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Enhanced levels of reclaimed asphalt in surfacing materials – a case study evaluating carbon dioxide emissions

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Transport Research Laboratory

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Enhanced levels of reclaimed asphalt in surfacing materials: A case study evaluating carbon dioxide emissions

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	Enhanced levels of recycled asphalt in surfacing materials: A case study evaluating carbon dioxide emissions
Client:	**Mouchel Ltd, M25 Sphere**
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Contents

Executive summary

This report documents a study on the energy used and relative carbon dioxide emissions associated with the resurfacing of the M25 from Junction 6 to 7 on the anti-clockwise carriageway, which was undertaken in August 2009. This study aimed at understanding the potential savings in energy and carbon dioxide realised by the choice of high recycled content material as opposed to a comparable conventional 100 % virgin aggregate mixture. The activities undertaken during the resurfacing works were, therefore, audited and compared with an hypothetical scenario where the conventional material would have been laid. This study compliments a similar study undertaken in 2007 where 23 % reclaimed asphalt (RA) was added to the new surface course . The key differences with this study are a much higher RA content (40% compared to 23%) and modifications made to the batching plant equipment and material handling processes in order to accommodate this higher rate of recycling.

The resurfacing works replaced the worn out porous asphalt surface course with a thin surfacing. A departure from Standard was required, to allow the inclusion of 40 % RA, from Clause 942 of the *Specification for Highway Works*. The new material laid was developed by Tarmac at the request of Mouchel using 40 % RA sourced from the existing worn out surface.

The energy and carbon emissions audit used a life cycle approach. This is a “bottom-up” approach that considers all activities related to a product or within an organisation, as included within a set of boundaries. This approach is the basis of the Publicly Available Specification PAS 2050 which has been developed by the Carbon Trust and the British Standard Institution to measure the greenhouse gas contribution of products and services.

The steps followed within the methodology are:

- Definition of boundaries and processes to be included and excluded;
- Collection of data and calculations; and
- Internal verification.

Processes included are transport of raw materials and bitumen bound materials to and from the site; production of input materials (e.g. bitumen, aggregates, fibres) and mixtures (both *MasterPave-R* and *MasterPave*), use of primary and ancillary equipment for heating, mixing, loading and paving.

A data collection template listing all activities to be considered was prepared and data gathered on quantities and type of energy used, the distances travelled and by which mode. All data for the actual scheme and for the alternative scenario were input into a custom built spreadsheet for the calculations of the energy and CO_2 emissions associated and relative savings.

The principal findings from this study, summarised below, show that savings of just under 9 tonnes of CO_2 (about 21.5 % reduction) and just over 134 GJ of energy were achieved by using *MasterPave-R* (with 40 % reclaimed asphalt) when compared with a conventional approach using 100 % virgin aggregates for this particular scheme. This saving is equivalent to the emissions produced by an average car travelling over 52,500 km (about 32,500 miles) or to the energy that would keep 37 typical 250 W motorway lights on for their entire average 4,000 h life.

Summary of energy and CO_2 savings

Savings realised by the scheme as compared to alternative *MasterPave* construction:	134.3 GJ of energy
	8.75 tonnes of CO_2
Equivalent to emissions resulting from an average car travelling approximately	52,350km (32,700 miles)
Equivalent to the number of typical motorway lights (250 W) that could be powered for their entire 4,000 h average life	37 lights

Abstract

The need for sustainable construction processes which conserve natural resources is well understood and recognized within the industry, and is often realised through recycling materials into layers below the surface course. However, this 'downgrades' the use of expensive and increasingly scarce high polished stone value (psv) aggregates. The incorporation of a proportion of an existing surface course layer into a new surface course system is, therefore, highly desirable because it maintains the 'high value' application of the high psv aggregate in a surface course layer. With the reduction in requirement for virgin materials, the inclusion of reclaimed asphalt in the surface course layer may also offer benefits in terms of reduced energy and emissions. This report documents a study on the energy used and relative carbon dioxide emissions associated with the recent resurfacing of the M25 scheme between Junctions 6 to 7, from MP43/2 to 47/3. The objectives of the case study were to gain an understanding of the differences and potential savings in energy and carbon dioxide that could be made by the incorporation of a high reclaimed asphalt content (40 %) into the surfacing compared with a 100 % virgin aggregate mixture. The activities undertaken during the resurfacing works were, therefore, audited and compared with a hypothetical scenario where the conventional material would have been laid.

