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Experimental study for elastic deformation under isolated footing

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ABSTRACT

The results of field studies of elastic deformations in the footing base, composed of loses soils. Elastic deformation is the result of compression partially bound water at the contacts between the mineral particles, the value of which depends on the wetness soil environment. It was found that deformation depends on the molecular moisture capacity of the soil while elastic settlement increases in proportion to pressure.

Keywords: Foundation, Pressure, Elastic sediment molecular moisture capacity, Mineral particles

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1. Introduction

At present, the estimated models apply the conditional value of the modulus of elasticity, which is determined by the increase the deformation modulus several times. The article describes the methodology and results of its value based on the results of testing in field conditions.
The results of measurements of elastic deformations in the foundations of experimental foundations were first published in [7, 8]. Elastic deformations in-depth increase according to a linear law and have a finite boundary, the depth of which is greater than the boundary of residual deformations.
In published works, the facts of changes in elastic deformations by the depth and their quantitative assessment by measured parameters are recorded. The nature of elastic deformations, factors affecting their growth, principles for evaluating their values are not determined.
The purpose of this article is to study the experimental substantiation for the methodology and the results of the determination the characteristics in the elastic deformation of soils.

2. Research results

The presence of elastic deformations in the soil under the foundations showed a close convergence of dependency load sediment to rectilinear obtained soil test results. This dependence is observed in the initial stages of loading. Justifying the possibility of applying the theory of elasticity to determine allowable loads on soils noted: "... after the first loading, the soil will not give the remaining sediment, but will only have elastic sediments ...". Conscious of the lack of experimental data, considered: "... For a scientific substantiation of permissible loads on the ground, a thorough study of the processes of soil destruction and the creation of a theory of this destruction is required" [3, 5, 6].

Elastic deformations, their boundary and change in depth were first measured by the results of field studies of soils by experimental foundations with an area of 1.0 m^2 and 4.0 m^2. At the intermediate steps, the load was removed and the values of the elastic lift of the foundation and the ground marks installed below their foot were measured [1, 2]. In later years, similar studies were carried out with experienced press for foundations with an area ranged between 0.03 to 1.0 m^2.

The studies were accomplished by experimental loading plates with an area of 0.03 m^2 in field conditions in the upper layers: Engineering Geological Element (EGE)-2 –loamy loses and upper horizon of EGE-3 - loses loam. The thickness of the losses strata in this area is about 18.0 m. The tests were started at a depth of 1.0 m from the bottom of the excavation and were made in a hole on eight horizons with a depth interval of 0.5 m. The installation of the plates is shown in Figure (1, a). According to test results, significant changes in physical characteristics in-depth were recorded. So, at the plate's level, the density varied from 1.39 to 1.65 g / cm^3, and the structural strength was 80 ... 150 kPa. The values of the characteristics at the plate installation are given in Table 1.

