TRANSPORT RESEARCH LABORATORY

Mechanical retexturing of roads: an experiment to assess durability

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Executive Summary

In 1989, TRL began a study for the Department of Transport (now the Department of the Environment, Transport and the Regions (DETR)) to assess mechanical retexturing techniques. The first phase of the study was to review the systems available and make an initial assessment of each method in terms of any improvements in skidding resistance or texture achieved in the early life of the treatments, together with any strengths and weaknesses for particular applications. That work was carried out by Queen Mary and Westfield College, University of London (QMWC) under contract to, and in close co-operation with TRL. It is reported in a companion report (TRL 298).

This report covers the second phase of the work, monitoring the durability of skidding resistance and surface texture depth of four techniques under similar trunk road conditions in a trial on the A12 near Ipswich.

An inevitable consequence of the polishing action of traffic is a reduction in microtexture on the surface of aggregates used in road surfacings and, hence, a reduction in the wet skidding resistance. Also, wear and embedment of chippings may cause a reduction in macrotexture over time, which not only results in lower wet skidding-resistance at higher speeds but can be associated with greater accident risk in dry conditions.

The advent of standards for the skidding resistance of in-service trunk roads in 1988 increased interest in methods of treating those sites which are found to fall below the investigatory level. In addition to conventional approaches, such as resurfacing or surface dressing, mechanical retexturing methods intended to restore the micro- and macrotexture of existing, but otherwise sound, surfacings are now being considered. A number of these have been developed in recent years, but they have been seen as short-term remedial measures to be used pending more conventional treatment. However, until this project was begun there had been no systematic study of the different methods available to assess their suitability and performance.

The first phase of the project assessed the range of retexturing techniques available. However, the wide variation in the nature and number of sites available for monitoring made comparison of techniques very difficult. The second phase of work, reported here, sought to address this difficulty by means of a controlled trial in which several processes were applied to one site. The site, on the southbound carriageway of the A12 near Ipswich, was a stretch of two lane, rural trunk road, with a traffic level of approximately 3000 commercial vehicles per day in each direction. Because most of the heavy traffic uses lane 1, the retexturing techniques were exposed to two levels of trafficking.

Four retexturing techniques were studied in the trial:

- Scabbling
- Bush hammering
- Orthogonal flail grooving
- Shot blasting

The scabbling and bush hammering were applied at three severities, where the most severe treatment was equivalent to that normally used by the contractor. Different treatment levels were not practicable with orthogonal grooving or shot blasting. Measurements of skidding resistance were made using SCRIM (Sideways-force Routine Investigation Machine) and texture depth was measured using either the HSTM (High-Speed Texture Meter) or an equivalent texture sensor mounted on SCRIM.

There was an immediate improvement in skidding resistance from all four retexturing techniques and some improvement has persisted in both lanes through the three summers covered by this trial. In practical terms, this enhancement is all that could be expected because even newly-laid material would be expected to polish to an equilibrium level in that time. Under heavy traffic, this period of improved performance may be even shorter.

The untreated surfacing also polished to some extent during the trial, indicating that either weather conditions or increasing traffic flow favoured polishing. The effect was to reduce the skidding resistance of the untreated surfacing to the point where the normal three-year routine monitoring cycle might be expected to trigger investigation for wet-skidding accident problems. The treated sections, on the other hand, while also suffering this same increased polishing action, remained above the investigatory level for two summers and, for the scabbling process, for three summers.

The effect of retexturing techniques on texture depth was more variable. The shot blasting improved texture depth in both lanes and this improvement has persisted for three summers. The orthogonal flail grooving process improved texture depth initially, but the grooves closed up in lane 1 under the action of the traffic. The scabbling process reduced texture in both lanes for all sections. The effect of bush hammering on texture depth was broadly neutral.

The study has shown that, when selected appropriately for a particular site, retexturing treatments are useful tools to enhance the skidding resistance of a surfacing which is at or near its investigatory level. The processes can be used all year round and can provide at least two and, in some cases, three or more full summer seasons of enhancement under non-event mainline trunk road conditions.

1 Introduction

Retexturing of road surfacings by mechanical means in order to restore skidding resistance properties has been carried out on a small scale in the UK for a number of years, mainly on county roads. In principle, the processes have the advantage of being quick, relatively cheap and offer the attraction of conserving materials by making use of what is already on the road. However, there has been no systematic study to assess the performance and durability of the various treatments and they have been regarded as short-life stop-gap measures. In particular, there have been no comparisons of treatments under trunk road conditions.

This is the second of two reports describing a project commissioned by the Department of Transport (now the Highways Agency, an executive agency of the Department of Environment, Transport and the Regions, DETR) to carry out a systematic investigation into the effectiveness of the treatments.

The first phase of the project was carried out from 1989-1993 in conjunction with Queen Mary and Westfield College. A variety of sites and retexturing techniques were examined to assess the treatments available and monitored for skidding resistance and surface texture depth (macrotexture) for up to two years. That work, described in a companion report (Roe & Hartshorne, 1997), showed that the retexturing techniques were effective in increasing the SCRIM Coefficient and that they therefore provided a useful immediate response measure in support of the Departmental Skidding Standards (DMRB 7.3.1). However, the nature of the sites studied was such that it was not possible to make a comparative assessment of different treatments under similar conditions.

Therefore, a second phase of work, the subject of this report, was carried out to investigate the longer-term durability of retexturing techniques under similar traffic conditions on a trunk road. This phase used only one site on which both lanes of the road were treated using four retexturing techniques, at up to three levels of intensity. This report describes and assesses the results of skidding resistance and texture measurements made over the thirty-two months of the trial.

