

New surface course specification for Scotland

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1 Introduction

European developments in asphalt technology in the mid-1990s brought about a change in the type of road surfacing used across the UK. The introduction of proprietary surfacing systems, known as “thin surfacing”, 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.

In general, the use of these new materials was welcomed in Scotland by both the road industry and road users. However, in 2006 there were several reported incidences of new surfacing deteriorating after only short periods in service. Safety concerns were also expressed regarding the presence of excess binder that could lead to a reduction in skid resistance.

In response to the above, Transport Scotland commissioned a programme of research to review the performance of thin surfacing laid on the Scottish Trunk Road Network. This comprised site inspections to identify and quantify surfacing defects. Industry professionals were invited to a series of workshops to discuss the findings of the review and suggest possible remedies to improve the performance of surfacing.

One outcome of these workshops was the creation of the Transport Scotland Pavement Forum (TSPF) in 2007. This group was established to encourage communication between clients, designers and suppliers/contractors and to promote and develop best practice across the road industry.

In an effort to improve the performance of surfacing and provide increased estimates of service life, annual monitoring was implemented by the TSPF. This consists of a group of surfacing experts known as the “Scottish Inspection Panel” (SIP).

A major recommendation resulting from the annual SIP surveys was that efforts to reduce the open texture appearance of surfacing by specifying the use of denser mixes using smaller stone sizes should be explored. As a result, a study visit was made to Germany to gain first-hand knowledge of current practices and experience. The visit highlighted the use of denser, smaller stone mixes with increased binder coating to enhance durability. The application of crushed grit to newly-laid surfacing to increase early-life skid resistance was also observed as standard practice.

Based on the above, and the fact that UK road trials (Roe *et al.*, 2008) were showing a trend for smaller stone mixtures to provide higher skid resistance, a road trial was arranged to test materials based on German specifications and experience. The trial comprised eight stone mastic asphalt (SMA) materials using nominal aggregate sizes of 14 mm, 10 mm, 8 mm and 6 mm. The materials were laid on the M8 between Edinburgh and Glasgow in 2008 and industry representatives were invited to attend.

The trial allowed the performance of the new surfacing and the German practice of using grit to be examined. It also provided the opportunity to identify any difficulties in the design, manufacture and laying of the SMA mixtures. A second visit was made to Germany to discuss the findings of the trial and quality production issues prior to finalising a new surface course specification.

This TRL Report describes the development path to a new surface course specification to be used on new construction and maintenance work on Scotland’s Trunk Roads. Following careful monitoring by Transport Scotland, it is intended that the new specification will be considered for general use.

2 Surface course

2.1 General

The surface course is the most demanding layer of a road pavement in terms of material requirements and properties. It needs to provide a running surface for road users and, in conjunction with the binder course, a seal against water infiltrating and harming the lower pavement layers. The surfacing is required to have a high resistance to permanent deformation and abrasion, and also provide good friction for safety reasons. It is also desirable to reduce noise levels generated, particularly if the road is near populated or noise-sensitive areas.

Asphalt surfacing is by far the most popular material for surfacing roads around the world. Asphalt surfacings differ in type by the proportion of different size aggregate (crushed rock), the amount of binder (bitumen) added and the presence of other additives. The binder used to hold the aggregate needs to be both reasonably stiff during hot weather and reasonably ductile during cold weather. Unlike the lower layers, the surface course experiences greater extremes of temperature and exposure to ultraviolet radiation.

2.1.1 Thin surfacing

Traditional asphalt surfacing in the UK consisted of a 40 mm or greater thickness of hot rolled asphalt (HRA) or dense bitumen macadam (DBM). In the mid-1990s, new technological advances in asphalt led to various thin surfacing systems being trialled in the UK (Nicholls, 2002). Originally developed in France and Germany, thin surfacing systems were modified to conform to UK surface texture depth requirements. The main advantages of thin surfacing include ease of installation and application, increased deformation resistance, noise and spray reduction properties and a relatively low initial cost.

In addition to the technical advances, new safe working practices were introduced by the Health and Safety Executive in the mid-1990s. The requirement for a safety zone between road works and the edge of live traffic meant that the application of chippings to the surface of HRA became problematical. In many instances, the width of the chipping machine, after including a safety zone, meant the operation could not proceed without a complete road closure. This new constraint was a significant factor in increasing the use of thin surfacing systems. As a result, thin surfacing quickly became the preferred choice of many specifying bodies and effectively replaced HRA as the standard surfacing material for trunk roads and motorways.

2.2 Scottish approval process

The approval process for thin surfacing systems laid on the Scottish Trunk Road Network has tended to require a more project-specific approach than the BBA-HAPAS certification scheme adopted in England. It recognises that many asphalt plants and quarries are required to supply the more remote and less developed parts of the country. The plants often produce small quantities of material and the low demand on production has, in some cases, resulted in suppliers not being able to justify the expense of the BBA-HAPAS approach. The diversity in mineral geology in Scotland also means that the BBA-HAPAS approach would, in theory, have to be applied to a large number of plants, because the aggregate properties change significantly from one area to another.

BBA-HAPAS-approved thin surfacing is accepted by Transport Scotland via its own approval system, but suppliers without BBA certification are requested to provide specific information and are given different levels of approval depending on the performance of the thin surfacing on the network. Approval can be withdrawn at the discretion of Transport Scotland.

3 Review of thin surfacing performance (2006)

3.1 Site selection

Information on existing surfacing schemes was collected from a range of sources including the Scottish Executive Road Information System, the Performance Audit Group, operating companies and asphalt suppliers. The information was used to shortlist a selection of sites that were considered to represent examples of surfacing that had performed well and not so well on the Trunk Road Network. Sites were also selected in an attempt to represent a good range of surfaces in terms of climate, terrain, traffic and surfacing type. A total of 57 sites were selected.

Table 3.1 provides information on the sites inspected, including material type, year laid and age at the time of inspection. The sites have been allocated specific acronyms for ease of reference while retaining anonymity. Average visual condition markings for each site are also given. The method of inspection, marking system and the fault types are described in detail in the Appendix.

3.2 Visual condition results

The sites were assessed visually and ranked in accordance with the TRL inspection panel methodology (Nicholls, 1997). The mean visual condition marks for the 2006 survey are shown in Figure 3.1. The assessment attributes a mark (*E*, *G*, *M*, *A*, *S*, *P*, *B* or midway between two adjacent marks) plus, when appropriate, defect suffixes to each site.

Table 3.1 Inspected sites

<i>Site no.</i>	<i>Year laid</i>	<i>Age (years)</i>	<i>Mark*</i>	<i>Site no.</i>	<i>Year laid</i>	<i>Age (years)</i>	<i>Mark*</i>
TAC1	2004	2.0	<i>M/A</i> _{-v}	TAC11	1999	7.3	<i>G/M</i> ₋
TAC2	2002	4.6	<i>S</i> ₋	TAC12	1999	7.0	<i>G</i>
TAC3	2002	4.6	<i>S/P</i> _{-s,v}	TAC13	2000	6.0	<i>M</i> ₋
TAC4	2001	4.9	<i>S</i> _{-s,v}	TAC14	1999	7.3	<i>G/M</i> _v
TAC5	2003	3.0	<i>G</i>	TAC15	2001	5.0	<i>G</i>
TAC6	2005	1.5	<i>M/A</i> _{+v}	TAC16	2001	4.8	<i>G/M</i> ₋
TAC7	2005	1.5	<i>G</i>	TAC17	2004	2.5	<i>G</i>
TAC8	2006	0.6	<i>M/A</i> _{g,v}	TAC18	2000	6.0	<i>G</i>
TAC9	2005	1.0		TAC19	2005	1.5	<i>E</i>
TAC10	2004	2.3	<i>M</i> ₊	TAC20	2003	3.5	<i>G</i>
TSMA1	2000	6.0	<i>M</i> ₋	TSMA19	2003	3.8	<i>P</i> _{v,-d,s}
TSMA2	2001	5.0	<i>G</i>	TSMA20	2005	1.8	<i>G</i>
TSMA3	2000	6.0	<i>M</i> _{-v}	TSMA21	2002	4.8	<i>A</i> _{v,-c,t}
TSMA4	2001	5.0	<i>G</i>	TSMA22	2002	4.8	<i>M</i> _{-c}
TSMA5	2005	1.0	<i>G/M</i> _{+v}	TSMA23	2002	4.8	<i>G</i>
TSMA5a	2005	1.0	<i>M/A</i> _{+v}	TSMA24	2002	4.8	<i>A</i> _{-c}
TSMA6	2005	1.3	<i>M</i> ₊	TSMA25	2006	0.8	<i>A</i> ₋
TSMA7	2005	1.3	<i>G/M</i> ₊	TSMA26	2001	5.0	<i>M</i> ₋
TSMA8	2006	0.5	<i>G/M</i> ₊	TSMA27	2004	2.5	<i>G/M</i> ₋
TSMA9	2003	3.5	<i>E/G</i>	TSMA28	2002	4.0	<i>G/M</i> ₊
TSMA10	2001	5.0	<i>E/G</i>	TSMA29	2001	5.0	<i>M</i> ₋
TSMA11	2005	1.5	<i>M</i> _{+v}	TSMA30	2001	5.0	<i>A/S</i> _{-t}
TSMA12	1996	10.0	<i>E/G</i>	TSMA31	2005	1.0	<i>M/A</i> _{-s}
TSMA13	2000	6.0	<i>M</i> _{-v}	TSMA32	2006	0.8	<i>M</i> ₊
TSMA14	2003	2.8	<i>G</i>	TSMA33	2006	0.5	<i>S</i> _{-s}
TSMA15	2002	4.0	<i>B</i> _{-s,d,c,v}	TSMA34	2002	4.5	<i>M/A</i> ₋
TSMA16	2002	4.0	<i>S/P</i> _{-c,v}	TSMA35	2002	4.5	<i>G/M</i> _{-t}
TSMA17	2002	4.0	<i>G</i>	TSMA36	2001	5.0	<i>G/M</i> _{-t}
TSMA18	2002	4.0	<i>M</i> ₋				
PLSD1	1996	10.5	<i>M</i> ₋				

* = As assessed by TRL inspection panel (see Section 3.2).

TAC = thin asphalt concrete. TSMA = thin stone mastic asphalt. PLSD = paver-laid surface dressing.

E = Excellent. *G* = Good. *M* = Moderate. *A* = Acceptable. *S* = Suspect. *P* = Poor. *B* = Bad.

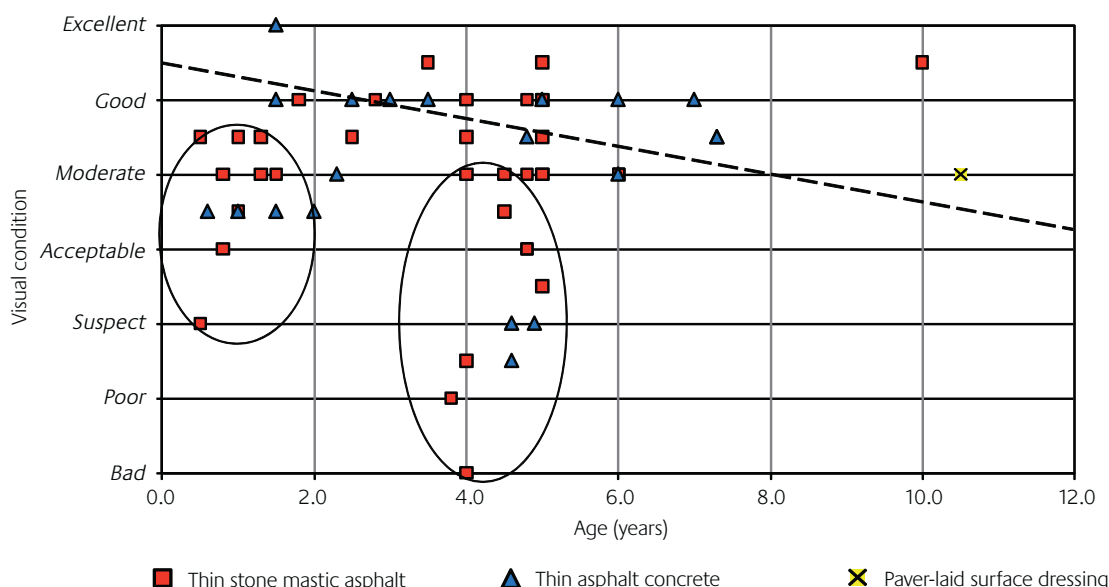


Figure 3.1 Average visual condition markings

Research carried out for the Highways Agency estimated that the average typical service life of thin stone mastic asphalt (TSMA) and thin asphalt concrete (TAC) is between 13 and 14 years (Nicholls *et al.*, 2010). This service life can be viewed as an optimum as it relates to a thin surfacing that has been manufactured and installed correctly in accordance with the appropriate specification.

The dotted line drawn on Figure 3.1 represents an idealised linear deterioration based on the Highways Agency data. The limit of serviceability for the surfacing is defined as when the visual condition drops to below *Acceptable*, i.e. 13 years.

The two circles superimposed onto Figure 3.1 highlight sites that were assessed to have low visual condition markings for their age. The circle on the left of the graph represents a cluster of sites that are less than two years old. In theory, these sites should be replaced or repaired under the manufacturer's warranty. However, the second circle, representing a cluster of sites that are between two and four years old, provided some evidence that this may not be occurring in practice. It is likely that the second circle represents materials that were previously in a poor condition after two years, but were not repaired under the warranty scheme and have deteriorated further. This theory was corroborated to some extent by anecdotal evidence. The findings of the survey raised concern that the applied thin surfacings were not representing good value for money.

3.3 Observed defects

3.3.1 Classification

Defects originating from the underlying layers were not considered when assessing the condition of the thin surfacing. For example, surfacing areas exhibiting structural rutting and localised failure were not marked down if other attributes were considered to be good, i.e. these other faults were not attributable to the surfacing itself.

Observed defects were divided into three main headings:

- loss of aggregate;
- loss of texture depth; and
- workmanship.

Examples of the defects recorded under these headings are given in Sections 3.3.2–3.3.4.

3.3.2 Loss of aggregate

Aggregate loss was the most commonly observed defect. Two main types were observed. The first related to new materials that appeared open in texture owing to a lack of fine aggregate or mortar. These materials were generally serviceable at the time of the inspection, but deemed to have poor long-term durability (Figure 3.2). It is considered that more permeable mixtures will allow greater access to water, resulting in the potential breakdown of the binder/aggregate matrix under trafficking.

The second type of aggregate loss observed is commonly described as fretting. This is where both coarse and fine aggregate are seen to be lost from the mix under the action of trafficking (Figures 3.3–3.5). In general, the severity of fretting was often related to the level of trafficking and type of site, i.e. highly stressed sites were more prone to fretting. Fretting can be a swift process and this was witnessed at Site TSMA33 (Figure 3.3) where the material was only six months old.



Figure 3.2 Surfacing deficient in fine aggregate (Site TAC8)



Figure 3.3 Surfacing showing excessive material loss (Site TSMA33)



Figure 3.7 General flushing of material (Site TSMA11)



Figure 3.4 Fretting of surface (Site TAC3)



Figure 3.8 Low surface texture depth (Site TSMA6)



Figure 3.5 Fretting of surface (Site TAC4)



Figure 3.9 Treated surface – after water jetting (Site TSMA8)

3.3.3 Loss of macrotexture

It is important that a surfacing provides an adequate level of macrotexture (or texture depth) in order to limit the loss of skid resistance at higher speeds. A number of sites exhibited areas of low texture depth. In certain instances, the incidence of low texture depth was confined to small discrete areas (Figure 3.6), but on other sites the defect was widespread (Figures 3.7–3.9). A loss of texture depth is often described as flushing or fatting-up, particularly where the loss is due to excess mortar being present on the surface. Figure 3.9 shows a low surface texture depth site that has been treated using a high-pressure water treatment to alter its surface characteristics by removing the binder.



Figure 3.6 Discrete area of low texture depth (Site TAC6)

3.3.4 Workmanship

Factors that can influence the overall quality of the surfacing include material manufacture, transportation and installation. A visual inspection, in itself, cannot categorically attribute the cause of poor quality, but it can assess the quality of workmanship associated with parts of the installation process. The most serious defects noted were related to the construction of joints. All asphalt surfacing joints are potential areas of weakness because they are likely to be less well compacted and can allow increased access to water penetration. It is important that joints are well constructed and sealed (Figure 3.10). On several sites that had been in service for several years, it was noticeable that joints were often the first place to show signs of deterioration (Figure 3.11), and subsequent deterioration often emanated from these points.

One site that was only one year old showed particularly poor joint construction and one sawn transverse joint showed no evidence of having being sealed (Figures 3.12 and 3.13).



