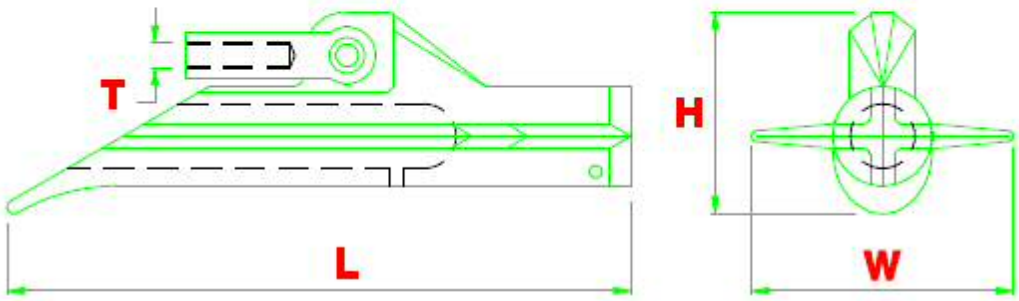
Anchor Systems (Europe) Ltd, Unit 45 Rowfant Business Centre, Rowfant, West Sussex, RH10 4NQ

DUCKBILL EMBANKMENT & SLOPE STABILISATION

Registered Office: North House 198 High Street, Tonbridge, Kent, TN9 1BE
Company Registration No. 04023935, VAT Registered No. 656490607

DUCKBILL ANCHOR SIZES



GROUND ANCHOR	Load Range kN	L mm	W mm	H mm	Surface Area mm^2	Bar Dia/Wire Dia. mm	Manufactured Material	Driven Depth Ave/week Ground (m)	Driving Equipment
AS-300	100-300	500	300	176	110,341	24 & 25	SG Iron/SS 316	9-12+	m/c DR
AS-200	90-200	500	172	150	73,200	24 & 25	SG Iron/SS 316	9-12	m/c DR
AS-140	60-140	500	258	140	96,111	16 & 20	SG Iron/SS 316	6	m/c DR
AS-120	70-140	500	300	134	110,456	20 & 25	SG Iron/SS 316	6-9	m/c DR
AS-100	50-100	422	180	139	57,384	16 & 20	SG Iron/SS 316	6-9	HH m/c
AS-50	30-50	375	98	110	32,525	16 & 20	SG Iron/SS 316	3-6	HH m/c
AS-30	15-30	293	88	107	24,579	12 & 16	SG Iron/SS 316	3	HH m/c
MR1	50-90	375	176	109	52,733	16 & 20	SG Iron/SS 316	6-9	HH m/c
MR2	30-50	375	98	110	32,525	16 & 20	SG Iron/SS 316	3-6	HH m/c
MR3	15-30	293	88	107	24,579	12 & 16	SG Iron/SS 316	3	HH m/c
MR4	10-20	200	88	95	10,625	12 & 16	SG Iron/SS 316	2-3	HH m/c
MR88	5-12	159	48	65	6,047	Wire/Paracore 4-6	SG Iron/SS 316	1.2-1.5	HDR
MR68	1-5	121	32	48	3,219	Wire/Paracore 4	SG Iron/ SS 316	1.2-1.5	HDR
DB88	5-10	159	48	65	6,047	Wire/Paracore 4-6	LM25	1.2-1.5	HDR
DB68	1-5	121	32	48	3,219	Wire/Paracore 4	Aluminium LM25	1.2-1.5	HDR

m/c DR - Machine Driven anchors (i.e. Using montebert 125SX Breaker or similar)
HH m/c - Hand Held Driving Equipment from Anchor Systems (Europe) Ltd
HDR - Hand Drive Rods to be used with a standard hand held hammer

Note: All Dimensions are in millimetres
All load values shown are SLS or Safe Working load recommended for the anchor
Anchor range available in Spheroidal Graphite, Grade 316 Stainless Steel or LM25 Aluminium

Duckbill Ground Anchor Holding Capacities (kN)

Anchor Systems (Europe) Ltd, Unit 45 Rowfant Business Centre, Rowfant, West Sussex, RH10 4NQ - **www.anchorsystems.co.uk**

Common Soil Type Description	Geological Soil Classification	Blow Count or "SPT"	AS10	AS20	AS100	AS140	AS200	AS300
Very Dense and/or Cemented Sands; Course Gravel & Cobbles	Caliche, Nitrate Bearing Gravel	60 - 100+	10	20	100	140	200	300
Dense Fine Sand; Very Hard Silts & Clays	Basal Till; Boulder Clay Caliche;	45 - 60	10	20	90	140	200	285
Dense Clays, Sands & Gravel; Very Stiff to Hard Silts & Clays	Glacial Till; Weathered Shale's; Schist Gneiss Siltstone	35 - 50	10	20	90	140	200	270
Medium Dense Sandy Gravel; Very Stiff to Hard Silts & Clays	Glacial Till; Hardpan	25 - 40	8	18	70	110	150	220
Medium Dense Course Sand & Sandy Gravel; Stiff to Very Stiff Silts & clays	Saprolites Residual Soils	14 - 25	8	16	70	110	150	210
Loose to Medium Dense Fine to Course Sand; Firm to Stiff Clays & Silts	Dense Hydraulic Fill; Compacted Fill; Residual Soils	7 - 14	7	16	60	70	110	190
Loose Fine Sand; Alluvium;Soft-Firm Clays; Varied Clays; Fill	Flood Plain Soils; Lake Clays; Abode; Gumbo Fill	4 - 8	7	14	50	60	80	150
Peat, Organic Silts; Inundates Silts Fly Ash	Miscellaneous Fill; Swamp Marsh	0 - 5	5	12	40	50	20 - 50	20 - 80

N.B: For Guidance Purposes Only – True Capacity must be tested with an Anchor Systems Load Locker within the area of soil to be stabilized

In weak soil conditions tests have conclusively shown that grouted anchors can enhance loading capacity

Note: All underground work requires proper safety and location procedures. Do not install anchors without understanding below ground conditions. It is imperative that in all cases, ground anchors are fully locked before being put into service.

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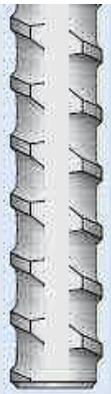
Galvanised Bar Sizes and Specifications

Standard Bar

Nominal Diameter mm	Steel Grade N/mm²	Ultimate Strength kN	Yield Strength kN	70% Ultimate Strength kN	Cross Sectional Area mm²	Diameter Over Threads mm	Thread Pitch mm	Weight Kg/m
16	500 / 600	121	101	85	201	18	8	1.58
20		188	157	132	314	23	10	2.47
25		295	246	206	491	28	12.5	3.85
28		370	308	259	616	32	14	4.83
32		482	402	337	804	36	16	6.31
40		754	629	528	1257	45	20	9.86
50		1178	982	825	1963	56	26	15.41
63.5	555 / 700	2217	1758	1552	3167	69	21	24.86

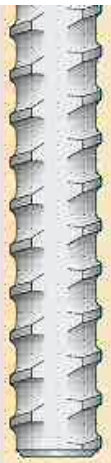


Key features of *GEWI*® Standard:

- Steel Grade: 500 / 600 N/mm² (except 63.5mm, 555 / 700 N/mm²)
- Coarse Pitch Threadform, d / 2 (except 63.5mm, d / 3)
- Left Hand Thread
- Standard Load Range

Standard Bar Plus

Nominal Diameter mm	Steel Grade N/mm²	Ultimate Strength kN	Yield Strength kN	70% Ultimate Strength kN	Cross Sectional Area mm²	Diameter Over Threads mm	Thread Pitch mm	Weight Kg/m
18	670 / 800	203	170	142	254	21	8	2.00
22		304	255	213	380	25	8	2.98
25		393	329	275	491	28	10	3.85
28		493	413	345	616	32	11	4.83
30		566	474	396	707	34	11	5.55
35		770	645	539	962	40	14	7.55
43		1162	973	813	1452	48	17	11.40
57.5		2078	1740	1455	2597	63	20	20.38
63.5		2534	2122	1774	3167	69	21	24.86
75		3534	2960	2474	4418	82	24	34.68



Key features of *GEWI*® *Plus*:

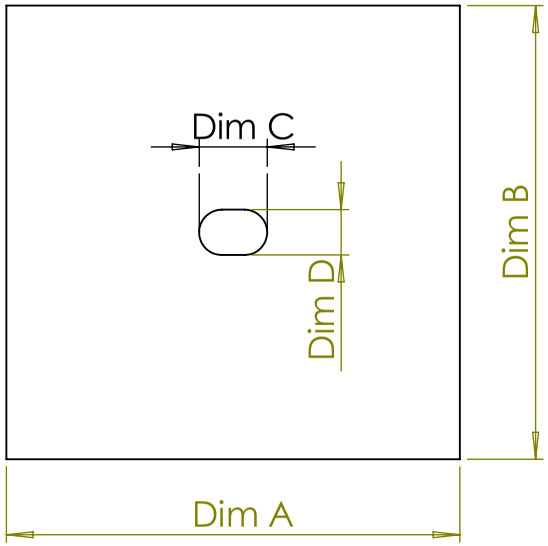
- Steel Grade: 670 / 800 N/mm²
- Reduced Pitch Threadform (d / 3)
- Right Hand Thread
- Increased Load Range Capacity

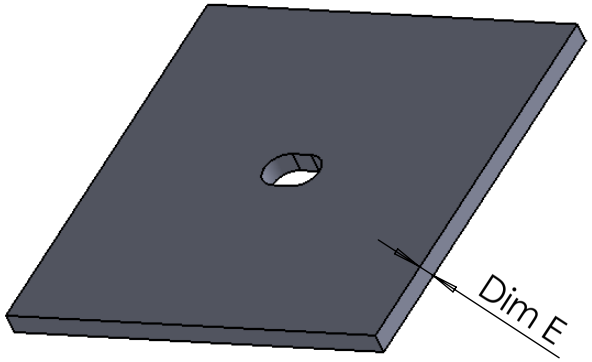
Technical Details:

Modulus of Elasticity: E = 205,000 N/mm2
Stock Length: 12m, Cutting Tolerance: +/–100mm
Standard Bar: Manufactured in accordance with German Approval Certificate
Standard Plus Bar: Manufactured in accordance with European CUAP

Corrosion Protection:

Sacrificial Corrosion Allowance: TRL 380 and CIRIA Soil Nailing Guide
Hot Dip Galvanising: BE EN ISO 1461 (zinc coating thickness of 85µm, bars remain fully threadable over entire length)





