A CONTINUING STUDY OF THE SKID RESISTANCE PERFORMANCE OF BOS SLAG USED AS A ROAD SURFACE COURSE AGGREGATE

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ABSTRACT

In August 1999, work was begun to investigate the more general use of Basic Oxygen Steel Slag (BOS) as a road surface course aggregate. Based on the evidence from initial on-road studies over a period of three years, the Highways Agency permitted the use of BOS slag in surface courses without the need for laboratory aggregate polishing tests, with the proviso that its performance continued to be monitored. Tarmac Group, responsible for the supply of steel slag, therefore commissioned TRL to continue the test and inspection programme. This paper provides an update on that ongoing work. Results from the extended monitoring confirm that BOS slag performs well in comparison with natural aggregates in a wide range of situations. There are indications that the skid resistance of BOS slag may improve over time but more detailed analysis of seasonal variation is required to confirm this.

INTRODUCTION

Until comparatively recently, the use of Basic Oxygen Steel Slag (BOS) as an aggregate in road surface courses was typically restricted to roads within the steelworks where it had been produced, or on local roads in their immediate vicinity. Wider use could both help reduce stockpiles of slag and reduce demand for premium aggregates. In August 1999, work was begun to investigate the more general use of BOS slag as a surface course aggregate, using laboratory studies and in-situ monitoring of the skid resistance of surface courses containing slag coarse aggregate. This work, (Roe, 2003), found that, for BOS slag aggregate, the measured PSV (polished stone value) did not sufficiently characterise the material and that it had the potential to provide better skid resistance than indicated by the standard laboratory test.

Based on the evidence from initial on-road studies over a period of three years, the Highways Agency permitted the use of BOS slag in surface courses without the need for PSV tests, with the proviso that its performance continued to be monitored. Tarmac Group, responsible for the supply of steel slag, therefore commissioned TRL to continue the test and inspection programme. This paper provides an update after a five-year monitoring period on that ongoing work.

MONITORING PROGRAMME

Routine monitoring of the Trunk Road network in the UK, and also on many local authority roads, is carried out using SCRIM (Sideway-force Coefficient Routine Investigation Machine). This equipment makes continuous measurements of wet skid resistance using a special test wheel set at an angle to the direction of travel.
Skid resistance changes over time, both due to the action of traffic gradually polishing the road and due to climatic effects that influence the polishing mechanism. These influences result in a cyclic process in which the skid resistance eventually reaches an “equilibrium” value dependent on the amount of traffic using the road (particularly heavy vehicles) and the polishing resistance of the aggregate.

While the equilibrium value normally remains essentially constant, skid resistance changes, both within a year and from one year to the next, usually higher in winter and lower during the summer, a process known as “seasonal variation”. For many years, seasonal variation has been taken into account by making three measurements spread over the summer period and calculating an average value, the Mean Summer SCRIM Coefficient (MSSC). This is the value that has, until recently, been used to compare measured skid resistance with investigatory levels (IL) in skidding standards applied on trunk roads, and on many local authority roads.

The original monitoring programme for this study of BOS slag was designed to determine MSSC each year. Where possible, measurements were also made on adjacent or nearby lengths of conventional natural aggregate surfacings that had been laid for some time. The purpose of these “control sections” was to provide an indication of any local or seasonal effects that could also have been influencing the response of the BOS sections.

From 2004, the pattern of routine monitoring and the assessment parameter changed for Trunk Roads in England. However, for the ongoing monitoring of the BOS slag sections, the original pattern of surveys has been continued. This enables the previous analytical approach to be followed, both for consistency and a fuller understanding of the behaviour of the sites, but it also provides data that potentially can be used to re-assess the measurements in the light of the new version of the skidding standard (Design Manual for Roads and Bridges, HD28/04).

Five sites were selected for longer-term monitoring. Each site, including any control sections, was measured using the TRL SCRIM three times during the summers of each year, normally in May, in July and in September. In addition, a separate visit to the sites was made in each year to make visual inspections of the surface condition in the light of the emerging results.
SITE DETAILS AND SUMMARY OF THE RESULTS

Table 1 provides a summary description of the sites chosen for longer-term monitoring. All five are located in the north-east of England. Although on Local Authority roads, most of them are representative in character of roads on the trunk road network.