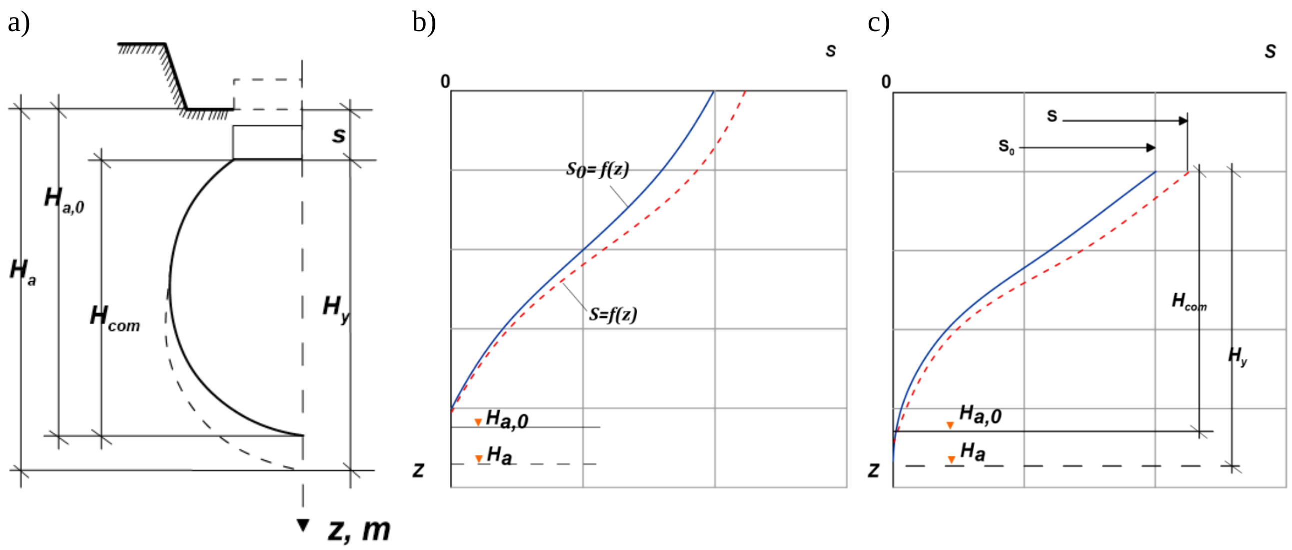


Figure 1. Graphs for soil testing with experienced plates loading: a) The height position of the plates; b) The initial position of the plate and soil deformation; c) Settlement parameters for the foundation-soil system at each loading steps

Table 1. Characteristics of soils in the grounds of experienced plates

№	ρ_{rts} MPa	ρ_d, g/cm^3			W %	W $_{com}$ %
		ρ_d	$\rho_{d,\ com\ max}$	$\rho_{d,\ com\ cp}$		
1.1	0,12	1,55	1,63	1,59	0,21	0,22
1.2	0,13	1,58	1,68	1,63	0,19	0,23
1.3	0,13	1,65	1,71	1,68	0,20	0,22
1.4	0,14	1,60	1,65	1,62	0,20	0,22
1.5	0,15	1,47	1,68	1,57	0,22	0,21
1.6	0,11	1,41	1,73	1,57	0,23	0,20
1.7	0,09	1,43	1,70	1,56	0,26	0,21
1.8	0,08	1,39	1,71	1,55	0,28	0,22

Notation: $\rho_{d,\ com\ cp} = (\rho_d + \rho_{d,\ com\ max})/2$

The studies were carried out under conditions of local soaking of the soils of the loading plate in experiments 1.1-1.5 and without soaking in 1.6-1.8 under conditions of high capillary moisture capacity. Measurements of layer-by-layer displacements, below the plate's bottom, were performed using magnetic signs installed in the bored well along the axis of the foundation with a depth interval of 5 cm, with an accuracy of 1.0 mm [4]. Scheme of installation of soil signs is shown in Figure 1, b.

The tests were fulfilled according to the method of the cyclically increasing load. Each stage is an independent cycle and consists of the application of the load, maintaining it until the conditional stabilization of deformations and unloading. Preloads and post loadings measure the total and residual values of the press, and their difference is elastic.

According to the results of measurements of the foundation settlements and displacements of soil signs for each load step, a graph of the variation of the settlement in depth is plotted - the diagram of layer-by-layer displacements. After removal of the load, an elastic lifting of the plate and soil signs occur. The measured values are plotted residual displacements. The intersection of these plots with the vertical axis determines the depth of the zone of total and residual deformations H_a and $H_{a,0}$ (Figure 1, b).

3. Nature of elastic deformations

Accepting mineral particles in-compressible under loads from foundations, the main cause of elastic deformations should be considered the processes occurring at their contacts. Each mineral particle is surrounded by a film of molecular water. The force of its attraction is (10 to 70) · 103 atmospheres. The intensity of molecular attraction decreases with distance from the particle surface. Under the influence of external load, elastic compression of molecular water films occurs at the contact points of particles, which disappears after the load is removed. Thus, the elastic part of the precipitation is a consequence of the elastic compression of molecular-bound water [9].

