Road surface texture inspection using high resolution transverse profile measurements

by C Mays, A Wright and G Furness

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ROAD SURFACE TEXTURE INSPECTION USING HIGH RESOLUTION TRANSVERSE PROFILE MEASUREMENTS

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by C Mays, A Wright and G Furness (TRL Limited)

Prepared for: Project Record: 3/302 New Techniques for the Assessment of Pavement Distress

Client: Pavement Engineering Group, Highways Agency
(Mr C Christie)

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Executive summary

Project Reference: New Techniques for the assessment of pavement distress
Project Officer: Mr Colin Christie Pavement Engineering Group, Highways Agency
Project Manager: Dr A Wright, TRL Ltd

Scope of Project

The objective of this project is to develop techniques for the automatic identification of defects present in the pavement surface, using traffic-speed techniques. The development of these methods will increase the accuracy and efficiency of the collection and interpretation of condition data on the network, expanding the capability of the TRACS survey, and thereby improving the reliability of the identification of sites in need of further investigation, enhancing the level of detail at which the condition data for these sites is provided, and reducing survey and maintenance costs.

The project comprises three separate tasks:

Task 1: To investigate the suitability of TRACS, HARRIS and detailed profile measurements, provided by scanning laser methods, for the identification of changes in pavement shape arising from deterioration.

Task 2: To develop methods to improve the measurement and assessment of surface texture and the noise levels generated by the surface-tyre interaction.

Task 3: To review the current interpretation of traffic-speed condition data and provide updated advice on the use of this data in the targeting of sites. To continue the development of methods for identifying surface distress, and investigate methods to improve the accuracy and the level of detail at which cracking is identified. Furthermore, to explore the use of alternative techniques to improve maintenance assessment.

The work described in this report has been carried out under Task 2 of this project.

Summary

Currently, the texture depth of the trunk road network is assessed using the TRACS (Traffic Speed Condition Survey) survey. TRACS texture data is processed to obtain the Sensor Measured Texture Depth (SMTD) in the nearside wheelpath, which is reported in Confirm over 10m or 100m lengths. Developments in the use of TRACS texture data, to estimate the surface type and the noise created at the tyre/road interface, have shown that the texture data has significant further potential to improve the assessment of surface condition. However, the TRACS measurement of texture is restricted to a single measurement line, which restricts the level of detail available to the engineer regarding the textural condition of the pavement. Although it is feasible to install further texture measurement lasers on the TRACS survey vehicle, each additional system only provides data over one further measurement line. To obtain detailed coverage would therefore require an excessive number of texture lasers, which would be both costly, and difficult to install.

Recent advances in scanning laser technology have delivered significant improvements in the measurement of transverse profile, such that it is now possible to record up to 1000 data points across the pavement width. This resolution is such that the transverse spacing of the profile data is sufficient to enable detection of wavelengths traditionally considered to describe texture, hence offering the potential to assess texture (and variation in texture) across the full width of the road surface using a single measurement system. However, it is not known whether this equipment, which was designed for the
measurement of transverse profile, will have the sensitivity required to measure the small amplitudes and short wavelengths associated with surface texture.

This report describes work that has been carried out to assess the potential of scanning laser techniques to assess the texture of the road surface. The scanning laser installed on the HARRIS2 survey vehicle has been used for this investigation.

A comparison has been undertaken between texture measurements obtained using traditional single fixed laser methods, and those obtained using scanning laser methods. It has been found that SMTD measurements obtained directly from the scanning laser cannot be consistently compared with measurements obtained from fixed laser techniques. The main reason for variability in the relationship between scanner and fixed laser measurements of SMTD is the wavelength response of the scanning laser system. Hence direct comparison can be made between the two methods after filtering the texture profile obtained using fixed laser methods to equalise the wavelength responses. It is therefore concluded that scanning laser methods are capable of accurately recording transverse profile data with a wavelength response that extends to the texture wavelength range. This offers significant potential benefits, as the scanning laser is not restricted to the measurement of texture in a single line, and therefore scanning lasers can provide measurements that are more representative of the general condition of the surface of the pavement.

Although the scanning laser is able to measure texture profile, the question is raised as to whether the restricted wavelength response would significantly affect network assessment. Simulation of scanner data has been used to determine the effects of reduced wavelength response. It has been found that the vast majority of lengths identified by current techniques to have low levels of texture depths would also be identified by a system having a reduced wavelength response (i.e. a scanning laser).

