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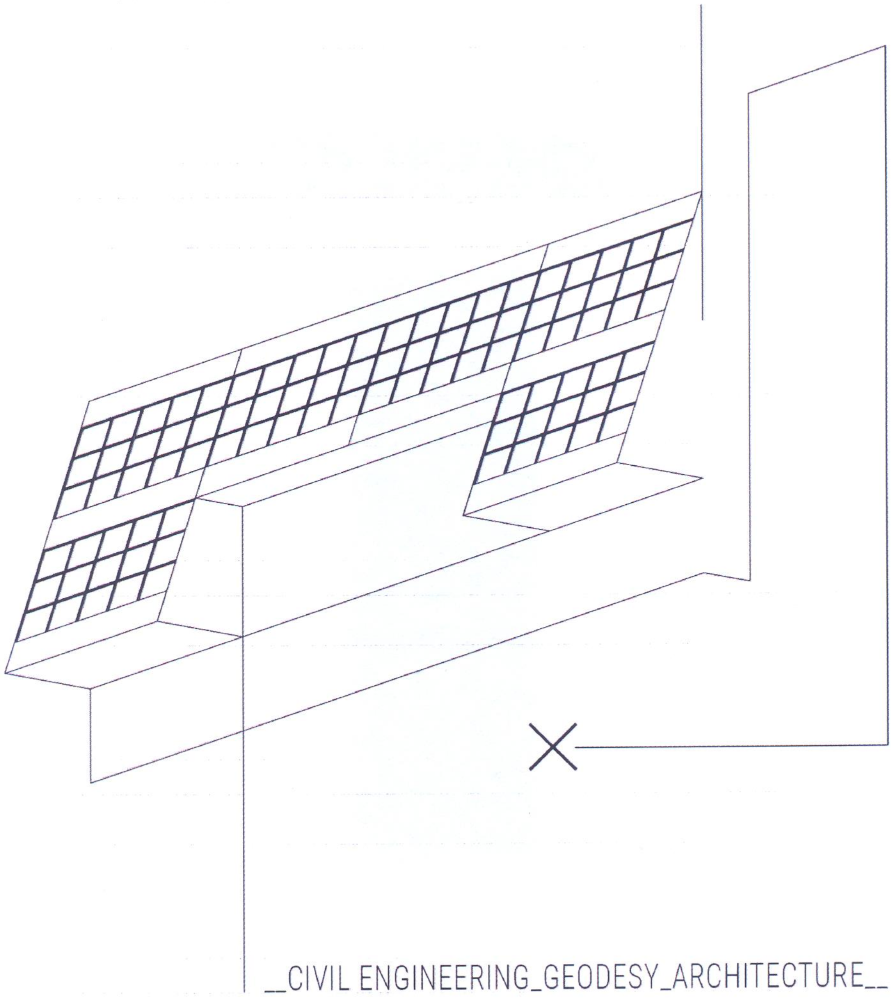

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IX INTERNATIONAL CONFERENCE
CONTEMPORARY ACHIEVEMENTS IN CIVIL ENGINEERING
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TOWARDS THE NEW GENERATION OF EUROCODE 7

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ABSTRACT

Between 1991. and 1999., three versions of the Construction Eurocodes were published as pre-norms ("EuroNorm Vornnorm", ENV). The duration of each version was 3 years, when they could be used but without the status of fully adopted European Norms (EN). The experiences gained during the application of these pre-norms were used to harmonize and modify the pre-norms according to the final form of the European Norms (EN). Many pre-norms underwent significant changes and revisions until the final transformation into the fully adopted European Norm (EN). Work on the final version of the Construction Eurocodes began in June 1996 and continued until November 2006, when the final part of Eurocode 9 was ratified. International working group CEN TC250 (European Committee for Standardization) works on the new generation of Eurocode 7, after the shortcomings were noticed and the problems that appeared during the application of the current Eurocode 7 were considered in detail. The standard has been reorganized so that it now consists of three parts (instead of 2), new chapters were added (methods for soil improvement, the influence of groundwater), design rules were simplified, "alternative" methods were avoided, and the selection of nationally determined parameters was reduced. The paper presents the key changes in relation to the current Eurocode.

