DEVELOPING AN OBJECTIVE MEASURE FOR FLUSHING

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ABSTRACT

As chipseals age in service they lose texture and can reach a condition described as flushed. Flushing can lead to a dramatic lowering of the skid resistance available to vehicles because the tyre rubber is supported on the low skid resistant bitumen.

Flushing, therefore, has a direct effect on the safety of the road network. Consequently, it is important that an objective measure be identified, so that:

- the extent of flushing can be quantified;
- areas of flushing can be located;
- quantitative targets for flushing can be established;
- strategies to reduce the amount of flushing on the network can be quantitatively evaluated;
- the remaining life of chipseals to provide adequate skid resistance can be predicted.

The objective of this study was to establish:

- a limiting texture threshold;
- appropriate texture values that could be set as a level of service to maintain the skid resistance and hence safety on the highway.

The paper describes the methodology used and recommends texture thresholds that should be applied to new construction and values of texture and skid resistance to identify sites that are either, flushed or are close to flushing.

It should be noted that the methodology within the paper is only able to be applied on networks where the appropriate asset information is available.

BACKGROUND

As chipseals age in service they lose texture and can reach a condition described as flushed. Should the surface of the bitumen be broken, bleeding occurs, leading to tracking of bitumen and pickup of bitumen and chips on tyres. A second effect of flushing is that it leads to dramatic lowering of the skid resistance available to vehicles. Inspection of sites requiring treatment due to low skid resistance shows that flushing is a major cause of loss of skid resistance on chipseals in New Zealand, because the tyre rubber is supported on the low skid resistant bitumen.

The New Zealand T/10 standard definition of flushing is:

A low textured road surface due to the upward migration of binder, reducing macrotexture.

The Austroads definition for flushing is:

> *A pavement surface defect in which the binder is near the uppermost surface of aggregate particles. The uppermost particles are still visible, but minimal surface texture exists.*

From the definitions it appears that the fundamental condition for a flushed area is a low texture. To identify low textures is relatively easy but, what would be more useful, is a measure that identifies the point when flushing starts to affect the skid resistance of a road surface.

Therefore, for the purposes of this study, a flushed road is defined as a road where there is a loss of texture, through the presence of binder high up around the sealing chip, and the wet skidding resistance, as measured by SCRIM, of the road surface, has been significantly reduced.

Flushing has a direct effect on the safety of the road network because of its effect on lowering the skid resistance. Consequently, it is important that an objective measure of texture that correlates well with the reduction of skid resistance be identified, so that:

- a limiting texture threshold can be established;
- the extent of flushing can be quantified;
- areas of flushing can be located;
- quantitative targets for flushing can be established;
- strategies to reduce the amount of flushing on the network can be quantitatively evaluated;
- the remaining life of chipseals can be predicted;
- appropriate texture values can be set as a level of service to maintain the skid resistance and hence safety on the highway.

As seen, there are good reasons to have an objective measure for flushing.

METHODOLOGY

Data Collection

All data was collected using SCRIM+ as part of the annual survey of the state highway network. The specific survey data required for this study is the texture and the skid resistance.

Skid Resistance Data

The skid resistance measure used in this study is the SCRIM coefficient (SC). The SC is calculated from a SCRIM reading, by applying a speed correction, temperature correction and an Index of SFC.

Texture Data

The texture data is collected at the same time as the SCRIM data and reported as 10m averages for the left and right wheel path and the mid lane. For the last 3 years the number of texture measures used to create the 10m averages was increased and include:

- Mean Profile Depth – Is the measure of the height of the highest peaks above the mean depth for 2 adjacent 50mm segments to produce an average for 100mm.;
- Modified MPD – Calculated by dividing each 100mm segment into four 25mm segments rather than two 50mm segments;
- Average Peak Count – Calculating the number of peaks per centimetre above 0.6mm higher than the mean profile line calculated every 100mm;

- Material Ratio – Percentage of the profile that lies above a line drawn 1mm below the highest peak calculated every 100mm;
- 10m average SMTD The sensor measured texture depth is a measure of the root mean square of the texture depths above and below the mean depth, calculated every 300mm;
- Texture Variability – the 5 and 95 percentile texture depths recorded over the 10m length and texture variance over the length.

