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Bio-bitumen – Lignin as a bitumen substitute

WSP1/Round 1 Hoe ki angitū Innovation Fund

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Contact Details

Matt Sharp

WSP
33 The Esplanade
Petone
Lower Hutt 5012
+64 4 587 0600
+64 27 255 3261
matt.sharp@wsp.com

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Prepared by
Matt Sharp, Abhirup B. Roy Chowdhury

Reviewed by
Phil Herrington

Approved for release by
Matt Sharp

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Executive Summary

Introduction

There are currently no sustainable, readily available options to replace bitumen in New Zealand. In the Waka Kotahi research report, Bitumen Alternatives (van den Kerckhof, 2021), lignin, a natural material that makes up about 30% of woody biomass, was identified as a possible long-term solution to this problem but acknowledged that much research is still needed.

WSP NZ has undertaken research and laboratory trials to investigate the feasibility of developing lignin as a bitumen substitute, as part of the Waka Kotahi Hoe ki angitū Innovation Fund, responding to the Round 1 first challenge, "Accelerating the use of recycled materials and sustainable practices".

The research and laboratory trials in this project are a key step in advancing the research and development of a more sustainable, recyclable road binder material which can significantly reduce the carbon footprint of future road surfaces.

Work Undertaken

The objectives of this work were:

1. Source and characterise lignin.

Three lignins were sourced and selected for this research in part due to their commercial availability, differing sources/origins, and processing techniques. For two of the lignins, the exact processes used in their production are proprietary.

	Lignin type and source
Lignin 1	Grass lignin (miscanthus) – proprietary process Netherlands
Lignin 2	Wood lignin (pine) – kraft process Finland
Lignin 3	Wood lignin (pine) – proprietary process New Zealand

The physical and chemical properties of the lignins were characterised by molecular weight, particle size analysis, and thermogravimetric analysis.

2. Evaluate lignin performance in bitumen.

The three lignins were blended into an M01-A conforming 80-100 penetration grade bitumen binder. Blends in which up to 30% of bitumen was replaced by the sourced lignin were produced using high shear mixing. The lignin-binder performances were evaluated through:

- a. Softening point, penetration, storage stability testing
- b. NZTA M01-A rheological tests – Viscosity, rutting factor, creep
- c. Investigation of the rheological performance as a function of temperature

3. Review environmental and economic impacts of lignin in bitumen.

The expected environmental and economic impacts in using lignin as a bitumen replacement were estimated through a review of publicly available information and literature, both domestic and international.

Key Findings

- The three lignins sourced and used in this work exhibited different characteristics and performances in testing, demonstrating the importance of understanding and fully characterising the lignin being used, and that lignins from different sources cannot necessarily be used interchangeably in road surfacing applications.
- The importance of not heating certain lignin above specific temperatures to avoid thermal degradation. This has important practical implications for use and handling of lignin-bitumen blends and may act to limit the ultimate lignin concentration possible.
- To fully integrate the lignin into the bitumen binder, 15 minutes of high shear mixing at 2000 rpm at 130-140 °C was required. This may have practical implications for use at industrial scale.
- Several rheological tests from the performance-based specification for asphalt binders, NZTA M01-A, were conducted on the lignin-bitumen blends. Eight of the nine blends tested met the performance test requirements of the specification.
- Replacing increasing amounts of bitumen with lignin was found to:
 - improve the pavement deformation resistance factor at every temperature for all lignins tested.
 - increase the viscosity, reduce the penetration value, and increase the softening point of the binder for all lignins tested.
 - increase the stiffness of the binders making them possibly susceptible to fatigue cracking at intermediate temperatures.
- Accurate estimates of the costs and benefits for the use of lignin as a bitumen replacement in New Zealand were difficult to quantify due to the lack of publicly available data and literature specific to New Zealand. A cradle to grave life-cycle analysis for local lignins are required and a high-level desk study can then be undertaken to estimate the economics of lignin use in New Zealand bitumen. Despite this, it appears highly likely New Zealand would benefit from the use of lignin as a replacement for bitumen based on a review of the international literature.

Outcomes

Support from the Hoe ki angitū Innovation Fund has enabled this successful investigation into the use of lignin as a bitumen replacement. The work has demonstrated it is feasible to easily blend lignin in quantities up to 30% and shown lignin to be a viable substitute for bitumen based on performance testing. This work has significantly advanced the process to ultimately develop a binder with 100% replacement of bitumen with lignin.

Next Steps

Since the completion of this project (as of 11 March 2024), WSP NZ has:

- Disseminated these results through the National Pavements Technical Group (NPTG) Research subcommittee.
- Prepared a research paper, accepted for presentation and publication at the 8th International Conference of Bituminous Mixtures and Pavements (ICONBMP) in June 2024.

- Begun research into understanding the interaction between bitumen and lignin, supported by the Ministry of Business, Innovation and Employment's Endeavour Fund research programme, Sustainable Biomass Replacement of Bitumen.
- Assessed the performance in asphalt of a new lignin source for a local supplier.

For this innovation to be implemented at a commercial scale, it will also be necessary to:

- Conduct laboratory and NZTA CAPTIF Road Research Centre (Canterbury Accelerated Pavement Testing Indoor Facility) performance testing of lignin-modified asphalt and chip seal.
- Conduct research into
 - correlating lignin performance testing with further material characterisation
 - modifying the lignin to increase bitumen replacement capacity
 - investigating emulsification potential for chip sealing application
- Life-cycle analysis of New Zealand-specific lignin.
- Field trials of best-performing 30% lignin blends with bitumen.

WSP plan to continue this research and development with industry support.

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