Technical Note

Measurement and Interpretation of Skid Resistance using a SCRIM® Machine

TN 110

November 2018

Purpose

This Technical Note provides an overview of road surface skid resistance, including the measurement and interpretation of skid resistance data. It contains advice on:

- factors influencing road friction, skidding and crash risk,
- undertaking site assessments, and
- skid resistance testing and reporting, including the use of Investigatory Levels.

The surface friction of arterial roads and freeways in Victoria is measured under standard conditions involving wetting of the surface. VicRoads uses a Sideways-force Coefficient Routine Investigation Machine (SCRIM®) for network level assessments and a British Pendulum Friction Tester for discrete or confined locations (e.g. bicycle lanes, pedestrian crossings).

Note : SCRIM® is a registered trademark of W.D.M. Limited.

Introduction

Skid Resistance Definition

Skid resistance is a condition parameter that characterises the contribution that a road surface makes to the total level of friction available at the contact patch between a road surface and vehicle tyre during acceleration, braking and cornering manoeuvres (Austroads, AGAM05F-09) [(1)]. Skid resistance is also relevant to constant speed driving. Road users are unable to visually recognise or distinguish any local variations in the skid resistance of a road surface.

Skid resistance has two components:

- Adhesion - the bonding of the tyre as the vehicle brakes and the tyre is forced against the surface of the stone under significant pressure; and
- Hysteresis – the energy which is generated as a result of the repeated deformation of the tyre between the stones and the resistance within the tyre to this deformation. This energy (a hysteresis effect) causes heating which softens the tyre, which has an effect on the friction resistance.

In dry conditions, all clean surfaced roads have a high level of skid resistance. Under wet conditions, the skid resistance of a road surface is significantly lower and much less uniform, when compared with the skid resistance of the same road surface in dry conditions.

Overview of Skid Resistance and Vehicle Travel

When a vehicle travels on a road, each part of the tyre in contact with the road surface (i.e. the tyre contact patch) is momentarily at rest on the road surface as the tyre rotates. The vehicle exerts forces on the road surface through the tyre contact patch. These vehicle forces are opposed by the friction between the tyre and road surface. Under non-skidding conditions, the applied vehicle forces of the vehicle will be less than the skid resistance available from the road surface.

On roads where vehicles mostly travel a straight path at a constant speed, the skid resistance requirements are at their lowest. Under these circumstances, skidding is unlikely to occur even on road surfaces with poor skid resistance. Skidding is most likely to occur during braking, acceleration or sudden changes in direction.

On curves, sideways forces between tyres and the road surface are necessary to enable vehicles to follow the curvature of the road. The level of skid resistance required to allow the vehicle to be controlled is dependent on the radius of the curve, its superelevation, the wetness of the surface and the vehicle speed.

Due to the effects of weight transfer when braking and/or cornering, vehicles are likely to require higher levels of skid resistance than they would require under straight travel. The skid resistance required to avoid skidding will increase further if, for example, tyre wear is uneven or the brakes are out of adjustment.

Factors Influencing Friction and Skidding

Austroads (AGAM05F-09) [(1)] lists factors that can influence the level of surface friction available:

1. Vehicle speed
2. Texture
3. Water depth and tyre characteristics
4. Seasonal effects
5. Temperature
6. Road geometry
7. Surface contamination
8. Surfacing aggregates
9. Surfacing type and age.

1. Vehicle Speed

In dry conditions, the level of surface friction is considered to be constant with increasing vehicle speed. However, in wet conditions, the level of surface friction reduces rapidly with increasing vehicle speed.

2. Texture

The microtexture (fine scale texture of less than 0.5mm depth) of the surfacing aggregate is the main contributor to sliding contact resistance and is dependent on the actual tyre contacting the road. Microtexture is the dominant factor in determining wet skid resistance at low to moderate speeds. Microtexture is still important at high speeds but the macrotexture (coarse texture in the range of 0.5 mm to 15.0 mm) becomes dominant, as it provides rapid drainage routes between the tyre and road surface. This allows microtexture contact to occur and also causes tyre rubber deformation.

As both components of friction (adhesion and hysteresis) are related to speed, the friction available to the vehicle is not constant during a single braking operation. When a wheel becomes "locked" during braking, microtexture becomes far more significant with the generation of a large amount of heat.

