An assessment of the performance of different aggregates in delivering skid resistance

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ABSTRACT

The delivery of a Skid Resistance strategy relies upon the appropriate selection of aggregates to provide different levels of skid resistance for different environments and site characteristics. In the United Kingdom the use of the Polished Stone Value (PSV) based on the recommendation in the Highway Agency standard HD36/06 is typically used to specify the PSV required for different site characteristics.

Somerset County Council has a comprehensive record of surface treatments undertaken on their network including the specification and source of the material used. In seeking to ensure that their Materials policy was striking an appropriate balance between the cost of premium aggregates and the need to achieve defined investigatory levels a study was undertaken to explore how different aggregates performed. The study involved linking the SCRIM coefficients with the material type and source to assess how different aggregates performed in service after 2 -8 years trafficking.

The results of the review have been used to refine the Somerset County Council materials policy, develop the balance between locally sourced and imported high PSV aggregate and to consider whether blends of different aggregate are acceptable.

1. INTRODUCTION

The implementation of a Skid Resistance policy relies upon the performance of aggregate used in road surfacing materials. The selection of appropriate aggregate has an impact on the life of individual treatments, and therefore the whole life costing achieved by a highway authority. For many years the Polished Stone Value (PSV) has been used as a measure of the resistance of an aggregate to polishing; however the test is specific to an aggregate tested under standardised conditions, and does not always relate to the in service performance. There are also a number of different sources of aggregate at a given PSV available, and often there is anecdotal evidence to suggest some perform better than others; however this is not always backed up by evidence.

Modern surface treatments involve the use of aggregate in a number of different types of surface, from surface dressing to negatively textured surfacing. These contribute to skid resistance by different mechanisms and can perform very differently with the same aggregate. In the United Kingdom the selection of aggregate is largely influenced by applying table 3.1; Minimum PSV of Chippings, or Coarse Aggregate in Unchipped Surfaces, for New Surface Courses of HD36/06: Surfacing Materials for New and Maintenance Construction (1).

Somerset County Council (SCC) delivers their structural maintenance project through a client/ contractor model where the client identifies schemes for treatment and the contractor undertakes design and construction activities. There has been a perception that the requirements of table 3.1 may be conservative for a local road network and could have an adverse impact on local sustainability through the reliance on imported aggregate. A number of authorities operate a local PSV policy, which often involves applying a different PSV to those published by the quarry based on local experience. This can involve ‘lowering’ the effective PSV, or promoting the use of local sources which provide better ‘in service’ performance than that predicted by the laboratory PSV.

This paper details the analysis undertaken to assess the performance of different aggregates in service in Somerset. It concludes by looking at some of the ways in which the findings can be implemented, and some of the difficulties experienced.

2. METHODOLOGY

Somerset County Council has maintained construction records within their Pavement Management System since 2002. SCRIM surveys are undertaken on the network defined by maintenance hierarchy over a two year cycle. Investigatory levels were established through a Skid resistance/ accident study completed in 2008, which broadly follows the recommendations of HD28/04 with some local variations.

2.1 CONSTRUCTION RECORDS

The specification of materials is undertaken by the contractor in Somerset. As part of the scheme completion records a return is provided that details the extent, date, material type and source and aggregate PSV for all surface treatments, which are subsequently updated in the Pavement Management System (PMS) database. Figure 1 shows a typical example showing the location, a schematic of the construction history and table entry.

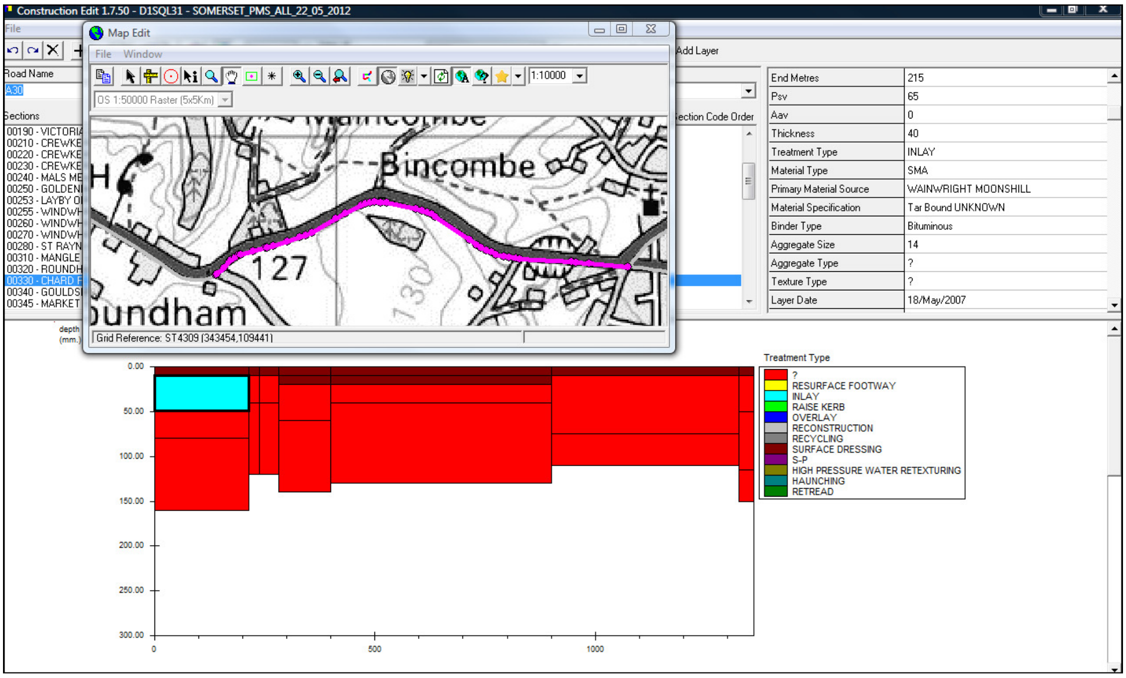

Figure 1: Typical construction details in Somerset PMS

For the purposes of the study construction records from 2002 to 2008 were analysed. A total of 9 principal 'sources' were identified, some of which were local, and other from recognised sources of high PSV in South Wales. 4 generic treatment types were identified.

