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

FOUNDATIONS

- CURS 8 -

Design of shallow foundations

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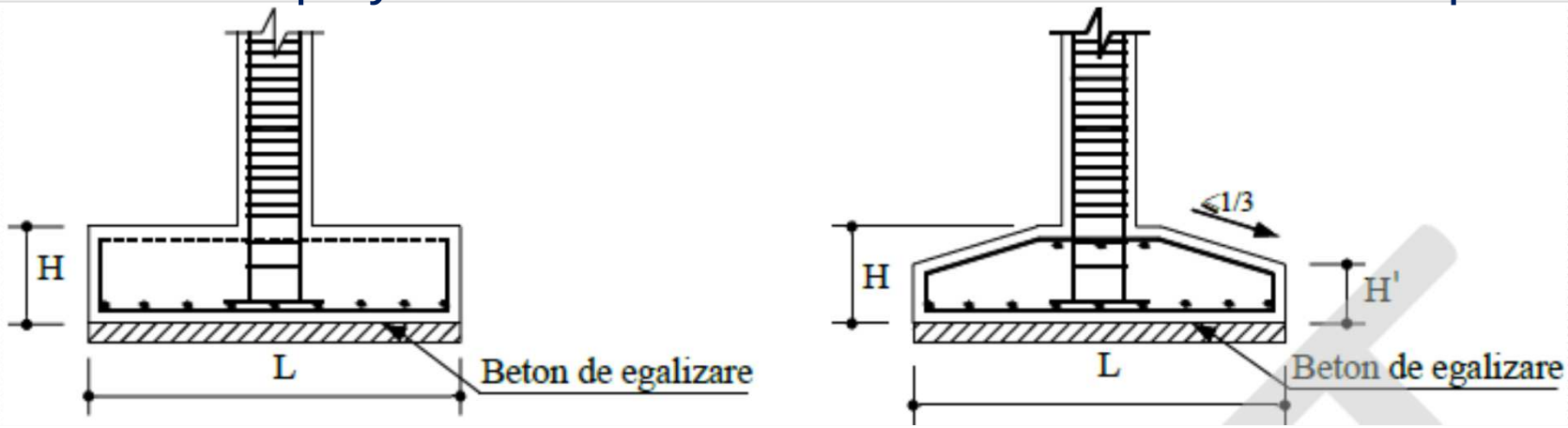
CHAPTER VI – SHALLOW FOUNDATIONS

§ 6.5 Design of reinforced concrete block foundations

- **Reinforced concrete block foundations** (also known as **elastic foundations**) are realized as reinforced blocks under cast-concrete columns.
- This type of foundation is generally used when the columns have high bending moments or when the water level is high.
- The reinforced concrete block foundations could be realized as prismatic or splayed blocks in function of their dimensions in plan.

