2nd generation
Decoding ^ Eurocode 7
2nd generation geotechnical design

DR ANDREW BOND (GEOCENTRIX)
CHAIR B/526 GEOTECHNICS
PAST-CHAIR TC250/SC7 GEOTECHNICAL DESIGN

Decoding 2nd generation Eurocode 7

2nd generation geotechnical design

- General rules
- Verification of limit states
- Obtaining appropriate values of ground properties
- Summary of key points

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General rules

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Scope of Eurocode 7 Part 1

"[Eurocode 7 Part 1] provides ***general rules for the design and verification of geotechnical structures****"*

EN 1997-1

- **EN 1997-1** establishes:
  - additional **principles and requirements** to those given in EN 1990 **for the safety, serviceability, robustness, and durability of geotechnical structures**
- Design and verification in EN 1997-1 are based on:
  - **partial factor method**
  - **prescriptive rules**
  - **testing**
  - **the Observational Method**

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Assumptions made by EN 1997

In addition to the assumptions given in EN 1990, EN 1997 (all parts) assumes:

- **ground investigations** are planned by individuals or organizations **knowledgeable about potential ground and groundwater conditions** New
- ground investigations are executed by individuals with appropriate skill and experience
- evaluation of test results and derivation of ground properties from ground investigation are carried out by individuals with **appropriate geotechnical experience and qualifications** New
- data required for design are collected, recorded, and interpreted by appropriately qualified and experienced individuals
- geotechnical structures are designed and verified by individuals with **appropriate qualifications and experience in geotechnical design** New
- adequate continuity and communication exist between individuals involved in data-collection, design, verification and execution

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Basic requirements of EN 1997-1

*"**The assumptions** given in [EN 1997-1] **shall be verified**"*

EN 1997-1, 4.1.1(1)

The following models shall be used to verify the requirements for safety, serviceability, robustness, and durability of geotechnical structures:

- **Ground Model** ← New
- **Geotechnical Design Model** ← New

Ground Model

- site specific outline of the disposition and character of the ground and groundwater based on results from ground investigations and other available data

Geotechnical Design Model

- conceptual representation of the site derived from the ground model for the verification of each appropriate design situation and limit state

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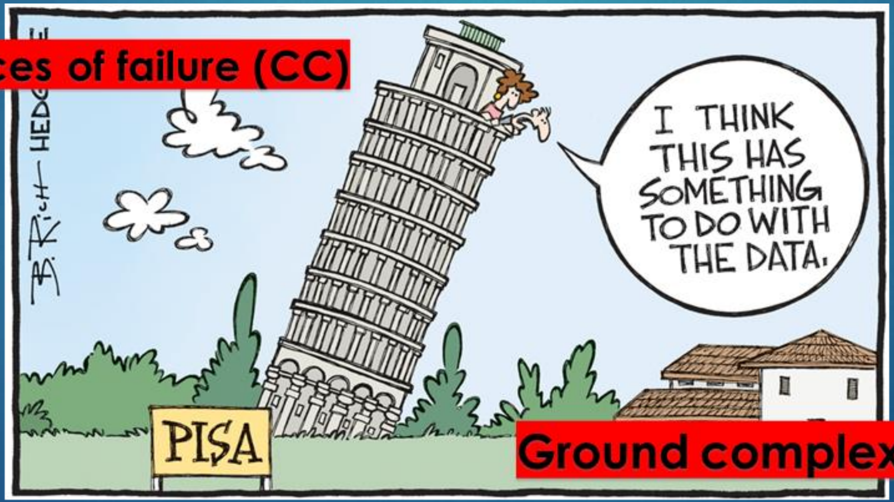
1st generation Eurocode 7 Definition of Geotechnical Category

*'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***

*'… **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 1997-1:2004, 2.1(8)P



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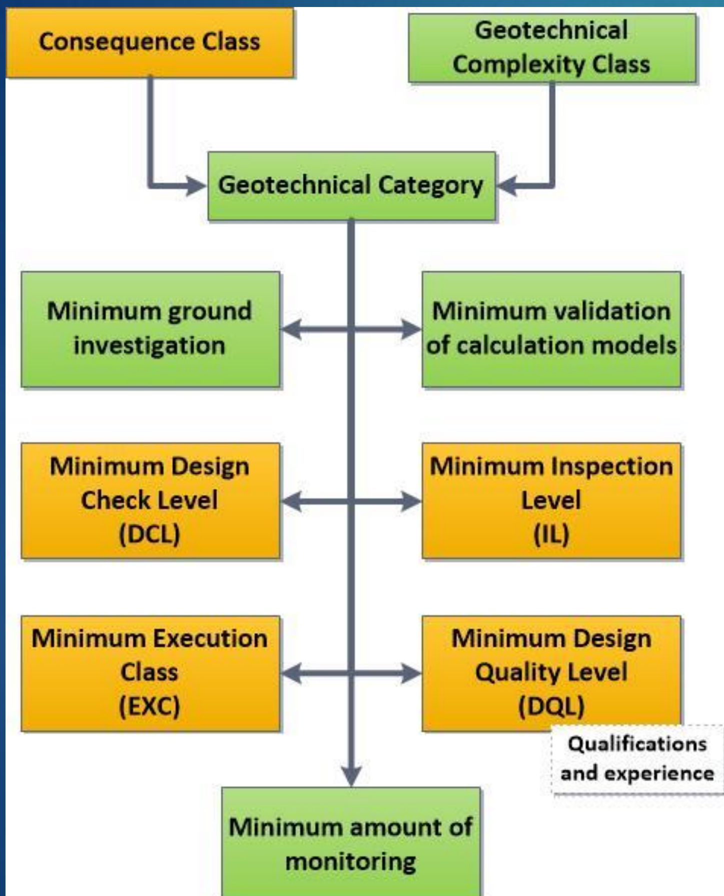
Quality management measures in EN 1997-1



