Development and validation of algorithms for the automatic detection of fretting based on multiple line texture data
Research into pavement surface disintegration: Phase 2 – interim report

S McRobbie, J Iaquinta and A Wright (TRL)
P Trumper and J Kennedy (Jacobs)
Development and validation of algorithms for the automatic detection of fretting based on multiple line texture data

Research into pavement surface disintegration: Phase 2 - interim report

McRobbie, S; Iaquinta, J; Wright, A; Trumper, P; Kennedy, J

McRobbie, Iaquinta, Wright – TRL Ltd
Trumper, Kennedy – Jacobs Engineering UK Ltd

Prepared for: Jacobs Engineering UK Ltd,
Project Ref: HA Ref No - 527 (1308) JCBS
(Jacobs Engineering / B1372141/0001)

Quality approved:
Stuart McRobbie
(Project Manager)
Jean Iaquinta
(Technical Referee)
Disclaimer

This report has been produced by the Transport Research Laboratory under a contract with Jacobs Engineering UK Ltd. Any views expressed in this report are not necessarily those of Jacobs Engineering UK Ltd.

The information contained herein is the property of TRL Limited and does not necessarily reflect the views or policies of the customer for whom this report was prepared. Whilst every effort has been made to ensure that the matter presented in this report is relevant, accurate and up-to-date, TRL Limited cannot accept any liability for any error or omission, or reliance on part or all of the content in another context.

When purchased in hard copy, this publication is printed on paper that is FSC (Forest Stewardship Council) and TCF (Totally Chlorine Free) registered.

Contents amendment record

This report has been amended and issued as follows:

<table>
<thead>
<tr>
<th>Version</th>
<th>Date</th>
<th>Description</th>
<th>Editor</th>
<th>Technical Referee</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>14/09/2012</td>
<td>Final draft issued to client</td>
<td>SMcR</td>
<td>JI</td>
</tr>
</tbody>
</table>
## Contents

Executive Summary .................................................................................................................. 3

1 Introduction ............................................................................................................................. 5

2 Previous work ......................................................................................................................... 6

3 Methodology .......................................................................................................................... 7
   3.1 Reference data .................................................................................................................. 7
      3.1.1 Stage 1: Validation of the driven survey .................................................................... 7
      3.1.2 Stage 2: Driven survey ............................................................................................... 10
      3.1.3 TRAMS Survey Images .......................................................................................... 11
   3.2 Traffic speed data .............................................................................................................. 13

4 Calculation of intermediate parameters ................................................................................. 15
   4.1 Intermediate parameters ................................................................................................. 16

5 HARRIS 1 and HARRIS2 repeatability .................................................................................... 18

6 Comparison against reference data and development of model ........................................... 19
   6.1 Use of reference data ....................................................................................................... 19
   6.2 Individual parameters ..................................................................................................... 20
   6.3 Combinations and model outputs ..................................................................................... 21
      6.3.1 Output parameter – issues to consider ...................................................................... 21
   6.4 Model development ......................................................................................................... 22
   6.5 Discussion of results ........................................................................................................ 23
      6.5.1 A28 and A268 ........................................................................................................... 23
      6.5.2 A249 ......................................................................................................................... 29
      6.5.3 A256 ........................................................................................................................ 32
      6.5.4 A259 ........................................................................................................................ 34
      6.5.5 A299 ........................................................................................................................ 35
      6.5.6 A2070 ....................................................................................................................... 37

7 Summary and recommendations ............................................................................................. 40
   7.1 Recommendations ........................................................................................................... 41

Acknowledgements ................................................................................................................ 42

References ............................................................................................................................... 43
Executive Summary

This report covers the research undertaken during the first phase of a larger project on surface disintegration, managed by Jacobs on behalf of the Highways Agency, and making use of TRL’s technical expertise to develop and validate a method to detect fretting at network level. The second phase of this project, which is not addressed in this report, will use 3-D imaging equipment to capture pavement surface features in greater detail and try to identify changes indicative of the very early signs of deterioration.

The work presented here has been carried out with a view to producing an algorithm and a set of parameters which enable the accurate and reliable reporting of fretting on the Highways Agency network to the best of the ability of the current generation of survey equipment. The input data that the algorithm requires comes from multiple line texture measurements collected across the whole carriageway.

The various fretting parameters produced over the years from Highways Agency TRAffic-speed Condition Survey data are known to have some shortcomings. To overcome these, algorithms better exploiting the potential of multiple line texture data collected across the whole carriageway have now been developed. The new parameters were designed to be surface type independent. Each of these parameters provides some useful information about the condition of the pavement surface in ways which are closely related to the presence or severity of fretting, but none of the parameters, taken in isolation, can be relied upon to give a definitive answer to the question of whether or not a particular length of the network is fretted.

The work described in this report discusses the intermediate parameters, and how they can be combined, in a simple and practical way, to give a final output parameter which can be used by the engineers responsible for planning and performing the maintenance of the Highways Agency network. This particular parameter has been designed, and is suitable, for use at network level, rather than for scheme level investigations, and makes use of some assumptions about the likely characteristics of fretting on the Highways Agency network.

The model makes use of a methodology in which the pseudo-texture characteristics of a short, local length of the pavement are compared with the pseudo-texture characteristics of a much larger surrounding, global length of pavement. The methodology essentially looks for localised lengths where the surface texture appears rougher than the surrounding length.

The method has known weaknesses in a number of situations:

- Long lengths of continuously bad surface condition lead to the global data reflecting the poor condition, and the local data no longer appears to be bad in comparison.
- Short lengths of pavement where a high surface texture material are surrounded by a material with a lower surface texture may lead to the algorithm reporting fretting (e.g. a short Hot Road Asphalt patch within a Thin Surfacing pavement).
- Metalwork within the surveyed area of the lane may also produce localised high pseudo-texture values which may be reported as fretting.

It is not anticipated that situations likely to cause such issues will frequently occur on the Highways Agency network.
Discussions of the agreement between the reference data and the algorithm output are presented, as are some specific in depth investigations on selected sites of interest.

Additionally, evidence is provided of the reproducibility of the intermediate parameters, regardless of which of two different data collection methodologies and systems have been used.

The output model is presented, along with a recommendation that the performance of the model and the intermediate parameters be reviewed following some network wide experience and feedback.
1 Introduction

Surface disintegration, often called fretting, or ravelling, is a defect of concern for those responsible for maintaining the Highways Agency network (Scott, et al., 2008). Factors such as age, traffic and weather cause the binder to harden, allowing the aggregate to be removed (Figure 1), which leads to costly and disruptive maintenance. If untreated the defect can totally remove the wearing course of a pavement and lead to large potholes. It is a commonly held belief that prevention is better than cure, and this is as true in this area as in others (Department for Transport, 2012).