Table 1 Sites included in the extended SCRIM monitoring programme

<table>
<thead>
<tr>
<th>Site Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>D</td>
<td>A single carriageway, gently curving, 40mph suburban A-road. 900m of BOS slag Stone Mastic Asphalt (SMA) laid late summer 1998, together with an adjacent 400m of conventional hot rolled asphalt. Traffic level estimated as &lt;250 Commercial Vehicles per lane per Day (CVD).</td>
</tr>
<tr>
<td>E</td>
<td>A lightly trafficked (estimated as &lt;750 CVD) rural dual carriageway A road. 11km of continuous proprietary surfacing using BOS slag coarse aggregate, laid in January/February 1999. Measured on the northbound carriageway in Lane 1 only.</td>
</tr>
<tr>
<td>F</td>
<td>A lightly trafficked (approx. 750 CVD) rural dual carriageway A road. 1.2km of BOS surfacing laid in September 1999, approx. 2km of adjacent older surfacings. Measured westbound in both lanes.</td>
</tr>
<tr>
<td>G</td>
<td>A single carriageway urban distributor road built on the line of a former railway, carrying medium levels of heavy traffic (approx. 1000-1250 CVD). Completed in late spring 1998. Straight, with both de-restricted and 30mph limit sections. The 30mph stretch has 3 traffic-light controlled junctions and a railway underpass section. Approximately 4km of proprietary surfacing with BOS coarse aggregate; the junction approaches were inlaid with sections using a &gt;65 PSV gritstone aggregate instead of BOS slag. 1.6km of adjacent old road. Measured in both directions. During the period covered by this paper, the surface course on a length of almost 1km of the northbound lane was replaced.</td>
</tr>
<tr>
<td>H</td>
<td>A heavily trafficked (&gt;3000 CVD) 3-lane dual carriageway. Proprietary surfacing with sections using BOS coarse aggregate from two sources, laid across all three lanes in late summer 2000. 350m Scunthorpe BOS, 250m Llanwern BOS. 65 PSV natural aggregate control sections (200m and 100m), also newly laid, at each end. Measured in all lanes.</td>
</tr>
</tbody>
</table>

Table 2 provides an overview of the results in the form of average MSSC values obtained for each site on each of the main test sections (in normal type) and any control sections (shown in italics). The results from the earlier test programme (2000, 2001 and 2002) have been included for completeness.

A general observation from the overall MSSC values in Table 2 is that MSSC levels in 2003 were either the same as or less than the values obtained in 2002. However, in 2004 the MSSC increased on all sites, generally returning to 2002 levels or greater. The effects can be seen to a greater or lesser extent both on the BOS sections and on control sections. This suggests that seasonal effects were playing a significant part in the variation of the values. On two sections, both of which were on Lane 2 of site F, the 2004 MSSC values, although greater than in 2003, were below those in 2002.

