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A procedure for justifying aggregate use
based on in-service skid performance

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Executive Summary

The Scottish Road Research Board commissioned a study to develop a procedure that could be used to assess and compare the relative in-service skid resistance of road surfacing made with different coarse aggregates. The aim of the study is to establish a method that compares the skid performance of two aggregates with a different Polished Stone Value (PSV), particularly where one has a lower PSV than would normally be required by published Standards. Such a system could generate several improvements, particularly in the north of Scotland, as it could reduce the need to import aggregates, resulting in reduced emissions from haulage providing a more cost effective and sustainable alternative.

With the assistance of Transport Scotland, BEAR Scotland, The Highland Council and WDM, a case study on the Isle of Skye was used to collect and analyse skid resistance measurements made on road surfacing that utilises a range of aggregate sources. This report documents the methods used to collect and analyse the data, and recommends a methodology that could be used in other areas of Scotland.

Sconser Quarry is located on the Isle of Skye and produces an aggregate with a PSV of 51. The aggregate is used on The Highland Council's local road network and anecdotal evidence suggests that it performs well in terms of both durability and skid resistance. However, the aggregate is not currently used on Skye's A87 trunk road as this requires aggregates with a PSV of 55 or higher. This is due to current national guidelines on selecting aggregate which is related to the physical layout of the road and traffic flow characteristics. The guidelines are intended to carry a degree of flexibility but are normally interpreted rigidly.

Friction measurements were collected on both local roads and the A87 trunk road using both SCRIM and GripTester devices. In an attempt to make a fair comparison, the friction data collected on local roads was divided up into site categories, which considers factors such as road geometry and traffic levels. This permitted the data collected on Sconser aggregate to be broadly matched with data collected on aggregates used on the trunk road.

The findings of the case study suggest that, despite Sconser aggregate possessing a low PSV of 51, it performs at a similar level to many of the imported aggregates currently being used on the trunk road when similar site categories and traffic levels are compared. On the basis of this in-service performance, it is recommended that Sconser aggregate be considered for use on non-event sites located on the A87 trunk road. It is proposed that this be done as part of a trial and be monitored by Transport Scotland's ongoing trunk road SCRIM surveys and assessment in line with HD28. The study showed that the use of smaller aggregate mixtures (6 and 8 mm) enhances the friction provided by asphalt mixtures, and consideration should be given to trialling the use of Sconser aggregate on site categories that demand a higher level of friction, e.g. gradient sites, but carry low levels of commercial traffic i.e. <100cv/d.

Based on the study, a method to justify the use of local or alternative aggregates is presented. Where the use of aggregate with a low PSV is being considered as an alternative aggregate, a procedure is outlined that could be used across similar areas of Scotland. It is intended that the proposed system will provide a method of gathering evidence that can be used by contractors and clients to provide more confidence in using and specifying alternative aggregate sources.

1 Introduction

The Scottish Road Research Board (SRRB) commissioned a study to develop a procedure that could be used to assess and compare the relative in-service skid resistance of road surfacing made with different coarse aggregates. A system is required that will provide designers and producers with an evidence base that will allow them to consider specifying alternative aggregate sources for new and maintenance construction. The absence of an existing method is considered to be a significant obstacle to designers wanting to specify aggregates that are known to perform well in service, but possess a lower polished stone value (PSV) than that required by existing design standards.

The establishment of a method that provides evidence that an aggregate with a low PSV can provide similar in-service performance to an aggregate with a higher PSV, has several potential advantages. For example, an increase in the use of local aggregates, particularly in the north of Scotland, would reduce the need to import aggregates, significantly cut emissions from haulage and provide a more cost effective and sustainable option.

1.1 Background

For the purposes of providing adequate skid resistance on the road network, current UK Standards stipulate that, if no other supporting information is available, the coarse aggregate used in a surface course must possess a minimum PSV. The minimum PSV value required is dependent on Site Categories that relate to the physical layout of the road and traffic characteristics, and is declared in HD36. One of the guiding principles behind the selection of a suitable aggregate is to ensure the aggregate in question retains its skid resistant properties throughout the service life of the surface course.

The northern Scottish trunk road network is predominantly single carriageway, with a high proportion of junctions and bends with radii of less than 500m. Many of these sites are categorised as higher risk or stress 'event' sections under HD28 (Skid Resistance) and the Scottish Ministers, Skid Resistance Policy. Aggregates with high PSVs (≥ 60) are generally required by HD36 to provide elevated levels of skid resistance. The bulk of the quarries located in the northern part of Scotland produce aggregates with PSVs in the range of 50-60. Given the diverse geographical nature of the Scottish trunk road network, the financial and environmental costs of importing aggregate with high PSVs to remote asphalt plants is arguably higher than in other parts of the United Kingdom.

It is recognised that the in-service skid performance is not wholly predicted by PSV. Advice in the form of a foot note to Table 3.1 of HD36 does permit designers to specify alternative (lower) PSVs where knowledge or experience suggests performance is acceptable. Experience in Scotland has been that in some situations local aggregates with lower PSV values perform well and provide adequate skid resistance during their service life. Wetter weather in combination with lower traffic volumes are considered to be two of the factors that contribute to this observed performance. However, the source of this knowledge is generally anecdotal in nature and can be difficult to demonstrate when questioned in more detail.

Transport Scotland's new surface course specification (TSIA 35, 2015) introduced a more flexible approach to the traditional selection of aggregates used in asphalt surfacing. Rather than aggregates being selected based on a single laboratory test method (PSV) and the surface of the material being controlled by an initial texture depth, surface courses are instead tested in service and the performance data collected is shared with designers and suppliers to improve their knowledge of the aggregate mixture's performance. The concept is that over time aggregate selection will be based on performance in service.

1.2 Objective and output

The study aims to establish a methodology that can be used to determine the relative in-service properties (in terms of skid resistance) of locally sourced aggregates of varying types and sizes, and compare and contrast with other materials (varying by nominal aggregate size and PSV) to determine if a more sustainable option can be specified on future maintenance schemes.

With the assistance of Transport Scotland, BEAR Scotland, The Highland Council and WDM, a case study on the Isle of Skye was used to collect and analyse data on a range of road surfacing. This report documents the methods used to collect and analyse the data and recommends a methodology that could be used across other areas of Scotland. The proposed system provides a method of gathering evidence that can be used by designers, suppliers and clients to provide more confidence in using and specifying alternative aggregate sources.

2 Case study – Sconser aggregate, Isle of Skye

Sconser Quarry is located on the Isle of Skye and produces an aggregate with a PSV of 51. The aggregate is not currently used on Transport Scotland’s trunk road (A87) as in most locations HD36 leads to the selection of aggregates with a PSV of 55 or higher due to the geometry of the road network. As a result, aggregates with a higher PSV are currently transported into Skye from the mainland, which results in an increase in the cost of laying surface courses on the Isle of Skye.

Figure 2.1¹ shows that the quarry is located off the A87 between Portree and Broadford. The quarry produces a quartzite aggregate and is used in surface courses laid on The Highland Council’s local road network. Anecdotal evidence suggests that it performs well in terms of durability and skid resistance.

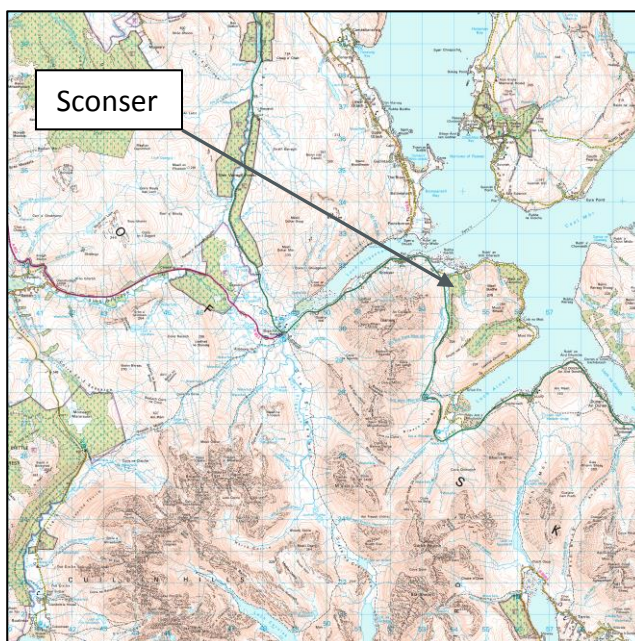


Figure 2.1: Location of quarry on Skye¹

Table 2.1 shows some of the key physical properties of Sconser aggregate. The data was provided by Sconser Quarry.

