

Transport Research Laboratory



**Measuring skid resistance without
contact**

2008-2009 progress report

by A Dunford

PPR393

PUBLISHED PROJECT REPORT



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by A Dunford (TRL)

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Executive summary

This report describes the most recent stage of a programme of experiments being undertaken by TRL for the Transport Research Foundation (TRF) to determine whether detailed imaging of the road surface has potential to be applied to the measurement of skid resistance. The ultimate objective of this work is to develop a method suitable for implementation on a traffic-speed survey vehicle.

Earlier stages of this project showed the possibility of determining skid resistance from images of laboratory samples of aggregate when they are artificially polished. Some success has also been demonstrated when comparing image-derived parameters with skid resistance on a continuous length of road surface. The work described in this report sought to build on that successful comparison by collecting a large number of images on the TRL research track, from a moving vehicle, and comparing parameters derived from them with skid resistance measured by more conventional means.

In addition to use of the algorithms developed in the previous stage of this project, a review of alternative roughness calculation methods that might be applicable to image intensity variation was carried out, and several alternative parameters were implemented in analysis software.

Initially, some agreement between the image-derived parameters and measured skid resistance was observed. However, it was found that parameter values were very sensitive to variations in the level of focus between images. Although a post-processing technique to identify poorly focussed images was trialled, the comparison of image-derived parameters with skid resistance requires much better quality, or consistent, images. Further research into the theoretical basis of assessing skid resistance from a road's surface texture is suggested.

1 Introduction

Routine monitoring of the skid resistance of road surfaces is an important component of ensuring that the road surface is maintained in a safe and serviceable condition. Various different types of equipment have been developed for measuring skid resistance, but all share a common principle of measuring the forces generated when a rubber tyre or slider is forced to slide across a wetted road surface. This presents a number of limitations that affect the safety and efficiency of data collection and the quality of the data obtained. These could potentially be overcome through the development of a contactless method of characterising the skid resistance properties of road surfaces. Such a method could be applied throughout the UK and in the many other countries that conduct skid resistance measurements.

A programme of experiments is being undertaken by TRL for the Transport Research Foundation (TRF) to determine whether detailed imaging of the road surface has potential to be applied to the measurement of skid resistance. The ultimate objective of this work is to develop a method suitable for implementation on a traffic-speed survey vehicle. The work reported in this document is part of the Transport Research Foundation's ongoing research programme.

2 Background and approach

It has been well documented that the skid resistance of a road surface is closely linked to its texture. There are two defined scales of texture that are particularly important for skid resistance: macrotexture (wavelengths between 0.5mm and 50mm), which is typically effected by the size of aggregate particles in the road surface and the spaces between them, and microtexture (wavelengths below 0.5mm), which is typically effected by the texture on the uppermost surfaces of aggregate particles in the road. It has further been shown that it is microtexture that influences skid resistance at low sliding speeds and macrotexture that influences the rate at which skid resistance changes as sliding speeds increase. Although it is already possible to measure macrotexture, without contact with the road surface, from traffic-speed vehicles using distance measuring lasers, current systems are not capable of making the more fine-scale measurements required to characterise microtexture and low speed skid resistance is therefore measured directly using the equipment described in Section 1.

Early stages of this project (Dunford, 2007) showed that it is possible to derive parameters from still images of stone surfaces which correlate well with friction measured on the surfaces. The correlation was very good when the surfaces were aggregate samples manufactured and artificially polished in the laboratory. A more recent stage of work (Dunford, Ruff, & Whiteoak, 2008) attempted to use images of real-road surfaces taken using a line scan camera mounted to a trolley that was pushed by hand. The work was carried out in two steps, firstly using images of cores taken from an experimental surface dressing site and secondly using images taken in-situ at various locations on the road network. A good relationship between image-derived parameters and skid resistance was found for measurements made on the cores, but the comparison did not hold for images of the road surfaces. However, where longer continuous sections of road were imaged, some clear similarities between patterns of changing skid resistance and patterns of changing image-derived parameters were observed.

The stage of the project reported here has therefore concentrated on the comparison of image and skid resistance data collected on longer sections of road surface.

Skid resistance was measured on the large loop of the TRL research track, and a large number of images were collected of the same surfaces – 2.1km in total. The image analysis algorithms used in the previous work were applied to the images and results compared against skid resistance measurements. A novel method of creating a visual interpretation of the image parameter values was created, and various sections of surface were ranked subjectively according to their perceived roughness.

A review of alternative roughness calculation methods that might be applicable to image intensity variation was carried out, and several alternative parameters were implemented in the analysis software.

3 Data capture

3.1 Skid resistance

In the previous work, image analysis results were compared with measurements made with SCRIM (Sideway Force Coefficient Routine Investigation Machine) on the basis that this is the primary device for the measurement of skid resistance on the trunk road network. However, other skid resistance measurement devices are also used (such as the GripTester (GT)), especially on local roads.

The relationship between SCRIM and GT depends on the surface. On the majority of road surfaces, SCRIM and GT measurements can be related using a linear conversion, provided the measurements are made under strictly controlled conditions (specifically the speed of measurement and the amount of water used to wet the surface). In some cases though, it has been shown that the GT will emphasise relative changes in skid resistance where the SCRIM would not (and vice versa). It has been suggested that the GT is more sensitive to changes in microtexture. Therefore it may compare more readily with parameters determined through image analysis.



