HAPAS

Linear Composites Ltd
Vale Mills
Oakworth
Keighley
West Yorkshire BD22 0EB

Tel: 01535 643363 Fax: 01535 643605
e-mail: mail@linearcomposites.com
website: www.linear composites.com

HAPAS Certificate
12/H191
Product Sheet 1

LINEAR COMPOSITES RETAINING WALLS AND BRIDGE ABUTMENTS SYSTEMS

PARAWEB STRAPS FOR REINFORCED SOIL RETAINING WALLS AND BRIDGE ABUTMENTS

This HAPAS Certificate Product Sheet(1) is issued by the British Board of Agrément (BBA), supported by Highways England (HE) (acting on behalf of the Overseeing Organisations of the Department for Transport; Transport Scotland; the Welsh Government and the Department for Infrastructure, Northern Ireland), the Association of Directors of Environment, Economy, Planning and Transport (ADEPT), the Local Government Technical Advisers Group and industry bodies. HAPAS Certificates are normally each subject to a review every three years.
(1) Hereinafter referred to as 'Certificate'.

This Certificate relates to Paraweb Straps for Reinforced Soil Retaining Walls and Bridge Abutments, geosynthetic straps comprising polyester fibres encased in a polyethylene sheath, used in conjunction with precast concrete facing units and compacted fill material to construct reinforced soil retaining walls and bridge abutments.

CERTIFICATION INCLUDES:

- factors relating to compliance with HAPAS requirements
- factors relating to compliance with Regulations where applicable
- independently verified technical specification
- assessment criteria and technical investigations
- design considerations
- installation guidance
- regular surveillance of production
- formal three-yearly review.

KEY FACTORS ASSESSED

Design — interaction between the soil and the straps has been considered, and coefficients relating to direct sliding and pull-out resistance are proposed (see section 6).

Mechanical properties and factor of safety for the extrapolation of data — the short- and long-term tensile strength and elongation properties of the straps, loss of strength owing to installation damage and reduction in strength at the connection to the facing panels have been assessed and reduction factors established for use in design (see sections 7 and 9).

Effects of environmental conditions and durability — the resistance of the straps to the effects of hydrolysis, chemical and biological degradation and exposure to UV light normally encountered in reinforced soil retaining walls and bridge abutments has been assessed and reduction factors established for use in design (see sections 8 and 11).

The BBA has awarded this Certificate to the company named above for the product described herein. This product has been assessed by the BBA as being fit for its intended use provided it is installed, used and maintained as set out in this Certificate.

On behalf of the British Board of Agrément

Date of Third issue: 18 June 2019

Originally certificated on 10 October 2012

Paul Valentine
Technical Excellence Director

Claire Curtis-Thomas
Chief Executive

British Board of Agrément
Bucknalls Lane
Watford
Herts WD25 9BA
©2019
tel: 01923 665300
clientservices@bbacerts.co.uk
www.bbacerts.co.uk

Requirements

In the opinion of the BBA, Paraweb Straps for Reinforced Soil Retaining Walls and Bridge Abutments, when used in accordance with the provisions of this Certificate, will meet the requirements of Highways England and local Highway Authorities for the design and construction of reinforced soil retaining walls and bridge abutments.

Regulations

Construction (Design and Management) Regulations 2015
Construction (Design and Management) Regulations (Northern Ireland) 2016

Information in this Certificate may assist the client, designer (including Principal Designer) and contractor (including Principal Contractor) to address their obligations under these Regulations.

See sections: 1 *Description* (1.1 and 1.2) and 3 *Delivery and sight handling* of this Certificate.

Additional Information

CE marking

The Certificate holder has taken the responsibility of CE marking the product in accordance with harmonised European Standard BS EN 13251 : 2016. An asterisk (*) appearing in this Certificate indicates that data shown are given in the Manufacturer's Declaration of Performance.

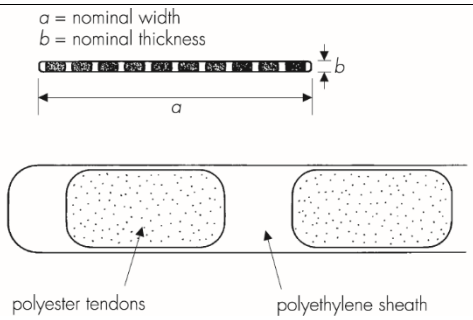
Technical Specification

1 Description

Paraweb Straps

1.1 Paraweb Straps for Reinforced Soil Retaining Walls and Bridge Abutments comprise tendons of high tenacity polyester fibres encased in a polyethylene sheath. The straps are manufactured in a number of grades and thicknesses (see Tables 1 and 2).

Table 1 Dimensions



Grade	Coil Length (m)	Nominal mass (kg)			Nominal width (a) (mm)			Nominal thickness (b) (mm)		
		Sheath type(1)			Sheath type(1)			Sheath type(1)		
		2E	2D	2S	2E	2D	2S	2E	2D	2S
30	100	8.7	12.7	14.8	83	83	85	1.5	1.9	2.2
40	100	10.9	16.7	18.5	83	84	85	1.7	2.2	2.5
50	100	12.4	19.5	23.0	87	90	90	2.0	2.5	3.5
70	100	16.7	24.1	28.6	90	90	90	2.5	3.0	4.0
75	100	17.9	25.6	30.0	90	90	90	2.6	3.1	4.1
100	100	24.1	31.1	37.7	90	90	90	3.1	3.7	6.0
		ME	MD	MS	ME	MD	MS	ME	MD	MS
27	100	6.4	8.5	9.4	46	47	48	1.8	2.2	2.5
36	100	8.1	10.8	12.0	47	49	49	2.2	2.8	3.0
37.5	100	8.2	10.9	12.1	47	49	49	2.3	2.9	3.1
45	100	10.1	13.2	14.5	48	48	49	2.7	3.3	3.6
54	100	12.7	17.4	21.4	63	65	65	2.5	3.2	3.6
63	100	14.4	20.4	22.7	63	65	66	2.8	3.7	3.9

(1) Sheaths in increasing order of thickness are 2E, 2D and 2S (equivalent to sheaths indicated by ME, MD and MS).

