Automated detection of fretting on HRA surfaces

by S McRobbie and G Furness

Published Project Report
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Version: 1.0

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Project Manager

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Executive summary

Information on the condition of the pavement surface is used in the UK to help determine its current state and deterioration rate, and hence assist in determining what type of treatment should be carried out, and when. Until recently, visual surveys have been the only way of assessing fretting. These are subjective, time consuming and potentially dangerous for the staff performing the surveys.

The development of a quantitative, traffic-speed technique for the measurement of fretting is highly desirable, as it will make the identification and prioritisation of lengths of the network requiring maintenance less subjective. Previous attempts to provide automatic, machine based fretting data have shown some promise, but have had drawbacks, notably that they have relied on texture data which is only provided in the nearside wheelpath.

Work has been undertaken to develop an algorithm to identify fretting on Hot Rolled Asphalt (HRA) surfaces using laser-measured transverse profile. The algorithm development has been based on a methodology previously developed for application to individual lines of texture profile data, and expanded to make use of data from all 25 profile lasers, and portrays it in three dimensions. This should therefore provide an assessment of the severity of the fretting across the entire carriageway. This has produced an algorithm which can be used for detecting fretting, and which has been shown capable of distinguishing between lengths containing high and low levels of fretting.

This work concentrated on detecting fretting by optimising the use of profile data which could be collected without major changes to TRACS hardware or software, and is restricted to HRA surfaces. It was conducted in the knowledge that it would not provide an end point in itself, but merely a stage point in the larger ongoing process of Highways Agency TRACS research.

Although the results to date show that there are sometimes considerable numbers of false positive readings, incorrectly identifying fretting as present, it may be possible to improve the algorithm operation, and remove some of these false positive reports. This could be done by excluding data measured from either edge of the carriageway, as these are sometimes adversely affected by road markings and debris.

The algorithm has been developed to detect fretting on HRA surfaces. Further research into the detection and reporting of fretting should extend onto other, non-HRA surfaces, and should concentrate on delivering a meaningful and useable parameter to the engineer. This may not necessarily report the precise location or extent of every missing chip on the pavement, but should be able to objectively, quantitatively and consistently report the relative amounts of fretting found on various parts of the network. This may be delivered every 10m as a single number reporting the percentage of the preceding 10m of pavement which is fretted. However, it is felt that the current approach has been developed as far as it can, and that significant further improvement will only be possible by adopting a different approach, possibly including the use of data obtained by processing the downward facing video images, and by making use of higher resolution profile data.
1 Introduction

There are known problems with the detection of fretting in automated surveys, such as TRACS. Fretting is often mistaken for cracking (Wright, 2004), leading to the misreporting of higher levels of cracking. Attempts have been made to help TRACS distinguish between cracking and fretting with a view to reducing the levels of false positive crack readings, however these have had mixed success. As well as causing problems for the reporting of cracking in automated surveys, fretting is an important defect in its own right, and should be reported accurately and reliably to assist the engineer in the task of monitoring and maintaining the network condition.

TRL were commissioned by Mott MacDonald to investigate the automatic detection and reporting of fretting on Hot Rolled Asphalt (HRA) surfaces. Mott MacDonald maintain Area 3 on behalf of the Highways Agency, and operate it with a forward thinking approach, allowing the use of the area’s roads as a ‘Living Laboratory’ in which they are keen to use innovative techniques and approaches to maintaining the condition of the network.

Work therefore has been carried out to develop a method of automatically detecting, identifying and objectively reporting fretting on HRA surfaces.

This work concentrated on detecting fretting on HRA surfaces. It was conducted in the knowledge that it would not provide an end point in itself (e.g. the detection of fretting on all surfaces), but forms part of the ongoing Highways Agency research into the use of condition data collected at traffic speed.

2 Background

Previous attempts to automatically detect the presence of fretting have concentrated on the use of the texture profile of the pavement. Methods developed by DWW in the Netherlands (Van Ooijen et al., 2004) have looked for characteristic profile shapes, which suggest the absence of a chip of aggregate. The DWW research led to the development of a method known as STONEWAY. This method follows the assumption that when a stone is lost from the surface then it will leave behind a hole of a characteristic depth and length. The depth and length are dependent on the aggregate size used in the pavement construction. For example a missing piece of 20mm aggregate will clearly leave a different profile behind than a missing piece of 12mm aggregate.

