TRANSPORT RESEARCH LABORATORY

Road trials of Stone Mastic Asphalt and other thin surfacings

Prepared for Pavement Engineering Group, Highways Agency

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Executive Summary

The research described in this Report is part of a project to assess the robustness of new techniques, materials and specifications for use on the surface course layer of trunk roads and motorways. This part of the project is concerned with:

- the assessment of stone mastic asphalt (SMA), a generic material developed in Germany, for use on trunk roads and motorways; and
- the assessment of the various categories of proprietary thin surface materials, now widely offered by UK Suppliers and Contractors.

SMA can be laid to the same thickness as conventional wearing courses or can be used as a thin surface course material, and has been used as the basis of some of the proprietary thin surfacings. These two aspects have much in common and are treated together in this Report.

Some wearing course mixtures have been applied in thin layers but, in practice in the UK, there have been few materials used between a veneer coat of surface dressing or slurry surfacing and a 40 mm thick wearing course. However, mixtures have been developed in other countries, particularly in France where the *Avis Technique* procedure is used to gain approval, to fill the perceived niche in the market for a thin layer with the potential to regulate. Starting in the early 1990s, such proprietary materials have been offered for use in the United Kingdom and road trials of the first two to be introduced, *UL-M* and *Safepave*, were set up and monitored by TRL on behalf of the Highways Agency.

Other approaches to producing a thin surfacing have subsequently been offered in the United Kingdom. These include:

- SMA, a generic material that was developed in Germany over 20 years ago as a surfacing material with good deformation resistance which can be laid and compacted in relatively thin layers if required. SMA, as used on the Continent, is not normally designed to have the texture required for UK high-speed trunk roads and motorways, although that property can be allowed for in the design.
- *Surphalt*, a proprietary thin surfacing produced from multiple surface dressings which is, therefore, of a very different nature to the hot-mix thin surfacings such as *Safepave*, *UL-M* and thin SMA.
- Other proprietary thin surfacings, not dealt with directly in this Report.

The initial results from early trials of *Safepave* and *UL-M* have already been reported. This report updates the condition of the existing *Safepave* and *UL-M* trials. Additional road trials have been laid with a surface course of SMA having the required texture depth to ascertain if the increase in texture causes any loss of durability compared to the continental mixtures. One of the trials of SMA also has sections of *Safepave* and *UL-M* to allow direct comparison between the three materials. A further trial was laid with *Surphalt* because the material is so different from the original types of thin surfacing. The new trials, which are described in this Report with early results, are intended to complement the existing trials of *Safepave* and *UL-M* in order to assess the effectiveness of the more common types of thin surfacing available in the United Kingdom, and to determine the extent of any difference between the performances of the various thin surfacing systems. Further trials have been and/or are being monitored to assess other proprietary thin surfacing systems, but these are not covered in this Report.

The research has shown that each material provides a surfacing with acceptable Sideway-Force Coefficients, with relatively low traffic noise levels and with a subjective reduction in spray. The materials generally also provide satisfactory initial texture depth which, after an initial reduction, stabilises at a lower, but acceptable, level. However, for these thin surfacings, the ratio of the sand-patch texture depth to the sensor-measured texture depth is very different from that experienced with rolled asphalt or surface dressing and, furthermore, changes with time.

The results of this research indicate that the thin surfacings under test can provide the required properties for use on trunk roads and motorways, although the long-term durability, in terms of proven service-life, will not be known until several sections surfaced with these materials reach the end of their useful lives. However, there are concerns about the reduction in texture depth with trafficking found with SMA on some, but not all, sites. Nevertheless, the introduction of these thin surface course materials into the United Kingdom has demonstrated that the maintenance engineer has a requirement for such materials, whether they are proprietary products such as *Safepave*, *UL-M* and *Surphalt* or the generic SMA.

For approval to be used on UK trunk roads and motorways, each proprietary material has to be assessed separately to demonstrate that it has equivalent performance to the conventional surfacing materials. These assessments are currently being carried out under the *Five-stage Highways Agency Procedure for Evaluating New Materials*, with four products (the initial two, *Safepave* and *UL-M*, together with *Hitex* and *Masterpave*) having received Departmental Type Approval from the Highways Agency at the time of writing. However, that procedure will be superseded in the near future by the British Board of Agrément *Highways Authorities Products Approval Scheme* for thin surfacing systems when some products have been assessed under it and received certificates.

1 Introduction

With rising volumes and loadings of road traffic and increasing disruption costs of maintenance, new surfacing materials have been, and are being, developed in many parts of the world that are expected:

- to provide longer, maintenance-free lives; and/or
- to be applied in a manner which minimises disruption to traffic.

These developments include thin surfacings and stone mastic asphalt (SMA). Several thin surfacings have been developed and approved in France through the *Avis Technique* system, but these systems are generally proprietary so that they are usually brought into the UK under licensing agreements with UK Contractors. Other thin surfacings have been developed locally based on the basic concepts. SMA, a generic material developed in Germany but also widely used in Austria and Scandinavia as well as being trialled in many other countries, can be designed and used as an alternative thin surfacing material.

Thin surfacings are materials that are used in layers with thicknesses between those of ‘traditional’ wearing courses (40 mm to 50 mm of rolled asphalt, dense macadam, asphaltic concrete or porous asphalt) and those of veneer coats (5 mm to 10 mm of surface dressing, slurry surfacing or resin-based high skid-resistant surfacing). As such, thin surfacings can be considered as a cross between ‘thin wearing courses’ and ‘thick surface dressings’ with typical thicknesses of 15 mm to 30 mm and an ability to be applied thicker in localised areas. Their advantages are that they can restore the skid-resistance and provide some regulating ability whilst minimising the need to raise ironwork and the loss of headroom at over-bridges. As with veneer surfacings (surface dressing and slurry surfacings), they should only be used where the supporting pavement is structurally adequate. In principle, they have all the advantages of a surface dressing without suffering the disadvantages of the aftercare service required for surface dressing. They also have the advantage that they can be laid in some seasonal weather conditions unsuitable for surface dressing.

The Highways Agency is interested in extending the range of surface treatments for use on trunk roads provided that each new surfacing material has demonstrated its inherent durability and capability of maintaining adequate texture depth and skid-resistance, as set out in the Skidding Resistance Standard (DMRB 7.3.1). The availability of a wider range of materials will allow engineers to make most economic use of surfacing materials whilst extending the intervals between maintenance on the road network. Therefore, the Highways Agency commissioned TRL to evaluate the thin surfacing systems then available in the UK.

The first two new thin surfacing systems which became available in the UK were *Safepave* (marketed by Associated Asphalt) and *UL-M* (initially marketed by Alfred McAlpine, subsequently by other Suppliers and Contractors under license from Jean Lefebvre (UK) Ltd). *Safepave* was introduced into the UK in late 1991 and there are now many sites in the UK where it has been used, of which some of the earlier ones were monitored by TRL. *UL-M* was introduced the following year and there are also many sites where it has been used, some of which were studied by TRL; there are now several alternative proprietary materials available that are similar, but not identical, to *UL-M*. Road trials have been underway on all of these materials for up to six years, together with control sections including a microsurfacing, or thick slurry surfacing using modified binders, system which has been available for many years in the United Kingdom.

SMA was developed in Germany and is capable of being laid in thin layers; the material was introduced into the UK at a pilot scale trial at TRL in October 1993. Four road trials were laid during 1995, three using rolled asphalt (HRA) as the control (including one monitored by Cumbria County Council rather than TRL) and one using *Safepave* and *UL-M*. Additionally, a road trial of another thin surfacing type, *Surphalt* (marketed by Lanfina Bitumen), a multi-layer surfacing dressing, was laid in 1995 using a racked-in surface dressing as the control.

This report gives details of the road trials laid during 1995, together with the results from monitoring of these, plus the earlier thin surfacing, road trials up to 1997. Observations during the application of the materials and general views from conversations with County Engineers are also discussed.

2 Material types

2.1 Stone Mastic Asphalt

Stone mastic asphalt (SMA) is a surfacing material that was developed from gussasphalt in Germany over 20 years ago as a deformation-resistant material, originally to offset the problem of studded tyres although these were subsequently banned. The material has proved successful and is now widely used in Germany, Austria and Scandinavia and it is being tried in the United Kingdom, the United States of America and several other countries.

SMA has a stone skeleton of interlocking crushed rock coarse aggregate, comprising largely single sized stone of a size appropriate to the laying thickness and required surface texture (Loveday & Bellin, 1998). The single sized nature of the aggregate skeleton leaves a relatively high void content between the aggregate particles which is partly filled with a binder rich mastic mortar. As such, the aggregate grading is similar to that of porous asphalt, but with the voids filled with mortar. The mortar comprises crushed rock fine aggregate, filler, bitumen or modified bitumen and a stabilising additive, generally fibres. The composition of the mortar is very important in determining the performance of the SMA; a very high binder content is essential to ensure durability and laying characteristics. Sufficiently high binder contents cannot be achieved using unmodified or unstabilised bitumens without binder drainage; hence the need for a fibre stabiliser, or absorptive fillers or modified binders.

The aggregate gradings in UK SMAs are shown in Figure 1 (Nunn, 1994) with the idealised ‘Fuller’ curve

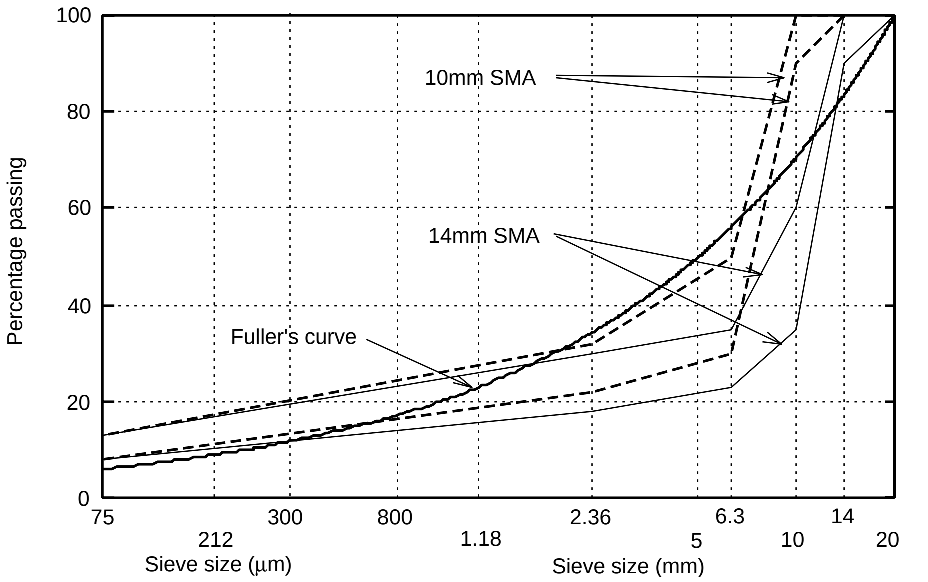

Figure 1 Stone Mastic Asphalt gradings

(Fuller & Thompson, 1907) included for comparison.

The process of designing a SMA mixture involves adjusting the grading to accommodate the required binder and void content rather than the more familiar process of adjusting the binder content to suit the aggregate grading. Maintenance of the consistency of grading during manufacture is also of great importance because loss of volumetric balance can result in the mastic mortar fatting up. The mixture is designed so that, when fully compacted, the voids in the aggregate skeleton exceed the volume of the mastic by 3 to 5 per cent. The interlocking aggregate skeleton can then carry all the traffic load applied to the material while the mortar binds the skeleton together and makes the layer impervious.

More detailed descriptions of SMA are given elsewhere (Nunn, 1994; Loveday & Bellin, 1998).

2.2 Thin surfacings

2.2.1 Categories of thin surfacing

Thin surfacings, or thin wearing course materials, can be categorised by several means, but the simplest approach is to consider the material type from which they were developed. These categories for thin surfacings, together with some of proprietary variations, are:

- Microsurfacings (Thick Slurry Surfacings)
  - *Ralumac*
  - *Reditex*
  - *Permatex*
- Multi-Layer Surface Dressings
  - *Surphalt*
- Paver-Laid Surface Dressings (Ultra-thin hot mix asphalt layers)
  - *Safepave*
  - *Combifalt*
- Thin Asphaltic Concrete (Very thin surface layers)
  - *UL-M*
  - *Hitex*
  - *Axoflex*
  - *Masterflex*
  - *Brettpave*
- Hybrids of Paver-Laid Surface Dressings and Thin Asphaltic Concrete
  - *Tuffgrip*
  - *Colrug*
  - *Thinpave*
  - *Euro-Mac*
- Thin Stone Mastic Asphalt
  - Generic Stone Mastic Asphalt
  - *Masterpave*
  - *Viatex*
  - *SMAtex*
  - *Axofibre*
  - *Brettmastic*
  - *Megapave*

This list of the proprietary products is not exhaustive.

Although many of these surfacings are being offered as proprietary products, the microsurfacings and the thin SMA can also be specified as generic types. It is anticipated that the thin asphaltic concretes will also be able to be specified by generic type if the proposal to prepare a harmonised European specification for thin surfacings is followed through. At the time that the 1995 set of trials were laid, the Highways Agency (HA) had provisional specification clauses for SMA and thin surfacings, which are reproduced for convenience as Appendices A and B, respectively. The clause for thin surfacings is about to be introduced into the 1998 edition of the *Specification for Highway Works* (MCHW 1) as Clause 942 with a requirement for the thin surfacing material to be approved. Initially, the only materials with Departmental Type Approval from HA for use with this clause were *Safepave* and *UL-M*, but these have been joined by *Hitex* (Nicholls, 1998) and *Masterpave* with others likely to follow soon (Nicholls, 1997a; further reports on other systems are as yet unpublished).

Brief descriptions of the materials currently under trial by TRL on behalf of the Highways Agency are given below.

2.2.2 Thin Stone Mastic Asphalt

Although SMA is generally used as a full-depth surfacing material on the continent, it can be used at reduced thicknesses as a thin surfacing. In introducing SMA as a generic material to the UK, the grading has been adjusted to provide the texture depths specified for high-speed roads; hence, the durability record of continental SMA requires to be verified for the modified grading.

2.2.3 Thin asphaltic concrete (*UL-M*)

UL-M is one of a number of proprietary thin asphaltic concrete surfacings that were developed in France as Very Thin Surface Layers through the *Avis Technique* system. *UL-M* was developed by Enterprise Jean Lefebvre, a leading French road construction company, as a maintenance treatment but it is sometimes used in new construction. It is basically a gap-graded mixture (and hence not truly an asphaltic concrete) with a nominal 10 mm size coarse high-PSV (polished stone value) aggregate and a modified binder. The material is bonded to the road surface by prior application of a tack-coat sprayed at a rate of 0.7 - 1.75 litres per square metre, depending on road porosity. *UL-M*, manufactured and laid to the French specification, was introduced into the UK by Alfred McAlpine although subsequently marketed by several Suppliers and Contractors under licence from Jean Lefebvre (UK). The bitumen is either a 70 pen or 100 pen, modified with an ethylene vinyl acetate (EVA), at a binder content within the range 4.5 to 7.0 per cent, depending on the mixture. The material is laid using conventional paving equipment to a nominal thickness of 20 mm. A more detailed description of *UL-M* is given elsewhere (Nicholls et al, 1995).

2.2.4 Paver-laid surface dressing (*Safepave*)

The idea of an ultra-thin surfacing was originally proposed as a process which would not have the drawbacks associated with surface dressing and it may be considered as a paver-laid hot mix surface dressing. Laboratoire Central des Ponts et Chaussées (LCPC) in conjunction with SCREG Routes developed *Euroduit*, renamed *Novachip* and subsequently marketed in the UK as *Safepave* by Associated Asphalt. The material is a hot bituminous mixture spread directly over a sprayed bond coat. A purpose built machine incorporates a binder sprayer and material distribution system to lay the mixed material. The long length of the machine enables an excellent longitudinal profile to be achieved. The sprayed binder is a modified emulsion, containing approximately 70 per cent solids, and is sprayed at a rate of 1 litre per square metre. The mixed material specification was originally to a French design, although subsequently modified for the UK market, with 100 penetration grade bitumen. The aggregates used are of a high quality and high PSV in order to achieve a good skid-resistance. A more detailed description of *Safepave* is given elsewhere (Nicholls et al, 1995).

2.2.5 Multiple surface dressing (*Surphalt*)

Surphalt is a proprietary multiple surface dressing process developed in Norway and brought to the UK under license by Lanfina Bitumen. *Surphalt* consists of successive applications of:

- polymer-modified bitumen emulsion at 1.1 L/m²;
- 14 mm chippings at 12 to 15 kg/m²;
- 10 mm lightly coated chippings at 11 to 13 kg/m²;
- polymer-modified bitumen emulsion at around 2.3 L/m²; and
- 6 mm chippings at 7 to 9 kg/m².

Rolling using 8 to 10 tonne vibratory rubber-tyred rollers is applied both after the 10 mm and after the 6 mm chippings have been laid, although only for a limited number of passes - as with surface dressing, slow-moving traffic is the preferred method of finishing. Other chipping sizes can be used, with each successive application employing chippings one nominal sieve size smaller. The rate of spread for the second application of binder is selected to fill a proportion of the voids in the dry aggregate skeleton already applied as well as acting as the binder for the final aggregate layer. *Surphalt* is claimed to be able to be applied at any time during the year providing the temperature is above 10°C.

