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BBA BRITISH BOARD OF AGRÉMENT
TECHNICAL APPROVALS FOR CONSTRUCTION

Roads and Bridges
Agrément Certificate
No 03/R133

PRODUCT SHEET 1 — ENKAGRID PRO GEOGRIDS

The Highways Agency requirements to which this Certificate is subject are detailed on page 2

PRODUCT SCOPE AND SUMMARY OF CERTIFICATE

This Certificate relates to Enkagrid PRO Geogrids, polymeric geogrids for use as reinforcement in embankments with slope angles up to 70°.

AGRÉMENT CERTIFICATION INCLUDES:

- factors relating to compliance with Building Regulations where applicable
- factors relating to additional non-regulatory information 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

Mechanical properties — the following key areas have been evaluated:

- short-term tensile strength and elongation and long-term tensile strength and elongation properties of geogrids (see sections 6.1 to 6.5)
- safety factors for manufacture and extrapolation of data (f_m), installation damage (f_d) and environmental effects (f_e) (see sections 6.7 to 6.9)
- soil/geogrid interaction (bond strength and direct sliding) (see sections 6.18 to 6.21).

Durability — geogrids have good resistance to hydrolysis, chemical corrosion, biodegradation, temperature and UV exposure used in fills normally encountered in civil engineering practice (see section 7).

The BBA has awarded this Agrément Certificate forEnkagrid PRO Geogrids to Colbond BV as fit for their intended use provided they are installed, used and maintained as set out in this Agrément Certificate.

On behalf of the British Board of Agrément

Date of First issue: 28 March 2003
Date of Second issue: 31 March 2008

Head of Approvals — Engineering

Chief Executive

The BBA is a UKAS accredited certification body — Number 113. The schedule of the current scope of accreditation for product certification is available in pdf format via the UKAS link on the BBA website at www.bbacerts.co.uk

Readers are advised to check the validity and latest issue number of this Agrément Certificate by either referring to the BBA website or contacting the BBA direct.

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Highways Agency Requirements

Approval procedures shall be in accordance with HA Standard HD 22/02 (DMRB 4.1.2) (*Design Manual for Roads and Bridges*).

The products are for use in embankments with an effective slope angle of up to 70°.

The design, materials specification and construction methods adopted shall be in accordance with HA Advice Note HA 68/94 (DMRB 4.1.4) and Manual of Contract Documents for Highway Works (MCHW)[1], Volumes 1 and 2.

(1) The MCHW is operated by the Overseeing Organisations: The Highways Agency (HA), Transport Scotland, the Welsh Assembly Government and The Department for Regional Development (Northern Ireland).

Regulations

Construction (Design and Management) Regulations 2007

Construction (Design and Management) Regulations (Northern Ireland) 2007

Information in this Certificate may assist the client, CDM co-ordinator, designer and contractors to address their obligations under these Regulations.

See sections: 1 *Description* (1.3) and 2 *Delivery and site handling* (2.2 and 2.3).

General

This Certificate relates to Enkagrid PRO Geogrids, polymeric geogrids for use as reinforcement in embankments with slope angles up to 70°.

The products provide lateral restraint to suitable cohesive or frictional soils in embankments, with stability achieved by the interaction and interlocking of the soil particles with the Enkagrid PRO Geogrids.

The design and construction of embankments must be in accordance with the requirements of the Highways Agency (HA); acting on behalf of the Department for Transport, the Scottish Executive, the Welsh Assembly Government, and the Department for Regional Development, Northern Ireland; and the conditions set out in the *Design Considerations* and *Installation* parts of this Certificate.

Enkagrid PRO is a registered trademark of the Certificate holder.

Technical Specification

1 Description

1.1 Enkagrid PRO Geogrids are planar structures consisting of a regular open-network of integrally-connected tensile bars. The bars are made from extruded polyester and welded into grids. Bars in weft direction can be either single or double.

