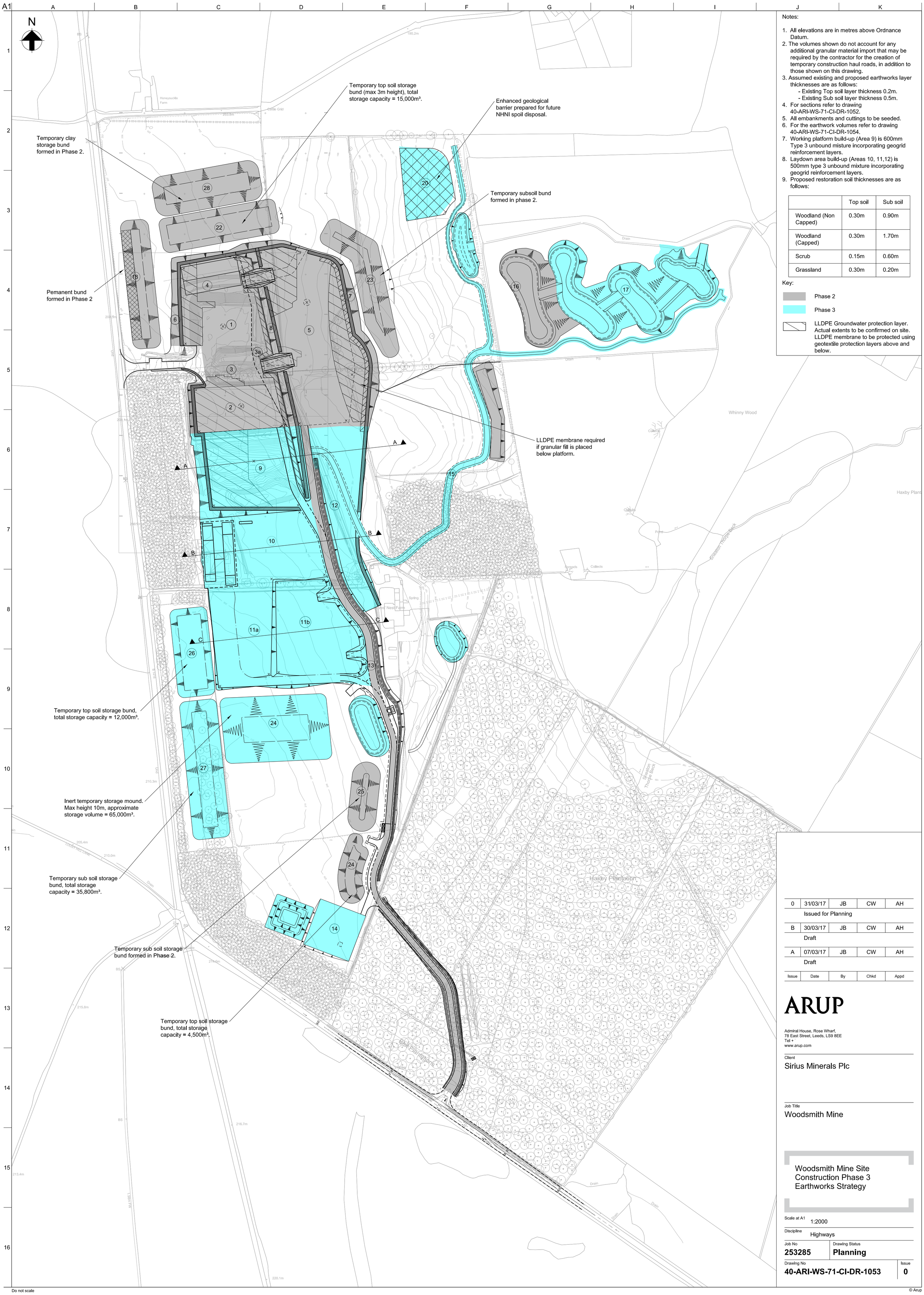


Notes:

1. All elevations are in metres above Ordnance Datum.
2. The volumes shown do not account for any additional granular material import that may be required by the contractor for the creation of temporary construction haul roads, in addition to those shown on this drawing.
3. Assumed existing and proposed earthworks layer thicknesses are as follows:
   - Existing Top soil layer thickness 0.2m.
   - Existing Sub soil layer thickness 0.5m.
4. For sections refer to drawing 40-ARI-WS-71-CI-DR-1052.
5. All embankments and cuttings to be seeded.
6. For the earthwork volumes refer to drawing 40-ARI-WS-71-CI-DR-1054.
7. Working platform build-up (Area 9) is 600mm Type 3 unbound misture incorporating geogrid reinforcement layers.
8. Laydown area build-up (Areas 10, 11,12) is 500mm type 3 unbound mixture incorporating geogrid reinforcement layers.
9. Proposed restoration soil thicknesses are as follows:

	Top soil	Sub soil
Woodland (Non Capped)	0.30m	0.90m
Woodland (Capped)	0.30m	1.70m
Scrub	0.15m	0.60m
Grassland	0.30m	0.20m

Key:

- Phase 2
- Phase 3
- LLDPE Groundwater protection layer. Actual extents to be confirmed on site. LLDPE membrane to be protected using geotextile protection layers above and below.

Issue	Date	By	Chkd	Appd
0	31/03/17	JB	CW	AH
	Issued for Planning			
B	30/03/17	JB	CW	AH
	Draft			
A	07/03/17	JB	CW	AH
	Draft			

