Specified Engineering Works Proposal

For

Construction of Cell No.6

At

Clonbullogue Ash Repository

Licence Register Number: W0049-02

Licensee: Bord na Mona Energy

Prepared by

Bord na Móna

A Submission to the Environmental Protection Agency by Bord na Móna Energy Limited

Bord na Móna

DOCUMENT CONTROL SHEET

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1.0 Foreword

This Specified Engineering Works Plan has been prepared to comply with condition 3.5 of the Waste Licence for Cloncreen Ash Repository.

The purpose of this Specified Engineering Works Plan is to set out the proposed developments to take place at the site and details of the specifications of these works.

These specifications will cover areas in relation to the following.

- Development of the facility including preparatory works and lining
- Final capping
- Installation of Leachate Management Infrastructure
- Installation of Groundwater Control Infrastructure
- Installation of Surface Water Management Infrastructure

Due to the nature of the works and materials involved, which include Geo-Synthetic Clay Liner. This Specified Engineering Works can only be read in conjunction with the specification for the aforementioned materials.

A specification is a collection of work descriptions written in the order chosen for the sequence of trades. The specifications furnished in this document cover the technical requirements for the raw materials, manufacture, testing, transportation, storage, handling, installation and testing of Geo-Synthetic Clay Liner *(Section 4.2)*.

2.0 General Requirements

2.1 Introduction

This document details the scope of the work to be carried out and also includes the specifications to which this work will be completed. The proposal has been prepared in accordance with Waste Licence WL0049-02, the Landfill Directive 1999/31/EC and the EPA Landfill Site Design Manual for Non-Hazardous Landfill.

It also outlines both the requirements for the installation of the lining system undertaken by Bord na Móna and the quality control procedures to demonstrate that the works have been undertaken in accordance with the Specification at:.

Clonbullogue Ash Repository.
Bord na Móna,
Cloncreen Bog,
Clonbullogue,
Co Offaly,

2.2 Definitions

For the sake of clarification, the following definitions are given:

Construction Quality Assurance (CQA) – A planned and systematic pattern of all means and actions designed to provide confidence that items or services meet contractual and regulatory requirements and will perform satisfactorily in service. Construction Quality Assurance refers to means and actions employed by the CQA Inspector, to assure conformity of the lining system preparation, production, and installation to the CQA plan.

Engineer – Shall mean “The Head of Civil Engineering” or such person or persons as he may authorise to act for the purpose of this Contract.

Employer – means the person or persons, firm or company or other body who own and have responsibility for the facility. For the works undertaken at the site, the Employer is Bord na Mona Renewable Energy.
Contractor – means the person or persons, firm, company or other body who will carry out the development Contract and includes the Contractor’s personal representatives or other parties, e.g. Sub-contractors, Manufacturer. The Contractor will undertake the execution of the Works under the terms of the Contract. The Contractor is Bord na Móna Operations.

Specification – Sets out the detailed requirements as to how the works should be constructed, tested, measured and quality assured.

2.3 Materials

All materials to be used or fixed on the Works shall be in accordance with this Specification and free from all defects. They shall comply with the Irish or European or (where none exist) the British Standard Specification applicable to them. They shall pass any tests required by the Engineer and be to his complete approval.

All materials are, wherever possible, to be obtained for manufacturers operating in Ireland. If any materials of Irish manufacture are not of sufficient quality and reasonable cost, the facts are to be reported to the Engineer, who will issue instruction as to the course to be followed.

Wherever materials of special design or manufacture, patented or otherwise, are given, it shall be understood that such references are given as a guide with respect to the nature and quality of the articles required.

The Engineer shall have power to order the removal of defective or improper materials from the site.

The Contractor shall keep a record on the site of all materials for the Contract showing the dates of arrival and issue, the name of the supplier and (if possible) the prime cost. The record shall be available for inspection by the Engineer.

The Contractor shall have sole charge of all unfixed materials on the site whether such materials are his own property or the Employers and he shall be responsible for all losses, breakages and defects resulting from the weather, improper handling: storing; sheltering; stacking or any other cause within his control to prevent.

2.4 Facilities

Storage Compound and Welfare Facilities

The Storage Compound and Welfare Facilities are located at the existing Bord na Móna tea centre and site compound.

Adequate provision will be made within the compound area for parking of all the plant, equipment and any private vehicles owned by operatives/subcontractors and visitors. Parking will not be permitted in any other areas of the landfill site.
Bord na Móna are responsible for the security of the works, plant, materials, services and machinery.

Fuel and Oil Installations

Bord na Móna take all the necessary steps to protect the environment from accidental spillage's arising from re-fuelling at the Ash Disposal Facility. All plant operators are familiar with the Emergency Response Procedure ERP 2.0 (Oil, Diesel & Petrol Spillages)

and the Emergency Response in the Event of Oil Spillage which is posted in the tea centre and in the cabs of all machines. Where reasonably practical, all machines are re-fuelled away from drains. The operator, either of service trains or machines, is present at the re-fuelling nozzle at all times during the re-fuelling. Diesel may be stored in a diesel bowser during certain times of the year or during certain operations. A service wagon fuels the diesel bowser and from which the front-end loader and tractors refuel. The re-fuelling hose is returned to the correct position on the service train/bowser after use. Re-fuelling never takes place across a railway line, in case of damage to the hose from other traffic.

All service trains / tractors contain a spill kit / dry peat, in the event of an oil / diesel spill. All oils and lubricants are stored in a bunded oil store adjacent to the site office.

2.5 Leachate Collection System

Bord na Móna has installed a leachate collection system across the site, including areas within and adjacent to the works. The collection system comprises a 150mm perforated pipe system at the base of the cell, leachate collection manholes for each cell and a network of lay flat hosing for leachate re-circulation. Disturbance of the existing Leachate collection system during the proposed works is not envisaged.

2.6 Waste Licence

The area of the works is encompassed by the existing Waste Licence WL0049-02 for the current landfill operations. The proposed works shall not directly or indirectly compromise Bord na Móna's ability to carry out its operations in accordance with the Licence. A copy of the Licence is available at the site compound.

3.0 CONSTRUCTION REQUIREMENTS

3.1 Regulations and Site Safety

The works come under the Safety Health & Welfare at Work Act 2005 & the Safety, Health and Welfare at Work (Construction) Regulations 2013.

Bord na Móna shall adhere to the site Health and Safety Rules and the performance with respect to these rules will be reviewed at each progress meeting.

3.2 Substances Hazardous to Health

The generation or use of substances hazardous to health during the works is not envisaged, however, where any substance hazardous to health is so used or generated during the works the Contractor shall provide:

- A copy of the assessment of the risks created by the use of that substance; and
- Details of the measures to be taken to prevent or adequately control the exposure of the persons working with or those who may be affected by the substance.

Where the measures referred to necessitate the use of protective clothing or other safety apparatus the Contractor shall:

- Provide staff with sufficient and suitable items of protective clothing and safety apparatus if not previously supplied;
- Arrange for the proper storage, maintenance and regular testing and replacement of the items provided to the Employer and his staff; and
- Arrange for appropriate training or instruction for staff in the use of such items.

3.3 Noise

The site is located on a remote bogland approximately 1.5km from the main site access points and local roads. Therefore, the risk of nuisance to adjoining properties from noise is negligible. The Contractor will, however, comply with the following specific requirements regarding noise:-

- No work other than the operation of plant and equipment for the control of the groundwater shall take place outside the permitted hours except in case of emergency.
- All mobile plant, equipment and vehicles under the control of the Contractor, his sub-Contractors and suppliers, and in use or calling at the site, shall be fitted with appropriate silencing equipment and shall be maintained to manufacturers' standards.
- PPE will be supplied to Contractor’s staff where noise levels are expected to exceed 85db.

3.4 Naked Flames and Smoking

Smoking will only be permitted in authorised areas.

3.5 Mobile Plant

All Construction vehicles shall be fitted with flashing amber beacons for vehicle awareness. These beacons shall be located in a visually prominent position. All mobile plant shall be assessed for restricted rear view vision and action agreed, dependent upon the outcome of this assessment, which may result in suitable equipment being fitted in order to minimise the potential risk to within acceptable limits.

3.6 Dust Nuisance

As outlined in section 2.3, the site is located on a remote bogland approximately 1.5km from the main site access points and local roads. Therefore, the risk of nuisance to adjoining properties and roads from dust is negligible.

As part of the landfill operations on the site, a programme of ash wetting for dust suppression is ongoing during the summer months and periods of dry weather. This includes the recirculation of leachate.

Water / Leachate required for dust suppression is sourced from the following:

1. The leachate collected in the monitoring manhole may be spread over the ash.
2. Leachate collected in the Leachate Lagoon.

All dust and mud from the works spreading onto highways, site and access roads shall be immediately cleared by the Contractor by use of mechanical plant.

3.7 Access

The general arrangement of the site is shown on the respective site layout drawings. The only entrances to the works are via the main site entrance. No other site entrances are to be used unless stated in the Specification. Areas for site offices, welfare facilities and plant standing are existing and located adjacent to the ash cells. The main access road is to be kept clear at all times, as it will be used primarily by Bord na Móna operations traffic.

The works vehicles must give way to landfill plant and locomotives and not impede the movement of the traffic involved in landfill operations. The specified speed limits within the landfill site shall be observed at all times. Non compliance may result in the exclusion of any offender from the site. Appropriate signage must be displayed to warn traffic of slow moving plant, particularly if the haul road access crosses the main access road.

All vehicles leaving the site must be free from mud and debris.

3.8 Permitted Hours of Working

The permitted site hours of working are:

Monday to Friday - 08.00 -18.00

Saturday - 08.00 -16.30

Working on Sundays and Bank Holidays is not envisaged.

3.9 Control of Surface Water

Bord na Móna shall carry out all necessary operations for the control of standing water, or surface water run-off, within the works area to enable the construction of the works and, by doing so, shall prevent damage to the works, the site, or adjoining cells and embankments.

3.10 Disposal of Exhumed Waste

In the event that it is necessary to excavate waste ash in order to achieve any element or elements of this specification, the excavated waste will be disposed of in the operational area of the landfill.

3.11 Protection of Boreholes

The Contractor shall locate and adequately protect existing deep ground water and leachate collector manholes within the works area from damage during the works. The locations of the manholes are to be confirmed prior to commencing the works.

3.12 Inclement Weather

No materials shall be placed or compacted during inclement weather conditions or if trafficking over compacted or un-compacted material would prove detrimental to the construction. Any such trafficking damage caused shall be repaired prior to recommencing the capping works. Inclement weather conditions may include, rain, snow, freezing conditions or excessive heat. Following wet weather conditions, any standing water on the surface of the construction must be removed. Earthworks placement operations following inclement weather conditions shall not proceed without the prior approval of the Engineer. Any frozen material shall be allowed to thaw before use. Previously compacted material that has become frozen shall be removed from the works and stockpiled until suitable for reuse.

4.0 SCOPE OF THE CONSTRUCTION WORKS

4.1 General Description

The design concepts for the Cell construction were developed in accordance with Waste Licence WL0049-02, the Landfill Directive 1999/31/EC and the EPA Landfill Site Design Manual for Non-Hazardous Landfill.

Construction of the Cell shall generally involve:

- Excavation of cell floor to required levels.
- Removal and storage of peat layer for future use.
- Construction of cell embankments 6-7m high with 1 in 1 side slopes.
- Installation of Geosynthetic Clay Liner (GCL);
- Installation of Drainage Geocomposite (CDL) to gradients;
- Installation of leachate collector drains in cell floor.
- Installation of Surface / Ground Water Control beneath the lining systems

4.2 Daily Journal

Bord na Móna will be required to keep a daily journal recording the information detailed below. Access to the daily journal will, if necessary, be made available to the Client, EPA or any other Authority during and after completion of the Works if required. This information shall be recorded in an acceptable form of daily journal which shall include the following:

- Date of shift;
- Names of personnel in attendance during the shift;
- Start and finish times of Contractor and CQA Inspector;
- Weather conditions, including ambient temperature;
- Type of plant used; plant breakdowns and hours;
- Record of earthworks completed
- Approximate totals for amount of lining materials deployed, seamed, tested and repaired including width of each panel installed;
- Summary of field and laboratory testing carried out;
- Sample type and material taken for particular testing;
- delays;
- Deliveries;

5.0 CQA SUPERVISION

5.1 General

The CQA Project Team will comprise the following:

The CQA Manager - Will be office based and responsible for the following:

- Administration of the CQA program;
- Attendance at selected progress or liaison meetings and is the key contact with ESB personnel, or regulatory officers;
- Production of the CQA Validation Report.

The CQA Inspector – The representative of the CQA Manager located full time at the site during works requiring CQA supervision and responsible for the following:

- The on-site representative of the CQA Manager;
- To be fully familiar with all CQA requirements for the project;
- Attendance at all CQA-related meetings (e.g. Pre-construction and Progress);
- Preparation, or overseeing the ongoing preparation of the as-built drawings;
- Assigning locations for testing and sampling where deemed necessary;
- Keeping daily reports and records;
- Reporting to the CQA Manager any relevant observations;
- Reviewing the results of laboratory testing and making appropriate recommendations;
- Reporting any unresolved deviations from this CQA Plan to the CQA Manager;
- Provision of all records and relevant data to the CQA Manager for the preparation of the final validation report.
- Noting and bringing to the attention of the Contractor any on-site activities that could result in damage to the liner system.

5.2 Daily Meetings

Meetings will be held daily between the CQA Inspector and Bord na Móna's site operations representative. The purpose of which is to:

- Review the work activities and locations for that day;
- Note the Contractor's installation personnel and plant for the day/shift;
- Review the previous days progress;
- Review the work schedule;
- Discuss/highlight any problems and identify solutions.

5.3 CQA Requirements

The CQA requirements associated with each component of the works are detailed in the following Sections.

6.0 EARTHWORKS REQUIREMENTS

6.1 General

This section outlines the requirements for excavation and placing the engineered fill materials to the details as shown on Drawing FK-DG-69-DR03 FK-DG-69-DR05

The compaction of all engineered fill materials shall be carried out in line with the National Roads Authority's Specification for Road Works.

It is not acceptable to place the backfill material and compact at a later stage when other layers have been placed, or compact excessive depths from the surface. Such a practice generally gives rise to excessive post-construction settlements and should not be permitted.

The Contractor shall employ only that plant and those working methods that are suited to the materials to be handled and traversed. He shall be responsible for maintaining the nature of the suitable material so that when it is placed and compacted it remains in accordance with the Specification. Suitability shall be determined in accordance with the definitions below.

The Contractor shall submit his proposals to the CQA Inspector regarding the extent and management of the excavations, stockpiling and filling of materials before starting works. Excavations shall not proceed without the prior approval of the CQA Inspector.

The Contractor shall not remove any materials from the site. After completion of the works, the Contractor is required to re-grade any stockpiles and surrounding areas where deemed necessary. This shall be carried out to the satisfaction of the CQA Inspector.

