Asperity height or asperity concentration: what matters more for interface shear resistance on textured polyethylene (PE) geomembranes?

Doyin Adesokan
Solmax International Canada

Eric Blond
Sageos Group CTT, Canada

ABSTRACT: Blond and Elie (2006) highlighted the parameters that influence interface shear behaviour in polyethylene (PE) geomembranes. Several parameters were evaluated in the study and the outcome indicated that asperity height was a key shear strength determining parameter. This paper presents a new way of texturing (micro texturing) that gives the geomembrane surface closer spaced asperity and a higher asperity concentration. These characteristics increases surface roughness and create a wider interface areal contact, enabling the micro textured surface to achieve higher interface shear resistance at moderate asperity heights. Initial results from interface shear testing on PE geomembranes with the micro textured surface extend the Blond and Elie's findings on the contribution of asperity height to interface shear strength, by indicating that in addition to asperity height, an equally important parameter to consider for increased interface shear resistance may be asperity concentration. This paper presents the micro textured geomembrane surface, and a comparison of the interface shear test results for micro textured geomembranes with an asperity height of 17 mils and other textured geomembranes with various asperity heights in contact with hydrated geotextile and geocomposite surfaces.

Keywords: interface friction, shear strength, textured geomembranes, asperity height, asperity dispersion, micro textured, adhesion, slope stability, drainage geocomposite, GCL, geotextile

1 INTRODUCTION

Texturing the surface of a geomembrane is beneficial for increasing interface shear resistance to prevent the geomembrane surface from being a critical slip plane that may induce, contribute to, or make worse potential sliding of materials. As a slope angle increases, higher interface shear resistance may be required along the geomembrane interface to prevent contact materials from sliding. Achieving higher interface friction along a geomembrane interface is sometimes associated with increasing the asperity height from texturing, but, some studies e.g. Blond and Elie (2006) have shown that higher asperity heights may not always result in higher interface shear resistance.

Blond and Elie (2006) completed a large number of interface shear testing involving geomembranes and geotextile interfaces, geomembrane and geocomposites interfaces, and geomembrane and soil interfaces. The study reported that although asperity height from texturing does increase interface shearing resistance, there is an optimum asperity height beyond which no further gains may be achieved in the interface shear resistance with the texturing technology that was available at that time.

This optimum asperity height was found to be approximately 20-25 mils. Beyond this asperity height, they reported that no considerable increase in interface shear resistance was achieved with higher asperity heights for all the geomembrane vs. geotextile, geocomposite interfaces tested. The study also highlighted the increase in manufacturing cost that may be associated with increasing the asperity height from texturing (Figure 1). Hence, there is a need to find the optimum asperity height and surface texturing required within the reported limits to strike the right balance between desired performance and material cost.

Given these considerations, the question that needed to be answered was this: if asperity height has a limit for increasing interface shear resistance, how else can the interface shear resistance be increased with textured geomembranes? The development of the micro textured finish came about because of the need to answer that question, and to find a balance between the optimum asperity height, material cost and high interface shear resistance.

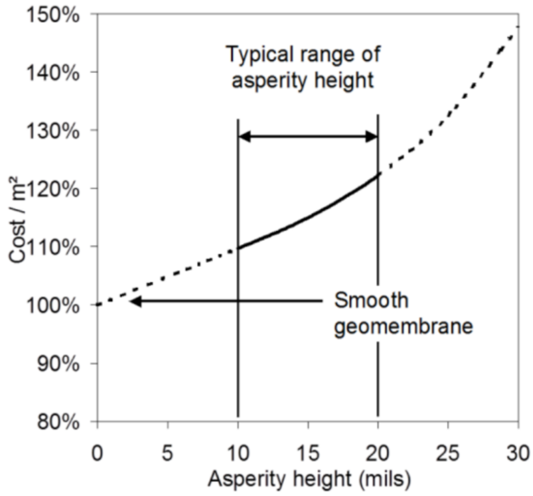


Figure 1. Potential impact of asperity height on manufacturing cost (after Blond and Elie 2006)

A proposition was made to increase the concentration of asperities and minimize asperity peaks, to create a "micro-textured" surface that will increase the number of contact points offered to resist interface shear stress, i.e. create a wider interface contact area, along the geomembrane surface. The expected outcome was a higher interface shear resistance at moderate asperity heights, potentially enabling the micro textured surface to strike the desired balance between material cost from asperity height and desired interface shear strength.