The most molecular moisture capacity when tested under conditions of local soaking is preserved in the process of compaction of the soil. Its value remains constant before, during and after compaction. The elastic compression of molecular water films at the particle contacts causes the elastic part of the settlement to disappear after the load is removed. This is illustrated by the results of proven research. With an increase in pressure, the depth of the zone of elastic deformations and the value of the elastic part of the draft increase proportionally. Their relative value for a given soil is a constant value both for soils of the undisturbed structure and during the compaction process: S_y/H_y = const. After removal of the load, the elastic part of the precipitation disappears as a result of the restoration of the thickness of the compressed sections of the molecular water film.

The total capacity of the displaced water during the compression of molecular films in a huge number of points of contact between the particles determines the value of the elastic component of the settlement.

For example, in lose soils about 75% of silty particles with sizes of 0.05 ... 0.005 mm, and clayey less than 0.001 mm - about 15%. If a silty particle with an average size of 0.01 mm is presented as a ball, then in one cubic millimetre their number will be 1.10^6 - without taking into account the presence in the intervals of smaller clay particles with six contact points. According to the results of the studies performed, 1.0 mm of the elastic part of the sediment is achieved by compressing about 200 mm^3 of the soil prism in depth.

4. Determination of elastic deformations

Elastic deformations increase with the onset of load and increase in proportion to its increase. Residual deformations are a consequence of compaction and lateral expansion of the compressible volume under the base area of the basement and have virtually no effect on the growth of elastic deformations.

At pressures of lower structural strength, the values of the elastic settlement and the depth of the deformation zone are measured. Table 2 and Figure 2 show the results of these measurements. According to the observations, graphs of the obtained parameters on pressure were plotted based on the test results on three depth horizons. A characteristic feature of elastic deformation is the constant value of the relative deformation on each horizon of the studies performed, independent of pressure.

