Geosynthetic Installation Quality Challenges from the construction of a Class A facility in South Africa

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Abstract

A double lined Class A facility with an excess of 300 000 square meters of different geosynthetics is a great application of current geosynthetic technology. However, installing such a large amount of geosynthetics comes with installation quality challenges. This paper will focus in on these challenges: from welding flaws on geomembranes to UV stability of geotextiles to manufacturing bespoke geosynthetic panels to fit site conditions. The solutions to these challenges will be discussed and preventative measures offered which may be of use in future projects.

Keywords: *Class A facility, installation quality challenges.*

1 Introduction

For hazardous waste facilities, the regulated Class A liner system in South Africa requires several geosynthetic layers. Each of these layers has their own construction quality control and assurance requirements. However, due to the large amount of geosynthetics installed, usually there are some interesting challenges that arise when installing each layer. Each of these challenges may have a preventative measure that prevents reoccurrence, which forms the lessons learnt from this paper. In one such facility, the project team was required to form solutions to solve the challenges arising and these are discussed below.

2 The liner system

The liner system constructed in this case study is shown in Figure 1. As required by the South African Class A Liner Standard in the national norms and standards (GN 636), it is a double composite liner separated by a drainage layer with a subsoil drainage layer below the liner and a ballast layer above. In this application the drainage layer and the ballast layer are replaced by geosynthetic alternatives.

Three quality assurance challenges will be discussed: Firstly, the UV resistance of the geotextiles bonded to the cuspated core of the drainage composite. Secondly, challenges of welding the geomembrane sheets together and lastly installation of the geosynthetic ballast layer above the liner.

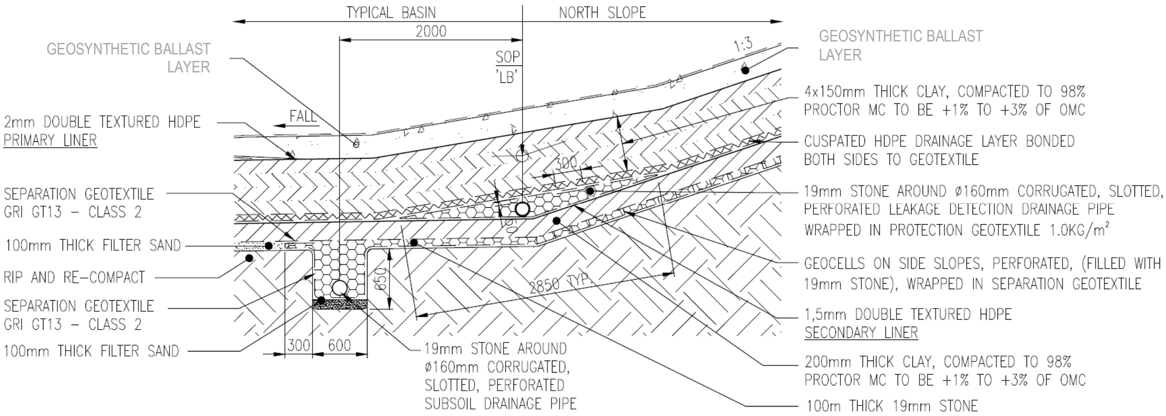

Figure 1: The Class A liner detail

3 The Challenges

As shown in Figure 1, the leakage detection layer was formed by a drainage composite formed by an HDPE cuspated sheet bonded on both sides to a non-woven geotextile. During construction, the installation of the drainage composite was carried out in conjunction with the secondary geomembrane, which was placed on a compacted clay layer. The primary clay layers were to follow after the drainage composite.

Likely the result of poor planning of the liner interface on the contractor's and liner installer's behalf, the composite drain was installed but was not timely covered by the following primary clay layers. After approximately 6 weeks of exposure (over a December break), the engineer raised a concern with the contractor regarding the decrease of durability of the geotextile bonded to the cuspated sheet due to UV exposure.