![Figure 1: Example of surface disintegration on hot rolled asphalt.](image)

Algorithms have been developed over a number of years to try to assess the condition of the surface of a length of pavement, looking for surface disintegration. These algorithms have been developed to produce a number of outputs, each of which tells something about the condition of the pavement, but none of which, in isolation, can be relied upon to give a definitive answer to the question of whether or not a particular length of the network is fretted.

The work discussed in this report has been carried out as part of larger project, managed by Jacobs Engineering on behalf of the Highways Agency, and making use of some of the technical expertise of TRL.

This work has been carried out with a view to producing a definitive set of algorithms, parameters and rules to enable the accurate and reliable detection of fretting on the Highways Agency network to the best of the ability of the current generation of survey equipment. The input data which the algorithms exploit comes from multiple line texture measurements obtained across the whole carriageway, and not from the wheel paths only.

The other focus of the project, which is not discussed in this report, will use high resolution 3-D cameras to look at pavements in great detail and try to identify changes which are indicative of the very early signs of deterioration.
2 Previous work

The automated identification of surface disintegration was introduced in the 1st Highways Agency TRAffic-speed Condition Survey (TRACS) contract, with the 'TRACS fretting' parameter. The approach was based on the Dutch 'Stoneway' algorithm (van Ooijen, van den Bol, & Bouman, 2004), which had been modified to be suitable for use on Hot Rolled Asphalt (HRA), which was more prevalent on the UK network than in the Netherlands, where Porous Asphalt was predominant. This approach uses data from a single line texture measurement in the nearside wheel-path of a survey vehicle and only applies on HRA, which means that the nature of the pavement first has to be reliably identified for the method to provide sensible results and this required the development of surface type classification algorithms (McRobbie, Wright, Sanders, Zohrabi, & Scott, 2008). Also any inaccuracy in the classification meant that Stoneway could be applied in inappropriate conditions and hence result in a significant amount of false positive reported.

However, it has been found that the 'Stoneway' parameter does not provide engineers with the information they need to determine the extent of fretting present. This is probably because the measurement is restricted to the nearside wheelpath, and is suitable for use on one surface type only. As a result engineers still rely on manual visual condition surveys. Unfortunately, these are not always performed in a controlled or consistent way, and often include a number of other defects which the inspector must look for and record, such as cracking or fatting up. This can result in inconsistencies in the interpretation and reporting of different severities of the defect. Failure to detect and report the early signs of disintegration can lead to more expensive repairs later or incorrect prioritisation of the wrong sites. It is therefore important to ensure that surface disintegration is properly detected and reported and that maintenance is not being either performed when it is unnecessary, or put off when it would have been necessary.

Work has therefore been undertaken to develop a new, network level, surface-type-independent method for detecting surface disintegration which uses data collected across the full width of the carriageway (McRobbie, Wright, Iaquinta, Scott, & Christie, 2010).

Although these methods showed promise, and have resulted in the development of a number of parameters which appear to correlate with the condition of the pavement surface as reported by engineers, none of the intermediate parameters taken in isolation can be relied on as a definitive answer to the question of 'is it fretted?' for any stretch of road. The development of such a 'synthetic fretting parameter' has been hindered by problems with reference data – previous work in this area has struggled to find a method of recording enough data which was objective, consistent, repeatable and reproducible.
3 Methodology

Overall this project will aim to collect reliable and reproducible reference data in an as objective way as possible, and then compare this against one or more intermediate parameters to produce a final model for producing a single ‘fretting’ parameter.

3.1 Reference data

The CVI (Coarse Visual Inspection) data collection method was proposed by Jacobs as a suitable means of collecting larger volumes of data compared to a walked survey, albeit at a lower level of detail and requiring some form of validation.

To achieve this, a two stage process was carried out:

• Stage 1 - Validation and refinement of the driven survey methodology against a walked survey based on trial sites;
• Stage 2 - Driven survey of approximately 100 lane km of network based on a mixture of surface types and surface condition on successful completion of Stage 1.

3.1.1 Stage 1: Validation of the driven survey

To validate this process an initial walked survey was carried out with TRL and Jacob’s staff together on 2 sites, using a grading system proposed by TRL. This was to ensure a consistency of the results between this study and previous TRL work.

The grading system aimed to provide an assessment of the level of fretting present in the nearside, middle and offside of the lane, for every 5m along the length of the site. The grading system for surface condition is given in Table 1.

<table>
<thead>
<tr>
<th>Defect Grade</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No deterioration</td>
</tr>
<tr>
<td>1</td>
<td>Some visible signs of deterioration</td>
</tr>
<tr>
<td>2</td>
<td>Definite surface disintegration</td>
</tr>
<tr>
<td>3</td>
<td>Serious surface disintegration present</td>
</tr>
</tbody>
</table>

This was followed by a driven survey of the sites using the TRAffic-speed Marking Survey (TRAMS) vehicle which is equipped with high-resolution cameras to additionally collect Forward Facing Images (FFI) with location referencing (chainage, latitude and longitude) and section markers. These are meant to facilitate the later alignment of the images with other data from the Highway Agency Road Research Information System (HARRIS).

The driven survey was carried out between 10mph and 20mph, to assess the optimum speed for the main 100km survey. It was further decided that the survey for each site would best be carried out to grade defects in three separate runs for the nearside, centre lane and offside wheel track. This allowed the survey operatives to concentrate on one section of the lane and therefore increased the accuracy of the reference data collection.
Two trial sites in Kent were selected for this validation process using Jacobs engineers’ local knowledge. These sites exhibited variable grades of surface disintegration; one was selected with a Thin Surface Course System (TSCS) exhibiting extensive and variable degrees of surface disintegration and the other a Hot Rolled Asphalt (HRA) surface which presented fewer and more isolated defects.

Each site selected was approximately 200m in length:

- A274 Sutton Road Langley (Kent CC maintained) - All-purpose carriageway with a Thin Surface Course (10mm aggregate);
- A2070 Bad Munstereifel Way, Ashford (HA maintained) - Dual 2 lane with a HRA Surface Course with PCC (Pre-Coated Chipping).

The location of these sites is shown in Figure 2.

The joint TRL-Jacobs walked survey was carried out on the 12 January 2012 and typical defects present are displayed in Figure 3 to Figure 6.

![Figure 2: Initial test site locations for validation of approach.](image)

The joint TRL-Jacobs walked survey was carried out on the 12 January 2012 and typical defects present are displayed in Figure 3 to Figure 6.

![Figure 3: A2070 Bad Munstereifel Way, Ashford. Level 0 defect on HRA.](image)
Figure 4: A274 Sutton Road, typical Level 2 defect on TSCS.

Figure 5: A2070 Bad Munstereifel Way, Ashford. Level 2 defect on HRA.

