GEOMEMBRANE PROTECTION USING CUSHIONING GEOTEXTILES

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ABSTRACT

Geotextiles are widely used to protect geomembranes from installation and in-service damage in applications where eliminating puncturing and the control of membrane strain are critical for the long-term performance of the lining system. In lining applications, protecting the membrane from excessive point loading from the overlying drainage stone and thus minimising potential for environmental stress cracking is desirable, if the long-term performance of the liner is to be assured. This paper furthers earlier work by Hornsey et al (2012) on test methods and the use of laser scanning techniques for calculation of geomembrane strain on testing of different families of geotextiles for liner protection applications. The testing reported followed the ASTM D5514-06 test procedure which was modified to include the use of a fixed stone profile and uniform pneumatic load application. To ensure repeatable loading onto the liner, fixed stone profiles were created using fibre-reinforced resin to hold the drainage stone in a rigid arrangement, yet provide a natural stone surface pattern and texture similar to that of stone as placed on site. Using this approach, different liner and geotextile combinations where tested against the same stone profile and loading conditions, thus enabling direct comparison of damage, geomembrane strain and cushioning performance. Testing on a newly introduced range of staple fibre geotextiles are presented, the results of which are be compared with earlier work on existing geotextiles and the effect of different polymer types discussed.

Keywords: Geomembrane, Protection, Cushioning, Geotextiles, Strain, Testing

1 INTRODUCTION

In containment applications geotextiles are commonly used as cushioning and protection layers to geomembranes, to prevent damage to the geomembrane from adjacent drainage materials such as drainage stone layers. Whilst the stone layers provide good long-term drainage capacity due to their angularity and hardness they provide a source of significant potential damage to the liner both physical damage and strain induced stress cracking, something which must be prevented if the long-term integrity of the liner is to be assured.

To ensure the suitability of a geotextile to act as a protection layer, performance testing is required using the geosynthetic material layers to be installed on the project and simulating the site condition and project specific loading conditions. To generate a database of results on various geotextiles for liner protection applications, a series of tests have been undertaken enabling the relative merits of different product types to be determined for a range of conditions. The testing reported in this paper was conducted using a modified version of the ASTM D5514-06 (2011) procedure with strain measurements undertaken by the use of a laser scanning technique on a metal indicator sheet. The testing reported herein extends earlier work undertaken by Hornsey and Gallagher (2012), Hornsey and Wishaw (2012) and Hornsey (2013) with additional results generated using the same test equipment and rock profile.

2 MATERIALS AND METHODS

Testing was undertaken using a fixed stone profile and through laser scanning of a metal strain indicator sheet to determine the strain in the geomembrane using the techniques developed by Hornsey and Wishaw (2012).

The test rig uses a 450mm diameter fixed stone profile, Figure 1, to ensure the stone arrangement and loading applied to the liner sample was the same for all tests thus allowing direct comparison of results. The stone profile is created by pouring loose stone onto a liquid rubber base. Once the rubber is cured, fibre reinforced epoxy resin is used to set the stone in a fixed arrangement. When cured, the profile is inverted and the rubber removed to expose the test surface. The laser scanning approach used provides a quick and repeatable method of strain analysis across the whole contoured surface of the membrane rather than relying on visual pre-selection of the highest strain regions of the membrane for detailed manual analysis. Pneumatic pressure is used to load the geomembrane to the designated test pressure and push it onto the strain indicator sheet, protection layer and drainage stone. Following the test loading period, the air pressure is released in a controlled manner, the test samples removed and the strain indicator sheet sent for laser scanning where the cumulative strain in the liner is calculated in 0.25% increments.

In the test rig, Figure 2, the geosynthetic material profile under test is inverted with the stone profile installed in the base of the rig underlying the protection geotextile, indicator sheet and membrane sample. Inverting the materials in this way, from their orientation onsite, permits easy installation in the test rig and enables the lower and upper halves of the test rig to seal against the geomembrane during closure of the rig with minimal effects on the membrane. To eliminate the influence of the test rig restraining the membrane, strain measurements are only reported for the central 350mm diameter of the test specimen. This configuration does not account for any support which may be provided by the site formation/subgrade material site which is regarded a conservative approach. The development of the test procedure, the repeatability of results for the fixed stone arrangement and the accuracy of the laser scanning technique are detailed in Hornsey & Wishaw (2012).

