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Characterising Texture & Chip Distribution in Hot Rolled Asphalt using 3D Modelling Techniques

RE-PAV-00003
February 2023

Prepared by PMS Management Services Ltd

RE Research

Technical

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TII Publications

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Contents

Contents Table

Executive Summary

Currently, Hot Rolled Asphalt (HRA) surfacings make up over 40% of the total pavement surface area on the Irish national road network. HRA is a dense, gap-graded bituminous mixture with a layer of cold coated chippings applied to the surface mat and then rolled. HRA is a positively textured surface, i.e., the surface macrotexture is formed by the peaks and ridges of the coated chippings projecting above the surface level of the mastic. Good workmanship is required on site to ensure the required embedment of the chippings to achieve a positive texture. It is also important to achieve an appropriate and consistent distribution of chippings both longitudinally and transversely along the mat.

These properties are traditionally assessed using the volumetric patch test and a visual inspection in accordance with CC-SPW-00900. A new assessment methodology based on Close Range Photogrammetry (CRP) was developed to objectively differentiate between positive and non-positive surface textures. Following further research, the CRP methodology was extended to use data collected with the Laser Crack Measurement System (LCMS). LCMS technology provides continuous and full-width coverage of the pavement surface and can be operated at traffic speeds as described in AM-PAV-06050.

The full-width coverage provided by LCMS enabled research into the evaluation of chip distribution on HRA surfaces. A pilot study covering 7 HRA sites was carried out. The data from these 7 sites was analysed to develop a proof of concept for the procedure, assessing the longitudinal, transversal and overall chip distribution on each site, with the aim of identifying a machine-based test that could evaluate the chip distribution more objectively than the current visual assessment methodology. An extended trial covering 15 additional HRA sites on the Irish national road network, was carried out to evaluate the practicality of employing the methodology at the project level.

This document will summarise the research leading to the development of the original CRP methodology and its extension to LCMS. The document will also present the research into the use of LCMS data to assess chip distribution, including the results of the 7 site pilot study and the 15 site extended study. The results of the test indicated a strong agreement between the independent visual assessment and the machine-based assessment of the HRA surfaces examined in the study. It was concluded that the methodology developed in the study presented a sound objective alternative to visual assessment for the characterisation of texture depth in terms of both chip embedment and chip distribution.

1. Introduction

According to a European study (European Asphalt Pavement Association, 2007), a well designed and properly constructed HRA may offer between 17 and 25 years of service life on heavily trafficked European roads. Surface texture in surface courses takes two forms:

1. 'positive' texture: a cluster of angular peaks or series of ridges above a datum level, typical of chip sealing, hot rolled asphalt with chips, slurry, and micro surfacings and brushed concrete, and
2. 'negative' texture: a network of voids or depressions below the general level, typical of thin surface course systems and porous asphalt. This 'negative' texture should not be a feature of HRA surfacing.

A well laid HRA surface has an appropriate and consistent level of positively textured chips. However, detailed visual inspections of relatively new HRA schemes constructed in Ireland indicated that the coated chippings were in many cases, clustered together forming voids below surface level, leading to inconsistent and/or insufficient chip distribution, and a 'non-positive' texture. The term "non-positive" is used here to distinguish it from the designed 'negative' texture provided by thin surface course materials.

Macrotexture acceptance criteria for HRA in Ireland was previously based on texture depth only. The texture depth was measured by the volumetric patch test using glass beads in accordance with EN 13036-1 (EN 13036-1, 2010) as set out in CC-SPW-00900. When the HRA schemes referred to above were tested using the volumetric patch method, it was possible to achieve the specified texture depth even though the pavement surface material had a non-positive texture and/or an inconsistent distribution of chippings across the mat. In the absence of objective tests to assess the nature of the macrotexture (positive/non-positive) and the consistency of the chip distribution, there was no contractual basis for refusing acceptance of these surfaces.

In order to address these problems, TII developed additional methods for assessing the presence of positive macrotexture in HRA using both visual assessment and 3D modelling techniques.

The method for visual assessment is described in TII Publications CC-SPW-00900, Specification for Road Works Series 900 - Road Pavements - Bituminous Materials and CC-GSW-00900, Notes for Guidance on the Specification for Road Works Series NG 900 (TII, 2017, 2020). The visual assessment examines four characteristics of the pavement surface texture, and scores them on an integer scale, typically ranging from 1 to 4. The four parameters examined are:

- Longitudinal Chip Distribution Consistency – 1 (Poor) to 4 (Very Good)
- Transverse Chip Distribution Consistency – 1 (Poor) to 4 (Very Good)
- Rate of Spread – 0 (Under/Overchipped) or 4 (Sufficient)
- Embedment – 0 (Mainly Non-Positive) to 4 (Positive)

The scores are summed to produce a total score. A total score of 11 or higher is required for visual acceptance of the HRA. Scores of less than 11 trigger a further assessment.

In 2017, TII commissioned a study to identify a method of objectively differentiating between positive and non-positive texture on new HRA surfaces using static close range photogrammetry (CRP). This is based on the methodology developed at Ulster University by Millar (2013) and McQuaid (2015), whereby a 3D model is created from a collection of 2D images. The results of this study were published in 2018 (McGowan et al., 2018a) and incorporated into TII Publications CC-SPW-00900, Specification for Road Works Series 900 (TII, 2017a) and CC-GSW-00900, Notes for Guidance on the Specification for Road Works Series NG 900 (TII, 2020).

In 2018 this research was extended to include data from driven surveys, with data collected using the Laser Crack Measurement System (LCMS) (McGowan et al., 2018b). The LCMS uses scanning lasers to create a 3D model of the pavement surface as described in AM-PAV-06050 Pavement Assessment, Repair and Renewal Principles (TII, 2020).

In 2019, TII commissioned a pilot study of 7 HRA sites to assess whether this data could be used to characterise the surface macrotexture as positive or non-positive and to evaluate the consistency of the chip distribution on these sites. The results indicated good agreement between machine parameters and visual assessment in characterising the texture and consistency of chip distribution. Preliminary thresholds for differentiating between consistent/inconsistent chip distribution were also produced.