Figure 6: A274 Sutton Road, Langley, typical Level 3 defect on TSCS.

3.1.1.1 Agreement between inspectors

The results from the trial sites show the following:
- The overall results for each site collected from the driven surveys matched well with the walked survey. The correlation was better on the TSCS site on the A274 Langley than the HRA on the A2070 Ashford. This may be due to the defects on the TSCS being more extensive and therefore more readily identifiable than on the HRA.

- Driven surveys were able to reasonably assess the percentage of a survey length with the all-important Category 2 defect (i.e., definite surface disintegration which will necessitate planned maintenance in the short term).

- Although each lane strip should be surveyed individually, there was considerable variation in the results. It was therefore deemed best in the assessment of each site to use the overall lane grading where correlation was good.

- The best survey speed was found to be between 15mph and 20mph based on the response of the survey operatives. This derived speed correlates well with the 15mph deemed as optimum from previous HA experience for CVI type surveys.

The methodology derived from the surveying of the trial sites was found to be suitable in terms of repeatability and consistency and was therefore carried through to Stage 2.

### 3.1.2 Stage 2: Driven survey

To provide a good range of reference data, a number of sites, either HA and Local Authority maintained within Kent, were proposed to be surveyed. A selection of sites totalling a length of approximately 90km were selected by Jacobs highway engineers who had detailed knowledge of the network and its condition, representing a combination of different surface types and also condition. These selected sites are listed in Table 2 and also represented on a location plan in Figure 7.

**Table 2**: Reference data sites – details.

<table>
<thead>
<tr>
<th>Site</th>
<th>Description</th>
<th>Site lane length [m]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A28. Godmersham to Chilham</td>
<td>7102</td>
</tr>
<tr>
<td>2</td>
<td>A28. St. Michaels, Tenterden</td>
<td>6490</td>
</tr>
<tr>
<td>3</td>
<td>A228. Colts Hill to Hale Street Bypass</td>
<td>9227</td>
</tr>
<tr>
<td>4</td>
<td>A249. Detling to Stockbury</td>
<td>8985</td>
</tr>
<tr>
<td>5</td>
<td>A256. Betteshanger to Guston</td>
<td>9583</td>
</tr>
<tr>
<td>6</td>
<td>A259. Rhee Wall</td>
<td>5186</td>
</tr>
<tr>
<td>7</td>
<td>A2070. Rhee Wall to Kingsnorth, Ashford</td>
<td>14305</td>
</tr>
<tr>
<td>8</td>
<td>A299. Thanet Way</td>
<td>23621</td>
</tr>
<tr>
<td>9</td>
<td>A28/A268 Sandhurst to Newenden</td>
<td>5281</td>
</tr>
<tr>
<td></td>
<td>Total length</td>
<td>89780</td>
</tr>
</tbody>
</table>
The surveys were carried out during February and March 2012.

### 3.1.3 TRAMS Survey Images

The FFI collected with the TRAMS vehicle were analysed to assess whether the images were suitable as a means of recognising and determining grades of surface disintegration at a scheme level.

The TRAMS vehicle was also used to collect the visual driven data and both sets of data have been fitted to the network referencing system with respect to the node and section identifiers related to either the HA or Kent CC networks. This was meant to compare the algorithm and reference data more accurately, to assess the performance of the method and identify any requirements for refinements.

To assess the suitability of the FFI two sites were arbitrarily selected to review by Jacobs Pavement Engineers’, these were on the A249 and the A256.

From this review the level of surface disintegration between the wheel tracks and the lane centre was readily distinguished by the contrast in hue of the surfacing, i.e. the darker the hue the greater the level of disintegration. This applied to either TSCS or HRA surface courses. Selections of typical FFI images from these sites with assessed grading are given in Figure 8, Figure 9 and Figure 10.
**Figure 8:** A256 Betteshanger to Guston - HRA surface course.

**Figure 9:** A256 Betteshanger to Guston - HRA surface course.
3.2 Traffic speed data

HARRIS1 surveys were carried out on the sites listed in Table 2. Unfortunately issues with the data collection meant that the runs from the A228 had to be excluded from the final analysis.

The traffic speed data was collected using the bar-mounted transverse profile lasers fitted on the front of HARRIS1 (shown in Figure 11).

This data was collected with a longitudinal spacing of 4mm and a transverse spacing of 150mm. There are 25 lasers on the HARRIS1 profile bar, giving 25 measurement lines. The data was processed and filtered to remove long wavelength features (i.e., larger than 100mm). The data from each of the 25 lasers was then split into 100mm subsections and the Root Mean Square Texture (RMST) for each 100mm length was calculated and reported.
This RMST (or ‘pseudo-texture’) dataset can be seen as a series of 25 longitudinal lines of data, with reported values at (approximately) 100mm intervals.

By assigning a colour to each of the RMST values in the data it was possible to produce a visual representation of the surface texture in which features such as road markings, metalwork, surface changes, potholes and fretting could be seen.

An example of an RMST display, showing a surface change from a thin surfacing to HRA (occurring at 307m) is shown in Figure 12. The data can be represented as a series of transverse profiles (vertically on the plot), with the direction of travel being from left to right on the plot. Lighter colours indicate higher RMST values. The data shown is from 282m to 326m on a site, which represents a 44m length. On the figure the data from one of the lasers exhibits an offset, which is clearly seen as a much brighter, straight, horizontal line, indicating that values from this laser are consistently higher than those from the other lasers. Such data was excluded from subsequent analysis and calculations, as was data from the lasers at the extreme outer edges of the surveys.

**Figure 12**: Example of 44m of RMST data displayed graphically as a grey scale image.

Figure 13 shows an example of the FFI taken at the same location, in which the surface change is clearly visible on the pavement.

**Figure 13**: FFI showing same surface change shown in RMST plot on Figure 12.
4 Calculation of intermediate parameters

The basic underlying concept used in the calculation of the intermediate parameters is the comparison of the distribution of RMST values in a small ('Local') area against those from a much larger surrounding ('Global') area. This approach will identify areas where the local texture (from a 10m length of pavement) is different from the surrounding global texture (from a 100m length, around the local area). By further investigating the data and characterising the ways in which the local and global RMST distributions differ it is possible to determine whether the local length is showing signs of surface distress, or whether, for example, it is a patch, or a surface change.

For example we may expect that a length of HRA containing surface disintegration to exhibit a larger number of high RMST values than a length not affected by surface disintegration. Figure 14 shows typical histograms obtained from a short length of HRA containing surface disintegration (blue line), located in a longer length that is generally sound (green line).

![Figure 14](image)

**Figure 14**: Histograms corresponding to a Local length (blue) containing surface disintegration, and a sound Global length (green) of HRA.

