Geosynthetics: Leading the Way to a Resilient Planet – Biondi et al (eds)

Advanced application of bituminous geomembrane (BGM) for waste capping in Australia

P. Kendall*
National Business Engineer, Axter Australia Pty, Australia

R. McIlwraith*
Director, Axter Australia Pty, Australia

ABSTRACT: A cap is an engineered impermeable barrier designed to cover the top of contaminated waste and prevent precipitation leaching from the waste and into the environment. In landfills, the cap also serves to control gas emissions from the waste. Materials used in a cap must not only survive aggressive installation conditions, but they must also be resilient to the deteriorating effects of long service life and environmental exposure. Bituminous geomembranes (BGMs) have been proposed by various authors as a material well suited to perform the barrier function of a cap in both exposed and unexposed conditions. In Australia, the application of BGMs for capping contaminated waste is growing rapidly. This paper describes three recent successful capping projects designed using a BGM barrier including one mining application and two landfill applications. For each project, the technical background of the site is explained and the important factors of the capping design and installation are described. The examples presented will give designers greater confidence in the use of a BGM as a cap in new and technically challenging applications.

1 INTRODUCTION

1.1 *Waste capping systems*

A waste capping system can have various design features but its primary function is to serve as a barrier to isolate waste from environmental exposure. By restricting the migration of liquid, solid, or gaseous mass into or out of the waste body, the liner plays the critical role of encapsulation. While the focus of this paper is on the liner, the capping system must safely manage the drainage of precipitation onto the barrier and expulsion of gas that may be generated within the waste. Compacted clay, geosynthetic clay liners, polymeric geomembranes, and engineered soil phytocaps are all examples of materials which have been used as hydraulic barriers in waste capping systems.

A wholistic evaluation of liner alternatives, which can include the use of Multi-Criteria Assessments (MCAs), works to optimize the technical, environmental, and economic outcomes of a capping system designs (Paulson 2018). Bituminous geomembranes have gained favor in this wholistic design approach due to their combination of physical properties as well as innovations in safe and measurably controlled electrical hot-air welding installation methods.

*Corresponding Authors: pkendall@axter.com.au and RMcIlwraith@axter.com.au

 DOI: 10.1201/9781003386889-194

1.2 *Bituminous geomembrane for waste capping systems*

1.2.1 *Composition of BGM*

BGMs have multiple components. The crucial components are the bitumen for is hydraulic properties and the geotextile for mechanical properties. The features of the bitumen and geotextile can be controlled for desirable properties. A common configuration of a BGM is shown in Figure 1 which features a needle punched continuous filament non-woven polyester geotextile and Styrene-Butadiene-Styrene (SBS) modified bitumen. The geotextile is fully impregnated with bitumen in the manufacturing process and additional bitumen coats the geotextile. The mass and mechanical properties of the geotextile can vary depending on the grade. Additional elements can be incorporated into the structure of the BGM. These elements include an anti-perforation root barrier film, a glass fiber fleece, and a sand or other mineral surface coating. A removable film can be manufactured as an alternative to the anti-perforation film. The removeable film is removed during installation to reveal a tacky bitumen layer which provides higher frictional properties for installation on steep slopes.

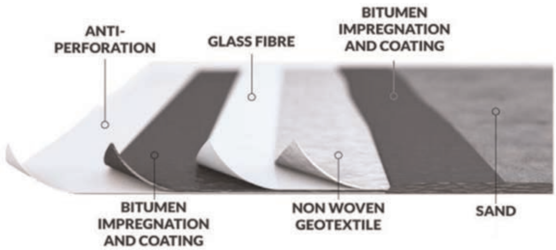

Figure 1. Diagram of a typical BGM composition.

1.2.2 *Material properties*

Different grades of BGM can be manufactured by varying the reinforcement geotextile and the amount of bitumen incorporated into the liner. In this manner, thickness and mechanical properties can be controlled. Intrinsic properties of the BGM can be identified and measured. The properties outlined in Table 1 describe some of the unique generally applicable properties of BGMs which result in various aspects of their design functionality.