Conse-quence Class	Geotechnical Complexity Class (GCC)		
	Lower (GCC1)	Normal (GCC2)	Higher (GCC3)
CC3			GC3
CC2		GC2	
CC1	GC1		

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Verification of limit states

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Ultimate limit states to be verified

The following ultimate limit states shall be verified, as relevant:

- failure of the structure or the ground, or any part of them including supports and foundations, **by rupture, excessive deformation, transformation into a mechanism, or buckling**
- **loss of static equilibrium** of the structure or any part of it (including buoyancy)
- failure of the ground by **hydraulic heave, internal erosion, or piping caused by excessive hydraulic gradients** (see EN 1997-1 for details)
- failure caused by **fatigue** (see other Eurocodes for details)
- failure caused by **vibration**
- failure caused by other **time-dependent effects**

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Serviceability criteria for foundations

*"The **design criterion for** the serviceability limit state $C_{d,SLS}$ for **foundation movement** beneath a building **shall be selected during the design of the supported structure**"*

EN 1990, A.1.8.4(1)

The sensitivity of a structure to foundation movement:

- should be classified separately for different modes of foundation movement
- should consider the ground conditions within the zone of influence of the structure

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Suggested maximum deformation of foundations (with examples)

Structural Sensitivity Class		Maximum differential settlement† $\Delta s_{Cd,SLS}$ (mm)	Maximum angular distortion† $\beta_{Cd,SLS}$ (%)	Maximum tilt $\omega_{Cd,SLS}$ (%)
SSC5	Highest	10	0.05	0.1 Towers* $h \geq 100$ m Lift and escalator operation
SSC4	High	15	0.075	0.2 60 m $\leq h <$ 100 m
SSC3	Normal	30	0.15 Framed buildings and reinforced load-bearing walls	0.3 24 m $\leq h <$ 60 m
SSC2	Low	60	0.3	0.4 $h <$ 24 m
SSC1	Lowest	100 Utility connections	0.5 Floor slabs	0.5

*Towers and tall buildings

†EN 1997-1:2004 Annex H gave:

- settlements ($s_{Cd,SLS}$) up to 50 mm "are often tolerable for isolated foundations"
- for sagging, $\beta_{Cd,SLS}$ = 0.05-0.33 % typically, with 0.2 % reasonable for most structures
- for hogging, $\beta_{Cd,SLS}$ = 0.1-0.66 % typically, with 0.4 % reasonable for most structures

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Verification of ultimate limit states

Ultimate limit states are verified by checking that:

$$\overbrace{E_{\mathrm{d}}}^{\substack{design\ effect\\ of\ actions}} \leq \overbrace{R_{\mathrm{d}}}^{\substack{corresponding\\ design\ resistance}}$$

where:

New

$$E_{\mathrm{d}} = \underbrace{\gamma_{\mathrm{Sd}}}_{\substack{model\\ factor}} \times \underbrace{E}_{function\ of} \left\{ \underbrace{\Sigma(\gamma_{\mathrm{f}} \psi F_{\mathrm{k}})}_{\substack{combination\\ of\ actions}} ; \underbrace{a_{\mathrm{d}}}_{\substack{geometrical\\ properties}} ; \boxed{\underbrace{X_{\mathrm{Rd}}}_{\substack{material\ properties\\ used\ to\ calculate\ R_{\mathrm{d}}\\ (either\ X_{\mathrm{d}}\ or\ X_{\mathrm{rep}})}}} \right\}$$

and:

New

$$R_{\mathrm{d}} = \frac{1}{\underbrace{\gamma_{\mathrm{Rd}}}_{\substack{model\\ factor}}} \times \underbrace{R}_{function\ of} \left\{ \frac{\eta X_{\mathrm{k}}}{\underbrace{\gamma_{\mathrm{m}}}_{\substack{material\\ properties}}} ; \underbrace{a_{\mathrm{d}}}_{\substack{geometrical\\ properties}} ; \boxed{\underbrace{\Sigma F_{\mathrm{Ed}}}_{\substack{combination\ of\\ actions\ used\ to\\ calculate\ E_{\mathrm{d}}}}} \right\}$$

