UDC 624.131

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COMPARISON OF THE SOIL DEFORMATION MODULUS VALUES RECEIVED BY THE LABORATORY AND IN SITU TESTS RESULTS

The soil deformation modulus largely depends on the obtaining method. There are various methods of determining E. In compression soil test a ring of small size is used. It causes a number of factors affecting the test results. The comparison of deformation modulus values obtained by in situ and laboratory methods is shown in article. It was believed for a long time that the oedometer deformation modulus of sands practically does not differ from the plate deformation test modulus, and therefore no transitional coefficients for this soil are given. However, it has been experimentally established that the results of oedometer tests of sands need to be corrected.

Key words: *oedometer deformation modulus, plate loading test modulus, in situ and laboratory soil tests.*

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ПОРІВНЯННЯ ВЕЛИЧИН МОДУЛЯ ДЕФОРМАЦІЇ ГРУНТУ, ОДЕРЖАНОГО ЗА РЕЗУЛЬТАТАМИ ЛАБОРАТОРНИХ ТА ПОЛЬОВИХ ВИПРОБУВАНЬ

Модуль деформації ґрунту значною мірою залежить від методу його отримання. Існують різні методи визначення Е. При компресійному стискуванні ґрунту використовується кільце невеликого розміру. Це обумовлює ряд факторів, що впливають на результати тесту. Наведено модуль деформації ґрунту, отриманий польовим і лабораторним методами, і порівняння їх величин. Довгий час вважалося, що одометричний модуль деформації пісків практично не відрізняється від штампового, а тому не наводяться перехідні коефіцієнти для цього ґрунту. Однак експериментально встановлено, що результати одометричних випробувань пісків потребують коригування.

Ключові слова*: одометричний модуль деформації, штамповий модуль деформації, польові та лабораторні випробування ґрунту.*

Introduction. The oedometer soil testing method is most common in our country to determine the deformation characteristics of soils due to its simplicity and accessibility, but it has a number of drawbacks. Therefore, its results should be monitored using other methods.

One of the most reliable methods for determining the dispersed soils deformation modulus (sandy, clay, organomineral and organic soils) is currently in situ stamp loading test metod. Usually, stamps of 5000, 2500 and 600 cm^2 are used, respectively, with diameters of 79,81, 56,43 and 27,65 cm. The first two sizes are used for testing soils in pits, pits and other mine workings, the smallest stamp is used for testing in boreholes. In the testing process a graph $S = f(p)$ is constructed. Then, in the initial section of the graph, the averaging straight line is drawn on the basis of the least-squares method by at least four test points. The deformation modulus are calculated on the basis of the Schleicher formula by the increments measured values of pressure on the stamp and the precipitation at a constant value of the coefficient ω = 0,79 for a rigid stamp and the values of the additional coefficient Kp = 1 ... 0,70, depending on the relative burial of the stamp and decreasing with its increase. [1]

Analysis of recent research sources and publications. In classical literature works, the basic ways of determining the deformation modulus are clearly established: plate loading, oedometer, pressuremeter, cone penetration and other tests. The carried out researches and analyzes of the obtained results can be found in the works of Agishev I.A., Ignatova A.I., Kornienko N.V., Zotsenko M.L., Vinnikova Y.L., Tertzagi and Pek, Joseph E. Bowles and many others.

These experiments were carried out on various soils, using various methods, but the question of the exact determination of the deformation modulus is still open.

Identification of general problem parts unsolved before. At the end of the 19-th century, it was began to assess the deformability of soils with the help of the plate loading tests. And only Terzagi transferred these tests to laboratory conditions, so like that oedometers appeared, and still occupy a leading position in deformation testing in our country. However, already in the sixties of the last century it was noted that the deformation modulus obtained by the results of odometer testing are underestimated and require correction [2 – 6].

These tests were widely conducted in KNUBC, SG SRIBC, PNTU, and others.

The widespread introduction of cone penetration simplified the evaluation of ground conditions, especially at the depth, but did not improve the accuracy of the deformation modulus as a result of the fact that the derivation of these values is based on correlation.

Today, great importance has been gained in obtaining the deformation modulus E by counting its value in terms of the real sediments values established by instrumental deformations observations of the building base in time.

The definition of E is a complex task that requires the complexity of research and the necessary analysis of data for soils obtained by different methods.

Problem definition. The aim of the study is to present a comprehensive evaluation of sandy soil based on the results of in situ plate loading tests and the oedometer soil tests in laboratory conditions.

Basic material and results. To date, plate loading tests are extremely rare and in quantities insufficient to obtain reliable soil characteristics. Even more rare are control tests by other methods. So to improve the foregoing, on the construction site in the Kiev region, complex tests were conducted by three different methods.

The laboratory tests

The soil specimens of natural structure were sampled at the in situ tests points of sections «a» and «b»to perform laboratory work.

