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D&S Technical Note 08-1

Model SSR-ER – Solar Reflectance Measurements of Irregular Surfaces

Introduction

The measurement of solar reflectance with the model SSR Solar Spectrum Reflectometer requires a flat sample about one inch in diameter. The instrument provides a diffuse source of radiation at the port and measures reflected energy in a narrow solid angle at twenty degrees from normal to the surface. Ideally, for the sample to be properly illuminated it must be flat and flush with the port. Materials that are basically flat but have a surface texture cannot be completely flush with the port and therefore may not be properly illuminated. Examples of textured surfaces are pavestones, embossed materials and rice crispy squares. These surfaces have hills and valleys or voids so that some portion of the surface is necessarily displaced from the measurement port. As a surface is moved away from the port, low grazing angle illumination is lost particularly around the edge of the measurement port. Also, at greater displacements, the portion of the surface that is viewed by the detector no longer receives full illumination at twenty degrees incidence and thus the specular component of reflectance is reduced. Both the loss of low grazing angle illumination and the clipping of the specular component cause the reflectance reading to be lower than it should be. This technical note proposes a measurement technique to estimate a correction for textured surfaces.

Discussion

Two examples of textured surfaces are illustrated in two dimensions in figure 1a and 1b. The surface in figure 1a has generally shallow features and a deeper void or valley near the center of the SSR measurement port. Assuming that the measurement port is essentially flush with the surface around the entire circumference of the port, in this particular case, this sample is properly illuminated. Hypothetically, for this type of sample the measurement error due to surface texture for a single measurement would be very small as long as the deeper valley remains well inside the edge of the measurement port. The reflectance measurement is of the composite surface which includes the effect of the surface geometry at this one point. If the measurement port is positioned with a void near or crossing the edge the sample will not be properly illuminated as is the case of the surface shown in figure 1b.

The surface depicted in figure 1b is not properly illuminated because portions of the surface are displaced from the port around the edges. Those areas do not receive the same illumination as would be present if the measurement port were arbitrarily large. The effect is similar to taking a flat surface and displacing it from the port.

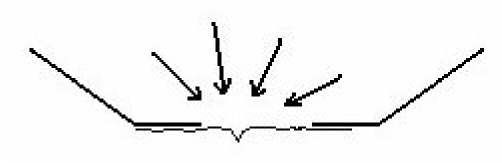

Figure 1a

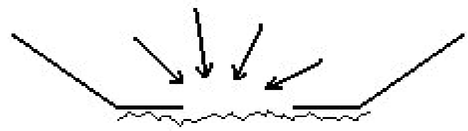

Figure 1b

Figure 2 shows the effect of displacement from the measurement port for some selected flat samples. The reflectance values were measured with SSR s/n 137 v6.3, set to air mass 1.5 direct reflectance (based on ASTM E891). The samples were displaced from the port using aluminum ring spacers, 1.38 inch ID by 1.67 inch OD, of varying thicknesses. The ring inside diameter was large enough to rest on the flat portion of the SSR measurement port, just outside the Teflon gasket. Displacement distances account for the thickness of the gasket. The samples are as follows:

Sample	AM 1.5 direct reflectance	Description
Diffuse white tile	0.845	Highly diffuse unglazed tile surface
Glossy white tile	0.825	Glazed white tile
Mirror	0.882	
Glossy black tile (157)	0.131	Glazed black tile
Glossy black tile (119)	0.099	Dark black glazed tile
Red Pavestone	0.243	white /gray/black crushed aggregate

