The skid resistance of aggregate blends on in-service pavements

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ABSTRACT

The demand for aggregates with a high polished stone value (PSV) has increased significantly in the UK with the introduction of thin surfacing, such as stone mastic asphalts (SMA). In traditional hot rolled asphalts only the aggregate spread on the asphalt carpet would have a high PSV. In thin surfacing the entire coarse aggregate component is of the PSV required. The possibility of reducing the demand for scarce high PSV aggregates in thin surfacing has been investigated through a series of blended aggregate trials on in-service roads. The skid resistance of the surfacing has been monitored for 8 years. The blended aggregates consisted of a mixture of low and high PSV aggregates from various known sources. These were compared with adjacent thin surfacing laid with single source aggregates. The study shows that a similar level of skid resistance can be obtained through the use of blended aggregates to that obtained from the use of single source high PSV aggregates.

1. INTRODUCTION

In the UK for many years the predominant form of pavement resurfacing for heavily trafficked roads was an overlay or inlay of hot rolled asphalt (HRA) with a scattering of pre-coated aggregate chips rolled into the top of the layer. On lower trafficked roads a surface dressing treatment was common. In both cases the polished stone value (PSV) of the aggregate that formed the tyre/pavement interface would be specified. In the case of HRA a wide range of often locally sourced, aggregates could be used in the matrix of the surfacing course bituminous mat, which was typically 50mm thick. In the last ten years the use of stone mastic asphalt (SMA) laid as an inlay or overlay and typically 20mm to 30mm thick has become a common maintenance technique for restoring the surfacing course of in-service pavements. As this material is laid as a uniform carpet all of the aggregate must be of the PSV specified for the surfacing as well as having other desirable characteristics. The consequence of this is that increased proportions of the high specification aggregates (HSA) are required relative to other aggregates used in the mix per unit of bituminous surfacing laid.

A detailed study of the high specification aggregates available in the UK has been prepared for the UK Government by Thompson et al (2004)

Some of the significant findings of this report are:

- The total demand for HSA within England, in 2002, is 2.3 times greater than the corresponding figure in 1992 (i.e. an increase of 130%).
- The portion of this market supplied from sites within England, in 2002, compared with 1992, has increased more than 120%.
- Over the same period, the portion supplied to England from other parts of the UK and northern France has increased by more than 150%.
- Despite the limited increase in total output from HSA sites within England, the current lifetime of permitted reserves has been reduced, from 20 years in 1992, to just 15 years, in 2002.

The map showing the UK resources of HAS aggregates is reproduced as Figure 1.

