

Transport Research Laboratory



**Further studies of the skid resistance of
asphalt surfaces in their early life**

by M J Greene, P D Sanders and P G Roe

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Prepared for: Project Record: 2/462_083

**Understanding and Reducing Skidding Accident
Risk on New Asphalt Surfaces**

**Client: Highways Agency, Network Services
(Louise Caudwell)**

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Executive summary

Modern asphalt road surfacings can offer advantages over their traditional counterparts such as faster and safer construction, reduced road/tyre noise and improved ride quality. Soon after their introduction onto UK roads in the mid-1990s, the new types of surfacing became the subject of anecdotal comment about their skid resistance, especially in the period soon after they had been laid. Comments were reinforced by lower than usual dry friction observed by the police in routine stopping distance skid tests.

A feature of these newer types of asphalt is a thicker film of bitumen binder material on the road surface than that found on traditional materials such as Hot Rolled Asphalt (HRA). It is possible that this thicker binder film could result in skid resistance characteristics that are different from those on roads which have been in service for longer. It was suggested that the binder film could have the effect of masking the microtexture of the aggregate (with an adverse effect on wet skid resistance) or it could soften in the heat generated during braking, in effect partially lubricating the underlying road surface and leading to the lower friction values recorded by the Police.

An initial study by TRL for the Highways Agency sought a greater understanding of the skidding resistance properties of new asphalt, using locked-wheel friction measurement techniques to assess the friction both on new and older examples of modern surfacings. That work, reported in PPR060 (Roe and Lagarde-Forest, 2005) found that the suggested phenomena were occurring and that they might present a small increase in accident risk on new surfaces in some circumstances. It was also noted that the effects observed on new types of asphalt may well have always been present on traditional materials but that they were perhaps shorter lived and so had gone undetected.

A recommendation from the earlier study was that "Specific research into any link between new surfacings and accident risk should be carried out". This was done and has been reported in PPR205 (Greene and Crinson, 2008). The accident study found, broadly, that there was a small increase in slight injury accidents in the first few months after laying a new surface on some types of road but that these accidents occurred in low-risk areas and were accompanied by a significant reduction in fatal accidents.

In parallel with and following on from that study, work has continued to address other recommendations made in PPR060, including investigating further the physical phenomena associated with the early life condition of new asphalt and possible approaches to mitigate any risks. This report is the third in the series and covers the work studying the physical phenomena. In particular, it addresses the following aspects of new asphalt surfaces:

- The development of skid resistance with time and traffic, especially in the very early life of new surfaces.
- Comparison of the early-life skid resistance effects on different types of asphalt surfacing.
- The influence of road surface temperature on early-life effects.
- The effects of gritting new asphalt surfaces.

To understand some of the effects, sections of the TRL test track were resurfaced with new asphalt materials and skid resistance measurements were made under several surface conditions. To support data collected from the TRL test track, and to answer the other fundamental questions within this study, opportunities were also taken to make relevant measurements on a number of ordinary in-service roads or trial sites on public roads that were being visited in the course of other work not directly part of this study.

Within the study a number of different measurements were taken; the Pavement Friction Tester (PFT) was used to make wet and dry locked wheel friction measurements; sideways force coefficient (SFC) data were collected using the Sideway-force Coefficient Routine Investigation Machine (SCRIM) and dry locked wheel braking measurements

were made using SkidMan, a device routinely used by the police for collision investigation purposes.

The main findings from the study were:

- The two effects of high dry friction and reduced dry friction reported in PPR060 have been reinforced.
- Detailed analysis of individual skid tests has found that initially during a skid, locked-wheel dry friction is very high (greater than would normally be expected from a clean, dry, well-trafficked road) and this condition can be maintained over a number of seconds. However, there can also be a sudden transition to a reduced friction condition, which is associated with the softening of the surface bitumen film.
- Once the reduced friction condition has occurred, the friction level recorded is typically in the range of $F_n = 50$ to 60 and is not affected by the sliding speed.
- The analysis found that either condition can occur at speeds as low as 20 km/h or at 50 km/h or higher. While the high-friction condition is more likely to be maintained at low sliding speeds and the low-friction condition appears to be more likely to develop at higher sliding speeds, it is not possible to predict which will predominate or at what speed the transition from one to the other occurs.
- Increasing the surface temperature of a new surfacing (as might occur on a hot day in bright sunlight) does not appear to increase the likelihood of a reduced-friction dry skid occurring. In fact the data suggest that increased temperature may result in the high-friction condition being more likely to occur at higher speeds.
- The work has confirmed that on new surfaces there is a greater rate of reduction in wet skid resistance at intermediate speeds, together with potentially lower than expected high-speed friction.
- The study has also demonstrated (as had previously been inferred) that all these effects can be observed on new HRA surfaces as well as on new thin surfacings, although they are likely to be shorter-lived on HRA at higher traffic levels.
- Some effects can become less noticeable over time as a result of weathering, without the passage of traffic.
- The study has confirmed that there is a period very early in the life of a new surfacing when the wet skid resistance reduces markedly and then increases again. This phenomenon appears to be associated with the combined effects of traffic and time. On busier roads, it is short-lived, often occurring in the first few days after opening to traffic. Typically, the effect is greatest after the passage of about 12,000 heavy vehicles and has disappeared after 45,000 heavy vehicles have passed.
- Application of grit to a newly-laid surface can have some short-term advantages mainly in terms of wet skid resistance by removing the effect of the greater rate of loss of skid resistance with increased speed when the surface is very new. The treatment may also reduce the likelihood of reduced dry friction occurring on older lightly-trafficked surfaces. Further detailed study of treatments of this type is needed to confirm the full range of any beneficial effects or disadvantages, however.

The report also reviews the implications for accident risk in the light of these results and concludes that the current study reinforces the observations made in PPR060 (Roe and Lagarde-Forest, 2005) and can explain the changes in accident risk on new surfaces identified in the subsequent accident analysis reported in PPR205 (Greene and Crinson, 2008).

It is therefore recommended that the current guidance provided in IAN 49/03 requires review and this is currently being progressed by HA.

1 Introduction

Modern asphalt road surfacing materials can offer advantages over their traditional counterparts such as faster and safer construction, a reduction in road/tyre noise and an improved ride quality. Soon after their introduction onto the UK road network in the mid 1990s, these new types of road surfacing became the subject of anecdotal comment relating to their skid resistance performance, especially in the period soon after they had been laid. These comments were reinforced by observations of lower than usual dry friction in routine stopping distance skid tests conducted by police collision investigators.

A feature of these newer types of asphalt is the presence of a thicker film of binder material on the road surface than that found on traditional materials such as hot rolled asphalt (HRA). (Most of the running surface of HRA comprises chippings that are given a thin coating of bitumen before they are rolled into the hot asphalt mat.)

It was suggested that the bitumen film could cause the new road surface to produce skid resistance characteristics that differ from roads which have been in service for longer. For example, the binder film could have the effect of masking the microtexture of the aggregate (with an adverse effect on wet skid resistance) or indeed soften under the heat generated during braking, in effect partially lubricating the underlying road surface and leading to the lower friction values recorded by the Police.

An initial study by TRL on behalf of the Highways Agency sought to obtain a greater understanding of the skid resistance properties of new asphalt surfacings. Locked-wheel friction measurement techniques were used to assess the friction both on new and older examples of modern asphalt surfacings. That study, reported in PPR060 (Roe and Lagarde-Forest, 2005), concentrated on modern asphalt surfacings because this appeared to be the main area of concern at the time and HA had already discontinued routine use of HRA for new or replacement works more than two years before the work began. It was found that the suggested phenomena could be observed and that these might present a small increase in accident risk on new surfaces in some circumstances. It was also noted, however, that the effects that had been observed on new types of asphalt may well have been present on traditional materials but that they were perhaps shorter lived and so had gone undetected.

One of the recommendations from PPR060 was that "Specific research into any link between new surfacings and accident risk should be carried out". This recommendation was implemented and has been reported in PPR205 (Greene and Crinson, 2008). The accident study found, broadly, that there was some evidence of a small increase in slight injury accidents in the first few months after laying a new surface on some types of road but that these occurred in low-risk areas and were accompanied by a significant reduction in fatal accidents.

In parallel with and following on from that study, work has continued to address other recommendations of PPR060, including investigating further the physical phenomena associated with the early life condition of new asphalt and possible approaches to mitigate any risks.

This report, the third in the series on the topic of early-life skid resistance, covers the recent work studying the physical phenomena.

2 Scope and Objectives

The work described in this report was aimed primarily at addressing recommendations made in PPR060, with the addition of some aspects that had been identified as worthy of attention subsequent to that report's publication. Three main areas of research are covered here:

- Development of skid resistance with time and traffic, especially in the very early life of new surfaces.
- Comparison of the early-life skid resistance effects on different types of asphalt surfacing.
- The influence of road surface temperature on early-life effects.

PPR060 also recommended further research into approaches to mitigate accident risks in areas where these might be increased as a consequence of early-life skid resistance phenomena. This recommendation has been pursued in parallel to this work, and will be reported separately. However, the approaches identified include surface treatment techniques, one of which is the application of grit to newly-laid surfaces and as the work progressed, opportunities arose to include measurements on surfaces treated in this way. This introduced a further strand to the research:

- The effects of gritting new asphalt surfaces.

2.1 The effects of time and traffic

The research in PPR060 found that most physical effects had disappeared after about six months of traffic but they could sometimes be observed on surfacings that had been in service for longer. However, the work had concentrated on surfacings on more heavily-trafficked roads. Therefore, there were concerns that the effects could be present for an extended period on parts of the network that carry less traffic. This would be of particular relevance to local authority rural roads but could also be important for remoter parts of the trunk road network and less-heavily trafficked lanes on motorways and dual carriageways.

Also, other workers had reported finding reduced levels of wet low-speed skid resistance in the first few days or weeks of the life of new surfacings that were not detected in the TRL research. Consequently, PPR060 recommended that this should be investigated, giving rise to the first objective of the present research, which was to answer the question:

- *How does skid resistance behaviour change with time and traffic, especially very early in the life of new surfaces?*

2.2 Comparison of different surfacing types

Questions about early-life skid resistance were first raised in the 1980s, at a time when HRA was the material most often used for surfacing work on major roads in the UK. However, the issues came to greater prominence with the increased use of modern asphalt surfacings a decade later. In 1998, the Highways Agency ceased using HRA for new surfacings, preferring to use modern asphalts for their low-noise properties and other advantages such as greater ease of laying. Many local authorities had followed suit. For this reason, the early research concentrated on modern asphalt materials, or "thin surfacings" as they are commonly known.

In recent years, however, some UK local authorities have reverted to using HRA in some situations, primarily in response to durability issues relating to thin surfacings, but also in part to reduce possible early-life risks. The authors of PPR060 noted that a question sometimes asked was whether such phenomena (and any associated short-term increase in accident risk) might always have been present on new asphalt surfacings but had

been passing undetected. The second objective of the present research, therefore, was to address this question:

- *To what extent are the physical effects associated with new modern asphalt surfacings found on traditional HRA?*

2.3 The influence of surface temperature on dry friction

One of the phenomena that gave rise to concern was the reduction in dry friction (compared with older well-trafficked roads) that can occur in locked-wheel skids on new asphalt. This effect, which has the potential to increase stopping distances in dry emergency braking, has been attributed to a softening of the bitumen film on the surface of the road associated with raised temperatures in the contact patches of skidding tyres.

New road surfacings are now laid throughout the year to comply with Journey Time Reliability requirements. However, it is known that in prolonged periods of hot and sunny weather, road surface temperatures can increase significantly above normal ambient conditions, reaching temperatures as high as 50 degrees Celsius in the UK.

For surfaces laid in the summer months this raises the possibility that, in such conditions, the raised temperature on a new asphalt surface could be closer to the softening point of the bitumen and might therefore make the reduced-friction effect more likely to occur. The third objective of this research has therefore been to consider the question:

- *Does increased road surface temperature affect dry friction?*

2.4 Initial gritting

A potential means of reducing the risk of skidding on new thin surfacings is to apply a surface treatment that has the effect of either removing the bitumen layer from the surface or accelerating its removal. Gritting is one such treatment, widely used in some countries (particularly in Germany) and also in one or two local authority areas in the UK. It is not, however, used on HA roads at present.

With this treatment, an abrasive grit is spread over and rolled into the still-warm asphalt surface in the final stages of compaction. The theory is that, initially, the grit provides some fine texture to replace that on the aggregate that is covered in bitumen and then under traffic the grit will abrade the surface and accelerate the removal of the bitumen film.

As the other strands of work progressed, opportunities arose to make measurements on surfaces where this technique had been used in comparative exercises and this provided some initial data to address the question:

- *What influence does initial gritting have on early-life skid resistance?*

3 Measurement techniques used

As part of this project a number of different measurements were taken; the Pavement Friction Tester (PFT) was used to make wet and dry locked wheel friction measurements; sideways force coefficient (SFC) data were collected using the Sideway-force Coefficient Routine Investigation Machine (SCRIM) and dry locked wheel braking measurements were made using SkidMan, a device routinely used by the police for collision investigation purposes.

3.1 Pavement Friction Tester

The PFT is a locked wheel road surface friction testing device owned by the Highways Agency and operated on its behalf by TRL. During testing, the test wheel contact patch slides over the surface at the same speed as the towing vehicle. This device can therefore measure skidding resistance at any practical speed up to about 120 km/h. Whilst testing, the load and drag forces on the tyre are measured every 0.01 seconds throughout the braking cycle. This produces a graph that usually follows the form illustrated in Figure 3.1.

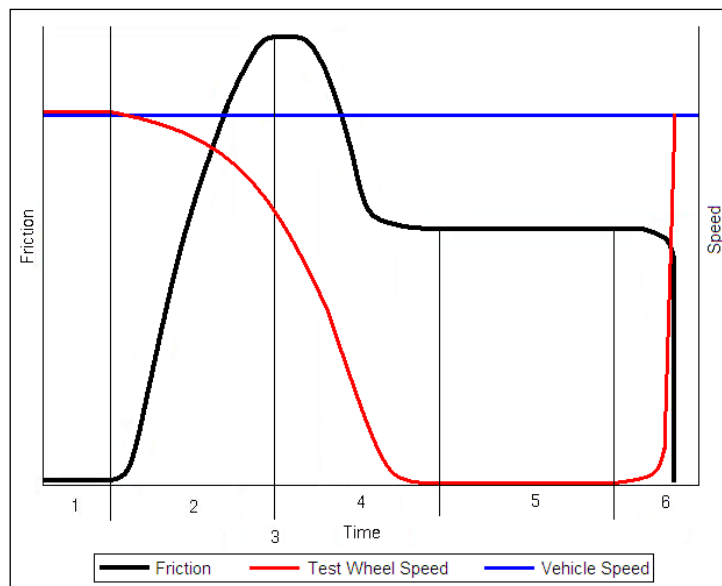


Figure 3.1 Idealised graph of an average wet PFT skid test

The friction-time relationship (referred to in this report as the skid profile) passes through six stages, marked 1 – 6 on the time axis of Figure 3.1:

1. *Free Rotation* - With the brake off and the test wheel rotating normally, the contact patch of the tyre is instantaneously stationary relative to the road surface. There is a small, but constant, frictional force acting on the tyre due to microscopic interaction between the tyre and the road surface and friction in the wheel bearings.
2. *Initial Friction* - When the brake is applied the wheel continues to rotate normally and the frictional force acting upon the tyre increases. As the brake force increases, the test wheel begins to slow down and the contact patch between the tyre and road begins to slip.
3. *Peak Friction* - At peak friction, the test wheel is still rotating but it is now slipping so that the tyre surface in the contact patch moves relative to the road surface, typically at about 85% of the vehicle speed.

4. *Lock and Settle* - Once the peak friction has been passed, the test tyre slows down rapidly under the action of the brake and the frictional force begins to decrease. Eventually, the wheel stops turning (the wheel is locked) and the contact patch settles into a condition in which it is skidding over the surface at the vehicle speed. In a standard test, the locked condition must be reached in less than two seconds from the brake application; 0.5s is allowed for the settling period.
5. *Measurement phase* - During this phase (which lasts one second in a standard test) the test wheel is completely locked and the tyre is in a full skid with the contact patch moving at the vehicle speed. The average ratio of the vertical and horizontal forces acting on the test wheel during this 1-second period provides the value for the friction measurement. The measurement is referred to in this report as F_n and is equivalent to the friction coefficient multiplied by 100.
6. *Free Rotation* - At the final stage, the brake is released, so the test wheel speed increases and the friction returns to its initial state.

Measurements are usually made under wet surface conditions using water pumped from an on board tank through a nozzle in front of the test wheel. The water supply can also be turned off enabling measurements to be taken in dry conditions. Previous research has shown that under dry conditions friction does not decrease significantly at higher speeds (even on recently laid asphalt surfacings). Because of this and to reduce tyre wear, dry testing with the PFT was restricted to a maximum speed of 50 km/h during this study. Figure 3.2 shows the PFT conducting a dry test.