Figure 1. 20-50mm aggregate fixed stone profile

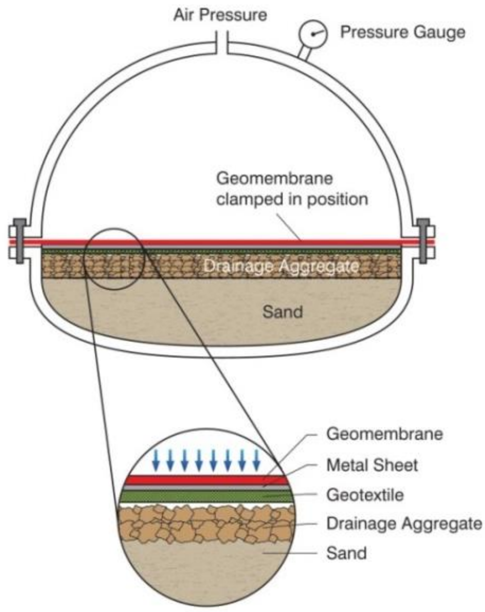


Figure 2. Test rig configuration

Hornsey (2013) reported on the testing of 40 different geotextiles from various manufacturers and of different types used as cushioning layers, additional products were assessed. Additional testing was undertaken extending this data, some of this additional testing is discussed by Austin et al (2014) and these results are further analysed in this paper as part of an extended data set together with the results for a new range of PET staple fibre geotextiles, reported below. Geotextile cushioning performance was tested and evaluated for the whole data set under the following test conditions:

1. 20-75mm igneous aggregate (fixed)
2. 2mm smooth HDPE geomembrane
3. 0.3mm aluminium recording plate
4. 600kPa confining pressure
5. 24 hour loading period.

Additionally, testing was undertaken using two different simulated subgrades in contact with the liner: a 9.5mm thick rubber layer with a Shore Hardness (A) of 80.6 and a GCL layer hydrated to approximately 60% moisture content. The introduction of the subgrade layer in contact with the liner was undertaken to assess the effect on strain on the liner under different support conditions and verify the assumption that tests with no liner support above the geomembrane in the test rig are conservative. For the simulated subgrade tests, the rubber or GCL support was placed above the test geomembrane and below the geomembrane responsible for applying the pneumatic pressure.

3 RESULTS AND DISCUSSION

Table 1 presents the complete data set compiled by the Authors based on earlier testing using the same test equipment and method plus the data from the latest testing with on a new staple fibre polyester geotextile range, Texel R. Table 1 provides test data on 4 different basic types of geotextile made with different manufacturing techniques and by different manufactures:

1. SF PP : Staple Fibre Polypropylene
2. CF PP : Continuous Filament Polypropylene
3. CF PET : Continuous Filament Polyester
4. SF PET : Staple Fibre Polyester

Table 1. Geotextile mass, thickness and recorded maximum geomembrane strain data

Test No.	*g/m^2*	*mm*	*%*	Test No.	*g/m^2*	*mm*	*%*
1	331	1.87	17.50	28	281	1.62	13.50
2	352	1.65	17.25	29	284	1.62	15.00
3	430	4.66	15.00	30	291	1.98	13.75
4	486	4.93	14.75	31	370	2.67	11.50
5	506	3.99	16.75	32	383	2.77	11.75
6	524	4.80	14.75	33	388	2.55	13.00
7	535	3.72	15.25	34	389	2.70	11.25
8	586	5.09	14.50	35	392	2.83	11.25
9	655	4.92	13.75	36	393	3.50	11.25
10	808	6.59	11.75	37	406	2.74	11.75
11	1026	8.12	12.00	38	486	3.93	9.00
12	1032	7.46	12.50	39	486	3.80	9.75
13	1324	8.68	8.25	40	499	4.65	10.00
14	1459	8.62	7.50	41	537	3.74	9.50
Type 2 - Continuous Filament Polypropylene (CF PP)				42	585	4.27	8.00
	Mass	Thickness	Max. Strain	43	737	5.49	8.00
Test No.	*g/m^2*	*mm*	*%*	44	744	5.78	7.75
15	399	3.09	15.25	45	767	5.62	7.50
16	528	*4.20*	12.25	46	778	5.52	7.50
17	717	*4.27*	8.50	47	788	5.86	5.75
18	763	*5.66*	8.75	48	996	5.03	6.00
19	773	*5.78*	8.50	49	1074	6.99	4.00
20	808	*6.22*	7.25	***Type 4 - Staple Fibre Polyester (SF PET)*** [a]			
21	815	*5.57*	7.75		***Mass***	***Thickness***	***Max. Strain***
22	1070	*7.06*	7.75	***Test No.***	***g/m^2***	***mm***	***%***
23	1081	*7.77*	6.75	***50***	***349***	***3.15***	***20.00***
24	1087	*7.11*	7.00	***51***	***337***	***3.08***	***19.00***
25	1172	*7.33*	6.50	***52***	***610***	***5.10***	***16.50***
26	1196	*7.57*	6.75	***53***	***615***	***4.77***	***15.75***
27	1199	7.56	6.25	***54***	***763***	***5.12***	***12.75***
				55	***759***	***5.19***	***14.00***
				56	***1251***	***7.08***	***11.00***
				57	***1246***	***6.83***	***12.00***

