Eurocode 7: Geotechnical design - Part 1: General rules - its implementation in the European Member states

Eurocode 7 : *Calcul géotechnique* – Partie 1 : *Règles générales* - mise en œuvre dans les Pays Membres de l'UE

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ABSTRACT

In December 2004 Eurocode 7: *Geotechnical design* - Part 1: *General rules* (EC 7-1) was unanimously ratified by the European Member States and the three language versions of EC 7-1 have been available since the end of 2004. Then the calibration period of two years started in which the Member States have to write the National Annex to EC 7-1 which is the link between EC 7-1 and the national standards. After the calibration period and a further 3-year coexistence period EC 7-1 will become valid in all Member States in around 2009. National standards covering the same items as EC 7-1 will then have to be withdrawn. This paper describes the provisions that will govern the implementation and evolution of the new system of Eurocodes, National Annexes and national standards. By way of an example, this process is illustrated for Germany where many "old" geotechnical design standards have to be adapted to fit into the new system of European and national standards. When EC 7-1 is implemented the Member States have to decide on the three design approaches for the verification of geotechnical ultimate limit states and the values of the partial factors. Questionnaires on the selection of the design approaches and the partial factors were sent to the delegates of Subcommittee 7 of CEN which is in charge of EC 7. Based on the results of these questionnaires an overview of the present situation of the implementation of EC 7-1 in Europe and an outlook for future work on maintenance, training and research is given.

RÉSUMÉ

En décembre 2004, Eurocode 7 : *Calcul géotechnique* – Partie 1 : Règles générales (EC 7-1) a été ratifié à l'unanimité par les Pays Membres de l'UE et les trois versions linguistiques sont disponibles depuis le début de 2005. La date de disponibilité de l'EC 7-1 marque le début de la période d'étalonnage de deux ans pendant laquelle les Pays Membres doivent rédiger l'annexe national à l'EC 7-1 qui constitue le lien entre l'EC 7-1 et les normes nationales. Après la période d'étalonnage et 3 autres années de coexistence, l'EC 7-1 entrera en vigueur dans tous les États Membres vers 2009. Les normes nationales régissant les mêmes matières que l'EC 7-1 devront être alors retirées. L'article décrit les dispositions qui règleront la mise en œuvre et l'évolution du nouveau système d'Eurocodes, d'annexes nationales et de normes nationales. L'Allemagne où beaucoup d'anciennes normes de conception géotechnique doivent être adaptées au nouveau système de normes européennes et nationales est un exemple d'application de ce processus. Une fois l'EC 7-1 mis en place, les Pays Membres doivent prendre les décisions concernant les trois approches de calcul pour vérifier les états limites ultimes géotechniques ainsi que les valeurs des facteurs partiels. Des questionnaires sur le choix des approches de calcul et des facteurs partiels ont été envoyés aux délégués du Sous-Comité 7 de CEN chargé de l'EC 7. Les résultats de ces questionnaires permettront d'obtenir une vue d'ensemble sur la situation actuelle quant à la mise en œuvre de l'EC 7-1 en Europe ainsi que les perspectives sur les travaux futurs de maintenance, de formation et de recherche

Keywords: standards, Eurocodes, partial factors of safety

1 PROVISIONS FOR THE IMPLEMENTATION IN THE MEMBER STATES

Under the *Public Procurement Directives* of the European Commission (EC, 2004), it will be mandatory for the Member States to accept designs to the EN Eurocodes. Therefore, EN Eurocodes will become the standard technical specifications for all public works contracts. It will not be mandatory to design to the EN Eurocodes in a particular Member

State, but a designer proposing to use alternative design standards will have to demonstrate that the alternative is technically equivalent to an EN Eurocode solution.

Three basic principles that have to be adhered to when harmonizing European standards have been set out by the European Commission in *Guidance Paper L - Application and use of Eurocodes* (2003a). The principles are as follows:

- Eurocodes must be introduced in all EU Member States by the National Standards Bodies.
- National standards in the technical fields in which European standards exist must be withdrawn after a transitional period but
- national standards in the technical fields not covered by European standards are permitted as long as they do not conflict with the Eurocodes.

The three language versions of Eurocode 7: *Geotechnical design* - Part 1: *General rules* (EC 7-1) were published by CEN Management Centre in November 2004. This is the official Date of Availability and from now on the European Member States have a period of two years - known as the National Calibration Period - in which to prepare the national versions of EC 7-1. These will comprise

- a national title page and national foreword,
- the full text of the Eurocode with all annexes and
- a National Annex.

The National Annex (NA) is needed as a link between the Eurocode and the national standards of the Member States. One of the most important principles for drafting and implementing the Eurocodes is stated in clause 2.1 *National Provisions for the structural design of works* of *Guidance Paper L:*

2.1.1 The determination of the levels of safety of buildings and civil engineering works and parts thereof, including aspects of durability and economy, is, and remains, within the competence of the Member States.

That is why the Eurocodes only state recommended values of the partial factors; the actual values may be set by the Member States in the NA. Moreover, *Guidance Paper L* states that the national competence to determine the level of safety may also comprise the use of alternative design methods (see 2.1.2). EC 7-1 has made use of this option of alternative design approaches for the verification of geotechnical ultimate limit states (GEO). To make EC 7-1 operational in the Member States, the NA will therefore

- define the values of the partial safety factors,
- select the national design approaches and
- draw up specifications on the use of the informative annexes of EC 7-1.

Then there are two more important rules for writing a national annex. *Guidance Paper L* also stipulates the following:

2.3.4 A National Annex cannot change or modify the content of the EN Eurocode text in any way other than where it indicates that national choices may be made by means of Nationally Determined Parameters.

That is why the foreword of each Eurocode includes a list of those paragraphs in which national choice is allowed. No other changes or modifications are permitted:

2.1.6 National Provisions should avoid replacing any EN Eurocode provisions, e.g. Application Rules, by national rules. ... When, however, National Provisions do provide that the designer may deviate from or not apply the EN Eurocodes or certain provisions thereof, then the design will not be called "a design according to EN Eurocodes.

