Universitatea Politehnica Timişoara
Facultatea de Construcţii
Departamentul de Căi de Comunicație Terestre, Fundații și Cadastru

FOUNDATIONS

- CURS 12 -

Design of shallow foundations

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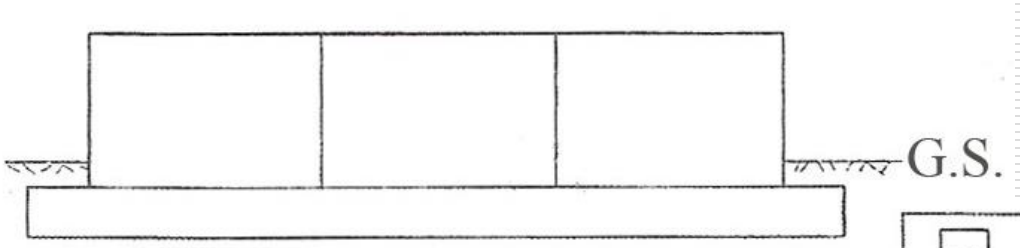
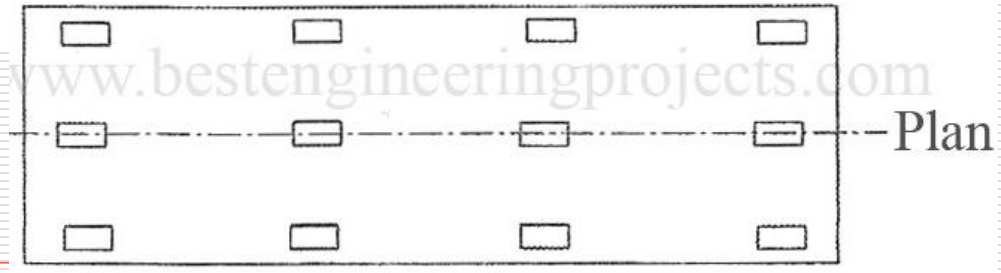
CHAPTER VI – SHALLOW FOUNDATIONS

§ 6.10 Mat foundations

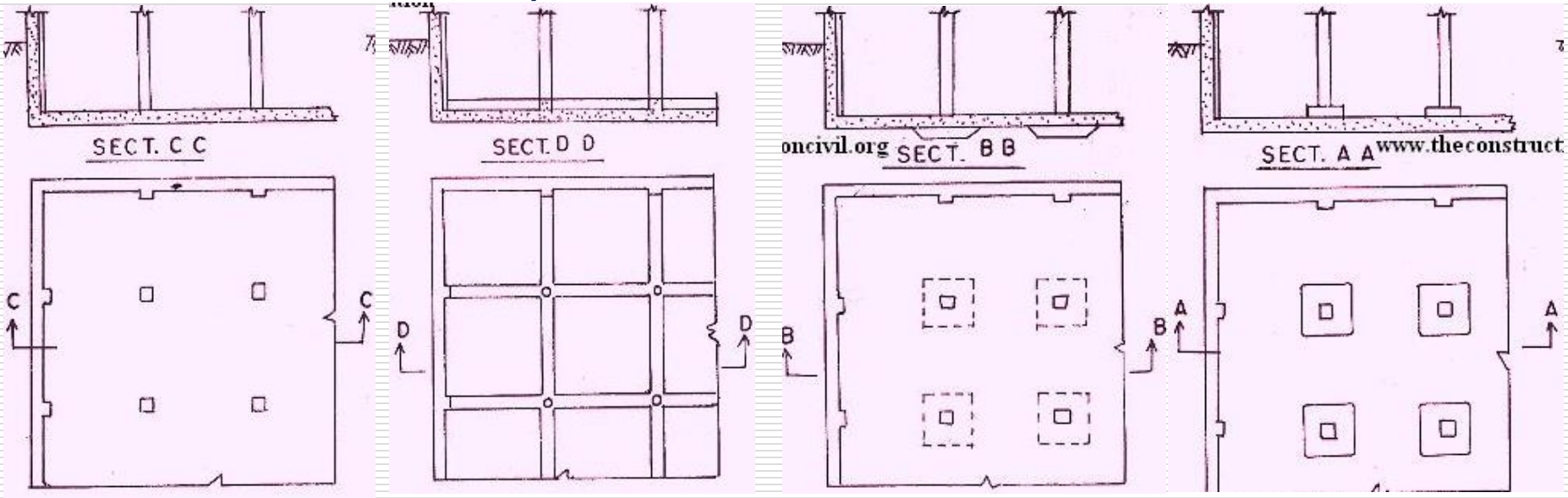
- **Mat (raft) foundations** consists of thick reinforced concrete slab covering the entire area of the bottom of the structure like a floor.
- The mat (raft) foundations are used in the following situations:
  - in case of soils having low bearing capacity or heavy structural loads;
  - if the structure is vulnerable to subsidence on being located in mining area or due to uncertain behavior of its sub-soil water condition;
  - mat (raft) foundations provides an economical solution to difficult site conditions, where pile foundation cannot be used advantageously and independent column footing becomes impracticable