2.2 SOMERSET SCRIM POLICY

The Somerset SCRIM policy is a local variation of HD28/04. The key differences are in the survey strategy which involves undertaking surveys on the SCRIM network over 2 years, and the adoption of local variations from the HD28 site categories and Investigatory Levels to meet the risk profile on the network. The survey data collected in 2009 and 2010 were used for the purposes of the study. The SCRIM data used is the Mean summer SCRIM Coefficient) MSSC based on the use of 2 control sites in the county. The trend of data from the control sites is shown in figure 2, which indicates that whilst the patterns are different between years the adjusted MSSC does not vary significantly and therefore the 2009 and 2010 survey results are comparable.

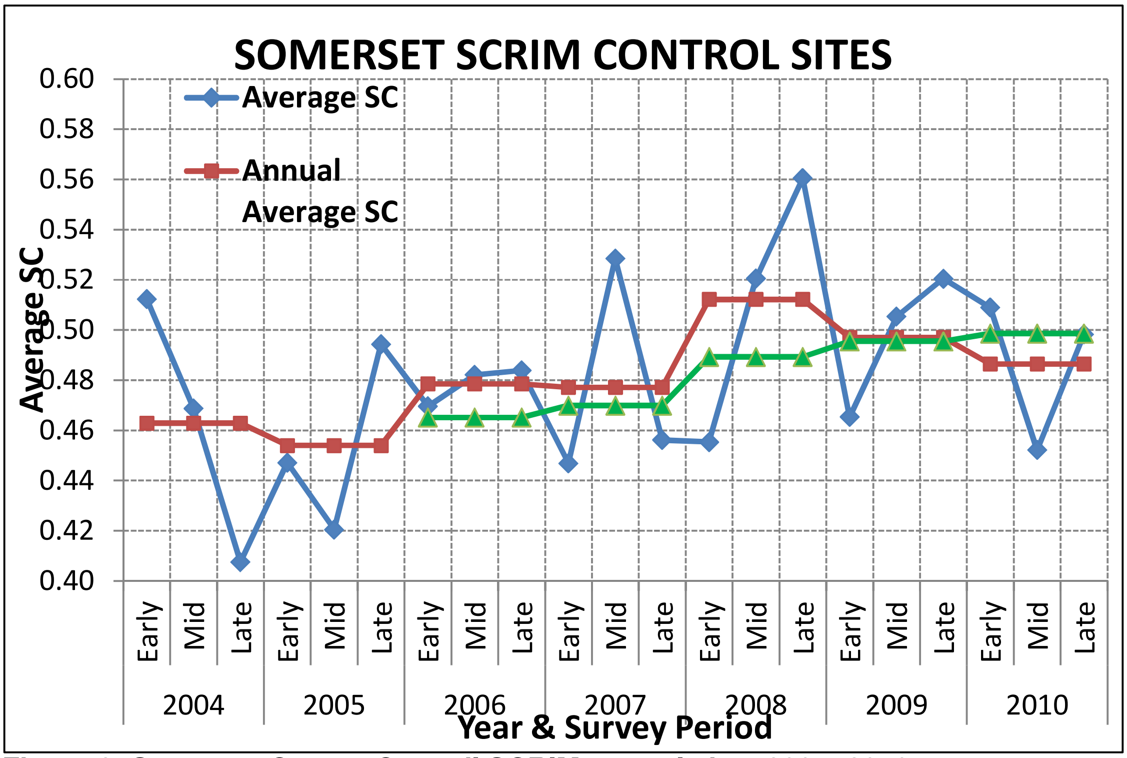

Figure 2: Somerset County Council SCRIM control sites 2004 -2010

2.3 SCRIM NETWORK

The Somerset SCRIM network is based on a maintenance hierarchy with surveys undertaken on the following parts of the network:

- Strategic Route
- Main Distributor
- Secondary Distributor

This represents approximately 20% of the county network by length, with the remaining roads defined as 'local roads.'

In the absence of detailed traffic information for the whole network this was used as a proxy to assess the impact of traffic on the relationship between skid resistance and PSV.

2.4 DATA MANAGEMENT

The construction data, SCRIM, road hierarchy, surface type and PSV were complied in a database and a series of analysis undertaken with the objective of assessing whether the data supported a local variation on aggregate selection.

3. RESULTS

A total of 1045km of data was available for use in the study, with the majority of records being for the secondary distributor network. This typically comprises unimproved A roads carrying 5000 – 12000 vehicles per day. The data indicates that approximately half of the construction records show an 'unknown' source. Figure 3 shows the distribution of data by maintenance hierarchy and age.

