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SKIDDING RESISTANCE: MEASUREMENT AND USE OF DATA

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ABSTRACT

The first Sideways-force Routine Investigation Machine was manufactured in 1967 by W.D.M. limited for the TRRL, following extensive research from the 1930's into measuring the skid resistance of road surfaces. It is proven that the provision of appropriate levels of skid resistance can provide significant benefits in reducing skid related accidents. Fifty years later it has become the principal means by which Highway Authorities in the United Kingdom, New Zealand and many other countries assess skid resistance, and WDM have manufactured over 80 machines. The principal of SCRIM is to measure the force exerted on the test-wheel at a 20^0 angle, which is a measure of the skidding resistance of the road surface.

Modern skid polices are investigatory by nature, and involve assessing the skid resistance against an Investigatory Level (IL). If the skidding resistance is below the IL the Highway Authority puts in place a series of measures to assess and manage the associated safety risks. This does not always involve surface treatment, but where it does, the design should ensure that the new surface would provide an acceptable level of skid resistance for the life of the surface. This can be done by a number of techniques, and typically involves the selection of coarse aggregates that meet a polishing criteria defined by the PSV test. Research from a number of authorities is presented which demonstrates the different performance of aggregates, and how they have been used by a number of authorities.

INTRODUCTION

The Sideway-force Routine Investigation Machine (SCRIM) is the principal method used to assess the skidding resistance of road surfaces in the United Kingdom, and many other countries. The first SCRIM was commissioned in 1967, and since the 1970's has been used on the UK trunk road network. Standards for the operation of SCRIM, interpretation of data and application have been developed, with a number of standards being published, the most recent of which is HD28/15 (DMRB 2015).

Figure 1:1967 SCRIM (TRRL)

SCRIM works on a sideways force principle. The test wheel is orientated at an angle of 20^0 to the direction of travel, and a fixed load of 200 kg applied. The Sideways force generated by the test wheel is measured, and this is used to determine the skid resistance of a road surface. Figure 2 illustrates the concept.

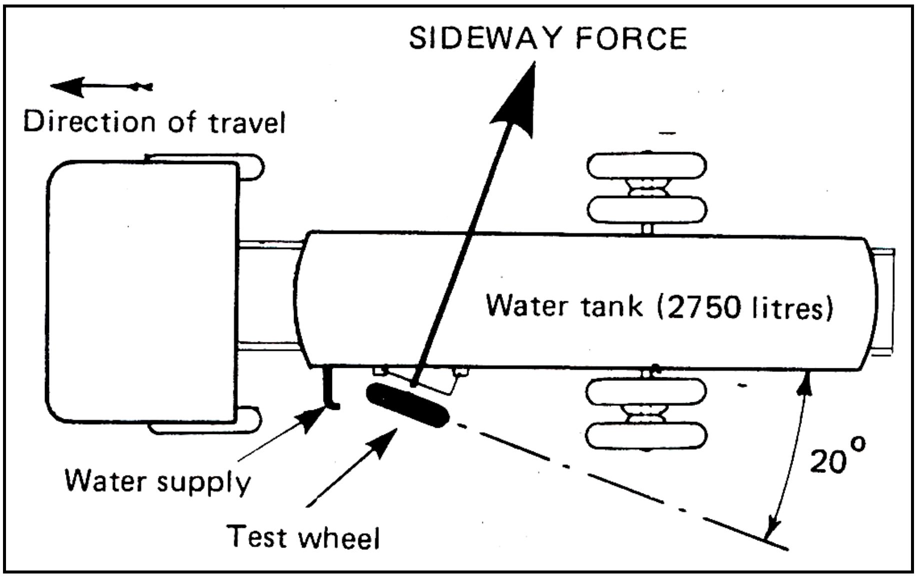


Figure 2: Sideways force concept.

