Ministry of Education and Science of Ukraine

Dnipro University of Technology

Faculty of Construction
Department of Construction, Geotechnics and Geomechanics

TUTORIAL ON TERM PROJECT IN SOIL MECHANICS, BASES AND FOUNDATIONS

(Part1)

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Dnipro

2019

I. INITIAL DATA

Table 1. Initial data

Parameters	Variants									
	1	2	3	4	5	6	7	8	9	10
L, m	6	6	6	6	6	6	6	6	6	6
b, m	6	5	4	6	5	4	6	5	4	6
d, m	1,5	1,5	1,5	1,4	1,4	1,4	1,6	1,6	1,6	1,3
N, t	100	100	100	100	150	150	150	180	180	180
Mx,t*m	2	2	2	2,5	1,1	2	1,1	2,5	2	2,5
My,t*m	1,5	1,5	1,5	0,0	1,2	1,5	1,2	0,0	1,5	0,0
Geology paremeters variant	1	2	3	1	2	3	1	2	3	2

Note: Data related to task variant 1 are marked in yellow

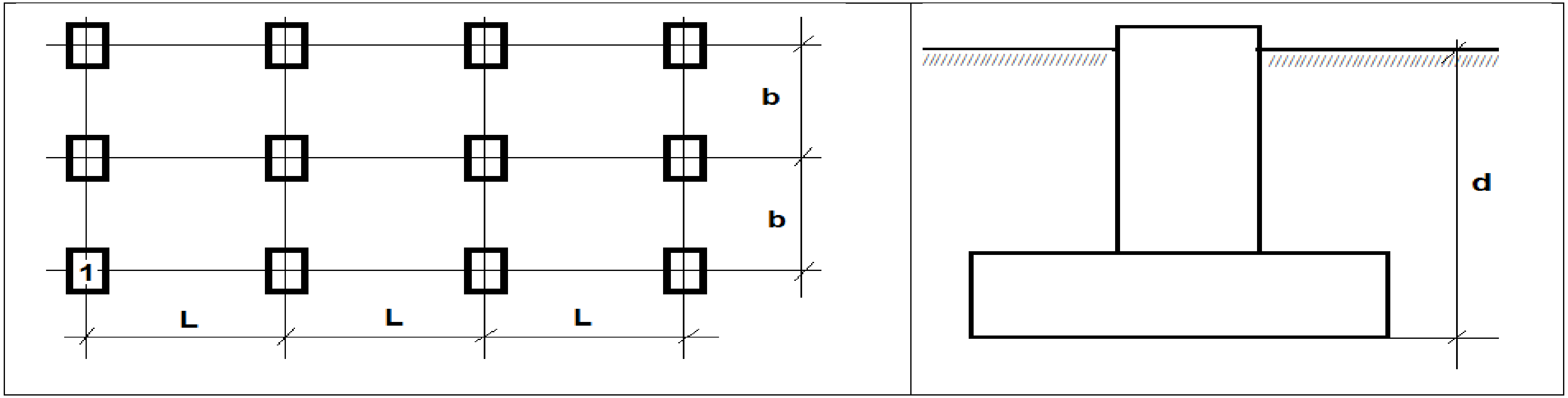


Fig. 1. Charts of placing foundations (left) and foundation bottom depth (right)

Table 2. Geology. Variant 1. Initial data

№	Type of soil	Thickness of the soil layer, m	γ_s	γ	W	W_p	W_L	ν	I_p	I_L	γ_d	e		S_r	φ	c	$\frac{E}{E_e}$
1	2	3	4	5	6	7	8	9	10	11	12	13		14	15	16	17
	Soil (Q_4)	1,4-1,6	-	16,00	0,13	-	-		-	-	-	-		-	-	-	
2	A loam is grey with the middle size sand particles ($d\ Q_2$)	5,6-6,4	26,60	17,80	0,17	0,14	0,22	0,37	0,08	0,38	15,21	0,75		0,60	25	13,0	$\frac{12{,}0}{12{,}6}$
3	Middle size sand ($al\ N_1$)	Unlimited.	26,50	18,80	0,17	-	-	0,20	-	-	16,07	0,65		0,69	35	1	$\frac{29{,}5}{31{,}0}$
	Water level depth = 7 meters																

Notes:

1. Units of measure in columns 6, 7, 8, 9, 10, 11, 13 and 14 are parts of unit.
2. Units of measure in columns 4, 5, 12, 16, 17 - $\frac{kN}{m^3}$.
3. Units of measure in column 15 is degrees
4. The blue colour column data is necessary to be specified.
5. The dark blue colour column data is necessary to be defined according to the building regulations tables (ДБН)

