Implementation of Eurocode 1997-1 in Finland

L'implémentation de l`Eurocode 1997-1 en Finlande

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ABSTRACT
Eurocode 1997-1 Geotechnical design–Part 1: General rules (CEN 2004) has been translated to Finnish language and was officially implemented in Finland November the 1st 2007, with its National Annex (Ministry of the Environment 2007). When designing according to EC7 and its National Annex in Finland, Design Approach 2 is mainly used. Design Approach 3 is used for analyzing overall stability and for stability analyses of slopes and embankments. Finland has adopted the possibility to combine actions using the Formulas 6.10a and 6.10b of EN 1990, as the most of other European countries use the basic Formula 6.10. To preserve the national safety level, comparative calculations have been made to find out the need for adjustment of the safety factors to be used in Finland. A Design Guide including EN1997-1 and its National Annex shall be published in spring 2009. The guide will present nationally important additions needed in geotechnical design and examples how to apply EN 1997-1 and its National Annex in Finland.

RÉSUMÉ
Eurocode 1997-1 Calcul géotechnique - Partie 1 : Règles générales (CEN 2004) a été traduite en finnoise et a été officiellement mis en œuvre en Finlande le 1er de Novembre 2007, avec son annexe nationale (Ministry of the Environment 2007). Quand on dessine selon EC7 nationale et son annexe, en Finlande, Design Approach 2 est principalement utilisé. Design approche 3 est utilisé pour analyser la stabilité de l'ensemble et pour les analyses de stabilité des pentes et remblais. La Finlande e adopté la possibilité de combiner les actions en utilisant les formules 6.10a et 6.10b de l'EN 1990, comme la plupart des autres pays européens utilisent la Formula 6.10 fondamental. Pour préserver le niveau de sécurité national, des calculs comparatifs ont été faits pour trouver la nécessité d'adaptation des facteurs de sécurité pour être utilisé en Finlande. A Design Guide, inclusivement l `EN1997-1 et de son annexe nationale seront publiés au printemps 2009. Le guide présentera des ajouts importants au niveau national géotechniques nécessaires à la conception et exemples sur la façon d'appliquer EN 1997-1et de son annexe nationale en Finlande.

Keywords : Eurocode 1997-1, National Annex, Geotechnical design

1 INTRODUCTION

Geotechnical design has been done in Finland mainly using Overall Factor of Safety (OFS) –method. The European prestandard ENV 1997 was translated into Finnish and a National Application Document was made for it in 1997. It has been possible to use ENV1997 for geotechnical design since that, but it has been used only occasionally in Finland.

The final version of *Eurocode 1997-1 Geotechnical design–General rules* (CEN 2004) was published at the end of the year 2004 and is also translated into Finnish language. It was implemented with its National Annex (NA, Ministry of the Environment 2007)in Finland November the 1st 2007. The NA includes nationally determined values of safety factors and other nationally important selections for geotechnical design. Finland has adopted the possibility to combine actions using the Formulas 6.10a and 6.10b of EN 1990 (CEN 2002), as the most of other European countries use the basic Formula 6.10. The principle when preparing the National Annex was to preserve the nationally approved level of safety in geotechnical design. To achieve this aim, the preparation work in other European countries was followed and comparative calculations were made. The values of safety factors differ somewhat from those recommended in the EN 1997-1 because of different decisions concerning the combination of actions and of other national reasons.

In Finland the coastal areas are often covered by soft clay deposits, which may cause large settlements and horizontal movements under loading. Glacial tills are also very common in Finland. These both materials are very frost susceptible and this combined with the cold winters in Northern Europe arises the need of frost design and protection both in ULS/SLS's. Eurocode 7 emphasis the importance of serviceability limit state design but does not give much guidance for SLS-evaluation. This paper describes shortly the use of EN1997-1 and its NA in Finland.

2 DESIGN APPROACHES, COMBINATION OF ACTIONS AND SAFETY FACTORS IN ULTIMATE LIMIT STATE

2.1 *Design approaches used in Finland*

The three design approaches of EN 7 differ in the way they distribute the partial factors between actions, ground properties and resistances. The choice of design approach may be determined nationally and should be stated in the National Annex to EN 7. Different design problems may be dealt with by different design approaches. The values of the partial factors to be applied in a given design approach are also to be determined nationally.