The micro textured finish has been tested in large scale interface shear testing in contact with various geotextiles and geocomposites. The test results, and a comparison of the frictional properties achieved with the micro textured finish and those for geomembranes with the same and higher asperity heights as the micro textured finish are presented in this paper.

2 EXPERIMENTAL

2.1 *Materials - Geomembranes*

Textured HDPE geomembranes of 60 mils thicknesses and various asperity heights were tested. The geomembranes tested consisted of micro textured geomembranes (Figure 2a), textured geomembranes – from the blown film manufacturing process (Figure 2b), and embossed – structured textured surfaces – from the flat die/calendaring manufacturing processes (Figure 2c). The asperity heights of the geomembranes tested ranged from 10 mils to 209 mils. The geomembranes with asperity heights ≥30 mils were from the embossed – structured texturing process.

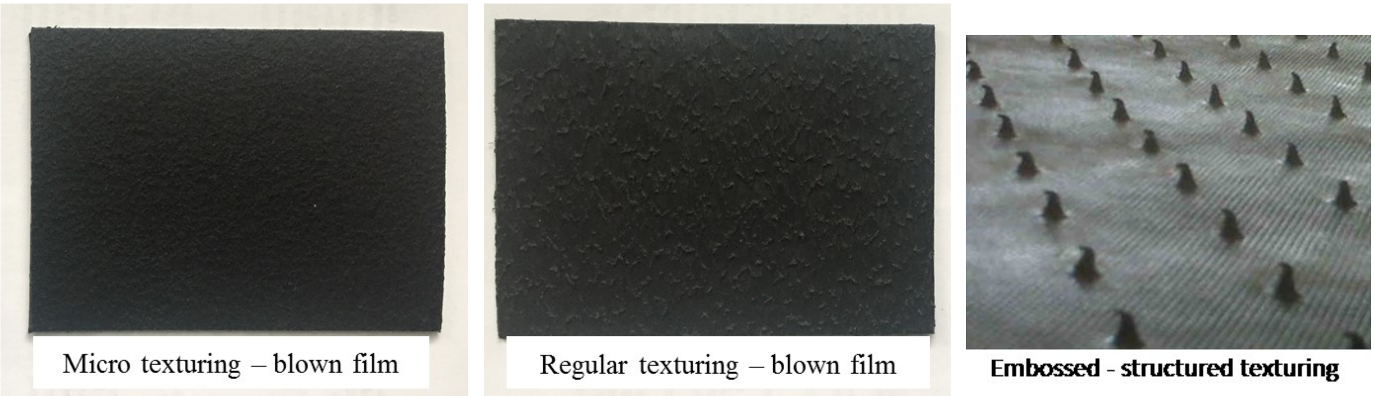


Figure 2. (a) Micro textured, (b) Regular blown film textured, (c) Embossed textured

2.2 *Materials - Geotextiles and geocomposites*

Geotextiles and geocomposites of different mass per unit area were tested. The geotextiles were nonwoven and the geocomposites consisted of both drainage geocomposites (geonet sandwiched between two geotextiles), and geosynthetic clay liner composites (bentonite sandwiched between two geotextiles). The geotextiles and geocomposites were hydrated prior to testing (see Figure 3 for sample pictures).

