USING FULL LANE 3D ROAD TEXTURE DATA FOR THE AUTOMATED DETECTION OF SEALED CRACKS, BLEEDING AND RAVELING

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3D transverse profiling techniques such as the LCMS (Laser Crack Measurement System) have proven reliable at detecting open cracks these systems have not been widely used to evaluate road texture. This article will present test results from the New Zealand Highway Authority (NZHA) that demonstrate that 3D transverse profiling lasers (LCMS) can be used to measure macro-texture as accurately as a single point texture lasers. Furthermore, because transverse profiling lasers measure texture on the entire road surface we will demonstrate that they can also be used to detect important surface features (sealed cracks, bleeding and raveling) that are missed by single point lasers.

Keywords: Laser Profiler, Texture Evaluation, LCMS, Automatic Crack Detection, Macro-texture

Introduction

In order to optimize road maintenance funds and improve the condition of road networks, asset managers need detailed and reliable data on the status of the road network. Transverse profiling systems such as the LCMS have been widely used for automated crack detection [1] [2] [3] [4] [5] [6] [9] [10] on a variety of road surfaces (DGA, porous, chipseal, concrete) in over 35 different countries. While 3D transverse profiling techniques for road surface condition evaluation such as the LCMS have proven reliable at detecting open cracks these systems have not been widely used to evaluate road texture. Part of reason is that current standards specify only the use of single point 32 or 64KHz macro-texture lasers that while accurate only measure texture in a single point (usually the wheel path).

This article will present test results from the New Zealand Highway Authority (NZHA) that demonstrate that 3D transverse profiling lasers can be used to measure macro-texture as accurately as a single point texture lasers. Furthermore, because transverse profiling lasers measure texture on the entire road surface they can also be used to detect important surface features (sealed cracks, bleeding and raveling) that are missed by single point lasers.

Hardware Configuration

The sensors used with the LCMS system are 3D laser profilers that use high power laser line projectors, custom filters and a camera as the detector. The light strip is projected onto the pavement and its image is captured by the camera. The shape of the pavement is acquired as the inspection vehicle travels along the road using a signal from an odometer to synchronize the sensor acquisition (see figure 1). All the images coming from the cameras are sent to the frame grabber to be digitized and then processed by the CPU. Saving the raw images would imply storing nearly 30Gb per kilometer at 100 km/h but using lossless data compression algorithms on the 3D data and fast JPEG compression on the intensity data brings the data rate down to a very manageable 20Mb/s or 720Mb/km. The critical specifications for the LCMS system can be found on table I. It is important to note that in addition to the 3D profiles the LCMS acquires the intensity of the reflection of the laser at each 3D point thus creating an intensity 2D image of the pavement while simultaneously measuring the shape. Figure 2 shows range (distance) image and intensity (2D) data acquired from the LCMS. A 3D image can be generated from the range and intensity data as shown.

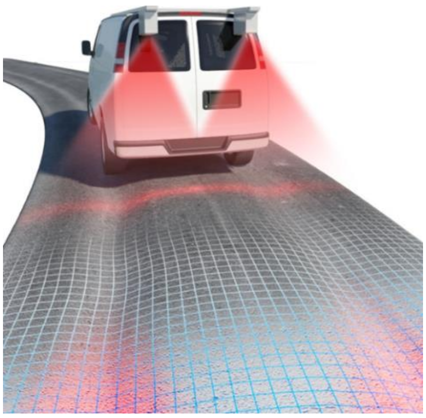


Figure 1. LCMS on an inspection vehicle.

Table I - *LCMS Specifications.*

Name of laser profilers	LCMS-1 / LCMS-2
Sampling rate (max.)	5,600 / 28,000 profiles/s
Vehicle speed	100 km/h (max)
Profile spacing	Adjustable
3D points per profile	4096 points
Transverse field-of-view	4 m
Depth range of operation	250 mm
Z-axis (depth) resolution	0.25 / 0.1 mm
X-axis (transverse) resolution	1 mm