1.2 The geogrids are manufactured in five standard grades of various strengths and mesh sizes with either single or double weft bars. Typical geogrids are illustrated in Figure 1 and the range and specification of the geogrids assessed by the BBA are listed in Table 1.

1.3 The longitudinal direction is along the roll length and is indicated by a black bar (see Figure 1). Single or double weft bars are transparent.

1.4 Factory production control is exercised throughout all stages of manufacture. The specification of the incoming bars is checked against the Certificate of Conformity from the supplier. Checks made on the welded bars include visual examination, dimensional checks and batch performance tests.

Table 1 General specification

Grade	Mass[1] (gm^{-2}) + 9%	Average grid size[2] (mm) *A* x *B*	Average aperture size[2] (mm) *C* x *D*	Colour code[3]	Roll width 2.45 mm		Roll width 5.0 m	
					Roll length (m)	Gross roll weight (kg)[4]	Roll length (m)	Gross roll weight (kg)[4]
PRO 40d[5]	236	50 x 100	41 x 94	white and yellow	50	42	100	144
PRO 60d[5]	302	50 x 100	37 x 94	white and green	50	50	100	177
PRO 90d[5]	409	50 x 100	35 x 94	white and blue	50	63	100	231
PRO 120d[5]	464	50 x 100	34 x 94	white and grey	50	70	100	258
PRO 180d[5]	656	50 x 100	34 x 94	white and black	50	93	100	354
PRO 40	223	50 x 120	41 x 111	white and yellow	50	42	100	144
PRO 60	292	50 x 120	37 x 111	white and green	50	50	100	179
PRO 90	407	50 x 120	35 x 111	white and blue	50	63	100	229
PRO 120	460	50 x 120	34 x 111	white and grey	—	—	100	264
PRO 180	626	50 x 120	34 x 111	white and black	—	—	100	361

(1) Mass/unit area measured in accordance with BS EN ISO 9864 : 2005.

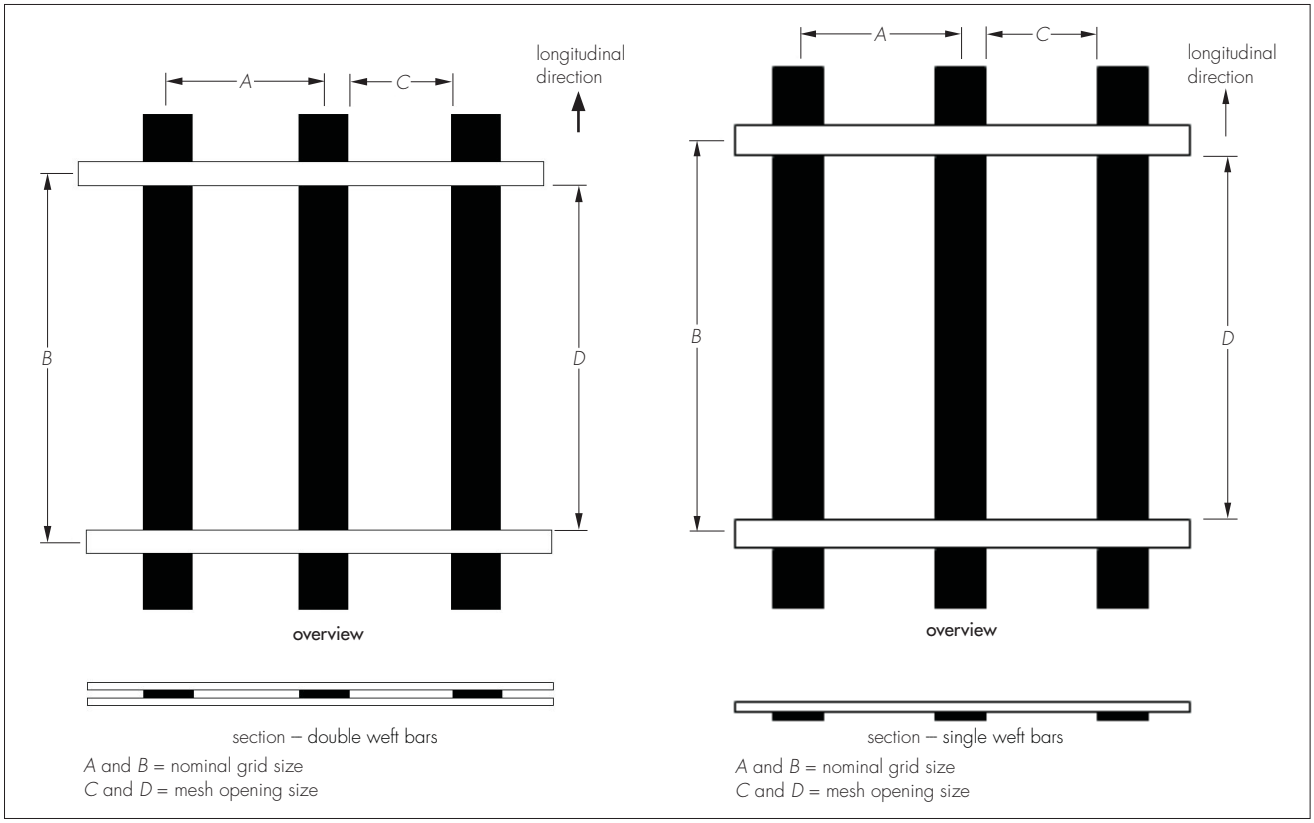
(2) Reference dimensions (see Figure 1).

