Measurement of skidding resistance
Part II. Factors affecting the slipperiness of a road surface
by
J. R. Hosking and G. C. Woodford
MEASUREMENT OF SKIDDING RESISTANCE
PART II. FACTORS AFFECTING THE SLIPPERINESS OF A ROAD SURFACE

by

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Any views expressed in this Report are not necessarily
those of the Department of the Environment

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MEASUREMENT OF SKIDDING RESISTANCE
PART II. FACTORS AFFECTING THE SLIPPERINESS OF A ROAD SURFACE

ABSTRACT

Measurements of skidding resistance are affected by the following two classes of factors:

(1) Factors affecting the slipperiness of the road, such as the state of polish of the surface.

(2) Factors affecting the skidding measurements themselves, such as the accuracy of the calibration of the test instrument.

Factors affecting the slipperiness of a road surface are considered in this report and estimates are given of their magnitude. These factors include seasonal variation, temperature, type and composition of the road surfacing material, type and condition of the road, age, traffic density, climate and any contamination of the road surface.

Methods of reducing variations due to these factors are discussed, particular emphasis being placed on the desirability of using mean summer values.

1. INTRODUCTION

SCRIM (Sideway-force Coefficient Routine Investigation Machine) has been developed by the Transport and Road Research Laboratory to provide a routine method of measuring the resistance to skidding of wet roads. This machine is a direct descendant of the fifth-wheel skid resistance testing machines that have been used by TRRL for research purposes since 1953 and which, in turn, were developed from the motor-cycle combination machine that was first used by the Ministry of Transport's experimental station at Harmondsworth (later to become the TRRL) in 1930.

At the time of writing there are 18 SCRIMs working all over the world and a series of three reports has been written to give guidance on the operation of the machine and on the interpretation of results. It is hoped that they will be of value not only to the SCRIM user, but also to those who make use of the results. Although some sections of the reports (such as those dealing with seasonal variation) are particularly applicable to conditions in the United Kingdom, the information given should provide a basis for a modified procedure suited to other climatic conditions.

Part I gives an outline of the principles and operation of SCRIM, briefly discusses the causes of variation in results (these are dealt with more fully in Parts II and III) and recommends a procedure to be adopted for routine SFC measurement.

Part II gives an account of the factors affecting the slipperiness of a road surface.
Part III\(^2\) gives an account of the factors affecting measurements made with SCRIM.

The work reported in Parts I, II and III is limited to measurements made at lower speeds (50 km/h). It is intended that a further Part be published when current research has been completed, that will give an account of factors, such as macro-texture, which influence high speed resistance to skidding.

2. FACTORS AFFECTING THE SLIPPERINESS OF A ROAD SURFACE

Each type of factor affecting the slipperiness of a road surface is discussed in turn in the following nine subsections.

2.1 Wet or dry conditions

The slipperiness (coefficient of friction between the surface and the tyre) of a road surface is determined by a number of factors of which the most basic is whether the surface is wet or dry. Under completely dry conditions and when the road is free from loose material, resistance to skidding is very high and the SFC is remarkably constant (about 0.90) for a wide range of different surfaces. For a smooth surface there is a large loss in resistance to skidding when the surface is slightly wet and further smaller losses according to the thickness of the water film\(^2\). Rough surfaces show the same effect, but to a lesser degree. Because of this and because accident studies have shown that the risk of skidding accidents is much greater when the road is wet, the wet road condition has been standardized for skid-resistance measurements in the UK and most other parts of the world. All further reference to resistance to skidding in this report refers to the wet condition.

2.2 Seasonal variation

It has been known since 1931\(^3\) that the skidding resistance of a wet road surface is greater in winter than in summer. For this reason it has been the practice of TRRL to measure SFC in the summer months (May to September inclusive) when the values are lowest. The mean of such measurements is termed the 'mean summer SFC' and is normally based on at least three measurements spread over the summer period.

The magnitude of the seasonal variation and the time at which the maximum and particularly the minimum SFC values are reached vary from year to year. Hot dry weather tends to produce low values and if such weather occurs early in the year then the minimum value will be reached early. In the same way if the autumn is warm and dry the value of SFC will not rise as quickly as in cooler wetter conditions. The proportion of time during which the road is wet seems to be more important than the temperature in this respect\(^4\).

Regular measurements of skid resistance using the portable tester\(^5\) were made at two-weekly intervals during the period 1958 to 1968 on a number of sites to study the seasonal variation. The results for the eleven years (Table 1) showed that minimum skid resistance occurred during the period May to October, that lowest values were obtained during the fine summer of 1959 and that the severe winter of 1962-3 was followed by high values during the following summer.

