Middle East Technical University
Civil Engineering Department

GENERAL INFORMATION ABOUT EUROCODE and DESGIN OF PILE FOUNDATIONS by EUROCODE 7

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OUTLINE

- General Information about Eurocode
- Terminology and Basic Principles of Eurocode
  - ✓ Limit States
  - ✓ Actions
  - ✓ Material Properties
  - ✓ Tolerance on Geometry
  - ✓ Resistances
- Design of Piles according to Eurocode 7
  - ✓ Design situations and limit states
  - ✓ Piles subject to Compression
  - ✓ Piles subject to Tension
  - ✓ Piles subject to Transverse Actions
- Reliability in the Design of Piles – Design Approaches
- References

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General Information about Eurocode

- The *Eurocodes* are becoming widely used in Europe as a design code in Civil Engineering works.
- The *Eurocodes* are accompanied by National Annexes of various European countries.
- The *Eurocodes* are implemented by the national standards body (NSB) of:
  - International Standardization Organization (ISO),
  - European Committee for Standardization (CEN).

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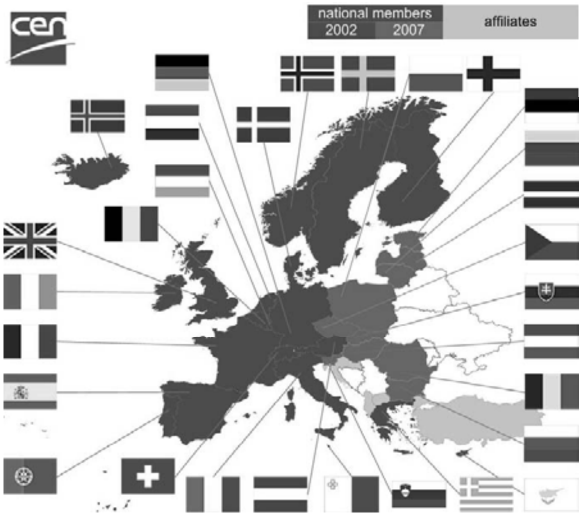
General Information about Eurocode



Members of European Committee for Standardization (CEN)

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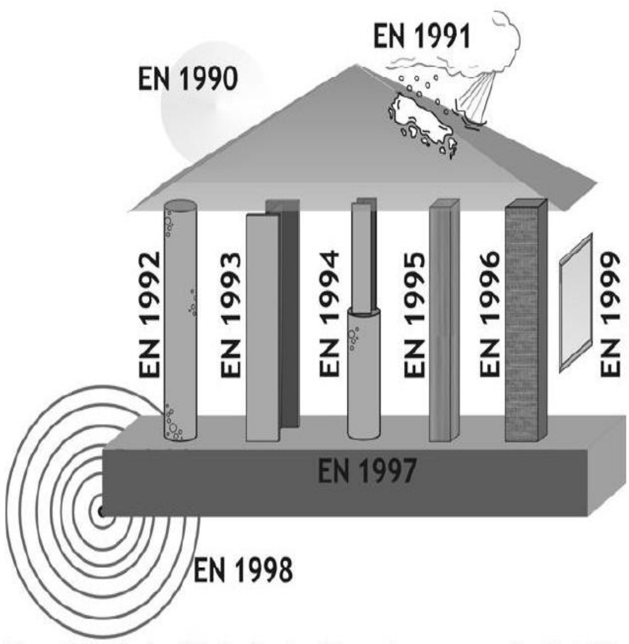

- **EN 1990:** Basis of Structural Design
- **EN 1991:** Actions on Structures
- **EN 1992:** Design of Concrete Structures
- **EN 1993:** Design of Steel Structures
- **EN 1994:** Design of Composite Steel and Concrete Structures
- **EN 1995:** Design of Timber Structures
- **EN 1996:** Design of Masonry Structures
- ***EN 1997: Geotechnical Design***
- **EN 1998:** Design of Structures for Earthquake Resistance
- **EN 1999:** Design of Aluminium Structures