[a] Italicised values in Bold represent new data
Other values as reported by Hornsey (2013) & Austin et al (2014)

Geotextiles Types 1-3 listed above include materials from a variety of countries and manufacturers. All geotextiles were grouped based on polymer type and production method.

Geotextile mass and thickness are often considered as indicators of geotextiles performance in protection applications; however other parameters also have a significant influence on the protection efficiency of a geotextile. To test this theory, the mass and maximum geomembrane strain data from Table 1 is shown graphically in Figures 3a and 3b with exponential regression curves applied. Figure 3a shows the previous data on geotextile Types 1-3 above and Figure 3b shows the complete data set including the data for Type 4 presented as a single group. From the R^2 value for the curve fitted through the data, it is clear there is a relatively poor correlation in mass vs. maximum strain results for Types 1-3 as a whole. Furthermore the addition of another type of geotextile in Figure 4b leads to an even poorer correlation than that which is obtained from Types 1-3 when analysed as a single set.

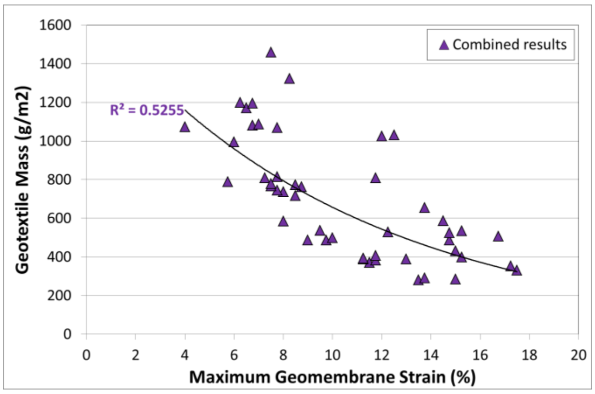


Figure 3a Data set from Austin et al (2014)

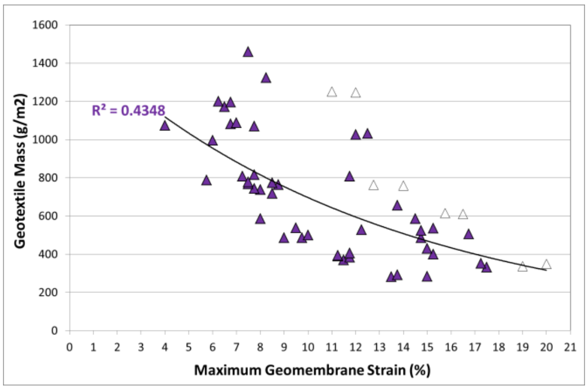


Fig 3b Extended data set including SF PET geotextile results

Figure 4 shows the mass vs. maximum strain relationship for the data separated into the 4 different product types. When similar regression analysis is performed for each product type separately, a much better correlation is achieved, as shown by R^2 values of 0.88-0.95 compared to that for the data set as a whole of 0.44. By inspection, from Figure 4 if the stain values for a given geotextile mass are compared, i.e. at 800 g/m^2, it is apparent that continuous filament geotextiles performed better than staple fibre geotextiles at limiting geomembrane strain and additionally, polymer type influences cushioning performance as well.