Table 2 Short-term tensile strength

Grade	Mean value (kN)(2) (*)	Tolerance (kN)(2) (*)	Characteristic short-term tensile strength for design T_{char} (kN)	Mean value (kN)(2) (*)	Tolerance (kN)(2) (*)	Characteristic short-term tensile strength for design T_{char} (kN)
	Sheath type(1)			Sheath type(1)		
	2E/2D			2S		
30	30.90	–0.74	30.16	34.50	–0.75	33.75
40	41.20	–1.00	40.20	46.00	–1.00	45.00
50	51.50	–1.23	50.27	57.50	–1.25	56.25
70	72.10	–1.72	70.38	80.50	–1.72	78.78
75	77.25	–1.85	75.40	86.25	–1.90	84.35
100	103.00	–2.46	100.54	115.00	–2.50	112.50
	ME/MD			MS		
27	27.81	–0.67	27.14	27.81	–0.67	27.14
36	37.08	–0.90	36.18	37.08	–0.90	36.18
37.5	38.63	–0.93	37.70	38.63	–0.93	37.70
45	46.35	–1.13	45.22	46.35	–1.13	45.22
54	55.62	–1.35	54.27	55.62	–1.35	54.27
63	64.90	–1.59	63.31	64.90	–1.59	63.31

(1) Sheaths in increasing order of thickness are 2E, 2D and 2S (equivalent to sheaths indicated by ME, MD and MS).

(2) Short-term tensile strength in accordance with BS EN ISO 10319 : 2015.

Specification for precast concrete facing units

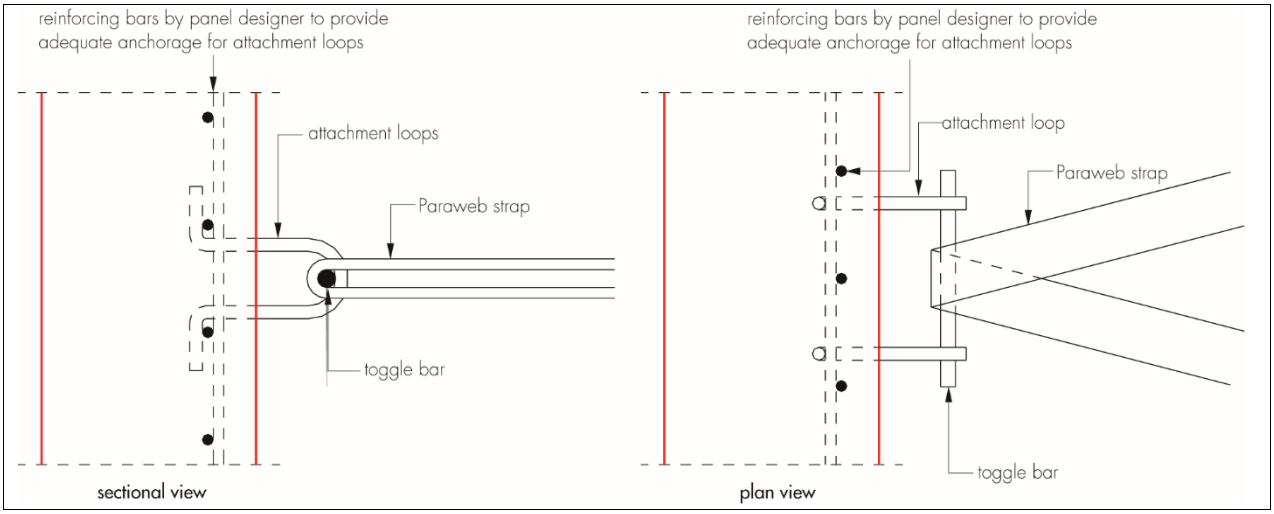
1.2 The precast concrete facing units used in conjunction with the straps must be designed and manufactured in accordance with BS 8006-1 : 2016, BS EN 14475 : 2006, BS EN 1990 : 2002 and BS EN 1992-2 : 2005 and their UK National Annexes, and the requirements of this Certificate (see sections 6.8 to 6.11).

Specification for connections

1.3 The straps are attached to the precast concrete facing units via galvanized steel attachment loops cast into the concrete and galvanized steel toggle bars (minimum diameter 25 mm), which span between attachment loops. The straps are wrapped around the toggle bars during installation (see Figure 1).

1.4 The attachment loops and toggle bars must be designed in accordance with BS 8006-1 : 2016, BS EN 14475 : 2006, BS EN 1990 : 2002 and BS EN 1992-2 : 2005 and their UK National Annexes, and the requirements of this Certificate (see sections 6.8 to 6.11).

Figure 1 A typical schematic connection detail



Specification for fill material

1.5 Fill material must comply with the requirements set out in BS 8006-1 : 2016 and the *Manual of Contract Documents for Highway Works* (MCHW), Volume 1 *Specification for Highway Works* (SHW).

Ancillary items used during installation

1.6 The following ancillary items are used during installation:

- temporary clamps — used for connection between the straps, manufactured from 8 mm diameter plain mild steel bar (grade 250) to BS 4449 : 2005 (see Figure 2). Ends of bar are to be filed smooth to avoid damage to the straps
- 12 to 20 mm diameter horizontal steel anchorage bars and 12 to 20 mm diameter vertical steel pins — used for holding the straps flat and taut temporarily, prior to further fill being placed (see Figure 3).