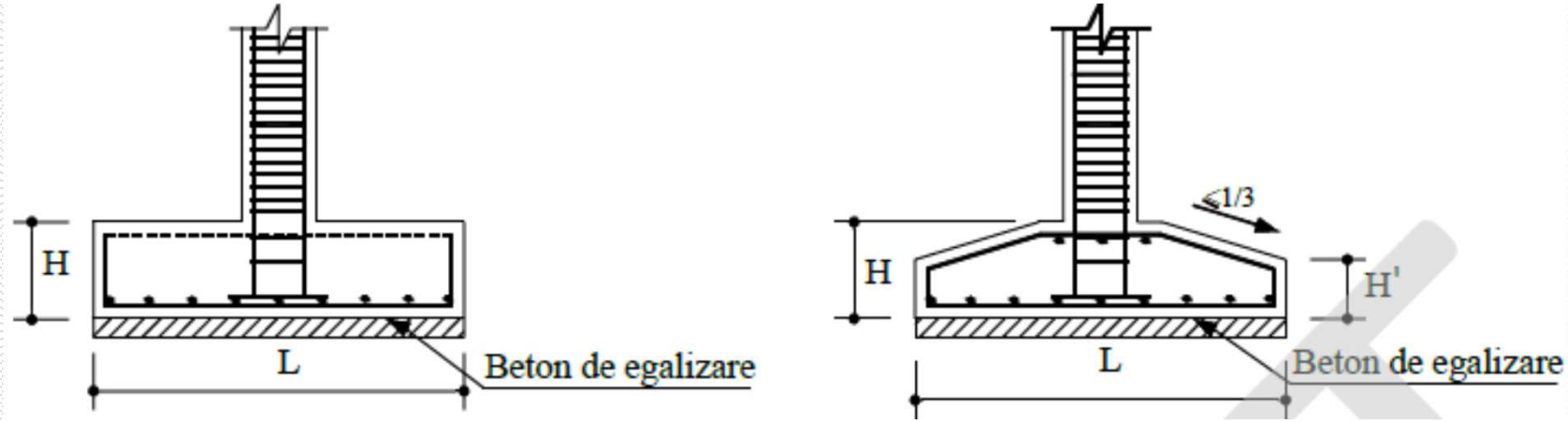


Obs: In order to obtain a horizontal footing level, a 5 to 10 cm equalizing concrete layer is cast (C8/10).

CHAPTER VI – SHALLOW FOUNDATIONS

§ 6.5 Design of reinforced concrete block foundations

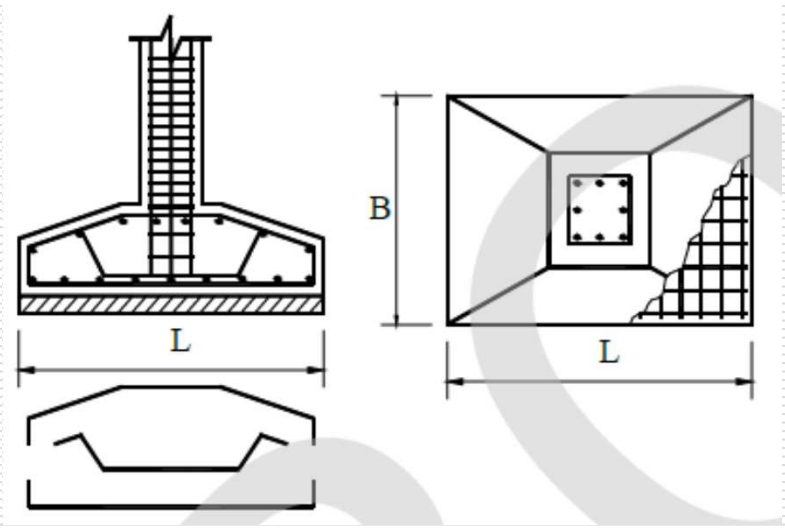
- **Minimum geometrical requirements**

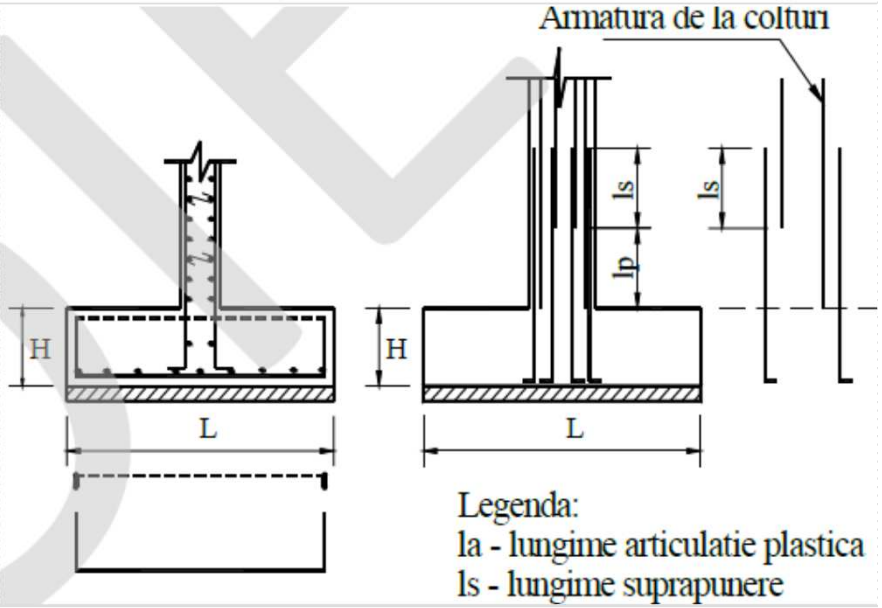


- Minimum height: $H_{min} = 300mm$
- In case of splayed concrete blocks: $H'_{min} = 250mm$
- In case of splayed concrete blocks: slope of inclined faces < 1/3
- Minimum concrete class: min C12/15

§ 6.5 Design of reinforced concrete block foundations (NP 112/2014)

☐ Reinforcement in block foundations:





☐ **Sole reinforcement**:

Results from the design to bending moment of the foundation.

