# Image Analysis and Laser Profiling for Measuring Properties of Asphalt Chip Seal

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## Introduction

Chip seals have been used dating back to the 1920s as a wearing surface to increase friction on asphalt pavement and to prolong the life of the pavement before rehabilitation. They keep moisture out of older pavements and restore some of the texture to worn away asphalt surfaces. Chip seals are a much cheaper option than doing a full pavement overlay and are used for maintaining asphalt roads before a full rehabilitation is necessary. The asphalt is mixed with water and sprayed on the road, immediately followed by crushed gravel that is pressed into the asphalt by rollers, after which the chip seal must cure for two days and the excess gravel must be swept off. There are two ways of measuring properties of the gravel, mean profile depth, also known as mean texture depth, and percent embedment. These two measurements are ways of determining how much of the gravel is embedded in the asphalt. The most common way of measuring this has been the sand patch test. The sand patch test uses "a known volume of specified sand is spread over a pavement surface by forming a circular shape, and then average diameter of the area covered by the sand is determined. Subsequently, the average pavement macrotexture depth is determined by dividing the volume of the sand with the covered area" (Boz et al., 51). The mean texture depth is found by the following equation:

$$Mean\ Texture\ Depth\ (mm) = \frac{4\,V}{\pi\,d^2} \quad 1)$$

Where V is the known volume of the sand used in $mm^3$, and d is the diameter of the sand patch circle in mm.

Figure. 1 The Sand Patch Test Being Done in the Field (Minnesota DOT)

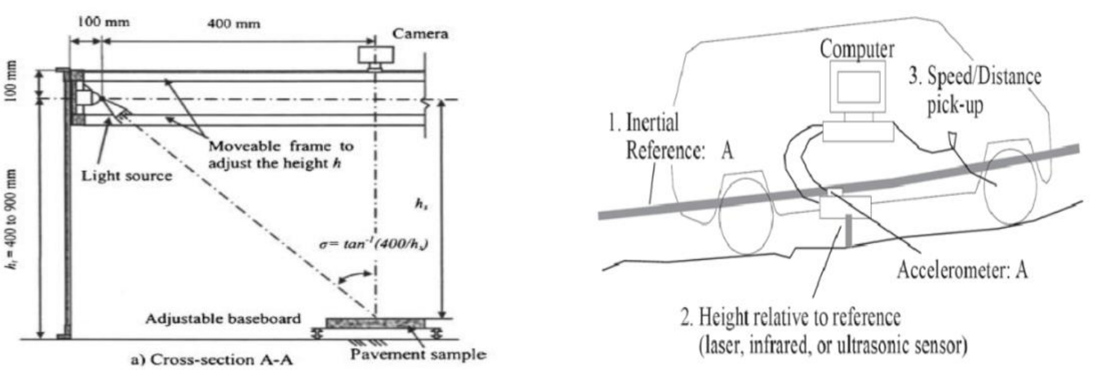
The sand patch test is a simple method and does a decent job at determining the mean texture depth, but now there are more sophisticated ways of measuring mean profile depth and percent embedment. These modern methods rely on laser profiling and image analysis to determine these measurements and are more accurate than the sand patch test.

## Comparison of methods

### Measuring Mean Profile Depth with a Portable Laser Profiler

The portable laser profiler method is a way to measure mean profile depth and is being proposed by a group in Korea as a better alternative to the sand patch test. This method measures the time it takes for a laser pointed at the asphalt to bounce off of it and come back. The laser is mounted on a vehicle as it travels slowly on the pavement and uses the reflection off the asphalt to calculate the mean profile depth. The mean profile depth is calculated by "the difference between the average profile depth of the macrotexture measured at 1mm interval in a total of 100 mm distance…and the average value of 'peak level 1st' and 'peak level 2nd' in 100 mm, after removing all texture information except macrotexture information" (Kim et al., 1579). This calculation is simplified in Equation 2 and the basics of the method can be seen in Figure 2.