Figure 2 Steel 'S' clamp

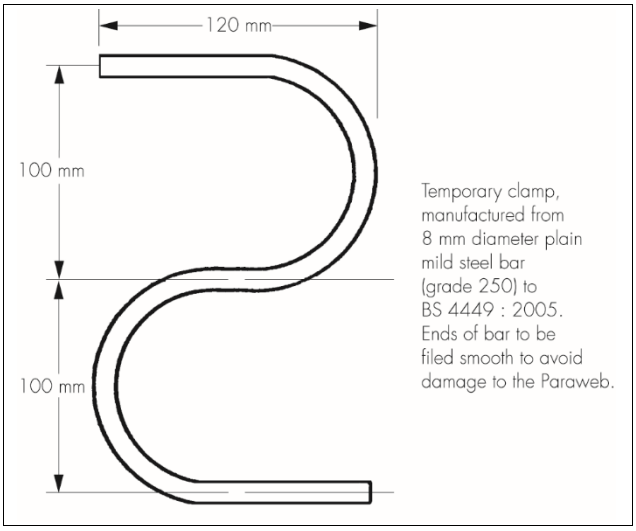
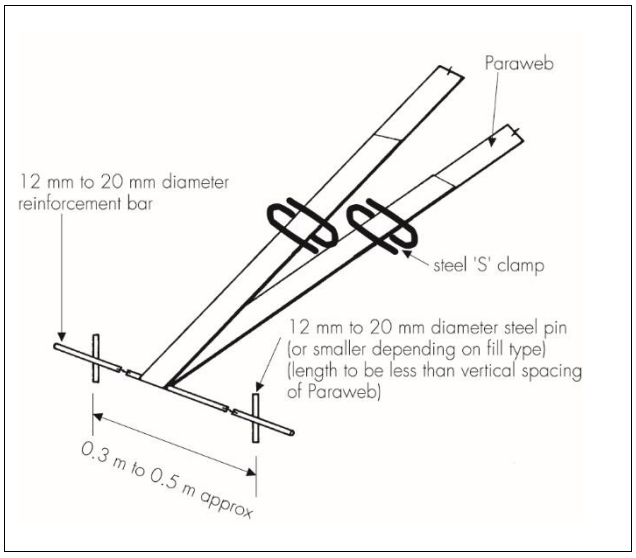


Figure 3 Anchorage bars



2 Manufacture

2.1 Paraweb Straps for Reinforced Soil Retaining Walls and Bridge Abutments are manufactured by the Certificate holder.

2.2 The straps comprise tendons manufactured from high tenacity polyester. The tendons are concentrated into separate bundles and coated with polyethylene using a vacuum die-coating process. The composite is passed through rollers to give a knurled finish on the sheath, cooled, cut to length and coiled. An impressed mark denoting the product grade is applied on one side of the product, at intervals of approximately 180 mm.

2.3 As part of the assessment and ongoing surveillance of product quality, the BBA has:

- agreed with the manufacturer the quality control procedures and product testing to be undertaken
- assessed and agreed the quality control operated over batches of incoming materials
- monitored the production process and verified that it is in accordance with the documented process
- evaluated the process for management of nonconformities
- checked that equipment has been properly tested and calibrated
- undertaken to carry out the above measures on a regular basis through a surveillance process, to verify that the specifications and quality control being operated by the manufacturer are being maintained.

2.4 The straps covered by this Certificate are manufactured in the UK and India. The management systems of Linear Composites Ltd (UK) and Maccaferri Environmental Solutions Pvt Ltd (India) have been assessed and registered as

meeting the requirements of BS EN ISO 9001 : 2015 by Lloyds Register Quality Assurance (Certificates 10070947 and 10055865 respectively).

3 Delivery and site handling

Paraweb Straps

3.1 The straps are supplied in coils of 100 m length (other coil lengths are made when required).

3.2 Each coil carries a label showing the product specification number, product type, grade, nominal length, nominal width, the date code/run number and coil number relating to the date of manufacture of the product, and the BBA logo incorporating the number of this Certificate.

3.3 Care should be taken to prevent damage to the product during transit, handling and whilst in storage.

3.4 The straps should be stored under cover, in clean, dry conditions and should be protected from sunlight and exposure to extreme temperatures.

Concrete facing units and other components

3.5 The precast concrete facing units and other components should be handled and stored in accordance with the manufacturers' instructions, the requirements of BS 8006-1 : 2016, BS EN 14475 : 2006 and the MCHW, Volume 1.

Assessment and Technical Investigations

The following is a summary of the assessment and technical investigations carried out on Paraweb Straps for Reinforced Soil Retaining Walls and Bridge Abutments.

Design Considerations

4 Use

4.1 When designed and installed in accordance with this Certificate, the straps are satisfactory for use in the construction of reinforced soil retaining walls and bridge abutments.

4.2 Structural stability is achieved through the strength of the straps, the connection strength between the straps and precast concrete facing units, and by the frictional interaction between the soil particles and the straps.

4.3 The fill specification and method of placement and compaction, design strength of the straps and length of embedment within the compacted fill are key design factors.

4.4 Prior to the commencement of work, the designer must satisfy the design approval and certification procedures of the relevant Highway Authority.

4.5 The BBA has not assessed the structures for supporting parapet loading caused by vehicle collision at the top of the precast concrete facing units.

4.6 Particular attention should be paid in design to:

- site preparation
- fill material properties
- specification for placing and compaction of the fill material
- drainage
- protection of the straps against damage during installation
- design of the precast concrete facing units and means of attachment of the straps
- the required construction tolerances for the completed structure.

4.7 Typical sectional and plan views of reinforced soil structures constructed using the straps are shown in Figures 4 and 5.

