DECODING EUROCODES 2 + 7: DESIGN OF FOUNDATIONS

Dr Andrew Bond (Geocentrix)

Outline of talk

April 2010: the death of British Standards?

UK implementation of Eurocodes

Verification of strength: limit states STR and GEO

Some technical pitfalls

Guidance on use of Eurocodes

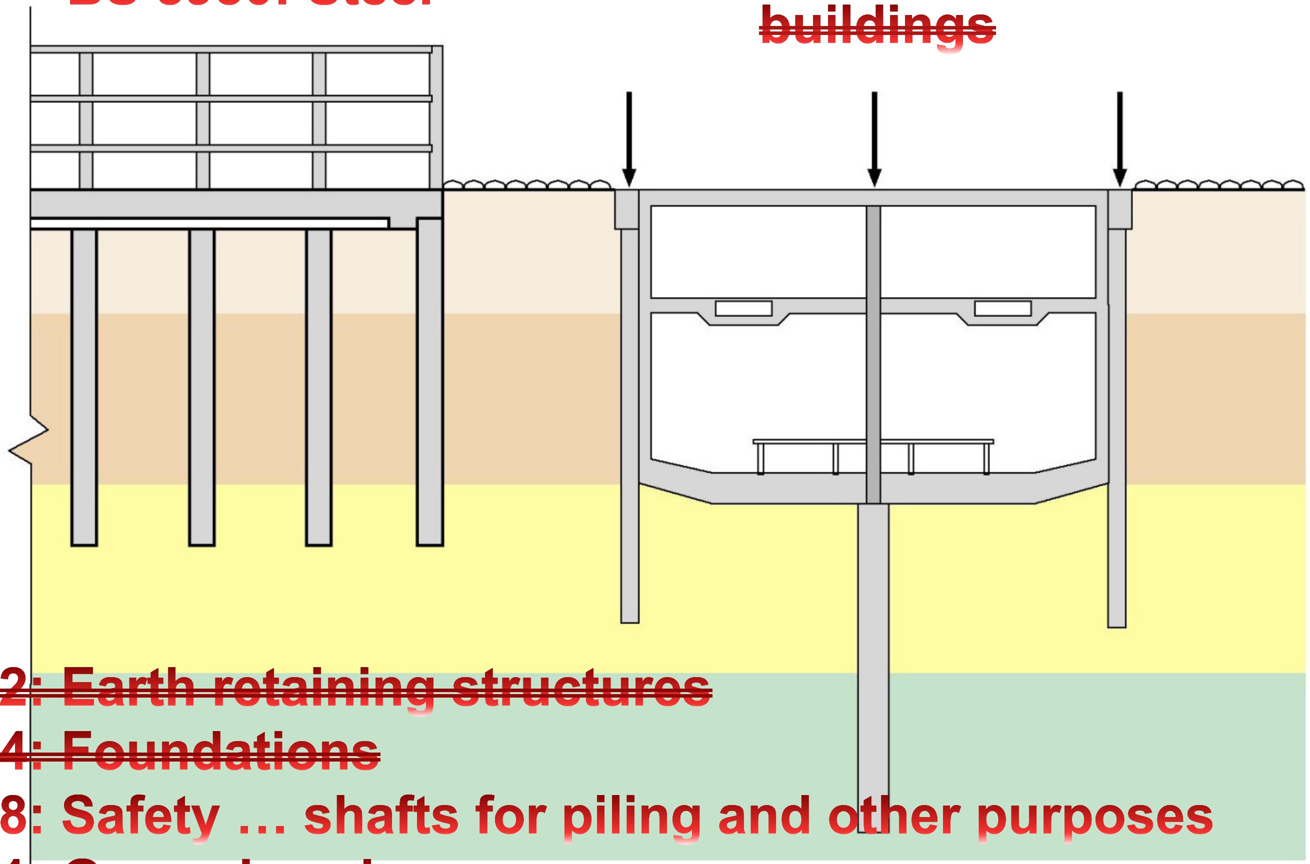
APRIL 2010: THE DEATH OF BRITISH STANDARDS?

British Standards for foundations prior to April 2010

~~BS 8110: Concrete~~

~~BS 5950: Steel~~

~~BS 6399: Loading for buildings~~



~~BS 8002: Earth retaining structures~~

~~BS 8004: Foundations~~

BS 8008: Safety … shafts for piling and other purposes

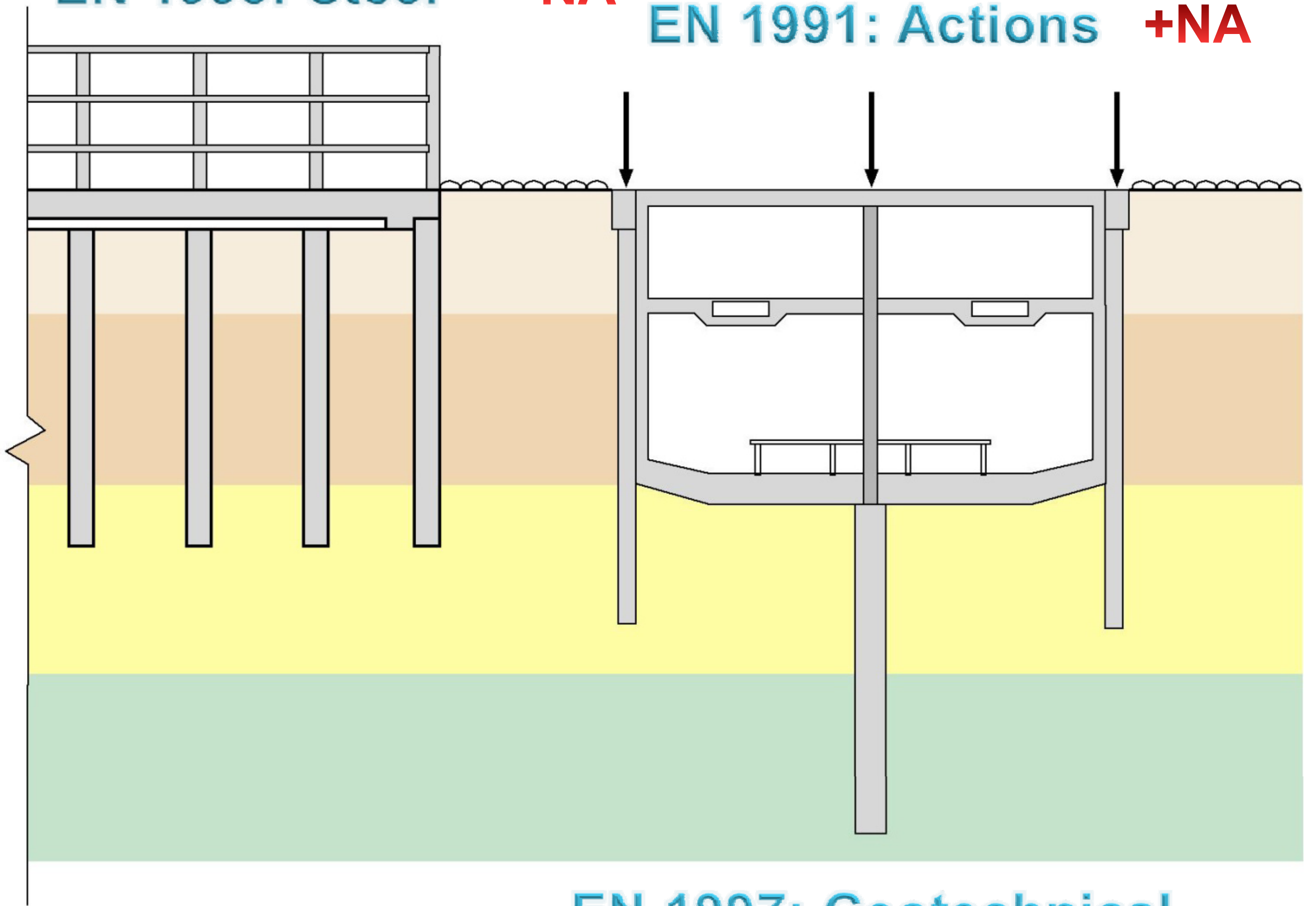
~~BS 8081: Ground anchorages~~

BS 8102: Protection of below ground structures against water from the ground

European design standards for foundations (Eurocodes)