KEYWORDS:

EUROCODE 7, SECOND GENERATION, KEY CHANGES

1 INTRODUCTION

In December 1988, the EU Commission adopted the joint directive 89/106/EEC (Construction Products Directive), which set basic requirements for constructions: "... the products must be adapted to the structures, ... fully intended for the purpose of construction ... to satisfy the following basic requirements: mechanical resistance and stability, safety in case of fire, to satisfy hygiene and health conditions as well as environmental protection and safety in use within a reasonable economic life of the structure."

The Commission has given an order to the European Committee for Standardization (CEN - Committe Europeen de Normalisation) to prepare a series of European standards (EN) which will determine unified methods for achieving the mechanical resistance of buildings and meet other required requirements. CEN established a technical committee (TC 250) to oversee the development of subject European standards known collectively as Construction Eurocodes or as they are now called EN Eurocodes.

"The Eurocodes will bring a broader way of thinking to Europe in the design and execution of building and construction work... and are vital to design and construction."

Between 1991. and 1999., three versions of the Construction Eurocodes were published as pre-norms ("EuroNorm Vornnorm", ENV). The duration of each version was 3 years, when they could be used but without the status of fully adopted European Norms (EN). The experiences gained during the application of these pre-norms were used to harmonize and modify the pre-norms according to the final form of the European Norms (EN). Many pre-norms underwent significant changes and revisions until the final transformation into the fully adopted European Norm (EN). Work on the final version of the Construction Eurocodes began in June 1996 and continued until November 2006, when the final part of Eurocode 9 was ratified.

The final step in the implementation of Construction Eurocodes is the publication of each individual Eurocode as a national standard (norm) in each of the countries affiliated to CEN.

From 2011 – 2016. topics for revision Eurocode 7 are defined. Drafting of 2nd Generation Eurocode 7 is planned from 2015-2025.

Eurocode 7 (EC7) consists of three parts: EN 1990:2002 – Basis of structural design, EN 1997 – 1:2004 – General (geotechnical) rules and EN 1997 – 2:2007 – Ground investigation and testing. Instead of this, there are four parts in new Eurocode 7: EN 1990:202x – Basis of structural and geotechnical design, EN 1997 – 1:202x – General rules for all structures, safety, characteristic values, EN 1997 – 2:202x – Ground properties (and how to derive them from tests) and EN 1997 – 3:202x – Geotechnical structures (rules for specific geotechnical structures with many calculation models).

2 EUROCODE 7 PART 1 – KEY CHANGES

Eurocode 7 Part 1 introduces two new geotechnical categories: consequence (CC) class and geotechnical complexity class (GCC), safety concept is improved, representative value determination is to be done by engineering judgement and by statistics. Also, groundwater issues (design groundwater pressures) are novelty in this part of EC7.

2.1 CONSEQUENCE CLASS (CC CLASS)

The choice of an appropriate level of reliability for the structure should take account of the following (Figure 1):

- possible consequences of failure in terms of risk to life,injury, and potential economic losses;
- the possible cause and mode of attaining a limit state;
- public aversion to failure;
- the expense and procedures necessary to reduce the risk of failure.

Minimum reliability levels can be set by the National Annex for use in a country. Different levels of reliability are commonly adopted for limit states relating to structural failure, serviceability, and durability. The consequence classes influence the value of the appropriate reliability. The partial factors may be altered with respect to consequence, using the consequence factor (K_F, K_M, K_R).

The reliability is not only to pick a value, it is to add measures to ensure that the geotechnical levels of reliability for structural failure and serviceability are achieved by:

- appropriate representation of the basic variables;
- accuracy of the mechanical models used and interpretation of their results;
- prevention of errors in design and execution of the structure, including gross human errors;
- adequate inspection and maintenance according to procedures specified in the project documentation structure are within the limitation that the value prescribe.

