CALIBRATION OF LASER DEVICES USED FOR THE MEASUREMENT OF PAVEMENT SURFACE TEXTURE: ACCURACY OF PAVEMENT TEXTURE MEASUREMENT

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ABSTRACT

Measurement of pavement texture is part of the asset management data collected relative to pavement friction. When undertaking the periodic calibration and correlation trials for DTEI equipment it was noted that the accuracy of results had fallen relative to previous work. Further investigations showed that this reduction related to the type of pavement being tested, positive or negative texture and was also dependent upon the type of device/equipment. This paper discusses the processes of addressing and resolving the problem.

INTRODUCTION

This paper documents the calibration of measuring equipment for the determination of pavement surface texture, using several test methods and equipment. The intent of this paper is to provide a more practical technical approach to the topic for people not associated with such matters.

Surface texture is a measure of a pavements ability to drain free water from the road during wet weather. Texture plays a part in road surface friction resistance by allowing the interaction between the tyres and road, which assists in the braking & steering of a vehicle.

While undertaking the biennial calibration work an anomaly was noticed that was not evident on previous calibration exercises. The anomaly occurred on what is described as negatively textured pavements.

BACKGROUND

Technical Services Group within DTEI operates an ARRB Twinlaser Profiler (2LP) for the automated high speed collection of surface macrotexture and also a WDM Texture Measure 2 (TM2) for the low speed collection of that data.

The calibration process involves correlating the results of the 2LP against the TM2 and also the Sand-Patch by carrying out testing with each method on a number of different pavement surfaces. As a result of this work, issues have been identified with the measurement of surfaces such as those of stone mastic asphalt (SMA) and also open graded asphalt (OGA) that are considered to be “negatively” textured.

When the variability of results became evident a literature survey was completed on the matter. The results of the survey were sparse, and personal communications with others associated with this work did confirm the fact but added little more other than that they were also addressing this issue.

EQUIPMENT DESCRIPTIONS

The expected operating range for texture measurement is from 0.5 to 2.0 mm. Measurements can go below 0.5 mm but are at the limits of the equipment operating range and so the error rate increases.

The equipment operated by DTEI for the purpose of texture measurement are described as follows.

Twinlaser Profiler

The 2LP consists of two Selcom class 3B lasers and two Accelerometers mounted on the front of the vehicle in both outer & inner wheel paths. The lasers operate at a frequency of 16kHz and sample every 5mm. The 2LP is operated at road speed, but no greater than 80 km/h based on previous work that has demonstrated that as the vehicle speed is increased the accuracy of the equipment decreases.

The data is collected as a continuous measure on a computer in the vehicle and provided as Sensor Measured Texture Depth (SMTD).

The processing software produces an equivalent Sand-Patch Texture Depth (SPTD) based upon a linear correlation undertaken of the SMTD against the Sand-Patch Mean Texture Depth (MTD). This follows recognition that SMTD and Sand patch MTD have a good linear relationship (Austroads 2009).

The Twinlaser is operated in accordance with a DTEI internal test procedure MAT-TP348 'Determination of Pavement Surface Roughness and Texture Using the Twinlaser Profiler'.

WDM Texture Measure 2

The TM2 is an automated texture measuring device that uses a single 16kHz Selcom Laser with a spot size 0.25mm diameter and calibration accuracy ± 0.4%. It is pushed at 5 km/h and produces a result for each nominal metre that is based upon a sampling frequency of every one millimetre. Data is reported as Mean Profile Depth considered equivalent to the sand patch MTD, and also as Sensor Measured Texture Depth.

The TM2 is operated in accordance wih a DTEI internal a test procedure MAT-TP351 'Determination of Road Surface Texture Using a WDM TM2 Device'.

Sand-Patch

The Sand-Patch test is a manual method involving the spreading of a known volume of graded sand over the pavement surface so that it is level with the tops of the aggregate. The dimensions of the resulting sand circle are used to calculate the Mean Texture Depth, in mm, as the volume of sand divided by the area covered.

The sand-patch test has been adopted as the datum or standard. It is a long-standing and well recognised test.

