TRAFFIC-SPEED MTD MEASUREMENTS OF ASPHALT SURFACE COURSES

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ABSTRACT

An important characteristic of a pavement surface is texture. Texture does relate to friction, noise and ravelling and does change over time due to aging, contamination and loss of aggregate. As such it is an important characteristic triggering maintenance measures when it does not meet the requirements anymore. The standard procedure is to measure texture based on the Mean Profile Depth (MPD), which is a single point measurement along a longitudinal track sampled at a high frequency. The actual requirement is a volumetric 3D based result to be directly representative for the characteristics required without the need of a conversion from a 2D based test.

This study was conducted to validate at traffic-speed measured MTD's using a Laser Crack Measurement System (LCMS) with the results of the static Sand Patch Test Method (SPTM). The LCMS does measure the volumetric properties of the road surface continuously over its full width and length based on 250 x 250mm squares. The evaluation did include static SPTM's, a static ELAtextur device measuring MPD and a traffic-speed road surface profiler equipped with a texture laser measuring MPD as well. The test were conducted over different time periods and multiple runs at a validation site used for calibrating testing equipment operating at roads in Singapore.

This paper discusses the results of the equipment used and does show the very good correlation between the SPTM results and the MTD's based on the LCMS device. A major advantage is that no conversion is required as the volumetric MTD is a direct output. The LCMS based automated MTD analysis is a machine based result not influenced by a human factor such as the SPTM. The results allow as well the automated analysis of loss of aggregate which is a major advantage in rating the severity and extent of ravelling in comparison to the non-consistent wind-screen surveys and manual rating of collected images. However, the next generation LCMS sensors will require an improved vertical resolution to improve on the reliability of ravelling for finer textured surface courses.

Keywords: MTD, MPD, SPTM, LCMS, ELAtextur

INTRODUCTION

The texture of a surface layer is an important mechanical characteristic related to noise, friction and reduction of spray. The specific texture based wearing courses such as Stone Mastic Asphalt (SMA), Porous Asphalt (PA), Open Graded Friction Courses (OGFC) or Noise Reducing Road Surfaces (NRRS) do all have one major disadvantage: their service life is reduced due to ravelling. This is the main distress type that dictates the timing of maintenance. However, the development of ravelling is not linear model but closer to an exponential development of loss of aggregate which does make the prediction of the timing of maintenance very difficult. In addition to this the quantification of the severity of ravelling using a manual visual distress approach or using pictures is far from accurate and does lack consistency. This makes it as well difficult to notice the onset of ravelling. Each wearing course has its own surface characteristics (finger print) which make it almost impossible to notice a change when using a manual based approach.

The picture shown in Figure 1 does make the rating of severe ravelling not that difficult but properly rating all the severity levels of ravelling of different surface courses does make it clear that the actual practice is much more difficult using a 'manual' based approach.

Figure 1: Ravelling Expressway Singapore

Ravelling is the loss of aggregate due to trafficking and /or environmental conditions. But the onset of ravelling can as well be caused by segregation which does already take place during construction (McGhee *et al*., 2003). Uniformity of production is as such not part of the compliance testing based on an objective procedure. Figure 2 taken from (McGhee *et al*., 2003) shows a clear picture of what is meant by segregation.

