Improving the Performance of Asphalt Surfacing

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ABSTRACT: A recent review of the performance of asphalt surfacing used in Scotland revealed examples of very short service lives and, in some instances, an inadequate provision of early-life skid resistance. As a result, Transport Scotland commissioned research to improve road surfacing to make it safer and more sustainable. Based on emerging experience from both the UK and Germany, road trials comprising eight stone mastic asphalt (SMA) materials using nominal aggregate sizes of 14, 10, 8 and 6 mm were laid on the M8 between Edinburgh and Glasgow. Four of the trial surfacings were treated with grit to improve early life skid resistance. The study to date has shown that the SMAs provide a very good riding quality surface with low noise and, owing to the low voids contents and higher bitumen contents targeted, a denser surfacing with the potential for improved durability. Wet locked-wheel friction measurements, at speeds ranging from 20 to 120 km/h, have been taken over the early life phase of the study and indicate some potential advantages in using grit. This relates particularly to high values measured prior to opening the surfacing to traffic. The trials are currently being monitored to provide further information on the modified SMA surfacings. Following confirmation of material characteristics and skidding performance, results will be used to recommend changes that optimise the needs for safety and durability for Scottish conditions.

KEY WORDS: SMA, durability, skid resistance.

1 INTRODUCTION

Transport Scotland, the national transport agency for Scotland, commissioned research to make surfacing safer and more sustainable. The work was prompted by reports of poorly performing material and observations during annual surfacing inspections. The latter are carried out by a team of surfacing experts who have assessed many new surfacings as having poor long term durability.

Experience from Germany has shown that improved durability can be achieved using denser, smaller-stone mixtures that possess a lower surface texture depth than surfacings normally used in the UK. Road trials in the UK are currently showing a trend for some smaller-stone mixtures to provide relatively higher skid resistance at both low and high speeds. Based on this emerging experience, a three stage study was implemented:

- Trial mixtures – Based on the latest research, prepare a new material specification that will improve material durability and enhance early life skid resistance.

- Evaluation – Carry out road trials to provide information on the performance of the trial mixtures, particularly their early life skidding resistance.
- Recommend changes to the current specification based on findings of the road trials and observed surfacing performance

This paper describes the findings of the study to date. It provides a brief background on the use of Stone Mastic Asphalt (SMA) in Scotland, and describes the design of road trials using surfacing with similar compositions to those used in Germany. Information on the trial material properties and characteristics, visual appearance and skid resistance performance after 10 months in service is reported.

2 BACKGROUND

Interaction with European developments in asphalt technology during the 1990s brought about a change in the type of road surfacing used across the UK. The introduction of new surface courses, known as thin surfacing systems, was driven by a range of factors, including the need for improved deformation resistance, speed of application, noise and spray reduction, and changes to traffic management practices (Nicholls, 2002). One of the most popular types of thin surfacing system is known as stone mastic asphalt (SMA).

2.1 Experience in Scotland

Since the late 90s, the use of SMA and other thin surfacing course systems have effectively replaced hot rolled asphalt (HRA) as the standard surface course material for trunk roads and motorways. The first SMAs used in Scotland were based on modified European mixture designs. An important difference was that the gradings and nominal aggregate sizes were adjusted to meet UK surface texture requirements. SMAs using smaller aggregates (0/10 mm, 0/6 mm) were considered unable to routinely meet the 1.5 mm texture depth required for new surfacing used on high speed roads. The consequence is that most Scottish SMAs are made using two nominal aggregate sizes: 0/14 mm and 0/10 mm. In general, they are laid at least 40 mm thick and are produced as proprietary products that contain either fibres or polymer-modified bitumen. Currently, the larger 0/14 mm aggregate size dominates the market because contractors find it easier to achieve the 1.5 mm texture depth requirement. Compared to German SMAs, the Scottish materials possess a more open texture on the surface of the mat and have shorter service lives.