1 Introduction

The need for sustainable construction processes and to conserve natural resources is well understood and recognized within the industry. The M25 J6-7 was surfaced in porous asphalt in 1996 and this had now reached the end of its serviceable life. Following a study undertaken by TRL (Carswell *et al.*, 2005), Mouchel sought to incorporate a proportion of the existing surface course layer into a new surface course system, thus maintaining the 'high value' application of the high polished stone value (psv) aggregate present in the existing surfacing. This was successfully achieved in 2007 and marginal carbon savings were realised as a result (Schiavi *et al*, 2007), which is referred to throughout as the '2007 study'. Subsequent to this 2007 study, a further question was asked: can higher recycling rates be achieved and what implications would this have in terms of the contribution of the process to climate change? To achieve higher recycling rates, a pre-dryer specifically for reclaimed asphalt (RA) wasretrofitted to Tarmac's Hayes asphalt plant. Product diversification at Hayes also meant that RA could no-longer be processed on-site and this processing had to be outsourced, therefore causing the RA to be handled twice. It was agreed to undertake this study to explore the implications of these modifications to the *Masterpave-R* production process and to compare them to the results of the 2007 study.

For this scheme, the energy consumed by each part of the process was evaluated to gain an understanding of its impact on the carbon footprint when RA is incorporated into the new thin surface course (TSC) compared with a TSC containing 100 % virgin aggregate. This analysis included taking into account the transport of RA and virgin materials (aggregates, filler, fibres, and binder) from source to site and the processing of those materials (planing, screening, mixing, paving, and compaction). The comparisons made are specific for this scheme because the geographical location of the site, source aggregates and transport modes will be unique for every site.

This report documents the details of the scheme, the methodology followed for the audit and the headline results.

2 Background

Proprietary thin asphalt surfacing systems were first introduced into the United Kingdom in 1991 and became the surfacing of choice in the late 1990s for the trunk road and motorway network in England as well as widely used elsewhere (Nicholls, 2002). Many of the early sites are now reaching the end of their serviceable lives. The need to recycle thin surfacing systems is more critical than with many other generic surfacing materials because of the quantity of relatively scarce aggregates with high skid-resistance properties within the layer.

The principle of recycling in this manner is now fairly well established and some of the benefits of doing so have been demonstrated. Laboratory investigations have been undertaken and trial sites have been successfully constructed with up to 30 % RA in the mixed asphalt (Carswell *et al.*, 2005). A scheme was also completed in 2006 on the M4 Cardiff where 25% of the existing porous asphalt (PA) was processed and incorporated into the new asphalt surface course (Nicholls *et al*, 2007). The 2007 M25 Junction 6-7 clockwise study (Schiavi *et al,* 2007) achieved 23 % recycling overall and the corresponding energy audit demonstrated that carbon reductions of 7 % could be realised.

This study provided the ideal opportunity to increase recycling rates and determine the implications by conducting a further energy audit in an identical manner. The results of this audit could be compared to the results of the previous study, and another scenario which used 100 % virgin aggregate.

TRL has undertaken research in the past to measure the carbon dioxide emissions associated with road construction and road resurfacing works in addition to the aforementioned 2007 study (Schiavi *et al*, 2007). The 'CO_2 Estimator Tool' was developed in a research project conducted for the Waste and Resources Action Programme (WRAP) (C4S at TRL Limited, Taylor Woodrow Technology and Costain Limited, 2006). The tool enables the user to evaluate the relative CO_2 savings of using alternative road construction materials (secondary and recycled) against traditional virgin materials. A collaborative piece of work, conducted by TRL, for the Highways Agency, Mineral Products Association and Refined Bitumen Association, conducted over the past 18 months, has recently culminated in the creation of the asphalt Pavement Embodied Carbon Tool (asPECT). asPECT consists of a standardised protocol and accompanying calculator tool for measuring the carbon footprints of asphalt and highway products according to the requirements of PAS 2050 (BSI PAS 2050:2008). asPECT is detailed in TRL PPR 439 (Wayman *et al*, 2009).

The value of undertaking studies on energy and carbon emissions associated with construction projects and products is clear in light of the current drive towards a low carbon economy and the Government commitment to reduce carbon emissions. Understanding how much energy is used to provide certain goods or services is the first step towards taking action on improving energy efficiency, thus reducing environmental impacts and realising cost savings. This is also true of other environmental impacts, for example, efficient use of natural resources through waste minimisation, reusing and recycling.