2.2.6 Microsurfacing

Slurry surfacings are mixtures of bitumen emulsion and aggregate, generally to a relatively fine grading. Cationic bitumen emulsions are the most widely used binders in the manufacture of slurry surfacings, in which the ‘positive’ charge of the cationic emulsion reacts immediately with the ‘negative’ charge of the mineral aggregate producing a rapid breaking asphaltic matrix. Microsurfacings are proprietary machine-applied thick slurry surfacing systems that are applied in two layers and which use aggregates of up to 10 mm nominal size and polymer-modified bitumen emulsion.

3 Road trial sites

3.1 Early sites

3.1.1 General

The details, including plans of the sites, of the trials on the A47 at Thorney, the A1033 at Hull and the A34 at Stafford which were laid in 1991 and 1992 and subsequently monitored, with the results given in this report, are given elsewhere (Nicholls et al, 1995). Nevertheless, brief descriptions of the trial sites are given below.

3.1.2 A47, Thorney, Cambridgeshire

Sections of *Safepave* and racked-in surface dressing were laid on the A47 at Thorney, a road with unstable (fen) ground conditions, in September 1991 and a section of rolled asphalt (HRA) was laid later that year.

3.1.3 A1033, Hull

Sections of *Safepave* and a microsurfacing were laid on the A1033 at Kingston-upon-Hull, a heavily trafficked site near the docks, in October 1991. In 1993, additional sections of the microsurfacing were laid at either end of the site, in one case overlaying a section of existing rolled asphalt that was being used as a partial control.

3.1.4 A34, Stafford

Opposite carriageways of Queensway, part of the Stafford ring road, were surfaced with *Safepave* and *UL-M* in September 1992; the *Safepave* section had to be replaced in April 1993 because the original had been laid in damp conditions. The results given after the first year are for the replacement *Safepave*.

3.2 A140, Creeting Bottoms, near Ipswich

The A140 through Creeting Bottoms was a Roman road that is now a two lane single carriageway with a junction from which the road rises on each side (Figure 2). The position of the junction at the bottom of a depression has created an accident black-spot and a high-friction system, *Shellgrip*, had been applied there. The 33 m length of high-friction system was retained with a 400 m long trial section of SMA to the south and a 492 m length of rolled asphalt to the north. Redland Aggregates was the contractor, and they laid the rolled asphalt first and then the SMA during March 1995. The SMA had a nominal aggregate size of 14 mm and was laid 30 mm thick.

On one length at the north end (towards Norwich) of the SMA section, the first pass was laid too thinly so that, when the second pass was laid up to it, it was only one stone thickness (14 mm) over the camber and had to be replaced. At another area, on the south end of the northbound lane, there was a hump in the existing pavement which was still present after the new basecourse had been laid. The SMA was used to compensate for this unevenness, so hand laying was needed to avoid a further area of low thickness. When completed, the surfacing was of generally good appearance and good texture. The longitudinal joint was a little open, possibly because SMA was found to be difficult to cut back for day and other joints.

The Resident Engineer considered that SMA was capable of rivalling rolled asphalt, particularly in areas with poor access for chipping spreaders. The construction gang also seemed to appreciate SMA, despite having limited familiarity with the material. This unfamiliarity resulted in both:

- over-ordering the quantity of SMA because of uncertainty about the spread rate; and
- over-surcharging the longitudinal joint.

It was noted that compaction produced only a reduction in thickness of about 3 mm, the rolling re-orienting the aggregate matrix and smoothing the surface rather than reducing the thickness.

3.3 A10, Littleport, Cambridgeshire

The A10 at Littleport is a single carriageway with limited intersections and in a continuous gradual curve. The total length of site was nearly 6.5 km with a control section of rolled asphalt at the southern ends and the remainder in SMA other than 700 m of existing rolled asphalt laid in 1993; for a short length of the southbound lane the SMA was made with 100 pen bitumen rather than 50 pen bitumen and grit was applied to the 50 m approaches to the roundabout with the A1101 (Figure 3). The SMA had a nominal aggregate size of 14 mm and was laid 30 mm thick. The contractor, Wimpey Asphalt, laid the rolled asphalt first and then the SMA during June 1995.

The surface generally gave a good appearance, but in one area near the south end of the southbound lane, the material had dragged, reputably due to a cold load. A similar appearance occurred at spots where additional shovels of SMA had been applied prior to rolling. The appearance was of ‘missing’ stones in the surface, presumably because the binder had cooled sufficiently to hold the aggregate in a more open matrix. Furthermore, the SMA was reportedly difficult to hand lay, a process required at field entrances. Both problems are assumed to be due to the ‘stickiness’ of SMA, with its high binder content, making it slow to work while the thin layer thickness at which it was laid here allowed relatively rapid cooling.

The Contractor’s agent considered that SMA was quicker and easier to lay than rolled asphalt because no chippings were required. Furthermore, the work could be carried out using fewer operatives.

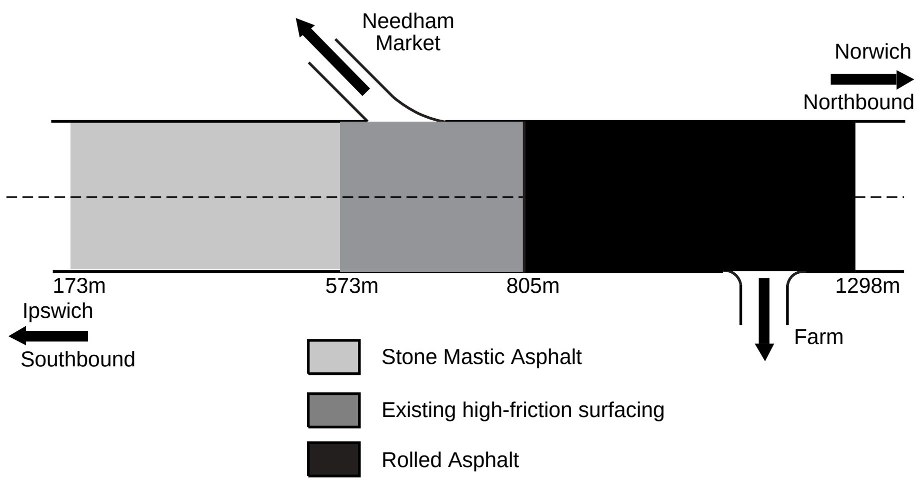

Figure 2 A140 site, Creeting Bottoms, near Ipswich

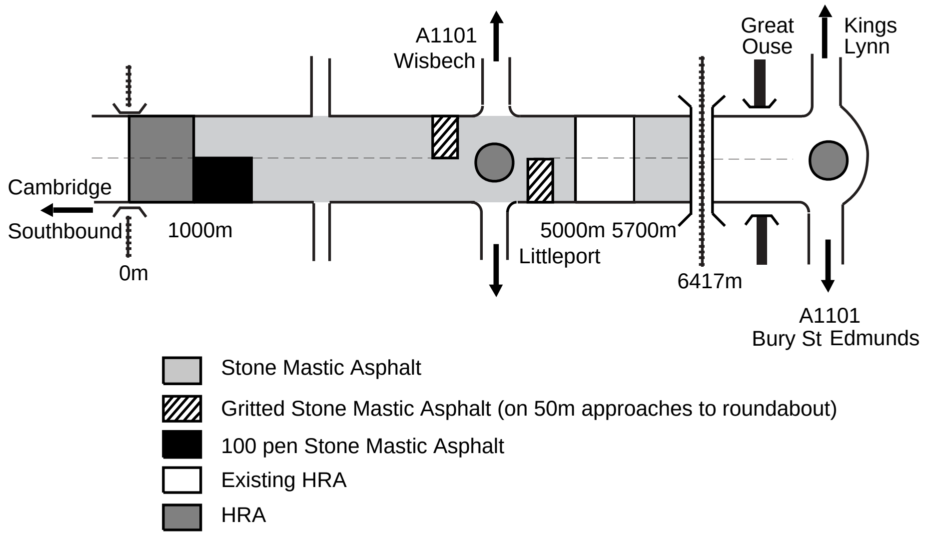

Figure 3 A10 site, Littleport, Cambridgeshire

3.4 A1, Eaton Socon, Cambridgeshire

The A1 at Eaton Socon is a two lane dual carriageway of jointed concrete construction, of which 1200 m of the southbound carriageway had been overlaid with *Safepave* having a 10 mm nominal maximum aggregate size in 1991 (Nicholls et al, 1995). The remainder of the concrete was overlaid using SMA having a 14 mm aggregate size (1600 m northbound, 900 m southbound), 10 mm *UL-M* (1900 m northbound, 300 m plus 500 m southbound) and 14 mm *Safepave* (1600 m northbound, 900 m southbound) (Figure 4) by SIAC Construction (UK) in June and July 1995.

Prior to work starting, a falling weight deflectometer survey was carried out on the northbound carriageway. The measurements were taken adjacent to joints in order to measure the load-transfer efficiency and confirm that there were no anomalous areas where potential load transfer, and consequential vertical movement, at the joints would influence the performance of the surfacings. The condition of the joints was consistent, so the exercise was not repeated on the southbound carriageway.

The SMA was supplied by Bardon Roadstone with a nominal aggregate size of 14 mm and was laid 30 mm thick. The *UL-M* was supplied by White Mountain (Asphalt) with a nominal aggregate size of 10 mm and was laid 20 mm thick. The *Safepave* was supplied by Associated Asphalt with a nominal aggregate size of 14 mm and was laid 30 mm thick. This site, with three different thin surfacings, is the most comprehensive trial but it should be borne in mind that the underlying road construction is rigid and, therefore, the relative performance of the surfacings may not be typical of the performance achieved on a flexible or composite substrate.

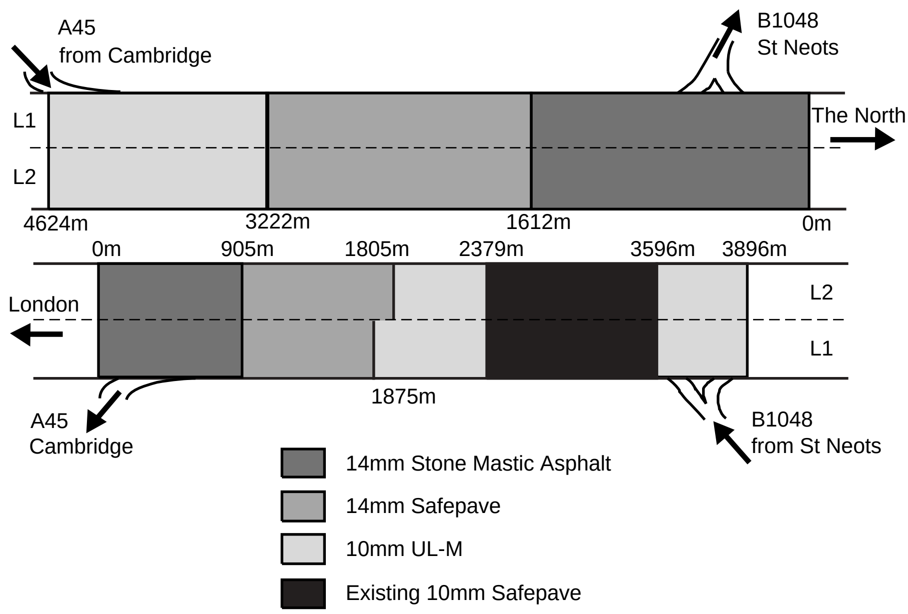

Figure 4 1995 A1 site, Eaton Socon

3.5 A614, Salterford crossroads, Nottinghamshire

The A614 at Salterford crossroads, Nottinghamshire, is a three-lane single carriageway that had been reduced to two-lanes by road markings (Figure 5). The S*urphalt* process was applied in October 1995 in three (in places four) rips of just over 1 km during the first day: the northbound lane, towards Ollerton, starting from the north; the centre starting from the north; and the southbound lane starting from the south. A further section of 250 m of *Surphalt* was laid at the south end on the following day followed by a short section of 33 m of racked-in surface dressing (14 mm/6 mm) as the control. Despite being late in the season, the first day was dry with sunny periods except for some light showers in the afternoon.

The trial was conducted outside the normal surface dressing season so the work team had to be reformed to carry out the work; Lanfina reported that the gang assembled had worked in three separate gangs previously. The operatives were local, but the equipment was brought in from some distance and, as a result, laying did not start until 11.00 am and had to be extended into the evening rush hour.

Problems occurred with the third chipping spreader, used for the 6 mm chippings, which could not get into third gear, and hence there were problems in pulling/being pushed by the supply wagon. At the start of the first of the three rips (northbound lane, starting at the north end), it took several attempts to get the correct speed, with excessive chippings spread in places which should have been removed with the final brushing. More seriously, two-thirds of the way along when going downhill, the weight of the wagon caused the chipping spreader to skid, ripping up a short length of the 14 mm/10 mm/binder mat already laid. This was repaired, but still visible when opened to convoyed traffic.

Further potential problems were caused by imprecise lapping and, in one case, a binder spillage. The result was localised double spread of binder which quickly came to the surface. It would have been preferable if work was re-started from transverse joints after building paper was applied so that excess quantities could be removed.

The processes can be carried out sequentially with a gap of only about a minute needed between the second binder application and that of the 6 mm chippings. However, at this trial there were considerable delays, exacerbated by the problems with the 6 mm chipping spreader. If each application is applied by separate equipment (the method used for the trial) and they follow each other closely, the system could be applied to any specific area quickly, even though the ‘train’ would be extensive. If there were any delays, as experienced on this trial, the traffic control on the road would need be extended compared to that required for other thin surfacing systems.

The visual appearance of the trafficked mat soon after opening was generally good, although with some blemishes. However, the excess 6 mm chippings dislodged by the early traffic had to be brushed up later.

3.6 A590, Barrow-in-Furness

As part of some improvements, just over 2 km of the A590 in Barrow-in-Furness was due to be resurfaced. The site was in a speed restricted zone, part to 30 miles/h and part to 40 miles/h, and the traffic flow in 1994 was 12,810 vehicles/day in each direction with 8.2 per cent of them being commercial, giving 1050 cv/l/d. As part of the works, a length of 1200 m was surfaced with SMA in place of the more conventional 30/14 rolled asphalt. The departure from standard practice was permitted as an additional trial because the Civil Engineering Laboratory of Cumbria County Council monitored the trial for the Highways Agency and provided the data to TRL.

The SMA was supplied by Wimpey Asphalt from their plant at Leapers Wood, Carnforth. The coarse aggregate was a Silurian gritstone from Holmescales Quarry with a polished stone value in the order of 61 - 63 at the time of supply. The surfacing was laid in stages between mid-June and late August 1995.

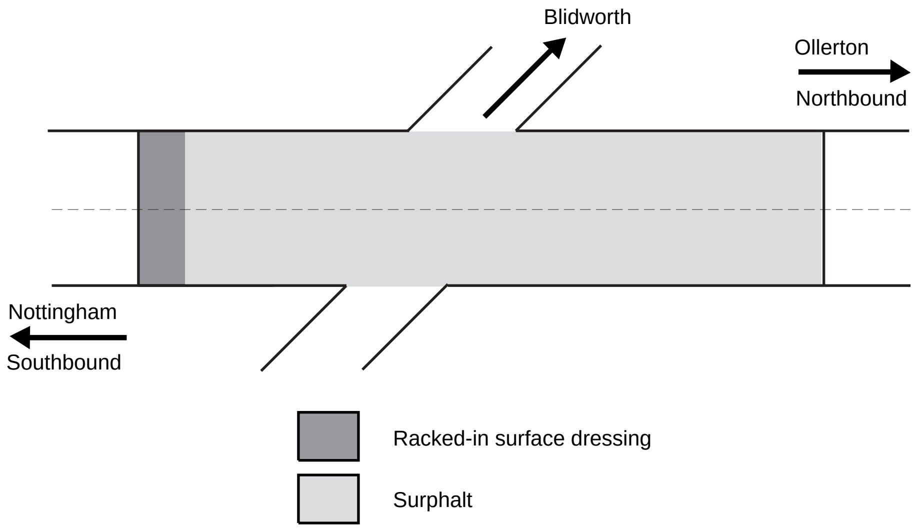

Figure 5 A614 site, Salterford Crossroads, Nottinghamshire

4 Results of monitoring

4.1 Compositional analysis

From the sites laid in 1995, the results of compositional analyses were available from the SMA laid on the A140 at Creeting Bottoms and the A10 at Littleport and the *Surphalt* laid on the A614 at Salterford Crossroads. No results were provided from the three materials laid on the A1 at Eaton Socon nor the SMA laid on the A590 at Barrow-in-Furness.

The compositional analyses of the SMA laid on the A140 at Creeting Bottoms (Table 1) showed that the material was marginally high on the proportion passing the 14 mm sieve, but otherwise generally within specification.

The compositional analyses of the cores taken from the SMA laid on the A10 at Littleport (Table 2) showed that the material complied with the specification.

The grading, flakiness index and rate of spread calibrations of the various chippings which combined to the Surphalt on the A614 are given in Table 3.

4.2 Skid-resistance

4.2.1 SCRIM

Skid-resistance was measured by TRL on the sites using the Sideway-force Coefficient Routine Investigation Machine (SCRIM) at 50 km/h, generally three times each year, and the Mean Summer SCRIM Coefficient (MSSC) determined. In addition, W S Atkins East Anglia took SCRIM readings early in the life of the two SMA sites in Cambridgeshire. The measurements made by W S Atkins included sections of the existing rolled asphalt on one end of the test sections as additional partial controls. The results from both sets of measurements, including those already reported (Nicholls et al, 1995), are given in Table 4.