Each of these texture measures has been evaluated as a possible measure to quantify flushing.

Seasonal Sites

The data from the seasonal sites were used for this study. There are 113 seasonal sites throughout New Zealand and each site is surveyed three times each year.

The specific reason for surveying the seasonal sites is to provide SCRIM data for seasonally correcting the SC values. However, all the other measures surveyed by SCRIM+ and the video are also collected at the same time so this provided an opportunity to evaluate the SCRIM and texture for each run. The SCRIM and the texture data for all 113 have been considered. These sites are surveyed three times a year in both wheel paths, which provided 6 sets of readings for each year and 3 years of surveys have been reviewed. This equates to 2034 possible sets of data for all the sites over the 3 years. The actual total was around 2000 because on occasions the seasonal sites are surveyed while they are damp, which is an acceptable practice for collecting SCRIM data, providing there is no standing water, but texture data cannot be collected on damp or wet roads.

Evaluating the Data

The various texture measures and skid resistance data were compared to determine any correlations that may exist.

Visual Evaluation

Each of the texture measures for the right hand wheel path was plotted on a line graph with the SC to determine any correlation between the 6 texture measures and the SC readings. All line charts for every run were evaluated. Figure 1 shows an example of a line plot for site 37 for the right hand wheel path using Mean Profile Depth (MPD). The MPD is in blue and the SCRIM coefficient (SC) is in red. Each of the texture measures was compared to the SC. Any correlation that may exist will be at the lower SC values since when the texture is high any dependence between the texture and the skid resistance is insignificant compared to the influence of microtexture. On flushed roads, however, the microtexture is obscured so there is a greater likelihood that there will be a relationship between low SC values and texture.

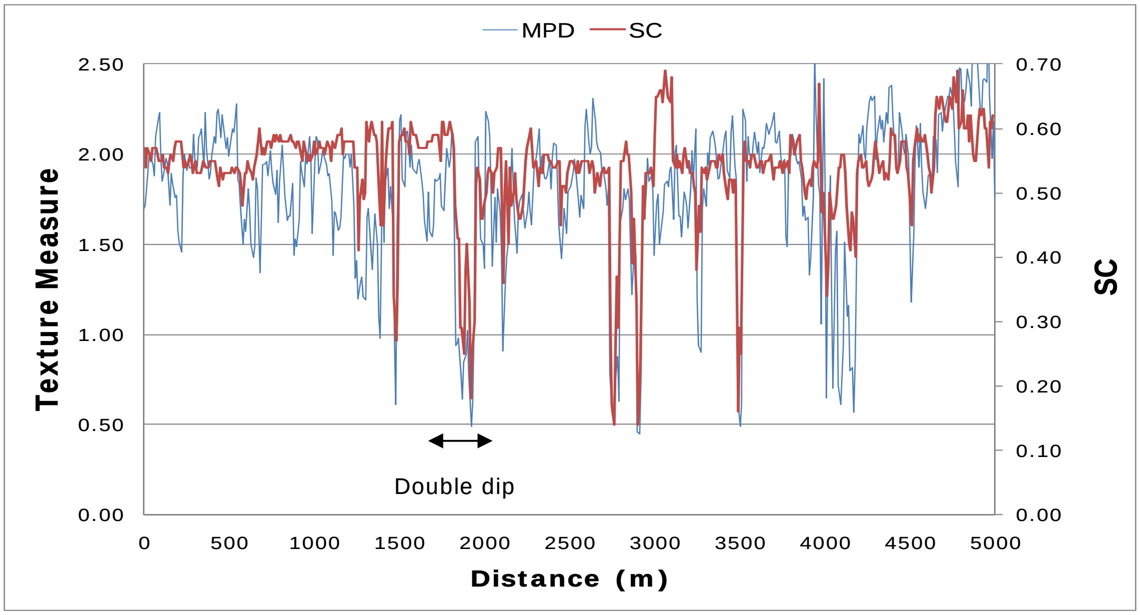

Figure 1: MPD versus SC

It can be seen that the MPD, does show some correlation between the texture measure and the low SC. This was also found for the modified MPD, SMTD and the Material Ratio.