Consequence class	Indicative qualification of consequences	
	Loss of human life or personal injury[a]	Economic, social or environmental consequences[a]
CC4 – Highest	Extreme	Huge
CC3 – Higher	High	Very great
CC2 – Normal	Medium	Considerable
CC1 – Lower	Low	Small
CC0 – Lowest	Very low	Insignificant
[a] The consequence class is chosen based on the more severe of these two columns.		

Figure 1: Qualification of consequence classes according to new EN 1990

2.2 GEOTECHNICAL COMPLEXITY CLASS

Geotechnical Complexity Class (GCC) shall be selected using engineering judgement, taking into account complexity and uncertainty in the ground, groundwater conditions and ground-structure interaction (Figure 2).

Geotechnical Complexity Class	Complexity	General features
GCC 3	Higher	**Any** of the following apply: — considerable uncertainty regarding ground conditions — highly variable or difficult ground conditions — significant sensitivity to groundwater and surface water conditions — significant complexity of the ground-structure interaction
GCC 2	Normal	GCC2 applies if GCC 1 and GCC3 are not applicable
GCC 1	Lower	**All** the following conditions apply: — negligible uncertainty regarding the ground conditions — uniform ground conditions — low sensitivity to groundwater and surface water conditions, — low complexity of the ground-structure-interaction
NOTE The terms 'considerable', 'significant', 'highly', etc. are relative to any comparable experience that exists for the particular geotechnical structure, design situation, and ground conditions.		

Figure 2: Selection of geotechnical complexity class according to new EN 1990

A preliminary GCC should be selected as part of the desk study (prEN 1997-2:2021, 5.2.1) or based on a site inspection. The GCC shall be assumed to be GCC3 unless a different class has been determined by the desk study or by preliminary, or design investigation.

2.3 REPRESENTATIVE VALUE OF THE GROUND PROPERTY

Representative value of the ground property is to be done either from formula: Xrep = Xnom, or from formula: Xrep = Xk. Nominal value (Xnom) is based on „cautious estimate“ and Characteristic value (Xk) is 5 % lower bound value, based on statistics.

2.4 SAFETY EN 1990 – FACTORS ON ACTIONS

1st Generation Design approaches changed to Design cases. New partial factors are shown in Figure 3.

2.5 GROUND WATER

Representative value of groundwater pressure ($G_{w,rep}$) is to be calculated as upper or lower value ($G_{w,k,sup}$ or $G_{w,k,inf}$) or as permanent mean ($G_{w,k,mean}$) + variable ($Q_{w,rep} = Q_{w,k}$; $Q_{w,comb}$; $Q_{w,freq}$ or $Q_{w,qper}$).

Design value is to be calculated through direct assesement (nominal value), by applying an offset to the representative waterpressure, or by applying a partial factor.

Action or effect				Partial factors γ_F & γ_E for Design Cases 1-4				
Type	Group	Symbol	Resulting effect	Struct-ural	Static equilibrium and uplift*		Geotechnical design	
				DC1	DC2(a)	DC2(b)	DC3	DC4
Permanent action (G_k)	All	γ_G	unfavourable/ destabilizing	1.35 K_F	1.35 K_F	1.0	1.0	G_k is not factor-ed
	Water	$\gamma_{G,w}$		1.2 K_F	1.2 K_F			
	All	$\gamma_{G,stb}$	stabilizing	not used	1.15		not used	
	Water	$\gamma_{G,w,stb}$			1.0			
	(All)	$\gamma_{G,fav}$	favourable	1.0	1.0		1.0	
Prestress (P_k)		γ_P		See other relevant Eurocodes				
Variable action (Q_k)	All	γ_Q	unfavourable	1.5 K_F	1.5 K_F		1.3	1.1
	Water	$\gamma_{Q,w}$		1.35 K_F	1.35 K_F		1.15	1.0
	(All)	$\gamma_{Q,fav}$	favourable	0				
Effects-of-actions (E)		γ_E	unfavourable	effects are not factored				1.35 K_F
		$\gamma_{E,fav}$	favourable					1.0

*worse outcome of (a) and (b) applies

Figure 3: Applicable Design case for geotechnical structures

2.6 PARTIAL MATERIAL FACTORS

Factor KM is novelty in new EC7. This factor depends on consequence class and it is national determined parameter, as well as whole M2 set (Figure 4).

