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BBA APPROVAL INSPECTION TESTING CERTIFICATION
TECHNICAL APPROVALS FOR CONSTRUCTION

Roads and Bridges
Agrément Certificate
No 01/R125
Product Sheet 1

FORTRAC GEOSYNTHETICS

FORTRAC 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 Fortrac Geogrids, polymeric geogrids for use as reinforcement in embankments with slope angles up to 70°.

THIS CERTIFICATE INCLUDES:

- factors relating to compliance with Highways Agency Requirements 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 — short-term tensile strength and strain and long-term tensile strength properties of the geogrids have been assessed (see section 6).

Material safety factors — partial safety factors for manufacture and extrapolation of data (f_m), installation damage (f_d) and environmental effects (f_e) have been established (see section 7).

Soil/geogrid interaction — coefficients relating to the direct sliding and pull-out resistance have been evaluated (see section 8).

Durability — the geogrids have good resistance to chemical degradation, biodegradation, temperature and weathering used in fills normally encountered in civil engineering practice (see section 10).

The BBA has awarded this Agrément 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

Date of First issue: 6 November 2008
Originally certificated on 18 October 2001

Brian Chamberlain
Head of Approvals — Engineering

Greg Cooper
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).

The products are for use in the following situation:

- embankments with an effective slope 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, August 1998 (as amended).

(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), 2 *Delivery and site handling* (2.2) and 11 *General*.

General

This Certificate relates to Fortrac 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 Fortrac 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.

Technical Specification

1 Description

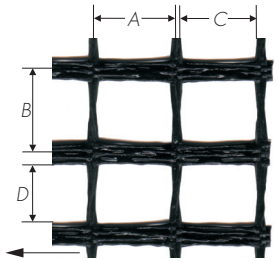
1.1 Fortrac Geogrids are planar structures consisting of a regular open network of integrally-connected tensile elements of yarn. The yarn, is made from high modulus polyester fibres of polyethylene terephthalate (PET).

1.2 The yarn is woven into grids and coated with a protective layer of black polymer, by the Certificate holder.

1.3 The geogrids are manufactured in four standard grades of various strengths and mesh sizes. A typical geogrid is illustrated in Figure 1 and the range and specification of the geogrids assessed by the BBA are listed in Tables 1 and 2.

1.4 The warp direction is along the roll length and is indicated by a wrap-around yarn bundle (see Figure 1).

Figure 1 Fortrac Geogrids



Fortrac classification is by warp/weft tensile strength and aperture size: eg FORTRAC 55/30-20 = 55 kNm^{-1} warp tensile strength, 30 kNm^{-1} weft tensile strength, 20 mm nominal aperture size

Table 1 General specification

Grade	Mass[1] (gm^{-2}) ± 9%	Average grid size[2] warp/weft (mm) A x B	Average aperture size[2] warp/weft (mm) C x D	Colour code[3]	Roll weight of 200 m rolls (kg ± 10%) 3.7 m width	5.0 m width
35/20-20	250	23 x 23	20 x 18	red	196	264
55/30-20	350	23 x 23	20 x 18	green	270	364
80/30-20	440	23 x 23	20 x 19	pink	336	454
110/30-20	490	23 x 23	20 x 19	white	373	504

(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.

Table 2 Performance characteristics

Grade	Short-term tensile strength[1] warp direction (MD) P_{char} (kN per m width)	α_s[2]	Ratio of bearing[3] surface to plan area α_b x B/2S	Strain at maximum tensile strength[4] (%)
35/20-20	35	0.28	0.020	12.0 +0/–3
55/30-20	55	0.28	0.024	12.5 +0/–3
80/30-20	80	0.26	0.038	12.5 +0/–3
110/30-20	110	0.27	0.030	12.5 +0/–3

(1) Short-term tests in accordance with BS EN ISO 10319 : 1996, the values given are characteristic values (P_{char}) of ultimate short-term tensile strength.

(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 coeffient (f_{ds}) (see sections 8.1 and 8.4).

(3) The ratio is required to calculate the bond coefficient in accordance with CIRIA SP123 : 1996 *Soil Reinforcement with Geotextiles*, Jewell R.A. (see section 8.4):

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.

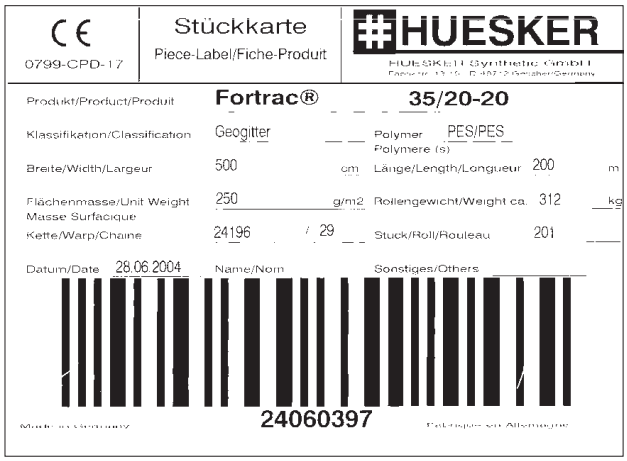
(4) Tests in accordance with BS EN ISO 10319 : 1996, the values given are the mean and tolerance values (±) of strain in accordance with BS EN 13251 : 2001.