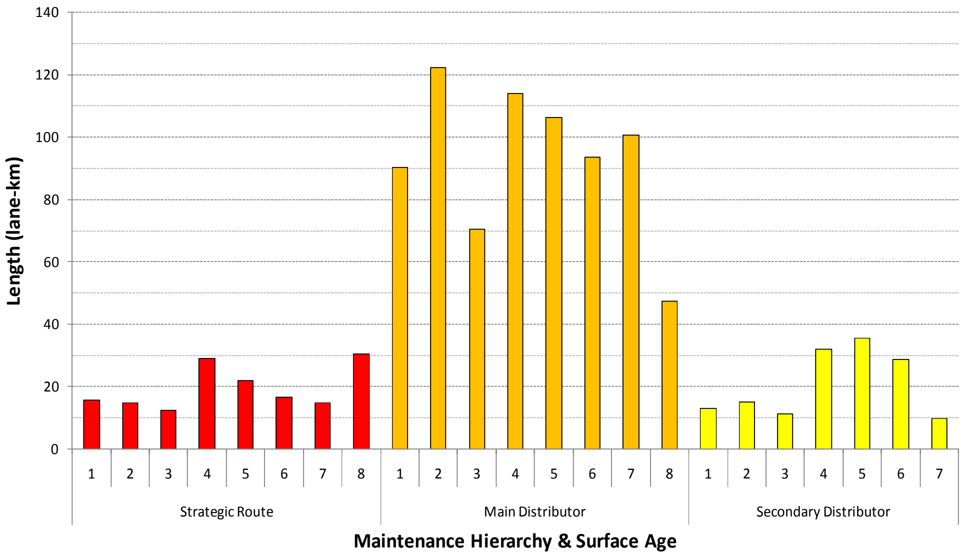

Figure 3: Maintenance Hierarchy and surface age.

3.1 MAIN FINDINGS

The construction records indicate that there are 9 principle sources and a significant length with an unknown source, much of which dates to before 2005.

The listed sources can be broadly split into two main categories, locations of batching plants, and known locations of high PSV aggregate. Moonshill, Torr Works and Colemans are batching plants in Somerset. The indigenous aggregate at threes range from 40 (Torr Works) to 55 (Moonshill) so it is assumed that much of the data from the study for these sites involves imported aggregate from other sources.

The remaining 'sources' are recognised sources of high PSV aggregates. Typical accredited PSV values are:

Builth Wells	60
Ystrad Meurig	60
Dolyhir	65+
Bayston Hill	64
Craig-Yr Hesg	68
Bwch Ffos	68

These quarries are typically 100km or more from Somerset, so it is considered likely that the aggregates may been incorporated into materials produced at more local batching plants.

Table 1 details the average SCRIM coefficient for material from the various sources at different stated PSV's.

Table 1: Average SCRIM coefficients by source, and lengths of network considered.

Source Group (total lane-metres)		PSV ?	PSV 55	PSV 60	PSV 63	PSV 65	PSV 68	PSV 70
1	UNKNOWN	**0.51** (71,588)	**0.49** (26,369)	**0.47** (248,190)	**0.53** (94,312)	**0.52** (131,959)	**0.52** (12,655)	**0.56** (545)
2	WAINWRIGHT MOONSHILL	**0.45** (80)	**0.43** (23,697)	**0.51** (31,740)	**0.47** (4,690)	**0.49** (31,213)	**0.50** (1,590)	**0.55** (1,403)
3	BUILTH WELLS	**0.59** (385)		**0.43** (88,799)				
4	YSTRAD MEURIG	**0.51** (170)		**0.49** (75,937)				
5	TORR WORKS	**0.50** (3,482)		**0.46** (18,534)	**0.50** (3,280)	**0.50** (40,265)	**0.51** (2,670)	**0.49** (1,190)
6	DOLYHIR			**0.50** (30,474)		**0.41** (2,780)		
7	BAYSTON HILL			**0.50** (30,332)				
8	CRAIG-YR HESG	**0.50** (15)		**0.47** (4,930)		**0.48** (7,390)	**0.57** (2,635)	
9	BWCH FFOS					**0.50** (1,530)	**0.54** (12,810)	
10	COLEMANS			**0.46** (11,680)		**0.49** (1,640)		

3.2 MAINTENANCE HIERARCHY

The Somerset maintenance hierarchy is used to determine different service levels for the network. The Somerset materials guidance recommends different surface course options by hierarchy, with the more durable materials used on the national primary and main distributer networks. The analysis of SCRIM coefficient by hierarchy for a selection aggregates is shown in figure 4. As anticipated this generally shows that the average SCRIM coefficient is higher on the secondary distributer roads.