$$Mean\ Profile\ Depth = \frac{(Peak\ Level\ 1st) + (Peak\ Level\ 2nd)}{2} - Average\ Level \qquad 2)$$




(a) Principle of MPD Test

(b) MPD Measurement Using Portable Laser Profiler

Figure 2. Measurement Principle of Mean Profile Test Using Portable Laser Profiler (Kim et al., 1579)

The laser used for the profiling is called a Greenwood Engineering 2207-155/260-A with a measurement range of 155 mm. Five different locations were measured using the portable laser profiler and the sand patch test and the results were compared. To determine the mean profile depth with the laser, all of the raw data from the laser had to be inputted into Equation 2 for the mean profile depth values and Equation 1 was used for the sand patch test. A total of 174 data points on asphalt road sections were found for each method and the results were compared. The data points were graphed, as seen in Figure 3, with a line of best fit. Equation 3 shows the estimated mean texture depth on the asphalt pavement.

$$Estimated\ Mean\ Texture\ Depth\ (Asphalt\ Pavement) = 0.56 * Mean\ Profile\ Depth + 0.27 \qquad 3)$$

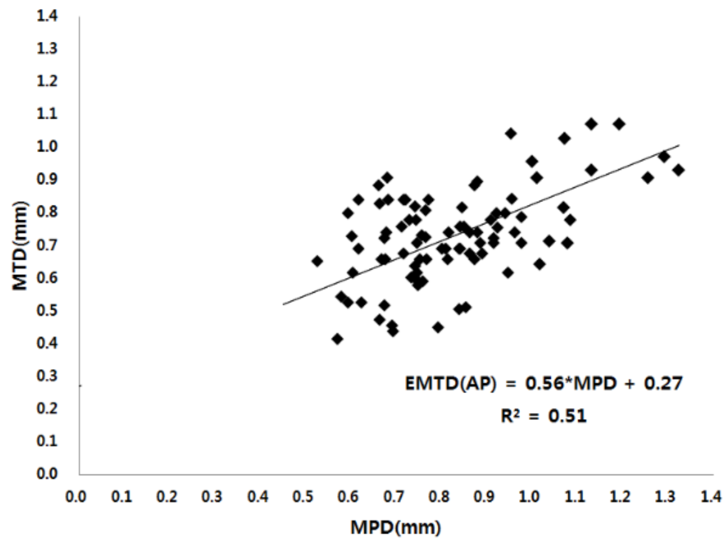



Figure 3. Correlation of Sand Patch Test and Portable Laser Profiler (Kim et al., 1586)

The MPD stands for mean profile depth as measured by the portable laser profiler and the MTD stands for mean texture depth as measured by the sand patch test. As seen in the figure, the correlation value of $R^2$ is only 0.51, so there is a correlation between the two and they both increase linearly, but the correlation is not very good. The group believes that one of the reasons that the correlation is not higher is because they used too small a range, 0.6 mm – 1.4 mm, and should have used a range closer to 0.2 mm – 2 mm (Kim et al., 1588). The portable laser profiler method shows promise if the range is increased and more testing is done.

**Measuring Mean Profile Depth Using Image Analysis**

A group of researchers at Michigan State University are working on using a 3D photogrammetric software called 3DF Zephyr to recreate samples of chip seals and using the 3D models they can measure the mean profile depth of the chip seal. To start the process, pictures were taken of a chip seal specimen and uploaded to the software so that the 3D model can be created. A picture of the 3D image that results is seen in Figure 4.

