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Mechanical retexturing of roads: a study of processes and early-life performance

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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. This work was carried out by Queen Mary and Westfield College, University of London (QMWC) under contract to, and in close co-operation with TRL. Subsequently, an experiment was carried out on a trunk road in order to assess the durability of the more promising treatments.

This report covers the first stage of the work; the durability study is reported in a companion report, TRL299.

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. The action of traffic in wearing and embedding 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 Standards for UK Trunk Roads and Motorways currently address these problems for new roads by defining both the polishing-resistance of the stone to be used and a minimum texture depth. For in-service roads, microtexture is covered by Departmental Skidding Standard HD28, which sets ‘investigatory levels’ of skidding resistance, measured by SCRIM, for different categories of site related to the risk of wet-skidding accidents. As yet, there are no national standards for macrotexture on in-service roads.

The advent of the skidding-resistance standards has meant increased interest in methods of treating those sites which are found to have SCRIM coefficients 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 work was carried out in two phases. In the first of these, covered by this report, available processes were identified and their initial performance was assessed. In a second phase of work, a more systematic assessment of longer-term durability was carried out.

Three generic methods of retexturing were identified: impact, cutting and fluid action.

These have been represented by the work of five UK contractors covering bush-hammering, scabbling and flailing, grinding and water-jetting. It was not possible to include shot-blasting among the techniques studied during the first phase of the project, although this method was added to the second phase.

A number of sites were the subject of ‘before and after’ studies of skidding-resistance and macrotexture, using high-speed measurement techniques (SCRIM and High-speed texture meter). Where possible, monitoring was continued for up to two years in order to gain an initial indication of durability. As part of the studies, the operation of the plant, environmental effects (such as dust and noise) and traffic management were observed.

Measurements from adjacent, untreated control sections were used to indicate the effects of seasonal variations so that changes in the treated sections could be assessed. The before-and-after studies indicated that, in many instances, an improvement in skidding resistance was being achieved initially and that, on some sites, this was maintained for up to two years. However, values achieved were found to be dependent on the initial condition of the surfacing, its type and constituent materials, particularly the surfacing aggregate, so that general conclusions are difficult to draw.

In spite of some difficulties, it was possible to gain some useful information on the various treatments. The report includes a comprehensive set of colour photographs in order to illustrate the techniques and their effects. The following general observations can be made based on the first phase of the project:

- Skidding resistance is generally increased when using a process with a significant impact component, exposing fresh stone surfaces. Water-jetting can increase skidding resistance where there is a film of binder on the aggregate. Grooving and grinding processes do not have a significant impact on skidding resistance and, in some cases, may reduce it.
- Texture depth can be reduced using bush hammering techniques by removing peaks from surface particles. Scabbling has a broadly neutral effect on texture. Grooving can increase texture while corduroy texturing will tend to reduce texture. Water-jetting and shot blasting can increase texture by eroding the matrix around the aggregate particles.
- Winter treatment is both practical and effective, provided care is taken in under freezing conditions.

The work indicated that mechanical retexturing techniques are a useful addition to the engineer’s options for road maintenance. Treatments are available to address the problems of polished aggregate, low macrotexture and excess binder. They often cost less than conventional treatments and can be applied quickly with minimum disruption to traffic.

1 Introduction

In 1988, standards for the skidding resistance of in-service UK trunk roads were introduced. As a result, there was an increased interest in techniques for restoring skidding resistance which could be used in circumstances, or under conditions, unsuitable for traditional methods. A number of different ways of retexturing road surfaces have been suggested as alternatives to conventional treatments for restoring skidding resistance. However, there has been little independent evidence of their effectiveness and, therefore, the then Department of Transport (now the Highways Agency, an executive agency of the Department of Environment, Transport and the Regions, DETR) commissioned TRL to carry out a systematic investigation.

The work was carried out in two phases. In the first phase:

- the different retexturing methods were identified
- the immediate effectiveness of each process was assessed and
- the initial durability of each of the different retextured surfaces was assessed.

This was done using skidding resistance and surface texture measurements taken shortly before and after the treatment, then at intervals over a period of about two years.

Much of this first phase of the work was carried out by Queen Mary and Westfield College (QMWC), University of London, on behalf of TRL under a research contract. The QMWC team was responsible for studying the retexturing methods available and plant used, liaison with contractors and highway authorities and appraisal of the suitability of sites. The QMWC team was also responsible for monitoring, including measurement of the skidding resistance using the manual ‘pendulum tester’ and texture depth using the ‘sand-patch’ method at selected sites and for initial analysis of the data. TRL provided project management support and the full-scale measurements of skidding resistance and texture depth using the Sideways Force Coefficient Routine Investigation Machine (SCRIM)[1], and the high-speed texture meter (HSTM)[2].

This report covers the work done in the first phase of the study of mechanical retexturing. It draws on the report provided by QMWC at the end of their contract but also takes account of subsequent measurements and analysis.

In the second phase of work, the longer-term durability of the more promising treatments was studied. That phase, which was based upon a full-scale controlled trial in which a number of retexturing treatments were applied to one site, is reported in a companion report (Roe & Hartshorne, 1997).

2 Background

2.1 Skidding resistance and surface texture

The maximum frictional force available between the tyre and a wet road surface is governed by the microtexture (small-scale asperities in the size range up to 0.2mm) in the surfacing aggregate. It has been known for many years that microtexture is polished by traffic and, as a result, the skidding resistance of a new road falls (usually within three years) to an equilibrium level. The level reached depends on the polishing resistance of the exposed aggregate (measured by its polished stone value or PSV) and the volume of traffic to which it is subjected (Szatkowski and Hosking, 1972).

This finding was included in a guide to desirable levels of skidding resistance published in LR 504 (Salt and Szatkowski, 1973) and subsequently became part of the Department of Transport’s specification for new roads (DTp, 1976). The PSV of aggregates was specified for new surfacings in terms of the level of traffic expected to use the road. However, this development did not regularise the situation for in-service roads because it was found that skidding resistance levels continued to fall as traffic volumes increased beyond those predicted at the design stage (as had been shown in LR 504).

By 1987, improved monitoring methods and correlation of accident data with skidding resistance made it possible for a standard to be set for the skidding resistance of in-service trunk roads, HD28, which is now embodied in Volume 7 of the Design Manual for Roads and Bridges (DMRB). The Standard specifies Investigatory Levels at, or below, which investigations of the characteristics and accident record of the site are required. The investigatory levels chosen depend on the type of site and the accident risk. The levels are lower on low-risk sites, such as non-event sections of dual carriageways or motorways, and higher at high-risk sites, such as the approaches to traffic lights or sharp bends. Unfortunately, the sites at which it is particularly important to maintain adequate skidding resistance are also those where vehicles brake or corner, and hence the polishing action of traffic is most severe and the largest decreases in skidding resistance are found.

However, wet-road skidding resistance also falls with increasing speed, the change being largest on smooth-textured surfaces. Therefore, on relatively high-speed roads, it is desirable that an adequate macrotexture is provided and maintained. In the context of wet roads, this has long been recognised and, at the same time that standards for polishing resistance were introduced, the specification also included a minimum texture depth for new asphalt surfacings of 1.5mm as measured by the sand-patch method (SP). There is a different value set for concrete roads. No standards have as yet been set for in-service roads. Attention has traditionally been focused on the problem of wet roads, the general assumption being that skidding resistance of dry roads was adequate for all but exceptional circumstances. However, recent work (Roe, Webster and West, 1991) has indicated that improved macrotexture could also benefit dry-road accident rates and further research on macrotexture is in hand.

2.2 Attractions of retexturing

For safety reasons, it is important that a road surface has both microtexture and macrotexture. Without them, unacceptable skidding resistance levels can often be reached even though the pavement is still structurally sound. It is not always feasible or economic to replace the aggregate when levels first fall below those required. Methods of in-situ retexturing can potentially offer rapid and convenient restorative treatments in such situations.

There are a number of factors which make retexturing an attractive option:

- natural resources are conserved
- the process may be more economical than some traditional methods
- the operation is often less weather-sensitive
- traffic disruption is reduced because of the speed of operation
- the treatment can be used as a ‘stop-gap’ measure (for example, to provide a short-term improvement until the next surface dressing season); and
- it may be possible to repeat the treatment periodically.

3 Mechanical retexturing methods

Methods in current use for mechanical retexturing in the United Kingdom can be classified into three generic categories - mechanical impact, cutting/grinding and fluid action.

3.1 Impact

Processes in this category involve striking the surface either with hard-tipped tools (bush hammering) or with hard particles (shot blasting).

3.1.1 Bush hammering

In this process, the surface is struck by a number of hydraulically-actuated impact heads with specially-developed, chisel-ended hammers with tungsten carbide tips. These are designed to rotate freely and have sufficient vertical movement to follow most degrees of profile deformation such as moderate wheel-track rutting.

The treatment is represented in this study (see Section 5.2) by Klaruw RMS Ltd using their Klaruwtex 190 machine (Photograph 1*). This large machine has 84 independent bush-hammering heads arranged in two banks in zig-zag formation to give a normal treatment width of 1.9m, although narrower widths can be treated by isolating selected heads. The degree of retexturing can be controlled by adjusting the impact of the heads and varying the machine’s speed, which is normally in the range of 6-10 metres per minute. A 4-wheel crab-steer capability enables the machine to manoeuvre in restricted areas and allows it to retexture very close to kerbs and walls.

Rolled asphalt, dense bituminous macadam and surface dressing sites have been included in the present study. The machine has also been used on cement concrete, for bitumen removal from newly-laid pre-coated chippings, and the removal of thin bituminous films from unchipped rolled asphalt. The contractor acknowledges that the treatment is unsuitable for block paving, cobbles, surface dressings which have fatted-up, and flint aggregate surfacings.

Photograph 2 is a close-up of a treated (right) and untreated part of the dense bituminous macadam surface seen being retextured in Photograph 1. The effect is to strike away some of the old, polished upper surfaces of the aggregate and to cut into some of the particles. The effect of the angled hammer-tips can just be observed.

3.1.2 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 shot and arisings are recovered. The foreign matter is then removed by an airwash separator and the steel shot is collected in a storage hopper for recirculation. Pulverised shot, dust and other small particles are carried away by the airstream and collected in a filter. Both the weight of shot and its projection velocity can be adjusted to vary the finish required. This can range from simply cleaning the surface to a more severe attrition of the aggregate and, in the case of rolled asphalt, the bituminous matrix.