This process while, simple and cheap, has some disadvantages including:

- Operator dependence, but that a large change in the sand circle dimension is necessary to significantly alter the result.
- Slow and labour intensive for the amount of data collected.
- Safety issues when being undertaken on an operating road.

The Sand-Patch is undertaken in accordance with the DTEI internal test procedure, MAT-TP346 'Determination of Average Texture Depth of a Pavement Surface Using the Sand-Patch Method'.

METHODOLOGY

The purpose of the calibration exercise was to review existing correlations between the 2LP and the TM2, in consideration of that texture measured by the Sand-Patch method, and due to an upgrade of the lasers of the 2LP. This involved performing the following work:

- Testing 13 sites consisting of spray seals, dense grade asphalt (DGA), open graded asphalt (OGA), stone mastic asphalt (SMA) and concrete using the 2LP, TM2 and the Sand-Patch method, comprising:

- 100m sections were used in this exercise.
- Only one wheel path was used (either inner or outer)
- 10m intervals used for Sand-Patch tests.
- Three runs used for each of the 2LP and TM2.

- Plotting and analysing data to find an appropriate slope and intercept in order to develop a linear relationship between various outputs.

Additionally, the analysis would investigate the suitability of the TM2 in becoming the reference device instead of the current Sand-Patch method.

DISCUSSION OF RESULTS

The investigation involved comparison of the raw measurements from both the 2LP and TM2 to assess the functioning of the lasers. Figure 5.1 compares the sensor measured texture depth from both devices and confirms that the lasers' measurements are equivalent of both machines.

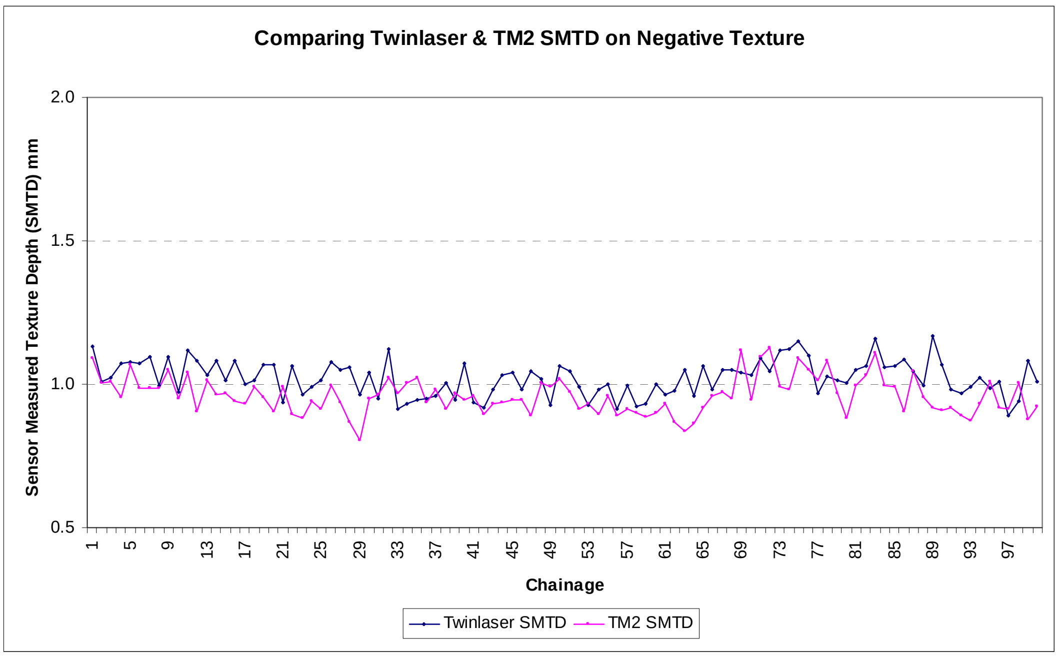

Figure 1: Twinlaser SMTD and TM2 SMTD – a negative textured pavement

When plotting results of all sites for both the MTD (Sand-Patch) and MPD (TM2) against the SMTD (Twinlaser) the results indicate a R2 correlation of 0.85 for the TM2 and 0.81 for the Sand-Patch as shown in Figure 5.2. The intent is to achieve a correlation at 0.95 or better. It was this that prompted further investigation of the accuracy of the testing with regards to the type of pavement surface being assessed. After removing data from the sites containing negative texture (SMA & OGA) the R2 for the MPD (TM2) improved to 0.97 and for the Sand-Patch to 0.96 (refer Figure 5.3). This indicates that compliance as determined by the correlations can be achieved for positive textured pavements.