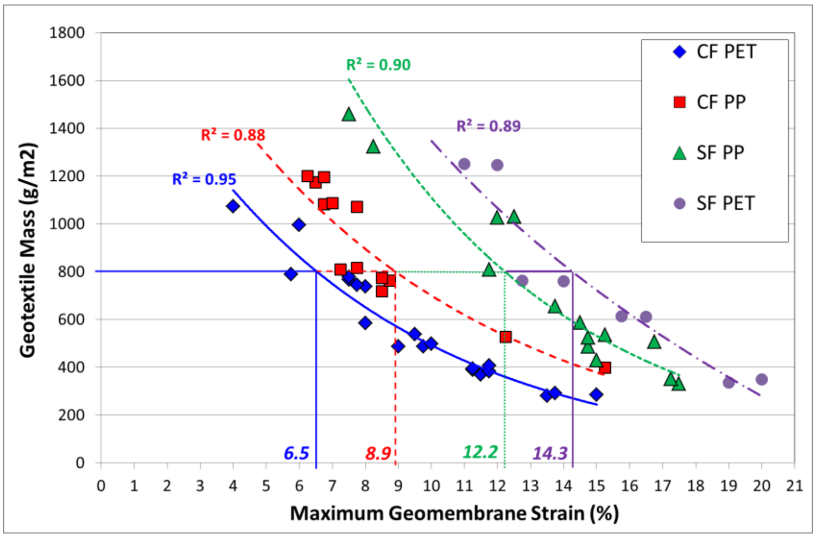


Figure 4. Geotextile mass vs. Maximum Geomembrane Strain

Similarly, Figure 5 presents the relationship between geotextile mass thickness and maximum strain for each individual product type. Apart from the SF PP type, relatively good correlations within each type are obtained when an exponential curve fit is applied. As for mass, the maximum strain values achieved by each type of geotextile vary considerably e.g. for a 6.0mm thick product, the strain range is 6.3 to 12.7mm i.e. the strain in the liner could more than double by selecting a cushioning layer on thickness alone.

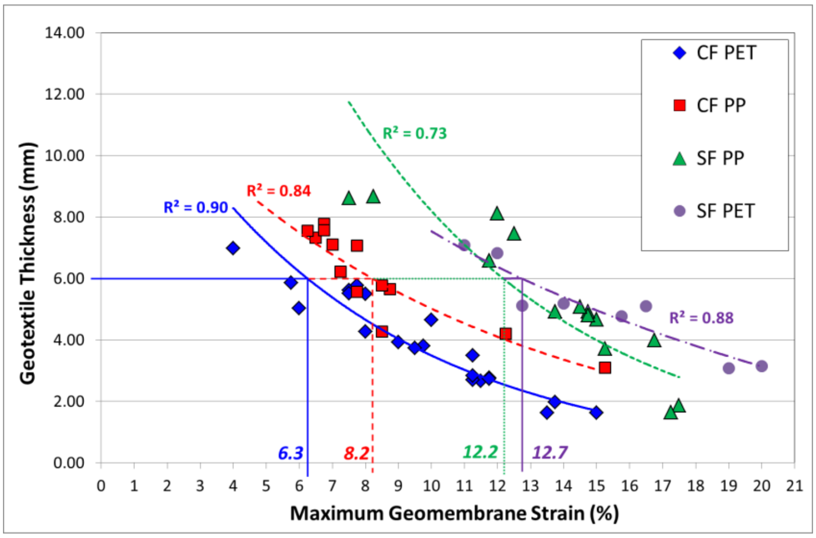


Figure 5. Geotextile Thickness vs. Maximum Geomembrane Strain

If we look to a mechanical property of the liner as being more indicative of the cushioning performance of that material, Figure 6 shows the relationship of CBR to geomembrane strain. Whereas Figure 6 shows a tighter grouping of the whole data set than shown in Figures 4 and 5, a significant difference in strain control is still evident between the product types tested, as indicated by the 4.6% range in maximum strains for a CBR of 6000N between the 4 product types.

