German Proposals for the Revision of Eurocode 7 “Geotechnical design”

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Abstract. After implementing the Eurocodes, concerns were raised that the set of rules and regulations is not suitable for the designer’s day-to-day use. The first generation of Eurocodes consists of 58 codes with more than 5,200 pages. Moreover, practitioners have to cope with national supplementary codes. As a result, an “Initiative on Improving the Practicability of Technical Rules for Building Constructions” (PRB) was established by the German construction industry and associations of structural engineers in 2011. As part of the initiative, a Project Group for Geotechnical Design was established alongside groups for the other Eurocodes, with the aim of streamlining Eurocode 7 and reducing the number of design approaches and partial safety factors. The paper will analyse the shortcomings of the two parts of Eurocode 7 and present a concept for a more concise and user-friendly code. Furthermore, comparative calculations have been performed for standard geotechnical design applications to investigate the potential for European harmonization in geotechnical design. The results are described and it is shown how they can be incorporated in the revision of EC 7. Moreover, a new formula for verifying geotechnical ultimate limit states is presented which formally covers all design approaches and also enables other parameters such as consequence classes, human error etc. to be incorporated by applying different multiplicative partial safety factors.

Keywords: codes, standards, geotechnical design.

Conference topic: Design experiences and theoretical solutions.

Introduction

The current, first generation of Eurocodes comprises 58 standards totalling over 5200 pages, not including the supplementary national standards. The number of pages is, in itself, enough to discourage users. This was the main cause of the harsh criticisms of the Eurocodes voiced above all by the German construction industry and construction engineers’ associations. The Eurocodes have been criticized as being

- too long,
- in some cases unclear,
- sometimes trivial, too academic and
- therefore lacking in user-friendliness.

These criticisms are certainly justified and we must ask ourselves how the Eurocodes came to be so extensive. There are three main reasons for this:

- It was unavoidable that the first generation of Eurocodes was a compilation of material from the standards and experience of the 27 states of the European Union and the three EFTA states as each country considered its own traditions to be indispensable.
- Both the writers of the Eurocodes and those who commented on them were, in many cases, seeking to incorporate the latest technical develop-

ments as well as the recognized rules of technology.

- There were no clear-cut, strict rules governing the content of the Eurocodes.

Consequently, both parts of Eurocode 7 (EN 1997-1:2004, EN 1997-2:2007), *General rules* (EC 7-1) and *Ground investigation and testing* (EC 7-2), include a great number of explanations, which really belong in commentaries or textbooks, in addition to precise normative requirements.

The construction industry and engineering associations in Germany therefore set up an initiative, the aim of which is to improve the practicability of the Eurocodes in collaboration with DIN. The work will include simplifying and considerably shortening the texts as well as making them more consistent. The German Geotechnical Society (DGGT) is also collaborating in the “Initiative on Improving the Practicability of Technical Rules for Building Construction”.

Six project groups (PG) were established for the Eurocodes with the exception of Eurocode 8 and 9 in 2011. PG 6 is dealing with both parts of Eurocode 7. It comprises members from the construction industry (2), from civil engineering consultancies (12), building authorities (2) and universities (3). Moreover, one colleague from Switzerland and one from Austria are involved in the work. The members of the project groups have contracts covering the work to be carried out with-

in a fixed period of time and receive a certain amount of funding for it.

The work of PG 6 initially took place in joint meetings. Later on, the discussions started being conducted in regular, well-prepared telephone conferences; this is a more effective way of working than the traditional joint committee meetings and is also less time-consuming.

Work packages of the Geotechnical Design Project Group

General

The project group's programme comprises four work packages:

- WP 1: Reorganization of the provisions for planning and evaluating ground investigations in EC 7-1 and EC 7-2;
- WP 2: Streamlining EC 7-2;
- WP 3: Streamlining EC 7-1;
- WP 4: Harmonization of the design approaches specified in EC 7-1.