The properties described in Table 1 translate to useful functional features of BGMs. The following is an overview of some of those features:

1.2.2.1 Virtually no thermal wrinkling

BGMs experience virtually no thermal wrinkling due to an extremely low coefficient of thermal expansion (Peggs 2008). Wrinkling of geomembranes can be problematic for installers as well as designers. Many other geomembrane materials such as polyethylene are

Table 1. Typical intrinsic properties of bituminous geomembranes.

Property	Standard	Units	Value
Coefficient of Thermal Expansion	ASTM D 1204-02	$°C^{-1}$	1E-05
Density	ASTM D 792-20	g/cm^3	1.27
Elongation at Break	ASTM D 7275	%	>60
Friction Angle (sand side)	NF EN 495-2	°	39.5
Cold Bending - Lowest Temperature	ASTM D 746	°C	−20
Water permeability	ASTM E 96	m/s	$< 6.10^{-14}$
Gas permeability methane transmission rate	ASTM D 1434-82	$m^3/(m^2.d.atm)$	$< 2.10^{-4}$

known to contract and expand dramatically with temperature. This can lead to extensive wrinkling during day and tensile strain at night if the liner is not covered immediately. Wrinkles prevent intimate contact between the liner and the subgrade which reduce its effectiveness as a barrier (Rowe 1998).

1.2.2.2 Extreme heat or cold exposure

BGMs have been installed in the extreme cold of Northern Canada and Siberia as well as the dry heat of the Australian Pilbara region and Chile's Atacama Desert.

1.2.2.3 Steep slope angles

Steep slope capability allows for more versatile design options and potentially more waste storage volume per unit area of cap. The BGM can be made with a peel off siliconized release paper which reveals a very tacky, high friction angle underside. Higher friction prevents sliding and allows cover soils to be placed at steeper angles. Angles as steep as 1:1.3 have been installed in Australia.

1.2.2.4 High wind resistance

Wind is an important consideration for both designers and installers. The weight of the liner is critical to resist wind uplift (Giroud 1995). BGMs are very dense and heavy with a specific gravity of 1.2 and a thickness of up to 5.6mm. The high weight allows for a safer installation in higher wind conditions and less need for temporary ballasting. For designers, the weight of the BGM is a positive factor to counter wind uplift suction forces.

1.2.2.5 High puncture resistance

BGMs are reinforced geomembranes with a strong polyester continuous filament geotextile imbedded within the liner. The geotextile, combined with the protective bitumen, is very resistant to puncture and abrasion. This makes the material well suited to accommodate the installation process as well as aggressive interfacing materials such an angular drainage aggregate (Blond 2014).

1.2.2.6 Single-layer construction

Unlike other polymeric geomembranes, BGMs do not suffer from the phenomena known as stress cracking. This is due to the geotextile and bitumen composition of the geomembrane. This allows a BGM to interface with aggressive soils and aggregates without the need of additional protection geotextiles. Lab tests have shown that a BGM can withstand extreme pressure over large stones without puncturing (Blond 2014).

1.2.2.7 Storage and installation in a wide range of weather conditions

A BGM can be installed in light rain and damp conditions. Prior to welding, the seams should be dry. A 200mm self-release protection strip, which keeps the seam dry and clean, should be removed prior to welding. The rolls can also be securely stored on site without risk of moisture or UV damage.

1.2.2.8 Strong seams

The BGM is installed with 200mm overlaps and heat welded seams. The weld fuses the bitumen together to form a strong hydraulically sealed barrier. Weld strength can be tested on site or sent to an independent third-party lab.