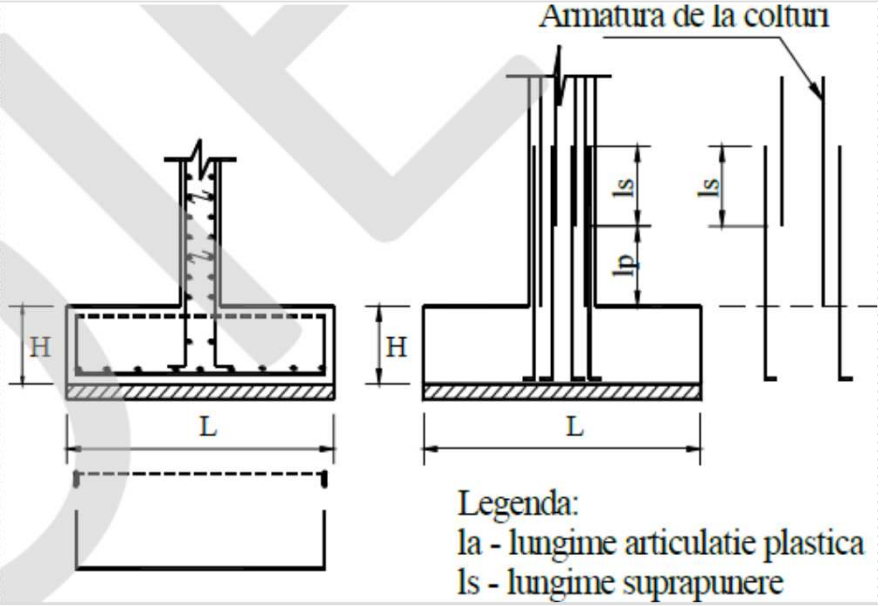
Minimum requirements: p_{min}=0.1%, Φ_{min}=10mm, d_{min}=100mm, d_{max}=250mm, anchoring hooks of minimum height (*d*).

§ 6.5 Design of reinforced concrete block foundations (NP 112/2014)

- Reinforcement in block foundations:
- **Superior reinforcement**:

At least three bars neat the column or grid distributed on foundation:

- constructive for foundations working in compression;
- resulting from bending check of the foundation block, considered as a cantilever and loaded by soil pressure



Minimum requirements: Φ_{min}=10mm, d_{min}=100mm, d_{max}=250mm,

- **Column reinforcement**:

Identical to the column reinforcements. Their design results from the column design.

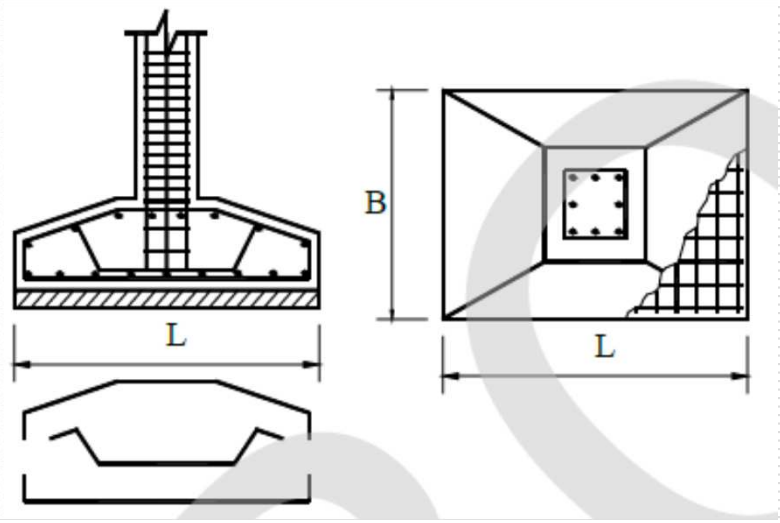
- the reinforcing bars are extended beyond the length of column plastic hinge;
- over this zone, the bars are driven over a length $l_{bd}=30\Phi$

§ 6.5 Design of reinforced concrete block foundations (NP 112/2014)

- Reinforcement in block foundations:
- **Transversal reinforcement**:

Needed to overtake the shear foundation forces or results from punching design.