In Finland, Design Approach 2 (DA2) is used in the design of spread foundations, pile foundations, anchorages and retaining structures. In the design of slopes and overall stability, Design Approach 3 (DA3) is used.

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2.1 *Combination of actions and safety factors in DA3*

When structural or geotechnical ultimate limit state is in question, according to Eurocode 1997-1 (CEN 2004) the actions are combined using the formula 6.10. This formula is used in Finland with Design Approach 3 for slope and overall stability analyses. The formula 6.10 with its safety factors shown as they appear in the Finnish National Annex (Ministry of the Environment 2007) is as follows:

$$1{,}0K_{FI}\sum_{j\geq 1} G_{kj,sup} + 1{,}3K_{FI}Q_{k1} + 1{,}3K_{FI}\sum_{i>1}\psi_{o,i}Q_{k,i} \qquad (1/6.10)$$

All actions (e.g structural actions, traffic load) for soil are treated as geotechnical actions using the set of safety factors A2-FI: $\gamma_G = 1.0K_{FI}$, $\gamma_{G:inf} = 1{,}0$, $\gamma_{Q,sup} = 1.3\ K_{FI}$ and $\gamma_{Q:inf} = 0{,}0$ The partial factors for ground are not applied to the resistances but to the soil parameters: angle of shearing resistance φ', effective cohesion c', undrained shear strength c_u or unconfined strength q_u. The selected values (set M2-FI) are: $\gamma_{\varphi'} = \gamma_{c'} = 1{,}25$ and $\gamma_{cu} = \gamma_{qu} = 1.5$. For weight density the recommended value is $\gamma_\gamma = 1{,}0$. The partial factors are applied at the source, i.e. to the representative values of the actions and to the characteristic values of the soil strength parameters. Thus, in Design Approach 3, the whole calculation is performed with the design values of actions or the effects of actions and the design values of soil parameters.

2.2 *Combination of actions and safety factors in DA2*

Design Approach 2 is used in the design of spread foundations, pile foundations, anchorages and retaining structures. When ULS design in STR/GEO-limit state is done, the actions are combined using Equations 6.10a or 6.10b from Eurocode 1990 (CEN 2002). According to the Finnish NA the Eq.6.10a includes only permanent actions. As a design equation the combination of actions can be expressed so that the less favorable of the two following expressions is decisive.

$$1{,}35K_{FI}G_{kj,sup} + 0{,}9G_{kj,inf} \qquad (2/6.10a)$$

$$1{,}15K_{FI}G_{kj,sup} + 0{,}9G_{kj,inf} + 1{,}5K_{FI}Q_{k,1} + 1{,}5K_{FI}\sum_{i>1}\psi_{0,1}Q_{k,i} \qquad (3/6.10b)$$

where K_{FI} depends on the reliability class in the NA-FI of SFS-EN1990 Annex B, Table B2 as follows:

- in reliability class RC3 $K_{FI} = 1{,}1$
- in reliability class RC2 $K_{FI} = 1{,}0$
- in reliability class RC1 $K_{FI} = 0{,}9$

Consequence classes CC3…CC1 clarifying the reliability classes are presented in the National annex SFS-EN 1990: Definition of consequence classes. Reliability class RC2 is used for "normal" cases and thus K_{FI}=1,0. When the consequences or possible failure of the structure are more serious, RC3 can be used and vice versa. The combination factor (ψ) is used when more than one variable loads affect and its values vary from 0,6 to 1,0 (ULS, no accidental actions), depending on the nature of the action and structure.

There are two ways of performing verifications according to Design Approach 2. In the design approach referred to as DA 2, the partial factors are applied to the characteristic actions and resistances at the start of the calculation and the whole calculation is performed with design values. However, in the design approach referred to as DA 2* (Frank et al. 2004), the entire calculation is performed with characteristic values and the partial factors are introduced only at the end when the ultimate limit state condition is checked. No distinction between favourable and unfavourable permanent actions is necessary when using this procedure. In all cases, all permanent actions and effects of actions are regarded as unfavourable actions and are thus relevant for design.

In Design Approach 2 the same values of partial factors are applied to geotechnical actions and to actions on or from the structure, i.e. $\gamma_{G,sup}$ = 1.35/1,15, $\gamma_{G:inf}$ = 0,9/0,9 and $\gamma_{Q,sup}$ = 0,0/1,50 (first is given the value used in formula 6.10a and the second value used in 6.10b). They are the same factors as in the structural design in Finland.

