CONCRETE CANVAS®
Concrete on a Roll

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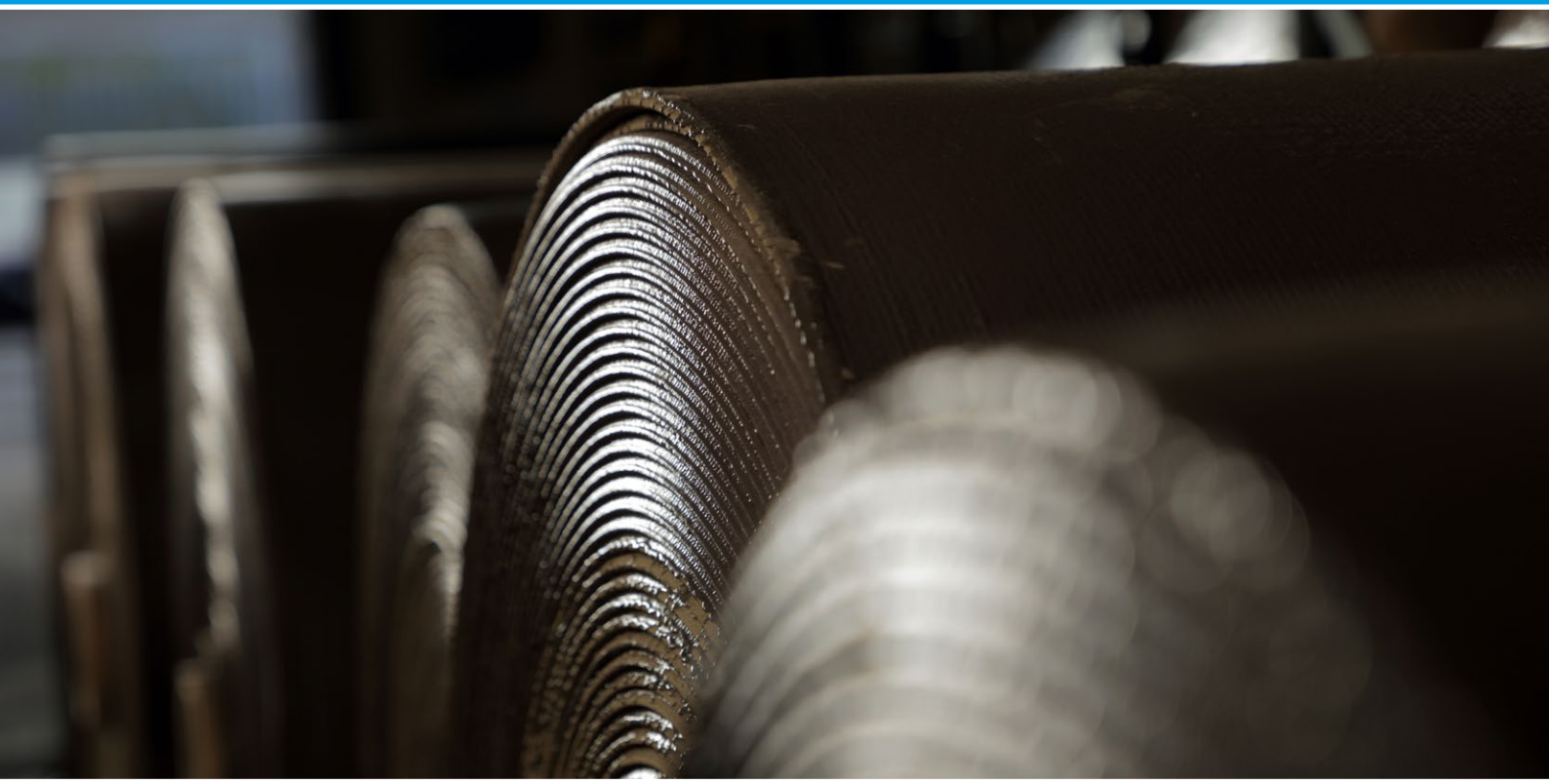