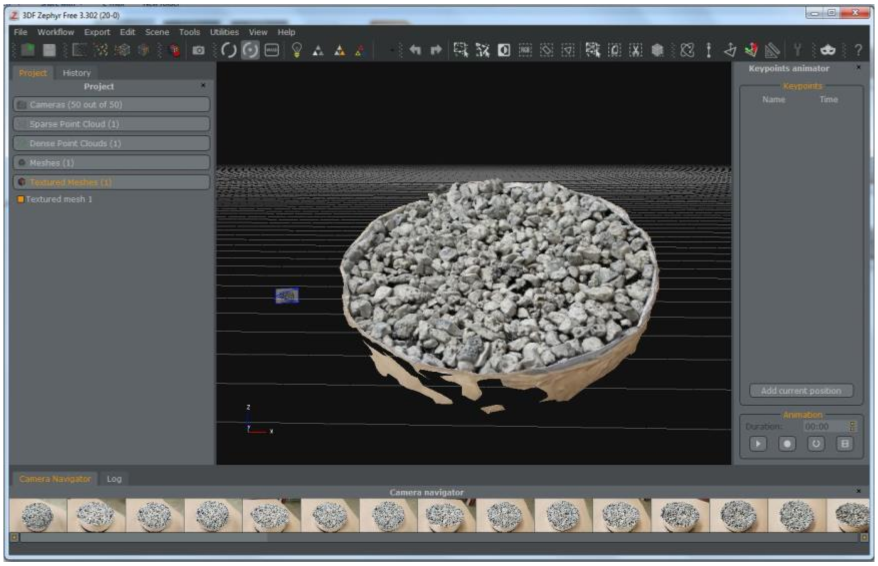



Figure 4. A 3D Model of a Chip Seal Specimen (Boz et al., 52)

Next, the 3D model is uploaded to Autodesk Netfabb to determine the 3D coordinates and those coordinates are then inputted into a MATLAB program to calculate the mean profile depth. The 3D coordinates in the Autodesk software can be seen in Figure 5.

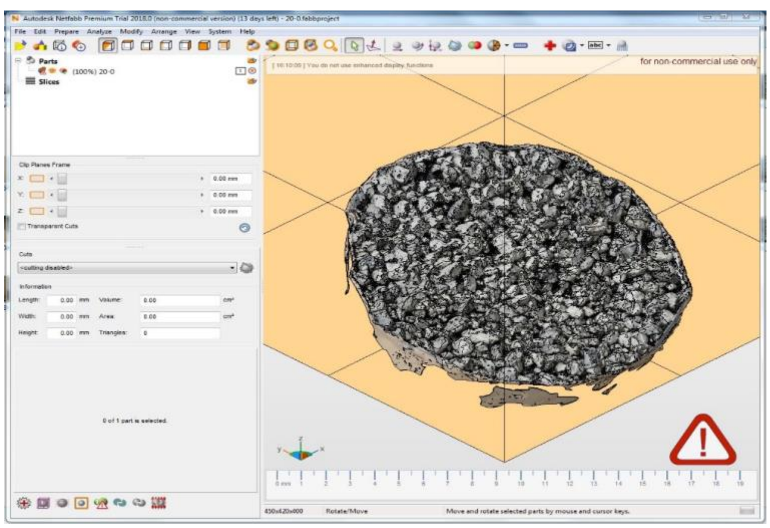



Figure 5. The Autodesk Software Extracting 3D Coordinates (Boz et al., 53)

Once the 3D coordinates are extracted, “a total of 30 lines in the longitudinal direction… were obtained at every 1-mm interval through the transverse direction within the wheel path. The MPD for each line was calculated in accordance with ASTM E1845” (Boz et al., 52). The MPD is the mean profile depth and the ASTM E185 is the “Standard Practice for Calculating Pavement Macrotexture Mean Profile Depth”. These mean profile depth data points were then compared to the mean profile depth data points from a laser texture instrument called the Ames Model 9300. The Ames instruments can measure the “macrotexture of the chip seal surfaces” (Boz et al., 53) and can be used to find very accurate mean profile depths. The data from both devices were graphed and there is a significant correlation between the two as seen in Figure 6.

