Construction Supervision of a Zinc Tailings Storage Facility and Return Water Dam

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Abstract

One of the largest diversified natural resource companies required a 110-hectare tailings storage facilities (TSF) as part of the new Zinc mine in the Northern Cape, South Africa. This facility and return water dam (RWD) were required to be covered by 1.5mm HDPE smooth and 1.5mm HDPE double textured geomembrane in specific areas to make up the barrier system. The main objective of the barrier system is to contain the slurry being deposited to ultimately prevent groundwater contamination. The geomembrane used in these facilities had to be securely connected to the various components making up the TSF and RWD. The in-situ basin material contained nodular calcrete that created challenges for surface preparation. In areas where the surface specification couldn't be met, a geotextile (300 GSM non-woven, needle punched) protection layer had to be implemented into the design and be deployed on site to prevent puncture damage to the primary geomembrane.

Keywords: *Geosynthetic, Protection, Quality Assurance, Supervision, Tailings.*

1 Introduction

A 110-hectare tailings storage facilities (TSF) was required to be constructed in the Northern Cape, South Africa. This facility must house Zinc tailings being deposited via cyclones (more detail of the facility can be found in section 3.1).

The slurry pumped from the plant was classed as a Type 3 waste. Measures were required to prevent groundwater contamination and therefore a Class C barrier system was implemented.

An optimised design was implemented to line the entire TSF and return water dam (RWD) with a combination of 1.5mm smooth and 1.5mm double textured HDPE liner. The 1.5mm HDPE smooth geomembrane was placed in a single layer over the entire TSF basin area and the 1.5mm HDPE double textured geomembrane was placed over the rest (from the toe wall, through the drain on the inner toe of the starter wall). The RWD was lined with two layers of the 1.5mm HDPE smooth geomembrane with a separating drainage layer.
This TSF and RWD had various components such as a spillway, anchor blocks and decant towers joining to the geomembrane that required secured connections. Special care was

required with the QA/QC to ensure that the work was done to a high standard and to comply with SANS 10409 (2005).

The in-situ basin material contained nodular calcrete that created challenges for surface preparation. In areas where the surface specification couldn't be met, a geotextile protection layer had to be deployed to prevent puncture damage to the primary geomembrane.

2 TSF and RWD footprint

This facility (RWD and TSF) was required to be constructed in a botanical sensitive area (sensitive areas were already identified before the project began). All the components of this facility were designed and implemented to have no ingress of contaminated water and to have as little negative effects on the environment as possible.

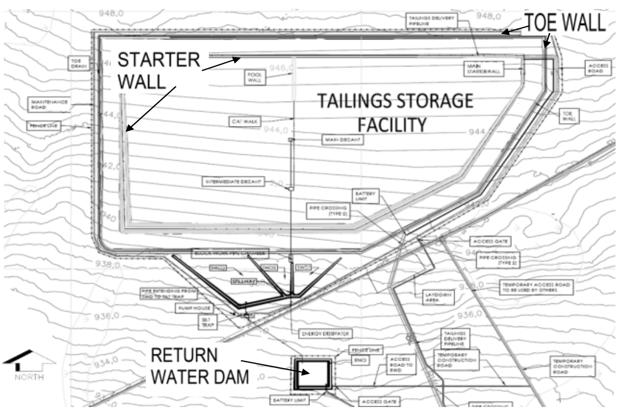

Figure 1. Site Layout

In Figure 1 above, the general layout of the TSF and RWD is illustrated. This is the facility that will be discussed throughout this paper.

3 Design

This section will deal with the design aspects of various components of the TSF and RWD with relation to the geomembrane and geotextile. These components are:

- TSF walls;
- TSF basin;
- Concrete structures;
- Drains;
- The location and order in which the geomembrane was placed; and
- RWD.

3.1 TSF walls

The TSF comprises of two walls (toe wall and starter wall) surrounding the entire perimeter of the facility. The starter wall has a maximum height of 6m at the lowest contour point and 1.5m at the highest contour point. The toe wall has a constant height of 1.5m around the perimeter.

The slurry from the mine will be deposited using cyclones located on the starter wall. When the slurry arrives at the TSF, the cyclones divide the material in a fine (overflow) and coarse (underflow) product that gets deposited on the upstream side (overflow) and between the toe wall and starter wall (underflow) respectively.