CONCRETE CANVAS®

Concrete on a Roll

ESSENTIAL PROPERTIES FOR GCCM SPECS

The Queen's Awards for Enterprise: International Trade 2019

Board of Trade Winner 2018

Ground Engineering Awards 2017 — Winner Technical Innovation Award

ice award winner 2017 — ICE Wales Cymru Project Awards — Innovation Award ICE Wales Cymru Awards 2017

BBA Approval Inspection Testing Certification — Certificate 19/5685 — British Board of Agrément Certified

CPD Certified — The CPD Certification Service — Certified CPD Provider

IGS — Corporate Member

Exporting is Great — Britain & Northern Ireland — Proud Supporter of Exporting is Great

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1.0 Introduction

The Concrete Canvas® (CC) material technology was developed by Concrete Canvas Ltd (CCL) in 2005 and is the original Geosynthetic Cementitious Composite Mat. GCCMs are typically used for erosion control applications including channel lining, slope protection, bund lining and concrete remediation, providing a robust and low-maintenance surface erosion control solution.

CC uses a proprietary GCCM manufacturing method that has been optimised over 15 years of production and field experience. CC products are used by some of the world's largest infrastructure companies and have been successfully installed in over 80 countries.

With any successful innovation others invariably look to follow. Unfortunately, that also carries a risk of sub-standard products entering the market, which could jeopardise the reputation of the GCCM class of material and more importantly lead to in-service failures.

GCCMs are unlike most geosynthetics as their properties change on hydration from flexible to rigid. Both the uncured (pre-set, soft and flexible) and cured (post-set, hardened and rigid) properties need to be reported to understand the GCCM capabilities in both deployment and in-service respectively.

GCCMs are a composite combining both geosynthetic and cementitious materials, both of which possess very different physical properties. Geosynthetics are typically buried and their performance is often assessed according to their tensile performance, whereas hardened cementitious materials are often exposed and their performance is typically assessed by their compressive strength, which is typically correlated with other key characteristics such as abrasion resistance, freeze thaw resistance and resistance to chemical attack.

GCCMs are the only geosynthetic to contain cementitious material so traditional geosynthetic test standards do not include methods for understanding the performance of the cementitious material contained within a GCCM, such as compressive strength. It is important therefore to test the properties of the cured cementitious material so that the behaviour of the GCCM as a hardened composite can be understood.