This treatment was not represented in the practical stages of the first phase of the project because no contractor was marketing the process in the UK at that time. However, a French company were exploring the possibility of offering the treatment in the UK and treated a section for the second phase (Roe and Hartshorne, 1997). Photograph 3 shows the equipment in operation: small manually-propelled machines were used here, treating a path about 0.5m wide and making several passes to cover a full lane width, although larger machines are available. At the time of writing, the technique is still not widely marketed in the UK although it is understood that some UK contractors can offer the process.

3.2 Cutting

This category includes cutting, sawing, grooving, grinding and scabbling/flail grooving. In the latter case, the cutting action is combined with impact on the cutting heads.

3.2.1 Grooving/grinding

These processes use diamond-tipped blades assembled in configurations to suit the pattern of cutting required. They have been used on cement concrete surfaces for many years both to provide discrete grooving patterns and for bump-cutting. However, they also have the potential for re-working the entire surface and for application to some types of bituminous pavements.

The programme of monitored sites included surfaces retextured by the Holemaster company. Its plant (Photograph 4) used disc-type cutting blades, with interleaved spacers where appropriate, assembled on a shaft in configurations to provide the pattern required (Photographs 5 and 6). Uni-directional, transverse, grooves would be cut with widths of 4-8mm, depths of 4mm and spacing of 25-50mm. These are typical of the regular finishes applied to cement concrete surfaces. When the spacers were omitted, a ‘corduroy’ finish was obtained.

In the trial, a short length of rolled asphalt was treated as well as a section of conventional brushed concrete. Conventional grooving leaves the microtexture of the surface areas remaining between the grooves unchanged whilst the ‘corduroy’ modifies both microtexture and

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* *For clarity, photographs are shown in Appendix A*

macrotexture. Photograph 7 compares the grooved and corduroy finishes on the cement concrete.

The machine used had a cutting width of 0.94m and was driven by a diesel engine. The treatment was a demonstration trial and difficulties were experienced with the machine which would not be expected in normal commercial operation. In particular, the amount of power available was barely sufficient to drive the cutters in the closely-spaced ‘corduroy’ arrangement. Since the trial sections were treated, the parent company has ceased trading and the current position regarding availability of this process in the UK is unknown. Overseas companies (for example, Robuco in Belgium) are able to offer this surface treatment; in principle, any company operating grooving machines should be able to provide a similar treatment.

3.2.2 Scabbling/flailing

This type of 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 across the road surface whilst being hydraulically-loaded onto it. The central hole in each washer is significantly larger than the diameter of the shaft on which it is mounted, resulting in an impact motion of each cutting tip superimposed on its rotation. This technique is not permitted by the Specification for Highways Works for concrete roads.

3.2.2.1 Longitudinal scabbling

Several companies offer retexturing treatments based on flail-grooving/scabbling. The Roadtex process (Photograph 8) applies the treatment longitudinally. The scabbling head (Photograph 9) is mounted on the rear of a lorry and treats a width of 1.25m in a single pass. The operator can control the intensity of the scabbling action by adjusting the load hydraulically-applied to the scabbling head and by varying the forward speed of the machine. On bituminous surfacings, the scabbling treatment (Photograph 10) can be combined with carbonising of the matrix by propane-fuelled burners (Photograph 11), the object being to further improve the macrotexture without undue aggression from the purely mechanical action.

Surfaces considered unsuitable for the scabbling treatment include very fatted-up surface dressings with aggregates less than 10mm in size, proprietary surface treatments such as Ralumac or slurry surfacings.

In addition to the six sites treated by Roadtex, the Phase 1 programme included one treated by Balvac Whitley Moran who, at that time, used scabbling plant (Photograph 12) operating on a similar principle and producing a similar surface finish (Photograph 13).

3.2.2.2 Orthogonal flailing

Another treatment using the scabbling principle included in the monitoring programme was Johnston’s Rapitex ‘Durogrip’. This consists of longitudinal and transverse grooving combined with scabbling. On the sites studied, each direction of treatment was applied by a different machine, that for transverse grooving (Photograph 14) being purpose-built. Whilst stationary, five banks of cutters (Photograph 15) moved laterally and cut strips of transverse grooves. They were then moved forward and the intervening strips similarly treated. A section 2.03m in length covering one lane width was treated in this two-stage pass. The longitudinal grooving/scabbling was applied separately, usually after the transverse treatment, typically using three 0.35m wide heads mounted on the rear of a tractor and hydraulically loaded onto the surface to give a longitudinal treatment width of 1.05m.

The grooves produced by this process are nominally 6mm in width by up to 5mm in depth. The depth of grooving is governed by the type of road surface and its hardness, but a maximum of 5mm is pre-set by depth limiters. The groove spacing can be set from 18-27mm to suit the type of surface and its condition.

The grooving action in both directions on bituminous pavements (Photograph 16) increases macrotexture by cutting though the aggregate and also by removing some of the matrix from around the aggregate. The scabbling action increases the microtexture of the aggregate by attacking its exposed surface. The treatment is considered unsuitable for concrete.

It is understood that this process now uses a single purpose-built machine which carries out both transverse and longitudinal cuts in one operation.

3.3 Fluid action

The third generic category involves the surface being subjected to the action of fluid at either high temperature (air) or high pressure (water).

3.3.1 Carbonising

As already indicated, carbonising or flame-scouring is offered in conjunction with the scabbling action of the Roadtex treatment. The process can also be used alone, to increase the macrotexture of rolled asphalt surfaces by burning away some of the matrix surrounding the aggregate particles. It is also commonly used to remove excess binder from fatted-up surface dressings.

This form of treatment is regarded as being outside the scope of this project and is not considered further here.

3.3.2 High-pressure water-jetting

This treatment involves modification of the surface by high-pressure water-jets. Successful small-scale trials were reported from Western Australia some years ago and a small number of companies operate in mainland Europe. A treatment based on the same principle and known as ‘Water-Tex’ has been available in this country from the Premier Road Treatments company. The monitoring programme included three sites treated in this way.

The Water-Tex plant used on the sites studied here (Photograph 17) consisted of a lorry-mounted water tank and pump unit supplying water at pressures of up to 14 000 lbf/in^2 (9.6 x 10^7 Pa) to a push-along rotary spray unit. This unit contained a rotor bar 500mm in length and fitted with high-powered jets (Photograph 18), up to four in number and 1.0mm to 1.5mm in diameter. Fan-jet nozzles can be used to dissipate the concentration of energy and avoid blowing out the aggregate chippings from bituminous surfacings. Jets can be changed and the pressure regulated to suit the characteristics and condition of the surface being treated. On rolled asphalt, the treatment removes some of the matrix from around the aggregate (Photograph 19). The surface can then be subjected to scabbling if improved microtexture is required. The process depends on suitable access to a supply of water, consumption of which is around 3000 gallons/day (13.6m^3).

The treatment is suitable for most bituminous surfacings, including surface dressings. Since these trials were begun, larger machines with banks of spray-heads capable of treating a full lane width have also been developed.

4 Environmental effects of the treatment processes

Mechanical retexturing processes are, by their nature, carried out very quickly, and therefore any particular location will be subject to any side-effects for only a short time. However, the nature of sites requiring treatment means that many will be in built-up areas and, therefore, potentially sensitive to environmental effects such as noise, dust and other detritus. In all cases some traffic control will be necessary.

4.1 Traffic control

The plant involved in each of the treatments observed operates within the width of one lane and, in principle, allows traffic to use the remaining part of the carriageway whilst retexturing is in progress. Some of the treatments produce a significant quantity of arisings, but with a sweeper on stand-by, lane occupancy can be restricted to only a short length which moves along as the work progresses. Of the different types of treatment observed, only orthogonal grooving necessarily involved two separate operations performed by different items of plant before sweeping left the section of road ready to be re-opened. Some systems are capable of working within a rolling closure, with retexturing vehicles and sweepers moving in convoy.

Particular care has to be taken at all times to ensure safe working and adherence to Health and Safety requirements. A cause for concern is the temporary intrusion of plant or staff into the ‘live’ traffic lane when working to the edge of that being treated. There will inevitably be some risk of this occurring if, as is often the case, a full lane width is to be treated, especially if the process involves sideways movement of the machine. Unless a temporary road closure is acceptable, this is a situation where the concept of a safety zone between working area and traffic lane may be impossible to maintain. Much then depends on the care and judgement of the crew, as is the case with traditional treatments carried out on trafficked roads such as surface dressing.

A point in favour of all retexturing operations is that, in general, the section of road can be re-opened as soon as the work (including sweeping where necessary) is completed. This keeps traffic disruption to a minimum and, in the event of an undue build-up of delayed traffic, it is easy to suspend work and temporarily remove plant from the carriageway.

4.2 Noise

Because all of these processes are mechanical, noise will be generated during the work. The noise comes from two main sources: the power plant (such as a compressor, generator and/or vehicle engine) and from the action of working the road surface. Noise during the retexturing process was assessed by the QMWC team for four of the treatments. Noise levels, measured at a distance of 5m from the operating plant, were:

bush-hammering: 76-78 dB(A)
longitudinal flailing: 82-84 dB(A)
concrete sawn grooving: 88-90 dB(A)
transverse flail grooving: 94-96 dB(A)

In each case, the ambient levels were at least 10 dB(A) below the measured levels.

As might be expected, the levels were relatively greater for the more aggressive treatments. Furthermore, an octave frequency analysis of the noise spectra generated by the three noisiest processes indicated that the highest levels were at the 1KHz and 2KHz centre frequencies; these are levels around which the human ear has its highest sensitivity. This may not be a significant problem in practice because the high texture depths which both the sawn and flail grooving processes are capable of producing will generally be more appropriate to the maintenance requirements of high speed roads, most of which are in non-built-up areas and may therefore be less noise-sensitive. It is of interest to observe that the shot-blasting process demonstrated as part of the durability experiment (Roe and Hartshorne, 1997) was subjectively significantly less noisy than the other impact and cutting processes. This is largely because the equipment is electrically powered (most of the other machines are hydraulic or belt-driven with large on-board engines or compressors) and, therefore, the main source of noise is the generator which, on this occasion, was not discernable above the noise of passing traffic.

The project did not include specific studies of vehicle noise on the retextured surfaces.