SCRIM allows the testing of skid resistance at speeds from 20 – 85 kph, and measurements are corrected to 50 kph for reporting purposes. The survey season in the UK runs from May to September, and relies upon the accreditation of devices by Highways England, and ongoing quality assurance and re-validation. Reporting is normally summarised for each 10 m length of road, based on the average of readings taken every 100 mm. A process of seasonal adjustment is applied to the data, which attempts to account for both in year, and between year variations in skid resistance.

Skid resistance measured using the SCRIM is expressed as a SCRIM coefficient, which is typically in the range 0.20 to 0.65.

Road condition in England 2015 (Department for Transport 2015) reports that 25% of the principal (A class) and 5% of the trunk network in England required further investigations to check whether the skid resistance was acceptable. The difference is largely due to the different characteristics of the networks, resulting in different requirements for skid resistance.

Skid Policy in the United Kingdom

HD28/15 describes the standard applied for the strategic road network in England, and is also the basis of practice on trunk roads in Scotland. Wales and Northern Ireland. Most Local authorities apply a policy derived from HD28/15 with local variations to suit the characteristics of their network.

The objectives of HD28/15 are to:

- Maintain a consistent approach to the provision of skid resistance,
- Provide a level of skid resistance appropriate to the nature of the road environment at each location.

Figure 3 outlines the overall process as detailed in HD28/15. It involves setting Investigatory Levels (IL), effectively risk rating the network for the demand for skid resistance based on geometry and road layout, and then an investigatory protocol for those sites below the specified IL's. Outcomes from investigations can vary from 'do nothing' to inclusion in the forthcoming programme of works.

Most local authorities base their skid resistance strategy on HD28/15 with local variations. Typically, surveys are undertaken on the busier parts of the local network as defined by class or hierarchy. These variations are typically to Investigatory levels, prioritisation of sites and the investigatory process.