The Investigatory Skidding-Resistance Levels of MSSC at 50 km/h (DMRB 7.3.1) for the sites are as follows:

A47, Thorney	0.40	
A1033, Hull	0.45	
A34, Stafford	0.35	
A140, Creeting Bottoms	0.40	(0.45 at junction in *Shellgrip* section)
A10, Littleport	0.40	(0.55 approaching roundabout)
A1, Eaton Socon	0.35	
A614, Salterford Crossroads	0.40	(0.45 at junction)

The mean results from the A47 at Thorney, the A1033 at Hull and the A34 at Stafford are shown graphically with these Investigatory Levels in Figure 6, 7 and 8, respectively.

4.2.2 Grip Tester

W S Atkins East Anglia took GripTester readings of the sites on the A10 at Littleport and A1 at Eaton Socon shortly after opening to traffic. The Civil Engineering Laboratory of Cumbria County Council monitored the skid-resistance on the A590 at Barrow-in-Furness using the Griptester at regular intervals. Both sets of results are given in Table 5.

4.2.3 Pendulum

W S Atkins East Anglia also measured the skid resistance values using the TRL pendulum on the A1 at Eaton Socon prior to opening. The results are given in Table 6.

There is no clear reason for the difference in SRV between the *UL-M* measured on the northbound (61) and southbound (55 and 58) carriageways.

4.2.4 High-speed skid-resistance

The brake-force trailer was used to measure the high-speed skid-resistance on surface dressing, *Safepave* and rolled asphalt on the A47 at Thorney (Nicholls et al, 1995). That

Table 2 Compositional analyses of SMA from A10, Littleport

	Specification	*Location 1*	*Location 2*
BS test sieve: proportion passing BS test sieve (per cent)			
20 mm	100	100	100
14 mm	90 - 100	94	91
10 mm	35 - 60	48	46
6.3 mm	23 - 35	28	25
2.36 mm	18 - 30	22	21
75 µm	8 - 16	11	11
Binder (per cent by mass)	5.9 - 7.1	6.6	6.6

Table 1 Compositional analyses of SMA from A140, Creeting Bottoms

		Chainage						
		North bound				*South bound*		
	Specification	*275*	*370 - 420*	*430 - 470*	*520 - 573*	*215*	*365 - 420*	*490 - 573*
BS test sieve:	***Proportion passing BS test sieve (per cent)***							
20 mm	100	100	100	100	100	100	100	100
14 mm	88 - 98	**99**	**100**	98	**99**	**100**	98	**99**
10 mm	31 - 51	47	48	**53**	51	**54**	47	49
6.3 mm	20 - 36	26	26	27	27	29	26	27
2.36 mm	15 - 22	22	22	23	23	23	22	23
75 µm	6.6 - 8.6	7.8	8.5	7.2	8.8	8.5	7.9	8.2
Binder (per cent by mass)	5.7 - 6.9	6.3	6.3	6.0	6.2	6.3	6.1	6.0

Table 3 Aggregate grading, flakiness index and rate of spread of chippings for *surphalt* on the A614, Salterford Crossroads

	14 mm chippings		*10 mm lightly coated chippings*		*6 mm chippings*	
	Specified	*Achieved*	*Specified*	*Achieved*	*Specified*	*Achieved*
BS test sieve:	***Proportion passing BS test sieve (per cent)***					
20 mm	100	100				
14 mm	85 - 100	98	100	100		
10 mm	0 - 35	20	85 - 100	94	100	100
6.3 mm	0 - 7	1	0 - 35	11	85 - 100	88
5 mm	-		0 - 10	2	-	
3.35 mm	-		-		0 - 35	12
2.36 mm	0 - 2	1	0 - 2	1	0 - 10	3
600 µm	-		-		0 - 2	1
75 µm	0 - 1	1	0 - 1	1	0 - 1	0
Flakiness	***Flakiness index (per cent)***					
	25 max.	11	25 max.	13	n/a	n/a
Rip	***Rate of spread of chippings from calibration (kg/m²)***					
Left	12 - 15	12.5	11 - 13	11.5	7 - 9	9.0
Left Middle	12 - 15	13.0	11 - 13	12.0	7 - 9	8.5
Right Middle	12 - 15	12.5	11 - 13	11.5	7 - 9	9.0
Right	12 - 15	13.0	11 - 13	12.0	7 - 9	9.0

Table 4 SCRIM results

			TRL MSSC results Year							*WSA SCRIM Results*	
Site	*Location*	*Material*	*1991*	*1992*	*1993*	*1994*	*1995*	*1996*	*1997*	*7/95*	*9/95*
A47, Thorney	Eastbound	Surface dress	0.55	0.57	0.59	0.60	0.57	0.55	0.56	-	-
		Safepave	0.67	0.60	0.59	0.62	0.58	0.58	0.59	-	-
		HRA	-	0.48	0.48	0.48	0.47	0.43	0.44	-	-
	Westbound	Surface dress	0.56	0.52	0.55	0.53	0.50	0.40	0.40	-	-
		Safepave	0.64	0.57	0.58	0.58	0.53	0.51	0.52	-	-
		HRA	-	0.47	0.47	0.48	0.44	0.44	0.44	-	-
A1033, Hull	Eastbound nearside lane	Microsurfacing	-	0.44	0.43	0.46	0.39	0.43	0.48	-	-
		Safepave	-	0.55	0.57	0.60	0.52	0.51	0.57	-	-
		HRA*	-	0.42	0.40	-	-	-	-	-	-
		Micro'ing	-	-	-	0.48	0.43	0.48	0.46	-	-
	Eastbound offside lane	Microsurfacing	-	-	0.45	0.47	-	-	-	-	-
		Safepave	-	-	0.57	0.60	-	-	-	-	-
		HRA*	-	-	0.45	0.55	-	-	-	-	-
	Westbound offside lane	Microsurfacing	-	-	0.45	0.51	-	-	-	-	-
		Safepave	-	-	0.58	0.63	-	-	-	-	-
		HRA*	-	-	0.42	0.58	-	-	-	-	-
	Westbound nearside lane	Microsurfacing	-	0.45	0.41	0.47	0.38	0.42	0.47	-	-
		Safepave	-	0.53	0.56	0.59	0.50	0.48	0.53	-	-
		HRA*	-	0.41	0.37	-	-	-	-	-	-
		Micro'ing	-	-	-	0.53	0.43	0.50	0.45	-	-
A34, Stafford	Southbound	*Safepave*	-	-	0.57	0.58	0.53	0.52	0.58	-	-
	Northbound	*UL-M*	-	-	0.52	0.56	0.48	0.46	0.54	-	-
A140, Creeting Bottoms	Northbound	SMA	-	-	-	-	0.48	0.52	0.56	-	-
		*Shellgrip**	-	-	-	-	0.66	0.66	0.68	-	-
		HRA	-	-	-	-	0.47	0.51	0.53	-	-

Continued....

Table 4 Continued

Site	Location	Material	*TRL MSSC results Year* 1991	1992	1993	1994	1995	1996	1997	*WSA SCRIM Results* 7/95	9/95
	Southbound	SMA	-	-	-	-	0.40	0.48	0.56	-	-
		*Shellgrip**	-	-	-	-	0.65	0.64	0.69	-	-
		HRA	-	-	-	-	0.46	0.49	0.54	-	-
A10, Littleport	Northbound	HRA*	-	-	-	-	-	-	-	0.34	0.36
		HRA	-	-	-	-	0.45	0.52	0.57	0.36	0.44
		SMA	-	-	-	-	0.40	0.51	0.57	0.34	0.47
		SMA + grit	-	-	-	-	0.46	0.51	0.53	0.37	0.53
		SMA	-	-	-	-	0.37	0.51	0.57	0.33	0.47
		HRA*	-	-	-	-	0.41	0.44	0.48	0.33	0.44
		SMA	-	-	-	-	0.34	0.52	0.55	0.32	0.46
		SMA + grit	-	-	-	-	-	-	-	0.32	0.49
	Southbound	HRA*	-	-	-	-	-	-	-	0.35	0.38
		HRA	-	-	-	-	0.39	0.51	0.57	0.35	0.47
		100 pen SMA	-	-	-	-	0.38	0.50	0.55	0.35	0.57
		SMA	-	-	-	-	0.41	0.51	0.56	0.33	0.49
		SMA + grit	-	-	-	-	0.46	0.48	0.51	0.39	0.49
		SMA	-	-	-	-	0.38	0.52	0.57	0.33	0.53
		HRA*	-	-	-	-	0.41	0.45	0.48	0.39	0.43
		SMA	-	-	-	-	0.37	0.51	0.57	0.33	0.47
		SMA + grit	-	-	-	-	-	-	-	0.36	0.46
A1, Eaton Socon	Northbound nearside lane	*UL-M*	-	-	-	-	0.37	0.53	0.54	0.42	0.59
		Safepave	-	-	-	-	0.37	0.48	0.49	0.37	0.56
		SMA	-	-	-	-	0.34	0.43	0.54	0.34	0.52
	Northbound offside lane	*UL-M*	-	-	-	-	-	-	-	0.43	0.52
		Safepave	-	-	-	-	-	-	-	0.37	0.53
		SMA	-	-	-	-	-	-	-	0.35	0.42
	Southbound offside lane	HRA*	-	-	-	-	-	-	-	0.44	0.44
		UL-M	-	-	-	-	-	-	-	0.37	0.50
		*Safepave**	-	-	-	-	-	-	-	0.55	0.57
		UL-M	-	-	-	-	-	-	-	0.37	0.49
		Safepave	-	-	-	-	-	-	-	0.40	0.56
		SMA	-	-	-	-	-	-	-	0.35	0.47
	Southbound nearside lane	HRA*	-	-	-	-	-	-	-	0.41	0.43
		UL-M	-	-	-	-	0.34	0.51	0.46	0.35	0.48
		*Safepave**	0.69	0.57	0.59	0.60	0.53	0.58	0.52	0.55	0.58
		UL-M	-	-	-	-	0.37	0.50	0.56	0.38	0.54
		Safepave	-	-	-	-	0.37	0.49	0.63	0.38	0.54
		SMA	-	-	-	-	0.35	0.42	0.55	0.34	0.43
A614, Salterford	Northbound	*Surphalt* day 1	-	-	-	-	0.52	0.51	0.53	-	-
		Surphalt day 2	-	-	-	-	0.59	0.48	0.54	-	-
		HRA*	-	-	-	-	-	-	0.53	-	-
Crossroads	Southbound	*Surphalt* day 1	-	-	-	-	0.51	0.50	0.54	-	-
		Surphalt day 2	-	-	-	-	0.56	0.51	0.53	-	-
		HRA*	-	-	-	-	-	-	0.54	-	-

**Existing materials used as partial controls*

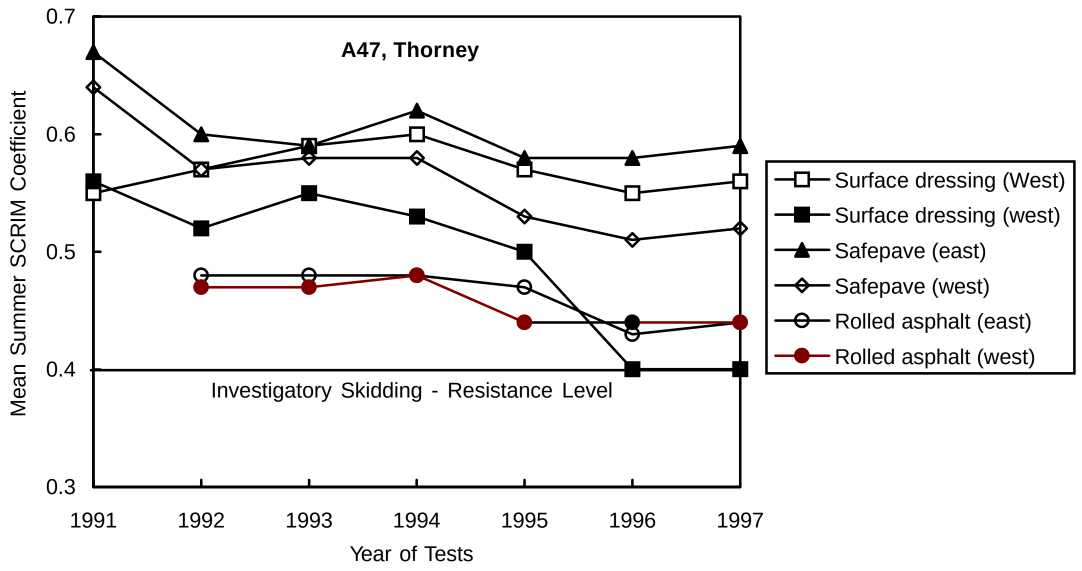

Figure 6 MSSC on A47, Thorney

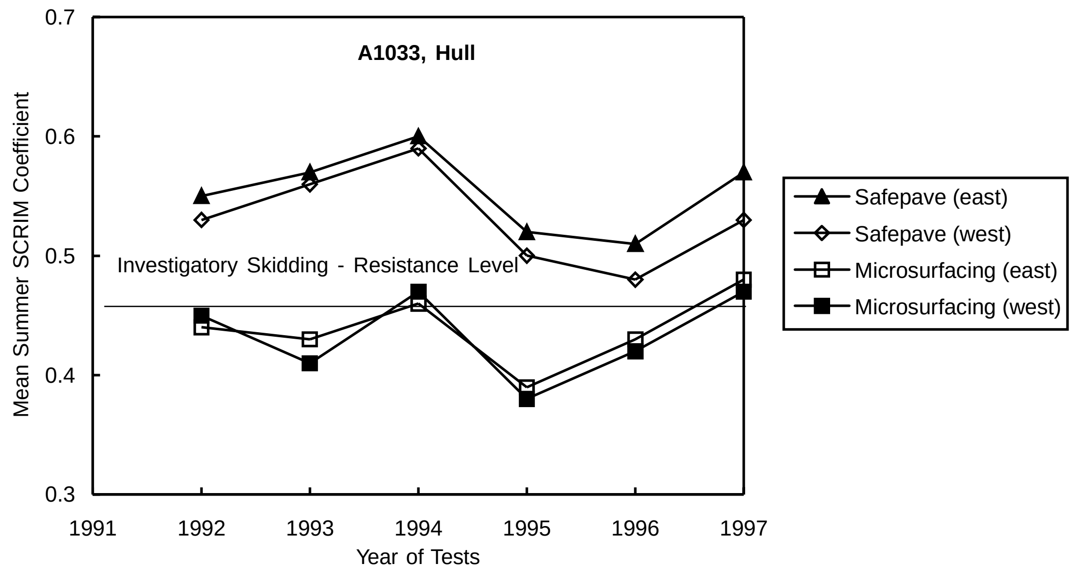

Figure 7 MSSC on A1033, Hull

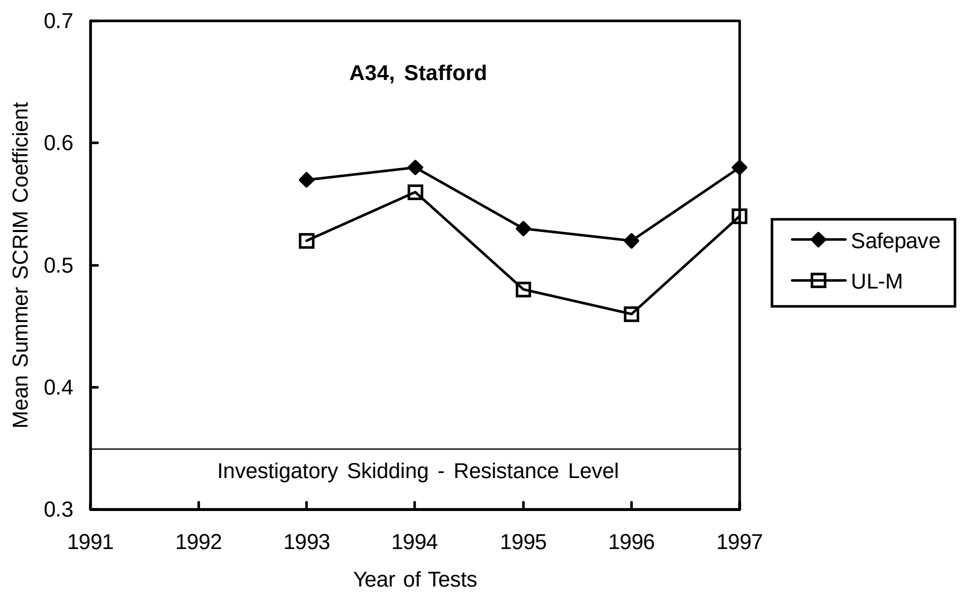

Figure 8 MSSC on A34, Stafford

Table 5 GripTester results

		GripTester number		
		Northbound		Southbound
Site	*Material*	*05/07/95*	*04/08/95*	*04/08/95*
A10, Littleport	HRA	-	0.54	-
	100 pen SMA	-	N/A	0.59
	SMA	-	0.57	0.55
	SMA	-	0.55	0.57
	SMA + grit	-	0.69	0.65
	SMA	-	0.55	0.54
	HRA*	-	0.56	0.57
	SMA	-	0.53	0.57
A1, Eaton Socon	*UL-M*	N/A	N/A	0.58
	*Safepave**	N/A	N/A	0.82
	UL-M	0.55	0.58	0.62
	Safepave	0.60	0.61	0.60
	SMA	0.62	0.59#	0.61

		Rolled asphalt		*Stone mastic asphalt*	
Site	*Survey date*	*Northbound*	*Southbound*	*Northbound*	*Southbound*
A590,	28/09/95	0.51	0.54	0.55	0.55
Barrow-	18/01/96	0.66	0.56	0.64	0.57
in-	21/06/96	0.58	0.59	0.56	0.60
Furness	08/08/96	0.60	0.61	0.57	0.60
	20/09/96	0.67	0.66	0.63	0.66
	18/06/97	0.67	0.60	0.64	0.63
	19/08/97	0.60	0.62	0.58	0.62
	01/10/97	0.72	0.69	0.71	0.70

**Existing materials used as partial controls*
#0.62 over first 400 m
-No measurements made

equipment was superseded by a Pavement Friction Tester manufactured by K J Law. The high-speed skid-resistances of SMA, *Safepave* and *UL-M* were measured with the Pavement Friction Tester on the northbound carriageway of the A1 at Eaton Socon in September 1996. The results, in terms of Skid Numbers at different speeds, are given in Table 7 and are shown graphically in Figure 9.