Results of WP1

There are considerable overlaps between the two parts of Eurocode 7 as well as duplication of the provisions for the planning and evaluation of ground investigations. As a result, EC 7 is not user-friendly for these essential aspects of geotechnical design. The aim of WP1 is to structure this topic more clearly and to streamline it by reorganizing the standard. It had already been decided at European level that the future EC 7-2 should include the provisions for planning and evaluating ground investigations up to and including the specification of derived geotechnical parameters, while EC 7-1 would include the evaluation of characteristic geotechnical parameters on the basis of the derived parameters. Large parts of Section 3 *Geotechnical data* of EC 7-1 anticipate Part 2 of Eurocode 7. Thus most of the present content of Section 3 can be deleted. Furthermore, it was decided to concentrate the provisions for specifying the characteristic soil parameters and the geometrical parameters used to describe the ground profile and the groundwater in this section. Section 3 of EC 7-1 has therefore been restructured and rewritten with the following contents:

- 3 Geotechnical data
 - 3.1 General
 - 3.2 Characteristic values for the geometrical ground model
 - 3.3 Characteristic values for geotechnical parameters
 - 3.4 Documentation

Guidelines and results of WP2 and WP3

Subsection 1.3 *Assumptions* of each Eurocode includes the provision that structures are to be "designed by appropriately qualified and experienced personnel". Based

on this assumption the following principles for streamlining the two parts of Eurocode 7 were formulated for WP2 and WP3:

- the text of the standard may only include normative specifications;
- justifications, explanations and textbook-style passages are to be deleted;
- repetitions are to be avoided;
- the rules and requirements must either be formulated precisely or deleted;
- the content should not be altered, changes are limited to editorial amendments.

Moreover, all paragraphs dealing with rock have been deleted in both parts of EC 7 as they are text-book material or do not contain any normative provisions for design.

These principles for streamlining are very similar to those set out in the request of Subcommittee 7 (SC7), which is responsible for EC 7 within CEN, for European Commission funding for the revision of EC 7. This request describes, for example, the aim of improving ease of use: "Remove material readily available in text books and other NCCI documents. Remove repetition of principles and application rules across the two parts of EN 1997. Restructure the two parts with respect to ground investigations: with the provisions for planning, execution and evaluation of derived geotechnical parameters in EN 1997-2 and the evaluation of characteristic geotechnical parameters based on the derived values in EN 1997-1."

The two parts of EC7 were then considered clause by clause. By way of illustration, Figure 1 shows the beginning of Section 2 Planning of ground investigations of EC 7-2. The original text is shown in the left-hand column, along with deletions and amendments, the latter being highlighted in red, as well as comments and justifications printed in italics and highlighted in yellow. The abridged text is shown in the right-hand column. Documenting the results of the work in two columns in this way will form the basis of the next stage of work which will involve discussions with SC7, and its Project Teams in charge of the revision of EC 7, beginning in 2015.

Planning of investigations is not only covered in this Section 2 but also in Section 3 *Soil and rock sampling and groundwater measurements*, Section 4 *Field tests in soil and rock* and Section 5 *Laboratory tests on soil and rock*. For larger projects in particular, such investigations are usually planned at the different stages of the planning process. It was therefore decided to delete the provisions for planning in Section 2 and concentrate them in the respective sections. A new title has therefore been proposed for this section: *Extent of geotechnical investigations*. Desk-top studies are very important for preparing in-situ investigations. Therefore the German proposal deals with them in a separate subsection. They should be covered in greater detail in EC 7-2. Moreover, Annex B.3 *Examples of recommendations for the spacing and depth of investigations* has been integrated into the core text of the new Section 2

Original version with deletions, corrections and comments as well as paragraphs to be moved	Shortened version
2 Planning of ground investigations <i>As we propose to deal with planning in the Sections 3, 4 and 5 the heading should be changed to "Extent of geotechnical investigations"</i>	2 Extent of geotechnical investigations
2.1 Objectives	2.1 Objectives
2.1.1 General <i>Subheading is superfluous.</i> (1)P Geotechnical investigations shall be planned in such a way as to ensure that the relevant geotechnical information and data are available at the various stages of the project. Geotechnical information shall be adequate to manage identified and anticipated project risks. For intermediate and final building stages, information and data shall be provided to cover risks of accidents, delays and damage. <i>Delete: The purpose of planning construction projects is out of place in this standard.</i> (2) The aims purpose of a geotechnical investigation are is to establish the soil, rock and groundwater conditions and to determine the properties of the soil and rock; and to gather additional relevant knowledge about the site. <i>Delete as not specific enough. It would be better for (2) to come before (1).</i> (3)P Careful collection, recording and interpretation of geotechnical information shall be made. This information shall include ground conditions, geology, geomorphology, seismicity and hydrology, as relevant. Indications of the variability of the ground shall be taken into account.	(1 2) P? The purpose of a geotechnical investigation is to establish the structure of the ground , the properties of the soil and rock and the groundwater conditions. Geotechnical investigations shall be planned in such a way that the relevant information required for reliable geotechnical design is available at all stages of the project. Geology, geomorphology, seismicity and hydro-geology shall be taken into account.