Table 2.1: Sconser aggregate’s physical properties

Property	Current Result	Category	Date
Flakiness Index	2 - 14	FI15	12-Mar-15
Resistance to fragmentation	16	LA20	01-Dec-14
Polished Stone Value	51*	PSV50*	16-Dec-14
Resistance to abrasion	2.2	AAV10	01-Dec-14
Durability – water absorption	0.8	WA241	12-Aug-13
Durability - soundness	1	MS18	21-Aug-13

*Average of last three PSV determinations.

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3 Methodology

In order to compare the in-service performance of the locally produced Sconser aggregate against other aggregates currently used on the A87 trunk road network, the study was broken into four main stages:

- selection of test sites;
- skid resistance testing on trunk and local roads;
- categorisation of local roads and allocation of Investigatory Levels; and
- comparison of data from similar sites.

The approach to the study was to collect friction data with two different devices: SCRIM and GripTester. Sections on the A87 trunk road (imported aggregate) would be tested along with sections of The Highland Council's local roads (Sconser aggregate).

In an attempt to make a fair comparison, it was recognised that the data collected on the Sconser aggregate needed to be broadly comparable with the A87 sections in terms of road geometry and traffic levels. For the trunk road data, Site Categories in accordance with HD28 already existed and could be accessed through Transport Scotland's pavement management system. However, only traffic data was available for The Highland Council's local roads that contained the Sconser aggregate. An exercise to determine Site Categories was therefore undertaken to categorise sections of road containing Sconser aggregate in accordance with HD28, i.e. to provide Site Categories in terms of general character (road layout and geometry) and traffic levels.

Once Site Categories for the test sections were established, SCRIM Investigatory Levels (IL) were allocated as defined in HD28. The IL represents the level of skid resistance above which performance is considered to be adequate, and below which a site will be investigated to see if the skid resistance should be improved. It is dependent upon the road geometry and environment, e.g. an approach to a junction or roundabout will require more skid resistance than a single carriageway on a relatively straight line. The IL for each site on the trunk road network was extracted from Transport Scotland's Pavement Management System, whereas the IL for sites on the local road network was determined by The Highland Council, aided by BEAR Scotland.

Once comparable sections had been identified, data collected on these sections were compared. In particular, data collected on the Sconser aggregate was examined to see what level of friction is likely to be provided if used on the A87 trunk road.

4 Skid resistance testing

In-service friction data was collected using both SCRIM (collected by WDM) and GripTester (collected by BEAR Scotland). The SCRIM surveys were carried out between 18 and 22 September 2015 and the GripTester surveys were carried out between 14 and 18 September 2015.

4.1 SCRIM

In the UK, skidding standards for in-service roads are defined in terms of low-speed wet skid resistance of the road surface. This property is normally assessed in terms of the SCRIM coefficient (SC). The sideways-force coefficient routine investigation machine (SCRIM) is an



Figure 4.1: SCRIM

HGV-type vehicle, which measures the Sideways Force Coefficient (SFC). Connected to the machine's chassis is a freely-rotating, loaded, smooth test wheel fitted at a 20° angle to the direction of travel. An on-board transducer is used to measure the ratio between the force developed perpendicular to the plane of the test wheel and the vertical load on the wheel and this is used to calculate the SFC. The test machine also consists of an automatic watering system (AWS) which wets the road in front of the test wheel.

SCRIM surveys are used annually for monitoring the Scottish trunk road network to identify locations where SCRIM values drop below a predetermined IL (HD28). Measurements and site data are uploaded onto Transport Scotland's pavement management system (PMS), from where it can be extracted for analyses.

Data used in this report was collected at 50km/h and taken at 10m intervals. It should be noted that all the data collected was adjusted from the original raw data to calculate the Characteristic SCRIM Coefficient (CSC) following the methodology defined in HD28, i.e. a small, similar correction was applied to all the SCRIM data to allow for seasonal variations.

4.2 GripTester

The GripTester provides results known as the grip number or GN. The device uses a different measurement principle to the SCRIM and the results are not directly comparable. In this report all GripTester data are reported as GNs. The use of a different device provides confidence in the skid resistance measurements made as part of the study.

The GripTester is a trailer-based surface friction measuring device. It consists of two drive wheels and a single smooth test wheel. In operation, a geared mechanism between the drive wheels and the test wheel, maintains a relative slip of just over 15% of the tow vehicle speed. This causes the test wheel to rotate at a slower rate than



Figure 4.2: GripTester in tow

the other two wheels thereby generating a braking force. Two strain gauges continuously measure the induced stress in the axle which is then used to calculate drag and load. The ratio of these forces is used to calculate the GN. The surface in front of the test wheel is wetted using an AWS, similar to SCRIM.

For this study the data collected was taken at 1m intervals using the standard speed of 50km/h. Location referencing markers were inserted by the operator and a Global Positioning System (GPS) was used to record the location of the vehicle.

5 Test sites and data collection

5.1 Test sites

In order to compare the in-service performance of the different surface courses, a range of sites were selected. All the sites consist of single carriageway layout. The Highland Council local road sites contain Sconser aggregate, and trunk road sites contain various imported aggregates with PSVs ranging between 55 and 65. Table 5.1 and 5.2 gives the general location of each site. The site numbering is based on the order that the sites were tested by the GripTester. The location of each site within Skye is provided in Appendix A.

Table 5.1: Test sites for Skye – local roads

Site No.	Road	General Location
1	A863	Drynoch
2	B8009	Satran
5	A855	Storr
6	A855	Score Bay
10	B8083	South of Broadford
12	A851	Kinloch
13	A851	Skulamus
16*	A890	Nostie Dam

*Site 16 is just off the Isle of Skye and on the Scottish mainland, but due to its very close proximity to Skye it was considered appropriate to include.

Table 5.2: Test sites for Skye – trunk road

Site No.	Road	General Location
3.1	A87	South of Portree
3.2	A87	South of Portree
4.1	A87	Sconser
4.2	A87	Sconser
4.3	A87	Sconser
7	A87	Earlish
8.1	A87	South of Borve
8.2	A87	South of Borve
9	A87	South of Sconser
11.1	A87	Skulamus
11.2	A87	Broadford, West
11.3	A87	Broadford, East

5.2 Material properties

Material properties for surfacing on the trunk road test sites were extracted from Transport Scotland's PMS, including: material type and specification; the nominal coarse aggregate size used; PSV; and surfacing date (age). Data for the local road sites was collated from The Highland Council's own laying records.

In general the local roads, containing Sconser aggregate, are surfaced with asphalt concrete (AC)² and the trunk road is surfaced with stone mastic asphalt (SMA) complying with Clause 942 (MCHW 1). In some instances tested sites contained lengths of hot rolled asphalt and high friction surfacing; data collected on these materials was removed.

Details of the surface properties for each of the test sites can be found in Appendix B.

5.3 Commercial traffic levels

Figure 5.1 shows the distribution of the commercial traffic levels throughout all of the test sites. Blue indicates traffic levels on local roads and red indicates traffic levels on the trunk road. The majority of traffic levels are similar i.e. <100cv/d. Volumes of commercial traffic carried at each site are given in Tables 6.1 & 6.2. All the traffic levels are within the lowest band in HD36 which is 0-250cv/d. It is noted that throughout Skye the highest recorded commercial traffic level is 181cv/d.

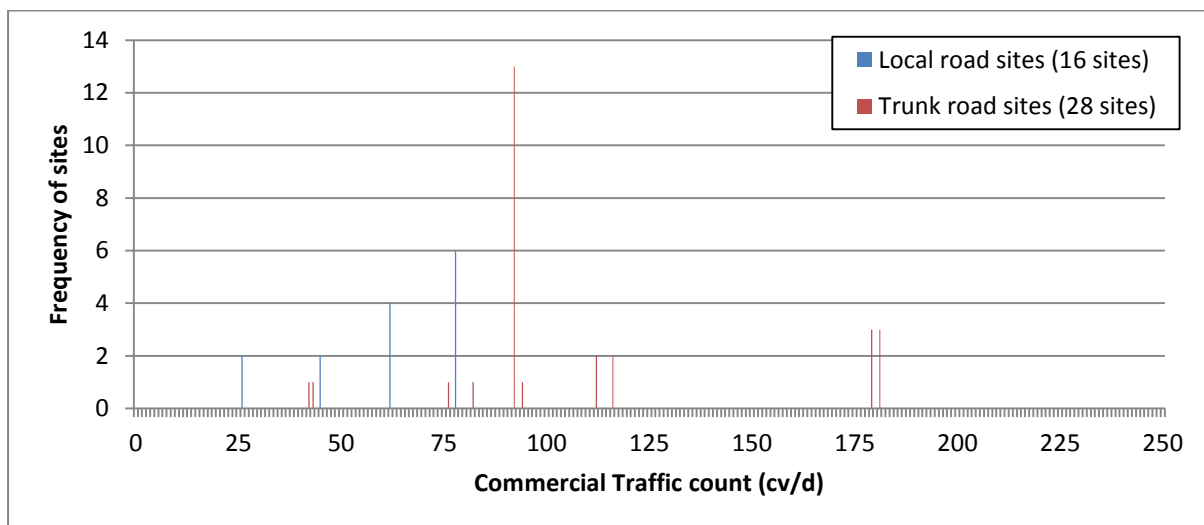


Figure 5.1: Commercial Traffic count for all test sites

5.4 SCRIM data

SCRIM results were extracted from Transport Scotland's PMS. Using easting and northing coordinates, SCRIM data was extracted for each site with start and end points corresponding to the GripTester surveys. SCRIM results for each site were then divided into IL categories for further comparison.

