Use of reclaimed asphalt in the surface course – the effect on friction

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ABSTRACT

A preliminary study, using asphalt specimens prepared in the laboratory incorporating different proportions of reclaimed asphalt, has demonstrated that concerns about skid resistance may not necessarily limit the use of reclaimed asphalt in the surface course. A further programme of laboratory experimentation will aim to give confidence in the use of increasing amounts of RA and define the maximum percentage usable without detrimental effect on skid resistance.

The paper will summarise the methodology employed, results so far, and suggestions for practical implementation of the findings.

1. INTRODUCTION

HA specifications currently permit the use of reclaimed asphalt (RA), directly incorporated into bituminous materials. While RA is often included in base layers, for example during new pavement construction, it is not widely used in surface course materials. A large proportion of the maintenance of the HA trunk road network comprises planing off and resurfacing with a proprietary material less than 50 mm thick. There is therefore considerable interest in increasing the use of RA in surface courses in order to continue to make use of this valuable resource.

This might be achieved by increasing the allowable proportion and/or by encouraging more widespread use. However, there are likely to be implications for the skid resistance provided by the surface when increasingly large amounts of RA are incorporated. This paper describes a preliminary investigation into the likely effect on skid resistance of adding RA to the surface course, by making measurements of friction on specimens prepared in the laboratory.

Current practice was reviewed and a laboratory programme, using samples of RA from different sources, was devised in order to investigate the effect on friction of using increasing proportions of RA in the surface course. The methodology and results from this experiment are presented, followed by a discussion of the implications and recommendations for implementation.

2. CURRENT PRACTICE

The two sections below summarise some aspects of current recycling operations in the UK, based on responses to a brief questionnaire, and the guidance that is available to operators relating to the use of RA in the surface course.

2.1 UK OPERATIONS

A survey of several companies with responsibility for asphalt recycling operations showed that stocks of RA were kept at various locations around the country and varied in size between 200 and 15,000 tonnes. In general, stockpiles are not separated by source (surface course, binder course, base course, or asphalt plant waste) except for specific trial purposes. Where it was stated, the estimated proportion of RA from various sources found within each stockpile differed significantly, and it was also noted that relative proportions depend on current projects in operation. Importantly, several companies recognised that RA stockpiles were likely to become dominated by surface course arisings in the future because of a reduction in structural works (as expected).

In general, very little testing is carried out specifically to determine the properties of the constituent aggregates in RA stockpiles. However, some petrographic classification is carried out, determining whether the majority of the aggregate is hardstone, limestone or gravel. Using current procedures, it would therefore be very difficult to predict the friction performance of a surface course incorporating significant proportions of RA, but it may be possible to restrict the amount of limestone, which is likely to have a detrimental effect on friction. Most testing carried out focusses on binder properties (e.g. penetration and softening point), probably because of the relatively large financial investment this material represents. While this type of testing is undoubtedly necessary for mix design purposes and to ensure asphalt durability when RA is incorporated, it is unlikely to provide information about the friction performance of a final product.

Current use of RA in surface courses is limited, although it is used in small quantities (5% to 10%), determined on a site by site basis, and occasionally in quantities up to 20% in trials.

2.2 UK GUIDANCE

Documentation is available that provides advice and good practice guidance for the use of RA, and some of it deals specifically with the use of RA in the surface course. Although the majority of the guidance focuses on mix design and durability that, of course, is an important consideration, there is some information about the testing required to ensure confidence in the skid resistance performance of a surface course containing RA.

Road Note 43, entitled “Best practice guide for recycling into surface course”, deals with closed-loop recycling of asphalt reclaimed from surface courses back into surface course materials (although most of the guidance may be relevant to recycling into other pavement layers). It is noted firstly that one of the reasons that more recycling is likely to be needed is because of the increased usage of high-specification aggregate (aggregates with good resistance to polishing in particular) in modern materials such as thin surface course systems. It is anticipated that, while the majority of RA will be used by incorporating proportions of 10% or less in as many new surfaces as possible, it is feasible to incorporate up to 30%.

Road Note 43 recommends that, provided the RA source is well known, and the PSV and AAV of the aggregate constituents comply with specifications for the job in hand then it can be used with a minimum amount of further testing. Further, it is suggested that, if the RA source is a surface course, and that surface course was in a location where aggregate with PSV of 60 was required, it can be assumed that the aggregate will have PSV of at least 60. An additional check that the skid resistance provided by the original surface course was sufficient may also be necessary.

