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*Virginia Transportation Research Council*

# *research report*

## Use of the Digital Surface Roughness Meter in Virginia

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<p><b>Abstract</b></p> <p>Pavement surface texture is measured in a variety of ways in Virginia. Two methods commonly used are ASTM E 965, Standard Test Method for Measuring Pavement Macrottexture Depth Using a Volumetric Technique, known as the "sand patch" test, and ASTM E 2157, Standard Test Method for Measuring Pavement Macrottexture Properties Using the Circular Track (CT) Meter.</p> <p>In September 2005, staff from the Virginia Transportation Research Council inquired about using the Digital Surface Roughness Meter (DSRM™) to measure the surface texture of several concrete and asphalt surfaces. Measurements were taken on concrete and asphalt surfaces using the DSRM™, CT meter, and sand patch test, and the results were compared.</p> <p>From the data obtained, there appears to be a good correlation among the results of the three methods. The DSRM™ and sand patch tests appear to be more accurate on surfaces that are not uniform. However, this may be because the center of the rotating arm of the CT meter may have missed particular non-uniform areas on the testing surface. The use of the DSRM™ and CT meter devices also reduces the probability of human error. The sand patch test is exposed to a greater probability of human error; it is a test that cannot be performed quickly without comprising accuracy. The DSRM™ is a better device to use under a time constraint.</p>				

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Virginia Transportation Research Council  
(A partnership of the Virginia Department of Transportation and  
the University of Virginia since 1948)

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## ABSTRACT

Pavement surface texture is measured in a variety of ways in Virginia. Two methods commonly used are ASTM E 965, Standard Test Method for Measuring Pavement Macrotexture Depth Using a Volumetric Technique, known as the “sand patch” test, and ASTM E 2157, Standard Test Method for Measuring Pavement Macrotexture Properties Using the Circular Track (CT) Meter.

In September 2005, staff from the Virginia Transportation Research Council inquired about using the Digital Surface Roughness Meter (DSRM™) to measure the surface texture of several concrete and asphalt surfaces. Measurements were taken on concrete and asphalt surfaces using the DSRM™, CT meter, and sand patch test, and the results were compared.

From the data obtained, there appears to be a good correlation among the results of the three methods. The DSRM™ and sand patch tests appear to be more accurate on surfaces that are not uniform. However, this may be because the center of the rotating arm of the CT meter may have missed particular non-uniform areas on the testing surface. The use of the DSRM™ and CT meter devices also reduces the probability of human error. The sand patch test is exposed to a greater probability of human error; it is a test that cannot be performed quickly without comprising accuracy. The DSRM™ is a better device to use under a time constraint.

## **FINAL REPORT**

### **USE OF THE DIGITAL SURFACE ROUGHNESS METER IN VIRGINIA**

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#### **INTRODUCTION**

Pavement surface texture is measured in a variety of ways in Virginia. Two methods commonly used are the “sand patch” test and the circular track (CT) meter. The first technique is performed in accordance with ASTM E 965, Standard Test Method for Measuring Pavement Macrot texture Depth Using a Volumetric Technique.<sup>1</sup> The second technique is performed in accordance with ASTM E 2157, Standard Test Method for Measuring Pavement Macrot texture Properties Using the Circular Track Meter.<sup>2</sup> Both methods can be used to measure surface texture in a localized area such as a bridge deck, stretches of pavement that are a discrete length, and situations in which live traffic is not a concern.

The CT meter and the sand patch tests were developed specifically for characterizing highway surface textures. At least one device with similar capabilities, the Digital Surface Roughness Meter (DSRM™), was developed for measuring “smoothness” of other constructed and fabricated finishes. The device is an optical laser-based imaging system that uses a laser profiling line to measure roughness.<sup>3</sup>

Previous work performed by the Virginia Transportation Research Council (VTRC) and others has demonstrated the validity of the CT meter and the sand patch test.<sup>4,5</sup> The applicability of the DSRM™ for use in characterizing highway surface texture has yet to be determined.