Fig. 1. Original text with comments (on left) and shortened text of Section 2 of EC 7-2 (on right)

as normative text. For the geotechnical designer planning investigations in situ, they are the most important provisions because they are fundamental for the safety of his geotechnical design. The proposed structure is as follows:

- 2 Extent of geotechnical investigations
 - 2.1 Objective
 - 2.2 Desk studies
 - 2.3 Investigations
 - 2.3.1 General
 - 2.3.2 Spacing and depth of field investigations

To eliminate duplications and repetitions, not only within EC 7 but also in other European standards, all provisions in Section 3 *Soil and rock sampling and groundwater measurements*, Section 4 *Field tests in soil and rock* and Section 5 *Laboratory tests on soil and rock*, which are already covered in European Standards on the execution of field- and laboratory tests as well as on borings, have been deleted. The remaining provisions of the subsections on these tests could then be merged in tables (see e.g. Table 1 for Section 4 *Field*

tests). The tables also give further provisions, which are not contained in the present version of EC7-2: the input the designer has to give to the laboratory or the field team for the execution of the tests and the geotechnical parameters that can be derived from the tests.

Tests that are only used in one or two countries have also been deleted. Each country still has the option of applying national standards for areas not covered by European Standards, such as Weight Sounding in Sweden, for example.

Table 2 demonstrates that, if the above principles are followed, the text of EC 7-2 can be substantially shortened and thus rendered considerably more user-friendly without any normative content being sacrificed.

Results of WP4

Work package WP4 involves developing harmonised design approaches, specifying partial factors and drawing up proposals for harmonised geotechnical analytical models for determining actions and resistances. To this

Table 1. Extract from the table for field tests of Section 4 Field tests

Test	Standards to be applied	Input of the designer for the execution of the test	Derived values	Annex
Cone penetration and piezocone penetration tests (CPT, CPTU)	EN ISO 22476-1 EN ISO 22476-12	Location of the investigation points Depth of investigation Type of test	Density index Effective angle of shearing resistance φ' Drained Young's modulus E' , Oedometer Modulus E_{oed} Values for pile resistance	D

Table 2. Streamlining Eurocode 7-2

Clause	Word count		Shortened by %
	original	revised	
1 General			
2 Planning of ground investigations	8,876	2,387	73
3 Soil and rock sampling and groundwater measurements	5,242	1,642	69
4 Field tests in soil and rock	15,134	2,389	84
5 Laboratory tests on soil and rock	23,296	4,047	83
6 Ground investigation report	2,176	952	56

end, extensive comparative calculations for spread foundations (pad foundations and cantilever retaining walls), pile foundations (axially loaded and transversely loaded piles), construction pits (with retaining structures braced at one level, with a free earth support or braced at several levels) and slopes (simple and complex slopes) have been performed with the design approaches (DAs) defined in EC7-1 and the nationally determined partial factors and analytical models.

Table 3 shows the design approaches defined in EC7-1. These differ in whether the partial factors are applied to the actions (F) or to the action effects (E) on the action side of the equation and to the ground parameters (X) or the ground resistances (R) derived from the soil parameters on the resistance side of the equation (for further details of the design approaches and their application see Frank *et al.* 2004).

A special feature of geotechnical engineering is that the ground resistances may depend on the actions. This dependency can be linear, nonlinear or non-existent. There are a few cases, such as the design of axially loaded piles, in which the ground resistances are not dependent on the actions. By contrast, the dependency is linear in calculations of slope failure for non-cohesive soils. In this case, both the driving moments

(effects of actions) and the resisting moments (resistance) depend on the permanent and, in some instances, on the variable actions. Increasing the actions by applying partial factors greater than unity causes the same increase in the driving and resisting moments in the event of slope failure so that applying a partial factor to the actions only gives a false impression of safety.

Bearing resistance calculations are one example of a non-linear dependency. The required width b_{req} of a foundation is plotted against the angle of shearing resistance for the various design approaches in Figure 2, using the partial factors and the calculation methods specified in EC 7-1. The non-linearity can be clearly seen as the lines are not parallel. In DA2, for example, the bearing resistance is calculated using the design values V_d and H_d of the vertical and horizontal and actions in the foundation base, whereas in DA2* the bearing resistance is calculated using characteristic values V_k and H_k .