3 Scheme details

Four continuous segments of surfacing of the M25 clockwise carriageway between Junctions 6 and 7 (MP 43/2 to MP 47/3) were identified as requiring treatment. Traffic flows on this carriageway were reported in 2005 to be 73,497 AAWT (average annual weekday traffic) and 70,302 AADT (average annual daily traffic) with 14 % of this traffic being HGVs. These figures represent a 6 % increase on reported flows in 2001. The scheme location is shown in figure 3.1.

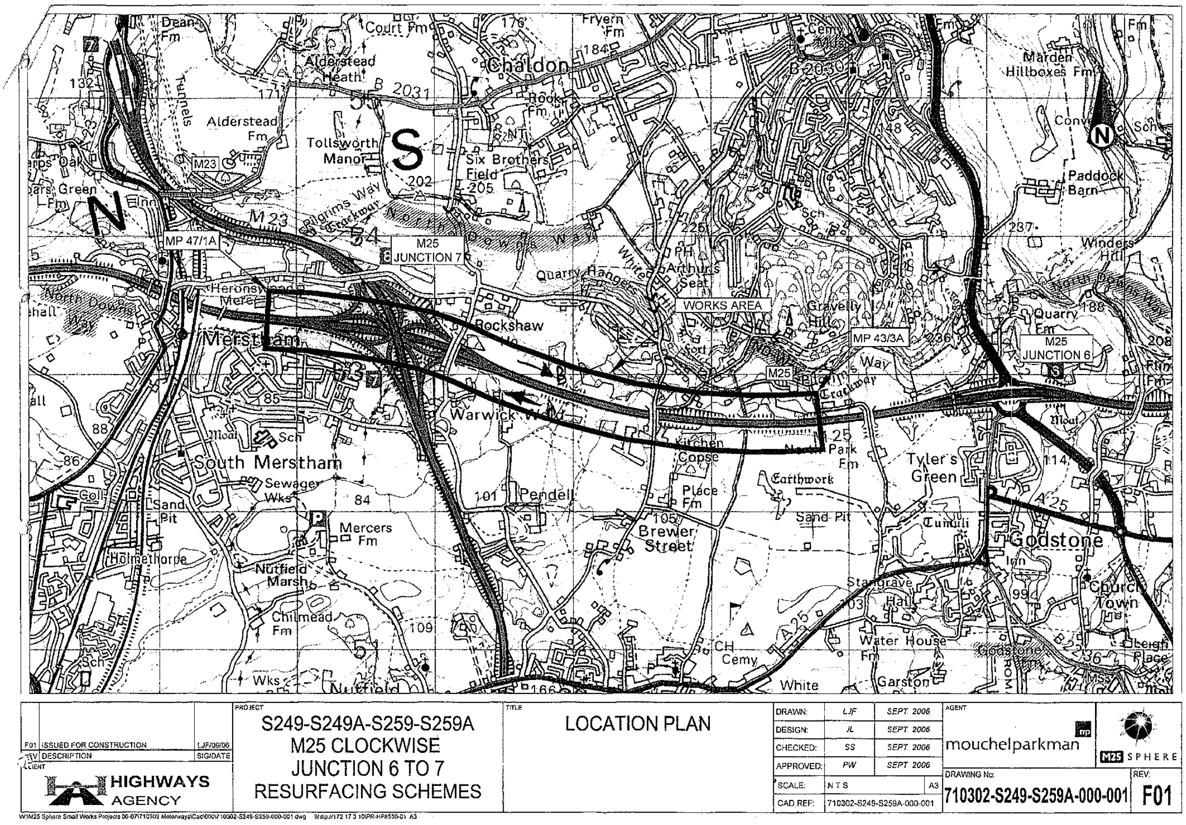


Figure 3.1 Location of scheme

The motorway was originally constructed in 1983, with the current construction consisting of 50 mm PA over 410 mm dense bituminous macadam over 206 mm Type 1 granular layer. There are sections where the PA surfacing has been replaced with thin surface course during maintenance carried out in 2006 between MP 44/6 and MP 45/7. Visual and TRACS surveys of the carriageway identified rut depths of over 10 mm together with fretting and general loss of material.

The proposed treatment was to replace the worn out PA surface course with a thin surfacing to Clause 942 of the Manual of Contract documents for Highway Works (HA *et al*, 2009) with a departure from standard to permit the inclusion of 40 % RA.

The existing surfacing on Reigate Hill was a 20 mm porous asphalt to BS4987 (BSI, 1993). The aggregates were originally sourced from Bardon Hill (60 psv) in combination with either Ballystockart or Millom (both 68 psv). The planings were processed to remove both the larger and smaller sizes of aggregate by using 22 mm screen and 4 mm screens to effectively give a 2/20 mm usable product compatible with 20 mm thin surface course (TSC). Removal of the fine aggregate sizes also removed any detritus that had built up and reduced the susceptibility of the RA to be used in the new surfacing to moisture.