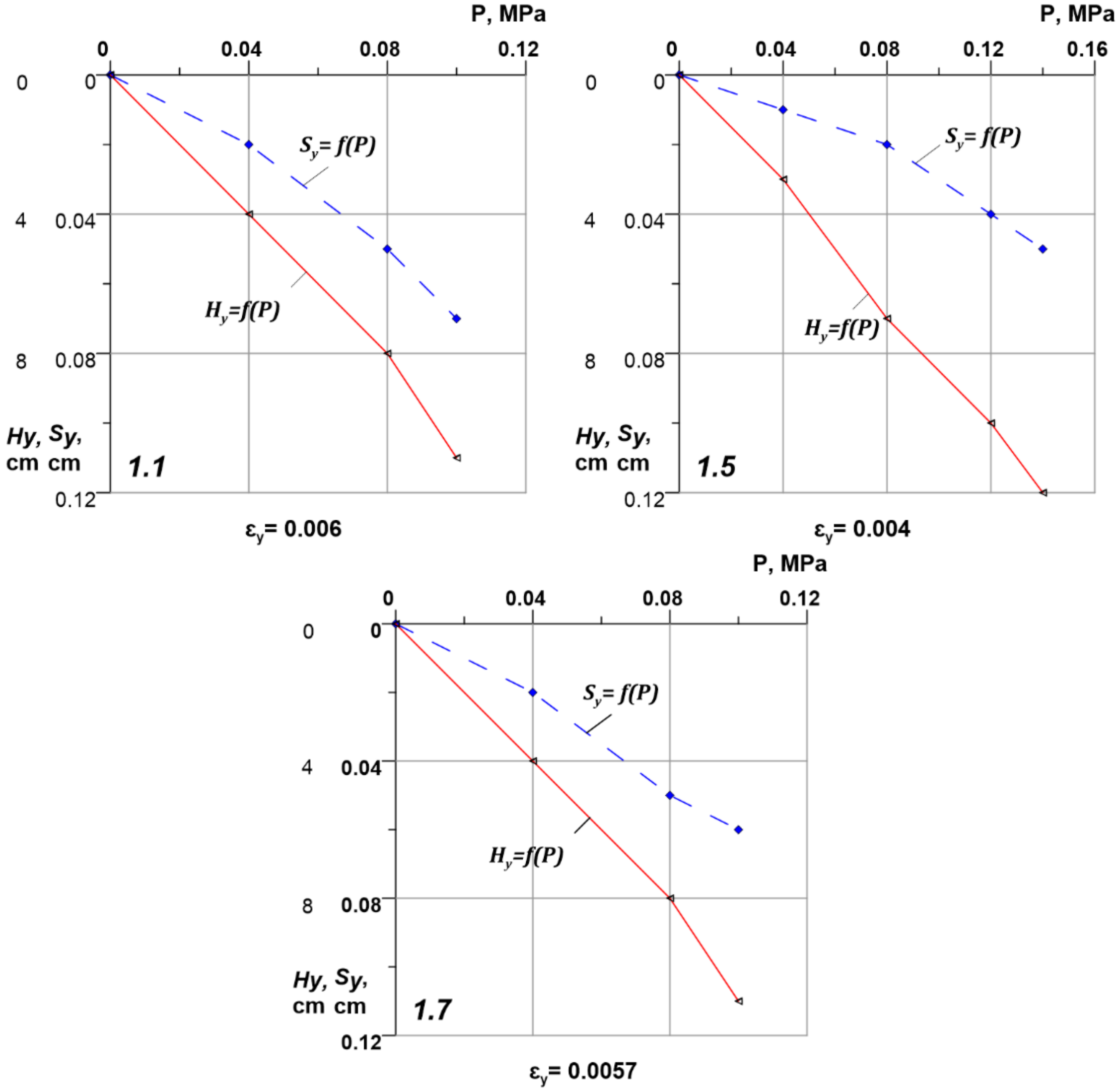


Figure 2. The dependence of the elastic component of settlement from the pressure and depth of the deformation zone at pressures, less than $p_{str.}$

The stress-strain state of the "foundation – soil system is characterized by the following parameters, given in Figure 2 and Table 2:

1) Pressure **P**; 2) settlement of the foundation **s**, it's plastic $\mathbf{s_0}$ and elastic $\mathbf{s_y}$ components; 3) parameters of the deformation zone - the total depth $\mathbf{H_a}$; the depth of plastic $\mathbf{H_{a,0}}$ and elastic deformations $\mathbf{H_y = H_a - s_0}$; $\mathbf{H_{com} = H_a - s}$ the compressed core depth.

Elastic deformations increase as a result of compression of molecular-bound water films within the depth of the elastic deformation zone. Their external manifestation is the elastic component of the precipitation s_y. After removal of the load, the thickness of the molecular-bound water films is restored and the elastic strains disappear.

The size of the elastic component of the settlement depends on the capacity of molecular-bound water. Tests were conducted under conditions of local soaking at most molecular moisture capacity. For lose soils, its value corresponds to a weight humidity of 0.16.

Table 2. Parameters of the elastic compression of the soil at $p \leq p_{str}$ in the grounds of the experienced stamps

p MPa	1.1			1.2			1.3			1.4		
	s_y	H_y	$\varepsilon_y \cdot 10^{-3}$	s_y	H_y	$\varepsilon_y \cdot 10^{-3}$	s_y	H_y	$\varepsilon_y \cdot 10^{-3}$	s_y	H_y	$\varepsilon_y \cdot 10^{-3}$
0,04	0,02	4	5,0	0,02	4	5,0	0,01	3	3,3	0,02	5	40
0,08	0,05	8	6,2	0,04	8	5,0	0,03	8	3,8	-	-	-
0,10	0,07	11	6,4	0,05	11	4,5	0,04	10	4,0	0,04	9	4,4
0,12	-	-	-	0,06	13	4,6	0,07	14	5,0	0,06	12	5,0
0,14	-	-	-	-	-	-	-	-	-	0,07	14	5,0
$\varepsilon_{y,cp} \cdot 10^{-3}$			5,9			4,8			4,0			4,6