ARUP

Admiral House, Rose Wharf,
78 East Street, Leeds, LS9 8EE
Tel +
www.arup.com

Client
Sirius Minerals Plc

Job Title
Woodsmith Mine

Woodsmith Mine Site
Construction Phase 3
Earthworks Strategy

Scale at A1 1:2000

Discipline Highways

Job No **253285**

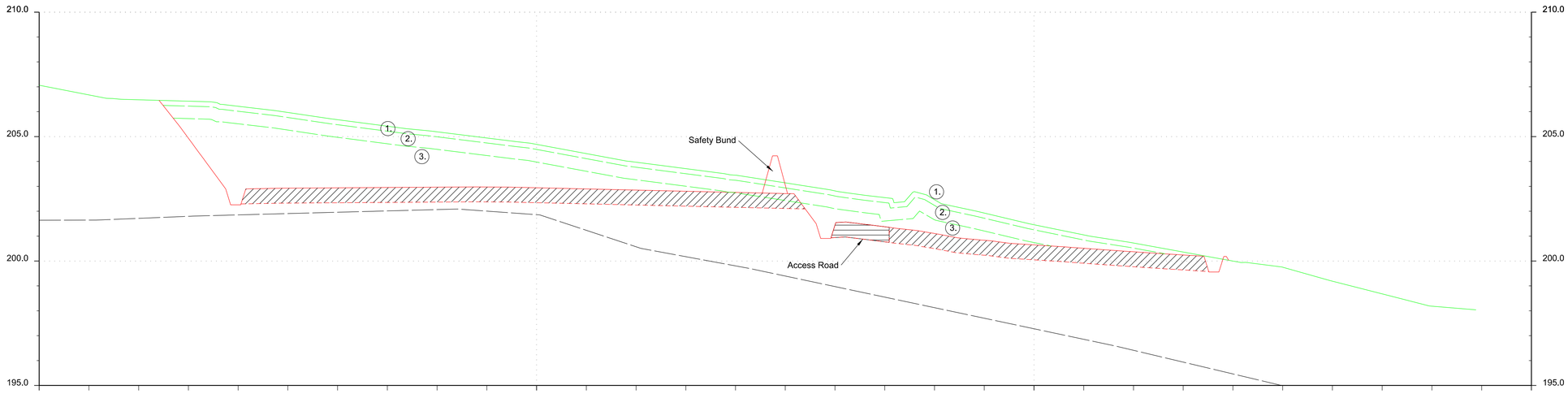
Drawing Status **Planning**

Drawing No **40-ARI-WS-71-CI-DR-1053**

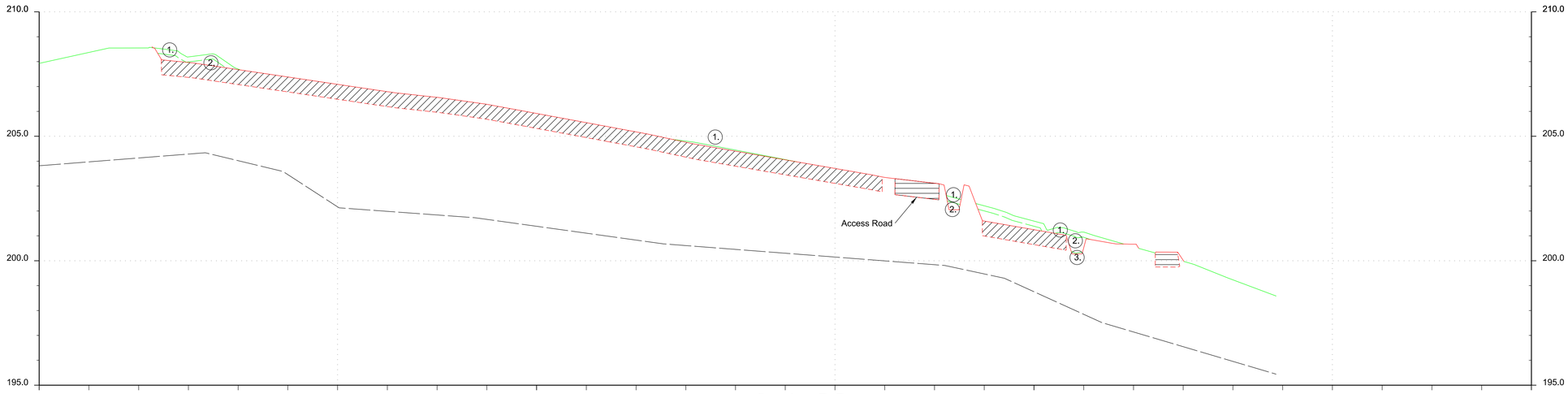
Issue **0**

\\Global\europe\Leeds\Jobs\250000\253285-00\1-2 Arup - P10 Platform Redesign\0-20 CAD P10 - Platform Redesign\0_Drawings\ 40-ARI-WS-71-CI-DR-1053.dgn

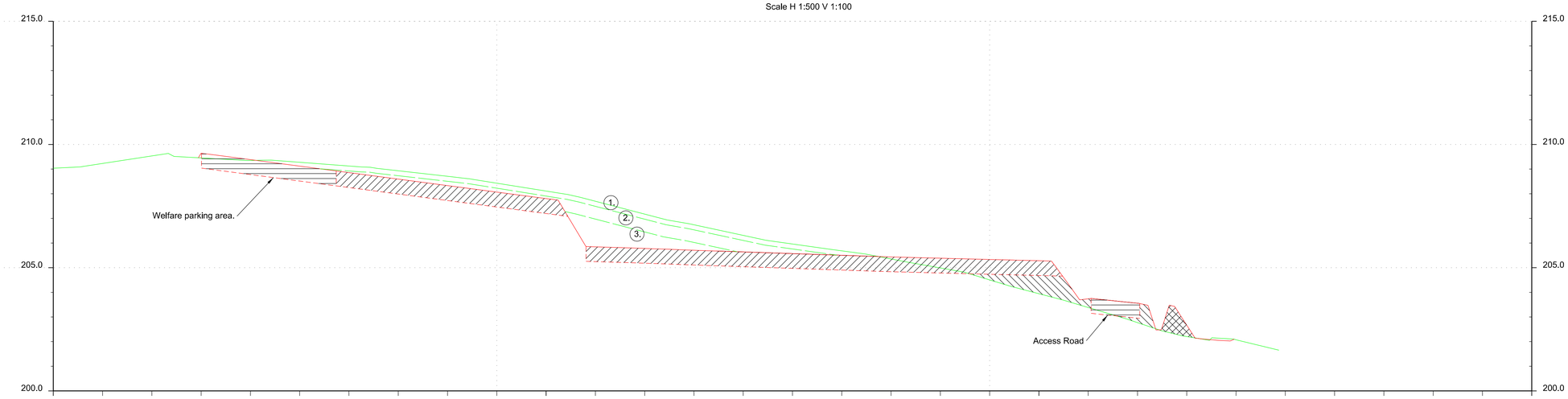
Do not scale



Section A-A
Scale H 1:500 V 1:100



Section B-B
Scale H 1:500 V 1:100



Section C-C
Scale H 1:500 V 1:100

Notes:

1. All levels are in metres unless stated otherwise.
2. For section location refer to drawing 40-ARI-WS-71-CI-DR-1053.

Key:

- Existing ground profile
- Proposed platform profile
- Approximate level of rockhead
- Base of new platform construction

Key to assumed platform pavement construction depths and details:

1. Top Soil Cut
2. Sub-Soils Cut
3. Superficial Soils Cut
- Platform Construction (Import)
- Class 1A Fill (Import)
- Superficial Soils / Clay
- Road construction

Issue	Date	By	Chkd	Appd
0	31/03/17	JB	CW	AH
	Issued for Planning			
B	30/03/17	JB	CW	AG
	Draft for comment			
A	07/03/17	JB	CW	AH
	Draft			

ARUP

Admiral House, Rose Wharf,
78 East Street, Leeds, LS9 8EE

www.arup.com

Client
Sirius Minerals Plc

Job Title
Woodsmith Mine

Woodsmith Mine Site
Construction Phase 3
Sections

Scale at A1 1:500

Discipline Highways

Job No **253285**

Drawing Status **Planning**

Drawing No **40-ARI-WS-71-CI-DR-1052**

Issue **0**

APPENDIX 2

ARUP GEOTXTILE DESIGN CALCULATIONS

ARUP

JOB TITLE	Sirius Minerals, Woodsmith Mine Site Preparation
JOB NUMBER	253285
MADE BY	TC
CHECKED BY	AGH
DATE	04/03/2017
Description of spreadsheet	To determine the mass per sq m of geotextile to protect a geomembrane groundwater protection layer within the working platform
Sheet Number prefix	
Member/Location	Services Shaft Platform, mobile plant working area 300mm cover
Drawing Reference	
Filename	

CONTENTS OF SPREADSHEET

Sheet	Description
Cover	
Notes	
Calc(P)	
Attachment	Type 3 grading certificate

AUTHORISATION OF LATEST VERSION

Type and method of check		input data check and manual calculation
Signatures & dates:	Made by	TC
	Checked	AGH

REVISIONS Current Revision 1

Rev.	Date	Made by	Checked	Description
0	06/03/17	AGH	TC	
1	03/04/17	TC	AGH	Updated to reflect plant and actual Type 3 aggregate grading

(1) Purpose of spreadsheet

To determine the mass per sq m of geotextile to protect a geomembrane groundwater protection layer within the working platform

(2) Key Assumptions

Type 3 unbound mixture is well graded aggregate. Protrusion height is assumed to be 15mm based upon the d_{50} value for Type 3.

(3) Basis of calculations

Robert Koerner Designing with Geosynthetics 4th Ed Section 5.6.7

(4) Sources of data & Links to other spreadsheets

Date	File path / URL	Description

(5) Special features

(6) Diary of development, including checking

(if supplement is needed to Cover page)

Date	Who	Description

Best Practice Guide

1. Don't duplicate raw data in the spreadsheet i.e. use cell references where possible.
2. Use colours to distinguish between fixed data, user-variable data, calculations and results.
3. Explicitly define constants to be used in equations, using named cells where appropriate.
4. Avoid password use unless essential and documented (to avoid loss of work with loss of password).
5. Ensure extracts copied to other documents can be traced back to the spreadsheet.
6. Plot to engineering scale whenever sensible to do so, and make units obvious.
7. For charts, use colours/patterns which will be distinguishable if printed or photocopied in black & white.
8. Give sheets & workbooks descriptive names.
9. Use comments to describe the purpose of individual cells and ranges of cells.
10. Use the revision facility on the cover page and maintain the diary where further details required.

