Epoxy Modified Surfaces

Theuns Henning and David Alabaster | December 2021

Roads are the backbone of any country's economy and community's socio-wellbeing. Sparsely populated regions around the world rely heavily on their roads for the transportation of goods and people. Unbound granular pavements with conventional chip seals are ideal for using local labour and materials. Surfaces require considerable maintenance using appropriately skilled labour, typically every 8-12 years on high volume roads. This makes them less than ideal for Low Income Countries (LICs) with restricted maintenance budgets. Pavements containing asphaltic layers can be designed to require little maintenance over long periods but are expensive to build and still require periodic resurfacing, requiring specialist skills and expensive construction machinery.

Of additional concern with traditional technologies in Africa's LICs is their performance on roads subject to prolonged periods of extreme temperatures since this can lead to bitumen bleeding/tracking down the road and road surfaces being torn apart. Climate change is expected to increase the duration and number of such extreme temperature events in parts of Africa and Asia. This research investigates the feasibility of using Modified Epoxy bitumen in Porous Asphalt (MEAC) and Chip Seals (MECS) which addresses climate related issues with conventional bitumen in asphalt and chip seal. This technology can be used to build unbound granular pavements (locally built with as much or as little labour as desired) with MECS and MEAC which would produce a long-life surfaces with little need for maintenance. It would also need low investment in machinery. Initial research outcomes suggested these surfaces having the potential to last more than 40-years.

This presentation details some early findings from the "Climate resilient sustainable road pavement surfacing (CRISPS)" research programme funded by the UK Aid's High Volume Transport Applied research Programme. The presentation covers an introduction to the Epoxy Modified Bitumen performance from laboratory tests, trials and application to date. It also provides the methodology used for calibrating HDM-4 deterioration models using Long-term Performance Programme data and laboratory results.

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CRISPS

Key Readings

Reading 1: Herrington, P., Alabaster, D., Arnold, G., Cook, S., Fussell, A., & Reilly, S. (2007). Epoxy modified open-graded porous asphalt. *Land Transport New Zealand Research Report 321*. **https://www.nzta.govt.nz/assets/resources/research/reports/321/docs/321.pdf**

Investigations into the cohesive properties and oxidation resistance of an acid cured, epoxy modified open-graded porous asphalt (OGPA) were undertaken and an associated accelerated loading test carried out at Transit New Zealand's CAPTIF facility.

Results from the Cantabro test (a test of mixture cohesion relating to the resistance of OGPA to surface abrasion losses) indicated that the early life cohesive properties of cured epoxy OGPA should be comparable to that of standard OGPA at 25°C and markedly superior at 10°C. The modulus of the cured epoxy mixture was much higher than that of the standard OGPA but this is probably of little benefit given that failure through rutting and deformation is uncommon for properly designed OGPA. The superior oxidation resistance of the epoxy material was clearly evident in Cantabro tests conducted at both 25°C and 10°C.

The CAPTIF trial demonstrated that full-scale manufacture and surfacing construction with epoxy OGPA could be easily undertaken without any significant modification to plant or the necessary operating procedures. Trafficking of the test sections resulted in early signs of surface abrasion in the control section but not in the epoxy. Early life rutting of epoxy mixtures is not likely to be greater than that of equivalent standard materials.

Reading 2: Herrington, P. R. (2010). Epoxy-modified porous asphalt. *NZ Transport Agency Research Report 410*. **https://www.nzta.govt.nz/assets/resources/research/reports/410/docs/410.pdf**

Investigations into the cohesive properties and oxidation resistance of an acid-cured, epoxy-modified open-graded porous asphalt (EMOGPA) were undertaken, and an associated field trial constructed on State Highway 1 in Christchurch in December 2007.

Open-graded porous asphalt (OGPA) specimens were treated in an oven at 85°C for up to 171 days, resulting in oxidation equivalent to approximately 20 years in the field. The modulus (25°C) of the oxidised epoxy mixture (12,000MPa) was also much higher than that of the control OGPA (7800MPa). Results from the Cantabro Test at 10°C indicated that the cohesive properties of the oxidised epoxy OGPA were markedly superior to those of conventional OGPA. On the basis of the Cantabro test results, lifetimes of up 144 years were estimated for an increase in cost of up to 2.3 times that of conventional OGPA. Similarly, the fatigue life of oxidised EMOGPA was found to be more than 25 times that of the control. Epoxy bitumen diluted with up to 75% standard 80–100 penetration grade bitumen had an estimated life of up 93 years for 1.3 to 1.6 times the cost of conventional OGPA. The fatigue life of the oxidised 25% and 50% EMOGPA mixes were similar to that of the control.

The field trial demonstrated that full-scale manufacture and surfacing construction with epoxy OGPA could be easily undertaken without any significant modification to plant or the necessary operating procedures. Epoxy OGPA sections with 20% and 30% air voids were constructed. Monitoring of the trial site for 27 months showed no difference in performance compared with the control section.