This ability to measure both wet and dry skid resistance at varying speeds meant the PFT was the primary piece of equipment used in this study. A feature of the PFT that is particularly useful is that it is possible to view the skid profile over the entire braking cycle. This information is valuable when assessing physical effects of surfacings as a change in the form of skid profile could highlight a change in physical effects occurring during the tests.



Figure 3.2 Pavement Friction Tester conducting a dry test at TRL

3.2 Sideway-force Coefficient Routine Investigation Machine

SCRIM is the standard device for monitoring the skid resistance condition of the UK trunk road network and is also used by many local authorities. An example of a SCRIM is shown in Figure 3.3. Measurements from this device provide data that can be used to compare surfacings with the skidding standards for the sites concerned. SCRIM was used in this study to record low-speed wet skidding resistance on some sites. One of the features of SCRIM is its ability to make continuous skid resistance measurements over many kilometres.



Figure 3.3 SCRIM testing a section of the TRL test track

A smooth test tyre is angled at 20° to the direction of travel and instrumentation records a SCRIM Reading (SR) for every 10m length of road. The SR is the average ratio between the measured sideways force and the 200kg vertical load, multiplied by 100. Measurements are usually made at a standard test speed of 50 km/h in the nearside wheel path. However as the test wheel is at a 20° angle, the effective speed at which the tyre contact patch moves over the surface (the slip speed) is 17km/h.

3.3 Police skid tests

Police collision investigators collect data to assess road surface friction at a specific accident location close to the time of the event. The measurements are most often carried out when the road is dry. They normally use a proprietary unit containing accelerometers and control electronics placed inside the police car (SkidMan and Brakesafe are versions commonly used in the UK).

To undertake a test, the antilock braking system is usually disabled. The vehicle is driven at a chosen speed and then subjected to emergency braking to force the wheels to lock (Figure 3.4). The skid is then maintained until the vehicle is stationary. The average acceleration is divided by the acceleration due to gravity and corrected for any gradient in the road; this then provides a measure of the average coefficient of sliding friction in the area of the skid.



Figure 3.4 SkidMan equipped police car conducting a test

This technique records the average coefficient of friction that results from four standard vehicle tyres, decelerating from a chosen target speed until the vehicle stops. Figure 3.5 is an example of the printout from a SkidMan device on a wet road showing the friction versus time curve. However, because the vehicle is slowing down, this is also a friction versus speed curve.

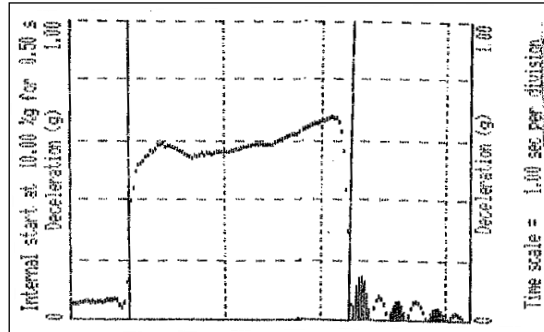


Figure 3.5 Typical results from a police SkidMan test

During these tests all four wheels are locked and therefore the skid takes place on whatever line the skid dictates. This may not necessarily be the same line as that traversed by normal traffic. Therefore, results from SkidMan and other similar police tests are not directly comparable with results from the other testing equipment used as part of this study.

4 Sources of data

To understand some of the physical effects occurring on new asphalt surfacings, sections of the TRL test track were resurfaced with new asphalt materials and skid resistance measurements were made under several surface conditions. To support data collected from the TRL test track, and to answer the other fundamental questions which are the subject of this report, opportunities were also taken to make relevant measurements on a number of ordinary in-service roads or trial sites on public roads that were being visited in the course of other work not directly part of this study.

4.1 TRL test track

A major component of this study was to directly compare the performance of different asphalt surfacings under controlled conditions. To achieve this, three sections of the TRL test track were resurfaced with the following materials:

- HRA with 20mm pre-coated chippings.
- 0/14 Fibre-reinforced bitumen thin surfacing (FRTS).
- 0/14 Polymer-modified bitumen proprietary thin surfacing (PMTS).

This made a site available on which comparative measurements could be taken between each of the main types of asphalt surfacing material, both in their as-laid state and as time passed, to assess the effects of weathering in the absence of traffic. Measurements were made for this purpose in the first few days and then several months after they had been laid. The trial sections on the TRL track were also used in a surface heating experiment to ascertain the effects of an elevated surface temperature on skidding resistance (see Section 7).

The photographs in Figure 4.1 show the laying of the HRA section, with the chipping spreader applying the chippings to the hot asphalt mat and the triple-roller completing the compaction process and rolling the chippings into the surface.



Figure 4.1 The spreading (left) and rolling (right) of chippings on the HRA section of the TRL test track

Figure 4.2 shows the finished surfaces of the HRA and one of the thin surfacing sections. The fresh, shiny, bitumen on the surfaces of the aggregate particles can be clearly seen on both types of material. The lighter patches that can be seen on a few aggregate particles occur where the individual chipping has been abraded or slightly crushed by the passage of the roller. To the naked eye, the two types of thin surfacing when freshly laid looked identical.



Figure 4.2 Newly laid surfacings on the TRL test track; HRA (left) and thin surfacing (right)

4.2 In-service roads

4.2.1 A140 and B1078, Suffolk

In 2006 Suffolk County Council (SCC) commissioned TRL to make dry and wet friction measurements on lengths of pavement that they had resurfaced as part of their normal maintenance programme. These surfaces included HRA and proprietary thin surfacings. SCC gave their permission to include data from these sites as part of this study and the opportunity was taken to re-visit them to make additional measurements. The first set of measurements was made fairly early in the service lives of the sites (about 1 month old); comparative measurements were taken after about a year of traffic.

4.2.2 Collaborative Research Programme trial sites

As part of an ongoing Collaborative Programme of research jointly sponsored by the Highways Agency, the Quarry Products Association (now the Mineral Products Association, MPA) and the Refined Bitumen Association, several different proprietary thin surfacing systems were laid on a number of test sites. These included examples of surfacings using different coarse aggregate sizes as part of a study to assess the influence of aggregate size on skid resistance (Roe, Dunford and Crabb, 2008).

The primary interest was the equilibrium skid resistance and high-speed friction characteristics that would be achieved by the different materials after some years in service. However, in order to help assess this, the measurement programme included tests with SCRIM and the PFT as the surfacings aged. The dates for the laying of these surfaces were known in advance, so it was possible to take measurements very early in the lives of some of them. This served two purposes: to confirm for the Collaborative Programme whether, in general terms, the early-life characteristics of the different materials were as expected from previous studies and to provide specific data that could be used for this study.

Measurements were made when the pavements were newly laid, one day old, three days old, ten days old, four months old and seven months old (monitoring is expected to continue until the surfaces are up to three years old). The measurements from the early life phase of the sites have been used in this study with the permission of the project steering group.

4.2.3 A389 St Issey, Cornwall

In 2006 the then Cornwall County Council (CCC) advised TRL of a trial that was being undertaken on the A389 at St Issey near Padstow, to assess the effects of applying grit to newly laid thin surfacings. The opportunity was made available to TRL to make skid resistance measurements using the PFT on this site.

Aided by traffic management provided by CCC, wet and dry locked-wheel friction measurements were made in September 2006, after the site had been subjected to several months of trafficking. Figure 4.3 shows the PFT conducting a wet test on the gritted section. In the left foreground of the photograph, residual skid marks from previous dry tests can be seen.



Figure 4.3 PFT conducting a wet test on the A389 trial site
(Tyre marks in the nearside wheel path are due to previous dry testing)

4.2.4 M8 Newhouse-Duntilland, Scotland

As part of a separate project to assess the durability of thin surfacing materials TRL were commissioned by Transport Scotland to make skid resistance measurements on a trial site on the M8. A number of dense stone mastic asphalt (SMA) surfacings (similar to those used in Germany) were laid on this site using different "coarse" aggregate sizes (0/6 mm, 0/8 mm, 0/10 mm and 0/14 mm).

In order to assess the effects of initial gritting as a possible remedial action to deal with early-life effects, two sets of sections were laid, the second set being treated with a 1/2.8 mm lightly coated grit (of the same aggregate as used in the trial sections) during the laying process. The grit was applied to the hot asphalt mat from a hopper mounted on the front of a tandem roller. This machine was operated (without vibration) just behind the rollers that were compacting the material (Figure 4.4). The photographs in Figure 4.5 illustrate the surfaces of the 0/14 mm section before and after gritting.

Wet and dry locked-wheel friction measurements were made with the PFT, together with low-speed wet skid resistance measurements with SCRIM. Measurements were made when the surfaces were newly laid and again after three days, six months and ten months of trafficking. This was the first example of a gritting process being applied to a major route in the UK; data collected have been included in this study with the permission of Transport Scotland.



Figure 4.4 Applying grit to newly-laid SMA on the M8 trial site

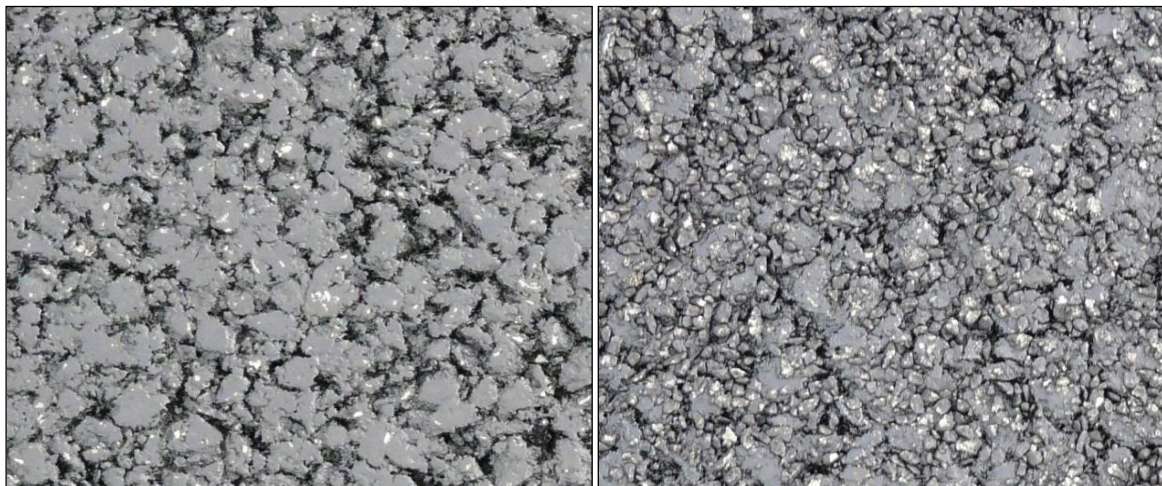


Figure 4.5 Close-up of 0/14 mm SMA on the M8 trial site before (left) and immediately after (right) gritting

4.3 TRL Database

The specific sources of data described in sections 4.1 and 4.2 represent some specific individual situations. In order to compare the skid resistance characteristics of these sites with UK asphalt surfacings more generally, a database was compiled that included all peak- and locked-wheel friction data still available from previous TRL studies in which the PFT had been used.

The database comprised data from over 3800 wet and 1500 dry friction tests representing many different sites, surfacings, surface conditions, ages and test speeds. Its main use in this study was to provide a larger data set than the specific study sites could offer to represent selected types of surfacing and trafficking conditions. By determining the typical data ranges (typically the 90th percentile ranges) for selected conditions on roads more generally as well as the newly-laid surfaces, a broader context was provided for assessing the specific site data.

5 Development of skid resistance with time and traffic

A component of this study was to ascertain how the skid resistance behaviour of new asphalt surfacings changes with time and traffic, especially in their very early life. To observe this behaviour, measurements of both dry and wet friction made during this initial period were used, including those on surfaces that had been subjected to extended periods with no traffic.

For this analysis, data from tests carried out on the TRL track and from the collaborative research programme trial sites (referred to subsequently in this report as the CP sites) were used. Table 5-1 lists the various sites and surfacings and indicates the times at which they were tested.

Table 5-1 Surfacing laid on each trial site and the ages at which these were tested

| Location | Material | Age when tested | | | | | | |
|-----------------------------|--------------------------|-----------------|-------|--------|---------|----------|----------|-------------------------|
| | | New | 1 Day | 3 Days | 10 Days | 4 Months | 7 Months | 8 Months (Untrafficked) |
| A5 Gibbet Hill | 0/6 PMTS | | | | | | | |
| | 0/10 FRTS | | | | | | | |
| | 0/14 FRTS | | | | | | | |
| | 0/14 FRTS | | | | | | | |
| A5 Tamworth | 0/14 FRTS | | | | | | | |
| | 0/10 FRTS | | | | | | | |
| A14 Creeping St. Mary | 0/6 PMTS | | | | | | | |
| | 0/10 FRTS | | | | | | | |
| | 0/14 FRTS | | | | | | | |
| A43 Brackley | 0/6 PMTS | | | | | | | |
| | 0/10 FRTS | | | | | | | |
| | 0/14 FRTS | | | | | | | |
| | 0/20 FRTS | | | | | | | |
| TRL test track | HRA 20mm chippings | | | | | | | |
| | 0/14 PMTS | | | | | | | |
| | 0/14 FRTS | | | | | | | |

5.1 Changes in dry friction characteristics

In a dry PFT measurement cycle on an older, well-trafficked road surface, a skid profile similar to that described in Figure 3.1 is typically observed, with the peak occurring just before the wheel locks. Of course, on a dry road the difference between the peak friction and locked-wheel friction is small and high F_n levels (typically around 80) are recorded.

In the work behind PPR060, reduced friction (with F_n values typically in the range 50 – 60) was observed under dry conditions on new surfaces. This was attributed to the heat generated during a skid leading to softening of the bitumen binder. Evidence cited for this was the observation that the skid process had the effect of smearing surface bitumen along the length of the skid, some of which collected on the test tyre at the front of the contact patch and was re-deposited in patches from the rotating wheel when released at its end¹.

Detailed study of the skid profiles has found that, on new asphalt surfaces, the skid profile has different characteristics to those expected in a normal wet skid or dry skid on a well-trafficked road: typically (although not exclusively), peak friction is reached *after* the wheel has locked and this is followed by a rapid decrease to the reduced friction level. This behaviour was also seen on the newly laid asphalt specimens on the TRL test track.

Figure 5.1 illustrates a skid profile from an example of this type of dry skid. It can be seen that the vehicle speed (pink line) is constant at just below the target speed of 30 km/h but the green line, which shows the speed of the test wheel, starts at this speed and then dips rapidly as the wheel locks and it can be seen that the maximum F_n of about 100 is recorded after the test wheel has stopped rotating.

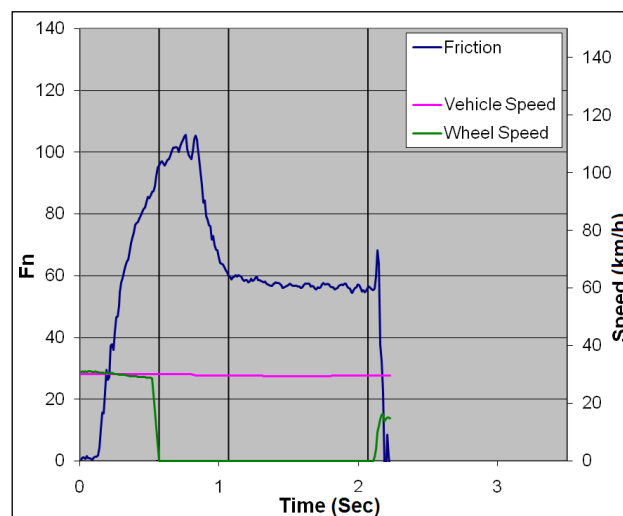


Figure 5.1 Example of a typical dry skid showing the softening bitumen effect in a 30 km/h skid on a thin surfacing

However, closer examination of the data revealed that an alternative mode of behaviour could sometimes be observed, in which the wheel would lock but the friction value would continue at a high level until the brake was released, a phenomenon that is referred to in subsequent discussion as a “constant peak friction skid”. This effect is illustrated in the example in Figure 5.2.

¹ Similar effects are observed in police dry skid tests.

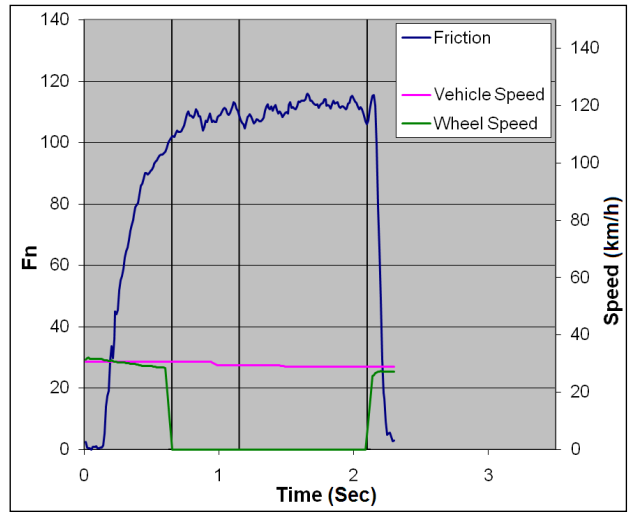


Figure 5.2 Skid profile showing "constant peak" conditions in a 30 km/h dry skid on a thin surfacing

A consequence of these two different effects was that two markedly different friction values were measured with no apparent change in surface or test conditions. Although Figure 5.1 and Figure 5.2 are examples of dry skids on new thin surfacings, the phenomenon was not confined to this type of material and was also observed on the newly-laid HRA. Figure 5.3 shows the results of a number of replicate dry tests on the new HRA made at two different target speeds, 30 and 50 km/h. This clearly shows the two effects occurring and giving two clusters of points at two different friction levels.