To detect these characteristic profile shapes resulting from the loss of a stone the method first of all determines a reference profile level, or baseline for relatively short lengths (in this work a baseline length of 200mm was used) of the texture profile. Each individual profile point in the baseline length being considered is then compared against the baseline reference level. Lengths where the individual points are sufficiently deep with respect to the reference level are noted, and where enough of these points occur successively then the affected length is recorded. The total of the recorded lengths from each metre of data is then reported as the amount of fretting in the baseline length. Typically these results are amalgamated and reported over 100m reporting lengths.

An earlier piece of TRL research to develop methods for reporting fretting using TRACS data adapted the STONEWAY method to operate more specifically on HRA surfaces. The implementation of the algorithm by TRL differed in a couple of key areas from that proposed by DWW (Wright, 2004). Notably the TRL implementation used different filtering techniques in the establishment of the reference. Additionally, the characteristic shape of the profile when missing stones were detected was seen to be different on HRA to the thin surfaces that DWW had considered. Therefore the algorithm parameters were optimised for use on HRA.

The STONEWAY and the TRL adaptation of STONEWAY methods both make use of texture profile data. Survey vehicles such as those used in TRACS only have a single texture laser, mounted in the nearside wheelpath of the vehicle. Therefore they can only measure fretting if and when it occurs in the nearside wheelpath. Fretting often occurs non-uniformly across the carriageway, with areas of fretting often being observed between the wheelpaths. The fact that fretting is only currently identified
in the nearside wheelpath is therefore one of the major weaknesses of the current implementation of the fretting algorithm.

Clearly, there would be some benefit in obtaining a measure of fretting across the full width of the survey (traffic lane). Research has been undertaken to explore the potential of using the lasers mounted transversely on the front of the survey vehicle to obtain this measure. The Highways Agency’s research survey vehicle, HARRIS1, which is operated on behalf of the Highways Agency by TRL, has been adapted to provide profile data from each of the 25 measurement lasers at a longitudinal spacing that, whilst less closely spaced than the texture profile data, is sufficient to provide a measure of the megatexture of the pavement. Work has then been carried out to develop algorithms, based on the current approach taken with the single texture profile data, that exploit the three dimensional data provided by the 25 measurement lines in an attempt to identify fretting across the width of the survey. This approach is referred to as the Enhanced Fretting Algorithm (EFA), which aims to provide a measurement of fretting across the carriageway width.
3 Methodology

3.1 Data

Visual assessments of the condition of the pavement, specifically considering the presence and severity of fretting, were carried out by inspectors at a number of sites. These sites were all surfaced with HRA, and were affected by varying degrees of fretting. Table 1 shows the details of the data used in the final algorithm development and analysis, and Figure 1 shows the approximate locations of the sites listed in Table 1.

<table>
<thead>
<tr>
<th>SITE</th>
<th>ROAD</th>
<th>DIRECTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>MP 24/0 - 23/4</td>
<td>A3</td>
<td>NB</td>
</tr>
<tr>
<td>MP 26/6 - 27/2</td>
<td>A3</td>
<td>NB</td>
</tr>
<tr>
<td>MP 27/0 - 26/5</td>
<td>A3</td>
<td>SB</td>
</tr>
<tr>
<td>MP 10/9 - 11/5</td>
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<td>NB</td>
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<tr>
<td>MP 43/2 - 41/85</td>
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<td>NB</td>
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<td>A3</td>
<td>SB</td>
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</tr>
<tr>
<td>MP 114/6 - 113/6</td>
<td>M4</td>
<td>EB</td>
</tr>
</tbody>
</table>

Table 1: Sites used in final development and assessment of Enhanced Fretting Algorithm.
HARRIS1 surveys were carried out on the same sites within a short time of the visual surveys being carried out. The short interval which elapsed between the two survey types (HARRIS1 and visual) ensured that the actual condition of the pavement would not have altered by any significant amount. During the HARRIS1 surveys the downward facing video system was used to capture images of the road surface, and the transverse profile lasers mounted on the front of the survey vehicle were used to collect profile information at 6mm longitudinal intervals, over 25 lines spaced at 150mm intervals transversally.

