Appendices

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Appendix 1: Uncoated plates

These plates were intended to be similar to actual chipseal road surfaces with the following exceptions:

1. The aggregate chips were packed more 'loosely' than would be the case for many actual road surfaces.
2. The substrate for the plates is flat, whereas the substrate for actual road surfaces is generally textured (e.g. basecourse or previously laid seal surface).

Figure A1.1 Grade 2, 0 % crushed, Pound Road quarry.

Figure A1.2 Grade 2, 25 % crushed, Pound Road quarry.

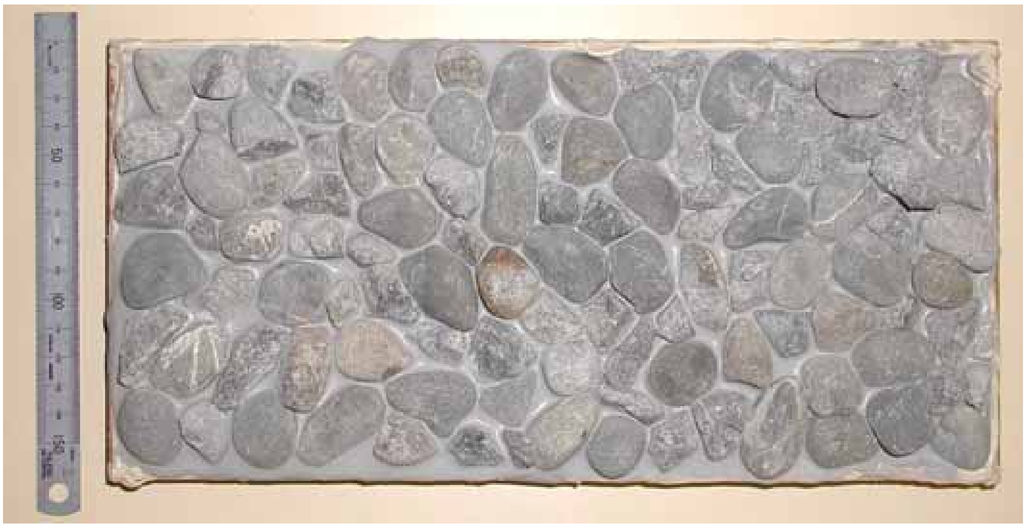

Figure A1.3 Grade 2, 50 % crushed, Pound Road quarry.

Figure A1.4 Grade 2, 75 % crushed, Pound Road quarry.

Figure A1.5 Grade 2, 100 % crushed, Pound Road quarry.

Figure A1.6 Grade 3, 0 % crushed, Pound Road quarry.

Figure A1.7 Grade 3, 25 % crushed, Pound Road quarry.

Figure A1.8 Grade 3, 50 % crushed, Pound Road quarry.

Figure A1.9 Grade 3, 75 % crushed, Pound Road quarry.

Figure A1.10 Grade 3, 100 % crushed, Pound Road quarry.

Figure A1.11 Grade 4, 0 % crushed, Pound Road quarry.

Figure A1.12 Grade 4, 25 % crushed, Pound Road quarry.

Figure A1.13 Grade 4, 50 % crushed, Pound Road quarry.

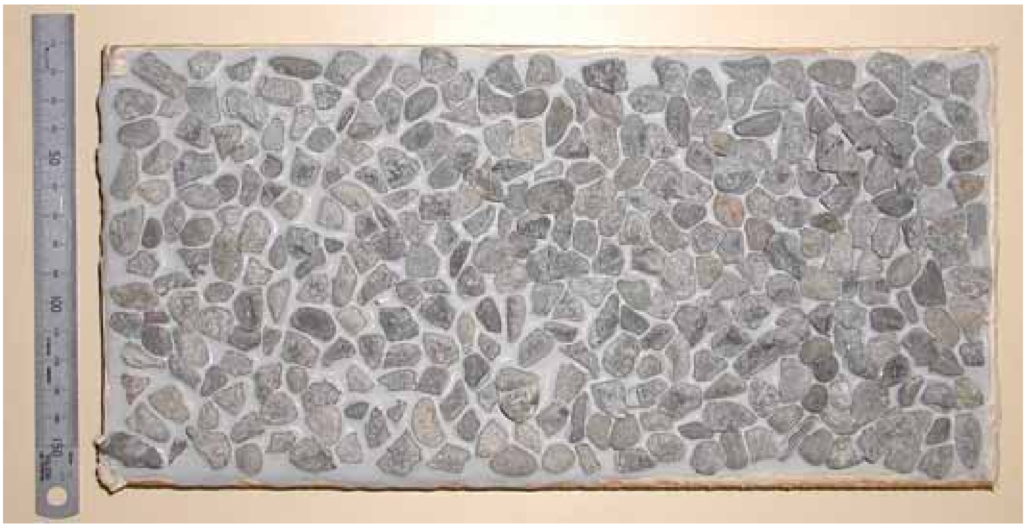

Figure A1.14 Grade 4, 75 % crushed, Pound Road quarry.

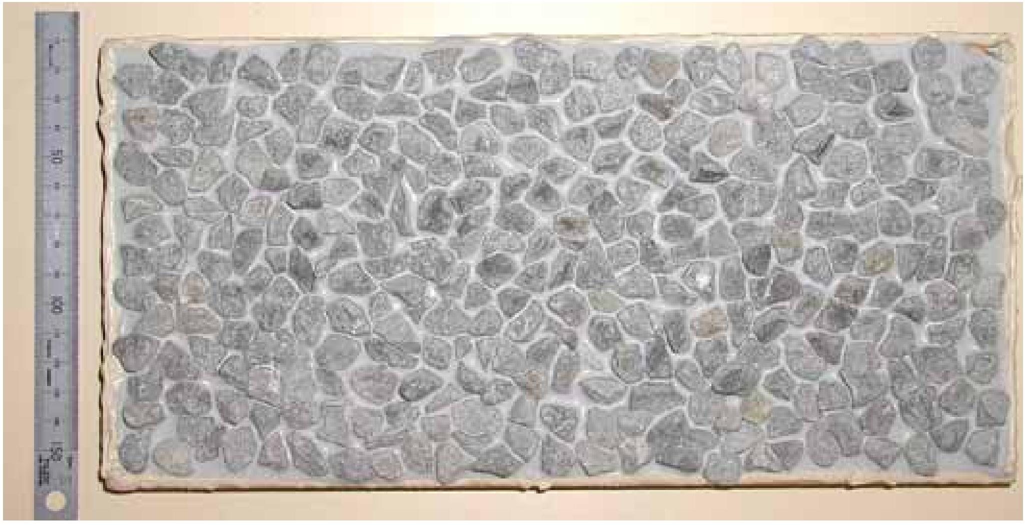

Figure A1.15 Grade 4, 100 % crushed, Pound Road quarry.

Appendix 2: Urethane-coated plates

Note: for Figures A2.1-A2.6, the strip of black on the peaks of the chips is the result of rubber deposition by the GripTester wheel.

Figure A2.1 0% crushed (top) and 50% crushed (bottom), Pound Road quarry, pass 13.2 mm, held 9.5 mm.

Figure A2.2 70% crushed (top) and 80% crushed (bottom), Pound Road quarry, pass 13.2 mm, held 9.5 mm.

Figure A2.3 90% crushed (top) and 100% crushed (bottom), Pound Road quarry, pass 13.2 mm, held 9.5 mm.

Figure A2.4 0% crushed (top) and 50% crushed (bottom), Hastings quarry, pass 13.2 mm, held 9.5 mm.

Figure A2.5 80% crushed (top) and 90% crushed (bottom), Hastings quarry, pass 13.2 mm, held 9.5 mm.

Figure A2.6 100% crushed, Hastings quarry, pass 13.2 mm, held 9.5 mm.

Note: These digital photographs have different colours depending on the lighting conditions when the photographs were taken. Thus colour differences between figures may not always be real, and may be only an artefact of the lighting.

Appendix 3: PSV' samples

Figure A3.1 PSV' samples, Pound Road quarry, pea-gravel.

Figure A3.2 PSV' samples, Hastings quarry, pea-gravel.

Figure A3.3 PSV' samples, Pound Road quarry, sealing chip.

Figure A3.4 PSV' samples, Hastings quarry, sealing chip.

Appendix 4: Road core samples

Figure A4.1 Pound Road aggregate, grade 3, left wheelpath, ‘low’ HCV passes (direction of traffic = ↔).

Figure A4.2 Pound Road aggregate, grade 3, left wheelpath, ‘medium’ HCV passes (direction of traffic = ↔).

Figure A4.3 Pound Road aggregate, grade 3, left wheelpath, 'high' HCV passes (direction of traffic = ↔).

Figure A4.4 Pound Road aggregate, grade 3, between wheelpaths, 'low' HCV passes (direction of traffic = ↔).

Figure A4.5 Pound Road aggregate, grade 3, between wheelpaths, 'medium' HCV passes (direction of traffic = ↔).

Figure A4.6 Pound Road aggregate, grade 3, between wheelpaths, 'high' HCV Passes (direction of traffic = ↔).

Figure A4.7 Hastings Quarry aggregate, grade 3, left wheelpath, 'low' HCV vehicle passes (direction of traffic = ↔).

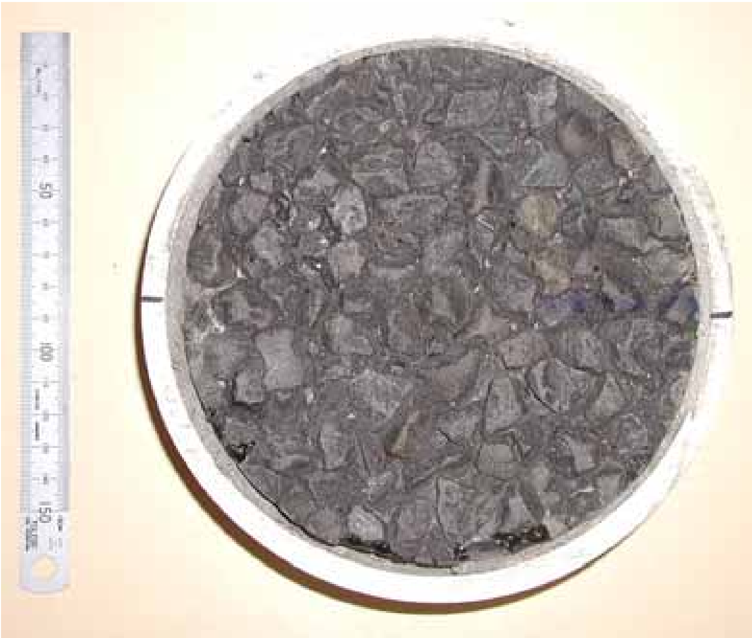

Figure A4.8 Hastings Quarry aggregate, grade 3, left wheelpath, 'medium' HCV vehicle passes (direction of traffic = ↔).

Figure A4.9 Hastings Quarry aggregate, grade 3, left wheelpath, 'high' HCV passes (direction of traffic = ↔).

Figure A4.10 Hastings Quarry aggregate, grade 3, between wheelpaths, 'low' HCV passes (direction of traffic = ↔).

Figure A4.11 Hastings Quarry aggregate, grade 3, between wheelpaths, 'medium' HCV passes (direction of traffic = ↔).

Figure A4.12 Hastings Quarry aggregate, grade 3, between wheelpaths, 'high' HCV passes (direction of traffic = ↔).

Appendix 5: Relationship between SLP profiles and % crushing

This Appendix contains details of the relationship between SLP profiles and the percentage of crushed chips that is summarised in Section 11.5 of the main body of this report. Images of the plates are shown in Appendix 1. A brief summary of the SLP and its operation is given in Section 3.3.

Table A5.1 Plate SLP measurement parameters.

