European Reinforced Soil Design – The Codes

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ABSTRACT: The introduction of EuroCodes for the design of civil engineering works has necessitated all countries in Europe to review the methods used in design of works including geosynthetics. All geotechnical design must be carried out using the methods described in EN1997-1 Geotechnical Design and the associated National Application Documents. EN1997-1 does not include specific procedures for the design of soil structures which include reinforcing geosynthetics, to ensure that national standards comply with European Regulations some countries have revised previous design codes.

This paper presents a review of the three principle updated design codes published in 2010 from the UK, Germany and France comparing the similarities and highlighting the differences by using a worked example for a faced retaining wall and providing comment on the current status to develop a single European design guide for reinforced soil.

Keywords: design standards, principles, comparison

1 INTRODUCTION

The use of geosynthetic materials (typically geogrids) to reinforce soil retaining structures has become an established technique in European construction practice. However, the design of reinforced soil is not specifically covered in Eurocode 7 (BS EN 1997-1). In 2010 three European countries produced updated guidance on geosynthetic reinforcement design

- **UK:** BS8006: Part 1: BSI: 2010
- **Germany:** EBGEO: DGGT: 2010
- **France:**
  - NF P 94270 : AFNOR 2009
  - XP G 38-064: AFNOR: 2010

* For retaining structure with front face inclinations ≥76° of the horizontal and < 76° respectively.

The design principles and procedures for each national code will be summarized and reviewed to highlight the similarities and differences. This will be demonstrated by a design example considering a 7.5m high faced retaining wall. A similar comparison was made previously (Thurlwell et al, 2004) which compared earlier version of the UK, German & Dutch guidance.

2 GENERAL PRINCIPLES OF DESIGN

The design principles in each code are similar and each follows the ‘limit state’ concept. In the design codes these limits are considered as two groups, ultimate limit states (ULSs) and serviceability limit states (SLSs). ULSs are associated with collapse either structural or geotechnical failure or excessive de-formation. SLSs correspond to unacceptable deformations, or minor structural damage, leading to increased maintenance requirements or reduced service life. A comparison of SLSs design limits stipulated in the UK & German guidance is discussed separately. (Scotland et al.) For each failure mode partial load factors are applied to the actions (disturbing forces) to increase their value and partial material factors are applied to resistances (restoring
forces) to reduce their values broadly in line with the principals in Eurocode 7, however, the codes differ in the application of the load and material partial factors

2.1 Principles of each design code

2.2 BS 8006:2010

British Standard BS8006 was first published in the UK in 1995. It was one of the first European codes to adopt the limit state concept. It detailed the design of retaining walls, steepened slopes and embankments overlying weak foundation soils. In additional general sections dealt with fundamental principles of design, materials, testing and construction considerations. This code was subsequently reviewed and updated to avoid any conflict with the European guidance on execution (construction): BS EN 14475:2006, and geotechnical design (BS EN 1997-1).

The UK National Annex to Eurocode 7, (BSI 2007), includes a specific clause which excludes the use of EC7 for reinforced soil design, “EN 1997-1 Geotechnical design does not cover the design and execution of reinforced soil structures. In the UK, the design and execution of reinforced fill structures... should be carried out in accordance with BS8006 and BS EN 14475”

Both external and internal ULS modes of failure are considered in the detailed design.

External stability
- Bearing and tilting failure
- Forward sliding
- Overall rotational or slip circle failure

Internal stability
- Local rupture or tensile failure of reinforcement
- Pull-out or adherence failure of reinforcement
- Sliding failure within the structure
- Wedge stability within the reinforced fill

BS8006 defines a boundary between steep slopes & walls and applied different design criteria for each designation. Reinforced soil ‘structures’ within 20° of the vertical are defined as a wall, reinforced soil ‘structures’ with inclination below 70°are defined as a steepened slope. For the design of reinforced soil walls BS8006 identifies two methods for detailed design. The coherent gravity method for inextensible reinforcement (≤1% strain: usually metallic), and the Tie-back wedge method for extensible reinforcement (>1% strain: usually polymeric). Three load cases are defined to ensure the worst case load combinations are considered for the design.

