CALCULATION OF THE FOUNDATION FOR PUNCHING

The minimum height of the slab part of the foundation at the ratio of the sides of its sole l / b = 1.2 ... 1.5 is determined based on the calculation of punching. At the same time, the punching force must be absorbed by the concrete section of the slab part of the foundation, as a rule, without the installation of transverse reinforcement. It is necessary to distinguish between two calculation schemes for compression, depending on the type of connection between the foundation and the column

- *the first scheme* - in the case of a monolithic connection of a column with a foundation or a column support with a slab part of the foundation with a height of the column support $h_{cf} \geq 0.5(l$cf – lc$)$, as well as with a cup conection of a prefabricated column with a high foundation that satisfies the condition $h_{cf} - d_p \geq 0.5(l_{cf} – l_c)$. In this case, the punching of the plate part is considered from the bottom of the monolithic column or column support under the action of the longitudinal force N and the bending moment M;

- *the second scheme* - with a cup connection of a prefabricated column with a low foundation - with a height of the column support that satisfies the condition $h_{cf} - dp < 0.5(l_{cf} – l_c)$. In this case, the foundations are designed to be pressed by the column from the bottom of the cup and to split due to the action of only the longitudinal force N.

The calculation for the punching of the plate part of centrally and eccentrically loaded square and rectangular foundations is carried out under the condition:

$$F \leq f_{ctd} \cdot u_m \cdot h_0,$$

where F is the calculated punching force, kN;

f_{ctd} – calculated value of concrete axial tensile strength, kPa;

for concrete class C8/10 f_{ctd}=800 kPa

for concrete class C12/15 f_{ctd}=1100 kPa

u_m – the average perimeter of the extrusion pyramid, m;

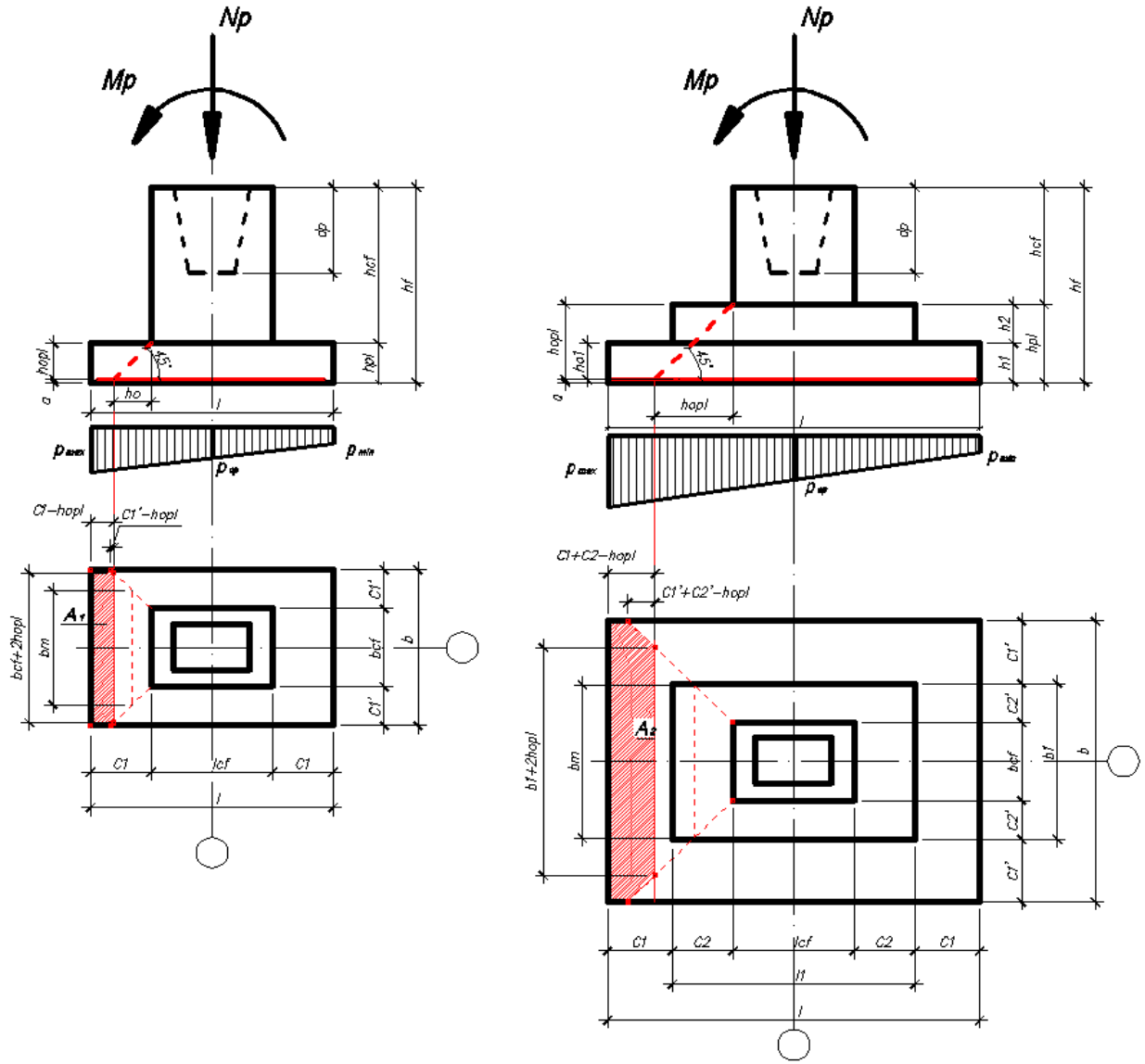
h_0 is the working height of the section for which the calculation is made, m.