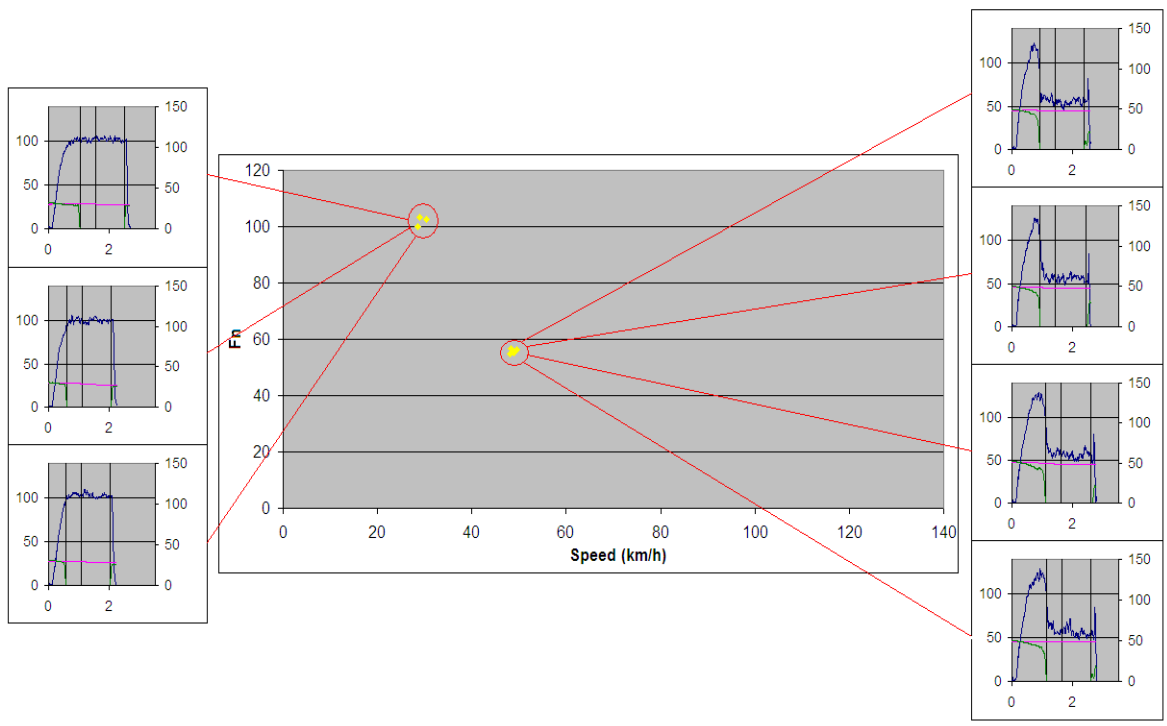


Figure 5.3 Dry locked friction results for newly laid HRA on the TRL test track

Figure 5.3 suggests that the low-friction condition is more likely to occur at higher test speeds, and typically this was observed to be the case. A possible explanation is that more heat is generated at the higher speeds, making softening of the bitumen more

likely, whereas at lower speeds the new surface provides some adhesive or mechanical properties that produce a constant peak friction level.

However, as Figure 5.1 shows, the low-friction condition can occur at low speeds. Furthermore, some skids were recorded in which the “constant peak” effect continued well beyond the settling phase and into the locked-wheel measurement phase of the skid profile, then suddenly switched to the reduced-friction mode.

Results from testing carried out in this study on sites after they had been trafficked did not show this behaviour. In those situations, profiles were typical of the reduced friction mode, suggesting that the probability of constant-peak skids occurring is reduced by the effects of traffic. However, most of the measurements on in-service roads for this study were made at the higher test speed of 50 km/h. Furthermore, the test team carrying out the work for PPR060 (which included one of the present authors) did occasionally observe unusually-high dry friction measurements on trafficked roads that could have been due to these effects, although they were not investigated at the time. It would appear that this is a random behaviour that has the potential to occur in all asphalt materials where there is bitumen on the road surface.

5.2 Changes in wet skid resistance characteristics with time

It is known that environmental factors such as ultraviolet light, rainfall and temperature can affect the way in which surface bitumen weathers and hence influence the frictional properties of asphalt surfacings. To assess this in the absence of traffic, measurements made on the surfacings on the TRL test track were used. Locked-wheel wet friction measurements were made when the surfaces were newly laid and after a period of eight months, which included one full winter. The data are summarised in Figure 5.4 in the form of friction versus speed curves: the measurements on the new surfaces are shown as solid lines, those after eight months of weathering as dashed lines.

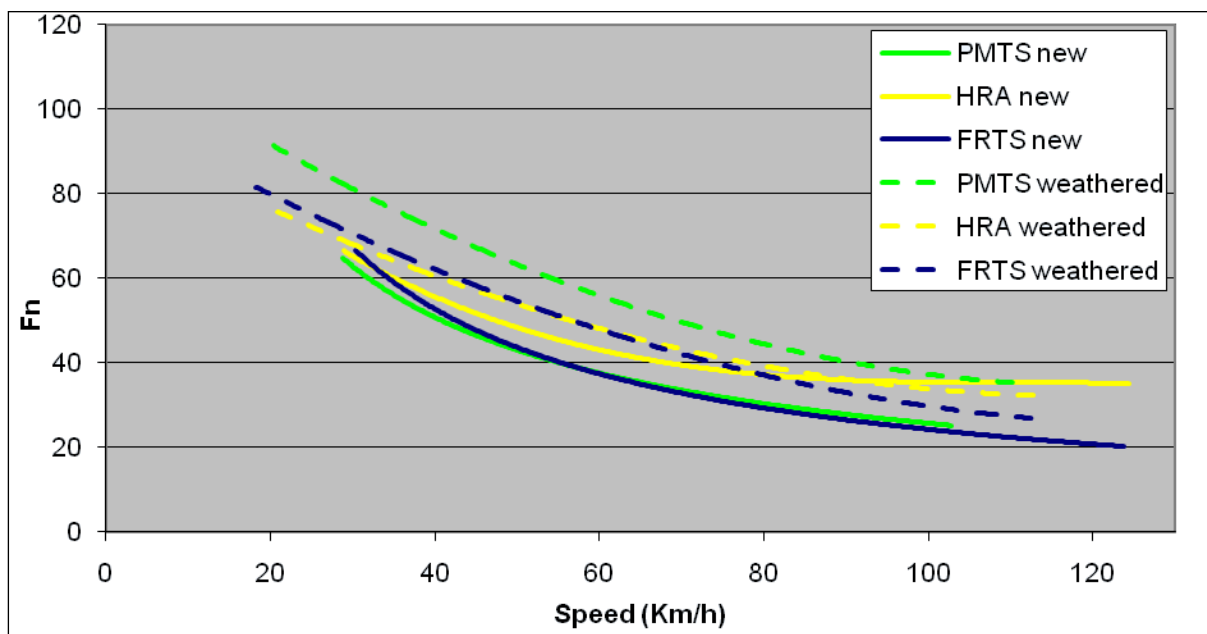


Figure 5.4 Average wet locked friction values for surfacings laid on the TRL test track

The results show that the levels of friction on the two thin surfacing systems increased markedly across all speeds after a period of weathering. The data also show that, for the thin surfacings, the rate of decrease in friction at low to intermediate speeds (20-60 km/h) is reduced following the period of weathering. The HRA surfacing does not

show the general increase in friction across the range of test speeds. However, the reduced steepness of the friction-speed curve in the intermediate speed range that was seen on the thin surfacings is evident, although the effect is less pronounced.

The results demonstrate that, for wet friction at least, the effects observed on new asphalt surfacings will be reduced with time by the effects of weathering alone. This could indicate that on lightly-trafficked roads the early life effects will be ameliorated to some extent even with little traffic present.

5.3 Changes in wet skid resistance characteristics with traffic

It has been reported by others that the low-speed skid resistance of new surfacings can reduce in the first few days or weeks of service. This phenomenon was not observed by Roe and Lagarde-Forest (2005), but they did recommend that it should be investigated further.

The CP sites provided a number of locations where the same or similar aggregates had been used in the same or similar types of material but on roads or lanes carrying different levels of traffic. These had been measured at different times as they aged. Using the assumed average daily trafficking levels for the sites reported in PPR324 (Roe et al, 2008) as a basis and multiplying these values by the ages of the surfaces at the time they were measured, it was possible to derive a cumulative trafficking level in terms of estimated numbers of commercial vehicles.

Figure 5.5 shows the results of this analysis, plotting locked-wheel friction against cumulative traffic for two material types and two test measurement speeds. To reduce possible inaccuracies that might arise from combining data from different sites, only surfacings of the same material type and with aggregates in the PSV range 65 to 68 were included in the analysis.

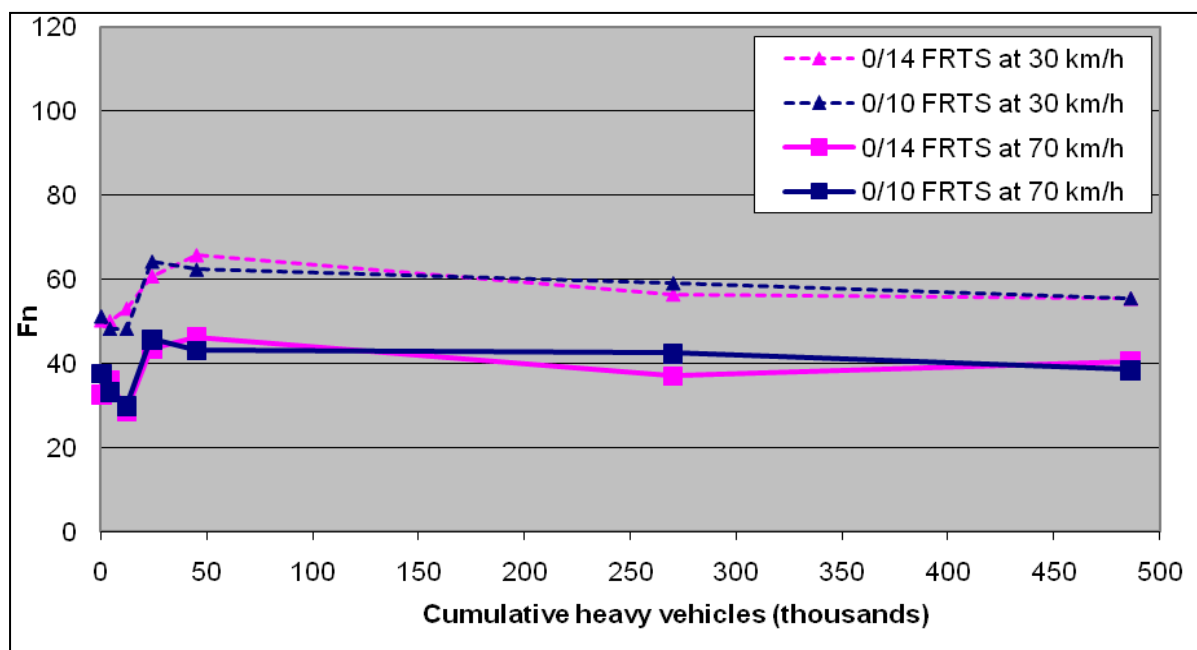


Figure 5.5 Change in average wet locked-wheel friction values at 30 km/h and 70 km/h with cumulative traffic

The 30 km/h lines in Figure 5.5 show that, for the thin surfacings investigated, there was a small decrease in friction after a limited amount of trafficking (about 12,000 heavy vehicles). This evidence supports the findings reported by other researchers, whose measurements were made mainly with the GripTester which is a low-speed skid

resistance measurement device. It is also evident that at higher speeds (70 km/h) the reduction in friction is more pronounced and friction drops to levels that are lower than would normally be expected on a well textured in-service road at this speed. However analysis of the TRL database found that, on average, the levels of friction achieved still lay within the broad range observed on roads generally.

This initial fall in friction values was also visible when results from individual CP sites were analysed.

Following this initial dip, the friction increased to levels similar to or above those of the newly laid surface and then reduced slightly with further trafficking, probably due to the concurrent effects of removal of the initial bitumen coating and polishing of the exposed aggregate surfaces.

Figure 5.6 presents the variation in skid resistance with speed for each lane of one of the CP sites after 10 days of trafficking. On this particular site, the overtaking lane (Lane 2), carries very little heavy traffic.

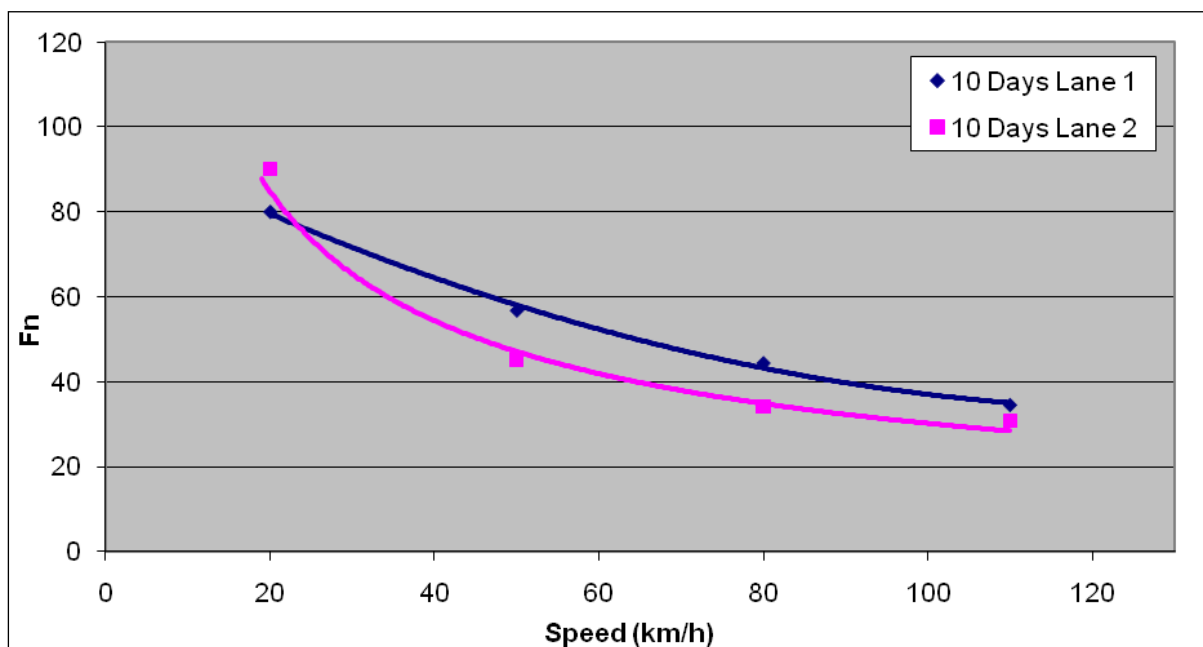


Figure 5.6 Average wet locked friction values for the 0/14 FRTS laid on the A5 Gibbet Hill site

It can be seen that for Lane 2 the friction-speed curve has a greater rate of change than that of Lane 1 and the friction levels in Lane 2 drop below those in Lane 1 at speeds above 30 km/h. This difference in the shapes of the friction-speed curves suggests that, at the time of testing, Lane 2 was still within the very-early life period of reduced friction seen in Figure 5.4 (for the new, un-weathered surfaces) and in Figure 5.5. By contrast, in the more-heavily trafficked Lane 1 the early life effects were starting to dissipate.

However after seven months of trafficking, as shown in Figure 5.7, the friction levels in the two lanes were still different, but now the levels in Lane 2 were higher than those in Lane 1.

It can be seen that the friction levels in Lane 1 at seven months were similar to, although slightly lower than, those observed after ten days but that the levels in Lane 2 had increased and the rate of reduction in friction at intermediate speeds had reduced. This is a result of the initial binder film being removed and the exposed aggregate being polished to a lesser extent than in Lane 1 due to the much lower levels of heavy vehicles. Such differences have been observed on many multi-lane carriageways.