2.2.1 Variation between years The extent to which differences between years can be expected to cause variation in SFC is shown in Fig 1. The values given are estimates of SFC that would be obtained for a surface with an overall mean summer SFC of 0.50 based on the skidding indices given in Table 1. The average SFC for the year varied from 0.51 to 0.59 and the mean summer values varied from 0.44 to 0.53 with a standard deviation of 0.03. Part of this variability is a result of variation between years and part is a result of variation in
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<td>102</td>
<td>101.5</td>
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</table>

* minimum value for the season
the measurement itself. However the latter has been reduced by taking the means of measurements at seven sites, tested twice a month for a period of five months and therefore the variation in mean summer SFC due to differences between seasons is probably about 0.02 when expressed as standard deviation. Differences between highest and lowest monthly figures varied from 0.10 in 1968 to 0.20 in 1959.

2.2.2 Variation during a year Fig 2 shows the month-to-month variation that can be expected in the south-east of England for a road with a mean summer SFC of 0.50. It is based on averages of the monthly values of skidding index given in Table 1. The figure shows a sine-curve type of relationship between the month of the year and SFC with a peak in mid-winter (January) and a trough in the summer (June to August). It also shows that the use of 'mean summer SFCs' not only has the advantage of giving a measure of resistance to skidding when it is at its lowest, but also when variation is the least. The standard deviation of the monthly variation over the whole season was found to be 0.06, whereas that during the summer period (May to September) was only 0.02. Part of both of these would arise from variations in the measurements themselves.

It should be emphasized that the seasonal variation discussed is that occurring in the south-east of England, and that different behaviour may occur in other regions of Britain and in other countries.

2.3 Temperature

2.3.1 Effect on skidding test results Rubber resilience increases (i.e., hysteresis losses become smaller) as temperature rises and so resistance to skidding tends to decrease. Lander* has studied this effect in relation to SCRIM measurements by heating (and cooling) a test tyre to a range of temperatures between 9°C and 26°C and testing a range of different surfacings (concrete and bituminous). He concluded that increasing the temperature reduced SFC by about 0.003 units per °C and that surfacings with a higher coefficient of friction tended to suffer a greater reduction.

Sabey* has carried out a similar study using the portable skid-resistance tester in which measurements on seven types of road surface (concrete and bituminous) were made at midday and during the night at a time when unusually wide ranges of air temperature were experienced. It was concluded that, on average, the skid resistance value (SRV) increased by 0.26 units (equivalent to approximately 0.003 units of SFC) per °C over the range 7°C to 35°C and that the effect appeared to account for about one-quarter of the overall change in skidding resistance from midsummer to midwinter. The results of these two studies are combined in Fig 3 where the ratio of the frictional value at each temperature (SFCt or SRVt) to the estimated value at 20°C (SFC20 or SRV20) has been plotted against the temperature. (Estimated values at 20°C were obtained by drawing smooth curves through plots of SFC (or SRV) against temperature). This figure shows that the results of the two sets of observations (even though one is of SFC and the other of SRV) give virtually the same relationship.

Linear regression analysis yielded the formula:

\[
\frac{SFC_t}{SFC_{20}} = 1.106 - 0.0054t
\]

with a highly significant correlation coefficient of −0.79 for the 64 observations.

* Unpublished report
Even better correlation (correlation coefficient = 0.81) was obtained with the hyperbolic relationship:

\[
\frac{\text{SFC}_t}{\text{SFC}_{20}} = 0.548 + \frac{44.69}{t + 80}
\]

### 2.3.2 Practical importance in SCRIM testing

Tyre, road and air temperatures were measured during the two series of tests described in 2.3.1 above. Analysis showed that better correlation was found between tyre temperature and the mean of the air and road temperature (correlation coefficient = 0.87) than with either of these measurements alone. Correlation took the form:

Tyre temperature (°C) = 12.3 + 0.96 mean temperature (°C)

For practical purposes an estimate of the tyre temperature can be made by adding 12°C to the mean temperature or, less accurately, to either the air or road temperature. This figure is in close agreement with Landers' estimate that a steady temperature is reached within about one kilometre of testing, the increase being of the order of 10 to 15 degrees C.

During the normal period of test in Great Britain (May to September) the tyre temperature will not often be outside the range 20°C to 57°C (corresponding to range of 8°C to 45°C for air/road temperature). The change in SFC over this range would be about 7½ per cent; for example, a surface giving an SFC of 0.50 at 20°C would give SFCs ranging from 0.50 to 0.44 according to the temperature at the time of test. This means that the temperature effect is not likely to be an important factor when mean summer values are used as a basis of measurement in the United Kingdom. However the effect could be more important in other countries, when testing at other times of the year and when individual measurements are made.