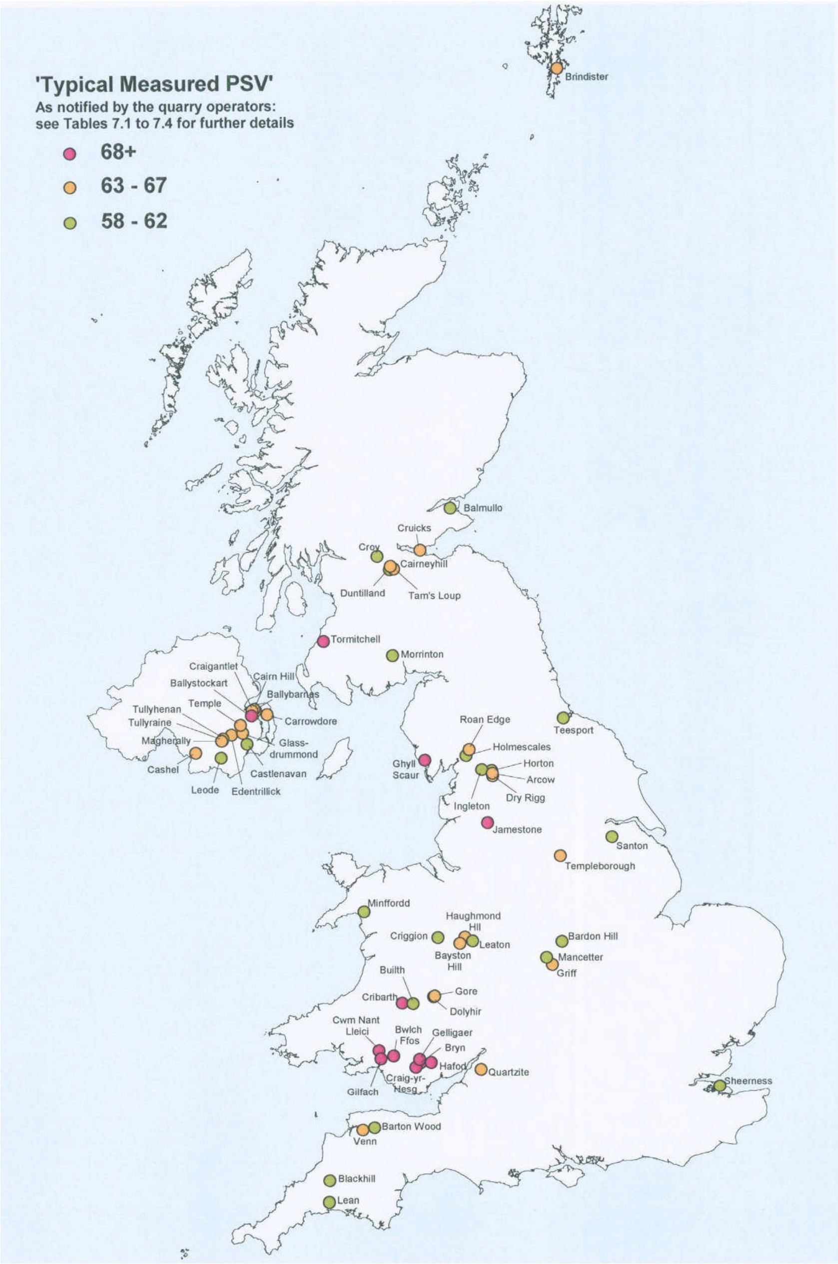

Figure 1. The Location of HAS Sources in the UK (Thompson et al 2004)

The higher PSV aggregates are relatively scarce and concentrated in the west and north of the UK. They tend to be more expensive (particularly if they have to be transported long distances) in the UK than other aggregates used to bulk the mix. Therefore there are financial and environmental reasons for seeking to use a lower proportion of high PSV aggregates in SMA type bituminous mixes.

2. TRIAL DESIGN

In 1998 Lafarge Redland Aggregates Ltd. carried out trials, as part of a re-surfacing scheme for Suffolk County Council, using aggregate blends in the proportion of 50/50 from different quarries laid in an SMA bituminous mixture. The blended aggregates were from sources at Dry Rigg, Mountsorrel and Hafod. Control sections of unblended aggregates from quarries at Cliffe Hill and Dry Rigg were also laid. Jacobs carried out SCRIM skid resistance surveys on this site in 1998 immediately after laying and in summers of 1999, 2000 and 2001. Routine monitoring surveys were carried out for Suffolk County Council on part of the site in 2003 and 2005. A surface texture survey was also carried out in 2000 and 2001. This paper analyses the skid resistance performance of the different aggregates and aggregate blends over time.

3. LOCATION

The trial site comprises parts of the B1115, C711 and C713 near Great Waldingfield in Suffolk, England.