In addition, to the line charts the SCRIM+ videos were viewed to determine the correlation between the texture and the SC and also between the texture and the existence of flushing. Figure 2, 3 and 4 show photos from the video taken at the point on the line plot where there is a double dip in SC around 2000m and marked..

Figure 2: Drop in SC 1880

Figure 2 is taken at the first drop in the SC at a chainage 1880m from the start of the site. As clearly shown both wheel paths are flushed although only the right wheel path is shown on the line charts.

Figure 3: Increase in SC on Right Wheel Path 1900m

Figure 3 shows the road 20m further on from Figure 2 and as can be seen there is some respite from the flushing in the right wheel path which corresponds to an increase in the SC from 0.2 to 0.55. This is accompanied by an increase in the modified MPD, MPD and SMTD and a decrease in the material ratio.

Figure 4: Second Dip in the SC 1920m

Figure 4 shows the road 40m further on from the first photograph and as can be seen the flushing in the right wheel path has returned with a consequent drop in the SC and is also registered by the texture measures.

Selecting Sites for Analysis

The objective of the study was to assess the correlation between texture and flushing so only sites that have some low texture values were selected for further study. The criterion used for selecting sites was that at least 10% of the site had low texture values namely SMTD values of ≤ 0.5mm, MPD or modified MPD values <0.7mm or Material Ratio >40. It was considered that texture above these values would not generally be considered as flushed. There were 32 sites that met these criterion. This dataset provided 3 runs per year for each site, for 3 years providing an analysis dataset with a total of 576 individual runs. This dataset is referred to in this paper as the “study dataset”.

There are some sites that have an asphaltic concrete (AC) surfacing along some of the length. AC can have a low texture regardless of whether it is flushed. Some of the sites included in the analysis are chipseals that have low texture values but are not flushed. Figure 5 shows the line chart for SC and, SMTD, for site 229. The SMTD texture between 390m and 1060 is relatively low. A photo of the site is shown in Figure 6.

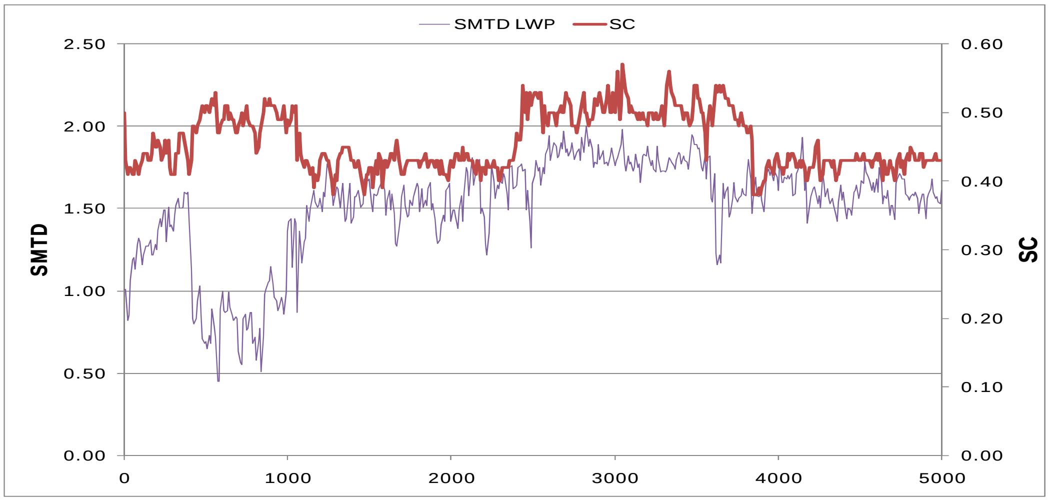

Figure 5: Site 229

Figure 5 shows a change in the surface from higher texture, SMTD ≈ 1.5mm to a fine texture SMTD ≈0.6. However, since the section is not flushed there is no decrease in the SC.