The capability demonstrated in the measurement of surface texture suggests that there is the potential to develop scanning laser measurement techniques for the assessment of pavement condition. A comparison between 2-dimensional maps of texture depth obtained from the scanner laser and the visual identification of surface defects has been carried out that shows that visual defects can be identified using the texture data obtained from the scanning laser measurements. The 2-dimensional maps of texture depth should enable us to identify fretting and other surface defects to a higher level of accuracy and detail than that achievable using current fixed laser techniques. It is recommended that further work, using a wider selection of sites and defects, be carried out, to fully develop the potential of the system in the identification of surface deterioration, and to determine how such methods could be implemented in the TRACS survey.
1 Introduction

The Highways Agency undertakes routine TRACS (Traffic Speed Condition Survey) assessments of the surface condition of the network, which records the transverse, longitudinal and texture profile of the pavement, and the surface cracking. Post processing of the TRACS Raw Condition Data is carried out to obtain a measure of the rutting from the transverse profile data, and to determine the ride quality from the longitudinal profile data.

For routine use the TRACS texture data is processed to obtain the Sensor Measured Texture Depth (SMTD). However, recent development work on the use of TRACS texture data has enabled the Agency to obtain an estimate of the surface type and the noise created at the tyre/road interface (McRobbbie et al, 2004, Dhillon and Wright, 2006), and determine whether fretting is present on Hot Rolled Asphalt Surfaces (Wright, 2004). It has therefore been shown that the texture data has significant potential in the assessment of surface condition.

In the TRACS survey texture is measured using a single laser located in the nearside wheel path. This method of measuring the condition of the surface texture of pavement surfaces has been found to be both repeatable and reproducible. However, the coverage of the lane width is restricted to the single measurement line, and therefore the capability of the measurement for identifying pavement distress is limited to defects present in the wheelpath. In practice deterioration of the surface is texture is often localised and may not be present in the wheelpath, such that a single line measurement will not always give the best representation of surface texture. It is feasible to install further texture measurement lasers on the TRACS survey vehicle, but each additional system only enables the measurement over one further measurement line. To obtain detailed coverage would therefore require an excessive number of texture lasers, which would be both costly and difficult to install.

Recent advances in scanning laser technology have delivered significant improvements in the measurement of transverse profile, such that it is now possible to record up to 1000 data points across a 4m survey width (Watson et al, 2005). The resolution of such measurements is such that the transverse spacing of the profile data falls within the range of wavelengths associated with the surface texture, hence offering the potential to assess texture (and variation in texture) across the full width of the road surface using a single measurement system. However, it is not known whether this equipment, which was designed for the measurement of transverse profile, will have the sensitivity required to measure the small amplitudes and short wavelengths associated with texture profile.

This report describes work that has been carried out to assess the potential of the scanning laser system installed on the Highways Agency Road Research Information System (HARRIS2) to assess the texture of the road surface, and determine whether this equipment has the further potential for the identification of surface deterioration.

2 Measurement Systems

2.1 Fixed laser

HARRIS1 is fitted with two SELCOM SLS texture profile lasers, configured to measure profile height in the nearside wheel path and in the centre of the carriageway respectively. The laser beam has a diameter of approximately 1mm on the road surface. A similar arrangement is used on TRACS vehicles such as the RAV1 and RST27, with measurements limited to the nearside wheelpath. On HARRIS1 measurements of texture profile are provided at user definable longitudinal intervals down to 0.2mm. As a measurement interval of 1mm is implemented on TRACS surveys, 1mm has been used for the fixed laser surveys undertaken within this study.
2.2 Scanning laser

The PPS2002 Laser Profile Measurement System developed by Phoenix Systems Inc. is fitted to the rear of the HARRIS2 survey vehicle. To obtain the transverse profile measurements a laser beam is swept across the road whilst surveying and the height at approximately 1000 points spaced equally in a radial direction over 4m scan width are each calculated from 12 overlapping individual measurements (see Watson et al, 2005). Transverse profile measurements can be reported at transverse spacings as low as 4mm. The laser beam has a size, in the centre of a scan, of 19mm (longitudinal dimension along the road) by 6.3mm (transversely). However, due to the change in angle of the beam in relation to the road surface during each scan, the laser beam’s effective cross section on the road surface varies as the laser performs each scan. Because the resolution limit of the system is related to the measurement area variation in the effective cross section of the laser may cause variation in the wavelength response of the PPS2002 across its scan width. However, this has not been investigated in this work.