The algorithms include ways of identifying significant changes of surface material, and of altering the calculations in the vicinity of these to avoid falsely reporting fretting when the surface material is changed.

There are three known inherent limitations with the method:

- If there is a long length of consistently fretted pavement then the Global data will start to reflect this, and the Local data will not look any different from it and will consequently not be reported as being fretted. It is felt that on the HA network there are very few lengths where there are consistently high levels of fretting over lengths of 100m or longer.

- Short patches of a more highly textured surface in a smoother surface (e.g. 10m of HRA in among a longer length of thin surfacing) can lead to erroneous reports of fretting. It is felt it is increasingly unlikely that repairs on the HA network will be carried out using such materials as most new surfaces laid during maintenance work these days are thin surfacings.
• Metalwork on the road, such as manhole covers or drains often give high RMST values, which can be wrongly interpreted as fretting. It is felt that, while these are common on local roads, they are relatively rare on the HA network and should not cause too many problems, also these features can easily be spotted on the RMST images.

4.1 Intermediate parameters

The following parameters have been selected as being most useful for helping determine whether or not a particular stretch of road is fretted or not:

4.1.1.1 Surface Consistency (SCorr)

SCorr characterises the consistency of the surface texture values within the whole global 100m length. This is calculated by correlating the distribution of the texture values in the first 50m and the second 50m of the dataset.

4.1.1.2 Local Global Correlation (LGCorr)

The distribution of filtered RMST values within the current 10m subsection of pavement is calculated. So is the distribution of RMST values for the current 100m length of data (surrounding the 10m subsection). LGCorr represents the correlation between these two distributions.

4.1.1.3 Local Global Difference (LGDiff)

The 90th percentile values of the local and global RMST distributions are found. LGDiff is the value of the local 90th percentile value minus the global 90th percentile value. Places where the local texture has more high values than the global texture does exhibit a higher 90th percentile value, and this parameter will be positive. Similarly, where the global texture has more high values than the local texture this parameter will be negative. Minor fluctuations about zero are to be expected due to the inherent variability of the data.

4.1.1.4 Nearside/Middle/Offside Correlations (N_MOCorr, M_NOCorr, O_NMCorr)

The local RMST data is split into separate nearside, middle and offside distributions. Each of these distributions is then compared against the other two to look for transverse differences in the distribution of texture values which can indicate the presence of surface disintegration (as for LGCorr).

- N_MOCorr shows the correlation between the local nearside data and the local middle and offside of the data;
- M_NOCorr shows the correlation between the local middle data and the local nearside and offside of the data;
- O_NMCorr shows the correlation between the local offside data and the local nearside and middle of the data.

4.1.1.5 Nearside/Middle/Offside Differences (N_MODiff, M_NODiff, O_NMDiff)

These transverse difference parameters are similar to the longitudinal LGDiff parameter described earlier, but are calculated transversally using the nearside, middle and offside of the local RMST dataset.
• **N_MODiff** shows the difference between the 90th percentile of the local nearside data and the 90th percentile of the local middle and offside of the data;

• **M_NODiff** shows the difference between the 90th percentile of the local middle data and the 90th percentile of the local nearside and offside of the data;

• **O_NMDiff** shows the difference between the 90th percentile of the local offside data and the 90th percentile of the local nearside and middle of the data.

### 4.1.1.6 Proportion of local high RMST values (PLEGM)

**PLEGM**, or the Proportion of Local RMST values Exceeding the Global Median value, is defined as the percentage of RMST values within the Local data which are greater than 1.75 times the Global Median RMST value. PLEGM is similar to LGCorr but considers the individual 100mm RMST values and was defined to identify those which are significantly different from their surroundings. This is a way to quantify the amount of ‘white’ pixels in a RMST plot (like that of Figure 12) which takes into account surface changes.

---

1 PLEGM is intended to provide an indication about the presence (or extent) of fretting, whereas LGCorr should be more related to severity. The transverse parameters are to indicate in which band fretting is occurring most across the carriageway.
5  HARRIS 1 and HARRIS2 repeatability

Although not strictly a goal of this project it was considered important to ensure that the parameters were consistently calculated regardless of the survey vehicle and equipment used to collect the data.

TRL obtained HARRIS1 and HARRIS2 data for part of the A23 and M23, and processed this to calculate the intermediate parameters.

The data shown in Figure 15 shows about 10km of data from the A23 to illustrate how closely the LGCorr parameter derived from HARRIS1 data matches that derived from the HARRIS2 data.

![Figure 15: HARRIS1 and HARRIS2 LGCorr data comparison.](image)

Based on the analysis of the data from sites where we have both HARRIS1 and HARRIS2 surveys we are happy that the two measurement platforms provide compatible data. There are, of course, inherent differences in the measurement width and data point spacing of the two survey platforms which mean that they are unlikely to produce perfectly identical datasets or results, but no major issues have been seen or are anticipated.
6 Comparison against reference data and development of model

6.1 Use of reference data

As discussed in Section 3.1 the reference data consisted of a series of fretting ratings reported every 5m, for each of the nearside, middle and offside of the lane. When comparing this data with the intermediate parameters, and later with the combinations of parameters leading to a final output fretting parameter, it is useful to reduce this to a single parameter, for ease of aggregating over longer lengths and plotting.

However, there are a number of possible ways of producing such a single parameter, including the sum of all fretting reports in a given length, or the count of all non-zero fretting reports. Figure 16 shows a few possible ways of reducing the reference data (from the A249 site) which can be scaled over whatever reporting length is appropriate. The sum of all fretting reports, a weighted sum, the count of all non-zero fretting reports, the maximum reported fretting value and the mean reported value in the reporting length (5m) were considered.

![Figure 16](image)

**Figure 16**: Examples of possible ways of representing reference data on A249.

All the possible ways of displaying the data show similar behaviour (much more fretting in the first half of the site than in the last), but there are differences in how they reflect the relative levels of fretting where the fretting is reported. In trying to decide on a method which would somehow reflect both the severity and the extent of the fretting reported it was decided to use a weighted sum of the data, where the sum of all the fretting reports in the length were multiplied by the maximum reported fretting value in this length.

Although the reference data has been collected with care and specifically for this research it is still important to note that the inherent difficulties in objectively and consistently collecting manual fretting data have meant that we do not expect the outputs of the algorithms to necessarily match it perfectly. We do not believe that the reference data is ‘wrong’, but close inspection of the FFI which accompanies the reference data often lead to an alternative interpretation which differs from the reference data in some way. Again, it is important to stress that we do not believe that this is wrong, but merely indicative of the subjectivity involved in determining whether or not a particular piece of road is fretted. There are many problems regarding the reliability and repeatability of visual inspection results which have been investigated and documented in a number of industries and studies (Jamieson, 1966), (Fox, 1971), (Poulton, 1977),
(Megaw, 1979), (Gallwey & Drury, 1986), (Moore, Phares, Graybeal, Rolander, & Washer, 2001)).

