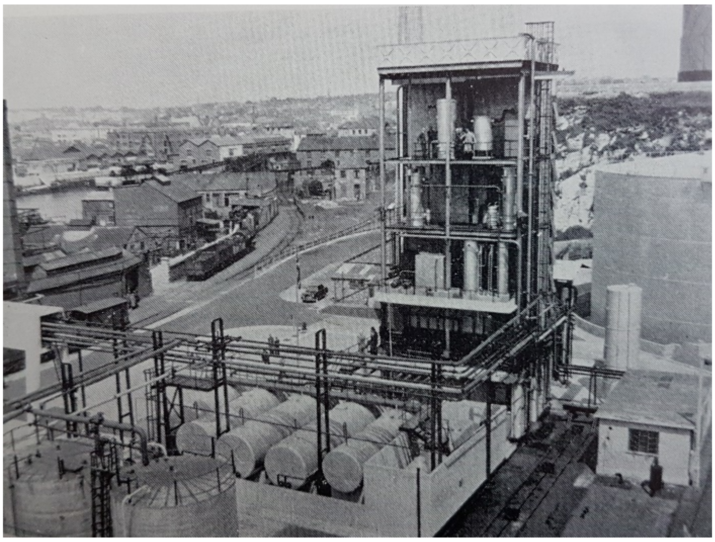
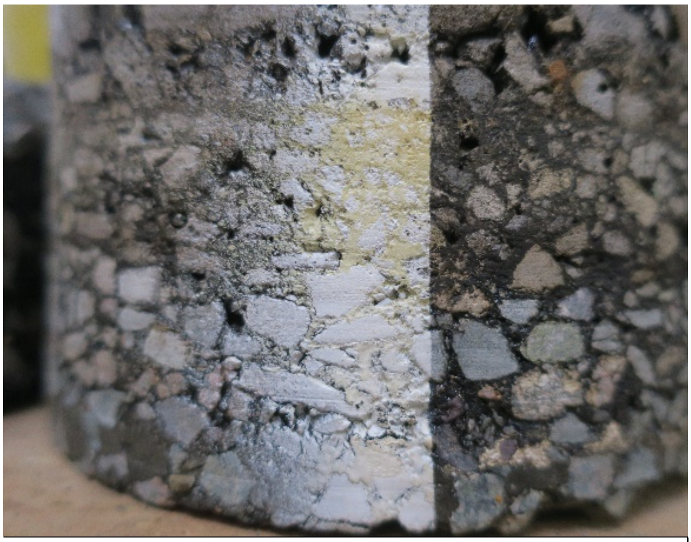
MANAGING RECLAIMED ASPHALT
HIGHWAYS AND PAVEMENTS

An ADEPT & Construction Demolition Waste Forum Guidance Note

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

Construction Demolition Waste Forum





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Contents

1.0 Introduction

This document supersedes the January 2016 version of this document, which is now withdrawn.

This guidance note is intended as an aid to classifying and reusing arisings from bituminous bound road materials. The main aim is to reduce the amount of hazardous, or non-hazardous, waste being sent to landfill, or even for incineration, and allow industry to reuse as much of this valuable material as possible.

The guidance outlines requirements and recommendations for sampling and testing strategies in order to correctly identify the arisings as product wherever possible.

The guidance explains who holds a Duty of Care in relation to arisings from roadworks.

If there is insufficient information on the nature of potential arisings it must be assumed that they are hazardous by anyone producing, handling or processing them. Evidence of accurate classification of arisings should be made available to others who may be involved in handling or processing the arisings.

This guidance does not attempt to cover the matter of permits or licences for handling, transfer, transport, storage, or processing, of waste materials.

This guidance is not intended as a complete guide to managing waste materials and should be read in conjunction with Regulations and guidance issued by the relevant Regulator, these will take precedence over this guidance in all cases.

It should be noted that in Scotland, hazardous waste is termed “special waste”.

As explained later in this guide (5.1), in situ stabilisation is not a ‘waste’ treatment process as the material is not excavated. In consequence in-situ stabilisation can be applied to any road, regardless of the presence or absence of tar. However this in- situ process does not change the contamination status of the road, and is not a contamination remediation treatment.

In the following text, phrases in italics are direct quotes from legislation or regulatory guidance.

The term tar should be taken to mean road tar unless otherwise qualified.

1.1 Review Process

This document will be reviewed by ADEPT and the Construction Demolition Waste Forum (CDWF) on a regular basis to help ensure that references and advice remain current.

1.2 Road Tar

Road tar could have been used in all pavement layers including surface dressings up until the mid-1980s. Isolated materials may occur at later dates in locations such as bus depots and lay-bys, where it may have been used for its resistance to diesel.

Bitumen, the alternative to road tar, is produced from crude oil. Bitumen was originally a waste product, but the chemical processing of oil has advanced so that bitumen now has to be deliberately retained. It was also common to blend road tar and bitumen. Bitumen is chemically complex and variable, there are no specific compounds that can be used to detect bitumen quantitatively using chemical analysis.

Asphalt is a manufactured product containing only aggregate and binder with some other minor components. It is not necessary to determine the bitumen content directly because anything not tar can be assumed to be bitumen. If necessary the binder content can be determined using one of the physical methods in BS EN 12697-1.

Road tar is a complex mixture of hydrocarbons; some of these have been shown to be carcinogenic, others are toxic to aquatic life, some are both. In the 5th edition of Standard Methods for Testing Tar and its Products road tar is defined as

A product prepared by treating high temperature coal tar in such a manner that the product conforms to a specification.

As such road tar is processed from coal tar and does not contain all the chemicals that are in unrefined coal tar. In particular there will be few volatiles, and it was usual for most of the phenols and cresols to be removed to make other products.
Coal tar and many tar derived products, such as high temperature distillate, are classed as carcinogens. Consequently road tar must also

contain fewer hazardous compounds than untreated coal tar.

Road Tar and bitumen are miscible, and over time it is possible for some tar products to migrate into adjacent bituminous layers and vice versa.

Road tar and bitumen share some physical characteristics but tar can be differentiated from bitumen by the presence of particular polycyclic aromatic hydrocarbons (PAH). A number of marker compounds are used to identify the presence of these potentially hazardous PAH compounds.

Road tar may also contain phenols and cresols, some of which are also hazardous.

Arisings from a road could potentially be contaminated with other substances from the vehicles that used the road, and these need to be included in any COSHH risk assessment, waste classification and assessment and, potentially, in any hazard assessment of the arisings from the road.

1.3 Road Tar Remediation

While it might be possible to remediate the road tar in a road construction, this document does not cover such processes. These would require suitable permits from the Regulator, including those for the handling, treatment and transfer of waste.

The processes considered here, whether in situ or not, are to improve, strengthen, or repair the existing road construction.

1.4 The Excavation Process

Road materials require replacement occasionally for a variety of reasons. This may be because of a breakdown of the integrity of the material, or because of a deficit of structural strength in it or the lower layers, or because of a loss of a surface property, such as skid resistance.

In the removal process the existing material is milled out using a powered device and the arisings are collected for disposal or, ideally, re-use.

The removal is a construction process, similar in nature to demolishing a building for instance. The removal process is not related to work on contaminated land and should not be treated as such.

Most UK roads have been constructed and maintained in an ad-hoc way such that tar and bitumen bound materials may be found in close proximity. In most cases any tar bound material will be below the surface and the start and end of the material will not be precisely known. Frequently the amount of material overlaid will also vary resulting in the depth of the tar material changing along the road.

In some cases tar and bitumen were used interchangeably in the same construction course so that, even in relatively recently constructed roads the location of tar bound material will be unpredictable.

The consequence of this is that the removal process cannot be exact and a mixed product, containing both tar and bitumen inevitably results.

1.5 The Hazards

Some phenols and cresols are toxic to aquatic organisms, and some are carcinogenic. Phenols are relatively soluble in water and can leach easily.

Some PAH types have been identified as carcinogenic and some are also known to be highly toxic to aquatic life. Some PAH are carcinogenic and toxic particularly 4 to 6 ring PAH. Most PAH are only very slightly soluble in water.