EN 1992: Concrete +NA
EN 1993: Steel +NA

EN 1990: Basis +NA
EN 1991: Actions +NA

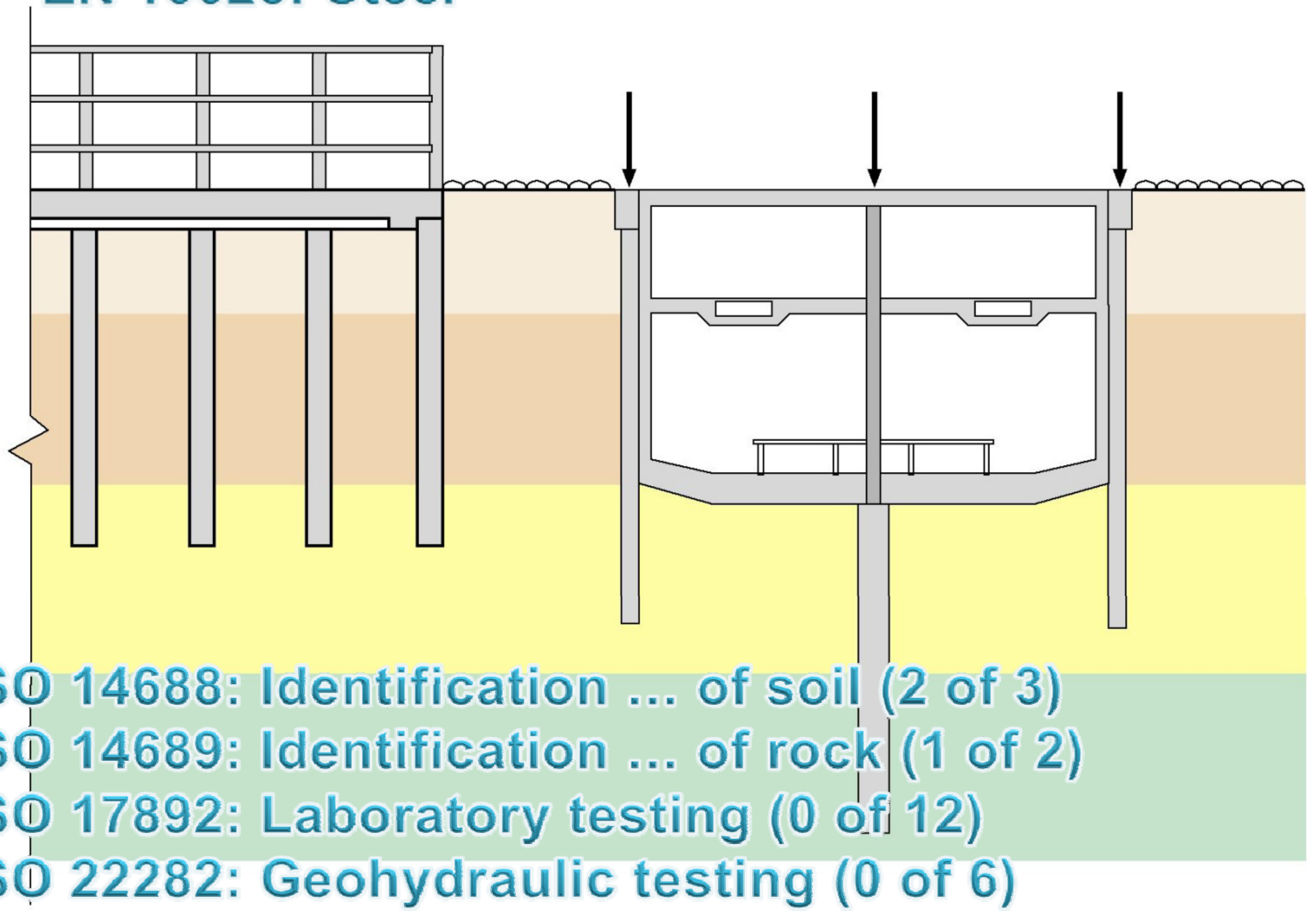


EN 1997: Geotechnical +NA
EN 1998: Earthquake resistance +NA

European specifications for materials (and testing standards)

EN 206-1: Concrete

EN 10025: Steel



EN ISO 14688: Identification … of soil (2 of 3)

EN ISO 14689: Identification … of rock (1 of 2)

EN ISO 17892: Laboratory testing (0 of 12)

EN ISO 22282: Geohydraulic testing (0 of 6)

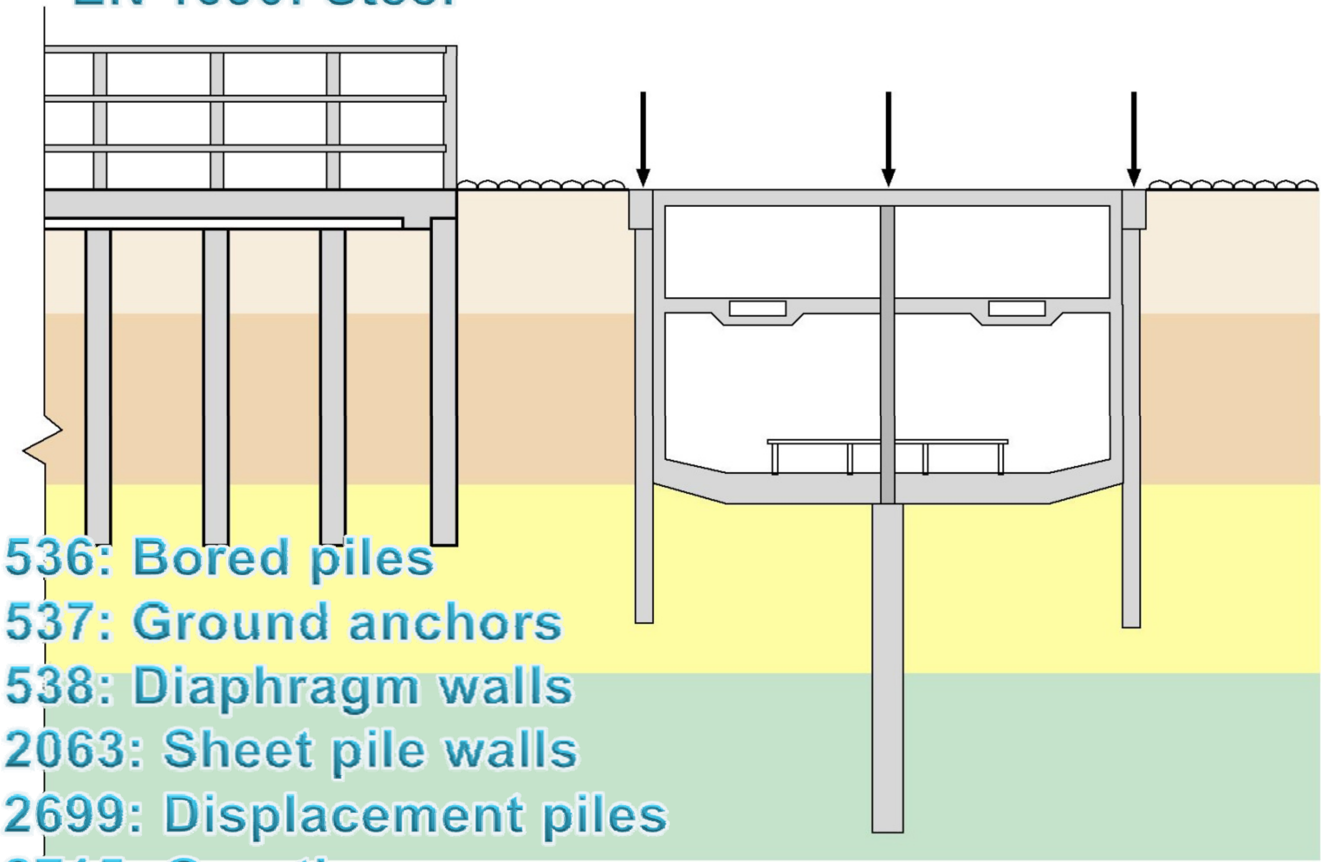
EN ISO 22475: Sampling & groundwater measurement (3/3)

EN ISO 22476: Field testing (5/13)

