Basis of design – EN 1990 and EN 1997-1 General Rules

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Outline of talk

Overview

Design requirements

Limit states

Actions and design situations

Geotechnical design

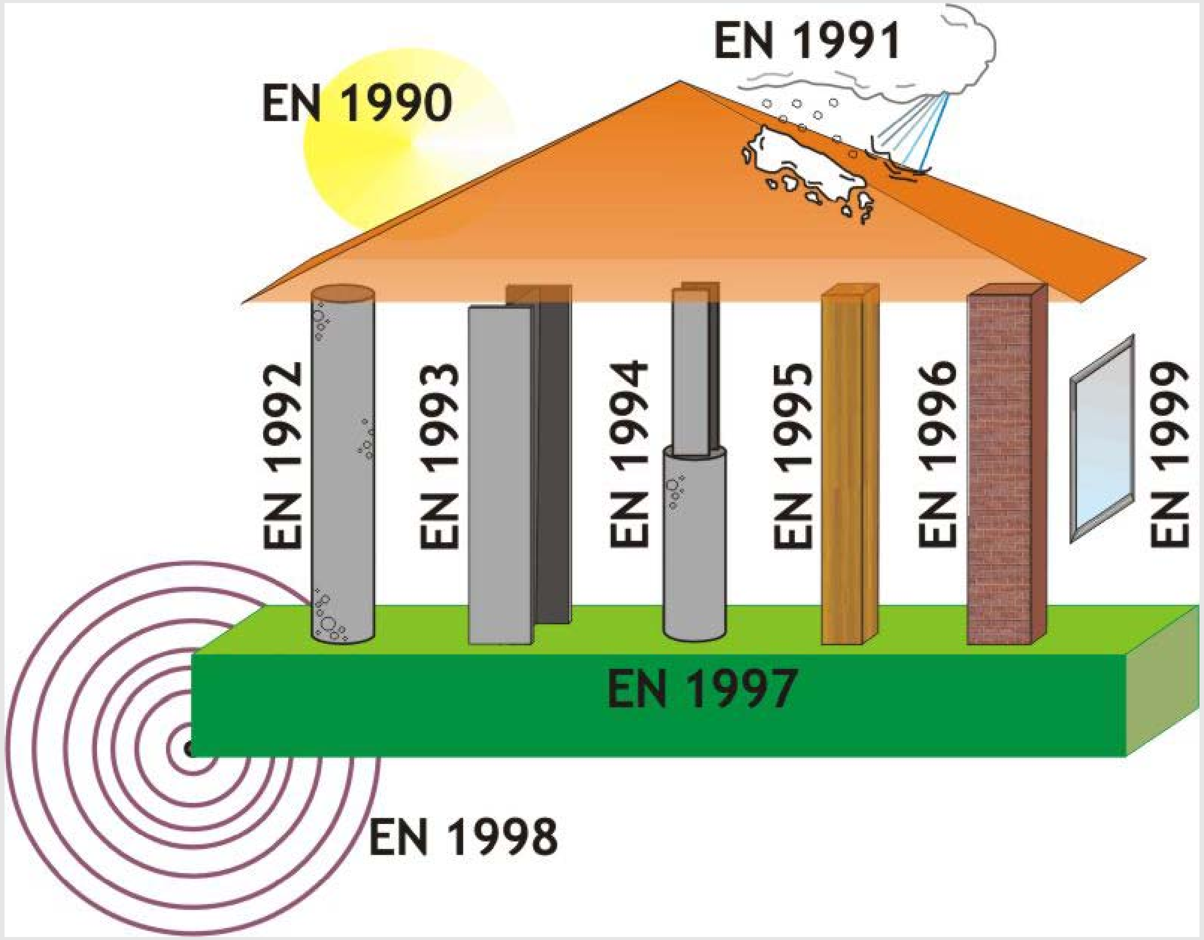
Parameters for design

Supervision, monitoring, and maintenance

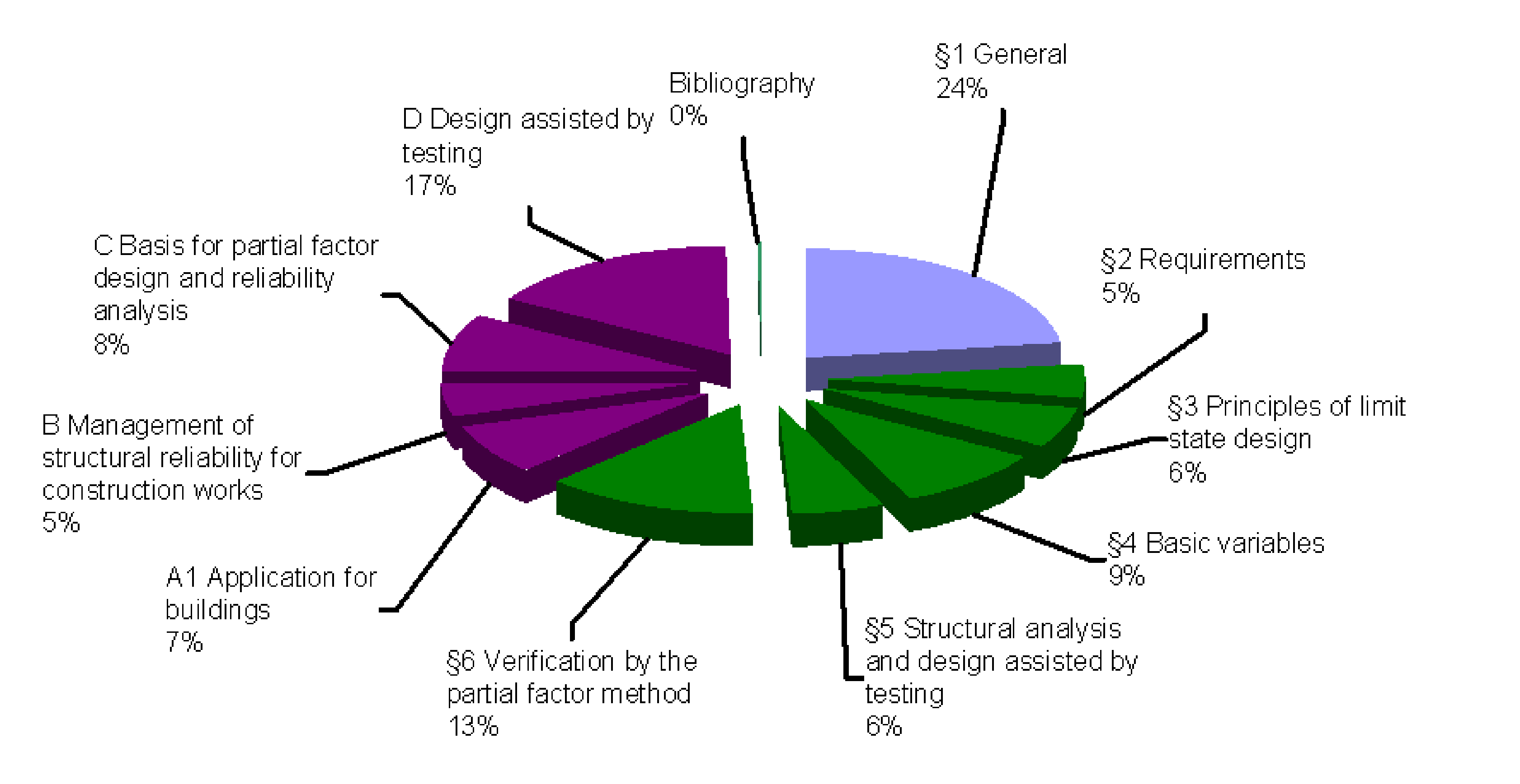
Summary of key points

Basis of design –
EN 1990 and EN 1997-1 General Rules
OVERVIEW

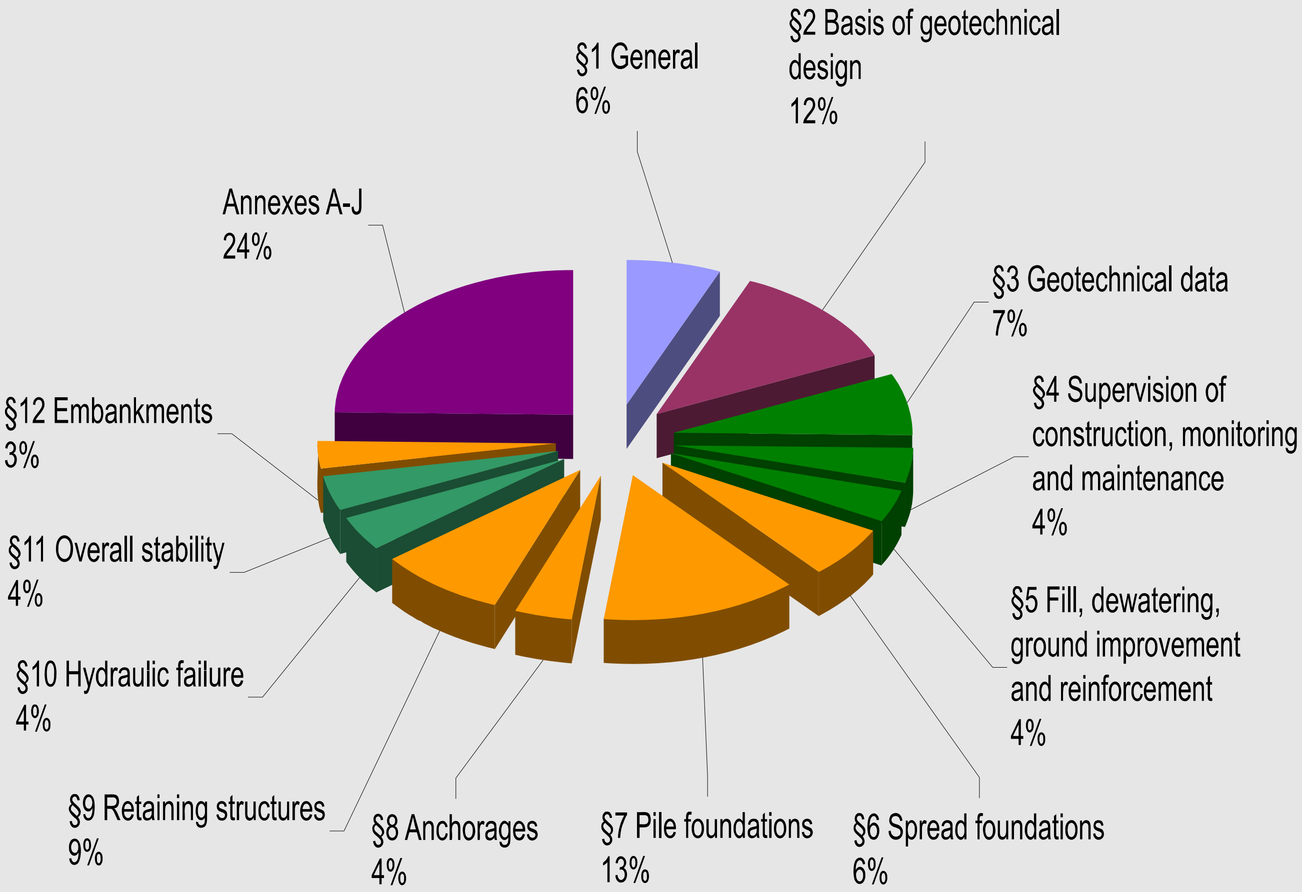
The Eurocode family (Bond and Harris, 2008)