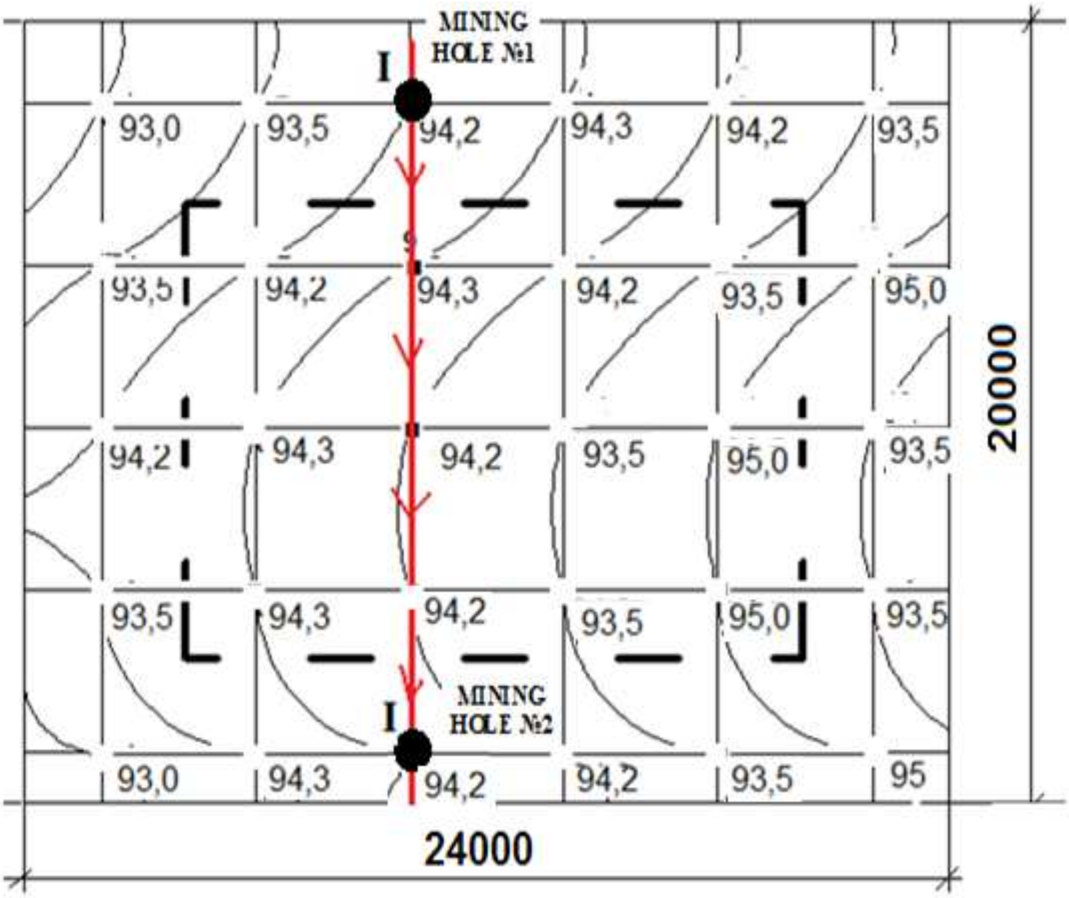


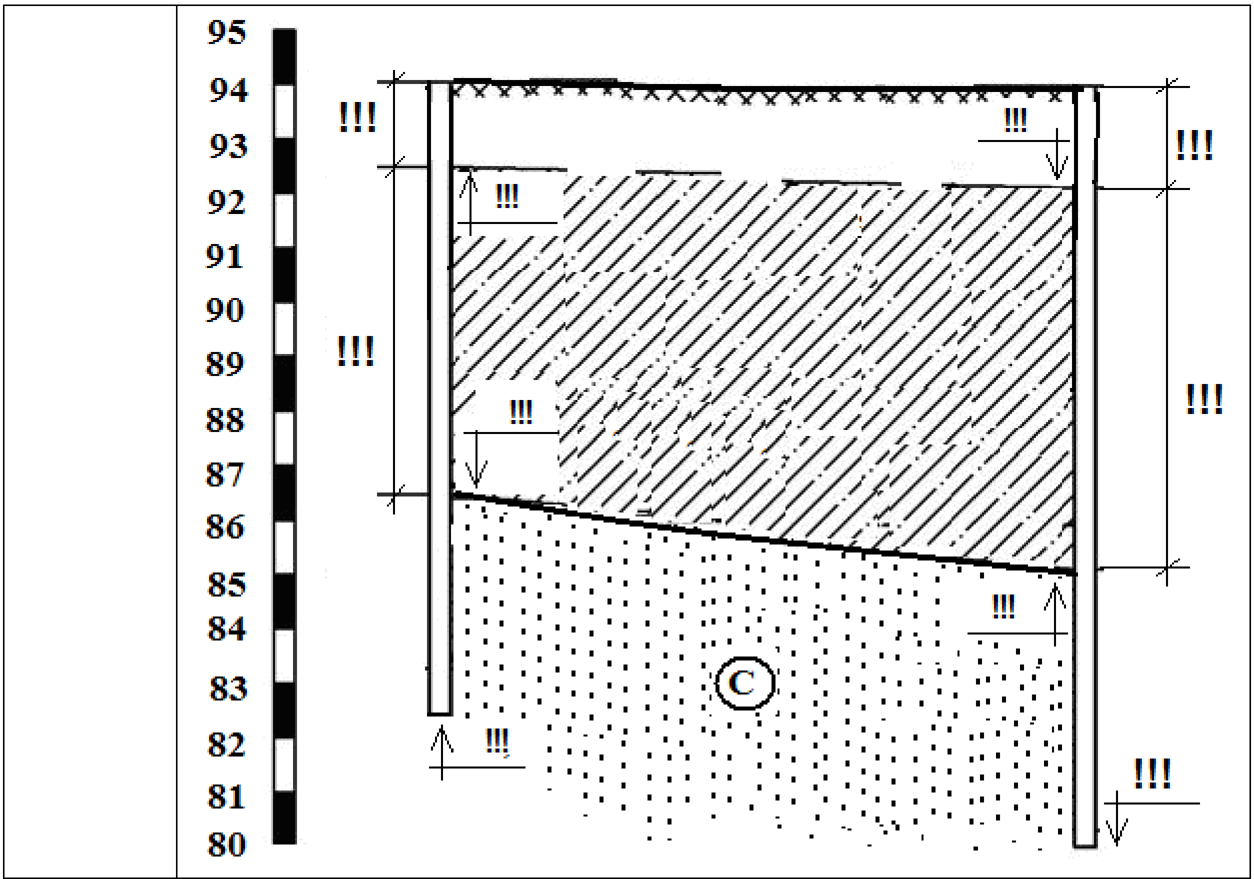
Fig. 2. Site plan (fragment). Geological intersection.

