Novel geocomposite liner system for the irrigation channels and waterways

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ABSTRACT: This paper discusses the use of a new and novel liner system for the lining of water channels. The PMC Liner is a polymer-modified cementitous coating impregnated into a reinforced woven geotextile to create an impervious, strong, durable and flexible liner system. The polyester geotextile reinforcement confers the mechanical strength and tear resistance while the impervious polymer modified cement coating is impermeable and protects the geotextile support from UV light and chemical attack. The PMC liner can be installed over aged concrete where it can bridge joints and cracks. The PMC liner prevents seepage through the cracks and joints of aged concrete channels. The PMC liner has the look and texture of concrete but the flexibility and chemical resistance of a polymeric liner.

1. INTRODUCTION

Many water channels have in the past been lined with reinforced or plain concrete and now require remediation due to leakage problems (see photograph 1 below). Leakage from such channels arises from leaching of calcium ions/erosion, settlement induced cracking, thermal cycle fatigue cracking, deteriorated expansion joints, opened construction joints, deterioration due to chemical attack etc. When a crack occurs in a concrete channel lining the amount of leakage that occurs can be staggering.

Photograph 1

The relative losses by evaporation and seepage from open water canals has been studied under controlled conditions using standing water in two blocked-off concrete-lined canal compartments having sealed and unsealed joint treatments respectively. Seepage losses of around 30%, on average, were measured for unsealed compartments while evaporation loss from both compartments averaged 11% monthly. (Bosman, 1993).

Cracked concrete water conveyance canals and channels have been lined with a range of materials including shotcrete, spray-on sealers and geomembranes. Traditionally ageing concrete channels have been remediated with a wide range of polymeric lining materials including HDPE, flexible polypropylene (fPP), EPDM rubber liners, heavy PVC laminates, Elvalloy-modified PVC) and polyurethane.

Polymeric geomembranes have been widely employed as remediation liners however in order for them to be successful the contact surface must be thoroughly cleaned and patched. No loose sections of concrete can remain in place. Furthermore often a needle punched geotextile is generally required to be placed between the liner and the concrete as a cushioning layer and to assist in the removal of infiltrated leakage water.

Polymeric liner materials generally have limitations with respect to either long-term UV stability or their tolerance to damage. Whilst softer membranes such as EPDM and PVC have good conformability to uneven substrates typical of old

concrete channels or earthen channels, they have relatively low tear resistance and puncture resistance.

Another important consideration in the design of the canal cross section is the tractive force developed by moving water. As measured per unit of wetted area, the tractive force equals the specific weight of water times hydraulic radius times slope of channel bed. The tractive force (or shear stress) is an important factor in the erosion of channel. Due to high tractive forces the liner ideally needs to be adhesively bonded to the concrete substrate and anchored to prevent shear forces moving the liner. It is necessary to hold the liner in place and to resist or dissipate the tractive forces.

Other important considerations for a geomembrane channel liner include:

• ability to withstand weathering (e.g. UV exposure and heat);
• strength to withstand tensile force;
• flexibility to accommodate elongation;
• good conformability to the subgrade
• resistance to punctures and other damage (e.g. animal hoof or claw damage, equipment or foot traffic);
• easy joining method; and
• ease of repair
• resistance to chemical attack.

An installed geomembrane should ideally be protected by a synthetic geotextile to protect against puncturing and load-induced damage.

1.1 HDPE Liners

HDPE is the most commonly used canal lining although PVC and polypropylene have also been widely used. Of particular concern for canal liners are the effects of exposure to UV radiation and general weathering. HDPE has good weathering properties if properly formulated however it does suffer from a number of shortcomings.

Issues with HDPE include:

- careful subgrade preparation (since HDPE is susceptible to installation damage and puncture by angular rocks
- under stressed conditions HDPE liner can undergo environmental stress cracking
- the need for specialized field welding (wedge welding of HDPE geomembranes is very dependent on environmental factors such as temperature, humidity and wind)
- it has a high degree of thermal expansion which leads to wrinkles. Large wrinkles can fold over under hydrostatic load leading to regions of high stress and potential for stress cracking.

In Australia some of the additional considerations for channel liners include:

- animal traffic damage (such as kangaroo claw intrusion)
- bushfires as well as propagation of fires along channels by burning umbrella grass or blow grass)

Unfortunately HDPE liners are both readily punctured by animal claws and susceptible to melting and burning.

1.2 Leaching of Calcium Ions

The leaching out of the calcium from the cement in the concrete has left sharp, angular rocks exposed in the channel wall (see photograph 2 below). In many there are settlement cracks in some instances holes have appeared. As a result water loss by seepage is significant. The water loss can also be accompanied by wash out of the support of the canal wall.