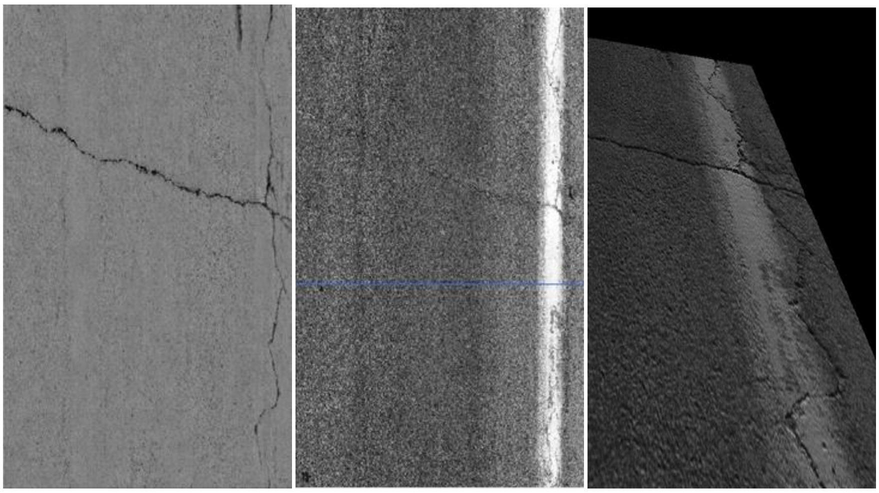


Figure 2. LCMS data type – Range (left) – Intensity (center) – 3D merged (right).

Macrotexture

Macrotexture is important for several reasons, for example it can help estimate the tire/road friction level, water runoff and aquaplaning conditions and tire/road noise levels produced just to name a few. Macrotexture can be evaluated by applying the ASTM 1845-01 norm[7]. This standard requires the calculation of the mean profile depth (MPD). To calculate the MPD, the profile is divided into small (10cm) segments and for each segment a linear regression is performed on the data. The MPD is then computed as the difference between the highest point on the profile and the average fitted line for the considered portion. MPD is the only way possible to evaluate texture using standard single point (32 or 64 kHz) laser sensors. The LCMS however acquires sufficiently dense 3D data to not only measure standard MPD but also to evaluate MTD texture (mean texture depth) using a digital model of the sand patch method (ASTM E965)[8] as shown on figure 4.

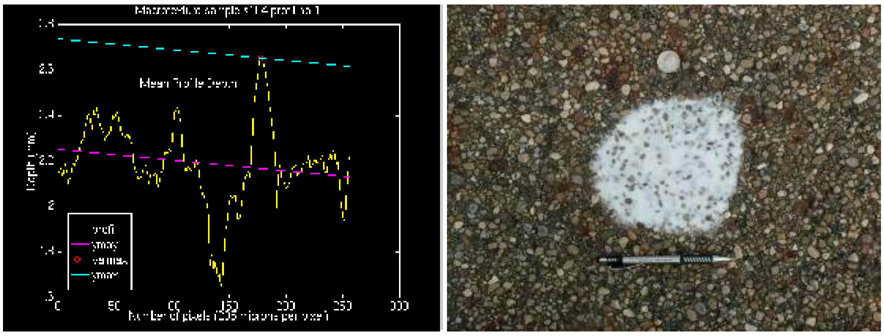
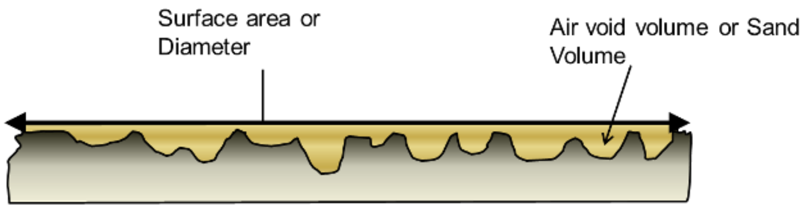


Figure 4. MPD vs sand patch.

The digital sand patch model MTD (Figure 5) calculates the volume of the voids in the road surface that would be occupied by the sand (from the sand patch method) divided by a surface area. The minimum size of the surface area used is 25cm x 25cm for a single texture MTD measurement.



$$MTD = \frac{(Volume_{air\ void})}{Surface\ Area}$$

Figure 5. MTD calculation (Digital Sand Patch Method)

Texture validation field tests (NZTA)

In order to validate texture measurements in New Zealand, the New Zealand Transit Authority (NZTA) developed an instrument called the SLP (Stationary Laser Profiler) see Figure 6. The SLP uses a 32kHz Selcom® laser with a spot size of 0.5 mm to take a profile measurement every 0.3 mm. The laser traverses along a 1.67m track by a drive from a toothed belt. It was laid end to end throughout the texture validation sites to provide the reference texture measurements (MPD). To compare with LCMS texture the SLP results were converted using the relationship as defined by the ASTM 1845 standard that MTD = 0.8*MPD +0.2mm.

