



## **PUBLISHED PROJECT REPORT PPR737**

### **Performance review of skid resistance measurement devices**

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## Executive Summary

The Highways Agency (HA) is responsible for providing appropriate levels of skid resistance on the English strategic road network in order to manage accident risk. The HA manages this risk by undertaking annual Sideway-force Coefficient Routine Investigation Machine surveys. This device was originally developed by the Ministry of Transport at TRL over many years and has subsequently been produced commercially under licence to TRL. It has proven itself as a useful tool to support the HA's skid resistance strategy over more than three decades.

There are, however, a number of other devices and design variants available in the UK that measure skid resistance and friction in different ways. These devices are:

- The Skid Resistance Development Platform (based on a Sideway-force Coefficient Routine Investigation Machine), measuring sideway-force. This device is the backbone of the HA's low speed skid resistance strategy.
- The Pavement Friction Tester, measuring locked wheel friction, which is used for research and ad hoc surveys.
- GripTester, measuring slipped wheel skid resistance, which is used by the HA for research.

In the light of European harmonisation of standards for the measurement of low speed skid resistance, via sideway-force coefficient, there is a need to review the HA's use of the Sideway-force Coefficient Routine Investigation Machine. This report provides information:

- To ensure that the device, and the technique, is the most appropriate tool, especially at high risk sites
- That clarifies the status and specification of the devices used by the HA, allowing better preparedness for European standard harmonisation

To this end, a test programme was undertaken to assess the performance of skid resistance devices whilst testing; at different speeds, under braking and navigating roundabouts and corners. The results from the testing showed that, for the strategic road network, more accurate or consistent measurement of skid resistance would not be obtained when testing high risk sites with alternative devices to SCRIM. The work also demonstrated that if the lower limit for the existing speed correction was reduced from 25 to 10 km/h then all but a small percentage of sites could be speed corrected and this would reduce the number of high risk sites where valid data are not currently obtained. The results of the testing indicated that applying the speed correction at speeds below 25 km/h would result in an underestimation of the actual skid resistance, i.e. the correction would fail safe. However, additional testing on in-service roads is recommended to validate these findings which were derived from measurements on a closed test track.

The report also summarises developments that have been incorporated into the UK SCRIM fleet in recent years such as vertical load measurement, controlled water flow and GPS location referencing that are beyond the key requirements for the device set out in BS 7941-1 (2006). Details of the capabilities of the current fleet are summarised and the implications for the UK fleet of the potential development of a European Standard for measuring the skid resistance of pavements are also considered. There are a number of features available on SCRIM that would be beneficial to include in a future

European standard, but the specification and supply of the test tyres will require careful consideration taking into account, the effects on measurement, supply chain and consistency between operators.

## 1 Introduction

The work described in this report was carried out in order to gain a better understanding of the performance of the skid resistance measurement devices used by the Highways Agency. In particular the work focussed on the performance of skid resistance devices when testing high risk sites (roundabouts, approaches to pedestrian crossings, junctions, etc...) and characterising the performance of the Sideways-force Coefficient Routine Investigation Machine (SCRIM), the device used for the routine assessment of the English strategic road network. A key aim of this work was to identify if devices other than SCRIM would be more appropriate for the testing of high risk sites.

This report is separated into three parts; the following chapter gives some background information to the current UK skid resistance policy and the main devices available in the UK for characterising pavement skid resistance. The implementation of the current skid resistance policy in terms of the assessment of roads with relation to their site category is discussed. The two main devices used for the assessment of low speed skid resistance, SCRIM and GripTester, are described. In addition the Pavement Friction Tester (PFT) a specialist research tool for the measurement of peak and locked wheel friction at a wide range of speeds is also described.

Chapter 3 concentrates on the work carried out to assess the performance of the devices when testing high risk sites. This chapter opens with the presentation of a desk study carried out to assess the amount of the network for which no valid skid resistance information is collected. The remainder of the chapter concentrates on experimental testing undertaken to assess the performance of skid resistance devices whilst testing; at different speeds, under braking and navigating roundabouts and corners.

In Chapter 4 the current state of the SCRIM fleet is defined and compared with British Standard 7941-1:2006 (British Standards Institution, 2006). Some comment is made regarding the future development of a European skid resistance standard.

## 2 Background

### 2.1 Management of the skid resistance on the HA network

The Highways Agency (HA) is responsible for the management of the English strategic road network (SRN). Part of their remit is to ensure that the skid resistance of the network is maintained to an acceptable standard. To achieve this, the HA operates a skid resistance policy, detailed in HD28/04 of the Design Manual for Roads and Bridges (Department for Transport, 2004). This policy can be summarised as making annual skid resistance measurements of the road network and comparing these with investigatory levels. Lengths of the network that are found to be at or below the investigatory level are then subject to further investigation to determine whether it would be beneficial to improve the skid resistance at these locations.

The investigatory level for any given section of carriageway is defined by the risk posed to road users at that location. Table 2-1 gives the site categories listed in HD28/04 (Department for Transport, 2004) and the investigatory levels that can be assigned at each of these sites.

**Table 2-1 Site category investigatory levels (Department for Transport, 2004)**

| Site category and definition |   | Investigatory level at 50 km/h |      |      |      |      |      |
|------------------------------|---|--------------------------------|------|------|------|------|------|
|                              |   | 0.30                           | 0.35 | 0.40 | 0.45 | 0.50 | 0.55 |
| A                            | Motorway  |                                |      |      |      |      |      |
| B                            | Dual carriageway non-event  |                                |      |      |      |      |      |
| C                            | Single carriageway non-event  |                                |      |      |      |      |      |
| Q                            | Approaches to and across minor and major junctions, approaches to roundabouts |                                |      |      |      |      |      |
| K                            | Approaches to pedestrian crossings and other high risk situations             |                                |      |      |      |      |      |
| R                            | Roundabout  |                                |      |      |      |      |      |
| G1                           | Gradient 5-10% longer than 50 m   |                                |      |      |      |      |      |
| G2                           | Gradient >10% longer than 50 m  |                                |      |      |      |      |      |
| S1                           | Bend radius <500 m – dual carriageway   |                                |      |      |      |      |      |
| S2                           | Bend radius <500 m – single carriageway                                       |                                |      |      |      |      |      |

Sites defined as category Q, K, R, G1, G2, S1 and S2 are collectively known as high risk sites. High risk sites represent locations where road users are more likely to have to conduct aggressive stopping or steering manoeuvres, and so have higher investigatory levels to reflect the increase in demand for skid resistance.

## 2.3 Measurement equipment

There are a number of devices available for the characterisation of pavement skid resistance, a comprehensive list of available, vehicle based devices is given in FEHRL report 2006/01 (FEHRL, 2006) and TYROSAFE report D04 (TYROSAFE, 2008). This section summarises the three main devices used in the UK.

### 2.3.1 Sideway-force Coefficient Routine Investigation Machine

Sideway-force Coefficient Route Investigation Machines (SCRIMs) are used for routine monitoring of the skid resistance of the English strategic road network. Figure 2-1 shows the Highways Agency Skid Resistance Development Platform (SkReDeP), which incorporates sideway-force measurement equipment. Measurements from this device provide information that can be used to compare the performance of surfacings with the requirements for skid resistance laid out in the HA Standards (Department for Transport, 2004).



**Figure 2-1 SkReDeP**

SCRIM uses a smooth test tyre installed in the nearside wheel path (NSWP) angled at 20 degrees to the direction of travel, which is mounted on an instrumented axle. The skid resistance value is the average ratio between the measured horizontal and vertical force, multiplied by 100. For the purpose of this study the raw measurements were used from SkReDeP which provide a vertical and horizontal load measurement at a sampling interval of approximately 0.09 m.

Measurements are typically made with SCRIM at 50 km/h, but because of the angle of the test wheel the tyre contact patch moves over the surface at approximately 17 km/h. SCRIM is therefore considered to measure low speed skid resistance.

### **2.3.3 GripTester**

GripTester is a small trailer based device used by many local authorities for measuring low speed skid resistance (Figure 2-2).



**Figure 2-2 GripTester**

This device operates under the fixed slip principle, with the test wheel in-line with the direction of travel. The test wheel is mechanically linked via a chain and sprocket to two 'drive wheels', geared so that the test wheel is forced to rotate at a speed slower than that of the drive wheels, thereby generating slip between the test tyre and pavement. Measurements are usually made with GripTester at a test speed of 50 km/h in the NSW with a sampling interval of 1 m.

### **2.3.4 Pavement Friction Tester**

The Pavement Friction Tester (PFT) is a locked-wheel road surface friction testing device comprised of a tow vehicle and trailer (Figure 2-3). The trailer holds the test wheel, which is mounted on an instrumented axle and can be independently braked. The forces acting upon it are measured to determine the friction between the test tyre and road surface.



**Figure 2-3 Pavement Friction Tester**

The key difference between the PFT and SCRIM or GripTester, is that during testing, the PFT tyre contact patch slides over the surface at the same speed as the towing vehicle. This device can therefore measure skid 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 three second braking cycle.

From these measurements, the peak<sup>1</sup> and locked<sup>2</sup> friction are determined. Measurements are typically made in the nearside wheel path at a speed of 90 km/h. To characterise the friction of a surface, typically 5 determinations of friction are made and the average of these measurements used. The PFT is used with reference to ASTM standards E274 (ASTM, 2011) and E524 (ASTM, 2008).

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<sup>1</sup> Peak friction is the maximum friction value reached as the test wheel begins to slip.

<sup>2</sup> Locked friction is the friction value experienced when the test wheel is locked.

### 3 Skid resistance measurement of high risk sites

The aim of the study was to assess the performance of skid resistance testing devices when operating on high risk sites, and to assess the effectiveness of current methodologies for testing these sites. Testing high risk sites may require devices to operate under conditions different to testing straight-line carriageway such as:

- On bends or roundabouts
- At non-standard speeds in the case of slip roads or approaches to junctions
- Whilst decelerating in the case of stopping at traffic signals or give-way lines.

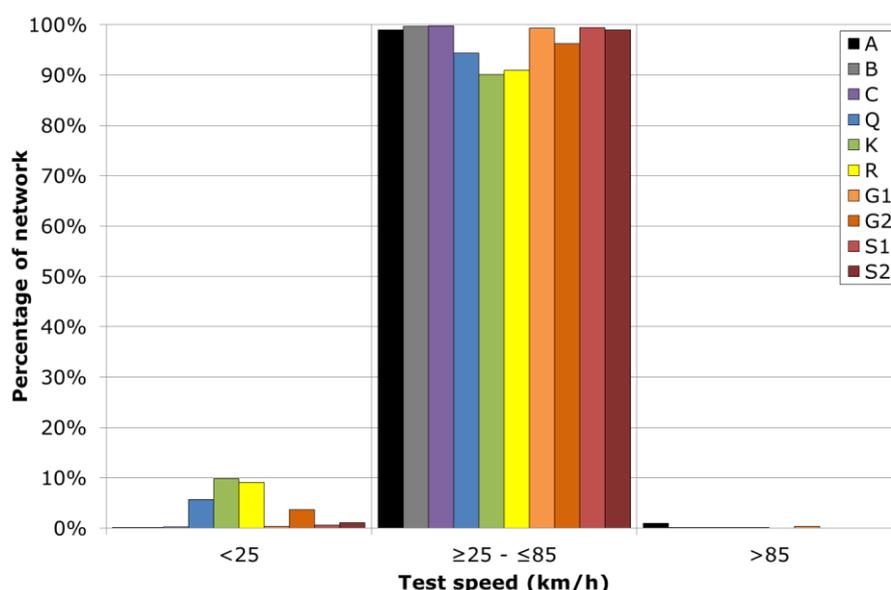
Testing under these conditions has the potential to affect the measurements made. The effectiveness of speed corrections or effects of load transfer on test wheels could contribute to changes in the measured skid resistance value.

The study was undertaken in two stages, the first was a desk study to assess the percentage of the SRN that is captured by the current procedures. The second was a series of experiments to replicate the conditions of high risk sites and the effects that these have on the measurements made by skid resistance devices. Experiments were set up to mimic sites were; a speed correction may be required, the vehicle may undergo braking, or manoeuvring around roundabouts and sharp corners.

#### 3.1 Desk Study

The objective of the desk study was to define the amount of the network not currently captured by the routine annual SCRIM surveys. When conducting SCRIM surveys the test vehicles aim to travel at a test speed of 50 km/h on single carriageway roads and 80 km/h on dual carriageways and motorways (subject to complying with the prevailing speed limit). Measurements are then corrected to a standard speed of 50 km/h using the speed correction given in HD28/04 (Department for Transport, 2004). The speed correction can be applied to measurements made between 25 and 85 km/h, which enables variations in speed resulting from traffic levels, road geometry or traffic control to be accounted for. Outside of these limits the speed correction may not be valid and so measurements made outside these limits are ignored. Routine measurements made on the SRN are stored in a central database; the Highways Agency Pavement Management System (HAPMS).

HAPMS was queried to identify the speed of measurements made for each 10 m section of lane 1 on the SRN between 2011 and 2013. The site category for each section was compared with the test speed and the percentage of each site category measured at various speeds was calculated (Figure 3-1).