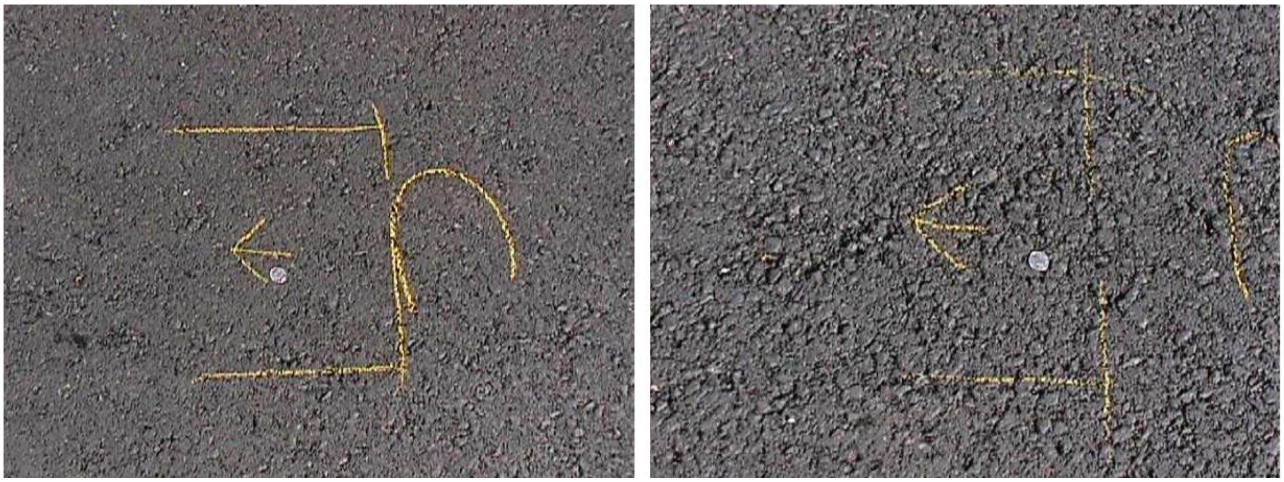

Figure 2: Segregation example (right)

Segregation is difficult to spot but LCMS data collected at roads in the Netherlands do show that it does exist but goes quite often unnoticed and when detected will be classified as ravelling. The multiple 3D transverse profiles collected at an interval of 2.5-5mm by the LCMS sensors do allow for measuring texture as a volumetric characteristic instead of the by default used single profile longitudinal texture lasers. Figure 3 does show the vehicle with the LCMS set-up at the back.

Figure 3: Vehicle with LCMS Sensors

The surface images produced by the LCMS analysis software are (see Figure 4):

1. Intensity (2D): the reflective properties of the pavement surface.
2. Range: the distance from the sensors to the road surface corrected to the same reference level.
3. 3D: merging the Intensity and Range images.

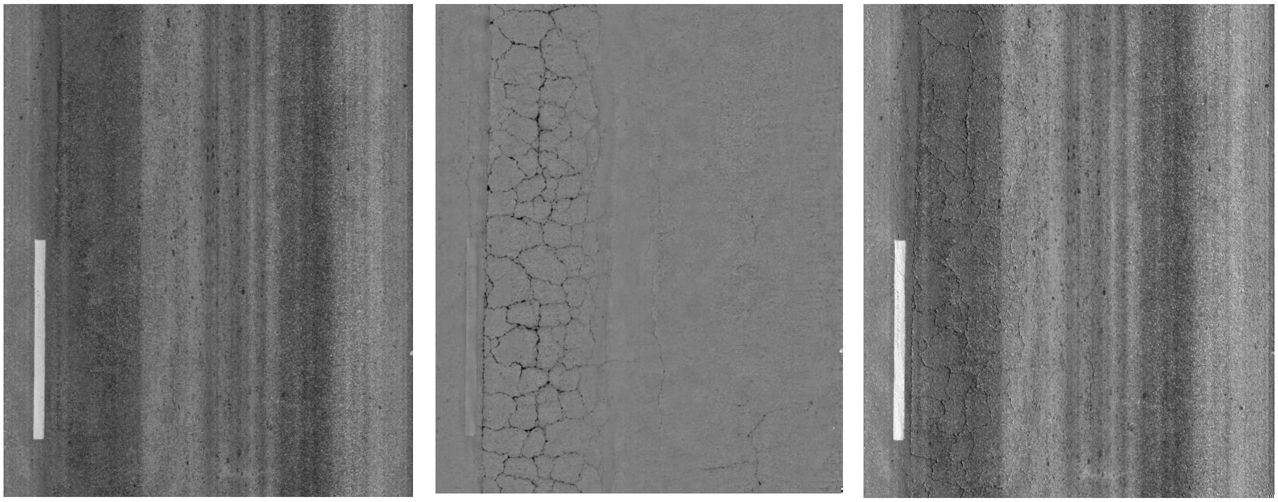

Figure 4: From left to right – Intensity/Range/3D pictures

The greater the distance from the sensors to parts of the pavement surface the more black the grey-scale range picture will be. The range image is the perfect tool to observe cracks, loss of aggregate (ravelling) and segregation. Figure 5 does give an example of segregation of a PA and shows the same lane but in between the pictures is about 25 meter. The segregation, visualised by the black speckles, had a length of about 10 meter but did grow in size each consecutive year as prove that segregation does trigger ravelling at an early age.