1.2.2.9 Bond with PE, concrete, and many other materials

Capping applications often interface with a wide variety of infrastructure elements such as concrete spillways, concrete pipe connections, older membrane installations, steel pipe connections and various other structures. Porous materials such as concrete are first coated with a bituminous primer to optimize direct welding to the concrete. For connections to polymer pipes, a bituminous mastic can be applied cold to seal around the pipe and a clamp can secure the BGM to the pipe. To bond to other types of geomembranes, self-adhesive bituminous strips of 0.5m or 1.0m width can be cold bonded to the geomembrane. The BGM can then be welded to the bituminous strip.

2 BGM CAPPING SYSTEMS FOR MINE WASTE IN AUSTRALIA

2.1 *Mineral sands mine, Western Australia*

2.1.1 *Site background*

A mining site in Western Australia processed mineral rich sand for over 40 years. Among the valuable minerals extracted from the sand are ilmenite, titanium dioxide, leucoxene, synthetic rutile, zircon, and various rare earth minerals. Mining of mineral sands produces a waste byproduct of a sandy composition. The sand is generally free draining and free of any large aggregate particles. After the processing and mineral extraction, this waste containing acid effluent, neutralized acid effluent, non-magnetic fines, char and iron concentrate can leach contaminants if precipitation is allowed to infiltrate the waste. An impermeable cap shown in Figure 2 was designed to function as the primary mechanism to prevent generation and mobilization of leachate and therefore no basal liner system was incorporated.

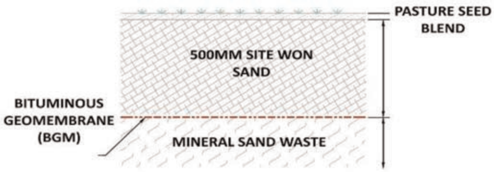

Figure 2. Schematic of mineral sand waste capping solution.

The aggregate-free, processed sand is a forgiving material to serve as a subgrade for the cap liner. The sand waste stockpile was designed with mild slopes of 9° to 14°. The lengths of the slopes were as up to approximately 50m. The site location mean daytime temperatures range from 31°C in February to 17°C in July with an annual average rainfall of 640mm, most of which occurs in the summer months of December to March.

2.1.2 *Capping solution*

A 500mm cover layer was approved as the favorable system for developing a grassy-herbaceous plant cover for surface erosion control. The 500mm sand cover layer is designed to suffice for 10 years. This 10 year period is the estimated time to complete the full mine waste remediation works and final closure of the facility. The soft sandy interfacing materials combined with the rapid covering of the BGM allowed for a lighter grade of BGM to be used. The liner used was called SC1 with an average thickness of 2.2mm and a reinforcing geotextile of 250gsm. The selection of a thin liner with heavier reinforcement allowed for relatively larger roll dimensions of 5.1m × 140m. Longer rolls are beneficial to installation, particularly on the slopes where transverse welds are not permitted.

The 500mm site won sand layer was designed with 90% maximum dry density compaction. The sand was installed using a GPS assisted D6 Dozer. The dozer traveled along a platform of sand and pushed new stockpiles of sand over the liner. The GPS controlled dozer blade ensured the specified 500mm sand thickness and the dozer weight provided the compaction effort. A construction photo can be seen in Figure 3.

Figure 3. Aerial image of site during construction.

3 BGM CAPPING SYSTEMS FOR LANDFILL AND MUNICIPLE WASTE

3.1 *Hervey range landfill, Queensland*

3.1.1 *Site background*

A municipal landfill presents a wide variety of dynamic phenomena to account for including stormwater runoff and gas collection to name a few. The material properties if a BGM can be taken advantage of for use on a municipal landfill cap, if the design can overcome the unique restrictions of that type of environment including:

- The BGM must bond to an existing capping system and integrate with various concrete and polymeric components of the landfill.
- The installation of the BGM must be done safely in the potential presence of flammable methane gas.

The site location mean daytime temperatures range from 30°C in February to 10°C in July with a mean annual rainfall of 1019mm.