Figure 3.1 SCRIM with GripTester inset bottom right

The images are not to scale, and the GripTester is towed by a transit van

The TRL research track provides a safe environment to trial image capture on road surfaces due to the absence of traffic. Additionally, the track has several different types of surface with a range of skidding resistance, including concrete and different types of asphalt surfacing. Skid resistance was measured around a complete loop of the track using both SCRIM and GripTester. Both devices record horizontal and vertical forces on the test wheel and report a value of skid resistance which is derived from these forces (horizontal divided by vertical), reporting it as SCRIM coefficient and GripNumber respectively.

Figure 3.2 shows the skid resistance measured on a complete loop of the TRL track using SCRIM and GripTester and Figure 3.3 shows the approximate linear relationship between the two for the range of skid resistances found on the track. The pattern of skid resistance from each device is very similar, although there are some noticeable differences such as the relatively greater increase in GripNumber at 200m compared to the same increase in SCRIM coefficient. Some of the smaller differences may, however, be attributable to noise in the data or slightly differing driving lines between the two devices.

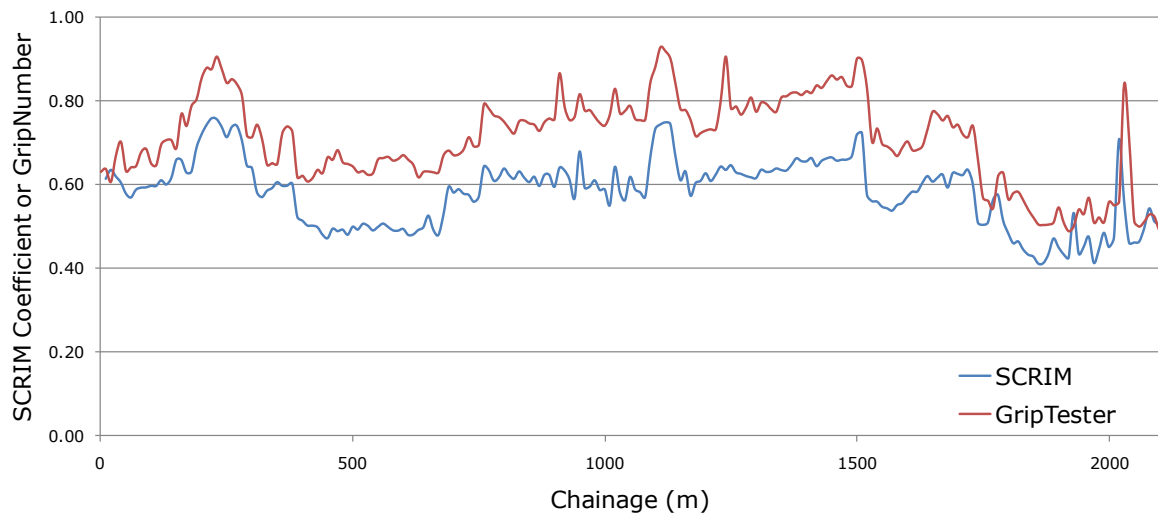


Figure 3.2 SCRIM and GripTester measurements of skid resistance for a complete loop on the TRL track

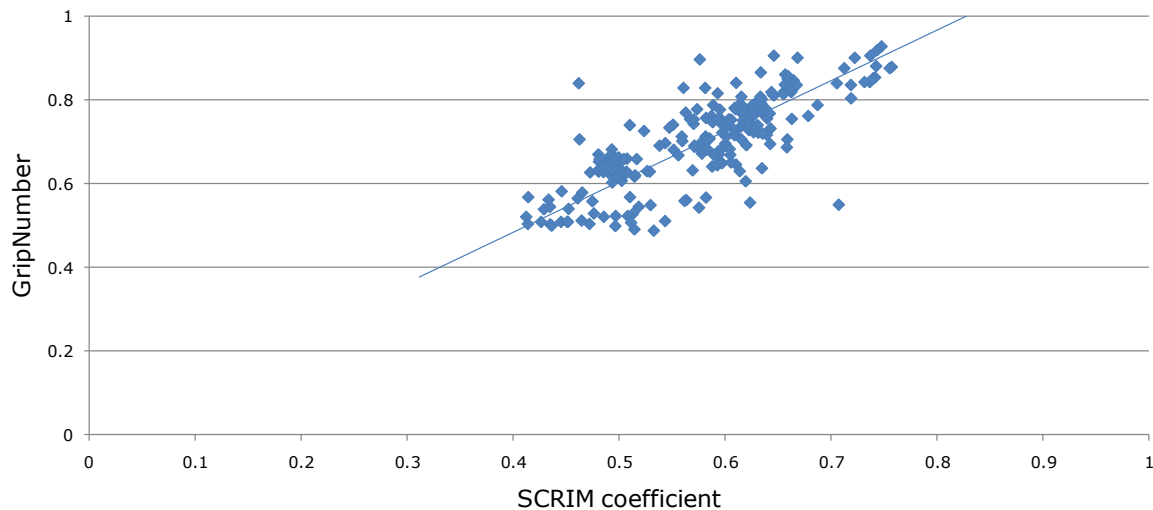


Figure 3.3 GripTester measurements against SCRIM measurements for a complete loop on the TRL track

3.2 Images

The equipment described by Dunford (2007), comprising a linescan camera, lighting, distance measuring system and image acquisition software, was used to capture images of the TRL track. The camera is focussed on a line on the ground and it records 1024 pixels along a line that is approximately 50mm long – this gives an image resolution of approximately 50 μ m per pixel. The distance measuring system triggers the camera to record one such line every 200 μ m, and, for ease of storage, the continuous strip of lines is split into individual, full colour, images that are approximately 50mm wide and 1m long.

