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Road Note RN43

Best practice guide for recycling into surface course

I Carswell, J C Nicholls, I Widyatmoko, J Harris and R Taylor





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Road Note RN43 Project: Best practice for recycling asphalt thin surfacing Road Note RN43

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GLOSSARY

Active binder – that part of the bitumen in reclaimed asphalt that can still assist in binding aggregate particles together.

Added bitumen – bitumen added to the asphalt mixing that has not been used previously in asphalt.

Black rock – that part of the bitumen in reclaimed asphalt that has hardened to an extent whereby it can no longer assist in binding aggregate particles together.

Note: The definition applies at the time of production. It is not currently known to what extent black rock interacts with the remaining binder over time, but it is assumed that, by the time that has occurred, the remaining bitumen would have hardened sufficiently for it not to make the mixture unstable.

Control mixture – asphalt mixture without reclaimed asphalt as a component constituent whose properties are used as the target when designing a recycled asphalt mixture.

Planings - material removed from an asphalt pavement by planing operations.

Reclaimed asphalt (RA) – planings intended for recycling or re-use in another pavement layer.

Recycled asphalt mixture – asphalt mixture with reclaimed asphalt as a component constituent.

Recycling – the reprocessing of wastes into the same material.

Note: Waste and Resources Action Programme (WRAP) defines recycling as "the reprocessing of wastes, either into the same material (closed-loop recycling) or a different material (open-loop recycling)". For this report, it is restricted to closed-loop recycling of surface course asphalt back into surface course asphalt.

Virgin aggregate – aggregate particles added to the asphalt mixing that have not been used previously in asphalt.

ABSTRACT

The incorporation of suitable reclaimed asphalt in thin surfacing materials is becoming an important issue with the availability of high-quality aggregate resources depleting and with the greater emphasis being placed on sustainability by society. The feasibility of using up to at least 30% has already been demonstrated in trials and on contracts on major UK motorways whilst the potential for lower proportions of up to 10% being added on a regular basis has already been accepted for the Highway Authorities Product Approval Scheme. This Road Note is intended to act as a guide to what is considered to be good practice when specifying, designing, producing and applying this approach and to facilitate a relatively rapid change to its wider acceptance and use. A method of designing the asphalt mixture taking into account the binder content and binder properties of the reclaimed asphalt is provided. More general advice on the changes needed in the different operations is also given.

EXECUTIVE SUMMARY

Proprietary thin asphalt surfacing systems were first introduced into the United Kingdom in 1991. Since the late 1990s, they have become the surfacing of choice on the Highways Agency (HA) network and their use is permitted on trunk roads provided the system is approved by HA. The approval is based on the durability of the products from their performance over their first two years in service. However, the first applications of these products took place nearly two decades ago and this type of surfacing will increasingly need replacing. As such, the old material is increasingly becoming available for recycling along with the previously used surface types. However, thin surfacings contain more aggregate with high polished stone values than their predecessor on trunk roads in the UK of hot rolled asphalt with pre-coated chippings and, therefore, are a more valuable resource for recycling.

The feasibility of recycling up to at least 30% of surfacing materials back into thin asphalt surfacing systems has been demonstrated in trials and contracts on some major UK motorways whilst the potential for lower proportions of up to 10% being added on a regular basis has already been accepted for the Highway Authorities Product Approval Scheme. The incorporation of suitable reclaimed asphalt (RA) into such materials is becoming an important issue with the availability of high-quality aggregate resources depleting and with the greater emphasis being placed on sustainability by society. To facilitate the swifter and wider acceptance of this approach to enhanced sustainability, a suitable source of advice on known good practice about the technique is needed. This Road Note is intended to act as a guide to what is considered to be good practice when specifying, designing, producing and applying this approach in order to facilitate a relatively rapid change to its wider acceptance and use. In particular, a method of designing the asphalt mixture with due allowance for the content and condition of the binder is explained, followed by more general advice on the changes needed in the different operations to gain sustainability and economic benefits.

With the help of this guide, it is hoped that the addition of up to 10% RA will become a routine minimum whilst the addition of larger amounts will occur on some larger jobs where the conditions are appropriate.

1 INTRODUCTION

1.1 NEED FOR RECYCLING

Traditional asphalt surface course layers for major roads have generally been laid at least 40 mm thick. Thinner surface course materials have been available historically, but were considered to be technically inferior and were only used on roads carrying low traffic levels within the county road networks. However, during the 1990s, various categories of thin surfacing that have beneficial medium-term properties were introduced into the United Kingdom, mostly from the continent. Because of these properties (reduced noise, reduced spray and improved deformation resistance), thin asphalt surfacing systems have now gained a major share of the surface course market in all parts of the network.

In 1993, a government assessment of high-specification aggregate natural reserves in the UK showed that limited remaining resources were available. Wales and Northern Ireland were found to be reasonably well resourced, with 62 and 35 years of reserves, respectively. However, England and Scotland had 21-year consented reserves at 1991 rates of extraction, which were well below the rate reached in the following years. Furthermore, much of the surfacing prior to 1991 was carried out with surface dressing or hot rolled asphalt (HRA) with pre-coated chippings (PCC), comprising about 12-14 kg/m² of aggregates having a high polished stone value (PSV). A thin surfacing will typically use 36 kg/m² of high PSV aggregate when used in a 15 mm thick layer alternative to surface dressing, and 71 kg/m² when used in a nominal 30 mm depth layer alternative to HRA. These increases are in the order of 300-500% with respect to the two older traditional systems, and the thickness at which "thin" surfacing systems are used is now increasing to include 50 mm.

Therefore, the need to make full re-use of the high PSV aggregate in surfacing layers is becoming increasingly important. The alternatives would be either transporting material from well-sourced to less well sourced areas or increasing imports from elsewhere. The cost and sustainability issues related to those choices justify the conservation of the already used materials through recycling activities.

In order to investigate and promote the recycling of reclaimed asphalt (RA) from existing surface courses back into surface course asphalt layers, the Highways Agency (HA) commissioned TRL, supported by Scott Wilson Limited, Lafarge Aggregates Limited and Shell Bitumen, to confirm the feasibility of recycling and the potential to then develop guidance on good practice. To that end, laboratory studies and a series of road trials were undertaken. In addition, two major contracts incorporating RA in the surface course asphalt were monitored. Brief details of these trials and contracts are given in Appendix A, with more details available in some of the papers in the bibliography. This best practice guide has been developed from the experience gained from those studies and trials.

1.2 FORMAT OF REPORT

The introduction and design chapters are drafted in the traditional manner for TRL Reports. However, each of the main sections from Chapter 3 onwards begins with one or more simple quotations or other short statements that have been selected to encapsulate the overall concept of that section. It is hoped that these statements will help the reader to understand the wider implications of recycling activities. Following the quotation or statement will be the principal themes giving general advice on what needs to be achieved to enhance, or at least not detract from, the goal of producing fresh asphalt incorporating RA that will perform with the required performance. This general advice will be kept relatively brief so that the essence is not hidden among detailed considerations. The advice is intended to inform the reader as to what issues should be covered, but does not provide detailed instructions on precisely what to do in all cases. The latter would require a very large document that would need continual updating.