3 TRIAL MIXTURE SPECIFICATION

As part of preparing a trial mix specification, study visits were made to Germany to obtain information on material design and construction practices, including the need to improve the early-life skid resistance on new surfacings by gritting new surfaces at the construction stage.

A draft specification for the trial was produced in accordance with the PD 6691 (BSI, 2007). The specification includes requirements for component materials, composition, air voids content, binder drainage, water sensitivity, resistance to permanent deformation, and temperature of the mixture. The document also describes the requirements for grit application to the surface course, including the type of grit, grading, binder content, spread rate, rolling and sweeping. It was agreed that the trials would be used to ‘fine tune’ the grit application process for incorporation in any future specification. The target grading of the mixtures is shown in Table 1.

Table 1: Limits for target composition of the SMA mixtures

D (mm)	6	8	10	14
Sieve	Proportion passing sieve (% by mass)			
20	–	–	–	100
14	–	–	100	93 – 100
12	–	100	–	–
10	100	–	93 – 100	35 – 60
8	–	93 – 100	–	–
6.3	93 – 100	–	28 – 52	22 – 36
4	22 – 45	22 – 40	–	–
2	20 – 34	20 – 33	20 – 32	16 – 30
0.5 *	–	–	–	–
0.25 *	–	–	–	–
0.063	8 – 14	8 – 14	8 – 13	6 – 12
B_{act} (% by mass)	6.6	6.4	6.2	5.8

4 EVALUATION TRIALS

The trial was made possible with the co-operation of Aggregate Industries Limited. The specific aims of the trial were:

- Evaluate the potential of SMA utilising smaller aggregates.
- Measure the effect of reduced texture on skid resistance.
- Assess the influence of treating SMA with grit.
- Identify any difficulties in the design, manufacture and laying of SMA to the trial mixture specification.

4.1 M8 Trial Description

The trial incorporates eight 150 m long test panels that are one lane wide and run sequentially for a total 1.2 km. Four of the panels are un-gritted and contain 0/14 mm, 0/10 mm, 0/8 mm and 0/6 mm materials. The remaining four panels match the former in terms of mixture composition, but are gritted. A schematic diagram of the trial is shown in Figure 1.

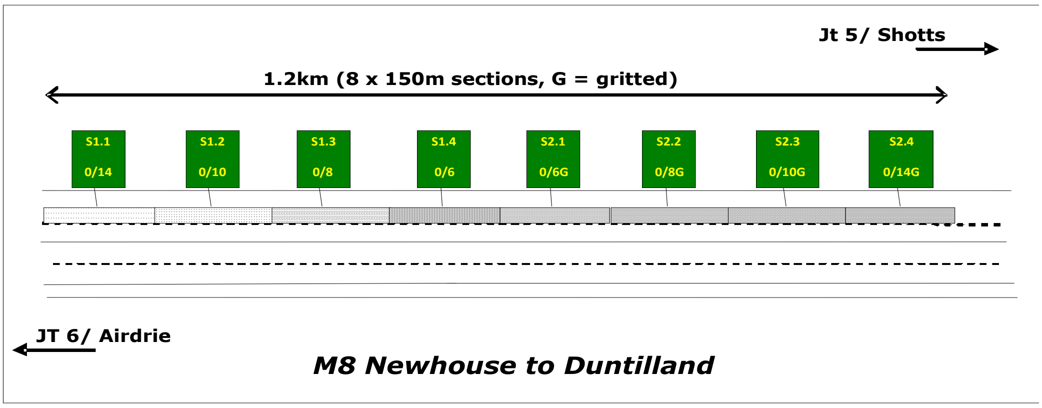

Figure 1: Schematic diagram of trial site

4.2 Laying and Compaction

The trial panels were laid over two days in 10 November 2008. A satisfactory and uniform surface texture was achieved under the cold and breezy conditions (5 °C with a wind speed in the range 9 to 25 km/h). The contract required that the surfacing materials were to be laid without transverse joints. Three 8-10 tonne vibratory tandem rollers were used to compact the material. The tandem roller operating closest to the paver compacted the material without vibration, but vibration was used when compacting the material adjacent to the longitudinal joint.   The materials had the appearance of being durable (rich in binder) but no significant signs of flushing during compaction were noted.