When determining the values of um and F, it is assumed that the punching takes place on the side surface of the pyramid, the smaller base of which is the area of action of the punching force (cross-sectional area of the column or column support), and the side faces are inclined at an angle of 45 ° to the horizontal.

The magnitude of the punching force F is taken equal to the value of the longitudinal force N acting on the compaction pyramid, minus the value of the reactive pressure of the soil applied to the larger base of the punching pyramid (taking into account the plane of the stretched reinforcement).

When calculating centrally loaded rectangular and eccentrically loaded square and rectangular foundations, the condition is considered compressive strength of only one most loaded face of the punching pyramid. In this case, the average perimeter of the indentation um is replaced by the average size of the checked boundary b_m.

Calculation according to the first scheme (foundation with developed column support)



The scheme of the formation of a punching pyramid for foundations with one and two steps according to the first scheme

1 *For the lower step*. The punching force is equal to

$$F_{пр} = A_n \cdot p'_{max},$$

$$P_{max} = \frac{N_c}{A} + \frac{M_c}{W}$$

where Nc, Mc are calculated values of longitudinal force and moment, respectively.

We determine the average size of the boundary being checked, m:

$$b_{m1} = \frac{b_1 + 2h_{01} + b_1}{2} = b_1 + h_{01}$$

The area from which the load is collected to determine the punching resistance force (compression area), m^2

$$A_1 = b\left(c_1 - h_{01}\right) - \frac{\left(c'_1 - h_{01}\right)^2}{2} 2$$

We compare:

$$A_1 p'_{max} \le f_{ctd}\, b_{m1} h_{01}.$$

In this case, c_1, c_2 are the cantilever overhang of the foundation slab of the first and second step, respectively, from side *l*; c'_1, c'_2 – cantilever overhang of the foundation slab of the 1st and 2nd staps, respectively, from side *b*.

2 *For the column support*. The average size of the boundary being checked is equal to, m:

$$b_{m2} = \frac{b_{cf} + 2h_{0,pl} + b_{cf}}{2} = b_{cf} + h_{0,pl}$$

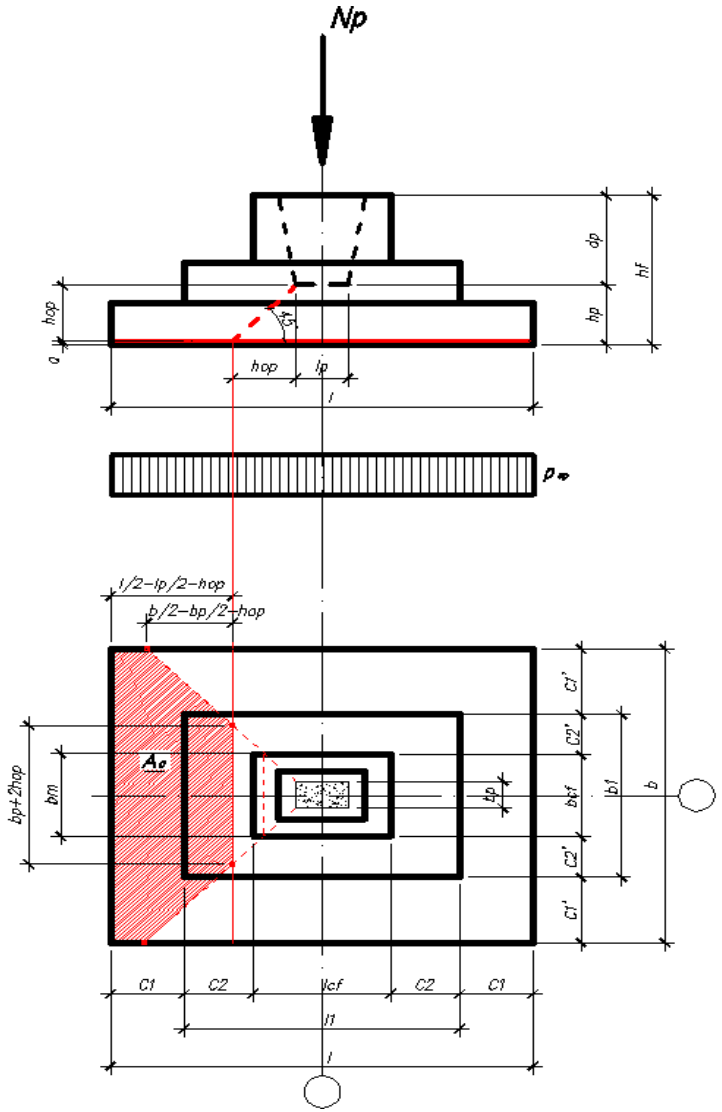
The area from which the load is collected to determine the punching resistance force is, m^2:

$$A_2 = b\left(c_1 + c_2 - h_{0,pl}\right) - \frac{\left(c_1' + c_2' - h_{0,pl}\right)^2}{2} 2$$

We compare:

$A_2 p'_{max} \leq f_{ctd} b_{m2} h_{0,pl}$

Calculation according to the second scheme (foundation with a developed slab part)



Scheme of the formation of the pyramid of punching for the foundation according to the second scheme

This calculation is performed in the following sequence.

We define b_m:

$$b_m = b_p + h_{0,p}$$

where $l_p = l_c + 2 \cdot 0.05$ m, $b_p = b_c + 2 \cdot 0.05$ m – dimensions along the bottom of the larger and smaller sides of the glass;

$h_{0,p}$ is the working height of the punching pyramid from the bottom of the cup to the plane of the stretched reinforcement.

The area from which the load is collected to determine the punching resistance force (Fig.), m^2:

$$A_0 = b\left(\frac{l}{2} - \frac{l_p}{2} - h_{0,p}\right) - 2\frac{\left(\frac{b}{2} - \frac{b_p}{2} - h_{0,p}\right)^2}{2} =$$

$$= 0{,}5b\left(l - l_p - 2h_{0,p}\right) - 0{,}25\left(b - b_p - 2h_{0,p}\right)^2$$

We compare: $A_0\, p'_{cp} \le f_{ctd} b_m h_{0,p}$.

In this case $p'_{cp} = N^p/A$.

If the condition is not met, then we increase the working height of the step (slab part) or (and) increase the class of concrete

Example

Geological structure and hydrogeological conditions of the construction site

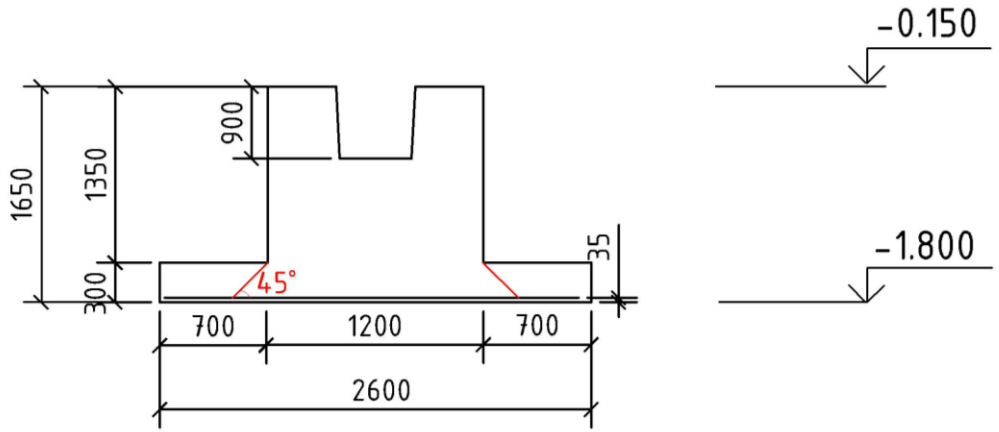
№ layer	Soil	Well number and the depth of the sole of each soil layer from the surface of the earth, m				
		1	2	3	4	5
1.	plant layer	0.3	0,3	0,3	0,3	
2.	Subsidence soil	4,8	4,6	4,9	4,8	
3.	Sand medium-sized	3,4	3,6	3,5	3,3	
4.	sandy loam	3,5	3,6	3,7	3,6	
5.	Clay gray	8,7	8,9	8,8	8,7	
	The depth of underground water	8,2	8,0	8,3	8,1	
	Well mark, m					