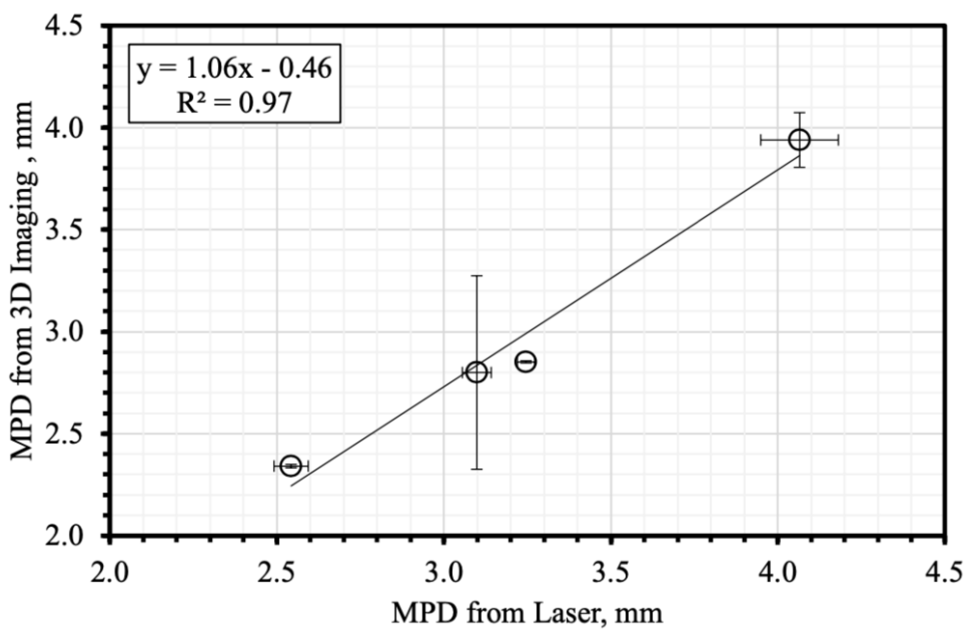



Figure 6. The Correlation Between the 3D Image-based Method and the Laser-Based Method (Boz et al., 53)

The correlation between the two methods is good with an $R^2$ value of 0.97. The data points show some variability with the highest coefficient of variation being 16.9 percent. This method shows promise because of the high correlation with the laser method, but the method was used on chip seal samples and it may be difficult to apply the method in the field without using samples.

## Measuring Percent Embedment with Image Processing

Another group at Michigan State University is using image processing to determine the aggregate embedment in chip seal samples. The first part of the process can be seen in Figure 7. They use 150-mm (6-in.) diameter and 38.1 mm (1.5 in.) tall, cored samples of the chip seal pavements and cut them vertically into five 50 mm wide slices using a tile saw. Next, Playdough is placed on top of the pavement slice to create a good background and fill the space in between aggregates. An image is captured using a document camera (Elmo Model TT02RX) and white, fluorescent lighting. The image is zoomed in so that it contains the desired image of the cross-section of the pavement with the Playdough filling the top of the image.