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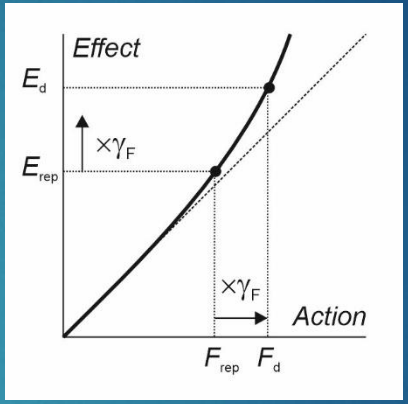
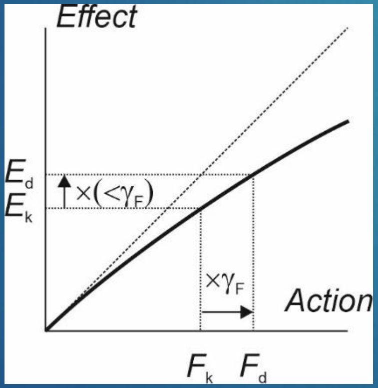
Partial factors on actions or actions-effects?

Partial factors on actions should be used for the design of:

- linear and non-linear structural systems
- **certain types of geotechnical structure (see EN 1997-3)**

This is used in Verification Cases 1-3





Partial factors on actions should be used for the design of:

- **certain types of geotechnical structure (see EN 1997-3)**
- ropes, cables and membrane structures

This is used in Verification Case 4

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Partial factors on material properties or resistance?

Partial factors on material properties should be used for the design of:

- certain types of structure (see the material Eurocodes)
- **certain types of geotechnical structure (see EN 1997-3)**

This is known as the **Material Factor Approach (MFA)**

Example: design strength of **concrete** (EN 1992-1-1) is:

$$\underbrace{f_{\mathrm{cd}}}_{\substack{design\\strength}} = \frac{\overbrace{\underbrace{(\eta_{\mathrm{cc}}k_{\mathrm{tc}})}_{\substack{conversion\\factors}} \times \underbrace{f_{\mathrm{ck}}}_{\substack{characteristic\\strength}}}^{representative\ strength}}{\underbrace{\gamma_{\mathrm{C}}}_{\substack{partial\ factor\\on\ strength}}}$$

Example: design tensile resistance of **steel** (EN 1993-1-1) is:

$$\underbrace{N_{\mathrm{t,Rd}}}_{\substack{design\\tensile\\resistance}} = \frac{\overbrace{\underbrace{A}_{\substack{cross-\\sectional\\area}} \times \underbrace{f_{\mathrm{y}}}_{\substack{nominal\\yield\\strength}}}^{representative\ strength}}{\underbrace{\gamma_{\mathrm{M0}}}_{\substack{partial\ factor\\on\ resistance}}}$$

Partial factors on resistance should be used for the design of:

- certain types of structure (see the material Eurocodes)
- **certain types of geotechnical structure (see EN 1997-3)**