Figure 6. SLP (Stationary Laser Profiler)

During the tests, 7 different survey sites in New Zealand were measured using the SLP as the reference. The length is each survey site was 200m except site V07 which was 300m. Texture values on the different sites ranged from 0.4mm (MPD) to 3.5mm (MPD). The SLP measurement paths are marked with paint (example figure 7). This is the transversal position where the SLP device was used to measure the texture. Texture values were recorded in each wheel path. The SLP device outputs one MPD value every 10cm, for each wheel path. During the tests multiple runs of LCMS data were collected on each survey site, at different speed (30km/h, 50km/h and 80km/h). The LCMS data was collected by DCL – Romdas.

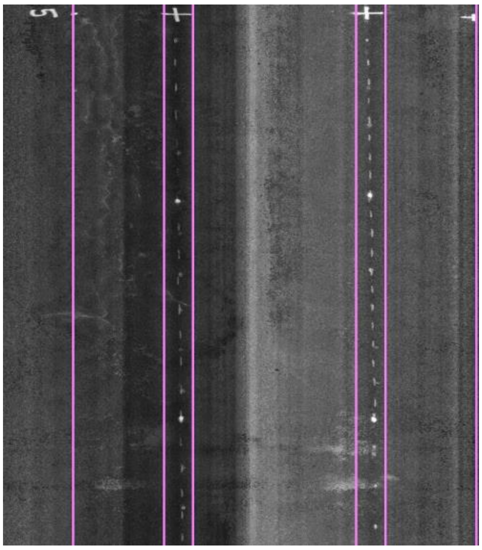


Figure 7. Example road test section paint marks SLP path (pink lines mars LCMS MTD measurement area 25x25cm area)

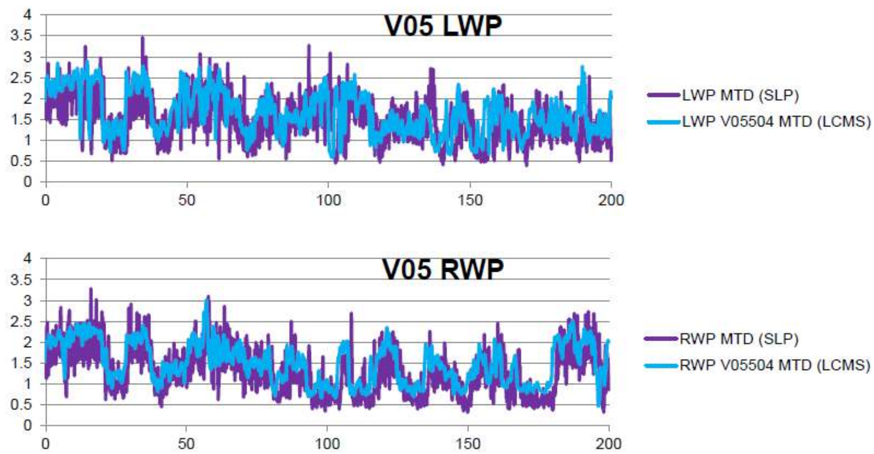


Figure 8. Example test section (unfiltered) texture results comparing SLP versus LCMS for test section V05, left and right wheel paths (LWP, RWP).

Figure 8, shows the (unfiltered) texture results output from both the SLP and the LCMS for test section 5. Visually it is easy to see that while the SLP texture measurements are noisier the average general shape of the texture profiles are the same. It is normal that the SLP gives noisier results since it outputs texture values using a single profile measured over 10cm while the LCMS measures the texture of a 25cm x 25cm area. The LCMS thus uses a lot more 3D points (900 points) to evaluate the texture as compared the SLP (30). To better compare the results, average texture measurements from both the SLP and LCMS were compiled for each 25m road section on each of the sites for both right and left wheel paths. The results are display in the graphs below (figures 9, 10). Overall the correlation between the MTD results of the SLP and the LCMS when averaged over 25m sections show excellent R^2 values of approx. 92%. Figure 11 shows the repeatability of the texture values using multiple runs of the LCMS at 30, 50 and 80km/h. Outstanding correlation results of R^2 values over 99% were demonstrated showing the high repeatability and the speed invariance of the LCMS texture measurements.

