CONCRETE CANVAS®
Concrete on a Roll

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CONCRETE CANVAS®
Concrete on a Roll

SPECIFICATION GUIDE: WATERCOURSES

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

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Glossary of Terms

ASTM	*ASTM International Standards Organization www.astm.org*
BBA	*British Board of Agrement www.bbacerts.co.uk*
CAD	*Computer Aided Design*
CC	*Concrete Canvas (Product)*
CCH	*CC Hydro (Product)*
CCHQ	*Concrete Canvas Ltd Headquarters*
CCL	*Concrete Canvas Ltd (Company)*
CQA	*Construction Quality Assurance*
CQC	*Construction Quality Control*
Cut Edge	*An open edge to a GCCM*
DIS	*Drop in Specification*
FFS	*Final Flexural Strength - the maximum strength of the GCCM during a flexural strength test*
GCCB	*Geosynthetic Cementitious Composite Barrier*
GCCM	*Geosynthetic Cementitious Composite Mat*
HDPE	*High-density Polyethylene*
H&S	*Health and Safety*
IFS	*Initial Flexural Strength - the first crack of the cementitious material in a GCCM during a flexural strength test*
LDPE	*Low-density polyethylene*
LLDPE	*Linear low-density polyethylene*
Machine Edge	*A closed, manufactured edge to a GCCM*
MQC	*Manufacturers Quality Control*
MQA	*Manufacturers Quality Assurance*
PPE	*Personal Protective Equipment*
PVC	*Polyvinyl Chloride*
Thermal Bond	*Heat fusion of two different materials (eg Polyester to PVC Concrete Canvas Joints)*
Thermal Weld	*Heat fusion of two identical materials (eg PVC to PVC CC Hydro Joints)*
UK	*United Kingdom*
V_{REC}	*An anchor fixings recommended allowable shear force as specified by the manufacturer*
Warmer Climate	*Arid, Tropical or Mediterranean climates in regions such as parts of Africa, the Middle East and Oceania where additional detailing is required to ensure successful installation.*
Water/cement ratio	*The ratio of water to cement in a concrete mix*
Water/cementitious materials ratio	*The ratio of water to the cementitious materials (cement, aggregate and additives in a GCCM cementitious layer*

1.0 Introduction

1.1 Background

Concrete Canvas® (CC) is the original Geosynthetic Cementitious Composite Mat (GCCM) and the first product to declare conformance to ASTM D8364 'Standard Specification for GCCMs'.

CC is a flexible, concrete filled geotextile that hardens on hydration to form a thin, durable and waterproof concrete layer. Essentially, it can be described as *Concrete on a Roll*™ and is used for a wide variety of applications including the rapid lining of drainage channels, providing slope protection, weed suppression, culvert repair and general concrete remediation.

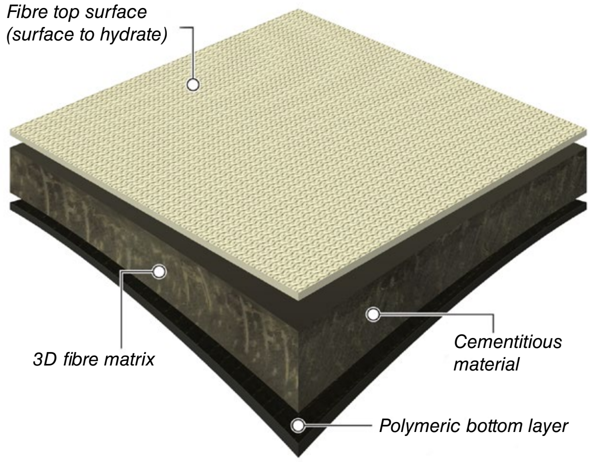


Figure 1.1 Typical CC cross section

1.2 Scope and General Disclaimers

CC is typically used to replace conventional concrete (in-situ, precast or sprayed) for erosion control and weed suppression applications. There are some fundamental differences in how CC should be specified and installed for each application so we have created individual Specification Guides as detailed in figure 1.2 below:

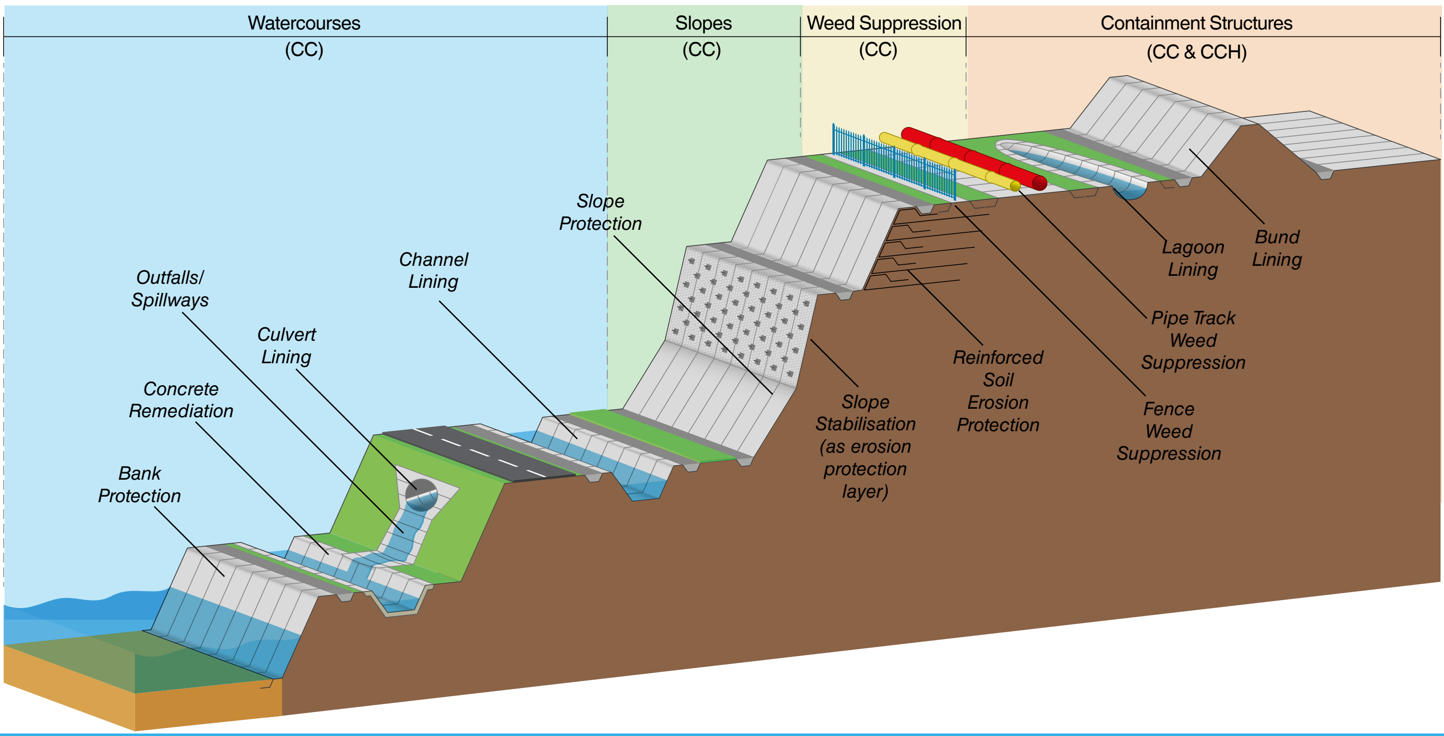


Figure 1.2 Typical CC applications

The information contained in this document is provided subject to the General Disclaimer on the last page of this document. A printable copy of the current version of our General Disclaimer is maintained at the following *link*. Subject to the above:

- This document provides information, based on standardised details, which may assist in the design, specification and installation of CC in **watercourses**. The designer must decide on the appropriate details to suit their site-specific needs and take into account the associated risks and health & safety implications.
- The performance of the CC is wholly dependent on the quality of its design and installation. It is the installer's responsibility to adhere to these guidelines where applicable and to the designer's project specification and drawings.

- The versatile nature of CC means that this document is not exhaustive and is intended for guidance purposes only. Exceptions to this may be required to address site-specific conditions.

1.3 Details to be Specified Before Procuring and Installing

Before CC installation begins, the following details should be specified by the designer:

1	GCCM TYPE	The product type required to suit the site-specific loading/abrasion conditions
2	SUBSTRATE	The substrate preparation requirements to provide adequate bearing capacity, protection to the CC backing layer and any required substrate drainage details
3	LAYUP	The layup orientation of the material (eg transverse or longitudinal for channels and culverts, vertical or horizontal for bank protection)
4	JOINT	The overlap joint specification in order to relieve the build-up of hydrostatic pressure or prevent water seepage
5	EDGE FIXINGS	The edge (perimeter) fixing details and the connection to existing infrastructure to prevent wind and water ingress
6	INTERMEDIATE FIXINGS	Determine if intermediate fixings are required to prevent movement under project specific load conditions and if so, determine the spacing and specification of the fixings
7	PROJECT SPECIFIC DETAILS	Project specific details such as accommodating pipe penetrations, junctions and baffling

1.4 Terminology Used in This Document

The terminology below is intended to assist the client, designer and installer in ensuring the design details are correctly specified and fully understood:

1.4.1 Watercourse Terminology

When GCCMs are used to provide erosion protection to watercourses they can either be used to line channelling structures or sloped structures as shown in figure 1.3 below