In each section, there is more specific advice on design, materials and laying, which is set out in differentcoloured boxes. Despite a wish for everybody to understand the full scenario of what can be done to ensure that the asphalt performs to the required level, the advice on each aspect is split in this way to improve the clarity. For these boxes, it is assumed that the overall objectives of the associated activities are as follows:

- The objective of design is to produce a specification against which high-quality asphalt incorporating RA can be produced with the required performance without onerous and unnecessary additional checks and restrictions that will make the operation uneconomic.
- The objective of material production is to produce asphalt that can be transported and laid without unnecessary difficulty in such a condition that it can meet all the functional requirements, including its long-term maintenance.
- The objective of laying is to install the asphalt under appropriate conditions and in a manner conducive to maximising the functional requirements, including durability.

However, the overriding objective for all involved must be to get it right first time. Replacement or even premature maintenance is not in the best interests of anybody – client, contractor or, most importantly, the road user.

The relative importance of the three specific sections giving advice on design, materials and laying varies on different aspects, as demonstrated by the amount of information contained within the boxes. The thinking behind this separation is for clarity, but the titles do not imply that the advice of the sections is solely for designers, materials suppliers and site staff, respectively. Everyone should read all three sections, even if they then concentrate on those most closely related to their particular responsibilities.

Finally, because of the format of most chapters in this report, direct references are not included, but a bibliography of documents that may be of use to those planning to use RA in thin surfacing materials, whether as specifier, supplier or contractor, is provided.

2 DESIGN

2.1 SUITABILITY OF RECLAIMED ASPHALT FOR RECYCLING INTO THE SURFACE COURSE

The recommended method for checking the suitability of RA for the properties of the aggregate is shown as a flowchart in Figure 2.1.



* The mechanical properties of the aggregate in RA can be assumed to at least comply with the limit set for the pavement from which it was taken.

† Chippings that have been recovered from bituminous materials may give misleading PSV results (BS 812-114:1989).

‡ A single source of RA is a road or roads known to have been laid with the same mixture, using the same component materials and laid at roughly the same time.

AAV = aggregate abrasion value; FI = flakiness index; LA = Los Angeles coefficient; MS = magnesium sulphate soundness; PSV = polished stone value; WA = water absorption.

Figure 2.1 Flow chart for acceptable aggregate properties of RA

2.2 LABORATORY DESIGN PROTOCOL FOR THIN SURFACING MIXTURES WITH RECLAIMED ASPHALT

The method of designing an asphalt mixture is broken down into five stages, which comprise 21 steps.

Stage 1 – Preliminary testing of the reclaimed asphalt

- Step 1 Carry out an initial evaluation of the properties of samples of the RA, including a review of any test reports relating to the original aggregate properties and a compositional analysis in accordance with BS EN 12697-1:2005 (solvent method, but leaving the sample and solvent to stand for 90 min in the metal bottle before rolling for 20 min) and BS EN 12697-2:2002 in order to determine the particle size distribution and binder content. (Note: The solvent method is becoming less used and in future the ignition method (BS EN 12697-39) is more likely to be available. If the ignition method is used, care needs to be taken that the amount of binder is not overestimated.)
- Step 2 Undertake a binder recovery test in accordance with BS EN 12697-3:2005, followed by determination of the recovered binder properties. For paving-grade binders, the relevant property is the penetration value to BS EN 1426:2007. It is also useful to measure the softening point of the binder. For polymer-modified binders, determination of the recovered binder rheology to BS EN 14770:2005 is recommended.

Stage 2 – Design of the initial trial mixture

- Step 3 Determine the penetration and softening point of the added bitumen to BS EN 1426:2007 and BS EN 1427:2007, respectively.
- *Step 4* Define the target "total" binder content of the recycled asphalt mixture as being the binder content of the relevant control mixture.
- Step 5 Based upon the results from Stage 1, calculate the amounts of added bitumen and virgin aggregate required. This calculation should assume the proportion of active binder in the RA. If required, cellulose fibre should be added at 0.3% of the total weight of mixture or other rate as used in the control mixture.
- Step 6 Manufacture the recycled asphalt mixture at the target binder content to BS EN 12697-35:2004 and then undertake a binder drainage test on that material to BS EN 12697-18:2004.
- Step 7 Proceed to Step 8 if the drainage is not greater than 0.3%; otherwise, review the proportion of active binder, and hence adjust the amount of added bitumen, before repeating steps 5–7.
- Step 8 Proceed to Step 9 if the RA content is greater than 10%; otherwise, proceed to Step 20 (Stage 5).
- *Step 9* Recover the binder from the recycled asphalt mixture to BS EN 12697-3:2005, followed by determination of the penetration of the recovered binder to BS EN 1426:2007.
- Step 10 If the recovered penetration value is not less than 50% of the penetration value of the added bitumen, as determined in Step 3, then proceed to Step 11 (Stage 3); otherwise, adjust the amount of added bitumen before repeating steps 6–9.

Stage 3 – Sample manufacture

- Step 11 Manufacture slabs of both the control mixture and the recycled asphalt mixture with a nominal thickness of 50 mm and a target air voids content of 2–6% using a laboratory roller compactor to BS EN 12697-33:2003.
- Step 12 Extract two sets of cores of 150 mm diameter from the slabs to
 BS EN 12697-27:2000 and then determine the bulk density of compacted specimens sealed by self-adhesive aluminium foil to
 BS EN 12697-6:2003 and the maximum density of loose coated samples to
 BS EN 12697-5:2002.
- Step 13 If the target RA content is greater than 20%, extract cores of 200 mm diameter from the slabs to BS EN 12697-27:2000 for wheeltracking tests.

Stage 4 – Testing

- Step 14 Determine the mixture volumetrics of the control mixture, including the percentage refusal density (PRD), air voids content, voids filled with binder (VFB) and voids in the mineral aggregate (VMA).
- Step 15 Determine the mixture volumetrics of the recycled asphalt mixture(s), including PRD, air voids content, VFB and VMA.
- Step 16 Compare the results from steps 14 and 15. If there is no significant difference in the results, proceed to Step 18; otherwise, go to Step 17.
- Step 17 Adjust the amounts of added bitumen and/ or virgin aggregate. If the theoretically calculated penetration (in the case of pavinggrade binder) does not differ by more than 15% from that measured in Step 9, repeat steps 15 and 16; otherwise, repeat steps 3–17 (stages 2–4).
- Step 18 If the target RA content is not greater than 20%, proceed to Step 20 (Stage 5); otherwise, carry out performance test(s) in accordance with the HAPAS SG3 guidelines the tests should include wheel tracking at 60 °C as a minimum.
- Step 19 If the results from the tests comply with the level of performance required, proceed to Step 20 (Stage 5); otherwise, adjust the amounts of added bitumen and/or virgin aggregate before repeating steps 3–19 (stages 2–4).

Stage 5 – Quality control

- *Step 20* Monitor the production and performance of the recycled asphalt mixture against the normal quality assurance protocol.
- *Step 21* The design is complete.

2.3 DESIGN OF ASPHALT WITH RECLAIMED ASPHALT

From the protocol in Section 2.2, the design of an asphalt mixture incorporating various quantities of RA is shown as a flowchart in Figure 2.2.



* A calculation procedure for the proportion of binder from RA is given in Section 2.4.

† It is assumed that such a departure will be agreed.

‡ For paving-grade binders, the relevant property is penetration.

Figure 2.2 Flow chart for design of thin surfacing system with RA

The requirements for the binder properties of the recovered binder and differences between the volumetric properties of trial and control mixtures that are considered acceptable are given in Tables 2.1 and 2.2, respectively.