#### **PURPOSE AND SCOPE**

The purpose of this study was to obtain a preliminary indication of the suitability of the DSRM™ for measuring macrot texture of pavement surfaces. This assessment was accomplished through comparison of the DSRM™ and the traditional CT meter and sand patch test procedures. This comparison was conducted using various concrete and asphalt pavement surfaces on Virginia roadways and at the Virginia Smart Road facility. A more detailed comparison of the three procedures will require a much larger data base.

#### **METHODS**

In September 2005, VTRC researchers took possession of the DSRM™ for a 6-week period. During this timeframe, surface measurements of a series of concrete and asphalt surfaces were made using the DSRM™ and sand patch and/or CT meter testing.

As stated previously, the sand patch test is conducted in accordance with ASTM E 965; it involves spreading a known volume of material into a circle until the surface texture is exposed. The diameter of this circle is then measured at the quarter points, and an average diameter for the circle is calculated. The average diameter is then used to calculate the mean texture depth (MTD), which is an indication of the surface texture. The MTD was calculated using Eq. 1.

$$MTD = \frac{4V}{\pi D^2} \quad (\text{Eq. 1})$$

where MTD = mean texture depth of pavement macrotexture, in (mm)  
V = sample volume, in<sup>3</sup> (mm<sup>3</sup>)  
D = average diameter of the area covered by the material, in (mm).

The CT meter analyzes the surface macrotexture profile using a charge coupled device (CCD) laser displacement sensor. The sensor is mounted on an arm that rotates in a circular track. A laptop computer with specific software is used to run the measurement operations. The information obtained from the CT meter is the mean profile depth (MPD), which is not the same as the MPD calculated in the sand patch test. The MPD gives an indication of the profile of the surface, not the texture. The CT meter measurements were conducted in accordance with ASTM E 2157, which contained an equation to convert the MPD to MTD.

$$MTD = 0.947MPD + 0.069 \quad (\text{Eq. 2})$$

DSRM<sup>TM</sup> testing was conducted in accordance with the manufacturer's user's manual.<sup>6</sup> The software needed to run the measurements was loaded onto a laptop computer. The device measures many parameters; the parameter most useful for this study was the average peak to valley roughness (R) value. This is fundamentally similar to the MPD calculated by the CT meter.

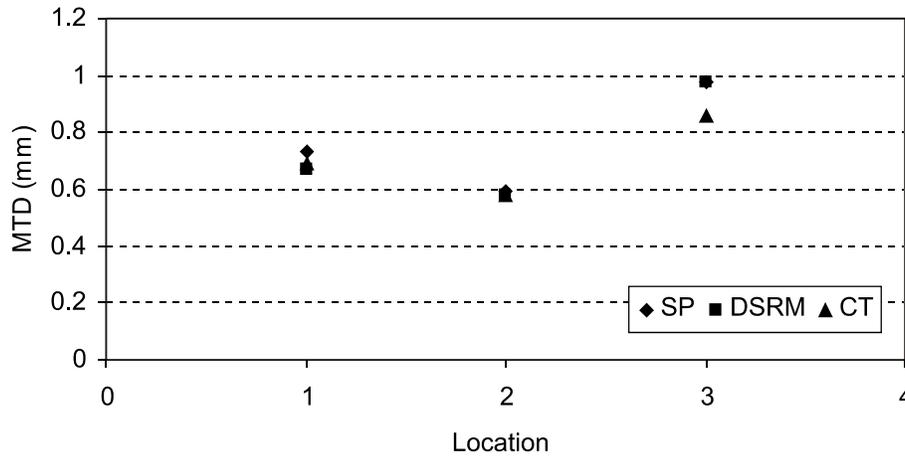
Data were collected using the three measurement techniques on concrete and asphalt surfaces. Then, the data were converted to MTD in order to compare the data and correlate the results.

## RESULTS AND DISCUSSION

The first measurements taken using the DSRM<sup>TM</sup> were on an asphalt parking lot. This was done mainly to allow the investigator to become accustomed to using the device and the operating procedures before testing it in the field. Sand patch and CT meter testing were conducted at the same locations. Three locations were selected; two had a uniform surface, and the third did not. Table 1 presents the MTD for each device at the various locations, and Figure 1 presents the data graphically.