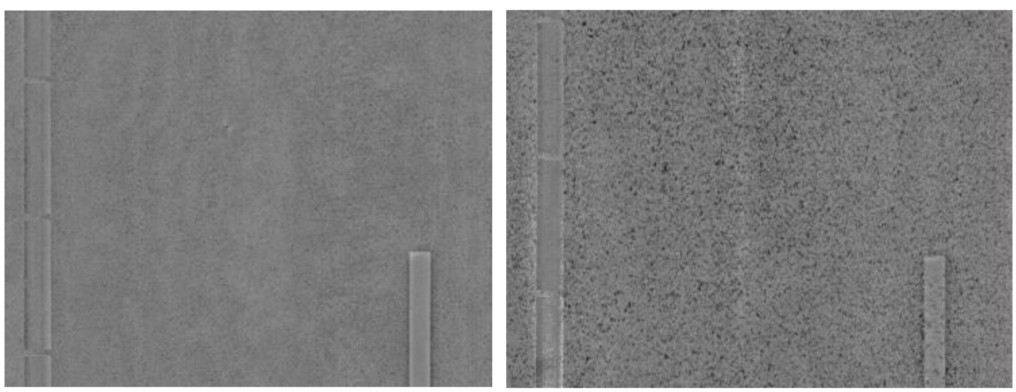

Figure 5: Segregation on the right

The time between detecting ravelling and speed at which it will develop into a serious defect is quite often very short. This does make the accuracy of comparing differences between successive surveys extremely important requiring a (3D) procedure to measure the level of detail of the surface to identify loss of stone (McRobbie *et al*., 2015).
The only way achieving this is using a volumetric mechanical based survey procedure to measure the condition of the surface objectively.

SAND PATCH VS LCMS COMPARISON

The SPTM (ASTM E965-96, 2006) is a static procedure for measuring the MTD by spreading a known volume of material over a pavement surface. The MTD is calculated based on the sample volume divided by the average diameter of the area covered by the material. Figure 6 shows a picture of the execution of the SPTM at the validation site.

Figure 6: SPTM in execution

According to (ASTM E1845-09, 2009) an Estimated Texture Depth [ETD], a value close to MTD, can be calculated based on the equation: ETD (MTD) = 0.2 + 0.8MPD to transform a 2D result into a volumetric SPTM result. Several publications can be found relating MPD’s to ETD’s, however number of publications does match the number of different relationships found which does show that this approach is not very accurate or relates only to the surface type used in the research.

The SPTM is a time consuming relatively inaccurate procedure requiring lanes to be closed for traffic and as such not very useful for measuring a change in the texture of a road surface over time. Twelve SPTM’s have been executed in the validation site having a length of 300 meter, split over the wheel tracks and in-between the wheel tracks. Figure 7 shows the location of SPTM No 8 and the pavement surface automatically divided in 250 x 250mm squares over its total width and length.

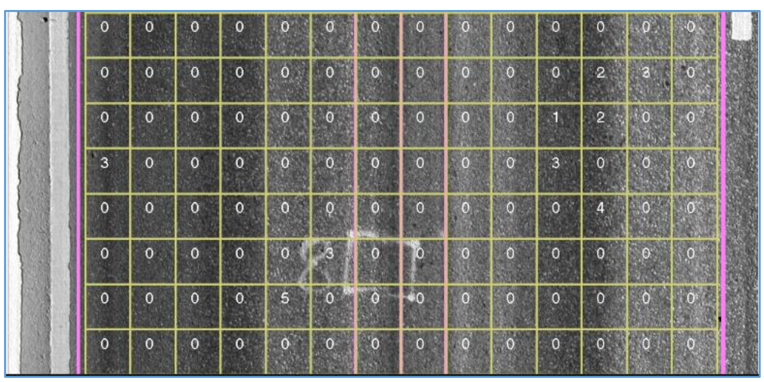

Figure 7: Location of SPTM No 8

The LCMS automatically detects the marking to locate the squares always at the same transverse location independently of the lateral wander. The index number in the squares does in this case relate to the presence of ravelling. The SPTM as well as the ELAtextur results have been compared which those of the LCMS in calculating the MTD’s of 250 x 250mm squares as shown in Figure 8. The computed R^2 of respectively 0.889 and 0.881 showing a very good linear correlation when taking into account the relative inaccurate procedure of the SPTM plus conversion of the ELAtextur MPD into MTD and the slightly larger area of the LCMS squares.