The results in Table 2 illustrate the problem of seasonal variation affecting skid resistance levels around the equilibrium from one year to another. The effects may be explained by differences in weather conditions during the winter period (affecting the extent to which the skid resistance recovers during the “roughening” phase of the seasonal cycle) and also during the summer when testing is carried out. If the weather is hotter, or dryer, for example, there may be greater polishing in a particular summer or such action may occur at a different time compared with the SCRIM survey.
<table>
<thead>
<tr>
<th>Site Code</th>
<th>Section</th>
<th>Overall length (km)</th>
<th>MSSC 2000</th>
<th>MSSC 2001</th>
<th>MSSC 2002</th>
<th>MSSC 2003</th>
<th>MSSC 2004</th>
</tr>
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<tr>
<td>D</td>
<td>BOS slag ‘Old’ surfacing (HRA)</td>
<td>1.8</td>
<td>0.42</td>
<td>0.44</td>
<td>0.48</td>
<td>0.45</td>
<td>0.49</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.2</td>
<td>0.39</td>
<td>0.40</td>
<td>0.42</td>
<td>0.41</td>
<td>0.44</td>
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<tr>
<td>E</td>
<td>BOS slag Lane 1</td>
<td>10.8</td>
<td>0.43</td>
<td>0.45</td>
<td>0.48</td>
<td>0.48</td>
<td>0.52</td>
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<tr>
<td>F</td>
<td>BOS slag ‘Old road’ approach</td>
<td>Lane 1</td>
<td>1.6</td>
<td>0.46</td>
<td>0.50</td>
<td>0.51</td>
<td>0.48</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lane 2</td>
<td>1.6</td>
<td>0.53</td>
<td>0.54</td>
<td>0.56</td>
<td>0.52</td>
</tr>
<tr>
<td>G</td>
<td>BOS slag lane 1</td>
<td>1.6</td>
<td>0.46</td>
<td>0.49</td>
<td>0.49</td>
<td>0.44</td>
<td>0.49</td>
</tr>
<tr>
<td></td>
<td>‘Old road’ follow-on</td>
<td>Lane 1</td>
<td>1.4</td>
<td>0.43</td>
<td>0.45</td>
<td>0.47</td>
<td>0.44</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lane 2</td>
<td>1.4</td>
<td>0.42</td>
<td>0.45</td>
<td>0.48</td>
<td>0.44</td>
</tr>
<tr>
<td></td>
<td>Derestricted section NB</td>
<td>1.4</td>
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<td>0.47</td>
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</tr>
<tr>
<td></td>
<td>Derestricted section SB</td>
<td>1.4</td>
<td>0.42</td>
<td>0.45</td>
<td>0.48</td>
<td>0.44</td>
<td>0.49</td>
</tr>
<tr>
<td></td>
<td>Main 30mph sections</td>
<td>2.2</td>
<td>0.41</td>
<td>0.44</td>
<td>0.45</td>
<td>0.43</td>
<td>0.46</td>
</tr>
<tr>
<td></td>
<td>underpass section</td>
<td>0.7</td>
<td>0.38</td>
<td>0.39</td>
<td>0.40</td>
<td>0.38</td>
<td>0.40</td>
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<tr>
<td></td>
<td>Inlaid junction approaches</td>
<td>1.0</td>
<td>0.46</td>
<td>0.49</td>
<td>0.49</td>
<td>0.44</td>
<td>0.49</td>
</tr>
<tr>
<td></td>
<td>Old town road</td>
<td>1.6</td>
<td>0.41</td>
<td>0.46</td>
<td>0.46</td>
<td>0.44</td>
<td>0.51</td>
</tr>
<tr>
<td>H</td>
<td>Scunthorpe BOS</td>
<td>Lane 1</td>
<td>0.37</td>
<td>0.60</td>
<td>0.48</td>
<td>0.48</td>
<td>0.48</td>
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<tr>
<td></td>
<td></td>
<td>Lane 2</td>
<td>0.37</td>
<td>0.60</td>
<td>0.42</td>
<td>0.45</td>
<td>0.47</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lane 3</td>
<td>0.37</td>
<td>0.58</td>
<td>0.46</td>
<td>0.47</td>
<td>0.47</td>
</tr>
<tr>
<td></td>
<td>Llanwern BOS</td>
<td>Lane 1</td>
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<td>0.61</td>
<td>0.44</td>
<td>0.48</td>
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<tr>
<td></td>
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<td>Lane 2</td>
<td>0.22</td>
<td>0.59</td>
<td>0.42</td>
<td>0.47</td>
<td>0.47</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lane 3</td>
<td>0.22</td>
<td>0.58</td>
<td>0.47</td>
<td>0.46</td>
<td>0.46</td>
</tr>
<tr>
<td></td>
<td>Natural aggregate</td>
<td>Lane 1</td>
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<td>0.57</td>
<td>0.48</td>
<td>0.50</td>
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<td></td>
<td>Control</td>
<td>Lane 2</td>
<td>0.32</td>
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<td>0.45</td>
<td>0.50</td>
<td>0.49</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lane 3</td>
<td>0.32</td>
<td>0.56</td>
<td>0.47</td>
<td>0.49</td>
<td>0.49</td>
</tr>
</tbody>
</table>

There has not been scope to investigate this in more detail at the time of writing but, as an illustration, Figure 2 (compiled from data from the Meteorological Office Web site) shows the average monthly recorded temperature, for 2001, 2002, 2003 and 2004, both for the UK as a whole and for the East and North East region. Average rainfall figures for the same period in the E and NE region are also shown.

