	-21.5%	-10.8%	100.00%
4% and 40 years	-19.8%	-24.5%	-30.1%	-18.3%	100.00%
8% and 40 years	-9.2%	-11.6%	-16.7%	-6.2%	99.97%

* Note each row uses a different set of random numbers to draw from the Beta distribution, and each occasion the model is run, a different set of random numbers is used.

Conclusion

Overall, the results demonstrate that the lifetime cost of concrete pavement is less than that for a wide range of different asphalt pavements under a wide range of different relative construction costs, maintenance costs and rehabilitation costs.

Of course, for any potential road pavement project the analysis has to be forward looking. In that case sensitivity analysis would need to encompass projections of future relative prices, implying that cost distributions could look quite different. For example, uncertainty in rehabilitation costs for asphalt pavement 20 years into the future would likely have a wider range than the 15% or so used above, as well as a much higher upper limit if the timing of the project happens to coincide with a period of rising oil prices.

In the next section we look at recent and possible future price trends for Petroleum Products and Non-Metallic Mineral Products.

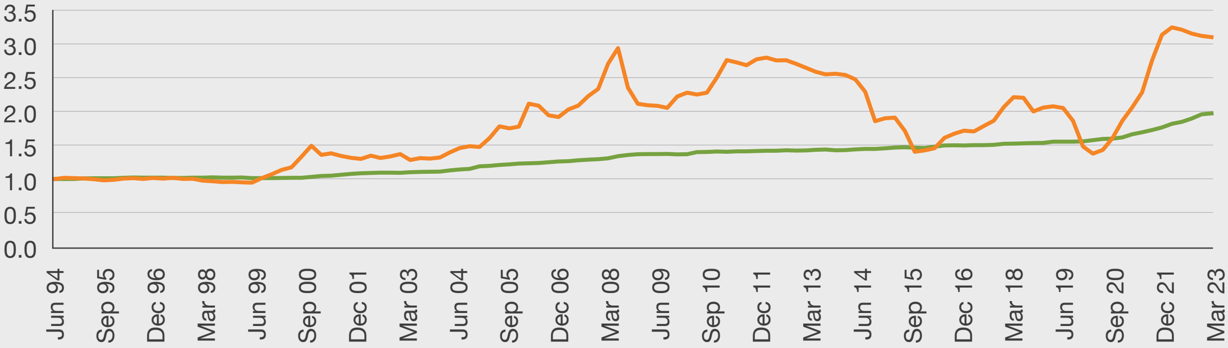
4 Price Trends

Historical Prices

Figure 2 shows the output Producer Price Indices (PPI) for two industries, Petroleum Products, and Non-Metallic Mineral Products (NMMP) manufacturing. These series are likely to be reasonable proxies for the trends in the prices of bitumen and concrete, respectively.

Over the last three decades NMMP prices have risen by an average 2.20% per annum while Petroleum Product prices have increased by 3.05% per annum. That may not seem much, but the compound effect over the time period is 91% versus 145%.

Figure 2: Price trends



However, as is also evident in Figure 2, the calculation of averages hides volatility. The detrended series for NMMP prices has a standard deviation of 4.7% of the mean, compared to 25.1% for Petroleum Product prices.

Some analysts use a higher discount rate to allow for additional volatility in prices, but this is not good practice as a higher discount rate for asphalt pavement lowers the discounted cost of asphalt, thereby encouraging its use. This is a perverse result that rewards greater uncertainty.

Where price volatility exists as an inherent feature, there is also the financial risk this poses to procuring organisations. Depending on the appetite for risk of an affected organisation, there is a premium attached to any management of risk to accommodate price volatility.