A 1/2.8 mm lightly coated grit was used on the trial. The grit was applied from a hopper attached to the front of a roller (Figure 2). Following an initial two or three passes by the roller, the grit was applied at a rate of 1 kg/m2. Final compaction of the gritted surfaces was achieved using a static triple-roller. Figure 3 illustrates the 0/14 mm material before and after gritting. Surplus grit was swept from the carriageway prior to the road being opened to live traffic.

Figure 2: Gritting process

Figure 3: Close-up of 0/14mm before (left) and immediately after gritting (right)

5 MATERIAL TESTING

Details of the materials laid on the main trial are given in Table 2. Compositional analysis on fifteen samples taken over the two-day trial showed reasonable compliance on aggregate grading. Only two samples showed non compliance: one 0/8 mm sample was slightly coarse; and one 0/14 mm sample was slightly fine.

Tests for binder contents in accordance with clause 5.2 of BS 598-102 (BSI, 2003c) showed the 0/14 mm and 0/8 mm SMA were found to be lower than specified. A summary of the results is shown in Table 3.

Table 2: Details of materials laid

SMA Mixture	14 mm	10 mm	8 mm	6 mm
Aggregate	Quartz-dolerite (Duntilland, North Lanarkshire)			
PSV	61			
AAV	6			
Magnesium sulphate	3			
Los Angeles (LA)	16			
Filler	Limestone			
Stabilising agent	Cellulose fibres			
Binder pen.	40/60			
Mean air voids content (%) (In-situ density gauge)	5.2	4.1	5.0	5.4

Table 3: Binder contents

SMA Mixture	14 mm	10 mm	8 mm	6 mm
Binder content (%)	5.7, 5.7, 5.5	6.9, 6.7, 6.8, 6.9	6.4, 7.7, 6.5, 6.9	6.9, 7.4, 7.1, 7.0
Spec. minimum (%) (Based on ρ_b*)	6.1	6.5	6.7	6.9

* ρ_b – mean particle density of aggregate taken as 2.790 Mg/m^3.

6 SURFACE CHARACTERISTICS

The trial comprises a number of SMAs that, owing to different aggregate sizes and compositions, possess different surface characteristics. A range of measurements were taken to assess this feature to allow comparisons with conventional materials, both in the longer term and during the early part of the life of the road while the bitumen film that initially covers the running surface of the road is present.

Measurements were made when the surfacings were newly-laid in November 2008, prior to opening to traffic, after three days of traffic, six months of traffic (May 2009), and 10 months (September 2009).

6.1 Testing Devices

Four types of measurement were undertaken as part of the trial:

- Sensor-measured Texture Depth (SMTD)
- Sideway-force coefficient (SFC)
- Grip Number (GN).
- Locked-wheel sliding friction (Friction Number, Fn)

All of the measurements were undertaken using specialised test vehicles. They carry special test wheels that are fitted with force sensors. The test wheels are either built on to the chassis or as one wheel of a trailer. The truck or tow vehicle carries a water tank to feed water at a controlled rate in front of the test wheel when measurements on a wet surface are required.

All the devices are shown in Figure 4. SCRIMtex measures SCRIM coefficient (SC) and is the standard device used to monitor wet skid resistance on UK trunk roads. The machine also carries a laser sensor to measure sensor-measured texture depth (SMTD). GripTester is a small trailer that measures skid resistance as “Grip Number” (GN) with a small test wheel mounted near the centre of the trailer; a gear arrangement makes the test wheel rotate more slowly than required for the vehicle speed, inducing about 15% slip. The Pavement Friction Tester (PFT) measures locked-wheel friction number (Fn) with a special smooth test wheel located on the left side of the trailer. During a test, the wheel is braked so that it locks momentarily while being towed over the surface at a steady speed.