![Figure 2 Temperature and rainfall in the East and North East region](image-url)
It can be seen that the mid- to late-summer months of 2003 were generally hotter and drier than in the surrounding years. Thus, the summer of 2003 provided a long, hot, dry spell which would probably have contributed to the lower skid resistance. It has been known for many years that roads are slippery in the first rainfall after such long dry periods, and it is possible that the SCRIM measurements could have been similarly affected. This could provide an explanation for some of the differences observed.

INDIVIDUAL SITES

The five sites were chosen to compare BOS material used in different circumstances. The following sections discuss the individual sites in more detail.

Site D

Site D is a typical outer-suburban principal road, with occasional side turnings and entrances, but no major junctions. Figure 3 shows the average MSSC in each year (a different colour representing each year) for 100m sections along the full length of the site, for the southbound lane. In this figure (and in subsequent equivalent figures for the other sites), the author’s assessment of a likely investigatory level for a road of this type is included for comparison.

![Figure 3 MSSC from 2000 to 2004 on site D, southbound](image)

It can be seen that the skid resistance on the BOS slag sections is higher than on the adjacent HRA surfacing. This general difference is probably due to the different aggregate used, and the rate of spread of chippings, on the HRA.

It can also be seen that, although there is some variation in skid resistance along the site, there is a broadly similar pattern in most years. This variation probably reflects slight differences in traffic behaviour. For example, there is a reduction in skid resistance at around 400m. This is associated with the approach to a side turn on to a housing estate and therefore there may be increased polishing action by vehicles braking for the turn (or those behind braking when turning vehicles slow down). Since 2001, the skid resistance tends to decrease markedly along the 300m or so at the northern end of the BOS section, near the join between the SMA and HRA. There is a side turn to the east, just north of this point, which gives access to further housing and a school. It is possible, therefore, that the reduction in skid resistance on the BOS
material here is due to traffic accelerating. Comparable effects were also observed on the northbound lane.

As well as the variation along the site, a tendency for skid resistance to increase with time can be seen on both types of surface. Figure 4 shows the overall average SCRIM Coefficient (SC) for the two surfacings at each summer visit, plotted against the time in months elapsed since the start of the original project (August 1999). Also shown are trend lines corresponding to these points. The trend lines suggest that the skidding resistance is increasing with time on both the HRA and on the BOS but that the increase is at a slightly greater rate on the BOS section. The groups of three measurements corresponding to each summer show that the traditionally assumed pattern of a minimum in mid-summer does not always occur and that, apart from 2000, there was a marked difference between the first measurement in May and the later summer values. In 2002 and 2003, the May result was much higher than later in the summer, while in 2001 and 2004 the converse occurred. In addition, the 2003 values tend to be rather lower than in the other years.

![Figure 4 Average SC against time on site D](image)

Although there is a possibility that the skid resistance of the BOS surfacing may be gradually increasing over time, without a more detailed analysis of the seasonal effects in the area, this cannot be stated with certainty. Importantly, however, notwithstanding the seasonal variations, at this site the BOS slag has continued to provide skid resistance that is generally well above any likely IL.

**Site E**

Site E was originally chosen to assess the performance of BOS slag over a long length of route. Figure 5 shows the MSSC measured in each of the last five years: the likely investigatory level for this type of site, 0.35, is also shown for comparison.

As was observed on Site D, skid resistance is at a generally consistent level along the site but with some localised variations. The skid resistance provided at this site continues to be well above the likely investigatory level, apart from the first 100m leaving the southern interchange roundabout. As was observed in the earlier phase of work, skid resistance there continued to be much lower than on the rest of the road. This has been attributed to the increased polishing action by heavy vehicles.
accelerating away from the roundabout on this more sharply curved section. The other variations along the site may be explained by the topography and site features.