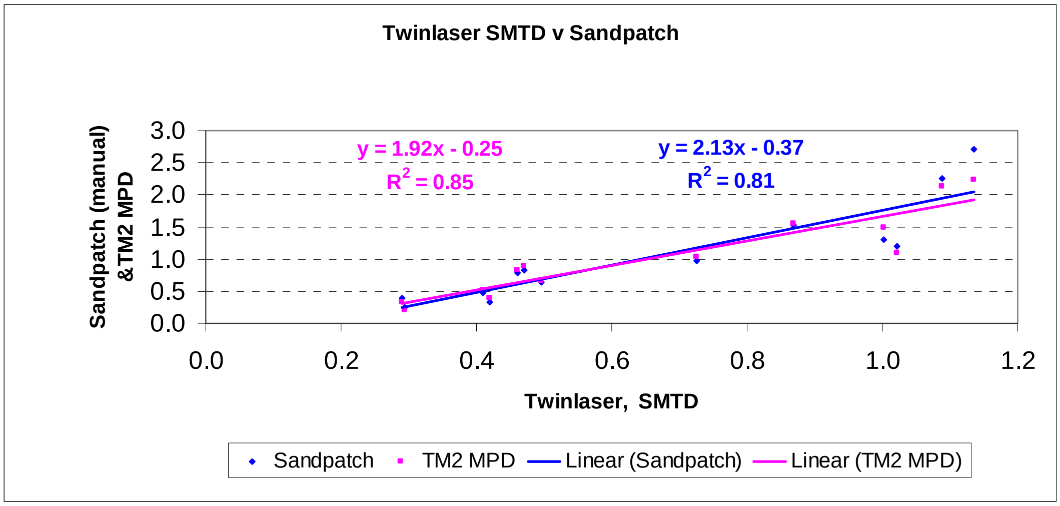

Figure 2: Twinlaser SMTD Vs Sand-patch MTD and TM2 MPD for all sites

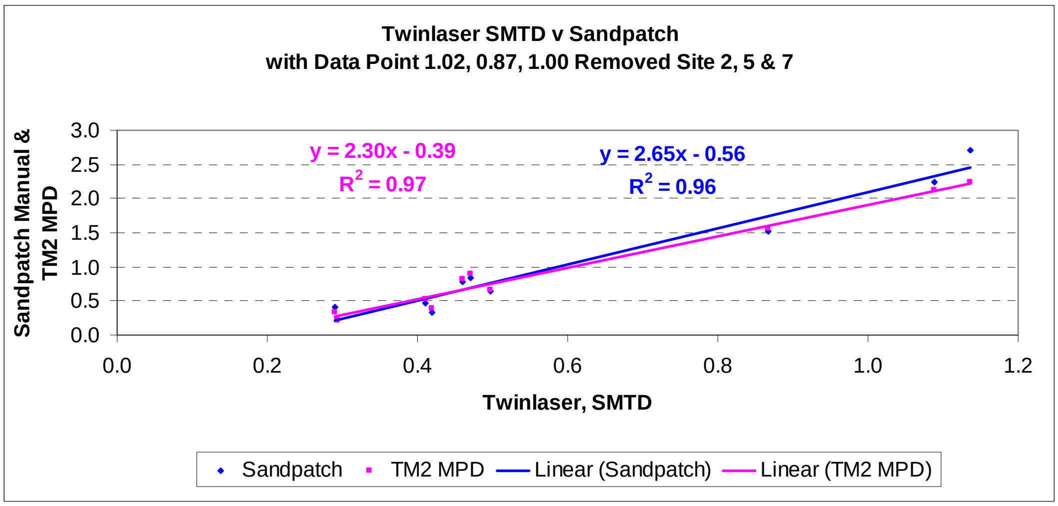

Figure 3: Twinlaser SMTD Vs Sand-patch MTD and TMS MPD for positive textured sites

