USE OF BITUMINOUS GEOMEMBRANE (BGM) LINER FOR AGNICO-EAGLE MINE IN KITTIĻĀ (FINLAND)

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Abstract: This paper briefly presents:
The mine in general: opening date, operating since how many years.
The purpose of these ponds: retain pollution. What kind of pollution and for how many years?
Structure of the bituminous geomembrane more than 5.10 meters wide. Its different uses in hydraulic applications and environmental protection.
Design and structure of the 2 ponds, including the weather that could be met during installation, as BGM allows an extension of the installation period. Interest for the client in terms of schedule, maximum aggregate size that the use of the BGM allows, therefore an economy for the client,
Construction details, BGM installation and quality controls, max output and installation average.
The paper will review changes to the initial HDPE design of the pond that the change of liner type allowed, identify areas of cost and schedule savings due to the installation during worse weather and at lower temperature. Some other case histories in very bad weather conditions above the Polar Circle during winter and spring with temperatures under -25°C will be cited.

Keywords: bituminous liner, mining, geomembrane, geosynthetic.

INTRODUCTION

Kittilä Gold Mine is operated and owned by Agnico-Eagle Mines Ltd. This mine is the second mine located north of Finland. Environmental permission for the mine operations was granted by Northern Finland Environmental Permit Authority in 2002

Mine will start its operations with open pit which depth is 150 m and construction time 3 years. After that, the tunnel will be opened down till 450 m depth. Key factors of the mine:
• Mine area 860 ha
• Annual ore mining 1 000 000 tonnes
• Annual siderock mining 4 000 000 tonnes
• Annual gold production 5 tonnes
• Roads 4 km
• Pipelines. 15 km

Location

Construction is well underway on the Kittilä mine (on the Suurikuusikko deposit) in northern Finland, approximately 900 kilometres north of Helsinki and 40 kilometres from Kittilä (see figure 1). The Kittilä mine, named after the nearby community of the same name, will initially be extracted via open pit followed by underground mining via ramp access. The mining operation will feed a 3,000 tonnes per day surface processing plant. The mine will open in the summer of 2008 and the estimated lifetime at the moment is 15 years.
Climate

The Kittilä Mine site lies within the Arctic Climatic Region (150 km north) where daylight reaches a minimum of 1 hour per day in winter and a maximum of 24 hours in summer. Temperatures are cool (see figure 2), with an average mean monthly temperature in July of 15 °C and in January of –15 °C. The mean annual air temperature at the site is approximately 0 °C. Winds are moderate and generally from the west. Average wind speeds are about 25 km/hr. Snow falls in every winter month, although rain generally only occurs between May and October. As you can see on figure 1 and 2, the hottest season is between June and September, but it is the wetest too.

Figure 1. Location

Figure 2. Temperatures

Figure 3. Precipitations

PROJECT

Purpose
Two ponds were designed for this project with a total area to cover of 540 000 m². The watertight liner was required for the environmental permit for mining structure by the Ministry of Environment. The purpose of these
ponds of area to store the water that comes from the process. Water from the ponds is circulating back to the process. So the water circulation is practically a closed system.

**Schedule**

The whole area must be installed by the autumn 2008. The period of work was between June, when the topsoil defrost for the excavation, and November. So it was decided to work in two phases:

- First phase in year 2007 to build and finish the smallest pond and to begin the bottom of the biggest pond.
- Second phase in year 2008 to finish the big pond including slopes.

At this time the project is on schedule.

![Aerial view](Image)

**Figure 3. Aerial view**

**DESIGN**

**Structure**

Dam walls are made from blasted rock with compound structure. This means that the main dam wall is made from maximum 600 mm diameter grain size blasted rock. The “wet” sides of the dam walls are made also from blasted rock (dam max. 300 mm grain size) and gravel (grain size 55 mm).

These layers are also compacted with an excavator equipped with a compacting plate (see figure 4). The idea for these structures is to prevent the dam walls from breaking. The grain sizes differ so that they don’t get squeezed in each other from the water pressure. If there is a leak in the dam walls the water will spread throughout the dam walls and come out like a simple percolation of water instead of making a big hole in the dam wall and causing a tidal wave.
Figure 4. Compaction

Mineral sealing layer will be constructed under the BGM-layer. Mineral sealing layer is made by using local excavated moraine, which is compacted. Thickness of the mineral sealing layer is 1000mm and water permeability less than 5x10^{-8} m/s. Mineral sealing layer and BGM act as a composite liner.

Liner

The bituminous geomembrane was chosen because:

- It can be installed directly over the prepared mineral sealing bottom layer instead of a layer of sand, and then geotextile and finally a polymeric liner. This provided a large cost savings for the ponds, compared to the global solution of other products because you don’t have to transport and screen these filter layers,
- The low thermal expansion coefficient allows keeping the liner exposed and flattened directly on the mineral sealing layer, which is a main point in the design. The combination of both moraine and BGM liner has a very long watertightness lifetime because the liner is always flat and in contact of the glacial till support which is the passive barrier (see figure 5).
- It can be installed at very low temperatures such as –30°C for the elastomeric grade of the BGM Liner,
- Installation is much less dependent on weather conditions. Due to the extended construction season of BGM, the completion of the geomembrane portion can be done in half the time of a HDPE solution. The reduced construction period means that the equipment used for the ponds can be used earlier in mine construction. For investors, this could have the mine operation up and running much sooner, and the financial impact could be huge.
In order to optimize the cost for the design of the lining system:

- Composite barrier system is made when BGM is installed directly on top of the mineral sealing layer.
- For the bottom, the 3.5 mm bituminous liner was used and for the slopes 4.0 mm.
- At the beginning of the work period, as it was in early July the contractor used a blown bitumen impregnated membrane (called NTP grade), which could be used till +5 °C. In September, when the temperature, mainly the morning, could be under +5 °C, they laid a liner impregnated with elastomeric bitumen (called ES grade), which could be used till –25 °C.