This landfill was constructed with a regular progression of intermediate waste compartments known as cells. As more waste is deposited into a landfill cell, the cell will eventually reach capacity. At this point, a cap is installed, and a new cell is built to accumulate new waste adjacent to the previous cell. An outline of this cap design is shown in Figure 4. Critical to this sequence is the ability to hydraulicly seal the capping of the new cell to the previous cell. In this case the previous cell was capped with a textured coated Geosynthetic Clay Liner.

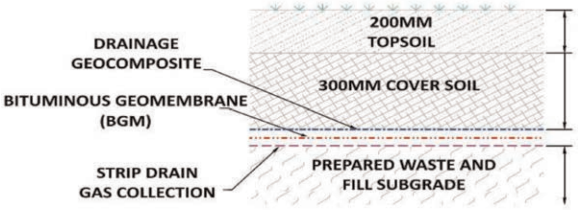

Figure 4. Schematic of Hervey Range Landfill BGM Cap.

3.1.2 *Capping solution*

One of the motivations for using a BGM on this landfill cap was the ability to bond the liner with an existing capping liner from a previous cap installation in what is known as a piggyback installation. A BGM can be bonded to other membrane materials using a tacky adhesive bitumen strip. The strips used on this site measured 1.0m × 10m. The adhesive strip has a siliconized film which is removed to reveal the tacky bitumen side. The tacky side was bonded to the clean textured polyethylene coated side of a Geosynthetic Clay Liner. A weighted steel roller was used to apply pressure to bond the strip in ambient temperatures. Once the bituminous strip is bonded, the BGM can then be welded to the strip using BGM welding techniques.

The concept of using BGMs in landfill caps, which can have flammable methane gas present, required new developments in welding methods. The conventional gas torch welding methods can pose a risk of fire or explosion if methane gas is detected. Electrically powered hot air welders represent an existing technology which has been in use in the roofing industry for many years. Welding trials at the BGM factory and on replicated local site conditions revealed that these machines could achieve the same or improved performance of conventional torch welding. The use of these welders presents a risk profile similar to wedge welders which have been used on landfill caps successfully for many years.

The schematic in Figure 4 illustrates the various components used in this landfill cap. The BGM served the barrier function. Underneath the BGM was a network of strip drains to collect and expel any gas derived from the waste. Above the BGM was a drainage geocomposite which covered the entire surface of the BGM.

The landfill had various structural protrusions which interfaced with the capping system including concrete and polymeric pipes. For each of these protrusions, there is a process for securing the liner mechanically and sealing it hydraulically. Concrete can be primed with a thin bituminous primer which penetrates the pores of the concrete. The BGM can then be welded directly to the primed surface using a handheld hot air welder if there is a risk of methane gas. A large stainless steel pipe clamp is then tensioned around the concrete pipe. Polymer pipes such as HDPE can be hydraulically sealed without heat by applying a bitumen mastic to a BGM sleeve. The sleeve can be welded to the primary liner and clamped to the pipe using a stainless steel clamp. This process is captured in Figures 5a and 5b.

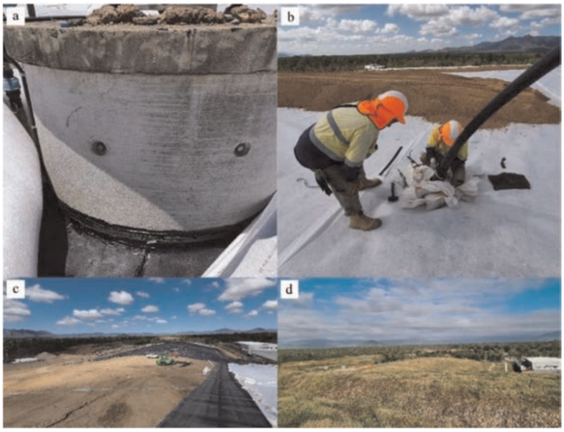

Figure 5. a) BGM to concrete connection, b) BGM to polymer pipe connection, c) photo during construction d) photo of completed cap with vegetation.