Continuation of table 2

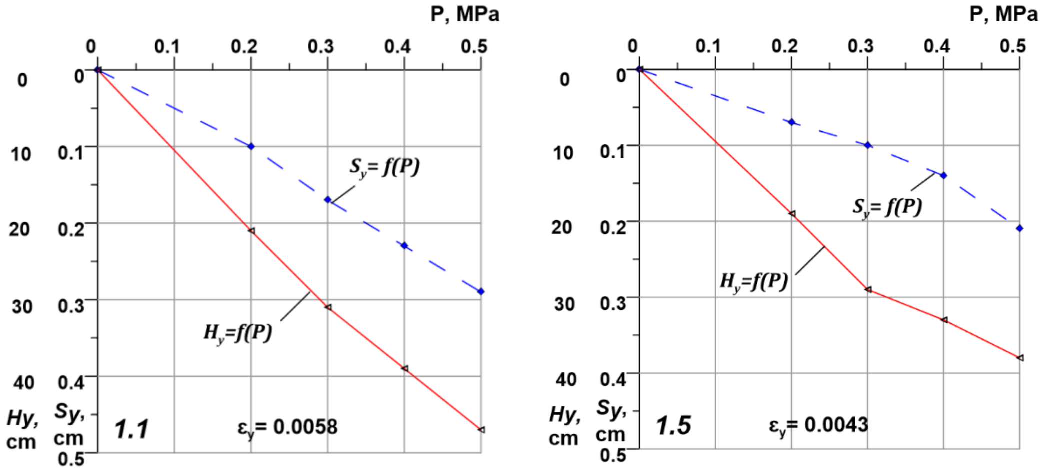
p MPa	1.5			1.6			1.7			1.8		
	s_y	H_y	$\varepsilon_y \cdot 10^{-3}$	s_y	H_y	$\varepsilon_y \cdot 10^{-3}$	s_y	H_y	$\varepsilon_y \cdot 10^{-3}$	s_y	H_y	$\varepsilon_y \cdot 10^{-3}$
0,04	0,01	3	3,3	0,02	4	5,0	0,02	4	5,0	0,02	4	5,0
0,08	0,02	7	2,9	0,04	7	5,7	0,05	8	6,2	0,05	9	5,5
0,10	-	-	-	0,05	9	5,6	0,06	11	6,4	-	-	-
0,12	0,04	10	4,0	-	-	-	-	-	-	-	-	-
0,14	0,05	12	4,2	-	-	-	-	-	-	-	-	-
$\varepsilon_{y,cp} \cdot 10^{-3}$			3,7			5,4			5,8			5,3

In the soil undisturbed structure in the process and after their compaction the capacity of molecular water is kept constant. Bounded water is not expelled during the compaction process. As a consequence, the relative value of the elastic part of the deformation is a constant value for a given soil environment and depends on its composition and state. Table 3 shows the results of measurements of parameters characterizing the processes of deformation of soils in the bases of the dies installed on three depth horizons.

Table 3. Results of measurements of parameters characterizing the processes of deformation of soils