The skid resistance of wet roads is reduced by the lubricating action of the film of water on the road surface. Drainage channels, provided by the macrotexture of the road surface and the tread on the tyre, assist in removing the bulk of the water and are of increasing importance as the speed becomes higher. A tyre can only displace the remaining water film if there is sufficient microtexture on which the tyre can build up high contact pressures to establish areas of "dry" contact between the road surface and the tyre.

3. Water Depth and Tyre Characteristics

In wet conditions, the degree of contact that can be established between the vehicle tyre and the road surface is largely determined by vehicle speed, the capacity of the surface to shed water, the depth of the water film present and the operational characteristics of the tyre (tread depth, width, tyre pressure).

Aquaplaning (also referred to as hydroplaning) is the condition where the vehicle tyres are completely supported by a layer of water and there is no contact with the road surface. Whilst high speed and a thick film of water on the road surface can encourage a vehicle to aquaplane, a relatively thin layer of water can also cause a problem if combined with low texture depth and "smooth" tyres. Although aquaplaning may be uncommon, partial aquaplaning can often occur where a high proportion of tyre/road contact is lost. This occurs as a wedge of water builds up at the front of the tyre contact area, and extends back as speed increases, thus separating more of the tyre from the road. Critical locations for aquaplaning are likely to include:

- right hand curve transitions (reversal of crossfall) in areas of high rainfall intensity;
- low crossfall and either flat or steep grades combine to give a long runoff path for water; and
- intersections where rutting can result in ponding, or
- road surfaces that are flushed

4. Seasonal Effects

During dry periods, road surfaces become polished under the action of traffic, but when wet for prolonged periods they tend to regain their former harshness (Gargett, 1990) [(2)] or microtexture. Wet skid resistance appears to change during the seasons with minimum values normally occurring during summer or early autumn. In Australia, the minimum skid resistance values at a location may vary from year to year and occur during different periods depending on the prevailing weather conditions and the extent of dry weather prior to testing. Given that seasonal variation is likely to occur, but may differ between climatic zones, a standard correction factor is not recommended (ARRB Special Report 37, *Seasonal Variation of Skid Resistance in Australia*) [(3)].

5. Temperature

Surface friction decreases with an increase in road surface temperature, due to both tyres and bituminous materials being visco-elastic. The hysteresis component of the total surface friction reduces as the road surface temperature increases.

6. Road Geometry

The highest rates of loss of surface friction are found at sites where the highest vehicle stresses are imparted onto the surface aggregates, such as at tight curves and the approaches to intersections. At these sites, polishing of the surface aggregate occurs more rapidly than on other parts of the network.

Crossfall and superelevation will also have an effect on the propensity of water to pond or be retained on a road surface.

7. Surface contamination

In addition to water (including ice and snow), the presence of contaminants such as mud, dust, loose gravel, oil, manure etc. results in a lower level of surface friction, when compared to the same road surface in dry, clean conditions.

8. Surfacing Aggregates

Locations where severe braking, cornering or accelerating occurs (i.e. high stress locations), the polishing action of traffic is greater and the skid resistance reduces to a lower level than at manoeuvre-free sites. Consequently, the greatest difficulty in obtaining the required performance of surfacing aggregates is encountered at high stress locations, where high skid resistance is most needed. This is significant because road users are unable to visually recognise any local reduction in skid resistance.

Sites where polishing is often found include:

- approaches to intersections, roundabouts, traffic-signals and railway level crossings
- pedestrian and school crossings
- curves, and
- on steep gradients

9. Surface type and age

The level of surface friction provided by some surfacing types (e.g. surfaces that incorporate polymer modified binders, such as stone mastic asphalt and open graded asphalt) immediately after placement can be less than the level that would normally be anticipated. The skid resistance of these surfaces improves to anticipated levels after trafficking removes excess bitumen from the aggregate surface.

Crash Risk

It is difficult to relate the skid resistance of a road surface to the number of crashes occurring on a section of road, as a crash is usually the result of a combination of factors, of which skid resistance may be one factor. In addition, determination of the contribution that each factor may make towards a crash is challenging. However, a change in the level of skid resistance can influence the number and severity of wet weather skidding crashes. The role of skidding in a crash is not always clear and may be either a 'cause' or an 'effect' of a crash.