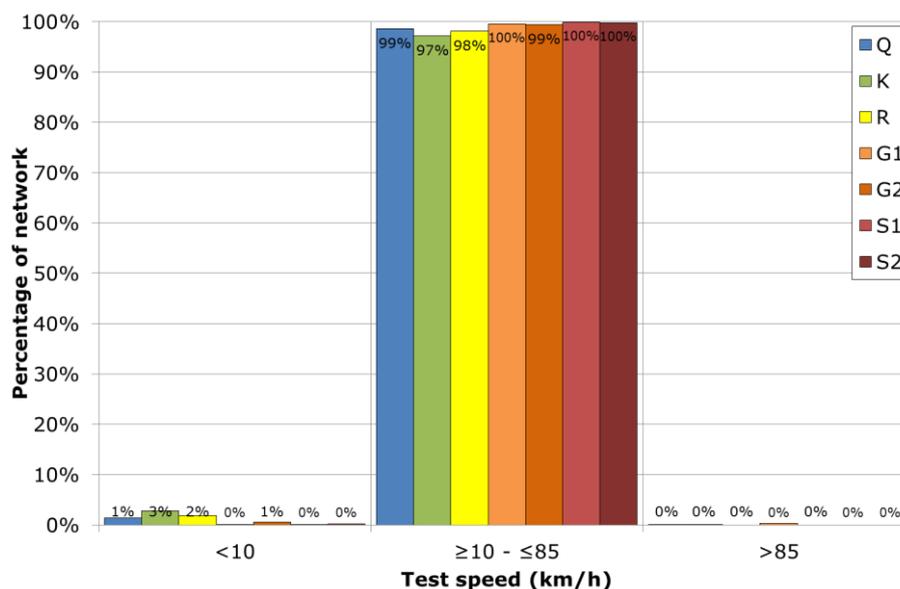
**Figure 3-1 Percentage lane 1 measured within survey speed range, 2013**

This shows that there is a small yet notable amount of missing information for site categories Q, K, R and G2. The percentages for each of the three years are shown in Table 3-1; this demonstrates that similar percentages are not captured for these site categories in 2012 and 2013. There are also some lengths that have not been surveyed at a valid speed in any of the three years.

**Table 3-1 Percentage of lane 1 measured below 25 km/h**

| Site category | 2011 | 2012 | 2013 | Same site(s) in each year |
|---------------|------|------|------|---------------------------|
| A             | 0%   | 0%   | 0%   | 0.1%                      |
| B             | 0%   | 0%   | 0%   | 0.0%                      |
| C             | 0%   | 0%   | 0%   | 0.0%                      |
| Q             | 6%   | 5%   | 6%   | 0.6%                      |
| K             | 11%  | 8%   | 10%  | 1.0%                      |
| R             | 13%  | 8%   | 9%   | 2.0%                      |
| G1            | 0%   | 0%   | 0%   | 0.0%                      |
| G2            | 2%   | 5%   | 4%   | 1.0%                      |
| S1            | 1%   | 0%   | 1%   | 0.1%                      |
| S2            | 1%   | 1%   | 1%   | 0.4%                      |

If the current speed correction could be applied to speeds below 25 km/h then substantially more of the measurements made on high risk sites would be valid. Figure 3-2 shows the same values, measured in 2013, but assumes that the speed correction is valid between 10 and 85 km/h. Figures for site categories A, B and C have been removed as these are not affected by the lower limit of the speed correction.



**Figure 3-2 Theoretical lane 1 percentage**

This shows that if the lower limit of the speed correction could be extended to 10 km/h it would be possible to capture valid information for all but a small percentage of sites.

### 3.2 Speed correction

Test speed has a considerable effect on skid resistance and therefore most skid resistance standards are written with reference to measurements made at a specific speed. This component of the study was designed to assess changes in the performance of the devices at various test speeds.

SkReDeP, GripTester and the PFT were used to make measurements on the surfaces used for the accreditation of the UK SCRIM fleet at MIRAs proving ground. A description of the surfaces tested is given in Table 3-2. These represent surfaces typically found on the English strategic road network. Unfortunately it was not possible to make measurements on all surface types, for example concrete or surface dressings.

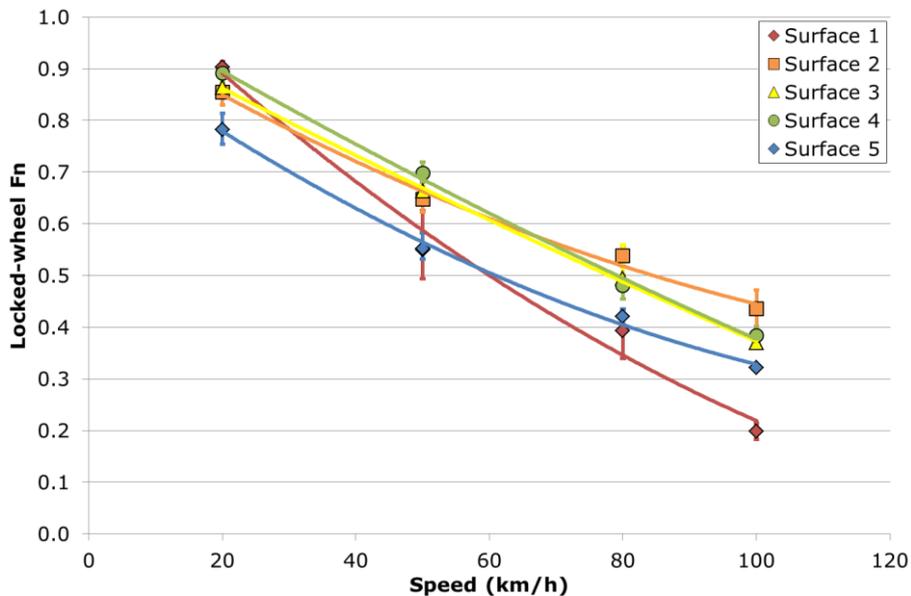
**Table 3-2 Description of surfaces tested**

| Surface   | Length (m) | Surface description   | Date Laid    |
|-----------|------------|---|--------------|
| Surface 1 | 130        | Normal track surface, thin surfacing.   | October 2013 |
| Surface 2 | 100        | A proprietary thin surfacing material using 6 mm coarse aggregate and polymer-modified bitumen.   | October 2010 |
| Surface 3 | 100        | A proprietary thin surfacing material using 10 mm coarse aggregate and a fibre-reinforced bitumen.  | October 2010 |
| Surface 4 | 100        | A proprietary thin surfacing material using 14 mm coarse aggregate.   | October 2010 |
| Surface 5 | 50         | A hot-rolled asphalt mat into which 20 mm chippings that have been lightly pre-coated with bitumen are rolled while the asphalt is still hot. | October 2010 |

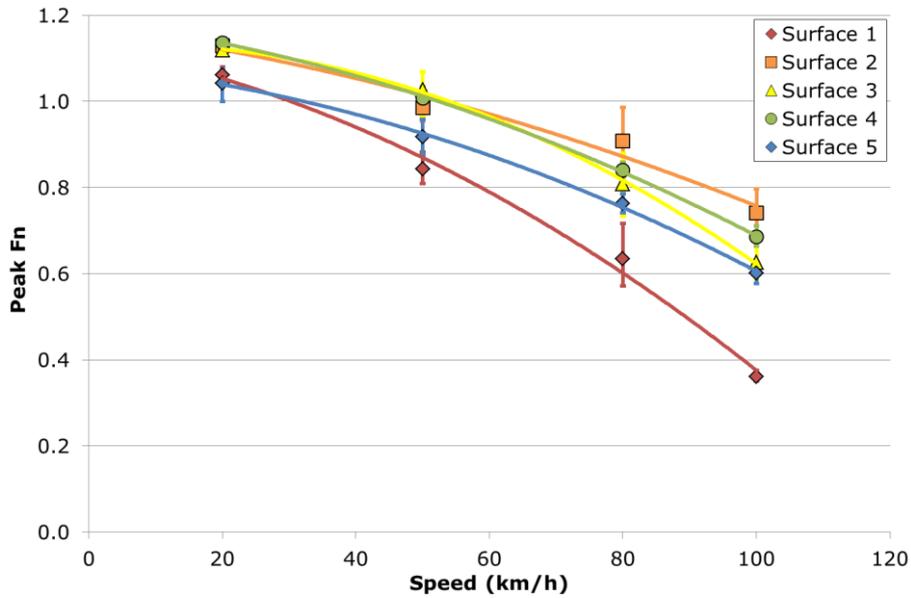
Measurements were made on each surface with SkReDeP and GripTester at the following test speeds: 10, 15, 20, 25, 30, 50, 70, 80 and 90 km/h; measurements were made with the PFT at 20, 50, 80 and 100 km/h. Making measurements at a number of test speeds allowed the generation of speed / skid resistance curves for each surface and device. These curves, based on a second order polynomial, were used to create speed correction equations. The equations were then in turn used to calculate the skid resistance (SR) value that would need to be measured at various speeds, to provide a measurement of 0.5 at 50 km/h once speed corrected, the SR(50) equivalent.

This approach was taken to normalise the results so that the variation in skid resistance with speed on different surfaces could be easily compared. In addition where existing speed corrections are available the results collected could be compared with them to assess the validity of measurements.

The speed / skid resistance curves derived from PFT measurements are shown in Figure 3-3 and Figure 3-4. These figures show that the form of the speed friction relationships differ to what is normally observed on in-service carriageways. Friction / speed curves for most surfaces typically obey a power, or second order polynomial relationship but the relationships shown here are more linear. This shows that the surfaces measured are displaying different characteristics than would be expected on an in-service carriageway. Caution should therefore be exercised when applying results gathered from these surfaces to in service carriageways.

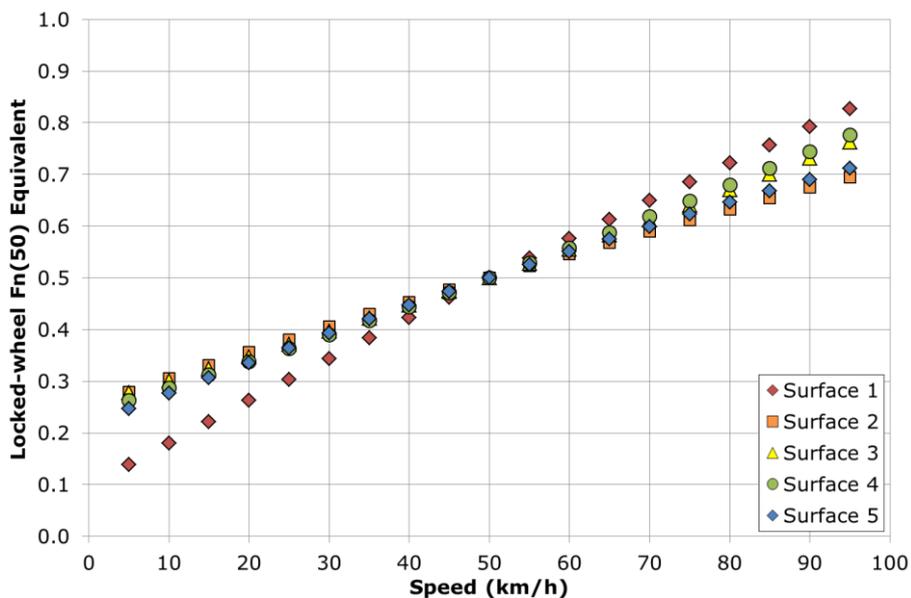


**Figure 3-3 Locked-wheel friction / Speed relationship**

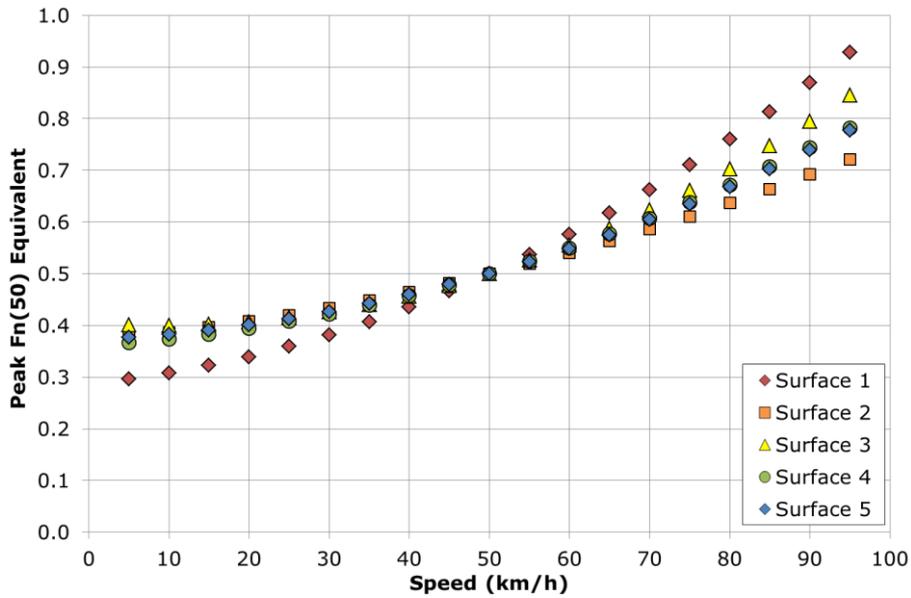


**Figure 3-4 Peak friction / speed relationship**

The locked-wheel and peak friction SR(50) equivalents presented in Figure 3-5 and Figure 3-6 show that Surface 1 is demonstrating a greater change in equivalent SR(50) value with speed than any other surface. It is worth noting that Surface 1 was laid in 2013, three years after the other surfaces, and so may be affected by weathering differently to the other surfacings. Below 50 km/h the equivalent SR(50) values for Surfaces 2 to 5 are in general agreement, however above this speed the values begin to diverge, showing that changes in SR with speed could be, in part, related to the surface type.