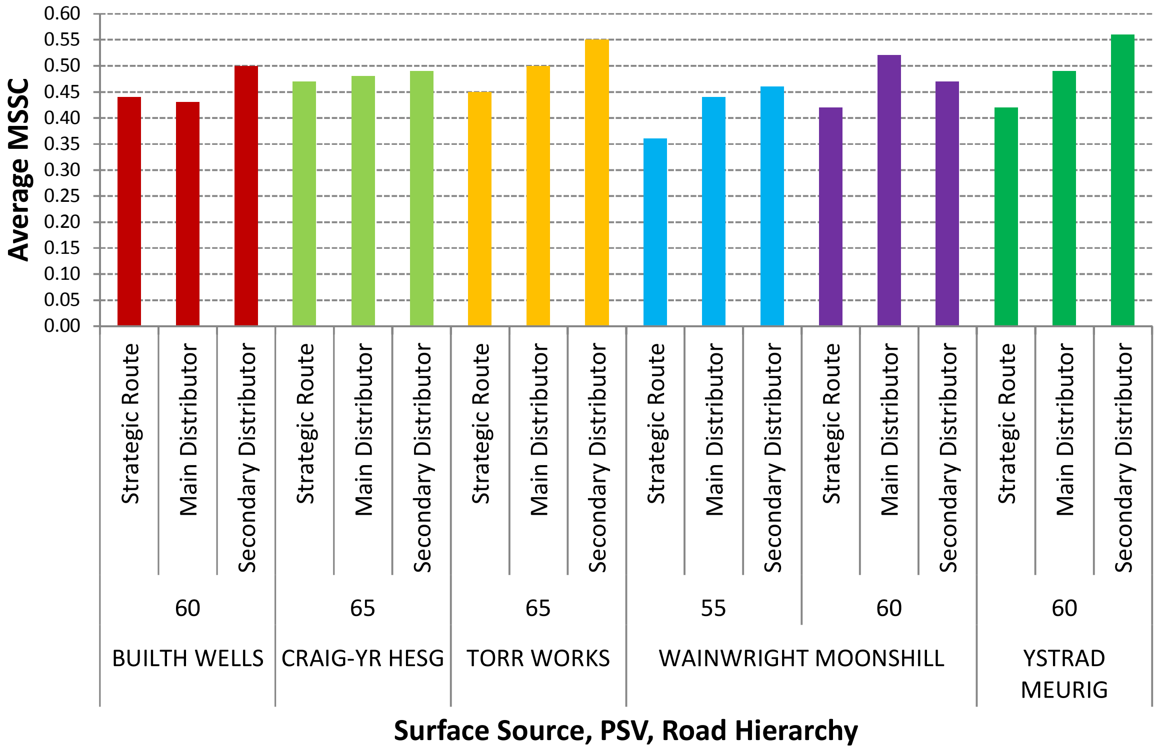

Figure 4: Average SCRIM coefficient by road hierarchy

3.3 SURFACE TYPE

The min surface types in the PMS database are Surface dressing, Stone Mastic Asphalt (SMA) and Hot Rolled Asphalt (HRA) with pre coated chippings, with a smaller length of 'High stone' Content Asphalt (HSCA). Figure 5 shows the average SCRIM coefficient for 3 sources by material type. This shows some variation suggesting that material type may have some influence in how a particular aggregate performs.

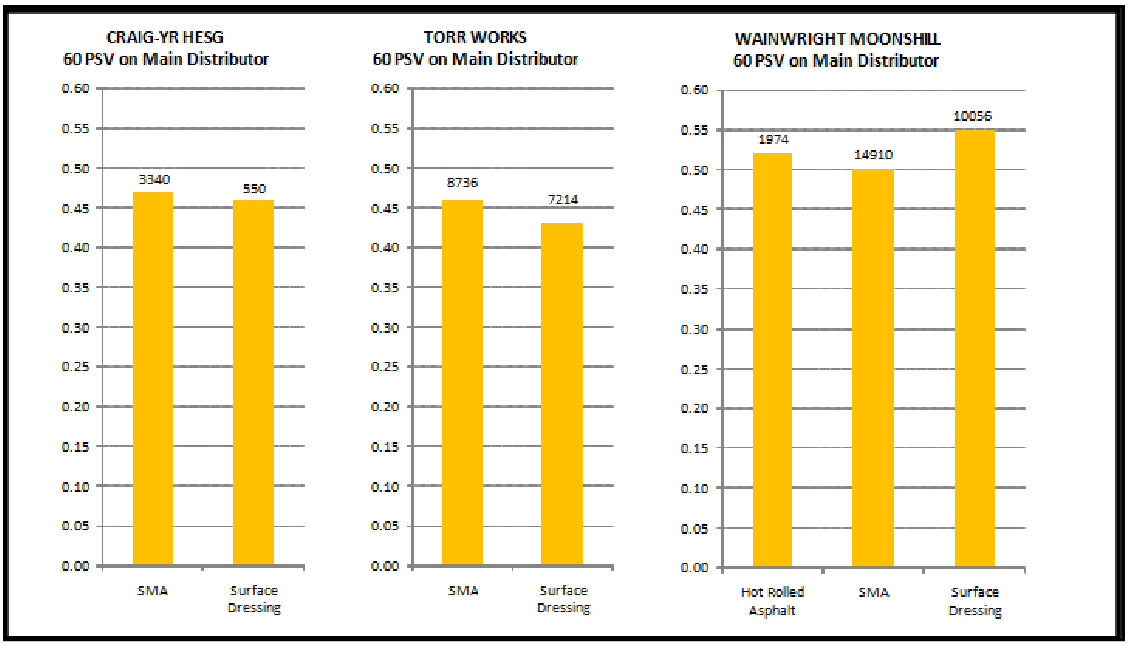

Figure 5: Average SCRIM coefficient by material type for 3 sources. (includes network length available for analysis(m))

3.4 MATERIAL FROM BATCHING PLANT

Section 3.1 details that the material sources are either batching plants or the source of coarse aggregate used. To review the relative performance of aggregate from one of the 3 batching plants Moonshill has been selected. Moonshill is a Basalt quarry located in Somerset, which produces aggregate for roadstone as well as surface dressing chippings. The indigenous aggregate is considered to have a PSV of around 55. It is therefore likely that the higher PSV materials produced by Moonshill utilise coarse aggregate from other sources, or involve blending the Moonshill material with imported aggregate. The records available do not provide this information.

The average SCRIM coefficient from the principal records is shown in table 2 and figure 6.

Table 2: Moonshill Quarry aggregate performance

	Average	**Standard deviation**	**15% ile**	**85% ile**
55 PSV surface dressing	0.42	0.07	0.35	0.49
60 PSV SMA	0.50	0.06	0.43	0.56
60 PSV surface dressing	0.54	0.07	0.46	0.60
65 PSV SMA	0.49	0.05	0.43	0.54

It is assumed that the 55 PSV surface dressing represents the indigenous material. The Investigatory Level (IL) adopted for ‘single non event’ sections in Somerset is 0.40.

Based on the analysis of performance the 55 Moonshill surface dressing aggregate typically meets this requirement, but there is a significant risk that it will not reach this value.

The use of 60 PSV aggregate provides a reasonable confidence of meeting a 0.45 IL and may meet a 0.50 Investigatory level. The 0.45 is used for lower risk events such as gradients and less severe bends; and the 0.50 is used for higher risk events, including approaches to junctions and tighter radius bends. On the basis of the data the 65 PSV SMA does not provide a significantly different performance to the 60 PSV.