Table 2.1 Acceptable properties of recovered billu	Table 2.1	Acceptable	properties	of recovered	binder
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Property	Criterion
Penetration	0.7 times lower bound to 0.9 times upper bound of specified range for binder as a component
Softening point	Not less than 0.8 times lower bound of specified range for binder as a component

	Table	2.2 A	cceptable	differences	between	volumetric	properties	of trial	and	control	mixture
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Name	Description	Control mixture	Acceptable range for trial mixtures	
Voids	Air voids content	T _{voids} %	$(T_{voids} \pm 1.5)\%$	
VMA	Voids in mineral aggregate	T _{VMA} %	$(T_{VMA} \pm 5)\%$	
VFB	Voids filled with binder	T _{VFB} %	$(T_{_{VFB}}\pm 3)\%$	
PRDPercentage refusal density T_{PRD} % $(T_{PRD} \pm 1.5)$ %				
Note: If the mixture is being designed to a specification with limits on these properties, then those limits take precedence				

2.4 ACTIVE BINDER CONTENT FROM RECLAIMED ASPHALT

The proportion by mass of the total binder that comes from the RA, p_{RA} , can be calculated using Equation 2.1:

$$\dot{P}_{RA} = P_{RA} \ge \frac{C_{RA}}{C_{mix}} \ge \frac{(100 - C_{mix})}{(100 - C_{RA})} \%$$
 (Equation 2.1)

where: P_{RA} = Proportion by mass of RA in the total mixture

 C_{RA} = Binder content of the RA

 C_{mix} = Binder content of the total mixture

Notes: (1) The binder content is defined as the ratio of the mass of binder divided by the mass of the total mixture rather than by the mass of just the aggregate.

(2) If C_{RA} is very similar to C_{mix} , then p_{RA} will be approximately equal to P_{RA} .

The proportion by mass of the active binder that comes from the RA, $p_{RA active}$, will be p_{RA} times the proportion of the binder in the RA that is active. Therefore, the binder content of added bitumen should be reduced by $p_{RA active}$ compared with the same mixture without RA as a component.

3 ADMINISTRATION

3.1 OVERALL APPROACH

The first step is often the most difficult

3.1.1 Little and often

Without a consistent source of RA and allowing for the limitations on the amount of RA that can be accommodated at some asphalt plants, the expected way forward is the incorporation of relatively modest proportions of RA, but on a routine basis. With such an approach, it is assumed that generally the planings from one site will be incorporated into thin surfacing for use on one or more other sites. Where planings are from a consistent source, addition rates of more than 10% could easily be added provided there was the capability to do so at the asphalt plant. If all thin surfacing asphalt contained 10% RA, the requirement for virgin aggregate would be reduced by that same proportion. Adding higher proportions from multiple sources of RA may require additional processing of the material, adding to costs and energy required.

3.1.2 Major schemes

On major road schemes where the asphalt being planed up is of the same material, the client can require that a minimum proportion is incorporated into the replacement surfacing. For this approach, the planings from one shift may be incorporated into thin surfacing for laying during a subsequent shift. Whilst the proportion of RA will be greater, the opportunities to take this approach are much more limited.

Planning advice

- Suppliers can plan for routine use of 10% of RA in their proprietary thin surfacing products.
- Clients can require large proportions of RA on large projects where the surface being replaced is of a consistent material.

3.2 OWNERSHIP OF RECLAIMED ASPHALT

Reclaimed asphalt is a valuable resource and worth owning

3.2.1 Options

In the past, planings have been considered as the property of the planing contractor. This was in order to keep down the cost of planing and to clarify whose responsibility it was to dispose of them. Now the situation is becoming more confused because those planings may be used as a high-quality product. Whilst the planing contractor may sell the planings on as RA for thin surfacings, there is less incentive for them to do so if there is no clear financial differential between that usage and other, lower grade options. The other options are for:

- the client to retain ownership of the planings either for use by their direct labour organisation, if they have one, or to give to a supplier on the same or another job for incorporation into the new surfacing, potentially at a discount;
- the main contractor, if different from the asphalt supplier, to retain the planings in a similar manner to the client; or
- the asphalt supplier to obtain control of the material for use in their thin surfacings.

The planings can be recycled as RA into thin surfacings for each of these options, but the impetus is likely to be greater with ownership by the client or asphalt supplier, and demands by the client for higher levels of RA addition.

3.2.2 Basis at tender stage

The ownership of the planings should be clarified at tender stage so that each party can calculate their prices accordingly. This clarification is particularly important on major contracts where a minimum proportion of the planings is required to be incorporated into the replacement surfacing.

Planning advice

- The ownership of the planings should be clearly defined in the tender documents.
- The ownership of the planings should be passed to a party that is interested in using them as RA at the highest level.

Mixture design advice

• For large proportions of RA, access to samples of RA as early as practicable should assist in meeting deadlines and increasing the opportunities for recycling into surface course layers.

3.3 APPROVALS

Early requests avoid later complications

3.3.1 Departures from standard

When working on trunk roads, the surfacing generally has to be a proprietary thin surfacing certified under the Highway Authorities Product Approval Scheme (HAPAS). That scheme permits the use of RA content up to 10% with appropriate controls on the feedstock and mixture design, but not currently greater amounts without further expensive assessments for certification of the modified product. Therefore, if larger amounts are required, a departure from standard will be required. Whilst there is a presumption that such departures are likely to be agreed, based on the fact that the requirement will generally be client driven, the formal application is needed and should be made as soon as practicable in case there is any problem. With the smaller proportions, a check should be made to ensure that the certificate is not invalidated by including RA.

Planning advice

- When working on trunk roads with more than 10% RA, apply for a departure from standard as soon as practicable.
- Assume that the PSV and AAV are at the set limit for the source site if no further information is available.

3.3.2 Aggregate properties

Many jobs require minimum values of the mechanical properties of the aggregate, in particular the PSV and aggregate abrasion value (AAV). If the actual properties of the aggregate in the RA are not known but the source is known, then the properties required on the source location can be taken as an estimate. It is generally better to ensure that both the aggregate from the RA and the virgin material comply with the requirements because the properties of a blend are not always a weighted mean of the properties of the components. With major contracts using a consistent source, it may be advantageous to test the blended aggregates when either source does not comply on its own, but this approach is not expected to be worthwhile on a routine basis. Small variations in the PSV and AAV for RA contents $\leq 10\%$ may not have a significant impact on the new surfacing.

Mixture design advice

- Ensure that the HAPAS certificate includes the use of the required proportion of RA if a certificated product is needed.
- Ensure that both sources of aggregate comply with the requirements rather than testing the blended aggregates if possible.

4 RECLAIMING ASPHALT

4.1 PLANING

Care during recovery will avoid more processing later

4.1.1 Layer separation

Traditionally, all layers of asphalt that need to be removed tend to be planed off together. However, the aggregates in layers other than the surface are unlikely to have the appropriate properties for use in a new surfacing layer. Therefore, when the planings are intended to be used as RA in a surface course mixture, the planing operation needs to be undertaken separately for the surface course and for other layers. Furthermore, the resulting planings need to be kept separate thereafter to make the process worthwhile.

4.1.2 Aggregate property classifications

The minimum classification of planings is into RA from the surface course and RA from other layers, with only the RA from the surface course being used for new surface course mixtures. However, if there is sufficient storage available, separate stockpiles can be kept with RA of similar grading and/or with aggregate in the same PSV category. The required level of classification needs to be undertaken before the planings from different sources are combined and is probably best done immediately. Classification beyond the minimum level is not expected to be practicable other than for large contracts and/or large proportions of RA addition.