The effect of nationally determined partial factors and analytical models on the bearing resistance is also illustrated in Figure 2, taking the provisions applied in Italy (IT) and Denmark (DK) as examples. It can be seen that the national provisions result in even greater ranges of values.

Table 3. Design approaches defined in EC7-1

Design approach	Design value of the effect of actions	Design value of the ground resistance
DA1.1	$E_d = E (\gamma_F \cdot F_{rep}; X_k; a_d)$	$R_d = R (\gamma_F \cdot F_{rep}; X_k; a_d)$ For piles and anchors (DA1.1 & DA1.2): $R_d = (1/\gamma_R) \cdot R (\gamma_F \cdot F_{rep}; X_k; a_d)$
DA1.2	$E_d = E (\gamma_F \cdot F_{rep}; X_k/\gamma_M; a_d)$	$R_d = R (\gamma_F \cdot F_{rep}; X_k/\gamma_M; a_d)$
DA2	$E_d = E (\gamma_F \cdot F_{rep}; X_k; a_d)$	$R_d = (1/\gamma_R) \cdot R (\gamma_F \cdot F_{rep}; X_k; a_d)$
DA2*	$E_d = \gamma_E \cdot E (F_{rep}; X_k; a_d)$	$R_d = (1/\gamma_R) \cdot R (F_{rep}; X_k; a_d)$
DA3	$E_d = E (\gamma_F \cdot F_{rep}; X_k/\gamma_M; a_d)$	$R_d = R (\gamma_F \cdot F_{rep}; X_k/\gamma_M; a_d)$

where:

a_d	= design value of geometrical data
E_d	= design value of the effect of actions
F_{rep}	= representative value of an action
R_d	= design value of the ground resistance
X_k	= characteristic value of the geotechnical parameters
γ_F	= partial factor for actions
γ_E	= partial factor for effects of actions
γ_M	= partial factor for geotechnical parameters
γ_R	= partial factor for ground resistances

Fig. 2. Required width b_{req} of a foundation obtained with the design approaches defined in EC7-1 and with national provisions of Denmark and Italy

Fig. 3. Influence of the specification of the characteristic geotechnical parameter ϕ_k and the Design Approaches on the required width b_{req}

Furthermore, it was established during the discussions with European colleagues at the first PRB workshop "Contributions for the Ease of Use of the EURO-CODES" that the methods used in individual countries to determine the characteristic geotechnical parameters have a considerable effect on the design. To demonstrate the effect of a more conservative selection of the geotechnical parameter the characteristic value ϕ_k of the angle of shearing resistance has been reduced by 3° . For example, the curves for DA2* and DA3 approach each other if the characteristic geotechnical parameters speci-

fied for the former are more conservative than those specified for the latter (see Fig. 3).

Conclusions

The results of the comparative calculations have shown that geotechnical design depends to a considerable extent on the way the parameters are factored, the national selection of partial factors, the analytical models used nationally and the specification of the characteristic geotechnical parameters. A design approach that is based on the general formula given in "Eurocode – Ba-

sis of structural design" (EN 1990) which will also take the actions into account in the resistances is therefore currently being developed. This more generalized design approach, referred to as DA0, includes, on the one hand, partial factors to cover uncertainties in the specification of the parameters and, on the other hand, partial factors to take account of the uncertainty in the model. This is achieved by factoring both the effects of actions and the resistances inside and outside the parentheses in the expressions in Table 3. The parameterisations within the parentheses thus have a direct effect on all non-linearities of the conditional equation for the design effect of actions and the design resistance while the factorisation outside the parentheses only has a linear effect. The following general analytical equation is thus obtained:

$$E_d = \gamma_{sd} \cdot E(\gamma_f \cdot F_{rep}; a_d) \leq R_d = (1/\gamma_{Rd}) \cdot R(X_k/\gamma_m; \gamma_f \cdot F_{rep}; a_d),$$

where:

γ_{sd} is the partial factor to take account of the uncertainties in the action model

γ_f is the partial factor to take account of the uncertainties in the actions

γ_{Rd} is the partial factor to take account of the uncertainties in the resistance model and

γ_m is the partial factor to take account of the uncertainties in the characteristic soil parameters.

This generalized expression not only enables the different procedures followed for the design approaches to be taken into account formally during factorisation by

setting certain partial factors to 1.0 but also permits aspects such as risk classes, classes of consequence or a factor for human error to be incorporated, resulting in a simplified way of ensuring robustness. This can be achieved by redefining the model factors γ_{sd} and γ_{Rd} which can include the above mentioned aspects.

Disclosure statement

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