The initial mixture designs incorporating RA were undertaken at Tarmac's Technical Centre prior to plant trials at Hayes asphalt plant. The plant trials were needed to check production and laying performance together with finished surface texture. Tarmac's Hayes asphalt plant has been modified so that it now has a parallel dryer system allowing up to 50 % RA to be used in asphalt mixtures. For this trial, 40 % RA was heated to 130°C before adding it to the mixer box.

The RA was incorporated into a 20 mm *MasterPave-R* thin surfacing system, this being a variant of Tarmac's 20 mm *MasterPave* thin surfacing system which has a Highway Authorities Product Approval Scheme (HAPAS) certificate from the British Board of Agrément (BBA).

The works were carried out and completed in August 2009.

4 Energy monitoring

4.1 Methodology

The energy and carbon emissions audit undertaken takes a life cycle approach. This is a "bottom-up" approach that considers all activities related to a product or within an organisation, as included within a set of boundaries. This approach, which is exemplified by environmental accounting methods such as Life cycle assessment and Life Cycle Inventories, is also the basis of current ISO standards on greenhouse gases estimation in BS ISO 14064-1:2006 and BS ISO 14064-2:2006. Furthermore, the Carbon Trust and the BSI are currently working on a Publicly Available Specification on carbon footprinting (PAS 2050:2008) which is based on Process Analysis, and current advice from the Carbon Trust is that this approach should be followed for developing carbon audits (Carbon Trust, 2007).

The steps followed within the methodology are listed below and explained in the following sections:

- Definition of boundaries;
- Definition of processes;
- Collection of data;
- Calculations and
- Internal verification.

Care has been taken in ensuring that the method followed at each step is transparent, accurate and consistent, as required within the ISO 14064 standards. The approach taken within this study is in line with the carbon footprinting methodology published by the Carbon Trust (Carbon Trust, 2007), although only CO_2 emissions have been considered, given that the processes analysed deal mainly with the combustion of fuel or the production of electricity.

