HAPAS

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HAPAS Certificate
16/H249
Product Sheet 1

LINEAR COMPOSITES SOIL REINFORCEMENT PRODUCTS

PARAGRID, PARAGRID HF AND PARADRAIN GEOCOMPOSITES

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 Paragrid, Paragrid HF and Paradrain[1] Geocomposites, comprising an open network of integrally connected straps of high tenacity polyester (PET) yarn coated with polyethylene, for use as reinforcement in embankments with slope angles up to 70°.
(1) Paragrid and Paradrain are registered trademarks.

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 geocomposites has been considered and coefficients relating to direct sliding and pull-out resistance are proposed (see section 6).
Mechanical properties — the short- and long-term tensile strength and elongation properties of the geocomposites and loss of strength owing to installation damage have been assessed and reduction factors established for use in design (see section 7).
Effects of environmental conditions and durability — the resistance of the geocomposites to the effects of hydrolysis, chemical and biological degradation, UV exposure and temperature conditions normally encountered in civil engineering practice 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 products described herein. These products have been assessed by the BBA as being fit for their intended use provided they are installed, used and maintained as set out in this Certificate.

On behalf of the British Board of Agrément

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Requirements

In the opinion of the BBA, Paragrid, Paragrid HF and Paradrain Geocomposites, when used in accordance with the provisions of this Certificate, will satisfy the requirements of Highways England and local Highway Authorities for the design and construction of reinforced soil embankments with slope angles up to 70°.

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* (1.2) and 3 *Delivery and site handling* of this Certificate.

Additional Information

CE marking

The Certificate holder has taken the responsibility of CE marking the products in accordance with harmonised European Standard BS EN 13251 : 2016.

Technical Specification

1 Description

1.1 Paragrid, Paragrid HF and Paradrain Geocomposites are planar structures, consisting of a biaxial array of composite geosynthetic straps which comprise cores of polyester tendons encased in a polyethylene sheath.

1.2 Paradrain is composed of geosynthetic materials, combining reinforcement and drainage functions, developed for the reinforcement of slopes constructed from poorly draining backfill.

1.3 The Paragrid, Paragrid HF and Paradrain Geocomposites grades covered by this Certificate are listed in Tables 1 to 3, and their associated performance characteristics are shown in Tables 4 to 9. The configuration of the geocomposites is illustrated in Figure 1.

Figure 1 Paragrid, Paragrid HF and Paradrain Geocomposites

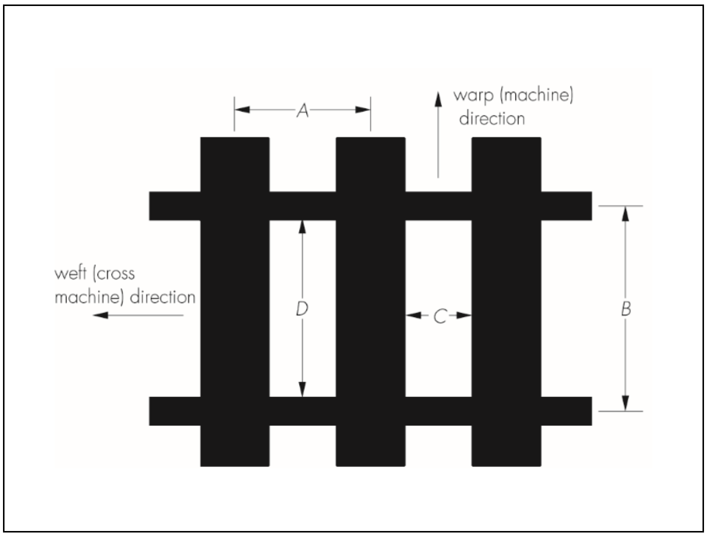


Table 1 General specifications for Paragrid Geocomposites

Grade	Nominal mass(1) (g·m^{-2})	Grid size(2) warp/weft A x B (mm)	Aperture size(2) warp/weft C x D (mm)	Nominal roll weight (3.9 m width) (kg)	Standard roll length (m)
30/5	213	75 x 450	51 x 426	93	100
40/5	218	75 x 450	51 x 426	95	100
50/5	244	75 x 450	51 x 426	105	100
65/5	312	75 x 450	51 x 426	108	80
80/5	362	75 x 450	51 x 426	123	80
90/5	397	75 x 450	51 x 426	134	80
100/5	416	75 x 450	51 x 426	140	80
110/5	441	75 x 450	51 x 426	148	50
120/5	452	75 x 450	42 x 426	99	50
135/5	510	75 x 450	42 x 426	110	50
150/5	567	75 x 450	42 x 426	121	50
160/5	604	75 x 450	42 x 426	128	50
175/5	656	75 x 450	42 x 426	138	50
200/5	705	75 x 450	42 x 426	147	50
30/15	328	75 x 225	51 x 201	73	50
50/15	367	75 x 225	51 x 201	79	50
50/50	568	75 x 75	51 x 51	117	50
100/100	811	75 x 75	51 x 51	164	50
80/15	435	75 x 225	51 x 201	93	50
100/15	488	75 x 225	51 x 201	103	50
120/15	547	75 x 225	42 x 201	108	50
150/15	671	75 x 225	42 x 201	130	50
160/15	700	75 x 225	42 x 201	138	50
200/15	781	75 x 225	42 x 201	156	50

(1) Mass/unit area measured in accordance with BS EN ISO 9864 : 2005.
(2) Mean measured dimensions (see Figure 1 for reference).

Table 2 General specifications for Paragrid HF Geocomposites

Grade	Nominal mass(1) (g·m^{-2})	Grid size(2) warp/weft A x B (mm)	Aperture size(2) warp/weft C x D (mm)	Nominal roll weight (4.5 m width) (kg)	Standard roll length (m)
90/5	314	180 x 1000	135 x 940	200	100
100/5	327	180 x 1000	135 x 940	280	150
125/5	365	180 x 1000	134 x 940	270	130
150/5	408	180 x 1000	134 x 940	330	150
175/5	465	180 x 1000	134 x 940	370	150
200/5	505	180 x 1000	133 x 940	410	160
250/5	603	180 x 1000	132 x 940	430	140

(1) Mass/unit area measured in accordance with BS EN ISO 9864 : 2005.
(2) Mean measured dimensions (see Figure 1 for reference).