Skid resistance depends on speed and so measurements are made at different speeds with the different devices. For each measurement, whichever device is used, the vehicle is operated at the chosen steady speed throughout a test run over the trial sections. SCRIMtex and GripTester were used to take measurements at 50 and 80 km/h. The PFT was used to take measurements at 20, 50, 80, 100 and 120 km/h. Some were made on the dry road surface, others using the device’s built-in wetting facility.

Figure 4: SCRIMtex (top left), GripTester (top right) and PFT (above).

6.2 Testing schedule

Skid resistance is a key safety parameter of any road surfacing that varies considerably over its life. A similar pattern of measurements was taken before opening to traffic, and then after three days, six months and ten months of traffic. It has been possible to gain an insight of the evolution of the behaviour of the materials relating to the three main phases of a road’s service life, viz. early life, polishing, and equilibrium.

The early life phase covers the initial period during which a film of bitumen that covers the surface of the newly-laid material gradually wears away to expose the aggregate that will eventually provide skid resistance over the bulk of the service life of the road. It generally lasts from about two to six months (in the wheel paths). The second phase can be described as a polishing phase in which aggregate exposed at the surface is gradually polished by traffic, particularly heavy vehicles, until skid resistance eventually reaches the final stage of equilibrium. The time taken for this process is influenced by a number of factors, including the traffic level, the time of year at which the surfacing is laid, the amount of bitumen initially on the surface and the time the bitumen takes to wear away. The third phase covers most of the life of the surfacing. In this phase, skid resistance varies cyclically through the year as a result of what is known as "seasonal variation". It is at its lowest in mid-summer and highest in the winter but usually remains at an equilibrium level.

6.3 Texture depth

Figure 5 shows the texture depth measured after ten months using the laser sensors on the SCRIM machine along the site, both in the wheel path and the centre of the lane (which has been traversed by the wheels of much less traffic). As would be expected, there is a marked difference between the two more open-textured 0/14 mm materials, i.e. control section and 0/14 mm. However, the effect of using grit on the 0/14 mm has reduced the texture depth on this section. There is a noticeable difference between the two test lines, suggesting that traffic has further compacted the material in the wheel path to close up the texture.

