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FOUNDATIONS

- CURS 1 -

Introduction
Basis of Design

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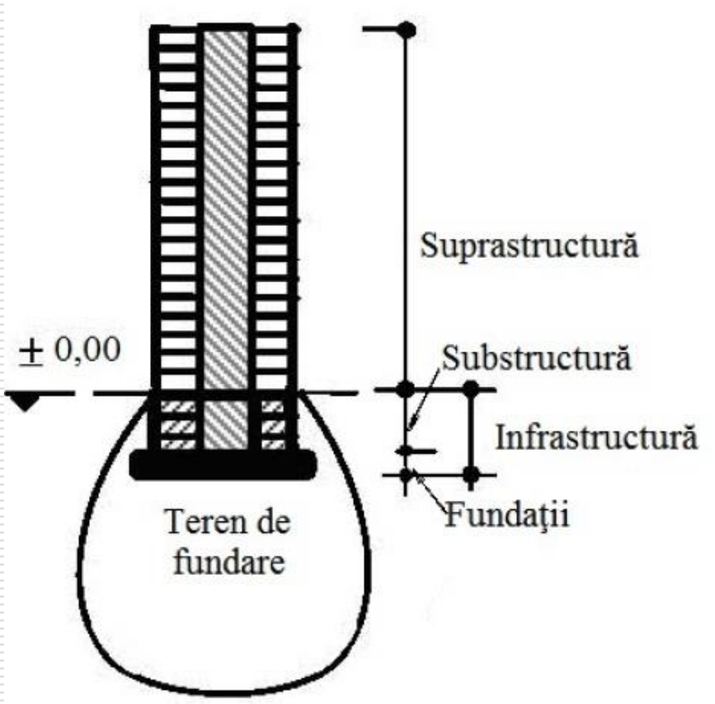
FOUNDATIONS

CHAPTER I – INTRODUCTION

§ 1.1 Introduction

- The constructional works conception includes generally two parts:
  - An over-ground part, formed of ground levels, stories and roofing – superstructure
  - An underground part, made of additional underground levels, technical ducts and nets and foundations – infrastructure.



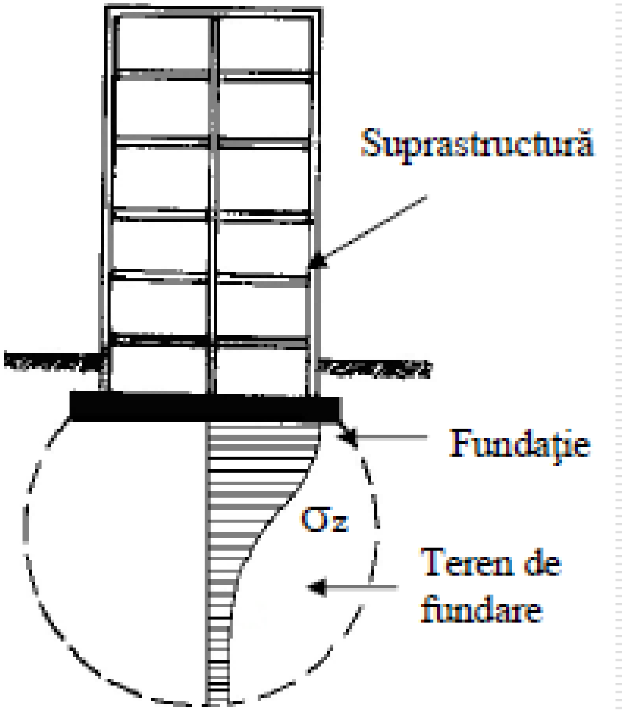
- The **foundations** represent the inferior part of the construction and has the aim to transmit the structural loads to the foundation soil.

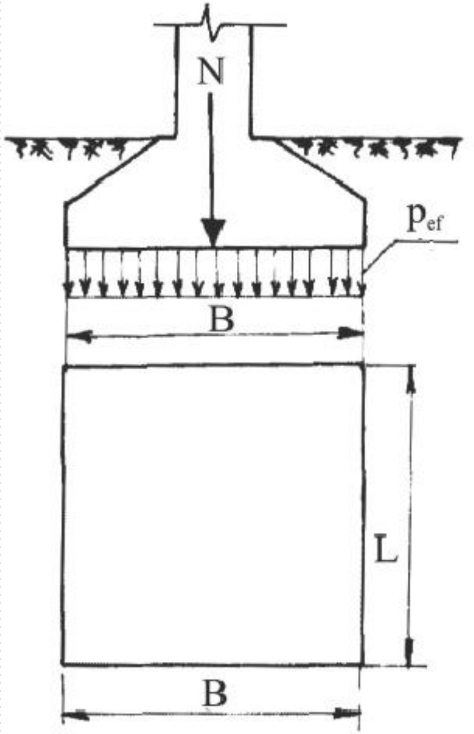
Obs: Between the construction and the foundation soil there is a continuous interaction. This interaction should be considered in structural design by engineers.