There was a requirement for a barrier system to prevent the water in the tailings from seeping into the soil and ultimately the groundwater. A Class C barrier system was required to contain the Type 3 waste generated.

The design incorporated a 1.5mm HDPE double textured geomembrane to be installed over the starter wall. This design included an anchor trench, with a road and berm being constructed on top of the wall.

3.2 TSF basin

The entire inner basin of the TSF, had to be lined with a 1.5mm HDPE smooth geomembrane and required a compaction of 98% MOD Proctor. The first areas that were ready to be lined, were achieved by rip and recompaction of the in-situ material. The rest of the areas achieved the required compactions by simply wetting and rolling the in-situ material.

3.3 Concrete structures

The design of the TSF required a decanting system to enable decanting of supernatant water from the pool that will be generated around the tower. The design also required an intermediate decant at a lower elevation that will be used until the tailings is at a suitable height for the main decant to be functional. The geomembrane surrounding these concrete structures required a secured connection. This was accomplished by using gaskets, flat bars and bolts to sandwich the geomembrane into a “leak proof” system against the concrete. This can be seen in Figure 3.

Figure 2. Typical anchor block on the upstream side of the starter wall

Anchor blocks were required where drains run through the starter wall and toe wall to provide a surface for the geomembrane to be attached to. These anchor blocks required the same secure connection as the main and intermediate decant structures with the geomembrane.

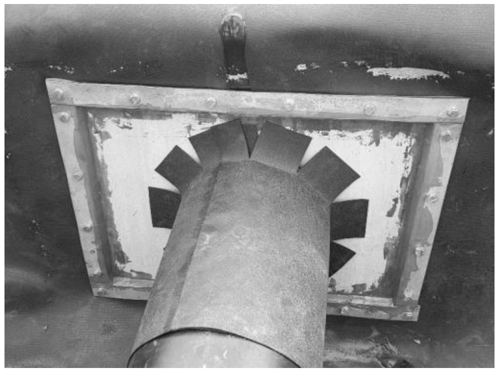

Figure 3. Battening system

3.4 Drains

The basin of the TSF incorporated a herringbone drain system to extract water from the tailings as seen in Figure 4. The arrows on the left herringbone drain stipulates how water will flow. This is the same for the rest of the herringbone drains.

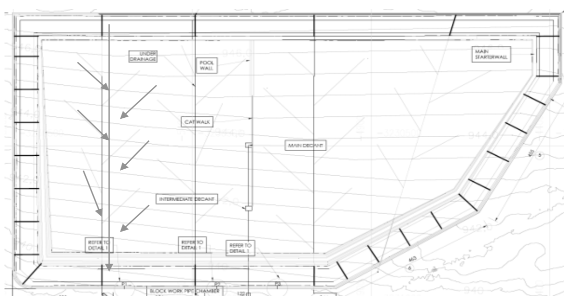

Figure 4. Herringbone drain layout

Circling inside the footprint of the TSF, two drains are located just inside and outside of the starter wall (A and B) and one adjacent to the toe wall (C). These drains are used to lower the phreatic surface within the tailings. These drains ultimately flow into the main drains nr.1-4 (collector drains) in Figure 5.

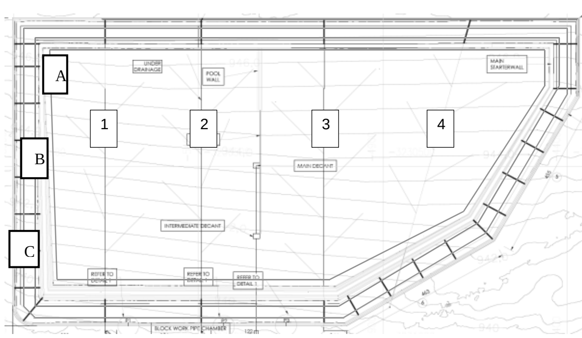

Figure 5. Ring drains

All the drains mentioned above were sunken into the basin which required the 1.5mm HDPE smooth/double textured geomembrane to go through the drains, and underneath the pipes and filter material to prevent the ingress of contaminated water into the soil and groundwater. This can be seen in Figure 6.

