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Innovative designs for extreme mining applications using bituminous geomembranes

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ABSTRACT: The paper describes how bituminous geomembranes (BGMs) are designed in innovative ways to solve engineering challenges on mining sites in extreme environmental conditions and to provide environmental protection. The design of BGMs in mine tailings facilities and environmentally sensitive mine waste capping are focused on, and the technical challenges facing these projects are discussed in detail. The protection of groundwater by using effective and puncture resistant BGM solutions contribute to creating a resilient planet. The innovative use of special high friction angle BGMs on the very steep (1V:1.75H) tailings storage embankments of the new large Ravenswood Gold Mine in Australia are discussed in detail. This mine is under construction from 2021 to 2023. BGMs are multi-layered composite geomembranes with each of the components providing a technical benefit on the mining site. These technical advantages include: Extreme puncture resistance, which allows rapid deployment on rougher subgrades; Excellent resistance to wind uplift due to their high surface mass and this means that installation can continue in winds up to 40km/h. Elastomeric BGMs also retain their flexibility in extremely cold conditions and can be installed and welded down to −25 deg C. This means that elastomeric BGMs are often used in the extreme mining conditions of Siberia, northern Canada and the high altitudes of the Andes mountains in South America. BGMs have a very low coefficient of thermal expansion and do not wrinkle with changes in temperature like other polymeric membranes do and this is particularly useful in high heat projects in Australia. This provides a more secure project in the long run, with less risk of wrinkle-induced cracks and failures. In summary, the paper describes how the technical attributes of the BGM's composite structure provides a wide range of practical on-site solutions for challenging mining applications and environmental protection.

1 INTRODUCTION

Bituminous geomembranes (BGMs) continue to be designed and used in innovative ways to solve engineering challenges on mining sites in extreme environmental conditions and to provide enhanced levels of environmental protection. Environmentally responsible mining will continue to play a vital role in the transition to a more resilient planet, as many of the key materials required for a low carbon future come from mining. For example, a large quantity of copper is required for electric vehicle motors, and lithium and graphite are required for electric vehicle batteries.

Due to their unique characteristics, BGMs are used extensively in four main applications on mine sites. These applications include:

- Tailings storage facilities (TSFs) where the excellent puncture resistance and lack of thermally induced wrinkles are important characteristics in the selection of a BGM. A key

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design element for TSFs is also the high mass per square metre of a BGM which gives outstanding wind uplift resistance. A technical design advantage of BGMs is that, due to their internal polyester reinforcement, they can easily be used on slopes up to 2H:1V. For steeper slopes up to 1.3H:1V, the innovated High Friction Angle (HFA) BGMs have been be used. These innovate HFA BGM grades have a releasable siliconized film on the underside of the BGM which is removed at time of deployment to give a self-adhesive underside to the BGM which maximizes interface friction angles on the slope.

Figure 1. Copper – gold tailings storage facility TSF in South Australia during construction. Note the straight panels on the BGM with no thermally induced wrinkles in extreme 45 deg C heat. This BGM is designed to provide embankment sealing and prevention of tailings migration into sensitive environmental lakes downstream.

- BGMs are also used extensively for capping and closure of mine waste facilities. The key design features of BGMs in these applications are:
  1) extremely low permeability (< 6 x 10^{-14} m/s) which prevents migration of contaminants into the groundwater and therefore providing a more resilient planet in the long term;
  2) the ability of the BGM to be used on rougher subgrades, typically with aggregate size up to 20mm, and this is a big advantage over other polymeric geomembranes;
  3) the ability to use High Friction Angle (HFA) BGMs on steep slopes on mine waste covers.

Figure 2. Innovative High Friction Angle (HFA) BGMs being deployed on slopes for mine waste capping and environmental protection. Northern Territory, Australia.

- The third major use of BGMs in mining applications is for containment of stormwater runoff in retention dams, as shown in Figure 3 below. These retention dams prevent runoff entering rivers directly during large rainfall events. Key design features of BGMs in these applications include: puncture resistance on rough subgrades; a specific gravity of 1.22 (which means the BGM is heavier than water and will not float upwards like other polymeric geomembranes which are lighter than water with specific gravities in the region of 0.94); and the excellent wind uplift resistance characteristics of BGMs (Giroud 1995). With little or no ballast required, this results in considerable cost savings and improvements in construction speed for the project.