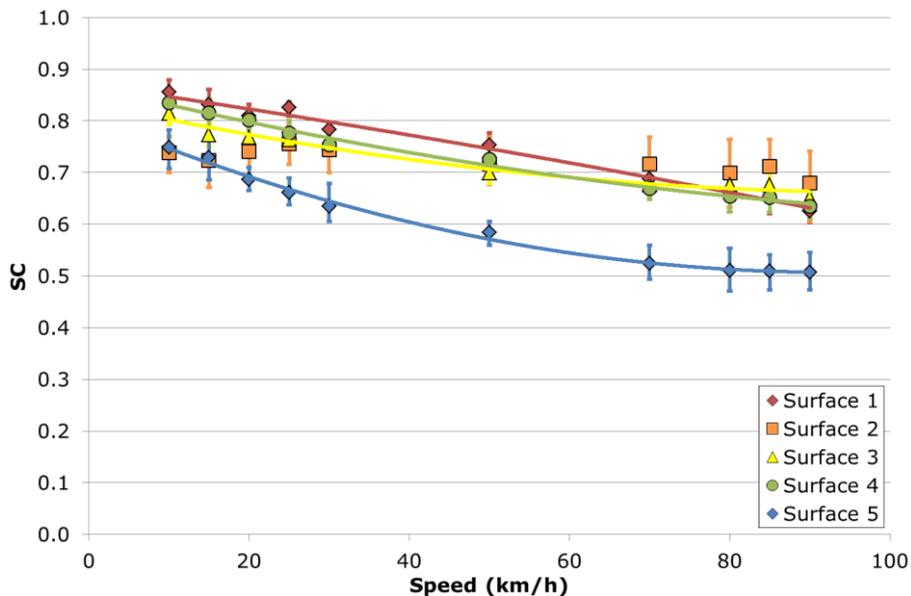


**Figure 3-5 PFT Locked-wheel SR(50) Equivalents**



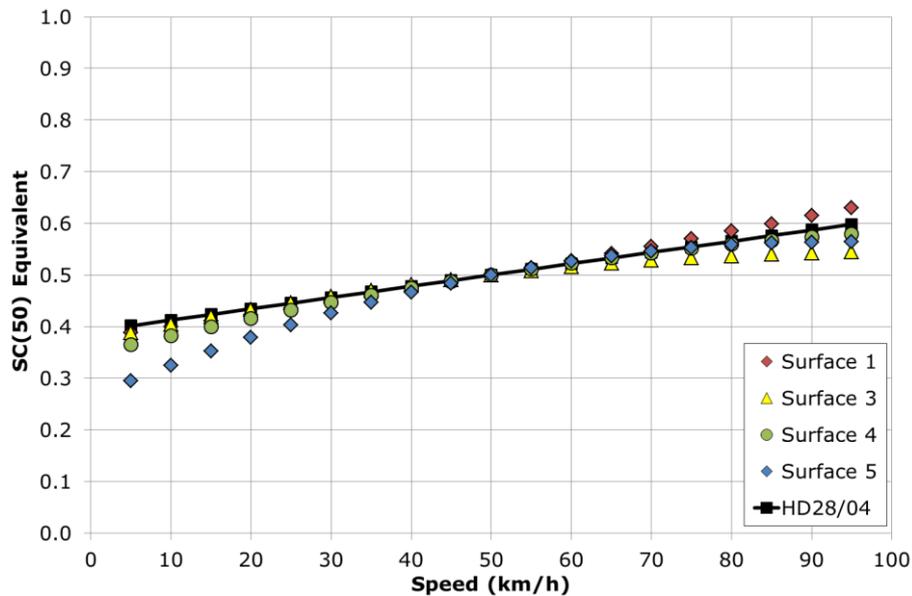
**Figure 3-6 PFT Peak friction SR(50) Equivalents**

Figure 3-7 shows the speed / skid resistance relationships measured using SkReDeP. For the majority of surfaces tested the results show a reduction in skid resistance with speed. However on Surface 2 this is not the case, and there is relatively little change in skid resistance with speed. This is unusual and further examination of the data revealed that there was a considerable reduction in skid resistance along the length of the section. For this reason the results from Section 2 were excluded from the remainder of the analysis of SkReDeP results.



**Figure 3-7 Scrim Coefficient / Speed relationship**

Figure 3-8 shows the SR(50) equivalents derived from the SkReDeP measurements. Included in this figure are SR(50) equivalents derived from the speed correction formula given in HD28/04 (Department for Transport, 2004).



**Figure 3-8 SkReDeP SR(50) Equivalents**

Figure 3-7 and Figure 3-8 show that for all but Surface 5 there is a broad agreement in the performance of each surface with changing speed. Surface 5 is a positively textured hot rolled asphalt (HRA) material, laid with aggregate chippings that have a light bitumen coating. The other surfaces are negatively textured thin surface course systems (TSCS) which are laid with a relatively thick bitumen layer on the aggregate. It is possible therefore that the bitumen layer on the HRA has begun to be removed by the limited trafficking on MIRA's test track, whereas the TSCS still have some bitumen remaining on the aggregate.

Figure 3-8 shows that the SR(50) equivalents derived from the negatively textured materials are generally in agreement with those derived from the speed correction listed in HD28/04. Crucially all of the SR(50) equivalents derived from the test surfaces, below 50 km/h are lower than those calculated from the HD28/04 speed correction. This demonstrates that, on the surfaces measured, the HD28/04 speed correction would underestimate the skid resistance at 50 km/h, essentially failing safe. This suggests that measurements made below those for which the current speed correction is valid (25 km/h) can be corrected to 50 km/h without overestimating the actual skid resistance at 50 km/h.

The speed / skid resistance relationships from GripTester measurements are shown in Figure 3-9. This clearly shows a different performance in the measurements made on Surface 1 than the other surfaces tested. Interestingly, the same flat performance on Surface 2 that was seen in the SkReDeP results is not observed here which could be due to differences in driving line.

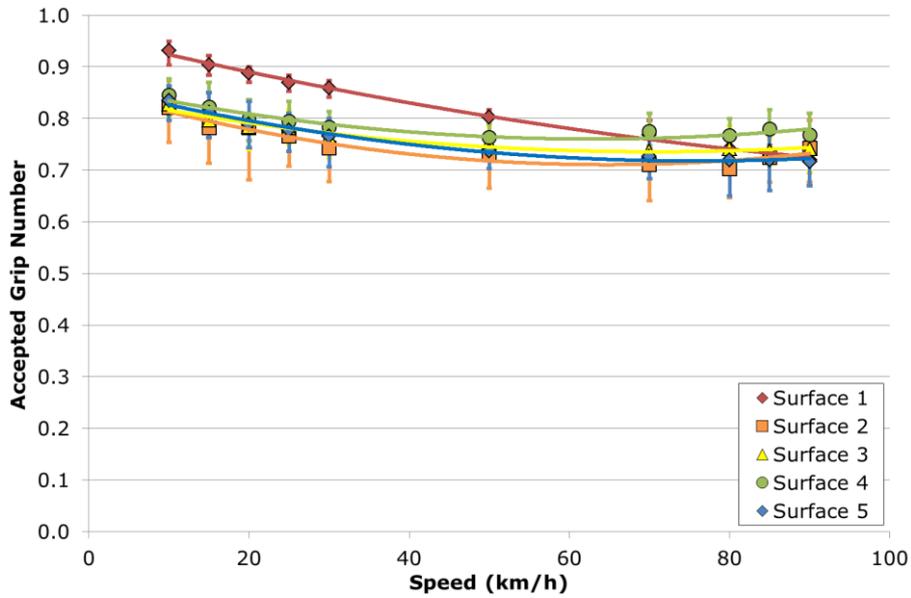


Figure 3-9 GripNumber / Speed relationship

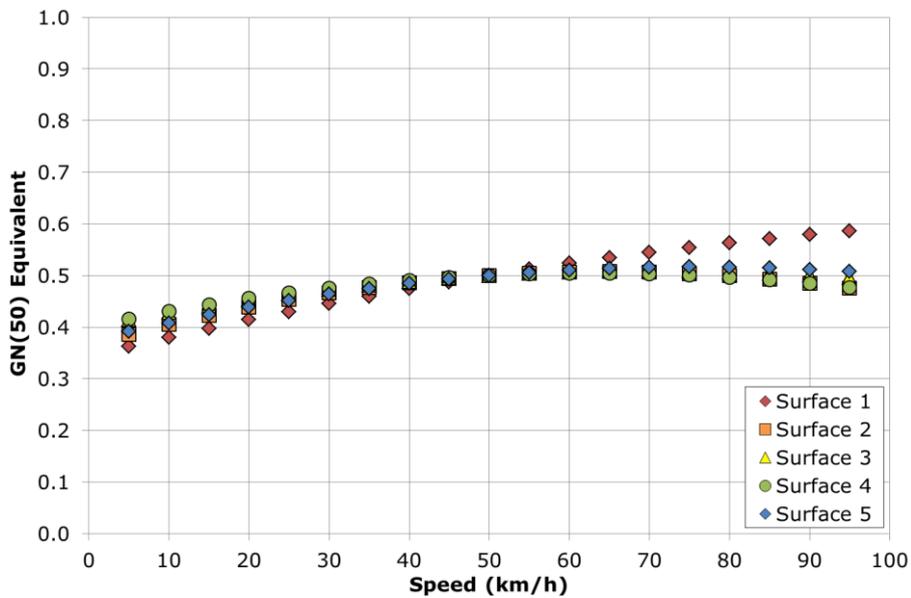


Figure 3-10 GripTester SR(50) Equivalents

Figure 3-10 shows that the variation in performance of Surface 1, compared to the other surfaces, is only markedly different at speeds over 50 km/h. Below this speed the relative performance of all the surfaces is similar. As with the PFT results this could be related to the age of Surface 1 and the lack of trafficking altering its performance.

### 3.3 Braking

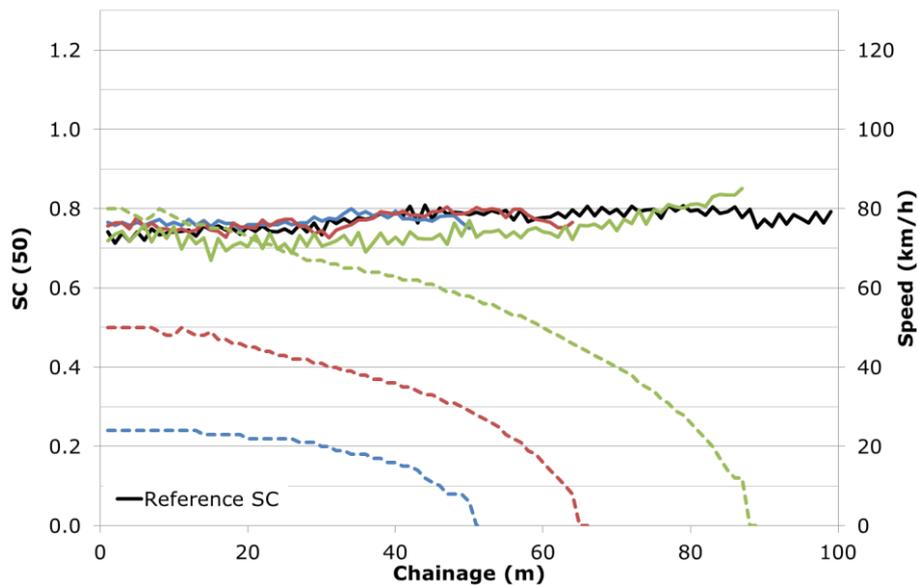
This component of the study was designed to assess the effects of deceleration on skid resistance devices. Measurements were made with SkReDeP and GripTester on a section of Surface 1 under braking conditions. The braking section was approached at 25, 50 and 80 km/h and the survey vehicles brought to a stop as fast as was deemed safe by

the driver. The measurements made under these conditions were then compared to measurements made under normal survey conditions.

