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Comparison of deformation modulus determined by triaxial, compression and plate load tests of loamy soils

Comparaison des modules de déformation déterminés par des essais triaxiaux, de compression et de charge de plaque de sols limoneux

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ABSTRACT: The article presents a study of the module of general deformation of loamy soils. The research included three fundamental methods for measuring modulus of general deformation, two of which relate to laboratory tests - odometric and stabilometric - and the third to a field plate load test. Comparisons of the deformation modulus obtained are made relative to the stamp test because the stamp tests are considered reference tests, are performed in the natural conditions of the soil base and are as close to the actual values as possible. According to the results, the values of the deformation modulus of loamy soils were found to be 1.20 to 1.32 times lower as a result of stabilometric tests, which may be caused by partial loosening of the soil, resulting in structural strength failure. The values of compression modules to stamps vary between 1.47 and 2.52 depending on the moisture content of the loamy soil.

RÉSUMÉ: L'article présente une étude du module de déformation générale des sols limoneux. La recherche comprenait trois méthodes fondamentales pour mesurer le module de déformation générale, dont deux se rapportent à des tests de laboratoire - odométriques et stabilométriques - et la troisième à un test de charge de plaque sur le terrain. Les comparaisons du module de déformation obtenu sont faites par rapport à l'essai de poinçonnage car les essais de poinçonnage sont considérés comme des essais de référence, sont effectués dans les conditions naturelles de la base du sol et sont aussi proches que possible des valeurs réelles. D'après les résultats, les valeurs du module de déformation des sols limoneux se sont révélées 1,20 à 1,32 fois inférieures à la suite d'essais stabilométriques, ce qui peut être causé par un relâchement partiel du sol, entraînant une rupture de résistance structurelle. Les valeurs des modules de compression aux timbres varient entre 1,47 et 2,52 selon le taux d'humidité du sol limoneux.

KEYWORDS: module of general deformation, odometric tests, stabilometric tests, stamp tests.

1 INTRODUCTION. FIRST LEVEL HEADING

One of the first researches of the module of compression tests in comparison with stamps was conducted by A.I. Agishev [1]. In 1957, he established that the values of the deformation modulus of soils based on the results of compression tests were 2-10 times lower than those of field stamp tests [2]. According to the regulations [3], when calculating the bases on the second limit condition, deformation modulus is used, which can be reduced by means of correction coefficient of compression modulus of deformation, but many researchers noted [4] that the values of correction coefficients, even for a particular type of soil, may differ significantly due to regional soil characteristics. In 1959, E.I. Medkov made a comparison of stabilometric deformation modules with field stamps [5]. The results of the stabilometric tests obtained are almost exactly the same as the module obtained by the stamp tests [4].

Thus, the purpose of the researches was to determine correction factors for the reduction of compression deformation modules to stamps, for soils in Astana.

1.1 *Soil sample selection*

Soil samples for laboratory tests were taken after stamp tests were carried out at a distance of no more than 1.0 m from the edge of the test hole set up for stamp tests at various depths of soil. Three test holes up to a depth of 6-6.5 m for stamp tests at 1 m depth intervals were drilled, as well as 9 test holes for sampling at intervals of every 0.25 m to a depth exceeding two die diameters (7.5-8.0 m). The distance between boreholes was 1-1.2 m. The number of boreholes was taken into account with 6 samples for laboratory testing and 3 as a reserve if the samples were not suitable for testing. After taking samples for laboratory testing of the deformation module, soil samples were taken for engineering and geological surveys at depths up to 30 m. A diagram of the location of the sampling is shown in Figure 1.

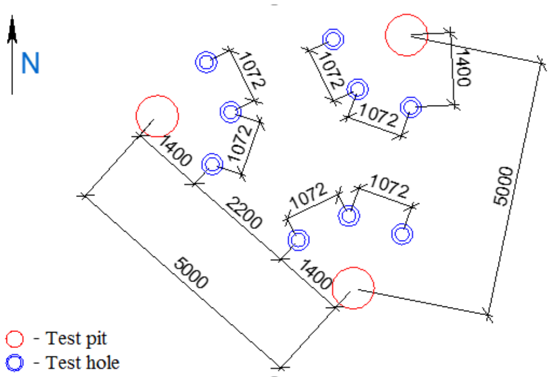

Figure 1. Soil sample selection for laboratory research

1.1 *Results of engineering and geological surveys*

Geological surveys of the construction site were carried out after field stamping tests and represent a set of laboratory tests.