Figure 3. BGM being used for environmental protection by containing stormwater run off from a mine before it reaches the river. New South Wales, Australia.

- The fouth main use of BGMs in mining applications is for evaporation and waste ponds. All the key advantages of BGMs play a part in these applications, including puncture resistance, thermal stability, heavy specific gravity and wind uplift resistance.

Figures 4 and 5. Lithium salt ponds in the extreme Atacama Desert of Chile. Note the thermal stability of the BGM with no wrinkles.

2 TECHNICAL COMPONENTS OF A BGM AND NEW INNOVATIONS

2.1 *Multi-component structure of BGM geomembranes*

A BGM is a multi-component geomembrane with each of the components providing a technical design or practical benefit on site. Figure 6 below shows a standard BGM structure. The sanded surface provides a non-slip surface for workers which enhances safety in wet conditions. The SBS elastomer modified bitumen provides elastic properties with extremely low water permeability characteristics (<6 x 10^{-14} m/s according to ASTM E 96). The internal non-woven geotextile is fully impregnated with elastomeric bitumen and this provides the mechanical properties of tensile strength and puncture resistance. Various grades of geotextiles can be used to provide different mechanical properties depending on the severity of the application. The puncture resistance of various strength BGMs in direct contact with various size aggregates up to 100mm and with overburden pressures exceeding 1000kPa have been tested (Blond 2014).

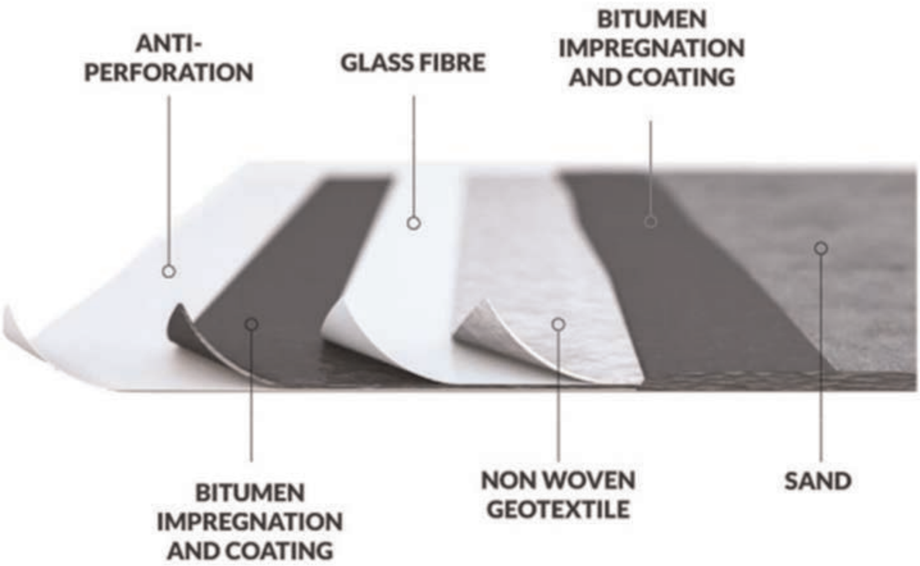

Figure 6. Technical components in the BGM geomembrane.

2.2 *High Friction Angle (HFA) grade of BGM*

For the High Friction Angle HFA grade of BGM, the underside of the BGM has a siliconized self-release film that is removed at time of installation to provide a bitumen surface to be in contact directly with the subgrade. This innovation provides a very high interface friction angle on the underside. This interface friction angle is in the order of 34 deg, but is based on the exact material the HFA BGM is in contact with, so interface friction testing is suggested for critical applications.