Visual surveys performed on site are the ‘gold standard’ of pavement condition data for most parameters, including fretting. Such data was therefore used as the primary reference source for the development and assessment of the fretting algorithms.

It is accepted that the results of any automated approach will never be a perfect match for visual data collected on site by an experienced inspector. Therefore a secondary reference source was used to assist the examination of any areas where particular anomalies occurred. Manual assessment of downward facing HARRIS1 video images was used to provide the secondary reference source.

3.2 Methodology for data collection

The following sections present details of the procedures used to collect and process each of the datasets used in the development and assessment of the fretting algorithms.
3.2.1 Primary reference data collection (VCS)

Visual assessments of the degree of fretting present were carried out by inspectors from the hard shoulder, inspecting lanes 1, 2 and 3. Lane 1, being closest to the inspectors, was inspected in more detail than the other lanes, and it was this data which was used in the research.

The carriageway was conceptually split into 5m long subsections, and each of these subsections was split transversally into 5 strips. The 5 strips within each subsection represented the nearside edge, the nearside wheelpath, the middle of the lane, or ‘oil lane’, the offside wheelpath and the offside edge of the carriageway. Nothing was used to physically demark the strips, or the 5m subsections.

Each of the 5 strips in each subsection was assigned a value based on the fretting observed by the inspectors. These values spanned the range zero (representing no fretting deemed worthy of reporting by the inspector) to 3 (denoting severe fretting).

Such an approach produces an output similar to that shown Figure 2 below, where each 5m subsection of the lane assessed has 5 values assigned to it.

![Figure 2: Example of VCS data. Primary reference source.](image)

The detailed data was used for visual assessment and direct comparison with the results of the algorithm during algorithm development. In addition, to obtain quantitative measures of the algorithm performance the data was aggregated to provide a single number for each 10m subsection of pavement, with no distinction regarding the location of the fretting within each 10m. This aggregated number was the sum of all the fretting values from within the 10m subsection.

3.2.2 Secondary reference data collection (manual image analysis)

The downward facing video system on HARRIS1 was used to obtain the secondary reference data. Figure 3 shows an example of such an image set from HARRIS1, with an enlarged section to show the detail present in the images.

![Figure 3: Example of HARRIS1 images showing fretting on HRA. Secondary reference source.](image)
The video images were examined by an inspector using ChartCrack – a proprietary TRL software application which enables visual surveys of video images to be performed and which records the locations and severities of defects.

The video analysis was performed by splitting the images into 0.5m x0.5m grid squares, and assessing whether or not each grid square contained any fretting, and if so, how much. The inspector was able to click on the screen wherever fretting was seen in the images, and could also choose how severe the observed fretting was using a scale from zero (no fretting observed) to 3 (large amounts of fretting observed). In this way a gridlike map was created of the survey section, showing where the fretting was located. This map could then be compared with the primary reference source, or the algorithm output.

The HARRIS1 video system uses 3 linescan cameras which combine to span the width of the carriageway, and a transverse light source which provides illumination. The configuration of the system, in which each image is taken looking directly downwards, with the lighting also being directed downward does tend to result in a ‘flattening’ of the image, making some defects hard to see. See Figure 3 for an example of the type of image obtained by HARRIS1 and used in the production of the secondary reference source.

The process of producing the secondary reference data is quite tiring for an inspector as the images can be hard to look at after prolonged exposure. It was observed that the results obtained by the same inspector on the same site when the assessment was repeated would be similar but not identical, and that the results obtained by another inspector on the same site would also be similar, but not identical, often with the introduction of an offset due to different interpretations of where the boundaries lay between the different fretting levels.

3.2.3 HARRIS1 laser data collection

HARRIS1 was used to collect transverse profile data at a longitudinal spacing of 6mm. This was done using the 25 profile lasers mounted on the front of the vehicle which are used for measuring the transverse profile of the pavement. The data was processed to extract megatexture information from each measurement line to effectively provide 25 sets of texture data. Figure 4 shows an example of such a processed profile for part of the pavement shown in Figure 3. The two red circles show locations where fretting appears to be present.

