# Past, present, and future of Eurocode 7

Dr Andrew Bond
Geocentrix Ltd
Chairman TC250/SC7

## Outline of lecture

1. Past: 1971-2010
2. Present: 2010-2015
   Intermission
3. (continued)
4. Future: 2015 and beyond
5. Summary and conclusion

## Past: 1971-2010

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## Harmonization of technical specifications

In 1975, the Commission of the European Community* (CEC) decided to create an action programme in the field of construction...

*"with the objective of promoting free trade between the member states by the elimination of technical obstacles and the harmonization of technical specifications"*

*At the time, the European Economic Community (EEC)

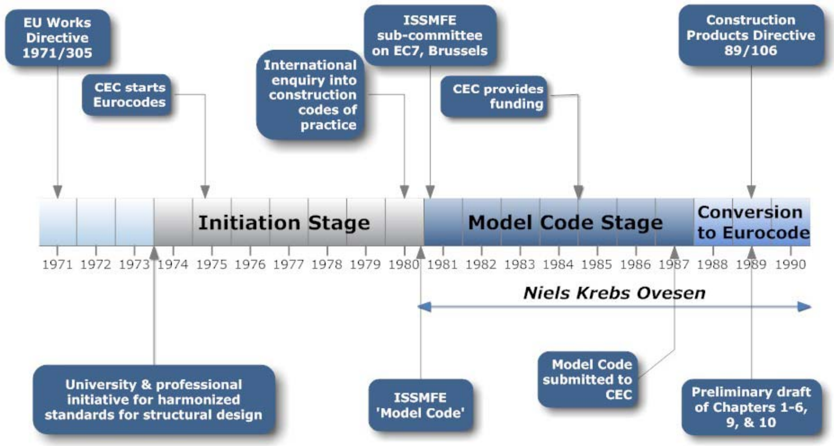
European Economic Community (aka 'Common Market') in 1974


## Stages in development of Eurocode 7

- 1974-1980: Initiation Stage
- 1981-1987: Model Code Stage
- 1988-1990: Conversion to Eurocode
- 1990-1994: ENV Stage
- 1994-1998: ENV Trial Stage
- 1998-2004: EN Stage
- 2005-2010: Implementation Stage

After Orr, T.L.L. (2008), *The Story of Eurocode 7, XIV European Conference on Soil Mechanics and Geotechnical Engineering*

# Eurocode 7 timeline 1971-1990

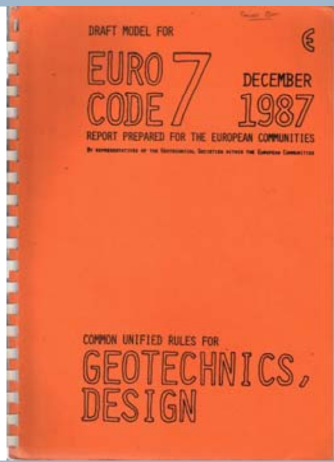





# Special features of soil and consequences for geotechnical design (from Orr, 2008)

| Soil | Steel | Consequences for geotechnical design |
|---|---|---|
| Natural material | Manufactured | Properties are determined, not specified, so ground investigation and testing part of design process |
| 2 or 3 phases | Single phase | Need to consider water and water pressures as well as soil |
| Heterogeneous | Homogenous | Characteristic value is not 5% fractile of test results |
| High variability | Low variability | Need to use judgement when selecting characteristic values |
| Frictional | Non-frictional | Loads affect resistances, so need care factoring permanent loads |
| Ductile | Not as ductile | Causes load redistribution in structures, so lower partial factors may be appropriate for structural loads |
| Compressible | Not compressible | Design often controlled by the SLS, not by the ULS |
| Non-linear & complex | Linear & simple | SLS calculations often difficult, so design is often carried out using ULS calcuations |

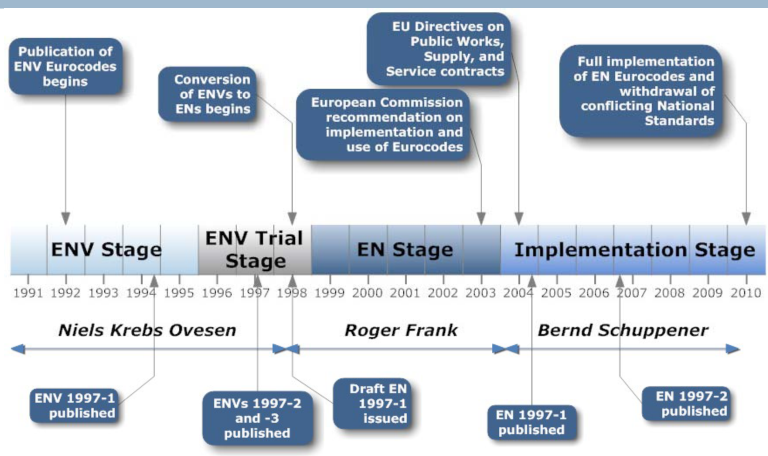
## (left) Ad-hoc committee 1983; (right) Draft Model for Eurocode 7 (from Orr, 2008)




Niels Krebs Ovesen (1934-2005) was the 1st Chairman of SC7; Eric Farrell, Trevor Orr, and Brian Simpson are still members of SC7



