ADEPT
Association of Directors of
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The use of bio-based binders in asphalt: Introductory Note

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1. Introduction

In recent years, there has been increasing interest in incorporating non-petroleum products into bitumen and bituminous binders in order to reduce the carbon footprint. Many of these materials are of natural origin (i.e. they are sourced from plant or animal species) and have been described as biomaterials or biogenic materials. Others may be generated from waste streams, such as waste food or used cooking oils. Many suppliers of asphalt are now marketing bio-based binders to reduce the carbon footprint of the asphalt mix, some of which results from the bitumen binder.

A bio-based binder is one where a percentage of material derived from biomass is mixed, in the majority of instances, 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 relevant European Standard for the product.

The source of the bio component and percentage added is sometimes deemed to be commercial in confidence by the supplier. It can vary from negligible to >50%.

In Whole Life Cost and Whole Life Carbon terms, the resulting asphalt mixture must not have its performance compromised. The binder plays a key role in this, as it slowly hardens or changes its properties in the presence of oxygen and UV light.

However, the role of the binder in the durability of the asphalt layers and hence the pavement asset is only one factor in achieving a durable pavement. Other factors include the pavement thickness design and materials' specifications, the mix design and manufacture the quality of installation itself, not forgetting any ongoing maintenance. The Client is primarily interested in the installed asphalt and the consistency of its performance.

This document starts with Specification recommendations for Local Authorities and then describes the current state regarding binder specifications, trials and usage.

2. Terminology

The use of "bio-based" gives no indication of the biomaterial content however the Eurobitume document "Recommended Terminology for Biomaterials in Bituminous Binders" (Ref 1) uses the following:

- Bio-modified binder – binder in which less than 10% of bitumen is typically replaced by bio-based material.
- Bio-extended binder - binder in which 10-75% of bitumen is typically replaced by bio-based material.
- Bio-replacement binder - binder in which more than 75% of bitumen is typically replaced by bio-based material.

3. Specification recommendations

Bio-based binders are supplied ready blended either to comply with BS EN 14023 (Ref 2), incorporating a PMB binder or to BS EN 12591 (Ref 3) with paving grade bitumen. These automatically include a range of tests including RTFOT for short term ageing during manufacture and laying. It is recommended that an additional requirement is requested for results after Pressure Ageing [PAV] which assesses longer term ageing.

After testing the product should be similar to one of the same properties without the biomaterial. It should demonstrate the fact that the bio-based binder is the same as conventional material without the bio-genic component. Wherever possible asphalt performance testing needs to be considered and preferred.

Once accepted, suppliers conduct routine quality control [QC] testing and can provide a Declaration of Performance certificate to give users the confidence that the material is not changing over time from that initial testing. QC tests should be appropriate to identify the contribution of the bio-component.

The Client should ask the material's supplier for details of the composition of the bio-binder and the percentage replacement.

The resulting mixture should, comply with BS EN 13108 (Ref 4) for the appropriate mix designation: Asphalt Concrete [AC], Hot Rolled Asphalt [HRA] or Stone Mastic Asphalt [SMA]; it may be a proprietary mixture or comply with PD 6691 (Ref 5).

Where the bio-component is added at the asphalt plant, the additive may or may not blend with the bitumen so compliance with the European Standards for the binder is not pertinent, but the mixture should still comply with the mixture standards as above. This method of production requires considerable technical expertise of the material supplier to develop and maintain the mixture quality and careful monitoring of the properties of constituents throughout the process.

An Environmental Product Declaration [EPD] provides details about the performance and carbon emissions generated by a product at each stage in its lifecycle, including the extraction and processing of raw materials, transport of raw materials to production site, manufacturing, transport to customer site, installation and then end-of-life and recycling stages. The methodology is set out in BS EN 15804 (Ref 6). It effectively combines the calculated environmental impacts, including Global Warming Potential [GWP], of the components used and the operations involved in the life cycle.

Specifiers are strongly recommended to ask in their contracts for the EPD of the materials used. It will typically only at this stage cover stages A1-A3, i.e. cradle-to-gate. An EPD requires a Product Category Rules (PCR) standard which does not yet exist for the UK. However, one is in existence produced by Transport Infrastructure Ireland [TII]. An example is given in the Asphalt Yearbook [Ref 7b].

In order to achieve a long life after installation, it is strongly recommended that the asphalt is specified with low void content of <5% and a binder- rich mix. The latter increases the carbon footprint and the product cost. This may require a proprietary mix design rather than one complying with PD 6691.