(3) In accordance with BS EN ISO 10320 : 1999.

(4) Gross weight = geogrid + core + packaging.

(5) 'd' indicates geogrids with double weft.

Figure 1 Enkagrid PRO Geogrids



2 Delivery and site handling

2.1 Geogrids are delivered to site in rolls of approximately 0.5 m diameter. Roll lengths are 50 m or 100 m in length and 2.45 m or 5.0 m in width. Each roll is wrapped in a black polythene bag and each bag labelled with the geogrid grade and identification and CE Marking (see Figure 2). Packaging should not be removed until immediately prior to installation.

2.2 The ends of the actual rolls are sprayed with colour-coded paint to assist identification on site of a particular grade of geogrid (see Table 1) in accordance with BS EN ISO 10320 : 1999.

2.3 Rolls should be stored in clean, dry conditions and in accordance with HA requirements. The rolls should be protected from mechanical or chemical damage and extreme temperatures. Toxic fumes are given off if the geogrids catch fire and, therefore, the necessary precautions should be taken following the instruction of the material safety data sheet for the product.

2.4 When laid horizontally, the rolls may be stacked up to five high. Other loads should not be stored on top of the stack.

Figure 2 Typical label

Assessment and Technical Investigations

The following is a summary of the assessment and technical investigations carried out on Enkagrid PRO Geogrids.

Design Considerations

3 General

3.1 Enkagrid PRO Geogrids are satisfactory for use as polymeric reinforcement to embankments with maximum slope angles of 70°. Structural stability is achieved through the frictional interaction and mechanical interlocking of soil particles with the welded grid.

3.2 Prior to the commencement of the work, the designer shall satisfy the HA geotechnical certification requirements.

3.3 The geogrids may be used in combination with soil types having an effective angle of shearing resistance in the range of 15° to 50°, and where the design is in accordance with the procedures given in HA Advice Note HA 68/94 (DMRB 4.1.4).

3.4 Prior to, during and after installation, particular care should be taken to ensure:

- site preparation and embankment construction is as detailed in sections 8, 9 and 10
- fill properties satisfy the design specification
- drainage is adequate at all stages of construction, as required by the contract documents
- the geogrids are protected against damage from site traffic and installation equipment
- the stability of existing structures is not affected.

4 Practicability of installation

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

5 Design

Reinforced soil structure

5.1 For reinforced embankment projects in the UK, when designs are carried out by, or on behalf of the manufacturer, these should be in accordance with the procedures given in HA Advice Note HA 68/94 (DMRB 4.1.4).