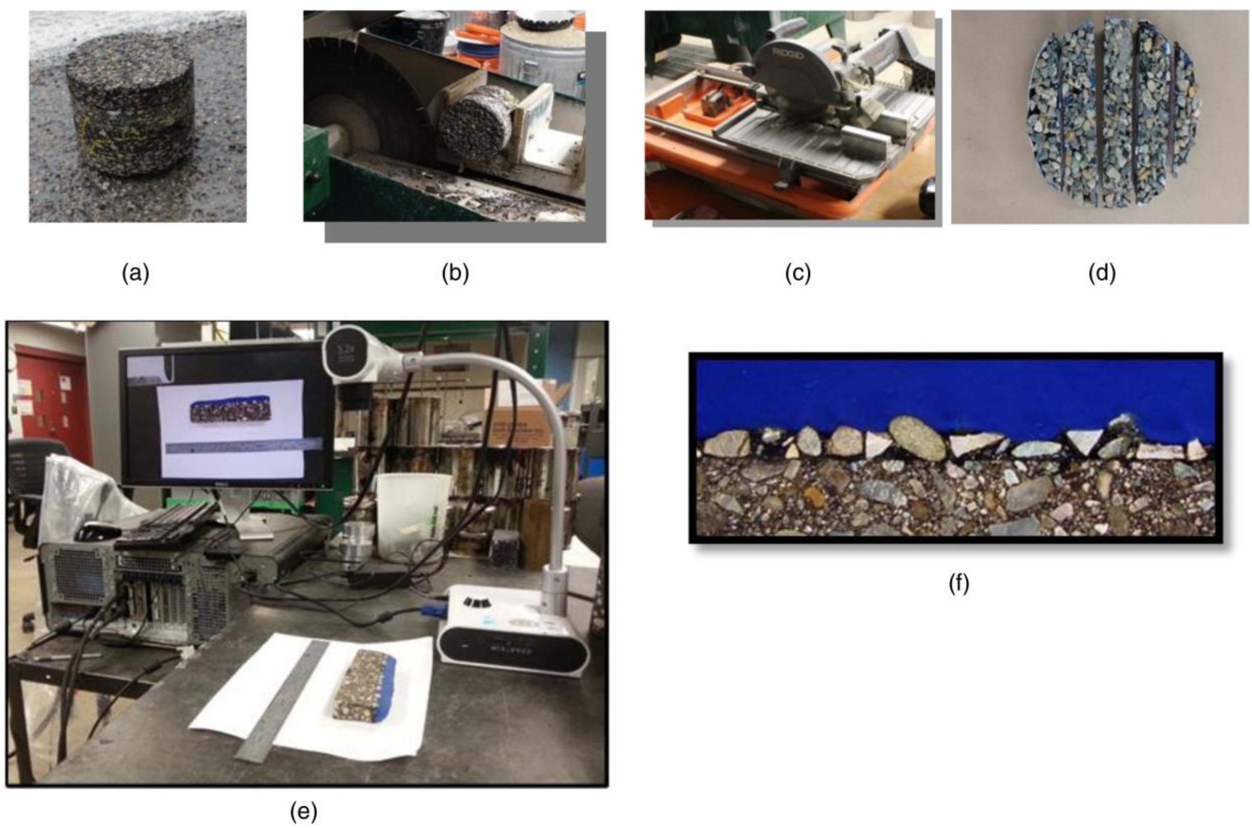



Figure 7. Preparation and picture of sample: a) coring in the field; b) horizontal cutting; c) vertical slicing; d) core slices; e) image acquisition of the core slice; f) the desired image of the cross-section (Ozdemir et al.)

The next steps are seen in Figure 8 where the computer algorithm they developed is used to create a line on the image of the old pavement by placing points at specific spots that were checked and manually adjusted to ensure they correctly represented the section. The algorithm then places a copy of that line 15 pixels above the original and the software located the binder between the two lines by checking the color of each pixel. The binder is black, or close to it, and has the lowest pixel intensity so the computer placed the line at the bottom of the new binder from the chip seal.

