



The Association of Directors of Environment, Economy, Planning & Transport

ADEPT Soils and Materials Group Design and Specification Panel

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The use of Bio-based binders in Asphalt - An introductory note

Introduction

Many suppliers of asphalt are now marketing bio-based binders to reduce the carbon footprint of the asphalt mix, the majority of which results from the bitumen binder.

A bio-based binder is one where a percentage of material derived from biomass is mixed with harder grade of penetration grade or polymer modified bitumen, to create one with similar properties to the same grade as one without the bio component, as defined by the European Standard.

The source of the bio component and percentage added is usually commercial in confidence. It can vary from negligible to >50%.

The bio component is not bitumen so in order to comply with these standards, it is classed as an additive, but the standards make no reference to additives and what percentage might be permissible. Discussions with producers indicate a maximum of 10% of additive may still be acceptable. This document starts with Specification recommendations for Local Authorities and then describes the current state regarding binder specifications, trials and usage.

Specification recommendations

It would be reasonable to ask for a bio-based binder to comply with BS EN 14023, but with an additional requirement for results after Pressure Ageing [PAV] by appending a data sheet to Appendix 7/1. These tests simulate the effect of short and long-term ageing.

The product should be similar to one of the same properties without the biomaterial. Once done, fingerprinting can be used to simplify test requirements. It should demonstrate the fact that the bio-based binder is the same as conventional material without the bio-genic component.

It is strongly recommended that the asphalt is specified with low void content <5% and a binder-rich mix. Except on high-speed roads, surface courses should have a low texture depth preferably <0.7mm [Patch]. This will minimize the ageing by oxidation in the body and on the surface of the layer leading to premature ageing.

Current position

Over the years suppliers of asphalt have used additives for a number of reasons but primarily to reduce the cost of production. This may include any of the following:

- by substituting the bitumen with cheaper alternatives such as recycled plastic or tyre rubber, both otherwise might be wasted
- by the use of a warm mix additive to reduce mixing temperatures
- by the use of planings in RAP which contains bitumen and locally produced aggregate reducing transportation.

Evidence of how these additives might affect short-term and long-term performance is not always obvious.

The use of PMB can significantly increase material and installed cost but evidence of their use for over 30 years in HRA and SMA has demonstrated their benefit in Whole Life Cost, particularly on heavily trafficked roads and urban streets.

Biogenic components add significantly to the cost of the binder, the extra cost depending upon the biomass used. This can only be justified if the carbon saving as performance is not yet proven.

It should be noted that the benefits of PMB were much larger in the early days when QC at plants and on-site were more rigorous. Supervision is always higher with innovations. NH has a simpler task with straightforward sites and large volumes of material. LA sites are clogged with ironworks criss-crossed with SU trenches and much smaller volumes of material are laid. This makes consistent quality very hard to maintain. Clients are recommended to have a knowledgeable presence on site when bio-based binders are being used.

European Standards for binders

The standards consist of specifications based upon traditional test methods for bitumen. Work on performance tests is ongoing, but delays within the Commission mean any changes are well into the future.

BS EN 12591:2009 Bitumen and bituminous binders — Specifications for paving grade bitumen.

Paving Grade Bitumen is characterized by Penetration and/or Softening Point with Viscosity also measured. Given the wide range of bio additives, with widely different properties, these three are sufficient to fully determine the suitability of these for blending nor the performance of these new [to UK] binders in-service. They have been used for some time in Australia, Netherlands and Scandinavia; in the latter, softer binder grades are commonplace so a greater percentage of bio component can be used.

In the UK, 40/60 pen and 100/150 pen are the two most commonly used grades of binder. A harder grade 30/45 has been available but is rarely used as it has led to problems in-service. EME 2 uses a hard Paving Grade binder to BS EN 13924.

Currently no bitumen supplier is marketing Paving Grade Bitumen with a biogenic additive; but it may be being added at the plant. It is also most likely to be present in RAP especially in the future.

BS EN 14023:2010 Bitumen and bituminous binders - Specification framework for polymer modified bitumens [PMB]

This is a framework standard with a long list of mandatory and optional tests to characterise the bitumen including cohesion and drop in softening point after RTFOT. The base bitumen for a PMB has to be consistent and suitable for blending with the polymer. These are also essential for use with the biogenic component.

The two parameters quoted by the suppliers are Penetration range and Softening Point. A typical PMB might be designated 75-130/75. Since an unmodified Paving Grade binder with this penetration would have a Softening Point of around 40 C, this gives an indication of the effect of the polymer.

The liquid biogenic component additive is helpful in enabling the polymer to combine with the bitumen. Shell market CarbonSink, Nynas Nypol RE103 and TotalEnergie Styrelf. These currently have the biogenic component as a modifier with ≤10% added.

PMBs are widely used in surface courses as they can provide excellent rut and crack resistance, and remain workable.