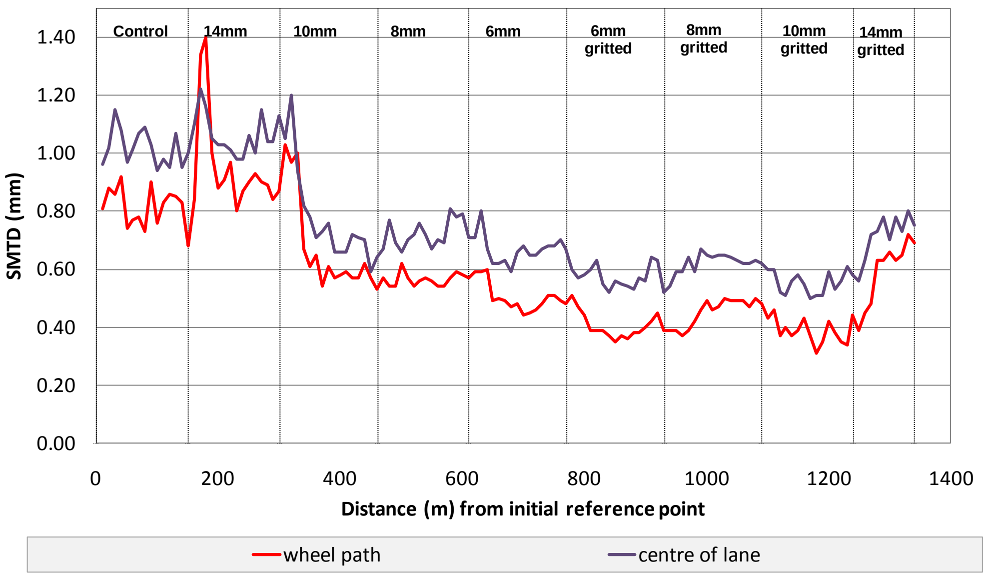

Figure 5: Texture depth along the trial site after 10 months of traffic

6.4 Low-speed Skid Resistance

Figures 6 shows the low-speed skid resistance measured along the site in the wheel path using SCRIM at 50 km/h at ten months, with the lines for the three-day and six-month visits included for comparison. It can be seen that after three days there was a marked difference between the gritted sections and the un-gritted lengths. The graph clearly demonstrates the transitional condition of the surfacing and the onset of polishing by traffic. In the trafficked wheel path the polishing process is clearly well established.

After 10 months, there is little or no difference between any of the trial sections and the skid resistance level had fallen below 0.60 SC. This was still a good level of skid resistance but it would be expected to increase slightly during the winter of 2009/10 and then decrease again towards its equilibrium level as a result of polishing during the following summer.

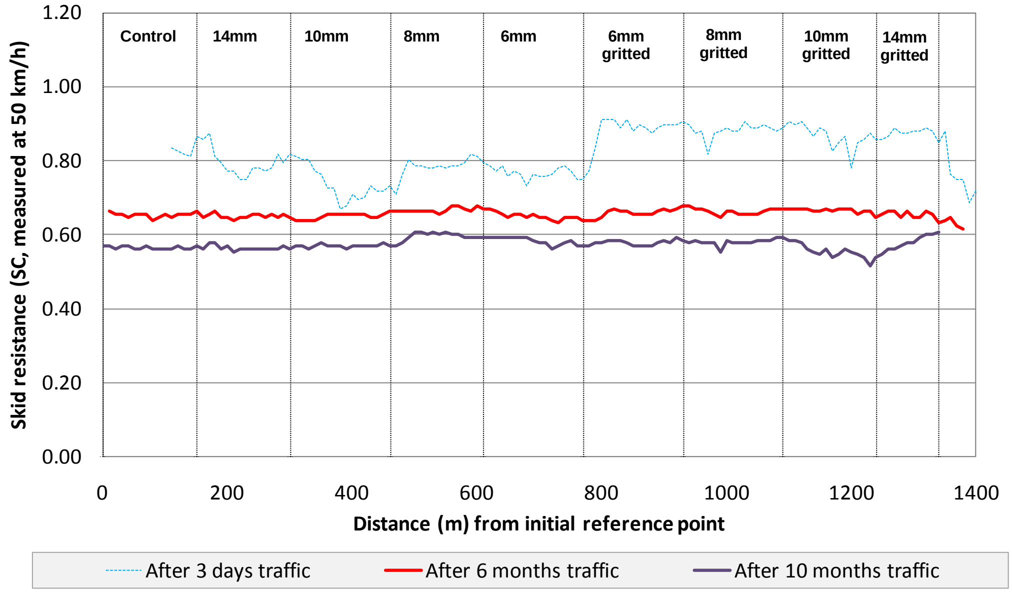

Figure 6: Skid resistance measured by SCRIM over time in the wheel path

6.4 Skid Resistance on the Newly Laid Surfacings

Having observed that low-speed skid resistance is generally very high on the newly-laid surfaces, and broadly similar for all four of the trial materials, the next stage of analysis was to consider what the behaviour might be at higher speeds. Figure 7 comprises two three-dimensional graphs illustrating the average Fn measured with the PFT at different target speeds on the various test sections before opening to traffic. Figure 8 shows the equivalent data after 3 days of traffic.