## Eurocode 7 timeline 1991-2010



## Contribution of Niels Krebs-Ovesen

*'The successful development of Eurocode 7 was largely due to [the late] Niels Krebs Ovesen's clear and deep understanding of geotechnical design principles, his excellent social and diplomatic skills, and his enthusiasm and ability to motivate people.'*

Trevor Orr (2008), *The Story of Eurocode 7*



## Eurocode 7 Prestandard (ENV 1997-1: 1994) Cases A, B, and C


EUROPEAN PRESTANDARD
PRÉNORME EUROPÉENNE
EUROPÄISCHE VORNORM

ENV 1997-1

October 1994

English version

Eurocode 7: Geotechnical design —
Part 1: General rules

Eurocode 7: Calcul geotechnique —
Partie 1: Règles générales

Eurocode 7: Entwurf, Berechnung und Bemessung in der Geotechnik —
Teil 1: Allgemeine Regeln

CEN

European Committee for Standardization
Comité Européen de Normalisation
Europäisches Komitee für Normung

Central Secretariat: rue de Stassart 36, B-1050 Brussels

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Ref. No. ENV 1997-1 : 1994 E

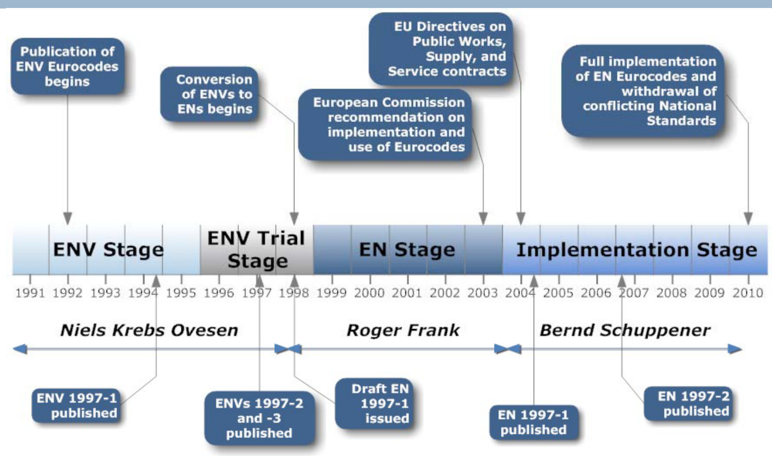
| Partial factors applied to | Case | | |
|---|---|---|---|
| | A | B | C |
| Permanent actions | ×1.0 | ×1.35 | ×1.0 |
| Variable actions | ×1.5 | ×1.5 | ×1.3 |
| tan $\phi$ | ÷1.1 | ÷1.0 | ÷1.25 |
| $c'$ | ÷1.3 | ÷1.0 | ÷1.6 |
| $c_u$ | ÷1.2 | ÷1.0 | ÷1.4 |

# Vasco da Gama bridge across River Tagus, Lisbon, Portugal, 1995-8 (courtesy Rui Correia)

- Client: Portuguese state
- Designer/Contractor: Lusoponte
- Geotechnical Consultant: LNEC
- Total length of the crossing: 17.2 km
- Total length of bridges and viaducts: 12.3 km
- Crossing over the river Tagus estuary: 9.0 km
- Total number of piles: 1916
- Diameter of the piles: from 0.80 m to 2.20 m
- Min. tip elevation of piles: 85 m below sea level
- Cost: €1000M



# Eurocode 7 timeline 1991-2010



## Challenges facing the drafters of Eurocode 7

Eurocode 7 had to...

1. Be based on limit state design principles and consistent with head Eurocode
2. Take account of the special features of soil
3. Be acceptable to the European geotechnical community



## Changes from ENV to EN of Eurocode 7

- Cases A, B, and C became EQU and STR/GEO limit states
- Introduced alternative ways of verifying STR/GEO via three 'Design Approaches':
  - DA1 'preserved' existing 'load and material factor method' (B/C)
  - DA2 introduced the load and resistance factor method
  - DA3 simplified DA1 from a two-step to a single-step verification
- Introduced additional limit states UPL and HYD

## Road cutting below groundwater level, Kildare, Ireland (photos courtesy Dr Trevor Orr)

UPL limit state: impermeable seal around excavation maintains aquifer's water level. Weight of fill selected using EC7's principle of 'characteristic' value



## Present: 2010-2015

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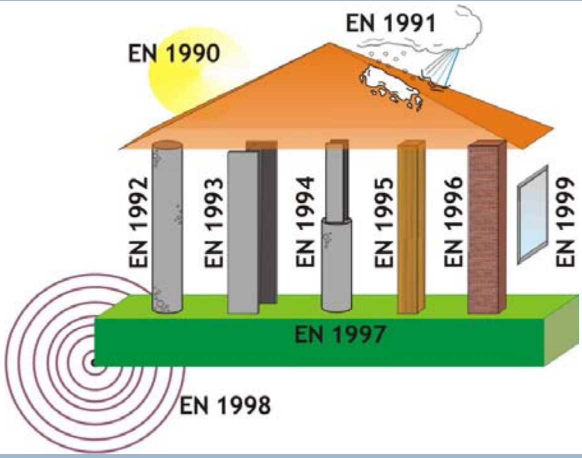
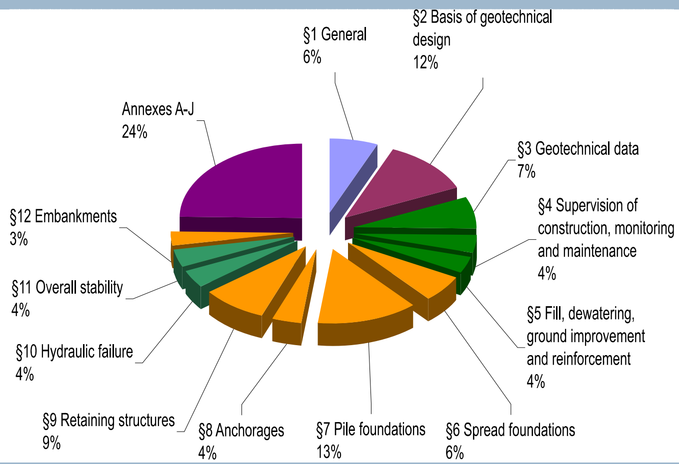
## Family of Eurocodes (Bond and Harris, 2008)