**Table 1. Initial MTD (mm) of DSRM™, Sand Patch, and CT Meter**

Location	DSRM™	Sand Patch	CT Meter
1	0.67	0.73	0.69
2	0.58	0.59	0.58
3	0.98	0.98	0.86



**Figure 1. Initial MTD of Sand Patch (SP), DSRM, and CT Meter Testing**

The data show a good correlation among the results of the three devices at the first two locations. At the third location, the DSRM™ and sand patch test yielded similar results but the CT meter data showed a smoother surface. This discrepancy was due to the fact that the CT meter uses an arm that rotates in a circular motion and only the outside part of the arm actually takes the measurement. The “rough spot” was not in the track of the rotating arm and was, thus, not detected. From these initial data, it appeared that the three devices would correlate well if the measurements were made on a uniform surface.

The next test series was performed on an interstate bridge deck being prepared for an epoxy overlay. The deck had been shot blasted in preparation for the overlay. The overlay consisted of an epoxy and a silica sand mixture that produces a skid-resistant surface suitable for highway traffic. For this test series, the DSRM™ and sand patch tests were performed. The CT meter was not used because of time constraints. The testing was performed while the overlay operations were being performed; thus there was not a lot of time to take measurements. Table 2 presents the data from the bridge deck surface before the overlay was placed, and Table 3 presents the data from the overlay. Figure 2 presents the MTD data for the bridge deck surface only for the two measurement techniques.

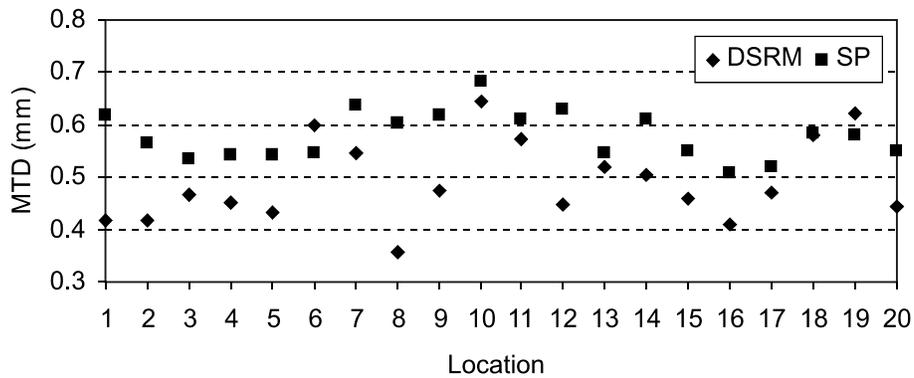
From the data it appears that the DSRM™ consistently measures a smoother surface than the sand patch on the bridge deck surface. This was probably due to the sand patch measurements being taken quickly because of work conditions on the deck. The measurements were taken at night, and the reduced lighting may have had an impact on the sand patch readings. The results of the two techniques do appear to follow the same trend. A correlation analysis was performed using the data from the bridge deck surface and the overlay surface. Figure 3 presents the correlation data from the bridge deck surface, and Figure 4 presents the correlation data from the overlay surface.

**Table 2. MTD (mm) of Bridge Deck Surface Before Overlay**

Location	DSRM™	Sand Patch
1	0.4176	0.6163
2	0.4165	0.5633
3	0.4661	0.5367
4	0.4533	0.5412
5	0.4307	0.5412
6	0.6007	0.5459
7	0.5465	0.6386
8	0.3568	0.6018
9	0.4760	0.6163
10	0.6434	0.6834
11	0.5722	0.6121
12	0.4487	0.6308
13	0.5199	0.5450
14	0.5051	0.6093
15	0.4606	0.5512
16	0.4116	0.5071
17	0.4689	0.5198
18	0.5815	0.5852
19	0.6203	0.5818
20	0.4452	0.5483

**Table 3. MTD (mm) of Overlay Surface**

Location	DSRM™	Sand Patch
1	1.4569	2.8780
2	1.4646	2.2122
3	2.0748	2.5342
4	1.5349	2.2767
5	1.3744	2.1731