Explanation:

1. Wavy lines are «horizontal lines»

2. The dotted line correspond to the contour of the designed building

3. I-I it is a geological intersection between mining holes 1 and 2



Number of mining hole	O 3	O27
Mark of top of mining hole	94,2	93,5
Distance	100	
Date	01.02.2019	10.03.2019

Fig. 3. Geological intersection according to I-I line between mining holes 1 and 2
Note. The current figure must be considered together with fig. №2

II. Information for the design

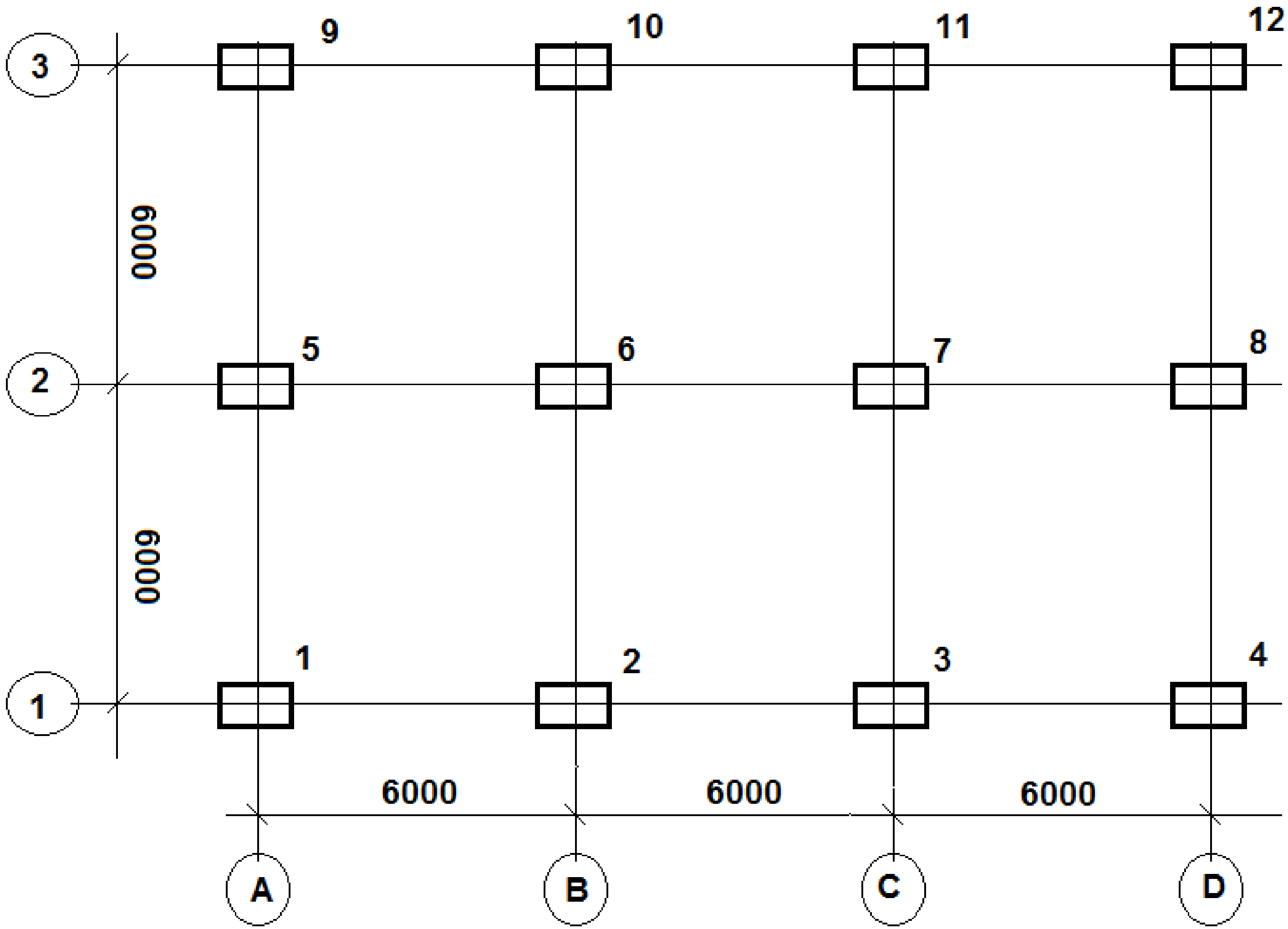


Fig. 4. Chart of foundations places. 1, 2,...,12 are numbers of foundations

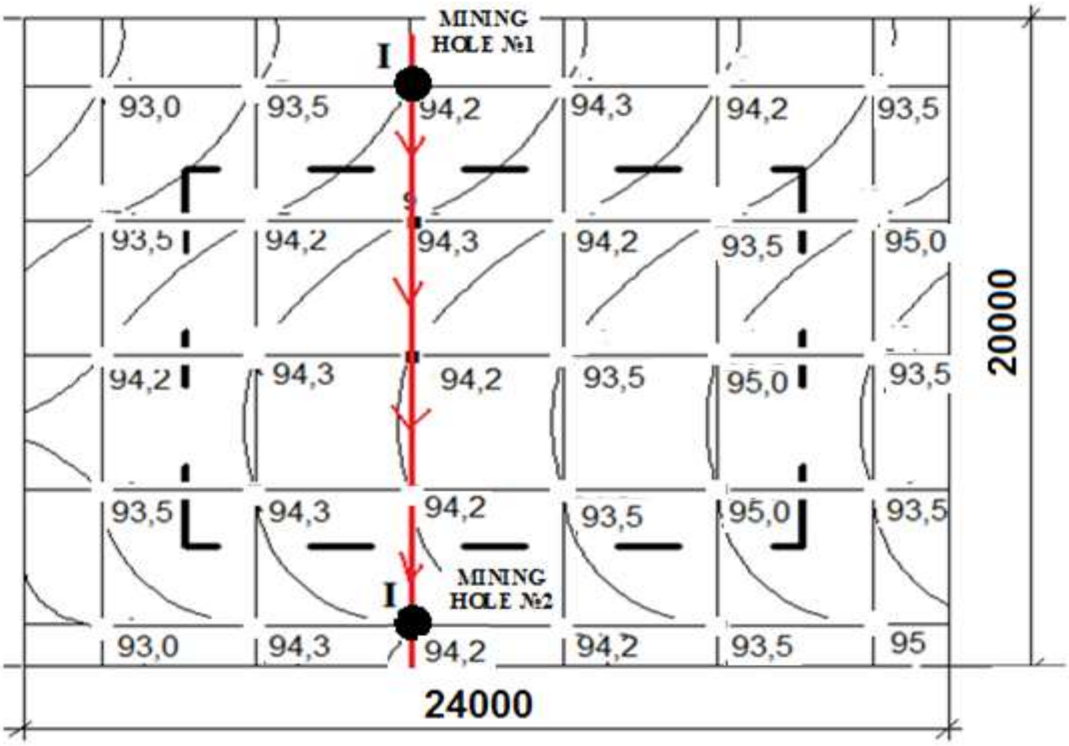


Fig. 5. Fig. 2. Site plan (fragment). Geological intersection.
Explanation: 1. Wavy lines are «horizontal lines»
2. The dotted line correspond to the contour of the designed building
3. I-I it is a geological intersection between mining holes 1 and 2