ARUP	Job No.	Sheet No.	Rev.
	253285		1
	Member/Location	Services Shaft Platform, mobile	
Job Title: Sirius Minerals, Woodsmith Mine Site	Drg. Ref.	plant working area 300mm cover	
Calculation: Preparation	Made by: TC	Date: 04/03/2017	Chd.: AGH

Calculation to determine weight of geotextile (g/sqm) required to provide puncture protection to a geomembrane. From Koerner, section 5.6.7

P_{allow} = FS (P_{act}) (eq1)

where

P_{allow} = allowable pressure
P_{act} = actual pressure due to plant
FS = Factor of safety against geomembrane puncture = 3

and

P_{allow} = $(50 + 0.00045M/H^2)[1/(MF_s \times MF_{PD} \times MF_A)][1/(RF_{CR} \times RF_{CBD})]$ (eq2)

where

M = geotextile mass g/m^2
H = protrusion height = d_{50}
MF_S = modification for protrusion shape
MF_{PD} = modification factor for packing density
MF_A = modification for arching in solids
RF_{CR} = reduction factor for long term creep
RF_{DBD} = reduction factor for long term chemical/biological degradation

For mobile plant working area

actual wheel pressure	335	kN/m²
platform thickness	0.3	m
contact width	0.9	m
contact length	5.36	m

For Type 3 unbond mixture, the following protrusion height and modification factors are adopted:

H	15	mm	(d_{50} is 15mm for Type 3)		
MF_S	1				
MF_{PD}	0.67		H^2	=	0.000225
MF_A	0.75		$1/(MF_s \times MF_{PD} \times M_{FA})$	=	1.99

The groundwater protection layer has a short service life of 6 to 8 months, therefore adopt

RF_{CR}	1.5		so		
RF_{CBD}	1		$1/(RF_{CR} \times RF_{CBD})$	=	0.67

assuming 45 degree spread of load through the aggregate layer, calculate p_{act} on membrane

P_{act} = 180.8 kN/m²

so

P_{allow} = 542.3 kN/m²

from eq2

M = 179 g/sqm

Comment on results
A 400g/sqm membrane will be specified above the LLDPE liner - based on previous loading and therefore still acceptable.
A 300g/sqm membrane will be specified below the LLDPE liner - based on previous loading and therefore still acceptable.

ARUP

JOB TITLE	Sirius Minerals, Woodsmith Mine Site Preparation
JOB NUMBER	253285
MADE BY	TC
CHECKED BY	AGH
DATE	04/03/2017
Description of spreadsheet	To determine the mass per sq m of geotextile to protect a geomembrane groundwater protection layer within the working platform
Sheet Number prefix	
Member/Location	Services Shaft Platform, excluding mobile plant working area 300mm cover
Drawing Reference	
Filename	

CONTENTS OF SPREADSHEET

Sheet	Description
Cover	
Notes	
Calc(P)	
Attachment	Type 3 grading certificate

AUTHORISATION OF LATEST VERSION

Type and method of check		input data check and manual calculation
Signatures & dates:	Made by	TC
	Checked	AH

REVISIONS Current Revision 1

Rev.	Date	Made by	Checked	Description
0	06/03/17	AGH	TC	
1	04/03/17	TC	AGH	Updated to reflect plant and actual Type 3 aggregate grading

(1) Purpose of spreadsheet

To determine the mass per sq m of geotextile to protect a geomembrane groundwater protection layer within the working platform

(2) Key Assumptions

Type 3 unbound mixture is well graded aggregate. Protrusion height is assumed to be 15mm based upon the d_{50} value for Type 3.

(3) Basis of calculations

Robert Koerner Designing with Geosynthetics 4th Ed Section 5.6.7

(4) Sources of data & Links to other spreadsheets

Date	File path / URL	Description

(5) Special features

(6) Diary of development, including checking

(if supplement is needed to Cover page)

Date	Who	Description

Best Practice Guide

1. Don't duplicate raw data in the spreadsheet i.e. use cell references where possible.
2. Use colours to distinguish between fixed data, user-variable data, calculations and results.
3. Explicitly define constants to be used in equations, using named cells where appropriate.
4. Avoid password use unless essential and documented (to avoid loss of work with loss of password).
5. Ensure extracts copied to other documents can be traced back to the spreadsheet.
6. Plot to engineering scale whenever sensible to do so, and make units obvious.
7. For charts, use colours/patterns which will be distinguishable if printed or photocopied in black & white.
8. Give sheets & workbooks descriptive names.
9. Use comments to describe the purpose of individual cells and ranges of cells.
10. Use the revision facility on the cover page and maintain the diary where further details required.

ARUP	Job No.	Sheet No.	Rev.
	253285		1
	Member/Location	Services Shaft Platform, excluding mobile	
Job Title: Sirius Minerals, Woodsmith Mine Site	Drg. Ref.	plant working area 300mm cover	
Calculation: Preparation	Made by: TC	Date: 04/03/2017	Chd.: AGH

Calculation to determine weight of geotextile (g/sqm) required to provide puncture protection to a geomembrane. From Koerner, section 5.6.7

P_{allow} = FS (P_{act}) (eq1)

where

P_{allow} = allowable pressure
P_{act} = actual pressure due to plant
FS = Factor of safety against geomembrane puncture = 3

and

P_{allow} = $(50 + 0.00045M/H^2)[1/(MF_s \times MF_{PD} \times MF_A)][1/(RF_{CR} \times RF_{CBD})]$ (eq2)

where

M = geotextile mass g/m^2
H = protrusion height = d_{50}
MF_S = modification for protrusion shape
MF_{PD} = modification factor for packing density
MF_A = modification for arching in solids
RF_{CR} = reduction factor for long term creep
RF_{DBD} = reduction factor for long term chemical/biological degradation

For areas trafficked by concrete wagons

actual wheel pressure	195	kN/m²
platform thickness	0.3	m
contact width	0.35	m
Contact length	0.35	m

For Type 3 unbond mixture, the following protrusion height and modification factors are adopted:

H	15 mm	(d_{50} is 15mm for Type 3)	
MF_S	1		
MF_{PD}	0.67	H^2 =	0.000225
MF_A	0.75	$1/(MF_s \times MF_{PD} \times M_{FA})$ =	1.99

The groundwater protection layer has a short service life of 6 to 8 months, therefore adopt

RF_{CR}	1.5	so	
RF_{CBD}	1	$1/(RF_{CR} \times RF_{CBD})$ =	0.67

assuming 45 degree spread of load through the aggregate layer, calculate p_{act} on membrane

P_{act} = 26.5 kN/m²

so

P_{allow} = 79.4 kN/m²

from eq2

M = 5 g/sqm

Comment on results

A 300g/sqm membrane will be specified above and below the LLDPE liner - based upon previous loading and therefore still acceptable.

ARUP

JOB TITLE	Sirius Minerals, Woodsmith Mine Site Preparation
JOB NUMBER	253285
MADE BY	TC
CHECKED BY	AGH
DATE	03/04/2017
Description of spreadsheet	To determine the mass per sq m of geotextile to protect a geomembrane groundwater protection layer within the working platform
Sheet Number prefix	
Member/Location	Services Shaft Platform, mobile plant working area 600mm cover
Drawing Reference	
Filename	

CONTENTS OF SPREADSHEET

Sheet	Description
Cover	
Notes	
Calc(P)	
Attachment	Type 3 grading certificate

AUTHORISATION OF LATEST VERSION

Type and method of check		input data check & manual calculation
Signatures & dates:	Made by	TC
	Checked	AGH

REVISIONS Current Revision 1

Rev.	Date	Made by	Checked	Description
0	06/03/17	AGH	TC	
1	03/04/17	TC	AGH	Updated to reflect plant and actual Type 3 aggregate grading

(1) Purpose of spreadsheet

To determine the mass per sq m of geotextile to protect a geomembrane groundwater protection layer within the working platform.

(2) Key Assumptions

Type 3 unbound mixture is well graded aggregate. Protrusion height is assumed to be 15mm based upon the d_{50} value for Type 3.

(3) Basis of calculations

Robert Koerner Designing with Geosynthetics 4th Ed Section 5.6.7

(4) Sources of data & Links to other spreadsheets

Date	File path / URL	Description

F

(5) Special features

(6) Diary of development, including checking

(if supplement is needed to Cover page)

Date	Who	Description

Best Practice Guide

1. Don't duplicate raw data in the spreadsheet i.e. use cell references where possible.
2. Use colours to distinguish between fixed data, user-variable data, calculations and results.
3. Explicitly define constants to be used in equations, using named cells where appropriate.
4. Avoid password use unless essential and documented (to avoid loss of work with loss of password).
5. Ensure extracts copied to other documents can be traced back to the spreadsheet.
6. Plot to engineering scale whenever sensible to do so, and make units obvious.
7. For charts, use colours/patterns which will be distinguishable if printed or photocopied in black & white.
8. Give sheets & workbooks descriptive names.
9. Use comments to describe the purpose of individual cells and ranges of cells.
10. Use the revision facility on the cover page and maintain the diary where further details required.