The hazardous nature of coal tar to humans has mainly been studied in workers from the coal tar industry who have had long and high exposures to coal tar products although many laboratory studies have been performed.

In considering risks to human health and the environment all pathways need to be considered.

For PAH in road planings the most likely human pathways are inhalation and ingestion of dust at ambient temperatures, with the possibility for release of PAH fumes at elevated temperatures. Dermal exposure is also a pathway for tar products, personnel should avoid handling road planings.

1.6 Physical and Chemical properties

Both PAH and phenols are classes of organic compounds. There are many different varieties of each type, too many to test for all together.

There are 16 PAH compounds, known as EPA PAH16, which are used as markers for both coal tar and road tar.

In their pure state these PAH have high boiling points, over 200 ºC. At room temperature all are solids in their pure form.

PAH are generally only slightly soluble in water. Most solubilities are less than 1 mg/litre and all those in the PAH16 group are less than 4 mg/litre.

2.0 The Regulators Position

2.1 Definition of Waste

In the UK the four environmental Regulators generally take the view that all arisings from construction processes should be classed as waste. As such anyone carrying these materials, recycling them, or reprocessing them, must possess all appropriate permits and licences.

Some in-situ stabilisation processes treat the material in place and do not produce arisings.

The Regulators have identified three methods for managing road planing arisings in the following documents:

1. EA Regulatory Position Statement 075 for the movement and use of treated asphalt waste containing coal tar / EA Regulatory Position Statement 157 which covers the treatment of asphalt containing coal tar (England).
2. SEPA Guidance on the Production of fully Recovered Asphalt Road Planings (Scotland)
3. Quality Protocol: Aggregates from inert waste (England, Northern Ireland and Wales)

The first documents allow the treatment, movement and use of asphalt waste containing coal tar in construction operations for hard paving structures in England only. They do not enable the producer to demonstrate that end of waste criteria has been met, but they do state that if followed correctly, the EA will not pursue an application for an environmental permit.
The second document provides approved methodology that allows producers to demonstrate when aggregate produced from asphalt has been fully recovered and has ceased to be a waste. This guidance is only applicable in Scotland. However, it is not applicable to tar bound aggregates, asphalt contaminated with other substances or asphalt removed/processed by any other method than a road planer.

The third document is applicable to England Northern Ireland and Wales. It identifies that certain specified inert wastes (including uncontaminated asphalt) may achieve end of waste status through treatment and use in compliance with the Quality Protocol for recycled aggregates from inert waste.

More information about the definition of waste can be obtained from the Defra Guidance on the Legal Definition of Waste and Its Application[i].

2.2 Duty of Care

If you have waste you have a legal 'Duty of Care'[ii]. The Duty of Care applies to everyone involved in handling the waste: from the person who produces it to the person who finally disposes of or recovers it.

This means that the road owner/operator and the contractor as well as any subcontractors have a legal duty to ensure that waste produced from a site is accurately assessed and described, handled correctly, carried by authorised carriers and disposed of at a suitably permitted site. Records of any waste transfer must be kept for at least 2 years. In general, responsibility for duty of care cannot be delegated to another company or contractor.

If any form of excavation in a bituminous pavement is required the Designer or scheme complier has a duty under the regulations[ii] to determine whether or not any materials encountered could be hazardous waste. The Designer also has a duty to minimise construction hazards, and inform the Contractor of any remaining hazards, under the Construction (Design and Management) Regulations 2015[iii].

2.3 Waste Classification

An important tool to use in the classification of waste is the EU List of Wastes[iv] (also known as the European Waste catalogue, EWC). This is essentially a list of six digit codes and associated descriptions of waste from various sources. The codes have been divided into four types of entry:

- Wastes that are always hazardous, known as 'absolute hazardous' (AH*) entries
- Wastes that are always non-hazardous, known as 'absolute non-hazardous' (AN) entries
- Wastes that may be hazardous or non-hazardous, known as 'mirror hazardous' (MH*) and 'mirror non-hazardous' (MN) entries

If the waste is classified under the mirror entries, further investigation and assessment of the waste will be required to determine if hazardous properties are present.

Non-hazardous wastes may be classified as inert in certain circumstances.

For bituminous road planings there are two waste codes likely to be considered:

17 03 01* bituminous mixtures containing coal tar (MH)
17 03 02 bituminous mixtures other than those mentioned in 17 03 01 (MN)

As these are mirror entries, a decision needs to be made by the waste producer as to which code is most suitable, following further investigation. The remainder of this document is essentially taken up in describing how to distinguish between these two codes. This has been summarised in the process map shown in Appendix A – The main stages & control mechanisms for the reuse of asphalt waste.

The joint Guidance on the classification and assessment of waste (1st Edition v1.1), known as Technical Guidance WM3, has been issued by all four of the environmental Regulators. It sets out how to assess if a waste displays a hazardous property and how to classify it.

2.4 Waste Classification

The Landfill Directive gives three general waste classifications:

Inert
Hazardous
Non–hazardous

These are described in more detail below:

2.4.1 Inert

A material is classed as inert if:

- *It is not hazardous waste; and*
- *It does not exceed the WAC limit values provided in the tables in Section 2.1.2.1 and 2.1.2.2 of the Council Decision. These relate to leaching and to total organic content parameters respectively*
- *It does not undergo any significant physical, chemical or biological transformations*

Here WAC stands for Waste Acceptance Criteria. To be classed as inert, the waste must meet all of the limits given in the inert WAC suite. WAC is only relevant for waste destined for landfilling.

2.4.2 Hazardous Waste

The WAC limits cannot be used to make an assessment of whether a waste is hazardous. These are for a different purpose and must not be confused.

Waste is hazardous if it possesses one or more of the 15 hazardous properties or persistent organic pollutants (POPs) listed in the Hazardous Waste Regulations / Special Waste Regulations or it is one of the absolute entries in the List of Wastes.

Technical Guidance WM3[v], sets out in detail how hazardous waste is classified. Road tar contains chemicals that are carcinogenic (HP7), ecotoxic (HP14), or both. For the purpose of this guidance it is noted that the hazard that results in the lowest limit is HP7, Carcinogenic. This will be used to formulate the testing guidance that follows.

2.4.3 Assessment of Hazard HP7: Carcinogenic

For further information, please refer to Appendix C7 of WM3v1.1.

HP7 Carcinogenic is defined as 'waste which induces cancer or increases its incidence'. There are two hazard statement codes (formerly risk phrases) that apply: H350 may cause cancer (class 1 carcinogens) and H351 suspected of causing cancer (class 2 carcinogens).

A waste will be classified as hazardous if the concentration of any one of the individual substances it contains is assigned either H350 or H351 and is ≥0.1%.

As tar is classed as a category 1 carcinogen it must not be present at a concentration greater than or equal to 0.1% (1000 mg/kg). Although this concentration cannot be directly determined, Section 2 of Chapter 3 of WM3v1.1 allows the following for asphalt:

Where the concentration of benzo[a]pyrene is at or above 50 ppm (mg/kg) in the black top alone (excluding other material) then the amount of coal tar should be considered to be sufficient (0.1% or more) for the material to be hazardous and thus coded 17 03 01.*

Any sampling of blacktop would need to ensure that layers with different concentrations of benzo[a]pyrene are identified and sampled.

It is therefore important that a representative sample of the road material is taken to ensure that the classification of the material is correctly applied – this should consider any distinct layers present in the waste.

There is data corroborating this assertion that 50mg/kg correlates to around 1000mg/kg road tar, this data is presented in Appendix D4.0.

2.4.4 Non Hazardous Waste

Non hazardous waste is simply any waste that is not hazardous. The vast majority of waste from all sources falls into this category.

In the case of road arisings any waste materials that are not assigned EWC codes 17 03 01* or 17 03 03* are non hazardous and can be assigned the category 17 03 02. For the purposes of the EA Quality Protocol: Aggregates from Inert Waste, materials classified as 17 03 02 can be recycled as aggregate and are treated as inert waste.

2.5 Mixing Wastes

The deliberate mixing of hazardous material containing tar with other material for the sole purpose of 'dilution' in order to render the resultant mixture non-hazardous or inert is prohibited by legislation.

