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Research paper

Increasing the Accuracy in Determining the Basis Foundation Compressibility

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Abstract

The disadvantages of the standard soil deformation characteristics are analyzed. Impact of different factors on the determination accuracy of soil characteristics is estimated. Devices to determine soil deformation parameters in the conditions of one axial compression aimed at increase in reliability of the soil compressibility evaluation results are improved; the mentioned improving eliminate disadvantages of the compression device that is absence of the soil sample lateral expansion and friction with ring walls decreasing the soil sample lateral expansion and reduces real soil compressibility. Results of the soil tests in the standard and improving device are compared with each other. Soil compressibility index is based. Such index represents the relative change in the soil sample porosity coefficient during the compression tests. There is increase in prediction accuracy of the building soil foundations settlements. To increase prediction accuracy soil compressibility index and account of the influence of pressure on the soil deformation parameters and soil porosity changing from the compressible thickness depth are used. Statistical analyze of the random variables of the soil base settlements, which are predicted by the both methodic are made.

Keywords:*compression device, soil porosity coefficient, soil deformation modulus, soil compressibility index, compressibility, soil base, settlement, reliability.*

1. Introduction

The conditions for calculating the buildings and structures foundations basis for deformations is their not exceeding the estimated values of deformations (absolute and average settlement of bases, relative unevenness of two foundations settlement, roll structures, etc.), which characterize the joint work of foundation and structure, the maximum permissible deformation rates for buildings and structures under consideration [1 – 3]. Therefore, the forecast of settlement basics is a priority task while designing the foundations of buildings and structures. The reliability of the determination of deformations depends on their reliability and profitability. Most of excessive buildings and structures deformations is precisely determined by mistakes in determining the characteristics of the soil base compressibility.

Compressibility of clay, including loes, soils depends on their genesis, mineralogical composition, degree of particle dispersion, porosity, humidity, structural adhesion. Compressibility of soils increases nonlinearly under pressure increasing. The deformation properties of the bases in the vast majority of cases are evaluated by the results of fairly cheap laboratory compression tests, that is, the compression by stepwise static pressure without the possibility of lateral expansion (in the rigid ring), selected from the soil samples. To evaluate the compressibility of soils, a change in their porosity, depending on the pressure reflecting the compression curves is usually used [3 – 10].

The deformation module E is used for the soil compressibility parameter, which is used in predicting sedimentation of buildings and structures bases. It depends on the initial coefficient of porosity e_0, soil compressibility index m_0, relative compressibility index m_v samples and coefficient of relative transverse deformation β. The reliability of these characteristics definition affects the accuracy of module E. The disadvantages of the deformation module are non-consideration of the nonlinear soil compressibility and the determination of its value in the narrow range of pressure for each sample, the properties of which, in addition to the objective information on compressibility, contain both subjective and compression of a particular sample [11, 12]. This leads to a large difference in data, which greatly reduces the accuracy of determining the parameters of the basis compressibility from which the samples are taken.

The variety of compression curves does not allow estimating the standard methods of soil compressibility over a wide range of pressure. The reliability of the deformation module is also affected by the lack of a compression device, in which the frictional forces of the sample behind the walls of the ring are reduced by 10-50% of the actual soil compression, which improperly increases the size of the deformation module and reduces the relative soil collapsibility.

The prediction of bases settlements by standard deformation parameters has insufficient reliability. The coefficients of relative porosity change A_{pw} and collapsibility B_{pw} are developed in PoltNTU [13]. They express the general compression dependence on the soil properties and invariant to the porosity coefficients of the samples tested for them, which allows displaying the compressibility and collapsibility of the base in a wide range of pressures taking into account the porosity of the soil.

The experience of forecasting settlements and collapsibility of foundations loes basics as engineering methods based on models of a homogeneous, isotropic, linear deformed medium and finite element method with the implementation of complex nonlinear environment models, the reliability of which depends mainly on

increasing accuracy of soil compressibility properties determination is accumulated [14, 15].
Therefore, the objective of the work is to improve the method of determining the base settlement from the foundation pressure on the basis of clay soils compression tests.