When designing with geosynthetics, the following is recommended (Koerner, R. M. (2012)):

> *It is clear that geotextiles must be shielded from prolonged ultraviolet light exposure. Geotextile rolls are always shipped with a protective plastic covering and only when the material is ready for use should it be unrolled and exposed. The manufacturer's recommendations for "timely cover" (backfilling) must be rigidly met. Cover placement (soil or another geosynthetic) for polypropylene geotextiles should generally be within fourteen days (per AASHTO M288), with polyesters being allowed longer exposure times*

The manufacturer's installation guide was referenced and it stated that exposure should be limited to the following:

> *Standard* Geocomposite *contains a UV stabiliser so that it can be exposed to sunlight for up to 14 days in temperate climates. Exposure should be limited to 3 days in climates with extreme sun. Prolonged exposure will cause some loss of strength.*

In this case, the challenge was to ensure that over-exposure didn't reoccur in the future installed composite drainage layer. In cases where effective planning couldn't result in the drainage layer being covered in a short span of time, a separation geotextile was used as a sacrificial layer to protect the drainage layer from UV radiation.

It is advisable to keep a record of exposure of geotextiles to limit over-exposure (Thiel R., 1992). If over exposure does occur and the engineering properties of the geotextile become questionable, samples should be sent for conformance testing. However, this introduces a time constraint to the project as samples would likely need to be shipped to an international laboratory.

One of the design intentions of this bonded geotextile was to ensure adequate friction between the drainage composite and the proceeding clay layers to ensure veneer stability on the side slopes. If the durability of the geotextile was reduced due to over-exposure, it may result in a lower factor of safety against slipping or ultimately failure.

A further part of the challenge was to decide what to do with the over-exposed drainage composite. As the veneer stability, and hence the durability of the geotextile, was only a concern on the side slope, it was decided to move the installed over-exposed drainage layer from the side slopes to the basin. This required the drainage composite to be rolled up and transported with a TLB using slings, while ensuring that no further mechanical damage occurred to the sheets.

The second challenge concerns the installation of the primary geomembrane as shown in Figure 1. During its installation, specifically during conducting wedge welds (production seams) of panels installed on the side slope, it was noticed that a groove was created within the air channel of the wedge weld as shown schematically in Figure 2. At first it was thought to be only at the start and end of the seam but after taking destructive test samples throughout the length, it was found that the groove was created for the entire seam length (approximately 20m).

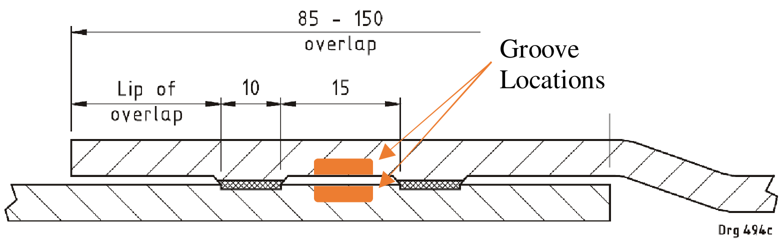

Figure 2: Location of grooves in air channel. Figure taken from SANS10409:2005

All non-destructive quality control tests carried out on the 27 affected seams had passed including air pressure tests and peel & shear tests on destructive samples. Upon further investigation it was found that the wedge-welding machine had a drag bar fitted that was creating the groove – See Figure 3. The drag bar appeared to be different to typical wedge welding equipment as it was circular and threaded instead of a flat bar. Samples of the welds containing grooves were sent by the liner installer to an independent laboratory and indicative measurements are shown in Table 1.

The project specification called for a 2.00mm thick textured primary geomembrane with a nominal thickness tolerance of -5% or 0.1mm. Therefore, the minimum thickness allowable was 1.9mm. The average thickness of the top geomembrane (2.013mm) met this requirement whereas the bottom geomembrane was 1.867mm thick on average, which is 0.033mm below the specification.

The engineer was unsure of whether the groove created within the air channel was considered a defect or not. It had clearly reduced the thickness of the base sheet, which raises a concern of future stress cracking. However, the groove is concealed within the air channel and therefore should not be exposed to the environment.

Table 1: Laboratory measurements of the grooves created in the wedge welds.