A foundation must be conceived, designed and built such that it will assure the strength and the global stability of the structure as well as the serviceability conditions.

§ 1.1 Introduction

- The **foundation soil** represents the shallow zone of the ground affected by the influence of the loads transmitted by the construction.





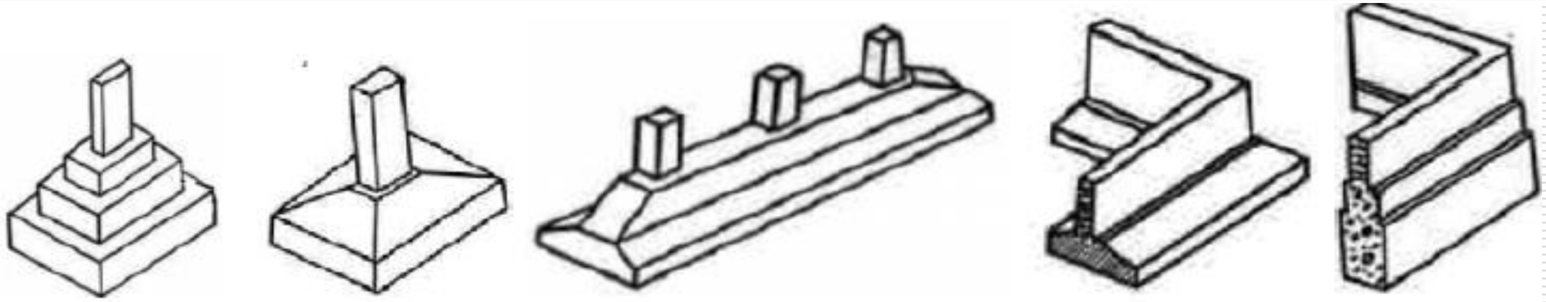
$$p_{ef} = \frac{N}{S} = \frac{N}{B \cdot L} \leq p_t$$

- The design of the foundation soil includes the limitation of forces transmitted to the foundation soil in order to assure the stability, strength and serviceability conditions of the building.