§ 6.10 Mat foundations

- Mat (raft) foundations consists of thick reinforced concrete slab covering the entire area of the bottom of the structure like a floor;
- The slab is reinforced with bars running at right angles to each other both near bottom and top face of the slab.

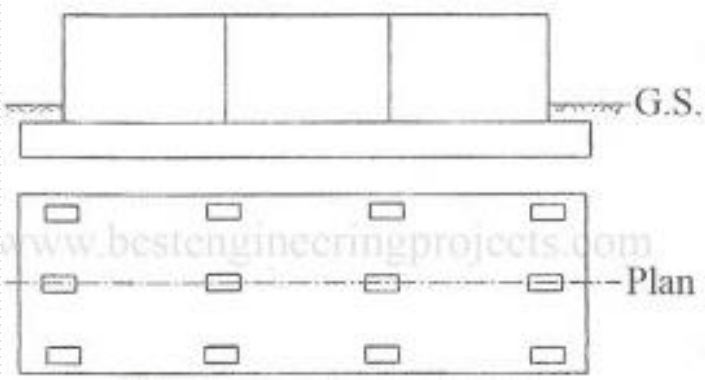


Obs: Sometimes it is necessary to carry the excessive column load by an arrangement of inverted main beams and secondary beams, cast monolithically with the raft slab.

§ 6.10 Mat foundations

- general typologies of mat foundations:

Flat plate mat foundations: flat plate mat is used for small and uniform column spacing and relatively light loads



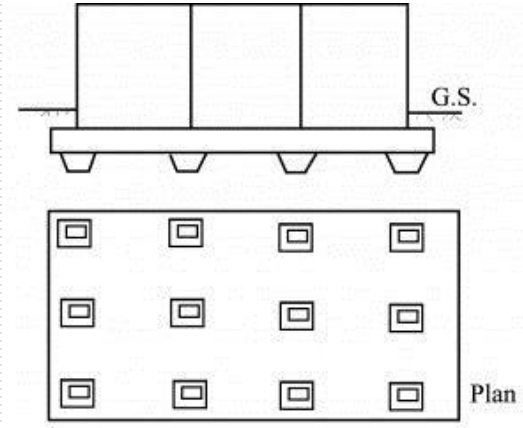
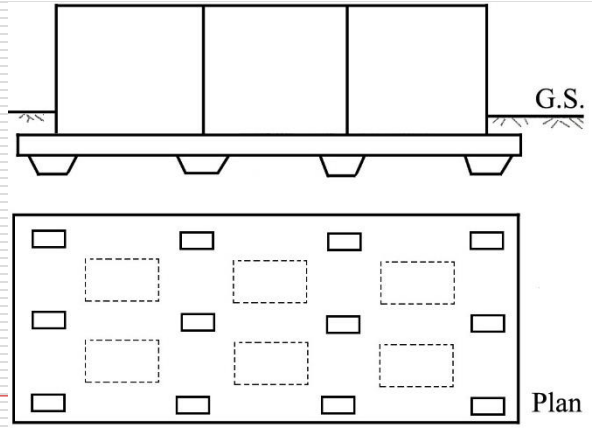


Plate thickened under columns: for columns subjected to very heavy loads usually the flat plate is thickened under columns against diagonal shear and negative moments

Two-way Beam and Slab: When the column spacing is large and carries unequal loads it would be more economical if a two-way beam and slab raft is used