This is known as the **Resistance Factor Approach (RFA)**

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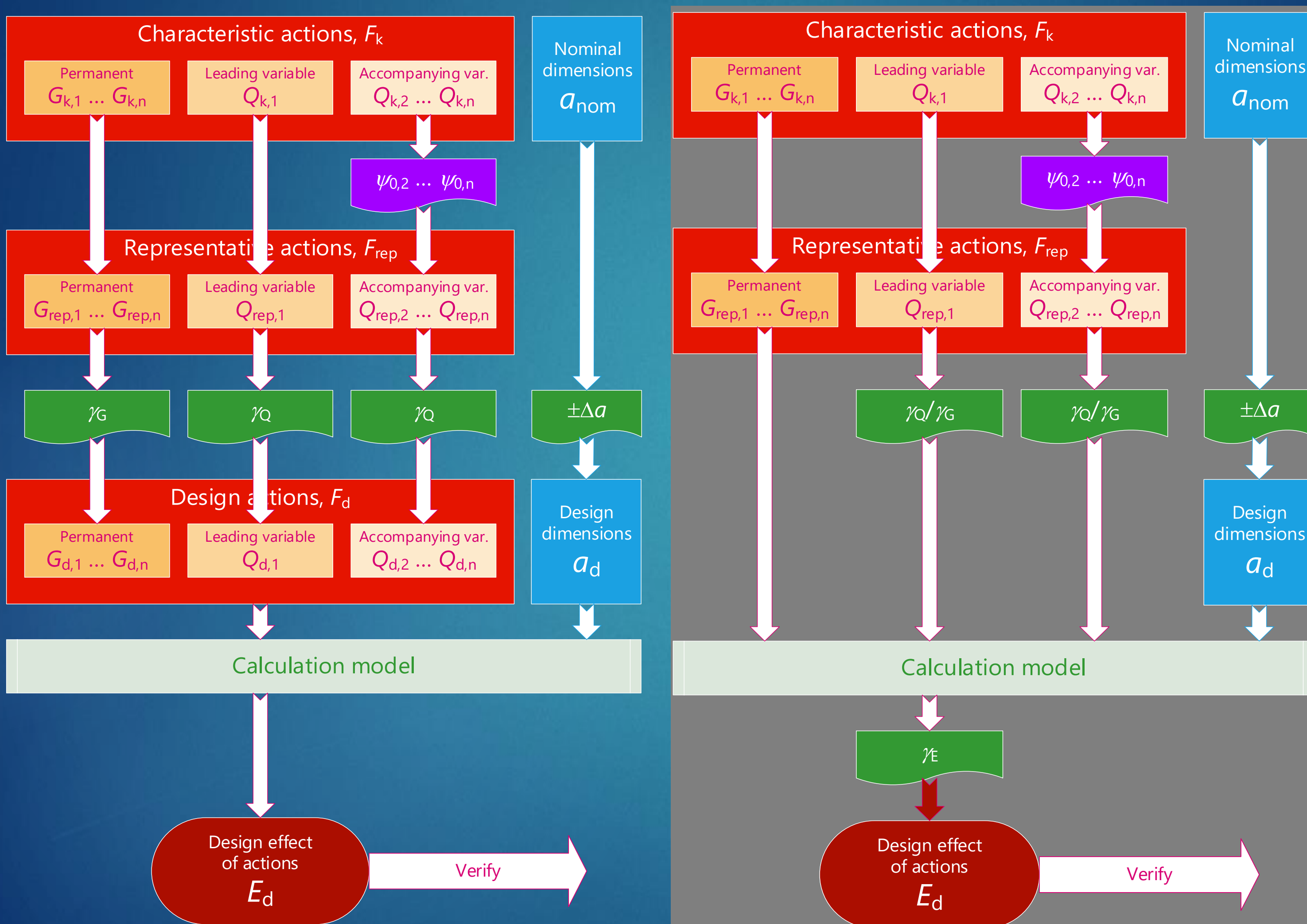
Factors on actions (left) vs factors on action-effects (right)



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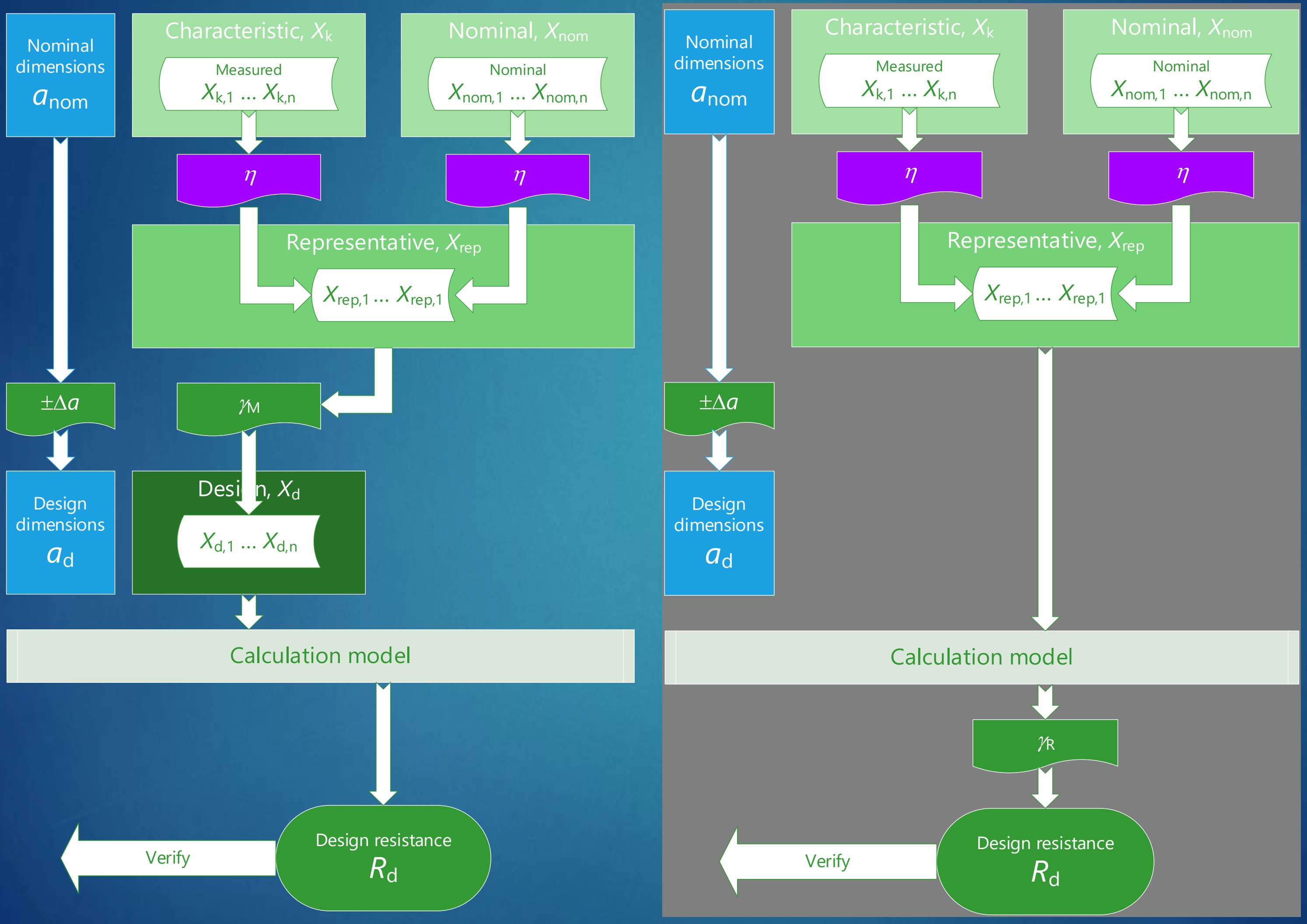
Factors on material properties (left) vs factors on resistance (right)