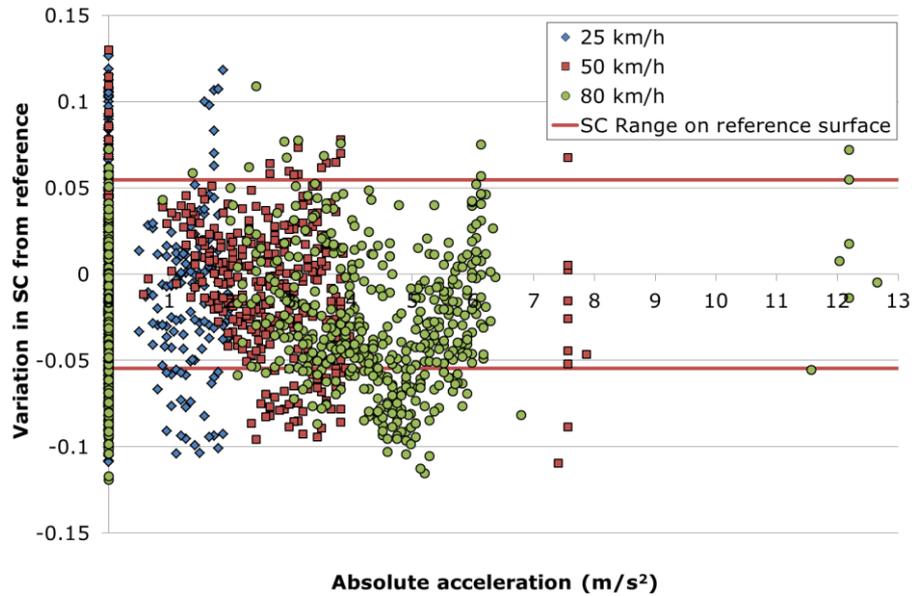
The measurements made were analysed in two stages and are presented as a pair of figures for each device. The first set of figures (Figure 3-11 and Figure 3-13) show an example of typical skid resistance and speed values measured on the braking section. The solid coloured lines in these figures represent the skid resistance value, speed corrected to 50 km/h using the speed correction formulae derived for surface 1. The broken coloured lines represent the speed recorded throughout the braking period. The solid black line shows the skid resistance measured at 50 km/h along the length of the section; the reference skid resistance.

The second set of figures (Figure 3-12 and Figure 3-14) shows how deceleration causes the skid resistance value to differ from the reference. The variation in skid resistance from the reference (reference SR – speed corrected SR) is shown against the absolute acceleration being experienced at each nominal approach speed. The red horizontal lines represent the range of skid resistance values measured on the reference surface at a constant speed of 50 km/h.

Figure 3-11 is an example of the skid resistance values measured under braking with SkReDeP. This shows that when braking from 25 and 50 km/h there is a good agreement in values with the reference. A deviation is shown when braking from 80 km/h, but this is slight.



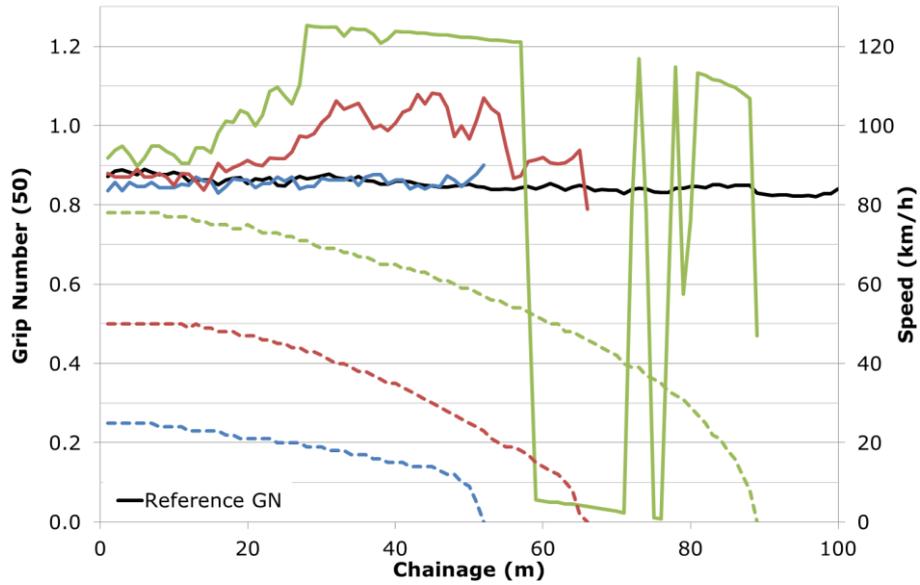
**Figure 3-11 Example of SkReDeP skid resistance values under braking**



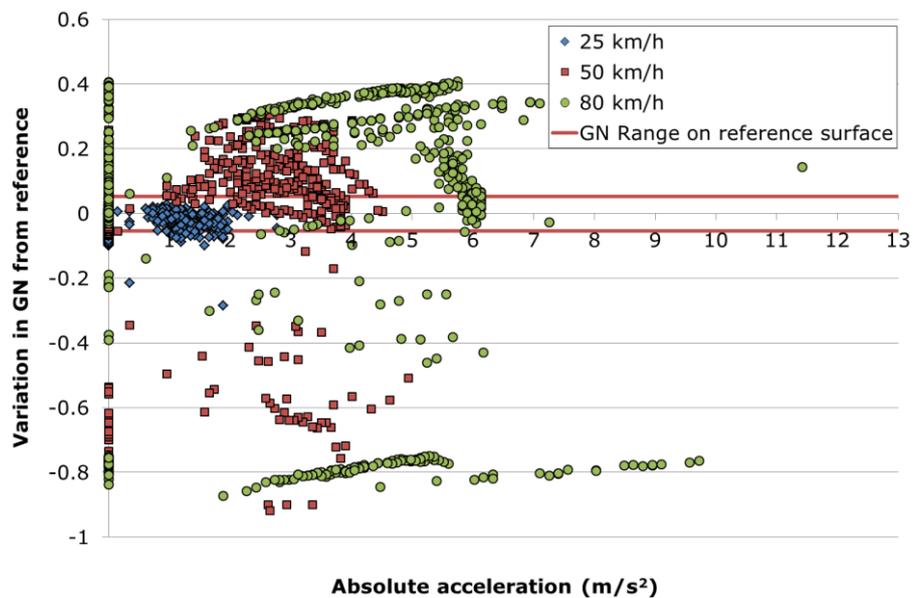
**Figure 3-12 SkReDeP Variation from reference**

Figure 3-12 shows that the variation in skid resistance measured using SkReDeP under braking is greater than that measured at a constant speed. The range of values measured under braking have a greater range than that of the variation on the reference. However with increasing acceleration there is little correlation with an increase in variation.

The results from GripTester are noticeably different to those from SkReDeP. Figure 3-13 shows that braking from 25 km/h produces a negligible deviation in values from the reference, but braking from 50 and 80 km/h has a marked effect. Observations of the GripTester show that under the influence of the inertial force caused by braking, the trailer pivots on its front wheels which lifts the rear test wheel. Under heavy braking the test wheel can lose contact with the surface entirely which causes the wheel to bounce. The Grip Numbers collected when braking from 80 km/h show that after approximately 50 m the values vary considerably as the force on the load cell exceeds the measurement range of the equipment.



**Figure 3-13 Example of GripTester skid resistance values under braking**



**Figure 3-14 GripTester Variation from reference**

Figure 3-14 shows that the majority of measurements made when braking from 25 km/h are within the variation expected when testing at a constant speed. Measurements made above a deceleration of approximately 2 m/s<sup>2</sup> rapidly move outside of this range and measurements made at 80 km/h show that the range of the measurement capability of GripTester is being exceeded.

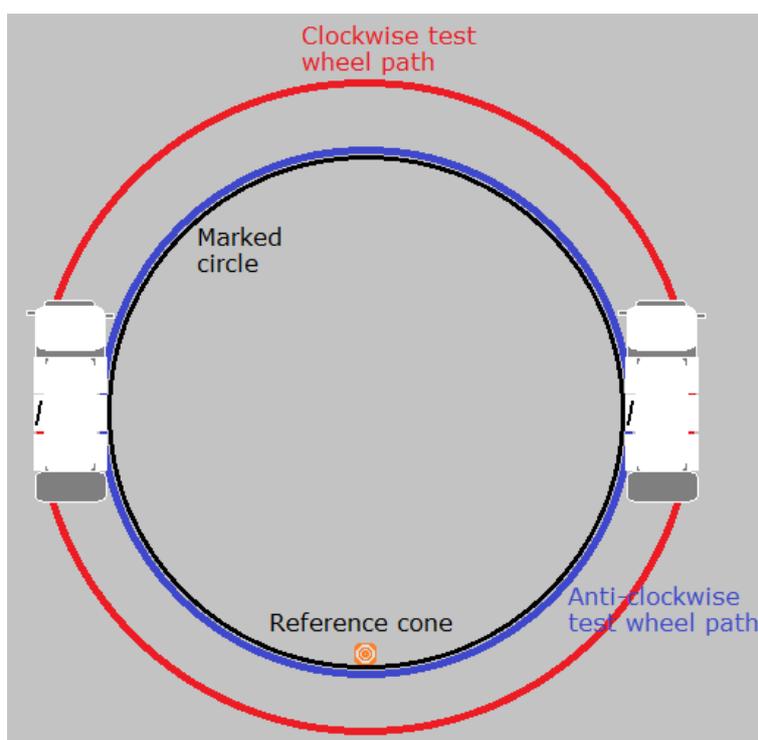
### 3.4 Roundabouts

SCRIM and GripTester typically make measurements in the NSW. The use of a test wheel mounted to the side of a vehicle could allow some weight transfer to occur when

testing on roundabouts and bends. The testing described in this section was designed to assess the effect of testing a constant radius on skid resistance measurements.

To simulate the conditions of testing on roundabouts SkReDeP and GripTester were used to make measurements in both directions of a circular path with radius 32.9 m on MIRA's steering pad. The measurements were undertaken at speeds between 10 and 35 km/h (35 km/h was the maximum test speed judged safe by the equipment driver) in 5 km/h increments. Typical roundabout radii on the SRN range between 20 and 110 m, a test area with a radius of 32.9 m was the largest area available within the budget constraints of this project.

During testing the vehicle was kept as close to the marked circle as possible as shown in Figure 3-15. The test path therefore differs between the clockwise (CW) and anti-clockwise (ACW) directions. To account for this, the skid resistance values calculated using an assumed vertical load and the vertical load measured by the device, were compared for each measurement. If lateral load transfer was affecting the skid resistance values it would be expected to see a difference in values calculated from assumed and measured vertical load between the two directions.



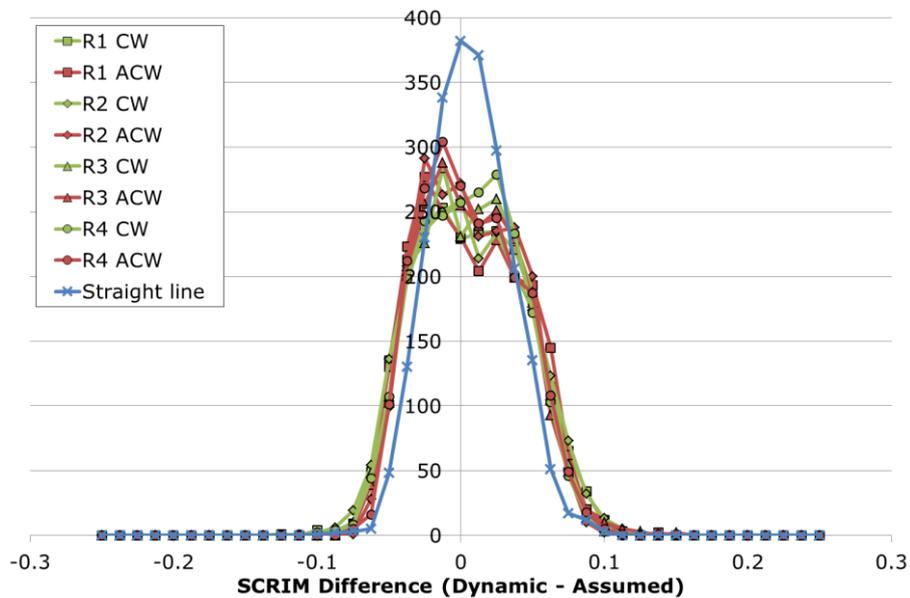
**Figure 3-15 Example of roundabouts testing with SkReDeP**

The data collected were analysed to produce histograms of the difference in skid resistance calculated using measured vertical load and an assumed constant vertical load. Differences in the histograms between the CW and ACW directions would demonstrate the effects of load transfer on the skid resistance values. Included with the histograms is the distribution of measurements made in a straight line, so that the performance of the machines testing in both scenarios can be compared.