² The introduction of European Standards (EN) in 2008 changed the way in which traditional UK asphalt materials were described and designated. The asphalt concrete referred to in the study was traditionally known as dense bitumen macadam (DBM).

5.5 GripTester analysis

Once the GripTester surveys were completed, spreadsheets containing all of the completed runs were submitted to TRL by BEAR Scotland for analysis. For each site, a minimum of two runs were completed in both directions. As is normal practice, the average grip number for a run was used if the subsequent run was within 0.02GN. Data from one site was deemed unreliable and excluded from the study as it was unable to produce at least two runs within 0.02GN.

The data was also reviewed to ensure the 10% speed tolerance was applied. The target speed was 50km/h and any 1m average GN that was not taken between the speeds of 45-55km/h was excluded. Attention was also given to the rate of water flow and location referencing to the start and end point of each site.

6 Skid resistance measurements

This section of the report summarises the skid resistance measurements taken at each site. Some of the data displayed in the Tables 6.1 & 6.2 was not used in further analysis as the section was deemed to be too short (<50m). Full details are given in Appendix B.

6.1 Skye, local road network

Table 6.1 shows the SCRIM and GripTester results for all local road sites including traffic levels and IL. Colour coding has been used to emphasise the demand for friction: low (light green), medium (orange) and high (pink). SCRIM results have been highlighted green or red to indicate whether they are above or below the IL, respectively.

Table 6.1: GripTester and SCRIM results for local road sites

Site	Location	Dir.	cv/d	Description	IL	SCRIM (CSC)	GripTester (GN)
1	Drynoch	EB	78	Single Non-event	0.4	0.51	0.77
				Single Tight Bend	0.5	0.53	0.71
				Approach to Junction	0.5	0.52	0.75
		WB	78	Single Non-event	0.4	0.63	0.76
				Single Tight Bend	0.5	0.66	0.72
				Approach to Junction	0.5	0.63	0.69
2	Satrin	EB	78	Single Non-event	0.4	0.54	0.76
				Single Tight Bend	0.5	0.55	0.74
		WB	78	Single Non-event	0.4	0.49	Unreliable data
				Single Tight Bend	0.5	0.49	
5	Storr	NB	45	Single Non-event	0.4	0.73	0.84
				Approach to Junction	0.5	0.64	0.83
		SB	45	Single Non-event	0.4	0.65	0.84
				Approach to Junction	0.5	0.68	0.80
6	Score Bay	NB	21	Single Non-event	0.4	0.51	0.64
				Gradient 5-10%	0.45	0.51	0.67
				Single Tight Bend	0.5	0.54	0.67
		SB	21	Single Non-event	0.4	0.53	0.66
				Gradient 5-10%	0.45	0.53	0.70
				Single Tight Bend	0.5	0.55	0.69
10	South of Broadford	NB	26	Single Non-event	0.4	0.55	0.77
				Gradient 5-10%	0.45	0.57	0.81
				Single Tight Bend	0.5	0.56	0.76
		SB	26	Single Non-event	0.4	0.56	0.80
				Gradient 5-10%	0.45	0.55	0.76
				Single Tight Bend	0.5	0.55	0.76
12	Kinloch	NB	62	Single Non-event	0.4	0.48	0.63
				Single Tight Bend	0.5	0.46	0.57
		SB	62	Single Non-event	0.4	0.47	0.64
				Single Tight Bend	0.5	0.44	0.53

Table 6.1: GripTester and SCRIM results for local road sites (cont.)

Site	Location	Dir.	cv/d	Description	IL	SCRIM (CSC)	GripTester (GN)
13	Skulamus	NB	62	Single Non-event	0.4	0.47	0.67
				Gradient 5-10%	0.45	0.48	0.68
				Single Tight Bend	0.5	0.42	0.67
		SB	62	Single Non-event	0.4	0.49	0.66
				Gradient 5-10%	0.45	0.48	0.61
				Single Tight Bend	0.5	0.47	0.57
16*	Nostie Dam	NB	78	Single Non-event	0.4	0.55	0.76
		SB	78	Single Non-event	0.4	0.55	0.75

*Site 16 is just off the Isle of Skye and on the Scotland mainland, but due to its close proximity to Skye it was considered appropriate to use.

6.2 Skye, trunk road

Table 6.2 shows similar results for all the trunk road sites. Note that sites 4.2 and 4.3 have been split, this is due to two different coarse aggregate sources used at these locations.

Table 6.2: GripTester and SCRIM results for trunk road sites

Site	Location	Dir.	cv/d	Description	IL	SCRIM (CSC)	GripTester (GN)
3.1	South of Portree	CL	92	Single Non-event	0.4	0.47	0.67
		CR	92	Single Non-event	0.4	0.44	0.63
3.2	South of Portree	CL	92-72	Single Non-event	0.4	0.50	0.74
				Gradient 5-10%	0.45	0.53	0.74
				Single Tight Bend	0.5	0.48	0.69
		CR	92-59	Single Non-event	0.4	0.49	0.73
				Gradient 5-10%	0.45	0.49	0.71
				Single Tight Bend	0.5	0.49	0.73
4.1	Sconser	CL	92	Single Non-event	0.4	0.45	0.63
		CR	92	Single Non-event	0.4	0.49	0.69
4.2	Sconser	CL	92	Single Non-event	0.4	0.53	0.75
		CR	92	Single Non-event	0.4	0.58	0.81
	Sconser	CL	92	Single Tight Bend	0.5	0.58	0.75
		CR	92	Single Tight Bend	0.5	0.59	0.80
4.3	Sconser	CL	92	Single Non-event	0.4	0.55	0.79
				Gradient 5-10%	0.45	0.57	0.81
		CR	92	Single Non-event	0.4	0.57	0.75
				Gradient 5-10%	0.45	0.54	0.75
	Sconser	CL	92	Approach to Junction	0.5	0.58	0.80
		CR	92	Approach to Junction	0.5	0.59	0.78

Table 6.2: GripTester and SCRIM results for trunk road sites (cont.)

Site	Location	Dir.	cv/d	Description	IL	SCRIM (CSC)	GripTester (GN)
7	Earlish	CL	42	Single Non-event	0.4	0.61	0.78
				Single Non-event	0.4	0.60	0.77
				Single Tight Bend	0.5	0.52	0.73
				Approach to Junction	0.5	0.52	0.76
		CR	43	Single Non-event	0.4	0.53	0.78
				Single Tight Bend	0.5	0.57	0.76
Approach to Junction	0.5			0.54	0.81		
8.1	South of Borve	CL	116	Single Non-event	0.4	0.52	0.79
				Gradient 5-10%	0.45	0.61	0.85
				Single Tight Bend	0.5	0.62	0.81
		CR	112	Single Non-event	0.4	0.52	0.83
				Gradient 5-10%	0.45	0.49	0.86
				Single Tight Bend	0.5	0.48	0.78
8.2	South of Borve	CL	116	Single Non-event	0.4	0.49	0.72
				Gradient 5-10%	0.45	0.52	0.76
				Single Tight Bend	0.5	0.48	0.69
		CR	112	Approach to Junction	0.5	0.46	0.78
				Single Non-event	0.4	0.49	0.75
				Gradient 5-10%	0.45	0.49	0.75
CR	112	Single Tight Bend	0.5	0.46	0.74		
		Approach to Junction	0.5	0.47	0.65		
9	South of Sconser	CL	181	Single Non-event	0.4	0.53	0.72
				Gradient 5-10%	0.45	0.52	0.70
				Single Tight Bend	0.5	0.42	0.67
		CR	179	Single Non-event	0.4	0.50	0.72
				Gradient 5-10%	0.45	0.52	0.71
				Single Tight Bend	0.5	0.48	0.63
11.1	Skulamus	CL	94	Single Non-event	0.4	0.42	0.62
				Gradient 5-10%	0.45	0.41	0.65
		CR	92	Single Non-event	0.4	0.43	0.59
				Gradient 5-10%	0.45	0.43	0.59
				Single Tight Bend	0.5	0.42	0.60
11.2	Broadford, West	CL	181	Single Non-event	0.4	0.48	0.69
				Single Tight Bend	0.5	0.47	0.65
				Approach to Junction	0.5	0.46	0.68
		CR	179	Single Non-event	0.4	0.57	0.68
				Single Tight Bend	0.5	0.44	0.68
				Approach to Junction	0.5	0.53	0.64
11.3	Broadford, East	CL	181	Single Non-event	0.4	0.49	0.67
				Single Tight Bend	0.5	0.49	0.69
				Approach to Junction	0.5	0.51	0.69
		CR	179	Single Non-event	0.4	0.46	0.65
				Single Tight Bend	0.5	0.47	0.61
				Approach to Junction	0.5	0.48	0.62

