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APPROVAL INSPECTION TESTING CERTIFICATION
TECHNICAL APPROVALS FOR CONSTRUCTION

Agrément Certificate
05/4266
Product Sheet 1

FORTRAC GEOSYNTHETICS

FORTRAC R GEOGRIDS

PRODUCT SCOPE AND SUMMARY OF CERTIFICATE

This Certificate relates to Fortrac R Geogrids, polymeric geogrids for use as basal reinforcement in embankment foundations.

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 — short-term and long-term tensile strength and strain properties of the geogrids have been assessed (see section 6).

Partial material factors — partial material factors for manufacture (f_{m11}), extrapolation of test data (f_{m12}), installation damage (f_{m21}) and environmental effects (f_{m22}) have been established (see section 7).

Soil/geogrid interaction — soil/geogrid interaction relating to 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	Brian Chamberlain	Greg Cooper
Originally certificated on 30 September 2005	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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Regulations

In the opinion of the BBA, Fortrac R Geogrids, if used in accordance with the provisions of this Certificate, will meet or contribute to meeting the relevant requirements of the following Building Regulations:

The Building Regulations 2000 (as amended) (England and Wales)

Regulation: 7 Materials and workmanship

Comment: The product is acceptable. See sections 10.1 to 10.2 and the *Installation* part of this Certificate.

The Building (Scotland) Regulations 2004 (as amended)

Regulation: 8(1)(2) Fitness and durability of materials and workmanship

Comment: The product can contribute to a construction satisfying this Regulation. See sections 9, 10.1 to 10.2 and the *Installation* part of this Certificate.

The Building Regulations (Northern Ireland) 2000 (as amended)

Regulation: B2 Fitness of materials and workmanship

Comment: The product is acceptable. See sections 10.1 to 10.2 and the *Installation* part of this Certificate.

Regulation: B3(2) Suitability of certain materials

Comment: The product is acceptable. See section 9 of this Certificate.

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: 2 *Delivery and site handling* (2.2) and 11 *General* (11.1).

Non-regulatory Information

NHBC Standards 2008

In the opinion of the BBA, the use of Fortrac R Geogrids, polymeric geogrids, in relation to this Certificate, are not subject to the requirements of these Standards.

Zurich Building Guarantee Technical Manual 2007

In the opinion of the BBA, the use of Fortrac R Geogrids, polymeric geogrids, in relation to this Certificate, are not subject to the requirements of this Technical Manual.

General

This Certificate relates to Fortrac R Geogrids, polymeric geogrids for use as basal reinforcement under embankments in situations where the following foundation conditions exist:

- soft foundation soils
- piled foundations
- areas prone to subsidence.

The products are planar structures consisting of a regular open network of integrally-connected tensile elements of yarn to form soil reinforcement materials with high uni-directional strength.

The design and construction of embankments must be in accordance with the conditions set out in the *Design Considerations* and *Installation* parts of this Certificate.

Technical Specification

1 Description

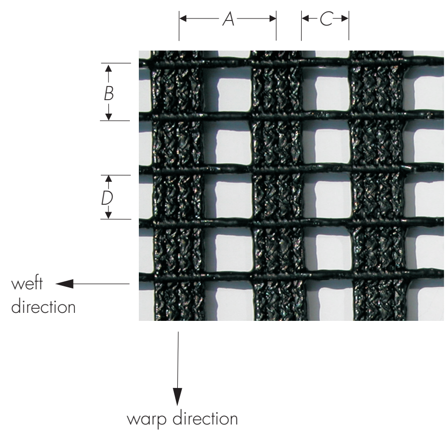
1.1 Fortrac R Geogrids are planar structures consisting of a regular open network of integrally-connected tensile elements of yarn. The yarn, is made from high modulus polyester fibres of polyethylene terephthalate (PET).

1.2 The yarn is knitted into grids and coated with a protective layer of black polymer by Huesker Synthetic GmbH.

1.3 The geogrids are manufactured in five 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 (machine) direction is along the roll length and is indicated by a paper tape (see Figure 1).