Anchor Systems Pattress Plate

REF	Dim A	Dim B	Dim C	Dim D	Dim E
Plate 75x75x8	75mm	75mm	45mm	22mm	8mm
Plate 150x150x8	150mm	150mm	45mm	22mm	8mm
Plate 200x200x8	200mm	200mm	45mm	22mm	8mm
Plate 350x350x8	350mm	350mm	45mm	30mm	8mm
Plate 200x200x10	200mm	200mm	45mm	22mm	10mm
Plate 250x250x10	250mm	250mm	45mm	22mm	10mm
Plate 300x300x15	300mm	300mm	45mm	30mm	15mm

Material SG Iron

Finish Galvanised

Revision

ANCHOR SYSTEMS (EUROPE) LTD

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www.anchorsystems.co.uk

Description Anchor Systems Pattress Plate

Drawing No. AS-PP-SG

Rev. 0

Drawn By	G Selvadurai	**Drawn Date**	21/10/2014
Approved By		**Approved Date**	

Tolerance - All Dimensions in mm
Whole Numbers: ±1
One Place Decimals: ±0.5
Angles : ±1°

THIRD ANGLE PROJECTION
DO NOT SCALE
IF IN DOUBT, ASK

A4

Anchor Systems (Europe) Ltd, Unit 45 Rowfant Business Centre, Rowfant, West Sussex, RH10 4NQ

Ultimate Tensile Stress (minimum)	**750**	**N/mm^2**
0.2% Proof Stress (minimum)	**650**	**N/mm^2**
Minimum Elongation	**15**	**%**
Typical Lengths	**6**	**m**
Straightness	**2**	**in 1000**
Standard Bundle Weight	**1**	**tonne max**

Ref	Nom Dia mm	CSA mm^2	0.2% Proof load kN	Ultimate Tensile load kN	Weight per metre Kg/m	Torque to develop 0.15% of UTS Nm
GB10	**10**	**62**	**40**	**46**	**0.49**	**50**
GB12	**12**	**91**	**54**	**64**	**0.73**	**60**
GB16	**16**	**167**	**108**	**124**	**1.30**	**90**
GB20	**20**	**261**	**170**	**196**	**2.10**	**135**
GB22	**22**	**322**	**203**	**235**	**2.60**	**155**
GB24	**24**	**378**	**246**	**283**	**2.90**	**180**
GB27	**27**	**492**	**320**	**368**	**3.90**	**220**
GB30	**30**	**596**	**388**	**446**	**4.70**	**265**
GB33	**33**	**737**	**480**	**552**	**5.75**	**325**
GB36	**36**	**873**	**568**	**653**	**7.00**	**375**
GB39	**39**	**1037**	**674**	**776**	**8.25**	**440**
GB42	**42**	**1197**	**778**	**896**	**9.50**	**495**
GB45	**45**	**1388**	**903**	**1038**	**10.90**	**570**
GB48	**48**	**1562**	**1016**	**1168**	**12.40**	**625**

Benefits of Stainless Steel Threaded Bar

- High strength thread rolled stainless steel
- Proven high bond strength
- Easily cut on site without any damage to the thread form
- Unique corrosive resistant product
- 6 metre lengths
- Superior ductility for seismic activity

Anchor Systems (Europe) Ltd, Unit 45 Rowfant Business Centre, Rowfant, West Sussex, RH10 4NQ

Anchor Systems (Europe) Ltd (ASEL) high strength stainless steel all thread bar is made from cold drawn bar feedstock. It benefits from superior strength, whilst retaining the elevated ductility associated with stainless steel.

ASEL all thread bar is manufactured in 6m fully threaded lengths or by special order, with a bespoke thread on the ends of the bar.

All stainless steel thread bar products utilise the thread rolling principle, which benefits from not removing the materials from the bar while generating the course thread. It is in principle a cold forging process, and hence the grain flow caused by this process improves the strength of the thread relative to that of a cut thread of the same size.

Corrosion Considerations

The selection of the correct grade of stainless steel must take a count of the following features

- The environment
- Structural requirements
- Maintenance
- Life of structure
- Surface finish

Factors which may influence the selection within an environment are temperature, pollutants, humidity, and presence of chloride ions. The strength of the bar is a structural matter and needs to be decided by the project designer.

In general it is reasonable to use grade 304 for most no-marine applications, however, highways and marine structures generally call for grade 316 due to high chloride concentrations. Duplex grade 1.4462 can be used in high chloride environments for increased resistance to stress corrosion, pitting and crevice corrosion.

Site Performance

ASEL stainless steel bar cold rolled thread provides a robust, self cleaning and user friendly thread which is easy to use on construction sites.

The coarse pitch thread is less susceptible to galling than the traditional metric thread; the large pitch certainly speeds up assembly.

The large flank angle on this bespoke thread design ensures that the crown of the thread is supported and will withstand significant site abuse and still remain serviceable.

Tensile Strength

Reinforcement bar to BS6744 has a proof strength of 500N/mm^2. To produce a thread on this bar requires reducing the bar section with a consequent reduction in strength. ASEL all thread bar is manufactured from bar with a proof strength of around 600N/mm^2 which after being work hardened by thread rolling gives a minimum proof strength of 650N/mm^2.

AS-20-SS-S- SS-BA-12-SS

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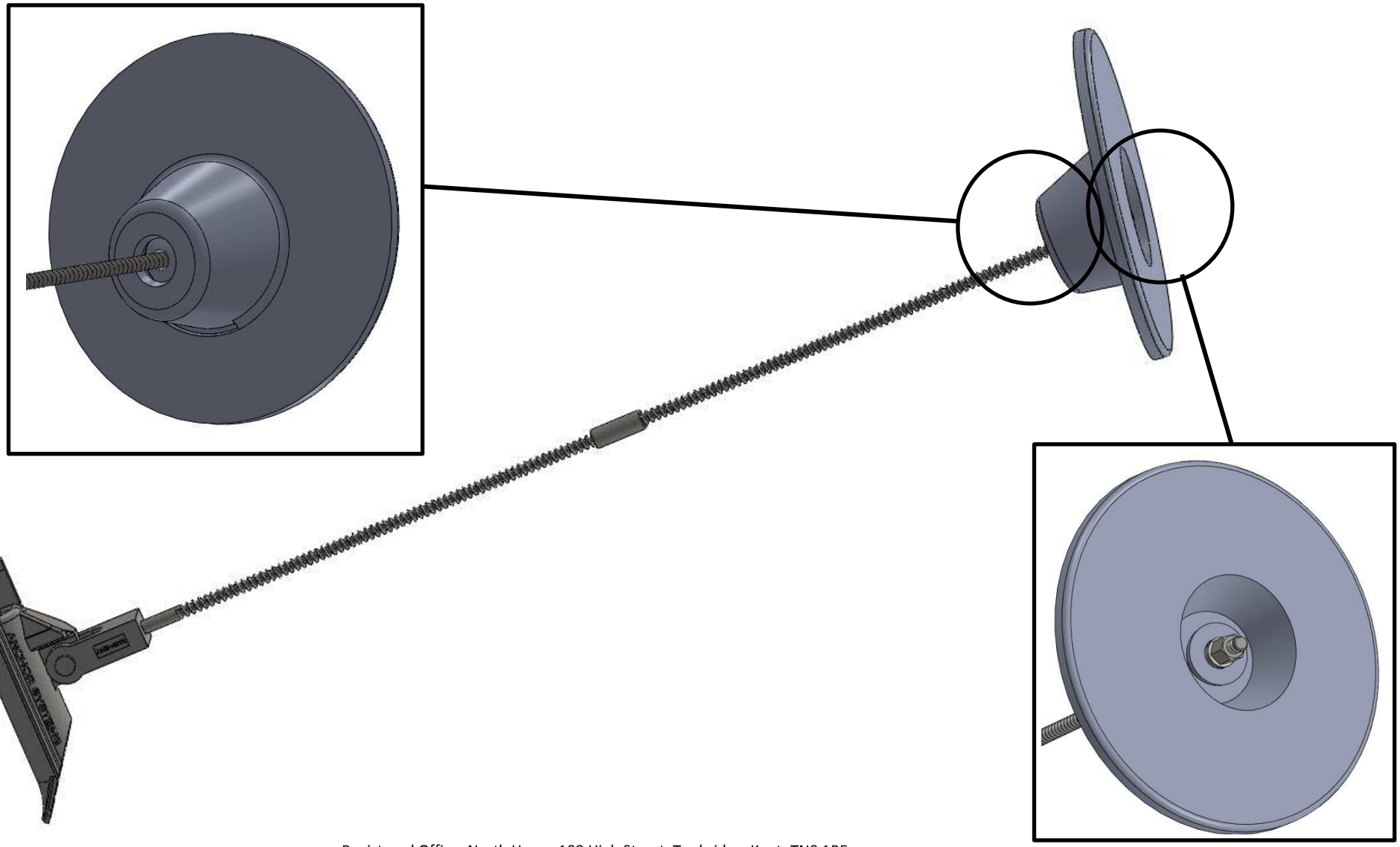

MR-3-SS-S-SS-BA-12-SS with Recess Plate

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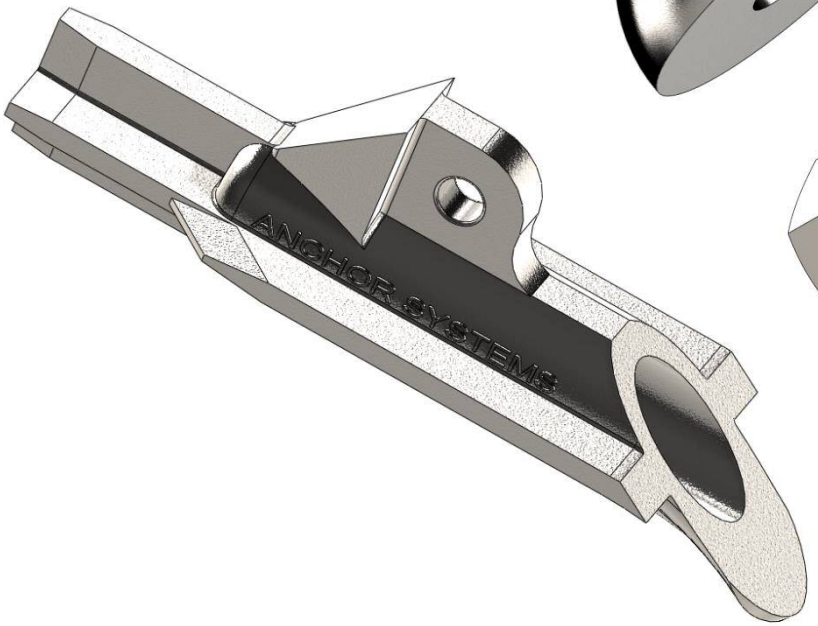
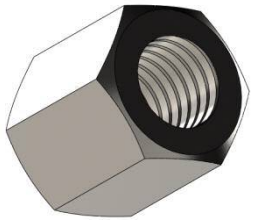
MR-3-SS-S-SS-BA-12-SS with Recess Plate