6.2 Definitions

The following definitions shall apply to the specifications wherever reference is made to the defined engineered fill material.

- "Suitable material" shall comprise all that is acceptable in accordance with the Contract for use in the works and deemed by the CQA Inspector to be suitable;
- "Unsuitable material" shall mean material other than suitable materials and shall include:
  - Logs stumps and perishable material;
  - Material in a frozen condition;
  - Material susceptible to spontaneous combustion; and
  - Any commercial or domestic waste.
- "rock" shall be deemed to mean hard material which, in the opinion of the CQA Inspector, necessitates for its loosening or removal the use of special machinery designed for rock cutting, but shall exclude any material that can be removed by normal excavating machinery and which, in any case, has a volume not exceeding 1 cubic metre or 0.25 cubic metres where the net width of the excavation is less than 2 metres.

6.3 Cell Floor Preparation

Excavation of the cell floor area will be carried out between the months of April and October using 1 No. 12t 360^{o} excavators and a D6 dozer.

Cell No.6 has an approximate depth of 1-2m of boulder clay covering the floor area. This clay layer over-lays a gravelly soil with medium to large boulders. The excavated material will be used to construct the 5m external embankments of the Cell. A quantity of approximately 24,500m^3 of fill will be required for the construction of the embankments

The cell floor will be excavated to within 500mm of the final design level to protect the formation during the embankment construction and the proposed drainage works. A quantity of approximately 25,000m^3 of soil is available from the cell floor for use in embankment construction. The balance required for the completion of the embankments will be sourced from neighbouring cutaway bog.

Once the final 500mm of soil has been removed, the remaining soil will be shaped to provide a maximum 1 in 100 slope angle to facilitate both the under-cell drainage and leachate collection. The surface of the soil may require minor re-grading works to remove any undulations, which may allow water to pond. The re-graded surface of the soil shall be compacted to minimise future differential settlement.

The cell floor formation to receive the Geosynthetic Clay Liner shall be smooth and free from debris, roots, angular or sharp rocks and any other deleterious materials that may cause damage to the capping system. Any such deleterious material shall be removed from the surface and any resulting depression repaired to the CQA Inspectors satisfaction.

Upon completion of the re-grading works the Contractor shall seek approval from the CQA Inspector as to the adequacy of the prepared surface to receive the Geo-Composite layer.

6.4 Embankment Construction

The proposed embankments for Cell No.6 will be 5m high with 45^{o} side slopes. As outlined above, a quantity of approximately 24,500m^3 of fill is required to construct the embankments. The excavation of the cell floor will provide approximately 25,000m^3 with the excess material stockpiled onsite for capping Cell No.5 or No.6.

The embankments will be constructed utilising the gravelly subsoil acquired during the cell excavation. Peat will be used to dress the embankment slopes

The embankment will consist of a series of compacted layers or lifts of suitable material placed on top of each other until the level of the sub-grade surface is reached. The thickness of the lift is limited by the type and size of compaction equipment used by the contractor. In this case, the

embankments will be formed in 1m compacted layers around the entire cell and compacted by the 12t excavators, the D6 dozer and a pneumatic roller. This method will allow adequate time for settlement and drying during the construction process. The embankment surfaces will be finished to the specifications required for lining the cells.

The compaction of all embankment fill materials shall be carried out in accordance with the National Roads Authority's Specification for Road Works

6.5 CQA Requirements

The CQA Inspector shall:

- Assess the method statements submitted by the Contractor for the installation of the preparatory earthworks;
- Ensure that all material within the working area deemed unsuitable in accordance with the specification is removed to an area agreed with the Site Manager;
- Ensure that only suitable soils are used where required as engineered fill;
- Monitor the placement and compaction of the engineered fill, ensuring that the works are carried out in accordance with the Specification;
- Ensure that all areas of non-compliance are remediated in accordance with the specifications;
- Take photographs during the construction;
- Ensure that surveys are undertaken to confirm that the requisite levels and layer thicknesses have been achieved.
- The CQA Inspector shall fully document each item above and the documentation shall be presented in the CQA Validation Report.

7.0 Site Development – Lining

7.1 Introduction

In accordance with Waste Licence WL0049-02, Cell No.6 will be lined with a Geosynthetic Clay Liner and a Composite Drainage Layer. The Geosynthetic Clay Liner (GCL) with a permeability of greater than $5x10^{-11}$m/s will underlay a composite drainage layer (CDL) with water flow properties of 0.9 l/m/s at 1% hydraulic gradient when tested on soft platen.

7.2 Geo-Synthetic Clay Liner Specification

Introduction

This specification covers the technical requirements for the furnishing and installation of the Geo-Synthetic Clay Liner described herein. All materials used shall meet the requirements of this specification, and all work shall be performed in accordance with the procedures provided herein.

Definitions

For the purposes of this specification guideline, the following terms are defined below:

“Geosynthetic Clay Liner (GCL)” A factory-manufactured hydraulic barrier consisting of sodium bentonite clay supported by geotextiles held together by needling, stitching or adhesives.

“Geomembrane” An essentially impermeable geosynthetic composed of one or more geosynthetic sheets.

“Geotextile” Any permeable textile used with foundation, rock, soil, earth or any geotechnical engineering related material as an integral part of a human-made project, structure or system.

“Minimum Average Roll Value” The minimum average value of a particular physical property of a material, for 95 percent of all of the material in the lot.

“Overlap”: where two adjacent GCL panels contact, the distance measuring perpendicular from the overlying edge of one panel to the underlying edge of the other.

“Employer” means the person or persons, firm or company or other body who own and have responsibility for the facility and for the purpose of this specification means the Bord na Mona

“Engineer” means the person, firm or company appointed by the Employer to act on his behalf for the proper execution of the works. For this specification the Engineer is Ms. Lisa Kealey of Bord na Móna PLC Civil Engineering Department. A personal representative may be appointed for the works.

“Contractor” means Bord na Móna Energy Limited.

References

ACC 1010 Free Swell Determination

API 13A/13B Specification for Drilling-Fluid Materials

ASTM D 4632 Test method for Grab Breaking Load and Elongation of Geotextiles

ASTM D 4643 Determination of Water (Moisture) Content of Soil by the Microwave Oven Method

ASTM D 5084 Hydraulic Conductivity of Saturated Porous Material Using a Flexible Wall Permeameter

ASTM D 5261 Test Method for Measuring the Mass per Unit Area of Geotextiles

ASTM D 5321 Bentonite Swelling Power

7.3 Manufacture

GCL

The thickness of the GCL shall be 6 mm and the total mass per unit area shall be 4900g/m^2. The roll width shall be 4.85m and the length shall be 40m.

Bentonite

The GCL shall contain granular natural sodium bentonite with the minimum quantity of 3300 g/m^2 when calculated with 0% moisture content. The bentonite shall have montmorillonite content approximately 90% by XRD and have a maximum 15% moisture content.

Quality Control and Quality Assurance

The GCL shall be manufactured under strict quality control. The manufacturer shall be certified to ISO 9001. The components and the final GCL shall undergo regular and frequent testing in the manufacturer's laboratories according to the quality management standard ISO 9001.

The component supplier shall guarantee consistent quality through careful selection, processing and handling at all times. The product specification shall be controlled again on arrival at the GCL factory.

The manufacturer (upon request) shall provide its own in-house test documents covering each roll delivered to the site.

Independent Testing

The GCL quality shall be assured by independent third party testing. This shall be in accordance with the quality assurance standard DIN 18200. Proof of this testing shall be provided for approval before orders to supply the GCL is placed.

Tests

MATERIAL	PROPERTY	TEST		CERTIFIED VALUE
Woven Geotextile	Strip tensile strength	DIN EN ISO 10319	required *	110 g/m^2
	Elongation at max strip tensile strength	DIN 53857 Part 2	required *	
	Mass / Unit Area	DIN EN 965	required *	
Needle Punched Geotextile	Strip tensile strength	DIN EN ISO 10319	required *	220 g/m^2
	Elongation at max strip tensile strength	DIN EN 10319	required *	
	Mass / Unit Area	DIN EN 965	required *	
Bentonite	Mass / Unit Area	DIN EN 965	required *	4,670 g/m^2
	Swell Index	ASTM D 5890	required *	≥ 25 ml
	Water Content	DIN 18121 (10h, 105^{0}C)	required *	≤ 15 %
	Water absorption	DIN 18132 (24hr)	required *	≥ 600 %
	Montmorillonite Content	XRD	required *	Approx 90%
	Methylene Blue consumption	VDG P69	required *	≥300mg/g
Manufactured GCL	1. Strip tensile strength	DIN EN ISO 10319	required *	10 kN/m 1) 10 kN/m 2)
	2. Elongation at max strip tensile strength	DIN EN ISO 10319	required *	10 % 1) 6 % 2)
	3. Peel Strength	ASTM D 12236	required *	≥ 60N / 10 cm
	4. Puncture Force	DIN EN ISO 12236	required *	1800N 3)
	5. Mass / Unit Area	DIN EN 965	required *	*5000g/m^2
	6. Dry Thickness	DIN EN 964 - 1	required *	6 mm
	7. Permittivity	Based on DIN EN 18130 ASTM D 5887		≤ 5 x 10^{-9} l/s
	8. Permeability	DIN 18130	required *	≤ 5 x 10^{-11} m/s

* The frequency of tests depends on the material, quality of production etc.

1) Machine Direction

2) Cross Direction

3) No extra protection during test

4) Certified values can vary 10% for the geosynthetics and 15% for bentonite mass.

Packaging

The GCL shall be wound around a plastic core 150mm in diameter to facilitate handling.

All rolls shall be labelled and bagged in packaging that is resistance to photo-degradation by ultraviolet (UV) light.

7.4 Transportation, Delivery, Storage and Handling

Product Labelling

Prior to shipment, the GCL manufacturer shall affix a label to each roll identifying the following characteristics:

- Product identification information (manufacturer name and address, brand name and product code).
- Lot number and roll number.
- Roll length and width.
- Total roll weight.

Shipping and Handling

The GCL Material shall be delivered, stored and handled strictly in accordance with the Manufacturer's requirements and recommendations. The Contractor shall provide adequate measures for protecting the materials at all stages of the work from all causes, including weather conditions, until completion of the contract.

The manufacturer assumes responsibilities for initial loading and shipping of the GCL. Unloading, on-site handling and storage are the responsibility of the Contractor. The Contractor should contact the manufacturer prior to shipment to ascertain the appropriateness of the proposed unloading methods and equipment to be utilised.

Each roll of GCL delivered to site shall be wrapped in black coloured polyethylene sheeting. A visual inspection of each roll should be made as it is unloaded to identify if any packaging has been damaged. Rolls with damaged packaging should be marked and set aside for further inspection. The packaging should be repaired prior to being placed in storage.

Storage

A designated area shall be prepared for the on site storage of the GCL rolls. The rolls shall be secure, stable, dry and formed from materials which will not damage the GCL.

The rolls of GCL shall be stored and handled in such a manner that no damage occurs. Rolls should be stored in a manner that prevents sliding or rolling from the stacks and may be accomplished by the use of chock blocks or by use of the dunnage shipped between rolls. Rolls should be stacked at a height no higher than that at which the lifting apparatus can be safely handled (typically no higher than four).

In order to protect the GCL from weather all rolls shall be covered by tarpaulin or additional plastic sheeting. Any rolls with damaged wrapping shall be marked for later inspection. The wrapping shall be repaired immediately to prevent any hydration of the bentonite before the mat is installed.

No GCL piece damaged during delivery, storage or handling shall be incorporated in the works it is properly repaired according to the manufacturer's recommendations.

7.5 Installation

Placement of the GCL shall be conducted in accordance with the manufacturer's recommendations and within the direction provided herein. Any deviations from these procedures must be pre-approved by the Engineer.

Installation shall not take place in strong wind, snow or during rainfall.

The use of equipment capable of freely suspending the GCL roll is required. A spreader bar and core pipe are also required for supporting the roll and allowing it to unroll freely. The core bar and spreader bar shall not bend or flex excessively when a full roll is lifted.

Panels placed on flat areas require no particular orientation. Panels should be placed from the highest elevation to the lowest within the areas to be lined, to facilitate drainage in the event of precipitation. Panels should be placed free of tension or stress yet without wrinkles or folds. It is not permissible to stretch the GCL in order to fit a designated area. Panels should not be dragged across the subgrade into position except where necessary to obtain the correct overlap for adjacent panels.

GCL panels shall be placed with the white side (non-woven geotextile) facing down. On sloped areas exceeding a steepness of 4H:1V, the long dimension of all panels shall be orientated parallel to the slope. The GCL shall be placed in an anchor trench where necessary and laid parallel to the direction of the slope. Anchor trench backfill shall be well compacted to minimise water intrusion and to prevent GCL pullout. The fill material shall not damage the GCL.

Where slopes are steeper than 15%, the GCL should not be unrolled across these slopes. Roll end overlaps shall be avoided in such slope areas. Double layers shall be used at all corners.
The outside edges shall be protected by plastic sheeting at the end of each day to ensure that they are clean and dry for the overlap for the next day's work.

At no time during the installation of the GCL or placing of protective layers shall plant or equipment be permitted to travel on the unprotected surface of the GCL.

GCL Panel Seaming

All GCL seams shall be formed by executing a bentonite enhanced overlap to ensure that a continuous seal is achieved between the panels.

A 150mm to 225mm overlap should exist at seam locations. The lap lines and match lines printed on the panels shall be used to assist in obtaining this overlap. The edges of the GCL panels should be adjusted to smooth out any wrinkles, creases or "fishmouths" in order to maximise contact with the underlying panel.

After the overlying panel is placed, its edge shall be pulled back to expose the overlap zone. Any soil or debris present in the overlap zone or entrapped in the geotextiles shall be removed. A fillet of granular bentonite shall then be poured in a continuous manner along the overlap zone (between the edge of the panel and the 150mm line) at a rate of at least 0.3kg per metre. The use of a watering can or line chalker is recommended to improve uniformity and consistency of the bentonite enhancement. This process shall be conducted in accordance with the Manufacturer's CQA plan. On gently sloping areas (gentler than 4H:1V) where seams may be placed across the slope, overlaps should be "shingled so as to prevent flow into the seam.

Detail Work

Detail work, defined as work necessary to seal the liner up to pipe penetrations, foundation walls, drainage structures, spillways and other appurtenances shall be performed as recommended by the GCL Manufacturer.

Damage Repair

In the event of damage occurring to the GCL, the damaged area shall be overlain by a GCL patch at least 200mm larger in all directions than the damaged area. The area to be overlain shall be cleared of all debris and swept clean. If this causes loss of the bentonite in the cover geotextile then extra bentonite powder – min 0.5 kg/m – (or bentonite paste when slopes or vertical surfaces are involved) shall be placed around the perimeter of the area and the patch placed in position. Cover materials shall be placed separately over patches to avoid these patches from moving when installed horizontally or the patch shall be bolted to the concrete as detailed above.