However, if the source is not known (which may be the case for the majority of current RA stockpiles) the requirement for further testing is dependent on the amount of RA to be used in the new surface. Carrying out tests on aggregate in reclaimed asphalt is unlikely to be straightforward or particularly accurate. In particular, the grading requirements of the PSV test and the amount of repeat testing that would be needed to characterise aggregate from combined sources may be restrictive.

Other guidance can be found in BS EN 13043 and BS EN 13108 as well as, briefly, in the Highways Agency's Manual of Contract documents for Highways Work (MCHW) Specification for Highway Works (SHW) and the WRAP (Waste and Resources Action Programme) quality protocol. Two definite requirements are highlighted:

- "the upper size of the reclaimed asphalt shall not exceed the upper size of the mixture"; and
- "the aggregate in the reclaimed asphalt shall conform to the requirements for aggregate in the mixture specification".

A limit of 10% is reiterated: more testing to verify the properties of aggregates in RA is required if the amount incorporated is to be above this limit.

3. METHODOLOGY FOR LABORATORY EXPERIMENTS

In this chapter, the methodologies for two complementary experiments are described. The scoping study was carried out in place of a larger experiment due to time constraints and material availability, and is described in more detail in PPR670 (Dunford, 2013). The further experiment is ongoing at the time of writing.

The laboratory experiments are designed to investigate the effect on friction of adding RA to the surface course. Other important considerations are beyond the scope of the experiments but may need to be reviewed in due course. For example, there are technical issues such as durability and mix design (especially new binder content), environmental issues such as tar content, and policy issues such as ownership and logistics.

3.1 SCOPING STUDY

Two samples of RA were obtained from stockpiles at one site: one from a stockpile of nominally 0/10 mm material and one from a stockpile of nominally 0/20 mm material. The samples were graded and that information was used to determine the maximum amount of RA that could be incorporated into the standard SMA design given in Table D.1 of PD6691 (British Standards, 2010). A 14 mm SMA design, incorporating 48%, by mass, of the RA from the 0/20 mm stockpile, represented the largest amount of RA that could be incorporated. This is clearly more than is currently recommended or regularly used in practice. To emphasise the effect on friction of RA incorporation, SMA specimens incorporating 10%, 20%, 30% and 40% were also prepared for later comparison with the performance of SMA without RA.

In order to conform to the requirement that “the upper size, D, of the aggregate in RA must not exceed the upper size, D, of the mix”, the 0/20 mm RA was graded to remove the relatively small amount of material larger than 14 mm. There is some evidence to suggest that, within a given mix, it is the coarsest aggregate that most affects skid resistance (Dunford, 2012): if the upper size of the RA were allowed to be larger than the upper size of the mix then the RA may have a disproportionate effect on skid resistance compared to the rest of the mix. The maximum size requirement may therefore be important and it highlights the need for careful handling and segregation of RA.

Stocks of 6/10 mm and 10/14 mm medium-PSV (nominally, 60) virgin aggregate were used to make up the balance of the mass required for SMA production, along with crushed rock fines (CRF) from the same source, and limestone filler. Table 1 shows the percentage of the constituent parts in each of six mix designs; a pair of asphalt slabs was prepared for each design. Aggregate constituents are shown as a percentage of aggregate mass, and the virgin binder added is shown as a percentage of total mass. Note that the amount of virgin binder that must be added to achieve the mix design reduces as the amount of RA increases. The resulting mixed binder (virgin and reclaimed) was not examined closely and, as stated above, its effect on durability is beyond the scope of this study.

Table 1 Percentage (by mass) of various constituents in six asphalt designs

Design ID	Virgin aggregate				RA	*Virgin binder*
	10/14	6/10	CRF	Filler	(0/20 mm stockpile)	
1	60	10	22	8	0	*5.0*
2	56	12	15	7	10	*4.7*
3	56	12	5	7	20	*4.3*
4	56	5.5	2	6.5	30	*3.8*
5	54.5	0	0	5.5	40	*3.3*
6	50	0	0	2	48	*2.9*

The graph in Figure 1 shows the grading envelope for the specified 14 mm SMA mix – the minimum and maximum specifications are shown in black (broken and solid lines respectively) - and the achieved total aggregate grading for the mixes containing 0 % and 48 % RA are shown in blue and orange respectively. It can be seen that it is predominantly the content of material passing a 6.3 mm sieve in the RA grading that restricted the amount of RA that could be incorporated.