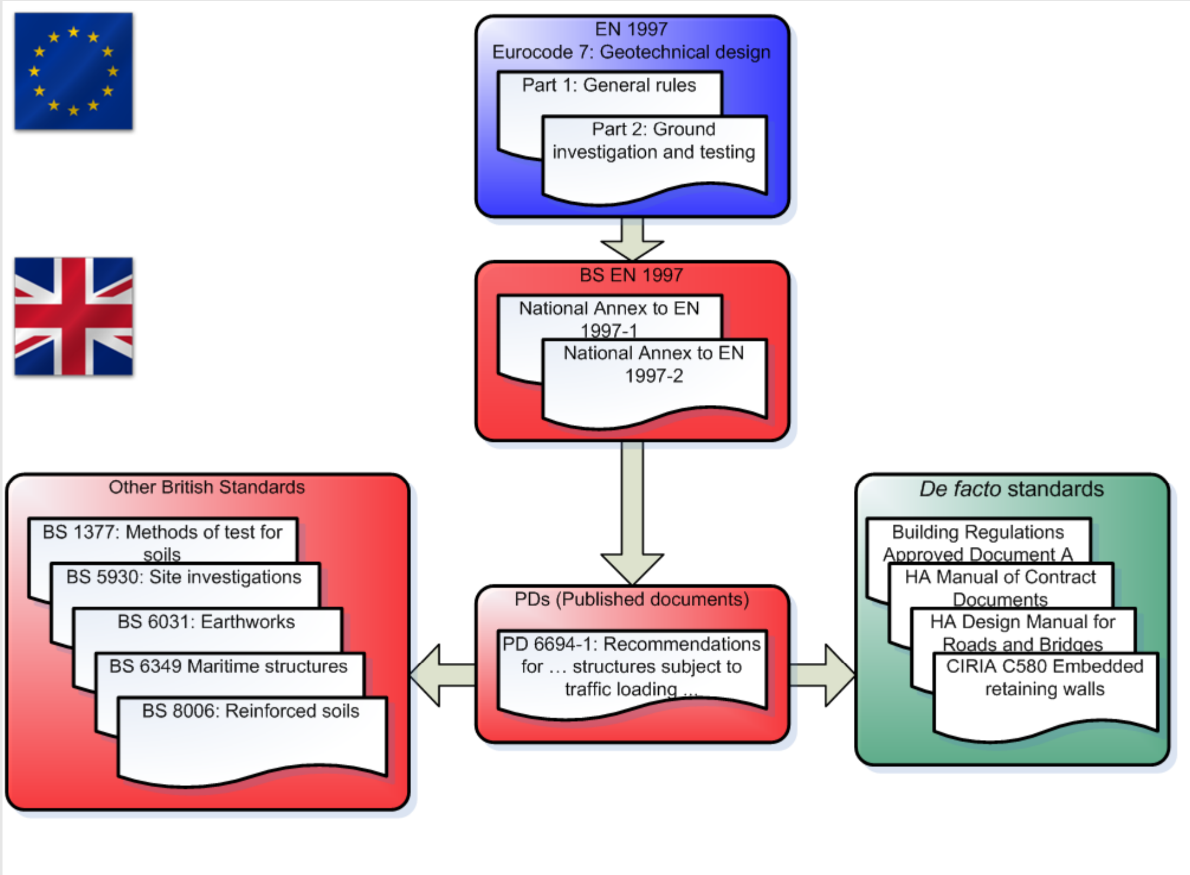
EN 1990: Basis of structural design (Bond & Harris, 2008)



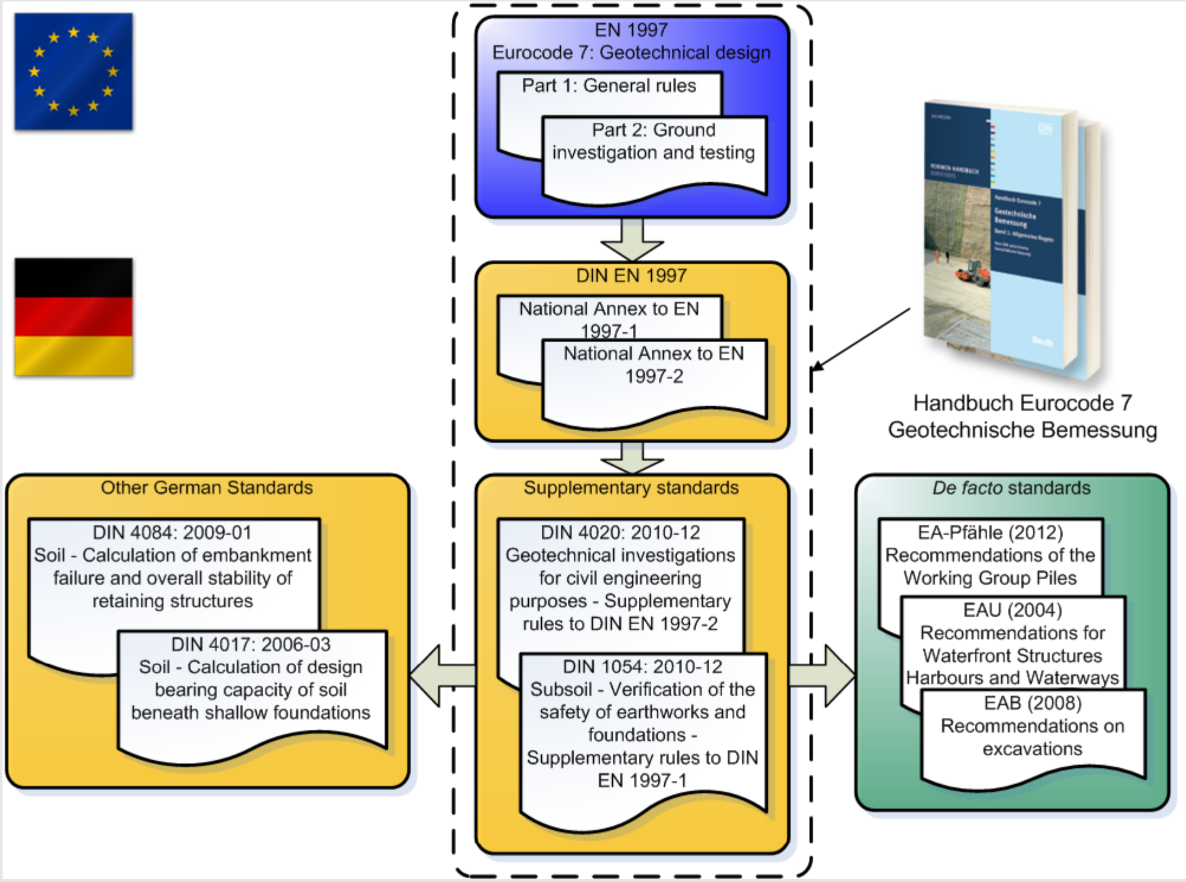
EN 1997-1: General rules (Bond & Harris, 2008)



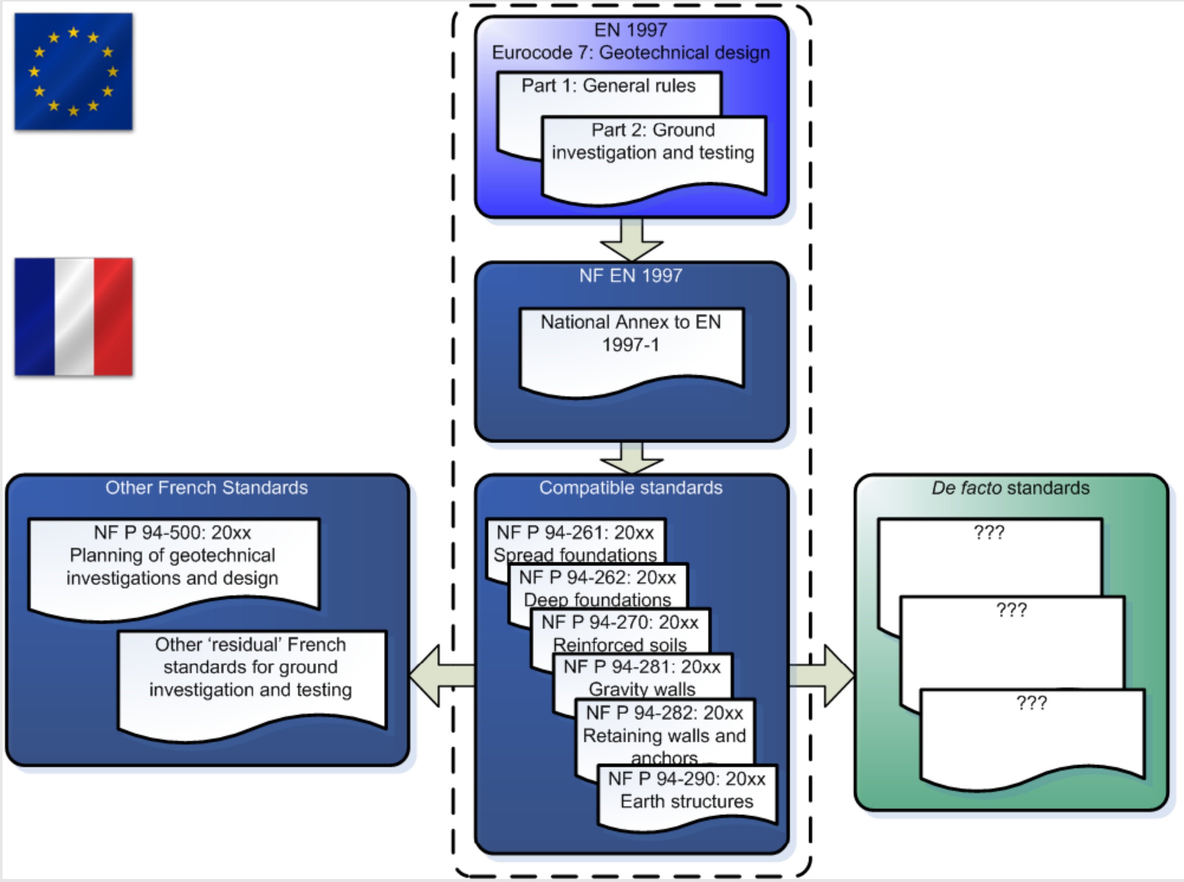
Role of Eurocode 7 in UK practice (after Bond & Harris, 2008)