4.3 Dust and water-borne detritus

All the treatments produce newly-exposed surfaces by the removal of material, albeit to varying degrees, with the more aggressive treatments removing the most. The QMWC team were unable to find a satisfactory method to monitor dust concentrations quantitatively but subjective observations indicated that significant quantities of airborne dust were produced, especially from those treatments involving more aggressive mechanical contact. Photographs 20 and 21 illustrate this problem. The composition of the dust will depend on the materials present, both in the road surface and in the plant used. It will contain particles of aggregate, bituminous material (from asphaltic pavements), traces of rubber deposits (from vehicle tyres), other hydrocarbons (from spilt oil and fuel) and, possibly, metallic wear particles from retexturing tools or media (such as unrecovered shot).

Dust emissions are reduced (but not eliminated) by wetting the surface, but it has been found that even this solution may be impractical under extremely cold conditions, such as those encountered during a period of sustained cold weather, when the water freezes in its tanks or on contact with the surface. The more debris which can be settled by the application of water to the surface, the less will remain to be circulated as dust in the air. However, this then creates a problem of fine particles being carried away by water drainage. Some processes also create water-borne detritus directly. High-pressure water-jet retexturing intrinsically produces a bituminous emulsion from asphalt roads; other treatments may do so as an outcome of the application of cooling water to steel cutting tools.

Most of the larger particulate matter is satisfactorily removed by sweeping, but attention needs to be paid to any water-borne slurry. Depending on the location, it may be necessary to prevent entry of slurry into the drainage system (see Photograph 22) or to positively arrange for its removal.

5 Programme of monitored sites

5.1 Development of the programme

The programme of sites for monitoring in the first phase of the study was developed by selecting suitable sites from those being treated as part of normal maintenance procedures or for demonstration purposes. The intention was that measurements of skidding resistance and texture depth would be made about a week before treatment was planned, followed by a further set of measurements as soon as possible after treatment, normally within one month. Regular monitoring would then be continued, initially at monthly intervals and then with decreasing frequency for up to two years.

In the event, this approach did not provide as wide a selection of sites and processes as had been hoped for. In some cases, sites were found to be unsuitable for operational or safety reasons or the data was of limited use because notification was too late to arrange for monitoring before retexturing. Some sites were rejected because their inclusion would have resulted in an increasing imbalance in the representation of different treatments, as well as reducing the capability to add sites from less-represented treatments later in the programme.

A total of thirty-four sites were included in the programme at some stage but monitoring at several of these had to be discontinued prematurely, in most cases very early in the life of the treatment. The commonest reasons for this were:

- safety problems encountered during monitoring
- subsequent maintenance operations affecting the surfaces.

The start dates for the sites ranged between May 1990 and January 1992 and this spread meant that the monitoring could not be completed during the QMWC contract; for some sites, the two-year initial monitoring period was not completed until early 1994.

5.2 Site details

There were 21 sites on which useful measurements are available for at least one year. Of these, nine were retextured by Klaruwtex, five by Roadtex, one by Holemaster, three by Premier Water-Tex, three by Johnston’s Rapitex Durogrip, and one by Balvac Whitley Moran’s scabbling process.

Table 1 summarises details of the sites monitored. Most sites involved sections with changed characteristics of some kind (e.g. surface type, geometry, direction of travel) or changed process (e.g. grooving or corduroy texture). Each site is identified in Table 1 by a number and each section by a letter appended to it. (Sites having uniform characteristics throughout are simply identified by a number). Thus each section has an individual identity as summarised in the Table and this is used in subsequent analysis. A dagger alongside the site number identifies those sites for which monitoring was discontinued after one year. On some sites it was not possible to obtain ‘before’ measurements but, nevertheless, some early-life durability measurements were made following treatment.

All sites except one were on class A roads with a mixture of urban and rural environments. The one class B road was a former A-road which had been re-classified a few weeks before treatment. Nine sites were associated with roundabouts and/or lengths of road in their immediate vicinity. The predominant surface type was hot-rolled asphalt with pre-coated chippings (HRA); five sites involved sections of surface dressing, one of concrete and one of bitumen macadam. Some sites had a change in surface type within their lengths and these are considered as separate sections.

Wherever possible, a sample of aggregate was extracted from the surface, a geological identification made and a specimen produced to be ‘run’ on the accelerated polishing machine. It must be borne in mind that, inevitably, the way in which resulting Polished Stone Values have been obtained does not conform to the BS 812 test procedure so that the values listed in Table 1 are only included for purposes of broad indication and relative to other samples similarly tested.

Requests were made to individual highway authorities for details of traffic counts and accident records, but few were received. Where these were unavailable, subjective estimates of traffic flow, based on general observation whilst monitoring, have been included in the table for comparison between sites.

6 Results from initial monitoring period

There are two issues which are of immediate interest in relation to the results from the initial period of monitoring:

- The extent to which the process modifies the skidding resistance and macrotexture.
- The length of time that the effects last.

Table 1 Summary of site details

Site No.	*Authority*	*Road type*	*Traffic Volume*	*Treatment*	*Section details*	*Surface type*	*Aggregate identification*	*PSV*
1	Hertfordshire	Urban A, single	medium	Klaruwtex	A - Northbound link, southern end	HRA*	(no sample)	66
					B - Northbound link, northern end	HRA		
					C - Southbound link, southern end	HRA		
					D - Southbound link, northern end	HRA		
3	E. Sussex	Urban A, single	low	Roadtex	Northbound link	HRA		46
8	Bedfordshire	Urban A, single	high	Klaruwtex	Westbound approach to roundabout	HRA	dolerite/basalt/rhyolite	-
9	Bedfordshire	Rural A, dual	high	Klaruwtex	Northbound exit from roundabout	HRA	granite/gritstone/porphyry	-
10	N. Yorkshire	Urban A, single	medium	Klaruwtex	A - Eastbound approach to roundabout	HRA *(lower rate of spread of chippings)*	(no sample)	-
					B - Eastbound approach to roundabout	HRA *(higher rate of spread of chippings)*		
					C - Westbound approach to roundabout	HRA *(lower rate of spread of chippings)*		
					D - Westbound approach to roundabout	HRA *(higher rate of spread of chippings)*		
11	N. Yorkshire	Urban A, single	high	Roadtex	A - Westbound approach to roundabout	HRA	(no sample)	52
					B - Eastbound approach to roundabout	HRA		
12	N. Yorkshire	Urban A, single	medium	Balvac W.M.	A - Westbound approach to roundabout	HRA		
					B - Eastbound approach to roundabout	HRA		
13	N. Yorkshire	Urban A, single	medium	Roadtex	A - Eastbound approach to roundabout	HRA	andesite/basalt	-
			low		B - Northbound approach to roundabout	HRA		
14	N. Yorkshire	Rural A, dual		Holemaster				
			medium	*Corduroy*	A1 - Southbound link, lane 1	HRA		
			medium	*Grooving*	B1 - Southbound link, lane 1	HRA	andesite/basalt	50
			medium	*Corduroy*	C1 - Southbound link, lane 1	concrete	(no sample)	-
			medium	*Grooving*	D1 - Southbound link, lane 1	concrete		
			low	*Corduroy*	A2 - Southbound link, lane 2	HRA	andesite/basalt	50
			low	*Grooving*	B2 - Southbound link, lane 2	HRA		
			low	*Corduroy*	C2 - Southbound link, lane 2	concrete	(no sample)	-
			low	*Grooving*	D2 - Southbound link, lane 2	concrete		
15	W. Sussex	Rural A, dual	medium	Roadtex	A - Northbound approach to roundabout	HRA	flints/basalt/dolerite	49
					B - Northbound exit from roundabout			
16	W. Sussex	Rural A, single	medium	Roadtex	A - Westbound approach to bend	HRA	quartz/gabbro/coke/basalt	56
					B - Westbound left-hand bend	HRA		
					C - Eastbound approach to bend	HRA		
					D - Eastbound right-hand bend	HRA		
20	Cornwall	Rural A, single	medium	Klaruwtex	A - Northbound approach/through village	HRA	sandstone	57
					B - Northbound, uphill link	macadam	(no sample)	-
					C - Southbound, downhill link	macadam		
					D - Southbound through and exit from village	HRA	limestone	57
21	Cornwall	Rural A, single	medium	Klaruwtex	A - Northbound link	HRA	sandstone	64
					B - Northbound link	SD**	dolerite	57

					C - Southbound link	HRA		
					D - Southbound link	SD		
22†	Cornwall	outer-urban A, single	medium	Klaruwtex	A - Northbound link	HRA	(no sample)	61
					B - Northbound link	SD	(no sample)	-
					C - Southbound link	HRA		
					D - Southbound link	SD		
24	Cornwall	Rural A, single	medium	Klaruwtex	A - Northbound link	HRA	dolerite/gypsum	-
					B - Southbound link	HRA		
25	Warwickshire	Urban A, single	medium	Water-Tex	A - Northbound link	HRA	sandstone	61
					B - Southbound link	HRA		
26	Warwickshire	Rural B, single	medium	Water-Tex	A - Westbound link	HRA	granite with shale and flint	61
					B - Eastbound link	HRA		
28	Somerset	Rural A single	410 cvd[+]	Water-Tex	A - Northbound link	HSA[***]	sandstone	61
					B - Southbound link			
31	DoT/ London Borough of Newham	Urban A, interchange roundabout	high	Klaruwtex	A - Roundabout inner lane	HRA	(no sample)	-
					B - Southbound to eastbound slip road	HRA		
32	Shropshire	Rural A, single	920 cvd	Rapitex	A - Southbound reverse bend	HRA	(no sample)	59
					B - Northbound reverse bend	HRA		
33	E. Sussex	Rural A, single	medium	Rapitex	A - Northbound reverse bend	HRA	(no sample)	-
					B - Southbound reverse bend	HRA		

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[*] *hot-rolled asphalt with pre-coated chippings;*

[**] *surface dressing;*

[***] *unchipped high stone-content asphalt;*

† *monitoring discontinued after 1 year following resurfacing;* [+] *commercial vehicles per lane per day*

Before examining the results of the measurements in an attempt to answer these questions, there are important points which need to be considered.

6.1 Seasonal variation of skidding resistance

Skidding resistance is not a constant and varies throughout the year. In the UK, it is at its lowest during the summer months as a result of polishing during warm, dry weather. During the winter, frost action and gritting result in coarser detritus on the surface which, combined with longer periods when the road is wet, leads to abrasion and attrition of the aggregate rather than polishing. As a result, microtexture is partially restored and the skidding resistance increases again. This cyclic action is known as ‘seasonal variation’ and must be taken into account when interpreting skidding resistance measurements.