Some mixing and resultant contamination by tar bound planings with other materials is inevitable as part of the normal removal process of highway activities. This is permissible.

The deliberate mixing of hazardous material with other materials is illegal. Anyone intending to mix hazardous waste must hold an environmental permit and demonstrate that the mixing of these wastes is the best available technique.

3.0 Testing for Coal Tar Products

3.1 Sample Preparation

It is vital that any samples presented for analysis are representative and homogenous. The chemical tests used for PAH analysis only require very small amounts of material, typically 5 g. A suitable method for sample preparation is given in Appendix C. Great care is therefore needed to prepare these small samples from core samples or other large bulk samples.

3.2 Determinants

In detecting tar products 2 tests are usually used:

Speciated PAH analysis (PAH16)
Phenols and cresols either by speciated analysis, or by phenol index.

The description of these tests is given in Appendix C.

Road tars do not generally contain a lot of phenol so the phenol index test may be used to judge the likely quantities. If the result from the phenol index test is >1000 mg/kg then the speciated Phenol analysis should be performed.

To establish whether a waste, or potential waste, is hazardous it is only necessary to test the material in the solid form. To obtain an accurate picture of the composition of the material it is vital that suitably representative samples are submitted for analysis. WM3v1.1 Appendix D provides the framework to ensure that accurate and representative samples are taken and a reliable assessment is made. A suggested protocol for sample preparation and testing is given in Appendix C. The number and type of samples will depend on the type of investigation and is discussed below.

3.3 Screening for PAH

It is possible to use an aerosol spray product specifically designed to detect PAH called PAK marker. The method for using this product is given in Appendix D. PAK spray triggers at a minimum of 125mg/kg of total PAH16 with a greater level of certainty above 150mg/kg. PAK spray can give false positive results. One instance of a false negative has been reported, the use of odour as an additional screening method is recommended although close personal contact should be avoided.

Other screening methods, e.g. acrylic white paint spray, can be used but should be calibrated against the analytical methods for PAH described in this document. Any screening method must be able to consistently detect PAH as measured by the method in Appendix C.

3.4 Leachate Testing

Leaving tar bound material undisturbed is acceptable without testing for leachate potential – it therefore never becomes waste and is the highest level in the waste hierarchy and the preferred methodology (economically and environmentally). Leachate testing is required if the material is to be disposed of in landfill. The leaching properties, as required by the appropriate WAC test, would then need to be established.

3.5 Planings Testing

If an investigation has not been carried out and the planings are not characterised then the planings must be tested instead. This will require significantly more testing than is described under production monitoring below. More detail is provided in Appendix C.

4.0 Site Investigation

Prior to any excavation operation in the highway it is recommended that an investigation is carried out to establish the location of any tar contaminated material, the properties of the in situ material and the anticipated properties of any excavated material. An investigation into existing road conditions and the assessment of the properties and quality of the arisings are essential to achieving proper re-use of the excavated material.

If records exist, or the provenance is known, showing the materials used do not contain tar, then no investigation is necessary.

Cores rather than trial pits are recommended for investigating the bound construction. Cores are generally convenient to take and allow individual layers to be easily distinguished. 150 mm diameter cores are appropriate for this type of investigation and will be needed to provide sufficient material for testing and analysis.

Trial pits are useful for investigating the unbound layers.

An investigation designed for the purposes of this guidance can be combined with a structural investigation of the road. This process is described in Design Manual for Roads and Bridges (DMRB) Volume 7 Section 3 Pavement Maintenance Assessment. Currently the document is HD29, but this will be replaced by CD229 in due course. In this case it may be necessary to adopt a 2 stage approach to the investigation as the scheme design could be affected by the properties of any arisings.

The first stage would be to test appropriately to develop a scheme design. The second stage would involve ensuring that the arisings have been properly characterised, with further testing as necessary.

Guidance on assessing the levels of contamination is provided by Appendix D to WM3v1.1. What follows is based on the guidance in that document. Reference should be made to the guidance in cases of doubt.

4.1 Investigation Design

To assess the nature of the arisings the variability of the source material must be considered. If the road construction is known, and the binders used can definitely be established, then the extent of the investigation and the frequency of sampling can be reduced or eliminated. The following is based on the assumptions that the existing road construction is unknown and variable.

Cores should be nominally 150 mm diameter and taken at between 25 and 50 m centres. This will ensure that any changes in construction are accurately located and any variation on a load by load basis can be identified. A minimum of 3 cores should be taken unless the site is less than 30 m^2 when 1 core is adequate.

During the design phase it is necessary to identify exactly the location and nature of any tar bound layers. This will allow the designer to formulate a suitable economic maintenance treatment. Options for maintenance treatments are discussed later in this document. Identification of potential tar bound material can be done using a screening technique. It may not be necessary to perform complete analysis at this stage as it is the composition of the arisings that is important, not that of individual layers.

If the investigation is solely for design purposes PAH analysis of individual layers can be done using the design assessment procedure given in Appendix C. Estimates of the PAH content of arisings can be made by volume proportioning using the thickness of the tested section, the concentration found, and the thickness of uncontaminated material. These estimates should be confirmed by further core testing as described in Appendix C 2.1 if reuse of the excavated material is intended as part of the design.

Once the design is known the properties of any arisings can be fully assessed. This should be done by splitting the cores at the appropriate depth and preparing the material as described in Appendix C or, if at the scheme design stage reuse of the excavated material is intended as part of the design, other properties can also be determined from these prepared samples.

The number of tests required for proper assessment of the PAH content will depend on the variability of the source material. It is necessary to determine the average and assess the variability of the PAH content so that the potential hazard from the excavated material can be properly determined. Guidance on test rates and the classifying criteria is provided in Appendix C.

A sampling plan should be made and recorded including the details of the decisions made.

4.2 Competence

The investigation project manager should have sufficient experience of highway investigation and be familiar with the legislation and guidance referred to in this document.

5.0 Treatment Options

Any treatment chosen must meet the engineering demands of the specific road and the appropriate permits and licences obtained from the relevant Regulators.

5.1 In-Situ Stabilisation

In-situ stabilisation can be used to repair roads containing tar. As the material is not removed from the road but is mixed in situ, the material under treatment does not become waste. In consequence all roads can be stabilised using this treatment, regardless of their contamination status.

In this process the material is milled in place and mixed with a new binder, recompacted and then resurfaced. The new binder can be cementitious, bituminous or a mixture of both. It is sometimes necessary to remove some material from the road to make space for the new surface course, the contamination state of this material must be considered, as this material does become waste upon removal from the road.

This process must be considered a mechanical stabilisation treatment. Currently there are no treatments that are permitted to remediate road tar contamination in situ and treatments should not be commissioned on this basis.

5.2 Ex-Situ Treatment

Ex-situ treatment involves the removal and treatment of the asphalt by crushing, grinding and screening.

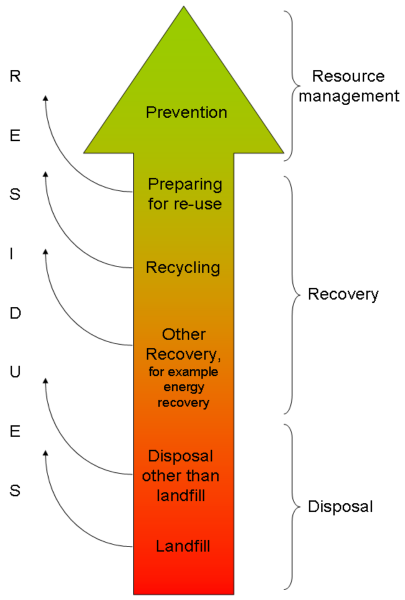
Ex situ treatment of road tar contaminated asphalt is permitted in England under

Environment Agency Regulatory Position Statement 075. This permits the use of asphalt waste containing coal tar (AWCCT) in 'construction operations for hard paving structures where:

- The treated AWCCT meets the requirements of clause 948, ex-situ cold recycled bound material, within the Specification for Highways Works Series 900, or clauses 810 to 880 for cement and other hydraulically bound mixtures within the Specification for Highway Works Series 800.
- The material is used only in bound sub-surface layers e.g. sub-base, base and binder layers. Use in surface applications is not allowed.
- You meet the relevant objectives of the Waste Framework Directive

The Quality Protocol: Aggregates from Inert Waste provides a framework for the treatment and recovery of uncontaminated asphalt in England, Northern Ireland and Wales.