Is realized as inclined bars under the column.



- **Stirrups**:

Their purpose is to fix the column reinforcement. They are identical to column stirrups.

Minimum requirements: at least three stirrups at maximum distance of 250mm.

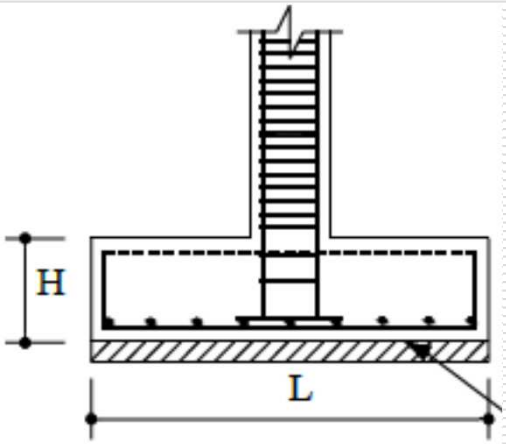
Obs: The proper foundation reinforcement does not need stirrups. The foundation reinforcement results as a reinforcement cage.

§ 6.5 Design of reinforced concrete block foundations (NP 112/2014)

- The dimensions of the foundation block results from the minimum requirements or from different checks characteristic for such systems.

- **Condition of rigid foundation**:

If ***H/L≥0.3*** then we can assume the hypothesis of the linear distribution of the ground pressures.



- **Foundation check to shear force**:

If the following relationship is fulfilled, the foundation does not need transversal reinforcement (characteristic to resist in shear): $V_{Ed} \leq V_{Rd,c}$.

with: V_{Ed} – maximum shear force, resulted from foundation analysis

$V_{Rd,c}$ – concrete shear capacity:

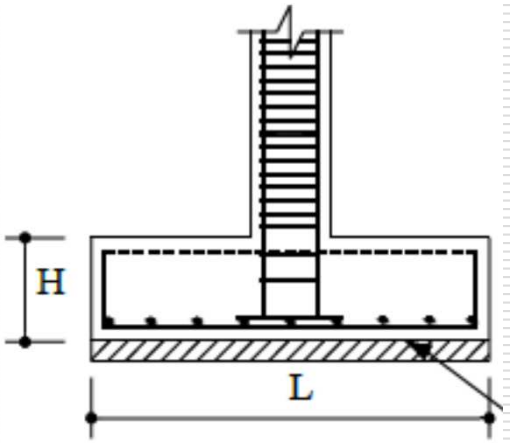
$$V_{Rd,c} = 0{,}12k \cdot (100\rho_1 f_{ck})^{1/3} \cdot B \cdot H$$

but $V_{Rd,c} \geq \nu_{\min} \cdot B \cdot H = 0{,}035k^{3/2} \cdot f_{ck}^{1/2} \cdot B \cdot H$

§ 6.5 Design of reinforced concrete block foundations (NP 112/2014)

$$V_{Rd,c} = 0{,}12k \cdot (100\rho_1 f_{ck})^{1/3} \cdot B \cdot H$$

with: $k = 1 + \sqrt{\frac{200}{d}} \le 2$ $\rho_1 = \frac{A_{sl}}{Bd} \le 0{,}02$



B – foundation width

$d = H - a$ is the effective height of the foundation

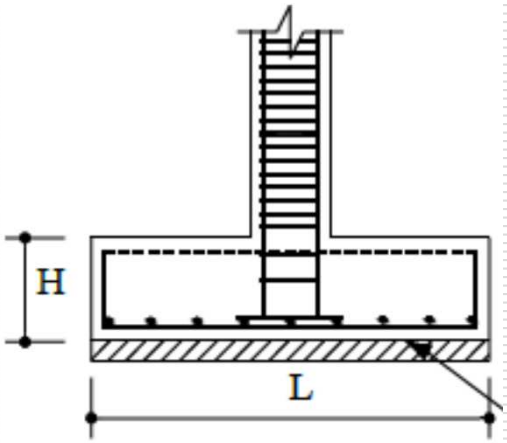
A_{sl} – area of the longitudinal reinforcement extended on a length $l \ge lbd + d$

Obs: If the above condition is not fulfilled, adequate shear reinforcement should be provided. This results from concrete design of the foundation.