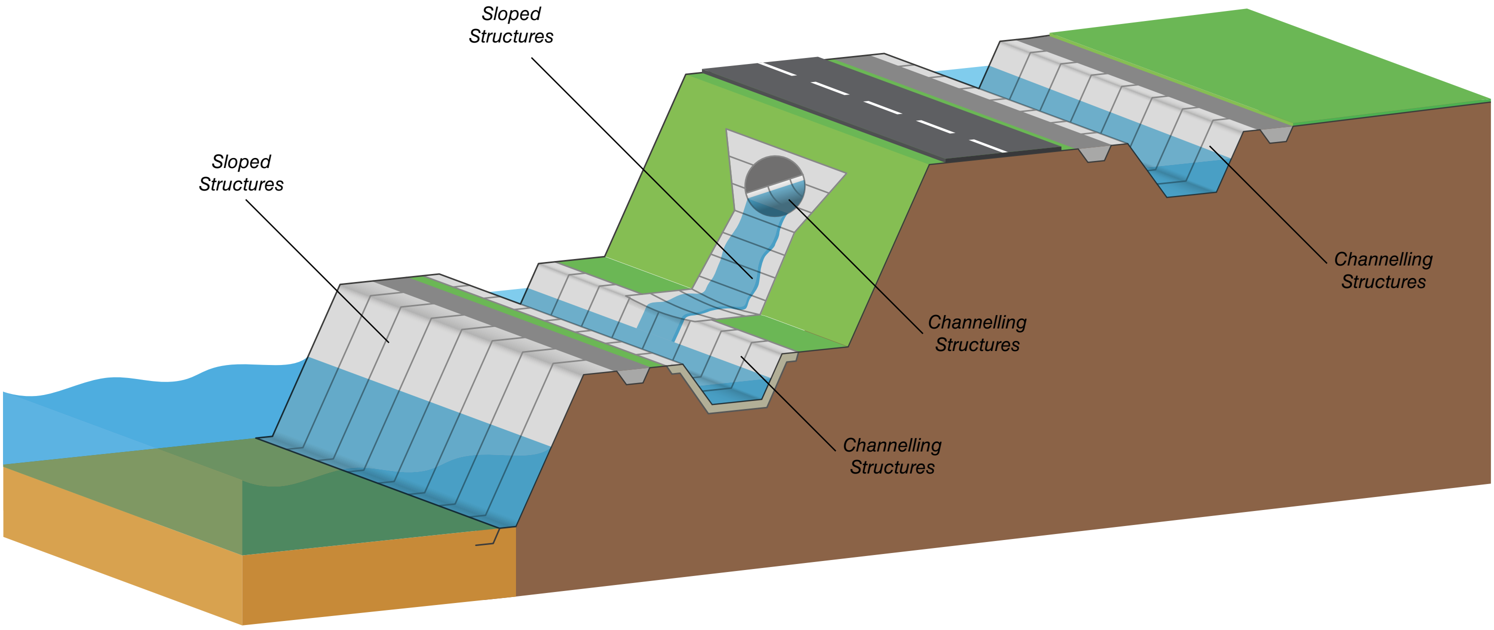


Figure 1.3 Typical watercourse structures

1.4.2 Channelling Structure Terminology

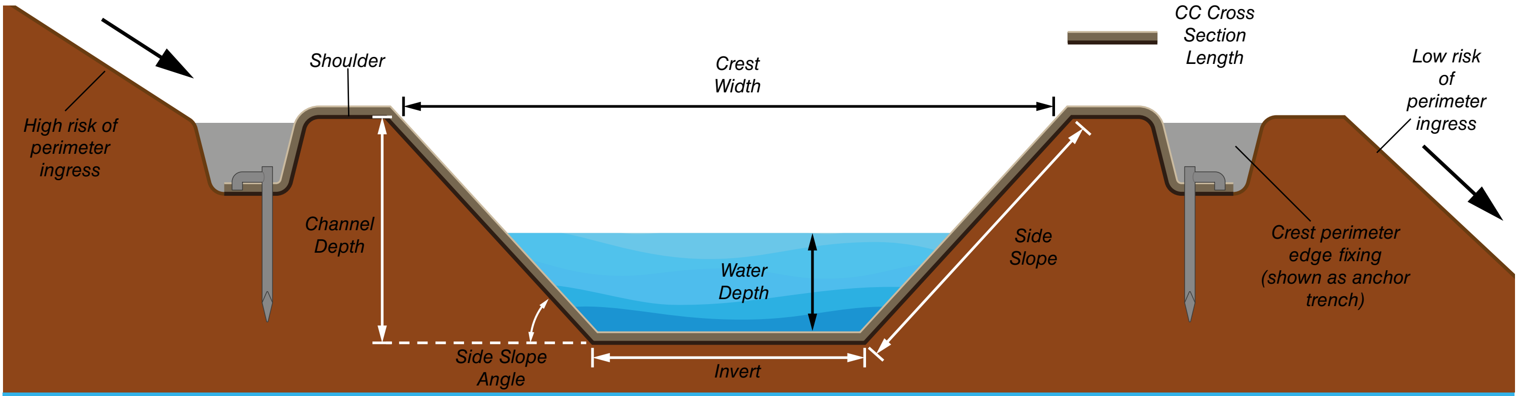


Figure 1.4 Channel cross section

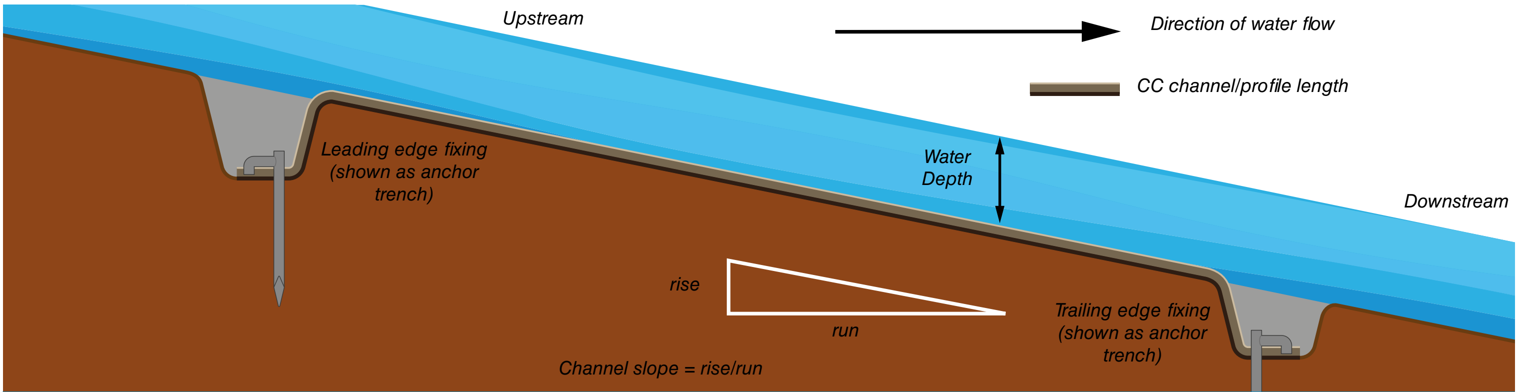


Figure 1.5 Channel profile

1.4.3 Sloped Structure Terminology

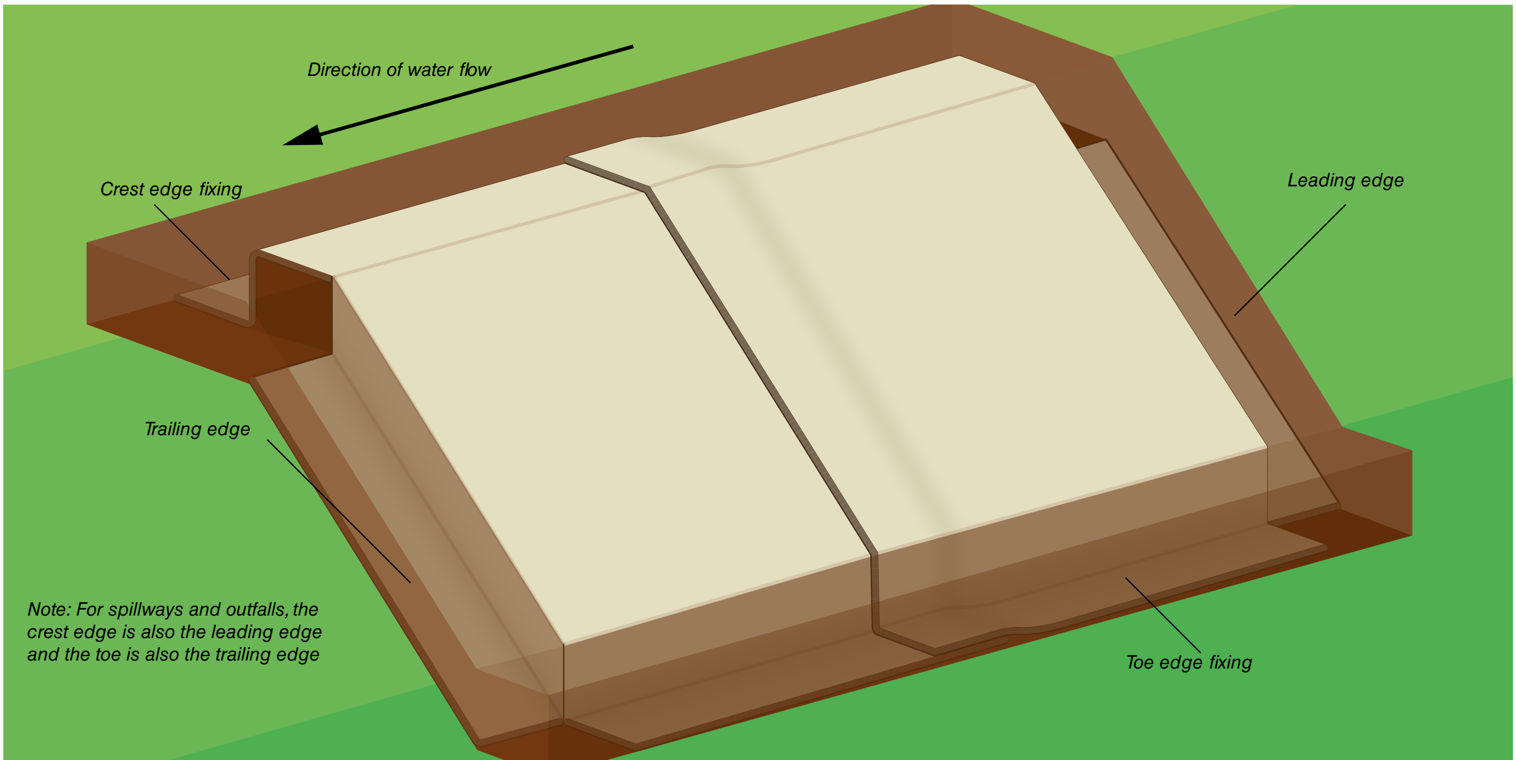


Figure 1.6 Bank isometric drawing

1.4.4 CC Material Terminology

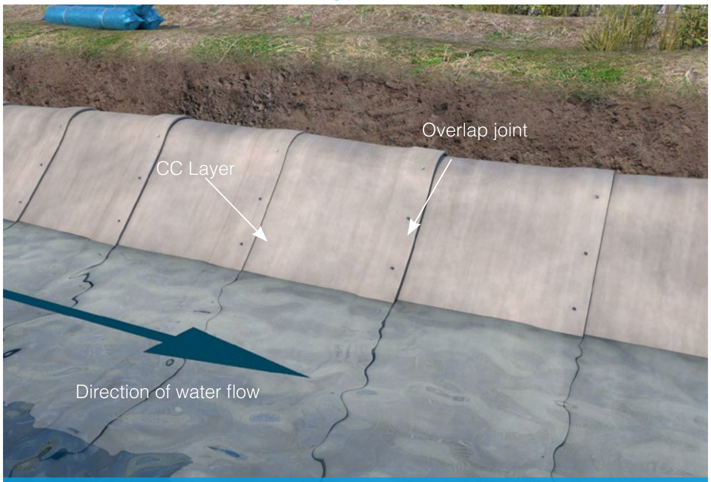


Figure 1.7 CC Layup

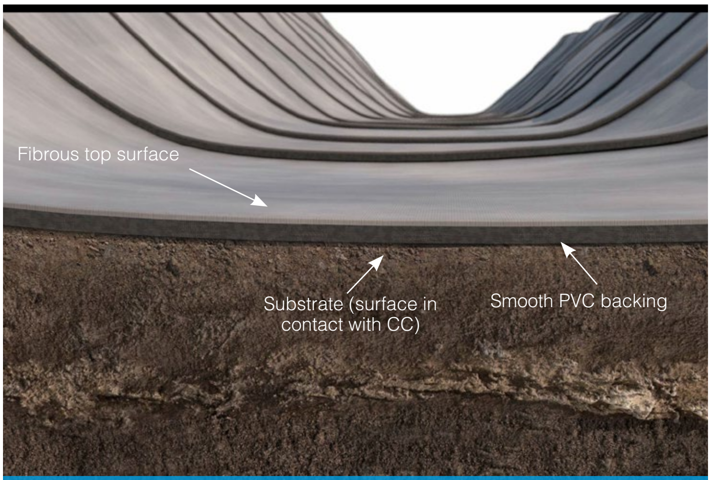


Figure 1.8 CC Cross Section

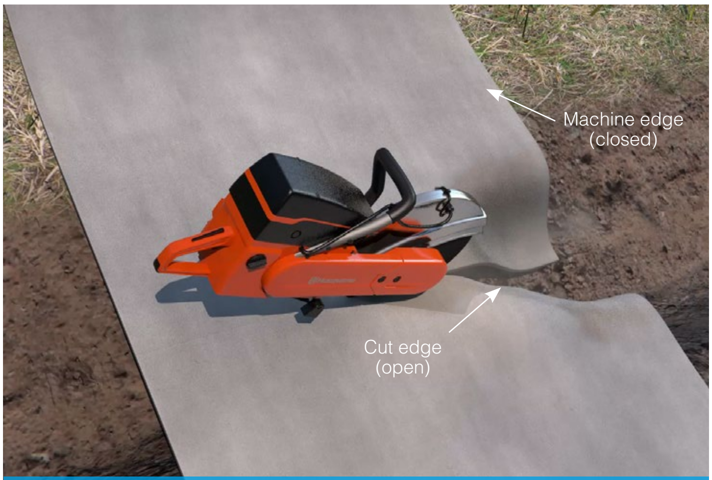


Figure 1.9 CC Edges

1.4.5 Warmer Climates

The symbol above denotes important information for use in 'Warmer Climates' - Arid, Tropical or Mediterranean climates in regions such as parts of Africa, the Middle East, Southern US and Oceania where additional detailing is required to ensure successful installation. 'Warmer climates' also covers projects where the material will be installed when drying conditions are present and there is a potential for drying shrinkage to occur – see section 7.4. Warmer Climate information is indexed with this symbol in the contents.

2.0 Specifying the Correct CC Material

2.1 Concrete Canvas Ltd Products

Concrete Canvas Ltd manufactures products in 2 material classes; GCCMs (e.g. Concrete Canvas®) and GCCBs* (e.g. CC Hydro™).

2.1.1 Erosion Control and Weed Suppression - GCCMs

GCCMs should be used to provide effective erosion control, armouring or weed suppression to watercourses that control stormwater, raw (untreated) water, salt water or non-pollutants. The British Board of Agrément (BBA), a globally recognised construction material certification body, has independently tested, assessed and certified CC for use in erosion control and weed suppression applications with a durability in excess of 120 years. For more details the BBA certificate can be viewed here.

2.1.2 Containment Critical Applications

Although GCCMs provide waterproofing properties, water can still migrate through the joints of adjacent layers. Several joint methods can be used to reduce water loss but these are reliant on the work of the installer, the overall permeability of an installed structure cannot be tested or proven.

If containment of water is critical, then a GCCB should be used as the product has testable joints for quality assured containment applications. See the Containment Structures Specification Guide for specific information on CC Hydro™.

2.1.3 Contact with Pollutants

If pollutants such as acids, leachates, hydrocarbons and sulphates will come into contact with the GCCM/GCCB, the suitability for use in the application will need to be assessed. Chemical data should be sent to Concrete Canvas Ltd for assessment, as constant immersion in pollutants (in particular acids below pH4) could affect the durability of the CC material.

2.2 CC Material Type

CC is manufactured in three types that are 5, 7 and 11mm thick respectively. The three types are used to suit site specific loading and erosion conditions. The designer of the CC installation should specify the appropriate CC type for the application:

- CCT1™ is a Type I GCCM and can be used to line structures with minimal requirements for abrasion and wear, be exposed to flow velocities up to 2m/s, is not expected to withstand impact loading and must be installed on a solid substrate such as concrete or rock. CCT1™ can also be used for some temporary installations. CCT1™ conforms to Type I requirements of ASTM D8364.
- CCT2™ is a Type II GCCM and is the standard thickness specified for watercourse applications, can be installed on soil substrates and is recommended unless either of the conditions above or below apply. CCT2™ conforms to Type II requirements of ASTM D8364.
- CCT3™ is a Type III GCCM and should be considered where a structure is exposed high abrasion or wear, or exposed to hydraulic jump and turbulent flow, or expected to withstand high levels of debris impact and loading, or resist dynamic loads such as wave action. CCT3™ conforms to Type III requirements of ASTM D8364.

ASTM D8364 is the Standard Specification for GCCM Materials and sets minimum performance properties for GCCM Types. See the *CC Spec Sheet to ASTM D8364* for more details on CC physical properties.

It should be noted that CC replaces conventional concrete for erosion control applications. CC shall not be used for structural applications or to provide a stabilisation/retention function.

* Geosynthetic Cementitious Composite Barrier

2.3 Roll Format

Consideration should also be given to the site access, watercourse dimensions and available roll format. CC is available in three standard formats (roll sizes) which are; Bulk Rolls, Batched Rolls and Wide Rolls.

Bulk Rolls are the most popular roll format and weigh between 1.5 and 1.6 tonnes. When unpackaged the rolls are approximately 1.2m in diameter and supplied on 150mm internal diameter cardboard cores for hanging from a suitable spreader beam and unrolling using appropriate plant.

Batched Rolls are supplied on 75mm internal diameter cardboard cores with carry handles designed for a 2 to 4 person lift for small or restricted access projects. Using Batched Rolls may be less economical if the CC watercourse structure dimensions results in excessive wastage. It is often preferred to minimise wastage by cutting bespoke batched lengths on site from standard Bulk Rolls. The Bulk Rolls can be suspended from oil drum jacks, then unrolled and cut to the site-specific batched length as required, see figure 2.2 below.

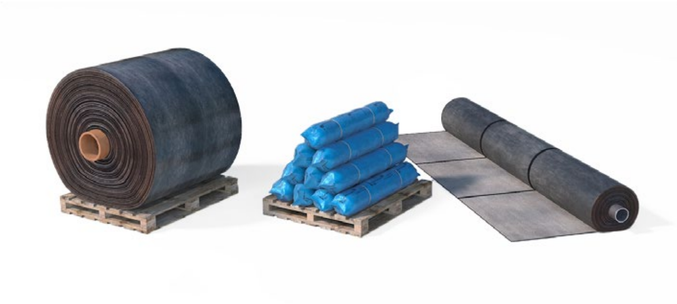


Figure 2.1 Bulk, Batched and Wide Rolls

Figure 2.2 Bulk Roll dispensed from oil drum jacks

Wide Rolls of CCT1™ and CCT2™ material can be manufactured to order by factory seaming Bulk Rolls to make them '2-Wide' or '3-Wide'. Wide Rolls are shorter in length than Bulk Rolls but can provide installation advantages by reducing jointing requirements. Wide Rolls are supplied on 126mm internal diameter HDPE cores for hanging from a suitable spreader beam and unrolling using appropriate plant.

All CC thicknesses can be supplied batched to custom lengths for a small additional charge.

The quantity per roll differs between the CC types and formats as shown in the table 2.1 below.

			Batched Roll			**Bulk Roll**		
CC Type	Thickness (mm)	Dry Weight (kg/m²)	Width (m)	Length (m)	Area (m²)	Width (m)	Length (m)	Area (m²)
CCT1™	5	8	1.0	10	10	1.0	170	170
CCT2™	7	12	1.1	4.55	5	1.1	114	125
CCT3™	11	19	N/A	N/A	N/A	1.1	73	80

			2-Wide Roll			**3-Wide Roll**		
CC Type	Thickness (mm)	Dry Weight (kg/m²)	Width (m)	Length (m)	Area (m²)	Width (m)	Length (m)	Area (m²)
CCT1™	5	8	2.0	53.5	107	3.0	31.3	94
CCT2™	7	12	2.2	25	56	3.3	20	66
CCT3™	11	19	N/A	N/A	N/A	N/A	N/A	N/A

Note 1: The reported 'Dry Weight' of Concrete Canvas material is the palletised material weight (eg 12kg/ m² for CCT2™). The material itself has a lower minimum weight to achieve in-service product performance, for example CCT2™ has a minimum QC pass weight of 10.5kg/m². Roll weights should not be used in an attempt to determine roll dimensions.

Note 2: Concrete Canvas material is supplied per square metre and our standard Bulk Rolls and Wide Rolls have an area tolerance of +5% / -2.5%. The tolerance on the width and length of each roll is balanced to ensure the correct area is supplied.

Table 2.1 CC Roll information

3.0 Specifying the Subgrade Preparation Requirements

3.1 Surface

If CC is being used to line an existing watercourse, first plan and specify measures for diverting any flowing water. Although CC can be installed in immersed conditions, it is much easier to install when the substrate does not contain water >0.1m deep. CC must not be installed in water flows in excess of 1m/s (although when properly designed, once cured it can be used in much higher flow rates, see section 7.3).

CC must be placed in direct contact with the substrate surface to prevent voids beneath the material. If the CC is unsupported by the substrate then it will be exposed to a greater risk of damage by external impact loading. Do not proceed with installation until satisfactory substrate conditions are established.

The substrate should be prepared so it provides the required bearing capacity, is geotechnically stable and has a smooth and uniform surface. CC will conform to the underlying substrate profile, an irregular substrate will result in an irregular surface to the hardened CC material and in some applications this may be desirable.

3.1.1 Soil Substrates

For soil substrates, remove any vegetation, sharp or protruding rocks or foreign matter and fill any large void spaces >50mm. Ensure the CC makes direct contact with the substrate to minimise soil bridging or potential soil migration under the layer. Typical preparation surface and cured CC appearances are shown below.

Figure 3.1 CC spillway installed on a trowelled sharp sand substrate (images taken before and after install)

Figure 3.2 CC channel prepared with a ditching bucket (images taken before and after install)

Figure 3.3 CC bank protection on a raked soil substrate (images taken before and after install)

Figure 3.4 CC channel prepared with hand tools (images taken before and after install)

3.1.1.1 Creating a Uniform Profile

The uniformity of the channel can vary depending on the soil type and tools available on site. Ditching buckets can be attached to excavators to save time in preparing channel side slopes, see figure 3.5. They are a fast, effective method of creating uniformity, but if the soil has a high stone content the profile may still not be consistently smooth.

Another cost-effective method of creating a uniform profile is to use a formwork. These can be made using timber and basic hand tools to create the channel profile, then lifted into position to allow soil to be tamped in to create a smooth surface on which to install the CC:

Figure 3.5 Ditching bucket to create profile

Figure 3.6 Large scale formwork to create profile

3.1.2 Solid Substrates (Concrete, Rock or Metal)

For concrete, blockwork or rocky substrates, remove any loose or friable material, cut away any protrusions and fill any large cracks or voids >50mm.

3.1.2.1 Metal Culverts

When lining metal culverts, remove vegetation, soil, gravel and any debris from previous linings (such as loose bitumen coatings) to expose the corrugations in the culvert. High pressure jet washing is often used. Non-structural damage to the culvert (eg voids or pitting created by the rust or corrosion) must be filled with concrete, grout or compacted gravel depending on the designer requirements. Large bolts or protrusions that may cause the CC to snag should be smoothed out using suitable concrete or grout.

The designer must confirm whether the corrugations are to be filled as part of the CC lining solution. Filling the corrugations ensures the material is properly supported, providing optimum durability and resistance to dynamic loading. In some low flow, low impact applications, culverts have been lined in CC without filling the corrugations. On these projects the working life of the culvert has been extended by 5-10 years.

If the designer confirms the corrugations are to be filled, this is typically carried out before installing the CC, by using a suitable rapid set, non-shrink grout. This method is often used when there is damage to the culvert that must be filled at the same time. Alternatively, if there is no significant damage to the culvert, the corrugations in the invert must be filled prior to placing the CC but the sides of the corrugations can be left unfilled until the CC has been hydrated and cured. Once cured the space between the CC and the side corrugations can be infilled using a suitable material, for example a cement grout or roofing tar (depending on environmental regulations). Additional intermediate fasteners may be required when filling behind cured CC to ensure the material does not lift from the culvert and should be specified by the designer.


Figure 3.7 Before the installation of channel remediation


Figure 3.8 After the installation of channel remediation


Figure 3.9 CC culvert lining with grouted corrugations


Figure 3.10 Completed CC culvert lining project

3.1.3 Hydraulic Features (e.g. Baffling, Cascades and Silt Traps)

Hydraulic features such as baffling, steps, cascades and silt traps can be incorporated into the subgrade prior by placing sandbags, sleepers or compacted soil prior to the installation of the CC. See section 8.1 for protection recommendations.

3.2 Perimeter Edge Preparation

The perimeter edge fixing (see section 6) should be considered at the time of preparing the substrate. If the CC is terminating into anchor trenches, they should be excavated at the time of substrate preparation. Anchors trenches are necessary when terminating into soil, but providing the substrate can be removed to form the required trench dimensions they can also be used on concrete or rock. Anchor trench dimensions must be a minimum of 150mm x 150mm but may need to be increased to suit the design requirements. See section 6.2.

When lining concrete structures or terminating into competent solid structures such as rock or steel culverts, perimeter edges can be secured by connecting with suitable mechanical fixings. See section 6.3.

3.3 Bearing Capacity and Differential Movement

When installing on soft soil substrates, CC should not be trafficked during installation. On restricted access projects where installers have no option but to walk on CC, the surface can be protected by using timber boards to prevent boots from creating depressions in the material prior to hydration and curing.

If trafficking is required for future maintenance or inspection, the designer can specify that the subgrade is improved by placing and compacting gravel beneath the CC to improve the bearing capacity. The substrate should be compacted to the bearing capacity as required by the design before deploying CC.

Heavy vehicular traffic must not be permitted directly on the CC unless the subgrade has been prepared with sufficient California Bearing Ratio (CBR) strength to support vehicle traffic without causing rutting. Rubber-tyre vehicles and trucks can traffic unhydrated Concrete Canvas (on a suitable substrate) if wheel contact pressure is less than 55 kPa. It is not recommended for vehicles to turn on CC as torsional loads can ruck the surface of the material. In areas of heavy traffic or when tracked vehicles will travel over the CC, the material must be protected by placing an adequate protective cover (such as protective mats, block paving or a suitable gravel layer) over the top of it.

Differential ground movement may occur when the substrate beneath a CC lined structure deforms, potentially due to significant settlement, surface loading conditions or expansion in soils by ground or frost heave. In such scenarios, CC is expected to deform to accommodate ground movement by extension, causing microcracking of the fibre reinforced concrete matrix of the CC material and strain of the PVC backing layer. Under microcracking conditions, the 3D fibre matrix in CC prevents crack propagation and spalling of the concrete layer. Therefore, in differential ground movement conditions the concrete matrix can still provide protection to the PVC backing so the material will continue to act as an effective erosion control and weed suppression layer. The PVC backing will provide effective waterproofing until it has strained to a point where its permeability is compromised.

Our *Differential Ground Movement* report provides an insight into how CC can accommodate settlements and movements.We conservatively advise that CCT1™ and CCT2™ can accommodate approximately 5% strain before the PVC waterproof backing could potentially become compromised, and 2% for CCT3™. Details of the testing and theoretical maximum allowable bending is summarised in the report.

3.4 Geotextile

To prevent migration of fine soil particles through unexpected leakage paths causing erosion beneath the CC, in particular when permeable joints are specified (see section 5.0), the designer can specify a suitable geotextile is installed on the prepared surface before installing the CC. Placing a geotextile on the substrate can also keep the working area clean and tidy, as well as protecting the CC from snags in deployment and is recommended for most erosion control projects.

Figure 3.11 CC installed on a geotextile

3.5 Substrate Drainage

To reduce the risk of a build-up of hydrostatic pressure in high ground water or rapid drawdown situations, the designer can specify substrate drainage measures are installed beneath the CC layer. A sub-CC drainage layer of gravel (see Figure 3.12) or drainage geocomposite can be installed beneath the CC. Perforated pipes running parallel to the direction of the CC structure and discharging at cross drainage points may also be incorporated into the design (See Figure 3.13). In localised areas of high ground water, pressure relief valves (which let water in but not out of the CC structure) may be specified. Weep holes can be incorporated (protected with gravel and geotextile filter, or no fines concrete,) but these also allow water out of the CC structure and should only be used for weed suppression applications or when water loss is not critical.


Figure 3.12 CC installed on a granular sub-drainage layer


Figure 3.13 CC channel remediation

3.6 Unsuitable Substrates

When using CC to line watercourses, the material should not be installed upon degradable substrates (such as wood), or on damaged structural surfaces. Covering with CC will prevent easy inspection and maintenance of the substructure, so any potential further structural degradation will go unnoticed until failure occurs.

CC can be used to protect PVC geomembranes, but careful design is required to cover other geomembranes, in particular HDPE. Daily temperature fluctuations cause HPDE to expand and contract, creating wrinkles in the geomembrane. The HDPE wrinkling can also create wrinkles in the CC cover as it cures, compromising aesthetics and generating permanent void space beneath the CC. If you are considering using CC to protect a geomembrane, please contact Concrete Canvas Ltd for specific advice.

4.0 Specifying the Deployment Layup

4.1 Layup

4.1.1 Channelling Structures

The designer must specify the orientation of the material layup.

CC can be laid along the length of the channelling structure (longitudinal layup) or across the width (transverse layup).