The oedometer tests were performed with samples of fine sand broken structure samples having a specified (determined in the field conditions) density and humidity in standard odometers at loads up to 0.4 MPa at natural humidity (6 determinations). A typical compression curve is shown in figure 1.

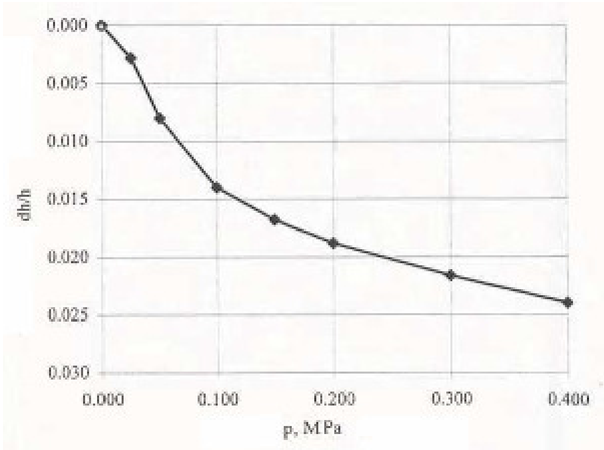

Figure 1 – Typical compression test graphic

Table 1 – Physical and mechanical soil test results

Stamp number	Soil sampling depth, m	Soil name	Mechanical characteristics		
			φ_0	c, MPa	E, MPa
53	0,2-0,3	dusty sand	26	0,010	20,9
54	0,2-0,3	fine sand	29	0,002	11,95
57	0,2-0,3	dusty sand	26	0,008	21,6
58	0,2-0,3	fine sand	28	0,004	22,25
61	0,2-0,3	fine sand	28	0,003	18,1
64	0,2-0,3	dusty sand	25	0,012	17,0
Average values			27	0,007	18,6

Stamp test

The static load tests with a round stamp of type I with an area of 5000 cm^2 are made in accordance with the Ukrainian normative documents [7]. On the central axis of foundation pits with a 10 m step on the surface of the foundation pits bottom at 24 points in two sections, to obtain a deformation modulus of bulk soils. Soil deformation modulus calculation according to the results of situ tests with load stages from 50 to 300 ... 350 kPa.

According to the data of plate loading test, the graphs of the dependence of the stamp residue on the pressure $S = f\,(p)$ are plotted, the values of Δp and ΔS are calculated on the averaging line.

The soil deformation modulus E, MPa is calculated for the linear part of this graph by the formula: $E = (1 - \nu^2) \times K_p \times K1 \times D \times \Delta p\, /\, \Delta S$.

The results of the work performed on sections «a» and «b».

The density of the skeleton average values of sandy soils are: $\rho_d = 1{,}79$ g/cm^3 (section «a»), $\rho_d = 1{,}78$ g/cm^3 (section «b»).

The average deformation modulus values of bulk soils, determined during in situ testing, are: E_{PLT} = 28 ... 31 MPa, the oedometer deformation modulus of bulk soils E_{oed} = 18,6 MPa. Thus, the correlation coefficient m_k = 1,6.

Typical dependence graphs of the soil deformation under the stamp from the load are shown in Figure 2.

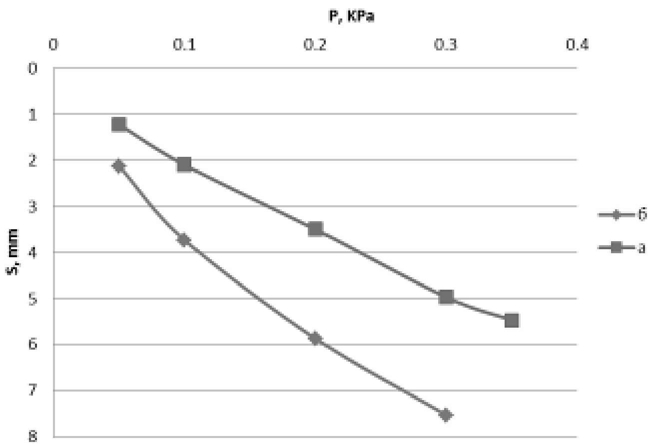

Figure 2 – Typical plate loading test graphics on sections «a» and «b»

Tests in sections «c» and «d»

In 2011, work was carried out on engineering-geological (geotechnical and geophysical) studies of foundation pits bottom deformations.

The following types of work were performed: seismic exploration by 2 profiles of 240 m in length (along the western and eastern branches of tracks). The results of seismic surveys are given below. And eight plate loading tests № 1 - 8. The test site is located between the sections «a» and «b», divided into two bands sections «c» and «d». Also it is given 11 additional tests of the same ground by plate loading.

Planning and construction work is carried out at the survey site. At the time of writing the report, the absolute marks of section «c» are 113.97 – 114.87 m, in section «d» 113.93 – 115.72 m.

