The Use of Bituminous Geomembranes (BGM) for Ponds and Shale Gas Ponds

Natalie Daly, P.Eng, PMP.,1 Bernard Breul, Eng.2

1 Axter Coletanche Inc, Montreal, Canada: ndaly@axtercoletanche.com
2 Axter SAS, Paris, France: breul@axter.eu

ABSTRACT

Bituminous geomembranes (BGM) have a specific composite structure including a non-woven polyester geotextile impregnated by an elastomeric compound based on bitumen that has specific advantages. Waterproofing a tailings reservoir and other specific shale gas reservoirs ask for a geomembrane with a high resistance to very hot water.

Project examples of tailings ponds built in the great North of Canada, in Finland, in Kazakhstan and in Russia will be described. There is interest for investors to use BGM as they can be installed in low temperatures and harsh weather conditions. With this advantage, BGM allows an extension of the installation period during the freezing months, which provides a flexible schedule and quicker return on investment. Furthermore, the possible use of larger grain sized aggregates as a bedding material without any geotextile for protection allows an economy of material layers.

BGM does not only have advantages in cold weather conditions but also in hot weather conditions from temperatures ranging -45 to +90 °C (-49 to +194°F). A shale gas project in Australia requires a high resistance to heat for the installation and storage of water between 70°C and 90°C (158°F and 194°F). In Ireland, a reservoir storing very hot 70°C (+158°F) water in an aluminum factory had BGM covered directly with a layer of asphalt concrete, which allows for cleaning the bottom of the reservoir, that helps maintain its full capacity of storage.

INTRODUCTION

Bitumen emerged as a standard 20th century waterproofing material in civil and water engineering in the form of bituminous concrete, asphalt, and bituminous geomembrane. The first applications of BGM were in France in 1975 near Grenoble and for potable water storage reservoirs at a 2,000 meter altitude around in the Alps.

GENERAL PRESENTATION OF BGM

The structure of BGM is multi-layered including a non-woven polyester geotextile at the core, providing the mechanical resistance and the high puncture resistance. This geotextile is impregnated in an elastomeric bitumen compound that provides the waterproofing properties and ensures the product’s longevity by impregnating the geotextile totally. The glass fleece, also
impregnated in the bitumen, provides the dimensional stability during fabrication. The sand coating improves the resistance to UV and grip, the anti-root film prevents puncturing from roots and vegetation (Figure 1).

Manufacturing is done under strict quality control procedures certified under an ISO 9002 quality assurance scheme, under a French and European ASQUAL certification and it is CE marked (European marked). The factory located in the North of France operates with an ISO 14001 environmental certification.

Some technical characteristics of BGM giving advantages for a use in pond projects:

- Low permeability at the same level of PE geomembranes is $6 \times 10^{-14}$ m/sec (ASTM E 96).
- High mass per unit area between 124 to 189 oz/yd² (4.20 to 6.40 kg/m²) giving an important resistance to lifting in windy regions and possible installation even in windy region at high altitudes (ASTM D 3776).
- The density is 1.2 ton/m³ so BGM can be installed under water without floatation. The seams under water are welded with a mastic (ASTM D 1505 and ASTM D 792 Method A).
- High puncture resistance for static puncture following ASTM D 4833 is between 101 lbf to 146 lbf (450 to 650 N), puncture by aggregates NF P84510 between 20 and 35 kN and hydrostatic puncture resistance ASTM D 5147 between 501 and 564 kPa for the range of 4.00 and 4.80 mm thickness and XP P84523 between 1050 and 1500 kPa for the range between 3.5 mm and 4.8 mm of thickness on a bedding with grain size of 25/50 mm. With this property, tire-mounted vehicles and equipment can drive directly on top of the geomembrane during installation and maintenance (Figure 2).
• BGM has a very low thermal expansion coefficient following ASTM D 1204, and is 100 times lower than HDPE. This means there are no wrinkles with thermal and temperature variations. Therefore, there is no fatigue phenomenon and it is possible for welding and covering of the geomembrane at any time during the day and the year, without interruption.
• The sand surfacing reinforces the UV resistance of the bitumen. This face has a friction angle of 34° and higher depending the material placed on top. This value is following ASTM D5321 tests done by Sageos (Quebec, Canada) and INSA (Lyon, France).
• BGM can store potable water conferring to the American international certification of NSF/ANSI 61.
• BGM has a high resistance to earthquakes as demonstrated in the field. The Milpo dam lined with BGM, had undergone an earthquake of a magnitude of 8.1 on the Richter scale. Laboratory testing was followed to verify the integrity of the geomembrane by Precision Laboratory in California for LADWP. They concluded no damage to the integrity of the liner.
• Easy to seal to rock and concrete structures, thus allowing to have the same permeability at any point of the lining (Figure 3).

![Figure 3. BGM connection to different materials: a) concrete pipe; b) rock; c) concrete lining](image)

• The manufacturer supplies personnel to train local teams of installers on site.