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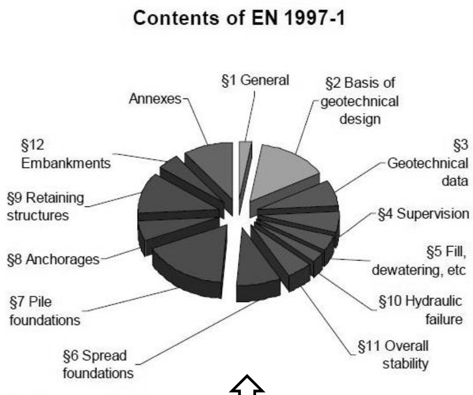

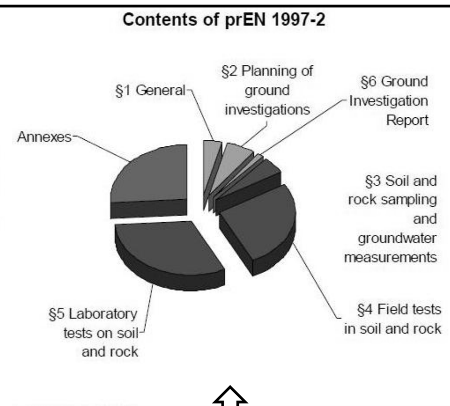

⇧ **Part 1: General Rules**

⇧ **Part 2: Ground Investigation and Testing**

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General Information about Eurocode

- **Why Eurocode?**
- ✓ Provides unique and common design criteria
- ✓ Increases competitiveness of European companies
- ✓ Provides common understanding in design between corparation parties (Owner, Contractor & Sub-contracters)
- ✓ Provides common basis for research and development
- ✓ Facilitates exchange of construction services
- ✓ Facilitates marketing and use of structural components
- ✓ Based on statistical, application and theoratical knowledge

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Terminology and Basic Principles of Eurocode

A) LIMIT STATES

EN 1990 defines mainly 4 ultimate limit states:

(i) Loss of equilibrium (EQU)

When;

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

$$\Lambda_{EQU} = [(E_{d,dst} / E_{d,stb}) \times 100] \geq 100\%$$

Where;

$E_{d,stb}$: Stabilizing Design Effects

$E_{d,dst}$: Destabilizing Design Effects

Λ_{EQU} : Utilization Factor

Example: Overturning problem

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Terminology and Basic Principles of Eurocode

(ii) Failure of excessive deformation (STR and GEO)
When;

$$R_d \leq E_d$$
$$\Lambda_{STR(GEO)} = [(E_d / R_d) \times 100] \geq 100\%$$

Where;
E_d : Design Effects of Actions
R_d : Design Resistance
$\Lambda_{STR(GEO)}$: Utilization Factor

Example: Moment developed on structure exceeds the design moment

(iii) Failure caused by fatigue and/or other time-related effects (FAT)
- Pronounced mostly in road & rail bridges and tall slender structures.

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Terminology and Basic Principles of Eurocode

(iv) Serviceability Limit States (SLS):
When;

$$C_d \leq E_d$$
$$\Lambda_{SLS} = [(E_d / C_d) \times 100] \geq 100\%$$

Where;
E_d : Design Effects of Actions (settlements,distortions, strains etc)
C_d : Limit Value of the Effect
Λ_{SLS} : Utilization Factor

Example: Maximum settlement exceeds the permissible settlement

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Terminology and Basic Principles of Eurocode

B) ACTIONS

ACTIONS (F)		
Classification	**Types**	**Notation**
According to type of application on the structure	Direct Actions	-
	Indirect Actions	-
According to their variation in time	Permanent (gravity) Actions	G
	Variable (live) Actions	Q
	Pre-stresses	P
	Accidental Actions	A
According to stabilization	**Stabilizing Actions (Favourable)**	Subscript by *fav*
	Destabilizing Actions (Unfavourable)	No subscipt