**Approval process**

The design and especially the use of bituminous geomembrane was subject to the authorization of all the public authorities affected by this project (from the local to the national decision-making services). The approval process succeed after three months and a public survey.

**Liner Structure**

The structure of the bituminous geomembrane used, is as follows (Figure 6):

- A non-woven polyester geotextile whose mass per unit area is 200 to 400 grams per m²,
- A glass fleece reinforcement which provides stability during fabrication and contributes to the strength of the geomembrane,
- A bituminous mastic consisting of a blown 100/40 pen bitumen, and filler. This mastic impregnates the whole structure and give the waterproofness of the product and ensure the longevity and the high resistance of the product,
- A Terphane film bonded to the underside when the membrane is hot, which prevents penetration of the membrane by plant roots,
- A coating of fine sand on the upper surface to provide a greater traction on slopes, giving greater operator safety and security, and to give protection from the degrading effects of UV radiation.
Figure 6. Typical cross-section

The bituminous geomembrane used is composed of a combination of needle punched, non-woven geotextile, glass reinforcement and bituminous impregnation. This system results in a long life expectancy due to its resistance to high levels of mechanical stress and negligible ageing characteristics. The manufacturer offers grades of the material appropriate to the end use, in thicknesses from 3.5 mm up to 5.6 mm. This reflects the wide range of uses for this geomembrane, from landfill lining and capping to the protection of groundwater from contamination in hydraulic, environment or transportation.

Uses

Bituminous géomembranes are used in many applications and mainly for the protection of environment:

- Solid wastes,
- Confining domestic, industrial and mining wastes,
- Capping,
- Storage of liquid wastes, tailings dam and pond,
- Ponds for recycling water,
- Biogas barrier.

Or in hydraulic fields:

- Dams,
- Canals,
- Protection of aquifer, rivers and spring of tap water,

LINER INSTALLATION

The installation was completed by a local company (Destia Oy) based in Helsinki (Finland). Its business area is the civil engineering sector, primarily the planning, construction, upkeep and maintenance of traffic routes and the traffic environment, as well as related products and services. The company which was the general contractor installed the bituminous geomembrane and provided the Quality Control testing and reporting after being trained by a supervisor of the distributor.

Installation crew

For the preparation of the support two workers were removing sharp gravel and natural organic fill of the laying surface with rakes and another one operating a compactor. The installer used a hydraulic beam for the slopes and a mechanical beam for the bottom, which means that two workers unrolled the geomembrane and one other operates the excavator.

Two welders were needed to weld the joints and one assistant to roll and seal the joints after welding (see figure 7).
Figure 7. Typical welding team
One worker was needed to visually inspect the quality of the seam and finish the joint.
One worker was following the quality manager to do the patches.

Installation rate
- On average, approximately 5,000 m²/day was installed with two welding teams,
- In some instances, mineral sealing layer work was delayed because of heavy rainfall.

Quality controls
One lab technician from the general contractor was trained by the supervisor of the distributor to follow the quality control plan all along the work. This technician was completely dedicated to this work.
All seam testing and destructive samples were documented daily and recorded in a computer-generated report.

Ultrasound testing
It was used to ensure quality of the total width of the seam on the project. The quality of the seam is essential for any geomembrane. The Ultrasound testing probe is used to check the entire 20 cm width of the seam. Ultrasound waves are able to detect imperfections in the seam and to measure the width of the defect.
- Patching was done accordingly
- There was very good compliance with the QC/QA requirements despite the conditions
- This procedure is straight forward, and the contractor and consultant on site were trained and certified by the distributor supervisor on the site, to do this procedure on their own.
CONCLUSION

The choices were confirmed by a successful construction of the two ponds. The use of bituminous geomembrane provides several benefits. The most important are:

- Cost reduction. Especially when the cost of the support and cover material is taken into consideration because sand and fine gravel are not required for liner bedding and cover material,
- Efficiency of the work. Installation rates for the BGM liner range from about 2,000 m²/day to 3,000 m²/day per welding crew and average about 2,500 m²/day. Installation rates are only slightly lower during cold weather periods.
- Reliability. A full documented QA/QC from the fabrication of the liner to the finished pond,
- The liner is installed at nearly any time of the year. Only during the coldest periods of the year when temperature are below -30 °C is liner installation not possible. This allows construction to be carried out nearly 10 months per year even in high latitude countries.
- Bituminous geomembranes can be installed easily by local workers, while polymeric geomembranes require special equipment operated by specialized workers. Extensions and repairs are easier because local people are trained to do the work or could be even done by the client’s maintenance workers.

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