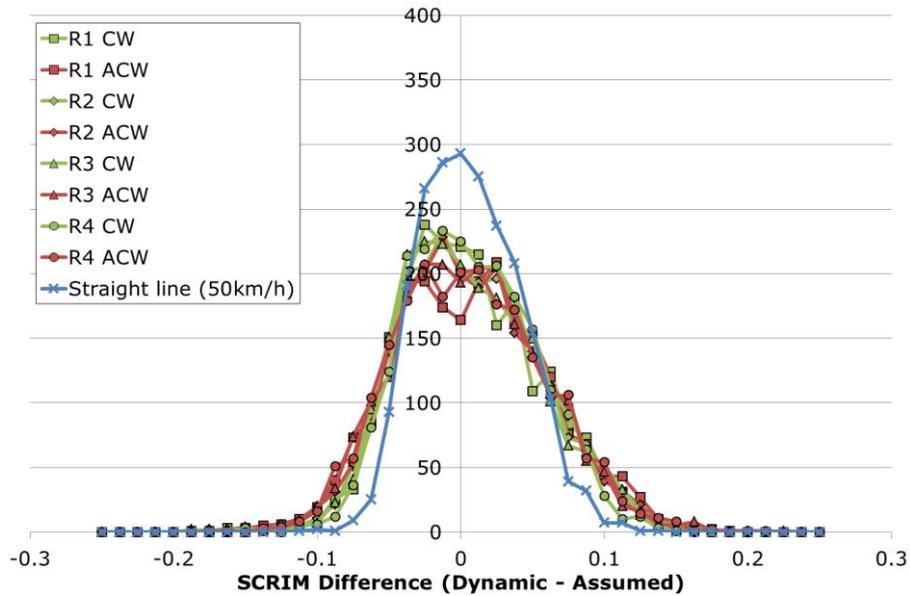
Histograms for measurements made at 10 km/h and 35 km/h are given to highlight differences in performance due to speed. Histograms for measurements made at intermediate speeds can be found in the appendices.

Figure 3-16 and Figure 3-17 show the distribution of values measured with SkReDeP at 10 and 35 km/h respectively. Both figures show that measurements made in both directions are providing similar distributions. This shows that the effect of load transfer on the results has the same effect regardless of the direction of travel.

The form of the straight line distribution at both speeds is narrower and taller than the distributions measured in a circular path. The straight line distribution at 10 km/h is taller and narrower than that measured at 35 km/h. This shows that measurements made in a circular path are more variable than those made in a straight line as are those made at a higher speed, but the average measurements made in all cases are likely to be similar.



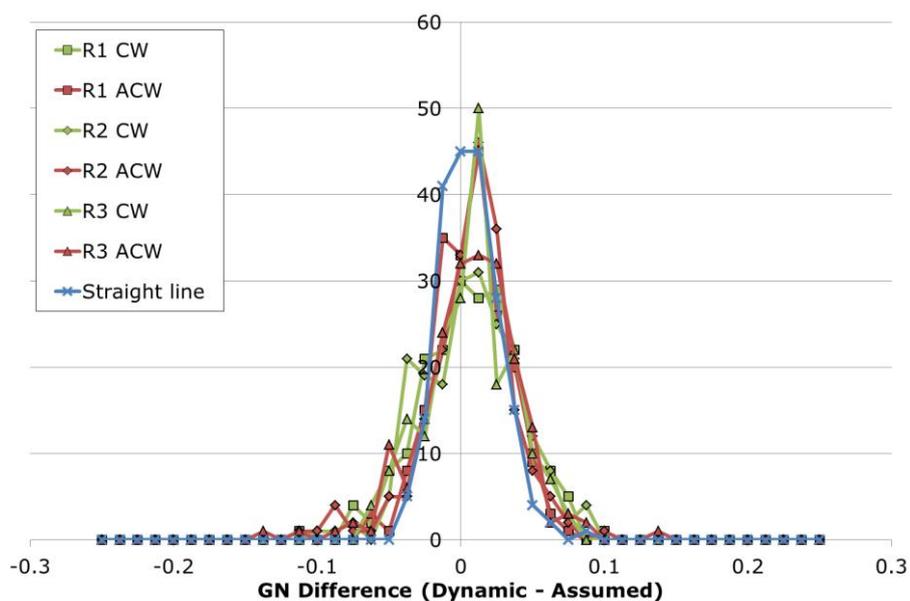
**Figure 3-16 SCRIM Difference at 10 km/h**



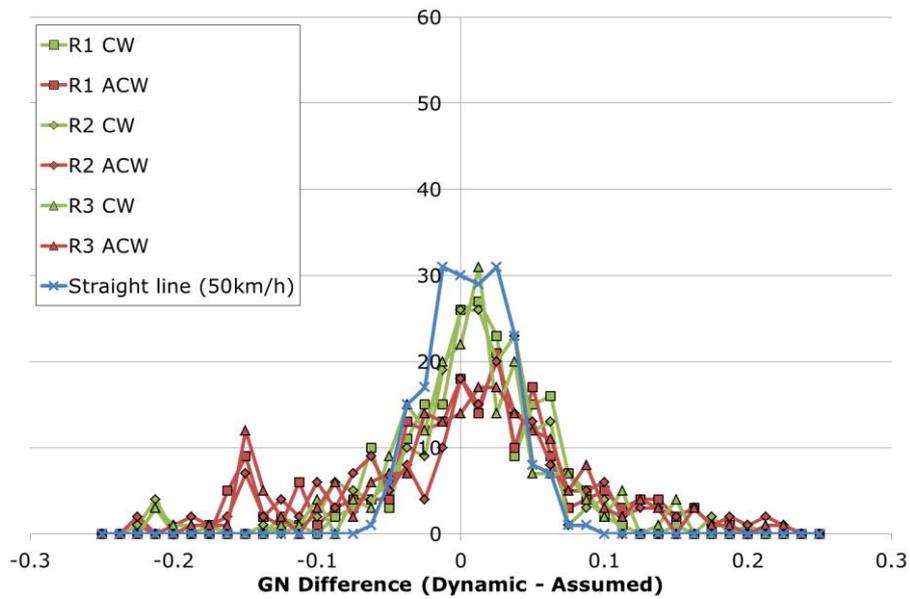
**Figure 3-17 SCRIM Difference at 35 km/h**

Figure 3-18 and Figure 3-19 show the distribution of values measured with GripTester. Notably these distributions appear to have more noise than the SkReDeP distributions; this is because they are based on fewer points given the averaging lengths used for each machine.

Broadly, the same behaviours are shown in the GripTester results as in the SkReDeP results. There is however an additional phenomenon shown in the results gathered at 35 km/h by the presence of a peak in the ACW results at approximately -0.15 GN Difference. It is possible that this behaviour could be related to an increase in vertical load experienced by some dynamic effects of traveling in an ACW direction with the machine attached on the nearside of the vehicle.



**Figure 3-18 Grip Number difference at 10 km/h**

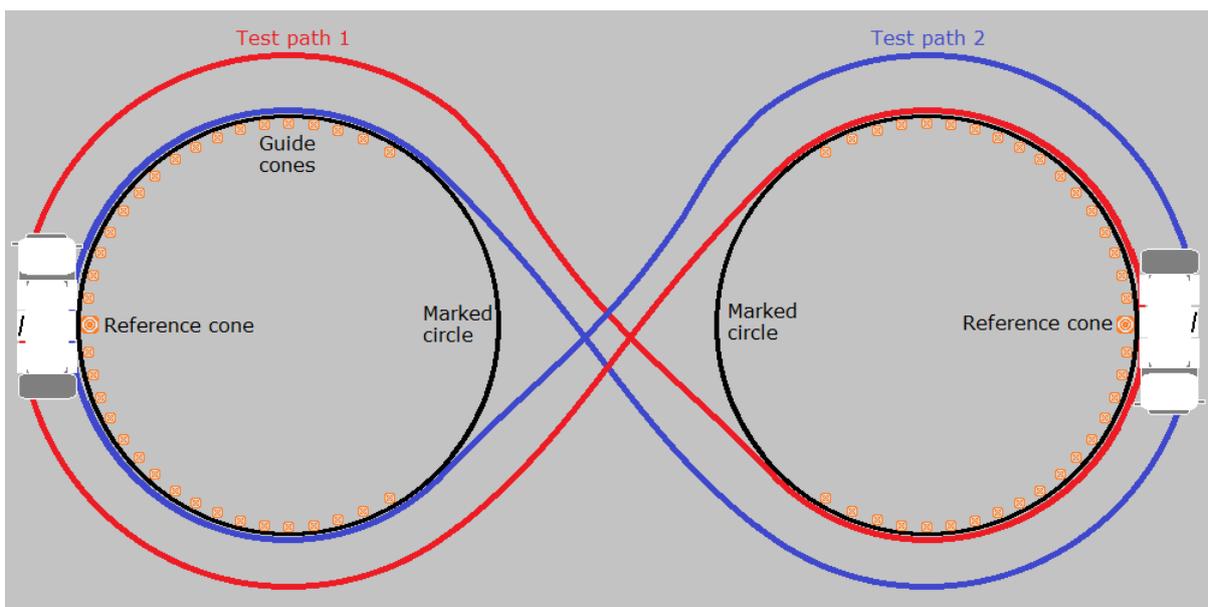


**Figure 3-19 Grip Number difference at 35 km/h**

### 3.5 Cornering

Where the testing described in the previous section was carried out to assess the effect of travelling in a circular path, the cornering testing was carried out to investigate the dynamic effects of testing between CW and ACW corners.

The worst case scenario of a vehicle transitioning from a CW to ACW curve was re-created by using a figure of eight test path, as shown in Figure 3-20. MIRA’s manoeuvres area provides two marked circles of 12.2 and 13.2 m radii with a distance between the centres of 36.4 m. Measurements were made in each direction of the figure of eight between 10 and 25 km/h in 5 km/h increments.



**Figure 3-20 Example of cornering testing**

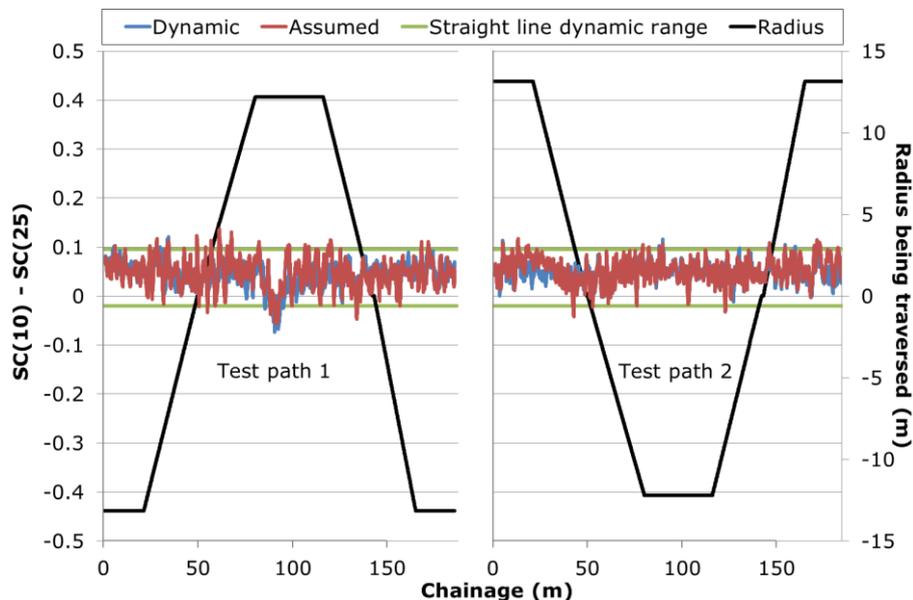
As with the roundabouts testing, the wheelpath tested in each direction is different and so a direct comparison between measurements taken in each direction is unadvisable. In addition, because the radius being traversed is not consistent, an analysis equivalent to that carried out for the roundabouts testing is not suitable.

A number of issues arose whilst carrying out the testing, for instance maintaining a constant speed around the whole test path was challenging, especially at one apex where a crash barrier narrowed the test path considerably. Testing at a wide range of speeds was also challenging owing to the geometry of the test path. Because of these issues only broad conclusions can be drawn from this testing and these should be treated with caution.

The results from the figure of eight testing were analysed by comparing the difference in values generated from testing at 10 and 25 km/h along the length of the test path. If load transfer was affecting the results it would be expected to see changes in this difference at the crossover point and apexes of the circles.

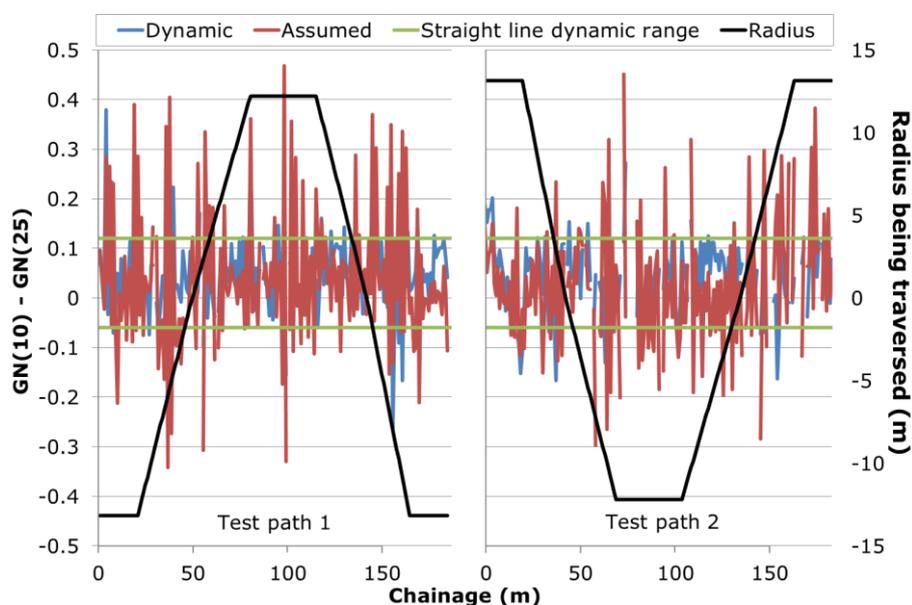
The following figures show the difference in skid resistance values measured at 10 and 25 km/h from a single test run, included in the figures are the radius being traversed and values measured in a straight line for reference.