2 Scope of study

The sites included in the first phase of work were diverse and often located at positions of high stress, for example on approaches to roundabouts or through bends. Further, only one treatment was represented at each location. The objective of the second phase of work, therefore, was to compare a number of treatments under conditions which were as nearly as possible identical and which were also representative of normal flowing traffic on a trunk road.

The site chosen, the southbound carriageway of the A12 at Copdock near Ipswich, was a non-event dual carriageway on a trunk road carrying three to four thousand commercial vehicles per day on each carriageway. The treatments started some distance from the Copdock Roundabout so vehicles had generally accelerated up to cruising speed and there were no junctions or bends along the trial length which might disrupt the traffic flow. Because the majority of commercial vehicles used lane 1, it was possible to compare the retexturing techniques under two traffic intensities.

The existing wearing course was of conventional chipped rolled asphalt with the same aggregate throughout. The surfacing had been in place for a number of years and had therefore been trafficked for sufficient time to reach its equilibrium level of skidding resistance. This study does not address the issue of retexturing on concrete surfaces.

2.1 Treatments used

Similar treatments were applied to both lanes of the southbound carriageway. Three treatments from the phase 1 work were chosen: scabbling (Roadtex), bush hammering (Klaruwtex) and orthogonal flailed grooving (Johnston Rapitex). In addition, a section of shot-blasting was carried out by France Grenaillage. The principles of the four treatments are described briefly below.

- *Scabbling.* This treatment uses a combination of cutting and impact actions. Hardened tips set into the edges of steel washers are loosely mounted side-by-side and drawn along the road surface whilst being hydraulically loaded onto it.
- *Bush-hammering.* In this process, the road surface is struck by a number of hydraulically actuated impact heads with specially developed chisel-ended hammers with tungsten carbide tips.
- *Orthogonal grooving.* This is another treatment using the scabbling principle. It consists of longitudinal and transverse flailed grooving combined with scabbling.
- *Shot-blasting.* In this process, the impact is achieved by steel shot projected at high speed from a rotating wheel. As the surface is scoured, both the shot and arisings are recovered and separated, with the steel shot stored for reuse.

2.2 Layout of the trial site

The scabbling and bush hammering processes were applied at three severity levels: nominally low, medium and high, where high represented normal practice. Each level of treatment was applied in adjacent 100m-long sections. For practical reasons, the orthogonal grooving could only be applied at one severity level. Time limitations meant that the shot-blasting technique was confined to one 100m length on both lanes.

In addition to retextured lengths, six untreated 100m sections were included along the trial site, with at least one untreated section separating each process type. This provided control sections to allow the homogeneity of the site to be assessed as the trial progressed.

2.3 Monitoring programme

The treatments were carried out during the third week of February 1994. Measurements of skidding resistance were made using SCRIM[1] and texture depth was recorded using the HSTM[2] during the week before retexturing work began. Measurements immediately after treatment were carried out on the day following completion of the retexturing work. Subsequently, monitoring continued at approximately monthly intervals until the end of the test season in October 1996.

3 Results

3.1 Skidding resistance

It is well known that the skidding resistance of a road changes on a seasonal basis. Skidding resistance falls through the summer period due to the effects of tyres polishing the surfaces of the aggregate particles. A recovery period occurs in the winter in which skidding resistance increases as a result of frost action and abrasion. For this reason, it is normal practice to make SCRIM measurements three times during the summer to provide an average value, known as the Mean Summer SCRIM Coefficient (MSSC).

The skidding resistance measurements in this study showed the typical seasonal trend for both treated and untreated sections. Superimposed on the winter/summer cycle, there was a general downward trend over time, particularly for the treated sections. In order to make comparison between treatments simpler to present, mean summer values were calculated for the three complete summer surveys. Table 1 gives these mean summer values together with the 'immediately after' single measurement for each section, presented in the sequence in which they occurred in the direction of travel. The results for the control sections in the 'immediately after' column represent the road in its untreated condition at the time that the treatments were carried out.

The table also includes the overall means and standard deviations, together with the percentage coefficients of variation, for the control sections. These clearly show the homogeneity of the skidding resistance on the site, which was maintained throughout the trial; the ranges covering the six sections are less than the repeatability of SCRIM measurements.

The results for the 'standard' treatments and the average of the six control sections on the two lanes are shown graphically in Figure 1. The 'before' measurements for all the sections have also been included in the graphs for comparison. The graphs illustrate the general behaviour of the site during the trial. The general difference in level between the two lanes is an obvious feature.

The initial increase in skidding resistance after retexturing can be seen clearly, followed by a gradual fall over time. The difference between the relatively higher winter levels of skidding resistance and the lower summer values is also apparent and the control sections indicate that there was a gradual decrease in MSSC on the untreated road during the trial. These effects are discussed further in Section 4.

3.2 Texture depth

Texture depth does not show seasonal variation but, for ease of comparison, a mean summer texture depth (MSTD) was calculated for each section in a similar way to MSSC. Table 2 shows these results in a similar way to Table 1.

As would be expected for a hot-rolled asphalt surfacing, there was more variation in texture between sections than there was in skidding resistance. However, the coefficients of variation are all well below ten percent, indicating a generally uniform surface.