European execution standards

EN 13670: Concrete

EN 1090: Steel



EN 1536: Bored piles

EN 1537: Ground anchors

EN 1538: Diaphragm walls

EN 12063: Sheet pile walls

EN 12699: Displacement piles

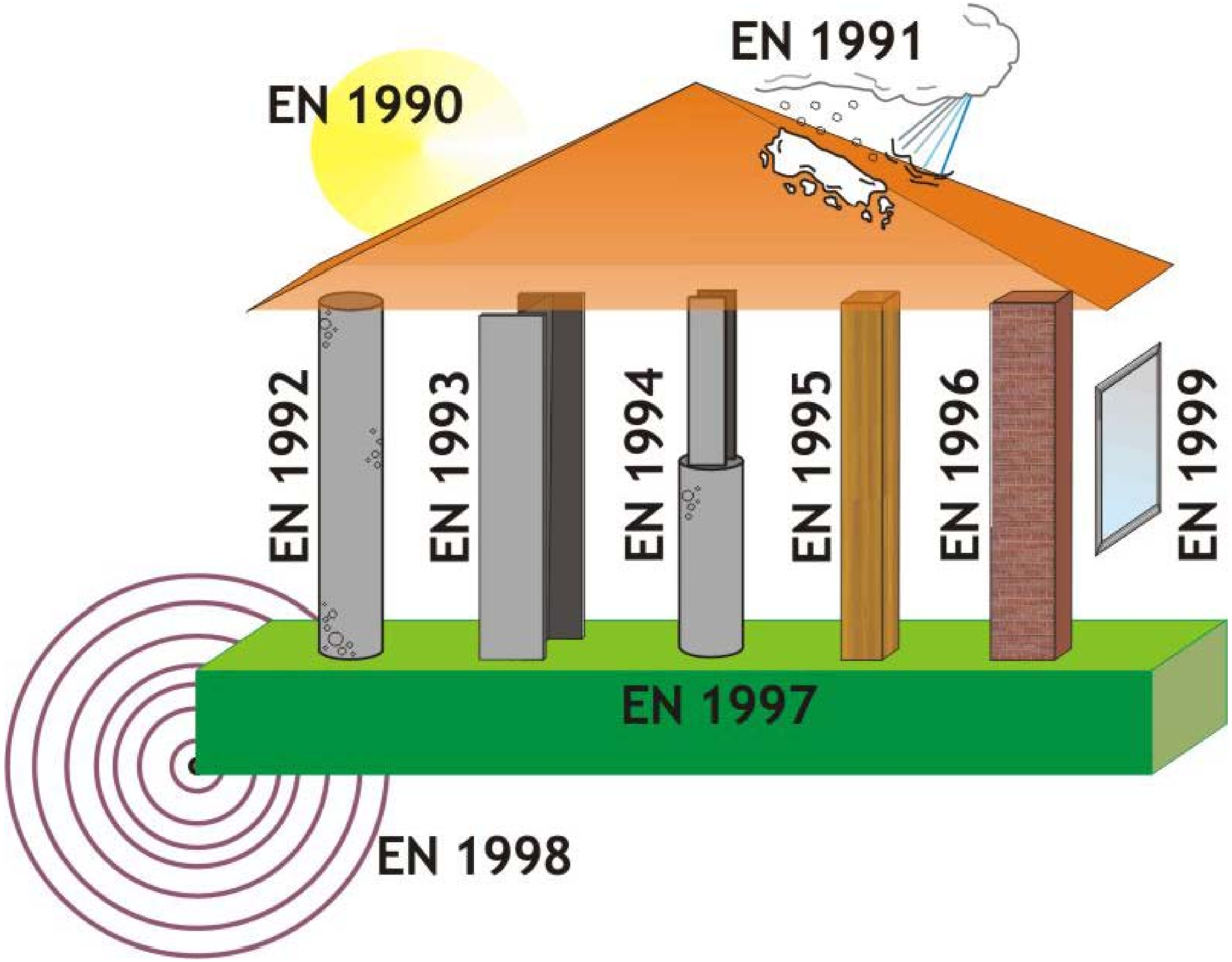
EN 12715: Grouting

EN 12716: Jet grouting

EN 14199: Micropiles

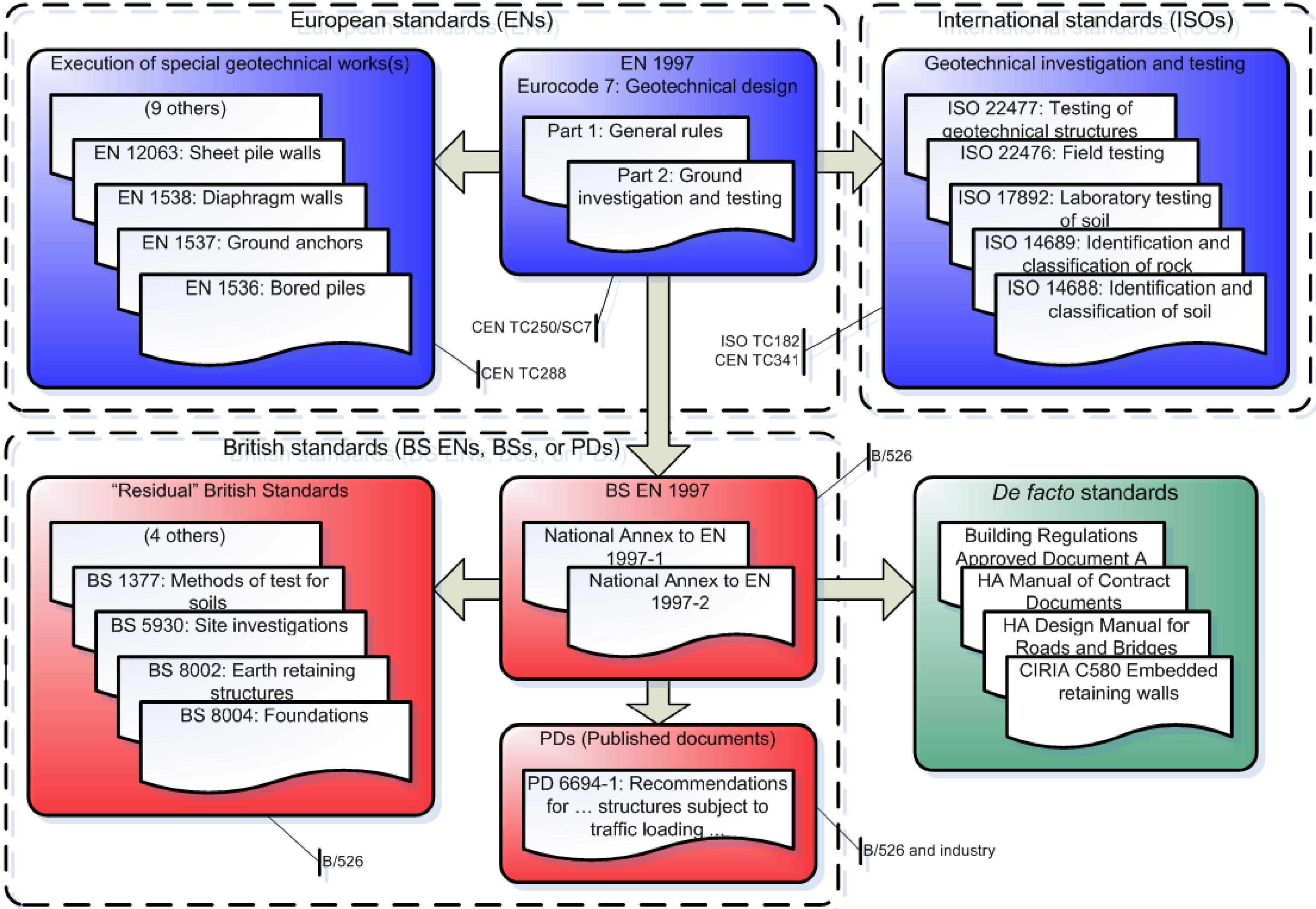
UK IMPLEMENTATION OF EUROCODES

The Eurocode family



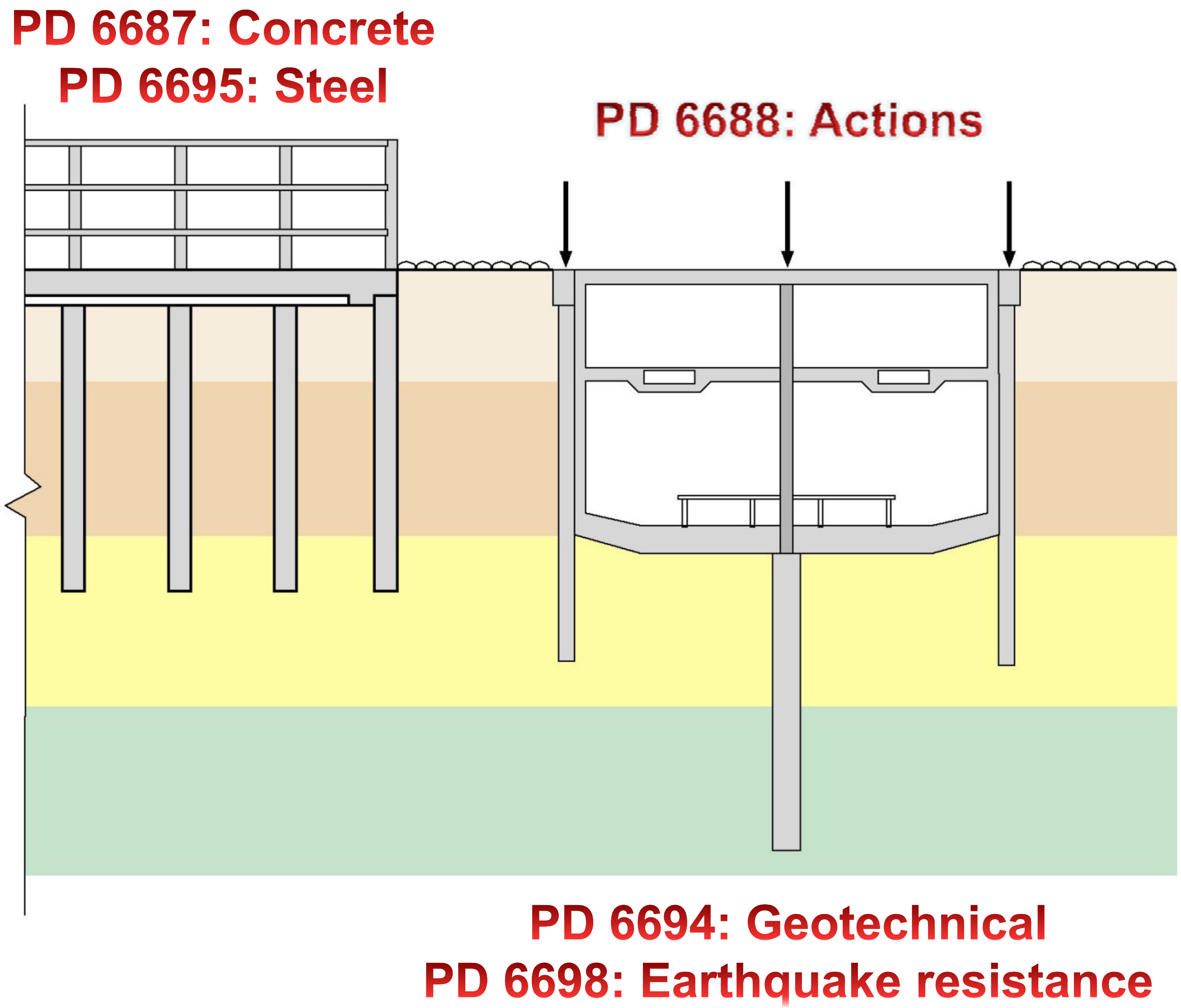
BOND AND HARRIS (2008)