It is usual in the UK to characterise a road by taking three SCRIM measurements over the summer period and calculating the average, calling this the ‘mean summer SCRIM Coefficient’, or MSSC. After several years under constant traffic, the road settles into what may be described as a ‘dynamic equilibrium’ and the average MSSC over time represents the ‘equilibrium SCRIM coefficient’. There may be variations about this equilibrium level but, nevertheless, the skidding resistance of a newly-laid or treated surface would be expected to tend to decrease initially and then gradually approach the equilibrium value over time, that value depending on the level of traffic and the polishing resistance of the aggregate.

This concept is important for the present study for two reasons. Firstly, in assessing immediate changes, the time of year at which the treatment is carried out will be significant. Secondly, the effect of seasonal variation will need to be considered when assessing longer-term durability.

6.2 Initial changes following retexturing

The ways in which microtexture and macrotexture are developed in the surfacing as a result of retexturing will depend on the surfacing type, the materials used and the kind of traffic to which the road has been subjected.

It is reasonable to suppose that the magnitude of any initial change will depend primarily on:

- the initial ‘before’ value of the quantity (which itself will depend on other factors such as time of year);
- the process involved
- the type of surfacing
- the type and size of aggregate present.

The nature of the test programme proved such that it was not practical to examine the various factors and variables systematically. Therefore, an approach that is essentially empirical has been taken.

The initial effects of the treatment were assessed by comparing results from measurements taken just before treatment with those taken soon afterwards. Tables 2A - C give the results from those sites where suitable data is available, broken down by generic treatment type. The tables indicate the month of the year when the treatment was carried out and, in addition to the ‘before’ and ‘after’ measurements (averaged over the whole of the sections indicated), give the change (‘after’ minus “before”) as a percentage of the ‘before’ value to the nearest 5% as a crude comparator. Some of the sections listed in Table 1 are omitted here because it was not possible to obtain valid measurements for comparison. The abbreviations for surfacing type are as defined in Table 1.

Table 2A Initial changes as a result of retexturing - Impact process

				SCRIM coefficient			*Sensor-measured texture depth (mm)*		
Site No.	*Month of treatment*	*Section type*	*Surfacing*	*Before*	*After*	*% change*	*Before*	*After*	*% change*
Bush-hammering									
1	May	A	HRA	0.45	0.58	30	0.6	0.6	0
		B	HRA	0.42	0.52	25	0.8	0.7	-10
		C	HRA	0.45	0.58	30	0.7	0.6	-10
		D	HRA	0.41	0.56	35	0.6	0.6	0
20	June	B	Macadam	0.60	0.61	0	0.7	0.5	-30
		C	Macadam	0.51	0.64	25	-	0.3	--
21	June	A	HRA	--	--	--	1.9	1.0	-45
		B	SD	--	--	--	1.4	1.1	-20
		C	HRA	--	--	--	1.4	1.1	-30
		D	SD	--	--	--	1.5	0.8	-45
22	June	A	HRA	0.58	0.69	20	--	1.1	--
		B	SD	0.58	0.68	20	--	0.6	--
		C	HRA	0.55	0.69	25	--	0.8	--
		D	SD	0.59	0.69	25	--	0.8	--
24	June	A	HRA	0.45	0.59	30	1.2	1.2	0
		B	HRA	0.48	0.61	25	1.1	1.1	0
10	January	A	HRA	0.62	0.61	0	2.0	2.0	0
		B	HRA	0.62	0.65	5	1.6	1.6	0
		C	HRA	0.58	0.64	10	1.5	1.7	15
		D	HRA	0.58	0.63	10	1.3	1.4	0
31	November	A	HRA	0.56	0.60	5	0.8	0.8	0
		B	HRA	0.51	0.61	20	0.8	0.8	0

Table 2B Initial changes as a result of retexturing - Fluid action

Site No.	Month of treatment	Section	Surfacing type	SCRIM coefficient Before	SCRIM coefficient After	SCRIM coefficient % change	Sensor-measured texture depth (mm) Before	Sensor-measured texture depth (mm) After	Sensor-measured texture depth (mm) % change
Water-jetting									
25	June	A	HRA	0.50	0.69	40	0.9	1.2	35
		B	HRA	0.57	0.64	10	0.9	0.2	35
26	June	A	HRA	0.51	0.51	0	1.3	0.5	15
		B	HRA	0.54	0.51	-5	0.9	1.1	25
28	October	A	HSA	0.46	0.62	35	0.3	0.5	65
		B	HSA	0.44	0.67	35	0.3	0.6	100

Table 2C Initial changes as a result of retexturing - Cutting processes

Site No.	Month of treatment	Section type	Surfacing	SCRIM coefficient Before	SCRIM coefficient After	SCRIM coefficient % change	Sensor-measured texture depth (mm) Before	Sensor-measured texture depth (mm) After	Sensor-measured texture depth (mm) % change
Longitudinal scabbling									
3	June	A	HRA	0.37	0.70	90	0.6	0.5	-15
15	May	A	HRA	0.46	0.56	20	0.7	0.8	15
			HRA	0.41	0.55	35	0.7	0.7	0
16	May	A	HRA	0.47	0.55	15	0.6	0.6	0
		B	HRA	0.43	0.53	20	0.6	0.6	0
		C	HRA	0.45	0.53	20	0.6	0.6	0
		D	HRA	0.40	0.50	25	0.6	0.6	0
11	May	A	HRA	0.54	0.64	20	1.1	1.5	35
		B	HRA	0.54	0.70	30	1.1	1.4	20
13	March	A	HRA	0.58	0.51	-10	1.2	1.4	15
		B	HRA	0.53	0.58	10	1.1	1.2	10
12	February	A	HRA	0.54	0.56	5	1.5	1.8	20
		B	HRA	0.54	0.53	0	1.3	1.4	10
Orthogonal flailing									
32	December	A	HRA	0.55	0.68	25	0.9	1.1	30
		B	HRA	0.59	0.66	10	1.0	1.3	25
33	January	A	HRA	0.43	0.62	45	0.8	1.3	60
		B	HRA	0.41	0.61	50	1.0	1.4	40
Diamond sawing									
14	March	A1	grooved HRA	0.51	0.51	0	1.2	1.5	25
		B1	corduroy HRA	0.54	0.54	0	1.1	0.7	-30
		A2	grooved HRA	0.65	0.62	-5	1.6	1.7	10
		B2	corduroy HRA	0.64	0.62	-5	1.4	1.1	-20
14	March	C1	grooved concrete	0.53	0.51	-5	0.5	0.8	60
		D1	corduroy concrete	0.55	0.50	-10	0.5	0.5	0
		C2	grooved concrete	0.60	0.62	5	0.5	1.0	100
		D2	corduroy concrete	0.62	0.55	-10	0.5	0.3	-40

6.3 Discussion of initial changes in skidding resistance

It is unlikely that a retexturing process will be able to increase skidding resistance beyond that possible with freshly-laid, unpolished aggregate. In practice, the observed values represent the average, derived from a combination of newly-exposed faces and remaining proportion of unaffected existing particle surfaces. When the treatment is carried out during the winter or very early spring, it might be expected that the 'before' value will be high compared with the mean summer readings as a result of the winter recovery process. In consequence, the relative increase in SCRIM Coefficient following retexturing would be expected to be smaller for treatments at this time of the year.

It can be seen from Tables 2A-C that there was a wide variation in the results obtained. Whilst Site 14 is clearly an exception, in general the skidding resistance increased immediately after treatment with most of the lower values occurring on winter-treated sites, as expected. There are, however, some specific points which can be drawn out from the observations:

i There was little difference in effect between the bush-hammering and flailing treatments. Of particular interest are sections 10A, 12B and 13A, which showed no change or a reduction in skidding resistance after treatment. The explanation of this effect may be wheel-track rutting limiting the impact action in the path tested by SCRIM. The skidding-resistance of sites 10 and 12 was already comparatively high (in mid-winter) and the effect was small. However, site 13A was on a bend approaching a roundabout and subsequent visual inspection confirmed the presence of rutting in the nearside wheel path. It is probable that, because of this rutting, the retexturing may have had no effect on the line tested by SCRIM and that what has been measured is simply the polishing effect of traffic in the interval between the before and after measurements in early summer.

ii Where the SCRIM Coefficient has increased, no site exceeded 0.70, reflecting the point that skid-resistance is unlikely to increase beyond that expected from a new surfacing. This is illustrated well on the macadam of site 20 which naturally had a high stone content in the road/tyre interface. Although the surfacing on this single-carriageway road is the same on both sides, the downhill section (C), which would be expected to suffer more polishing from braking traffic, starts from a much lower level (0.51) than its uphill counterpart (0.60) yet after treatment both are similar.

iii Interestingly, although it was being used primarily to address the perceived low macrotexture on the sites concerned, the water-jetting process showed marked increases in SCRIM coefficient on sites 25 and 28. This can be attributed to the water action cleaning excess bitumen from the recently-laid surfaces and exposing the microtexture. Site 26, however, showed no measurable effect or even a slight loss, but in any event the skidding resistance was generally good there.

iv On site 14, the results show very small effects, most of them negative. This site was chosen for the purpose of demonstrating the ‘corduroy’ technique on both concrete and HRA, with conventional grooving included for comparison. There was no perceived problem with skidding resistance; initial values of SCRIM coefficient for this non-event dual carriageway were already high (0.53 in lane 1 and 0.63 in lane 2, on average, with no significant difference between the asphalt and concrete surfaces). The retexturing did not alter this position, even though it tended to reduce the skidding resistance. Grooving was not expected to have a marked effect because the surfaces which remain in contact with the tyre are unaltered by this process.

The trend to a decreased skidding resistance in this case can probably be attributed to lower microtexture in the asphalt matrix or cut aggregate in the concrete replacing the higher microtexture of the chippings or brushed concrete mortar. Whether the ‘corduroy’ type of treatment could actually bring about an improvement in skidding resistance on a concrete surface which had polished and worn to give a low initial value is unproven but, from observation of this site, it is considered unlikely.