Figure 3-21 shows that the measurements made with SkReDeP in the figure of eight path are relatively consistent and that load transfer does not appear to be a significant issue. An anomaly is shown in test path 1 at 95 m, but this is not shown in test path 2 and is probably due to subtle differences in driving line between the 10 and 25 km/h measurements. There is no obvious change in the overall skid resistance value over the figure of eight path.



**Figure 3-21 SkReDeP Variation**

Results gathered using GripTester (Figure 3-22) shows a very noisy profile, with values based on an assumed vertical load being particularly noisy. Despite this there is no obvious trend for the values to change as a result of the figure of eight path.



**Figure 3-22 GripNumber Variation**

### 3.6 Conclusions

The key conclusions that can be made from the work presented in this chapter are:

- That a considerable amount of skid resistance measurements made on high risk sites are conducted below the current accepted limits for speed correction.
- If the limits of the speed correction could be extended so that they are valid between 10 and 85 km/h then measurements made on all but a small percentage of sites could be speed corrected.
- The speed correction results from SkReDeP suggest that lowering the limit of the current speed correction below 25 km/h could fail safe. However given the unusual behaviour of the track surfaces a firm conclusion cannot be made and additional testing on in-service roads is recommended.
- The results gathered from the braking tests have shown that SCRIM values can be successfully speed corrected under braking conditions, but the measurements can be expected to be more variable than travelling at a constant speed.
- The results from GripTester under braking conditions highlighted a mechanical property of the machine that causes the test wheel to rise, affecting the skid resistance measurements
- Measurements made with SCRIM and GripTester made in a circular path can be expected to be more variable than measurements made in a straight line.
- More variable results can be expected when travelling in a figure eight path than measured in a straight line.

- On balance the testing has shown that, for the strategic road network, more accurate or consistent results would not be obtained when testing high risk sites with alternative devices to SCRIM.
- It is therefore recommended that changes should not be made to the current skid resistance survey strategy, but it would be appropriate to amend the lower limit for survey speed (given in section A3.4 of HD28 (Department for Transport, 2004)) from 25 km/h to 10 km/h, whilst continuing to use the current speed correction.
- If the current speed correction range is maintained then it should be expected for some high risk sites to return no valid skid resistance data during any given survey season. The results from this study have shown that extending the lower end of the speed correction range would fail safe, that is, it would be expected for some surface types to show slightly lower speed corrected values than would be measured at the reference speed of 50km/h. With this in mind, a lower limit could be applied, without the need for further on-road trials, without increasing the risk to motorists.

## 4 Current status of the UK SCRIM fleet

British Standard 7941-1:2006 (British Standards Institution, 2006) (hereto referred to as "the BS") defines the requirements for SCRIM test equipment and operation. Furthermore in the light of the development of European harmonisation of standards (hereto referred to as "the CEN standard") for skid measurement devices, the HA is reviewing the current status of the UK SCRIM fleet. This chapter summarises information gathered from the SCRIM manufacturer (W.D.M Limited) about the current status of the development of SCRIM and compares this to the BS. Some comment is also made as to the possible considerations that could be made in developing the CEN standard.

### 4.1 SCRIM features compared to the British Standard

The BS was first written in 1999 and since then a number of developments have been made to SCRIM with a view to improving the quality and efficiency of measurement. All machines in the UK fleet conform to the BS but a number of significant developments have been made, these are summarised below.

#### 4.1.1 *Dynamic vertical load measurement*

The BS states that the mass of the test wheel assembly shall provide a static vertical load of  $(200 \pm 8 \text{ kg})$ . Furthermore the BS states that the mass acting on the test wheel should be measured using a load cell. The measurement of dynamic vertical load was introduced in the UK in 2004. Machines use one of two types of systems; referred to as the "old system" and the "new system". The old system utilises a sacrificial shear pin which is sensitive to wear, causing it to affect the load measurement. The new system does not use a shear pin and has been found to be more robust and reliable.

Unpublished works carried out into the performance of dynamic vertical load measurement concluded that there are a number of advantages in using dynamic vertical load measurements, namely:

- Less variation between machines, since all would be measuring SFC using the actual applied load at any time
- More precise measurements from individual machines, especially at higher operating speeds
- Better detection of changes in skid resistance previously masked by changes in vertical load

To this end it would be beneficial for the CEN standard to include the requirement for the measurement of vertical load.

#### 4.1.2 *Temperature measurement*

There is no requirement for the measurement of temperature in the BS. However should such a requirement be introduced in the CEN standard, the fitting of temperature sensors is expected to be straightforward because SCRIM has been designed to allow the addition of this feature if required. If more than two temperatures are required then this may be problematic, especially for machines utilising older style data logging electronics.

The CEN standard may need to address ways to deal with extreme temperatures in some of the countries/regions (for example, limiting surveys to a particular temperature range).

#### **4.1.3 Water application**

The BS stipulates the following for water supply and flow control:

- Water is to be controlled by a manual flow valve that can be adjusted to allow different flow rates depending on test speed
- The water control system should activate water flow before the test wheel contacts the ground and should not deactivate until the wheel has left the ground
- The water shall contact the surface  $400 \pm 50$  mm in front of the centre line of the test wheel along the direction of the line of travel.
- The water shall be free from contaminants
- The theoretical water film thickness shall be 0.5 mm at 50 km/h

SCRIM can be fitted with a dynamic control system that adjusts the water flow automatically to ensure that the correct flow rate is achieved at a range of test speeds. The essential elements of a dynamically controlled water flow system are; a flow meter, proportional control valve, and an electronic control system. Either a header water tank or an electric pump is used to ensure that the correct water flow is achievable at high speeds.

Dynamically controlled water flow is appealing from an environmental and resource conservation point of view, but there is as yet no evidence to suggest that measurements are markedly improved as a result.

#### **4.1.4 Test wheel and tyre**

The BS specifies the size and resilience of the test tyre; standard test tyres for SCRIM are manufactured by Avon tyres and distributed through the equipment manufacturer who also carries out quality assurance checks. Current standards do not stipulate whether the slip angle of the test tyre ( $20^\circ$ ) should be in toe-in or toe-out. SCRIM uses the toe-in position; anecdotally, this seems to have been chosen in the early development of the machine to ensure stability of the vehicle when cornering.

In the UK, skid resistance measurements are normally made in the left wheel track of the most heavily trafficked lane, which is usually the leftmost lane. Due to the UK fleet having the test tyre on the nearside of the vehicle (left), they will be unable to test the nearside wheel track on some European roads, and vice-versa for European machines.

Work carried out in 2014 (reported in (Brittain, 2014)) assessed the performance of SCRIM tyres with the equivalent tyres used in Germany (SKM tyres). This work showed a good correlation between the two tyres but the SKM tyres produced skid resistance values approximately 4-8% greater than SCRIM tyres. The specification and supply of test tyres and wheels in the CEN standard will require careful consideration taking into account, the effects on measurement, supply chain and consistency between operators.

#### **4.1.5 Location referencing**

Historically location referencing of results has been managed using manually inputted markers at specific locations that can identify points in the results, this is the method of location referencing required in the BS. As technology has developed it has been possible to collect GPS information during surveys and use this information as a location reference. The advantages of GPS over marker input are that (assuming Differential GPS is used) the accuracy of location referencing is improved and data can be automatically matched to a client's road network, assuming that it is pre-defined based on a similar referencing system such as the Ordnance Survey Grid Reference (OSGR).

#### **4.1.6 Data reporting**

Below is an excerpt from the BS:

*"An electronic recorder shall be provided, capable of measuring the horizontal load, vertical load and distance travelled. The electronic recorder shall display the speed, SR, and length for the subsection and the distance travelled from a predetermined reference point."* (British Standards Institution, 2006)

Typically skid resistance results are reported in 10 m averaging lengths after having been corrected for speed and temperature. None of the UK machines automatically correct for speed or temperature, this is carried out as a post process if required (as detailed in HD28 (Department for Transport, 2004)). However in some cases, if detailed investigations are required, the raw vertical and horizontal load measurements are valuable.

The UK fleet operates using one of two electronics systems, known as the National Instruments (NI) and the 4000 systems. Machines using the NI system are able to output data at intervals of approximately 100 mm and separate the measurements of horizontal and vertical loads. The 4000 systems also make measurements at similar intervals but these are not stored or available for output, the measurements are averaged in real time and output at larger intervals, normally 10 m.

Data processing specifications should be addressed outside of the CEN standard, but it would be beneficial for machines to be able to provide raw data for clients for their own interpretation.

#### **4.1.7 Calibration**

The calibration procedure for the horizontal load cell given in the BS is based on the rolling trolley principle; a load is applied to the tyre sidewall which acts in the same direction as the horizontal load cell, but in a different plane.

As with the specification of tyres, the specification of calibration procedures in the CEN standard will require some careful consideration. Alternative procedures such as removal of the load cell for calibration in a laboratory could result in different results compared to the rolling trolley method. This is because the rolling trolley method acts on the tyre and wheel (to replicate the loads applied during testing) whereas in a laboratory the load is applied directly to the load cell. When using the rolling trolley method, subtle differences in tyre or wheel properties, or the surface that the calibration is being carried out on can affect the calibration result.

The calibration method currently used for the vertical load system is different to that described in the current BS. The BS states during calibration the loads should be applied in increasing steps of 20 kg from 0 kg to 200 kg, while the current procedure is to remove load in 20 kg steps from 200 kg to 0 kg.

## 4.2 The fleet of UK accredited SCRIM machines

The Pavement Condition Information Systems website (PCIS, 2015) holds information on the machines currently accredited to operate on the SRN. Discussions with the equipment manufacturer enabled the production of a high level summary of features available on all machines in operation in the UK (Table 4-1).

**Table 4-1 Summary of features in UK SCRIM fleet**

| Operator                    | Reg plate  | Current accreditation | Test wheels | System electronics | Ability to supply raw data | Vertical load system <sup>3</sup> | Dynamic water flow control | Temp. sensors          | Retro-reflective marker input | Water level indication | Forward facing imaging |
|-----------------------------|------------|-----------------------|-------------|--------------------|----------------------------|-----------------------------------|----------------------------|------------------------|-------------------------------|------------------------|------------------------|
| DoE NI                      | IKZ 2203   | Yes                   | LHS         | 4000               | No                         | Old                               | No                         | Air & surface          | LHS                           | Discrete               | No                     |
| Highways Surveyors          | AU53 BZM   | Yes                   | LHS         | 4000               | No                         | Old                               | No                         | Air & surface          | LHS                           | Discrete               | No                     |
| PMS Eire                    | 01-KK-1138 | Yes                   | LHS & RHS   | 4000               | No                         | Old                               | No                         | None                   | LHS                           | Discrete               | No                     |
|                             | 04-G1-3042 | Yes                   | LHS         | 4000               | No                         | Old                               | No                         | Air & surface isolated | LHS                           | Discrete               | No                     |
| Suffolk Pavement Evaluation | W965 SVG   | Yes                   | LHS         | 4000               | No                         | Old                               | No                         | Air & surface          | LHS                           | Discrete               | No                     |
|                             | YD02 XSN   | Yes                   | LHS         | 4000               | No                         | Old                               | No                         | None                   | LHS                           | Discrete               | No                     |
| Surrey CC                   | KX07 YXH   | Yes                   | LHS         | 4000               | No                         | Old                               | No                         | Air & surface          | LHS                           | None                   | No                     |
| TRL                         | WX60 AXN   | Yes                   | LHS         | NI                 | Yes                        | New                               | Yes                        | None                   | LHS                           | Continuous             | No                     |
| WDM                         | S10 WDM    | Yes                   | LHS & RHS   | NI                 | Yes                        | New                               | Yes                        | Air & surface with     | LHS & RHS                     | Continuous             | Yes                    |

<sup>3</sup> Old = shear pin, New = No shear pin

| Operator | Reg plate | Current accreditation | Test wheels | System electronics | Ability to supply raw data | Vertical load system <sup>3</sup> | Dynamic water flow control | Temp. sensors | Retro-reflective marker input | Water level indication | Forward facing imaging |
|----------|-----------|-----------------------|-------------|--------------------|----------------------------|-----------------------------------|----------------------------|---------------|-------------------------------|------------------------|------------------------|
|          |           |                       |             |                    |                            |                                   |                            | display       |                               |                        |                        |
|          | S11 WDM   | Yes                   | LHS & RHS   | NI                 | Yes                        | New                               | Yes                        | None          | LHS & RHS                     | Continuous             | Yes                    |
|          | S12 WDM   | Yes                   | LHS         | NI                 | Yes                        | New                               | Yes                        | None          | LHS                           | Continuous             | Yes                    |
|          | S13 WDM   | Yes                   | LHS         | NI                 | Yes                        | New                               | Yes                        | None          | LHS                           | Continuous             | Yes                    |
|          | S14 WDM   | Yes                   | LHS         | NI                 | Yes                        | New                               | Yes                        | None          | LHS                           | Continuous             | Yes                    |
|          | S15 WDM   | Yes                   | LHS & RHS   | NI                 | Yes                        | New                               | Yes                        | Air & surface | LHS & RHS                     | Continuous             | Yes                    |
|          | S16 WDM   | Yes                   | LHS & RHS   | NI                 | Yes                        | New                               | Yes                        | Option        | LHS & RHS                     | Continuous             | Yes                    |
|          | S7 WDM    | Yes                   | LHS         | 4000               | Yes                        | New                               | Yes                        | Air           | LHS                           | Continuous             | No                     |
|          | S800 WDM  | Yes                   | LHS         | NI                 | Yes                        | New                               | Yes                        | Software only | LHS                           | Continuous             | No                     |
|          | S900 WDM  | Yes                   | LHS         | NI                 | Yes                        | New                               | Yes                        | None          | LHS                           | Continuous             | Yes                    |
| Yotta    | KX07 YVH  | Yes                   | LHS         | 4000               | No                         | Old                               | No                         | Air & surface | LHS                           | Discrete               | No                     |

### 4.3 SCRIM machines used in other European countries

According to the equipment manufacturer, the following is a summary of the number of SCRIM machines that operate in other European countries.