2. Main Body

The basis of the method for evaluating the accuracy of determining the soil compressibility parameters is the principle of division into measurement errors during compression tests and the error of calculations of deformation characteristics values. This division of errors allows us to determine at what stage efforts have to be concentrated to improve the method of evaluating the deformation properties of the soil during compression tests.
According to the results of errors estimation in determining the coefficient of porosity 350 samples of loes loams, light silty, taken from the depths of 2, 4, 6; 8 and 10 m and compressed under natural humidity and in a water-saturated state with different degrees of pressure, it was established that the relative errors of soil density and moisture determination do not exceed 1%, and the porosity coefficient is 2%, which can not be a reason for values low accuracy of the soil deformation properties.
Measurement errors in determining the deformation characteristics of soil samples were analyzed by compression tests of 150 samples of loes loam, light silty, selected from the depths of 2, 4, 6, 8 and 10 m. Relative errors were calculated for coefficient of compressibility m_0 – 4,8%; relative coefficient of compressibility m_v – 5,7%; coefficient of relative porosity change A_{pw} – 4,15%; relative collapsibility ε_{sl} – 2,8%; coefficient of collapsibility B_{pw} – 3,7%. The error of determining the deformation properties of samples under compression tests does not exceed 6%, which indicates a rather high accuracy of their evaluation. Consequently, it does not significantly affect the reliability the base deformation prediction, but it was found that due to the significant gradation of the coefficient β, taking into account the lateral expansion of the soil, the relative error of its deformation module estimation reaches 20% [13].
The distribution of the soil deformation module values depends not only on its initial coefficient of porosity e_0, but also on the range of values of the porosity coefficient in a certain compression pressure range, as shown in Table. 1

Table 1: Effect of the soil porosity coefficient *e* on the deformation module *E*

Selection depth, m	Soil porosity coefficients range e_0	module values deformation range *E*	porosity coefficient effect e_0 on the value E_{max}/E_{min}
2	0,782÷1,037	5,02÷1,66	3,02
4	0,830÷0,964	5,16÷2,06	2,51
6	0,630÷1,053	6,74÷1,82	3,71
8	0,703÷0,855	13,20÷8,85	1,49
10	0,747÷0,896	4,71÷2,73	1,71

Tabl. 1 shows that the largest spread of initial soil porosity coefficients e_0 is from 0,630 to 1,053 in a layer at a depth of 6 m. Such a fluctuation of the porosity factor affects the soil deformation module value where E_{max}/E_{min}=3,71. That is, the disadvantage of the deformation module is the failure of taking into account its value from the coefficients of soil samples porosity on which it is calculated, which significantly reduces the reliability of the determination of this compressibility characteristic.
The magnitude of the deformation characteristics of the base, in addition to the measurement errors, also affects the errors of the technique of processing the compression tests results. Thus, by means of deformation parameters statistical analysis, based on the results of 350 samples of loes loams, light silty from 3 horizons (2, 4, 6 m) compression tests it was found that the coefficients of variation were the following: deformation module E – 32,4%; relative collapsibility ε_{sl} – 41,1%; coefficient of relative porosity change A_{pw} – 2,8%.