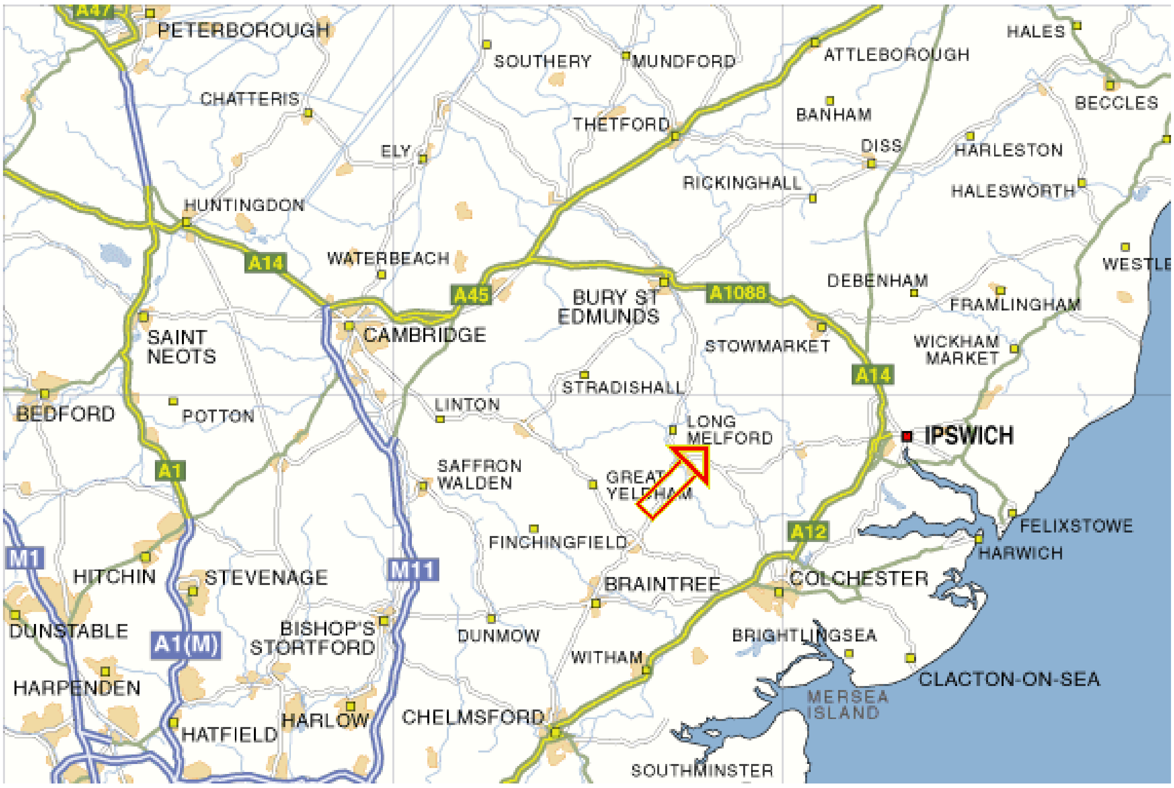

Figure 2. Location of the Trial Site

The map in figure 3 shows the approximate location of the surfacing and the Suffolk County Council (SCC) section identifiers. All survey data was referenced to the SCC sections. The exact locations of the surfacing trial have also been recorded with reference to the SCC section identifiers.