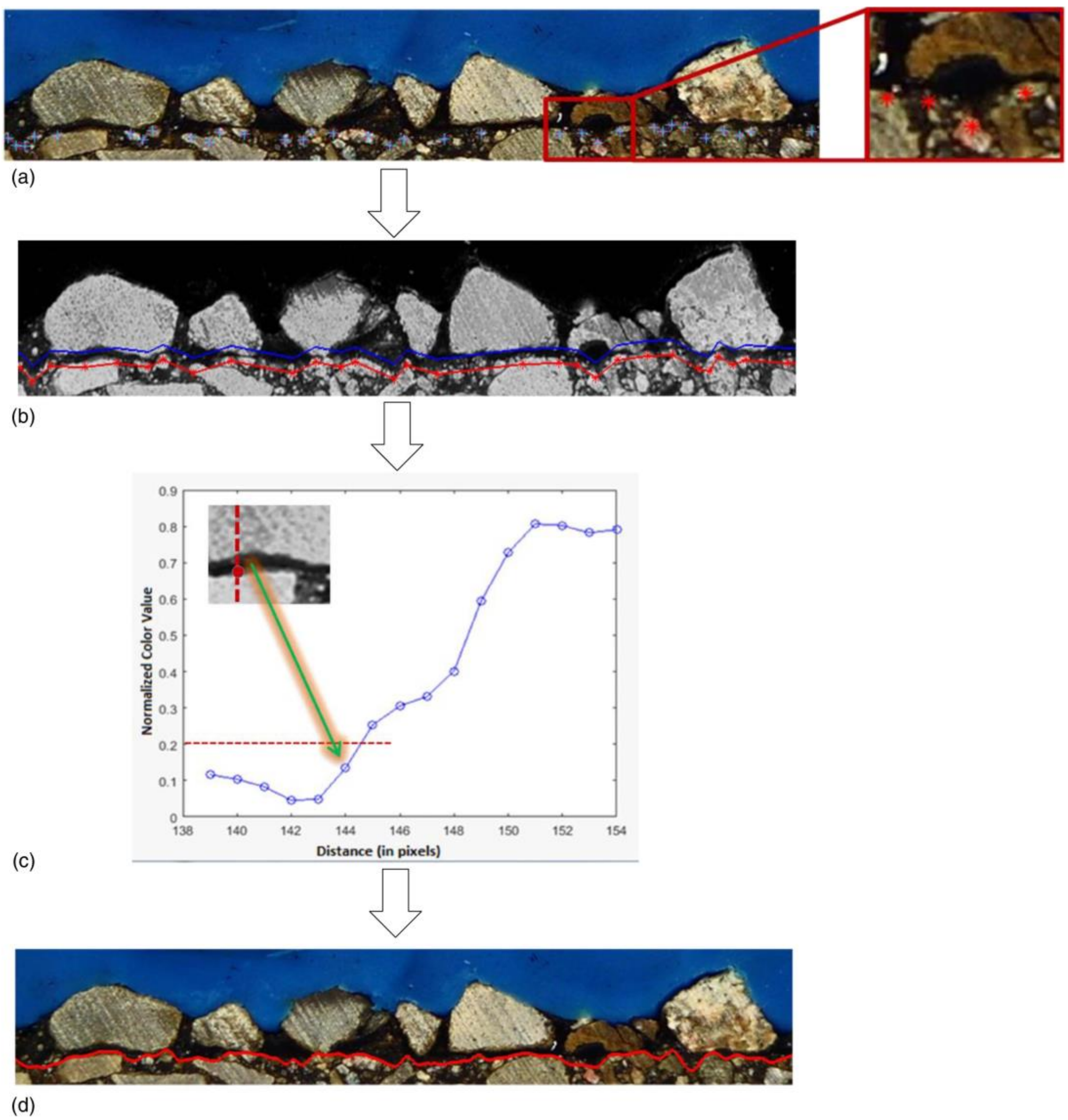



Figure 8. Steps of Determining Existing Pavement (Ozdemir et al.)

Next, the algorithm applies color contrast of black binder and blue playdough to find peaks (top of aggregates) and valleys (top of binder layer) between aggregates (Figure 9.).