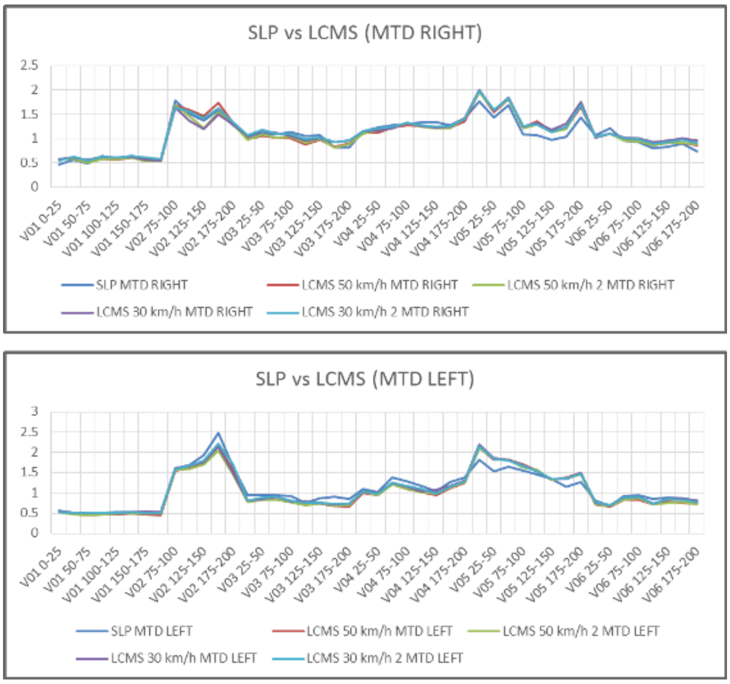


Figure 9. Average MTD texture results (25m) SLP versus LCMS (30, 50km/h) all runs compiled together for sites 1 to 6.

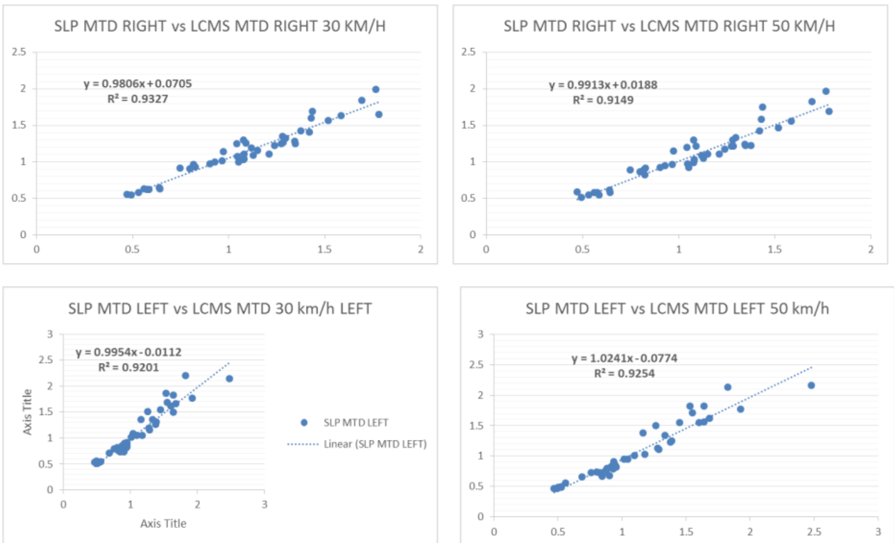


Figure 10. Average MTD texture results (25m) SLP versus LCMS at either 30km/h or 50km/h for sites 1 to 6.

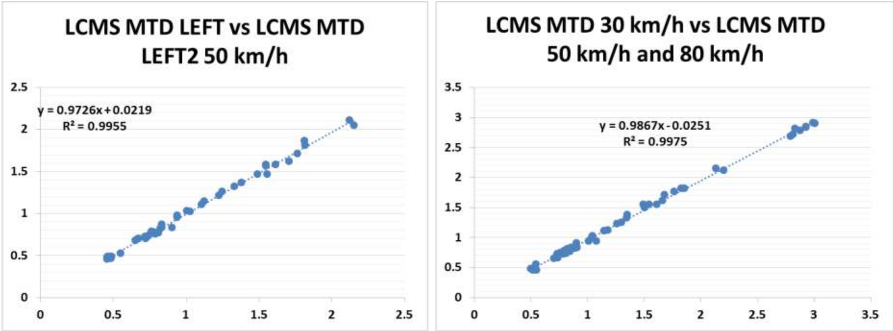


Figure 11. Repeatability of MTD texture values (multiple runs) of the LCMS at 50km/h (left graph) and 30km/h, 50km/h and 80km/h (right graph).