1.5 Factory production control is exercised throughout all stages of manufacture. The specification of the incoming yarn is checked against the Certificate of Conformity from the supplier. Checks made on the woven grid and the polymer protective coating include visual examination, dimensional checks and batch performance tests.

2 Delivery and site handling

2.1 The geogrids are delivered to site in rolls of 0.5 m to 0.6 m diameter approximately and 200 m long. Each roll is wrapped for transit and site protection in a black polyethylene bag. Each bag is labelled with the geogrid grade and identification (see Figure 2). Packaging should not be removed until immediately prior to installation.

Figure 2 Label



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

2.3 Rolls should be stored in clean, dry conditions. 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 instructions of the material safety data sheet for the product.

2.4 When laid horizontally, the rolls may be stacked up to five high. No other loads should be stored on top of the stack.

Assessment and Technical Investigations

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

Design Considerations

3 General

3.1 Fortrac 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 woven 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 11 to 13
- 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 are in accordance with the procedures given in HA Advice Note HA 68/94 (DMRB 4.1.4).

5.2 The design strength of the reinforcement (P_{des}) should be derived from the unfactored long-term characteristic strength (P_c) (see section 6.4) using the formula:

$P_{des} = P_c / f_m \times f_d \times f_e$

where: f_m, f_d and f_e are safety factors (see section 7).

5.3 Guidance on the soil/geogrid interaction coefficients applied in the calculations to derive the direct sliding and pull-out resistance is given in section 8.

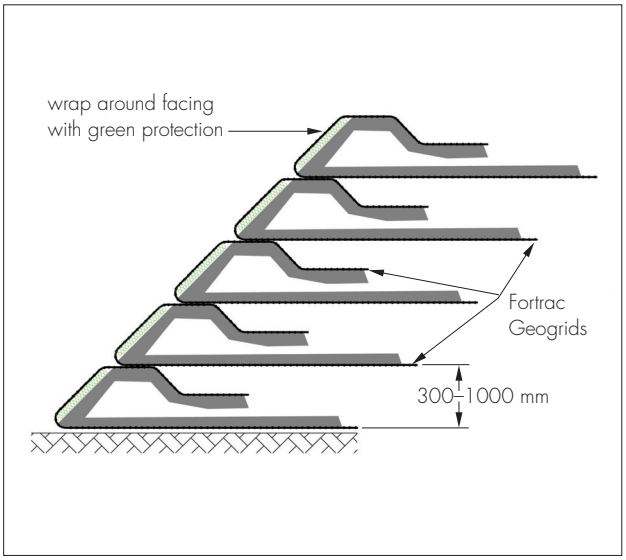
5.4 Working drawings should show the correct orientation of the geogrids. Each layer of reinforcement must be continuous in the direction of load, ie no overlaps.

5.5 If the geogrids are cut or punched to allow for the placing of vertical drains, ducts or planting, only weft strands should be cut. The integrity of the reinforcing length (warp) must not be interfered with in any way.

Facings

5.6 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.

Figure 3 Facings



Fill properties

5.7 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 the Manual of Contract Documents for Highway Works (MCHW), Volume 1 and HA Advice Note HA 68/94 (DMRB 4.1.4).

6 Mechanical properties

Tensile strength — short-term

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

Tensile strength — long-term

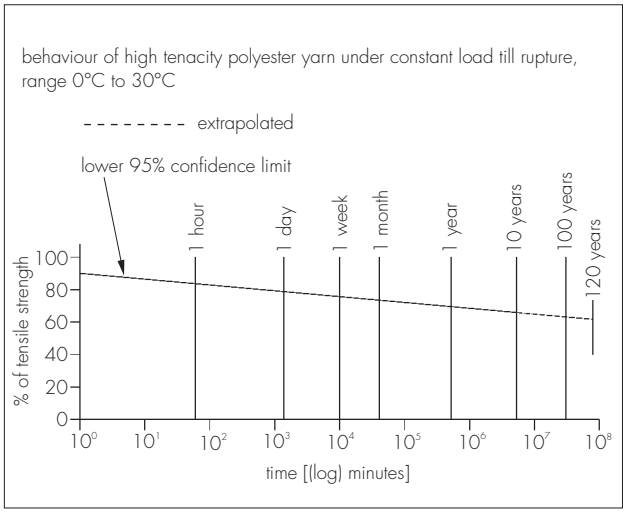
6.2 Long-term creep rupture testing, generally in accordance with the principles of BS EN ISO 13431 : 1999, has been carried out for periods in excess of 10 years and at varying test temperatures, to cover the range of geogrids detailed in this Certificate.