For the road surface to play its part in reducing the likelihood of wet weather crashes, the resistance to skidding must be appropriate to the friction demanded by the vehicles. As these demands vary from site to site and from vehicle to vehicle, the corresponding required levels of skid resistance will also vary.

Given there is no clear indicator between "safe" and "dangerous" conditions, there is no skid resistance value above which there will be guaranteed freedom from wet weather skidding crashes. As skid resistance increases, its influence as a factor in crashes will be reduced. Vehicle design, speed, road geometry and type and condition of tyres are some of the other factors.

Research has established a relationship between the risk of wet weather skidding crashes and the level of skid resistance, with separate relationships for different site categories as indicated in Table 1, attached to this Technical Note. It is important to note that sites within the same category may have a higher or lower wet weather skidding crash potential according to their particular characteristics.

Whilst crash studies can assist to identify sites with a high wet weather crash rate, some measurement of skid resistance is required to detect sites with low skid resistance.

Information to consider gathering and assessing when undertaking a site assessment for the influence of skid resistance on crash risk includes:

- measured skid resistance
- weather records
- road surface condition
- traffic volumes, including heavy vehicles
- road geometry and signing
- texture depth
- crash history
- potential for aquaplaning
- prevailing speed of vehicles
- properties of road surface aggregate

Investigatory Levels

Table 1 provides Investigatory Levels of skid resistance for seven site categories - five at 50 km/hr and two at 20 km/hr.

The Investigatory Levels in Table 1 are default values based on the use of an average vehicle at sites of average difficulty within each site category.

At sites where the measured skid resistance is below the Investigatory Level for the site category, investigations can be conducted into the characteristics and crash potential of the sites. The sites should be assessed according to their layout, geometry and potential for wet weather skidding crashes.

Whilst the assigned Investigatory Levels in Table 1 will be acceptable for the majority of sites, there can be special circumstances where it may be necessary to increase the Investigatory Level of a site.

For example, if a site has a wet weather crash rate significantly higher than the average, but the skid resistance is above the default Investigatory Level, this could be an indication that the level of frictional demand is higher than expected and consideration should be given to increasing the Investigatory Level at the site.

Examples of variables that may warrant increasing the Investigatory Level include:

- sub-standard vertical alignment
- adverse crossfall
- narrow lane widths, and
- poor visibility or sight distance.

Adjacent land use can have an influence on the crash risk of a site. Additional actions to address crash risk may be required in the vicinity of shops, schools, bus stops and industrial site accesses.

Vehicle speed is another important factor to consider when undertaking a site assessment. Even in areas subject to a 60 km/hr or lower speed limit, unexpected curves can still warrant increasing the Investigatory Level, especially if other improvements are impracticable or until such time that improvements can be undertaken.

There may also be instances when the Investigatory Level can be reduced below the default level. The reduction of the Investigatory Level should only be by one level at a time after consideration of the site's layout, geometry, wet weather crash history and crash potential. Where a lower Investigatory Level is set, it is important to monitor that the revised level remains appropriate over time.

Assigning non-default Investigatory Levels involves a degree of subjective judgment and research has shown that this can vary considerably. It is therefore important to review the non-default Investigatory Levels at intervals to ensure that any under or over valuations do not persist. A three-yearly reassessment of sites is suggested.

A site may not always fit into a single site category, as indicated in Table 1. For example, a signalised intersection may be located within a curve with a radius less than 250 metres. In these type of scenarios, consideration should be given to whether the higher Investigatory Level is likely to be adequate. These decisions must be treated on merit and take into consideration site specific information.

It is recommended that a visual inspection and assessment of the site conditions be undertaken by experienced personnel when assigning non-default Investigatory Levels.

Technical Note TN 111(4) gives further information on Investigatory Levels to provide an understanding of their purpose and how they relate to skid resistance.

Skid Resistance Testing

VicRoads uses two methods to assess skid resistance.

SCRIM® Survey

The Sideways-force Coefficient Routine Investigation Machine (SCRIM®) is a self-contained machine that measures the surface friction of a wet road under standard conditions. Testing is usually undertaken at a constant speed of 50 km/hr and both wheel paths are tested simultaneously.