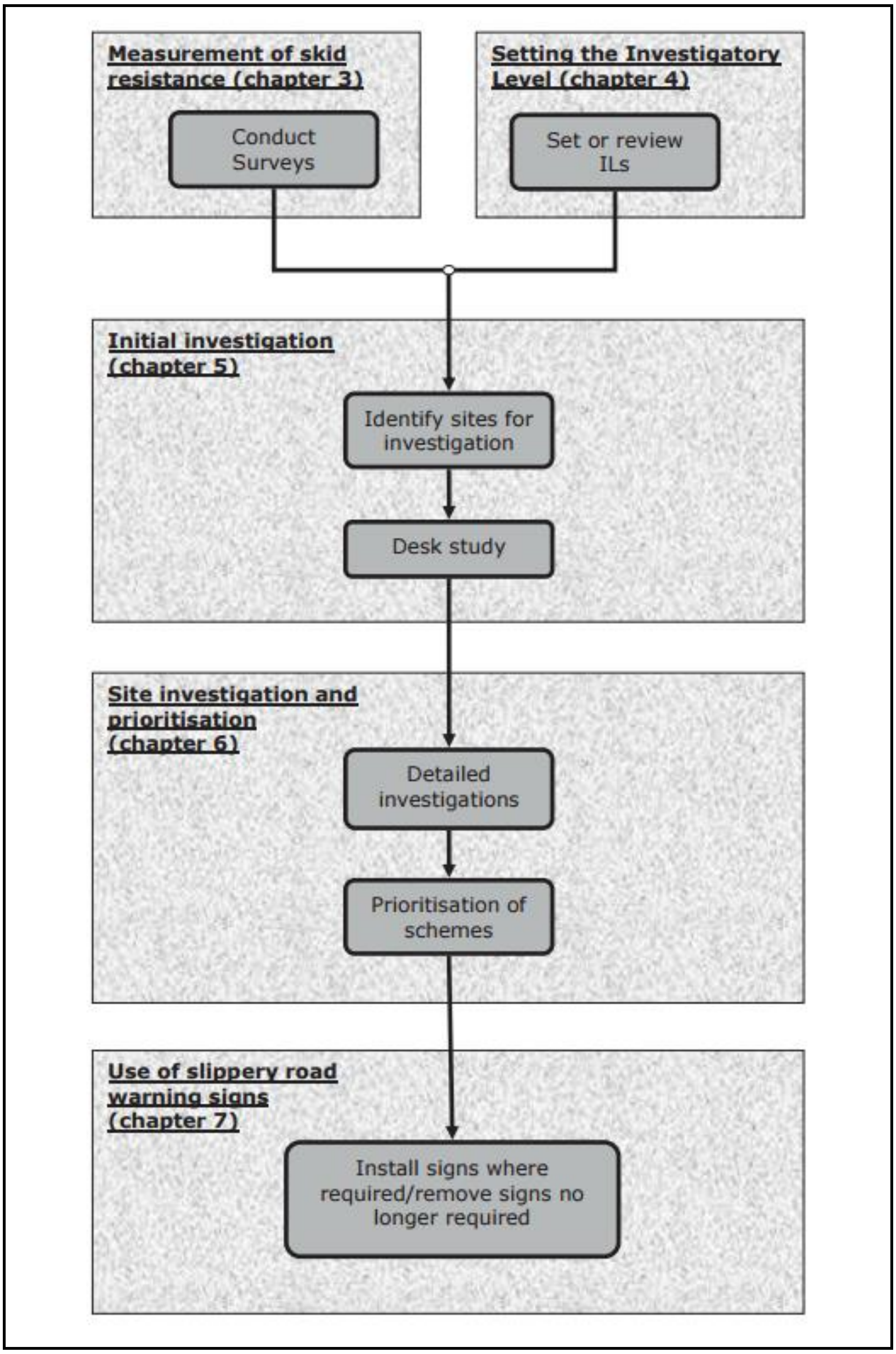


Figure 3: HD28/15 Skid Resistance- operation of standard

Skid Policy in the New Zealand

New Zealand has a skid policy that applies similar principles to that in the United Kingdom, with some modifications. The stated objective of the New Zealand Transport Agency (NZTA) skid resistance policy is to provide a cost effective surface that has appropriate skid resistance for road vehicles in wet and dry conditions.

A key difference between New Zealand and the UK is the extensive use of Chip seal (surface dressing) on the State Highway network. T10 (NZTA 2013) is the current standard. Similar to HD28/15 it defines an investigatory process, but also includes reference to macrotexture requirements, and introduces the concept of 'Intervention levels.' A key process in the management of skid resistance is the exception reporting, a 'fast track' investigation into sites that are below the SCRIM or texture Intervention Level. This approach enables a programme of retexturing to be accelerated to deal with these sites.

Following this initial response there an investigatory process for sites where a combination of crashes, low SCRIM and low Texture depth are prioritised. NZTA also apply an Aggregate Performance methodology to select aggregates for use in surface courses. The current NZTA maintenance contract includes performance criteria with financial penalties for failure to meet threshold/ intervention levels after a specified life.

NZTA research has indicated that an increase in skid resistance of 0.1 reduced crash rates by around 30% over the state highway network (Davies et al 2005), and that since the inception of T10 the rural state wet crash rate had reduced by 20% (Owen et al 2008). The estimated benefit/ cost ratio of the T10 policy has been calculated between 13 and 35 (Cook et al 2011).

Determining Investigatory Levels

Survey data is fitted to digital road networks using GPS fitting. A skid strategy relies upon accurately defined site categories with appropriate Investigatory levels (IL's). These IL's can either be adopted from national standards or adapted to local circumstances. IL's in HD28/15 range from 0.35 for Motorway non-event to 0.55 for the highest risk sites such as <100 m radius bends and approaches to pedestrian crossings.

Figure 4 shows the data for single carriageway bends from three English local authorities. This shows the crash rate v skid resistance for different bends radii. HD28/15 applies one category to bends < 500m radius; however local authority networks are more diverse. This indicates that there is a strong basis to introduce different IL's based on radius of curvature for local authority roads. The determination of the actual IL will depend on safety strategies, funding and the availability of aggregate.

