NEW GEOSYNTHETIC CEMENTITIOUS CONCRETE MAT (GCCM) LINER FOR REDUCING IRRIGATION CANAL LOSSES

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ABSTRACT

A new class of geosynthetic has recently emerged known as GCCMs (Geosynthetic Cementitious Composite Mats) defined by the ASTM D-35 committee in 2017 as *'a factory-assembled geosynthetic composite consisting of a cementitious layer contained within a layer or layers of geosynthetic materials that becomes hardened*'.

GCCMs consist of a three-dimensional fibre structure filled with a dry cement/concrete mix, overlain by a hydrophilic filter layer and underlain by a watertight membrane, which is typically a PVC or LDPE film. The material is delivered in its dry format and unrolled into place using similar installation techniques to traditional geosynthetics. Once in place, it is hydrated by spraying with water and the cement/concrete mix hardens. The result is a watertight polymeric film which is overlain by a protective fibre-reinforced concrete layer, with a thickness typically between 5 and 13mm and an equivalent coefficient of permeability in the region of 10^{-9}m/s.

GCCMs have been in use since 2009 and are predominantly used for the lining of water channels for small scale drainage. This paper explores their use as a potential lining solution for large scale irrigation canal structures by examining selected case studies from around the world.

Keywords: Canal liner, GeosyntheticBarrier, Geomembrane, Concrete, GCCM, GCCB, Concrete Canvas.

1. INTRODUCTION

A relatively new class of geosynthetic has recently emerged known as GCCMs (Geosynthetic Cementitious Composite Mats) defined by the ASTM D-35 committee in 2017 as *'a factory-assembled geosynthetic composite consisting of a cementitious layer contained within a layer or layers of geosynthetic materials that becomes hardened'*.

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GCCMs consist of a three-dimensional fibre structure filled with a dry cement/concrete mix, overlain by a hydrophilic filter layer and underlain by a watertight membrane, which is typically a PVC film (**Figure 1**). The material is delivered in its dry format and unrolled into place using similar installation techniques to traditional geosynthetics. Once in place, it is hydrated by spraying with water and the cement/concrete mix hardens. The result is a watertight polymeric film which is overlain by a protective fibre-reinforced concrete layer, with a thickness typically between 5 and 13mm and an equivalent coefficient of permeability in the region of 10^{-9}m/s. Overall GCCM structure permeability relies on the method of joining adjacent

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layers, which can vary from using mechanical fixings and adhesive sealants to heat bonding.

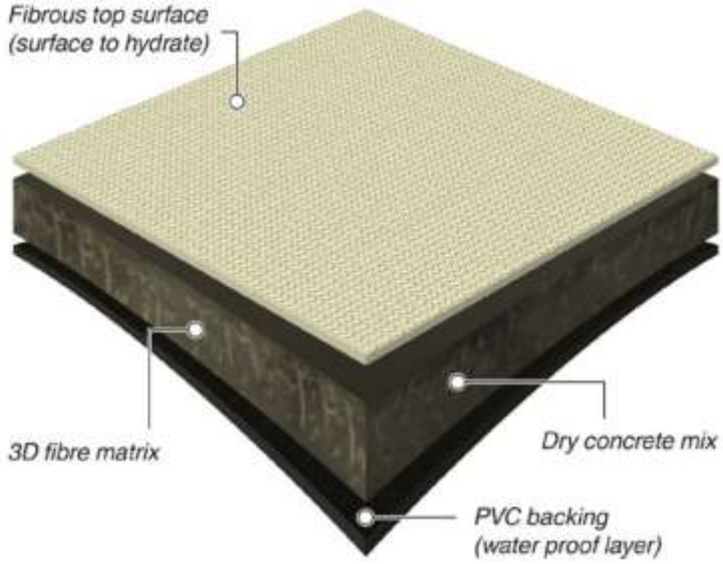

Figure 1. Section of a GCCM

A variant of GCCMs was released to the market in 2015 known as GCCBs (Geosynthetic Cementitious Composite Barriers), which incorporates a thicker (1.2mm) PVC geomembrane with reinforcing scrim on the rear surface. GCCBs incorporate an 'edge flap' which allows for adjacent layers to be thermally welded together with an air channel to allow testing of joint strength and joint permeability for onsite quality control. GCCBs are designed for use where an even lower level of permeability is required (10^{-14} m/s), such as where a significant head of water is present or in critical locations where leaks pose a contamination risk. For ease of reference this document will refer to them both generically as GCCMs.

