TRANSPORT RESEARCH LABORATORY

Assessment of SMATEX, a Bardon thin asphalt surface course

Prepared for Bardon Aggregates Limited (now known as Aggregate Industries Limited)

J C Nicholls

TRL REPORT 435

First Published 2000
ISSN 0968-4107

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Executive Summary

Thin surfacing systems were developed in France and brought into the United Kingdom in 1992 and two were initially approved by the Highways Agency for use on the trunk road network, including on motorways, in England. To gain similar approval, other thin surfacing systems need to be assessed using the *Highways Agency 5-Stage Procedure for Evaluating New Materials* until the British Board of Agrément's *Highway Authorities Product Approval Scheme* is in operation. To date, a further fourteen systems have gained approval in this manner including three from Bardon Aggregates Limited (now known as Aggregate Industries Limited) – MILLOM HITEX, THINPAVE and SMATEX.

Of these, SMATEX is a thin surfacing system, developed in the UK and offered by Bardon Aggregates Limited, that is based on stone mastic asphalt. The material has been laid and monitored for up to three years at a number of sites, including the A1 at Eaton Socon. The results obtained from the various sites are detailed and their implications reviewed.

The review of the available data on SMATEX shows that:

- 14 mm SMATEX has achieved the minimum texture depth of 1.5 mm required for high-speed trunk roads.
- SMATEX can provide the appropriate skid-resistance that would be expected, although there is a more extended period before the binder film is removed by traffic after laying than for some other materials.
- SMATEX has good deformation resistance properties, as measured by the wheel-tracking test at 45°C and 60°C.
- SMATEX has stiffness modulus and fatigue characteristics which, while being marginally less than hot rolled asphalt, are of the same order as those of similar materials.
- SMATEX will generate less noise than a hot rolled asphalt surfacing; the level is similar to or better than that of other thin surfacings but not as quiet as porous asphalt.
- 14 mm SMATEX, after being heavily trafficked for three years, shows no obvious major defects or signs of distress.

Therefore, 14 mm SMATEX has successfully complied with all stages of the *Highways Agency 5-Stage Procedure for Evaluating New Materials* and was granted Type Approval by the Highways Agency for use on trunk roads, including motorways, in England as a thin surfacing in accordance with Clause 942.

1 Introduction

Thin surfacing systems were developed in France and brought into the United Kingdom in 1992. The early systems were monitored by the Transport Research Laboratory (TRL) on behalf of the Highways Agency (HA) to determine their suitability for UK conditions, in particular the requirements for skid-resistance and texture depth on high-speed trunk roads. These trials proved successful (Nicholls et al, 1995; Nicholls, 1998a), and two thin surfacing systems were approved by the HA for use on the trunk road network through a new specification clause, now included as Clause 942 in the *Specification for Highway Works* (MCHW 1).

An alternative mixture for thin surfacings to that developed in France is stone mastic asphalt. Stone mastic asphalt (Nunn, 1994; Loveday and Bellin, 1998; Nicholls, 1998a) was developed in Germany over 20 years ago as a deformation-resistant material, originally to offset the problem with wear from studded tyres. The material has proved successful and is now widely used in Germany, Austria and Scandinavia as well as being evaluated in the UK, USA and other countries. The aggregate grading is similar to that of porous asphalt, but with the voids filled with mortar. Stone mastic asphalt is generally used as a full-depth surfacing material in continental Europe, but it can be used at reduced thicknesses as a thin surfacing. In introducing stone mastic asphalt 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 stone mastic asphalt is required to be verified for the modified grading.

The Highways Agency has a 5-stage procedure for evaluating new materials that can be applied to thin surfacings. The five stages (desk study, laboratory study, pilot-scale trials, full-scale trials and HA specification trials) are described in Appendix A of this report. The first four stages can be carried out by any suitable body on behalf of the promoter of the new material; however, the HA requires that TRL evaluates the results in order to assess the stage which has been reached and advises them accordingly. The HA will give approval to use a material when they are satisfied that all stages have been successfully completed.

For thin surfacings, those systems that are being promoted and have been laid on local authority roads, or as trials on trunk roads, generally have sufficient supporting evidence to demonstrate compliance with Stages 1, 2 and 3. Stage 5, which is carried out by the HA, is unnecessary for thin surfacings because the specification is already available. Therefore, it is the position with regard to the Stage 4 *Full-Scale Trials* that needs to be assessed. The main points that need to be demonstrated in order for the material to comply with this stage are:

- The thin surfacing can be laid successfully with all the properties required of any wearing course (texture depth, profile, lack of surface defects, etc., as set out in the *Specification for Highway Works* (MCHW 1));
- The thin surfacing can achieve a skid-resistance value, as measured by SCRIM, above the relevant investigatory level; and
- The thin surfacing can maintain a texture depth of at least 1.0 mm and a skid-resistance above the relevant investigatory level after two years in service with a traffic flow of at least 1,000 commercial vehicles per lane per day, but preferably at least 2,000 cv/l/d.

Other data on the thin surfacing system will also be useful in obtaining an overall assessment of the material.

However, HA approval is provisional until the British Board of Agrément's *Highway Authorities Product Approval Scheme* (HAPAS) is in operation, under which *Roads and Bridges Certificates* will be issued for thin surfacings. Once HAPAS has been implemented, Departmental Type Approval will be withdrawn, although it may be assumed that approval under the *Highways Agency 5-Stage Procedure for Evaluating New Materials* will be strong supporting evidence that a thin surfacing is suitable for a *Roads and Bridges Certificate*.

Bardon Aggregates Limited (now known as Aggregate Industries Limited, but hereafter referred to as Bardons) commissioned TRL to carry out assessments on three of their thin surfacing materials with regard to the *Highways Agency 5-Stage Procedure for Evaluating New Materials*. The assessments for MILLOM HITEX (Nicholls, 1998b) and THINPAVE (Nicholls, 2000) are reported elsewhere whilst that for SMATEX with particular reference to the section that was laid in 1995 on the A1 at Eaton Socon, is given in this report.