6. The Waste Hierarchy



When removing planings and therefore creating waste, the waste hierarchy should be applied in order.

Further information about the waste hierarchy is readily available. Below is a summary of how this applies to road planings.

6.1 Prevention

If possible the tar contamination can be left in place. This may only be a short term solution. Road tar has not been used for many years and is susceptible to oxidation and weathering. The extent to which this has occurred will depend on many factors. If the road tar remains competent then it should not be disturbed.

6.2 Preparing for Re-use

Currently planings containing tar can only be re-used in cold mix processes. The preparation should follow a similar path to that described in BS EN 13108-8. This is precautionary until evidence of the effects of re-heating road tar to higher mix temperatures is available.

Some form of binder must be added to planings containing road tar to ensure they are made into a dense, non-permeable, material that has suitable properties for the purpose intended. At present all re-use is back into road construction. The processing can take place in a mobile plant local or remote to the source, or at a permanent installation. Any mobile plant used must hold a mobile plant permit, and the associated deployment form must be registered with the Regulator before processing commences.

6.3 Recycling

Recycling is defined as turning waste into a new substance or product. At present planings identified as hazardous waste cannot be recycled, only re-used.

Road planings when processed according to the Quality Protocol for Aggregates from Inert Waste, are an accepted product in the industry and have value provided they are classified correctly. In general Type 4 sub base, 6F3 capping, or BS EN13108-8 feedstock, can be produced directly from the planer. Re-claimed asphalt can be successfully utilised as a feedstock in hot mix asphalt.

6.4 Other Recovery

Other recovery processes continue to be developed, for example those that remove road tar from the aggregate using biological agents, or by pyrolysis of the tar. Aggregates recovered from any process may be suitable for re-use subject to end of waste criteria being met.

6.5 Disposal

This should be the option of last resort. Incineration or landfill may be available. Material destined for landfill should be assessed for leaching potential in accordance with the appropriate WAC, prior to excavation. This leachate assessment can be made using the same samples used to assess the PAH content.

7.0 Production Monitoring

Regardless of the use, hazard classification, or destination of the planings some monitoring must be done to ensure the findings of the investigation were correct and to confirm compliance with the appropriate quality plan.

Quality monitoring for products should be done at the rates appropriate to the relevant standard, e.g. BS EN 13108-8.

Monitoring for road tar content should be done at a rate of 1 per 100 tonne, with a minimum of one per site.

8.0 Health, Safety and Environment

8.1 Health & Safety Considerations

A proper assessment of all the hazards associated with handling asphalt arisings should be carried out. This should include a full COSHH assessment.

Some hazards have been discussed earlier. PAH can become absorbed through ingestion, skin contact, inhalation of dust, fume inhalation if the tar is heated enough.

The HSE does not set any maximum workplace exposure limits for PAH as there is potentially a wide range of exposure types and levels across industries making an overall exposure limit impossible to set.

Even so it is possible to measure airborne PAH concentrations using personal sampling, HSE and NIOSH guidance exists for performing these measurements[vi,vii].
There is a Biological Monitoring Guidance Value (BMGV) for PAH quoted in HSE publication EH40, Workplace Exposure Limits. The BMGV listed in Table 2 of EH40/2005 for Polycyclic aromatic hydrocarbons as 4 μmol 1-hydroxypyrene per mol creatinine in urine. The appropriate sampling time is stated as post shift.

This guidance value does not help to limit or prevent exposure, but can be used to assess ongoing exposure in order to gauge whether that exposure is of significance, and whether control measures in place are working

Testing should be performed by appropriately qualified personnel and laboratories.

8.2 Environmental Considerations

As well as posing a risk to human health, PAH can affect other organisms. Transmission can be by air, surface or groundwater or direct contact.

Asphalt plants, and other processing areas, can be monitored for PAH emissions, either as dust or vapour.

This summary is not intended as a full treatment of all the environmental aspects of removing, storing and treating asphalt planings and a suitable risk assessment should be carried out and appropriate experts consulted if necessary.

9.0 Whole Life Costing

A separate report has been prepared to consider Whole Life Costing aspects of Ex-situ Recycled Asphalt in comparison with conventional hot mix asphalt materials.

Due to resource constraints the WLC exercise was carried out solely to compare ex-situ recycling with conventional hot mix asphalt.

Further theoretical comparisons between hot mix inlays and overlays, and hot mix inlays and in-situ recycling and documented site trials would provide additional comparative data should ADEPT members wish to add to the knowledge base.

The Executive Summary of that report is shown in Appendix E, and the full report is available from the ADEPT website.
https://www.adeptnet.org.uk/documents/adept-guide-managing-reclaimed-asphalt-ex-situ-recycling-whole-life-costing .

10.0 Acknowledgements

This guidance note was written by John Booth of SOCOTEC on behalf of ADEPT.

Additional input to the original version was provided by Robert Gossling of Lafarge Tarmac and by the Mineral Products Association.

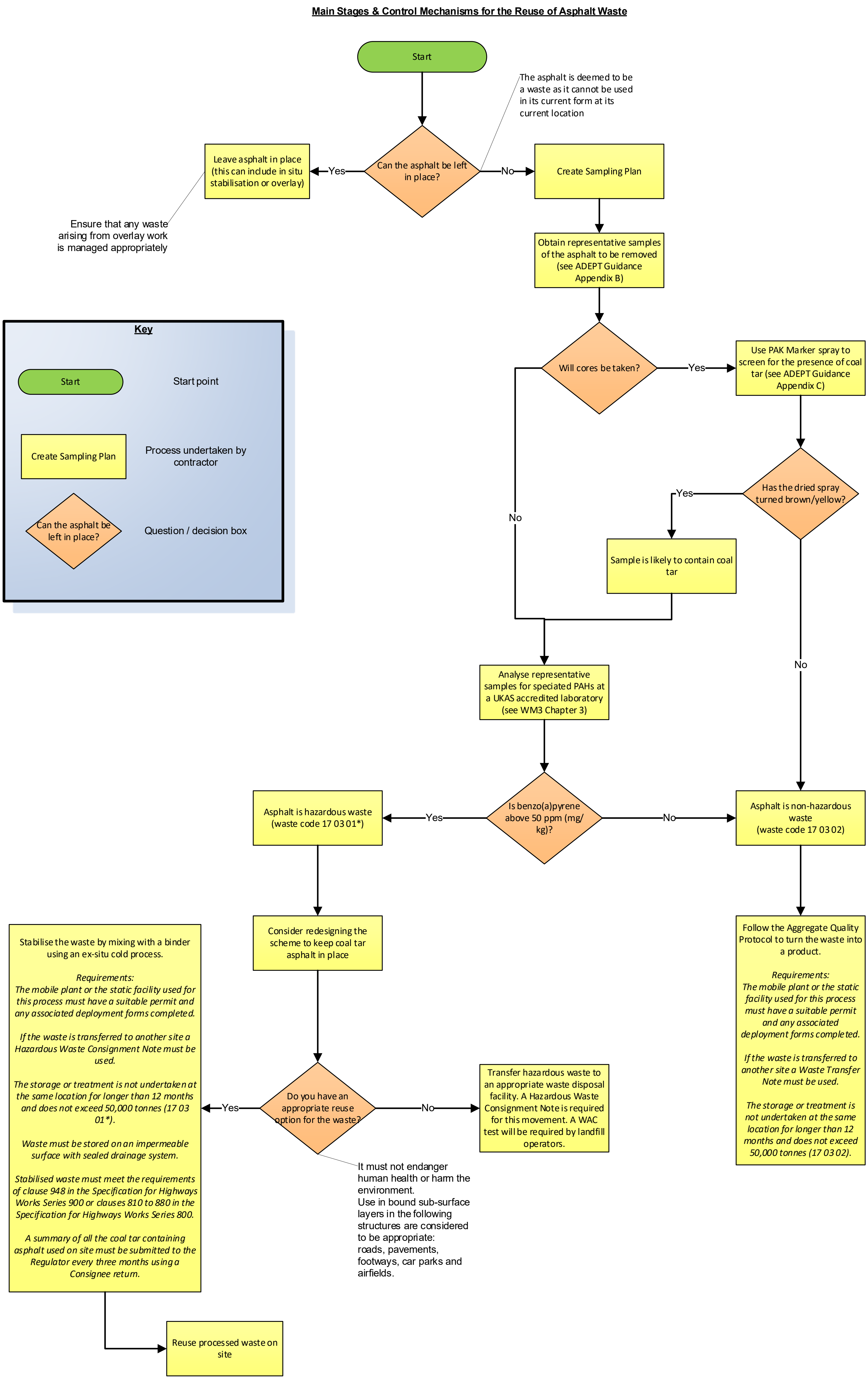
Version 2019.2 was updated by Maxine Townsend of Skanska on behalf of ADEPT and CDWF.

