UDC 624.15

Tambov State Technical University

D. Sc. in Engineering, Prof. of Department

of Construction of Buildings and Installations V. V. Ledenyov

Postgraduate student of Department of Construction

of Buildings and Installations Diavara Sonda

Russia, Tambov, tel.: +7(4752)72-10-19;

e-mail: kzis@nnn.tstu.ru

V. V. Ledenyov, Diavara Sonda

INFLUENCE OF HORIZONTAL REINFORCEMENT ON BEARING CAPACITY OF CLAY BED

Laboratory researches results of bearing capacity of clay bed reinforced by reinforcing fabric are presented. Multiple classification analysis of influence of reinforcement on durability and deformation of fill ground is carried out. Functional dependences of soil settlement and breaking loads on reinforcement parameters are offered.

Keywords: reinforced ground, soil settlement, bearing capacity.

Introduction

Foundations are one of the most widespread structures in industrial, civil and agricultural engineering. In modern industrial engineering foundations costs amount to as much as 15…20 % of the total building costs. As for certain structures, i. e., chimneys, tower blocks, transmission towers, foundations costs may run to 50 % of total costs.

Development of foundation structures and increase in bearing capacity of building bases are problems of great importance in the context of increase of loads on foundations under reconstruction, changing a number of storeys and equipment weight, development of lands which were held to be unsuitable for construction. Various methods of ground base engineering are worked out and implemented in an effort to strengthen the bases and decrease their deformation with retention of reliability and durability.

Currently soil reinforcement method has received wide acceptance in many countries. New efficient materials, products, designs and technologies are applied. The method becomes more efficient in conditions of layer-by-layer artificial foundation formation.

It is advantageous to use reinforcement in the following cases:

- when constructing foundations in narrow conditions such as reconstruction, strengthening and annexe);
- when constructing on earthfill and hydraulic foundations and in the presence of considerable loads if other ways of foundations strengthening are not efficient;
- in combination with other methods, for example, when constructing ground base.

Considering lack of normative document, regulating designing and use of reinforced foundation, comprehensive analysis of reinforced soils is hot-button issue.

Multiple Classification Analysis of influence of horizontal reinforcement on bearing capacity and deformation of foundation has been performed during 6 years in soil mechanics laboratory of Tambov State Technical University.

The influence of the type and location of reinforcing fabric, its proportions, foundation-to-reinforcement distances, type of application of load on magnitude and rate of deformations, bearing capacity was analyzed. Punching tests (D_{st} = 120 мм) were performed in metal tray.

Loads on punch with smooth contact surface were transmitted by lever with reduction ratio 1:6, shifts were registered by indicators ИЧ-10 МД (Fig. 1). Loading was carried out till destruction or sharp increase in shifts rates or till maximum relative foundation settlement $[S]_u \approx$ 12 mm (0.1 D_{st}).

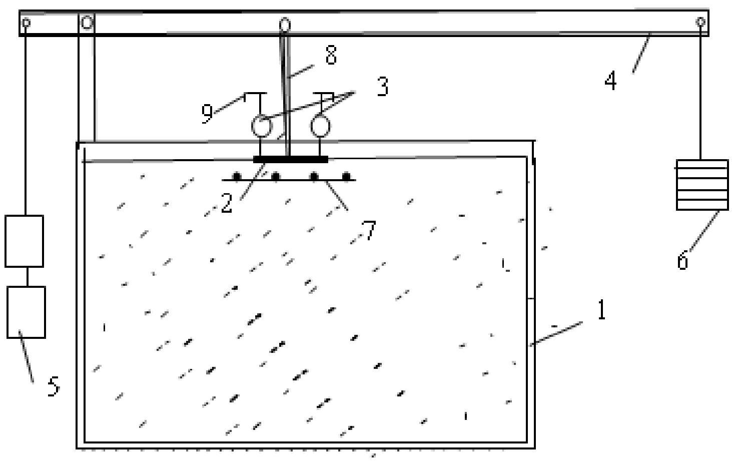

Fig. 1. Pilot unit scheme:
1 – metal tray; 2 – punch; 3 – indicators; 4 – lever; 5 – balance; 6 – weights;
7 – reinforcing element; 8 – knife; 9 – frame

Clay soil of damaged structure from Pokrovsky borrow (Tambov) was used as foundation. Several series of tests have been carried out, in which foundation soil had different clay particles contents and consistence.