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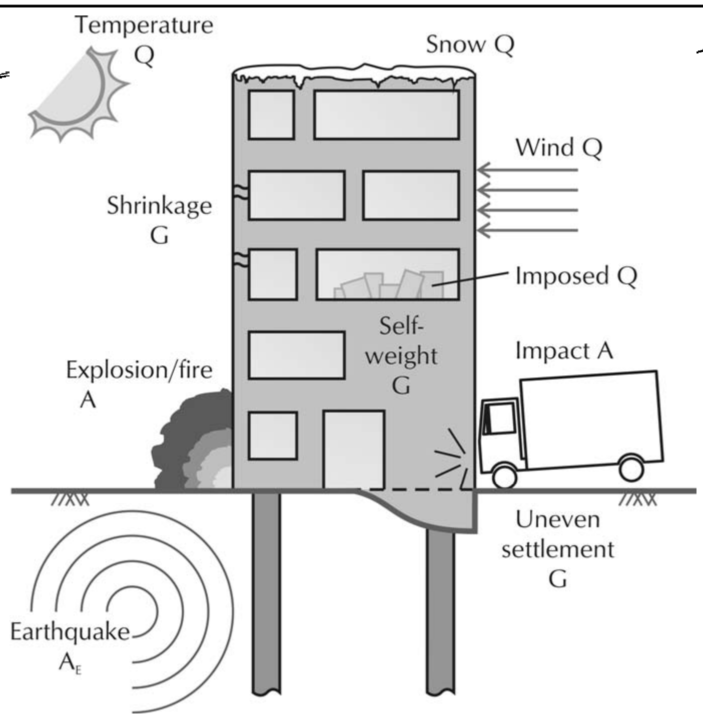

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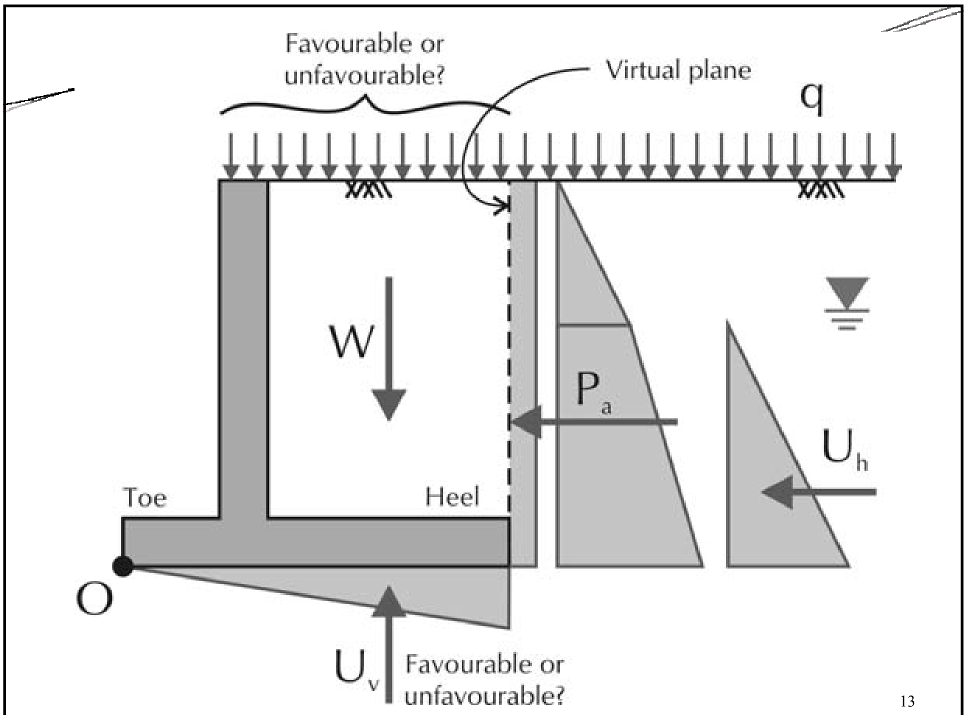