4.3 Texture depth

4.3.1 Sand-patch texture depth

The initial texture depth was measured by the sand-patch method in accordance with BS 598: Part 105 (BSI, 1990a) as part of the normal control on most sites. The surface regularity was also measured by the TRL Rolling Straight Edge (Young, 1977) and complied with the specification. The results of the sand-patch texture depth tests, each the mean of ten determinations over a 50 m diagonal length within the lane, are given in Table 8.

On the A1 at Eaton Socon, a limited series of texture depth measurements was carried out in the nearside wheel-track of the nearside lane on the northbound carriageway in November 1997 after the sections had been trafficked for over 2 years. Ten determinations were made on each surfacing, giving one texture depth result. The results, with the range for the individual determinations, are also

Table 6 Pendulum results on A1, Eaton Socon

	Skid resistance value (untrafficked)	
Material	*Northbound*	*Southbound*
UL-M	N/A	55 (54-55)
*Safepave **	N/A	-
UL-M	61 (57-67)	53 (51-57)
Safepave	58 (52-69)	58 (56-59)
SMA	61 (55-72)	60 (55-63)

**Existing materials used as partial controls*
-No measurements made

Table 7 Pavement friction tester measurements on A1, Eaton Socon

10 mm UL-M		*14 mm* Safepave		*14 mm SMA*	
Speed	*Skid number*	*Speed*	*Skid number*	*Speed*	*Skid number*
20.6	68.5	20.2	62.0	20.8	63.5
49.4	49.6	48.8	48.9	47.7	43.9
80.6	36.5	78.9	40.2	82.1	37.1
109.8	28.1	108.3	34.3	111.4	26.4
128.5	31.2	127.8	35.5	131.4	30.4

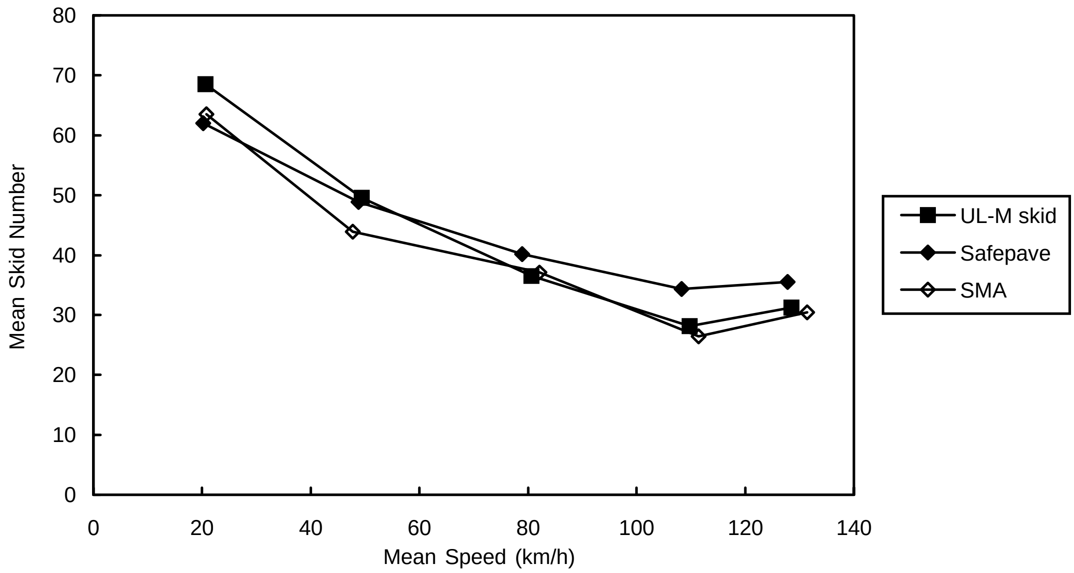

Figure 9 Pavement friction tester results from A1, Eaton Socon (Locked-wheel friction with blank tyre and 1 mm water depth)

Table 8 Sand-patch texture depth results

				Northbound		Southbound	
Site		*Age*	*Material*	*Mean*	*Range*	*Mean*	*Range*
A140, Creeting Bottoms		New	SMA	1.95 mm	1.7 - 2.2 mm	(both carriageways)	
A10, Littleport		New	HRA	1.6 mm	1.5 - 1.7 mm	1.6 mm	1.5 - 1.6 mm
			SMA*	2.1 mm	1.8 - 2.5 mm	2.1 mm	1.8 - 2.6 mm
A1, Eaton Socon	Nearside lane	New	SMA	2.3 mm	1.6 - 3.1 mm	2.1 mm	2.1 - 2.1 mm
			Safepave	3.0 mm	2.2 - 3.9 mm	2.1 mm	2.0 - 2.2 mm
			UL-M	1.6 mm	1.4 - 2.0 mm	1.2 mm	1.1 - 1.3 mm
	Offside lane	New	SMA	2.6 mm	2.2 - 3.0 mm	2.0 mm	1.7 - 2.3 mm
			Safepave	3.2 mm	2.3 - 4.0 mm	3.1 mm	2.6 - 3.6 mm
			UL-M	1.7 mm	1.3 - 2.2 mm	1.3 mm	1.1 - 1.6 mm
A1, Eaton Socon	Nearside wheeltrack	2 years	SMA	1.8 mm	1.6 - 2.0 mm		
			Safepave	1.8 mm	1.5 - 2.1 mm		
			UL-M	1.1 mm	1.0 - 1.1 mm		
A614, Salterford Crossroads		New	*Surphalt*	2.8 mm	2.7 - 2.8 mm	(2 tests)	

**Mean value for all sections*

given in Table 8.

The texture depths on the A590 at Barrow-in-Furness at two locations on the SMA and one on the rolled asphalt were monitored at regular intervals by the Civil Engineering Laboratory of Cumbria County Council using the sand-patch method. All the texture depth measurements were taken using 10 sample points at 5 m spacing diagonally across the lane width. The results are given in Table 9. The results from those sampling points lying in the wheel-tracks on the SMA have been identified and their mean values repeated separately. The mean values for rolled asphalt, all SMA and SMA in the wheel-track are plotted in Figure 10.

When the north-bound lane of the A1 at Eaton Socon was closed to measure the high-speed skid-resistance in September 1996 (just over a year after laying), the opportunity was taken to measure the sand-patch texture depth. The weather was damp, so the measurements were made as transverse sections under the bridges over the three sections. The results are shown in Figure 11.

4.3.2 Sensor-Measured Texture Depth

Sensor-measured texture depth (SMTD) is a measurement of the root-mean square (rms) of the variation in texture depth and, as such, measures a slightly different property to the sand-patch test. The sensor can be mounted in a number of ways, including in a hand-propelled mini-texture meter and on a vehicle.

The mean of 8 runs with the mini-texture meter carried out over *Surphalt* on the A614 at Salterford Crossroads was 1.13 mm from a range of 1.09 to 1.19 mm compared to 2.8 mm by sand-patch (Table 8), giving an estimate of the ratio between sand-patch and sensor-measured texture

Table 9 Sand-patch texture depth on A590, Barrow-in-Furness

	HRA		*Stone Mastic Asphalt*							
	Diagonally		*Diagonally*				*Wheel-Track*			
	Northbound	*Southbound*	*Northbound*		*Southbound*		*Northbound*		*Southbound*	
Survey date			*1*	*2*	*1*	*2*	*1*	*2*	*1*	*2*
06/12/95	1.54	1.86	1.09	1.17	1.21	1.19	1.16	1.27	1.23	1.39
21/06/96	1.49	1.79	1.19	1.13	1.25	1.16	1.37	1.22	1.38	1.32
08/08/96	1.52	2.04	1.16	1.16	1.07	1.07	1.41	1.25	1.16	1.16
20/09/96	1.57	2.16	1.23	1.19	1.15	1.17	1.43	1.26	1.17	1.35
01/10/97	1.51	1.83	1.02	1.03	1.03	1.09	1.19	1.17	1.18	1.32

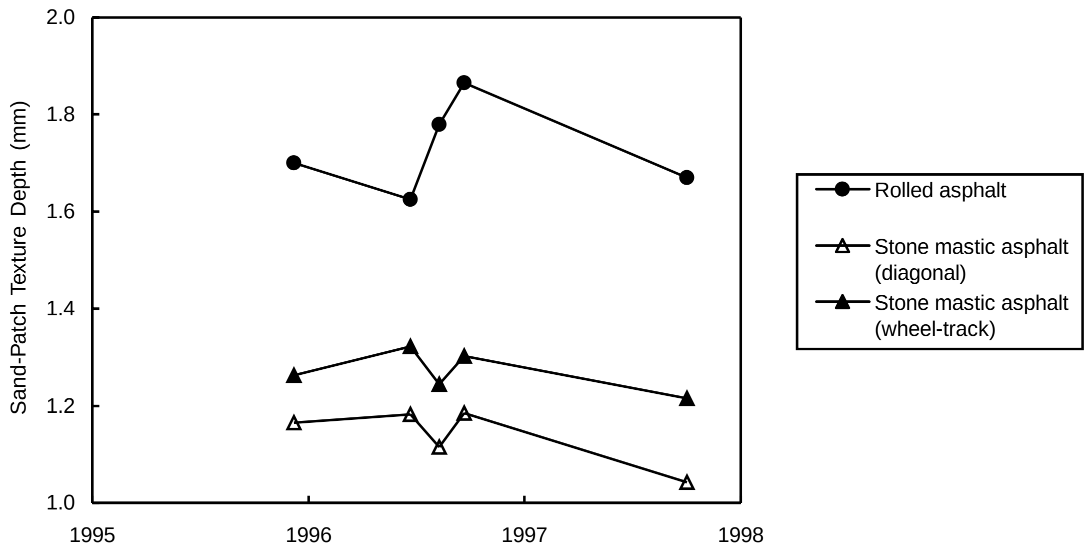

Figure 10 Change in sand-patch texture depths on A590 at Barrow-in-Furness

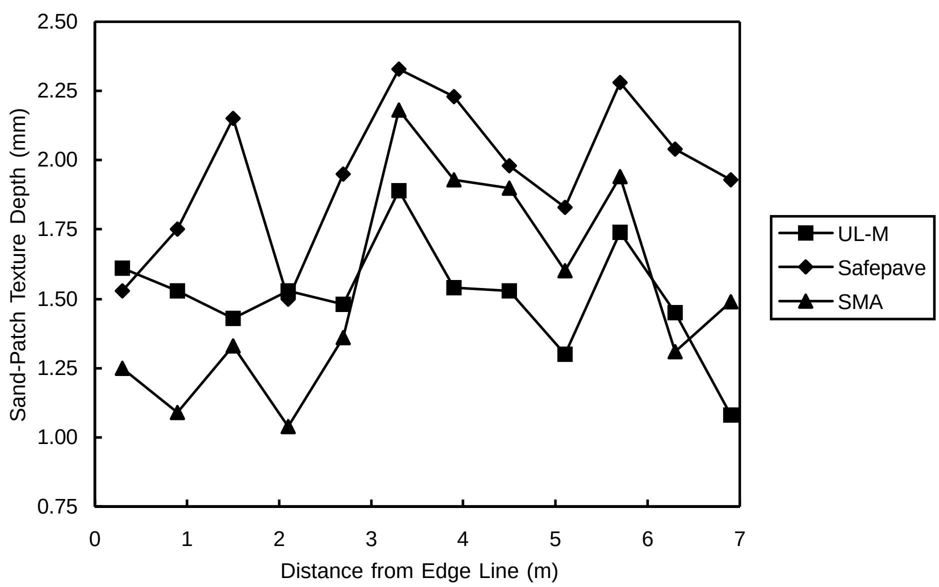

Figure 11 Texture profiles on A1, Eaton Socon after 1 year of trafficking

depth of 2.5 for this material.

The SMTD was measured by TRL at the same time as SCRIM with the equipment mounted on the SCRIM so that it is capable of making the measurements at normal traffic speeds. The results, including those already reported (Nicholls et al, 1995), are given in Table 10.

The mean results from the A47 at Thorney, the A1033 at Hull and the A34 at Stafford are also shown graphically in Figure 12, 13 and 14, respectively.

4.4 Visual condition

The visual condition of the various sites were assessed by an Inspection Panel using a standardised methodology (Nicholls, 1997b) with a marking scheme giving a basic assessment classification with fault suffixes as applicable; the possible markings for thin surfacings are reproduced in Appendix C. The results, including those already reported (Nicholls et al, 1995) for continuity, are given in Table 11.

The results from the A47 at Thorney, the A1033 at Hull and the A34 at Stafford are also shown graphically in Figure 15, 16 and 17, respectively.

4.5 Structural properties

Cores were taken from three locations on the A10 at Littleport, one where the SMA was made with 100 pen bitumen and two where it was made with 50 pen bitumen. Cores were also taken from two locations on the A1 at Eaton Socon, one each from the north- and southbound carriageways with SMA. The cores were tested for wheel-tracking rate to DD 184 (BSI, 1990b), indirect tensile stiffness modulus to DD 213 (BSI, 1993), creep stiffness to DD 185 (BSI, 1990c), density and voids content. The results of individual determinations (as opposed to the mean values required in the respective test methods) are given in Table 12.

Cores of 100 mm diameter were taken from the A140 at Creeting Bottoms for analysis by the indirect tensile fatigue test using the Nottingham Asphalt Tester in accordance with the Link Bitutest protocol. The results are shown in Figure 18 as a logarithmic plot of the maximum tensile strain generated at the centre of the specimen and the number of cycles to crack initiation. However, this test is normally limited to cores with a minimum thickness of 30 mm whereas these cores varied between 25 mm and 30 mm. The regression analysis on the results gives Equation 1.

$$Log_{10}(\mathrm{N}) = -\,2.56\mathrm{x}Log_{10}(E_{x,max}) + 9.78 \qquad (1)$$

where $E_{x,max}$ is the maximum tensile strain generated at the centre of the specimen; and

N is the number of cycles to crack initiation.

Hence, the life of SMA to crack initiation, based on the material laid on the A140, is 45,700 cycles with a maximum tensile strain generated at the centre of the specimen of 100 microstrain.

4.6 Noise

The maximum vehicle noise levels were measured on various thin surfacings that were claimed to be ‘low noise surfacings’ by the suppliers at road trial sites, including those being studied here. The noise was measured using the statistical pass-by method (Franklin et al, 1979) at 7.5 m from the centre of the test lane and normalised to that at a vehicle speed of 90 km/h. The results, including those reported previously (Nicholls et al, 1995), are given in Table 13 together with results for two other sites with UL-M in Norfolk, the A140 at Aylsham and the A148 at Holt. In addition, for the three surfacings laid on the A1 in 1995, the noise frequency spectra measured at 90 km/h are shown in Figure 19.

During the noise survey for *Surphalt* on the A614 trial, an insufficient number of noise measurements could be made from heavy goods vehicles because very few passed the measurement point during the survey.

4.7 Spray generation

To investigate the extent to which these materials are porous, as is sometimes claimed, the relative hydraulic conductivity was measured on each material on the A1 at Eaton Socon prior to trafficking. The results are given in Table 14.

5 Discussion

5.1 Laying Stone Mastic Asphalt

Thin SMA has been shown to be capable of being laid with a generally good appearance and good texture. Reduction in laid thickness by compaction under rollers is limited to only about 3 mm, the rolling appearing to re-orientate the aggregate matrix and smooth the surface rather than reducing the volume of, that is compacting, the material. This mechanism would be expected for a successful thin surfacing given the relatively rapid cooling of such layers.

The potential problems with the material that have been identified are:

- longitudinal joints may be rather open because SMA is difficult to cut back for day and other joints;
- the material may drag if a load is too cold or if additional quantities of SMA are applied by hand prior to rolling; and
- the material is difficult to hand lay.

These problems are considered to be due to the ‘stickiness’ of SMA, with its high binder content, making it difficult to work while the thin layers encourage relatively rapid cooling. Nevertheless, they can be overcome by appropriate planning, to avoid cold loads and the need for hand laying, and a high standard of workmanship, primarily by the use of operatives experienced in laying the material.

Those involved with the construction considered that SMA was quicker and easier to lay than rolled asphalt because chippings are not required. Consequently, there were none of the access problems for feeding the chip-spreader.