For this reason, although the comparisons of the weighted sum reference data and the algorithm and parameter data will be the source of the primary performance assessment, there will be further investigations and close examination of the RMST and FFI data in selected sites of interest which may supplement or overrule the basic reference data.

### 6.2 Individual parameters

The two intermediate parameters which were felt to be most closely related to the presence or otherwise of fretting on the pavement were LGCorr and PLEG. These have been plotted against the weighted sum of the reference data in Figure 17 (LGCorr) and Figure 18 (PLEGM).

The marks along the horizontal axis of the graph indicate where one road/survey run start and stop. The chainage in these plots refers to the chainage along the final dataset in which all the sites were arranged as if from a continuous dataset.

The data plotted in Figure 17 and Figure 18 reports a value for each parameter every 10m. Examination of the raw parameters in this way, without applying any rules or thresholds shows that there are certainly some areas of good agreement, particularly between LGCorr and the weighted sum reference data.

Although the magnitude of the LGCorr response does not necessarily match the magnitude of the reference data it is clear that the line representing LGCorr has more ‘activity’ in areas where there has been fretting reported in the reference data. This suggests that the parameter and the reference data are highlighting the same general
areas as being fretted or not fretted. In addition to this there are also some notable successes in identifying particular spikes, or isolated areas of fretting, such as at about 3300m, 123900m, 41700m and 48000m.

There are fewer obvious similarities between the magnitude of the PLEGM plot and the reference data (although the two do match each other very closely between 10000m and 150000m). Higher values of the PLEGM parameter tend to correlate well with the locations of areas of fretting (with some false positives).

None of the individual intermediate parameters matched the reference data closely enough to provide an output fretting parameter on its own (as was known from the earlier research). It was therefore decided that ways of combining and merging the intermediate parameters to produce a final output parameter would be investigated.

6.3 Combinations and model outputs

When combining the various parameters available some attention was paid to making sure that, as well as producing results which matched the reference data as closely as possible, the combinations and parameters used also made good logical sense and that they would be likely to respond to the types of surface conditions likely to be reported as fretting on the Highways Agency network.

6.3.1 Output parameter – issues to consider

As well as producing a parameter which best reflects the condition of the pavement there were some other issues to consider regarding the form of the output parameters:

- **Reporting length:** should we aim to produce fretting output parameter(s) every 10m, or 100m?

If a value is reported every 10m then this can potentially identify very localised defects, and can provide a great deal of detail to the engineer, but conversely reporting at 10m intervals is likely to produce noisy data, with lots of spurious spikes, and slight problems with the alignment of the data can make any benefits associated with having fine detail in the data completely pointless. Reporting at 100m will result in the loss of some of the fine detail, and smooth out some of the isolated features, but the data will be easier to interpret. Most other TRACS parameters are provided to the engineer at 100m detail, and this is the length of data which the engineers are used to dealing with when considering and planning maintenance.

- **Reporting format:** should we report a single parameter which merely tries to indicate the presence or absence of fretting, or try to somehow quantify this to reflect those locations where the fretting is more serious? If we are trying to indicate more than simply the presence of fretting should this be done with a single or multiple parameters, and should the output be quantised into different categories of fretting severity?

A single parameter just reporting a ‘yes/no’ answer would be of limited use to the engineers. By providing a parameter which includes some information as to the extent and/or the severity of the fretting this will enable the identification of those parts of the network which have comparatively more fretting than other parts, or where the fretting has become more advanced. It will also be possible to apply thresholds to this parameter to retrospectively produce a presence ‘yes/no’ indicator,
or to quantise the reports into different categories or levels of fretting severity, as is done with other traffic speed parameters.

### 6.4 Model development

It was known that none of the intermediate parameters alone would be satisfactory, but that PLEG and LGCorr were closely related to the presence and severity of the fretting, respectively. It was also known that LGCorr would respond to any differences in the distributions of RMST values in the Local and Global datasets, not just to those which were indicating that the texture was rougher locally. By considering LGDiff along with these others it was possible to rule out those instances where the local texture was smoother than the global texture, and to use LGCorr and PLEG to moderate the behaviour of the other to reduce the instances of false positives which were seen in the data.

After some investigation, it was decided that, for every 10m of data, the value of LGCorr would be reported whenever LGDiff was positive and above a small threshold value to remove the effect of the small fluctuations about zero (currently set to be a value of 0.25), and PLEG was greater than a threshold value, which was set at a value of 2.5%. This was known as ‘Model 8’, and is shown, plotted against the 10m weighted sum of the reference data in Figure 19.

![Figure 19](image-url)

**Figure 19:** Comparison of output from ‘Model 8’ (combining LGCorr, LGDiff and PLEG) with weighted sum of reference data [10m data].

In order to reduce the noise and variability in the data it was decided to amalgamate the data into 100m reporting lengths. Additionally, scaling factors were applied to the algorithm model output to try to get results which were more directly comparable with the reference data.

The best agreement between the reference data and the traffic speed algorithm data was found when using the following set of rules:

- Split the data into 100m reporting lengths;
- For each 10m subsection within the 100m reporting length:
  - If PLEG>2.5 AND LGDiff>0.25 report LGCorr;
  - Find the SUM of these reports in each of the 100m lengths;
  - Multiply these SUM values by a scaling factor.
- Report this scaled SUM of LGCorr values (where LGDiff and PLEG conditions are met) as the output value for the 100m length.
6.5 Discussion of results

Figure 20 presents the model output data (this is shown as a single value every 100m, calculated as the sum of all ‘Model 8’ output values within that 100m length, multiplied by a scaling factor for display) and the reference data (displayed as the sum of all weighted sum values within a 100m length) on a single plot for the final dataset. This shows generally a good agreement, with the same areas usually being picked out by higher values, and a few areas where the local trends and shapes of the lines follow each other well. There are also some areas where the two lines differ – these will be discussed in detail in the following sections which consider each of the surveyed roads individually.

As before, the marks along the horizontal axis of the graph indicate where the different roads/survey runs start and stop.

![Figure 20](image)

**Figure 20**: Plot showing alignment and agreement of the 100m sum of model output and reference data for entire final dataset.

### 6.5.1 A28 and A268

Figure 21 shows the model output against the reference data on the A28/A268 sites. The data from 0m to 7100m is from the A28 Godmersham site, and then from 7100m to 14500m is from the A28 Tenterden site. The next short part of data, from 14500 to 17000m is from the A28 Sandhurst site, and after 17000m to approximately 20000m, the data comes from the A268, also at Sandhurst. These chainages also show the position of the associated data on Figure 20, which shows the whole dataset.