Figure 5 MSSC from 2000 to 2004 on site E

A trend for skid resistance to increase with time is more apparent on this site than was the case on Site D. However, at this site there was no directly adjacent surface with which to compare this increase. Further analysis of seasonal effects in the locality is planned to assess whether the apparent increase of skid resistance with time is attributable to the BOS material rather than a more general effect.

Site F

Site F, a rural dual carriageway, has been tested in both lanes to compare the evolution of skid resistance under two different traffic levels. Lane 1 carries approximately 750 CVD, whereas lane 2 carries only overtaking vehicles and at any particular point these are almost exclusively light vehicles. Figure 6 shows the results of SCRIM measurements for both the lanes, for comparison. In this case, while the different coloured lines still represent the different years, Lane 1 is shown with ‘filled symbols’ while Lane 2 is shown with ‘open symbols’.

Figure 6 MSSC between 2000 and 2004 on site F

One of the most noticeable features of the graph is the difference in skid resistance level between the two lanes (see Table 2). This is the expected result of different
traffic levels on each lane. As with the other sites, changes in skid resistance occur on the different sections that can be attributed to surface changes, topography and traffic behaviour.

Figure 7 shows the average SC against time for each of the three sections on Lane 1. This graph, like its counterpart on Site D (Figure 4), suggests that the skid resistance on the BOS section has increased at a greater rate than on the older surfaces. However, as on Site D, some significant seasonal variation also appears to be affecting the measurements.

![Figure 7 Average SC against time on site F, lane 1](image1)

Figure 7 Average SC against time on site F, lane 1

Figure 8 shows the equivalent lines for Lane 2. In this case, the trends are different: the approach “control” section shows no real change with time and the BOS and follow-on control sections show an apparent decrease in skid resistance, albeit with a wide scatter. More careful examination of underlying seasonal effects is needed here. However, a possible explanation for the reduction on the BOS section is that, in this lightly trafficked lane, the material has taken longer to reach an equilibrium level and this may only just have been being established during the last monitoring period.

![Figure 8 Average SC against time on site F, lane 2](image2)

Figure 8 Average SC against time on site F, lane 2

The fact that the downstream HRA section in Lane 2 appears to show a decrease over time is unexpected. Whether or not this is a real trend, or is driven by the “low” summer of 2003, for example, will become clearer as monitoring continues. It may be
that the presence of the BOS slag has had an influence on the natural aggregate but unfortunately there are no data from before the laying of the steel slag to provide evidence as to this possibility. There were also major road works during the monitoring period when the route immediately west of these sections was upgraded to dual carriageway standard: changing traffic patterns from the resultant traffic management arrangements may also have had an effect on the way in which the skid resistance of this westernmost section of the site has developed. Once again, however, it is clear that the steel slag continues to perform at least as well as, if not better than, the adjacent surfaces, and provides skidding resistance well above the likely IL.

Site G

Site G is the most complicated of the sites studied in this project. It was chosen to provide evidence of the performance of BOS slag under the same general traffic level, but in different circumstances. There is a long, derestricted, rural section, feeding directly from and to an urban section with several traffic light controlled junctions. Figure 9 shows the results of the SCRIM measurements on this site in the northbound direction. Similar patterns could generally be observed on the southbound lane. As with the other sites, there has been a tendency for skid resistance to increase over the monitoring period, but with relatively lower values occurring in 2003.

![Figure 9 MSSC between 2000 and 2004 on site G, northbound direction](image)

The variation in skid resistance along this site can be readily related to the physical road layout and associated traffic behaviour. Figure 10 shows the SCRIM coefficients at 10m intervals during the most recent visit, in September 2004. Marked on the figure are the approximate positions of traffic lights along the site, and the positions of various physical features.

Most of the changes in skid resistance along the site can be ascribed to:

- Changing surface aggregates (on the high friction surfacing on the traffic calming bends and the high-psv natural aggregate inlays at the traffic light approaches).

- Braking and acceleration zones near the junctions.
• Build-up of fine detritus and contaminants in the dip under the railway bridge at the north end of the BOS surfacing.