6.4 Discussion of initial changes in texture depth

The effects of retexturing on macrotexture will depend on what already exists combined with the interaction between cutting new grooves or creating new peaks and the removal of existing high-points. As with skidding resistance, there are wide variations in the effects observed but, in this instance, there are clearer differences between the different treatment types:

i *Bush-hammering* (Table 2A) had a variable effect on macrotexture. On most sections the effect was very small, presumably because only a small amount of material was removed from the tops of the asphalt chippings. In some cases (especially sites 20 and 21), however, there was a marked reduction in texture, probably because rather more material was removed. Two sites showed a small increase in an already comparatively high texture depth. In general, these results suggest that bush-hammering has either a neutral effect on macrotexture or a tendency to reduce it.

ii *Water-jetting* would be expected to increase macrotexture because its primary action is to remove fine particles from the surface of the matrix. This is confirmed by the results on the three sites where it was used (Table 2B), which all showed significant increases. The best results, in terms of final level of texture, were obtained on the two rolled asphalt surfaces. This is to be expected because the treatment removed excess asphalt mortar to expose previously-embedded chippings (see Photograph 19). On site 28, there was a marked increase, in percentage terms, but the texture depth achieved remained very low, limited in this case by the nature of the material (unchipped, high stone content asphalt).

iii *Longitudinal scabbling* (Table 2C) also had small but variable effects. Where the texture was initially low, the effect was small and tended to reduce texture whilst, at higher levels, there was a general increase. Site 13A (where the skidding resistance measurements and site inspection suggested that, as a result of rutting, the treatment may have missed part of the wheelpath) showed an increase after treatment. This is probably explained by a difference in the line followed around the bend with the HSTM sensor on its trailer passing just to the edge of the rutted area, on which some cutting action had occurred, whereas the SCRIM wheel followed more closely in the rut generated by goods vehicles.

iv *Orthogonal flailing* is the only one of the treatments expressly designed to have a significant impact on macrotexture by cutting grooves in two directions. This is clearly being achieved, with both of the sites included in the program having shown significant initial increases.

6.5 Initial assessment of durability

Intuitively, one would expect to be able to assess durability by comparing the values immediately after treatment with those taken over a longer period of time. However, seasonal effects, especially on levels of skidding resistance, will always be superimposed on the remaining effects of the retexturing operation. The kind of problems encountered are illustrated by results from sites 32 and 33 which were both treated by the ‘Rapitex’ orthogonal grooving process. Figures 1 and 2 show the average skidding resistance of the retextured sections on each site over time compared with the average of their corresponding control sections.

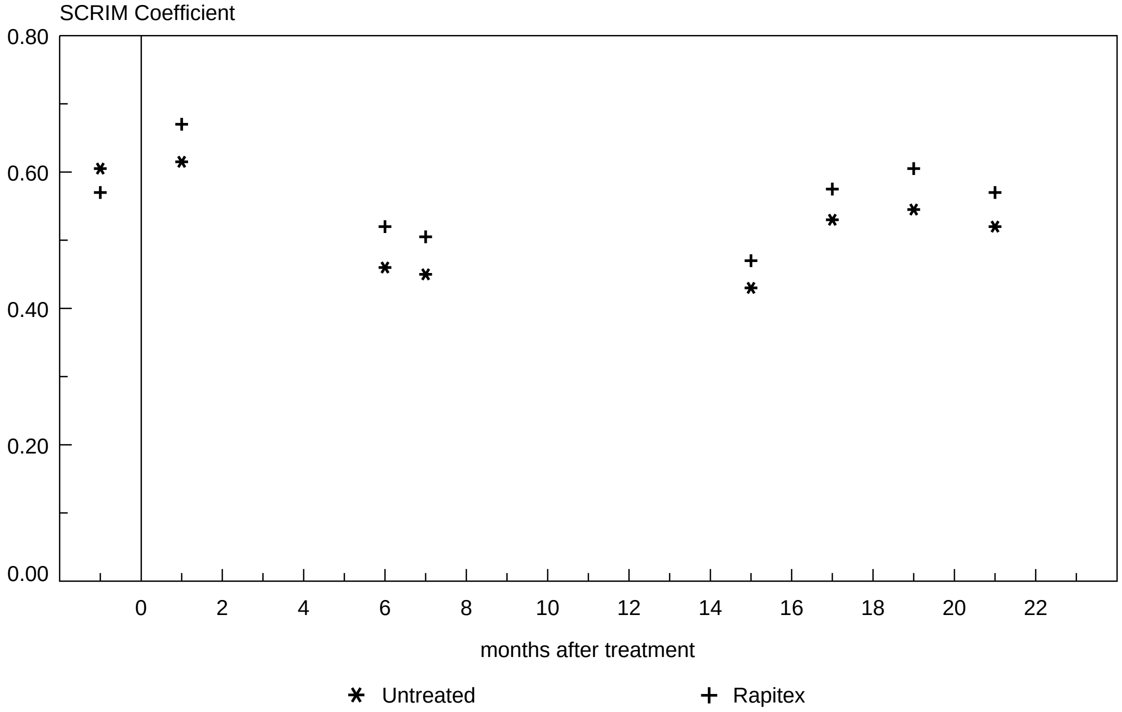

Figure 1 Skidding resistance on Site 32

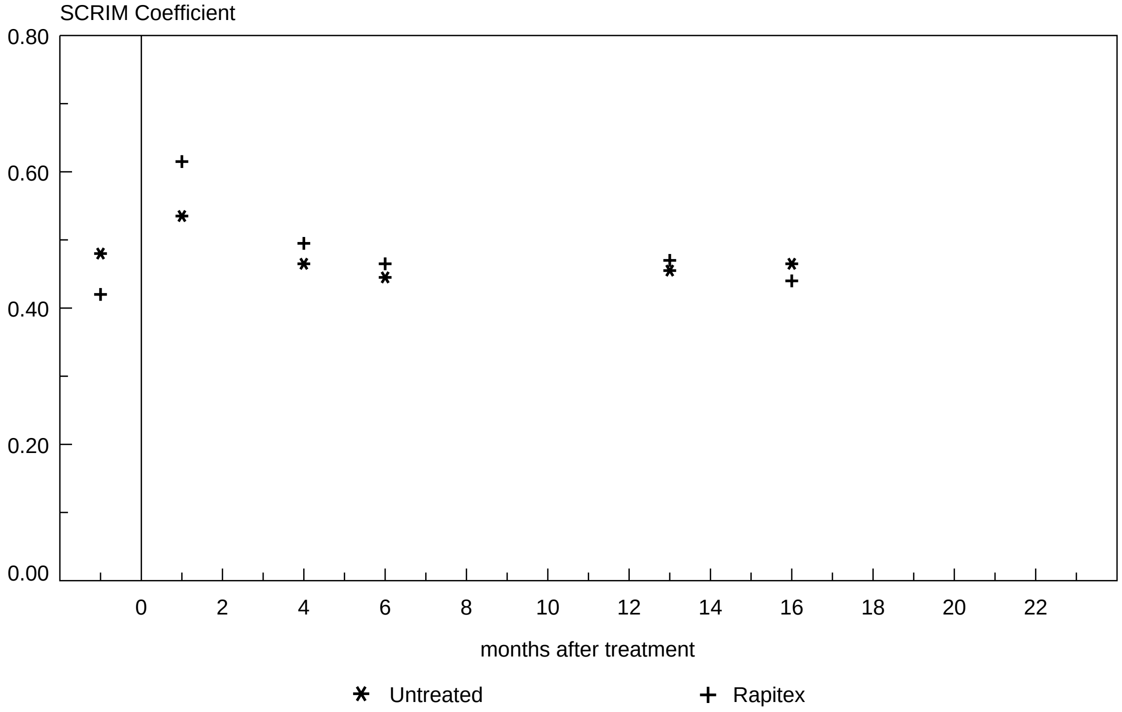

Figure 2 Skidding resistance on Site 33

The ‘before and after’ effect on these two broadly similar sites (both rolled asphalt, both on reverse bends on class A roads and treated within a month of one another) can be seen clearly. There are, however, marked differences in behaviour over time. On both sites, the control sections show the seasonal variation in skidding resistance. On site 32 the increase in skidding resistance compared with the control section is maintained over nearly two years whilst, on site 33, the treated section gradually converges to meet the control section.

It was found that the reverse was true for texture depth on these sites. An initial increase in texture on site 32 was lost over time whereas on, site 33, it was maintained and actually increased towards the end of the two-year monitoring period.

Site inspections approximately two years after treatment showed marked differences in the general condition of the surfacings and the appearance of the aggregate particles. On site 32, the upper surfaces of the chippings were rounded and noticeably proud of the asphalt matrix, ensuring that good microtexture was making contact with the SCRIM wheel. However, the grooves in the wheelpath (where texture and skidding resistance are measured) had closed up, and this accounted for the recorded fall in texture. At site 33, the chippings, which were of a different aggregate, remained generally flush with the matrix and the grooves were still apparent. There was an added complication on this site in that there was a general deterioration in both the treated and control surfacings with cracking and general chipping-loss evident, which would account for the late increase in texture recorded on both control and treated sections here.

6.5.1 The 'enhancement' concept

The essential requirement for assessing durability is to compare the measured parameter at a given time after the retexturing with the value which it would have had at that same time if the road had been left untreated. The difference would then represent the 'enhancement' due to retexturing remaining at that time. The difficulty lies in establishing what the 'remained untreated' value would have been.

In their original work, the QMWC team used the control section as a guide to the seasonal effect on each site and derived an enhancement at a given time, T, by computing the difference in the control section (between the 'before' and the 'after at time T') as a measure of seasonal change and subtracting this value from the corresponding difference for the treated section.

This worked reasonably well at first, but when the method was extended to cover the full range of sites over the two-year monitoring period, it was found that it was difficult to compare sites and treatments, especially where different times of year for initial treatment (and hence initial 'before' values) were involved and where control sections were not of the same material type as the treated sections. Further, using this approach, it appeared that the durability of enhancement appeared less for sites treated in winter than for those retextured in the summer and raised questions over whether the out-of-season treatments were worthwhile. Alternative approaches were therefore considered.

Ultimately, the object of retexturing to improve skidding resistance is to increase it to a point where it is above the required standard for the site and remains so for a useful period of time. The usual method of comparing skidding resistance with standards is by means of the mean summer SCRIM coefficient (MSSC) which, in turn, becomes the equilibrium SCRIM coefficient over time with traffic remaining at a constant level. It was decided, therefore, to assess durability by comparing the MSSC of the treated section with the expected 'untreated' equilibrium value. By normalising data in this way a value representing the enhancement due to retexturing could be computed which would allow sites and treatments to be assessed on a broadly comparable basis.