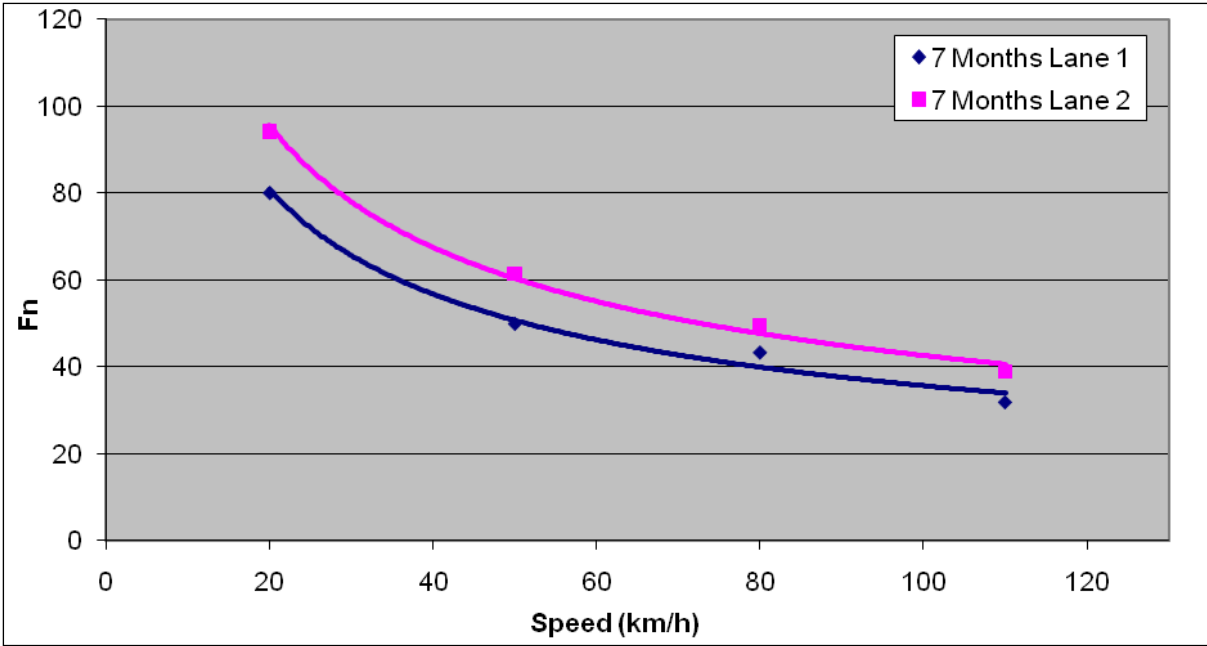


Figure 5.7 Average wet locked friction values for the 0/14 FRTS laid on the A5 Gibbet Hill site

Lane variations were not evident on all of the CP sites, however, as is demonstrated in Figure 5.8, which shows the wet friction versus speed relationship after seven months of trafficking at Tamworth. Here, the average friction levels were similar in both lanes.

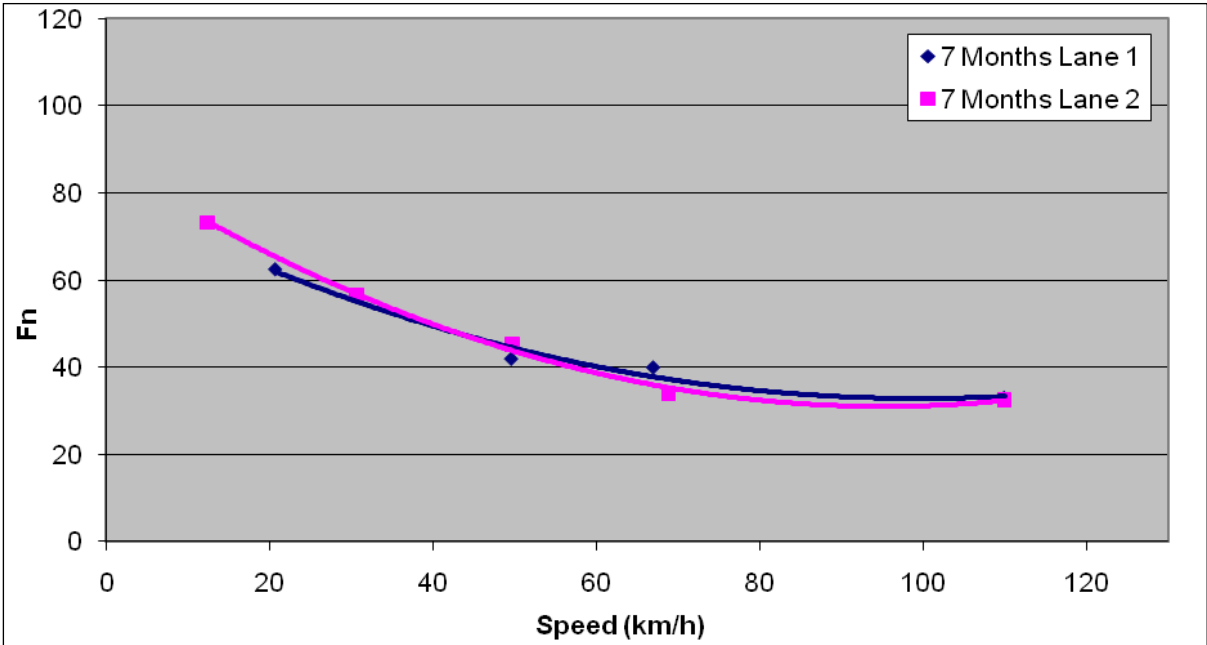


Figure 5.8 Average wet locked friction values for the 0/14 FRTS laid on the A5 Tamworth site

It might have been expected that the two sites would provide similar results. They are on the same major route, in the same general area of the country (about 35 kilometres

apart) and the surfacings were laid within a few days of one another. They carry similar levels of heavy traffic and broadly similar materials were used, although at the Tamworth site the coarse aggregate had a PSV of 60 compared with the 65 PSV aggregate used on Gibbet Hill.

A number of factors could have given rise to the difference in behaviour between the two sites. Although similar, the surfacings used different proprietary materials and there may therefore have been some differences in behaviour due to components in the asphalt other than the coarse aggregate. The different coarse aggregates may have had different affinities to bitumen, thus affecting the rate at which the surface film was worn away to expose the aggregate surface to traffic. The difference in PSV of the aggregate at the two locations could also have had an effect, especially in combination with a relatively greater proportion of heavy vehicles in Lane 2 at the Tamworth site.

The results from these two sites demonstrate the difficulties in comparing skid resistance measurements and in applying general rules to individual sites.

5.4 Changes in wet skid resistance with time and traffic

5.4.1 Changes in locked friction behaviour

As can be seen in Figure 5.6 trafficking can affect the rate of change in locked friction with speed; this was noticed at a number of sites during data analysis. This behaviour was analysed further using specific site data collected from the collaborative research trial sites and historic data gathered as part of TRL Report 367 (Roe et al, 1998).

Historic data from the study in TRL Report 367 (Roe et al, 1998) were used rather than the larger TRL database (of which these data are a constituent) as the former data set provided texture information whereas the TRL database did not. Previous studies have shown that texture depth and surface friction are related and that texture depths lower than 0.75mm (SMTD²) produce lower friction values than surfaces with a SMTD higher than this. Surfacing with SMTD less than 0.75mm were therefore removed from this analysis.

Data collected as part of the collaborative research trial provided individual site data at various levels of trafficking; this gives a specific analysis of thin surfacings at various stages of polishing. The data used as part of TRL Report 367 provided average data for a range of different surfacings for a holistic view of different surfacing types. Friction speed curves were plotted as second order polynomials for each set of data. The corresponding curve equation was then differentiated to provide an equation for calculating the rate of change in friction at different speeds. These data are displayed in Figure 5.9. It appears in the figure that some of the lines could continue below the x-axis, which would suggest that there is an improvement in friction at speeds greater than where the axis is crossed. This, however, is not the case; rather it is a function of applying a second order polynomial to the friction versus speed curves, particularly where low-speed friction is high.

² Sensor Measured Texture Depth

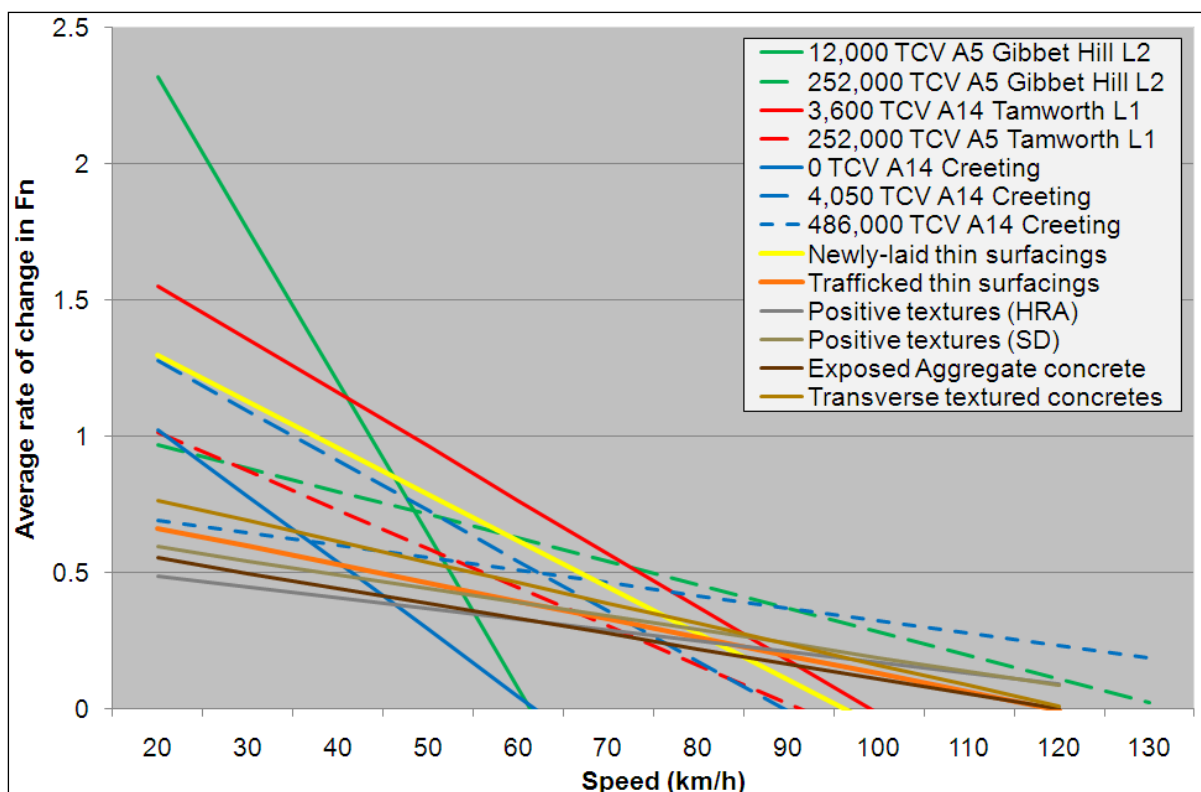


Figure 5.9 Rate of change of locked wheel friction with speed

Figure 5.9 demonstrates that the rate of change of friction with speed is greater for newly laid thin surfacings compared to typical in service pavements. The high levels of low-speed wet friction found on newly laid thin surfacings are likely to contribute to this initial high rate of change. In addition the data show that the minimum levels of friction are reached at lower speeds for the newly laid thin surfacings.

As the surfaces are trafficked, there is a decrease in the rate of change in friction and an increase in the speed at which the minimum level of friction is reached. The data for the A14 Creeting site suggest that after trafficking of about 500,000 commercial vehicles the thin surfacing behaves in a similar manner to the range of in service surfacings.

These behaviours are also demonstrated in Figure 5.10 where the second derivatives of the individual friction speed curves (i.e. the slope of the lines in Figure 5.9) are presented. For one of the thin surfacings sites (A5 Gibbet Hill), it can be seen that the magnitude of the second derivative is starting to reach a level similar to some of the in-service surfacings after traffic of about 250,000 commercial vehicles.

These data suggest that any early life behaviour is dissipated at trafficking levels between 0.25 and 0.5 million commercial vehicles.

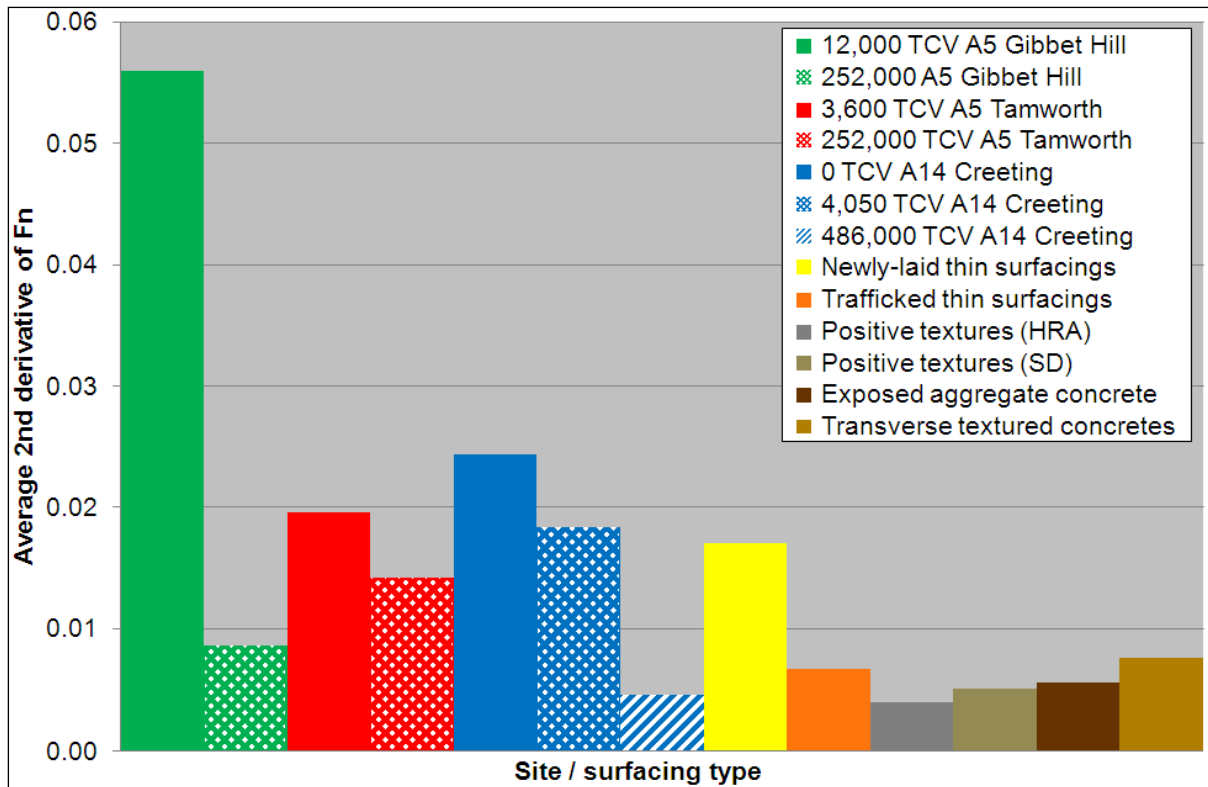


Figure 5.10 Second derivative of the friction speed curve for a range of surfaces

5.4.2 Changes in peak and locked friction

Initial analysis of the data from the CP sites and the TRL test track suggested that levels of wet peak friction on new asphalt surfacings could be high, leading to a greater difference between peak and locked wheel friction on such surfacings. To investigate this further, the peak and locked wheel friction speed curves for both Thin Surfacing and HRA at different periods after laying were plotted and are presented in Figure 5.11. For comparison the 90th percentile ranges for thin surfacings greater than 12 months old, derived from the TRL database, are also provided.

The data show that the initial levels of peak friction are high, particularly for the thin surfacings, but that they decrease with time. A similar effect is seen for locked wheel friction but here the change is confined mainly to low speeds.

Both thin surfacings and HRA show a similar pattern of behaviour.

It should also be noted that the values of peak and locked wheel friction for thin surfacings less than 12 months old fall broadly in the upper half of the range of values found for older thin surfacings. This demonstrates that friction values in the wet on new thin surfacings are not untypical of those commonly found on older surfaces on the network.