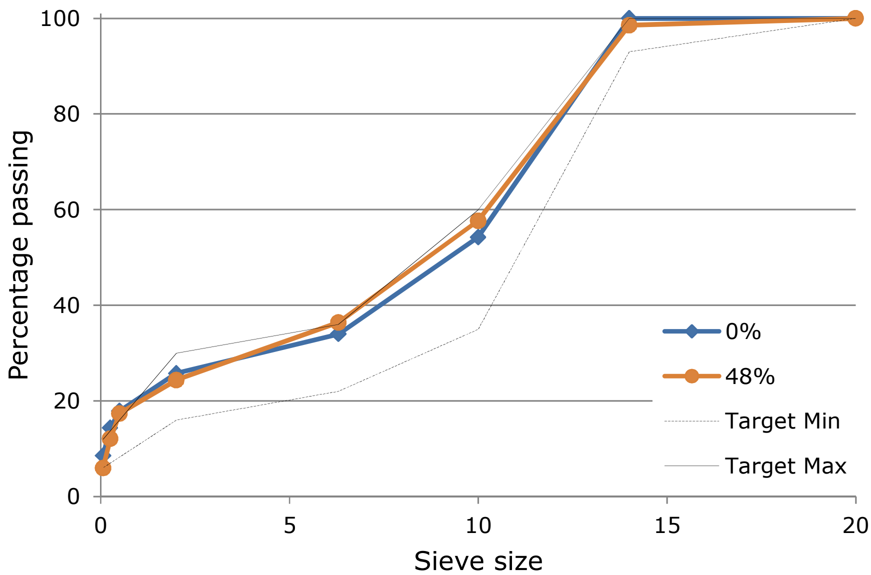

Figure 1 Grading envelope and achieved grading for 14 mm SMA with addition of RA at 0% and 48% by mass

For comparison, the same virgin aggregate was used in blends with a low-PSV (nominally, 40) limestone. Limestone coarse aggregate in sizes 4/10 mm, 2/6 mm and crushed rock fines were used to simulate the grading of the RA and were then added to virgin aggregate in the same proportions, up to 40% by mass. In terms of addition of RA, a worst-case scenario might be that the RA is made up entirely of limestone with low resistance to polishing.

In every case, after the asphalt slabs had been prepared in the laboratory their surfaces were subjected to grit-blasting to remove excess bitumen and reveal the aggregate surfaces. The specimens were polished for an hour using the Highways Agency's Wehner-Schulze machine and then friction was tested (again, using the Wehner-Schulze machine) to provide a measurement for each slab and an average measurement for each mix design (using results from the pair of asphalt slabs). Although it is not yet used in specification, the friction measured by the Wehner-Schulze machine might be considered as a proxy for skid resistance that would be measured on site (Dunford & Roe, 2012).

3.2 PROPOSED FURTHER EXPERIMENT

The scoping study will be extended to examine the effects of more than one source of RA. In particular, both combined stockpiles and surface course only stockpiles will be sampled. In the latter case, if surface course segregated RA is not readily available, surface course planings from local maintenance operations will be sought.

For each sample of RA, an initial visual assessment will determine simple petrographic classification for the aggregates present (i.e. apparent proportion of hardstone or limestone). The following laboratory analyses will then be carried out:

- Binder content, penetration, softening point
- Grading
- Acid soluble test (to determine proportion of limestone present)

The maximum proportion of as-received RA that can be incorporated into a standard SMA mix design will be determined and specimens will be prepared in the laboratory for polishing and testing using the Wehner-Schulze machine. Further specimens will be prepared if it is found that further grading of the RA would enable a larger amount of the material to be incorporated.

Perhaps, by comparison with results from laboratory analyses (petrographic classification, acid soluble test etc.), it may be possible to investigate appropriate tests that might be carried out on RA in the future to ensure satisfactory skid resistance performance when it is used in the surface course.