The SCRIM® machine has been developed as a rapid and economical monitor of skid resistance. Its output, used carefully and within its limitations, will provide information on which to assess skid resistance. The SCRIM® machine is the main skid resistance testing method used by VicRoads.

For tight radius curves, generally less than 100 metres, it may be impractical to test skid resistance using the SCRIM® machine at 50 km/hr and to maintain correct tracking of the test wheels. For those situations, testing can be undertaken at 20 km/hr on the basis that Investigatory Levels appropriate for this speed are used.

Pendulum Friction Tester

At specific locations or in confined areas, a Pendulum Friction Tester (PFT) is used in accordance with AS 4663 [(5)]. The tester has a small contact area which simulates the action of a patterned tyre. Given the SCRIM® machine measures skid resistance with a smooth tyre, the texture depth/skid resistance relationship generated by the PFT differs from that obtained using the SCRIM® machine.

A generalised regression equation between the PFT and SCRIM® results is referred to in ARRB Special Report 37, *Seasonal Variation of Skid Resistance in Australia* [(3)]. This provides a guide for individual measurements but cannot be relied on as a rigorous conversion at a specific site.

Testing and reporting using the SCRIM® machine

Network Condition Survey

A network condition survey using the SCRIM® machine includes measuring the skid resistance as detailed in RC 421.02[(6)], as follows:

- one test run of both wheel paths of the most heavily trafficked lane, and
- an assessment of reasons why the survey may not be representative of the normal skid resistance, e.g. an especially dry summer preceding the test run may create conditions for a lower than expected result.

Crash Site Investigation

Skid resistance testing using the SCRIM® machine can be undertaken at crash sites. The testing should be in accordance with the current test procedures for SCRIM® machine e.g. RC 421.02[(6)].

For sites where a fatal wet weather crash has occurred, the following additional requirements are recommended:

- test to include 100 metres prior to and past the site of the crash, and
- test all lanes using a repeat of five runs in each lane, where the first run is used to wet the road surface and the result is discarded. The remaining four results are averaged to provide the test result for each lane.

Note: SCRIM® test results may not represent the skid resistance at the time of the crash because of possible changes to the surface and different climatic conditions. For this reason, testing should take place as soon as practicable after the crash.

SCRIM® Data

Sideways Force Coefficient (SFC)

SFC is the measure that the SCRIM® machine uses to represent the skidding resistance that a road surface provides. The higher the SFC, the greater the level of skid resistance that the road surface provides. Skid resistance results from the SCRIM® machine are reported as SFC_{50} or SFC_{20}, the sideways coefficient at 50 and 20 km/hr, respectively.

Differential Friction Level (DFL)

DFLs between the left and right wheel paths can be of concern where heavy braking or turning is undertaken. High DFLs increase the risk that the rotation of a vehicle skidding with locked wheels may cause sufficient change of direction for the vehicle to enter another lane or for the vehicle to leave the road. The notes in Table 1 provides criteria regarding DFLs.

SCRIM® Reports

The SCRIM® data reports are presented in a graphical form, an example of which is provided in Figure 1.

The left (LWP) and right (RWP) wheel path SFCs are plotted against the nominated Investigatory Levels. The information presented is adjusted for temperature and speed of travel.

Recommended Actions

Where low surface friction has been found to be a potential factor to a wet weather crash, the subject site should be inspected and consideration given to signing the road section in accordance with the VicRoads *Guideline for Signing Roads in Poor Condition* [(7)].

Treatments

When a surfacing treatment is required, the type and extent of the treatment needs to take into account the length of defective surface, vehicle braking and accelerating requirements and the implications for road users losing control. Minimum practical resurfacing lengths also need to be considered.

Although abrupt changes in skid resistance cannot be avoided, for example at the ends of special treatments, care should be taken to try to ensure that such changes are not located at sites where a high degree of polishing is found or where complicated manoeuvring may be required.

Information on various treatments can be obtained from Austroads Guide to Pavement Technology Part 3, *Pavement Surfacings* [(8)].