3 Test sites and data collection

Data was collected with the fixed laser and scanning laser systems fitted to the HARRIS1 and HARRIS2 survey vehicles on the seven sites listed in Error! Reference source not found.. A minimum of two surveys were obtained from each site.

Fixed laser measurements of texture profile were obtained in the direction of travel along the nearside wheel path and the centre of the carriageway with a measurement interval of 1mm by two lasers fitted to HARRIS1. Transverse profile scanning laser measurements (when installed on the rear of either HARRIS1 or HARRIS2) were obtained with a measurement interval of 50mm in the direction of travel.

<table>
<thead>
<tr>
<th>Site</th>
<th>Survey direction</th>
<th>Length (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>M27</td>
<td>Eastbound</td>
<td>13.1</td>
</tr>
<tr>
<td>M27</td>
<td>Westbound</td>
<td>12.8</td>
</tr>
<tr>
<td>A329M</td>
<td>Eastbound</td>
<td>1.8</td>
</tr>
<tr>
<td>A329M</td>
<td>Westbound</td>
<td>0.8</td>
</tr>
<tr>
<td>M4</td>
<td>Eastbound</td>
<td>16.5</td>
</tr>
<tr>
<td>M60</td>
<td>Anti-clockwise</td>
<td>10.7</td>
</tr>
<tr>
<td>M60</td>
<td>Clockwise</td>
<td>7.6</td>
</tr>
<tr>
<td>Hampshire</td>
<td>Southbound</td>
<td>12.7</td>
</tr>
<tr>
<td>Leicester</td>
<td>Southbound</td>
<td>7.0</td>
</tr>
<tr>
<td>TRL Track</td>
<td>Clockwise</td>
<td>0.89</td>
</tr>
</tbody>
</table>

Table 3-1: Test Sites
4 Characterising texture

4.1 SMTD

Currently, for network level assessment, texture depth is reported as Sensor Measured Texture Depth (SMTD). SMTD has been shown to be related to the high speed wet skid resistance properties of the pavement. SMTD sensitive to the assessment of texture profile features having wavelengths between 2mm and approximately 600mm, and is calculated according to Equation 1.

\[
SMTD = \frac{n \sum y^2 - (\sum y)^2 - 12(\sum xy)^2 + P - (n^2 - 1)}{n^2}
\]

[1]

Where:

\[P = \frac{5(n^2 - 1)\sum y - 12\sum x^2 y^2}{4(n^2 - 4)}\]

\[n = \text{Number of height measurements in a 300mm length and is always forced to be odd.}
\]

\[y = \text{Laser height measurement (mm).}
\]

\[x = \text{Nominal scaled distance between measurements (mm).}
\]

SMTD measurements are calculated over lengths of 300mm ± 15mm. These measurements are then typically averaged over lengths of 10m or 100m for network level assessment.

4.2 Fixed lasers

For this work values of SMTD were reported for the texture profile data obtained by the fixed texture lasers for the measurements in the nearside wheelpath and the centre of the vehicle. The SMTD calculated in this way, which was typically reported as 10m averages, will be referred to as ‘Fixed Laser SMTD’ throughout this report.

4.3 Scanning laser

As discussed above, the scanning laser system provides a measure of the transverse profile of the pavement and, to date, has been applied in the assessment of rutting. The use of the scanning laser to assess the surface texture of the pavement is novel, and it was therefore necessary to define an appropriate approach to determine whether the scanning laser would be suitable for this application. The key areas of concern for investigation were:

- Does the scanning have the sensitivity to measure the small amplitudes associated with the texture of the pavement?
- Does the scanning laser have the ability to measure the short wavelengths associated with the texture of the pavement?

Direct comparison of the profile data provide by the scanning laser with the texture profile provided by the fixed laser was considered unrealistic because of difficulties in aligning datasets and defining appropriate comparison techniques. Furthermore, for network level assessment it is the derived
parameters that are important, and not the raw texture profile measurements. Therefore we have assessed
the capability of the scanning laser in relation to its ability to measure texture depth reported as SMTD. It
was felt that if the scanning laser data could provide SMTD measurements comparable to the fixed laser
systems then the system could be considered as an appropriate tool for the measurement of texture at the
network level, with the further potential to be developed for the measurement of localised surface
deterioration.