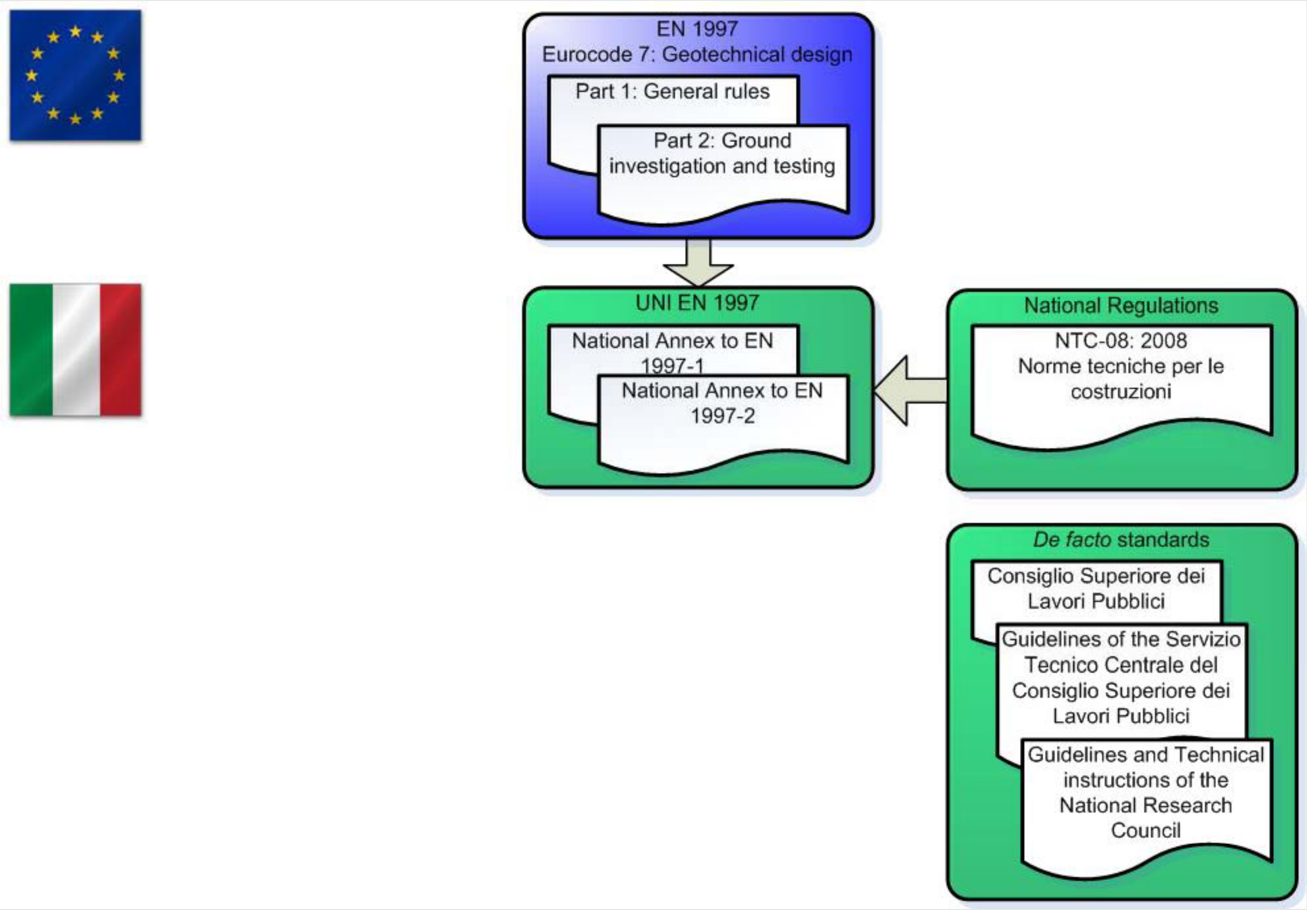
Role of Eurocode 7 in German practice



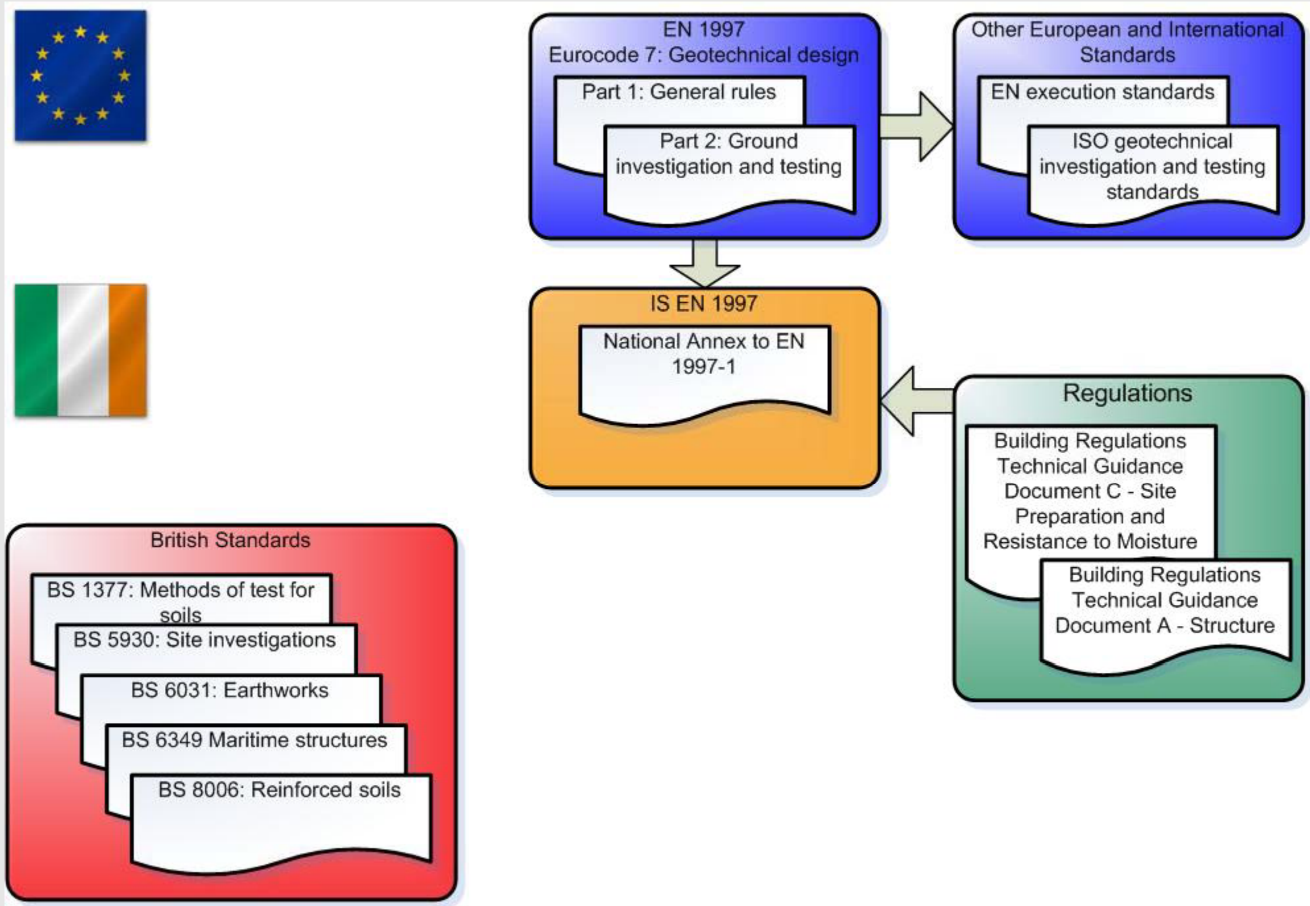
Role of Eurocode 7 in French practice



Role of Eurocode 7 in Italian practice



Role of Eurocode 7 in Irish practice



"Designers' Guide to EN 1997-1" by Frank et al (2004)

Book published 2004

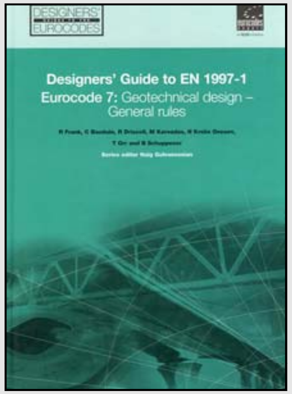
Key features

- Detailed guide to new geotechnical design Eurocode
- Describes and explains many unique features of ground engineering
- Comprehensive checklists of aspects to be considered in design

Authors: Roger Frank, Christophe Bauduin, Richard Driscoll, Mike Kavvadas, Neils Krebs Ovesen, Trevor Orr, and Bernd Schuppener

Published by Thomas Telford in hardback

ISBN: 07277-3154-8

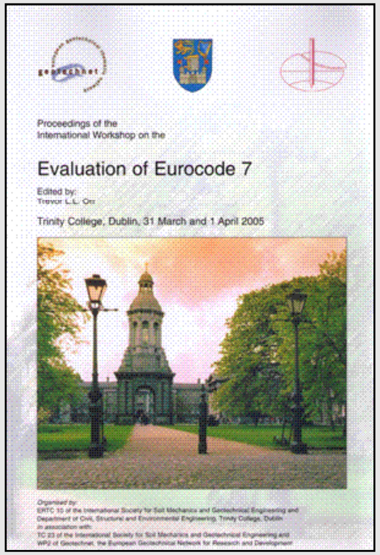


ETC 10 International Workshop in Dublin (2005)

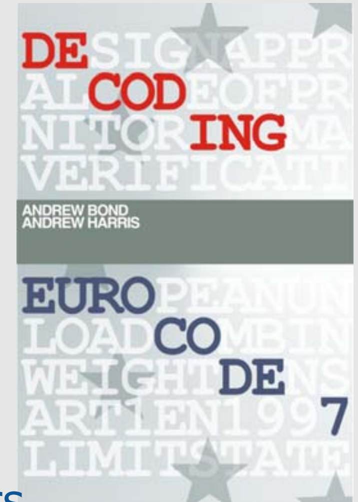
10 examples presented

- Pad foundation with vertical central load
- Pad foundation with inclined eccentric load
- Pile foundation designed from soil parameter values
- Pile foundation designed from pile load tests
- Cantilever gravity retaining wall
- Embedded retaining wall
- Anchored retaining wall
- Uplift of deep basement
- Failure by hydraulic heave
- Road embankment on soft clay

www.tcd.ie/civileng/pdf/Eurocode 7.pdf



“Decoding Eurocode 7” by Bond and Harris (2008)



- Book published August 2008
- Key features
  - Covers ENs 1997-1 and -2
  - Plus relevant parts of other Eurocodes
  - Also covers associated execution and testing standards
  - Explains key principles
  - Illustrates application rules with real-life case studies
  - Material extensively tested on training courses over 5 years
- Authors Andrew Bond (Geocentrix) and Andy Harris (ex-Geomantix)
- Published by Taylor and Francis in hardback, with colour section
- ISBN: 9780415409483
- www.decodingeurocode 7.com

‘EC7 for geo. design – a model code for non-EU countries?’

Paper published at 17th Int. Conf. On Soil Mechanics and Geotechnical Engineering, October 2009

Subjects covered

- Eurocode 7Geotechnical design’
- Applicability of Eurocode 7 Part 1: design examples from the 2005 Dublin Workshop
- ‘Comments of non-European countries

Authors:

- B. Schuppener
- A.J. Bond
- R. Frank
- T.L.L. Orrr
- G. Scarpelli
- B. Simpson


Eurocode 7 for geotechnical design – a model code for non-EU countries?
L'Eurocode 7 pour le calcul géotechnique – un code modèle pour les pays non Européens?

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A. J. Bond
P. Day
R. Frank
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B. Simpson

ABSTRACT

RÉSUMÉ

Modern geotechnical design codes of practice (2013)

International Workshop on *Safety Concepts and Calibration of Partial Factors in European and North American Codes of Practice*, Delft University in December 2011

Book includes several papers devoted to Eurocode 7:

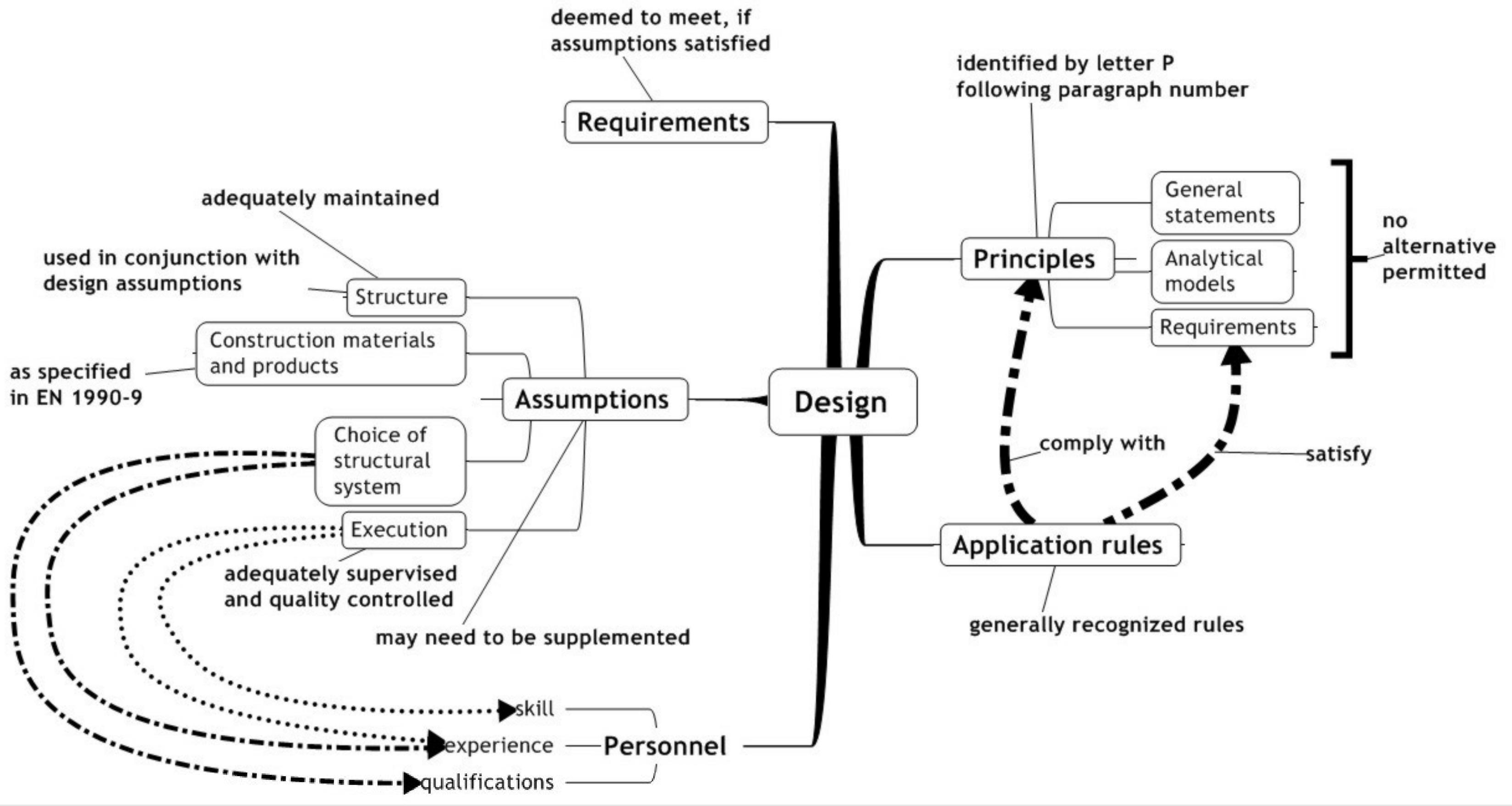
- *Implementation and evolution of Eurocode 7* by Andrew Bond
- *Implementation of Eurocode 7 in German geotechnical design practice* by Kerstin Lesny
- *Implementation of Eurocode 7 in French practice by means of national additional standards* by Jean-Pierre Magnan and Sébastien Burlon
- *Implementing Eurocode 7 to achieve reliable geotechnical designs* by Trevor Orr
- *The safety concept in German design codes* by Bernd Schuppener
- *British choices of geotechnical design approach and partial factors for EC7* by Brian Simpson
- *Dutch approach to geotechnical design by Eurocode 7, based on probabalistic analyses* by Ton Vrouwenvelder, Adriaan va Seter, and Geerhard Hanni

Basis of design –

EN 1990 and EN 1997-1 General Rules

DESIGN REQUIREMENTS

Eurocode design (Bond & Harris, 2008)



Complexity of design

"In order to establish minimum requirements for the extent and content of geotechnical investigations, calculations and construction control checks, the complexity of each geotechnical design shall be identified together with associated risks"

EN 1997-1 §2.1(8)P

"… a distinction shall be made between light and simple structures and small earthworks for which … the minimum requirements will be satisfied by experience and qualitative geotechnical investigations, with negligible risk; [and] other geotechnical structures"

EN 1997-1 §2.1(8)P continued

"For structures and earthworks of low geotechnical complexity and risk, such as defined above, simplified design procedures may be applied"

EN 1997-1 §2.1(9)

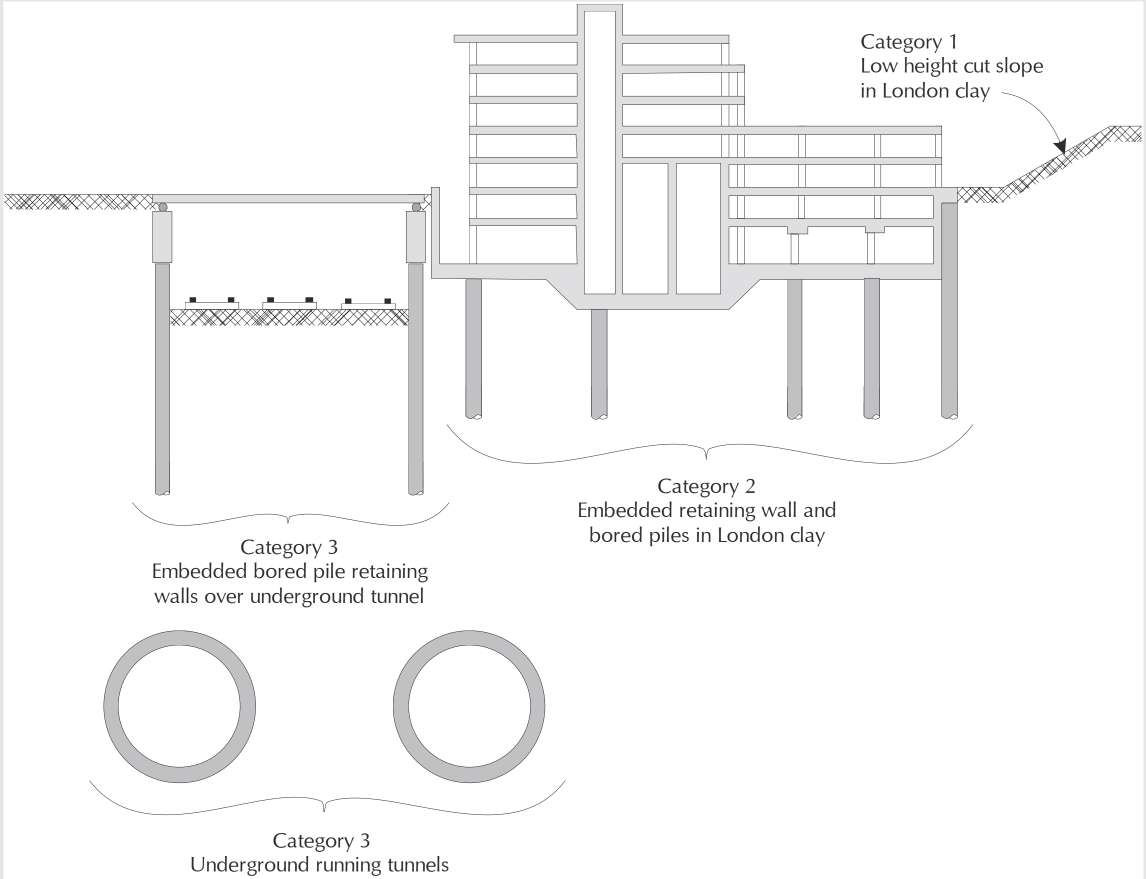
Geotechnical categories

GC	Includes…	Design requirements	Design procedure
1	Small and relatively simple structures… with negligible risk	Negligible risk of instability or ground movements Ground conditions known to be straightforward No excavation below water table (or such excavation is straightforward)	Routine design & construction methods
2	Conventional types of structure & foundation with no exceptional risk or difficult soil or loading conditions	Quantitative geotechnical data & analysis to ensure fundamental requirements are satisfied	Routine field & lab testing Routine design & execution
3	Structures or parts of structures not covered above	Include alternative provisions and rules to those in Eurocode 7	

Examples of structures in Geotechnical Categories 2 and 3

GC	Risk	Examples
1	Negligible	None given in Eurocode 7
2	No exceptional	§2.1(19) Spread; raft; & pile foundations; walls & other structures retaining or supporting soil or water; excavations; bridge piers & abutments; embankments & earthworks; ground anchors & other tie-back systems; and tunnels in hard, non-fractured rock and not subjected to special water tightness or other requirements.
3	Exceptional	§2.1(21) Very large or unusual structures; structures involving abnormal risks, or unusual or exceptionally difficult ground or loading conditions; structures in highly seismic areas; and structures in areas of probable site instability or persistent ground movements that require separate investigation or special measures

Example Geotechnical Categories (Bond & Harris, 2008)



Basis of design –

EN 1990 and EN 1997-1 General Rules

ACTIONS AND DESIGN SITUATIONS

Design situations from basis of design

Design situations are:

"sets of physical conditions representing the real conditions occurring during a certain time interval for which the design will demonstrate that relevant limit states are not exceeded"

EN 1990 §1.5.2.2

Persistent (conditions of normal use)

Period = same order as design working life (DWL) of structure

Transient (temporary conditions, e.g. execution or repair)

Period << DWL and high probability of occurrence

Accidental (exceptional conditions)

e.g. fire, explosion, impact, local failure

Seismic (exceptional conditions during earthquake)

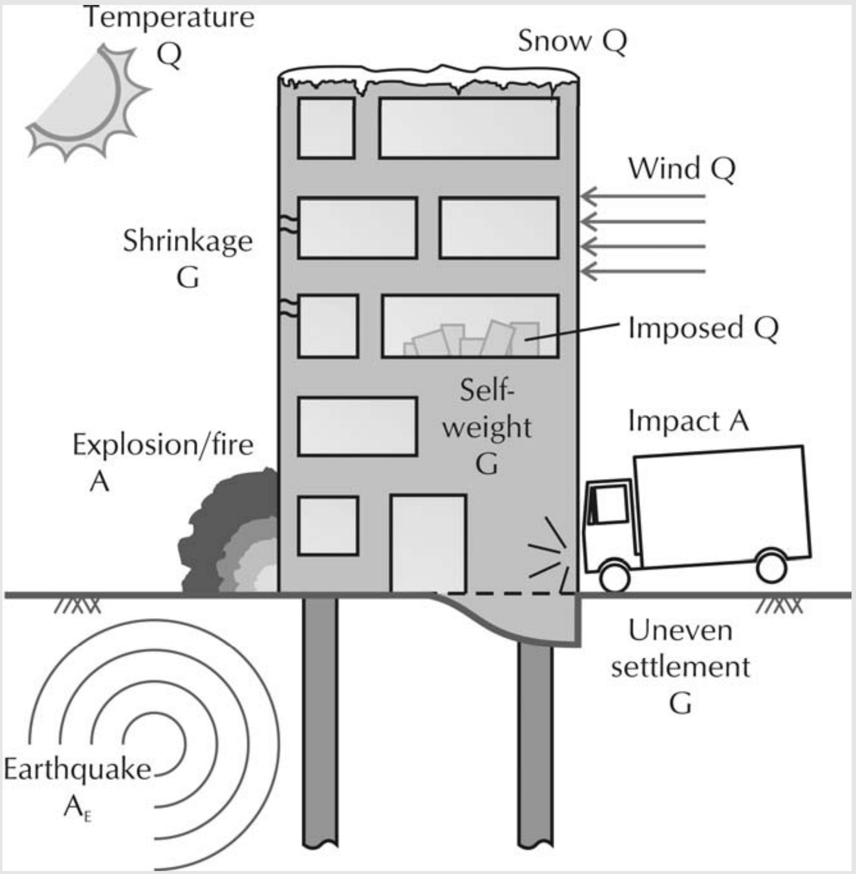
Actions according to EN 1990: Basis of design

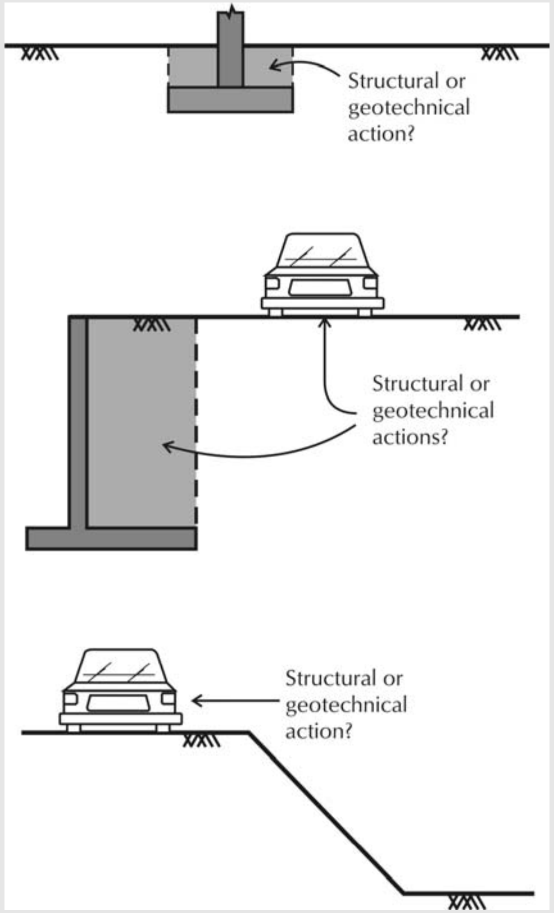
Action		Duration	Variation w/ time	Examples
Permanent	G	Likely to act throughout reference period	Negligible or monotonic	Self-weight of structures, fixed equipment and road-surfacing; indirect actions§ caused by shrinkage and uneven settlements
Variable	Q		Neither negligible nor monotonic	Imposed loads on building floors, beams and roofs; wind*; snow*
Accidental	A	Usually short	Significant magnitude	Explosions, vehicle impact*, seismic* (AE, due to earthquake ground motions)