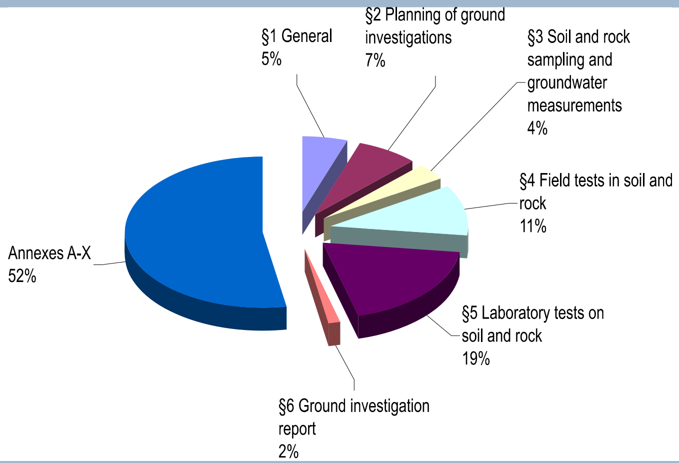





## EN 1997-1: General rules

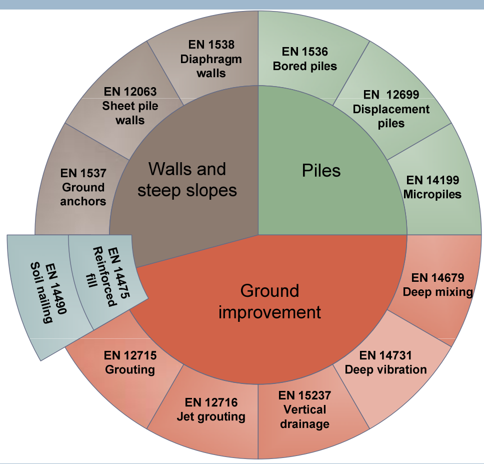


# EN 1997-2: Ground investigation and testing

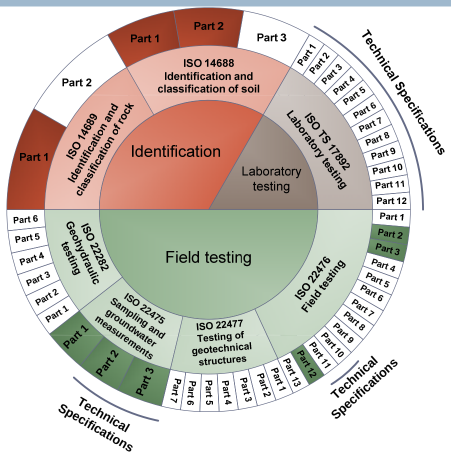





# Standards for execution of special geotechnical works



## Standards for geotechnical investigation and testing






## Key features of Eurocodes

- Distinction between Principles and Application Rules
  - Principles are statements and definitions for which there is no alternative; requirements and analytical models for which no alternative is permitted
  - Application Rules are generally recognized rules which comply with the Principles
- Verifications based on limit state principles
  - Check ultimate (ULS) and serviceability limit states (SLS)
- Reliability introduced by partial factors
  - Factors calibrated against historical/empirical methods
  - (If possible) Factors justified by semi-probabilistic methods

## Verification of ultimate limit states

Verification of strength (limit states STR and GEO):

$$E_d \leq R_d$$

Verification of static equilibrium (limit state EQU):

$$E_{d,dst} \leq E_{d,stb}$$

Verification of uplift (limit state UPL):

$$E_{d,dst} \leq E_{d,stb} + R_d$$

$E_d$ = design effect of actions (dst = destabilizing; stb = stabilizing)
$R_d$ = design resistance corresponding to that effect



## Coventry University Engineering and Computing Building, UK (courtesy Dr Brian Simpson, Arup)

Sand and clays
Governed by long term bearing capacity (ULS)
Careful consideration of relevant load combinations

## Architect's vision of Coventry University Building (courtesy Dr Brian Simpson, Arup)



## Verification of serviceability limit states

Verification of serviceability:

$$E_d \leq C_d$$

Alternative verification allowed in some situations:

$$E_d \leq \frac{R_d}{\gamma_{R,SLS}}, \gamma_{R,SLS} \geq 3$$

$E_d$ = design effect of actions
$C_d$ = limiting value of design effects (i.e. design serviceability criteria)