Role of Eurocodes in UK practice

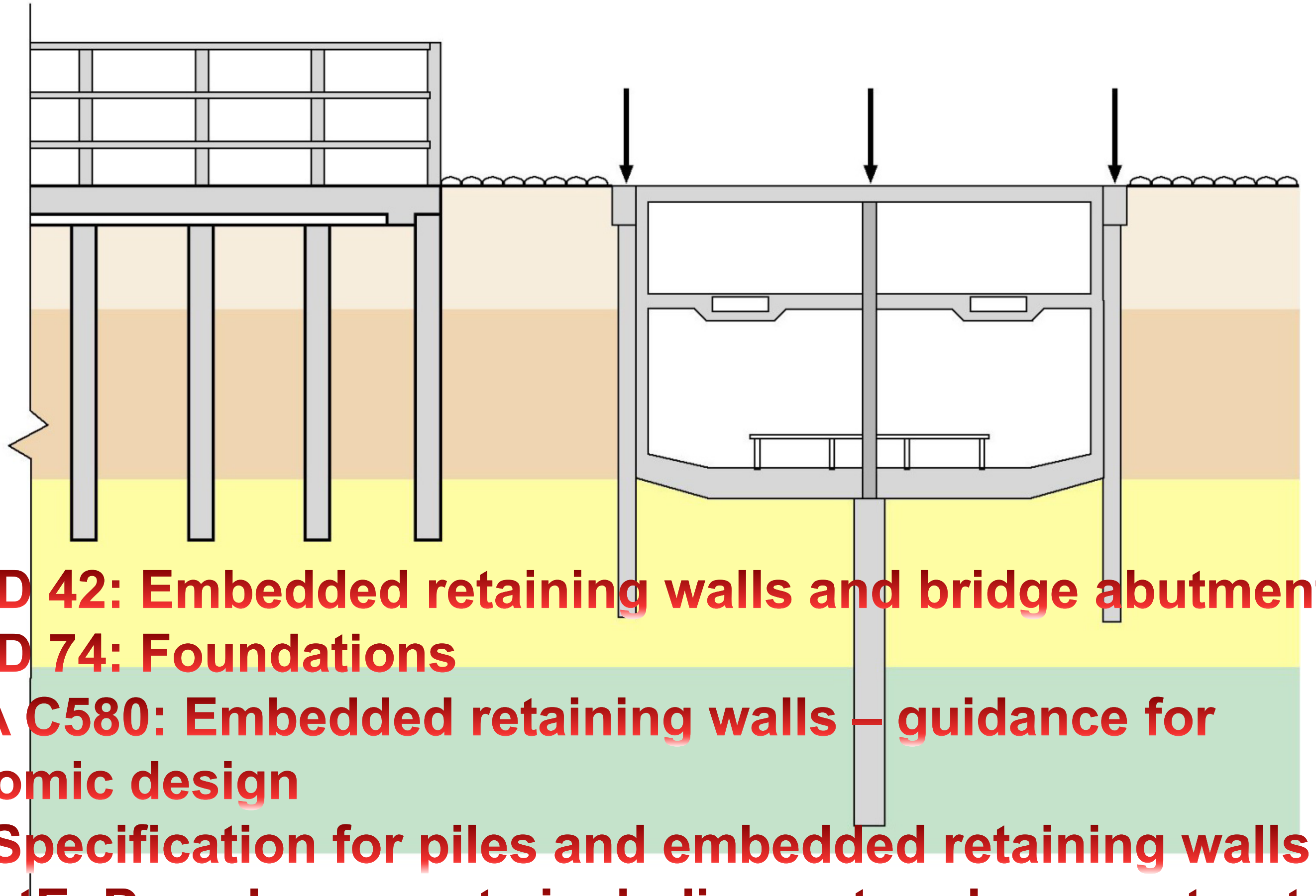


Bond and Harris (2008)

BSI 'Published Documents' to support the Eurocodes



‘De facto’ UK standards for basement design



HA BD 42: Embedded retaining walls and bridge abutments
HA BD 74: Foundations
CIRIA C580: Embedded retaining walls – guidance for economic design
ICE: Specification for piles and embedded retaining walls
IStructE: Deep basements including cut-and-cover structures
Arcelor: Piling Handbook

VERIFICATION OF STRENGTH: LIMIT STATES STR AND GEO

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 = design resistance corresponding to that effect

Applies to GEO:

"Failure or excessive deformation of the ground, in which the ***strength of soil or rock is significant*** *in providing resistance'*

EN 1997-1 §2.4.7.1(1)P

…and to STR:

"Internal failure or excessive deformation of the structure or structural elements … in which the ***strength of structural materials is significant*** *in providing resistance"*

EN 1997-1 §2.4.7.1(1)P

EN 1997-1 §2.4.7.1(1)P

Application of partial factors and tolerances

Actions

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

Material properties

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

Geometrical parameters

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

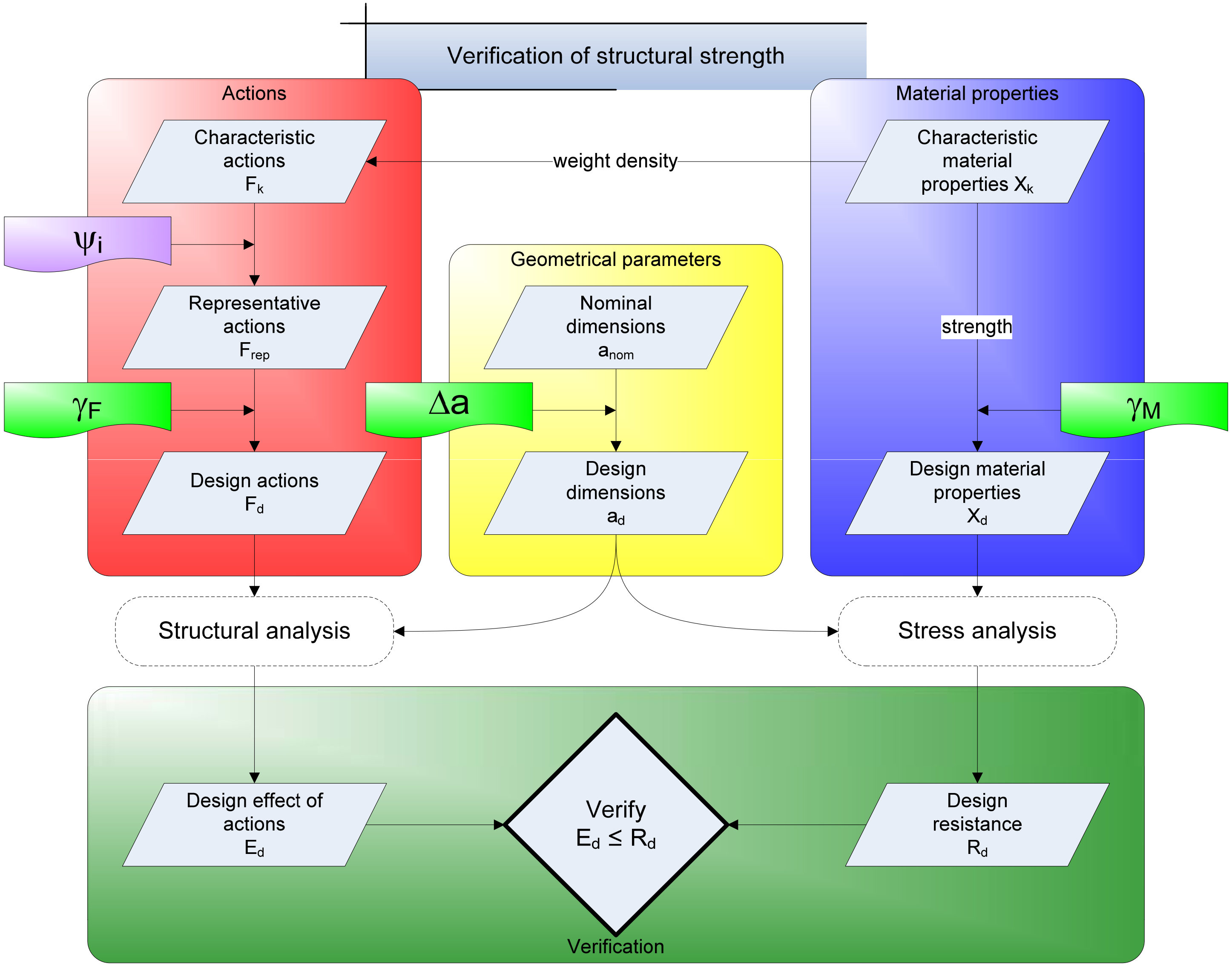
Effects of actions

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

Resistances

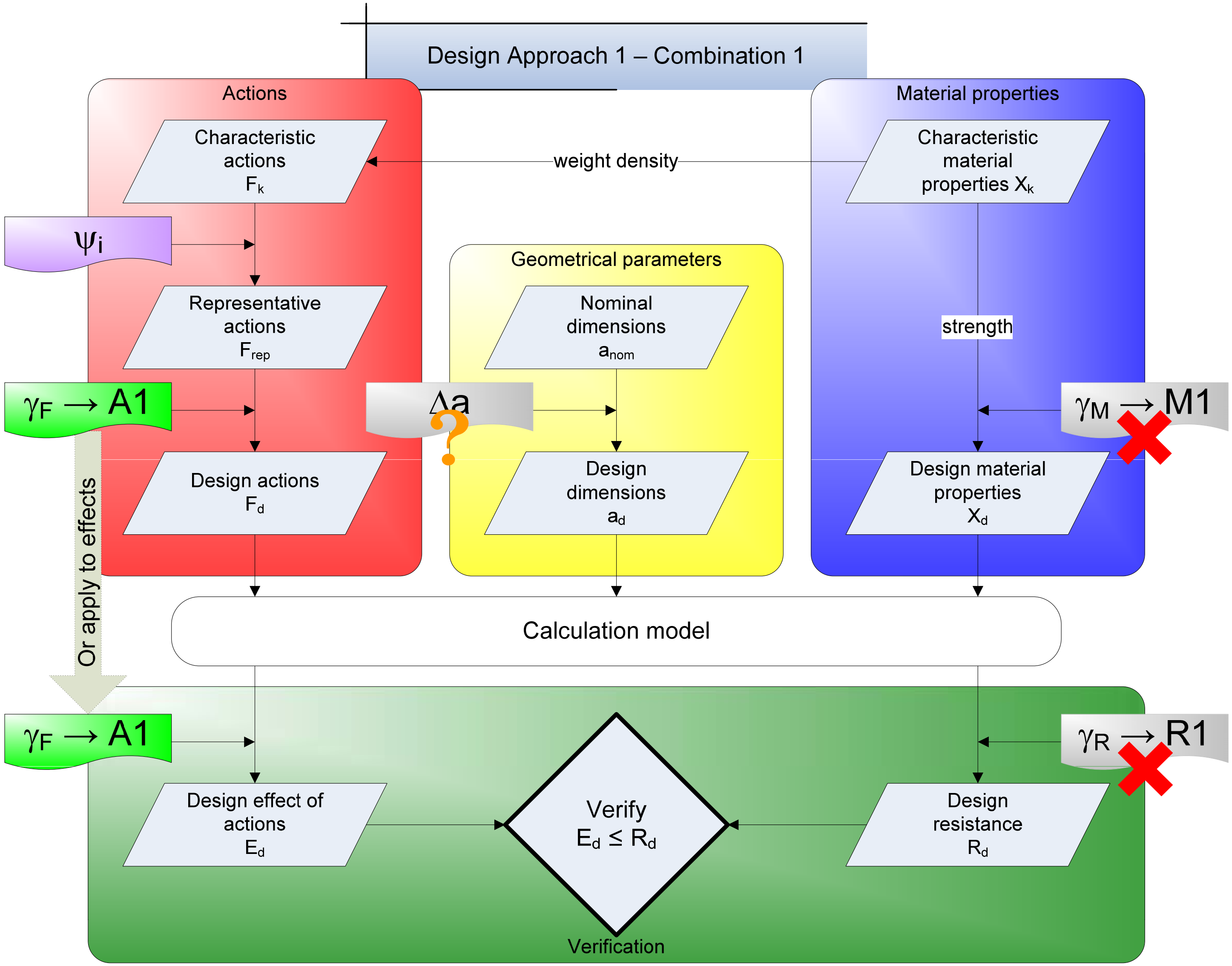
$$R_d = \frac{R\left\{F_d, X_d, a_d\right\}}{\gamma_R}$$