2.3 *Thermal properties of BGMs in extreme temperatures*

BGMs are inherently thermally stable with an extremely low coefficient of thermal expansion of 1 x 10^{-6} C^{-1} when tested to ASTM D 1204-02. This means that BGMs are not effected by heat induced wrinkles that other polymeric membranes suffer from. This

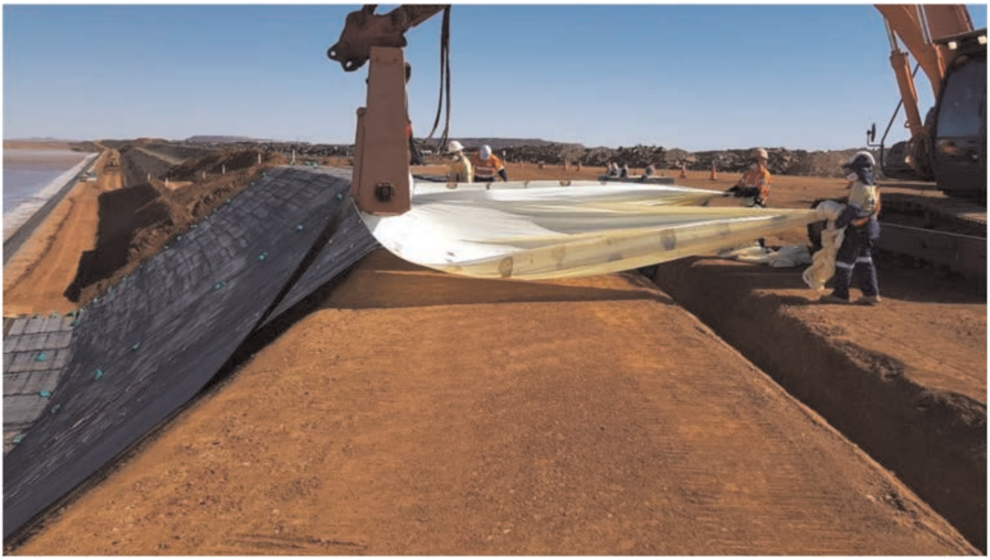

Figure 7. The innovative High Friction Angle BGM being deployed on a steep 1.3H:1V Tailings Storage Facility The white siliconized layer is removed at time of installation to provide a bitumen surface on the underside which maximizes the interface friction angle with the subgrade. This photo also shows another innovation in terms of safety with regard to geosynthetic installations, with the hydraulically operated deployment beam, which uses hydraulics from the excavator. The hydraulic beam enables a safe and control deployment on these steep slopes and it also helps reduce worker fatigue on extremely hot sites.

provides a more secure project in the long run, with less risk of wrinkle-induced cracks and failures.

In extremely cold conditions, elastomeric BGMs have a distinct advantage over polymeric geomembranes. Most geomembranes cannot be welded below 0°C due to brittleness at these temperatures, but BGMs can be installed and welded down to −25°C, which is particularly useful for the many mines in extremely cold environments including the high altitude mines in the Andes of South America, and the mines in Canada. Although there are different types of BGMs, most elastomeric BGMs when tested for Cold Bending according to ASTM D 746 can go down to −25°C.

3 RAVENSWOOD GOLD TAILINGS STORAGE FACILITY USING BGMS

The Ravenswood Gold Mine is Queensland's largest gold mine. It is situated 130km south west of Townsville, Australia.

The photo on the previous page shows the steep 1.75H:1V slopes using High Friction Angle (HFA) BGMs to maximize interface friction angle between the subgrade and the underside of the geomembrane. On the base, a standard BGM is used, as the high interface angles are not required. Both grades of BGM have internal reinforcement providing excellent puncture resistance and they use the same elastomeric bitumen, so they can be bonded directly to each other. The specific gravity characteristic of BGMs being heavier than water, as well as the excellent wind uplift resistance features were also important design considerations when selecting the geomembrane for this application. Due to the large size of the project (more than 1 million m^2 of geomembrane) it was important that the correct type of geomembrane was chosen for the application.

Figure 8. Ravenswood Gold tailings storage facility.

The sanded non-slip surface of the BGM was an important consideration in membrane selection for construction safety as the tailings storage facility is being raised in a number of incremental stages while there are tailings in the facility.

4 CONCLUSIONS

BGMs have a wide range of technical benefits, due to their multi-component composition, and these benefits are well suited to solving the challenges in mining applications. BGMs have proven themselves on many large mining projects around the world in extreme environmental conditions. The use of BGMs with their excellent puncture strength and thermal stability ensure that they provide excellent environmental protection in an innovative way, which ensures a more resilient planet in the long term.

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