Core thickness and asperity height of textured geomembranes: a critical review

By Nazli Yesiller, Ph.D.

Core thickness and asperity height are used for the general characterization of textured geomembranes in manufacturing quality control, conformance and acceptance testing. The core thickness measurement is used to determine the average minimum thickness for a textured geomembrane, in accordance with ASTM D 5994 (*Test method for measuring core thickness of textured geomembrane*). Asperity height is used to determine the maximum variation in height between peaks and valleys on a given surface of a textured geomembrane in accordance with GRI Test Method GM12 (*Asperity measurement of textured geomembranes using a depth gage*). Core thickness is a measure of thickness characteristics of a geomembrane; whereas asperity height is a measure of surface roughness of a textured geomembrane.

Core thickness and asperity height are commonly determined using mechanical test methods. For core thickness determination, a specimen is placed horizontally in a thickness gage between two measurement points (tips). The rounded conical tips are constructed with an apex of 60° ± 2° and a radius of 0.8 mm ± 0.1 mm at the tip. Measurements are taken at a constant average load of 0.56 N. The specimen is located in the thickness gage such that the tips are placed in the deepest valleys on opposing surfaces of a geomembrane to obtain the minimum thickness of the geomembrane. For asperity height determination, a setting block (50 mm – length x 20 mm – width x 15 mm – height) with a hole at the center is placed on a given surface of a textured geomembrane. A measurement probe with a diameter of 1.3 mm that is tapered to a contact point protrudes through the central hole in the block. The block is placed on a specimen such that it rests on the high points (peaks) of the specimen and the contact point rests on the lowest point (valley) on the surface of the specimen. This arrangement provides a measurement of the localized maximum elevation difference on the surface of the geomembrane.

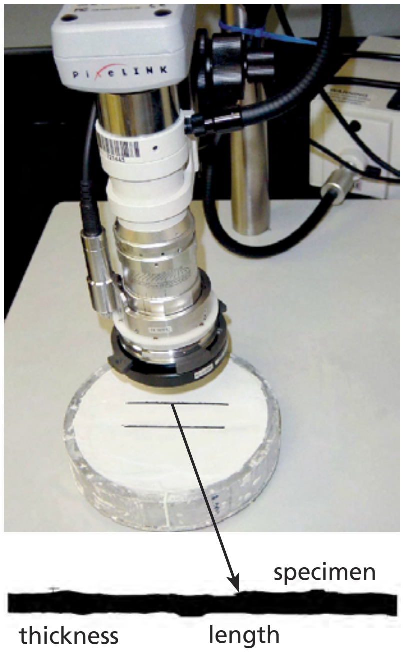

Photo 1. Image analysis test setup and example of cross-sectional image obtained in a measurement (not to scale). Seen here: a specimen holder with 2 specimens.

Discrete measurements are made on multiple locations on a geomembrane for both test methods. Operators try to obtain the lowest core thickness and the highest asperity height by adjusting the measurement locations based on visual observation of test specimens. Specific methods or approaches are not available to ensure finding locations with limiting values, minima and maxima, respectively for mechanical core thickness and asperity height tests.

Experimental case study

An assessment was conducted to determine the effectiveness of the common mechanical test methods in determining the core thickness and asperity height of textured geomembranes. An image analysis method was used to provide extensive characterization of thickness and surface texture characteristics. Comparisons were made between the parameters determined using mechanical and image analysis methods. Tests were conducted on a total of eight geomembranes that consisted of six HDPE and two LLDPE geomembranes. The geomembranes were manufactured by co-extrusion and embossing. These materials used in the test program represent commonly available textured geomembranes. The mechanical and image analysis tests were conducted on the same test specimens that allowed for direct comparison of the test methods.

Initially mechanical measurements were made to obtain the core thickness and asperity height of the specimens. Then the specimens were inserted vertically into a specimen holder and surrounded by plaster of paris for the image analysis measurements. Cross sectional images (length by thickness) of the specimens were obtained in this arrangement at a magnification of 50X using an optical microscope (**Photo 1**). In this way, a continuous record of the entire cross section of a specimen was obtained. Specimen thickness was determined as the straight-line distance between the top and bottom sides of a specimen. A total of 9600 thickness measurements were recorded for a specimen with a length of 75 mm at a resolution of 8 μm. Core thickness was identified as the lowest thickness along the entire cross section of a specimen. The cross-sectional images were further processed to determine the surface texture characteristics of the geomembranes. A computer algorithm was used to extract the surface profiles from the cross sections. These profiles were then processed using a surface metrology software to determine various texture parameters. The maximum peak-to-valley height was determined for each specimen. This parameter is intended for measurement using the mechanical asperity height test.