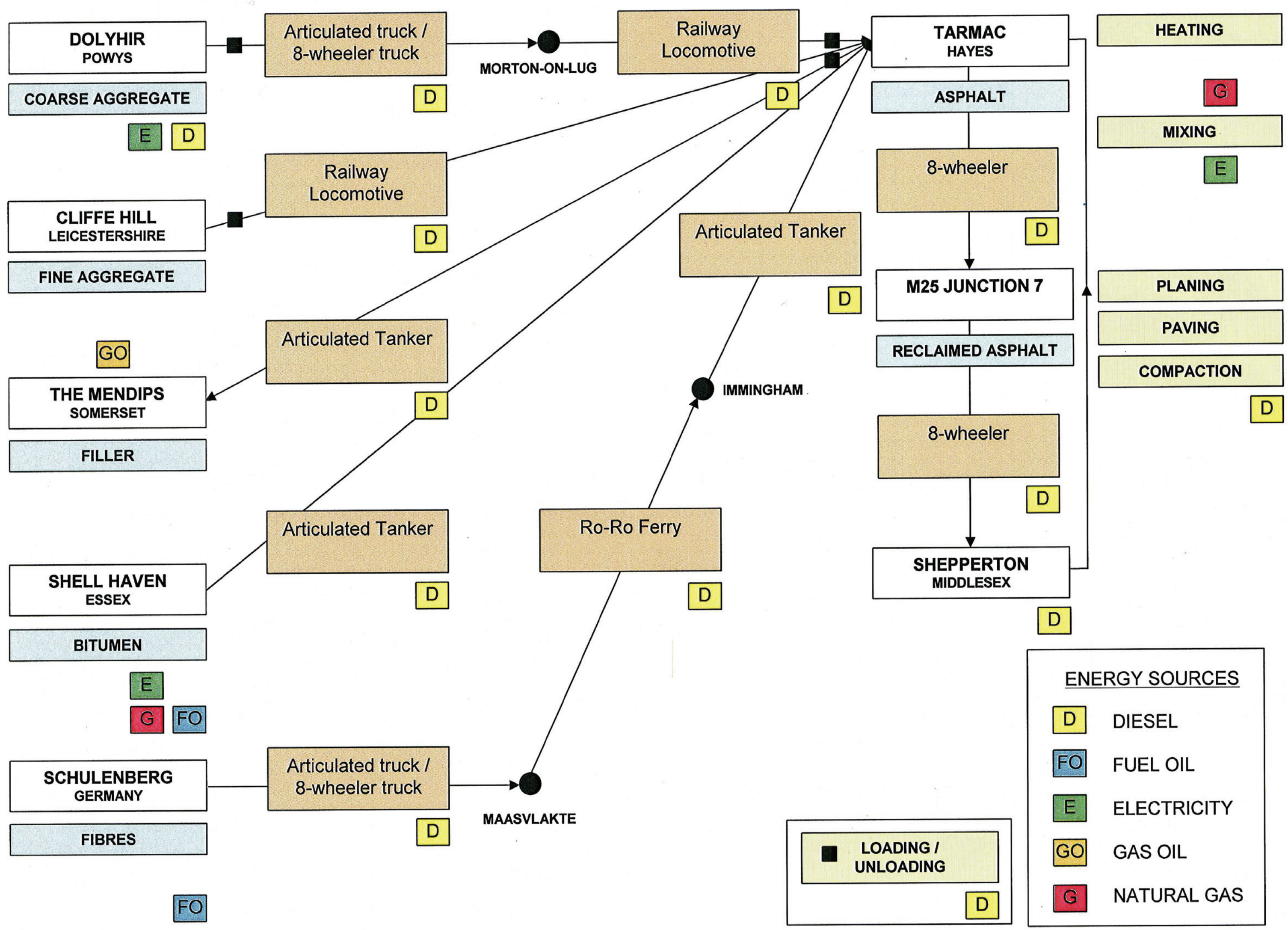
4.1.1 Definition of boundaries

The definition of the system to be analysed within an environmental audit is key to the credibility of the audit. The approach taken for this project is based on the "level of control". That is, the system includes processes from the extraction and transportation of raw materials up to the laying of the material but does not consider, for example, the use of the road by traffic or the manufacture of the equipment. A representation of the system, with some details of the processes included, is given in Figure 4.1. This was made identical to the 2007 study.

Points of note are:

- The system has a double application: for the *MasterPave-R* mixture and for a comparative "what if" scenario where a *MasterPave* (100 % virgin aggregate) mixture would be used for the same scheme; details on the differences are provided in section 4.1.2.
- Emissions associated with input materials from third parties have been accounted for by using "embodied" energy and emissions, i.e. quantity of fuel and electricity used to produce the raw materials up to the "gate" of the processing unit (e.g. the factory manufacturing fibres and the refinery producing bitumen). These are overall figures provided by the supplier or sourced from literature, but details are not available about how they have been calculated. This is discussed in more depth in section 4.1.3.
- Travel of personnel to and from the site is not accounted for.

Figure 4.1 Representation of the system and processes



4.1.2 Definition of processes

The processes included within the defined boundaries need to be identified. This was agreed with the customer at the outset and further refined during the data collection phase, when more details on the process were provided by the supply chain. The processes included can be grouped by type:

Transport of:

- raw materials from factory gate to plant, including asphalt planings from site to plant;
- *MasterPave-R* from plant to site;
- asphalt planings to a site depot, for the "what if" scenario; and
- planing and paving equipment, which was taken on site every evening and brought back to the depot every morning.

Production of:

- input materials from third party supply, i.e. fibres and bitumen – represented by their embodied energy;
- aggregates at Tarmac's quarries; and
- *MasterPave-R.*

Use of primary and ancillary equipment, such as for:

- loading and unloading aggregates onto/from trains;
- planing;
- laying; and
- compacting.

4.1.3 Collection of data

A data collection template listing all activities to be considered was prepared and data gathered on quantities and type of energy used and distances hauled using various transport modes. The data inventory was largely identical to the 2007 study, with the exception of energy consumption data at the Hayes asphalt plant, the mixture recipe for *Masterpave-R* with a higher recycled content, and haulage data, plant to construction site. Only a few data were not available from the supply chain and were substituted with the best available information from literature, particularly life cycle assessment studies, government sources and technical specifications.

4.1.4 Calculations

All data for the scheme constructed and for the alternative scenario were inserted in a custom built spreadsheet for the calculations. This calculator was developed using the data found and provided from equipment and materials suppliers.