Figure 1 Fortrac R Geogrids



A and *B*: average grid size
C and *D*: average aperture size

Fortrac classification is by warp/weft tensile strength and aperture size:
eg Fortrac R 200/30-30 = 200 kNm^{-1} warp tensile strength,
30 kNm^{-1} weft tensile strength, 30 mm nominal aperture size

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

Table 1 General specification

Grade	Mass[1] (gm^{-2}) ± 10%	Average grid size warp/weft[2] (mm) *A* x *B*	Average aperture size warp/weft[2] (mm) *C* x *D*	Roll width 5 m Roll length (m)	 Gross roll weight (kg) ±10%
R 200/30-30	680	41 x 33	31 x 28	200	760
R 400/50-30	1300	42 x 30	30 x 25	100	730
R 600/30-30	1600	48 x 31	26 x 26	100	880
R 800/100-30	2400	90 x 33	25 x 26	100	1230
R 1000/100-30	3400	97 x 37	30 x 27	75	1355

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

Table 2 Performance characteristics

Grade	Short-term tensile strength[1] warp (machine direction) T_{char} (kN per m width)	a_s[2]	Ratio of bearing[3] surface to plan area a_b x B/2S	Strain at maximum tensile strength[4] warp (machine direction) (%)
R 200/30-30	200	0.36	0.015	12.5 +0/−2
R 400/50-30	400	0.40	0.027	12.5 +0/−2
R 600/30-30	600	0.55	0.017	12.5 +0/−2
R 800/100-30	800	0.78	0.015	12.5 +0/−2
R 1000/100-30	1000	0.77	0.009	12.5 +0/−2

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

(2) a_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 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).

a_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.

2 Delivery and site handling

2.1 The geogrids are delivered to site in rolls of 0.5 m to 0.9 m diameter, approximately 5 m wide and 75 m, 100 m or 200 m long. Each roll is wrapped for transit and site protection in a black polyethylene bag. Each bag is labelled with geogrid grade and identification (see Figure 2). Packaging should not be removed until immediately prior to installation.

Figure 2 Label

2.2 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.

2.3 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 R Geogrids.

Design Considerations

3 General

3.1 Design of basal reinforcements should be in accordance with the recommendations of BS 8006 : 1995.

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

- site preparation and foundation 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

5.1 The design should be carried out by a suitably qualified engineer, taking account of all requisite partial reinforcement material factors (f_m) described in section 7 and applying all other appropriate load factors, soil material factors and soil/reinforcement interaction factors in accordance with BS 8006 : 1995.

5.2 The ultimate limit state design strength of the reinforcement, T_D, should be taken as T_{CR}/f_m where T_{CR} is the characteristic tensile creep strength of the reinforcement, at the appropriate times and design temperature (see section 6.4), and f_m is the partial material factor for the reinforcement (see section 7).

5.3 The serviceability limit state design strength of the reinforcement, T_D, should be taken as T_{CS}/f_m where T_{CS} is the maximum tensile load in the reinforcement which does not cause the prescribed serviceability limit state strain (ε_{max}) to be exceeded during the design life (see section 6.5), and f_m is the partial material factor for the reinforcement (see section 7). The prescribed serviceability limit state strain (ε_{max}) should be taken from BS 8006 : 1995 for the various structures.

5.4 Guidance on soil/geogrid interaction coefficients applied to calculate direct sliding and pull-out resistance can be found in section 8.

5.5 Working drawings should show the correct orientation of the geogrids.

5.6 The designer should specify the relevant properties of the fill material for the construction of the reinforced soil structure deemed acceptable for the purposes of the design. Acceptable materials should meet the requirements of the Manual of Contract Documents for Highway Works (MCHW) Volume 1.

6 Mechanical properties

Tensile strength — short-term

6.1 The short-term values of tensile strength, and strain for the geogrids are given in Table 2.

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 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 cycles to allow the characteristic tensile creep strength (T_{CR}) for design lives of up to 120 years to be determined. Using the principles of stepped isothermal methods 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, T_{CR} is 60% of characteristic short-term tensile strength (T_{char}), and for a 60-year design life, 64% of characteristic short-term tensile strength (T_{char}) (see Figure 3). The values for T_{char} are given in Table 2.

Creep

6.5 The isochronous curves for the product are given in Figure 4 and can be used to predict strain under load over the design life of the reinforced soil structure. Alternatively, if strain is limiting (ε_{max}), the maximum allowable tensile load, T_{CS}, can be established for a given design life.