Measurement parameter	Grade 2	Grade 3	Grade 4
Ordinate spacing (mm)	0.23979	0.23246	0.24248
Scan length, L (m)	0.27408	0.27384	0.27376
Number of scans	58	54	53

Five methods were used in the attempt to predict the percentage of crushed faces from macrotexture. These are summarised in Table A5.2.

Table A5.2 Methods for predicting the percent crushing from SLP profiles.

Method	Description
1	Profile statistics
2	Linear approximation of profile to distinguish 'crushed' faces
3	Quadratic curve approximation of profile to distinguish 'uncrushed' faces
4	PSD of SLP profile
5	PSD of SLP profile slope

Method 1: Profile statistics

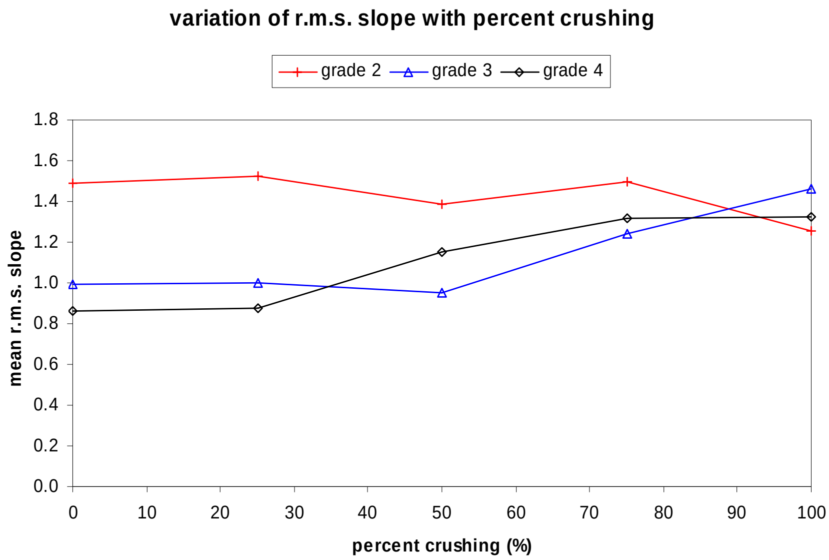

Figure A5.1 Prediction of percent crushing by method 1 (grade 2 aggregate, 0% crushed).

Method 2: Linear approximation of profile for 'crushed' faces

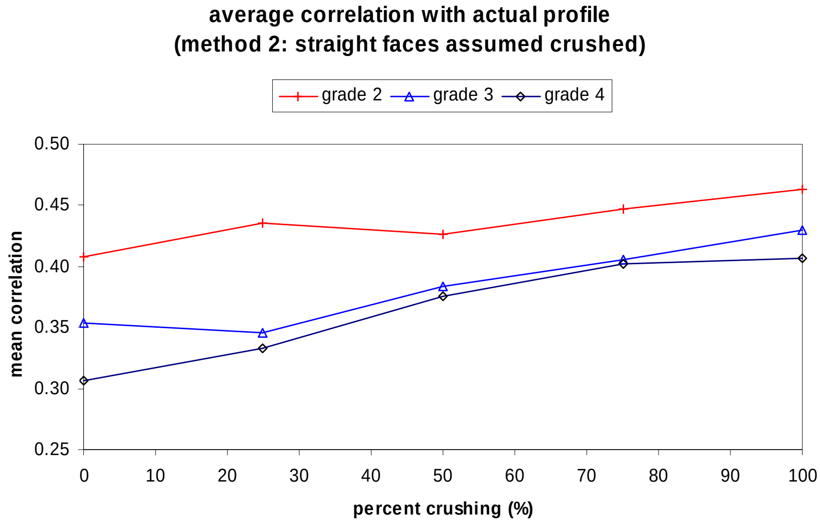

Figure A5.2 Correlation with actual profiles using method 2.

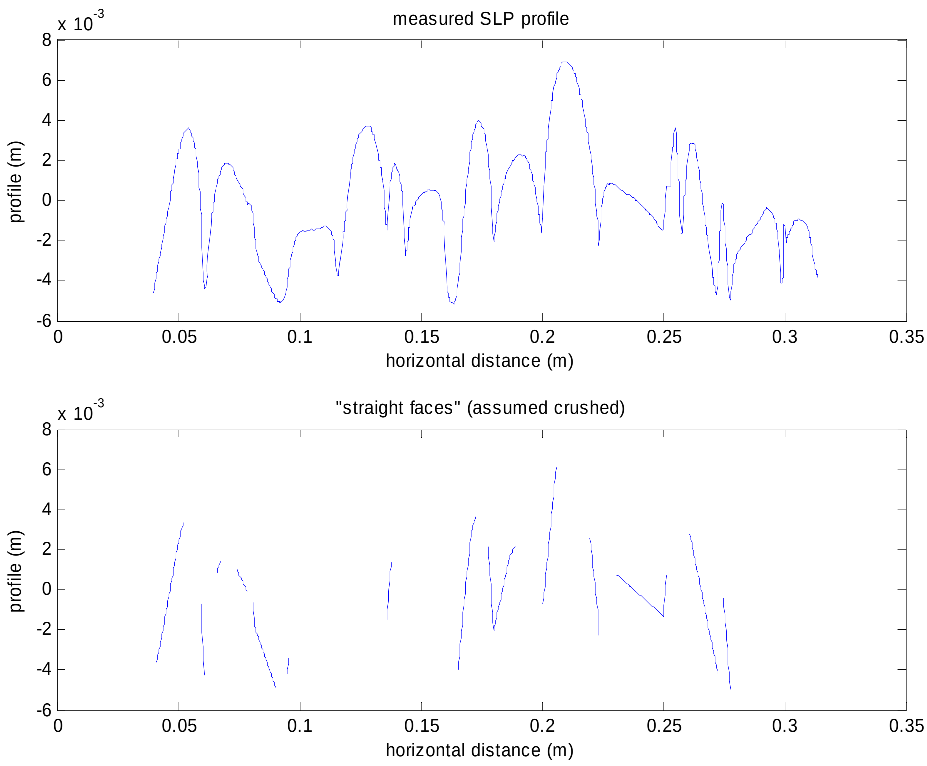

Figure A5.3 Example profiles using method 2 (grade 2 aggregate, 0 % crushed).

Method 3: Quadratic curve approximation of profile for 'uncrushed' faces

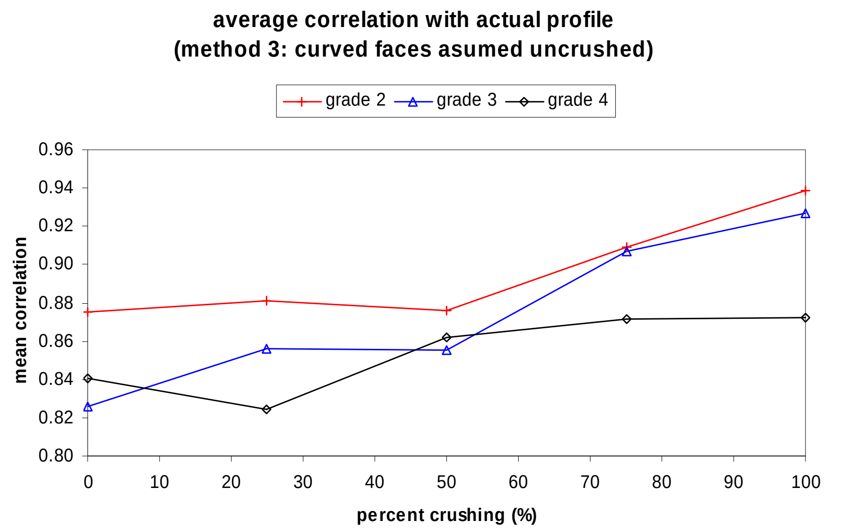

Figure A5.4 Correlation with actual profiles using method 3.

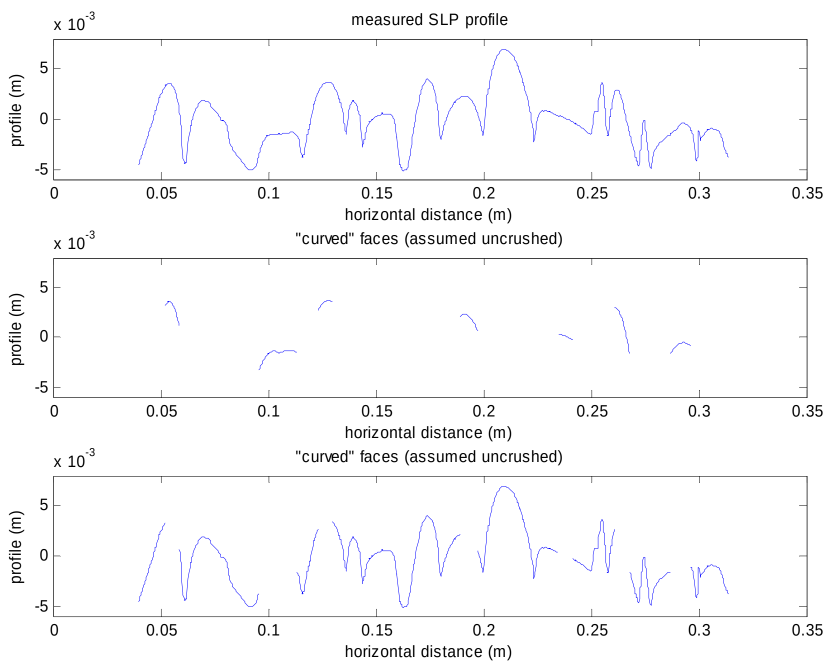

Figure A5.5 Example profiles using method 3 (grade 2 aggregate, 0 % crushed).

While methods 2 and 3 significantly under-predict the percentage of crushed faces (e.g. Figures A5.2 and A5.4) in terms of absolute correlations, this is not a concern as the methods rely only on how the correlation changes with percentage crushing rather than on actual values.

Method 4: PSD of SLP profile

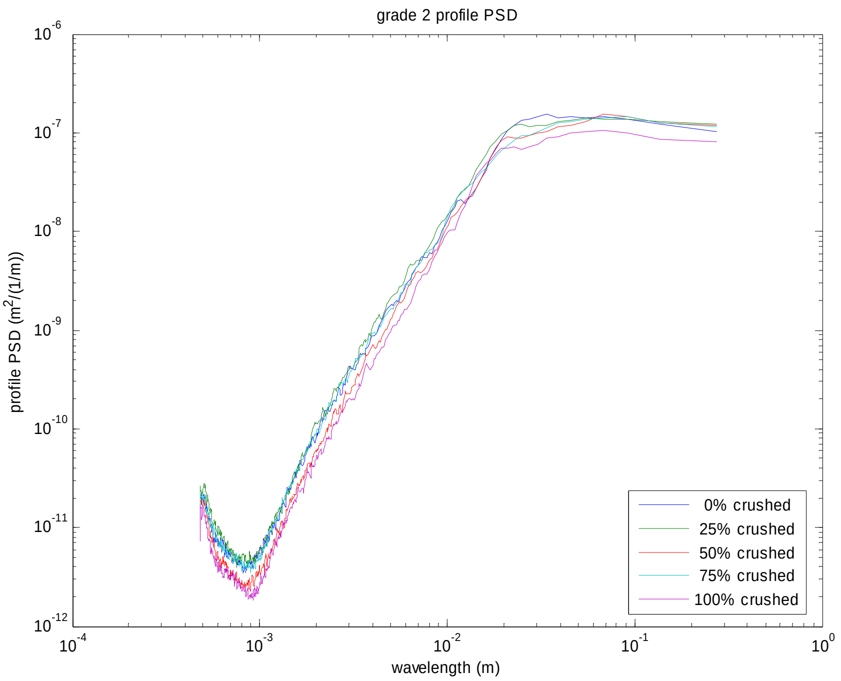

Figure A5.6 PSD of grade 2 SLP profile (method 4).