![Figure 4: Example of fretting of surface shown in Figure 3, as measured by a single transverse profile laser.](image)

Figure 5 shows all 25 measurement lines displayed as a 3-D surface. The direction of travel in the survey shown in Figure 5 is left to right, and the data shown represents a distance travelled of just over 10m.
Figure 5: Example of 25 individual profiles obtained from the 25 transverse profile lasers, and displayed as a 3-D profile of the pavement surface.
4 Algorithm development

The development of the fretting algorithm has built on existing methods employed in the identification of fretting using single texture lasers, which have been applied elsewhere in Europe (Van Ooijen et al., 2004) and implemented by the Highways Agency in the UK for use in TRACS surveys. The fretting algorithm uses the profile data to characterise the underlying texture of the pavement, and then identify local differences from this characteristic level. Locations which differ from the characteristic level by a sufficient depth and, over a significant length, are deemed to be fretted. The proportion of the road affected by fretting is reported. A summary of the main steps involved in the fretting algorithm is given in the following section.

4.1 Summary of algorithm operation

For each of the 25 lines of profile data:

1. The measured profile is filtered to remove long wavelengths, such as those representing the shape of the road, leaving only data which is representative of the surface texture of the pavement.

2. A baseline is established, against which the measured, filtered values are assessed. This baseline value is calculated over relatively short lengths to enable the baseline value to react to changes in surface texture. In this case the Mean Profile Depth or MPD was used. This is an internationally defined method used in the assessment and measurement of surface texture depth, which uses the minimum profile heights in two halves of the baseline length to calculate the baseline value.

3. Each filtered measured profile point is compared against the baseline value. If the measured filtered profile value meets certain criteria in relation to the baseline then the presence of fretting is reported. These criteria are referred to as D (which is a unitless parameter defining the required difference which must be observed between the baseline and the filtered profile before fretting can be reported) and L (which is the length of profile over which D must be exceeded before fretting can be reported).

Figure 6 shows a representation of a filtered profile (red line) being compared against the baseline profile (green line). The filtered profile is lower than the baseline profile at three locations – L₀, L₁ and L₂. However, at L₀ the difference between the baseline and the filtered profile is not maintained for a long enough length, and so this is not deemed fretting.

4. The percentage of all filtered measurement data points in the preceding baseline length which have satisfied the criteria and which are deemed to indicate the presence of fretting is reported. The amount of fretting reported from the example shown in Figure 6 would be L₁ + L₂.

![Figure 6: Calculation fretting by assessing deviation from a baseline.](image-url)
Typically the baseline calculation length was 200mm. This produced 25 values (one per laser) across the road, giving an indication of the amount of fretting found in that laser’s path in the previous 200mm of road.

- **NOTE:** The parameter D is unitless, and is not a measurement of the depth of the fretting, but is related to the difference between the baseline, and the profile.

The results are aggregated to report the amount of fretting present at different levels of detail. Two resolutions were used: one at 0.5m which maintained the spatial information regarding the location of the fretting along and across the carriageway, and matched the resolution used in the secondary reference data produced by image analysis; and the other at 10m which did not retain the spatial information, but made it easier to look at large datasets, and replicated the TRACS regime of reporting parameters as single values at 10m intervals.

### 4.2 Development and assessment of the Enhanced Fretting Algorithm

Following the adaptation of the fretting algorithm to operate in 3 dimensions using the transverse profile lasers the remaining step in the optimisation of the fretting detection was the selection of the best values for D and L within the algorithm.

This was done by iterating through a range of different D and L values, processing the data, and comparing the outputs against the Primary and Secondary reference data sources. It was then possible to establish different levels of algorithm performance for the different parameter settings.

Each adjustment of parameters resulted in different overall performance. In some cases this meant the performance improved in one location, but degraded in another location. The performance of the algorithm using the different parameter settings was assessed visually, but it was not easy to objectively gauge the performance. A method of providing a quantitative assessment of the algorithm performance was required, and was partly developed, although this needs further work if it is to become a useful tool for assessing the performance and honing the algorithms to ensure they deliver the best, most useful result.
5 Assessment procedure

Even with a high quality primary reference data set, and a good secondary reference, some thought had to be given to the correct way in which to assess the algorithm performance.

It was accepted that it would not be realistic to expect the fretting algorithm to deliver a direct like-for-like comparison with the Primary reference (visual survey) data. A fundamental objective was to obtain an algorithm that was able to highlight fretted lengths of pavement that were also reported in the reference, whilst not falsely reporting fretting on lengths which are in fact sound.

