DECODING EUROCODE 7

Impact of Eurocode 7 on basement design

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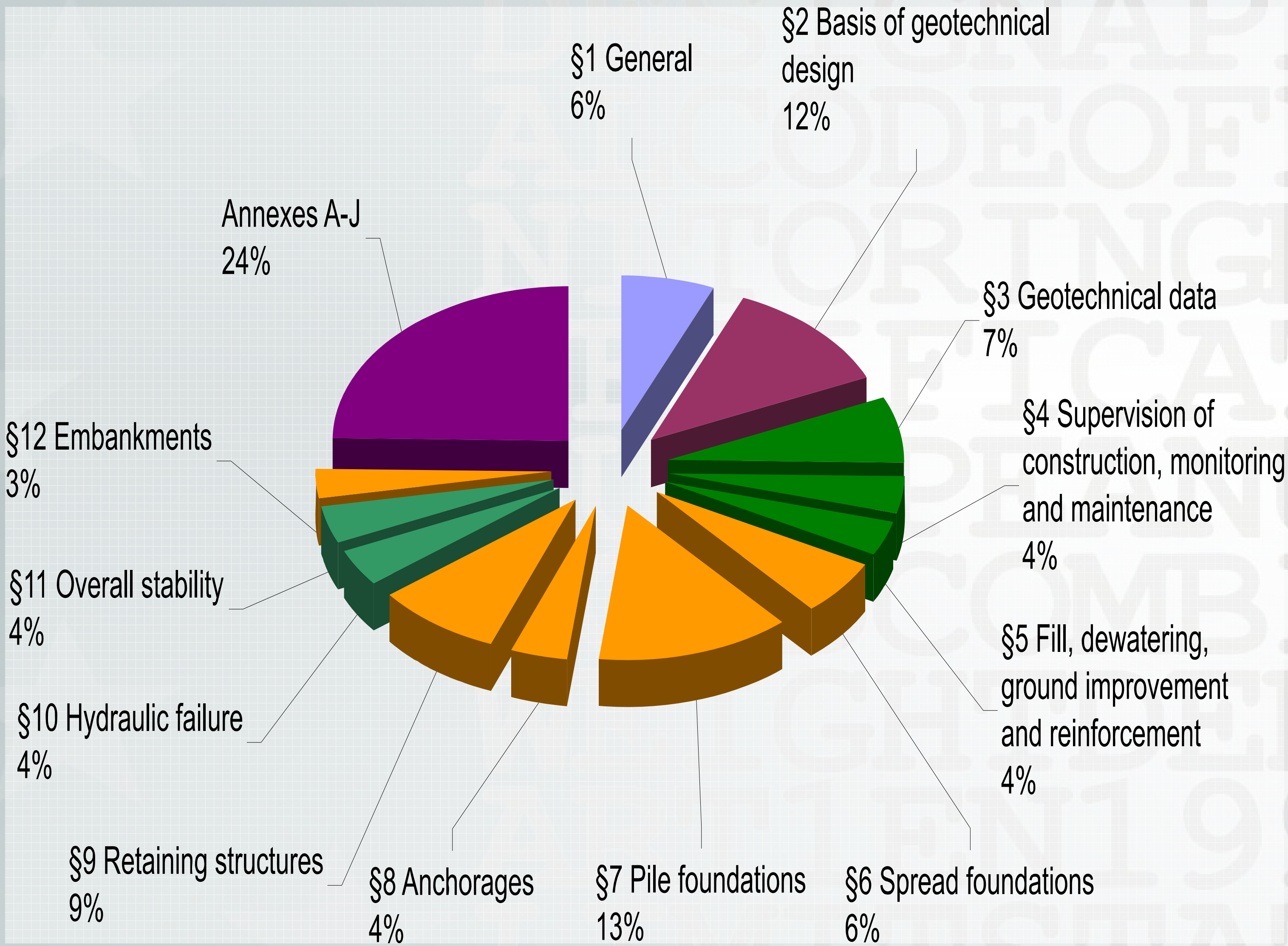