Below the results of the experiments with following properties of soil model of natural composition are considered:

$$I_p = 0.18;\ W_l = 0.41;\ W_p = 0.23;\ I_l < 0;\ \varphi\ 20^\circ;\ c = 60 \text{ кПа};\ E = 11.33 \text{ МПа}.$$

Soil has been put in the tray and compacted by hand rammer.

Efficiency of impact of reinforcement type, sizes ($L_s \cdot B_s \cdot t_s$), diameter of reinforcement bars (d_s), depth of reinforcement nets (h_s) (see Fig. 2) has been evaluated on the basis of following parameters:

– specific bearing capacity of reinforced foundation:

$$\overline{F} = F_{su} / V_s, \text{ кН/см}^3, \tag{1}$$

where F_{su} is the bearing capacity of reinforced foundation soil; V_s is the volume of reinforcement;

– relative bearing capacity of reinforced foundation soil:

$$\overline{F} = F_{su} / F_u, \tag{2}$$

where F_u is the bearing capacity of unreinforced foundation soil;

– relative foundation settlement $\overline{S}_u$:

$$\overline{S}_u = S_u / D_{st}, \tag{3}$$

where S_u is the maximum settlement of foundation soil.

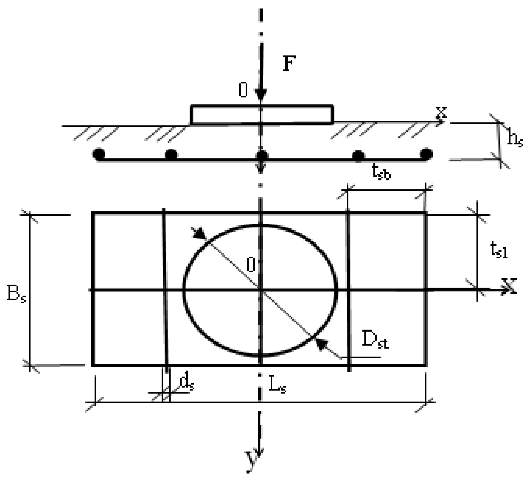

Fig. 2. Reinforced net placement

Reinforced net properties used in experiments are presented in Table 1.

Relative values are obtained dividing absolute values *b* punch diameter D_{st}.

Table 1

Reinforced net properties

Net type	Net parameters, mm						Relative parameters					
	L_s	B_s	t_{sl}	t_{sb}	d_{sl}	d_{sb}	$\overline{L}_s$	$\overline{B}_s$	$\overline{t}_{sl}$	$\overline{t}_{sb}$	$\overline{d}_{sl}$	$\overline{d}_{sb}$
C1	400	200	100	100	4	4	3.33	1.67	0.83	0.83	0.03	0.03
C2	400	200	100	100	5	5	3.33	1.67	0.83	0.83	0.04	0.04
C3	400	200	100	100	7	7	3.33	1.67	0.83	0.83	0.06	0.06
C4	400	200	100	100	9	9	3.33	1.67	0.83	0.83	0.07	0.07
C5	400	200	66.67	66.67	4	4	3.33	1.67	0.56	0.56	0.03	0.03
C6	400	200	66.67	66.67	5	5	3.33	1.67	0.56	0.56	0.04	0.04
C7	400	200	66.67	66.67	7	7	3.33	1.67	0.56	0.56	0.06	0.06
C8	400	200	66.67	66.67	9	9	3.33	1.67	0.56	0.56	0.07	0.07
C9	400	200	40	50	4	4	3.33	1.67	0.33	0.42	0.03	0.03
C10	400	200	40	50	7	7	3.33	1.67	0.33	0.42	0.06	0.06
C11	400	200	40	50	9	9	3.33	1.67	0.33	0.42	0.07	0.07

Influence of bars of the net on deformation of reinforced clay soil of foundation

The reinforcing nets of following types (on clay bed $I_p = 0.18$; $\omega = 0.18$ and $\rho = 1{,}53$ г / см^3) have been used in experiments:

- C1; C2; C3; C4 in increments of $t_s = 100$ mm;
- C5; C6; C7; C8 in increments of $t_s = 66.67$ mm;
- C9; C10; C11 in increments of $t_{sl} = 40$ mm, $t_{sb} = 50$ mm

with constant depth $h_s = 0{,}2D_{st} = 24$ mm.

It was found out that bearing capacity of foundation increases with 1.3…1.46-times increase in reinforcement diameter from $d_s = 4$ mm to $d_s = 9$ mm with different increments of the net:

- 1.3-times increase at $t_s = 100$ mm;
- 1.34-times increase at $t_{sl} = 40$ mm, $t_{sb} = 50$ mm;
- 1.46-times increase at $t_s = 66.67$ mm.