However, this could only be done where there was a control section sufficiently similar to the treated section to act as a surrogate for the 'left alone' condition. The enhancement at a particular period was defined as follows:

$$E = 100 \text{ x } (M - Q)/Q$$

where E is the enhancement over the equilibrium value, expressed as a percentage

M is the mean of all the measurements for the treated section for the period concerned

Q is the mean of all the summer measurements for the untreated sections available over the complete monitoring period.

It has been found, and the results from the present study generally bear this out, that typically texture changes only slowly with time. It was also found that, where control sections are of the same type, the initial average texture depths on control and retextured sections were similar. It was therefore decided that, for texture depth, a simple comparison between the value at a given time and the 'before' value of the section would suffice, with texture enhancement therefore being defined as

$$I = 100 \text{ x } (A - B)/B$$

where I is the enhancement in texture over the initial value, expressed as a percentage

A is the mean texture depth of the retextured section at the time or over the period concerned

B is the mean texture depth of the retextured section before treatment.

The results from the various sites were analysed on these bases for the measurements immediately after treatment and for the one or two summers following treatment. The enhancements, rounded to the nearest 5%, are given in Tables 3A-C.

6.5.2 Discussion of durability of skidding resistance

In comparing the results in Tables 3A-C, it is necessary to consider the practical significance of any enhancement that is produced by retexturing. Clearly, a zero or negative value is of no benefit or a disbenefit, but a positive enhancement will only be of significance if it represents a move into a higher investigatory-level band in the Departmental Skidding Standards. These increase in steps of 0.05 units of SCRIM Coefficient (SC) and therefore, for the Phase 1 sites (which are mostly in the range 0.4-0.6 equilibrium SC), an increase of ten percent or more in the summer after treatment would be needed to be of practical value.

Of the 39 sections for which data was available, 24 met this criterion immediately after treatment. In the first summer, 14 met the criterion and, by the second summer, this number had reduced to seven, with four showing a lower value than the equilibrium. Site 31 was unusual

Table 3A Initial durability assessment - Impact process

				Enhancement in SCRIM coefficient (% of equilibrium)			*Enhancement in texture depth (SMTD) (% of 'before')*		
Site No.	*Month of treatment*	*Section*	*Surfacing type*	*after treatment*	*first summer*	*second summer*	*after treatment*	*first summer*	*second summer*
Bush-Hammering									
1	May	A	HRA	30	20	10	0	-5	--
		B	HRA	10	0	-5	-10	-10	--
		C	HRA	30	15	5	-10	-10	--
		D	HRA	10	5	0	0	0	--
8	June	A	HRA	0	5	10	0	-10	--
9	August	A	HRA	0	5	0	--	--	--
20	June	B	Macadam	0	10	5	-30	-30	--
		C	Macadam	30	10	5	--	--	--
21	June	A	HRA	--	--	--	-45	-35	--
		B	SD	--	--	--	-20	-60	--
		C	HRA	--	--	--	-30	-45	--
		D	SD	--	--	--	-45	-50	--
22	June	A	HRA	20	10	--	--	--	--
		B	SD	25	10	--	--	--	--
		C	HRA	20	10	--	--	--	--
		D	SD	30	10	--	--	--	--
24	June	A	HRA	30	5	10	20	20	20
		B	HRA	30	10	10	10	15	15
10	January	A	HRA	25	5	-10	5	-5	-10
		B	HRA	5	10	5	0	-5	-10
		C	HRA	10	10	5	15	0	-5
		D	HRA	10	5	0	0	0	0
31	November	A	HRA	-5	0	0	0	20	--

Table 3B Initial durability assessment - Fluid action

				Enhancement in SCRIM coefficient (% of equilibrium)			*Enhancement in texture depth (SMTD) (% of 'before')*		
Site No.	*Month of treatment*	*Section*	*Surfacing type*	*after treatment*	*first summer*	*second summer*	*after treatment*	*first summer*	*second summer*
Water-jetting									
25	June	A	HRA	5	-5	-10	40	35	40
		B	HRA	20	10	10	30	30	15
26	June	A	HRA	0	0	0	15	15	20
		B	HRA	0	0	0	30	30	30
28	October	A	HSA	--	--	--	65	35	--
		B	HSA	--	--	--	100	65	--

Table 3C Initial durability assessment - Cutting processes

				Enhancement in SCRIM coefficient (% of equilibrium)			*Enhancement in texture depth (SMTD) (% of 'before')*		
Site No.	*Month of treatment*	*Section*	*Surfacing type*	*after treatment*	*first summer*	*second summer*	*after treatment*	*first summer*	*second summer*
Longitudinal scabbling									
3	June	A	HRA	--	--	--	-15	-15	0
15	May	A	HRA	20	5	0	15	5	5
			HRA	20	0	0	-5	-5	-5
11	May	A	HRA	10	0	0	35	30	35
		B	HRA	15	0	0	20	30	30
13	March	A	HRA	0	0	-5	15	0	0
		B	HRA	5	5	0	10	0	-10
12	February	A	HRA	0	0	0	20	10	0
		B	HRA	0	0	0	10	5	-5
Orthogonal flailing									
32	December	A	HRA	20	15	10	30	20	-5
		B	HRA	10	10	10	25	20	10
33	January	A	HRA	20	5	-10	70	70	80
		B	HRA	15	5	0	40	40	35
Diamond sawing									
14	March	A1	grooved HRA	0	0	0	25	15	-10
		B1	corduroy HRA	5	0	0	-30	-40	-30
		A2	grooved HRA	5	0	0	10	0	-10
		B2	corduroy HRA	5	5	--	-20	-30	-15
14	March	C1	grooved conc.	0	10	5	60	60	80
		D1	corduroy conc.	0	5	0	0	-20	-30
		C2	grooved conc.	15	5	10	100	100	100
		D2	corduroy conc.	0	5	5	-40	-40	-40

because at first it showed a *reduction* in skidding resistance compared with the equilibrium and subsequently recovered to show no enhancement. This is an unexpected result and may be due to differences in the control and retextured sections; however, it could also be a result of the control section actually having been retextured (which could have been done and remained invisible to the observer checking the heavily-trafficked site after treatment) so that it closely followed the behaviour of the retextured section.

Because of the great variation between sites, it is not possible to generalise or observe patterns in behaviour which allow fair comparison of treatments.

6.5.3 Discussion of durability of texture depth

The longer-term effects of retexturing on texture depth reflect the variability of the initial results.

On the bush-hammered sites, the initial effect was generally maintained at least over the first summer. On Site 10, there was a gradual worsening of the texture depth of the surface, but it is difficult to tell whether this due to retexturing because there was also some loss in texture on the control sections over this period. Similar comments may be made of the longitudinal-scabbled sections.

The enhancement generated by water-jetting to expose the over-rolled chippings was maintained over the full two-year period.

On the orthogonal-flailed sections, the differences in behaviour commented on earlier in section 6.5 can be clearly seen. Between the first and second summers, the 'enhancement' on site 32 was eliminated as the grooves in the wheelpath closed up whilst, on site 33, the enhancement increased a little on average, although this is thought to be due to general fretting and chipping loss independently of the retexturing.

The sawing treatments on site 14 showed the enhancement gained by grooving the asphalt being lost as the grooves closed, with little change in the already-reduced corduroy sections on this material. On the concrete, the grooving remained unaltered whilst the most heavily-trafficked of the corduroy sections showed a further deterioration.

7 Discussion

7.1 General observations

In spite of the limitations of the work in the first phase of this study, some useful broad observations can be made:

Skidding resistance

- *Processes with a significant impact component* generally increase the SCRIM Coefficient. Because these processes expose fresh, unpolished stone, a useful enhancement in comparison with the untreated material can be observed for some time after treatment, at least through the following summer. There is some doubt about how long any enhancement would last on the most-heavily trafficked roads, but there is potential for retreatment with some of these retexturing systems.

- *Water-jetting* can increase skidding resistance initially, particularly where there is a binder film on the aggregate. However, because no new stone surfaces are exposed, the surface can then be expected to follow a normal polishing pattern.
- *Grooving/grinding processes* do not have a significant impact on skidding resistance and, in some cases, may reduce it.

Texture depth

- *Bush-hammering* has been observed to reduce texture depth in some cases, by removing the peaks from the surface particles.
- *Scabbling* has a broadly neutral effect on texture, removing some of the matrix at the same time as removing material from the upper faces of the surfacing.
- *Grooving techniques*, depending on the severity of the treatment, can increase macrotexture significantly by cutting significantly more material away than is removed from the surface. The corduroy technique tends to reduce texture by evening out the surface.
- *Water-jetting and shot-blasting* can increase macrotexture by removing some of the softer matrix around the harder aggregate particles.

Winter treatment

In most cases, treatment during the winter period is both practical and effective, although care needs to be taken under freezing conditions where water is being used in some stage of the process. The apparent gain following retexturing may be small at the time of treatment because the skidding resistance of the surface may already have improved as a result of the normal seasonal cycle. However, where the treatment has exposed fresh stone faces, an improvement relative to the untreated condition should still be apparent in the following summer.

7.2 Limitations

It is clear from the range of effects observed that care should be exercised in selecting the most appropriate treatment for a particular situation.

There are instances where some retexturing techniques clearly would not be suitable. For example, the more severe impact and cutting methods are not appropriate for concrete pavers or cobbles; cutting techniques are not suitable for surface dressings or thin-veneer surfacings; shot-blasting or bush-hammering will not be effective where there is a serious excess of binder such as on a fatted-up surface dressing.

The actual condition of the particular surfacing to be treated should also be taken into account when deciding on the treatment to be used. For example, if the macrotexture is already high, it would be inappropriate to select a treatment expected to yield a large increase in macrotexture - this could result in serious damage to the surfacing. Conversely, treatments expected to reduce macrotexture may not be appropriate if this is already low or could be rendered unacceptable after treatment. Attention to detail, such as the presence of rutting in the wheelpaths, may also be important in enabling the process to give the best possible result.

