

Overview of the Evolution of EN1997: Eurocode 7 – Geotechnical Design

November 1st, 2020

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Structure of this slide deck

- General overview of the evolution of EN 1997
- Specific overview of the evolution of EN 1997
 - Part 1 – General rules
 - Part 2 – Ground properties
 - Part 3 – Geotechnical structures

General overview of the Evolution of EN1997: Eurocode 7 – Geotechnical Design

November 1st 2020

Agenda – Evolution of EN 1997

- Key changes to EN 1997
- New content included in the scope of EN 1997
- How ease of use has been enhanced

The following slides provide a general overview of the evolution of EN 1997. Complementary slides provide greater details for individual Eurocode Parts.

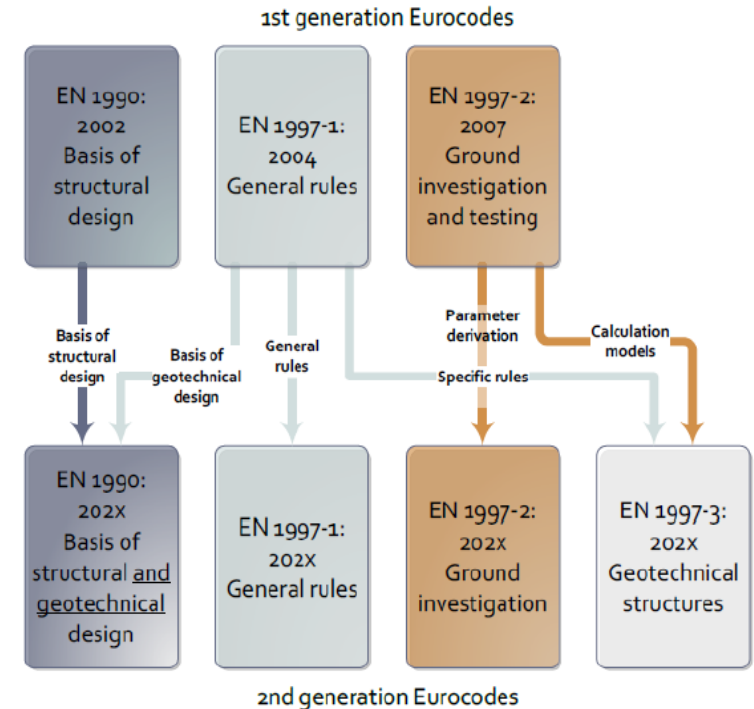
Key changes to EN 1997

→ 1st Generation Eurocode 7 (3 parts)

1. EN1990 - Basis of design
2. EC7 Part 1 – Geotechnical rules
3. EC7 Part 2 – Testing and derivation of parameters

→ 2nd Generation Eurocode (4 parts)

1. EN1990 – Basis of design – also geotechnical rules!
2. EC7 Part 1 – General rules for all structures, safety, characteristic values
3. EC7 Part 2 – Geotechnical Parameters and how to derive them from tests
4. EC7 Part 3 – Rules for specific geotechnical structures, many calculation models in Annex



New content included in scope of EN 1997

→ New concepts

- Rock engineering included everywhere (Soil + Rock = Ground!)
- Geotechnical Category is now combination of Complexity of structure (CC) and Ground (GCC)
- Representative value - “cautious estimate” and/or “statistical approach
- New Focus for Part 2 – “How do I derive a ground property?” Focus change from “Output from Testing” to “Input for Design”

→ Inclusion of New technical developments in Part 3

- Pile groups, piled rafts
- Reinforced fill
- Rock bolts, soil nails
- Ground Improvement techniques: stone columns, grouting, rigid inclusions
- Measures for groundwater control