6.3 Real time data for the yarn has been extrapolated by <1.0 log cycle to allow the characteristic long-term strength (P_c) for design lives of up to 120 years to be determined. Using principles of stepped isothermal method for both the geogrid and virgin yarn material, predicted long-term strengths for a design life of 60 years at design temperatures of 20°C have been obtained from the measured data, without the need for direct extrapolation.

6.4 For ultimate limit state, for a 120-year design life P_c is 60% of the characteristic short-term tensile strength (P_{char}) and for a 60-year design life, 64% of P_{char} (see Figure 4). The design life for reinforced slopes should be taken as 60 years in accordance with HA 68/94 (DMRB 4.1.4). The values for P_{char} are given in Table 2.

6.5 A sustained load testing programme is in progress to monitor the creep performance of the yarn.

Figure 4 Time to rupture



7 Material safety factors

7.1 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 7.2 to 7.4) are not covered by this Certificate and advice should be sought from the manufacturer.

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

7.2 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[1] (years)	Safety factor (f_m)
120	1.10
60	1.05

(1) The design life for reinforced slopes should be taken as 60 years in accordance with HA 68/94.

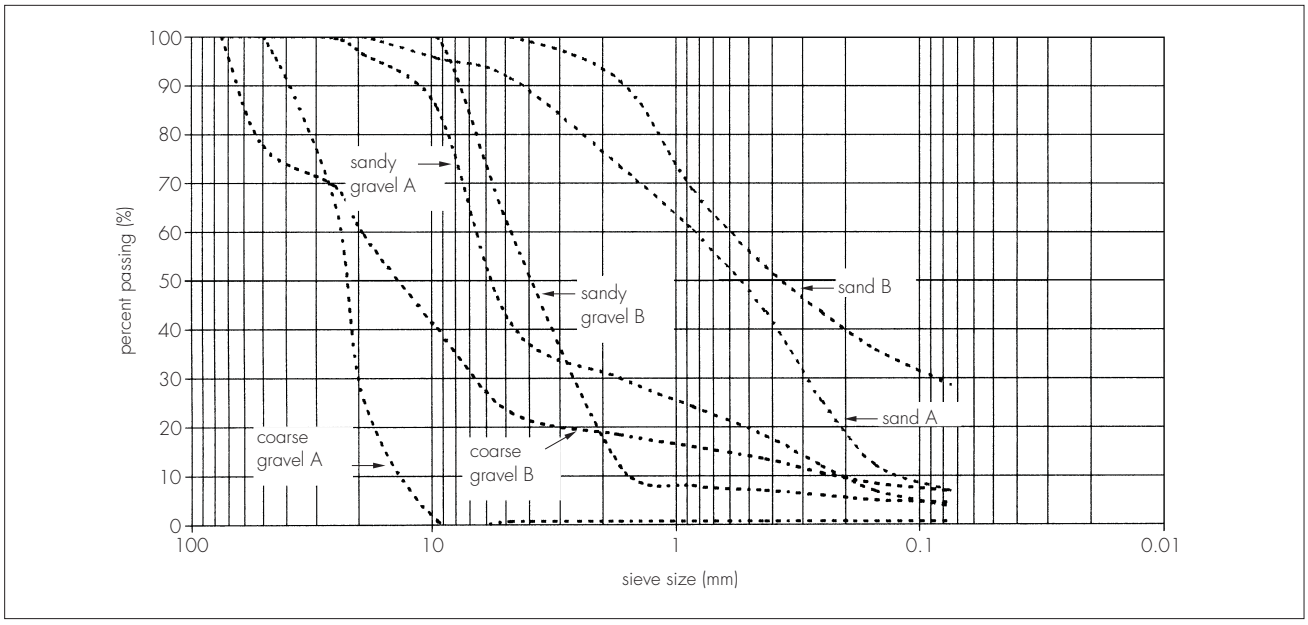
Installation damage — partial safety factors (f_d)

7.3 To allow for loss of strength due to mechanical damage that may be sustained during installation, the appropriate value for f_d may be selected from Table 4. These partial safety factors were established from full-scale installation damage tests using a range of materials whose gradings can be seen in Figure 5 with a minimum compacted depth of 200 mm. For fills 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.