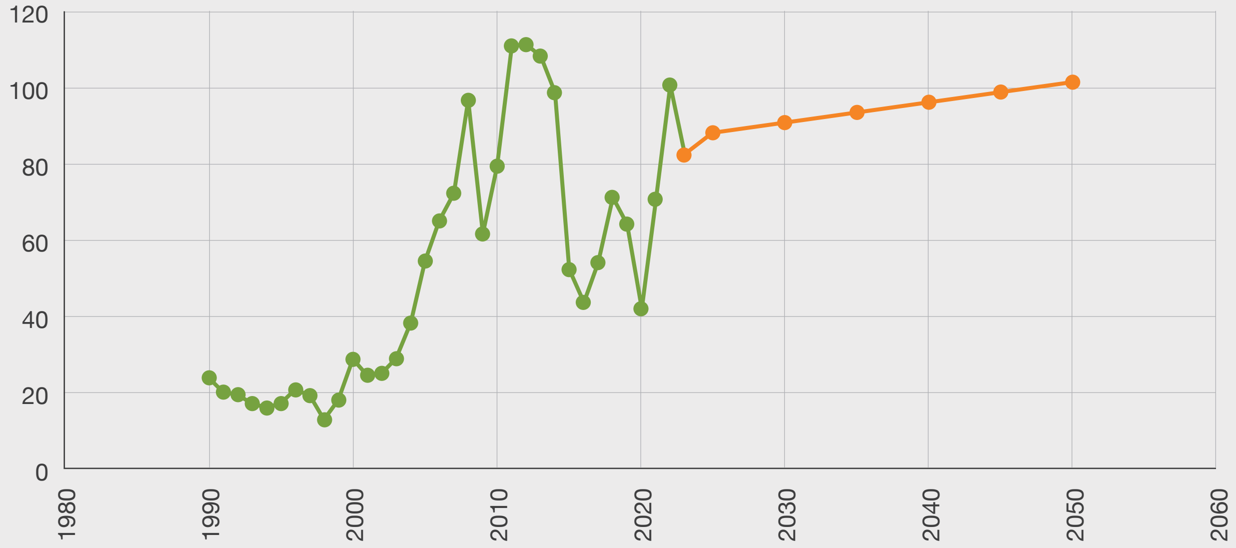
The point is that concrete roading poses significantly less uncertainty in terms of cement prices, than does asphalt in terms of bitumen prices. A further aspect in favour of concrete is that cement is both domestically manufactured and imported, whereas New Zealand has 100% reliance on imports for its bitumen supply, with a corresponding elevated supply chain risk.

Future Prices

We are not aware of any published forecasts of asphalt prices, but as discussed in Section 2, we do expect its price to largely follow changes in the oil price. Figure 3 presents Brent crude oil prices projected to 2050 by the International Energy Agency (IEA).[5] The IEA does not forecast month to month or even year to year volatility. Political conflict, cartel pricing, the uptake of electric vehicles and the marginal cost of supply can create large swings in prices. Thus, all we may infer is that the general trend is slightly upwards – about 0.8% per annum – out to 2050. Continued volatility can be expected around this trend, including from changes in the USD-NZD exchange rate.

With regard to concrete prices, again we fall back on the general PPI output price index for Non-Metallic Mineral Products. As may be seen from Figure 4, the NMMP price index has consistently tracked below the All Industries price index, at 2.2% and 2.5% per annum respectively. Although the last two years have seen an unusual surge in NMMP prices (consistent with general price inflation in the wider economy), we expect a return to the long-term trend of 2-2.5% per annum this year, assuming no major changes in New Zealand's monetary policy.

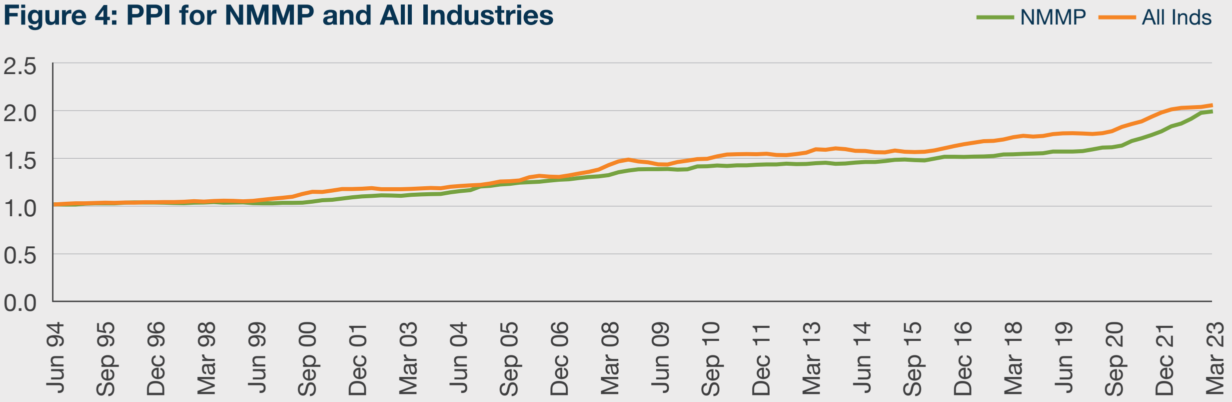
Figure 3: Crude oil price trend projections (USD/bbl)