§ 6.10 Mat foundations

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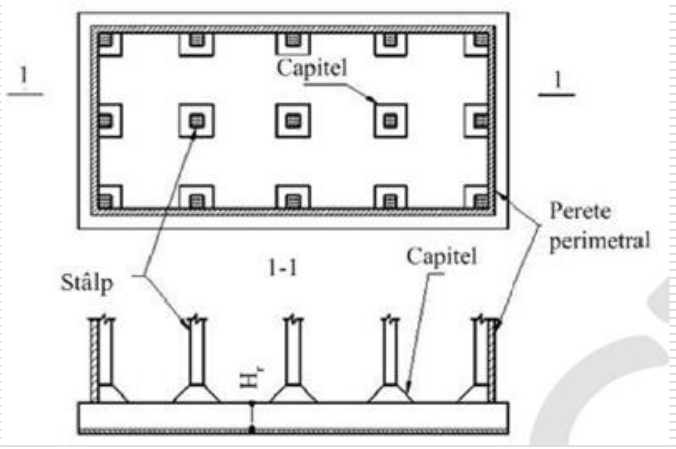
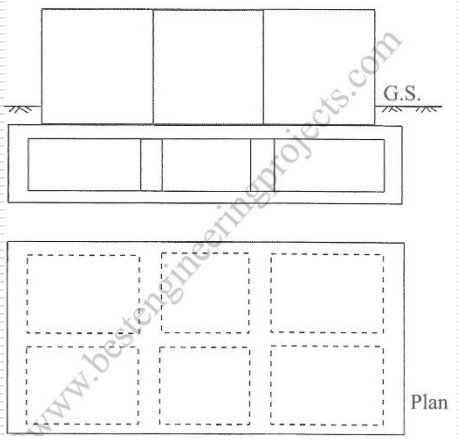
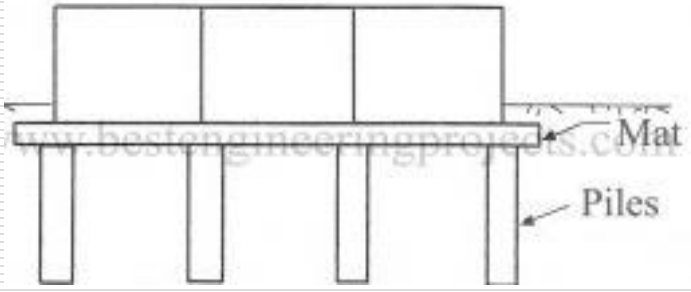


Plates with Pedestals: The function of this mat is same as that of flat plate thickened under columns. The pedestals are provided at the base of the columns.



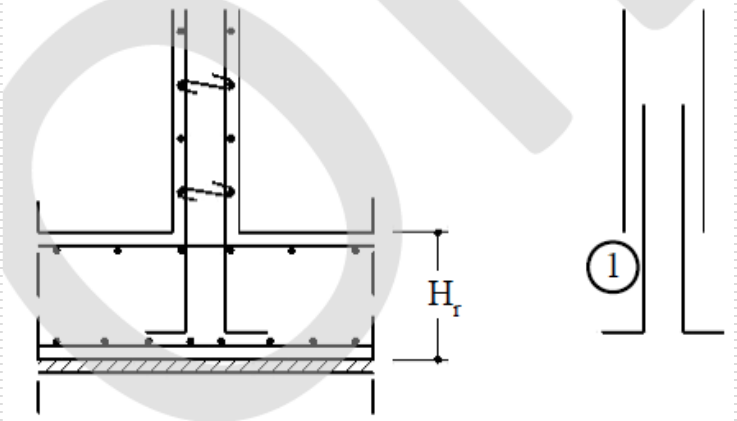
Rigid Frame Mat: is used when columns carry extremely heavy loads so that the basement walls act as ribs or deep beam. If the depth of beam exceeds 90 cm in simple beam and slab mat, a rigid frame mat is preferred.