## Eurocode method for verifying strength

$$E_d \leq R_d$$

$$\gamma_E E\left\{F_d, X_d, a_d\right\} \leq \frac{R\left\{F_d, X_d, a_d\right\}}{\gamma_R}$$

$$F_d = \sum_i \gamma_{F,i}\psi_i F_{k,i}, X_d = \frac{X_k}{\gamma_M}, a_d = a_{nom} \pm \Delta a$$

E = action-effect; R = resistance; F = action; X = material property; a = geometrical data; $\gamma_F$, $\gamma_M$, $\gamma_E$, $\gamma_R$ = partial factors; $\Delta_a$ = safety margin $\psi$ = combination factor



## LRFD (Load and Resistance Factor Design) vs Eurocode method for verifying strength

$$\sum_i \eta_i \gamma_i Q_i \leq \phi R_n = R_r$$

$\eta_i$ = load multiplier; $\gamma_i$ = load factor; $Q_i$ = force effect
$\phi$ = resistance factor ($\leq$ 1.0); $R_n$ = nominal resistance; $R_r$ = reduced resistance

$$\sum_i \gamma_{E,i}\psi_i E_{k,i} \leq \frac{R_k}{\gamma_R}$$

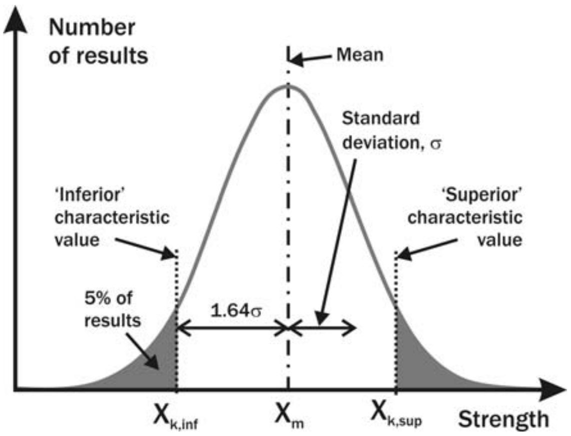
F = actions; X = material properties; a = geometrical data
$\gamma_F$, $\gamma_M$, $\gamma_E$, $\gamma_R$ = partial factors; $\Delta_a$ = safety margin/tolerance; $\psi$ = combination factor

## Key questions

1. How do we select 'characteristic' values?
2. Where should be put the partial factors?
3. Should we factor water pressures?



## 'Structural' definition of characteristic value



## Characteristic value of a geotechnical parameter

Eurocode 7 defines the characteristic value as:

*"a cautious estimate of the value affecting the occurrence of the limit state"*

EN 1997-1 §2.4.5.2(2)P

This means that there is no such thing as the characteristic value of a geotechnical parameter – rather there are potentially several characteristic values, one for each limit state being considered.

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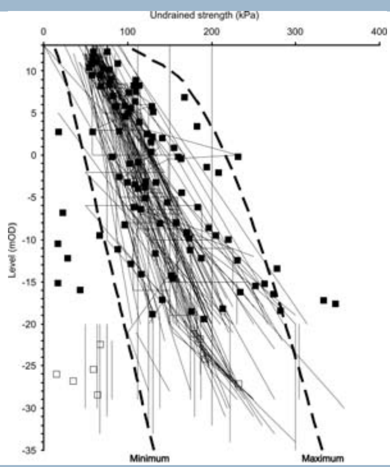
## Difficulty of selecting characteristic values

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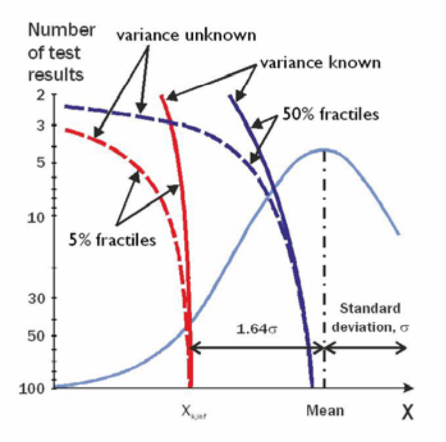
## Mapping the possible values of $X_k$






## Simone de Beauvoir footbridge in Paris, France (courtesy Prof. Roger Frank)

## Intermission

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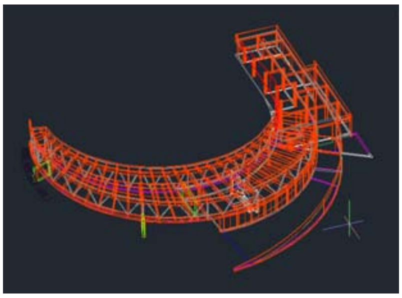
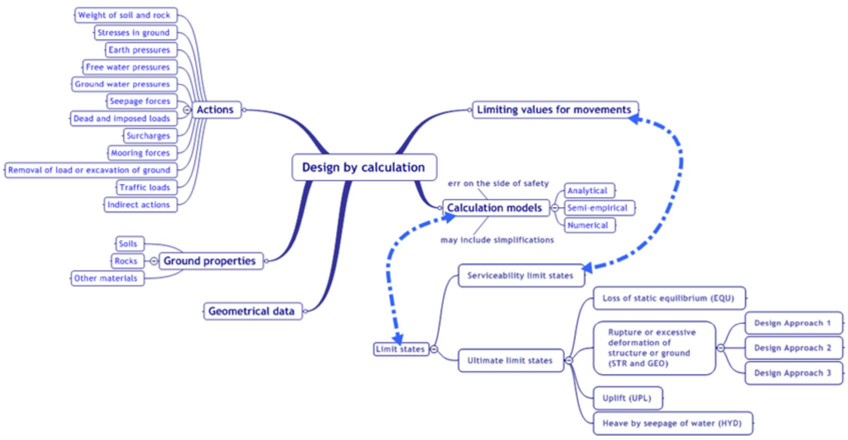
## Administrative building, Bacău, Romania (courtesy Dan Ungureanu, Romania)