Figure 4.1 Longitudinal Layup

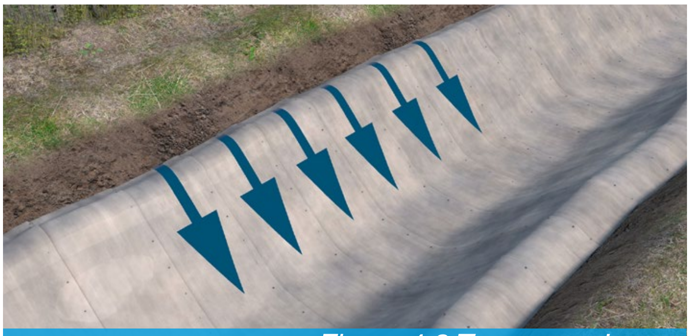
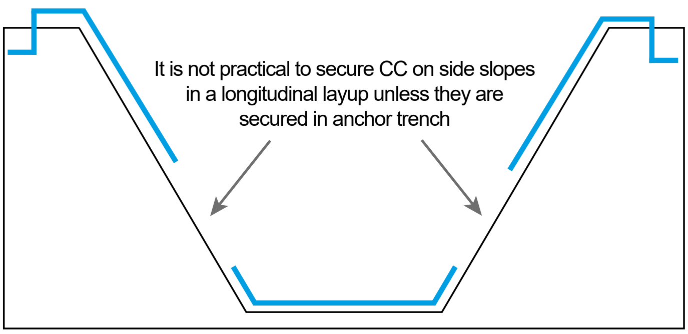


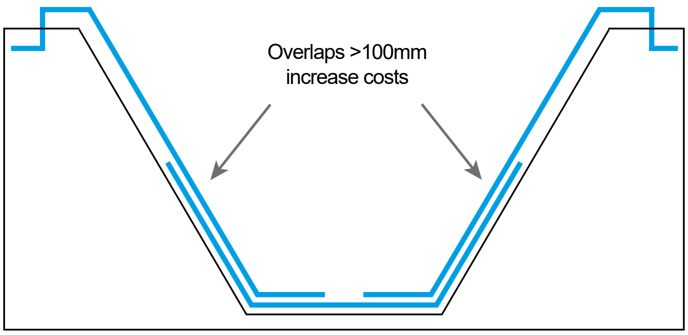
Figure 4.2 Transverse Layup

Laying longitudinally is typically faster than laying transversely but is often only suitable for straight channels where low-permeability joints are specified (see section 5.0). A transverse layup is the most common layup for channelling structures and is specified when any of the following conditions apply:

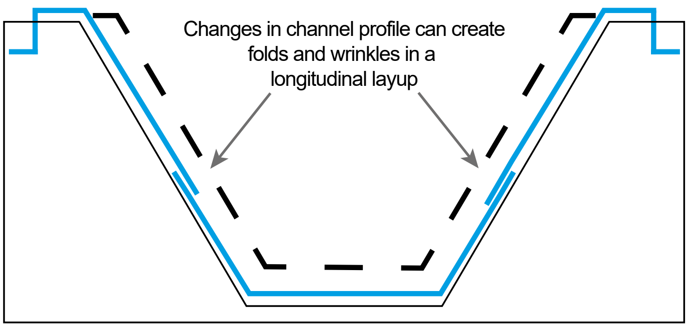
The channel side slopes are greater than the specified CC roll width (more than 3 longitudinal layers are required).



The channel geometry means that a longitudinal layup is materially wasteful.



The channel profile varies significantly along its length.



The channel has significant and/or frequent sharp bends.

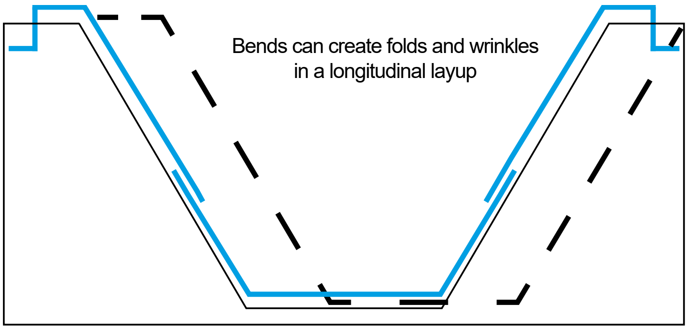


Figure 4.3 Transverse laying requirements

Typical 1-Wide layups are shown below. CC is available in Wide Roll widths allowing for larger channel profile installations, consult the *CC Standard Detail Drawings* for detailed dimension information.

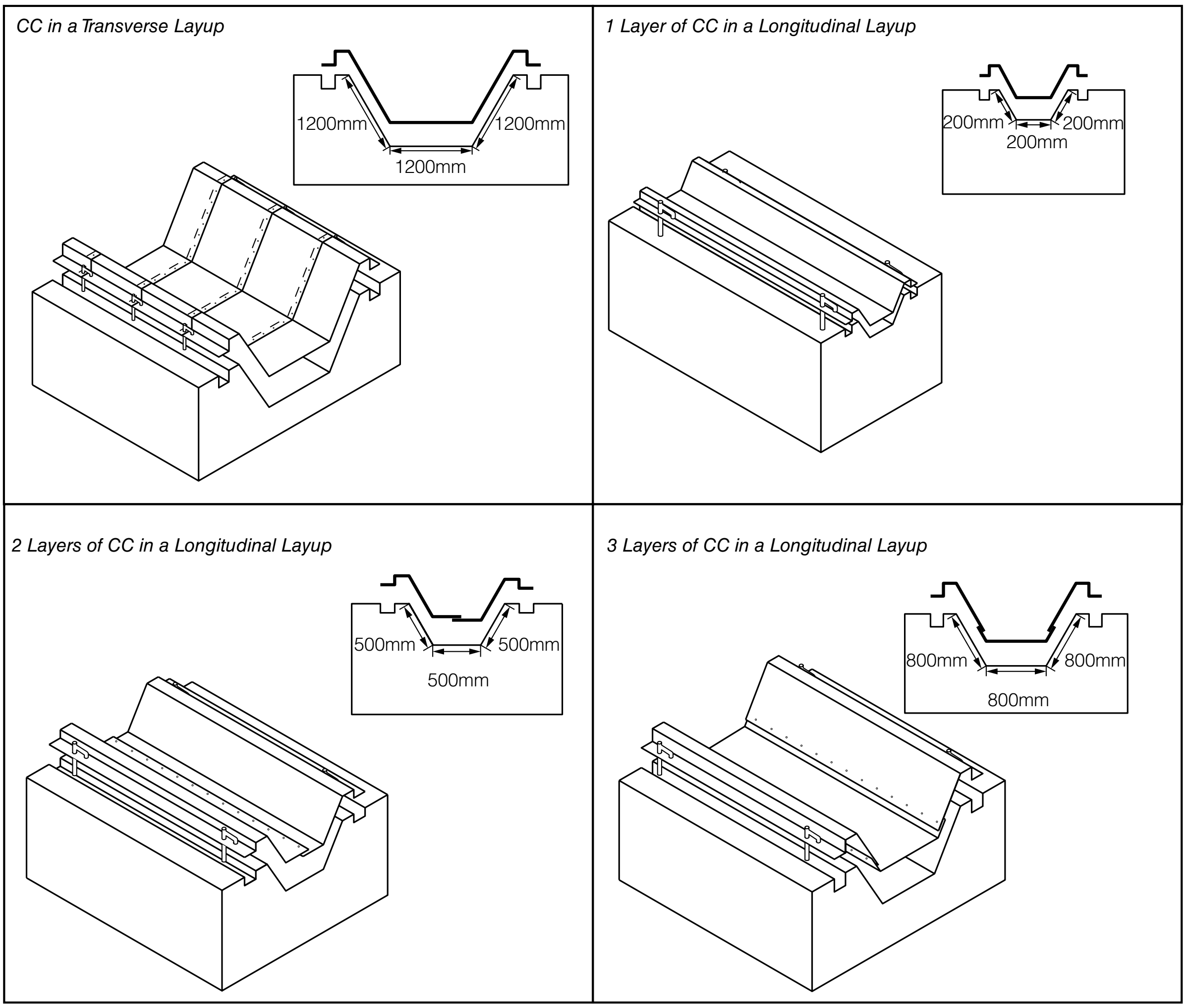


Figure 4.4 Typical channel layups

4.1.2 Sloped Structures e.g. spillways, outfalls and bank protection

Standard practice for bank protection is to lay CC vertically down the length of the sloped structure as this provides the fastest method of installation and allows each roll to be securely fixed at the crest of the slope. If the slope is designed to act as a flood bund or is in contact with a watercourse, care should be taken to position the overlap in the direction of water flow (like shingled roof tiles, see section 5.0). A horizontal layup can be practical for spillway or outfall applications to prevent water seeping through joints.

Figure 4.5 CC deployed for bank protection

Figure 4.6 CC deployed for a spillway

4.1.3 Culverts/Piped Structures

Culvert structures have limited access for heavy lifting equipment and for the majority of projects the CC is moved into position by hand. This will limit the length of CC material that can be handled into position and may dictate which layup is most practicable. Batched Rolls or bespoke batched lengths cut on site from standard Bulk Rolls are often used, Wide Rolls are not typically specified.

It is not common for CC to be installed above the springline (or maximum span for non-circular culverts). If the design requires the CC to extend beyond the horizontal, please contact Concrete Canvas Ltd for specific detailing and installation advice.

4.2 Laying

CC must be placed to ensure direct contact with the surface to prevent void space. It is recommended to begin CC installation downstream and work up gradient towards the source of the water flow (this ensures the overlaps are shingled correctly without requiring any material re-handling).

Remove packaging (making sure to note the Roll ID) and unroll CC to suit the specified layup, ensuring the fibrous top surface faces upwards, with the PVC membrane in contact with the substrate. This is achieved by dispensing the roll by naturally unrolling along the ground rather than pulling material from the top.

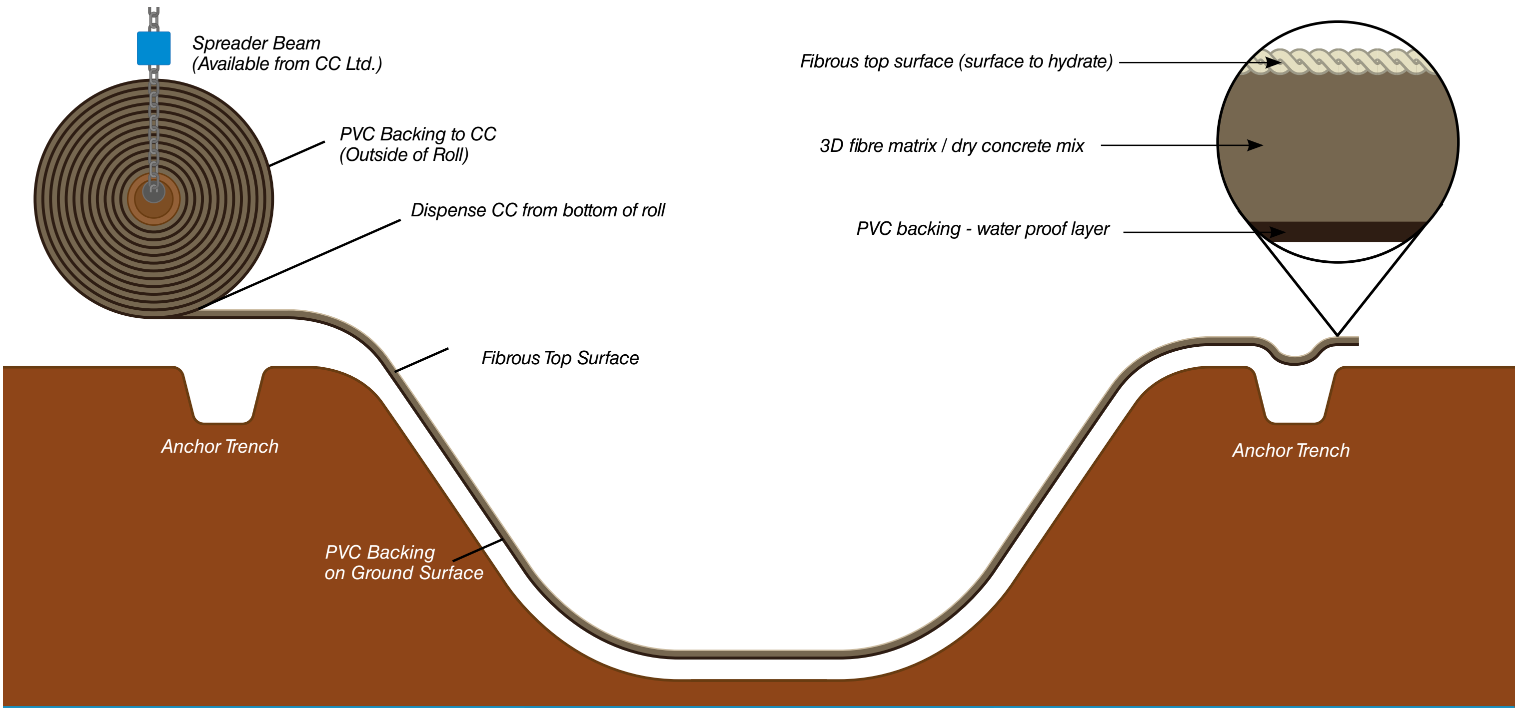


Figure 4.7 CC deployment

When installing transversely, dispense the CC from the crest of the slope, raising from the ground using the lifting frame with installers taking care to minimise snagging of the CC on the substrate. CC should not be released on a slope and allowed to unroll freely. This can overstretch the CC.

It is important to relax the material to relieve any tension generated in deployment. This can be achieved by lifting the CC layer by hand and repositioning. The installer can adjust the material to remove any wrinkles and ensure the CC conforms to the substrate when hand repositioning. Ensure the CC makes direct contact with the substrate to minimise void space, soil bridging or potential soil migration under the layer. If intermediate fixings are required (see section 7.0) secure from the top of the slopes to the bottom to minimise tension on the CC.

Ensure the edges of the first and last layers (trailing and leading edges) are either suitably terminated into existing infrastructure or tucked into the anchor trench to prevent water ingress and prevent scour beneath the material
See section 6.0 for leading and trailing edge details.

If necessary, prior to hydration the Installer must place temporary ballast, such as sandbags, on top of the laid Concrete Canvas to prevent wind uplift and ensure that it lies flat to the substrate on undulating ground to prevent voids from forming underneath the material. Only install what can be fully installed and hydrated before the end of the construction day to minimise any adverse effect on the installation and/or performance capabilities of the product.

4.3 Protection of the CC Surface

Personnel must not wear damaging shoes and trafficking of the product must be kept to a minimum to avoid staining of the surface, particularly with wet footwear prior to hydration. On restricted access projects where installers have no option but to walk on CC, the surface can be protected by using timber boards to prevent boots from creating depressions in the material prior to hydration and curing.

Smoking is not to be permitted on the product.

If installation continues the following working day, protect the edge of the last layer of CC overnight with waterproof sheeting to enable jointing on return to work.

4.4 Cutting

Tuck the perimeter edge of the CC into the crest anchor trenches, or ensure there is sufficient excess for securing to existing infrastructure, before cutting to length.

When cutting unset CC, a 15-20mm allowance should be left from the cut edge due to potential loss of fill.

A ‘snap-off blade’ utility knife can be used for cutting CC before it is hydrated or set. Use sharp blades and a smooth cutting action to prevent tearing or damage to the CC.

For larger projects where numerous cuts are required it is recommended to use a powered disc-cutter, angle grinder or a self-sharpening fabric cutter. If cutting with a disc cutter, it is recommended to wet the cut beforehand to minimise dust generation.

Note it may be possible for installers to peel the PVC from the cut edges of CC but this should be avoided to prevent unnecessary cement loss.

4.5 Overlapping

When positioning subsequent layers ensure there is at least a 100mm overlap in the direction of water flow (so they are shingled like roof tiles and water flows over the joints) and that the lapped material layers are in intimate contact with each other.

Ensure there is no rucking at the joint and there are no gaps, soil or debris between overlapped material as this might allow weed growth.

5.0 Specifying the Correct Joint Method

CC does not self-adhere and the CC overlaps must be physically joined together to create a monolithic system. Concrete Canvas Ltd has conducted extensive research to determine the most suitable methods for joining CC together to suit a variety of underlying substrates and permeability requirements.

All Concrete Canvas Ltd recommended joints have been laboratory tested and have a tensile shear strength greater than the 1st crack tensile strength of the cementitious material in the CC itself. This means that any settlements or movements will be accommodated by microcracking of the CC instead of joint separation. Microcracking is an acceptable deformation mode for CC, but joint separation could cause serviceability issues allowing water loss and weed growth between layers.

Note that in warmer climates, joint fixing specifications are more stringent as detailed in the following sections.

Each joint type provides different functions and the designer must specify the most appropriate joint for their specific application, based on the loading and water impermeability requirements of the project.

5.1 General Guidance

5.1.1 Overlapping

CC must always be overlapped by a minimum of 100mm and jointed to form a continuous GCCM structure. When used in hydraulic applications, the overlaps must be shingled in the direction of water flow so that water flows over the joints rather than in to them (see Figure 5.1).

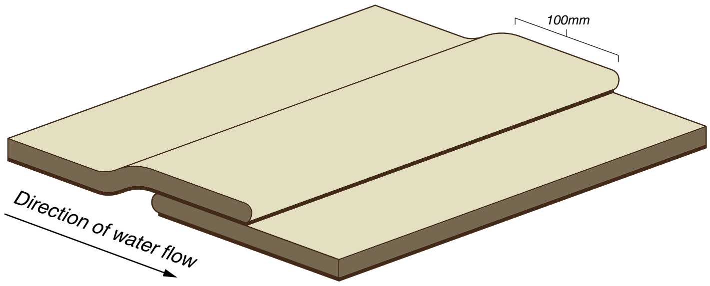


Figure 5.1 Shingled overlap layup prior to fixing

5.1.2 Joint Methods

For the majority of CC joints mechanical fixings are required to secure the materials together. Screws are typically used on soil substrates and throughbolts or screw anchors are used in solid substrates. Note that nails and shot fired nails are not recommended for jointing CC. The only instance when CC does not typically require mechanical fixings is when a thermal bond overlap joint is used.

5.1.3 Hydration of the Overlaps

5.1.3.1 Screwed and Screwed and Sealed Overlap Joints

When jointing CC using screws and adhesive sealants it is important to hydrate under the overlap prior to jointing. This is necessary to provide sufficient moisture for curing of both of the cementitious layer and the adhesive (if used). Adhesive sealants benefit from pre-hydration as this cleans the jointing surface of dry cement dust prior to the application of adhesive and the moisture helps to cure the adhesive during setting. When adhesive sealant is used, joints may be damp during installation, but have no standing water.

In some circumstances it may not be possible to hydrate underneath the screwed/ screwed and sealed overlap prior to fixing. This is not generally advised, as the underlap material will only be partially hydrated, however it may be acceptable if certain conditions exist. For example, if the joint is going to be continually exposed to water due to the nature of the application, the underlap material will slowly hydrate through infiltration.

Please be aware, that in these instances, the joint strength may be compromised. For example a screwed joint relies on the CC setting around the thread of the screw, therefore the short-term strength will be significantly lower until full hydration is achieved. If the CC underlap is not hydrated prior to screwed/screwed and sealed jointing, the joints will typically achieve a long-term strength which is 30-40% lower than if the underlap was hydrated prior to jointing. This has the potential to cause serviceability issues.

When planning a CC installation, the installer must ensure water resources are available for hydration of underlaps.

The following minimum water requirements are necessary to hydrate a 200mm wide, 1m length of CC:

CCT1™ - 700ml
CCT2™ - 1,000ml
CCT3™ - 1,500ml

For small projects or when water is not freely available on site, water can be stored in jerry cans which can be used to hydrate the underlaps until the entire structure is hydrated at the end of the day using a larger scale water supply (see section 9.0).

5.1.3.2 Thermal Bond Overlap Joints

When jointing CC by thermal bonding, it is important not to hydrate under the overlap prior to jointing. the CC material must be dry and protected from exposure to water prior to thermal bonding.

5.1.4 Suitability of Adhesive Sealants

It is important that only adhesive sealants that have been tested and approved by Concrete Canvas Ltd are used. Soudaseal 250XF is stocked at CCHQ, but a number of other products have also been approved for use and a full list of approved CC sealants can be provided on request. Concrete Canvas Ltd approval of a particular adhesive sealant is based on the long-term mechanical durability, and the designers/installer should check that it is suitable for site specific conditions such as risk of contamination or harm to aquatic life. It is recommended that when considering specifying an adhesive sealant, the safety data sheet and technical data sheet are reviewed and approved by the designer/client as being suitable for their project.

Adhesive sealants have a shelf life and it is not recommended to used products past their expiration date.

5.2 Installing on Soil Substrates

5.2.1 Screwed Overlap Joints

Impermeability Rating: ●○○○○
Mechanical Strength: ●●●○○

This joint is suitable for the majority of CC watercourse erosion control applications. It is fast and simple to apply, providing good mechanical strength and sufficient impermeability for flowing water, while providing a weep path to relieve ground water pressures.