Load case A (1.5) partial load factor applied on all loadings. This is usually the critical condition for reinforcement rupture, wedge stability and bearing capacity. Load Case B considers maximum load factors applied to the earth pressure and loads behind the reinforced soil block (1.5) and minimum partial factors (1.0) applied to self-weight. This combination is normally critical for pull-out or adherence failure and forward sliding. Load Case C considers self-weight in the working condition and is used for the SLS limit states only.

Figure 1. Typical isochronous curve used for restricted service tensile stress capacity
BS 8006 prescribes a SLS limit on the internal PC strain occurring between the end of construction and the end of the design life. This is limited to 1% in walls (non-abutments) and 0.5% for abutments. The restricted tensile capacity of the geogrid, $T_{cs}$ is obtained using isochronous load-strain curves.

### 2.3 German Design Standard EBGEO

In Germany design follows the Recommendations for Design and Analysis of Structures using Geosynthetic Reinforcements, (EBGEO) (Deutsche Gesellschaft für Geotechnik, 2011), which are based on the German National Standard for Earthworks: DIN 1054 (Beuth, 2005). In contrast to the approach taken in France and UK EBGEO does not distinguish between wall and slope. This includes the magnitude of partial factors as well as the definition of potential failure modes to be analysed and the design approach. However the geotechnical category varies depending on the structure’s height, difficulty or risk (e.g. bridge abutments). Furthermore design must not contradict DIN 4084:2009-01 (Calculation of embankment failure and overall stability of retaining structures) where geosynthetic reinforcement is considered a "non pre-stressed tension member". Hence it is important to consider a correction factor $\psi$ which is depending on the type of fill-material.

Beside conventional checks of sliding, bearing and tilting failure design calculations shall include the check of all potential slip surfaces regardless of whether they are surrounding or intersecting the reinforced structure entirely, partly or without cutting a reinforcement layer. Special attention also needs to be given to prove the stability at the front facing where the classification of the facing types has been adopted as per DIN EN 14475. Depending on its capacity to compensate for absolute and differential deformation EBGEO enables to apply a calibration factor $\eta$ to reduce the coefficient of active earth pressure at the front. With regard to the serviceability limit state EBGEO recommends the following post construction deformation components are considered: foundation settlement; internal settlement of reinforced fill; horizontal movement, of the front of the structure and face deformation. Each component should be estimated as precise as possible, however adequate numerical analysis would be used only for more complex structures most commonly. In other cases it is sufficient to rely on empirical data or observational methods to be put in place, explicit proof of the SLS can be omitted for structures falling in geotechnical category GC 1 or GC 2 resp. provided that the utilisation factor $\mu$ is $\leq 0.75$ for the check of ULS.

