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Concrete on a Roll

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CONCRETE CANVAS®
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HYDRAULIC DESIGN GUIDANCE NOTES

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Introduction

Concrete Canvas® (CC) GCCM* is predominantly used to provide weed suppression and erosion protection to drainage channels. Whilst the majority of CC lined channels operate at relatively low flow rates and can be designed and installed in accordance with the standard *CC Installation Guide – Channel Lining*, it may be necessary for certain design aspects to be given additional consideration on large profile, high gradient or high flow rate channels. This document provides additional guidance notes to the following areas:

- Anchor Trenches
- Check Slots
- Substrate Drainage
- Intermediate Fixings

Anchor Trenches

All CC material perimeter edges must be captured (typically buried in anchor trenches) in order to prevent water ingress and undermining of the structure. The leading/perimeter edge that receives water flow is at particular risk of undermining. The material used for anchor trench backfill must be 'non-erodible', which is dependent on the erosion forces that the anchor trench will be subjected to over the design life of the structure. A poured concrete or cement stabilised trench is preferred for leading edges and at the crest of interceptor drains which collect adjacent water runoff. A soil/aggregate backfill may be sufficient when there is no water flowing over the anchor trench and into the channel. Perimeter edges can be connected to existing infrastructure with mechanical fixings and gaskets/adhesive sealants to reduce water ingress. Contact Concrete Canvas Ltd for standard detail drawings.

Check Slots

CC acts as a low permeability erosion control layer, channelling flowing water along the surface of the material. A fundamental design consideration is that water is not permitted to flow beneath the material, as this would reduce inter-facial friction, create dynamic uplift pressure and potentially displace CC layers. Water flow beneath the CC can typically be prevented by burying all perimeter edges in backfilled anchor trenches and shingling overlapped layers in the direction of water flow to prevent ingress.

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 channels are located alongside stockpiles of large boulders, which may become dislodged and fall into the channel (Figure 1). 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 far 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 amount of debris that could enter the channel and the impact energy. If the likelihood of severe debris impact or the consequence of unzipping is high, a designer/client may wish to limit the extent by which an unzipping event can occur (and therefore commercial risk to repair) by introducing check slots into a channel. A check slot is essentially a mid-channel anchor. On soil substrates the check slot is typically a concrete filled anchor trench (Figure 2) and for concrete remediation projects the check slot is a stainless steel batten bolted to the substrate (see Figure 3). Check slots are installed across the width of the channel and divides the length of the channel 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.

Figure 1. Section of channel at risk of boulder impact and potential damage

Figure 2. Poured concrete check slot being installed in channel

Figure 3. Stainless steel batten check slot

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. Previous projects have included check slots at 30m centres as the likelihood of trees or boulder impact was high, but for other projects the check slots were spaced to limit potential risk to one full roll of CC material.

*Geosynthetic Cementitious Composite Mat

Substrate Drainage

In large channels, negative water pressure behind the CC has the potential to cause damage to the CC layer and there are several potential modes of failure that need to be considered. Apart from the stress (and potential material uplift) caused by a simple build up of pore water pressure, the secondary effects of washing out of soil fines and consequent piping failure have to be guarded against.

There are primarily two situations where external pore water pressure may develop:

High ground water situations (or whenever there is a risk of water flow beneath the CC layer). In small channels the self-weight of hardened CC is often sufficient to resist any uplift but if required, intermediate fixings can be specified to improve resistance. Installing a geotextile under the CC can prevent washout of fines through permeable joints and is recommended for most channel lining projects. Substrate drainage measures can also be designed to alleviate pressures. A sub-CC drainage layer of gravel (see Figure 4) or drainage geocomposite can be installed beneath the CC. Perforated pipes running parallel to the direction of the channel and discharging at cross drainage structures can also be incorporated into the design (See Figure 5). In localised areas of high ground water, pressure relief valves (which let water in but not out of the channel) can be installed. Weep holes can be incorporated (protected with gravel and geotextile filter, or no fines concrete,) but these also allow water out of the channel and should only be used for weed suppression applications when water loss is not critical.

Rapid drawdown of the channel. This can occur in channels with permeable joints that temporarily store water. If the surrounding soil has been saturated by seepage through the CC joints and the channel is then quickly emptied, the water in the saturated soil applies a pressure against the CC as it slowly escapes through the joints. The effects of rapid drawdown can be restricted by specifying reduced permeability joint methods or by using CC Hydro™ to prevent seepage to surrounding soil.