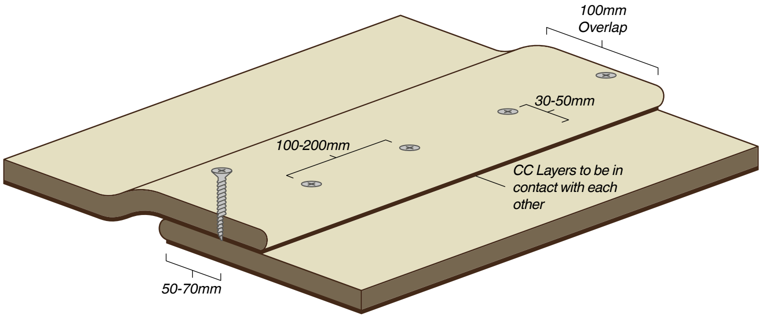


Figure 5.2 Standard screwed overlap joint

The following equipment is required:

- 30mm long stainless steel screws (grade 304), minimum 4mm diameter with a coarse fully threaded shank, collated screws are recommended for large projects (available from Concrete Canvas Ltd).
- Battery powered screwdriver or autofed screwdriver for large projects
- Supply of water for hydration under the overlaps

Procedure:

1. Joint Alignment: Overlap the layers by a minimum of 100mm in the direction of water flow and ensure that the two layers are in contact along the length of the joint.
2. Surface Preparation: The overlap should be lifted so that the CC material underneath can be hydrated. Once hydrated, fold back the top CC layer to ensure both layers are in contact again.
3. Installation of Screws: Once hydrated CC has a 1-2 hour working time in ambient temperatures of 10-22°C reduced in warmer climates). Screws must be applied before setting begins so the concrete within CC will set around the thread of the screws. The screws should be applied at 200mm spacing (maximum 100mm in warmer climates) and 30-50mm from the edge of the CC, see Figure 5.2.

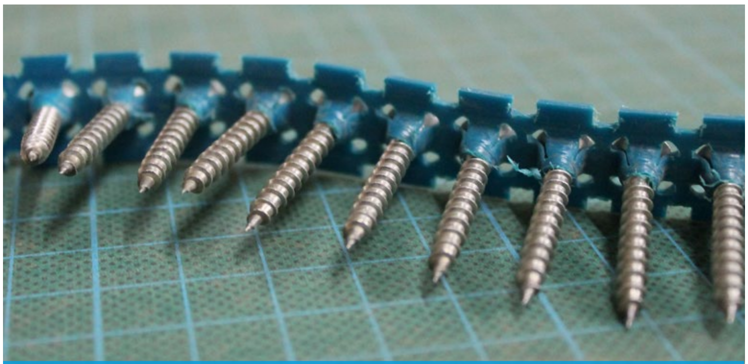


Figure 5.3 Stainless steel collated screws

Figure 5.4 CC joint fixed using an autofed screwdriver

Notes:

- Positioning screws too close to the edge will reduce joint strength.
- Correct screw placement will help ensure intimate contact between CC layers, prevent washout of the substrate, and limit potential weed growth.
- Collated screws allow for the use of an auto-fed screwdriver which provides a rapid means of creating a screwed joint.
- It is not acceptable to replace screws with nails, as the smooth shank provides inferior pullout strength.
- Screw layouts can be installed in a Zig Zag pattern to reduce edge curling and weed growth, see section 5.2.4 for details.

5.2.2 Screwed and Sealed Overlap Joints

Impermeability Rating: ●●○○○
Mechanical Strength: ●●●◐○

For applications where improved impermeability is required, such as when standing water is present or seepage is a concern, the screwed overlap joint can be installed in combination with a Concrete Canvas Ltd approved adhesive sealant.

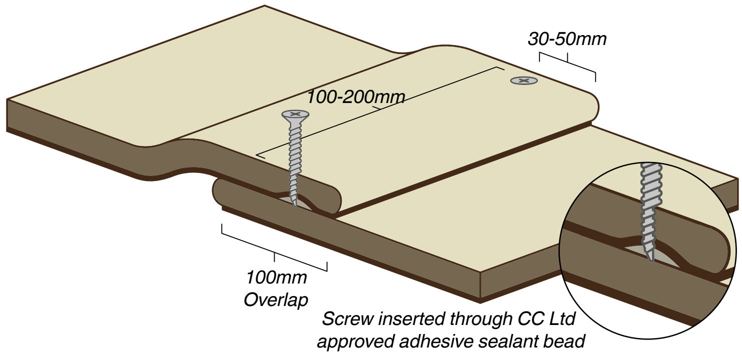


Figure 5.5 Screwed and sealed overlap joint

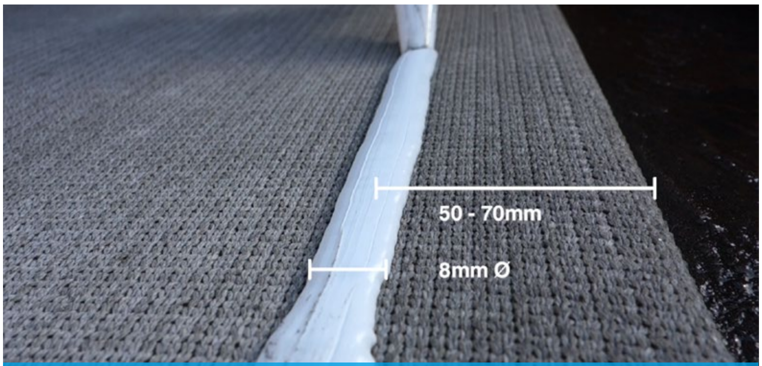


Figure 5.6 Sealant applied to under-lapped layer

The following equipment is required:

- 30mm long stainless steel screws (grade 304), minimum 4mm diameter with a coarse fully threaded shank, collated screws are recommended for large projects (available from Concrete Canvas Ltd).
- Battery powered screwdriver or autofed screwdriver for large projects
- Supply of water for hydration of the underlaps
- Concrete Canvas Ltd approved adhesive sealant and applicator (eg cartridge or barrel caulking gun depending on the format of the adhesive sealant)

Procedure:

1. Joint Alignment: Overlap the layers by a minimum of 100mm in the direction of water flow and ensure that the two layers are in contact along the length of the joint.
2. Surface Preparation: The overlap should be lifted so that the CC material underneath can be hydrated. **It is important to hydrate under the overlap prior to applying the adhesive sealant in order to remove excess dust, ensuring contact with the fibrous top surface of the bottom CC layer and to provide moisture for curing.** Surfaces may be damp during installation, but have no standing water.
3. Adhesive Sealant: Apply as an 8mm continuous bead, 50-70mm from the edge of the hydrated CC layer. An 8mm bead is equivalent to a coverage of 50ml/m which is equivalent to 5.8m of joint from a 290ml cartridge or 12m of joint from a 600ml cartridge
4. Installation of Screws: Once hydrated and sealant has been applied, fold back the top CC layer to ensure both layers are in contact again and the adhesive sealant is compressed. Once hydrated CC has a 1-2 hour working time in ambient temperatures of 10-22˚C (reduced in warmer climates) and screws must be applied before setting begins so the concrete within CC will then set around the thread of the screws. The screws should be applied at 200mm spacing (100mm for warmer climates) and 30-50mm from the edge of the CC through the sealant bead where possible to minimise leakage, see Figures 5.5 and 5.6.

Notes:

- Positioning screws too close to the edge will reduce joint strength.
- Correct screw placement will help ensure intimate contact between CC layers, prevent washout of the substrate, and limit potential weed growth.
- Collated screws allow for the use of an auto-fed screwdriver which provides a rapid means of creating a screwed joint.
- It is not acceptable to replace screws with nails, as the smooth shank provides inferior pullout strength.
- Screw layouts can be installed in a Zig Zag pattern to reduce edge curling and weed growth, see section 5.2.4.

5.2.3 Thermal Bond Overlap Joint

Impermeability Rating: ●●●○○
Mechanical Strength: ●●●●●

Thermal Bonding can be used to provide an improved impermeability joint. It can also be supplemented with screws for improved mechanical performance. The joint is formed using a hand-held heat gun to form a bond between the PVC backing of the CC and the polyester top surface.

The following equipment is required:

- **Automated hot-air welder** (eg Leister Twinny S or T) with a 50mm solid wedge set up

OR

- **Hand-held heat gun** with closed loop temperature control (eg. Leister Triac AT) with a 60mm perforated slot nozzle
- **Power supply** sufficient to provide uninterrupted power to the heat gun or welder (check manufacturers recommendations)
- **Seam Roller** 45mm (or similar)
- **Stiff Brush** for cleaning the CC surface
- **Wire Brush** for cleaning the equipment nozzles
- **Cleaning rags** for wiping the PVC backing
- **Safety Gloves**
- **Mask** (A2P3 filter or equivalent)

Procedure:

1. Joint Alignment: Overlap the layers by a minimum of 100mm in the direction of water flow and ensure that the two layers are in contact along the length of the joint. NOTE: unset material can be bonded to both set and unset material, but the uppermost layer must be unset.
2. Surface Preparation: the fibrous top surface should be cleaned of any surface dust using a stiff brush and the PVC backing should be clean and dry.
3. Tool Preparation: The automated hot-air welder or hand-held heat gun (fitted with the 60mm perforated slot nozzle) should be adjusted to achieve the required joint strength using the calibration guidance in step 5 below (450°C is a good starting temperature) to create a 'Trial Joint'. Leave the gun on for approximately 5 minutes to reach temperature. If using a tool with a digital read-out this should be indicated on the display. Wear heavy gloves and a mask as the heat gun will be hot and give off fumes. Only thermal bond in a well ventilated area.

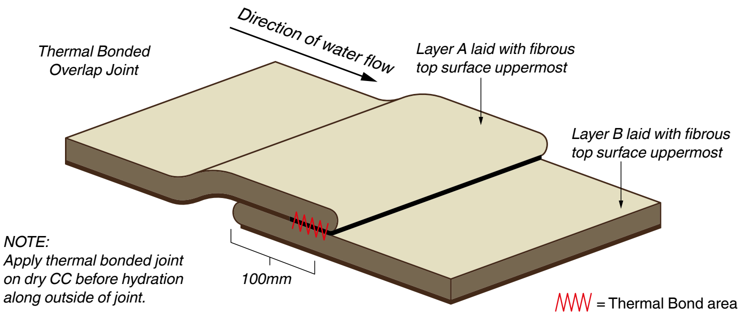


Figure 5.7 Thermal bonded overlap joint

Figure 5.8 Thermal bond details

4. Thermal Bonding:

A) Bonding with an automated hot-air welder: Once up to the required temperature, position the welding nozzle between the two layers of CC and start the automatic welding as per the Leister instructions. A 'Trial Joint' is essential since the speed and temperature settings will vary depending on ambient temperature and humidity. Reasonable starting settings are: Speed = 1.4 Heat = 4.5 (450°C). While running, adjust the path of the welder as required to maintain joint alignment. Note: Overtightening of the clamping pressure setting may result in the welder running off track.

OR

B) Bonding with a Hand-held heat gun: Once up to temperature, position the heat gun nozzle just inside the joint, with the nozzle perforations upper-most, directing the hot air onto PVC backing. Aim to bond the overlap along a strip nearest to the outside of the joint (see figure 5.8). Working your way from one end of the joint to the other, follow the welder with the 'Seam Roller' to apply pressure to the softened PVC and top fibres to form a bond. Weld rate is approximately 1m/min.

5. Trial Joint / Calibration: Prior to welding a field joint, it is necessary to conduct a 'Trial Joint' to set the Automated welder/heat gun to the correct temperature and weld rate. As a rule of thumb the following can be used as a guide:

A. Too slow / Too hot: Fibres char and turn black whilst producing large amounts of blue/white smoke.

B. Too fast / Too cold: Joint will pull apart after cooling without causing delamination of the PVC.

C. Correct Speed / Temperature: Some smoke produced during welding. Joint will pull apart after cooling with delamination of the PVC.

Note that once hydrated, the cementitious material from both CC layers will cure together to increase joint strength.

6. Cooling and Hydration: Leave the welded joint to cool for approximately 5 minutes prior to applying any load. The CC can be hydrated as normal (see CC User Guide: Hydration). Particular attention should be paid to the overlap area to ensure sufficient hydration through wicking.

Notes:

- A standard Twinny S or T can be used for bonding CCT1™, however it is necessary to fit a 'Comet' chain guard and shortened nozzle for bonding CCT2™ and CCT3™. Please contact Concrete Canvas Ltd for further information.
- When powering down the welder or heat gun it is recommended to turn down the heating element while allowing the air to remain running in order to cool the element and avoid damage.
- Routine maintenance of the welding equipment is required and particular attention should be paid to the hot air nozzle which should be regularly cleaned with a wire brush to prevent the build-up of PVC residue.
- On uneven ground, sandbags may be used to ensure joints are in contact with the substrate and prevent voids beneath the CC.
- A stiff brush can be used to clean the surface of the CC prior to hydration in order to remove footprints, dust accumulation and prevent staining on the set material.
- Overlaps jointed by Thermal Bonding do not typically require anchor fixings, unless they are needed as intermediate fixings, see section 7.0.
- For containment critical applications, CC Hydro™ should be used.

5.2.4 Zig Zag Screw Pattern

Applying screws in a Zig Zag pattern can be beneficial, particularly for weed suppression specific applications and when working in warmer climate conditions. In some warmer climate conditions, the edge of the CC layers can curl upwards as the material dries. Edge curling is most common on applications in high temperature drying conditions. Although the strength of the joint is unaffected, the curling can affect the aesthetics of a structure and act as a trap for wind-blown debris.

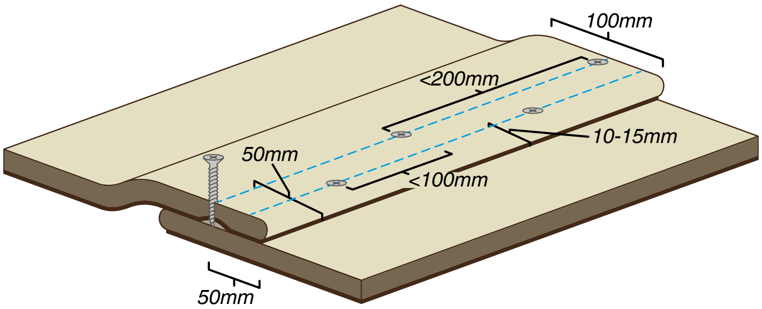


Figure 5.9 Zig Zag joint to prevent edge curling

Edge curling can be prevented by either ballasting the overlap joint for 24 hours after hydration (such as by using sandbags), or by staggering the screws to create a 'Zig Zag' pattern. The first row of screws should be at 50mm from the edge of the top CC layer and the second row of should be 10-15mm from the edge. The maximum screw spacing on each row should be a maximum of 200mm, so that the maximum staggered screw spacing along the CC edge is a maximum of 100mm. See 5.2.1 for details of hydration requirements and screw specification.

5.2.5 Joint Comparison Table

	TENSILE SHEAR STRENGTH*			IMPERMEABILITY*	INSTALLATION				
					Speed	*Skill*	*Tools Required*	*When to use*	**Recommendation**
Screwed (200mm spacing)	●●●○○			●○○○○	Fast	Low	Autofeed Screwdriver	Most common joint used on 95% of applications	>30mm stainless steel screws with 200mm spacing installed using autofeed screwdriver
	CCT1™	CCT2™	CCT3™						
	2.0 kN/m	4.0 kN/m	5.0 kN/m						
Screwed and Sealed (200mm spacing)	●●●◐○			●●○○○	Med	Low	Autofeed Screwdriver and Caulking Gun	For applications where a level of impermeability is required	>30mm stainless steel screws with 200mm spacing. Sealed with a CC approved adhesive sealant
	CCT1™	CCT2™	CCT3™						
	3.5 kN/m	5.0 kN/m	5.0 kN/m						
Thermal Bond	●●●●●			●●●○○	Med-Fast	Med-High	Manual or Automatic Thermal Welder and Power Supply	Used where screws are not suitable due to a concrete substrate etc under the CC**▲	Use automatic welder such as a Leister Twinny T or S (The Twinny T has data logging capability) or manual welder such as Leister TRIAC AT with a 60mm slot nozzle
	CCT1™	CCT2™	CCT3™						
	10.5 kN/m	17.0 kN/m	17.0 kN/m						

* Joint strength and impermeability data is intended for guidance purposes only. Joint performance may vary depending on the quality of the installation and the application conditions. Strength data is based on the ultimate strength of a tensile shear test in laboratory conditions, test based on BS EN 12317 1:2000.

** For when a level of impermeability is required, and/or when screws are not suitable due to a non-penetrable substrate beneath, such as concrete.

▲ For containment critical applications, CC Hydro™ should be used.

Table 5.1 Joint Comparisons

5.3 Installing on Solid Substrates (Concrete, Rock & Metal)

When installing on solid substrates where screws cannot penetrate the surface, such as concrete, rock or metal, the screws can be replaced with other suitable mechanical fixings, such as stainless steel concrete screw anchors, through bolts or tech screws.

The anchor fixings must be suitable for anchoring into the underlying substrate, eg screw anchors for concrete, through bolts for rock, or tech screws for metal culverts. For maximum durability they should be manufactured from stainless steel (unless the CC is being secured to a non-compatible metal structure where bimetallic corrosion could occur) and suitable for watercourse applications. They must have sufficient embedment depth to prevent pull out and on metal culvert structures they must be secured through the culvert and not into the filled corrugations.

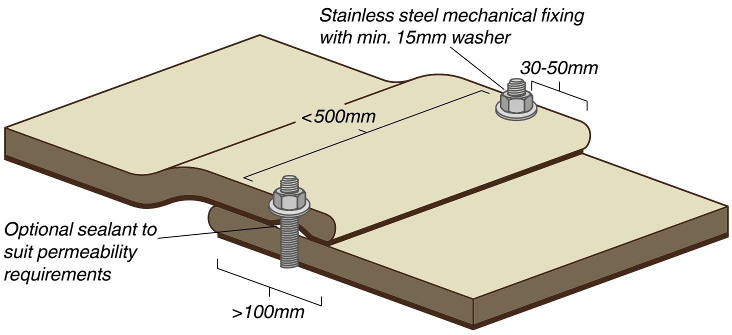


Figure 5.10 Mechanical fixing overlap joint

The mechanical fixings must have a minimum head/washer diameter of 15mm and installed 30-50mm from the edge of the overlap at a maximum spacing of 500mm along the joint as shown in figure 5.10 (300mm in warmer climates). The permeability of the mechanical fixing joint can be reduced using adhesive sealant or by thermal bonding as described in sections 5.2.2 and 5.2.3. Note that the use of shot fired nails is not recommended.

5.4 Other Joint Methods

Concrete Canvas Ltd have conducted extensive research into the suitability of alternative joint methods. With the exception of thermal bond overlap joints, all CC overlap joints must be joined using appropriate mechanical fixings. If you are considering using a different joint method to those described in this document, please contact us for advice.

Please note that it is not suitable to use adhesive sealant or grout in isolation when jointing CC or fixing to other structures. Adhesive sealant and grout bonds have long-term tensile shear strengths that are lower than the tensile first crack strength of the CC material itself. This means that any subsequent loading to a CC structure (such as those caused by drying conditions, differential settlements, wind or hydraulic loading) causes movement of the adhesive sealant/grout bond which could cause joints to open and result in serviceability issues.

5.5 Jointing onto Cured (Hardened) CC

There may be instances where new, soft CC must be joined to existing, hardened CC, such as for modifications or when the insitu material has been prematurely hydrated and set. It may therefore be necessary to drill a pilot hole in the hardened CC material. This can be achieved using a masonry drill bit. When using screws supplied by Concrete Canvas Ltd for jointing, the pilot hole should be a maximum of 3mm diameter. Alternatively, 5mm self-tapping tech screws may also be used, without the need for pilot drilling.

It is possible to thermally bond soft CC to hardened CC, but the hardened surface must be dry and clean.

6.0 Specifying Perimeter Edge Fixings

6.1 General Guidance

Concrete Canvas® must be firmly secured around the perimeter of the installation in order to eliminate water and wind ingress which can result in material movement, scour and undermining of the structure. The leading perimeter edge(s) that receives water flow is at particular risk of undermining and protection of these edges is critical.

The most common surfaces to secure CC perimeter edges into are soil substrates and existing infrastructure such as concrete, steel culverts or masonry headwalls. The designer must specify the edge fixing details required to resist pull out forces, erosion and undermining.

The perimeter edge must be fixed in place prior to hydration of the CC to ensure the material cures to the correct profile.