An asphalt layer, whether with bio-based binders or otherwise, deteriorates by the effect of oxygen and water on the binder in the body and in addition, UV light, on the surface of the layer on high-speed roads, surface courses, having a dense layer with a low texture depth, preferably <0.8mm,

measured by Volumetric Patch Test, will minimise the ageing which leads to surface deterioration.

4. Current position

The use of PMB can increase initial material and installed cost and carbon footprint but evidence of their use for over 40years in HRA and SMA, has demonstrated their benefit in Whole Life Cost and Whole Life Carbon Cost, particularly on heavily trafficked roads and urban streets.

Bio- components can add to the initial cost of the binder, the extra cost depending upon the biomass used and on the concentration. This can only be justified by the whole life carbon saving if service life is not negatively affected. Currently long-term performance is still to be proven and laboratory testing only gives an incomplete picture.

It should be noted that the benefits of trials may not be reflected in routine works where workmanship is less tightly controlled. Supervision is always higher with innovations, to identify issues and minimise the risk. National Highways (NH) has a simpler task with straightforward sites and large volumes of material. Local Authority (LA) sites are clogged with ironworks criss-crossed with Statutory Undertaker (SU) trenches and generally much smaller volumes of material are laid. This makes consistent installed quality hard to maintain.

Clients are recommended to have a knowledgeable presence on site, especially when new products, such as mixtures incorporating bio-based binders, are being used, and to only use installers certificated to NHSS 16 which contains requirements for operative competency.

5. 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 European Commission mean any changes are well into the future. Notwithstanding it is hoped to have a voluntary standard in 2028.

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

In the UK, 40/60 pen and 100/150 pen are the two most commonly used paving grades of bitumen. A harder grade 30/45 is available but is rarely used. EME 2 uses a hard Paving Grade binder to BS EN 13924 (Ref 8).

Paving Grade Bitumen is currently characterised in the standard by Penetration and/or Softening Point and short-term ageing, with Viscosity along with other tests also being measured. Given the wide range of bio-based products, with widely different properties, these tests are not sufficient to fully determine the suitability of these products for blending, nor the performance of these new [to UK] bio-binders in-service. They have been used for some time in Australia, Netherlands and Scandinavia; in the latter, softer binder grades are commonplace in mixtures, so a greater percentage of the bio component can be used.

Paving Grade Bitumen with a bio-based product is available from major bitumen suppliers. The resulting bio-based binder should comply with the testing requirements in the European standards for Paving Grade bitumen of the same grades.

Alternatively, the bio-based product may be added at the asphalt plant. However, it is not then possible to check for compliance with BS EN14023 or BS EN 12591.The resulting mixture should comply with the relevant European Standard.

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

This is a framework standard with a lengthy list of mandatory and optional tests to characterise the bitumen including cohesion and an increase in softening point after the RTFOT ageing test. The base bitumen for a PMB has to be consistent and suitable for blending with the polymer. These requirements are also essential for use with the biogenic component. Binders containing biofluxes and biopolymer materials would comply with the requirements of this standard.

The two parameters quoted by the suppliers are Penetration range and Softening Point. Various PMBs are available and a commonly used 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.

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

Relevant current specifications and standards for both binder and mixtures should be used to control the use of such materials together LA provisions.

6. Bio-based products

There are two forms of bio-based products; liquids and granulates.

There are various bio-based binders on the market such as those currently available from Shell (Ref 9), Nynas (Ref 10) and TotalEnergie (Ref 11) for example binders.

The liquids are the result of processing vegetable matter into an oil/resin. The two most commonly used are lignin and Tall Oil Pitch. The latter is used by suppliers to produce a pre-blended bio-binder. The liquid in the bio-modified binder may be helpful to enable the bio-component to combine with the bitumen.

Tall Oil Pitch is made by distilling the tall oil which is the byproduct of sulphate pulp mill, containing lower boiling alcohol, ethers and palmitic acids.

Lignin is a by-product of paper production and there is a large supply since 20% to 30% of a tree is lignin and is often considered as waste. It is a complex organic polymer which provides flexibility to trees and grasses. There are multiple types, dependent on the processing, and this affects the optimal addition to the bitumen. It is added at the asphalt plant either as a powder/pellet or dissolved in a light oil carrier. It is only partially soluble in bitumen to form a bio-based binder and is very absorbent.

