A38: Ex-situ recycling of a trunk road in South Devon

Product: Cold recycled bitumen bound base material

Material: Recycled aggregate / Recycled asphalt

Application: Bitumen bound base (roadbase)

Project Type: Pavements - roads, car parks, etc.

Location: South West

Date: September 2005 – March 2006

Specification: TRL 611 and the Specification for Highway Works

Conditions of contract: (NEC) ECC Option B: Priced Contract with Bill of Quantities
Introduction

This case study describes how a sustainable alternative to full pavement reconstruction can be delivered by traditional contractual and supply chain mechanisms. As of May 2006 it was the largest single recycling contract on the Highways Agency network.

Ex-situ recycling in the form of Foamix was selected in preference to conventional reconstruction to provide the required pavement performance criteria for financial reasons and environmental benefits such as reduced pollution and congestion. The structural layers of the existing pavement were recycled to produce the material Foamix, which is a cold lay asphalt with a binder consisting predominantly of foamed bitumen. The high-volume, low viscosity fluid with low surface tension enables a wide range of moist, cold recycled aggregates to be coated with bitumen. The significant reduction in truck movements and waste disposal costs on the A38 enhanced the sustainability aspects of the solution adopted.

The experience of the subcontractor and the uniformity of the material being recycled facilitated design of the Foamix and made the recycling process relatively straightforward to control.

Background

The length of the A38 that was recycled is found on the southern side of Dartmoor adjacent to Ashburton and is one of the most heavily trafficked roads in Devon, taking most of the traffic between Exeter and Plymouth, the two largest centres in the Southwest.

Typically the Annual Average Daily Traffic (AADT) volume is around 37,000 (2-way) with around 10% of this volume being heavy goods vehicles. The road was identified as needing major structural maintenance in 2004 when the increasing amount of patching was brought to the attention of the Highways Agency. Following increasing amounts of patching, the road was identified by the Highways Agency as needing major structural maintenance in 2004.

The first indication that the pavement was not performing properly was the appearance of star-shaped cracks that extended over an area of around 0.5 m x 0.5m, normally in the wheelpaths. After a short while depressions formed around these cracked areas before the cracked material developed into loose blocks a few weeks later. As a health and safety risk to the public these defects were treated as soon as possible, which became increasing costly and more disruptive as the incidence of the defects increased. Eventually a road closure was required for major patching, soon after which, failure of adjacent material began and moved along the road.

Deflectograph test results indicated that around 65% of the pavement had less than 5 years residual life. Recycling was subsequently carried out in three phases over six months on 4km.
of the northbound carriageway and 8km of the southbound carriageway. The extent of the site is indicated in Figure 1.

Figure 1  Site map

One of the reasons that recycling was preferred to conventional hot-mix reconstruction was that since the original construction in the 1970s the pavement had been overlaid and inlaid and the bound layers partially replaced in 1998, and so the structure of the pavement was relatively uniform. This meant that there were few changes in mixture design along the works. This is often not the case where roads have been built, maintained and widened over a number of years.

The recycling option chosen was to use foamix with existing asphalt base materials to a thickness of approximately 255mm. An additional 100mm of conventional asphalt surfacing (40mm SMA on 60mm DBM) was applied to provide a high quality interface with traffic loads.

Supply chain

The structure of the supply chain for this project is illustrated in Figure 2 and is quite conventional with a client, main contractor and subcontractors.
The main contractor on the project was Tarmac with Roadstone Recycling as the subcontractor for recycling works, and also responsible for the mixture design. The recycling contract was awarded after tenders were assessed for both quality and price. Due to the size and nature of the works the pre-tender process incorporated a workshop where prospective tenderers were able to discuss areas of concern with members of the Highways Agency and industry specialists. This ensured that all parties were aware of the overall objectives and constraints of the contract and issues of concern for the client. A result of this was the particular focus on traffic management during the works, and the inclusion of Trafficmaster in the supply chain.

**Figure 2 Contract structure**

![Diagram of contract structure]

**The Highways Agency**

The Highways Agency is an Executive Agency of the Department for Transport (DfT), and is responsible for operating, maintaining and improving the strategic road network in England on behalf of the Secretary of State for Transport. The Agency is committed to re-use and recycling wherever practical by increasing the recycled content within highway construction and avoiding the disposal of the recycled materials to landfill. This is in line with government policy and in its document ‘Building Better Roads: Towards Sustainable Construction’ The Highways Agency has set out that it will aim ‘to develop techniques to ensure that the Trunk Road Network is managed in the most sustainable manner,
conserving the existing resource, generating less waste and removing barriers that prevent or inhibit the use of secondary or waste materials.'