Figure 5.11 also shows that there may be a substantial difference in peak and locked friction on asphalt surfacings less than six months old, particularly at intermediate and higher speeds. Figure 5.12 compares the peak and locked friction values for the same data set reported in Figure 5.11

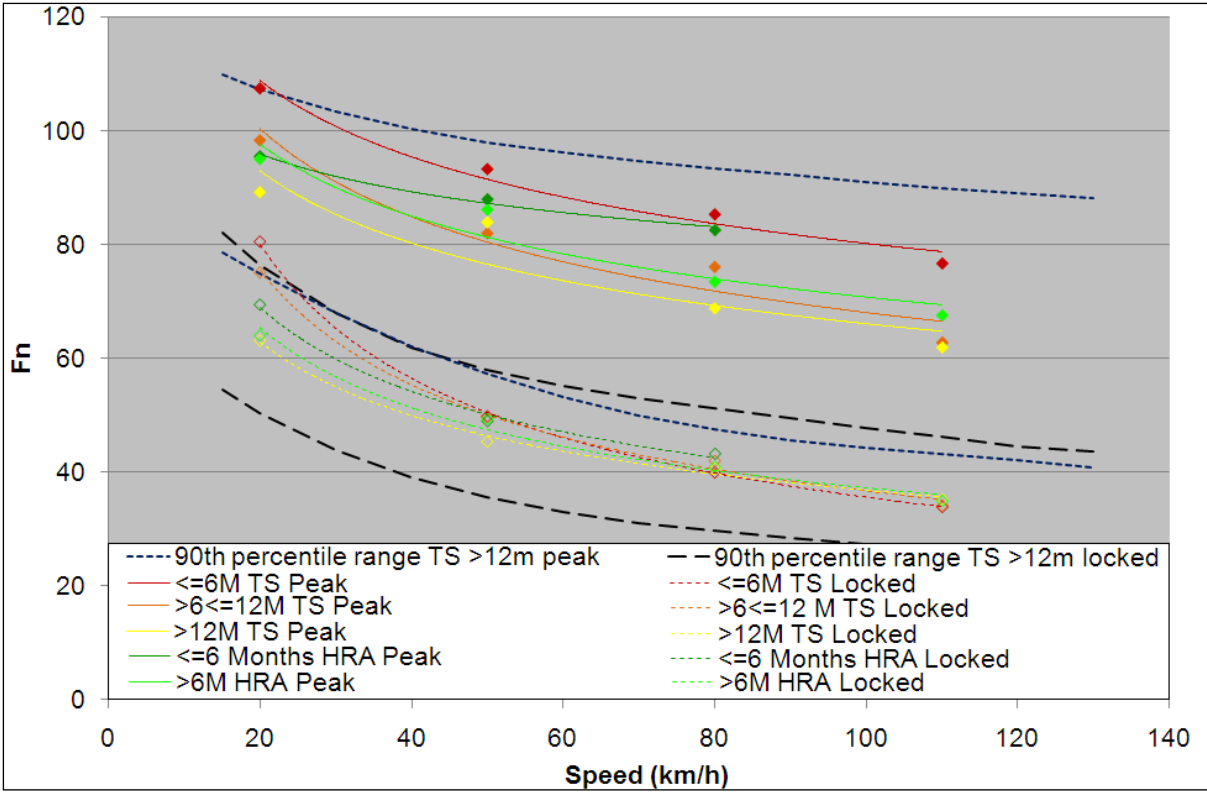


Figure 5.11 Comparison of peak and locked wheel friction

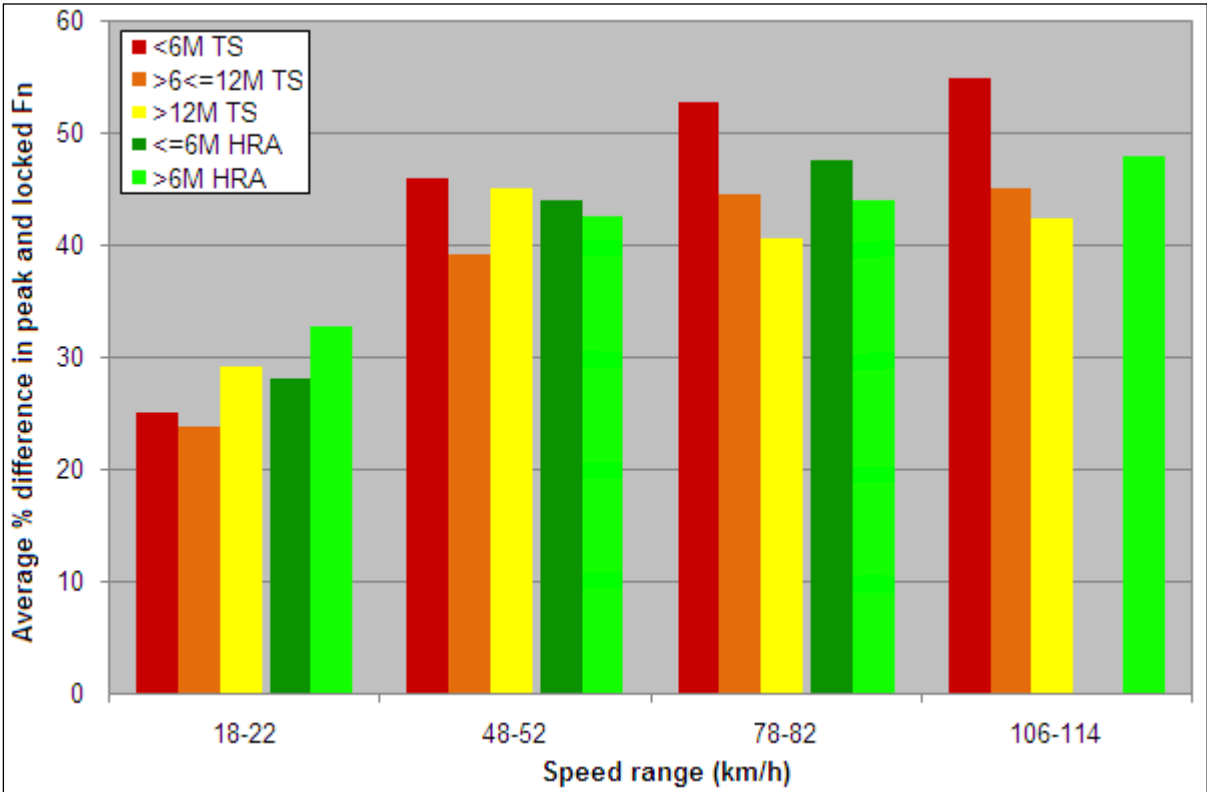


Figure 5.12 Difference in wet peak and locked friction as a percentage of the peak friction

As can be seen in Figure 5.12, at higher speeds there is a proportionately larger difference between peak and locked wheel friction for thin surfaces less than or equal to six months old compared to older surfacings of the same type. However, at lower speeds the difference between surfaces less than six months old and those between 6 and 12 months is less noticeable and on older surfacings the difference increases. This pattern is likely to be a result of the very high low-speed friction found on new surfacings which then reduces under the influence of trafficking.

The data also suggest that a similar, but less pronounced, behaviour occurs for HRA surfacings at intermediate speeds. However there are insufficient data to provide evidence of an increase in the difference between peak and locked wheel friction at higher speeds.

It should also be noted that at higher speeds thin surfacings between six and twelve months old show a slightly greater difference in friction than surfacings over twelve months old. This suggests that these effects can be observed on some thin surfacings over six months old.

These phenomena may have an influence on accident risk and this is discussed further in Section 10.2.

6 Comparison of different surfacing types

One of the main objectives of this study was to assess whether the early-life skid resistance characteristics found on modern asphalt surfaces were also observable on traditional surfacings, such as HRA. Measurements on the TRL track, together with those from the A140 and B1078 in Suffolk were used for this purpose, with results from the TRL test track providing comparative data for newly-laid, un-trafficked HRA and thin surfacings, and the Suffolk sites giving some comparisons after various periods of trafficking.

6.1 Wet skid resistance effects on new surfaces

Data presented in Section 5 have shown that, when compared to typical in service roads, high-speed wet friction values on thin surfacings are lower in the first few weeks of service life but that the levels increase as the bitumen binder layer on the aggregate is abraded. Importantly, the rate at which skid resistance decreases with speed on thin surfacings is also greater in very early life than after some time in service.

There were insufficient data available to make direct comparisons of wet skid resistance characteristics between the different surface types over the full speed range other than on the very new HRA and thin surfacings on the TRL track. To aid the comparison with performance in-service, Figure 6.1 compares the measurement points and trend lines of the friction-speed curves for the three newly-laid surfaces on the TRL track³ with the range of wet friction values typically observed on HRA after some time in service (from Roe et al, 1998).

In viewing these data it should be borne in mind that the range lines do not represent a specific friction-speed curve but rather the range of values observed. In particular, the low values show the lowest recorded in the earlier study and these may be a result of different combinations of highly-polished aggregate and/or low texture depth. Furthermore, they represent values observed at the time and do not necessarily imply that such values were, or are, acceptable.

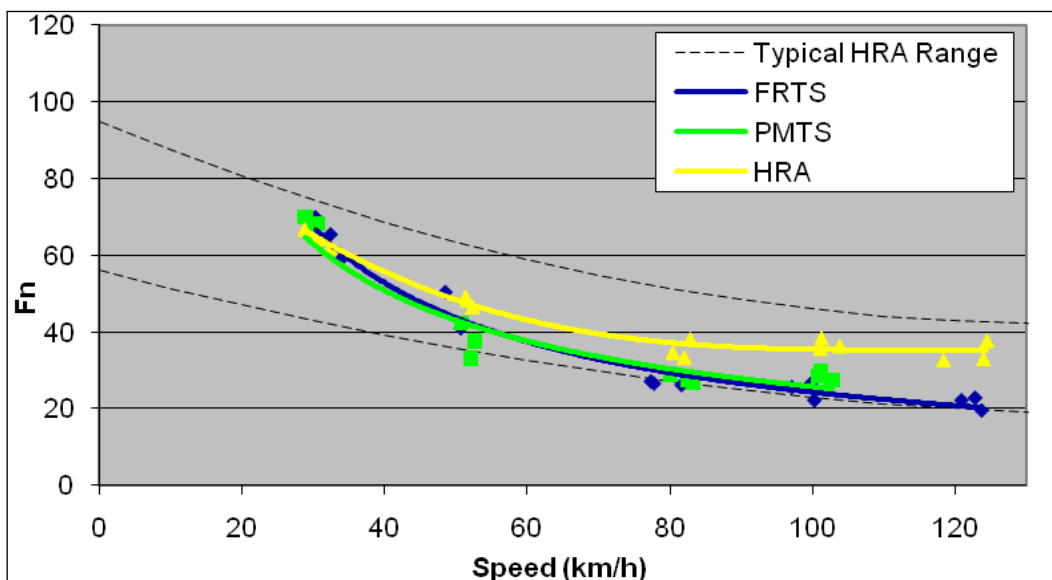


Figure 6.1 Wet locked-wheel friction for newly laid surfacings on the TRL test track

³ The trend lines are the same as the "new" surfaces curves that were used in Figure 5.4 to illustrate a different point.

Figure 6.1 clearly demonstrates the low values of high-speed friction at higher speeds on the thin surfacings and the relatively steep reduction in friction from low to intermediate speeds, a form that Figure 5.9 has shown to be typical of modern asphalt materials when new. The HRA curve also shows a relatively steep decline in friction to intermediate speeds but, on this example at least, the high-speed friction is close to the centre of the typical in-service range at 80 km/h and remains essentially constant as speed increases further. All three surfaces show similar, very high, wet friction levels at low speed.

On the Suffolk sites, speed limitations prevented measurements being made at high speeds but the one-month old HRA on the B1078 and three-month old HRA in Lane 2 of the A140 showed exactly the same form up to 80 km/h – in fact, on both sites, the 80 km/h friction values on the HRA were comparable to or slightly lower than on the newly-laid thin surfacings on the TRL track. Also, as with the thin surfacing on the CP site shown in Figure 5.6 and Figure 5.7, after three months of traffic, Lane 1 of the A140 showed lower friction than Lane 2.

The implications of these results are that, when asphalt surfaces are very new, the early life wet effects can occur on both types of surface. There is some suggestion that the thinner binder film on the HRA wears away more rapidly so that any adverse effects are reduced more quickly on more-heavily trafficked roads.

6.2 Dry friction effects on very new surfaces

In contrast, the dry friction measurements, presented in Figure 6.2, show only very small differences between the different types of surfacing. This graph shows friction values of about 60 at both 30 and 50 km/h, but with higher values of about 100 also being recorded at 30 km/h. Analysis of the individual skids showed that these higher values were the result of constant peak friction skids, as described in Section 5.1. These data demonstrate that this phenomenon occurs both on HRA and thin surfacings.

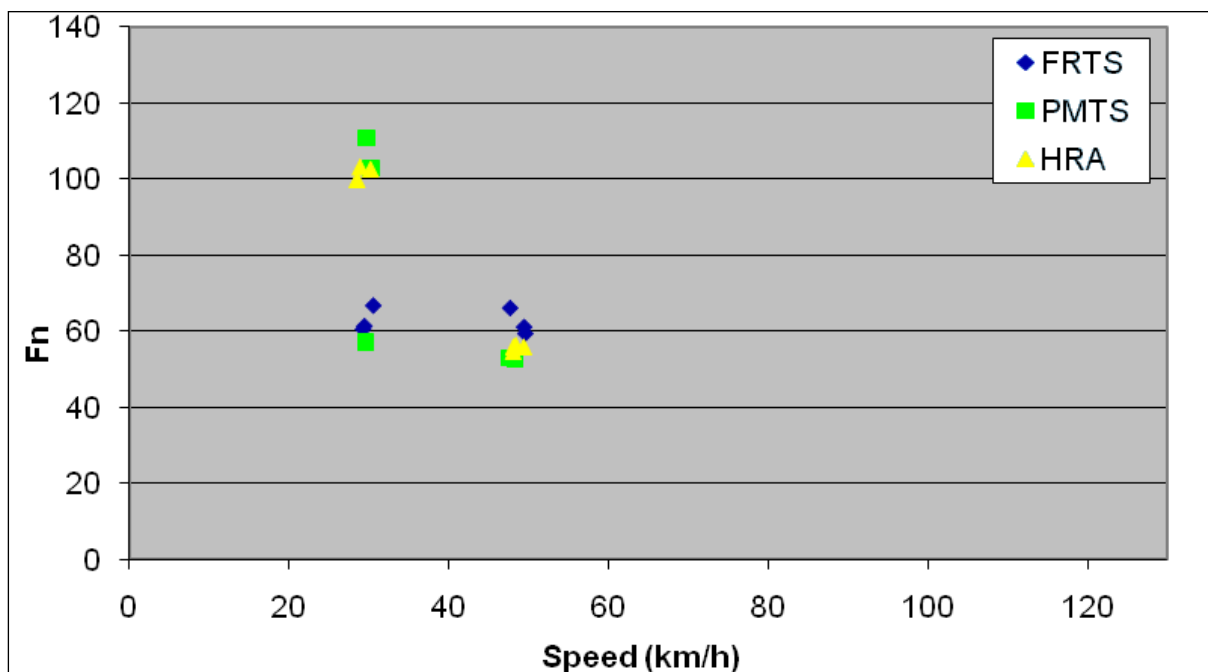


Figure 6.2 Dry locked friction for newly laid surfacings on the TRL test track

The dry friction measurements on the one-month and three-month old HRA surfaces in Suffolk also showed the same effects – combinations of reduced friction and high friction at similar levels. Figure 6.3 is a photograph of part of a skid mark from one of the lower-friction skids on the one-month old HRA on the B1078. The characteristic

smearing of the bitumen from the tops of the chippings across the surface of the asphalt can be seen, especially to the centre-left of the photograph.



Figure 6.3 Skid mark from a dry PFT test on 1-month old HRA

6.3 Effects after some time with traffic

Measurements made on the Suffolk sites after the surfaces were at least a year old are compared in Figure 6.4 (based on average F_n values at each speed for the respective surface types). It can be seen that both the HRA and the thin surfacings show very high dry friction levels, with the HRA slightly higher than the thin surfacings. The wet friction-speed curves at this age appear more characteristic of trafficked surfaces with little difference between them. In this example, the thin surfacings show slightly lower skid resistance than the HRA but this will have been influenced by differences between traffic levels and aggregate PSV on some of the sites affecting the average values shown.

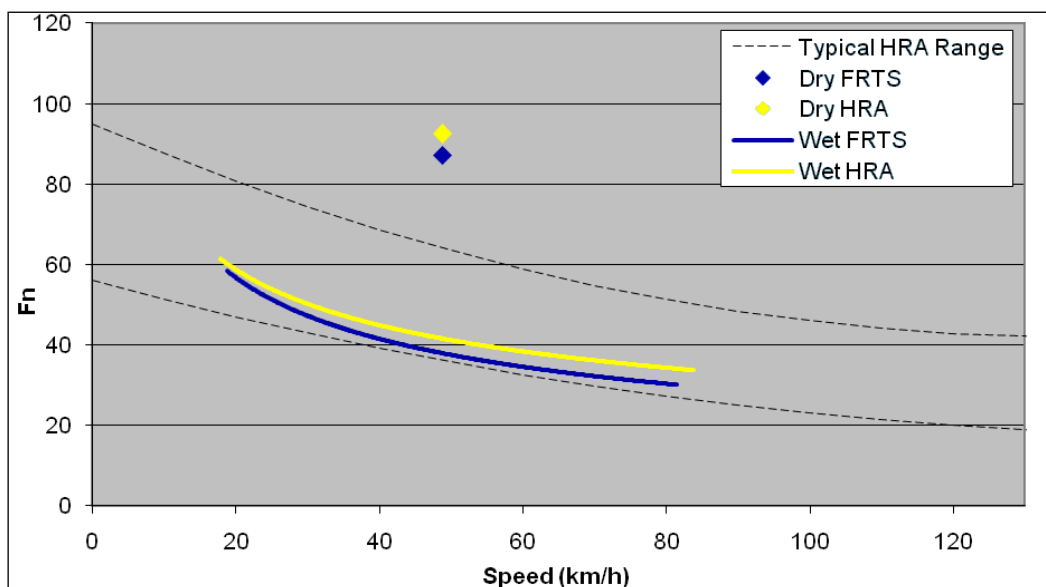


Figure 6.4 Average data for >1 year old surfacings from the A140 and B1078

7 Influence of road surface temperature

The early life effects observed in the skid resistance characteristics of new asphalt surfacings appear to include a softening process of the bitumen binder under the heat created during heavy braking. Concern has therefore been expressed that during periods of high temperature the risk of skidding on such surfaces could increase. To assess any possible changes in surface friction as a result of an increase in surface temperature, dry friction measurements both at ambient and at elevated temperatures were directly compared, in an experiment conducted on the TRL test track after the laying of the new surfacings in October 2007.