The design of the drain materials were different for the areas on the inside the starter wall compared to the areas between the toe wall and starter wall because of the particle size split at the cyclones. The design comprised of a constant 19mm stone for the bottom of the drain to cover the perforated pipe. Another material (a 6.7mm stone layer and a filter sand layer in the basin and a blended material layer between the toe wall and starter wall) was placed on top of the 19mm stone to suite the filter requirements for the specific area. Because the specification required stones of no larger than 3mm to be in direct contact with the geomembrane, the inside of the drain required a layer of geotextile (300 GSM non-woven, needle punched) to be placed as a protection layer against the 19mm stone. This order can also be seen in Figure 6.

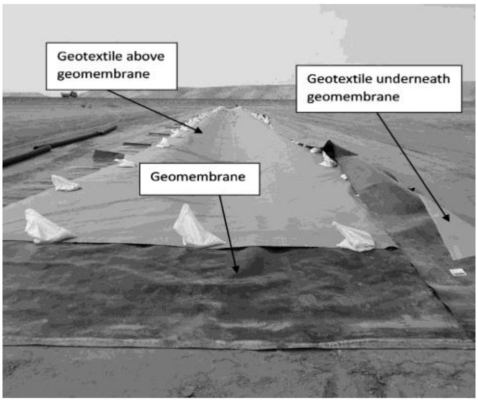

Figure 6. Order in which the drain was lined

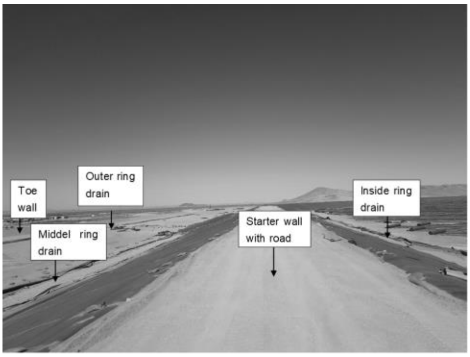

Figure 7. The relative positions of the drains in relation to the toe wall and starter wall

3.5 Various geomembrane placement

The TSF barrier system consisted out of a single 1.5mm HDPE smooth geomembrane covering a certain portion of the facility and a single 1.5mm HDPE double textured geomembrane covering the rest of the facility, not covered by the smooth geomembrane.

The double textured geomembrane was placed over the entire area reaching from the toe wall up until the basin inside the starter wall, stopping when reaching through the inside drain. The smooth geomembrane covered the entire area inside the starter walls.

A geotextile (300 GSM non-woven, needle punched) was placed underneath every piece of double textured geomembrane for protection and to comply with DWS's specification that a geotextile is required to be placed from the outer perimeter inward for a width of 210m.

3.6 Return Water Dam (RWD)
The RWD is the final stop for the water from the TSF before returning to the plant. It is a cut-to-fill, approximate square structure with side slopes of 1:2.5. It primarily consists out of a concrete spillway, concrete supported outflow pipe extending from the base, a leakage detection system and an anchor trench around the crest.

The original design called for a first layer of smooth 1.5mm HDPE geomembrane overlayed with a drainage layer to drain leakage through the primary liner to the leakage detection sump.

The concrete structures in the RWD were fixed to the geomembrane in the same manner as the concrete structures in the TSF.

4 Problems and solutions

This section deals with case studies identified throughout the construction of this facility and the mitigation actions taken.

4.1 TSF walls problems and solutions
One of the options considered was to have the geomembrane run underneath the starter wall. Unfortunately, construction was already in progress and the geomembrane was therefore deployed over the starter wall.

This resulted in the following problems:

- Deployment of the geomembrane;
- Expansion and contraction problems of the geomembrane due to large variance in day and night temperatures;
- Access road required to be constructed on top of the lined area;
- Obtaining the required surface finish of the slope areas; and
- Wind problems.