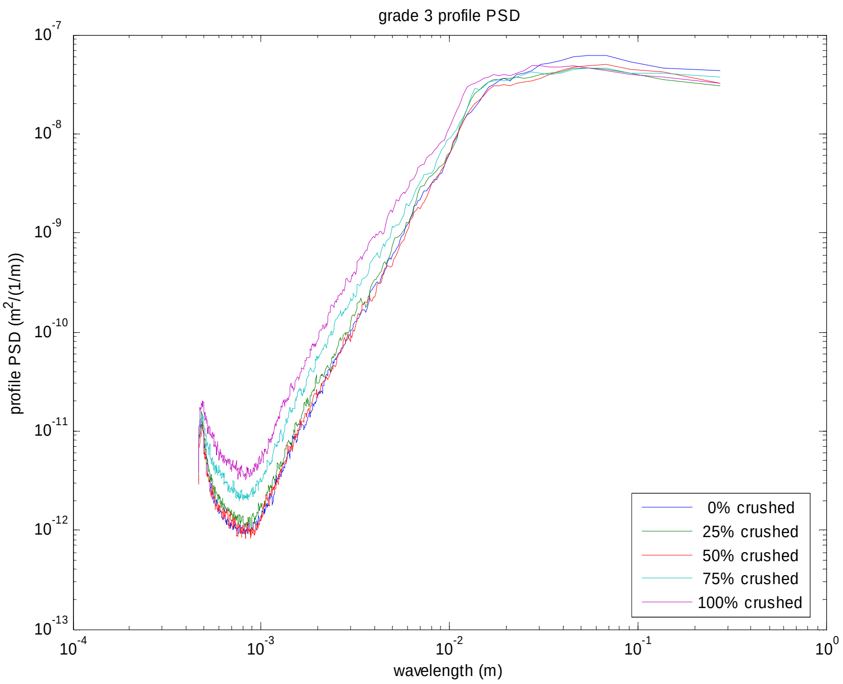

Figure A5.7 PSD of grade 3 SLP profile (method 4).

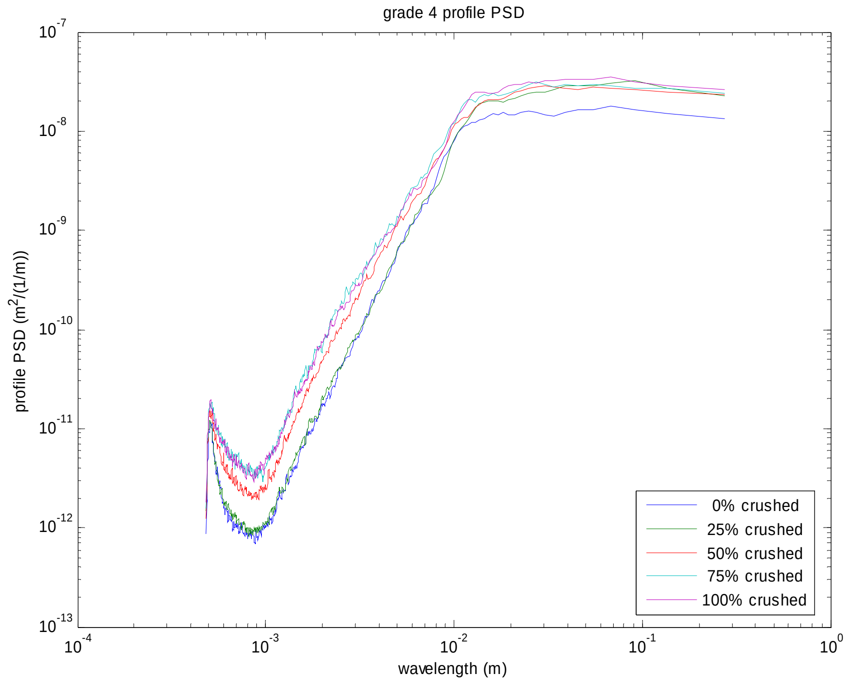

Figure A5.8 PSD of grade 4 SLP profile (method 4).

Observations from Figures A5.6-A5.8 are:

1. The profile PSD is larger (i.e. the profile is roughest) at longer wavelengths.
2. The profile PSD is largely constant for wavelengths greater than approximately 0.01 m (10^{-2} m) for grade 4 chip, increasing to approximately 0.02 m (2×10^{-2} m) for grade 2 chip. (This coincides with the wavelengths of the aggregate peaks for the three chip grades.)
3. The profile PSD is at a minimum at around 0.9 mm (9×10^{-4} m).
4. The minimum profile PSD is similar for all chip grades.
5. The profile PSD for different percentages of crushed chips can be distinguished most readily for the smallest chip grade (Gr 4), and less so for larger chip grades (e.g. Gr 2) (i.e. small chip grades have the most noticeable differences in profile PSD with various levels of crushing).
6. The smallest wavelengths (e.g. less than 0.5×10^{-3} m = 0.5 mm) correspond to (a) microtexture, and (b) crushed-crushed/crushed-uncrushed interfaces. As expected, profile PSD for the plates with larger percentages of crushed chips have greater magnitudes, although this relationship does not hold true for the largest chip size (Gr 2, Figure A5.6).
7. Profile PSD cannot predict percent crushing with enough accuracy to be useful.

Method 5: PSD of SLP profile slope

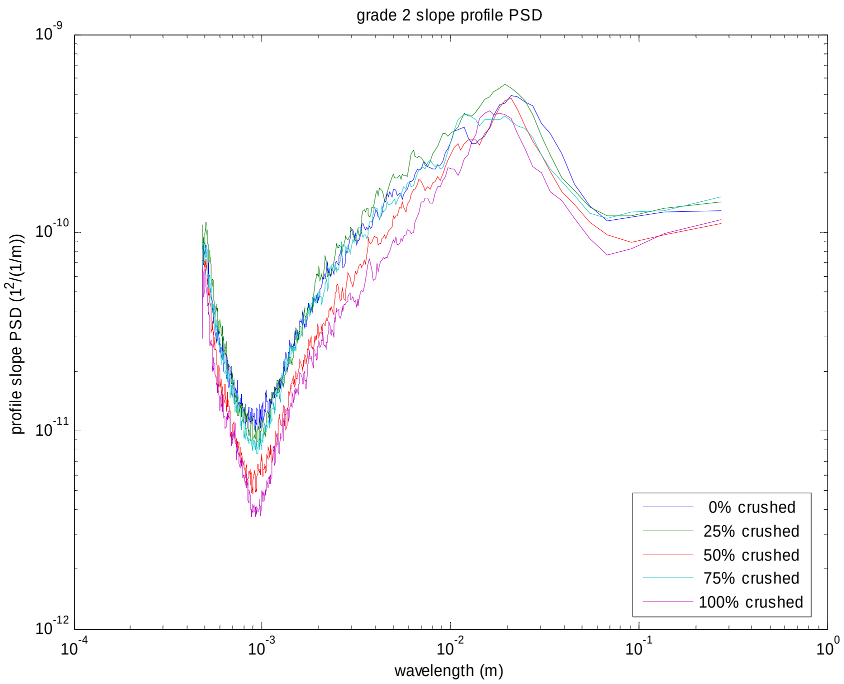

Figure A5.9 PSD of grade 2 SLP profile slope (method 5).

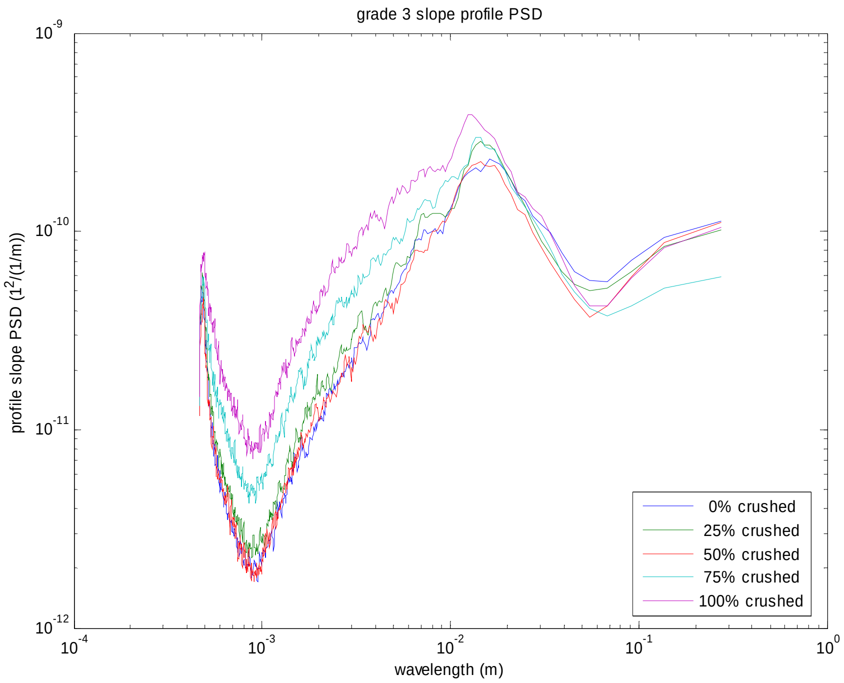

Figure A5.10 PSD of grade 3 SLP profile slope (method 5).

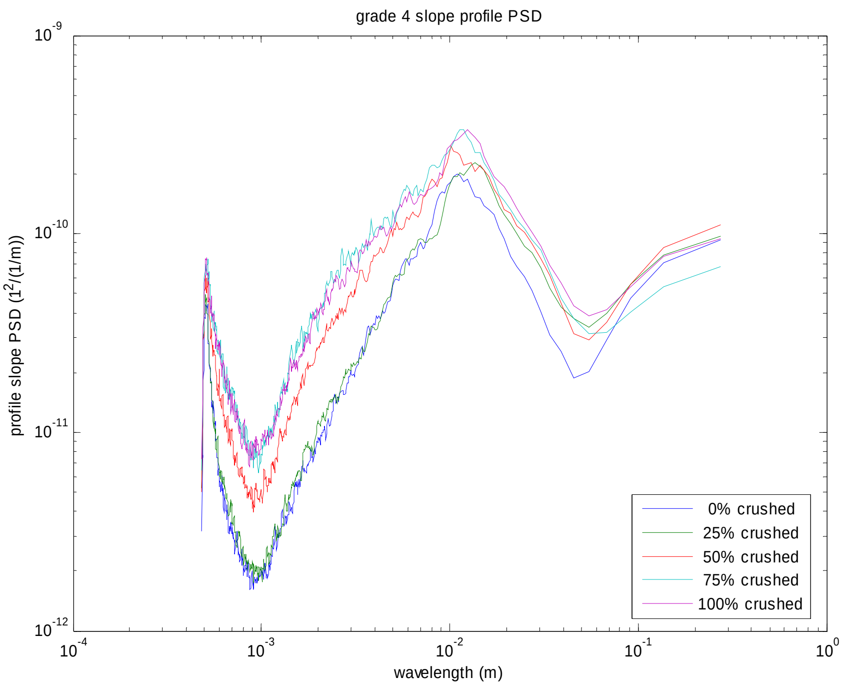

Figure A5.11 PSD of grade 4 SLP profile slope (method 5).

Observations from Figures A5.9-A5.11 are:

1. The PSD of the slope profile reaches a maximum at the chip spacing wavelength (approximately 0.01 m (10^{-2} m) for grade 4 aggregate, and 0.02 m (2×10^{-2} m) for grade 2 aggregate).
2. The maximum PSD of the slope profile is similar for all chip grades (i.e. the aggregates for the three chip grades have similar slopes).
3. The PSD of the slope profile has a minimum at a wavelength of around 0.9 mm (9×10^{-4} m).
4. PSD of the slope profiles for different percentages of crushed chips can be distinguished most readily for the smallest chip grade (i.e. Gr 4), and less so for larger chip grades (i.e. Gr 2). In other words, small chip grades have the most noticeable differences in PSD of slope profiles with different levels of crushing.
5. The smallest wavelengths (e.g. less than 0.5×10^{-3} m = 0.5 mm) correspond to (a) crushed-crushed/crushed-uncrushed interfaces and (b) microtexture. As expected, PSD of the slope profiles for the plates with larger percentages of crushed chips have greater magnitudes, although this relationship does not hold true for the largest chip size (Gr 2, Figure A5.9).
6. PSD of SLP slope profiles cannot predict percent crushing with enough accuracy to be useful.