BGM IN SHALE GAS PONDS EXAMPLES

The use of BGM in tailings ponds built in very cold temperatures and harsh weather conditions allows for an extension of the installation period during the freezing months (i.e. - 49°F or -45°C in February in Siberia on the Kupol gold mine) which provides in a quicker return on investment by not delaying the installation time.

In the great North of Canada, the Diavik Diamond Mine is located on a 20-sq-km island in Lac de Gras, 300 kilometers northeast of Yellowknife in the Northwest Territories of Canada. The mine is owned by a subsidiary of Rio Tinto and Aber Diamond Limited Partnership. Average minimum and maximum daily temperatures are around -25°C (-13°F) and precipitation is heavy and under different forms of drizzle, rain, hail, sleet and snow. The processed kimberlite containment retention pond was initially completed in HDPE, but owners and the consultant Golder Associates were looking to improve the quality and reduce the cost of the PKC Pond and other ponds. By avoiding contamination of the purity of the water of the lake of Gras, BGM was able to present a more economical solution by offering a larger period of installation and welding.
that can tie into 1600 lineal meters (5,250 ft) of existing HDPE. The extension to the existing pond was to be an additional height of 5 m (16 ft). Installation was completed by a local company based in Yellowknife, specializing in geomembrane installation in cold weather conditions and they have appreciated BGM’s flexibility even when stored and unrolled at –40°C (-40°F). No special precautions such inside tunnels to protect from the cold were required during welding, which was performed in the open air at –25°C (-13°F). This means the installation and welding of BGM is largely independent of temperature and weather conditions (Eldridge, T.).

For the installer, working with BGM was the same at –25°C (-13°F) as it would have been at +20°C (+68°F). The geomembrane maintained its flexibility and was as easy to install and weld at both temperatures. Even when it snowed, the installation of the geomembrane continued as usual. BGM can thus be installed at any time of the year. For the initial HDPE solution, the grain size for the bedding and cover material was specified a 50-mm minus (2 inch minus). Tests carried out on site showed that a 150-mm minus (6 inch minus) material could be used for bedding and a 400-mm minus could be used for cover without damage to the BGM geomembrane. The 150-mm minus bedding material was compacted then the surface was raked by hand to remove the larger particles protruding above the surface, as typically performed on every work site (Figure 4). The cover material was then dumped along the crest and pushed by a track loader, down the slope over the geomembrane. The use of relatively coarse bedding cover materials and cushion materials as well as the elimination of the need for a protective geotextile (not recommended in regions which have a lot of wind) under and above the geomembrane reduced the total cost of construction. Only one geosynthetic (BGM) was needed to be installed which saved on cost for material layers and installation time in a very extreme weather region (Elliott, C.).

![Figure 4. Grain size of the support - Installation and welding - Welding HDPE/BGM](image)

In Finland, the Kiitilä Mine lies within the Arctic Climatic Region. Temperatures are cold, with an average mean monthly temperature in July of 15°C (59°F) and in January of –15°C (5°F). The mean annual air temperature at the site is approximately 0°C (32°F). The mine facility plan called for a small and a large pond for an initial area of 54 hectares (today more than 100 hectares) to receive the processed water from the gold processing plant. Water from the ponds then recirculates back to the process, which makes the water circulation a closed system. As part of the environmental permit for the mine, a watertight liner was required and BGM was accepted by the Finnish Ministry of Environment (Figure 5) (Huru, M.).
The design of the ponds called for an excavation surrounded by dikes to get the required volume. The cross section of the dam consists of a core built with blasted rock with particle size up to 600 mm (2 ft) in diameter. The upstream side of the dike was covered with a layer of blasted rock but with a maximum diameter of 300 mm (1 ft) and protected by a layer of gravel not exceeding 55 mm in diameter. This last layer was compacted using an excavator equipped with a compacting plate to provide a smooth surface with no ruts. The dikes were designed to function like a zoned dam built with material recovered from the mining operation. A 1 meter thick sealing layer was then placed on the bottom of the pond that consists of the excavated moraine rolled and compacted, exhibiting a saturated hydraulic conductivity less than $5 \times 10^{-8}$ m/s. BGM has a low thermal expansion coefficient so there are no wrinkles throughout the day when temperature varies. With this characteristic, the geomembrane lays flat on the ground (Figure 4) and provides in combination with the low permeability moraine, a permanent and durable double layer of watertightness. The project was initially designed with a polymeric geomembrane (HDPE or LLDPE) but the client expressed interest in switching to a bituminous geomembrane to line the ponds at Kiitilä for the mentioned economic reasons and because BGM can be installed at temperatures as low as $-15^\circ$C ($5^\circ$F), which was a critical element with respect to the schedule in the northern region since the construction was anticipated to extend until October, the most moist and humid period of the year. A local contractor did the installation with an output of 8000 m$^2$ (0.8 ha) per day after on-site training by manufacturer monitor.