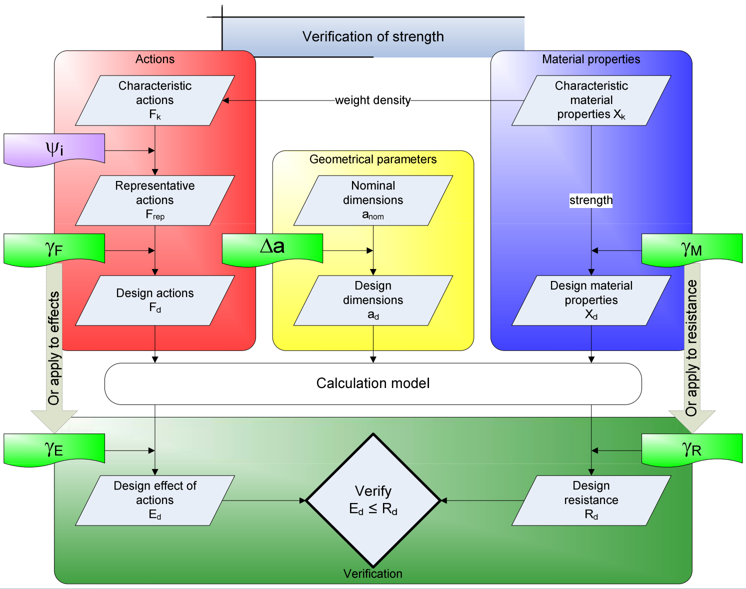




## Design by calculation to Eurocode 7 (Bond and Harris, 2008)



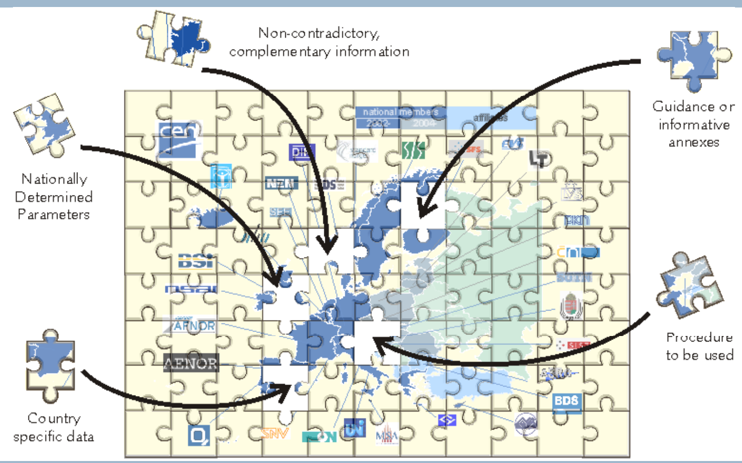
## STR/GEO in geotechnical design




## Design Approaches for STR/GEO

| Partial factors applied to | Design Approach 1 | | 2 | | 3 |
|---|---|---|---|---|---|
| | Comb. 1 | Comb. 2 | | (2*) | |
| Actions | ✓ | | ✓ | | ✓ |
| Material strengths | | ✓ | | | ✓ |
| Effects of actions | | | | ✓ | |
| Resistance | | | ✓ | ✓ | |

# National Annex completes the Eurocode jigsaw

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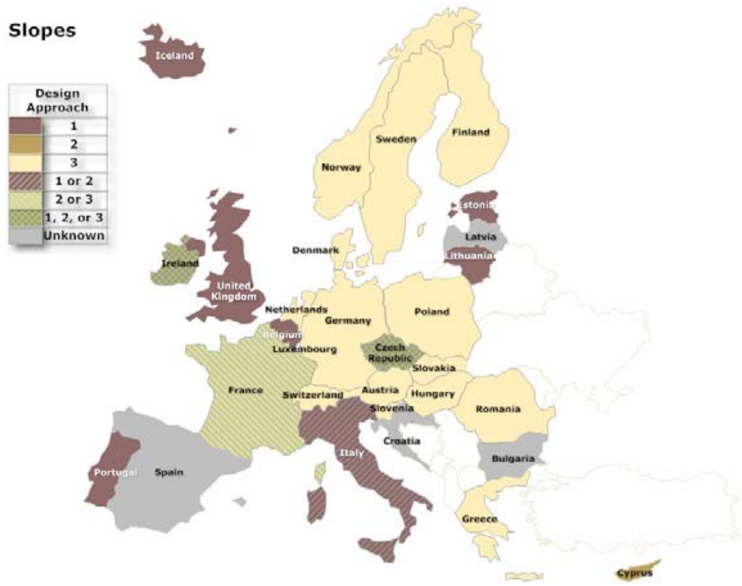
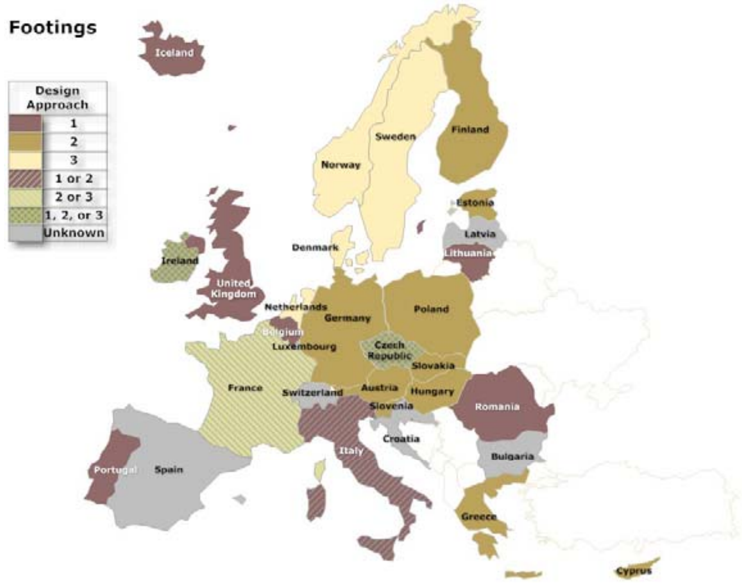
# Design Approaches adopted for slopes