To confirm the existence of the problem with the measurement of negative texture using the 2LP, a further seven sites comprising both SMA and OGA were tested, giving a total of 10 negative texture sites. Again the sand patch MTD & MPD (TM2) data were plotted for all those negative textured sites against the SMTD (2LP) and the correlation returned a R^2 of 0.53 for the TM2 and 0.58 for the Sand-Patch. This further reinforced the poor correlation of both the TM2 and Sand patch tests both against the Twinlaser (refer Figure 5.4), for such negative textured sites.

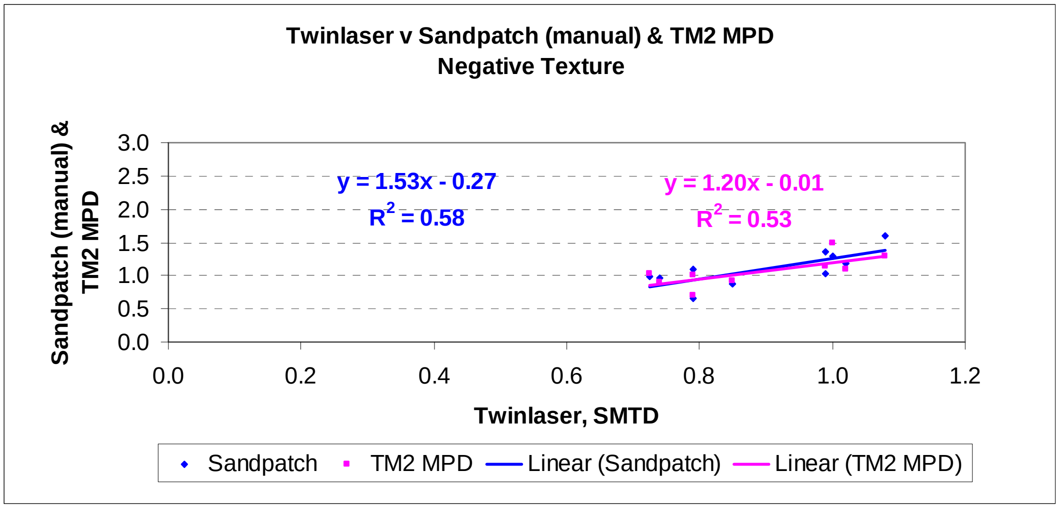

Figure 4: 2LP SMTD Vs Sand-patch MTD & TM2 MPD - negative textured sites

Processing the 2LP data (shown in figure 5.1) using the correlation gained in Figure 5.3 yielded sand patch texture depth for this negative textured pavement, on average 0.8mm greater that obtained from the positive textured pavement surfaces as shown in Figure 5.5. This emphasised the necessity for an appropriate correlation to be adopted for negative textured pavements, and especially in the provision of data in a contractual environment.