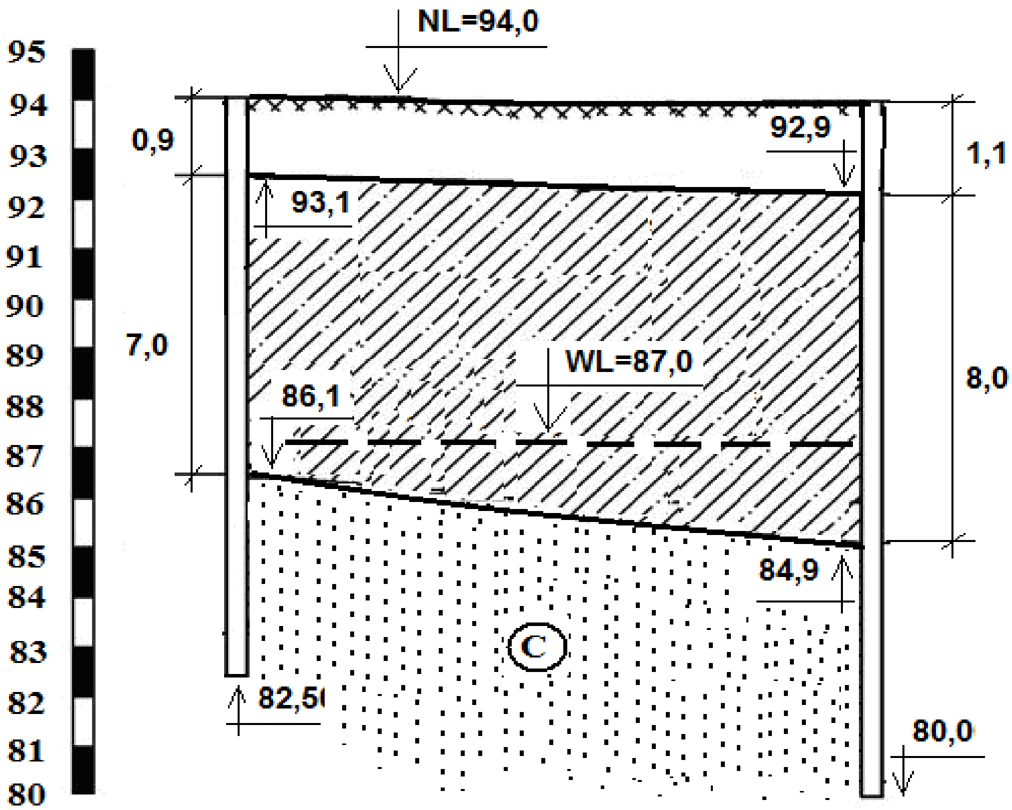


Fig. 6. Geological intersection according to I-I line between mining holes 1 and 2
Note. The current figure must be considered together with fig. № 4, 5, 6