Specific bearing capacity of foundation increases with 3.46…3.91-times decrease in reinforcement diameter from $d_s = 9$ mm to $d_s = 4$ mm.

The results of the experiments are shown in Table 2.

Table 2

Reinforced soil bearing capacity dependence on bar diameter

Марка сетки	F_u, kN	F_{su}, kN	$\overline{F}_{su}$	V_s, cm^3	$\overline{F}$, kN/cm^3	S_u, mm	$\overline{S}_u$
C1	2.88	4.32	1.50	27.63	0.16	13.16	0.11
C2	2.88	5.04	1.75	43.17	0.12	13.47	0.11
C3	2.88	5.22	1.81	84.62	0.06	12.79	0.11
C4	2.88	5.58	1.94	139.89	0.04	13.87	0.12
C5	2.88	5.04	1.75	37.68	0.13	13.65	0.11
C6	2.88	5.40	1.87	58.87	0.09	13.17	0.11
C7	2.88	6.48	2.25	115.39	0.06	13.03	0.11
C8	2.88	7.38	2.56	190.75	0.04	12.49	0.10
C9	2.88	4.68	1.62	52.75	0.09	12.48	0.10
C10	2.88	5.76	2.0	161.55	0.04	13.41	0.11
C11	2.88	7.56	2.62	267.06	0.03	13.13	0.11

Influence of reinforcing net depth location on deformation of reinforced clay soil of foundation

Test (under constant humidity and density) were carried out with different relative depth location ($\overline{h}_s$= 0; 0.2; 0.4; 0.6; 0.8; 1.0; $\overline{h}_s = h_s / D_{st}$) of reinforcing net C1 under vertical central loading.

Maximum value of bearing capacity of reinforced foundation is achieved under depth location of reinforcing net $\overline{h}_s = 0.2$. Efficiency of reinforcement decrease with increase in depth location of reinforcing net and also at $\overline{h}_s \rightarrow 0$.

The results of experiments are shown in Table 3 and Figure 3.

Table 3

Reinforced soil deformation dependence on depth location of reinforcing net

$\overline{h}_s$	F_{su}, kN	S_u, mm	$\overline{S}_u$
0.0	3.24	12.55	0.105
0.2	4.32	13.15	0.11
0.4	3.96	12.78	0.106
0.6	3.78	12.59	0.105
0.8	3.24	12.83	0.107
1.0	3.06	12.27	0.102

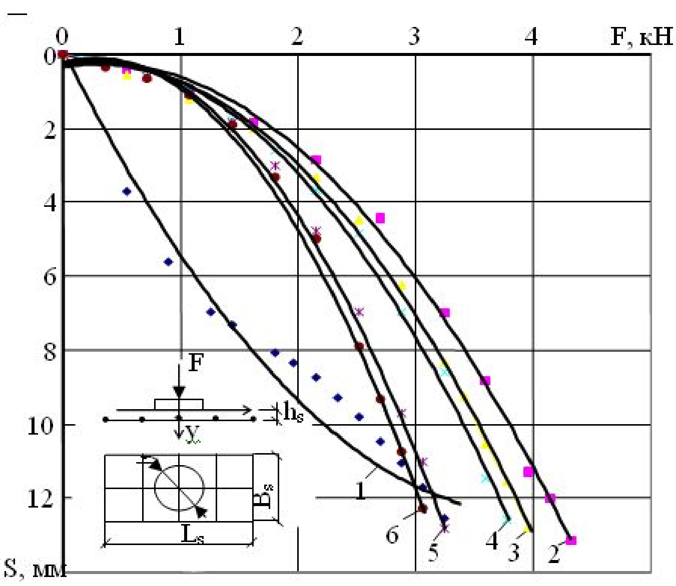

Fig. 3. Graphs of settlement dependences on load for foundation reinforced by net C1 with $\bar{h}_s$:
1 – 0; 2 – 0.2; 3 – 0.4; 4 – 0.6; 5 – 0.8; 6 — 1

The obtained functions have been approximated using Microsoft Excel:

$$1:\ S = -0.497\hat{F}^2 + 5.019\hat{F} + 0.781;$$

$$2:\ S = 0.799\hat{F}^2 - 0.478\hat{F} + 0.298;$$

$$3:\ S = 0.932\hat{F}^2 - 0.571\hat{F} + 0.360;$$

$$4:\ S = 0.996\hat{F}^2 - 0.541\hat{F} + 0.261;$$

$$5:\ S = 1.526\hat{F}^2 - 1.155\hat{F} + 0.339;$$

$$6:\ S = 1.695\hat{F}^2 - 1.309\hat{F} + 0.372$$

Influence of density of reinforced clay soil on its deformation

Foundation was reinforced by the net C1. The tests have been carried out using the same pattern with h_s = const = 24 mm and ω = 0.17. Soil was laid layer-by-layer and compacted using metal rammer. Soil density has been checked using cutting ring and calibrated densimeter. Axial vertical load increasing stepwise has been transmitted on foundation model.