**Figure 2. MTD (mm) for Bridge Deck Surface. SP = sand patch.**

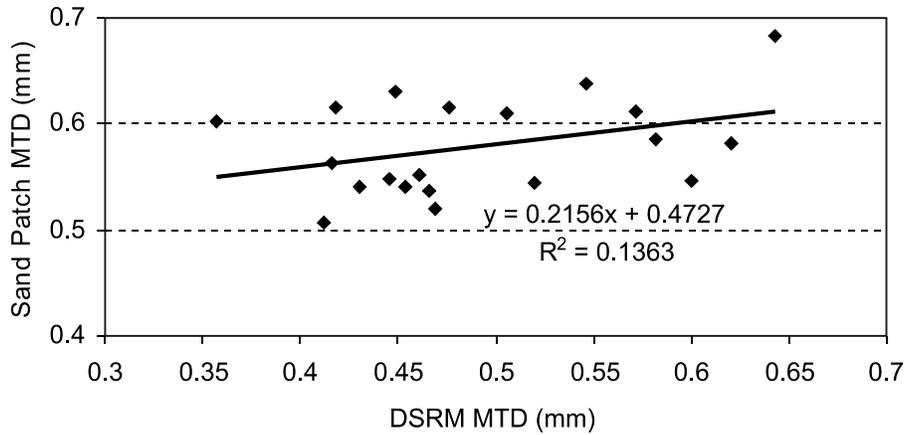


Figure 3. Correlation Between DSRM™ and Sand Patch Testing for Bridge Deck Surface

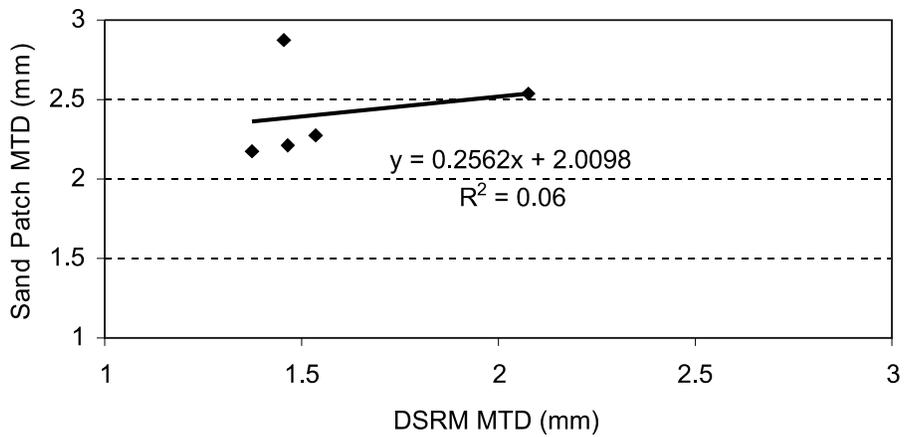


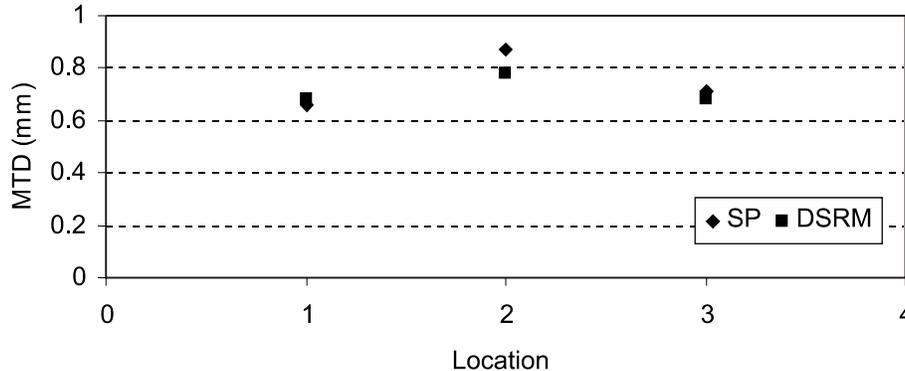
Figure 4. Correlation Between DSRM™ and Sand Patch Testing for Overlay Surface

From the data there does not appear to be a strong correlation between the two measurement techniques. This was probably due to the fact that the sand patch measurements were taken quickly due to time constraints. This probably also led to the rougher surface calculated for the sand patch measurements. For the overlay, the surface was rough and an accurate reading on the sand patch measurements was difficult to obtain; it is possible that the sand grains were lost in the open surface of the overlay, which led to a higher surface texture reading. One encouraging aspect of this test series was that the results of the two measurement techniques for smooth and rough test locations did appear to follow a similar trend.