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

Soil type	D_{90} particle size (mm)	Grade	f_d
Sand A	≤4	35/20-20	1.17
		55/30-20	1.06
Sand B	≤2	80/30-20	1.03
		110/30-20	1.04
Sandy gravel A	≤12	35/20-20	1.17
		55/30-20	1.09
Sandy gravel B	≤8	80/30-20	1.13
		110/30-20	1.07
Coarse gravel A	≤65	35/20-20	1.29
		55/30-20	1.19
Coarse gravel B	≤40	80/30-20	1.19
		110/30-20	1.18

Figure 5 Particle size distributions of fills used in installation drainage treating



Environmental effects — partial safety factor (f_e)

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

Table 5 Partial safety factor — environmental effects (f_e)

Soil pH level (pH)	Safety factor[1] (f_e)
9.0–10.0	1.10
4.1– 8.9	1.03
2.0– 4.0	1.15

(1) An additional safety factor of 1.11 should be applied when the geogrids are exposed to natural daylight and weathering for more than one year but less than three years.

8 Soil/geogrid interaction

Direct sliding

8.1 The theoretical expression for direct sliding recommended for design is:

$f_{ds}\tan\phi'$ where f_{ds} is the direct sliding coefficient [synonymous with the term 'interface sliding factor ($\propto$)' defined in HA Advice Note HA 68/94].

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

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

a_s is the proportion of plane sliding area that is solid (see Table 2).

8.2 For Fortrac Geogrids the coefficient of skin friction ($\tan\delta/\tan\phi'$) 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 $f_{ds} \geqslant 1.0$ can be achieved.

Formulae notation

δ = angle of friction between soil and plane reinforcement surface

ϕ' = effective angle of friction of soil.

Pull-out resistance (bond strength)

8.3 The theoretical expression for bond is:

$f_b\tan\phi'$ where f_b is the bond coefficient [synonymous with the term 'bearing factor ($\propto$')' defined in HA Advice Note HA 68/94].

8.4 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 calculation method of Jewell (CIRIA SP123,

1996 *Soil Reinforcement with Geotextiles*, section 4.6). For Fortrac Geogrids, the coefficient of skin friction (tan δ/tan ϕ') may be assumed, for routine design purposes, to be 0.6 for compacted frictional fill and the ratio of bearing surface to plane area can be taken from Table 2. The BBA recommends 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 $f_b \geq 1.0$ have been reported based on site and soil specific testing.

9 Maintenance

As the product is confined within the soil and has suitable durability (see section 10), maintenance is not required.

10 Durability

10.1 The geogrids may be used in fills normally encountered in civil engineering practice (see section 5.7).

10.2 Evidence from tests show that the geogrids have good resistance to chemical degradation, biodegradation, temperature and weathering (see sections 10.3 to 10.8).

Chemical degradation

10.3 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 the geogrids is not adversely affected by hydrolysis, for applications where sustained soil temperatures are below 30°C.

10.4 The yarn has a high resistance to degradation from the types of chemicals typically found in soils used for civil engineering purposes.

Biological degradation

10.5 The yarn is highly resistant to microbial attack.

Effects of temperature

10.6 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.

10.7 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. Sustained temperatures of greater than 30°C can increase the rate of hydrolysis of polyester and further reduction factors may be necessary.

Resistance to weathering

10.8 The geogrids do not show significant reductions in strength after three years' exposure to natural daylight and weathering. The BBA recommends that natural or artificial protection should be provided to protect exposed geogrids and fill materials within one year of initial exposure to natural daylight. If the geogrids are exposed for more than one year, an additional partial safety factor should be applied in accordance with the footnote to Table 5.

Installation

11 General

In general, the execution of reinforced soil structures should be carried out in accordance with BS EN 14475 : 2006. Care should be exercised to ensure Fortrac Geogrids are laid with the warp (longitudinal) direction parallel to the direction of principal stress. Design drawings should indicate geogrid orientation (see section 5.4).

12 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.

13 Procedure

13.1 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.

13.2 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. Strip 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.

13.3 Particular care should be taken to ensure that the grids are adequately covered before compaction or trafficking. Construction traffic will damage unprotected Fortrac Geogrids.

13.4 Fill materials and the thickness and compaction of the fill should be in accordance with MCHW1 and in line with those conditions used to determine the installation damage partial safety factors in the design (see section 7.3).

13.5 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

14 Investigations

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

14.2 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 BS EN ISO 13431 : 1999
- synergy of mechanical damage and chemical degradation on long-term creep performance
- chemical degradation
- resistance to biological attack
- resistance to weathering
- effects of temperature
- site damage trials and resistance to mechanical damage
- coefficients of interaction between the geogrids and the soil fill
- an assessment of the proposed design method in relation to the recommendations of HA Advice Note HA 68/94 (DMRB 4.1.4).

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

Additional Information

The management systems of Huesker Synthetic GmbH have been assessed and registered as meeting the requirements of EN ISO 9001 : 2000 by TÜV, Germany (Certificate No 041007084).

Bibliography

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

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

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)

15 Conditions

15.1 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.

15.2 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.

15.3 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 the Highways Agency.

15.4 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.

15.5 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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