Figure 4. CC installed on a granular sub-drainage layer

Figure 5. CC remediation with sub-drainage perforated pipe discharging at 10m centres along structure

Intermediate Fixings

The flow of water in the drainage channel creates a shear force that acts on the invert and side slopes of the substrate. If the destabilising hydraulic shear force is greater than the resistive frictional force of the substrate, erosion will occur. Conventional erosion control geosynthetics such as Turf Reinforcement Mats (TRMs) rely on improving the resistance of vegetation to erosion, whereas CC is used as an alternative to conventional concrete, providing a hard armour barrier to prevent water coming into contact with the substrate and eroding the surface. CC is used when higher levels of protection are required than TRM's can offer, or when vegetation needs to be prevented from establishing in order to avoid long term maintenance issues.

Although CC lined channels prevent erosion of the substrate, the hydraulic shear forces still need to be considered in the design to ensure suitable mitigation measures are taken to prevent CC material movement. For the majority of CC channel lining applications, the interface friction between the underside of the CC and substrate provides sufficient resistance, but when this is exceeded, Intermediate fixings such as earth percussion anchors are required. Intermediate fixings have been successfully utilised on CC lined channels, 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 Concrete Canvas® 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'.

Intermediate Fixings Continued...

While developing the calculator, researchers identified that there are three channel parameters that can be used to determine whether intermediate fixings are likely to be required on CC lined structures:

- Channel slope (gradient), S
- Substrate internal angle of friction, ϕ
- Channel degree of curvature, K_C.

The Hydraulic Shear - Intermediate Fixing Requirements Graph (Figure 6.) has been developed to assist designers of CC lined channels. The three key channel parameters are used to determine whether intermediate fixings may be required.