Ground property	Symbol	M1[a]	M2[a]	
		Persistent Transient Accidental	Persistent Transient	Accidental
Soil and Fill parameters				
Shear strength in effective stress analysis[b] (τ_f)	$\gamma_{\tau f}$	1,0	1,25 K_M	1,1
Coefficient of peak friction ($\tan \varphi'_p$)[d]	$\gamma_{\tan\varphi,p}$	1,0	1,25 K_M	1,1
Peak effective cohesion (c'_p)	$\gamma_{c,p}$	1,0	1,25 K_M	1,1
Coefficient of friction at critical state ($\tan \varphi'_{cs}$)[d]	$\gamma_{\tan\varphi,cs}$	1,0	1,1 K_M	1,0
Coefficient of residual friction ($\tan \varphi'_r$)[d]	$\gamma_{\tan\varphi,r}$	1,0	1,1 K_M	1,0
Residual effective cohesion (c'_r)	$\gamma_{c,r}$	1,0	1,1 K_M	1,0
Shear strength in total stress analysis[b] (c_u)	γ_{cu}	1,0	1,4 K_M	1,2
Unconfined compressive strength (q_u)	γ_{qu}	Same as γ_{cu}		
Rock parameters				
Shear strength[b] (τ_r)	$\gamma_{\tau r}$	1,0	1,4 K_M	1,2
Coefficient of friction along discontinuities ($\tan \varphi'_{dis}$)[d]	$\gamma_{\tan\varphi dis}$	1,0	1,4 K_M	1,2
Unconfined compressive strength[c] (q_u)	γ_{qu}	1,0	1,4 K_M	1,2
Interface parameters				
Coefficient of ground/structure interface friction ($\tan \delta$)	$\gamma_{\tan\delta}$	1,0	1,25 K_M	1,1

[a] M1, and M2 are alternative sets of material factors. prEN 1997-3:2022 specifies which set to use for specific geotechnical structures.
[b] Intended to be used for numerical models and non-Mohr-Coulomb strength criteria.
[c] Used for foundations only.
[d] Partial factor is applied to $\tan\varphi$

Figure 4: Partial factors on ground properties for persistant, transient and accidental design situations

3 EUROCODE 7 PART 2 – KEY CHANGES

EN1997 – 2 is completely reorganized, focusing design instead ground investigation. Testing is transferred to the Part 3 (calculation models), Figure 5.

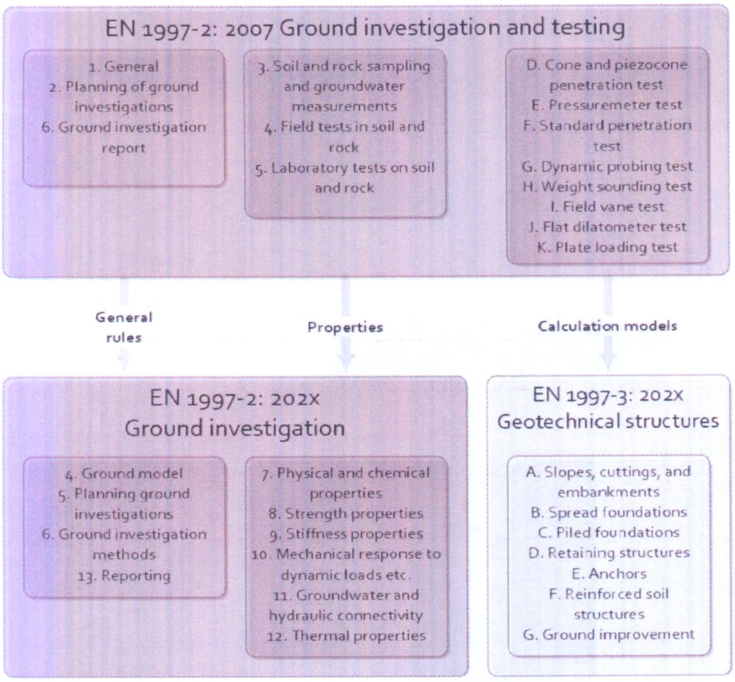

Figure 5: Key changes in EN 1997:2007

4 EUROCODE 7 PART 3 – KEY CHANGES

Rock engineering is included in all geotechnical structures.