As a result of these basic provisions the following hierarchy of Eurocodes will exist in future. At the top are the Eurocode *Basis of design* and Eurocode 1 *Actions on structures* with several parts and annexes. They form the basis of structural design throughout Europe. All other Eurocodes - from EC 2 *Design of concrete structures* to Eurocode 9 *Design of Aluminium structures* – refer to those two Eurocodes. Most of the Eurocodes are more or less umbrella codes. So a design cannot be performed using Eurocodes alone as the values of the partial factors are recommended values, for example. Moreover, most of the Eurocodes only offer options for design approaches (DA). National standards are still needed for geotechnical design as EC 7-1 gives no mandatory geotechnical calculation models. So an NA is absolutely essential, not only to lay down the special application of EC 7-1 in each Member State with respect to the selected DA but also the specify the values of the partial factors. Moreover, it constitutes the link between the Eurocode and the national standards and makes the Eurocodes operable in each Member State.

In the following it will be shown how the process of introducing EC 7-1 and adapting national geotechnical standards is progressing in Germany. There are a great number of "old" geotechnical standards and recommendations containing valuable experience in geotechnical design. It goes without saying that such experience must be preserved so that it is possible to benefit from it in future. This is possible as there is no conflict with the principles and application rules of EC 7-1. These situations and the associated problems are therefore typical of many European countries.

2 NATIONAL ANNEX AND IMPLEMENTATION IN GERMANY

The situation in geotechnical engineering in Germany is characterized by the fact that there are now two standards:

- Eurocode 7: *Geotechnical design, Part 1: General rules* and
- DIN 1054 *Verification of Safety of Earthworks and Foundations*.

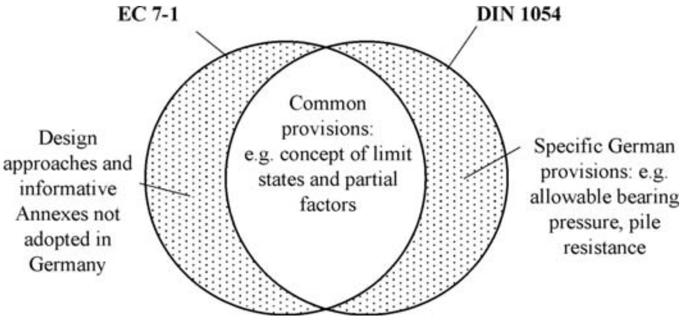

Figure 1: Areas of EC 7-1 and DIN 1054 in Germany

The contents of both standards are shown by the areas of the two circles in Figure 1. The circles overlap as the bulk of the rules are identical, e.g. the concept of limit states and partial factors. The overlap represents the normative part of EC 7-1. In addition, there are a number of rules in EC 7-1 that are not included in DIN 1054, e.g. the design approaches and those informative annexes that will not be adopted in Germany. Moreover, there are specific German geotechnical design rules that have been laid down in DIN 1054 but have not been incorporated into EC 7-1, e.g. allowable bearing pressures for the design of shallow foundations and characteristic values for pile base and shaft resistances as a function of the cone resistance of the CPT for pile design. Germany certainly wishes to preserve these design rules and may do so as long as they do not conflict with the Eurocode.

Guidance Paper L states that national provisions may not be incorporated into the NA (see 2.3.3). The latter may only contain references to non-conflicting complementary information to assist the user in applying the Eurocode. The easiest and most elegant way would be to refer to DIN 1054 in the NA. However, DIN 1054 must be withdrawn in 2009 because it conflicts with EC 7-1. To make DIN 1054 compatible with the system of European standards it must be revised,

- deleting those parts of DIN 1054 already covered in EC 7-1 and
- re-organising the rest according to the structure and contents of EC 7-1 to make it more user-friendly.

The revised DIN 1054 called "German Application Rules for EC 7-1" will then only contain additional provisions and information and will no longer conflict with EC 7-1. Moreover it will contain the values for the partial factors and the selection of the DA to be used in the verification of the various geotechnical ultimate and serviceability limit states. Thus the German National Annex will just contain a list of references and has an informative status as stated in clause 2.3.7 of *Guidance Paper L*.

Figure 2 shows how DIN EN 1997-1, which will be the German version of EC 7-1, the National Annex and the national standards will be linked in future. As from 2009, the basic document will be DIN EN 1997-1 with the National Annex in which reference will be made to the revised edition of DIN 1054 for all complementary provisions and information concerning the safety of geotechnical design. As for the analytical models to be used in design, the National Annex will refer to DIN standards dealing with the calculation of bearing pressure for shallow foundations, slope failure and earth pressure, for example.

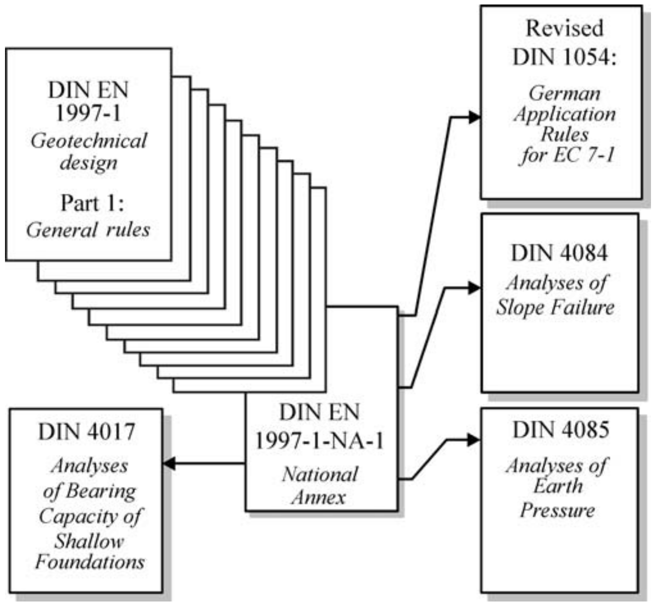

Figure 2: Future system of German Standards for geotechnical design

The time-table for the implementation of EC 7-1 is shown in Figure 3. As mentioned before there are currently two standards containing rules for the verification of the safety of geotechnical design EC 7-1 and DIN 1054.