2 Constituents of SMATEX

2.1 Aggregate

SMATEX is a stone mastic asphalt with a range of maximum nominal aggregate sizes from 6 mm to 20 mm. To provide early life skid-resistance, the application of 3 mm grit at 800 g/m^2 to erode the layer of mortar covering the aggregate is recommended by Bardons. The grit is applied after the first pass of the roller and is brushed into the interstices before being compacted into the mat with subsequent passes of the roller.

2.2 Binder

The binder generally used for SMATEX is 50 pen unmodified bitumen. However, polymer-modified binders can be used in severe conditions, such as where reflective cracking is anticipated due to thermal or mechanical movement of concrete roadbases. In order to carry the relatively high binder content, cellulose fibres are included in the mixtures.

The bond coat is usually K1-40 emulsion spread at a similar rate of application to that used for macadam wearing courses, although K1-70 can also be used.

2.3 Mixture Design

The target grading for a mixture of SMATEX is selected from the envelopes given in Table 1.

The maximum mixing temperature with 50 pen bitumen is 180 °C and the compaction has to be substantially complete before the temperature of the mat falls below 90°C. The compaction required is generally equivalent to 5 passes of an 8/10 tonne static roller. The use of vibration is not recommended.

Table 1 Nominal grading envelopes

	Proportion passing (per cent) For maximum nominal aggregate size		
BS sieve size	*6 mm*	*10 mm*	*14 mm*
20 mm			100
14 mm		100	90 – 100
10 mm	100	90 – 100	27 – 47
6.3 mm	90 - 100	32 – 48	18 – 30
2.36 mm	30 - 40	17 – 27	16 – 28
75 µm	8 - 12	8 – 12	8 – 12
Binder content by mass	6.5 - 7.7	6.0 - 7.2	5.4 - 6.6

2.4 Thickness

The nominal thickness that SMATEX can be laid is dependent on the maximum nominal size of aggregate, as shown in Table 2.

Table 2 Nominal thickness to which SMATEX may be laid

Maximum nominal aggregate size (mm)	*Typical nominal thickness (mm)*	*Minimum nominal thickness (mm)*
6	15	10
10	25	20
14	35	30
20	50	40

3 Assessment of SMATEX

3.1 Highways Agency procedure for evaluating new materials

The stages of the assessment procedure (see Appendix A) are reviewed with specific reference to SMATEX.

3.1.1 Stage 1, desk study

There has been no formal record of a desk study of the viability of SMATEX. However, the current interest in thin surfacings and the successful laying of the material on the pilot-scale (Section 3.1.3) and full-scale (Section 3.1.4) trials indicates that the understanding of the situation required from a desk study has been acquired.

3.1.2 Stage 2, laboratory study

The laboratory study has been carried out as part of the various trials of SMATEX; both laboratory tests on samples taken from the trials and the compliance tests have been carried out.

3.1.3 Stage 3, pilot-scale trial

Pilot-scale trials of SMATEX have been laid, but no measurements have been reported.

3.1.4 Stage 4, full-scale road trial

Sites where SMATEX has been laid include:

- 14 mm SMATEX on both carriageways of the A1 at Eaton Socon;
- 14 mm SMATEX on the London-bound carriageway of A4, Ealing;
- 14 mm SMATEX on the A4127, Greenford Road, London Borough of Ealing;
- 14 mm SMATEX on A2, Blackheath Hill;
- 14 mm SMATEX on Ealing Road, Greenford;
- 14 mm SMATEX on Horseshoe Lane, Watford; and
- 10 mm SMATEX for 500 m on Greenford Avenue, London Borough of Ealing.

The A1 at Eaton Socon is a two lane dual carriageway of jointed concrete construction that carries approximately 17,000 vehicles, of which 2,210 are heavy goods vehicles, in each direction daily. Assuming that the lane split is 80:20, then the nearside lanes will carry 1,770 commercial vehicles per lane per day (cv/l/d).

At this site, 1200 m of the southbound carriageway had been overlaid with Safepave, 10 mm nominal maximum aggregate size, in 1991 (Nicholls et al, 1995). The remainder of the concrete was overlaid as a TRL trial for the Highways Agency (Nicholls, 1998a) (see Figure 1) by SIAC Construction (UK) in June and July 1995 using:

- SMATEX with 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).

The SMATEX was laid at a nominal thickness of 30 mm.

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 areas where poor load transfer, and consequential vertical movement, at the joints would influence the performance of the surfacings. The condition of the joints was found to be consistently good, so the investigation was not repeated on the southbound carriageway.

The A4, Bath Road, Ealing is an urban two lane dual carriageway. A manual count by WSP Civils in June 1998 during the peak hours of 07.00-10.00, 12.00-14.00 and 16.00-19.00 gave two-way flows of 6,323, 4,076 and 6,054 vehicles, respectively, of which 128, 174 and 101