4.1.3 Consideration of future usage

When setting up the classification system for a contract or plant, the use intended for the RA must be the primary consideration. If the RA is to form a large proportion of the asphalt, then complex classification at an early stage can avoid extensive processing later, but if the RA will be incorporated at a proportion of 10% or less in routine material, the classification needs to be simple and avoid unnecessary expense.

4.1.4 Surface treatments

When a surface dressing or micro-surfacing is present, a decision needs to be made as to whether or not to include it as part of the RA. The aggregate properties should be similar to those of the surface course because they were selected for the same road, but they will not necessarily be the same, whereas the aggregate grading and the binder will probably be very different, the latter both in terms of grade and content. Generally, these differences and the resulting potential additional variability mean that such treatment will need to be removed, although there are difficulties in removing such thin layers.

4.1.5 Inherent contamination

With the increasing interest in the use of secondary material in asphalt, there is potential for the source asphalt having components other than mineral aggregate/filler and bitumen. Some of the alternatives, such as various slags and polymer modifiers, have proved to be acceptable and should not cause any problem as part of the RA. However, there are other materials that could cause problems, of which the most likely to be found is tar. If there is a possibility that the layer being planed is tar-bound, then it should not be used as an RA source for hot-mix surface course. Other potential contaminants should be considered on an individual basis in terms both of their health and safety implications for workers and the public and of their potential effect on the durability of the resulting asphalt.

4.1.6 Contamination during collection

The surface course of an aged pavement is not likely to be without contaminants, some of which need to be considered. At the top surface, there needs to be no mud, vegetation or piles of dirt, although it is impractical to remove all detritus. On the underside, it is important to avoid dragging up the top of the layer below, particularly when it is of a dissimilar material, such as concrete, and where higher percentages of RA are being considered for use in the new surface course. With concrete substrates, there is also a need to avoid collecting any of the joint seals with the RA. The other contaminant that is likely to be within the pavement is any tack or bond coats used to seal the layers and/or rips together, but these cannot easily be excluded and may increase the overall binder content and affect the recovered binder properties.

4.1.7 Water

Water is expensive to remove from RA when it is introduced into an asphalt mixture. Therefore, it is preferable not to introduce any more water than is necessary during the planing operation.

Planning advice

- The planings should be separated into that from surface courses and that from other layers as a minimum.
- · Further classification needs to be justified.

Production advice

- Avoid contamination as far as possible.
- Excessive water should not be added during planing as this can lead to additional requirements for processing and drying at the plant later. Add just enough water to plane effectively.
- Carry out routine visual assessment; if noticeable, assess the extent of contaminants.

4.2 TRANSPORT

Efficient transport movements can reduce the carbon footprint and save money

4.2.1 Extent of transportation

As a minimum, the RA will have to be taken from the planing operation to the mixing plant and from there to site. Often, the material will also have to be transported to locations where it is stored and to where further processing and/or testing is to be performed. For each journey, different categories of the RA will need to be kept separate.

4.2.2 Separation of categories

The surface layers need to planed and transported separately from the lower asphalt layers. The surface course then needs to be stored separately from the lower layers at all times. However, if the RA is collected from several sites on a loop or if the site contains lengths with different materials, multiple categories could be collected by a single vehicle, which will therefore need to be fitted with barriers or containers to keep the categories separated. However, such sophistication will only be needed with a sophisticated recycling regime. Where the RA is to be used for low, routine levels of addition, separation of the surfacing materials may not be necessary.

4.2.3 Maintaining cleanliness

Whilst the most obvious contamination is crosscontamination between categories, the vehicles should also be modified to stop other contamination such as precipitation and falling leaves.

4.2.4 Co-ordination of journeys

Particularly if recycling is being undertaken as a means of facilitating more sustainable construction, the journeys made between the source sites, the storage area, the processing plant, the mixing plant and the laying site should be co-ordinated in order to minimise vehicles travelling empty. Furthermore, the various locations should be as close as practicable with, in most cases, several of them being co-located. The ability to keep distances down and using vehicles to both deliver asphalt and return with RA can be both economically and environmentally beneficial.

4.2.5 Size of loads

Avoiding too many journeys with only partial loads can also enhance the sustainability of any operation. However, some partial loads are likely to be unavoidable.

Production advice

· Avoid contamination and cross-contamination of RA during

• Co-ordinate the transport to minimise empty or partial load journeys.

Planning advice

4.3 STORAGE

Keep it clean, avoid contamination

4.3.1 Past practice

The storage of RA has often been in a single pile to which all material is added. Whilst this approach is adequate when the RA is intended for use in lower grade applications, if some of the RA is to be recycled into a surface course material, then at the very least the material suitable for recycling into the surface course needs to be kept separately from other RA. Ideally, there would be a number of stockpiles of RA, each having different properties and being separated so that there is no inter-mixing, but there is rarely sufficient room at plants for this ideal, particularly in urban areas.

4.3.2 Categorisation

transit

The number of categories needed for a recycling operation will depend on the sophistication of the intended operation. Ideally, the number of categories should match the classifications in Tables 13 (for PSV) and 14 (for AAV) of BS EN 13043:2002, together with petrographic type, but fewer categories will almost certainly have to be used because there are unlikely to be sufficient storage facilities. In particular, the ideal storage requirements will be too extensive to be practical in more built-up locations. The number of categories should be reviewed in terms of practicality before a procedure for recycling RA back into surface course mixtures is implemented.

4.3.3 Separation of categories

RA from each source, particularly from different nominal aggregate sizes, should be kept separate until its properties are identified and it can be allocated to the appropriate stockpile. The classification can be done at any stage, but the earlier it is completed, the fewer number of stockpiles or further processing will be needed. If the classification is not done until after it has arrived at the plant, then the RA will need to be kept isolated at the source location, both whilst being transported and when it first arrives at the plant. The alternatives would be storing all the RA together initially and then either trying to separate out fractions of particles with similar aggregate properties (particularly PSV and AAV) that are coated with a similar thickness of bitumen of a similar grade, or the mixture design would have to be revised as the aggregate properties, bitumen content and binder properties changed. In either case, aggregates with inappropriate properties will need to be reclassified for use in another layer other than the surface course.

4.3.4 Changes

Any known change in the mixture of surface course can be considered as a separate source. As soon as practicable, the aggregate properties of the surface course material should be established in order to ensure that that material is suitable for use in surfacing layers. Any unsuitable aggregate should be excluded.

4.3.5 Protection from rain

Ideally, the stockpiles should be protected from the rain in order to avoid the need to dry the RA before it is added at the mixing plant. The simplest option is to cover with tarpaulins, but this approach will be more labour-intensive than a fixed roof.

4.3.6 Protection from contamination

Ideally, the stockpiles should also be protected from contamination. In a fixed storage area, contamination is unlikely to be a problem, but in temporary storage areas, the flooring may need to be raised to protect the RA from loose material and vegetation that may be present.

Planning advice

- Separate storage areas need to be made available for each classification of RA used.
- Production advice
 Ensure that the storage facilities will minimise contamination
 and moisture ingress.

5 ANALYSIS AND PROCESSING

5.1 PARTICLE DISTRIBUTION

Know your limits, and stay within them

5.1.1 Available fractions

The particle distribution of an RA source after the soluble binder is removed is the best estimate available. However, it is impractical to remove the binder from more than selected samples of any source.