Andy Simms of Skanska and Lucia de Ferrariis of Skanska (Oxfordshire CC) prepared the Whole life Costing Report summarised in Section 7.3 on behalf of ADEPT.

Data for Appendix D was provided by SOCOTEC and Lafarge

Thanks to the Environment Agency for providing assistance and guidance with regards to end of waste criteria and hazardous waste classification and assessment.

Reuse of Asphalt Waste Flowchart



Appendix B

Web Links

B1 Duty of Care

England and Wales
https://www.gov.uk/government/publications/waste-duty-of-care-code-of-practice
Northern Ireland
https://www.daera-ni.gov.uk/publications/waste-management-duty-care-code-practice
Scotland
https://www.gov.scot/publications/duty-care-code-practice/

B2 Definition of Waste

Legal Definition of Waste Guidance, applies to England, Northern Ireland and Wales
https://www.gov.uk/government/publications/legal-definition-of-waste-guidance

Is it waste? Understanding the Definition of Waste in Scotland
https://www.sepa.org.uk/regulations/waste/guidance/#Definition
Size:

A3 Regulatory Position Statements

Environment Agency Regulatory Position Statement 075 – The movement and use of treated asphalt waste containing coal tar.

SEPA Guidance on the Production of Fully Recovered Asphalt Road Planings
https://www.sepa.org.uk/media/154246/road_planings_guidance.pdf

B4 Waste Acceptance at Landfills

https://www.gov.uk/government/publications/waste-acceptance-at-landfills
http://www.sepa.org.uk/waste/waste_regulation/landfill.aspx (link on page)

B5 Technical Guidance WM3

https://www.gov.uk/government/publications/waste-classification-technical-guidance

B6 Guidance on Sampling and Testing Wastes to Meet Landfill Waste Acceptance Procedures

https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/321207/Sampling_and_testing_of_waste_for_landfill.pdf

B7 Quality Protocol: Aggregates from Inert Waste

https://www.gov.uk/government/publications/quality-protocol-production-of-aggregates-from-inert-waste

B8 Waste Hierarchy Guidance

https://www.gov.uk/government/publications/guidance-on-applying-the-waste-hierarchy
https://www.gov.uk/government/publications/guidance-on-applying-the-waste-hierarchy-to-hazardous-waste

Appendix B

Web Links

B9 Manual of Contract Documents for Highway Works

http://www.standardsforhighways.co.uk/ha/standards/mchw/index.htm

B10 Waste Legislation

https://www.gov.uk/guidance/waste-legislation-and-regulations
http://www.netregs.org.uk/legislation/scotland/current/waste_legislation.aspx
http://www.netregs.org.uk/legislation/northern-ireland-environmental-legislation/current-legislation/waste/

B11 ADEPT Guide to Managing Reclaimed Asphalt – Report on Ex Situ Recycling – Whole Life Costing

https://www.adeptnet.org.uk/documents/adept-guide-managing-reclaimed-asphalt-ex-situ-recycling-whole-life-costing

B11 Contact Information

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

http://www.adeptnet.org.uk/

Construction Demolition Waste Forum

www.ciwm.co.uk

Appendix C

Sample Preparation and Testing

C1.0 Introduction

The methods of sample preparation are intended to produce representative samples of the existing road materials that can be tested for road tar contamination and other properties that may be needed to characterise the type of product of the planing process.

Sample reduction should be done using the methods in BS EN 932 - 2. Ensure that the sample is mixed thoroughly at each stage.

C1.1 Competence

Ideally laboratories should be UKAS accredited for the methods given. As a minimum a laboratory performing sampling and sample preparation to **C2** to **C5** should hold UKAS accreditation for BS EN 932-1, BS EN 932-2, BS EN 12697-28 and BS EN 12697-6.

Laboratories performing chemical analysis should hold UKAS accreditation for that analysis. A list of accredited laboratories can be obtained from the UKAS website, www.ukas.org.

C2.0 Test Frequency for Contamination Analysis

C2.1 From a Core Survey for Arisings Assessment

For waste characterisation it is necessary to know the mean Benzo[a]pyrene (BaP) content with sufficient accuracy by testing an appropriate number of cores. This number will depend on the variability of the road construction. The following suggested frequencies are based on experience.

Criteria that should be considered are:

- Level of the tar bound layer(s) within the core
- Thickness of the tar bound layer(s)
- Type of tar bound material (i.e. surface dressing, surface course, base material)
- Frequency of occurrence of road tar at any level

Site Variability	Test Frequency	Minimum Test Frequency
High, with all the criteria above changing	All cores	3 tests
Medium, where 3 criteria vary	Two thirds of the cores	3 tests
Slight, where only level or thickness vary	One third of the cores	3 tests
Consistent	One fifth of the cores	3 tests

Notes:
A minimum of 3 tests is recommended because it is difficult to have confidence about the assessment of even a small amount of planings with fewer results.

The above is based on judgement of what is necessary. For large projects it would be appropriate to use the statistical analysis described in C8.2 to assess the accuracy of the result.

If there are a number of similar results forming a contiguous area it would be appropriate to divide the area into zones of similar BaP level as described in C7.0. These zones can then be assessed separately.

C2.2 From a Core Survey for Design Assessment

A representative selection of cores containing the positively screened layers should be tested for BaP as described below. At least one sample of each type of material should be selected.

Audit tests should also be made of material at similar depths which have shown a non-hazardous result. At least 1 audit test per site should be performed.

If there are a number of similar results forming a contiguous area it would be appropriate to divide the area into zones of similar BaP level as described in C7.0. These zones can then be assessed separately.

C2.3 From Planings Derived From Any Source

Samples should be taken as described in BS EN 932-1.

PAH screening can be used to identify potentially hazardous material, note that this screening must be done on samples, random screening of the planings heap or load is not recommended.

Samples that show a positive screening result must be sent for analysis and the load quarantined until the result is obtained. Routine, random, testing of negative screening samples must also be undertaken at a rate of 1 in 20.

The number of samples necessary must be adequate to assess the composition of the whole, taking into account any information already available.

- Where there is no knowledge of the source samples must be taken per load.
- For stockpiles or deliveries of unknown variability but from a single source, samples should be taken at a rate of 1 per 100 tonnes with a minimum of 3 samples per stockpile.
- For stockpiles or deliveries from a known source that has already been characterised for road tar content as described in this document, a sample rate of 1 per 1000 tonnes, with a minimum of one per site.

C3.0 Core Preparation

C3.1 Cores being tested for production control

Cut the core at the depth to which the planing will extend. Assess, by inspection and measurement, the largest nominal size of the aggregate within the selected core section. Crush the core section to pass this nominal size, or 20 mm whichever is the larger. 10% of oversize is permissible. Oversize is defined as passing 1.4D where D is the nominal size, or 20 mm.