Anchor Systems (Europe) Ltd, Unit 45 Rowfant Business Centre, Rowfant, West Sussex, RH10 4NQ





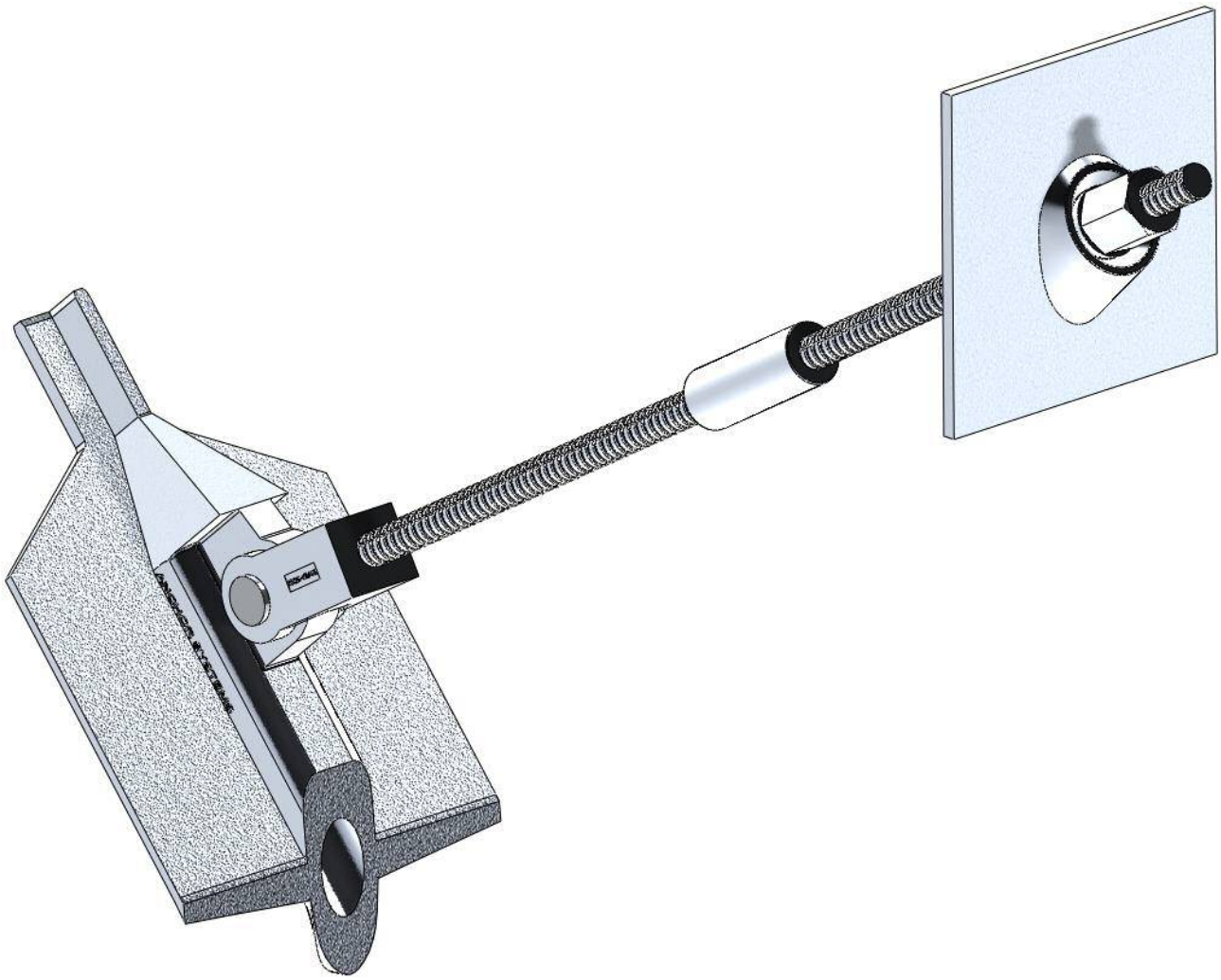
Registered Office: North House 198 High Street, Tonbridge, Kent, TN9 1BE
Company Registration No. 04023935, VAT Registered No.656490607

Mechanical Anchoring Systems
DUCKBILL® **ANCHORS • HELICAL ANCHORS**
SOCK ANCHORS • ANCHOR POSTS

Cert No.6087
ISO 9001

AS-300-SG-S-SG-BA-25-SG with Wedge Boss

Anchor Systems (Europe) Ltd, Unit 45 Rowfant Business Centre, Rowfant, West Sussex, RH10 4NQ



AS-90

→ Galvanised, Galvanised Ali Bronze, 316 Stainless Steel

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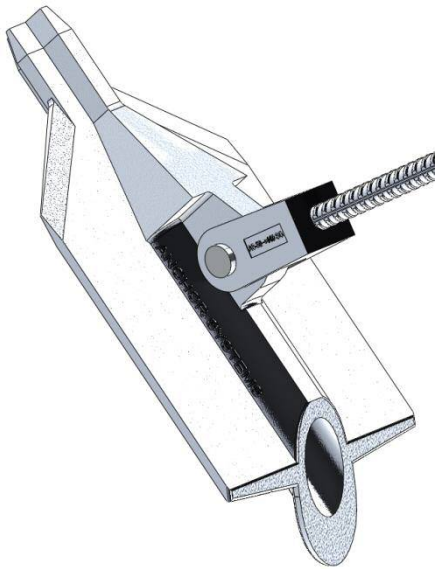

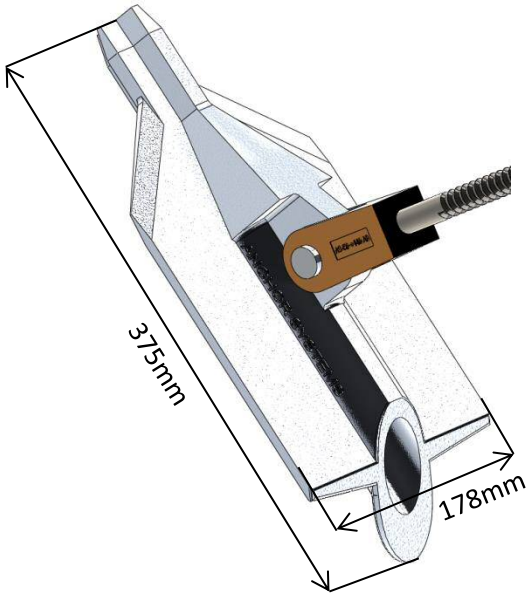

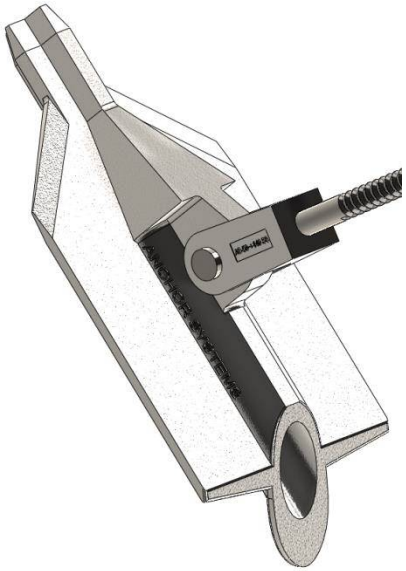

MR-1-SG-S- SG -BA-16- SG

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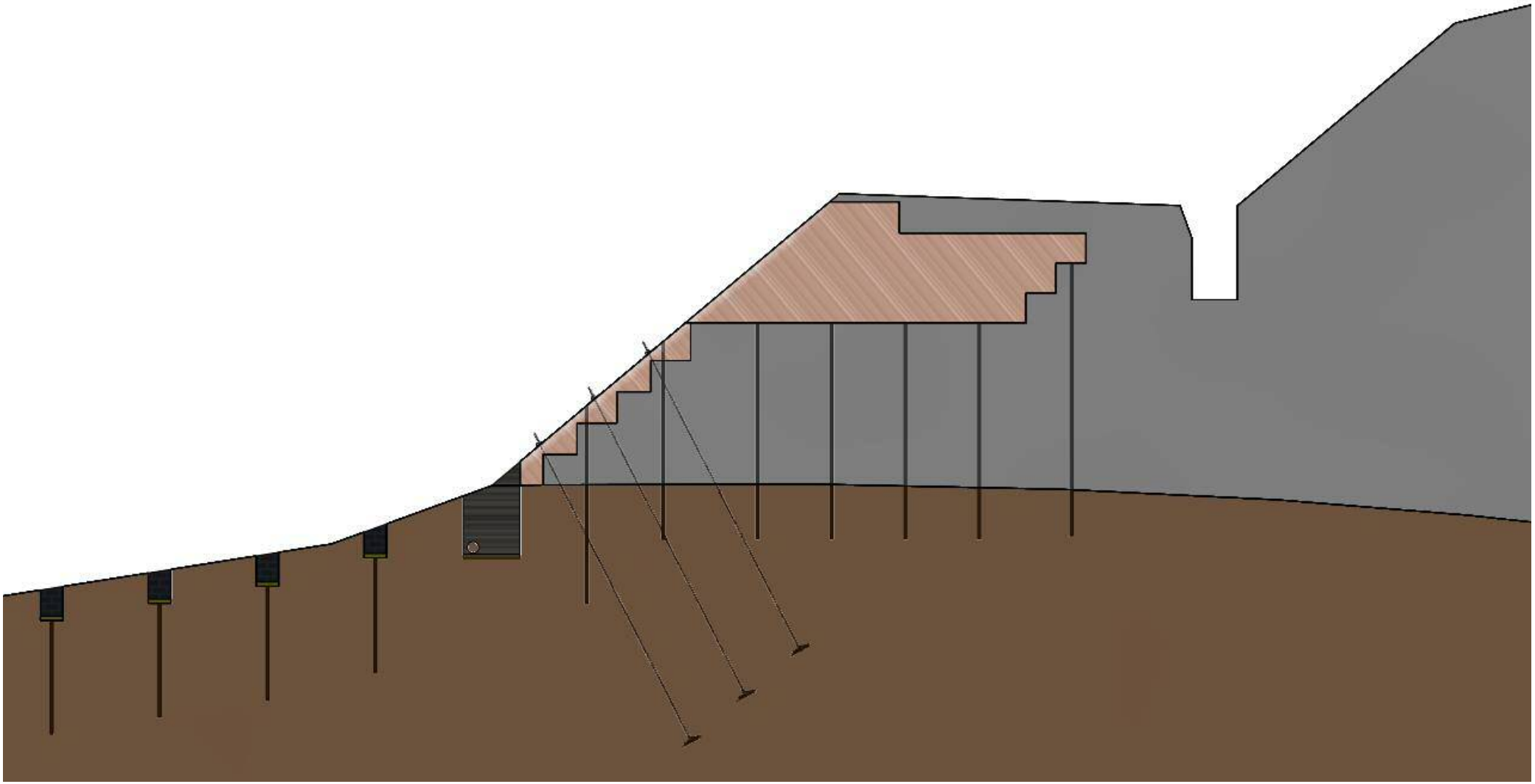
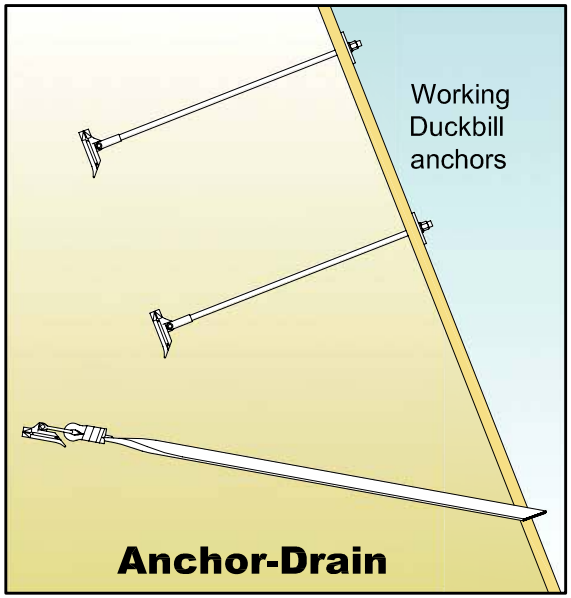