Its use necessitates a capital cost and considerable technical and chemical expertise, a consistent source of quality bitumen, and not all bitumens may be suitable for this purpose. Chemical analysis generates a fingerprint for the modified binder which can reduce subsequent testing.

Lignin causes a very dry mix and as a bio-based binder, some issues with analysis. It contains antioxidant compounds (phenolics) that may reduce oxidative ageing of bitumen and hence the material made with it.

Notwithstanding, widespread adoption faces several challenges, including brittleness at low temperatures, inconsistent research data, issues for the use in asphalt plants, possible risk of

inconsistent mix quality and limited long-term performance data.

Also available is biogenic material made from the pyrolysis of food waste, insects, new and recycled vegetable oils and cashew nutshell, the last, has been used in an installation by Associated Asphalt. Pyrolysis residues need to be considered carefully with regard to carbon footprint and regulatory status. There are competing uses for these products e.g. biofuels, which affects availability and price.

These liquid products have a softening effect on the base bitumen and at higher percentages can affect the adhesion to the aggregate which can be rectified with an adhesion agent. The bitumen supplier delivers a quality assured product containing the bio-component as discussed in Section 2.

Bio-based products can enhance/replace the aromatics lost during manufacture or through ageing. A primary use is with Recycled Aggregate Product (RAP) as the aggregate/bitumen source where the bio-binder combines to soften the aged binder and function as a rejuvenating agent. As the bio-binder is added with the 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.

Where 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 of RAP from urban areas.

The retention of modifying properties during mixing and laying can be measured; the effect on the asphalt layer long-term is still under investigation and a matter of concern regarding long term properties. The current consensus is that bio-based binders do show a 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. Long term performance in-service is essential for any reasoned judgment about whole life costing, but prediction is difficult with highway materials as the life cycle is so long and accelerated testing is not definitive. It is one of the deliverables from the NH trials. [See Section 9].

As the bio-component will soften the bitumen, one would expect the resulting bio-based binder to enhance low temperature performance and fatigue life of the asphalt but reduce its rut resistance. Appropriate blending and mix design, perhaps with the addition of a polymer, can counteract the latter.

7. Other components

There are other components that, although not bio-binders, can be used to reduce the embedded carbon in an asphalt mixture. These are added at the plant as pellets or powders.

They do not modify the bitumen to create a bio-binder, but function as stiffening fillers and/or an aggregate replacement in the mixture. They include carbon black, graphene and biochar and are usually categorised as additives. However, they have a similar aim in that they can reduce the 'carbon footprint' of the mixture.

Biochar is defined by UK Biochar Research Centre (UKBRC) (Ref 12) as the solid material obtained from the thermochemical conversion of biomass [Ref 1] in an oxygen-limited environment; the latter being double price of the bitumen it replaces. These materials should not affect the durability of the asphalt.

8. Mix design

Where the binder is supplied pre-blended, it will be provided with extensive test data. The blend will normally be manufactured to mirror an unmodified paving grade bitumen or PMB. When used with primary aggregates the standard mixes, as given in PD 6691, or the asphalt manufacturer's proprietary recipe, may be used and the standard performance related tests reported.

When used with recycled aggregate, the Penetration and Softening Point of the binder contained in the RAP must be determined. Other information and/or test data from various sources may also be used to assess suitability. If a goodly stockpile of RAP is available, evaluated and approved, such as may be the case on a NH maintenance contract, it may be possible to order a suitable pre-blended binder product to give the required performance. Where the data on the RAP is variable, this does give the technical staff at the plant significant binder blending problems perhaps needing both unmodified and modified binders to be added at the asphalt plant.

Where additives are used, rather than a pre-blended binder, this adds significant technical complexity to the mix design process as different lignin products have a different effect on the bitumen, and a liquid carrier will soften the binder in the RAP.

9. Installation trials

Bio-based 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 has been published in the IAT Yearbook 2025 (Ref 7), and the current phase of the project is scheduled for completion in 2026.

Tarmac conducted a trial with Shell CarbonSink 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 are on trial with Transport Scotland. Holcim had a trial on the A590 for National Highways using a lignin-based composite bio-binder Xylobind (Ref 13) with the lignin added at the plant as a powder. 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), low-carbon technologies to produce mixtures are being trialled. This includes the use of a bio-based binder as described below:

- Polymer-modified biogenic binders – incorporating bio-derived components to reduce reliance on fossil-based bitumen and lower whole-life carbon.
- Lignin-enhanced asphalt – partially replacing bitumen with lignin-based composite pellets or as a powder, to reduce embodied carbon and improve resistance to ageing, oxidation, heat and UV exposure.