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Partial factors for ground properties for use in fundamental design situations

Material property		Partial factor γ_M for Set …		
Material	Ground property	Symbol	M0	M1
Soil and fill	Shear strength in effective stress analysis	$\gamma_{\tau f}$	1.0	1.25 k_M
	Coefficient of peak friction	$\gamma_{\tan\varphi,p}$		
	Peak effective cohesion	$\gamma_{c,p}$		
	Coefficient of friction at critical state	$\gamma_{\tan\varphi,cs}$		1.1 k_M
	Coefficient of residual friction	$\gamma_{\tan\varphi,r}$		
	Residual effective cohesion	$\gamma_{c,r}$		
	Shear strength in total stress analysis	γ_{cu}		1.4 k_M
	Unconfined compressive strength	γ_{qu}	Same as γ_{cu}	
Rock material and rock mass	Shear strength	$\gamma_{\tau r}$	1.0	1.25 k_M
	Unconfined compressive strength	γ_{qu}		1.4 k_M
Rock discontinuities	Shear strength	$\gamma_{\tau dis}$	1.0	1.25 k_M
	Coefficient of residual friction	$\gamma_{\tan\varphi,dis,r}$		1.1 k_M
Interface	Coefficient of ground/structure interface friction	$\gamma_{\tan\delta}$	1.0	1.25 k_M
Values taken from EN 1997-1				

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Obtaining appropriate values of ground properties

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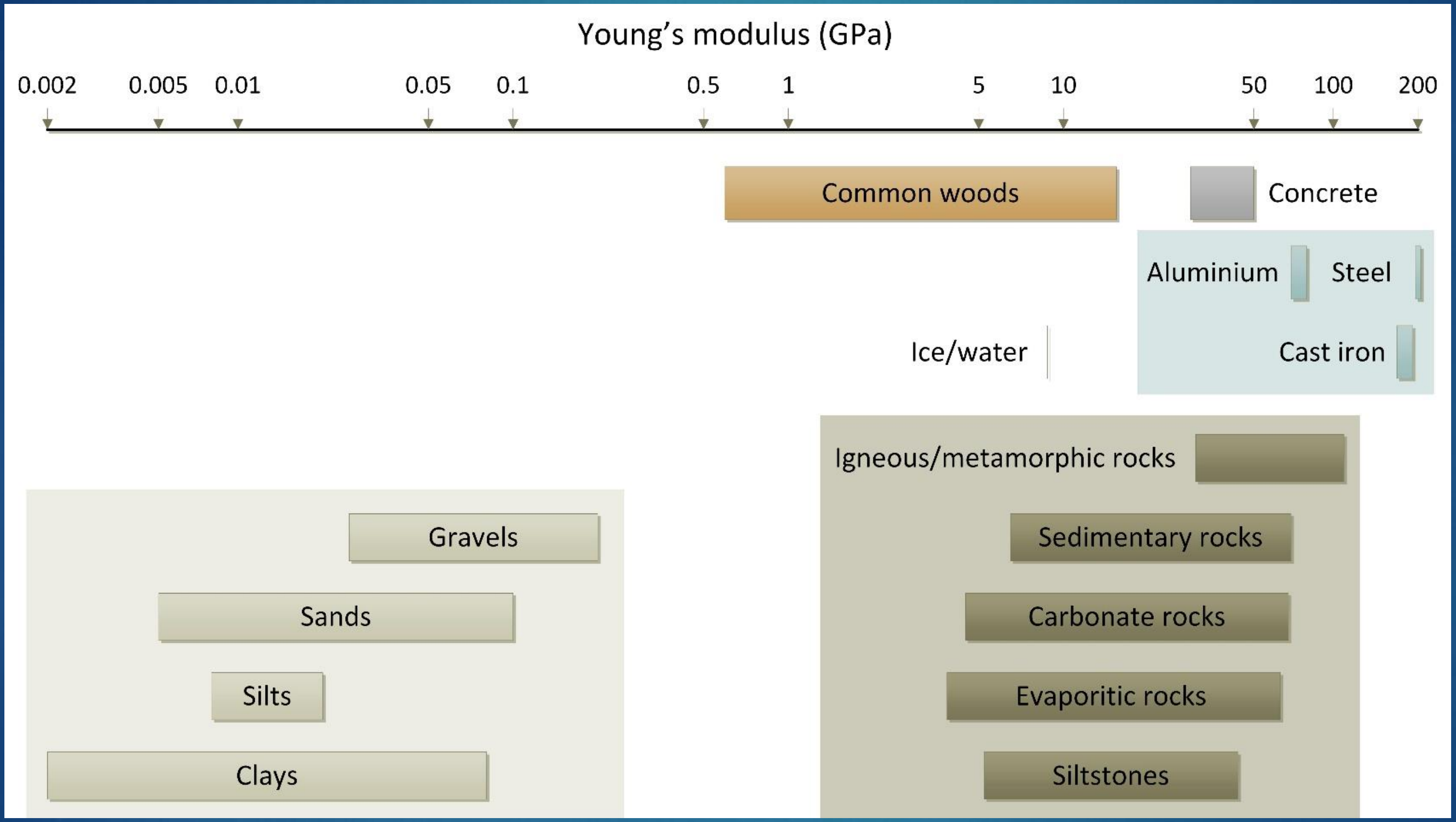
Stiffness of common construction materials