If the incorporation of any of the RA samples appears to have a significant detrimental effect on friction then, as before, further asphalt preparation may be carried out, incorporating intermediate proportions of RA (e.g. 10%, 20%, 30% etc.).

4. RESULTS

The graph in Figure 2 shows the effect on friction, measured using the Wehner-Schulze machine and denoted μ_{PWS60}, of adding up to 48% RA, and the effect of adding up to 40% limestone, to an SMA prepared using medium-PSV (nominally, 60) virgin natural aggregate. It can be seen that the addition of this particular RA has no significant effect on friction, whereas the addition of limestone results in a substantial decrease when the proportion of limestone is greater than 20%. The RA used in this experiment probably contains a large proportion of surface course planings. It is therefore not surprising that the effect of its addition is minimal.

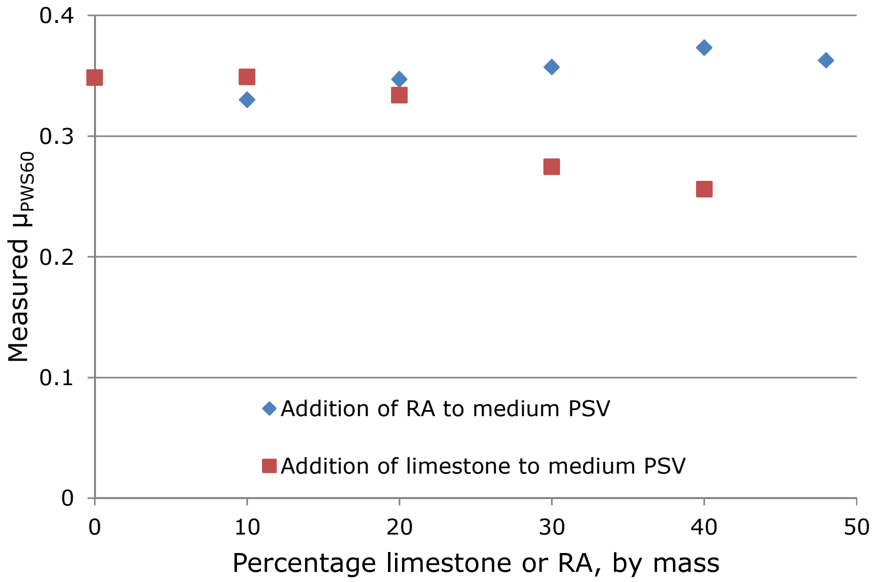

Figure 2 The effect on friction of adding RA or limestone to an SMA

The results from further experimentation, using a range of different reclaimed asphalt samples will be published when they are available. It is anticipated that the effect on friction will depend heavily on the source of the reclaimed asphalt: surface course planings will have little or no effect (or, feasibly, a positive effect), whereas RA primarily from lower courses may have a reducing effect on friction.

5. DISCUSSION AND CONCLUSIONS

The work completed so far is not extensive enough to be conclusive. However, the following scenarios and implications have been proposed. It should be emphasised that the work carried out was concerned solely with the effect on skid resistance of adding RA to thin surface course systems. In practice, more consideration would be required to handle other aspects and binder properties in particular.

If RA is reclaimed from an existing thin surface course system, is handled properly, and segregated then, in terms of potential skid resistance:

- Provided the original source is well known and its specification meets the specification required of the new thin surface course then, subject to quality control constraints, no restriction should be placed on the amount of RA used.
- If the original surface course is well known but its specification does not meet the specification required of the new thin surface course then the virgin aggregate should be chosen carefully. It may be possible to select an appropriate virgin aggregate using a mass ratio formula to predict the result of blending with the RA.
- If the original surface course is not well known then the advice will depend on the specification of the required new thin surface course. If an aggregate with PSV less than, say, 53 is required then the effect on skid resistance of any surface course RA will be minimal and there should be no restriction on the amount of RA used. If the new specification is for high-PSV aggregate (63 and above) then a restriction of 10 % RA might be adopted unless a laboratory investigation can demonstrate results to the contrary.

If the RA is reclaimed from mixed sources then, until further work to assess the effect of variability in RA is carried out, a 10 % restriction should remain in place.

In any case, measurements of skid resistance should be made to verify that the surface is performing as expected initially, and after a period of service.