4 BGM CAPPING FORSYSTEMS FOR INDUSTRIAL WASTE

4.1 *Industrial waste at undisclosed site location*

4.1.1 *Site background*

For over 50 years paper was manufactured at this undisclosed industrial site in Australia. The site consisted of 7 hectares of industrial buildings, 30 hectares of wastewater treatment ponds, and 28 hectares of on-site landfill. The site is intended to be remediated to a state suitable for development and public use. Adjacent to the site is a sensitive woodland with a protected koala population. As a result of the long and varied use of the site, many known contaminants have been detected and incorporated into the remediation process. These contaminants include per and polyfluroalkyl substances (PFAS), asbestos, metals, dioxins, polychlorinated biphenyls (PCBs), ash and coal wastes, paper wastes and fuel storage residues. A capping system is critical to prevent the mobilization of any residual contaminants remaining in the solid waste and to make the surface safe and suitable for future use. Due to decomposition of certain waste constituents, the liner was to be installed in the potential presence of methane gas and a gas collection system was incorporated into the capping system. A depiction of the capping system can be seen in Figure 6.

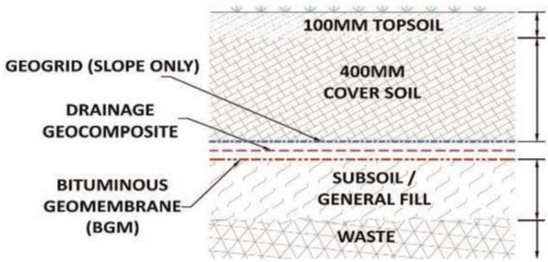

Figure 6. Schematic of industrial waste site cap profile.

4.1.2 *Capping solution*

A multi-component cap was designed to encapsulate the wide range of waste constituents and account for gas generation. A heavy BGM installed with electrically powered hot air welders was designed to function as the barrier of the capping system. The heavy BGM provides a strong geotextile which provides greater protection against installation damage and a robust barrier for varied future use cases of the cap.

As Figure 6 indicates, a drainage geocomposite was installed above the liner to accumulate and direct stormwater runoff away from the waste body. The drainage geocomposite was composed of a geonet with nonwoven geotextiles on both sides.

For the areas of the cap with higher slope, a geogrid was used to help retain the 500mm of soil covering the cap.

5 CONCLUSION

The three distinct capping projects described above were installed between the years 2020 and 2023 and were designed by three separate engineering design consultants. This snapshot in time highlights the increased adoption of BGM capping systems in Australia. While BGM technology has been in exitance and in use for many decades, innovative installation methods like the hot-air welder have created new application areas for BGMs in caps. A wholistic evaluation of a capping system presents a design engineer with wide variety of barriers including compacted clay and polymeric liners. Consideration of the unique material properties of BGMs in such an evaluation has driven increased usage in waste capping systems in Australia.

REFERENCES

Blond, E. & Breul, B. 2014. Behavior of Bituminous Geomembranes under Elevated-Compression Stress. *Proceedings of Geosynthetics Mining Solutions*. September 8–11, 2014. Vancouver, Canada.

Giroud, J.P., Pelte T., & Bathurst, R.J., 1995. Uplift of Geomembranes by Wind. *Geosynthetics International*, IFAI, Roseville, MN, USA, Vol 2 No 6, pp 897–952.

Paulson, S. 2018. Multi-criteria Assessment of the Landfill Capping Profile, an Innovative Engineering Approach to Select Capping System. *Proceedings of the 11th International Conference on Geosynthetics*. 16–21 September 2018. Seoul, Korea.

Peggs, I.D. 2008. Prefabricated Bituminous Geomembrane: A candidate for Exposed Geomembrane Caps for Landfill Closures. *The First Pan American Geosynthetics Conference & Exhibition*. Cancun.

Rowe, R. K. 1998. Geosynthetics and the Minimization of Contaminant Migration Through Barrier Systems Beneath Solid Waste. *Proceedings of the 6th International Conference on Geosynthetics*, Atlanta, IFAI, St Paul, MN, Vol. 1, pp. 27–103.