Samples should not be combined for PAH analysis. It may be necessary to combine samples from cores for certain sorts of testing. If different types of testing are required the crushed sample can be divided. One part can then be prepared and tested for PAH, as described in C5.0, and the remainder can be used for product characterisation testing, see C7.0

C3.2 Cores for scheme design (see 2.3)

Sample Preparation and Testing

Sections containing the potentially contaminated material shall be cut from the core. Sections should be a minimum of 20 mm thick but should otherwise be the same thickness as the course being tested. 20 mm is used because this is deemed to be thinnest layer a planer could excavate consistently, this value can be changed to reflect the capabilities of the plant used, where known.

Measure and record the thickness of section removed and prepare for PAH analysis as described in C5.0.

The potential BaP content of arisings can then be calculated for any planed depth by calculation the overall BaP content in the proportions of the thickness of the layers.

C4.0 Planings Preparation

Obtain a suitable test sample, by riffling or quartering, from the bulk sample. General size requirements are given in BS EN 12697-28 for bituminous material testing, and in BS EN 932-2 for testing aggregate properties such as particle size distribution. Some tests, e.g. penetration testing, may require larger test samples than those given in 12697-28. For chemical contamination tests the BS EN 12697-28 sample sizes can be used.

C5.0 Preparation of Test Sample for Contamination Testing

The test sample should be air dried to constant mass. Constant mass is defined as successive weighings after drying at least 1 h apart not differing more than 0,1 %.

If the nominal size is larger than 20 mm crush the sample to pass a 20 mm sieve and reduce to a mass between 1000 and 1500 g.

Crush all the material to pass 10 mm and then reduce the test portion to between 250 and 350 g.

Crush this sample to all pass 4 mm and reduce to between 100 and 150 g.

This sample is suitable for submission to the analytical laboratory for PAH and phenol analysis in the solid.

If samples are being tested for leachate potential for waste acceptance, then a further 250 g sample of passing 4 mm should be prepared.

C6.0 PAH analysis for Benzo[a]pyrene content

The most common method for PAH analysis is GC-MS, gas chromatography and mass spectrometry. Other methods can be used provided they can accurately distinguish the required PAH types and have a detection limit of 1 mg/kg or less. There is no standard method for this test, laboratories that are UKAS accredited for PAH analysis must be used.

The US EPA set of 16 PAH types is sufficient for normal analysis, in fact only benzo[a]pyrene (BaP), CAS number 50-32-8, is needed. If also testing for waste characterisation coronene must be added to the PAH16 suite to meet the inert WAC criterion for total PAH.

C7.0 Assessment of Hazard

This is potentially a complex assessment requiring consideration of a number of factors. The following should ensure compliance with Appendix D of WM3v1.1. In cases of doubt it is Appendix D of WM3v1.1 that should be followed.

Appendix C

Sample Preparation and Testing

The following assumes that the sampling or coring rates discussed above are applied. It also assumes that the distribution of test results will approximate to a normal distribution. This is a reasonable assumption given the nature of the source material. On larger projects it would be advisable to confirm this using an appropriate statistical test.

It is not possible to divorce the assessment from the use of some simple statistics without loss of discrimination. A simplified scheme is presented but a grey area remains where full analysis will be needed.

Different heaps of planings should be judged as separate batches. The test results from each batch should be analysed as described in C8.1 and C8.2.

For cores, it may be necessary to divide the area of the road that is to be planed into zones with similar concentrations of BaP. Areas that can clearly be defined in this way must be treated separately. The results from each zone should be analysed separately as described in C8.1 and C8.2 to decide the classification of the planings, when produced. For most roads safe traffic management would have to be considered when allocating zones.

All results and calculations must be recorded and traceable to the sample plan.

C8.1 Simple assessment

Case 1

If all the following apply:

a) The guidance on sample numbers has been observed
b) All the BaP concentrations are below 25 mg/kg
c) There are 3 or more results

The planings can be classed as inert for the purposes of the Quality Protocol for Aggregates from Inert Waste.

Case 2

If all the BaP concentrations are above the hazardous threshold, 50 mg/kg, then the planings are classed as hazardous and must be treated accordingly. Note: If all the results are close to the threshold, and there are only a few results, there may be some doubt. In this case testing further samples and applying the full statistical assessment may be appropriate.

Case 3

Material with some, or all, results above 25 mg/kg and below 50 mg/kg. This is anything that does not meet Case 1 or Case 2.

These materials cannot be classed as non-hazardous without performing the analysis in C8.2. If the expertise to perform the assessment in C8.2 is not available then the material can be classed as hazardous but this will cause some non-hazardous material to be incorrectly assigned.
.

C8.2 Full statistical assessment

Only those with expertise in simple statistical analysis should carry out this assessment. If this expertise is not available then refer to Case 3 in C8.1.

The following analysis is identical in result to the one described in Step 3 of Appendix D to WM3v1.1.

Calculate the mean and sample standard deviation of the BaP results.

Calculate the 90 % confidence interval for the mean result as follows:

$$n = number\ of\ BaP\ results$$

$$Standard\ Error\ (SE) = \ (Standard\ Deviation\ of\ BaP)/\sqrt{n}$$

$$Margin\ of\ Error\ (ME) = SE\ \times Critical\ value\ of\ t - distribution$$

$$Confidence\ Interval = Mean\ BaP\ \pm ME$$

The critical values of the t-distribution are determined for (n-1) degrees of freedom and a two tailed probability of 0.10.

The figure below shows 4 different scenarios:

A: The material is non-hazardous and can be treated as inert for the purposes of the Quality Protocol for Aggregates from Inert Waste.

B and C: The status is uncertain. Either further samples should be tested and their results included in the analysis to reduce the uncertainty, or the planings should be classed as hazardous.

D: the planings should be classed as hazardous.

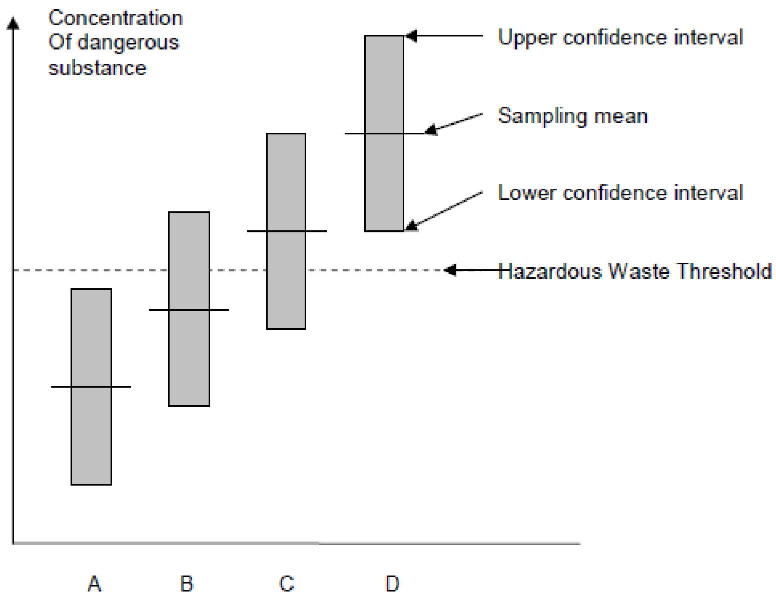
Notes:

i. These calculations are the same as those described in Appendix D to Technical GuidanceWM3v1.1.

ii. Functions are available in Excel to perform these calculations.

iii. The analysis should be performed by a competent person.

iv. The results of chemical analysis are never reported as zero, if the value is reported as less than the detection limit, <0.1 for example, then the detection limit should be used in calculations.



C8.3 Critical values for use in C9.2

Critical values for the t - distribution, 0.10 2 tailed test

Degrees of freedom = one less than the number of samples (n-1)

Degress of freedom	Critical value	Degress of freedom	Critical value	Degress of freedom	Critical value
1	6.314	11	1.796	21	1.721
2	2.920	12	1.782	22	1.717
3	2.353	13	1.771	23	1.714
4	2.132	14	1.761	24	1.711
5	2.015	15	1.753	25	1.708
6	1.943	16	1.746	26	1.706
7	1.895	17	1.740	27	1.703
8	1.860	18	1.734	28	1.701
9	1.833	19	1.729	29	1.699
10	1.812	20	1.725	30	1.697
				40	1.684
				60	1.671
				120	1.658

C8.4 Examples

Example 1

This example actually meets the simple assessment test for non-hazardous and shows why the simple assessment can be used.