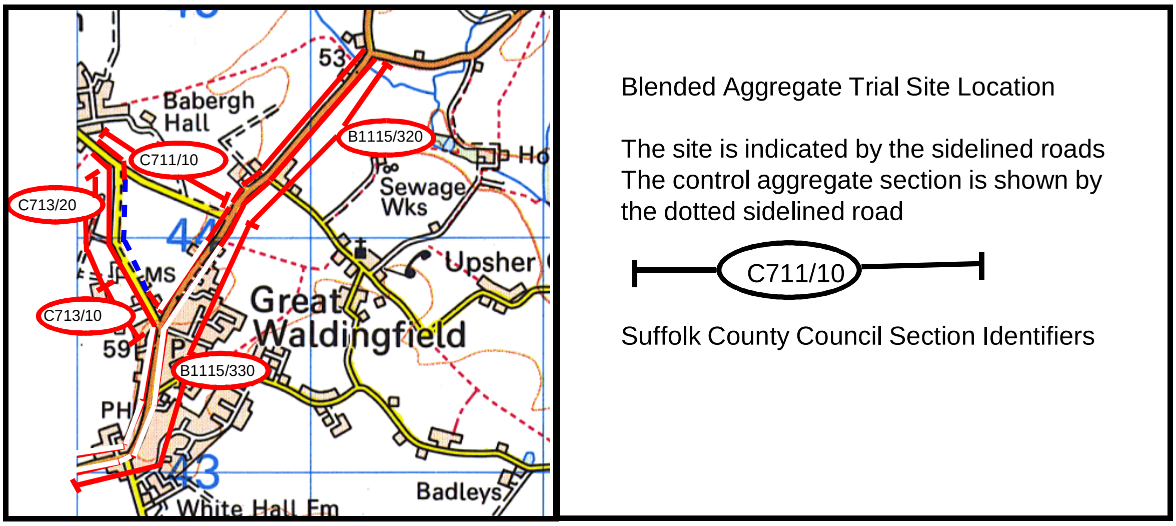

Figure 3. Detail of trial site

4. Visual Inspection

Although laying records indicated the approximate areas where the different aggregate blends had been used it was essential for the analysis of the test data that accurate location information was available. A site visit was therefore made on 23rd November 2000. The binder had mostly worn off from the exposed surface of the aggregates enabling a visual recognition of the different types of aggregate or aggregate blends to be made. These observations have been used to define the lengths of road included in the data analysis.

The location of the different aggregates laid is tabulated below. The chainages are relative to the direction in which the sections are referenced.

SCC Section Reference	**From chainage (m)**	**To chainage (m)**	**Track**	**Comments**
C713/10 Northbound	0	190	Both	Blended pink and dark grey Aggregate (Dry Rigg/Mountsorrel)

	190	318	Northbound	Blended pink and dark grey Aggregate (Dry Rigg/Mountsorrel)
	190	318	Southbound	Control Section single aggregate (Cliffe Hill)
C713/20 Northbound	0	414	Northbound	Blended pink and dark grey Aggregate (Dry Rigg/Mountsorrel)
	0	414	Southbound	Control Section single aggregate (Cliffe Hill)
C711/10 Westbound	545	689	Both	Blended pink and dark grey Aggregate (Dry Rigg/Mountsorrel)
B1115/330 Eastbound	1324	1745	Eastbound	Pink/grey blended aggregate (Hafod/Mountsorrel)
	1425	1745	Westbound	Dark single type aggregate (Dry Rigg)
B1115/320 Eastbound	0	501	Eastbound	Pink/grey blended aggregate (Hafod/ Mountsorrel)
	0	237	Westbound	Dark single type aggregate (Dry Rigg)

Table 1. Aggregate type locations

5. AGGREGATE PROPERTIES

An important indicator of the likely skid resistance performance of an aggregate in-service is its PSV (Hosking 1976). The table of recommended PSV for aggregates to be used under varying traffic loading and site risk ratings was further developed and later incorporated in the Design Manual for Roads and Bridges (Roe and Hartshorne 1998). The PSV is normally determined at the quarry source.

The PSV for the various aggregates used in this trial were stated by the suppliers to be as shown in table 2

Aggregate Source	**Quoted PSV**
Cliffe Hill	56
Dry Rigg	62
Mountsorrel	52
Hafod	68

Table 2. Quoted PSV of aggregates used in trial

6. TESTING REGIME

The sites were tested by the SCRIM (Sideways force Coefficient Routine Investigation Machine) soon after laying in autumn 1998 and on three occasions during the summers of 1999, 2000 and 2001. The results from each set of three summer runs were averaged to obtain the MSSC (Mean Summer SCRIM Coefficient) value. A single run SCRIM test covering part of the site was carried out in summers of 2003 and 2005. In autumn 2000 and summer 2001 the texture depth was measured by laser means to obtain an SMTD (sensor measured texture depth) value. All of these measurements were made in the nearside wheel track in both directions on these single carriageway roads. The short section of the trial site which occurred in the C711 was not tested in 1998 and 1999 as it was considered too short to give reliable readings and so has been excluded from the data analysis.

The results of the testing at the various locations where different aggregate combinations were laid are shown in table 3