In Kazakhstan, BGM was used for a project of irrigation ponds at Kopa between Almaty and the Kirghizistan border with a client called TOO Green Farm, who specializes in walnuts. For consecutive years separate ponds with the depth of about 5 m (16.4 ft) were lined with exposed BGM. BGM was installed directly on natural soil (sandy clayish, fine grain), levelled and compacted with a small vibrating roller pulled by tractor. Installation was completed by the maintenance team of the farm trained by the BGM manufacturer. The weather conditions during the installation were sunny with air temperatures reaching 40°C (105°F). Despite the hot temperature, the works continued throughout the day. The reasons of the choice for the BGM were due to ability to remain exposed, possibility to be installed by a local team or workers that is economical in this region, expected stability of liner without wrinkles, intimate contact to the clayish support giving an additional safety and easy maintenance if needed by the own workforce of the client (Figure 6).
In Russia, the Kinross Kupol gold mine is in the northwest part of the Anadyr foothills in the Chukotka Autonomous Okrug, which has a site access by helicopter or fixed wing aircraft. Every winter a 400 km (249 miles) ice road is constructed from the northern port of Pevek to site which is used to transport goods to the site. The Kupol gold mine requires a tailings dam to store tailings produced by the milling process. The Kupol tailings impoundment is formed by a rockfill dam that utilizes an upstream face BGM liner to minimize seepage through the structure. A deep cut off trench to anchor the liner at the base in front of the dam over frozen ground was used to minimize the potential seepage through the dam foundation. To ensure permafrost was retained in the foundation, the foundation preparation, liner placement and covering were carried out from January through March and late October through December where ambient temperatures were often near -40°C (-40°F). Installation of the liner was carried out through all seasons. Every extension of the rockfill dam from 2006 until today is watertight with a BGM of 5.6 mm thickness (Figure 7).

BGM does not only have advantages in cold weather conditions but also in hot weather conditions from temperatures ranging -49°F to +194°F (-45 to +90 °C).

In Ireland, RUSAL Alumina is a large bauxite processing plant based in southwest Ireland. The clarifier pond had been badly leaking for quite a while due to inadequate performance of the existing HDPE membrane, which must store high temperature liquid at around 90°C (195°F). BGM uses a special bitumen compound of which the temperature of penetration which measures the penetration of a needle (test NF T 666004 or BS 200: Part 49) is 130°C (266°F). To meet the plant’s waste license requirements by the Irish Authorities of Protection of Environment, RUSAL decided to upgrade the lining of the clarifier pond by installing BGM. The overall scope involved the site set-up, and the removal and disposal of existing semi-solid wastes. The final elements of the project involved pouring a 150mm (6 inch) deep asphalt concrete slab directly over the entire base for regular maintenance cleaning works (Figure 8).
A shale gas project in Australia required a high resistance to heat for the installation and storage of water between 158°F and 194°F (70 to 90°C). The embankment of this large process water pond belonging to the Queensland Gas Corporation needed remediation because the clay in the embankment was dispersive and was getting eroded away. 1.7 km (1.05 miles) of embankment was required to be remediated and covered to prevent future erosion. The main considerations in choosing a liner for this application were the liner’s ability to resist the wind uplift and wind generating waves, as well as the ruggedness of the site.

The heaviest BGM with mass of 6 kg/m² was selected to prevent wind erosion generated by waves on the dam embankment. The ruggedness and puncture resistance of the BGM means that rocks could be placed directly on top of the liner at the base of the slope preventing uplift of the liner. The liner was placed into an anchor trench at the top of the slope and installed at an ambient air temperature of 39°C (102°F) (Figure 9).

CONCLUSION

BGM has been used successfully for over 40 years in hydraulics and environmental protection applications. BGM possesses high physical and mechanical properties allowing it to remain exposed. Its installation is straightforward using propane torch welding and its high unit weight allows it to be installed in rough weather conditions with local installers trained by the manufacturer on site, with no wrinkling due to temperature variations. Subgrade preparation for this liner is reduced to the minimum, as well as there is no need for geotextile cushion layers. Finally, maintenance is easy and can be performed by a local on-site maintenance team.

The BGM applications mentioned in this paper were done at the satisfaction of international consultants and owners (public and private) on time and without any delay due to bad weather, low temperatures or strong winds.
REFERENCES

Elliott, C., (2007), Reducing the cost, increasing the quality and productivity in –30ºc with bituminous geomembrane for protecting the environment in a very rocky and cold region, OttawaGéo2007, Ottawa, ON, Canada.

Eldridge, T., Harman, A., (2006), Installing a bituminous geomembrane in extremely cold conditions 2006, IGS World Congress, Yokohama, USA.

Huru, M., Palolahti, A. Breul, B. (2008), Use of Bituminous Geomembrane (BGM) liner for Agnico-Eagle Mine in Kittilä (Findland), EuroGeo 4, Edinburgh, UK.


NF P 84510. Détermination de la résistance au percement par granulats sur support rigide, Association Française des Applicateurs de Géomembranes, France.

XP P 84523. Détermination de la résistance au poinçonnement sous charge hydrostatique, Association Française des Applicateurs de Géomembranes, France.