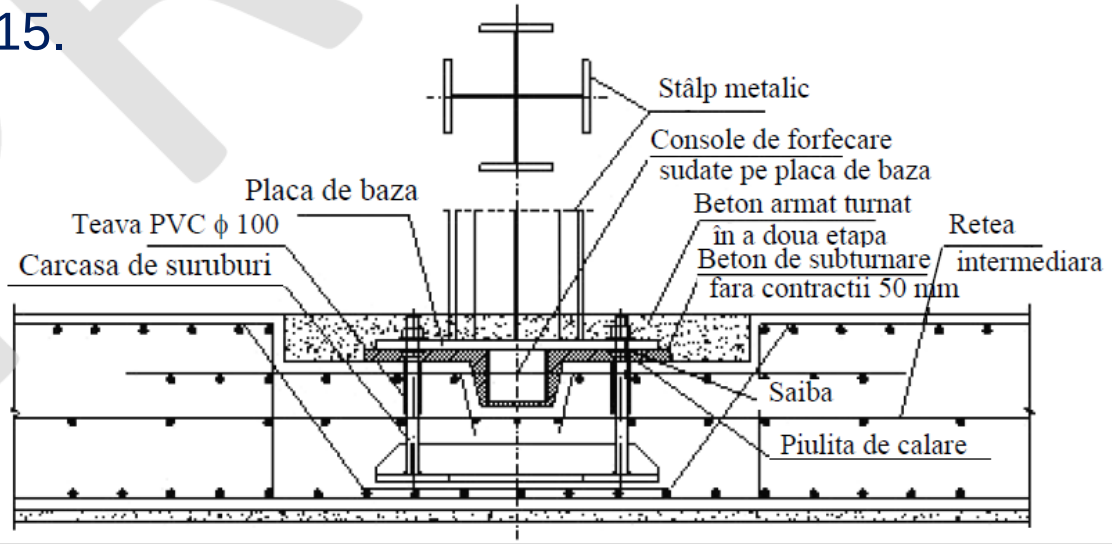
Piled Raft: the mat is supported on piles. It is used where the soil is highly compressible and the water table is high. This type reduces settlement and control buoyancy.



§ 6.10 Mat foundations

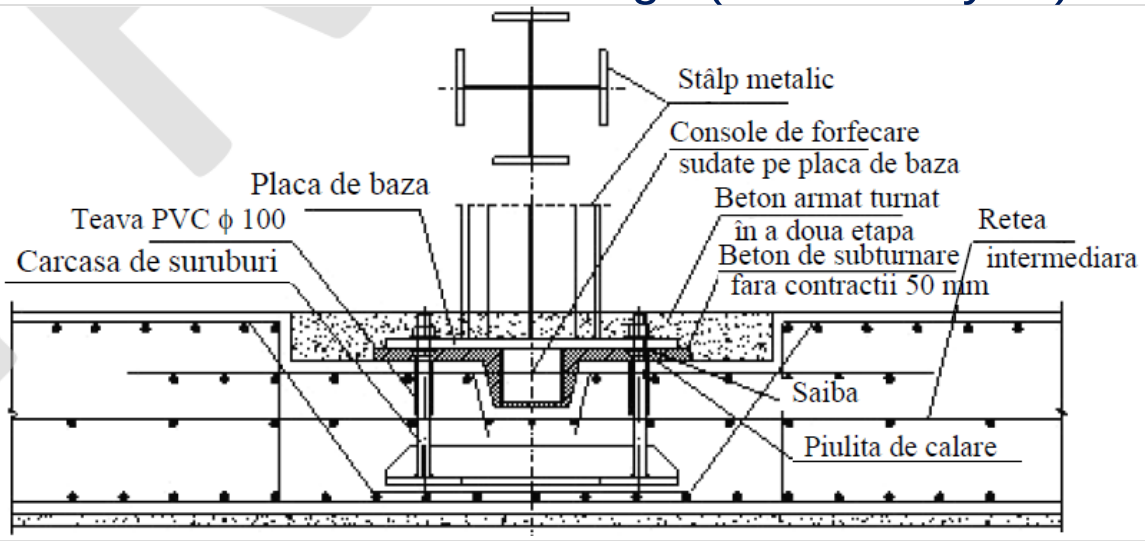
- Geometrical requirements (proportioning):
  - the minimum thickness of the mat is taken as 1/10 of the column span, but greater than 400mm;
  - minimum reinforcing: $p_{min}>0.15\%$ for each layer and direction (0.075% for intermediary reinforcement);
  - distance between bars: $d_{min}>150mm$, $d_{max}<400mm$;
  - Reinforcing bars: $\Phi_{min}>14mm$ for upper / lower layers, $\Phi_{min}>12mm$ for intermediary layers;
  - Concrete class: min C12/15.