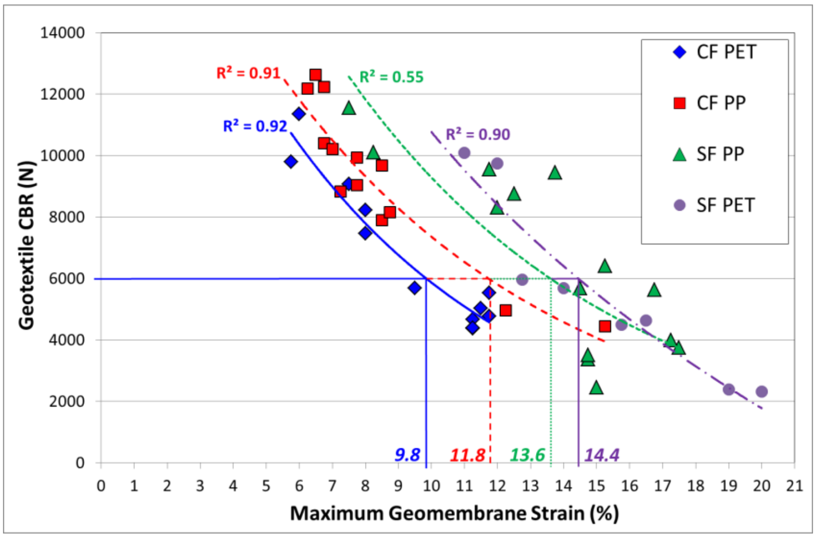


Figure 6. Geotextile CBR vs. Maximum Geomembrane Strain

3.1 Repeatability and Influence of Subgrade

To further verify the results from the test method adopted, repeat tests on one product were undertaken both with and without a supporting backing to the geomembrane with the intention of demonstrating that the results obtained without liner support were conservative. This testing was conducted with a bidim A64 CF PET geotextile, the results of which are shown in Figure 7.

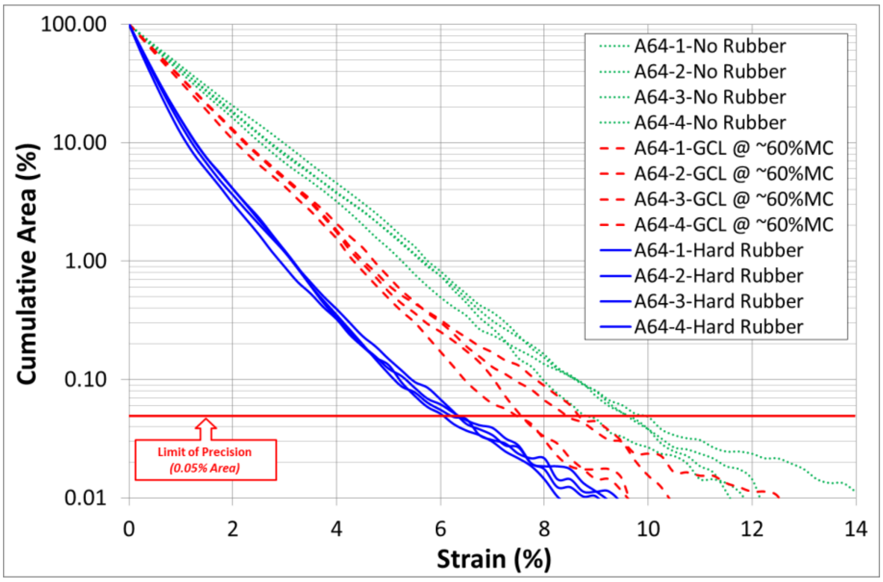


Figure 7. Cumulative Area vs. Geomembrane Strain for different support conditions.

Figure 7 shows the strain vs. cumulative area relationship for testing of 4 No. repeat tests in 3 No. separate test configurations, all subjected to a test pressure of 600kPa i.e. no liner support, liner supported by a 9.5mm rubber sheet and liner supported by a 60% moisture content GCL liner. The curves presented in Figure 7 generally show good repeatability, particularly for the rubber subgrade condition. Figure 8 shows mean strain /area curves for the same configurations. From Figure 8, it can be seen that when a simulated subgrade is introduced into the test configuration adjacent to the membrane, the maximum strain in the liner reduces. In addition, the use of a firm rubber subgrade resulted in lower geomembrane strains than when the weaker subgrade (simulated by the hydrated GCL) was used. Hence results obtained from the test rig with an inverted geosynthetic material profile subjected to pneumatic loading without any subgrade support were found to be conservative.