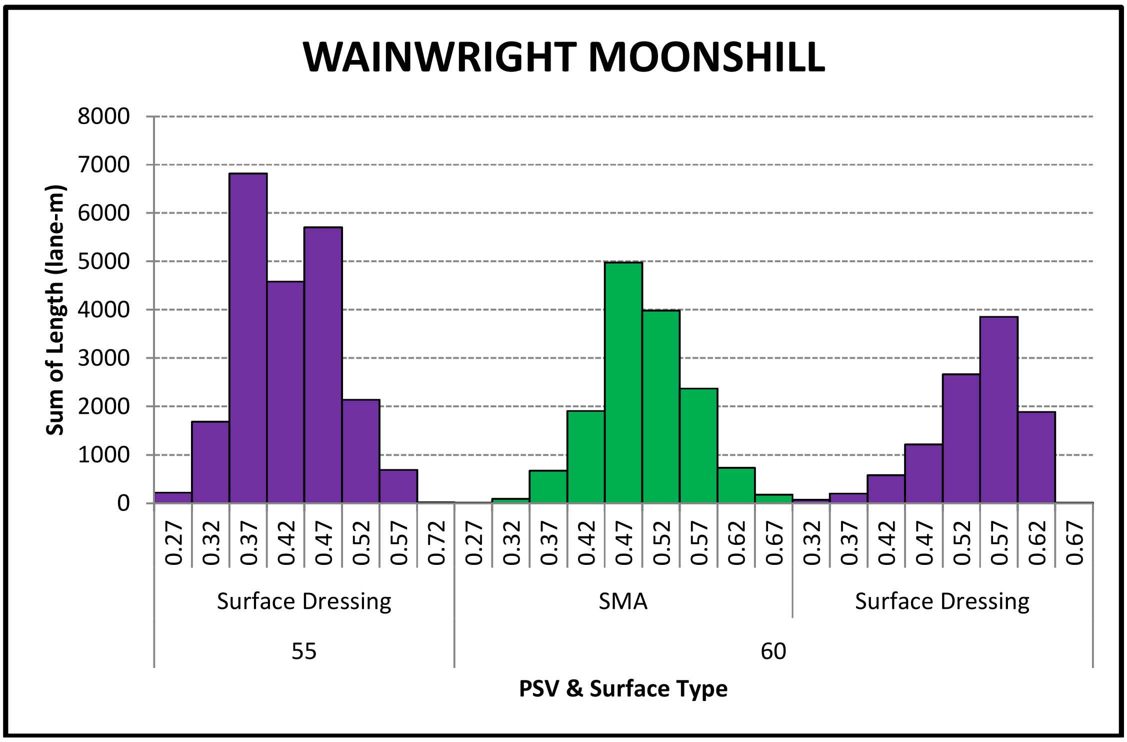

Figure 6: SCRIM coefficients for Moonshill material

3.5 HIGH PSV AGGREGATE

Section 3.1 details a number of sources of high PSV aggregate used in Somerset. To illustrate the performance of high PSV aggregate in Somerset Craig Yr Hesg is used. Craig Yr Hesg is a carboniferous Pennant Sandstone and is widely recognised as one of the highest quality sources of high PSV aggregate in the United Kingdom.

Based on the construction records Craig Yr Hesg has been reported as a 60, 65 and 68 PSV aggregate. The 68 PSV aggregate would appear to be based on the acknowledged PSV of the material. From the records held it is not clear whether the lower PSV materials incorporate Craig Yr Hesg aggregate blended with other material sources.

The average SCRIM coefficient from the principal records is shown in table 3 and figure 7.

Table 2: Craig Yr Hesg aggregate performance

	Average	Standard deviation	15% ile	85% ile
60 PSV SMA	0.47	0.06	0.40	0.52
60 PSV surface dressing	0.47	0.05	0.44	0.53
65 PSV SMA	0.48	0.05	0.43	0.53
68 SMA	0.57	0.05	0.52	0.63