As discussed previously, the application of the fretting algorithm calculated 25 values every 200mm. This produced a large volume of data which was hard to analyse. The level of detail in the results of the fretting algorithm data was therefore reduced by calculating the level of fretting present on the pavement over grid squares of size 0.5m by 0.5m. Following a degree of experimentation it was concluded that each of the 0.5 by 0.5m grid squares would contain a value representing the mean value of the fretting algorithm values reported within the grid square. This fretting grid data could then be directly compared with the reference data.

However, because the reference data was only reported over four levels of intensity it was also necessary to develop threshold values for the fretting algorithm to enable direct comparison of the results.

Following the calculation of the performance metrics for the entire dataset, a series of threshold values were selected. The threshold values were selected using a combination of data analysis to determine various percentile levels within the fretting algorithm data, and expert judgement. The threshold values enabled the categorisation of the results into four categories (0, 1, 2 and 3) depending on how much fretting was reported within the length. This then allowed a more direct comparison of results from three different data sources.

Therefore, for each subsection of the pavement, there was a categorisation value (0 to 3) derived from the primary reference data, the secondary reference data, and the EFA data.

By varying the parameters D and L, a new set of EFA results was obtained, which then produced a new set of categorisations. These EFA categorisations were then compared with the reference data categorisations, and any differences were investigated.

5.1 Comparison with Primary reference source (VCS)

Figure 7 shows approximately 75m of reference and fretting (algorithm) data (chainage increasing from left to right – each black square represents the start of a 10m subsection) with the different data sets separated by the grey bars. The red areas show Category 3 fretting, the amber areas show Category 2 fretting, Category 1 is shown in light green, and white shows Category 0. The two algorithm outputs show the effect of maintaining the D value, but altering the value of L, in effect changing the length over which a feature needs to deviate sufficiently from the baseline in order to be classed as fretting.

![Figure 7: Grid representation of fretting showing Primary reference data, Secondary reference data, and the results of the EFA using two different settings for the L parameter.](image-url)
It is clear that looking for longer features (i.e. increasing L) reduces the amount of fretting detected, and produces a much better match with the reference data sources.

Figure 8 shows another 75m of reference and output fretting data (chainage increasing from left to right – each black square represents the start of a 10m subsection) with the different data sets separated by the grey bars. The red areas show Category 3 fretting, the amber areas show Category 2 fretting, Category 1 is shown in light green, and white shows Category 0. This shows the effect of increasing D (the size of the deviation between the baseline and the profile) while maintaining the value of L. It can be seen that increasing D reduces the amount of fretting reported.

The plots such as those shown in Figure 7 and Figure 8 were very useful for assessing the algorithm response to the parameter changes, and to identify locations where there were problems with the data, such as alignment issues, or problems caused by the driving line taken during the HARRIS1 survey.

Although development of the algorithms is assisted by localised comparisons, as shown in Figure 7 and Figure 8, examination of the entire test dataset (and comparison with the reference dataset) requires further reduction of the data into longer lengths. Therefore the reference and fretting algorithm results were amalgamated into 10m subsection lengths, with one representative value for the entire carriageway width. This was done by calculating the 95th percentile of all the 0.5m grid values across the carriageway in a 10m length. These values were thresholded using appropriate values to again produce four categorisations of fretting severity, for each 10m length.

Figure 9 compares the thresholded reference and automated (fretting algorithm) data over approximately 3km of the test data set (with D=2.2, and L=12). It can be seen that there is general agreement in the data sets. Where the reference data indicates the presence of fretting, it is usually reflected in the output of the algorithm, especially when the fretting is severe. However, Figure 9 also shows that there are lengths where discrepancies exist between the reference fretting data and the results of the algorithm (e.g. 1700m to 1900m).
Figure 9: 10m aggregated plots showing sum of all primary reference fretting across carriageway in 10m subsection, and 95th percentile value of all EFA fretting across carriageway in 10m subsection.

Figure 10: Primary reference and EFA output metrics for dataset.

Figure 10 compares the algorithm and the primary reference data for the data used in the final analysis of the algorithm. The algorithm was tested with a D of 2.2, and an L of 12. It can be seen that there is some agreement between the two data sets, particularly in areas where the primary reference data reported a lot of fretting, but there is a lot of noise in the algorithm data which makes it hard to properly judge its performance. It is also worth noting that the algorithm almost always reports a value (very few reports of zero) so the data is offset.
Figure 11: Primary reference and EFA categorisation for dataset.