In 2021, 15 new sites of recently laid HRA were assessed, both visually and with LCMS for chip distribution. The sites were spread over a large geographical area, covering a range of suppliers, contractors, and chip sources. Sites on both National Primary and National Secondary routes were examined. The sites ranged in length from 800 metres to 7200 metres, averaging 2900 metres. All sites were open to traffic at the time of surveying.

This document summarises the research carried out in the original 2017 and the 2018 studies, and presents the results of a further extension to the research between 2019 and 2021, focusing on the objective assessment of chip distribution in recently laid HRA surfaces.

2. 3D Modelling Techniques

2.1 Close Range Photogrammetry

The CRP technique developed at Ulster University is called the Ulster University Photogrammetric Method of Highway Surface Recovery and 3D Modelling or UUTex3D (Millar & Woodward, 2017). The technique uses a bundle of 12 images to generate the 3D model. While technically, three images are sufficient to create a 3D model, acquiring 12 images offers redundancy enabling poor quality images to be rejected from the study while still enabling a 3D model to be extracted.

CRP is typically carried out on a rectangular patch of approximately 300 mm x 300 mm. This allows a circular area of 280 mm diameter to be extracted for analysis in accordance with TII standards. The area of interest is enclosed by a set of scale rules or other calibrated measuring device (Figure 2.1). The scale rules are captured in each image so that they can later be used to scale the model and enable measurements to be made. A calibrated 3D model is created from these images using 3DF Zephyr Pro, a software package designed to automatically create 3D models from photos. The software creates a dense point cloud representation of the pavement surface, which is used in the subsequent analysis.

Figure 2.1 Area of Interest for CRP enclosed by Calibrated 300 x 300 mm Frame.

Data collection equipment for CRP is relatively low cost, and data collection is easy to carry out. However, it is a static test requiring lane closures and traffic management and causes significant disruption to site operations or user traffic. It is also a point sampling methodology with actual measurements being taken on a very small percentage of the pavement surface. This can be problematic for non-homogenous surfaces.

2.2 Laser Crack Measurement System (LCMS)

LCMS comprises two scanning lasers capable of operating at 5600 Hz. The lasers have a lateral resolution of 1 mm over a 4-metre-wide field of view and a vertical resolution of 0.25 mm. The longitudinal resolution is user definable but is limited by survey speed. A 1 mm longitudinal resolution was used in this study, allowing a maximum survey speed of 25 km/h.

The output from LCMS includes greyscale images based on reflected laser intensity, laser range values, and a combined intensity/range “3D” image. A 3D point cloud of the pavement surface can also be extracted directly from the survey data, requiring no post-mission model recreation or calibration.

LCMS equipment is significantly more expensive than CRP. Data collection also requires more expertise. However, LCMS offers 100 % coverage of the test site and can be carried out with minimal disruption to traffic. Examples of LCMS from a positively texture surface are shown in Figure 2.2.

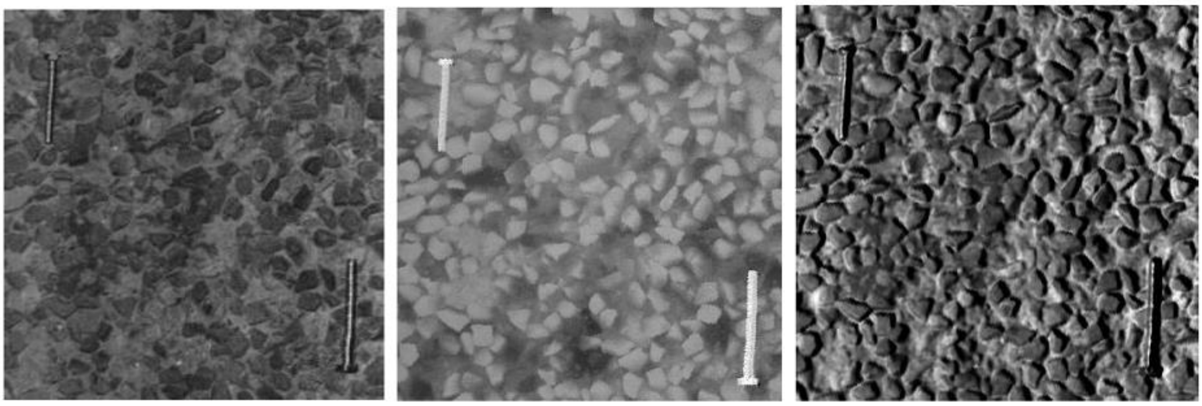

Figure 2.2 LCMS Intensity, Range and 3D Images (left to right)

3. Positive vs Non-Positive Texture

The models used in the initial development of the method were recovered using CRP, with the resulting analytical methods subsequently applied to LCMS data. The CRP and LCMS datasets were captured on the same day for all test sites. The 280mm diameter CRP and LCMS models were extracted from identical points (as close as was practicably possible) on each site for every test location. Recovery of the CRP models was carried out using the UUtex3D procedure to produce an appropriate analysis surface. The LCMS models were extracted directly from the LCMS laser elevation data.

The Islands module, available from the surface Structural Analysis group in MountainsMap, is used to quantify the volume of islands, i.e., of distinct areas of material above a given height in a surface (Digital Surf, 2016). Effectively a virtual horizontal slice is taken through a textured surface at a user defined threshold. The islands are the portions of the model which project above this virtual slice. This is analogous to discrete stone chips protruding above the surface of the mastic in a positive-textured HRA. Islands Analysis was applied to the 3D models recovered from both the CRP and LCMS data collection methodologies. The application is described below.

The application of the islands analysis in TII specifications (TII, 2017b) inserts a horizontal slice at 1.5 mm below the highest point in each model. The number of islands projecting above this slice and the area of each island is calculated. A new parameter, Count50, was introduced based on a combination of the number of islands and the individual island areas. For a given test location, Count50 for that location is the minimum number of islands (N) such that

$$\sum_{i=1}^{N} \frac{Area(i)}{Total\ Island\ Area} \times 100 \geq 50\%$$

Where Area(1) = area of largest Island, Area(2) = area of second largest island…area(N) = area of Nth largest island, i.e. Count50 is the minimum number of islands required to make up at least 50% of the total island area for a given test location.