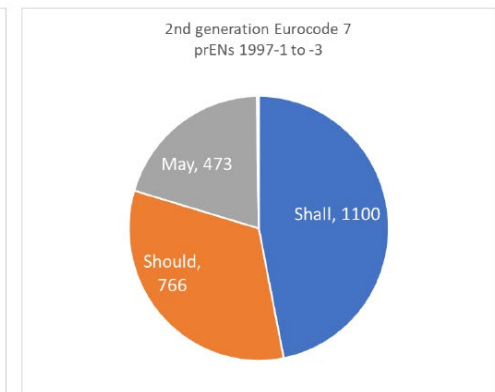
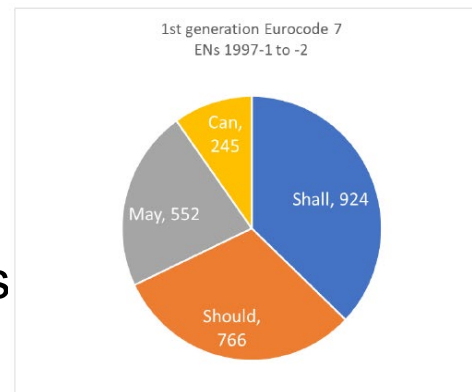
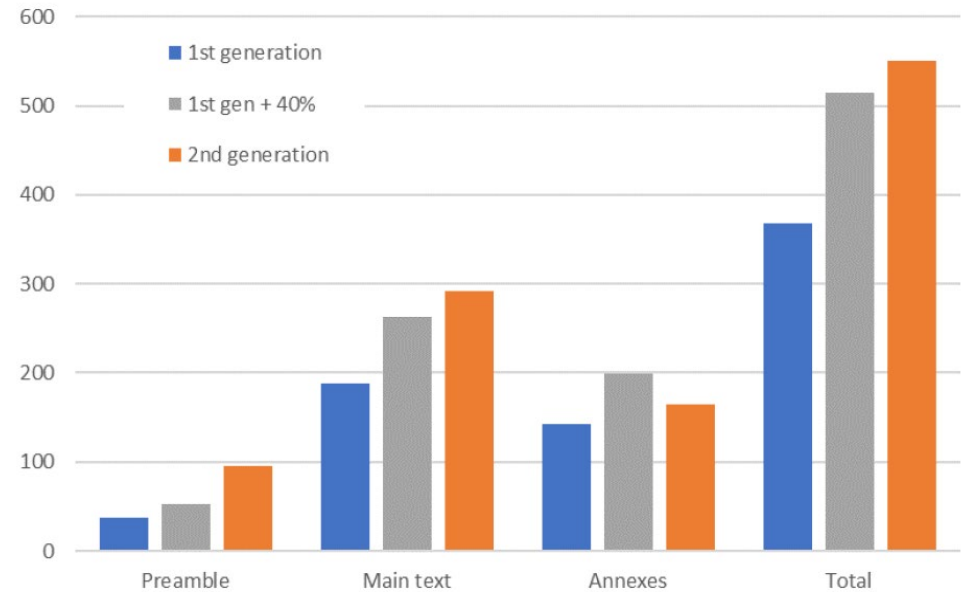
How ease of use has been enhanced

→ Harmonisation of Table of Contents between EN 1990 and EN 1997 and between various structures in Part 3

→ In 2nd generation: 40 % more Geotechnical structures covered:

- About same No of Pages (550)
- More specific code writing:
 - Less clauses (2350 vs 2500)
 - Less “May” / “Can” subclauses
 - More “Shall” subclauses

1st vs 2nd generation Eurocode 7



Overview of the Evolution of EN1997-1: Geotechnical Design – General rules

November 1st 2020

Agenda – Evolution of EN 1997-1: Geotechnical Design – General rules

- Key changes to EN 1997-1
- New content included in the scope of EN 1997-1
- How ease of use has been enhanced

Key changes to EN 1997-1

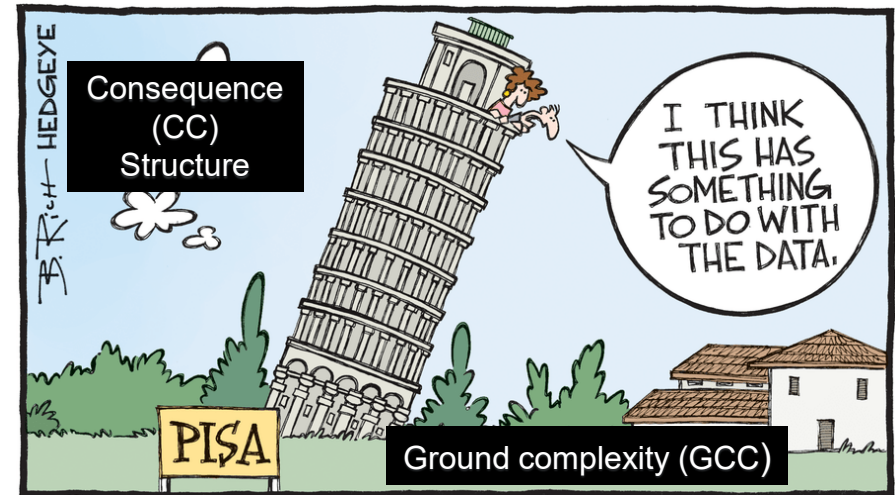
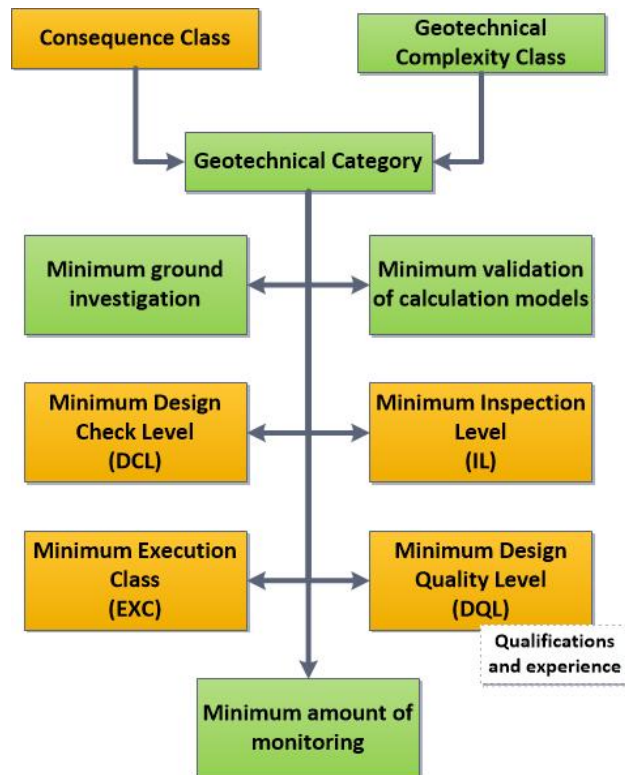
- New Geotechnical Category: Consequence (CC)-class and Ground Complexity (GCC)
- Improved Safety concept EN 1990 / EN 1997
- Representative value determination
- Groundwater issues - design groundwater pressures
- Numerical methods implementation