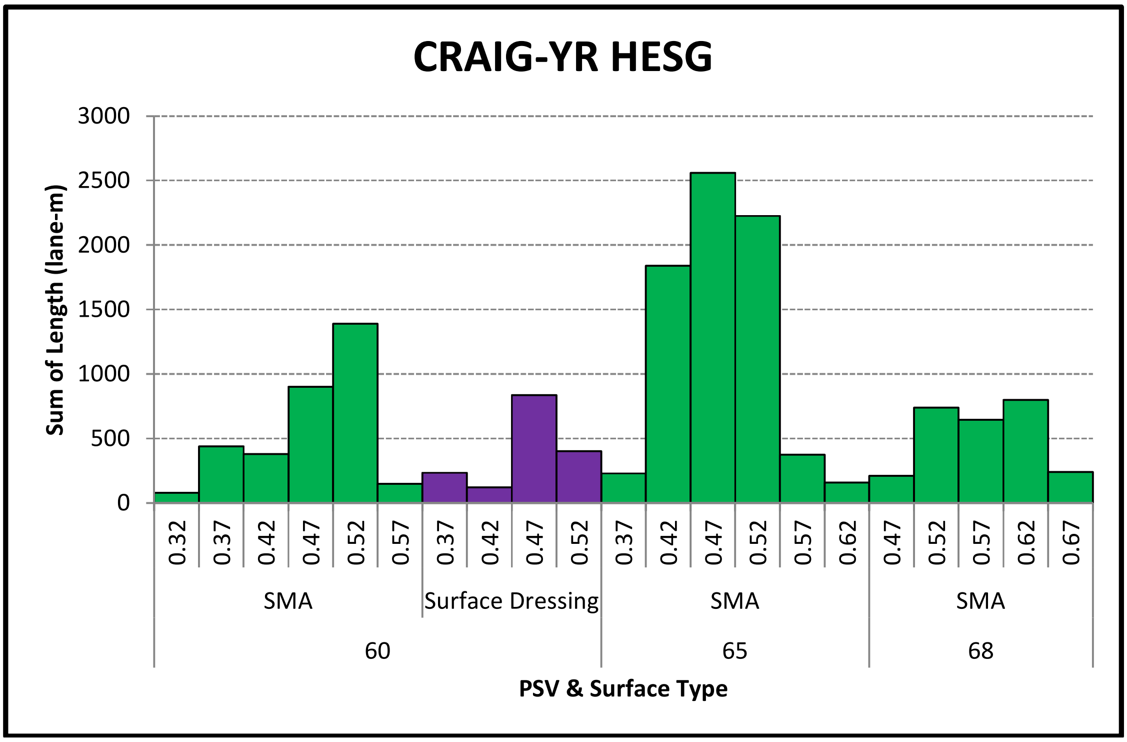

Figure 7: SCRIM coefficients for Craig Yr Hesg material

Whilst there is a comparatively short length of 68 PSV aggregate the data indicates that this has provided very high SCRIM coefficients. A more recent review based on data to 2012 indicates that with 39.855km of 68 PSV aggregate in the database, the average SCRIM coefficient is 0.56, with a standard deviation of 0.06. This gives high confidence in the use of Craig Yr Hesg at the sites requiring the highest Investigatory Levels, including ‘approaches to crossings’ and less than 100m radius bends.

3.6 SITE CATEGORY

Most treatment sites combine a number of different site categories, with different Investigatory levels, and therefore could be treated with a variety of aggregate sources. Typical practice is to use just one aggregate on any given site, with the occasional specification of a higher PSV at specific locations. Figure 8 shows the average SCRIM coefficient for Craig Yr Hesq aggregate at different reported PSV’s. This suggests that there are different rates of polishing experienced at the different site categories; for example there is greater evidence of polishing on < 100m radius bends for the 68 PSV than the roundabout site category.

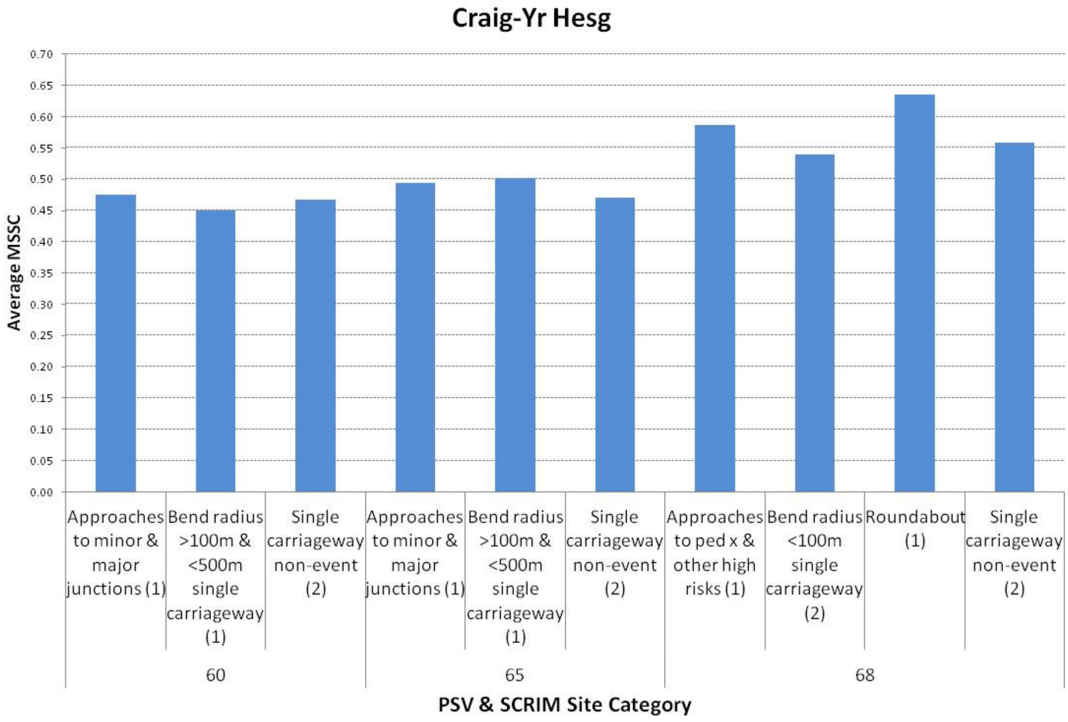

Figure 8: SCRIM coefficients for Craig Yr Hesg material at different site categories.

3.7 SUMMARY OF AGGREGATE PERFORMANCE

Error! Reference source not found. summarises the statistics derived for the main surfacing products used in Somerset.

This table provides a quick indication of the performance, variability and the level of risk involved in selecting the main surfacing types. The values presented in the table would enable SCC to make an informed decision on material selection by considering the required skid resistance on site (meeting the IL of the Site Category), cost of aggregate, and accepted level of risk (using standard deviation and 15th & 85th percentile values).

There are seven suppliers of 60 PSV Surface Dressings listed in the table. They have a large range of variability in performance dependent upon the source (range of Average MSSCs from 0.43 to 0.53).

The study found four main suppliers of 60 PSV SMA. Their Average MSSC values ranged from 0.45 to 0.49. Here, the variability is smaller than for 60 PSV Surface Dressings; possibly reflecting the greater control available through the use of a coated material, than a surface dressing aggregate.

The main suppliers providing HRA and SMA surfaces using 65 PSV aggregate showed very little variability in Average MSSC. 68 PSV SMA surfaces from Craig-Yr Hesg performed better than the equivalent product from Bwch Ffos.