Reading 3: Herrington, P. R., & Bagshaw, S. A. (2014). Epoxy modified bitumen chip seals. *NZ Transport Agency Research Report 558*. **https://www.nzta.govt.nz/assets/resources/research/reports/558/docs/558.pdf**

The research investigated aspects of the use of epoxy modified bitumen for construction of chip seals. Changes in the shear modulus, needle penetration and cohesive energy of the epoxy bitumen were used to monitor changes in the material as it cured at 35ºC and 45ºC and after accelerated ageing at 85ºC for 177 days. Wheel-tracking tests were used to determine the ability of the material to resist chip embedment and flushing. The adhesion to aggregate and resistance to water-induced stripping was also measured. Epoxy bitumen curing rates would enable seal construction within timeframes used with conventional binders. However, although the ultimate strength of the materials was satisfactory, the curing rate would be too slow for epoxy bitumens to be useful as a lower cost substitute for commercially available high-friction surfacing binders. Epoxy bitumen demonstrated good resistance to water stripping without added adhesion agents. Epoxy bitumen seals were highly effective in resisting chip embedment into a soft substrate and potentially might be a means of controlling or eliminating flushing in the field. The materials used in this study were prototype formulations that may need to be optimised for low temperature flexibility. Further investigation is needed to properly characterise low temperature behaviour.

Reading 4: ITF (2017). *Long-life Surfacings for Roads*. OECD Publishing, Paris. **https://doi.org/10.1787/9789282108116-en**

This report is the third and final output of a ten-year international research project studying the costs and viability of long-life road pavement surfacings. It describes the results of tests conducted with epoxy asphalt and high performance cementitious materials (HPCM) on real road sections in France, New Zealand and the United Kingdom. The project was initiated to address a growing problem for road administrations and road users: frequent closures of roadways for repairs and repaving as a result of surface pavements that have improved but still barely kept up with increased loads and traffic density.

Reading 5: Jeremy P. Wu, Philip R. Herrington & David Alabaster (2019) Long-term durability of epoxy-modified open-graded porous asphalt wearing course, International Journal of Pavement Engineering, 20:8, 920-927, DOI: 10.1080/10298436.2017.1366764

Abstract

The durability of epoxy-modified open-graded porous asphalt (EMOGPA) was measured against mixes using unmodified 80–100 penetration grade base binder as well as modified binder with 4% Sytrenebutadiene-styrene

(SBS) polymer. Multiple tests were conducted to verify the durability of EMOGPA aged up to 194 days at 85 °C using an OGPA mix design (20% air void) typical of that used in New Zealand.

Generally, the indirect tensile moduli of the mixes improved as the concentration of epoxy bitumen increased. The fatigue life of EMOGPA was significantly better than those without epoxy modification. A modified abrasion test was developed and used to support claims that epoxy bitumen is less prone to oxidative ageing and thus can extend the life of standard porous asphalt. Even with substantial dilution of the binder with standard bitumen (as a potential means of reducing cost), the diluted EMOGPA mix was more durable than the 4% SBS binder mix both in terms of Cantabro loss and fatigue life but the SBS mix did perform better than the 80–100 control mix.

Reading 6: Dinnen, J., Farrington, J., & Widyatmoko, I. (2020). Experience with the use of epoxy-modified bituminous binders in surface courses in England. *Asphalt Professional*, *82*. **https://www.researchgate.net/publication/339229441**

This paper presents some historical showcases on the use of epoxy modified bituminous binders in surface courses in England. The binders comprise typically two components that, when cured, become a two-phase epoxy polymer that contains bitumen extender. The continuous phase is an acid cured epoxy and the discontinuous phase is a mixture of bituminous materials; so practically, it is a thermosetting polymer.

Questions to guide reading

1. What are the design/construction considerations for applying epoxy modified surfaces?
2. What impact can the use of epoxy modified surfaces have on road infrastructure investments?
3. How can the use of epoxy modified surfaces address climate related issues?
4. What is the expected life of an epoxy modified surface compared to traditional surfaces?
5. Where have epoxy modified roads been trialled, and what have been the results?

References

Herrington, P., Alabaster, D., Arnold, G., Cook, S., Fussell, A., & Reilly, S. (2007). Epoxy modified open-graded porous asphalt. *Land Transport New Zealand Research Report 321*.

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ITF (2017). *Long-life Surfacings for Roads*. OECD Publishing, Paris.

Wu J.P., Herrington P.R. & Alabaster D (2019) Long-term durability of epoxy-modified open-graded porous asphalt wearing course, International Journal of Pavement Engineering, 20:8, 920-927, DOI: 10.1080/10298436.2017.1366764

Dinnen, J., Farrington, J., & Widyatmoko, I. (2020). Experience with the use of epoxy-modified bituminous binders in surface courses in England. *Asphalt Professional*, *82*.