Table 10 Sensor-measured texture depths

			Annual mean SMTD (mm)						
Site	*Location*	*Material*	*1991*	*1992*	*1993*	*1994*	*1995*	*1996*	*1997*
A47, Thorney	Eastbound	Surface dress	1.84	1.25	1.08	0.84	0.73	0.59	0.52
		Safepave	1.11	0.73	0.66	0.73	0.63	0.72	0.73
		HRA	-	1.33	1.18	1.19	1.18	1.29	1.32
	Westbound	Surface dress	1.68	0.93	0.81	0.48	0.38	0.30	0.30
		Safepave	1.06	0.80	0.77	0.90	0.84	0.91	1.01
		HRA	-	1.28	1.13	1.13	1.10	1.25	1.24
A1033, Hull	Eastbound nearside lane	Microsurfacing	-	-	0.37	0.38	0.36	0.48	0.42
		Safepave	-	-	0.91	0.87	0.85	0.75	0.97
		HRA*	-	-	0.48	-	-	-	-
		Micro'ing	-	-	-	0.49	0.63	0.66	0.55
	Eastbound offside lane	Microsurfacing	-	-	0.55	0.51	-	-	-
		Safepave	-	-	1.07	1.02	-	-	-
		HRA*	-	-	0.65	0.63	-	-	-
	Westbound offside lane	Microsurfacing	-	-	0.61	0.61	-	-	-
		Safepave	-	-	1.05	1.02	-	-	-
		HRA*	-	-	0.48	0.76	-	-	-
	Westbound nearside lane	Microsurfacing	-	-	0.39	0.45	0.41	0.54	0.80
		Safepave	-	-	0.87	0.87	0.92	0.78	0.78
		HRA*	-	-	0.49	-	-	-	-
		Micro'ing	-	-	-	0.62	0.55	0.66	0.63
A34, Stafford	Southbound	*Safepave*	-	-	0.95	0.72	1.01	0.96	1.03
	Northbound	*UL-M*	-	-	0.90	0.66	0.81	0.74	0.77
A140, Creeting Bottoms	Northbound	SMA	-	-	-	-	1.02	0.74	0.86
		*Shellgrip**	-	-	-	-	0.70	0.63	0.78
		HRA	-	-	-	-	1.27	0.92	1.06
	Southbound	SMA	-	-	-	-	1.09	0.77	0.74
		*Shellgrip**	-	-	-	-	0.65	0.58	0.57
		HRA	-	-	-	-	1.35	1.00	0.99
A10, Littleport	Northbound	HRA	-	-	-	-	1.14	1.15	1.11
		SMA	-	-	-	-	1.02	0.98	0.94
		SMA + grit	-	-	-	-	0.86	0.52	0.45
		SMA	-	-	-	-	1.03	1.03	1.02
		HRA*	-	-	-	-	1.07	1.02	1.04
		SMA	-	-	-	-	1.08	1.06	1.05
	Southbound	HRA	-	-	-	-	1.16	1.16	-
		100 pen SMA	-	-	-	-	1.05	1.02	0.98
		SMA	-	-	-	-	1.07	0.97	0.92
		SMA + grit	-	-	-	-	0.64	0.46	0.41
		SMA	-	-	-	-	1.10	0.98	0.97
		HRA*	-	-	-	-	1.24	1.19	1.20
		SMA	-	-	-	-	1.11	1.00	0.98
A1, Eaton Socon	Northbound	*UL-M*	-	-	-	-	0.78	0.66	0.56
		Safepave	-	-	-	-	0.86	0.83	0.69
		SMA	-	-	-	-	0.85	0.84	0.73
	Southbound	*UL-M*	-	-	-	-	0.77	0.65	0.72
		*Safepave**	0.74	0.77	0.69	0.76	0.78	0.73	0.60
		UL-M	-	-	-	-	0.71	0.55	0.45†
		Safepave	-	-	-	-	0.88	0.76	0.57
		SMA	-	-	-	-	0.88	0.79	0.49†
A614, Creeting Bottoms	Northbound	*Surphalt* day 1	-	-	-	-	1.12	0.94	1.00
		Surphalt day 2	-	-	-	-	1.35	1.32	0.92
		HRA*	-	-	-	-	-	-	1.06
	Southbound	*Surphalt* day 1	-	-	-	-	1.14	1.05	0.81
		Surphalt day 2	-	-	-	-	1.63	1.14	0.92
		HRA*	-	-	-	-	-	-	1.20

**Existing materials used as partial controls*
†Apparently anomalous result

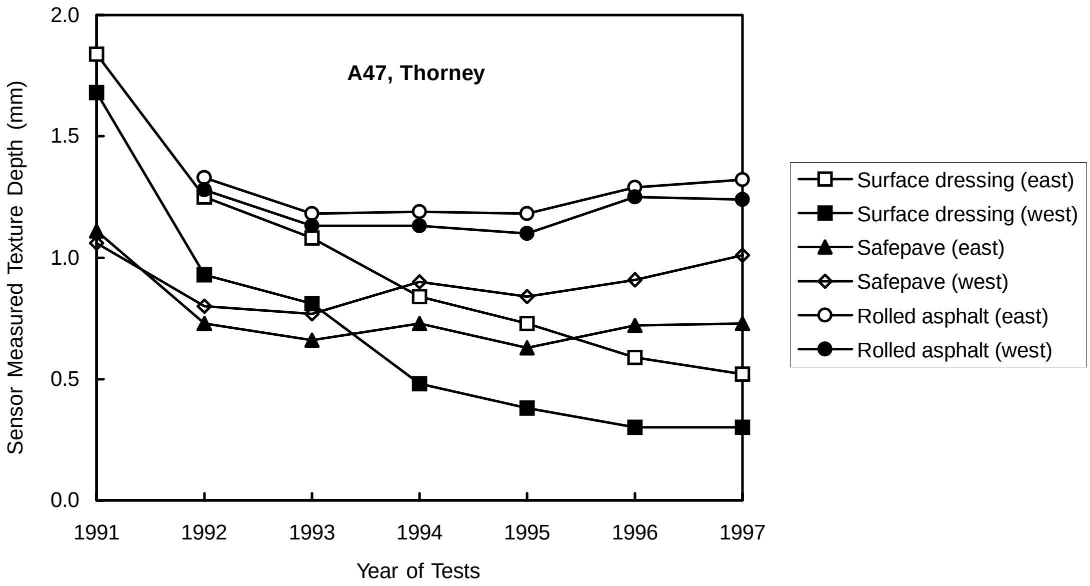

Figure 12 SMTD on A47, Thorney

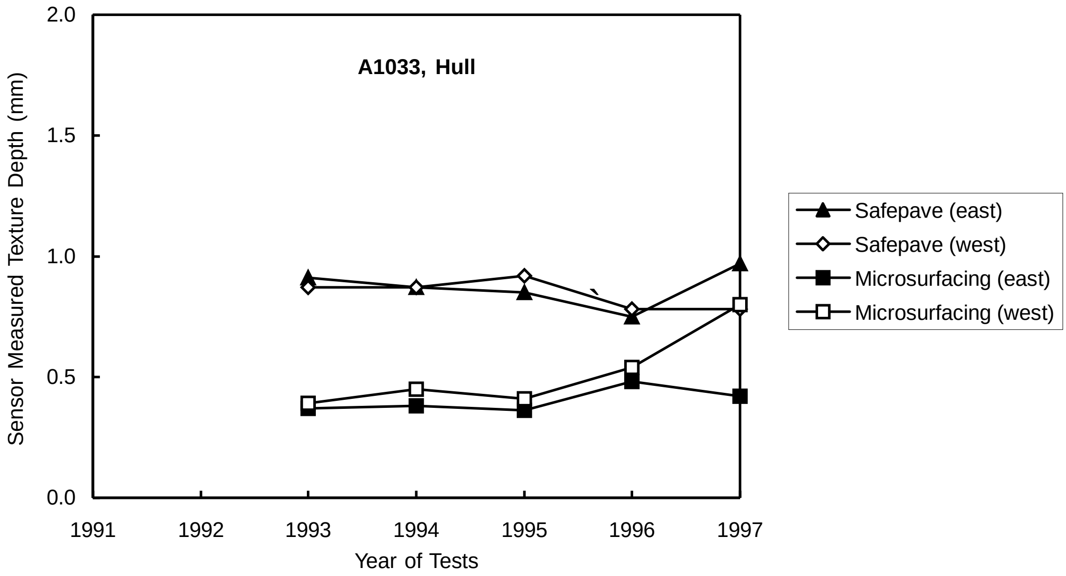

Figure 13 SMTD on A1033, Hull

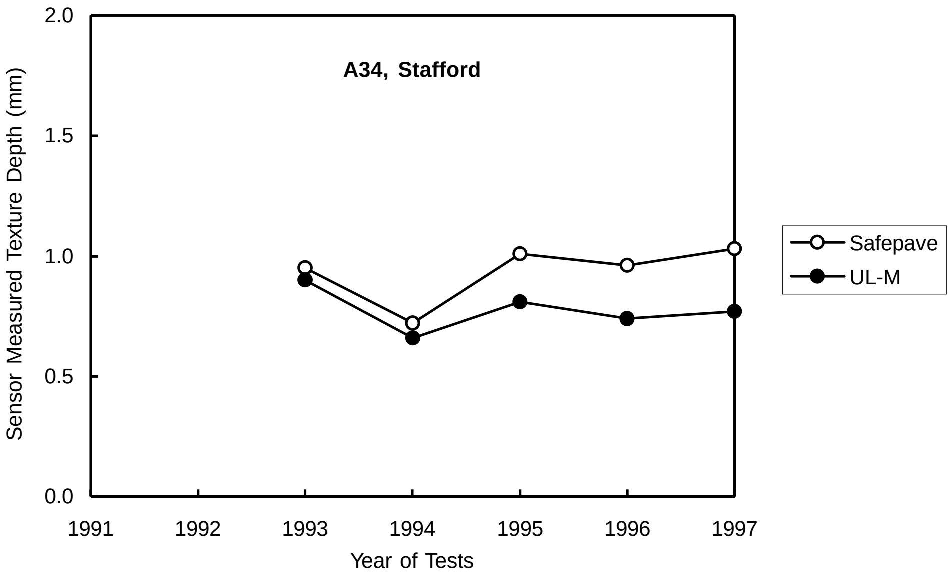

Figure 14 SMTD on A34, Stafford

Table 11 Visual assessments by inspection panel

Site	*Location*	*Material*	*Date of inspection* 1992	1993	1994	1995	1996	1997
A47, Thorney	Eastbound	Surface dressing	S_t	G/M	G	S/P_+	$A_{t,+}$	$M/A_{+,v}$
		Safepave	E/G	E/G	G	M	G/M	M
		Safepave	E/G	G	G	G/M_-	M_-	M_-
		HRA	E	E/G	E	G	G	G
	Westbound	Surface dressing	A	M/A_+	M/A_+	$S/P_{t,+}$	$A_{t,+}$	$A_{+,v}$
		Safepave	E/G	G/M	G	G/M	G/M_-	M_-
		Safepave	E	E	*	*	*	*
		HRA	E/G	E/G	E/G	G	G	G
A1033, Hull	Eastbound	Microsurfacing	M/A	M_f	$S_{-,v,s}$	$M_{v,c}$	M_v	M/A_v
		Safepave	G	M_v	A_-	$M_{v,c}$	M/A_v	$S_{c,v}$
	Westbound	Microsurfacing	-	-	$M/A_{-,v}$	$A/S_{s,v,c}$	M_v	$S_{t,d,-}$
		Safepave	-	M_v	M_v	$M/A_{v,c}$	$A_{t,-}$	$S_{c,v,d}$
A34, Stafford	Southbound	*Safepave*	-	G	E#	G	G	$M_{v,-}$
	Northbound	*UL-M*	-	E	E/G	G	G/M	$M_{v,-}$
A140, Creeting Bottoms	Both lanes	SMA	-	-	-	E/G	E	E
		HRA	-	-	-	E/G	G	E/G
A10, Littleport	South end, southbound	HRA	-	-	-	E	E	E
		100 pen SMA	-	-	-	G	G	G
	South end, northbound	SMA	-	-	-	E/G	E/G	E/G
		HRA	-	-	-	E/G	E	E
	Roundabout, southbound	SMA + grit	-	-	-	G/M	G/M_t	E/G
		SMA	-	-	-	G	G/M_t	G
	Roundabout	SMA	-	-	-	G	E/G	G
	Roundabout, northbound	SMA + grit	-	-	-	G	$G_{t,+}$	E/G
		SMA	-	-	-	G/M	G_t	G
A1, Eaton Socon	Northbound	*UL-M*	-	-	-	G	E/G	G
		UL-M	-	-	-	G/M	G	$M_{v,c}$
		Safepave	-	-	-	E/G	E/G	G
		Safepave	-	-	-	E/G	G	G
		SMA	-	-	-	G/M_t	G/M_t	G
		SMA	-	-	-	G/M_t	$G/M_{t,+}$	G
A614, Salterford Crossroads	Northbound	*Surphalt* day 1	-	-	-	-	$M/A_{v,-}$	$M/A_{v,-}$
		Surphalt day 2	-	-	-	-	G	G
		Surface dressing	-	-	-	-	-	G/M
	Southbound	*Surphalt* day 1	-	-	-	-	G	$A_{v,-}$
		Surphalt day 2	-	-	-	-	G	G
		Surface dressing	-	-	-	-	-	$M_{v,-}$

**lane replaced due to failure of underlying pavement*
#Marking on replaced section
-Trial not laid or no assessment made
Key to marking scheme given in Appendix C

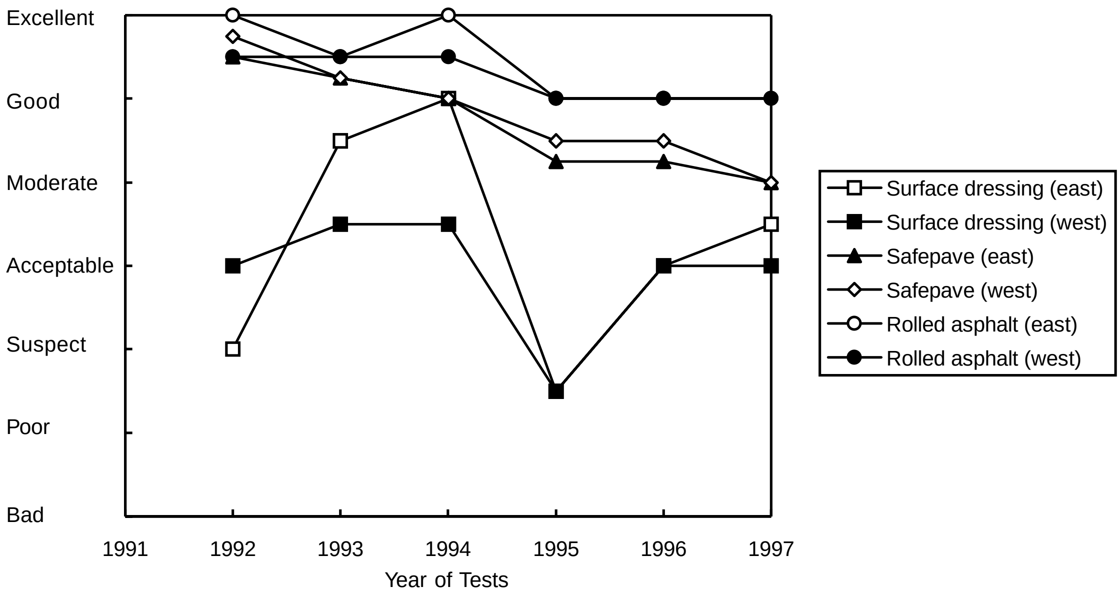

Figure 15 Visual condition on A47, Thorney

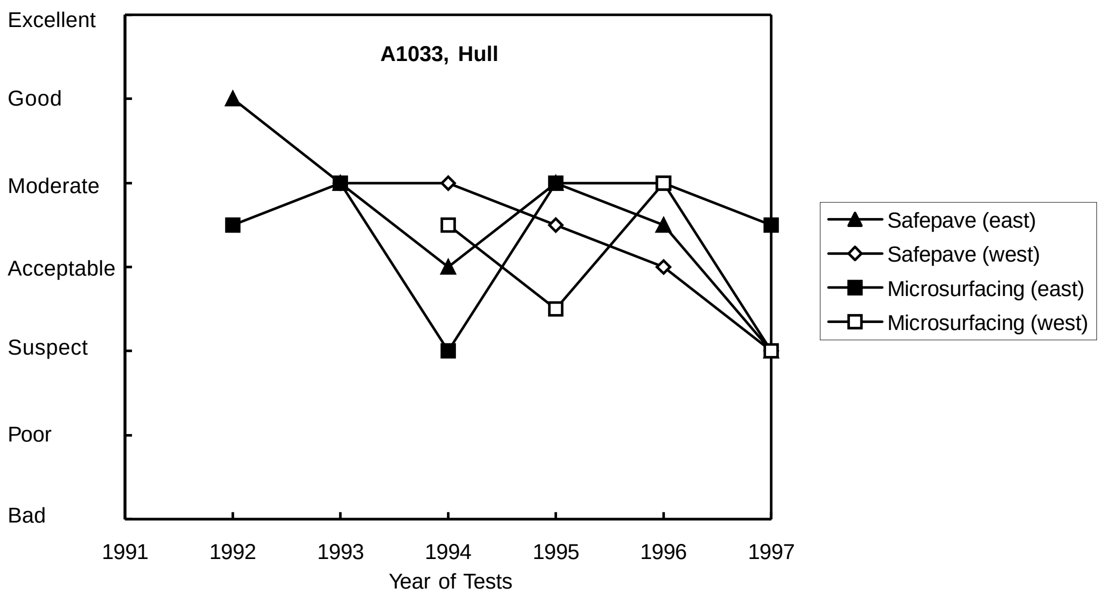

Figure 16 Visual condition on A1033, Hull

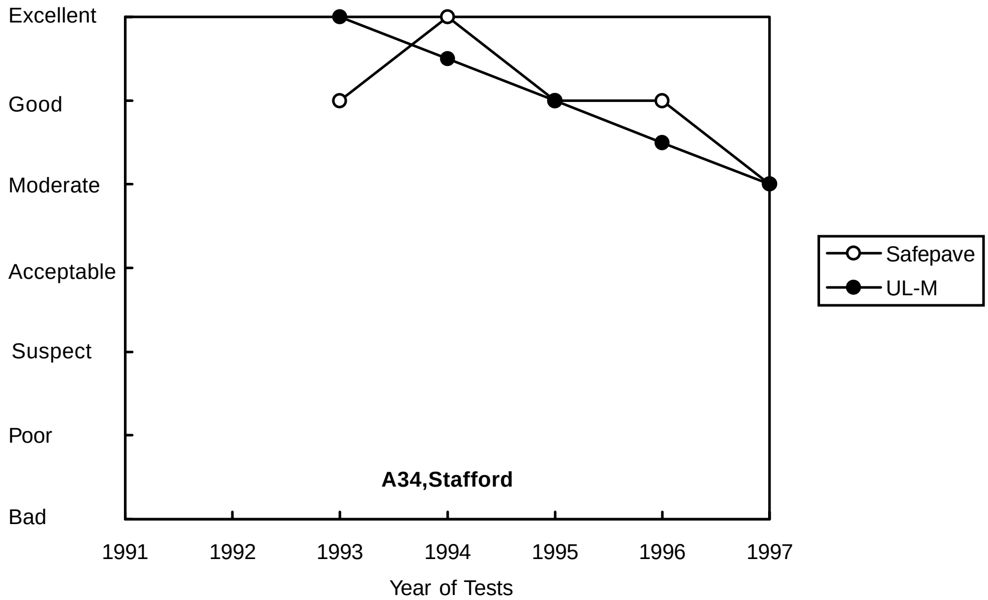

Figure 17 Visual condition on A34, Stafford

Table 12 Tests on cores taken from A10, Littleport and A1, Eaton Socon

Site	*Location or lane*	*Material*	*Mean density (kg/m³)*	*Theoretical max. density (kg/m³)*	*Air voids content (per cent)*
A10, Littleport	Spot 1	100 pen SMA	2286	2352	2.8
	Spot 2	50 pen SMA	2259	2392	5.6
A1, Eaton Socon	Eastbound	SMA	2359	2505	5.8
	Westbound	SMA	2325	2486	6.5
	Combined	*Safepave*	2361	2535	6.9
	Combined	*UL-M*	2315	2427	4.6