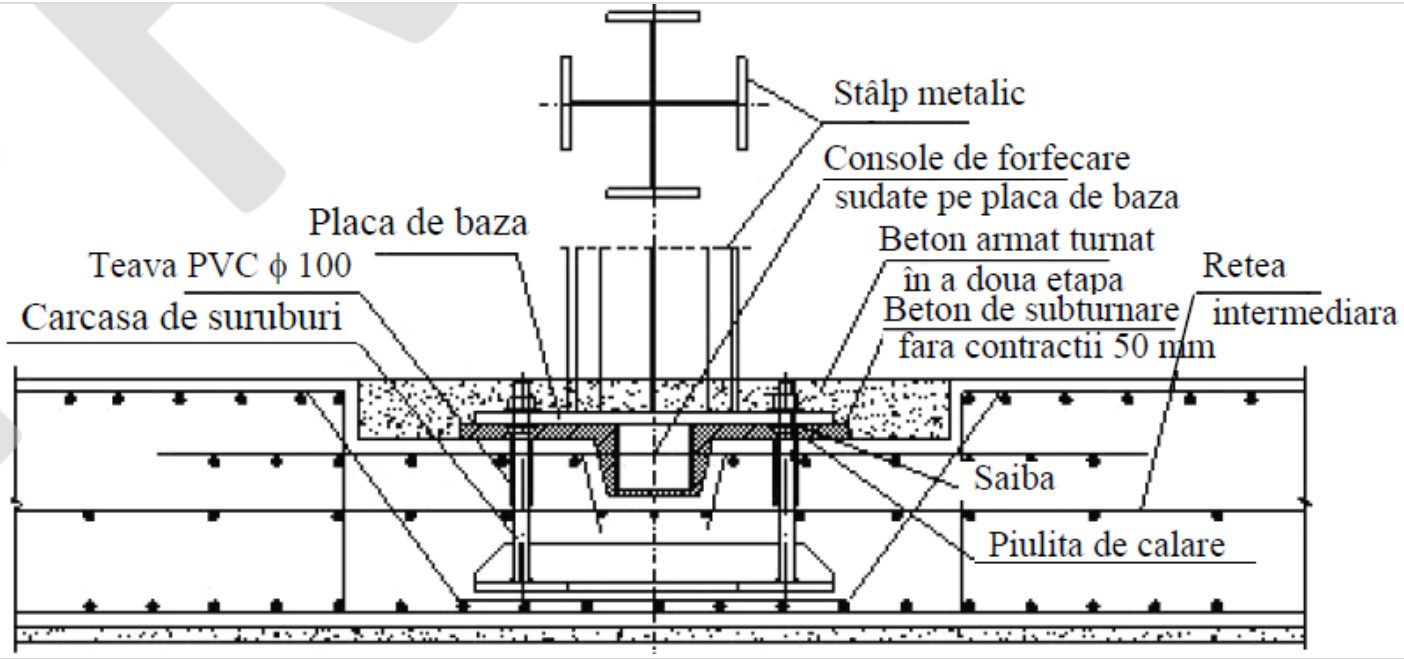
§ 6.10 Mat foundations

- **Mat foundations - longitudinal reinforcement**:
  - are disposed for overtaking the positive and negative bending on the horizontal surface of the slab;
  - the reinforcement is disposed on top and bottom surfaces, considering the concrete cover;
  - if necessary (against high level of contraction or *h>600mm*), intermediary reinforcement is disposed on height;
  - the number and disposition of bars results from design (static analysis) and Eurocode 2 design.



§ 6.10 Mat foundations

- **Mat foundations - transversal reinforcement**:
  - are disposed and design for overtaking shear forces;
  - are checked against punching;
  - could be disposed vertically or inclined;
  - the number and disposition of bars results from design (static analysis) and Eurocode 2 design.
- **Column reinforcement**:
  - will be extended to the bottom of the mat;
  - their design is done in structural checks.



§ 6.10 Design of mat foundations

- Annex L of the norm NP 112/2014 provides design methods for mat foundations.
- In design, the mat could be considered as rigid or flexible.
- For general mats with rectangular shapes (LxB) and uniform height (h), the rigidity index is computed by:

$$K_G = \frac{12 \cdot \pi(1-\nu^2)}{1-\nu_s^2} \cdot \frac{E_s}{E} \cdot \left(\frac{L}{2h}\right)^2 \cdot \frac{B}{2h}$$

Where:

E, Es are the elastic modulus of concrete and the modulus of linear deformation for the soil;

υ, υ_s are the Poisson coefficient for concrete and soil respectively;