7 Data comparison

In order to provide a sensible comparison between the skid resistance performance of the Sconser aggregate and those materials laid on the trunk road, this chapter examines the data by stress levels or Site Category, viz. non-event, gradient, tight bend and approach to a junction. For each Site Category a brief site description is given together with graphs that show both SCRIM and GN results along with age of surfacing. The scatter plots show the skid resistance data for the local roads (Sconser, PSV 51) and trunk roads (various PSV as indicated in the key to the graphs). The graphs displaying SCRIM results have been annotated to show the ILs as declared in HD28. It is important to note that the IL does not mean that the surfacing requires to be replaced, but is a trigger for investigation. A detailed comparison of local roads and trunk roads is then given based on the graphs.

For each site tested there are generally two results, one for each direction of traffic flow, these results will appear one above the other as they are of a similar age. Some sites do not have two results owing to one of the runs being considered unreliable or when the site has a particular stress level in one direction but not in the other.

7.1 Non-event sites

Single non-event sites are described in HD28 as single carriageways where traffic is generally free-flowing on relatively straight lines. With the exception of dual carriageways and motorway non-event sites, these sites require a low skid resistance in comparison to other site classes.

Figures 7.1 and 7.2 show the SCRIM and GripTester results on single non-event test sites, respectively. Sites of particular interest are numbered with dark circles and can be cross referenced to tables in section six.

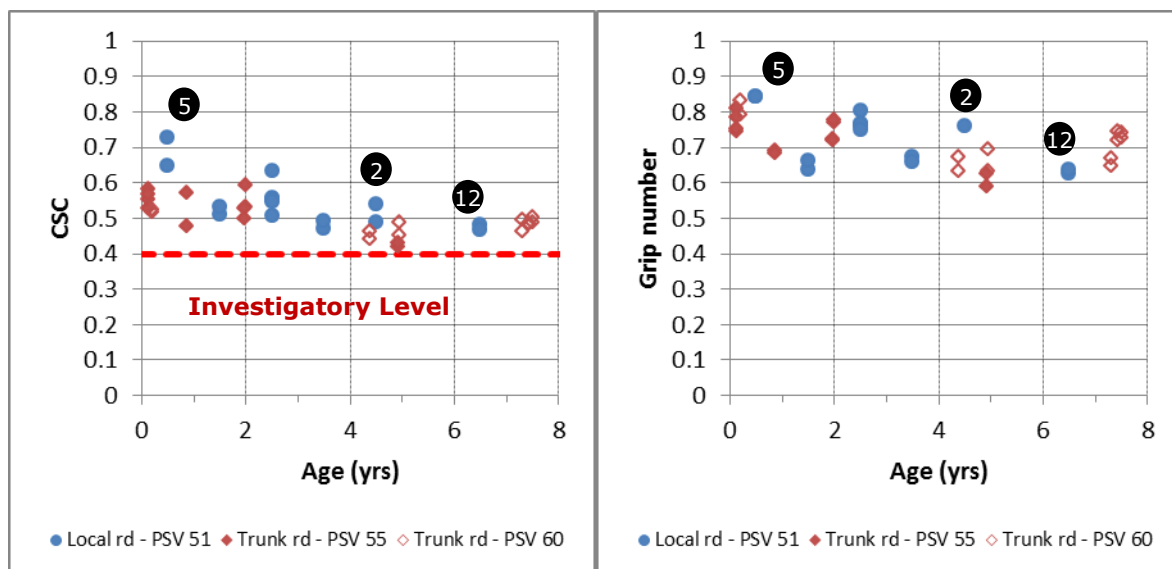


Figure 7.1: Non-event SCRIM results

Figure 7.2: Non-event GripTester results

It can be seen from Figures 7.1 and 7.2 that there is some scatter in the data but both the SCRIM and GripTester results broadly show a similar trend of skid resistance falling with age

or cumulative traffic. However, the trend is less pronounced if early-life data is removed, i.e. results for material that is less than one year old.

The skid resistance of a road surfacing over its life is known to change and can be generally broken into three phases: early life, polishing and equilibrium. The duration of each phase varies depending on the traffic levels and other conditions to which the road is subject. Normally sites that are less than one year old are excluded from CSC calculations because of early life effects, such as a film of bitumen covering the surface of newly-laid material, or the extent of polishing means the aggregate has not reached an equilibrium level. This should be borne in mind when reviewing the results in the material's early life.

The site providing the highest friction is Site 5 (Figures 7.1 & 7.2). It comprises a 10mm AC made with Sconser aggregate and has been in service for six months. It can be seen from Figure 7.3 that the aggregate at Site 5 is still partially coated with bitumen and there is no significant signs of aggregate polishing. This contrasts well with Site 2 (4.5 years old), where the bitumen has been removed and the Sconser coarse aggregate has been exposed and polished. It is likely that the high results measured on Site 5 are due to its young age and the fact that not much polishing of the aggregate has occurred. Nonetheless, it is encouraging that the material is providing high friction in its early life when compared to the results of similarly aged materials located on the A87 trunk road.



Figure 7.3: Site 5, 10mm AC



Figure 7.4: Site 2, 6mm SMA

It can be seen from Figures 7.1 & 7.2 that Site 2 is providing slightly higher CSCs and GNs than the surrounding sites that are located on the trunk road. Sites 3.1, 4.1 and 11.1 have PSVs of 60, 60 and 55 respectively. Site 2 carries 78cv/d compared to the trunk road sites which carry between 92 and 94cv/d. One of the main differences apart from the PSV values is the nominal aggregate size. Site 2 comprises a 6mm SMA and the trunk road sites are all 14mm SMAs. Nonetheless, this site shows that the 6mm Sconser aggregate performs as well or better than aggregates with PSVs of 55 & 60 on non-event sites at the age of 4.5 to 5 years with similar traffic levels.

The oldest local road site (Sconser aggregate) tested was Site 12. It was approximately 6.5 years old at the date of testing. This site provides slightly lower friction than the trunk road sites that are a little older in age (symbols to the right), but with a higher PSV of 60. The three trunk road sites are approximately 7.5 years old and carry traffic levels that vary between 59 and 181cv/d.

7.2 Gradient sites

Gradient sites are classed, in accordance with HD28, as sections of road which are longer than 50m and have a gradient of >5%, in the case of single carriageway this covers both uphill and downhill directions.

Figures 7.5 and 7.6 show the SCRIM and GripTester results on single gradient test sites, respectively.

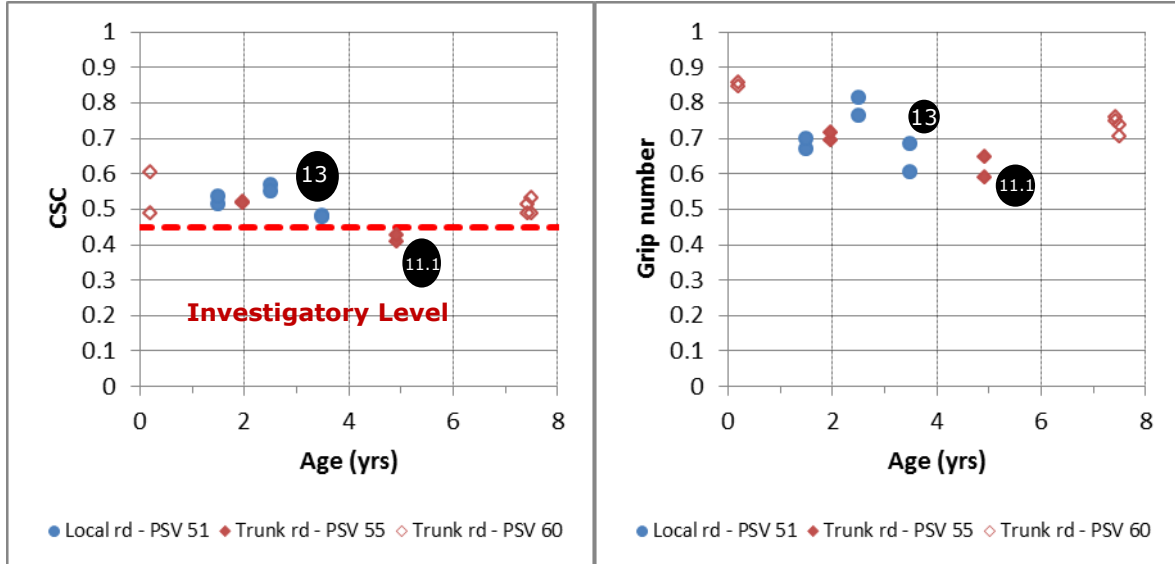


Figure 7.5: Gradient site SCRIM results

Figure 7.6: Gradient site GripTester results

The oldest sites tested were 7.5 years old and located on the trunk road and contain 60 PSV aggregates. The oldest local road site (Site 13) is 3.5 years old and carries 62cv/d. The SCRIM results are close to the IL of 0.45. Site 11.1 is located on the trunk road with a PSV 55 and carries 94cv/d, and is noted to be just below the IL after five years in service.