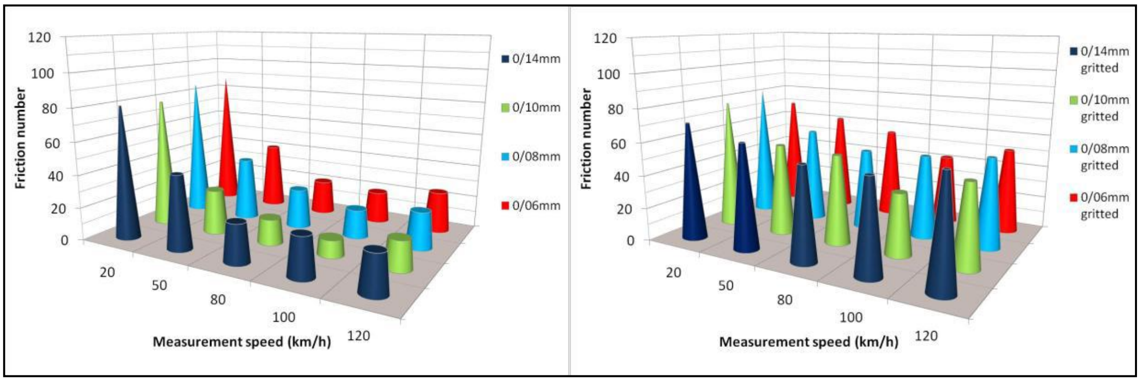

Figure 7: Effect of speed on wet friction for the un-trafficked surfaces

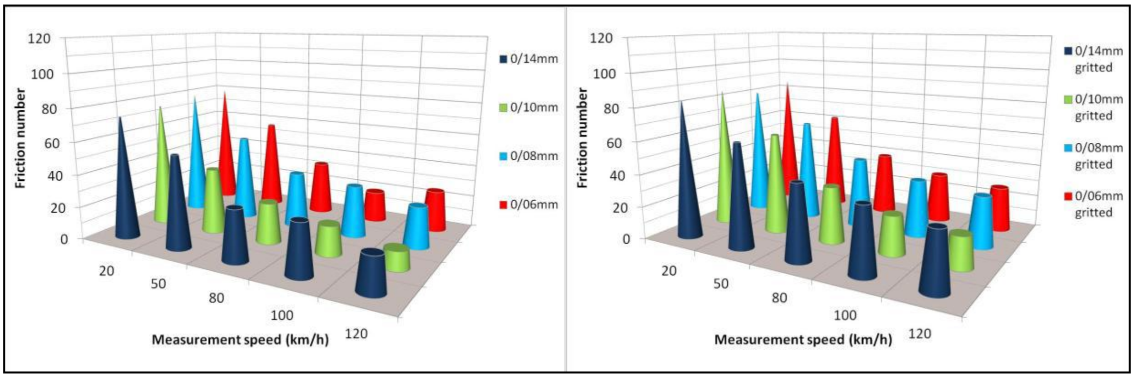

Figure 8: Effect of speed on wet friction after 3 days of traffic

The results of this analysis show that before trafficking, the un-gritted sections (the left-hand graph in Figure 7) show the classic reduction in friction with increasing speed but the gritted sections show almost no change. After trafficking, both the un-gritted and the gritted sections show a reduction in friction with increasing speed. The un-gritted 0/10 mm section gave particularly low Fn values at higher speeds compared with the other sections, especially at intermediate speeds, possibly reflecting the "dip" observed with SCRIM (Figure 6). It would appear that there may have been something unusual about this particular trial panel that would merit further investigation.

6.5 Comparison with Historic Data on other Surface Types

Figure 9 plots the Fn values at 20 and 100 km/h after 10 months against texture depth for the wheel path and superimposes them on historic data (which have been greyed-out for greater clarity). Un-gritted sections are represented with square markers and gritted sections with circles; values at 20 km/h are shown with open symbols and those at 100 km/h are filled.