Installation trials

Bio-binders fall within the scope of a range of lower-carbon initiatives NH are currently trialling within asphalt surfacing. An update on progress on this work will be published in this year's IAT Yearbook, and the project is scheduled for completion in 2026

Tarmac carried out a trial with CarbonSink [which contains Tall Oil] on the A64 with National Highways (NH). Heidelberg has both Shell and Nynas products on trial for NH on the A30 and with Shell on the A2 and A34. These are still being monitored with the report due in March 2026. Nynas RE 103 and TotalEnergie Styrelf Bio10 (containing 10 bio component) are on trial with Transport Scotland. Holcim had a trial on the A590 for Rotherham using Lignin in XYLOBind. These have been covered in the press.

As part of a Live Labs 2 project in the West Midlands, partnered with the Centre of Excellence for Decarbonising Roads (CEDR), the following low carbon technologies are being trialled:

- Graphene-enhanced asphalt – using graphene-modified binders to extend pavement life and reduce maintenance needs
- Polymer-modified biogenic binders – incorporating bio-derived components to reduce
- Lignin-enhanced asphalt – partially replacing bitumen with lignin to reduce embodied carbon and improve resistance to ageing, oxidation, heat and UV exposure
- Carbon-negative aggregates and biochar – used within recycled and cold-bound materials to offset emissions and deliver near-zero carbon performance.

Further information on the results of these trials will be made available. However, it is recognised that the trials can assess carbon, mixing and laying issues, but cannot provide information about durability

Biogenic components

There are two types of biomaterials; liquids and granulates.

The liquids are the result of processing vegetable matter into an oil/resin. The two most commonly used are lignin and Tall Oil Pitch. Lignin is a complex organic polymer which provides flexibility to trees and grasses. It is a by-product of paper production and there is a big supply since 20% to 30% of a tree is lignin. It is only partially soluble in bitumen and is very absorbent. This causes a very dry mix and some issues with analysis. It contains antioxidant compounds (phenolics) that may reduce oxidative ageing of bitumen. Tall Oil Pitch is made by distilling the tall oil which is the byproduct of sulphate pulp mill, contain lower boiling alcohol, ethers and palmitic acids. Also available is biogenic material made from the pyrolysis of food waste, insects, new and recycled vegetable and engine oils and cashew nutshell, the last has been used in an installation by Aggregate Industries (AI). There are competing uses for these products e.g. biofuels, which affects availability and price.

All these products have a softening effect on the base bitumen and higher percentages affect the adhesion to the aggregate, which can be rectified with an adhesion agent. These blends are supplied by the bitumen supplier. They may be blended at the plant, which necessitates a capital cost and considerable technical and chemical expertise as not all bitumen's are suitable for blending and a consistent source of quality bitumen. Chemical analysis generates a fingerprint for the binder which can reduce subsequent testing. If RAP is a significant component, it is essential that a consistent RAP stockpile of known binder characteristics is available; this is much easier on Strategic Route Network (SRN) sites, this may be difficult to achieve for small volumes from urban areas.

Biogenic products enhance/replace the aromatics lost during manufacture or through ageing. A primary use is with RAP as the aggregate/bitumen source where the biomaterial acts to soften the aged binder and act as a rejuvenating agent. As the product is added with additional binder and RAP at the plant the cooler temperature for RAP should mean less volatiles are lost and incorporation will be much more effective than for example, sprayed rejuvenation in-situ.

The retention of modifying properties during mixing and laying can be measured; the effect long - term is unknown at present, a matter of considerable concern to a number of engineers. The current consensus is that they do show differing ageing behaviour to those that are petroleum based, with some ageing quicker but It is very dependent on biogenic source and addition rates, which is why knowledge of these is important. It is essential for any reasoned judgment about whole life costing, but very difficult with highway materials as the life cycle is so long and accelerated testing not definitive.

In an asphalt one would expect the modifiers to enhance low temperature performance and fatigue life but reduce rut resistance as they soften the bitumen. Appropriate addition of polymer can counteract the latter.

Granulate biogenic materials do not modify the bitumen but act as stiffening fillers and aggregate replacement. They include carbon black and biochar [ACLA], the latter being double price of the bitumen it replaces. Graphene is also very expensive but it enables a thickness reduction; this could help cost reduction and still provide a carbon saving. They should not affect the durability of the bitumen.

Environmental benefits

Bitumen is derived from a limited resource, and so whilst energy is used in the refining process it is not (usually) burnt, and therefore does not contribute significantly to global warming. Bio additives have to be processed and take up agricultural space that could be used for growing food, so it is not a simple sum.

A bio-based binder with lignin has an Environmental Product Declaration [EPD] showing about – 1.97 tonnes CO₂ per ton of lignin (thanks to biogenic carbon storage). This directly cuts the asphalt's embodied carbon. Typically 0% is incorporated into the bitumen.

A bio-based binder with 8.5% of Tall Oil Pitch reduces the carbon footprint of the bitumen by about 250 kg/t, [5.0% binder content], which equates to 13 kg/t reduction in the asphalt carbon footprint. Based on a single surface layer - 50mm depth, 3.5m wide and 5% binder content, this equates to 6t of CO₂e locked per km of road. The additional cost is: £12-15 per tonne of asphalt or about £6000 on the contract. Only the Client can decide if paying £1000 per tonne CO₂e saved is worth it.

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