To calculate SMTD from the scanning laser transverse profile data each scan was divided into a number
of measurement bins as shown in Figure 4-1. Due to the requirements of the SMTD algorithm each bin
was 300mm wide. Values of SMTD were calculated from the transverse profile measurements recorded
within each bin, providing nine values of SMTD across the central 2.7m of the measurement (Figure 4-1).
These calculations were carried out for each reported transverse profile. The resulting two dimensional
grid of SMTD measurements was then averaged over 10m longitudinal lengths for each bin.

The SMTDs calculated from the scanning laser could then be compared directly with those provided by
the fixed lasers by selected the appropriate bin. As shown in Figure 4-1, the 10m averaged SMTD values
calculated from bin 3 can be compared with the 10m averaged SMTD calculated from measurements
made by the Nearside texture laser.

SMTD calculated in this way will be referred to as ‘Scanner SMTD’ throughout this report.

![Figure 4-1: Illustration of scanning laser and fixed laser measurement lines.](image)

### 4.4 Known differences between scanner and fixed laser systems

Although the scanning and fixed lasers both record the profile of the pavement, there are a number of
differences between the systems that should be considered when comparing these devices.

Firstly, the area of pavement over which each measurement is obtained (the laser spot size) largely
determines the lowest wavelength a system can measure, as wavelength smaller than the size of the
measurement area will therefore be averaged out within each measurement. Differences in the size and
shape of the laser spot affect the response of each system to profile height variations over the wavelengths
of interest to texture measurement.

Secondly, the measurement of SMTD from the fixed laser data is collected longitudinally, whereas the
scanner measurement is derived from a transverse measurement. Each SMTD measurement could
effectively be considered to represent the texture depth of a 300mm by 300mm square on the pavement,
with the fixed laser measuring along one side, and the scanner measuring along the other. Any
comparison assumes that the texture within the box is homogeneous.
A further consequence of obtaining the measurements in different directions is the influence of longer wavelength features on the measured SMTD. For the fixed laser the texture profile will contain long wavelength features resulting from the vehicle movement and longitudinal profile of the pavement. For the scanning laser the profile data will contain features resulting from the transverse profile (e.g. rutting, crossfall and vehicle roll). In theory such long wavelengths should be attenuated in the SMTD calculation. However, the characteristics of the long wavelength attenuation have not been established, and therefore, to minimise potential effects of differences due to measurements of wavelengths outside of the range of texture wavelengths, the raw profile data from both systems was filtered prior to calculation of the SMTD.

The filtering attenuated profile features with wavelengths outside the range of 2.5-1000mm, using a digital finite impulse response band-pass filter. This upper wavelength was chosen on the basis that features larger than 1000mm are not associated with pavement macro texture. Although neither system is expected to have significant response to variations in profile over wavelengths less than 2.5mm, the shorter wavelength filter is applied to reduce the effects of noise in the data that may be present in either measurement system. It was therefore assumed that the filter would have a minimal effect on the measurement of SMTD, whilst ensuring that the contribution of low wavelength noise is minimised.

Finally, during the commissioning and assessment of the scanning laser it was identified that highly reflective surfaces could adversely affect the measurements of transverse profile provided by the system (Watson and Nesnas 2005). Although this has not been found to be a significant concern to date for the measurement of transverse profile over the range of reflectivities present on the Trunk Road network, it is possible that the effect of reflectivity on the transverse profile may have greater effect on the measurement of surface texture. The scanning laser system provides a measure of the reflectivity of the surface of the pavement being surveyed, which can be used to monitor the presence of highly reflective surfaces. However, this has not been investigated in this work.