(a) (b) (c)

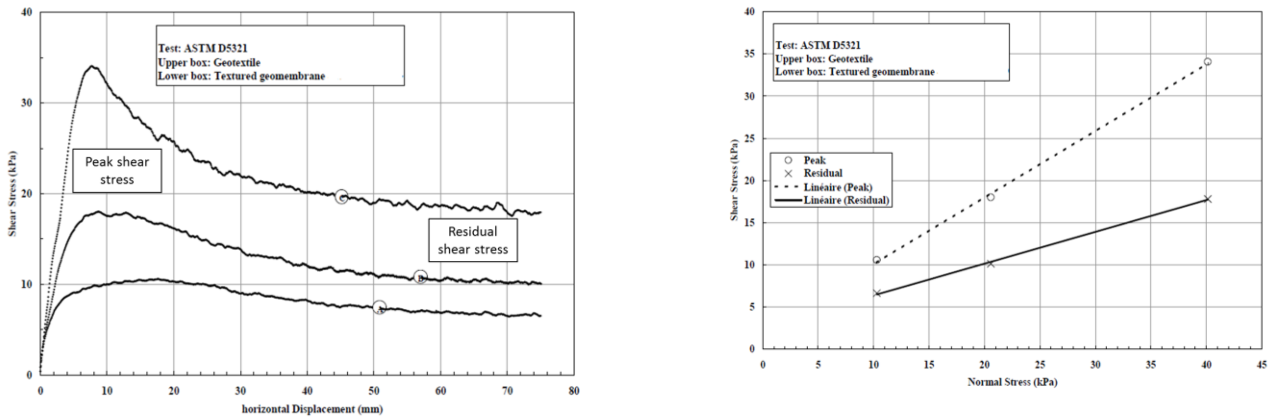
Figure 3. (a) Hydrated geotextile surface, (b) hydrated drainage geocomposite surface, (c) wet textured geomembrane surface

2.3 *Interface shear testing*

Tests were completed as per ASTM D5321 – *Standard Test Method for Determining the Shear Strength of Soil-Geosynthetic and Geosynthetic-Geosynthetic Interfaces by Direct Shear*, using a large sized (minimum dimension 300 mm by 300 mm) direct shear box.

Generally, the geotextile and geocomposites were placed in the upper box of the direct shear unit and the geomembrane was placed in the lower box. Normal stresses were applied to the setup, and shear forces were applied at a controlled strain rate. The tests were performed at a minimum of three applied normal stresses that were spaced considerably apart.

From the measurements of shear forces and displacements, the peak and residual shear strength values were determined (see sample in Figure 4a) and these values are plotted against the applied normal loads to determine the interface shear resistance parameters (friction and adhesion) – see sample in Figure 4b.



(a) (b)

Figure 4. (a) Sample interface shear stress vs. displacement results, (b) sample shear stress vs. normal stress results (a textured geomembrane vs. geotextile shown)

3 RESULTS & DISCUSSION

3.1 *Geomembranes vs. Geotextiles*

Plots of the peak and residual shear strength values of textured geomembranes with geotextiles are presented in Figures 5 and 6. MT in the legends represents the micro textured geomembranes.