The date of availability for the three language versions of EC 7-1 was November 2004. According to *Guidance Paper L* there is a calibration period of two years until the end of 2006 to write the German National Annex. To preserve specific German geotechnical experience, DIN 1054 *Verification of Safety of Earthworks and Foundations* will be revised concurrently with DIN 1054 *German Application Rules for EC 7-1* so that it can be referred in the National Annex. After the calibration period, the German building authorities will have to introduce

EC 7-1 as DIN EN 1997-1 with the National Annex, which will be a separate paper (DIN EN 1997-1-NA-1). It will still be permitted to use DIN 1054 *Verification of Safety of Earthworks and Foundations* as a national standard in the following three years of the coexistence period but, at the end of 2009, all national standards will have to be withdrawn in the fields where Eurocodes exist - including DIN 1054 *Verification of Safety of Earthworks and Foundations*.

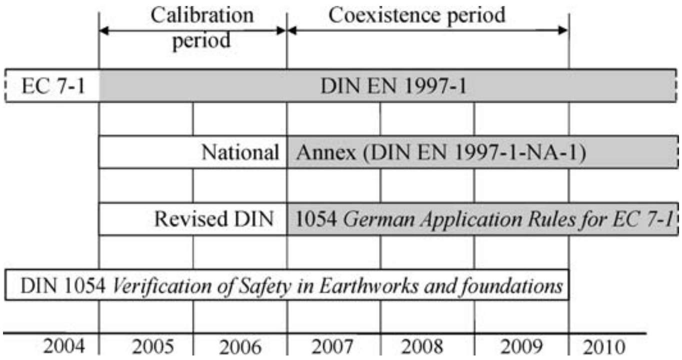

Figure 3: Time-table for the implementation of EC 7-1 and DIN 1054 "German Application Rules for EC 7-1"

The three documents, DIN EN 1997-1 *Geotechnical design* - Part 1 - *General rules* (EC 7-1), the German National Annex and DIN 1054 *German Application Rules for EC 7-1* are by no means user-friendly as the user has to work with three different documents. It is for this reason that, parallel to the work on the NA, a *DIN Technical Report* combining these documents is being drawn up. In the *DIN Technical Report* it will be indicated typographically which provisions originated in which standard. This will certainly be the most practical solution for the user.

3 VERIFICATIONS OF ULTIMATE LIMIT STATES BY CALCULATION

3.1 *General*

EC 7-1 offers three different design approaches (DA 1, DA 2 and DA 3) for the verification of the ultimate limit states of rupture or excessive deformation of a structural element or section in the ground (STR and GEO limit states) in persistent and transient situations. The three design approaches of EC 7-1 differ in the way in which they introduce the partial factors on the actions and resistances. The choice of the design approach can be determined nationally by each Standards Body (e.g. AFNOR, DIN, etc.). Yet different design approaches can be used to verify different limit states. The numerical values of the partial factors to be applied in a given design procedure can also be determined nationally and specified in the NA to EC 7-1.

Only one equation is given in EC 7-1 for the verification of the ultimate limit states of uplift (UPL) and of failure by hydraulic heave (HYD) due to seepage of water in the ground. Thus only the numerical values of the partial factors can be determined nationally in the NA.

3.2 *Design Approach DA 1*

In Design Approach DA 1, two combinations of partial factors have to be investigated. Combination 1 aims to provide safe design against unfavourable deviations of the actions from their characteristic values. Thus, in Combination 1, partial factors greater than 1.0 are applied to the permanent and variable actions from the structure and the ground (see Table 2). The factors are the same as those used in other fields of structural engineering and they are consistent with those specified in EN 1990: *Basis of structural design*. By contrast, the calculations for the ground resistance are performed with characteristic values, i.e. the partial factors γ_φ, γ_c and γ_{cu}, which are all set at 1.00, are applied to the shear parameters; the partial factor for the ground resistance, γ_R, is also 1.00.

Combination 2 of Design Approach DA 1 aims to provide safe design against unfavourable deviations of the ground strength properties from their characteristic values and against uncertainties in the calculation model. It is assumed that the permanent actions correspond to their expected values and the variable actions deviate only slightly from their characteristic values. The partial factors are applied to the representative values of the actions and to the characteristic values of the ground strength parameters at the beginning of the calculation. Thus the entire calculation is performed with the design values of the actions and the design shear strength.

Of the two Combinations, the one resulting in the larger dimensions of the foundation will be relevant for designs according to Design Approach DA 1. More details on the use of the three Design Approaches are given in Frank et al. (2004), for instance.

3.3 *Design Approaches DA 2 and DA 2**

In Design Approach DA 2, only one verification is required unless different combinations of partial factors for favourable and unfavourable actions need to be dealt with separately in special cases. In DA 2, the partial factors applied to the resistances of the ground and the partial factors to geotechnical actions and effects of actions are the same as those applied to the actions on or from the structure (see Table 2).

There are two ways of performing verifications according to Design Approach DA 2. In the design approach referred to as "DA 2" by Frank et al.

(2004), the partial factors are applied to the characteristic actions right at the start of the calculation and the entire calculation is subsequently performed with design values. By contrast, in the design approach referred to as “DA 2*” by Frank et al. (2004), the entire calculation is performed with characteristic values and the partial factors are not introduced until the end when the ultimate limit state condition is checked. As characteristic internal forces and moments are obtained in the calculation, the results can generally also be used as a basis for the verification of serviceability.

3.4 *Design Approach DA 3*

Similarly, only one verification is required for Design Approach DA 3. The partial factors applied to the actions on the structure or coming from the structure are the same as those used in Design Approach DA 2. However, for the actions and resistances of the ground, the partial factors are not applied to the actions and resistances but to the ground strength parameters, φ´, c´ or c_u instead. The partial factors are applied to the representative values of the actions at the beginning of the calculation and to the characteristic values of the ground strength parameters. Thus, in Design Approach DA 3, the entire calculation is performed with the design values of the actions and the design shear strength.