No vehicles should be driven directly on the GCL until the proper thickness of cover has been placed. Care should be taken to avoid damaging the GCL by making sharp turns or pivots with equipment.

7.6 Documentation

The following parameters shall be recorded by the Contractor during the installation:-

1. Precipitation
2. Relative humidity
3. Air Temperature
4. Wind speed
5. Temperature or sheet surface

A record of the above shall be submitted by the Contractor to the Engineer on a day to day basis as installation proceeds.

7.7 CQA Requirements

The CQA Inspector shall:

- Ensure that the materials are delivered, handled and stored in accordance with the manufacturers recommendations;
- Make a visual inspection of each roll as it is unloaded to identify any damage and record the relevant information for each roll;
- Assess all manufacturers' quality control certificates to confirm that the material meets the requirements of the specifications prior to installation;
- Assess and approve, with respect to the requirements set out in the specifications, the proposed panel layout for the geomembrane to be submitted by the Contractor;
- Assess the methods statement submitted by the Contractor detailing his proposed deployment and seaming techniques:
- Provide written certification to the Contractor that the surface on which the geomembrane is to be installed is acceptable prior to installation. *Note the CQA Inspector may withdraw the certificate should the surface deteriorate for any cause prior to installation and only reissue upon remediation works being compliant with the specifications*;
- Witness all panel deployment ensuring compliance with the specifications;
- Witness all seam constructions to ensure compliance with the specifications:
- Ensure that all defects are identified on the geomembrane and witness that they are repaired in accordance with the specifications;
- Ensure that a defect free tie-in with the existing geomembrane is constructed;
- Ensure that geomembrane and seam construction continues to the back of the anchor trenches;
- Ensure that on completion of the geomembrane installation the Contractor produces a fully referenced as-built panel layout plan including all the detail listed within the specifications.

The CQA Inspector shall fully document each item above and the documentation shall be presented in the CQA Validation Report.

8.0 LEACHATE COLLECTION

8.1 Drainage Geocomposite (CDL) Introduction

The Geo-Synthetic Clay Layer (GCL) will be overlain with a Composite Drainage Layer (CDL) such as Finesse Pozidrain 12S250NW8, or similar approved. The CDL must provide a minimum hydraulic conductivity of 1 x 10^{-3}m/s. and the flow capacity must be equal to or greater than 0.01 l/s/m at 1% Hydraulic Gradient.

The CDL will consist of a three-dimensional drainage core. The drainage core will be covered on at least one side with a geotextile separation membrane to prevent ash clogging the drainage core.

The CDL will be installed immediately on top of the GCL in accordance with the Manufacturer's specifications. A protective layer with a minimum of 300mm of ash will then be placed on the CDL on the same day of installation. This protective layer will prevent the drainage layer from being crushed. No vehicles should be driven directly on the CDL until the proper thickness of cover has been placed.

The Contractor will be required to:

- Supply and install a CDL on geomembrane surface; and
- Provide all material quality control certificates and other information described below.

8.2 Delivery, Handling and Storage

The material will be delivered, handled and stored in accordance with the manufacturer's recommendations and should be delivered and stored in tight wrappings in order to offer protection from ultra violet degradation. Each roll of CDL delivered to site will be identified with:

- Manufactures name, address and telephone number;
- CE mark with accrediting bodies number;
- Product identification and polymer type;
- CDL batch and roll number;
- Roll length and width in metres;
- Roll weight in kilograms

Lifting and transportation of the CDL materials shall be by appropriate machinery with the use of slings and core bars. The material is not to be handled with the tines of a forklift machine, the bucket of an excavator, or any similar equipment under any circumstances.

The Contractor shall provide adequate and acceptable measures for protecting the material at all stages of the work, from all sources of potential damage such as sharp objects, boulders, cobbles etc, including weather conditions and will be located out of the way of the way of moving plant. The rolls of CDL will not be stacked more than 3 high. Any damaged material will be excluded from the works.

8.3 Manufacturers Quality Control

Quality control certificates will be supplied to cover each roll of material delivered to site. The certificates will be supplied prior to delivery of the material to site and will contain the relevant quality control data

Quality Control Certificates will be provided prior to installation and for inclusion in the CQA Validation Report as follows:

- A specification for the CDL which includes all properties measured using the appropriate test methods;
- Written certification that minimum specification values are guaranteed by the Manufacturer;
- Written confirmation that testing to detect needle fragments and removal of needle fragments prior to delivery of the product has taken place.

8.4 Installation

The CQA Inspector will assign panel identification codes and maintain a record of panel/roll correspondence and the date and location of installation. Each panel will be observed for defects and a record will be kept to assure that all defects are properly repaired and tested.

CDL panels will be placed directly over and in direct contact with the geomembrane. The minimum panel overlap on basal areas and across slopes shall be 300mm and down slopes the minimum panel overlap shall be 500 mm (or in accordance with the manufacturers recommendations).

Along the perimeter of the installation, the CDL will be placed on the embankment slope to a vertical height of 1m in accordance with Drawing FK-DG-69-DR05. In windy conditions and at the end of the working day, all exposed edges of the CDL should be weighted down. The CDL should be held down using sandbags or similar weights that will not damage the material. The CQA Inspector shall visually check for such damage. All CDL sheets will be visually inspected for damage and imperfections after deployment and any repairs required will be undertaken.

8.5 Repairs

Any faulted areas on the CDL shall be overlain with a single piece of compatible CDL. The patch shall have a minimum overlap of 500 mm in all directions.

8.6 CQA Requirements

The CQA Inspector shall:

- Ensure that the materials are delivered, handled and stored in accordance with the manufacturers recommendations;
- Make a visual inspection of each roll as it is unloaded to identify any damage and record the relevant information for each roll;

- Assess all CDL manufacturers' quality control certificates to confirm that the CDL meets the requirements of the specifications prior to installation;
- Assess and approve, with respect to the requirements set out in the specifications, the proposed panel layout for the CDL to be submitted by the Contractor;
- Assess the methods statement submitted by the Contractor detailing his proposed deployment and seaming techniques:
- Provide written certification to the Contractor that the surface on which the CDL is to be installed is acceptable prior to installation. *Note the CQA Inspector may withdraw the certificate should the surface deteriorate for any cause prior to installation and only reissue upon remediation works being compliant with the specifications*;
- Witness all panel deployment ensuring compliance with the specifications;
- Witness all seam constructions to ensure compliance with the specifications:
- Ensure that all defects are identified on the CDL and witness that they are repaired in accordance with the specifications;
- Ensure that a defect free tie-in with the existing CDL in adjacent cells is constructed;
- Ensure that CDL and seam construction continues to the back of the anchor trenches;
- Provide written certification to the Contractor of areas approved to be covered with leachate drainage stone and ensure that approved areas are covered as soon as possible upon approval;
- Ensure that on completion of the CDL installation the Contractor produces a fully referenced as-built panel layout plan including all the detail listed within the specifications.

The CQA Inspector shall fully document each item above and the documentation shall be presented in the CQA Validation Report.

8.7 Leachate Collection Drain

The cell floor will be constructed with a fall of 1:100 west to east as shown on Drawing No FK-DG-69-DR03. A leachate collector drain will be excavated along the centre of the cell floor. The lining system of GCL and CDL will be continued through the drain excavation as shown in the Leachate Collector Drain Detail of Drawing No. FK-DG-69-DR05. A slotted polypropylene pipe (175mm Internal Diameter / 200mm Outside Diameter) will be placed in the collection drain. The pipe will be bedded and surrounded with 22mm to 32mm rounded, washed, non calcareous stone. The pipe will be laid at a self cleansing gradient of 1/70 hence the depth of excavation of the drain will vary accordingly.

The leachate collection pipe itself will be a type 2 co-polymer polypropylene, which has a greater chemical resistance and is capable of operating at greater temperatures than polyethylene. The external ring stiffness of the pipe will be 8kN/m^2. The internal surface of the pipe is smooth bore. The external surface of the pipe is a corrugated system with a spigot and socket jointing method incorporating an EPDM seal. The pipe is slotted around two-thirds of the circumference of the pipe to DIN4262/1, with one-third of the invert solid to allow for media flow.

The leachate collection pipework will carry the leachate to a reinforced concrete manhole. This manhole will be located at the lowest point of Cell 6 (Centre of East Embankment). The manhole will be constructed of pre-cast concrete units and consist of a pre-cast base and 1200mm internal diameter chamber rings. The interface between the base and rings will be sealed with sealing gaskets. The manhole rings (1200mm) will be added to the base as the ash level in the cell rises.

9.0 Surface Water Drainage

9.1 Under-Cell Drainage

As outlined above, the cell floor has been constructed with a fall of 1:100 towards the centre of the eastern embankment of the cell as shown on Drawing No. FK-DG-69-DR03. A surface water collector drain will be excavated along the centre of the proposed cell floor. This collecter drain will continue to operate until lining operations commence. At this point it will be re-filled and the leachate collection drainage will take its place.

10.0 CQA VALIDATION REPORT

Upon completion of the cell development and lining works the CQA Inspector will prepare a Certification Report summarising the works undertaken and including all CQA documentation prepared. As a minimum this shall include:

- Description of the works
- Completed Summary Sheets detailing the installation of each element of the works
- Contractor's and Manufacturers' Documentation
- As Built Drawings: Topographic and Panel Layout
- Photographic Record of the Construction
- Daily Diaries
- Description of Non-conformances and the Subsequent Remediation

The above report will confirm that the works have been carried out in accordance with the specifications as incorporated in this Construction Quality Assurance Plan. The report will be certified by the CQA Manager.

11.0 Appendix A

Drawing No: FK-DG-69-DR-03

Drawing No: FK-DG-69-DR-05

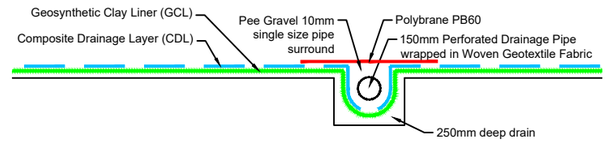
Notes:

Leachate Sump

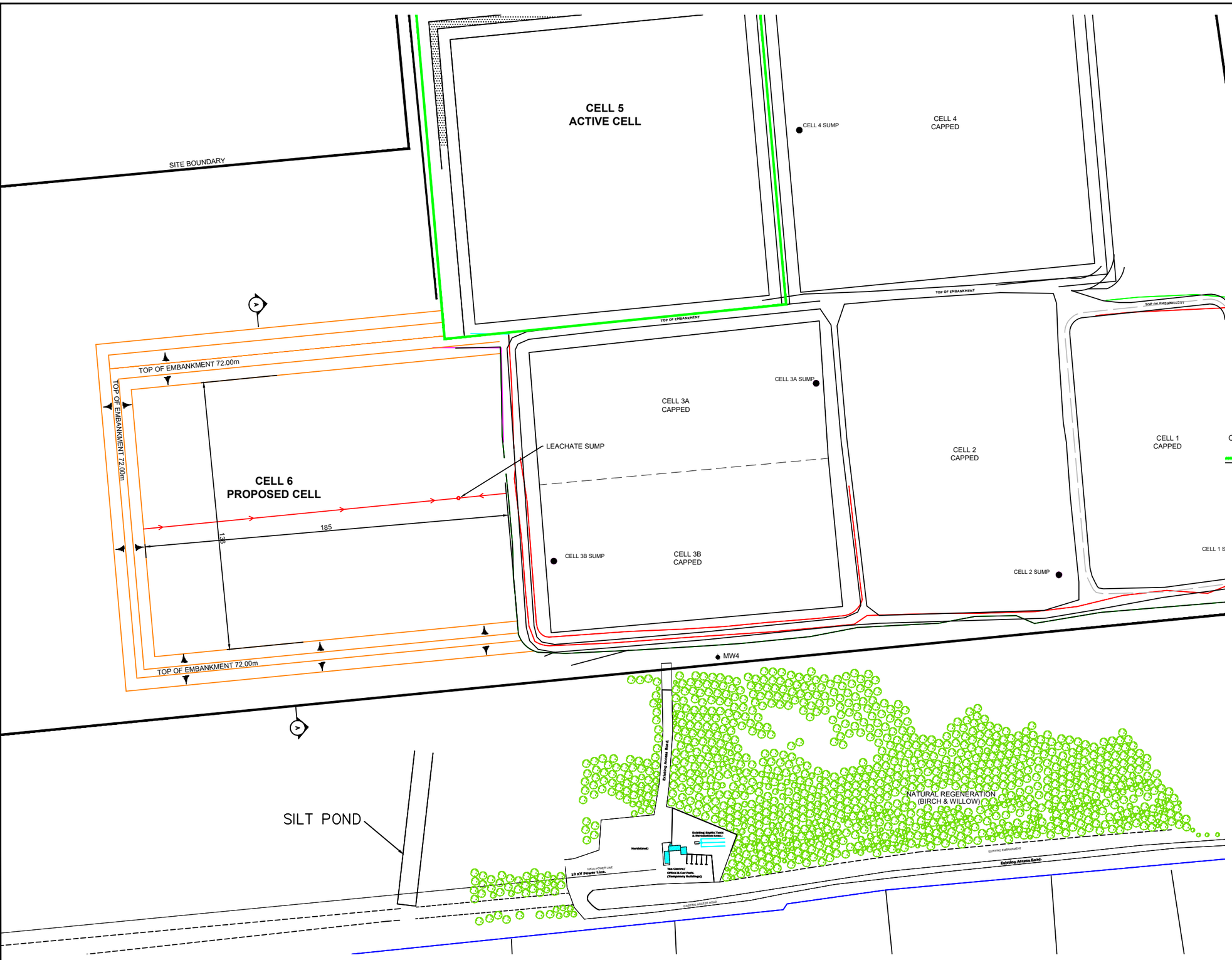
Precast Concrete Manholes Units 1200mm Ø ID Produced to I.S. 420:2004 and I.S. EN 1917.
Supplied and fitted with steps to EN 13101:2002 Type D Class. 1
All rings to be fitted with Elastomeric joints seals in compliance to EN681.
Precast Concrete Base unit to be supplied with 2nr preformed opes of 180mm diameter @ 0° & 180°.
Ground to to prepared for the proposed Leachate Sump prior to lining, excavation of a minimum of 3m diameter and depth of 1m to be replaced with stone and compacted in layers of max 300mm.

Leachate Pipe

Twinwall Perforated drainage pipe 150mm Ø ID. To be wrapped in geotextile membrane before installation.