*may be variable or accidental depending on statistical distribution

§may be permanent or variable

Structural and geotechnical actions (Bond & Harris, 2008)





Basis of design

LIMIT STATES

Key design requirement

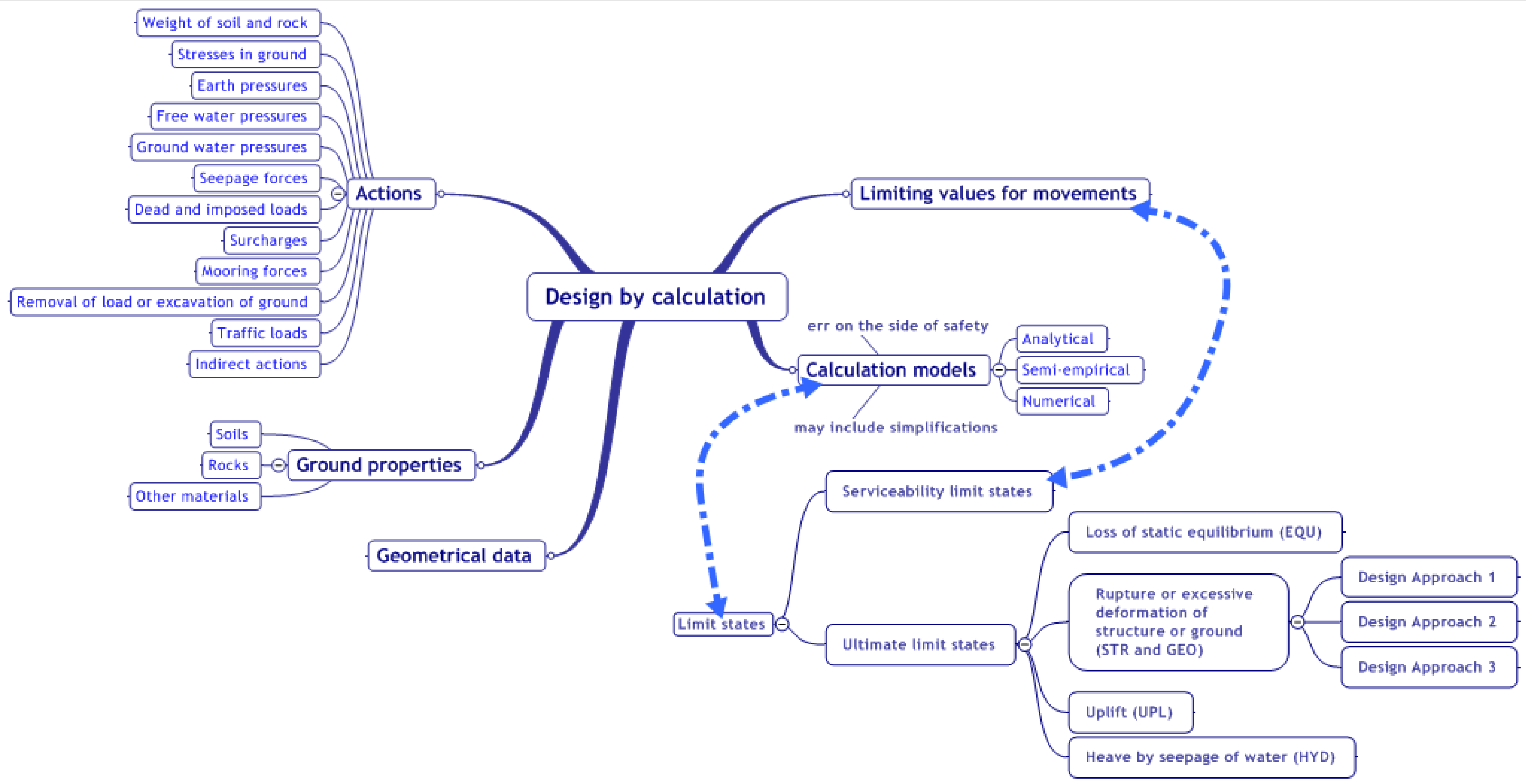
"For each geotechnical design situation it shall be verified that no relevant limit state … is exceeded"

EN 1997-1 §2.1(1)P

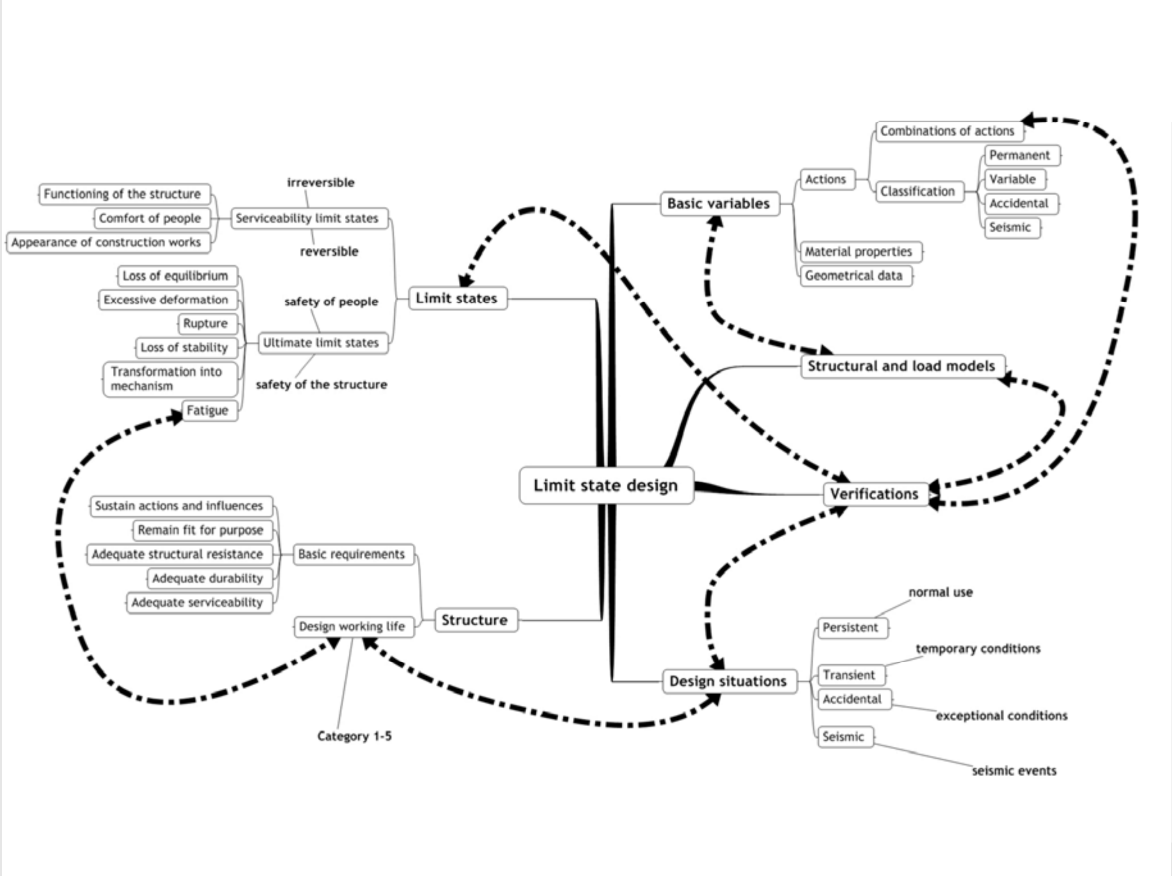
Limit states should be verified by one or a combination of…

- Use of calculations
- Adoption of prescriptive measures
- Experimental models and load tests
- An observational method

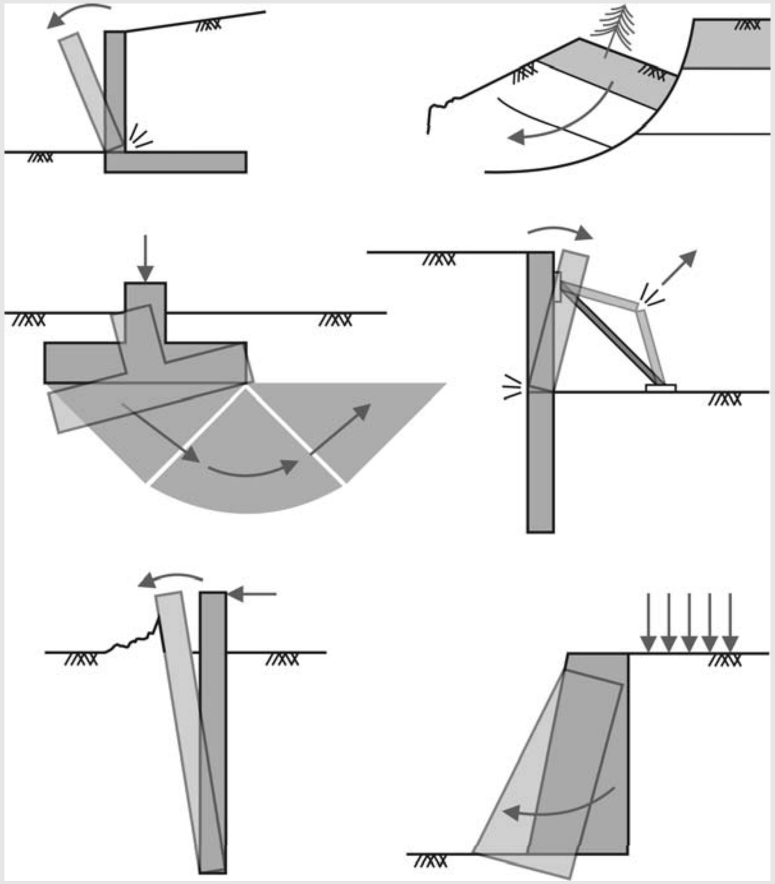
Design by calculation (Bond & Harris, 2008)



Overview of limit state design (Bond & Harris, 2008)



Ultimate limit states for strength: STR / GEO (Bond & Harris, 2008)



Verification of strength

Verification of strength is expressed in Eurocode 7 by:

$$E_d \leq R_d$$

E_d = design effect of actions; R_d = corresponding design resistance

GEO: 'Failure or excessive deformation of the ground, in which the <u>strength of soil or rock is significant</u> in providing resistance'
EN 1997-1 §2.4.7.1(1)P

STR: 'Internal failure or excessive deformation of the structure or structural elements … in which the <u>strength of structural materials is significant</u> in providing resistance"
EN 1997-1 §2.4.7.1(1)P

'Degree of utilization' vs 'overdesign factor'