§ 6.5 Design of reinforced concrete block foundations (NP 112/2014)

☐ Foundation check to punching:

If the following relationship is fulfilled, the foundation does not need transversal reinforcement against punching: $v_{Fd} \le v_{Rd,c} = 0{,}12k \cdot (100\rho_1 \cdot f_{ck})^{1/3}$



This check is considered on a perimeter u_1, located at a distance *2d* from the column edge.

with: $\rho_1 = \sqrt{\rho_x \rho_y}$ ρ_x, ρ_y the reinforcement percent on x and y directions

$$v_{Fd} = \beta \frac{N_{Fd}}{u_i d}$$

β - a coefficient that accounts for the distribution of bending moments: $\beta=1.15$ for central columns and $\beta=1.5$ other situations.

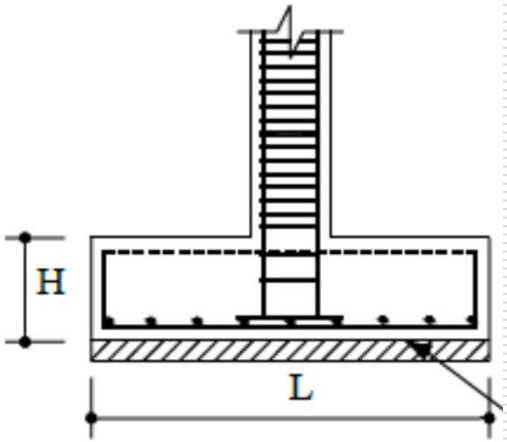
If needed, other punching checks should be performed, on perimeters located at distances smaller than *2d*. In this case $v_{Rd,c}$ will be multiplied with *2d/a* (*a* – distance from the column edge).

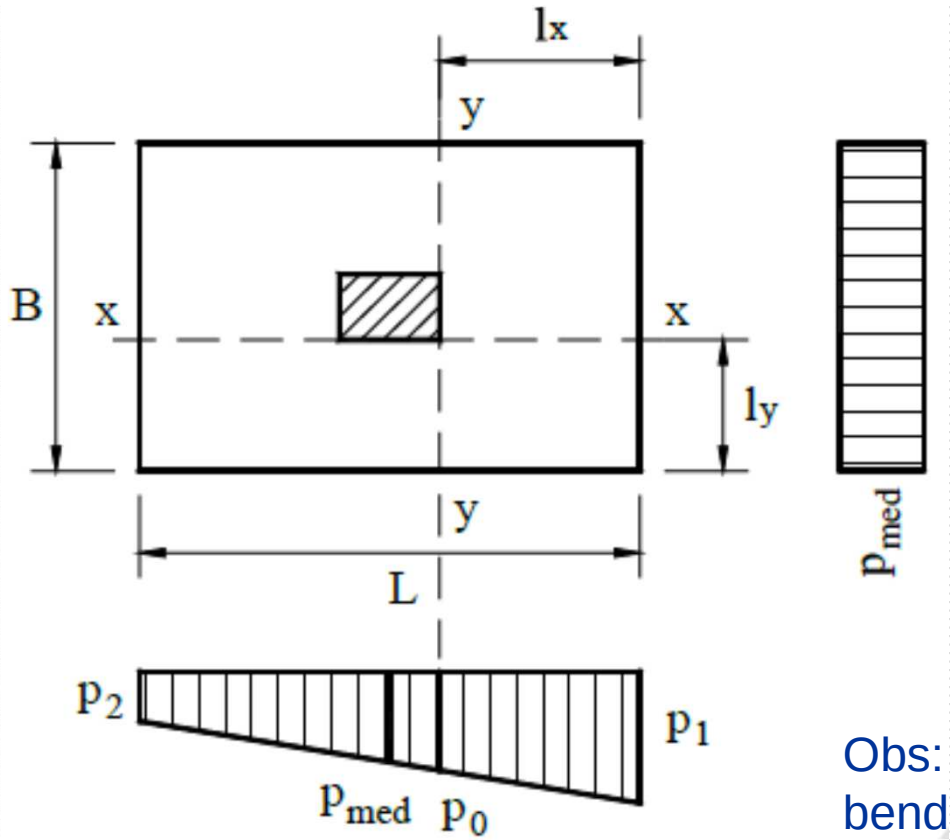
Obs: If the above condition is not fulfilled, adequate punching reinforcement should be provided. This results from concrete design of the foundation.

