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

Bituminous geomembranes (BGM) to reduce water losses in irrigation canals

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ABSTRACT: The world population increases decade after decade straining global food demand. During this time drought becomes more accentuated thus irrigation must become more efficient. Many irrigation canals are built of soil with a poor waterproofing quotient and concrete sections which, after 15 years or less, meet seepage through cracking. Geosynthetic lining is the solution. The main challenges for irrigations districts when lining canals are that during construction canals are taken out of service, this paper will illustrate these processes. It is important that the choice of material enables efficient installation in diverse weather conditions, is economically competitive and can withstand time when left exposed to the elements with an easy maintenance component. Through case studies, this paper demonstrates that bituminous geomembranes (BGM) meet and exceed these challenges. The paper reviews briefly the characteristics of BGM as uniquely qualified for usage when lining canals: low thermal coefficient, a low Manning coefficient, a density greater than 1, and proven longevity when left exposed. Thanks to their flexibility and bituminous properties that can be connected to any surface. Case studies presented in this paper highlight the BGM specific properties. In Romania, renovation of irrigation canals, in North America, BGM began a partnership with the Roza Irrigation District (USA), to line a complete irrigation scheme reservoir and irrigation canals throughout the Columbia River Basin, in Chile rehabilitation work on canals supplying water for a small irrigation scheme, in India and in France.

1 INTRODUCTION

Thousands of miles of canals move billions of cubic meters of water annually. Most of these canals are built of material ranging from soil to concrete. Water losses through bottom and side leakage and associated economic losses are an important concern for owners and operators. Lining canals or building recovery systems are the solutions used to control water losses, especially since summers are getting hotter and drier and water resources are becoming scarcer. We could observe that engineering is not well enough informed about geomembrane performances and continue to line canals with concrete or clay. Five years after completion, the rate of satisfactory projects has been known to drop significantly due to poor project design.

DOI: 10.1201/9781003386889-215

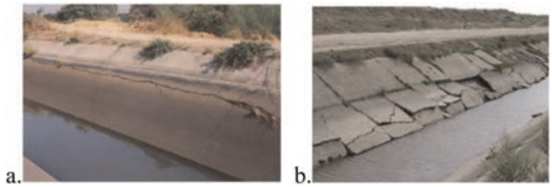

Figure 1. a. Peru: San Lorenzo, longitudinal crack / 1.b. Tajikistan: Fergana Valley, effect of frost-heave.

A lined canal system Figure 2a. Llangollen Canal (UK), and Figure 2b. Canal de Provence (France), when properly operated and maintained, are more efficient in many aspects of operation because of a higher conveyance capacity.

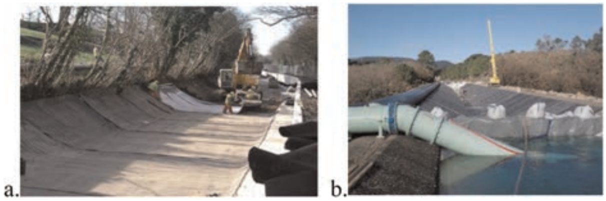

Figure 2. a. Llangollen Canal (UK) / 2.b. Canal du Provence (France).

The other major challenge when making canals watertight is taking the canal out of service during construction. Typically, this type of work is performed during winter with the possibility of delay due to weather and the associated cost. The choice of materials that are easy to install in diverse weather conditions (humidity, snow, rain, wind) maintaining an economically competitive advantage, and one that will withstand the test of time as an exposed lining system is a crucial component. Through case studies, this paper demonstrates that bituminous geomembranes (BGM) can meet these challenges with a long durable life even when directly exposed to UV, offering an ease of maintenance and repairs and supplying a very viable technical and economical option for lining canals. Furthermore, the manufacturer provides an in-situ training in all aspects of the installation process.