Figure 6: Change of Surface

Statistical Evaluation

A common test for determining the correlation between variables is regression. In this test, one variable is plotted against another and the coefficient of determination (r^2) is calculated to assess the correlation. If the r^2 is close to 1.0 then the fit between the two variables is considered good; as the r^2 value decreases, the correlation is considered less robust. The problem with using regression in this study is there would need to be a relationship between the SC and texture for all values and, as stated previously, it unlikely that there is a strong relationship between texture and SC at higher SC values.

Therefore, an alternative test, the Pearson's Chi squared test, was used to study the dependency between texture and SC at lower texture values.

Pearson's Chi Squared Test

The Chi squared (χ^2) test can be used to assess independence by testing whether paired observations on two variables, expressed in a contingency table are independent of each other.

The (χ^2) test was used to test whether any of the potential texture measures Modified MPD, MPD, SMTD or Material Ratio values at selected threshold are independent of SC at ≤ 0.35

The threshold band selected are shown in Table 1

Table 1: Threshold Band for Texture

Texture Measure	Threshold Band
Modified MPD	0 - 1.0mm
MPD	0 - 1.0mm
SMTD	0 - 0.5mm
Material Ratio	40% - 100%

The SC values of ≤0.1 and associated texture values were discarded since these very low SC values indicate that the test wheel has been raised.

In the χ^2 test the expected and the observed frequency is compared as shown in the equation.

$$X^2 = \sum_{i=1}^{n} \frac{(O_i - E_i)^2}{E_i},$$

Where:

X2 = the test statistic that asymptotically approaches a χ2 distribution.

Oi = an observed frequency;

Ei = an expected (theoretical) frequency, asserted by the null hypothesis;

n = the number of possible outcomes of each event.

The number of observations in the left wheel path (LWP) and right wheel path (RWP) for the study dataset where the SC is ≤ 0.35 and >0.1 is 7077 and 5565 respectively.

To determine the expected number of observations the combined texture frequency has been collated for 4 Network Maintenance Area's viz. Rotorua, Bay of Plenty East, Napier and Gisborne. The data was plotted as histograms for the MPD, modified MPD, SMTD and Material Ratio. The number of observations for each texture measure in the threshold bands listed in Table 1 were calculated as a percentage and these percentages were used to calculate the number of expected observations in the study dataset.

Table 2: Expected No. of Values within the Threshold Band for the study dataset

Wheel Path	Texture Measure							
	MPD		Mod MPD		SMTD		Material Ratio	
	%	Number	%	Number	%	Number	%	Number
Left Wheel Path	4.8	336	10.7	756	3.7	259	7.3	519
Right Wheel Path	4.9	272	11.9	662	4.0	223	7.1	395

The actual numbers of observations in the threshold band for the study dataset for the various texture measures in the dataset are shown in Table 3.

Table 3: Actual Observation for the Dataset

Wheel Path	Texture Measure			
	MPD	Mod MPD	SMTD	Material Ratio
	Number	Number	Number	Number
Left Wheel Path	2709	1491	2566	2917
Right Wheel Path	1933	1093	2169	2099

The calculated X^2 values for each texture measure are shown in Table 4

Table 4: Chi Squared Values

Wheel Path	Texture Measure			
	MPD	Mod MPD	SMTD	Material Ratio
	X2	X2	X2	X2
Left Wheel Path	16759	4333	20549	11080
Right Wheel Path	10143	3431	16982	7351

The Table value for the 0.001 probability at one degree of freedom is 10.827 therefore we can reject the null hypothesis and state that there is a dependency between all the texture measures in the threshold band and the low SC values.

The $\chi 2$ values for the modified MPD and the Material Ratio are lower than the MPD and the SMTD, therefore, the MPD and the SMTD show the greatest potential as measures for identifying flushing so only these 2 measures were considered for the remainder of the study.

SETTING THRESHOLD LEVELS FOR TEXTURE

The optimum texture thresholds for the SMTD and the MPD were evaluated by determining the percentage of 10m lengths below a specified SC values at specific texture values for each wheel path. For example, the proportion of 10m lengths with an SC < 0.350 and an SMTD <0.4mm in the left wheel path is 50.5%. Therefore, in this example, of all the 10m lengths with an SMTD <0.4mm, (1448), 50.5% of them will have an SC <0.350.