Ease of Use:

- Table of content matches directly with EN1990
- All common text from Part 2 and 3 is removed to Part 1
- Better navigation between Parts and Clauses

New Geotechnical Category

→ Geotechnical Category =
 Consequence Class x
 Geotechnical Complexity Class



Consequence Class (CC)	Geotechnical Complexity Class (GCC)		
	Lower (GCC1)	Normal (GCC2)	Higher (GCC3)
High (CC3)			GC3
Medium (CC2)		GC2	
Low (CC1)	GC1		

Improved Safety Concept EN 1990 / EN 1997

- 1st Generation Design Approaches changed to Design Cases
- Applicable Design Case in part 3 – Geotechnical Structures

Action or effect				Partial factors γ_F & γ_E for Design Cases 1-4				
Type	Group	Symbol	Resulting effect	Structural	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	$\gamma_{G,stab}$	stabilizing	not used	1.15		not used	
	Water	$\gamma_{G,w,stab}$		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

*Note 1: Outcome of (a) and (b) applies

Representative Value of a Ground property

→ Representative value – 2 options:

- Nominal value – “cautious estimate”
- Characteristic value – 5 % lower bound value – Statistics
(Informative Annex – Student t-distribution)

Groundwater – New Clause 6 in EN 1997-1

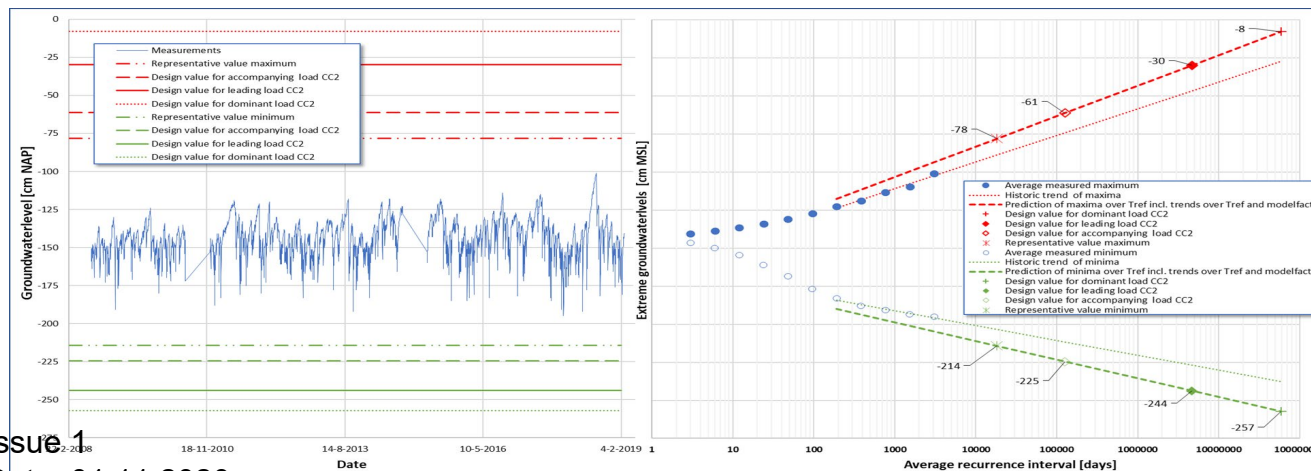
→ Groundwater level measurements and groundwater pressures

→ Representative value of Groundwater pressure $G_{w,rep}$:

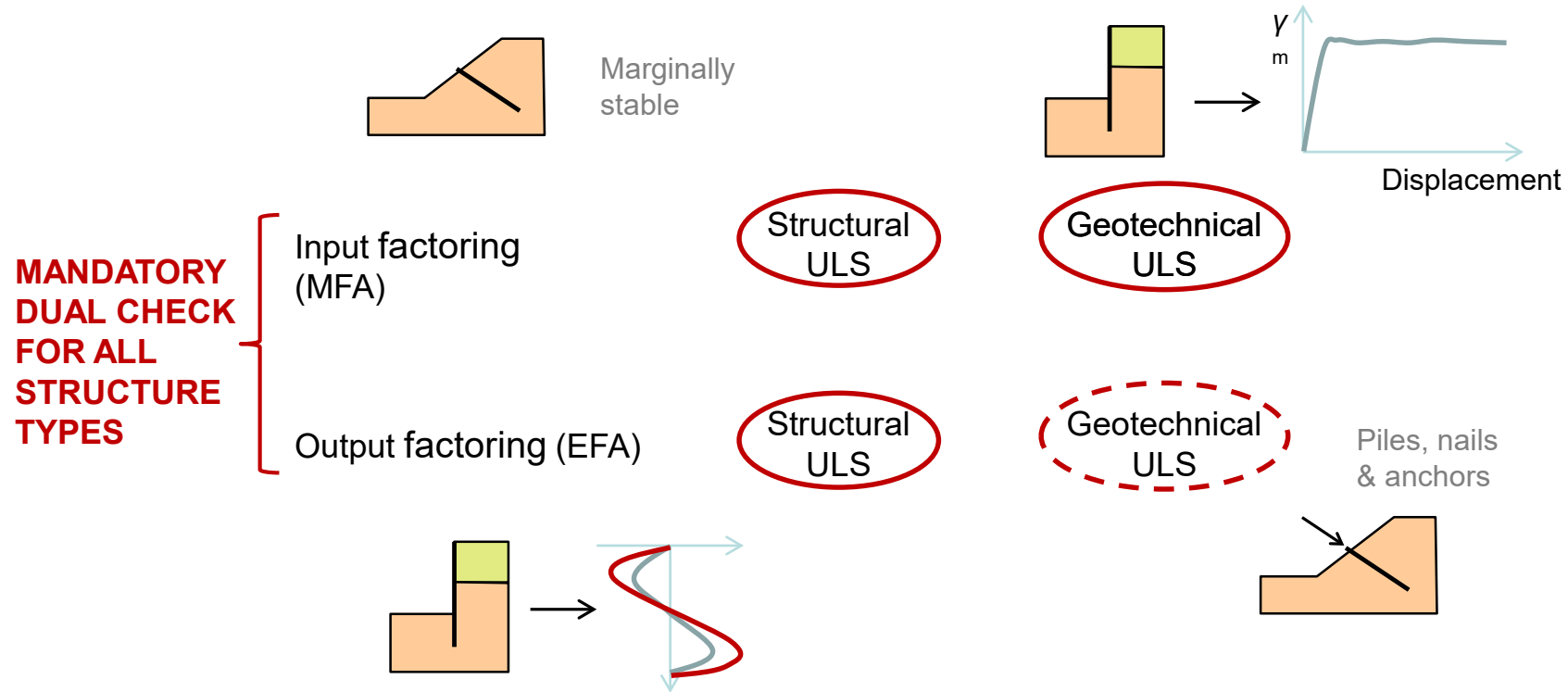
- Alternative 1: Upper or Lower value $G_{w;k;sup}$ or $G_{w;k;inf}$
- Alternative 2: Permanent mean $G_{w;k;mean}$ + Variable $Q_{w;rep}$
with variable $Q_{w;rep} = Q_{w;k}, Q_{w;comb}, Q_{w;freq}$ or $Q_{w;qper}$

→ Design value:

- Direct Assessment (Nominal value)
- Apply an offset to the representative waterpressure
- Apply a partial factor (see EN 1990)



Numerical Methods in EN 1997 for ULS



→ Two verifications: (1) Input Factoring, (2) Factoring Effect of Actions

Other clauses

- 8 – Ultimate Limit State
 - ULS in General
 - ULS for specific subjects: Excessive deformation, Hydraulic failure
- 9 – Serviceability Limit State
 - Limiting values for movements in Annex B
- 10 – Implementation of Design during execution and service life
- 11 – Testing
 - Testing for ground properties, design assisted by testing, verification of capacity of a structural member (pile, anchor), quality control, verification of behaviour of the structure.
- 12 – Reporting – Geotechnical Design Report (also Annex C)