- Italy – 7
- Spain – 8
- France – 4
- Belgium – 3
- Portugal – 1
- Slovenia – 1

Please note that these numbers indicate those that have been sold to that country, however, they may or may not be in the particular country at the moment. For example, anecdotal information suggests that one SCRIM that was in France is now operating in Spain.

The equipment manufacturer also informs that some of these machines were produced and supplied many years ago, and that some may not be operational at the moment.

The above numbers suggest that SCRIM machines are reasonably widely used in Europe; as such, several countries may wish to see the existing features of SCRIM incorporated into any future European standard for measuring the skid resistance of pavements.

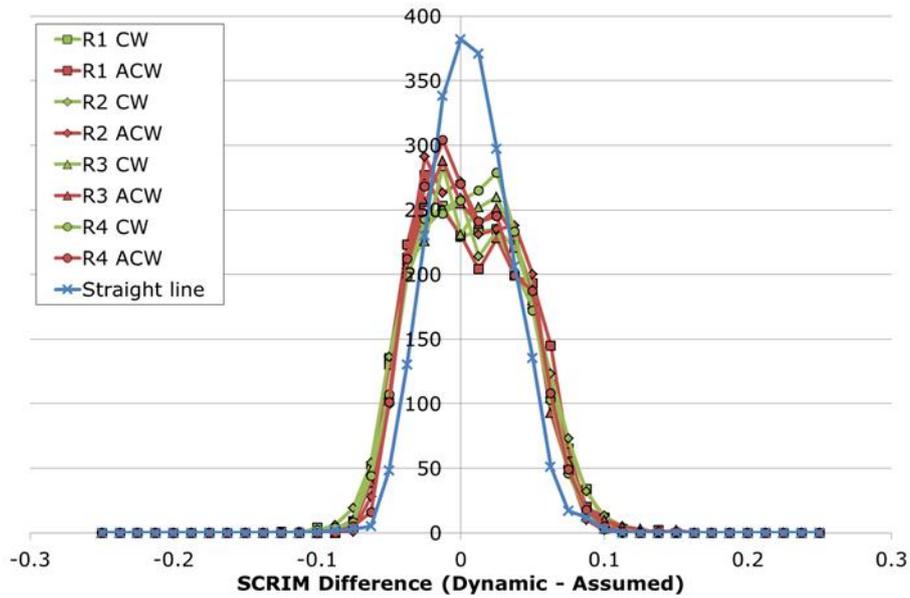
## 5 References

- ASTM. (2008). *E524-08 Standard specification for standard smooth tire for pavement skid-resistance tests*. West Conshohocken: ASTM.
- ASTM. (2011). *E274/E274M-11 Standard test method for skid resistance of paved surfaces using a full-scale tire*. West Conshohocken: ASTM.
- British Standards Institution. (2006). *BS 7941-1:2006 Measurements for measuring the skid resistance of pavement surfaces - Part 1: Sideways-force coefficient routine investigation machine*. London: BSI.
- Brittain, S. (2014). *PPR702 Comparison of SCRIM and SKM sideways-force skid resistance devices*. Wokingham: Transport Research Laboratory.
- Department for Transport. (2004). *HD 28/04 - Skid resistance (DMRB 7.3.1)*. London: The Stationery Office.
- FEHRL. (2006). *FEHRL Report 2006/01 Harmonisation of European routine and research measuring equipment for skid resistance*. Forum of European National Highway Research Laboratories.
- PCIS. (2015). Retrieved from Pavement Condition Information Systems: [www.pcis.org.uk](http://www.pcis.org.uk)
- TYROSAFE. (2008). *D04 Report on state-of-the-art of test methods*. Tyre and Road Surface Optimisation for Skid Resistance and Further Effects.

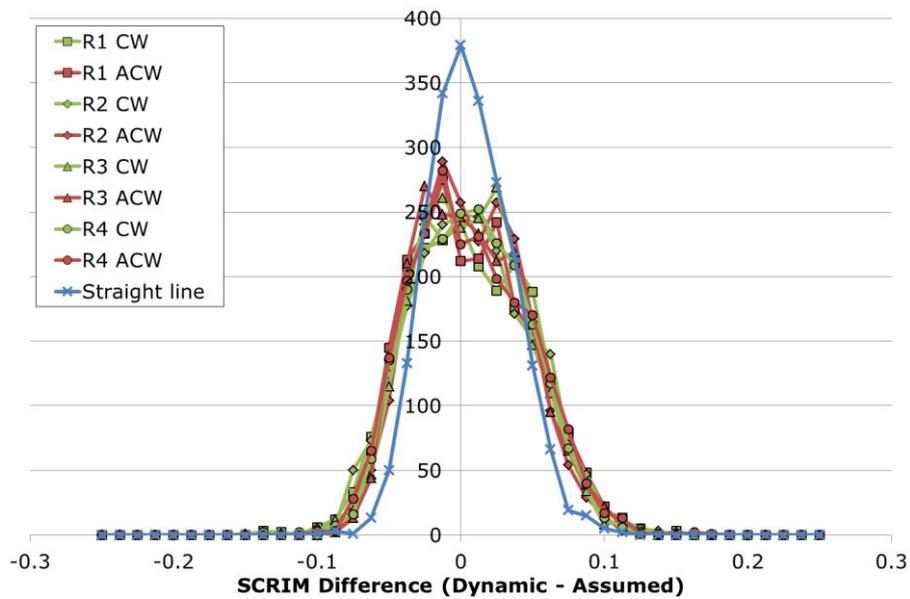
## Acknowledgements

The contribution from W D M. Limited in providing information on SCRIM devices is acknowledged and appreciated.

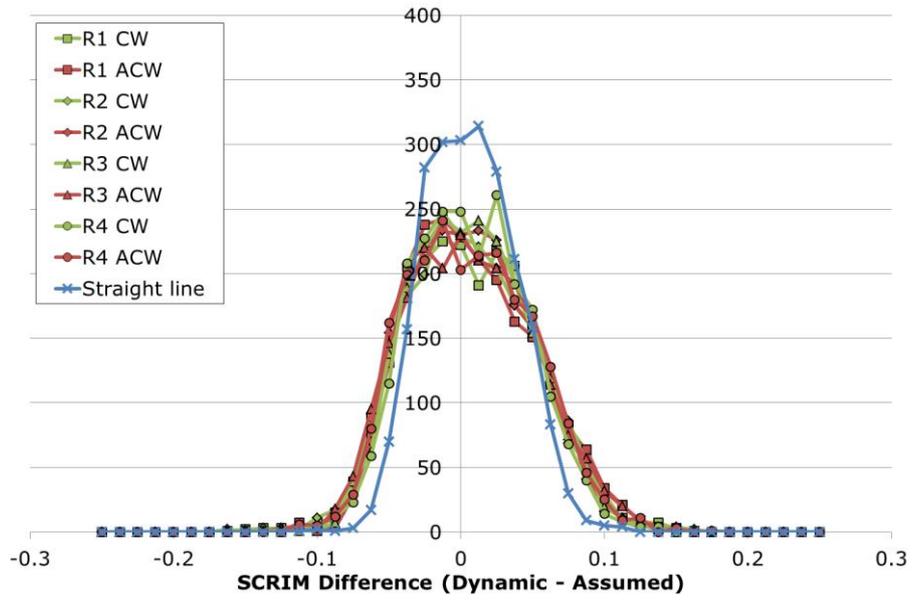
## Appendix A SCRIM Differences



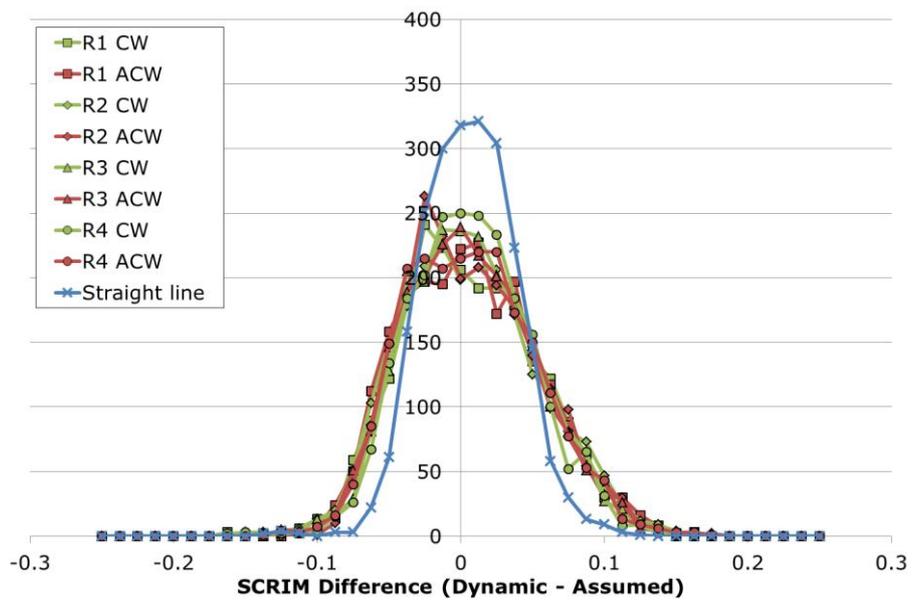
**Appendix A 1 SCRIM Difference at 10 km/h**



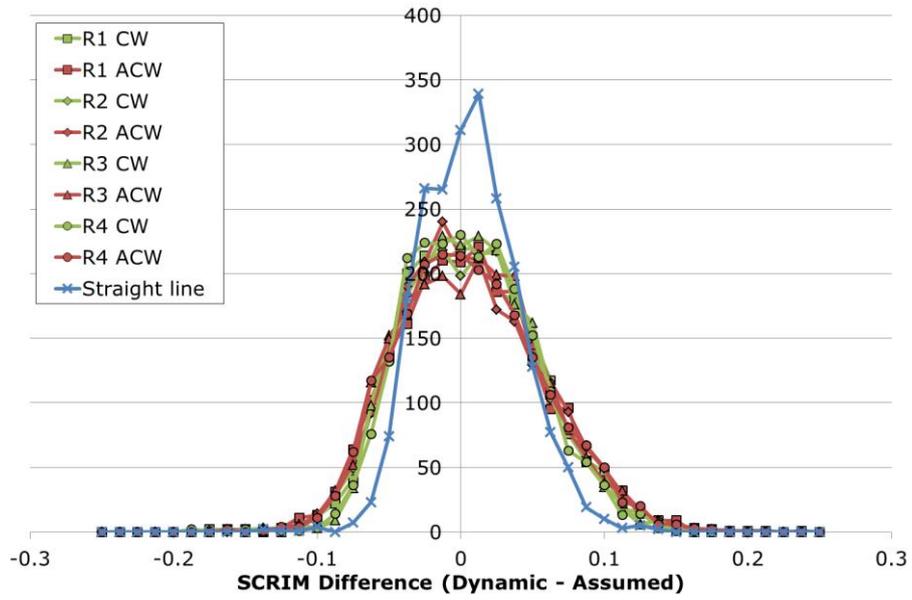
**Appendix A 2 SCRIM Difference at 15 km/h**



