Installation of HDPE Geomembrane for a Lined Embankment Dam – a Summary of Construction Best Practices

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ABSTRACT: Water retaining structures such as embankment dams have typically controlled water flow by the use of clay zones within the embankment; however the use of HDPE geomembranes as liners for civil engineering applications has increased in recent years due to advances in technology, and reduction in cost. The use of such materials as HDPE liners is not generally covered in undergraduate Civil Engineering courses and as such Civil Engineers may be unfamiliar with terminologies and construction techniques associated with HDPE liners. This paper aims to provide a broad overview of the processes and methodologies associated with the installation of a HDPE liner, by presenting a case study and 'lessons learnt' from a large lined embankment dam construction located in central Queensland, Australia. The design of geomembrane based retention systems is not covered in the scope of this paper.

1 INTRODUCTION

The inherent variability of natural materials can present risks to the performance of structures such as embankment dams. Nowadays, such risks can be mitigated via the use of uniform man made materials such as geomembranes. This paper presents a summary of 'lessons learnt' relating to installation of geomembranes, by drawing on the site experience of the authors. Due to our client's preferences the site location and project specifics are not provided in this paper. Therefore the project will be discussed in general terms.

In 2013, the authors were based full time on site, overseeing the construction of a large embankment dam (Fig. 1), which included the installation of around 40ha of HDPE geomembrane, which overlaid embankments constructed from well compacted site won fill. The general installation process comprised delivery of geomembrane to site in several rolls (each of 80m x 6m), installing a geofabric cushioning layer (for protection of the geomembrane), positioning the geomembrane panels via a combination of machinery and by hand, creating a watertight seam between each panel using a number of welding techniques, and performing quality assurance testing. Each of these stages are discussed in the sections below.

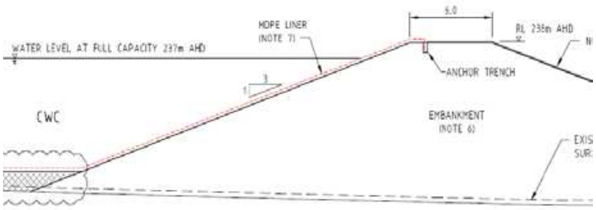

Fig. 1 Typical Dam Cross Section

2 INSTALLATION

2.1 Subgrade Preparation

Although geomembranes can be relatively tough, they are at risk of puncturing by sharp sticks, rocks and other debris remaining within the subgrade. Therefore it is vital that the subgrade is prepared in such a way as to create a smooth unyielding surface, free of sharp objects.

At the coal mine in central Queensland, typical subgrade preparation works included trimming of dam floors and embankment slopes with a CAT 16H grader, removing rocks, sticks and sharp objects remaining at the surface by hand, filling voids with compacted fill or sand as necessary, and compaction of the subgrade with a smooth drum roller.

The combined surface area to be covered with geomembrane was relatively large (approximately 40ha) therefore it was prepared, inspected and approved in sections. Initially subgrade preparation was verified via compaction testing, however due to testing turnaround times, proof rolling was adopted. Any 'soft spots' that were identified during the proof roll were reworked by excavating loose / soft material and replacing with engineered fill.

The geomembrane should be placed soon after subgrade preparation because, if left exposed to the elements, the subgrade may be eroded and/or softened which may result in re-work, potentially including ripping and re-compacting.

2.2 Geofabric Cushioning Layer

Before the placement of HDPE liner, a geotextile-cushioning layer was installed in order to mitigate the risk of punctures to the HDPE liner from any sharp stones or sticks. This may not always be necessary, and is not included in many lined dams; however the cost of repairs and difficulty in identifying the location of punctures, should be considered when deciding whether to include a geofabric cushioning layer in the design.

2.3 Liner Placement

The geomembrane (and geofabric) was installed via the use of a telescopic handler (Fig. 2), and a spreader bar by traversing up the batter slopes and the reversing back, allowing the roll of HDPE to unroll onto the batter slope. Any final adjustment to the positioning of the liner was carried out by hand.