4 STATE OF IMPLEMENTATION AND DECISIONS ON THE DESIGN APPROACHES OF EC 7-1 BY THE EUROPEAN MEMBER STATES

4.1 *General*

Questionnaires were sent to the Member States in 2005 and 2006 to collect information about the stage that had been reached in the implementation of EC 7-1, the drafting of the National Annex and the selection of the partial factors and design approaches. The questionnaire of 2006 was more detailed in so far as the selection of the design approaches and the numerical values for the partial factors was linked to practical examples. The examples were taken from geotechnical design examples prepared for the International Workshop on the Evaluation of EC 7-1 held in Trinity College, Dublin on 31st March and 1st April 2005 (Orr, 2006). The aim of the questionnaire was

- to stimulate the discussion on problems of implementing and applying EC 7-1 in the European Member States and
- to support and discuss with the Joint Research Centre (JRC) of the European Commission the next steps in their mandate to contribute to the implementation, harmonization, international promotion and further development of the Eurocodes.

The questionnaires were sent to the National Standard Bodies of the Member States of the European Union and to the affiliated Member States of CEN. Not all were returned up until January 2007. Some of them were not filled in completely as some Member States had not concluded their decision-making process on which design approaches and partial factors to use in geotechnical verifications. Other questionnaires contained quite detailed explanations and reports on the state of the discussions. The following sections can therefore only give an overview of the most important aspects of the implementation of EC 7-1 reached by January 2007.

4.2 *GEO ultimate limit states*

The decisions of the Member States with respect to the selected design approaches for the GEO ultimate limit states are presented in Table 1. The design approaches had to be given for the design of

- a shallow foundation where the ground bearing capacity and sliding failure had to be verified;
- a pile foundations for bored and driven piles based on soil parameter values and pile load tests;
- a retaining structure of an anchored sheet pile quay wall - design of embedment depth - and
- a road embankment constructed over soft clay where the maximum height had to be determined based on an analysis of the slope stability.

Table 1: Selection of Design Approach in the European Member States (as at January 2007)

<table>
<tr><th rowspan="2">Design example</th><th rowspan="2">No/incomlete answers from</th><th colspan="5">Design approach of EC 7-1</th></tr>
<tr><th>all DAs</th><th>DA 1</th><th>DA 2</th><th>DA 2*</th><th>DA 3</th></tr>
<tr><td rowspan="2">Shallow foundation</td><td rowspan="5">N, CZ, M, S, EST, LV, CY, IS, H, BG</td><td rowspan="2">IRL</td><td rowspan="2">B, UK, P, LT, I, RO</td><td>F, SK, I</td><td>D, A, E, PL SLO, GR</td><td rowspan="2">CH, NL, DK</td></tr>
<tr><td colspan="2">SF, L</td></tr>
<tr><td>Piles</td><td>IRL</td><td>B, UK, P, LT, I, RO</td><td colspan="2">F, SK, CH, SF, D, A, E, NL, SLO, PL, DK, GR, L</td><td>NL</td></tr>
<tr><td>Retaining structures</td><td>IRL</td><td>B, UK, P, LT, I, RO</td><td colspan="2">F, SK, CH, SF, D, A, E, SLO, PL, GR, L</td><td>NL, DK</td></tr>
<tr><td>Slopes</td><td>IRL</td><td>B, UK, P, LT, I</td><td colspan="2">F,E</td><td>NL,F,SK,CH,SF,D,A, PL, DK, SLO, GR, L, RO</td></tr>
<tr><td>Total:</td><td>10</td><td>1</td><td>5-6</td><td colspan="2">2 - 13</td><td>2 - 13</td></tr>
</table>

One Member State has decided to admit all three design approaches. Five countries have decided to use Design Approach DA 1 in all GEO ultimate limit states. Between 11 and 13 Member States have made design approaches DA 2 and DA 2* mandatory for shallow foundations, piles and retaining structures whereas two or three have chosen Design Approach DA 3. However, almost all Member States that have selected Design Approach DA 2 or DA 2* for shallow foundations, piles and retaining structures have decided that Design Approach DA 3 will be mandatory for slope stability, except for Spain. In most cases, the use of DA 3 for slopes is effectively similar to use of Combination 2 in DA 1.

The partial factors for the three design approaches recommended in Annex A of EC 7-1 are presented in the first line of each design example in Tables 2, 3 and 4. The second line contains the Member States and their choice of partial factors if they differ from the recommended values.