5.2 Working drawings should show the correct orientation of the geogrids. Each layer of reinforcement must be continuous in the direction of load, ie no overlaps.

5.3 If the geogrids are cut or punched to allow for the placing of vertical drains, ducts or planting, only cross-direction bars should be cut. The integrity of the reinforcing longitudinal bar should not be interfered with in any way. Advice on openings should be sought from the Certificate holder.

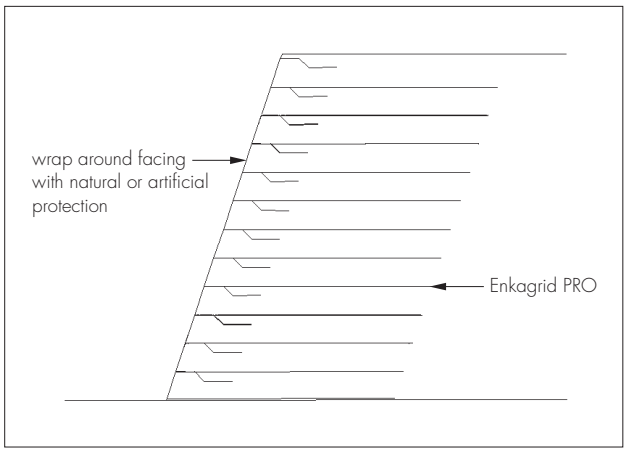
Facings

5.4 Where the geogrids are used to form the facing, natural or artificial protection should be provided for the geogrids and the fill material (see Figure 3), to protect the geogrids against damage from ultraviolet light (UV), fire and vandalism, and the fill material from erosion. Other facing covers or panels may be used but these are beyond the scope of this Certificate.

Fill properties

5.5 The designer should specify the relevant properties of a fill material deemed 'acceptable' for the purpose of the design. 'Acceptable' materials should meet the requirements of MCHW1 and HA Advice Note HA 68/94 (DMRB 4.1.4).

Figure 3 Facings



6 Mechanical properties

Tensile strength — short-term

6.1 The short-term tensile strength and strain values are given in Table 2.

Table 2 Performance characteristics

Grade	Short-term tensile strength[1] MD (machine direction) P_{ult} (kNm^{-1})	α_s[2]	Ratio of bearing[3] surface to plan area $\alpha_b \times B/2S$	Strain at maximum tensile strength[4] MD (machine direction) %
PRO 40d[5]	44 –4	0.24	0.005	6 ±2
PRO 60d	70 –6	0.30	0.005	6 ±2
PRO 90d	105 –7	0.35	0.005	6 ±2
PRO 120d	127 –7	0.36	0.005	6 ±2
PRO 180d	199 –9	0.36	0.004	6 ±2
PRO 40	44 –4	0.25	0.003	6 ±2
PRO 60	70 –6	0.31	0.002	6 ±2
PRO 90	105 –7	0.36	0.002	6 ±2
PRO 120	127 –7	0.37	0.002	6 ±2
PRO 180	199 –9	0.37	0.002	6 ±2

(1) Short-term tests in accordance with BS EN ISO 10319 : 1996, the values given are mean values of strength (P_{ult}) and tolerance (–) values correspond to the 95% confidence level ($P_{ult,c}$) in accordance with BS EN 13251 : 2001.

(2) 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}.

(3) The ratio is required to calculate bearing resistance in accordance with CIRIA SP123 : 1996 *Soil Reinforcement with Geotextiles*, Jewell R.A. (see section 6.19)
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

(4) Tests in accordance with BS EN ISO 10319 : 1996, the values given are the mean and tolerance values (+) of strain in accordance with BS EN 13251 : 2001.

(5) 'd' indicates geogrids with double weft.