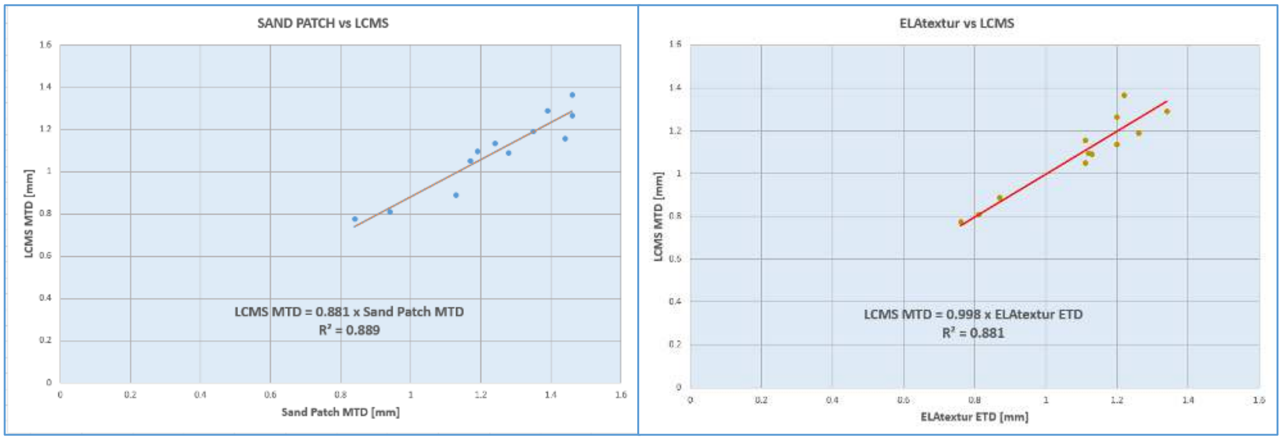

Figure 8: Correlation LCMS MTD with SPTM and ELAtextur

LCMS BASED MTD DATA

The width of a lane can be divided into multiple longitudinal bands based on usage. For instance AASHTO is recognising the central band, both wheel tracks and the bands outside the wheel tracks resulting into 5 bands. By default the central band width is 1000mm and both wheel tracks 750mm, however in the software analysing the LCMS data this can be adjusted transversely based on the requirements. The output of the analysis (MTD, MPD, and Ravelling) can be averaged longitudinally for every 250mm. To match the position of a texture point laser in the Road Surface Profiler (RSP) attached to the front of the vehicle the central band width has been adjusted to 1500mm and the wheel track bands to a width of 250mm as shown in Figure 9. Figure 9 is overlain by the grid shown in Figure 7 to get output data per 250mm square.

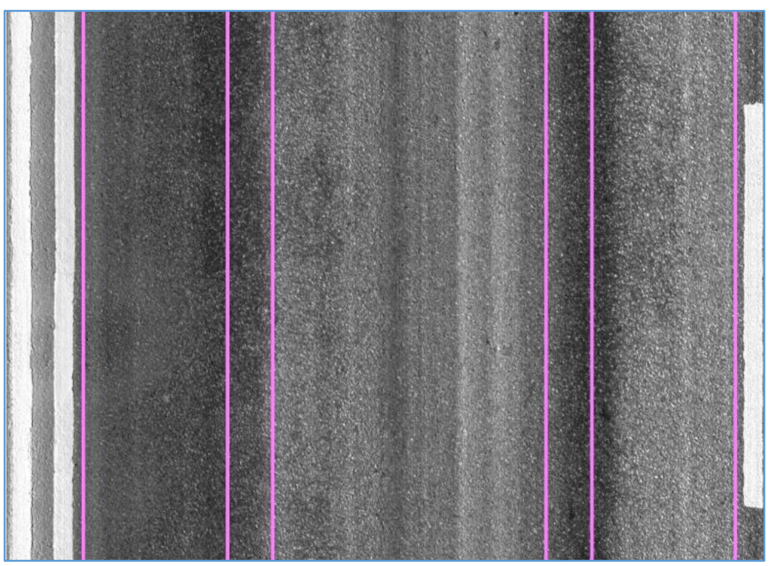

Figure 9: Bands as shown by the purple lines

To get a better insight in the repeatability of multiple LCMS runs over the same road section the results of the MTD's of 5 runs sampled at the validation site are shown in Figure 10. These MTD results are calculated for the left wheel track band (nearest to the verge) shown in Figure 9 being the average of a 250x250mm square.