Appendix 6: Preparation and measurement for all tests

Preparation

For PSV' tests, friction tests, and profile measurements, the test surfaces (PSV sample plates, road cores and laboratory plates) were prepared by washing with water and a fine brush to remove any contaminants. For the APM-polished sample plates, washing occurred at 0, 3, 4, 5, 6, and 9 hours of APM-polishing to remove the slurry introduced by the polishing process.

Measurement

For both skid resistance determinations and profile recording, the measurement direction was chosen to be in the direction of any polishing, i.e.:

1. Along the length of PSV′ sample plates.
2. Along the length of laboratory prepared plates.
3. In the direction of traffic for core samples taken from the road.

Microtexture measurements were undertaken on the same chip and at similar positions, although there the exact positions of the two scans is probably different.

Microtexture profile measurement parameters

A number of Surtronic 3+ measurement parameters control characteristics of the microtexture profiles. These are summarised in Table A6.1.

Table A6.1 The effect of microtexture measurement parameters.

Parameter	Result
Scan direction	There is no clear relationship between any of the microtexture statistics (Cenek et al. 2004) and the direction of profile measurement (perpendicular or parallel to the direction of polishing). The effect of scan direction is not relevant in this research, as all profile measurements are made along the direction of polishing for both the APM sample plates and cores.
Vertical resolution/range	The Surtronic 3+ has a number of scan lengths and measurement ranges. These are: • scan lengths (mm): 0.25, 0.80, 1.25, 2.5, 4.0, 8.0, 12.5, 16.0, 25.0. • measurement ranges (μm): 10, 100, 500. (Note measurement ranges are total, i.e. peak-to-trough.)

	The vertical resolution reduces for increased measurement ranges as follows: **measurement range | vertical resolution** 10 µm | 0.01 µm 100 µm | 0.1 µm 500 µm | 0.5 µm Because longer scans on the aggregate surfaces caused the measurement range to be exceeded, measurements were a balance between choosing a longer scan with a coarser vertical resolution, or a shorter scan at a finer vertical resolution. Given that it was not clear which measurement range is preferable, both 100 µm and 500 µm ranges were used for the measurements. In practice, the 100 µm range could only be used for scan lengths of up to 0.25 mm and the largest measurement range of 500 µm had to be used for scan lengths of 1.25 mm on the more irregular cores, and 2.5 mm on the 'flatter' APM sample plates. The relationship between PSV' and the microtexture statistics was found to improve slightly for profile measurements made at the 100 µm range but, surprisingly, no definitive measurement range or scan length was found to be preferable.
Effect of N	Correlations between the calculated texture statistics and (a) hours of APM-polishing for the APM plates, (b) PSV´ for the APM plates, and (c) HCV vehicle for the cores, were found to be largely independent of 'N' (the number of sampling lengths per assessment length L_n/L_c). This was somewhat surprising and the optimal value 'N' probably would be a balance between giving a greater population, and shorter effective profile length.
Medians or means	In an effort to reduce the effect of 'outliers', microtexture statistics and PSDs were calculated as the median of the profile statistics rather than as means (i.e. averages). Calculating and using medians rather than means were found to give very similar results, with medians being marginally preferable. For this reason, medians rather than means were used exclusively.

In summary, none of the measurement parameters summarised in Table A6.1 were found to have a clear effect on the relationship between microtexture statistics and (a) measured PSV', (b) the hours of APM-polishing, or (c) HCV vehicle passes.

Appendix 7: PSV microtexture profiles

No discernible difference between the microtexture profiles was obvious for unpolished, partially polished, or fully polished aggregates. Profiles tended to vary substantially, with some profiles exhibiting longer wavelength roughness, and others minimal long-wave roughness with substantial short-wavelength roughness. Likewise no discernible systematic difference was seen in profiles measured on pea-gravel and crushed faces.

An example profile is given in Figures A7.1 and A7.2 for a profile length of 2.5 mm (range = 500 µm), and Figures A7.3 and A7.4 for a profile length of 0.25 mm (range = 100 µm). Note that, while Figures A7.1–A7.2 and A7.3–A7.4 show profile measurements on the same aggregate in similar position, the exact measurement position is different.

In Figures A7.1 and A7.3, (a) shows the profile where the vertical scale has a greater resolution than the horizontal scale to show profile details, whereas (b) shows the same profile, but the horizontal and vertical axis have the same resolution and scale.

All the figures illustrate microtexture profiles for PSV' samples. Profiles for road-polished core samples are similar and are not shown here.

Parameters for Figures A7.1 and A7.2

Source quarry:	Pound Road, Fulton Hogan
Composition:	Sealing Chip
PSV'-polishing:	3 hours of flour
Chip grade:	4
Filtering:	none
Evaluation length:	2500 μm
Range:	500 μm
Ordinate spacing:	0.5 μm

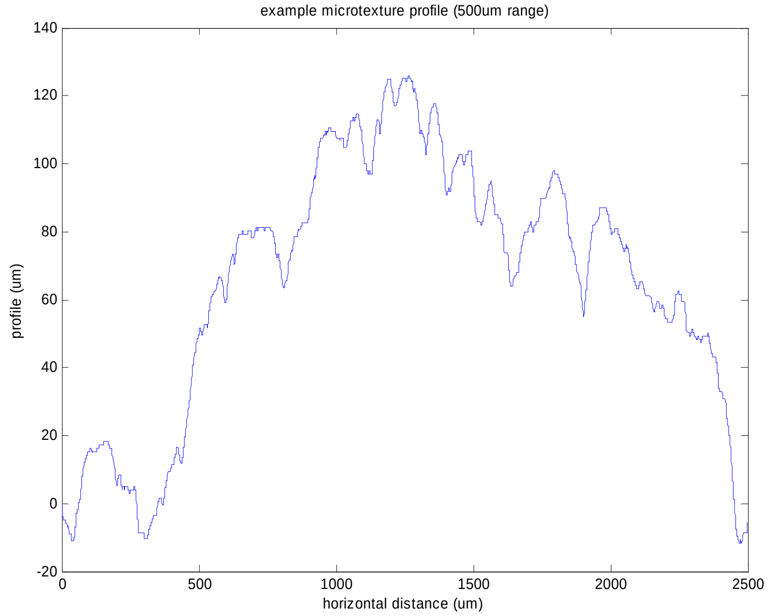

Figure A7.1 Example microtexture profile (axes not scaled equally): 500 μm range.

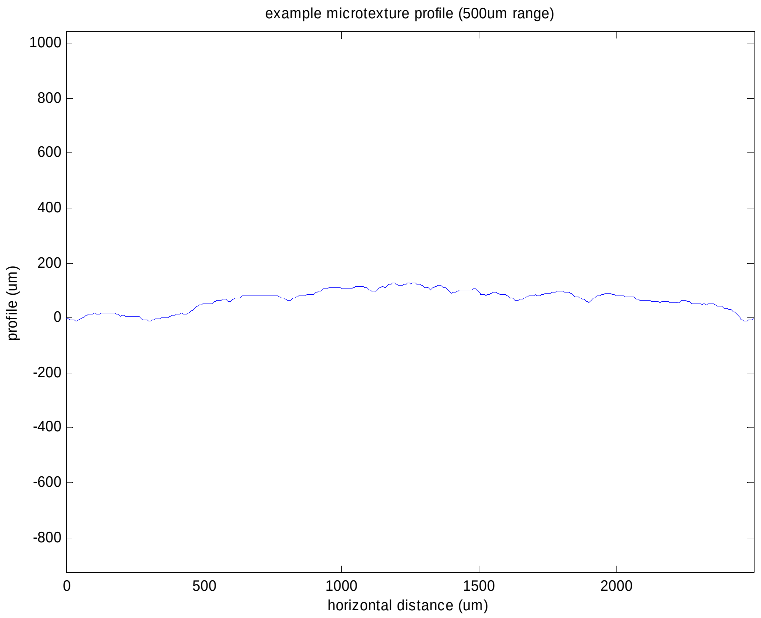

Figure A7.2 Example microtexture profile (axes equally scaled): 500 μm range.

Parameters for Figures A7.3 and A7.4

Source quarry:	Pound Road, Fulton Hogan
Composition:	Sealing Chip
PSV'-polishing:	3 hours of flour
Chip grade:	4
Filtering:	none
Evaluation length:	250 μm
Range:	100 μm
Ordinate spacing:	0.5 μm

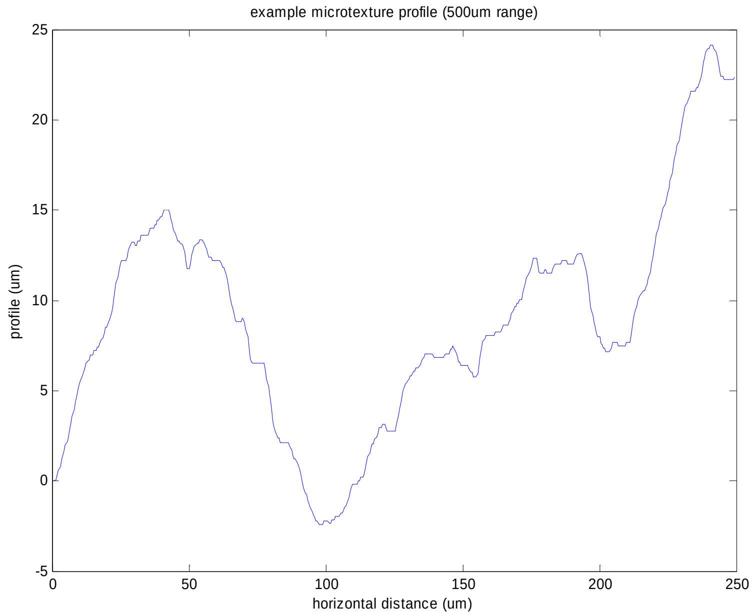

Figure A7.3 Example microtexture profile (axes not scaled equally): 100 μm range.

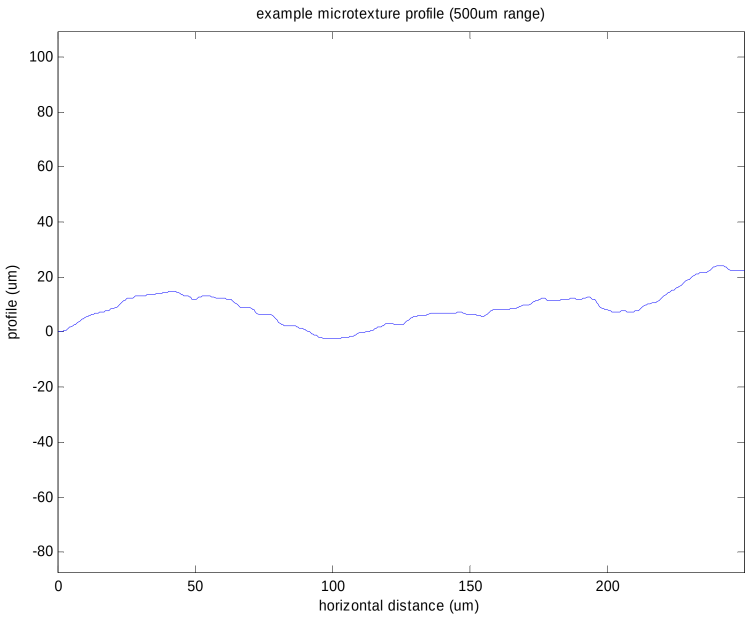

Figure A7.4 Example microtexture profile (axes equally scaled): 100 μm range.