For this project, alterations were made to the equipment so that it could be attached to the rear of a survey vehicle, in an attempt to increase the speed and ease of image capture. Each complete lap of the large loop on the TRL track resulted in the collection of approximately 2100 bitmap images in the nearside wheel path of the lane (which is where skid resistance measurements are made).

The image analysis method used in the previous stage (Dunford, Ruff, & Whiteoak, 2008) relied on the assumption that pixel intensity is a good surrogate for texture such that if the surface is smooth, then pixel intensity will not vary greatly, and a parameter can be designed to reflect this, e.g. by yielding a low number. Conversely, a rough surface will have high variation in pixel intensity, and correspondingly high parameter values. The parameter CMT3, which makes calculations of the localised variation in pixel intensity, was developed. A value of CMT3 can be calculated for every pixel within an image, and these pixel values can be averaged to give CMT3 for each image.

When CMT3 values for each image taken around the a complete loop of the track are plotted, as shown in Figure 3.4, the effect of the different surface types (concrete, thin surfacing asphalt and hot rolled asphalt) can be seen. The section centred about 500m is concrete, and it is an expected effect that the image parameter responds differently to this much lighter material.

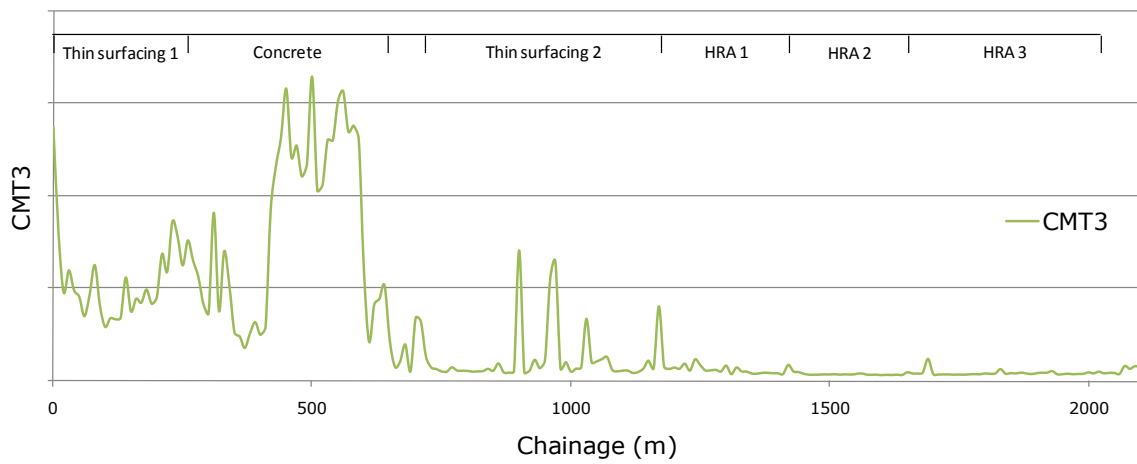


Figure 3.4 CMT3 for a complete loop on the TRL track

The following sections describe the various methods used to analyse the images. In the initial analysis, the first section of track measurements was used to reduce processing time. This enables validation of successful analysis methods using the remainder of the images.

4 Semi-automatic inspection of images

The CMT3 parameter generates a value for every pixel in an image relating to the localised variation in intensity. It is possible to map these values back onto an intensity scale – the higher the value, the darker the pixel for example – to generate a 'CMT3' image.

Figure 4.1 shows an example of an image taken approximately 68m from the start of the track loop – referring to the graph in Figure 3.2, this section of surfacing has SCRIM coefficient of approximately 0.6 and GripNumber of approximately 0.65. Figure 4.2 shows the 'CMT3' image, in which each pixel's intensity relates to the localised variation in intensity of the original image.



Figure 4.1 Image from track surface at 68m



Figure 4.2 'CMT3' image from track surface at 68m

Figure 4.3 shows an example of an image taken approximately 248m from the start of the track loop - referring to the graph in Figure 3.2, this section of surfacing has SCRIM coefficient of approximately 0.75 and GripNumber of approximately 0.9 –and Figure 4.4 shows the equivalent 'CMT3' image.