5 Scanner measurements of texture depth

5.1 SMTD measurements

The 10m average SMTD calculated from the fixed laser in the nearside wheel path is compared with the Scanner SMTD in Figure 5-1, for 40km of the M4, M60 and M27. It can be seen that there is an apparent relationship between the datasets, although some noise is present. It is also apparent that there is more than one cluster of data within the figure (for example centred at (0.5,1) and (1,1)). This may represent lengths of different types of pavement surface type on these roads, and is discussed further below. A linear line of best fit provides the relationship shown in Equation 2. Forcing the constant offset to be zero obtains the relationship shown in equation 3. Visually it is clear that neither of these relationships provided a good description of the data. However, it does appear that, in general, the scanning laser SMTD is lower than the SMTD reported by the fixed laser.

\[
\text{Fixed laser SMTD} = \text{Scanning laser SMTD} \times 0.738 + 0.627 \quad [2]
\]

\[
\text{Fixed laser SMTD} = \text{Scanning laser SMTD} \times 1.1275 \quad [3]
\]

Figure 5-2 assesses the differences between the Scanner and Fixed laser SMTD data, and also shows the differences obtained after the application of equations 2 and 3 to the Fixed Laser SMTD. It can be seen that the application of both a scale factor and a constant (Equation 2) provides a more symmetrical and narrower distribution of differences than those seen between the original Scanner data and the Fixed laser data. In both cases the distribution of differences is quite broad, and the shape again reflects the different clusters of datasets in Figure 5-1.
Figure 5-1: Comparing fixed laser SMTD with Scanner SMTD (nearside wheelpath).

Examination of the behaviour of the scanner SMTD showed that, on some sites such as the A329M and the M60, the data exhibited distinctly different types of behaviours over different lengths. On these sites different lengths of pavement required different scaling and/or offset values to achieve the best agreement over the full site with the fixed laser SMTD. This change in behaviour was found to occur at the approximate locations of changes in surface type, although on the M60 the change was subtle and associated with a change from one type of thin surfacing to another. Similar behaviour was observed on M27 Eastbound site.

Figure 5-2: Distributions of the difference between fixed laser SMTD and scanning laser SMTD.
5.2 The effect of wavelength response

As noted in Section 4.4, there are known differences between the methods used to obtain profile measurements by the fixed and scanning laser systems that we would expect to affect each system’s response to the texture of the pavement. This could cause the texture profiles obtained from each method to follow the same trends (i.e. when one increases the other increases) but have different intensities.

In particular, the large area over which measurements are made by the scanning laser (19mm by 6.3mm) may attenuate short wavelength features to a greater extent than the 1mm diameter spot of the fixed laser. The use of 12 overlapping measurements to calculate each height reported by the scanning laser (explained in Section 3.2) may also have the effect of attenuating the contribution of short wavelength features.

To establish the effect of wavelength response on SMTD, texture profile measurements made by the fixed laser were filtered to reduce the amplitude of short wavelength features. A digital finite impulse response band-pass filter was applied in the ranges shown in Table 5-1. The filtered, fixed laser SMTD measurements were compared visually with the SMTD measurements obtained from the scanning laser. Note that, to ensure that the upper wavelength responses of the fixed and scanning laser were equivalent a band-pass filter of 2.5mm-100mm was applied to the scanning laser data for this comparison. This reduces the upper wavelength response of the scanning laser data without significantly affecting the capability of the scanning laser to record short wavelength features.

The effect of applying the filters is shown for a length of the M27 WB site in Figure 5-3. On this site it can be seen that the attenuation of short wavelength components of the fixed laser texture profile delivers an “SMTD” value that agrees reasonably well with that obtained from the scanning laser. This behaviour was consistent over a number of sites and indicates that the differences in the level of texture reported by each system can primarily be attributed to differences in the wavelength response of each system.

<table>
<thead>
<tr>
<th>Measurement system</th>
<th>Filter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scanning laser</td>
<td>2.5mm-100mm</td>
</tr>
<tr>
<td>Fixed laser</td>
<td>2.5mm-100mm</td>
</tr>
<tr>
<td>Fixed laser</td>
<td>15mm-100mm</td>
</tr>
<tr>
<td>Fixed laser</td>
<td>20mm-100mm</td>
</tr>
<tr>
<td>Fixed laser</td>
<td>25mm-100mm</td>
</tr>
<tr>
<td>Fixed laser</td>
<td>35mm-100mm</td>
</tr>
</tbody>
</table>

Table 5-1 Filters applied to data to identify the effect of wavelength response on reported SMTD.
Review of the results of applying each filter shown in Table 5-1 found that the best agreement between the scanning laser and fixed laser SMTD measurements could be obtained following the application of the 20-100mm filter. Figure 5-4 shows the distribution of Fixed SMTD and Scanner SMTD measurements obtained in the nearside wheelpath over 30km of the M27WB and the M4. When the fixed laser measurements are filtered (20mm-100mm) the shape of the distribution is shifted to agree closely with the Scanner SMTD.