Site	*Location or lane*	*Material*	*(RLIT) Elastic modulus (GPa)*	*(RLAT) Creep stiffness* (MPa)*	*Wheel-tracking @ 45°C Rate (mm/h)*	*Wheel-tracking @ 45°C Rut depth (mm)*
A10, Littleport	Spot 1	100 pen SMA	1.66	7.0	1.1†	1.3†
	Spot 2	50 pen SMA	2.03	5.9	0.4†	1.0†
	Spot 3	50 pen SMA	2.28	6.2	-	-
A1, Eaton Socon	Eastbound	SMA	2.02	8.4	0.6	1.4
		Safepave	-	-	1.0	1.2
		UL-M	-	-	0.13	0.8
A1, Eaton Socon	Westbound	SMA	1.69	5.6	1.2	1.0
		Safepave	-	-	0.9	0.7
		UL-M	-	-	3.1	2.3

**After 1800 pulses with axial test stress of 100 kPa*
†Based on testing 2 cores only

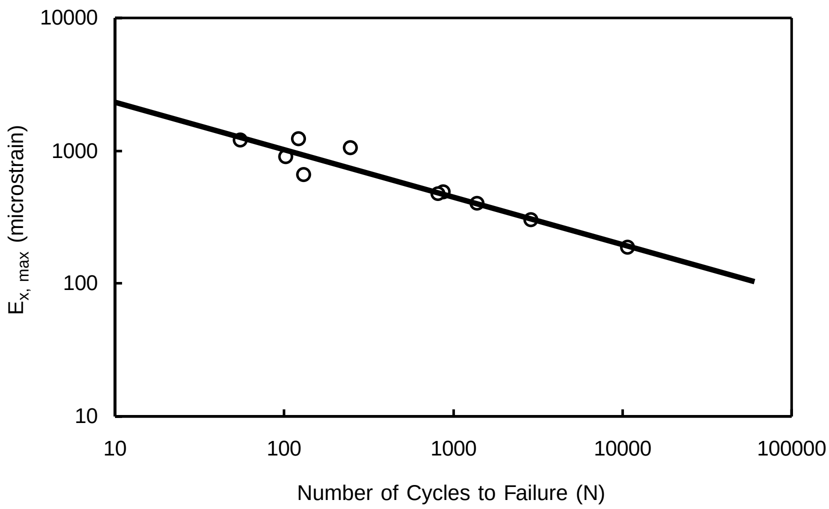

Figure 18 Fatigue plot for SMA from A140 at Creeting Bottoms

Table 13 Noise-reducing properties of thin surfacings

Site	Surface type	Survey date	Age (months)	*Vehicle category* Light	Heavy
A47, Thorney, Cambridgeshire	10 mm *Safepave*	12/91	3	79.8 dB(A)	85.5 dB(A)
	Rolled asphalt	9/91	not known	81.0 dB(A)	85.5 dB(A)
A1, Eaton Socon, Cambridgeshire	10 mm *Safepave*	12/91	3	81.1 dB(A)	85.1 dB(A)
	10 mm *Safepave*	12/91	3	81.8 dB(A)	86.2 dB(A)
	Brushed concrete	12/91	not known	82.9 dB(A)	87.9 dB(A)
	14 mm SMA	10/95	5	78.3 dB(A)	85.2 dB(A)
	10 mm *UL-M*	10/95	5	78.5 dB(A)	-
	14 mm *Safepave*	10/95	5	79.9 dB(A)	85.4 dB(A)
	10 mm *UL-M*	10/95	5	77.6 dB(A)	84.1 dB(A)
A140, Creeting Bottoms, Suffolk	14 mm SMA	5/95	2	75.2 dB(A)*	84.3 dB(A)*
A10, Littleport, Cambridgeshire	14 mm SMA	7/95	0	76.4 dB(A)	83.1 dB(A)
	Rolled asphalt	7/95	0	83.2 dB(A)	89.0 dB(A)
A140, Aylsham, Norfolk	10 mm *UL-M*	not known		79.2 dB(A)	85.0 dB(A)
A148, Holt, Norfolk	10 mm *UL-M*	not known		76.3 dB(A)	85.1 dB(A)
A614, Salterford Crossroads Nottinghamshire	*Surphalt*	2/96	5	82.0 dB(A)	-

**The levels measured at Creeting Bottoms should be treated with care as the site does not fulfil all the acoustical requirements for a standard vehicle noise measurement due to intervening soft ground.*

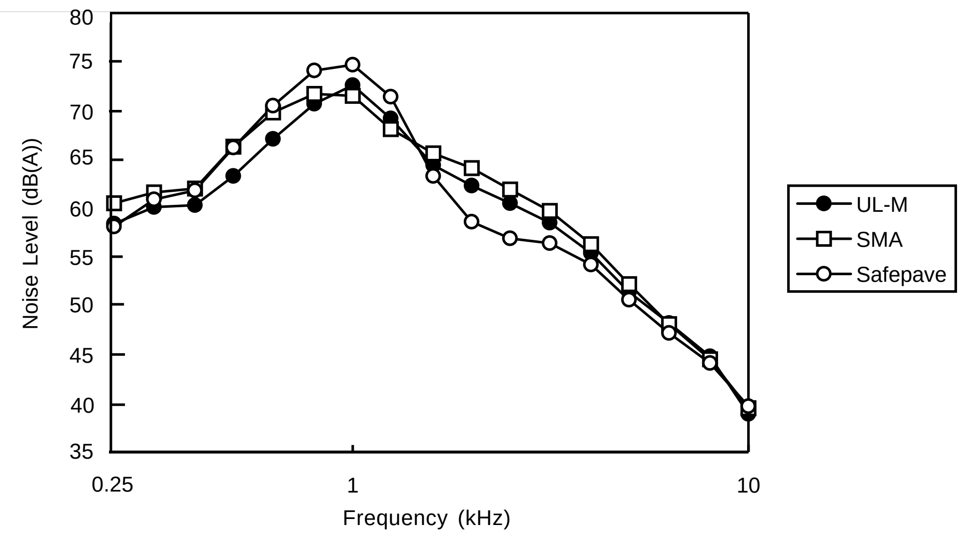

Figure 19 Frequency spectra of noise on A1 surfacings

Table 14 Relative hydraulic conductivity on A1, Eaton Socon

Material	*Northbound* Mean	Range	*Southbound* Mean	Range
14 mm SMA	0.03 s^{-1}	0.00-0.09 s^{-1}	0.03 s^{-1}	0.01-0.04 s^{-1}
14 mm *Safepave*	0.07 s^{-1}	0.02-0.12 s^{-1}	0.07 s^{-1}	0.05-0.09 s^{-1}
10 mm *UL-M*	0.01 s^{-1}	0.00-0.02 s^{-1}	0.01 s^{-1}	0.00-0.03 s^{-1}

Furthermore, the number of operatives needed to lay SMA is less than required for rolled asphalt. If the material proves durable, it is considered capable of competing effectively with rolled asphalt wearing course on many jobs on a cost effective basis.

Both the advantages and disadvantages of laying SMA are also applicable to other thin asphalt surfacings to a greater or lesser extent.

5.2 Skid-resistance

5.2.1 Initial skid-resistance

5.2.1.1 General

There are concerns that surfacings with relatively thick binder films, which occur with thin surfacings, SMA and porous asphalt, will have low skid-resistance in the period after opening until the binder is worn away by the traffic. The SCRIM data on the newly laid materials at Littleport and Eaton Socon (Table 4) gathered by W S Atkins in July, TRL in August (reported as MSSC in Table 4) and W S Atkins in September can be used to study the probity of this phenomena.

5.2.1.2 A10, Littleport

There was little difference between the results from the two SCRIM runs over three of the four sections of existing rolled asphalt measured (0.02 and 0.11 increases northbound, 0.03 and 0.4 southbound), indicating that any changes on the trial sections can be regarded as a good indication of the actual performance despite the normal variability in readings with season. This allows a direct comparison to identify changes that occurred to the skid-resistance of different sections between 3 to 5½ weeks in service and 14 to 16½ weeks in service. All the July SCRIM coefficients, including those measured on the existing rolled asphalt, were less than the Investigatory Skid-Resistance Level of MSSC for the site of 0.40 generally and 0.45 approaching the roundabout, as were all but one of the ungritted SMA sections and the southbound rolled asphalt for the August readings. By September, it was only the existing rolled asphalt that was below the Investigatory level.

The value for the new section of rolled asphalt increased from an average of 0.36 to 0.46 whilst the ungritted SMA with 50 pen bitumen started only marginally lower with a mean of 0.33 but rose further with trafficking to 0.48; with gritting, the change was from the same value as rolled asphalt of 0.36 to about the same as the ungritted SMA with 0.49. The smaller increase for the rolled asphalt does indicate that the SMA may have a ‘depressed’ value due to the thicker binder film until between one to three months on roads with the traffic levels comparable with the A10. However, it should be borne in mind that there was a considerably longer length of ungritted SMA than either new rolled asphalt or gritted SMA, so that there is more assurance that the mean value of the former represents that of the theoretical population of the ungritted SMA than the means of the latter two represent the theoretical population of the rolled asphalt or of the gritted SMA respectively.

5.2.1.3 A1, Eaton Socon

The existing *Safepave* and rolled asphalts provide similar controls, again demonstrating only minor changes in SCRIM values between the two dates with means of 0.42 and 0.44 for the rolled asphalt and 0.55 and 0.57 for the *Safepave*. However, in the northbound nearside lane, a visible binder film was observed on the existing rolled asphalt immediately north of the final SMA section which was assumed to have been carried over from the SMA on vehicle tyres. The binder film was quite prominent for several weeks after opening to traffic and could have affected the SCRIM results; visually, it was finally worn away between the July and September SCRIM runs.

Of the newly laid materials, all were within 0.01 of the Investigatory Skid-Resistance Level of MSSC for the site of 0.35. The average SCRIM coefficient for SMA increased from 0.34 to 0.46, that for *Safepave* increased from 0.38 to 0.55 and that for *UL-M* increased from 0.39 to 0.53 from an initial 2 to 3½ weeks trafficking to 10½ to 12 weeks trafficking. Therefore, all the materials initially had lower SCRIM values than the existing rolled asphalt, with the SMA having the lowest. After the additional trafficking, the SMA was marginally better than the rolled asphalt whilst the proprietary thin surfacings were nearly up to the value of the older *Safepave*. These comparative changes indicate that the phenomena of low early skid-resistance is real for all thin surfacings and not just SMA. The concern about this phenomena, and the need to implement additional safety measures during the early life of such surfacings, must be tempered by the fact that it also occurs, to a lesser extent, on rolled asphalt where additional measures have not been found to be necessary on a routine basis.

The time taken to remove the excess binder is dependent on the traffic level, as demonstrated by the difference between the changes in SCRIM coefficients on the two lanes of the A1 at Eaton Socon. The difference for the two lanes between the mean change from the results for July to those in September was 0.02 greater in the nearside lane than the offside lane for the new *Safepave* and 0.04 for both the SMA and *UL-M*. Whilst these differences are not that great, they do show a consistent pattern.

5.2.1.4 Summary

For SMAs and other thin surfacings, there is more of an excess binder film on the surface which has to be worn away by traffic than on ‘traditional’ surfacings such as rolled asphalt with pre-coated chippings. This abrasion occurs relatively quickly to produce satisfactory SCRIM coefficients but, in the early life of these surfacings, there is an increased risk of skidding until sufficient of that binder film is removed. The implications of this low early-life skid-resistance will depend on the Investigatory Skid-Resistance Level of MSSC for the site and the initial SCRIM coefficient of the material.

5.2.2 Use of grit

The use of grit on the A10 did enhance the early life skid-resistance although, as expected, this enhancement was not maintained. An initial improvement of about 0.04 in the SCRIM coefficient (0.37 with grit, 0.33 without after one month) had effectively gone after 3 months (0.49 average both with or without grit). Therefore, the use of grit is effective in the very short-term where there are concerns about the early life skid-resistance of SMA (or other thin surfacing) until the binder film at the surface has worn away to expose the coarse aggregate. However, the texture depth readings indicate that the application of grit may have a detrimental effect on the texture, significantly reducing the longer-term texture depth. Nevertheless, those results may be biased because the gritted SMA results were all close to the roundabout whereas that area, which had visibly lower texture depth, represented only a proportion of the ungritted SMA.

5.2.3 In-service skid-resistance

The in-service skid-resistance is primarily dependent on the polished stone value of the aggregate, the traffic flow and the severity of the site. Nevertheless, the results do confirm that SMA and the other thin surfacing can produce the appropriate skid-resistance and do not ‘mask’ the potential of the aggregates.

5.2.4 High-speed skid-resistance

The high-speed skid-resistance found on three thin surfacing types laid on the A1 were similar, both to each other and with conventional rolled asphalt at other sites. Therefore, although further data is required to confirm these initial findings, it can be assumed that thin surfacing can provide satisfactory high-speed skid-resistance.

5.3 Texture depth

5.3.1 Relevance of texture depth methods

The use of the sand-patch method to measure texture depth can give inconsistent results on ‘negative texture’ materials, particularly those designed for drainage purposes such as porous asphalt and, to a lesser extent, *Safepave* and some of the other thin surfacings. The inconsistency results from the amount of sand which penetrates into the voids, which will depend on the size of the surface voids and the rate at which the sand is spread into the circle.

Sensor-measured texture depths are sometimes low on a newly laid asphalt surface because of the binder film on the aggregate. This dark layer can absorb a significant proportion of the laser pulses emitted from the texture meter and, as most of the binder is retained within the negative texture in these materials, the measured SMTD can be below that expected for the actual geometry of the surface. The laser pulses that are not received back by the sensor are known as ‘dropouts’ and the proportion of dropouts are generally high for newly laid asphalt. Dropouts can also occur due to dampness of the road surface and, on negative texture surfaces, due to laser pulses being ‘trapped’ in the voids so as not to be detected.

Therefore, neither method of measuring texture depth is ideal for negative textured materials such as thin surfacings and SMA. Nevertheless, they are the best quantitative measures available at present.

5.3.2 Initial texture depth

All the thin surfacings were found to be capable of complying with the requirement for high-speed trunk roads and motorways of an initial texture depth by the sand-patch method of a mean over a kilometre of not less than 1.5 mm and no individual test (the mean of 10 determinations) being less than 1.2 mm. The thin surfacings with 14 mm nominal aggregate, including SMA, had no problem complying with the requirement whilst the materials with 10 mm nominal aggregate were capable of complying with the requirement, but did not always do so. In particular, on the A1 at Eaton Socon, the initial texture depth results for the SMA and *Safepave* complied with the current requirement for high-speed trunk roads and motorways whilst those for the *UL-M*, with its smaller nominal aggregate size, complied on the northbound carriageway but did not on the southbound carriageway. The reason for this difference between the *UL-M* supplied for the two carriageways is not known, but it does demonstrate that:

- it is possible for thin surfacings using 10 mm aggregate to meet the texture depth requirement for high-speed trunk roads and motorways; but
- care is needed with them to ensure that they do so.

5.3.3 Maintenance of texture depth

The results from the A590 at Barrow-in-Furness show that there was not very much loss of texture on that site, but the initial texture depth of SMA was not adequate for a high-speed trunk road. The results from the northbound carriageway of the A1 after 2 years in service showed that the texture had been reduced considerably with the SMA at about 70 per cent of its initial value, the *UL-M* at 65 per cent and the *Safepave* at 55 per cent. However, the texture was still in excess of the minimum initial requirement for both SMA and *Safepave* whilst the *UL-M*, which had started from a lower value, was above 1.0 mm.