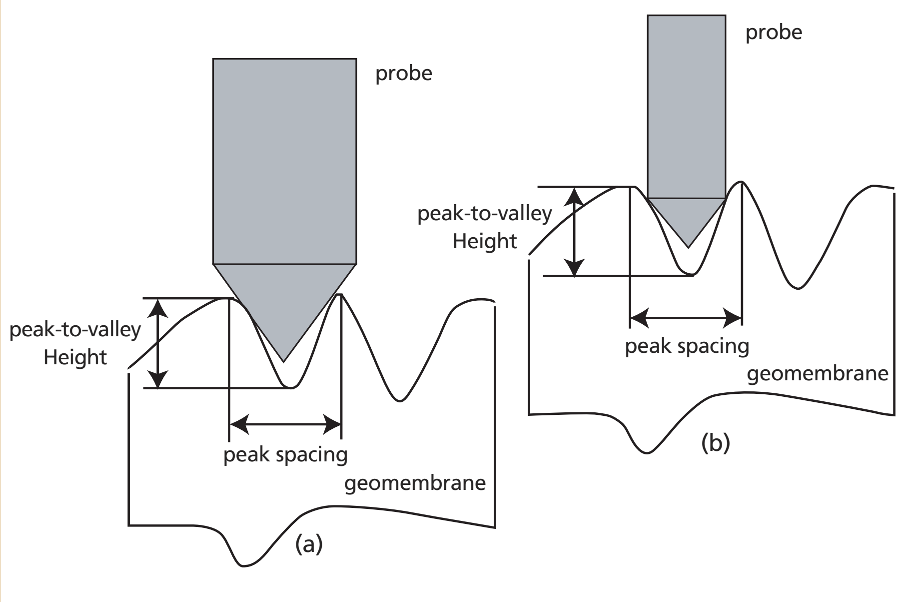

Figure 1. Various probe arrangements that do not allow for representative measurements.
(a) Probe tip is too large to fit between peaks at the given peak-to-valley height
(b) Probe diameter too large to fit between peaks at the given peak-to-valley height (not to scale)

The image analysis tests provided an extensive data set for thickness and surface characteristics of the textured geomembranes. Details of this extensive study are presented in Yesiller and Cekic (2005). Average thicknesses were determined for each specimen. Also, the distributions of thicknesses along the length of the specimens were determined. Frequencies of occurrence of thickness ranges for a given geomembrane were represented using histograms. The variation of average thicknesses was low (1–3%) for a particular geomembrane. The thicknesses had skewed distributions: 80% of the thickness data was within the range of nominal thickness to 25–50% higher than the nominal thickness. The range for the majority of data decreased as the thickness of the geomembranes increased, indicating that the manufacturing processes generate texturing that is independent of the thickness of the geomembranes. It was determined that the amount of thickness data below the nominal thicknesses were low (1– 8%) for the tested geomembranes.

The comparisons of test results indicated that the core thickness and asperity height values obtained using the mechanical and image analysis test methods were statistically dissimilar (determined using t-tests at 95% confidence interval). The mechanical core thicknesses were 6 to 22% higher than the image analysis core thicknesses. While the mechanical core thicknesses were higher than the nominal thicknesses of the geomembranes (with the exception of one sample), the image analysis core thicknesses were lower than the nominal thicknesses of the geomembranes. The mechanical core thicknesses were less than 1 to 18% higher than the nominal thicknesses and the image analysis core thicknesses were 3 to 14% lower than the nominal thicknesses. The image analysis asperity heights ranged between 0.63 mm to 0.90 mm, whereas the mechanical asperity heights ranged between 0.38 mm to 0.70 mm. The mechanical asperity heights were 23 to 42% lower than the image analysis asperity heights.

The mechanical tests overestimated the core thicknesses and underestimated the asperity heights. Overall, the mechanical tests did not produce representative measurements for the test geomembranes. The main reason for this is the configuration (size and shape) of the

Is there a problem here? Essentially, no

Nazli Yesiller's article is the fourth that *GFR* has published in the past 18 months regarding asperity height, textured geomembranes and ultrasonic testing methods. The other three were Ivy (2003), Yesiller (2004), and Koerner (2005). Does this growing discussion sign a problem with the materials? No. It's more of a professional drive borne out of user requests.