Examples of CRP based Islands analyses are shown in Figure 3.1 for a non-positive (left) and a positive (right) location using a 1.5 mm threshold. The equivalent images for LCMS are shown in Figure 3.2.

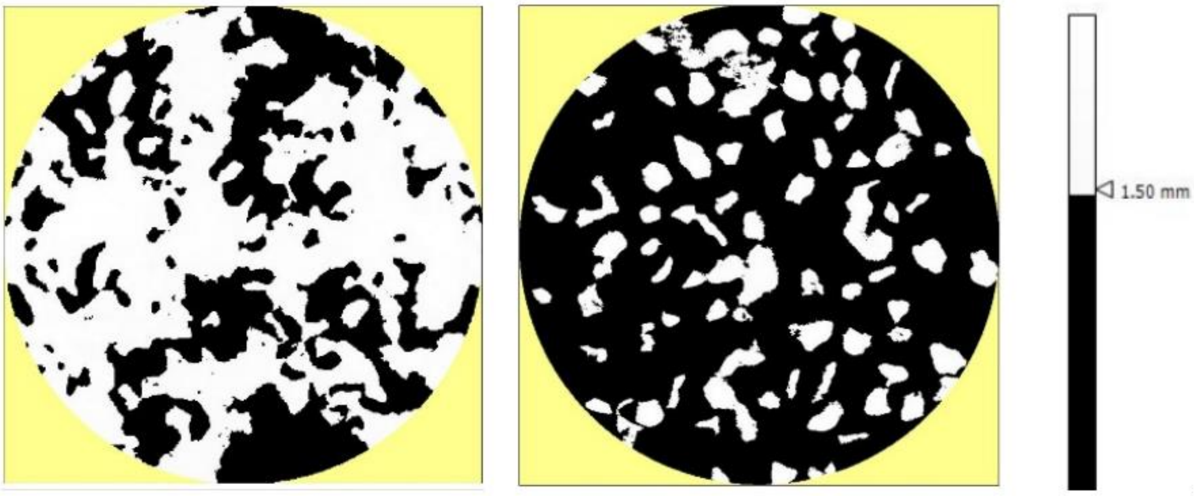

Figure 3.1 CRP Islands

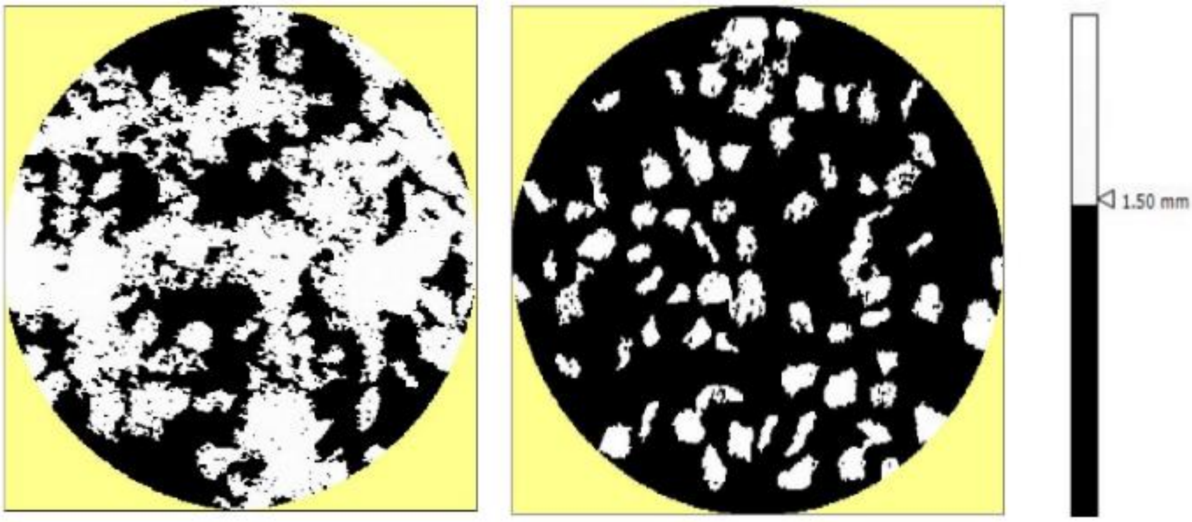

Figure 3.2 LCMS Islands

Both the CRP and LCMS islands applications showed that the methodology can reliably differentiate between positive and non-positive macrotexture on recently laid HRA surfaces using the Count50 parameter. Low Count50 values tend to indicate the presence of one or two very large islands, typically mastic at the surface level or an amalgam of chips and mastic, which account for a very large proportion of the total island area. Higher Count50 values are driven by large numbers of discrete chip-like islands with few, or no larger areas of mastic identified, more typical of a positively textured pavement surface. A threshold Count50 value of 4 is used in TII standards for models recovered using CRP i.e., Count50 > 4 = positive texture. The research into the application of the methodology to models recovered from LCMS data indicated that a slightly higher threshold value (5-6) may be more appropriate. However, there is still a very clear distinction between positive and non-positive locations (McGowan et al., 2018b).

4. Consistency of Chip Distribution

4.1 Chip Distribution – Pilot Study

The original 6 sites used in the development of the CRP Positive/Non-Positive texture characterisation were further analysed to develop a methodology to assess the consistency of chip distribution. A seventh HRA site with positive texture and good chip distribution (assessed visually) was also added to the study. The small sampling regime (10 points over a 50-metre length of pavement) used in the CRP data collection meant the CRP dataset was of limited utility in the assessment of chip distribution over a large area. The 100% coverage provided by LCMS allowed the extraction of many more samples, providing a more suitable dataset for the research.