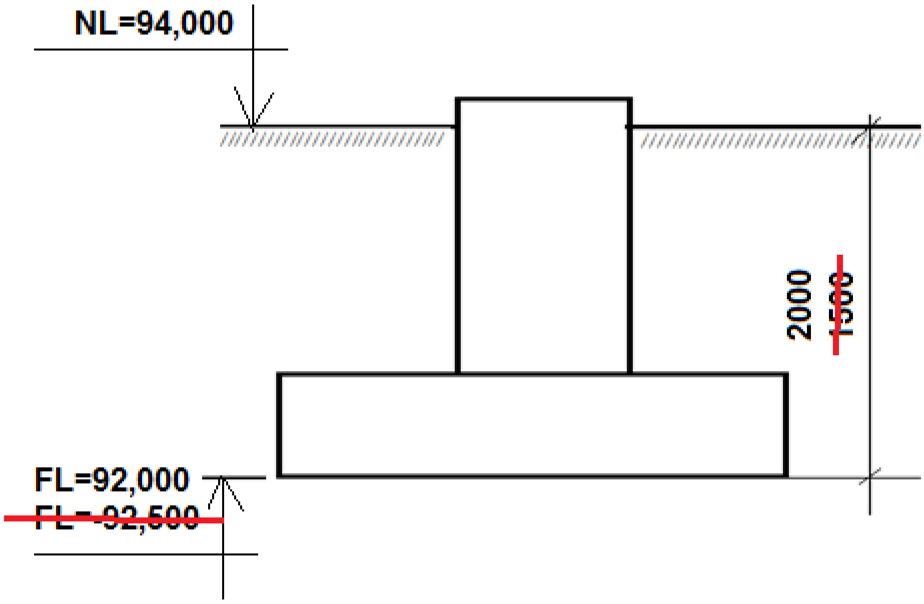


Fig. 7. Absolute marks of foundation surface and bottom of foundation

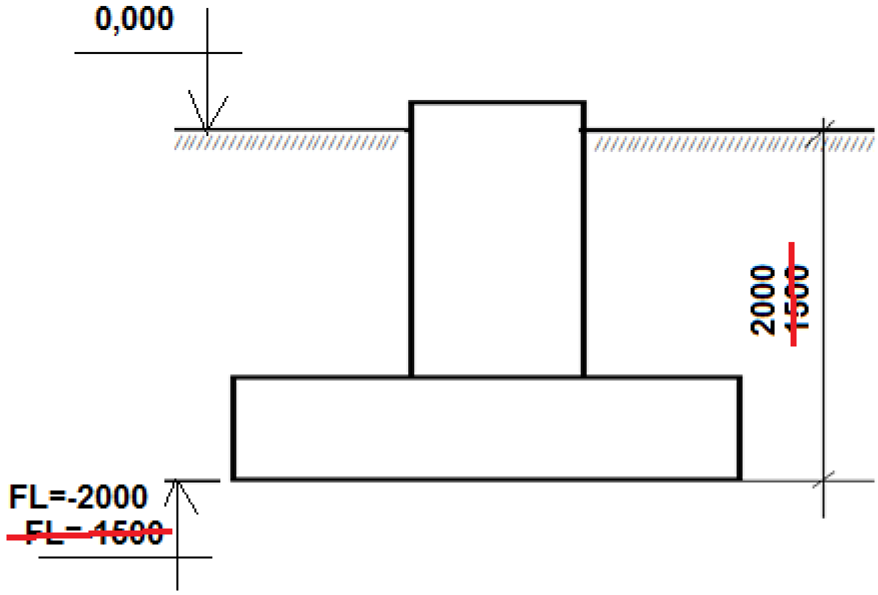


Fig. 8. Mark of foundation bottom from the level of “a clean floor”

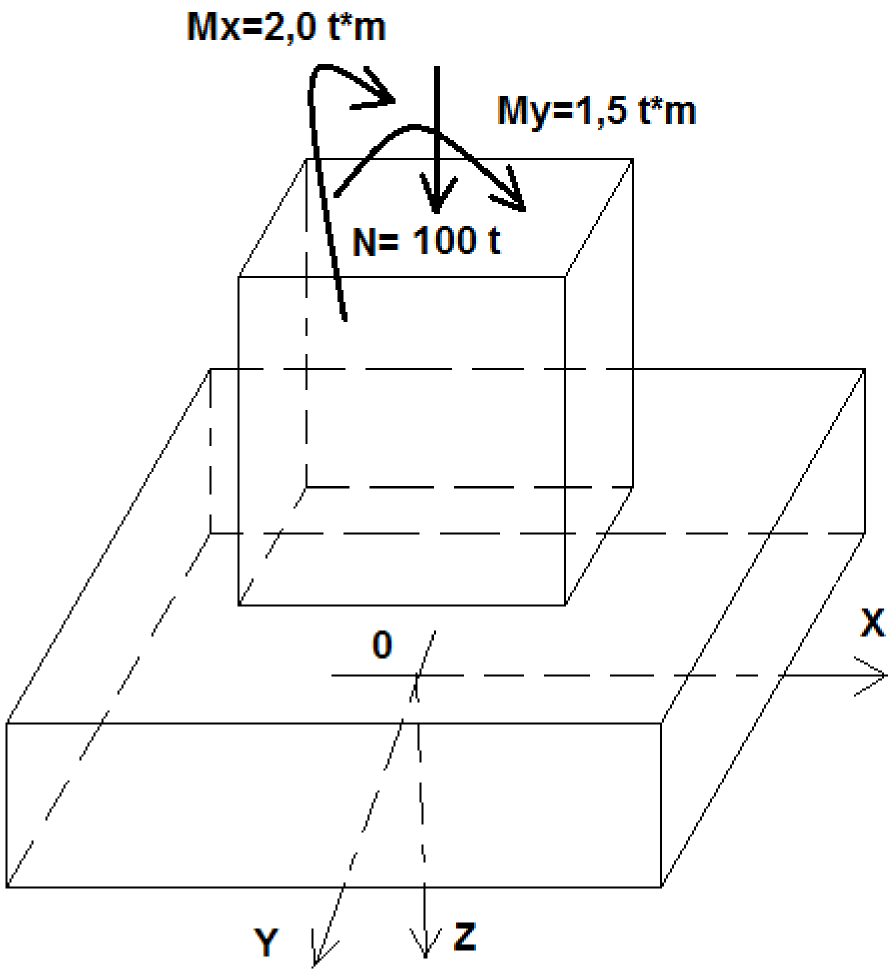


Fig. 9. Operating on foundation loadings (chart)

III. Design data verification

Information was verified according to the following way:

1. Unit weight of dry soil:

$$\gamma_d = \frac{\gamma}{1+W}, \qquad (1)$$

where γ is unit weight of soil; γ_d - the same for a dry soil; W - humidity (moisture)

2. Coefficient of porosity

$$e = \frac{\gamma_s - \gamma_d}{\gamma_d} \qquad (2),$$

where e - is a coefficient of porosity; γ_s - unit weight of soil particles.

3. Number of plasticity:

$$I_p = W_L - W_P \qquad (3).$$

де I_p - показник текучості; W_p - вагова вологість на границі розкочування; W_L - те ж саме, на границі текучості.

here I_p - number of plasticity, W_p - humidity at pinning-out limit, W_L - humidity at fluidity limit,

4. Fluidity ratio

$$I_L = \frac{W - W_p}{I_p} \qquad (4),$$

where W is weight humidity, I_L a number of humidity.

5. Humidity ratio:

$$S_r = \frac{W \cdot \gamma_s}{e \cdot \gamma_w} \qquad (5),$$

where S_r - humidity ratio; γ_d =10 $\frac{кН}{м^3}$ unit weight of water.

For calculations the program "Excel" was used (fig. 10),

Calculations results are given in a table 3.