Table 1 Skidding resistance

	Lane 1				*Lane 2*			
Section	*SC after*	*MSSC 1994*	*MSSC 1995*	*MSSC 1996*	*MSSC after*	*MSSC 1994*	*MSSC 1995*	*MSSC 1996*
control	*0.42*	*0.36*	*0.34*	*0.29*	*0.45*	*0.41*	*0.38*	*0.34*
scabbling light	0.56	0.47	0.40	0.35	0.62	0.54	0.48	0.43
scabbling moderate	0.59	0.50	0.43	0.37	0.67	0.56	0.51	0.46
scabbling standard	0.59	0.50	0.43	0.37	0.68	0.56	0.50	0.44
control	*0.44*	*0.37*	*0.35*	*0.30*	*0.51*	*0.41*	*0.39*	*0.34*
bush hammering light	0.49	0.41	0.37	0.32	0.57	0.46	0.44	0.38
bush hammering moderate	0.51	0.42	0.38	0.33	0.58	0.46	0.44	0.39
bush hammering standard	0.54	0.43	0.38	0.33	0.62	0.50	0.45	0.41
control	*0.43*	*0.34*	*0.33*	*0.29*	*0.50*	*0.41*	*0.39*	*0.37*
	0.46	*0.36*	*0.35*	*0.30*	*0.50*	*0.41*	*0.40*	*0.36*
orthogonal flail grooving	0.57	0.45	0.40	0.34	0.61	0.51	0.48	0.42
	0.55	0.45	0.39	0.34	0.61	0.50	0.47	0.41
control	*0.44*	*0.37*	*0.36*	*0.31*	*0.49*	*0.41*	*0.41*	*0.37*
	0.44	*0.36*	*0.35*	*0.30*	*0.49*	*0.41*	*0.41*	*0.37*
shot blasting	0.59	0.44	0.37	0.32	0.63	0.51	0.46	0.40
all controls mean	*0.44*	*0.36*	*0.35*	*0.30*	*0.47*	*0.41*	*0.40*	*0.35*
std. dev.	*0.012*	*0.010*	*0.009*	*0.007*	*0.019*	*0.000*	*0.011*	*0.014*
c.o.v (%)	*2.77*	*2.78*	*2.72*	*2.30*	*3.91*	*0.00*	*2.79*	*3.89*

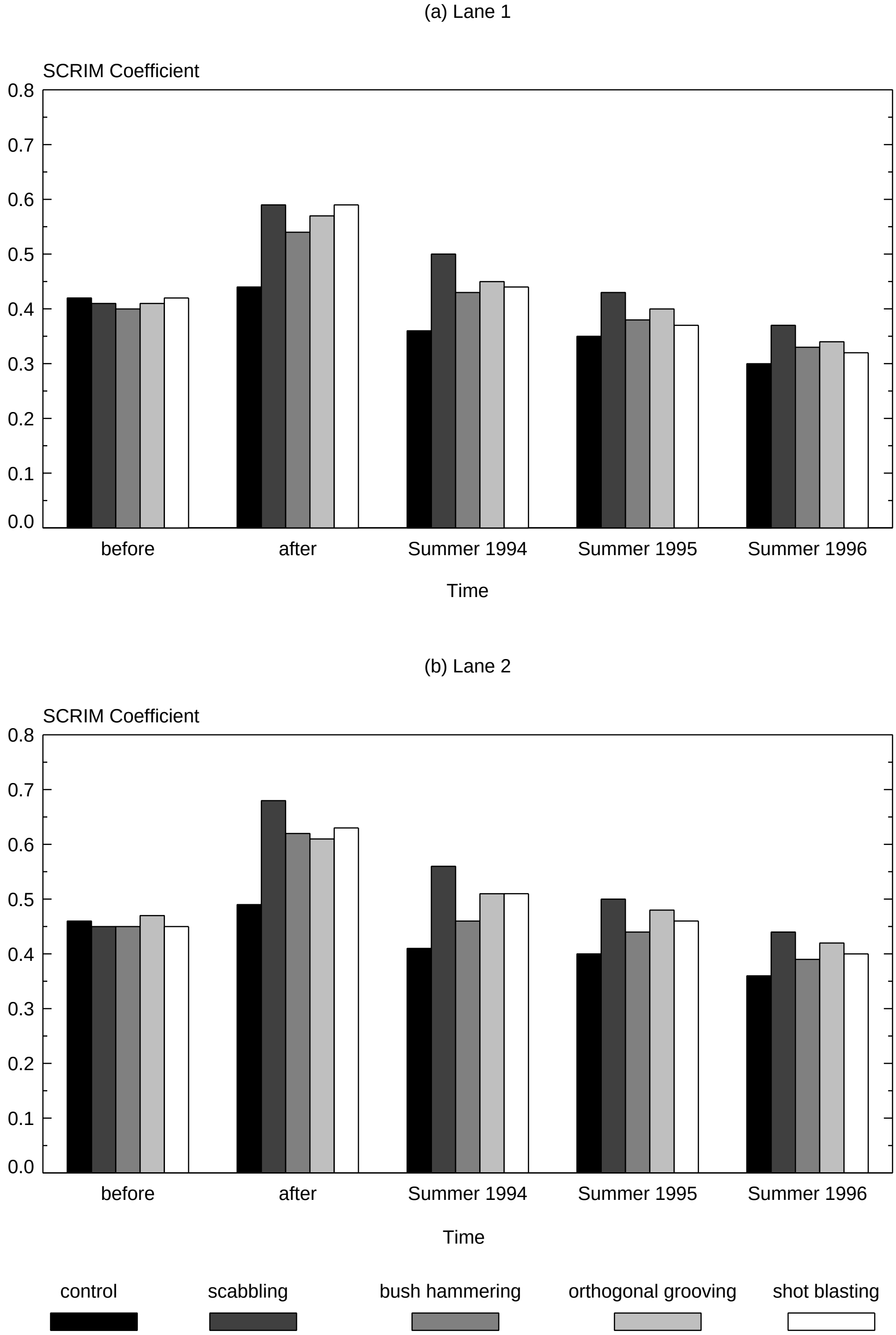

Figure 1 Skidding resistance

Table 2 Texture depth (mm)