For the resistance side of the limit state equation, the partial factors are applied to the ground resistance, e.g. $\gamma_{R;e} = 1.50$ for passive earth pressure, $\gamma_{R;v} = 1.55$ for the ground bearing resistance and $\gamma_{R;h} = 1.10$ for the resistance to sliding.

Finland has used previously the concept of OFS for before mentioned design situations. This approach using these modified safety factors with Design Approach 2 gives similar results of design as we have been used to achieve with our national design methods. DA2* gives especially in cases with considerable eccentricity (big vertical actions) smaller size of footing for spread foundations than DA2. Therefore, when using DA2*, the value of eccentricity is limited to less than B/3, when B is the breadth of a rectangular foundation.

2.2.1 *Example of the level of safety for spread foundation*

Figure 1 shows the Overall Factor of Safety for a spread foundation with centric loading as the relative amount of variable and permanent actions vary. The straight line at OFS=2,0 is the level of needed safety according to the national building code (B3: Foundations, Ministry of the Environment 2003). The dotted, inclined, straight line describes the recommended level of safety of EN1997-1. The bended (angular) line describes the level of safety according to EN1997-1 with its Finnish National Annex, when the reliability class is RC2 (K_{FI} = 1,0), obtained using formulas 6.10 a and b.

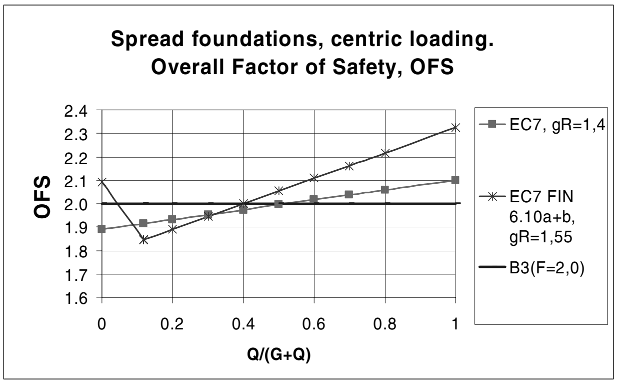

Figure 1. Overall Factor of Safety with different design methods for spread foundation with varying amount of variable and permanent actions.

2.2.2 *Example of the level of safety for a foundation on piles*

Figure 2 shows the level of safety for piles in ULS, when static loading is used to check the bearing resistance for different number or percentage of piles. Here again the vertical actions are combined with equations 6.10a and 6.10b (assuming K_{FI} = 1,0). In Finland the partial resistance factors for base, shaft and total/combined compression are $\gamma_b = \gamma_t = \gamma_s = 1{,}2$. The value of correlation factor ξ_1 varies between 1,4 (for single static pile load test) to 1,0 (when at least 5 or all piles are tested). Straight horizontal line describes the present national requirements (B3: F=1,6).

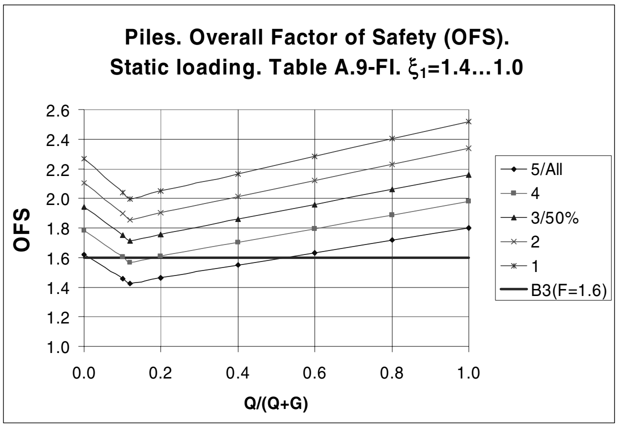

Figure 2. Overall Factor of Safety for piles with different design methods with varying amount of variable and permanent actions and varying number of tested piles (static loading).