Tensile strength — long-term

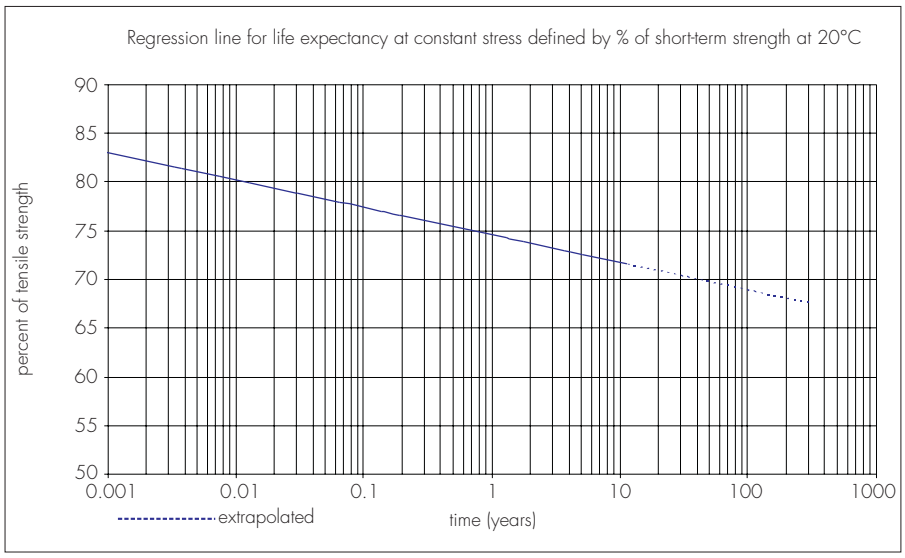
6.2 Long-term creep strain and rupture testing, generally in accordance with the principles of BS EN ISO 13431 : 1999, has been carried out for periods in excess of 10000 hours and at varying test temperatures, to cover the range of Enkagrid PRO Geogrids detailed in this Certificate.

6.3 Real time data for the bar has been extrapolated by <1.0 log cycles to allow the characteristic long-term strength (P_c) for design lives of up to 120 years to be determined.

6.4 Using principles of the stepped isothermal method for the geogrid material, predicted long-term strengths for a design life of 120 years at a design temperature of 20°C have been obtained from the measured data, without the need for direct extrapolation.

6.5 For ultimate limit state, for a 120-year design life P_c is 68% of characteristic short-term tensile strength ($P_{ult,c}$) and for a 60-year design life, 69% of characteristic short-term tensile strength ($P_{ult,c}$) (see Figure 4).

Figure 4 Time to rupture



Material safety factors

6.6 In establishing the permissible tensile strength of the geogrids and ensuring that during the life of the embankment the geogrid will not fail in tension, the BBA recommends that in line with the method of HA Advice Note HA 68/94, a set of partial material safety factors should be applied to P_c. Conditions of use outside the scope for which partial safety factors are defined (see also sections 6.7 to 6.9) are not covered by this Certificate and advice should be sought from the manufacturer.

Manufacture and extrapolation of data — partial safety factor (f_m)

6.7 To allow for variation in manufacture and product dimensions and to account for extrapolation of data the value for the safety factor (f_m) is given in Table 3.

Table 3 Partial material safety factor — manufacture and extrapolation of data

Design life (years)	Safety factor (f_m)
120	1.10
60	1.05

Installation damage and environmental effects — partial safety factors (f_d and f_e)

6.8 To allow for loss of strength due to mechanical damage that may be sustained during installation, the appropriate value for fd may be selected from Table 4. These partial safety factors were achieved using a range of materials whose gradings can be seen in Figure 5 with a minimum compacted depth of 200 mm. For soils not covered by Table 4, appropriate values of f_d may be determined from site specific trials or the engineer may exercise engineering judgement to interpolate between the values given.

6.9 To account for environmental conditions the appropriate value for f_e should be selected from Table 5.

Table 4 Partial safety factor — mechanical installation damage (f_d)

Soil type	D_{90} particle size (mm)	Grade					
		PRO 40d[1]	PRO 90d[1]	PRO 180d[1]	PRO 40	PRO 90	PRO180
Coarse gravel	⩽35	1.05	1.06	1.02	–	–	–
Coarse gravel with sand	⩽30	–	–	–	1.03	1.05	1.03
Silty sand	⩽4	–	–	–	1.04	1.02	1.02
Sandy silt	⩽0.25	1.02	1.02	1.06	–	–	–

(1) 'd' indicates geogrids with double weft.