Figure 3.10 Good joint at Site TSMA12 (ten years)



Figure 3.11 Fretting of joint at Site TAC4 (five years)



Figure 3.12 Poor joint construction at Site TAC9 (one year)



Figure 3.13 Sawn joint not sealed at Site TAC9 (one year)

3.4 Acceptable performance

Several sites were assessed as having a good visual condition for their age. One site in particular showed no significant defects and had been in service for ten years (Figure 3.14). There was a trend to suggest that schemes constructed as part of larger new construction contracts had performed well (Figure 3.15). However, there were also examples of smaller maintenance schemes that were assessed as performing well with little or no significant defects (Figures 3.16 and 3.17), demonstrating that thin surfacing systems could perform successfully in Scotland.



Figure 3.14 Site TSMA12 (ten years)



Figure 3.15 Site TAC11 (seven years)



Figure 3.16 Site TAC12 (seven years)



Figure 3.17 Site TSMA10 (five years)

4 Industry workshops

Following the review of thin surfacing performance in 2006, professionals representing the road industry were invited to workshops held on 3–4 May 2007 to discuss the findings. The first workshop comprised representatives from Transport Scotland and its agents (i.e. operating companies and the Performance Audit Group). The second workshop was attended by material suppliers and contractors. In total around 60 industry professionals were asked to address the following questions:

- Are we selecting the right surfacing materials for all locations?
- Is there adequate discussion between client and supplier?
- Is the quality of surfacing consistently of a high standard?
- Is the client receiving value for money?
 - If not, what are the causes of poor quality?
- What are the problems?
- How can material selection and workmanship be improved?
- Would material warranties help and how should they be regulated?

4.1 Material selection

It was concluded by Transport Scotland and its agents that the right material was not always selected. Examples of where inappropriate material selection occurred included high-stress areas such as slip roads, junctions, roundabouts and steep inclines. Bridge decks were also cited as locations where inappropriate material was often used. Reasons for poor material selection included the use of prescriptive specifications, lack of knowledge, ambiguity regarding who is responsible for making decisions, and programming pressures. It was suggested that designers need to undertake inspections of sites to assess the most appropriate material for the location. Some representatives felt that guidance on the selection of surfacing materials for different locations would be beneficial.

The supplier and contractor representatives broadly agreed that the right material was not always used and there was room for improvement. There was a temptation to use one material throughout a scheme in a “one size fits all” approach for convenience. It was stated that this was commonly reflected in specifications where Appendix 7/1 (Highways Agency *et al.*, 2008a) stated or inferred that the same material was to be used throughout the site. Some representatives felt that the current texture depth requirements were overly restrictive and often drove the selection of mixes, i.e. the supplier/contractor was reluctant to use a smaller stone size because it may not meet the 1.5 mm texture depth requirement and also may not win the contract on price. A lack of skills and knowledge was cited as a problem, e.g. the belief that a material containing a polymer-modified bitumen (PMB) was the optimum selection for all locations. Commercial considerations were stated to contribute to the choice or preference for a material. It was explained that rates for surfacing were priced well in advance of a contract and certain types of material may appear attractive for financial rather than engineering reasons.

4.2 Communication

Transport Scotland and its agents were split on whether there was enough discussion between client and supplier. Some felt that communication was good at the beginning of a project lifecycle such as the approval stage. However, more communication was required during the project and particularly towards the end. It was felt that discussions regarding the use of surfacing did not take place early enough in the project and the use of surfacing was often treated as an afterthought. Communication regarding defects and performance of a surfacing needed to be increased. The current procurement methods were cited as a barrier to good communication. It was recommended that a forum involving all stakeholders should be established to allow feedback of individuals’ experience to aid designers and suppliers.

Suppliers and contractors felt that there was not enough discussion between parties. Some suppliers felt they needed to be consulted earlier in the process, and questions asked were seldom answered. As a result, some issues were not resolved prior to the contract commencing. They felt they were not allowed to provide sufficient input, and when allowed to contribute it was often too late in the process. Tender documents were deemed to be too restrictive and alternative tendering should be considered to encourage discussion. It was recommended that a joint approach was required and Transport Scotland should engage in dialogue with both operating companies and all supply chain members.

4.3 Quality and value for money

Views on whether quality was consistently high were mixed. Some representatives felt that suppliers and contractors were taking more responsibility for quality. However, others felt that quality was compromised by factors outside their control, such as the time of year. Poor supervision was cited as leading to reduced quality, and it was felt that standards could be improved through better application and monitoring of sector (quality management) schemes. There was a consensus that the client was generally receiving value for money. This was based on everything going well, quality standards being achieved and taking into account all aspects, such as delays and disruption to the public. Some questioned whether surfacing could be laid thinner, and there was a desire to elevate the importance of sustainability. It was agreed that value for money was not being achieved if materials exhibited poor durability.

Suppliers and contractors felt that the quality of material was high most of the time. Improvements were cited such as computer-controlled plants and quality assurance schemes that considered transport and planning issues. There was a feeling that the suppliers and contractors delivered what was asked for. They felt the question (i.e. ‘Is the client receiving value for money?’) was subjective and they had a lack of knowledge of what the public perception was. Some questioned whether the lowest price resulted in the best product. The time of year that the works took place was cited as a factor affecting quality, with winter laying and night working leading to increased risk of defects. Poor quality was also suggested to be caused by external factors such as poor drainage and structural support.

The suppliers and contractors were less sure that the client was receiving value for money. Some felt the client may not be achieving value for money because specifications were based on short-term thinking rather than whole-life costing. Examples cited included the programming of schemes that would predominantly be undertaken in the winter, the use of lane rental and the fact that no quality criterion was demanded of the supplier.

4.4 Poor quality and problems

Transport Scotland and its agents cited the following factors as influencing quality and causing problems:

- poor design/specification resulting in the wrong material being selected for a site;
- lack of site supervision and the associated poor quality of workmanship;
- contract timescales, tight deadlines and restricted working hours;
- weather (rain, wind, low temperature);
- long haulage distances; and
- poor policing of sector schemes.

The suppliers and contractors added the following factors to the above:

- poor drainage;
- poor communication;
- shortage of suitably trained and experienced personnel with the loss of skills through lack of road building in the last 15 years;
- Transport Scotland resourcing problems;
- commercial pressures;
- manufacturing problems at plants;
- lane rental and other traffic restraints;
- transfer of risks and changes in procurement procedures;
- the quality of the product not being assessed or rewarded;
- joint construction and compaction control; and
- the future programme and the annual nature of expenditure.

4.5 Improvements

Delegates representing Transport Scotland and its agents felt more time should be allocated to allow consultation between client, designer and supplier/contractor. Training and guidance was required to improve the design and delivery of schemes. It was recommended that improved monitoring was required, particularly at the end of the maintenance period. Delegates generally felt that sector schemes required improvement. Consideration should be given to the use of thinner surfacing where appropriate, and techniques such as echelon paving should be encouraged wherever possible in order to minimise the occurrence of longitudinal construction joints.

The suppliers and contractors echoed the plea for better communication between parties at all stages of a road project. They felt incentives should be made to reward value engineering and there should be a willingness to accept alternative tenders. The weather was seen as a significant factor in reducing material quality and a plea was made to move the main volume of work away from the year-end towards better weather. The current system of budget setting and procurement timetables did not help. Best practice should be incorporated into current specifications. It was recommended that “close out” meetings after completion of a project involving all parties would improve future schemes by taking on board lessons learned. Information collected as part of the “close out” meetings should also be fed back to the technical forum recommended as part of improving communications.

4.6 Use of material warranties

There was a split in opinion as to whether a five-year warranty would assist in improving the standard of surfacing. Opponents queried the cost/value for money and the practicality of operating such a scheme. They felt it would be difficult to enforce on maintenance schemes (thin inlays), as opposed to reconstruction, and would generate contractual issues with schemes containing time restrictions, such as night working. Owing to the observation that most defective surfacing deteriorates in its early life, it was questioned whether five years was required. Transport Scotland and its agents felt that consultation was required to agree a protocol between all parties for the monitoring of schemes. The TRL seven-point scale was suggested as a possible assessment procedure.

Again, the response to a five-year warranty by the suppliers and contractors was mixed. Some felt it would improve quality, but at a cost. Others could see issues, including those caused by operating company contract changes, if they were forced to carry out the work over the winter months, and where the substrate conditions were less than ideal. In agreement with the client body, Transport Scotland and its agents felt a standard objective procedure needed to be established. One suggestion was that a two-tier system may be the best way forward: if the surfacing was assessed to be in *Good/Excellent* condition after two years then the warranty would be terminated, but if the condition was considered to be *Moderate* or below then the warranty would be extended to five years. Some felt that an independent body would be required on any panel to remove bias. There was a general agreement that a spin-off of such a system would be that it would encourage discussion and generate learning points.

5 Transport Scotland Pavement Forum

Poor communication was highlighted by the industry workshops as a key factor that cut across many of the issues debated. All attendees welcomed the opportunity for increased dialogue, particularly at a technical level. Transport Scotland set up the Surface Course Forum in 2007 to improve communication within the road industry. The name was later changed to the Transport Scotland Pavement Forum (TSPF) to reflect the increasing remit of the forum: to share knowledge, raise standards and implement good practice initiatives across Scotland. The TSPF membership includes representatives from Transport Scotland, Trunk Road maintenance companies, TRL, engineering consultants, material suppliers and other organisations or specialists, as deemed necessary by Transport Scotland.

5.1 Scottish Inspection Panel

One important topic given priority by the TSPF is to improve the durability and sustainability of surfacing materials used on the Trunk Road Network. In an effort to improve the performance of surfacing and provide an estimate of service life based on performance, an annual monitoring procedure has been implemented by the TSPF. It consists of a group of surfacing experts known as the Scottish Inspection Panel (SIP). The panel members represent Transport Scotland, the Performance Audit Group, the Quarry Products Association (QPA) Scotland and TRL. Each year the SIP is responsible for assessing the visual condition (Figure 5.1) of a random selection of surfacing sites from across the Scottish Trunk Road Network and identifying factors that affect service life in terms of both good performance and typical modes of failure.



Figure 5.1 Scottish Inspection Panel

5.2 Scottish Inspection Panel findings

Using a similar approach to the 2006 surfacing review, SIP sites are assessed visually and ranked in accordance with the TRL inspection panel methodology (Nicholls, 1997). Figure 5.2 shows the distribution of mean visual condition marks for the 2008, 2009 and 2010 surveys. The data relate to sites that were approaching two years in service. The nominal period of two years is selected as it is generally accepted that the condition of a surfacing after two years is a good indicator of its potential to achieve its predicted design life. In general a period of two years ensures that the surfacing has carried a reasonable amount of traffic and has been subjected to the environmental effects of seasonal change.

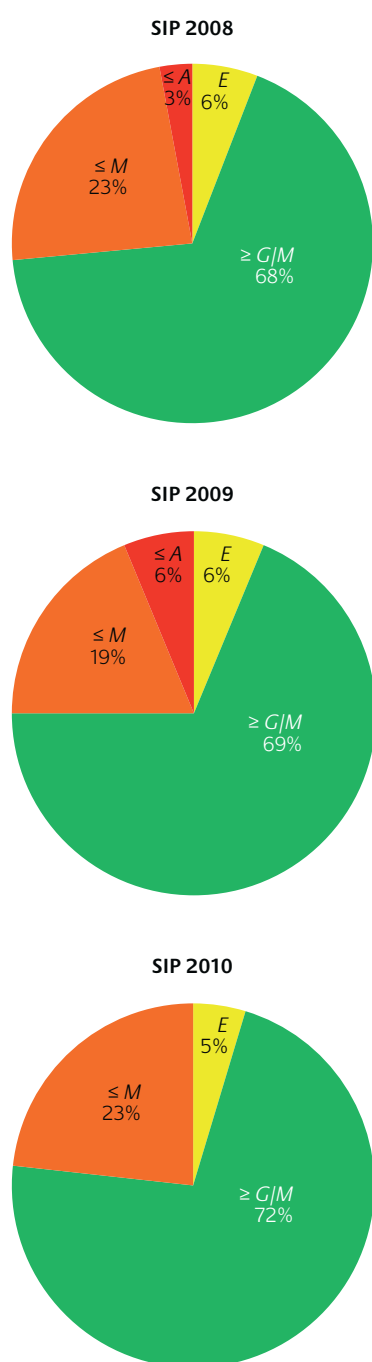


Figure 5.2 Scottish Inspection Panel survey results

The yearly markings over the three-year time period show a similar trend. Around 25% of the sites assessed each year represent sites that fall short of the standard expected. These sites are represented by the areas coloured amber and red. Most of these sites were assessed by the panel to have suffered some aggregate loss. The decision to give an inspected material an aggregate loss suffix is not always unanimous. This is partly due to the fact that the assessments are, in their nature, subjective. It is possible that aggregate has been lost from the mat, but it is also possible that the perceived defect is more related to an open texture that has existed since the surfacing was laid (Figure 5.3). Despite the truth of the matter, it is generally accepted that the observed open surface texture on some sites is likely to lead to future durability problems and a reduced service life, i.e. less than ten years.

One of the major recommendations resulting from the annual SIP surveys was that efforts to reduce the open texture appearance of surfacing by specifying the use of denser mixes and smaller stone sizes should be explored.



Figure 5.3 Open texture

6 Stone mastic asphalt in Germany

6.1 General

SMA was originally developed from a combination of asphalt concrete and gussasphalt in Germany in the 1960s to resist the wear of studded tyres. It made its first appearance in 1968 and incorporated asbestos as a stabilising additive. Initially, it was a proprietary product but recognition of its good performance led to its standardisation in the German Technical Specifications in 1984. A demonstration trial to evaluate the performance of SMA was arranged at TRL in 1994 (Nunn, 1994). The trial showed that SMA could be designed, produced and laid successfully using existing plant by contractors in the UK.

Today, it is widely used on the road network in Germany and variants of SMA have been adopted in many other countries. Experience in countries that have adopted SMA has shown it to be resistant to deformation and surface cracking. This resistance is due to its stable aggregate skeleton structure. The voids in the stone matrix are filled with a mastic of bitumen, crushed sand or filler to which fibres are added to prevent binder drainage. The addition of the latter increases the thickness of binder coating and thereby reduces the rate of oxidation.

In addition to good stability and durability, SMA when laid produces a good longitudinal and transverse evenness. The smooth surface is between 12% and 24% quieter than traditional surfacing such as HRA, depending on the maximum aggregate stone size of the SMA.

6.1.1 Experience in Scotland

Since the late 1990s, SMA-type thin surface course systems have effectively replaced HRA as the standard surface course material for trunk roads and motorways. The use of HRA has diminished considerably but still remains a popular choice for specific parts of the network, such as bridge decks and roundabouts.

The first SMAs used in Scotland, and throughout the UK, were based on modified German mixture designs. An important difference was that the gradings and nominal aggregate sizes were adjusted to meet UK surface texture depth 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 SMAs used in Scotland tend to produce a more open texture on the surface of the mat, have higher air voids and lower binder contents, and are therefore less durable than their German equivalents.

Most thin surface course systems used in Scotland are variants of SMA and are laid at least 40 mm thick. In most cases, they are produced as proprietary products and contain either fibres or PMB. They are made using two nominal aggregate sizes: 0/14 mm and 0/10 mm. In general, the larger 0/14 mm aggregate size dominates the market because contractors find it easier to achieve the 1.5 mm mean texture depth required for the new surfacing of high-speed roads. It is also cheaper to produce as less binder content is required for the larger aggregate size.

6.2 Current use of stone mastic asphalt in Germany

In November 2007, meetings and site visits were held in Erfurt and Munich to discuss policy, specification and technical matters associated with the use of SMA as a surface course in Germany. Formal presentations were given by representatives of Bavaria's Principal Building Authority (Oberste Baubehörde, OBB), which is part of the Bavarian State Ministry of the Interior (Bayerisches Staatsministerium des Inneren). The OBB arranged for 12 autobahn sites to be visited in the Munich area; these included inspecting SMAs ranging from new to 18 years old on the A96, A99 (Munich orbital) and A9. It was stated that the average service life expected from SMA was 16 years, with many sites providing 20 years of service.

6.2.1 Stone mastic asphalt mixture design

Copies of the current standard for surfacing, TL Asphalt-StB 07 (2007), were provided during the first visit to Germany. The technical guidelines describe three SMA mixtures that are currently used, i.e. 0/11 mm, 0/8 mm and 0/5 mm. It should be noted that Germany uses the basic plus set 1 sieve sizes whereas the UK uses the basic plus set 2 sizes. The document includes conditions and requirements for the mixture design of SMA, such as grading, binder type and contents, stabilisers, mixture compaction and air voids content, surface thickness and degree of compaction.

Bavaria's preferred choice of material is a 0/8 mm SMA because it is regarded as giving the best performance in terms of providing long-term durability and reducing noise emissions from heavy vehicles. A larger 0/11 mm SMA is also used on heavily-trafficked roads and autobahns. The materials include a lightly modified binder and fibres. The type of binder is dependent on the road traffic category but PMB 45 was reported to be common. Mixtures are designed to have a design air voids content of 2–4%, with < 6% in the constructed layer. Special mention was made of the importance of mixing times when adding cellulose fibres that are used as a binder carrier.