The next test series involved measuring a diamond-ground concrete surface. This was performed on an interstate highway pavement in order to have a smoother riding surface. Measurements were taken using the DSRM™ and the sand patch techniques. Again, because the measurements were taken in the field during grinding operations, the CT meter was not used because of time constraints. Table 4 presents the MTD (mm) data for the diamond-ground surface, and Figure 5 presents the data graphically.

**Table 4. MTD (mm) for Diamond-ground Concrete Surface**

Location	DSRM™	Sand Patch
1	0.68	0.66
2	0.78	0.87
3	0.68	0.71



**Figure 5. Data for Diamond-ground Concrete Surface. SP = sand patch.**

The data presented from this series showed a strong correlation between the DSRM™ and sand patch measurements. The surface was uniform, and testing was performed under better conditions (not as much of a time constraint) than with the previous test series.

The final test series occurred at the Virginia Smart Road in Blacksburg. The road is currently being used as a test bed and will eventually connect Blacksburg to I-81. Three sections were tested using the DSRM™, sand patch test, and the CT meter. The first section was called the loop and consisted of stone-matrix asphalt (SMA) with a nominal maximum aggregate size of 19.0 mm. Sections J and L were also tested. Section J was a 9.5 mm Superpave® mixture. This is a dense-graded mixture that usually creates a fairly smooth surface. Section L was a 12.5 SMA mixture. Table 5 presents the MTD data for each test section for the three testing methods. From these data, the results of all three techniques appeared to follow the same trend. Figure 6 presents the data graphically.

A correlation analysis was performed on the results of the three measurement techniques. Figures 7 through 9 present the correlations. From these data, the correlation was good. The surfaces were uniform, and there were no time constraints while taking the measurements. Figure 10 presents the correlation between the sand patch and DSRM™ test results for all test locations. As may be seen, the correlation was good.

**Table 5. MTD (mm) for the Virginia Smart Road**

Location	DSRM™	Sand Patch	CT Meter
Loop 1	0.80	0.73	0.77
Loop 2	0.93	0.83	0.99
J1	0.62	0.73	0.77
J2	0.61	0.55	0.65
J3	0.66	0.53	0.66
L1	0.94	0.95	0.91
L2	1.08	0.95	1.08
L3	0.97	0.95	1.10

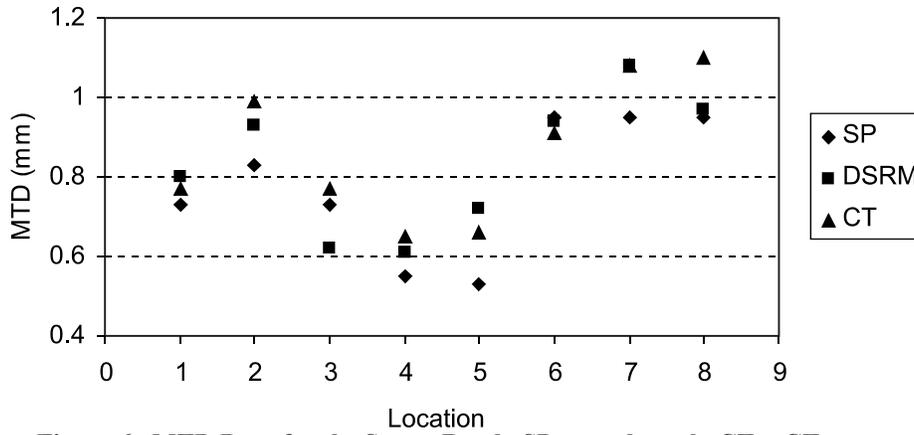


Figure 6. MTD Data for the Smart Road. SP = sand patch, CT = CT meter.