Table 3 General specifications for Paradrain Geocomposites

Grade	Nominal mass[1] ($g \cdot m^{-2}$)	Grid size[2] warp/weft A x B (mm)	Aperture size[2] warp/weft C x D (mm)	Nominal roll weight (3.9 m width) (kg)	Standard roll length (m)
50/5	358	75 x 450	51 x 426	82	50
80/5	441	75 x 450	51 x 426	96	50
100/5	489	75 x 450	51 x 426	105	50
150/5	685	75 x 450	42 x 426	144	50
200/5	781	75 x 450	42 x 426	160	50

(1) Mass/unit area measured in accordance with BS EN ISO 9864 : 2005.
(2) Mean measured dimensions (see Figure 1 for reference).

Table 4 Performance characteristics — machine direction (MD) for Paragrid Geocomposites

Grade	Performance values[1]			Values used for design	
	Short term tensile strength[2] (kN per m width)		Mean strain at maximum tensile strength[2] (%)		
	Mean value	Tolerance		T_{char}[3] (kN per metre width)	Nominal strain at T_{char} load (%)
30/5	37	-7	11 ±1	30	9
40/5	46	-6	11 ±1	40	9
50/5	57	-7	11 ±1	50	9
65/5	70	-5	11 ±1	65	9
80/5	86	-6	11 ±1	80	9
90/5	96	-6	11 ±1	90	9
100/5	106	-6	11 ±1	100	9
110/5	116	-6	11 ±1	110	9
120/5	125	-5	11 ±1	120	9
135/5	141	-6	11 ±1	135	9
150/5	160	-10	11 ±1	150	9
160/5	170	-10	11 ±1	160	9
175/5	185	-10	11 ±1	175	9
200/5	212	-12	11 ±1	200	9
30/15	37	-7	11 ±1	30	9
50/15	57	-7	11 ±1	50	9
50/50	57	-7	11 ±1	50	9
100/100	106	-6	11 ±1	100	9
80/15	86	-6	11 ±1	80	9
100/15	106	-6	11 ±1	100	9
120/15	130	-10	11 ±1	120	9
150/15	160	-10	11 ±1	150	9
160/15	170	-10	11 ±1	160	9
200/15	212	-12	11 ±1	200	9

(1) Performance values as declared on the Certificate holder's CE Marking Declarations of Performance.
(2) Values derived from short-term tests in accordance with BS EN ISO 10319 : 2015.
(3) The characteristic short-term tensile strength (T_{char}) values are the mean short-term tensile strength minus 1 x the tolerance value, in accordance with BS EN 13251 : 2016.

Table 5 Performance characteristics — machine direction (MD) for Paragrid HF Geocomposites

Grade	Performance values(1) Short term tensile strength(2) (kN per m width) Mean value	Tolerance	Mean strain at maximum tensile strength(2) (%)	Values used for design T_{char}(3) (kN per metre width)	Nominal strain at T_{char} load (%)
90/5	96	-6	10.5 ±1	90	9.5
100/5	106	-6	10.5 ±1	100	9.5
125/5	135	-10	10.5 ±1	125	9.5
150/5	160	-10	10.5 ±1	150	9.5
175/5	185	-10	10.5 ±1	175	9.5
200/05	212	-12	10.5 ±1	200	9.5
250/05	265	-15	10.5 ±1	250	9.5

(1) Performance values as declared on the Certificate holder's CE Marking Declarations of Performance.
(2) Values derived from short-term tests in accordance with BS EN ISO 10319 : 2015.
(3) The characteristic short-term tensile strength (T_{char}) values are the mean short-term tensile strength minus 1 x the tolerance value, in accordance with BS EN 13251 : 2016.

Table 6 Performance characteristics — machine direction (MD) for Paradrain Geocomposites

Grade	Performance values(1) Short term tensile strength(2) (kN per m width) Mean value	Tolerance	Mean strain at maximum tensile strength(2) (%)	Values used for design T_{char}(3) (kN per metre width)	Nominal strain at T_{char} load (%)
50/5	57	-7	11 ±1	50	9
80/5	86	-6	11 ±1	80	9
100/5	106	-6	11 ±1	100	9
150/5	160	-10	11 ±1	150	9
200/5	212	-12	11 ±1	200	9

(1) Performance values as declared on the Certificate holder's CE Marking Declarations of Performance.
(2) Values derived from short-term tests in accordance with BS EN ISO 10319 : 2015.
(3) The characteristic short-term tensile strength (T_{char}) values are the mean short-term tensile strength minus 1 x the tolerance value, in accordance with BS EN 13251 : 2016.

Table 7 Performance characteristics — cross machine direction (CMD) for Paragrid Geocomposites

Grade	Performance values[(1)]			Values used for design	
	Short term tensile strength[(2)] (kN per m width)		Mean strain at maximum tensile strength[(2)] (%)		
	Mean value	Tolerance		Tchar[(3)] (kN per metre width)	Nominal strain at T_{char} load (%)
30/5	6	-1	11 ±1	5	9
40/5	6	-1	11 ±1	5	9
50/5	6	-1	11 ±1	5	9
65/5	6	-1	11 ±1	5	9
80/5	6	-1	11 ±1	5	9
90/5	6	-1	11 ±1	5	9
100/5	6	-1	11 ±1	5	9
110/5	6	-1	11 ±1	5	9
120/5	6	-1	11 ±1	5	9
135/5	6	-1	11 ±1	5	9
150/5	6	-1	11 ±1	5	9
160/5	6	-1	11 ±1	5	9
175/5	6	-1	11 ±1	5	9
200/5	6	-1	11 ±1	5	9
30/15	17	-2	11 ±1	15	9
50/15	17	-2	11 ±1	15	9
50/50	57	-7	11 ±1	50	9
100/100	106	-6	11 ±1	100	9
80/15	16	-1	11 ±1	15	9
100/15	16	-1	11 ±1	15	9
120/15	17	-2	11 ±1	15	9
150/15	17	-2	11 ±1	15	9
160/15	17	-2	11 ±1	15	9
200/15	17	-2	11 ±1	15	9

(1) Performance values as declared on the Certificate holder's CE Marking Declarations of Performance.

(2) Values derived from short-term tests in accordance with BS EN ISO 10319 : 2015.

(3) The characteristic short-term tensile strength (T_{char}) values are the mean short-term tensile strength minus 1 x the tolerance value, in accordance with BS EN 13251 : 2016.