Alluvial medium quaternary sediments *a(Qii-iv)* presented as loamy soil layers. The thickness of the geological element is from 3.0 to 3.2 m. The geological element is part of the thick slightly water-saturated soils (soft plastic, fluid plastic and fluid) spread across Astana. The results of physical and mechanical properties of soils based on laboratory and field research are presented in Table 1.

Table 1 - Physical and mechanical properties of the EGE 2

Parameter	*value*
Moisture of soil, %	14,2 - 21,3
Limit of liquidity, %	21,0-25,0
Limit of plasticity, %	14,0-16,0
Specific weight, g/cm^3	2,67-2,74
Density, g/cm^3	1,73-1,92
Porosity coefficient	0,56-0,68
Degree of water saturation	0,80-0,90

2 TEST RESULTS

2.1 *Stabilometric tests*

Soil tests were carried out at a constant value of all-round stresses Δσ3=0, with the vertical loads of the specimen specified in the test programme. Stabilometric tests were carried out using a consolidated-drained test scheme, which is used to determine the deformability of soils in a stabilised state. This scheme involves testing the soil samples for unlimited compression (as a result of open drain valves during the entire test) with very low stress levels.

Three-axis compression testing of the soil is performed in the following sequence:

- preparation of a sample of disturbed addition in a specially constructed 40x40x60 stand;

- installation of the sample in a triaxial chamber, preparation of the device for testing in accordance with GOST 12248-96;

- step sealing of the sample with all-round pressure in the chamber according to the test programme with open drain valves, to ensure that water is pressed out of the ground sample;

- vertical step loading of the sample, which is 20% of the full pressure.

Each pressure stage is maintained until the vertical deformation of the specimen is conditionally stabilised, the criterion for which is an increase in relative vertical deformation not exceeding 0.0001 in 6 hours of observation. Countdown of the soil sample strain gauges was recorded every 1, 5, 15, 30 minutes, 1, 2, 4, 6 and 8 hours.

The all-round pressure of σ3 on the soil sample was determined from the initial ground stress condition as a result of domestic pressure. When calculating the stress-strain condition of the soil, the hydrostatic law of distribution of initial (natural) stresses in the soil mass is generally used. In this case, the initial stress is assigned based on the depth of the soil in question and is defined as a product of the specific gravity of the soil at the monolithic depth, i.e. σ3=ϒ·z. In our case, three different values will be considered for stabilometric tests, σ3, based on the depth of the stamp tests.

The initial stress distribution graph for clay soils at different densities is shown in Figure 2.

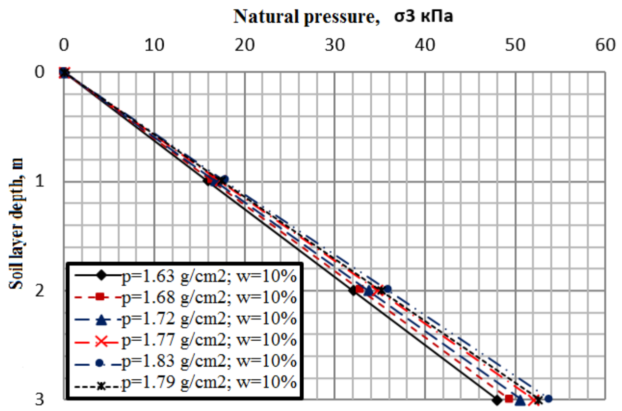

Figure 2 - Distribution of natural pressure of loamy soil by depth

The distributions of the deformation modulus as a function of the depth of loamy soils are shown in Figure 3.

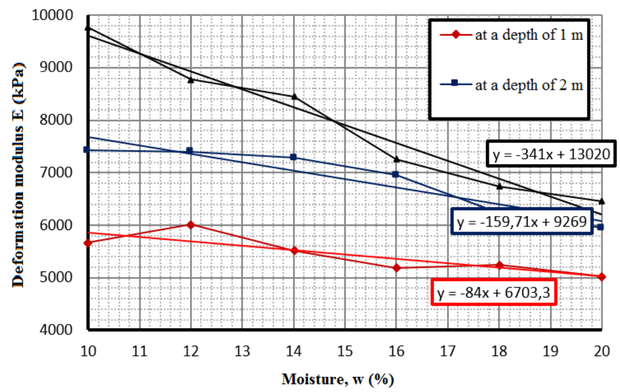

Figure 3 - Dependence of the stabilometric module of deformation on the moisture of loamy soil

2.2 *Compression tests*

The deformation of naturally formed soil is a bilineal dependence characterized by modulus of elastic deformation and a module of compaction. Elastic deformation, however, is a result of the structural strength of the soil, the sample does not have structural strength in the disturbed state and therefore the resulting deformations under loading of such soil are classified as elastoplastic. To find the modulus of deformation during compression testing, both the elastic and the elastoplastic deformation zone characterized by the general deformation modulus (hereinafter referred to as the compression modulus of deformation) corresponding to the pressure range of the soil sample in the range from 0.1 to 0.2 MPa is considered.