The results are shown in Tables 5 and 6

Table 5: Proportion below set SC Values and below set MPD levels

MPD (mm)	SCRIM Coefficient									
	0.30		0.325		0.350		0.375		0.40	
	LWP	RWP	LWP	RWP	LWP	RWP	LWP	RWP	LWP	RWP
0.5	39.2%	49.2%	43.6%	53.7%	51.8%	57.0%	54.7%	61.6%	59.1%	62.4%
0.7	32.6%	40.7%	42.0%	47.8%	52.2%	53.9%	58.6%	58.8%	65.2%	63.4%
0.8	26.4%	29.9%	35.5%	37.9%	46.1%	46.2%	52.9%	51.7%	59.6%	57.3%

Table 6: Proportion below set SC Values and below set SMTD levels

SMTD (mm)	SCRIM Coefficient									
	0.30		0.325		0.350		0.375		0.40	
	LWP	RWP	LWP	RWP	LWP	RWP	LWP	RWP	LWP	RWP
0.3	39.4%	30.4%	47.4%	34.6%	56.0%	39.1%	60.8%	42.5%	67.0%	45.3%
0.4	29.2%	24.3%	39.5%	31.0%	50.5%	38.8%	57.4%	44.0%	64.2%	48.9%
0.5	18.8%	15.4%	26.8%	21.4%	36.6%	28.7%	43.9%	34.2%	51.2%	39.6%

The higher the percentage within the tables, the greater the correlation between the texture and the SC. However, the lower the values used for the MPD and SMTD the less number of 10m lengths are included. For example at an SMTD of 0.2mm there are only 64 10m lengths that have an SC<0.40, therefore using 0.2mm would produce a large number of false negatives, areas that are flushed but are not identified. However, if a value too high is selected there will be a large number of false positives, areas that are not flushed but have been identified as being flushed. Therefore, there is a balance required in selecting the optimum texture value.

Detailed Visual Evaluation

Each of the 32 sites have been reviewed to determine how best to set a texture threshold level. As an example, a detailed evaluation of site 5 LWP is shown in Figures 7 to 11.

Figure 7 shows the texture and SC line chart for site 5. Three lines have been added to the line chart to facilitate the visual assessment. The red line is at an SC of 0.35, and the blue line and purple line are at a texture of 0.7 and 0.4 respectively indicating possible threshold levels for the MPD and SMTD.