Table 8 Performance characteristics — cross machine direction (CMD) for Paragrid HF Geocomposites

Grade	Performance values[(4)]			Values used for design	
	Short term tensile strength[(5)] (kN per m width)		Mean strain at maximum tensile strength[(5)] (%)		
	Mean value	Tolerance		Tchar[(6)] (kN per metre width)	Nominal strain at T_{char} load (%)
90/5	6	-1	2.7 ±1	5	3
100/5	6	-1	2.7 ±1	5	3
125/5	6	-1	2.7 ±1	5	3
150/5	6	-1	2.7 ±1	5	3
175/5	6	-1	2.7 ±1	5	3
200/05	6	-1	2.7 ±1	5	3
250/05	6	-1	2.7 ±1	5	3

(1) Performance values as declared on the Certificate holder's CE Marking Declarations of Performance.

(2) Values derived from short-term tests in accordance with BS EN ISO 10319 : 2015.

(3) The characteristic short-term tensile strength (T_{char}) values are the mean short-term tensile strength minus 1 x the tolerance value, in accordance with BS EN 13251 : 2016.

Table 9 Performance characteristics — cross machine direction (CMD) for Paradrain Geocomposites

Grade	Performance values[1]			Values used for design	
	Short term tensile strength[2] (kN per m width)		Mean strain at maximum tensile strength[2] (%)		
	Mean value	Tolerance		Tchar[3] (kN per metre width)	Nominal strain at T_{char} load (%)
50/5	6	-1	11 ±1	5	9
80/5	6	-1	11 ±1	5	9
100/5	6	-1	11 ±1	5	9
150/5	6	-1	11 ±1	5	9
200/5	6	-1	11 ±1	5	9

(1) Performance values as declared on the Certificate holder's CE Marking Declarations of Performance.
(2) Values derived from short-term tests in accordance with BS EN ISO 10319 : 2015.
(3) The characteristic short-term tensile strength (T_{char}) values are the mean short-term tensile strength minus 1 x the tolerance value, in accordance with BS EN 13251 : 2016.

2 Manufacture

2.1 The products comprise an open array of geocomposite straps, pressure and heat bonded together at specified centres to give the required performance characteristics. The geocomposite straps are made from tendons of high tenacity PET yarn coated in polyethylene using a vacuum die-coating process, then passed through rollers to give a knurled finish on the sheath. An impressed mark denoting the product grade is applied on one side of the straps at intervals of approximately 180 mm.

2.2 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.

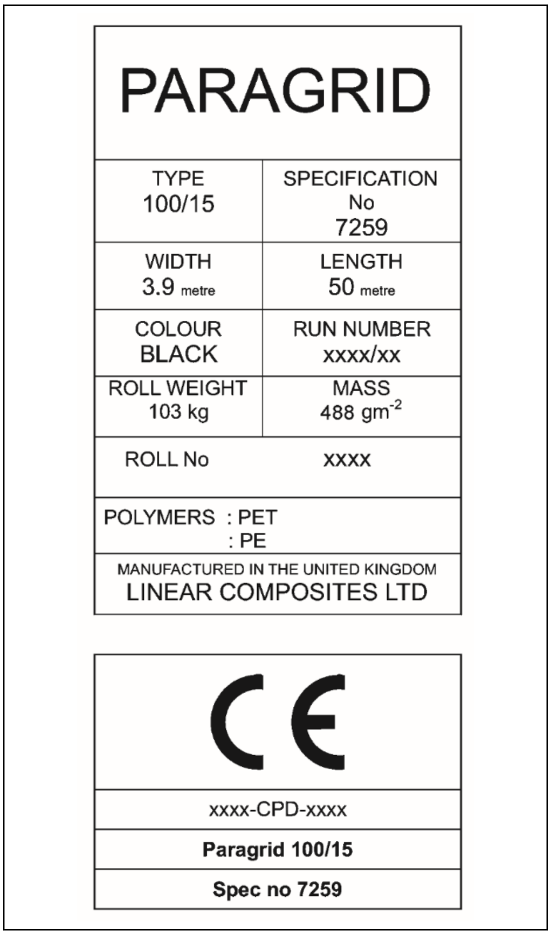
2.3 The management system of Linear Composites Ltd has been assessed and registered as meeting the requirements of BS EN ISO 9001 : 2015 by Lloyd's Register Quality Assurance (Certificate 10070947).

3 Delivery and site handling

3.1 Paragrid and Paradrain Geocomposites are delivered in rolls 3.9 m wide[1]. Paragrid HF is delivered in rolls 4.5 m wide[1]. Each roll is wrapped in a black polythene bag for transit and site protection, and labelled with the grade and identification. The packaging should not be removed until immediately prior to installation. Each roll has the product grade printed at regular intervals.

(1) Other sizes are available on request.

Figure 2 Label



3.2 Rolls should be stored in clean, dry conditions and protected from mechanical or chemical damage and site temperatures in excess of 30°C. When laid horizontally, the rolls may be stacked up to five high. Other loads must not be stored on top of the stack.

3.3 Toxic fumes are given off if the geocomposites catch fire and, therefore, the necessary precautions should be taken, according to the instructions of the material safety data sheet for the products.

Assessment and Technical Investigations

The following is a summary of the assessment and technical investigations carried out on Paragrid, Paragrid HF and Paradrain Geocomposites.

Design Considerations

4 Use

4.1 Paragrid, Paragrid HF and Paradrain Geocomposites are satisfactory for use as reinforcement in slopes and embankments with maximum slope angles of 70°, when designed in accordance with this Certificate.

4.2 Structural stability is achieved through the frictional interaction of the soil particles and the geocomposites, and the tensile strength of the geocomposites.

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

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

4.5 Particular attention should be paid in design to:

- site preparation and embankment construction
- fill material properties
- drainage
- protection of the products against damage from site traffic and installation equipment
- the stability of existing structures in close proximity
- design of the embankment facing.

4.6 The working drawings should show the correct orientation of the geocomposites. Each layer of reinforcement must be continuous in the direction of load, ie without overlaps.

5 Practicability of installation

The products must be installed by trained ground engineering contractors in accordance with the specifications and construction drawings (see the *Installation* part of this Certificate).

6 Design

Design methodology

6.1 Reinforced soil embankments constructed using Paragrid, Paragrid HF and Paradrain Geocomposites should be designed in accordance with BS 8006-1 : 2010 and the *Manual of Contract Documents for Highway Works*, Volume 1 *Specification for Highway Works*.

6.2 The typical service life given in BS 8006-1 : 2010, Table 7, for reinforced soil embankments is 60 years.

Geocomposite reinforcement

6.3 In accordance with the methodology set out in BS 8006-1 : 2010, Annex 3, the design strength of the reinforcement (T_D) is calculated as:

$T_D = T_{CR}/f_m$

where:

T_{CR} is the long-term tensile creep rupture strength of the reinforcement at the specified design life and design temperature

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 required to establish the above reduction factors.