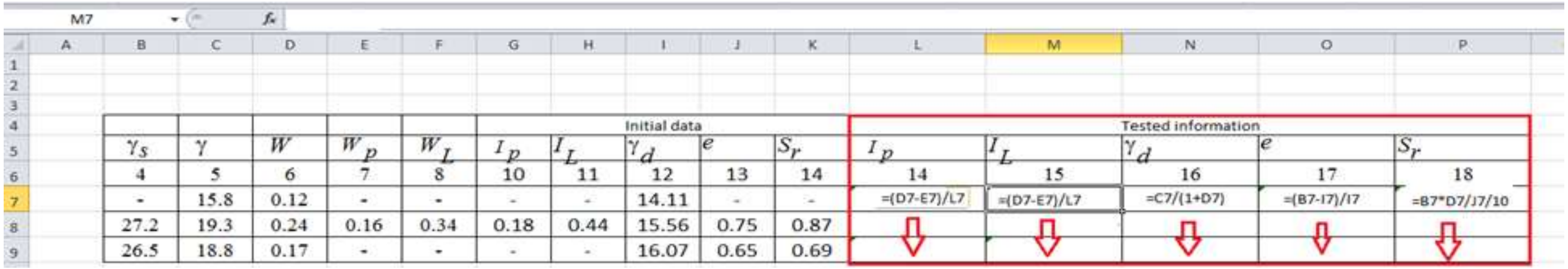
Conclusion: It is possible to use tables data for the further calculations.

The normative strength properties of sand c, φ, and the total deformation modulus E were determined according to the table B-1 of Annex “B” ДБН-В.2.1-10-2009.

These data are presented in table 4.

The normative properties of the clay strength c, φ and the total deformation modulus were determined according to tables B-2 and B-3 of Annex “B” DBN-B.2.1-10-2009.

These data are presented in tab. 5 and tab. 6.



	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
4						Initial data					Tested information				
5	γ_s	γ	W	W_p	W_L	I_p	I_L	γ_d	e	S_r	I_p	I_L	γ_d	e	S_r
6	4	5	6	7	8	10	11	12	13	14	14	15	16	17	18
7	-	15.8	0.12	-	-	-	-	14.11	-	-	=(D7-E7)/L7	=(D7-E7)/L7	=C7/(1+D7)	=(B7-I7)/I7	=B7*D7/J7/10
8	27.2	19.3	0.24	0.16	0.34	0.18	0.44	15.56	0.75	0.87	⇩	⇩	⇩	⇩	⇩
9	26.5	18.8	0.17	-	-	-	-	16.07	0.65	0.69					

Fig. 10. Order of using "Excel" program

Table 3. Geology. Initial data verification

№	Title of soil	Thickness of the soil layer,	γ_s	γ	W	W_p	W_L	Initial data					Calculated data				
								I_p	I_L	γ_d	e	S_r	I_p	I_L	γ_d	e	S_r
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
2	Soil (Q_4)	1,4-1,6	-	16,00	0,13	-	-	-	-	-	-	-	-	-	14.159	-	-
	A loam is grey with the middle size sand particles ($d\ Q_2$)	5,6-6,4	26,60	17,80	0,17	0,14	0,22	0,08	0,38	15,21	0,75	0,60	0.08	0.375	15.214	0.748	0.603
3	Middle size sand ($al\ N_1$)	Unlimited.	26,50	18,80	0,17	-	-	-	-	16,07	0,65	0,69	-	-	16.068	0.649	0.693
Water level depth = 7 meters																	

Table 4. Geology. Initial data verification. Determination of sand properties

ДБН- В.2.1-10-2009

Table B.1 - Normative values of specific cohesion c_n, kPa, angle of internal friction φn, degree, and modulus of deformation E, MPa, for sands of Quaternary sediments

Sands	Indication of soil characteristics	Soil Characteristics at Porosity Ratio *e*			
		0,45	0,55	0,65	0,75
Gravelly and large	c_n	2	1	-	-
	φ_n	43	40	**38**	-
	E	50	40	**30**	-
Medium size	c_n	**3**	**2**	**1**	-
	φ_n	**40**	**38**	**35**	-
	E	**50**	**40**	**30**	-
Small	c_n	6	4	2	-
	φ_n	38	36	32	28
	E	48	38	28	18
Dusty	c_n	8	6	4	2
	φ_n	36	34	30	26
	E	39	28	18	11

Table 5. Geology. Initial data verification. Determination of the strength properties of clay

ДБН- В.2.1-10-2009
Table B.2 - Normative values of specific cohesion Cn, kPa, angle of internal friction φn, degree, Clay non-forest soils Quaternary sediments

Titles of soils and limits of normative values of their yield ratio		Indication of soil characteristics	Soil Characteristics at Porosity Ratio *e*						
			0,45	**0,55**	**0,65**	**0,75**	**0,85**	**0,95**	**1,05**
Sandy loam	$0 \le I_L \le 0{,}25$	c_n	21	17	15	13	-	-	-
		φ_n	30	29	27	24	-	-	-
	$0{,}25 \le I_L \le 0{,}75$	c_n	19	15	13	11	9	-	-
		φ_n	28	26	24	21	18	-	-
Loam	$0 \le I_L \le 0{,}25$	c_n	47	37	31	25	22	19	-
		φ_n	26	25	24	23	22	20	-
	$0{,}25 \le I_L \le 0{,}5$	c_n	39	34	28	**23**	18	15	-
		φ_n	24	23	22	**21**	19	17	-
	$0{,}5 \le I_L \le 0{,}75$	c_n	-	-	25	20	16	14	12
		φ_n	-	-	19	18	16	14	12
Clay	$0 \le I_L \le 0{,}25$	c_n	-	81	68	54	47	41	36
		φ_n	-	21	20	19	18	16	14
	$0{,}25 \le I_L \le 0{,}5$	c_n	-	-	57	50	43	37	32
		φ_n	-	-	18	17	16	14	11
	$0{,}5 \le I_L \le 0{,}75$	c_n	-	-	45	41	36	33	29
		φ_n	-	-	15	14	12	10	7

Table 6. Geology. Initial data verification. Determination of the total deformation modulus clay

ДБН- В.2.1-10-2009
Table B.3 - Normative values of the deformation modulus of clay non-forest soils