The distinctive feature of soils is that soils of the same composition within a single geological element represent an anisotropic structure and in terms of depth have heterogeneous strength, density, moisture, etc. For example, the moisture of clays in Astana varies between 10.2 - 27.7%, density 1.84 - 2.09 and the porosity coefficient 0.51 - 0.68. Such diverse soil characteristics do not give an unambiguous deformation modulus value within a single geological element.

As the loam soil samples are within a limited range of moisture and density typical only of the construction site investigated, i.e. (14.4-18.7%, according to the engineering and geological surveys), these studies can be applied to loam soil of a limited moisture range and cannot be applied to loam soil of the same composition but different moisture and density.

Therefore, the research was carried out on both undisturbed and disturbed soil samples with different moisture and density of the sample, with the results of the disturbed structure samples being used to determine the pattern of deformation modulus change from the moisture of a wide range inherent in the Astana loamy soil, and the results of the undisturbed soil samples (as a result of the limited moisture range of the site) being used to correct the undervalues of the deformation modulus in the soil samples.

The dependence of the modulus of compressive deformation on moisture obtained from tests of loamy soil samples of disturbed addition is shown in Figure 4. The results of compression tests on 18 natural structure loam soil samples are shown in Figure 5.

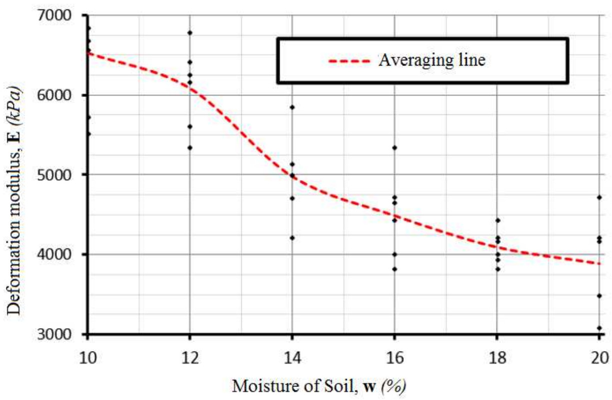

Figure 4 - Dependence of compression deformation modulus on the moisture of the loamy soil of the disrupted addition.

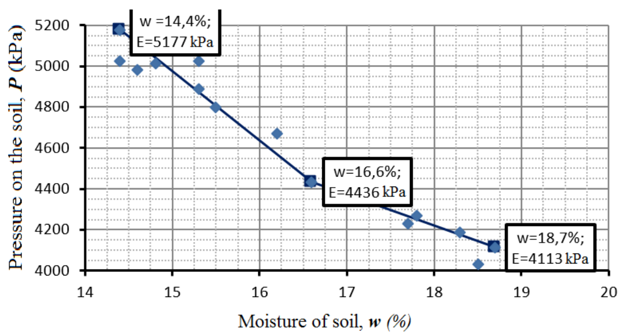

Figure 5 - Dependence of compression deformation modulus on the moisture of naturally compounded loamy soils.

2.3 *Stamp tests*

Stamp soil tests are carried out to determine the deformation modulus according to a graph of the dependence of horizontal soil movements on the horizontal pressure of the stamp, as well as to determine the structural strength of the soil. The tests were carried out with a plain round stamp with an area of 5000 cm2.

The loamy soil was tested from the bottom of the excavation at a depth of 0.2 to 0.4m, at a depth of 1, 2 and 3m. At the end of the tests, soil samples were taken to determine moisture and density. Table 4 shows the soil moisture values for the three test points (Figure 1) at different loam depths. Stamped deformation modules were determined for the linear sections of the graphs and Table 5 shows the results of stamped deformation modulus of loams depending on the depth of the soil and its natural moisture.

Table 2 - Moisture values of loam samples by depth

Depth of test, m	Soil moisture values, ***w*** (%)		
0.2-0.4	14.5	14.3	14.2
1	14.3	14.5	13.4
2	16.7	15.2	16.2
3	19.7	19.9	19.3

Table 3 - Values of stamped deformation module of loam

Depth of test, m	Values of deformation module, ***E*** (kPa)		
0.2-0.4	8232	8423	8890
1	7940	7429	7109
2	7898	8698	9213
3	6545	5465	6092

Graphs of the dependence of stamp S settlements on the applied load P by the depth of loamy soils are shown in Figure 6.