Direct comparison of scanner SMTD with unfiltered and filtered fixed (20-100mm) laser SMTD is presented in Figure 5-5 and Figure 5-6 respectively for 30km of the M4 and M27 WB sites. A reasonable linear relationship exists in both. However, the spread of the data is improved when the scanner SMTD is compared with the filtered fixed SMTD, although some noise remains. To place this spread in context, Figure 5-7 shows the SMTD calculated from texture profiles collected by the HARRIS1 fixed laser and the RAV fixed laser systems for 40km of the M27EB, M27 WB, M60ACW and M60CW sites.

**Figure 5-3**: SMTD values obtained following filtering of the profile data obtained on the M27 WB site.

*Figure 5-4* Effect of applying a 20-100mm band pass filter to distribution of SMTD values obtained.
**Figure 5-5:** Comparison of Fixed SMTD and Scanner SMTD measurements on the M4 and M27WB

**Figure 5-6:** Comparison of Filtered Fixed SMTD and Scanner SMTD measurements on the M4 and M27WB
5.3 Discussion - using the scanning laser for the measurement of texture on the test sites

This investigation has shown that there is a reasonable agreement between Scanner SMTD and fixed laser SMTD measurements. However, a consistent relationship is not observed over all test sites. The main reason for the variability in the relationship between scanner and fixed laser measurements of SMTD is the wavelength response of the scanning laser system, which is probably due to a large effective measurement area of approximately 19mm², compared to 1mm² of the fixed laser systems fitted to vehicles such as HARRIS1 and RAV1. The linear agreement observed between the fixed laser and scanning laser SMTD when the fixed laser measurements are filtered to remove wavelengths smaller than 20mm appears to confirm this observation. However, detailed analyses of the data have identified occasional lengths where the behaviour cannot be fully explained (or differences resolved) by filtering. It was noted above that a recognised issue with the scanning laser was that of the effect of high surface reflectivity on the measurement. Analysis of the data could not establish any clear link between the surface reflectivity and occasional inconsistencies in the measurement of texture. However, although the behaviour cannot be fully explained by the limited wavelength range of the scanner, it does explain most of the behaviour. Furthermore, the clustered datasets appear to lie reasonably close to the broadly linear relationship between the scanner SMTD and filtered fixed laser SMTD, and clearly within the band of reproducibility observed for fixed laser SMTD measurements collected by difference machines (Figure 5-7).

It is felt that the observed behaviour of the scanner SMTD confirms that the scanning laser is capable of accurately recording transverse profile data with a wavelength response that extends to the texture wavelength range, although this does not extend down to the short wavelengths capable of being measured by fixed laser systems. This offers significant potential benefits as the scanning laser is not restricted to the measurement of texture in a single measurement line in the wheelpath, as is the case for fixed laser systems, and therefore could provide measurements that are more representative of the general condition of the pavement. However, the question remains as to whether the limited wavelength range of the scanner prohibits its use as a network level tool for the assessment of texture. This is explored further in Section 5.4.
5.4 Using Scanner SMTD for network assessment

The above work has shown that scanner SMTD could be considered to be equivalent to fixed laser SMTD, for fixed laser measurements having a reduced wavelength response. We can simulate the effect of using a measurement system with a reduced wavelength response (i.e. simulate scanner SMTD) by applying filters to the fixed laser data before calculating the SMTD.

Fixed laser SMTD values were obtained from 600km of RAV1 texture profile data (RAV SMTD) collected in a TRACS survey for the A1, A1M, A10 and A11. The same RAV1 texture profile data was then filtered using a 20-100mm band pass filter and further filtered SMTD values obtained. The two datasets were then assessed to determine the percentage of the network reported to have low levels of texture in each data set.

![Graph showing simulated scanner SMTD vs RAV SMTD](image)

**Figure 5-8**: SMTD reported by RAV1 (fixed texture measurements) compared with the simulated scanner SMTD calculated from the same texture data using a 20-100mm band pass filter.