Bond and Harris (2008) recommend using the ratio of the design effect of actions to the corresponding resistance to verify strength:

$$\Lambda_{GEO} = \frac{E_d}{R_d} \leq 100\%$$

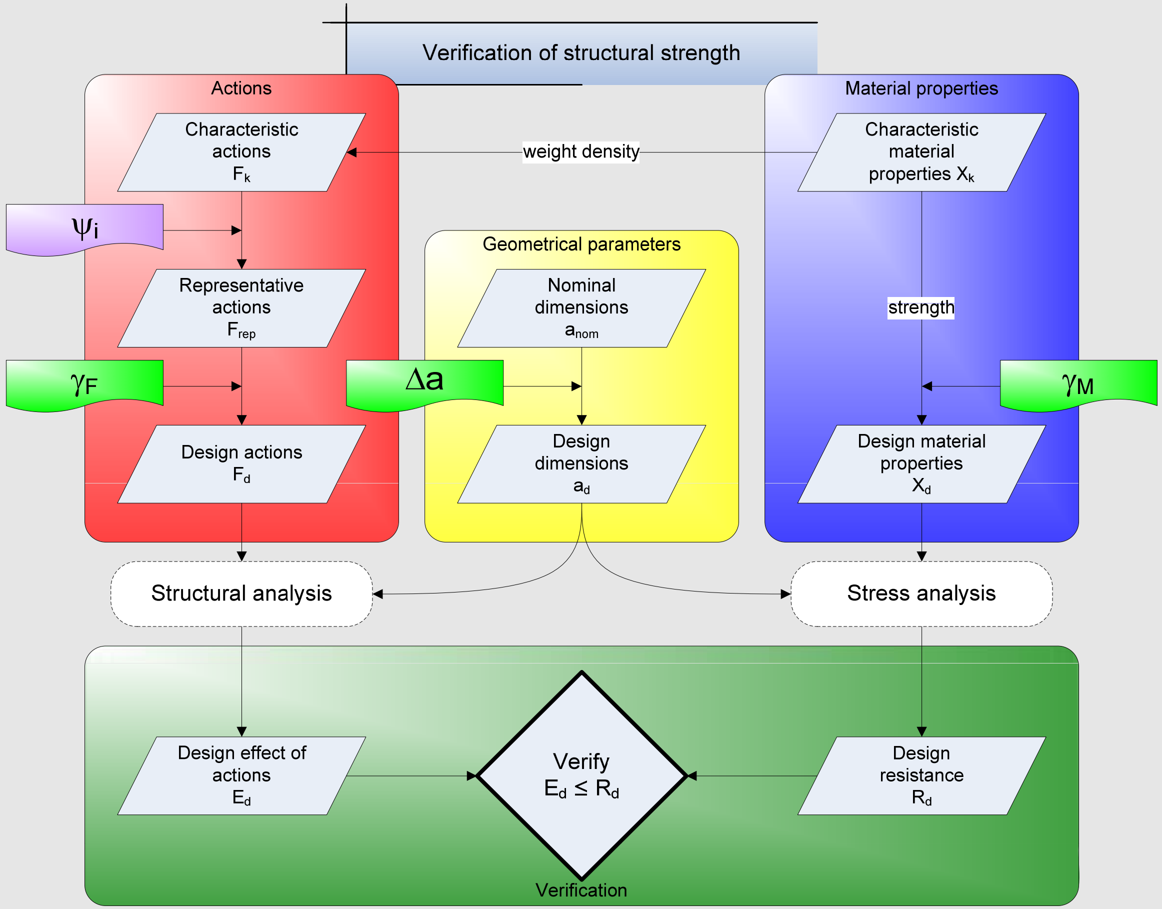
Λ = 'degree of utilization'

Frank et. al. (2004) define the ratio of the design resistance to the corresponding design effect of actions:

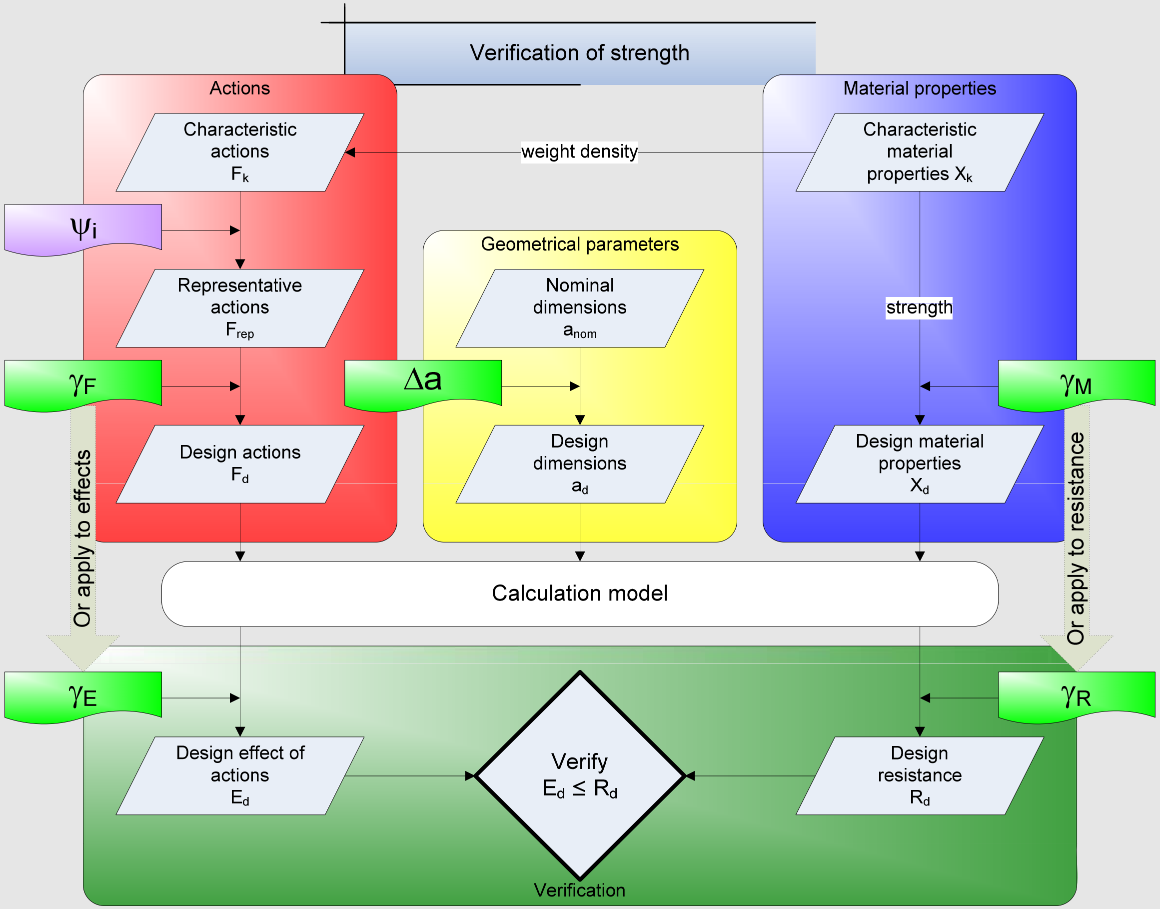
$$ODF = \frac{R_d}{E_d} \geq 1.0$$

ODF = 'overdesign factor' = $1/\Lambda$

Verification of strength for STR in structural design (Bond and Harris, 2008)



Verification of strength for STR/GEO in geotechnical design (Bond & Harris, 2008)



Design Approaches for STR / GEO

"The manner in which equations [for GEO/STR] are applied shall be determined using one of three Design Approaches

Design Approaches apply ONLY to STR and GEO limit states

Each nation can choose which one (or more) to allow"