Road surface texture maps

The digital sand patch method implemented allows texture to be evaluated continuously over the complete road surface instead of measuring only a single point inside a wheel path. The MTD results can be mapped into road surface texture image where the color corresponds to texture levels of a 25cm x 25cm surface area. MTD texture maps of the road can be made very useful in order to detect local texture differences that correspond to local surface features such as bleeding, raveling and sealed cracks.

In the example bleeding or flushing on the road surface corresponds to areas of very low MTD (0.2mm) shown in blue (figure 12).

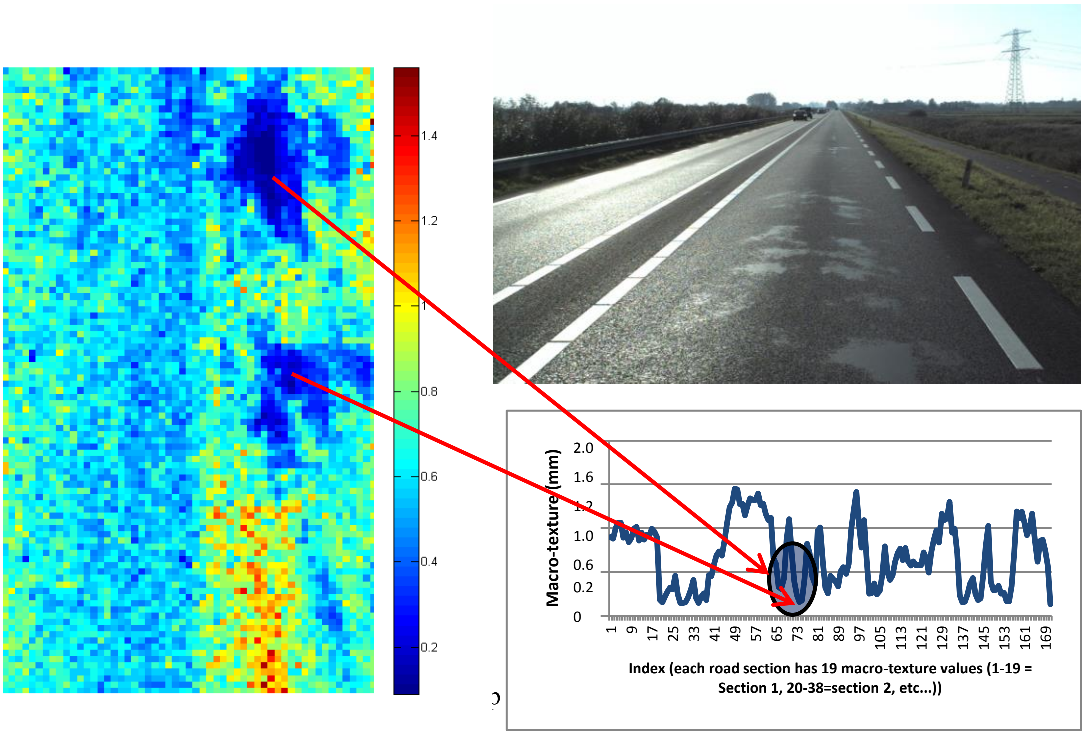


Figure 12. MTD texture color map showing areas of bleeding (low texture).

For 3D systems detecting sealed cracks can be a major problem because 3D crack detection algorithms look for crack points that are deeper than the road surface. In the case of a sealed crack by definition the crack has been sealed and thus has no measurable depth. Most crack sealants show up in images as being very dark, so one could think of detecting sealed cracks using intensity images however as figure 13 shows sealed cracks can appear as either light or dark pixels in such images. However, a sealed crack will always have a smooth texture associated with its surface by its nature as the sealant used not only fills the crack but also the air voids of the asphalt texture. Thus the use of texture based analysis of pavements does allow for the detection of such cracks.