Mixture design advice

• Binder film must be allowed for when separating RA fractions.

5.1.2 Allowance for binder

The apparent particle distribution resulting from a sieve analysis of the RA that includes the binder will not be identical to the particle distribution of the aggregate after the binder has been removed. The larger particles will be coated by a film of mortar consisting of binder plus filler whilst other small particles will be bound together, both of which will increase the apparent coarse aggregate content at the expense of the finer fractions. If the RA is to be processed into fractions for subsequent recomposition into asphalt mixtures with large proportions of RA, an allowance for the finer particles in each coarse fraction will have to be made by comparison of analyses with and without removing the binder.

5.2 **PROCESSING**

Processing needs to be kept to a minimum for economy, but insufficient processing can invalidate the basis of the whole process

5.2.1 Variability

The amount of processing required will depend on a combination of the proportion of RA being added and the variability of the RA source(s). If the amount of RA is no more than 10%, then the effect of a 10% change in its grading will only change that of the recycled asphalt mixture by 1% at most, which is insignificant for most sieve sizes. However, if large proportions of RA are to be incorporated and the RA source is variable, extensive processing and subsequent recombination will be needed to ensure a consistent grading. The processing needed will generally be proportional to the quantity of RA added and the benefits to be gained.

5.2.2 Removal of oversize particles

The simplest processing is to remove the particles from the RA that are oversize to the required grading of the intended recycled asphalt mixture by screening. It is obviously necessary if there is any inconsistency between these gradings.

5.2.3 Removal of fine particles

For incorporation at larger proportions, there is often also a screen of the smaller sized fractions. The finer material will include particles produced during the planing operation and detritus that has built up either on the surface or within the surface layer during service. These fine particles, particularly any detritus present, can be very susceptible to moisture. The remaining middle fraction will, however, still contain some of the finer fraction from the mortar attached to the larger aggregate particles.

5.2.4 Water

One additional advantage to removing the fine particles is that any moisture present in the RA is likely to be predominantly in this fraction. Any reduction in the moisture content will ease the mixing process by reducing the amount of heat needed to drive off the water.

Planning advice

 The extent of processing is dependent on the proportion of RA added and the RA variability.

Production advice

- The removal of oversize particles is essential.
- The removal of fine material should reduce moisture content and susceptibility to moisture and is essential where detritus is present.

5.3 **BINDER CONTENT AND CONDITION**

The binder on the RA is a valuable resource, but could be considered an inconvenience because its effectiveness is often not known

5.3.1 Soluble binder

Bitumen becomes more difficult to extract from asphalt as the material ages, particularly when it is polymermodified bitumen. Therefore, the analysis process has to be modified for a majority of the aged soluble bitumen to be extracted. It has been found that, when using a solvent method to BS EN 12697-1:2005, the sample and solvent need to be left to stand for 90 min in the metal bottle before rolling for 20 min. If an ignition method were used on very old RA, the result may be marginally greater because some of the flammable binder may no longer be soluble.

5.3.2 Active binder

Although the soluble bitumen may be determined, the extent to which it is still an active binder may differ. With age, the bitumen tends to harden, as measured by a reduced penetration, and its ability to adhere to aggregate particles is inhibited. The proportion of active binder is needed because the recycled asphalt mixture needs a high enough binder content (consisting of the active binder and the added binder) to bind the particles together and provide durability without the binder draining and/or allowing the aggregate to move relative to other particles when loaded, resulting in deformation. A simple test to check for an excess of binder is to carry out a binder drainage test, increasing the assumed proportion of the RA binder that is active, if binder drainage is $\geq 0.3\%$, and reducing the need for added bitumen.

5.3.3 Binder retained on aggregate

Some of the binder will not be able to be recovered because it has been absorbed into the aggregate particles. As such, it can be regarded as irrelevant because it will not take part in the mixture design considerations. However, it does have some effect because the aggregate can no longer absorb as much bitumen when recycled, so reducing the binder demand of that aggregate. However, the effect is usually less than the other uncertainties and can usually be ignored.

5.3.4 Requirement for added binder

The objective is to add the specific quantity of bitumen of a specific grade that, when combined with the active binder from the RA, produces a binder content and binder grade that would have been used had no RA been incorporated. The quantity of added binder required can be calculated in accordance with Section 2.4 whilst, when more than 10% of RA is to be included, the penetration of the added bitumen can be adjusted until that of the combined binder is corrected when calculated in accordance with Annex A of BS EN 13108-2. The penetration of the actual bitumen added may need to be rounded to meet a standard grade to avoid unnecessary complexity. In the case of small proportions of relatively new RA, this adjustment may result in using the target grade for the added bitumen.

Mixture design advice

- The analysis process (solvent method) has to be modified for a majority of the aged soluble bitumen to be extracted.
- · The binder drainage test can be used as a simple screening test to assess the active binder in the RA.
- The requirement for the penetration of the added binder can be calculated, but will not be necessary for 10% RA or less.

6 MIXING AND CONSTRUCTION

6.1 ASPHALT PLANTS

Limitations on reclaimed asphalt content will often come from the plant

6.1.1 Ability to take reclaimed asphalt

The capability for incorporating RA in asphalt plants is quite varied. Batch or continuous drum mix plants could be used for incorporation of RA. At the time of writing in 2009, and based on a limited industry response:

- between 10% and 20% of plants had the capability to include between 10% and 15% RA;
- up to 20% of plants had the capability to include over 30% RA; whilst
- the remaining plants could only accept up to 10%, with some being unable to accept any RA.

6.1.2 Limitations of reclaimed asphalt

The quantity of RA that is actually added in the plants also depends partly on the quantity of planings available; that is, sufficient quantities of a suitable source are needed. Small un-processed quantities can be added relatively easily without adversely affecting the end product performance.

6.1.3 Plant modification

Plants can be modified to take more RA, and modern plants are designed to take RA when built. The costs of improving the capability of other plant needs to be justifiable in economic and sustainability terms for the quantity of RA that could be included in the asphalt as a result. For example, it is understood that improving some plants to include 10% RA would cost £160 000, and the incorporation of higher proportions of RA would require significant plant upgrades at an even greater cost. The need for improved sustainability and reduced carbon footprint should provide the drivers to make these investments worthwhile.

Planning advice

 If wanting to use RA in surfacing mixtures, the supplying plant needs to be selected accordingly.

Production advice

• Plants can be modified to take (more) RA, but it will not always be viable economically.

6.2 MIXING

The aim is homogeneity

6.2.1 Trials

Plant trials may be needed to check production and laying performance together with finished surface texture when larger proportions of RA are to be added. The trials are envisaged as being for the supplier to optimise his operational processes rather than as a contractual issue.

6.2.2 Control of reclaimed asphalt added

The amount of planings included in the mixture needs to be controlled through accurate monitoring of the "RA feed mechanism(s)" on the plant.

6.2.3 Method of addition

On a batch mixer, the RA can be added, unheated, to the virgin aggregate at the base of the hot elevator after the virgin aggregate has left the dryer. To compensate for the RA being unheated and to drive off the moisture within the planings, the virgin aggregate has to be superheated. The temperature has to be raised by about 1.2 °C for each 1% addition of unheated RA so that the finished product is produced at the same temperature as it would be for a completely virgin material. By adding (some of) the RA at the base of the hot elevator, there is a thorough mixing of the two fractions and the inherent moisture in the RA is quickly converted into steam and removed via the normal dust extraction system. On a drum mix plant, the RA is normally added through the recycled collar.