6.2.2 Stone mastic asphalt skid resistance

It was explained that Germany acknowledges the risk of accidents caused by insufficient grip of new SMA with no surface texture depth requirement being specified for the surface course. The current standard, TL Asphalt-StB 07 (2007), requires the treatment of the surface prior to the opening of the surface to road users. Gritting is usually applied at a rate of 1–2 kg/m². The aggregate size is generally 1–3 mm. It can be used clean, but the current trend is to lightly coat the grit with bitumen. The latter is to stop the material clumping and gathering dust, which can reduce adhesion to the surfacing. Aggregate greater than 3 mm is not used owing to the risk of increased noise emissions. Within four weeks of being opened to traffic, the surfacing is tested with the SKM (Seitenkraftmessung), which is a device very similar to TRL's Sideway-force Coefficient Routine Investigation Machine (SCRIM), and must achieve a value (known as μ SKM) in excess of 0.46.

7 Evaluation trial

The trial was made possible with the co-operation of Bardon Contracting, part of Aggregate Industries Limited. Bardon Contracting was appointed following an open tender process that incorporated a quality/price assessment. Bardon Contracting carried out the mix designs, and mixed and laid the materials.

7.1 Objective

The specific aims of the trial were to:

- evaluate the potential of SMA mixtures that utilise smaller aggregate sizes;
- measure the effect of reduced texture depth on skid resistance;
- assess the influence of treating SMA with grit;
- identify any difficulties in the design, manufacture and laying of the SMA mixes.

7.2 Trial mixture specification

The trial mixture specification was based on information on material design and construction practices collected as part of the study visit to Germany. This included advice on the application of grit to improve early-life skid resistance of the surfacing.

A draft specification for the trial was produced in accordance with PD 6691:2007 (BSI, 2007). The specification included requirements for component materials, composition, air voids content, binder drainage, water sensitivity, resistance to permanent deformation, and temperature of the mixture. The document also described 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.

7.3 Description of trial

The trial was located on Lane 1 of the eastbound carriageway of the M8 that runs between Newhouse and Duntilland, and carries an estimated 60,000 vehicles per day. The choice of site was based on some basic site requirements: two-lane, non-event dual carriageway; consistent geometry; minimum length of 1.6 km; and the provision of easy access for specialist skid testing.

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 ungritted 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 7.1.

7.4 Pilot trial

The contractor conducted a pilot trial at Duntilland Quarry on 25 September 2008. Batches of approximately 15 tonnes of the four SMA types were produced using nominal maximum aggregate sizes of 14 mm, 10 mm, 8 mm and 6 mm and were laid 40 mm thick. The pilot trial was undertaken to provide material property data, and the opportunity was taken to trial a range of grit sizes and spread rates.

7.4.1 Contractor's mix design

Single size aggregates (14 mm, 10 mm, 8 mm and 6 mm) and dust from Duntilland Quarry, limestone filler and 40/60 penetration-grade bitumen from Nynas were used in the design of the SMA materials in accordance with the trial mixture specification. The composition of the designed mixtures is shown in Table 7.1.

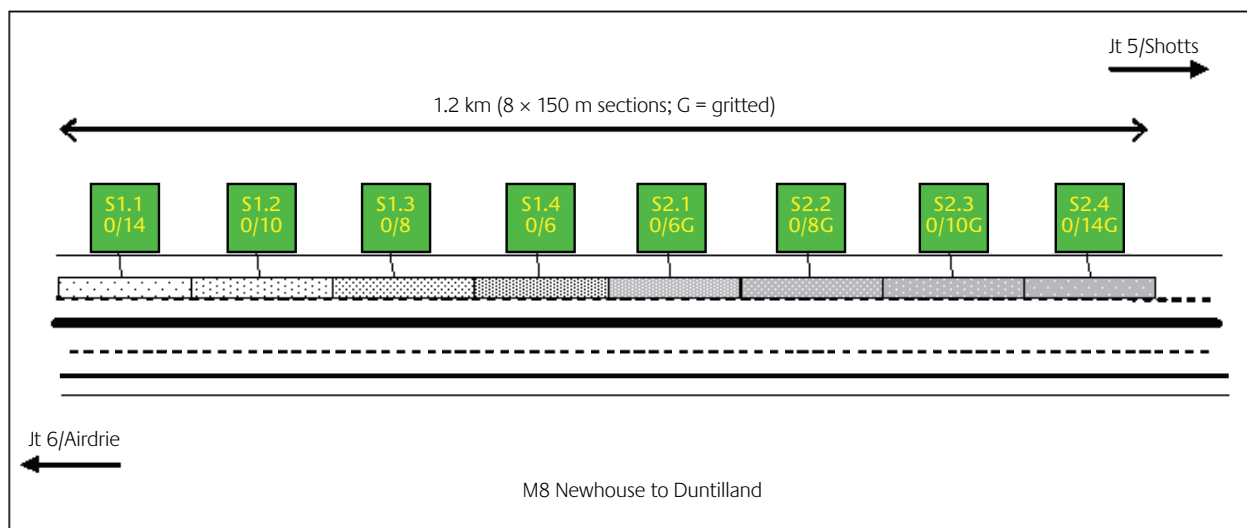


Figure 7.1 Schematic diagram of trial site

Table 7.1 Composition of SMA materials

Material/component	Mixture proportion (%)			
	14 mm SMA	10 mm SMA	8 mm SMA	6 mm SMA
14 mm	56.3	–	–	–
10 mm	6.1	55.6	–	–
8 mm	–	5.6	56.9	–
6.3 mm	–	–	3.7	60.4
Dust	22.7	24.4	24.8	24.8
Limestone filler	8.5	7.5	7.5	7.5
Fibres	0.4	0.4	0.4	0.4
Binder (40/60 pen)	6.0	6.5	6.7	6.9

7.5 Main trial

7.5.1 Laying and compaction

The trial panels were laid over two days in November 2008. The first four panels were laid without grit on 10 November 2008. The first material to arrive was 0/14 mm SMA followed by 0/10 mm, 0/8 mm and 0/6 mm materials. The ambient air temperature was 5 °C with a wind speed in the range of 9–25 km/h. A satisfactory and uniform surface texture was achieved under the cold and breezy conditions, although there were signs of some closing-up of the macrotexture under the rolling of the 0/10 mm mix. The contract required that the surfacing materials were to be laid without transverse joints. The change in material appearance from 0/14 mm to 0/10 mm can be seen in Figure 7.2.

On 11 November an additional four panels were laid with the application of grit. The first material to arrive was 0/6 mm SMA followed by 0/8 mm, 0/10 mm and 0/14 mm materials. The ambient air temperature was 7 °C with a wind speed in the range of 10–14 km/h. All of the gritted materials appeared to be satisfactory and a uniform surface macrotexture was achieved.

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 (i.e. rich in binder) but no significant signs of flushing during compaction were noted (Figures 7.3 and 7.4).

7.5.2 Gritting process

The contractor opted to use a 1/2.8 mm lightly-coated grit on the day of the trial. The grit was applied from a hopper attached to the front of a roller. Following an initial two or three passes by the roller, the grit was applied at a rate of 1 kg/m² (Figure 7.5).

Although initially a slow process, the contractor quickly developed a consistent application method that avoided overspreading grit and managed to keep up with the paving works. Final compaction of the gritted surfaces was achieved using a static triple roller. Figure 7.6 shows 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 7.2 Newly-laid surfaces – 0/14 mm SMA (background) and 0/10 mm SMA (foreground)



Figure 7.3 Compaction process



Figure 7.4 Rich-looking 0/6 mm SMA



Figure 7.5 Gritting process



Figure 7.6 Close-up of 0/14 mm SMA before gritting (left) and immediately after gritting (right)

7.6 Laboratory and field measurements

7.6.1 Material testing

A summary of the material component details and property tests supplied by Bardon Contracting is given in Tables 7.2 and 7.3.

7.6.2 Air voids content

The mean air voids contents in the compacted mats (Table 7.2) were determined using a pulse-density modulation (PDM) test. The PDM provides an indication of the density and compaction achieved. Experience suggests that the PDM can produce higher-than-actual air voids content determined from core extraction. However, the relative measurements, rather than absolute measurements, can be usefully compared. The 0/10 mm SMA produced the lowest air voids content, i.e. 4.1% as opposed to an average of 5.2%. The contractor was of the opinion that the relatively lower air voids content is connected with the 0/10 mm SMA appearing to close up slightly under compaction.

7.6.3 Binder content

Low binder contents were reported for the 0/14 mm SMA (Table 7.3), i.e. average 5.6% as opposed to 6.1% minimum specified in the trial. The material did not appear to be lean or dry when laid. The contractor stated that the lower site measurements for the larger 0/14 mm SMA are not uncommon and are typically 0.3% lower than samples taken at the plant. One possible explanation offered by the contractor was that the site material was collected in paper bags and that bitumen was retained in the sample bag owing to the coarser 0/14 mm SMA containing a higher proportion of bitumen.

The high binder results for the 0/10 mm SMA (average 6.8%, target 6.5%), in combination with a possible low air voids content, are likely to have contributed to the closing-up of the macrotexture under compaction.

7.6.4 Grading

Compositional analysis on 15 samples taken over the two-day trial showed reasonable compliance on aggregate grading. Only two samples showed non compliance: one sample of the 0/8 mm was slightly coarse and one sample of the 0/14 mm was slightly fine.

Table 7.2 Details of materials laid

Property	SMA mixtures			
	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

PSV = polished stone value. AAV = aggregate abrasion value.

Table 7.3 Binder contents

Material	SMA mixtures			
	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
Trial mixture specification 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/m³.

8 Surface characteristics

8.1 Approach

The trial comprised a number of SMAs that, owing to different aggregate sizes and compositions, possessed 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 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, after six months of traffic (May 2009), and finally after ten months of traffic (September 2009). A description of the types of measurement is given below with results of texture depth and visual assessments.

8.2 Types of measurement

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

- sideways-force coefficient (SFC);
- grip number (GN);
- locked-wheel sliding friction (expressed as the friction number, F_n);
- sensor-measured texture depth (SMTD) and mean texture depth (MTD);
- statistical pass-by (SPB) method; and
- visual assessment.

All of the measurements were undertaken using specialised test vehicles or equipment, with the exception of the MTD and visual assessment. The vehicles 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.

The SCRIMtex (i.e. the SCRIM fitted with a device to measure texture; Figure 8.1) measures the SFC and SMTD and is the standard device used to monitor wet skid resistance on UK trunk roads. It uses a special wheel set at an angle to the direction of travel to measure the SFC. It is mounted on the side of the vehicle and lowered on to the road for the tests. The machine also carries a laser sensor to measure the SMTD.



Figure 8.1 The SCRIMtex measures the SFC and SMTD

The GripTester (Figure 8.2) is a small trailer that measures the GN with a small test wheel mounted near the centre of the trailer and a gear arrangement to make it rotate more slowly than required for the vehicle speed. The GripTester was included as part of the trial as it has the potential to provide a substitute for SCRIM testing of new surfacing during early life (less than two years old) and is more cost effective to operate.

The Pavement Friction Tester (PFT; Figure 8.3) measures the F_n 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. The following tests were carried out:

- the SCRIMtex and GripTester were used to take measurements at 50 km/h and 80 km/h;
- the PFT was used to take measurements of wet friction at 20 km/h, 50 km/h, 80 km/h, 100 km/h and 120 km/h; and
- some PFT measurements were also made on the dry road surface.

The analysis of the skid resistance measurements is given in Section 9 of this report.



Figure 8.2 The GripTester



Figure 8.3 The PFT

8.3 Measurements of surface texture depth

MTD measurements were made using both sand and glass beads to form the volumetric patches. The measurements were made on the panels in September 2009 and the results are shown in Tables 8.1 and 8.2, respectively. SMTD measurements were recorded in September 2009 using the SCRIMtex and the results are given in Table 8.3.

8.4 Visual inspection

The visual condition of the trial site was inspected when newly constructed and after three days, ten months and two years of trafficking.

8.4.1 After three days of traffic

After the eight test panels had been opened to traffic for three days, the opportunity was taken to visually inspect them in detail. The difference in visual appearance between the gritted and ungritted panels was distinct. The ungritted panels had a smooth, dark and shiny appearance compared with the gritted material, which displayed a rougher appearance and slightly lighter colour. This difference is demonstrated with the aid of images taken of gritted and ungritted 0/6 mm SMA (Figure 8.4).

Table 8.1 MTD measurements using sand to form the patches (mm)

Surface test area (average of sets of five readings)	Maximum aggregate size of SMA mixture			
	14 mm	10 mm	8 mm	6 mm
Ungritted	1.1	0.8	0.9	0.8
Gritted	1.0	0.6	0.8	0.7

Table 8.2 MTD measurements using glass beads to form the patches (mm)

Surface test area (average of sets of five readings)	Maximum aggregate size of SMA mixture			
	14 mm	10 mm	8 mm	6 mm
Ungritted	1.3	0.9	1.1	1.0
Gritted	1.0	0.7	0.9	0.8

Table 8.3 SMTD measurements (mm)

Test section and line (average for middle of length)		Control	Maximum aggregate size of SMA mixture			
		14 mm	14 mm	10 mm	8 mm	6 mm
Ungritted	Wheel path	0.82	1.00	0.68	0.56	0.50
	Centre of lane	1.03	1.05	0.79	0.71	0.66
Gritted	Wheel path	–	0.57	0.39	0.44	0.39
	Centre of lane	–	0.70	0.54	0.63	0.56



Figure 8.4 0/6mm SMA gritted (left) and ungritted (right)

(The marks running from top to bottom near the centre of these pictures are skid marks left by PFT skid tests in these areas)

8.4.2 After ten months and after two years of traffic

The opportunity was taken to include the trial in the annual SIP programme. The trial sites were assessed visually on 9 September 2009 and ranked in accordance with the TRL inspection panel methodology (Nicholls, 1997). The results of the panel assessment are given in Table 8.4.

All, with the exception of the 10 mm gritted section where there were known issues at the time of construction, are still performing well after two years of service, with the panel markings in 2010 being *G* or *E/G*.

8.5 Tyre noise

Transport Scotland commissioned AECOM to conduct a roadside noise survey to assess the acoustic performance before and after resurfacing. The first phase of the survey was to assess the acoustic performance of the existing HRA. The second phase was to assess the acoustic performance of the eight trial surface courses. All surfaces were assessed by the SPB method.

The noise surveys were carried out on the original HRA in September 2008 and on the trial surfacing in June 2009. The trial surfacings were around seven months old at the time of the second survey.

8.5.1 Findings

The general conclusions drawn from the noise survey measurements (AECOM, 2009) were as follows:

- After resurfacing, traffic noise levels were reduced by 3 dB(A) on average, which corresponds to an equivalent reduction in traffic noise caused by halving the traffic flow.
- The largest reduction in noise level was achieved with the ungritted 6 mm SMA. Traffic noise levels were estimated to have reduced by 6.4 dB(A), equivalent in noise terms to a four-fold reduction in traffic flow.
- The influence of aggregate size on traffic noise levels for the trial surfaces showed the expected trend that noise levels increased with aggregate size. This trend was more noticeable for the surfaces that were not gritted.
- For the ungritted surfaces, the average reduction in traffic noise compared with a HRA surface was 3.9 dB(A). The corresponding value for the gritted surfaces was 2.9 dB(A).

Table 8.4 Scottish Inspection Panel marks

<i>M8 trial section</i>	<i>Panel mark</i>	
	<i>2009</i>	<i>2010</i>
Control 14 mm	<i>G</i>	<i>G</i>
10 mm ungritted	<i>E/G</i>	<i>G</i>
8 mm ungritted	<i>E</i>	<i>E/G</i>
6 mm ungritted	<i>E</i>	<i>G</i>
6 mm gritted	<i>E/G</i>	<i>E/G</i>
8 mm gritted	<i>E/G</i>	<i>E/G</i>
10 mm gritted	<i>E/G</i>	<i>M_{vt}</i>
14 mm gritted	<i>G</i>	<i>G</i>

E = Excellent. G = Good. M = Moderate.

9 Analysis and discussion of skid resistance measurements

9.1 The context of the analysis – the different phases in the life of a road surfacing

9.1.1 General

During the course of four visits to the M8 trial site, a very large number of skid resistance and associated measurements were made. In this section of the report the results are summarised and applied to specific contexts that were the focus of this aspect of the study.

Skid resistance is a key safety parameter of any road surfacing, and varies considerably over the surfacing's life. The skid resistance measurement programme was, therefore, designed to gather data that would permit analysis of the results in a number of different contexts. By making a similar pattern of measurements before opening to traffic, and then after three days, six months and ten months of traffic, it was possible to gain an insight into the evolution of the behaviour of the materials relating to the three main phases of a road's service life.

9.1.2 Phase 1 – early life

The first phase, typically known as “early life”, covers the initial period in the life of an asphalt surfacing, 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. The duration of this initial phase varies depending on the traffic and other conditions to which the road is subject. It generally lasts from about two to six months (in the wheel paths). On roads with light traffic, or in less heavily-trafficked parts of the road such as the centre and edges of the traffic lanes, the bitumen may take longer to wear away and so this phase could last longer.