Consequently, due to normative method disadvantages of processing the compression tests results, the deformation characteristics variation coefficient of loes soils is within 30-40%.
The method of generalization the compression soil tests results has fewer flaws inherent in the standard method, since the influence of the natural distribution of samples porosity on the value of the A_{pw}, factor is eliminated, which reduces the coefficient of variation of this soil characteristic to 3%.
To exclude the influence of individual samples porosity on the soil compressibility, the comparison was carried out according to the deformation curves reflecting the relative change in the porosity coefficient for the soil compressibility. This enables conducting more accurate analyze of influence of moisture and water saturation coefficient, soil macroporosity on its compressibility. The deformation properties of buildings soil basis of are influenced by external factors of its previous existence in time, which should be taken into account when predicting its subsidence.
The tests have been conducted to determine the effect of moisture on soil compression, depending on the humidity at the yield point W_L and on the flipping edge W_p and plasticity index I_p in compressor devices K-1 of loes loams, heavy silty three engineering-geological elements (EGE): EGE-1 ($W_L = 0,333$; $W_P = 0,206$; $I_P = 0,127$); EGE-2 ($W_L = 0,352$; $W_P = 0,198$; $I_P = 0,154$); EGE-3 ($W_L = 0,403$; $W_P = 0,233$; $I_P = 0,170$). From the broken structure soil samples of different initial humidity from W_0 = 0,047 to W_0 = 0,241 and porosity (the initial coefficient of porosity within e_0 = 0,70 – 0,90) were artificially prepared. In each test, 5 soil samples of the same moisture content were used. Soil moisture was determined before the beginning of W_0 and after the test W_f . The samples were successively loaded with pressure p = 0; 0,05; 0,1; 0,2; 0,3 MPa. By compression results of 125 samples deformation curves of the soil of the excited structure were plotted at different values of its humidity $A_{pw} = f(p)$. And graphs of the soil compressibility dependence on the change in moisture at constant pressure are plotted $A_{pw}=f(w)$.
The analysis of these dependencies determined that the broken structure loam compression can be divided into four stages (phases), which are given in Table. 2

Table 2: Effect of moisture on the compressibility of disturbed structure clay soil

Soil compressibility stage	Soil moisture interval	Moisture influence on soil compressibility	Pressure influence on soil compression intensity	Deformation curve fForm
I	$w = 0,5W_p$	does not affect	intensity of compressibility is proportional to the pressure	straight
II	$0,5W_P \le w \le$ $\le 0,88W_P$	affect	intensity of compressibility is proportional to the pressure	close to line
III	$0,88W_P \le w \le W_L -$ $-0,65W_P$	affect	intensity of compressibility increases with increasing pressure	curve convex up
IV	$W_L - 0,65W_P \le w$	affect	intensity of compressibility decreases with increasing pressure	curve convex down

The separation of soil compressibility at the stage and its connection with the yield and plasticity limits of the soils allows prediing the base compressibility when changing its moisture content. If the nature of soil compression depends on their yield and plasticity limits, then the compression intensity depends on the number of plasticity. The soil with less plasticity index is more intensively compressed at the same humidity and pressure. When decreasing I_P = 0,170 до 0,127 the soil compression intensity increased in 2 times.
The humidity content and water saturation coefficient of the soil during compression tests were analyzed. As a result, the depend-

ence of the change in humidity on the compression of loes loam was found. Also, the relationship between deformations and humidity characteristics of soil samples with different initial porosity coefficients was found. Deformations of the broken structure soils compressibility in the water-saturated state depend on the pressure at which the soaking occurred. The deformations of loes soils samples, water-saturated at lower pressure levels, have a greater ultimate deformation than those that were water-saturated at higher pressure. This is explained by the fact that, after collapsibility deformation, the samples, which are then loaded with subsequent degrees of pressure, further deform in the water-saturated state.

Deformation of water-saturated soils compressibility occurs with water displacement from the soil. As a result, the soil moisture decreases. Upon reaching certain moisture level the deformation of the soil stops. Each type of soil is characterized by its moisture index, in which the soil will withstand a certain amount of pressure. This moisture value depends only on the type of soil and does not depend on the pressure at which it is soaked, and can be determined by a formula with an error of up to 5%. These patterns give new possibilities for forecasting deformations of the soil by changing its moisture content.

To detect the influence of macroporosity on soil compressibility, samples of loes loam were tested (W_L = 0,320; W_p =0,222; I_p = 0,127), wich were taken from the bore tip. At first 12 samples of natural structure with humidity w = 0,178 i e_0 = 0,756 were investigated. They were then thinned to obtain a homogeneous mass from which the samples of the broken structure were made. The rings put the same mass of soil of the broken structure. The mean porosity of the samples was e_0 = 0,756. Next, in the sample, vertical tubules were made by pushing the wire in a 1 mm diameter wire while maintaining its initial volume. This achieved the invariability of the total porosity of the soil in the ring. In each of the three rings, 10, 20, 30 tubules were made, and in the three rings there were no tubules. These samples were tested on compression devices at humidity: w = 0,085; 0,128; 0,172. A total of 45 tests have been conducted.