Owing to the relatively young nature of the local road (Sconser) data for this road category, it is not possible to say how the Sconser aggregate would perform over time, but based on the collected data it appears to perform to a similar level as the trunk road (PSV of 55) in its early life.

7.3 Tight bend sites

Tight bends are classed as bends on all road classes with a radius of <500m as well as other hazards that require combined braking and cornering.

Figures 7.7 and 7.8 show the SCRIM and GripTester results on single tight bend test sites, respectively.

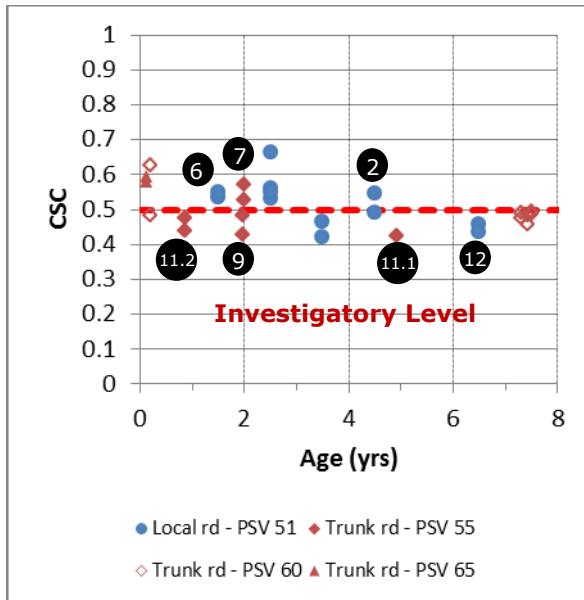


Figure 7.7: Tight bend SCRIM results

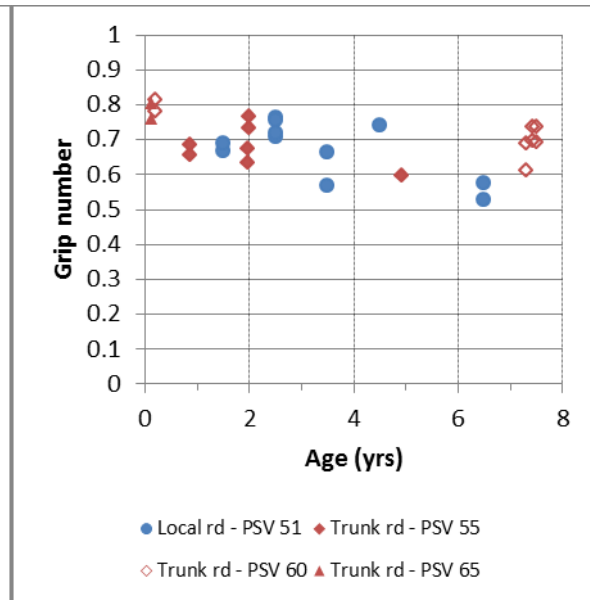


Figure 7.8: Tight bend GripTester results

Figure 7.7 shows that two of the younger trunk road sites (PSV 55) are below the SCRIM IL. These sites comprise Site 11.2 and 9, which are approximately one and two years old, respectively. These sites both carry the highest commercial traffic levels on the sites tested in Skye at 180cv/d.

Between these two trunk road sites is a local road site (Site 6), aged approximately 1.5 years. But this site carries a much lower level of commercial traffic (21cv/d) and does not make a good comparison. It can be seen from Figure 7.9 that, although lightly trafficked, the Sconser aggregate has lost most of its binder coating.



Figure 7.9: Site 6, 10mm DBM

A better comparison can be made if Site 6 is compared with Site 7 on the trunk road. Site 7 is approximately two years old and contains an aggregate with a PSV of 55. This trunk road site has a similar level of commercial traffic (42cv/d). These materials are both still young but are performing in a similar manner.

Aged at 4.5 years, Site 2 (6mm SMA Sconser) can be observed to be performing well, providing a higher level of friction than Site 11.1 which has a similar age (4.9 years) and traffic level but contains an aggregate with a PSV of 55.

The oldest local road site (Site 12) is an 8mm SMA (Figures 7.7 & 7.10) and has been in service for approximately 6.5 years and carries 62cv/d. This site is noted to have fallen below the IL SCRIM level but is noted to perform only slightly lower than the three trunk road sites with 60 PSV aggregates that are slightly older. It is observed that the grip numbers for the latter are higher than the SCRIM results. The three trunk road sites of 60 PSV carry higher volumes of commercial traffic 116-181cv/d versus 62cv/d.

From the results collected it can be observed that, on tight bends with relatively low commercial traffic volumes, the Sconser aggregate can perform at a similar level up to around 7 years, particularly if a smaller aggregate size is used in the mix.



Figure 7.10: Site 12, 8mm SMA

7.4 Approach to junction sites

Approach to a junction is classified as a site on an approach to a major or minor junction on a dual or single carriageway where frequent or sudden braking occurs in a generally straight line.

Figures 7.11 and 7.12 show the SCRIM and GripTester results on approach to junction test sites, respectively.

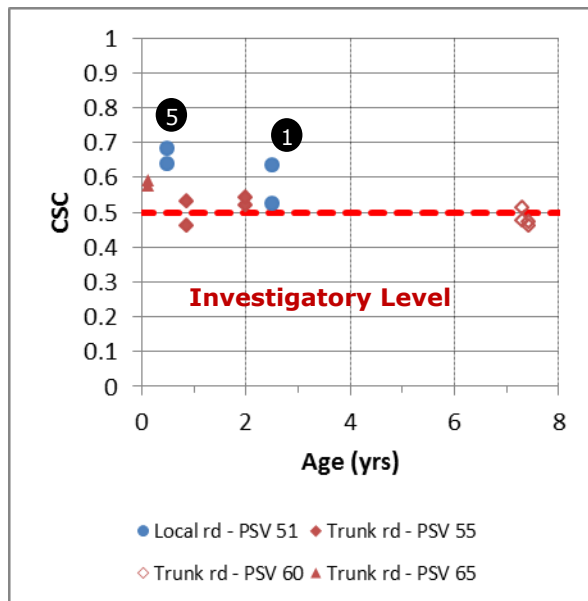


Figure 7.11: Approach to junction SCRIM results

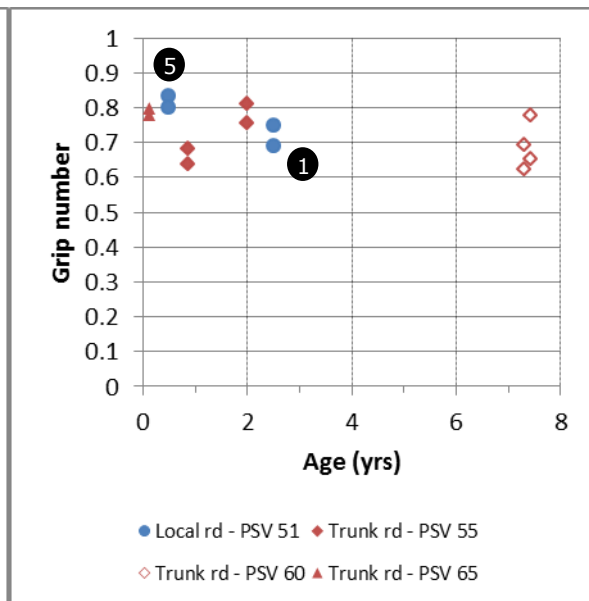


Figure 7.12: Approach to junction GripTester results

Only two local road sites were categorised as approach to junction sites. Although young (<3 years), the two sites (Sites 1 & 5) are observed to be performing similarly to trunk road sites of similar age.