After a year of trafficking, the visual appearance of the SMA on the A1 indicated a significant variation between the material in the wheel-tracks, which looked closed, and that around it, which looked more open. From the transverse profiles taken of the texture depth (Figure 11), both wheel-tracks in both lanes can be identified as having lower texture in the SMA whereas, for *Safepave* and *UL-M*, it is more difficult to identify the location of both wheel-tracks in each lane from their texture depth profiles. Furthermore, there is a more marked reduction in average texture depth between lane 1 and lane 2 for SMA than for the other two thin surfacings. From the appearance, it might be due to secondary compaction, although no quantifiable measurements have been made, or it may be due to poor design and the mortar flushing up to the surface (Section 5.3.4). It should also be borne in mind that the location of the measurements was under bridges, so that the materials would not be subject to quite the same climatic conditions as the majority of the trial surfacing.

The general pattern of sensor-measured texture depths from the early trials of hot-mix thin surfacings shows that the initial loss of texture, where it does occur, usually levels out after the first year or two.

5.3.4 Variation of texture with Stone Mastic Asphalt

If the general pattern of any initial loss of texture usually being completed after the first year or two is replicated for SMA, which looks to be the case, the material will have shown that it can retain an acceptable texture depth. However, the texture measurements are, of necessity, averaged and this can sometimes hide localised deficiencies. The localised loss of texture in the wheel-tracks that was observed in the vicinity of the roundabout on the A10 site at Littleport is not illustrated by the results in Table 10; the texture elsewhere appeared significantly more open in the wheel-tracks and generally uniform across the mat. The variation in texture depth is also demonstrated in the sand-patch texture depth across the mat found on the A1 at Eaton Socon (Figure 11).

The reason for the variability is ascribed to the design approach needed for SMA. The process of designing an SMA mixture is very much one of adjusting the grading to accommodate the required binder content (6.5 to 7.5 per cent) and voids content (3 to 5 per cent) rather than the more familiar process of adjusting the binder content to suit the aggregate grading (Loveday & Bellin, 1998). If the binder content is excessive or the aggregate unsuitable for that binder content, then the mortar tends to flush up in warm weather and 'smear' over the surface, particularly in areas with high traffic stresses.

5.3.5 Texture depth of microsurfacings

The results from the A1033, Hull, indicate that the sensor-measured texture depth of the microsurfacing laid in 1991 are very low at around 0.4 mm in the nearside lane throughout its service life. The exception is in 1997, when the SMTD result for the nearside westbound lane increased to 0.8 mm, the same level as the abutting *Safepave*, for no apparent reason. Unfortunately, no results of sand-patch texture depth are available from this site. The microsurfacing laid in 1993 appears to have significantly higher texture at about 0.6 mm. Nevertheless, the results demonstrate that microsurfacings do not consistently provide the texture depths required for high-speed trunk roads and motorways.

5.3.6 Relationship between sand-patch and sensor-measured texture depth

The relationship between sand-patch and sensor-measured texture depths are not necessarily the same as for 'conventional' rolled asphalt and surface dressings. From the results of sections with both sand-patch and SCRIM-mounted sensor-measured texture depth (Tables 8 and 10, respectively) determined around the same time, the approximate relationships (sand-patch texture depth divided by sensor-measured texture depth) were found to be as given in Table 15. However, there is some scatter in the values (as shown by *Surphalt*, which has a ratio of 2.1 here whilst it was 2.5 when calculated using MTM results in Section 4.3.2), so that the ratio could be influenced by other factors. One such factor is time, because the relationships will change with time if the 'shape' of the texture is modified with trafficking.

Table 15 Ratio of sand-patch to sensor-measured texture depths as found on trial sites

Material	*Roads from which data are taken*	*Relationship when surfacing is* New	*Relationship when surfacing is* 2 years old
Rolled asphalt	A1	1.4	-
14 mm *Safepave*	A1	2.9	2.6
10 mm *UL-M*	A1	1.8	1.5
14 mm SMA	A140, A10 & A1	2.2	2.5
Surphalt	A614	2.1	-

These values are only indicative and need to be validated by measurements from a wide selection of other sites to ascertain the extent to which they are universal and the extent to which they vary between suppliers, between sites and with time.

5.4 Visual condition and durability

The visual inspections of the thin surfacings show the gradual decline that is normally expected with time. The principal difference was with the microsurfacing section on the A1033 at Hull, which started poorly after one year in service with only a 'Moderate to Acceptable' but then varied around this value, presumably depending on the weather conditions which can affect the visual appearance, ending up (on the eastbound lanes) with the same marking after a further five years. However, these markings would have been lower if texture (or lack of it) was not ignored because it was being measured quantitatively in a separate operation (Section 4.3.2). Nevertheless, such microsurfacings do seem to have a visual appearance that belies their true potential durability, although they cannot be considered for high-speed trunk roads or motorways due to their low texture depths.

Of the earlier sites that have been trafficked for several years, the deterioration with time for *Safepave* on the A47 at Thorney was only marginally steeper than for the rolled asphalt while that of the *Safepave* and *UL-M* were very similar on the A34 at Stafford, although the *Safepave* did start a year later due to its being replaced. Therefore, the durability of the thin surfacings can be estimated as being only marginally less than that of the conventional rolled asphalt, although the actual durability of each material will only be known with any assurance after several documented sites have reached the end of their useful lives.

It may be noted that the visual condition rating of the surfacing dressing on the A47 varied considerably, but the dressing was not entirely satisfactory when laid and required repeated remedial measures which tended to improve the visual condition, at least temporarily. The poor initial workmanship and subsequent remedial measures reduced its value as a control material.

Of the later sites, they have not been in service long enough to give any clear indication of their longer-term durability. However, to date there are indications that SMA appears to have comparable durability to other types of surfacing.

5.5 Other aspects

5.5.1 Structural properties

5.5.1.1 Wheel-tracking rate

The wheel-tracking rate of all three materials is excellent, as would be expected for materials with good aggregate interlock which are laid relatively thinly. The results from the *UL-M* in the different carriageways on the A1 at Eaton Socon are very different, ranging from the least to the greatest values of the various thin surfacings. This variation could be due to the limited number of specimens tested relative to the six required for each test in accordance to BS 598: Part 110 (BSI, 1996), the successor to DD 184 (BSI, 1990b). Nevertheless, it is noteworthy that all results were well within the limit for 'moderate to heavily stressed sites requiring high rut resistance' in the performance-related clause for rolled asphalt that should soon be incorporated into the *Specification for Highway Works* as Clause 943.

5.5.1.2 Elastic modulus

Although not required for surfacing properties, the elastic modulus of thin surfacings can be important structurally. The limited results obtained indicate that SMA with 50 pen bitumen has a mean elastic modulus, when measured in accordance with DD 213 (BSI, 1993), of 2 GPa at 20°C which is similar to that of more conventional surfacing materials, with values for rolled asphalt varying between 0.9 GPa to 3.3 GPa in one limited survey.

5.5.1.3 Fatigue

The fatigue behaviour of SMA, as represented by the results of tests on samples from a single site, is 45,700 cycles to crack initiation with a maximum tensile strain of 100 microstrain generated at the centre of the specimen. This value is also similar to the lower range of that expected with rolled asphalt, where values between 40,000 and 200,000 cycles were found in a limited survey.

5.5.2 Noise

Based on the values in Table 13 and without any allowance for normalising the texture depth (and hence indirectly skid-resistance), a ranking order from the average values for these materials (excluding the results from the A140) can be derived as follows:

Rank-ing	*Material type*	*Light vehicles*	*Heavy vehicles*
1	14 mm Stone mastic asphalt	77.4 dB(A)	84.2 dB(A)
2	10 mm *UL-M*	78.3 dB(A)	84.7 dB(A)
3	14 mm *Safepave*	79.9 dB(A)	85.4 dB(A)
4	10 mm *Safepave*	80.9 dB(A)	86.3 dB(A)
5=	*Surphalt*	82.0 dB(A)	-
5=	Rolled asphalt	82.1 dB(A)	87.3 dB(A)
7	Brushed concrete	82.9 dB(A)	87.9 dB(A)

Hence, the limited data available (particularly as not all the measurements on rolled asphalt and brushed concrete were made on relatively new surfacings, as was the case for the other materials) indicate that, without consideration of whether they are as safe, these thin surfacings (other than *Surphalt*) are quieter than traditional rolled asphalt or brushed concrete, with SMA being the quietest of these materials. However, this ranking is based on very limited data in which there is considerable variation for those categories derived from two or more measurements.

5.5.3 Spray generation

The hydraulic conductivity results indicate that *Safepave* is the most porous of the three materials tested, with a performance that would not quite be satisfactory for a porous asphalt, whilst *UL-M* is the most impermeable and little different from rolled asphalt. The results for SMA were unexpected in that it is a binder-rich material which should be impermeable. Therefore, it is probable that part of the apparent permeability is due to seepage through the 'valleys' in the relatively high texture (significantly greater than the texture for the impermeable *UL-M*); this seepage has been noted previously (Nicholls et al, 1995).

5.6 Reflective cracking

The use of thin surfacings, including SMA, over jointed concrete can be considered because one of the major sites consisted of overlaying an old concrete wearing course. The reflective cracking was studied on the earlier trial on the A1 at Eaton Socon (Nicholls et al, 1995), but no explicit measurements were made to assess the impact of the transverse joints on the second trial. Nevertheless, the emergence of reflective cracking can be observed on the site.

The first trial of laying a thin surfacing, *Safepave*, over jointed concrete on the A1 at Eaton Socon indicated that the most effective solution for minimising reflective cracking at transverse joints appeared to be the technique of saw-cut and seal. However, the degree of success with this method relied on the accurate positioning of the sawn groove above the transverse joint in the concrete slabs. In the second trial at Eaton Socon over a longer length, this operation was carried out on the majority of joints, although some joints were left uncut. However, on this trial the saw-cut and seal technique was found to be inappropriate with secondary cracks appearing within a few centimetres of the saw-cut (Figure 20). Given that thin surfacings are not as thick as conventional wearing courses, there was insufficient weight to hold the sliver of asphalt on the road once any bond to the substrate and adjacent material was lost. The SMA appears to have the least damage, but this is probably due to its slightly greater thickness. Therefore, it may be prudent not to saw-cut thin surfacings until a reflective crack begins to emerge so that the saw-cut can be accurately positioned.

5.7 System assessment

To date, the introduction of these materials has been welcomed by design and maintenance engineers who have a requirement for thin wearing course materials, whether they are proprietary products, such as *Safepave*, *UL-M* and *Surphalt*, or generic SMA. Based on the results from these and other trials, the Highways Agency initially accepted *Safepave* and *UL-M* for use on trunk roads and motorways

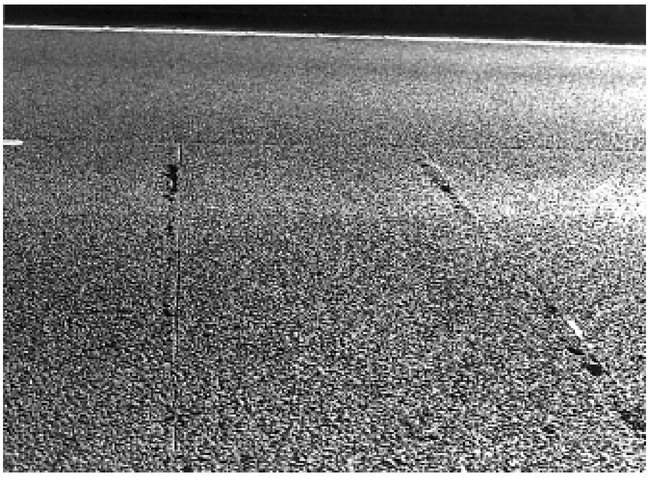

Figure 20 Loss of material between saw-cut and reflective crack

provided that they comply with the specification clause, with *Hitex* and *Masterpave* gaining approval later. However, there are many other proprietary materials that may also give an acceptable performance and many of the suppliers are getting their products assessed in order to demonstrate that they can also provide acceptable performance.

Currently, this assessment is carried out by the *Five-Stage Highways Agency Procedure for Evaluating New Materials* (Appendix D: Desk Study; Laboratory Study; Pilot-Scale Trials; Full-Scale Trials; and Specification Trials), which was devised to cover any new material or technique. At the time of writing, a scheme run by the British Board of Agrément, is being developed for the certification of specific groups of highway materials, including thin surfacings, under the title of the *Highway Authorities Products Approvals Scheme* (HAPAS). Nevertheless, until HAPAS is implemented for these products and some of the thin surfacing systems have received certificates under the scheme, the *Five-Stage Highways Agency Procedure for Evaluating New Materials* will need to be maintained.

6 Conclusions

The principal conclusions that can derived from the data collected are:

1 Stone mastic asphalt and multiple layer surface dressings can be laid successfully as textured thin wearing courses. However, it is premature to assess their long-term durability although the early performance is encouraging.

2 All the thin surfacing materials trialled can achieve the required levels of low-speed skid-resistance, as measured by SCRIM; however, the value is ultimately dependent on the traffic and the polished stone value of the aggregate used.

3 All the surfacings after first being opened to traffic exhibit SCRIM results which are lower than those attained a few weeks or months later, although these initial values can still be greater than the Investigatory Skid-Resistance levels; rolled asphalt with pre-coated chippings shows the same characteristic, but to a lesser extent.

4 The initial results indicate that the thin surfacings tested have high-speed skid-resistance similar to that of rolled asphalt.

5 All the thin surfacings trialled with 14 mm nominal size aggregate can achieve the initial texture depth requirement for high-speed trunk roads and motorways whilst, with 10 mm nominal sized aggregate, some systems need careful design in order to ensure that they can consistently achieve that level.

6 Generally, stone mastic asphalt can retain its texture depth as well as other thin surfacings. However, there are some indications of localised loss of texture, possibly due to flushing up of excess mortar and/or secondary compaction.

7 The relative hydraulic conductivity results indicate that *Safepave* could be regarded as being ‘semi-porous’, having the properties approaching those of porous asphalt. Of the other types of thin surfacing studied, *UL-M* is impermeable while thin stone mastic asphalt shows some permeability.

8 The results of noise measurements on these limited trials indicate that the thin surfacings, other than the one based on multiple surface dressing, are generally quieter than traditional rolled asphalt or brushed concrete surfaces; the multiple-surface dressing thin surfacing system generates similar noise levels to rolled asphalt.

9 If thin surfacings are laid directly onto jointed concrete, the saw-cut and seal technique for minimising reflective cracking is not recommended at the time of construction. Instead, it is recommended that the appearance of reflective cracks are awaited in order to be able to position the saw-cuts accurately at a later date.

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Appendix A: Highways Agency draft specification for Stone Mastic Asphalt

A.1 General

A.1.1 Stone mastic asphalt shall comply with the general requirements of BS 4987 for coated macadam, the Specification for Highways Works and the specific requirements of the following sub-clauses.

A.2 Materials

A.2.1 Aggregates and filler

A.2.1.1 Coarse aggregate shall be crushed rock or crushed slag complying with Clause 901.

A.2.1.2 When tested in accordance with the procedures of BS 812, the coarse aggregate shall additionally have the following properties:

Polished Stone Value - not less than 45, or as specified in Appendix 7/1.

Ten Per Cent Fines Value - not less than 180 kN when tested in a dry condition, or as specified in appendix 7/1.

Maximum Aggregate Abrasion Value - not more than 12, or as specified in Appendix 7/1.

Maximum Flakiness Index - for the coarse aggregate only, 30 per cent, or as specified in Appendix 7/1.

A.2.1.3 Fine aggregate shall comply with Clause 901 and shall comprise crushed rock, crushed slag or crushed gravel fines, which may be blended with not more than 50 per cent natural sand.

A.2.1.4 Added filler shall be hydrated lime, crushed limestone or Portland Cement, in accordance with the requirements of BS 594: Part 1 and shall be at least 2 per cent by mass of total aggregate.

A.2.2 Binder

A.2.2.1 Unless specified otherwise in Appendix 7/1, either a modified binder or, alternatively, bitumen with a stabilising additive, shall be used, at the choice of the Contractor. Modifiers include any material added to or blended with the base bitumen.

A.2.2.2 Bitumen shall comply with BS 3690: Part 1 and shall have a nominal penetration of 50 or 100, unless specified otherwise in Appendix 7/1.

A.2.2.3 If a modified binder is used, the base bitumen, before modification, shall comply with BS 3690: Part 1, and shall have a nominal penetration of 50 or 100, or 200, unless specified otherwise in Appendix 7/1.

A.2.2.4 The choice of bitumen grade or type of modified binder shall be notified to the Engineer before the commencement of work.

A.2.3 Stabilising additive or modified binders

A.2.3.1 When bitumen complying with BS 3690: Part 1 is used as the binder, at least 0.3 per cent by mass of total mixture of stabilising additive shall be used to ensure binder drainage does not occur during transport and handling. Stabilising additives shall be cellulose or mineral or other suitable fibre.

A.2.3.2 Proposals to use a bitumen and stabilising additive, or a modified binder, shall be submitted to the Engineer, complete with all details, including binder drainage test results, manufacturer's recommendations for addition or means of incorporating any stabilising additives or modifiers, homogeneously, without segregation, into the mix.

A.2.3.3 Before agreeing the use of an additive or modified bitumen, the Engineer shall be satisfied it has proved satisfactory in use under circumstances, similar to the Contract, elsewhere or that it has undergone appropriate performance trials. For the purpose of this sub-clause, documented evidence of use and trials of the additive or modifier, in any member state of the European Economic Area, will be acceptable.