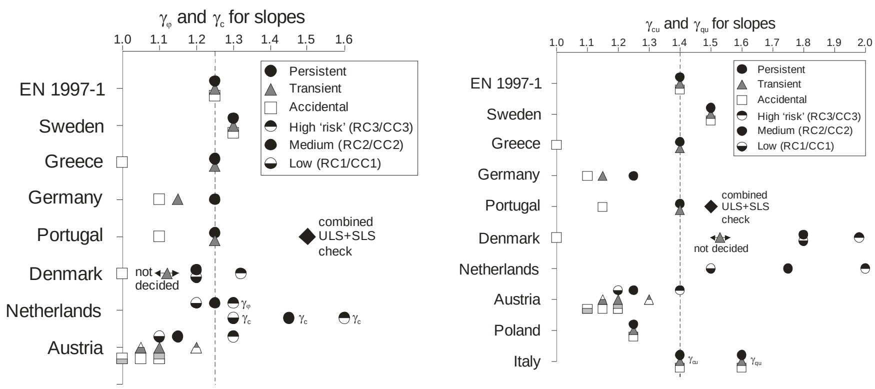
## Design Approaches adopted for shallow foundations




## Partial factors for different Design Approaches

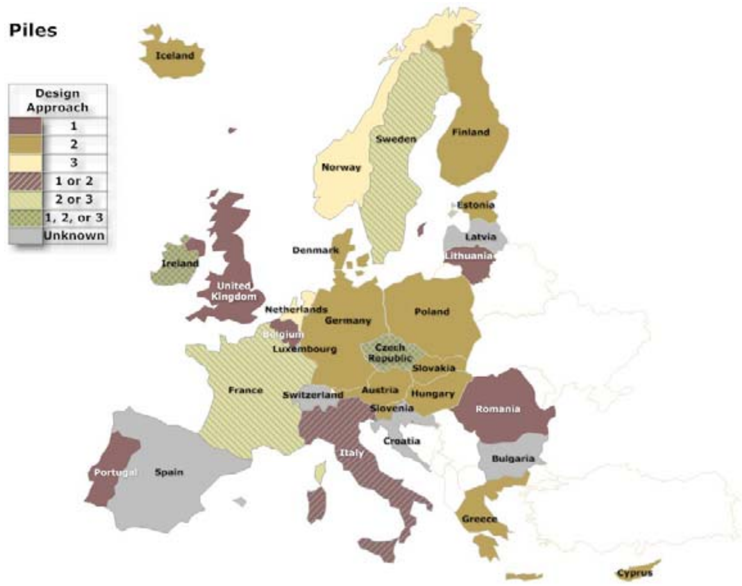
| Partial factors applied to | Design Approach | | | | |
|---|---|---|---|---|---|
| | 1 | | 2 | | 3 |
| | Comb. 1 | Comb. 2 | | (2*) | |
| Permanent actions | x1.35 | x1.0 | x1.35 | x1.0 | x1.35 str.<br>x1.0 geo. |
| Variable actions | x1.5 | x1.3 | x1.5 | x1.0 | x1.5 str.<br>x1.3 geo. |
| Material strengths | ÷1.0 | ÷1.25-1.4 | ÷1.0 | ÷1.0 | ÷1.25-1.4 |
| Effects of actions | x1.0 | x1.0 | x1.0 | x1.35<br>x1.5 | x1.0 |
| Resistance | ÷1.0 | ÷1.0 | ÷1.1-1.4 | ÷1.1-1.4 | ÷1.0 |

## Material factors for (left) drained and (right) undrained slopes






## Design Approaches adopted for pile foundations

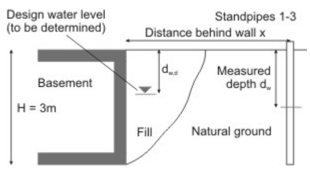


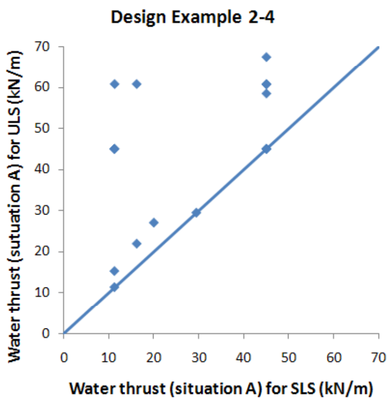
## Piles and pile testing for Berth 7, Port of Koper, Slovenia (courtesy Prof. Janko Logar)