Figure 4 Typical diagrammatic sectional view

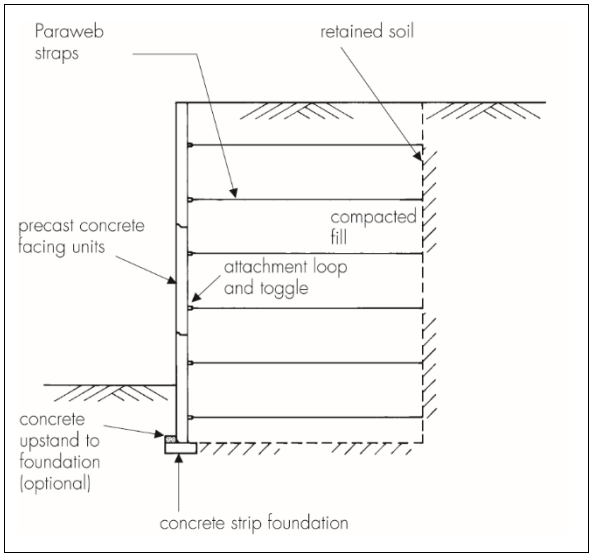
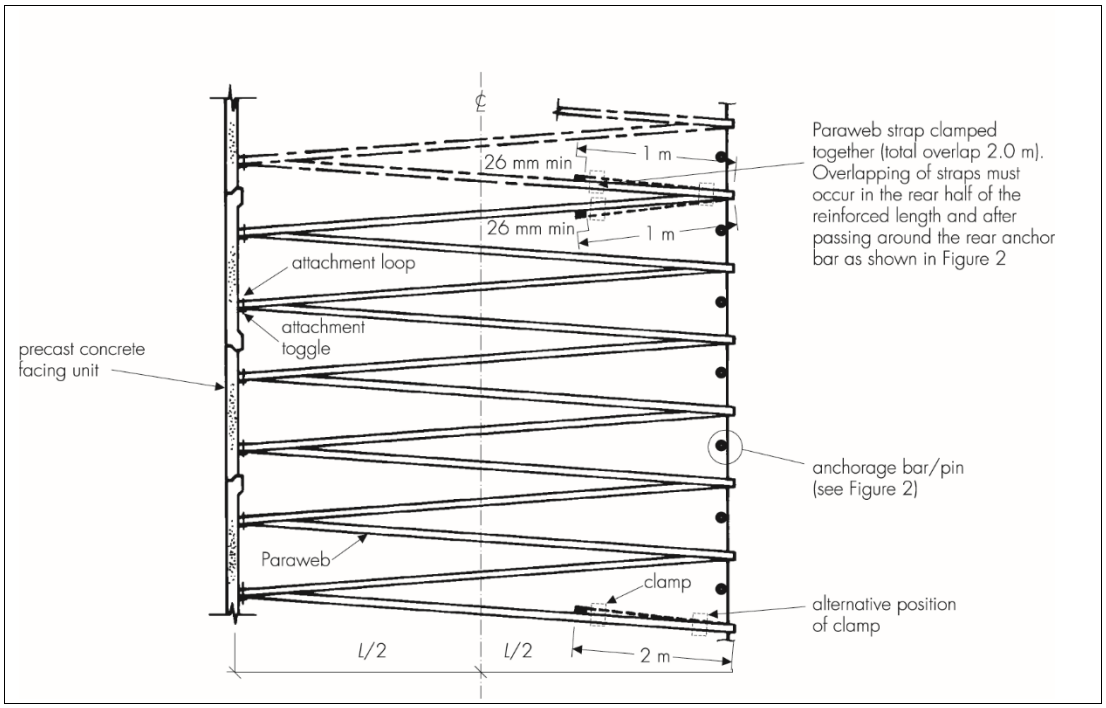


Figure 5 Typical diagrammatic plan view



5 Practicability of installation

Paraweb Straps for Reinforced Soil Retaining Walls and Bridge Abutments are installed, in accordance with the specifications and construction drawings, by trained contractors.

6 Design

Design methodology

6.1 Reinforced soil retaining walls and bridge abutments constructed using the straps should be designed in accordance with BS 8006-1 : 2016 and the MCHW, Volume 1.

6.2 In accordance with BS 8006-1 : 2016, Annex B, the required design life for permanent walls and bridge abutments is 120 years.

Paraweb Straps

6.3 The design strength of Paraweb Straps (T_D) is calculated as:

for ultimate limit state (ULS): $T_D = T_{CR}/(f_n \times f_m)$
for serviceability limit state (SLS): $T_D = T_{CS}/f_m$

where:

T_{CR} is the long-term tensile creep rupture strength of the reinforcement at the specified design life and design temperature
T_{CS} is the maximum allowable tensile load to ensure that the prescribed post-construction, limiting strain specified for the SLS is not exceeded
f_n is the partial factor for ramification of failure in accordance with BS 8006-1 : 2016, Table 9
f_m is the material safety factor to allow for the strength reducing effects of installation damage, weathering (including exposure to sunlight), chemical and other environmental effects and to allow for the extrapolation of data used to establish the above reduction factors.

6.4 The long-term tensile creep rupture strength (T_{CR}) for each grade of strap is calculated using the formula:

$T_{CR} = T_{char}/RF_{CR}$

where:

T_{char} is the characteristic short-term strength taken from Table 1
RF_{CR} is the reduction factor for creep (see section 7).

6.5 The material safety factor (f_m) used in determining T_D is calculated as:

$f_m = RF_{ID} \times RF_w \times RF_{CH} \times f_S$

where:

RF_{ID} is the reduction factor for installation damage
RF_w is the reduction factor for weathering, including exposure to ultraviolet light
RF_{CH} is the reduction factor for chemical/environmental effects
f_S is the factor of safety for the extrapolation of data.

6.6 Recommended values for RF_{CR}, RF_{ID}, RF_w, RF_{CH} and f_S are given in sections 7 to 9. Conditions of use outside the scope for which the reduction factors are defined are not covered by this Certificate and advice should be sought from the Certificate holder.

Soil/Paraweb Strap interaction

6.7 For the purposes of checking direct sliding and pull-out resistance, the friction coefficient (α') in accordance with BS 8006-1 : 2016 relating soil friction angle to the soil/strap bond (tanδ'/tanφ') can be taken conservatively as 0.70. Significantly enhanced values of α' can be justified in design, by carrying out soil and site-specific pull-out tests in accordance with BS EN 13738 : 2004.

Precast concrete facing units

6.8 The precast concrete facing units must be designed in accordance with the relevant provisions of BS 8006-1 : 2016, BS EN 14475 : 2006, and BS EN 1990 : 2002 and BS EN 1992-2 : 2005 and their UK National Annexes.