Microtexture profile PSD

Note that all figures here shows PSD for scans made using the 100μm range. Scans made at the 500μm range are similar and are not shown.

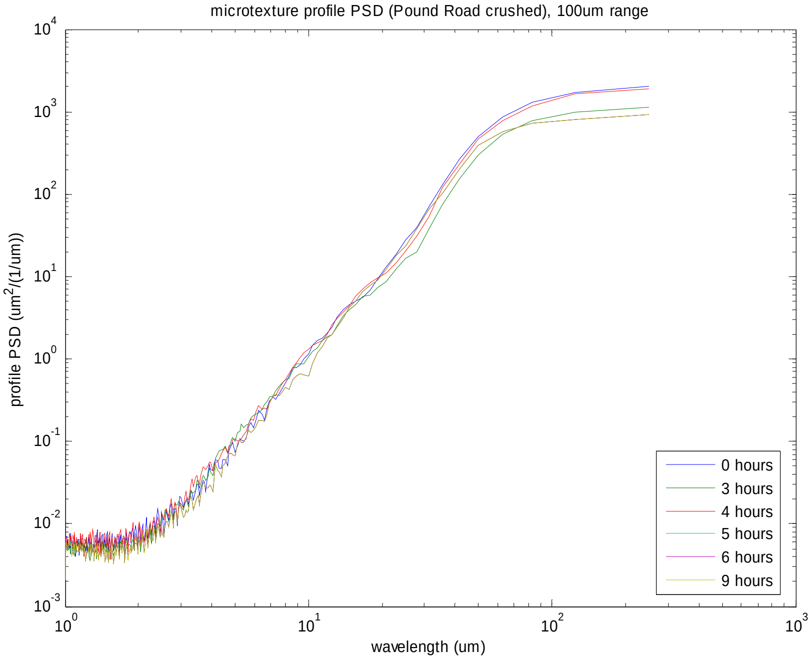

Figure A7.5 Microtexture profile PSD variation with APM-polishing (Pound Road crushed, 100 μm range).

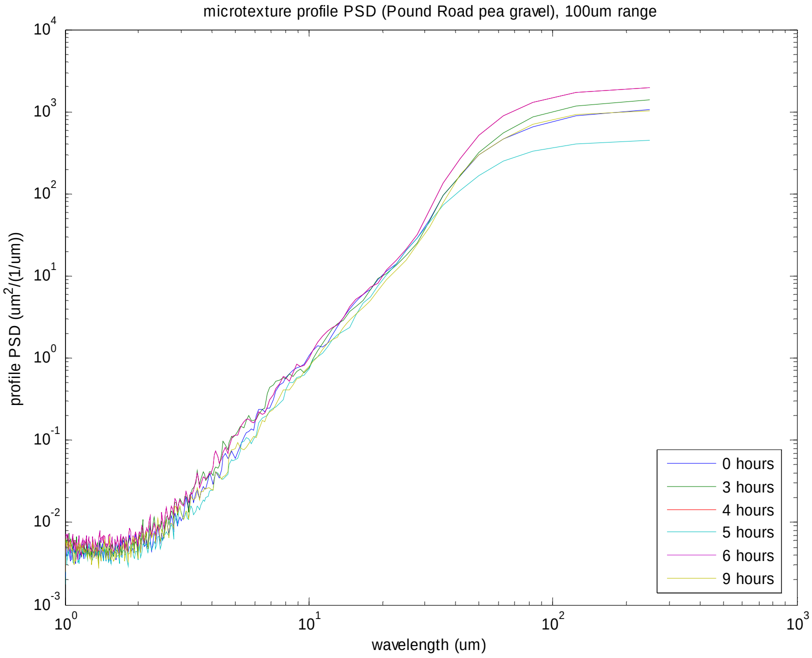

Figure A7.6 Microtexture profile PSD variation with APM-polishing (Pound Road pea-gravel, 100 μm range).

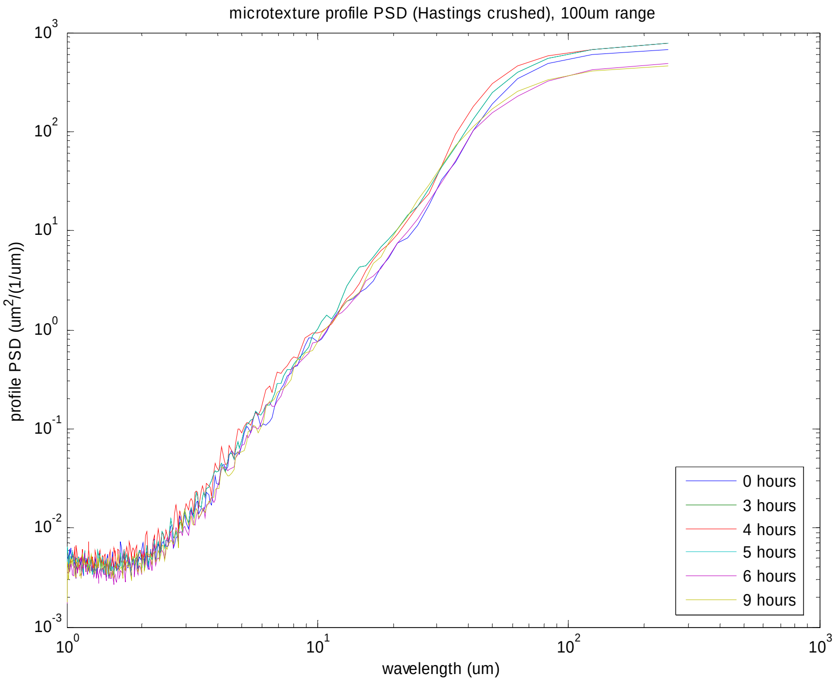

Figure A7.7 Microtexture profile PSD variation with APM-polishing (Hastings crushed, 100 μm range).

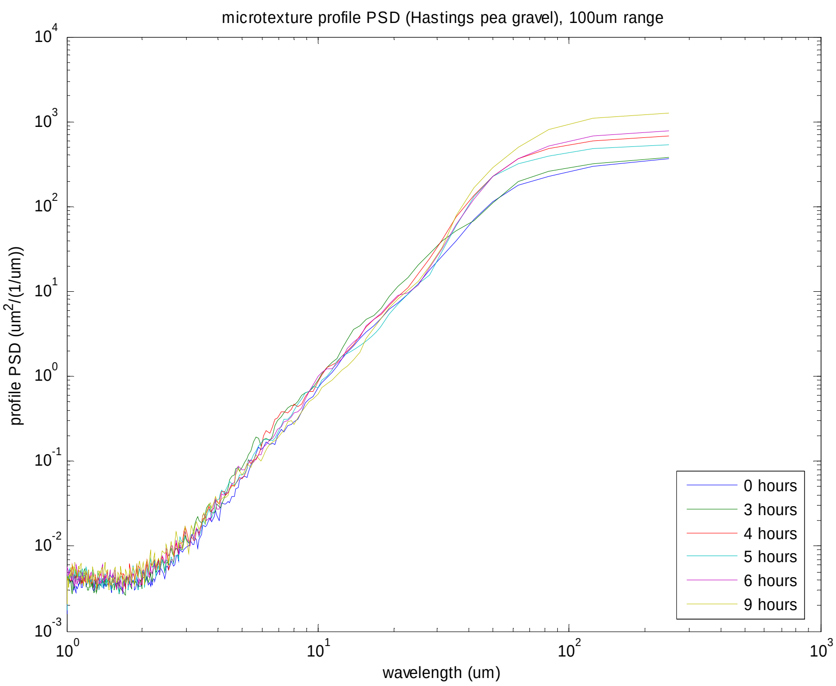

Figure A7.8 Microtexture profile PSD variation with APM-polishing (Hastings pea-gravel, 100 μm range).

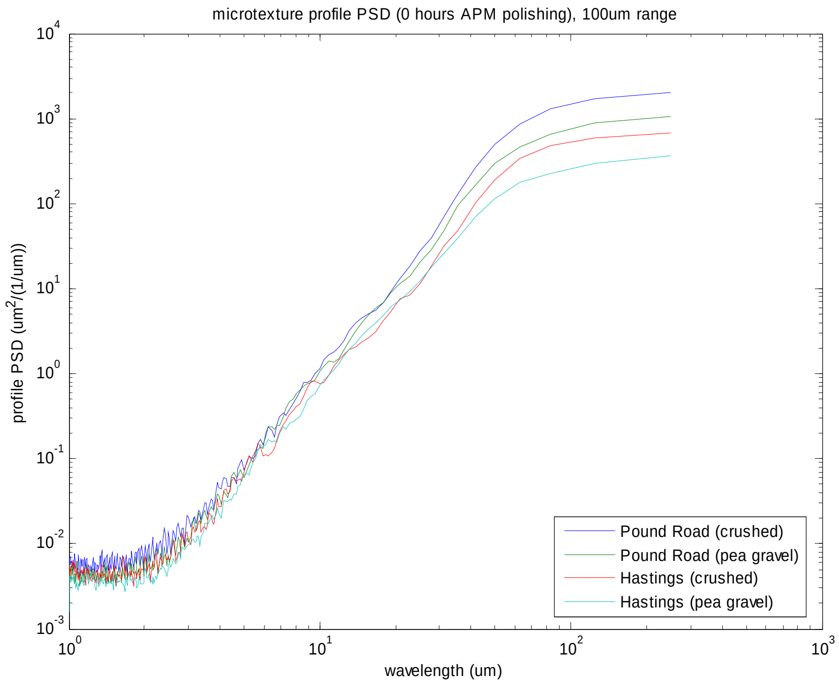

Figure A7.9 **Microtexture profile PSD variation with quarry and percent crushing (0 hours APM-polishing, 100 μm range).**

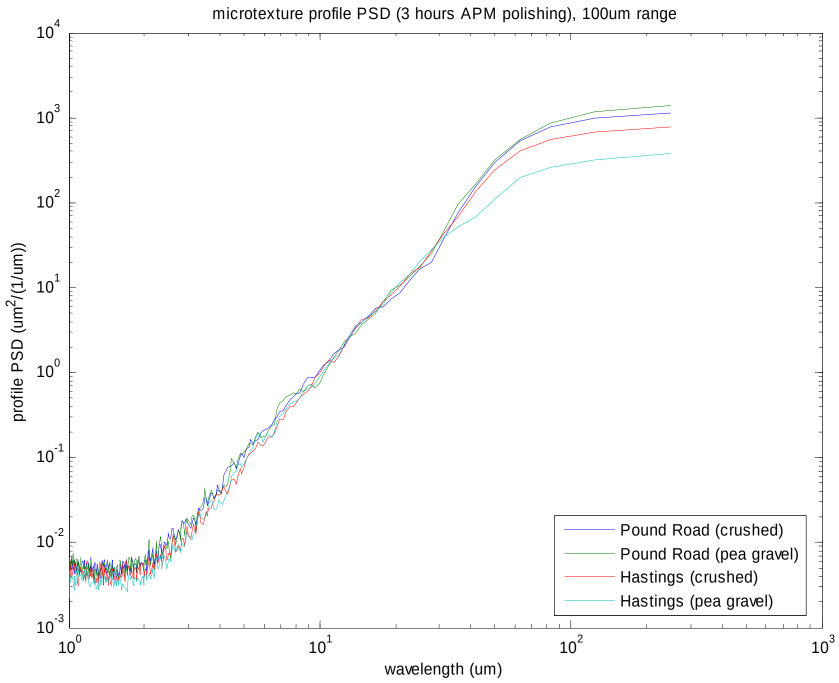

Figure A7.10 **Microtexture profile PSD variation with quarry and percent crushing (3 hours APM-polishing, 100 μm range).**