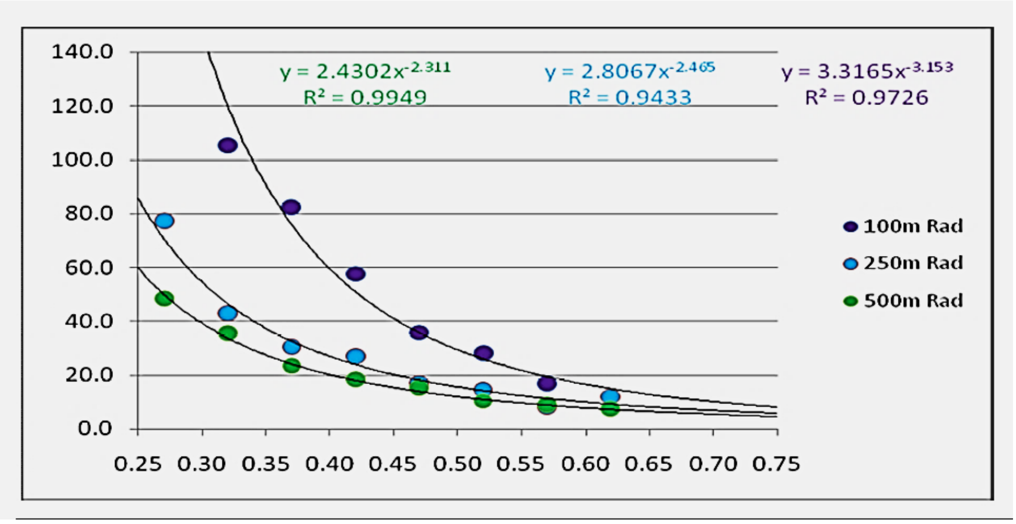


Figure 4: Crash rate v SCRIM for three English local authorities.

In New Zealand, a process of risk rating curves on the state highway network has been undertaken. Police records indicate that a higher number of crashes occur on curves defined as 'moderate' by the police. This risk rating considers a number of factors, including curvature, cross fall and approach speed. It also considers the concept of 'Out of Context' curves, where the approach speed is significantly higher than the curve speed. Figure 5 shows the range of IL's applicable to curves on the state highway network. The 'black' cells indicate default IL's and the hatched cells variations based on risk rating.

Site category	Skid site description	Investigatory level (IL), units ESC					
		0.35	0.40	0.45	0.50	0.55	0.60
2	a) Urban curves <250m radius						
	b) Rural curves <250m radius			L	M	H	
	c) Rural curves 250-400m radius		L	L	M	H	
	a) Down gradients >10%. b) On ramps with ramp metering.						

Figure 5: T10 Investigatory levels for curves.

The adopted Investigatory Levels directly affect the reporting of SCRIM performance at network level.

Achieving Investigatory Levels

The skid resistance of a road surface is generally accepted to be due to a combination of the micro texture of the coarse aggregate used in the surface course, the macrotexture of the road surface, as well as the material and construction characteristics. Figure 6 illustrates Macro and Micro texture.

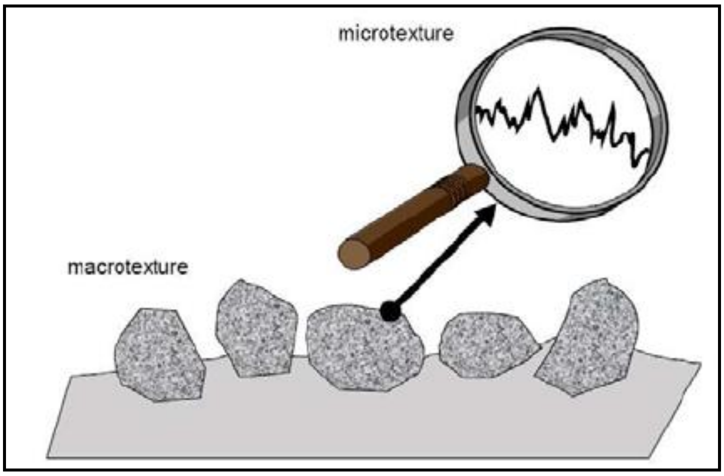


Figure 6: Macro and Micro texture

Micro-texture is defined by the mineralogy of the aggregate, and macro-texture by how the aggregate is orientated in the road surface. It is generally accepted that the absolute level of skid resistance available is determined by micro texture, and the macrotexture influence the level of skid resistance available at a particular location, especially at higher speeds.