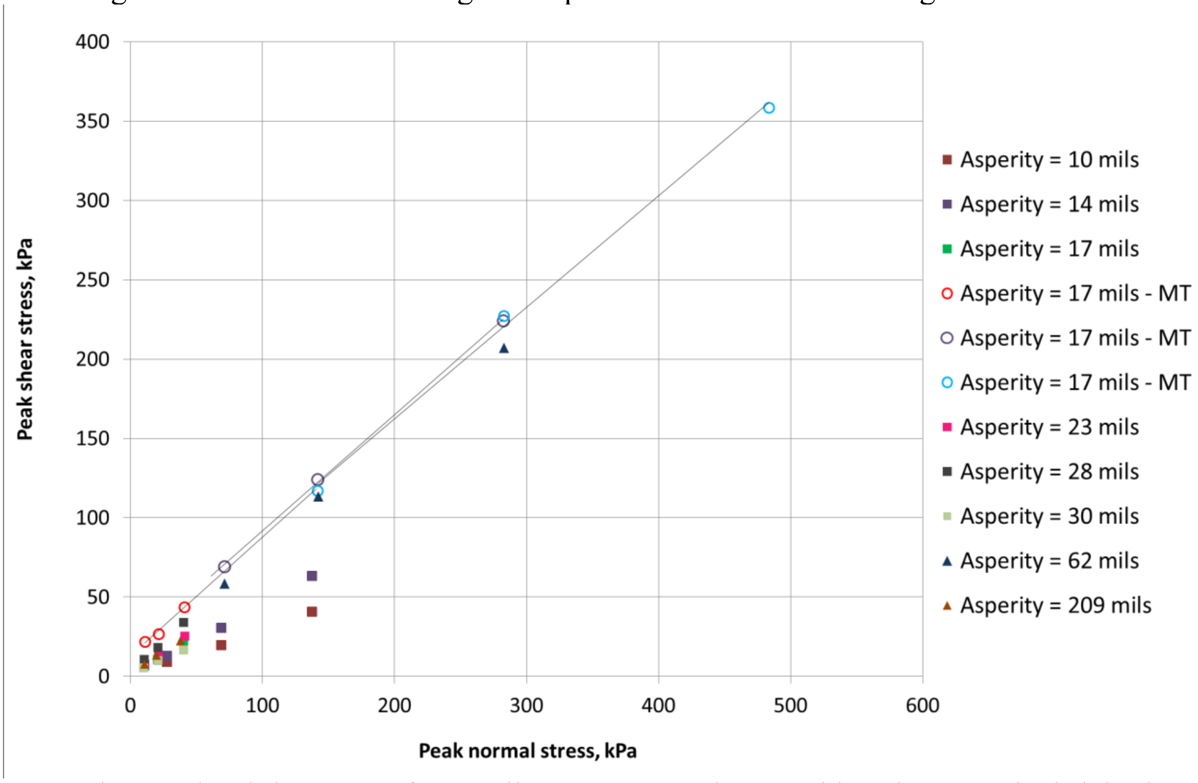


Figure 5. Peak normal and shear stress for 60 mil HDPE geomembranes with various asperity heights in contact with geotextiles