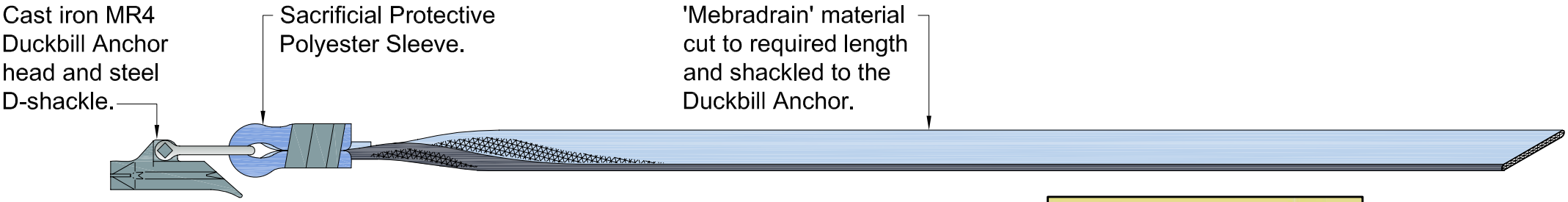
ANCHOR-DRAIN

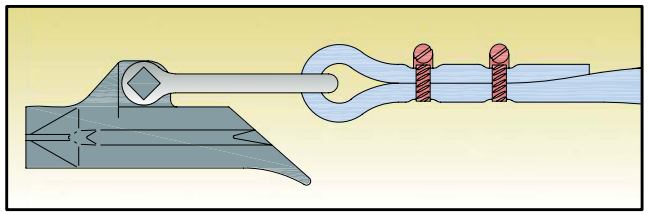


Typical installation.

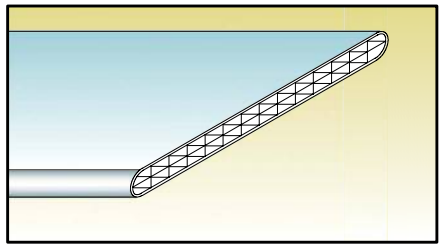
The Anchor-Drain system provides a simple method for reducing water puddling within clay slopes and behind retaining walls.

A length of 'Mebradrain' drainge material is attached to the the Duckbill Anchor with a D-shackle and hose clamps. This attachment is protected during installation by a sacrificial sleeve. The ANCHOR-DRAIN is towed into position in the temporary void left behind the Duckbill Anchor when it is installed to the required depth in the usual way. The drive rods are withdrawn leaving the Anchor-Drain to provide an instant drainage path. The anchor head remains in the ground.





Detail of Mebradrain attachment under the protective sheath.
The material is folded at one end, looped through the shackle and secured with hose clamps. The shackle is then attached to the anchor head.



Semi-rigid drainage channels in a non-woven polyester membrane.

ANCHOR SYSTEMS (EUROPE) LTD.
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Anchor Drain – Concise Drainage Solutions

Anchor Drain has been further developed by Anchor Systems (Europe) Ltd as a result of working within the Civil and Rail industries. Situations have continued to occur where contractors and clients have experienced saturated soils particularly where clay and peat soils are evident. The problem has been exacerbated when a heavy load, such as a road embankment or a structure is placed on top of these types of soils and excessive consolidation occurs as a result of Hydrostatic pressure. This also becomes a problem on retaining walls were weep holes have been omitted or blocked.

Pressurized water in the pores of the soils due to load can lead to sub soil instability which can in turn lead to the development of slope failures. Saturated soils will cause considerable construction problems with any form of foundation work if a sustainable solution for drainage is not sought.

Anchor Systems (Europe) Ltd have worked with Cofra who is the developer of the MebraDrain® product to produce the Anchor Drain. The Anchor Drain utilises the MebraDrain® filter material by securely attaching the membrane to Anchor Systems (Europe) Ltd Duckbill® Ground Anchor. The Ground Anchor is then percussion driven in the normal way to achieve the required depth and position.

Main Benefits of the Anchor Drain System: -

- Can be fitted to new build structures or retrofitted to existing structures
- Can be driven through most soil materials
- Can be installed to depths in excess of 15m (a larger anchor may be required to create the void)
- Small areas of saturated soil can be reached within a soil block due to directional installation
- The drainage system works immediately after installation
- Both shallow and deep slip planes can be prevented

Drive rods are used during the installation of the Ground Anchor, which are removed after the Duckbill® Ground Anchor has reached its target depth. The Duckbill anchor has the dual purpose of being an easy means driving the drainage membrane into the soils and on its passage through the soils forming a void in its wake causing a natural channel for the membrane to sit. The Ground Anchor is sacrificial and remains in the ground after the drainage membrane is installed.

Once the area of saturation has been penetrated, the water within this area will permeate the MebraDrain® material flow to the outlet created at the edge of the structure. Water from the outlet should be channelled away to a suitable drainage area. The MebraDrain® will only allow water to permeate the outer sleeve of the MebraDrain® material. Fines from the soil cannot penetrate this material and therefore obstruct the flow of water.

DUCKBILL®
Ground Anchor Systems

PROJECT REPORT

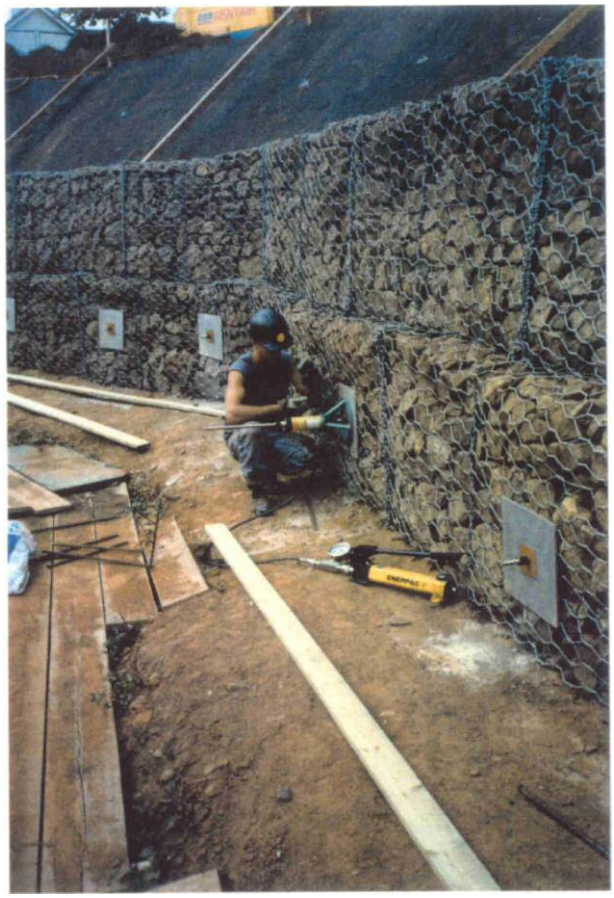
LANDSLIP PREVENTION, NELSON CLOSE, EXETER

Client: **Exeter City Council**
Main Contractor: **Dean & Dyball**
Installer: **Celtic Rock Services**

Requirements

To avoid the possibility of a landslip endangering nearby houses in Nelson Close, Exeter City Council appointed Dean & Dyball to stabilise an adjacent embankment.

The ground was secured by means of geotextiles and a gabion basket wall, all anchored using Duckbill mechanical ground anchors.



Installation

About half way up the 10m embankment a shelf was cut into the sandstone to allow the construction of a gabion basket wall which was to retain the soil, dense gravels and marl on the top half of the slope.

Material on the top half of the slope was stabilised with geotextile matting. This was anchored into the gravels and soil, to a depth of 1.2m, using Duckbill DB68 geotextile anchors.

The steel mesh gabion baskets were anchored into the sandstone, using Duckbill MR2 stainless steel anchors with 16mm high yield grip bars, before being filled with rocks to create a wall 2m high, 1m wide and some 45m long.

Anchor holes were pre-drilled by Celtic Rock Services who installed the anchors to a depth of 6m using a hand-held breaker. Anchors were proof tested to 45kN and then set to a working load of 20kN and terminated using a 400x400x10mm galvanised plate, nylon spacer (due to dissimilar metals) and load nut.

The completed project provides a fully anchored and stabilised embankment that should now pose no threat to nearby residents.

DUCKBILL®
Ground Anchor Systems

PROJECT REPORT

COASTAL LANDSLIP STABILISATION - THE LEAS, FOLKESTONE

Client: **Shepway District Council**
Installer: **Shepway Contract Services**

Requirements

As a result of heavy rainfall saturating the sandy soils, a surface landslip occurred along a 75m stretch of The Leas in Folkestone, a steeply sloping coastal area.

Shepway District Council required the ground to be rapidly and cost-effectively stabilised to prevent any further erosion and appointed Shepway Contract Services who chose Duckbill mechanical ground anchors to secure plastic coated wire meshing installed over turf to prevent further movement of the coastal embankment.

Solution

Shepway Contract Services first had to clear the section of uprooted bushes and trees and level the 45m high embankment, to the same gradient as the surrounding terrain, before covering the area with turf to help bind the surface.

Coated wire mesh was placed over the slope and secured with Duckbill MR88 ground anchors with stainless steel wire tendons. Using hand-held air breakers, over 1200 anchors were installed to depths of between 1.5m and 2.5m and locked into position.