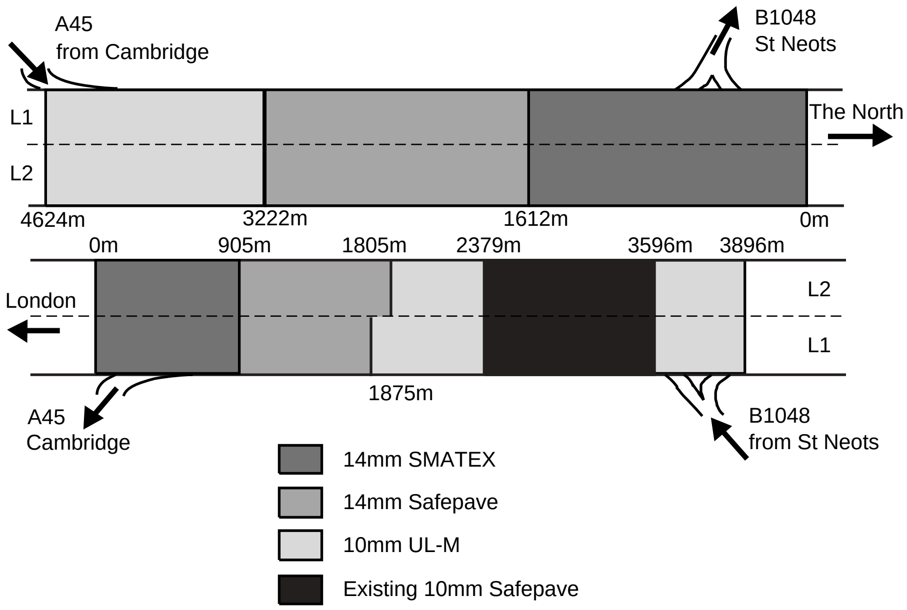

Figure 1 A1 site, Eaton Socon

were commercial. Assuming that half the total daily flow occurs during those 8 hours and that 80 per cent of the commercials travel in lane 1, the nearside lanes carry approximately 320 cv/l/d. Ringway Limited laid SMATEX on the London-bound carriageway in the June 1995.

The A4127 Greenford Road site is a single 2-lane carriageway of composite construction that was badly cracked, both longitudinally and transversely, with overbanding having been applied to some cracks. The road runs north/south linking the east/west dual carriageway routes of the A40 Western Avenue and the A4090 Whitton Avenue. The road has a 40 mile/h speed restriction and is on a bus route.

A site investigation of the A4127 by Bardons using 150 mm diameter cores found that the total thickness of bitumen-bound material was between 100 mm and 160 mm. The construction overlying the concrete roadbase generally consisted of layers of 28 mm open graded macadam roadbase, 30/10 hot rolled asphalt wearing course, 30/14 hot rolled asphalt wearing course and a 6 mm surface dressing, but the materials varied along the length. SMATEX with 14 mm Bardon Hill Andesite aggregate (PSV 60, AAV 4, Flakiness Index 20 per cent) was laid for a carriageway length of 550 m on the site by Ringway Limited in November 1994 after planing off the upper 40 mm.

3.1.5 Stage 5, specification trial

The Highways Agency has already produced Clause 942 for use in specifying thin surfacings. Therefore, there is no requirement for carrying out a specification trial specifically for SMATEX.

3.2 Properties required

The requirements for a satisfactory thin surfacing material are that it should:

- be capable of providing the properties required of all surfacing materials (texture depth, skid-resistance, surface regularity, etc) (Section 4);
- provide the additional properties claimed by the promoter (noise reduction, rapid construction, etc) (Section 5);
- not result in any adverse aspects (such as limited texture depth with reduced noise or vice versa; a property that can only be attained with great care, etc) which have not been identified (Section 6); and
- remain durable, whilst maintaining those properties referred to above, compared with that of conventional surfacing materials (Section 7).

The properties of SMATEX that have been investigated will be discussed in order.

4 Standard properties

4.1 Compliance

Compositional analyses (BSI, 1996a) were carried out to check the compliance of the material supplied with the specification by Bardons on the A4127, Greenford Road and by Kent County Council on the Horseshoe Lane, Watford. The results are given in Tables 3 and 4, respectively. Non-compliances are identified by being shown in **bold**.

The specification against which the Greenford Road material was supplied had a relatively low binder content. Hence, there were some non-conformities due to excess binder content.

Table 3 Compositional compliance of 14 mm SMATEX on A4127, Greenford Road

BS sieve size	*Proportion passing (per cent)*								
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*Specified*
20 mm	100	100	100	100	100	100	100	100	100
14 mm	98	97	92	96	98	92	95	95	90 – 100
10 mm	35	46	31	38	31	37	42	35	24.5 – 49.5
6.3 mm	23	23	21	23	22	23	26	21	16 – 28
2.36 mm	21	21	19	21	20	20	24	19	14 – 26
600 μm	18	18	16	17	16	16	20	16	—
212 μm	12	12	11	12	12	13	13	11	—
75 μm	9.5	9.7	8.5	9.4	9.8	10.5	10.5	9.1	6.7 – 11.7
Binder content	**6.0**	5.7	5.7	5.8	**5.9**	**6.1**	**5.9**	5.8	5.2 – 5.8

Table 4 Compositional compliance of 14 mm SMATEX on Horseshoe Lane

	Proportion passing (per cent)	
BS sieve size	*Found*	*Specified*
20 mm	100	100
14 mm	95	90 – 100
10 mm	44	27 – 47
6.3 mm	31	16 – 32
2.36 mm	27	15 – 29
75 μm	10	8 – 12
Binder content by mass	5.9	5.7 - 6.3

4.2 Skid-resistance

4.2.1 SCRIM

Skid-resistance was measured by TRL on the A1 at Eaton Socon using the Sideway-force Coefficient Routine Investigation Machine (SCRIM) (Hosking, 1996) at 50 km/h, generally three times each year, and the Mean Summer SCRIM Coefficient (MSSC) determined. The skid resistances on the A4127 Greenford Road and on Greenford Avenue were monitored regularly with a SCRIM by Brown & Root Projects Limited. The results, which are from single annual visits and, therefore, not mean summer SCRIM coefficients (MSSC), are given in Table 5.

In addition, W S Atkins East Anglia took SCRIM readings early in the life of the A1 site at Eaton Socon. This monitoring included sections of the existing rolled asphalt on one end of the test sections as additional partial controls. These results are given in Table 6.

4.2.2 Grip tester

In addition to the SCRIM surveys, GripTester surveys were carried out on the A1, Eaton Socon by W S Atkins East Anglia, on the A4127, Greenford Road by Babtie Highway Laboratories and on the A2, Blackheath Hill by the Shire Consultancy. The results, converted into equivalent SCRIM coefficients, are given in Table 7.