It was established that at humidity up to w = 0,128 the difference in macroporosity does not affect the compressibility of soil. The macroporosity of the samples is applied by the same coefficients of porosity on the compressibility of the soil. With the increase in heterogeneity (20 and 30 tubules), the porosity increases the compressibility of the soil unevenly at the same values of its porosity and humidity. Macro porosity of the soil for the same values of the porosity coefficient at a slight pressure $p \leq 0{,}1$ MPa almost does not affect its compressibility. For the pressure $p = 0{,}3$ MPa and humidity w = 0,172 compressibility due to heterogeneous porosity of the soil increased by 1.5 - 2 times.

The deformation curves of soils, selected from three bore tips of one site, have been analyzed. It has been shown that one and the same base can change the values of compressibility parameters depending on the previous history of existence. The preliminary local soiling of the soil in the area of bore tips number 1 and number 2 led to the implementation of the collapsibility properties of loes soils to a depth of 10 m. Preliminary moistening of the upper layers of the soil in the bore tip No.3 with their sealing from the construction materials reduced the compressibility by 2 times and settlements of the soil at a depth of 2 m. At a depth of 4 m, the reduction in compressibility occurred on a third - in comparison with the corresponding layer of soil No. 1 and No. 2

The disadvantage of a compression device is the impossibility of simultaneously ensuring the creation of a natural, that is, its own weight of soil, pressure on the soil and the possibility of its lateral expansion. There are also significant forces of the soil sample friction on the inner walls of the ring in which it is selected, which arise when compressing the soil. Due to the fact that the diameter of the stamp almost coincides with the inner diameter of the rigid ring, the actual compressibility of the soil is reduced by 10-50%.

As a result, the values of the parameters of soil compressibility, in particular the deformation module, are overestimated compared to the actual ones, which during designing leads to underestimation of the foundations settling values of the buildings foundations. To eliminate these drawbacks a stamp for the laboratory determination of soil deformation characteristics under conditions of one-piece compression was developed. The proposed rigid, perforated, round, planned stamp is divided into two separate parts - the inner, round plan, which transfers to the ground, placed in a rigid ring, both natural and additional, that is, from the weight of the foundation and load on it, pressure, and external, which has in the form of a ring that transfers to the soil, placed in the ring, only natural pressure (Fig. 1).

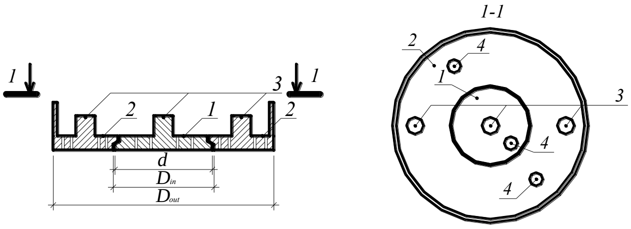


Fig.1: Diagram of the stamp for the laboratory determination of the soil deformation characteristics under conditions of uniaxial compression: 1 – round inner stamp in the plan with a diameter d; 2 – external stamp, which in the form of a ring has external shape D_{out} and inner D_{in} diameters; 3 – cavity for barriers for boot devices; 4 – places for indicators

Also CLES device (compressibility with lateral expansion of soil) to determine the characteristics of soil deformation under conditions of single-ended compression have been developed and patented. It ensures the simultaneous creation of natural and additional pressures on the soil, placed in a rigid ring, and the possibility of lateral expansion of this soil in the elimination of the frictional forces of the sample on the inner walls of the ring, due to the separation of the hard, perforated, round in the direction of the stamp into two separate parts, making it hard. The deformed state of the soil in the ring approaches the actual state of the base foundations (Figures 2 and 3).