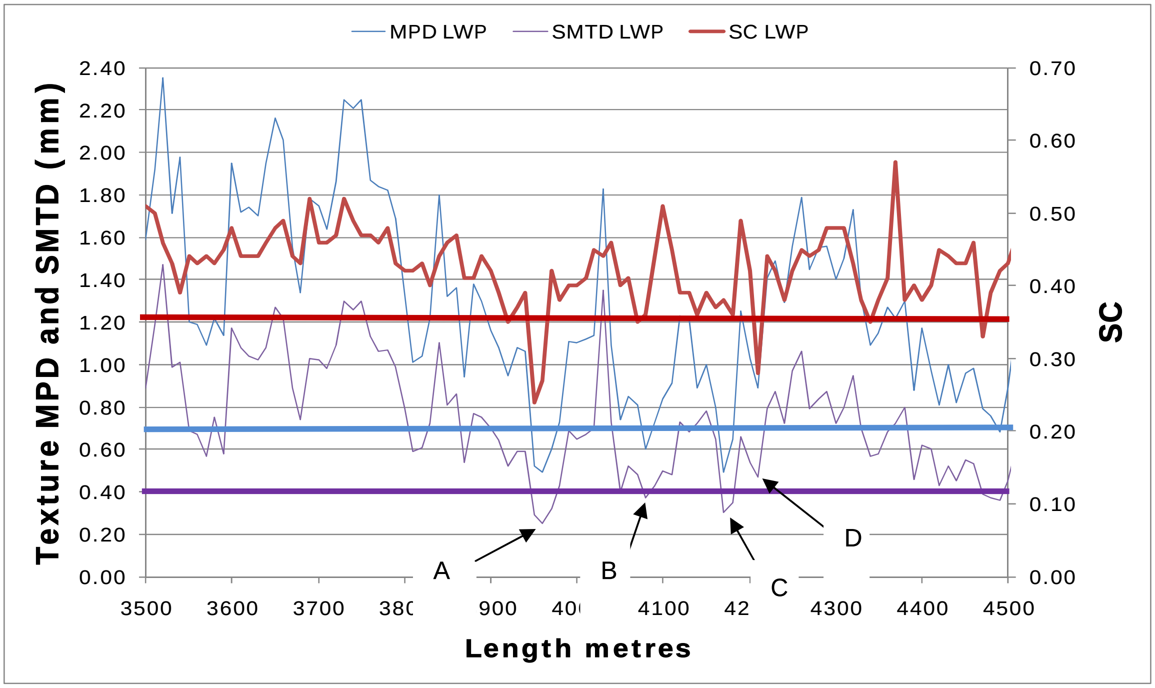

Figure 7: Line Chart for Site 5 from 3500m to 4500m LWP

Individual points have been labelled on the chart from A to D. At point A the SMTD and the MPD is below their respective threshold levels and the SC is < 0.30. A photo of point A is shown in Figure 8. As would be expected the site was found to be flushed.

Figure 8: Point A at Site

The SMTD and MPD for point B are just below the threshold for texture 0.34 and 0.61 respectively and the SC is 0.34. A photo of the site is shown in Figure 9.

Figure 9: Point B at Site 5

As seen in Figure 9 there is a road marking in the road at point B, which may be exaggerating the reduction in the texture and skid resistance.

Point C has a low texture but the SC is >0.35 a photo the area is shown in Figure 10.

Figure 10: Point C at Site 5

The 10m section included in Point C is the flushed area just after the surface change at the end of the bridge, shown in the circle. The fact that the SC is not <0.35 is surprising at first, since the flushed area appears to be completely obscuring the underlying aggregate. However, the texture sensor is set 100mm inside the SCRIM test wheel and consequently the SCRIM may be measuring to the left side of the flushed patch whereas the texture sensor may be measuring directly on top of the flushed patch. Further evidence for this hypothesis is provided by point D, which is shown in the distance in Figure 18 as a patch surrounded by flushed pavement and as a close up in Figure 11.

Figure 11: Point D at Site 5

At this point the texture is above the threshold but the SC <0.35. It is feasible that at this site, the texture sensor is partially measuring the patch but the SCRIM is measuring the flushed area.

Quantifying the Amount of Flushing on the Network

As seen, there are a number of variables that can influence the texture and the SC so a low texture or a low SC is no guarantee that flushing exists, but using both the texture and the SC together should produce a satisfactory measure to quantify flushing. The challenge is, to set the measures at a level so that there are an acceptable number of false negatives and positives as defined in Section 3.0.. Setting the texture and SC threshold high will produce more false positives and less false negatives, while setting the thresholds at a low level will produce more false negatives and less false positives.

As stated in Section 1 of this report "a flushed road is defined as a road where there is a loss of texture through the presence of binder high up around the sealing chip and the wet skid resistance, as measured by SCRIM, of the road surface has been significantly reduced".

Therefore, the SC should be set at a level low enough to represent a road that has had its skid resistance compromised by the existence of flushing. A possible value to represent this is <0.35. The associated texture value can be set initially taking into account the results shown in Tables 5 and 6 and visual assessments of the lines charts. An SMTD of ≤0.4 and an MPD ≤ 0.70 would appear appropriate as initial values.

To test these values all 10m sections from the study dataset that had an SMTD ≤0.4 and an SC of<0.35 for year 3, run 1 for the LWP were viewed by video. The total number of 10m sections viewed was 132 over 19 different sites. This process was repeated using an SMTD of ≤0.5, this expanded the sample pool to 215 10m sites.

It was found for the SMTD ≤ 0.4 all sites except 2 were obvious flushed. The surfacings for the 2 sites not exhibiting flushing were both asphaltic concrete that did not appear to be flushed but the texture was very smooth. When the SMTD was increased to ≤0.5 there were another 15 false positives or a total of 7%. This number of false positives is considered reasonable. The main difference in appearance of the sites with an SMTD of >0.4 and ≤0.5 compared to the sites with an SMTD of ≤0.4 were that some of the texture of the underlying surface was still visible even though the binder seemed to be covering the aggregate.