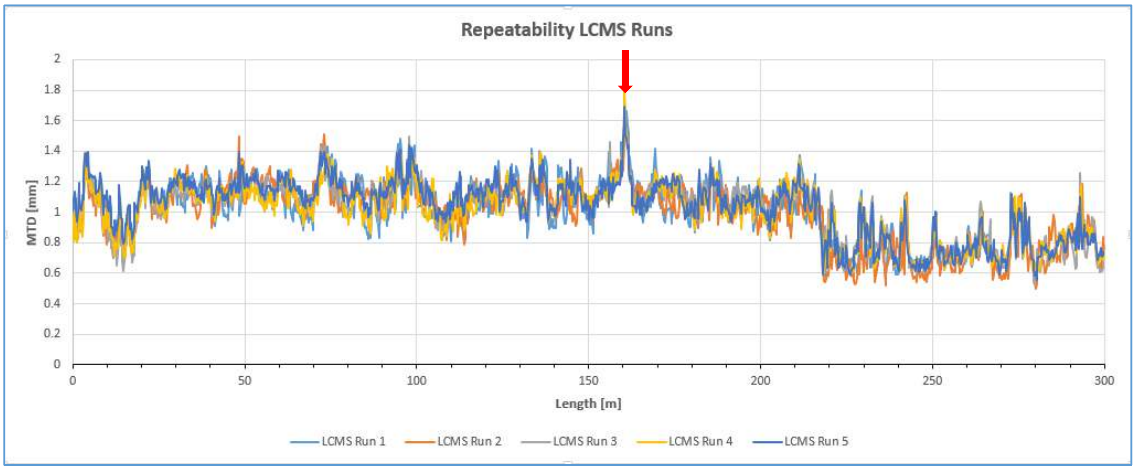

Figure 10: MTD results of 5 runs validation site

The quality of the repeatability is checked by comparing each run against the average of all runs. This does show that all runs are comparable having a very good repeatability with R^2-values of respectively 0.854, 0.831, 0.900, 0.917 and 0.936. Figure 11 does show the repeatability of run 5 as example.

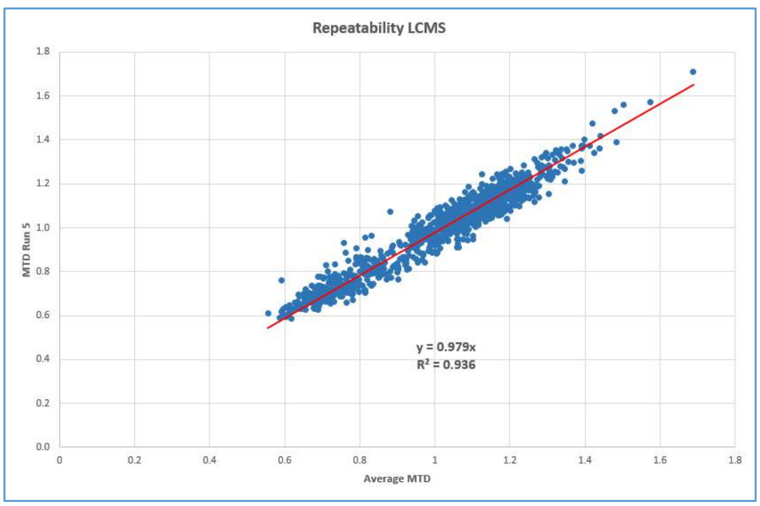

Figure 11: Repeatability MTD run 5

The validation site does show that the wearing course is having two different textures types. The 3D images of the LCMS do make this clear by a construction joint at approximately 218m which was difficult to see based on ROW images only. Of the 12 SPTM's 3 are located in the section after 218m (the 3 lowest MTD values shown in Figure 8).