This phase is important because there is evidence that skid resistance performance can be adversely affected by some physical phenomena during this period of a surfacing's life, which may increase accident risk in a small number of specific circumstances (Roe and Lagarde-Forest, 2005; Green and Crinson, 2008).

9.1.3 Phase 2 – polishing

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 an equilibrium level. The time taken for this process is influenced by a number of factors, including the traffic level, the time of year that the surfacing is laid, the amount of bitumen initially on the surface and the time the bitumen takes to wear away. This phase can be over, at least in the wheel paths, in around six months on the most heavily-trafficked surfaces if the surfaces are laid very early in the spring, but more usually takes at least a year, and sometimes even longer, to reach equilibrium.

This transition phase in the life of a road is less important overall than the early life or later equilibrium phase, but in the context of this study it provides an indication of the changes that occur between the two main phases.

9.1.4 Phase 3 – equilibrium

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. It is the lower equilibrium level achieved during the summer that is monitored for comparison with skid resistance standards.

The equilibrium level of skid resistance achieved in a particular situation is governed by the interaction between the polishing action of traffic during the summer, abrasion during the winter (which leads to the seasonal winter increase) and the general polishing resistance of the aggregate. Once achieved, the equilibrium level will remain essentially constant provided that the general level of traffic remains constant. If traffic is reduced, equilibrium skid resistance may increase a little. Conversely, if traffic increases skid resistance may decrease. However, research has shown that aggregates generally have a limiting level beyond which they will not polish.

9.2 Types of measurement made and their use in the trial

9.2.1 Timing of the measurements and pattern of the tests

In the UK, skidding standards for in-service roads, set out in HD 28/04 (Highways Agency *et al.*, 2004), are defined in terms of the low-speed wet skid resistance of the road surface. This property is normally assessed in terms of a parameter known as the “characteristic SCRIM coefficient” (CSC). The CSC is derived from SFC measurements made with the SCRIM during the summer months over a three-year period that have then been adjusted to take account of seasonal variation both within and between successive years. In order to avoid undue influences from the early-life and polishing phases of a surface, measurements in the first year after a surfacing has been laid are specifically excluded from CSC calculations.

The measurements made on the M8 trial site were made to provide “snapshots” of the skid resistance condition of the trial sections at specific times in the lives of the surfacing. The initial two visits were made in winter (well outside the normal summer test season), while the later measurements were made in early and late summer.

At each visit, measurements of wet skid resistance were made with all three devices, in the nearside wheel path (the most heavily-trafficked part of the road) and in the centre of Lane 1 (the more lightly-trafficked area that was used as a surrogate to represent a less heavily-trafficked road). In addition, the PFT was used to make dry friction tests during the earlier visits. These were made in the offside wheel path to avoid the risk of residual skid marks influencing the wet tests. The term “skid resistance” is normally used in relation to wet conditions and, more usually, to low slip speeds (which, for the SCRIM and GripTester, are much lower than the test vehicle speed).

For the above reasons, care should be taken when reviewing the results presented in this section. Specifically, the measurements should not be compared directly with the trunk road skid resistance standards, although the SCRIM coefficient (SC) values measured at 50 km/h do provide an approximate indication of current performance in relation to those requirements.

9.2.2 SCRIM measurements

In routine surveys, SCRIM measurements are made in live traffic at target test speeds of 50 km/h or 80 km/h, depending on the type of road. However, when operating in traffic, significant variations from the target speed can occur during the survey and the measurements (at either target speed) are therefore adjusted to a standard test speed of 50 km/h when the data are processed.

The SCRIM measurements on the M8 trial site were generally made at both 50 km/h and 80 km/h target speeds, for the specific purpose of observing any effects that the different speeds might have on the different surfaces. The tests were made under controlled conditions on a closed carriageway. No speed correction was therefore necessary for the 50 km/h tests and no correction was applied for the higher-speed measurements. In all cases, where the context requires it, the different measurement speeds with any device are distinguished in the text of this report by means of a subscript. For example, SC_{50} and SC_{80} refer to SC measurements at 50 km/h and 80 km/h, respectively.

9.2.3 GripTester measurements

The GripTester provides results in a form known as the “grip number” or GN, in this case recorded for every 1 m of road. Because the device uses a different measurement principle to the SCRIM, the results are not directly comparable. Empirical equations to convert GN into CSC have been published but there is some disagreement within the industry at present as to which of these is most appropriate for the different variants of the GripTester currently in service. The conversion equations are typically used to convert GNs into a SCRIM-equivalent value where SCRIM data are not available (and the results are to be compared with standards based on SC values) but, in the context of this analysis, all GripTester data are reported as GNs.

9.2.4 PFT measurements

The PFT measures the locked-wheel sliding friction between its smooth test tyre and the road surface, reporting a value known in the UK as the “friction number” or Fn. In scale, this parameter is equivalent to the coefficient of friction multiplied by 100.

The PFT was used to assess the effect of speed on wet skid resistance, especially in relation to the lower texture depth expected on some of the trial panels. Measurements were generally made at target speeds of 20 km/h, 50 km/h, 80 km/h, 100 km/h and 120 km/h.

Dry friction measurements were made at 20 km/h and 50 km/h. Higher speeds were not used because previous research has demonstrated that speed does not affect dry measurements outside this range and the effects that do occur are confined to those associated with the early-life phase.

Measurements of the Fn with the PFT are derived from individual skid tests in which the test wheel passes through a lock-and-release cycle. A fixed time interval is used for each phase of the cycle as the test wheel slows down to the locked condition and settles into the skid before being released again. Consequently, the length of road sampled during the test cycle varies depending on the test vehicle speed. For

this reason, in order to obtain sufficient coverage, replicate measurements were made at the lower test speeds. At the highest speeds used (120 km/h), the skid effectively sampled the whole of the test section. There was insufficient time available during the site closure period to make replicate measurements at the highest speeds.

Like any measurement, PFT measurements are subject to variability as a result of variations in the road surfacing (particularly if the test line changes from one measurement to the next) and due to differences in the actual test speed achieved. For much of the analysis, therefore, rather than use individual measurements and the target speed, the relationship trend on the friction–speed curve was established from the actual Fn and speed data (using a second-order polynomial) and the relationship used to derive an estimate of friction at any particular test speed where this was appropriate. This approach also allowed obvious outlying individual skids that occasionally occur to be identified and eliminated without significant loss of information overall.

The Fn is normally determined for the locked phase of the test. However, the device records the friction throughout the test cycle and it is, therefore, possible to compute a value for what is known as the “peak” friction. This value is the maximum level of friction that is developed just as the wheel begins to slip over the road surface before it locks completely and skids. This “peak” value is indicative of the maximum friction that might be available in the early stages of braking or when cornering without slipping sideways significantly.

9.2.5 Texture depth measurements

All road surfaces show a reduction in wet friction with increasing speed. Previous research has indicated that the reduction in friction can be greater on surfaces with lower texture depth (Roe *et al.*, 1998); hence, the requirement in the *Specification for Highway Works* (Highways Agency *et al.*, 2008a) for a minimum texture depth on new road surfaces on high-speed roads. Texture depth is also considered on in-service roads with associated thresholds in HD 29/08 (Highways Agency *et al.*, 2008b) and a requirement to take it into account in site investigations under the skid resistance standards in HD 28/04 (Highways Agency *et al.*, 2004).

Because the surfacings being trialled on the M8 were designed primarily with durability in mind, they tend to have lower texture depth than normally permitted at present. This safety-related aspect of their behaviour, both when new and in the longer term, was of particular interest in the trial.

9.3 Early-life skid resistance on the trial surfacings – low-speed skid resistance

9.3.1 Before opening to traffic

Figure 9.1 shows the results from the SCRIM tests along the site prior to opening the road to traffic. This figure provides an indication of the general level of skid resistance on the trial sections when they were first laid. The graph compares the measurements at the two test speeds, which were all made on a line approximating to what would become the nearside wheel path. Figure 9.2 is a similar graph showing the results from the GripTester. In this case, the 1 m measurements have been smoothed and plotted as a moving ten-metre average. The two figures are shown together for ease of comparison.

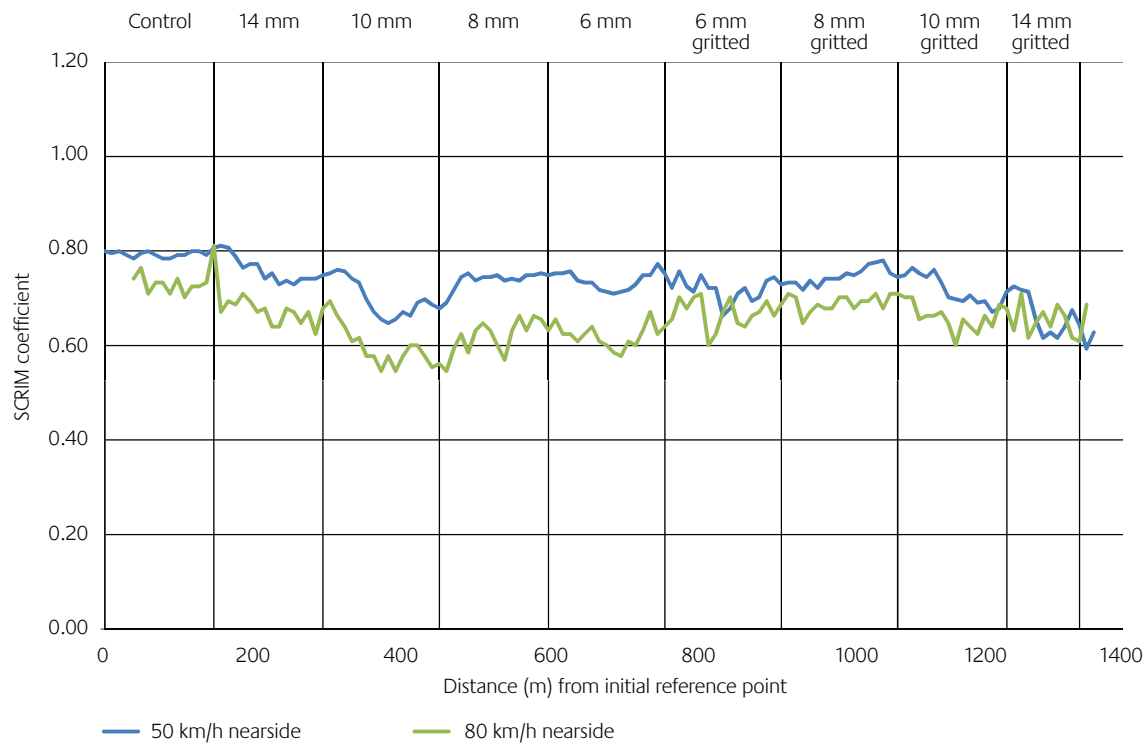


Figure 9.1 SCRIM measurements before opening to traffic

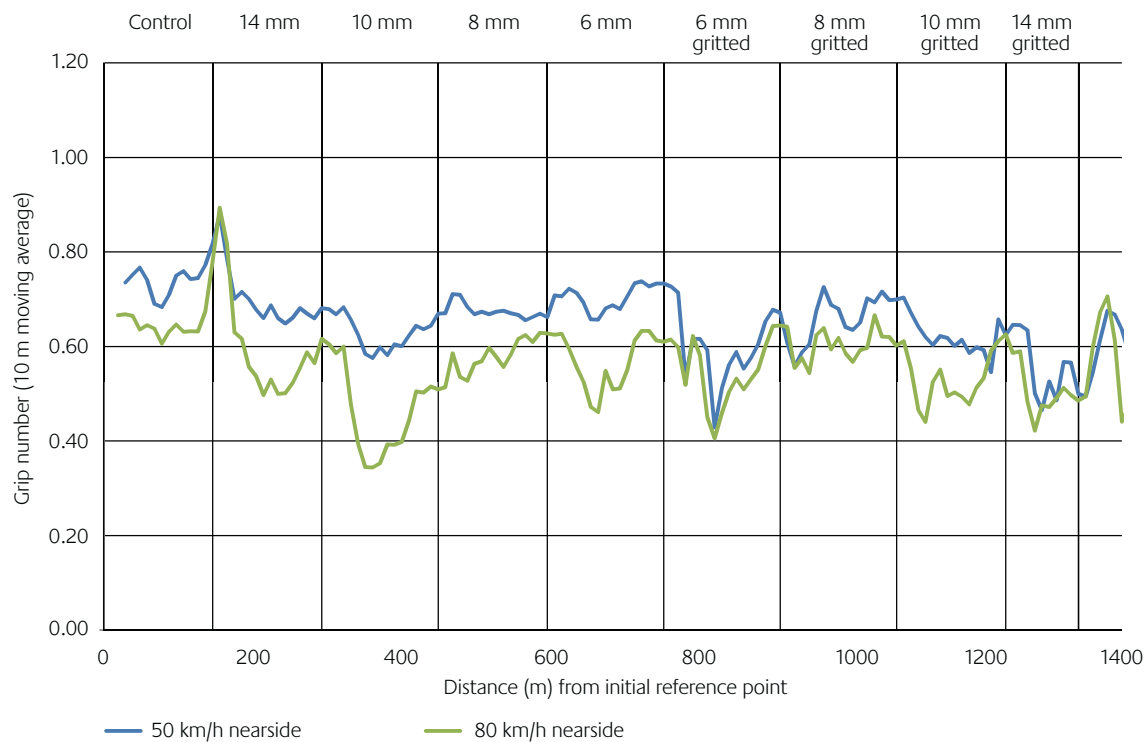


Figure 9.2 GripTester measurements before opening to traffic

For convenience and clarity in these graphs, as with others in the report, the forms “6 mm”, “8 mm”, “10 mm” and “14 mm” have been used as shorthand to indicate 0/6 mm SMA, 0/8 mm SMA, 0/10 mm SMA and 0/14 mm SMA, respectively. The word “Gritted” is added to indicate the gritted sections. Markers are included to indicate the approximate areas where the various surfacings are located. In practice, there is a transition of 5–10 m where the material changes between the panels, except between the ungritted and gritted lengths, where the joint was cut. The area marked as “Control” is a length of the proprietary 0/14 mm thin surfacing used on the remainder of the resurfacing works.

The levels of SC_{50} in Figure 9.1 are generally very high – in fact, they are much higher than would be expected on trafficked surfaces and comparable with specialised high-friction surfacing. The SC_{80} values are generally lower, as would be expected, but are still high. The difference between the speeds is slightly less on the gritted sections, with the 0/14 mm material showing little difference in SC between the two test speeds.

The SC values on the trial panels appear to be lower generally than on the control section, but in this untrafficked state there are no obvious general differences between the different materials. It does appear, however, that there is a marked reduction in the SC_{50} level on the 0/10 mm ungritted section. There is a similar dip in the SC_{80} values, although at this test speed the reduced level is maintained along all the smaller-size sections. There are also some fluctuations in the measurements on the gritted sections.

The general pattern of the GripTester results is very similar to the SCRIM measurements but there are some noticeable differences in detail. The GripTester shows a marked “spike” at the transition from the control to the 0/14 mm ungritted section (which is also visible in the SC_{80} measurements in Figure 9.1). The dip on the 0/10 mm ungritted section observed with the SCRIM is particularly noticeable in the GN_{80} data. There is also a marked dip in the GN at both speeds in the centre of the 0/6 mm gritted section that is visible, which is less obvious in the SCRIM measurements. This reduction will be due in part to the fact that the SCRIM averages its results over 10 m but the GripTester results shown here are based on 1 m data.

9.3.2 Three days after opening to traffic

Figures 9.3 and 9.4 show the results of the measurements with the SCRIM and GripTester made after the road was opened to traffic for three days. On this occasion, in addition to measuring skid resistance in the nearside wheel path, measurements were also made in the centre of the lane in order to assess how the results compared for this relatively untrafficked area.

In Figure 9.3 it can be seen that the pattern of measurements on the ungritted section of the site was very similar to that observed prior to opening to traffic, with a tendency for SC_{50} to have increased. There appears to be a greater reduction in skid resistance at the higher of the two speeds, but in practice this difference appears to be due to the increase in SC_{50} because the SC_{80} values are very similar after traffic to the untrafficked state. There was also a small difference between the wheel path and the centre of the lane, with the centre of the lane showing slightly lower values. Nevertheless, the SC_{50} measurements remained high compared with most in-service roads.

There was a marked difference between the gritted sections and the ungritted lengths: the gritted sections had increased noticeably with the influence of traffic. Furthermore, the detailed variations along the sections, particularly on the 0/6 mm and 0/10 mm sections, were still visible. The GripTester results in Figure 9.4 tell a similar story but, in this case, the differences between the ungritted and gritted sections were even more marked.