- The mat is considered rigid if:

$$K_G \leq \frac{8}{\sqrt{\frac{L}{B}}}$$

§ 6.10 Design of mat foundations

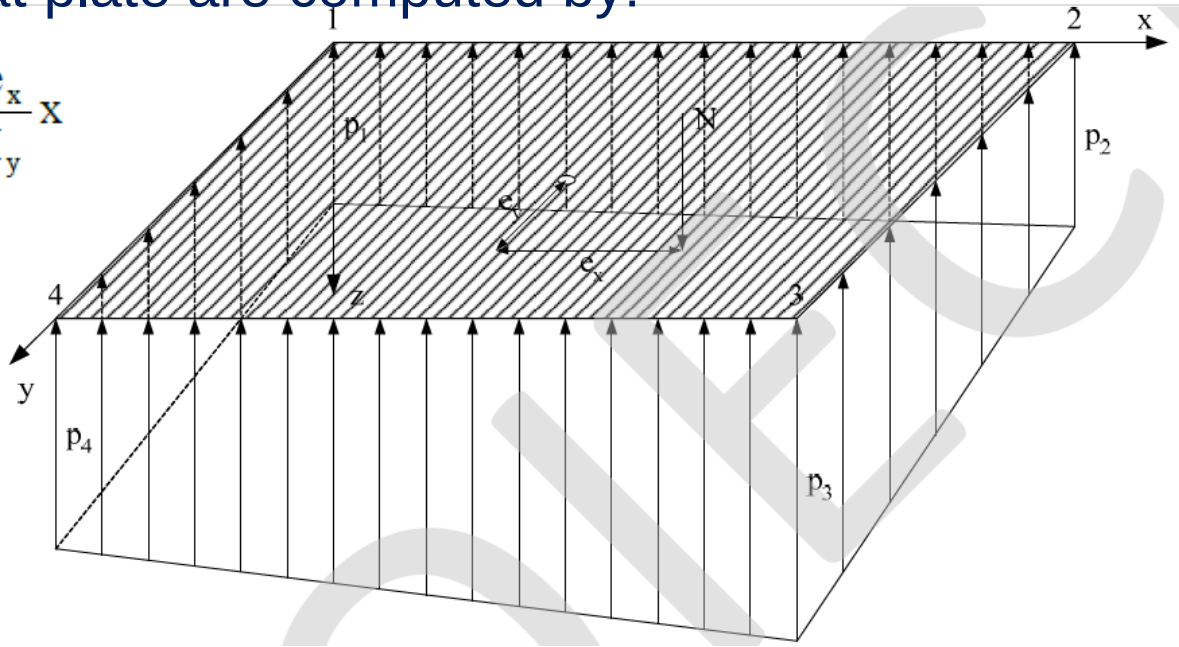
- **Method of reducing the loads in the centroid of the mat**
- This method could be adopted for rigid mats when the interaction between the structures and the foundation soil is not considered.
- The pressures on the mat plate are computed by:

$$p_{(1\div4)} = \frac{\sum N}{A} \pm \sum N \frac{e_y}{I_x} y \pm \sum N \frac{e_x}{I_y} x$$

Where:

N is the vertical load;

e_x ,e_y – eccentricities on x and y direction respectively;