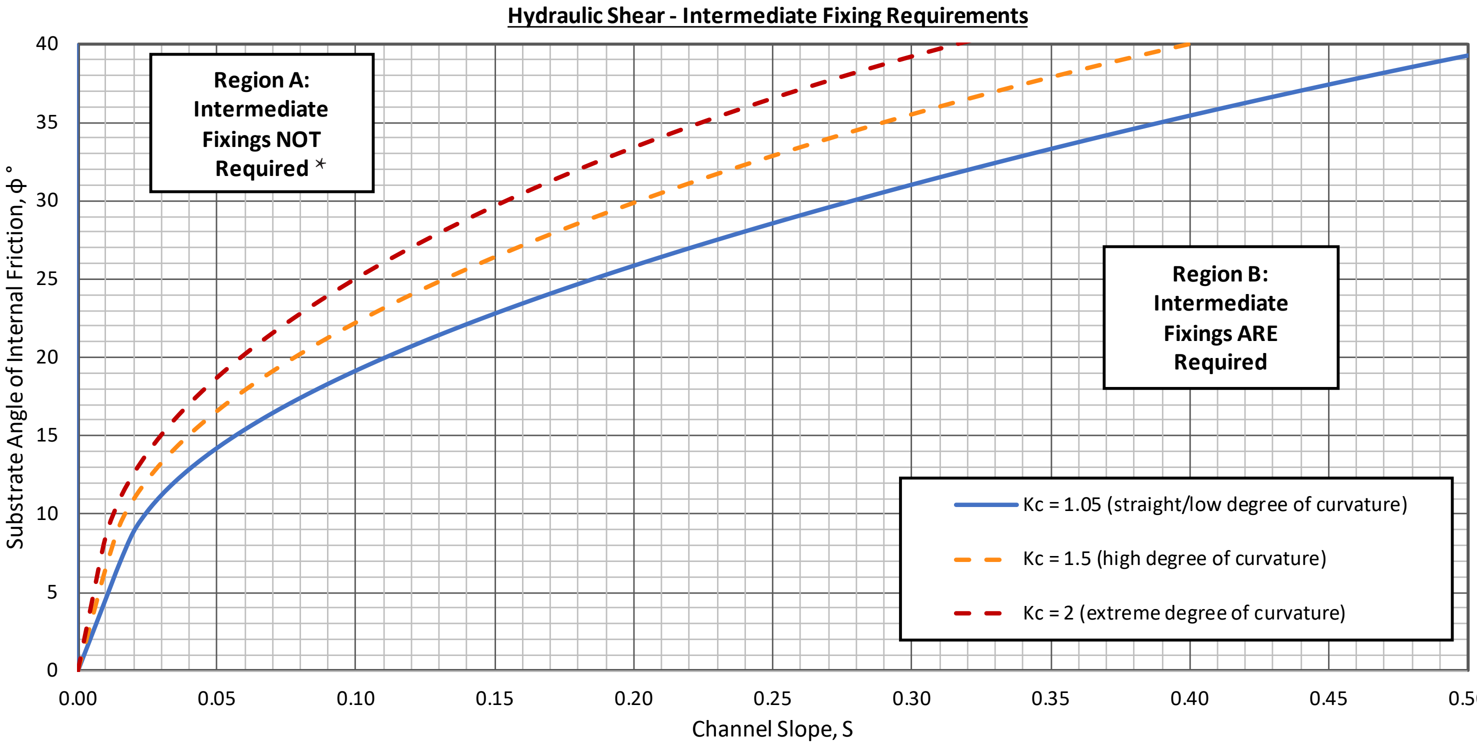

Figure 6. Hydraulic Fixture Requirement Graph

Instructions for Use:

1. Find out the Channel Slope (S=rise/run). It is recommended to use the highest S value of any section of the channel.
2. Determine the **minimum** ϕ (Angle of Internal Friction) of the underlying substrate, up to a maximum value of of 35˚. For concrete substrates use ϕ =28˚, when placing on a geotextile, use the lower of 31˚ or the δ (Inter-facial Friction Angle) between the geotextile and the substrate.
3. Find the position on the graph that corresponds to the channels 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:

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.

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.

If a designer identifies a potential CC lined channel 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 can complete the appended Hydraulic Analysis Input Parameters table and send to Concrete Canvas Ltd for analysis and advice.

Appendix

Determining Curvature Factor:

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

1. Calculate the radius of curvature (R_C) of the most severe bend in the channel (see Figure 7.)
2. Find out the exposed surface width (w_e, see Figure 8.)
3. Divide R_C by w_e.
4. Using Figure 9. below, read the K_C value that corresponds to the R_C by w_e value.