BaP results mg/kg	Calculated Parameter	Value	Formula
5	Mean result	17.3 mg/kg	
23	Sample standard deviation	10.69 mg/kg	
24	Standard error (SE)	6.17 mg/kg	$\frac{10.69}{\sqrt{3}}$
	Degrees of freedom	2	$3-1$
	Critical value for the t distribution	2.920	Look up in table
	Margin of Error (ME)	18.0 mg/kg	2.92×6.17
	Upper confidence interval	35.4 mg/kg	$17.3 + 18.0$
	Lower confidence interval	-0.7 mg/kg	$17.3 - 18.0$

Example 2

This example actually meets the simple assessment test for hazardous and shows why it can be pessimistic as the lower confidence interval is below the hazardous threshold. The assessor must decide how likely it is that further testing will bring the upper confidence interval below the threshold.

BaP results mg/kg	Calculated Parameter	Value	Formula
55	Mean result	58.7 mg/kg	
70	Sample standard deviation	10.02 mg/kg	
51	Standard error (SE)	5.78 mg/kg	$\frac{10.02}{\sqrt{3}}$
	Degrees of freedom	2	$3-1$
	Critical value for the t distribution	2.920	Look up in table
	Margin of Error (ME)	16.9 mg/kg	2.92×5.78
	Upper confidence interval	75.6 mg/kg	$58.7 + 16.9$
	Lower confidence interval	41.8 mg/kg	$58.7 - 16.9$

Example 3

This example extends example 2 to show that it is feasible, though unlikely, for further results to change the assessment. If these results were from cores and the 3 high results were from a contiguous area, then this should be allocated as a zone and excavated separately.

BaP results mg/kg	Calculated Parameter	Value	Formula
55	Mean result	17.7 mg/kg	
70	Sample standard deviation	28.68 mg/kg	
51	Standard error (SE)	9.07 mg/kg	$\frac{28.68}{\sqrt{10}}$
0.1	Degrees of freedom	9	$10-1$
0.1	Critical value for the t distribution	1.833	Look up in table
0.1	Margin of Error (ME)	16.6 mg/kg	1.833×16.56
0.1	Upper confidence interval	34.3 mg/kg	$17.7 + 30.4$
0.1	Lower confidence interval	1 mg/kg	$17.7 - 30.4$
0.1			
0.1			

C9.0 Product characterisation testing

It is not possible to anticipate all the uses that planings might be put to. Appropriate testing is covered in the Quality Protocol for Aggregates from Inert Waste.

Appendix D

PAH Screening Methods

D1.0 Introduction

The previous version of this document suggested 3 methods of screening for tar, PAK marker, white acrylic spray paint, and a filter paper test. PAK marker is presented as the preferred method in this version, but other methods are given for those who wish to use them and have confidence in them. All screening methods should be monitored on a frequent basis by full PAH analysis. The frequency will depend on confidence in the method.

D2.0 PAK Marker

PAK marker can be obtained from Interlab BV in Holland (www.interlab-bv.nl) and LabQuip in the UK. http://www.lab-quip.co.uk/pakmarker

PAK Marker is sprayed on the suspect contaminated material and left to dry. If the white spray discolours to a light brown/yellow this is an indication that PAH may be present. Accuracy is improved using a UV lamp. Under UV light material the discoloured PAK spray lightens and becomes yellow/ green. In cases of doubt UV should be used.

D3.0 Other Screening Methods

a. White acrylic spray paint (goes brown in the presence of tar, little affected by bitumen)
b. Adding a drop of Methylene Chloride to a fragment of material on a filter paper. Tar gives a yellow-brown stain; bitumen gives a dark brown stain)
c. Most people can detect tar by its odour and this can be used as a coarse screening method.

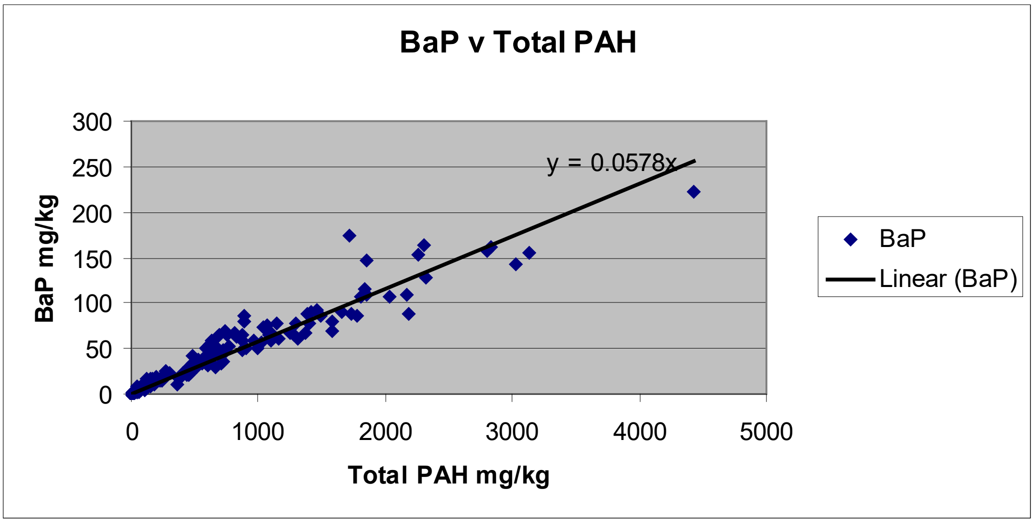
These methods should be checked for accuracy before use.

D4.0 Relationship between Benzo[a]pyrene and Total PAH

The graph shows BaP plotted against total PAH for 197 data points. This data was collected from several different areas of England and demonstrates that road tar is generally a quite consistent product, in terms of its PAH content. The linear correlation indicates quite a strong relationship and shows that 50 mg/kg of BaP is equivalent to 865 mg/kg total PAH. Since road tar contains other constituents besides PAH this strongly supports that the assertion that 50 mg/kg BaP is a good indicator of the presence of 1000 mg/kg road tar.

Appendix D

PAH Screening Methods



Appendix E

Whole Life Costing Exercise – Ex Situ Recycling

Below is the Executive Summary from the Ex-Situ Recycling Process – Whole Life Costing Exercise report, which supports this ADEPT Guidance document.

1. Executive Summary

1.1. The potential options for managing asphalt and asphalt containing tar binder have been described above in this document. All of the solutions identified have advantages and disadvantages with regard to technical performance, practicality, initial cost and whole life cost. However, little work has been undertaken to date to quantify these advantages and disadvantages, particularly with regard to comparison between the different techniques. A series of carefully designed full scale instrumented trials would be needed to assess long-term comparative performance of the four different processes, and to confirm whole life costing benefits. Confirmation that *Ex-situ Cold-Recycled Bound Material* (CRBM) lasts at least 20 years in service is relatively unproven.

1.2. In order to start the process, a comparison between CRBM and conventional hot mix asphalt has been made in the Ex-Situ Recycling Process – Whole Life Costing Exercise report (**link here for full document**). It must be stressed that similar comparisons between the various treatment processes pertinent to remediation of pavements containing tar bound material could be made; these have not been carried out as part of this study due to time and cost constraints. Consequently the findings of this report are limited to assessment of ex situ CRBM.

1.3. Ex situ recycling of reclaimed asphalt containing tar binder involves processing it for re-use in accordance with Manual of Contract Documents for Highways Works (MCHW) Volume 1 Specification for Highway Works Clause 948 *Ex-situ Cold-Recycled Bound Material*. Works must also be carried out in accordance with Environment Agency Regulatory Position Statement 075 *Movement and Use of Treated Asphalt Waste Containing Coal Tar*, ref. MWRP RPS 075 Version 4 Sept 2014.

1.4. One of the aspects of producing and installing Ex-Situ CRBM is whether this technique is cost effective, both in terms of initial treatment and installation, considering the cost of disposal of any tar-bound arisings, as well as the service life of the resulting road construction in which CRBM has been used.