#### Table 1. Partial factors for actions (effects).

<table>
<thead>
<tr>
<th></th>
<th>BS 8006</th>
<th>BS 8006</th>
<th>BS 8006</th>
<th>EBGEO</th>
<th>EBGEO</th>
<th>EBGEO</th>
<th>NF P 94270, XP G 38-064</th>
<th>NF P 94270, XP G 38-064</th>
<th>NF P 94270, XP G 38-064</th>
</tr>
</thead>
<tbody>
<tr>
<td>Combination A</td>
<td>$f_{ck} = 1.5$</td>
<td>$f_{ck} = 1.0$</td>
<td>$f_{ck} = 1.0$</td>
<td>$\gamma_G = 1.35$</td>
<td>$\gamma_G = 1.0$</td>
<td>$\gamma_G = 1.2$</td>
<td>$\gamma_G = 1.35$</td>
<td>$\gamma_G = 1.0$</td>
<td>$\gamma_G = 1$</td>
</tr>
<tr>
<td>Combination B</td>
<td>$f_{ck} = 1.5$</td>
<td>$f_{ck} = 1.5$</td>
<td>$f_{ck} = 1.0$</td>
<td>$\gamma_Q = 1.5$</td>
<td>$\gamma_Q = 1.3$</td>
<td>$\gamma_Q = 1.0$</td>
<td>$\gamma_Q = 1.35$</td>
<td>$\gamma_Q = 1.0$</td>
<td>$\gamma_Q = 1.3$</td>
</tr>
<tr>
<td>Combination C (ULS)</td>
<td>$f_{ck} = 1.5$</td>
<td>$f_{ck} = 1.5$</td>
<td>$f_{ck} = 1.0$</td>
<td>$\gamma_Q = 1.5$</td>
<td>$\gamma_Q = 1.3$</td>
<td>$\gamma_Q = 1.0$</td>
<td>$\gamma_Q = 1.35$</td>
<td>$\gamma_Q = 1.0$</td>
<td>$\gamma_Q = 1.3$</td>
</tr>
<tr>
<td>Limit State 1B</td>
<td>$f_{ck} = 1.5$</td>
<td>$f_{ck} = 1.5$</td>
<td>$f_{ck} = 1.0$</td>
<td>$\gamma_Q = 1.5$</td>
<td>$\gamma_Q = 1.3$</td>
<td>$\gamma_Q = 1.0$</td>
<td>$\gamma_Q = 1.35$</td>
<td>$\gamma_Q = 1.0$</td>
<td>$\gamma_Q = 1.3$</td>
</tr>
<tr>
<td>Limit State 1C</td>
<td>$f_{ck} = 1.5$</td>
<td>$f_{ck} = 1.5$</td>
<td>$f_{ck} = 1.0$</td>
<td>$\gamma_Q = 1.5$</td>
<td>$\gamma_Q = 1.3$</td>
<td>$\gamma_Q = 1.0$</td>
<td>$\gamma_Q = 1.35$</td>
<td>$\gamma_Q = 1.0$</td>
<td>$\gamma_Q = 1.3$</td>
</tr>
<tr>
<td>Limit State 2 (SLS)</td>
<td>$f_{ck} = 1.5$</td>
<td>$f_{ck} = 1.5$</td>
<td>$f_{ck} = 1.0$</td>
<td>$\gamma_Q = 1.5$</td>
<td>$\gamma_Q = 1.3$</td>
<td>$\gamma_Q = 1.0$</td>
<td>$\gamma_Q = 1.35$</td>
<td>$\gamma_Q = 1.0$</td>
<td>$\gamma_Q = 1.3$</td>
</tr>
<tr>
<td>External (ULS)</td>
<td>$f_{ck} = 1.5$</td>
<td>$f_{ck} = 1.5$</td>
<td>$f_{ck} = 1.0$</td>
<td>$\gamma_Q = 1.5$</td>
<td>$\gamma_Q = 1.3$</td>
<td>$\gamma_Q = 1.0$</td>
<td>$\gamma_Q = 1.35$</td>
<td>$\gamma_Q = 1.0$</td>
<td>$\gamma_Q = 1.3$</td>
</tr>
<tr>
<td>Internal (STR)</td>
<td>$f_{ck} = 1.5$</td>
<td>$f_{ck} = 1.5$</td>
<td>$f_{ck} = 1.0$</td>
<td>$\gamma_Q = 1.5$</td>
<td>$\gamma_Q = 1.3$</td>
<td>$\gamma_Q = 1.0$</td>
<td>$\gamma_Q = 1.35$</td>
<td>$\gamma_Q = 1.0$</td>
<td>$\gamma_Q = 1.3$</td>
</tr>
<tr>
<td>Mixed (GEO and STR)</td>
<td>$f_{ck} = 1.5$</td>
<td>$f_{ck} = 1.5$</td>
<td>$f_{ck} = 1.0$</td>
<td>$\gamma_Q = 1.5$</td>
<td>$\gamma_Q = 1.3$</td>
<td>$\gamma_Q = 1.0$</td>
<td>$\gamma_Q = 1.35$</td>
<td>$\gamma_Q = 1.0$</td>
<td>$\gamma_Q = 1.3$</td>
</tr>
</tbody>
</table>

#### 2.4 French Design Standard

The reinforced soil structures are separated in two standards in function of the front face inclination.