References

1. Austroads, *Guide to Asset Management Part 5F: Skid Resistance*, AGAM05F-09, 2009
2. Gargett, T., *The Introduction of a Skidding-Resistance Policy in Great Britain*, First International Symposium on Surface Characteristics (1988) published in ASTM's STP 1031 (ASTM 1990)
3. Oliver, J.W.H., Tredrea, P.F. and Pratt, D.N., ARRB Special Report No.37, *Seasonal Variation of Skid Resistance in Australia*
4. VicRoads Technical Note TN 111 – *Understanding VicRoads' Skid Resistance Investigatory Levels*, 2018
5. Australian Standard AS 4663 – *Slip resistance measurement of existing pedestrian surfaces*
6. VicRoads Test Method RC 421.02 - *Skid Resistance of a Road Pavement using a SCRIM® Machine,* 2018
7. VicRoads, *Guideline for Signing Roads in Poor Condition*, 2011
8. Austroads, *Guide to Pavement Technology Part 3: Pavement Surfacings,* AGPT03/09*,* 2009

Further Reading

- Austroads Technical Report, *Road Surface Characteristics and Crash Occurrence: A Literature Review*, AP-T96-08, 2008.
- Austroads, *Guidelines for the Management of Road Surface Skid Resistance*, AP-G83-05, 2005

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VicRoads Technical Note - Revision Summary

TN 110 – Measurement and Interpretation of Skid Resistance using a SCRIM® Machine

Date	Clause	Description of Revision	Authorised by
November 2018	Investigatory Levels Table 2 Full document	Insert reference to TN 111 – Understanding VicRoads' Skid Resistance Investigatory Levels Revert to "Curves with radius ≤ 250 meters" for Site Category 2. Add Note (e) Editorial changes and additional information included	Principal Advisor – Pavement, Geotech. & Materials
March 2018	Full document Table 1	Revised to reflect SCRIM® is a registered trade mark of W.D.M. Limited Added separate investigatory levels for SFC_{50} and SFC_{20} as reported and typical international practice Defined lower limit (>100m) of the tight curves Revised and added notes	Principal Advisor – Pavement, Geotech. & Materials
November 2015	All	New document	Principal Advisor – Pavement, Geotech. & Materials

Table 1: Investigatory Level for Skid Resistance

Site Category	Site Description	Investigatory Levels of SFC_{50} (At 50km/hr or equivalent – local format)						
		30	35	40	45	50	55	60
		Investigatory Levels of SFC_{50} (At 50km/hr or equivalent – typical international practice)						
		0.30	0.35	0.40	0.45	0.50	0.55	0.60
1#	▪ **Signalised intersections** ▪ **Pedestrian/school crossings** ▪ **Railway level crossings** ▪ **Roundabout and approaches**	**INVESTIGATION IS ADVISED**						
2	▪ **Curves with tight radius ≤ 250 m** ▪ **Gradients ≥ 5% and ≥ 50 m long** ▪ **Freeway, highway; on and off ramps**							
3#	▪ **Intersections**							
4	▪ **Manoeuvre-free areas of undivided roads**							
5	▪ **Manoeuvre-free areas of divided roads**							

Site Category	Site Description	Investigatory Levels of SFC_{20} (At 20km/hr or equivalent – local format)						
		30	35	40	45	50	55	60
		Investigatory Levels of SFC_{20} (At 20km/hr or equivalent – typical international practice)						
		0.30	0.35	0.40	0.45	0.50	0.55	0.60
6@	▪ **Curves with radius ≤ 100 m**	**INVESTIGATION IS ADVISED**						
7#	▪ **Roundabout and approaches**							

Key to Thresholds below which Investigation is Advised

Black	Roads with more than 2,500 vehicles per lane per day
Grey	Roads with less than 2,500 vehicles per lane per day

NOTES:

(a) **#** - Indicates Investigatory Level for Site Categories 1, 3 and 7 are based on the minimum of the four-point rolling average skid resistance form 50 m before to 20 m past the feature, or for 50 m approaching a roundabout.