All except one of the sites studied had a bituminous surfacing of some kind. None of the treatments, apart from conventional grooving to increase macrotexture, are well-suited to be used on brushed-concrete surfaces. This is because the friction characteristics are provided by the sand fines in the mixture; once these have been worn or polished away, retexturing is unlikely to restore them. Rather, the retexturing processes are more likely to expose the coarse aggregate in the concrete which often may be easily polished. Flint-aggregate concretes present a particular difficulty because of the wear the flint particles inflict on the cutting tools. Nevertheless, some processes may help in some situations. For example, exposed-aggregate concrete, with its similarity in finish to some conventional chipped bituminous surfacings, may be capable of being retextured.

7.3 Phase 2 of the study

As has been seen, it was difficult to draw generalised conclusions, particularly on the durability of the various treatments, from the results of the work in the initial phase of the project. Further, apart from two exceptions which were themselves special cases, there were no sites on typical heavily-trafficked trunk roads in the programme.

A major potential advantage of retexturing is the possibility of enhancing skidding resistance for a time to defer alternative, more costly, treatments. This would be of value on main-line sections of route, not just at higher-risk, less heavily-trafficked sites which dominated this study.

For these reasons, a second phase of work was carried out with the primary objective of investigating longer term durability. A controlled trial was set up to compare a number of treatments under practically identical conditions on a trunk road. Details of this work are reported in the companion report TRL 299 (Roe and Hartshorne, 1997).

8 Conclusions

This study has shown that mechanical retexturing techniques are a useful addition to the engineer’s options for road maintenance. Treatments are available to address the problems of polished aggregate, low macrotexture and excess binder. They often cost less than conventional treatments and can be applied quickly with minimum disruption to traffic. However, the majority of processes are not well-suited to use on concrete roads.

The results from early-life studies of the treatments indicate that most of them are effective in raising the SCRIM Coefficient above investigatory levels and therefore provide a useful short-term or immediate-response measure in support of the Skidding Standard.

The early-life study was dominated by short-length, higher-risk sites on rural roads. There was evidence that, except in the most heavily-trafficked situations, the enhancements produced will last a useful length of time.

A second study, described in a companion report, has been carried out in order to provide a clearer indication of the usefulness of these processes for restoring skidding-resistance or macrotexture on longer lengths of non-event trunk roads, to make comparative studies of the main treatments under heavily-trafficked conditions and to give further data on durability.

Further work would be necessary to assess the processes on the newer types of materials, such as proprietary thin surfacings, or to provide a more thorough assessment of the options for treating concrete roads.

9 Acknowledgements

This study was carried out in the Civil Engineering Resource Centre (Manager P Jordan) on behalf of the Highways Agency. Much of the early work described in this Report was carried out by staff of the Civil Engineering Department of Queen Mary & Westfield College, University of London under contract to TRL. The work of Dr D Powell and Mr M Etemadi is particularly acknowledged. The authors also wish to acknowledge the help and co-operation received from the various contractors and Local Authorities involved on the various sites.

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Notes

[1] **SCRIM**. Sideways-force 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° 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 equipment.

Appendix A: Photographs

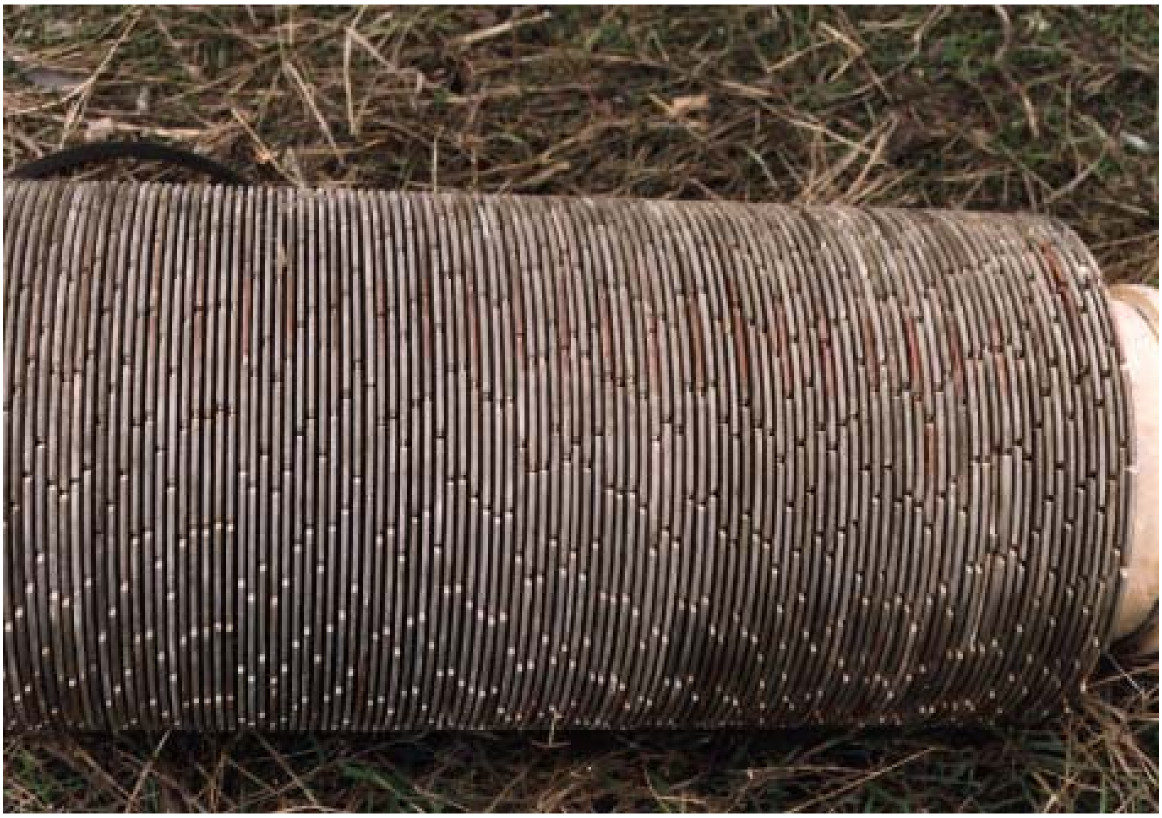
Photograph 1 Klaruwtex 190 bush hammering machine

Photograph 2 Macadam surface before and after Klaruwtex treatment

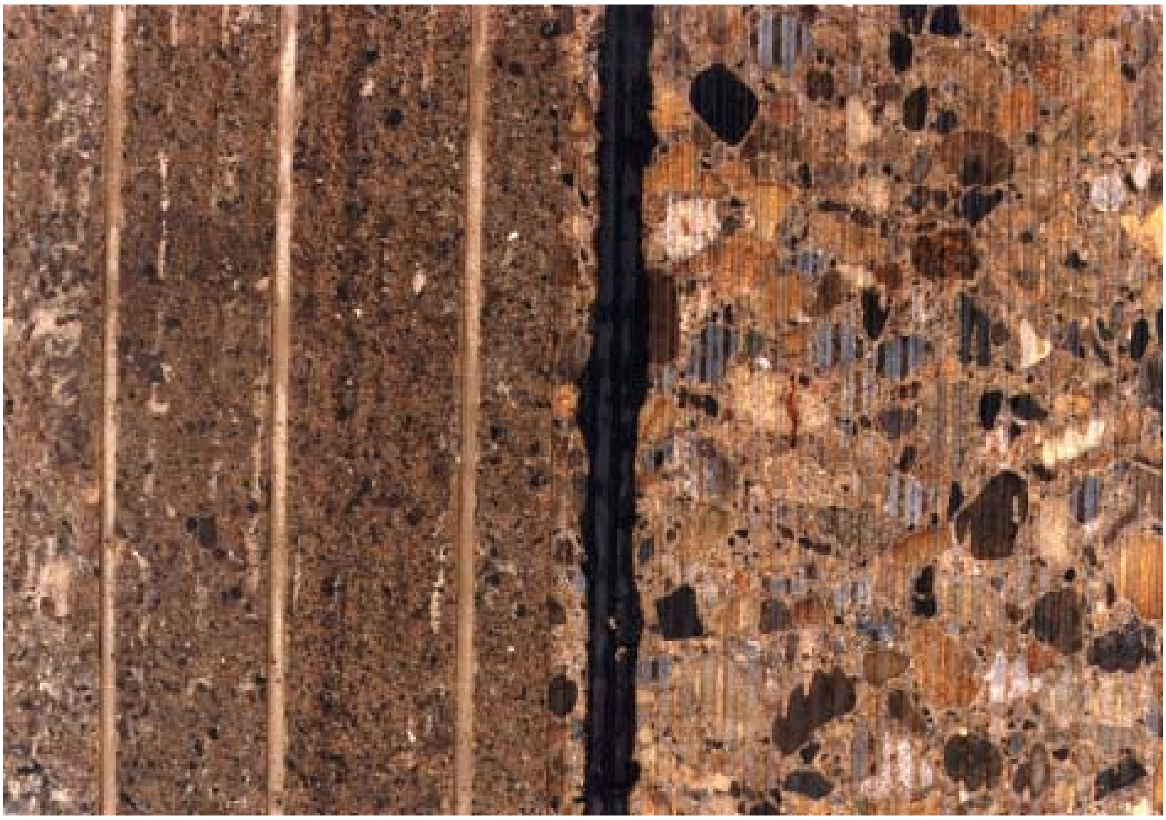
Photograph 3 France Grenaillage shot-blasting machine