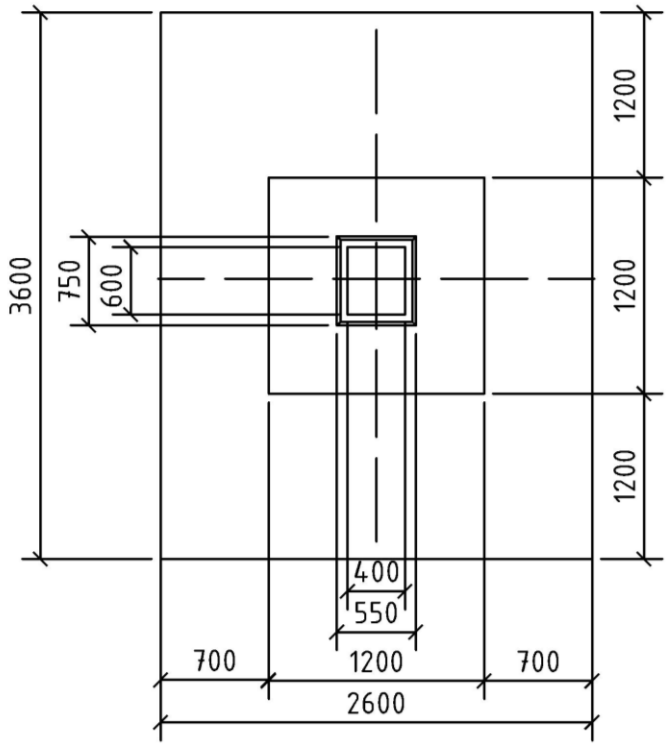
Variant	Cross section of the column, mm	Combination			
		I		II	
		N,MN	M, MNm	N,MN	M,MNm
	600x400	2,1	0,26	1,2	0,41

b = 2,6 m, l = 3,6 m.

Characteristics of soil properties

Name	Legend	Units of measurement	Layer number				
			1	2	3	4	5
Density	ρ_{II}	t/m^3	1,39	1,72	2,01	1,98	2,06
Solid Particle density	ρ_S	t/m^3		2,73	2,68	2,69	2,70
Water content	W			0,15	0,24	0,26	0,22
Liquid limit	W_L			0,35		0,28	0,40
Plastic limit	W_P			0,19		0,22	0,20
Angle of internal friction	φ_{II}	degree		21	33	20	15
Specific cohesion	C_{II}	kPA		25	1	12	80
Modulus of Deformation	E	MPa		20	30	15	50
Relative subsidence under pressure p, МПа	ε_{SL}	p=0,1		0,04			
		p=0,2		0,073			
		p=0,3		0,082			
Angle of internal friction water-saturated soil	$\varphi_{II,sat}$	degree		19			
Specific cohesion water-saturated soil	$C_{II,sat}$	kPA		5			
Modulus of Deformation water-saturated soil	E_{sat}	MPa		6			





we check the condition

$h_{cf} - d_p \geq 0.5(l_{cf} - l_c)$

1,35-0,9=0,45 ≥ 0,5(1,2-0,6)=0,3- *the first scheme*

$$A_2 p'_{max} \leq f_{ctd} b_{m2} h_{0,pl}$$

$$P_{max} = \frac{2100 * 1{,}2}{2.6 \cdot 3.6} + \frac{260 * 1{,}2}{5{,}616} = 279{,}9\ kPa < 338{,}6\ kPA$$

the working height of the section:

$h_{0,pl}$=h-0.035=0.3-0.035=0.265m

The average size of the boundary being checked is equal to, m:
700

$$b_{m2} = \frac{b_{cf} + 2h_{0,pl} + b_{cf}}{2} = b_{cf} + h_{0,pl} = 1200 + 265 = 1465 \text{ мм}$$

The area from which the load is collected to determine the punching resistance force is, m^2:

$$A_2 = b\left(c_1 + c_2 - h_{0,pl}\right) - \frac{\left(c_1' + c_2' - h_{0,pl}\right)^2}{2} 2 = 2{,}6(0.95+0-0.265) - (0.7+0-0.265)^2 = 1{,}59\ m^2$$

We compare:

$$A_2 p'_{max} \le f_{ctd} b_{m2} h_{0,pl}$$

$$A_2 p'_{max} = 1{,}59 \cdot 279{,}9 = 445{,}5\ kN \not\le f_{ctd} b_m h_{0,pl} = 800 \cdot 1{,}465 \cdot 0{,}265 = 310{,}6\ kN$$

The condition is not met. We assume a step height of 450 mm

$$A_2 p'_{max} = 1{,}96 \cdot 279{,}9 = 548{,}5\ kN \le f_{ctd} b_m h_{0,pl} = 1100 \cdot 1{,}615 \cdot 0{,}415 = 737{,}2\ kN$$