It should be noted that the SFC recorded is the measure of wet-road resistance to skidding under the conditions of test, and that any temperature 'correction' gives no more than an estimate of what the SFC would have been had the temperature been different. The value of 'correction' lies in that it can be used to enable comparisons to be made of surfacings tested under different temperature conditions.

### 2.4 Type and composition of the surfacing material

#### 2.4.1 Bituminous surfacings

Research\(^7\) has shown that a major factor determining the resistance to skidding of bituminous surfacings containing a high proportion of aggregate at the tyre/road interface is the polishing resistance of the aggregate used. Further research\(^8\) has shown that the British Standard polished-stone value determination\(^9\) yields values (PSVs) such that each unit difference in PSV is equivalent to 0.01 units in mean summer SFC for the same traffic intensity. SFC has also been found to be influenced by the type, size and durability of the aggregate\(^10\).

The skidding resistance of bituminous surfacings has also been found to be affected by the type of surfacing, the weathering characteristics of the binder\(^11\) and the mix design\(^12,13,14,15,16\).

#### 2.4.2 Concrete

Research\(^17\) has shown that a major factor affecting the resistance to skidding of concrete is the choice of fine aggregate. Best results were achieved with fine aggregates having a high resistance to polishing and abrasion. This work suggested that the compressive strength of the concrete and the proportion of fine aggregate also affected resistance to skidding, but the characteristics of the coarse aggregate had little effect.

* Unpublished report
The resistance to skidding of concrete has also been found to be affected by the method of texturing used, the presence (if any) of exposed coarse aggregate and the mix design.

2.4.3 Resin-bound skid-resistant surfacings The skid resistance of the special surfacings that employ a hard nominal 3 mm aggregate bonded to the road surface by a resin binder system has been found to be related to the PSV of the aggregate used. These surfacings give a higher resistance to skidding than conventional surfacings using the same aggregate, probably because of the smaller size of the aggregate used and because the aggregate particles are not rotated during rolling or by traffic to present flat faces to the surface.

2.5 Age

Other factors being equal the surface of a road is polished most rapidly immediately after opening to traffic and progressively less until by the end of about 12 months it has settled down to an asymptotic value. Apart from variation between seasons (see 2.2) this level of mean summer SFC is maintained until either the surfacing deteriorates or traffic density changes. In practice the traffic density has been rising each year at most road sites and so the mean summer SFC has gradually become lower (see 2.6 below).

2.6 Traffic density

It has been observed that the SFC of flexible road surfacings with a high proportion of aggregate at the tyre/road interface varies inversely with the commercial traffic density, the relation being:

\[
SFC = 0.024 - 0.0000663 T + 0.01 PSV
\]

where T is the traffic density in commercial vehicles per lane per day. The effect is reversible, a decrease in traffic leading to an increase in the equilibrium value of SFC.

Preliminary studies of the effect of traffic density on the skidding resistance of concrete suggests that the effect is of about half the magnitude of that on flexible surfacings.

2.7 Road site

A relatively lower resistance to skidding is encountered at sites where horizontal forces are set up. Examples are where vehicles are braking, accelerating or failing to maintain the correct speed/super-elevation relationship on a bend. SFC can be expected to be 0.05 or more lower than at uncomplicated sites.

2.8 Climate

Climatic conditions play a part in determining the skidding resistance of road surfaces (see 2.2). Warm dry conditions promote polishing (but wet conditions are required before the effect on skidding is noticed) and cold wet conditions promote roughening. Most published work quoting SFC values refers to mean summer values obtained during the period May to September inclusive. Differences in climate should be borne in mind when relating these values to conditions in other countries and to seasons other than summer in Great Britain.

2.9 Contamination of the road surface

Apart from accidental spillage of oil, fuel, grit, clay and other contaminants, more regular contamination has been observed during long dry road conditions. Thick black deposits have been observed, particularly on motorways, which lower SFC by about 0.10 units and impair high speed resistance to skidding. Lower results...
## TABLE 2
Factors affecting the slipperiness of a road surface