Sample:	Top Sheet			Bottom Sheet		
	A	B	C	D	E	F
	mm	mm	mm	mm	mm	mm
Sample 1	2.090	0.100	1.990	2.010	0.190	1.820
Sample 2	2.090	0.050	2.040	2.180	0.140	2.040
Sample 3	2.090	0.080	2.010	2.030	0.280	1.740
Average	2.090	0.077	2.013	2.073	0.2033	1.867

A : Top liner thickness
B : Top liner, bottom side – groove thickness /depth in channel
C : Remaining thickness in top geomembrane
D : Bottom liner thickness
E : Bottom liner, top side – groove thickness /depth in channel
F : Remaining thickness in bottom geomembrane

The liner installer's opinion was that it did not constitute a defect and this led to an impasse on the way forward. It was agreed to request opinion from 3 internationally recognised leaders in the field (designated A, B and C). They were requested to comment on whether they would insist on equipment that did not create grooves going further and whether to remove the affected welds on not. Their statements are summarized in Table 2.

Figure 3: Groove bar fitted to wedge welder

In agreement with the experts, J&W insisted that the equipment was replaced. By instructing the liner installer to stop welding until he could show evidence that his welding equipment did not create the grooves, it was ensured that no further grooves would occur. The welding equipment was replaced with new equipment within a few days and production continued.

However, there were still 27 panels on the side slopes that contained these grooves and expert opinion was split on removing the seams. It was agreed with the liner installer that the seams would be cut out of the installation and replaced with a patch that would be the length of the panel and approximately 500mm wide. This would result in one wedge weld being replaced by two wedge welds. The employer would initially pay for this work, however, it was agreed that a testing program would follow which would determine if the grooves were a defect or not. The liner installer, confident in his opinion that this was not a defect, agreed to the following test program:

Three samples would be tested:

- A normal 2.00mm geomembrane sheet to serve as the baseline
- A typical 2.00mm wedge weld without the groove
- A 2.00mm wedge weld with the groove

Table 2: Comments on grooves by internationally recognized experts

International Recognised Expert:	A	B	Comments
1	YES	NO	It is believed that if the air pressure tests have passed then the welds will be of good quality. It is also believed that even with the grooves there is still +2.0mm over the width of the wedge weld.
2	YES	YES	It is believed that there is a large potential for stress cracks to occur especially if there are sharp notches in the groove. The comment was also made about +2.00mm over the width of the wedge weld, which would lead to peel and shear tests passing.
3	YES	YES	It was stated that long-term durability would be a concern in terms of stress cracking. It was also stated that this kind of groove was not experienced before.

A : Agree with preventing further welds with grooves
B : Agree with cutting out the seams that contain grooves

An internationally recognized laboratory was approached to do the testing. To gauge the effect of the groove, the lab recommended carrying out *Testing of Fused Joints on liners of Polymer Materials - Tensile Creep test on PE* to DVS 2226-4.

This test aims to judge welds on HDPE liners under long-term stress conditions. The test involves inducing a constant tensile load under a set temperature (in a bath of wetting agent) and measuring the time taken to failure. To shorten the test times the samples are tested at elevated temperatures. The test tensions are chosen such that only brittle fracture will occur. The time to failure was recorded.

A plot of stress (imposed tensile stress) and service life is typically provided at the end of the test. Different points for different tested tensile loads will result in a line on the graph for each type of test that can be compared. Before testing commenced, it was agreed that should the weld samples with grooves have less than 80% of the tensile strength of the welds without grooves at failure, the liner installer would pay for the testing as well as the repair works.

The samples were sent for testing at the laboratory. After 2686 hours (16 weeks), none of the samples showed any signs of brittle failure and it was decided to end the test. This was after increasing the load after 900 hours and replacing the wetting agent after 1800 hours. The lab issued a report at the end of the testing period which stated that the tests were inconclusive, and no results were provided that could declare a liable party for the testing.

Although, the test was inconclusive in terms of the effect of the groove, the test indicated that the groove did not cause significant decrease in the durability of the geomembrane and were therefore considered not to be a defect – the employer covered all the costs. However, due to the inconclusive results and uncertainty of the long-term effects, the engineer was relieved that the grooves were no longer part of the installation.

The third challenge, also on the geomembrane installation, was the curious case of damage occurring to the base geomembrane sheet during wedge welding. The damage consists of the bottom liner being slit on the outside of the wedge weld below the overlap – See Figure 4. This is not picked up during air pressure testing.