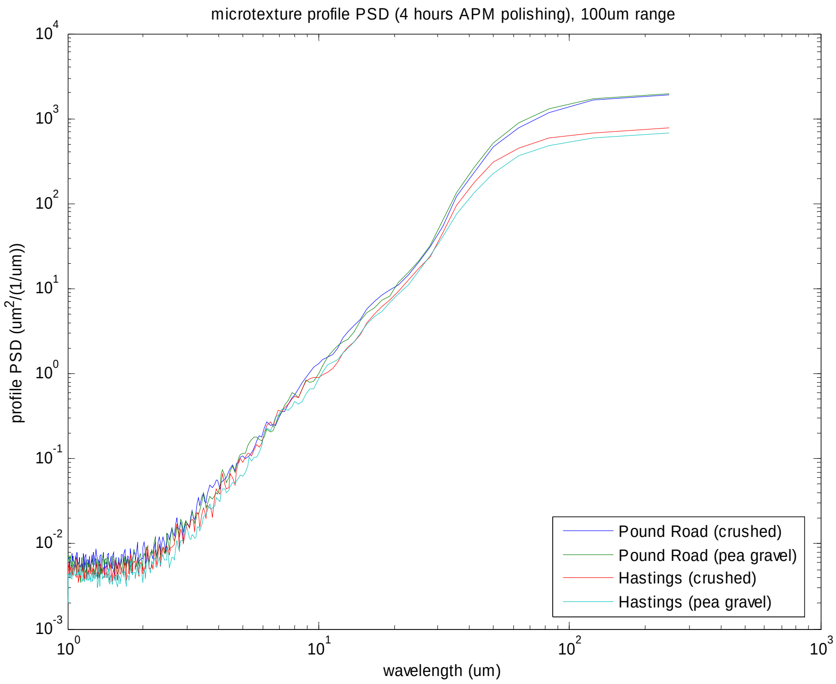

Figure A7.11 Microtexture profile PSD variation with quarry and percent crushing (4 hours APM-polishing, 100 µm range).

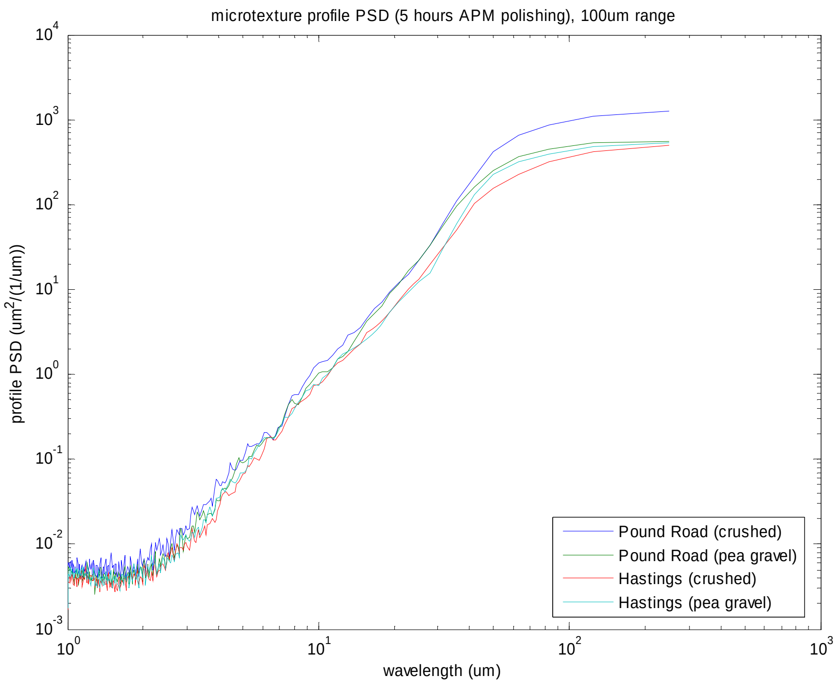

Figure A7.12 Microtexture profile PSD variation with quarry and percent crushing (5 hours APM-polishing, 100 µm range).

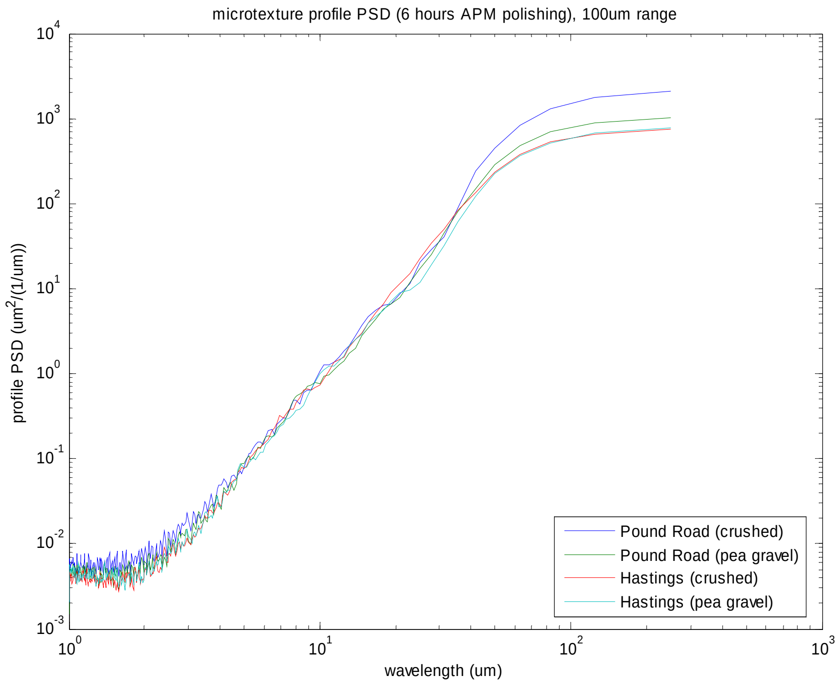

Figure A7.13 Microtexture profile PSD variation with quarry and percent crushing (6 hours APM-polishing, 100 μm range).

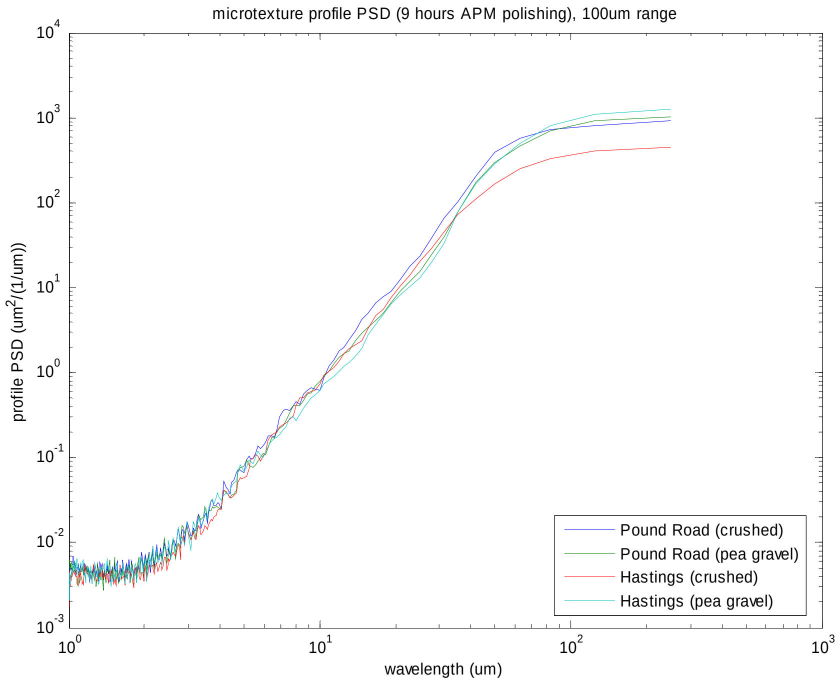

Figure A7.14 Microtexture profile PSD variation with quarry and percent crushing (9 hours APM-polishing, 100 μm range).

Appendix 8: Core sample selection

Possible errors in core sample selection would include:

- Inaccurate data in the RAMM database.
- Inaccurate estimation of the percentage of HCVs.
- Inaccurate estimation of AADT.
- A sudden change in AADT due to major new or altered roads.

The exact locations and number of HCV vehicle passes are given in Table A7.1.

Table A8.1 Core sample locations.

Site	Region	Quarry	SH	RS	Displace-ment (km)	Lane	HCV Vehicle Passes†	Core Size
C1	Canterbury	Pound Rd	1	365	11.3	L1	1,371,000	Ø8”
C2	Canterbury	Pound Rd	1	381	0.55	L1	1,539,000	Ø8”
C3	Canterbury	Pound Rd	1	381	10.55	L1	2,552,000	Ø8”
N1	Hawke’s Bay	Holcim®	2	661	14.39	L1	370,000	Ø6”
N2	Hawke’s Bay	Holcim®	2	678	6.00	L1	1,206,000	Ø6”
N3	Hawke’s Bay	Holcim®	2	678	8.815	R1	1,789,000	Ø6”

† The calculations for the total number of HCV vehicle passes assume:

1. the increase in traffic volume (AADT) is 2% per annum;
2. the cores were taken on 15/03/2004 (note the cores were not taken on this exact date, but during the month of March 2004).

Appendix 9: Core sample microtextures

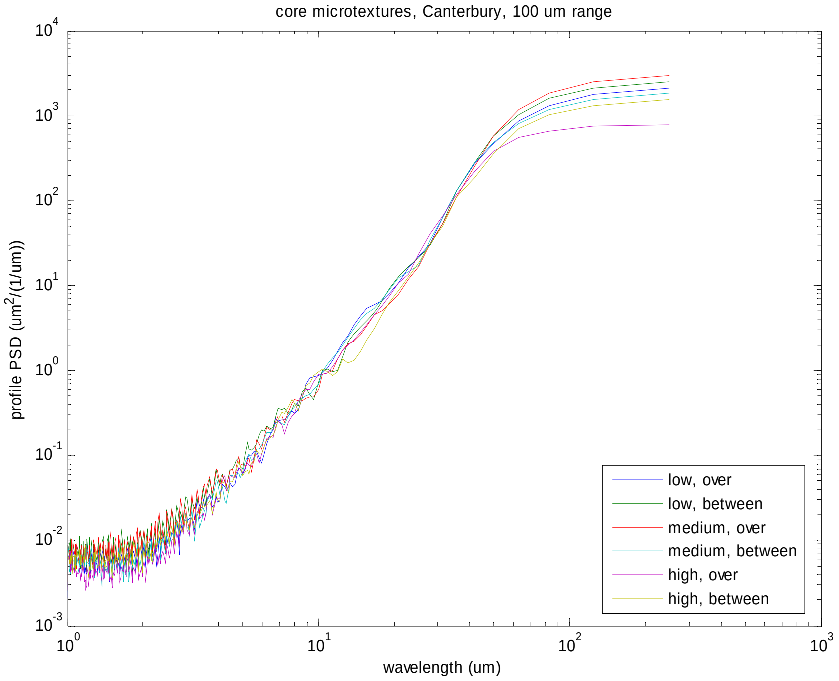

Figure A9.1 Microtexture profile PSD variation with road-polishing (Canterbury cores, 100 μm range).