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

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

where:

T_{char} is the characteristic short-term strength of the reinforcement taken from Tables 4 to 9.

RF_{CR} is the reduction factor for creep (see section 7).

6.5 The material safety factor (f_m) 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 UV 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/geocomposite interaction

6.7 There are two modes of interaction between the soil and the reinforcement that need to be considered during the design:

- direct sliding — in which the soil above the layer of reinforcement can slide over the reinforcement
- pull-out — in which the layer of reinforcement pulls out of the soil, after it has mobilised the maximum available bond stresses.

6.8 CIRIA SP123 : 1996, Sections 4.5 and 4.6, describes the following methods for determining resistance to direct sliding and maximum available bond, to which the appropriate partial factors should be applied in accordance with BS 8006-1 : 2010.

Direct sliding

6.9 The theoretical expression for the coefficient for resistance to direct sliding is:

$f_{ds} \times \tan \phi'$

where:

f_{ds}	is the coefficient of direct sliding
$\tan \phi'$	is the shearing resistance of the soil
ϕ'	is the angle of shearing resistance for the soil.

6.10 The direct sliding coefficient (f_{ds}) is calculated as:

$f_{ds} = \alpha_s \times (\tan\sigma/\tan \phi') + (1 - \alpha_s)$

where:

α_s	is the proportion of plane sliding area that is solid
σ	is the angle of skin friction, soil on planar reinforcement surface
$\tan \sigma/\tan \phi'$	is the coefficient of skin friction between the soil and geocomposite material.

6.11 For initial design purposes, the coefficient of skin friction for Paragrid, Paragrid HF and Paradrain ($\tan \delta/\tan \phi'$) for determining the resistance to direct sliding for the geocomposites when buried in compacted frictional fill may be conservatively taken as 0.7 for compacted frictional fill (ϕ' = 30°) and 0.4 for compacted cohesive fill (ϕ' = 15°). Values for the proportion of plane sliding area that is solid (α_s) are given in Tables 10, 11 and 12 for Paragrid, Paragrid HF and Paradrain, respectively.

Table 10 Soil geocomposite interaction parameters for Paragrid Geocomposites

Grade	α_s[(1)]	Ratio of bearing[(2)] surface to plan area α_b x B/2S
30/5	0.36	0.0006
40/5	0.36	0.0006
50/5	0.36	0.0006
65/5	0.36	0.0006
80/5	0.36	0.0006
90/5	0.36	0.0006
100/5	0.36	0.0006
110/5	0.36	0.0006
120/5	0.58	0.0004
135/5	0.58	0.0004
150/5	0.47	0.0005
160/5	0.58	0.0004
175/5	0.58	0.0004
200/5	0.47	0.0005
30/15	0.39	0.0012
50/15	0.39	0.0012
50/50	0.54	0.0041
100/100	0.54	0.0059
80/15	0.39	0.0012
100/15	0.39	0.0012
120/15	0.50	0.0010
150/15	0.50	0.0010
160/15	0.50	0.0010
200/15	0.50	0.0010

(1) α_s is the proportion of the plane sliding area that is solid and is required for the calculation of the bond coefficient (f_b) and the direct sliding coefficient (f_{ds}) (see sections 6.10 and 6.14).
(2) The ratio of bearing surface to plan area is required to calculate the bond coefficient (f_b) in accordance with CIRIA SP123 : 1996 (see section 6.14 of this Certificate):
- α_b is the proportion of the grid width available for bearing
- *B* is the thickness of a transverse member of a grid taking bearing
- *S* is the spacing between transverse members taking bearing.

Table 11 Soil geocomposite interaction parameters for Paragrid HF Geocomposites

Grade	α_s[(1)]	Ratio of bearing[(2)] surface to plan area α_b x B/2S
90/5	0.30	0.00041
100/5	0.30	0.00041
125/5	0.30	0.00041
150/5	0.30	0.00041
175/5	0.30	0.00041
200/5	0.31	0.00041
250/05	0.31	0.00040

(1) α_s is the proportion of the plane sliding area that is solid and is required for the calculation of the bond coefficient (f_b) and the direct sliding coefficient (f_{ds}) (see sections 6.10 and 6.14).
(2) The ratio of bearing surface to plan area is required to calculate the bond coefficient (f_b) in accordance with CIRIA SP123 : 1996 (see section 6.14 of this Certificate):
- α_b is the proportion of the grid width available for bearing
- *B* is the thickness of a transverse member of a grid taking bearing
- *S* is the spacing between transverse members taking bearing.

Table 12 Soil geocomposite interaction parameters for Paradrain Geocomposites

Grade	α_s(1)	Ratio of bearing(2) surface to plan area α_b x B/2S
50/5	0.36	0.0006
80/5	0.36	0.0006
100/5	0.36	0.0006
150/5	0.47	0.0005
200/5	0.47	0.0005

(1) α_s is the proportion of the plane sliding area that is solid and is required for the calculation of the bond coefficient (f_b) and the direct sliding coefficient (f_{ds}) (see sections 6.10 and 6.14).

(2) The ratio of bearing surface to plan area is required to calculate the bond coefficient (f_b) in accordance with CIRIA SP123 : 1996 (see section 6.14 of this Certificate):

- α_b is the proportion of the grid width available for bearing
- *B* is the thickness of a transverse member of a grid taking bearing
- *S* is the spacing between transverse members taking bearing.

6.12 For detailed design, the resistance to direct sliding should be determined from soil and geocomposite specific shear box testing.

Bond

6.13 The theoretical expression for the coefficient for bond shearing resistance is:

$f_b \times \tan \phi'$

where:

f_b	is the bond coefficient
$\tan \phi'$	is the shearing resistance of the soil
ϕ'	is the angle of shearing resistance for the soil.

6.14 The bond coefficient may be calculated as:

$f_b = \alpha_s \times (\tan \sigma / \tan \phi') + (\sigma'_b/\sigma_n) \times (\sigma_b \times B/2S) \times (1/\tan \phi')$

where:

a_s	is the proportion of plane sliding area that is solid
$\tan \sigma/\tan \phi'$	is the coefficient of skin friction between the soil and geocomposite material
σ'_b/ σ'_n	is the bearing stress ratio
$\alpha_s \times B/2S$	is the ratio of bearing surface to plan area
ϕ'	is the angle of shearing resistance in terms of effective stress
σ	is the angle of skin friction, soil on planar reinforcement surface
σ'_b	is the effective bearing stress on the reinforcement
σ'_n	is the normal effective stress.