GCCMs were designed to provide a prefabricated alternative to geomembrane liners where they need to be covered with a protective layer of concrete. Although they are heavier than most geomembranes, they offer similar installation speeds to conventional geosynthetics, eliminating the logistical complexities and slow installation times associated with poured or sprayed concrete surfaces. When tested to ASTM C-1353, the fibre reinforced concrete layer for the market leading GCCM has an abrasion resistance more than 7.5 times that of a 17MPa Ordinary Portland Cement concrete. This thin fibre reinforced concrete layer acts to protect the underlying geomembrane from damage and therefore eliminates the need for additional protective cover layers.

2. APPLICATIONS IN CANAL LINING

The US Bureau of Reclamation (USBR) ten-year field tests as reported by Swihart& Haynes (2002) demonstrate that a geomembrane with a concrete cover provides the highest B/C (Benefit to Cost) ratio when compared to exposed geomembranes, fluid applied membranes and concrete alone.

Whilst GCCMs provide similar long-term benefits to a geomembrane with concrete cover, they also offer a number of additional benefits:

- **Installation Damage.** The risk of damage to geomembranes during installation is well documented (Schiers 2009). Some studies have attributed as much as 71% of geomembranes leakage to damage during the installation of a protective top cover. Whilst there is no substitute for careful installation, the prefabricated nature of the protective layer in GCCMs significantly reduces risk of puncture during installation.

- **Side Slope Incline.** The internal fibre matrix of GCCMs prevents the dislocation of the dry concrete powder during transportation and the wet mix during hydration. This allows GCCMs to be laid on vertical slopes without slump or strength loss. By contrast non-reinforced concrete is typically unstable during placement on side slopes steeper than 1.5H:1V as reported in Giroud & Plusquellec (2017).

- **Constant Thickness.** The prefabricated nature of GCCMs allows for tightly defined thickness control which helps to avoid the long-term cracking often associated with thickness variation present in poured concrete as reported in Giroud & Plusquellec (2017).

- **Manning's Value.** The Manning's value provides an indication of resistance to hydraulic flow and allows engineers to calculate a suitable channel profile and slope for a given flow rate requirement. A 'low' Manning's value represents materials with less resistance to flow compared to those with a 'high' Manning's value. GCCMs have been tested by the Texas Research Institute (TRI) in the USA (2016) and shown to have a Manning's value of 0.011. This is similar to a smooth poured concrete surface (0.01) and significantly lower than a rough poured concrete surface (0.015).

- **Composite Liner Effect.** The prefabricated nature of GCCMs means that the geomembrane liner on the lower surface is in intimate contact with the concrete impregnated fibre matrix on the upper surface - an inherent aspect of the manufacturing process. This results in a reduced leakage rate when compared to a geomembrane liner on its own, due to the "composite liner effect" as discussed in Giroud (2016)

- **Embodied Carbon.** A report to assess the carbon footprint of a leading GCCM product using ISO 14040 full Life Cycle Assessment method (Mironov V. 2017), found that when considering raw materials alone, a GCCM (8mm) lined channel contained less than 45% of the embodied carbon of a conventional channel lined with 150mm of poured concrete.

3. APPLICTAIONS IN CANAL REMEDIATION

In addition to their use in lining new structures with a consolidated soil substrate, GCCMs are increasingly being used as a method for the remediation of dilapidated concrete infrastructure which may have cracked and spalled. There are a number of specific benefits that GCCMs provide when relining existing water channels:

- **Speed of Install.** Re-lining of in-service water channels is often extremely time sensitive in order that disruption to associated downstream industries, such as hydro-electric plants or agricultural farmland, is minimised. GCCMs are typically ten times faster to install than a poured concrete surface for channel lining applications (Engineers Incorporated 2011).