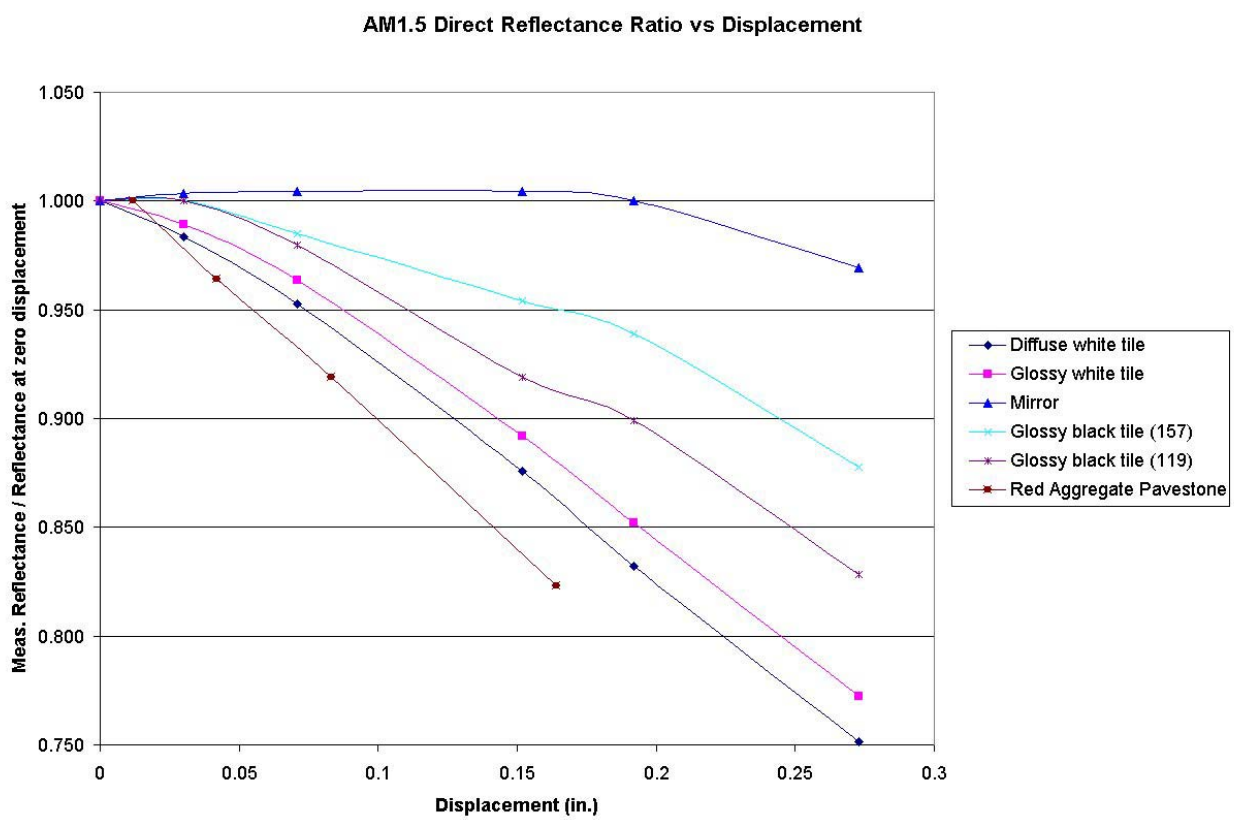

Figure 2. SSR Reflectance ratio versus displacement

Notice that the indicated reflectance of the mirror surface remains largely unchanged until the displacement from the port is nearly 0.2 inches. This is because the illumination that is missing is at low grazing angles and thus would not have been reflected in the direction of the detectors. In addition, the detector is aligned so that the portion of the sample viewed is off center to the port to allow measurement of a thicker second surface reflector[1]. Because of this offset, the specular component begins to be clipped at a greater displacement than it would be if the detector were aligned on the center of the port.

The displacement error is greatest for a highly diffuse sample as shown for the diffuse white tile. Glossy black tiles are included because they have a significant specular component of reflection. Notice in the plots for the two glossy black tiles that the clipping of the specular component appears at about the same displacement as for the mirror.

Proposed correction to measurements of textured surfaces

For textured surfaces a reflectance reading with the port resting on the surface will be low because portions of the surface will be displaced from the port and therefore not properly illuminated. The proposed method of correcting the reflectance reading is to measure the reflectance with the port in contact with the textured surface and at two or more displacements away from the surface. The displaced measurements would in effect be used to approximately characterize the surface for specular versus diffuse reflectance as compared to the measurements of displaced flat surfaces as shown in Figure 2. Then by estimating an average displacement of the textured surface from the measurement port when it is "in contact", a correction to the reflectance reading can be estimated from the data in Figure 2.

Practical Measurements

In practice, because the surfaces are often variegated in color in addition to being textured, a large number of measurements are required to get good average values. Data for a red aggregate pavestone is included in Figure 2. Forty eight each reflectance values were measured with the port in contact with the surface and with three different thicknesses of spacer rings. In addition, using one of the spacer rings and a micrometer at numerous random locations, the average displacement of the surface from the port (in contact) was estimated to be 0.012 inches. The plot in Figure 2 shows the average reflectance values normalized to the average reflectance in contact with the port. The pavestone surface behaves like the diffuse flat samples although the shape of the curve does not match perfectly. This is believed to be more due to measurement uncertainty rather than to the effect of the surface texture. Using the average displacement of 0.012 inches, the correction for the highly diffuse tile is only about 1% of reflectance. The average reflectance of the pavestone was 0.241 and adding 1% the corrected reflectance is about 0.243.

Similar measurements were made for a gravel aggregate pavestone with an average surface displacement of about 0.055 inches. Again the reflectance variation with displacement was similar to that for the diffuse tile for which the correction at 0.055 inches is about 3%. The average reflectance for the gravel aggregate pavestone measured in contact with the port was 0.221 and the corrected reflectance is 0.228.

Unless a surface has a high gloss finish it is likely that the reflectance variation with displacement will be similar to that for the diffuse tile. Therefore, since the correction to reflectance is usually small it may only be necessary to measure the "in contact" reflectance and the average displacement of the surface from the port to estimate a correction.

Note that the reflectance versus displacement data for flat surfaces that is used for estimating corrections may vary somewhat for different instruments. It is recommended that this data be generated for each Solar Spectrum Reflectometer.

Reference 1. Technial Note 82-1 “Solar Spectrum Reflectometer Updates and Design Modifications.”