Photograph 4 Holemaster's diamond saw grooving machine

Photograph 5 Grooving blades on Holemaster machine

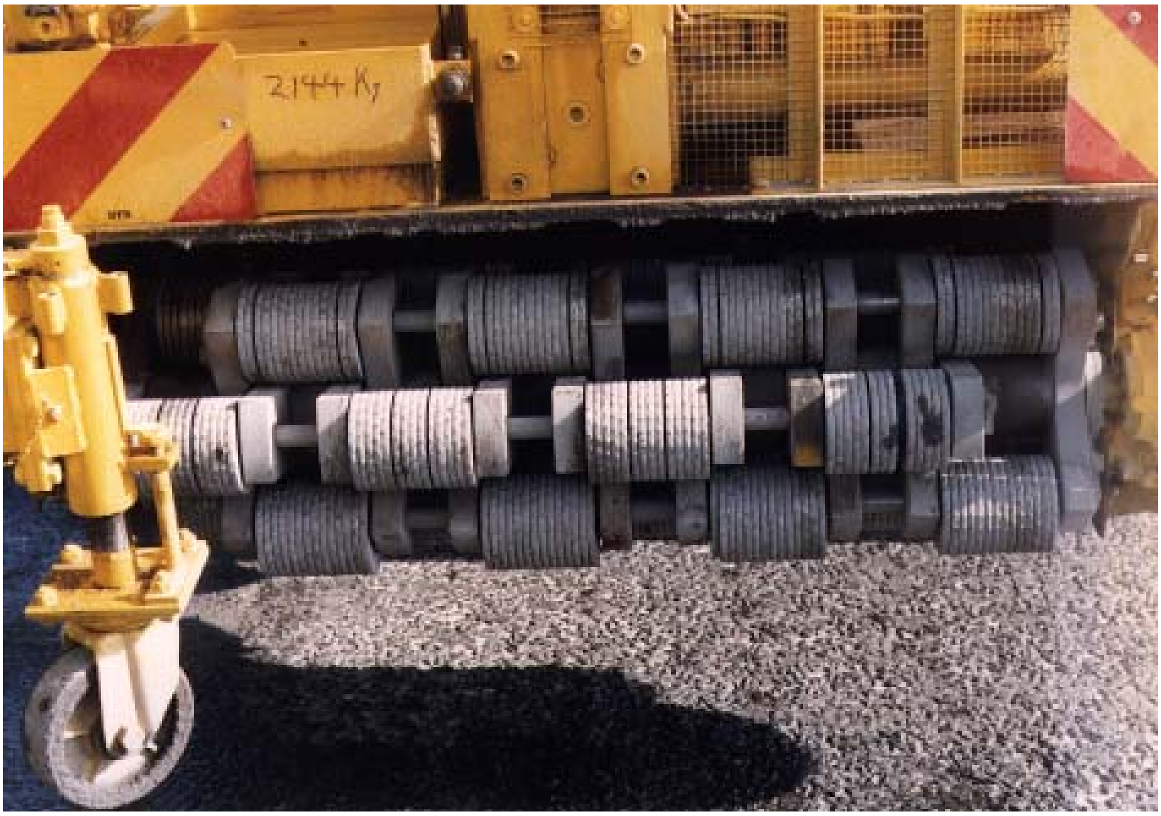


Photograph 6 Corduroy blades on Holemaster machine



Photograph 7 Holemaster grooving/corduroy finish on concrete

Photograph 8 Roadtex machine for flail grooving

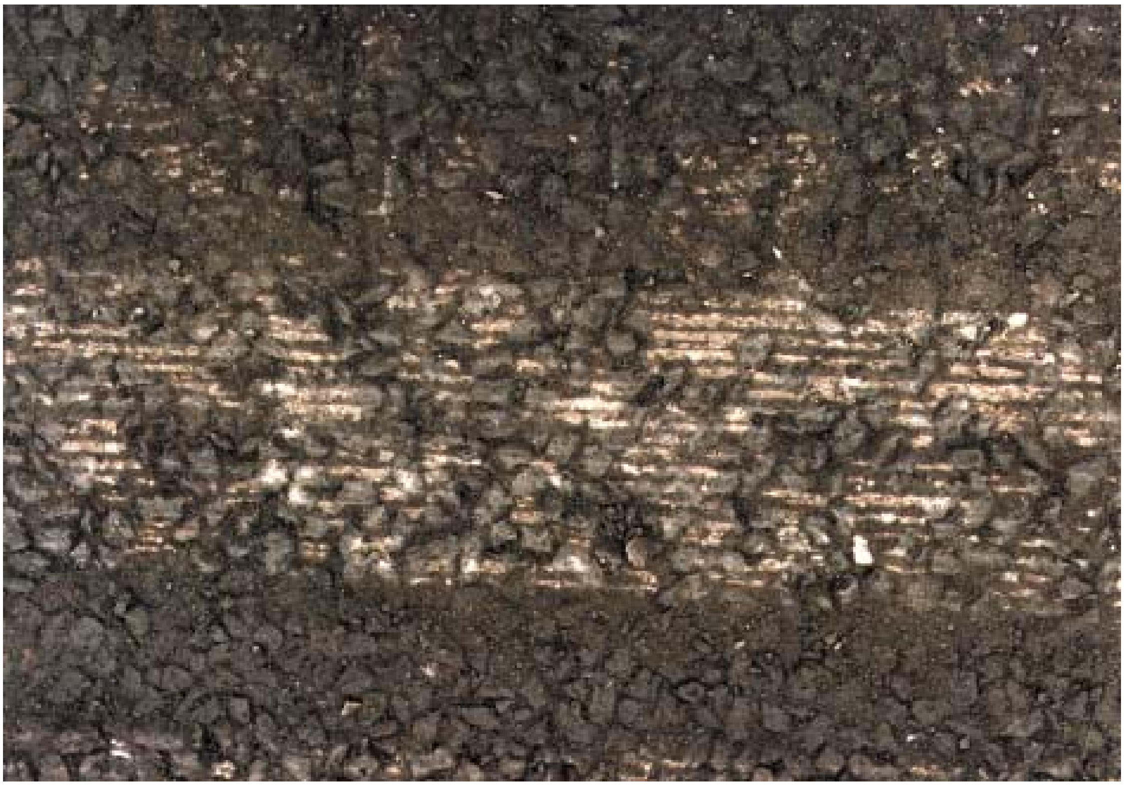


Photograph 9 Flail grooving cutters on Roadtex machine

Photograph 10 HRA surface retextured by Roadtex

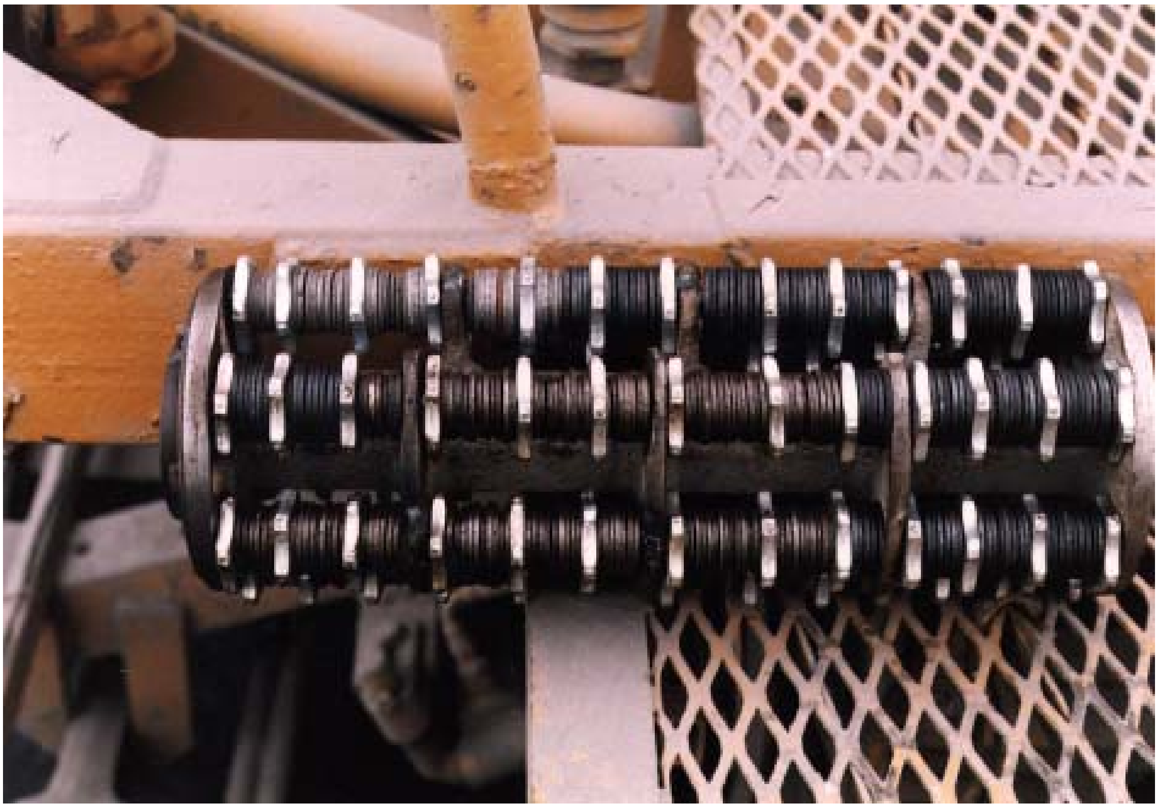
Photograph 11 Carbonising in conjunction with Roadtex treatment

Photograph 12 Balvac Whitley Moran flail grooving machine



Photograph 13 HRA surface treatment by BWM flail grooving

Photograph 14 Johnston Rapitex Durogrip machine



Photograph 15 Flail grooving blades on Rapitex Durogrip machine

Photograph 16 HRA surface treated by Rapitex Durogrip process

Photograph 17 Premier Road Treatment’s Watertex machine

Photograph 18 Rotor bar and water jets on Watertex machine

Photograph 19 HRA surface before and after Watertex treatment

Photograph 20 Dust emissions from Rapitex Durogrip treatment

Photograph 21 Dust emissions from Balvac Whitley Moran treatment

Photograph 22 Waterborne arisings running into gully outlet

Abstract

This report describes the results of a project assessing mechanical retexturing techniques. It reports on work carried out by QMWC and TRL identifying and assessing retexturing techniques available in the UK. The sites were subject to a ‘before and after’ study of skidding resistance and macrotexture. It was seen that skidding resistance is generally increased when using a process with a significant impact component, and fluid action processes can increase skidding resistance where there is a film of binder on the aggregate. Grooving and grinding processes do not have a significant impact on skidding resistance. Texture depth can be reduced using impact techniques. Scabbling has a broadly neutral effect on texture. Grooving can increase texture while corduroy texturing will tend to reduce texture. Fluid action processes can increase texture by eroding the matrix around the aggregate particles.

Related publications

TRL299	*Mechanical retexturing of roads: an experiment to assess durability* by P G Roe and S A Hartshorne. 1997 (price code E, £20)
TRL291	*Alternative textures for concrete roads: results of M18 and A50 trials* by A P Hewitt, P G Abbott and P M Nelson. 1997 (price code H, £30)
RR297	*Measurement of the macrotexture of roads, Part 3. Development of the high-speed texture meter* by P G Roe. 1992 (price code E, £20)
RR296	*The relation between the surface texture of roads and accidents* by P G Roe, D C Webster and G West. 1991 (price code, B, £15)
RR267	*Bitumen permittivity and surface texture in rolled asphalt* by M E Daines. 1991 (price code B, £15)
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