Photograph 2

Over time the concrete walls have been weakened by the dissolution of the cement at the surface and has now reached the point where the large aggregate is starting to come loose. The deterioration of the surface of the concrete is a function of the rate at which calcium can be leached out of the concrete and this is in turn dependant on the concentration of calcium in the water and the pH. The less calcium in

the water (e.g.in soft water) and the lower the pH, the faster the deterioration.

2. PMC LINER CONSTRUCTION

2.1 Base Liner Characteristics

The geotextile base for the PMC liner is either a non-woven geotextile incorporating glass filaments or a polyolefin membrane laser-bonded between two non-woven geotextile layers.

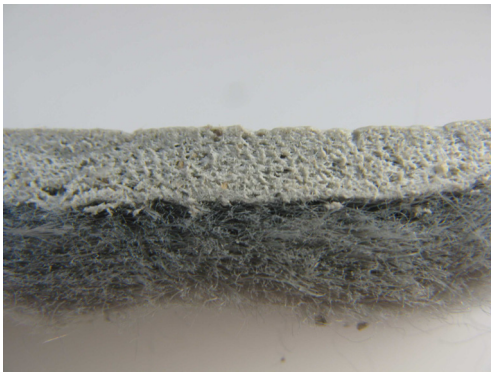
The flexibility of the geotextile base it allows it to be factory fabricated into panels which can then be easily deployed by unfolding along the top of the slope of the channels. By utilising the large sheets the number of field seams can be minimised.

Because of the integral reinforcing of the PMC liner, the material has very high puncture resistance. Therefore, additional puncture resistance provided by geotextile cushioning layers is not needed. In contrast, HDPE liners generally require expensive subgrade protection unless the subgrade is completely flat and without protrusions.

Panels are overlapped and heat welded using commercially available hot air welding equipment. Either hot wedge or hot air could be used, but hot wedge was chosen because the technique works well in the field with geotextile materials.

2.2 PMC Coating

The coating is based on a polymer modified cementitious render which is mixed with water on site to a spraying consistency and then applied to the geotextile support layer *in situ* in the channel using high-pressure spray equipment. The coating can be applied to near vertical canal walls to a thickness of 3-6 mm without slump or sag problems (see photograph 3 below). On the channel base the coating is self-levelling.



Photograph 3

The entire lining and coating process is very cost effective because of the very high cost of the alternative methods of joint repair and sealing. Large areas can be sprayed using commercial high-pressure spray equipment.

The resulting PMC Liner provides an impervious, strong, durable and flexible liner system. The polyester geotextile reinforcement produces the mechanical strength and tear resistance while the impervious polymer modified cement coating is impermeable and protects the geotextile from UV light and chemical attack.

The PMC coating provides the liner with:

- Erosion resistance.
- UV light, oxidation and ozone protection
- Protection from damage caused by water action, plant growth, animals, fire, vandalism and canal maintenance equipment.

3. INSTALLATION PROCEDURE

The application process consist of the following steps:

(i) The channel is cleared and shaped if required (with limited compaction) for PMC Liner placement and anchoring channel structures. Note: the liner can be installed on damp substrates. A cuspated HDPE drainage cell is installed in the base of the channel to allow infiltrated water to be captured and diverted through a channel sump to overflow spillways. (see photograph 4 below).

Photograph 4

(ii) For concrete channels the base liner is adhesively bonded with a bituminous adhesion and secured to the channel edges using steel batten strips (see photograph 5 below). Seam-joint overlaps are formed in the downstream direction.

Photograph 5

(iii) The PMC Coating is sprayed onto the geotextile (using a textured spray gun) to a 3mm build. The overlaps are also sprayed with the PMC mixture so an integral coating is present over the entire liner. This virtually eliminates leaks due to poor welds. Photograph 6 below shows PMC being applied over the nominated geotextile.

Photograph 6

(iv) The coating takes approximately 24 hours to cure under good weather conditions. Hardening of the coating can be tracked using a Shore A Durometer hardness probe. The ultimate hardness reaching 82 Shore A in about 4 days under normal conditions.

(v) The applicators must be cleaned after use and are washed in water.