Section	*Lane 1* SMTD after	MSTD 1994	MSTD 1995	MSTD 1996	*Lane 2* MSTD after	MSTD 1994	MSTD 1995	MSTD 1996
control	*1.21*	*1.19*	*1.19*	*1.13*	*1.40*	*1.53*	*1.60*	*1.52*
scabbling light	1.20	1.14	1.08	0.97	1.34	1.49	1.52	1.45
scabbling moderate	1.08	1.00	0.91	0.83	1.04	1.18	1.22	1.06
scabbling standard	1.04	0.98	0.84	0.78	1.02	1.27	1.19	1.09
control	*1.14*	*1.07*	*1.07*	*1.03*	*1.53*	*1.58*	*1.64*	*1.60*
bush hammering light	1.26	1.05	0.99	0.97	1.49	1.57	1.72	1.60
bush hammering moderate	1.22	1.08	1.03	0.97	1.26	1.28	1.40	1.34
bush hammering standard	1.18	1.18	1.09	0.99	1.19	1.27	1.44	1.34
control	*1.11*	*0.99*	*0.97*	*0.92*	*1.27*	*1.24*	*1.48*	*1.41*
	1.11	*1.04*	*1.02*	*0.94*	*1.32*	*1.37*	*1.58*	*1.49*
orthogonal flail grooving	1.42	1.07	0.90	0.80	1.67	1.76	1.82	1.69
	1.50	1.14	0.90	0.81	1.54	1.63	1.67	1.55
control	*0.95*	*0.97*	*0.92*	*0.87*	*1.40*	*1.48*	*1.72*	*1.66*
	1.02	*1.07*	*1.01*	*0.97*	*1.38*	*1.38*	*1.61*	*1.56*
shot blasting	1.32	1.33	1.19	1.14	1.55	1.67	1.75	1.69
all controls mean	*1.09*	*1.06*	*1.03*	*0.98*	*1.38*	*1.43*	*1.61*	*1.54*
std. dev.	*0.084*	*0.071*	*0.085*	*0.084*	*0.081*	*0.113*	*0.072*	*0.080*
c.o.v (%)	*7.69*	*6.74*	*8.26*	*8.60*	*5.82*	*7.93*	*4.46*	*5.18*

Figure 2 summarises these results graphically on the same basis as Figure 1. The most striking features of the graphs are the differences between the lanes. Lane 2 had a generally greater texture depth than lane 1 but the behaviour of the texture in the two lanes over time was quite different. The effects are discussed further in Section 4.

4 Effects of retexturing

4.1 Underlying trends and the enhancement concept

Before comparing the effects of the different retexturing treatments, it is necessary to consider the underlying trends which will have been influencing all the surfaces. The key factors here are those of climatic conditions and traffic. Their influence may be assessed by considering the performance of the control sections.

4.1.1 Skidding resistance of control sections

The control sections had been in service for a sufficient length of time to have polished to their equilibrium summer values. This means that the aggregate had achieved a balance between the polishing action of the traffic during the summer and the recovery of skidding resistance during the winter period. It would therefore be expected that there would be relatively small changes in the mean summer values over the period of the study.

The measurements before the trial and those immediately after the retexturing treatments had been applied were both made in mid-winter. The road was in the recovery phase of the annual cycle and, therefore, skidding resistance would have been still increasing or near its peak. This was confirmed by the control sections (see Figure 1) which showed a slightly higher level at the end of the severely cold week in which the treatments were carried out than they had shown just before the trial. The skidding resistance then fell to the lower mean-summer value as a result of the polishing action of traffic.

There was also a slight fall in MSSC in both lanes from year to year. The average decrease from 1994 to 1995 was 0.01 units for both lanes; this is less than the repeatability of the measurements and unlikely to have been a significant change. However, from 1995 to 1996 the average MSSC decreased by 0.05 units for both lanes. This possibly reflects a longer polishing period (a dry spring followed by a dry summer); an increase in traffic over the period could also have a similar effect.

The difference in mean level of MSSC between the two lanes was 0.05 throughout the trial. This is a clear indication of the different levels of polishing caused by the different levels of traffic in the two lanes.

4.1.2 Texture depth of control sections

There was some variation in texture between the control sections along the length of the road but this was consistent with that expected for this type of surfacing. Of greater interest is the difference between the lanes.

