Introduction

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This series of Technical Notes consider the importance of using GCCM* specific ASTM standards when selecting GCCM materials for use on erosion control projects:

The Problem:

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 contain 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 strength, whereas hardened cementitious materials are often exposed and their performance is typically assessed according to 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 unset cementitious material and pre-existing geosynthetic test standards do not include methods for understanding the performance of the cementitious material contained within a GCCM. It is therefore important to test the properties of the cured cementitious material so that the behaviour of the GCCM as a hardened composite can be understood. It is also critical to ensure the cementitious material is cured at a water/powder ratio that is representative of field (in-service) hydration and not artificially controlled in the laboratory.

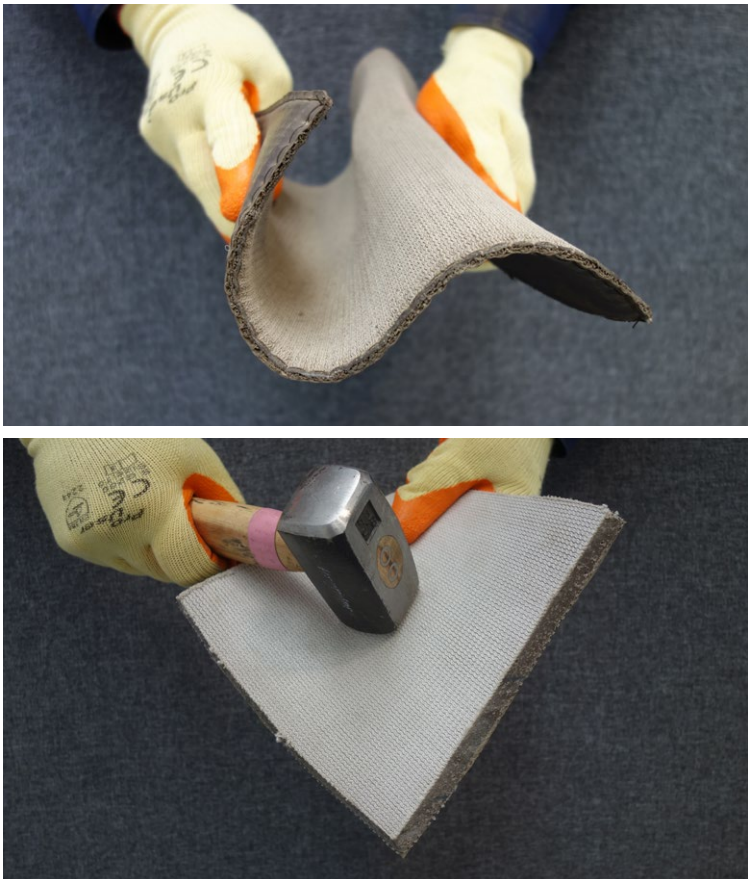

Figure 1. The change of GCCM properties from flexible to rigid on curing means that when assessing GCCM properties, appropriate test methods should be used to determine the cured, in-service GCCM cementitious layer performance.

The Solution:

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 pre-existing geosynthetic or concrete standards. These GCCM specific standards enable consistent, accurate reporting of essential GCCM properties.

They include:

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

These standards have been created to ensure that repeatable testing and reporting of GCCM properties is conducted on specimens that have been prepared in a manner that is consistent with their use in the field, so the test results are representative of GCCMs installed in real-world operating conditions. Applying non-GCCM tests can result in properties that vary by an order of magnitude from field properties.

*Geosynthetic Cementitious Composite Mat

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This Technical Note 2 focusses on the importance of using ASTM D8329 for determining the compressive strength of the cementitious layer of GCCMs.

ASTM D8329 GCCM Compressive Strength:

The only accurate method of determining the compressive strength of the cured cementitious material within a GCCM is by testing to ASTM D8329 'Standard Test Method for Determination of Water/Cementitious Materials Ratio for GCCMs and Measurement of the Compressive Strength of the Cementitious Material Contained Within'.

What is ASTM D8329:

Conventional concrete compressive strength testing (for example ASTM C109) is conducted by casting a cube (typically 50 or 100mm) and loading it to failure. Since GCCMs cannot be cast into cubes, the cementitious material must be removed from the GCCM and cast into a cube at the appropriate water/cement ratio prior to load testing.

GCCMs are hydrated in the field by spraying or immersion and whilst the hydration water is often applied by spraying, immersion almost always occurs in the field due to pooling of water on the surface of the GCCM. When testing for GCCM compressive strength it is essential that the water/cement ratio used in the cube testing is representative of the ratio achieved during hydration of the GCCM on site, in the worst-case situation.

Figure 2. GCCM hydrated by spraying resulting in pooling water in the invert. These parts of the GCCM structure cure in immersed conditions.