Table 2: Selection of partial factors for GEO limit states for pad foundations

Design example	DA 1: recommended factors MS: Differing values	DA 2: recommended factors MS: Differing values	DA 3: recommended factors MS: Differing values
Example 2: Pad foundation – verification of ground bearing capacity	C.1: $\gamma_G = 1.35$; $\gamma_{G,fav} = 1.0$; $\gamma_Q=1.50$ C.2: $\gamma_G= 1.0$; $\gamma_Q= 1.30$; $\gamma_\varphi= 1.25$; $\gamma_{c'}= 1.25$, $\gamma_{cu}= 1.40$;	$\gamma_G =1.35$; $\gamma_{G,fav} =1.0$; $\gamma_Q=1,5$, $\gamma_{R;v} = 1,4$	$\gamma_\varphi= \gamma_c=1.25$;$\gamma_{cu}=1.40$;$\gamma_Q= 1.3$, structure: $\gamma_G= 1.35$; $\gamma_{G,fav}= 1.0$; $\gamma_Q=1.5$
	IRL: C.1: $\gamma_{cu} = 1.25$ B: C.2: $\gamma_Q = 1.10$ LT: $\gamma_{G,fav} = 0.90$; I: C.1: $\gamma_G = 1.5$, $\gamma_{G,fav} = 1.3$; C.2: $\gamma_{G,fav} = 1.0$, $\gamma_G = 1.3$; $\gamma_c= 1.4$, $\gamma_{R,v} =1.8$;	E: global Factor $\gamma_{R;v} = 3.0$, F: $\gamma_{R;v} = ?$ I: $\gamma_G =1.5$,$\gamma_{G,fav} =1.3$, $\gamma_{R,h}=1.1$ L, SK undecided	CH: $\gamma_\varphi= 1.2$; $\gamma_c= 1.5$;$\gamma_{cu}= 1.5$; structure: $\gamma_{G,fav}= 0.8$ NL: $\gamma_\varphi=1.15$, $\gamma_c=1.6$; $\gamma_{cu}=1.35$; structure: $\gamma_{G,fav}= 0.90$; DK: $\gamma_\varphi= 1.2$; $\gamma_c= 1.2$, $\gamma_{cu}= 1.8$; structure: $\gamma_G = 1.2 / 1.0$; $\gamma_{G,fav}= 1.0 / 0.9$
Example 2: Pad foundation – verification of sliding resistance	C.1: $\gamma_{G;unfav}=1.35$; $\gamma_{G,fav}=1.0$; $\gamma_Q=1.50$ C.2: $\gamma_G= 1.0$; $\gamma_Q= 1.30$; $\gamma_{\varphi'}= \gamma_{c'}= 1.25$, $\gamma_{cu}= 1.40$;	$\gamma_{G;unfav}= 1.35$; $\gamma_{G,fav}=1.0$; $\gamma_Q= 1.50$, $\gamma_{R;h} = 1.10$	$\gamma_\varphi= \gamma_c=1.25$; $\gamma_{cu}=1.40$;$\gamma_Q= 1.30$, structure:$\gamma_G= 1.35$; $\gamma_{G,fav}=1.0$; $\gamma_Q=1.5$
	B: C.2: $\gamma_Q = 1.10$ I: C.1: $\gamma_G = 1.5$, $\gamma_{G,fav} = 1.3$, C.2: $\gamma_c= 1.4$, $\gamma_{G,fav} = 1.0$, $\gamma_{R;h} = 1.1$ LT: $\gamma_{G,fav} = 0.90$;	IRL: $\gamma_{R;h} = 1.40$ E: global factor $\gamma_{R;h} = 1.5$ F: $\gamma_{R;h} = ?$ L, SK undecided	CH:$\gamma_\varphi=1.2$; structure:$\gamma_{G,fav} = 0.8$ NL: $\gamma_\varphi=1.15$, $\gamma_c=1.6$; $\gamma_{cu}=1.35$; structure: $\gamma_{G,fav} = 0.90$; DK: $\gamma_\varphi= 1.2$; $\gamma_c= 1.2$, $\gamma_{cu}= 1.8$; structure: $\gamma_G = 1.2 /1.0$; $\gamma_{G,fav}= 1.0 / 0.9$

C.1: combination 1 of DA 1, C.2: combination 2 of DA 1,
γ_G: partial factor for unfavourable permanent actions,
$\gamma_{G;fav}$: partial factor for favourable permanent actions
γ_Q: partial factor for unfavourable variable actions (for favourable variable actions $\gamma_Q = 0$)
$\gamma_{R;e}$: partial factor for passive earth pressure on the side of the shallow foundation
$\gamma_{R;v}$: partial factor for ground bearing resistance
$\gamma_{R;h}$: partial factor for resistance to sliding
γ_φ : partial factor for the angle of shearing resistance
γ_c : partial factor for the effective cohesion
γ_{cu} : partial factor for the undrained shear strength

There are no great deviations from the recommended values of the partial factors for the verification of the pad foundation (see Table 2) when the design approaches DA 1 and DA 2 are adopted, with the exception of Spain which has retained the old concept of global factors using a factor, $\gamma_{R,v}$ of 3.0. It is interesting to note that Finland has additionally introduced model factors to account for three different reliability classes and Austria and Germany apply reduced partial factors in transient design situations during construction or repair. However, the variance in partial factors is greater for Design Approach DA 3. The Netherlands reduces almost all factors except the factor on the cohesion intercept c′ in terms of effective stresses; Switzerland reduces the factor on the effective angle, φ′ of shearing resistance but increases the factor on the cohesion intercept, c′. For favourable permanent actions Switzerland even uses a factor of $\gamma_{G,fav} = 0.80$.

For piles design approaches DA 1 and DA 2 were chosen by all Member States except for The Netherlands (see Table 3). For bored piles no Member State adopted the recommended values unaltered and five Member States have not yet decided on the values of the partial factors. The situation is more homogeneous for the pile design of driven piles from pile load tests as the pile tests give a more reliable basis for the design.

Most Member States will use those recommended in EC 7-1 for the verification of the embedment depth of anchored sheet pile quay walls (see Table 4), but there are some changes to the conservative and some to the less conservative side. However, it is interesting to note that the Netherlands has chosen noticeably lower partial factors for the soil parameters and for the actions coming from a structure. It should also be noted that Switzerland has a highly differentiated way of factoring earth and water pressures, Germany and Austria apply reduced partial factors in transient design situations and Spain again uses the global concept.