For a front face inclination $\eta \leq \arctan(1/4) \sim 14°$ of the vertical: NF P 94270, AFNOR 2009.

For $\arctan(1/4) < \eta \leq \arctan(1) = 45°$: XP G 38-064, AFNOR 2010.

These standards are written to complete the Eurocode 7 (NF EN 1997-1: 1995) for reinforced soil structures. The considered walls or slopes (given their inclination) reinforced with geosynthetics layers or strips, belonging to geotechnical class 2 (average geotechnical, for human and other structures risk) should be justified following these standards. French standards introduce limit states for structures (STR) and geotechnical limit states (GEO). External local and general (GEO), Internal (STR) and Mixed (GEO and STR) ULS modes are considered in the design.

External stability, reinforced structure is considered as a block:

- Local: Bearing capacity and overturning
- Local: Forward sliding of the retaining structure
- General: Slip surface failure outside of the retaining structure

Internal stability:
- Rupture in the reinforced fill caused by tensile failure of the reinforcement
- Rupture in the reinforced fill caused by adherence failure of the reinforcement
- Rupture in the facing caused by insufficient facing resistance
- Rupture in the facing cause by insufficient facing - reinforcement connection.

Mixed stability:
- Slip surface failure crossing at least one of the reinforcement layers.

Internal stability verification is not mandatory for slopes attached to the standard XP G 38-064. SLS justification consists in verifying displacement and deformations.

The ultimate limit states are checked using two approaches, which determine the partial factors to use. The “Approche 2” determines the combination of partial factors for external local (GEO) and internal stability (STR). The “Approche 3” gives the combination of partial factors for External general (GEO) and mixed stability (GEO and STR). The partial factors for actions are given in table 1, for soils parameters, reinforcement elements and, geotechnical resistances are given in table 2.

Table 2. Partial factors for resistances.

<table>
<thead>
<tr>
<th>Soil resistance</th>
<th>BS 8006</th>
<th>BS 8006</th>
<th>BS 8006</th>
<th>EBGEO</th>
<th>EBGEO</th>
<th>EBGEO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Combination A</td>
<td>Combination B</td>
<td>Combination C (ULS)</td>
<td>Limit State 1B or LC1</td>
<td>Limit State 1C or LC2</td>
<td>Limit State 2(SLS) or LC3</td>
<td>ULS Approche 2</td>
</tr>
<tr>
<td>Foundation Bearing Capacity</td>
<td>f handicapped = 1.35</td>
<td>f handicapped = 1.35</td>
<td>f handicapped = 1.0</td>
<td>γGR = 1.4</td>
<td>γGR = 1.4</td>
<td>γR,d ≥ 1.1</td>
</tr>
<tr>
<td>Base Sliding</td>
<td>f_s = 1.2</td>
<td>f_q = 1.2</td>
<td>f_q = 1.0</td>
<td>γGf = 1.4</td>
<td>γGf = 1.4</td>
<td>γR,h = 1.1</td>
</tr>
<tr>
<td>Soil Strength factors</td>
<td>fms = 1.0</td>
<td>fms = 1.0</td>
<td>fms = 1.0</td>
<td>γF_s = 1.25</td>
<td>γF_s = 1.25</td>
<td>γϕ = 1.25</td>
</tr>
<tr>
<td>Tan φ</td>
<td>fms = 1.6</td>
<td>fms = 1.6</td>
<td>fms = 1.0</td>
<td>γF_s = 1.25</td>
<td>γF_s = 1.25</td>
<td>γc' = 1.25</td>
</tr>
<tr>
<td>Pull out resistance</td>
<td>f_p = 1.3</td>
<td>f_p = 1.3</td>
<td></td>
<td>γM,H = 1.4</td>
<td>γM,H = 1.35</td>
<td>γM,H = 1.1</td>
</tr>
<tr>
<td>Reinforcement material factor</td>
<td></td>
<td></td>
<td></td>
<td>γM_H = 1.4</td>
<td>γM_H = 1.3</td>
<td>γM_H = 1.2</td>
</tr>
</tbody>
</table>