Table 3: Summary of Main Aggregate Sources

Aggregate Source, PSV, Surface Type (lane-metres analysed)	Average of MSSC	Standard Deviation of MSSC	15% Percentile of MSSC	85% Percentile of MSSC
55 PSV Surface Dressing				
Wainwright Moonshill (21,857)	0.42	0.07	0.35	0.49
60 PSV Stone Mastic Asphalt				
Wainwright Moonshill (1,491)	0.50	0.06	0.43	0.56
Torr Works (11,196)	0.48	0.06	0.41	0.56
Craig-Yr Hesg (3,340)	0.47	0.06	0.40	0.52
Colemans (11,680)	0.46	0.05	0.40	0.51
60 PSV Surface Dressing				
Wainwright Moonshill (1,047)	0.54	0.07	0.46	0.60
Dolyhir (30,474)	0.50	0.06	0.44	0.56
Bayston Hill (30,332)	0.50	0.05	0.45	0.54
Ystrad Meurig (75,937)	0.49	0.09	0.40	0.59
Craig-Yr Hesg (1,590)	0.47	0.05	0.44	0.53
Torr Works (7,214)	0.43	0.06	0.36	0.50
Builth Wells (88,799)	0.43	0.07	0.36	0.50
63 PSV Stone Mastic Asphalt				
Wainwright Moonshill (4,690)	0.47	0.08	0.40	0.58
65 PSV Hot Rolled Asphalt				
Torr Works (7,430)	0.48	0.04	0.45	0.52
Wainwright Moonshill (5,800)	0.48	0.03	0.44	0.51
65 PSV Stone Mastic Asphalt				
Torr Works (29,755)	0.49	0.05	0.43	0.55

Aggregate Source, PSV, Surface Type (lane-metres analysed)	Average of MSSC	Standard Deviation of MSSC	15% Percentile of MSSC	85% Percentile of MSSC
Wainwright Moonshill (25,133)	0.49	0.05	0.43	0.54
Craig-Yr Hesg (7,390)	0.48	0.05	0.43	0.53
65 PSV High Stone Content Asphalt				
Torr Works (3,080)	0.58	0.04	0.54	0.62
65 PSV Surface Dressing				
Dolyhir (2,780)	0.41	0.04	0.37	0.45
68 PSV Stone Mastic Asphalt				
Craig-Yr Hesg (2,635)	0.57	0.05	0.52	0.63
Bwch Ffos (12,810)	0.54	0.05	0.47	0.59

The above table only summarised the main surfacing products. A further data analysis was undertaken on all the data included in the original dataset (approximately 1045 lane-km of data). All sections in the dataset were summarised based on the combination of the following variables. The number indicated within brackets is the number of possibilities within each variable.

- SCRIM Site Category (15)
- Maintenance Hierarchy (3)
- PSV (7)
- Surface Type (10)
- Surface Source Group (21)

An example of a combination of variables would be as follows:

SCRIM Site Category:	Approaches to Minor and Major Junctions
Maintenance Hierarchy:	Strategic Route
PSV:	60
Surface Type:	Surface Dressing
Surface Source Group:	Builth Wells

Each combination was selected based on a minimum total length criterion of 500m,resulting in 256 combinations with more than 500m in total length.

4. DISCUSSION

The Skid Resistance Policy established in SCC, requires engineers to take a reactive approach to addressing SCRIM deficient sites in the network. SCRIM deficiency is measured using an annual survey of skid resistance, and testing the survey data against ILs specified for site category lengths.

A direct objective of the policy is to ensure that the required skid resistance is achieved from the aggregate and the surface type chosen for surfacing treatments as part of the structural maintenance project.

Table 3.1 of HD36/06 lists the minimum recommended PSV for given IL, traffic level and type of site (essentially site category). However, no consideration is given to aggregate source or surfacing type. It is advisable that, in addition to the factors specified in HD36/06, further consideration is given to aggregate source, and perhaps surfacing type, when selecting a surfacing the required PSV for a specific site.

Roe and Hartshorne (1998)[1] assessed the relationship between PSV and MSSC, and concluded that different aggregate with the same polishing resistance provide a range of skidding resistance in practice, even at the same traffic levels. The Somerset study substantiated that.

From the data obtained from the study period, it was found that the performance of a given PSV aggregate could differ based on the aggregate source. The study also found that Maintenance Hierarchy (proxy for traffic levels) affected aggregate performance, such that locations with low traffic levels achieved higher MSSC than locations with high traffic. In general, various surface types using the same aggregate achieved similar skid resistance, except in one instance where High Stone Content Asphalt surfacings achieved significantly higher Average MSSC than compared to SMA and HRA using the same aggregates. From the data, the age of the surface did not appear to affect performance.

The findings presented in this paper enabled SCC materials guidance to be provided on selecting aggregates that provide the required level of service, which is fundamental to effective implementation of the skid resistance policy. Currently the surfacing and surface dressing programmes are delivered through the term contract. This was awarded in 2010 for 5 years (extendable). Whilst the contract provides a range of options for aggregate PSV there is no provision for SCC to specify which aggregate sources are used. Therefore if SCC were to start specifying which aggregates sources are acceptable this could be considered a compensation event. SCC would have to consider whether any additional costs associated with implementing the PSV policy are worth the higher confidence in aggregate performance over the remaining term of the contract.

Most of the aggregate sources usually specify their indigenous aggregate as having a specific PSV (with an allowance for a small variability). The data in the PMS suggests that some aggregate sources provided a full range of PSV values (i.e. from 55 to 70) as obtained from the same source. This is very unlikely, and what may have happened is that aggregates with various PSVs may have been processed at the same batching plant, and the data entered into the PMS may not have specified the original sources of the material. The guidance document on the selection and use of materials suggests that the following data (table 4) is recorded for all surfacing schemes.