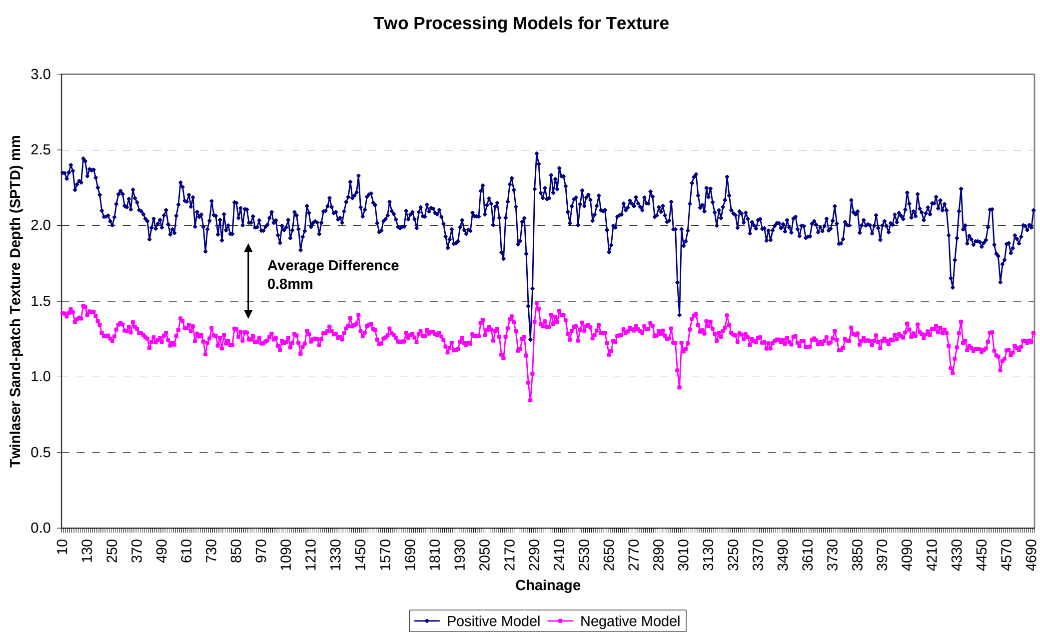

Figure 5: Difference in the two correlations

The derivation of the SPTD based upon the raw data gained the 2LP can be based upon those relationships as determined in Figure 5.3 for positive texture and Figure 5.4 for negative texture. When that SPTD is compared against the MPD (TM2), as the reference device, an R^2 of 0.96 for positive texture and 0.72 for negative texture was achieved and as shown in Figure 5.6. An R^2 0.72 would suggest that an expanded confidence limit of 0.2mm should be applied to the 2LP data when being reported.

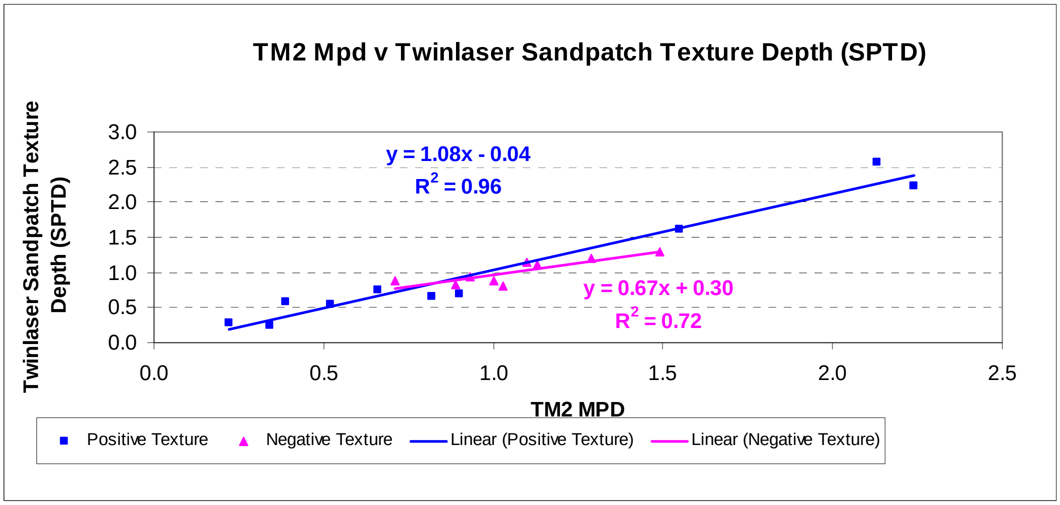

Figure 6: TM2 Vs 2LP

Analysis of the data has confirmed the need to separately determine the texture measurements of positive and negative textured pavements.

UNCERTAINTY OF MEASUREMENT

As with all test work being undertaken by DTEI Technical Services the Uncertainty of Measurement (U of M) is determined in accordance with ISO/IEC 17025 and Cook (2002). Uncertainties of measurement were completed and the results are listed in Table 6.1.