New structures are: pile groups and pile rafts (Clause 6), reinforced fill structures (Clause 9), ground reinforcing elements (soil nails and rock bolts, Clause 10), ground improvement (Clause 11) and ground water control (Clause 12).

Existing, but completely updated clauses are: slopes (Clause 4), spread foundations (Clause 5), piled foundations (Clause 6), retaining structures (Clause 7) and anchors (Clause 8).

Spread foundations have one or two checks, without national determined approach. (Figure 6).

Partial factor on		Material factor approach			Resistance factor approach	
		(a)	(b)	(c)	(d)	(e)
Spread foundations		2 checks: (a) and (b)				H / V < 0.2
Actions/effects	γ_F, γ_E	DC1 $\gamma_G = 1.35\ K_F$ $\gamma_Q = 1.5\ K_F$	DC3 $\gamma_G = 1.0$ $\gamma_Q = 1.3\ K_F$	DC1 $\gamma_G = 1.35\ K_F$ $\gamma_Q = 1.5\ K_F$	DC1 $\gamma_G = 1.35\ K_F$ $\gamma_Q = 1.5\ K_F$	DC4 $\gamma_E = 1.35\ K_F$ $\gamma_Q = 1.11$
Ground properties	γ_M	M1 $\gamma_{\tan\varphi} = 1.0$ $\gamma_{cu} = 1.0$	M2 $\gamma_{\tan\varphi} = 1.25\ K_M$ $\gamma_{cu} = 1.4\ K_M$	M2 $\gamma_{\tan\varphi} = 1.25\ K_M$ $\gamma_{cu} = 1.4\ K_M$	Not factored	
Bearing resistance	γ_{Rv}	Not factored			1.4	
Sliding resistance	γ_{Rh}	Not factored			1.1	

Figure 6: New partial factors for spread foundations

Model pile method with model factors is the biggest novelty in pile calculation. Compressive resistance can be calculated from following expression:

$$Rc;d = \frac{R_{b,rep}}{\gamma_{Rb}\gamma_{Rd}} + \frac{R_{s,rep}}{\gamma_{Rs}\gamma_{Rd}}$$

Where: Rb – base resistance, Rs – shaft resistance, γ_{Rb} and γ_{Rs} – resistance factors on shaft and base and γ_{Rd} is model factor (Figure 7).

Verification by		Model factor γ_{Rd}	
Ground Model Method	Ultimate Control Tests as specified in Table 6.2 (NDP)	1.2	
	Extensive comparable[1,2] experience without site-specific Control Tests	1.3	
	Serviceability Control Tests as specified in Table 6.2 (NDP)	1.4	
	No pile load tests and limited comparable experience[1,3]	1.6	
	Pile on competent rock using properties determined from field and laboratory tests	1.1	
		Compressive resistance	Tensile resistance
Model Pile Method	Pressuremeter test[4]	1.15	1.4
	Cone penetration test[4]	1.1	1.1
	Profiles of ground properties based on field or laboratory tests[4,5]	1.2	1.2

Figure 7: Model factor for verification of axial pile resistance by calculation

5 CONCLUSIONS

Second generation of EC7 has numerous changes, some of them are:

- New concepts: limit state check – 4 options, ground model, representative value, geotechnical category, groundwater, supporting elements (anchors, nails), numerical methods;

- New geotechnical techniques: reinforced fill, ground improvement, ground reinforcing elements, groundwater control, piled rafts, pile groups, horizontally loaded piles;
- New focus: complete restructuring of Part 2: how to derive ground parameters for design;
- New link with EN1990: "EN1990 is now 4th part of EN1997"; Basis of structural and geotechnical design;
- New writing style: more "prescriptive" code, more "shall" clauses, less "may" clauses.

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