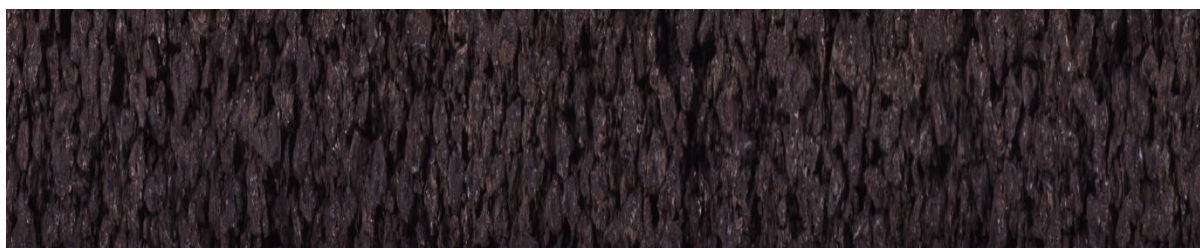


Figure 4.3 Image from track surface at 248m



Figure 4.4 'CMT3' image from track surface at 248m

A number of images from each of two lengths of the surface were converted to 'CMT3' images. Five images at around 70m and five images at around 250m were printed and shown to several people who were asked to rank the images in order on the basis of their opinion of the apparent "roughness" in the CMT3 image.

Table 4.1 shows the order in which each image was ranked by each participant, with each image denoted by the approximate distance from the start of the loop. The colour of each cell in the table shows whether the image was from an area of lower skid resistance (SCRIM coefficient 0.65 to 0.75), in blue, or higher skid resistance (SCRIM coefficient 0.8-1.0), in orange.

Table 4.1 subjective ranking of 'CMT3' images

Participant	Roughest	Image number								Smoothest
		→								
1	83	255	242	247	248	257	57	72	78	68
2	83	255	242	247	248	57	72	257	68	78
3	83	255	242	247	57	248	72	257	68	78
4	83	242	255	247	248	72	257	57	68	78
5	83	255	242	247	248	57	72	257	68	78
6	83	242	255	247	57	248	72	257	68	78
7	83	255	242	247	248	72	257	57	68	78
8	83	242	255	247	72	257	248	57	68	78

It can be seen that, although there is an anomalous result with one of the lower skid resistance images always being ranked as the roughest, in general the images can be allocated to either higher skid resistance or lower skid resistance. It is possible that the 1m length of surface at 83m from the start of the track loop is genuinely more rough without this being shown in the skid resistance measurements.

This subjective analysis method was extended to consider more images. A bespoke software utility, Chartcrack, was used to display the first 260 images. The software allows a user to identify an area of interest within the image simply by pointing and clicking with a mouse – it is normally used for visual analysis of pavement condition. In this case, particularly rough areas of each image were highlighted and the number of highlighted areas were recorded and plotted against distance from the start of the track loop. The higher the number of rough areas on each image, the higher the skid resistance would be expected to be. Figure 4.5 shows a comparison between the GripTester and SCRIM measurements of skid resistance with this subjective visual survey for the first part of the track. All are shown with 1m readings and 10m averages overlaid. It can be seen that there are similarities in the shapes of the three lines, but there is a lot of noise in the visual survey data when it is reported at 1m intervals.

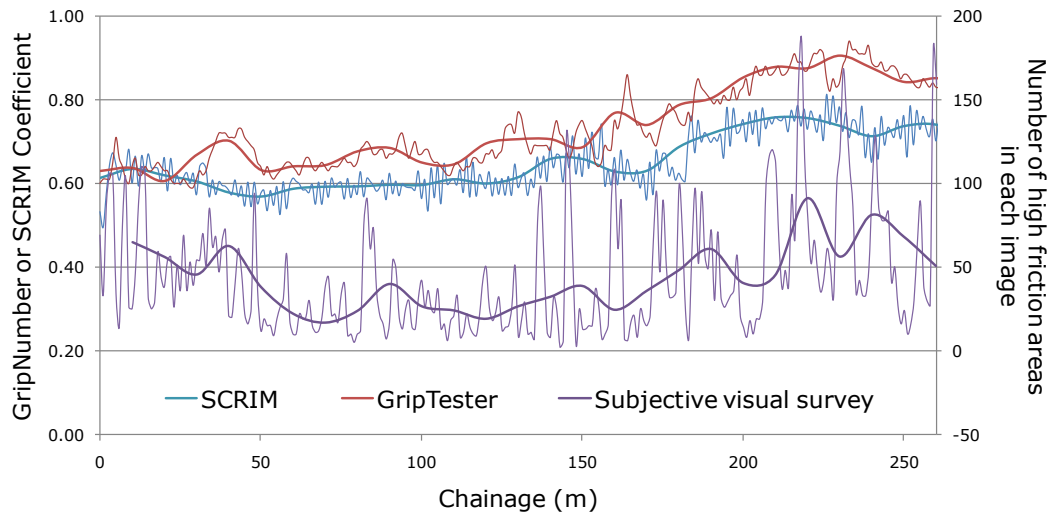


Figure 4.5 SCRIM, GT and subjective visual survey on 'CMT3' images

The automatically calculated CMT3 values, as an average for each image, for the same section of track are shown in Figure 4.6 for comparison.