*SLS in French standards are linked to creep. Strain of the geosynthetic after the construction of the wall or slope, is limited to 3%

2.5 Comparison of Design strength

BS 8006 prescribes a limit on the internal PC strain occurring between the end of construction and the end of the design life. This is limited to 1% in walls (non-abutments) and 5% in slopes. The restricted tensile capacity of the geogrid, Tcs is obtained using isochronous load-strain curves (figure 2), before reducing this value to the SLS design strength TD using equation 1.

\[ T_D = \frac{T_c}{f_m} = \frac{T_c}{R \cdot R' \cdot W' \cdot c \cdot t_s} \]  

Where:
RF_D = reduction factor (RF) for installation damage;
RF_W = RF for weathering;
RF_CHEM = RF for chemical and environmental effects;
f_s = factor of safety for the extrapolation of data.

These factors are determined in accordance with PD ISO/TR 20432 (British Standards Institute, 2007). Considering EBGEO the long term strength of the geosynthetic FB,d is determined from equation 2:
Where:

- $F_{B,d}$: Design strength
- $F_{B,k0}$: Characteristic tensile strength (EN ISO 10319)
- $A_1$: Reduction factor for creep strain or creep rupture
- $A_2$: Reduction factor considering any damage during transportation, installation and compaction
- $A_3$: Reduction factor for joints and connections
- $A_4$: Reduction factor for environmental effects (weathering and resistance to UV light, effects of temperature, chemical resistance, microbiological resistance)
- $A_5$: Reduction factor for dynamic action
- $\gamma_M$: Partial safety factor for the structural resistance flexible reinforcement elements

It is to be noted that above reduction factors are meant to be mean values. $F_{B,k0}$ however is denoted as based on 95% confidence level.

EBGEO defines the serviceability limit state, as structural deformation as a consequence of characteristic dead loads and soil parameters.

Table 3. Partial safety factors for flexible reinforcement DIN 1054.

<table>
<thead>
<tr>
<th>Load Case</th>
<th>LC1</th>
<th>LC2</th>
<th>LC3</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\gamma_M$</td>
<td>1.4</td>
<td>1.3</td>
<td>1.2</td>
</tr>
</tbody>
</table>

Considering the French standards, the long term strength of the geosynthetic Rt,d is calculated from equation 3:

$$R_{t,d} = \rho_e \cdot \rho_{fl} \cdot \rho_d \cdot \frac{R_{t,k}}{\gamma_{M,t}} = \frac{R_{t,k}}{\rho_e \cdot \rho_{fl} \cdot \rho_d \cdot \gamma_{M,t}}$$

Where:

- $R_{t,d}$: Design strength
- $R_{t,k}$: Characteristic tensile strength
- $\rho_{end}$: Reduction coefficient for damages due to mechanical aggressions during construction.
- $\rho_{fl}$: Reduction coefficient for the evolution of the material under creep.
- $\rho_{deg}$: Reduction coefficient for the chemical or biochemical degradations due to the environment.
- $\gamma_{M,t}$: Partial safety factor for the structural resistance of the geosynthetic reinforcement. $\gamma_{M,t} = 1.25$

The reduction coefficients are determined with lab tests. In case of lack of tests, the French standards prescribes conservative default values. Table 4 shows exemplarily the design strength for a polyester geogrid type Fortrac 80/30-20T and 55/30-20T computed using reduction coefficients from lab tests (a) and compared with a product of same characteristic strength using default values. (b).

Table 4. Design strength of Fortrac 55/30-20T & 80/30-30T for $D_{90} \leq 63$mm.