6.2 Edge Fixing into Soil

6.2.1 Anchor Trenches

When installing CC on soil substrates, perimeter edge fixing is achieved by securing the CC within an anchor trench. This will help prevent undermining from surface water and provide a neat edge termination. Typically anchor trenches are used along the shoulders of a watercourse and at leading and trailing edges (when the material is not being connected to headwalls).

The material used to backfill anchor trenches must be classed as "non-erodible backfill" and is dependent on the erosion forces that the backfill will be subjected to over the design life of the product. For example, soil and vegetation may be suitable at the shoulders of a watercourse when there is no water flowing over the anchor trench and onto the CC.

A poured concrete or cement stabilised trench is often required when there is a high risk of water ingress, for example on leading edges and at the crest of interceptor drains which collect adjacent water runoff. 'Rock roll' cylindrical gabions may be used at the leading and trailing edges in the invert of a watercourse to slow water flow and prevent scour beyond the CC lining.

CC should be pegged into position in the anchor trench to secure it in place prior to hydration and backfilling.

Galvanised steel J-pegs are available from Concrete Canvas Ltd in lengths of 250mm and 380mm and are suitable for most soil types. Pegs may be sourced from alternate suppliers but must have a sufficiently sharp point to penetrate the CC and a head design that will capture the surface of CC. Peg length and spacing should be selected based on the soil conditions. For clay, soil and sandy substrates, pig tail anchors (such as Gripple TL-P1 pins) may also be suitable.

Typically, pegging should be through each overlap joint or at maximum 2m centres on a longitudinal installation.

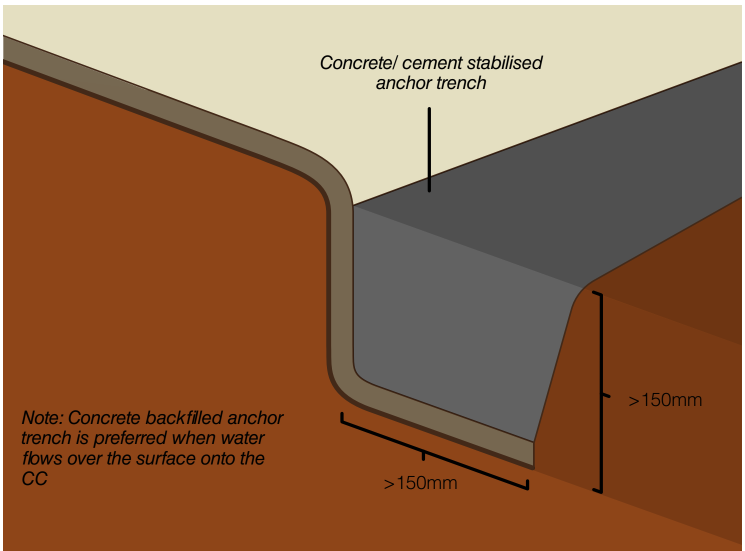


Figure 6.1 Concrete backfilled anchor trench

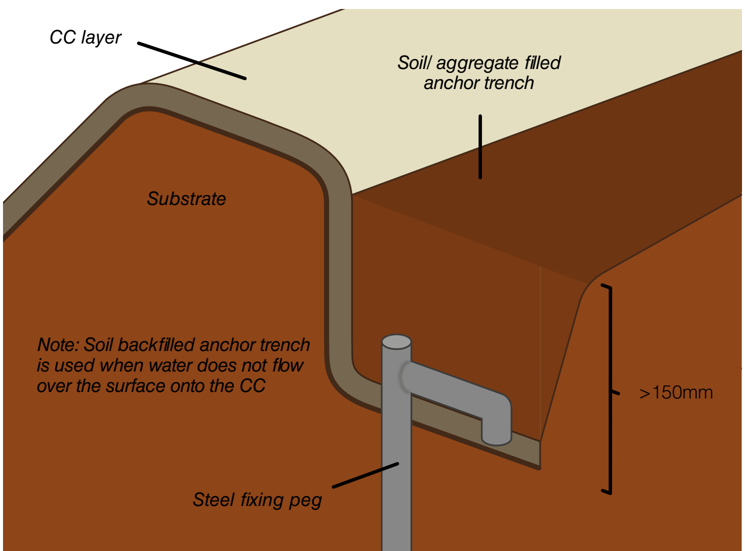


Figure 6.2 Soil backfilled anchor trench

In warmer climates it is not recommended to backfill anchor trenches until the CC has hardened to allow for hydration shrinkage. If high winds are expected within 24 hours of hydration, temporary ballasting (e.g. sandbags) can be used.

6.2.2 Anchor Trench Dimensions

Pegged anchor trenches should be a minimum of 150mm x 150mm but may need to be increased to suit the designer's requirements, for example when there is a high risk of perimeter ingress or scour.

In some applications it may be possible to remove the requirement for pegging by increasing the size of the anchor trench, but this must be specified by the designer. Concrete Canvas Ltd have calculated the recommended minimum anchor trench dimension to prevent pull-out of the CC due to self-weight, see figure 6.3 and table 6.1 below:

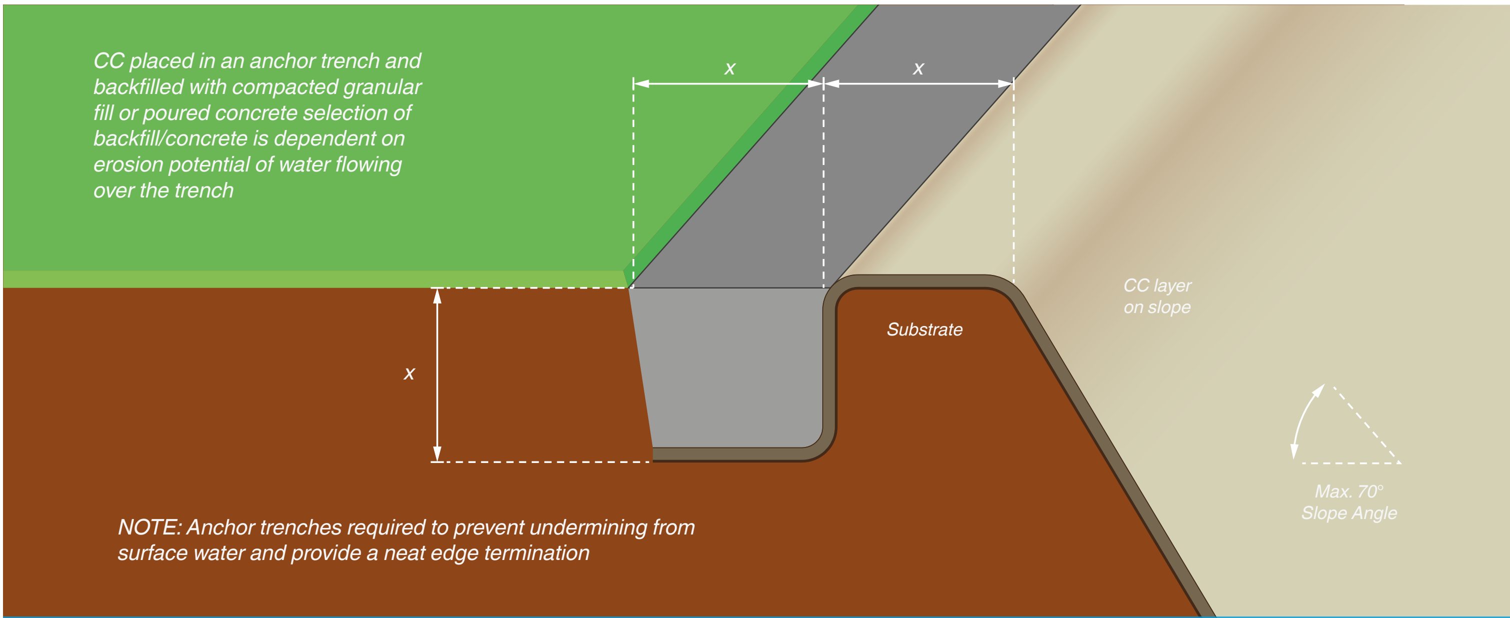


Figure 6.3 Unpegged anchor trench dimension illustration

	'X' Dimension (mm) based on a maximum slope angle of 70°		
CC Type	0-2m Slope Length	2-4m Slope Length	4-6m Slope Length
CCT1™	150	250	300
CCT2™	200	300	350
CCT3™	250	350	450

Assumptions:

'X' dimensions provided are minimum values to prevent the self weight of CC from pulling out of the trench. The effects of wind loading or hydraulic shear on pull-out of the CC layer are not considered. Slopes are to be geotechnically stable and CC is not to provide structural support. Anchor trench backfill material to be compacted granular fill with a bulk density >16kN/m³ and Phi >30°

Table 6.1 Minimum unpegged anchor trench dimension requirements

Additional pegging on the surface of the CC may still be required, particularly when slope lengths exceed 3m, see section 7.0 on intermediate fixings.

6.2.3 Mid-structure Anchor Trenches - Check Slots

For installations that take more than one day to install and require the watercourse to be reopened outside of working hours to allow water to flow over the material, anchor trenches can be created to protect the edge of last layer of CC installed to prevent undermining and erosion. These mid-watercourse anchor trenches are also known as check slots – see section 7.3.1. The following working day, once the watercourse is dewatered, the next upstream CC layer is installed over the check slot and jointed to the downstream CC layer before continuing the installation.

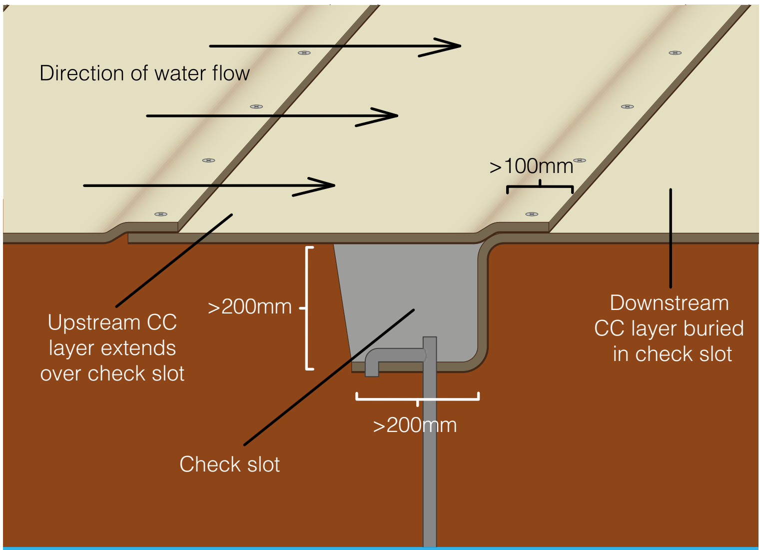


Figure 6.4 Intermediate check slot detail

6.3 Edge Fixing into Concrete/Masonry

When the perimeter edges interact with existing infrastructure such as concrete or masonry headwalls, CC must be secured to prevent water from entering through the interface. It is not acceptable to simply butt the CC to the structure, a physical connection must be formed using poured concrete anchor trenches or mechanical terminations.

6.3.1 Poured Concrete Anchor Trenches

If space permits, anchor trenches can be excavated in front of the structure, which are then backfilled with poured concrete or mortar to connect the CC to the structure and prevent water seepage. Alternatively, the CC can be pegged to the substrate before a concrete beam is poured on top. Most off-the-shelf mortars will bond well to the fibrous surface of CC. It is recommended that non-shrink concrete/grout/mortar is used that will be durable for the project specific environmental conditions.

We recommend applying the concrete/grout/mortar to the CC immediately after hydration or wetting the CC surface if applying post-set.

Figure 6.5 Concrete anchor trench connection

Figure 6.6 Concrete beam covering edge of CC

6.3.2 Mechanical Terminations

CC can be secured to existing infrastructure using mechanical fixings. It is recommended to use stainless steel concrete screw anchors or through bolts, in combination with a stainless-steel clamping bar, securing the CC to the structure by sandwiching a gasket or adhesive sealant to prevent water ingress. Where the risk of water ingress is low, the perimeter edge can be secured using mechanical fixings and washers. Shot fired nails are not recommended due to their insufficient pull-out strength and poor durability in watercourse applications.

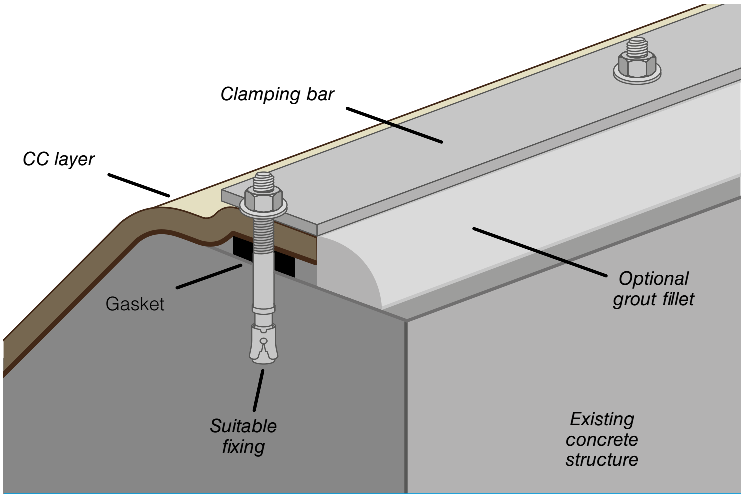


Figure 6.7 Clamping bar detail

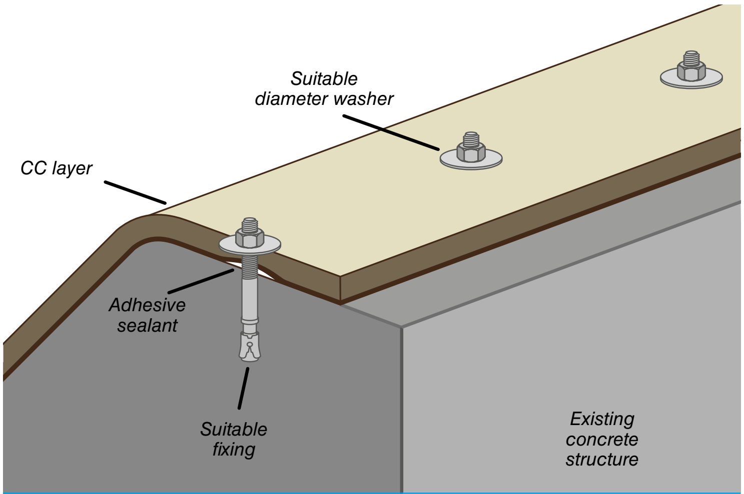


Figure 6.8 Washer detail

When using mechanical fixings, they should be evenly spaced across the CC layer, with 1 fixing in each overlap, 30-50mm from the edge of the CC so that there is sufficient cementitious material surrounding the fixing to prevent pull out.

The designer must specify the fixing to be used along with the washer diameter and fixing spacing. This is to ensure the CC is suitably secured to the structure and does not pull out or shear under shrinkage forces.

It is critical not to substitute fixings without checking with the designer. This is because the minimum spacing of mechanical fixings is governed by the fixing manufacturers recommended shear force (V_{REC}), and the surface area of the fixing (plate/clamp bar/ washer size).

The minimum V_{REC} and fixing requirements to provide sufficient perimeter mechanical fixing anchorage are provided in Tables 6.2, 6.3 and 6.4.

Table 6.2 Min. mechanical fixing requirements for CCT1™

		CCT1™	
Number of fixings/ layer width	Fixing spacing (mm)	Min V_{REC} per fixing (kN)	Min washer Ø (mm)
10	100	1.71	15
7	150	2.57	35
4	300	5.13	Use Clamping Bar
3	450	7.70	Use Clamping Bar

Table 6.3 Min. mechanical fixing requirements for CCT2™

		CCT2™	
Number of fixings/ layer width	Fixing spacing (mm)	Min V_{REC} per fixing (kN)	Min washer Ø (mm)
11	100	1.88	15
6	200	3.77	25
5	250	4.71	40
3	500	9.42	Use Clamping Bar

Table 6.4 Min. mechanical fixing requirements for CCT3™

		CCT3™	
Number of fixings/ layer width	Fixing spacing (mm)	Min V_{REC} per fixing (kN)	Min washer Ø (mm)
11	100	2.66	15
6	200	5.33	25
5	250	6.66	40
3	500	13.32	Use Clamping Bar

The cut edge of the CC layer can be neatened by applying a grout fillet, or by cutting the cured CC with a disc cutter (while ensuring a minimum of 30-50mm of CC extends beyond the fixings). See section 7.5.1 and 7.5.2 for worked examples of edge fixings.

6.4 Fixing into Rock

Similar to connecting to concrete/masonry surfaces (see previous section), CC can be secured to rocky substrates using mechanical fixings. Rock bolts should be used and the number/specification of rock bolt should be selected by the designer based on the pull-out and shear force requirement (as in tables 6.2, 6.3 and 6.4). A suitable head design should be selected to prevent stress concentrations, square plates are not typically recommended. A minimum head diameter of 15mm is normally required and plates up to 150mm are often used.


Figure 6.9 CC fixed to rock

Due to the uneven nature of rocky substrates, it is essential to ensure that the CC is in intimate contact with the surface to prevent water ingress beneath the CC. Once secured in place, the perimeter edge must be encapsulated with a suitable UV stable adhesive sealant, bituminous mastic or mortar to provide a seal between CC and the rocky surface. The Designer must approve a suitable perimeter sealing solution based on the long-term durability and environmental conditions.

6.5 Fixing to Metal Culverts

CC can be secured to culverts using suitable screw anchors or self- drilling tech screws and washers. Suitable adhesive sealant, bituminous mastic or mortar must be used to provide a seal between CC and the culvert. If the corrugations of the culvert have been filled with grout (see section 3.1.2 for subgrade preparation), a steel clamping bar can be used as discussed in section 6.3.2 for fixing to concrete. The fixings must be secured into the metal culvert and not into the grout alone.


Figure 6.10 CC fixed to culvert

6.6 Gabions

CC can be secured to gabions and reno mattresses using the same steel ring fasteners or lacing wire that is typically used to assemble gabion units. Considering that gabions are porous and allow water to flow through them, the designer must determine the most appropriate location to fix the CC to the gabion structure ensuring undermining of the CC is prevented. The ring fasteners or lacing should coincide with every aperture of the gabion mesh. For leading edges, the CC must be buried beneath the Gabion structure to prevent ingress.


Figure 6.11 CC fixed to gabions

6.7 Asphalt

When installing CC adjacent to a highway, the perimeter edge of the CC can be captured by covering it in asphalt. The CC must still be pegged into position and temporarily ballasted as the material cures, typically by covering in sandbags. Research by Concrete Canvas Ltd has shown that the CC material is unaffected when covered by hot rolled bitumen.


Figure 6.12 CC fixed to asphalt

7.0 Specifying Intermediate Fixings

7.1 General Guidance

Intermediate fixings may be necessary to profile CC on uneven substrates or large structures to ensure the material conforms to the underlying surface, or to resist the following load conditions:

- Hydraulic Shear Loads: e.g. lining watercourses with an incline >10%
- Warmer Climate Detailing: e.g. where CC profile lengths exceed 3m
- Detailing for Large Structures: e.g. where lengths between profile changes exceed 5m on a concrete structure
- To prevent CC from lifting from a metal culvert when corrugations are filled after the CC has cured

The intermediate fixing type, performance requirements and installation locations should be specified by the designer to suit the anticipated load conditions.

Typical intermediate fixings for soil substrates include ‘Round Head’ fixing pegs for profiling or warmer climate detailing. These should be galvanised mild steel, typically 12-16mm shaft diameter, up to 400mm long and have a minimum 50mm diameter head.

When a greater head plate diameter or pull-out strength is required, for example when designing to resist hydraulic shear, larger intermediate fixings such as Earth Percussion Anchors may be specified.