Figure 5 Particle size distributions of fills used in installation damage testing

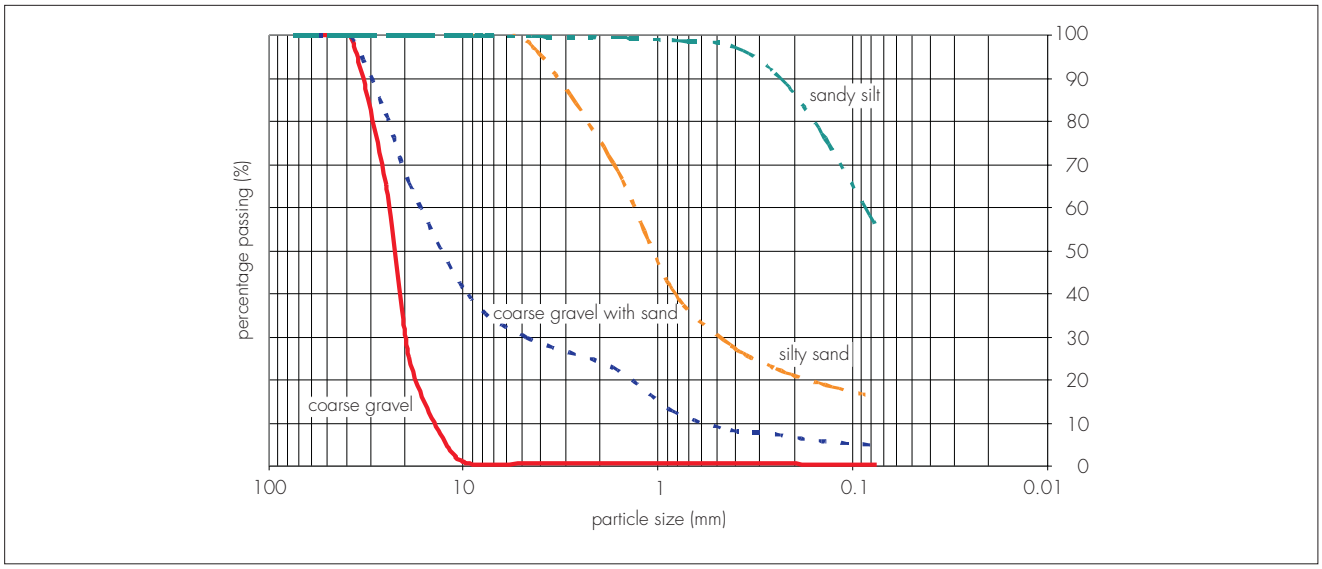


Table 5 Partial safety factor — environmental effects (f_e)

Soil pH level (pH)	Safety factor (f_e)
2.0–4.0	1.10
4.1–8.9	1.00
9.0–10.0	1.10
10.1–12.5	see section 6.11

Hydrolysis

6.10 Within a soil environment where pH ranges from pH 2.0 to 10.0 and temperatures are typical of those normally found in embankments in the United Kingdom, the strength of Enkagrid PRO Geogrids is not adversely affected by hydrolysis, for applications where sustained soil temperatures are below 30°C.

6.11 Within a soil environment where pH ranges from 10.1 to 12.5 and sustained soil temperatures are below 20°C, a partial safety factor for environmental effects (f_e) of 1.16 for a 60-year life and 1.34 for a 120-year life should be applied.

Chemical resistance

6.12 The bars have a high resistance to degradation from the types of chemicals typically found in soils used for civil engineering purposes.

Microbial attack

6.13 The bars are highly resistant to microbial attack.

Effects of temperature

6.14 The long-term creep performance of the geogrids is not adversely affected by the range of soil temperatures typical of embankments in the UK for service loads of up to 50% short-term tensile strength (P_{ult}).