<table>
<thead>
<tr>
<th>Design Strength (kN/m)</th>
<th>BS8006</th>
<th>EBGEO LC1/LC2/LC3</th>
<th>NF P 94270 or XP G 38-064</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fortrac 55 T</td>
<td>26.4</td>
<td>22 /23.7/25.6</td>
<td>22.2 (a) / 8.2 (b)</td>
</tr>
<tr>
<td>Fortrac 80 T</td>
<td>41.0</td>
<td>34.1/36.7/39.8</td>
<td>33.7 (a) / 11.9 (b)</td>
</tr>
</tbody>
</table>

3 DESIGN COMPARISON

The example analysed for each design approach, considers, a vertical wall with an overall height of 7.5m (including 0.5m embedment depth). A permanent surcharge of 10 kN/m² acting across the top of the wall
and a variable load equivalent to 5 kN/m² 2m back from the crest of the front face of the wall is also be considered.(see Figure 2)

Figure 2. Reinforced soil wall design example

Each design is based on utilising the Huesker’s Fortrac T range of geogrids, namely the Fortrac 55 T & Fortrac 80 T detailed in Table 4 and is based on utilising a fill with a D₉₀ ≤63mm. The vertical spacing between geogrids is limited to 0.5m and a full connection capacity is assumed between the facing unit and the geogrid.

The soil parameters used in the Analysis are summarized in Table 5 below:

<table>
<thead>
<tr>
<th></th>
<th>Friction Angle</th>
<th>Cohesion</th>
<th>Unit Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Peak φ' p (°)</td>
<td>Constant Volume φ' cv (°)</td>
<td>(kN/m²)</td>
</tr>
<tr>
<td>Reinforced Fill</td>
<td>40</td>
<td>34</td>
<td>0</td>
</tr>
<tr>
<td>Backfill</td>
<td>40</td>
<td>34</td>
<td>0</td>
</tr>
<tr>
<td>Foundation</td>
<td>37</td>
<td>31</td>
<td>0</td>
</tr>
</tbody>
</table>

The design procedure involves:
- Initial sizing of the structure
- Satisfy reinforced soil block for External stability modes
  - Bearing and tilting failure
  - Forward sliding
  - Overall rotational or slip circle failure
- Satisfy internal stability
  - Local rupture or tensile failure of reinforcement
  - Pull-out or adherence failure of reinforcement
  - Sliding failure within the structure
  - Wedge stability within the reinforced fill
- Finally check serviceability

3.1 External Stability

The length of the geogrid reinforcement is often governed by the minimum ratio of reinforcement length to effective retained height (BS8006 ≈0.7 H or 3m) and then the external stability is checked in a similar manner to traditional retaining wall analysis.
The French standards recommend length of the geogrid reinforcement over 2.5 m. The overall required reinforcement length is summarised in Table 6.

Table 6. Required length of Geogrid Reinforcement

<table>
<thead>
<tr>
<th>Wall height (m)</th>
<th>BS 8006 Reinforcement length (m)</th>
<th>EBGEO Reinforcement length (m)</th>
<th>NF P 94270 Reinforcement length (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.5</td>
<td>5.25</td>
<td>5.25</td>
<td>4m in the first 7 layers from 0 to 3 m high</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- 3m in the next 7 layers from 3.5 to 6.5 m high</td>
</tr>
</tbody>
</table>

3.2 Internal Stability

Internal stability is assessed by each guide/code using a similar approach however, using dissimilar partial load and material factors, resulting in differing stresses and strains. Additionally differing geogrid design strengths are used (See Table 4.) The overall required capacity and provided strength of the geogrid layers is compared in Table 7.