[1] Roe, P.G and Hartshorne S.A, The polished stone value of aggregates and in-service skidding resistance, TRL report 322, Transport Research Laboratory, 1998

Table 4 – Data to be collected on Surfacing Schemes

Location	
Road	
Section	
Chainage	*Whole site, or for every significant variation along site*
Date	*Date of surface course (and binder course/ inlay if required)*
Surface Treatment	
Thickness	
Treatment Type	*Surface Dress, Overlay, Inlay, Reconstruction, High Friction Surfacing, Re-texture*
Material Type	*SMA, HRA, AC, SD,HSCA*
Material Source	*Quarry details (i.e. batching plant)*
Coarse Aggregate Size	
Coarse Aggregate Source	*Quarry Source (in particular where coarse aggregate has been imported)*
Aggregate Type	*Gritstone, Granite, etc*
PSV	
AAV	

5. CONCLUSION

- This investigation used surfacing records from the Somerset PMS. The study period was 2002 to 2008 during which all the surfacing activities have taken place. The maintenance activities were then linked with skid resistance values (MSSC) collected from the 2009 and 2010 SCRIM surveys.

- The study found that the same PSV aggregate from different aggregate sources achieved different levels of skid resistance. The different skid resistance was mainly due to the aggregate source, and likely to have affected by Maintenance Hierarchy and the type of surfacing as well.

- The most used surfacing type in Somerset during the study period (in terms of length coverage as found in the PMS data) is 60 PSV Surface Dressings, and they were supplied by seven main suppliers. The achieved Average MSSC ranged from 0.43 to 0.53. That is a variability of 0.1 MSSC (two increments in the standard IL scale).

- The effect of Maintenance Hierarchy on the Average MSSC was investigated, and the study found that, in general, the achieved Average MSSC reduced as the hierarchy increased. This is expected, as maintenance hierarchy is primarily defined based on traffic levels.

- Selecting the correct aggregate source to meet the required service level (i.e. the specific skid resistance demand at the particular site) is quite important. This is a variable that is currently not considered in HD36/06. The information presented in this document is expected to assist SCC with making informed decisions on surfacing material selection.

- For the main surfacing products used during the study period, the average and standard deviation were determined. In order to indicate a level of confidence in achieving the required skid resistance, the 15th Percentile and the 85th Percentile were also determined. The former suggests that 85% of the time, the achieved MSSC would be above the percentile value, and the latter suggests that 15% of the time the achieved MSSC would be above the percentile value. In simple terms, for a given aggregate source and PSV, the aggregate is 85% likely to achieve its 15th Percentile MSSC.

- There are various surfacing products laid in the Somerset network during the study period, and the study showed that not all of them have provided the skid resistance requirements on site. Each surfacing product can be successful at the location where it is fit for purpose. The findings of this study would assist SCC in selecting products that are fit for purpose and/or are best value options.

Author Biographies

David Jones

Currently the Highway Asset Commissioner for Somerset County Council and the immediate past Chairman of the South Western Branch of the Institute of Highway Engineers (IHE). David has 30 years highway maintenance experience in both the private and public sectors covering all aspects of highway management including; Contract Management, Business Management, Operational and Financial Systems Management, Asset Management and Service Improvement. David has a scientific background with a 1st Class Honours Degree in Physics which has lead to a very successful analytical and technical approach both as Client and Contractor.

Scott Davies

Having graduated from the University of Plymouth in 1998 with a degree in Civil and Coastal Engineering my career commenced with Kier Construction as a Site Agent constructing a large Hotel Complex at Cricket St Thomas (previously home to Noel Edmunds and Mr Blobby!). In 2000 I joined Atkins Global as a Traffic Engineer which in turn lead to opportunities within Transport Development and most notably assignment within the Somerset County Council Development Control Team. It was during this period that I gained a great insight into the fabric of highway engineering and construction and the realisation of the benefits of good practice. Since 2012 I have been the Highway Service Manager and the Structural Maintenance Project Manager for Somerset County Council delivering an annual programme of works in excess of £18million.

Mark Stephenson

Mark Stephenson is a Chartered Civil Engineer and Head of Consultancy Services with W.D.M. Limited a post he has held since 2008. He is responsible for a range of projects undertaken for UK and overseas clients. These have involved the interpretation of highway condition surveys together with the development of tools and analysis to achieve cost-effective maintenance programmes. His current areas of interest include the measurement and management of skid resistance, Highway Asset Management, including lifecycle plans, scheme identification and prioritisation and policy implementation for clients.

He worked for twenty years at the Cornwall County Council where he was responsible for highway maintenance and construction. He represented the council on a number of national working groups and chaired the Highway Condition Assessment Group which reports to the UK Roads Board.

Dr Anuradha Premathilaka CEng MICE MIAM

Anu is a Senior Asset Management Engineer at CH2M HILL's (formerly Halcrow) Transport planning and Advisory Business Group. He has worked both in the UK and in New Zealand, and has a range of experience in transportation asset management from a consultant, contractor, and researcher perspectives. His key experiences include lifecycle analysis, deterioration/financial modelling, economic evaluation, maintenance programme development and prioritisation, skid resistance, PAS55 assessments, and quantitative risk assessment. Anu undertakes consultancy work for a number of UK transport authorities. His recent projects include asset management and lifecycle modelling projects for the Highways Agency and the High Speed 1 railway, and risk assessment work on the Bristol Bus Rapid Transit Network project. Prior to joining CH2M HILL, Anu was a Senior Project Engineer in the Consultancy Services Division at W.D.M. Limited. In New Zealand, he worked at Downer EDI as a Project Engineer, then at Fulton Hogan as a Regional Technical Engineer. Anu has a Doctor of Philosophy (Civil) specialising in transport asset management, a Master of Engineering Studies specialising in transportation, and a Bachelor of Engineering in civil engineering. He is a Chartered Engineer and a Member of the Institute of Asset Management.