Table 3: Selection of partial factors for GEO limit states in pile foundations

Design example	DA 1: recommended factors	DA 2: recommended factors	DA 2: recommended factors
	MS: Differing value	MS: Differing value	MS: Differing value
Example 3: foundation with bored piles – design of the pile length from soil parameter values	C.1: γ_G =1.35; γ_Q=1.50; γ_b=1.25; γ_s= 1.0; γ_t= 1.15; C.2: γ_G=1.0; γ_Q=1.30; γ_b= 1.6; γ_s= 1.3; γ_t= 1.5	γ_G=1.35; $\gamma_{G;fav}$=1.0; γ_Q=1.5; γ_b= 1.1; γ_s= 1.1; γ_t= 1.1;	γ_G =1.35; $\gamma_{G;fav}$=1.0; γ_Q=1.5; γ_b= 1.1; γ_s= 1.1; γ_t= 1.1;
	UK: C.2: γ_t= 1.6 P, IRL: C.1 and C.2: γ_R =1.5 LT: C.1 and C.2: γ_R =1.4 I: C.1: γ_G = 1.5, $\gamma_{G,fav}$ = 1.3, γ_b= γ_s= 1.0; γ_t= 1.2; C.2: γ_G = 1.3, γ_b= γ_s= 1.35, γ_t= 1.6 RO: C.1:γ_b=γ_s= γ_t= 1.0; C.2: γ_b= γ_s= γ_t= 1.3; B: undecided	CH: γ_t= 1.4 E: global γ_R = 3.0 D: γ_b= 1.4; γ_s= 1.4; γ_t= 1.4; SLO, SF, GR, A: γ_R = 1.3 + ξ (Table A.10) DK: γ_G= 1.2 / 1.0; γ_b= 1.3; γ_s= 1.3; γ_t= 1.3; γ_R= 1.0; ξ = 1.5 PL, F, L, SK: undecided	NL: CPT-method: $\gamma_{G,fav}$=0.90; material factor on q_c: γ_b =γ_s=γ_t=1.2 and ξ (Table A.10)
Example 4: pile foundation – determination of the number of piles from pile load tests on driven piles	C.1: γ_G= 1.35; γ_Q= 1.50; γ_b= γ_s= γ_t= 1.0; C.2: γ_G= 1,0; γ_Q= 1.30; γ_b= 1.3; γ_s= 1.3; γ_t= 1.3	γ_G =1.35; γ_Q=1.50; $\gamma_{G;fav}$= 1.0 γ_b= 1.1; γ_s= 1.1; γ_t= 1.1;	γ_G =1.35; $\gamma_{G;fav}$= 1.0; γ_Q=1.5; γ_b= 1.1; γ_s= 1.1; γ_t= 1.1;
	IRL: C.2: γ_t=1.3; C.2: γ_t=1.50; LT: C.1: γ_t= 1.1, γ_R =1.3; C.2: γ_t = 1.5, γ_R =1.3 P: C.2: γ_R =1.0 I: C.1: γ_G= 1.5; $\gamma_{G,fav}$ = 1.3, γ_b= γ_s= 1.0, γ_t= 1.2 ; C.2: γ_G= 1,3; γ_b= 1.35; γ_s= 1.3, γ_t= 1.6 RO: C.1: γ_t= 1.6, C.2: γ_t= 1.3; B: undecided	CH: γ_t= 1.3; D: γ_t= 1.20 ; γ_R = 1.05 DK: γ_G = 1.2 / 1.0; γ_t= 1.3 ; γ_R = 1.0; ξ = 1.1 / 1.25 E, F, L, SK, PL: undecided	NL: γ_G = 1.20; γ_R = 1.2 and ξ (Table A.9)
List of symbols see also Table 2 γ_b: partial factor on the base resistance γ_s: partial factor on the shaft resistance γ_t: partial factor for the total resistance of the pile γ_R: model factor			

Most Member States have introduced Design Approach DA 3 for the verification of slope stability. However, none of the countries has adopted all of the partial factors recommended in Annex A of EC 7-1 although the differences are not very great. The Member States that selected Design Approach DA 1 adopted the recommended partial factors of Annex A except for Belgium which reduced the partial factor for the variable action in combination 2 to γ_Q = 1.10 and Lithuania which reduced the partial factor on favourable actions to $\gamma_{G;fav}$ = 0.90. Ireland mentions that it will not distinguish between favourable und unfavourable permanent actions in Combination 1. This matter was not explicitly addressed in the questionnaire because it was tacitly assumed that, irrespective of the applied design approach, no Member State would make such a distinction. Design Approach DA 2 was only selected by Spain which retained the global safety concept.

The evaluation of the results of the comparative design for the workshop in Dublin (see Orr, 2005) indicates that, for slope stability, Design Approach DA 1 combination 2 will be relevant for design, which is very similar to Design Approach DA 3. So, in a next step towards harmonization, a reduction in the number of design approaches and partial factors could be possible for the verification of slope stability, taken in isolation. However, it will be necessary to ensure that situations which include slopes, retaining structures and foundations, acting in combination, are accommodated, which is the benefit claimed for DA 1. A result which is also quite promising for future harmonization is the fact that all Member States use the partial factor on weight density, γ_γ of 1.0 as is recommended in Table A.4 of EN 1997-1.

4.3 *UPL and HYD limit state*

The decisions of the Member States with respect to the selection of partial factors for the verification of uplift of a deep basement and the verification of failure by hydraulic heave (HYD and UPL ultimate limit states) are presented in Table 5. The partial factors for the limit states recommended in Annex A of EC 7-1 are presented in the first line of each design example. The second line contains the Member States and their choice of partial factors if they differ from the recommended values.

It can be seen that there are only minor variations from the recommended values for the verification of uplift of a deep basement. As regards friction on the wall, most countries have chosen to apply a partial factor to the angle of shearing resistance instead of applying the partial factor for stabilising actions to the characteristic value of the wall friction.

There are also minor variations in the partial factors selected for the verification of failure by hydraulic heave. It should be noted, however, that Switzerland and Germany have higher values for the destabilising actions in unfavourable soil. Both equations – 2.9a using total stresses and 2.9b using effective stresses in the analysis of hydraulic heave – have been adopted by approximately the same number of countries. Some Member States are still undecided as to which values of the partial factors and which equation should be used.