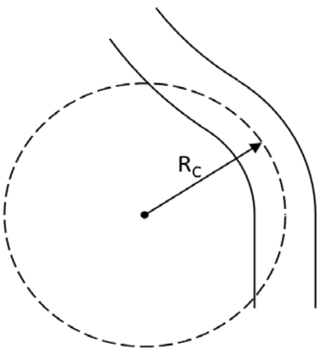

Figure 7. Channel plan view showing radius of curvature

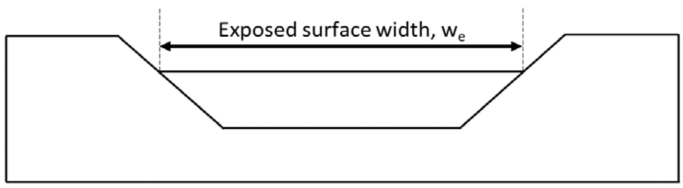

Figure 8. Channel section view showing exposed surface width

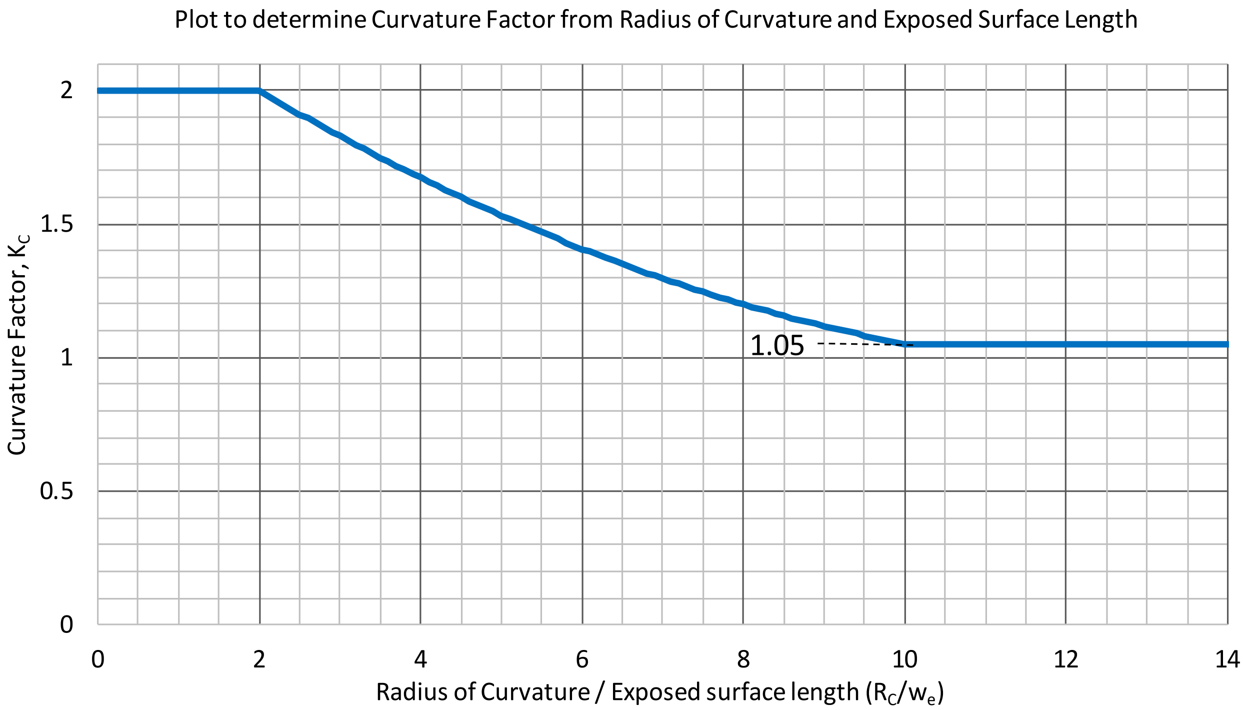

Figure 9. Graph to determine the curvature factor of a channel

This report is provided to assist the designer in considering the requirement for fixings to resist hydraulic forces. The designer should satisfy themselves on the fixings required and specify these under their indemnity insurance. Concrete Canvas Ltd will not be liable for any loss or damage arising from any use of or reliance on this information for construction purposes.

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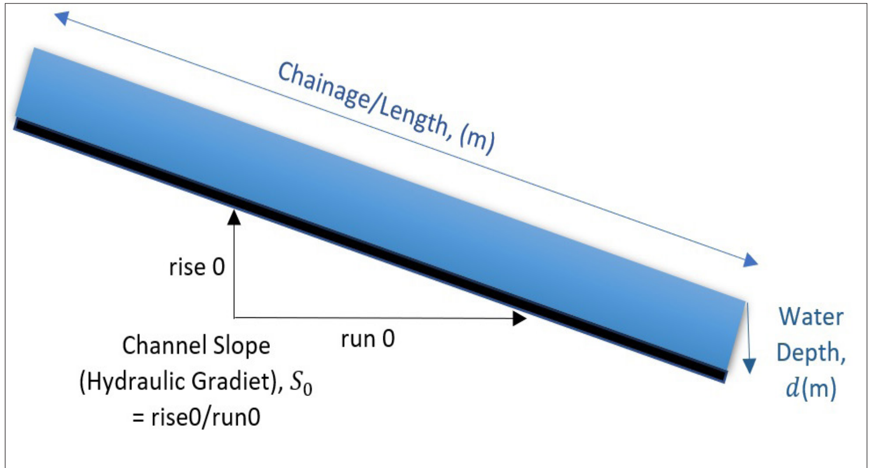
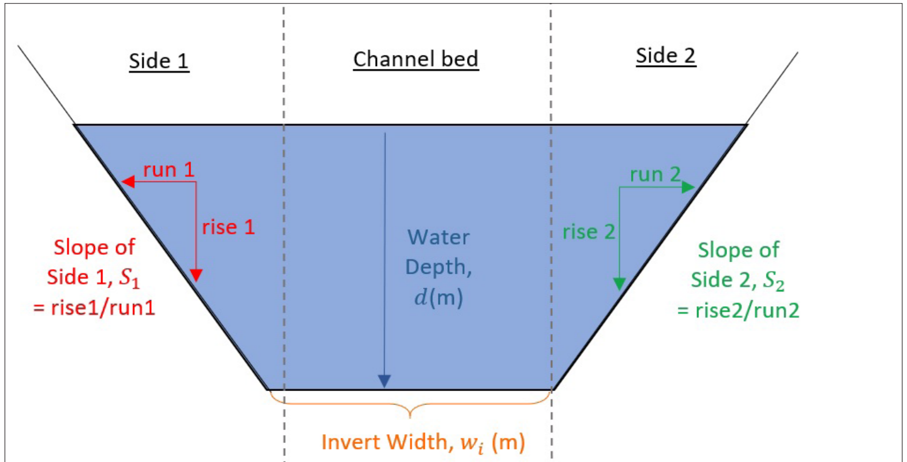
Hydraulic Analysis Input Parameters (to be completed and sent to Concrete Canvas Ltd for advice on intermediate fixing requirements)

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	MINIMUM 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 (Inter-facial Friction Angle) between the geotextile and the substrate.



Channel Profile



Channel Cross Section

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