Fig. 2 Geomembrane Placement

Once positioned, geomembrane panels along the dam floor were temporarily secured via the use of sand bags located along the edges of the panel, primarily to secure the panel from overturning / moving out of position due to wind. For the batter slopes, geomembrane panels were secured into position by anchoring the geomembrane into a trench positioned at the top of the batter slope (Fig. 1). The trenches were 600mm deep and 600mm wide and were offset from the embankment crest by 1m.

The anchor trenches should be backfilled as soon as possible as the weight of the geomembrane combined with movements associated with thermal expansion and contraction can result in the geomembrane being 'pulled' down slope. Once this has occurred it becomes very difficult to re-position the geomembrane and satisfy the minimum amount of liner required in the trench.

Geomembrane panels can be manufactured with either two smooth surfaces, two textured surfaces or a smooth surface and a textured surface. For applications that include a batter slope, a smooth-textured geomembrane is preferred. The smooth surface should be installed in contact with the subgrade and/or geofabric cushioning layer, as the smooth surface permits ease of re-positioning by hand (i.e. the textured surface tends to stick to the geofabric). The textured surface should be installed face up, as this provides additional safety for the installation team (i.e. the workers operating on foot have more grip when working on the textured side compared with working on the smooth side).

Finally, it should be noted that the on-site windspeed can significantly affect the installation rate as it becomes unsafe to position geomembrane once the windspeed has surpassed a certain limit (typically in the range of 10m/s – 15m/s). This should be considered and a contingency should be included when programming installation works.

2.4 Welding

In order to create a watertight connection between separate panels of geomembrane, a number of welding techniques can be adopted. During installation of the geomembrane at the coal mine in central Queensland, two welding techniques were adopted, as discussed in the sections below.

2.4.1 Fusion Welding

A fusion weld is an automatic travel hot air weld made by a machine (Fig. 3), i.e. once the welding equipment is set up, the equipment has the ability to self-propel along two overlapping panels of geomembrane and create a seam. Fusion welding creates a double weld (Fig. 4a) separated by an air gap for weld integrity testing (discussed in section 3.4.3). Fusion welds are used for the majority of connections and have advantages such as uniformity of welds and speed.

Fig. 3 Fusion Welding Equipment

2.4.2 Extrusion Welding

Extrusion welds are primarily used for patching (repairs), curves and other welds not accessible to the automatic fusion welding machines. These welds are performed by hand held extrusion-welding equipment (Fig. 5) and create a single weld (Fig. 4b).

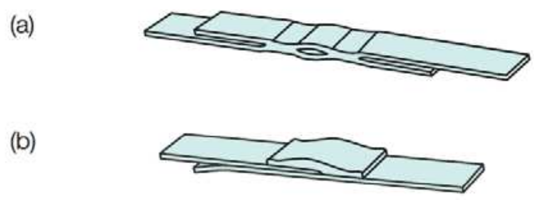

Fig. 4 (a) Fusion Weld; (b) Extrusion Weld (Darilek, 2012)

Fig. 5 Extrusion Welding

2.4.3 QA Testing of Welds

The quality of extrusion and fusion welds were assessed via field and laboratory testing and also by destructive and non-destructive testing. A brief summary of the various testing types is presented below:

Air pressure testing (Non-Destructive): Performed on fusion welds by inserting a needle in the gap between the parallel fusion welds and applying a positive air pressure. The weld is deemed to have passed if the pressure is maintained for a period outlined in the project specification.

Field tensometer testing (Destructive): A section of weld is cut from the installed geomembrane panels. This sample is then cut into 25mm wide strips (Fig. 6) and tested until failure for peel and shear using a tensometer (Fig. 7). The weld is deemed to have passed if the weld meets a percentage of the strength of the virgin material as outlined in the specification.