ARUP	Job No.	Sheet No.	Rev.
	253285		1
	Member/Location	Services Shaft Platform, mobile	
Job Title: Sirius Minerals, Woodsmith Mine Site	Drg. Ref.	plant working area 600mm cover	
Calculation: Preparation	Made by: TC	Date: 03/04/2017	Chd.: AGH

Calculation to determine weight of geotextile (g/sqm) required to provide puncture protection to a geomembrane.

From Koerner, section 5.6.7

P_{allow} = FS (P_{act}) (eq1)

where

P_{allow} = allowable pressure
P_{act} = actual pressure due to plant
FS = Factor of safety against geomembrane puncture = 3

and

P_{allow} = $(50 + 0.00045M/H^2)[1/(MF_s \times MF_{PD} \times MF_A)][1/(RF_{CR} \times RF_{CBD})]$ (eq2)

where

M = geotextile mass g/m^2
H = protrusion height = d_{50}
MF_S = modification for protrusion shape
MF_{PD} = modification factor for packing density
MF_A = modification for arching in solids
RF_{CR} = reduction factor for long term creep
RF_{DBD} = reduction factor for long term chemical/biological degradation

For mobile plant rig working area

actual wheel pressure	335	kN/m²
platform thickness	0.6	m
contact width	0.9	m
Contact length	5.36	m

For Type 3 unbond mixture, the following protrusion height and modification factors are adopted:

H	15	mm	(d_{50} is 15mm for Type 3)		
MF_S	1				
MF_{PD}	0.67		H^2 =		0.000225
MF_A	1		$1/(MF_s \times MF_{PD} \times M_{FA})$ =		1.49

The groundwater protection layer has a short service life of 6 to 8 months, therefore adopt

RF_{CR}	1.5	so		
RF_{CBD}	1	$1/(RF_{CR} \times RF_{CBD})$ =		0.67

assuming 45 degree spread of load through the aggregate layer, calculate p_{act} on membrane

P_{act} = 117.3 kN/m²

so

P_{allow} = 351.9 kN/m²

from eq2

M = 152 g/sqm

Comment on results

A 300g/sqm membrane will be specified above and below the LLDPE liner - based upon previous loading and therefore still acceptable.

APPENDIX 3

DESIGN REQUIREMENTS FOR THE GEOMEMBRANE LINER AND GEOTEXTILE PROTECTION

DESIGN REQUIREMENTS FOR THE GEOMEMBRANE LINERS

3.1 Specification of the 1.0 mm Linear Low-Density Polyethylene (LLDPE) Liner

The selected geomembrane is to meet the following minimum requirements.

Properties	Test Method	Test Value	Testing Frequency
Thickness – mm (min, avg)	D5199	1.0mm	
• Lowest of individual 10 values		-10%	Per roll
Density g/ml (max)	D1505/D 792	0.939	90,000kg
Tensile properties (1) (min, avg) • Break Strength N/mm • Break elongation - %	D6693 Type IV	 27 800	9,000kg
2% Modulus –N/mm (max)	D5323	420	Per formulation
Tear resistance – N (min, avg)	D1004	100	20,000kg
Puncture Resistance – N (min, avg)	D4833	250	20,000kg
Axi-symmetrical Break Resistance Strain - % (min)	D5617	30	Per formulation
Carbon Black Content	D1603	2-3	20,000kg
Carbon Dispersion	D5596	Carbon Black Dispersion (only near spherical agglomerates) for 10 different views- 9 in categories 1 or 2 in Category 3	20,000kg
Oxidative Induction Time (OIT) (min, avg) Either 1. Standard OIT or 2. High pressure OIT	 D3895 D5885	 100 400	90,000kg
Oven aging at 85% (% retained after 30,60 & 90 days) Either 1. Standard OIT or 2. High pressure OIT	D5721 D3895 D5885	 35 60	 Per formulation
UV Resistance (min avg) The condition of the test should be 20hr. UV cycle at 75°C followed by a 4hr condensation at 60°C 1. High pressure OIT -% retained after 1600hrs	 D5885	 35	Per formulation

3.2 Specification of the 2.0 mm High Density Polyethylene (HDPE) Textured Sooth / Rough Liner

The selected geomembrane is to meet the following minimum requirements.

Properties	**Test Method**	**Test Value**	**Testing Frequency**
Thickness – mm (min, avg)	D5199	2.0mm	
• Lowest of individual 10 values		-10%	Per roll
Density g/ml (max)	D1505/D 792	0.94	90,000kg
Tensile properties (1) (min, avg) • Break Strength N/mm • Break elongation - %	D6693 Type IV	 53 >700%	9,000kg
2% Modulus –N/mm (max)	D5323	420	Per formulation
Tear resistance – N (min, avg)	D1004	249	20,000kg
Puncture Resistance – N (min, avg)	D4833	640	20,000kg
Carbon Black Content	D1603	2-3%	20,000kg
Carbon Dispersion	D5596	Carbon Black Dispersion Category 1 or 2	20,000kg
Oxidative Induction Time (OIT) (min, avg) Either 1. Standard OIT or 2. High pressure OIT	 D3895 D5885	 100 min 400 min	90,000kg
Oven aging at 85% (% retained after 30,60 & 90 days) 1. Standard OIT	 D3895	 55%	 Per formulation
UV Resistance (min avg) The condition of the test should be 20hr. UV cycle at 75°C followed by a 4hr condensation at 60°C 1. High pressure OIT -% retained after 1600hrs	 D5885	 50%	Per formulation

3.3 Specification for the Construction Quality Assurance Testing on Geomembranes

The following CQA testing will be carried out on materials delivered to the site under the CQA Engineer's supervision. The testing must be performed in laboratories having UKAS accreditation for each of the specific tests.

Property	Test	Frequency
Conformance sampling and testing Thickness Density Puncture resistance Tear resistance Carbon black content Carbon black dispersion Tensile properties (yield and break stress, yield and break elongation)	See Section 3.2	One sample per 5000m^2, or every five rolls delivered to site whichever is the greatest number of tests. In the event that materials from different resin sources or manufacturing lines are supplied, at least one additional sample of this material must be taken and tested.
Stress crack resistance Oxidation induction time	See Section 3.2	One sample per 10,000m^2, or resin type or manufacturing run
Start-up test weld – welding equipment and welding operative	See Section 3.4	Daily at start of works and after all stoppages of greater than one hour. Also after significant changes in welding conditions.
Non-destructive weld testing Dual track weld extrusion weld	Air pressure test Vacuum box, spark testing, ultrasonics	Continuous – every weld
Destructive weld testing i) On site ii) Off site – weld seam strength in peel and shear	 ASTM D 6392-99 failure mode only (Film tear bond) by hand tensiometer in peel and shear. ASTM D 6392-99	 Every weld One per 200m of seam
Subgrade	Smooth and firm Particle size	Five per hectare (see section 5) Continuous
CQA engineer Visual inspection of geomembrane Thickness of geomembrane (taken at the edge of the sheet)	Tears, hole, stretching Micrometer	Every roll Five per 100m, 10 – 20m apart

3.4 Specification for the Start Up Weld Tests for Geomembranes

The geomembrane installer will undertake a start-up weld test: -

- at the start of each day
- after any welding stoppage exceeding one hour
- where weather conditions have changed, affecting the welding efficiency of the machinery

If any of the above conditions exist, carry out the following sequence of testing under the supervision of the third party independent quality assurance inspector or engineer:

a) A test weld greater than 3m in length. The test must be carried out under the same conditions as exist for the membrane welding. Mark the test weld with the time, date, ambient temperature, geomembrane temperature and welding machine type and number.

b) Cut six specimens, each 25mm wide and at least 105mm long from the weld. Test three in peel and three in shear using a hand tensiometer to confirm failure of the weld takes place in the Film Tear Bond Mode (as per ASTM D6392-99). For fusion welds, test both tracks of the weld in peel.

c) If any specimen fails, repeat the entire operation.

d) If any of the additional specimens fail, inspect the welding equipment reporting any defects and the corrective action taken. If you can correct the problem, the equipment may be used after two further consecutive full trial seams are achieved without failure

e) If the equipment fails five times in any 48 hour period, returned it for repair keeping records of the service.

f) A record of the results must form part of the validation report.