One of the trunk road sites (Site 11.2, PSV 55) has fallen below the SCRIM IL (0.5 SCRIM) in one direction. This site is noted to carry the highest volume of commercial vehicles (181cv/d). This may indicate that the relatively higher volumes of traffic does generate a higher degree of polishing, particularly where there is higher demand for friction, e.g. bends, junctions, etc.

The local road site (Site 1), aged at 2.5 years, is observed to have a large gap between the two different SCRIM results (run directions) and a smaller gap with GripTester results. The layout of this site was examined in more detail. The junction includes a turn into a minor road leading to a whisky distillery which many HGVs will break at as they approach from the direction of the Scottish mainland. However, HGVs are much less likely to approach the junction from the other direction. As a result, it is likely that there is more polishing (through braking of HGVs) in the westbound direction. Despite the lower reading of this site being close to the IL it is noted that the Sconser aggregate is performing in a similar manner to a trunk road site containing an aggregate with a 55 PSV.

Although there is limited data on this Site Category, it has been observed that the Sconser aggregate can perform to a similar level as the current aggregate being used on Skye's trunk road network up to an age of approximately three years.

8 Discussion

8.1 General observations

Despite Sconser aggregate possessing a low PSV of 51, the friction measurements collected as part of this study show that it performs at a similar level to many of the higher PSV aggregates (55 to 60) used on the A87 trunk road.

In general, the skid resistance measurements on the Sconser aggregate provide a similar performance to aggregates with a 55 PSV when comparing similar site categories, traffic levels and ages. The results for the Sconser aggregate are generally above the IL for the non-event categories, but it seems that the materials incorporating the Sconser aggregate are unable to deliver skid resistance above the IL for the event categories. It should be noted that much of the imported aggregate is equally unable to deliver the required IL for the event categories.

Friction data from the study provides some evidence that where the Sconser aggregate contains smaller nominal aggregate sizes (6 & 8mm), the material can provide similar friction to 0/14mm SMA mixes with PSV values of up to 60 PSV. These findings are in agreement with road trials in the UK (Roe et al, 2008; McHale et al, 2011) that show a trend for smaller stone mixtures to provide higher skid resistance than the larger aggregate sizes currently used.

It should be highlighted that the comparisons made in this report between asphalt containing Sconser aggregate and asphalt containing imported aggregates with higher PSV values are under low volumes of traffic, varying from 21cv/d to 181cv/d. These equate to the lowest band in HD36 which is 0-250cv/d. It is also noted that even within this tight traffic band, the data suggests that slight increases in traffic levels (>100cv/d) can have an effect on the performance of all the aggregates.

It is important to note that the asphalts made with Sconser aggregate were compared directly with the nearby A87 trunk road surfacing comprising imported aggregates. This means that the sites share a similar geography, climate and traffic levels. The results should not be compared to materials used elsewhere in Scotland where conditions may be different. The climate in Skye can be characterised by relatively high rainfall and short periods between rainfall, even during summer, which will restrict the amount of polishing of road surfacing by vehicular traffic.

8.2 Method to justify the use of local aggregates

Based on this study, a proposed method for collecting road friction data to justify the use of local aggregates with low PSV values based on their performance in service is outlined below.

8.2.1 *Selection of survey sites*

Where a local aggregate has been proposed for consideration, it is important that test sites are selected so that they can be compared to the trunk road sites. For a reasonable comparison to be made, the sites need to share similar characteristics, as follows:

- Materials – it is important that the materials are broadly comparable, e.g. an SMA can be compared with another SMA or AC, but not compared to a positively textured material such as HRA.
- Age & traffic levels – selected sites need to contain materials that have been in service for a similar time period and carry similar levels of traffic.
- Site Category – sites selected should include sections with a similar road geometry to the trunk road, e.g. non-event, gradients, tight bends and approaches to a junction.
- Environment – it is important that the test sites are close to the trunk road being used for comparison and that they share a similar environment in terms of typical rainfall, temperature and climate.

8.2.2 *Survey and data comparison using SCRIM*

Minimum values of wet skidding resistance occur in the summer and early autumn. As a result, testing with SCRIM should be restricted to between May and September. Once sites have been selected, SCRIM surveys should be carried out on the test sites and trunk road sites, preferably within a short timescale and under similar weather conditions.

The current standard for skidding resistance (HD28) uses the term ‘Site Category’ to classify the road network according to the risk of skidding. For the trunk road sites, site categories will already exist and be accessible through Transport Scotland’s pavement management system.

For the local road test sites, an exercise will need to be undertaken to determine the test Site Category and Investigatory Level in accordance with HD28, e.g. non-event, gradients, tight bends and approaches to a junction, etc.

The collection of the SCRIM data will permit a comparison against Investigatory Levels to be made and reported. Based on the findings of the analyses, a decision should be made as to the suitable use of the aggregate. A summary of the SCRIM method is shown in Figure 8.1.

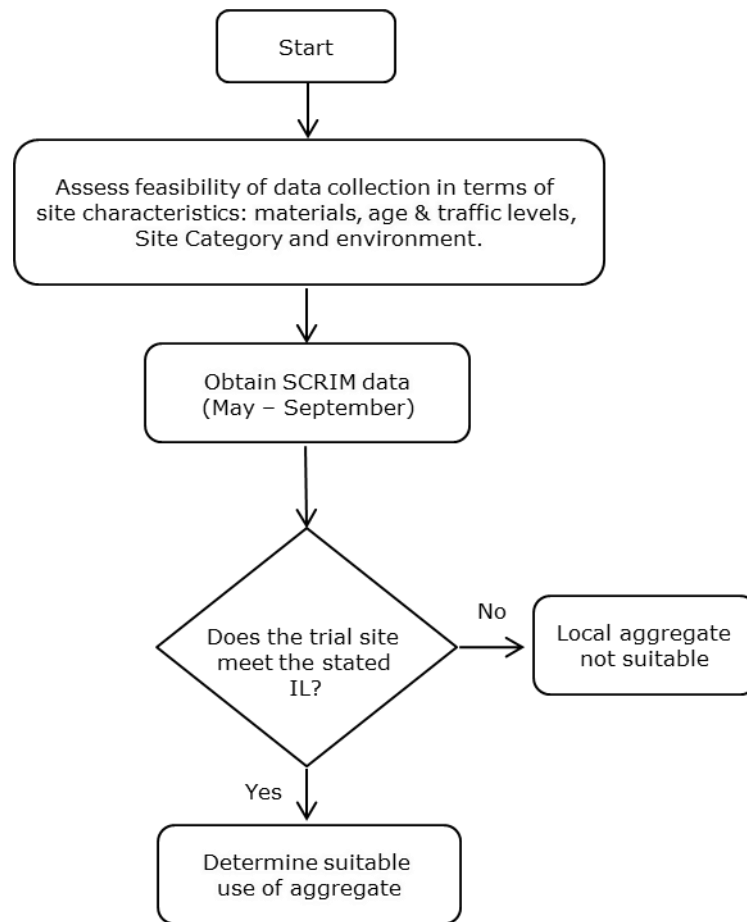


Figure 8.1 Data collection using SCRIM method

8.2.3 Survey data and comparison using GripTester

The simplest approach would be to replace each SCRIM Investigatory Level (IL) with a grip number (GN) IL. A GripTester/SCRIM conversion is available ($SC = 0.89 * GN$) although it is recommended that it be used with caution (Dunford, 2010). An examination of the SCRIM and GN data collected as part of the Skye case study does not show a strong linear relationship and a conversion based on a zero-intercept correlation is regarded to be unreliable. Data collected from GripTester precision trials in Scotland also suggest that the lighter GripTester apparatus may be more sensitive to different surfacing types, i.e. influence of aggregate size, texture depth, etc. For these reason a different approach is recommended and described below.

Similar to the SCRIM method, friction measurements using the GripTester should be carried out between May and September. Once sites have been selected, GripTester surveys should be conducted on both the test sites and trunk road sites, preferably within a short timescale and under similar weather conditions. In addition, the trunk road sites selected should cover a range of Site Categories and have achieved the required SCRIM ILs over recent survey years. These sites should subsequently be defined as 'benchmark sites'. GripTester data collected on benchmark sites can be used to assess the performance of the aggregate used on the local road sites.

For the local road test sites, an exercise will need to be undertaken to determine the test Site Category and Investigatory Level in accordance with HD28, e.g. non-event, gradients, tight bends and approaches to a junction, etc.

The collection of GripTester data on a range of Site Categories will permit a comparison with the relevant benchmarks sites, i.e. average GNs should be compared and reported. Based on the findings of the analyses, a decision should be made as to the suitable use of the aggregate. A summary of the GripTester method is shown in Figure 8.2.