Table 5 Mean annual SCRIM results

		SCRIM Result		
Lane	*Material*	*1995*	*1996*	*1997*
A1, Eaton Socon				
North	14 mm SMATEX	0.34	0.43	0.54
	14 mm Safepave	0.37	0.48	0.49
	10 mm UL-M	0.37	0.53	0.54
South	14 mm SMATEX	0.35	0.42	0.55
	14 mm Safepave	0.37	0.49	0.63
	10 mm UL-M	0.37	0.50	0.56
	10 mm Safepave ‡	0.53	0.58	0.52
Greenford Road				
South	14 mm SMATEX	0.45	0.39	0.43
	Rolled asphalt	0.49	0.42	0.47
	High-friction	0.45*	0.67	0.75
North	14 mm SMATEX	0.43	0.39	0.44
	Rolled asphalt	0.46	0.39	0.44
	High-friction	0.45*	0.63	0.63
Greenford Avenue				
South	10 mm SMATEX	0.45	0.45	0.43
	Rolled asphalt	0.45	0.44	0.43
North	10 mm SMATEX	0.45	0.46	0.46
	Rolled asphalt	0.44	0.42	0.40

** Prior to application of high-friction surfacing*
‡ Existing surfacing

Table 6 Early life SCRIM results

	SCRIM Coefficient			
	Nearside lane		*Offside lane*	
Material	*July '95*	*Sept '95*	*July '95*	*Sept '95*
A1 northbound				
14 mm SMATEX	0.34	0.52	0.35	0.42
14 mm Safepave	0.37	0.56	0.37	0.53
10 mm UL-M	0.42	0.59	0.43	0.52
A1 southbound				
14 mm SMATEX	0.34	0.43	0.35	0.47
14 mm Safepave	0.38	0.54	0.40	0.56
10 mm UL-M	0.38	0.54	0.37	0.49
10 mm Safepave ‡	0.55	0.58	0.55	0.57
Hot rolled asphalt ‡	0.41	0.43	0.44	0.44

‡ Existing surfacing

4.2.3 Pendulum

The skid-resistance of the four 200 mm diameter cores extracted from Horseshoe lane, Watford by Kent County Council were measured using the portable skid-resistance tester (RRL, 1969). The results are given in Table 8.

4.2.4 High-speed skid-resistance

The high-speed skid-resistances of SMATEX, Safepave and UL-M were measured with the ASTM Pavement Friction Tester manufactured by K J Law on the northbound carriageway of the A1 at Eaton Socon in September 1996.

Table 7 Grip tester results converted into SCRIM coefficients

Date and age (months)		*Equivalent SCRIM Coefficient ** Southbound	Northbound
A1, Eaton Socon			
5/ 7/95	0	—	0.44
4/ 8/95	1	0.43	0.42‡
A4127, Greenford Road			
12/ 1/95	2	0.44	0.46
29/ 8/95	9	0.37	0.42
8/12/95	13	0.42	0.43
24/ 5/96	18	0.45	0.48
23/10/96	23	0.37	0.37
		Eastbound	*Westbound*
A2, Blackheath Hill			
16/ 4/96	n/a	0.49 (n/s) 0.52 (o/s)	0.47

** Based on SCRIM coefficient = 0.789 x GripNumber - 0.049*
‡ 0.44 over first 400 m length
n/a = information not available
n/s = nearside lane
o/s = offside lane

Table 8 Portable skid-resistance tester results

	Skid-resistance Wet	*Value @ 20 °C Dry*
Cores	54	94
	56	97
	58	91
	55	92
Mean	56	94

The Pavement Friction Tester measures locked-wheel friction with a smooth tyre at 1 mm water depth. The results, in terms of Skid Numbers at different speeds, are given in Table 9 and are shown graphically in Figure 2.

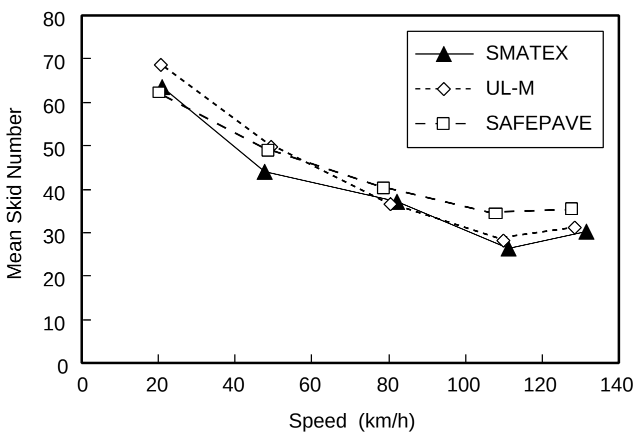

Figure 2 High-speed skid-resistance

Table 9 Pavement friction tester measurements on A1, Eaton Socon

10 mm UL-M Speed	Skid Number	*14 mm Safepave* Speed	Skid Number	*14 mm SMATEX* 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

4.3 Texture depth

4.3.1 Sand-patch

The initial texture depth was measured on the A1 at Eaton Socon by the sand-patch method in accordance with BS 598: Part 105 (BSI, 1990a) as part of the normal control. 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. The texture depth was measured by the sand-patch method on the A4127, Greenford Road, initially and after one month by Bardons and after 3½ years by Flexitec Limited. The results, where each result is the mean of ten determinations, are given in Table 10.

Table 10 Texture depth results

Site		*Date measured*	*Age (months)*	*Texture depth (mm)* Mean	Range	No.
14 mm SMATEX						
A4127,		Nov. 1994	0	2.0	1.9 - 2.1	3
Greenford		Dec. 1994	1	1.7	1.6 - 1.9	9
Road		July 1998	44	1.3	1.2 - 1.3	5
14 mm SMATEX						
A1,	Nearside	July 1995	0	2.3	1.6 - 3.1	
North-		Nov. 1997	28	1.8	1.6 - 2.0	
bound	Offside	July 1995	0	2.6	2.2 - 3.0	
A1,	Nearside	July 1995	0	2.1	2.1 - 2.1	
South-						
bound	Offside	July 1995	0	2.0	1.7 - 2.3	

As can be seen in Figure 3, the appearance of the texture was still good after 3½ years in service on Greenford Road.