---

[5] International Energy Agency, *International Energy Outlook 2023*, Reference scenario.

Figure 4: PPI for NMMP and All Industries



Conclusion

Overall, if the IEA is correct, over the long-term future asphalt prices may rise at a slightly slower rate than future concrete prices. In the short term, however; the higher volatility in oil prices than in concrete prices could easily reverse that picture. In other words, it is not possible to forecast with confidence the relative future paths of concrete and asphalt prices.

For evaluation of potential paving projects sensitivity analysis with a number of cost escalation scenarios is highly recommended.

CO_2 Emissions

In our previous report we included the following table from Eupave,[6] showing that over 30 years bitumen and concrete have similar emissions.

Table 4: kt of CO_2e /km (30 years)

	Concrete	Asphalt
Construction	2.1 – 2.8	1.4 – 1.7
Maintenance	0.1 – 0.2	0.9 – 1.4
Total	2.2 – 3.0	2.1 – 3.1

In fact the CO_2 released in the construction and maintenance of roads is much less than the emissions released by vehicles that use the road, but that is irrelevant to an agency that pays for road construction and maintenance.

The Eupave study did not include CO_2 absorption (the natural process of uptake into hardened concrete of atmospheric CO_2) which, as shown by Ferrebee (2023) using figures from the MIT Concrete Sustainability Hub, is significant.[7] The Intergovernmental Panel on Climate Change (IPCC) (2021-2022) states that carbon uptake reabsorbs 15-30% of clinker manufacturing CO_2 emissions, over time.[8] Measured over a 50-year life cycle, including the construction, use, maintenance/rehabilitation and end-of-life phases, carbon uptake produces a net CO_2 advantage to concrete over asphalt of 35% for a local street, 51% for a rural state highway, and 53% for urban interstate highways.

These CO_2 differences are greater than the life cycle cost differences. However, neither the Eupave study nor the Ferrebee study mention discount rates, giving the impression that the numbers are not discounted. That would certainly promote the case for concrete, because of a higher weighting in that event on the costs of road maintenance which penalises asphalt more than concrete.

When the Marsden Point oil refinery was operating it was exempt from the Emissions Trading Scheme (ETS), as it had a pre-existing Negotiated Greenhouse Agreement which obliged it to move to ‘world best practice’ production technology. As refining has ceased that agreement is redundant. Therefore, as long as imported bitumen has no carbon border adjustment tax of the type being promoted by the EU, costs are slightly tilted in favour of asphalt pavement, although the lack of domestic production may raise supply-side risk.

Cement production is subject to the ETS, but had an initial 90% free allocation. Since 2021 this has declined at one percentage point per annum, although changes to how free allocation is calculated may be implemented this year. Absorption of CO_2 by concrete pavement could theoretically assist the industry, but currently such absorption is not recognised within the ETS. However, CO_2 absorption could see its way into government procurement of roading through the Infrastructure Sustainability Council’s (ISC) rating tool for infrastructure sustainability.