6.9 The appropriate combination of concrete exposure classes should be selected from Table A.1 of BS 8500-1 : 2015 and Table 1 of BS EN 206 : 2013 to suit the proposed location and level of exposure of the proposed structure. Design and detailing of the precast concrete facing units should provide adequate durability for an intended design life of at least 100 years.

6.10 Where the precast concrete facing units are to be embedded in soils which could potentially be aggressive, the guidance given in BRE Special Digest 1 : 2005, Part C, should be followed.

6.11 Attachment loops and toggle bars used for connection of the straps should be designed in accordance with the requirements of BS 8006-1 : 2016 and have adequate anchorage strength.

Fill materials

6.12 Fill materials should meet the requirements of BS 8006-1 : 2016 and the MCHW, Volume 1.

7 Mechanical properties

Short-term tensile strength

7.1 The characteristic short-term tensile strength (T_{char}) of each grade of the straps is given in Table 2.

7.2 A typical short-term stress/strain curve is shown in Figure 6. The elongation at maximum load for all grades of straps covered by this Certificate is 10.5% ± 1% (*).

Figure 6 Typical short-term stress/strain curve for Paraweb Straps

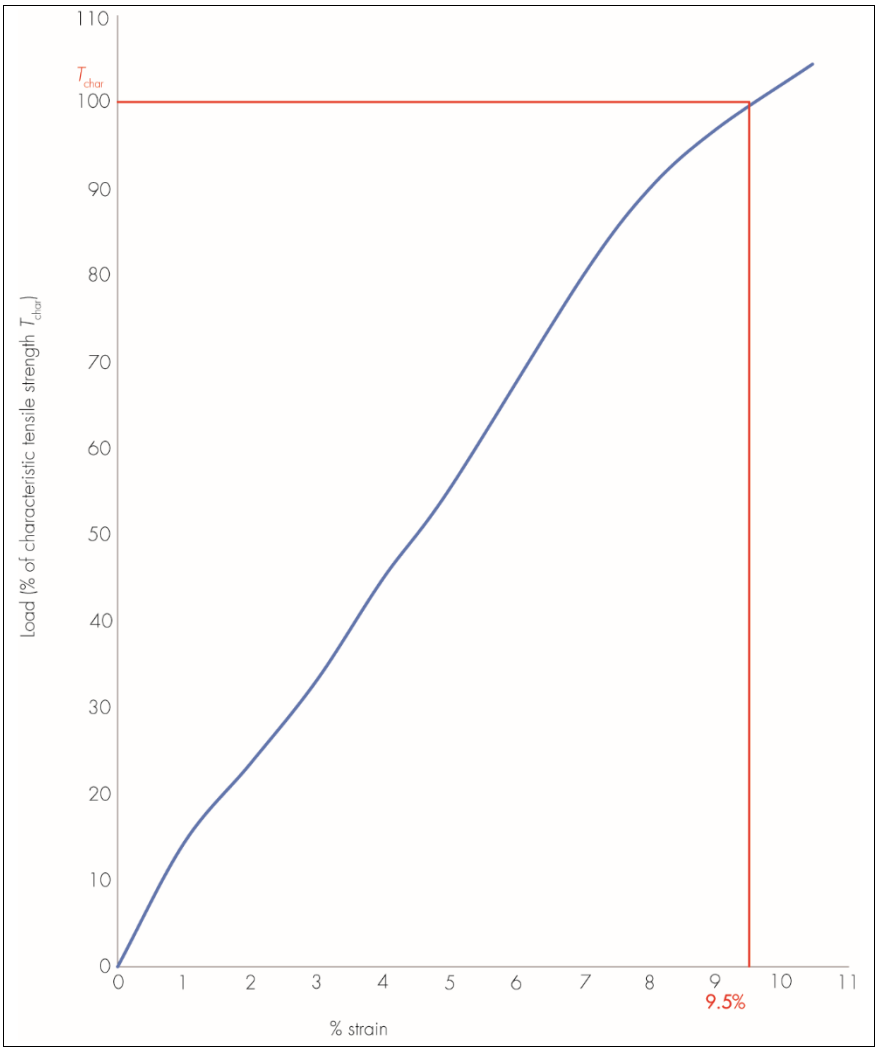


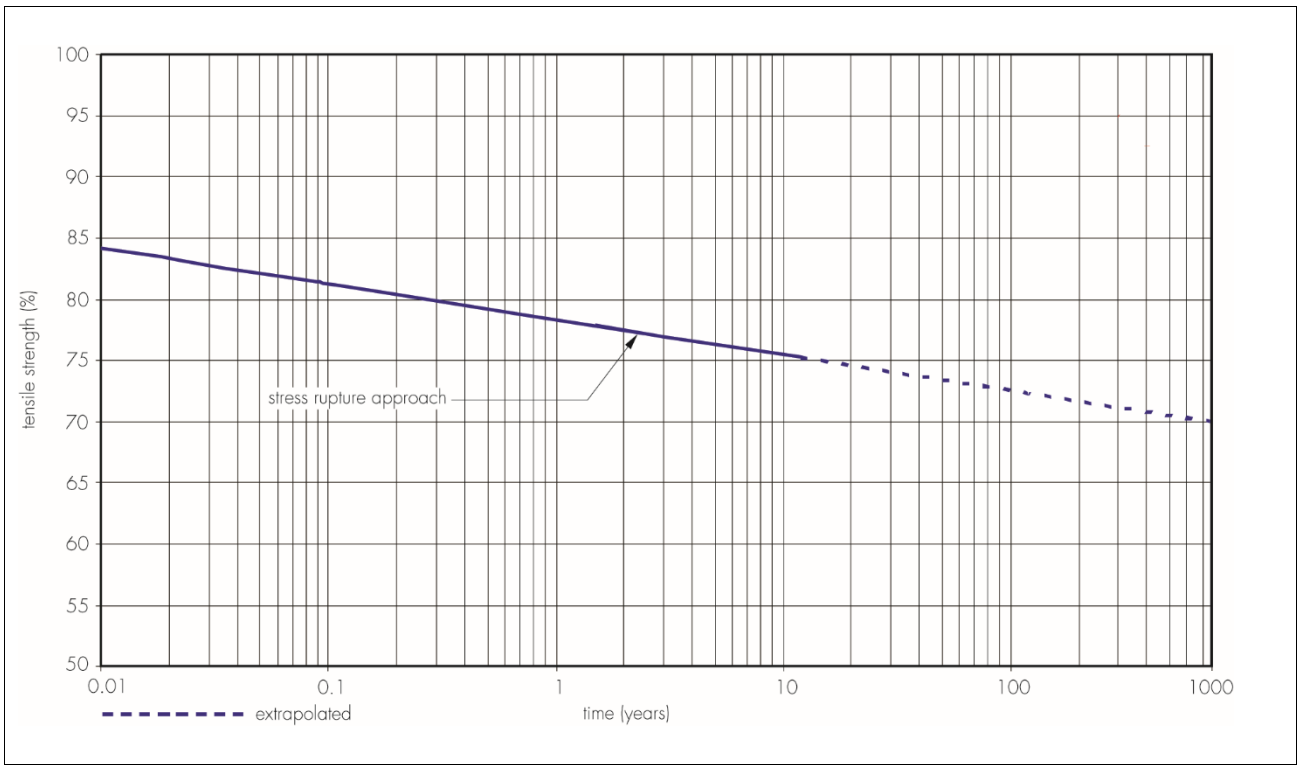
Table 3 Typical short-term strain against load (as percentage of the T_{char})