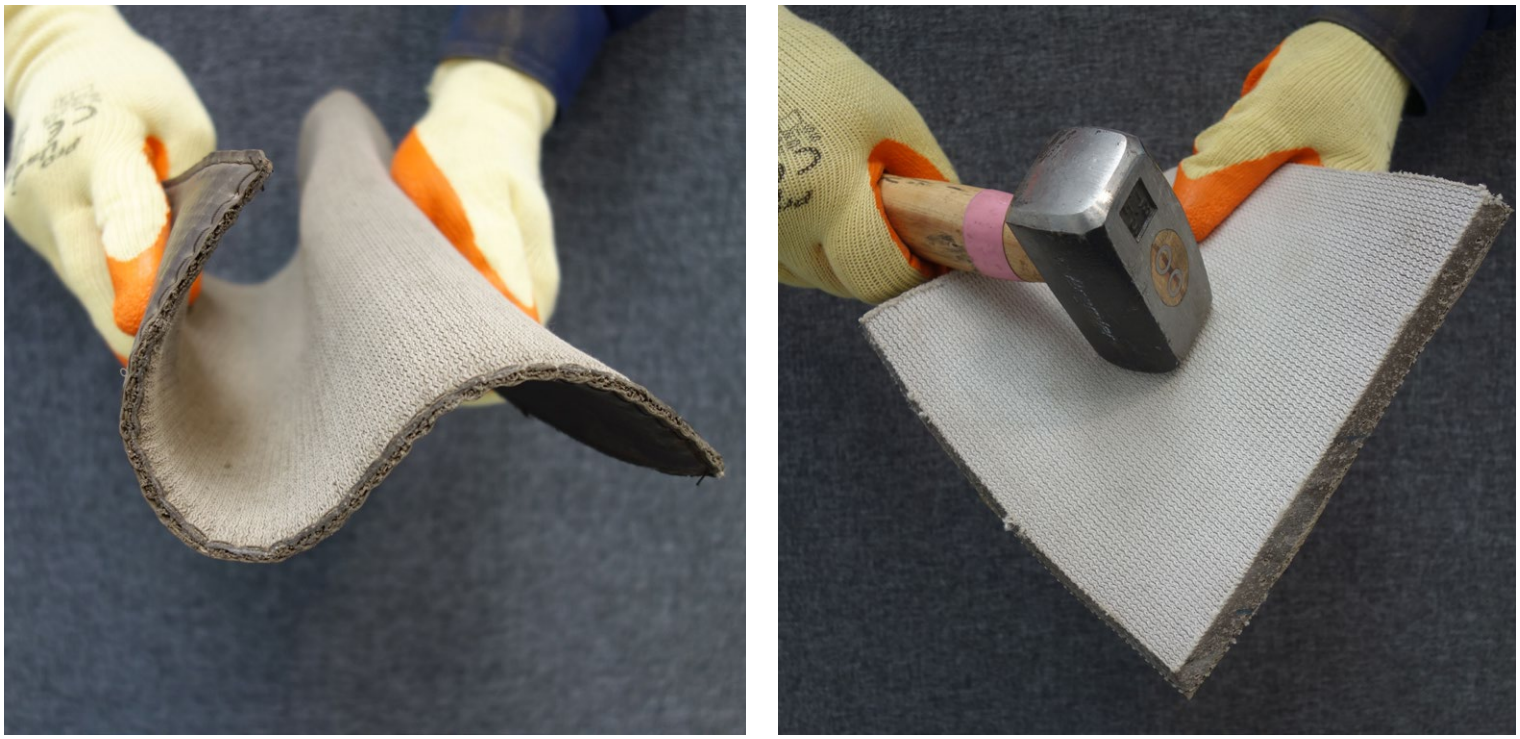

Figure 1. The change of GCCM properties from flexible to rigid on curing means that when assessing GCCM properties, appropriate test methods should be used to determine the cured, in-service GCCM cementitious layer performance.

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2.0 GCCM Specific ASTM Standards

Since 2015, the ASTM International Standards Organisation and its D35 Geosynthetics Committee has published a number of standards specifically for GCCMs to address the shortfalls in using traditional geosynthetic or concrete or fibre reinforced cement sheeting standards. These GCCM specific standards enable consistent, accurate reporting of essential GCCM properties. They include:

- ASTM D8364 'Standard Specification for GCCM materials'
- ASTM D8030 'Standard Practice for Sample Preparation for GCCM'
- ASTM D8058 'Standard Test Method for Determining the Flexural Strength of a GCCM Using the Three-Point Bending Test'
- ASTM D8329 'Standard Test Method for Determination of Water/Cementitious Materials Ratio for GCCMs & Measurement of the Compressive Strength of the Cementitious Material Contained Within'

These standards have been created to set the benchmark levels for manufacture and testing of GCCM properties, conducted on GCCM specimens that have been prepared in a manner that is consistent with their use in the field and are therefore representative of material installed in real-world operating conditions.

The physical performance properties of GCCMs can be assessed to the GCCM specific ASTM standards to ensure they are suitable for erosion control applications:

2.1 ASTM D8364 - GCCM Specification Standard

In 2021 the ASTM International Standards Organization defined the minimum performance requirements of GCCMs in ASTM D8364 'Standard Specification for GCCM Materials'. This standard defines 3 classes of GCCM suitable for different erosion control and weed suppression applications. The use of this ASTM Specification helps ensure the quality and performance of a GCCM is suitable for the intended application and helps protect against project failures.

There are 2 test methods specific to GCCMs within this standard, the compressive strength test (ASTM D8329) and the flexural strength test (ASTM D8058). In the opinion of CCL, non-GCCM standards for assessing the concrete performance in a GCCM should not be relied on. Standards designed for testing mixed concrete products provide scope to artificially prepare GCCM test samples that will give misleadingly high compressive and flexural strengths. See sections 2.3 and 2.4 for more information.

For more information on ASTM Specification Standard D8364 please see Technical Note 1 and the CC Spec Sheet to ASTM D8364.