Verification of strength for STR (structural design)



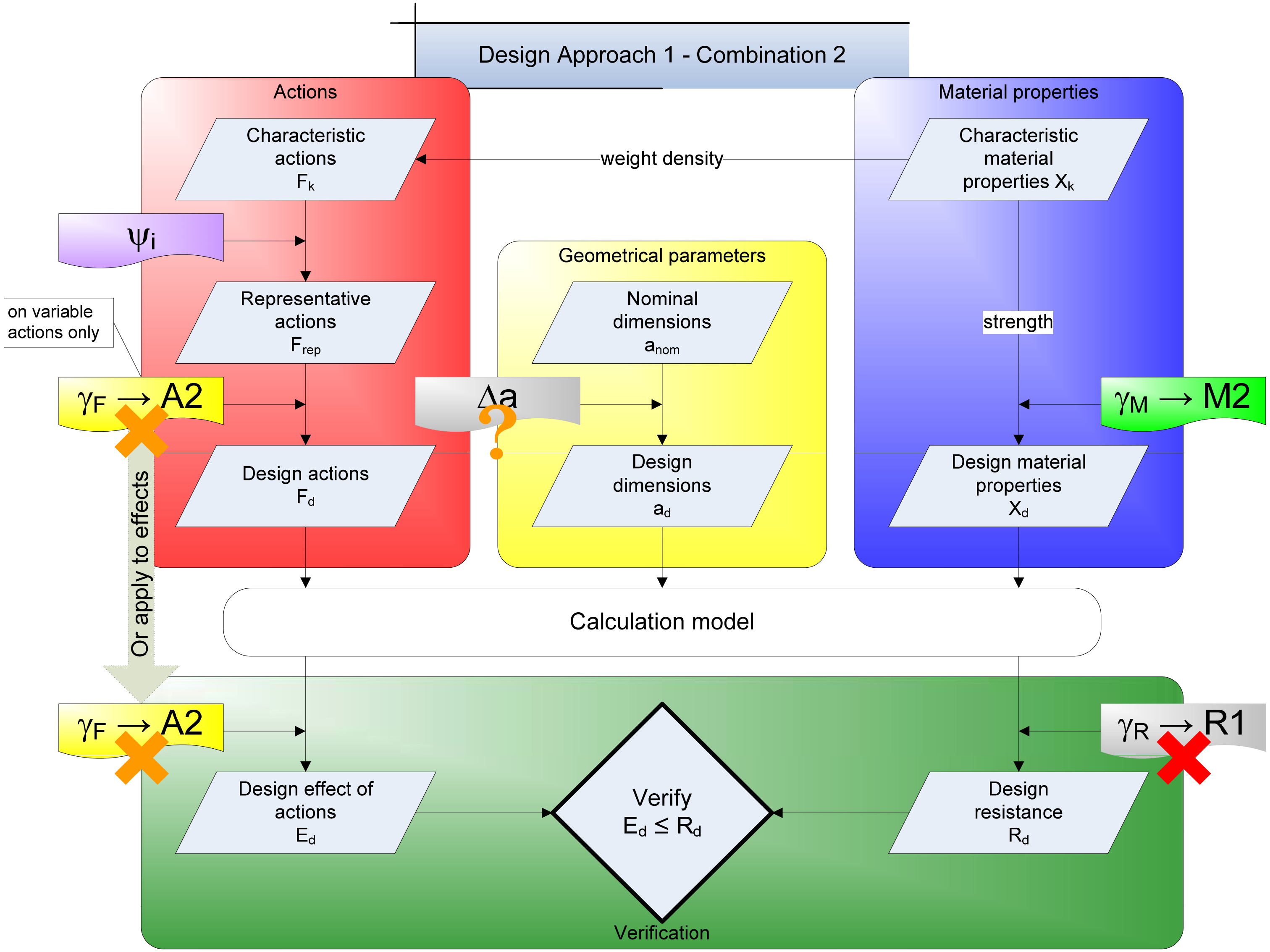
BOND AND HARRIS (2008)

Verification of strength for GEO/STR (DA1-1) †



BOND AND HARRIS (2008)

Verification of strength for GEO/STR (DA1-2) †



BOND AND HARRIS (2008)

Partial factors for 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}						

SOME TECHNICAL DETAILS

Design strength of concrete

Design compressive strength of concrete is:

$$f_{cd} = \alpha_{cc} f_{ck} / \gamma_c$$

f_{ck} = characteristic compressive strength of concrete (from cylinder tests)

γ_c = partial factor for concrete in compression

α_{cc} = factor for long term effects on compressive strength and unfavourable effects resulting from the way the load is applied

Design tensile strength of concrete is:

$$f_{ctd} = \alpha_{ct} f_{ctk,0.05} / \gamma_c = 0.21 \times \alpha_{ct} f_{ck}^{2/3} / \gamma_c$$

$f_{ctk,0.05}$ = characteristic tensile strength of concrete (5% fractile value)

α_{ct} = factor for long-term effects on tensile strength, etc.

[f_{ck} has units of MPa in this expression]

EN 1992-1-1 EXP (3.15-3.16) & TABLE 3.1

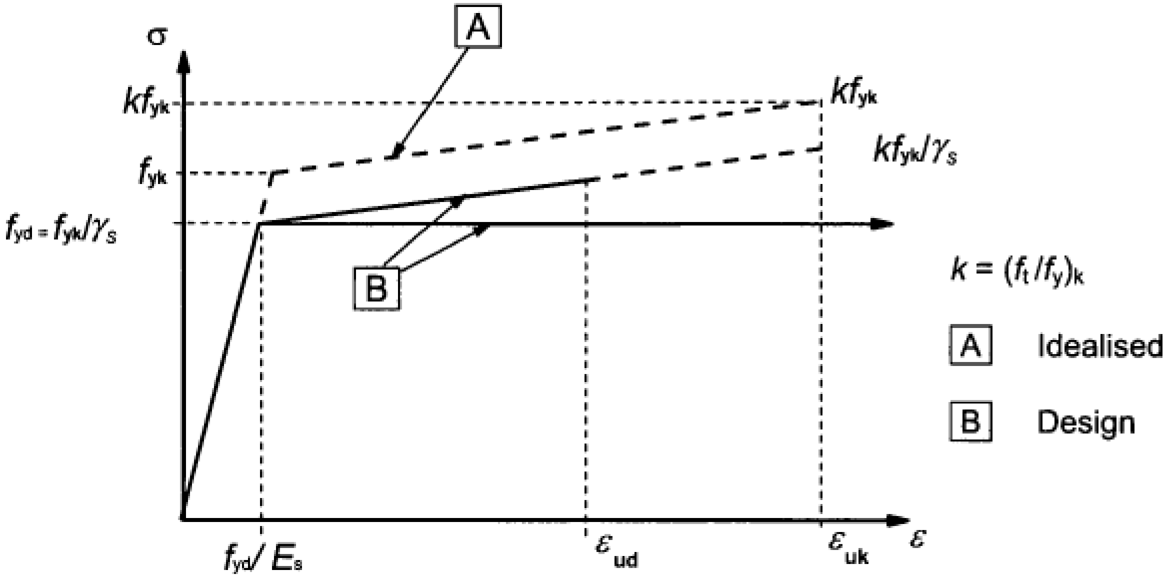
Design strength of reinforcing steel

Design yield strength of reinforcing steel is:

$$f_{yd} = f_{yk} / \gamma_s$$

f_{yk} = characteristic yield strength of reinforcing steel

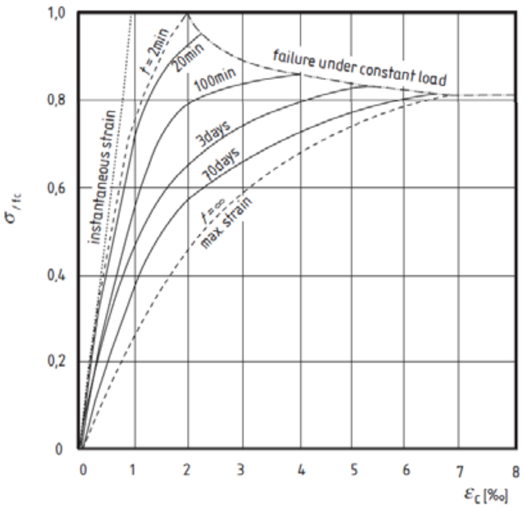
γ_s = partial factor for reinforcing steel



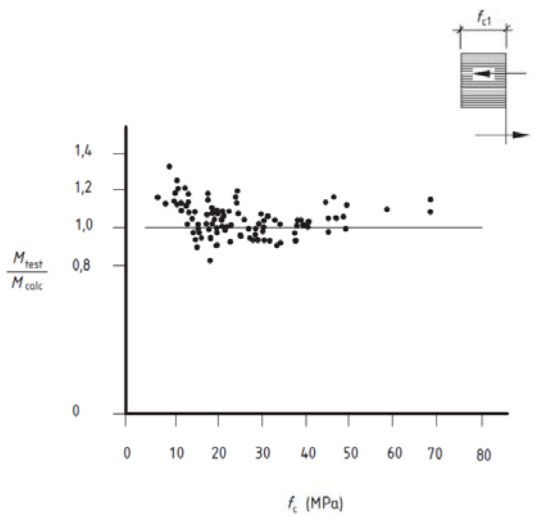
Factor for long-term effects on concrete strength