Leachate Drainage Detail
Scale NTS



	REVISION	By	Date	Chk'd

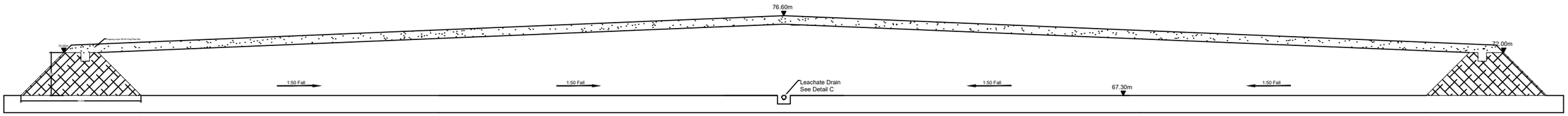
Project: CLONBULLOGE ASH REPOSITORY
CLONCREEN BOG

Title: CELL 6 LAYOUT
LEACHATE DRAINAGE

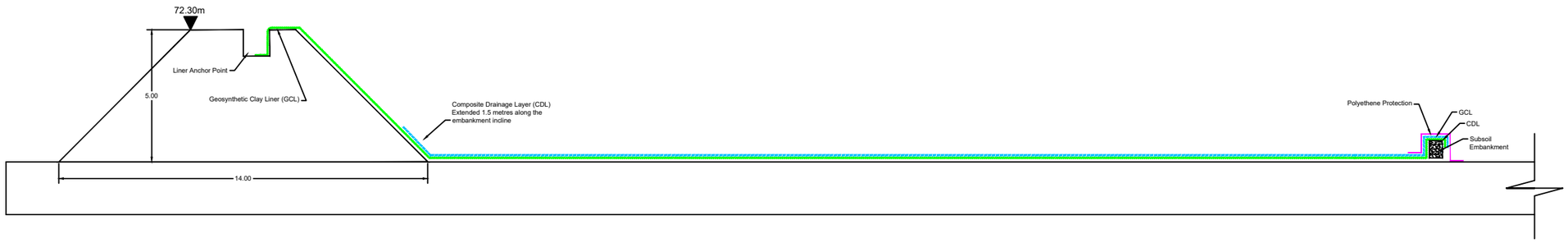
Dimensions in.	mm	
Scale.	AS SHOWN	
Drawn By.	J.C.	28/01/2022
Checked By.	P.N.	28/01/2022
Approved By.	P.N.	28/01/2022

Bord na Móna
LEABEG, TULLAMORE CO. OFFALY
Tel. 057 9345900. Fax. 057 9345160

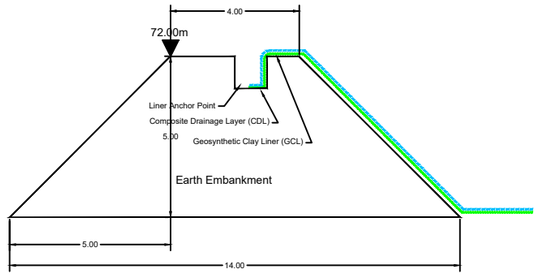
Drawing No.	Revision.	Sheet
FK-DG-69-DR03	1	1 of 1



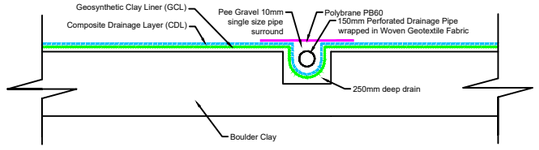
Section A-A
Scale 1:250



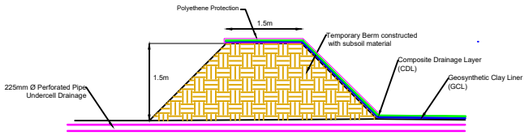
Lining System Detail
Scale 1:100



Detail A
Liner Anchor Point
Scale 1:100



Detail B
Leachate Drainage Detail
Scale 1:100



Detail C
Temporary Bund Detail
Scale 1:50

Project:	CLONBULLOGUE ASH REPOSITORY CLONCREEN BOG		
Title:	LINING DETAILS CELL 6		
Dimensions in.	METRES	Bord na Móna	
Scale.	As Shown	LEABEG, TULLAMORE CO. OFFALY Tel. 057 9345900. Fax. 057 9345160	
Drawn By.	J.C. 01/02/2022		
Checked By.	P.N. 01-02-2022	Drawing No. FK-DG-69-DR05 / Revision. A / Sheet 1 of 1	
Approved By.			

11.0 Appendix B

CDL Pozidrain 12S250/NW8 Datasheet & Install Guidelines

GCL Bentofix Datasheet & Install Guidelines

Pozidrain 12S250/NW8

abg creative geosynthetic engineering

Data Sheet

POZIDRAIN 12S250/NW8 is a geocomposite drainage layer comprising a high performance second generation single cuspated HDPE (High Density Polyethylene) core with a geotextile filter thermally bonded on one side. The textile filter has a flap extending beyond the core on one edge. The major application is its use instead of stone drainage layers in landfill containment systems.

Geocomposite Properties						
Thickness at 2kPa	(mm)	12.0			±10%	EN ISO 9863-1
Mass per unit area	(g/m^2)	1 070			approx	EN ISO 9864
Tensile strength MD / CMD	(kN/m)	18 / 15			-10%	EN ISO 10319
Elongation at peak MD / CMD	(%)	45 / 45			nominal	EN ISO 10319
CBR puncture resistance	(N)	2 300			-20%	EN ISO 12236
Perpendicular Water Inflow	(dimple side only)					
Water flow at 50mm head	(l/m^2-s)	103			±30%	EN ISO 11058
At 2kPa permeability *(coefficient)*	(m/s)	2.5×10^{-3}			±30%	EN ISO 11058
Breakthrough head	(mm)	0				BS 6906 part 3
In-plane water flow MD and CMD		HG = 1.0		HG = 0.1		Hydraulic gradient
at 20kPa confining pressure	(l/m·s)	4.25	-35%	1.25	-35%	EN ISO 12958
at 100kPa confining pressure	(l/m·s)	3.20	-35%	0.85	-35%	EN ISO 12958
at 200kPa confining pressure	(l/m·s)	1.80	-35%	0.45	-35%	EN ISO 12958
with soft foam contact surfaces to simulate textile intrusion into the core due to soil pressure						
Resistance to weathering		To be covered in 14 days				EN 12224
Resistance to chemicals		Excellent				EN 14030
Design life		120 years (manufacturer's declaration)				
Geotextile Properties						
Thickness at 2kPa	(mm)	1.2			±20%	EN ISO 9863-1
Tensile strength MD/CMD	(kN/m)	9.5 / 9.5			-13%	EN ISO 10319
Pore size O_{90}	(µm)	120			±30%	EN ISO 12956
CBR puncture resistance	(N)	1600			-20%	EN ISO 12236
Dynamic perforation cone drop	(mm)	32			+20%	EN ISO 13433
Type and material	Non-woven needle-punched and heat-treated long staple fibre polypropylene					
Product Dimensions						
Standard roll dimensions	4.4 x 50 m. Other sizes on request.					

Notes

1. The values given are indicative and correspond to nominal results obtained in our laboratories and testing institutes. In line with our policy of continuous improvement the right is reserved to make changes without notice at any time.
2. The tolerance on roll length is 1.5% and on roll width is 1.0%; in multi-core products this may manifest itself between core elements.
3. Guidance on interface shear strength, creep and certain other parameters is available. Site specific tests are strongly recommended.
4. Final determination of the suitability of any information is the sole responsibility of the user. ABG will be pleased to discuss the use of this or any other product but responsibility for selection of a material and its application in any specific project remains with the user.
5. Please refer to separate sheets for fixing instructions. A COSHH certificate is available on request.

CE

0799-CPD-30

POZI 12S250.NW8-D.CE

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Water Flow within a Drainage Layer

Measuring In-plane flow, Transmissivity and Permeability

Technical Note

Introduction

This Technical Note discusses the ways of measuring the water flow within a drainage layer in a laboratory. The most important property to specify for a drainage layer is adequate water flow along the length of the drainage layer - which could be in the form of a drainage geocomposite or porous drainage gravel. This could be direct flow testing of a drainage geocomposite, or assessment of the permeability of porous drainage gravel. Further information comparing the use of geocomposites with porous drainage gravel can be found in the Technical Note 'Groundwater Drainage – Geocomposites vs. Gravel' (ABG, 2020a).

There are three terms that are typically used to specify the required water flow within a drainage layer: In-plane flow, transmissivity, and permeability.

In-plane Flow

In-plane flow is measured in accordance with EN ISO 12958 and it is the recommended method for measuring water flow within a drainage geocomposite. The test involves measuring water flow through a sample of the drainage geosynthetic at a specific hydraulic head (see Figure 1). The test sample is placed in the test rig under a defined compressive stress between either soft, or occasionally hard, platens. Soft platens are used to simulate soil causing geotextile intrusion into the core of the geocomposite which may restrict flow – something that can be very significant in some situations and is explained in more detail in 'Groundwater Drainage – Geocomposites vs. Gravel' (ABG, 2020a). As a default, soft platens should be used for all test data as hard platens represent unusual practice applications.

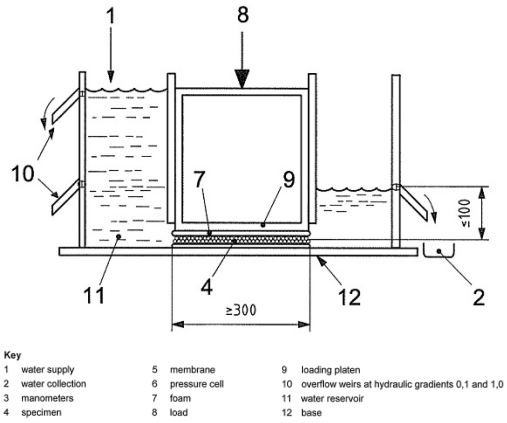

Figure 1: EN ISO 12958 test set up

In-plane flow is defined as the outflow rate (in litres per second) divided by the width of the sample tested.

$$In-plane\ Flow = \frac{Outflow\ rate}{Sample\ Width} = \frac{[l/s]}{[m]} = \frac{l}{m \cdot s}$$

Each flow test is reported with the hydraulic gradient, compressive stress, and type of platens used during tests. By testing at several different hydraulic gradients for each compressive stress, and interpolating between results, a flow chart can be assembled which will allow the maximum flow rate in the geocomposite to be estimated for any given hydraulic gradient (see Figure 2).

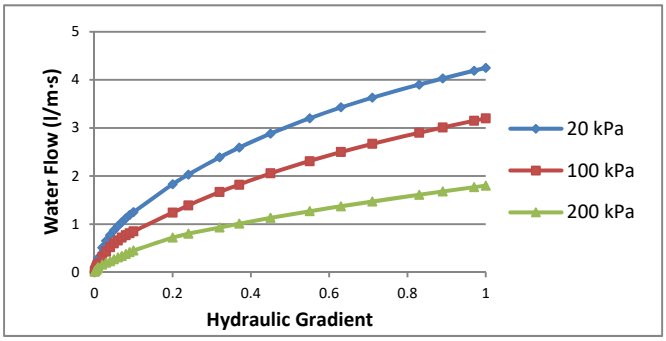

Figure 2: Typical In-plane water flow in a geocomposite

Transmissivity

The test method for measuring transmissivity (or hydraulic transmissivity to give it its full name) is defined by ASTM D4716 and the test method is effectively the same as EN ISO 12958. The difference between these two methods is in the reporting of the results. Transmissivity is defined as the outflow rate (in cubic metres per second) divided by the width of the sample tested and the hydraulic gradient.

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$$Transmissivity = \frac{Outflow\ rate}{Sample\ Width} / Hydraulic\ gradient = \frac{\left[m^3/s\right]}{[m]} \Big/ \frac{[m]}{[m]} = \frac{m^2}{s}$$

Transmissivity is based on the idea that flow is directly proportional to hydraulic gradient. That is, a plot of flow vs. hydraulic gradient would be a straight line as would be expected in laminar flow situations. However, in drainage geocomposites the flow is not laminar and the relationship between flow and hydraulic gradient is not linear (see Figure 2).

Permeability

When considering the water flow through a drainage layer made of porous gravel it is standard practice to use permeability to assess the maximum flow rate within the drainage layer. "*The permeability of a soil is a measure of its capacity to allow the flow of water through the pore spaces between solid particles*" (BS 1377-5:1990). Further information on soil permeability can be found in the ABG Technical Note titled 'Soil Properties: Permeability' (ABG, 2020b). When considering drainage gravel, permeability is measured in the laboratory using the methods described in BS 1377-5:1990 (see Figure 3). The test procedure is similar in principle to that used with drainage geocomposites in that a constant hydraulic gradient is applied to a saturated gravel sample and the rate of outflow is measured. The permeability of the gravel (k) is assessed in a similar manner to assessing transmissivity in a drainage geocomposite.

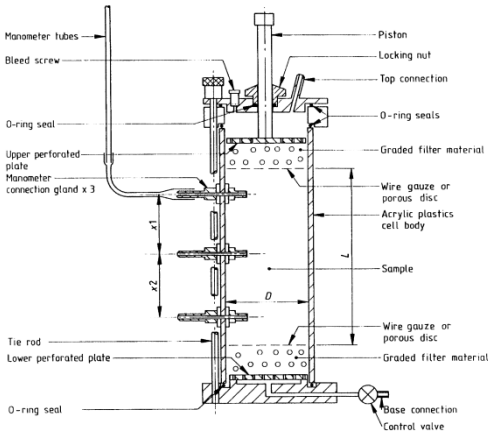

Figure 3: BS 1377-5 Test Set up diagram

$$Permeability = \frac{Outflow\ rate}{Sample\ Area} / Hydraulic\ gradient = \frac{\left[m^3/s\right]}{[m^2]} \Big/ \frac{[m]}{[m]} = \frac{m}{s}$$

As with transmissivity, this assumes that flow is laminar and that flow is directly proportional to hydraulic gradient. With finer grained soils where permeability is low this is approximately correct. However, in coarser grained soils such as drainage gravel the flow rates are very low, the relationship between flow and hydraulic gradient is not linear (Mulqueen, 2005). However, as the relationship is close to linear it is standard practice to assume constant permeability in drainage gravel.

Comparison

In-Plane Flow vs. Transmissivity

In-plane flow testing in accordance with EN ISO 12958, and transmissivity testing in accordance with ASTM D4716 are effectively the same test. However, when comparing values of transmissivity and In-plane flow it is important to understand the test conditions. Principally, the hydraulic gradient, compressive stress, and type of platens used during testing. If the tests for two products were conducted in different conditions it is difficult to accurately compare the results as the relationship between flow and hydraulic gradient in a geocomposite is not linear, and the flow behaviour under different platens and compressive stresses can vary significantly between drainage geocomposites.