Table 4: Selection of partial factors for GEO limit states of retaining walls and slopes

Design example	DA 1: recommended factors	DA 2: recommended factors	DA 3: recommended factors
	Member State: Differing value	Member State: Differing value	Member State: Differing value
Example 7: anchored sheet pile quay wall	C.1: γ_G=1.35; $\gamma_{G;fav}$= 1.0; γ_Q= 1.50 C.2: γ_φ= 1.25; γ_G= 1.0; γ_Q= 1.30	$\gamma_{G;unfav}$=1.35; $\gamma_{G;fav}$ =1.0; γ_Q= 1.5; $\gamma_{R;e}$ = 1.40	γ_φ= γ_c= 1.25; γ_{cu}=1.40; γ_Q= 1.30; structure: γ_G=1.35; $\gamma_{G,fav}$=1.0; γ_Q=1.5
	B: C.2. γ_Q = 1.10 I: C.2: γ_c=1.40 IRL: C.1: γ_G=$\gamma_{G;fav}$= 1.35 LT: undecided	D: $\gamma_{G;fav}$=1.35 CH: γ_G(Water)= 1.20; $\gamma_{G;fav}$= 0.80; E: global $\gamma_{R;e}$ = 1.8 F, SK, L, PL: undecided	NL: γ_φ = 1.15, γ_c =1.05, γ_{cu} =1.6; structure: $\gamma_{G,fav}$= 0.9; γ_Q=1.0 DK: γ_φ = 1.2; structure: γ_G=1.2/1.0; $\gamma_{G,fav}$= 1.0/0.9;
Example 10: road embankment – determination of the maximum height using the slope stability as criterion	C.1: γ_G = 1.35; $\gamma_{G,fav}$= 1.0; γ_Q= 1.5; C.2: γ_G= 1.0; γ_Q= 1.3,γ_φ= γ_c= 1.25, γ_{cu}=1.40;	γ_G = 1.35; $\gamma_{G;fav}$= 1.0, γ_Q= 1.5; $\gamma_{R;e}$= 1.1 $\gamma_{\varphi'}$ = $\gamma_{c'}$ = γ_{cu}=1.0;	γ_φ= γ_c=1.25; γ_{cu}=1.40; γ_Q= 1.30; $\gamma_{R;e}$=1.4; structure: γ_G= 1.35; $\gamma_{G,fav}$=1.0; γ_Q=1.5, $\gamma_{R;e}$= 1.0
	B: C.2: γ_Q = 1.10; IRL: C.1: γ_G= $\gamma_{G;fav}$ =1.35 LT: C.1: $\gamma_{G,fav}$ = 0.90;	F: $\gamma_{R;e}$ = 1.5 for soft soils E: global $\gamma_{R;e}$ = 1.5	D, A: γ_{cu}= 1.25; CH: γ_φ=1.2; γ_c= 1.5, γ_{cu}= 1.5; NL: γ_c= 1.45, γ_{cu}= 1.75; GR, IRL: $\gamma_{R;e}$= 1.1; DK: γ_φ = 1.2; γ_c= 1.2, γ_{cu}= 1.8; Structure: SF, D, GR, CH: γ_G=$\gamma_{G,fav}$ =1.0 NL: $\gamma_{G,fav}$= 0.9 DK: γ_G = 1.2 / 1.0; $\gamma_{G,fav}$= 1.0 / 0.9 PL, F, L, SK: undecided
List of symbols see Table 2 and 3 $\gamma_{R;e}$: partial factor for earth resistance			

Table 5: Selection of partial factors for HYD and UPL limit states in the European Member States

Design example	Recommended factors in Annex A of EC 7-1
	Member State: Differing value
Example 8: verification of uplift of a deep basement	$\gamma_{G;stb}$ = 0.90 ; $\gamma_{G;dst}$ = 1.0 $\gamma_{Q;dst}$ = 1.5;
	CH: $\gamma_{G;dst}$ = 1.05; SF, UK: $\gamma_{G;dst}$ = 1.10; ES, RO, B: undecided for friction on the wall: CH: friction is generally neglected, a): partial factors of Table A.16 (γ_φ= 1.25): SF, NL, IRL, UK, A, PL, I, P, DK (γ_φ= 1.2) b): friction as a stabilising action: D ($\gamma_{G;stb}$ = 0.72), SF, GR, DK, P + LT: ($\gamma_{G;stb}$ = 0.9)
Example 9: verification of failure by hydraulic heave	$\gamma_{G;stb}$ = 0.90; $\gamma_{Q;stb}$ = 1.50; $\gamma_{G;dst}$ = 1.35,
	CH: $\gamma_{G;dst}$=1.40; in unfavourable soil: D: $\gamma_{G;dst}$ =1.8; CH: $\gamma_{G;stb}$= 1.6; DK: $\gamma_{G;stb}$= 0.9; $\gamma_{G;dst}$= 1.1? E, RO, B undecided verification using equation: 2.9a (total stress): SF, PL, I, NL, DK 2.9b (effective stress): D, CH, SF, GR, DK UK: Use either equation; application of the single source principle means they both lead to the same result. A, IRL, P, LT: undecided which equation

5 FURTHER STEPS TOWARDS IMPLEMENTATION AND HARMONIZATION

5.1 *Education and training*

Establishing the design approaches and the values of the partial factors for the verifications in each Member State and laying them down in a National Annex is only the first step in the implementation of a Eurocode. It is obvious that extensive training is required in the Member States if the EN Eurocodes are to applied adequately. The training of staff is the responsibility of industry in cooperation with national authorities and National Standards Bodies and will be supported by the European Commission. Training programmes have been established in all the Member States and numerous courses and seminars have been held. Even in Croatia, a future EU Member State, a course on EC 7-1 will be held in May 2007.

5.2 *Maintenance*

Maintenance of the Eurocodes is essential to preserve their credibility, integrity and relevance, as well as to ensure that they do not contain errors. Especially after their implementation and the initial application, the Eurocodes are likely to give rise to technical, editorial and possibly legal questions. Therefore maintenance will involve:

- correction of errors
- technical amendments with regard to urgent matters of health and safety
- technical and editorial improvements
- resolution of matters of interpretation
- elimination of inconsistencies and misleading statements
- development of new items.

CEN/TC250 is responsible for the maintenance of the Eurocodes which will proceed according to CEN rules. A special Maintenance Group of SC 7 was established at the meeting in Copenhagen in October 2006 to deal with these items with respect to EC 7-1.

All feedback from the application of the Eurocodes in the Member States should be submitted to the National Standards Bodies (NSB) using templates and processed by the responsible and competent national standardization committee according to the national rules (see Figure 4). The comments should be dealt with as far as possible by the NSBs in the Member States only comments that have an effect on corrections or amendments and matters of interpretation should be forwarded to SC 7 or its Maintenance Group.