Table 1: Uncertainty of Measurement

Device	**Uncertainties All data**	**Uncertainties Data from Positive Textured Sites**	**Uncertainties Data from Negative Textured Sites.**
TM2 MPD	4.1%	4.7%	3.5%
Twin laser SPTD	4.2%	5.0%	3.4%
Sand Patch (manual method)*	13.9%	11.3%	16.5%

* As indicated earlier the Sand-Patch test is operator dependent and has much greater uncertainties.

From the results above it would appear that the U of M of the two test methods using automated systems are similar when testing any form of textured pavement.

Research from other bodies (Keighan, K 2006, McGhee, K, Flintsch, G 2003, Ramsak, M, Kotot, D, Tusal, M) confirms the correlation between laser texture depth and Sand-Patch texture depths are better on positive texture than they are on negative texture surfaces.

The sand patch method encounters a problem of the interference fit of the sand particles into the openings of the negative textured pavement.

BEHAVIOUR OF THE LASER

There are other aspects to laser measurement systems to consider when measuring texture, such as surface condition and colour. Very dark surfaces of a pavement may not reflect sufficient light to be detected from materials with high bitumen contents and if there is any surface water on the pavement the situation is further exacerbated (Feighan, 2006).

Observations of the TM2 laser on a new surface with negative texture suggest that the laser light becomes fractured when inside the voids. Figure 7.1 shows the laser light from the TM2 being reflected from a positively textured asphalt surface, being quite a sharp image. While that same light appears quite weakened and dispersed upon the negative textured pavement as shown in Figure 7.2. The signal is fractured and spread around the cavity and the movement of the source and receiver over the cavity making the signal recovery all that more difficult.