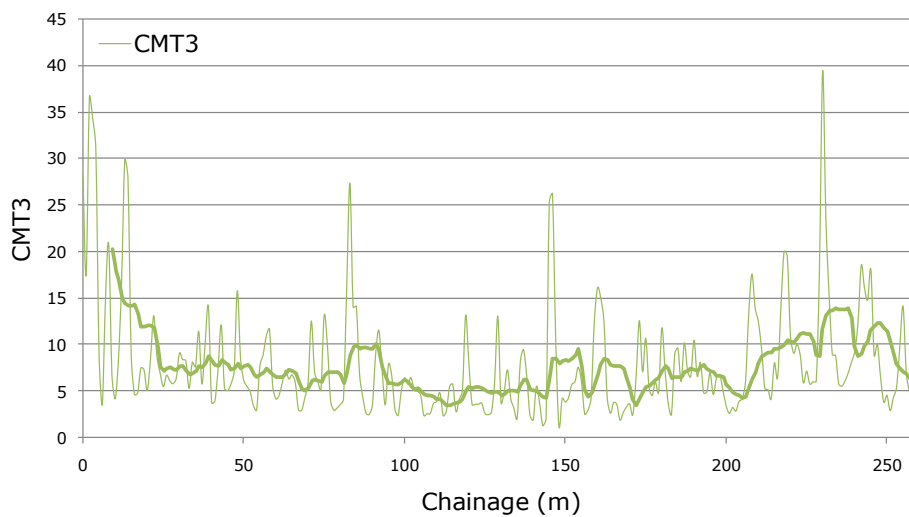


Figure 4.6 CMT3 values for first section of track

5 Fully automatic inspection of images

A number of image processing algorithms were trialled on the images taken on the TRL track in order to give a series of values that could be compared with SCRIM and/or GripTester measurements. The first, called "sharpness", is an adaptation of a parameter that was developed in the previous stage of this project, which was found to achieve similar results to CMT3 but with less noise associated. Two further algorithms were based on measurements of surface roughness that are commonly used for measurement of roughness on machine parts.

5.1 Sharpness

This type of algorithm is based on a simplified method following work by Do (2005) that considered the shape of asperities at the road surface. Unless consecutive pixel values are identical, one pixel will always have either a greater or lesser value than the next. The sharpness angle is the angle calculated between the line joining these two values and the horizontal – by selecting the upper horizontal it is possible to ensure that a positive value is always calculated. This is demonstrated in Figure 5.1. In the case of the images taken of the TRL track, only transverse intensity variation, and the angle between adjacent pixels in the direction, was considered.

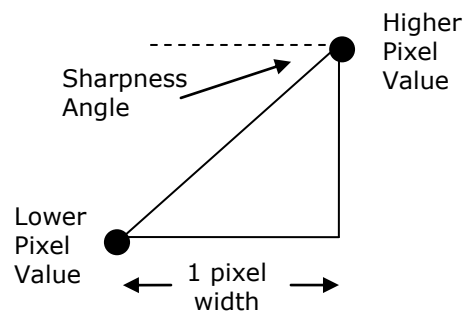


Figure 5.1 The sharpness angle for two adjacent pixels

In an attempt to automatically quantify image roughness (i.e. the microtexture profile variations on the surface) the pixel intensity values were scaled so that their range, instead of being 0-255 (black to white), was equivalent to possible height variations. With previous knowledge of actual height variation, it was decided that local variations in texture were unlikely to exceed 100 μ m and therefore each pixel intensity value was simply divided by 2.5. So, the sharpness angle, in degrees, is calculated from:

$$\theta_{sharpness} = \frac{360}{\pi} \tan^{-1} \left(\frac{Intensity_{Higher} - Intensity_{Lower}}{2.5 \times Pixel\ resolution} \right)$$

where the pixel resolution is assumed to be 50 μ m as discussed in Section 3.2.

5.2 R_a

This is a common roughness measurement parameter used to characterise the surface of metal machine components. It is a measure of the arithmetic mean of the absolute departures of the roughness profile from a mean line within an assessment length (l) - illustrated in Figure 5.2.