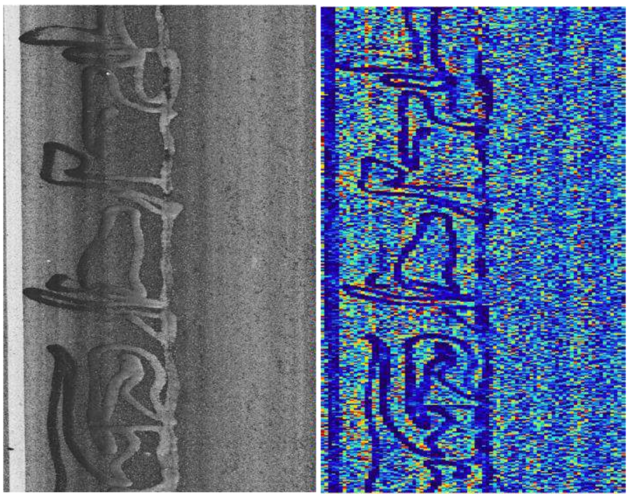


Figure 13. Example sealed cracks: a) Intensity image b)Texture map

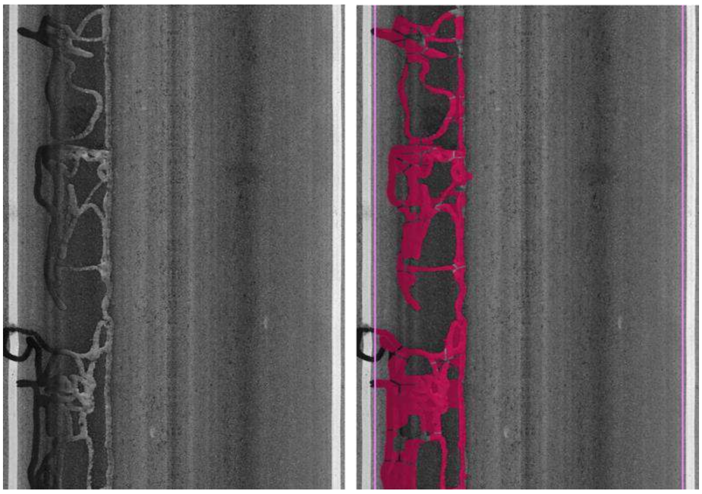


Figure 14. Example result of sealed cracks detection

The detection of raveling is another important use of full lane 3D texture surface maps of roads. Raveling can be a major problem especially associated with porous asphalt roads that are common in both Europe and Asia. The LCMS system has been used in the Netherlands since 2012 to evaluate raveling conditions on porous (ZOAB) asphalt using texture analysis. The work done in the Netherlands by TNO and RWS (Rijkswaterstaat) used texture analysis first to identify the type of asphalt present and secondly to evaluate the amount of raveling as compared to what in field visual evaluators reported. Figure 15 shows an example of raveling on a porous asphalt surface that can be evaluated visually because of the difference in the appearance of the texture in the road. Ravelling appears as an area of much higher texture than the surrounding pavement. Figure 16 shows examples of texture maps that were correlated to visual raveling evaluations by operators in the field. Results[11] reported by RWS are correlations R^2 of 93% with visual evaluations in the field. Since 2012 the LCMS system is gradually replacing the use of operators in the field for raveling detection in the Netherlands.

Figure 14. Example result of sealed cracks detection

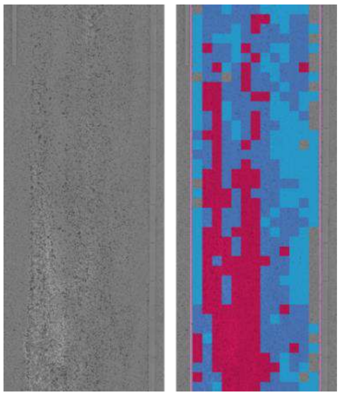


Figure 15. Color texture map of a raveled road surface.

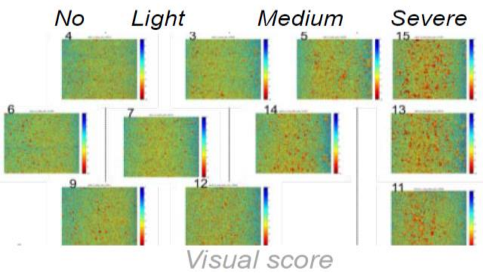


Figure 16. Examples of texture maps that were correlated to visual evaluations of raveling conditions in the field.

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Conclusions

The use of a 3D transverse profiling system, LCMS, has been proposed to evaluate road texture as an alternative to current standards that specify only the use of single point 32 or 64KHz macro-texture lasers.

Results conducted in the field by Romdas and the New Zealand Highway Authority (NZHA) demonstrate that the LCMS can be used to measure macro-texture as accurately as a single point texture lasers. MTD measurements on multiple runs at 7 different sites were done at three different speeds and show a 92% correlation with the ground truth data with a repeatability of 99%.

Furthermore, because transverse profiling lasers measure texture on the entire road surface they can also be used to detect important surface features (sealed cracks, bleeding and raveling) that are missed by single point lasers. Examples of the use of full lane road surface texture maps have been presented to detect these defects including network level results from the Netherlands regarding raveling on porous asphalt.

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