This data is, as in Figure 19, shown at 100m resolution. In general the trends shown in the data are good, with little fretting at the start of the site, some ‘clumps’ of fretting between 7000m and 13000m, then little or no fretting until the A268 data begins just before 17000m along the site.
There is a small disagreement between the reference data and the algorithm at about 3400m, where the model has a higher value than the reference data which is reporting some, but not much, fretting, and at about 14500m to 15300m, where again the model reports more fretting than the reference data. On the other hand, at approximately 6000m to 13000m the model output follows the reference data very closely, particularly in identifying spikes at 6800m, 7600m, 8200m, 10300m and 12500m.

6.5.1.1 Detailed example of site investigation: spike at 3400m

The analysis of the first of these will be discussed in a high level of detail, with less detail on the subsequent investigations once the processes and data have been explained.

Figure 22: Screenshot showing some intermediate parameters in area surrounding 3400m in final dataset.

Figure 22 corresponds to the data in the area of interest. The data shows that the spike in the model output at 3400m is largely caused by a large value at chainage 1480m along Section 1300221/005.
Figure 23 shows a screenshot from ChartCrack (TRL software used to align and process the survey data) with the FFI as recorded by Jacobs during their survey of the site, and the location of the route and data from the GPS data.

**Figure 23:** FFI at approximately 1460m along Section 1300221/005.

Examination of the FFI images from this area did not reveal a great deal of fretting hence the reference data is probably correct. However, what can be seen in the image is a patch of coloured surfacing, marked with ‘SLOW’ and closely followed by a drain cover. A close up of this drain cover is shown in Figure 24, taken from an image recorded about 20m further along the site.

**Figure 24:** Close up FFI of drain cover located approximately 1480m along Section 1300221/005.
Figure 25 shows another ChartCrack screenshot, this time displaying the HARRIS1 RMST measurements, along with the GPS location of the route and the data. In this display the direction of travel is up the page, with the nearside of the data on the left of the display and the offside of the lane on the right. Lighter colours indicate higher RMST values. As before, one of the lasers, approximately 1/3 of the way across from the left of the data, can be seen to show an offset and is consistently lighter than its neighbours. Another laser appears to show consistently lower RMST values in the offside of the data, but this actually corresponds to the road marking (solid, no-overtaking line) visible in the FFI at this location. As discussed previously, data from the extreme outer edges of the survey, and data from lasers with a clear and consistent offset were excluded from the calculations, but are left in these displays for clarity, and to avoid discontinuities in the display.

Figure 25: ChartCrack screenshot showing RMST from approximately 1464m to 1507m along Section 1300221/005.

The dark patch with straight edges, extending across most of the lane, from 1467m to 1471m (in the data for this particular section) is the coloured surfacing. This does not reach all the way to the nearside of the data, just as the patch visible in the FFI does not reach all the way across to the kerb. There is also a bright white patch in the RMST data at 1480m. This clearly corresponds to the location of the drain cover. The high response to this particular feature is the cause of the spike in the model output at this location.

This type of feature (drains in the carriageway) will seldom be encountered on the Highways Agency network, and, although it is one of the known limitations of the system, it is not anticipated that too many false positive reports of fretting will be the result of such situations.

There is another small bright patch visible in the offside of the data at approximately 1495m (within this section). This will have also contributed to the spike. Examination of the FFI in this area (Figure 26) shows that there is a feature of some kind here, although
it is not clear precisely what – possibly some sort of trench reinstatement, which has started to deteriorate around the edges.

Figure 26: Close up of FFI showing feature visible in RMST data at approximately 1495m.

In summary, this spike, at 3400m in final dataset, in the model output data should not be here, or at least should not be so big, as the pavement shows little sign of fretting. However, the presence of the drain in the survey area, along with a few minor features affecting the RMST values, explains why the algorithm output was high in this location: the algorithm has behaved as expected and produced an output consistent with the input measured RMST values. This potential effect of metalwork on the algorithm performance is a known weakness, but the lack of metalwork within the carriageway on the Highways Agency network means it is not as concerning as might appear to be the case.

6.5.1.2 Site investigation: spike at 8200m

Figure 21 showed a spike being reported by both the model output and the reference data at approximately 8200m. This is caused by data from around 1500m along Section 1300034/005.

Figure 27 shows the FFI from the area of interest, and Figure 28 shows a close up of the image. These clearly show an area in the offside of the carriageway where the surface is fretted, including a patch where the surface has worn away completely, exposing the surface underneath.
Figure 27: FFI from approximately 1500m along Section 130034/005.

Figure 28: Close up of FFI from approximately 1500m along Section 130034/005.

Figure 29 shows the ChartCrack screenshot with the RMST data display from the same location. Here it can clearly be seen that there are a lot of light areas, representing high RMST values. The patch where the wearing course has been stripped away can also be seen as a dark patch in the offside (right) of the data at about 1509m (just above halfway up the display). This is highlighted with an ellipse in Figure 28 and Figure 29.
This spike should be here, as the reference data reported fretting in this location, and the FFI support this assessment. Examination of the RMST also shows a higher proportion of high RMST values in this area, which are reflected in the high intermediate parameter values, and ultimately in the model output correctly reporting the presence of an increased level of fretting at this location.

6.5.2 A249

Figure 30 shows the model output against the reference data on the A249 site at 100m resolution.

In general the trends shown in the data are on the correct lines, with more fretting being reported by both the reference and the model data in the first half of the site (from 20100m to 25000m) than in the second. The spike at the end of the data showing an increase in fretting right at the end of the site (29500m) is also reflected in both datasets, although the alignment may be slightly off.

However, the magnitude of the model output fretting does not match the reference data particularly closely with a lot of the shape and trends in the fretting reference data being lost between about 22000m and 25000m.
Figure 30: Plot showing alignment and agreement of the 100m sum of model output and reference data for A249.

Figure 31 shows the FFI from part of this data where both the reference and the model data indicate a high amount of fretting. The fretting is shown more clearly in the close up view given in Figure 32.

Figure 31: FFI from A249, approximately 820m along Section 24200448/010, 21200m along final dataset.
Figure 32: Close up of pavement from FFI in Figure 31.

Figure 33 is a screenshot from ChartCrack of the RMST values from the same location as shown in Figure 31 and Figure 32, in which the areas of particularly bad fretting can be clearly seen. Here however, the fretting has progressed to such an extent that the whole of the top surface of the pavement has been removed. The smoother surface underneath has been exposed, actually leading to patches of low RMST values. Because the rest of the pavement in this location is also quite fretted there are enough high RMST values to make the algorithm respond in the correct manner, and report the lack of correlation between the Local and Global RMST distributions as being indicative of fretting – had the algorithm relied on a single parameter here it is likely that this area of fretting may have been missed.