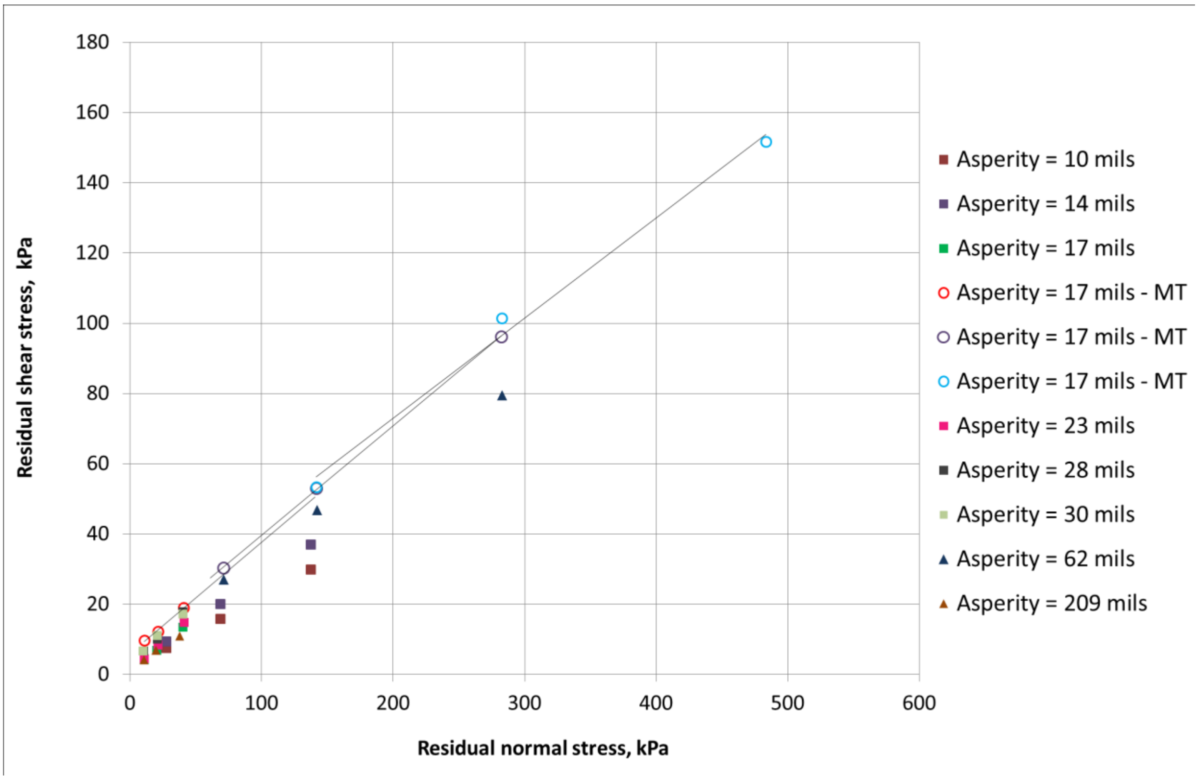


Figure 6. Residual normal and shear stress for 60 mil HDPE geomembranes with various asperity heights in contact with geotextiles

The peak and residual interface shear resistance parameters for the geomembranes in Figures 5 & 6 in order of their appearance on the legends of the Figures are presented in Table 1.

Table 1: Peak and residual interface shear resistance parameters – friction angle and adhesion for the geomembranes in Figures 5 and 6 in order of their appearance on the legends of the Figures. ***MT = micro textured**

Asperity (mils)	Peak friction (degrees)	Peak adhesion (kPa)	Residual friction angle (degrees)	Residual adhesion (kPa)
10	16.1	0.9	11.4	2.0
14	24.8	0.0	14.1	2.6
17	25.0	1.5	17.0	0.8
17 (MT)	**37.0**	**12.8**	**18.0**	**6.0**
17 (MT)	**36.0**	**19.0**	**17.0**	**8.5**
17 (MT)	**37.0**	**13.2**	**19.0**	**4.6**
23	31.0	0.8	19.0	1.1
28	38.0	2.2	21.0	2.6
30	28.0	5.5	19.0	3.4
62	35.0	10.4	14.0	10.3
209	28.0	2.2	14.0	1.6

3.2 *Geomembranes vs. Geocomposites*

Plots of the peak and residual shear strength values of textured geomembranes with geocompoistes are presented in Figures 7 & 8. MT in the legends represents the micro textured geomembrane.