At the 2012 Geo-Americas Geosynthetics Conference, a panel discussion was held to discuss this type of defect (Thiel, R 2012). It was found that:

> *All of the above welds appear to be perfectly constructed based on visual appearance, and all pass the "Standard" non-destructive tests (air channel for fusion, vacuum box for extrusion).*

The suspected causes were likely re-alignment of welding machine, often with jerking motion as it is running, especially on hot days, trimming of the top sheet or sharp material caught on the machine plate of the wedge welder. It was suggested that the best detection measure is vigilant observation of every weld operation and marking any alignment adjustments and using a hand probe / air lance on all flaps or water-puddle / electrical leak location. This is sufficient motivation for constant quality control and assurance during every weld in an installation. It has been reported that failure of welds could be as high as 1% - 1m in every 100m (Erickson R.B. et al, 2008). In the case of this project, the seam was cut out and a new wedge weld was carried out.

The last challenge faced was the installation of a geosynthetic ballast layer that was researched and developed specifically for this facility. For this reason, panels were manufactured to size based on a panel layout that was created based on the design model. Each of the panels were designated a panel number and were manufactured with the panel number on. The manufacturer issued a setting out drawing, which could be used to align the panels on site.

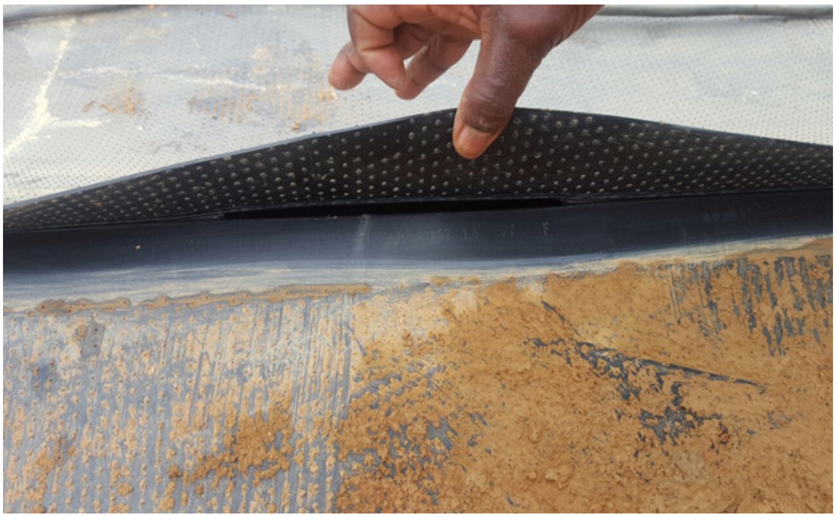
Figure 4: Slit created in base geomembrane of a wedge weld.

However, the design model approximates site conditions. Earthworks are carried out to a specified tolerance and it is not unheard of that the works could be out by 100mm or more. Generally, the panels manufactured to size, fit the as-built shape of the facility well. However, it was found towards the end of the installation that the last panels were too short to fully cover the basin. Due to the wedge-shaped geometry of the basin, the deficit increased in size. It was decided to shift the panels downwards to cater for the deficit. However, eventually there was an area that was not fully covered.

This was solved by replacing the panels with separation geotextile to ensure that the geomembrane is not exposed to UV radiation for an extended period. Additional panels will need to be ordered from the manufacturer to replace this area.

However, it must be noted that if panels are going to be manufactured to size, stricter controls must be placed on the setting out of the works. This is challenging in multilayer liner works but if a stricter tolerance is applied there will be less chance of future occurrence.

4 Conclusion

Effective planning is required during construction to ensure that geosynthetics, specifically geotextiles, are not exposed to UV for extended periods of time unless acting as a sacrificial layer. If exposure is likely to be longer than advised by the manufacturer, apply a temporary cover.

Always ensure that machinery used for welding is in good condition; any concerns should be raised with the installer and the machinery replaced with similar in good condition immediately. This will prevent questionable damage to the geomembrane, which will require judgment on acceptance. Always ensure constant visual observation when carrying out wedge welds – any changes to the nature of the process must be scrutinized in detail as there may be a slit formed in the base geomembrane. To reach the highest confidence that these haven't occurred in the installation – carry out electric leak detection.

Lastly, ensure stricter control on survey if geosynthetics are going to be manufactured to site conditions so that there is not a shortage in panels at the end of construction.

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