3.5 Specification for the Protective Non-Woven Geotextile

The selected geotextile is to meet the following minimum requirements.

1.	The function of the Geotextile is to protect the geomembrane within the shaft platform. The geotextile shall be manufactured under factory production control guidelines set out within EN 13257; Geotextiles and geotextile related products – characteristics required for use in solid waste disposals. The manufacturer must be able to supply accompanying CE documentation upon request. The functional characteristics and relevant test methods to this specific condition of use are identified below:
2.	The geotextile shall have the following properties:

Physical Properties:				
Polymer type:	Prime quality polypropylene fibre (UV stabilised) with no post-consumer fibres			
Fabric construction:	Nonwoven fabric manufactured from mechanically entangled fibre			
	Approved test method	Units	**Typical mean value**	**Tolerance**
Mass per unit area [1/3]	EN ISO 9864	g/m^2	300	-20%
Thickness @ 2kPa [1/3]	EN ISO 9863-1	mm	2.4	-20%
Mechanical Properties:				
Static puncture strength (CBR)	EN ISO 12236	kN	4000	-10%
Tensile strength (md/cmd)	EN ISO 10319	N/m	250	-10%
Tensile extension (md/cmd)	EN ISO 10319	%	55	+/- 30%
Puncture resistance		N	75	
Burst resistance		kPA	500	
Transverse Permeability		$l/m^2/sec$	100	

Durability (according to annex B: EN 13253)*:			
Resistance to weathering @ $50MJ/m^2$ radiant exposure[2]	EN 12224	Retained strength	80%
Resistance to oxidation (100 years)	EN ISO 13438	Retained strength 56 days	50%
Resistance to liquids	EN 14030	Retained strength	50%
1. To be used at the discretion of the Engineer and property not used as part of harmonised testing within EN 13257			

2. 1-4 months UV exposure depending on location/season *3. Property can be used at the discretion of the designer where required* **Durability test data can be supplied by the manufacturer – test frequency must not exceed 3 years.* **Manufacturer may use alternative means of assessing oxidation to achieve 100 years.*	
3.	The above geotextile is specified as an initial estimate for use with typical stone. It is a requirement that a cylinder test should be carried out prior to installation of the geotextile and stone in accordance with the Environment Agency *Standard:* Cylinder testing geomembranes and their protective materials: A methodology for testing protector geotextiles for their performance in specific site conditions. A report must be provided in accordance with the cylinder test guidance above. Laboratory accreditation to ISO 17025 alone is not acceptable. Testing must be performed using site specific aggregate and membrane. For membrane the **maximum** allowable strain value shall be 0.25% on any individual indentation.
4.	Geotextiles shall be delivered to site in packaging, which will protect the product from damage during handling, storage. Packaging must be suitable to protect the product from UV degradation. Product must be kept in appropriate packaging until such time that it is required for installation. The geotextile shall be clearly and indelibly marked with the product name along the edge of the roll at regular intervals no greater than 5m. The labelling shall clearly identify the product supplied in accordance with EN ISO 10320: Geotextile and Geotextile related products – Identification on site.
5.	The geotextile manufacturer shall provide production test certificates on mechanical properties at the rate of one set of tests per 6,000m^2 delivered to site and a minimum of one set per contract. Test methods employed shall be in accordance with the above specification. Certificates relevant to a full delivery of geotextile, identifying each roll, shall be furnished to the Engineer prior to that batch of Geotextile being incorporated in the works.
6.	The rolls of geotextile shall be stored on level ground. It is suggested that they are stacked not more than five rolls high and no other materials shall be stacked on top of the geotextiles.
7.	The geotextile shall be laid and installed in the positions and to the line and levels described on the drawings. Construction plant must not operate directly on the geotextile.
8.	Joints shall be formed by overlapping by a minimum of 300mm (500mm on downslope overlaps). The contractor should satisfy the Engineer that no material can migrate between layers at the overlap. Alternatively the joint may be reduced to a minimum of 100mm and continuously jointed by the use of an approved jointing technique.
9.	On site quality control should be performed in accordance with CEN/TR 15019. Test specimens should be taken every 6,000m^2 with a minimum of 1 test above 1000m^2 For sampling EN ISO 9862 should be applied, except that samples should be taken no less than 5m from the end of the roll in machine direction and over the whole width in the cross machine direction. The location of the sample should be described exactly. For evaluation of conformance, statistical procedure should be used in line with section 5.2 of CEN/TR 15019: 2004.
10.	The following definitions shall apply when considering test results:

	A *set of test results* shall be those results derived from specimens cut from one sample. The *mean* value for any set of test results shall be the arithmetic mean of that set of results. The *characteristic value* is the value below which not more than 5% of the test results may be expected to fail. This represents the value at 1.645 standard deviations below the mean value.

3.6 Subgrade Inspection

All earthworks shall be undertaken in accordance with the principles of the Specification for Highway Works (SHW) (Ref. 8).

The subgrade design aspects which require the most detailed attention are: -

i) The surface on which the geomembrane and basal geotextile is to be laid must be smooth, dry and flat and free to a depth of at least 150mm from any objects that may puncture the membrane. Subgrade surfaces must be trimmed and compacted to provide a firm smooth surface free of all debris, roots, sharp objects and rounded stones larger than 20mm for 2mm thickness HDPE liners and 10mm for 1mm LLDPE and free of objects protruding more than 10 mm.

ii) For subgrades comprising exposed rockhead this is to be reprofiled by placing a sand blinding layer of 150mm minimum thickness to minimise the risk of membrane rupture.

iii) The surface onto which the membrane / geotextile is to be laid must be as flat as possible. There should be no sharp angles in the subgrade which exceed +10mm under a 1000mm lath and no large rounded irregularity should exceed +50mm under a 3000mm lath. As detailed in Section 2.4 of Appendix 2 measurements of smoothness and flatness are to be taken at a rate of five per hectare and recorded in the CQA report.

iv) The sub-grade must be sufficiently well compacted to prevent localised settlement and possible elongation and rupture of the membrane after construction when the weight of the working platform is applied. Where subgrade materials are placed >0.25m thick compaction is in excess of 95% of the maximum dry density using a 4.5kg rammer.

v) For cohesive subgrade materials this will have a shear strength of greater than 50 kN/m^2.

vi) For subgrades beneath the shaft platform the subgrade is to have a maximum slope angle of 1 vertical in 10 horizontal and a minimum slope angle of 1 in 100.

vii) Where anchor trenches are required these shall be set back a minimum distance of 1m back from the slope crest, comprise a V shaped trench and be backfilled with a low permeable soil.

3.7 Installation

A Quality Control Plan will be prepared for the geomembrane / geotextile installation by the Specialist Contractor that will comply with the Manufacturer's product specific requirements and current guidance (Ref 6 and 7). This Plan will be submitted for approval by the Environmental Engineer in advance of commencement of geomembrane / geotextile installation.

Installation of the Geomembrane will be undertaken by the Specialist Contractor in accordance with the approved Quality Control Plan.

Prior to covering, the surface of the geomembrane is to be inspected by the Specialist Contractor and the Environmental Engineer and any damage, installation faults etc. to be repaired immediately.

On completion of installation, a Quality Control Report will be prepared by the Specialist Contractor for submission to the Environmental Engineer for inclusion in the Geomembrane Construction Validation Report.

Following preparation of an area to be lined, the Environmental Engineer shall inspect the area to ensure that the subgrade complies with the Specification and provide a record for presentation within the Geomembrane Construction Validation Report.

3.8 Documentation and Reporting

The Contractor will keep and maintain records of the delivery of the geomembrane / geotextile materials, compliance testing and installation records.

The Contractor will keep and maintain a daily record of the progress of the Works which shall include:-

a) Date;
b) Weather conditions;
c) Delivery of materials;
d) Plant and labour;
e) Roll numbers deployed;
f) Panels installed;
g) Areas of non-conformance;
h) Repairs;
i) QA installation checklist;
j) Site meetings;
k) Progress photographs;
l) Any other relevant information.

The Contractor will provide the Environmental Engineer with copies of the site diary on a daily basis and a Quality Control Report of all the results and “as built” details on completion of the works.