On average, the control sections in lane 2 had a texture depth about 0.05 mm higher than lane 1 before the

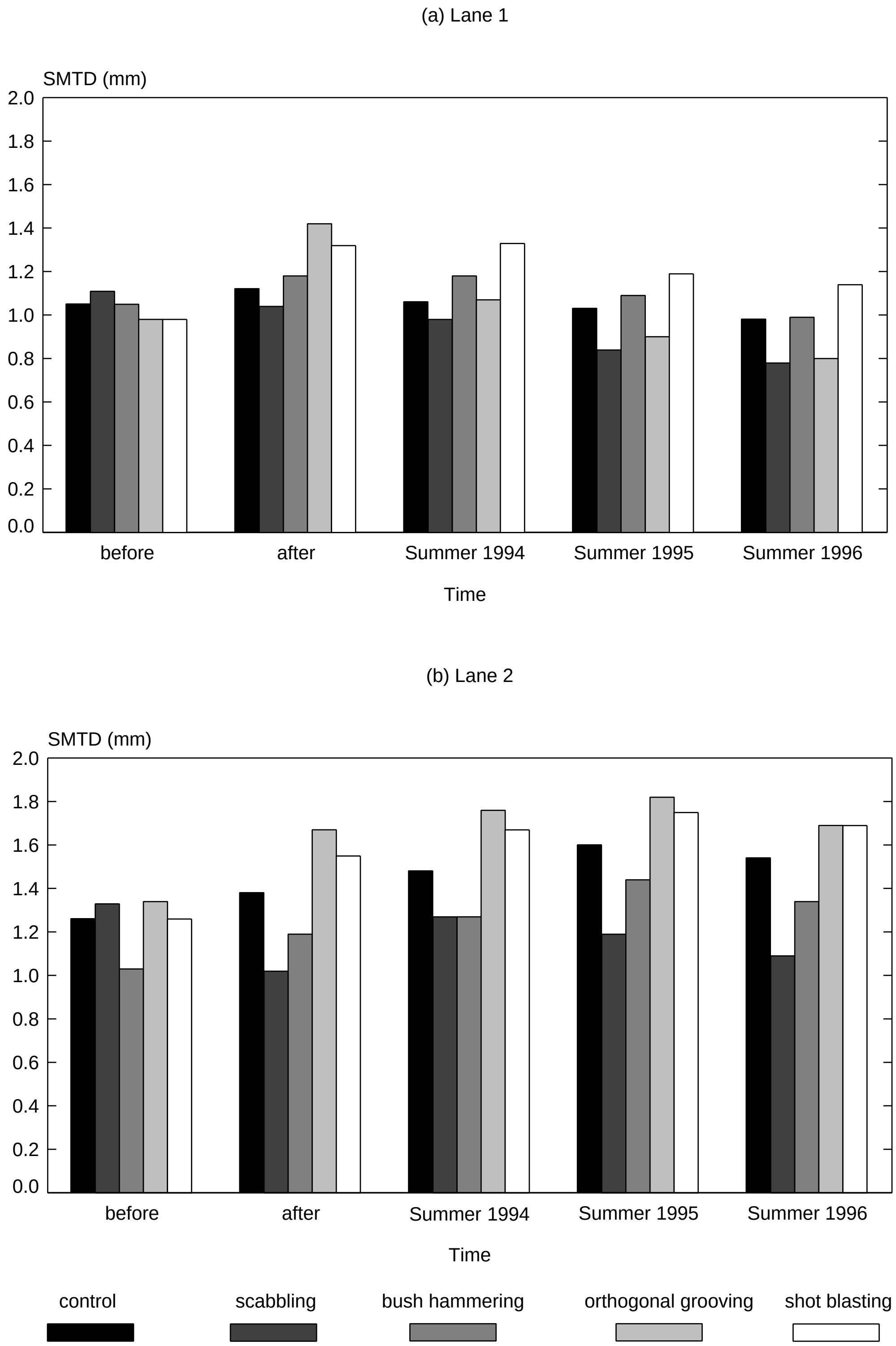

Figure 2 Texture depth

retexturing trial. This is to be expected because the different levels of traffic will have different influences on the material; in particular, greater chipping embedment would be expected in lane 1 under the influence of the greater numbers of heavy vehicles. However, as can be seen in Figure 2, the marked difference in behaviour between the lanes during the subsequent periods is of greater significance.

In lane 1 there was a small, but not significant, increase after the retexturing had been carried out on the adjacent sections, followed by a return to the original level in the summer. There was gradual small decrease in texture from year to year leaving lane 1 on average 0.05mm lower in the summer of 1996 than it was before the trial began. This was probably due to a gradual embedment and wear of the chippings under the heavy traffic.

In contrast, the texture in lane 2 showed a steady increase through 1994 and 1995. It reduced slightly in 1996 but was still 0.26 mm higher on average that summer than in the week of the trial. A possible explanation for this is that, with only light traffic using lane 2, there may have been greater weathering of the asphalt matrix without corresponding wear or embedment of the aggregate particles. The hot 1996 summer may have created conditions in which some embedment could occur, leading to the slight reduction in that year.

4.1.3 The concept of enhancement

The results for the control sections have shown that, although the road itself was homogeneous along the site and therefore provided a fair basis for comparison of the treatments, there were some small differences between the various sections, particularly for texture depth. Further, there were underlying trends affecting the untreated sections which would also have been having an influence on the retextured lengths.

In the first phase of the project (Roe and Hartshorne, 1997), the concept of 'enhancement' was introduced to compare the measured parameter at a given time after retexturing with the value that it would have had at the same time if the road had been left untreated. A similar idea was therefore used to compare the effects of the different retexturing techniques on skidding resistance and texture depth for this study.

Because control sections with similar properties were available, it was possible to make direct comparisons with the 'left alone' condition at any time during the trial (which had been a problem in the phase 1 work). Therefore, for this study, the 'enhancement' for a particular section at a particular time was defined as:

> *"the difference between the value for the treated section and the average of the adjacent control sections, divided by the average value of those control sections and expressed in percent".*

Enhancement values were calculated for the retextured sections immediately after treatment and for the three subsequent summer means. The values are recorded in Tables 3 and 4 for skidding resistance and texture depth respectively. For this purpose, the two orthogonal grooving sections, which were identical in treatment level, were regarded as a single section.