$$R_a = \frac{1}{l} \sum_{i=1}^l |y_i|$$

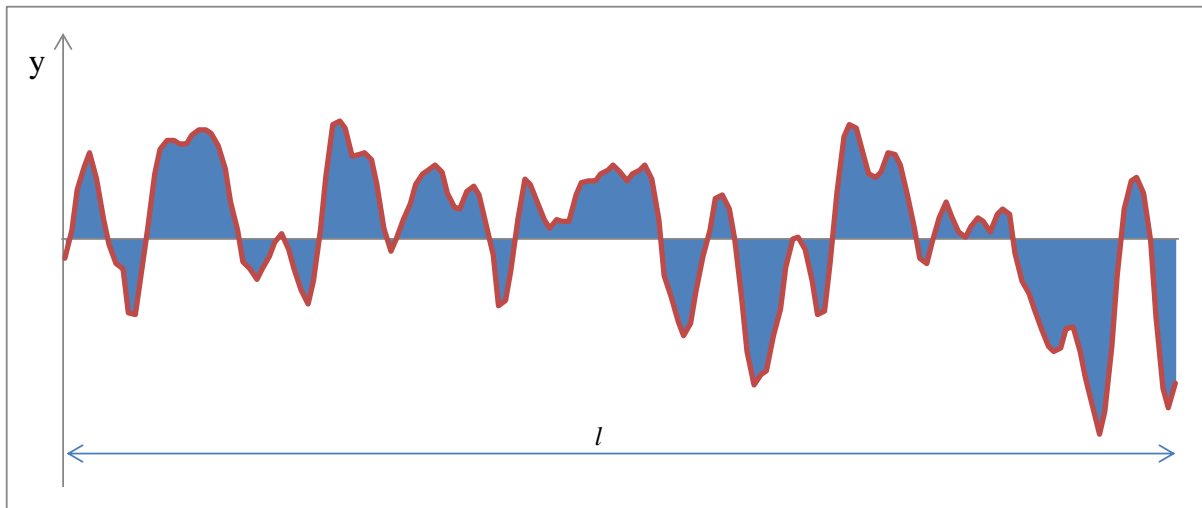


Figure 5.2 Example profile length and method for measuring R_a

In the case of image analysis, several different assessment lengths were investigated (11 pixels and 101 pixels for example). An average value of R_a was calculated over all transverse lines for each image.

5.3 R_z

R_z is also commonly used to measure surface roughness, and it also uses the average of profile deviations. However, instead of the average of all values, the average height difference between the five highest peaks and the five lowest valleys is calculated over a sample length (l). This is illustrated in Figure 5.3.

$$R_z = \frac{1}{5} [(y_{p1} + y_{p2} + y_{p3} + y_{p4} + y_{p5}) - (y_{v1} + y_{v2} + y_{v3} + y_{v4} + y_{v5})]$$

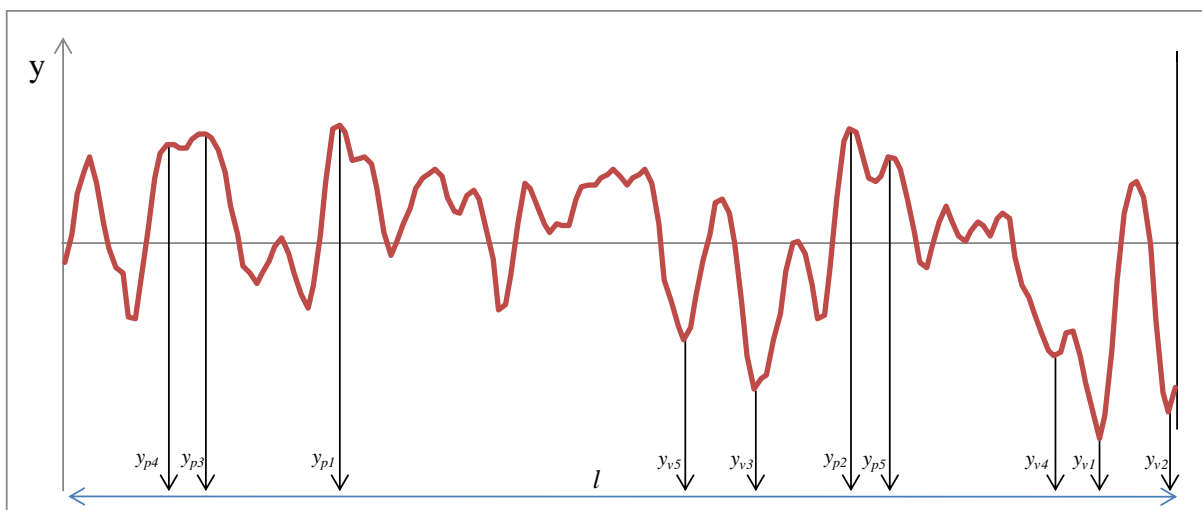


Figure 5.3 Example profile length and method for measuring R_z

For image analysis, various sampling lengths were used, and the results averaged over each image.

5.4 Comparison of image analysis methods

The graphs in Figure 5.4 show values of CMT3, R_a , R_z and Sharpness for the images in the first section of TRL track. The parameter values have been normalised to a

percentage of the highest value within that section, and a 10 point moving average is also shown on each graph.