The ability of an aggregate to provide skid resistance is described by the Polished Stone Value (PSV), which is derived by laboratory testing. It is accepted that the test has a number of limitations, and other methods such as the Werner Shulze may provide a better means of assessing in service performance.

PSV's used in road surfaces can vary from 50 – 70, with high friction surfacing using Calcined Bauxite providing higher values. In the UK HD36/06 (DMRB 2006) and IAN156/16R1 (DMRB 2016) recommends minimum PSV's for a combination of Investigatory level, site category and commercial traffic. This is used widely for the specification of new surfacing; however, there is often a compromise between the requirement for higher PSV aggregates at 'high risk' sites and a lower PSV for adjoining 'non-event' lengths.

The NZTA approach uses an Aggregate Performance Model, where based on a statistical analysis of over 100 primary sources of aggregate the SCRIM performance of the aggregate is forecast. Where there is insufficient data available the PSV is used applying the following formula

$$PSV = 100*SR + 0.00663*HCV + PSF$$

Where:

SR = investigatory level for the site
HCV = estimated heavy commercial vehicles per lane per day at the end of the surfacing life
PSF = polishing stress factor selected for the site
PSV = polished stone value

Aggregate Performance

The United Kingdom is fortunate to have a number of sources of high PSV (> 65) aggregates; however, stocks are limited. The application of the design guidance HD36/06 tends to lead to greater use of these higher PSV aggregates. It is therefore useful to gain a better understanding of how different aggregates perform in different situations. W.D.M. limited have carried out a number of studies into the performance of different aggregate sources by linking SCRIM data to construction records. Figure 7 shows the average of MSSC (seasonally corrected SCRIM coefficient) by road hierarchy and stated PSV for an English county. This shows an increase in MSSC as the PSV increases, and that there is evidence that the higher hierarchy roads typically have a lower MSSC for the same PSV. The averages are largely in the range 0.45 – 0.50, which aligns well with typical IL range. Figure 8 shows the distribution for the different PSV aggregates.