The results of experiments are shown in Table 4 and Figure 4.

Table 4

Reinforced soil deformation dependence on its density with ω = 0.17

ρ, g /cm^3	F_{su}, kN	S_u, mm	$\bar{S}_u$
1.35	2.52	12.96	0.108
1.51	2.70	13.15	0.11
1.54	4.14	12.61	0.105
1.65	4.32	13.08	0.109
1.71	4.68	12.99	0.108

Maximum value of foundation bearing capacity F_{su} = 4.68 kN is obtained at ρ_{max} = 1.71 g /cm^3; minimum value F_{su} = 2.58 kN at ρ_{min} = 1.35 g /cm^3.

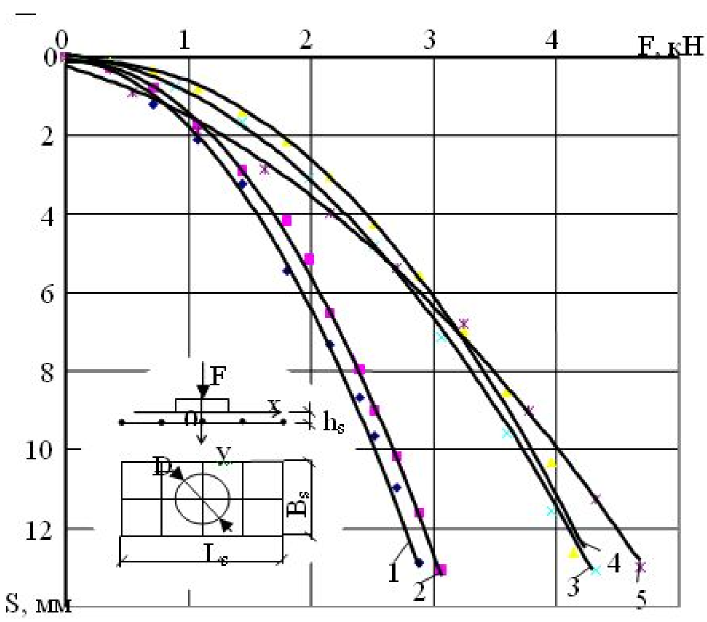

Fig. 4. Graphs of settlement dependences on load for foundation reinforced by net C1 with ω = 0.17, ρ(g / cm^3): 1 – 1.35; 2 – 1.51; 3 – 1.54; 4 – 1.65; 5 – 1.71

The obtained functions have been approximated using Microsoft Excel:

$$1:\ S = 1.388\hat{F}^2 + 0.351\hat{F} + 0.054\,;$$

$$2:\ S = 1.458\hat{F}^2 - 0.222\hat{F} + 0.111\,;$$

$$3:\ S = 0.635\hat{F}^2 + 0.366\hat{F} - 0.070\,;$$

$$4:\ S = 0.759\hat{F}^2 - 0.304\hat{F} + 0.131\,;$$

$$5:\ S = 0.387\hat{F}^2 + 0.877\hat{F} + 0.234$$

Conclusion

Thus, following conclusion can be drawn from results of experiments.

Reinforced soil is the combined material. In this material cohesion increases, soil lateral motions reduces, mode of deformation changes through force redistribution between soil and compared to unreinforced soil.

Maximum value of bearing capacity of reinforced clay foundation soil is achieved under relative depth of net location $\bar{h}_s$ = (0.2 …0.25). EFficiency of reinforcement decreases with $\bar{h}_s$ > 0.5.

Forces of soil-reinforcement contact and strength characteristics of reinforced soils increase with increase of foundation density.

References

1. Antonov, V. M. Influence of reinforcement on bearing capacity and deformation of sandy base: abstract of Ph. D's thesis. Volgograd, 1992. 32 pp.

2. Johns, K. D. Reinforced soils structures; translated from English by V. S. Zabavina; Ed. by V. G. Menshikov. Moscow: Stroyizdat, 1989. 280 pp.

3. Ledenyov, V. V. Durability and deformability of bases of sunken foundation. Voronezh, 1990. 224 pp.