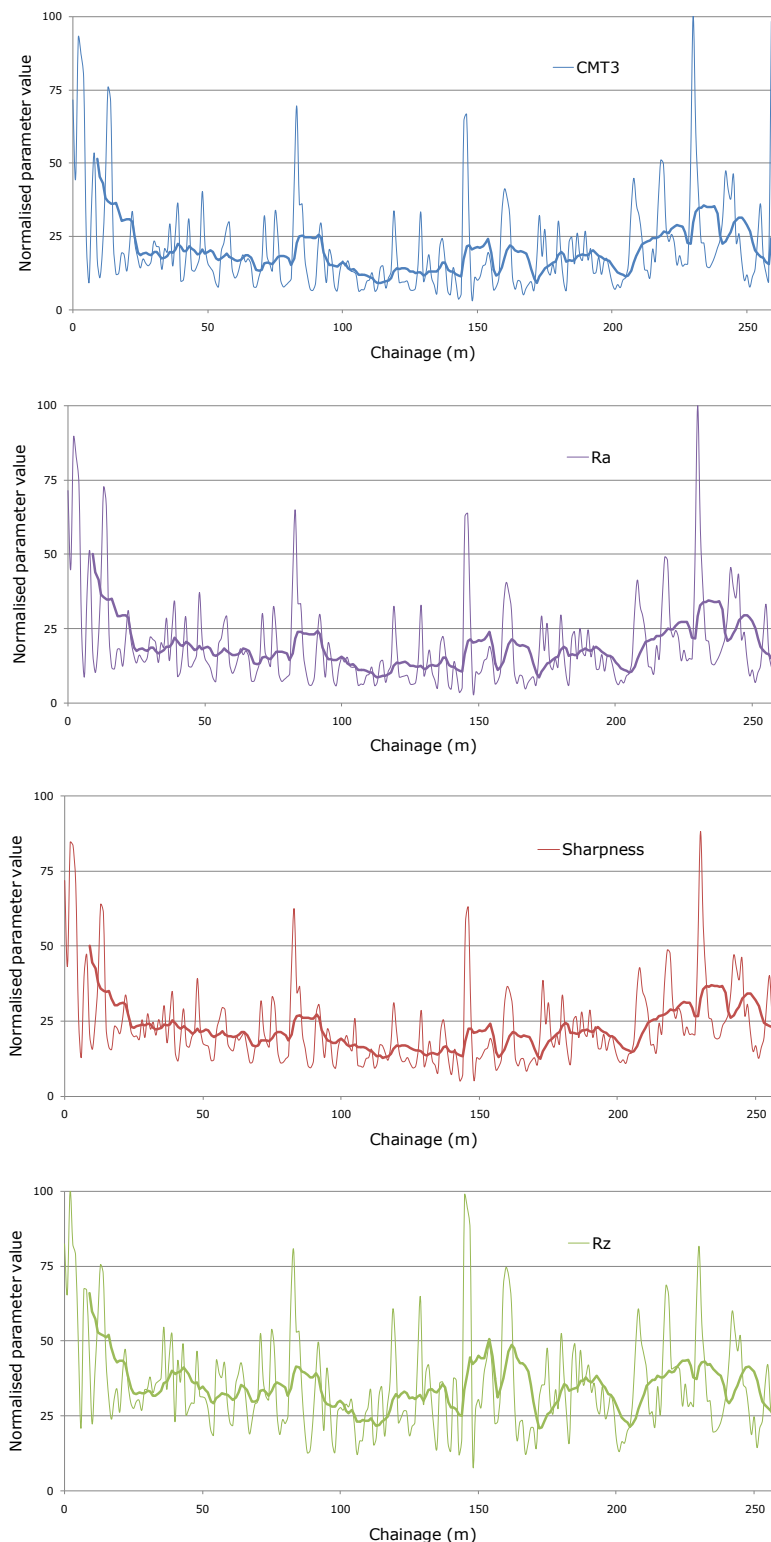


Figure 5.4 Various parameter values for the first section of track

The results are all extremely similar, and only the 'sharpness' parameter shows lower noise about its moving average line compared with CMT3. However, a bigger difference between the various algorithms might be expected and therefore some more detailed investigation into features of the images was carried out as discussed in Section 6.

6 Image quality

It was discovered, when inspecting the images visually to see if common trends could be spotted for the peaks in the data, that several of the images were not sharply focussed.

In order to assess the number of images that were in or out of focus, a subjective survey of all the images from the first section of track was carried out. This was achieved by a person looking at each image from the first section of track on a PC screen and rating its level of focus on a scale of 1 to 10 (1 being blurry and 10 being crisp and clear). The ratings are plotted on the graph in Figure 6.1 and there is some significant similarity with the results of automatic analysis (compare the graphs in Figure 5.4).

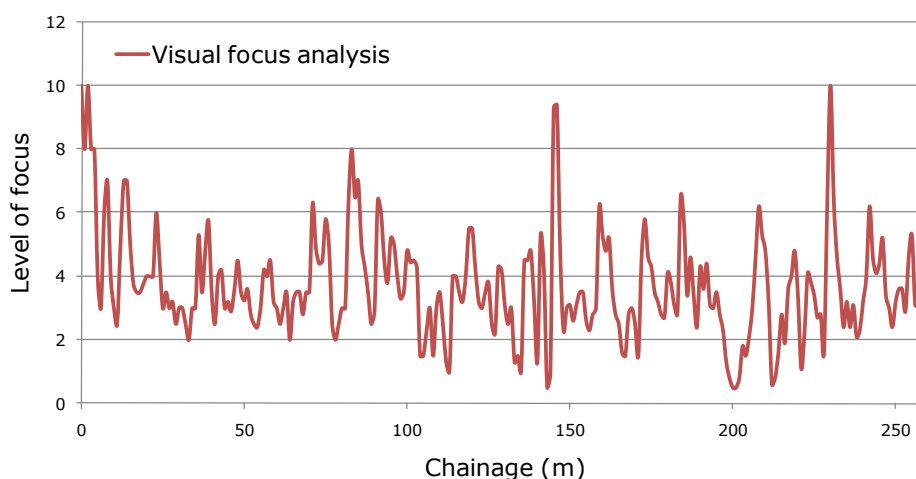


Figure 6.1 Relative focus values for the first section of track
(1 is blurry, 10 is in focus)

It is apparent that the automatic analysis methods investigated are very sensitive to the quality of the images used. Therefore, an automatic measurement of the level of focus would be useful in the long term, so that poor images can be rejected before analysis is undertaken. An initial attempt to do this was made by modifying analysis methods detailed above to try to increase the level of sensitivity to image focus. One method that proved useful was a reduction in the sampling length. The graph in Figure 6.2 shows average values of R_a for the first section of track calculated using only three pixels in the sampling length.