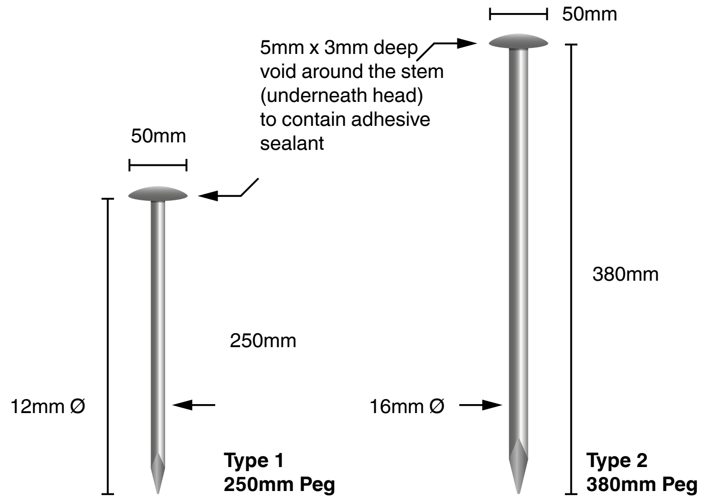


Figure 7.1 Typical round head peg dimensions


Figure 7.2 Earth percussion anchor intermediate fixing

For rock, concrete or metal substrates, suitable screw anchors, through bolts or tech screws can be used in conjunction with washers with a specified diameter needed to resist the anticipated loads. When anchor fixings are used for jointing over solid substrates, they can also perform the function of intermediate fixings in most cases.

Intermediate fixings should be secured from the top of slopes to the bottom of the structure to minimise tension on the CC. When applying intermediate fixings in watercourses it is important to reduce the potential for water ingress through openings created by the fixing. Some Round Head pegs and earth percussion anchors may incorporate a washer or rebate which allows adhesive sealant to be applied in order to limit water ingress.

Alternatively, the fixings can be installed into the underlap of a joint so that the head of the fixing is protected from impact by the overlapping CC layer. It may be necessary to reduce fixing spacing in this case, contact your local Concrete Canvas Ltd representative for advice.

Figure 7.3 Round head peg intermediate fixing

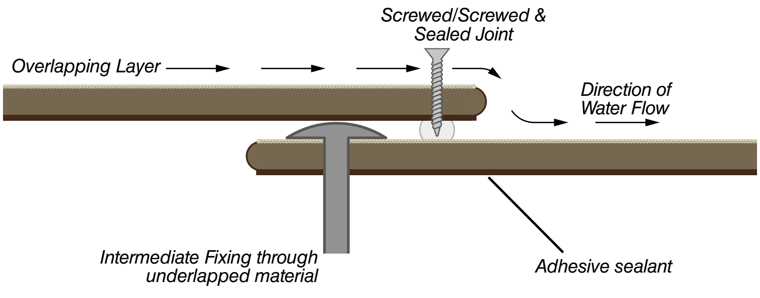


Figure 7.4 Intermediate fixing through underlapped layer

7.2 Profiling

Intermediate fixings can be used for profiling to remove void space beneath the material, reducing the risk of damage from external impact loading on unsupported CC surfaces.

Intermediate fixings for profiling are typically determined on site, but installers should consult the designer if they are required for in order to agree the most appropriate fixing to use, based on the substrate and permeability requirements.

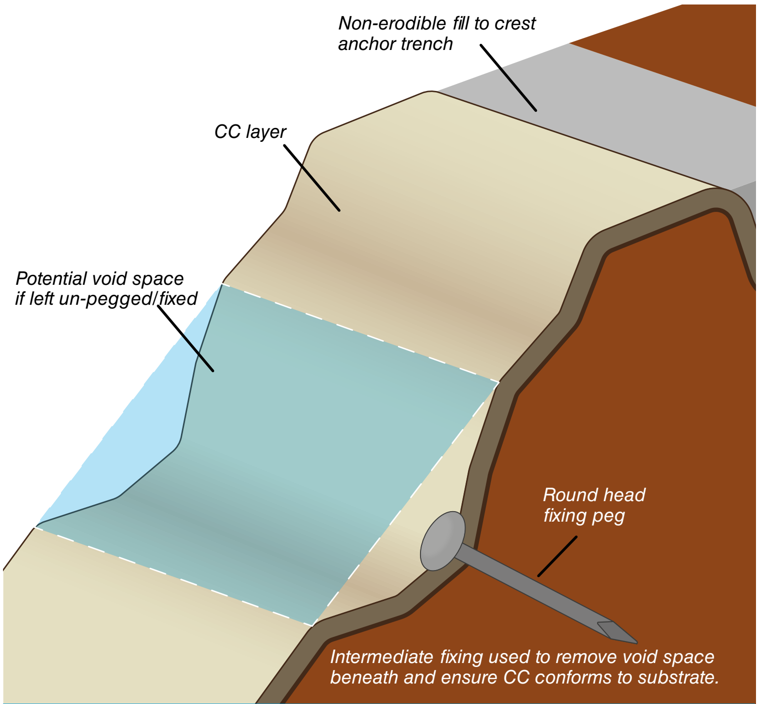


Figure 7.5 Profiling anchoring for voids

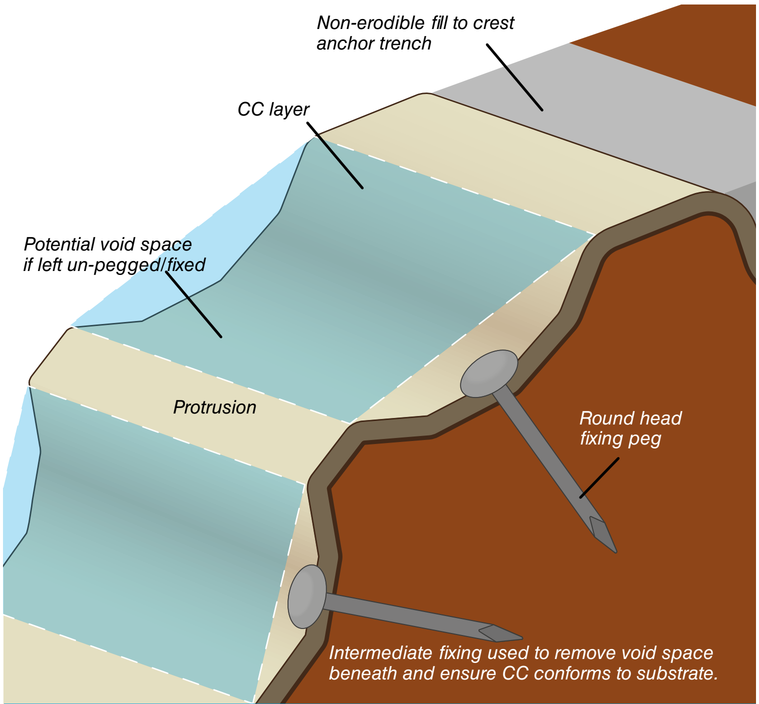


Figure 7.6 Profiling anchoring for protrusions

7.3 Hydraulic Shear Loads

Although CC lined watercourses prevent erosion of the substrate, the hydraulic shear forces still need to be considered by the project designers in the design to ensure suitable mitigation measures are taken to prevent CC material movement. For the majority of CC watercourse lining applications, the interface friction between the underside of the CC and substrate provides sufficient resistance, but when this is exceeded, intermediate fixings are required. Intermediate fixings have been successfully utilised on CC lined watercourses, such as *Myra Falls* which was designed to accommodate flow velocities up to 20m/s.

Concrete Canvas Ltd have developed a 'Hydraulic Shear - Intermediate Fixing Calculator' to determine the likelihood of CC material movement under destabilising shear forces. The calculator has been produced based on the principles of hydraulic engineering and US Federal Highway Administration guide FHWA-NHI-05-114 'Design of Roadside Channels with Flexible Linings'.

The research has shown that there are three watercourse parameters that can be used to determine whether intermediate fixings are likely to be required on CC lined structures:

- Watercourse slope (gradient), S
- Substrate internal angle of friction, ϕ
- Watercourse degree of curvature, K_C (see section 11.1)

The Hydraulic Shear - Intermediate Fixing Requirements Graph (Figure 7.7 below) has been developed to assist designers of CC lined watercourses. The three key watercourse parameters are used to determine whether intermediate fixings may be required.

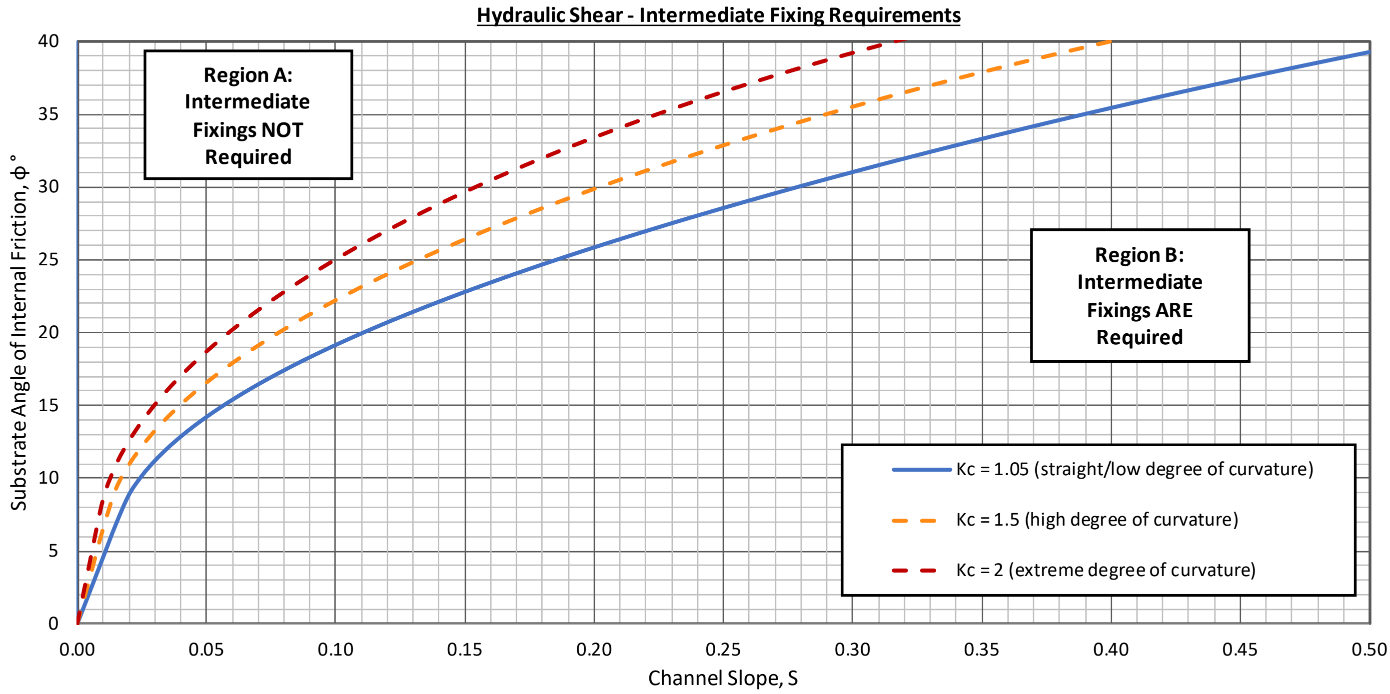


Figure 7.7 Hydraulic fixing requirements graph

Instructions for Use:

1. Find out the watercourse Slope (S=rise/run). It is recommended to use the highest S value of any section of the watercourse.
2. Determine the minimum ϕ (Angle of Internal Friction) of the underlying substrate, up to a maximum value of 35˚. For concrete substrates use ϕ =28˚, when placing on a geotextile, use the lower of 31˚ or the δ (Interfacial Friction Angle) between the geotextile and the substrate.
3. Find the position on the graph that corresponds to the watercourses S and ϕ values.
4. Find the K_C (curvature factor - see appendix) and use this to choose which of the three line colours to use.
5. If the (S, ϕ) is above-left of the relevant line, Intermediate fixings are unlikely to be required for the installation.
6. If the (S, ϕ) is below-right of the relevant line, Intermediate fixings need to be considered for the installation.
7. If the (S, ϕ) is close to the line, Intermediate fixings may still be considered to provide a safety factor.

Additional Considerations:

Laminar, steady, uniform flow conditions are assumed. The effects of turbulent flow are not considered in the analysis. Additional fixings may be required to resist turbulent flow conditions which may be created by hydraulic jump, changes in channel cross section, changes in slope or high velocities.

The CC is considered to be in complete contact with the substrate and water is not able to collect under the CC.

Substrate drainage measures may be required to prevent uplift due to the presence of water under the CC.

The channel is considered to be adequately protected to prevent debris impact from causing damage to the CC. The designer may wish to consider including check slots in their design to limit the extent of damage due to CC movement if damage causes undermining of the CC channel.

The slope gradients are considered to be geotechnically stable and the CC is not providing any retention benefit to the channel i.e. the CC will be providing erosion protection rather than improving slope stability.

If a designer identifies a potential CC lined watercourse that may require intermediate fixings (the S, ϕ point on the chart is close to or below the relevance K_C line), the Concrete Canvas® Intermediate Fixing Calculator can be used to help determine the fixing specification and density to resist the shear forces. Designers should complete the appended Hydraulic Analysis Input Parameters table (see section 11.1) and send to Concrete Canvas Ltd so that we can provide a copy of the calculator and explanation of the methodology for the designer to consider in their design. Use of this calculator template is at the user's sole risk and is provided subject to the General Disclaimer referred to in section 1.2 above.

7.3.1 Check Slots

An intermediate fixing can also take the form of mid-watercourse anchor trenches, also known as check slots, which are recommended to be incorporated in designs of large structures.

CC acts as a low permeability erosion control layer, channelling flowing water along the surface of the material. However, conditions may occur where the water can flow beneath the CC layer, for example if the material is damaged by puncture due to debris impact. There may also be circumstances where watercourses are located alongside stockpiles of large boulders, which may become dislodged and fall into the CC lined structure (Figure 7.8). If this occurs, it may be possible for large impacts to punch a hole through the CC (although it should be noted that CC has a superior puncture resistance compared to other geomembranes). A hole in a CC layer could allow water ingress, creating areas of dynamic pressure and potentially causing uplift, 'unzipping' the CC layers.

The likelihood of occurrence is dependent on the volume of debris that could enter the watercourse and the impact energy. If the likelihood of severe debris impact or the consequence of unzipping is high, the designer should design appropriate systems to prevent debris ingress (such as catch fences or sediment traps). The designer/client may also wish to limit the extent by which an unzipping event can occur (and therefore commercial risk to repair) by introducing check slots into a watercourse which are backfilled with poured concrete (Figure 7.9). Check slots are installed across the width of the watercourse and divides the length of the structure into smaller sections, such that if a dynamic failure were to occur the quantity of material that could potentially be damaged is limited to an acceptable commercial value as determined by the client.

If check slots are incorporated, the spacing should be determined by the designer/client as a balance between an increase in the initial installation cost and reduction of potential future repair cost if unzipping were to occur. Check slots should have sufficient pull-out strength to resist maximum load exerted by the material in the case of an unzipping event.

Figure 7.8 Section of channel at risk of boulder impact

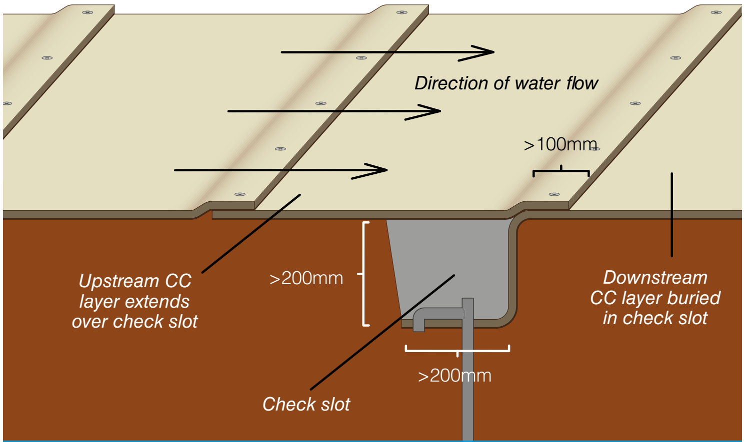


Figure 7.9 Intermediate check slot detail

7.3.2 Hydraulic Test Data

In 2012 research was conducted at TRI Environmental's erosion testing Lab in the United States to determine the hydraulic performance of the CCT2™ material. Large scale channel testing was conducted to ASTM D6460 to calculate the Manning's roughness coefficient for the surface of the material when installed in both a longitudinal and transverse layup. The overall average Manning's n was calculated to be 0.011, similar to a smooth concrete surface. This roughness coefficient can be used by designers to calculate the velocity of water flowing down a CC lined watercourse. It should be noted that flow velocities can be reduced by introducing baffling in the watercourse, such as by placing sandbags in the invert before draping the CC on top, see section 8.1.

TRI Environmental also conducted flume testing on the CCT2™ material to determine the flow velocity at which the material is dislodged, uplifted or washed away. TRI subjected the material to the highest water velocities and shear forces possible at their test facility. The CC did not fail during the test, enduring water velocities in excess of 8.62 m/s.

Test reports for the ASTM D6460 Manning's testing and flume testing can be found in the appendix.

As stated in section 2.2, Concrete Canvas Ltd recommend that the CC type is specified based on the anticipated watercourse flow velocities:

- Below 2m/s, primarily laminar flow and only when lining concrete, steel or rock substrates – CCT1™ is recommended
- Above 2m/s, when lining soil substrates, or solid substrates exposed to sediment flow – CCT2™ is recommended
- Above 2m/s, and when the risk of debris impact, excessive wear, hydraulic jump or turbulent flow is anticipated – CCT3™ is recommended.

Note – intermediate fixings may still be required to secure the CC to resist the hydraulic shear forces present in the watercourse.

7.4 Warmer Climate Detailing

As stated in section 1.4.5, a warmer climate is typically found in parts of Africa, the Middle East, Southern US and Oceania. Warmer climates are considered to be Arid, Tropical or Mediterranean, but also covers projects where the material will be installed when drying conditions are present and there is a potential for drying shrinkage to occur.

A drying condition can happen to CC in a climate that causes an excessive loss of hydration water in CC. Drying conditions occur when there is one or more of:

- Ambient air temperature >22°C
- Sustained strong direct sunlight
- Wind speed >12km/h
- Humidity <70%

Drying conditions reduce the volume of water held within the cementitious core of the CC. Most cementitious or concrete materials are at risk of drying shrinkage, where the concrete mixture contracts due to the loss of capillary water. For GCCMs there are two shrinkage processes that are possible:

- Hydration shrinkage - occurs during the curing process and causes the CC to contract by approximately 0.1-0.15%.
- Drying shrinkage - can occur in drying conditions and after the CC has hardened. CC may contract up to 0.4% in the most extreme drying conditions.

CC lined structures must be designed so that shrinkage is accommodated internally through the 3D fibre matrix or transferred to the substrate, rather than by cumulative material movement and deformation at joints, profile changes and around the perimeter edge.

In warmer climates, intermediate fixings are required on all CC layers greater than 3m in length in order to prevent overlap joint movement. It is recommended that suitable 'round head' pegs are positioned through each overlap joint at 3m centres, on large structures they can be staggered on each adjacent overlap panel to form a diamond pattern. Intermediate fixings transfer the load from hydration shrinkage into the underlying substrate, preventing the accumulation of shrinkage displacement in large structures or in drying conditions.

It is also recommended to install intermediate fixings within 100mm from each internal profile transition and to minimise void space when profiling on uneven substrates.