Because time and logistical constraints forced the contactor to construct the walls before the geomembrane could be placed, solutions had to be found for these problems

These solutions involved:

- The double textured 1.5mm HDPE geomembrane were divided into separate smaller panels that were delivered to the top of the starter wall with a telehandler. These panels were rolled down the slope and welded together with the adjacent panels;
- The expansion and contraction problems were mended by placing the sandbags or the road on top of the starter wall before any closure weld could be done. If this was not possible (wind ingress) and the closure weld had to be done, the drains adjacent to the starter wall were recommended to be filled when it was a colder part of the day (morning). An example of this can be seen in Figure 10;
- The geomembrane had to cross over the starter wall which required the road (approved mix of ±13mm stones and screened sand) to be constructed on the

geomembrane. The solution was to place the protective geotextile directly on top of the 1.5mm HDPE double textured geomembrane before the approved mix of ±13mm stones and screened sand was placed;

- The walls were constructed with the approved material in the area which contained nodular calcrete. Because the slopes were a 1:2.5 angle, surface preparation was problematic for construction equipment. Before the drains adjacent to the starter wall was excavated, a vibratory pad foot roller compacted the slope. It was followed by a smooth drum roller to get as close as possible to the required finish. This was followed by screened sand, tipped at the top of the starter wall and spread across the slopes' surface. Some of the screened sand had particles just over 3mm and thus it was decided to place a protective geotextile on the slopes underneath the geomembrane; and
- There were some instances where the crest of the starter wall's geomembrane was lifted due to wind uplift. Many square meters of geotextile moved from its original position underneath the double textured geomembrane. This was mended by cutting open the geomembrane, re-placing the geotextile, tack welding the outer edges of the adjacent geotextile panels together and then welding the geomembrane panels. Sand bags were placed in the anchor trench at the top of the starter wall to combat the wind uplift further. The problem and solution can be seen in Figure 8 and Figure 9.

Figure 8. Newly opened (cut) starter wall

Figure 9. Re-placed geotextile with tacked edges

4.2 TSF basin problems and solutions

The inner TSF basin (inside the starter walls) was divided into separate areas to be tested for compaction.

The first few areas were ripped and recompacted which caused the following problem:

- Shallow calcrete nodules were ripped up with the in-situ basin material which caused many surface preparation difficulties;
- A very time consuming and costly exercise to prepare the basin to an acceptable finish; and
- Wind uplift and ingress created wrinkles in the geomembrane. During the lining process, many of the geomembranes leading edges were not connected to another fixed (drain) piece of geomembrane. This resulted in wind ingress and uplift over the geomembrane which caused excessive wrinkles in localized areas.

To avoid these issues moving forward, the following solutions were implemented:

- Due to the aforementioned problem, all rip and re-compaction activities were stopped;
- Areas that were rip and re-compacted, were compacted by means of various passes of the pad foot roller, smooth drum roller and pneumatic roller with a layer of screened sand placed afterwards;
- Moving forward the surface to be lined, was only wetted and rolled various times with the vibratory smooth drum roller to acquire the specified compaction. After this, screened sand was placed to be wetted and rolled by the pneumatic roller to achieve the required surface finish;
- In both areas, an assigned work force walked the surface during and after prep work to remove rocks that did not meet the specification; and
- The wrinkles created were cut and pulled out. Sand bags were placed in a pattern to combat this from happening further as can be seen in Figure 10 below.

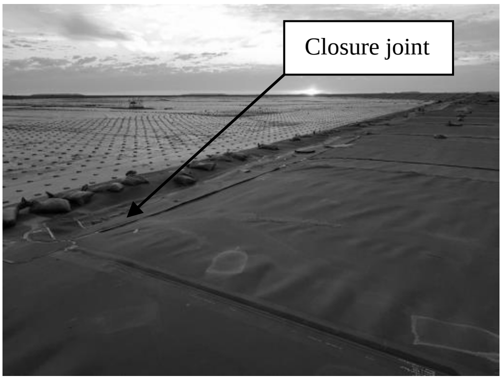

Figure 10. Crest on the starter wall being ballasted with sand bags

4.3 Concrete structures

The connection of the geomembrane to the concrete structures did not result in any meaningful problems. Boots were placed as an extra barrier at the anchor blocks that were constructed in the toe of the starter wall and toe wall. The boots can be described as a patch welded against the primary geomembrane and pipe to cover the gaskets, flat bars and bolts making up the buttoning system. This can be seen in Figure 3 where the piece of geomembrane surrounding the pipe is still required to be connected to another piece of geomembrane to cover the entire concrete face.