№	p MPa	Settlement, cm			s_y / s	Deformation depth, cm				$H_a/H_{a,0}$	$\varepsilon_y \cdot 10^{-3}$	
		s	s_0	s_y		H_a	$H_{a,o}$	$H_{a,com}$	H_y		ε_y	$\varepsilon_{y,cp}$
1,1	0,2	0,18	0,08	0,10	0,55	21	11	11	21	1,9	4,8	5,6
	0,3	0,79	0,62	0,17	0,21	32	23	22	31	1,39	5,5	
	0,4	1,50	1,27	0,23	0,15	41	29	28	39	1,41	5,9	
	0,5	2,57	2,28	0,29	0,11	50	36	34	47	1,39	6,2	
1,5	0,2	0,28	0,21	0,07	0,25	19	11	11	19	1,73	3,7	4,2
	0,3	1,67	1,57	0,10	0,06	31	21	19	29	1,48	3,4	
	0,4	4,03	3,89	0,14	0,035	37	31	27	33	1,19	4,2	
	0,5	5,99	5,78	0,21	0,03	44	35	29	38	1,26	5,5	
1,7	0,2	0,95	0,85	0,10	0,105	21	15	14	20	1,4	5,0	5,8
	0,3	2,99	2,84	0,15	0,050	28	25	22	25	1,12	6,0	
	0,4	5,76	5,57	0,19	0,033	38	32	24	32	1,19	5,9	
	0,5	9,16	8,93	0,23	0,025	46	42	33	37	1,09	6,2	

The measured data were used to plot the dependence of the elastic values of the settlement and the depth of the strain zone on pressure. From figure 3 it can be seen that the relative values of the elastic strains ε_y do not depend on the deformation process. In each experiment, their values coincide in determining pressures of lesser or greater structural strength.



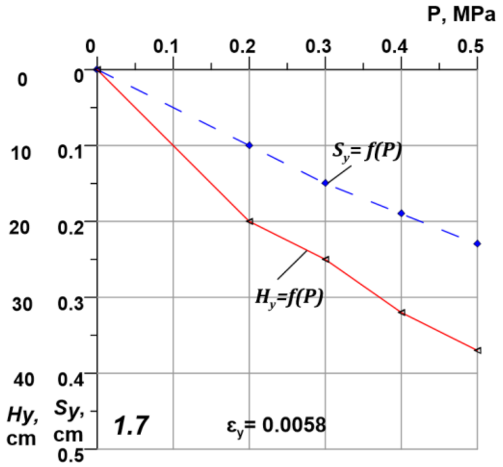


Figure 3. Plots of the elastic component of the settlement and the depth of the deformation zone as a function of pressure at p > p_{str}

Table 4. shows the results of measurements of the parameters of elastic deformations for all experiments in this series

№	s_y, cm at p, MPa				H_y, cm at p, MPa				$\varepsilon_y \cdot 10^{-3}$ at p, MPa				$\varepsilon_y \cdot 10^{-3}$
	0,2	0,3	0,4	0,5	0,2	0,3	0,4	0,5	0,2	0,3	0,4	0,5	
1	2	3	4	5	6	7	8	9	10	11	12	13	14
1.1	0,10	0,17	0,23	0,29	21	31	39	47	4,8	5,5	5,9	6,2	5,6
1.2	0,10	0,17	0,23	0,28	20	25	29	32	5,0	7,4	6,8	8,7	7,0
1.3	0,07	0,11	0,14	0,17	19	23	31	34	3,7	4,8	4,5	5,0	4,5
1.4	0,07	0,13	0,19	0,25	20	25	30	33	3,5	5,2	6,3	7,6	5,6
1.5	0,07	0,10	0,14	0,21	19	29	33	38	3,7	3,4	4,2	5,5	4,2
1.6	0,08	0,14	0,18	0,22	21	28	34	40	3,8	5,0	5,3	5,5	4,9
1.7	0,10	0,15	0,19	0,23	20	25	32	37	5,0	6,0	5,9	6,2	5,8
1.8	0,09	0,15	0,19	0,26	24	31	39	46	3,8	4,8	4,9	5,7	4,8
	0,085	0,14	0,19	0,24	21	27	33	38	4,1	5,2	5,5	6,3	5,3

5. Conclusions

1. The elastic component of the foundation settlement is a consequence of the elastic compression of the films of molecular-bound water at the points of contact between the mineral particles.
2. The elastic settlement and the corresponding depth of the zone of elastic deformations increase in proportion to pressure, and their ratio (relative deformation) remains constant, ceteris paribus.
3. The relative value of the elastic deformations depends on the molecular moisture capacity of the soil.

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