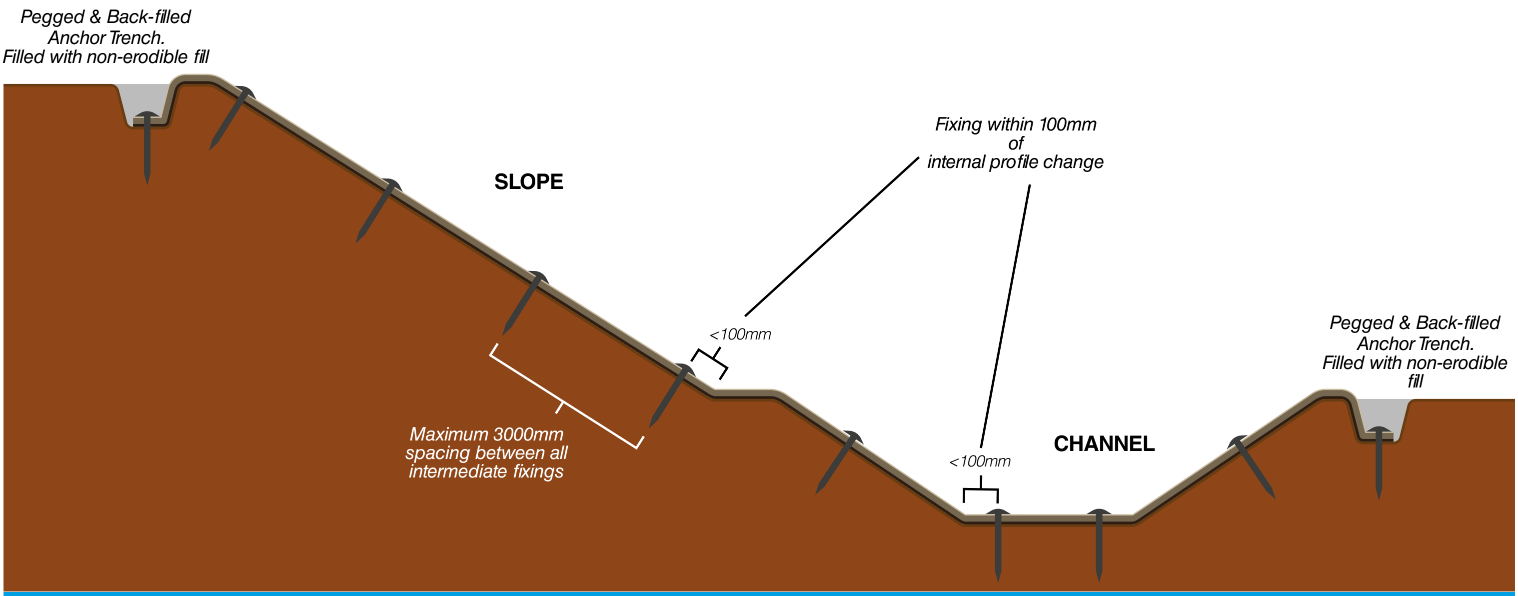


Figure 7.10 Typical intermediate fixing detailing

7.5 Designing for Large Structures (where side slope or invert length(s) exceed 5m)

To mitigate the potential effects of drying shrinkage (see previous section), which may occur on larger structures in all climates, additional intermediate fixings are required at a 'concave profile change' when the distance from the profile change to the next fixing is greater than 5m (see Figure 7.11 below). This is particularly important when lining smooth substrates such as remediating concrete canal structures.

Fixing arrangements required to mitigate the potential effects of drying shrinkage:

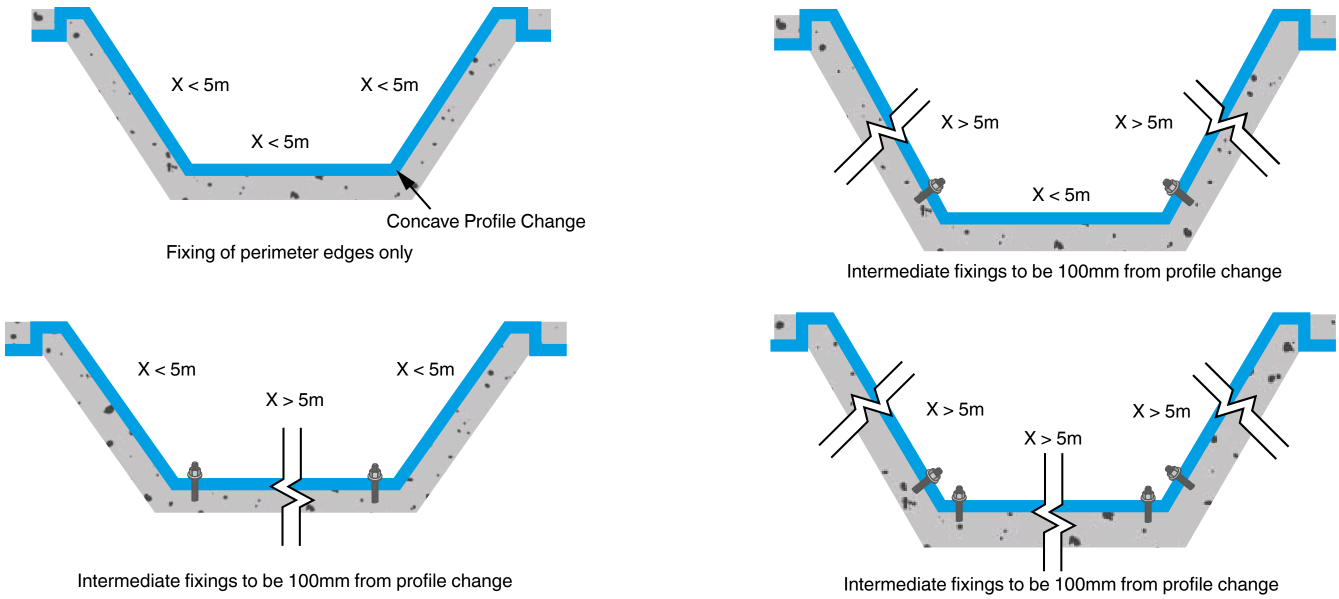


Figure 7.11 Requirements for fixings on intermediate structures

The fixings should be located along the length of the channel and approximately 100mm from the profile change. Fixings should be evenly spaced across the CC layer width, with 1 fixing in each overlap, 50mm from the edge of the layer. When lining soil substrates intermediate fixing pegs or earth percussion anchors can be used. For concrete remediation, the fixings should be stainless steel concrete screw anchors or through bolts in combination with appropriate washers or stainless-steel clamping bar. The total restraining shear and minimum fixing requirements provided by the mechanical anchor must be in accordance the relevant tables in section 6.3.2. It is therefore important to check the fixing manufacturers datasheet for V_{REC} per fixing in a given strength of concrete. The fixings per unit width of CC may therefore need to be increased for a poor-quality substrate or reduced embedment depth as the V_{REC} may be reduced.

The number of fixings per linear metre of channel is determined as per the relevant table in Section 6.3.2.

7.5.1 Worked Example 1

To fix a layer of CCT1™ to a cracked concrete structure that has an invert and side slopes <5m (see figure 7.12):

For the perimeter, in this example we choose to secure CC in a concrete anchor trench as per figure 6.1. For the intermediate fixings, since the invert and side slopes are <5m, no intermediate fixings are required, but fixings for jointing/profiling are always necessary. Adjacent layers of CC are to be overlapped by 100mm (shingled in the direction of water flow) and secured using stainless steel fixings with a 15mm washer/head diameter, positioned 30-50mm from the edge and at maximum 500mm centres along the joint. This is illustrated in figure 7.12.

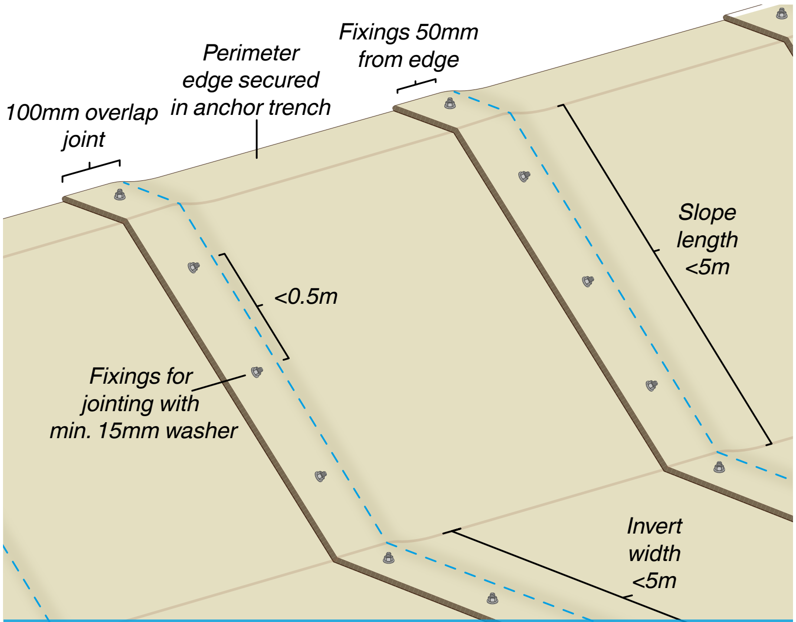


Figure 7.12 Fixing arrangement - worked example 1

7.5.2 Worked Example 2

To fix a layer of CCT1™ to a cracked concrete structure that has an invert >5m (see figure 7.13). For the perimeter, in this example we choose to secure CC by mechanically fixing as per as per figure 6.7. For the intermediate fixings, since the invert is >5m, we need one intermediate fixing row for drying shrinkage along the invert (100mm from the profile change). Fixings for jointing are always required (as described in Example 1). The designer has proposed 'M8 Rawlplug R-HPTII-A4 "D" Stainless Steel Throughbolts' with stainless steel washers for the perimeter and intermediate fixings. According to the manufacturers data sheet, the Recommended Fixing Load (V_{REC}) of this fixing in cracked concrete (assuming a reduced embedment depth) is 3.1kN. Referring to table 6.2 in section 6.3.2 of this document, for a fixing V_{REC} of 3.1kN, the maximum fixing spacing is 150mm and a stainless steel washer with a minimum diameter of 35mm is required. 7 fixings are required per 1.0m CCT1™ layer width with one fixing through each overlap, 50mm from the edge. The fixing arrangement is illustrated in Figure 7.13. Alternatively, a stainless steel clamping bar could be used in lieu of the 35mm washers.

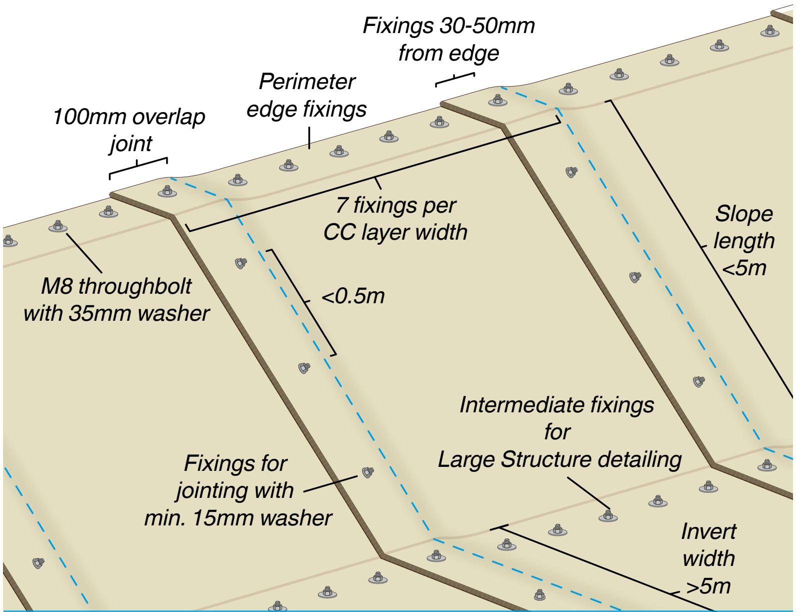


Figure 7.13 Fixing arrangement - worked example 2

8.0 Project Specific Detailing

8.1 Hydraulic Features (e.g. Baffling, Cascades and Silt Traps)

CC has a Manning's roughness coefficient of 0.011 and the surface does not create significant drag to slow water flow. If the flow velocity needs slowing, hydraulic features can be incorporated into the design to control the flow of water in a watercourse. Baffling can be formed by draping CC over a suitable structure/soil profile, see examples below. Please note than the inclusion of steps, cascades or baffling is likely to generate a turbulent flow of water which could cause significant dynamic loading in CC material under high flow velocities (>2m/s) and the surface must be protected. Often this includes placing poured concrete or concrete slabs on the downstream CC surface to reduce the impact on the material.

In low velocity channels, baffling can be used to create silt traps by causing upstream silting and may introduce the requirement for maintenance, see section 10.0.

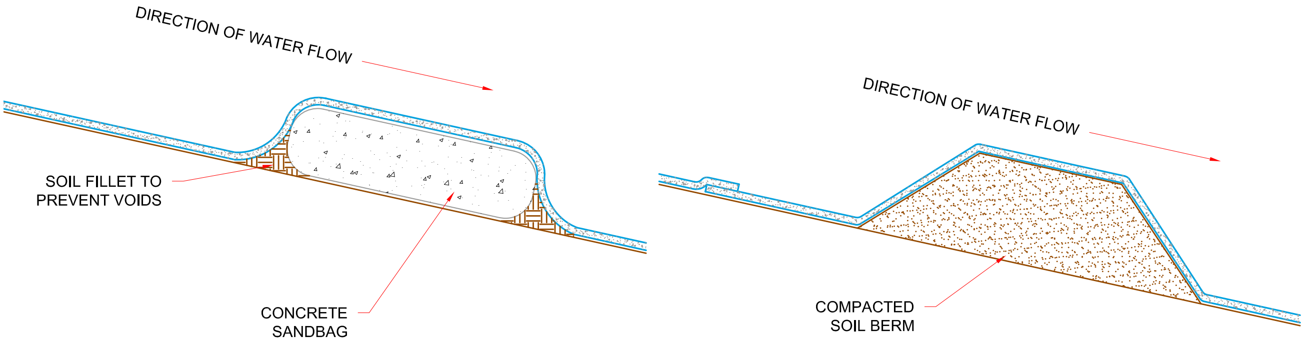


Figure 8.1 Baffling details

8.2 Pipe Penetrations

CC can be cut and tailored to fit around existing penetrations such as drainage pipes. It is important to ensure that there are no gaps around penetrations which may enable water loss or weed growth to establish. Any cuts or gaps should be covered with an additional CC layer, or filled with a suitable UV stable adhesive sealant or grout.

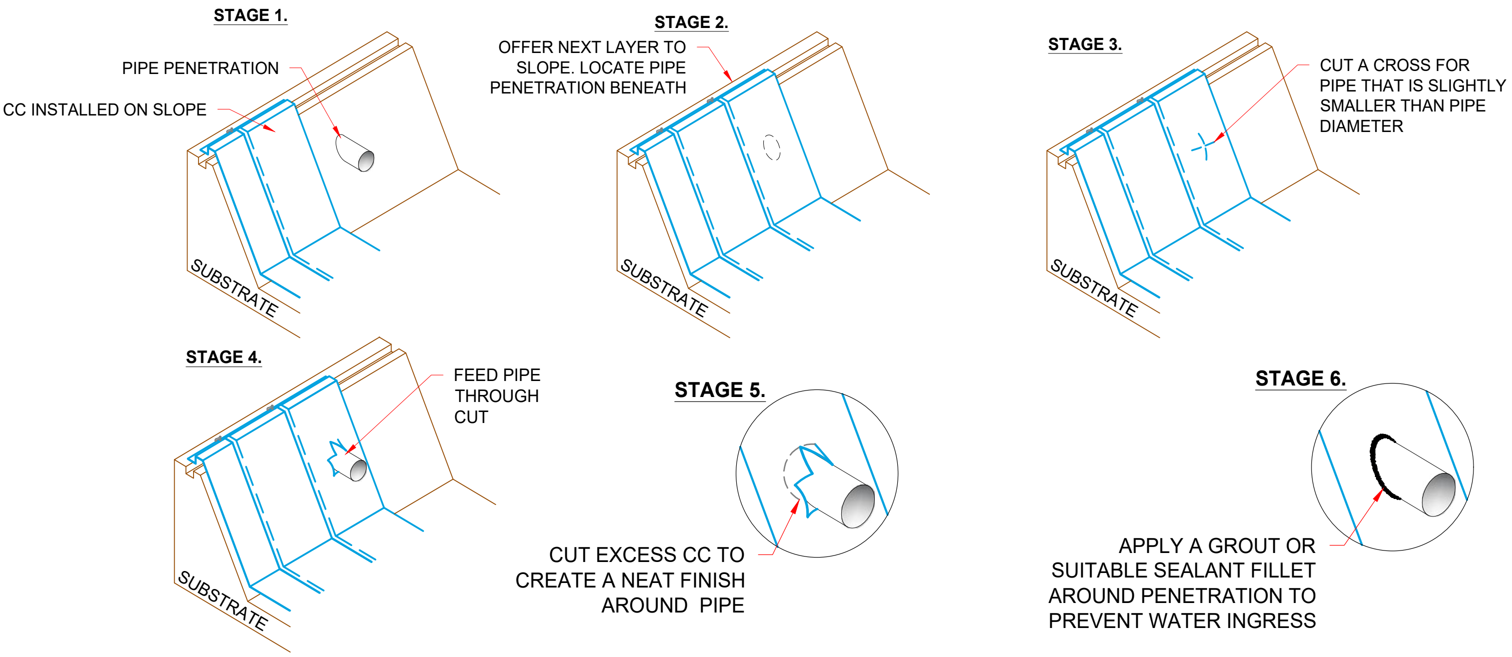


Figure 8.2 Pipe penetration details

8.3 Typical Project Specific Detailing Examples

Concrete Canvas Ltd and its Sales Partner distribution network may be able to provide additional detailing examples or ideas based on the success of previous projects, please contact us to discuss your requirements.


Figure 8.3 Form baffles by laying CC over structures


Figure 8.4 Sandbags to compress joints at setting


Figure 8.5 Mortar used to seal to existing infrastructure


Figure 8.6 Retrospective pipe penetration


Figure 8.7 CC manipulated to form junctions


Figure 8.8 CC installed around existing infrastructure

9.0 Hydration

9.1 Surface Preparation

A stiff brush may be used to clean the surface of the CC prior to hydration in order to remove hand prints, footprints and dust accumulation to prevent staining on the set material.

9.2 Hydration Guidance

Concrete Canvas® materials must be actively hydrated to harden and it is not advised to rely on rainfall alone for hydration. Follow the guidance in our *Hydration Guide*, which is supplied with every Bulk Roll which provides specific climatic advice.

9.2.1 General Guidance

- CC cannot be over hydrated and will cure underwater. Potable water is not necessary, salt water can be used but any hydration water must be above pH6.
- Water must be sourced or made available for active hydration. The minimum water requirement is half by dry weight as in the table below.

	Dry weight, kg/m²	Minimum hydration, Litres/m²
CCT1™/CCHT1™	8	3.5
CCT2™/CCHT2™	12	5.0
CCT3™	19	7.5

Table 9.1 Hydration water requirements

- Water also needs to be available for hydrating underlaps of screwed and screwed and sealed joints as discussed in section 5.1.3.
- Spray the fibre surface multiple times until the CC is fully saturated. The wet CC will first darken and then become lighter as it absorbs the water.
- Water should be applied over the entire CC surface, do not allow water to run down the surface in rivulets only.
- Do not spray high pressure water directly onto the CC as this may wash a channel in the material.
- On sloped structures it is best to hydrate with one pass from top to bottom, then alternate bottom to top on the second pass, then alternate again for the third pass.
- Do not rely on rainfall to provide hydration.
- Hydrate any overlapped areas and anchor trenched material prior to backfilling.

To check proper hydration, the CC should feel wet to the touch several minutes after hydration. To determine whether the CC has been sufficiently hydrated simply press your thumb into the CC and release. If water is present in the depression in the CC, it has been sufficiently hydrated. If no water is observed, then more water must be applied.

When using CC to line an existing watercourse, it is sometimes possible to use the diverted water for hydration by releasing it back into the watercourse. The release of water must be controlled and the maximum water flow must be below 1 metre per second to prevent the cementitious material washing out of the CC.

It is recommended to hydrate the installed CC material before the end of each working day. If installation continues the following working day the edge of the last layer needs to be kept dry, so that it remains in its flexible state for jointing to the next layer deployed on return to work. Protect the edge of the last layer with a waterproof sheeting (eg with a plastic tarpaulin) and raise it above ground level prior to hydrating the structure to protect it from moisture or rainfall which may cause partial hardening and impinge on the next phase of jointing work.

Hydration is also dependent on the project climatic conditions and there is specific guidance for hydrating in warmer climates/drying conditions and cold weather working.

9.2.2 Environmental Considerations

CC has a low alkaline reserve and a low washout rate, meaning that the hydration water runoff does not typically need to be treated before it is released into a watercourse. CC has been used by environmental agencies globally to line existing natural watercourses. The *CTL leachate report* provides data on the typical composition of the material lost from CC on hydration. These are below American Environmental Protection agency limits.

Although CC is often suitable for raw (natural) water applications, the adhesive sealants or grout mixes used for jointing and perimeter fixings must also be checked for suitability when there is a risk of discharge of hydration water into natural watercourses.