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, in terms of profiles of texture depth across the carriageway, are shown in Figure 4.

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

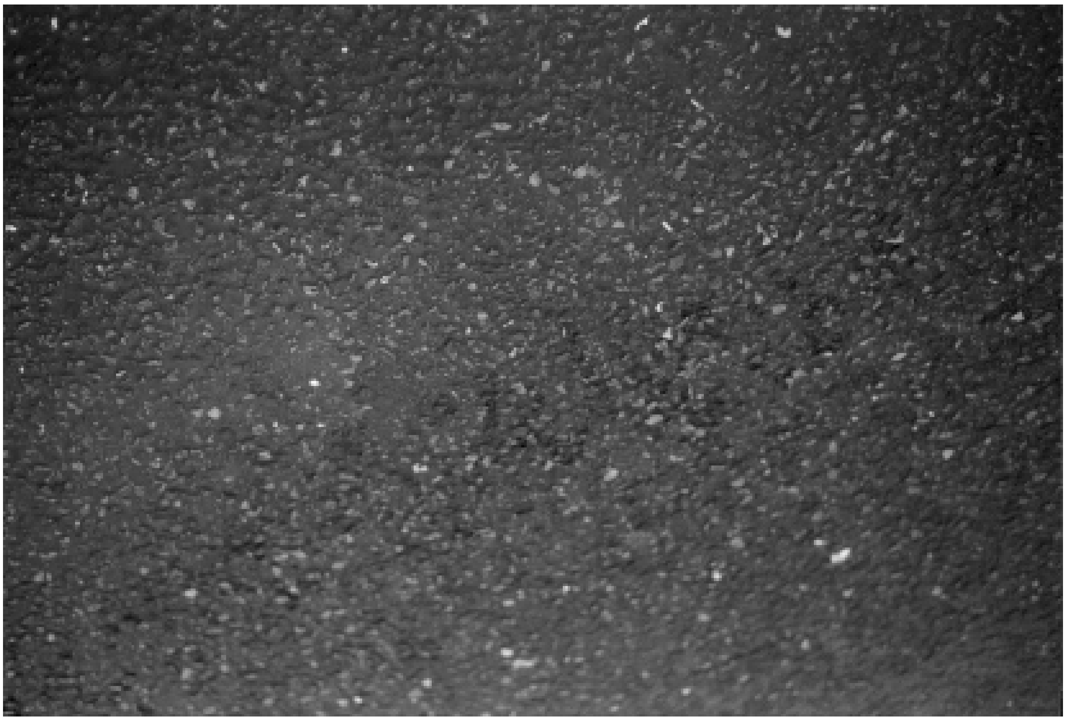

Figure 3 Texture of SMATEX after 3½ years in service

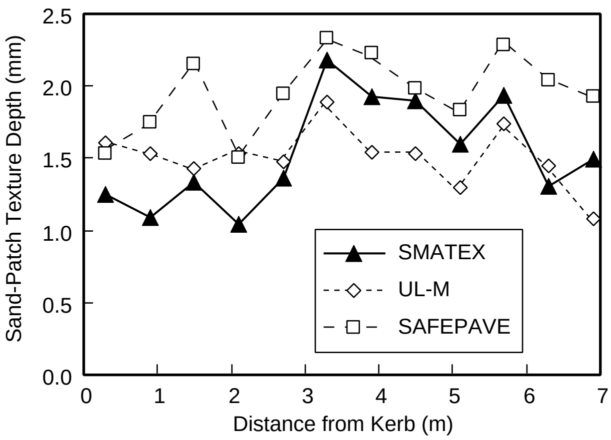

Figure 4 Texture profiles on A1, Eaton Socon after 1 year of trafficking

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 SMTD was measured on the A1 at Eaton Socon 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 are given in Table 11.

4.4 Marshall design

For the A4127 job, Bardons carried out the Marshall design procedure (BSI, 1990b) on two mixtures of 14 mm SMATEX. The gradings are given in Table 12 and the results in Table 13.

Table 11 Sensor measured texture depth results

		Sensor-measured texture depth (mm)		
Material	*Site*	*1995*	*1996*	*1997*
14 mm	A1 northbound	0.85	0.84	0.73
SMATEX	A1 southbound	0.88	0.79	0.49*

** Apparently anomalous result for which contamination is suspected*

Table 12 Gradings of 14 mm SMATEX mixtures

	Percentage passing (per cent)		
BS sieve size	*Mixture A*	*Mixture B*	*Envelope*
20 mm	100	100	100
14 mm	92	95	90 - 100
10 mm	37	43	27 - 47
6.3 mm	24	26	18 - 30
2.36 mm	22	22	16 - 28
75 µm	10.4	10.2	8 - 12
Binder content by mass	6.0	6.2	5.4 - 6.6

Table 13 Design properties of 14 mm SMATEX mixtures

Binder content (per cent)	*Density (Mg/m^3)*	*Maximum density (Mg/m^3)*	*Air voids content (per cent)*	*Stability (kN)*	*Flow (mm)*
Mixture A					
5.1	2.42	2.56	5.6	7.7	3.0
5.4	2.44	2.55	4.5	7.6	2.8
5.7	2.44	2.54	3.9	7.7	3.0
6.0	2.45	2.53	3.2	7.6	3.1
6.3	2.45	2.52	2.6	6.5	3.5
6.6	2.44	2.50	2.4	7.0	4.2
6.9	2.44	2.49	2.0	6.7	4.5
Mixture B					
n/a	2.48		5.4	7.3	3.0
	2.48		5.7	6.6	3.6
	2.49		5.7	7.6	3.3
	2.49		6.0	6.9	3.4
	2.48		6.0	6.8	3.4
	2.46		6.0	4.6	3.7
	2.48		6.3	6.9	3.6
	2.47		6.3	6.3	4.0
	2.49		6.6	6.8	4.1
Mixture B					
6.2	2.48		6.0	6.7	3.6

n/a Data not available

4.5 Deformation resistance

4.5.1 Wheel-tracking

Wheel-tracking tests (BSI, 1998) were carried on:

- two cores of 14 mm SMATEX from the A1, Eaton Socon at 45°C by W S Atkins;
- two cores of 14 mm SMATEX from the Ealing Road, Greenford at 45°C by Surrey County Council; and
- on four cores of 14 mm SMATEX from Horseshoe Lane, Watford at 60°C by Kent County Council.