Document	Reinforced concrete		Plain/lightly-reinforced conc.	
	Compression	Tension	Compression	Tension
	α_{cc}	α_{ct}	$\alpha_{cc,pl}$	$\alpha_{ct,pl}$
EN 1992-1-1	1.0	1.0	0.8	0.8
UK NA (Amd 1)	0.85 flexure/axial 1.0 otherwise	1.0	0.6	0.8

Long- vs short-term strength



Justification for α_{cc} = 0.85



EN 1992-1-1 §3.1.6 & PD 6687

Partial factors for reinforced concrete

Limit states	Design situation	Reinforced concrete		Reinforcing and pre-stressing steel
		General	Piles*	γ_s
		γ_c	$k_f\gamma_c$	
Ultimate	Persistent	1.5	1.65	1.15
	Transient	1.5	1.65	1.15
	Accidental	1.2	1.32	1.0
	Seismic	1.0†	1.0†	1.0†
Serviceability		1.0	1.0	1.0

*Cast-in-place piles without permanent casing; k_f = 1.1

†Recommended value for situations not explicitly covered by EN 1992

EN 1992-1-1 §2.4.2.4 & 2.4.2.5

Bending resistance of singly-reinforced beam

Verification of bending resistance requires:

$$M_{Ed} \leq M_{Rd}$$

M_{Ed} = design value of applied bending moment effect

M_{Rd} = design bending resistance, given by:

$$M_{Rd} = A_s f_{yd} d \left(1 - \frac{f_{yd} A_s}{2 \eta f_{cd} b d} \right)$$

A_s = area of steel reinforcement

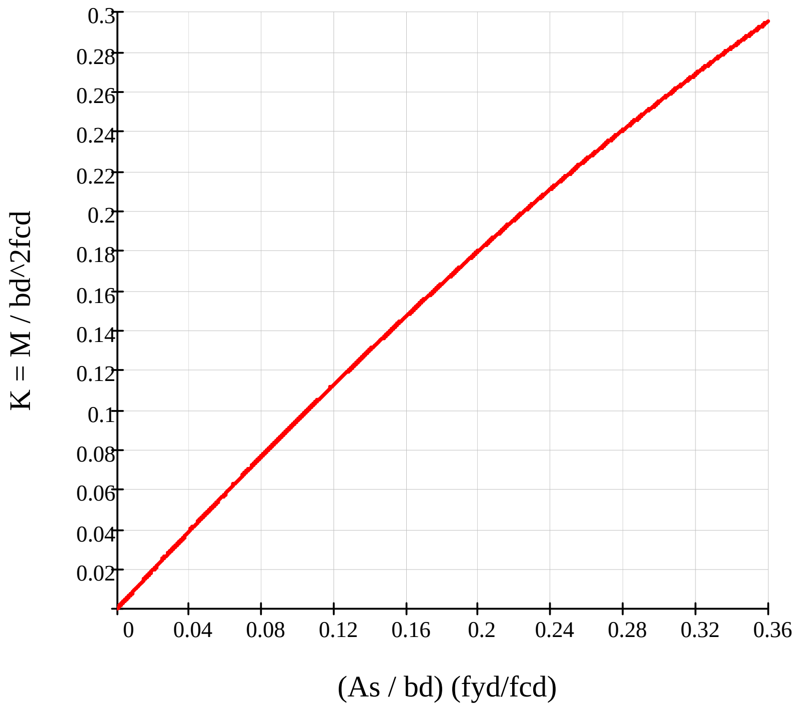
f_{yd} = design yield strength of reinforcing steel

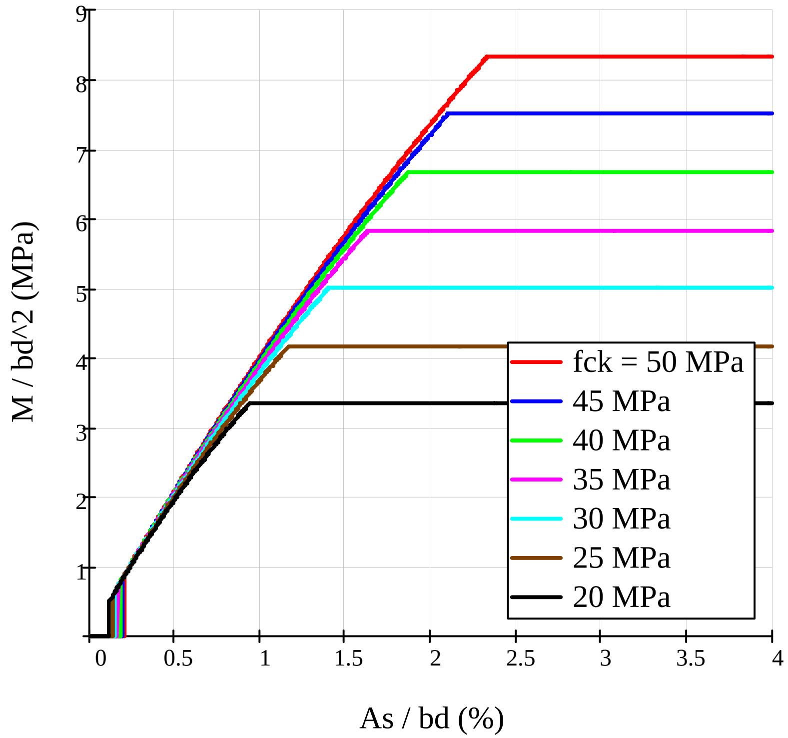
b = width of cross-section; d = its effective depth

f_{cd} = design compressive strength of concrete

η = 1.0

Design chats for singly-reinforced beams



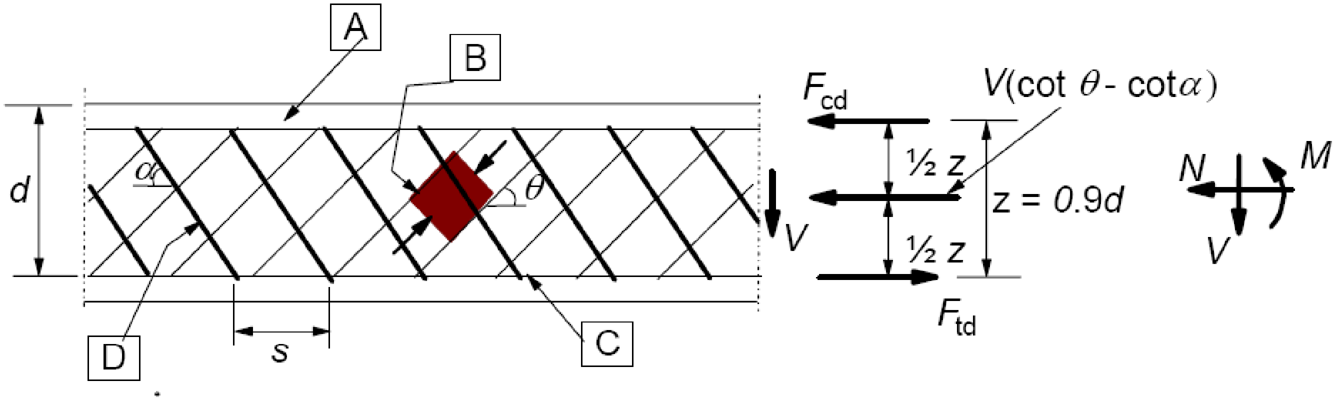


Differences between design aids

Design aids for Eurocode 2 that have appeared to date present N:M interaction diagrams in subtly different ways:

Author/Guide	Axes	Contours
TT Designer's Guide	$\frac{N_{Ed}}{h^2 f_{cd}} \text{ vs } \frac{M_{Ed}}{h^3 f_{cd}}$	$\frac{A_s f_{yd}}{h^2 f_{cd}}$
Concrete Centre	$\frac{N_{Ed}}{h^2 f_{ck}} \text{ vs } \frac{M_{Ed}}{h^3 f_{ck}}$	$\frac{A_s f_{yk}}{h^2 f_{ck}}$
TCC Spreadsheets	$N_{Ed}(kN) \text{ vs } M_{Ed}(kNm)$	A_s (e.g. 4B32)

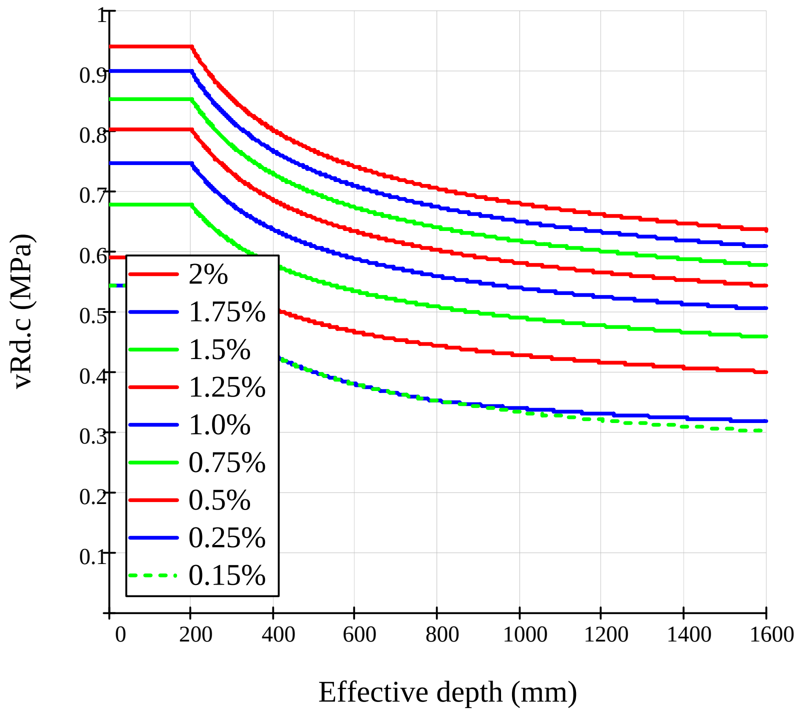
Truss model for variable strut inclination method