9.3 Setting

Once hydrated, CC typically remains workable for 1 to 2 hours. This may be reduced to approximately 40 minutes in hot climates or when hot/saline water is used. This time should be used to make any minor adjustments to the material rather than carry out jointing or securing edge fixings.

After hydration anchor trenches should be backfilled, taking care not to stain the surface of the CC.

CC hardens in 24 hours and is then ready for use.

9.4 Warmer Climates/Drying Conditions

Drying conditions typically occur in warmer climates and can affect CC in the first 5 hours after hydration resulting in excessive loss of water and preventing the specified strength gain.

Drying conditions occur when there is one or more of: high air temperature (>22°C), wind (>12km/h), strong direct sunlight or low humidity (<70%).

Specific drying condition hydration guidance is provided in the *Hydration Guide* and summarised below:

- Hydrate at dusk where possible.
- Hydration Methods:

  Option 1 - Hydrate and respray as soon as the surface ceases to be wet to the touch, with at least one respray at 2-3 hours. Continue to monitor for the first 5 hours from initial hydration and respray as necessary.

  Option 2 - Hydrate with 3 passes at maximum 20 to 30 minute intervals. Continue to monitor for the first 5 hours from initial hydration and respray as necessary.

  Option 3 - Hydrate and respray at hourly intervals for the first 5 hours.

- Other methods to reduce evaporation (such as covering the material) may also be used.
- It is also recommended to give all installed CC a final hydration prior to completion of the days work.
- In drying conditions, the CC should be inspected after 24 hours. If it is suspected that the material has over-dried, re-wet, in accordance with these instructions. This will normally enable the CC to gain the specified strength, provided it has not been heavily trafficked or mechanically damaged prior to full set.

9.5 Low Temperature Hydration Conditions

CC is widely used through cold temperature climates across the globe including Canada, Russia, Northern Europe, Japan and the United States. In principle, providing the ground surface temperature remains above -4°C within 24 hours of initial hydration and if a contractor has liquid water available on site, then it is possible to install CC.

Cold temperature installation does not affect the ultimate strength or performance characteristics of CC, but will retard the time it takes to achieve those values. Material that has been hydrated 2-4 hours prior to exposure of freezing temperatures will not suffer setting performance, only a retarded setting time.

When cured, CC exhibits excellent freeze thaw resistance making it suitable for the most extreme conditions. The speed of CC installation allows contractors to operate within tight construction periods in cold temperature climates. Note that installing CC on frozen ground that may move significantly when it thaws, may create voids underneath the set CC.

When installing CC in low temperature conditions, standard cold-weather concreting practices should be observed.

Practical Measures to consider when installing CC in cold conditions are:

9.5.1 Construction Programme (timing of deployment and hydration)

In order to take advantage of the highest ambient temperatures at critical points in a single day construction period for CC, the programme should be adjusted to consider when best to deploy the material and when best to hydrate the material.

Deployment

- If practically feasible, it is recommended to deploy material at midday of construction, to take advantage of the warmest ground temperatures during the day.

Hydration

- If practically feasible, it is recommended to hydrate deployed CC in the morning phase of construction, to take advantage of rising temperatures during the day.

9.5.2 Application of Covering Sheet

If the ground surface temperature is between 0°C and 5°C and rising the CC should be covered with plastic sheeting, curing blankets or heat retention systems immediately after hydration. CC setting is exothermic and it is important to retain the generated heat within the material during the setting period.

Figure 9.1 Plastic sheeting on CC during curing

9.5.3 Warm Water Accelerant Dosing and use of Water

If the surface temperature is expected to fall below 0°C in the 8 hours following hydration, in addition to using covering sheets the hydration water should be warmed and dosed with accelerant. It is important to only use accelerant recommended by Concrete Canvas Ltd as some admixtures may delay set or impair performance. Typical dosage values are 150g/1000 litres of water but please contact Concrete Canvas Ltd with your specific temperature profile for a recommendation on the dosage of accelerant required. Hydration water is ideally 20°C above ambient temperature, but no greater than 40°C in total. Using hot water to increase concrete temperature is a common winter practice and hot water bowsers, submersible heat pumps or similar are typically locally available to contractors. High pressure heated jet washers are not recommended.

9.5.4 Inspection

It is recommended to carefully check the CC at 24-48 hours after hydration by applying pressure using your hand to check that the CC is curing. If the material is not curing, re-hydrate using the practical measures listed above.

10.0 Inspection and Post Installation Treatments

10.1 Inspection

It is recommended to carry out periodic inspection of CC lined watercourses in the first days/weeks after installation, after thefirst storm event, and as part of routine maintenance schedules (or at least annually), in order to check for any signs of damage including structural or hydraulic compromise. Any observed scour/erosion around the CC (in particular to the backfill of crest anchor trenches) must be repaired and protected to prevent the risk of water or wind ingress which could compromise the CC lined structure. Similarly, any observed bulging/movement of side slopes must be inspected for geotechnical stability by an appropriately qualified engineer and repaired/protected if necessary.

10.2 Cleaning and Maintenance

For the majority of projects, CC does not require cleaning or maintenance after installation. However, applications which incorporate baffling will require periodic maintenance to remove the accumulated silt, which by design will collect around these structures.

In cases where CC has been poorly jointed and a void space occurs between the overlapped layers, it is possible for wind-blown debris to accumulate which may provide a base for limited vegetation growth.

If cleaning or maintenance is required, consult the *User Guide – Inspection, Cleaning and Maintenance*.

10.3 Surface Finishes

Sometimes the uncured CC has a 'striped' pattern where the concentration of cement powder on the top surface varies across the material width and is a natural part of the CC manufacture process. The striped pattern is purely a visual variation, the entire CC material contains the same mass of cementitious material to achieve a full QC pass and will achieve the long-term performance properties. If the striped appearance is a concern the installer can brush the surface of the CC before hydration.

Typical hydration of CC reduces the striped appearance and a mottled grey finish that becomes uniform over time. The fibrous top surface can also darken if wind-blown dust and soil is trapped in the fibrous surface.

Figure 10.1 Striped surface prior to hydration, more uniform surface after hydration, darkening of surface 3 years later

In damp and shady environments the surface of CC provides a favourable base for moss growth. This is not harmful to the material and helps it blend in with the surrounding natural environment.

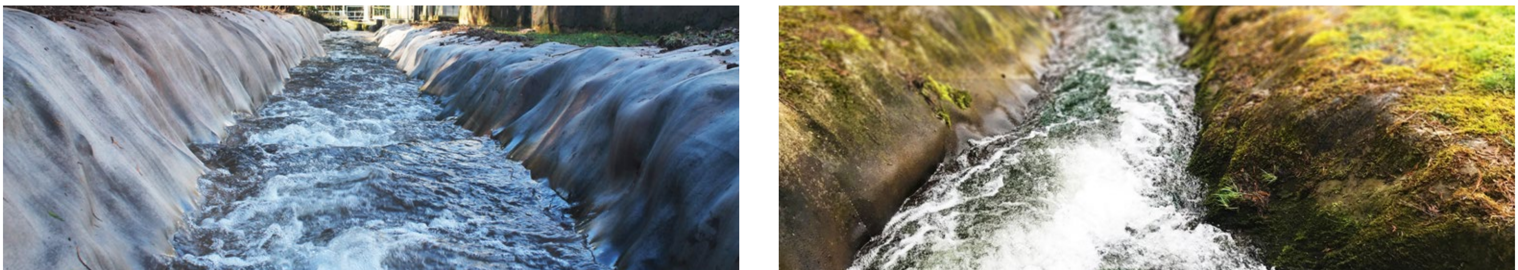


Figure 10.2 Completed CC lined channel and 4 years later - darkened surface with moss growth

If the client wants an immediate uniformity in the finished appearance, once the CC has cured it can be jet washed to return the top surface fibres of the material to a bright white finish. Use a fixed nozzle at least 150mm from the surface and move continuously in a sweeping pattern.

Striped appearance immediately after installation

Uniform surface achieved after jet washing surface

CC can also be painted to change the aesthetic to blend in with vegetation, soil or sand. It is recommended to use masonry paints and take into consideration environmental sensitivities.

Standard CC colouring

Applied coating to change aesthetic

If the surface of CC the will be walked upon, then it is advised to apply a textured coating to provide an anti-slip high friction surface and prevent non-root organic growth on the top fibrous surface of the CC. It is possible to brush on screed mix or floorgum paints. All paints or treatments must only be applied once the CC has fully cured. This is at least 24 hours after adequate hydration, but ideally at least 3-7 days afterwards.

Heavy vehicular traffic must not be permitted directly on the CC unless the subgrade has been prepared with sufficient California Bearing Ratio (CBR) strength to support vehicle traffic without causing rutting. It is not recommended for vehicles to turn on CC as torsional loads can ruck the surface of the material. In areas of heavy traffic or when tracked vehicles will travel over the CC, the material must be protected by placing an adequate protective cover (such as protective mats, block paving or a suitable gravel layer) over the top of it.

10.4 Modifications

If modifications are required to existing structures (for example to insert a service pipe through the material), set CC can be cut using the same tools used for cutting conventional concrete, such as disc cutters or angle grinders. New (uncured) CC can be secured to existing (cured) CC using the guidance stated in section 5.5.

10.5 Repair

Damage is rare but may occur due to large debris impact or acts of vandalism. If small, localised damage is found, the damaged can be filled with a suitable grout/mortar mix, or a patch can be placed over the damaged area extending a minimum of 100mm in all directions beyond the damaged area and attached with tech screws, then sealed with mortar or an approved sealant.

For larger areas of damage, CC layers can be cut out and replaced. Consult Concrete Canvas Ltd for more information on how to repair damage to CC structures.

11.0 Appendix

11.1 Hydraulic Design Guidance

Determining Curvature Factor:
To calculate the curvature factor for a section of a channel, follow the instructions below:

1. Calculate the radius of curvature (R_c) of the most severe bend in the channel (see Figure 11.1).
2. Find out the exposed surface width (w_e, see Figure 11.2).
3. Divide R_c by w_e.
4. Using Figure 11.3. below, read the K_c value that corresponds to the R_c by w_e value.

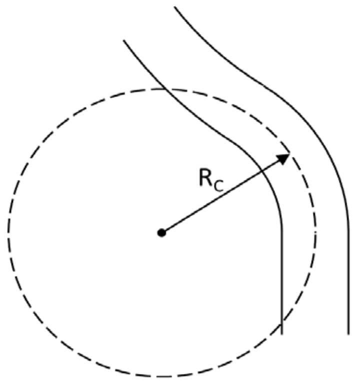


Figure 11.1. Channel plan view showing radius of curvature

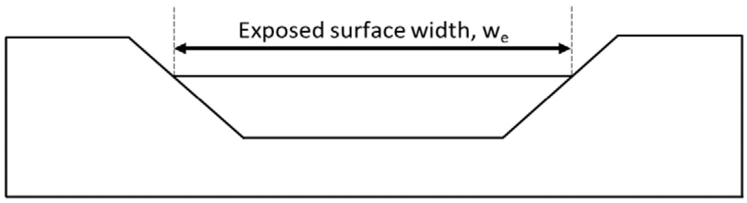


Figure 11.2. Channel section view showing exposed surface width

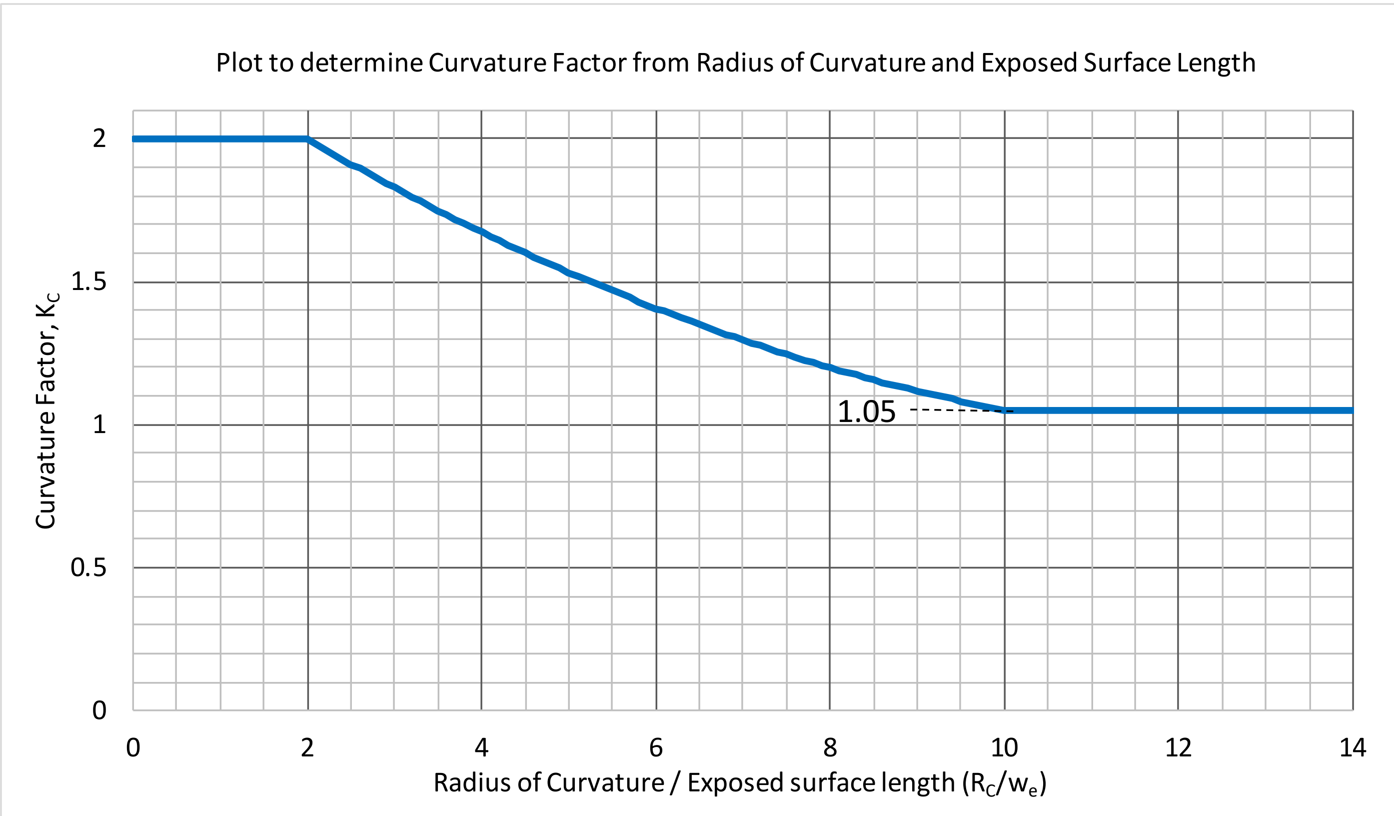
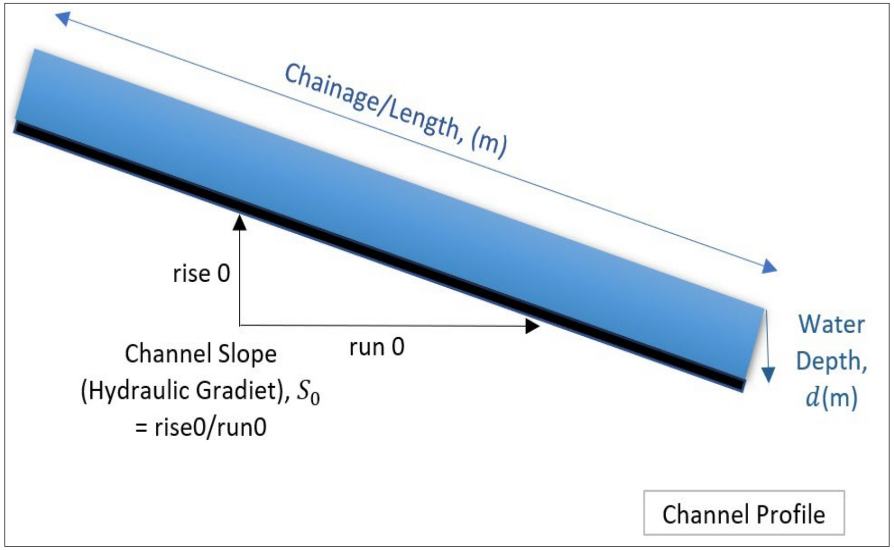


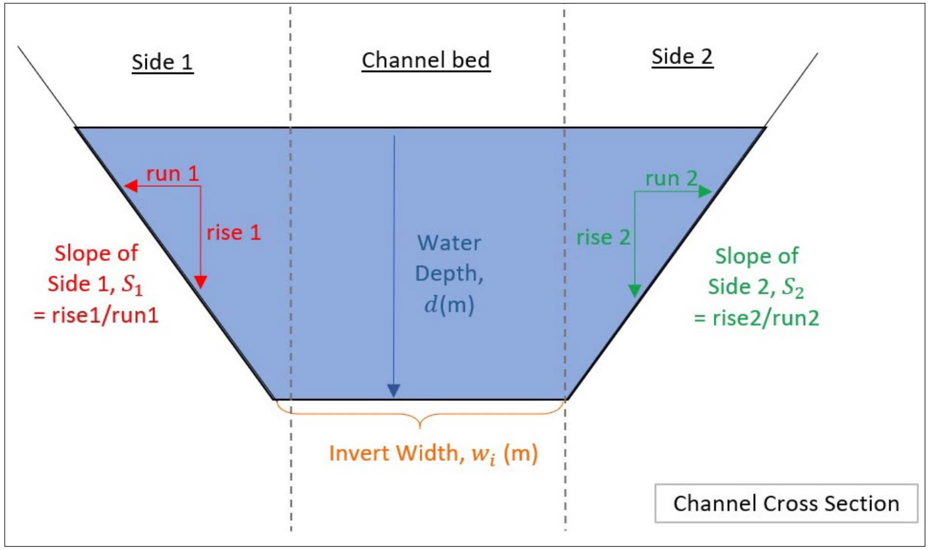
Figure 11.3. Graph to determine the curvature factor of a channel

Figure 11.4 Hydraulic Analysis Input Parameters (to be completed and sent to Concrete Canvas Ltd for advice on intermediate fixing requirements)

Channel Description	Channel Profile			Channel Cross Section				Additional Parameters				
	Chainage/ Length, (m)	Channel Slope (Hydraulic Gradient), S_0	Radius of Curvature R_c (m)	Invert Width, w_i (m)	Slope of Side 1, S_1	Slope of Side 2, S_2	Water Depth*, d (m)	Substrate Surface Type	Substrate Angle of Friction⁺, φ	CC Type	CC Layup (transverse/ longitudinal)	Anchor Head Plate Diameter, D_f (mm) (if known)

* Water depth (d) can be replaced with flow rate (Q) or velocity (V), but d is recommended as it provides the most accurate results.
⁺ When installing CC on concrete surfaces, use a φ of 28°, when installing CC on geotextiles, use the lower of a φ of 31°, or the δ (Interfacial Friction Angle) between the geotextile and the substrate.





11.2 Reference Documents

General Guidance

- CC Civil Brochure
- CC Logistics Guide
- CC Hydration Guide
- CC Equipment List
- CC User Guide: Thermal Bonding
- Inspection, Cleaning and Maintenance Guide
- Safety Data Sheet

Other Specification Documents

- Specification Guide: Slope Protection
- Specification Guide: Weed Suppression
- Specification Guide: Containment Structures

Installation Guides

- Channel Lining
- Remediation
- Culvert Lining
- Slope Protection
- Weed Suppression
- Bund Lining

Webinars

- 1 Introductory Presentation
- 2 Designing with CC
- 3 Specifying GCCMs to D8364

Technical Data

- CC Data Sheet
- CC Spec Sheet to ASTM D8364
- CC BBA Certificate
- CC ETA
- Technical Note 1
- Technical Note 2
- Technical Note 3
- GCCM Index Testing
- CC Abrasion Resistance Report
- CC Flume Testing
- CC Manning's Transverse Testing
- CC Manning's Longitudinal Testing
- CTL Leachate Report
- CC Saline Resistance Report
- CC Shear Interface Data
- CC Surface Fibre Weathering Resistance
- CC Differential Ground Movement

Specification Tools

- Essential Properties for GCCM Specs
- CC Drop in Specification
- CC Specification Tables
- CC Standard Detail Drawing Library