It is unlikely that results of the further experimentation will greatly affect the scenarios proposed above. It may be possible to supplement advice with recommendations for appropriate laboratory testing that will increase confidence in the performance of surface courses incorporating RA.

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Author biographies:

Alan Dunford

Alan manages a portfolio of projects related to measurement research and advice. The projects are generally focussed on material properties, skid resistance and monitoring of other pavement surface characteristics as well as aspects of road user safety such as splash/spray generation and asphalt durability. Alan leads a team of staff, coordinates activities in over 20 projects and provides technical input and guidance. Alan leads research into new devices such as the Wehner-Schulze polishing machine and novel techniques such as the contactless measurement of microtexture; the latter formed the basis for his part-time study for a PhD at the School of Civil Engineering at the University of Nottingham.

Helen Viner

An experienced scientist and manager, Helen joined TRL in 1997 after two years of post-doctoral academic research. In January 2013, she was appointed as Chief Scientist and Research Director for Infrastructure Division, a role that includes developing collaborative research partnerships, preparing proposals for research funding, oversight of technical quality, and communicating our activities internally and externally. She is also the UK Research Coordinator within FEHRL (the Federation of European Highway Research Laboratories). Prior to this role, Helen led Infrastructure Division's Safety and Consultancy Group, with 11 technical specialists and a portfolio of projects for Government, private sector and overseas clients. Helen has worked extensively on the surface characteristics of road pavements, being responsible for innovative research and developing associated advice and standards. Her expertise includes tyre-road interaction (friction, splash/spray, rolling resistance and noise), accident trends, condition monitoring and management performance indicators.

Martin Greene

Martin has over 20 years' experience at TRL working, for a range of customers. His work is currently focussed on the development of skid resistance strategies for several national highway authorities and he has lead work on the development of guidance for the submission and prioritisation of highway maintenance works. He has organised and presented at training workshops on both these topics and has presented the findings of his research work at international conferences. More recently he has undertaken work for Highways Agency MACs to develop pavement maintenance options for schemes seeking renewals funding. Martin is a highly experienced Project Manager and in recent years has managed much of TRL's skid resistance and maintenance prioritisation related work with contracts in excess of £500k. He has also managed several EC funded collaborative projects.

Stuart Brittain

Stuart joined TRL in October 2005. Since that time he has worked on many projects in the pavement assessment field. He is currently the project manager for the ASPECT 4 project which covers the accreditation and QA of devices used on the Highway Agency (HA) trunk road network. Recently this work involved the review and update of the accreditation criteria and QA specification. He is also the project manager of the team supporting and developing the skid policy (HD28) for the HA. As part of this work Stuart calculates the seasonal correction factors for the SCRIM survey data collected on an annual basis (LECFs) and was deeply involved in the recent update to the skid policy standard (due to be published this year). Stuart is also involved in the calculation of the NPC value for the condition of the HA Network, which is reported monthly to HA. Stuart has also carried out work for other teams within the organisation to provide assistance with data processing and VBA programming.

Ian Carswell
Ian has over 30 years' research and management experience. He has been responsible for managing the Design and Maintenance Group in the Infrastructure Division since 2004. He has also produced many technical reports and papers and given presentations at seminars and conferences. Ian has extensive experience with project management and has been responsible for the management and delivery of many complex and collaborative projects for clients including the Highways Agency, Transport Scotland, Transport for London, Mineral Products Association, Refined Bitumen Association, Materials suppliers, Contractors, Maintaining Agents and Defence Estates. He has extensive practical and analytical skills and has been responsible for the design of numerous full scale field trials. He is a current convenor of the Transport Scotland Inspection Panels for surfacing materials.

Owen Ardill
Owen Ardill joined the Highways Agency Pavements Team in 2013 as a senior policy advisor in the field of skid resistance. Owen manages a number of packages of research in this area to better understand skid resistance and to develop policy. Owen is also responsible for the Highways Agency's annual routine assessment of skid resistance. Owen Ardill began his career in the Highways Agency in 2009 as a graduate engineer where he has worked in a number of roles with the Intelligent Transport Systems Research Group, the Structures Delivery Team, the National Health and Safety Team and on site on capital construction projects. Owen Ardill studied engineering at the National University of Ireland, Galway, graduating with a Bachelor of Civil Engineering Degree in 2007 and was awarded a Masters in Engineering Science in 2009 for research in bituminous materials.