6.15 Where the geogrids may be exposed to temperatures higher than 30°C or lower than 0°C for significant periods of time, consideration should be given to the temperature levels, the range of temperatures, period of exposure and stress levels at the location in question.

Resistance to UV light

6.16 The BBA recommends that natural or artificial protection should be provided to protect exposed the geogrids and fill materials within four months of initial exposure to natural daylight.

Design load (P_{des})

6.17 The maximum design load (P_{des}) that the reinforcement can be relied upon to deliver at the end of the design life and at the design temperature, can be calculated from:

$$P_{des} = \frac{P_c}{f_d\, f_e\, f_m}$$

Soil/geogrid interaction

Bond strength

6.18 The bond strength for geogrid reinforcement may be expressed as:

$f_b \tan\phi'$ where f_b is the bond coefficient[1].

(1) Synonymous with the term bearing factor (∝') defined in HA Advice Note HA 68/94.

6.19 The use of laboratory pull-out testing to determine the value of the bond coefficient (f_b) is not recommended at present. For routine design purposes, values may be estimated using the theoretical method of Jewell (section 4.6 of CIRIA SP123, 1996). The BBA recommend that site specific pull-out testing is carried out to confirm the value of bond coefficient (f_b) used in the final design. Values of f_b >1.0 have been reported based on site and soil specific testing.

Direct sliding

6.20 The direct sliding resistance of geogrid reinforcement may be expressed as:

$f_{ds} \tan\phi'$ where f_{ds} is a direct sliding coefficient[1]

$$f_{ds} = \alpha_s \left(\frac{\tan\delta}{\tan\phi'}\right) + (1-a_s)$$

where $\left(\frac{\tan\delta}{\tan\phi'}\right)$ is the coefficient of skin friction (f_{sf}), and

α_s is the proportion of plane sliding area that is solid (see Table 1).

(1) Synonymous with the term interface sliding factor (∝) defined in HA Advice Note HA 68/94.

6.21 For the geogrids the coefficient of skin friction (f_{sf}) may be assumed, for routine design purposes, to be 0.6 for compacted frictional fill. This is a conservative value. Where more precise values are required, for use in design, suitable soil and geogrid specific shear box testing may be carried out. Soil specific testing has shown that values of f_{ds} >1.0 can be achieved.

Formulae notation

δ = angle of friction between soil and plane reinforcement surface

ϕ' = effective angle of friction of soil.

7 Durability

7.1 The geogrids may be used in fills normally encountered in civil engineering practice (see section 5.5).

7.2 Evidence from tests show that Enkagrid PRO Geogrids have good resistance to chemical corrosion, biodegradation, temperature, hydrolysis, and UV exposure (see sections 6.9 to 6.14).

7.3 All factors contained in Table 13 of BS 8006 : 1995 relevant to the durability of the geogrids for their proposed use have been considered.

Installation

8 General

Care should be exercised to ensure Enkagrid PRO Geogrids are laid with the warp (longitudinal) direction parallel to the direction of principal stress. Design drawings should indicate geogrid orientation (see section 5.2).

9 Preparation

The formation is prepared by levelling and compacting the subgrade in accordance with MCHW1. The surface must be free of root growth, logs, frozen matter and any other obstacles that may damage the geogrids.

10 Procedure

10.1 The geogrid is laid by unrolling the grid to the length required and cutting with a sharp knife or scissors. The unrolling of the grid may be carried out manually or mechanically.

10.2 The grids should be laid flat without folds, parallel to each other and with widths in contact. Each reinforcing layer must be continuous in the direction of loading and there should be no overlapping of the grids. Bar misalignment must not exceed 50 mm over a distance of 5 m. Pins or a stretching device may be used to control alignment and also to induce a small prestressing load prior to filling.

10.3 Fill is placed to a minimum compacted depth of 200 mm, with particular care being taken to ensure that the grids are adequately covered before compaction or trafficking. Construction traffic will damage unprotected Enkagrid PRO Geogrids.