The Duckbills were set to a proof load of 10kN and the wire tendons were then connected to 120mm high density geogrid discs which held the mesh in position.

DUCKBILL®
Ground Anchor Systems

PROJECT REPORT

AVON CYCLEWAY, BRISTOL

Client: **South Gloucestershire Unitary Authority**
Engineers: **WS Atkins**
Main Contractor: **Christiani & Nielsen**

Requirements

A cycle route on the Avon Ring Road around Bristol was to be widened and refurbished by Christiani & Nielsen as part of the national Cycle Way scheme which will create a countrywide network of interconnected, traffic-free, cycle routes and footpaths.

A section of the route contained a potentially unstable embankment that needed to be stabilised to prevent any possibility of future collapse which may endanger cyclists or pedestrians.

The system used to secure the embankments also had to satisfy South Gloucestershire Unitary Authority's requirement for an approved method which did not use grout and would therefore protect the environment in a sensitive area.

The load plates remain visible on three rows of Duckbill MR2 stainless steel anchors following installation to secure the embankment.

Solution

To ensure the stability of the route-side slopes, Duckbill mechanical ground anchors were specified by project engineers, WS Atkins, as they provided a rapid, cost-effective solution to the problem while complying with the Authority's other requirements.

In total, 130 stainless steel Duckbill MR2 anchors with 16mm high yield bars were driven 4m into the clay soils, using a special drill rig, by sister company, WT Specialist Contracts Ltd.

The anchors were proof tested to 40kN before being set to a working load of 20kN and terminated with 350mm^2 load plates.

In addition, Duckbill DB68 geotextile anchors were used to secure geogrids that will aid the growth of vegetation, to grip the top soil and prevent surface erosion, and enable cyclists and pedestrians to use the finished route in safety.

The completed cycle route with geogrids and top soil in place on the fully stabilised embankment.

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PROJECT REPORT

CLIFF FACE STABILISATION
NEFYN, GWYNEDD

Client: **Gwynedd Council**
Main Contractor: **Colin Jones (Rock Engineering) Ltd**
Project Engineers: **Ove Arup & Partners**

Requirements

At the beginning of 2001, prolonged heavy rainfall caused a major landslide at the coastal town of Nefyn in North Wales which resulted in a fatal accident.

Gwynedd Council required a fast and reliable means of securing nearly 100m of the 25m high cliff to prevent any further collapses.

Solution

To secure the unstable cliff face, main contractor and installer, Colin Jones (Rock Engineering) Ltd of Porthmadog, used a combination of biodegradable seeded matting covered by plastic coated wire mesh rock netting and Duckbill mechanical ground anchors.

The matting will allow vegetation to take hold before degrading while the anchors not only retain the rock netting but also secure the cliff face to a depth of 6m.

Duckbill mechanical ground anchors were specified by Ove Arup & Partners because of their installation speed, reliability and instant loading capabilities.

Using a specialist rig on a 20m high scaffold platform, the stainless steel Duckbill MR1's and MR2's with 16mm high yield bars were driven 6m into the stiff sand substrate. They were then locked, fitted with load plates and nuts and tensioned to a proof load of 80kN.

Together with the netting the Duckbills have now securely stabilised this section of cliff, which stands above a busy public car park at the coastal resort of Nefyn.

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Ground Anchor Systems

PROJECT REPORT

EMBANKMENT STABILISATION ON THE M25 AND THE A2

Client: **Carillion Highway Maintenance**
Forward Spread
Engineers: **WS Atkins**
Installer: **WT Specialist Contracts**

Requirements

On two different projects, slippage of embankments supporting major trunk roads was causing concern and the ground needed to be stabilised to avoid serious future problems.

In both cases Carillion Highway Maintenance was main contractor and the Duckbill mechanical ground anchors were specified by the project engineers, WS Atkins, because of their reliability, rapid installation and ability to accept immediate loads.

Duckbills installed in an embankment on the M25 near Junction 29, the A127 in Essex

MR1 Duckbill anchors securing the A2 embankment at Boughton near Canterbury.

Installation

At the M25, in various zones over a 200m stretch both sides of the motorway, anchors were driven 6m and 8m into the clay substrate to prevent the embankments from slipping and rotating out.

WT Specialist Contracts used machine mounted breakers to drive in 180 of the large MR1 stainless steel Duckbill ground anchors with 20mm high yield bars. Each anchor was then fitted with a 350mm load plate and set to a working load of 50kN.

The A2 project for Forward Spread (where Carillion H.M. was again the main contractor) also involved MR1 anchors, 60 of which were driven 6m into mixed ground conditions of stiff chalk/silt clays in two sections on the same side of the road and set to working loads of 60kN. The installation followed careful term monitoring of progressive creep tests to establish stringent load testing requirements.

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PROJECT REPORT

ANCHOR SYSTEMS (EUROPE) LTD

KEW TOWPATH
RIVER THAMES LONDON

Client: The Environment Agency
Engineers: Black & Veatch
Anchor Design: Mitchell-Horton Structural Engineers
Contractor: J T Mackley

Requirements:
The Victorian embankment was slumping and failing as it was too steep to support itself. Granite sets began to dislodge and fall out causing more stability problems and a flood threat to houses behind the towpath. Several solutions were put forward, some of which were ruled out due to the need for cements and grouts which could have contaminated the river. Subsequently the Duckbill® system was selected as the most appropriate anchor. A design life of 50 years was required in a 'brackish' marine splash zone.

The Solution:
This meant that all the components of the system; anchor, bar, bearing plate and load nuts needed to be produced in Duplex Stainless Steel grade 1.4462 to comply with BS EN 1008 and BS EN 3100. Compositional analysis, tensile strength tests, impact and hardness tests were required on all the components.

Site tests were carried out by Anchor System (Europe) Ltd to determine suitability and a F.O.S. of 3 was required on the system.
330nr Duckbill MR-2 Duplex anchors were installed and these were driven to various design depths and subsequently load-locked onto a specially machined load plate and hemispherical washer with an ID tag and load nut into a recessed, precast revetment panel. The anchors also needed to be left such that they could be re-tested for maintenance purposes in the future. Each anchor was numbered on both the load plate and ID tag with the load capacity achieved.

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DUCKBILL®
Ground Anchor Systems

PROJECT REPORT

FORTH & CLYDE CANAL MILLENNIUM LINK, GLASGOW

Client: **British Waterways**
Main Contractor: **Morrison Construction**
Project Engineers: **Babtie Group**
Installers: **WT Specialist Contracts and Morrison Construction**

Requirements

The Millenium Link in Glasgow forms part of the extensive regeneration of the Forth & Clyde Canal between Edinburgh and Glasgow.

This major engineering project for British Waterways involves re-opening and upgrading the canal that had long since fallen into disuse with large sections around Glasgow actually being filled in some 30 years ago.

Consequently, the contract has involved digging out areas of filled canal, dredging other parts and re-aligning sections of the original route. Banks have been reformed and new bridges have been constructed over the revitalised waterway. A rapid and efficient means was needed to secure both geogrids for stabilising the new banks and sheet piling used to form a new landing stage.

Solution

Project engineers the Babtie Group specified Duckbill ground anchors, from WT Anchor Systems, as the range contains anchors able to do both jobs reliably.

Beneath various bridges, including the A82 crossing, the banks either side of the canal below the bridges were stabilised using geogrids secured using over 550 lightweight Duckbill MR88 anchors with 6mm stainless steel cables, all installed by Morrison Construction using hand held equipment.

To secure the sheet piling into wet and soft made ground, much larger Duckbill Stingray anchors were installed by WT Specialist Contracts using a JCB mounted breaker. The 30 heavyweight Stingray anchors with 20mm grip bars were driven 6m into the ground, grouted and locked to a working load of 66kN. The sheet piling was then capped with concrete to provide a robust landing stage for both pleasure and freight traffic once the canal reopens.

The Millennium Link project demonstrated the range and versatility of the well-proven Duckbill ground anchors. Their rapid ease of installation and long term reliability, coupled with the contractor's bad experience of other makes of anchor, made Duckbills ideally suited for securely anchoring both the geogrids and the sheet piling.

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M4 M5 Junction

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M4 M5 Junction

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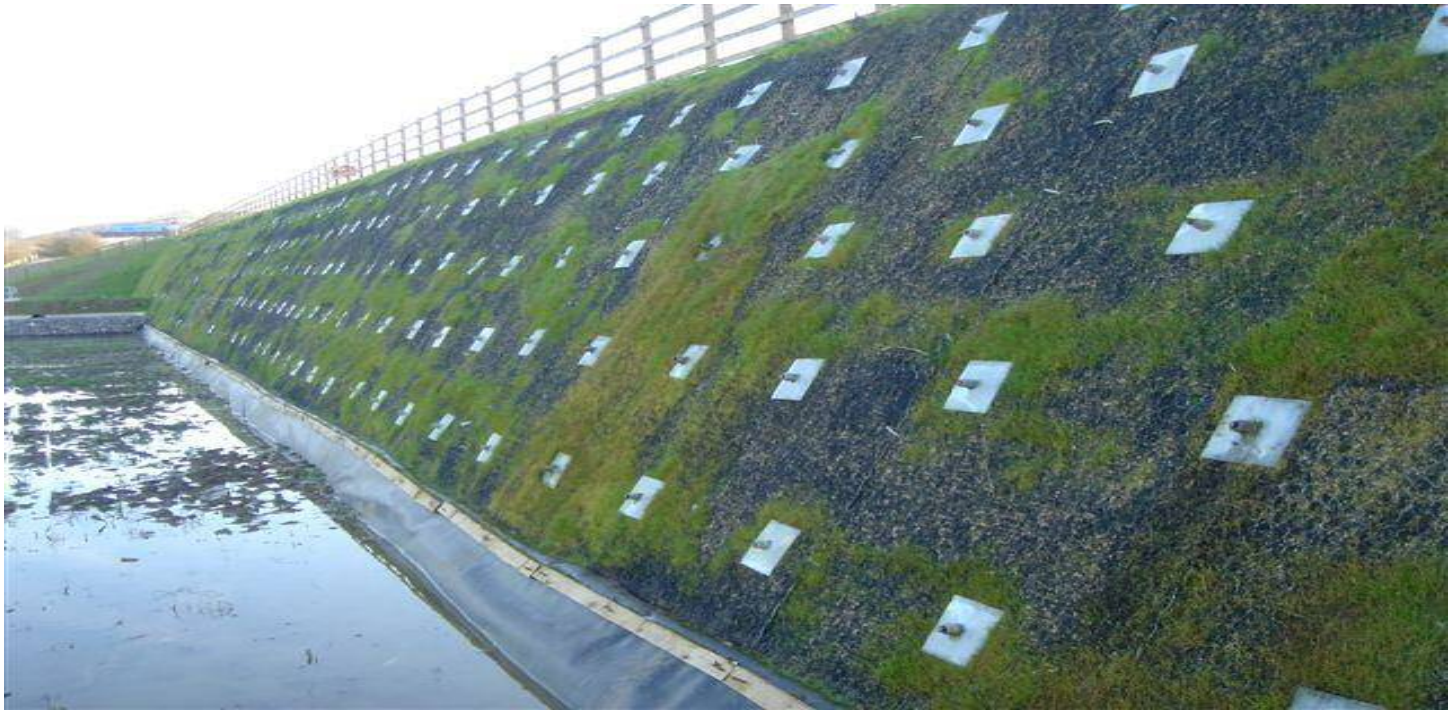