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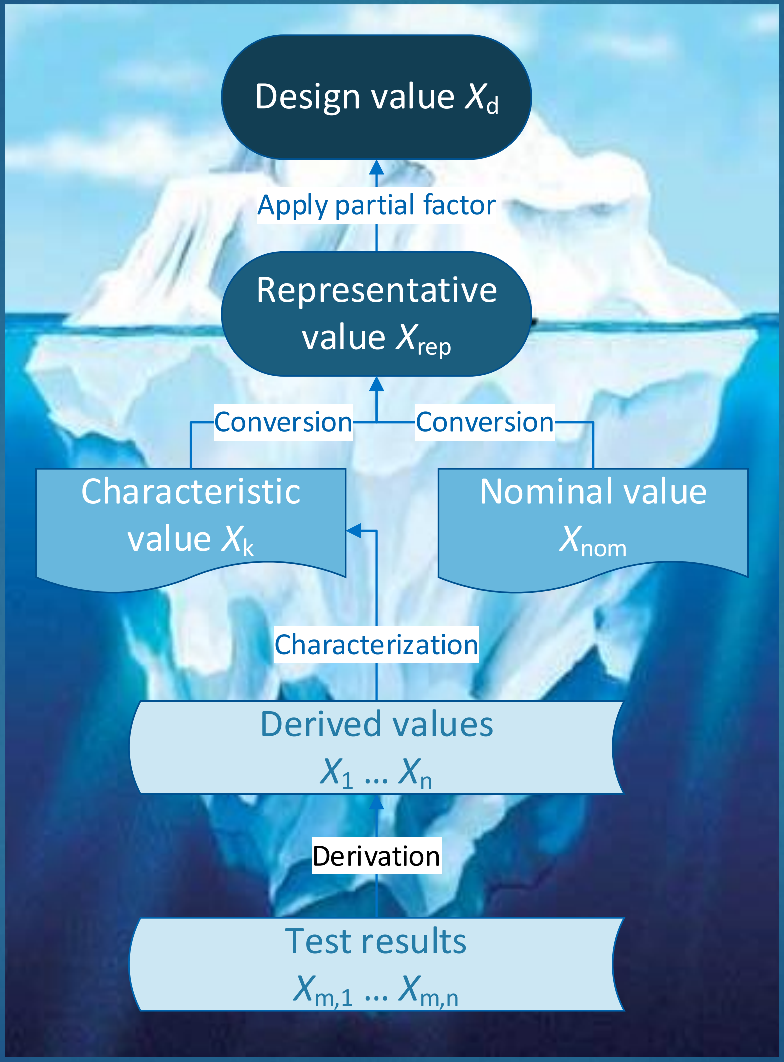
Progression from test results to design values of ground properties