For network level assessment the primary method of analysis for network level assessment is to identify lengths containing low levels of texture. “Low” levels of texture are defined using two thresholds in Highways Agency Interim Advice Note 42/02. These thresholds are 0.4mm and 0.8mm. However, the identification of lengths containing low levels of texture in the simulated scanner dataset requires the use of revised thresholds, due to the fact that there is not a one to one relationship between the fixed laser SMTD and the simulated scanner SMTD. These revised thresholds were obtained by applying linear regression to the data of Figure 5-8, and hence using the relationship

\[
\text{Filtered SMTD} = 0.7476 \times \text{unfiltered SMTD} - 0.0014
\]

[4] to obtain revised thresholds of 0.3mm and 0.6mm. These were applied to the 600km test dataset to determine the length of the network containing low levels of texture depth, when assessed using the fixed and (simulated) scanner SMTD methods. The results are summarised in Table 5-2. It can be seen that there is close agreement in the percentages of the network identified to have low levels of texture by each method. Given the method of calculating the revised thresholds, this behaviour is probably as expected. However, further confidence that the (simulated) scanner SMTD exhibits similar behaviour in the identification of lengths having low levels of texture to that of fixed laser measurements can be drawn from the observation that the individual lengths identified by each method are the same. This is shown by
the right hand column in Table 5-2, which quantifies the percentage of the individual 10m lengths that were reported to lie below the threshold by the fixed laser SMTD that were also reported to lie below the threshold by the simulated scanner SMTD. Hence 6km (0.98%, or 600 10m lengths) of the data set was reported to have a fixed SMTD below 0.4mm, 99.29% of these specific lengths (595 lengths) were also identified by the simulated scanning laser method. For the 0.8mm threshold 78km of fixed SMTD measurements lay below the threshold. 76km (98.32%) of these lengths were identified by the simulated scanning laser method.

<table>
<thead>
<tr>
<th>Threshold</th>
<th>Percentage below threshold – Fixed Laser SMTD</th>
<th>Percentage below threshold – simulated Scanner SMTD</th>
<th>Agreement (Length by Length) (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.4mm (fixed) 0.3mm (scanner)</td>
<td>0.98%</td>
<td>0.98%</td>
<td>99.29%</td>
</tr>
<tr>
<td>0.8mm (fixed) 0.6mm (scanner)</td>
<td>12.96%</td>
<td>13.78%</td>
<td>98.32%</td>
</tr>
</tbody>
</table>

Table 5-2 Network level assessment of lengths of 600km network identified to have low levels of texture using fixed and (simulated) scanner SMTD.

As an additional assessment of the scanning laser method to identify lengths in need of investigation we have compared the actual (not simulated) values of scanner SMTD and fixed laser SMTD obtained in approximately 60km of surveys carried out on the network. The scanner SMTD and fixed laser SMTD data were ranked to identify lengths having levels within the lowest 5th and 10th percentiles. The 10m lengths falling within each percentile range were then compared, as shown in Table 5-3.

It can be seen from Table 5-3 that over 90% of the 10m lengths reported to have a fixed laser SMTD within the lowest 5th percentile also fell within the lowest 5th percentile within the Scanner SMTD data. Approximately 85% of points reported to have a fixed laser SMTD within the lowest 10th percentile also fell within the lowest 10th percentile within the Scanner SMTD data. This behaviour appears to show that, although the scanner measurement of SMTD has a restricted wavelength range, it is able to identify the majority of lengths that traditional fixed laser techniques report to have low levels of texture.
6 Measurements of defects

The work reported in Section 5 has assessed the capability of the scanning laser in the measurement of the general texture depth of the pavement, and found that the system is sufficiently sensitive to identify lengths of pavement having low levels of texture. This result is important, because it offers a range of possibilities for the use of scanning laser measurement techniques in the assessment of pavement condition. Many defects that occur on pavement surfaces affect the surface profile within the range of wavelengths associated with pavement texture. Therefore there is potential to apply the scanning laser in the general assessment of visual condition, and to identify specific defects.

Manual analysis of HARRIS2 downward facing images collected on the Hampshire site was carried out to identify surface defects. The manual analysis used software to overlay a 200mm by 200mm grid on the HARRIS2 images. Grid squares containing defects were filled-in, using a numbering system to separate each defect identified. The purpose of this investigation was to determine if there is potential to identify the presence of the surface defects using the scanning laser measurements. The manual analysis identified the following features to report the texture of the pavement across the full width of the road.