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Water Flow within a Drainage Layer

Measuring In-plane flow, Transmissivity and Permeability

Geocomposite Flow Results vs Gravel Flow

The best method for comparing geocomposite flow results with water flow in a drainage layer is to compare results in the conditions that are expected on site. For example, in a vertical drainage situation behind a retaining wall, the geocomposite flow results should be at a hydraulic gradient is 1.0, using soft platens, at a pressure related to the maximum horizontal earth pressure at the base of the wall. The maximum water flow rate in gravel can be assessed using Darcy's Law (see Figure 4), and compared directly with suitable geocomposite flow results. Further details on this are provided in the Technical Note 'Groundwater Drainage – Geocomposites vs. Gravel' (ABG, 2020a).

$$Q = k \cdot i \cdot A$$

Where

Q = Water flow (l/s)
k = Permeability (m/s)
i = Hydraulic gradient (decimal)
A = Cross sectional area of flow (mm x m)

Consider a one metre width of filter stone, of thickness 't':

$$Q = k \cdot i \cdot (t \cdot 1)$$
$$= k \cdot i \cdot t \text{ l/m·s (l/s per m width)}$$

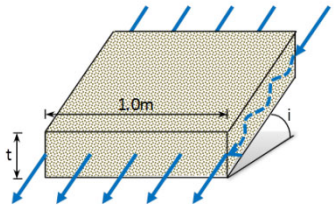

Figure 4: Water flow in a gravel drainage layer using Darcy's Law

Conclusion

Water flow in a drainage geocomposite should be measured by In-plane flow testing in accordance with EN ISO 12958, or transmissivity testing in accordance with ASTM D4716. These methods are effectively the same test but they report the results differently. When comparing values of transmissivity and in-plane flow it is important to understand the test conditions. Principally, the hydraulic gradient, compressive stress, and type of platens used during testing.

Water flow in a gravel drainage layer is assessed by measuring the permeability in accordance with BS 1377 5:1990. These results can be compared directly with geocomposite water flow results using Darcy's Law for the conditions that are expected on site.

References

ASTM D4716 / D4716M-20, *Standard Test Method for Determining the (In-plane) Flow Rate per Unit Width and Hydraulic Transmissivity of a Geosynthetic Using a Constant Head*, ASTM International, West Conshohocken, PA, 2020, www.astm.org

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British Standards Institution, BS EN ISO 12958:2020 – *Geotextiles and geotextile-related products – Determination of water flow capacity in their plane (ISO 12958:2020)*

ABG Geosynthetics (2020a) *Geosynthetic Properties |Groundwater Drainage – Geocomposites vs. Gravel | ABG Technical Note*. [online] Available at: http://www.abg-geosynthetics.com/technical/groundwater-drainage-geocomposites-vs-gravel [Accessed 15 December 2020].

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Mulqueen, J. (2005). The Flow of Water through Gravels. Irish Journal of Agricultural and Food Research, 44(1), 83-94.

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Pozidrain S, SD, GS, GSD

Installation Guide

General Advice

These instructions should be read in conjunction with the contract specification and drawings. They are intended to provide guidance in normal installation situations and are addressed to the installer on site. If there are any questions related to the design, unusual installation challenges, or any doubt, consult ABG for further advice. In all situations, responsibility for installation remains with the Installer.

Description

Pozidrain is a thin, preformed sub-surface water drainage or gas vent geocomposite consisting of a HDPE cuspated core laminated to a geotextile on one or both sides. The geotextile on the studded dimple side of the core is a filter drainage geotextile and the geotextile on the flat side is to provide enhanced interface shear strength. The geotextile flap extends beyond the black core. The geotextile on the studded dimple side of the core is a filter drainage geotextile and the geotextile on the flat side is to provide enhanced interface shear strength. The geotextile flap extends beyond the black core. Usually fluid entry is only possible from one side of **Pozidrain.** Typical applications are landfill and mining containment and capping, cut-off trenches, capillary breaks, gas vents etc.

Supply

Pozidrain is supplied in cylindrical rolls typically 4.4m or 5.5m long, 0.8m diameter and may weigh up to 500 kg. Each roll unwinds to cover an area of 4.4m or 5.5m wide by the roll length. Rolls labelled REV and identified with blue tape are reverse wound.

Equipment Required

- Appropriate PPE
- Safety knife
- Sand bags or fill material for ballasting

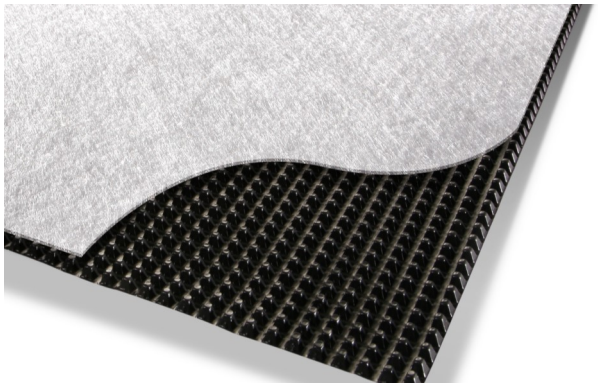

Fig. 1: Pozidrain—Fluid entry from above

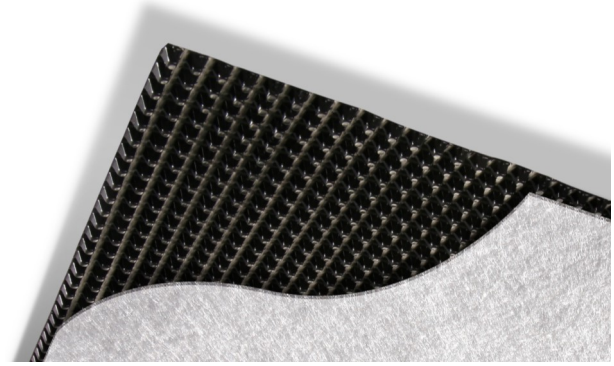

Fig. 2: Pozidrain—Fluid or gas entry from below

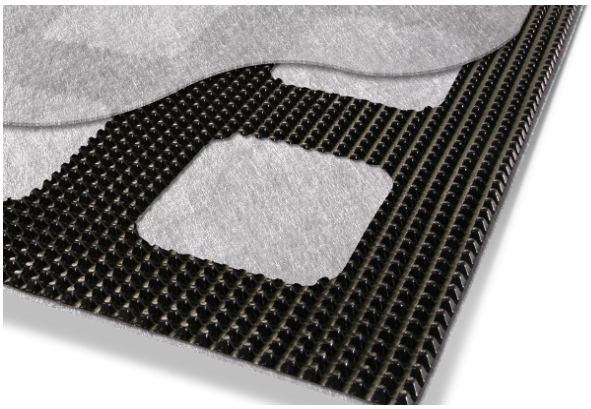

Fig. 3: Pozidrain G

Fig. 4: Pozidrain rolls stacked

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Installation Guide

Setting out

Step 1

Pozidrain is supplied in rolls wrapped for protection against UV light. Do not remove the wrapper until ready to install. Single use slings may be provided for the safe off-loading of rolls. These slings are designed for single use to remove the rolls from the delivery vehicle to an appropriate site storage location. Store on a firm base and do not stack more than six rolls high. Inspect all rolls for damage/defects during offloading and immediately report to **ABG**.

Step 2

Roll or carry **Pozidrain** rolls to the place of work, using suitable lifting equipment that does not damage the product. Do not drag the rolls as this could cause damage to the geotextile covering. Avoid contact with machine buckets. Lift the rolls with a boom or pole & frame through the centre tube or by means of lifting straps around the roll.

Step 3

Pozidrain maybe laid onto a GCL , CCL or HDPE barrier. Alternatively, the formation on which **Pozidrain** is to be laid should be firm, free of roots and sharp objects and be graded smooth so that there are no ruts or ridges greater than 50mm high. **Pozidrain** will bend to follow stepped or benched ground profiles.

Step 4

In choosing the commencing point and direction of laying, consider the outfall positions, the prevailing wind direction, site slope and access point for materials. **Pozidrain** is designed to be laid so that the major flow of water is longitudinally along the roll length.

Step 5

Identify the side of **Pozidrain** that is intended for the primary inflow of fluid or gas. It is essential that this is laid as shown on the drawings. The rolls will unwind when rolled out with the drainage side uppermost. For fluid or gas entry from below, the drainage side needs to be on the underside. This can be achieved by ordering the product reverse wound (identified by REV at the end of the product code and a blue tape on the packaging), alternatively, the standard roll can be unwound from a boom.

Fig. 5: Pozidrain rolling out

Fig. 6: Pozidrain placed on steep slope

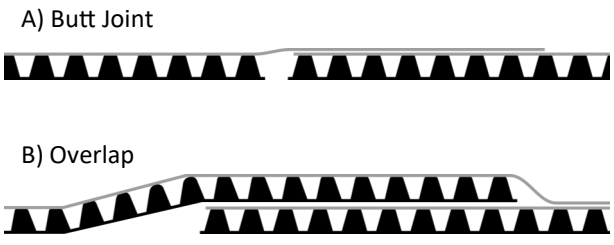

Fig. 7: Single Textile Pozidrain Edge Joint Options

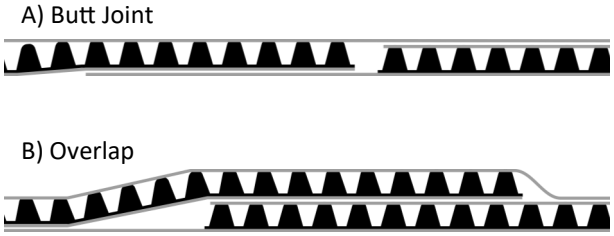

Fig. 8: Double Textile Pozidrain Edge Joint Options

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Installation Guide

Installation

Step 1

Unroll the first roll of **Pozidrain** into position (allowing enough material to fold into the anchor trench if required). Note the roll ID on the label and the end of the roll for the CQA plan.

Step 2

The next roll should be placed such that the black drainage cores are either overlapped or butted together along the edge **(Fig. 8 & 9).** The geotextile edge flap overlaps onto the textile of the adjacent roll. The flaps may be held down by sandbags, sewing, adhesive, tack welding with great care, jointing tape or staples (if lining operations permit).

Step 3

On steep slopes, it is easiest to commence laying **Pozidrain** from the top of the slope and allow the material to unroll gently down the slope.

Step 4

Continue to lay rolls to create a continuous layer. Subject to site safety procedures, rolls can be cut to length using a safety knife or disc saw. Offcuts may be re-used but waste pieces must be disposed of according to the site waste management plan.

Step 5

A trapezoidal anchor trench will be required at the top of steep slopes to securely locate **Pozidrain**. Long steep slopes should be constructed with intermediate berms and anchor trenches. Such details are normally provided in the contract drawings. On steep slopes the rolls must be continuous from top to bottom - there must be no end joints on the slope between berms.

Step 6

On shallow slopes, the end of one length of **Pozidrain** may be continued onto the next length of **Pozidrain by** overlapping the ends by 500mm like roof tiles in the downslope direction **(Fig. 12).**

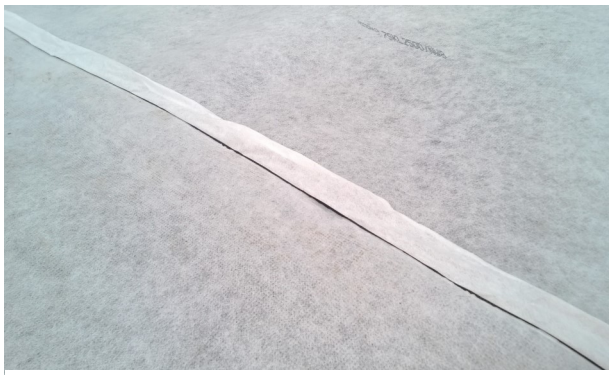

Fig. 9: Geotextile flap overlap

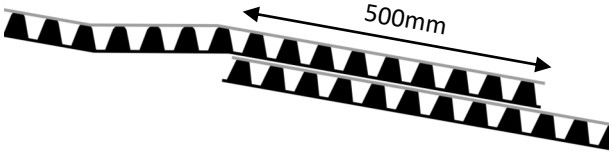

Fig. 10: End Jointing of rolls on shallow slopes

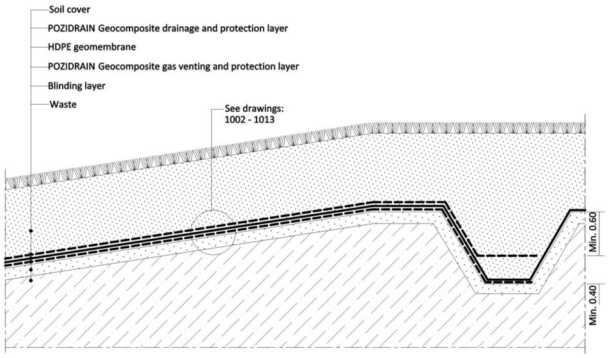

Fig. 11: Pozidrain laid in anchor trench

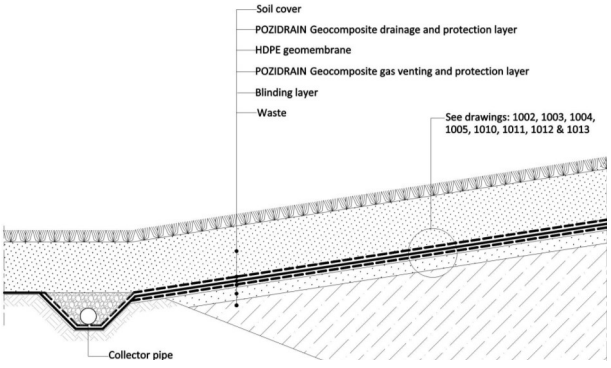

Fig. 12: Collector pipe outfall trench

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Step 7

Before backfilling make sure there are no gaps in the geotextile cover where soil or clay could enter into the drainage core. Ensure that water/gas can exit freely from **Pozidrain** into the ground collection trench.

Step 8

Backfilling must always commence from the bottom of the slope upwards unless a geogrid has been designed and installed to take account of the additional forces.

Step 9

To prevent damage, mechanical plant must not operate directly on **Pozidrain**. The first layer of backfill should be at least 150 mm thick or twice the maximum particle size (if greater) and spread by tracked plant. Fill material should be tipped on the advancing layer, not directly onto **Pozidrain**, and the fill should be compacted closely behind the spreading operation.

Step 10

A minimum cover of 450 mm of acceptable fill is recommended over **Pozidrain** before general use by site traffic. Heavy plant must not be used on steep slopes.

Step 11

In the event that **Pozidrain's** geotextile cover is damaged either before or after installation, small areas can be repaired using a patch of similar textile at least 300 mm larger than the damaged area. If the dimpled drainage core has been damaged, this should be cut out carefully and a new piece of **Pozidrain** inserted together with an over-size patch of geotextile.