The dependences of the stamp deformation module on the soil moisture, taking into account their occurrence, as well as the linear functional dependence of the distribution of the deformation module by soil moisture, determined by the average values of deformation modulus at different depths of occurrence are shown in Figure 7.

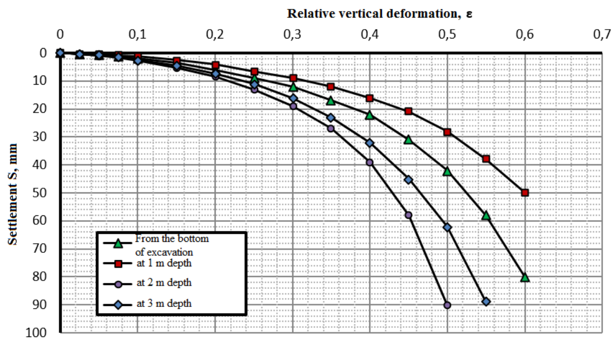

Figure 6 - Graphs of the dependence of stamp settlement on the depth of loamy soils

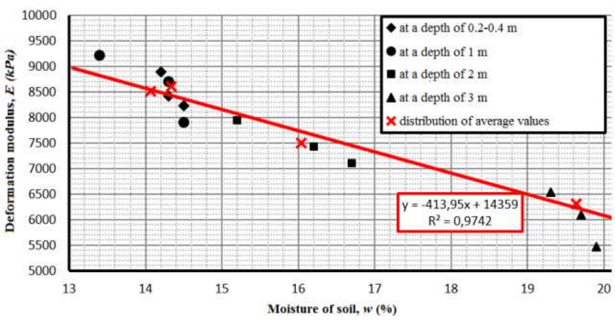

Figure 7 - Linear dependence of average values of stamp deformation modules on loamy soil moisture

3 COMPARISON OF TEST RESULTS

3.1 *Comparison of results of stabilometric and stamp tests*

The correction factors for stabilometric reduction to stamps are shown in Figure 8. The values of the correction factors obtained to bring the stabilometric modules of deformation to stamps for loamy soils are shown in Table 4.

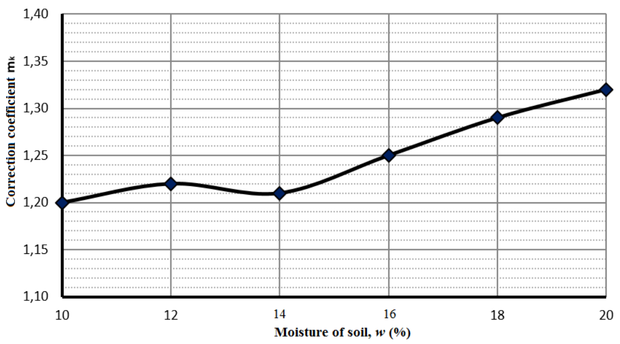

Figure 8 - Correction coefficients for setting stabilometric modulus of deformation to stamps (for loamy soils)

Table 4 - Correction coefficients for setting stabilometric modulus of deformation to stamps (loams)

Soil moisture, ***w (%)***	Stabilometric to stamp (average)
10	1.20
12	1.22
14	1.21
16	1.25
18	1.29
20	1.32

3.2 *Comparison of compression and stamp test results*

For determining of correction coefficients, the obtained values of deformation modulus by depth and soil moisture were compared.

The values of the obtained correction coefficients for the reduction of compression modulus of deformation to stamps for loamy soils are shown in Table 4.

Table 4 - Correction coefficients for setting compression modulus of deformation to stamps (loams)

Soil moisture, ***w (%)***	Compression to stamps (averages)
10	1.47
12	1.59
14	1.91
16	2.13
18	2.18
20	2.52

4 CONCLUSION

According to the research results, the following conclusions can be drawn:

- The dependences of stabilometric and stamped deformation modules on the moisture of loamy soil have been obtained. Correction coefficients of stabilometric and stamped deformation modules for clay soil in Astana have been revealed. The reason for the difference in stabilometric deformation modules from stamped tests (1.20-1.32) may be partial soil decompaction, resulting in structural strength failure that cannot be fully recovered or compensated by the full pressure on the soil sample during the stabilometric tests.
- The dependences of compression and stamped deformation modules on the moisture of the loamy soil have been obtained. Correction coefficients of compression and stamped deformation modules for clay soil in Astana have been identified. The resulting correction coefficients for conversion of compression modules to stamps vary from 1.47 to 2.52 depending on the moisture of the loamy soil. The values of the coefficients for loamy soil in 2-3 differ from the classical ones, which in turn confirms the influence of regional soil features on the values of these coefficients.

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