1. Longitudinal cracks
2. Transverse cracks
3. Fine cracking (crazing)
4. Sealed Patches
5. Unsealed patches
6. Fretting – Individual chip loss
7. Fretting – Patches of surface lost
8. Potholes
9. Ironwork and cat eyes

Note that the list does not include fatting up. Although this defect probably existed at some locations it was not easily identifiable from images obtained with HARRIS2.

Each scanning laser transverse profile measurement was filtered with a 2.5 to 100mm filter. The filtered transverse profile data was then separated into 200mm lengths (transversely) and the values of the Root Mean Square filtered profile calculated for each 200mm length (giving 20 RMS values across each transverse profile). These were reported as averages over 1m intervals in the direction of travel. This generated a “map” of RMS texture values that could be compared with the reports of visual defects obtained in the manual analysis of the HARRIS2 images. Figure 6-1 shows an example of such a comparison. A key is presented in Table 6-1.

<table>
<thead>
<tr>
<th>Site</th>
<th>Length (km)</th>
<th>5%</th>
<th>10%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leicester</td>
<td>6.15</td>
<td>92</td>
<td>87</td>
</tr>
<tr>
<td>South Liphook</td>
<td>5.81</td>
<td>91</td>
<td>81</td>
</tr>
<tr>
<td>Hampshire</td>
<td>6.81</td>
<td>91</td>
<td>85</td>
</tr>
<tr>
<td>M27EB, M60ACW &amp; M4</td>
<td>39.23</td>
<td>92</td>
<td>86</td>
</tr>
</tbody>
</table>

Table 5-3: Comparison of Fixed Laser SMTD and Scanner SMTD in 10m sections identified as having the lowest 5% and 10% of SMTD reported.
Figure 6-1: Colour coded defect map (lower) aligned with thresholded RMS texture values (upper) for 50m of the Hampshire (south Liphook) data.

Table 6-1: Key for colour coding of defect maps and assessment of texture data.

It can be seen in Figure 6-1 that the presence of visual defects can be visually compared with locations where the texture has significant local variability (i.e. high RMS values). This is because the visual defects such as fretting, failed patching and severe cracking present a localised variation in the texture profile. Visual assessment of a number of sites has found that the trends in the local texture can often be related to the presence of surface features. Also, there is evidence to suggest that significant variability in the texture across or along the length of the pavement can be associated with the presence of visual deterioration. The scanning laser offers the potential to assess this variability because of its ability to report texture along many longitudinal measurement lines.
This introductory trial of the scanner system for identification of surface defects has shown encouraging potential for using the variation in scanner texture values across the carriageway. Further investigation of the relationship between patterns in the texture data and visual condition may lead to the development of alternative methods for localised defect detection.

7 Conclusions and Recommendations

This work has investigated whether the transverse profile measurements provided by the PPS2002 scanning laser can be used to assess the surface texture of the pavement. Our approach has been based on demonstrating the agreement between the texture depth derived from the scanner data and that derived from traditional techniques. Therefore we have developed software facilities to obtain values of SMTD from the scanning laser transverse profile measurements – the so called scanner SMTD.

The assessment has shown that the scanning laser measurement of transverse profile has sufficient sensitivity and resolution to measure components of the transverse profile within the range of wavelengths covering surface texture. However, because of the system’s limited short wavelength response the full range of texture wavelengths is not reported in the scanner data. This may affect the ability of the system to fully measure texture on surfaces having very small aggregate size. However, tests have shown that this appears not to affect the potential for the use of the system at the network level. Furthermore, this is balanced by the advantages offered by the use of the system over fixed laser methods. The measurement of texture can be provided over the full width of the pavement, and hence in multiple measurement lines, giving much improved coverage. Furthermore, the data is provided by a single laser that also provides measurements of transverse profile, thereby reducing equipment costs and size. It is therefore recommended that scanning laser techniques be considered as a potential alternative to traditional methods for network level analysis of texture.

The capability that has been demonstrated in the measurement of surface texture suggests that there is the potential to develop scanning laser measurement techniques for the assessment of pavement condition. The 2-dimensional maps of texture depth provided by the scanning laser should enable us to identify fretting and other surface defects to a higher level of accuracy and detail than that achievable using current fixed laser techniques. It is recommended that further work, using a wider selection of sites and defects, be carried out, to fully develop the potential of the system in the identification of surface deterioration, and to determine how such methods could be implemented in the TRACS survey.

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References