The results are given in Table 14.

4.5.2 Creep

The static creep (BSI, 1995) and the dynamic creep (BSI, 1996b), both at 30°C, of 14 mm SMATEX were measured by Kent County on two 150 mm diameter cores each taken from Horseshoe Lane, Watford. The results were a mean static creep after 3,600 s of 0.85 per cent (0.92 and 0.79) and a mean dynamic creep after 1,800 cycles of 0.91 per cent (1.09 and 0.73).

Table 14 Wheel-tracking results

	Results of individual cores		
Site	*Test temper -ature (°C)*	*Wheel -tracking rate (mm/h)*	*Rut depth (mm)*
14 mm SMATEX			
A1, Eaton Socon	45	0.6	1.4
		1.2	1.0
14 mm SMATEX			
Ealing Road	45	0.5	1.7
		0.4	1.7
14 mm SMATEX			
Horseshoe Lane	60	0.6	2.0
		0.7	1.9
		1.2	4.0
		1.6	3.0

5 Additional desirable properties

5.1 Thickness

Bardons claim that 14 mm SMATEX should be laid at a nominal thickness of 35 mm that 10 mm SMATEX should be laid at 25 mm. The results of measuring cores taken by Bardons from Greenford Road were thicknesses of 40 mm, 42 mm and 46 mm and by Kent County Council from Horseshoe Lane were thicknesses between 30 mm and 41 mm, both for 14 mm SMATEX.

5.2 Noise

The maximum vehicle noise levels were measured on the A1 at Eaton Socon by TRL using the statistical pass-by method (ISO, 1997) 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 for SMATEX were a noise level of 78.3 dB(A) for light vehicles and 85.2 dB(A) for heavy vehicles. The noise frequency spectra measured at 90 km/h for the three surfacings are shown in Figure 5.

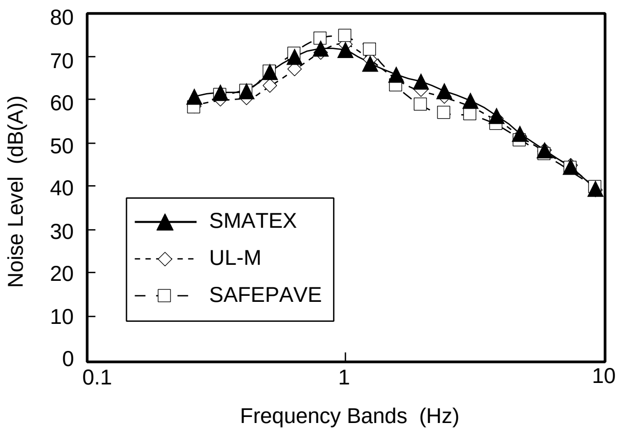

Figure 5 Frequency spectra of noise on A1 surfacings

Noise measurements were also made on the A4127, Greenford Road by the Environmental Health Division of the London Borough of Ealing. Measurements were made at the mid-point of the trial length both before and after SMATEX had been laid. For both sets of measurements, noise levels were measured over a Sunday night to Monday evening at 3.5 m from the building line (approximately 6 m from the kerbside) at a height of 1.5 m. Short-term measurements were obtained on the Monday morning at an adjacent position. The before survey was carried out on 13/14 November 1994 when there was rain overnight with occasional very light rain in the morning whilst wind conditions were generally light with occasional gusts. The after survey was carried out on 5/6 March 1995 when the wind speeds were generally light but with some strong gust and light rain fell at midday with a hailstorm around 3:00 p.m.

The mean equivalent sound pressure level, $L_{A,eq}$, and the sound pressure level exceeded for ten per cent of the total measurement time, $L_{A,10}$, are given in Table 15 for both daytime and night-time. The equivalent sound pressure level is a hypothetical constant sound pressure level for a specified period (taken here as five minutes) that has the same total sound energy as a real fluctuating sound pressure level in the specified period (taken here as one hour). The daytime and night-time values are calculated by logarithmically averaging the available data in the periods 07:00 to 23:00 and 23:00 to 07:00, respectively. All the values are ‘A’ weighted across the frequency spectrum to simulate the subjective human ear.

Table 15 Mean noise results

	$L_{A,eq}$		$L_{A,10}$	
Material	*Daytime*	*Night-time*	*Daytime*	*Night-time*
14 mm SMATEX	67	62	70	65
Existing rolled asphalt	69	64	72	67

5.3 Stiffness modulus

The elastic stiffness modulus (BSI, 1993) was measured on two cores extracted from the A1 by W S Atkins and on three sizes of cores taken from Horseshoe Lane, Watford by Kent County Council. The results are given Table 16.

Table 16 Elastic stiffness results

	Elastic stiffness modulus (GPa)					
Core diameter	*200 mm*		*150 mm*		*100 mm*	
A1, Eaton Socon						
	2.0	1.7	—		—	
Horseshoe Lane, Watford						
Individual results	3.1	3.0	3.0	3.3	2.8	2.7
	2.7	2.9	3.0	3.3	2.7	2.7
			3.1		2.3	2.8
Mean	2.9		3.1		2.7	

5.4 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 17.

Table 17 Relative hydraulic conductivity on A1, Eaton Socon

	Relative hydraulic conductivity (s^{-1})		
Northbound		*Southbound*	
Mean	*Range*	*Mean*	*Range*
14 mm SMATEX			
0.03	0.00 - 0.09	0.03	0.01 - 0.04
14 mm Safepave			
0.07	0.02 - 0.12	0.07	0.05 - 0.09
10 mm UL-M			
0.01	0.00 - 0.02	0.01	0.00 - 0.03

5.5 Fatigue resistance

The fatigue properties were measured by Kent County Council on cores taken from Horseshoe Lane, Watford. The resulting plot, together with typical plots for rolled asphalt and dense bitumen macadam, is shown in Figure 6.