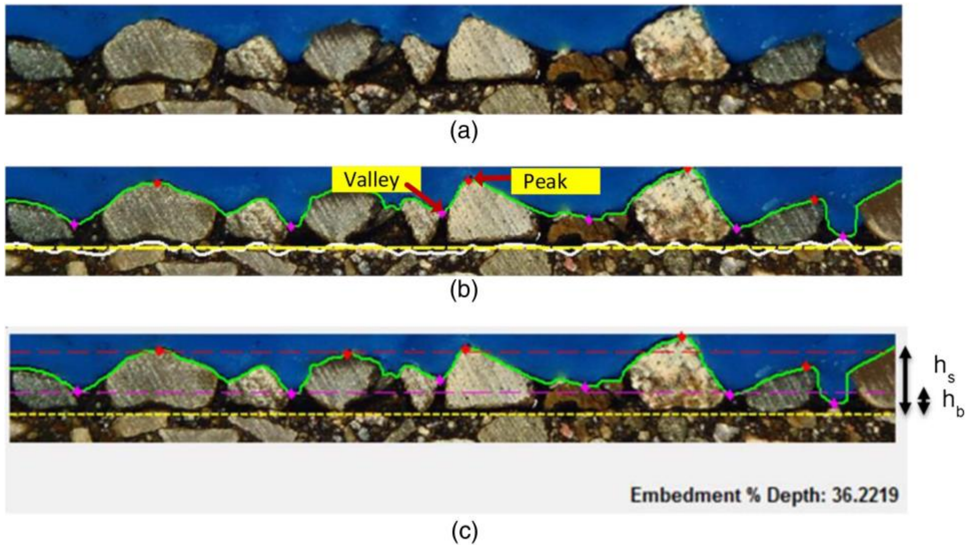



Figure 9. Steps of the peak and valley method: (a) original image; (b) finding peak and valley points—existing pavement's determination; and (c) embedment depth calculation (Ozdemir et al.)

With these measurements, the percent embedment can be computed as shown in Equation 4:

$$PE_{pv}(\%) = \frac{h_b}{h_s} * 100 \qquad 4)$$

Where $PE_{pv}$ is the percent embedment via the peak/valley method, $h_b$ is the average binder height, and $h_s$ is the average height of aggregate (Ozdemir et al.). This method was validated by comparing the results to "idealized images with known percent embedment" (Ozdemir et al.) and had a good correlation with the idealized images. This method is time-intensive and expensive and is also hard to use in the field long term, but the results are promising.

## Conclusions and Recommendations

The portable laser profiler, image analysis, and image processing methods all showed promise and are a step in the right direction to more accurate measurements of mean profile depth and percent embedment for chip seals. However, even though they are more accurate than the sand patch, they are all more expensive and time-consuming. I recommend further testing be done with all methods to determine which is the most suitable for future use. At this point, the measurement of percent embedment with the image processing method seems the most likely to be used in the future. It may not be used in the field, but with the results from this method, it is possible to develop a correlation with an easier test that could be used in the field.

## Acknowledgments

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## References


Boz, Ilker et al. *Establishing Percent Embedment Limits To Improve Chip Seal Performance*. Michigan State University, East Lansing, MI, 2018, https://www.michigan.gov/documents/mdot/SPR-1679_635048_7.pdf. Accessed 17 Apr 2020.

"Chip Seal." *WSDOT*, 6 May 2019, wsdot.wa.gov/construction-planning/preservation/chip-seal.

Gransberg, Douglas D., and Musharraf Zaman. "Analysis of Emulsion and Hot Asphalt Cement Chip Seal Performance." *JOURNAL OF TRANSPORTATION ENGINEERING*, Mar. 2005, pp. 229–238., doi:10.1061/(ASCE)0733-947X(2005)131:3(229).

Kim, Hyung et al. *Measurement Of Texture Depth Of Pavement Using Portable Laser Profiler*. Journal Of The Eastern Asia Society For Transportation Studies, Hwa-Sun, Korea, 2013, https://www.jstage.jst.go.jp/article/easts/10/0/10_1576/_pdf/-char/en. Accessed 20 Apr 2020.

Kouchaki, Sareh et al. *Development Of A Three-Dimensional Laser Scanning Prototype For Pavement Preservation Applications*. Center For Transportation Research At The University Of Texas At Austin, 2019, Accessed 14 Apr 2020.

Ozdemir, Ugurcan et al. *Quantification Of Aggregate Embedment In Chip Seals Using Image Processing*. Journal Of Transportation Engineering, Part B: Pavements, 2018, https://ascelibrary-org.proxy2.library.illinois.edu/doi/full/10.1061/JPEODX.0000068. Accessed 11 Mar 2020.

*Texture – Sand Patch*. Minnesota Department of Transportation, June 2010, www.dot.state.mn.us/mnroad/data/pdfs/MnROAD%20Texture%20Sand%20Patch%20FINAL_062410.pdf.

Zhao, Guangyuan et al. *Quality Assurance Procedures For Chip Seal Operations Using Macrotexture Metrics*. Joint Transportation Research Program, West Lafayette, IN, 2018, https://docs.lib.purdue.edu/jtrp/1671/. Accessed 19 Mar 2020.