4.2 Effect of retexturing on skidding resistance

4.2.1 Initial enhancement

Table 3 shows that, in both lanes, there was an immediate enhancement in skidding resistance from all four retexturing techniques. The different levels of treatment for the bush hammering and the scabbling processes can be seen, with the light treatments yielding less enhancement than the normal levels. There is little to distinguish the moderate treatment from the normal, in the case of scabbling, or from the light in the case of bush-hammering, but this is probably due to the ad-hoc way in which the contractors chose to set their machines and may simply reflect the physical limitations on controlling the processes.

Based on initial enhancement, the normal treatments ranked, from greatest to least, in the same order on both lanes (although there was only one percentage point on lane 2 and none on lane 1 between the last two), as follows:

- longitudinal scabbling (39% lane 1, 42% lane 2);
- shot blasting (35% lane 1, 29% lane 2);
- bush-hammering (24% lane 1 and lane 2);
- orthogonal flailing (24% lane 1, 23% lane 2).

Table 3 Enhancement of skidding resistance

	Enhancement (percent) Lane 1				*Enhancement (percent) Lane 2*			
Treatment	*Immediate*	*Summer 1994*	*Summer 1995*	*Summer 1996*	*Immediate*	*Summer 1994*	*Summer 1995*	*Summer 1996*
scabbling light	32	28	15	19	29	34	23	26
scabbling moderate	38	38	24	25	39	38	30	35
scabbling normal	39	36	24	25	42	37	29	29
bush hammering light	13	16	9	8	14	14	12	7
bush hammering moderate	18	18	11	12	15	14	13	10
bush hammering normal	24	21	12	12	24	22	14	15
orthogonal flail grooving	24	25	13	12	23	24	17	13
shot blasting	35	21	8	7	29	24	11	8

Table 4 Enhancement of texture depth

Treatment	Enhancement (percent) Lane 1 Immediate	Summer 1994	Summer 1995	Summer 1996	Enhancement (percent) Lane 2 Immediate	Summer 1994	Summer 1995	Summer 1996
scabbling light	2	1	-4	-10	-9	-5	-6	-7
scabbling moderate	-8	-11	-19	-23	-29	-4	-24	-32
scabbling normal	-11	-13	-25	-28	-30	-18	-27	-30
bush hammering light	12	2	-3	-1	6	11	10	6
bush hammering moderate	8	5	1	-1	-10	-9	-10	-11
bush hammering normal	5	15	8	2	-15	-10	-7	-11
orthogonal flail grooving	43	11	-6	-10	17	22	5	2
shot blasting	29	25	19	18	12	21	9	8

4.2.2 Durability of the enhancement

It can be seen from Table 1 that by the first summer (1994) all the surfaces had polished and reduced in skidding resistance, but the treated sections (Table 2) continued to show a significant enhancement over the untreated sections. The enhancements for each treatment remained of a similar order in both lanes. In terms of MSSC, all the treated sections were at least 0.05 units and, in some cases, 0.10 units higher than the untreated sections, which is of practical significance in terms of the Highways Agency skidding resistance standards (DMRB 7.3.1). At that stage, differences between the levels of severity of treatment could still be seen, although the range had reduced in comparison with the initial value.

It is of interest to observe that, in terms of enhancement, the orthogonal grooving process had retained or slightly improved while the other ‘normal’ treatments had reduced and, as a result, moved to second place in the ranking order.

In 1995, the retextured sections still had a higher MSSC than the control sections but the differences due to treatment intensity had almost disappeared. Further, the degree of enhancement had fallen to relatively low levels. In 1996 these lower enhancement levels were retained but relative to a further reduced skidding resistance on the control sections (see Figure 1). Nevertheless, this small residual enhancement after three summers could be of practical significance in relation to the Highways Agency skidding standards, as will be discussed in Section 5.

4.3 Effect of retexturing on texture depth

Unlike skidding resistance, where all the treatments had similar effects in both lanes, the influence of the different processes on texture depth varied both between processes and between lanes. Each process will be considered in turn.

4.3.1 Scabbling

As might be expected, the scabbling process generally had a ‘negative enhancement’, that is to say, it reduced the texture depth. As with skidding resistance, there was little difference between the normal and moderate treatment levels. The light treatment showed a slight positive enhancement in lane 1, possibly a result of cutting small grooves without having a significant impact on the aggregate particles. The more severe applications of this treatment, however, removed the tops of the chippings without cutting deeper grooves at the same time, thus leading to a net loss of texture.

By the 1996 summer, the relative loss of texture was more marked in lane 1 (about -30% compared with the initial value of -11%) whereas lane 2 remained unchanged at about -30%.

4.3.2 Bush hammering

The effects of bush-hammering were more varied. On lane 1 there was an initial enhancement of texture, the lighter treatment giving the greatest enhancement, with the light treatment having a similar effect on lane 2. This was probably due to the hammer- heads cutting short, fine grooves into the surfaces of the chippings without breaking away much material and hence increasing texture depth slightly. However, on lane 2 the more severe levels of treatment led to a reduction in texture, probably a result of removing a greater amount of material from the more-exposed chipping surfaces.

On the higher-textured, lightly-trafficked, lane 2 the effects of this treatment remained effectively unchanged throughout the trial. However, on lane 1 the texture reduced so that by 1996 the effect of this process on texture was neutral.