Overview of the Evolution of EN1997-2: Geotechnical Design - Ground properties

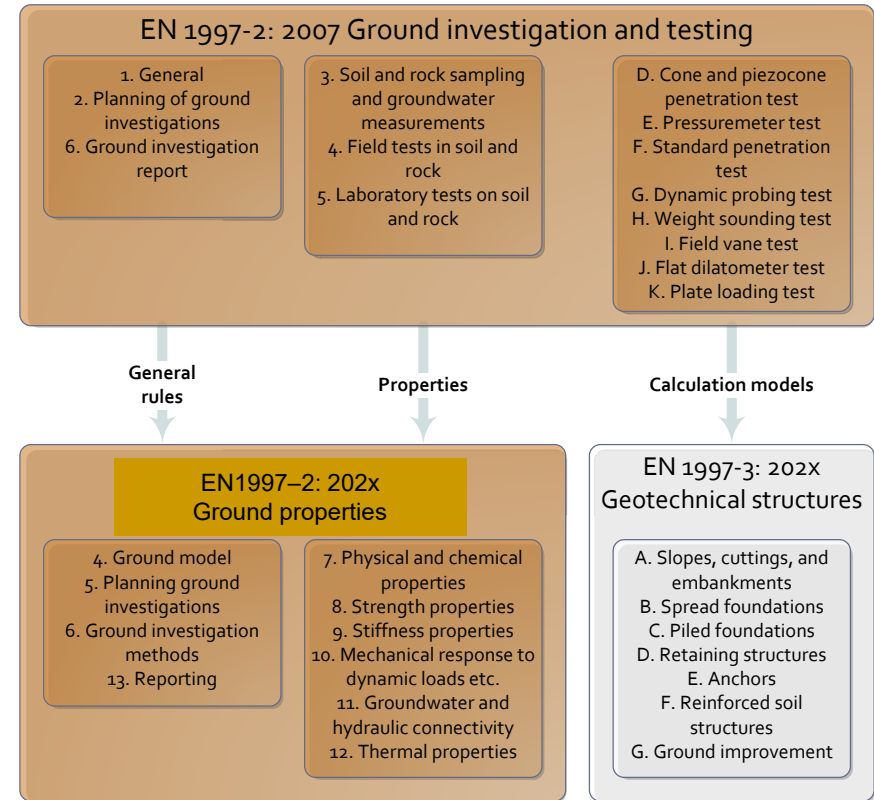
November 1st 2020

Agenda – Evolution of EN 1997-2: Geotechnical Design – Ground properties

- Key changes to EN 1997-2
- New content included in the scope of EN 1997-2
- How ease of use has been enhanced

Key changes to EN 1997-2

- Complete reorganisation of EN1997-2
- Focus on DESIGN instead of GROUND INVESTIGATION
- Calculation models in Old Annexes → PART 3



Ease of Use:

- Table of contents of Clauses 7 – 12 is similar
- Tables with: parameter, how to obtain it (test codes), confidence
- 1 Table with all guidelines for Ground investigation

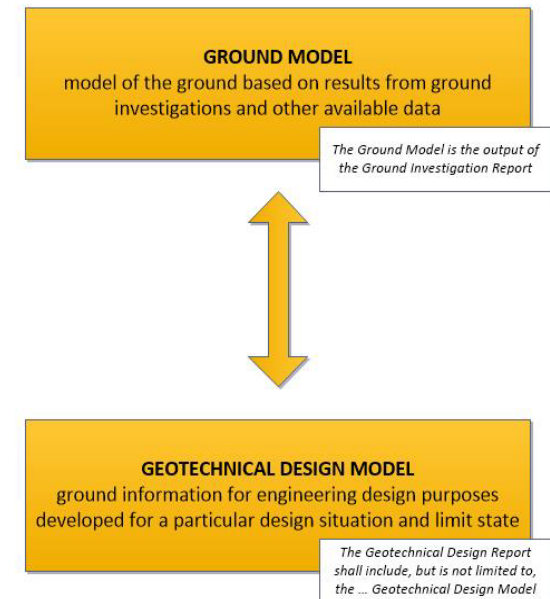
EN 1997-2 – Ground model

Second generation of Eurocode 7

- *In EN 1997-2:*
 - GROUND MODEL – site specific outline of disposition and character of ground and groundwater based on ground Investigation

- *In EN 1997-1 and EN 1997-3:*
 - GEOTECHNICAL DESIGN MODEL – conceptual representation of the site derived from the Ground Model for verification of limit state

- Reporting of Ground Model in Clause 13 and Annex G



EN 1997 – 2 - Minimum number and maximum spacing of Ground Investigation (NDP)

→ Recommendations for Ground Investigation (part of Table 5.4, NDP)

Table 5.4(NDP). Maximum spacing and minimum number of in-situ testing locations for structures in Geotechnical Category 2

Structures		Maximum spacing X_{max}	Minimum number ^a N_{min}
Low-rise structures		30 m	3
High-rise structures	4-10 storeys	25 m	<u>3-4</u> ^b
	11-20 storeys	20 m	<u>3-5</u> ^b
	>20 storeys	15 m	<u>3-6</u> ^b
Estate roads, parking areas and pavements		40 m	2
Silos and tanks		15 m	3
Bridges piers and abutments		1 per pier/base	
Power lines		1 per pylon	
Wind turbines		2 per turbine	
Retaining structures		150 m	-
Slopes and cuttings	< 3 m high	100 m	-
	≥ 3 m high	50 m	-
Embankments and reinforced fill structures	< 3 m high	200 m	-
	≥ 3 m high	100 m	-
Excavations in urban areas > 5 m deep from ground surface		25 m	3

^a Where no spacing or number of locations is given this should be assessed on a project-specific basis.

^b Underlined numbers are more appropriate for difficult structures

EN 1997 – 2 – How to derive Ground properties

→ Methodes for deriving Ground Properties:

- Physical, chemical and state properties (Clause 7)
- Strength properties (Clause 8, Annex D)
- Stiffness and consolidation properties (Clause 9, Annex E)
- Cyclic, Dynamic and Seismic properties (Clause 10, Annex F)
- Groundwater and geohydraulic properties (Clause 11)
- Thermal properties (Clause 12)

→ All these Clauses have same table of content:

- Direct determination – directly from test results
- Indirect determination – through correlations

→ ROCK is included!