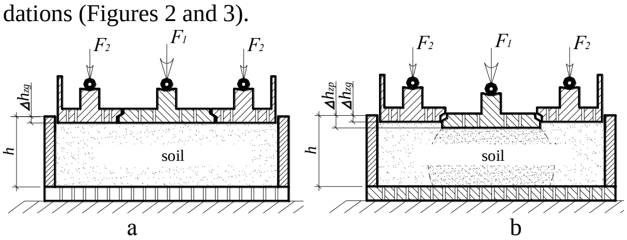
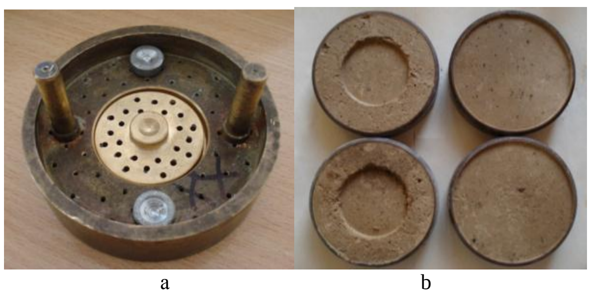


Fig. 2: Scheme of the soil sample deformation in the ring to the joint effect of natural and additional pressures: a – a sample of soil with deformation Δh_{zg} ; b – a sample of soil with deformation Δh_{zg} and Δh_{zp} ; F_1 – force that creates pressure under the inside of the stamp; F_2 – force that creates pressure under the outside of the stamp; h – initial height of the soil sample; Δh_{zg} – vertical deformation of the sample placed in the ring, under the outer part of the stamp; Δh_{zp} – vertical deformation of the sample placed in the ring under the inner part of the stamp



a b

Fig. 3: Device appearance: a - stamp; b – ground samples after testing on the patented device (left) and on the compression device (right)

The fig. 3 represents the diagram of the sample deformation in the ring from the combined effect of the natural σ_{zg} and additional σ_{zp} pressures under the circular plane of the inner part of the stamp, as well as the natural σ_{zg} pressure under the outer part of the stamp having the shape of the ring in plan. In the CLES device additional boot devices and measuring devices with the bolt of their racks on both parts of the stamp are introduced. This ensures the simultaneous creation for the sample in a ring, of natural and additional pressures. Under compression, the lateral expansion of the sample and the exclusion of the sample friction on the inner walls of the ring, which is closer to the actual state of the base foundations, is possible. This increases reliability of these tests in determining the deformation properties of soils.

The method of conducting soil tests on the CLES device has been developed. In comparative trials, the loam with the same physical properties in the devices without (compression device K-1) and with the possibility of its lateral expansion (CLES device) graphs were constructed $E = f(p)$ (Fig. 4). It is established that the deformation module of the soil, defined in the first case, has overestimated values; with increasing pressure on the soil, this difference increases. This is due to the fact that there is no lateral expansion of the soil and significant frictional forces behind the walls of the ring that arise when compressing the soil, reducing pressure to the sample.

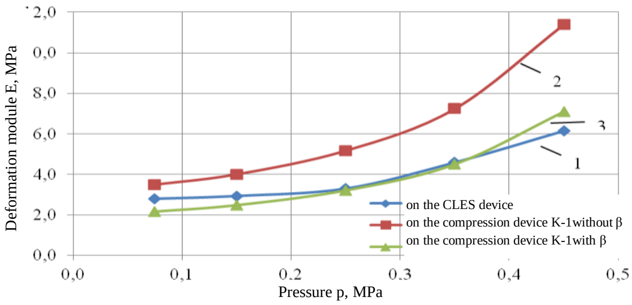


Fig.4: Graphs $E = f(p)$ according to test data: 1 – on the CLES device; 2 – on the compression device K-1without β; 3 – on the compression device K-1with β

The constant coefficient β for each type of soil must take into account the lateral expansion of the soil and reduce the size of the deformation module, that is, to actually quantify the error. In order to increase the accuracy of the soil compressibility parameters, it makes sense to conduct tests on the CLES device, which eliminates the need for adjusting coefficients, and, accordingly, additional errors.