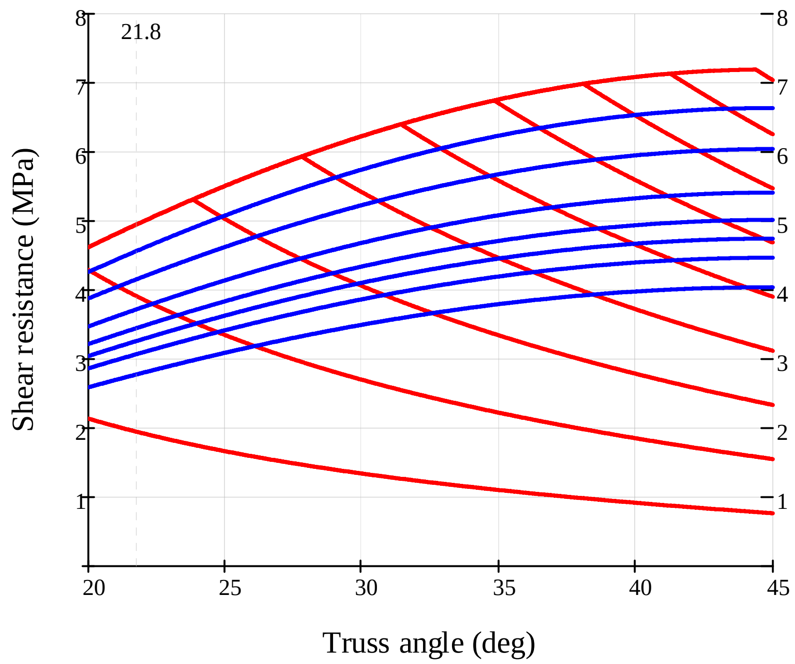


A - compression chord, B - struts, C - tensile chord, D - shear reinforcement

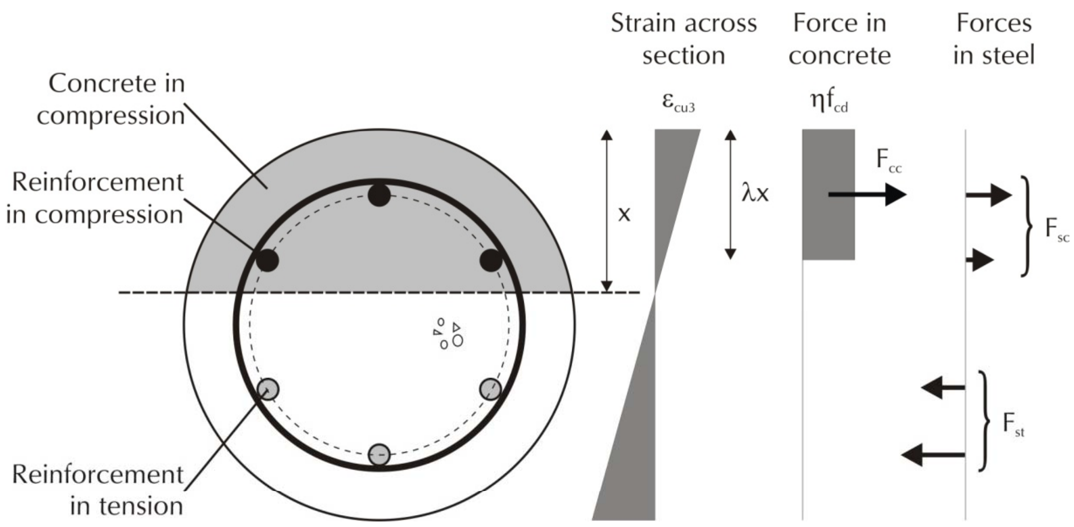
EN 1992-1-1 §6.2.3(1)

Design charts for shear resistance





Assumptions used to develop N:M interaction charts



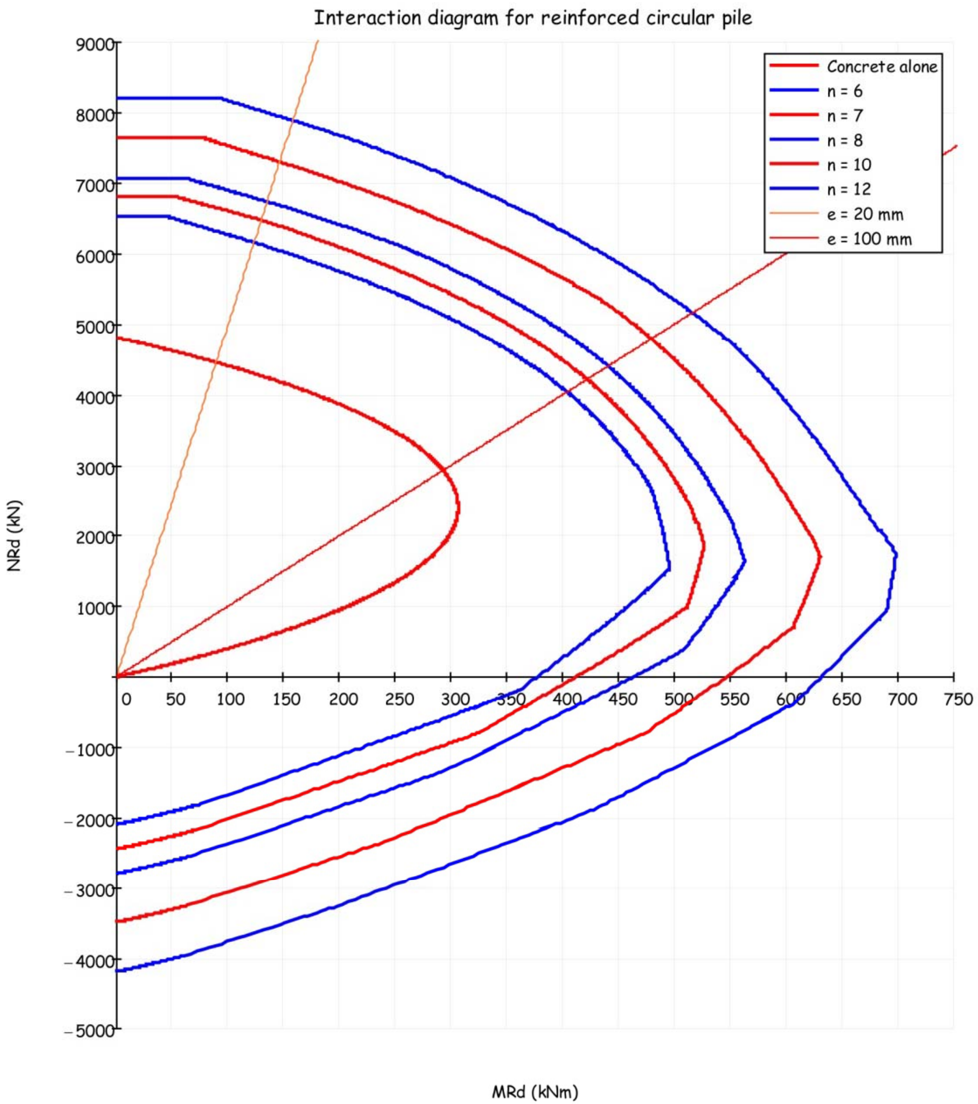
Reinforcing bars are (rotationally) symmetrical about the pile centre

Above neutral axis, concrete and reinforcing bars provide compression force

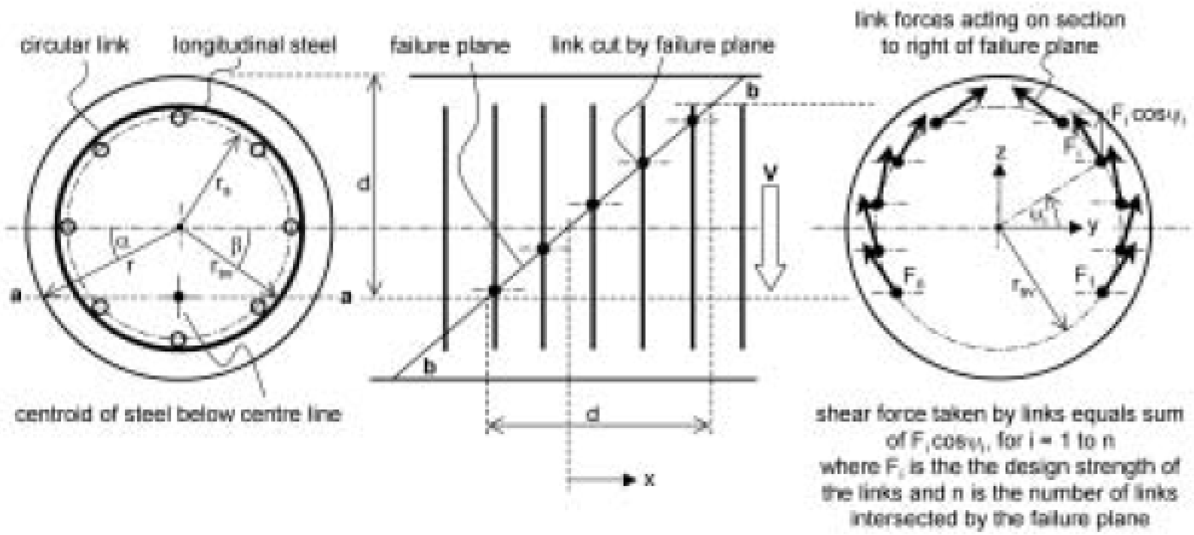
Below neutral axis, only reinforcing bars provide tension