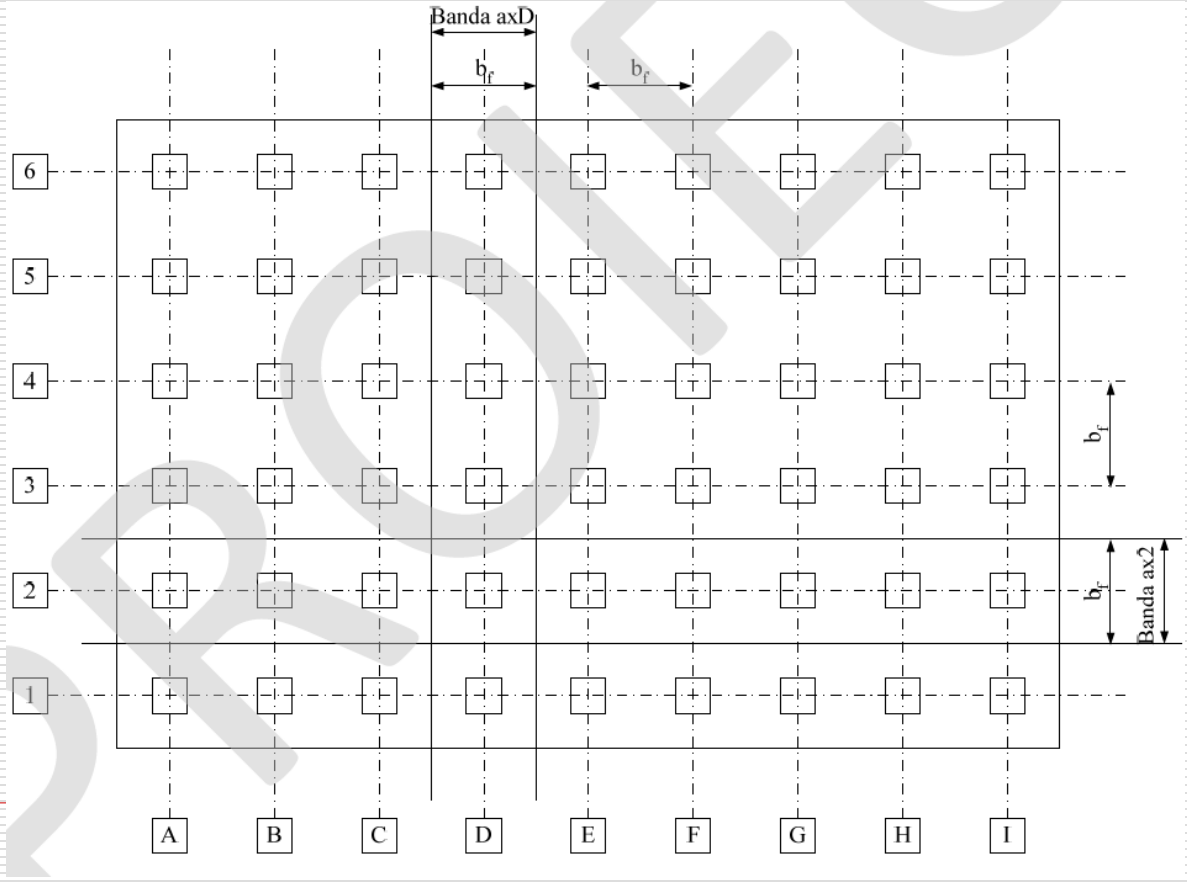


Obs: According to this method the mat is considered as a rigid body on both x and y directions: Shear forces and bending moments are computed as for a rigid body;

The method does not allow the design to bending (shear) in longitudinal directions.

§ 6.10 Design of mat foundations

- **Method of division of the mat in strips**
- When the column loads and spans do not differ with more than 20%, the mat could be divided and analyzed in strips;
- Each strip is loaded by column forces sitting on analyzed strip.
- the pressures are computed on strips, by a linear variation;
- the values of bending moments and shear forces will lead to reinforcing of the mat by using the reinforcing concrete design rules (Eurocode 2).



§ 6.10 Design of mat foundations

- **Exact methods**
- Exact methods used in design of mat foundations consider the interaction between the mat and the foundation soil:
  - **Winkler's method:** the foundation soil is replaced with independent springs;
  - **Boussinesq's method** (model of discrete medium): the foundation soil is elastic, homogeneous and isotropic material: this behavior is considered for the entire foundation as well as in the influenced zone of the mat;
  - **Hybrid model:** the foundation soil is replaced by springs defined by constitutive laws modelling the behavior of the continuous medium.

§ 6.10 Design of mat foundations

- The design to shear force and to punching is done similarly to the checks of the reinforced concrete block foundations:
- Check to shear force: $V_{Ed} \leq V_{Rd,c}$

(width of the element is taken as 1m)

- Check to punching: $v_{Fd} \leq v_{Rd,c}$

with $$v_{Fd} = \beta \frac{N_{Fd}}{u_i d} \leq v_{Rd,c}$$

Obs: For other design details on shear and punching check the design of *reinforced concrete block foundations*.

§ 6.10 Mat foundations – joints

- Being massive, the mat foundations need **construction joints**:
- Construction Joints should be carefully located at the sections of low shear. The common practice is to locate them along the center lines between columns. An elapse of at least 24 hours is desired between pours in adjacent areas.
- Reinforcing bars should be continuous across the joints.
- The concrete should be strong enough to transfer the shear stress across the joint. This is commonly done by providing a **shear key** along the joint.
- If necessary, the mat may be thickened to provide sufficient strength in the joints.