The statistical analysis of the standard deformation properties of soils, selected from the five horizons, has shown that the accuracy of the deformation module is within the range of 15%, the relative subsidence is 18%, and the accuracy of the determination according to these data is the coefficient of relative porosity change A_{pw} – to 2%, the coefficient subsidence B_{pw} –to 2%. Greater accuracy A_{pw} and B_{pw} is achieved due to the fact that they reflect the relative change in the porosity coefficient for soil deformations common to all samples of one soil type at the same humidity and pressure. But parameters A_{pw} and B_{pw} are not convenient to apply in geotechnical practice.

All these deformation parameters of the soil combine the fact that they reflect the state of the sample after its deformation. It is more correct in the compressibility parameter to reflect the value of the soil's compression itself from pressure, and not its state after deformation. The compressiveness of the soil depends on its initial porosity and, accordingly, on the initial coefficient of porosity. To exclude the effect of porosity of individual samples on the compressibility parameter of its value, it is expedient to determine how the relative reduction of the porosity coefficient with compressing the sample by expression

$$N^i_{pw} = (e^i_0 - e^i_p) / e^i_0 = \Delta e^i_p / e^i_0 , \qquad (1)$$

where N^i_{pw} – compression ratio of the i-th sample; e^i_0, e^i_p – coefficients of porosity of the i-th soil sample, respectively, initial and after applying pressure p; Δe^i_p – reduction of the coefficient of porosity of the i-th sample after the addition of pressure p.

It makes sense to call this compressibility parameter as an index of soil compression N_{pw} and define it as average values of sample compression indices N^i_{pw}

$$N_{pw} = \sum_{i=1}^{n} \frac{e^i_0 - e^i_p}{e^i_0 \cdot n} = \sum_{i=1}^{n} \frac{\Delta e^i_p}{e^i_o \cdot n} = \sum_{i=1}^{n} \frac{N^i_{pw}}{n} , \qquad (2)$$

where N_{pw} – index of soil compression of a certain humidity w from pressure p.

Index N_{pw} indicates that it is determined at specific values of pressure p and humidity w. The soil compression index N_{pw} reflects a relative decrease in its porosity coefficient with compressed by pressure p. Results of indicators determination N^i_{pw} on the example of tests of clay soil, selected in the area of Poltava, in the device of the CLES and the compressor device K-1 are given in the form of charts in Fig. 5 and Fig. 6. It can be seen that the amount of soil compression in the CLES device is greater than that of the K-1 at all stages of pressure. The difference between the compression of soil in these devices increases with increasing pressure. This can be explained by the fact that there is no lateral friction of the soil behind the walls of the ring on the SBRD device. Friction of the soil behind the walls of the ring in the K-1 device reduces the compression of the sample. With increasing pressure, the effect of friction of the samples on the walls of the ring increases, which leads to an underestimation of the compression data samples in the compression device.

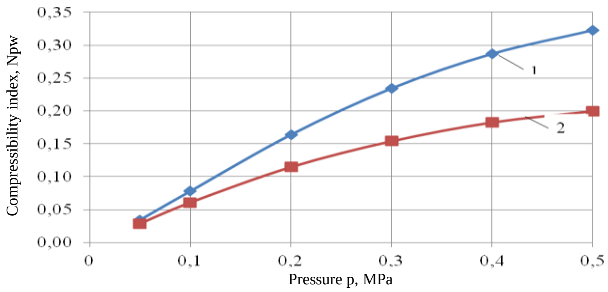


Fig. 5: Graphs $N_{pw} = f(p)$ to the test data in davices CLES (1) and K-1 (2)

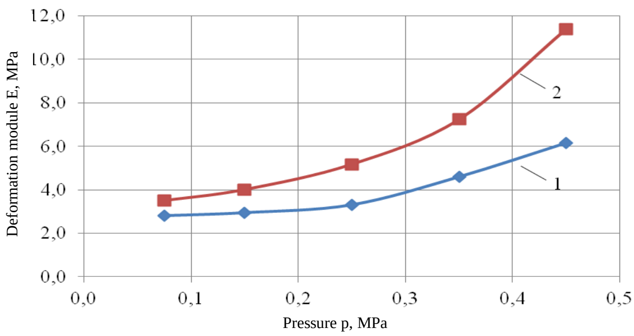


Fig. 6: Graphs $E = f(p)$ to the test data in davices CLES (1) and K-1 (2)