2 TECHNICAL CHARACTERISTICS OF BGM

2.1 *BGM structure*

The product's main structure is based on a non-woven polyester geotextile which is completely impregnated by elastomeric bitumen, with a glass fleece inside to help its manufacture

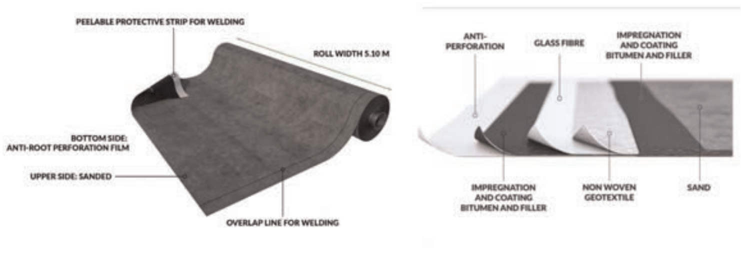

Figure 3. BGM structure.

Table 1. Summary of some physical and mechanical properties of a BGM 4.00 mm thick, the most common used in efficiency waterproofing.

Properties		Standard	Unit	BGM	Commentary
Physical properties	Thickness	ASTM D 5199	mm	4.0	BGM is thicker and heavier than any other liners making it more resistant to wind uplift or flotation and consequently requires less ballast to keep it in place. It can be placed in most weather conditions and since the seaming is by torching, humidity is not an issue.
	Density	ASTM D 1505	g/cm^3	1.276	
	Surface mass	ASTM D 5261	kg/m^2	4.85	
Mechanical properties	Tensile Stress at Break	ASTM D 7275 4073	kN/m	27	Due to its important thickness and its enclosed geotextile, BGM is far more resistant to puncture than the other liners and thus require less bedding and can be placed over very coarse granular fill without the threat of being damaged. Also, since the tear resistance of BGM is very high, this liner is less vulnerable to mechanical damages during in situ transport and placement.
	Tensile Elongation at Break	ASTM D7275	%	60	
	Tensile-Tear Resistance	ASTM D 4073	N	825	
	Puncture Resistance	ASTM D 4833	N	530	
Thermal Stability		ASTM D 1204	%	<0.1	Approximately 100 times lower than PE liners, BGM doesn't produce wrinkles or waving when temperatures vary onsite.
Friction Angle		ASTM D 5321	°	32	BGM friction angle is much higher than other liners and is therefore easier to install on deep slopes and safer for installation crews.

by strengthening the product at a temperature of 180°C. On top of the structure is sand to enhance UV resistance and provide traction for installation workers. On the bottom is an anti-root film to prevent permeation of any vegetation roots through the liner. The BGM Geomembrane is produced in France under severe QC/QA control. the BGM factory is ISO-9001, and the Geomembrane is CE (European Standards) and ASQUAL (France) certified. The ASQUAL certification includes the auditing of the production line as well as the Geomembrane performance.

The BGM compounded with elastomeric bitumen can be installed to a temperature of −40°C and is therefore more suitable to be used in cold weather countries like Canada, North of USA, North and East of Europe or in altitude. Product is manufactured in 4 thicknesses ranging from 3.5 to 5.6 mm.

2.2 *BGM specific advantages in irrigation watertightness*

The technical characteristics of BGM namely those unique for use in lining canals:

- No wrinkles as BGM has a low thermal coefficient,
- A low Manning coefficient allowing the passage of more water for a same cross-section of the canal,
- Longevity even when exposed more than 60 years and more than 300 years buried as proven by nuclear laboratories in France and USA,
- A density (1,276) greater than water, enabling an economical option as BGM can be installed in canals while water is flowing. Panels can be welded underwater using a specific mastic to provide weld under water by a phenomenon of vulcanization,

– Can be connected to any type of surface: concrete see Figure 4 entry of a concrete siphon, steel or HDPE pipe.
– Local personnel and maintenance teams of an irrigation district or of any local installer can be trained in-situ by a manufacturer's monitor, keeping installation costs very low,
– Mechanical resistance: due to its enclosed geotextile, BGM is very resistant to puncture (530 N or more). The hydrostatic puncture and the resistance to puncture by aggregates (1550 kPa and 25 kN respectively) are thought to be much higher than other liners like PE. From an economical point of view, this liner will require no protection (use of Geotextile) on one or both sides. BGM is therefore much more resistant during construction and maintenance work.

Figure 4. Canal in UK along deep slope.

Figure 5. Traffic of heavy equipment for maintenance Yakima (Washington State USA).