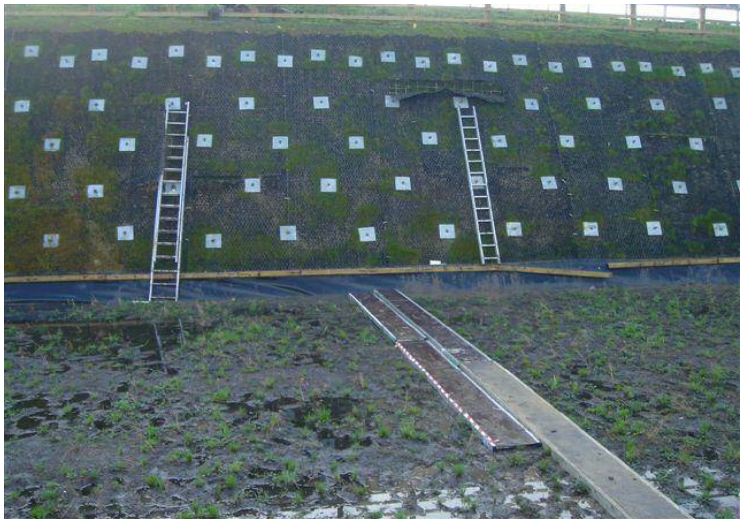

Anchor Systems (Europe) Ltd, Unit 45 Rowfant Business Centre, Rowfant, West Sussex, RH10 4NQ

- MR-3 316 stainless steel duckbill anchors complete with 3m x 12mm stainless steel bar, 300mm recess patress plate separated with nylon gaskets.

SALMONS BROOK FLOOD ALLEVIATION SCHEME, SALMONS WALK, RIGHT BANK

DUCKBILL® GROUND ANCHORS FOR SLOPE STABILISATION, PRELIMINARY DESIGN CALCULATIONS - REVISION 0

FEBRUARY 2014

Tellus Design Limited

SE008, e-Innovation Centre, Telford Campus, Priorslee, Telford, Shropshire, TF2 9FT, UK
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1 Introduction

This report contains preliminary design calculations for a river bank slope stabilised with mechanical ground anchors (Duckbill® system). Salmons Brook lies to the west of the Lee Navigation in the London Borough of Enfield. As part of this flood alleviation scheme (FAS) project, a section of the river bank will be re-profiled and bank levels raised to provide flood protection. To the south side of the brook, the position of the site boundary in relation to the watercourse necessitates a steep river bank profile and piled flood wall. The ground anchors are required to ensure the stability of the slopes against shallow and deep seated failures.

As part of the design brief for this report (see Appendix 1), three typical cross sections have been identified as being representative of the conditions along the length of the works. Their locations are shown on Figure 1.1 below:

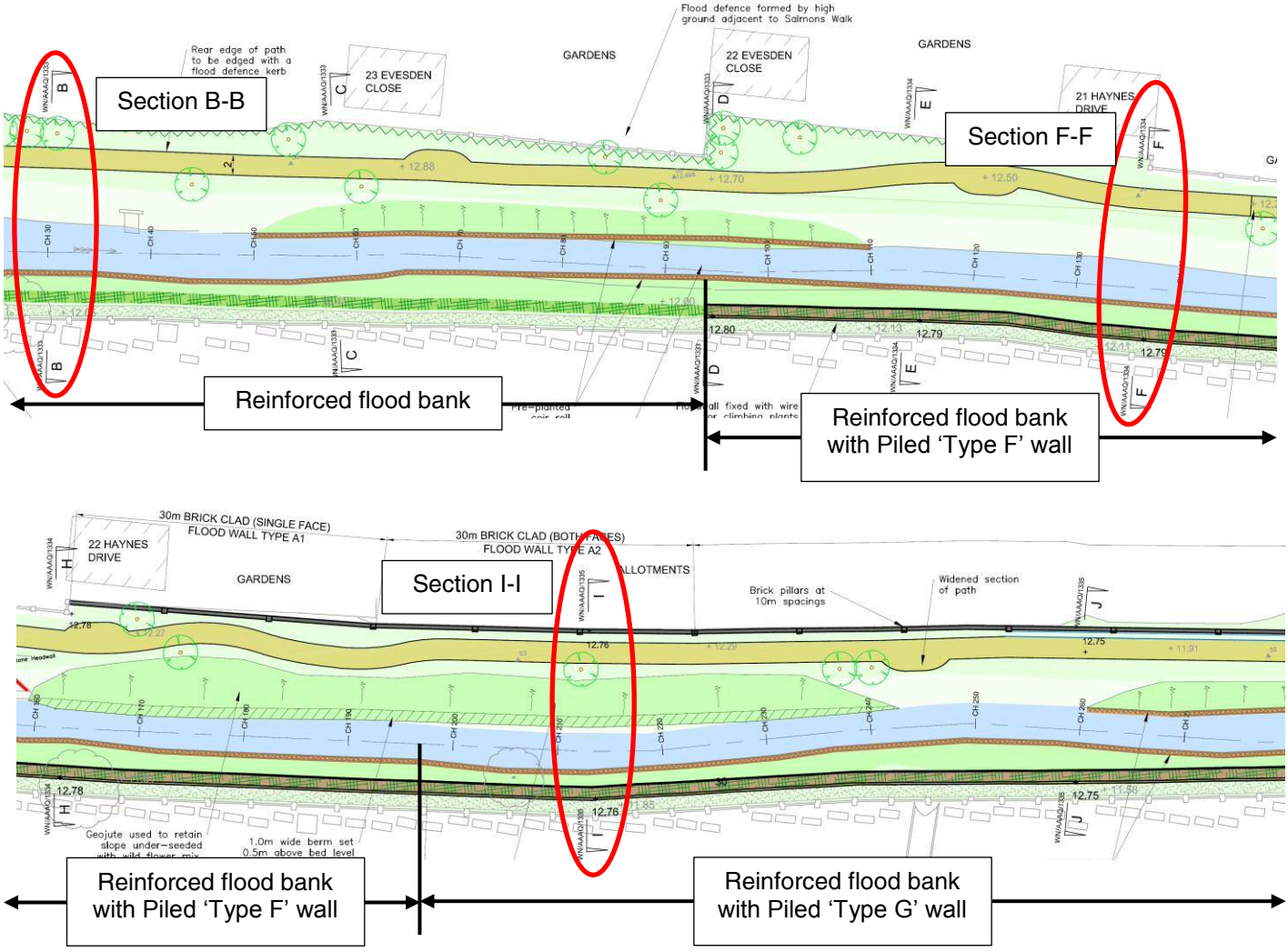


Figure 1.1. Plan showing locations of cross sections (extracts from Halcrow drawing WN-AAAQ-1331-E)

The scope of this preliminary design is limited to assessing the geotechnical stability of these three cross sections of the river bank slope in accordance for BS EN 1997-1:2004 (i.e. Eurocode 7). The objectives of these calculations are to determine the required design anchor forces to ensure the stability of the slope and provide a preliminary anchor design indicating the layout in terms of anchor lengths and spacings.

2 Reference Documents

The preliminary design has been based upon the following documents issued by Anchor Systems Limited:

Drawings

- WN-AAAQ-1331-Revision E – Salmons Walk Plan – Sheet 1 of 2 (Halcrow)
- WN-AAAQ-1332-Revision E – Salmons Walk Plan – Sheet 2 of 2 (Halcrow)
- WN-AAAQ-1333-Revision D – Salmons Walk Cross Sections – Sheet 1 of 5 (Halcrow)
- WN-AAAQ-1334-Revision D – Salmons Walk Cross Sections – Sheet 2 of 5 (Halcrow)
- WN-AAAQ-1335-Revision D – Salmons Walk Cross Sections – Sheet 3 of 5 (Halcrow)
- WN-AAAQ-SK13-1 Revision 3 – Salmons Walk Right Bank Stabilisation at Federation Cemetery (Halcrow)

Ground Investigation Report

- Technical Note WN/AAAQ/GI/002 – Material Parameter Derivation for Salmons Brook Walk (Halcrow)

Ground Anchor Technical Data

- Duckbill® Ground Anchor Systems – Products, Applications and Technical Information

Using data from the above drawings, the three cross sections shown in Figures 2.1, 2.2 and 2.3 were used for preliminary design purposes.