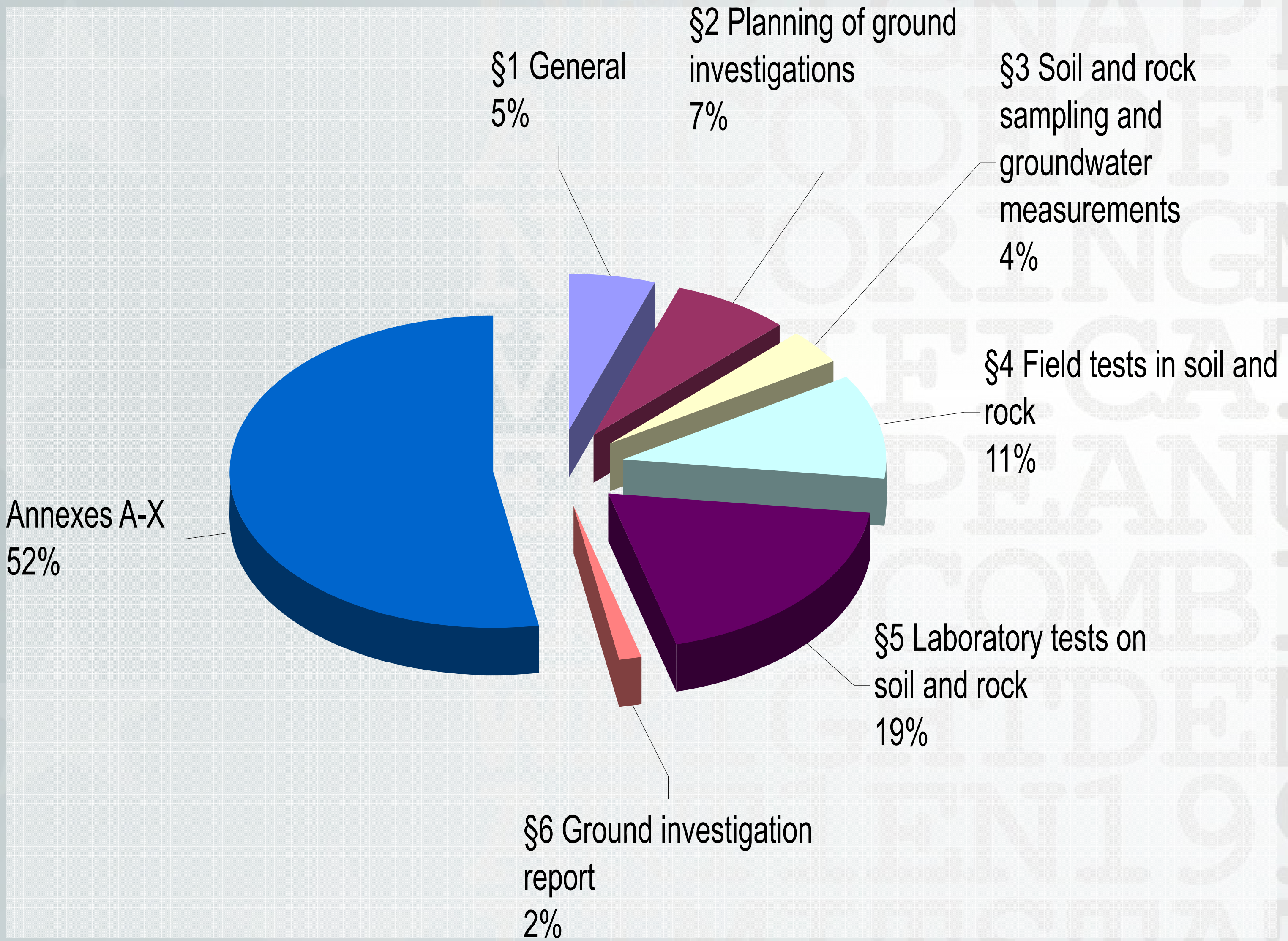
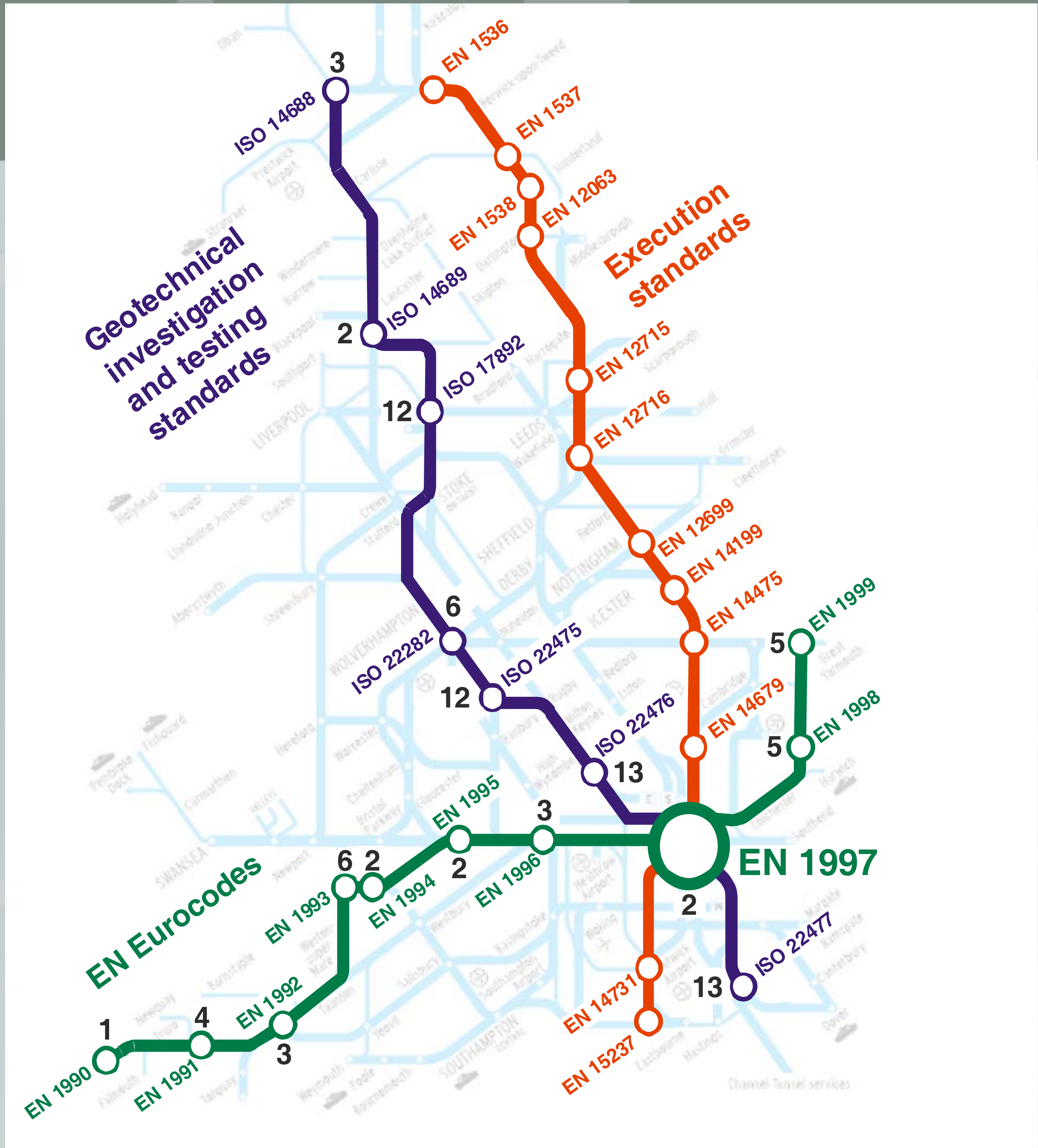
Contents of EN 1997-1: General rules