The Environmental Engineer will on completion of the works prepare a Geomembrane Validation Report including the manufacturer’s quality control documentation, construction details, as-built drawings, inspection records, records of repairs and the Quality Control test results. The as-built drawings shall detail the following:-

a) Construction details including levels and slope angles;
b) Locations and identification marks of each geomembrane / geotextile panel;
c) Locations of damaged areas;
d) Locations of samples;
e) Locations of penetrations.

APPENDIX 4

DESIGN DETAILS FOR THE DRAINAGE DITCH CONCRETE CANVAS LINER

INSTALLATION GUIDANCE:

GROUND PREPARATION:

Preparation of substrate: CC will conform closely to the underlying surface contours of the ditch profile, therefore any vegetation and sharp or protruding rocks should be removed. The ditch should have a uniform profile for ease of future maintenance. If installing on soft ground, a compacted layer of granular fill can be placed in the invert to create a solid substrate.

Anchor trench: IMPORTANT NOTE: CC requires an anchor trench to prevent undermining from surface water run off and provide a neat edge termination.

INSTALLATION

Unpacking: Remove the packaging and unroll CC into the ditch profile ensuring the fibrous top surface faces upwards, with the PVC membrane in contact with the ground.

Laying: For projects requiring a transverse layup, tuck the leading edge of the CC into the anchor trench before cutting to length.

Cutting: Use a 'snap-off blade' utility knife for cutting CC before it is hydrated or set. Allow 15- 20mm from the cut edge due to potential loss of fill. A powered disc-cutter or angle grinder can be used for repeated cutting.

Positioning and fixing: Ensure there is at least a 100mm overlap between CC layers.

IMPORTANT NOTE: Care should be taken to position the overlap in the direction of water flow (like shingled roof tiles). Peg the CC along the anchor trench, through each overlap joint. Hydrate the material under the overlapped sections of the CC.

Jointing: Insert stainless screws at 200mm centres, 30 - 50mm from the edge of the joint. Impermeability of joints can be improved by applying Adhesive Sealant between the layers, prior to screwing.

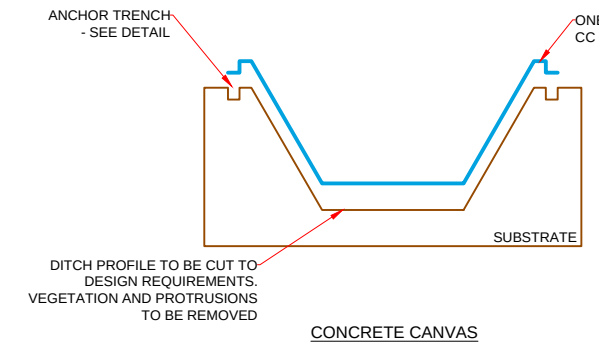
IMPORTANT NOTE: it is essential that CC layers are in direct contact with each other. To prevent CC layers from separating, joints can be weighed with sandbags during setting or additional screws can be used.

Hydration: Spray the fibre surface with water until it feels wet to touch for several minutes after spraying. CC cannot be over hydrated and an excess of water is always recommended. Minimum ratio of water:CC is 1:2 by weight. Do not jet high pressure water directly onto the surface as this may wash a channel in the material. Once hydrated, the material remains workable for 1 to 2 hours. Do not rely on rainfall to hydrate CC.

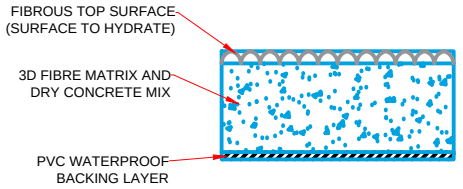
Setting: CC hardens to 80% strength in 24 hours and is ready for use.

FOR INSTALLATION SEE:

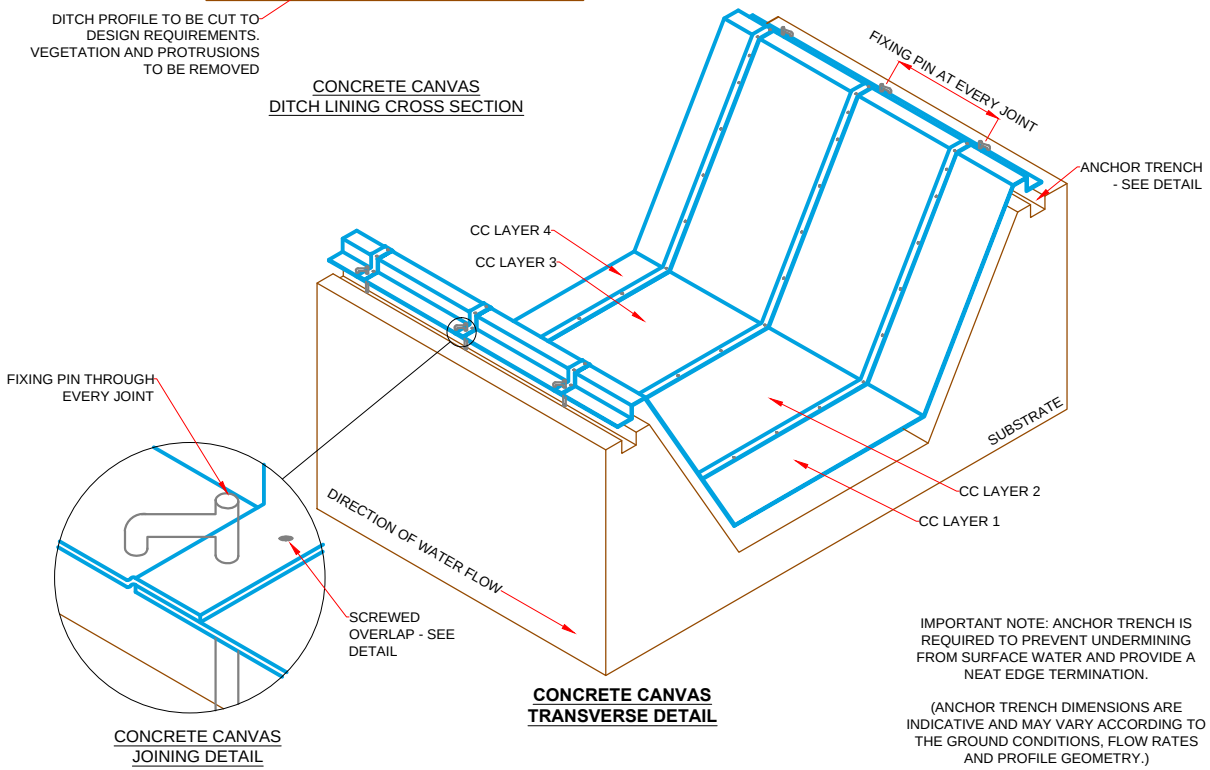
CLICK TO SEE DITCH LINING ANIMATION
CLICK TO SEE BEST PRACTICE INSTALL
CLICK TO SEE REQUIRED EQUIPMENT LIST



CONCRETE CANVAS
DITCH LINING CROSS SECTION



CONCRETE CANVAS
CROSS SECTION

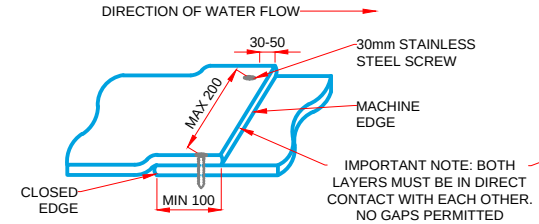


CONCRETE CANVAS
TRANSVERSE DETAIL

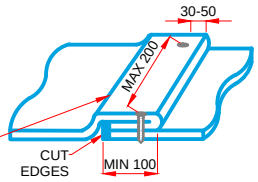
CONCRETE CANVAS
JOINING DETAIL

IMPORTANT NOTE: ANCHOR TRENCH IS REQUIRED TO PREVENT UNDERMINING FROM SURFACE WATER AND PROVIDE A NEAT EDGE TERMINATION.

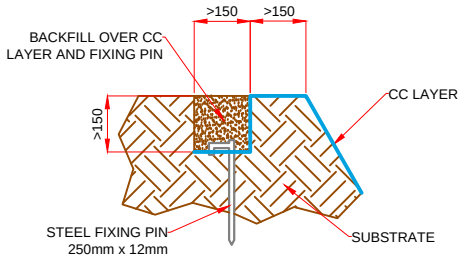
(ANCHOR TRENCH DIMENSIONS ARE INDICATIVE AND MAY VARY ACCORDING TO THE GROUND CONDITIONS, FLOW RATES AND PROFILE GEOMETRY.)