4.4 Drains problems and solutions

The design of the drains caused the following problems for geomembrane placement:

- The drains were sunken into the basin, which contained nodular calcrete; and
- Difficulty for machinery to compact the basin of the drain.

The following solutions were implemented on site to efficiently line the drains:

- After the drains had been excavated, another assigned workforce collected the oversized rocks and dug out any pinnacles of rocks sticking out on the side of the drain;
- The drain was wetted and rolled with a smooth drum roller perpendicular to the flow direction of the drain;
- A screened sand layer was placed in the drain and then wetted to keep in place before any geomembrane could be placed; and
- The contractor decided to place geotextile as a protection layer underneath the geomembrane inside the drains because the screened sand had some particles larger than the required/specified 3mm.

4.5 Various geomembrane placement

The variation in geomembrane type did not result in any meaningful problems as expected. It was expected that the double textured geomembrane would be difficult to install across the geotextile, but this problem was not encountered.

4.6 RWD problems and solutions

The RWD had the following problems:

- It was difficult to produce a surface to comply with the 3mm specification because the basin of the RWD was excavated into the nodular calcrete and the walls were constructed from the nodular calcrete acquired from the borrow pits;
- Concrete structures; and
- The RWD is small with walls that concentrate the suns heat into the basin. There were large temperature variations in the RWD throughout the day. These variations caused burn throughs and problems with pressure testing.

The following solutions were implemented:

- The same process was followed in the RWD as was done on the slopes of the starter wall (4.1 second last point of the solutions). It was also decided to install a geotextile as protection throughout the entire RWD;
- The spillway was securely connected to the geomembrane as described earlier (3.3). The pipe support for the outflow pipe was also connected in the same manner; and
- After the first geomembrane layer was placed, heat was becoming an increasing factor in welding the second layer. Special attention was given to the welding temperature of the double wedge welder and it was ensured that the person doing the pressure testing was following the method statement.

5 QA&QC – Data capturing and site supervision

The appointed lining contractor had an online system of data capturing which was used to log all the necessary information. The process involved doing the work on site and then a specialized person captures the data that was written down on the panels. The system has categories for every type of geomembrane installed, which also included the various installation procedures information for the panels, t-joints, patches, extrusion work, etc. The process followed is described in the section below:

- The process started by the contractor handing over an area that was ready to be lined (checked by the engineer);
- Thereafter the liner contractor delivered the approved geomembrane role to a specific area;
- Trial welding started before any machine could start welding on site;
- The geomembrane roles were deployed and welded to the adjacent panels;

- Necessary work trailed from each section, which included t-joints, patches, etc.;
- After all this work was completed, spark testing of the patches and pressure testing of the seams commenced;
- Destructive samples were taken at a specified interval and sent for testing;
- All the necessary information such as the panel numbers, seaming information, joint information, etc. were required to be written down on the panels;
- Data capturing of all the information commenced after this;
- The Engineer checked to see if the liner contractor complied with their method statement.

The advantages of this system were that the captured information was readily available and makes all stakeholders involved in the project more aware and proactive towards quality control and quality assurance. This was because the information could be viewed, sorted and filtered by anyone given access at any time.

6 Conclusion

During the construction process of this site, many problems arose, and solutions were found to implement the design in the most optimized manner. To have enough QA/QC personnel on site was of utmost importance. If there were not enough qualified personnel, problems could quickly sneak past and cause havoc.

One of the components that contributed the most problems, was the fact that the geomembrane was placed over the starter wall. Many square meters of geomembrane were required to be cut to place the geotextile back in its original position. Unnecessary welds were placed in the geomembrane. Many unnecessary risks could have been avoided if the geomembrane could have been placed underneath the wall. In the beginning of the project, a learning curve was still at play to get the specified surface finish. Many methods were attempted, which ultimately boiled down to the method the contractor used till the end. It was noted that almost the worst of surfaces could be broken down to achieve a near perfect finish.

Wind uplift and ingress also contributed to many problems. From the start of the lining project, the contractor only placed temporary sand bags on the edges of the geomembrane. This was not enough to combat the uplift force. Wrinkles formed which could have been avoided if permanent sand bags were placed from the start. Every site will have its own unique problems, but through good documentation, problems can be sorted out in a well-organized and heightened manner.

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