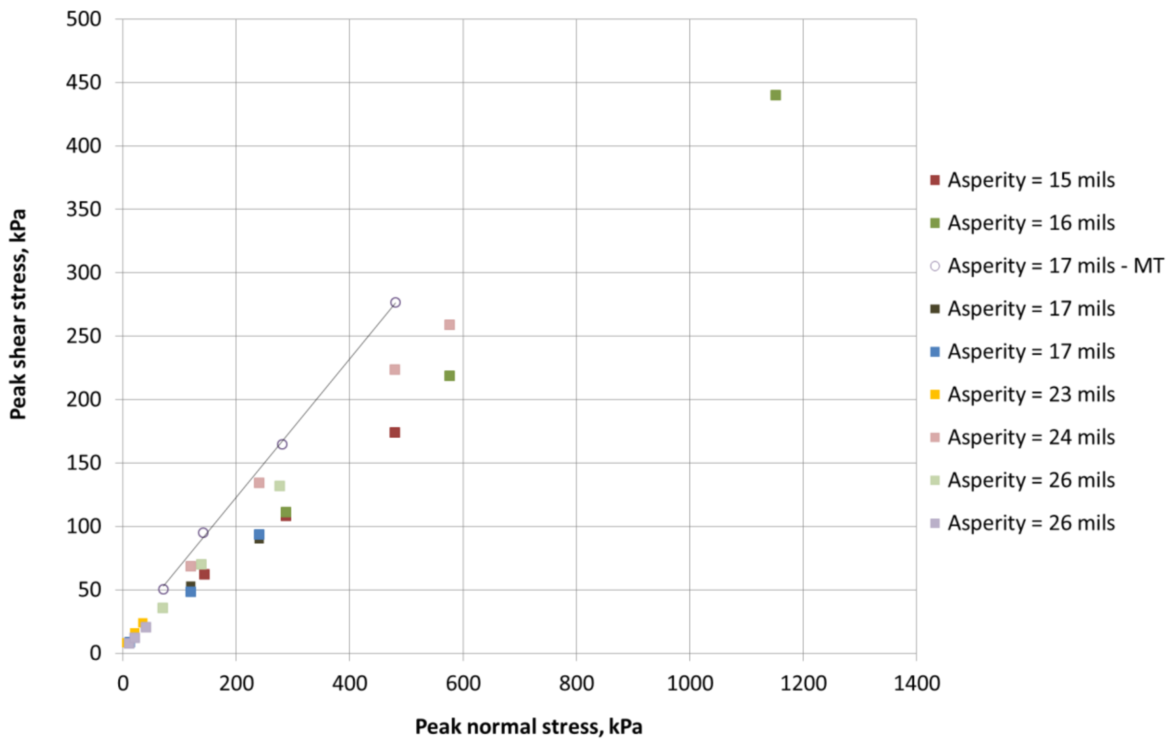


Figure 7. Peak normal and shear stress for 60 mil HDPE geomembranes with various asperity heights in contact with geocomposites.