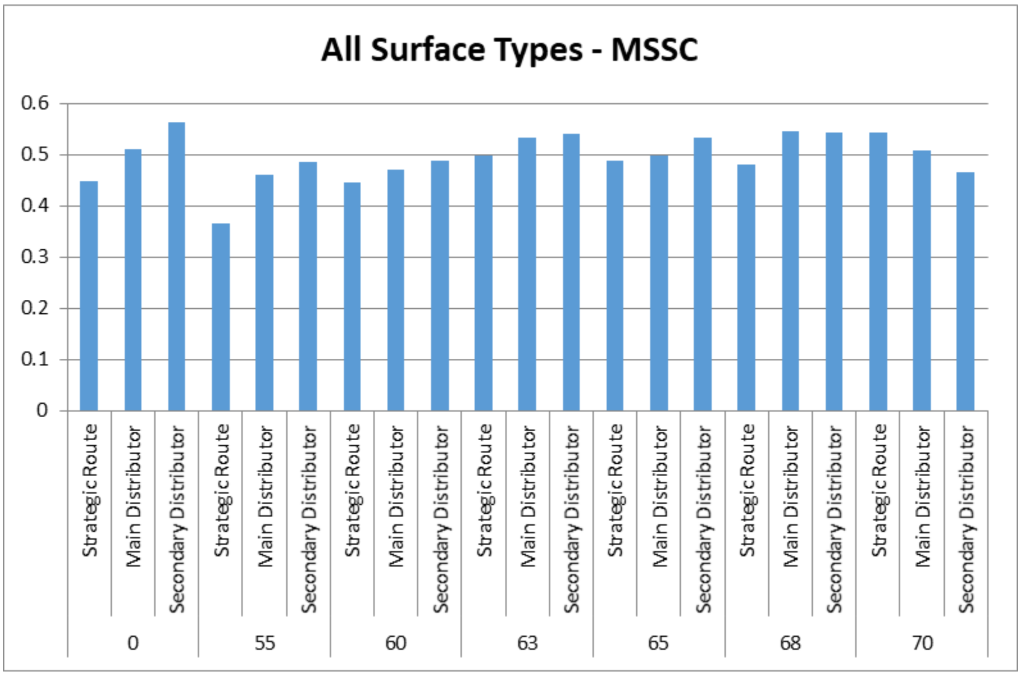


Figure 7: SCRIM v PSV and road hierarchy

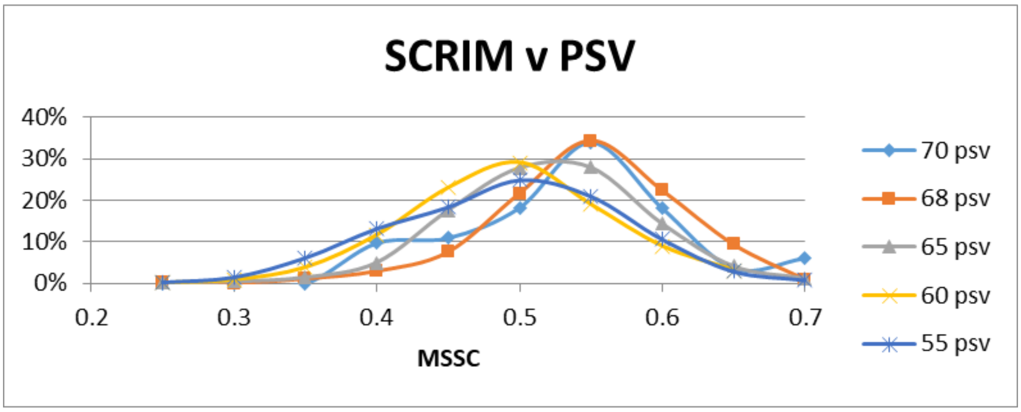
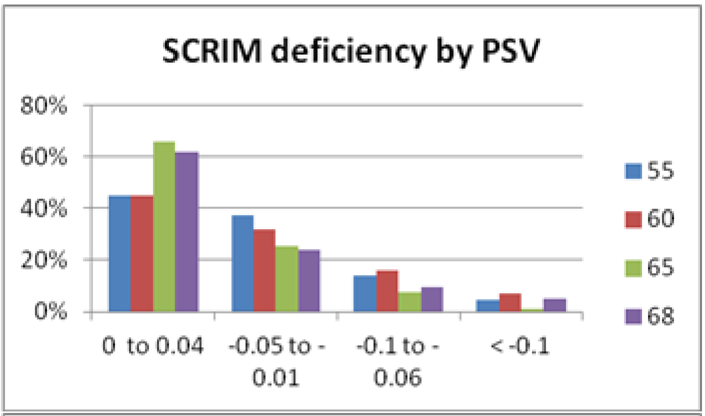


Figure 8: SCRIM v PSV distributions

Figure 8 indicates that all PSV's have a wide distribution and that the standard deviation is typically 0.05 or greater. This suggests that where the IL is 0.40 (non-event) most aggregates used in the county provide a high probability that the IL will be exceeded; however, as the IL increases a greater proportion of the roads surfaced with the aggregate type are likely to be below IL, indicating that there is an increased safety risk that the authority will need to manage. A more recent review of surfaces up to 5 years old in the same authority indicates that deficiency increases by IL, and that different treatment/ material types broadly have a similar deficiency profile.