Consequently, the proposed compression index N_{pw} reflects the relative change in the porosity coefficient in the soil compression and more correctly for the standard compressibility parameters characterizes the deformation properties of the base for specific values of stresses that vary in depth of the compressive layer un-

der the foundation, taking into account the effect of porosity on the soil compressibility.
The compression of each base layer occurs with the lateral expansion of the soil from additional pressure, which varies in depth. Simulation of this process occurs when using the soil compression index N_{pw}, the value of which is determined by testing soil samples in the device CLES. It is proposed to calculate the settlement of the base by the method of layer summing according to soil compression index N_{pw} by the formula

$$S=\sum_{i=1}^{n} S_i=\beta\sum_{i=1}^{n} N^{i}_{pw}\frac{e^{i}_{0}}{1+e^{i}_{0}}\cdot h_i\,, \quad (3)$$

where S_i is settlement of soil base from the loading of the foundation; coefficient β = 0,8; N^{i}_{pw} – compression index of the i-th soil layer; e^{i}_{0} – initial soil porosity coefficient of the i-th layer; h_i – the thickness of the i-th soil layer.
The calculation of settlement by the method of layer summing using the index N_{pw} takes into account the change of the stress state on the depth of the soil base from the vertical load and the effect of soil porosity on its compression.
In order to compare the base settlement, it was determined by two deformation characteristics (deformation module E and soil compression index N_{pw}) obtained in K-1 and CLES devices.
In accordance with the test method when conducting on specific types of devices, proper methods of calculation were applied.
It was found, in particular, that the values of the base settlement, calculated by the deformation module, determined as a result of soil tests in the compression CLES device, were by 10.0 - 18.6% (13% on average) less than the values calculated for compression index.
The values of the base settlement on the results of soil tests in the compression device K-1 is similar to 21.0 - 37.6% (28% on average).
In order to confirm the greater reliability of the values of the base settlement on the soil compression index, the comparative analysis of the long-term geodetic observations results on a natural object settlements (section of a six-floor residential house in Poltava) was carried out, and the calculations based on both methods of the settlement of its bases were calculated.
The average pressure on strip foundation base with a width of *b* = 2,4 m on a natural subsoil, composed of water-saturated loessial loams, amounted to *p* = 180 kPa with the design strength of foundation soil *R* = 200 kPa.
Calculation of settlement of this base is performed by the method of layer summing through: 1) the deformation soi module E; 2) the soil compression index N_{pw}, which is determined in each layer at appropriate pressure at depth, taking into account the initial porosity soil coefficient of this layer.
The comparison of the calculated values results of base settlements of the building section in two methods with the data of natural observations is given in table 3, from which it is evident that the value of base subsidence by the soil compression index by 36% exceeds the value calculated by the deformation module. At the same time, the base settlements, determined by the soil compression index, is 13.8% higher than the value obtained by geodetic observations, and the base settlements, calculated through the soil deformation module, is by 26% less than the observations data [16].

Table 3: Comparison of the calculations results based on two methods of the values of settlement of soil base of the building with the data of field observations

№ EGE	Initial soil porosity coefficient e_0	soil module deformation E, MPa	Base settlement S, m, determined through the deformation module E [2]	Soil compression index N_{pw}	Base settlement S, m, determined through the compression index N_{pw}	Base settlement S, m, determined by geodetic observations
2	0,92	6,0	0,088	7,62	0,138	0,119
3	0,78	8,0		6,45		
4	0,84	11,0		5,61		

In order to compare the base settlements as a function of random arguments in accordance with the methodology of norms and developed by the authors, the apparatus of statistical simulation was used. In particular, the Monte-Carlo statistical test method was used while comparing the settlement results with these techniques.
According to the results of statistical modeling, random functions of base settlement of foundations S under two calculated conditions are obtained.
It is established that the distributions of random arguments functions of the base settlement of foundations are correctly approximated by Gauss's normal law. The results of the search for the function of random arguments based on the Monte Carlo method for a homogeneous soil base with e_0=0,860 are shown in Fig. 7.