1.5. There are many variables that could influence the durability of CRBM and hence its service life. These include mixture properties, layer thickness, the amount of traffic the road will carry and the condition of the layer onto which the CRBM will be laid. Many of these factors are site specific, and in order to estimate whole life costs, several assumptions are therefore necessary.

1.6. The design principles and assumptions made to enable this comparison are technically complex and outside the scope of the ADEPT *Guide for Managing Reclaimed Asphalt*. Consequently, this detailed technical report has been prepared. This executive summary is used as a basis for a summary in the ADEPT Guide, with a hyperlink to this report.

1.7. Three Whole Life Costing scenarios have been considered with different combinations of inlay thickness (140mm, 190mm, 240mm) and traffic loading. Three traffic loading values selected; low traffic (2.5 million standard axles (msa)), moderate traffic (5 msa) and high traffic (10 msa), equating to 180, 350 and 700 commercial vehicles per lane per day respectively. These construction thicknesses and traffic loadings are considered typical of a local authority network.

1.8. Two different ex situ CRBM materials (Class B3 and B4 CRBM binder course) were compared with conventional Hot-mix Asphalt (AC20 Dense Binder course). Class B4 CRBM is stiffer than Class B3 CRBM, and consequently has different performance characteristics.

1.9. Treatment types used in the Whole Life Costing calculations are described in Table 1 below. The Dense Surface Course is new asphalt to provide a durable skid resistant surface. Patching and surface dressing would also be carried out using new materials.

Appendix E

Whole Life Costing Exercise – Ex Situ Recycling

Treatment Reference	Description
TB4 (140)	140mm Inlay: 40mm Dense Surface Course ; 100mm Class B4 recycled binder course
TB3 (190)	190mm Inlay: 40mm Dense Surface Course; 150mm Class B3 recycled binder course
TB3 (240)	240mm Inlay: 40mm Dense Surface Course; 200mm Class B3 recycled binder course
TAC20 (140)	140mm Inlay: 40mm Dense Surface Course ; 100mm Hot Mix Binder Course (Control)
TB4 (190)	190mm Inlay : 40mm Dense Surface Course; 150mm Class B4 recycled binder course
TB4 (240)	240mm Inlay: 40mm Dense Surface Course ; 200mm Class B4 recycled binder course
TSD	Minor Patching (up to 20% of the total area) + Surface Dressing
TSC	40mm Dense Surface Course Replacement
TAC20 (190)	190mm Inlay: 40mm Dense Surface Course; 150mm Hot Mix Binder Course (Control)
TAC20 (240)	240mm Inlay: 40mm Dense Surface Course ; 200mm Hot Mix Binder Course (Control)

Table 1 Treatment Types used in the Study

1.10. The Whole Life Cost exercise indicates that, based on the many assumptions made in the main body of this report, there appear to be savings associated with the use of ex situ CRBM in comparison with new Hot Mix Asphalt as shown in Figure 1 below.

20 Year Design Traffic (million std axles)	Depth of Treatment (mm)	Whole Life Costing 20 years (£'000)			Whole Life Costing Savings 20 years (£'000)	
		CBRM Class B3 TB3	CBRM Class B4 TB4	AC20 Dense binder course TAC20	CRBM Class 3 vs. AC20 Δ B3	CRBM Class 4 vs. AC20 Δ B4
2.5	140		420	597		177
5	190	448	366	448	0	82
10	240	406	336	443	37	107

Appendix E

Whole Life Costing Exercise – Ex Situ Recycling

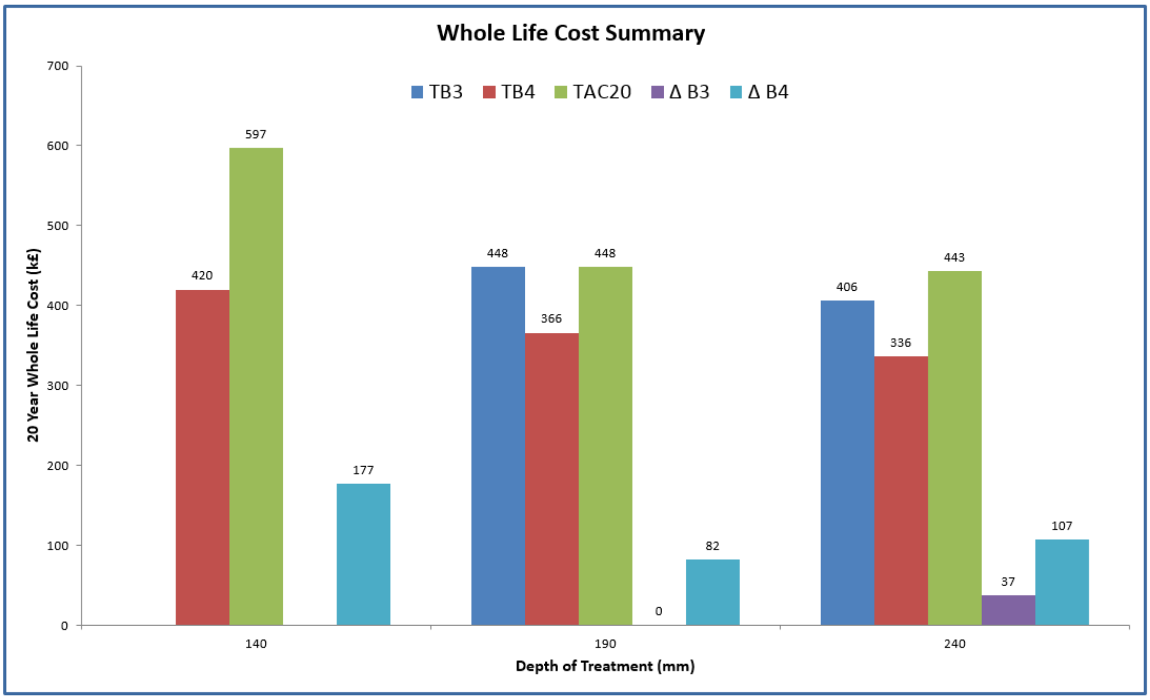


Figure 1 Whole Life Costing Summary

1.11. The differences in Whole Life Cost appear greatest when comparing the cost of Class B4 CRBM with the Hot Mix asphalt control. This difference appears to be evident over the range of design thickness and traffic loadings assessed.

1.12. The Whole Life Costing comparisons shown in Figure 1 are based on several assumptions relating to the service life of the various mixtures, maintenance profiles and project specific cost estimates. It is recommended that these assumptions and estimations, particularly the pavement modelling and stiffness variations are validated. This could be achieved by installation of a series of carefully designed full scale instrumented trials to assess long-term performance and to confirm the indicated whole life costing benefits.

1.13. Notwithstanding the assumptions made, it does appear that there are cost benefits associated with the use of ex-situ recycled materials within the treatment layers in comparison with hot mix asphalt. These benefits appear to be realised across the range of traffic loadings and treatment depths considered in this report. It must not be assumed that the performance of ex-situ CRBM is superior to that of in-situ treatment, or indeed inlay or overlay with conventional material. It must be reiterated that carefully designed full scale instrumented trials to assess long-term performance and to confirm whole life costing benefits would be needed to progress this study further.

Appendix F

References

[i] Guidance on the legal definition of waste and its application DEFRA 2012, Part 2 updated May 2016

[ii] See above for links to all DoC CoPs

[iii] The Construction (Design and Management) Regulations 2015

[iv] EU List of Wastes http://ec.europa.eu/environment/waste/framework/list.htm

[v] Technical Guidance WM3: Guidance on the classification and assessment of waste (1st Edition v1.1 May 2018) Environment Agency

[vi] NIOSH Manual of Analytical Methods 5515 Polynuclear Aromatic Hydrocarbons by GC

[vii] MDHS 72 Volatile Organic Compounds in Air - Laboratory method using pumped solid sorbent tubes, thermal desorption and gas chromatography; HSE, and MDHS 96 Volatile organic compounds in air - Laboratory method using pumped solid sorbent tubes, solvent desorption and gas chromatography. Health and Safety Executive