EN 1997 – 2 – ANNEX A – Suitability of test methods

- ANNEX B - Desk Study and Inspection

→ Annex A (informative):

- Guidance on *type of investigation* is needed for a *particular project type*
- Confidence levels for suitability of a certain test for a specific parameter

→ Annex B (informative):

- Guidance on subjects for desk study and site inspection

Overview of the Evolution of EN1997-3: Geotechnical Design - Geotechnical structures

November 1st 2020

Agenda – Evolution of EN 1997-3: Geotechnical Design – Geotechnical Structures

- Key changes to EN 1997-3
- New content included in the scope of EN 1997-3
- How ease of use has been enhanced

Key changes to EN 1997-3

→ Rock engineering included in all Geotechnical Structures

→ New Structures:

- 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)
- Ground water control (Clause 12)

Ease of Use:

- Table of contents of all Clauses of Part 3 is same
- All common text from Clauses of Part 3 is removed to Part 1
- Partial factors per Clause in one table, similar for each structure
- Better navigation between Parts and Clauses

- Slopes in Soil and Rock
- Ultimate Limit State:
 - Material Factoring Approach, partial factor on the friction properties of the ground material
- (Harmonisation – 1 method)**
- Evaluation of Calculation methods in Annex A.
- Clause 4 is basis for other structures:
 - Rock bolts and soil nails
 - Reinforced fill
 - Spread foundations on slopes



EN 1997-3 – Clause 5 – Spread Foundations

- Analytical models
- Ultimate Limit State:
 - Material Factoring Approach, partial factor on friction
 - Resistance Factoring, partial factor on the bearing resistance
- Serviceability Limits
 - Settlement Analysis
- Informative Annex B:
 - Bearing capacity and Settlements



EN 1997-3 – Clause 6 – Piled Foundations (1)



→ Pile classification system (Examples in Annex) → Partial Factors

Pile type	Description	Class
Displacement pile	Pile installed in the ground without excavation of material	Full displacement
		Partial displacement
Replacement pile	Pile installed in the ground after the excavation of material	Replacement
Pile not listed above	---	Unclassified

- Axial loading – single piles; only Resistance Factoring (RFA)
- Transverse loading: only Material Factoring (MFA)
- Ground model method (averaging ground parameters over site)
- Model pile method (averaging calculated capacities over site)
- Correlation factors (depend on number of load tests/ground investigation and variation of results)

EN 1997-3 – Clause 6 – Piled Foundations (2)

- Pile bearing resistance verification by:
- Static load tests
 - Rapid Load test
 - Dynamic Impact tests (calibrated, comparable experience)
 - Wave Equation Analysis (restricted)
 - Pile Driving Formulae (restricted)
- Model factors are given for various methods.

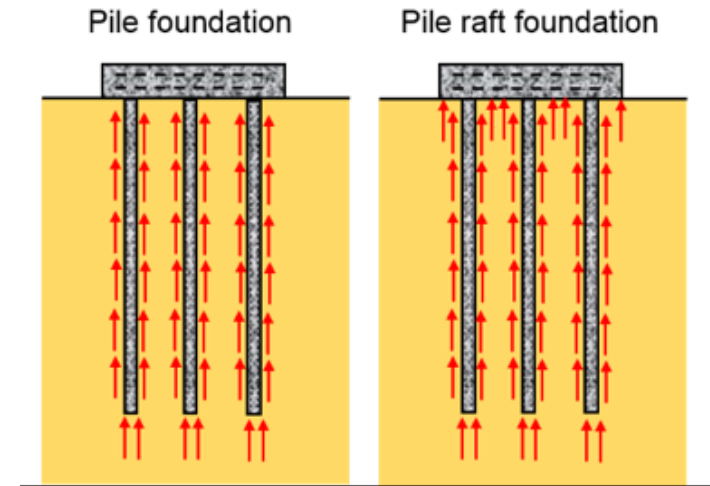


EN 1997-3 – Clause 6 – Piled Foundations (3)

→ Pile groups and piled rafts

→ ULS verification:

- Axially loaded: MFA and RFA
- Transverse loads: MFA



→ Annex: models for group bearing capacity – tension/compression

→ Annex: model for negative shaft friction

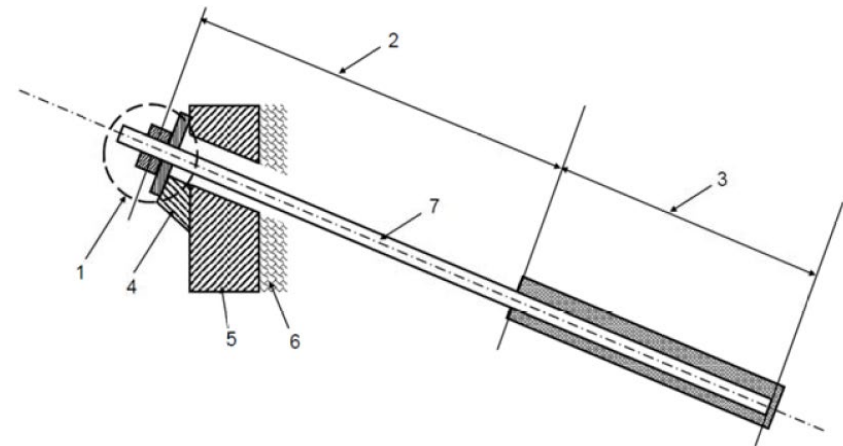
EN1997 – 3 - Clause 7 – Retaining structures

- Analytical (spring) and continuum models
- Maximum active and passive pressures
- Many failure mechanisms
- Material factoring MFA or:
- Resistance factoring RFA (Effect of actions)
- Observational Method!



EN 1997 – 3 – Clause 8 - Anchors

- Anchors with free length
- Design Based on testing or comparable experience
- 3 Types of tests:
 - Investigation test (failure)
 - Suitability test (on anchor in project)
 - Acceptance test (control test)
- Resistance factoring in design
- ULS-verification by testing!
- Steel strength → EN1993-5



EN 1997 – 3 – Clause 9 – Reinforced Fill



→ Reinforced Fill

- Reinforced fill
- Embankment bases
- Overbridging systems
- Veneer stability

→ Failure modes (RFA):

- Rupture of reinforcement
- Failure along fill/reinforcement interface
- Failure of connections

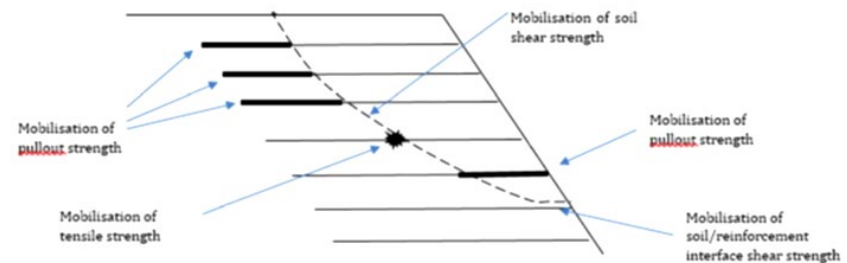


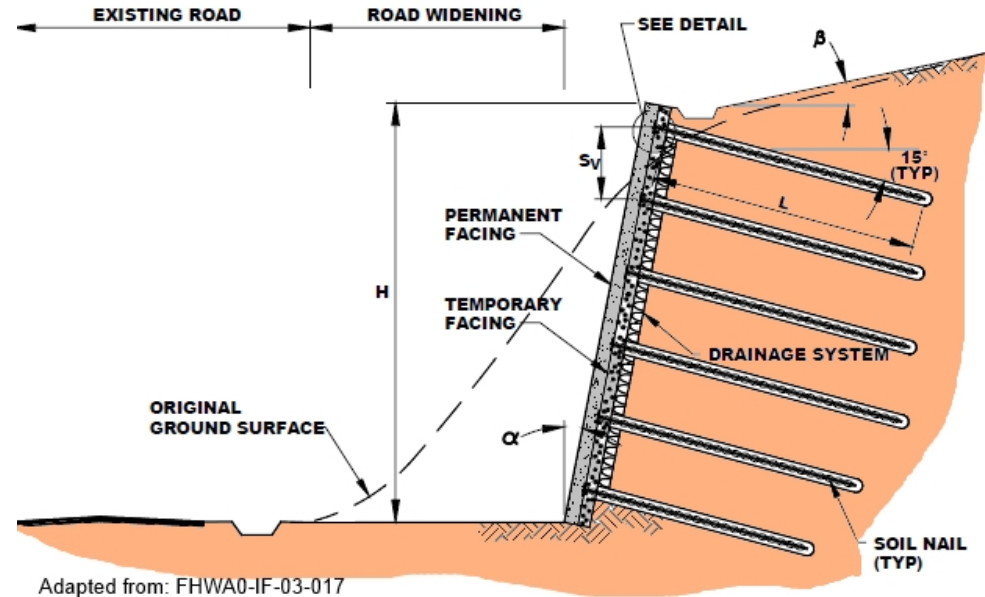
Figure F1: Soil/reinforcement interaction examples

EN 1997 – 3 – Clause 10 – Reinforcing elements

→ Clause 10 includes:

- rock bolts
- soil nails (see figure)
- sprayed concrete
- wire mesh
- facing elements.