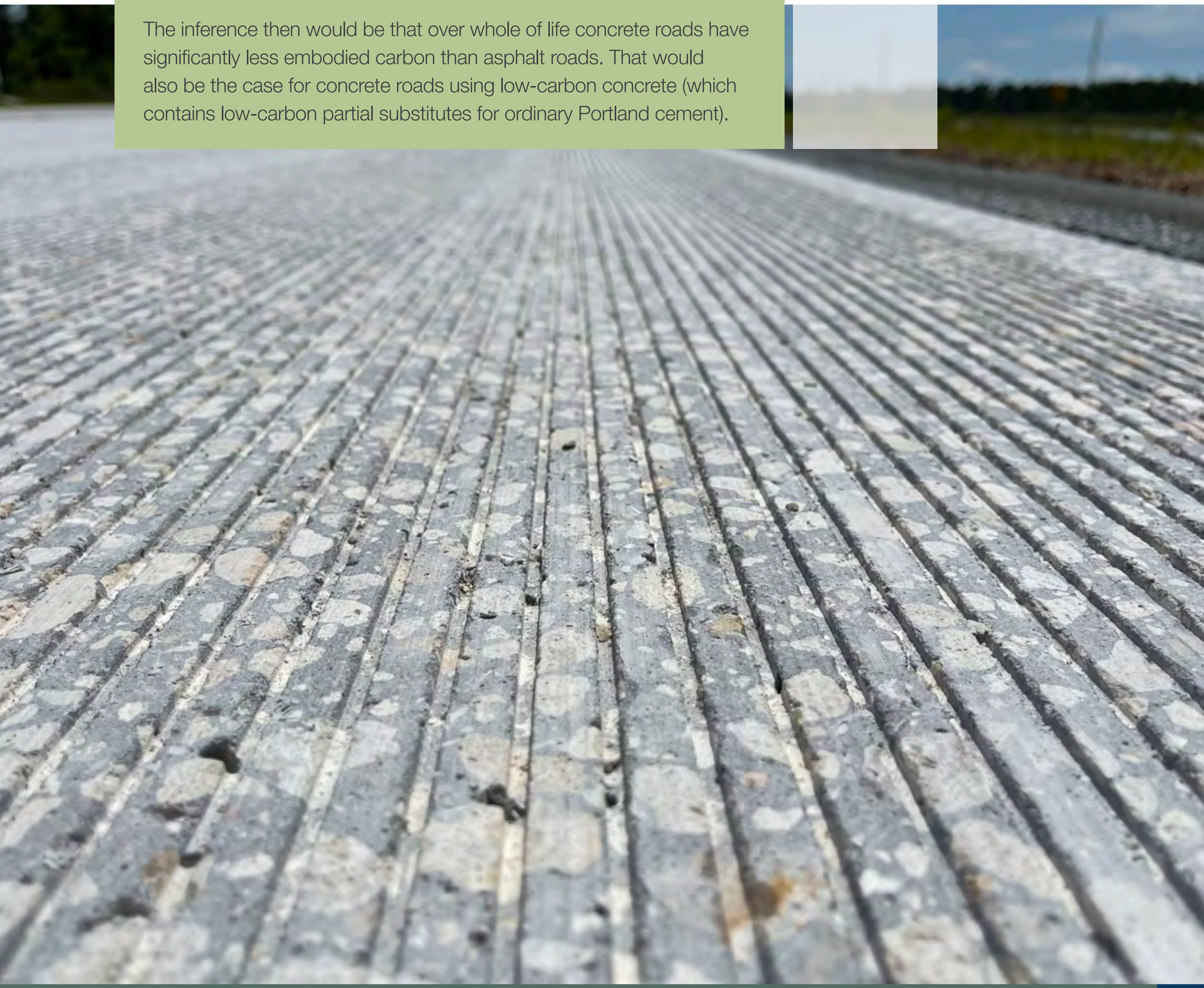
---

6. European Paving Concrete Association (2017). Life Cycle Assessment for Road Construction and Use.
7. Ferrebee, E. (2023). Concrete Pavements and Overlays – A US Perspective on Sustainable Concrete Pavements. Presentation to Future Roads Conference, Hamilton, NZ, November 2023.
8. IPCC 6th Assessment Report (2021-2022).

Conclusion

In conclusion, the CO_2 emissions of constructing and maintaining roads may be more or less equal between concrete and asphalt pavement, at face value, while recognition of concrete's CO_2 absorption potential would present a more accurate comparison.

The inference then would be that over whole of life concrete roads have significantly less embodied carbon than asphalt roads. That would also be the case for concrete roads using low-carbon concrete (which contains low-carbon partial substitutes for ordinary Portland cement).



Infometrics