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Terminology and Basic Principles of Eurocode

COMBINATION OF ACTIONS

- Represantative actions (F_{rep}) are defined from the characteristic actions (F_k) by means of combination factor (Ψ):

$$F_{rep} = \Psi F_k$$

- Design actions (F_d) are defined from the represantative actions (F_{rep}) by means of partial factor (γ):

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

- Thus design actions (F_d) used in calculations are:

$$F_d = \sum \sum \gamma_{(j)} \Psi_{(i)} F_{k,(i,j)}$$

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Terminology and Basic Principles of Eurocode

TYPE of ACTION	Ψ	γ	
		Unfavourable	Favourable
G	1.0	≥1.0	≤1.0
$Q_{k,(1)}$ (leading)	1.0		
$Q_{k,(i)}$ (accompanying)	<1.0		

There are:
- 2 different combinations of Ψ in case of F=F(G,Q)
- 4 different combinations of Ψ in case of F=F(G,Q,A)
- 3 different combinations of γ depending on the limit states

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Terminology and Basic Principles of Eurocode

C) MATERIAL PROPERTIES

- Design material properties (X_d) are defined from the characteristic material properties (X_k) by means of partial factor (γ_M):

$$X_d = \gamma_M X_k$$

(γ_M depends on persistant / transient design situations and material type)

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Terminology and Basic Principles of Eurocode

D) TOLERANCES ON GEOMETRY

- Design geometrical dimensions (a_d) are obtained by adding/subtracting the tolerance/safety margin (Δa) nominal geometrical dimensions (a_{nom}):

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

(Δa depends on persistant / transient design situations)

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Terminology and Basic Principles of Eurocode

E) RESISTANCES

- Design resistance (R_d) is obtained whether by:

  (i) By applying a single partial factor (γ_R)

$$R_d = [R\{F_d; \mathbf{X_k}; a_d\}] / \gamma_R$$

(ii) By using design values of all components

$$R_d = [R\{F_d; \mathbf{X_d} = (\mathbf{X_k} / \gamma_M); a_d\}]$$

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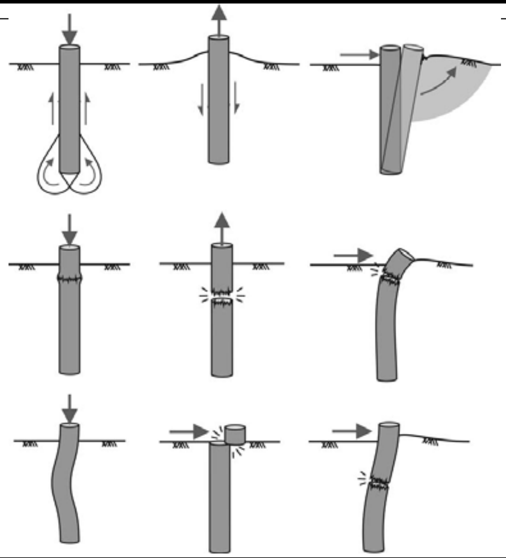
Design of Piles According to Eurocode 7

A) DESIGN SITUATIONS and LIMIT STATES



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Design of Piles According to Eurocode 7

B) PILES SUBJECT to COMPRESSION

- A pile can carry the design compressive action without exceeding the limit state if:

$$F_{cd} \leq R_{cd}$$

Where;

F_{cd} : Design compressive action

R_{cd} : Design bearing resistance

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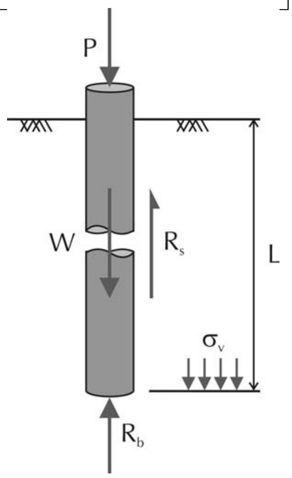
Design of Piles According to Eurocode 7