9.3.3 Comparing the three devices in the first few days

The SCRIM and GripTester measure low-speed skid resistance by virtue of the measurement principles that they use. For the SCRIM, with its test wheel angled at 20 degrees, the speed at which the contact patch slides over the road surface is just 17 km/h at a test speed of 50 km/h. The gear ratio on the GripTester means that the contact patch slip speed is approximately 7 km/h at a 50 km/h test speed. For the PFT, using a locked wheel, the slip speed is the same as the test speed. For the PFT, the 20 km/h test speed is close to the slip speed of a 50 km/h SCRIM test. The issue of slip speed is one of the reasons for the differences between the various types of measurement, although other factors, including test tyre properties and the reaction of the tyre to the road surface macrotexture, are also important.

It is not possible to harmonise the results and present them on a common scale, but it is nevertheless of interest to compare the three measurement techniques. This comparison has been done in Figure 9.5, which plots SC_{50} , GN_{50} and Fn_{20} on the same graph for the measurements made in the nearside wheel path before opening to traffic. Figure 9.6 shows the equivalent measurements after three days of traffic. On these graphs, the average Fn of the set of 20 km/h skids made on each section has been calculated and plotted as a single (purple) point in the centre of each section.

A striking feature of these graphs is the general similarity between the three devices. The devices measure on slightly different scales, as is expected, but they each reflect similar characteristics of the road, all indicating very high levels of skid resistance at low speeds with higher levels on the gritted sections after trafficking.

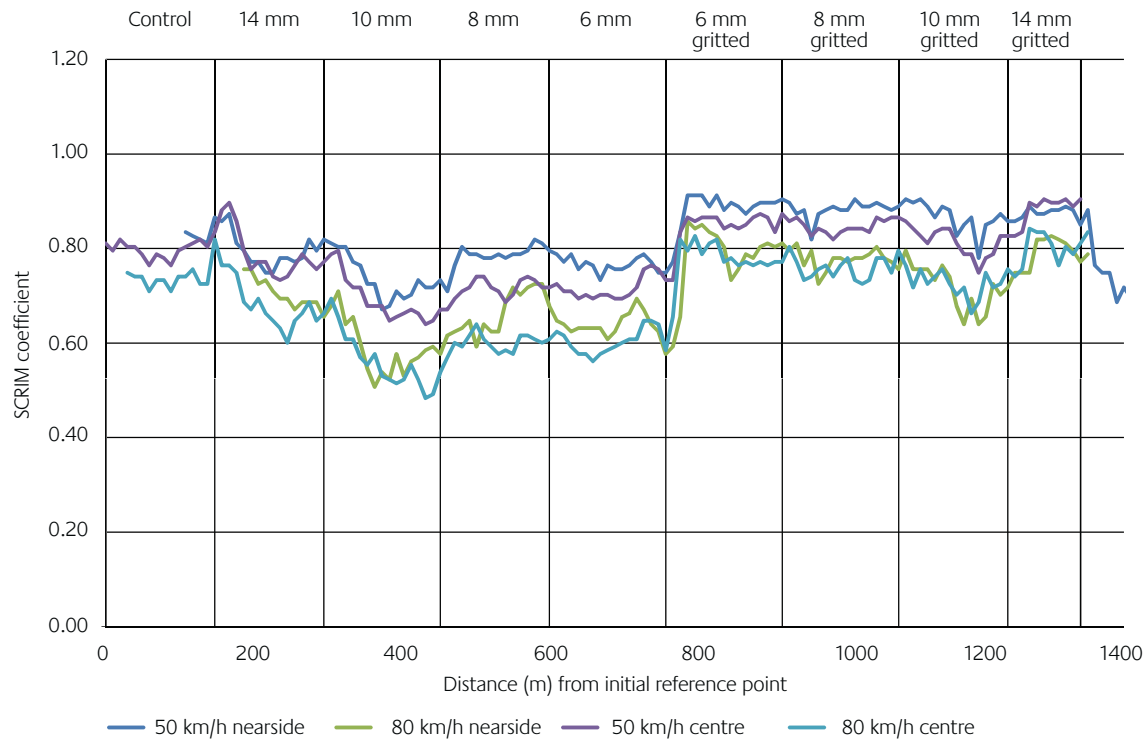


Figure 9.3 SCRIM measurements after three days of traffic

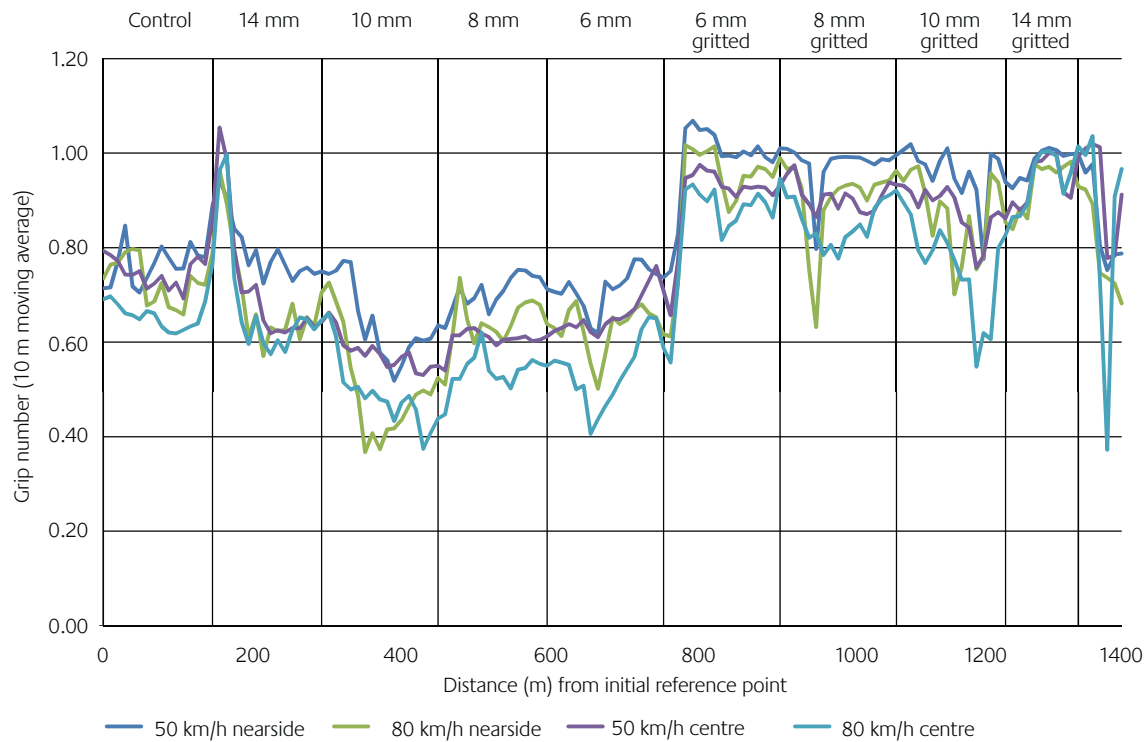


Figure 9.4 GripTester measurements after three days of traffic

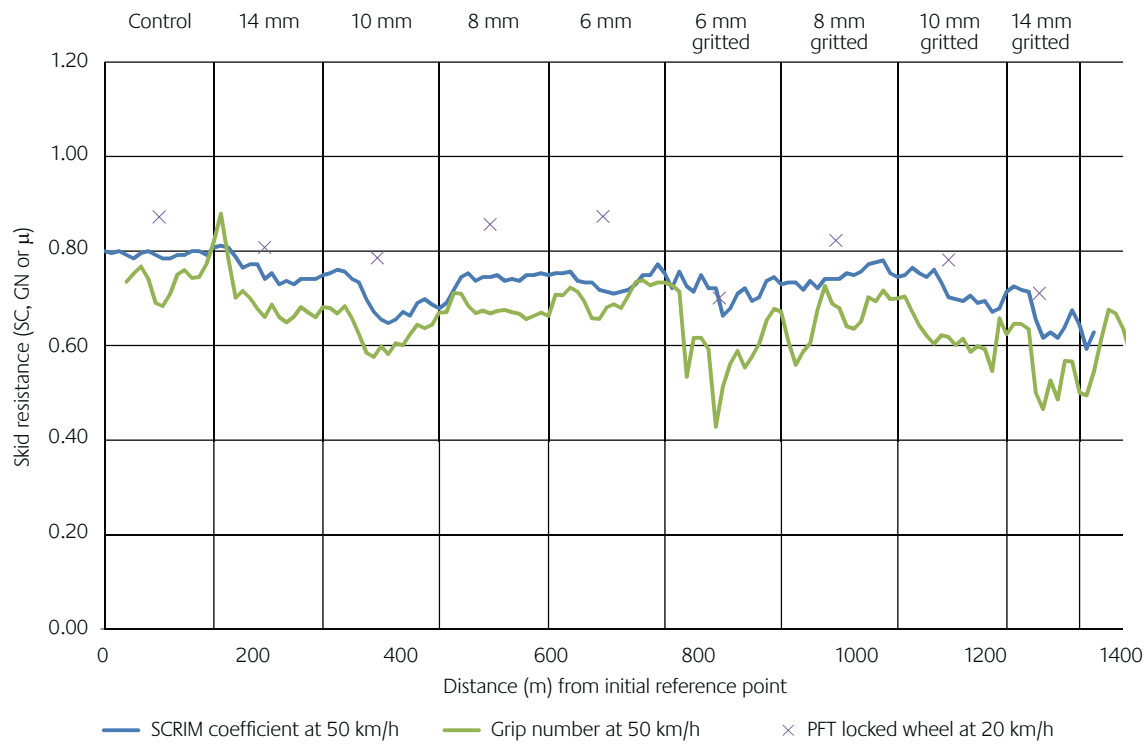


Figure 9.5 Comparison of low-speed skid resistance measurements from the SCRIM, GripTester and PFT before opening to traffic

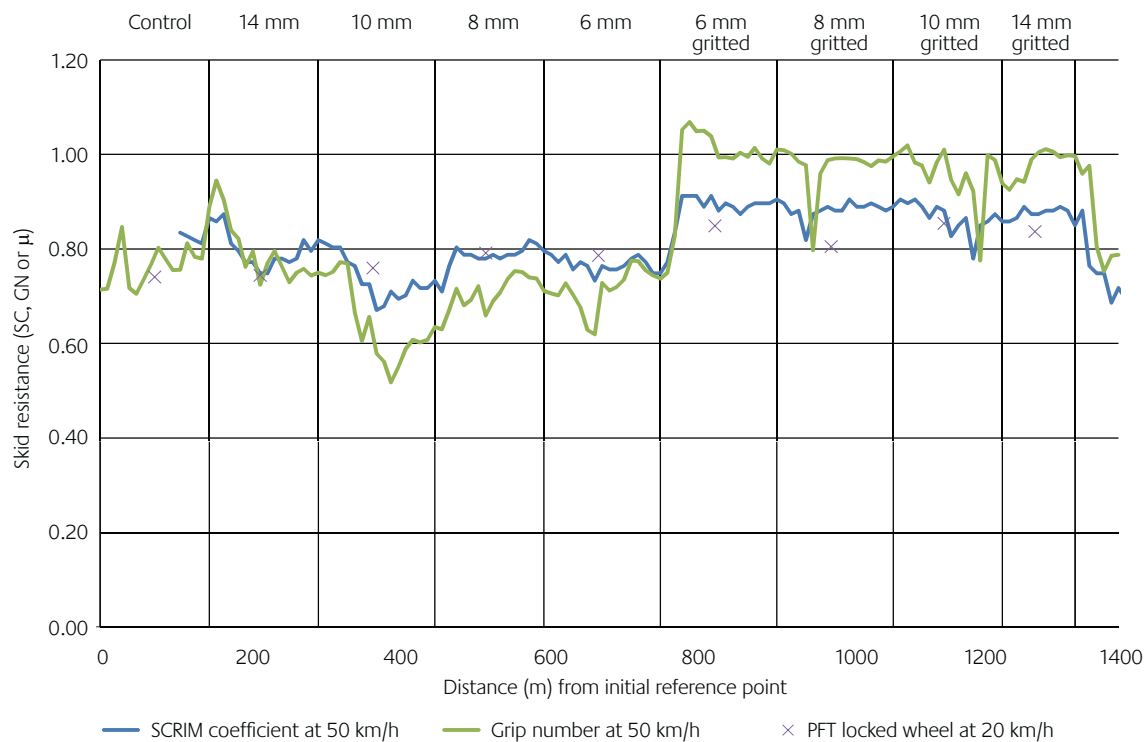


Figure 9.6 Comparison of low-speed skid resistance measurements from the SCRIM, GripTester and PFT after three days of traffic

9.3.4 Low-speed wet skid resistance after six months of traffic

Under the influence of traffic and weather, the bitumen is worn away and the aggregate is gradually exposed. Initially, the newly-exposed aggregate tends to give higher skid resistance than the bitumen-rich surface but the exposed areas then begin to be polished by traffic and the skid resistance reduces, more noticeably during the summer months. After about six months of heavy traffic, it would be expected that the early-life phase would be over, at least in the wheel paths.

On the trial site, the surfaces were laid in early November 2008. Consequently the measurements at six months were made the following May, a time of year when the summer polishing process is only just beginning. Figure 9.7 shows the results from the SCRIM measured at 50 km/h along the site, in both the wheel path and the centre of the lane, six months after opening to traffic. The values from three days after opening are included for comparison (the green line).

It is apparent from the graph that, in the wheel paths, the exposure of the aggregate and the normal polishing process was well under way at this time, with no practical differences to be seen between any of the test sections, including the gritted and ungritted lengths. In the less trafficked centre of the lane, however, the skid resistance was higher than in the wheel path, with some indication of relatively higher skid resistance on the gritted areas. This observation suggests that, although the process of aggregate exposure had begun, it was less far advanced than in the wheel paths. On both lines, although polishing was under way, the actual level of skid resistance was uniformly high.

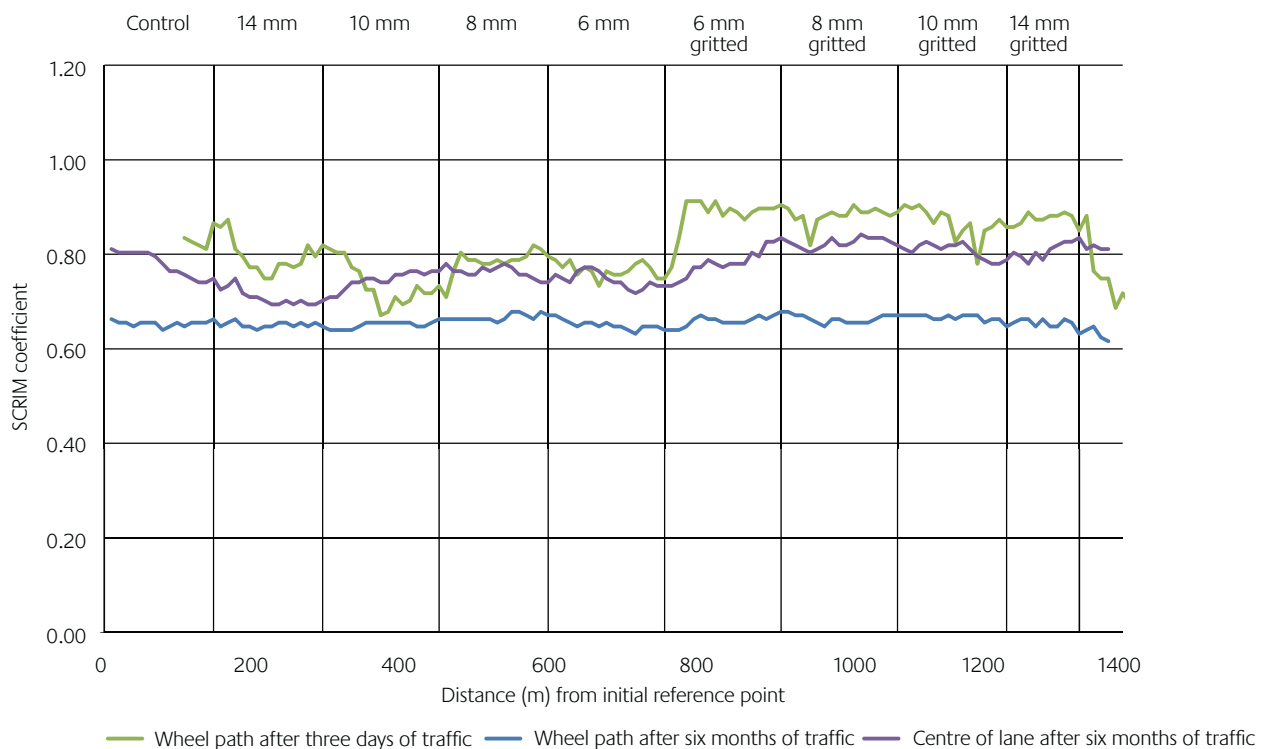


Figure 9.7 Low-speed skid resistance measured with the SCRIM after three days and six months of traffic

9.4 Early-life skid resistance – friction at higher speeds

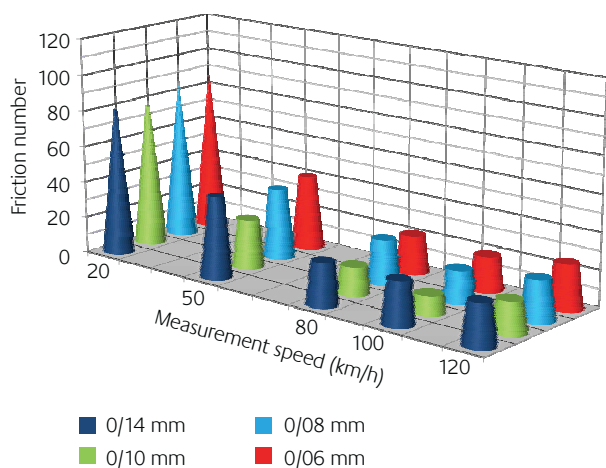
9.4.1 On the newly-laid surfaces

Figure 9.8 comprises two three-dimensional graphs illustrating the average F_n measured with the PFT at different target speeds on the various test sections before opening to traffic. Figure 9.9 shows the equivalent data after three days of traffic.