Fig. 13: Placing cover soil

Notes

1. There are no known COSHH hazards associated with the installation of **Pozidrain** but refer to the MSDS and take care when cutting.
2. Plan only to lay as much **Pozidrain** as can be covered in a day, to avoid uplift in strong winds and the risk of inundation by silt-laden runoff. Unused rolls may be used as ballast on flat areas. **Pozidrain** can be secured temporarily by means of sandbags or small heaps of fill material.
3. The UV exposure limit is stated on the datasheet.
4. On steeply sloping sites, the rolls of **Pozidrain** must be laid up and down the slope, not across the slope and suitable anchor trenches or run-out lengths must be used.
5. On steeply sloping sites there must be no joints in the **Pozidrain** between berms.
6. **Pozidrain** can be unrolled progressively up a steep slope with the rolls held in place on the slope using large wooden chocks or wedges and possibly by cables.
7. Outfalls for the water or gas collected by **Pozidrain** may consist of a perforated pipe laid in a gravel / filter stone trench. **Pozidrain** may discharge to a toe ditch (Fig. 13) or upwards to a gas venting stack.

Terms and Conditions

Site specific engineering design should be carried out after site investigation has provided all the necessary information.

The assessment of suitable safety factors in relation to each particular project must always remain the responsibility of the design engineer.

Installation Guide

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Fibre-reinforced Geosynthetic Clay Liner (GCL)

Bentofix® NSP 4900

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The following table lists properties of **Bentofix® NSP 4900**, a shear strength transmitting geosynthetic clay liner, continuously needle-punched through all components. Additional bentonite powder is impregnated into a 50 cm overlapping area on both longitudinal sides of the cover layer. The 30 cm longitudinal overlapping area is marked on the bottom side.

Property	Test method*	Unit	Values
Geotextile layers:			
Cover layer (polypropylene nonvowen):			
Mass per unit area	EN ISO 9864	g/m²	220
Carrier layer (polypropylene woven):			
Mass per unit area	EN ISO 9864	g/m²	110
Bentonite layer (sodium bentonite powder):			
Mass per unit area	EN 14196 (ρ_{TON})	g/m²	4,670
Swell index	ASTM D 5890	ml/2g	24
Fluid Loss	ASTM D 5891	ml/2g	≤ 18
Water content	DIN 18121 / ISO 11465 (5hrs, 105 °C)	%	approx. 10
Geosynthetic Clay Liner:			
Mass per unit area	EN 14196 (ρ_{GBR-C})	g/m²	5,000
Thickness	EN ISO 9863-1	mm	6.0
Max. tensile strength, md/cmd**	EN ISO 10319 / ASTM D 4595	kN/m	12.0 / 12.0
Elongation at break, md/cmd**	EN ISO 10319 / ASTM D 4595	%	10.0 / 6.0
Peel strength	ASTM D 6496	N/10 cm*** N/m	≥ 60 ≥ 360
Permeability / Hydraulic Conductivity	DIN 18130 / ASTM D 5887	m/s	2×10^{-11}
Index Flux	DIN 18130 / ASTM D 5887	(m³/m²)/s	5×10^{-9}
Roll dimensions:			
width x length, / diameter	-	m x m / m	4.85 x 40 / Ø 0.65

** = based on; **md = machine direction, cmd = cross machine direction; ***max. peak*

The listed technical values are guiding values, achieved in our laboratories and/or independent testing institutes. Our products are subject to changes without prior notice.

Bentofix® B types
Geosynthetic Clay Liner
without a polyethylene (PE) coating
Installation Guidelines
NAUE GmbH & Co. KG

Contents

The following installation recommendation contains general installation guidelines. It is presented as a general format, not as a direct substitute for a project specific specification. In the event of a conflict, the requirement of the project specification will supersede these recommendations. This recommendation does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this guideline to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

Further, this installation guideline does not purport to establish specific procedure for all climatic, geographical, hydraulic, or topographical conditions that may exist at a site. Appropriate installation procedures under atypical field conditions should be modified as necessary to maintain the integrity of the GCL and adjacent components. The information contained herein has been compiled by NAUE GmbH & Co. KG, Germany, and is, to the best of our knowledge, true and accurate. There is no implied or expressed warranty. Final determination of suitability for use contemplated is the sole responsibility of the user. This information is subject to change without notice.

NAUE makes no warranty of any kind and accepts no responsibility for the results obtained through this installation guideline or for the correctness of the GCL use in an application. For further information or questions please consult the specifier, designer or NAUE GmbH & Co. KG. The information contained herein is the best to our knowledge, true and accurate. This installation guide is subject to changes without prior notice.

1. Scope

1.1 Bentofix® geosynthetic clay liners (GCLs) are needle-punched, reinforced composites that combine two durable geotextile outer layers and a uniform core of high-swelling powder sodium bentonite clay. This construction forms a shear resistant hydraulic barrier with self-sealing characteristics.

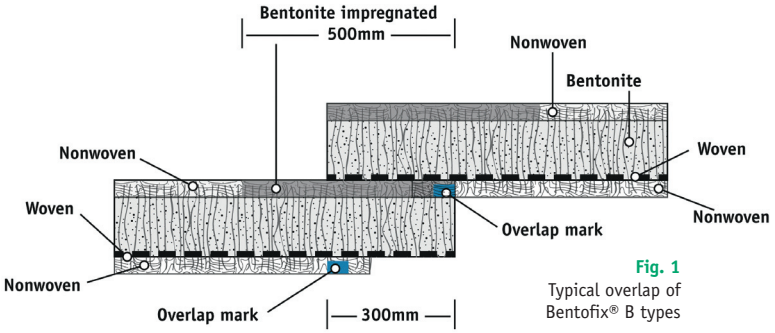


Fig. 1
Typical overlap of Bentofix® B types

1.2 During the manufacturing process the cover nonwoven geotextile of Bentofix® B types is impregnated during the production with bentonite powder at the edges on both sides in length direction in a width of 500mm (logitudinal overlaps) (fig. 1). This bentonite impregnation allows a simple self-sealing overlap at the edges in length direction, without any supplemental bentonite placement on site.

1.3 The subbase, the Bentofix® GCL as well as the minimum 300mm thick cover soil make the sealing system. Bentofix® GCLs are a sealing element and are not designed to absorb tensile strengths.

1.4 Bentofix® is produced following strict ISO 9001 quality control procedures. Failure to follow good practice may result in the unnecessary failure of the geosynthetic in a properly designed application.

1.5 This installation guideline is applicable for all Bentofix® B types without any additional coating barrier.

1.6 This Bentofix® installation guideline is not applicable for underwater installation applications.

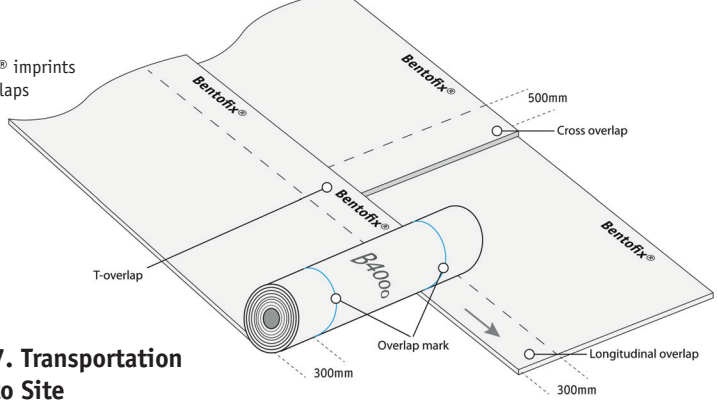


Fig. 4
Bentofix® imprints and overlaps

1.7 This guideline must be present to the installer and the responsible site engineer.

2. Quality Statement

2.1 NAUE GmbH & Co. KG as the inventor of needle-punched GCLs in 1987 is dedicated to continuous quality. This commitment begins with the manufacture of the Bentofix® Geosynthetic Clay Liner (GCL) material and its components (as well as the quality control of these and their components), and continues until our customer has accepted the GCL.

2.2 NAUE GmbH & Co. KG is fully ISO 9001 (2008) registered.

3. Packaging

3.1 Manufactured Bentofix® rolls are usually rolled on cores that have a crushing strength sufficient to avoid collapse or other damage in normal use.

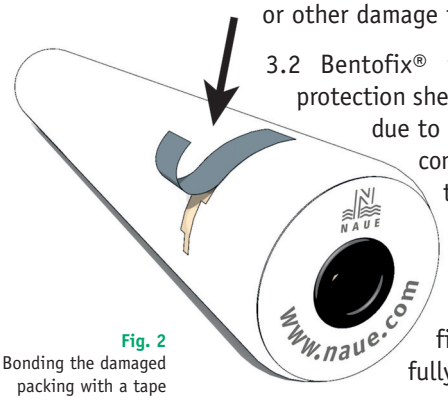


Fig. 2
Bonding the damaged packing with a tape

3.2 Bentofix® rolls are wrapped with a protection sheet to avoid effects to the roll due to shipment, water, sunlight or contaminants while being stored, transported or handled.

3.3 In the unlikely case of a damage to the wrapping, the damaged area is either fixed with tape (fig. 2) or is fully replaced.

Fig. 3
Typical Bentofix® roll label

4. Labeling

On the wrapping of each roll a label with handling guidelines and an identification label (fig. 3) is fixed which includes:

- Name of manufacturer
- Product identification
- Roll dimension
- Unique roll number
- Total mass per unit area

5. Roll Imprint

Each roll of Bentofix® B type geosynthetic clay liner is printed on the slit-film woven side with the product name and type name as well as with a continuous overlap line on each side of the woven, 300mm from the edge. The product imprint and the overlap lines after unrolling are, if not otherwise requested, faced down against the subgrade.

6. Plant Storage

6.1 Bentofix® rolls are transported in the manufacturing facility by means of stinger bars and are stored so that no damage affects the performance of the material or of the wrapping.

6.2 Bentofix® rolls are stored covered on elevated, dry and smooth ground, which will prevent any damage to the wrapping of the rolls.

7. Transportation to Site

7.1 Bentofix® GCL rolls are delivered to the working area of the site in their original packaging on trucks or in containers. The storage surface should be elevated, dry and smooth, to prevent any damage to the wrapping of the rolls.

7.2 In general no supplementary bentonite powder is needed for Bentofix® B type overlaps in length direction. Exceptions that require additional bentonite powder may be where there is a requirement for penetrations, cross overlaps or speciality connection details of the Bentofix® GCL. In this case bentonite powder in bags as well as approximately 200mm wide nonwoven strips are required. The necessary amount needed must be ordered prior to shipment. These are typically transported such that they do not get wet.

7.3 Before Bentofix® rolls are unloaded it is recommended to identify and verify the shipment and check whether any rolls are damaged. In the unlikely case of damage, details should be noted and reported to the forwarding company and the supplier.

8. Unloading Procedures

8.1 As with any lifting or loading operations, appropriate safety equipment should be employed and proper safe handling methods practised. This includes an appropriate and firm subbase for the vehicle and the Bentofix® storage. The party responsible for unloading the Bentofix® GCL should contact the manufacturer prior to shipment to determine the correct unloading methods and equipment if different from the pre-approved and specified methods. Use Appendix B to make notes if necessary.

8.2 The storage area for Bentofix® rolls must follow section 9.

8.3 Lifting the rolls can be accomplished with a 63mm - 75mm outside diameter steel pipe/bar (preferably solid), with a wall thickness capable of providing sufficient beam strength to support the weight of the roll without bending, which is (GCL type dependent) generally between 900 and 1,200kg (for 5m wide Bentofix® GCLs). The core pipe is inserted through the centre core of the Bentofix® roll. Heavy-duty slings or chains are attached to each end of the pipe, which are then fastened to a spreader bar (fig. 5).

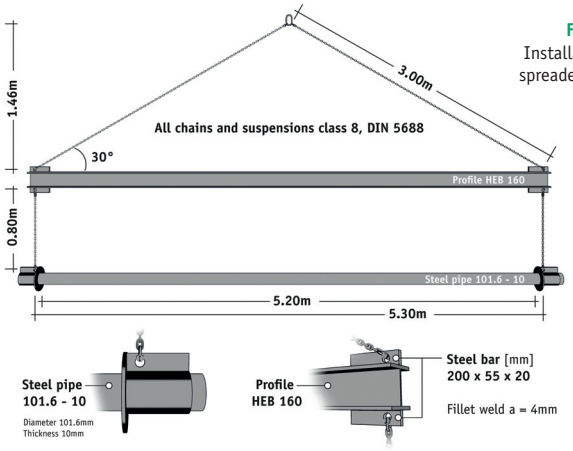


Fig. 5
Installation spreader bar

A crane, backhoe, frontend loader or any other suitable piece of equipment can then lift the entire assembly.

An all-terrain, extendable boom or fork lift, can be fitted with a special, solid steel pole ≥ 4.0m in length, having an outside diameter of no more than 86mm. The pole is inserted into the core of the Bentofix® roll. The roll should not be fully lifted until the pole extends its full length into the core so that the core does not break. This pole has a long reach and is particularly useful for unloading containers or covered vans. Bentofix® GCLs must be supported during handling to ensure workers safety and prevent damage to the liner and the core pipe (inner diameter approx. 125mm). Under approved and monitored circumstances only, should the rolls be dragged, lifted from one end, lifted with only the forks of a lift truck or pushed to the ground from the delivery vehicle.

8.4 The Construction Quality Assurance (CQA) inspector should verify that proper handling equipment exists which does not pose any danger to the installation crew or risk of damage or deformation to the liner material itself.

8.5 Additional handling equipment is described below:

Spreader Bar Assembly - A spreader bar assembly shall include both a core pipe or bar and a spreader beam. The core pipe shall be used to uniformly support the roll when inserted through the GCL core while the spreader beam will prevent chains or straps from chafing the roll edges.

Stinger - A stinger is a rigid pipe or rod with one end directly connected to a forklift or other handling equipment. If a stinger is used, it should be inserted to its full length into the roll to prevent excessive bending of the roll when lifted.

Roller Cradles - Roller cradles consist of two large diameter rollers spaced approximately 75mm apart which both support the GCL roll and allow it to freely unroll. The use of roller cradles shall be permitted if the rollers support the entire width of the GCL roll.

Slings - two slings (≥ 70mm width) with sufficient strength (approx. 1/3rd of the roll width away from the edge), which are fixed to the lifting device, with which (depending on the strength of the slings) one or more rolls can be moved without damaging the GCL or the packaging.

8.6 In the unlikely case of damage to the wrapping, the damaged area is either fixed with tape (fig. 2) or is fully replaced.

9. Storage on Site

9.1 A storage area is required that is flat, dry, and well drained to keep the Bentofix® GCL dry and large enough to store the delivered amount of GCL rolls. The surface should be free of sharp rocks or other objects that could damage the GCL. The storage area must be as close as practicable to the work area to minimize on site handling.

9.2 The storage area must be secure to prevent vandalism, theft, and must be such that rolls are unlikely to be damaged by passing vehicles. Rolls of Bentofix® and bentonite for the overlap areas need to be covered with a plastic sheet or tarpaulin until their installation.

9.3 Any rolls that come in contact with moisture while in storage should be examined prior to installation to ensure that subsequent physical damage has not occurred. Physically damaged rolls should be set aside for further examination to determine the plausibility of repair.