3 CASE STUDIES

Case studies presented in this paper highlight the specific property of BGM that was the decision factor in the choice.

3.1 *In Romania*

Romania has some secondary canals requiring renovation. BGM was used for re-lining:

– Original concrete irrigation canal (see Figure 7): principal canal with concrete panels 2,5 m by 1,2 m with a slope 50% and width 18 m canals,
– And, at the terminal part, earth canals.

In certain parts (see Figure 6), due to the high damage of the concrete lining the concrete slabs will be removed and will be constructed as earth canals with BGM lining with a thickness of 4.0 mm or even 4.8 mm.

Figure 6. concrete for canals some years after due to unstable soil underneath.

Figure 7. Wasteway No.5 Regulation Reservoir, feeding Yakima and Roza Districts Irrigation canals.

3.2 *In North America:*

3.2.1 *California State (USA)*

Two of the three leaking sections of the Caspa District canal in Wyoming, USA, were repaired with BGM in 1992 and 1994 respectively. The third, slightly larger (80,000 m^2) section was repaired in 1995 by the canal operator's own highly trained employees.

3.2.2 *Washington State (USA)*

In 2005, BGM began its partnership with the Yakima district (Washington State, USA) for providing a watertight solution year after year of old irrigation canals. The project was intended to provide irrigation services to the many farms and agricultural regions of the Yakima Valley (best cherries for USA). In 2016, there was an extension of this cooperation to the Roza Irrigation District for lining the Wasteway No.5 Reregulation Reservoir outside of Sunnyside, Washington State on the West Coast of the United States (See Figure 7).

The project is expected to conserve roughly 10 million cubic meters of water each season. It was completed by the end of August ensuring permitting a large storage of water in autumn and winter. This ability to sustain schedule was due to the complete absence of wrinkles permitting the installers and welders to work without any delay even during warm season. This reservoir is completely and permanently monitored by a certain number of piezometers,

Water is pumped from the Columbia River. There are 3 main irrigation districts in this region that work in cooperation with dozens of smaller regional irrigation districts of which the Roza Irrigation District belongs. In the last 17 years, BGM has been used to line irrigation canals throughout the Columbia River Basin with successful projects in Naches-Selah, Quincy, Moses Lake, Wenatchee, Yakima and Ellensburg. All these districts appreciated the robustness of BGM, the fact it is able to be installed in low temperature, it can be installed by internal teams after training by a manufacturer representative giving greater flexibility in the use of their teams.

3.3 *In Latin America: Chile*

The Elqui River and Tributaries Board of Control (Junta de Vigilancia del Río Elqui y sus Afluentes, JVRE), administers 121 irrigation canals in Elqui Province in north-central Chile to irrigate an area in the order of 200 km^2 and the Rio Choapa Board of Control (Junta de Vigilancia del Rio Choapa) administers more than 660 km of canals to irrigate more than 220 km^2 of land in central Chile. The area covered by these districts which produce grapes, citrus fruits, avocados, and vegetables for export – is a very dry area where water is a scarce resource, meaning canals need to be lined to avoid water loss. The Rio Choapa and the Rio Elqui irrigation districts decided to look for alternatives to concrete liners to reduce costs. As a result of these search efforts, more than 62,000 m^2 of irrigation canals in these two districts were lined with a 3.5 and 4 mm thick BGM. These canals were lined at a cost of about 30% less than a concrete lining and have been operating successfully with a longer lifespan than with concrete in this unstable soil.

a.  b. 

Figure 8. a. Irrigation canals in Chile: Rio Elqui / 8.b. Irrigation canals in Chile: Rio Choapa.

It is worth noting that in smaller canals where the perimeter is less or equal than the width of the BGM roll, construction joints are less frequent and thus the deployment of the liner is very fast.

Reasons for choice of BGM:

- Resistance to UV and longevity in exposed conditions,
- Ability to be fixed to concrete,
- High friction angle permitting animals to walk across,
- Low Manning coefficient,
- A lot less expansive and faster to deploy than a conventional concrete lining.