6.15 For initial design purposes, the coefficient of skin friction for Paragrid, Paragrid HF and Paradrain ($\tan \delta/\tan \phi'$) for determining bond when the geocomposite is buried in compacted frictional fill may be conservatively taken as 0.7 for compacted frictional fill (ϕ' = 30°) and 0.4 for compacted cohesive fill (ϕ' = 15°). Values for the ratio of bearing surface to plan area ($\alpha_b \times B/2S$) are given in Tables 10 to 12. Typical values for the bearing stress ratio (σ'_b/ σ'_n) are given in CIRIA SP123 : 1996, Table 4.1.

6.16 The BBA recommends that site-specific pull-out tests are carried out in accordance with BS EN 13738 : 2004 to confirm the value of bond coefficient (f_b) used in the final design. Values of fsf>1.0 have been reported based on site and soil specific testing.

Fill material

6.17 The designer should specify the relevant properties of fill material deemed acceptable for the purpose of the design. Acceptable materials should satisfy the requirements of BS 8006-1 : 2010 and the MCHW, Volume 1.

Facings

6.18 Where the products are used to form the facing, natural or artificial protection must be provided to the geocomposites and fill material to protect the geocomposites against damage from UV light, fire and vandalism, and to protect the fill material from erosion.

6.19 Other types of facing including preformed panels, gabions/gabion sacks and other proprietary systems may be used, but are outside the scope of this Certificate. Further guidance is given in BS 8006-1 : 2010.

7 Mechanical properties

Tensile strength — short-term

7.1 Characteristic short-term tensile strength (T_{char}) and strain values for the products are given in Tables 13 and 14. A typical short-term stress/strain curve is shown in Figures 3 and 4. Short-term strain at varying percentages of characteristic strength is given in Tables 13 and 14.

Figure 3 Typical short-term stress/strain curve for Paragrid and Paradrain Geocomposites

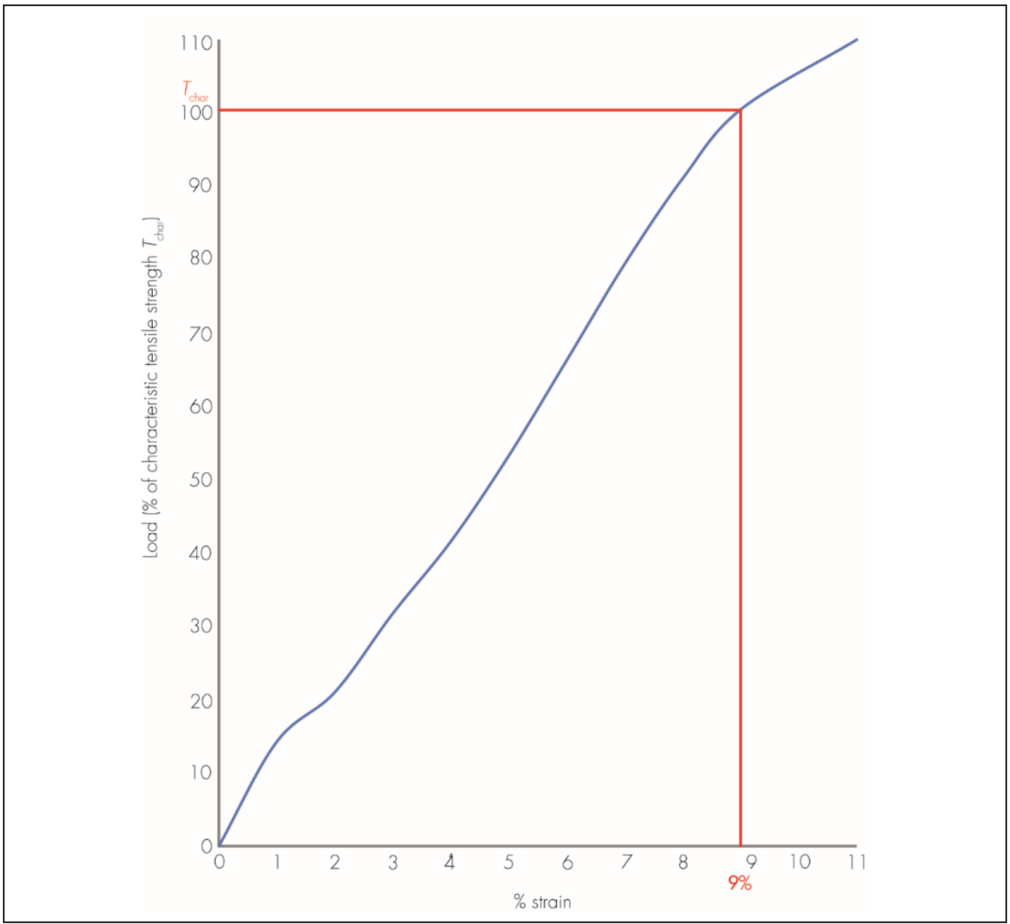


Table 13 Typical short-term strain against load (as percentage of the T_{char}*)*