The results of the analysis indicate that:

- before trafficking, the ungritted sections (the left-hand graph in Figure 9.8) show the classic reduction in friction with increasing speed but the gritted sections show almost no change; and
- after trafficking, both the ungritted and the gritted sections show a reduction in friction with increasing speed.

The ungritted 0/10 mm section gave particularly low F_n values at higher speeds compared with the other sections, especially at intermediate speeds, possibly reflecting the “dip” observed with the SCRIM and GripTester that became more marked in the 80 km/h tests.



9.4.2 After six months of traffic

After six months of traffic, in the wheel path (Figure 9.10) the loss of friction with speed remained apparent, with the 0/10 mm SMA section continuing to show a greater reduction in friction with speed. There was a less obvious difference between the ungritted and gritted sections in the centre of the lane (Figure 9.11), although the differences between the gritted and ungritted sections were marked.

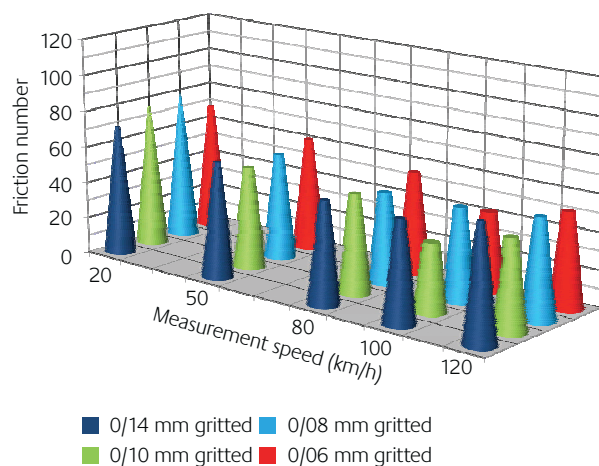


Figure 9.8 Effect of speed on wet friction before opening to traffic

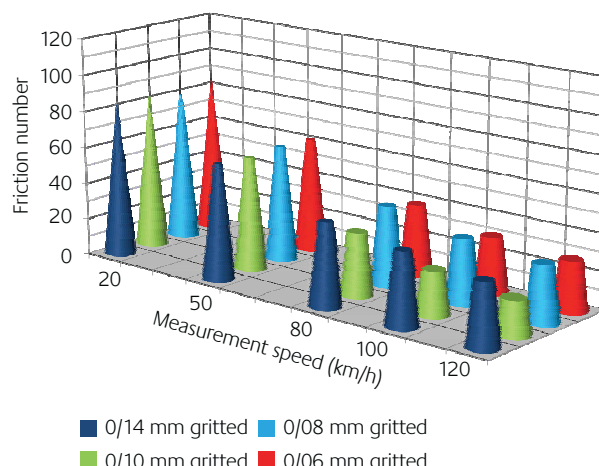
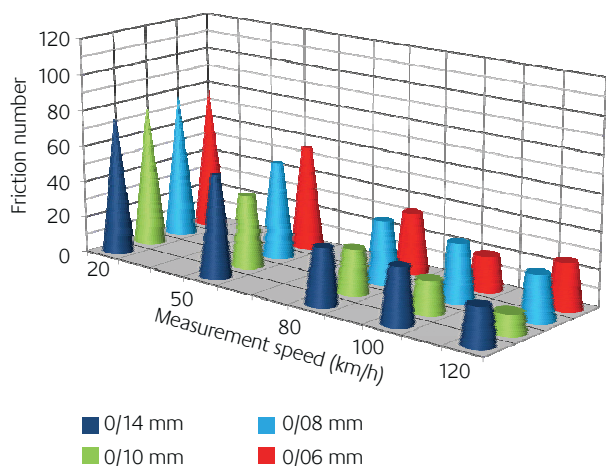


Figure 9.9 Effect of speed on wet friction after three days of traffic

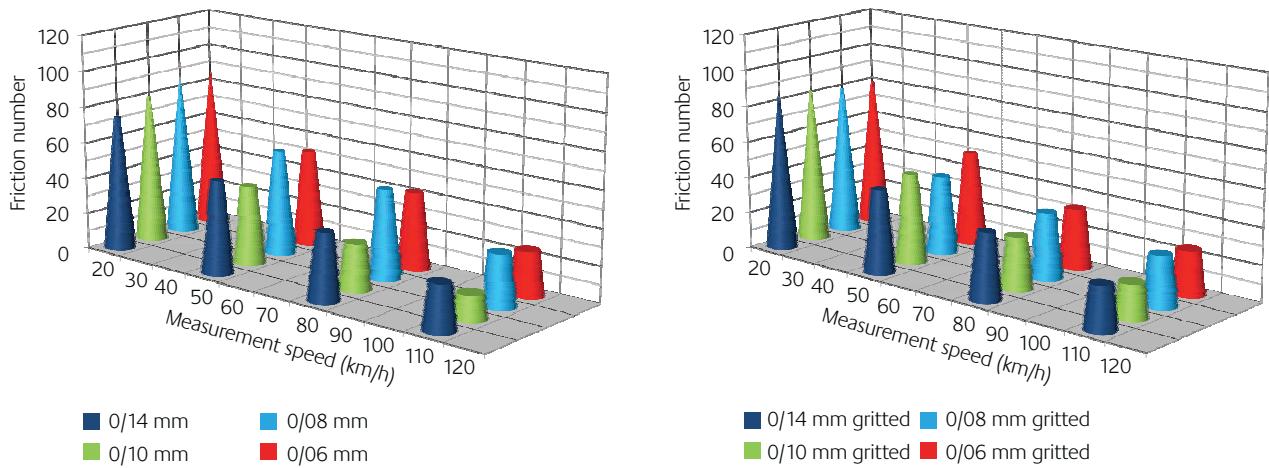


Figure 9.10 Effect of speed on wet friction after six months of traffic in the wheel path

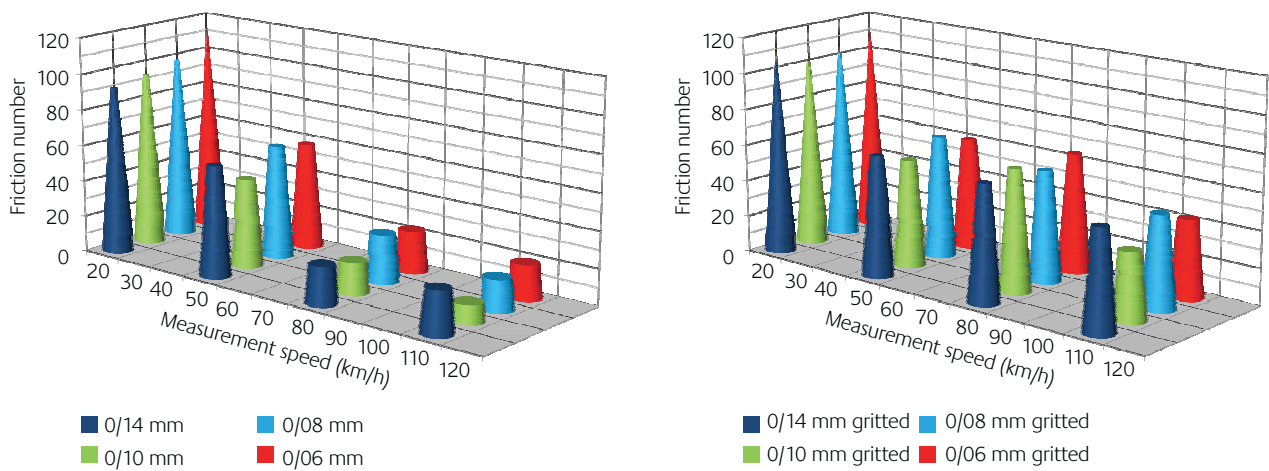


Figure 9.11 Effect of speed on wet friction after six months of traffic in the centre of the lane

9.5 Early-life skid resistance – dry friction

An aspect of early-life skid resistance that has caused concern is the potential for reduced friction in dry conditions. Tests with the PFT were carried out in dry conditions, initially at three speeds and later at 20 km/h and 50 km/h only. Figure 9.12 shows the PFT during one of its 20 km/h test runs on the untrafficked surfaces. The marks from the dry skids left on the road can be seen clearly behind the vehicle. The pairs of cones on the hard shoulder were placed to help the operators to identify the section boundaries. It will be noticed that these measurements were made in the offside wheel path, in order to avoid altering the surface characteristics for the wet tests.

The expectation from previous research on newly-laid asphalt (with ungritted surfaces) is that the dry F_n value will either be very high, over 70 (usually, but not uniquely, at the lowest speeds), or be lower, at around 50–60 (more likely at higher speeds). The latter condition is associated with softening of the bitumen. However, unlike in wet conditions, the friction level does not decrease markedly below this as speeds increase above 50 km/h.

It is not unusual to observe both high and lower friction conditions on the same surface (or even within the same skid) but it is more likely that the lower friction condition ($F_n \approx 50$ –60) will occur at higher speeds because of the greater amount of energy available to soften the bitumen and the longer time for this condition to be established.



Figure 9.12 The PFT making a test pass to measure dry friction at 20 km/h

Figure 9.13 shows the results of the dry friction tests on the trial sections prior to opening to traffic. On the ungritted sections the F_n values are mostly in the expected 50–60 range but the 0/6 mm material gave an average F_n of 76 at 20 km/h. This level of friction is broadly typical of most clean, dry road surfaces at any speed. On the gritted sections, F_n values are generally higher; the lowest value observed was 59, at 50 km/h on the 0/14 mm surface.

After three days of traffic, the behaviour changed somewhat (Figure 9.14). The results for the ungritted sections are generally similar to their untrafficked condition, although the 0/10 mm and 0/8 mm sections join the 0/6 mm in giving high F_n values at 20 km/h. On the gritted sections, there is a wide range of behaviour with some very high values indeed on some sections and lower values on others, with F_n values just under 50 observed on the 0/14 and 0/10 mm sections at 50 km/h.

After six months of traffic, the dry friction measurements had generally increased further. Average values of $F_{n_{20}}$ were > 90 on all sections and $F_{n_{50}}$ values were generally > 70 with the exception of the 0/10 mm ungritted section and the control section, which both gave $F_{n_{50}} = 67$. It would appear that, by this time, the risk of relatively low dry friction levels occurring had passed.

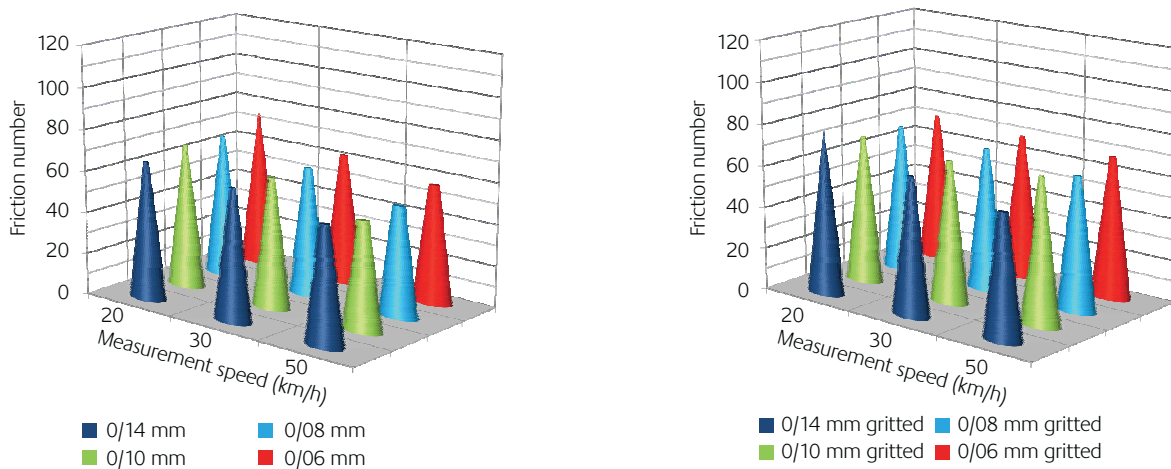


Figure 9.13 Dry friction measured at three speeds before opening to traffic

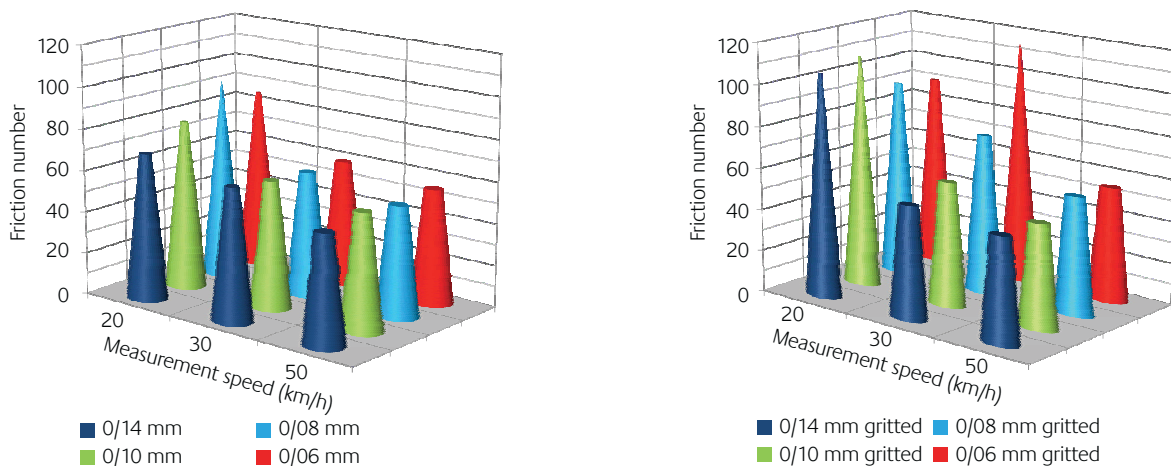


Figure 9.14 Dry friction measured at three speeds after three days of traffic

9.6 Low-speed skid resistance after ten months of traffic

Figure 9.15 shows the low-speed skid resistance measured along the site in the wheel path using SCRIM at 50 km/h after ten months of traffic, with the lines for the three-day and six-month visits included for comparison. Figure 9.16 is the equivalent graph for the centre of the lane.

These graphs clearly demonstrate the transitional condition of the surfacing and the onset of polishing by traffic. In Figure 9.16, it can be seen that on this less well trafficked part of the road the effects of gritting were still evident. However, on the control section in particular, and to a lesser extent on the ungritted sections, polishing of the surface aggregate had begun. Overall, the low-speed skid resistance levels were still very high.