For each of the 7 sites, 2 no. 60-metre lengths were selected for evaluation of chip distribution, one at each end of each site. An increased sampling regime (compared to standard CRP) was applied to each section as follows:

Each section was sampled at 8 locations laterally across the width of the pavement, at 10-metre stations along the length of the section. The lateral locations were +/- 300 mm, +/- 800 mm, +/- 1200 mm and +/- 1500 mm offset from the centreline of the LCMS. It is assumed that the centreline of the LCMS corresponds with the centreline of the driving lane, with +/- 800 mm being located in the left and right wheel paths. This layout provided 48 individual samples for analysis, as shown in Figure 4.1 below.

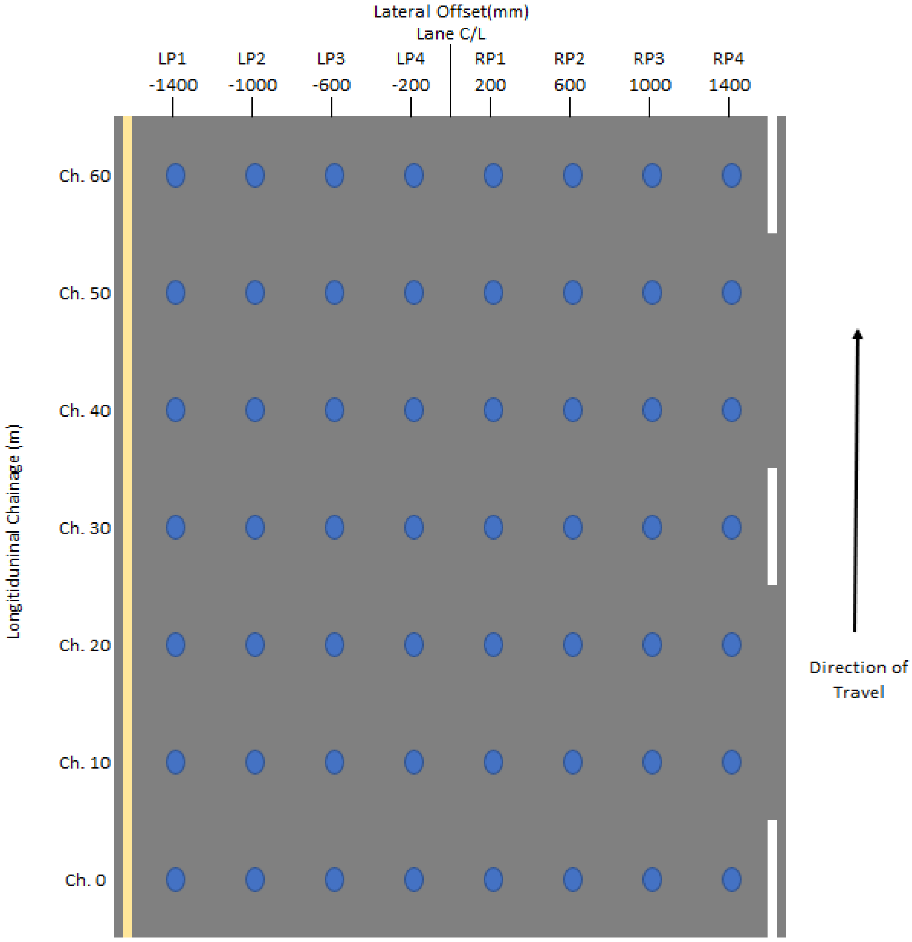

Figure 4.1 Chip Distribution Sampling Layout – Pilot Study

For each sample, the island analysis was carried out using a standard 280 mm diameter model. The islands analysis was carried out in a similar way to that used in standard CRP, with the following important differences:

- A variable slice depth was used rather than a single slice depth of 1.5 mm throughout. This change was implemented to recognise that chips may be well distributed but not sufficiently proud of the surface to be considered positive, e.g., due to over-embedment, wear, etc. A sample-specific slice depth was determined for each sample based on the ISO25178 texture characteristics. A slice depth equal to the root mean squared of the model elevations (Sq) was used. This provides a consistent method of selecting the slice depth and maximises the number of discrete chip-like islands in each sample.
- In determining whether a pavement surface is positive or non-positive, all islands with a surface area of less than 50 square mm are removed from the analysis as it is felt that these are too small to represent discrete chips. All other islands, regardless of size, are included in the Count50 calculation. In establishing the consistency of chip distribution, it is considered that excessively large islands are more likely to be mastic at the surface or an agglomeration of chips in an over-chipped area. In either case, these large islands do not function as discrete chips and are also removed from the analysis. An area of 1000 square mm was used as the upper threshold.
- The chip distribution calculations are based solely on the absolute number of islands present, not the number of islands required to make up 50% of the islands area used in the Count50 parameter

The chip count was compared laterally at each 10-metre location and longitudinally along each offset from the lane centreline (-1500 mm to + 1500 mm) to establish the consistency of chip distribution in each direction over the entire pavement mat. The consistency is evaluated by calculating the Coefficient of Variation (CV = Standard Deviation / Mean) for each longitudinal and transverse band and for the mat as a whole. CV is a standard metric used in various engineering applications to evaluate consistency.

4.1.1 LCMS Data Extraction and Analysis Methodology

Using the variations detailed above, the following analysis methodology was used in determining the chip distribution from LCMS:

1. Two 60-metre long areas are selected on each site, one near the site start and the other near the site end.
2. At 10-metre longitudinal stations along each area, 8 no. 140 mm radius patches are extracted. The patches are spread across the width of the lane, 4 from the left LCMS laser (LP1 to LP4) and 4 from the right laser (RP1 to RP4). Where non-pavement materials occur inside a patch, e.g., pavement markings, manhole covers, etc., that patch is either moved slightly or excluded. Figure 4.1 shows a schematic of the chip distribution sampling layout.
3. For each area, this gives a 7 x 8 grid of patches or:
   a) 8 longitudinal bands with 7 patches per band
   b) 7 transverse strips with 8 patches per strip
4. For each patch, the root mean square (RMS) of the laser elevations is calculated (Sq ISO 21758).
5. An Islands analysis on each patch is performed using a slice threshold = Sq.