**Tarmac Group**

Tarmac Group is the market leader in the UK in aggregates, mortar, concrete blocks and asphalt and is dedicated to developing sustainable solutions to road surfacing. Through its enhanced network of regional production units and plants, Tarmac provides a vast range of products for the construction industry nationwide including many innovative recycled products, and is the country's leading supplier of building materials. Tarmac National Contracting is the UK's market leader in Motorway and Highway resurfacing and Reconstruction.

**Roadstone Recycling Ltd**

Roadstone Recycling Ltd has been established for eight years as a specialist ex-situ road recycling business. In that time the company has manufactured over 450,000 tons of recycled foam bitumen material which has been used on all grades of road and footway in the UK.

The Roadstone Recycling specification for Foamaster (recycled foam-mixed road base and binder course) has formed the basis for the current national specification and was also used by the Highways Agency on recycling contracts on the M6 and M62 motorways from 2003 to 2005.

**Trafficmaster**

Founded in 1988, Trafficmaster is an established technology company, focusing on satellite navigation and digital traffic information.

**Details**

In 1998 parts of the A38 dual carriageway were reconstructed with the structure shown in Figure 3. Then, after seven years of trafficking, cracking and potholes began to form and the bituminous materials started to deteriorate progressively. These defects were treated using deep patching and were required first in Lane 1 and then in Lane 2 with increasing frequency. It soon became obvious that the bound layers would require large scale replacement, as within a few weeks after the patches were placed, material on either side of the patch started to disintegrate and break up.

The site lies adjacent to the southern part of Dartmoor National Park and the towns of Ashburton and Buckfastleigh. Because there has been considerable traffic disruption from recent works on the road and due to the fact that much of the road has had to be replaced after only seven years the project has become politically delicate. This in turn has led to special consideration of traffic control to reduce disruption to locals and the travelling public
using the main Exeter to Plymouth highway. Also, to avoid the main tourist season the recycling had to be carried out in a four-month window. The works commenced in September 2005 and were completed in March 2006.

**Figure 3** Existing pavement

- 35 mm surface course
- 70 mm binder course
- High modulus base
- Unbound granular base 150 mm- 180 mm (wet mix)*
- Type 1 sub base

**Figure 4** ‘New’ recycled pavement

- 30 mm surface course
- 70 mm binder course
- 230-280 mm Foamix
- Type 1 sub base

* Wet mix is a term for an obsolete method of road base construction

Ex-situ recycling in the form of Foamix was selected in preference to conventional reconstruction to conform to the policy of sustainability being followed by the Highways Agency. The recycling option provided the pavement performance criteria required with various environmental benefits such as reduced pollution and congestion (see below).

Foamix is a term commonly used to describe cold lay asphalt with a binder consisting predominantly of foamed bitumen. The ex-situ process involves breaking down planed materials and grading them into different sizes. Foamed bitumen is produced by the injection of 1 to 2% cold water with air into hot penetration grade bitumen. This process produces a high-volume, low viscosity fluid with low surface tension; these properties enable the foamed bitumen to coat a wide range of moist, cold recycled aggregates. The significant reduction in truck movements and waste disposal costs further enhanced the sustainability aspects of the engineering solution adopted.

[www.aggregain.org.uk](http://www.aggregain.org.uk)
The materials used in the Foamix on the A38 are as shown in Table 1. The mixture had been developed following extensive investigation and sampling of materials along the site using 26 trial pits and more than 30 cores and Dynamic Cone Penetration (DCP) tests. This was a key factor in risk management and developing confidence in the mixture design.

### Table 1  Constituents of the Foamix Mixture

<table>
<thead>
<tr>
<th>Material</th>
<th>Percentage by mass</th>
<th>Compliance criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recycled aggregate from the A38.</td>
<td>88%</td>
<td>Zone A (TRL 611)</td>
</tr>
<tr>
<td>Pulverised Fuel Ash (PFA)</td>
<td>5%</td>
<td>Incorporated in the end performance requirements</td>
</tr>
<tr>
<td>Bitumen (100/150 pen.)</td>
<td>3%</td>
<td>3% ±0.5%</td>
</tr>
<tr>
<td>CEM 1 (previously Ordinary Portland Cement)</td>
<td>1.5%</td>
<td>1.5% ±0.3%</td>
</tr>
<tr>
<td>Added water</td>
<td>Varied through the Contract (typically 2%)</td>
<td>3.4% minimum, 7.4% maximum</td>
</tr>
</tbody>
</table>

The recycled pavement has been designed for a traffic loading of 35 million standard axles (msa), which exceeds what was previously seen as a limit for this recycling technique (30 msa). However, due to the development of recycling technology and the reducing level of risk associated with recycled materials the permitted design traffic is increasing. The predicted 35 msa design traffic is not therefore considered a risk, especially due to the consistent nature of the material to be recycled. As of May 2006 the volume of material to be recycled on this project is larger than any other single pavement recycling works undertaken by the Highways Agency.