6.2.4 Superheating part of the reclaimed asphalt

Adding all the RA cold into the mixture may be unsuccessful despite superheating the virgin aggregate, particularly with larger proportions of RA. In such situations, the target mixture temperatures can be achieved by adding, say, 10% of the RA via the hot elevator and the remainder added cold directly into the mixer. If RA is heated, then care must be taken to ensure that the binder in the RA is not excessively aged and that it does not form a fire hazard whilst at the elevated temperature in the plant. The actual method of addition will be for the supplier to determine based on plant design and capability.

6.2.5 Order of addition

The order of addition of component materials into the asphalt mixer should be no different from that of an asphalt mixture without RA. The RA is generally added at the same time as the virgin aggregate.

6.2.6 Mixing time

The mixing time needs to be sufficient to achieve homogeneous blending of the active binder and the added bitumen.

Planning advice

· Trials may be advantageous to the supplier to

achieve a workable homogeneous mixture.

Production advice

- The RA can usually be added through the cold feed on batch mixers.
- For larger proportions of RA, some RA may need to be added via a hot feed on batch mixers.
- For drum mix plants, the RA can be added through the recycled collar.

6.3 CONSTRUCTION

No change here, then

The construction with recycled asphalt mixtures is no different from a conventional asphalt mixture that does not contain any RA. The principles of Road Note RN42, *Best practice guide for durability of asphalt pavements*, should be followed for the laying and compaction of asphalt material.

Production advice

 No change in technique from laying asphalt mixtures without RA.

7 QUALITY CONTROL

7.1 MONITORING OF RECLAIMED ASPHALT

Designs need to be validated, but the level of checks should be appropriate

7.1.1 Routine analysis

RA can be considered as another component material in the manufacture of asphalt. As such, the RA should be tested at least as often as the more traditional components such as virgin aggregates, filler and binder. However, the variability in the RA can be greater than that of aggregate won from a single source, depending on where it comes from, so that this level of monitoring will often need to be increased for the RA, particularly for the higher levels of RA addition. The RA should be classified and tested to comply with BS EN 13108-8.

7.1.2 Aggregate properties

The mechanical properties (in particular, AAV and PSV) of the aggregate in the RA need to be checked to ensure that it is suitable. The identification can be made:

- from records of the component materials in the original mixture, when available;
- by assuming that it complied with the requirements with the road from which it was taken when originally laid; or
- by direct testing when necessary.

The assumption of compliance needs to allow for any changes in those requirements/properties whilst the old material was in service. Furthermore, it is likely to be a conservative approach because the properties will often have been greater than the minimum required. Therefore, direct testing may still be needed when that minimum is marginally below the level now required.

7.1.3 Particle distribution

If the RA is to be used without being split into separate fractions, the grading of the RA needs to be established before the material is incorporated into a new mixture. The frequency at which gradings need to be taken will depend on the proportion of RA to be added (because the more that is added, the more influence it will have on the grading of the final mixture) and the consistency of previous results. If the RA is separated into separate fractions, the need for grading will be reduced depending on the width of the fractions used. When the split is to be around just one or two sieves, there can still be more than one fraction used in the mix design in each RA fraction and some grading, at a lower frequency, should be used. However, when the split is into the fractions used in the mix design, no further grading is necessary, but the processing required usually makes this option uneconomic.

7.1.4 Distribution analysis

Grading (particle size distribution) can be carried out either as delivered to a laboratory or after removing the bitumen. Ideally, all the bitumen from the old asphalt should be removed so that it does not cause some particles to stick together, so forming fewer, larger particles and distorting the result. In practice, the intention should be to establish what the effective grading would be during the mixing, transporting and laying of the new asphalt when the asphalt components will be subject to fairly aggressive forces. Therefore, it is suggested that the initial grading is undertaken after the majority of active bitumen has been removed using traditional methods such as solvent extraction. Subsequent gradings can then either be carried out in a similar manner or on the as-delivered material provided the initial grading had been repeated on an as-delivered sample. When using the as-delivered grading, only when that grading differs from the initial as-delivered analysis by more than the normal repeatability given in BS EN 9331:1997 should the binder-free analysis need to be repeated to establish how the actual grading had changed.

7.1.5 Frequency of grading analyses

The particle distribution of the aggregate in the RA needs to be tested. Sector Scheme 14 gives a minimum frequency of one test per 500 tonnes of RA. If the variability of the material grading is $\leq 5\%$ then this frequency of testing is appropriate. If the variability of the material is higher then a more frequent testing regime may be required; recommended minimum test frequencies are proposed in Table B.1 of Appendix B, depending on the proportion of RA to be added and the variability of previous analysis results.

7.1.6 Petrological classification

Sector Scheme 14 requires petrological classification of the RA by a visual check at the same frequency as the particle distribution, so it would be logical to undertake the petrological classification with the grading at the same enhanced frequency. However, such a classification should be restricted to when large proportions of RA are to be added and should consist primarily of a visual check that the aggregate in the RA has not changed radically from past inspections.

Planning advice

 The aggregate grading and physical properties and binder content and physical properties need to be monitored regularly.

7.1.7 Binder testing

The bitumen in the RA needs to be tested for bitumen content and recovered penetrationas required in BS EN 13108-8. Sector Scheme 14 gives a minimum frequency of one test per 500 tonnes of RA, but it is proposed to revise the minimum frequency of assessment depending on the proportion of RA to be added and the variability of previous analysis results. The proposed minimum frequencies are given in Table B.2 of Appendix B.

Mixture design advice

• The variability of RA needs to be allowed for in any mixture design.

7.2 RECLAIMED ASPHALT MIXTURE DESIGN

The design needs to be correct; aim for success, not perfection

7.2.1 Initial design

The mixture design, in accordance with the guidance given in Chapter 2 or another suitable method, will need to be carried out initially and then repeated in part when the source RA has changed significantly. The property changes that can cause the need to adjust the mixture design are the aggregate grading, the binder content and/ or the recovered bitumen grade and binder properties.

7.2.2 Changes in particle distribution

If the grading of the RA changes, the proportion of each fraction of virgin aggregate will need to be adjusted accordingly. The extent of adjustment will depend not only on the extent of the change, but also on the proportion of RA being incorporated into the new mixture. The change, once the correction has been implemented, should not affect the mechanical properties of the mixture because the grading will remain intact. Problems may only occur when the majority of a particular fraction of the new grading is coming from the RA. If the amount of that fraction from the RA would then significantly exceed the amount required in the new mixture, either the proportion of RA will need to be reduced or some of that fraction will have to be screened out from the RA.

7.2.3 Changes to added bitumen

If the binder content and/or the recovered bitumen grade changes, the amount and/or grade of the added bitumen may need to be changed. Again, the extent of adjustment will depend not only on the extent of the change, but also on the proportion of RA being incorporated into the new mixture. The size of change needed to initiate a review of the design could be, say, that the binder content, in per cent, changes by more than ten divided by the proportion of RA to be added (that is, 1% with 10% RA but 0.33% with 30% RA) and/or the recovered penetration, in 0.1 mm, changes by more than 100 divided by the proportion of RA to be added (that is, 10 pen with 10% RA but 3.3 pen with 30% RA). However, the change to the new mixture would be expected to be more critical than the change in aggregate grading because of the uncertainties of mixing disparate binders to form a (hopefully) homogeneous blend. Therefore, if the fresh penetration bitumen grade has to be changed by one or more grades, the initial design may need to be repeated. Note: If a polymer-modified binder is used, then changing "grade" is not an option.