Strain	% of T_{char}
At 2%	21
At 3%	32
At 4%	42
At 5%	53
At 6%	66

Figure 4 Typical short-term stress/strain curve for Paragrid HF

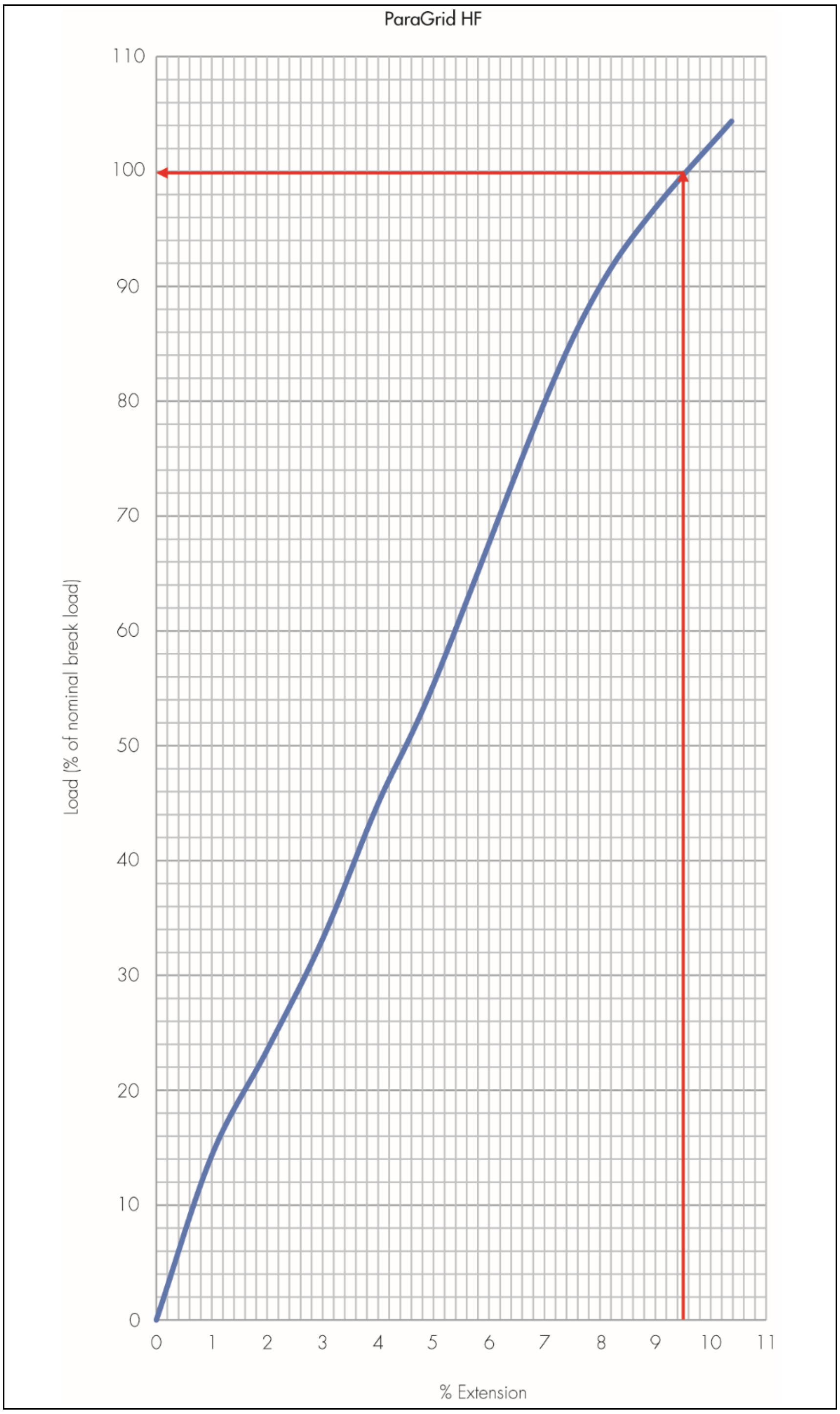


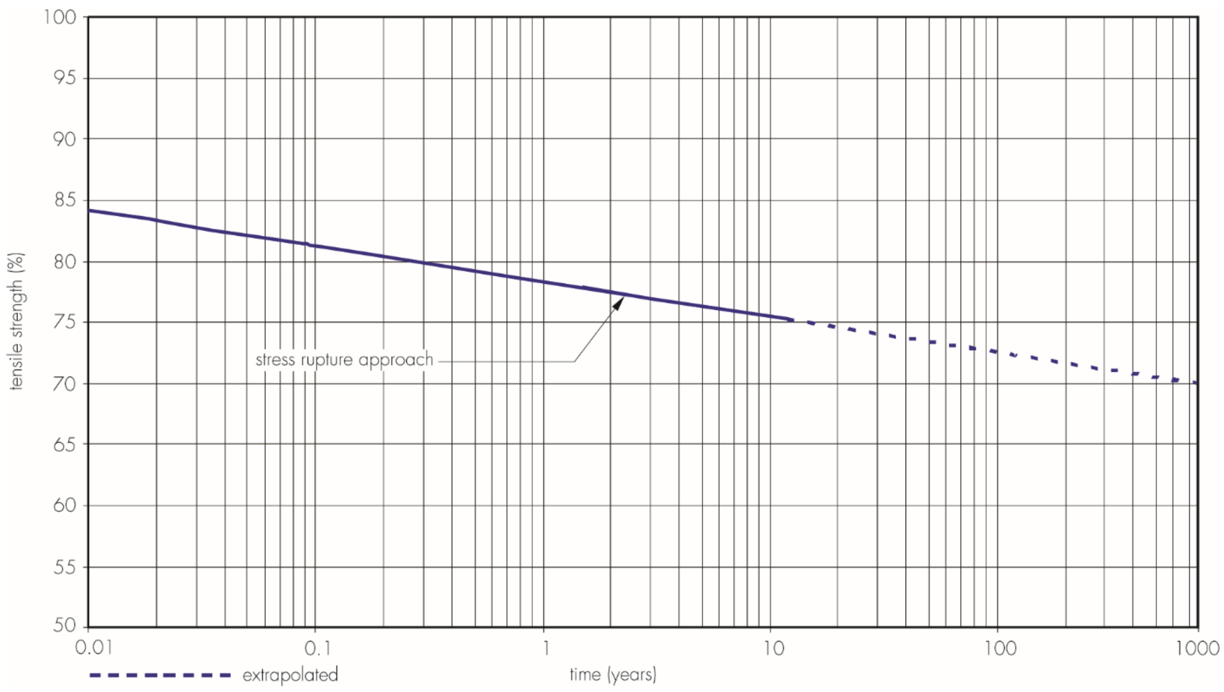
Table 14 Typical short-term strain against load (as percentage of the T_{char})

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

Tensile strength — long-term

7.2 The long-term tensile creep rupture strength performance of Paragrid, Paragrid HF and Paradrain Geocomposites has been determined in accordance with the principles of PD ISO/TR 20432 : 2007. A stress rupture line (see Figure 5) 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 the value of the tensile creep rupture strength (T_{CR}) can be determined for the appropriate design life. By applying temperature shift factors determined for Paragrid, Paragrid HF and Paradrain Geocomposites, tensile creep rupture strength values (T_{CR}) can be determined for other design temperatures.

Figure 5 Regression line for life expectancy at constant stress defined by percentage of characteristic short-term strength at 20°C



7.3 Long-term tensile strength (T_{CR}) for Paragrid, Paragrid HF and Paradrain Geocomposites can be derived for a 60- and 120-year design life and design temperatures of 0, 20, 25, 30 and 40°C, using the formula given in section 6.4 and the long-term creep reduction factors (RF_{CR}) shown in Table 15.