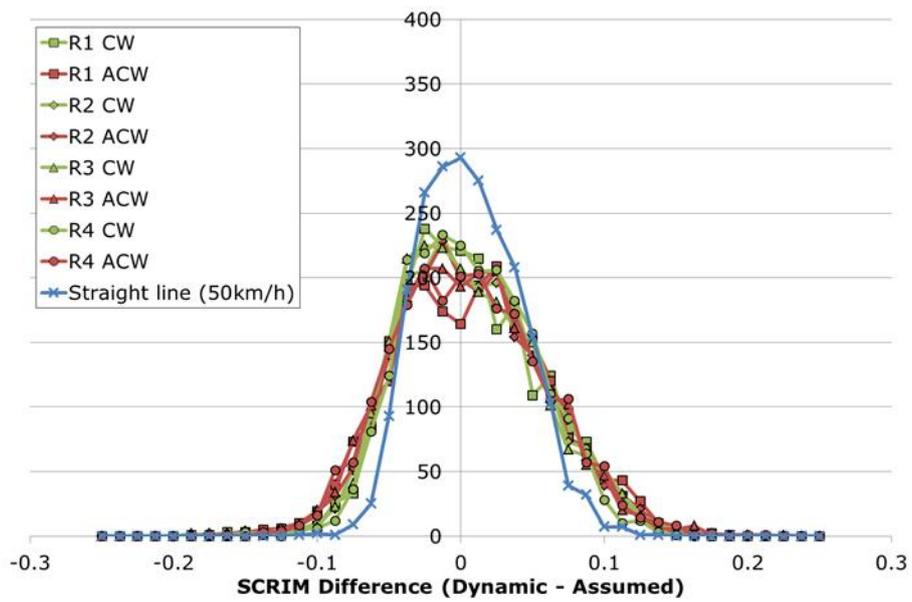
**Appendix A 3 SCRIM Difference at 20 km/h**



**Appendix A 4 SCRIM Difference at 25 km/h**

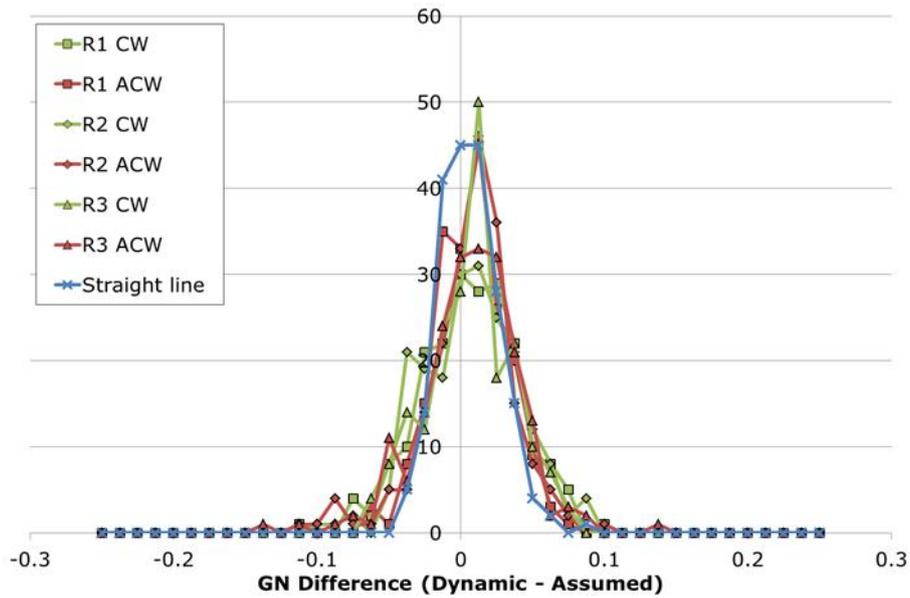


**Appendix A 5 SCRIM Difference at 30 km/h**

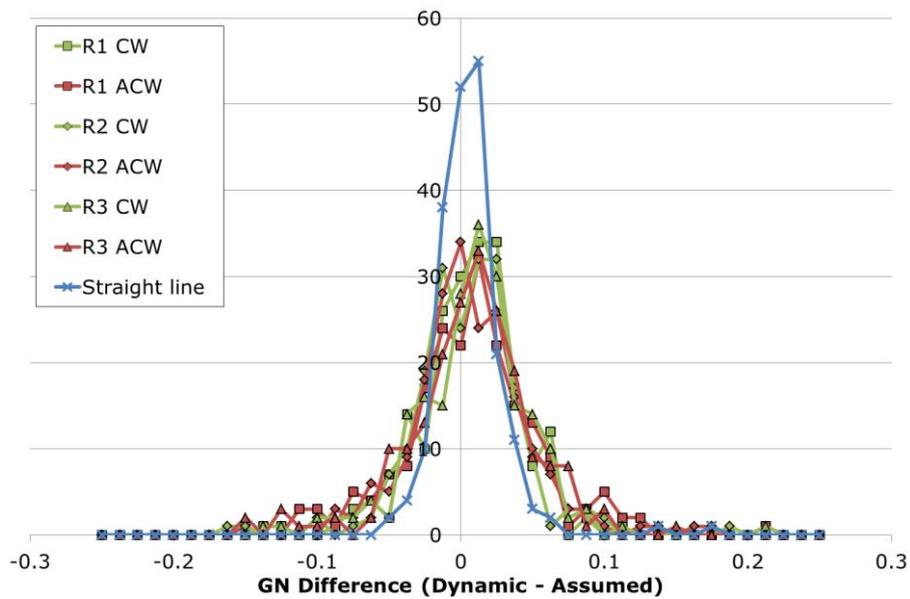


**Appendix A 6 SCRIM Difference at 35 km/h**

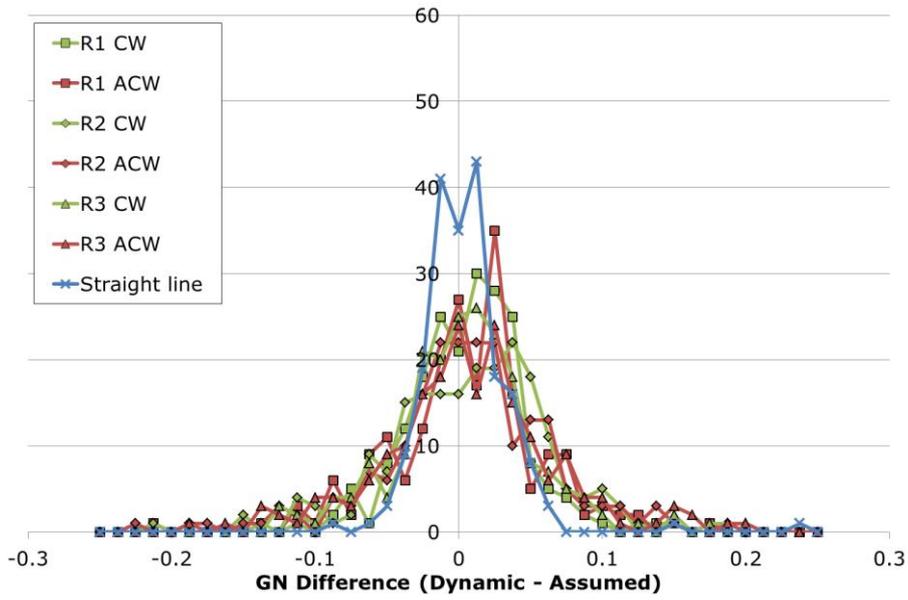
## Appendix B GripNumber Difference



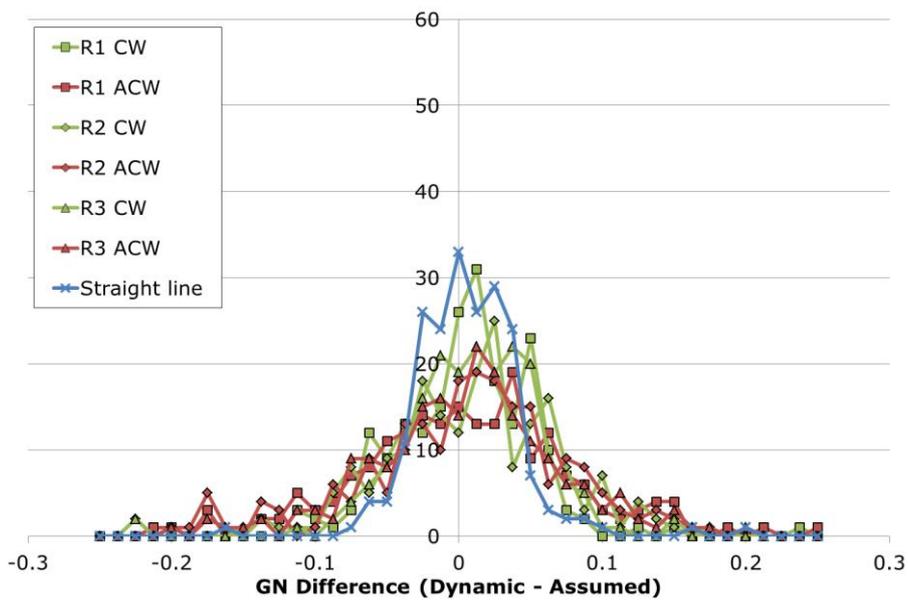
**Appendix B 1 GripNumber Difference at 10 km/h**



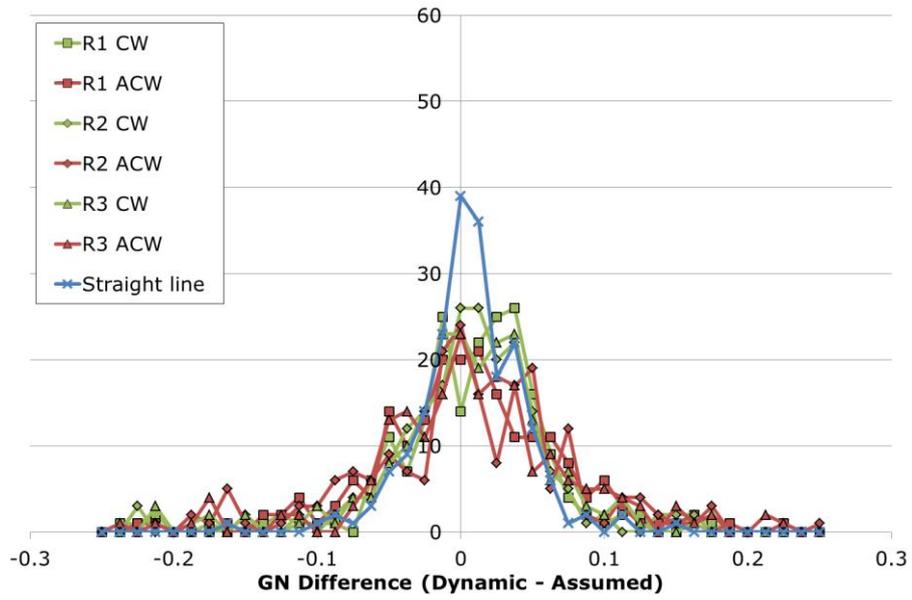
**Appendix B 2 GripNumber Difference at 15 km/h**



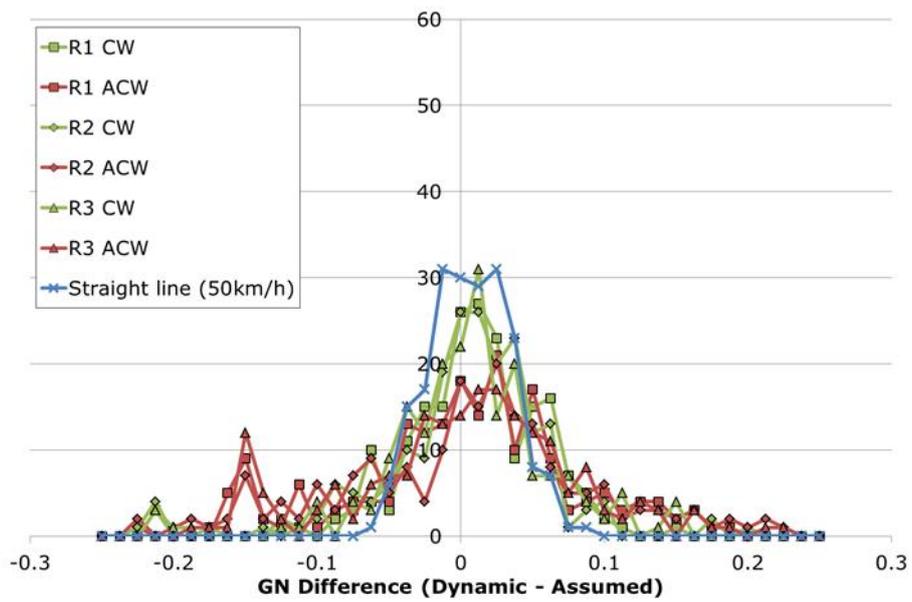
**Appendix B 3 GripNumber Difference at 20 km/h**



**Appendix B 4 GripNumber Difference at 25 km/h**



**Appendix B 5 GripNumber Difference at 30 km/h**



**Appendix B 6 GripNumber Difference at 35 km/h**