Figure 33: RMST from A249, approximately 820m along Section 24200448/010, 21200m along final dataset.
Figure 34 displays data taken from approximately 24600m along the final dataset. This shows an area of darker fretting on the image. The RMST data is displayed on the left of Figure 34, and shows a series of localised bright patches along the survey.

Figure 34: RMST and FFI data from approximately 240m along Section 24201370/020 (approximately 24600m along dataset).

Closer examination of the data in this area suggests two things which may account for the lower outputs from the algorithm compared to the reference data:

- Firstly, the reference data seems to report constant values of fretting along relatively long lengths with little or no variation (including a length of almost 1200m in which 94% of all reference data were reporting level 2 fretting). Examination of the FFI (and RMST) data suggests that there is in fact a bit more variability in the condition of the pavement than this, with small areas of better and worse condition being alternated along the site. The reference data perhaps does not reflect this variability, as the lengths involved are quite short and it is perhaps understandable that the overall condition being poor would influence the delay or inertia in the inspector switching from one level to another repeatedly when it is simpler to just continue reporting a constant level.

- Secondly, it may be the case that the FFI are giving a misleading impression of the variable nature of the fretting and that the condition is genuinely and consistently bad over a long length. If this is the case, then it is to be expected that the algorithm performance may degrade here, as the method relies on detecting relatively short areas of poor condition with relatively sound surroundings, as is expected to be encountered on the Highways Agency network. Sites such as this with long lengths (>1km) of constantly poor fretting are more characteristic of local roads, and are not expected to be encountered frequently on the Highways Agency network, and are not what the method has been designed to detect.

6.5.3 A256

Figure 35 shows the model output against the reference data on the A256 site at 100m resolution.

In general the trends shown in the data are not as good as on a lot of the other sites. There is some agreement between the datasets, with features at 31700m, 34500m – 35500m being well picked out, but there are also too many places where the reference
data is reporting fretting at a much higher level than the model output (e.g. 30000m, 37300m, 39000m).

**Figure 35:** Plot showing alignment and agreement of the 100m sum of model output and reference data for A256.

For example, the levels of fretting reported by the algorithm at approximately 32000m and 37000m are not noticeably different, whereas the reference data clearly reports more fretting in the 37000m area. Figure 36 shows the ChartCrack displays of RMST and FFI data from this location. Examination of the data here suggests that there genuinely is a lot of fretting here – Section 11301377/005 is almost 3000m long and only 170m of it is not reported as being fretted at any level.

**Figure 36:** RMST and FFI from approximately 770m along Section 11301377/005 (37200m along dataset).

As mentioned before, this long length of continuous fretting is not really what the system has been designed for, and is a known weakness. If there is a long length of fretting then the Global data begins to reflect the higher RMST values, and the Local, fretted data does not look significantly different from the Global, also fretted, data. This is why the algorithm output appears to indicate less fretting at the 37000m mark.
6.5.4 A259

Figure 37 shows the model output against the reference data on the A259 site at 100m resolution.

In general the trends shown in the data are excellent, with low levels of fretting well reported apart from at a few locations. The slight bump in fretting at about 39750m, the relative absence of fretting until about 41500m, the poor condition of the pavement from about 41500m to 43000m and the lower levels of fretting after this are all successfully reported in the model output data, although the severity of the model reported fretting is perhaps overstated at the start of the data.

Figure 37: Plot showing alignment and agreement of the 100m sum of model output and reference data for A259.

Figure 38 shows the RMST data and FFI from the location of the first of the spikes at the start of the data. The RMST clearly shows a patch of higher RMST values, but closer examination of the FFI in this location has not found any evidence that there is under-reporting of fretting in the reference data. It is unclear whether the reference data or the algorithm output provides the clearest indication of the extent and severity of fretting at this location.
6.5.5 **A299**

Figure 39 shows the model output against the reference data on the A299 site, and as before, this data is shown at 100m resolution.

In general the trends shown in the data are very good, with good agreement in both location and magnitude between the reference and the model output data.

Both the reference and algorithm report fretting at the start, then the improvement in condition between 47000m and 48000m. The increase in deterioration is then shown up to about 49200m, with excellent agreement here between the two datasets. The model output correctly responds in the areas of fretting at approximately 51000m to 55000m, and from about 60000m to 68000m is again a close match for the reference data.

There are a couple of areas (for example with spikes at 55300m and 59100m, and from 68000m until the end) where the model output is higher than the reference data.
Figure 40 shows the FFI from the start of section 5602373/025. This corresponds to the location of the spike at 59100m in the data. There is a clear patch of higher texture visible on the pavement surface in this image, which has not been reported in the reference data at this location.

![Figure 40: FFI showing pavement condition at start of section 5602373/025.](image)

Figure 41 shows the RMST data from this location, which also reveals (as well as the offset in one of the lasers) a clear patch of lighter colours towards the bottom of the data. This corresponds to the higher RMST values which have been measured on the surface shown in Figure 40.
Figure 41: ChartCrack screenshot of RMST at start of section 5602373/025.

It would appear, following a closer investigation of the data that the spike at 59100m should in fact have been reported in the reference data, as the FFI would appear to support the RMST and model output in the conclusion that the surface here is showing signs of fretting.

6.5.6 A2070

Figure 42 shows the model output against the reference data on the A2070 site at 100m resolution.

The model outputs here perhaps show the worst agreement with the reference data of all the sites. There are some areas of agreement in the first half of the site, but the model output in the second half continues to report a level of fretting which is simply not reflected in the reference data. Additionally, there are a number of high spikes in the output data at 78400m, 79600m, 80500m, 81100m and 82400m.
Figure 42: Plot showing alignment and agreement of the 100m sum of model output and reference data for A2070.

Figure 43 shows RMST data and FFI from about 550m along Section 2200A2070/723, the location of the spike in the whole dataset at 78300m.

The reference data shows no spike in the fretting, and investigation of the FFI also finds no reason or evidence of fretting here. The RMST does show some local variability, but nothing that looks like it should lead to a large spike in the fretting output. Closer examination suggests that the bridge deck visible in Figure 43, which has been surfaced with a different material from the surroundings, may be short enough not to trigger the surface change parameter, but is long enough to change the distribution of the Global RMST values. As the algorithm moves through the data on and off of this location the change in Local and Global distributions appears to be enough to produce anomalously large values.

This is a case of a false positive report of fretting where none should be reported. No obvious solutions to this have been found yet.
Figure 44: RMST and FFI showing data from approximately 410m along Section 2200A2070/739 (approximate location of spike at 81100m in dataset).

Figure 44 shows the FFI and RMST data from 410m along Section 2200A2070/739, the location of the spike in the algorithm data visible at 81100m in the data.