3 COMPARATIVE CALCULATIONS AND NATIONAL DESIGN GUIDE

To preserve the national level of safety, comparative calculations have been conducted to find out the need for adjustment of the safety factors to be used in Finland. The calculations included 12 different geotechnical design situations that have been calculated according to both Eurocode 7 and the earlier Finnish national designing rules. The calculated examples comprise calculations of footings, driven piles, gravity walls, sheet pile walls, natural slopes and embankments on soft soil. The comparative calculations were made in Helsinki and Tampere Universities of Technology (Gustavsson 2008).

A design guide (RIL 207-2009) will be published in Finland in spring 2009. It will include EN1997-1 with its NA and additional, nationally important information for geotechnical designers. Examples of calculations using Finnish NA will also be presented in the annexes of the design guide.

4 SERVICEABILITY LIMIT STATE DESIGN

All Eurocodes emphasis the importance of serviceability limit state design. This is also true for EN 1997-1. In principle there are two ways to check the serviceability limit states. One may calculate the design value of deformation, differential settlement, etc and compare to the limiting values. Secondly a simplified method, based on comparable experience is suggested. Ideally the first method should be preferred. However, this can be a very complicated task. The limiting values of deformations should be specified to each structure in close cooperation with the structural designer. If too conservative values are used, it probably leads to uneconomic design. In addition the calculation of deformations might for some cases be quite complicated. In this respect EN 1997-1 gives very few rules or guidelines on how the different serviceability limit states calculations should be addressed. As an alternative to calculations, one may use the simplified procedure to guarantee that a "sufficiently low fraction of the ground strength is mobilized to keep deformations within the required serviceability limits". This requires comparable experience from similar ground conditions and structures. EN 1997-1 weakly refers to the simplified method in connection to spread foundations, piles and retaining structures. However, no indication about what is "sufficiently low fraction" is given. In the following section a solution based on the simplified method to overall stability is presented.

4.1 *Overall stability*

As discussed in section 2.1, design approach 3 is used for overall stability in Finland. In design approach 3 safety is put on material strength and loads. For loads equation 6.10 is applied. As the partial safety factor for permanent actions is $\gamma_G = 1.0$ and for variable actions $\gamma_Q = 1.3$, there will be many situations, where the safety is put solely on the material properties. For effective strength properties the safety factor is 1.25 according to the Finnish NA.

In Finland there are lot of soft clays and gyttja with water content near 100%. For soft clays it is often found that horizontal deformations start to increase when the conventional overall safety factor (OFS) in undrained analyses is less than 1.5 (Leroueil et al. 1990). According to what's presented above, EN 1997-1 allows for the long term situation calculated with effective stress analyses an overall safety as low as 1.25. Although such safety margin may be sufficient for the ultimate limit state it will not prevent horizontal deformations. Such deformations may be critical to structures such as piles. A serviceability analysis would thus be needed to calculate the actions of possible ground movement to structures. Such analyses are however very difficult to perform as also noted by the Eurocode. To overcome this Eurocode suggest that the occurrence of serviceability limit states can be avoided by e.g. limiting the mobilized shear strength. In the Finnish design guide (RIL 207-2009) this will be utilized by introducing a new set of material safety factors for serviceability analysis. The idea is, that first the designer should do the ultimate limite state stability analyses according to the Finnish NA. Then, if the designer wants to avoid the calculation of e.g. horizontal deformations and their effect on structures, the designer should do a serviceability limit state stability calculation. There the material safety factors are as presented in table 1, while the partial safety factors for loads are all equal to 1.0. Loads are thus incorporated with their characteristic values, and the method is actually an overall safety method with required overall safety factors (OFS) equal to the partial factors given in table 1.

Table 1. Partial factors of safety for serviceability limit state stability calculations.

Soil parameter	Symbol	M2 for different CC		
		CC1	CC2	CC3
Friction angle	$\gamma_{\phi'}$	1,5	1,65	1,8
Cohesion	$\gamma_{c'}$	1,5	1,65	1,8
Undrained shear strength	γ_{cu}	1,65	1,8	2,0
Unconfined strength	γ_{qu}	1,65	1,8	2,0
Weight density	γ_γ	1,0	1,0	1,0

4.1.1 *Example*

To exemplify the two phase stability analyses discussed above an example is presented. Consider the shore-line slope presented in figure 3. The ground consists of a soft clay layer on top of a relatively dense moraine. The properties of the soils are; clay $c'_k = 4$kPa, $\phi'_k = 24^o$, $\gamma = 16{,}5$kN/m^3 and moraine $c'_k = 10$kPa, $\phi'_k = 38^o$, $\gamma = 20$kN/m^3.