4.3.3 Orthogonal grooving

Initially, the orthogonal flail grooving process significantly increased texture in both lanes. The enhancement in lane 1 was 43% and in lane 2 was 17%. This was to be expected from the most aggressive of the treatments, which cut away a significant amount of material to create a checkerboard groove pattern.

Over time, however, the effect was reduced as the traffic gradually closed up the grooves. In lane 1, in fact, there was an ultimate loss of texture by 1996, presumably because the grooves had closed up and, at the same time, the loss of material cut away from the tops of the chippings by the scabbling mechanism which was part of this process began to be significant. Further, the spaces created where chippings had been broken or plucked from the surface by the flails had also closed up.

4.3.4 Shot blasting

This process enhanced texture throughout the trial. The effect was greatest in lane 1 where the initial texture was lower. The shot-blasting technique would be expected to have this effect because the shot is able to penetrate and remove some of the asphalt matrix evenly at the same time as it refreshes the surfaces of the chippings. There was a gradual loss of enhancement over time in both lanes.

5 Discussion

In discussing the results of this trial, it is important to recognise that different treatments will, by their very nature, have slightly different effects and may not always be suitable for particular sites. Although the treatments used here were all compared under as similar conditions as was possible, some of the less-satisfactory aspects of the results may have been due, in part, to circumstances on the site. Nevertheless, the work does allow a discussion of the performance of the individual treatments and enable an overall assessment to be made.

5.1 Scabbling

This process produced and maintained the greatest enhancement in skidding resistance of all four processes, on both lanes and at all levels of treatment. However, the process reduced macrotexture, with the most severe treatment showing a texture depth loss of about 30% at the end of the third summer.

The convergence towards the end of the trial of the MSSC values for both the moderate and standard treatments suggests that the more severe treatment reduced the texture depth without further improving skidding resistance. The light level of treatment showed a comparable durability of skidding resistance to the normal level with this process and also to the other processes. Therefore, with this technique, where loss of texture is likely to be a problem, lighter applications might be worth considering.

5.2 Bush hammering

This process also enhanced the skidding resistance but, with the treatment intensities used here, not as much as some other processes. Some enhancement was retained throughout the trial but it had reduced to half its initial value after three summers under the heaviest traffic. The impact on texture depth was small, generally resulting in a decrease, although on lane 2 the light application produced a slight increase. These changes were maintained at similar levels throughout the trial.

The contractor claims that this process can be repeated to achieve a desired skidding resistance but this concept was not tested in this study. The measurements suggest that increasing severity of treatment does increase skidding resistance, albeit at the risk of losing texture, although it is not known what limiting value could be achieved. It may be worthwhile experimenting with the effects of applying several repeated light treatments to a site rather than a single, more severe treatment, in order to limit any reduction in texture depth. However, there would, of course, be cost implications with such an approach.

5.3 Orthogonal flail grooving

This process resulted in an enhancement in skidding resistance comparable to the bush hammering process. The process also increased texture depth initially, markedly so in lane 1, but the effect was lost in the wheelpaths of both lanes as the grooves closed under the action of traffic and, by the end of the trial, the net effect in the heavily-trafficked lane 1 was a loss of texture.

This process is clearly effective in increasing macrotexture where this is required but it needs to be used with caution. On this site, where texture was already acceptable, especially in lane 2, the process probably damaged the surface even though the texture was, numerically, enhanced; there was a significant amount of plucking of chippings. Under heavy traffic over two relatively hot summers, the grooves in the asphalt matrix were not durable. Further, the regular grooves generated within the road surface could give rise to undesirable side-effects such as increased road noise and reduced ride stability for motorcycles and other two-wheeled motor vehicles.

Consideration should be given to applying the grooving treatment on an angle rather than perpendicular to and in line with the traffic flow. It may be less suitable for heavily-trafficked roads where enhanced macrotexture is required but the heavy traffic will rapidly deform the asphalt and close the cut grooves.

5.4 Shot blasting

This process produced a good initial enhancement in skidding resistance but this was not maintained as well as the other treatments over the whole trial. The texture depth was initially enhanced for both lanes, with lane 1 continuing to show a significant improvement over all other processes after three summers.

This treatment was the best of the four at enhancing the macrotexture of the chipped rolled asphalt surfacing, both numerically and physically, by removing the weathered asphalt matrix whilst leaving the chippings (with renewed faces) exposed.

5.5 Overall assessment of durability

The phase 1 work had shown that localised, short-term enhancements in skidding resistance and texture could be achieved with appropriate treatments. This was confirmed here, but the primary objective of the study was to assess the durability of the treatments under trunk-road traffic.

The work has clearly shown that all four retexturing processes produced an enhancement in skidding resistance over the untreated road which lasted for at least three summers. In practical terms, this level of durability is all that could be expected because even newly-laid material would be expected to polish to an equilibrium level in that time. Under heavy traffic this period of improvement may be even shorter.

On this site, the untreated surfacing lost some skidding resistance during the trial, indicating that either weather conditions or increasing traffic flow favoured polishing. The effect was to reduce the MSSC of the control sections to a level where the normal three-year routine monitoring cycle might be expected to trigger investigation for wet-skidding accident problems. However, the treated sections, which were also exposed to the same increased polishing action, remained above the investigatory level for two summers and, for the scabbling process, for three summers.