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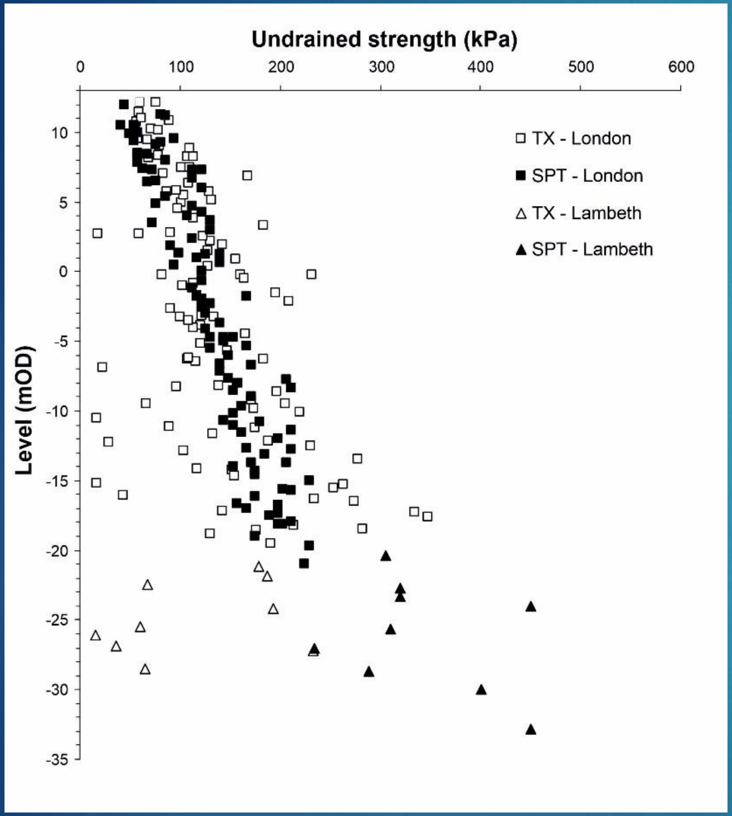
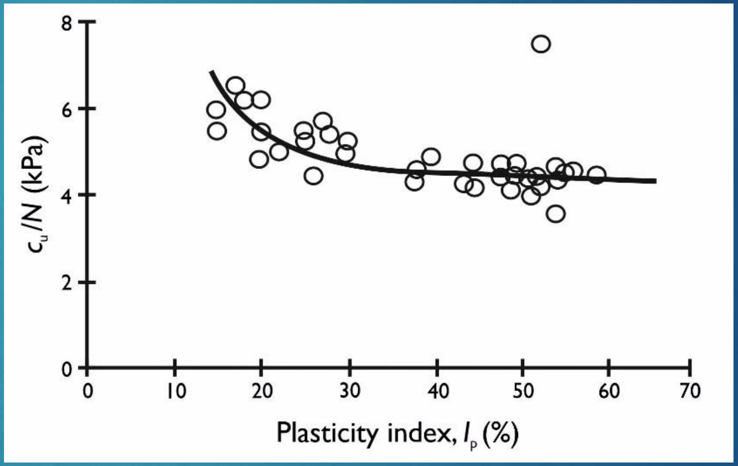
Example of derived values of ground properties from correlation





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Indicative values of ground properties for fine soils (from NEN 9971-1)

Soil type			γ	q_c	φ'	c'	c_u
			kN/m³	MPa	°	kPa	kPa
Loam	Slightly sandy	Soft Firm-stiff Stiff-hard	19 20 21-22	1 2 3	27½-30 27½-32½ 27½-35	0 1 2.5-3.8	50 100 200-300
	Very sandy		19-20	2	27½-35	0-1	50-100
Clay	Clean	Soft Firm-stiff Stiff-hard	14 17 19-20	0.5 1.0 2.0	17½ 17½ 17½-25	0 5 13-15	25 50 100-200
	Slightly sandy	Soft Firm-stiff Stiff-hard	15 18 20-21	0.7 1.5 2.5	22½ 22½ 22½-27½	0 5 13-15	40 80 120-170
	Very sandy		18-20	1.0	27½-32½	0-1	0-10
	Organic	Soft Firm-stiff	13 15-16	0.2 0.5	15 15	0-1 0-1	10 25-30
Peat	Small* overburden	Soft	10-12	0.1	15	1-2.5	10-20
	Large* overburden	Firm-stiff	12-13	0.2	15	2.5-5	20-30

Table also gives values (not shown here) of C_p, C_s, $C_c/(1+e_0)$, C_α, $C_c/(1+e_0)$, E_{100}
*Small overburden ≈ 5-25 kPa; large ≈ 50 kPa