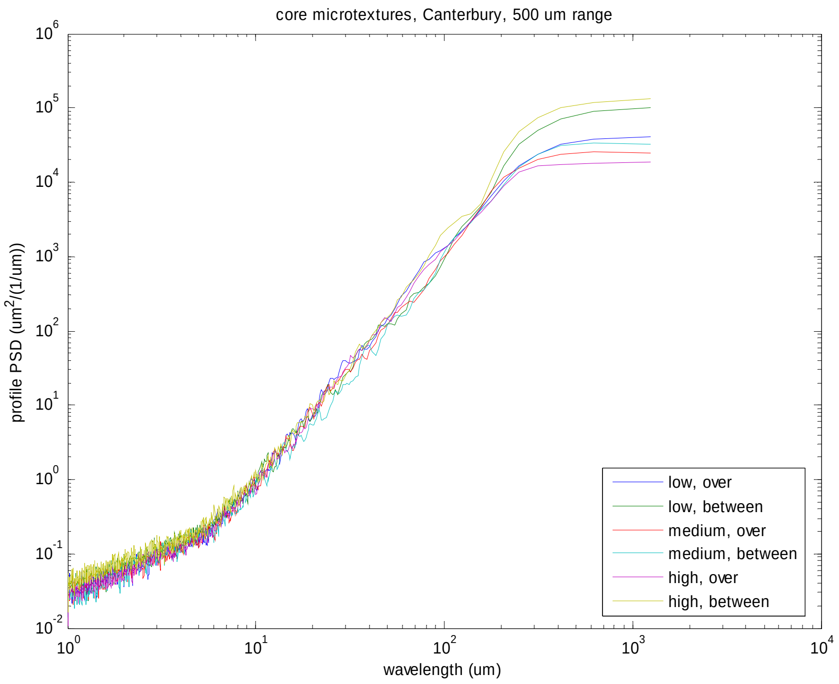

Figure A9.2 Microtexture profile PSD variation with road-polishing (Canterbury cores, 500 μm range).

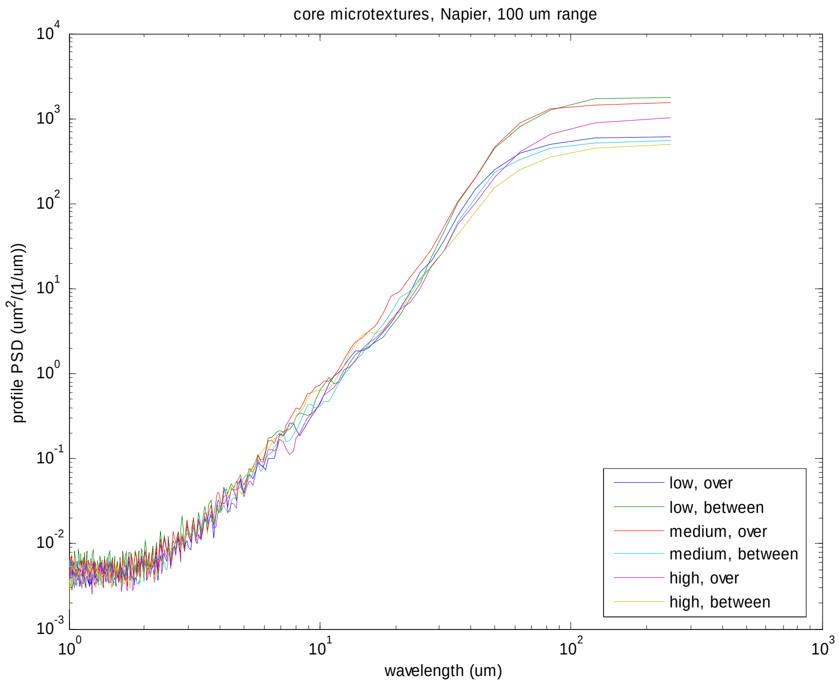

Figure A9.3 Microtexture profile PSD variation with road-polishing (Hawke's Bay cores, 500 μm range).

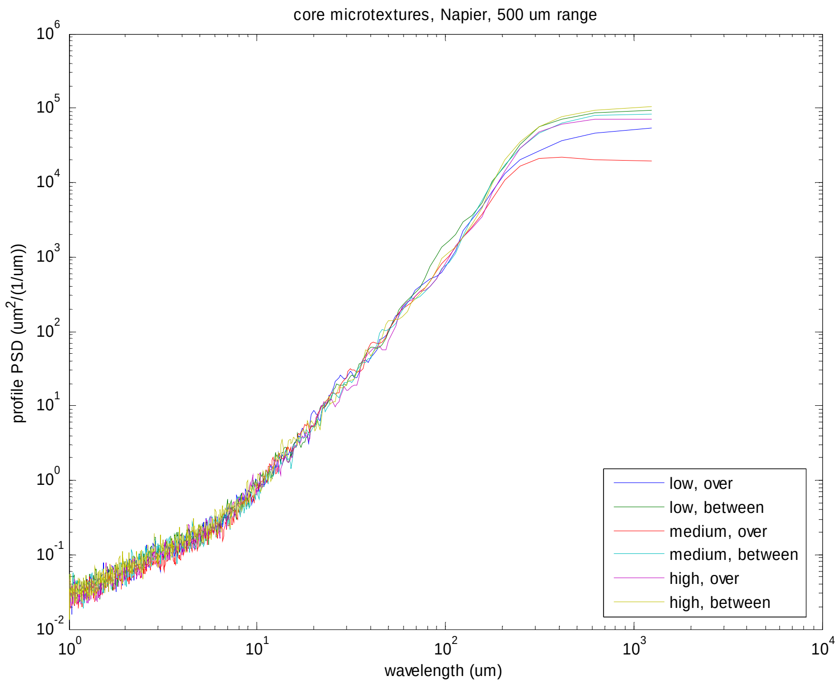

Figure A9.4 Microtexture profile PSD variation with road-polishing (Hawke's Bay cores, 500 μm range).

Appendix 10: GripTester measurements

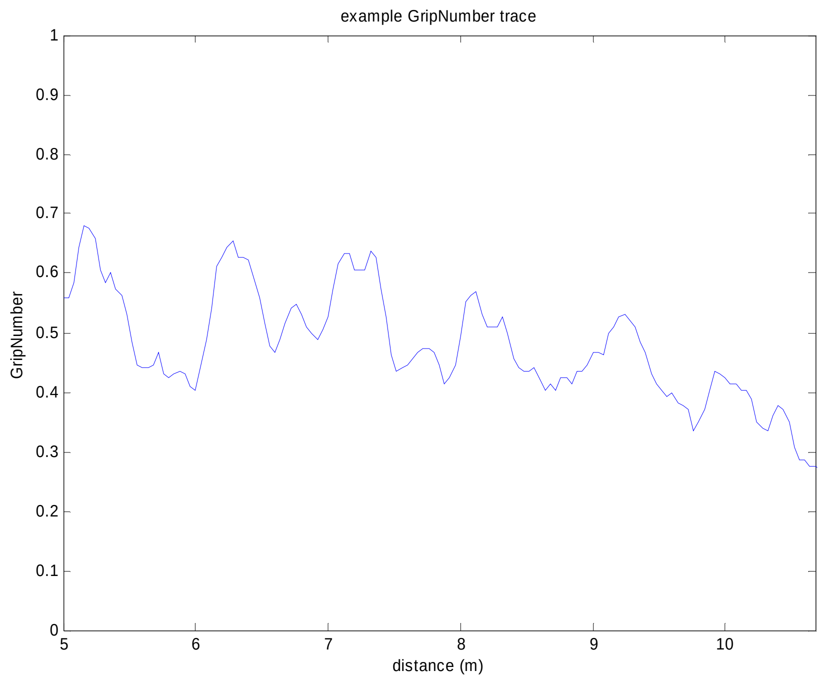

Figure A10.1 Example of a GripNumber trace.

Figure A10.1 shows an example of GripNumber data. The peaks in the trace coincide with GripTester bounce between plates. There are 11 plates in total.

Appendix 11: Model development

For this research, the increase in the adhesion component of friction caused by crushing can be calculated directly from the BPN of the uncoated and urethane plates. If the adhesion component at 0% crushing is arbitrarily taken to be zero, then any increase in friction is caused by hysteresis alone.

SFC predictions

Equation A11.1 equates the SFC and BPN using the harmonisation relations developed by PIARC (1995):

$$0.03258 \quad + 0.8717 \quad \frac{SFC}{0.78} \; e^{\left(\frac{50\sin(20) \quad - 60}{9.74 \quad + 104.71MPD}\right)} = 0.0436 \quad + 0.00953 \quad BPN \quad e^{\left(\frac{10 \; - 60}{9.74 \quad + 104.71MPD}\right)}$$

Equation A11.1

where:

SFC = SFC Sideways Force Coefficient (the friction coefficient measured by the SCRIM. For this application, the survey speed is taken to be 50 km/h)

MPD = Mean Texture Depth (mm)

BPN = British Pendulum Number

In the absence of laser-derived MPD measurements, texture depths were determined using the sand circle technique. The formula used was MTD = $57300/Ø^2$. Results are shown in Table A11.1.

Table A11.1 Texture depths.

% Crushed Chip	Quarry	Sand Circle Diameter, Ø (mm)	Mean Texture Depth, MTD (mm)
0	Pound Road	121	3.91
50	Pound Road	111	4.65
70	Pound Road	119	4.05
80	Pound Road	117.5	4.15
90	Pound Road	115	4.33
100	Pound Road	114	4.41
average			**4.38**

Potential differences in predicted and actual skid resistance

Table A11.2 Limitations of the laboratory tests.

Test Method	Limitation of Laboratory Tests	Consequence	Summary
BPN tests were carried out using laboratory prepared chipseal surfaces rather than actual cores taken from roads.	Aggregate packing is 'looser' than would be typical of chipseals found on the road.	The adhesion component of BPN friction (μ_a) measured by the BPT increases with contact area (FWA, 2003). Given that contact area increases with aggregate density, the BPN of the laboratory test plates might be less than for road surfaces.	The variation in BPN for a doubling of contact area is approximately 3 BPN (Fwa et al. 2003). The change in BPN going from 0%-100% crushed chips will be much less, and is estimated negligible.
		Both the constant (μ_c) and variable components of hysteretic friction ($\Delta\mu_v$) measured by the BPT would be expected to increase with aggregate density (Fwa et al. 2003; Liu 2004). Therefore the BPN of the laboratory test plates might be less than for road surfaces.	The variation in BPN for a doubling of aggregate spacing from a gap width of 2.5 mm to 5.0 mm is approximately 2.5 BPN (Fwa et al. 2003). The change in BPN in going from 0%-100% crushed chips will be less, and estimated negligible.
	The base surface for the laboratory plates is flat, whereas in practice a chipseal would be laid on a textured surface (either basecourse or overlaid on a previous surface).	The upper level of the aggregates is not as uniform in height on the laboratory plates as would be obtained for road surfaces. The contact area of the laboratory plates would therefore be less than the contact area on roads.	As above.
	The base surface for the laboratory plates is rigid, whereas in roads the base surface would be expected to deform under the action of chip rolling.	The upper level of the aggregates is not as uniform in height on the laboratory plates as would be obtained for road surfaces. The contact area of the laboratory plates would therefore be less than the contact area on roads.	As above.

Test Method	**Limitation of Laboratory Tests**	**Consequence**	**Summary**
BPT tests continued:	The aggregate was 'rolled' using a flat-sided wooden block rather than vehicle tyres.	The upper level of the aggregates is not as uniform in height on the laboratory plates as would be obtained for road surfaces. The contact area of the laboratory plates would therefore be less than the contact area on roads.	As above.
	The binder level is probably less than for many road surfaces.	The BPT slider contacts only the upper part of a chipseal surface in a manner similar to that shown in Figure 7.1. Therefore the binder level is irrelevant provided it is below the level of the BPT slider.	The binder level for the laboratory plates is less than the height of the BPT slider. Therefore this source of error is not relevant.
	The chip was sieved before use (Pass = mm, Held = mm). The size of the aggregate (a) supplied and/or (b) used for plate construction might not be typical of that found on the road.	Hysteretic friction would be expected to increase with chip irregularity. Visual inspection indicated that the aggregate from Hastings Quarry was more irregular than aggregate from Pound Road.	The predicted trend of terminally-polished chipseals using aggregate from Hastings Quarry having greater friction than for chipseals using aggregate from Pound Road is purely due to hysteretic friction. This is related to the increased irregularity of aggregate from Hastings Quarry used for laboratory plate manufacture. The trends predicted may not be representative of those on the road if (a) the aggregate samples, or (b) the sieving method are not representative of what would be found on the road.
The model (Equation 9.3) is based on BPN tests only with SFC values being derived from these BPN results.	The slip speed is 10 km/h for the BPT and 17.1 km/h for the SCRIM. Correlations between the BPN and SFC will be limited in accuracy for this reason.	Given that adhesion friction reduces with speed, the contribution of hysteretic friction (F_h) as a proportion of adhesion friction (F_a) might be greater for the SCRIM than for the BPT.	The PIARC conversion reports good correlations between BPN and SFC (PIARC 1995).
The model has been calibrated using only grade 4 aggregate from Pound Road Quarry.	No comment.	No comment.	Based on BPN tests undertaken for this project, there is no clear relationship between chip grade and BPN (Figure 8.5).

