EUROCODE 8 – PART 5

– Foundations
– Retaining Structures
– Geotechnical Aspects

Owing to the combination of uncertainties in seismic action and ground material properties, Part 5 may not cover in details every possible design situation and its proper use may require specialised engineering judgment and experience.

DOMAIN OF APPLICATION

- (1)P This part of EC8 establishes the requirements, criteria and rules for the sitting and foundation soil of for earthquake resistance design.

  It covers the design of different foundation systems, the design of earth retaining structures, and soil structure interaction under seismic actions.

  As such it complements EC7 which does not cover the special requirement of seismic design

DOMAIN OF APPLICATION

- (2)P The provisions of Part 5 apply to buildings (EN 1998-1), bridges (EN 1998-2), towers, masts and chimneys (EN 1998-6), silos, tanks and pipelines (EN 1998-4).

- (3)P Specialised design requirements for the foundations of certain types, when necessary, shall be found in the relevant Parts of Eurocode 8.

GENERAL FORMAT

- Main text (24 pages)
- Six annexes :
  - A : Topographic amplification factor (I)
  - B : Liquefaction (N)
  - C : Pile head stiffnesses (I)
  - D : Dynamic soil structure interaction (I)
  - E : Earth retaining structures (N)
  - F : Seismic bearing capacity of shallow foundations (I)
- National Annex

(N) : normative (I) : informative

- Nationally Determined Parameters :
  - Informative Annexes A, C, D et F
  - Partial factors for material properties
  - Safety factor against liquefaction
  - Reduction of pga with depth from ground surface

- What does the standard define? :
  - Requirements (P)
  - Rules for conceptual design (P)
  - Calculation methods
  - Criteria for safety verifications (P)
  - Construction detailing

(P) : *principle*

MECHANICAL CHARACTERISTICS

- Fundamental parameters
  - Shear wave velocity (or shear modulus G)
  - Material damping
    - *Depend on shear strain amplitude (# pga)*
  - Shear strength
  - Undrained cohesion C_u
  - Cyclic undrained shear strength $\tau_{cy,u}$
- Material factor γ_m
  - C_u , $\tau_{cy,u}$, $tg(\phi')$

→ **1.4 , 1.25 , 1.25**

Class	Description	Parameters		
		$V_{S,30}$ (m/s)	N (SPT)	C_u (kPa)
A	Rock – < 5m weak material	> 800	-	-
B	Very dense sand and gravel, very stiff clay; h>10m	360 - 800	> 50	> 250
C	Deep deposits medium dense to dense sand; stiff clay; h=10 – 100 m	180 - 360	15 - 50	70 - 250
D	Loose to medium dense sand, soft to firm cohesive soil	< 180	< 15	< 70
E	Alluvium C or D, h=5 – 20 m above rock (A)			
S_1	Soft clay /silts h>10m with high PI	< 100 (indicative)	-	10 - 20
S_2	Liquefiable soils, sensitive clay; any soil type not listed above			

MECHANICAL CHARACTERISTICS

αS	Damping	V_S / V_{Smax}	G / G_{max}
0.10	0.03	0.90 (±0.07)	0.80 (±0.10)
0.20	0.06	0.70 (±0.15)	0.50 (±0.20)
0.30	0.10	0.60 (±0.15)	0.36 (±0.20)

$V_{smax} \leq 360 m/s$

LIQUEFACTION

- Verification under free field conditions
- Seed – Idriss method (1971) for seismic demand
- Seismic resistance from SPT (annexe) or CPT; *corrections specified* (σ'_v , E_R)
- Safety factor > 1.25
  - *if foundation stability affected* $\Rightarrow$ *soil improvement*
- No verification required if : $\alpha S < 0.15$ and either
  - % clay > 20% and PI > 10%
  - % silt > 35% and $N_1 > 20$
  - Clean sand and $N_1 > 30$

SLOPE STABILITY

- Ultimate limit state : unacceptable displacements
- Study required for all structures close to slope
  - (except importance category I)
- Seismic action must take into account topographic amplification 1.2 à 1.4 $\leq S_T$
- Psuedo static analysis :

$$\mathbf{F_H = 0.5\,\alpha\,S\,W} \qquad , \qquad \mathbf{F_V = 0.33\,à\,0.50\,F_H}$$

  - *Valid only if loss of shear strength negligible*

FOUNDATIONS (I)

- Forces from superstructure shall be transferred to the ground without excessive deformations
- Homogeneous foundation system
  - except dynamically independent units
- Actions effects on foundations
  - *Based on capacity design principle for dissipative structures with overstrength*
  - Based on results of elastic analysis for non dissipative structures

FOUNDATIONS (II)

- Transfer of action effects to ground :
  - Friction under base F_{H1}
  - Friction on lateral sides F_{H2}
  - Passive resistance F_B

$$F \leq F_{H1} + F_{H2} + 0.3\, F_B$$

- Shallow foundations
  - *Sliding on base allowed* (Under certain conditions)
  - *Evaluation of seismic bearing capacity (annex)*
  - Requirement for tie beams

CODE REQUIREMENT

$$\mathbf{S_d \leq R_d}$$

$$S_d\left(\gamma_F . \text{actions}\right) \leq \frac{1}{\gamma_{Rd}} R_d\left(\frac{\text{strength parameters}}{\gamma_m}, \text{geometry}\right)$$

γ_F : Load factor

γ_m : Material factor

γ_{Rd} : Model factor

PROPOSED VALUES FOR γ_{Rd}

Medium to dense sand	Loose dry sand	Loose saturated sand	Non sensitive clay	Sensitive clay
1.0	1.15	1.50	1.0	1.15

FOUNDATIONS (III)

- Pile foundations
  - Shall be designed for both :
    - Inertia forces
    - Kinematic forces : mandatory for
      - soil types D , S_1 , S_2
      - $\alpha_g S > 0.1$
      - Importance category I or II
  - Constructive arrangement:
    - Inclined piles not recommended but can be tolerated (under certain conditions)
    - *Plastic hinge can be tolerated at the pile cap connection*

SOIL - STRUCTURE INTERACTION

- Mandatory
  - Structure sensitive to P-δ effects
  - Massive or deep seated structures
  - Slender tall structures
  - Structure supported on very soft soil *(V_{smax} < 100 m/s)*

- Annex describes the main effects of soil structure interaction

RETAINING STRUCTURES (I)

- Based on pseudo-static analysis

$$E_d = \tfrac{1}{2}\,\gamma^*\,(1 \pm k_v) K H^2 + E_{ws} + E_{wd}$$

- K calculated from Mononobe-Okabe formula
  - $k_h = \alpha S / r$ $\qquad k_v = \pm\ 0.33$ à $0.50\ k_h$
- Seismic coefficient depends on amplitude of allowable displacements ($1.0 \leq r \leq 2.0$)
- (Very) detailed normative annex for calculations of K and γ^* depending on permeability of backfill

RETAINING STRUCTURES (II)

- Safety factor against liquefaction higher than 2.0
- Anchoring system :
  - Must accommodate soil displacements
  - Increase in distance for anchors with respect to static design

$$L = L_S (1+1.5 \alpha S)$$