7.2.4 Design checks

The design should be repeated whenever the source of RA changes significantly. If the policy is to combine the incoming RA that has complying aggregate into a single source, then the use of a source would not constitute a new source unless there was something different about it, such as using a 0/10 mm stone mastic asphalt (SMA) when all previous sources were 0/14 mm SMA or a HRA when all previous sources where SMA.

Mixture design advice

- The design will need to be changed if the RA properties vary.
- The influence of any change will depend upon how much RA is being added.
- Changes in the binder properties will be more significant for large proportions of RA.

7.3 HIGHWAYS AUTHORITIES PRODUCT APPROVAL SCHEME

"Everything should be made as simple as possible, but not one bit simpler" – Albert Einstein ...or

Nothing is as simple as we hope it will be

7.3.1 Small proportions of reclaimed asphalt

Thin surfacing system producers who have HAPAS certificates for their products should be able to get those certificates modified to permit the routine addition of up to 10% RA into those products, provided that the certification body agrees. Such an agreement should require the certificate to have set out a regime for use with this addition that includes any additional testing required and a review of the quality control for the recycled material and the production methods.

7.3.2 Larger proportions of reclaimed asphalt

Rates of inclusion of RA greater than 10% are generally only feasible when there is a source of RA that will remain consistent for a significant time, which is usually when that source is the planings from a major job that did not have extensive repairs prior to being replaced. Here, the additional testing necessary is to ensure consistency rather than allow adjustments to the mixture design. On a job-specific basis when the client has requested the inclusion of more than 10%, the lack of a HAPAS certificate covering the thin surfacing may not be a problem. However, if such higher rates of inclusion were required on a regular basis, the product would probably require a specific certificate that would clarify the acceptable sources of RA and its subsequent processing. The processing would need to ensure consistent grading, aggregate properties, bitumen content and bitumen properties - not easy to achieve concomitantly given the range of sites that RA can come from. However, if the processing was too extensive, it is unlikely to be economically viable or sustainable.

7.3.3 Method statement

Appendix B has been prepared as a method statement that certificate holders can use as the basis of their specific method statement in order to satisfy the HAPAS certification authority that their certification should be amended to include RA as a component material.

Planning advice

 HAPAS certificates will need to be explicitly extended before the addition of RA is permitted within the scheme.

Mixture design advice

• The methodology for the design, and redesign, will have to be explicitly documented for HAPAS products.

Production advice

• If RA is added to a mixture without direct reference in the certificate, it will not be a HAPAS product.

7.4 LONG-TERM MONITORING

We can only advance through knowledge of how past works performed

7.4.1 Objective

With any relatively new procedure, it is important to check how it is performing in order to see if that performance can be improved and/or to demonstrate that the concept works. There are some "demonstration" sites (Appendix A) that will continue to be monitored, but others could find it useful to have local trials with their specific materials for similar reasons. The primary responsibility for long-term monitoring is with clients in order to have sites with proven performance that can justify their use of, or even encouragement for, the use of RA in thin surfacings. The monitoring of the sites in Appendix B for HA is an example of this approach. However, the suppliers of the products also have an interest, which is demonstrated by the heavy involvement of Lafarge Aggregates in the trials and CEMEX and Tarmac in their respective motorway contracts.

7.4.2 Approach

For any meaningful monitoring, a control section without RA is needed for comparison. On major contracts where the RA is taken from the same site for inclusion in the mixture the following day, the first shift generally involves no RA and can form that control section. Monitoring the performance can be simply done via regular visual examinations to check that the recycled asphalt mixture is not performing any worse than the control, and this method would be recommended. However, if more detailed information is required, samples can be taken at regular intervals for comparative wheel-tracking rates, stiffnesses, recovered binder properties or other measurements to produce plots of how the selected measurements change with time for the control and RA mixtures.

Planning advice

Mixture design advice

· Long-term monitoring can be used to influence future policy.

• Long-term monitoring may lead to improvements in the mixture design procedure.

8 CONCLUSIONS

Recycling of RA from a surface course back into a thin surfacing mixture has been shown to be feasible and practicable, and its use is expected to increase. It is assumed that the routine addition of up to 10% RA will become the norm whilst the addition of larger amounts will occur on some larger jobs where the conditions are appropriate. Sustainability issues will be the drivers for increased adoption of RA into surface course layers and technological developments in asphalt plants will allow for increased and routine use of RA in surfacing layers.

Various issues of good practice have been compiled into this report in order to encourage this development. Much of the advice is also applicable for including RA into lower asphalt layers, although some of the restrictions with regard to surface course layers are no longer applicable.

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APPENDIX A: EXISTING TRIALS AND CONTRACTS

A.1 RENISHAW

Pilot-scale trials of SMA incorporating RA from the A50 Doveridge were carried out on the access road to Lafarge Aggregates' Renishaw Asphalt Plant near Sheffield on 24 June 2002. Three trial panels were constructed: a control SMA without RA and two panels incorporating 15% and 30% RA, respectively. The site has been monitored annually by TRL and Lafarge Aggregates, the last survey being carried out in September 2008, 75 months after construction. The site is subjected to heavy turning traffic, and the visual assessment to the HA/TRL Inspection Panel 7 point scale ranked all three sections as "Moderate".

A.2 A1(M), HATFIELD

Lane 1 of the northbound carriageway on the A1(M) in Hertfordshire between junctions 3 and 4 was surfaced during a nightshift in January 2004. Four sections were laid - two control and two with 10% RA. The site has been monitored annually with TRL surveying the trial site on the A1(M) Hatfield in August 2008, 55 months after construction, during a night-time tunnel closure. At that time, there was little difference between the penetration, softening point and viscosity values from bitumen recovered from the control and 10% RA sections. Similarly, the measured deformation resistance properties of both the control and RA sections were comparable, with all mean results in the range 0.4 mm/h to 0.5 mm/h at 60 °C and minimal rutting had occurred on site with the mean results in the range 1.3 mm to 1.9 mm. The visual assessment was "Good" for all sections, although the survey was undertaken during night-time working when there is limited visibility.

A.3 A405, BRICKET WOOD

Lane 1 of the northbound carriageway of the North Orbital Road, Bricket Wood, between junction 6 of the M1 and junction 21a of the M25, was surfaced during a nightshift in August 2004 after heavy rainfall during the previous day. Six sections were laid – a control, 10% and 30% RA sections of both the thin asphaltic concrete (TAC) and SMA materials. The site has been visited annually with TRL surveying the site in August 2008, 49 months after construction. Wheel-tracking test measurements on cores showed an increase in the deformation resistance with time, but no particular correlation between the deformation resistance and the added RA content. The properties of bitumen recovered showed the lowest penetration for the SMA sections, followed by the TAC with 30% RA, then with 10% RA and finally the control; the softening points were, however, all very similar. The visual condition of each of the test sections was assessed by the HA/TRL inspection panel during September 2008, when all the TAC sections were assessed as "Good" to "Moderate" whilst structural problems adversely affected the SMA sections that were unrelated to RA content.