2.2 ASTM D8030 - Standard Practice for Sample Preparation for GCCM

ASTM D8030 specifies the procedure for the hydration and curing of GCCM material for subsequent physical property testing. This standard specifies that GCCMs are hydrated by full immersion for 24 hours which is representative of in-field hydration conditions as water pools on GCCM surfaces, producing the highest water/cement ratio possible in the GCCM.

Hydration of GCCM specimens by surface spraying can produce misleading physical property test results, as the water/cement ratio is lower than in parts of the GCCM structure that will cure under the immersed conditions. In virtually all concrete based materials the water/cement ratio governs the final compressive strength of the cured product.

This is discussed in BR331 - Design of Normal Concrete Mixes: second edition: 'A major factor in providing durable concrete is the production of a dense, impermeable concrete, having an adequate cement content and low free-water/cement ratio, which is fully compacted and properly cured'. If the water/cement ratio is too high, the compressive strength of the cured concrete will be extremely weak, as illustrated in Figure 2 (©IHS Markit, reproduced with permission from Design of Normal Concrete Mixes - BRE Report BR 331).

It is therefore important to control the water/cement ratio of all concrete materials to ensure they cure to provide the required durability. For conventional concretes, the addition of water is carefully controlled when batching. This is not so simple for GCCMs, as by their ASTM D4439 definition they are supplied in a flexible, uncured state and only harden when hydrated, which can only take place once the GCCM has been installed.

This means the GCCM manufacturer cannot directly control the quantity of water used by the installer when hydrating and must rely on the quality and structure of the GCCM to consistently limit the water to powder ratio. GCCMs are often used to line channels and culverts that naturally contain horizontal or concave surfaces that will pool water, so it is therefore likely that even if hydrated by spraying, some parts of a GCCM will cure under fully immersed conditions. Immersed curing results in the highest water/cement ratio the GCCMs will be subjected to, resulting in the lowest in-service compressive strength and (according to BR331) the poorest durability of the cementitious material. It is critical that the performance of a construction material is assessed based on the physical properties present at the weakest point in the structure, as a failure will usually occur at this location. It is therefore critical to understand the in-service performance of GCCMs that have been hydrated by full immersion. In channel lining GCCM installations, pooled water and the highest hydraulic loads usually occur at the base of the channel.

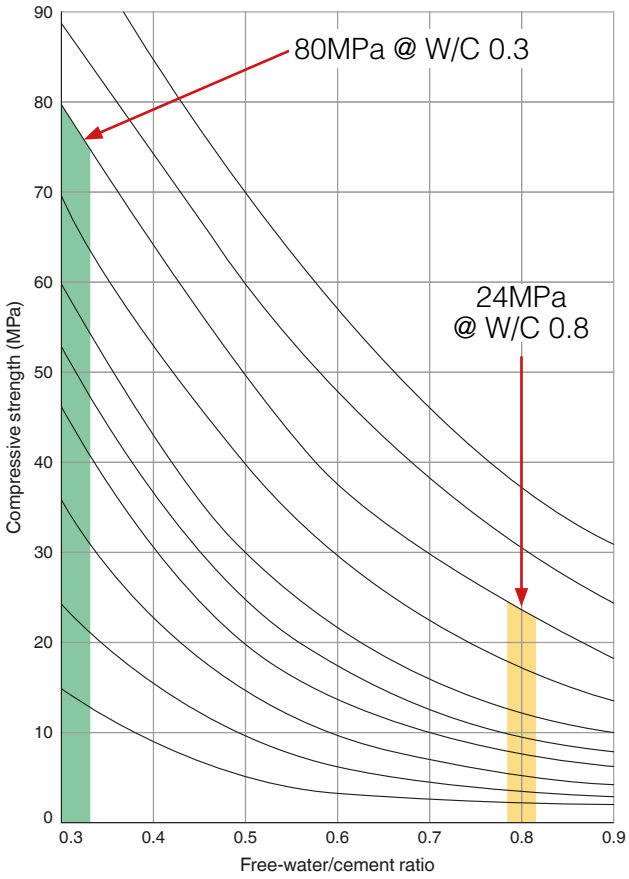

Figure 2 Compressive strength vs water/cement ratio

NOTE: CCL recommends that when comparing the cured physical properties of GCCMs, the checker must verify that the specimens were prepared in accordance with ASTM D8030. Otherwise, there may be a risk that the cured properties reported are not representative of real-world conditions and the data is artificially high.