Strain	% of T_{char}
At 2%	23
At 3%	34
At 4%	45
At 5%	55
At 6%	69

Long-term tensile creep rupture strength

7.3 The long-term tensile creep rupture strength performance of the straps has been determined in accordance with the principles of PD ISO/TR 20432 : 2007. A stress rupture line (see Figure 7) has been determined using conventional long-term creep rupture test data (up to 41,945 hours) and time-shifted stepped isothermal method (SIM) test data (up to 7.8 x 10^6 hours) for a design temperature of 20°C. From this graph, for the ULS, the value of the tensile creep rupture strength (T_D) can be determined for the appropriate design life at 20°C and by applying temperature shift factors determined for the straps, for other design temperatures.

Figure 7 Regression line for life expectancy at constant stress defined by percentage of characteristic short-term tensile strength at 20°C



7.4 For a 120-year design life and design temperatures of 0, 20, 25 30 and 40°C, the long-term tensile strength (T_{CR}) for the straps can be derived using the formula given in section 6.4, with the long-term creep reduction factors (RF_{CR}) shown in Table 4.

Table 4 Long-term creep reduction factors at various temperatures

Design temperature (°C)	Creep reduction factor (RF_{CR})	Percentage of T_{char} (%)
0	1.30	77
20	1.38	72
25	1.40	71
30	1.43	69
40	1.48	68

Post construction strain

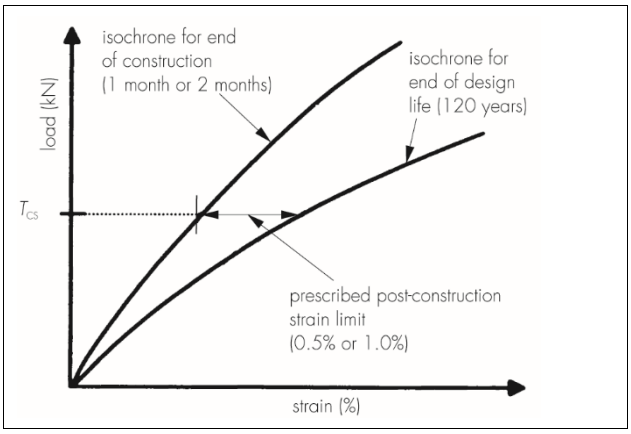
7.5 The prescribed maximum allowable post-construction creep strains allowed by BS 8006-1 : 2016 for the SLS of reinforced soil retaining walls and bridge abutments are shown in Table 5.

Table 5 SLS on post-construction internal strains for bridge abutments and retaining walls

Structure	Strain (%)	Design period for the purposes of determining limiting strain
Bridge abutments and retaining walls with permanent structural loading	0.5	2 months – 120 years
Retaining walls, with no applied structural loading, ie transient live loadings only	1.0	1 month – 120 years

7.6 The relationship between the prescribed post-construction strain limit and the tensile load (T_{CS}), causing that post-construction strain, is illustrated in Figure 8.

Figure 8 Definition of T_{CS}



7.7 Reduction factors $RF_{CR(SLS)}$ for determining T_{CS} from the characteristic short-term tensile load (T_{char}) for each grade of the straps are given in Table 6. The following formula is used to calculate T_{CS}:

$$T_{CS} = T_{char}/RF_{CR(SLS)}$$

Table 6 Long-term creep reduction factors for SLS for a 120-year design life and design temperature of 20°C

Prescribed allowable post-construction strain (%)	$RF_{CR\ (SLS)}$
0.5	2.00
1.0	1.54

Reduction factor for installation damage (RF_{ID})

7.8 To allow for loss of strength owing to mechanical damage sustained during installation, the appropriate reduction factor (RF_{ID}) for ULS should be selected from Table 7. These reduction factors have been established from full-scale installation damage tests using a range of materials. For soils not covered by Table 7, appropriate values of RF_{ID} may be determined from site-specific trials or the engineer responsible for design of the project may exercise engineering judgment to interpolate between the values given. The reduction factors shown assume that well-graded material is used (coefficient of uniformity >5) with a minimum compacted depth of 150 mm. For the SLS, the value of RF_{ID} may be taken as 1.0.