§ 6.5 Design of reinforced concrete block foundations (NP 112/2014)

☐ Design of sole reinforcement:

The number and distribution of sole reinforcement bars results from the values of bending moments:





Axial load with eccentric bending

$$M_{Fd,x} = B \cdot \left[p_0 \frac{l_x^2}{2} + (p_1 - p_0) \frac{l_x^2}{3} \right]$$

$$M_{Fd,y} = L \cdot p_{med} \cdot \frac{l_y^2}{2}$$

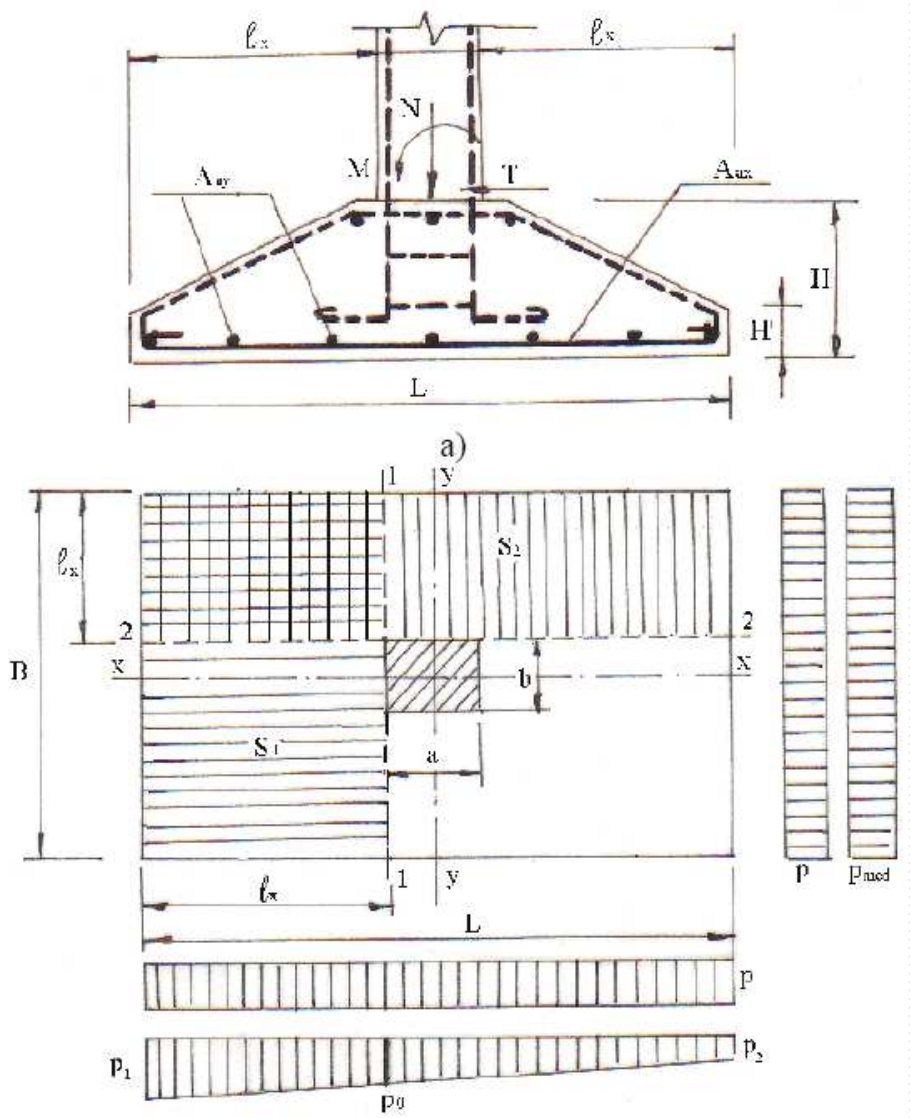
With: $p_{med} = (p_1 + p_2)/2$

Obs: Different formulae are derived for eccentric bending on two directions.