2.3 Cementitious Material Performance – GCCM Compressive Strength to ASTM D8329

GCCMs are hydrated in the field by spraying or immersion (immersion almost always occurs due to pooling of water). The GCCM must be engineered to mechanically control the water to cementitious materials ratio in order to achieve consistent high-performance concrete. ASTM D8329 is specific to GCCMs as it determines the representative water to powder ratio of a GCCM hydrated by immersion. This water to powder ratio is then used to prepare cube specimens of the cementitious material for compressive strength testing.

As discussed in 2.2, it is essential that the water/ cement ratio used in the cube testing is representative of that which the GCCM exhibits during the uncontrolled hydration on site.

Using the incorrect water/cement ratio can result in properties that are substantially different to the actual performance. ASTM D8329 sets out the procedure for determining the appropriate water/cementitious materials ratio in a GCCM that is representative of site hydration conditions. The water/cementitious materials ratio is not the same as the water/cement ratio of a GCCM. If the cementitious material contains a high percentage of sand, aggregate or other additives, a low water/cementitious material ratio obtained using ASTM D8329 may still result in a high water/cement ratio. It is therefore important when determining the compressive strength of a GCCM that the cementitious powder is extracted directly from the unset GCCM test sample so that the formulation is representative of the actual product. Testing of a powder sample only may not be accurate.

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NOTE: As can be seen in Figure 2, the compressive strength of a cementitious material is significantly controlled by the water/cement ratio. For example, a cementitious material may achieve a compressive strength of 80MPa at 28 days at an optimum water/cement ratio of 0.3 in laboratory conditions, but at a water/cement ratio of 0.8 the compressive strength drops below 25MPa at 28 days. CCL recommends that to assess the compressive strength of a GCCM, the water/cementitious materials ratio is first determined in accordance with the GCCM specific compressive strength standard ASTM D8329 and then test cubes are prepared at this ratio using cementitious powder extracted from the test sample.

The GCCM Specification Standard ASTM D8364 requires all classes of GCCMs used in erosion control to have a minimum compressive strength of 40MPa at 28 days when tested to ASTM D8329. Other non-GCCM standards such as ASTM C109 are usually designed for mixed concretes using a relatively low water to cement ratio, which can be significantly lower than the GCCMs exhibit in actual use so test results to this standard may not represent real world GCCM performance.

In the opinion of CCL, GCCMs with a low compressive strength (<40MPa at 28 days to ASTM D8329) are unsuitable for erosion control and weed suppression applications and present a substantial risk of project failure when used in this manner.

For more information on GCCM compressive strength and ASTM D8329 please see Technical Note 2.

2.4 Protecting GCCM Specifications

Flexural Strength testing of cured GCCMs provides the best overall indication of the in-service performance of a GCCM and is the standard index test for this class of material. Flexural Strength testing on cured GCCMs provides a means to evaluate the performance of both the geosynthetic **and** cementitious components of the material. Testing must be done in accordance with ASTM D8058 which requires that both the Initial Flexural Strength (IFS) value (which relates to the performance of the cementitious component of the GCCM), and the Final Flexural Strength (FFS) value (which relates to the performance of the geosynthetic component of the GCCM) are recorded in the test report. The IFS of a GCCM may have a significantly lower strength than its FFS.