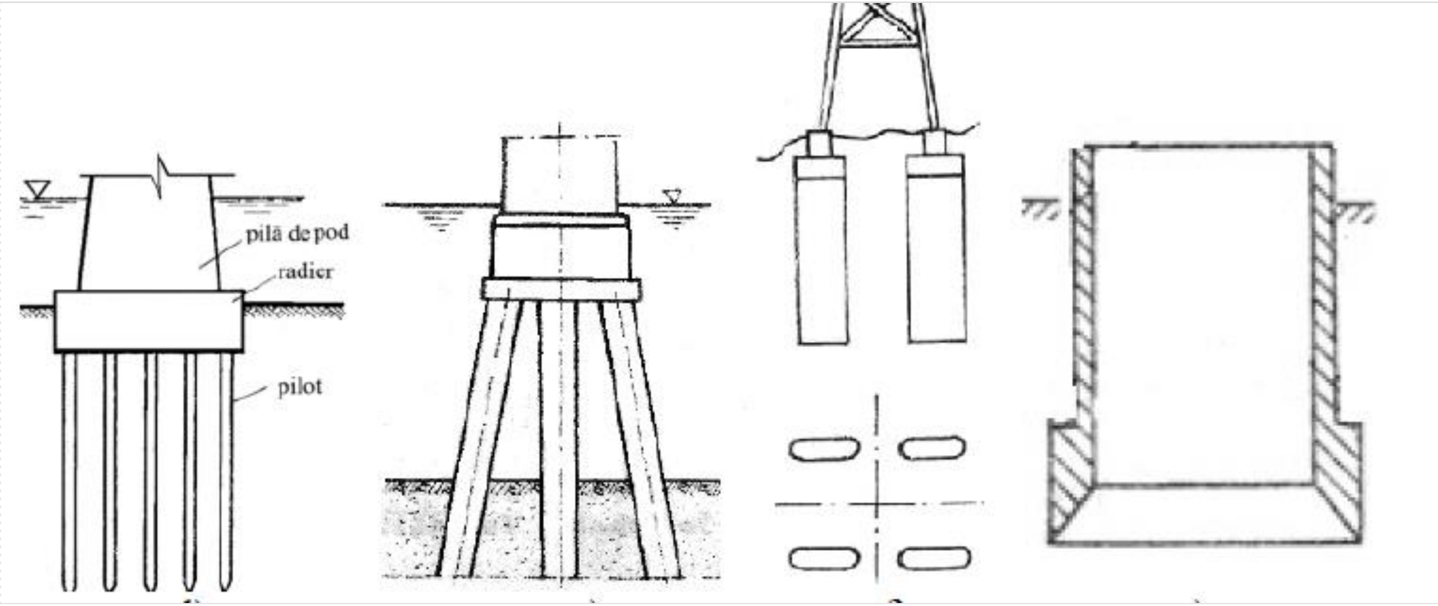
§ 1.2 Classification of foundations

- In function of the **foundation depth**, the foundations can be:

Shallow foundations

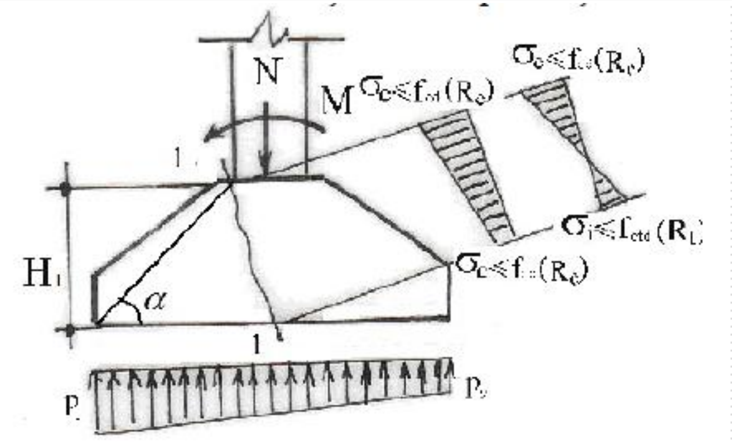


Deep foundations

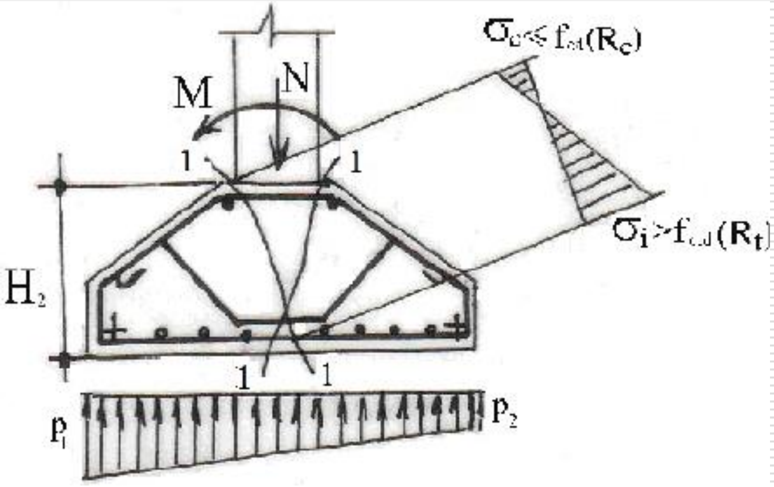


§ 1.2 Classification of foundations

- In function of **overtaking of the structural forces**, the foundations can be:
  - Rigid foundations, working in compression only. Can be made of plain concrete or masonry.



  - Elastic foundations working in bending and compression. Must be made of reinforced concrete.



§ 1.2 Classification of foundations

- In function of the **transmission of loads**, the foundations can be:
  - Direct foundations in which the transmission of loads is assured by direct contact between the foundation base and the ground: single, continuous, grid, mat, box foundations.
  - Indirect foundations in which the transmission of loads is assured throughout the tip of the foundation and lateral friction: pile, column strip

- Other classifications of foundations:
  - In function of loading: compression, tearing, bending.
  - In function of the foundation material: compacted earth, plain or reinforced concrete, steel foundations;
  - In function of the design procedure: gravity, fixed
  - In function of typology: single, split, special
  - In function of execution: in-situ, precast

CHAPTER II – BASIS OF DESIGN
§ 2.1 Introduction in basis of design

- The design of the foundations and foundation soils is done in accordance with the **EN 1997 - Geotechnical design**.
- The design situations are given in **EN 1990 – Basis of design**.
- Specific actions are offered by **EN 1991 – Actions on structures**.