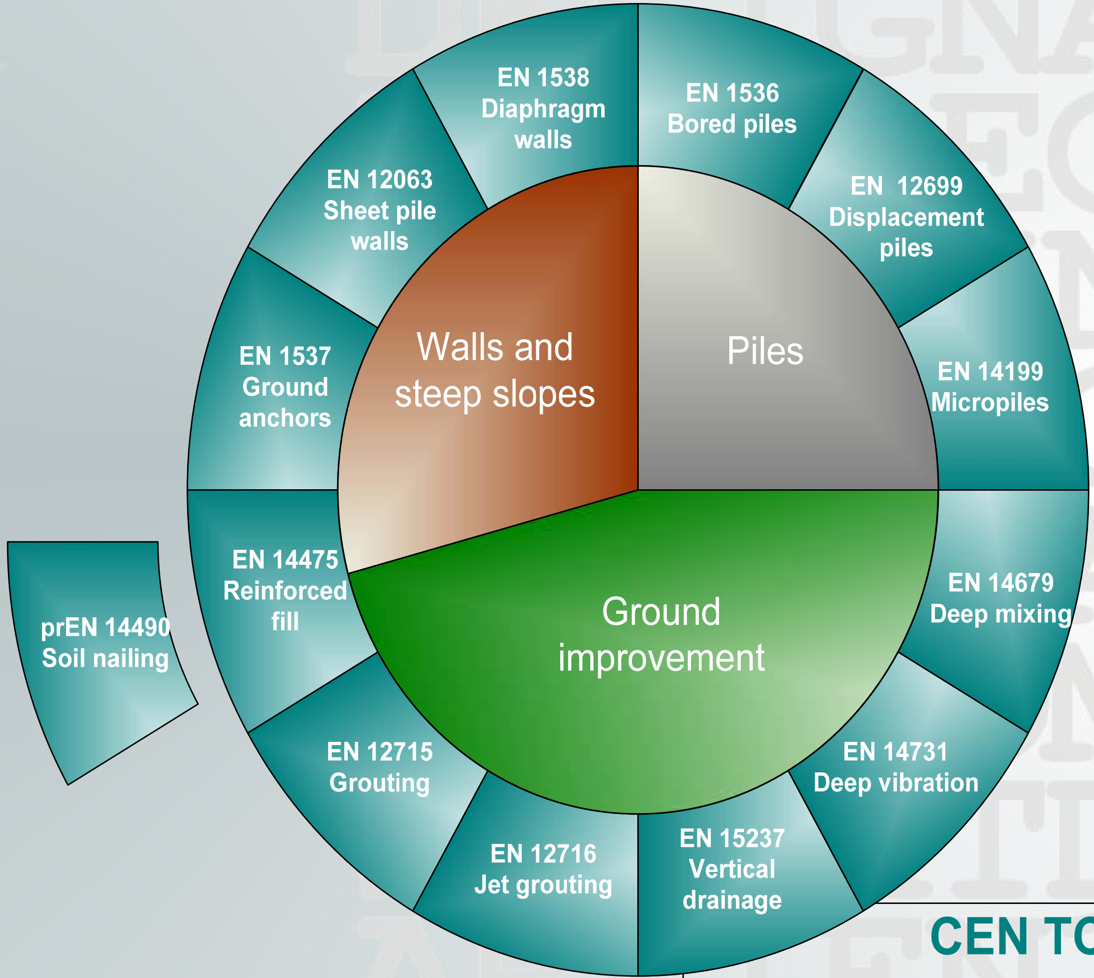
Contents of EN 1997-2: Ground investigation and testing





Geotechnical investigation and testing standards
ISO 14688
3
ISO 14689
2
ISO 17892
12
ISO 22282
6
ISO 22475
12
ISO 22476
13
ISO 22477
13
Execution standards
EN 1536
EN 1537
EN 1538
EN 12063
EN 12715
EN 12716
EN 12699
EN 14199
EN 14475
EN 14679
EN 14731
EN 15237
EN Eurocodes
EN 1990
1
EN 1991
4
EN 1992
3
EN 1993
6
EN 1994
2
EN 1995
2
EN 1996
3
EN 1997
2
EN 1998
5
EN 1999
5

Execution of special geotechnical works



CEN TC288
Execution of special geotechnical works

DECODING

Design of embedded retaining walls

EUROCODE 7

Impact of Eurocode 7 on basement design

Contents of EN 1997-1 Sections 8 and 9

Section 8 Anchorages

Section 9 Retaining structures

- §x.1 General (12/6 paragraphs)
- §x.2 Limit states (1/4)
- §8.3 Design situations and actions (2)/§9.3 Actions, geometrical data and design situations (26)
- §x.4 Design and construction considerations (15/10)
- §8.5/§9.7 Ultimate limit state design (10/26)
- §8.6/§9.8 Serviceability limit state design (6/14)

Section 8 only

- §8.7 Suitability tests (4)
- §8.8 Acceptance tests (3)
- §8.9 Supervision and monitoring (1)

Section 9 only

- §9.5 Determination of earth pressures (23)
- §9.6 Water pressures (5)

Scope of EN 1997-1 Sections 8 and 9

- Section 9 covers retaining structures supporting:
  - Soil, rock or backfill (i.e. ground)
  - Water
- Material is retained if it is *‘kept at a slope steeper than it would eventually adopt if no structure were present’*
- Silos are NOT covered (see EN 1991-4 instead)

- Section 8 covers temporary and permanent anchorages to:
  - Support retaining structures
  - Stabilize slopes, cuts, or tunnels
  - Resist uplift forces on structures
- Soil nails are NOT covered (see BS 8006 and EN 14490 instead)