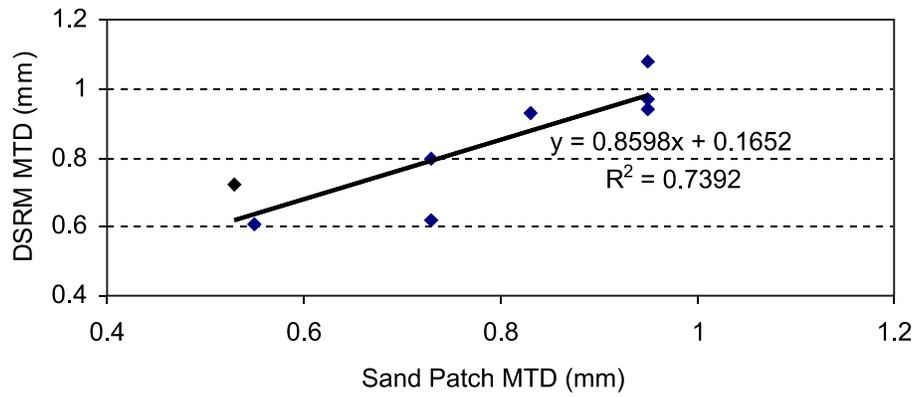


Figure 7. Correlation Between DSRM™ and Sand Patch Results

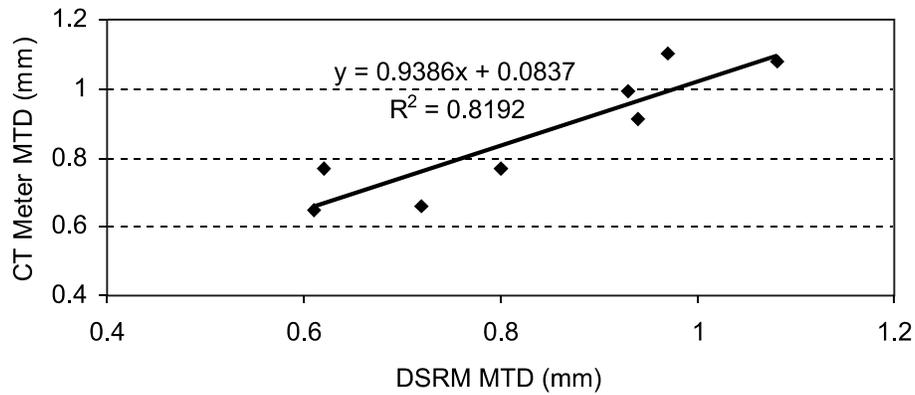


Figure 8. Correlation Between DSRM™ and CT Meter Results

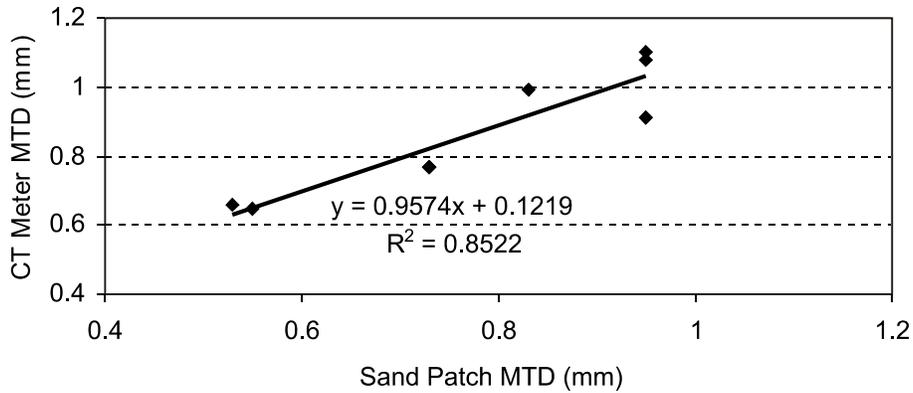


Figure 9. Correlation Between Sand Patch and CT Meter Results

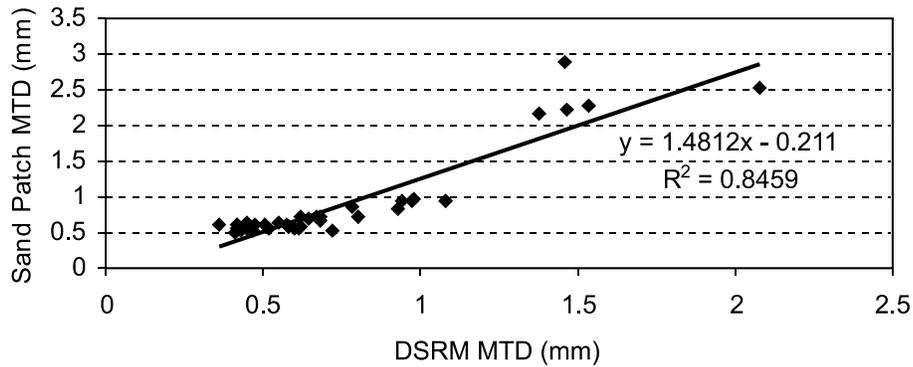


Figure 10. Correlation Between Sand Patch and DSRM™ Results

### Analysis of Measurement Techniques

From the data obtained in this study, there appears to be a good correlation among the results of DSRM™, sand patch, and CT meter testing. The DSRM™ and sand patch methods measure a smaller area than does the CT meter, with the CT meter employing a rotating arm. These differences in areas measured could produce different texture results. One way to reduce such differences would be to take a series of DSRM™ and sand patch measurements that cover the entire area of the CT meter measurement. The average of these series of measurements might then be closer to the CT meter measurement. The use of the DSRM™ and CT meter also reduces the probability of human error. The sand patch test is exposed to a greater probability of human error; it is a test that cannot be performed quickly. If the test is performed too quickly, the accuracy is compromised. The DSRM™ is a better device to use when there is a time constraint. The test can be performed quickly without compromising accuracy.

In situations with no time constraint, lighting is good, and the test surface is uniform, there is a good correlation among the three testing techniques. All three are easy to perform. As for limitations, the sand patch test can produce a lot of variability. The test appears to be user-dependent with a lot of variability among users. With the DSRM™ and CT meter, there is less variability among users. However, the equipment associated with the DSRM™ and CT meter is more costly than a sand patch kit. The developers of the DSRM™ are in the process of developing a newer version of the device that can be operated by one person. This would enhance the efficiency of the device in the field in the sense that only one person would be

needed to take the measurement and collect the data. As it stands now, the device requires two people to operate: one to take the measurement, and the other to collect the data through the laptop computer.