CONCRETE CANVAS
SCREWED OVERLAP JOINT



(FOR CUT EDGE ONLY)
CONCRETE CANVAS
SCREWED KNUCKLE JOINT



CONCRETE CANVAS
ANCHOR TRENCH DETAIL

NOTES:
Ditch liner to be Concrete Canvas Geosynthetic Cementitious Composite Mat (CC).

SPECIFICATION:

CC Type: CC8

Thickness: 8mm

Dry density: 12kg/m^2

Compressive strength

(ASTM C109 - 02 (initial crack)): 40MPa

Abrasion resistance

(DIN 52108): Max 0.1g/cm2

Manning's value

(ASTM D6460): n=0.011

Chemical resistance

Acid, Alkaline, Hydrocarbon, Sulphate resistance (BS EN 14414): CC to pass minimum requirements

Age testing - Freeze-Thaw, Soak-Dry, Heat-rain, Water Impermeability

(BS EN 12467:2004) CC to pass minimum requirements

TITLE:

CONCRETE CANVAS
DITCH LINING
TRANSVERSE DETAIL

DATE:	REVISION:
05 APR 2016	0
SCALE:	PRODUCED:
N.T.S.	VM

CONCRETE CANVAS

CONCRETE CANVAS LTD
UNIT 3: BLOCK A22, SEVERN RD,
TREFOREST INDUSTRIAL ESTATE,
PONTYPRIDD,
CF375SP

DRAWING NUMBER:

UK-CC-GEN-SDL-001 REV 0

CONCRETE CANVAS

HYDRATION GUIDE

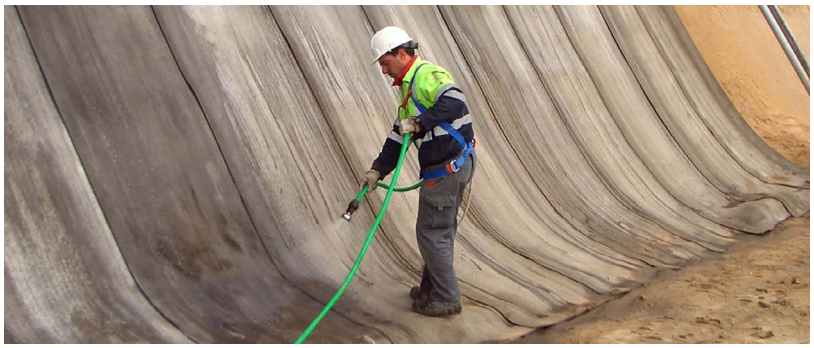
Concrete Canvas® GCCM Hydration Instructions

Concrete Canvas® is a Geosynthetic Cementitious Composite Mat (GCCM), part of a revolutionary new class of construction materials. It is a flexible, concrete impregnated fabric that hardens on hydration to form a thin, durable, water proof and fire resistant concrete layer. Follow the instructions below to correctly hydrate Concrete Canvas® GCCM (CC) once laid.

Minimum volume of water required for each CC type:

	kg/sqm	L of water / sqm
CC5™	7	3.5
CC8™	12	6
CC13™	19	9.5

SPRAY THE FIBRE SURFACE WITH WATER UNTIL IT FEELS WET TO TOUCH FOR SEVERAL MINUTES AFTER SPRAYING



Re-spray the Concrete Canvas® GCCM again after 1 hour if:

- Installing 5mm CC (CC5™)
- Installing CC on a steep or vertical surface

Notes:

- An excess of water is always recommended. CC will set underwater and in seawater.
- CC must be actively hydrated. For example do not rely on rainfall or snowmelt.
- Use a spray nozzle for the best results (see CC equipment list). Do not jet high pressure water directly onto the CC as this may wash a channel in the unset CC.
- CC has a working time of 1-2 hours after hydration. Do not move or traffic CC once it has begun to set.
- Working time will be reduced in hot climates and increased in very cold climates.
- CC will set hard in 24 hours but will continue to gain strength over time.
- If CC is not sufficiently wetted, or dries out in the first 5 hours, the set may be delayed and strength reduced. If the set is delayed avoid trafficking the material and re-wet with an excess of water.

Installation in Drying Conditions:

Drying conditions can affect CC in the first 5 hours after hydration resulting in excessive loss of water and preventing the specified strength gain.
1) 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%). - Hydrate at dusk, where possible, and rehydrate 2 to 3 hours after initial hydration.
2) Where conditions are very drying (eg temperature >28°C, moderate to strong breeze (>20km/h), strong direct sunlight, or low humidity < 70%, hydrate at dusk where possible. Monitor for first 5 hours and respray as soon as the surface ceases to be wet to the touch or respray at hourly intervals. Other methods to reduce evaporation such as covering the material may also be used.
- 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 the CC has not been heavily trafficked or mechanically damaged prior to full set.*

Installation in Low Temperature Conditions:

1) If the ground surface temperature is between 0 and 5°C and rising: CC should be covered with plastic sheeting immediately after hydration. CC may exhibit a delayed set at low temperatures.
2) If the surface temperature is expected to fall below 0°C in the 8 hours following hydration*: use warm water (>15°C) mixed with CC accelerant and cover with plastic sheeting. It is important to only use accelerant supplied by Concrete Canvas Ltd as some admixtures may delay set or impair performance. Please contact Concrete Canvas Ltd with your specific temperature profile for a recommendation on the dosage of accelerant required.*
- It is not recommended to install CC if the ground surface temperature is likely to fall below -4°C within 24 hours of initial hydration.
- It is not recommended to install CC on frozen ground as the ground may move significantly when it thaws, creating voids underneath the set CC.

Storage

- CC should be stored under cover in dry conditions away from direct sunlight and in the manufacturer's sealed packaging.
- It is not recommended to store in shipping containers in direct sunlight where temperatures may exceed 40°C for prolonged periods.
- If stored correctly CC has a shelf life of 24 months. If stored for longer it may remain usable in many instances.

CE

Concrete Canvas Ltd.
CF37 5SP, United Kingdom
11

EN12467:2004
Concrete Canvas:
Fibre cement sheet
NT
Oversize sheets
Class 1, Category A
Reaction to Fire B-s1,d0

+ www.concretecanvas.com

CONCRETE CANVAS®

Concrete Impregnated Fabric

1601.EN.BR

MADE IN UK

CONCRETECANVAS

RAIL ROAD MINING PETROCHEM AGRO UTILITIES MUNICIPAL DEFENCE DESIGN

2014 Fast Track 100 16th fastest growing company in the UK.

2014 Queen's Award for Enterprise in Innovation

2013 Macrobert Award Finalist

2013 Innovation Award Winner Railtex Exhibition

2012 R&D 100 Award winner R&D Magazine

2011 Expert's Choice Winner Most Innovative Product

2011 Brit Insurance Designs of the Year Nominee

2009 Winner Material Connexion Medium Award Material of the Year

2007 Winner D&AD Yellow Pencil Award Product Design

www.concretecanvas.com

CONCRETE CANVAS

Concrete Canvas® GCCM

What is it?

Concrete Canvas® is part of a revolutionary new class of construction materials called Geosynthetic Cementitious Composite Mats (GCCMs). It is a flexible, concrete impregnated fabric, that hardens on hydration to form a thin, durable, water proof and fire resistant concrete layer. Essentially, it's concrete on a roll. Concrete Canvas® GCCM (CC) allows concrete construction without the need for plant or mixing equipment: just add water.

CC consists of a 3-dimensional fibre matrix containing a specially formulated dry concrete mix. A PVC backing on one surface of the CC ensures the material is completely water proof. CC can be hydrated either by spraying or by being fully immersed in water. Once set, the fibres reinforce the concrete, preventing crack propagation and providing a safe plastic failure mode. Concrete Canvas® GCCM is available in 3 thicknesses: CC5™, CC8™ and CC13™, which are 5, 8 and 13mm thick respectively.

Concrete Canvas® GCCM User Benefits

Rapid Install

CC can be laid at a rate of 200sqm/hour, up to 10 times faster than conventional concrete solutions.

Easy to Use

CC is available in man portable rolls for applications with limited access. The concrete is pre-mixed so there is no need for mixing, measuring or compacting.