Origin and age of soils		Titles of soils and limits of normative values of their of I_L-fluidity ratio		The modulus of deformation E, MPa, at the porosity coefficient e										
				0,35	0,45	0,55	0,65	0,75	0,85	0,95	1,05	1,2	1,4	1,6
Quaternary deposits	**Alluvial, deluvial, lake, lake-alluvial**	**Sandy loams**	$0 \le I_L \le 0{,}75$	-	32	24	16	10	7	-	-	-	-	-
		Loam	$0 \le I_L \le 0{,}25$	-	34	27	22	17	14	11	-	-	-	-
			$0{,}25 \le I_L \le 0{,}5$	-	32	25	19	**14**	11	8	-	-	-	-
			$0{,}5 \le I_L \le 0{,}75$	-	-	-	17	12	8	6	5	-	-	-
		Clay	$0 \le I_L \le 0{,}25$	-	-	28	24	21	18	15	12	-	-	-
			$0{,}25 \le I_L \le 0{,}5$	-	-	-	21	18	15	12	9	-	-	-
			$0{,}5 \le I_L \le 0{,}75$	-	-	-	-	15	12	9	7	-	-	-

Table 7. Geology. Initial data verification

№	Title of soil	I_L	e	Initial data			Tabular data			Calculations data		
				φ	c	$\frac{E}{E_e}$	$φ^n$	c^n	$\frac{E^n}{E_e}$	φ	c	$\frac{E}{E_e}$
1	2	3	4	5	6	7	8	9	10	11	12	13
2	Soil (Q_4)	-	-	-	-	-	-	-	-	-	-	-
	A loam is grey with the middle size sand particles ($d\ Q_2$)	0,44	0,75	19	10,0	$\frac{17,5}{18,4}$	21	23	$\frac{14}{-}$	18.26	15.33	$\frac{14}{70}$
3	Middle size sand ($al\ N_1$)	-	0,65	35	1	$\frac{29,5}{31,0}$	35	1	$\frac{30}{-}$	32,8	0,67	$\frac{30}{150}$

The normative soil properties required for the calculation were determined according to the table B-1 of Annex “B” ДБН-В.2.1-10-2009.

Designes characteristics of soils are given in tables B.1-B.3

In this case, the calculated values of soil characteristics should be taken according to values of soil reliability coefficients:

- at bases calculations according to deformation γg = 1;
- at bases calculations according to bearing capacity:

for the unit cohesion $\gamma_{g(c)}$ = 1,5;

for the internal friction angle: sands $\gamma_{g(\varphi)}$ = 1,1; clay soils $\gamma_{g(\varphi)}$ = 1,15.

1. Designed properties of sand:

$$E = \frac{E^n}{\gamma_g} = \frac{30}{1} = 30\ MPa$$

$$E_e = 5 \cdot E = 5 \cdot 30 = 150\ MPa$$

$$\varphi = \frac{\varphi^n}{\gamma_g(\varphi)} = \frac{35}{1{,}1} = 32{,}8\ degrees$$

$$c = \frac{c^n}{\gamma_g(c)} = \frac{1}{1{,}5} = 0{,}67\ kPa$$

2. Designed properties of clay:

$$E = \frac{E^n}{\gamma_g} = \frac{14}{1} = 14\ MPa$$

$$E_e = 5 \cdot E = 5 \cdot 14 = 70\ MPa$$

$$\varphi = \frac{\varphi^n}{\gamma_g(\varphi)}$$ =21/1.15=18.26 degrees

$$c = \frac{c^n}{\gamma_g(c)}$$ =23/1.5= 15.33 kPa

Conclusions:

1. The soil properties calculated from the ДБН tables (tabl. 7) differ from the table 2 data.

2. The data presented in table 2 were obtained by testing the soil, and in table 7 using the calculation.

3. Therefore, we will use the table 2 data.

VI. Foundation bottom depth determination

1. Foundation bottom depth determination (Annex ''B'' of ДБН)

Foundation bottom depth should be determined taking into account:

1. Depths of seasonal freezing.
2. Engineering and geological features of soil structure.
3. Features of the designed structure (for example, the presence or absence of a basement).
4. Landscape of territory which the building is erected.
5. The value and nature of the load acting on the foundation.
6. Foundation bottom depths of neighboring buildings.
7. Location in plan and according to depth of engineering communications.

1. Consideration of the seasonal freezing depth:

The depth of laying foundation bottom is determined according to the formula:

$$d_1 = d_{fn} = d_0 \cdot \sqrt{M_t} \,, \qquad (6)$$

where d_{fn} - regulatory depth of seasonal freezing; M_t - dimensionless temperature coefficient; $d_0 = 0{,}23$ - for loam and clay; $d_0 = 0{,}28$ for sandy loam, sandy and fine sand; $d_0 = 0{,}30$ for sands of gravelly, large and medium size; $d_0 = 0{,}34$ for large rubble soils.

For the Dnipro city $M_t = 20$

For loam $d_0 = 0{,}28$

We have:

$d_1 = d_{fn} = d_0 \cdot \sqrt{M_t} =$ 0.23*(20)^0.5= 1.03 м

The final design depth of freezing is determined by the formula:

$$d_f = k_h \cdot d_{fn} \,, \qquad (7)$$

where k_h is the coefficient which depends on the thermal regime of the designed structure, the location of the designed foundation and the construction features (it should be taken in accordance with Table ДБН. В2 Annex В).

According to the lecturer data we accept k_h = 1.

We have:

$d_1 = d_f = k_h \cdot d_{fn}$=1*1,03=1,03 м.

2. Taking into account engineering and geological soil structure features

The foundation bottom should be immersed in the bearing soil layer no less than 0.5 meters (Fig. 10). The following soil types cannot be used as a soil bearing layers:

- fluid consistency clay soils;
- loose sands;
- soil vegetation layer.