The upper part of the geological section is composed of sands with a thickness of 0.5-2.4 m, under them lie upper and middle quaternary alluvial deposits lined at a depth of 31-32 m by the rocks of the Kiev suite of the middle paleogene (Eocene). At the explored depth of 5.4 m, the depositions of the flood plain facies ($a^2{}_3pr$) are involved – these are predominantly sands of different sizes with rare interbeds of sandy loam.

In order to clarify the determination of the soil deformation modulus values along the sections «c» and «d», seismic surveys were carried out on two profiles.

On the basis of the obtained velocity characteristics and density of soils, the value of Young's modulus (E_{dyn}) was determined and the modulus of deformation (E_{def}) of soils was calculated from the correlation dependence proposed by V.I. Bondarev: $E_{def} = 0.088 \times E_{\text{dyn}} + 10.25$. The correlation equation is refined in the process of performing works on numerous objects as a result of comparison with the data of experimental works (plate loading).

The obtained average values of the deformation modulus were: «c» $E_{def} = 24.6$; and at the section «d» $E_{def} = 27.8$.

Plate loading testing. Plate loading tests with a stamp of type I – 5000 cm^2 are carried out according to [7] to obtain a deformation modulus of bulk soils. Test points from 1 to 8.

The soil deformation modulus calculation by the results of in situ tests was carried out with load stages from 0.05 to 0.3 MPa. 8 stamp tests of sandy soils were performed. The deformation modulus in section «d» amounted up to 22.1 - 29.4 MPa, in section «c» amounted to 18.1 - 21.7 MPa.

All the results of the in situ deformation modulus E definitions are summarized in Table 2.

Table 2 – Determination of the deformation modulus by in situ tests results

№ b/p	Test site	Deformation modulus E_{PLT}, MPa	№ b/p	Test site	Deformation modulus E_{PLT}, MPa
1	Section «a»	38,4	25	Additional	32,8
2	Section «a»	27,1	26	Additional	31,9
3	Section «a»	22,0	27	Additional	22,7
4	Section «a»	27,6	28	Additional	28,2
5	Section «a»	26,6	29	Additional	18,9
6	Section «a»	31,9	30	Additional	28,0
7	Section «a»	35,9	31	Additional	29,2
8	Section «a»	33,1	32	Additional	28,7
9	Section «a»	33,1	33	Additional	32,1
10	Section «a»	33,9	34	Additional	31,3
11	Section «a»	39,1	35	Additional	31,5
12	Section «a»	31,0	Av. val.		29,4
13	Section «b»	26,9	36	Section «c»	18,1
14	Section «b»	27,4	37	Section «c»	18,9
15	Section «b»	28,9	38	Section «c»	21,7
16	Section «b»	24,9	39	Section «c»	18,2
17	Section «b»	25,8	Av. val.		19,2
18	Section «b»	22,6	40	Section «d»	22,1
19	Section «b»	28,5	41	Section «d»	26,5
20	Section «b»	27,8	42	Section «d»	27,2
21	Section «b»	28,3	43	Section «d»	29,4
22	Section «b»	27,8	Av. val.		26,3
23	Section «b»	31,2	Av. val.	(Common)	28,1
24	Section «b»	35,0			

It should be noted that according to seismic data and the results of in situ tests, the deformation modulus along section «c» is somewhat lower than in section «d».

Based on the results of previous determinations and taking into account the deformation modulus values obtained in the present investigations, Tables 3 and 4 and histograms (Fig. 3 and 4) are constructed for the distribution of deformation modulus values determined by the in situ plate loading tests.

Table 3 – Deformation modulus determination by in situ plate loading tests results

Deformation modulus E_{PLT}, MPa	Number of values
18-20	4
20-25	6
25-30	18
30-35	13
38,4	1
39,1	1