6. Islands with an area less than 50 square mm or greater than 1000 square mm are removed on the assumption that these are either too small or too large to represent discrete chips.
7. The total remaining island count for each circular patch is calculated.
8. For each area, three measures of chip distribution consistency are calculated based on the Island count. These are:
   a) The coefficient of variance (CV) of the Island count for each longitudinal band
   b) The CV for each transverse strip
   c) The overall CV for each area

4.1.2 Chip Distribution Results – Pilot Study

Figures 4.2 and 4.3 below summarise the LCMS chip distribution assessment results for each Site (Fig. 4.2) and each Site-Area (Fig. 4.3).

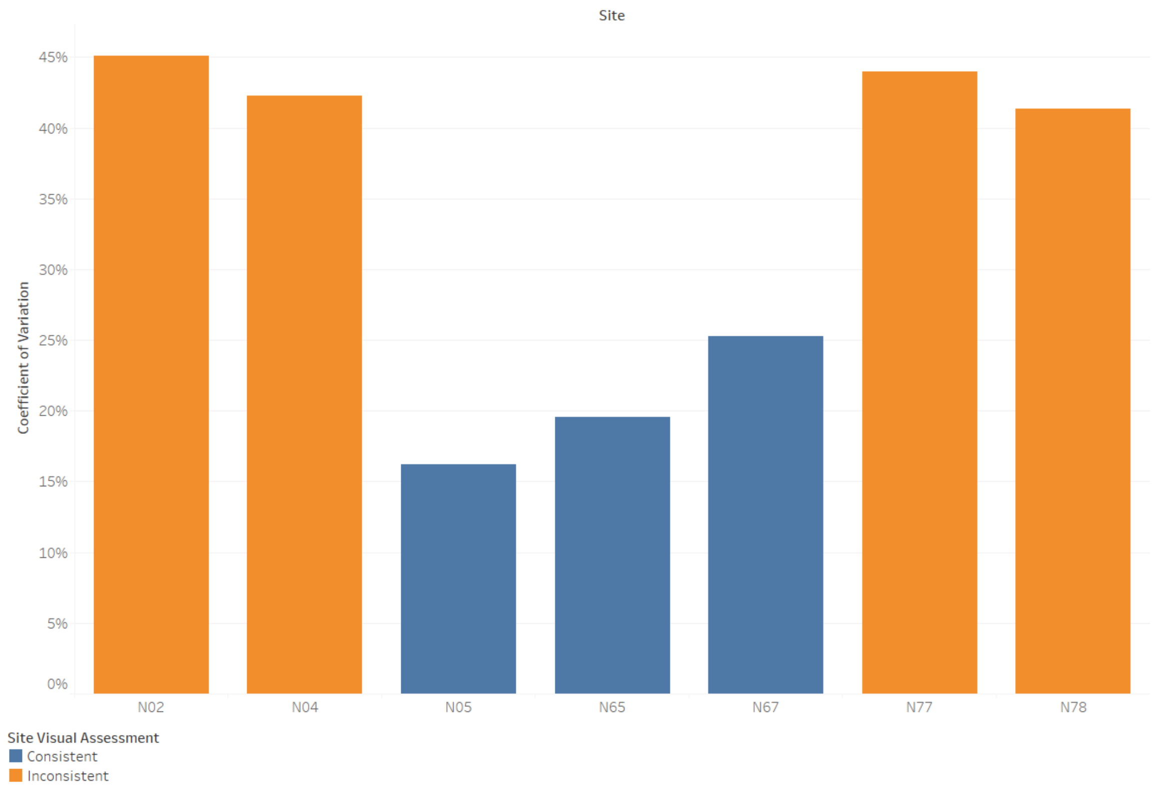

Figure 4.2 Site Coefficient of Variance

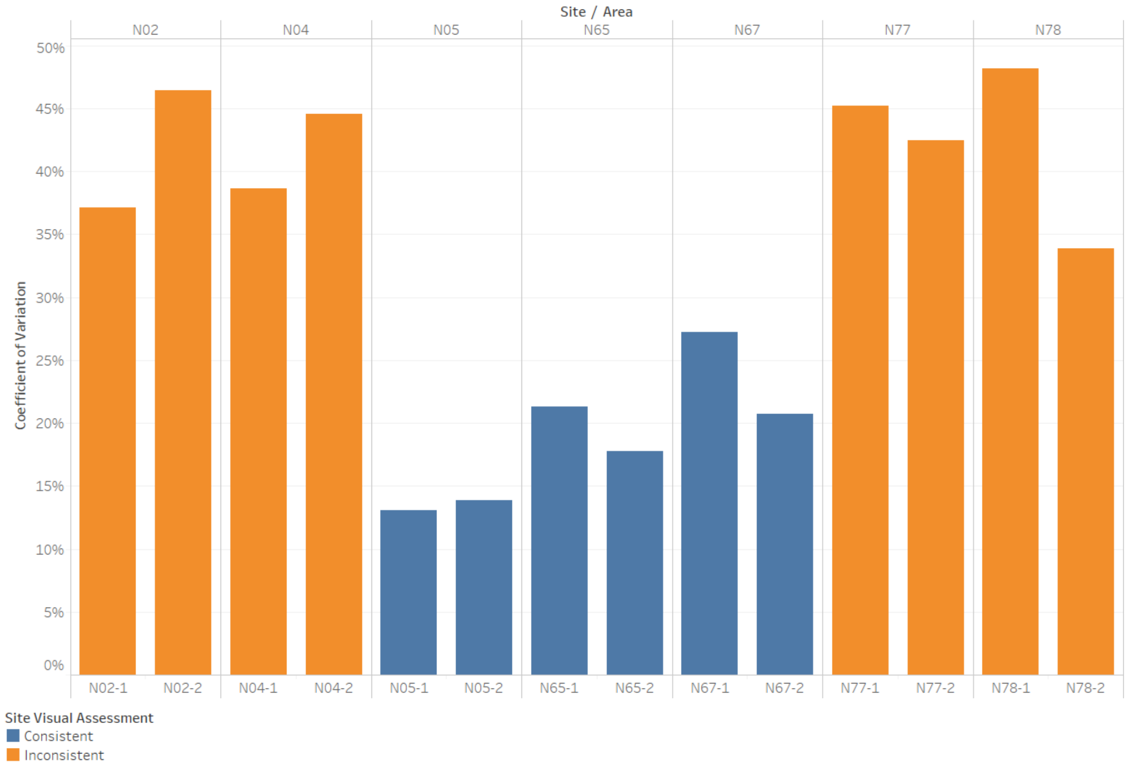

Figure 4.3 Site-Area Coefficient of Variance

Table 4.1 presents a more detailed summary showing the range of CV values obtained for each longitudinal band and transverse strip examined in the study, and the overall variability for each survey area and site, as determined using the analysis methodology in Section 6.2. The areas examined on the N65 showed abnormally high variation along one longitudinal strip (LP4) relative to the rest of the area. The N65 variability with these strips removed is also shown for comparison.

Table 4.1 Results of the LCMS Chip Distribution Assessment

		CV				Consistency from Visual Assessment
		Trans.	**Long**	**Area**	**Site**	
N02-1	**Min**	17%	23%	37%	45%	Inconsistent
	Max	46%	44%			
N02-2	**Min**	26%	27%	46%		Inconsistent
	Max	65%	60%			
N04-1	**Min**	20%	24%	39%	42%	Inconsistent
	Max	48%	58%			
N04-2	**Min**	29%	22%	45%		Inconsistent
	Max	40%	60%			
N05-1	**Min**	9%	3%	13%	16%	**Consistent**

		CV				Consistency from Visual Assessment
		Trans.	**Long**	**Area**	**Site**	
	Max	15%	13%			
N05-2	**Min**	7%	6%	14%		**Consistent**
	Max	20%	18%			
N65-1	**Min**	16%	11%	21%	20%	**Consistent**
	Max	27%	40%			
N65-2	**Min**	12%	7%	18%		**Consistent**
	Max	22%	29%			
N67-1	**Min**	12%	15%	27%	25%	**Consistent**
	Max	30%	38%			
N67-2	**Min**	12%	7%	21%		**Consistent**
	Max	30%	23%			
N77-1	**Min**	26%	16%	45%	44%	Inconsistent
	Max	79%	64%			
N77-2	**Min**	29%	19%	42%		Inconsistent
	Max	56%	78%			
N78-1	**Min**	29%	7%	48%	41%	Inconsistent
	Max	57%	65%			
N78-2	**Min**	20%	26%	34%		Inconsistent
	Max	42%	57%			
N65-1*	**Min**	10%	11%	16%	15%	**Consistent**
	Max	25%	20%			
N65-2*	**Min**	8%	7%	16%		**Consistent**
	Max	19%	22%			

**excluding LP4 results*

4.1.3 Discussion of Results – Pilot Study

The objective of the pilot study was to determine whether LCMS data could provide a method of estimating the consistency of chip distribution on a range of HRA pavement surfaces. There is clearly different behaviour between the areas of the N05, N65, and N67 which were assessed, and those of the other areas. All three have low CVs both transversely, longitudinally, and overall.