4. PMC LINER ATTRIBUTES

PMC liners offer the following performance properties over alternative geomembrane liners:

- the liner construction is substantially thicker (3-6 mm) than other geomembranes (usually 1.5-2.5 mm)
- it has high puncture resistance and hence tolerance to field damage by kangaroos for example (see photograph 7 below)
- it has good frictional characteristics due to the polymer modified cementitous compound that is impregnated into the reinforced woven geotextile (textured surface similar to concrete)
- it has very high grab tensile strength (up to 50 kN/m)

Photograph 7

PMC also exhibits excellent tear resistance due to the use of geotextile-glass filament composites.

The use of a woven and nonwoven geotextile allows installation of the PMC liner on very aggressive subgrade with angular rocks due to the anti-puncture protection provided by the geotextile layer.

The PMC liners are formulated and fabricated to withstand continuous UV exposure, animal traffic, impact/puncture by floating debris (such as tree branches), action of water movement and even passing bushfires.

5. PERFORMANCE PROPERTIES

Some of the advantageous performance properties of PMC liner in regard to channel applications include:

Adhesion to Substrate: The PMC base liner can be adhered to concrete and other substrates to provide permanent bonding, resisting tractive forces of the water and eliminating cyclic flex fatigue. In contrast, HDPE liners cannot be adhered to substrates due to their low surface energy and poor wettability.

Installation in Adverse Weather: The base liner can be installed under damp conditions on moist subgrade. Of particular importance is that the PMC coating can be sprayed onto wet substrates even if pooling water is present. Due to the high specific gravity of the PMC coating it sinks to the bottom of free standing water and begins to cure underwater.

Flexible & Conformable: The flexibility of the liner allows it to conform to uneven subgrade and integrate into existing channel headwalls and containment structures. The photograph below (photograph 8) shows the base liner installed before the application of the PMC spray coating.

Photograph 8

Resistance to Installation Damage: The PMC liner offers double protection against installation damage in the form of:
-a reinforced geotextile layer
-a relatively thick protective impregnating coating

Good Elongational Properties: Considerable elongation allows flexibility to move with subgrade expansion/cracking

Puncture Resistance: The liner construction incorporates an integral cushioning geotextile for lining aggressive subgrades (especially those with angular protrusions)

Hard Wearing Textured Surface: The cementitious coating provides grip and can tolerate mechanical, human and fauna traffic (‘walk in walk out’ thus no fencing is required) (photograph 9 below shows the finished PMC liner)

Photograph 9

Durability: The liner provides an impermeable membrane with a 30+ year life

Low VOC: The coating is compliant for potable water and will not leach extractables once cured. The PMC coating is water bourne and hence no organic solvents are required as diluents.

Non Flammable: The thick cementitous coating renders the PMC liner non-flammable making it resistant to bushfires as well as channel fires that propagate in channels by consuming the blow grass or umbrella grass (see photograph 10 below).

Photograph 10

Repairability: The liner can be maintained by cleaning and respraying eroded or damaged areas.

Whole of Life Benefits: The PMC liner has considerable lower whole of life cost compared with conventional polymer geomembranes.

A comparison of the properties of HDPE and PMC liners are presented in Table 1.

Table 1. Comparison of HDPE liner and PMC Liner

Property	*HDPE liner (1.5 mm)*	*PMC liner (6 mm)*
Resistance to Sunlight	Excellent	Excellent
Resistance to Stress Cracking	Fair	Excellent
Resistance to Oxidation	Good	Excellent
Ease of Panel Installation	Good	Excellent
Ease of Installation in Adverse Weather (drizzle, fog, dew)	Poor	Good
Resistance to Thermal Expansion/Contraction	Fair	Excellent
Ease of Field Seaming	Poor	Good
Ease of Field Repair Procedures	Poor	Excellent
Resistance to Organic Wastewater	Excellent	Excellent
Conformability to Uneven Subgrade	Poor	Excellent
Ability to be adhered to concrete	Poor	Excellent
General Lay Flat Characteristics	Poor	Good
Resistance to Installation Damage	Fair	Excellent
Resistance to Installation Wrinkles	Poor	Excellent
Resistance to Surface Slippage (Surface Friction)	Poor	Good
Overall Long Term Durability	Good	Excellent
Average Cost per mm thickness/sq. m.	Good	Excellent

6. CONCLUSIONS

The PMC Liner has been successfully applied to remediated aged concrete water channels as well as earthen channels. The polymer-modified cementitous coating protects the underlying reinforced woven geotextile from the effects of ageing and provides an impervious, strong, durable and flexible liner system.

The PMC liner can be installed over aged concrete where it can bridge joints and cracks. The PMC liner prevents seepage through the cracks and joints of aged concrete channels. The PMC liner has the look and texture of concrete but the flexibility and chemical resistance of a polymeric liner.

7. REFERENCES

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