- **Crack Bridging.** The internal fibre matrix acts to provide tensile reinforcement to the cement/concrete mix and prevent cracks from propagating. This helps to prevent the phenomenon of large crack spread often seen in conventional concrete structures but also provides reinforcement to the geomembrane on the rear surface to increase the co-energy of the composite material. This is particularly important when relining existing concrete infrastructure where the GCCM will need to bridge cracks in the existing substrate. The use of co-energy to compare geomembranes ability to accommodate differential settlement is described by Giroud and Soderman (1995) and further by Giroud (2005).

- **Channel Flow Capacity.** Resurfacing damaged concrete infrastructure with conventional concrete will normally result in a reduction of channel profile and hence flow capacity since concrete pour thicknesses are typically 100-150mm. This can be a significant issue as most channels will have been designed to carry a maximum volume of water, for example to service a specific area of farmland, feed a hydro-electric plant or dissipate storm water from a 1 in 100 storm events. Typical GCCM thicknesses are 5-13mm thick and therefore allow concrete channels to be relined with negligible effect on their flow capacity.

4. GCCM PROJECT EXAMPLES

4.1 Bella Vista: Irrigation Channel – Chile

In 2017, 18,000sqm of GCCM were installed in the La Serena, 4th region of Chile. The aim of the project was to eliminate as far as possible water losses for a 2.4km long section of an irrigation channel known as the Bellavista channel which supplied water to a large agricultural community. A particular challenge was that water supply could only be shut-off for a maximum of 8 days at any one time since the channel was still servicing active farmland. This limited timeframe ruled out the use of traditional cast in situ and prefabricated linings.

Figure 2. GCCM on the Bella Vista Irrigation Channel. Compaction formwork shown in background.

The soil substrate was prepared using a wooden formwork with stabilised backfill in order to ensure a uniform flow profile and consistent slope gradient. This was overlaid with layers of GCCM supplied in roll format and then hydrated. In order to maximise the install rates over the 8-day work window, multiple teams were active on site so that ground preparation, material install and hydration could occur concurrently. The entire channel was line in 5 shut off periods.

Figure 3. Sections of complete installation prior and during service.

4.2 Bowburn: Hydropower Channel Remediation – UK

In 2013, 7,500sqm of GCCM were used to remediate an existing poured concrete hydropower channel in Scotland, UK. The original channel structure had been cast in-situ in the 1950's and become severely cracked over time, in part due to the harsh climatic conditions of the area. This led to substantial water loss over the 1.5km channel length, with an associated cost to the hydro-electric operator.

Figure 4. Sections of the Hydropower canal before and after lining with GCCM.

The original concrete structure was kept in place, but large voids in the substrate were filled prior to being overlaid with a layer of GCCM. This provided a minimum of another 50 years of usable life with a substantial cost savings compared to replacement or repairment of the channel using conventional methods.

The fibre reinforcement within GCCMs provides excellent resistance to freeze-thaw compared to conventional concrete structures and they have been used successfully on projects with annual temperature fluctuations as great as 75 degrees C such as in Siberian Russia.

Figure 5. Complete installation showing GCCMs ability to conform to channel curvature.

4.3 Myra Falls: Mine Water Channel – Canada

In 2016 11,000sqm of GCCM were installed in Vancouver Island to replace an existing shotcrete storm water channel that had degraded over time. A wider channel was excavated parallel to the existing shotcrete lined channel to enable a greater flow capacity to accommodate future flood events. This was then lined with GCCM prior to diverting flow from the original channel into the newly formed channel**.**

Figure 6. GCCM being installed from a spreader beam at Myra Falls.

The channel was approximately 735m in length and between 5 & 8 m in width, with an average depth of 1.5m.

Sections of the channel were at a gradient of 16% and the design required that the structure be capable of handling flow velocities of up to 20m/s. In order to withstand the high shear forces at these velocities, the GCCM was secured to the substrate with an array of earth percussion anchors. Check slots (anchor trenches across the profile width) were also introduced to provide additional anchoring and redundancy.

Figure 7. Aerial view of the complete installation with flowing water.

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