In the event a new DSRM™ is developed, there is a current application that may be well suited for this device. The Virginia Department of Transportation has a special provision for the planing of asphalt concrete pavement, which specifies a MTD for a planed surface that is to be exposed to traffic on limited access roadways. The specified MTD is currently measured using the sand patch test in accordance with ASTM E 965. If the single-operator device is developed, it could be used for taking the measurements required by this special provision. The average time required for a single sand patch test is approximately 5 minutes; the single-operator DSRM™ test could be performed in less than 1 minute. The new device would have the potential to decrease the time required to measure surface texture for this special provision.

## **CONCLUSIONS**

- In situations with no time constraints where the testing surface is uniform, there is a good correlation among results of the DSRM™, sand patch, and CT meter measuring techniques.
- The DSRM™ measuring technique appears to be more efficient than the sand patch test for taking measurements when there is a time constraint or inadequate lighting.

## **RECOMMENDATIONS**

1. Because the DSRM™ device is expensive and requires two people to operate, it is not recommended at this time that the device be used as a replacement for the sand patch technique for measuring macrotexture of pavement surfaces.
2. In the event a new lower cost single-operator DSRM™ device is developed, VTRC should compare its efficiency in taking field measurements with that of the sand patch test.

## **BENEFITS AND COSTS ASSESSMENT**

The cost of the equipment associated with the three measurement techniques investigated in this report varies by device. The CT meter is the most expensive, with a cost of approximately \$20,000. The DSRM™ has a cost of approximately \$9,500, which includes the device and software but not the laptop computer. However, the equipment and software are compatible with most computers. The sand patch test kit can be fabricated for less than \$200.

The benefits of the CT meter and the DSRM™ are that there is a smaller probability of variability than with the sand patch testing. The use of the CT meter and DSRM™ would most likely increase the accuracy and repeatability of the measurements. Another benefit associated

with the DSRM™ is that the tests can be performed under field conditions where there are time constraints more easily than with sand patch testing.

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