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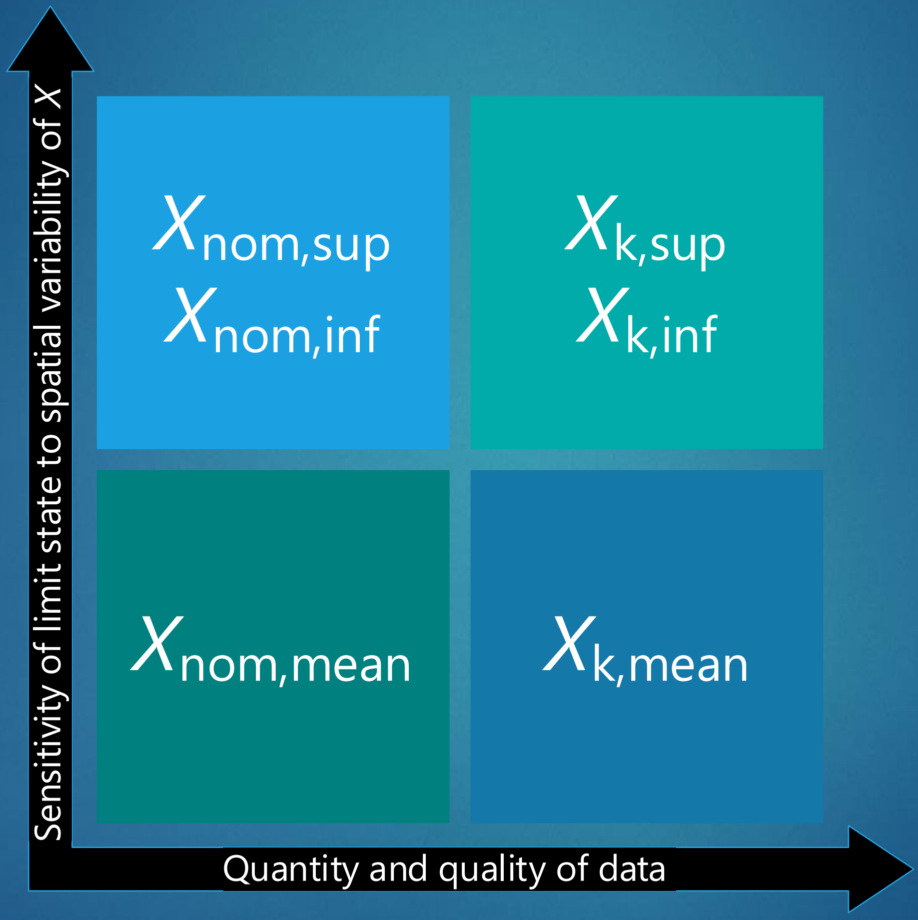
Options for selecting the representative value of a ground property



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Design values of ground properties

The **inferior design value** of a ground property (used in most design situations) is given by:

$$\overbrace{X_{\mathrm{d,inf}}}^{\substack{design\\value}} = \left(\overbrace{X_{\mathrm{rep,mean}}}^{\substack{mean\\value}} \mid \overbrace{X_{\mathrm{rep,inf}}}^{\substack{inferior\\value}}\right) \Big/ \gamma_{\mathrm{M}}$$

The **superior design value** of a ground property (used when more critical, e.g. for downdrag):

$$\overbrace{X_{\mathrm{d,sup}}}^{\substack{design\\value}} = \left(\overbrace{X_{\mathrm{rep,mean}}}^{\substack{mean\\value}} \mid \overbrace{X_{\mathrm{rep,sup}}}^{\substack{superior\\value}}\right) \times \gamma_{\mathrm{M}}$$

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Summary of key points

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Summary of key points

The main changes in the 2nd generation EN 1997-1 are:

- scope extended to include rock ("ground" = soil, rock, and fill)
- Geotechnical Category redefined as a combination of Consequence Class and Geotechnical Complexity Class
- robustness, durability and sustainability introduced
- the representative value of a ground property defined as either
  - a nominal value (cautious estimate)
  - a characteristic value (based on statistical evaluation)
- new clause on the determination of groundwater levels and pressures
- new procedure for verifying ultimate limit states using numerical models
- greater emphasis given to serviceability limit states
- new clause on the implementation of design (supervision, inspection, monitoring, and maintenance)
- new clause on testing
- clause on reporting has been revised
- new requirements for Geotechnical Construction Records

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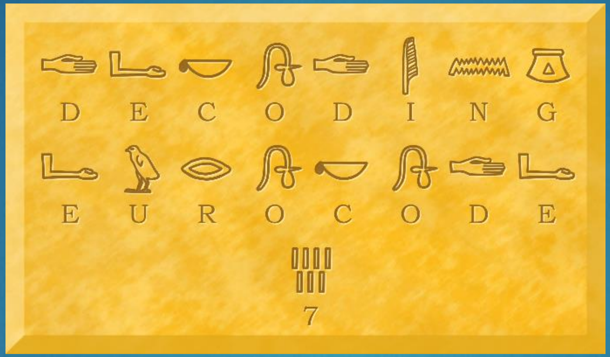

Our **2nd generation** courses include …

- Decoding Eurocode 7 –
  - Basis of geotechnical design
  - Ground properties and ground investigation
  - Shallow foundations
  - Deep foundations
- Decoding Eurocode 3 – Steel foundations

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