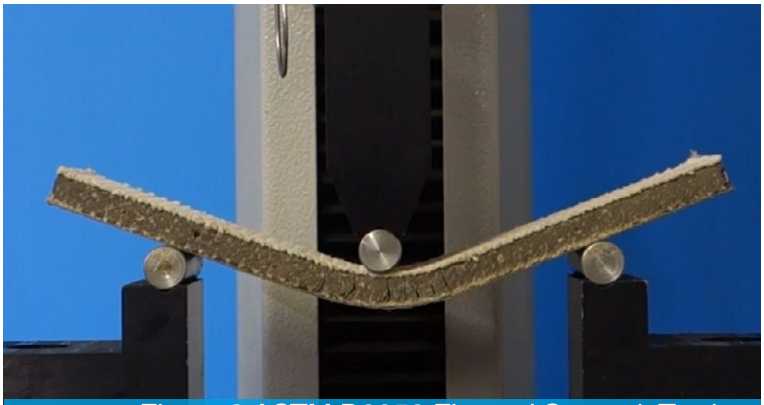

Figure 3 ASTM D8058 Flexural Strength Testing

Figure 3 shows ASTM D8058 Flexural Strength testing of cured Concrete Canvas® CC8™.The photo was taken after the 1st crack of the cementitious material (IFS) and before geosynthetic failure (FFS). As can be seen, the composite behaviour causes multiple cracks to form in this region of the test as tensile load transfers from the set cementitious material to the geotextile.

The GCCM Specification Standard ASTM D8364 requires GCCMs to have a minimum 1-day IFS of 3.5MPa when tested to ASTM D8058. CCL Quality Control procedure dictates that at 24 hours after curing, a minimum machine direction IFS of 4.0MPa is required. In the opinion of CCL, GCCMs with an IFS lower than 3.5MPa will contain a weaker cementitious layer that is more likely to fail over time.

NOTE: The Initial Flexural Strength is the load at which the cementitious material in a GCCM first cracks and its composite behaviour is changed as the fibres take up that load that was previously carried by the rigid concrete. The ultimate strength may not be recorded until very large deflections are reached. Such large deflections are unlikely to be seen in any typical application. CCL therefore recommends that when assessing the Flexural Strength of GCCMs, the primary index for comparison should be the Initial Flexural Strength. Specimens must be prepared in accordance with GCCM sample preparation standard ASTM D8030 and tested in accordance with GCCM flexural strength standard ASTM D8058. Other non-GCCM standards (such as PN EN 12467:2013 for testing set fibre cement cladding boards) do not specify how the test samples should be set, meaning they could be hydrated and cured in conditions that are not representative of field performance.

For more information on GCCM flexural strength and ASTM D8058 please see Technical Note 3.

2.5 Other key performance properties

2.5.1 Peel Strength (Strength of Internal Linking Fibres)

When installing a GCCM, the top and bottom geosynthetic layers must be securely connected in order to constrain the cementitious material when dragging/tensioning the GCCM into position. This is necessary in order to control the water/cement ratio on hydration. If the top/bottom layers become detached during handling, the cementitious material is no longer constrained and can potentially wash out from the GCCM. The Peel Strength (strength of internal linking fibres) provides an indication of the strength of the connection between the top geosynthetic layer and the connecting fibres/yarns and the ability of a GCCM to withstand installation damage. In-service, the layers must remain securely bonded to ensure the material continues to behave as a composite. Within a set GCCM the attachment of the top layer is a function both of the quality of the set cementitious layer, the embedment of the top surface and the peel strength of the connecting yarns/fibres.

When lining channels and culverts, GCCMs are subject to hydraulic shear forces. The GCCM acts as a homogenous waterproof barrier to prevent erosion of the soil beneath. If the connection strength of the GCCM top geosynthetic layer and connecting fibres/yarns is below the hydraulic shear force generated by water flow in the channel, then the top layer of the GCCM can detach from the cementitious material.

NOTE: The engineer designing the structure must check that the hydraulic shear force generated in the channel is below the connection strength of the top layer of the GCCM, otherwise the top layer of the GCCM may detach in operational flow conditions.

2.5.2 Tensile Strength

The Ultimate Tensile Strength (UTS) of a GCCM is governed primarily by the geosynthetic components within the GCCM and this applies both to uncured and cured material. As cementitious materials typically have lower tensile strength than geosynthetics, when testing the tensile strength of a cured GCCM, multiple cracks will typically form in the cementitious material transferring loads to the reinforcing fibres before the ultimate tensile strength of the GCCM is reached. In certain applications, engineers need to know the 1st crack tensile strength of the GCCM, which is when the cementitious material breaks and the materials rigidity is reduced, not just the ultimate tensile strength which is governed primarily by the geosynthetic elements. The upper layer of geosynthetic in a GCCM is particularly exposed to degradation from UV exposure and abrasion, especially in abrasive conditions such as watercourse lining applications with high levels of sedimentation. It is important that reported values take account of the effects of environmental degradation where this has a significant effect on in-service performance. Concrete Canvas® GCCM surface fibres have been shown to have excellent resistance to UV exposure.