![Graph](image)

**Figure 10 SC for 10m sections on site G, northbound, September 2004**

It was found that, on a 1km section of the northbound lane at the southern “rural” end of the site, there had been a relatively greater increase in skid resistance in 2004 than might have been expected. It has subsequently been established that, for reasons unrelated to the skid resistance of the BOS slag, the surface course on this length was replaced, again using BOS coarse aggregate, during the summer of 2004.

Changes in skid resistance pattern could also be detected on the “old road” sections at the northern end of the site. This section has undergone considerable changes during the extended monitoring period which make it difficult to assess directly any seasonal effects on this site, although they might be expected to be similar to those encountered on Site D, which is on a roughly parallel road about 1km to the east.

On this site, an increase in skid resistance was observed with time and the old surface section appeared to have increased at a greater rate than the BOS sections. In this case, however, the changes in overall average values over the last two years will have been influenced by the renewal of the surfacing at several points along the road and therefore more detailed analysis is required. Overall, in regard to their skid resistance, the BOS sections have continued to perform at least as well as they did during the earlier stages of the study.

**Site H**

The surfacings at Site H, which comprises three lanes of dual carriageway, were laid as an experiment to compare two sources of BOS aggregate (Llanwern and Scunthorpe) with a natural aggregate (PSV65), all laid at the same time, and subject to the same traffic conditions. Traffic on this site (>3000 CVD) is considerably heavier than on any of the others. Figure 11 shows the skid resistance measurements on Lane 1 over the monitoring period. Figure 12 and Figure 13 show equivalent graphs for Lane 2 and Lane 3 respectively.
The first measurements (dark blue line on each graph) were made in September 2000, only a week or so after the surfaces were laid, which is why the results are generally much higher on this occasion than the MSSC values for the subsequent years. During the winter of 2000/2001 most of the bitumen on the aggregate surface would have
worn away and the normal polishing process begun. On Lane 1, the “Control 1” section is mostly on a slip road and acceleration lane that carries less traffic than the remainder of the site (or the other lanes) and this is a likely explanation for the “dip” in skid resistance half-way along this site during the first survey. This is probably a phenomenon associated with the early life of the surfacing: experience gained elsewhere during the period of this study has suggested that wet low-speed skid resistance can dip in this way during the first week or so after opening to traffic. The effect is not noticeable on the other two lanes, probably because, with the heavier traffic on those lanes, the effect was short-lived.

On all three lanes, the initial polishing towards equilibrium appears to have occurred comparatively quickly, probably by the end of 2001. However, on Lanes 1 and 3 the levels in 2002 and 2003 are generally similar to 2001 while on Lane 2 there was an increase between 2001 and the level achieved in 2002-2003. The most striking feature of all three figures, however, is the much higher MSSC in 2004 than in the three previous years over most of the site.

There has been very little discernable difference in the measurements between the lanes during the last three years. In effect, the presence of the interchanges at each end of the site means that the three lanes almost function as two separate roads, one with a single lane, the other a dual carriageway, along most of the length of the site. This means that Lane 3 can be used by heavy vehicles for overtaking (which it would not be on a three-lane motorway, for example). There is also considerable weaving between Lanes 1 and 2 along most of the length as a proportion of the traffic changes to an alternative route.

The natural aggregate section “Control 1” shows a decrease in skid resistance along its length in both Lane 1 and Lane 2, the effect being most marked in Lane 2. This is probably attributable to traffic braking for merging and weaving traffic ahead, compounded by the fact that much of this section is on the down-slope from a flyover. Overall, there is little discernable difference between the two slag sources.

Again, after an initial reduction from the “as laid” condition, it was observed that there is a trend for an increase with time and all sections (BOS and natural aggregate) showed approximately the same rate of increase.

During the extended monitoring period, the BOS slag has continued to perform well under heavy traffic, and compares well to the adjacent surfaces of high PSV natural aggregate.

**DISCUSSION**

The ongoing monitoring demonstrates that the BOS slag is continuing to provide good skid resistance on the sites being studied. The data also continue to suggest that, after an initial polishing period, there may be a trend for BOS slag to increase in skid resistance over time. However, the results are clearly being influenced by seasonal variation, as well as the changes to some of the test sites, and further monitoring and analysis are planned to assess these aspects further.