<table>
<thead>
<tr>
<th>Reference Number</th>
<th>Factor</th>
<th>Standard deviation of SFC (where applicable)</th>
<th>Maximum likely difference in SFC</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Type and composition of the surfacing, traffic, age, road-site and climate</td>
<td>—</td>
<td>from under 0.05 to over 1.00</td>
<td>These factors determine the basic SFC of the surface being measured.</td>
</tr>
<tr>
<td>2</td>
<td>Contamination of the road surface</td>
<td>—</td>
<td>about 0.10</td>
<td>Contamination by oil, rubber, dust, etc.</td>
</tr>
<tr>
<td>3</td>
<td>Wet or dry road</td>
<td>—</td>
<td>—</td>
<td>A perfectly dry road gives a constant SFC (~0.90) for all surfaces: tests should be made on wet roads.</td>
</tr>
<tr>
<td>4</td>
<td>Between years (mean summer values)</td>
<td>0.02</td>
<td>±0.04†</td>
<td>Dependent on weather conditions.</td>
</tr>
<tr>
<td>5</td>
<td>Within year</td>
<td>0.06</td>
<td>±0.12†</td>
<td>Reduced if tests are made during summer period only: see below.</td>
</tr>
<tr>
<td>6</td>
<td>Within summer season</td>
<td>0.02</td>
<td>±0.04†</td>
<td>Reduced if mean summer values are used.</td>
</tr>
<tr>
<td>7</td>
<td>Temperature</td>
<td>—</td>
<td>±0.03*</td>
<td>Over full range of temperatures likely to be found in summer season. A correction factor may be applied.</td>
</tr>
</tbody>
</table>

* Proportional to SFC level, estimated for a SFC of 0.50
† per cent confidence limits
have also been recorded by Greater London Council during long dry road conditions. These reductions of between 0.02 and 0.13 units of SFC may be due to the presence of similar, but thinner, deposits. Samples of the motorway deposits have been found to consist of a mixture of oil, rubber and mineral matter, and have been found to disperse quickly when heavy rain occurs.

The presence of contamination should be noted when SFC measurements are being made.

3. DISCUSSION

The SFC measurements obtained by using SCRIM are dependent on both the actual slipperiness of the road and a number of factors affecting the measurement itself.

The slipperiness of a road is basically determined by the type and composition of the surfacing, traffic density, type of site and any texturing that has been performed. It is also affected by the other factors summarized in Table 2. Except for Factor 3 they are independent of SCRIM and its operation, but need to be taken into consideration when interpreting the results of SCRIM testing and when deciding what action needs to be taken. The use of mean summer measurements reduces the variation caused by Factors 5, 6 and 7 and enables a reasonably precise estimate to be obtained of the slipperiness of a road section. For much of the research work at TRRL, the means of three consecutive mean summer SFCs have been used; this reduces the effect of Factor 4 and further reduces the effects of Factors 5, 6 and 7. Temperature effects (Factor 7) are of particular interest in that formulae may be used to estimate the SFC at any required temperature from that obtained at the temperature of test. This can be of value when comparisons need to be made, but it must be remembered that the effective SFC of a surface is the measurement obtained under the conditions prevailing at the time of test.

The effects summarized in Table 2 and the factors affecting the measurement itself\(^2\) highlight the need for care in both testing and interpretation of results when testing under difficult conditions, such as outside the summer period, on irregular surfaces (eg setts and pot-holed surfacings), at low speeds, on very short sections and on bends.

4. ACKNOWLEDGEMENTS

The work described in this Report was carried out in the Materials Division (G F Salt, Division Leader) of the Highways Department of the Transport and Road Research Laboratory in co-operation with Experimental Equipment Design Section (F G Taylor, Section Leader). Use has also been made of unpublished reports by F TW Lander and Barbara E Sabey also of TRRL.

5. REFERENCES


Fig. 1 VARIATION IN SFC FROM YEAR TO YEAR (ESTIMATED FROM SKIDDING INDICES (TABLE 2) AND ASSUMING AN OVERALL MEAN SUMMER SFC OF 0.50)
Fig. 2 ESTIMATE OF THE SEASONAL VARIATION OF SFC OF A SITE WITH A MEAN SUMMER SFC OF 0.50
Fig. 3 RELATION BETWEEN CHANGE IN RESISTANCE TO SKIDDING AND TEMPERATURE

- Ratio = $1.106 - 0.054t$ ($r = -0.79$)
- Ratio = $0.548 + \frac{44.69}{t + 80}$ ($r = 0.81$)

- Skid resistance values
- Sideway force coefficients
Abstract

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1. Factors affecting the slipperiness of the road, such as the state of polish of the surface.

2. Factors affecting the skidding measurements themselves, such as the accuracy of the calibration of the test instrument.

Factors affecting the slipperiness of a road surface are considered in this report and estimates are given of their magnitude. These factors include seasonal variation, temperature, type and composition of the road surfacing material, type and condition of the road, age, traffic density, climate and any contamination of the road surface.

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