Lower Project Costs

The speed and ease of installation mean Concrete Canvas® GCCM is more cost-effective than conventional concrete, with less logistical complexity.

Eco-friendly

CC is a low mass, low carbon technology which uses up to 95% less material than conventional concrete for many applications.

Concrete Canvas® GCCM Key Properties

Water Proof

The PVC backing on one surface of the CC ensures that the material has excellent impermeability.

Strong

The fibre reinforcement prevents cracking, absorbs energy from impacts and provides a stable failure mode.

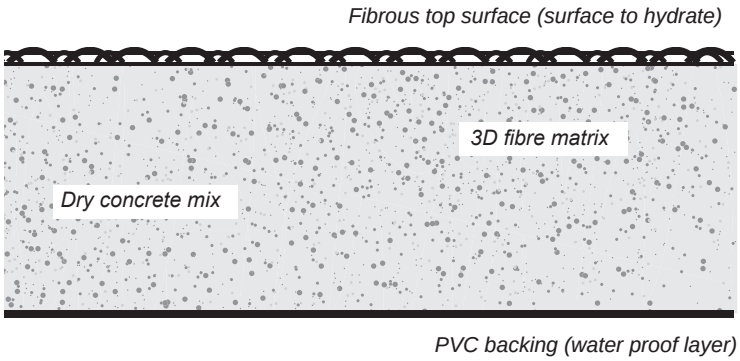
Durable

CC is twice as abrasion resistant as standard OPC concrete, has excellent chemical resistance, good weathering performance and will not degrade in UV.

Flexible

CC has good drape characteristics and will closely follow the ground profile and fit around existing infrastructure. Unset CC can be cut or tailored using basic hand tools.

Concrete Canvas® GCCM section



Batched rolls

Bulk roll

www.concretecanvas.com

CONCRETE CANVAS

Concrete Canvas® GCCM Applications

Ditch Lining

CC can be rapidly unrolled to form a ditch or channel lining. It is significantly faster, easier and less expensive to install than conventional concrete ditch lining and requires no specialist equipment. The matting can be laid at a rate of 200sqm/hour by a 3 person team.

Slope Protection

CC can be used to stabilise and protect slopes as a replacement for shotcrete and steel mesh. It is typically faster to install, more cost effective, requires less specialist plant equipment, and eliminates the risks associated with shotcrete rebound and debris.

Bund Lining

CC provides a cost-effective alternative for lining secondary containment bunds. It acts as an effective weed supressant, reducing maintenance costs as well as providing additional levels of impermeability and fire protection. Its ability to be installed quickly reduces time on site, whilst the availability of man-portable rolls allows for installation in areas with reduced access.

Remediation

CC can be used to rapidly reline and refurbish existing concrete structures suffering from environmental degradation and cracking.

Culvert Lining

CC can be used as a cost-effective alternative to bitumen spraying or re-building damaged culverts, whilst offering a durable means of providing erosion protection.

CONCRETE CANVAS®
+
www.concretecanvas.com

CONCRETE CANVAS

DATA SHEET

Concrete Canvas® GCCM Material Data

Concrete Canvas® GCCM Physical Properties*

Product	Thickness (mm)	Batch Roll Size (sqm)	Bulk Roll Size (sqm)	Roll Width (m)
CC5™	5	10	200	1.0
CC8™	8	5	125	1.1
CC13™	13	N/A	80	1.1

Product	Mass (unset) (kg/m²)	Density (unset) (kg/m³)	Density (set) (kg/m³)
CC5™	7	1500	+30-35%
CC8™	12	1500	+30-35%
CC13™	19	1500	+30-35%

Pre-Set Concrete Canvas® GCCM Properties

Setting

Working Time

1-2 hours subject to ambient temperature

CC will achieve 80% strength at 24 hours after hydration.

Method of Hydration

Spray the fibre surface with water until it feels wet to touch for several minutes after spraying.

Re-spray the CC again after 1 hour if:

- Installing CC5™
- Installing on a steep or vertical surface

Notes:

- An excess of water is always recommended. CC will set underwater and in seawater.
- CC must be actively hydrated. For example do not rely on rainfall or snowmelt.
- Use a spray nozzle for the best results (see CC equipment list). Do not jet high pressure water directly onto the CC as this may wash a channel in the unset CC.
- CC has a working time of 1-2 hours after hydration. Do not move or traffic CC once it has begun to set.
- Working time will be reduced in hot climates and increased in very cold climates.
- CC will set hard in 24 hours but will continue to gain strength over time.
- If CC is not sufficiently wetted, or dries out in the first 5 hours, the set may be delayed and strength reduced. If the set is delayed avoid trafficking the material and re-wet with an excess of water.

Refer to the *Concrete Canvas Hydration Guide* for installation in low temperatures or drying conditions.

- Low Temperature Conditions occur the ground surface temperature is between 0 and 5°C and rising or is expected to fall below 0°C in the 8 hours following hydration.
- 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%).

Post Set Concrete Canvas® GCCM Properties

Based on Concrete Canvas GCCM ® hydrated in accordance with the Concrete Canvas® Hydration Guide.

Strength

Very high early strength is a fundamental characteristic of CC. Typical strengths and characteristics are as follows:

Compressive tests based on ASTM C109 – 02 (initial crack)
- 10 day compressive failure stress (MPa) 40

Bending tests based on BS EN 12467:2004 (initial crack)
- 10 day bending failure stress (MPa) 3.4

Tensile data (initial crack)

	Length direction (kN/m)	Width direction (kN/m)
CC5™	6.7	3.8
CC8™	8.6	6.6
CC13™	19.5	12.8

Reaction to Fire

CC has achieved **Euroclass B certification**:
BS EN 13501-1:2007+A1:2009 B-s1, d0

Flame Resistance: **MSHA ASTP-5011**
Vertical and Horizontal Certification Passed

Age Testing (minimum 50 year expected life)

Freeze-Thaw testing (ASTM C1185) 200 Cycles
Freeze-Thaw testing (BS EN 12467:2004 part 7.4.1) Passed
Soak-Dry testing (BS EN 12467:2004 part 5.5.5) Passed
Heat-Rain testing (BS EN 12467:2004 part 7.4.2) Passed
Water impermeability (BS EN 12467:2004 part 5.4.4) Passed**

Other

Abrasion Resistance (ASTM C-1353)
Approximately 7.5x greater than 17MPa OPC Passed

Manning's Value (ASTM D6460) n = 0.011

Root Resistance (DD CEN/TS 14416:2005) Passed

Chemical Resistance (BS EN 14414)
- Acid (pH 1.0) (56 day immersion at 50°C) Passed
- Alkaline (pH 13.0) (56 day immersion at 50°C) Passed
- Hydrocarbon (56 day immersion at 50°C) Passed
- Sulfate Resistance (28 day immersion at pH 7.2) Passed

Impact Resistance of Pipeline Coatings
ASTM G13 (CC13™ only) Passed

Permissible Shear & Velocity CC8™ (ASTM D-6460)
- Shear (Pa) 1200
- Velocity (m/s) 10.7

Product exceeded large scale testing capabilities and was not tested to failure.

To achieve these permissible values, the CC material must be properly anchored with a system designed to meet or exceed these values.

Other Information

* Occasionally there will be a Beam Fault (fabric imperfection under 100mm wide running across the width) in a Bulk Roll. This fault is unavoidable due to the manufacturing process and the fault will be clearly marked with a white tag, there will be a maximum of (1) one Beam Fault in any Bulk Roll. A joint may need to be made on site where there is a Beam Fault as the material at a fault will not reach the performance specified in this Data Sheet. The maximum un-useable material due to any Beam Fault will be 100mm. There are no beam faults in standard batched rolls.

* Indicative values

** For containment applications it is recommended to use CC Hydro™

The information contained herein is offered free of charge and is, to the best of our knowledge, accurate. However, since the circumstances and conditions in which such information and the products discussed therein can be used may vary and are beyond our control, we make no warranty, express or implied, of merchantability, fitness or otherwise, or against patent infringement, and we accept no liability, with respect to or arising from use of such information or any such product.

CE

Concrete Canvas Ltd.
CF37 5SP, United Kingdom
11

EN12467:2004
Concrete Canvas:
Fibre cement sheet
NT
Oversize sheets
Class 1, Category A
Reaction to Fire B-s1,d0

+ www.concretecanvas.com