Table 7 Reduction factors for installation damage (RF_{ID})

Paraweb grade	Sheath type	RF_{ID} particle size d50 (mm)			
		<0.1	<1.0	<15	>15
27	ME/MD/MS	1.10	1.10	1.10	1.10
30	2E/2D/2S	1.05	1.05	1.10	1.07
36	ME/MD/MS	1.05	1.05	1.10	1.10
37.5	ME/MD/MS	1.05	1.05	1.10	1.10
40	2E/2D/2S	1.05	1.05	1.10	1.07
45	ME/MD/MS	1.05	1.05	1.10	1.08
50	2E/2D/2S	1.05	1.05	1.05	1.05
54	ME/MD/MS	1.05	1.05	1.05	1.08
63	ME/MD/MS	1.05	1.05	1.05	1.06
70	2E/2D/2S	1.05	1.05	1.05	1.05
75	2E/2D/2S	1.05	1.05	1.05	1.08
100	2E/2D/2S	1.05	1.05	1.05	1.06

Connection strength

7.9 Tests have shown that provided a toggle diameter of at least 25 mm is used, there is no reduction in tensile strength in the straps at the point where the strap is attached to the precast concrete facing units (see Figure 1). A reduction factor for connection strength is therefore not required if the straps are connected to the precast concrete facing units in this manner.

8 Effects of environmental conditions

Weathering (including exposure to ultraviolet light)

8.1 Evidence from tests in accordance with BS EN 12224 : 2000 shows that the straps have adequate resistance to weathering and UV exposure, when protected in accordance with the recommendations of this Certificate and provided they are covered within one month of installation. Subject to compliance with this exposure time limit, a reduction factor (RF_W) of 1.0 may be used for design purposes for both ULS and SLS. Exposure periods of up to four months may be acceptable depending upon the season and location, but are outside of the scope of this Certificate. Further guidance is given in PD ISO/TR 20432 : 2007.

Chemical and biological degradation

8.2 Evidence from tests in accordance with BS EN 12447 : 2001 shows that the straps have adequate resistance to hydrolysis for soil environments typically encountered in the UK.

8.3 Evidence from tests in accordance with BS EN 12225 : 2000 shows that the straps are highly resistant to microbiological attack.

8.4 To account for environmental conditions, the appropriate reduction factors (RF_{CH}) should be selected from Table 8.

Table 8 Reduction factor RF_{CH} according to design life and pH of the soil

Design temp (°C)	Reduction Factors (RF_{CH})								
	2 year design life			60 year design life			120 year design life		
	4<pH<9	9.1<pH<9.5	9.6<pH<11	4<pH<9	9.1<pH<9.5	9.6<pH<11	4<pH<9	9.1<pH<9.5	9.6<pH<11
20	1.00	1.00	1.01	1.02	1.03	1.07	1.03	1.05	1.12
25	1.00	1.00	1.01	1.03	1.05	1.09	1.07	1.09	1.15
30	1.01	1.01	1.02	1.06	1.10	1.14	1.15	1.17	1.25

8.5 For the SLS, the value of RF_{CH} may be taken as 1.0.

8.6 The polyethylene sheath used on the straps acts as a chemical barrier and provided it is not broken or damaged, will reduce the risk of chemical attack on the polyester fibres. It should be noted that the most aggressive fills are usually of fine particle sizes which may cause little or no damage to the polyethylene sheath. Compaction can also reduce the high pH level of a fill and tests have shown that, 48 hours after the compaction stage, the pH level of a soil-lime mix reduced from 12.5 to 11. As a result, where site and soil specific testing confirms that the fill material will cause no damage to the polyethylene sheathing and where this reduction is verified, the straps may be used in soils with pH levels up to 12, without further increase to the reduction factors (RF_{CH}) given in Table 8 for pH levels 9.6 to 11.0.

9 Factor of safety for the extrapolation of data (f_s)

9.1 For Paraweb Straps for Reinforced Soil Retaining Walls and Bridge Abutments the factor of safety for the extrapolation of data (f_s) for a 120-year design life and design temperatures of 20, 25 and 30°C should be taken as 1.05.

9.2 The above value has been calculated in accordance with PD ISO/TR 20432 : 2007, using the R_1 and R_2 values given in Table 9.

Table 9 R_1 and R_2 values for determination of f_s

Factor	Taking account of:	Value
R_1	Extrapolation of creep rupture data	1.00
R_2	Extrapolation of accelerated chemical data	1.05

10 Maintenance

As the product is confined within the soil and has suitable durability, maintenance is not required.

11 Durability

11.1 Paraweb Straps for Reinforced Soil Retaining Walls and Bridge Abutments will have adequate durability for a design life of 120 years, when used and installed in accordance with the provisions of this Certificate.

11.2 The precast concrete facing units will have adequate durability for the proposed life of the structure under the exposure conditions normally encountered in reinforced soil retaining walls and bridge abutments in the UK, when designed and installed in accordance with the provisions of BS 8006-1 : 2016, BS EN 14475 : 2006 and the requirements of this Certificate (see sections 6.8 to 6.11).

12 Reuse and recyclability

12.1 The precast concrete facing units can be crushed and re-used as aggregate. The fill material can be re-used.

12.2 The steel loops and toggle bars can be readily recycled.

Installation

13 General

13.1 Installation of Paraweb Straps for Reinforced Soil Retaining Walls and Bridge Abutments must be carried out in accordance with the Certificate holder's Installation instructions, BS EN 14475 : 2006 and the MCHW, Volume 1.

13.2 Formation levels are prepared by levelling and compacting the substrate in accordance with the MCHW, Volume 1.

14 Procedure

14.1 Fill material is placed and compacted behind the precast concrete facing units to the level of the first layer of the straps (see Figure 4).

14.2 The straps are laid, attached to the precast concrete facing units (see Figure 4), pulled and held flat and taut using a horizontal anchor bar and vertical pins as shown in Figure 3, prior to further fill being placed. The connection between the straps is held using the temporary mild steel 'S' clamp (see Figures 2 and 3).

14.3 Further courses of precast concrete facing units, as required, are fixed and fill material is placed and compacted until the specified height is reached for the next layer of the straps to be installed.