7.1 Experimental technique

In order to simulate the effect of prolonged sunlight heating the surface, the pavement surface was heated artificially using gas-powered radiant heaters commonly used in pavement repair. The heaters were of a size sufficient to heat a 0.5 m by 20 m section of the test track. This length enabled PFT skids to be undertaken at speeds up to 50 km/h.

The arrangement for heating a length of surfacing is illustrated in Figure 7.1.



Figure 7.1 Heating rig used to heat the test sections

To simulate the natural heating of a pavement the heaters were used on the coolest setting so the surface would be heated gradually. This gradual heating also allowed the heat to penetrate the pavement to a depth of 10-20 mm allowing the surface to retain its temperature once the heaters were removed. The heaters were moved along the strip as necessary to maintain even heating and cover "dead" spots between the units; once the target temperature had been reached, the units were quickly pushed to one side to allow the waiting test vehicle to pass over the surface. Friction measurements were taken at pavement temperatures of 30-40 °C and 50-60 °C.

PFT measurements on the heated surfaces were undertaken in dry conditions at test speeds of 20, 30 and 50 km/h. These were supplemented by police SkidMan tests made on the same day (discussed in Section 8) in which the surfaces were heated to similar temperatures. For these tests, however, to take account of the four-wheel skid-to-a-stand technique, parallel wheel paths were heated over a shorter length.

The surface temperature was monitored during the heating process and just before a test using a hand-held infrared temperature sensor. Three infrared sensors were mounted to the PFT trailer as shown in Figure 7.2 to measure the temperature of the

road in front of and immediately behind the test wheel and on the surface of the wheel. These sensors were connected to a data logger that recorded temperatures every 0.01 seconds during each skid test.

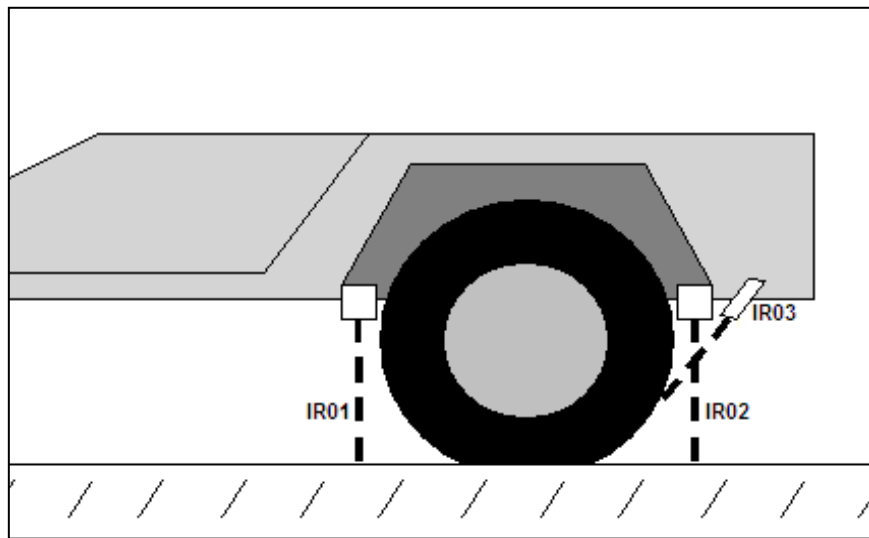


Figure 7.2 Diagram of infrared sensors fitted to the PFT trailer

In addition to the hand-held thermometer and sensors on the PFT trailer, a static thermal imaging camera was used, both to confirm that the pavement surface had been evenly heated and to validate the measurements from the other thermometers.

Figure 7.3 is a still image from the camera, showing a heated section with the PFT completing a locked-wheel test. The cones in the foreground were positioned to assist the driver to find the correct test line (to the naked eye, the heated area was indistinguishable from the rest of the surface) and the cone on the right of the test area in the background (near the waiting heater units) was used to provide a reference point for the operator to initiate the test sequence so that the locked phase of the skid would occur near the centre of the heated length.



Figure 7.3 Thermal image of testing on a heated test section

The image in Figure 7.3 shows the track surface and test vehicle at a moment where the brake has just been released after the locked phase of the skid. The heated zone on the road surface can be clearly seen and, in the centre of this area, just behind the PFT trailer, a narrower band of higher temperature can be observed where the test wheel has just skidded. The contact patch of the test tyre that was in contact with the road during the skid has appeared in the picture as the wheel has begun to rotate again and the area of the tyre heated during the skid can be clearly seen.

7.2 Results from the PFT tests on the heated surfaces

Figure 7.4, Figure 7.5 and Figure 7.6 show the dry locked wheel friction recorded for each of the surfaces tested over a range of surface temperatures. The experiment was conducted on a cold day when temperatures were typically at eleven degrees Celsius or lower. The initial ambient temperature dry tests on the surfaces as laid have been included for comparison.

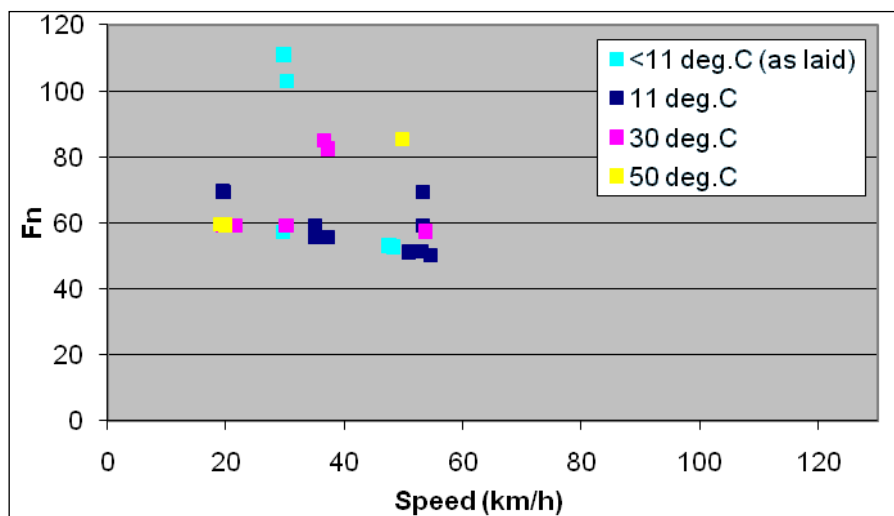


Figure 7.4 Dry locked friction values for newly laid PMTS at four surface temperatures

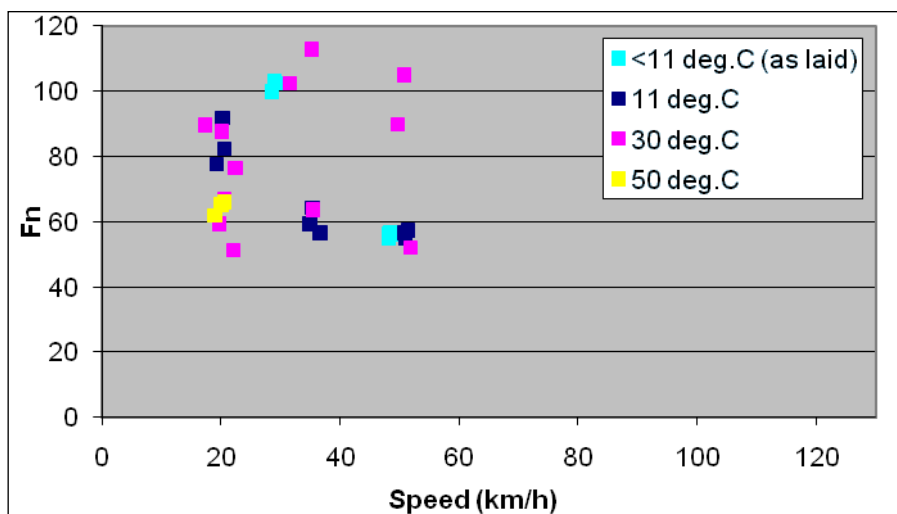


Figure 7.5 Dry locked friction values for newly laid HRA at four surface temperatures

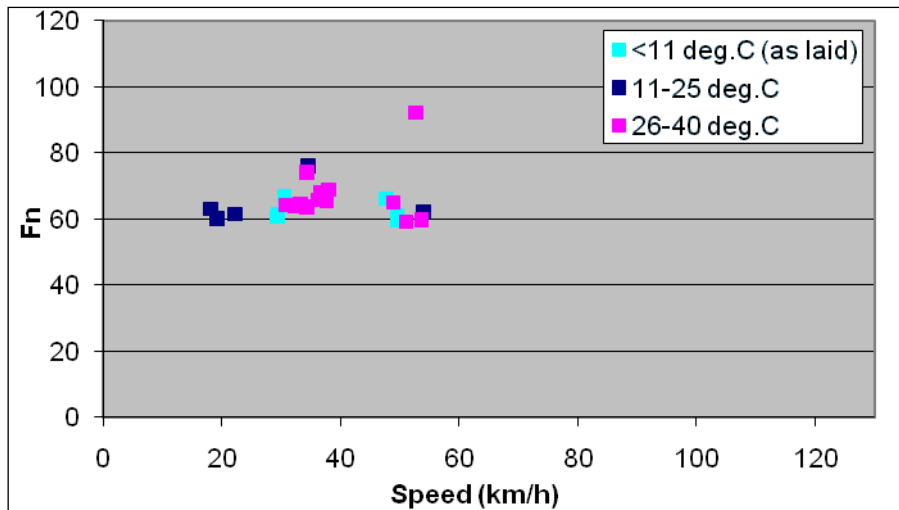


Figure 7.6 Dry locked friction values for newly laid FRTS at three surface temperatures

The figures all appear to display a large amount of scatter in each data series. However on reviewing the individual skid profiles it was evident that this scatter was attributable to the occurrence of either the constant-peak or the lower-friction skid behaviour discussed in section 5.1. As commented in section 5.1, the likelihood of either mode of skidding seems unpredictable. However, there appeared to be a greater likelihood of higher values at the 50 km/h test speed. Importantly, the lower values recorded on the heated surfaces were similar to those measured under ambient conditions.

Analysis of the images taken from the infrared camera showed that the heat generated at the tyre-pavement interface during a skid far exceeds the temperature of the pavement prior to the skid occurring. This suggests that unless the pavement surface temperature exceeds that generated in the tyre-pavement interface during a dry locked wheel skid (about 70°C), then the pavement temperature is unlikely to affect the skidding resistance performance.

The results of this experiment indicate that any concerns that natural heating of the surface of a new road would make the low-friction dry skid condition more likely to occur are not justified.

8 Police SkidMan tests

As explained in the Introduction to this report, concerns regarding the frictional properties of new surfaces have often been expressed by police collision investigators when they find lower than expected values during routine dry skid tests with ABS systems disabled. Work reported in PPR060 (Roe and Lagarde-Forest, 2005) included some basic comparisons between dry PFT measurements and police deceleration tests (see 3.3).

For this study, Thames Valley Police provided an officer and car to carry out SkidMan tests on the new surfaces on the TRL track. These tests were made initially at ambient conditions when the surfaces were new and a few days later to supplement the measurements made with the PFT during the surface heating experiment (Section 7). Measurements were attempted at initial speeds of 32 km/h (20 mph) and 50 km/h (30 mph), the latter being the speed most often used by the police routinely.

In the event, practical issues and conditions at the time of the police tests created some problems for making the measurements, limiting the data available. These included partially damp surfaces preventing full lock-up of all four wheels during some of the ambient temperature tests. For the tests on the heated surfaces, although both wheel paths were heated, the short length available limited the range of speeds that could be used. Consequently, timing of the brake application to coincide with all four wheels arriving on the heated surface and then to achieve four-wheel lock-up was difficult. These problems led to differential braking effects on the different wheels especially at higher speeds. The results that could be used are summarised in Figure 8.1.

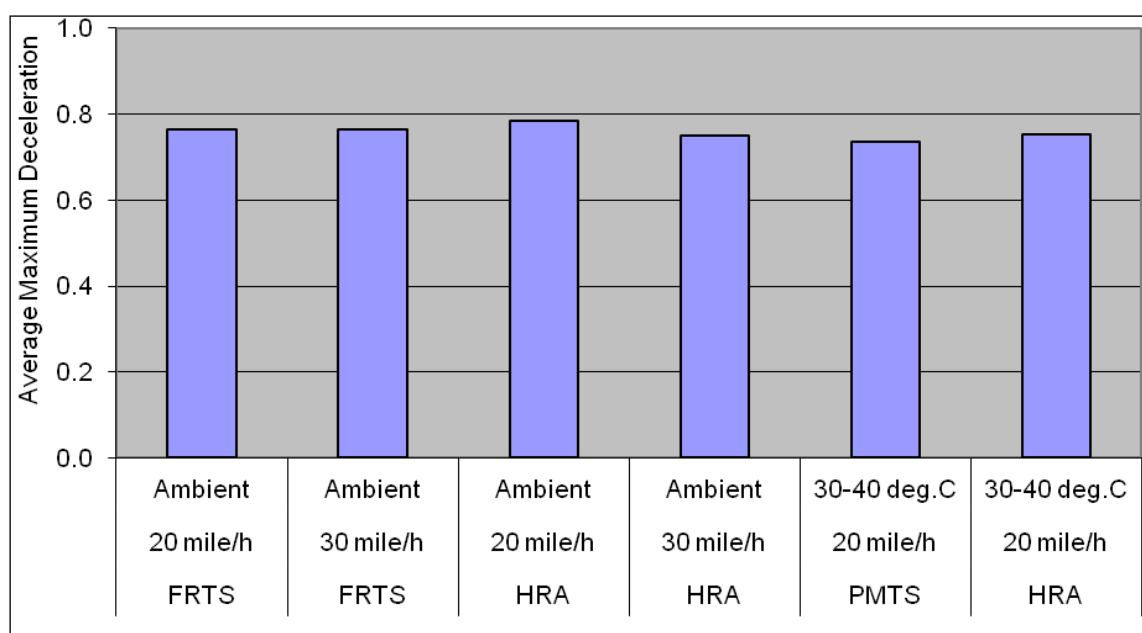


Figure 8.1 SkidMan results for dry asphalt surfacings

Overall, the results showed that between 20 and 30 mile/h there was very little variation in the average maximum deceleration on the new surfacings, either between surfacing types, initial speed or the different initial temperature conditions. The values were generally in the higher range typical of dry roads rather than the reduced friction effect.

It might be expected that achieving full lock-up would be more difficult with the lower starting speed. The effect of the bitumen softening during the locked phase was observed on some tests but this was often associated with incomplete lock-up of the rear wheels of the car: consequently the measured deceleration would have indicated a higher coefficient of friction on average in those tests.

9 The use of initial gritting

As explained in 2.4, initial gritting is one option with potential to ameliorate possible accident risks associated with early-life effects. Measurements made with the PFT on the A389 in Cornwall (see Section 4.2.3) and with the PFT and SCRIM on the M8 in Scotland (see Section 4.2.4) provide some indications of the effects of this type of treatment.

9.1 PFT measurements on the A389

The measurements with the PFT on the A389 were made after the treated and untreated surfaces had been open to traffic for several months. The physical constraints on the site limited the range of speeds that could be achieved.

9.1.1 Wet friction and speed

Figure 9.1 summarises the results of the wet locked-wheel friction tests. The graph suggests that the untreated surface produced higher friction values on average. However, the scatter in the data is such that the differences are within what can be expected from experimental error, so it must be concluded from these measurements that at this stage of their lives both surfaces were showing similar wet skid resistance characteristics.