Client: Port of Koper; Contractor: Primorje, Slovenija; Designer: Institute for Water, Republic of Slovenia from Ljubljana; Cost: €4M

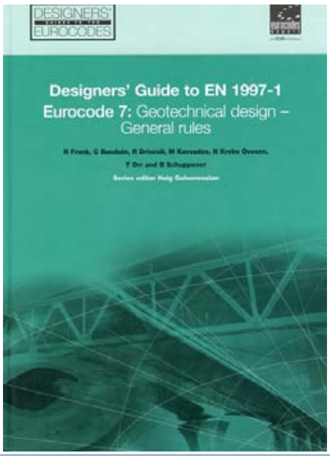


## Difficulty of selecting water pressures



## ‘Designers’ Guide to EN 1997-1’ (2004)
## ‘Decoding Eurocode 7’ (2008)







## SWOT analysis of Eurocode national annexes

One of the biggest *strengths* of the Eurocode system is the flexibility provided by national annexes.

However, one of its biggest *weaknesses* is the variability allowed by those same national annexes.

National annexes provide the *opportunity* for non-European countries to adapt the Eurocodes to their particular needs.

The added complexity of the national annexes is a *threat* to the acceptance of the Eurocodes into practice.

# Future: 2015 and beyond

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## Practical rules for construction?

Interest groups in Germany want more practical codes:

*'We want [the 'PraxisRegelnBau' initiative] to be an engine for preparing practical regulations in the building profession. … The current generation of Eurocodes is a good first step ... However, there is a second step, [to improve and] to simplify. Only if this second step is done, will the Eurocodes be a success.'*

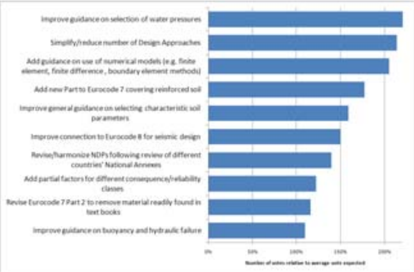
Professor Nußbaumer (Chairman)

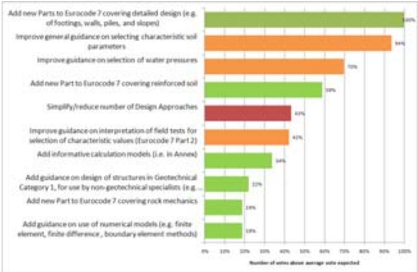
Founding members include:

- Federal Chamber of Engineers eV, Confederation of German Construction Industry, National Federation of Building Trade, and many others

Members admit they did not engage in the process of code development in the past!

## Results of questionnaires (left) National Standards Bodies; (right) practising engineers






## EC Mandate M/466 to 'initiate the process of further evolution of the Eurocodes'

1. New Eurocodes or Eurocode parts
2. Further development of the existing Eurocodes ENs 1990-1999

## Further development of existing Eurocodes

a) Assess existing Eurocodes to reduce the number of Nationally Determined Parameters (NDPs)
b) Incorporate recent research on innovation, e.g. performance-based and sustainability concepts
c) Incorporate recent research on sustainability
d) Adopt ISO standards to supplement the Eurocode family, e.g. atmospheric icing of structures and actions from waves and currents on coastal structures
e) Simplify rules, where relevant, for limited and well identified fields of application
f) Facilitate feedback from stakeholders and practical local implementation
g) Consider on going work and results of Mandate 420, CEN/CENELEC Guide 6 and ISO/DIS 21542



## SC7's highest priorities for development in next revision of EN 1997

1. Harmonization (see next slide)
2. Incorporation of recent research results and technical studies
   Add/improve guidance on ground water pressures; numerical models; selection of characteristic parameters; use of EN 1997 with EN 1998 for seismic design
3. Sustainability
   Remove conservatism from connection with structural Eurocodes; provide better treatment of consequence/ reliability classes
4. New parts to Eurocode 7
   Covering reinforced soil, rock mechanics, and tunnelling
5. Simplification of rules
   Revise EN 1997-2 to remove material readily found elsewhere; revise/remove text duplicated across ENs 1997-1 and -2

## SC7's hopes for harmonization

1.1. Simplify/reduce number of Design Approaches

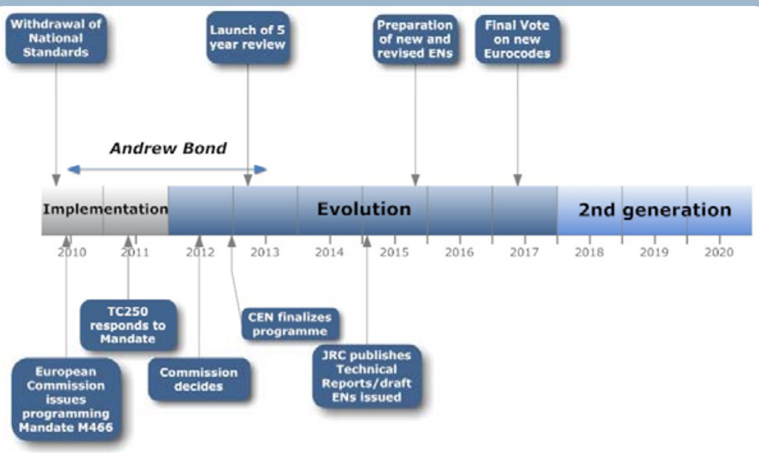
Eurocode 7 currently permits designs to be performed using one (or more) of three design approaches (DAs) … These will be simplified and (potentially) reduced based on recent experience of using Eurocode 7.