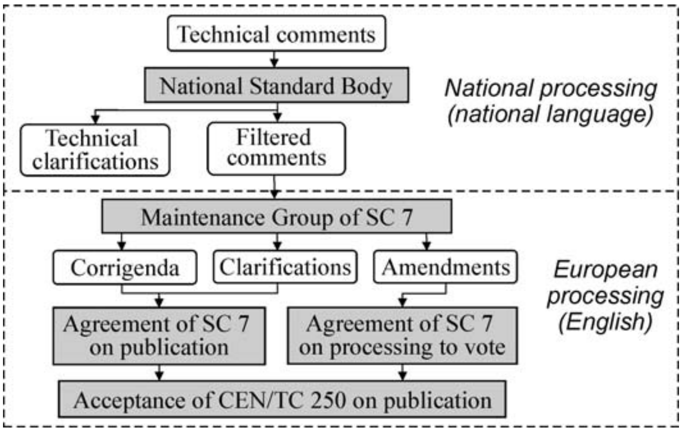

Figure 4: Flowchart for the maintenance of the Eurocodes

The maintenance activities should be divided into three parts:

- the short term (immediate or within a year)
- the medium term (the regular five-year review)
- the long term (greater than five years)

The short-term activities involve the technical amendments with regard to urgent matters of health and safety and the correction of technical and editorial errors (e.g. mistakes in symbols, typographical mistakes). Corrigenda will eventually be issued at the end of the short-term period.

Reviews of European Standards are initiated by the relevant Technical Committee (TC) four years after ratification of the EN at the latest. The appropriate SC is responsible for the scientific and technical aspects of those parts of the EN Eurocode that fall within its responsibility and field of competence. The review of the technical and editorial improvements and the resolution of matters of interpretation will be prepared by the Maintenance Group which will collect, identify and analyse the comments. The Maintenance Group will also consider whether liaisons need to be established with other SCs and CEN/TCs for structural components, execution or testing. Eventually, drafts for corrigenda, clarifications of matters of interpretation and amendments will be prepared for the SC. These drafts must all be agreed upon by the SC by resolution. To ensure efficiency and consistency, CEN/TC 250 will coordinate the publication of corrigenda and amendments to the EN Eurocode Parts produced by the SCs.

The general issues for further harmonization are laid down in a recommendation of the Commission as follows:

Member States should use the recommended values provided by the Eurocodes. When nationally determined parameters have been identified in the Eurocodes, they should diverge from those recommended values only where geographical, geological or climatic conditions or specific levels of protection make that necessary.

Member States should, …, compare the nationally determined parameters implemented by each Member State and assess their impact as regards the *technical differences for works or parts of works. Member States should, at the request of the Commission, change their nationally determined parameters in order to reduce divergence from the recommended values provided by the Eurocodes.* (EC (2003b))

Although the Member States retain sole responsibility for the levels of safety of works they are strongly encouraged to minimize the number of cases in which recommendations for a value or method are not adopted for their National Determined Parameters (NDP). Therefore, the principal objectives of further harmonization are as follows:

- the reduction of NDPs in the EN Eurocodes resulting from different design cultures and procedures in structural analysis
- the reduction of NDPs and their variety through the strict use of recommended values
- the gradual alignment of safety levels across Member States.

Moreover, it is important to harmonize not only the values of the NDPs (harmonization across national borders), but also the design procedures.

In the long term, matters relating to the development of new items will be examined, e.g. the harmonization of calculation methods or the evaluation of test results with respect to the selection of characteristic values of ground parameters in geotechnical design. New EN Eurocodes or Parts can only be developed following appropriate studies and research along with substantial practical experience. Research is encouraged by the following recommendation of the Commission:

Member States should undertake research to facilitate the integration into the Eurocodes of the latest developments in scientific and technological knowledge. Member States should pool the national funding available for such research so that it can be used at Community level to contribute to the existing technical and scientific resources for research within the Commission, in cooperation with the Joint Research Centre, thus ensuring an ongoing increased level of protection of buildings and other civil works, specifically as regards the resistance of structures to earthquakes and fire. (EC (2003b))

For geotechnical design this may include, e.g.

- comparative studies of the different design approaches and values of partial factors used in geotechnical verifications in the Member States to evaluate the potential for further harmonization and
- investigations of the interpretation und evaluation of field and laboratory tests in the Member States with respect to the establishment of characteristic values of ground parameters.

This work of the Maintenance Group will be supported by the development and maintenance of an EN Eurocodes informatics platform by the Joint Research Centre of the EC in Ispra, Italy. The platform includes the NDPs and National Annexes database as well as a database of background documents on the recommended values and on the reasons for deviations in the National Annexes. This will permit the statistical analysis of the NDPs and support both the expert analysis and the elaboration of technical justification documents.

6 CONCLUDING REMARKS

The work on the elaboration of a common framework for geotechnical design throughout Europe, i.e. Eurocode 7, started nearly 25 years ago. Part 1 of EC 7 - *General rules* - has been completed and the European Member States are now starting to implement it in their national system of standards. EC 7-1 is an umbrella code as analytical geotechnical models are given in informative annexes instead of the normative core text. Moreover, EC 7-1 contains a number of options which have to be decided upon by the national standards bodies, such as three design approaches for the verification of geotechnical ultimate limit states and the values of the partial factors. On the one hand, this is of course a shortcoming for a code but, on the other hand, it constitutes an openness which makes the adoption and the implementation of the code attractive, not only for Europe but also world-wide, as a gradual evolution of national traditions of design procedures is possible. The evaluation of questionnaires on the selection of the three design approaches for the verification of geotechnical ultimate limit states and the values of the partial factors in the Member States shows that there are distinct majorities for the application of certain design approaches - e. g. for Design Approach DA 3 for the verification of slope stability - and that there is a moderate variety in the adopted values of partial factors. So there is still a lot of work to do for SC 7 to improve harmonization in geotechnical design by maintenance, training and research.

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