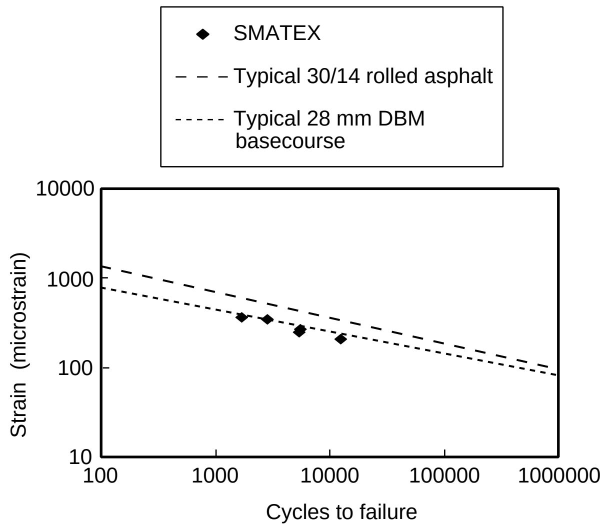

Figure 6 Fatigue characteristics of 14 mm SMATEX

6 Adverse properties

No particular adverse factors have been identified.

7 Durability

7.1 Air voids content

Bardons measured the air voids content of both laboratory-compacted samples and of cores taken from the A4127, Greenford Road. Kent County Council measured the air voids content of cores taken from Horseshoe Lane, Watford. The bulk densities were measured in accordance with BS 598: Part 104 (BSI, 1989) and the maximum density in accordance with BS DD 228 (BSI, 1996c); the results are given in Table 18.

As can be seen, the actual air voids content was relatively low at less than 5 per cent on Greenford Road and just over 3 per cent on Horseshoe Road. However, the laboratory compaction of the Greenford Road material was about 1 per cent lower than that achieved on site.

7.2 Refusal density

The refusal density of 150 mm diameter cores (BSI, 1989) taken from Horseshoe Lane, Watford was measured by Kent County Council. The results are given in Table 19.

7.3 Binder content

The binder content, at (6.0 ±0.6) per cent for 14 mm and (6.6 ± 0.6) per cent for 10 mm SMATEX, is relatively high for asphalt mixtures, which is generally considered good indicator for their durability. However, the binder content is not as high as for some stone mastic asphalt mixtures, which are traditionally high-binder content mixtures (hence the need for fibres in order to avoid binder drainage).

7.4 Visual condition

The visual condition of the northbound carriageway of the A1, Eaton Socon site was assessed by an Inspection Panel using a standardised methodology (Nicholls, 1997) with a marking scheme giving a basic assessment classification with fault suffixes as applicable. The possible markings for thin surfacings are reproduced in Appendix B and the results are given in Table 20.

Site visits were carried out by TRL and Bardons to the A4127 Greenford Road and the London-bound carriageway of the A4 Bath Road, Ealing, on 3rd March 1998. At Greenford Road, SMATEX had been laid over a badly cracked composite pavement by Ringway in November 1994 and, after 3½ years, some cracks were beginning to show through (Figure 7). Nevertheless, the condition of the surfacing was still good. The A4 was also in generally good condition other than some transverse variability in the texture at one end of the site (Figure 8) and a poor reinstatement by a utility at the other end.

Table 18 Air voids content

Sample type	*Bulk density (Mg/m^3)*	*Maximum density (Mg/m^3)*	*Air voids content (per cent)*
A4127, Greenford Rd			
Laboratory-compacted	2.42	2.50	3.2
	2.42		3.1
	2.41		3.6
	2.41		3.5
	2.40		3.7
	2.40		3.8
A4127, Greenford Rd			
Cores	2.38	2.49	4.5
	2.39	2.49	4.0
	2.37	2.48	4.4
Horseshoe Lane			
	2.41	2.47	2.8
	2.40		3.0
	2.38		3.9
	2.39		3.5

Table 19 Refusal density results

In-situ bulk density (Mg/m^3)	*Bulk density at refusal (Mg/m^3)*	*Percentage refusal density (per cent)*	*Voids content at refusal (per cent)*
Individual cores			
2.40	2.44	98	1.8
2.41	2.46	98	2.0
2.39	2.44	98	1.9
2.41	2.45	98	1.8
2.40	2.44	98	1.7
Mean			
2.40	2.45	98	1.8

Table 20 Visual assessments on A1, Eaton Socon

	Panel markings		
	1995	*1996*	*1997*
A1, Eaton Socon, northbound			
South end	G/M_t	G/M_t	G
North end	G/M_t	$G/M_{t,+}$	G

8 Discussion

The range of parameters that have been measured for SMATEX is relatively extensive, partly because a section was laid in a TRL trial that was monitored annually.

The skid-resistance of 14 mm SMATEX is similar to that of other thin surfacings. The initial skid resistance, as measured by SCRIM, does appear to be marginally lower than that of other systems, but this is probably due to the relatively thick binder film; however, the effect is not maintained for very long. Furthermore, when tested by the Pavement Friction Tester, the skid-resistance of SMATEX did not drop off excessively with speed, so that its high-speed skid-resistance is similar to that of other thin surfacings.