Figure 3 Time to rupture

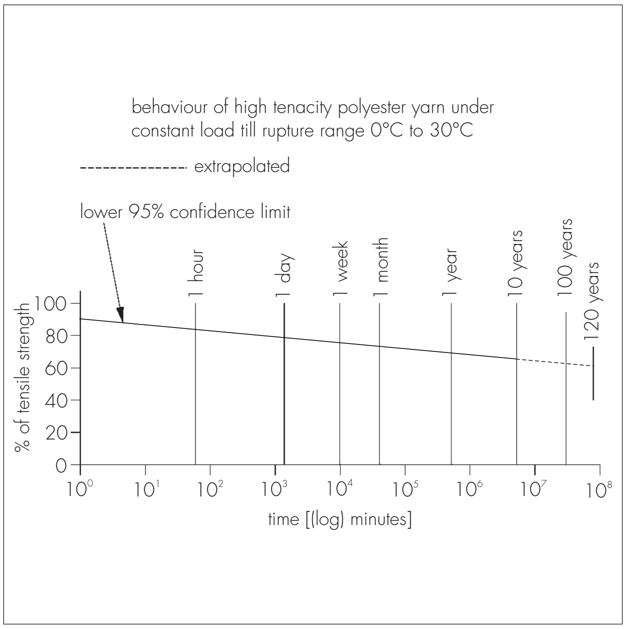
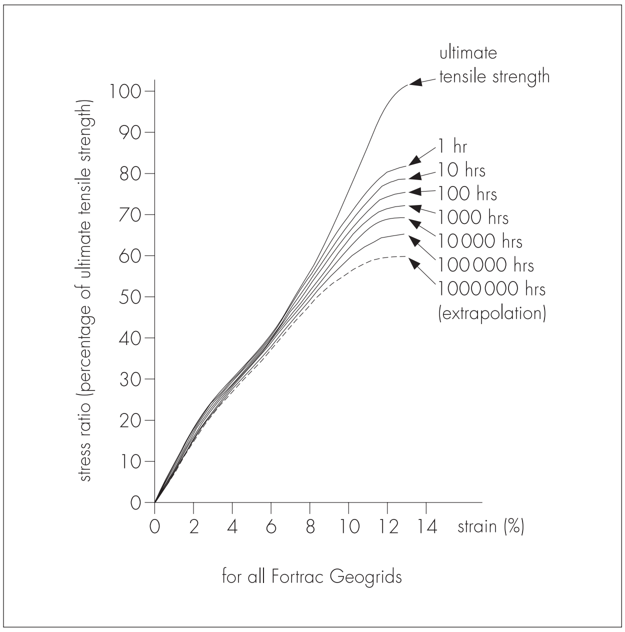


Figure 4 Stress/strain isochronous curves



7 Partial material factors

7.1 In establishing the design tensile strength, T_D, of the product and ensuring that during the life of the reinforced soil structure the geogrid will not fail in tension, the BBA recommends that in line with BS 8006 : 1995, a set of partial material safety factors should be applied to T_{CR} or T_{CS}. Conditions of use outside the scope for which partial safety factors are defined (see also sections 7.3 to 7.5) are not covered by this Certificate and advice should be sought from the manufacturer.

7.2 The total material factor, f_m, is given by $f_m = f_{m11} \times f_{m12} \times f_{m\,21} \times f_{m\,22}$, where f_{m11} is a material factor relating to manufacture, f_{m12} is a material factor relating to extrapolation of test data, f_{m21} is a material factor relating to susceptibility of installation damage and f_{m22} is a material factor relating to environmental effects.

Manufacture and extrapolation of data — partial material factors ($f_{m11} \times f_{m12}$)

7.3 To allow for variation in manufacture and product dimensions and to account for extrapolation of data the value for the partial material factors ($f_{m11} \times f_{m12}$) is given in Table 3.

Table 3 Partial material factor — manufacture and extrapolation of data

Design life (years)	Partial material factor ($f_{m11} \times f_{m12}$)
120	1.10
60	1.05

Installation damage — partial material factor (f_{m21})

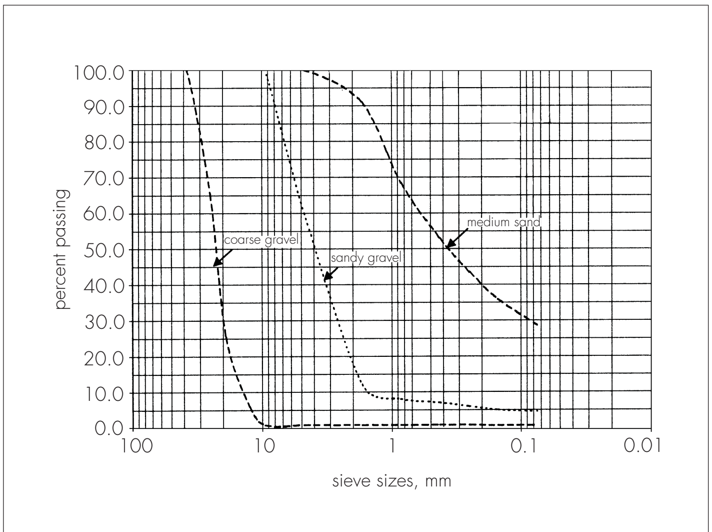
7.4 To allow for loss of strength due to mechanical damage that may be sustained during installation, the appropriate value for f_{m21} may be selected from Table 4. These partial material factors were established from full scale installation damage tests using a range of materials whose gradings can be seen in Figure 4 with a minimum compacted depth of 200 mm. For fills not covered by Table 4, appropriate values of f_{m21} may be determined from site specific trials or the engineer may exercise engineering judgement to interpolate between the values given.