Spacing of investigation points

Annex B.3 of EN1997-2 provides outline guidance on the spacing of investigation points for geotechnical investigations

<table>
<tr><th colspan="2">Structure/example</th><th>Spacing</th><th>Arrangement</th></tr>
<tr><td colspan="2">High-rise and industrial</td><td>15m to 40m</td><td>Grid</td></tr>
<tr><td colspan="2">Large-area</td><td>60m</td><td>Grid</td></tr>
<tr><td>Linear</td><td>roads, railways, channels, pipelines, dikes, tunnels, retaining walls</td><td>20-200m</td><td>-</td></tr>
<tr><td colspan="2">Dams and weirs</td><td>25-75m</td><td>Along vertical sections</td></tr>
<tr><td>Special</td><td>bridges, stacks, machinery foundations</td><td colspan="2">2-6 per foundation</td></tr>
</table>

Depth of investigation points for retaining walls

Groundwater below formation:

$z_a \geq 0.4\ h$

$z_a \geq (t + 2\ m)$

Groundwater above formation:

$z_a \geq (H + 2\ m)$

and (if stratum is impermeable):

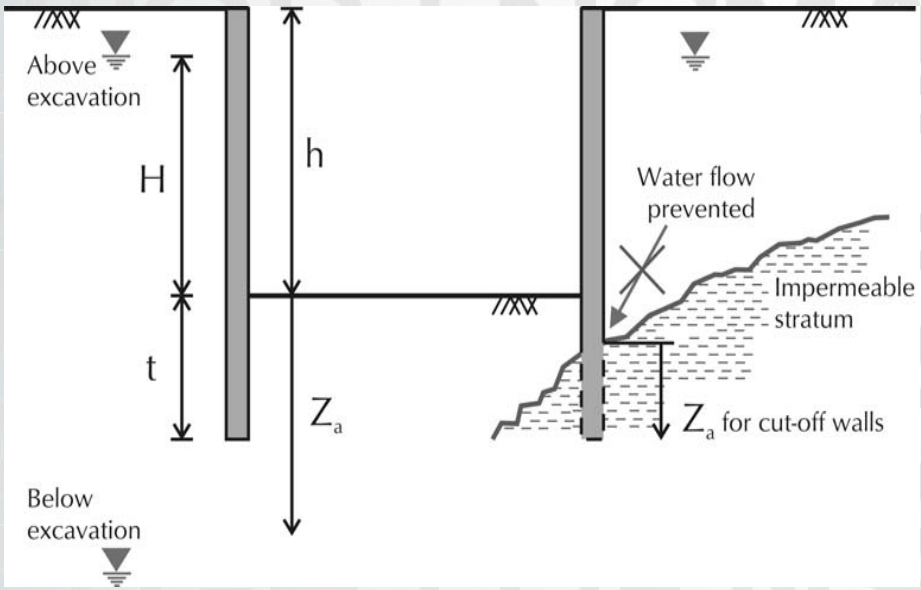
$z_a \geq (t + 2\ m)$

or (if all strata are permeable):

$z_a \geq (t + 5\ m)$

For cut-off walls:

$z_a \geq 2\ m$



UK National Annex to BS EN 1997-1

- National Annex published November 2007
- References to non-contradictory complimentary information (NCCI) cites:
  - BS 8002, Code of practice for earth retaining structures
  - CIRIA C580, Embedded retaining walls – guidance for economic design
- Future of BS 8002 is uncertain:
  - Basic philosophy (critical state soil mechanics with mobilization factors) contradicts Eurocode 7
  - Code won't be re-written
  - Possible PD containing "left-over" clauses covering gravity walls
- Highways Agency intends to commission minor update to CIRIA C580 to remove any contradictory information