In order to provide engineers with the information they need for a successful design, CCL provides tensile data for its products both with surface fibres, and with the surface fibres abraded off, so that the correct data can be used for the specific project conditions.

NOTE: In the opinion of CCL, reporting the UTS of only the geotextile components is not representative of the composite behaviour of a GCCM, as the 1st crack strength of the cementitious material and the negative effects UV degradation or surface fibre abrasion when in-service are not considered, the engineer will need to consider the first crack in tension and the UTS of the GCCM as a composite to understand the performance of the installed GCCM. It is therefore possible that using the manufacturer's reported data for design calculations could lead to inappropriate conclusions. Unless the test conditions are fully understood the UTS reported by some manufacturers may not be representative of long term installed GCCM performance.

2.5.3 Abrasion Resistance

Abrasive conditions typically occur in GCCM hydraulic applications (such as channelling works or culvert remediation)

where the top surface of the lining is subject to a range of water flow velocities and bed loads of silt, sand or cobbles during storm events. These actions can wear the surface of the lining. In the opinion of CCL, abrasion resistance is therefore an essential characteristic of GCCM materials and is assessed based on testing to ASTM C1353 "Test Method Using Taber Abraser for Abrasion Resistance". ASTM D8364 specifies that all GCCMs must have a maximum depth of wear of 0.3mm/1000 cycles when tested to ASTM C1353.

NOTE: When assessing the abrasion resistance of a GCCM to ASTM C1353, a low depth of wear represents good abrasion resistance; a higher depth of wear represents a lower resistance to abrasion, meaning over the same period of time, more of the GCCM will be abraded away under the same sediment flow conditions.

3.0 Specifying GCCMs

There are a number of ways that all parties can ensure they are using suitable GCCM material. The simplest method is to specify a GCCM Classification in accordance with Table 1 of ASTM D8364 'Standard Specification for GCCM Materials' and insist that manufacturers provide independent test data showing that their material meets the minimum performance properties when tested to the specified test standards. Designers should not accept test reports to standards not listed in the classification table. It is possible to obtain substantially higher results for the same GCCM using inappropriate testing methods or inappropriately cured samples. We would encourage customers to obtain unset samples and conduct their own independent testing of key properties such as compressive strength.

GCCM Specification:

Geosynthetic Cementitious Composite Mat (GCCM) to have the following in-service performance properties:

Property	Test Method	Minimum Value	Unit
GCCM Classification (delete as app)	ASTM D8364	Type I / II / III	
Thickness (delete as app)	ASTM D5199	4.5/ 7.5/ 12	mm
Initial Flexural Strength MD (1day)	ASTM D8058	4	MPa
Compressive Strength (28 days)	ASTM D8329	70	MPa
Durability	BBA Certification*	120	Years

*GCCM to be manufactured in accordance with BBA certificate 19/5685

Figure 4 Concrete Canvas GCCM Specification Table

ASTM Specification standard D8364 provides a simple way to specify GCCMs for erosion control and weed suppression applications. Using this standard ensures appropriate performance levels are defined and helps to protect Clients, Designers and Installers against project failures, particularly given the typical lifespan of erosion control projects and the likelihood of significant storm events. CCL recommends that Clients, Designers and Installers avoid the risk of project failure by specifying and installing a GCCM that meets the GCCM Specification standard and ensure that the manufacturers physical properties are reported to the specified test standards.