Texturing is common on geomembranes. These products make up a robust portion of the marketplace. Take, for example, the high-density polyethylene (HDPE) geomembrane data posted in the 2005 edition of the *GFR* Specifier's Guide. Of the 53 products, 21 are textured. Another handful are structured.

Some practitioners use these terms interchangeably, while others strike a difference. Those who give them narrower meanings generally use the term "textured" to indicate a geomembrane that's been randomly textured by its manufacturing process. (See George Koerner's article for a concise synopsis of manufacturing methods.) "Structured" is then used to sign more controlled patterning that results from proprietary manufacturing methods.

This search for faster, nondestructive testing methods for textured geomembrane data follows the demands of construction quality assurance (CQA) and design validation; but it does not question the relevance and performance of the materials being discussed.

-Christopher Kelsey, editor

References

Ivy, N. 2003. "Asperity height and variability effects." *GFR*, vol. 21, no. 8.

Koerner, G. and Koerner, R. 2005. "In the lab: Thickness and asperity tests of textured geomembranes." *GFR*, vol. 23, no. 3.

Yesiller, N. 2004. "Ultrasonic testing for geomembranes." *GFR*, vol. 22, no. 4.

mechanical devices. The image analysis asperity heights were almost exclusively obtained as peak-to-valley heights at locations separated by a distance, which was higher than the longest dimension of the mechanical asperity height setting block (50 mm). The tips of the measurement probes (both core thickness and asperity height) could not physically fit in the valleys between the peaks on the surface of the geomembranes tested in the study (**Figure 1**). Average peak spacings and average peak-to-valley heights on the surfaces of the geomembranes were determined using the image analysis tests. The combination of the diameter of the probe and taper length compared to the average peak spacing and the average peak-to-valley height, respectively, of the asperities on the surface of the geomembranes prevents the probes from reaching the lowest valleys.

It was determined that a probe diameter of less than 0.6 mm over a probe length of more than 0.9 mm at the probe tip is required for the mechanical gages based on the measured surface features of the tested geomembranes (i.e., average peak spacing and peak-to-valley height). Devices with these dimensions reach the bottom of the deepest valleys between peaks on the geomembranes to obtain representative measurements.

In addition to the size and shape characteristics of the mechanical devices, the discrete nature of the test methods affects the measured parameters. Even though the locations for the measurements are adjusted in a test, it is not possible to visually estimate the location with the minimum core thickness or maximum asperity height for a geomembrane. While the recommended probe dimensions will improve the effectiveness of the measurements, the basic conduct of the tests with discrete measurements at visually selected locations prevent capturing the limiting values (minima or maxima) for the measured parameters.

Conclusions

The currently available and commonly used mechanical devices are not fully conducive to obtaining representative measurements of core thickness and asperity height of textured geomembranes. The mechanical tests tend to overestimate core thickness and underestimate asperity height. The image analysis method used for this study provides representative measurements of both parameters. However, the method is not highly practical for routine use. Nondestructive test methods such as laser, ultrasonic, magnetic or profilometry techniques can be used to obtain continuous measurements for thickness and surface characteristics that provide representative values for the measured parameters. Various surface parameters in addition to asperity height can be determined using surface profiles for textured geomembranes. These parameters may better correlate to the engineering behavior of textured geomembranes than asperity height. Furthermore, in the image analysis tests, it was determined that the test geomembranes exhibited anisotropy (between machine and cross-machine directions) and also directionality (“forward” and “backward” directions that are 180° apart along a given manufacturing direction) (Yesiller and Cekic 2005). Anisotropy and directionality should be considered in the placement of these materials in the field. These characteristics can be determined only by fully analyzing surface texture of geomembranes. Asperity height cannot be used for such analysis. It is believed that detailed surface analysis of textured geomembranes is required to fully characterize texture features that influence performance of these materials for appropriate use in the field.

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IAA Call for submissions

The Industrial Fabrics Association International (IFAI) invites geosynthetic project entries for its International Achievement Awards (IAA) competition. The competition is open to designers, manufacturers or subcontractors. Submitted entries must be of projects completed between 15 July 2003 and 15 July 2005.

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Winning entries will be featured in *GFR* and may be published in a special IAA supplement magazine, profiled in other publications, and promoted by cooperating media organizations. *GFR* reserves the right to consider all entries for publication.

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