Application of partial factors and tolerances

Actions

$$F_d = \gamma_F F_{rep}$$

Material properties

$$X_d = \frac{X_k}{\gamma_M}$$

Geometrical parameters

$$a_d = a_{nom} \pm \Delta a$$

Effects of actions

$$E_d = \gamma_E E\left\{F_d, X_d, a_d\right\}$$

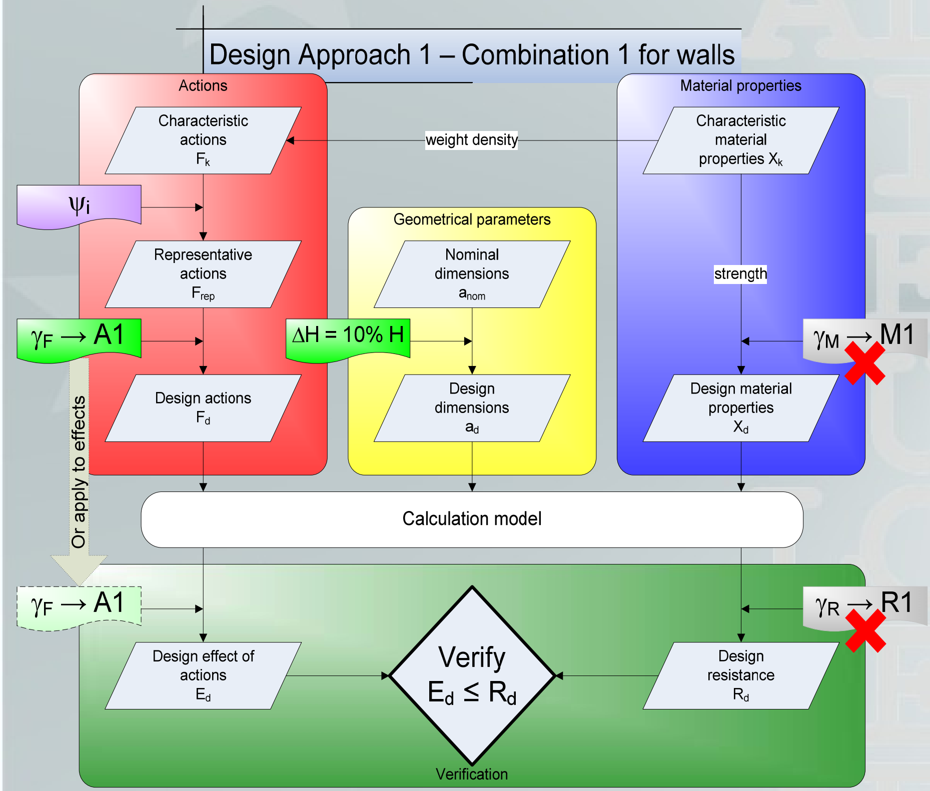
Resistances

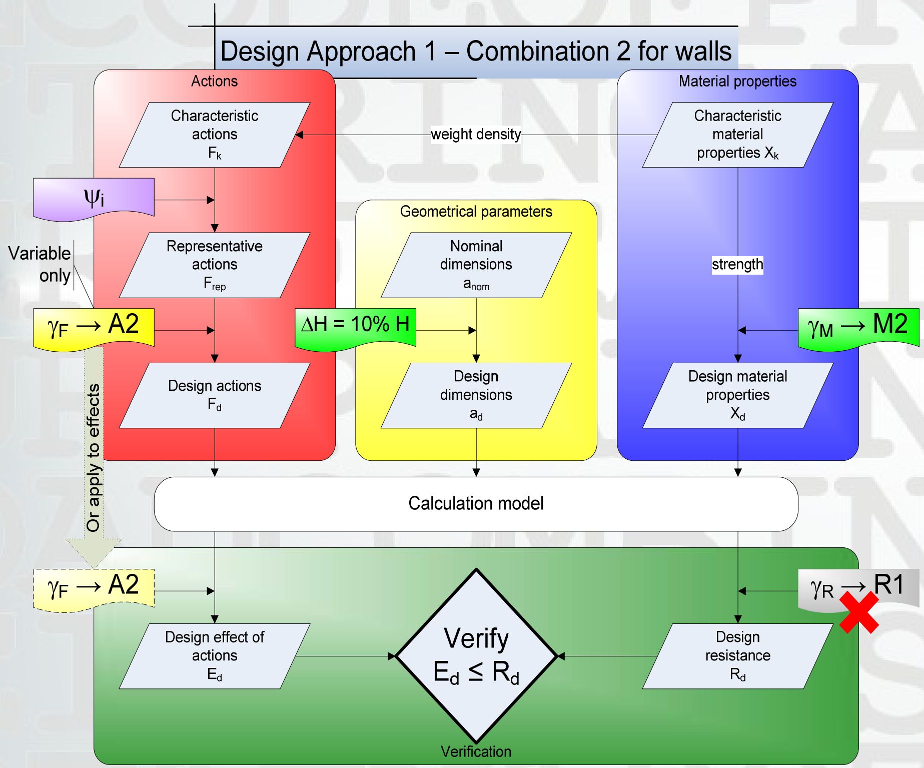
$$R_d = \frac{R\left\{F_d, X_d, a_d\right\}}{\gamma_R}$$

Partial factors for limit states GEO/STR (DA1) – footings, walls, and slopes

Parameter		Symbol	Combination 1			Combination 2		
			A1	M1	R1	A2	M2	R1
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			1.0
Sliding resistance (R_h)		γ_{Rh}						
Earth resistance (R_e)		γ_{Re}						

Design Approach 1 for retaining structures





Partial factors: C580 vs Eurocode 7 Design Approach 1

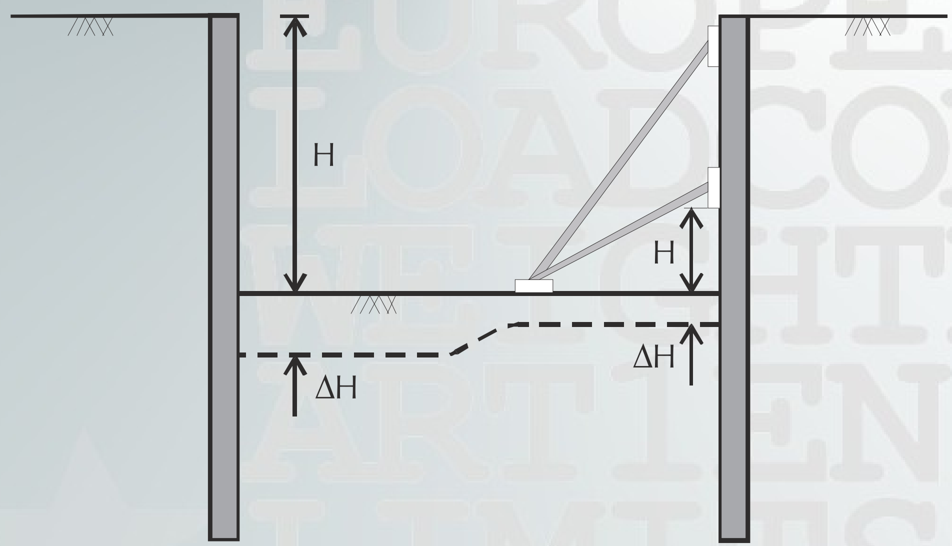
Limit state		Design Approach		Partial factors				
				γ_G	γ_Q	γ_φ	γ_c	γ_{cu}
CIRIA C580	ULS	A	Moderately conservative	1.0	1.0†	1.2	1.2	1.5
		B	Worst credible	1.0	1.0†	1.0	1.0	1.0
		C	Most probable	1.0	1.0†	1.2	1.2	1.5
	SLS	A and C		All factors = 1.0				
Eurocode 7 DA1	ULS	1	Combination 1	1.35	1.5	1.0	1.0	1.0
			Combination 2	1.0	1.3	1.25	1.25	1.4
	SLS			All factors = 1.0				