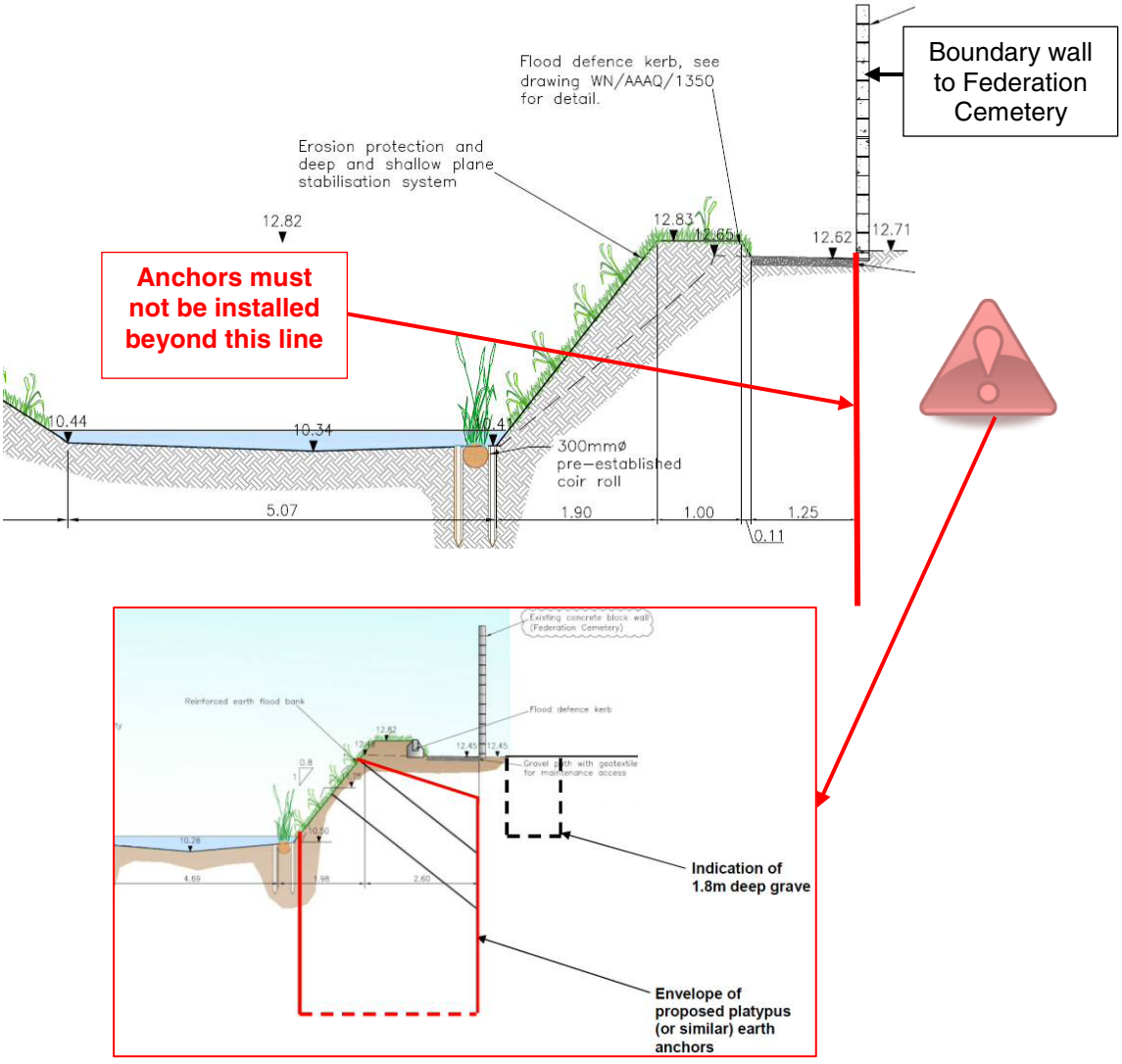


Figure 2.1. Cross section B-B – Reinforced Flood Bank

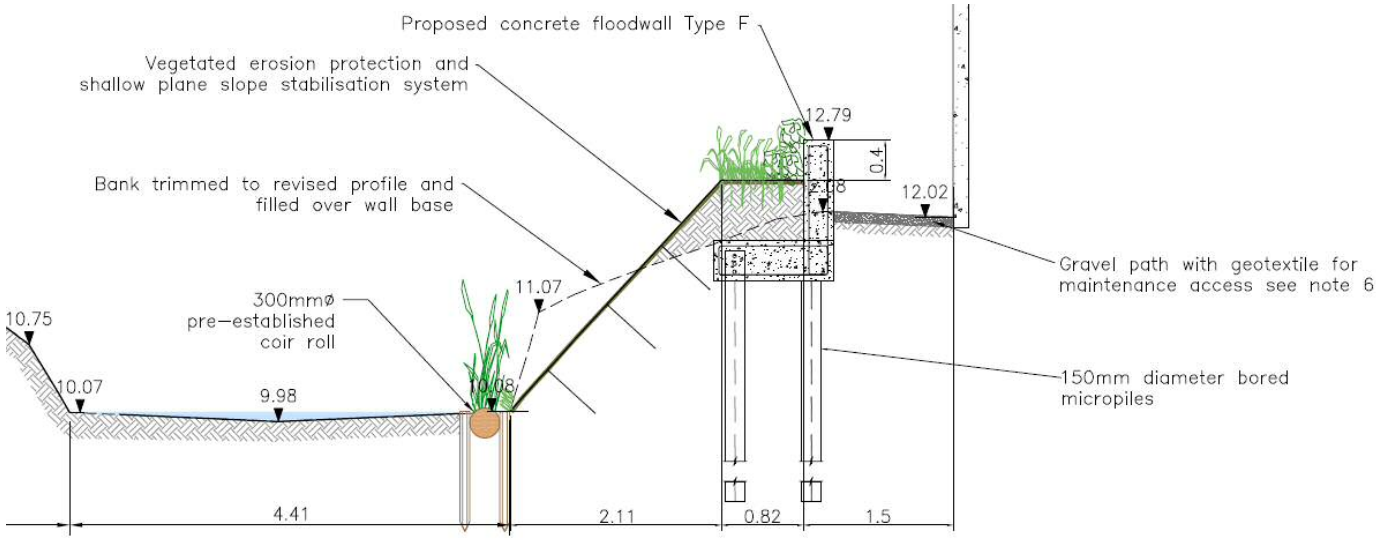


Figure 2.2. Cross section F-F – Reinforced Flood Bank with Piled 'Type F' Flood Wall

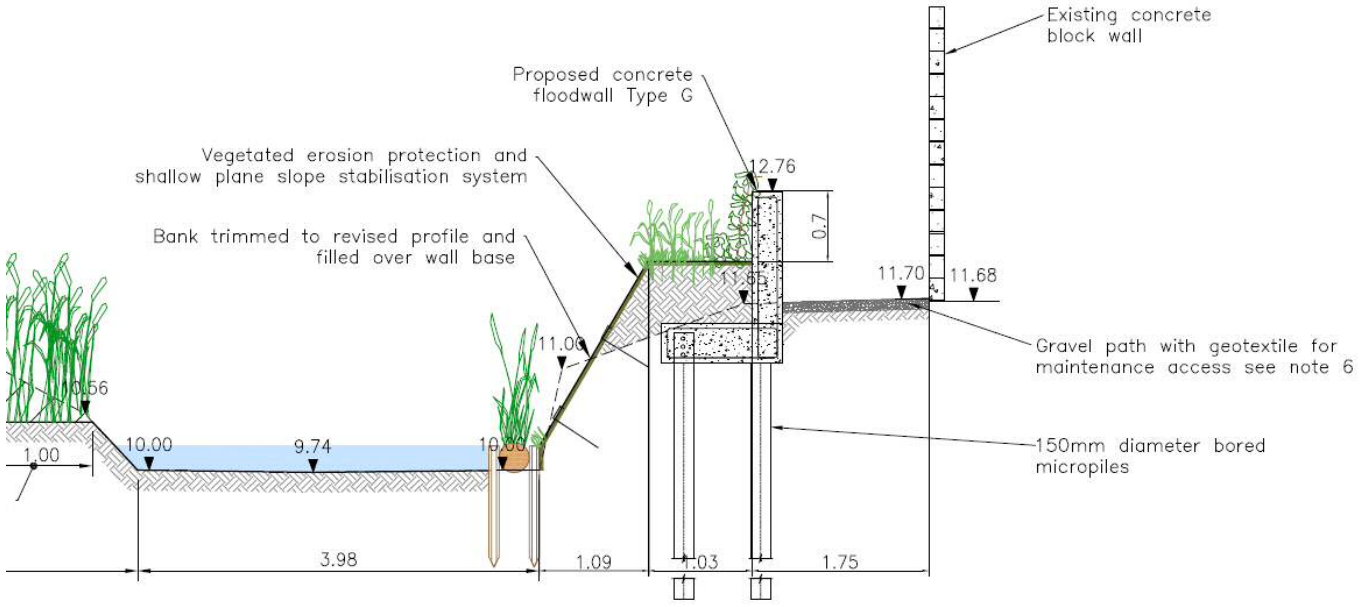


Figure 2.3. Cross section I-I – Reinforced Flood Bank with Piled 'Type G' Flood Wall

4.3 River Bank Slope – With mechanical ground anchors installed

Three cross sections were analysed in LimitState GEO using the models shown in Figure 4.13, 4.14 and 4.15. The magnitude of the restoring force was steadily increased until adequate stability was achieved (i.e. 'Adequacy Factor' AF ≥ 1.0). The failure mode for long term effective strength parameters and all partial factors set to DA1-2 are shown in Figures 4.16, 4.17 and 4.18 below. Full results of the analysis are to be found in Appendix 4.

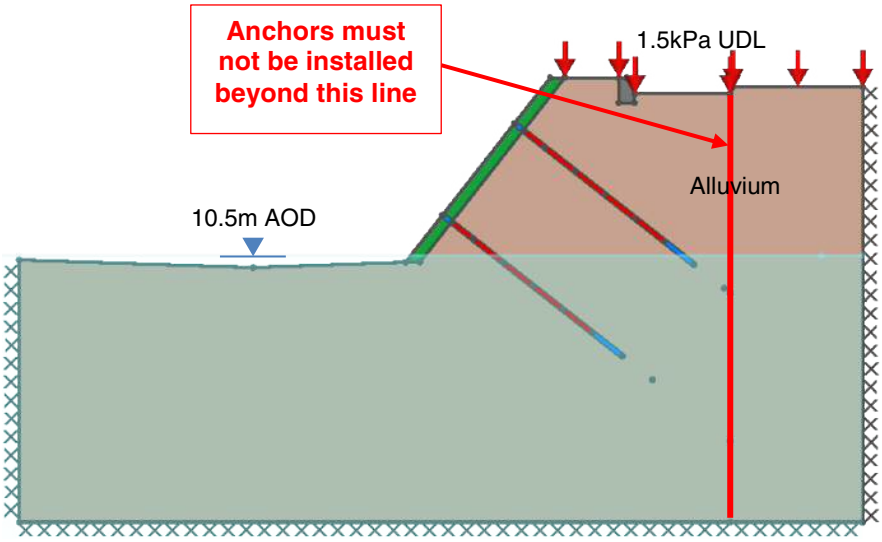


Figure 4.13. LimitState GEO model for cross section B-B – Reinforced slope

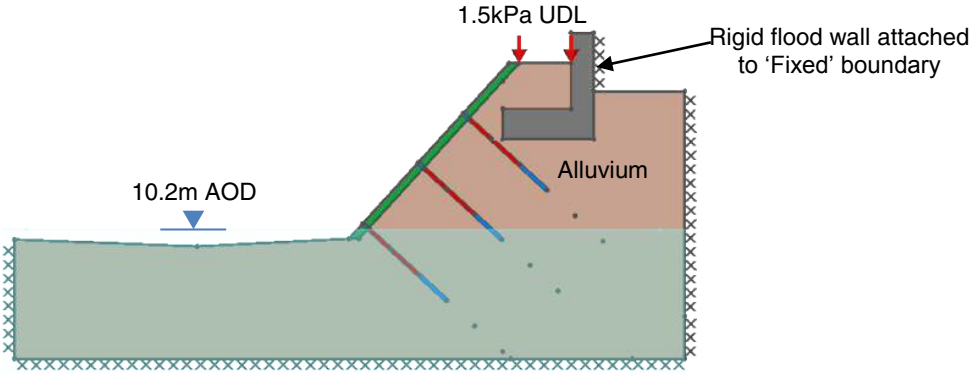


Figure 4.14. LimitState GEO model for cross section F-F – Reinforced slope

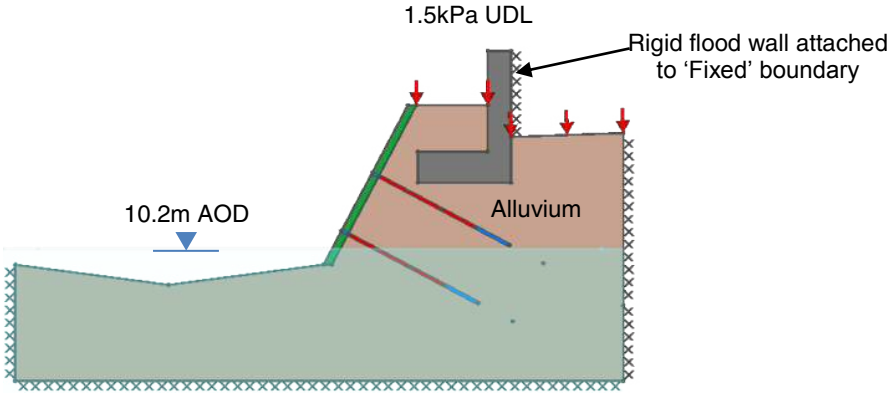


Figure 4.15. LimitState GEO model for cross section I-I – Reinforced slope

5 Summary of Results

The results of the LimitState global stability analyses are summarised in Table 5.1. below:

Table 5.1. Summary of LimitState Global Stability Analyses

Cross Section	*Unreinforced slope model*	*Restoring pressure model*			*Mechanical anchor model*			
	DA1-2 'Adequacy Factor' on strength	*Surcharge pressure q (kPa)*	*Slope face area (m^2/m)*	*Total force (kN/m)*	*Anchor length (m)*	*No. of rows*	*Force per row, P_d (kN/m)*	*Total force (kN/m)*
B-B	0.53	10	3.1	31	3.0	2	16	32
F-F	0.52	7	3.1	22	1.5	3	7	21
I-I	0.42	10	2.3	23	2.0	2	11	22

Based upon the results above, the river bank slope will require each row of anchors to provide a maximum design resistance of 16kN/m. It is anticipated that the anchors will be installed within the Alluvium. For this type of material (alluvium with a characteristic value of c_u = 40kPa) the equivalent SPT 'N' value would be approximately 8. Therefore, the expected ultimate holding capacities of a 30kN range MR-3 anchor and a 50kN range MR-2 anchor would be 22kN and 26kN respectively (see Table 5.2 below).

Table 5.2. Duckbill Ground Anchor Capacities

Duckbill Ultimate Holding Capacities in kNs

COMMON SOIL TYPE *Description*	**GEOLOGICAL SOIL** *Classification*	**Typical Blow Count 'N'**	**MR-88**	**MR-4**	**MR-3**	**MR-2**	**MR-1**	**SR1**
Very Dense and/or Cemented Sands; Coarse Gravel and Cobbles	Caliche; Nitrate-Bearing Gravel/Rock	60-100+	20	45	55	90	100	300
Dense Fine Sand; Very Hard Silts and Clays	Basal Till; Boulder Clay Caliche; Weathered Rock	40-60	20	40	50	80	100	250
Dense Clays; Sands and Gravels; Hard Silts and Clays	Glacial Till; Weathered Shales; Schist Gneiss; Siltstone	35-50	18	35	45	75	95	250
Medium Dense Sandy Gravel; Very Stiff to Hard Silts and Clays	Glacial Till; Hardpan	25-40	16	30	40	60	90	180
Medium Dense Course Sand and Sandy Gravel; Stiff to Very Stiff Silts and Clays	Saprolites; Residual Soils	14-25	14	25	35	60	80	180
Loose to Medium Dense Fine to Coarse Sand; Firm to Stiff Clays and Silts	Dense Hydraulic Fill; Compacted Fill; Residual Soils	7-14	12	20	30	50	70	150
Loose Fine Sand; Aluvium; Soft-Firm Clays; Varied Clays; Fill	Flood Plain Soils; Lake Clays; Adobe; Gumbo Fill	4-8	4-7	7-11	13-22	22-26	50	100
Peat; Organic Silts; Inundates; Silts; Fly Ash	Miscellaneous Fill; Swamp Marsh	0-5	0.9-4	1.3-7	3.5-13	9-22	13-37	20-60

The design value of the anchorage resistance, $R_{a,d}$, is derived from the characteristic value of pull-out resistance $R_{a,k}$ based on suitability tests. The design value, $R_{a,d}$, is obtained from the characteristic value by applying a partial factor, γ_a. In EN1997-1, the recommended value for the partial factor γ_a. is 1.1. A correlation factor ξ_a that accounts for the number of tests and variability of results is applied to the test results. Allowing for a correlation factor of ξ_a =1.20 based upon the results of one test, the design value is:

$$R_{a,d} = R_{a,k} = R_{ult} / \xi_a \times \gamma_a = 22 / (1.20 \times 1.10) = 16.7\text{kN per anchor (Type MR-3)}$$

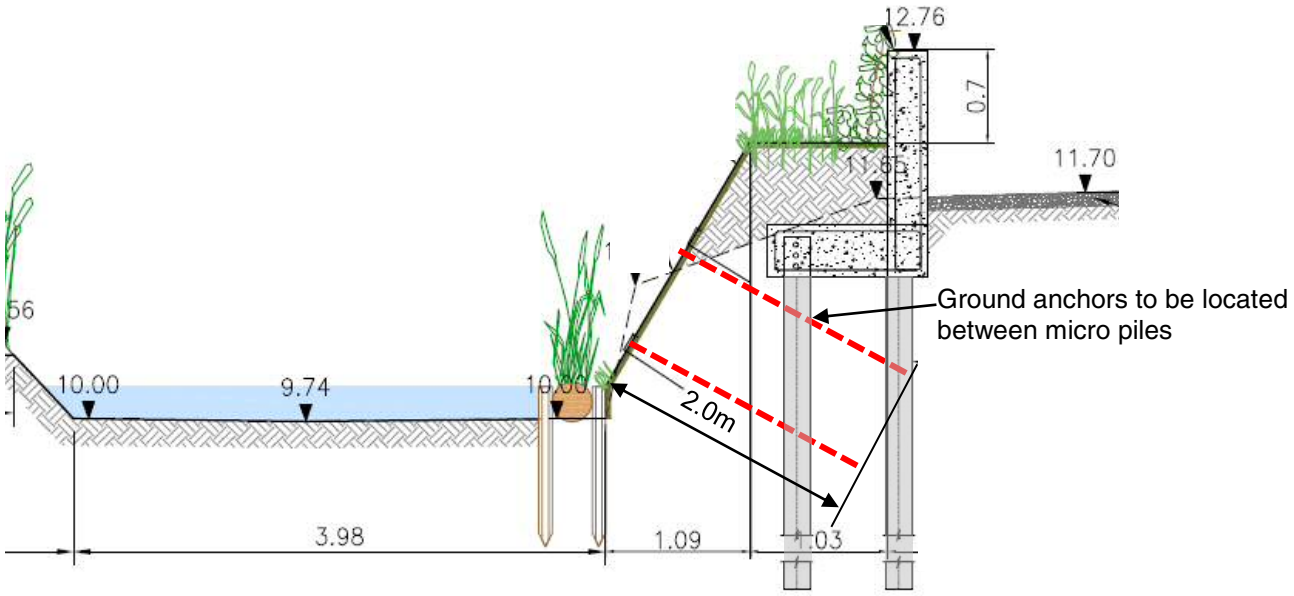
$$R_{a,d} = R_{a,k} = R_{ult} / \xi_a \times \gamma_a = 26 / (1.20 \times 1.10) = 19.7\text{kN per anchor (Type MR-3)}$$

Provisional horizontal anchor spacing = $R_{a.d} / P_d$

Table 5.3. Preliminary anchor design

Cross Section	*Anchor length (m)*	*No. of rows*	*Force per row, P_d (kN/m)*	*Anchor Type*	*Anchor resistance, $R_{a.d}$ (kN)*	*Horizontal spacing (m)*
B-B	3.0	2	16	MR-2	19.7	1.2
F-F	1.5	3	7	MR-3	16.7	2.0
I-I	2.0	2	11	MR-3	16.7	1.5

The proposed horizontal spacing should be compatible with the spacing between the micro piles supporting the flood walls.



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Report No:	13010519
PO Number:	DB0013642
Date of Issue:	15/01/2013
Test Date :	14/01/2013
Tested in accordance with :	MTP 2 & Cust Req's

Testing Report

Description: Duckbill Anchor C/W Steel Pin, Shackle and all threaded bar

Method of Test:

The samples were tested in a universal testing machine serial number T49 calibrated to national standards.
The samples were held using fittings suitable for both the machine and the items under test.
Loading was applied uniformally in tension until no further load could be applied or failure occurred.

Results:

Test Number	Marks	Maximum Load kN	Maximum Load Ton	Remarks
--	MR1 II 90kN	195.3	19.60	Fracture occurred across both sides of the clevis

Issued By:

B Bullen

Assistant Manager Mechanical Testing

TEST REPORT

Client: ANCHOR SYSTEMS EUROPE LTD
UNIT 45 ROWFANT BUSINESS CENTRE
WALLAGE LANE
ROWFANT
RH10 4NQ

Order No: DB00 12887

Test Date: 02/02/2010

Tested In Accordance With: Customer Requirements

Certified.....

Authorised Signatory L Mangham
Manager Mechanical Testing

Results of a Pull Test applied to One Cast Iron Anchor assembly

Description	Maximum Load		Remarks
	Tonne	kN	
MR-2 Cast Iron Anchor with 15mm Bar	16.99	166.4	Fracture occured across the hollow section of the cast iron anchor assembly

END OF RESULTS

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Report No:	13010521
PO Number:	DB0013642
Date of Issue:	15/01/2013
Test Date :	14/01/2013
Tested in accordance with :	MTP 2 & Cust Req's

Testing Report

Description: Duckbill Anchor C/W Steel Pin, Shackle and all threaded bar

Method of Test:

The samples were tested in a universal testing machine serial number T49 calibrated to national standards.
The samples were held using fittings suitable for both the machine and the items under test.
Loading was applied uniformally in tension until no further load could be applied or failure occurred.

Results:

Test Number	Marks	Maximum Load kN	Maximum Load Ton	Remarks
--	MR3 II 30kN	112.6	11.30	Fracture occurred across one side of the clevis (Pin hole position)

Issued By:

B Bullen

Assistant Manager Mechanical Testing