Figure 11 compares the fretting categorisations as provided by the primary reference data with the algorithm (D = 2.2 and L = 12) of the final dataset. This is the same data as shown in Figure 10, but thresholds have been applied to determine categories. The two plots in Figure 11 are slightly vertically offset for clarity of display, with the algorithm using the right hand scale and the reference using the left. It can be seen that there is some agreement with the general trends, but there are significant discrepancies, notably between about 4000 and 5000m where the reference data shows there to be no fretting of note, but the EFA regularly reports fretting at Category 1.

In order to objectively assess the performance of the algorithm it was necessary to develop a quantitative approach. This was done by calculating how well the fretting category reported by the algorithm for any given 10m subsection compared with the reference fretting categorisation on the same subsection: i.e. how often were the two categorisations an exact match, how many times was the EFA categorisation different by “1” from the reference categorisation, etc? This was carried out using data aggregated over 10m lengths for the whole width of the carriageway, as illustrated in Table 2.

<table>
<thead>
<tr>
<th>EFA within x categories of reference data</th>
<th>Number of occurrences</th>
<th>Percentage of dataset (%)</th>
<th>Cumulative percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 (exact match)</td>
<td>717</td>
<td>51.4</td>
<td>51.4</td>
</tr>
<tr>
<td>1</td>
<td>488</td>
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<td>3</td>
<td>24</td>
<td>1.7</td>
<td>100.0</td>
</tr>
</tbody>
</table>

Table 2: Data showing how often the EFA categorisation result was within x categories of the reference data categorisation.

As can be seen in Table 2 the EFA correctly (according to the primary reference data) categorises the fretting for over 50% of the 10m lengths, with over 86% of the data being categorised within ±1 category of the reference data. These levels of performance look very encouraging but do not tell the whole story in terms of whether the algorithm performs best on areas which should be in higher categories of fretting, or lower categories. More work is necessary in order to fully gauge the performance of the algorithm, and the resulting implications for the end user.
6 Conclusions

The tests conducted so far have found that enhancing the fretting algorithm to utilise profile data collected across the whole width of the carriageway, provides a useful measurement of the levels of fretting observed on HRA pavements. However the algorithm performance is affected by the parameters (D and L) used within it. The research considered a number of different parameter value combinations and concluded that the best results were obtained with D = 2.2, and L = 12. The performance of the algorithm is reasonable in relation to identifying lengths of severe fretting. However, in some cases, the algorithm also falsely identifies lengths which manual surveys report to contain no fretting.

It may be possible to improve the algorithm operation, and remove some of the false positive reports of fretting, by excluding data measured from either edge of the carriageway, as these are sometimes adversely affected by road markings and debris. Research into the use of cracking data gathered by TRACS vehicles has also observed these edge related issues, and has shown that the edge data can be excluded without compromising the representative nature, or the accuracy of the final output cracking data (Furness, et al., 2007).

The algorithm has been developed to detect fretting on HRA surfaces. Further research into the detection and reporting of fretting should extend onto more surfaces than HRA, and should concentrate on delivering a meaningful and useable parameter to the engineer. Although it is unlikely to be able to report the precise location of every missing chip on the pavement, it should, at a macro level, be able to objectively, quantitatively and consistently report the relative amounts of fretting found on various parts of the network. This may be delivered every 10m as a single number reporting the percentage of the preceding 10m of pavement which is fretted.

Once this approach has been adopted for both HRA and other surfaces it is felt that any significant further improvements will require a change of approach. Such an approach could make use of data obtained by processing the downward facing video images, and by making use of higher resolution profile data.
Acknowledgements

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References


G Furness, S Barnes and A Wright (2007), Crack Detection on Local roads – Phase 2, TRL Published Project Report, PPR 147, TRL, Crowthorne.

Abstract

The development of a quantitative, traffic-speed technique for the measurement of fretting is highly desirable, as it will make the identification and prioritisation of lengths of the network requiring maintenance less subjective. Previous attempts to provide automatic, machine based fretting data have shown some promise, but have had drawbacks, notably that they have relied on texture data which is only provided in the nearside wheelpath.

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