†Minimum surcharge of 10kPa for retained heights ≥ 3m

Unplanned excavation

- Design geometry shall account for anticipated excavation or possible scour in front of the retaining structure

  $a_d = a_{nom} + \Delta_a$
- For normal site control
  - Cantilever: Δ_a = 10% of retained height
  - Supported wall: Δ_a = 10% of height below lowest support
  - Maximum Δ_a = 0.5m



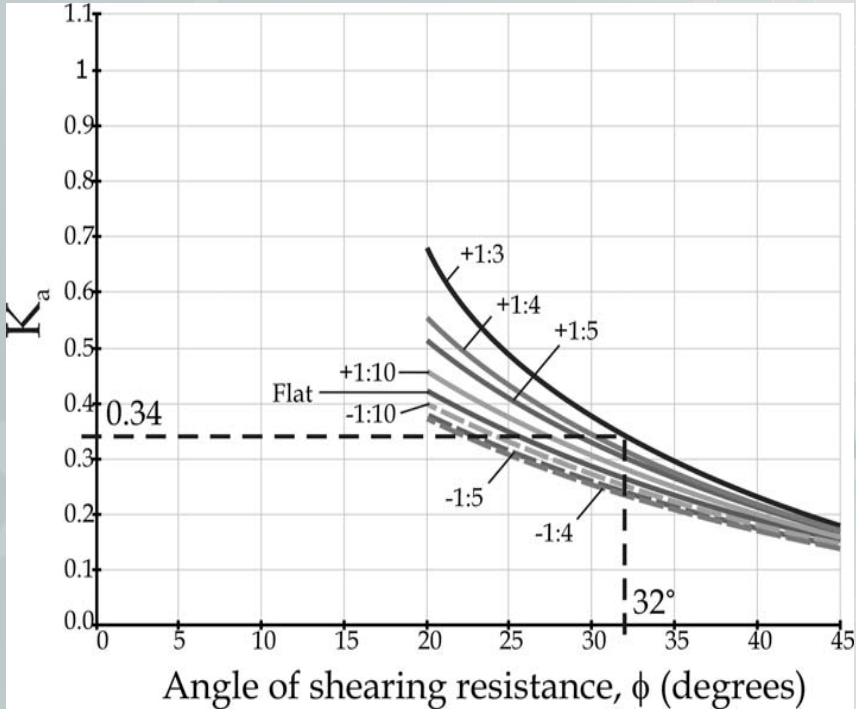
New formulation for active and passive earth coefficients

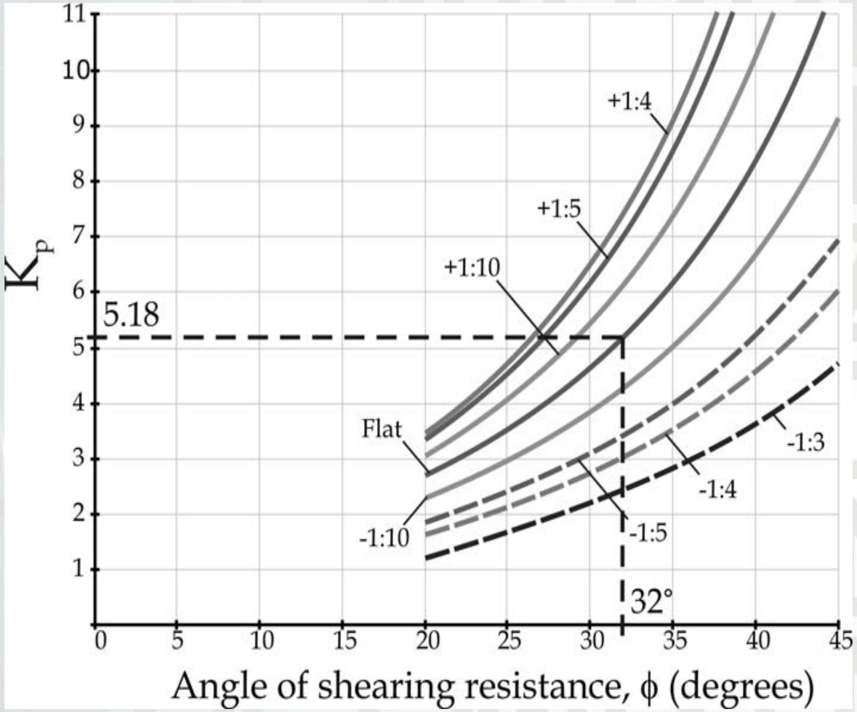
$$\left.\begin{matrix} K_a \\ K_p \end{matrix}\right\} = \frac{1 \pm \sin\varphi \times \sin(2m_w \pm \varphi)}{1 \mp \sin\varphi \times \sin(2m_t \pm \varphi)} e^{\pm 2(m_t + \beta - m_w - \vartheta)\tan\varphi}$$

$$2m_t = \cos^{-1}\left(\frac{-\sin\beta}{\pm\sin\varphi}\right) \mp \varphi - \beta$$

$$2m_w = \cos^{-1}\left(\frac{\sin\delta}{\sin\varphi}\right) \mp \varphi \mp \delta$$

Charts of earth pressure coefficients from from Bond & Harris (2008)





Charts given for:

- Angle of shearing resistance φ = 0 to 45°
- Angle of interface friction δ = 0 to 30°
- Ground inclinations tan β = flat, ±1:10, ±1:5, ±1:4, ±1:3, ±1:2.5, ±1:2, and ±1:1.5
- Angle of wall inclination θ = 0 °