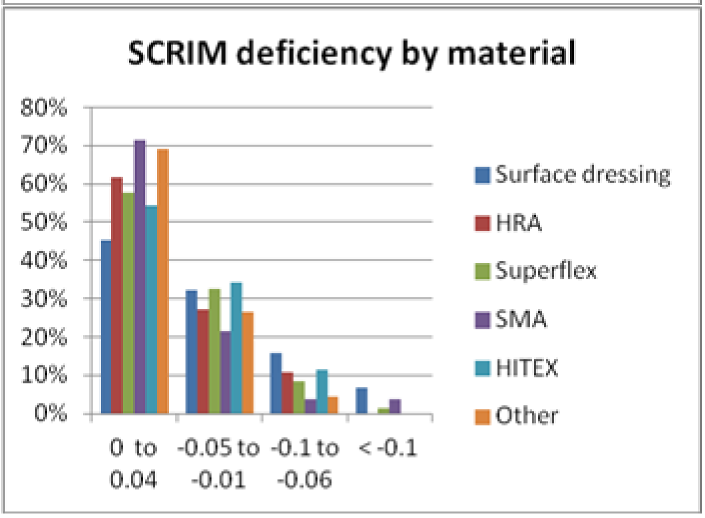


Figure 9: SCRIM performances on new surfaces

The data shown in figure 9 depends on the quality of the PSV specified at the time of design. Figure 10 illustrates how the performance of an aggregate varies when compared to that recommended in HD36/06. Figure 10 shows the relationship between the proportion of the network below IL, against the recommendation in HD36/06 and the actual aggregate used.

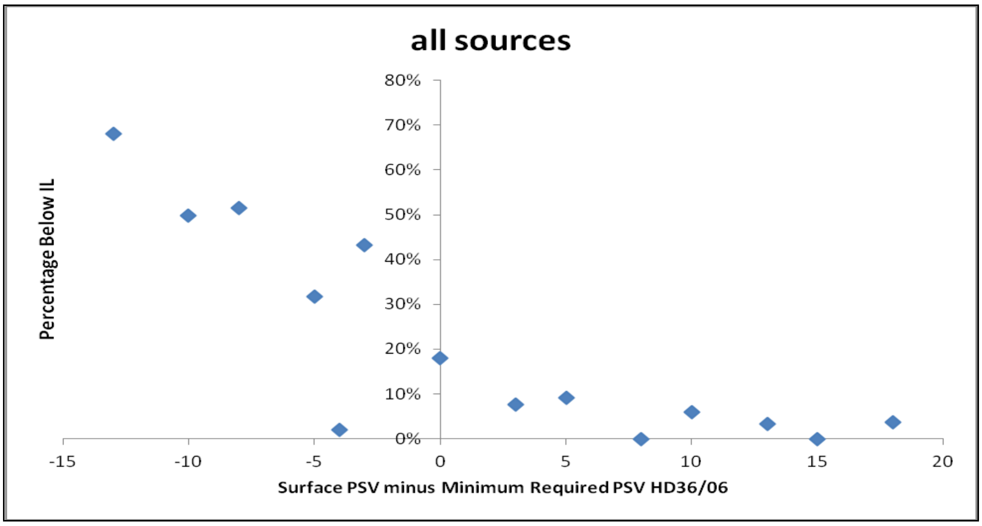


Figure 10: SCRIM against design PSV.

Figure 10 indicates that where the specified PSV is below IL there is a higher probability that the road will be below IL, and that even when the correct IL to HD36/06 has been specified there is still around a 20% probability that the MSSC will be below IL.

Providing skid resistance at high Investigatory level sites

The data presented indicate that authorities have a safety risk to manage where the SCRIM performance is below IL, and this risk is likely to be greater where the IL is at its highest. This is typically at two types of sites; rural bends and approaches to crossings. From accident studies undertaken by W.D.M. limited for a number of authorities these site categories typically have the highest crash rate and the consequences of crashes are likely to be more severe.

A study into the performance of High Friction Surfacing (HFS) in London (Stephenson and Hodgson 2014) considered the performance of HFS in London, and compared it with high PSV 'conventional' surfacing materials.