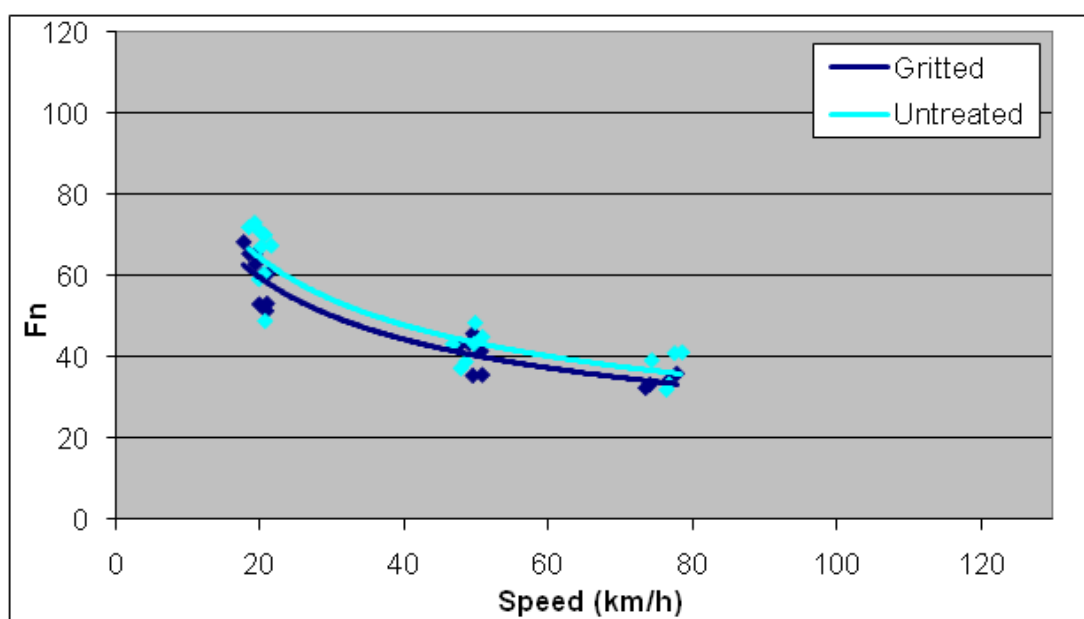


Figure 9.1 Wet locked friction values of gritted and untreated thin surfacing on A389 near Padstow

9.1.2 Dry friction tests

The dry friction tests on the A389 were made in a sequence of repeat skids along the site during a single pass, at target test speeds of 20 and 50 km/h. However, the friction levels at 20 km/h throughout the site and at 50 km/h on the gritted section were so high that it was not possible to achieve lock-up within the required time interval of a standard test and so no valid results were obtained. This suggests that the dry friction levels on the gritted surface were very high.

Figure 9.2 shows the skid profiles from the two tests at 50 km/h on the untreated area of the site for which a valid skid was recorded. These two tests showed a very high peak level ($F_n = 129$) but the wheel did not lock until very late in the initial two-second brake

application phase. When the wheel did lock, a reduced friction level in the typical 50-65 range was recorded, suggesting that softened-bitumen conditions were then occurring.

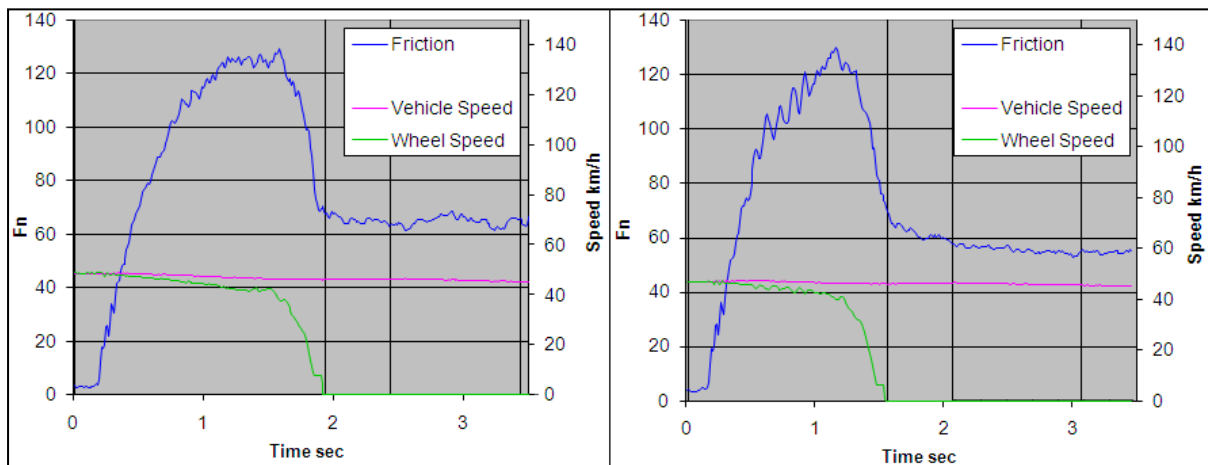


Figure 9.2 Dry skid profiles collected from the A389

Overall, the dry tests showed that, on these roughly four-month old surfaces on a relatively-lightly trafficked road, the dry friction was high on the gritted area and generally high on the untreated surface. However, there were some places on untreated areas where lower-value conditions could still occur.

9.2 Results from tests on the M8

9.2.1 Dry friction

The results of the dry friction PFT tests on the surfaces before they were opened to traffic are shown in Figure 9.3. No attempt has been made to break down the data in this figure by coarse aggregate size. As seen elsewhere, the un-gritted surfaces show a mixture of high friction and reduced friction, with lower friction values (in the F_n range of 50-60 typically observed elsewhere) more likely at 50 km/h than at very low speeds. The gritted surfaces performed similarly at low speeds but at 50 km/h the gritted surfaces generally (but not exclusively) gave higher friction values than their un-gritted counterparts.

Figure 9.4 gives equivalent values after three days of traffic. In this case, there are marked differences between the measurements at 20 km/h, which exhibit a very wide range (again, characteristic of the constant-peak and reduced friction modes discussed in 5.1), and those at 30 or 50 km/h. Importantly, after three days, all the dry friction measurement at 50 km/h were in the "lower" band with the gritted sections giving slightly lower values than the un-gritted sections at 30 km/h.

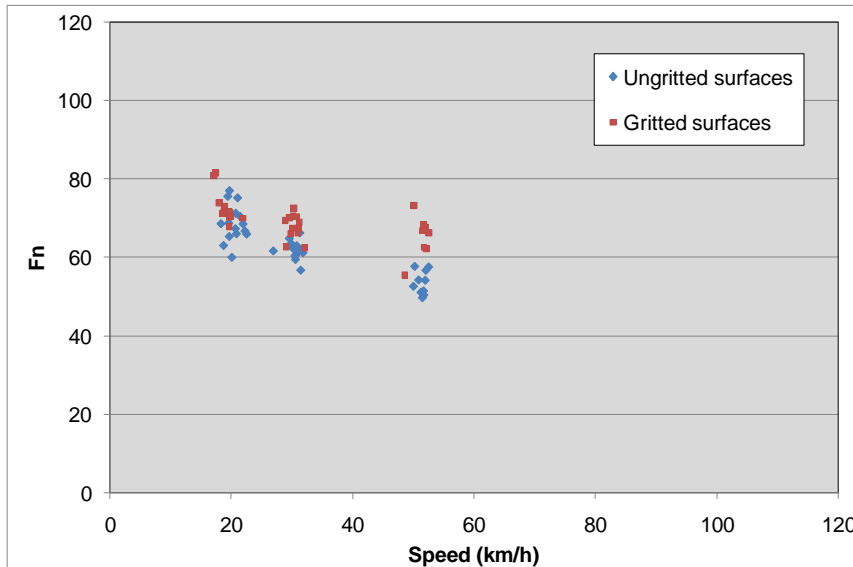


Figure 9.3 Dry friction on un-trafficied surfaces on M8 trial sections

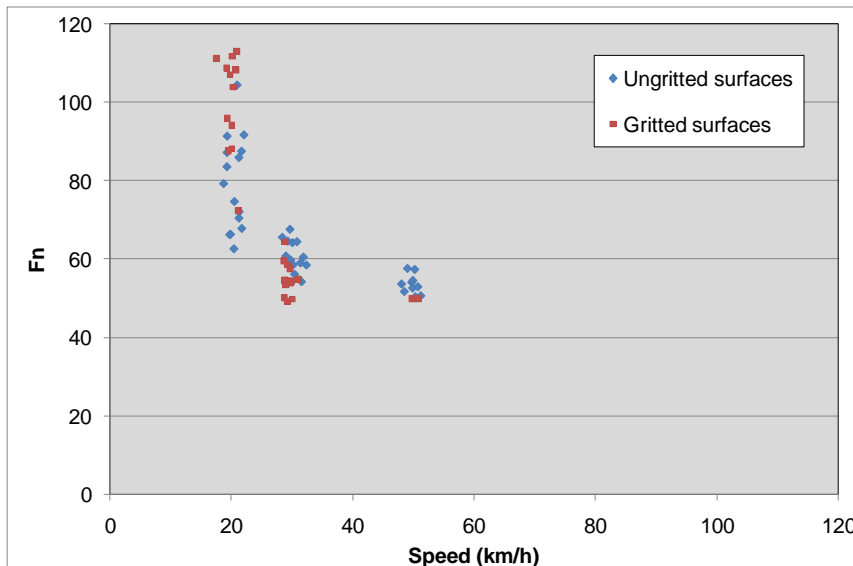


Figure 9.4 Dry friction after 3 days of traffic on M8 trial sections

These results suggest that gritting is of limited value in relation to the dry friction phenomena; gritted surfaces appear to perform no better than the surfaces in their un-gritted state.

9.2.2 Wet skid resistance

SCRIM was used to make continuous low-speed wet skid resistance measurements along the length of the trial site. Initially, the left wheel path (the usual test line) was measured prior to opening to traffic and then, after three days of traffic, this line was measured again together with a test along the centre line of the lane, which would have carried less traffic than the normal wheel paths. These tests were repeated after six and ten months of trafficking. Table 9.1 summarises the results of these tests, giving the average SCRIM Coefficient⁴ over the untreated and gritted sections for each of the three passes after different periods of trafficking.

⁴ SC measured at the standard test speed of 50 km/h. This test speed gives a slip speed of 17 km/h for the contact patch of the test wheel and is approximately equivalent to a PFT wet test at 20 km/h.

Table 9.1 Summary of SCRIM measurements on M8 trial sections

| Period of traffic | Mean SC at 50 km/h | | | |
|-------------------|--------------------|-----------------|---------------------|------------------|
| | Wheel path no grit | Wheel path grit | Centre line no grit | Centre line grit |
| None | 0.73 | 0.71 | - | - |
| 3 days | 0.77 | 0.88 | 0.78 | 0.82 |
| 6 months | 0.65 | 0.66 | 0.74 | 0.81 |
| 10 months | 0.58 | 0.57 | 0.71 | 0.75 |

SCRIM typically measures very high values on very new surfaces. This is consistent with the very high values measured with the PFT for wet skids at 20 km/h.

It can be seen in Table 9.1 that in the first few days the wet low-speed skid resistance of the new surfaces was very high indeed on both the untreated and the gritted sections (measurements on in-service roads rarely exceed 0.6 and then usually on specialised high-friction surfaces). After three days, the gritted sections gave noticeably higher SC values than on the un-gritted length in the wheel path and slightly higher values along the centre line. However, this observation is of limited practical significance since the SC values were already exceptionally high.

After six and ten months of traffic, which corresponded to the start and end of the 2009 summer period, the average SC decreased in the wheel path, which would be expected as the aggregate becomes exposed and begins to polish under heavy traffic such as that on this site. However, no influence of grit could be observed.

In contrast, along the centre line, there was only a small decrease in SC, which remained very high and the small difference between the gritted and un-gritted lengths was maintained. This is unsurprising given the much lighter level of trafficking on this area of the road. Although this indicates that gritting might provide a small increase in low-speed skid resistance over a longer period on more lightly-trafficked routes, as when new, the high SC levels on the un-gritted sections make this of limited practical value.

9.2.3 Wet locked-wheel friction and speed

Figure 9.5 illustrates the average wet friction measured with the PFT at different speeds on the various test sections prior to opening to traffic. The left-hand graph of the pair shows the values on the untreated sections and the right-hand graph shows the gritted sections. In this case, the different aggregate sizes are also shown. Figure 9.6 presents equivalent graphs after three days exposure to traffic.

Before traffic, the untreated sections all showed the expected very high values of friction at low speeds with a rapid reduction with increasing speed that has been typically observed on new asphalt surfaces (see Section 6.1). The gritted sections, however, show a consistent high friction level with only a very small reduction at high speed.

After three days of traffic (this is a heavily-trafficked site), the position had changed. On the untreated sections, the behaviour was much closer to that expected from a trafficked road, with a more gradual reduction in friction with speed. However, after trafficking, the gritted sections also showed the typical behaviour of a reduction in friction values with an increase in speed, albeit with higher friction levels than on the untreated sections.

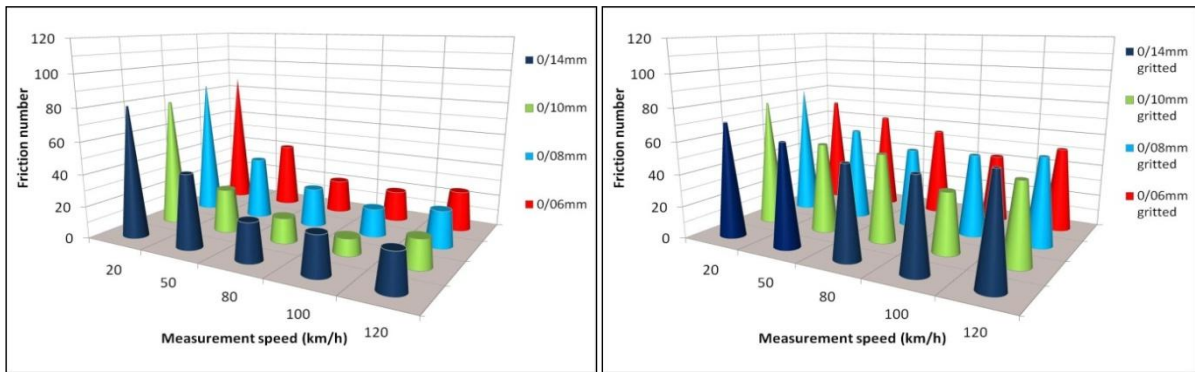


Figure 9.5 Effect of speed on wet friction for the un-trafficked surfaces

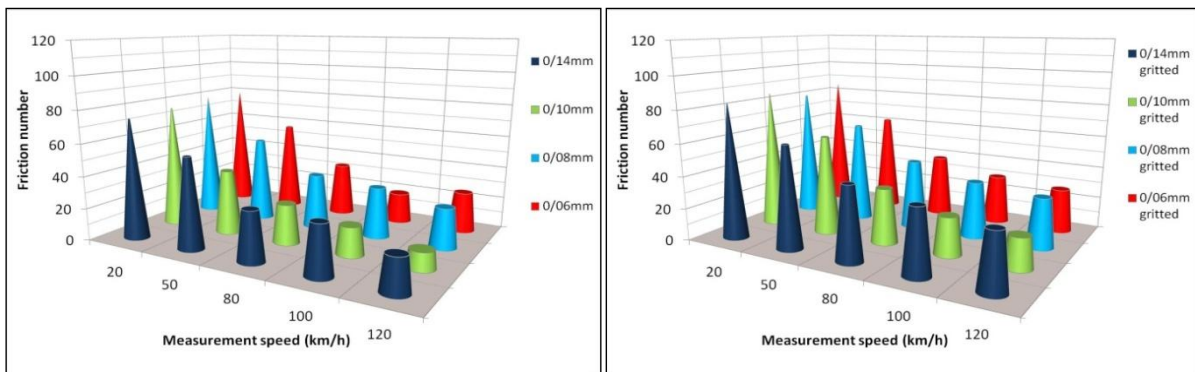


Figure 9.6 Effect of speed on wet friction in the wheel path after 3 days of trafficking

These results show that the application of grit can provide a significant improvement in intermediate and higher-speed wet friction for the first few days of traffic but that these benefits may be lost quite quickly with the passage of traffic and time.

Compared with Figure 5.5, the M8 surfaces at three days old would have carried cumulative traffic of about 6,000-10,000 heavy vehicles and so would probably have just begun to come out of the initial "dip" in friction. In this context, the grit may offer an advantage, even if the effects have largely disappeared after a few days under heavy traffic.

However, this enhancement in higher-speed wet friction could be rather more long-lasting on routes that carry much lighter traffic, which would include the outer lanes of some less-busy motorways and dual carriageways.

Evidence that this might be the case emerged after six months of traffic. The measurements at that time showed that there was little difference in behaviour between the gritted and un-gritted sections in the wheel paths. In the centre of the lane, however, a similar pattern to that observed in the wheel path before traffic could be seen, with the grit apparently enhancing the high-speed friction (Figure 9.7).

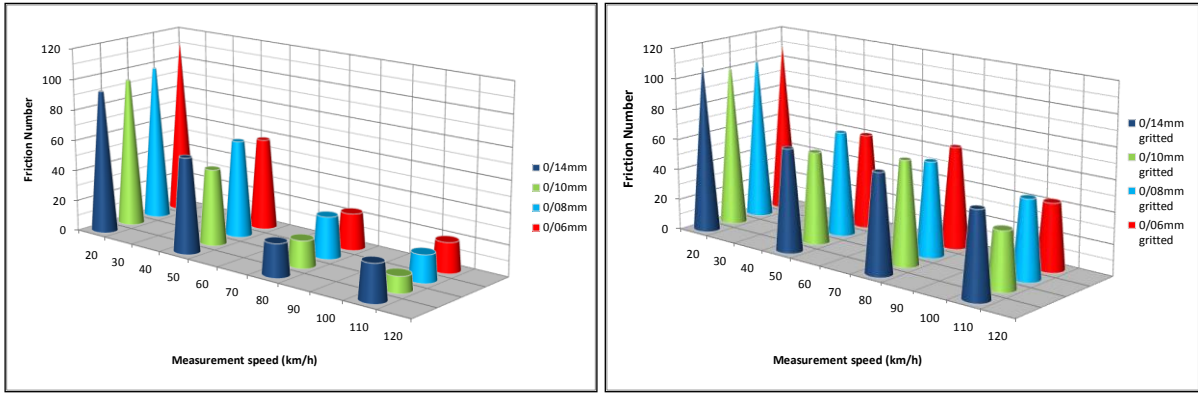


Figure 9.7 Speed and wet friction in the centre line after 6 months of trafficking

However, after ten months of traffic there was very little difference between the gritted and un-gritted sections on either test line in terms of high-speed friction performance.