Therefore, the results confirm that retexturing treatments are useful tools to enhance the skidding resistance of a surfacing which is at, or near, its investigatory level and can provide at least two and, in some cases, three or more full summer seasons of enhancement under non-event mainline trunk road conditions.

These results apply to rolling traffic. It is possible that durability will be less in higher-stress situations where, for example, frequent braking occurs. However, in such situations the same stresses apply to new materials and they, too, would be expected to polish more rapidly than in the free-flowing traffic situation. Similar remarks could be made regarding heavier traffic conditions, but in such cases repeated treatments might be appropriate where the surfacing is otherwise sound.

As far as macrotexture is concerned, only two of the treatments studied here had a marked effect on increasing texture depth. This was to be expected both from the nature of the processes and the generally good levels of texture on the road. The durability of any enhancement was limited because of the plastic nature of asphalt. The best results are likely to be achieved by processes which remove the matrix evenly, as shot-blasting did here and water-jetting did in the phase 1 work. However, care needs to be taken to ensure that chippings are not loosened by removing too much supporting material.

5.6 Other considerations

Although this work has shown retexturing to be a useful option for engineers to consider when addressing problems of skidding resistance or texture depth, there will always be other factors to take into account.

- *Limitations of individual processes:* clearly, some treatments will be more appropriate for some surfacings than others. For example, scabbling or flail grooving, which use a potentially aggressive cutting action, would not be suitable for a surface dressing or other surfacing type where small aggregate particles are relatively loosely bound to the substrate or surrounding matrix.
- *Effects of individual treatments in relation to desired outcome:* The effect of an individual process on both skidding resistance and texture depth must be considered in the light of what is required in a particular situation. For example, where the surface texture is already at an acceptable level or when increasing it is undesirable (perhaps because of increased tyre noise), a treatment which did not increase surface texture would be appropriate. Conversely, where texture is low and this is a concern, treatments which could reduce it further should be avoided.
- *Speed of application:* a major advantage of retexturing processes is that they can be applied quickly and lead times can be short. The speed of application can vary from 1500m^2 to over 8000 m^2 per day, which compares favourably with treatments which involve laying new materials. With some retexturing processes, for example bush hammering, the whole lane or carriageway can be treated in one pass (machines working in echelon can be used to treat wider roads) and traffic management can be simple.
- *Seasonal requirements:* most surface treatments which involve the application of new material to the road have a restricted working season. Seasonal effects are generally less important for retexturing of road surfaces. The work for this trial was carried out during a period of very cold weather but it was completed satisfactorily. However, there were practical difficulties with some processes relating to the use of water for dust suppression in freezing conditions. Most techniques can be used throughout the year, with the added advantage that (apart from requiring caution in extreme conditions) retexturing is useful as a rapid-response autumn or winter treatment in preparation for the following summer.
- *The general condition of the road*: Retexturing is most effective on road surfacings which are generally sound. If some sealing action is required in addition to improved skidding resistance or texture, retexturing will be inappropriate. Similarly, a surface which is fretting or losing chippings may be damaged further by mechanical action. However, where a road is approaching a point where structural weakness may mean reconstruction is imminent, retexturing can be effective in enhancing skidding resistance properties during the final years of the surfacing's life.

6 Conclusions

The trial on the A12 has demonstrated that mechanical retexturing techniques can provide both immediate and durable benefits in the improvement of skidding resistance in comparison with similar untreated surfacing under the same traffic conditions.

Useful benefits lasted for at least two and, in some cases, more than three full summers under rolling traffic on a dual carriageway trunk road carrying over three thousand commercial vehicles per day in lane 1.

The following conclusions may be drawn from the study:

- Retexturing is clearly a useful tool available to maintenance engineers; its increased use in appropriate circumstances should be considered.
- Retexturing is of particular value where:
  - a generally sound road is at, or approaching, its investigatory level for skidding resistance
  - rapid intervention is required
  - reconstruction is anticipated but an improvement in the skidding resistance of the wearing course is needed for the last years of the road's life.
- Care needs to be exercised in selecting the process to be used in a particular situation.

Further research is necessary to study the longer-term effects of retexturing on concrete surfaces.

7 Acknowledgements

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8 References

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Notes

[1]**SCRIM**. Sideways-force Coefficient Routine Investigation Machine. The SCRIM was developed by TRL to enable highways engineers to monitor the skidding resistance of their roads. The test wheel is mounted at an angle of 20^{o} to the direction of travel and generates a sideways force at right angles to the plane of the test wheel. The ratio of this force to the vertical force between the test wheel and the road gives a measure of the skidding resistance.

[2]**HSTM.** High Speed Texture Meter. The HSTM was developed by TRL to enable the highways engineer to monitor the texture depth of large road networks, something that is not possible using the traditional sand-patch method. A contactless laser sensor mounted on a trailer continuously measures the distance from the sensor to the road. Some SCRIM vehicles are also fitted with the laser sensor equipment.

Abstract

This report is the second in a series describing the results of a project examining the effects of mechanical retexturing of road surfaces. It reports the work done to study the durability of four processes (scabbling, bush hammering, orthogonal flailed grooving and shot blasting) on a rolled asphalt surfacing. These were applied to both lanes of a length of dual carriageway trunk road in February 1994. The study compared the skidding resistance and texture depth of the retextured sections with untreated control sections at the time of treatment and, subsequently, through the summers of 1994, 1995 and 1996. It was found that all four processes improved skidding resistance compared to the control sections and some improvement was still in evidence at the end of the thirty-two month trial. The scabbling and bush-hammering reduced the texture depth.

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