On the London Principal road network there are 4500 separate sites identified as 'approaches to crossings.' The accident rate at these crossings is higher than for any other site category, with the potential to realise the best rate of return from targeted investment to improve the skid resistance. HFS is routinely used at new crossings, but is not always maintained. Construction records were obtained for a number of sites and the SCRIM performance analysed. Figure 11 shows the performance of a number of different 68+ PSV aggregates compared to two different HFS surfaces, and table 1 shows the proportion of data from different sources above different IL's. This data indicates that some of the 68+ PSV aggregate asphaltic materials provide a high probability of achieving an IL of 0.50; however, a less than 50% probability of achieving 0.55. The HFS provides a higher skid resistance than the asphaltic materials and therefore a greater confidence in meeting the IL's. The adopted IL's for approaches to crossings in London are 0.55 as default, which can be reduced to 0.50 following a site audit.

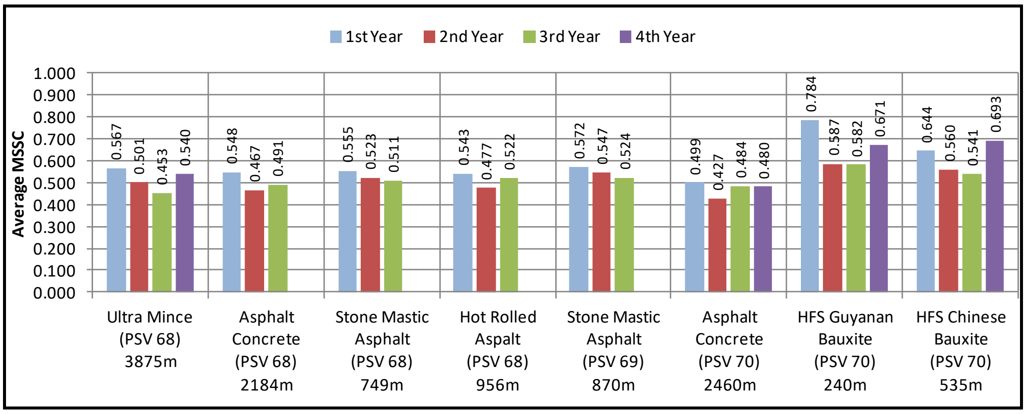


Figure 11: High PSV and HFS performance on approaches to crossings

Table 1: Level of Skid Resistance by Surface Type

Surface Type	Length Above 0.50 (%)	Length Above 0.55 (%)
ULM Ultra Mince (PSV 68)	86%	69%
Asphalt Concrete (PSV 68)	79%	46%
Stone Mastic Asphalt (PSV 68)	79%	48%
Hot Rolled Asphalt (PSV 68)	84%	52%
Stone Mastic Asphalt (PSV 69)	61%	50%
Asphalt Concrete (PSV 70)	52%	3%
HFS Guyanan Bauxite (PSV 70)	100%	100%
HFS Chinese Bauxite (PSV 70)	81%	72%

Conclusion

SCRIM has been used to measure Skidding Resistance since 1967, and is accepted as the primary measurement technique in the UK, New Zealand and many other countries. The application of a skid policy based on SCRIM has been demonstrated to offer a significant benefit cost ratio in terms of crash reduction when set against the cost of new surfaces.

Skid policies have been developed that take an investigatory approach, with targeted interventions on those sites where there is the greatest potential benefit. An integral part of any skid strategy is the selection and use of appropriate aggregates in new construction and maintenance. There are different approaches that can be adopted; but an understanding of how an aggregate performs over the predicted life of a surface is critical to an effective asset management strategy. The analysis of data for a number of highway authorities indicate that it is difficult to guarantee that all roads will perform above investigatory level; however, through the judicious selection of aggregate the safety risks of lower than desirable skidding resistance can be managed.

This may mean, for the highest risk sites a requirement for more extensive use of High Friction Surfacing.

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