B) PILES SUBJECT to COMPRESSION

$$F_{cd} = \gamma_G (P_{Gk} + W_{Gk}) + \sum_i \gamma_Q \psi_i P_{Qk,i}$$

$$R_{ck} = R_{sk} + R_{bk}$$

$$R_{cd} = \frac{R_{sk}}{\gamma_s} + \frac{R_{bk}}{\gamma_b} \text{ or } R_{cd} = \frac{R_{tk}}{\gamma_t} = \frac{R_{sk} + R_{bk}}{\gamma_t}$$



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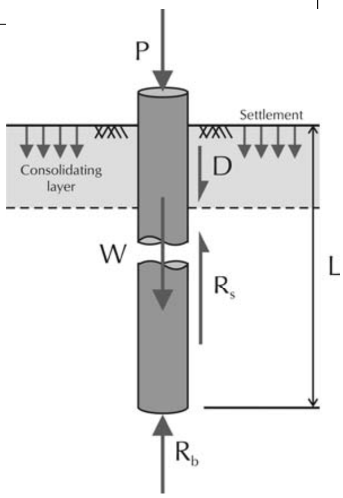
Design of Piles According to Eurocode 7

Downdrag:

$$F_{ck} = P_{Gk} + W_{Gk} + D_{Gk}$$

$$D_{Gk} = \alpha \times c_{uk} \times A_{s,D}$$

$$D_{Gd} = \alpha \times c_{ud} \times A_{s,D} = \alpha \times (\gamma_{cu} \times c_{uk}) \times A_{s,D}$$



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Design of Piles According to Eurocode 7

B) PILES SUBJECT to TENSION

- A pile can carry the design tension action without exceeding the limit state if:

$$F_{td} \leq R_{td}$$

Where;

F_{td} : Design tension action

R_{td} : Design tensile resistance

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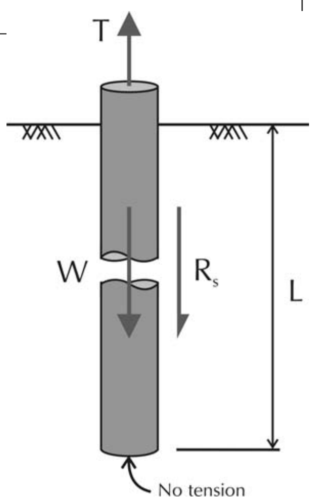
Design of Piles According to Eurocode 7

B) PILES SUBJECT to TENSION

$$F_{td} = \left(\gamma_G T_{Gk} - \gamma_{G,fav} W_{Gk}\right) + \sum_i \gamma_Q \psi_i T_{Qk,i}$$

$$R_{tk} = R_{stk}$$

$$R_{td} = \frac{R_{stk}}{\gamma_{st}}$$



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Design of Piles According to Eurocode 7

C) PILES SUBJECT to TRANSVERSE ACTIONS

- A pile can carry the design transverse action without exceeding the limit state if:

$$H_k \leq H_{Rk}$$

Where;

H_k : Characteristic Horizontal Action

H_{Rk} : Characteristic Horizontal Resistance of pile

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Design of Piles According to Eurocode 7

C) PILES SUBJECT to TRANSVERSE ACTIONS

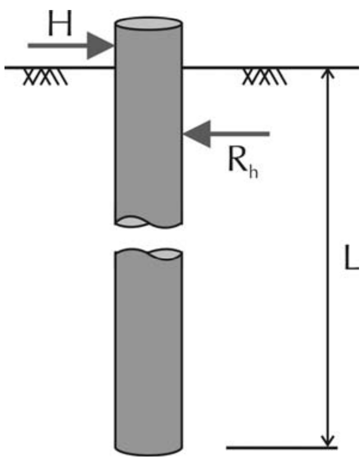
$$H_k = H_{Gk} + \sum_i \psi_i H_{Qk,i}$$