Aggregate Type	**Quoted PSV**	**Road**	**SFC**	**SFC**	**SFC**	**SFC**	**SFC**	**SFC**	**SMTD**	**SMTD**
			1998	**1999**	**2000**	**2001**	**2003**	**2005**	**2000**	**2001**
Dry Rigg / Mountsorrel		C713	0.55	0.55	0.55	0.48	0.50		0.74	0.80
Dry Rigg / Mountsorrel		C713	0.53	0.55	0.52	0.48	0.49		0.79	0.87
Dry Rigg / Mountsorrel		C713	0.57	0.57	0.52	0.52			0.81	0.93
Dry Rigg / Mountsorrel	**62/52**	**Mean**	**0.55**	**0.55**	**0.53**	**0.49**	**0.50**		**0.78**	**0.86**
Cliffe Hill		C713	0.52	0.52	0.49	0.48			0.77	0.89
Cliffe Hill		C713	0.51	0.57	0.54	0.51			0.83	0.94
Cliffe Hill	**56**	**Mean**	**0.51**	**0.55**	**0.51**	**0.49**			**0.80**	**0.91**
Hafod / Mountsorrel		B1115	0.54	0.52	0.52	0.51			0.77	0.82
Hafod / Mountsorrel		B1115	0.52	0.53	0.54	0.53			0.74	0.85
Hafod / Mountsorrel	**68/52**	**Mean**	**0.53**	**0.53**	**0.53**	**0.52**			**0.75**	**0.83**
Dry Rigg		B1115	0.39	0.52	0.52	0.48		0.49	0.83	1.00
Dry Rigg		B1115	0.46	0.53	0.52	0.48		0.51	0.75	0.87
Dry Rigg	**62**	**Mean**	**0.42**	**0.53**	**0.52**	**0.48**		**0.50**	**0.79**	**0.94**

Table 3. SCRIM and SMTD test results for various parts of the trial sites.

The change in SFC value over the 7 years of the different aggregates is shown graphically in figure 4.

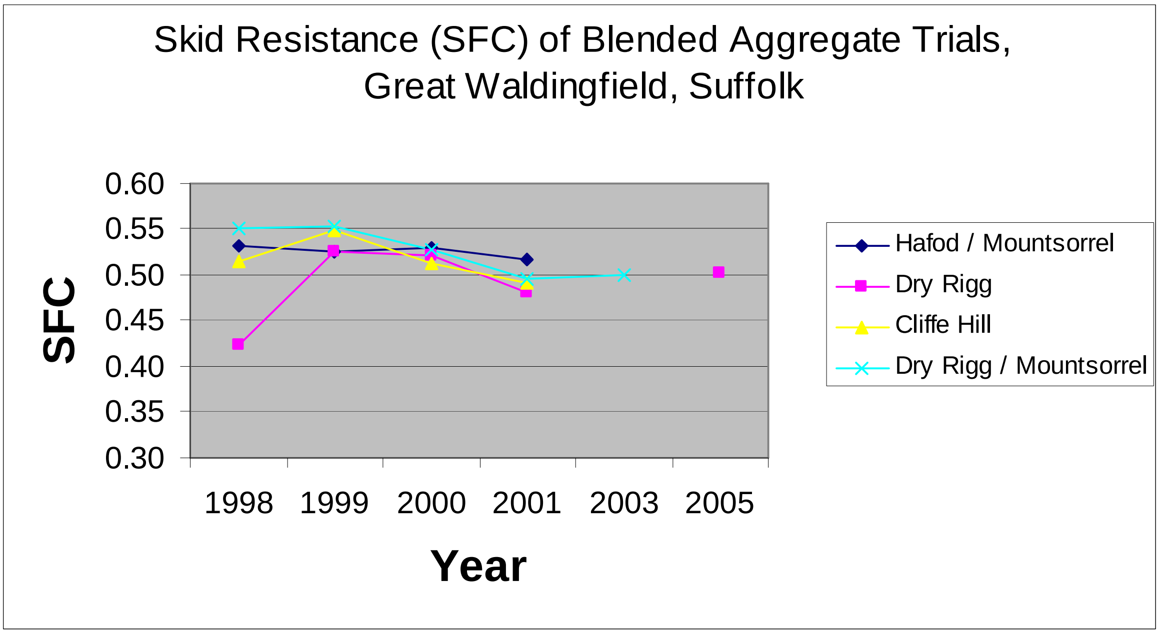

Figure 4. Skid Resistance of Trial Site

7. TRAFFIC

The traffic flow on these roads had been counted by Suffolk County Council in May 1999. A summary of the flows is in table 4. More recent traffic counts are not available but there are no factors to suggest that traffic growth is not in line with national averages at around 2% per annum