The following approaches and assumptions applied are of note:

- The 'number of trips' is calculated by dividing the tonnage required by the capacity of the transport vehicle. If this is not equivalent to a integer number, energy and emissions are attributed pro-rata and the number of trips is not rounded up to the nearest unit.
- The character of each transport operation was discussed with the Contractor. This was to specifically identify trips where the vehicles were definitely going back empty (e.g. bitumen tankers) and those where the vehicles would continue their

trip to other destinations, picking up/consigning other materials (e.g. all the transport undertaken by logistics companies, such as the delivery of the fibres to the warehouse). In the former, the full round trip was accounted for as contributing to energy use and carbon dioxide emissions generation; in the latter, only the trip from the source of materials to the plant or site was accounted for.

4.1.5 Internal verification

The calculation spreadsheet was developed and reviewed by the senior researchers of the team and circulated for internal verification, to ensure data consistency and accuracy of calculations and assumptions. The verification was an iterative process because assumptions taken were discussed until agreement was reached that they represented reality as closely as possible.

4.2 Measurements

Auditing of energy use is a relatively simple, yet time consuming, exercise that requires full commitment and buy-in from the supply chain. Tarmac, the material supplier and paving contractor, were fully collaborative and provide very good quality data. Examples of measurements that were required and were provided are:

- mixture recipes actually used and energy required for heating and mixing the *MasterPave* and the *MasterPave-R* mixtures, from the job cards and from monitoring carried on at the Hayes plant;
- energy used for producing different aggregate sizes: this figure came from the quarries supplying the Hayes plant as quantity of energy per tonne of aggregates, deriving from metering of energy consumed in a certain period (month or year) divided by the tonnage of aggregates production in the same period; and
- transport and transfer patterns: Tarmac provided a full picture of how the aggregates were moved and transferred between transport modes, the types and capacity of the vehicles used, any back haulage carried out or likely to be carried out.

The models of the equipment used for planing, paving and compacting the materials were either checked during the site visits or ascertained with the supply chain, and information on their power consumption obtained from manufacturers.

Information sourced from literature and used in the calculations included:

- Embodied energy of bitumen (EuroBitume 1999);
- CO_2 emissions factors for electricity, diesel, fuel oil, gas oil (Carbon Trust, 2006);
- Consumption of the Class 66 locomotives, used for transporting aggregates, from a study for the Strategic Railway Authority (AEA Technology, 2001); and
- Guidance on how to measure and report your greenhouse gas emissions (Defra, 2009).

5 Findings

The audited resurfacing scheme is estimated to have produced approximately 33 t of CO_2 and used in the region of 488 GJ of energy. All of these emissions are attributable to the use of *MasterPave-R*, which directly replaced conventional *MasterPave* in this application. However, if conventional *MasterPave* had been used instead, then it is estimated that over 42 t of CO_2 would have been generated and in the region of 622 GJ of energy would have been used.

The savings associated with using *MasterPave-R* are, therefore, of the order of just over 9 t of CO_2 and just under 134 GJ of energy. This is equivalent to the emissions produced by an average car[1] travelling over 52,500 km (about 32,500 miles) or to the energy that would keep 37 typical 250 W motorway lights on for their entire average 4,000h life. A summary of the data for the scheme impact and savings are given in Tables 5.1 and 5.2 respectively.

Table 5-1 Scheme Impact

Units	Energy used (GJ)	CO_2 Generated (tonnes)
Impact of the scheme	487.6	32.85
of which:		
Equivalent to approximately, per tonne of asphalt laid	0.728	0.049
Impact of the alternative "what if" scenario (only *MasterPave* used, total of 670 tonnes)	621.9	41.6
Equivalent to approximately, per tonne of *MasterPave*	0.928	0.062

Table 5-2 Scheme savings

Measurement	Quantity
Savings realised by the scheme as compared to alternative *MasterPave* construction:	134 GJ of energy 8.75 tonnes of CO_2
Equivalent to emissions resulting from an average car travelling approximately[1]	52,350km (32,700 miles)
Equivalent to the number of typical motorway lights (250W) that could be powered for their entire 4,000 hour average life	37 lights

At this stage, it is useful to compare the results of the study to the corresponding study which was conducted in 2007. Table 5-3 and Table 5-4 show the results.