A.4 M4, CARDIFF

Porous asphalt had been laid on 4.7 km of the M4 motorway between junctions 32 and 33 in 1994. Cemex Construction Services resurfaced this material between mid-July and the end of August 2006 with a requirement from the National Assembly for Wales to incorporate at least 25% of the reclaimed porous asphalt into the new thin surfacing material. The work was undertaken during night closures, with the RA from one night being used in the asphalt the following night after processing. As such, the first night's production, with no RA, acted as a control section. The processing was to remove both the undersize (0/6 mm) and oversize (>18 mm)aggregate fractions, with these fractions being used on other jobs. The site has been monitored annually by the HA/TRL inspection panel, with both the control and main sections being rated as "Good" in July 2008, when the visibility was poor due to heavy rain, down from "Excellent" the previous year.

A.5 M25, REIGATE

Similar to the M4 in Cardiff, this scheme involved planing out an existing porous asphalt surfacing and replacing it with a thin surfacing incorporating 23% RA from the existing material by Tarmac Limited National Contracting. The material was transported to an asphalt plant for processing, with the undersize and oversize aggregate fractions removed, to enable the RA to be incorporated into a new thin surfacing system. The resurfacing works took place at night during August 2007 under lane closures with the carriageway reopened to traffic during the day. Initial trial mixtures were undertaken to establish the best method of RA addition to the mixture whilst still being able to maintain sufficient temperature within the mixed material for transportation and laying on site. An energy study was undertaken during the works to establish differences between using 100% virgin aggregates and incorporating 23% RA, which demonstrated carbon savings from reduced transport operations.

APPENDIX B: METHOD STATEMENT FOR HIGHWAYS AUTHORITIES PRODUCT APPROVAL SCHEME CERTIFICATION

B.1 STORAGE OF RECLAIMED ASPHALT

- 1. Material from different layers will be kept separate at all times after planing, including whilst they are being transported. When appropriate, material from different sources will also be kept separate where, for this purpose, any known change in the mixture of surface course can be considered as a separate source.
- 2. As soon as practicable, the aggregate properties of the surface course material will be established in order to ensure that the material is suitable for use in thin surfacing systems. The identification will be made from records of the component materials in the original mixture when available, by assuming that they just complied with the requirement for the road when laid or by direct testing when no other information is available. Any unsuitable aggregate will be discarded from this process and the remainder will be classified as suitable RA.
- 3. When practicable, the RA will be kept in separate stockpiles for each category of their properties. Ideally, the number of categories will match the classifications in Tables 13 (PSV) and 14 (AAV) of BS EN 13043:2002 whenever possible, but fewer categories will be used when there are insufficient storage facilities. In the latter case, the RA will be treated as having the properties of the least variable category of those combined.
- 4. When the material needs to be transported, the RA from different stockpiles will be treated separately without cross-contamination or other contamination to the location for testing, further processing and/or use.

B.2 PARTICLE DISTRIBUTION OF RECLAIMED ASPHALT

- 5. The initial grading for particle distribution of an RA source will be carried out after removing the binder by solvent (or ignition) method. This particle distribution will be used for the mixture design. At the same time, a grading will be carried out on the as-delivered material for reference. Subsequent gradings will be carried out on the as-delivered material after removal of binder and the particle distributions compared with the reference initial particle distribution. If the particle distributions differ by more than the repeatability quoted in BS EN 933-1:1997, a grading will be carried out after removing the binder by solvent and used for the mixture design in place of the initial analysis.
- 6. Unless the RA is to be split into separate fractions, the repeat grading and binder content of the RA will be determined at the minimum frequencies of RA given in Table B1. In general, if the variability of the analysis is $\leq 5\%$ it should only be necessary to test at the Sector Scheme 14 level of one in 500 tonnes. If the variability is greater, a higher testing frequency will be needed and adjustments to the mixture design may also be required, particularly for high rates of RA addition.
- 7. For this purpose, the variability is defined as the weighted mean difference between the maximum and minimum results from the last six determinations for one sieve across all sieves used in the analysis, weighted by the mean proportion by mass in that fraction.

Table B1 Proposal for minimum frequency* of testing grading of RA

Proportion of RA	<i>≤10%</i>	> 10% and < 30%	≥30%	
Variability $\leq 5\%$	1 in 500 tonnes	1 in 500 tonnes	1 in 500 tonnes	
Variability ≤ 10%	1 in 400 tonnes	1 in 350 tonnes	1 in 300 tonnes	
Variability > 10% 1 in 300 tonnes 1 in 200 tonnes 1 in 100 tonnes				
* For single source; multiple sources may require more frequent testing until the variability has been established.				

B.3 BINDER TESTING

- 8. When the RA has been separated into separate fractions in order to make the mixture design simpler, the frequency will be halved to that given in Table B1 for each sieve used. When the RA is to be added at proportions greater than 10%, a visual check on the petrological classification of the RA will be undertaken at the same frequency. This check will be primarily to ensure that the visual appearance of the aggregate in the RA has not changed radically since the last check
- 9. The binder coating the aggregate particles in the RA will be tested for binder content and recovered penetration at the minimum frequencies given in Table B2. The current minimum requirements are for binder content, and recovered binder penetration and softening point, to be tested at a frequency of one in 500 tonnes. With a move to the binder ignition method for content, the requirement for recovered properties could potentially reduce to those shown in Table B2.

Table B2 Proposal for minimum frequency of testing binder content and recovered penetration of RA

Proportion of RA			
≤10%	> 10% and < 30%	≥30%	
1 in 500 tonnes	1 in 500 tonnes	1 in 500 tonnes	
1 in 5000 tonnes	1 in 3000 tonnes	1 in 2000 tonnes	
	 ≤ 10% 1 in 500 tonnes 1 in 5000 tonnes 	Proportion of RA ≤ 10% > 10% and < 30%	

B.4 MIXTURE DESIGN WITH RECLAIMED ASPHALT

- 10. The mixture design will be carried out in accordance with the guidance given in Chapter 2 of this Road Note based on the initially determined RA grading, binder content and binder grade.
- 11. If the grading of the RA is shown to have changed from the initial grading by a repeat grading, the proportion of each fraction of fresh aggregate will be adjusted to reinstate the intended grading.
- 12. If the adjustment cannot be completed because the amount of one (or more) fractions from the RA (that is, the proportion of aggregate in that fraction of RA times the proportion of RA to be added) is more than is required in the final mixture, then either the proportion of RA to be added will be reduced or some of that fraction will be screened out from the RA. The adjustment will then be completed.
- 13. If the binder content changes by more than ten divided by the proportion of RA to be added (that is, 1% with 10% RA but 0.33% with 30% RA) and/ or the recovered penetration, in 0.1 mm, changes by more than 100 divided by the proportion of RA to be added (that is, 10 pen with 10% RA but 3.3 pen with 30% RA), the content and grade of fresh binder required in the mixture design shall be recalculated.
- 14. If the fresh binder has to be changed by a grade or more (penetration grade bitumen), the test regime in Chapter 2 of this Road Note will be repeated.

Best practice guide for recycling into surface course



The incorporation of suitable reclaimed asphalt in thin surfacing materials is becoming an important issue with the availability of high-quality aggregate resources depleting and with the greater emphasis being placed on sustainability by society. The feasibility of using up to at least 30% has already been demonstrated in trials and on contracts on major UK motorways whilst the potential for lower proportions of up to 10% being added on a regular basis has already been accepted for the Highway Authorities Product Approval Scheme. This Road Note is intended to act as a guide to what is considered to be good practice when specifying, designing, producing and applying this approach and to facilitate a relatively rapid change to its wider acceptance and use. A method of designing the asphalt mixture taking into account the binder content and binder properties of the reclaimed asphalt is provided. More general advice on the changes needed in the different operations is also given.

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