Road	Average daily flow (both directions) – all vehicles**
C711	4089
C713 *	2862
B1115	8231

*The flow on the C713 is estimated from the actual count on the C711
**Commercial Vehicles comprise approximately 10% of all vehicles

Table 4. Traffic Flows on trial site – 1999

8. DISCUSSION

The skid resistance relationship to be expected on an asphalt pavement newly surfaced has been discussed by Roe and Lagarde-Forest (2005). This includes typically an initial increase in skid resistance as the binder wears off the surface of the aggregate enabling direct contact between vehicle tyres and the aggregate to occur. The longer term equilibrium skid resistance characteristics of a pavement have been documented by Hosking, JR and Woodford, GC (1976). After the initial increase in skid resistance referred to above, as the surface of the aggregate polishes under the further action of traffic the skid resistance should drop to an equilibrium level whereby the rate of polishing of the aggregate equals the rate of abrasion. Eventually there will be a long term gradual decline in skid resistance, normally over many years, as the aggregate abrades away or embeds into the bituminous mass.

This classic relationship is shown by the Hafod/Mountsorrel mix and the Cliffe Hill aggregates, which accord well with this expected view. The Dry Rigg and Dry Rigg/Mountsorrel mix have behaved in a different way. The pure Dry Rigg aggregate has shown a gradual, but steady increase in SFC over the three years followed by a slight decline. The Dry Rigg/Mountsorrel Mix has shown little change in SFC values in the first year but then a gradual slight decline.

After two years of trafficking the Dry Rigg aggregate performed marginally better with a steady, but gradual, increase in SFC. The Cliffe Hill and the aggregate blends have now all reached a similar level of SFC. This level appears to be the equilibrium value for the aggregates under the relatively lightly trafficked conditions on these roads. On these sites the maximum SFC investigation level that would be required using DMRB Vol. 7 HD28/94 would be 0.45. All the aggregates are currently performing so as to maintain skid resistance comfortably above this level.

For the flow of traffic found on the busiest part of this site it would normally be recommended that an aggregate with a PSV of 65 be used in order to maintain skid resistance above the investigatory level (Roe, P and Harsthorne, S 1998). For the less trafficked parts of the site a PSV of 60 would be required. The measured SFC is above the level that would normally be expected from the lower PSV aggregates.

The Dry Rigg/Mountsorrel mix has maintained a more constant level of SFC than the Hafod/ Mountsorrel and Cliffe Hill aggregates. It would seem that the high PSV of Hafod aggregate dominates the performance of the overall blend. During the seven years which the aggregate mix has been exposed to traffic the use of lower PSV aggregates in the blend does not appear to have significantly reduced the SFC of the finished pavement surface from that which could be expected from Hafod aggregate alone.

The limited SCRIM monitoring carried out in 2003 and 2005 indicates that the long term equilibrium skid resistance for the aggregate at the traffic levels on the site has now been reached.

The macro texture, as measured in the near side wheel track, has increased slightly between 2000 and 2001. There is no obvious reason for this change. It can only be assumed that some of the binder has worn away from the surface of the aggregate thereby increasing the size of the voids or that loose grit trapped in the surface has been washed out.

9. CONCLUSIONS

The most consistent performance is that obtained from the bituminous mix made from Hafod/Mountsorrel aggregate.

The aggregate blends have skid resistance values seven years after laying which are similar to the single aggregate control sites, the range of the average SFC in 2001 of all four materials being 0.04.

The low early life skid resistance observed with Dry Rigg aggregate is not seen when blended.

The lower PSV aggregate does not detract from the skid resistance characteristics of the surfacing course when used in a 50/50 blend.

Additional trials are required to observe the behavior of blended aggregates under high traffic loads

10. REFERENCES

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Presenter Information

Donald Burton is a technical director with Jacobs, having formally worked for Suffolk County Council and Babtie Group. He has spent more than 20 years working in the field of skid resistance measurement, data analysis, and risk rating of road networks. He is currently responsible for the operation of one of the UK's largest fleet of SCRIM vehicles providing data for highway authorities and for privately operated road networks throughout the UK.

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