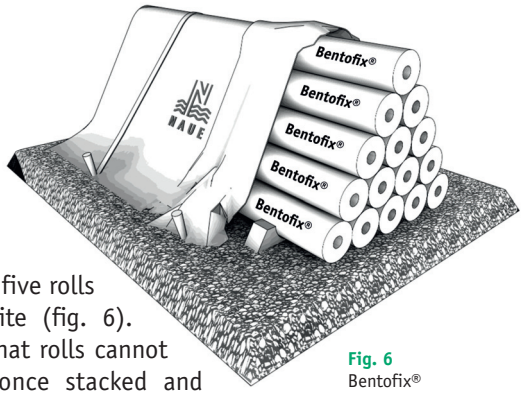


Fig. 6
Bentofix® storage on site

9.4 Bentofix® GCLs can be stacked up to five rolls high if stored on site (fig. 6). It must be ensured that rolls cannot move at any time once stacked and stored. If rolls need to be stacked higher please contact NAUE or their representative.

9.5 Arrange storage so that access can be maintained to one or preferably two sides of the stored GCL rolls. Pulling of rolls should be avoided.

9.6 On site delivered bags with bentonite and nonwoven strips should also be stored dry and if necessary protected with a waterproof and resistant plastic sheet.

10. Recommended Equipment

- Approved Vehicles, e.g. excavator
- Bagger
- Spreader bar
- Utility knife
- Trowel
- Bucket
- Shovel
- Marker
- Yardstick

11. Qualification for Installer

11.1 The installation crew must have knowledge of the Bentofix® installation guidelines and be trained on the installation procedure of Bentofix® GCLs.

11.2 It is recommended to note the date of training in the construction journal. Appendix A can be used as a general format.

11.3 NAUE or their local representative personnel staff can train installers if requested. Details are to be determined prior to the training.

12. Weather conditions for Installation

12.1 The weather conditions should allow a dry installation of Bentofix® GCLs and the placement of the cover materials.

12.2 The subbase must fulfill the specification or requirements as stated in section 13.

12.3 Installation should follow the procedures described in Sections 13 to 19 (incl).

12.4 If the GCL is hydrated (typically ≥ 50% according to DIN 18121) when no confining stress is present, it may be necessary to remove and replace the hydrated material. The project engineer, Construction Quality Assurance (CQA) inspector, and GCL supplier should be consulted for specific guidance if premature hydration is suspected to have occurred.

13. Subgrade Preparation

13.1 The surface upon which the Bentofix® GCL is installed should be smooth and free of debris, roots, sticks, and sharp rocks/boulders larger than 50mm. Site specific compaction requirements should be followed in accordance with the project plans and specifications.

13.2 At a minimum, the level of compaction should be such that installation equipment or other construction vehicles that traffic the area of deployment do not cause significant rutting.

13.3 In applications where the Bentofix® GCL will be subjected to a hydraulic head that exceeds the cover soil confining stress, subgrade surfaces consisting of gravel or granular soils may not be acceptable due to their large void content. For these applications, the top 150mm of the subgrade soil should possess a particle size distribution where at least 80 percent of the soil is finer than 0.2mm with a maximum particle size of 12mm. Directly prior to deployment of the Bentofix® GCL, the subgrade shall be final-graded to fill in any remaining voids or desiccation cracks and proof-rolled to ensure that no sharp irregularities or abrupt elevation changes exist greater than 25mm.

13.4 The surfaces to be lined shall be maintained in this condition, free of standing water.

13.5 If required the subgrade preparation and surface should be inspected and certified by a CQA inspector prior to Bentofix® GCL placement. Upon approval by the CQA inspector, it should be the installer's responsibility to indicate to the engineer any change in the condition of the subgrade that could cause it to be out of compliance with any of the requirements of the project specific specification.

14. Slopes

14.1 In all cases it is required that the responsible designer approves the slope stability analysis of the system.

14.2 On slopes with an inclination larger than 17% (9.65°; 1V:6H) and 3m length it is necessary to install Bentofix® in direction of the slope. In any cases the relative friction angles should be confirmed with shear box tests. Cross-overlaps are to be avoided. Should this not be possible, then cross-overlaps have to be in the direction of the water flow (fig. 7; roof tile system).

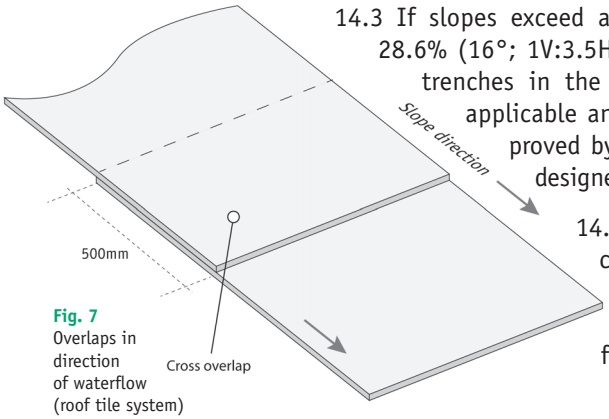


Fig. 7
Overlaps in direction of waterflow (roof tile system)

14.3 If slopes exceed an inclination of 28.6% (16°; 1V:3.5H) hidden anchor trenches in the slope might be applicable and should be approved by the responsible designer.

14.4 If anchor trenches are specified at the top of the slopes, then follow section 15.

15. Anchoring

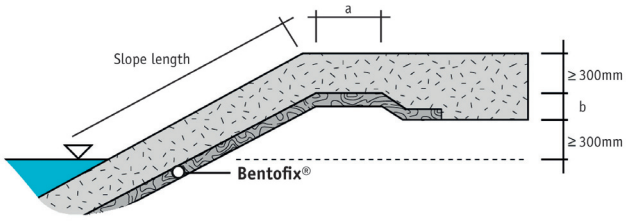
15.1 Bentofix® GCL is typically anchored in a trench on the top of slopes, e.g. around the perimeter of the containment basin to provide the required pullout resistance. In most cases Bentofix® GCLs can be anchored in the same trench as any adjacent geosynthetic liner components (if used).

15.2 Dimensions and location of the trench should be provided in the project drawings or from figure 8. Alternately, the material may be anchored by deploying additional run-out of material past the slope crest.

15.3 The front edge of the trench should be rounded so as to eliminate any sharp corners that could cause excessive stress on the GCL.

15.4 When an anchor trench is required, it shall be excavated no more than two days ahead of GCL placement. This should prevent the trench sides from falling in and requiring re-excavation.

15.5 When the panels are placed in position, the anchor trench must be loosely backfilled or loaded with sandbags immediately.



Slope length	a	b
< 10m	≥ 500mm	≥ 500mm
10 - 40m	≥ 800mm	≥ 600mm
> 40m	≥ 1000mm	≥ 800mm

Fig. 8
Anchor trench details

15.6 The appropriate backfill procedures should be in accordance with the project drawings and specifications.

15.7 The lowest point of any anchorage should be minimum 300mm higher than the highest water table, e.g. in a containment application.

16. Installation of Bentofix®

16.1 GCL rolls are to be delivered to the working area of the site in their original packaging.

16.2 As Bentofix® rolls are selected for deployment, the roll labels should be removed and recorded by the installer or the quality control inspector along with any other pertinent information. Only approved material may be installed (Appendix C can be used to make notes).

16.3 Immediately prior to deployment, the packaging shall be carefully removed without damaging the GCL. Overlap marks on both sides indicate the bottom side which is placed on the subgrade.

16.4 The layout and sequence of panel placement is determined by direction of water run-off. Panels are laid out according to the previously approved panel layout drawings, when such drawings are available.

16.5 Generally, the installation is started at the top of the slope and at the highest elevation so that any rainfall runs off the lower part of the impoundment, this prevents water from hydrating the GCL.

16.6 When in position, panels are checked for any physical damage.

16.7 All Bentofix® GCL rolls should be installed in a relaxed condition, and be free of wrinkles and folds.

16.8 Rolls of Bentofix® material are unrolled using a front-end loader or other approved handling equipment. A spreader bar (fig. 5) or other approved apparatus is attached to the bucket or the front of the equipment.

16.9 Panels on slopes are placed so that the seam runs parallel to the direction of the slope. Flat areas are laid in no particular orientation, but the panels should be shingled in the down-slope direction to facilitate drainage.

16.10 If required, a smooth piece of geomembrane will be used as a rub sheet to facilitate deployment of other geosynthetic layers. The rub sheet does not need to run the entire length of the slope, only the top crest and first few metres of the slope need to be covered to facilitate deployment. After use, the rub sheet has to be removed.

16.11 No equipment that could damage the GCL shall be allowed to travel directly on the GCL. Acceptable installation, for example, may be accomplished such that the GCL is unrolled in front of the backwards-moving deployment equipment, such as a frontend loader or bulldozer. If the equipment causes rutting of the subgrade, the subgrade must be restored to its originally accepted condition before placement continues.

16.12 Only as much Bentofix® GCL as can be covered by the end of the day should be deployed, or such amount that can be covered in a reasonably short time in the event of precipitation. Uncovered overlap edges should be protected overnight with a plastic membrane (fig. 9) to prevent bentonite hydration. The edges of exposed sheets should be weighted down with sandbags or equivalent ballast, which does not cause any damage to the GCL, to prevent uplift in the event of strong winds.

16.13 Cutting of Bentofix® GCLs may be required at some times, e.g. around penetrations. This can be accomplished by using a sharp utility knife. Frequent blade changes are recommended to avoid damage to the geosynthetic components of the GCL during the cutting process. Removed blades should not be discarded on or under installed Bentofix®.

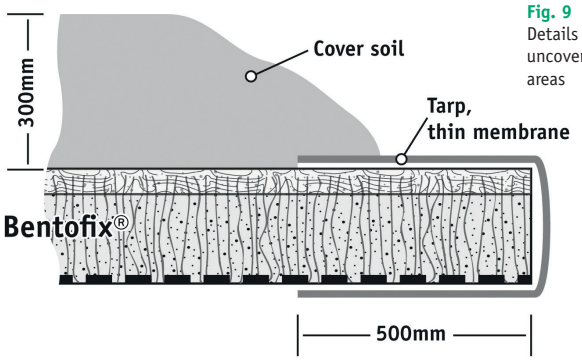


Fig. 9
Details for uncovered areas

17. Overlaps and Seaming

17.1 GCL seams are constructed by overlapping their adjacent edges. Care should be taken to ensure that the overlap zone is not contaminated with loose soil or other debris.

17.2 Do not walk on or drive over overlap areas.

17.3 Do not lay identical Bentofix® surfaces over each other (e.g. slit-film woven on top of slit-film woven).

17.4 Seams should be constructed such that they are shingled in the direction of the grade in a manner that prevents the potential for flow entering the overlap zone.

17.5 T-shaped seams (fig. 10) should be reduced to a minimum.

17.6 Two adjacent laying end overlaps (cross overlaps) are not allowed.

17.7 Overlaps in low points should be avoided.

17.8 Unless otherwise specified, the minimum dimension of the longitudinal overlap should be 300mm. The edge overlap lines of Bentofix® allow the line-up during the unrolling process (fig. 10). End-of-roll overlapped seams should be constructed similarly but the minimum overlap should measure 500mm.

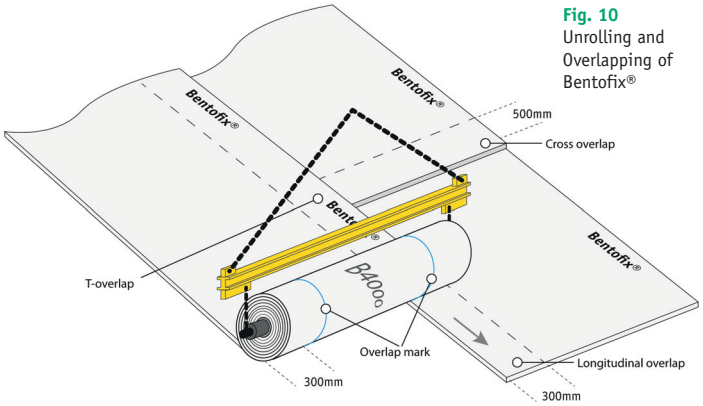


Fig. 10
Unrolling and Overlapping of Bentofix®

Care should be taken to maintain these overlap dimensions at the time of covering, in all climatic conditions.

17.9 To prevent uplift in the event of strong winds it may be necessary to place sand bags or approved soil material over overlap areas.

17.10 Rolls should be adjusted to smooth out wrinkles or creases between adjacent panels while leaving the proper overlap and be free of wrinkles, folds or "fish-mouths" when covered.

17.11 Overlaps in length direction (longitudinal overlaps): It is necessary that the woven side of Bentofix® B types are overlapped with a minimum of 300mm onto the bentonite impregnated area of the nonwoven side. If this is not possible, the overlaps shall be treated according to section 17.12.

17.12 Cross overlaps:
Cross overlaps of Bentofix® B types are not impregnated during manufacturing with additional bentonite. It is therefore necessary that cross overlaps are sealed on site with supplemental bentonite powder (section 17.12.1) or bentonite paste (17.12.2).

17.12.1. Bentonite powder:
These overlapping edges are pulled back and bentonite similar to that used in the product should be poured in a suitable manner 200m wide continuously along all seam edges, typically 0.6kg/m (fig. 11).

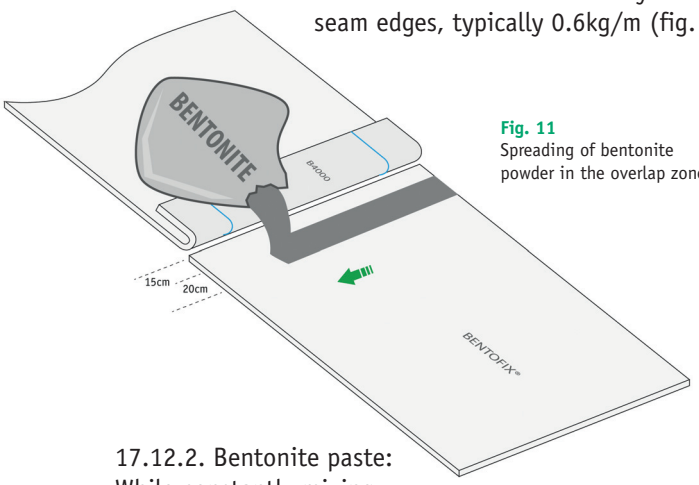


Fig. 11
Spreading of bentonite powder in the overlap zone

17.12.2. Bentonite paste:
While constantly mixing, bentonite should be added to water (approx. 4-6 times the amount of bentonite) in a sufficient large bucket. Typically an electrical mixer with an attached mixing paddle is recommended.