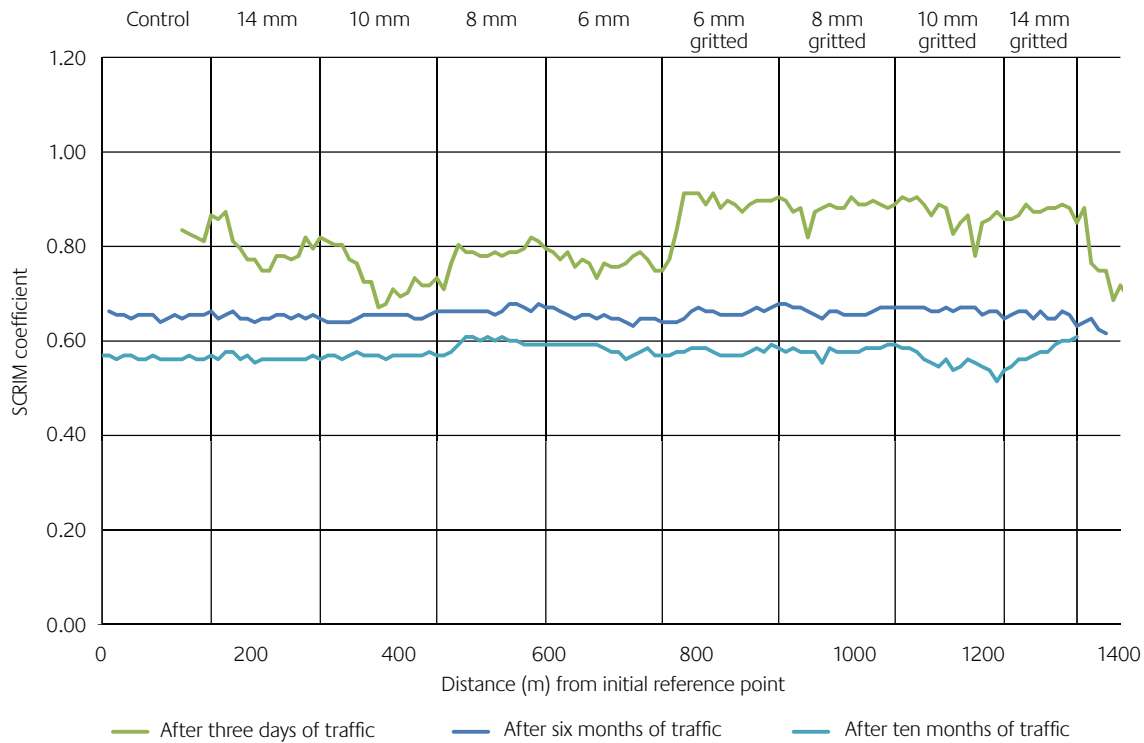


Figure 9.15 Skid resistance measured with the SCRIM over time in the wheel path

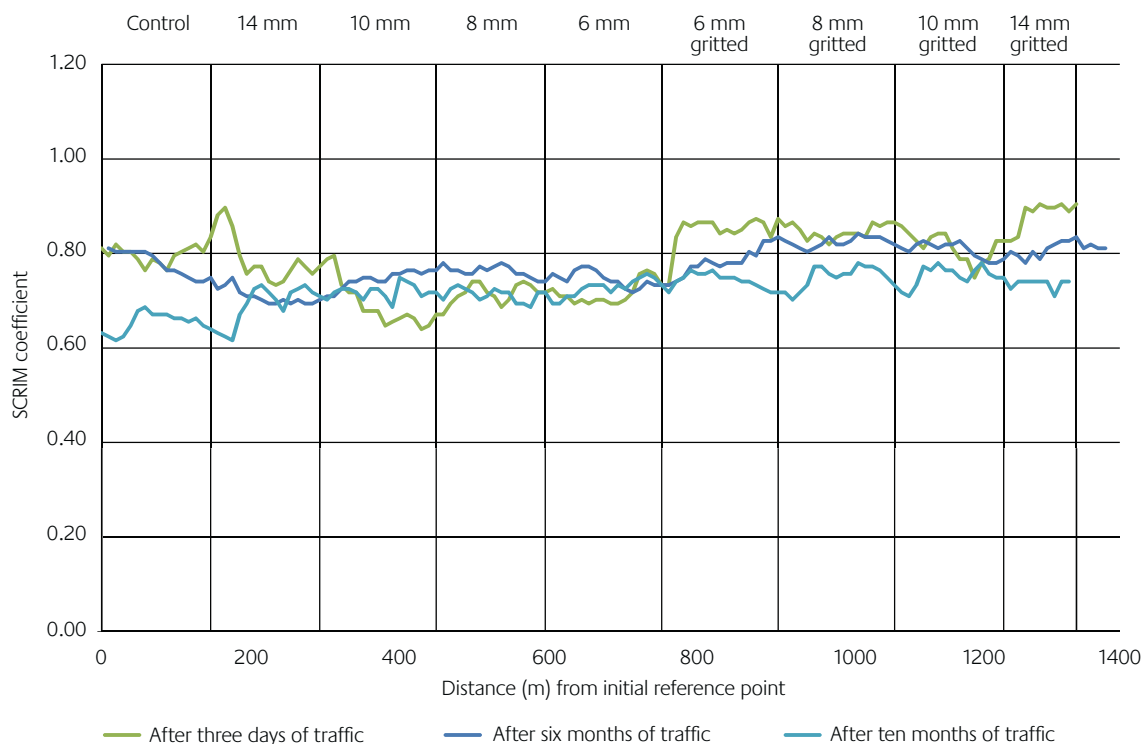


Figure 9.16 Skid resistance measured with the SCRIM over time in the centre of the lane

In the trafficked wheel path (Figure 9.15), the polishing process was clearly well established. There was 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 2009–2010 and then decrease again towards its equilibrium level as a result of polishing during the following summer.

9.6.1 Texture depth after ten months of traffic

An important aspect of the trial surfacings that can influence the higher-speed performance of the materials is their texture depth. Figure 9.17 shows the texture depth measured using the laser sensors on the SCRIM along the site, both in the wheel path and the centre of the lane.

As would be expected, there is a marked difference between the two more open textured 0/14 mm materials. It also appears that the grit has had the effect of reducing the texture depth on those sections. 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 macrotexture.

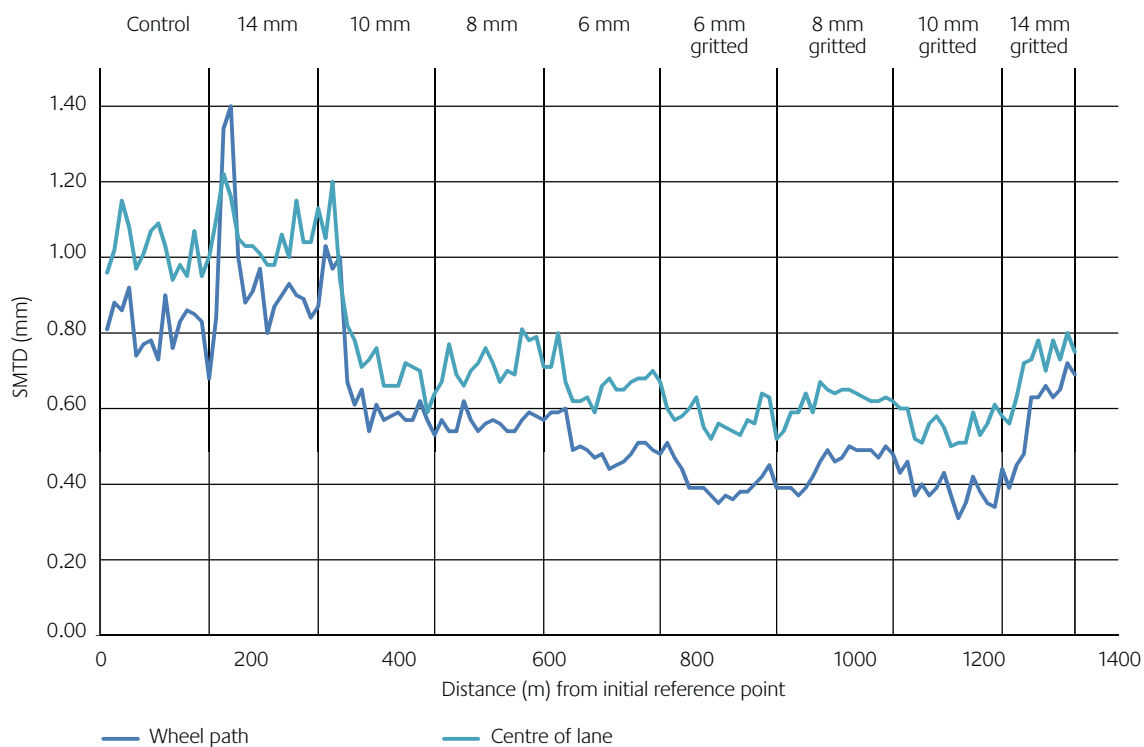


Figure 9.17 Texture depth along trial site after ten months of traffic

9.7 High-speed skid resistance after ten months of traffic

Figure 9.18, derived from data used to produce a diagram in TRL367 (Roe *et al.*, 1998), shows the relationship between locked-wheel friction and texture depth measured at 20 km/h and 100 km/h on a range of different types of surfacing. It can be seen that at 20 km/h there is a wide range of friction levels at any particular texture level (simply reflecting the range of levels measured in the experiments) and that texture depth has little or no influence. However, at 100 km/h, not only does the F_n value decrease markedly, but there is also a much greater loss of friction with speed at the lowest textures.

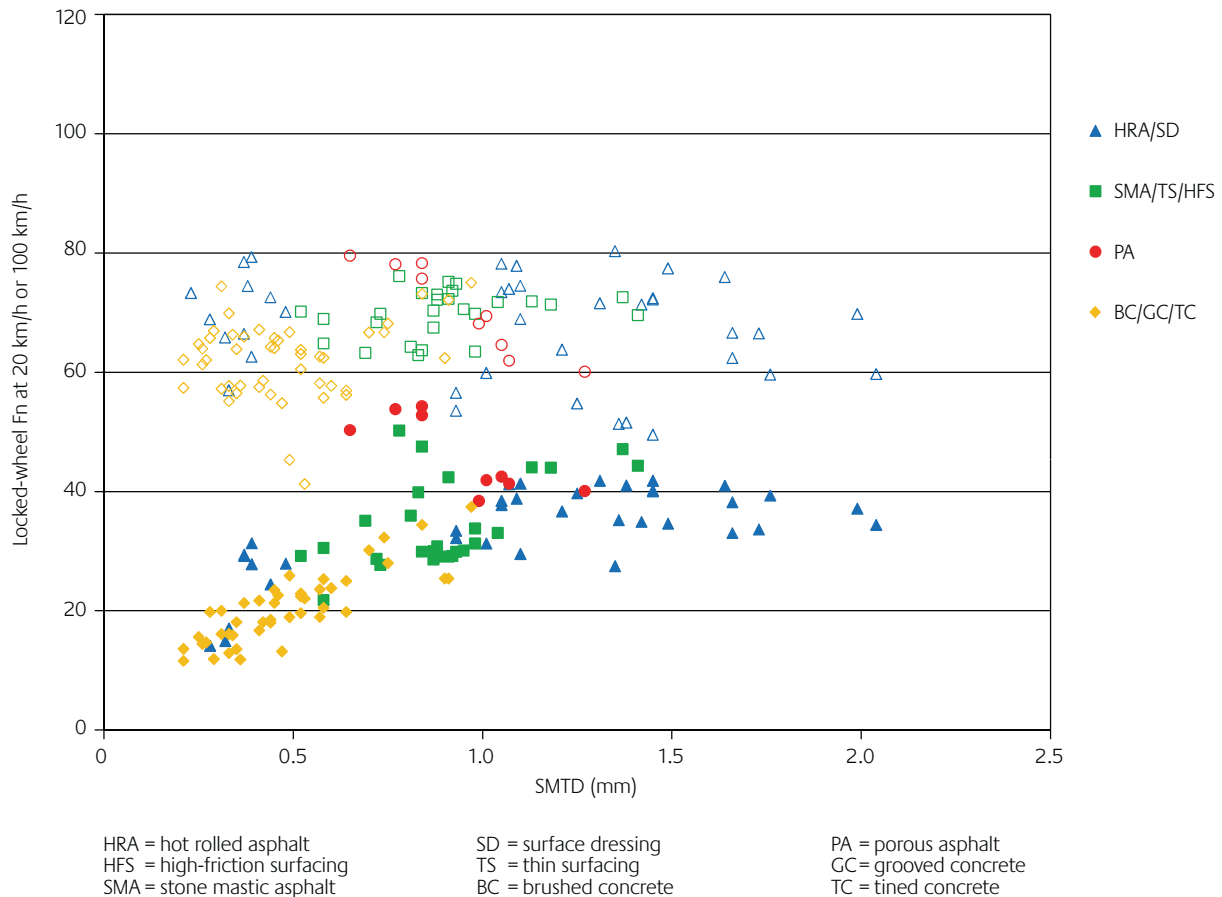


Figure 9.18 Relationship between friction and texture depth at low and high speeds (after TRL367)
(Open symbols represent F_n values at 20 km/h; filled symbols represent F_n values at 100 km/h)

9.7.1 Comparison with historical data on other surface types

Figure 9.19 plots the F_n values at 20 km/h and 100 km/h calculated from the trend lines against texture depth for the wheel path, and superimposes them on the historical data shown in Figure 9.18 (which have been greyed out for greater clarity). Figure 9.20 is an equivalent graphic for the measurements on the centre line. On these graphs, ungritted 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.

Some important observations may be made from these two figures:

- After ten months of traffic, all the trial surfaces are performing well at low speeds, regardless of their texture depth.
- The 0/6 mm, 0/8 mm and 0/10 mm materials all have texture depths below the 0.75 mm SMTD level.
- With the exception of the 0/6 mm materials, the gritted sections have lower texture depth than the ungritted sections, suggesting that the grit has filled the texture to some extent.
- Comparison of the centre-line and wheel-path data shows lower texture depths in the wheel paths, indicating that the passage of heavy traffic has resulted in some secondary compaction, causing a reduction in macrotexture.
- Generally, the high-speed performance of the surfaces is consistent with their texture depths, falling within the historical ranges.
- The 0/10 mm has particularly low high-speed friction.
- High-speed friction for the 0/14 mm and 0/8 mm gritted sections was at the upper range for their texture depth.

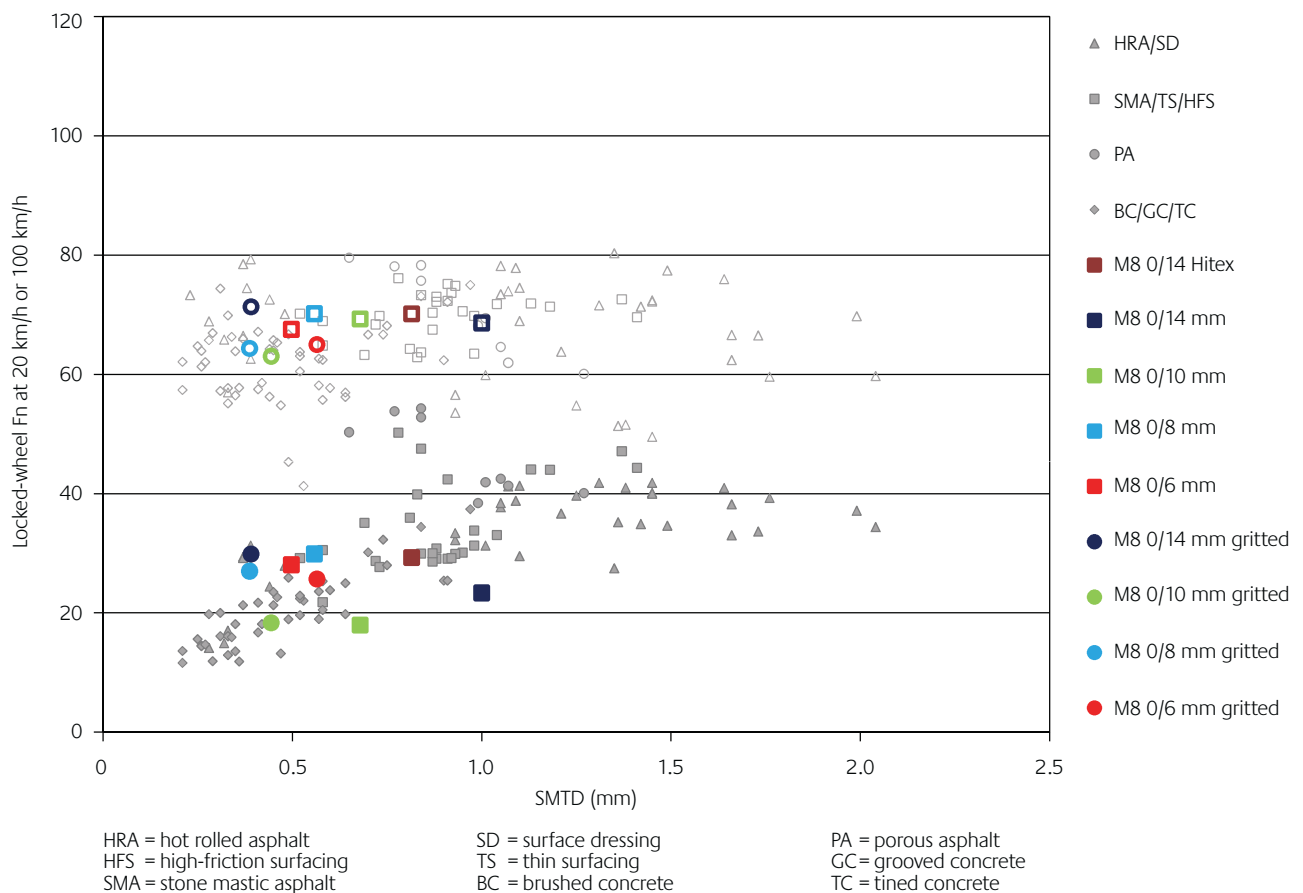


Figure 9.19 Locked-wheel friction and texture depth at 20 km/h and 100 km/h in the wheel path after ten months of traffic compared with historical data
(Open symbols represent F_n values at 20 km/h; filled symbols represent F_n values at 100 km/h)