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.

10. Environmental benefits

The binder in an asphalt mixture is a significant source of carbon as bitumen is a hydrocarbon manufactured from crude oil.

The use of bio-based binders makes an important contribution to the overall initial carbon footprint of the installed asphalt layer as shown in Figure 1, up to 20% in the case of the NH A30 trial.

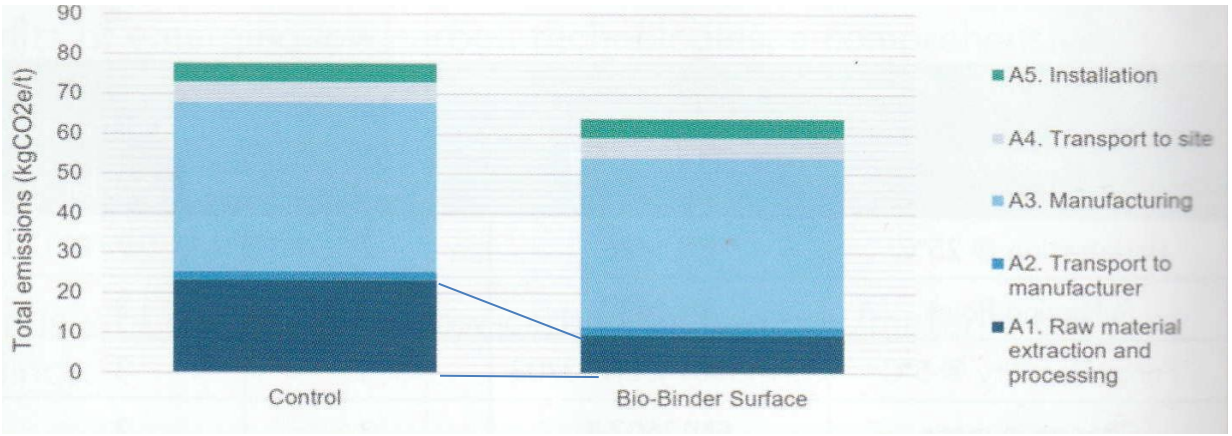

Figure 1 Total Carbon emissions from installed material (Data from A30 NH trial length)

The carbon reduction of a bio-binder is based upon a cradle–to-gate calculation [EN 15804 A1- A3] and this information is available from the suppliers. The MPA website [REF 11] gives more information.

The carbon footprint [A1] of a binder is a combination of the energy used in the refining process as well as the intrinsic hydrocarbon content. In the case of bitumen, the latter is very high, in the bio-component it is nil, or even negative if it can absorb CO_2.

The intrinsic carbon value of the binder does not contribute significantly to global warming; however, the crude extraction, refining/processing and transportation costs do. In addition, bitumen is derived from a limited resource and whilst there is limited refining capacity, supply is not currently at risk.

Bio-additives come from infinitely renewable sources. These must be processed, and if not made from trees or vegetation cuttings/prunings will utilise agricultural space that could be used for growing food, so it is not a simple sum.

As an example, a bio-based additive using lignin has an Environmental Product Declaration [EPD] showing about – 1.97 tonnes CO_2 per ton of lignin *(thanks to biogenic carbon storage).* This directly cuts the asphalt's embodied carbon.

A further example is that a bio-based binder, with say 10% 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 carbon locked in the asphalt. Based on a single surface layer - 50mm depth, 3.5m wide and 5% binder content, this equates to 6t of CO_2e locked as biogenic carbon per km of road. The additional cost could be in the range of £12-15 per tonne of asphalt or about £6000 on the contract.

11. Summary

Specifying the use of a bio-based binder in an asphalt, or other additive component can make a contribution to the overall carbon reduction of an asset when used to renew or maintain the highway.

The binder suppliers' and asphalt manufacturers' quality control procedure and the EPD give confidence that the supplied mixture will provide the claimed carbon footprint. Clients should ask for this and note that it is more difficult with products added at the asphalt plant.

Work is ongoing on suitable laboratory tests and monitoring of field installations to give specifiers increased confidence in long term performance. Test data should be provided for approval purposes.

Only the Client can decide if paying the significant cost per tonne CO_2e saved is worth it. It could be wasted if the material is used inappropriately or poorly installed, as these have significant effect on durability and whole life costing.

NB The subject of this document is at a time of change and ongoing development hence it will be updated as necessary.

ADEPT SMDS Group March 2026

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