[1] In the UK, the average car owner drives 13,438 km per year, emitting 2.246 tonnes of carbon dioxide. From http://www.carplus.org.uk/carclubs/car-clubs-&-carbon-savings.htm

Table 5-3 Scheme Impact 2007

Units	Energy used (GJ)	CO_2 Generated (tonnes)
Impact of the scheme	3,235.3	220.02
of which:		
attributable to *MasterPave-R* mixture (total of 3,096 t used at 22.3 % RA content)	2,830	192
attributable to *MasterPave* mixture used in first section (total of 447 t used)	407	28.05
Equivalent to approximately, per tonne of asphalt laid	0.913	0.062
Impact of the alternative "what if" scenario (only *MasterPave* used, total of 3,543 t)	3,488	236.
Equivalent to approximately, per tonne of *MasterPave*	0.984	0.067

Table 5-4 Scheme savings 2007

Measurement	Quantity
Savings realised by the scheme as compared to alternative *MasterPave* construction:	252.73 GJ of energy 16.30 t of CO_2
Equivalent to emissions resulting from an average car travelling approximately	97,500 km (60,900 miles)
Equivalent to the number of typical motorway lights (250 W) that could be powered for their entire 4,000 h average life	70 lights

There are some key differences between the two studies which should be noted. The 2007 scheme was larger, using over five times as much asphalt as the 2009 scheme. The 2007 scheme also used a combination of conventional *MasterPave* and *MasterPave-R* to complete the highway section on which the analysis was based and the 2009 scheme only used *MasterPave-R* containing the enhanced levels of RA. It was, however, a relatively straightforward exercise to isolate the performance of *MasterPave-R* from the 2007 study (containing 23 % recycled content) in order to compare it to the performance in 2009 (which contained 40 % recycled content).

Additionally, the transport distances and plant energy consumptions are slightly different in the two studies. Transport distances were slightly higher and plant energy consumption lower in 2009, the overall result being to lower absolute footprints in 2009. Because of these differences it is most useful to compare relative savings *MasterPave* to *MasterPave-R* to obtain a true picture of the effect of increasing recycled content levels. In 2007, the footprint of *MasterPave-R* was 7 % lower than conventional *MasterPave*. In 2009, this relative difference was increased to 21.5 %, which is a marked improvement.

6 Discussion

It is important to note that this audit has focused on carbon dioxide emissions only. A full carbon footprint, following the latest guidance from the Carbon Trust and the BSI, should include all greenhouse gases within the 'basket of six' agreed upon by the Intergovernmental Panel on Climate Change (IPCC, 1996). However, carbon dioxide accounts for 85 % of the greenhouse gases and it is by far the most important greenhouse gas emitted from combustion of fuel.

The CO_2 figures, as normalised to a tonne of MasterPave and *MasterPave-R,* are 0.062 and 0.049 respectively. These figures are only relevant to the specific job audited because they are made up of components strictly dependent on the location and circumstances of the scheme. For example, the distance from the plant, amount of arisings used, mixture recipes, and equipment type. As a consequence, those figures cannot be used to represent the embedded emissions of the two mixtures or the emissions associated when used in other schemes. This fact is illustrated by the results of the 2007 study, in which a tonne of conventional *MasterPave* was calculated to have a CO_2 footprint of 0.067 t/t, a figure that was calculated to be 0.062 t/t in 2009. Plant modifications and slightly different transport distances are reflected in the lower figure for 2009.

Carbon emissions represent only one indicator of environmental impacts and sustainability.

The findings of this study reinforce those which were determined in 2007; the use of reclaimed asphalt within *MasterPave-R* represents a more environmentally sustainable solution, from the point of view of carbon dioxide emissions, than a *MasterPave* would have been in this specific case. The findings also suggest that a higher recycled content lowers emissions further. The following sustainability considerations should also be added:

- Use of recycled materials reduces extraction of virgin materials from quarries;
- Recycling of surfacing material in surfacing material is a high value application: although reclaimed asphalt is seldom disposed of, it might often be downgraded;
- Due to planings being used in the new material laid, back haulage of the RA from site becomes a practicable option, with an associated reduction of truck movements and, consequently, congestion and cost. However, this was not an option which was pursued between construction site and re-processing site for this job. Should re-processing have been undertaken at the asphalt plant site, and backhauling have been maximised between construction site and plant, then *MasterPave-R* could have been produced with a footprint of 0.044 t of CO_2 per tonne, thereby giving potential CO_2 savings of 29 % relative to conventional *MasterPave*.