Test Method	Limitation of Laboratory Tests	Consequence	Summary
The aggregate was thoroughly washed with water before tests.	No comment.	On the road, chipseal skid resistance (a) shows seasonal fluctuations, (b) varies with contaminants, and (c) varies with environmental conditions (precipitation, temperature, etc.).	By using laboratory tests, the mechanisms causing variation in skid resistance not due to percentage crushing can be controlled and/or eliminated. While the BPN measured in the laboratory will not necessarily be the same as that measured in the field using actual road surfaces in absolute terms, the trends of skid resistance variation with percent crushing in the laboratory will be clearer.
The model is based on BPN tests of new and unpolished aggregate.	Observation of polished cores (e.g. Appendix 4) shows that sharp asperity tips become rounded and flat with the action of HCV-polishing.	The extent to which sharp asperities at the junction of crushed-crushed or crushed-uncrushed faces polishes is likely to depend partly on the durability of the aggregate. This may be reflected in tests such as the Aggregate Abrasion Value test (AAV, BS 812, Part 113: 1990).	The assumption that the variable component of hysteretic friction (μ_v) is zero for terminally-polished chipseals may not be true (i.e. there might be an increase in the variable hysteretic friction component using crushed chips as opposed to uncrushed chips.) The assumption that μ_v = 0 represents the 'worst case' as far as reduction in skid resistance due to polishing is concerned.

Appendix 12: Angularity test results

Angularity tests were based on the British Standard BS 812: Part 1:1975, 7.5 *Determination of angularity number.*

In accordance with the Standard, equipment used was as follows:

Metal cylinder: 3-litres
Scales: Sartorius® 0-60 kg digital scales
Tamping rod, Scoop, and Sieves

Before testing, the aggregate was sieved, washed, and dried. A total of six determinations were made for each aggregate sample. In total, three aggregate samples were tested. These results of tests are shown in Table A12.4 below:

Table A12.4 Angularity test results.

Source Quarry	Sieve Size: pass, held (mm)	Percent Crushing (%)	M, test 1	M, test 2	M, test 3	M, test 4	M, test 5	M, test 6	M, mean
Hastings	9.5, 6.7	0	5445	5398	5416	5422	5400	5435	5419
		50	5185	5198	5211	5205	5252	5221	5212
		75	5132	5108	5112	5130	5165	5157	5134
		100	5025	5024	5042	5064	5093	5024	5045
Pound Road	9.5, 6.7	0	5522	5553	5506	5538	5558	5533	5535
		50	5329	5317	5330	5315	5350	5352	5332
		75	5222	5225	5216	5219	5202	5217	5217
		100	5078	5091	5070	5117	5097	5090	5091
	13.2, 8.0	0	5475	5478	5488	5521	5500	5532	5499
		50	5314	5334	5347	5333	5358	5334	5337
		75	5192	5249	5223	5229	5229	5223	5224
		100	5028	5078	5074	5091	5118	5092	5080

where:
M = mass of compacted aggregate (g)

BS 812: Part 1:1975, 7.5 specifies that three tests should be carried out, and that the mass M should not differ from the mean by more than 25 g, otherwise three additional tests are to be undertaken. For the work described here, six tests were undertaken to determine the likely range of values of M. The mean value reported in Table A12.4 is that for six tests. The variability of three consecutive tests is generally more than 25 g and so does not meet the requirements of the Standard. This variability was considered to be caused by:

1. The operators lack of familiarity with the test.
2. Inconsistent decisions on when the container was fill with aggregate.

Appendix 13: Microtexture statistics

The roughness average (R_a) is the most commonly used statistic for comparing the roughness of surfaces and was chosen for comparing the microtexture of the APM-polished sample plates and traffic-polished cores. While all the statistics detailed by Cenek et al. (2004) were used in this study, R_a only is illustrated here.

The scan lengths used are recorded in Table A13.1.

Table A13.1 Microtexture profile measurement parameters.

Sample	Scan length (mm)	Range (μm)	N
APM	0.25	100	1
Road cores	0.25	100	1
APM	2.50	500	2
Road cores	1.25	500	1

Figure A13.1 compares the microtexture of aggregate for a Surtronic 3+ range setting of 100 μm. Figure A13.2 makes the comparison for a setting of 500 μm.

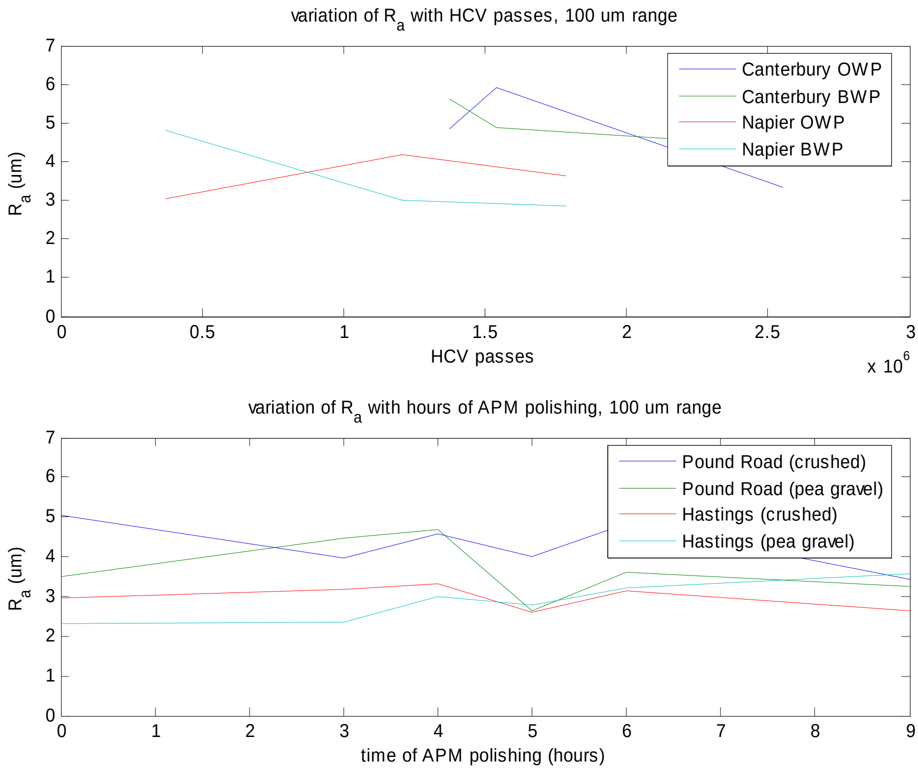

Figure A13.1 Variation of R_a with HCV-polishing (top) and hours of APM-polishing (bottom), 100 μm range.

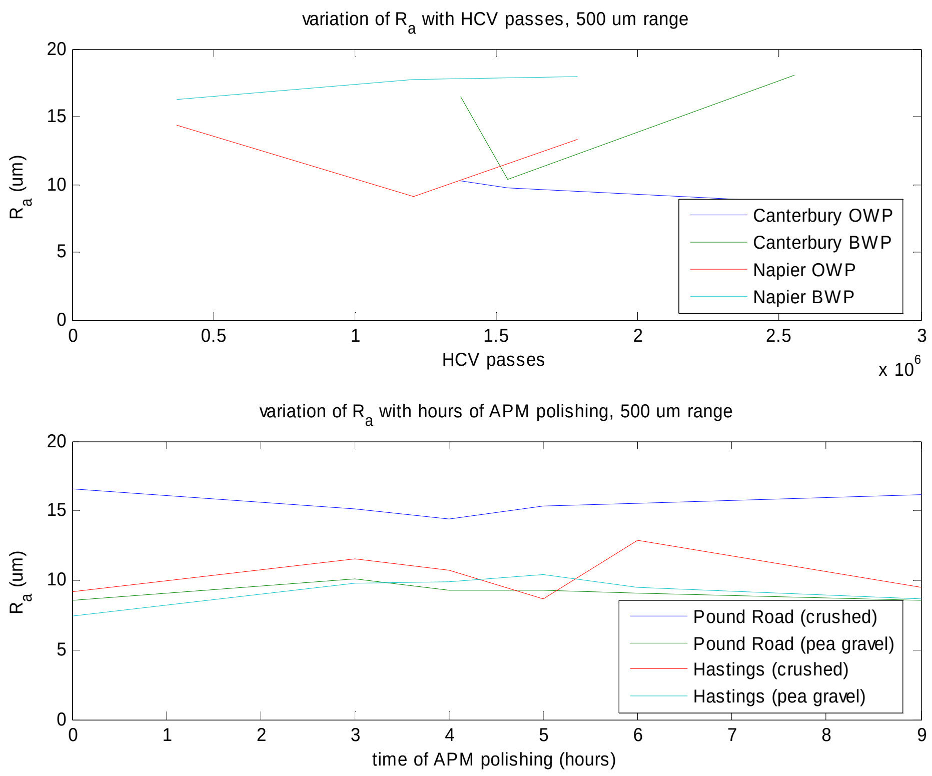

Figure A13.2 Variation of R_a with HCV-polishing (top) and hours of APM-polishing (bottom), 500 μm range.

It was expected that:

1. The measured microtexture statistics (R_a for Figures A13.1 and A13.2) and PSD (Appendices 7 and 9) would increase with polishing (either APM or HCV).
2. Microtexture profile PSD (Appendices 7 and 9) might exhibit peaks coinciding with inclusion size, grain size or emery grit size.

Both of these expectations were not born out in practice and it was concluded that:

1. Microtexture profiles can be used to differentiate between aggregates, but not degrees of polishing for the same aggregate.
2. The scans with a length of 2.5 mm (range = 500 μm) are better at distinguishing between aggregates from different sources than scans with a length of 0.25 mm (range = 100 μm).
3. Aggregate asperities with wavelengths between 0.01 mm and 0.1 mm would appear to be larger in aggregate from Pound Road Quarry than from Hastings Quarry.
4. The microtexture of aggregate from Pound Road has a similar microtexture whether APM-polished or Road-polished.
5. The microtexture of aggregate from Hastings Quarry has more microtexture when APM-polished rather than road-polished.
6. Based on items 4 and 5, how an aggregate polishes on roads compared to polished in a PSV test may depend on the aggregate itself.

Appendix 14: Flow cone tests

Table A14.1 Flow cone tests.

Trial Number	Cone outlet Diameter, d (mm)	Aggregate Mass (grams)	Time (sec.)	Comment
1	31.0	9000	n/a	cone blocks intermittently
2	33.0	9000	n/a	cone blocks intermittently
3	34.0	9000	n/a	cone blocks occasionally
4	35.5	9000	n/a	cone blocks very occasionally
5	36.5	9000	n/a	cone blocks very occasionally
6	37.5	9000	n/a	cone blocks very occasionally
7	39.0	9000	n/a	cone blocks very occasionally
8	39.5	9000	n/a	cone blocks very occasionally
9	41.0	9000	n/a	cone blocks once
10	41.0	9000	n/a	cone blocks twice
11	41.0	9000	~10	cone doesn't block, rapid flow
12	41.5	9000	~10	cone doesn't block, rapid flow
13	41.5	9000	n/a	cone blocks once
14	43.0	9000	~10	cone doesn't block, rapid flow
15	43.0	9000	~10	cone doesn't block, rapid flow
16	43.0	9000	~10	cone doesn't block, rapid flow