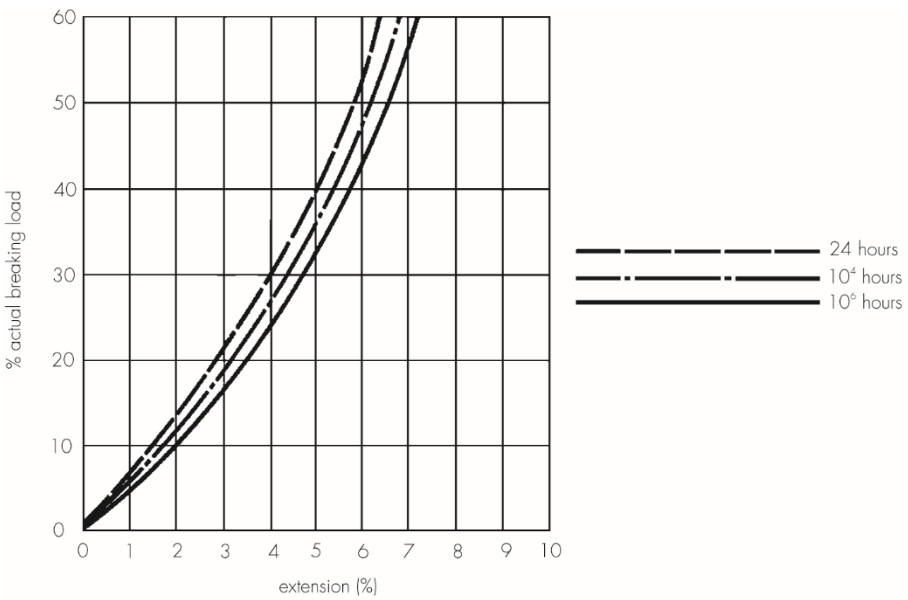
Table 15 Long-term creep reduction (RF_{CR}) for Paragrid, Paragrid HF and Paradrain Geocomposites at various temperatures and design life

Design temperature (°C)	Creep reduction factor (RF_{CR})	
	60-year design life	120-year design life
0	1.28	1.30
20	1.37	1.38
25	1.39	1.40
30	1.41	1.43
40	1.46	1.48

Creep strain

7.4 Creep strain is not normally considered an issue for the design of embankments and slopes. However, for situations where creep strain is applicable, the isochronous curves for Paragrid, Paragrid HF and Paradrain Geocomposites are shown in Figure 6.

Figure 6 Load extension curve



Installation damage (RF_{ID})

7.5 To allow for loss of strength owing to mechanical damage that might be sustained during installation, the appropriate value for RF_{ID} may be selected from Tables 16 and 17. These reduction factors have been established from full-scale installation damage tests using a range of materials, the gradings of which can be seen in Figure 7. For soils not covered by Tables 16 and 17, appropriate values of RF_{ID} should be determined from site-specific trials.

Table 16 Reduction factor – installation damage for Paragrid and Paradrain (RF_{ID})

Soil type	D_{50} particle size[1] (mm)	D_{90} particle size[1] (mm)	Paragrid and Paradrain grade	Reduction factor (RF_{ID})
Silty sand 1[2]	0.15	0.70	30/5	1.04
			80/5	1.01
			150/5	1.01
Silty sand 2[3]	0.09	0.45	30/5	1.05
			50/5	1.04
			80/5	1.03
			100/5	1.02
Concrete sand 1[2]	0.70	4.0	30/5	1.08
			50/5	1.02
			150/5	1.01
Concrete sand 2[3]	0.09	0.45	30/5	1.05
			50/5	1.04
			80/5	1.03
			100/5	1.02
Coarse gravel 1[2]	13	23	30/5	1.10
			50/5	1.03
			150/5	1.02
Coarse gravel 2[3]	22	28	30/5	1.16
			50/5	1.15
			80/5	1.12
			100/5	1.10

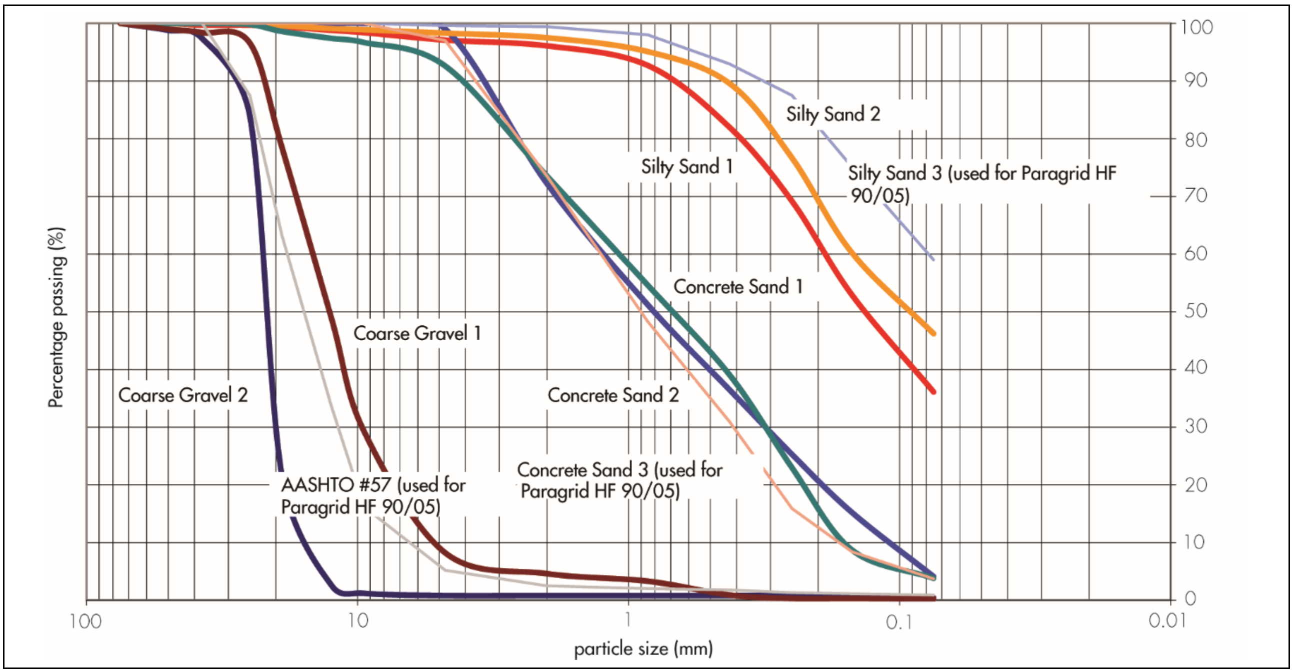
(1) Detailed particle size distributions are shown in Figure 4.
(2) Depth of soil layer before compacting: 200 mm; weight of vibrating roll: 1600 $kg \cdot m^{-1}$; number of passes: 8.
(3) Depth of soil layer before compacting: 200 mm; weight of vibrating roll: 2030 $kg \cdot m^{-1}$; number of passes: 10.