The validation site has a dense mix surface course showing only locally loss of aggregate. There was however one distinct small location at approximately 160.5m in the left wheel track (band 2 250mm wide) showing a higher severity level of ravelling. Figure 13 does show this location with in the top part a camera picture of this location, the range image in the middle part and the range image overlaid by the 250mm ravelling indices (94) as the bottom part. Figure 10 shows the same location as a peak in the MTD-values (see red arrow) at a distance of approximately 160.5m from the start of this section.

Figure 13: Detected ravelling

A second set of data was collected at the Expressway shown in Figure 1 having an OGFC as surface layer. There was a very pronounced sub-section showing high severity ravelling. In Figure 14 the measured texture is presented based on the MTD as sampled by the LCMS.

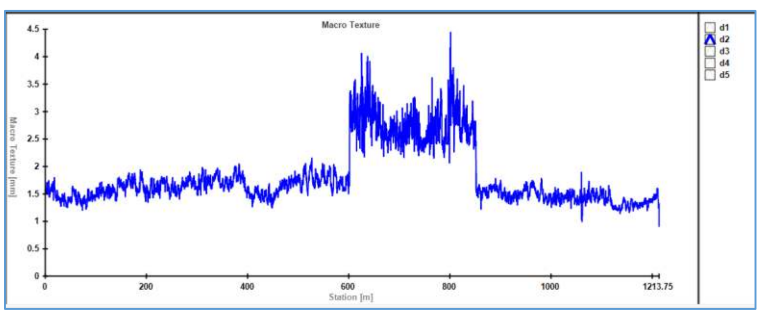

Figure 14: LCMS MTD

To have a check on the repeatability of this OGFC surface course over the same road section the results of the MTD's of 5 runs over a length of 300m (375-675m according to Figure 14) are shown in Figure 15. The LCMS based MTD results are calculated for the same left wheel track band (nearest to the verge) showing a very good repeatability (average R^2 around 0.95). The sub-section with the high severity ravelling is of course showing more variation in the results.

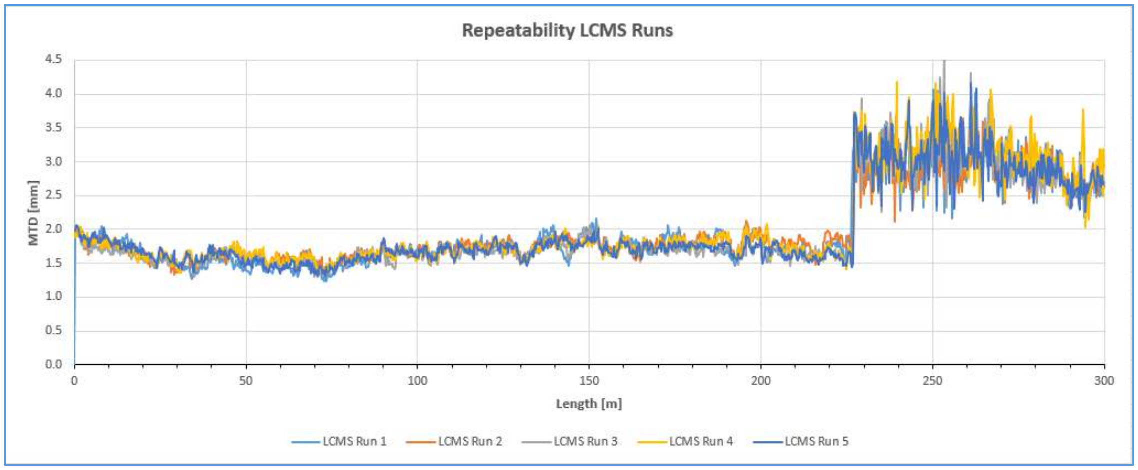

Figure 15: MTD results of 5 runs sampled at the Expressway

The LCMS data of the OGFC surface course has been analysed for rating the level of ravelling. In Figure 16 a range image is shown located in the first 225 meter of Figure 15. The top part does show the range image without overlay whereas the bottom part is showing the ravelling index per 250 square. The range in index values is representative for the variation in texture. A shift factor has to be used to correct the index into an absolute level of ravelling which will require the ‘finger print’ of the type of surface course as well as its initial texture value/porosity.