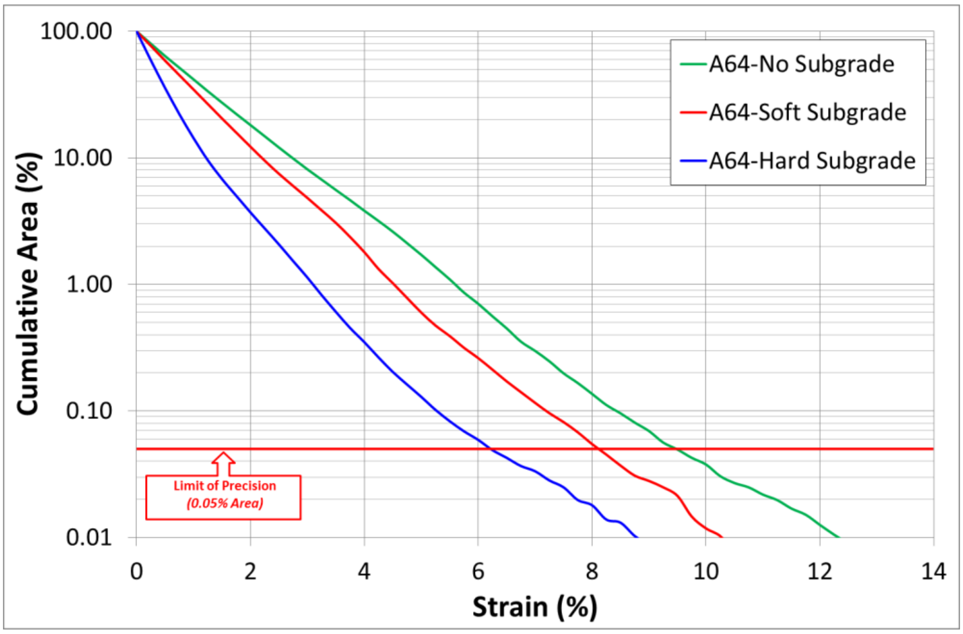
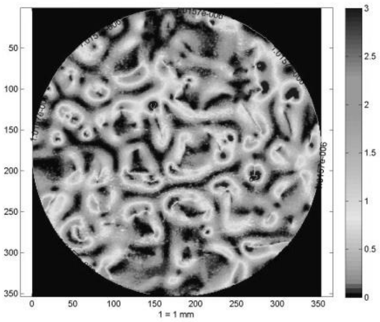
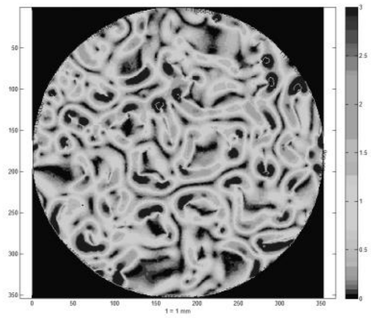


Figure 8. Mean Cumulative Area vs. Geomembrane Strain Curves for different support conditions.

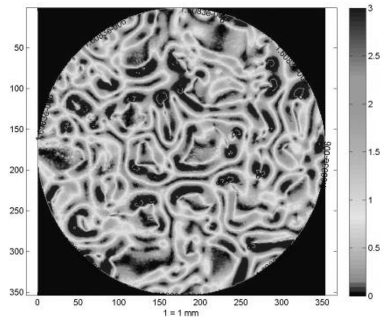
Another method for characterising the relationship between one or more tests is the use of topographical strain diagrams produced from the laser scanning of the metal indicator sheets (Figure 9). The topographical strain diagrams highlight the distribution and magnitude of strain across the liner specimen. These scans show areas of similar levels of strain the same colour, and their distribution across the aluminium indicator sheets. The strain diagrams therefore not only show the number of places where high strain in the liner is achieved, but their relative distribution.



Hard Subgrade
(Rubber)



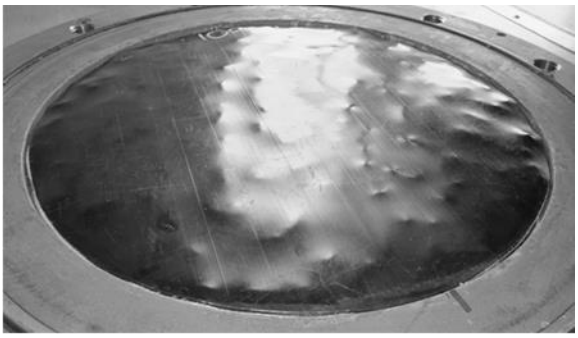
Soft Subgrade
(GCL)