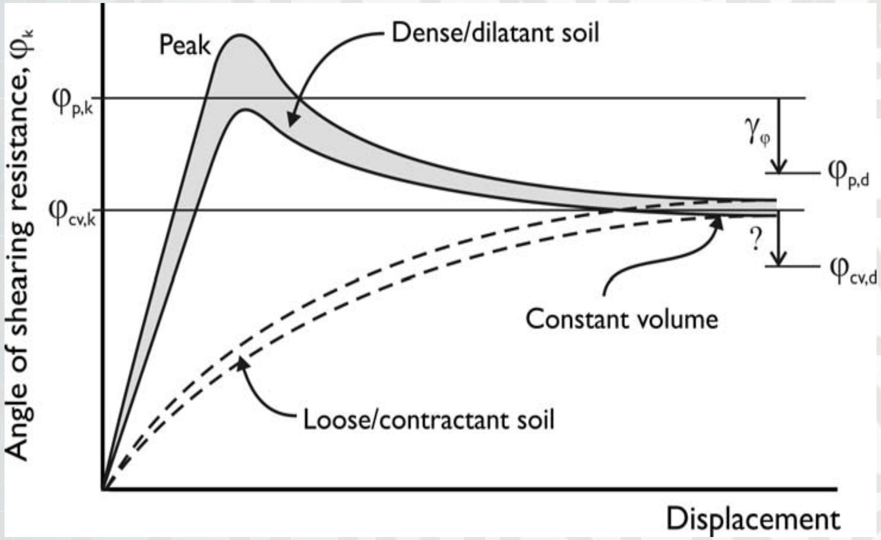
Angle of interface friction

Eurocode 7 allows δ_d to be determined from the soil's design constant-volume angle of shearing resistance $\varphi_{cv,d}$

$$\delta_d = k\varphi_{cv,d} = k\tan^{-1}\left(\frac{\tan\varphi_{cv,k}}{\gamma_\varphi}\right)$$

Values of k are:

- 1 for soil against cast in-situ concrete
- ⅔ for soil against precast concrete



The UK National Annex states:

It might be more appropriate to select the design value of φ_{cv} directly

Perhaps it is better to use $\gamma_{\varphi,cv} < \gamma_\varphi$ to determine $\varphi_{cv,d}$?

$$\delta_d = k\varphi_{cv,d} = k\tan^{-1}\left(\frac{\tan\varphi_{cv,k}}{\gamma_{\varphi,cv}}\right)?$$

Should water pressures be factored?

For ultimate limit states (ULSs)…

design values [of groundwater pressures] shall represent the most unfavourable values that could occur during the design lifetime of the structure

For serviceability limit states (SLSs)…

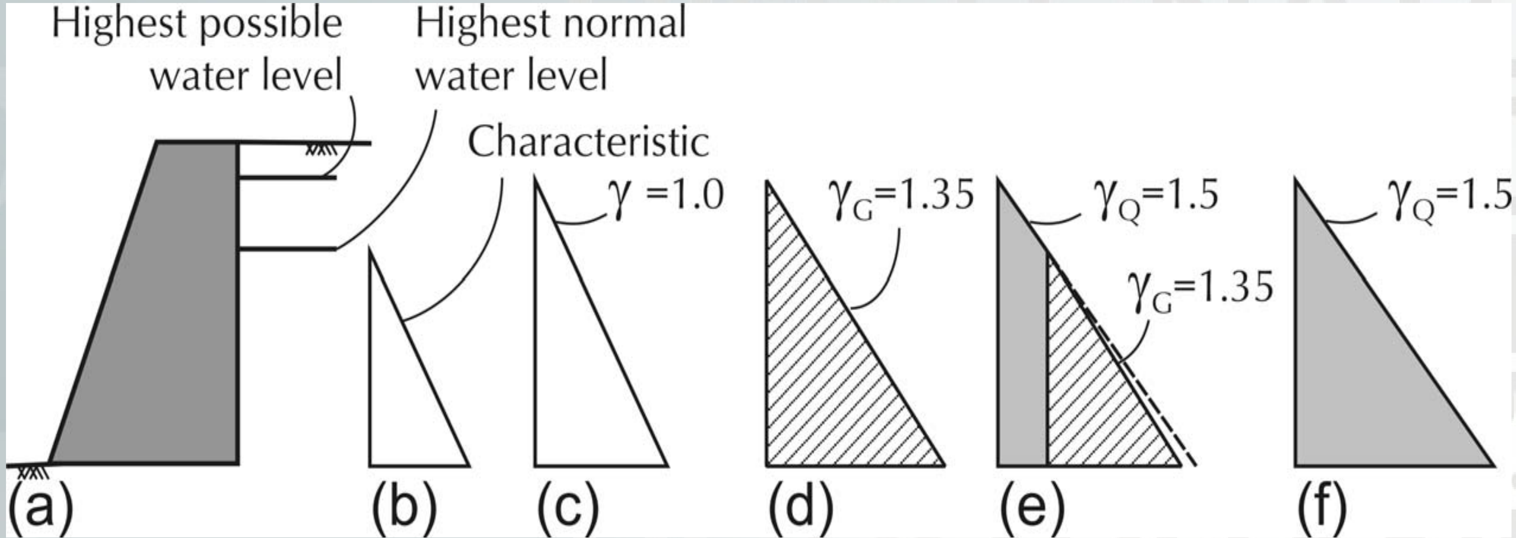
design values shall be the most unfavourable values which could occur in normal circumstances

[EN 1997-1 §2.4.6.1(6)P]

Design values of ground-water pressures may be derived either by applying partial factors to characteristic water pressures or by applying a safety margin to the characteristic water level…