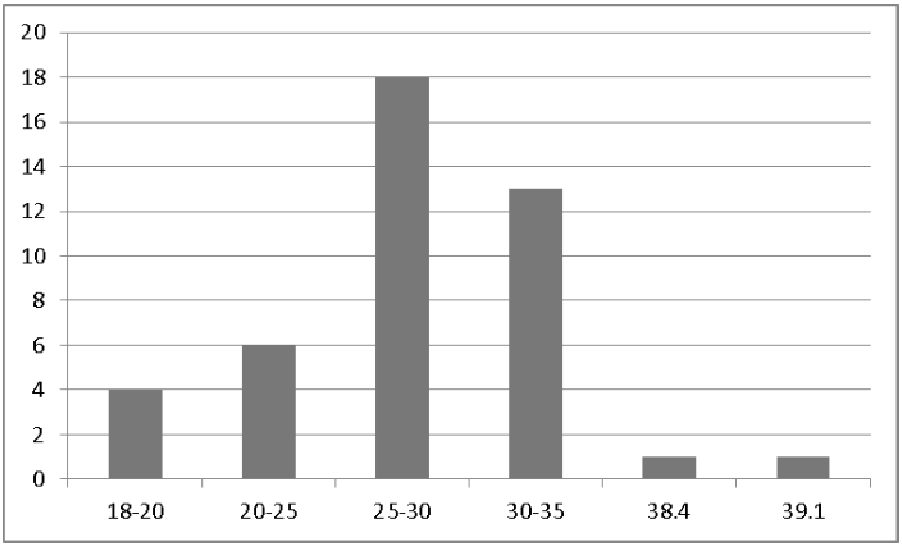

Figure 3 – The diagram of the E_{PLT} definition is quantified

Table 4 – Determination of the deformation modulus obtained by the in situ plate loading tests results (in the percentage)

Deformation modulus E_{PLT}, MPa	Number of values
18-20	9,30%
20-25	13,95%
25-30	41,86%
30-35	30,23%
38,4	2,33%
39,1	2,33%

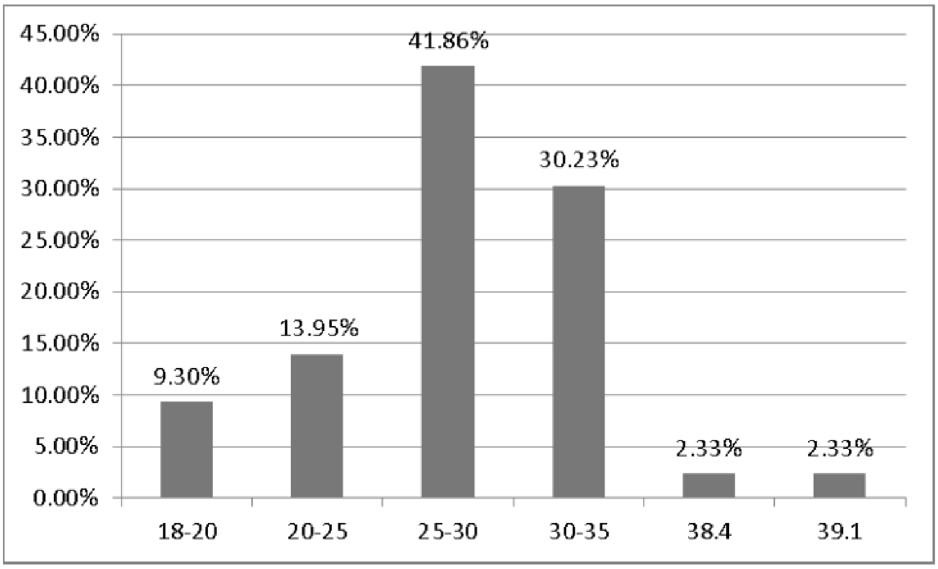

Figure 4 – Diagram of the E_{PLT} definition as a percentage definitions of the deformation modulus by plate loading tests

As a result of the above, it can be concluded that the soil testing are sufficiently well-converged by different methods. Histograms show that according to two methods of investigation, the values of the deformation modulus in the range 25-30 MPa constitute the largest percentage of all the obtained values. It indicates the correctness and possible application in future the seismic survey method in combination with other methods for the soil investigations, as more timely, which is advisable under conditions of radiation pollution.

Conclusions.

1. For a long time it was believed that the oedometer deformation modulus of sands practically does not differ from the modulus by the results of plate loading tests, and therefore no transitional coefficients for this soil are given. However, it has been experimentally established that the results of oedometer tests of sands need to be corrected. The difference between the plate loading and the oedometer moduluses was 1.5 times. The average values were: E_{PLT} = 28.1 MPa, E_{oed} = 18.6 MPa.

2. The problem of obtaining a reliable, E should be solved considering the soil structural strength and the stress-deformation state formation of the base within the thickness of the layer.

3. The deformation of the soil sample is uneven in height of the sample. The deformation of the crumbling significantly affects the value of the deformation modulus. The crumbling zone also occurs when testing the soil with a plate load, it is commensurate with the crumbling zone in the odometer. When calculating the sediment of the test base, the crumbling of the ground at its base can be neglected, but in the case of compression tests because of the small sample dimensions, the deformation of the crumbling zone significantly underestimates the values of the deformation modulus, overstates the draft of the building and, as a consequence, increases the cost of construction.

4. In the foreign literature [8, 9], in order to avoid inaccuracy in the determination of the deformation modulus, a differentiated definition is adopted, and in oedometer tests, it is often used with some approximation along the unloading compression curve branch.

5. The correlation coefficients m_k given in [10] are established in Ukraine as general average values for clays, loam and sandy loam, do not take into account the structural strength, loading range and depend on the type, density and condition of the soil.

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Received 09.09.2017