It was found that the total number of 10m sites that had an SC <0.35 and an MPD≤0.7 was 61, less than half of the sites identified using an SMTD of 0.4. To produce the same number of 10m sites as that using an SMTD of 0.5 the MPD would need to be set at 1.09. At an MPD of 1.09, there is concern that the number of false positives would be untenable.

A final assessment was undertaken using an SMTD of ≤0.5 and an SC ≤0.40, this expanded the number of sites to 370. The number of false positives increased to 37, 10% which is still a reasonable proportion. The sites that had an SC >0.35 ≤0.4 and an SMTD ≤0.5 were quite interesting, most of the sites still had aggregate exposed as shown Figure 12 and 13 but there was definite binder rise up the chip or fatting up.

Figure 12: Site showing signs of fatting up

Figure 13: Zoom of area in Ring

The ring indicates the area on this site that has been identified by the thresholds viz. SC≤0.4 and SMTD≤0.5. This area has been blown up and shown in Figure 13. The binder rise is quite evident.

Therefore, measures of SMTD≤0.50 and SC≤0.40 could be used to identify not only areas of flushing but also include those areas that are just starting to flush. These measures were applied to the LWP of the analysis dataset and the results are shown in Table 7.

Table 7: Proportion of the Study Dataset Meeting the criteria SMTD≤0.50 and SC≤0.40

Year	Proportion meeting Threshold for all runs	Proportion meeting Threshold for individual Run		
		Run 1	Run 2	Run 3
2007/08	2.8%	2.1%	3.3%	2.8%
2008/09	2.3%	1.9%	2.8%	2.1%
2009/10	3.6%	2.5%	4.2%	4.0%

As seen quite a small overall percentage of the seasonal sites meet the flushing criteria. This provides a level of confidence regarding the sites and their use to provide seasonal adjustments.

The amount of flushing in 2007/08 was greater than 2008/09 but the amount of flushing has increased in the 2009/10 season.

It is generally believed that flushing increases from the beginning of the summer season to the end. The figures in Table 4 indicate that the amount of flushing peaks during the second run. The dates for surveying the seasonal sites for run 1 is generally between October and December, Run 2 is between December and February and run 3 is between February and March. The temperatures during Run 2 are likely to be highest, which could influence the amount of flushing developed. It is uncertain why the amount of flushing should decrease after February. This may be due to treatment occurring on the flushed area after February, or possibly a function of the binder viscosity, which will increase during lower temperatures, which may facilitate the removal by vehicle tyres.

CONCLUSIONS

The objective of the study was to determine if texture data could be used to identify flushed areas. The data used for the study was from the NZTA seasonal sites; these sites are surveyed 3 times a year. The surveys of the sites are specifically to provide data to seasonally adjust the SCRIM data, but providing the site is dry, other high speed measures including texture are collected at the same time. Three years of seasonal site data was evaluated.

There are 6 different texture measures collected by SCRIM+ and it was found that some of the texture measures correlate with areas of low skid resistance and could be used to identify flushing. From a visual analysis, comparing texture and skid resistance on a line chart it was found that 4 measures in particular appeared to correlate reasonably with low SCRIM coefficients these were the modified MPD, MPD, SMTD and the Material Ratio. It was also found from looking at videos that the area was often flushed when these texture measures were at low levels for modified MPD, MPD and SMTD or high level for material ratio.

Seasonal sites that did not have areas of low texture were removed from the study dataset.

The four texture measures were evaluated further on the study dataset to ensure there was a statistical dependency between them and low SC levels by using the Pearson's Chi Squared Test. This test showed there was a high probability of all the 4 texture measures being considered having a dependency on the low SC values. The MPD and the SMTD gave the highest Chi squared values, therefore the study proceeded only using these measures.