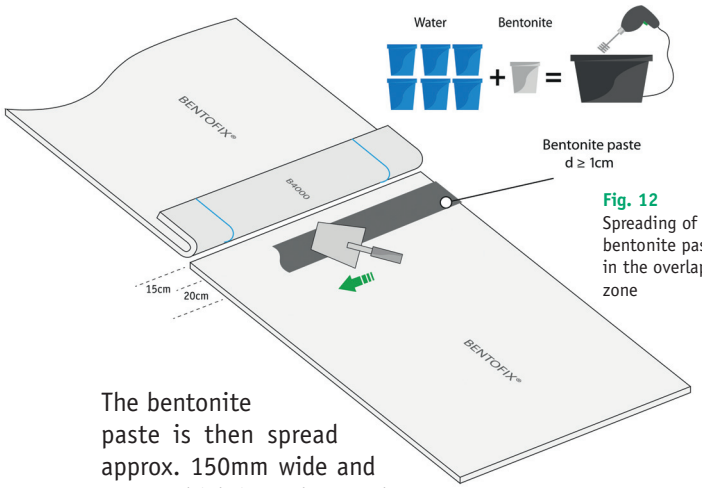


Fig. 12
Spreading of bentonite paste in the overlap zone

The bentonite paste is then spread approx. 150mm wide and 10mm thick into the overlap zone and pressed into the nonwoven component of the GCL with a trowel, shovel or similar device (fig. 12).

17.12.3
After placing the bentonite powder or paste in the overlap zone, it is necessary to overlap the area with the neighbouring Bentofix® roll (e.g. fig. 13). If using bentonite paste this should occur shortly after placing the bentonite paste to avoid a drying of the wet bentonite.

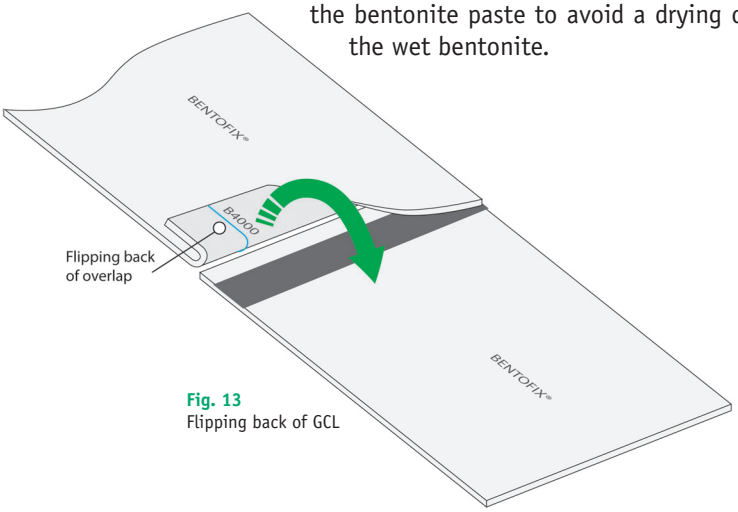


Fig. 13
Flipping back of GCL

18. Attachment Details

18.1 Bentofix® GCL should be installed around penetrations, pipes, and other structures according to the contract drawings and guidelines. Sealing of these areas are main priority.

18.2 Bentofix® may be secured to the structures by use of a stainless steel batten or clamp, mechanical fasteners, or other appropriate device if necessary for minimizing movement.

A typical Bentofix® attachment to a concrete structure is shown in the figure 14.

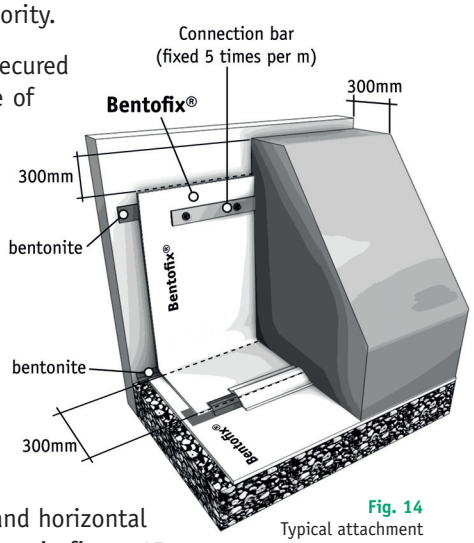


Fig. 14
Typical attachment to a structure

18.3 Typical Bentofix® attachment to vertical and horizontal pipe penetrations is shown in figure 15.

18.4 Cutting the GCL should be accomplished using a sharp utility knife. Frequent blade changes are recommended to avoid damage to the synthetic components of the GCL during the cutting process.

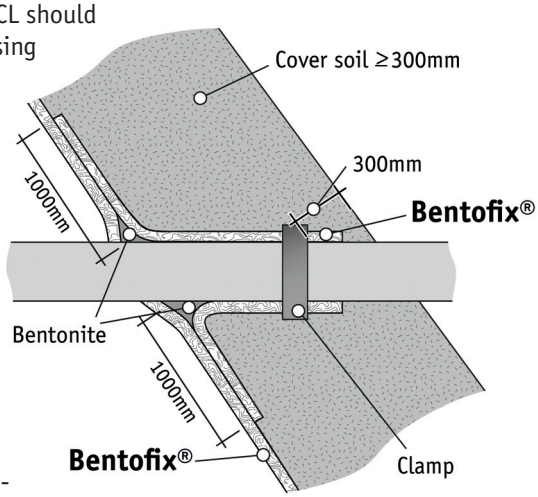


Fig. 15
Typical penetration detail

18.5 Additional bentonite or bentonite paste is necessary to maximize the seal.

18.6 Contact the manufacturer or local representative regarding attachments to structures or details.

19. Cover Placement

19.1 In all cases it is required that the responsible designer approves the slope stability analysis of the system.

19.2 Cover soils shall be free of sharp-edged stones or other foreign matter that could damage the GCL. Cover soils should be an approved material with respect to particle size uniformity, moisture content, and chemical compatibility. Recommended cover soils typically have a well-graded particle size distribution ranging between fines and 25mm.

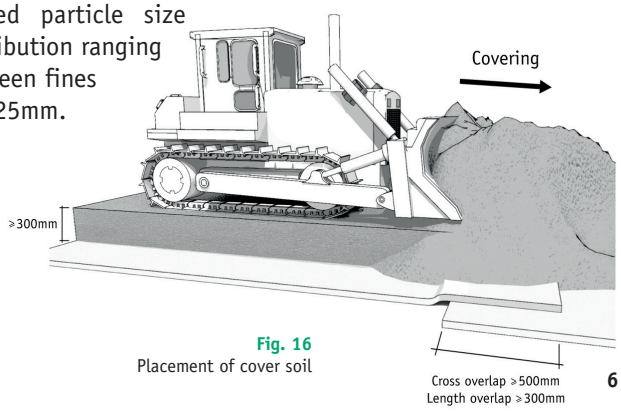


Fig. 16
Placement of cover soil

Soils with greater than 50% of material (by weight) larger than 20mm may require a field-scale test using the proposed subgrade surface, cover soil, and placement and compaction equipment.

19.3 Placement of sandy soils over Bentofix® should be preferred.

19.4 Soils can be placed on top of Bentofix® if the bentonite moisture content is less than 50%.

19.5 Soil cover shall be placed over the GCL using construction equipment that minimizes stresses on Bentofix®. In any case a minimum of 300mm of cover shall be maintained between the equipment tires/tracks and the GCL at all times during the covering process (fig. 16).

19.6 Frequent traffic can be run over a soil coverage of at least 800mm. Differing thickness or soil material might be possible due to site conditions and soils. In this case please contact NAUE or their local representative.

19.7 Soil cover should be placed on Bentofix® by carefully pushing the soil on top of the GCL (fig. 16), without causing any damage and in a manner that prevents the soil from entering the GCL overlap zones.

19.8 To prevent overlaps being separated during soil placement, it is possible to manually place soil ontop of the overlaps.

19.9 When another geosynthetic material is placed over the GCL, care must be taken to avoid using equipment and construction practices that could damage the GCL.

19.10 Typically the 300mm cover soil placement should also be placed directly on top of the geosynthetic material (see 19.9), prior to any bentonite hydration over 50% moisture content.

19.11 After placement of the minimum 300mm thick cover soil layer over a Bentofix® roll as a single sealing system, the final cover soil thickness should be placed in less than two weeks.

20. Interruptions during Installation

20.1 Uncovered areas should be protected at the edges overnight with a plastic membrane (fig. 9) to prevent bentonite hydration.

20.2 In the event of rainfall, which could cause a pre-hydration of the bentonite portion of the unconfined GCL of more than 50%, a temporary cover consisting of a waterproof tarpaulin or plastic sheet to protect the GCL should be placed over the GCL.

20.3 The edges of exposed sheets should be weighted down with sandbags or equivalent ballast, which does not cause any damage to the GCL, to prevent uplift in the event of strong winds.

21. Repairs

21.1 In the event that an area of Bentofix® GCL becomes damaged, torn or punctured during installation, the affected area should be repaired.

21.2 On relatively level surfaces, the damaged area should be covered with a separate piece of Bentofix® GCL extending at least 500mm beyond the damaged area in every direction (fig. 17).

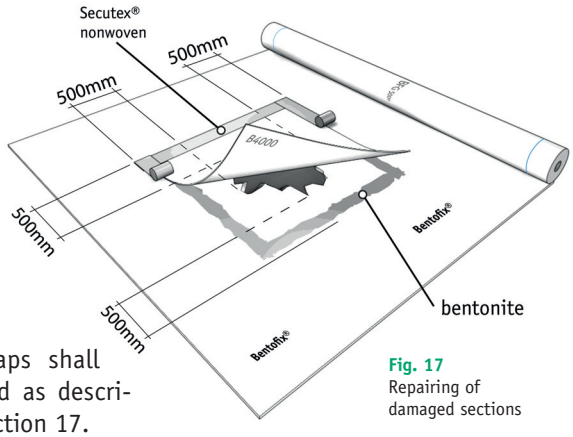


Fig. 17
Repairing of damaged sections

21.3 All overlaps shall be treated as described in section 17.

21.4 Damaged GCL material on slopes shall be repaired by the same procedures as described in section 21.2 and 21.3. Additional it should be ensured that the slope stability is not endangered.

21.5 Care must be taken during the placement of cover materials to ensure that the patch is not displaced.

21.6 Areas that are exposed to standing water or excess precipitation with resulting excessive bentonite hydration (≥ 50%) prior to soil covering should be examined for damage by subsequent activities. If it is determined that the GCL has been hydrated and damaged, the GCL should be covered with a new GCL piece over the affected area or removed and replaced.

21.7 All Bentofix® GCLs where bentonite was exposed to hydrocarbon fuels, chemicals, non-compatible liquids, or other harmful liquids during the installation should be removed and replaced with non-affected Bentofix® GCL.

22. Inspection

22.1 After deployment and seaming, a close visual inspection of the Bentofix® GCL rolls and seams shall be made by the project engineer or an approved person. This is done as soon as possible after deployment has been completed.

22.2 The inspection should include overlaps, alignments, penetrations, connections, detections of any defects, including installation damage. Detected falsely installed areas shall be marked, repaired and the repairs shall be inspected and approved by the project engineer or an approved person.

22.3 This inspection/repair process is to be carried out in a systematic manner as soon as possible to ensure that no defective area stays unrepaired.

22.4 Once the inspection has passed the next layer of geosynthetics may be installed or the spreading of the cover soil can begin in a method not harmful to the installed GCL.

23. Hydration of Bentonite

23.1 In cases where the containment of non-aqueous liquids is required, it may be necessary to hydrate the covered GCL with water prior to use.

23.2 If necessary prehydration may be accomplished (provided that the clay component of the GCL is covered by permeable materials) by introducing water into the containment area, either by flooding or by the use of sprinklers. NAUE GmbH & Co. KG or their local representative should be contacted for specific procedures if manual hydration is necessary.

23.3 Traffic running over hydrated areas should not damage the Geosynthetic Clay Liners by bentonite squeezing. Higher cover soil thicknesses are recommended in these cases.

24. Special Conditions

For other specific procedures contact a NAUE representative.

Installation Briefing practical ☐ theoretical ☐

1. Name of site: _____

2. Date: _____ **Time** from: _____ to: _____

3. Product-type: _____

Visual inspection of geosynthetic: _____

4. Contractor: Company: _____

Name: _____

Tel.: _____ Fax.: _____

Email: _____

5. Installer: Company: _____

Name: _____

Tel.: _____ Fax.: _____

Email: _____

6. Weather:

Temperature: _____ sunny ☐ cloudy ☐ Rain/Snow light ☐ medium ☐ strong ☐

7. Installation guideline available on construction site: yes ☐ no ☐

Status of guideline: _____

8. Subbase condition: _____

9. Contractor/installer informed on placement of cover material:

Type of cover/geosynthetic material ☐ min. thickness of cover ☐ Direction of placement ☐

Direction of spreading ☐ Overlapping ☐ Geosynthetic storage area ☐

10. Photo documentation: yes ☐ no ☐ GPS position _____

Photos filed: yes ☐ no ☐ File location _____ Marked in installation plan: yes ☐ no ☐

11. Notes on additional pages: yes ☐ no ☐ _____

12. Confirmation of briefing:

Name: _____ Name: _____

Company: Company: _____

Date, signed: _____ Date, signed: _____

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E-Mail info@naue.com
Internet www.naue.com

Bentofix® unloading

Typ

Status and No. of installation guideline

Date	Roll Nr.	Weather	Damages	Fixed	Comments	Name symbol
			☐ YES ☐ NO	☐ YES ☐ NO		
			☐ YES ☐ NO	☐ YES ☐ NO		
			☐ YES ☐ NO	☐ YES ☐ NO		
			☐ YES ☐ NO	☐ YES ☐ NO		
			☐ YES ☐ NO	☐ YES ☐ NO		
			☐ YES ☐ NO	☐ YES ☐ NO		
			☐ YES ☐ NO	☐ YES ☐ NO		
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			☐ YES ☐ NO	☐ YES ☐ NO		
			☐ YES ☐ NO	☐ YES ☐ NO		
			☐ YES ☐ NO	☐ YES ☐ NO		
			☐ YES ☐ NO	☐ YES ☐ NO		
			☐ YES ☐ NO	☐ YES ☐ NO		
			☐ YES ☐ NO	☐ YES ☐ NO		

Onsite storage according to chapter 9 of Bentofix® installation guidelines		Comments	Name symbol
	☐ YES ☐ NO		

Name symbol	Name	Company

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Bentofix® installation

Typ

Status and No. of installation guideline

Date	Roll Nr.	Weather	Overlap checked	Chapter 1 - 24 followed	Differences /comments	Name symbol
			☐ YES ☐ NO	☐ YES ☐ NO		
			☐ YES ☐ NO	☐ YES ☐ NO		
			☐ YES ☐ NO	☐ YES ☐ NO		
			☐ YES ☐ NO	☐ YES ☐ NO		
			☐ YES ☐ NO	☐ YES ☐ NO		
			☐ YES ☐ NO	☐ YES ☐ NO		
			☐ YES ☐ NO	☐ YES ☐ NO		
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			☐ YES ☐ NO	☐ YES ☐ NO		
			☐ YES ☐ NO	☐ YES ☐ NO		

Name symbol	Name	Company

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