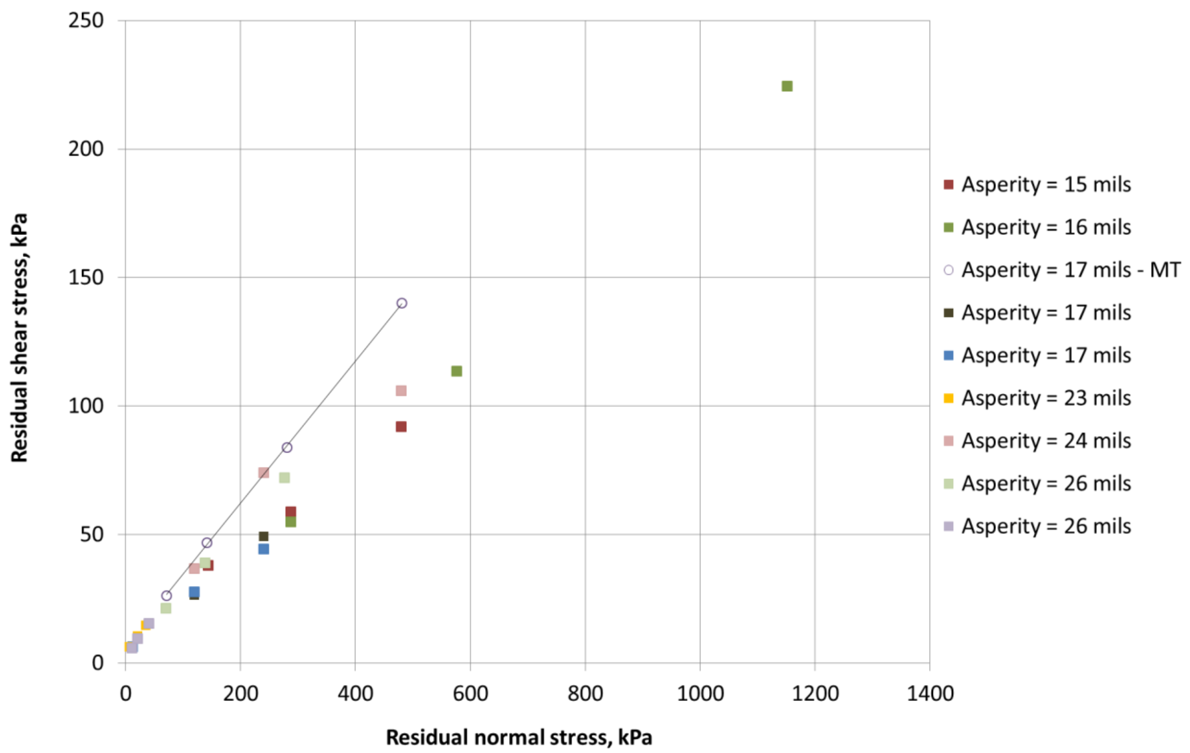


Figure 8. Residual normal and shear stress for 60 mil HDPE geomembranes with various asperity heights in contact with geocomposites

The peak and residual interface shear resistance parameters – friction angle and adhesion for the geomembranes in Figures 7 and 8 in order of their appearance on the legends of the Figures are presented in Table 2.

Table 2: Peak and residual interface shear resistance parameters – friction angle and adhesion for the geomembranes in Figures 5 and 6 in order of their appearance on the legends of the Figures. ***MT = micro textured**

Asperity height (mils)	Peak friction angle (degrees)	Peak adhesion (kPa)	Residual friction angle (degrees)	Residual adhesion (kPa)
15.0	18.5	13.4	9.1	14.0
16.0	20.9	0.1	11	0.4
17 (MT)	**28.0**	**15.4**	**15**	**7.4**
17.0	20.4	5.1	9.3	6.0
17.0	20.6	3.6	9.6	5.7
23.0	28.9	4.2	16.7	4.2
24.0	22.2	26.7	9.3	24.8
26.0	25.0	4.5	14	4.4
26.0	23.0	3.1	18	2.2

4 DISCUSSION

Generally, for both the geotextile and geocomposite interfaces, the micro textured surfaces with an asperity height of 17 mils achieved higher friction angle and adhesion values than those with asperity heights ≥ 17 mils. For instance, from Table 1 for the geotextile interface, micro textured with an asperity height of 17 mil (see: Figure 2a) was able to achieve interface higher friction angle values of 36° to 37°, while those with higher asperity heights such as 30 mils (see: Figure 2b) and the embossed - structured textured surfaces (Figure 2c) at 62 and 209 mils, achieved lesser values between 28° to 35°. Similarly, for the geocomposite interface in Table 2, the micro textured geomembranes achieved higher interface friction angle values than majority of the other textured geomembranes with higher asperity values.

5 CONCLUSION

Blond and Elie (2006) showed that asperity height matters for interface shear resistance in PE geomembranes; but up to a certain value – approximately 20 to 25 mils, after which no significant gains in interface resistance may be achieved with the texturing technology that was available at that time. The need to find a textured geomembrane surface that will balance maximum interface shear resistance with optimum asperity height was a driver for the research and development of the micro textured surface finish that was presented in this paper.

The micro textured geomembrane finish contains closely spaced and finer asperity concentration, which gives it maximum surface roughness and a wider areal contact with materials. Initial interface shear laboratory testing results presented in this paper demonstrate that these characteristics enable it to adhere more to materials and resist interface shear better. They also suggest that if Blond and Elie's findings are valid for a particular type of texturing technology, asperity concentration also matters for interface shear resistance considerations.

Sample test results from large scale interface shear testing were presented in this paper. Under similar applied stresses, for both the geotextile and geocomposite surfaces, a micro textured surface with an asperity height of 17 mils was able to achieve higher shear resistance than majority of the textured finishes with higher or same asperity heights. The findings presented in this paper therefore indicate that when there is a need to increase interface shear resistance, asperity concentration may be one to focus on increasing.

REFERENCES

ASTM D5321 / D5321M-17, Standard Test Method for Determining the Shear Strength of Soil-Geosynthetic and Geosynthetic-Geosynthetic Interfaces by Direct Shear, ASTM International, West Conshohocken, PA, 2017,

Blond, E., & Elie, G. 2006. Interface Shear-Strength Properties of Textured Polyethylene Geomembranes. Proc. 59th CGS Conference, Vancouver