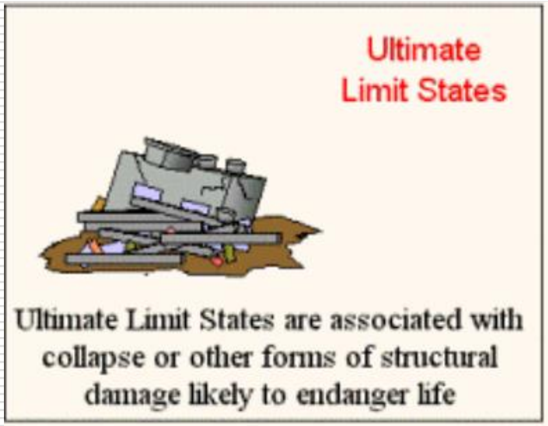
- The structure and the foundation soil are in continuous interaction. According to EN 1997 - *Any interaction between the structure and the ground shall be taken into account when determining the actions to be adopted in the design*

§ 2.1 Introduction in basis of design

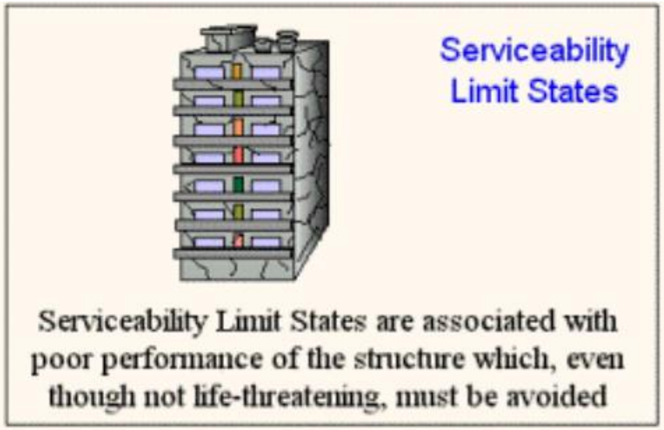
- In geotechnical design, the following **actions** should be considered:
  - the weight of soil, rock and water;
  - stresses in the ground;
  - earth pressures and ground-water pressure;
  - free water pressures, including wave pressures;
  - ground-water pressures;
  - seepage forces;
  - dead and imposed loads from structures;
  - surcharges;
  - mooring forces;
  - removal of load or excavation of ground;
  - traffic loads;
  - movements caused by mining;
  - swelling and shrinkage caused by vegetation, climate or moisture changes;
  - movements due to creeping or sliding or settling ground masses;
  - movements due to degradation, dispersion, decomposition, self-compaction;
  - movements and accelerations caused by earthquakes, explosions, vibrations and dynamic loads;
  - temperature effects, including frost action;
  - ice loading;
  - imposed pre-stress in ground anchors or struts;
  - downdrag.

§ 2.2 Limit State Design

- **Limit State Design**. Limit states: states beyond which the structure no longer fulfils the relevant design criteria. They represent idealizations of undesirable events or phenomena. In accordance with EN 1990, the following limit states should be considered:
  - Ultimate limit states (ULS)
  - Serviceability limit states (SLS)



- **Ultimate limit states:** states associated with collapse or with other similar forms of structural failure
- **Serviceability limit states**: states that correspond to conditions beyond which specified service requirements (deflections, vibrations, cracks) for a structure or structural member are no longer met



§ 2.2 Limit State Design

- **Ultimate Limit states in geotechnical design:**
  - **EQU:** Loss of static equilibrium of the structure or any part of it considered as a rigid body
  - **STR:** Internal failure or excessive deformation of the structure or structural members, including footings, piles, basement walls, etc., where the strength of construction materials of the structure governs
  - **GEO:** Failure or excessive deformation of the ground where the strengths of soil or rock are significant in providing resistance
  - **FAT:** Fatigue failure of the structure or structural members.
  - **HYD**: Resistance to failure by heave due to seepage of water in the ground
- When considering a limit state of rupture or excessive deformation of a section, member or connection (STR and/or GEO), it shall be verified that

$$E_d \leq R_d$$

where:

- E_d is the design value of the effect of actions (internal force, moment etc.);
- R_d is the design value of the corresponding resistance

§ 2.2 Limit State Design

- **Serviceability Limit states in geotechnical design:**
  - At the SLS it shall be verified that:

$$E_d \leq C_d$$

where:

- C_d is the limiting design value of the relevant serviceability criterion.
- E_d is the design value of the effects of actions specified in the serviceability criterion, determined on the basis of the relevant combination

- In general the serviceability conditions in geotechnical design are resumed to checking the settlement conditions – related to the deformability of the soils under foundation actions.

§ 2.3 Partial Safety Factors

Partial Safety Method Factors.

- Assessment of the reliability of structures in Eurocodes is based on the concept of limit state design and verification by the partial factor method.
- Using this method, a structure is considered to be reliable if no relevant limit state is exceeded for all selected design situations, when using the design values of basic variables:
  - actions
  - material properties
  - geometrical data

§ 2.3 Partial Safety Factors

Partial Safety Method Factors - Actions.

- The design value Fd of an action F can be expressed in general terms as:

$$F_d = \gamma_f \cdot F_{rep}$$

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

where:

- F_k is the characteristic value of the action.
- F_{rep} is the relevant representative value of the action.
- γ_f is a partial factor for the action which takes account of the possibility of unfavourable deviations of the action values from the representative values

- Ψ is either 1,00 or Ψ_0, Ψ_1 or Ψ_2.
  - the combination value $\Psi_0 Q_k$
  - the frequent value $\Psi_1 Q_k$
  - the quasi-permanent value $\Psi_2 Q_k$

§ 2.3 Partial Safety Factors

Partial Safety Method Factors – Design values of actions.

- For a specific load case the design values of the effects of actions (Ed) can be expressed in general terms as:

$$Ed = \gamma_{Sd} \cdot E\{\gamma_{f,i} \cdot F_{rep,i}\ ;\ a_d\}\ i \geq 1$$

where:

- a_d is the design values of the geometrical data;
- γ_{Sd} is a partial factor taking account of uncertainties:
  - in modelling the effects of actions;
  - in some cases, in modelling the actions.
- $E\{\gamma_{f,i} \cdot F_{rep,i}\ ;\ a_d\}$ is the effect of action for the design value of the force F_d and the design geometrical characteristics a_d

§ 2.3 Partial Safety Factors

Partial Safety Method Factors – Materials.

- The design value X_d of a material or product property can be expressed in general terms as: $Xd = \eta(X_k/\gamma_m)$

where:

- X_k is the characteristic value of the material property;
- η is the mean value of the conversion factor taking into account:
  - – volume and scale effects,
  - – effects of moisture and temperature, and
  - – any other relevant parameters;
- γ_m is the partial factor for the material or product property to take account of:
  - – the possibility of an unfavourable deviation of a material or product property from its characteristic value;
  - – the random part of the conversion factor η.

§ 2.3 Partial Safety Factors

Partial Safety Method Factors – Geometrical Data.

- Design values of geometrical data such as dimensions of members that are used to assess action effects and/or resistances may be represented by nominal values:

$$a_d = a_{nom}$$

- Where the effects of deviations in geometrical data (e.g. inaccuracy in the load application or location of supports) are significant for the reliability of the structure (e.g. by second order effects) the design values of geometrical data shall be defined by:

$$a_d = a_{nom} \pm \Delta_a$$

Where Δ_a takes account of:

- the possibility of unfavourable deviations from the characteristic or nominal values;
- the cumulative effect of a simultaneous occurrence of several geometrical deviations.

§ 2.3 Partial Safety Factors

Partial Safety Method Factors – Design Resistances (R).

- Partial factors may be applied either to ground properties (X) or resistances (R) or to both:

$R_d = R\{\gamma_F\ F_{rep};\ X_k/\gamma_M;\ a_d\}$ or

$R_d = R\{\gamma_F\ F_{rep};\ X_k;\ a_d\}\ /\gamma_R$ or

$R_d = R\{\gamma_F\ F_{rep};\ X_k/\gamma_M;\ a_d\}\ /\gamma_R$

- In design procedures where the effects of actions are factored, the partial factor for actions $\gamma_F = 1{,}0$.

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