The RMST shows localised areas of high values, which explain in terms of the algorithm why the spike in the data has occurred. However, the reference data did not reflect this, and attempts to look more closely at the FFI have been made more difficult by the shadows on the road. These make it hard to see whether there is fretting there or not. This highlights one of the problems with trying to detect surface defects from image data alone – the images are hugely affected by the lighting conditions at the time of the survey, and changes in the lighting (cloud cover, time of day) or the surface (wet, dirty, drying out) can really affect the appearance of the surface and the ease and accuracy of detecting defects.
7 Summary and recommendations

The investigation of the data has led to the development of a model for combining some of the intermediate parameters and reporting a single value which can be interpreted by the engineer as a ‘fretting parameter’. This parameter is based on the different ways of considering and comparing RMST data from a local (10m) area and the surrounding global (100m) area to try to find areas where the local texture is rougher, which is a good indication that fretting may be present.

The method has a number of known weaknesses:

- Long constant lengths of fretting will cause the global area to reflect the fretting, such that the local area will not look any different and will consequently be deemed to be sound.
- Localised patches of a higher texture material in long areas of smoother texture may result in false positive reports of fretting.
- Metalwork in the carriageway being surveyed may also result in locally high RMST values, which may be incorrectly reported as fretting.

In spite of these weaknesses the agreement between some intermediate parameters and the manually collected visual reference data is good – notably for the LGCorr parameter and the reference data.

By combining the intermediate parameters it has been possible to produce a model that reduces the incidence of false positives, and which in general accurately tracks the trends in the reference data. This output model can be calculated every 10m, based on 10m data available from TRACS vehicles.

To avoid problems with noise in the data it is recommended that the 10m data be amalgamated to produce a single value for each 100m. This output parameter could have thresholds applied to it to categorise the data into categories 0 to 4 (for example) reflecting different levels of fretting on pavements.

The best agreement between the reference data and the traffic speed algorithm data was found when using the following set of rules:

- Calculate the intermediate parameters for each 10m of the data.
  - LGCorr
  - LGDiff
  - PLEGM
- Split the data into 100m reporting lengths.
- For each 10m subsection within the 100m reporting length:
  - If PLEGM>2.5 AND LGDiff>0.25 report LGCorr;
- Find the SUM of these reports in each of the 100m lengths.
- Multiply these SUM values by a scaling factor:
  - In this analysis a scaling factor of 15 was used.
- Report this scaled SUM of LGCorr values (where LGDiff and PLEGM conditions are met) as the output value for the 100m length.

The results of this model have been shown to agree in general terms with the reference data, and some of the discrepancies have been established as being due to ambiguities and difficulties in the process of collecting reference data in a consistent, objective and reproducible way. It is believed that adoption of this parameter based model will result
in more consistent fretting data being made available to the engineers responsible for maintaining the Highways Agency network.

However, throughout the development of these parameters and models there have been on-going difficulties in obtaining reliable and consistent reference data. This is not due to a failing on anyone’s part; rather it is just fundamentally a difficult thing to achieve. The model has therefore been developed to the best of our ability using the available data.

7.1 Recommendations

The following recommendations arise as a result of this research:

• The model should be adopted straight away for implementation in TRACS, based on the set of rules and thresholds defined in this document. This will provide engineers with a more objective, more repeatable measurement of fretting than is currently available.

• Following a period of data collection and real world use of the model outputs it would be beneficial to revisit the rules and the way in which the intermediate parameters are combined. This should take into consideration the comments and criticisms (if any) of those for whom the data is intended to tune the thresholds.

• Further analysis is required to make information about the transverse location of the fretting across the carriageway exploitable. It is believed that this is essential in particular in places where fretting is asymmetrical and likely to affect vehicle stability, given that not all of them are fitted with ABS (Antilock Braking System) or ESP (Electronic Stability Program).

• Having encountered on-going difficulties with the collection of reference data it may be beneficial for any future network level testing and validation of the methods proposed to consider a different approach to the way in which the algorithm performance is assessed.

• The work discussed in this report has considered the development and validation of the network level fretting parameters and model. It is however necessary to tackle the development of more scheme specific measurement methods, particularly in terms of the detection of the very early signs of deterioration (which the second phase of this project will investigate).

• It is also believed that a fundamental understanding of the mechanisms which ultimately lead to the development of potholes, but start with the trivial loss of a few stones, is needed so that appropriate actions can be triggered in a cost effective and timely fashion.
Acknowledgements

This work has been carried out within the Technology Development Group of the Infrastructure Division of TRL, supported by staff at Jacobs Engineering UK Ltd, who provided the reference data which was essential for the work. The authors would like to thank all those involved in the collection and processing of the data, and would also like to express their gratitude for the support of Donald Burton and Colin Christie at the Highways Agency.
References


Development and validation of algorithms for the automatic detection of fretting based on multiple line texture data
Research into pavement surface disintegration: Phase 2 – interim report

The current TRACS fretting parameter is known to have some shortcomings. To overcome these a number of intermediate parameters have been developed which are designed to be surface type independent, and which make use of data collected across the whole survey lane. Each of these parameters provides some useful information about the condition of the pavement surface in ways which are closely related to the presence of fretting, but none of the parameters, taken in isolation, can be relied upon to give a definitive answer to the question of whether or not a particular length of the network is fretted.

The work described in this report discusses the intermediate parameters, and how they can be combined, in a simple and practical way, to give a final output parameter which can be used by the engineers responsible for planning and performing the maintenance of the Highways Agency network. The parameter has been designed, and is suitable, for use at a network level, rather than for scheme level investigations, and makes use of some assumptions about the likely characteristics of fretting on the Highways Agency network.

The model makes use of a methodology in which the pseudo-texture characteristics of a short, local length of the pavement are compared with the pseudo-texture characteristics of a much larger surrounding, global length of pavement. The methodology essentially looks for localised lengths where the surface texture appears rougher than the surrounding length. The method has known weaknesses in a number of situations, however, it is not anticipated that situations likely to cause such issues will be frequently encountered on the Highways Agency network.

Discussions of the agreement between the reference data and the algorithm output are presented, as are some specific in depth investigations on selected sites of interest. Additionally, some evidence is provided of the reproducibility of the intermediate parameters, regardless of whether the raw data has been collected using HARRIS1 or HARRIS2. The output model is presented, along with a recommendation that the performance of the model and the intermediate parameters be reviewed following some network wide experience and feedback.

Other titles from this subject area

TRL674 Durability of thin surfacing systems. Part 4: Final report after nine years’ monitoring.
J C Nicholls, I Carswell, C Thomas and B Sexton. 2010

PPR497 Grip Tester trial – October 2009 including SCRM comparison. A Dunford. 2010