As in 2007, the original aim of adding RA to the new thin surface course was to conserve resources of high psv stone. This aim has been achieved in 2009 to a greater extent, with 40 % recycling levels achieved; 17 % higher than the average level achieved in 2007. Energy and CO_2 savings of 7 % were achieved in 2007, which exceeded the 'carbon neutral' aspiration at that time. Plant modifications, specifically a separate RA feed and dryer unit, meant that, in 2009, it was no-longer required to superheat the virgin aggregate fraction to compensate for un-dried RA. Higher levels of RA could be incorporated with less energy required overall, because energy inputs were more effectively directed in 2009. This increase has been shown to yield a more appreciable CO_2 reduction of 22 %, far exceeding the 'break even' aspiration of 2007. However, there are a one or two provisos which should accompany these figures. The durability of the 40 % RAP content *MasterPave-R* needs to be comparable to that of conventional *MasterPave* to realise all of the benefits; should it need to be replaced more frequently than conventional *MasterPave* then these savings will diminish. Previous trials (Carswell *et al*, 2005; Carswell *et al*, 2009) have shown comparable performance in the medium term. Consistent monitoring of surface course materials with RA is now required to provide this information in the longer term. Furthermore, it is important to highlight that much depends on the energy consumption figures and any possible inconsistencies in the measurement process, 2007 compared to 2009. However, because this process is a relatively straightforward, it is not thought to be a significant factor in this study.

7 Conclusions

The project undertook an energy audit of a resurfacing scheme where arisings of planed asphalt from a length of the M25 motorway were recycled within the new material laid and compared the results to that of a similar study conducted in 2007. The audit considered the energy used and the associated carbon dioxide emissions generated by the manufacturing and placing of the materials as used. An alternative scenario was also analysed where an equivalent, containing 100 % virgin materials, bituminous mixture would be used to quantify the savings in energy and emissions realised by the actual construction material used.

From the energy auditing of this scheme where 40 % RA, obtained from the existing worn out surfacing, was included into the new surface course, the following conclusions can be made:

- Comparision of the results from a similar study in 2007 where 23 % RA was added showed an improvement in CO_2 savings compared with a 'what if' scenario of using 100 % virgin materials.
- It is estimated that the scheme realised savings of about 9 t of CO_2 (about 21.5 % saving) and 134 GJ of energy with respect to the alternative scenario.
- The most savings were realised from the reduction in use of primary aggregates, particularly the 6/14 fraction, and the bitumen together with the heating and mixing energies which were imparted on each mixture.
- The energy required to heat and mix the high recycled content *MasterPave-R* was less than for the conventional *MasterPave*, thought to be due to the efficiency of new equipment retrofitted to the the plant specifically to pre-dry RA, which now works in tandem with the pre-existing drying equipment which was designed to deal with primary (clean) aggregates only.
- Because of the distance of the RA reprocessing site (63 km) from the work site, transport of the mixture and the planings from and to the plant required more energy and generated more CO_2 emissions than it would have if a *MasterPave* mixture was used and the planings were taken to the depot 16 km away from the site.
- Savings could have been realised if logistics between site, asphalt plant and RA reprocessing site could have been made more efficient by co-locating RA reprocessing and asphalt batching and introducing backhauling between this site and the construction site.

The study has, therefore, demonstrated that, for this particular scheme, the use of *MasterPave-R* has realised significant energy and carbon dioxide emissions savings when compared to the use of *MasterPave*. Comparing these results to those of a similar study with lower recycling rates undertaken in 2007, the benefits achieved in 2009 were higher per tonne of asphalt laid. This would suggest that modifying the asphalt plant to deal with higher RA mixture compositions was worthwhile and should be considered for other plants where RA needs to be dried in high quantities before mixing. To achieve further savings, more efficient logistics options should be explored, particularly the co-location of the reprocessing site with the asphalt plant which could facilitate savings in material haulage.

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Enhanced levels of reclaimed asphalt in surfacing materials – a case study evaluating carbon dioxide emissions

The need for sustainable construction processes which conserve natural resources is well understood and recognized within the industry, and is often realised through recycling materials into layers below the surface course. However, this 'downgrades' the use of expensive and increasingly scarce high polished stone value (psv) aggregates. The incorporation of a proportion of an existing surface course layer into a new surface course system is, therefore, highly desirable because it maintains the 'high value' application of the high psv aggregate in a surface course layer. With the reduction in requirement for virgin materials, the inclusion of reclaimed asphalt in the surface course layer may also offer benefits in terms of reduced energy and emissions. This report documents a study on the energy used and relative carbon dioxide emissions associated with the recent resurfacing of the M25 scheme between Junctions 6 to 7, from MP43/2 to 47/3. The objectives of the case study were to gain an understanding of the differences and potential savings in energy and carbon dioxide that could be made by the incorporation of a high reclaimed asphalt content (40 %) into the surfacing compared with a 100 % virgin aggregate mixture. The activities undertaken during the resurfacing works were, therefore, audited and compared with a hypothetical scenario where the conventional material would have been laid.

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