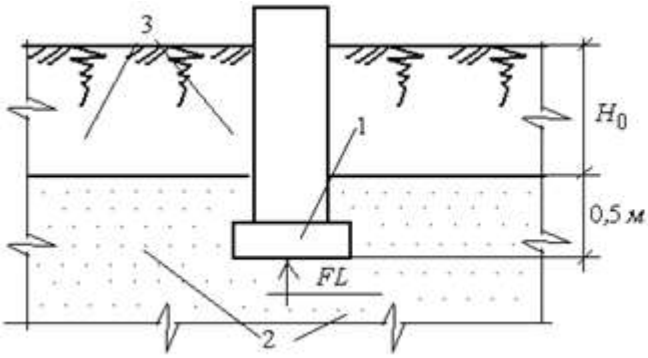


Fig. 10. Scheme of determining the foundation bottom depth:
1 - foundation; 2 - bearing layer; 3 - cover layer

The calculation is performed according to the formula:

$$d_2 = d_z = H_0 + 0{,}5 \text{ m}, \tag{8}$$

where d_z - the foundation depth; H_0 - the soil layer thickness which is composed of soils that cannot be used as a bearing layer (Fig. 10).

We have (see table 2, column 3):

$$H_0 = (1{,}4+1{,}6)/2=1{,}5 \text{ m}.$$
$$d_2 = d_z = H_0 + 0{,}5 \text{ m}=1{,}5 \text{ m} +0{,}5 \text{ m}=2{,}2 \text{ m}.$$

3. Taking into account the designed structure features (presence or absence of a basement)

The calculation is doing as follows (Fig. 11):

$$d_3 = d_p = H_p + d_{p1} + d_{p2} + 0{,}9 \text{ m}, \tag{9}$$

where d_p - depth of foundation; H_p - depth of the basement; d_{p1} - basement floor thickness; d_{p2} - thickness of preparation layer for basement floor; 0,9 - the thickness of soil layer above the foundation bottom according to the basement side.

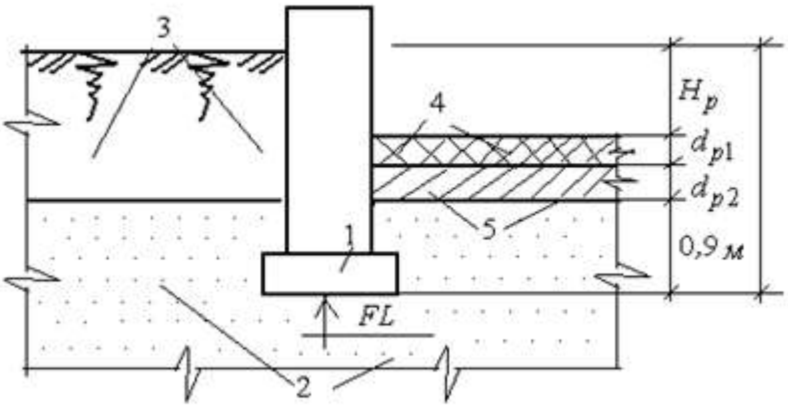


Fig. 11. Scheme of determining the foundation bottom depth:
1 - foundation; 2 - bearing layer; 3 - cover layer; 4 – basement floor; 5 - preparation

Since there is no basement in the considered building, we accept

$$d_3 = 0,0$$

4. Taking into account the designed structure features (presence or absence of different foundation bottoms marks)

The calculation is performed according to the following (Fig. 12):

$$d_4 = \Delta h \le a \cdot \left[tg\left(\varphi_I\right) + \frac{c_I}{p} \right], \quad (11)$$

where Δh - difference of foundations' bottoms marks located on a slope; a - the distance between the side edges of foundations; φ_I and c_1 - the angle of internal friction and specific cohesion respectively; p - average pressure under the foundation bottom, located higher according to slope (see Fig. 12).

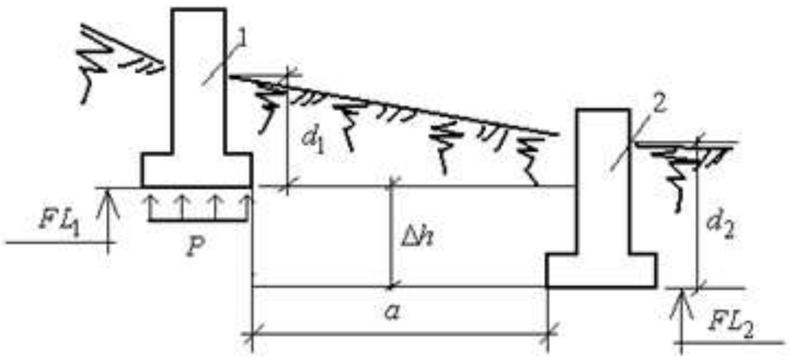


Fig. 12. Scheme of determinating the foundations bottom depth:
1 and 2 are the foundation numbers)

Since FL1 = FL2 (see Fig. 12 and Fig. 5) we accept:

$$d_4 = \ 0{,}0$$

5. Value and the nature of the load acting on the foundation

Taking into account the magnitude of the vertical load N acting on the foundation should be performed as follows:

- if the vertical force is $N \leq 1000$ kN, then the depth of the foundation bottom should be taken equal to 1,0 m;
- if the vertical force is $1000 < N \leq 2000$ kN, then the depth of the foundation bottom should be taken equal to 1,5 m;
- if the vertical force is $2000 < N \leq 3000$ kN, then the depth of the foundation bottom should be taken equal to 2,0 m;
- if the vertical force is $3000 < N \leq 5000$ kN, then the depth of the foundation bottom should be taken equal to 3,0 m.

The foundation load is 150 tons = 1500 kN.

If the vertical force is $1000 < N \leq 2000$ kN, then the foundation bottom depth should be taken equal to;

$$d_5 = 1{,}5 \text{ m};$$

Calculation results are put in Table 8.

Table 8. The results of determining the foundation bottom depth

№	Designation, m	d_i, m
1	d_1	1,03

2	d_2	2,0
3	d_3	0,0
4	d_4	0,0
5	d_5	1,5

We accept the biggest value of the foundation bottom depth. It is equal to:

$$d = 2{,}0 \text{ м.}$$

Conclusion: the designed depth is $d = 2.0$ m and it is more than given in the task ($d = 1.5$ m).

Therefore, we change $d = 1{,}5$ m to $d = 2{,}0$ m in Fig. 7 and Fig. 8.