Another possible factor that may be influencing the measurements is that the BOS surfacings are all of the “thin surfacing” type. In their recent report on the durability of
these types of material, Nicholls and Carswell (2004) observed that, for some types of material at least, there may be a trend for skid resistance to increase with time. It may be that this phenomenon is affecting the BOS sections in this study. However, it is also likely that year-on-year seasonal effects were influencing Nicholls’ results.

Changes are being made in the way in which routine SCRIM survey data will be used in comparison with investigatory levels, so further detailed analysis of the data from this study is to be made using the new approach. With this new approach, a “Characteristic SCRIM Coefficient” (CSC) is calculated to represent the underlying equilibrium skid resistance. On trunk roads in England, rather than measure the MSSC on one third of the network every three years, the whole network will now be surveyed once a year, in a different part of the season in successive years, and correction factors will be used to take account of the seasonal variation within and between years.

The correction factors use areas of the local road network or route (called a “locality”) to provide an average value for the underlying equilibrium skid resistance in the area for the three-year period preceding the survey and comparing this with the average value for the same locality when the survey being considered was carried out. The ratio of the two provides a weighting factor that is used to adjust the current readings by a small amount to take account of whether the survey in the current year was yielding “high” or “low” values compared with the underlying long-term trend. The method has been adopted in order to provide an improved estimate of the underlying skid resistance of an in-service road and to reduce the influence of “high” and “low” years when assessing sites in comparison with skidding standards.

In this project to date, each site has been tested with SCRIM three times a year for five years; it should therefore be possible to follow a similar analytical approach with the data from this study. Potentially, therefore, this kind of approach could be used to provide an indication of whether the measurements taken in 2004 are really high, whether those taken in 2003 were unusually low and whether the apparent increase in skid resistance of the BOS slag over time is actually greater than might have been expected to occur as a result of local seasonal fluctuations affecting all roads in the areas concerned.

However, to avoid any particular stretch of road having an undue influence on the results, the “locality” used to determine the local correction factors should comprise at least 50km of route (100km of road tested). The scope of this project to date did not extend to gathering sufficient data from local roads for this purpose. An attempt was made to calculate CSC values using the data from this project but, not surprisingly given the limited “control” lengths available to substitute for a “locality”, this was inconclusive.

In future, however, it will be possible to draw on the national database of SCRIM measurements on trunk roads to provide a fuller assessment of seasonal variation in the locality of the test sites and hence to make more detailed studies of the relative changes in the skid resistance of the BOS aggregate.

It is also clear that there are localised variations in skid resistance along the sites that may be related to traffic behaviour in the context of the local geometry. In order to understand these effects further, consideration is being given to including
measurements of curvature, gradient and surface profile in the next phase of monitoring.

CONCLUSIONS

Monitoring of the skid resistance of sections of road with BOS slag coarse aggregate in the surface course has continued for five years and is ongoing. On the basis of the monitoring to date, it is concluded that:

(i) On the sites being studied, the BOS slag continues to provide low-speed skid resistance (as measured by SCRIM) that is at or above any likely investigatory level. Where direct comparisons have been possible, the skid resistance is as good as that provided by natural aggregates appropriate to the sites.

(ii) Ongoing monitoring continues to support the general conclusion that was reached after the first three years of the study (Roe, 2003): the BOS slag appears to perform at least as well as a natural aggregate in locations where materials using PSV 60 aggregate would normally be used.

(iii) There continues to be an indication that skid resistance of BOS slag may gradually improve over time following the initial polishing period but there is as yet, insufficient data to distinguish this from underlying seasonal variation.

Monitoring of these sites will continue for the 2005 survey season. Work is now in hand to analyse further local seasonal effects over a longer length of roads in the areas of the test sites and consider the corresponding influence of these effects on the measured skid resistance of the BOS slag. It is expected that measurements of physical surface parameters such as curvature and cross-fall will also be made, to assist assessment of the influence of these factors on the skid resistance at the test sites.

ACKNOWLEDGEMENTS

The work described in this paper was carried out in the Infrastructure Division of TRL under a project for Viridis, with funding from the Tarmac Group.

REFERENCES