14.4 The above sequence is repeated up to the formation level for the parapet base or finished level as appropriate.

14.5 Fill material is placed to a depth of not less than 150 mm. The fill material should be placed from the anchor pin to within two metres of the precast concrete facing units, and compacted thoroughly. The remaining two metres of fill material should be placed and compacted using lighter compaction plant. However, the required compaction should be achieved.

14.6 Particular care should be taken to ensure the straps are adequately covered before compaction or trafficking. To avoid excessive movement of the precast concrete facing units, heavy compaction plant must not be used within two metres of the face where the depth of fill material before each pass may be less than 150 mm to suit the compaction plant used.

14.7 Joints in the straps are made adjacent to the steel pin bar and horizontal steel anchor bars, as shown in Figure 5. Lengths of straps are overlapped by a distance of two metres and clamped together as shown in Figure 3. Joints are made adjacent to the anchor bar. The clamp is a construction aid and is redundant once the fill material has been placed and compacted.

14.8 The ends of the strap are treated with a bitumastic-based sealant to reduce ingress of moisture.

Technical Investigations

15 Investigations

15.1 The manufacturing process was evaluated, including the methods adopted for quality control, and details were obtained of the quality and composition of the materials used.

15.2 An assessment was made of data relating to:

- evaluation of long- and short-term tensile properties
- evaluation of long- and short-term load/strain characteristics
- effects of temperature
- resistance to damage caused during installation
- resistance to ultraviolet light
- resistance to hydrolysis
- resistance to microbial attack
- assessment of material safety factors
- coefficient of friction between the straps and material fill
- assessment of fill material/straps interaction.

Bibliography

BRE Special Digest 1 : 2005 *Concrete in aggressive ground : Part C Assessing the aggressive chemical environment*

BS 4449 : 2005 + A3 : 2016 *Steel for the reinforcement of concrete — Weldable reinforcing steel — Bar, coil and decoiled product — Specification*

BS 8006-1 : 2016 *Code of practice for strengthened/reinforced soils and other fills*

BS 8500-1 : 2015 + A1 : 2016 *Concrete — Complementary British Standard to BS EN 206 — Method of specifying and guidance for the specifier*

BS EN 206 : 2013 + A1: 2016 *Concrete — Specification, performance, production and conformity*

BS EN 1990 : 2002 + A1 : 2005 *Eurocode — Basis of structural design*
NA to BS EN 1990 : 2002 + A1 : 2005 UK National Annex for *Eurocode — Basis of structural design*

BS EN 1992-2 : 2005 *Eurocode 2 — Design of concrete structures — Concrete bridges — Design and detailing rules*
NA to BS EN 1992-2 : 2005 UK National Annex to *Eurocode 2 — Design of concrete structures — Concrete bridges — Design and detailing rules*

BS EN 12224 : 2000 *Geotextile and geotextile-related products — Determination of the resistance to weathering*

BS EN 12225 : 2000 *Geotextile and geotextile-related products — Method for determining the microbiological resistance by a soil burial test*

BS EN 12447 : 2001 *Geotextiles and geotextile-related products — Screening test method for determining the resistance to hydrolysis in water*

BS EN 13251 : 2016 *Geotextiles and geotextile-related products — Characteristics required for use in earthworks, foundations and retaining structures*

BS EN 13738 : 2004 *Geotextiles and geotextile-related products — Determination of pullout resistance in soil*

BS EN 14475 : 2006 *Execution of special geotechnical works — Reinforced fill*

BS EN ISO 9001 : 2015 *Quality management systems — Requirements*

BS EN ISO 10319 : 2015 *Geosynthetics — Wide-width tensile test*

PD ISO/TR 20432 : 2007 *Guidelines for the determination of the long-term strength of geosynthetics for soil reinforcement*

16 Conditions

16.1 This Certificate:

- relates only to the product/system that is named and described on the front page
- is issued only to the company, firm, organisation or person named on the front page – no other company, firm, organisation or person may hold or claim that this Certificate has been issued to them
- is valid only within the UK
- has to be read, considered and used as a whole document – it may be misleading and will be incomplete to be selective
- is copyright of the BBA
- is subject to English Law.

16.2 Publications, documents, specifications, legislation, regulations, standards and the like referenced in this Certificate are those that were current and/or deemed relevant by the BBA at the date of issue or reissue of this Certificate.

16.3 This Certificate will remain valid for an unlimited period provided that the product/system and its manufacture and/or fabrication, including all related and relevant parts and processes thereof:

- are maintained at or above the levels which have been assessed and found to be satisfactory by the BBA
- continue to be checked as and when deemed appropriate by the BBA under arrangements that it will determine
- are reviewed by the BBA as and when it considers appropriate.

16.4 The BBA has used due skill, care and diligence in preparing this Certificate, but no warranty is provided.

16.5 In issuing this Certificate the BBA is not responsible and is excluded from any liability to any company, firm, organisation or person, for any matters arising directly or indirectly from:

- the presence or absence of any patent, intellectual property or similar rights subsisting in the product/system or any other product/system
- the right of the Certificate holder to manufacture, supply, install, maintain or market the product/system
- actual installations of the product/system, including their nature, design, methods, performance, workmanship and maintenance
- any works and constructions in which the product/system is installed, including their nature, design, methods, performance, workmanship and maintenance
- any loss or damage, including personal injury, howsoever caused by the product/system, including its manufacture, supply, installation, use, maintenance and removal
- any claims by the manufacturer relating to CE marking.

16.6 Any information relating to the manufacture, supply, installation, use, maintenance and removal of this product/system which is contained or referred to in this Certificate is the minimum required to be met when the product/system is manufactured, supplied, installed, used, maintained and removed. It does not purport in any way to restate the requirements of the Health and Safety at Work etc. Act 1974, or of any other statutory, common law or other duty which may exist at the date of issue or reissue of this Certificate; nor is conformity with such information to be taken as satisfying the requirements of the 1974 Act or of any statutory, common law or other duty of care.

British Board of Agrément
Bucknalls Lane
Watford
Herts WD25 9BA

tel: 01923 665300
clientservices@bbacerts.co.uk
www.bbacerts.co.uk