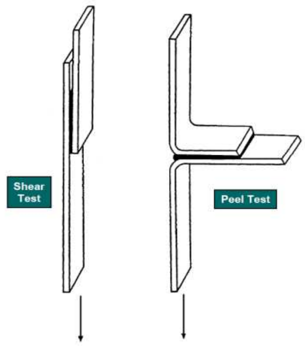

Fig. 6 Peel and Shear modes of failure (ASTM D6392)

Independent Laboratory Testing (Destructive): Similar to the above, samples cut from installed panels are sent to an independent laboratory for testing. The acceptance criteria is similar as for field tensometer testing.

Pre-Weld testing (Destructive): In order to check if the welding machine is operating correctly each shift, pre-weld tests are carried out. A weld is made connecting two off-cuts of geomembrane, and then similar to above, tested for peel and shear using the tensometer. If the minimum strengths are not achieved the settings of the fusion welding machine are to be amended (i.e. temperature, speed etc.).

Fig. 7 Tensometer

Vacuum Box Testing (Non-Destructive): Vacuum box testing is carried on extrusion welds. A rigid rectangular box with an open bottom with rubber seals and a clear plastic window is placed on a section of extrusion weld. A negative pressure is applied to the extrusion weld. Failures within the weld can be identified by the presence of bubbles within the clear window.

2.4.4 Repairs

Repairs are required if localised damage (i.e. scratches, cuts etc.) are identified, or at weld locations where the specification was not achieved. Repairs would typically comprise applying a patch over the affected area using an extrusion weld. The extrusion weld would then be tested using the vacuum box.

3 PROBLEM AREAS

3.1 Thermal Movements

Significant thermal movements (i.e. expansion and contraction) are expected when using HDPE. This can impact installation and should be taken into account when sequencing the works. The biggest problem that thermal movements pose arises when entire sections of geomembrane are connected during daytime when the temperature is the highest. When the temperature reduces during the night, the geomembrane contracts that can lead to 'bridging' over low points, pulling the geomembrane out of the anchor trench (if not properly secured) and in the most severe cases, cause a welded seam to fail.

In order to prevent this, seams that connect entire sections of geomembrane (i.e. connecting one side of the dam to the other) also known as tie in seams, should be welded either at first light in the morning, or if possible at night.

3.2 Connections to Other Structures

Connections joining HDPE geomembrane to other structures including concrete can be difficult to achieve, especially if the connection is required to be watertight. In the authors experience two techniques have been utilised.

HDPE to HDPE using a 'Polylock' System: It is the author's opinion that the preferred method of achieving a watertight connection is to maintain a HDPE to HDPE connection. This can be achieved by using a 'Polylock' HDPE strip (Fig. 8) that is cast into concrete during construction. The geomembrane is then connected to the 'Polylock' strip with an extrusion weld.

Fig. 8 Polylock HDPE Strip (gseworld.com)

Bolt and Batten: If there is a requirement to make a connection to an existing concrete structure, where casting the above system is not possible, a connection can be made by bolting the geomembrane to concrete using a steel batten and a gasket. This type of connection is only recommended for connections above the waterline, as it is prone to leakages, especially under large head.

3.3 Horizontal Welds

Horizontal welds should not be constructed on batter slopes, i.e. welds that run perpendicular to the slope direction. This is associated with the ability of the weld to reliably accommodate tensile loads.

4 USEFUL LITERATURE

In the authors' experience, several useful documents including HDPE specifications are available from the Geosynthetic Institute (www.geosynthetic-institute.org). this resource is a valuable starting point when developing a specification.

REFERENCES

ASTM D6392 - Standard Test Method for Determining the Integrity of Nonreinforced Geomembrane Seams Produced Using Thermo-Fusion Methods.

Darilek, G.T.; Laine, D.L. (2012). Nondestructive Testing of Geomembranes. American Society of Nondestructive Testing.