10.4 Maximum thickness of compaction layers depends on the type of fill and compaction equipment employed, but depths should not exceed 500 mm.

10.5 Facings are positioned as detailed on the engineer's design drawing. Where the geogrids are used as facings, the geogrid must be wrapped around and anchored back into the fill. Formwork is used to assist in maintaining the shape of the facing. Facings, prefabricated or otherwise, are beyond the scope of this Certificate. A typical example is shown in Figure 3.

Technical Investigations

11 Investigations

11.1 The manufacturing process of the Enkagrid PRO Geogrids was examined, including the methods adopted for quality control, and details were obtained of the quality and composition of the materials used.

11.2 An examination was made of data relating to:

- evaluation of long- and short-term tensile properties
- an assessment of the test method for determining tensile creep rupture and creep strain results in comparison with the method given in EN ISO 13431 : 1998
- chemical resistance
- resistance to biological attack
- UV and environmental degradation
- effects of temperature
- site damage trials and resistance to mechanical damage
- the synergy of mechanical damage and chemical degradation on long-term creep performance
- the coefficient of friction between the geogrids and soil fill
- the proposed design method in relation to the recommendations of HA Advice Note HA 68/94 (DMRB 4.1.4).

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

Additional Information

The management systems of Colbond BV have been assessed and registered as meeting the requirements of EN ISO 9001 : 2000 by Lloyd's Register Quality Assurance, Approval Certificate No 935136.

Bibliography

BS 8006 : 1995 *Code of practice for strengthened/reinforced soils and other fills*

BS EN 13251 : 2001 *Geotextiles and geotextile-related products — Characteristics required for use in earthworks, foundations and retaining structures*

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 : 1996 *Geotextiles — Wide-width tensile test*

BS EN ISO 10320 : 1999 *Geotextiles and geotextile-related products— Identification on site*

BS EN ISO 13431 : 1999 *Geotextiles and geotextile-related products — Determination of tensile creep and creep rupture behaviour*

EN ISO 9001 : 2000 *Quality management systems — Requirements*

HA 68/94 *Design methods for the reinforcement of highway slopes by reinforced soil and soil nailing techniques (DMRB 4.1.4)*

HD 22/02 *Design Manual for Roads and Bridges : Volume 4, Geotechnics and Drainage, Section 1, Earthworks : Part 2, Managing Geotechnical Risk*

Manual of Contract Documents for Highway Works, Volume 1 *Specification for Highway Works,* August 1998 (as amended)

Manual of Contract Documents for Highway Works, Volume 2 *Notes for Guidance on the Specification for Highway Works,* August 1998 (as amended)

12 Conditions

12.1 This Certificate:

- relates only to the product/system that is named and described on the front page
- is granted only to the company, firm or person named on the front page — no other company, firm or person may hold or claim any entitlement to this Certificate
- 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.

12.2 References in this Certificate to any Act of Parliament, Statutory Instrument, Directive or Regulation of the European Union, British, European or International Standard, Code of Practice, manufacturers' instructions or similar publication, are references to such publication in the form in which it was current at the date of this Certificate.

12.3 This Certificate will remain valid for an unlimited period provided that the product/system and the manufacture and/or fabrication including all related and relevant 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
- remain in accordance with the requirements of Highways Agency.

12.4 In granting this Certificate, the BBA is not responsible for:

- 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
- individual installations of the product/system, including the nature, design, methods and workmanship of or related to the installation
- the actual works in which the product/system is installed, used and maintained, including the nature, design, methods and workmanship of such works.

12.5 Any information relating to the manufacture, supply, installation, use and maintenance 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 and maintained. It does not purport in any way to restate the requirements of the Health & Safety at Work etc Act 1974, or of any other statutory, common law or other duty which may exist at the date 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. In granting this Certificate, the BBA does not accept responsibility to any person or body for any loss or damage, including personal injury, arising as a direct or indirect result of the manufacture, supply, installation, use and maintenance of this product/system.

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