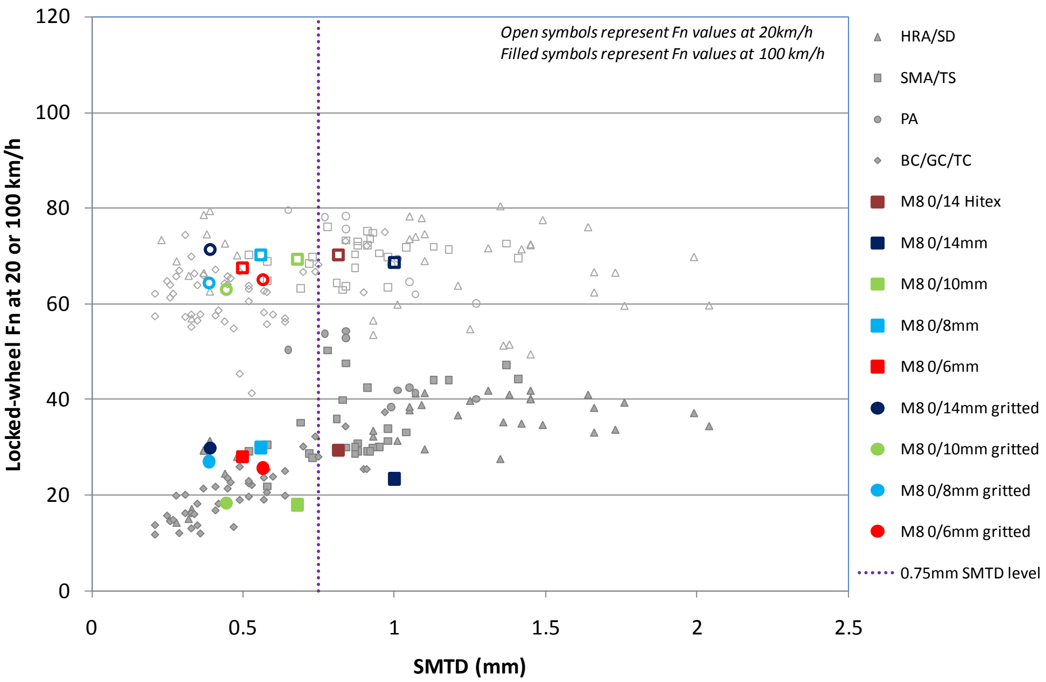

Figure 9: Locked-wheel friction and texture depth at 20 and 100 km/h

From Figure 9 it can be seen that after 10 months of traffic, all the trial surfaces performed well at low speeds, regardless of their texture depth. The 0/6 mm, 0/8 mm and 0/10 mm materials all had texture depths below the 0.75 level which is used in the UK to warn of potential loss of high-speed friction on in-service roads. With the exception of the 0/6mm materials, the gritted sections have lower texture depth than the un-gritted sections, suggesting that the grit has filled the texture to some extent. All of the materials fall at or below the Fn = 30 level. The 0/10 mm has particularly low high-speed friction. At this time, high-speed friction for the 0/14 mm and 0/8 mm gritted sections was at the upper range for their texture depth.

7 SUMMARY

The M8 trial to date has shown that SMAs, with similar compositions to those used in Germany, can be successfully manufactured and laid. The trial surfacings provide a good riding quality surface and, owing to the low voids contents and higher bitumen contents targeted, a denser surfacing with the potential for improved durability. Compared to the original hot-rolled asphalt (HRA) surface, reduce traffic noise on average by 3 dB(A). In traffic noise terms this corresponds to halving the traffic flow, and for the ungritted 0/6 mm SMA, the reduction was equivalent to a four-fold reduction in traffic flow.

The overall objective of this ongoing research is to produce a specification that optimises the safety and durability performance of road surfacings for Scottish conditions. Based on a comparison of historical friction and texture data collected across the UK, the trial surfacings are currently performing well at low speeds but producing lower locked-wheel friction at high speeds. At present, a minimum texture depth is specified for new surfaces to limit loss of friction with increasing speed, but there are no explicit requirements regarding in-service levels of high-speed friction on UK roads, However, with the advent of a wider use of surfacings with smaller aggregates and lower textures, some kind of criterion is needed that will allow specifiers and manufacturers to optimise durability while providing acceptable high-speed friction performance. Further skid and friction testing is planned for the summer of 2010 to provide longer term skid resistance performance of the materials on the M8. The collection of friction data using the PFT test on equivalent German materials in-service is being considered.

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