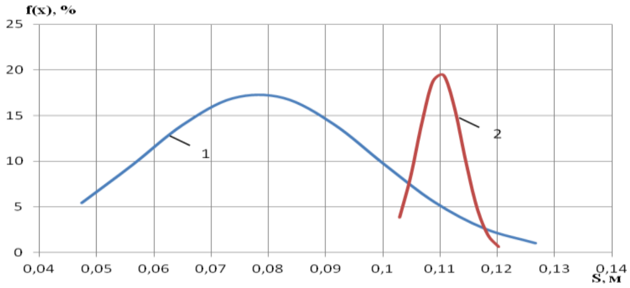


Fig. 7: Charts of the base settlement distribution values of S of the square form base for a homogeneous soil basis with e_0=0,860 as a function of a random argument: 1 – deformation module *E*; 2 – compression index N_{pw}

From the comparison of base settlement statistical processing data it is clear that the significance of their statistical parameters for the method with the compression index is much lower than for the normative method [2]: the standard error and deviation are 5.1 and the interval is 4.4 times, respectively. Consequently, the statistical analysis of the distribution of random variables of the predicted base settlement proved the higher reliability of the results by the method with the compression index for the normative method.

3. Conclusions

Due to the disadvantages of the normative method of data processing compression tests, measurement error up to 6%; significant gradation of the coefficient taking into account the lateral expansion of the soil increases the deformation module estimation error by 20%; a significant range of values of the porosity coefficient at a certain pressure interval, the coefficient of deformation characteristics variation of loessial soils reaches 30-40%. The method of results generalization of soil compression tests has fewer disadvantages than standard ones. When obtaining the coefficient of relative change in soil porosity A_{pw}, the effect of natural dispersion of samples porosity on its value is excluded, which reduces the coefficient of this parameter variation by 3%.
Under the same humidity and pressure, the soil with a smaller plasticity index I_p compresses more intensively: with decreasing from 0.170 to 0.127 by 2 times. Deformations of loessial soils, saturated with water at a lower pressure, have a greater ultimate deformation than saturated with greater pressure. Each type of soil is inherent in its value of humidity, at which it withstands a certain pressure, which depends on the type of soil and does not depend on the pressure at which it is soaked.

Increasing heterogeneity of soil porosity with the same values of the porosity coefficient and humidity causes a nonlinear increase in compressibility. Under the pressure of $p \le 0{,}1$ MPa macroporosity almost does not affect the soil compressibility, and for $p = 0{,}3$ MPa due to heterogeneous porosity compressibility increases by 1,5 - 2 times. When predicting the base deformations, the effect of preliminary soaking conditions and the corresponding consolidation of soils under their own weight should be taken into account.

New devices provide simultaneous creation on the soil, located in a rigid ring, natural and additional pressure and the possibility of lateral expansion of the soil with the exclusion of no friction of the sample behind the walls of the ring, and therefore the state of the soil in the ring is close to the actual state of the foundation base. The need for corrective coefficients is eliminated, and, accordingly, additional errors, which increases the reliability of the definitions of the the soil compressibilitparameters.

By comparative compression tests of light silty loam with the same physical properties in devices without the possibility of lateral expansion of the soil and with this possibility, it has been established that the soil deformation module, determined in the first case, has overestimated values; with an increase in the pressure on the soil, the relative difference between them increases from 20% in the pressure interval p = 0,05 - 0,1 MPa to 46% in the range p = 0,4 - 0,5 MPa.

The compression index reflects the relative change in the porosity coefficient in soil compression and, more correctly, in the standard compressibility parameters, characterizes the base deformation properties for specific values of stresses that vary in depth of the compressive layer under the foundation, taking into account the effect of porosity on the soil compressibility. The accuracy of determining method the foundations base settlement increased using the soil compression index. The foundations base settlements, determined by means of this index, are up to 27% higher, when calculated by means of a soil deformation module.

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