1.2 Revise/harmonize NDPs following review of countries' National Annexes

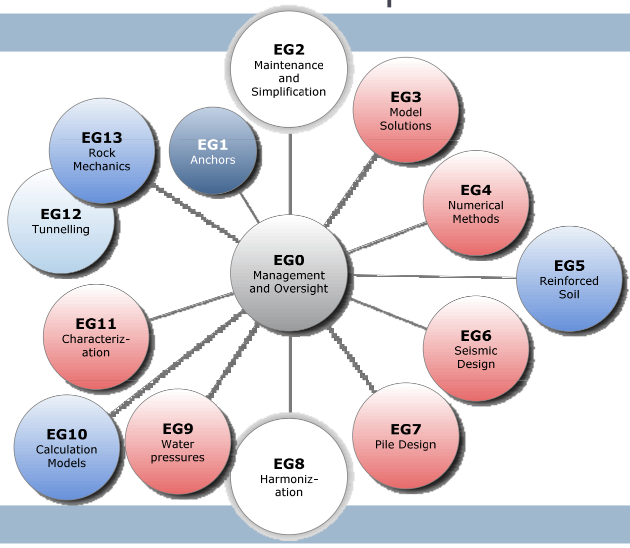
Eurocode 7 Part 1 currently includes over 120 NDPs, many of which have had their values adjusted in National Annexes. The project would study all NDPs and reduce their number to an acceptable minimum.



## Eurocode 7 timeline 2010-2020



## Eurocode 7 'Evolution Groups'






## Summary and conclusion

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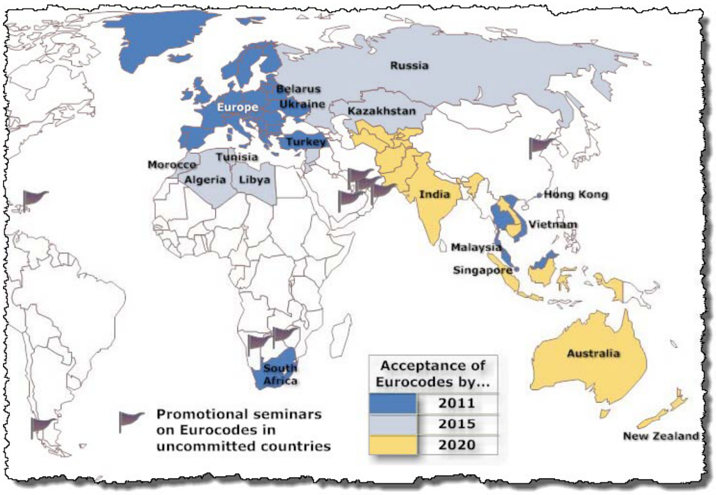
## Global acceptance of Eurocodes (forecast: Malcolm Greenley, 2011)




## Summary of key points

- European Commission has issued a Mandate for the 'evolution of the Eurocodes' – decision expected 2012-13
- 'Version 2' Eurocodes are planned for 2018
- National Standards Bodies want:
  - greater harmonization + fewer Design Approaches + better coverage of numerical methods
- Practising engineers want:
  - more detailed guidance on routine calculations + better guidance on soil characterization + better guidance on water pressures
- SC7 has established 12 'Evolution Groups' to aid the development of Eurocode 7

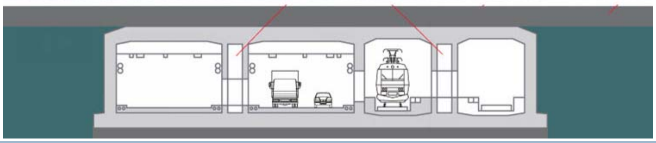
## Eurocodes have vital role in future built environment

*"The Eurocodes reflect a new universal technical culture in civil engineering. The transparency of their safety concepts and of their fundamental requirements, the scientific quality of their design rules and their flexible conditions of use will liberate innovation to contribute to sustainability in construction works. Undoubtedly, they will play a vital role in the development of the future built and social environment"*

Prof. Jean-Armand Calgaro (Chairman, CEN/TC 250)



## Fehmarn Belt between Germany and Denmark, 2018 (courtesy Dr Bernd Schuppener)



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blog.eurocode7.com
www.eurocode7.com

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## References

Bond, A.J. and Harris, A.J. (2008), *Decoding Eurocode 7*, London: Taylor & Francis, 598pp.
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Orr, T.L.L. (2008), 'The story of Eurocode 7', Spirit of Krebs Ovesen Session – Challenges in Geotechnical Engineering, *XIV European Conference on Soil Mechanics and Geotechnical Engineering*, Bulletin 23, Danish Engineering Society, November 2008, pp41-58.