10 Discussion

As explained earlier, the work described in this report was carried out in the light of the findings from the first study of physical effects relating to early-life skid resistance made by TRL and reported in PPR060. One of the recommendations in that report was to carry out specific research into any link between new surfacings and accident risk, work that has since been carried out and reported in PPR205.

This Chapter brings the findings of the two earlier studies together with the current work so that the results can be discussed in a unified context.

10.1 Summary of the main findings from the three studies

10.1.1 *Original study of nature and scope of physical effects (PPR060)*

In summary, the original work carried out by TRL identified four main effects in relation to early-life friction on modern asphalt surfaces:

- High levels of dry locked-wheel friction at very low speeds.
- Reduced levels of dry locked-wheel friction compared with normal dry roads at intermediate or higher speeds, associated with softening of the bitumen in a locked-wheel skid.
- Unusually high levels of wet friction at low speeds.
- Lower levels of wet friction at intermediate and high speeds than might be expected for a new surface with good texture depth.

The study included measurements covering a range of roads with surfacings of various ages carrying varying amounts of traffic. It was found that, generally, the physical effects became less likely to occur on surfaces more than about six months old, although on lightly-trafficked routes effects could sometimes be observed up to eighteen months after the resurfacing had been completed.

Concerns expressed by the police and others about accident risk at that time were largely anecdotal and related essentially to the potential for increased stopping distances that could be associated with reduced friction and hence an increase in the risk of a collision occurring. PPR060 therefore included an extensive discussion of the potential implications that the effects observed might have for accident risk.

Roe and Lagarde-Forest (2005) pointed out that reduced skid resistance is rarely the first cause of an accident but it may become a contributory factor when other circumstances require a driver to brake or steer, particularly in an emergency situation. They examined the implications for stopping distance and potential collision speeds and the circumstances in which risks might be increased and concluded that, on the basis of the information then available, in most circumstances, on most roads, the increased risk of accidents associated with early-life effects was likely to be small.

However, it was recognised that the physical effects observed might lead to an increased accident risk in some situations. Consequently, one of their recommendations was to carry out specific research into any link between new surfacings and accident risk, work that has since been carried out and reported in PPR205.

10.1.2 *Study of accident risk on new surfacings (PPR205)*

In their accident study, Greene and Crinson (2008) used data from the Highways Agency Pavement Management System (HAPMS) to identify those sections of the trunk road network that had been resurfaced in the period January 2001 to December 2004. The national STATS19 road traffic accident database was interrogated to provide information relating to accidents that had occurred on those sections of road. Accidents that

happened in the year prior to the start of the resurfacing works, during the period when resurfacing would have occurred and for the year afterwards were identified. A total of 2136 sections, representing 1834 carriageway-km were included in this analysis.

Accident data for the year before resurfacing were compared with annual equivalent figures derived from the numbers of accidents occurring in the three-month period in which the section was resurfaced (Q0)⁵ and in each quarter of the subsequent year following completion of the works (Q1, Q2, Q3 and Q4).

That initial study has since been supplemented by a further analysis covering sections of the HA network that were resurfaced between 2003 and 2006.

In both studies a large number of different analyses were made and some variations in behaviour were observed but the essential results can be summarised thus:

- Overall, there is a small but statistically significant increase (about 11%) in slight injury accidents in the first few months after resurfacing on trunk roads.
- There is also a marked statistically significant *decrease* (about 70%) in the number of fatal accidents in the same period.
- However, the increased accident risk was not occurring primarily at high skidding risk locations, as might have been expected. Rather, it was associated with all types of trunk road, including those that would be regarded as low-risk in skid resistance terms, such as main-line non-event motorways and dual carriageways.

There were not enough data for new HRA surfaces to permit reliable comparison of risks between older and newer types of surfacing and for the same reason it was not possible to make a meaningful analysis of risks for motorcycles in comparison with cars.

The accident analysis was based on data from motorways and trunk roads and injury accidents. However, the anecdotal comment was more widespread and there remained a possibility that accidents could be occurring on new surfaces that were not being recorded in the national statistics. To assess this, the initial analysis was supplemented by means of a questionnaire sent to local highway authorities and trunk road maintaining agents, supported by selected interviews with key staff in some areas. This survey found that, apart from one or two widely-reported incidents from the early years of the use of thin surfacing materials, so far as engineers on the ground were aware there were no recognisable instances of increased accident risk on new surfacings.

10.1.3 Developments in this study

The work in this third stage of study has been focussed on specific issues arising from the earlier work that had either not been identified or were not possible to assess at that time. Key observations can be summarised thus:

- The two effects of high dry friction and reduced dry friction previously observed have been reinforced.
- More detailed analysis possible in this study has found that initially within an individual skid, locked-wheel dry friction is very high (greater than would normally be expected from a clean, dry, well-trafficked road) and this condition can be maintained over a number of seconds. However, there can also be a sudden transition to a reduced friction condition, which is associated with the softening of the surface bitumen film.

⁵ It was found necessary to include the "Q0" period because on many sections the works took place over some time, moving progressively along the road. The records indicated when maintenance works had begun or were completed but did not necessarily indicate exactly when the new surface course was laid and opened to traffic. Inclusion of this period also allowed for the possibility of a change in accidents as a consequence of the works themselves.

- Once the reduced friction condition has occurred, the friction level recorded is typically in the range of $F_n = 50$ to 60 and this level is not affected by the sliding speed.
- The more detailed analysis possible in this study has found that either condition can occur at speeds as low as 20 km/h or at 50 km/h or higher. While the high-friction condition is more likely to be maintained at low sliding speeds and the low-friction condition appears to be more likely to develop at higher sliding speeds, it is not possible to predict which will predominate or at what speed the transition from one to the other occurs.
- Increasing the surface temperature of a new surfacing (as might occur on a hot day in bright sunlight) does not appear to increase the likelihood of a reduced-friction dry skid occurring.
- The work has confirmed that on new surfaces there is a greater rate of reduction in wet skid resistance at intermediate speeds, together with potentially lower than expected high-speed friction.
- The study has also demonstrated (as had previously been inferred) that all these effects can be observed on new HRA surfaces as well as on new thin surfacings, although they are likely to be shorter-lived on HRA at higher traffic levels.
- Some effects can become less noticeable over time as a result of weathering, without the passage of traffic.
- The study has confirmed that there is a period very early in the life of a new surfacing when the wet skid resistance reduces markedly and then increases again. This phenomenon appears to be associated with the combined effects of traffic and time. On busier roads, it is short-lived, often occurring in the first few days after opening to traffic. Typically, the effect is greatest after the passage of about 12,000 heavy vehicles and has disappeared after 45,000 heavy vehicles have passed.
- The study has also shown that during this early life period there is a marked increase in the relative high speed wet peak and locked friction ratio. This seems to be greatest at speeds above 50 km/h with the absolute difference in peak and locked friction on surfaces less than six months old at 50-55% of the peak friction. Whereas on surfacings over twelve months old the absolute difference in peak and locked friction is at 40-45% of the peak friction within this speed range
- Application of grit to a newly-laid surface can have some short-term advantages mainly in terms of wet skid resistance by removing the effect of the greater rate of loss of skid resistance with increased speed when the surface is very new. This effect is lost after trafficking but may last for a few months on more-lightly trafficked roads. The treatment may also reduce the likelihood of reduced dry friction occurring on older lightly-trafficked surfaces. However, further detailed study of treatments of this type is needed to confirm the full range of any beneficial effects or disadvantages.

10.2 Review of implications for accident risk

10.2.1 Views from the earlier studies

In normal driving, on surfaces in an acceptable condition, drivers do not usually demand greater friction than the road can provide. Generally, the condition of the surfacing will only come into play when other factors lead to a sudden and marked demand for braking or steering. This was reflected in the accident study which found that the general level of accident occurrence did not change markedly from one year to the next. In other words, the presence of new surfacings may have affected the outcomes of incidents but would not have been a major part of causation.

In PPR060, Roe and Lagarde-Forest reached their view that any increased accident risk due to the reduced dry friction effect was likely to be small based upon an analysis of stopping distances and speeds. Although the greater rate of decrease in wet skid resistance and low levels of wet friction at high speeds had been observed, the friction values measured were generally within the range that would be expected on the network. It was therefore inferred that these effects were not likely to constitute a markedly increased skidding risk in wet conditions in most circumstances. Nevertheless, it was possible to conceive of situations in which accident risks might be increased and hence their recommendation for the accident study to be made.

While the practical work relating to that report was in progress, the potential influence of the reduced dry friction level (F_n in the range 50-60) was also assessed by analogy to the skid resistance levels normally used to set investigatory levels on the network for wet conditions. Since the reduced dry friction was actually greater than is often encountered in wet conditions, the inference was made that the increased accident risks due to reduced dry friction were likely to be greatest where wet skidding risks have been found to be greater. These principles had been applied in preparing the interim advice to engineers (IAN49/03) which was introduced in 2003 (and which was considered to remain the best advice available in 2005).

The subsequent accident study showed that there was indeed a small increase in accident risk on new surfaces but, unexpectedly based on the previous reasoning, Greene and Crinson (2008) found that the increased risk was occurring predominantly on sections of road that would normally be regarded as "low risk" in a wet skidding context. A recent small-scale study to update the accident analysis has largely confirmed the previous findings, including the indications that, in practice, there is not a significant increase in accident risk on new surfaces on high-risk sites.

It is therefore appropriate to consider how the studies of physical effects and accident risk can be reconciled.

10.2.2 Low-risk sites

Motorways have a generally low accident risk in skid resistance terms. However, they are high-speed roads and the reduced locked-wheel friction observed at intermediate and higher speeds on new surfaces when the road is wet (including the marked reduction in wet skid resistance in the first few days) may contribute to a general increase in collision risk during the affected period in situations where extreme braking, or sudden manoeuvres, are called for in wet conditions.

The increase in "slight" accidents on the new surfaces, which occur predominantly in dry conditions, could be attributed to situations where sudden braking occurs and leads to wheel-lock. If a vehicle experiences the associated reduction in dry friction, this would result in a slightly longer braking distance resulting in the vehicle striking the obstacle. Similarly, if the affected vehicle was following closely behind another and the vehicle in front did not experience the reduced-friction condition, there would be a risk of a so-called "shunt" collision. The reduced wet friction in very early life might also be relevant in these circumstances in wet conditions.

However, the very high levels of low-speed and peak friction observed on new surfaces in both wet and dry conditions may mean that greater grip is available when brakes are first applied and so speeds may be reduced more quickly (before wheel lock occurs); this could be contributing to the observed reduction in accident severity.

10.2.3 Higher-risk sites

On higher-risk sites, wet skid resistance investigatory levels are higher and closer to the values achieved in the lower-friction dry skid condition but the accident study did not find a significant increase in risk in these locations. A possible explanation for this is that at such sites, although braking may frequently be called for, they are more obviously

high risk and drivers have to reduce speed to negotiate the relevant section of road. Consequently, speeds may be low enough in most cases to take full advantage of the higher grip available, especially if wheel lock does not occur.

On curves, the important level of friction is the peak friction which governs the tendency for wheels to slip sideways. New surfaces offer very high peak friction values in both wet and dry conditions and since, for comfort, most drivers typically negotiate curves with side forces requiring much lower friction levels, the newer surfaces probably provide an additional safety factor compared with older roads. It is unlikely that a vehicle would slip sideways sufficiently fast to generate the reduced-friction condition on a dry road. However, if a driver is operating close to the peak friction on a wet surface there is a risk that the peak could be exceeded, leading to a rapid reduction in grip and loss of control.

10.2.4 The potential implications for ABS or non-ABS braking

Comment is sometimes made about the differences in stopping distance experienced by vehicles fitted with anti-lock braking systems (ABS) compared with those without ABS, were they to encounter the reduced friction condition on a new dry surface. Anti-lock systems operate by preventing the wheel establishing a locked-wheel skid and therefore maintain friction levels near to peak values. Clearly, on new asphalt surfaces (whether wet or dry) the high peak friction levels should not have an adverse effect on accident risk.

However, in heavy or emergency braking on a new surface, vehicles without ABS are more likely to enter a locked wheel skid, with the associated lower levels of wet friction or, possibly, reduced dry friction. If a non-ABS vehicle is following one fitted with ABS, the difference in friction levels encountered will result in different stopping distances which could contribute to an increase in the risk of a collision. This may also be a factor in the increase in slight injury accidents discussed in the previous section.

It is likely, however, that this problem will be more significant in wet conditions and it should also be noted that differences in braking distance between ABS and non-ABS vehicles are already present on all roads, especially wet ones, however old they are.

10.2.5 Implications for motorcycles

The anecdotal comment surrounding the issue of skid resistance on new surfaces often refers to problems for what are known as powered two-wheel (PTW) vehicles. Such vehicles, of course, are more vulnerable to sudden changes in grip than cars would be.

The different types of dry skid that have been observed in this study could result in a degree of unpredictable behaviour, particularly at lower speeds or when road surface temperatures are high. This could lead to a change in the level of friction available to a vehicle during a steering manoeuvre, or braking, that would increase the risk of the driver being able to successfully complete that manoeuvre and this behaviour may have a greater impact on powered two-wheelers.

Drivers of PTWs often follow a driving line that is away from the wheel paths of other traffic. This would take them on to areas of the road that carry less traffic and there could therefore be markedly different levels of wet skid resistance. A situation that might increase risk on a new surface would be the potentially greater difference (compared with older, polished aggregate surfaces) between the un-trafficked areas and wheel paths in the very early life period. Also, on more-lightly trafficked routes, the reduced wet friction period might last longer.

However, it should be borne in mind that areas of different grip levels occur on any wet road surface. The accident study did investigate whether there was any significantly greater injury accident risk on new surfacings for powered two-wheel vehicles, but there were too few data for a reliable analysis to be completed.

The situation discussed in Section 10.2.3, where a vehicle is operating close to peak friction when negotiating a bend in wet conditions may present a greater risk to PTW users if peak friction is overcome.

11 Conclusions

This study continues ongoing research into the skidding resistance properties of asphalt surfacings early in their lives. An earlier study in the programme (PPR060) made a number of recommendations and this report has addressed those related to the physical phenomena associated with new asphalt surfacings, and some additional aspects that were identified as worthy of investigation after that report was published.

Measurements of wet and dry locked-wheel friction were made on a range of new or recently-laid asphalt surfaces under different conditions with the objective of answering four principal questions relating to new asphalt surfaces. The questions addressed by the work and the conclusions to be drawn are as follows.

1. *How does skid resistance behaviour change with time and traffic, especially very early in the life of new surfaces?*

- In dry conditions, friction is initially very high but as a skid develops a reduced level can occur associated with softening of the bitumen.
- Which of these conditions will occur in a particular situation is unpredictable although the lower-friction condition appears to be more likely to occur if wheels are locked at higher speeds.
- In wet conditions, low-speed friction is very high but, as speed increases, friction decreases more rapidly and to potentially lower levels than would be expected on older well-textured roads. Nonetheless, the levels of friction observed still fall within the broad range found on roads generally.
- Some effects can become less noticeable over time as a result of weathering, without the passage of traffic.
- There is a period very early in the life of a new surfacing when the wet skid resistance reduces markedly and then increases again. This phenomenon appears to be associated with the combined effects of traffic and time. On busier roads, it is short-lived, often occurring in the first few days after opening to traffic.

2. *To what extent are the physical effects associated with new modern asphalt surfacings found on traditional HRA?*

- The study has demonstrated that the physical effects can be observed on new HRA surfaces as well as on new thin surfacings.
- However, they are likely to be shorter-lived on HRA at higher traffic levels.

3. *Does increased road surface temperature affect dry friction?*

- Increasing the surface temperature of a new surfacing does not appear to increase the likelihood of a reduced-friction dry skid occurring.
- The data suggest that increased temperature may result in an increase in the probability of the high-friction condition occurring.

4. *What influence does initial gritting have on early-life skid resistance?*

- Application of grit to a newly-laid surface can have some short-term advantages, mainly in terms of wet skid resistance, by removing the effect of the greater rate of loss of skid resistance with increased speed when the surface is very new.
- The beneficial effects are rapidly lost under heavy traffic but may last for about six months on more lightly-trafficked roads.
- This type of treatment may also reduce the likelihood of reduced dry friction occurring on older lightly-trafficked surfaces.

- However, further detailed study of treatments of this type is needed to confirm the full range of any beneficial effects or disadvantages.

The findings of this study reinforce the observations made in PPR060 (Roe and Lagarde-Forest, 2005) and can explain the changes in accident risk on new surfaces identified in the subsequent accident analysis reported in PPR205 (Greene and Crinson, 2008).

In the light of the findings from this and the earlier studies, the guidance provided in IAN49/03 will need to be reviewed. This is currently being progressed by HA.

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