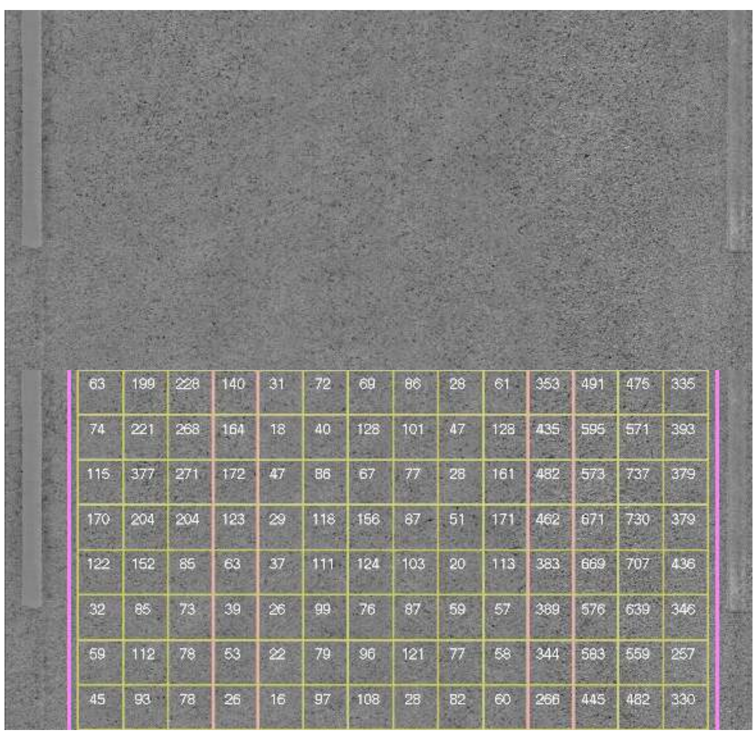

Figure 16: ‘Non-ravelled’ range image

Figure 17 does show the same OGFC but at the transition of the ‘non-ravelled’ to the ravelled sub-section (see Figure 1). The majority of the types of surface course do have a MTD ranging between 0.5 and 2.0mm being shifted by the level of ravelling. In a process of surveying a road network data of different types of surface courses with a difference in age are periodically sampled. This database of surface courses will allow for a detailed analysis of the variation of the texture and level of ravelling.

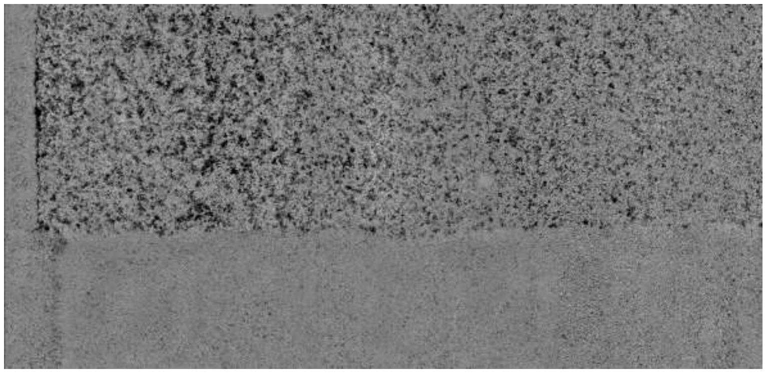

Figure 17: Transition from 'non-ravelled' to ravelled

CONCLUSIONS

When (macro) texture is discussed the volumetric component (3D) is actual fact being meant instead of the single point laser (2D) value. As a reliable LCMS-based volumetric measurement of texture at traffic-speed is now available a move from MPD to MTD should be aimed at to overcome the inconsistency of multiple correlations. Based on LCMS data analyzed over the last 5 years the following conclusions and recommendations can be made:

- LCMS texture data collected over the total width and length of road sections does show that there is much more variation than thought, starting already when a pavement surface is new.
- Windscreen surveys or HD pictures are capable of giving only a relative subjective rating of the level of ravelling and are unable to detect changes in texture.
- Segregation of a surface layer does take place more often than anticipated and an objective traffic-speed based approach measuring MTD should be made part of a compliance testing procedure.
- The variability of texture will have a negative influence on the noise reducing characteristics of a surface course.
- The variability of texture will influence the sensitivity for ravelling, influenced by the mix quality, construction procedures and the weather conditions during construction.
- The variability of texture will influence the frictional characteristics of a surface course.
- The LCMS measured MTD data is compatible with the SPTM and highly repeatable.
- All defects are detected and progression of the severity can predicted based on the results between consecutive surveys.

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