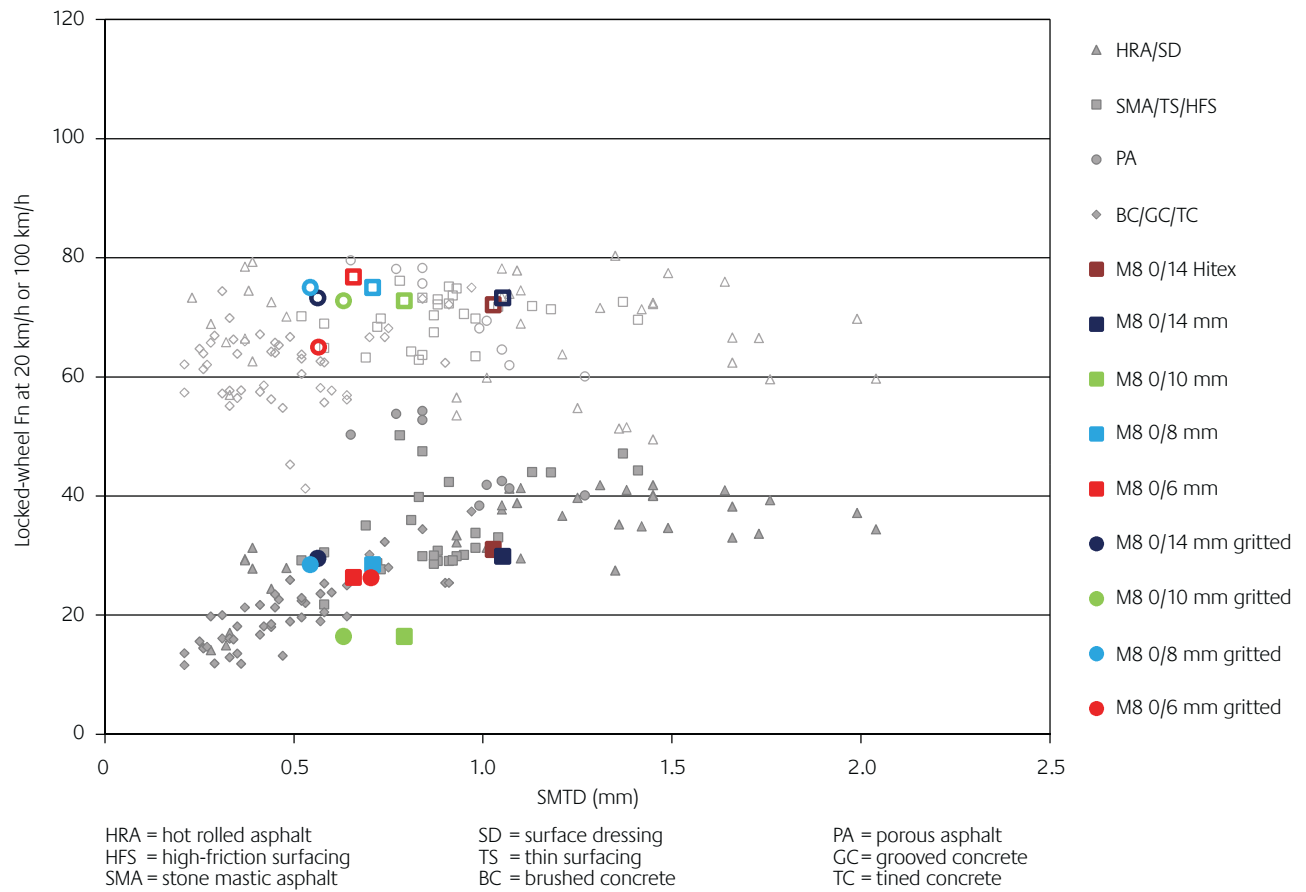


Figure 9.20 Locked-wheel friction and texture depth at 20 km/h and 100 km/h in the centre of the lane after ten months of traffic compared with historical data
(Open symbols represent Fn values at 20 km/h; filled symbols represent Fn values at 100 km/h)

10 M8 trial findings and discussion

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, compared with the original 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. Owing to the low air voids contents and higher bitumen contents targeted, the denser surfacing has a greater potential for improved durability.

One of the trial surfacings produced a lower surface texture depth than was expected and as a consequence produced the lowest high-speed friction measurements. In finalising a new surface course specification, it was recommended that the trial findings be discussed with German colleagues and that the collection of specific information on quality production issues and compliance testing be carried out. In introducing the use of modified SMAs for use on the Scottish Trunk Road Network, it was also recommended that producers would have to demonstrate the required performance characteristics as part of a Type Approval Installation Trial (TAIT). This would include a four-stage approval process, which would be required for each mixture at each plant and covers:

- laboratory mixture;
- product mix trial;
- Trunk Road Network trial; and
- final approval by Transport Scotland.

The German approach has strict controls on aggregate grading, binder content, air voids content and an in-service performance requirement for skid resistance. The in-service skid resistance requirement marks a step change in approach from that currently used in Scotland or elsewhere in the UK. However, one of the key drivers for this approach in Germany is durability, and an increase in serviceability is one of the main aims of this research.

Gritting was shown to have an influence on increasing early-life skidding resistance. It significantly improves friction at intermediate and high speeds initially, but the effect disappears with traffic. It is likely that the benefits of gritting will be short lived on motorways, but gritting is likely to be of value in reducing the skid risk on roads where traffic is lighter and the bitumen coating of surface aggregates is present for longer.

11 Development of a specification and notes for guidance

The need to make significant improvements to surfacing durability and to provide value for money have been the key drivers for this development.

11.1 Consultation with German professionals

In April 2010 representatives of Transport Scotland, QPA Scotland and TRL visited northern Germany to discuss the findings of the trial and quality production issues prior to finalising a new surface course specification. Meetings were held with the German Asphalt Paving Association; asphalt producers and contractors DEUTAG, KEMNA and Kam; and a leading asphalt expert.

Presentations were given and, following input from German practitioners and academics, several changes were made to the specification used on the M8 trial. Problems with 0/10 mm SMA were discussed at length. The German Asphalt Paving Association recommended the use of a PMB. This advice was based on problems experienced in Germany in 2005 with flushing, or loss of texture depth, under the action of heavy traffic. They recommended a PMB that utilised styrene-butadiene-styrene, a synthetic rubber. The introduction of the new European Standards in 2008 to harmonise National Standards, and the need for compliance with National Standards, gave an opportunity for Germany to make other changes to their specification, including refinements to mixture grading envelopes, use of fibres, air voids content limits for both the design and construction stage, and general guidance on the paving and construction of joints.

11.2 Consultation with the Quarry Products Association Scotland and the Transport Scotland Pavement Forum

As the specification was developed, updated versions of the specification and notes for guidance were issued for comment to the TSPF and industry representatives throughout the UK through the Quality Products Association. This process ensured that all comments were considered and refinements made.

11.2.1 Type Approval Installation Trial

As part of the above consultation, a TAIT process was developed for inclusion in the specification. The purpose of the TAIT is to demonstrate that the material is able to be consistently produced in accordance with the requirements of the specification.

The TAIT comprises a four-stage process: laboratory study; product mix trial, Trunk Road Network trial (interim approval) and final approval by Transport Scotland. The laboratory study (stage 1) relates to designing a mixture that meets the specification. The product mix trial (stage 2) provides the opportunity to assess the behaviour of the mix under compaction and enables the collection of information that provides the necessary properties of the laid and compacted material. Following the completion of a satisfactory product mix trial, a Trunk Road Network trial (stage 3) can then be undertaken. Following satisfactory completion of stage 3, confirmation of formal interim approval to use the product will be given by Transport Scotland after six months. If after the minimum period of two years all requirements of the specification are satisfactorily completed, final approval will be issued (stage 4).

11.3 TS 2010 Surface course specification and guidance notes

Taking on board the advice from the consultations with German paving experts and the lessons learned from the M8 trials, on 10 December 2010 a Transport Scotland Interim Amendment (TSIA No. 35; Transport Scotland, 2010a) was issued to introduce a new specification for surface course known as “TS 2010, Surface course specification and guidance notes” (Transport Scotland, 2010b). TSIA No. 35 and TS 2010 were released in December 2010.

The key elements of this specification are:

- strict grading requirements to ensure the correct extent of gap grading;
- performance-based in-service low-speed skid resistance requirement;
- addition of cellulose fibres;
- high PMB content;
- maximum air voids contents; and
- gritting of all new surfaces.

The strict grading requirements should ensure that mixtures obtain the required voids criteria and will inherently provide a certain amount of texture. While texture depth is not a requirement, it is being measured to gain a database of information that can be compared with the skid resistance performance as mixtures are developed and approved for use on the Trunk Road Network. The performance-based requirement for low-speed skid resistance has the potential advantage of using alternative PSV and locally won materials. The use of fibres and PMB ensure the material is rich in binder, which has a direct link with material durability. With the addition of the thick polymer binder film it is mandatory to grit all new surfaces to promote early-life skid resistance. The size of grit specified depends on the maximum aggregate size in the mixture: 1.0–2.8 mm for up to 10 mm, and 2–4 mm for 14 mm.

12 Conclusions

A review of surfacing performance on Scotland's Trunk Road Network in 2006 indicated that generally the surfacings were not providing good value for money. The open nature of the materials and poor joint construction were of particular concern.

Workshops held with industry in 2007 led to the formation of the TSPF. The forum meets on a quarterly basis and has been considered a very effective medium to share experience and promote and develop best practice.

Further network surveys in 2009 and 2010 have shown small improvements in performance, and it is recommended that these should continue to ensure further improvements.

Study trips to Germany, and initial trials of German-style SMA laid on the M8, have allowed lessons to be learned and a new surface course specification to be developed for use on the Scottish Trunk Road Network.

The specification, issued in December 2010, marks a step change in approach as it is performance based and has skid resistance requirements both when new and in service. The key elements of this specification are:

- strict grading requirements to ensure the correct extent of gap grading;
- performance-based in-service low-speed skid resistance requirement;
- addition of cellulose fibres;
- high PMB content;
- maximum air voids contents; and
- gritting of all new surfaces.

The approval of new materials under the new specification for use on the Scottish Trunk Road Network will be through a TAIT, which has four key stages covering laboratory study, product mix trial, Trunk Road Network trial and final approval by Transport Scotland.

The introduction of the new specification should provide significant improvements to material durability and value for money, and allow for the use of locally won materials. It is anticipated that further refinements to the specification will follow based on experience in practice.

Acknowledgements

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Appendix: Scottish Inspection Panel marking system

The Scottish Inspection Panel (SIP) is a body organised by TRL on behalf of Transport Scotland. The aim of the SIP is to provide an indicator of the in-service performance of surfacing used on the Scottish Trunk Road Network. It consists of a group of surfacing experts and the panel members represent Transport Scotland, the Performance Audit Group, Quarry Products Association Scotland and TRL. Each year the SIP team is responsible for assessing the visual condition of a random selection of surfacing sites. In addition, the survey team records any features that appear to affect the service life of material and documents typical modes of failure.

The panel utilises a seven-point scale ranging from *Bad* to *Excellent*. Each site is assessed on the basis of its current serviceability, irrespective of the elapsed time since it was laid. In considering the serviceability of the surfacing, the aspects in Table A.1 for the specific type of surfacing are considered, together with any project-related aspects given in the initial briefing. If any of the aspects are evident to a significant degree on the site, the relevant suffix from Table A.1 is applied to the basic marking.

Once any appropriate fault suffixes are assigned, the basic mark is allocated from the seven-point scale in Table A.2. When considering the markings, any sections that warrant a suffix cannot have a basic mark of *G* (i.e. *Good*) or better. When each panel member has reported their individual result, the convener (TRL staff member) converts the findings into the overall basic mark.

Table A.1 Defects and associated suffixes

Suffix	Description	Notes
v	Variable	Random variations from point to point within the section only, not “traffic laning” or of obvious variations from load to load
t	Variability with traffic intensity	Marked transverse differences caused by variations in traffic intensity between lanes
+	Fatting-up	Macadam, surface dressing
–	Loss of chippings	Hot rolled asphalt
	Loss of aggregate	Porous asphalt, macadam, thin surfacings, slurry surfacing
	Loose chippings	Surface dressing
	Wearing causing substrate to “grin” through	High-friction surfacing
j_o / j_f	Joint issue	j_o = open joint / j_f = fretting at joint
f	Fretting of mortar	Hot rolled asphalt
g	Growth of vegetation	Porous asphalt
p	Ponding	Porous asphalt
d	De-lamination from substrate	Porous asphalt, thin surfacings, surface dressing, high-friction surfacings, slurry surfacing
s	Stripping	All except high-friction surfacings
c	Cracking	Hot rolled asphalt, macadam, thin surfacing, high-friction surfacings

Table A.2 Basic seven-point scale

Mark	Description	
<i>E (Excellent)</i>	No discernible defect	
<i>G (Good)</i>	No significant defect	Termed serviceable
<i>M (Moderate)</i>	Some defects but insufficient for serious problem	
<i>A (Acceptable)</i>	Several defects but would usually be just acceptable	
<i>S (Suspect)</i>	Seriously defective but still serviceable in the short term	
<i>P (Poor)</i>	Requires remedial treatment	Termed unserviceable
<i>B (Bad)</i>	Requires immediate remedial treatment	

Recent reports on thin surfacings and/or durability

Increasing the environmental sustainability of asphalt

Great strides have been made to improve the environmental sustainability of asphalt, including thin surfacing systems, with the industry implementing measures to improve its durability, re-use reclaimed asphalt and incorporate secondary materials. This Insight Report describes these measures and considers the resulting life-cycle implications.

INS007, £97.50

Durability of thin asphalt surfacing systems (part 4)

Thin surfacing systems, as the term is currently understood, were introduced into the UK in 1991. Many sites with thin surfacing systems have reached or are approaching the end of their assumed lives so that a review of the service that can be expected from such surfacings can now be made with some confidence. The information collected from a selection of sites with thin surfacing systems has been evaluated to establish this understanding of their serviceable life. In this TRL Report, the results from visual condition, SCRIMtex and recovered binder properties are given for sites monitored over the last three years of a nine-year review (begun in 2001) together with analysis of these data and the results from preceding years on a total of 137 sites.

TRL674, £80

Best practice guide for recycling into surface course

The incorporation of suitable reclaimed asphalt in thin surfacing materials is becoming an important issue with the depletion of high-quality aggregate resources and greater emphasis on sustainability. This Road Note is a guide to good practice when specifying, designing, producing and applying the approach to enhance sustainability through recycling surface materials.

RN43, £45

Best practice guide for durability of asphalt pavements

One of the recent tasks carried out by TRL for the Highways Agency, Mineral Products Association and Refined Bitumen Association focused on the durability of asphalt pavements, including thin surfacing systems. A principal aim of this task was to identify the techniques and procedures currently considered to be best practice and to produce a best practice guide based on that knowledge. The aim of this guide is to encourage everyone working in the asphalt industry to contribute to making pavements as durable as practical.

RN42, £55



Reports on the introduction of thin surfacing systems

A history of the recent thin surfacing revolution in the United Kingdom

This TRL Report reviews the major changes that have occurred in the surface course materials used in the United Kingdom during the 1990s. In 1991, trials of thin surfacings from France were started while trials of stone mastic asphalt from Germany started from 1994. From these trials and later ones, thin surfacing systems were accepted as a surfacing that now provides the majority of material used in the UK.

TRL522, £35

Road trials of thin wearing course materials

This Project Report describes a series of road trials of two proprietary thin surfacing techniques, UL-M (one site) and Safepave (seven sites), that are now called thin surfacing systems. The report summarises the performance of the materials during their early service life. Most of the claims made for the materials appear to be confirmed, but there were reservations regarding surface texture.

PR79, £45

Road trials of stone mastic asphalt and other thin surfacings

This report is the second, after PR79, on a series of road trial sites with thin surface course materials that were then innovative in the UK and had been monitored for up to six years at that time. This TRL Report describes the later sites, four with sections of stone mastic asphalt surface course and one with a multiple surface dressing thin surfacing system.

TRL314, £45



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A review of the performance of asphalt surfacing used in Scotland in 2006 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 a programme of research to improve road surfacing to make it safer and more sustainable. The work included annual surfacing inspections, industry workshops, study trips to Germany to view their stone mastic asphalt (SMA) surfacings and full-scale road trials in Scotland. The trials comprised eight SMA materials using nominal aggregate sizes of 14 mm, 10 mm, 8 mm and 6 mm, with four of the trial surfacings being treated with grit to improve early-life skid resistance. This TRL Report describes the research and how the results were used to develop a new performance-based surface course specification for use on Scotland's Trunk Roads. The new specification marks a step change in approach for specifying surfacing material that should provide key benefits in improved durability and value for money.

Related publications

- TRL674** Durability of thin asphalt surfacing systems. Part 4: Final report after nine years' monitoring. J C Nicholls, I Carswell, C Thomas and B Sexton. 2010
- RN43** Best practice guide for recycling into surface course. I Carswell, J C Nicholls, I Widyatmoko, J Harris and R Taylor. 2010
- RN42** Best practice guide for durability of asphalt pavements. J C Nicholls, M J McHale and R D Griffiths. 2008
- RN41** Best practice guide for overlaying concrete. R W Jordan, C Coley, H M Harding, I Carswell and K E Hassan. 2008

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