Table 7. Required/provided strength of Geogrid Reinforcement

<table>
<thead>
<tr>
<th>Wall height (m)</th>
<th>Overall Required/Provided Geogrid Strength (kN/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Required</td>
<td>BS 8006 =300</td>
</tr>
<tr>
<td>Provided</td>
<td>EBGEO</td>
</tr>
<tr>
<td>Fortrac 80 T</td>
<td>454</td>
</tr>
<tr>
<td>Fortrac 55 T</td>
<td>290 (11 layers)</td>
</tr>
<tr>
<td>UTS</td>
<td>925</td>
</tr>
</tbody>
</table>

4 CONCLUSION

Three European design guides have been compared to highlight their similarities and differences. The design principles in each code are similar and follow the ‘limit state’ concept and consider ultimate limit states (ULSs) and serviceability limit states (SLSs).

Similar load factors are applied to the actions (disturbing forces) to increase their value and partial material factors are applied to resistances (restoring forces) to reduce their values broadly in line with the principals in Eurocode 7. Although principal differences exist in how each code applies the load and resistance factors. Currently differences exist in how each code determines the long term design strength for the geogrid reinforcement resulting in variation in the long term design strength for identical geogrids.

The comparison of three European standards / recommendations for the design of reinforced soil retaining structures has demonstrated that there is quite significant discrepancy between the resulting geogrid requirements for the identical wall example.

One of the aims of ongoing collaborative efforts will be to try to agree on the common design procedure and partial factors to be applied in determining the overall required forces and to eliminate the variance in available long-term design strength by reaching a consensus on the most appropriate method for the determination of the long term design strength of the geogrids.

5 ISSUES FOR PRACTICE

All products produced by Huesker Synthetic GmbH are manufactured under our ISO 9001 quality scheme which provides consistency in the manufacture and distribution of geosynthetic reinforcement. Consideration therefore of variation in the long term design strength for identical design case example appears illogical.

European Technical committee TC250/SC7 for Eurocode 7 has established an evolution group (EG5 - Reinforced soil) to compare and contrast current European practice for the design of reinforced soil structures, with the ultimate aim of trying to establish if the design of reinforced soil design practice could be brought in line with EC7.
One step to achieving this principal aim is to reach a consensus on the most appropriate method for determination of the long term design strength of geogrids. Such guidance is already provided in PD ISO/TR 20432: Guidelines for the Determination of the Long-Term Strength of Geosynthetic for Soil Reinforcement, and is the approach recommended in BS8006: Part 1: 2010.

EG5 members have already reached agreement that the PD ISO/TR 20432 is the preferred method for determination of long term design strength. The other aim of EG5 is to unify the design procedure within the scope of Eurocode 7 and existing partial factors. The design of reinforced earth structures however requires additional partial factors that are not yet introduced within the EC7 scope and the EG5 is going to identify those and will have to agree on the general values which will be than inserted into the Annex A of EC7. The final and probably most difficult aim of EG5, in order to unify the reinforced earth structures design, is to agree on the common design procedure, which is, as indicated in the above paper, different in all the above mentioned design procedures. Hopefully this goal will be achieved and the proposed design procedure will be made available as a new Annex to EC7.

6 DISCUSSION

The comparison of three European standards / recommendations for the design of reinforced soil retaining structures has demonstrated that there is quite significant discrepancy between these guides. A common base EC7 has been put into practice already for 10 years. In light of the fact that some Nordic countries (Finland, Norway, Sweeden, Denmark) and the Netherland, have published or are currently discussing their own guidance for this application, it seems necessary to promote active contribution to the European Evolution Group EG5. The aim is that a revision of EC7 incorporating reinforced soil will be published on or about 2020 based on EG5 work.

REFERENCES

Association Française de Normalisation (AFNOR), 2009. NF P 94-270. Calcul géotechnique- ouvrage de soutènement- remblais renforcés et massifs en sol cloué, AFNOR, Cedex
Association Française de Normalisation (AFNOR), 2010. XP G 38-064 Utilisation des géotextiles et produits apparentés. Murs inclinés et talus raidis en sols renforcés par nappes géosynthétiques, AFNOR, Cedex
British Standards Institute, 2006. BS EN 14475: Execution of special geotechnical works – Reinforced fill, London: British Standards Institute