→ ULS – Resistance factoring

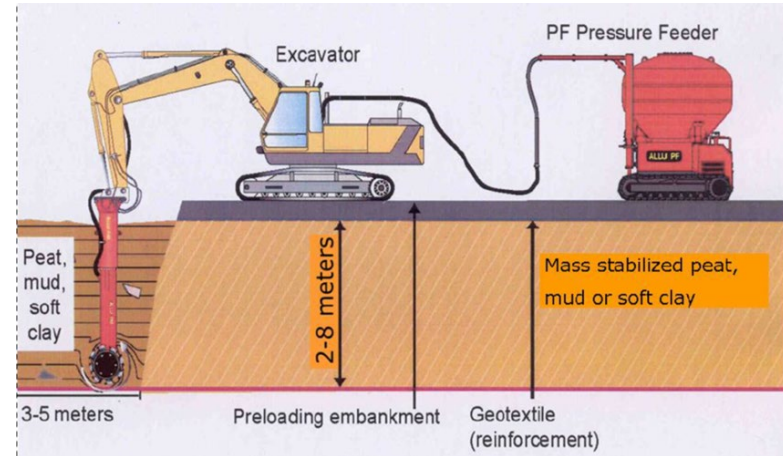


Adapted from: FHWA0-IF-03-017

EN 1997-3 – Clause 11 – Ground Improvement

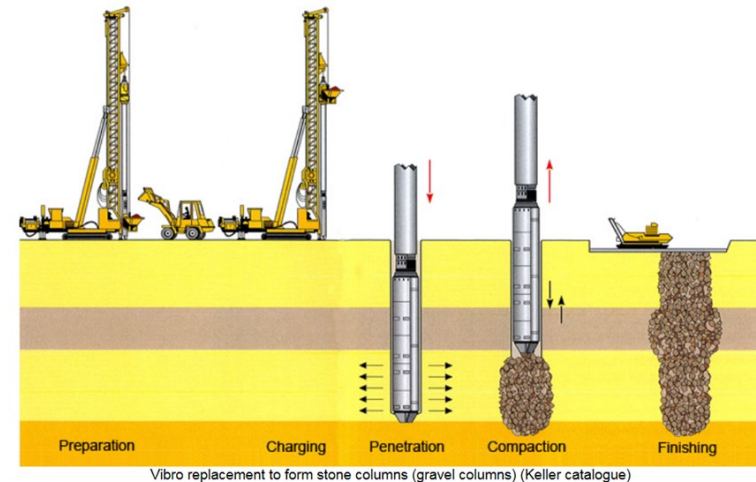
→ Diffused methods:

- compaction
- replacement
- grouting
- deep mixing (figure)



→ Discrete methods:

- stone/sand columns (figure)
- jetgrouting
- deep mixing
- steel/concrete columns

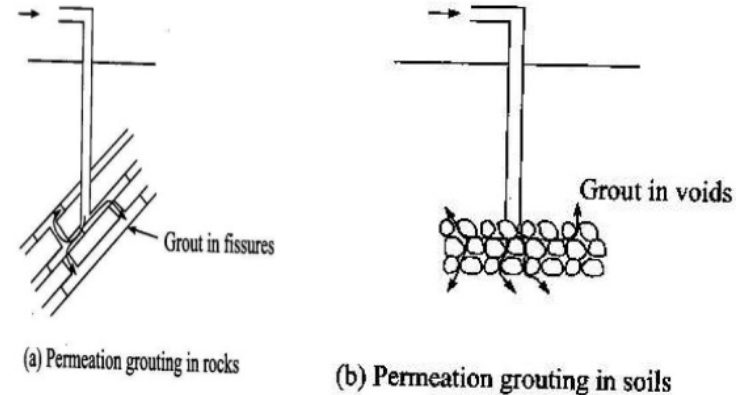


EN 1997 - 3 – Clause 12 – Groundwater control

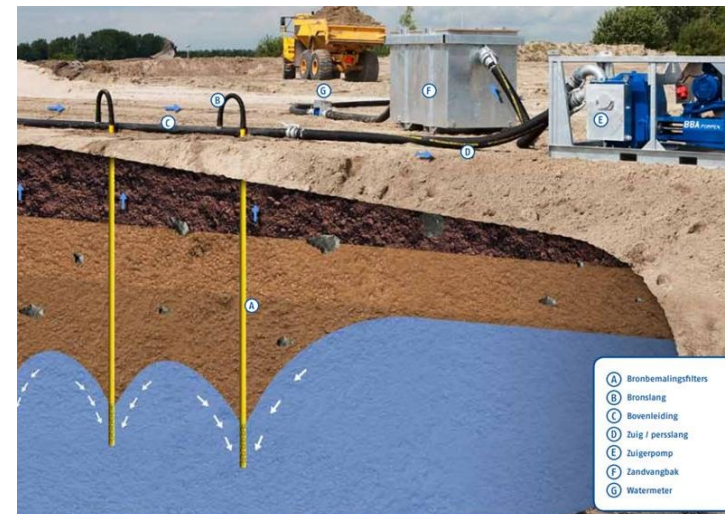
→ Groundwater control:

- Grouting
- Drainage systems and pumping
- Vertical barriers

Permeation Grouting



→ For hydraulic conductivity check: Serviceability Limit State governs!





Thank you

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Issue 1
Date: 01.11.2020

Photo: Frank Jansen (2018)