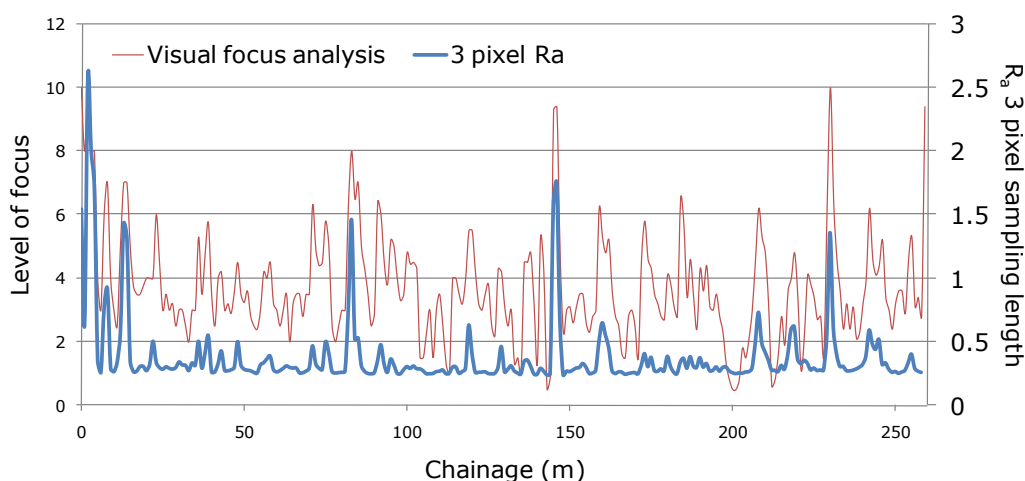


Figure 6.2 3 pixel R_a and subjective focus analysis

In fact, standard autofocus mechanisms (as found in many cameras) basically perform an analysis of the variation in pixel intensity between adjacent pixels. The focus is determined to be best when the sum of differences between adjacent pixels is greatest

(which is achieved by altering the focus of the lens). The R_a calculation using short sampling length effectively achieves the same thing – when the difference between a pixel's intensity and the average intensity of its neighbouring pixels is high then the focus of the image will be best.

In summary, the method used to collect the images was not capable of collecting consistently well-focussed images. The fact that there is a similarity between the level of focus and CMT3 values calculated for each image casts doubt on the robustness of the previous comparisons of CMT3 with measured skid resistance. This limitation highlights a need to improve image collection techniques before attempting to draw conclusions from analysis of images collected from a moving vehicle.

7 Conclusions and next steps

The work carried out for this stage of the project concentrated on collecting a large number of images of road surfaces from a moving vehicle in order to compare parameters derived from the images with the skid resistance of the surface over longer continuous lengths. The parameter developed from the previous stage of work, CMT3, was calculated from images of the surfaces on the TRL track, and a subjective comparison with skid resistance showed some agreement. Although skid resistance was measured with both SCRIM and GripTester, and some subtle differences between the values reported between these devices were apparent, the agreement with CMT3 was fairly imprecise and a better correlation with one or the other cannot be suggested.

In attempts to improve the observed similarity with skid resistance, further image analysis algorithms, based on research literature, or on standardised roughness measurements used in other fields, were implemented. Although there was some suggestion that a reduced amount of noise might be achieved while still retaining the same pattern, very little difference between the various algorithms could be found. Further inspection of the images revealed that the standard of focus achieved varied considerably from image to image. The parameters generated by the image analysis algorithms were found to be very sensitive to this fluctuating level of focus and the need for consistently good quality images has been highlighted.

It was shown that it is possible to automatically post-process the images to identify those which are poorly focussed. However, the images collected on the track were found to be too poorly focussed and too variable to allow a rigorous comparison with skid resistance. In order to develop a traffic speed system it will therefore be necessary to develop high quality image collection equipment that is able to maintain image focus. This will require considerable investment in equipment development. It will also be necessary to develop robust data processing algorithms to quantify the microtexture within the images.

To provide a firm basis for the development of the processing methods, it is suggested that research into the fundamental principle of comparing microtexture with skid resistance be continued. This will enable a robust method comparing roughness and skid resistance to be developed that might later be adapted to work with images (and intensity variation), in anticipation of appropriate technology for image capture becoming available.

Acknowledgements

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References

Brittain, S., & Dunford, A. (2007). *Development and optimisation of a prototype microtexture capture system*. Crowthorne: TRL.

Dunford, A. (2007). *Measuring skid resistance without contact; 2006-2007*. Crowthorne: TRL.

Dunford, A., Ruff, A., & Whiteoak, R. (2008). *Measuring skid resistance without contact - 2007-2008 progress report*. Crowthorne: TRL.

Minh-Tan Do (2005). *Relationship between microtexture and skid resistance (255 pp117-136)*. Bullitin Des Laboratoires des Ponts et Chaussees: LCPC.