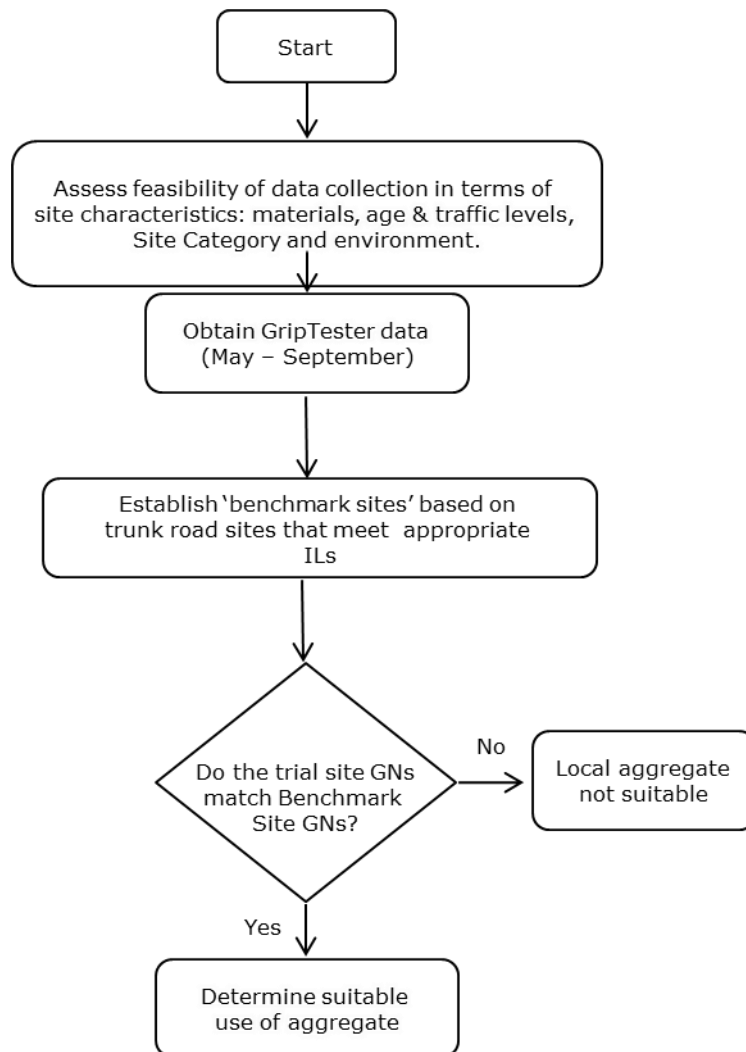


Figure 8.2 Data collection using GripTester Method

9 Conclusions and recommendations

- The friction measurements collected as part of the Skye case study show that the local Sconser aggregate (PSV of 51) performs at a similar level as many of the higher PSV aggregates (55 to 60) currently imported and used on the A87 trunk road.
- On the basis of in-service performance, Sconser aggregate should be considered for use on non-event sites located on the A87 trunk road. It is recommended that this be done as part of a trial and be monitored by virtue of Transport Scotland's ongoing trunk road SCRIM surveys and assessment in line with HD28.
- The study provides some evidence that the use of smaller aggregate mixtures (6 and 8 mm) enhances the friction provided by asphalt mixtures.
- Consideration should be given to trialling the use of Sconser aggregate on site categories that demand a higher level of friction, e.g. gradient sites, but carry low levels of commercial traffic i.e. <100cv/d. In particular, the use of smaller aggregates should be encouraged in this instance.
- Where the use of a local aggregate with a low PSV is being considered as an alternative aggregate, the procedures outlined in this report should be considered as a method to justify its use.

Acknowledgements

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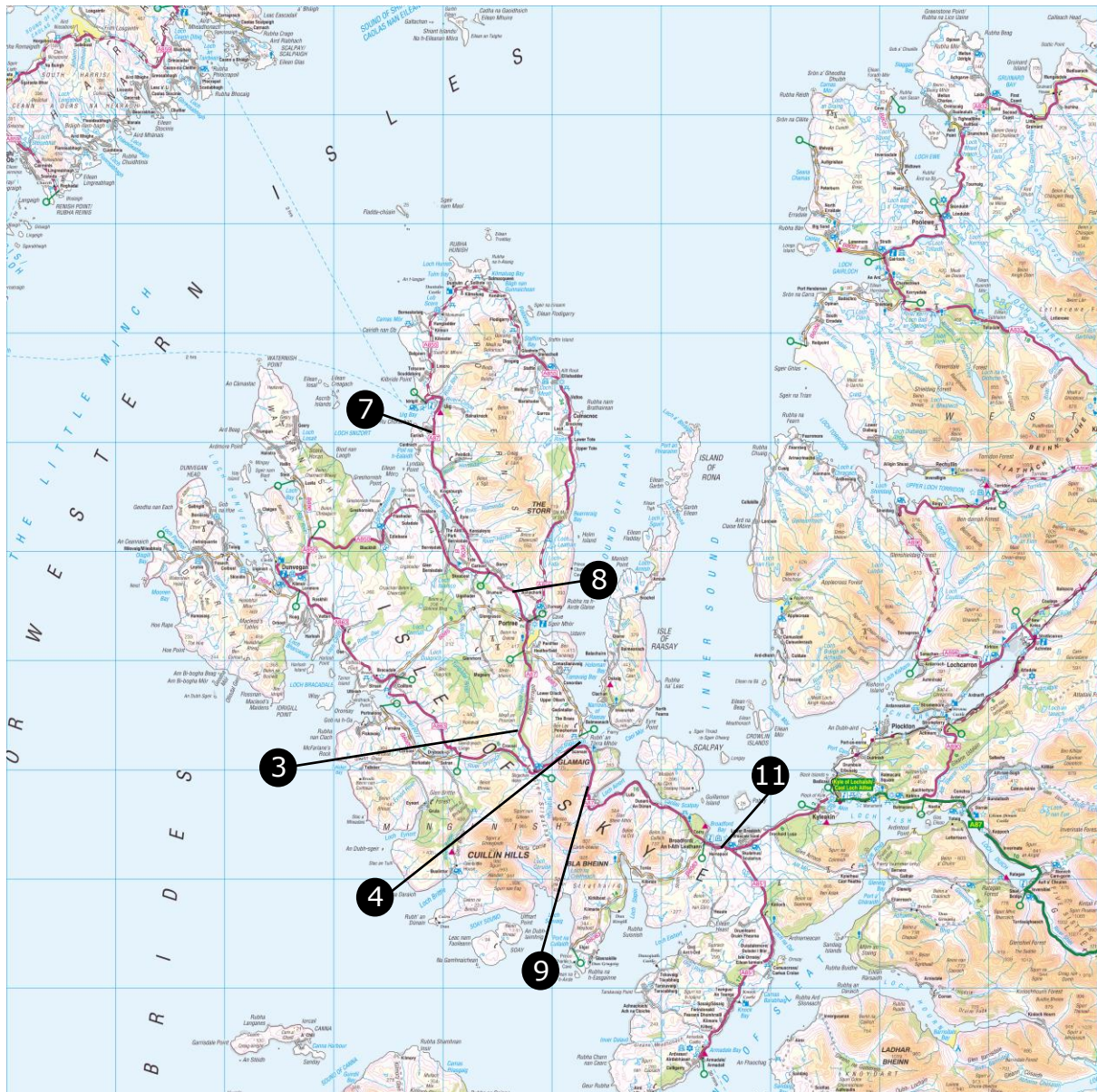
Appendix A – Maps

Figures A.1 and A.2 show the locations of the test sites on Skye. Note that some of the sites on the trunk road (Figure A.2) may have been split, i.e. Site 3 in the figure represents both Sites 3.1 and 3.2. The maps have been sourced from the Ordnance Survey†.



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Figure A.1: Local road sites on Skye



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Figure A.2: Trunk road sites on Skye

Appendix B – Site details and results

Tables B.1 and B.2 show the details and results of test sites for both local road and trunk road, respectively.