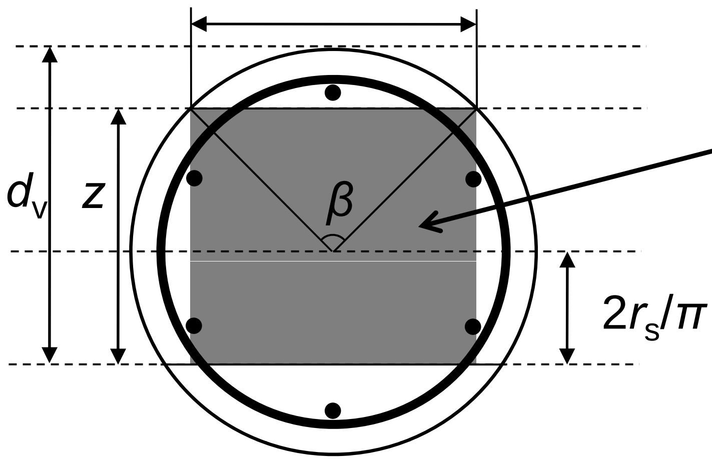
Shape of concrete in compression = segment of circle; must deduct area of steel in compression zone from it

Circular pile (D = 600 mm, c = 75 mm, ϕ_l = 32 mm, ϕ_t = 8 mm)

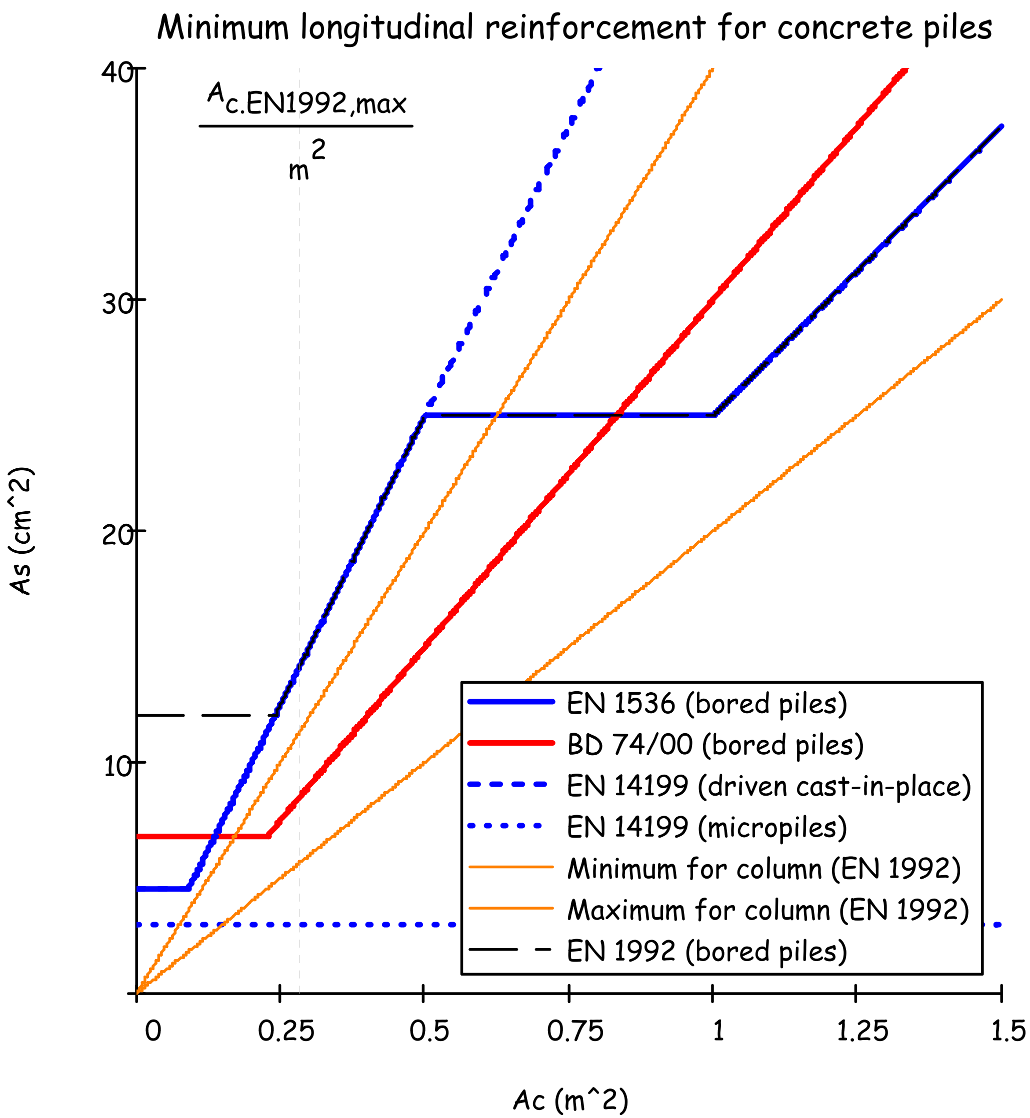


Feltham (2004), paper in *The Structural Engineer*





Comparing minimum reinforcement for concrete piles



GUIDANCE ON USE OF EUROCODES

Guidance from SCI/BCSA/Corus/Concrete Centre

Designers' Guides, 'Decoding' book and blog

Decoding the Eurocodes
News and views about the Structural Eurocodes

14 APRIL 2010

Resolution 91

Resolution 91, Pavia, 14 April 2010

Subject: nomination of chairman

> CEN/TC 250/SC 7 Geotechnical design, taking account of the CEN Internal Regulations Part 2, art 2.3.3 and 2.4, agrees with the nomination made by the secretariat of Dr. A.J. Bond as chairman of CEN/TC 250/SC 7, for a period of 3 years, starting on 1 June 2010.

This resolution was agreed by unanimity.

***

I am very honoured to have been selected to chair the Eurocode 7 committee and I hope to emulate the success of its three previous chairs, the late Niels Krebs-Ovesen, Roger Frank, and Bernd Schuppener.

Andrew Bond

04:57 PM in CEN, Eurocode 7 | Permalink | Comments (0) | TrackBack (0)

12 APRIL 2010

Found the missing NAs

Clare Price of BSI has explained to me why I cannot find the UK National Annexes to six of the 57 Eurocodes needing them ...

For BS EN 1993-3-2, no UK NA is required as the responsible BSI committee does not expect users to use this document in the UK as CICIND will continue to be used instead.

For the remaining five standards, no UK NA will be issued because the National Forward states:

- all the Recommended Values should be used
- all Informative Annexes may be used
- no NCCI have currently been identified

This applies to these standards:

- BS EN 1993-1-6
- BS EN 1993-1-7

Recent Posts

- Resolution 91
- Found the missing NAs
- TC250/SC7 meeting in Pavia
- Eurocode newsround
- Eurocode 7: the more things remain the same, the more things change!
- Why we need standards: PowerPoint centimeters different from actual centimeters
- Another UK NA published ... but 6 still outstanding
- EN-day comes ... and goes
- Where in the world are ... the investigation and testing standards?
- 14th Danube-European Conference on Geotechnical Engineering

Pages

- When an irresistable force meets an immovable object

Categories

BGA Books BSI CEN Earthworks ETC10 Eurocode 0 Eurocode 2 Eurocode 3 Eurocode 7 Ground investigation Head Eurocode ICE Ireland IStructE JRC Seminars Singapore South Africa Structural Eurocodes Training courses

WWW.EUROCODE7.COM

‘Decoding’ training courses from Geocentrix

Speakers

Andrew Bond (Geocentrix)
MA MSc PhD DIC MICE CEng
... is Chairman of the Eurocode 7 Committee TC250/SC7, co-author of the book ‘Decoding Eurocode 7’, and architect/developer of the design programs ReWaRD, Repute, and Redoubt. He has 30 years experience in foundation design.

Owen Brooker (Modulus)
BEng CEng MICE MIStructE
... is a Member of IStructE's Technical Publications Panel and a former member of Eurocodes Expert Advisory Group. He has written many publications and guidance on Eurocode 2 and advised Highways Agency on EC2 implementation.

David Brown (SCI)
BEng MICE CEng
... is Associate Director at the Steel Construction Institute, a member of ECCS Technical Committee on Stability and BSI's Committee on Loading. He has authored several SCI Publications including Eurocode publications on steel. He regularly gives lectures on Eurocode 3.

The ‘Fundamentals’ courses require no prior knowledge of Eurocode 7 and serve as starters for the ‘Design’ courses

Basis of geotechnical design

- Standards for geotechnical design
- Eurocode 7 Part 1 General rules
- Verification of strength (GEO) + Workshop
- Verification of stability (UPL/HYD/EQU) + Workshop
- Verification of serviceability
- Execution standards

Fundamentals
Leeds 24/25 August
London 22/23 September

Design of shallow foundations

- Standards for geotechnical design of shallow foundations
- Basis of design for shallow foundations
- Geotechnical design of spread foundations + workshop
- Geotechnical design of gravity walls + workshop
- Geotechnical design of slopes and embankments + workshop

Geo/structural design
Leeds 19/20 October
London 23/24 November

Design of deep foundations

- Standards for geotechnical design of deep foundations
- Basis of design for deep foundations
- Geotechnical design of embedded walls + workshop
- Geotechnical design of pile foundations + workshop
- Field testing of pile foundations + workshop

Geo/structural design
Leeds 7/8 December
London 12/13 January

Ground investigation and testing

- Standards for ground investigation and testing
- Eurocode 7 Part 2 Ground investigation and testing
- Planning site investigations + workshop
- Ground characterization + workshop
- Geotechnical reports (GDR and GIR) + workshop

Design of concrete foundations

New!

- Standards for structural design of concrete foundations
- Basis of design for concrete foundations
- Structural design of spread foundations + workshop
- Structural design of semi-gravity walls + workshop
- Structural design of pile foundations + workshop
- Connections between structure and foundation

Design of steel foundations

New!

- Standards for structural design of steel foundations
- Basis of design for steel foundations
- Structural design of sheet pile walls + workshop
- Structural design of steel bearing piles + workshop
- Structural design of walings + workshop
- Connections between structure and foundation

WWW.GEOCENTRIX.CO.UK/TRAINING

‘The Eurocode Scream’

JACK OFFORD (WITH APOLOGIES TO MUNCH)

FURTHER INFORMATION IS AVAILABLE AT ….

Eurocode 7 training: www.geocentrix.co.uk

Eurocode 7 book: www.decodingeurocode7.com

Eurocode 7 blog: www.eurocode7.com