The N05 is significantly lower than both the N65 and N67 overall, with a CV of 13% and 14% on the two areas examined, compared to the N65 with CVs of 18% and 21% and the N67 with CVs of 21% and 27%. A closer examination of the results of the N65 shows that one longitudinal strip in each area has a much higher CV than the rest of the strips. If these are removed, the overall CV drops to 16% on both areas of the N65, very similar to the N05. It is interesting to note that the abnormally high CV occurs in the same strip in both areas of the N65, possibly indicating a slight variance in the chipper configuration or a long wavelength feature in the pavement surface, e.g., rutting, pavement joint, etc.

The remaining areas (N02, N04, N77 & N78) show significant variation in all directions, with overall CVs typically in the 40% to 50% range.

The difference in consistency of chip distribution is consistent with the visual inspections on-site. The N05, N65, and N67 were all identified as having good rates of chip application with consistent distribution in both the transverse and longitudinal directions. The size and shape of the chips were also consistent throughout.

By contrast, the N02, N04, N77, and N78 were all characterised as having poor to very poor consistency in terms of chip application rate, chip distribution, and chip size and shape. All of these sites contained both highly over-chipped and highly under-chipped patches. The rate of spread was inconsistent in both directions. There were also large areas of very over-embedded chips, i.e., level with the surrounding mastic, which cannot be differentiated from the surrounding mastic in Islands analysis. This was a particular issue on the N78, which visually had slightly better chip distribution consistency than the other sites but with highly over-embedded chips.

4.2 Chip Distribution – Extended Study

In 2021, TII commissioned a further study to expand on the pilot study. In this further study, 15 new sites of recently laid HRA were assessed, both visually and with LCMS for chip distribution. The sites were spread over a large geographical area, covering a range of suppliers, contractors, and chip sources. Sites on both National Primary and National Secondary routes were examined. The sites ranged in length from 800 metres to 7200 metres, averaging 2900 metres. All sites were open to traffic at the time of surveying.

4.2.1 Data Collection Method – Extended Study

The entire length of each site was surveyed using LCMS with a 1 mm longitudinal and transverse resolution. Each site was broken into discrete 50-metre sections. A sample of these 50-meter sections was selected for LCMS analysis. Initial sampling was carried out in line with the sampling methodology for evaluating surface macrotexture, given in section 10.1.11 of CC-SPW-00900. A subset of this sample was then selected for visual inspection. The subset was selected such that visual inspections could be carried out safely on site while minimising disruption to traffic. The sampling procedure resulted in 96 no. 50-metre sections across the 15 survey sites where LCMS and visual assessment data were collected. This study reports on the 50-metre sections where a direct LCMS and visual assessment comparison was made.