A.2.3.4 Where information on use or trials is inadequate or lacking, in the opinion of the Engineer, trials may be required to be undertaken before agreeing the use of the additive or modifier.

A.3 Mixture

A.3.1 The target aggregate grading and target binder content proposed by the Contractor shall fall within the envelope formed by the limits given in Table A.1, unless agreed otherwise by the Engineer before the commencement of work.

Table A.1 Aggregate grading

	Per cent by mass of total aggregate passing nominal size	
BS sieve size	*14 mm*	*10 mm*
20 mm	100	
14 mm	90 - 100	100
10 mm	35 - 60	90 - 100
6.3 mm	23 - 35	30 - 50
2.36 mm	18 - 30	22 - 32
75 micron	8 - 13	8 - 13
Binder content	6.0 - 7.5	6.5 - 7.0

Adjustments may be required to the above binder content ranges to account for the varying density of slag aggregates should these be used.

A.3.2 The Contractor shall demonstrate the properties of the proposed mixture, at the target composition, by preparing loose mixture and compacted specimens in accordance with the general requirements of BS 598: Part 107. The loose mixture and compacted specimens shall comply with the requirements of Clause 3.3 and 3.5 below.

A.3.3 When tested at the target composition, the loose mixture shall demonstrate not more than 0.3 per cent binder drainage, by total mass of mixture, at a temperature of 175 degrees C. The test shall be carried out using the apparatus and general principles stated in Clause 939. The drainage shall be calculated as:

Binder drainage = $[(W_2 - W_1) / (110 + B)] \times 100$ per cent

Where B is the initial mass of binder in the mixture, W_1 and W_2 are the mass of tray and foil before testing and tray and foil and drained binder after testing and the mass of combined aggregate before addition of binder was 1100 g, all as stated in Clause 939.

A.3.4 Three compacted specimens shall be manufactured at the target composition and the air void contents of these shall be measured by the procedure described in DD 228, Methods for determination of maximum density of bituminous mixtures, or ASTM D 3203 using:

a the maximum density of the mixture, obtained using the theoretical maximum specific gravity of the loose mixture, determined in accordance with ASTM D 2041 and converted to relative density using the appropriate correction factor.

b the bulk density of the specimen, determined in accordance with BS 598: Part 104: Clause 4, as the bulk density required by ASTM D 3203, except the specimens shall not be coated in wax.

A.3.5 At the target composition, the air void content of the mixture shall be within the range 2 - 4 per cent.

A.4 Mixing

A.4.1 Stone mastic asphalt shall be mixed in accordance with the requirements of BS 4987: Part 1, such that an homogeneous mixture of aggregate, filler, bitumen and, when used, additive, is produced at a temperature of 150 - 190 degrees C. At the time of mixing, the coarse aggregate shall be in a surface dry condition.

A.5 Transportation

A.5.1 Stone mastic asphalt shall be transported to site in double-sheeted or tented and sealed ridge sheeted insulated vehicles.

A.5.2 To facilitate discharge of stone mastic asphalt, the floor of the vehicle may be coated in accordance with the requirements of BS 598 Clause 4.3. When a coating is used, then prior to loading the body shall be tipped to its fullest extent, with the tailboard open, to ensure drainage of any excess. The floor of the vehicle shall be free from adherent bituminous materials or other contaminants.

A.6 Surface preparation

A.6.1 Existing surfaces shall be prepared in accordance with the requirements of BS 4987 and the Series 700. Tack coat shall be K1-40 cationic bitumen emulsion complying with BS 434: Part 1. It shall be spray-applied at a rate of 0.3 - 0.5 L/m^2 to completely cover the surface and shall be allowed to completely break before the stone mastic asphalt is laid.

A.6.2 Where necessary, or when required by the Engineer, existing surfaces shall be repaired, and regulated in accordance with the requirements of Clause 907.

A.6.3 Unless raised prior to surfacing, iron-work and reflecting road studs shall be located for lifting and relaying after completion of surfacing works. Gullies shall be covered prior to surfacing.

A.7 Laying

A.7.1 Unless required otherwise, stone mastic asphalt shall be laid and compacted in accordance with the requirements of Clause 901, to the thickness stated in Appendix 7/1.

A.8 Compaction

A.8.1 Stone mastic asphalt shall be compacted immediately, to practical refusal, using at least two steel-wheeled rollers, with a minimum mass of 6 tonne, per paver. One roller shall be a tandem drum roller.

A.8.2 The tandem drum roller shall operate directly behind the paver, while the other roller shall be used for completion of rolling and the removal of all roller marks.

A.9 Surface texture

A.9.1 When stated in Appendix 7/1, the texture depth of the surfacing shall be in accordance with the requirements of Clause 921 after compaction.

A.10 Compliance of mixture

A.10.1 The agreed mixture shall be that obtained following completion of mixture design and the agreement of a target binder content and target aggregate grading for the mixture.

Note for guidance: The agreed mixture is that obtained after the Contractor demonstrates a mixture which complies with the above requirements, and then proposes that mixture to the Engineer for agreement.

A.10.2 When sampled and tested in accordance with the procedures of BS 598: Parts 101 and 102, the approved aggregate grading limits for compliance purposes shall be those obtained by applying the tolerances given in Table A.2 to the grading of the agreed mixture. The grading curve of the aggregates shall not vary from the low limit on one size of sieve to the high limit on the adjacent size of sieve or vice-versa.

A.10.3 When tested in accordance with the methods of BS 598, the sampling and testing tolerance for binder content shall be ± 0.6.

Table A.2 Tolerances for aggregate grading 14 mm and 10 mm size

BS test sieve	*Tolerances for aggregate grading in per cent by mass of aggregate passing BS test sieve*
14 mm	± 5
10 mm	± 10
6.3 mm	± 8
2.36 mm	± 7
75 micron	± 2

Application of the above tolerances to the target grading may result in limits outside those permitted by the appropriate envelope in Table A.1. This is acceptable.

A.11 Details to be Supplied

A.11.1 The Contractor shall supply all the details required in this Clause to the Engineer before commencement of work under this Clause and when requested during the work.

A.11.2 The Contractor shall supply the Engineer with test certificates stating the properties of the materials used. Samples of emulsion tack coat, modified or unmodified bitumen, additive or mixed bituminous materials from the pavement surface or other suitable sampling point shall also be supplied to the Engineer by the Contractor when so instructed by the Engineer.

Appendix B: Highways Agency draft specification for thin wearing course systems

B.1 General

B.1.1 Thin wearing course systems are proprietary systems comprising an emulsion tack coat sprayed onto an existing surface before placing a hot bituminous-bound mixture which after compaction forms a textured surfacing course that may be trafficked immediately on cooling. The tack coat may be polymer-modified and sprayed hot, but this depends on the system used.

B.1.2 The nominal thickness of systems complying with this Clause which are currently available is 10 to 25 mm. These systems are not directly comparable and, in particular, the engineer should consider the need for a modified mixture and the minimum thickness required for the particular application. The systems permit minor regulating of existing surfaces, but this shall be limited to a maximum local thickness of 50 mm. The surfacing systems shall be laid either in one pass by a single purpose-built machine or in one pass of a sprayer followed by a conventional paving machine.

B.2 Materials

B.2.1 Aggregates and filler

B.2.1.1 Coarse aggregate shall be crushed rock complying with Clause 901 and BS 63: Part 2: Table 2, unless agreed otherwise by the Engineer before commencement of work. Gravel is not permitted.

B.2.1.2 When tested in accordance with the procedure of BS 812, the coarse aggregate shall additionally have the following properties.

Polished Stone Value (PSV) - as specified in Appendix 7/1.

Ten Per Cent Fines Value (TPV) - not less than 180 kN, or as specified in Appendix 7/1.

Maximum Aggregate Abrasion Value (AAV) - not more than 12, or as specified in Appendix 7/1.

Flakiness Index (IF) - not more than 25 per cent.

B.2.1.3 Fine aggregate shall comply with Clause 901 and shall be either crushed rock fines or natural sand or a blend of both. Fine aggregate shall be added as required to suit the particular system.

B.2.1.4 Filler shall be crushed limestone complying with the requirements of BS 594: Part 1. Filler shall be added as required to suit the particular system.

B.2.1.5 When sampled and tested in accordance with the procedures of BS 598: Parts 100, 101 and 102, the aggregate grading shall fall within the envelope formed by the limits given in Table B.1, unless agreed otherwise by the Engineer before the commencement of work.

B.2.1.6 The design and selection of aggregates, filler and bitumen proportions shall be the responsibility of the Contractor, who shall supply the necessary details to the Engineer for information only.

Table B.1 Aggregate grading

	Per cent by mass of total aggregate passing nominal size	
BS sieve size	*14 mm*	*10 mm*
20 mm	100	
14 mm	90 - 100	100
10 mm	55 - 75	55 - 100
6.3 mm	15 - 35	30 - 65
5.0 mm	12 - 30	20 - 55
2.36 mm	10 - 20	15 - 45
1.18 mm	9 - 15	10 - 35
600 micron	7 - 13	7 - 30
300 micron	5 - 12	5 - 25
75 micron	5 - 8	0 - 15

B.2.2 Binder

B.2.2.1 The binder shall be petroleum bitumen complying with BS 3690: Part 1. The penetration of the bitumen shall be grade 70, 100 or 200 penetration, as selected by the Contractor, unless stated otherwise in Appendix 7/1. A polymer may be added, as selected by the Contractor.

B.2.2.2 The choice of bitumen grade and the penetration and softening point of the modified or unmodified binder shall be notified to the engineer before the commencement of work.

B.2.2.3 When sampled and tested in accordance with the procedures of BS 598: Parts 100. 101 and 102, the binder content of the surfacing material shall be in the range 3.5 to 7.5 per cent, by mass of total mixture.

B.2.2.4 Where appropriate to the system, the target binder content shall be determined by the binder drainage test in Clause 939, except that the range to be tested shall be amended to suit the grading of the aggregates proposed for use. The target binder content determined in the laboratory may be adjusted to suit the mixing plant and the aggregate type which is used, subject to plant trial and delivery distance. The adjusted binder content shall be notified to the Engineer prior to delivery and shall not be lower than that specified above. The tolerance on sampling and testing for binder content shall be ± 0.3 per cent.

B.2.3 Tack coat

B.2.3.1 Tack coat shall be a hot-applied cationic bitumen emulsion complying with BS 434: Part 1, with a minimum bitumen content of 38 per cent. To suit the particular system, it may be modified with a polymer. The choice of tack coat shall be notified to the Engineer before commencement of work.

B.3 Surface preparation

B.3.1 Existing surfaces shall be cleaned using steel brooms and suction sweeping or other appropriate means. The surface may be moist but not wet and standing water shall not be present. All mud, dust, dirt and other debris and organic material shall be removed.

B.3.2 Where necessary or required by the Engineer, existing surfaces shall be repaired, and regulated in accordance with the requirements of Clause 907, in advance of laying surfacing material to this clause.

B.3.3 Unless raised prior to surfacing, iron-work and reflecting road studs shall be located for lifting and relaying after completion of surfacing works. Gullies shall be covered prior to surfacing.

B.3.4 Where possible, existing road markings shall be removed.

B.4 Mixing

B.4.1 The material shall be mixed in accordance with the requirements of BS 4987: Part 1, such that an homogeneous mixture of aggregate, filler and bitumen is produced at a temperature of 150 - 180 degrees C.

B.5 Transportation

B.5.1 Mixed materials shall be protected from contamination and undue heat loss by being transported to site in sheeted lorries. To facilitate discharge of the materials, the floor of the lorry may be coated with the minimum of light vegetable oil or liquid soap or other non-solvent solution. When such coating is used, the lorry body shall be tipped to its fullest extent with the tailboard open to ensure drainage of any excess, prior to loading. The floor and sides of the lorry shall be free from adherent bituminous materials or other contaminants before loading the surfacing material.

B.6 Laying

B.6.1 Tack coat shall be spray-applied, in accordance with the requirements of the SHW Series 900, at a rate selected by the Contractor and notified to the Engineer before the commencement of work, to completely cover the surface where the material is to be placed. The particular spray rate shall be dependent on the proprietary system and the porosity of the surface being covered.

B.6.2 Bituminous materials shall be applied at a suitable temperature and compacted by at least two passes of a tandem roller, capable of vibration, and with a minimum deadweight of 6 tonnes, before the material cools below 80 degrees C, measured at mid-layer depth. Excessive compaction shall be avoided.

B.7 Surface texture

B.7.1 Where stated in Appendix 7/1, the texture depth of the surfacing shall be in accordance with the requirements of Clause 921 after compaction.

B.8 Details to be supplied

B.8.1 The Contractor shall supply all the details required in this Clause to the Engineer before commencement of work under this Clause and when requested during the work.

B.8.2 Checks shall be made at the end of each working day and records kept, to determine the quantities used of both tack coat and bituminous material.

B.8.3 The Contractor shall supply the Engineer with test certificates stating the properties of the materials used. Samples of emulsion tack coat, modified or unmodified bitumen or mixed bituminous materials from either the spray bar or storage tank or the pavement surface or other suitable sampling point shall also be supplied to the Engineer by the Contractor when so instructed by the Engineer.

B.9 Guarantee

B.9.1 The Contractor shall guarantee the surfacing materials and workmanship for a period of two years from the date of completion to this Section of the Works. This guarantee shall exclude defects arising from damage caused by settlement, subsidence or failure of the carriageway on which the material has been laid.

Appendix C: Inspection panel marking scheme

Table C.1 Basic 7-point scale

	Mark	*Description*	
E	Excellent	No discernable fault	Termed satisfactory
G	Good	No significant fault	
M	Moderate	Some faults but insufficient for serious problem	
A	Acceptable	Several faults but would usually be just acceptable	
S	Suspect	Seriously faulted but still serviceable in the short term	Termed unsatisfactory
P	Poor	Requires remedial treatment	
B	Bad	Requires immediate remedial treatment	

Table C.2 Fault suffixes

Suffix	*Description*
+	Fatting up
-	Loss of aggregate
c	Cracking
d	De-lamination from substrate
f	Fretting of the mortar
s	Stripping
t	Variability with traffic intensity, marked transverse differences caused by variations in traffic intensity between lanes.
v	Variable with random variations from point to point within the section only, not 'traffic laning' or of obvious variations from load to load.

Table C.3 Inspection panel members

John Mercer/John Williams	Pavement Engineering Group, Highways Agency
Maurice White	Quarry Products Association
David Williams/John Harris	Redland Aggregates Limited
Nigel Preston	Shell Bitumen
Chris Curtis	ARC Group Head Office
Colin Underwood/Eddie Bracewell	Road Surface Dressing Association
Jim Carswell	BP International
Cliff Nicholls	Transport Research Laboratory
Local representatives	
David Laws	W S Atkins East Anglia
Jeff Farrington	Staffordshire County Council
David Harrison	Humber Authorities Engineering Services
Steve Merry	Suffolk County Council
Nigel Barlow	Nottinghamshire County Council

Appendix D: Highways Agency procedure for evaluating new materials

The procedure for evaluating new materials is carried out in 5 stages.

Stage 1 Desk study

Assess and evaluate existing information on the material.

Stage 2 Laboratory study

Test the mechanical properties of materials to allow theoretical predictions to be made of their performance.

Stage 3 Pilot-scale trials

Evaluation of construction and performance of materials in small scale trials.

Stage 4 Full-scale trials

Full-scale trial on a trunk road to establish whether the previous assessments obtained from Stages 2 and 3 are realised.

Stage 5 HA specification trials

This stage is necessary to carry out further evaluation of the material and to test the specification under contract conditions.

Notes

1. Stages 1 to 4 are financed by the manufacturer of the material. For Stage 5 the additional cost, if any, of the material is borne by the manufacturer.
2. Stages 1 to 4 can be carried out by the TRL or other independent organisations. In the latter case, the reports are appraised by the TRL.
3. In all cases, the new materials are compared with conventional materials to obtain comparative performance.

Abstract

This is the second report on a series of road trial sites with surface course materials that are innovative in the United Kingdom and have now been monitored for up to six years. This report describes the later sites, four with sections of stone mastic asphalt surface course and one with a multiple surface dressing thin surfacing system. These sites complement the previously reported sites with proprietary thin surfacing systems. The initial results from the new sites are reported, together with the results of the regular monitoring of all the trial sites. There are concerns about the reduction in texture depth with trafficking which was found with stone mastic asphalt on some, but not all, sites. Nevertheless, the overall performance of the various materials is encouraging, with several of the proprietary thin surfacings now having Departmental Type Approval for use on trunk roads and motorways in England.

Related publications

TRL292 *Assessment of MILLOM HITEX, the Bardon thin asphalt surface course* by J C Nicholls. 1998 (price £15, code C)

TRL218 *Assessment of AXOFLEX, the Redland thin asphalt surface course* by J C Nicholls. 1997 (price £20, code E)

TRL176 *Laboratory tests on high-friction surfaces for highways* by J C Nicholls. 1997 (price £30, code H)

PR79 *Road trials of thin wearing course materials* by J C Nicholls. J F Potter, J Carswell and P Langdale. 1995 (price £20, code H)

PR65 *Evaluation of stone mastic asphalt (SMA) : a high stability wearing course material* by M E Nunn. 1994 (price £20, code E)

LR896 *Road surfaces and traffic noise* by R E Franklin, D G Harland and P M Nelson. 1979 (price £10, code AA)

SR290 *Calibration, maintenance and use of the rolling straightedge* by J C Young. 1977 (price £10, code AA)

CT68.1 *Deterioration of road surfaces update (1994-1996)*. Current Topics in Transport: abstracts selected from TRL Library’s database. (price £15)

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