ASTM D8329 therefore sets out the procedure for determining the appropriate water/cementitious materials ratio in a GCCM that is representative of site hydration conditions based on full immersion.

Cured GCCMs typically consist of three components; the polymeric/geosynthetic materials, the dry cementitious materials (powder) and the hydration water. ASTM D8329 provides a step-by-step process for using GCCM sample material to record the mass per unit area of each GCCM component so that the hydration water to cementitious materials ratio can be calculated.

This ratio is then used to prepare cubes of the cementitious material for compressive strength testing. The cementitious material used to form the cubes must be extracted from the GCCM itself and cubes should not be made from manufacturer supplied pre-batched powder mixes that may have a different cement content to the actual GCCM product.

Note: 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 due to the low cement content in the cementitious material. 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 or cement sample pre-batched by the GCCM manufacturer may not be accurate.

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Why use ASTM D8329:

The compressive strength of any cured cementitious material is heavily dependent on the water/cement ratio during hydration. If the water/cement ratio is too high, the compressive strength of the cured concrete will be extremely weak. For example, a cementitious material may achieve a compressive strength of 80MPa at an optimum water/cement ratio of 0.3, but at a water/cement ratio of 0.8 the compressive strength drops below 25MPa (see Figure 3*).

Pre-existing concrete Compressive Strength test standards (designed for testing dry mix concrete products) allow for the water/cement ratio to be determined in the lab to achieve optimum results. This is understandable since the cement content is known and the quantity of water added to a conventional dry mix is normally controlled on site. This of course is not possible with GCCMs and so pre-existing test methods provide scope to publish misleadingly high compressive and strength values by using unrepresentative water/cement ratios. Performance values can be increased by more than 10 times in some cases.

ASTM D8329 is, therefore, the only standard that should be used for GCCM compressive strengths because it measures the water/cementitious materials ratio to give a strength that represents field performance.

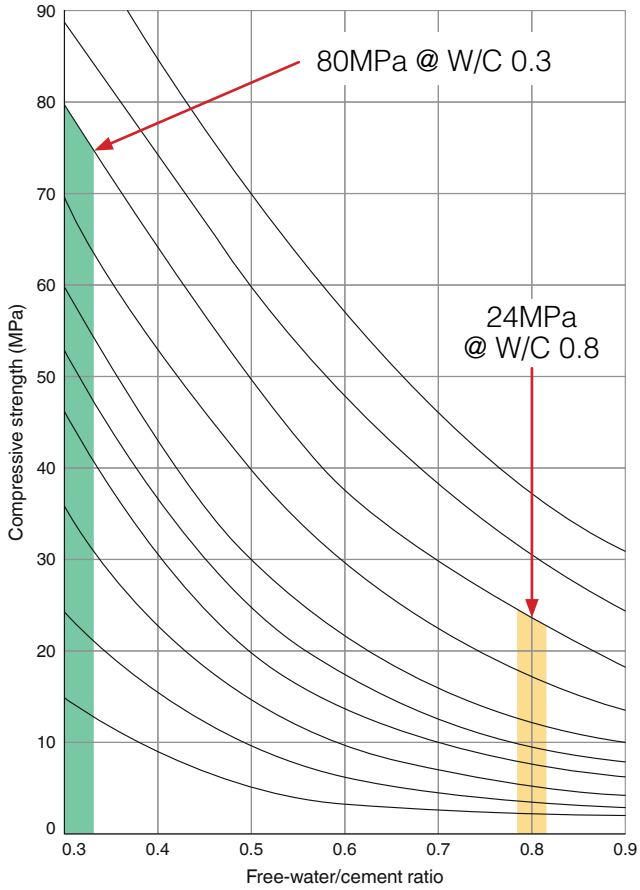

Figure 3. Relationship between compressive strength and water/cement ratio.

The compressive strength of a GCCM can be used as an indication of other key GCCM physical properties for erosion control applications such as abrasion resistance, flexural strength, freeze-thaw durability and chemical resistance. In the opinion of Concrete Canvas Limited, GCCMs with low compressive strengths (<40MPa) are unsuitable for erosion control applications.

This has also been recognised in ASTM D8364 'Standard Specification for GCCM Materials', as the performance properties of GCCMs table requires even the lowest grade GCCMs to have a minimum 28-day Compressive Strength of more than 40MPa when tested to ASTM D8329.

Recommendations:

Specifying a minimum GCCM compressive strength to ASTM D8329 will ensure that the compressive strength reported is comparable with real world GCCM performance.

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

Make sure the GCCM has appropriate test certificates from an independent test lab. BICS Laboratories Ltd have followed ASTM D8329 procedure to calculate the compressive strength of Concrete Canvas® GCCMs. CCT1™, CCT2™ and CCT3™ GCCMs all have a minimum 28-day Compressive Strength of over 70MPa. Please see the CC Spec Sheet to ASTM D8364 for details.

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