A quantitative evaluation was undertaken to determine the proportion of SC at particular levels in bands of SMTD and MPD. This provided upper and lower limits of texture for a more detailed evaluation. It was found using these limits, that flushed areas could be identified, but there was also a large number (>40%) of false positives, areas that had low texture but also had reasonable SC values. Therefore, it was decided to use both the texture and the SC to set threshold levels for the identification of flushed areas. Several different threshold values were tested by identifying the location of the sites that met the thresholds and reviewing the videos and it was found that an SMTD of ≤ 0.50 and an SC ≤ 0.40 was the most useful for identifying areas that just started to flush. It was found that the threshold level for the MPD would need to be set at a relatively high level >1.0mm, with an associated risk of large numbers of areas falsely identified as flushed.

The thresholds can be used to identify flushed areas on the network and also be used to determine the quantity of flushing on the network.

The skid resistance and texture thresholds were applied to the analysis dataset and it was found that the largest quantity of flushing occurred in the mid survey run and tapered off for the final run. This result was unexpected since it is generally thought that flushing continues to increase throughout the summer season, although it does agree with anecdotal evidence from some survey operators.

RECOMMENDATIONS

The following threshold levels for texture and skid resistance are recommended to identify flushed areas.

Threshold	Texture		SC	Comments
	SMTD	MPD		
1	≤0.50	≤1.0	≤0.4	To identify areas that are starting to flush.
2	≤0.40	≤0.7	≤0.35	To identify areas that are fully flushed.

It is recommended that:

- SMTD be used as a texture measure rather than the MPD.
- Threshold 1 should be used to identify areas on the network that are starting to fat up and flush.
- Threshold 1 should be used to quantify the amount of flushing on the network.
- Threshold 2 should be used to identify areas which need attention as soon as practicable
- Minimum specified texture levels for new construction should be at least ≥0.6 for SMTD and ≥1.1 for MPD.

The criteria derived from this study should be validated by applying them to a significant sample of the main 20010/11 survey of the State Highway network. The areas of flushing identified should be compared with the video record.

It is further recommended that if the criteria are validated then the production of a threshold report identifying flushed areas, by the survey contractor, should be implemented as part of the 2011/12 high speed data survey of the state highway network and that provision should be made in future survey contracts for this to be a standard deliverable.

AUTHOR BIOGRAPHIES

Dave Whitehead

Dave Whitehead has over 30 years experience in a variety of roles within the highways engineering sector or which the last 25 have been in highway maintenance and asset management. He has worked largely in the UK in both the private and public sectors but prior to moving to New Zealand in 2008 had previous overseas experience in Sri Lanka.

Dave currently holds the position of Senior Asset Manager within the Asset Group at the NZ Transport Agency's National Office in Wellington. He is responsible for specifications relating to skid resistance as well as involvement in a wide range of projects related to asset management. Dave is also currently the chair on the Skid Technical Advisory Group (STAG) within NZTA.

John Donbavand

John began work in NZ after completing his PhD in the UK in 1983. John worked in NZ for 18 years and has held a number of positions including research scientist studying bitumen for the New Zealand Ministry of Works, Surfacing Scientist for the National Roads Board and Engineering Policy Manager for Transit New Zealand.

John returned to the UK in 2001 to take up the position as Project Development Manager at WDM Limited in 2001. In this position, John has been involved with a wide range of projects, including: developing procedures to estimate the national maintenance budgets for Highway Agencies, asset valuation for local roads, providing scheme prioritisation techniques for Highway Authorities, providing skid policies and training for site investigation. John was also a member of the TRL group that assisted the Highway Agency to develop the latest HD28, to be published in 2011.

James Mitchell

James Mitchell has 13 years experience in highway engineering with W.D.M. Limited, most recently 3 years as a Consultancy Project Manager after 5 years as Survey Project Manager and before that 5 years working as equipment operator developing first hand knowledge of operational processes on highway maintenance management projects.

Since joining W.D.M. Limited, he has been responsible for developing software and procedural documents. He has also been Project Manager for a number of different engineering projects involving high speed data collection. These projects have included surveys on networks operated by NZTA in New Zealand, Department of Energy, Infrastructure and Resources in Tasmania, Highways Agency in England, Transport Scotland and Welsh Assembly, as well as many Local Authorities in the UK.