Visual inspections were carried out in accordance with CC-GSW-00900 by experienced pavement engineers. Chip distribution was visually assessed in terms of consistency along and across the mat. Using CC-GSW-00900, the consistency in each direction is given an integer score between 1 (Poor) and 4 (Very Good). For this study, a composite score for overall consistency was also calculated by summing the longitudinal and transverse scores. For overall consistency, composite scores of 1 to 4 are banded into “Poor to Fair”, scores of 5 or 6 are banded into “Fair to Good” and scores of 7 or above are banded into “Good to Very Good”.

4.2.2 Modified LCMS Data Extraction and Analysis Methodology

Based on the experience gained in the pilot study, a modified data extraction and analysis methodology was developed for the extended study. A reduced sampling regime was used in the transverse direction, with 4 samples selected for analysis instead of the 8 used in the initial pilot.

The 50-metre analysis sections within each site are segmented at 10-metre stations. At each station four circular patches of 280 mm diameter (140 mm radius) are extracted from across the width of the lane. One patch is extracted from each wheelpath, with two further patches extracted from the central strip between each wheelpath. Where non-pavement materials occur inside a patch (e.g., pavement markings, manhole covers, etc.), that patch is either moved slightly or excluded from the analysis. This results in a 5 x 4 grid of patches in each 50 metre analysis segment. A schematic of the sampling regime is shown in Figure 4.4.

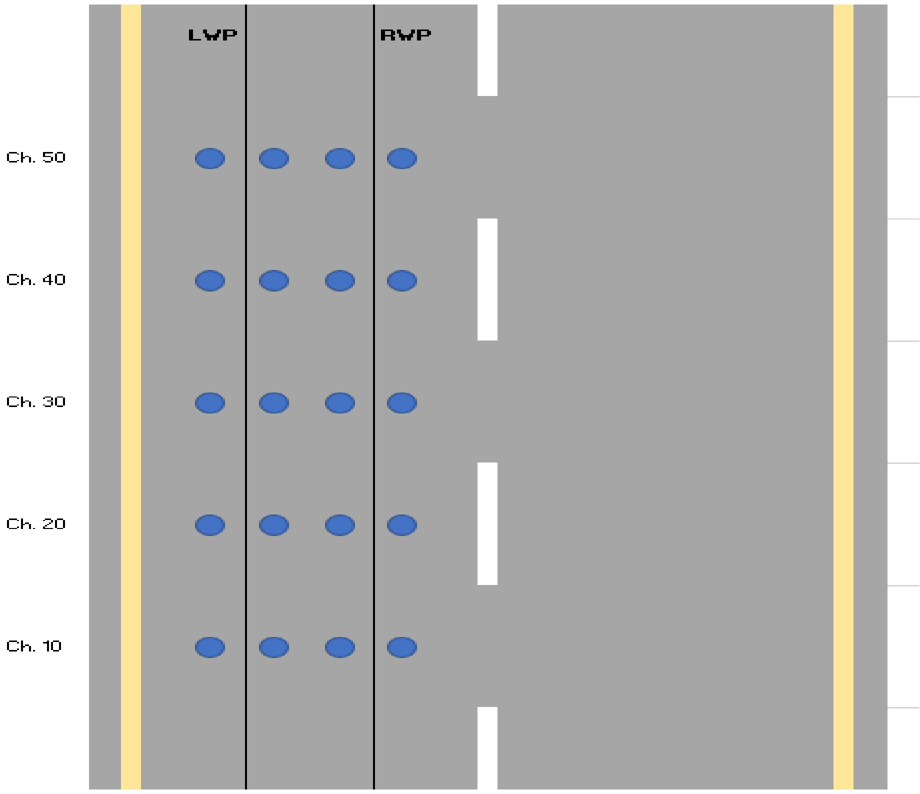

Figure 4.4 Extraction Pattern from LCMS Data – Extended Study

Each 50-metre section in the extended study was analysed, and the Longitudinal, Lateral, and Overall Coefficient of Variance was calculated.

4.2.3 Chip Distribution Results – Extended Study

Tables 2 to 4 present overall summaries of the visual assessment scores and the CV calculations for the 96 sections examined. Table 4.2 shows the spread of visual assessment ratings of chip distribution across the 96 sections. Generally, all three scores are Fair or better, with only a single 50-metre section in the Poor category longitudinally.

Table 4.2 Spread of Visual Ratings of Chip Distribution

<table>
<tr><th></th><th colspan="3">No. of 50-metre Sections</th></tr>
<tr><th>Visual Rating</th><th>Long</th><th>Trans</th><th>Overall</th></tr>
<tr><td rowspan="2">Poor</td><td rowspan="2">1</td><td rowspan="2">0</td><td></td></tr>
<tr><td rowspan="2">12 (Poor to Fair)</td></tr>
<tr><td rowspan="2">Fair</td><td rowspan="2">15</td><td rowspan="2">18</td></tr>
<tr><td rowspan="2">51 (Fair to Good)</td></tr>
<tr><td rowspan="2">Good</td><td rowspan="2">48</td><td rowspan="2">50</td></tr>
<tr><td rowspan="2">33 (Good to Very Good)</td></tr>
<tr><td rowspan="2">Very Good</td><td rowspan="2">32</td><td rowspan="2">28</td></tr>
<tr><td></td></tr>
</table>

Tables 4.3 and 4.4 show the overall average CV by overall visual score band and the overall average score by overall CV band, respectively. Both tables show reasonable trends with lower overall scores having a higher overall CV and, conversely, lower overall CV bands having higher overall scores.