Some of the most important issues identified during the works are as follows:

- A high quality detailed assessment of the volume, type and condition of the existing pavement is required.
- Early Contractor Involvement (ECI) is advantageous.
- During the works, close attention to material quality through quality control procedures must be given. This is especially important in providing a consistent final product if the existing materials are variable.
Design and specifications

The design was based on TRL Report 611, A guide to the use and specification of cold recycled materials for the maintenance of road pavements (2004) and the practical knowledge of Roadstone Recycling. The table below shows who designed the final pavement thicknesses and materials.

### Table 2  Summary of design responsibility

<table>
<thead>
<tr>
<th>Basis of design</th>
<th>Design Responsibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>TRL 611 and experience of</td>
<td>Pavement thickness design was carried out by Parsons Brinkerhoff</td>
</tr>
<tr>
<td>Roadstone Recycling</td>
<td>Roadstone Recycling developed materials designs that were approved by Tarmac</td>
</tr>
</tbody>
</table>

Approximately 30 Trial Pits were excavated and logged and Dynamic Cone Penetration (DCP) tests were carried out to define the condition of the foundation in detail. This played a significant part in reducing risk in design and construction.

**Specifications** for material types and thickness were based around recommendations made in TRL611 (Merrill, Nunn and Carswell, 2004).

**Design traffic** was estimated as being 35 msa over 20 years.

Although 35 msa is marginally beyond the confirmed performance line in Figure 7.8 of TRL 611, there appears little risk in premature failure as the foundation is fairly consistent and relatively strong and little variation in the recycled Foamix base mixture was required along the site.

The **compliance testing** used can be summarised that the Contractor had to declare the Indirect Tensile Stiffness Modulus (ITSM) in accordance with British Standard Draft for Development (BSDD) 213 together with predicted stiffness values for 360 days (with a minimum threshold value of 3.1 GPa). Tests were required with a frequency of 3 per 1000 tonnes of material with a minimum of three per working day.

During construction it was possible to mill, recycle and relay around 1500 tonnes of material during a single day.
Construction options

Table 3 shows the differences between the (chosen) recycling option and the more traditional reconstruction option.

**Table 3  Estimated amounts of materials for the two scenarios**

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Option/ layers</th>
<th>SHW Classification</th>
<th>Volume (m³)</th>
<th>Mass (Tonnes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recycle</td>
<td>Surface course</td>
<td>SMA¹</td>
<td>4,345</td>
<td>10,428</td>
</tr>
<tr>
<td></td>
<td>Binder course</td>
<td>HDM²</td>
<td>8,070</td>
<td>19,368</td>
</tr>
<tr>
<td></td>
<td>Base course</td>
<td>Foamix</td>
<td>29,270</td>
<td>70,244</td>
</tr>
<tr>
<td></td>
<td>New asphalt</td>
<td></td>
<td>12,415</td>
<td>29,796</td>
</tr>
<tr>
<td>Full Reconstruction</td>
<td>Surface course</td>
<td>SMA</td>
<td>4,345</td>
<td>10,428</td>
</tr>
<tr>
<td></td>
<td>Asphalt base</td>
<td>HDM</td>
<td>8,070</td>
<td>29,800</td>
</tr>
<tr>
<td></td>
<td>Base course</td>
<td>HDM</td>
<td>29,270</td>
<td>70,244</td>
</tr>
<tr>
<td></td>
<td>New asphalt</td>
<td></td>
<td>41,685</td>
<td>100,044</td>
</tr>
</tbody>
</table>

1. Stone Mastic Asphalt
2. Heavy Duty Macadam

It is clear from Table 3 that through recycling there is a reduction in the volume of fresh hotmix material of around 70,000 tonnes. This in turn reduces the energy required for extraction, heating and transportation.

As this road has been subject to various repairs and maintenance of late and the bound layers have had to be replaced after only seven years in service, a prime measure of the success of the works was the level of traffic disruption. As a consequence of this Trafficmaster was subcontracted to deal with traffic monitoring and reporting. Trafficmaster already monitored the route using their Automatic Number Plate Recognition (ANPR) system. Under the subcontract Trafficmaster developed and hosted a web page linked to the Highways Agency's Traffic England web site. The A38 web page displayed current delay information for the road works area, current speeds on approaches to the road works if below 30mph, and the current message being displayed on the Variable Message Signs (VMS). Trafficmaster were also disseminating the journey information through their usual channels i.e., mobile phone services, internet sites, the RAC and their own products.