Residential buildings founded on piles are planned in the area. For simplicity no other loads are considered. For the ultimate limit state design the design ground water and free-water levels should be chosen to represent the most unfavorable conditions that can occur. For this case, it is considered, that the ground water level may rise to ground surface. As no loads are directed to the slope the calculations can be performed either by characteristic strength values and require that the overall safety factor (OFS) is higher than the partial safety factor for strength, or by design strength values and require that the over design factor (ODF) is above one.

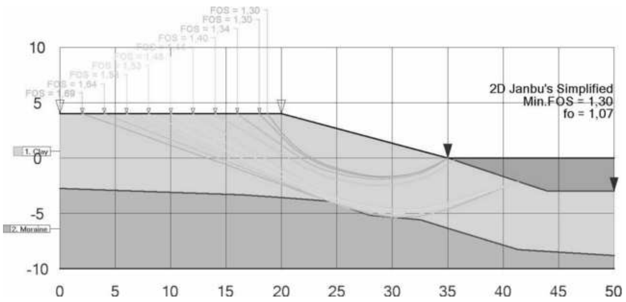

Figure 3. Ultimate limit state stability calculation with characteristic values.

According to the calculations, the overall factor of safety is in all parts of the slope higher than 1.25, ranging from 1.30 to 1.69 in Figure 3. Thus, the ultimate limit state design criteria is satisfied. However, if structures on piles are built in such an area, one needs to consider the possibility and magnitude of horizontal deformations and their impact on the piles. In practical problems this is a very difficult task. The pore pressure conditions and loading history of the site, including possible fill make the prediction quite unreliable. Following the simplified procedure described before, one may do a serviceability state stability calculation applying the partial safety factors presented in table 1. For the serviceability limit state the groundwater conditions should be chosen to represent less severe conditions that represent a cautious estimate of the typical long term conditions. As the safety is solely placed on material strength, the calculations can always be performed with characteristic values. Then one may directly evaluate also the influence of chosen consequence class. The results of the calculations are presented in figure 4. The calculated overall factors of safety range from 1.51 to 1.95.

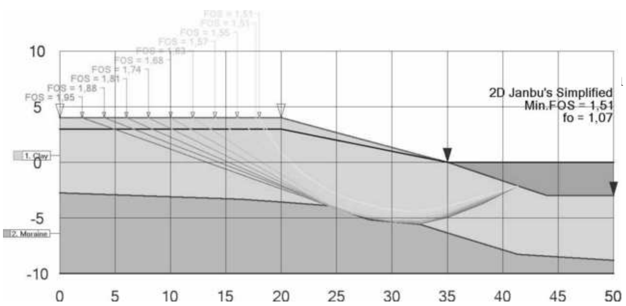

Figure 4. Serviceability limit state stability calculation with characteristic values.

According to table 1, the partial safety factor (as well as the OFS) for effective strength parameters is 1.65 in consequence class 2 and 1.8 in consequence class 3. One may thus built from a distance of 14 m from the crest of the slope in consequence class 3.

Additionally one have to take into account the effects of the installation of piles (displacements and the temporary increase of pore water pressure).

5 DISCUSSION

The development of Eurocodes has taken a very long time. It has not been an easy task to find a common design language for all the European countries involved with their different civil engineering cultures and backgrounds. Now we are in the final implementation phase where Eurocodes exists parallel with old design guides. After 1st of April 2010 Eurocodes will be the principal design guide for house building in Finland. Although a long time has past since the beginning of writing the codes everything is not ready. EN 1997-1 lacks detailed information in many areas. National guidelines that are following the principals of the Eurocodes are thus needed. As for this date, these are not all ready in Finland.

Another concern is the training of all engineers to understand and use the new design standard. The extent of this effort depends on how much is changed from previous codes of practice, and varies thus much from country to country. Nevertheless, the implementation phase is very critical. If necessary the coexistence of old design standards should be prolonged at least unofficially, to ensure safe and economical design.

For the future Eurocodes needs to be developed so that it gives more practical and detailed information about e.g. how to handle different serviceability limit states. Also there is still a need to harmonize the standard and decrease the national variability. How far this is possible to take, with the vast variation in geology in Europe as well as the differences in civil engineering culture, is an open question.

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