Table 17 Reduction factor – installation damage for Paragrid HF (RF_{ID})

Soil type	D_{50} particle size[1] (mm)	D_{90} particle size[1] (mm)	Paragrid HF grade	Reduction factor (RF_{ID})
Silty sand 3[2]	-	0.30	90/5	1.01
Concrete sand 3[2]	0.90	3.7	90/5	1.02
Coarse gravel 3[2]	17	28	90/5	1.04

(1) Detailed particle size distributions are shown in Figure 5.
(2) Depth of soil layer before compacting: 200 mm; weight of vibrating roll: 3750 $kg \cdot m^{-1}$; number of passes: 10.

Figure 7 Particle size distributions of soils used in installation damage testing



8 Effects of environmental conditions

Weathering (including exposure to UV light)

8.1 A reduction factor (RF_W) of 1.00 may be used for design provided the geocomposites are protected from exposure to sunlight in accordance with the recommendations of this Certificate and provided the periods of exposure are limited to a maximum of one month. Further investigation is required for exposure periods exceeding one month.

Chemical/environmental effects

8.2 The polyethylene sheath used on Paragrid, Paragrid HF and Paradrain Geocomposites acts as a chemical barrier which, if 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 cause little or no damage to the polyethylene sheath. Compaction can reduce the high pH level of a fill. Tests have shown that, 48 hours after the compaction stage, the pH level of a soil-lime mix reduces from 12.5 to 11. Where appropriate, site and soil specific testing should be carried out to verify the reduction in the pH of the soil.

8.3 The geocomposites are highly resistant to microbial attack.

8.4 To account for environmental conditions, the appropriate reduction factors (RF_{CH}) should be selected from Table 18.

Table 18 Reduction factor RF_{CH}

Design temperature (°C)	Reduction Factors (RF_{CH})					
	60 year service life			120 year service 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
20	1.02	1.03	1.07	1.03	1.05	1.12
25	1.03	1.05	1.09	1.07	1.09	1.15
30	1.06	1.10	1.14	1.15	1.17	1.25

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

9.1 For Paragrid, Paragrid HF and Paradrain Geocomposites, the factor of safety for the extrapolation of data (f_s) should be taken as given in Table 19.

Table 19 Factors of safety for extrapolation of data	
Design life (years)	f_s
60	1.02
120	1.05

9.2 The values in Table 17 have been calculated in accordance with PD ISO/TR 20432 : 2007, using the R_1 and R_2 values given in Table 20.

Table 20 R_1 and R_2 values for determination of f_s			
Factor	Taking account of:	Design life (years)	
		60	120
R_1	Extrapolation of creep rupture data	1.00	1.00
R_2	Extrapolation of chemical data	1.02	1.05

10 Maintenance

As the products are confined within the soil and have suitable durability, maintenance is not required.

11 Durability

When designed and installed in accordance with the requirements of BS 8006-1 : 2010, BS EN 14475 : 2006 and this Certificate, Paragrid, Paragrid HF and Paradrain Geocomposites will have a service life of up to 120 years, exceeding the typical design life required for reinforced soil embankments.

Installation

12 General

12.1 The construction of reinforced soil embankments incorporating Paragrid, Paragrid HF and Paradrain Geocomposites should be in accordance with the Certificate holder's installation instructions, BS EN 14475 : 2006 and the MCHW, Volume 1.

12.2 Care should be taken to ensure that the products are laid with the warp (longitudinal) direction parallel to the direction of principal stress. Design drawings should indicate orientation of the product (see section 4.6).

13 Procedure

13.1 The product is laid by unrolling manually or mechanically to the length required and cutting with a sharp knife or scissors.

13.2 Lengths of Paragrid, Paragrid HF and Paradrain Geocomposites are laid flat without folds, parallel to each other and with widths in contact. Each reinforcing layer must be continuous in the direction of loading without overlapping of adjacent strips. Strip misalignment must not exceed 50 mm over a distance of 5 metres. Pins or a stretching device may be used to control alignment and also to induce a small pre-stressing load prior to filling.

13.3 Fill material is placed to a minimum compacted depth of 150 mm, with particular care being taken to ensure that the products are adequately covered before compaction or trafficking. Construction traffic will damage the unprotected products.

13.4 The maximum thickness of compaction layers depends on the design, type of fill material and compaction equipment employed, but depths should not exceed 500 mm.

13.5 The products must be covered with fill within the time specified in the design to prevent degradation caused by UV light (see section 8.1).

13.6 Facings are positioned as detailed on the engineer's design drawing and, where the products are used for this purpose, they must be wrapped around and anchored back into the fill. Formwork is used to assist in maintaining the shape of the facing but, whether prefabricated or otherwise, such facings are outside the scope of this Certificate.

Technical Investigations

14 Tests

14.1 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.

14.2 An assessment was made of data relating to:

- evaluation of long- and short-term tensile properties
- chemical resistance including hydrolysis
- resistance to biological attack
- resistance to weathering
- effects of temperature
- site damage trials and resistance to mechanical damage
- soil/geocomposites interaction.

14.3 Calculations were made to establish the plane sliding area that is solid and the ratio of bearing surface to plane area.

14.4 The practicability of installation and ease of handling were assessed.

Bibliography

BS 8006-1 : 2010 + A1 : 2016 *Code of practice for strengthened/reinforced soils and other fills*

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

BS EN 13738 : 2004 *Geoxtextiles and geotextile related products — Determination of pullout resistance*

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

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

BS EN ISO 9864 : 2005 *Geosynthetics — Test method for the determination of mass per unit area of geotextiles and geotextile-related products*

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

CIRIA SP123 : 1996 *Soil Reinforcement with Geotextiles, Jewell R.A*

Manual of Contract Documents for Highway Works, Volume 1 *Specification for Highway Works*

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

Conditions of Certification

15 Conditions

15.1 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.

15.2 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.

15.3 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.

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

15.5 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.

15.6 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.

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