3.4 *In India*

The Pench Left Bank Canal, located in central India, brings water from the Pench River to the region's crops. The original canal consisted of a concrete lining that was collapsing due to clay swelling underneath. In a state where water resources are becoming scarcer over the years, the Nagpur Water Resources Department decided to re-seal the canal using a long-lasting geomembrane (see Figure 9). A BGM 4 mm thick was laid on the substrate and anchored at the head of the slope. Works both started in June 2019 and 2022 and were scheduled to be completed before the monsoon season. BGM could be installed so quickly that the entire projects (2019 phase) finished in 15 days at an average of 2,200 m^2 laid and welded per day. The customer needed a strong, flexible geomembrane. They chose BGM for its ability to withstand:

- Substrate settlement,
- The region's extremely high temperatures.

a. 

b. 

Figure 9. a. Irrigation canals in India – before / 9.b. Irrigation canals in India – during installation.

3.5 *In France: Canal de Provence*

The Canal de Provence supplied water to 116 cities in the south-east of France which represents around 3 million inhabitants, the irrigation of 80,000 hectares of agricultural land and feeds more than 8,000 industries. They water originates in the Alps (Figure 10).

Figure 10. Canal de Provence in the French Alps.

Figure 11 below shows a typical section of its channels. The width at the bottom is between 2.7 and 3.0 meters. The width in the upper region can be from 10.0 to 17.2 meters. The depth is between 2.4 and 3.6 meters. On each side, there are 2 tracks of 2 m. asphalted for assuming the maintenance and security. The slopes are between 27 and 34°.

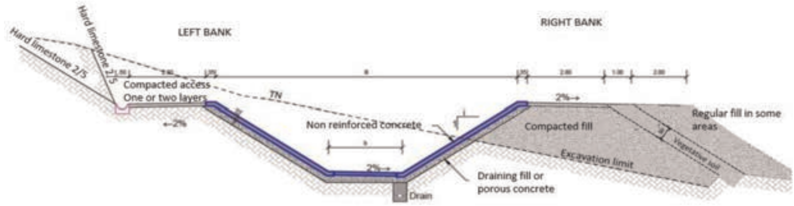

Figure 11. Cross-section type of the Canal de Provence.

Canal de Provence could note that their network suffers from pathologies of geotechnical origin (dissolution of gypsum or clay in the presence of water from leaks) which induce displacements of the ground. The main objective of conveyance efficiency was to reduce the risk of geotechnical disorders caused by infiltration. The pre-feasibility studies consisted of a catalogue of canal renovation techniques. Subsequently, a dozen companies were consulted based on creating a competitive dialogue. The choice fell on the implementation of a thick BGM weighted in raft of a concrete slab. BGM was chosen for the following reasons:

– Sealing coating that does not adhere to the support and allows centimeter displacements of the support to be resumed,
– BGM has a high surface mass allowing installation in high speedy wind (Venturi effect in canals). In addition, the welding system allows installation in wet or hot weather,
– Sandblasted on upper face offering adhesion to allow the ascent of fallen animals or humans in the canal (high friction angle). Thickness sufficient to resist blows of hooves for animals,
– Robustness even exposed confirmed by feedback from several decades in similar situations,
– Without expansion, the geomembrane is in permanent contact with its support, no wrinkles, slowing down the current. The Manning coefficient stays consistent,
– It can be welded and then fixed by rulers and fasteners at the head of the joffers to overcome the impossibility of making anchor trenches,
– Exposed at the level of the joffers, due to its great UV resistance.

To ensure the supply of users downstream of the works, the interventions were carried out in successive sections of 200 meters in length allowing the implementation of a bypass (see Figure 12).

Figure 12. Dewatering work on a section without interrupting water circulation.

4 CONCLUSION

BGM since its inception of manufacturing in a factory (1974) has become a very famous geomembrane being employed and appreciated on every continent due to its robustness, its ability to be installed and left exposed with an expected lifespan of more than 20 years and to be installed by any team of any district after onsite training by a manufacturer's representative. The overall cost of the lining system should be considered for the entire project cost for comparison, inclusive of subgrade preparation, no need of geotextile to protect a thinner and less robust geomembrane, eliminating difficulties induced by windy conditions due to its high unit mass, maintenance and installation costs are reduced by employing internal teams.

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