The Variable Message Signs were used to warn traffic coming into the area around 15 km prior to entering the site and displayed a static message with a current 'expected delay time'. This sign linked directly into the Trafficmaster ANPR system via GPRS and was updated every five minutes.
Benefits

Financial
The recycling costs were approximately £2M out of a total contract cost of £8M. Tarmac has estimated that a saving of around £300k could be generated by using recycled materials compared to traditional primary material reconstruction.

Environmental
If full reconstruction was carried out an additional 70,000 tonnes of primary asphalt would have been required. This in turn would have required considerable energy for extraction, mixing and transportation, with attendant pollution and emissions of (inter alia) CO₂. It has been estimated that using the recycling with Foamix option led to a reduction in CO₂ emissions. This has been estimated using a new CO₂ estimator tool developed for WRAP (see following section).

Congestion
Although the recycling operation was ex-situ, the recycling plant was only around a kilometre from the northern end of the works which meant that materials only had to be transported on average 4km. This reduced the need to transport hot mix materials from a remote asphalt plant. Also, easy access to the quarry where the recycling plant was located meant that site traffic avoided the local towns and villages. The effects of traffic congestion was minimised by monitoring traffic flows and informing the public using the Trafficmaster system.

Disposal of material
It has been estimated that through the reduction of new asphalt needed, around 11,500 tonnes of waste has been saved together with the reduction in the land take needed for new materials of around 19 hectares.

CO₂ emissions
The WRAP CO₂ estimator tool was used to compare the recycled material option chosen by the team with a traditional primary material alternative to estimate any difference in carbon dioxide emitted.

This freely available tool on the WRAP AggRegain Website can be used to analyse different construction processes and practices to help identify the most sustainable project construction and material options.

The tool was employed to analyse two options as follows:
Option 1 - The traditional option with primary aggregates for the bituminous bound materials (hot mix).

Option 2 - As built option with recycled asphalt used for 100% of the base course aggregates (cold mix).

The outputs generated as show below:

<table>
<thead>
<tr>
<th>Construction Options</th>
<th>CO₂ Emissions Tonnes</th>
<th></th>
<th>Comparison with As Built</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bituminous</td>
<td>Total</td>
<td></td>
</tr>
<tr>
<td>1) All Primary Aggregates (Hot mix base course)</td>
<td>3,565</td>
<td>3,565</td>
<td>+ 1,914 (+116%)</td>
</tr>
<tr>
<td>2) As Built (Cold mix base course)</td>
<td>1,651</td>
<td>1,651</td>
<td>-</td>
</tr>
</tbody>
</table>

A large proportion of the difference in CO₂ emissions, 1,884 tonnes, results from the different method of producing the base course. The standard full reconstruction with all primary aggregates would have used a hot mix process and the as built used a cold mix process (Foamix) incorporating the recycled aggregate.

The ex-situ cold bituminous mix process using foamed bitumen (Foamix) incorporating recycled aggregate used in this project had a lower level of total carbon emissions compared to the traditional full reconstruction of a pavement with all primary aggregates and a new hot bituminous mix.

Clients such as the Highways Agency are becoming increasingly interested in the environmental performance of projects because of the requirement to support government targets alongside the basic economic considerations.

Providing clients with lower CO₂ emitting options and processes can help differentiate a tenderer in an increasing competitive market where overall tender prices are likely to be very similar to each other.
Conclusions

This case study illustrates how a sustainable alternative to full pavement reconstruction can be delivered by traditional contractual and supply chain mechanisms if the client is willing to drive the sustainability agenda. The experience of the specialist subcontractor allowed a design mixture to be developed with confidence early in the design phase.

A feature of the contract that made recycling relatively straightforward to control was the uniformity of the material being recycled, i.e. approximately 200 mm of HMB and 180 mm of unbound granular base. This meant that little variation in the mixture was required. For other sites a comprehensive investigation of materials would be needed to assess their variability and there would be a need for variation in mixture design.

The early involvement of prospective tenderers in a pre-tender workshop ensured that all parties were aware of all important relevant issues. This led to the needs of the Highways Agency (with respect to congestion and traffic management) being addressed during the contract by the appointment of Trafficmaster as a sub-contractor.

The project was successfully delivered in a very tight timescale between September 2005 and March 2006 and is the largest recycling contract undertaken by the Highways Agency to date (May 2006). The project delivered major sustainability benefits in terms of reduced use of materials and energy, reduced transport and reduced emissions of CO₂ compared to conventional reconstruction of the pavement.

References

Aggregates Case Study

A38 Planing existing pavement base

A38 Paving with foamed bitumen base
Details of Parties

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