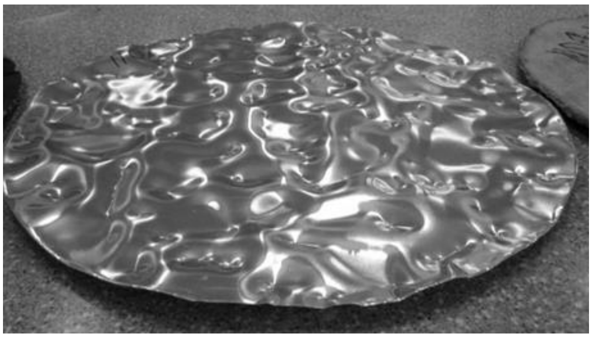
No Subgrade

Figure 9. Topographical strain diagrams

Following pneumatic loading at the end of a test, the geosynthetic material profile is removed from the test rig, examined and the strain indicator sheet sent for analysis. Typical stone impressions on the various materials in the material profile are shown in Figure 10.

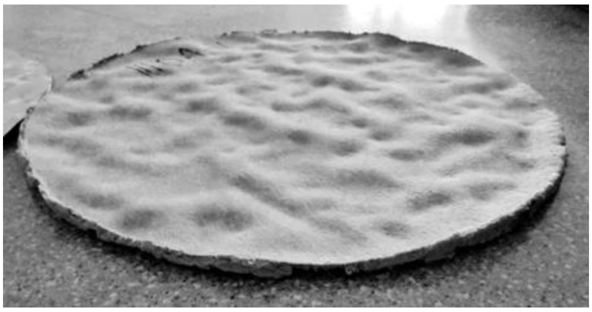


Geomembrane with 6% maximum strain



Aluminium Strain Indicator Sheet

Geotextile Protection Layer



GCL Liner Support Layer

Figure 10. Images showing the effect the drainage medium has on the various layers

Whilst not included in the previous data, Figure 11 shows testing under the same conditions for different grades of a CF PET geotextile range. From Figure 11, the benefit of using higher grades and mechanical properties of the geotextile is evident through their ability to reduce strain, to within the 6% strain limit postulated be Peggs (2003), over a small percentage of the liner area. 6% strain being a typically accepted strain limit for designs in Australia.. For any particular strain design limit, the area of the geomembrane achieving that strain, under short-term loading, can be determined and the protection layer design approved or revised accordingly.

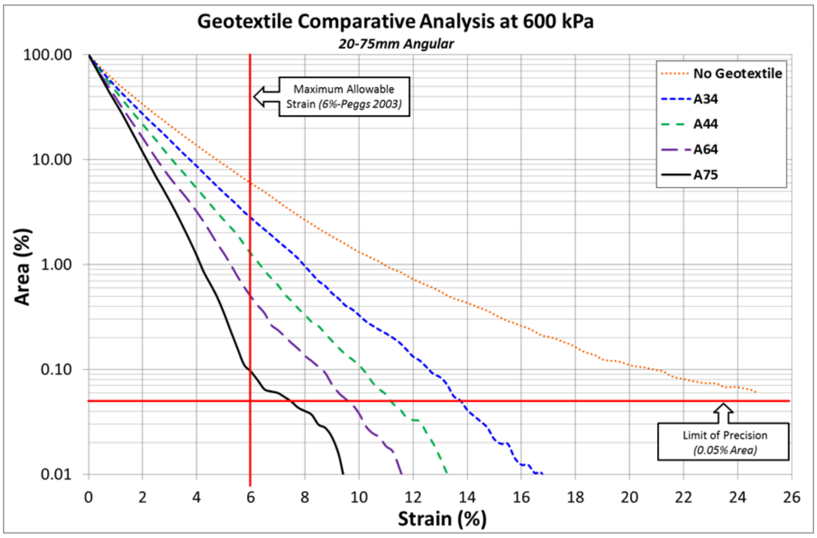


Figure 11. Differences in strain performance between different grades of CF PET

4 CONCLUSION

The data presented in this paper summarises an extensive test programme for liner protection applications and highlights large differences in the cushioning performances of various geotextiles. The results of this testing show the cushioning performance of geotextiles made from different polymers and production methods but with similar mass, thickness and CBR to be significantly different. Although it is possible to generate usable design guidance based on different parameters within a single product family, it is apparent that it is not appropriate to develop design guidance based on the results of analysis of a group of products of different types i.e. polymer, manufacturer and manufacturing method. Caution should be used in the selection of geotextiles for cushioning applications based on physical and mechanical properties alone. Design verification testing on the specific lining system profile to be installed is the best approach when determining the suitability of the cushioning geotextile component to ensure the long-term integrity of the geomembrane.

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