For Short Piles

$$H_{Rk} = R\left\{X_{k,ground}\right\}$$

For Long Piles

$$H_{Rk} = R\left\{X_{k,ground}, M_{Rk,pile}, V_{Rk,pile}\right\}$$



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Reliability in Design of Piles – Design Approaches

➢Countries wanted to adopt different partial factors to:

- Actions (A)
- Materials (M)
- Resistances (R)

➢In order to accomodate **different point of view** of countries in design, Eurocode7 provides mainly three different "Design Approaches" :

(i) Design Approach 1 (DA1) (both combinations **must** be considered)

- Combination 1
- Combination 2

(ii) Design Approach 2 (DA2)

(iii) Design Approach 3 (DA 3)

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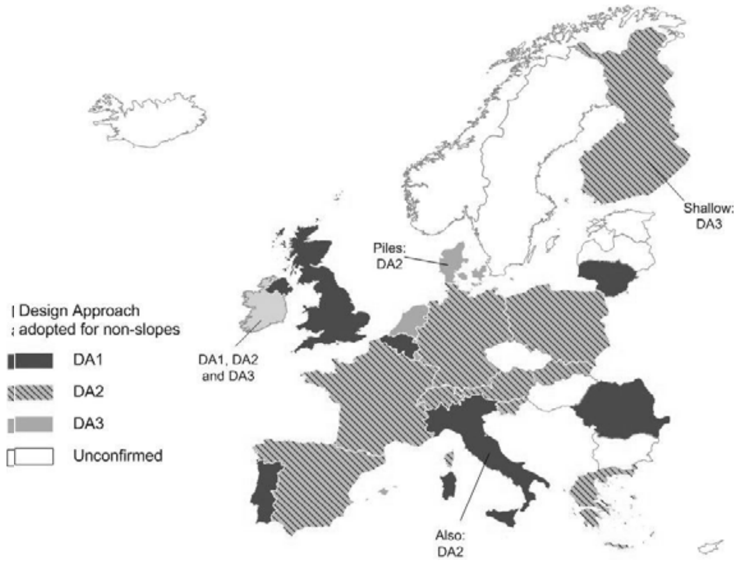
Reliability in Design of Piles – Design Approaches



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Reliability in Design of Piles – Design Approaches

For design of piles:

Design Approaches		**Partial Factors (γ)**			**Tolerance (Δa)**
		Actions (A)	Materials (M)	Resistances (R)	Dimensions (a)
DA 1	**Combination 1**	√	X	√ (smaller and dep. on PILE TYPE)	X
	Combination 2	√ (variable)	X	√ (larger and dep. on PILE TYPE)	X
DA 2		√	X	√ (smaller and indep. from PILE TYPE)	X
DA 3		√ (dep. on STR/GEO)	√	√ (smaller and indep. from PILE TYPE)	X

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Reliability in Design of Piles – Design Approaches

Design of piles may be performed by:

- Testing

  -Static Load Test
  -Dynamic Impact Test
  -Ground Tests

- Calculation

➢In design by testing some specific correlation factors are used depending on the test type. To be consistent with the design by testing, one may use a “model factor, γ_{Rd}” by applying it to skin and end-bearing resistances seperately in design by calculation.

➢Since no such a value is given in Eurocode 7, γ_{Rd} = 1.5 can be taken into account in DA 1 and DA 2 according to Irish National Annex (*Decoding Eurocode 7, 2008*).

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Reference

• Bond A. And Harris A. (2008). *Decoding Eurocode 7*, Taylor & Francis, UK.

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THANKS FOR YOUR ATTENTION…

Any question ?

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