The initial sand-patch texture depth of 14 mm SMATEX is generally in excess of the 1.5 mm required for motorways and other high-speed trunk roads. The texture depth is maintained at an acceptable level after trafficking;

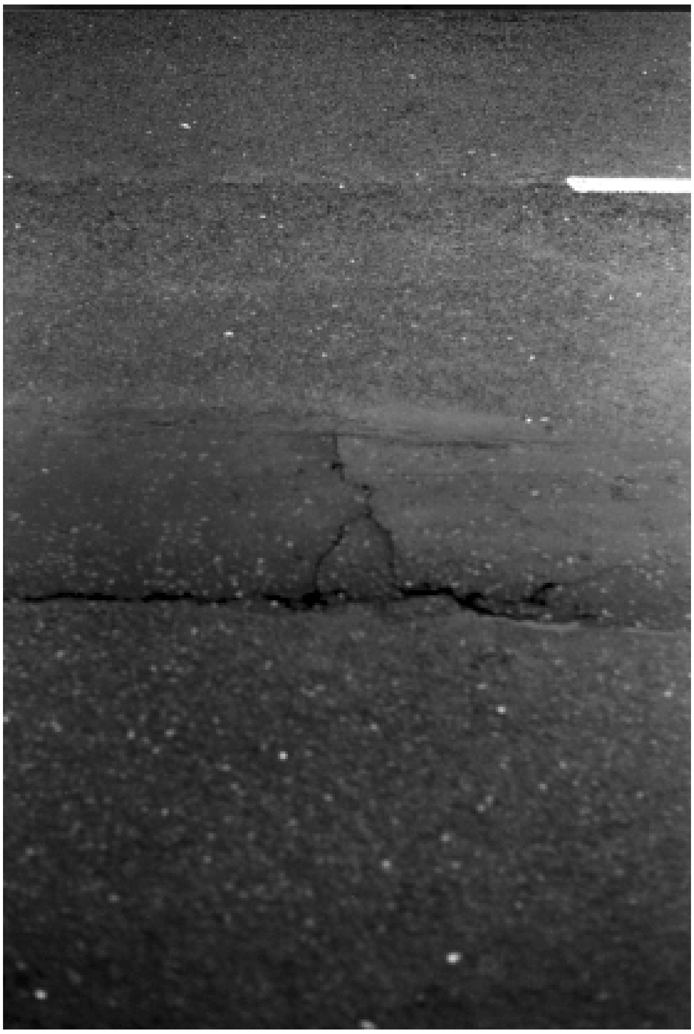

Figure 7 Crack emerging on Greenford Road

Figure 8 Transverse variation in the texture on the A4

that on the nearside lane of the A1 northbound, for sensor-measured texture depth, dropped by only 15 per cent in the wheel-paths after two years.

The deformation resistance of SMATEX is very good and would comply with both categories of Clause 943 of the *Specification for Highway Works* (MCHW 1). This performance is as expected from a properly-designed stone mastic asphalt. The structural properties of elastic modulus and fatigue are acceptable; however, these properties are not required of a surfacing material.

The durability can only be fully proved by experience of the full service life of the material. However, the indications are that it should be good, provided that adequate control of the proposed grading and binder content is maintained; the record from Greenford Road indicates that control could be improved.

The additional properties that are most desirable at present are those that minimise the impact of a road on the environment, in particular noise and spray. The noise reduction with SMATEX is similar to, or greater than, that achieved by other thin surfacings, but it is not as great as that of porous asphalt. The spray reduction is likely to be about half that of a semi-porous thin surfacing, assuming that spray-reduction is proportional to hydraulic conductivity. Therefore, SMATEX can contribute to the environmental acceptability of highway surfacings.

9 Conclusions

The principal conclusion from this review of data on SMATEX is that the material with a nominal maximum aggregate size of 14 mm has completed the Highways Agency 5 stage procedure for evaluating new materials. As such, it was granted Type Approval by the Highways Agency for use on trunk roads, including motorways, in England as a thin surfacing in accordance with Clause 942 by the Highways Agency. This approval is valid until the BBA-HAPAS scheme for thin surfacings is fully operational.

The particular findings were:

1 14 mm SMATEX has achieved the minimum texture depth of 1.5 mm required for high-speed trunk roads.

2 SMATEX can provide the appropriate skid-resistance that would be expected, although there is a more extended period after laying before the binder film is removed by traffic than for some other materials.

3 SMATEX has good deformation resistance properties, as measured by the wheel-tracking test at 45°C and 60°C.

4 SMATEX has stiffness modulus and fatigue characteristics which, while being marginally less than hot rolled asphalt, are of the same order as those of similar materials.

5 SMATEX will generate less noise than a hot rolled asphalt surfacing; the level is similar to or better than that of other thin surfacings bur not as quiet as porous asphalt.

6 14 mm SMATEX, after being heavily trafficked for three years, shows no obvious major defects or signs of distress.

10 Acknowledgements

The work described in this paper was carried out in the Infrastructure Division of the Transport Research Laboratory. The assistance of Mr D M Colwill, OBE, in reviewing the paper is acknowledged.

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Appendix A: Highways Agency procedure for evaluating new materials

The procedure for evaluating new materials is carried out in five 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 organisation. 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.

Appendix B: Inspection panel marking scheme

Table B.1 Basic 7-point scale

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

Table B.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.

Abstract

Proprietary thin surfacings are being offered by materials suppliers in the United Kingdom, including SMATEX by Bardon Aggregates Limited (now known as Aggregate Industries Limited). Information has been assembled on the properties and performance of SMATEX, with particular emphasis on the section of the A1 at Eaton Socon, where the material was laid in June/July 1995. SMATEX has been assessed and found to comply with all stages of the *Highways Agency 5-Stage Procedure for Evaluating New Materials* and has been granted Departmental Type Approval by the Highways Agency for use as a thin surfacing on trunk roads, including motorways, in England.

Related publications

TRL434 *Assessment of THINPAVE, a Bardon thin asphalt surface course* by J C Nicholls. 2000 (price £25, code E)

TRL314 *Road trials of stone mastic asphalt and other thin surfacings* by J C Nicholls. 1998 (price £35, code H)

TRL292 *Assessment of MILLOM HITEX, the Bardon thin asphalt surface course* by J C Nicholls. 1998 (price £20, code C)

TRL234 *Highways: principles to practice edited* by R Hosking. 1997 (price £50, code P)

PR79 *Road trials of thin wearing course materials* by J C Nicholls, J F Potter, J Carswell and P Langdale. 1995 (price £35, code H)

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