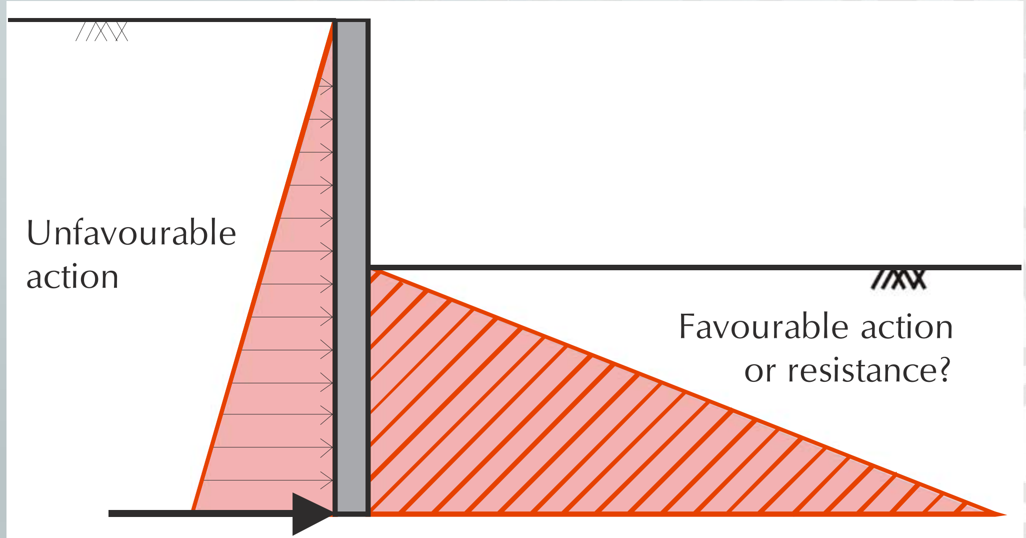
[EN 1997-1 §2.4.6.1(8)]

Possible ways of treating water pressures



a) Design water levels for ULS and SLS design situations
b) Characteristic water pressures for SLS design situation
c) Characteristic pressures for ULS = design pressures if no factor applied
d) Design pressures for ULS with factor on permanent actions (1.35)
e) Design pressures for ULS with factor on permanent actions (1.35) applied to normal water level and factor on variable (1.5) applied to rise highest possible water level
f) Design pressures for ULS with factor on variable actions (1.5)

Passive earth pressure: resistance or action?



Passive earth pressure	Multiply or divide by …	Design Approach (-Combination)			
		DA1-1	DA1-2	DA2	DA3
Resistance	Divide by γ_R	÷ 1.0	÷ 1.0	÷ 1.4	÷ 1.0
Favourable action	Multiply by $\gamma_{G,fav}$	x 1.0	x 1.0	x 1.0	x 1.0
Unfavourable action	Multiply by γ_G	x 1.35	x 1.0	x 1.35	x 1.0

Possible outcomes influenced by the ‘single source principle’

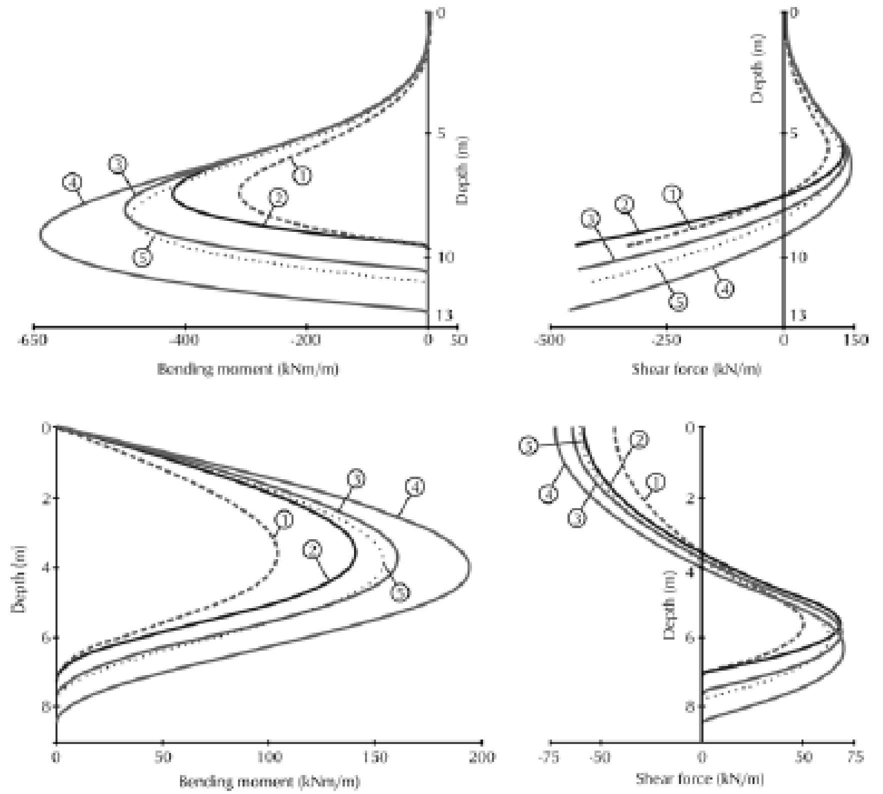


Figure 165. Bending moments (left) and shear forces(right) for (top) a cantilever and (bottom) a propped embedded wall, both retaining 5m of soil

“Unfavourable (or destabilising) and favourable (stabilising) permanent actions may in some situations be considered as coming from a single source. If … so, a single partial factor may be applied to the sum of these actions or to the sum of their effects”

EN 1997-1 §2.4.2(9) NOTE

DECODING

Summary of key points

EUROCODE 7

Impact of Eurocode 7 on basement design

Summary of key points

- Eurocode 7 replaces BS 8002 for geotechnics
  - Eurocode 2 replaces BS 8110 for concrete
  - Eurocode 3 replaces BS 5950 for steel
- Partial factors are similar, but the way they are applied is open to interpretation
- Design water pressures need to be selected carefully to balance reliability against realism
- Overall impact should be:

little change in what we build

more thought about how we design

‘Decoding Eurocode 7’

- 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 (Geomantix)
- Published by Spon in hardback, with colour section
- ISBN: 9780415409483