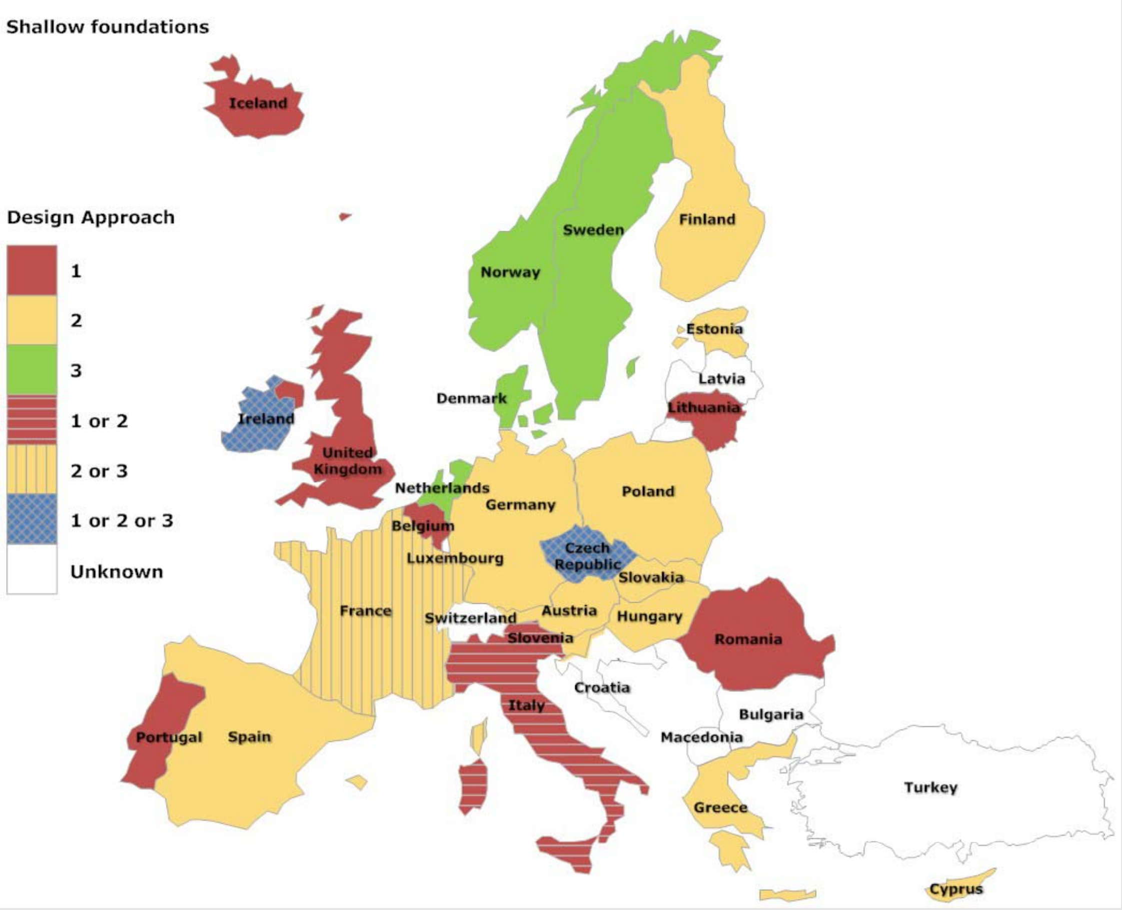
EN 1997-1 §2.4.7.3.4.1(1)P

Design Approaches explained

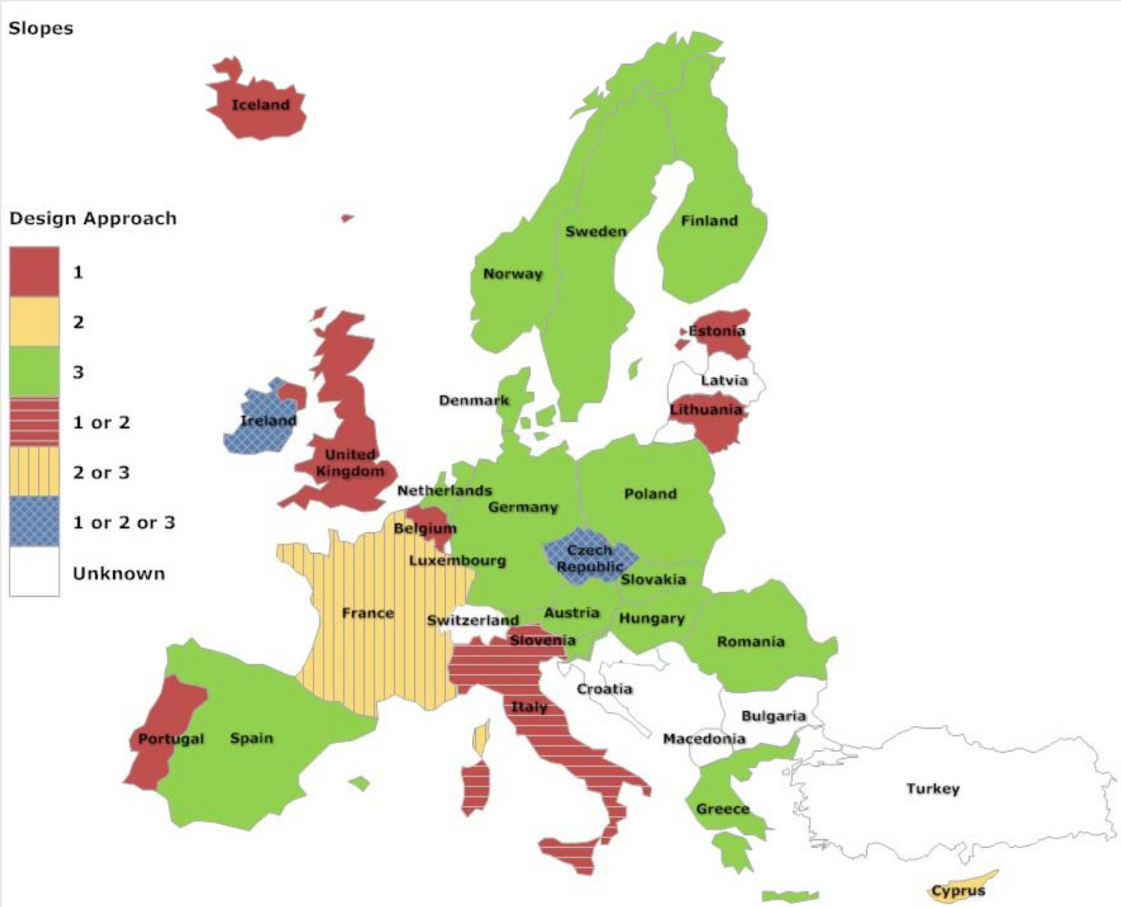
Design Approach			
1		2	3
Combination 1	Combination 2		
Actions	Material properties	Actions/effects & resistances	Structural actions/effects & material properties
A1 + M1 + R1	A2 + M2 + R1	A1 + M1 + R2	A1/A2 + M2 + R3

(Major) factors >> 1.0; (minor) factors > 1.0
A1-A2 = factors on actions/effects
M1-M2 = factors on material properties
R1-R3 = factors on resistances

National choice of Design Approach for shallow foundations (Bond, 2013)



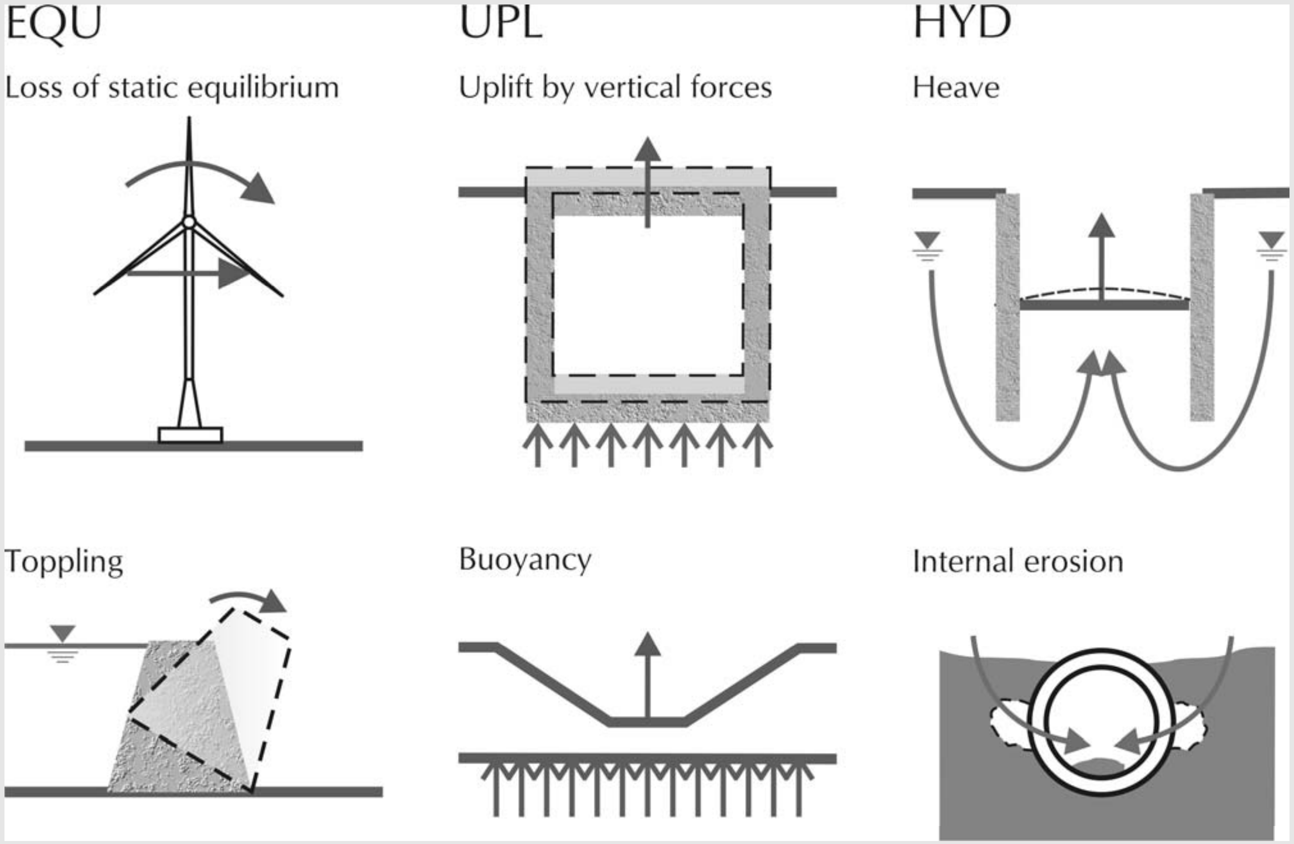
National choice of Design Approach for slopes (Bond, 2013)



Partial factors for limit states GEO / STR

Parameter		Sym-bol	Action factors		Material factors		Resistance factors			
			A1	A2	M1	M2	R1	R2	R3	R4
Permanent action (G)	Unfavourable	γ_G	1.35	1.0						
	Favourable	$(\gamma_{G,fav})$	1.0							
Variable action (Q)	Unfavourable	γ_Q	1.5	1.3						
	Favourable	-	(0)	(0)						
Shearing resistance (tan φ)		γ_φ			1.0	1.25				
Effective cohesion (c′)		γ_c								
Undrained shear strength (c_u)		γ_{cu}				1.4				
Unconfined compressive strength (q_u)		γ_{qu}								
Weight density (γ)		γ_γ				1.0				
Bearing resistance (R_v)		γ_{Rv}					1.0	1.4	1.0	(1.0)
Sliding resistance (R_h)		γ_{Rh}						1.1		
Earth resistance (R_e)	Walls	γ_{Re}						1.4		
	Slopes							1.1		
Pile resistance							See separate table			
Factors given for persistent and transient design situations										

Ultimate limit states for stability: EQU / UPL / HYD (Bond & Harris, 2008)



Limit state EQU (EN 1997-1 version)

Ultimate limit state EQU is defined as

"Loss of equilibrium of the structure or the ground considered as a rigid body, in which the strengths of structural materials and the ground are insignificant in providing resistance"

EN 1997-1 §2.4.7.1(1)P

Verification of static equilibrium

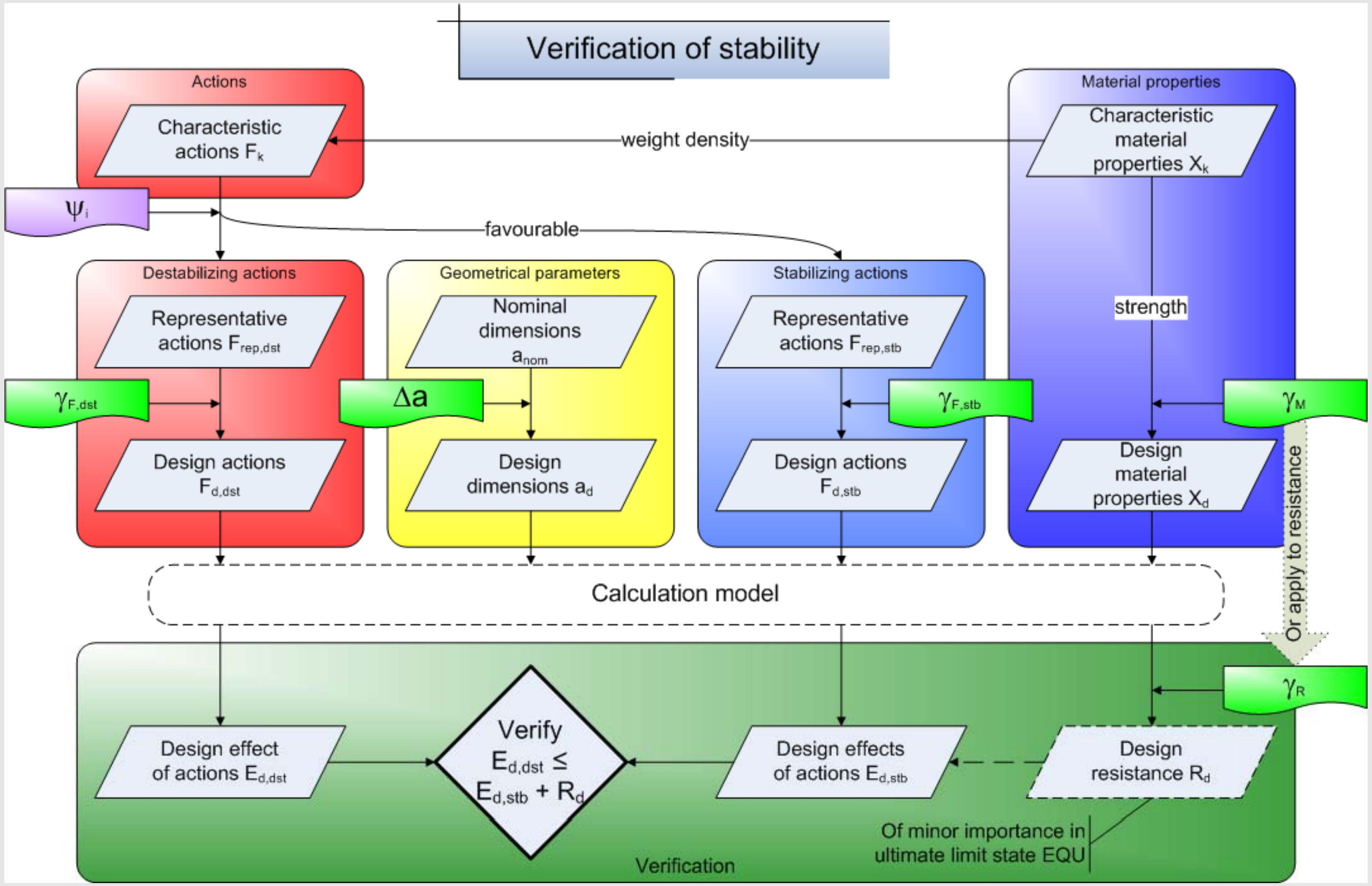
$$E_{dst;d} \leq E_{stb;d} + T_d$$

$E_{xxx;d}$ = effects of actions (here, overturning moments)

Subscripts 'dst' and 'stb' signify de-stabilising and stabilising

T_d = total shearing resistance that develops around the part of the structure in contact with the ground

Verification of stability for EQU (Bond & Harris, 2008)