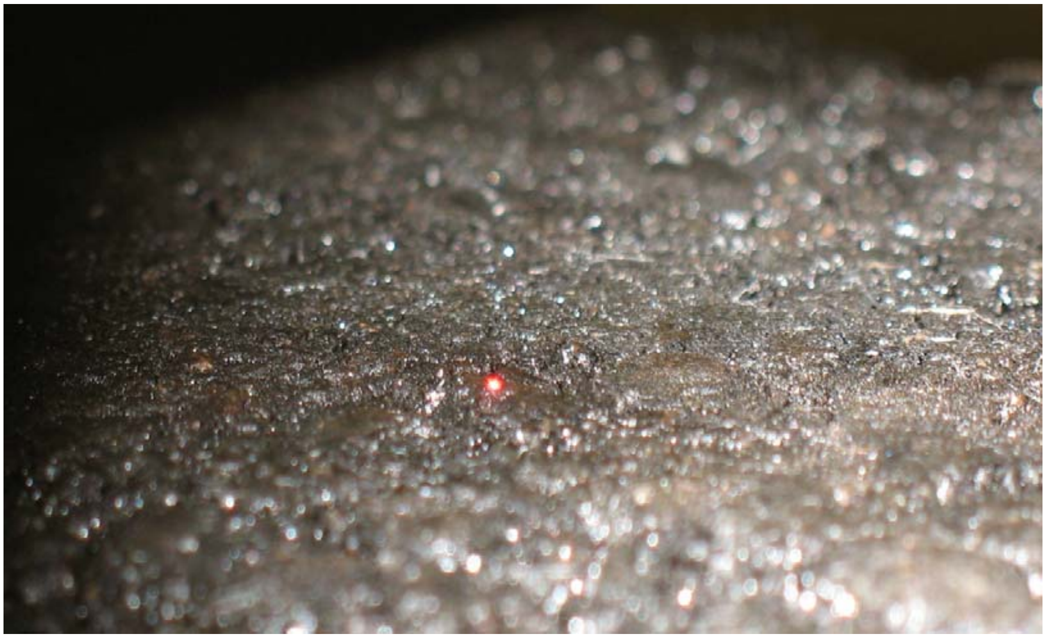

Figure 7: TM2 laser light on dense graded asphalt

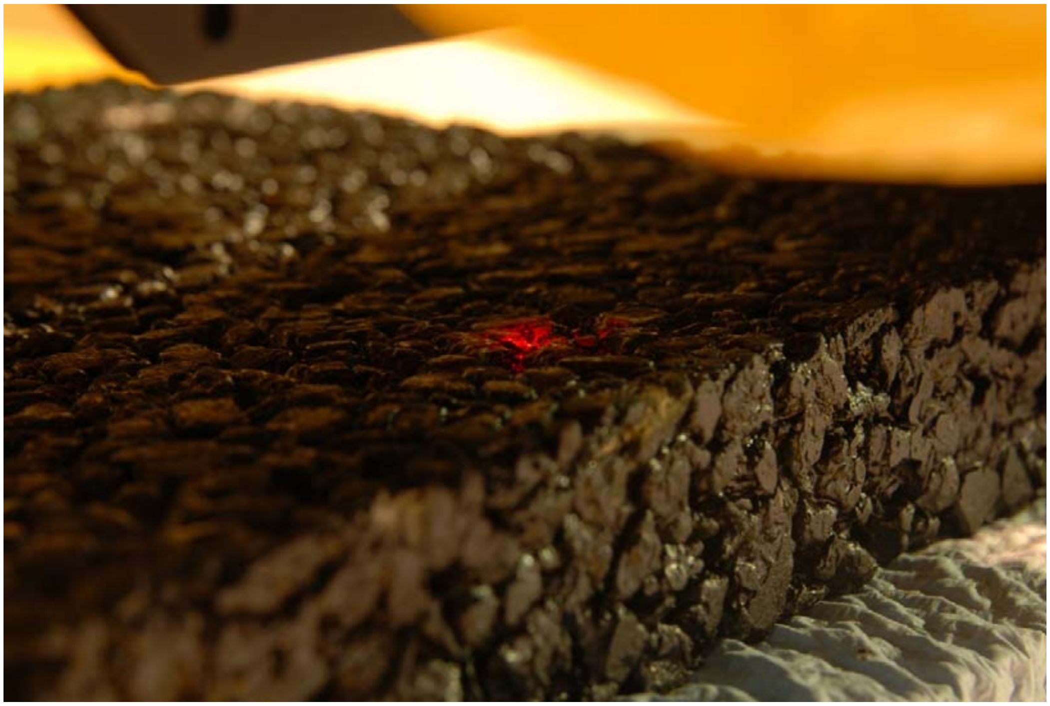

Figure 8: TM2 laser light inside of a void in a SMA

CONCLUSIONS

It can be concluded:

- The 2LP is a fast and efficient device for the continuous collection of texture data, requires little to no traffic control. It does however require the use different models to determine the measurement of texture of the negative and positive surfaced pavements.
- The TM2 has the greater accuracy of all systems but is unsuited for extensive testing, being slow in speed and having safety issues on operating roads. It is excellent for testing of small areas and it has been demonstrated that it is ideal as a reference device.
- The Sand-Patch test has in the past been used as master reference for the calibration of the 2LP Sand-Patch Texture Depth (SPTD); however it is slow, labour intensive, has safety issues and is operator dependent. The sand patch test (manual) can now stop as the master control and the TM2 can take up this role.
- Error rates and uncertainties increase when measuring negatively textured pavements.

RECOMMENDATIONS

As a result of this exercise it is recommended that the following action be taken:

- The TM2 with its good correlation with the Sand-Patch test, now replace the Sand-Patch test as the method for obtaining texture for the calibration of the 2LP.
- Separate relationships for positive and negative texture be used to convert the 2LP raw data into SPTD readouts.
- When any upgrade or alteration to the 2LP occurs a similar calibration exercise is undertaken.

FURTHER WORKS

There still remains a necessity for further testing to study the influence of speed when measuring texture. Further investigation of the mean profile depth from the 2LP will be undertaken and has only recently become available following an upgrade of laser equipment.

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AUTHOR BIOGRAPHIES

I have been employed by the Department for Transport, Energy and Infrastructure for 25 years. My current position is Superintending Field Testing Officer managing the collection of road asset data, such as roughness & texture using the Twinlaser Profiler, deflection testing using the Deflectograph & Falling Weight Deflectometer and skid resistance testing using the Grip Tester. Other equipment that I manage is the walking Texture Measurement 2, Walking Profiler and British Pendulum.