Alternatively, if engineers wish to specify only Concrete Canvas® products, Drop-in-Specifications and AutoCAD Specification Tables (see figure 4) are provided in the appendix. In CCL's opinion, there are five key requirements to ensure successful GCCM specification:

3.1 Initial Flexural Strength to ASTM D8058

As discussed in 2.4, the Initial Flexural Strength of a GCCM provides the best indication of the GCCM composite performance and long-term durability. ASTM D8364 'Standard Specification for GCCM Materials' requires all GCCMs to have a minimum 1 day Initial Flexural Strength of more than 3.5MPa when tested to GCCM specific flexural strength standard ASTM D8058. When specifying Concrete Canvas Ltd GCCMs, we recommend specifying a minimum 1 day Machine Direction IFS (Initial Flexural Strength) of 4MPa to ASTM D8058. 1 day IFS can also be used as part of Material Quality Assurance to verify that the material supplied to a project meets the specifications. This is a relatively inexpensive test that can provide an indication of cured GCCM performance in 24 hours.

It is important not to accept only the Final Flexural Strength result, or data conducted to flexural strength test standards other than ASTM D8058, as these other standards often do not specify how a sample is hydrated. This provides scope for samples to be artificially treated to give results that do not represent actual field performance.

3.2 Compressive Strength to ASTM D8329

Specifying a GCCM compressive strength to ASTM D8329 will ensure that the compressive strength reported is comparable with real world GCCM performance. Other compressive strength standards developed for mixed concretes allow manufacturers to specify low water/cement ratios. This can result in strengths many times greater than is achieved by their concrete mix design achieves in a GCCM at the actual water/cement ratio that the manufacturer's GCCM achieves in the field.

ASTM D8364 'Standard Specification for GCCM Materials' requires all GCCMs to have a minimum 28 day Compressive Strength of more than 40MPa for the lowest Type of GCCM, when tested to GCCM specific compressive strength standard ASTM D8329. When specifying Concrete Canvas Ltd GCCMs, we recommend specifying a minimum **28 day Compressive Strength** of **70MPa** to **ASTM D8329**.

Always check the water/cementitious materials ratio used in the testing and verify that this has been determined in accordance with GCCM specific compressive strength standard ASTM D8329. Otherwise, results may be artificially high and unrepresentative of the installed GCCM.

3.3 Independent Durability Certification

Rather than relying on the manufacturers reported data alone, independent third-party certification can be used to provide the reassurance that the manufacturers claims are accurate and correct. The British Board of Agreement, also known as the BBA, has over 50 years' experience of independent product certification and is recognised globally. The BBA has assessed the durability of the Concrete Canvas Ltd GCCMs and certified the use of Concrete Canvas® material's erosion control and weed suppression applications with a life expectancy in excess of 120 years. The BBA certificate can be accessed here.

When specifying Concrete Canvas GCCMs, we recommend specifying that the GCCM has a **BBA certificate** stating **120 years** durability for erosion control and weed suppression applications.

3.4 Proven Track-Record

Concrete Canvas Ltd has manufactured over 2,000,000m² of GCCM since 2005 and operate a Quality Assurance system independently certified under ISO 9001. Some of the oldest Concrete Canvas® installations are now over 10 years old.

Concrete Canvas Ltd recommends requesting case study evidence of any GCCM that is proposed for use on a project, showing that it has been used in a similar environment. Case studies should contain photographs at the time of installation and several years afterwards to demonstrate how the climate affects the appearance and performance of the GCCM. In the opinion of Concrete Canvas Ltd, if an established GCCM manufacturer cannot provide such case studies without good reason (e.g. they are a new market entrant), it may be because the material has poor durability and/or in high UV conditions the top surface may have degraded.

3.5 Verification of GCCM Properties

Where necessary, customers can conduct their own GCCM material testing either themselves or by engaging test houses to verify properties to GCCM standards, such as ASTM D8058 Flexural Strength and ASTM D8329 Compressive Strength.

When engaging a test laboratory, **testing should always begin with samples of soft (uncured) material** so that the test house can harden the material in accordance with ASTM D8030.

For project specific guidance on protecting your GCCM specification, please contact your Concrete Canvas representative.

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References:

Technical Data

- CC Spec Sheet to ASTM D8329
- CC BBA Certificate
- CC ETA
- Technical Note 1 – GCCM Specification Standard ASTM D8364
- Technical Note 2 – GCCM Compressive Strength Standard ASTM D8329
- Technical Note 3 – GCCM Flexural Strength Standard ASTM D8058
- GCCM Index Testing
- CC Abrasion Resistance Report

Specification Tools

- CC Drop in Specification
- CC Specification Tables

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