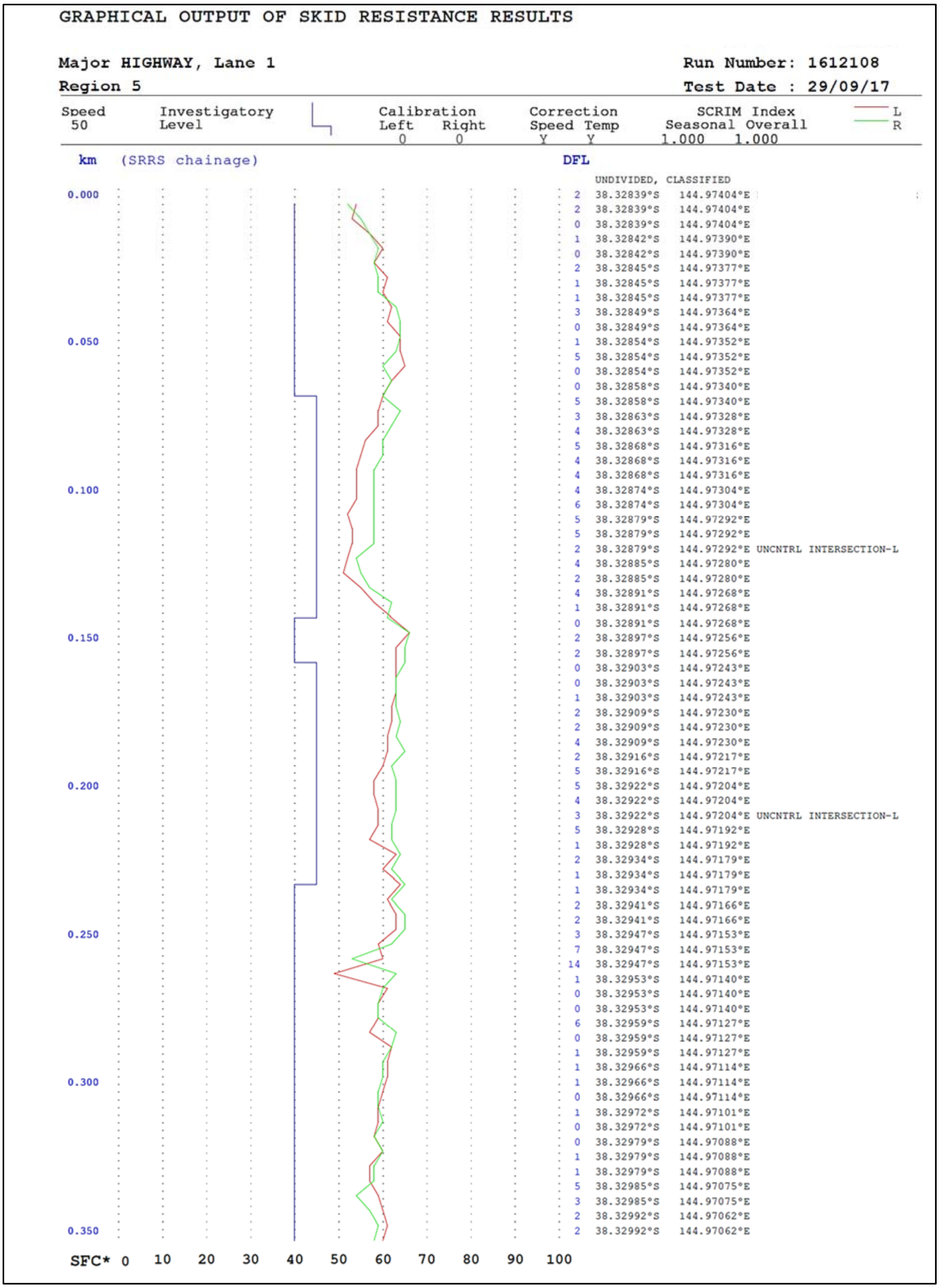
(b) Investigatory levels for Site Categories 2, 4, 5 and 6 are based on the minimum of the four-point rolling average skid resistance for each 100 m section.

(c) The difference in Sideways Force Coefficient values between wheel paths (Differential Friction Levels) should be less than 0.10 (or 10 for local format) where the speed limit is greater than 60 km/hr; or less than 0.20 (or 20 for local format) where the speed limit is 60 km/hr or less.

(d) Curves with radius > 250 m and road sections with a gradient < 5 % are to be considered as either Site Category 4 or 5.

(e) @ - applicable only if the curve cannot be travelled at 50 km/hr

Figure 1: Graphical Output of Skid Resistance Results From the SCRIM® Machine.



Note: * SFC values as reported