Table 4.3 Average of Overall CV by Overall Visual Rating Band

Overall Visual Rating	Average of Overall CV	No. of 50m Sections
Poor to Fair	53%	12
Fair to Good	32%	51
Good to Very Good	27%	33

Table 4.4 Average Visual Rating Score by Overall CV Band

Overall CV	Average Visual Rating Score	No. of 50m Sections
< 30%	6.6	49
30 to 40%	6.1	22
40 to 50%	6.1	11
50 to 60%	5.7	7
> 60%	4.9	7

A more detailed breakdown of the results of the CV analysis is given in Figure 4.5. Figure 4.5 shows the cumulative frequency of 50-metre sections falling into bins of CV for each CV metric (Longitudinal, Transverse & Overall). The bins are defined at 10% intervals and are reported separately for each visual assessment rating. For clarity, the cumulative frequency plot for Poor has been removed from the Longitudinal and Transverse plots as only a single 50-metre section fell into the Poor category visually.

Figure 4.5 generally shows a strong relationship between the visual assessment of the chip distribution and the corresponding CV. Typically, almost all 50-metre sections that have good or very good consistency visually have a CV of less than 40%, with a significant portion having a CV of less than 30%. A distinctly different cumulative frequency response for sections rated as Fair (or "Poor to Fair" overall) can be seen in Figure 4.5, with the curve shifted much further to the right on all three metrics.

These results are higher than those observed in the pilot study. This may be due to the reduced sampling regime, where single outlier points have a greater effect on the overall results than when a larger sample size is used. Most importantly, the results of the extended study show a clearly different response (Figure 4.5) between sections rated visually as Poor/Fair and Good/Very Good in the context of the analysis carried out.

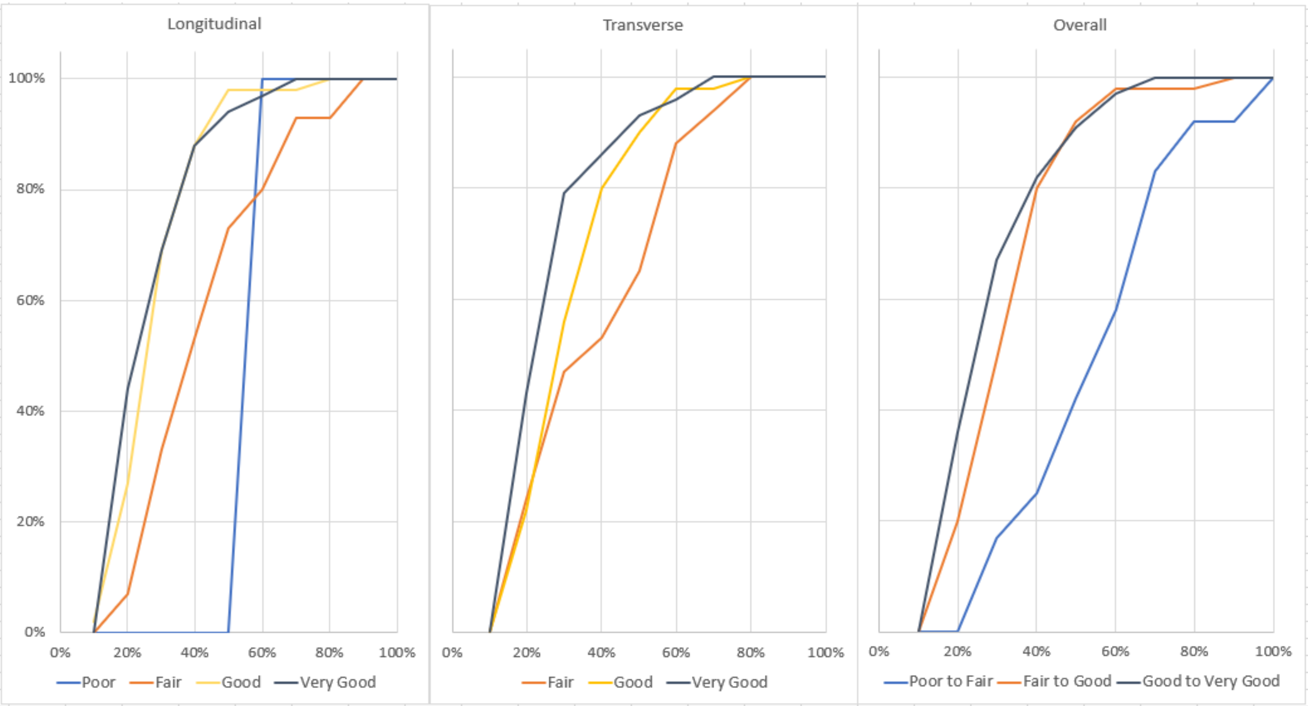

Figure 4.5 Cumulative Frequency Response for Coefficient of Variation (CV) Analysis

5. Conclusions

Both the CRP and LCMS islands applications showed that the methodology can reliably differentiate between positive and non-positive macrotexture on recently laid HRA surfaces using the Count50 parameter.

For chip distribution, there is good agreement between the visual assessments carried out on site and the coefficient of variation derived from the machine data. On average, sections with low CV have high visual assessment scores and conversely, sections with low visual assessment scores have higher CVs. Over 80% of 50-metre sections with a visual rating of Good or Very Good have a CV of less than 40%. These all indicate that machine data can be reliably used to determine the degree of consistency of chip distribution on HRA surfaces. A threshold CV in the 30 to 40% range appears to be optimal for this level of sampling.

It is likely that a denser sampling regime would lead to increased accuracy, particularly in assessing an individual longitudinal strip or transverse band. This was evidenced in the pilot study, where sites with good chip distribution showed significantly lower CVs than similar sites in the extended study. The increased sampling frequency reduces the effect of individual outlier patches, which gives a better estimate of the consistency of chip distribution in a section. However, the sampling regime used in the extended study still effectively differentiates between consistent and inconsistent sections. Given the range of quarry sources, material suppliers, and pavement contractors covered by the extended study, it is entirely reasonable that a higher level of variability would be observed. Considering this, further research would be required to assess the necessity and benefit/cost ratio of implementing an increased sampling regime.

It should be noted that a low CV value only indicates that the chip distribution is consistent, not that the rate of spread is sufficient, the embedment is acceptable, etc. The CV should be used in conjunction with the other standard measures, e.g., rate of spread, positive/non-positive texture character, texture depth etc, to derive an overall assessment of the quality of HRA surface macrotexture.

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