B.1 Results and details of local road sites

Site	Material Type	Coarse Agg.	PSV	Date Laid	Age at testing (yrs.)	Direction	Traffic cv/d	Description	IL	Length (m)	SCRIM (CSC)	GripTester (GN)
1	AC 10 (DBM)	Sconser	53	2013	2.50	EB	78	Single Non-event	0.4	490	0.51	0.77
								Single <500m	0.5	70	0.53	0.71
								Approach to Junction	0.5	70	0.52	0.75
						WB	78	Single Non-event	0.4	490	0.63	0.76
								Single <500m	0.5	70	0.66	0.72
								Approach to Junction	0.5	70	0.63	0.69
2	SMA 6	Sconser	53	2011	4.50	EB	78	Single Non-event	0.4	280	0.54	0.76
								Single <500m	0.5	420	0.55	0.74
						WB	78	Single Non-event	0.4	280	0.49	Unreliable data
								Single <500m	0.5	410	0.49	
5	AC 10 (DBM)	Sconser	53	2015	0.50	NB	45	Single Non-event	0.4	200	0.73	0.84
								Approach to Junction	0.5	100	0.64	0.83
						SB	45	Single Non-event	0.4	200	0.65	0.84
								Approach to Junction	0.5	100	0.68	0.80
6	AC 10 (DBM)	Sconser	53	2014	1.50	NB	21	Single Non-event	0.4	320	0.51	0.64
								Gradient 5-10%	0.45	150	0.51	0.67
								Single <500m	0.5	190	0.54	0.67
						SB	N/A	Single Non-event	0.4	320	0.53	0.66
								Gradient 5-10%	0.45	150	0.53	0.70
								Single <500m	0.5	140	0.55	0.69

B.1 Results and details of local road sites (cont.)

Site	Material Type	Coarse Agg.	PSV	Date Laid	Age at testing (yrs.)	Direction	Traffic cv/d	Description	IL	Length (m)	SCRIM (CSC)	GripTester (GN)
10	AC 10 (DBM)	Sconser	53	2013	2.50	NB	26	Single Non-event	0.4	470	0.55	0.77
								Gradient 5-10%	0.45	100	0.57	0.81
								Single <500m	0.5	310	0.56	0.76
						SB	26	Single Non-event	0.4	470	0.56	0.80
								Gradient 5-10%	0.45	100	0.55	0.76
								Single <500m	0.5	260	0.55	0.76
12	SMA 8	Sconser	53	2009	6.50	NB	62	Single Non-event	0.4	540	0.48	0.63
								Single <500m	0.5	180	0.46	0.57
						SB	62	Single Non-event	0.4	540	0.47	0.64
								Single <500m	0.5	180	0.44	0.53
13	AC 10 (DBM)	Sconser	53	2012	3.50	NB	62	Single Non-event	0.4	570	0.47	0.67
								Gradient 5-10%	0.45	120	0.48	0.68
								Single <500m	0.5	60	0.42	0.67
						SB	62	Single Non-event	0.4	570	0.49	0.66
								Gradient 5-10%	0.45	120	0.48	0.61
								Single <500m	0.5	60	0.47	0.57
16	AC 10 (DBM)	Sconser	53	2013	2.50	NB	78	Single Non-event	0.4	940	0.55	0.76
						SB	78	Single Non-event	0.4	940	0.55	0.75

B.2 Results and details of trunk road sites

Site	Material Spec	Material Type	Coarse Agg.	PSV	Date Laid	Age at testing (yrs)	Direction	Traffic cv/d	Description	IL	Length (m)	SCRIM (CSC)	GripTester (GN)
3.1	Leiths SMA	CL942 0/14	Kishorn	60	04/05/2011	4.37	CL	92	Single Non-Event	0.4	240	0.47	0.67
							CR	92	Single Non-Event	0.4	240	0.44	0.63
3.2	Leiths Rigaphalt	CL942 0/14	Edston, Peebles	60	22/03/2008	7.49	CL	92-71	Single Non-Event	0.4	2090	0.50	0.74
									Gradient 5-10%	0.45	30	0.53	0.74
									Single <500m	0.5	1440	0.48	0.69
							CR	92-59	Single Non-Event	0.4	2120	0.49	0.73
									Gradient 5-10%	0.45	40	0.49	0.71
									Single <500m	0.5	1370	0.49	0.73
4.1	Leiths SMA	CL942 0/14	Kishorn	60	04/10/2010	4.95	CL	92	Single Non-Event	0.4	580	0.45	0.63
							CR	92	Single Non-Event	0.4	580	0.49	0.69
4.2	Breedon Fibre	CL942 0/10	Banavie	55	28/07/2015	0.13	CL	92	Single Non-Event	0.4	330	0.53	0.75
							CR	92	Single Non-Event	0.4	330	0.58	0.81
	Breedon Fibre	CL942 0/10	Goathill	65	28/07/2015	0.13	CL	92	Single <500m	0.5	250	0.58	0.75
							CR	92	Single <500m	0.5	250	0.59	0.80
4.3	Breedon Fibre	CL942 0/10	Banavie	55	28/07/2015	0.13	CL	92	Single Non-Event	0.4	1450	0.55	0.79
									Gradient 5-10%	0.45	50	0.57	0.81
	CR	92	Single Non-Event	0.4	1450	0.57	0.75						
			Gradient 5-10%	0.45	50	0.54	0.75						
Breedon Fibre	CL942 0/10	Goathill	65	28/07/2015	0.13	CL	92	Approach to Junction	0.5	520	0.58	0.80	
						CR	92	Approach to Junction	0.5	520	0.59	0.78	
7	Breedon Fibre	CL942 0/14	Banavie	55	18/09/2013	1.99	CL	42	Single Non-Event	0.4	50	0.61	0.78
									Single Non-Event	0.4	1150	0.60	0.77
									Single <500m	0.5	170	0.52	0.73
									Approach to Junction	0.5	10	0.52	0.76
							CR	43	Single Non-Event	0.4	1150	0.53	0.78
									Single <500m	0.5	170	0.57	0.76
Approach to Junction	0.5	60	0.54	0.81									

B.2 Results and details of trunk road sites (cont.)

Site	Material Spec	Material Type	Coarse Agg.	PSV	Date Laid	Age at testing (yrs)	Direction	Traffic cv/d	Description	IL	Length (m)	SCRIM (CSC)	GripTester (GN)
8.1	-	CL942 0/14	Balmullo	60	08/07/2015	0.19	CL	116	Single Non-Event	0.4	700	0.52	0.79
									Gradient 5-10%	0.45	70	0.61	0.85
									Single <500m	0.5	150	0.62	0.81
							CR	112	Single Non-Event	0.4	710	0.52	0.83
									Gradient 5-10%	0.45	70	0.49	0.86
									Single <500m	0.5	150	0.48	0.78
8.2	Leith Rigaphalt	CL942 0/14	Edston, Peebles	60	17/04/2008	7.42	CL	116	Single Non-Event	0.4	510	0.49	0.72
									Gradient 5-10%	0.45	200	0.52	0.76
									Single <500m	0.5	370	0.48	0.69
									Approach to Junction	0.5	60	0.46	0.78
							CR	112	Single Non-Event	0.4	510	0.49	0.75
									Gradient 5-10%	0.45	200	0.49	0.75
									Single <500m	0.5	330	0.46	0.74
									Approach to Junction	0.5	60	0.47	0.65
9	Breedon Fibre	CL942 0/14	Banavie	55	30/09/2013	1.96	CL	181	Single Non-Event	0.4	350	0.53	0.72
									Gradient 5-10%	0.45	620	0.52	0.70
									Single <500m	0.5	170	0.42	0.67
							CR	179	Single Non-Event	0.4	350	0.50	0.72
									Gradient 5-10%	0.45	620	0.52	0.71
									Single <500m	0.5	170	0.48	0.63

B.2 Results and details of trunk road sites (cont.)

Site	Material Spec	Material Type	Coarse Agg.	PSV	Date Laid	Age at testing (yrs)	Direction	Traffic cv/d	Description	IL	Length (m)	SCRIM (CSC)	GripTester (GN)
11.1	Leith SMA	CL942 0/14	Achilty	55	13/10/2010	4.93	CL	94	Single Non-Event	0.4	620	0.42	0.62
									Gradient 5-10%	0.45	140	0.41	0.65
									CR	92	Single Non-Event	0.4	420
							Gradient 5-10%	0.45	50		0.43	0.59	
							Single <500m	0.5	290		0.42	0.60	
							11.2	-	CL942 0/14	Banavie	55	31/10/2014	0.87
Single <500m	0.5	200	0.47	0.65									
Approach to Junction	0.5	140	0.46	0.68									
CR	179	Single Non-Event	0.4	1040	0.57	0.68							
		Single <500m	0.5	80	0.44	0.68							
		Approach to Junction	0.5	140	0.53	0.64							
11.3	Leiths Rigaphalt	CL942 0/14	Edston, Peebles	60	30/05/2008	7.30	CL	181	Single Non-Event	0.4	740	0.49	0.67
									Single <500m	0.5	80	0.49	0.69
									Approach to Junction	0.5	50	0.51	0.69
							CR	179	Single Non-Event	0.4	550	0.46	0.65
									Single <500m	0.5	210	0.47	0.61
									Approach to Junction	0.5	80	0.48	0.62

A procedure for justifying aggregate use based on in-service skid performance



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