Table 4 Partial material factor — mechanical installation damage (f_{m21})(1)

Soil type(1)	D_{90} particle size (mm)	Grade	f_{m21}
Medium sand	⩽2	R 400/50-30	1.04
		R 1000/100-30	1.01
Sandy gravel	⩽8	R 400/50-30	1.04
		R 1000/100-30	1.01
Coarse gravel	⩽35	R 400/50-30	1.06
		R 1000/100-30	1.06

(1) For soil grading see Figure 5.

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



Environmental effects — partial material factor (f_{m22})

7.5 To account for environmental conditions the appropriate value for f_{m22} should be selected from Table 5.

Table 5 Partial material factor — environmental effects (f_e)

Soil level (pH)	Partial material factor[1] (f_{m22})
9.0–10.0	1.10
4.0–9.0	1.03
2.0–4.0	1.15

(1) An additional material 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 a direct sliding coefficient [synonymous with the 'term interaction coefficient ($\propto'$)' defined in BS 8006 : 1995 relating to sliding across the surface of the reinforcement].

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

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 the 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 site testing should be carried out.

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 interaction coefficient ($\propto'$)' defined in BS 8006 : 1995 relating to pull-out resistance of the reinforcement].

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 section 4.6). For the 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 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.

9 Maintenance

As the product is confined within the soil and it 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 5.6).

10.2 Evidence from tests show that the products 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 2.0 to 10.0 and temperatures are typical of those normally found in embankments in the United Kingdom, the strength of the products are not adversely affected by hydrolysis, for applications where sustained soil temperatures are below 30°C.

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

Biological degradation

10.5 The geogrids are highly resistant to microbial attack.

Effects of temperature

10.6 The long-term creep performance of the products are not adversely affected by the range of soil temperatures typical of embankments in the UK for service loads 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 a significant reduction 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 within one year of initial exposure to natural daylight. If the geogrids are exposed for more than one year, an additional partial material factor should be applied in accordance with the footnote to Table 5.

Installation

11 General

11.1 In general, the execution of the reinforced soil structures should be carried out in accordance with BS EN 14475 : 2006.

11.2 Care should be exercised to ensure the Fortrac R Geogrids are laid with the longitudinal direction parallel to the direction of principal stress. Design drawings should indicate the geogrid orientation.

11.3 Rolls should be placed on the formation in the position where the length of the products are required to start and with the roll as closely as possible at right angles to the line of the run. Accurate alignment at the start is essential to ensure a satisfactory positioning of the laid material.

12 Preparation

To ease the laying and proper performance of the run, the formation on which it is to be laid, generally, should be flat without ruts and sharp undulations.

13 Procedure

13.1 The roll should be unwound a small amount by pushing the roll in the direction of the run. The loose end of the product now exposed should be secured by weighting or pinning it to the formation. The roll should then be unwound carefully, ensuring that no slack or undulations occur as it is laid. If these do occur they should be corrected immediately before proceeding. When the roll is completely unwound, the free end of the product should be hand tensioned and secured by weighting or pinning.

13.2 The run of the product should be straight and all strip elements should be flat and not twisted. No undulations should be evident.

13.3 Where the product is to be used in two layers at right angles to each other, the edge joints will normally be simple butt joints. The drawings should be consulted to verify this as certain circumstances may dictate otherwise.

13.4 Where a number of rolls are to be laid at one time, this should be done with the rolls slightly in a staggered formation to avoid the lifting tubes interfering with one another.

13.5 Fill material in immediate contact with the product should be placed and spread in the longitudinal direction only. If this results in some undulations of the product, the secured end should be released and the undulations removed by pulling the free end.

13.6 Site vehicles should not be allowed to traffic over the laid, unprotected product.

13.7 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 partial material factors in the design (see section 7.4).

13.8 Fortrac R Geogrids are a structural material and, where joints are necessary in its longitudinal direction, such joints should be full structural joints capable of carrying the full design tensile force. This will normally be shown as a full anchorage bond length on the drawings. The anchorage bond length depends on the type and characteristics of the fill in which the product is being used. In the case of spanning pile caps, this length is unlikely to be less than the distance across three pile caps. Where the products are being used to span subsidence voids it will depend upon the size of the void anticipated by the designer.

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 : 1991
- synergy of mechanical damage and chemical degradation on long-term creep performance
- chemical degradation
- resistance to microbial attack
- resistance to weathering
- effects of temperature
- site damage trials and resistance to mechanical damage
- coefficients of interaction between the geogrids and the fill and pull-out test results.

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 041007084).

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

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

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)

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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 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.

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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