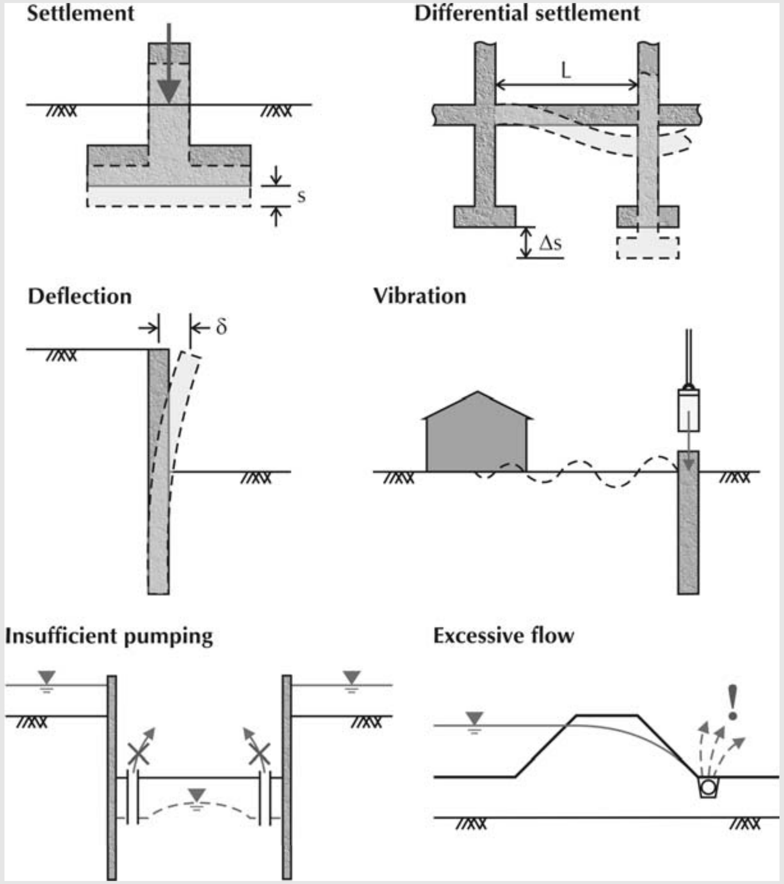


Partial factors for limit state EQU for buildings

Parameter		Symbol	Partial factors on...		
			Actions	Material properties	Resistances
Permanent action (G)	Unfavourable	$\gamma_{G,dst}$	1.1		
	Favourable	$\gamma_{G,stb}$	0.9		
Variable action (Q)	Unfavourable	$\gamma_{Q,dst}$	1.5		
	Favourable	-	0		
Coeff. of shearing resistance ($\tan \varphi$)		γ_{φ}		1.25 [1.1]	
Effective cohesion (c′)		γ_{c}			
Undrained shear strength (c_u)		γ_{cu}		1.4 [1.2]	
Unconfined compressive strength (q_u)		γ_{qu}			
Weight density (γ)		γ_{γ}		1.0	
All resistances (R)		γ_{R}			(1.0)

Values underlined provide safety (i.e. are ≠ 1.0)
Values in (rounds brackets) are not explicitly given in EN 1997-1 but can be inferred
Partial factors = 0 mean that the corresponding action is omitted from design calculations
Values in [square brackets] from NA to BS EN 1997-1

Serviceability limit states (Bond & Harris, 2008)



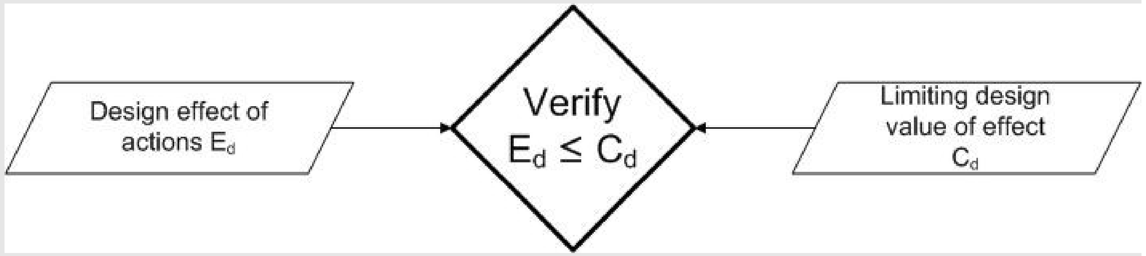
Verification of serviceability

Verification of serviceability is expressed in Eurocode 7 by:

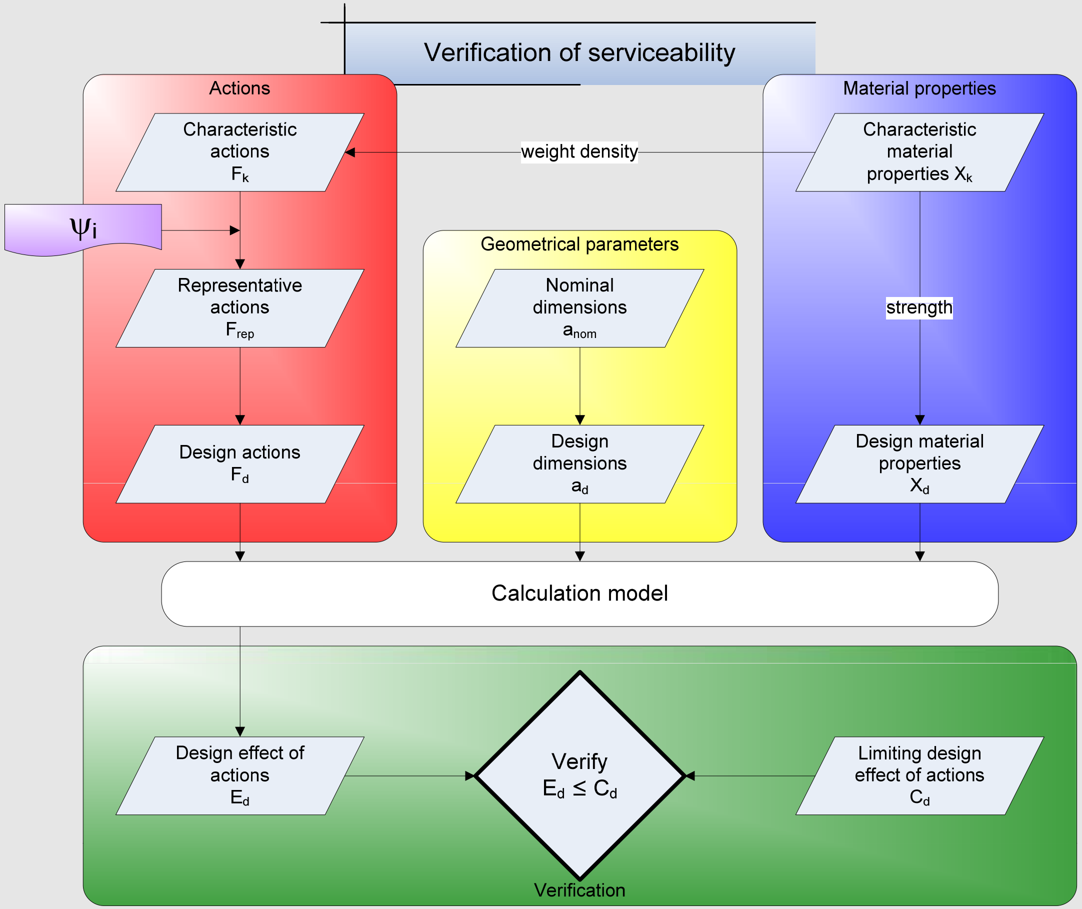
$$E_d \leq C_d$$

E_d = design effect of actions (e.g. displacement, distortion)
C_d = design constraint (i.e. limiting value of design effect)

"partial factors … should normally be taken equal to 1.0"
EN 1990 §2.4.8(2)



Verification of SLS (Bond & Harris, 2008)



Basis of design –

EN 1990 and EN 1997-1 General Rules

SUPERVISION, MONITORING, AND MAINTENANCE

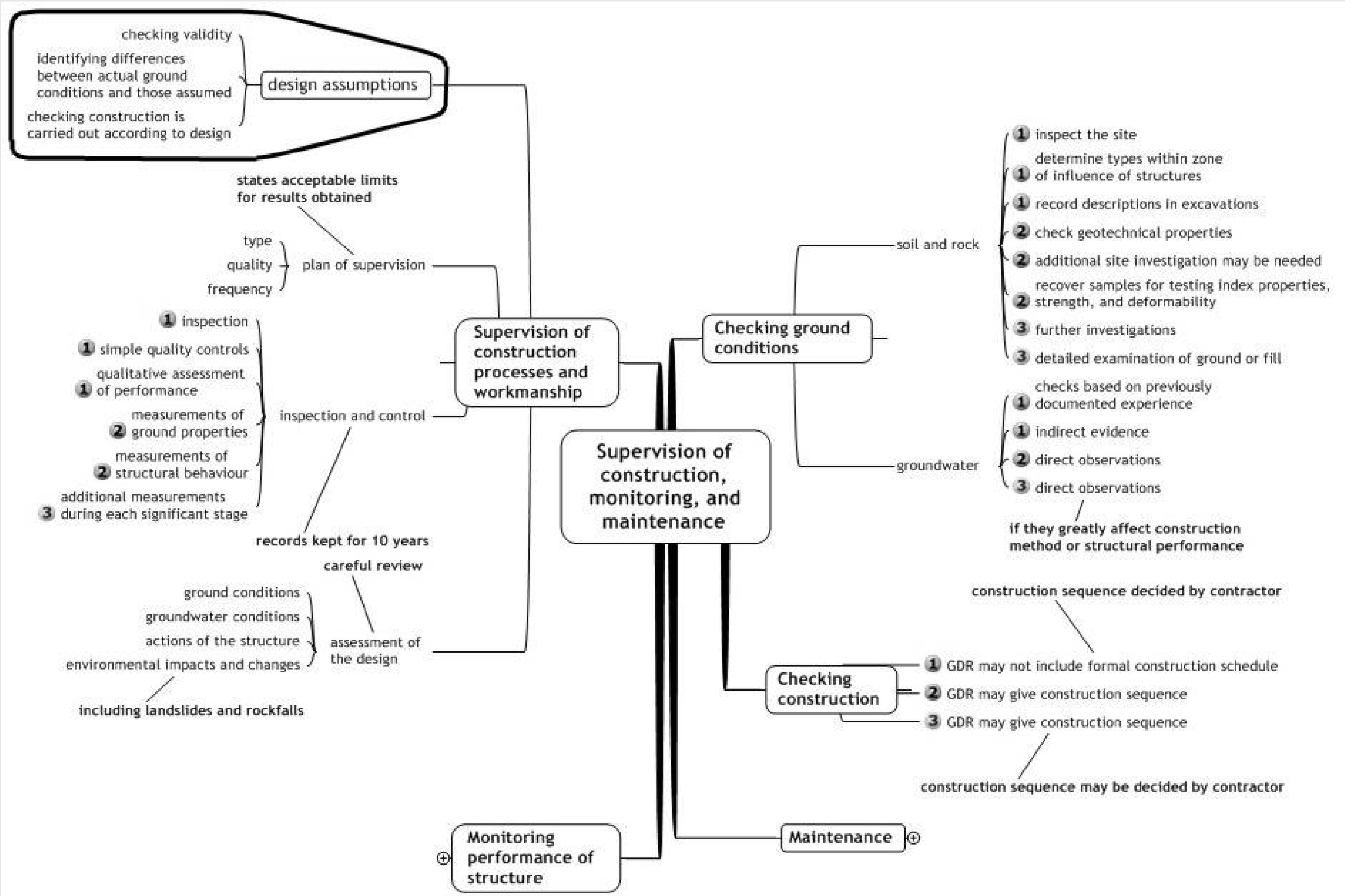
Requirement for supervision, monitoring, and maintenance

To ensure the safety and quality of a structure, the following shall be undertaken, as appropriate:

- the construction processes and workmanship shall be supervised
- the performance of the structure shall be monitored during and after construction
- the structure shall be adequately maintained

EN 1997-1 §4.1(1)P

Overview of supervision, monitoring, and maintenance (Bond & Harris, 2008)



Basis of design –

EN 1990 and EN 1997-1 General Rules

SUMMARY OF KEY POINTS

Summary of key points

Design requirements:

- Complexity of design
- Geotechnical Categories (GC1-3)

Geotechnical design by...

- Prescriptive measures
- Calculation
- Observation or testing

Limit states

- Overall stability
- Ultimate limit states (GEO, STR, EQU, UPL, and HYD)
- Serviceability limit states

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