§ 6.5 Design of reinforced concrete block foundations (NP 112/2014)

- **Design of sole reinforcement**:
- In this design, it is considered that the sole is loaded by the geological pressure on a bandwidth l_x (l_y)
- Maximum bending is obtained in cross-sections 1-1 and 2-2 located at the column edge.
- The design is conducted following the usual reinforced concrete rules.

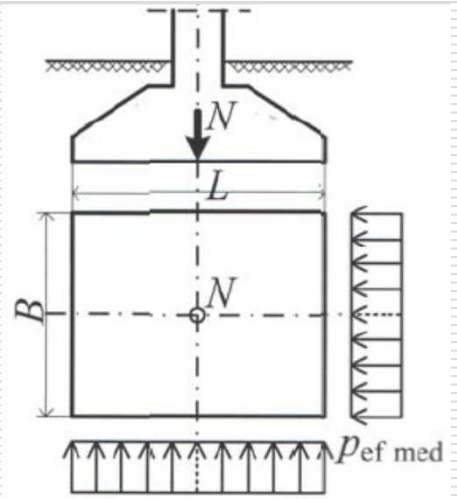
Obs: Upper reinforcement is not needed. However, distribution reinforcement is provided against concrete cracking.



§ 6.5 Design of reinforced concrete block foundations (NP 112/2013)

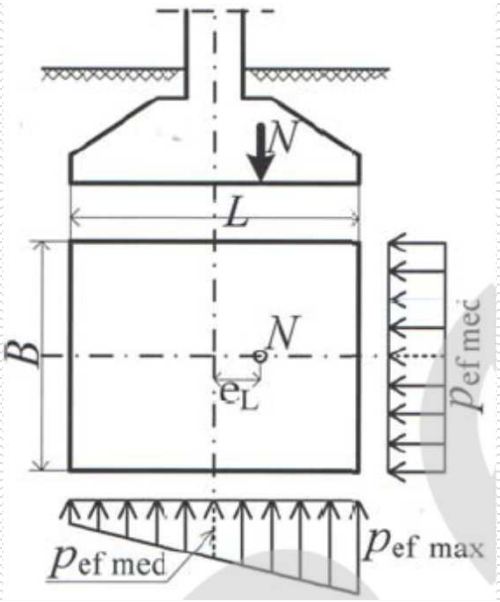
- **Check of soil pressure** :
- Centric loading:

$$p_{\text{ef med}} = N_F / A \leq p_{\text{conv}}$$



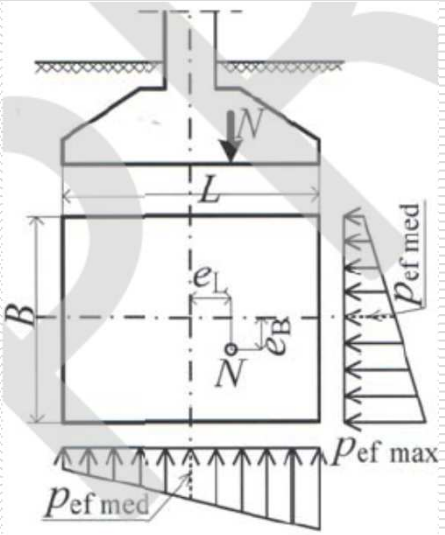
- Uni-axial eccentric loading:

$$p_{ef\,\max} = \omega \frac{N_F}{L \cdot B} \leq 1{,}2\, p_{\text{conv}}$$



- Bi-axial eccentric loading:

$$p_{ef\,\max} = \omega \frac{N_F}{L \cdot B} \leq 1{,}4\, p_{\text{conv}}$$



Obs: From these formulae is excluded the seismic (special) combination of actions.