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TESTING A SAND PRESSIOMETER IN MODEL AND NATURAL CONDITIONS

Abstract: In the paper discusses the results of experimental studies of the strengthened and deformed state of the soil around the walls of the borehole under axisymmetric loading. Analytical expressions are given for determining the soil deformation modulus during the test with a sand pressiometer.

Key words: strength, deformation, displacements, load, lateral stress, soil stress on the borehole wall, modeling of soil test, correlation coefficient, axisymmetric task, deformation modulus.

Language: English

Citation: Nabieva, N. A. (2020). Testing a sand pressiometer in model and natural conditions. ISJ Theoretical & Applied Science, 08 (88), 1-6.

Soi: http://s-o-i.org/1.1/TAS-08-88-1   Doi: crossref https://dx.doi.org/10.15863/TAS.2020.08.88.1

Scopus ASCC: 2200.

Introduction

UDC-624.131.38

The reliability of buildings and structures under construction largely depends on the qualitative determination of the basic deformation and strength properties of soils. The results of the calculation of the bases depend on the accuracy of determining the quantitative values of the deformation characteristics of the soil. Currently, in the world practice, the tendency to comprehensively determine these characteristics remains, giving preference to in-situ methods for determining direct tests in the soils [1-4]. These include all plate [5], in-situ and pressiometric tests [6-9], as well as methods of static and dynamic sounding of soils [10-13]. The first two methods are mainly used for quantitative comparison of the results of determining soil resistance by the depth of the base with static (penetrometer) and dynamic sounding methods. As you know, the last two methods make it possible to test and determine the soil resistance at a depth of more than 20 m. These results are necessary when designing pile foundations or when substantiating the depth of the foundations [14]. But when calculating deformation bases, preference is still given to classical parameters, such as the deformation modulus, determined by stamp and pressiometric tests

[15]. For stamp tests of soils, it is necessary to use special anchor and frame bulky equipment, jacks, dynamometers and other measuring instruments. Stamp tests are mainly carried out on the bottom surface of pits. In contrast, pressiometric tests are carried out relatively on compact equipment and, most importantly, allow testing at different depths of the soils. In this regard, pressiometry tests have gained quite a lot of popularity in engineering surveys. In terms of accuracy, pressiometric readings are second only to plate tests in pits. Plate and pressiometric tests are carried out in accordance with GOST 20276-2012 [1,16].

The aim of the experiments is to compare the results of various parameters of soil deformability obtained in in-situ experiments, in particular: plate, pressiometric tests and dynamic sounding of soils in depth. The comparison is subject to classic plate and radial pressiometers. In some cases, when comparing the results, the results of penetration and dynamic test methods are also taken into account.

In respect that loess soils are widespreaded [17,18], on the basis of Geofundamentprojekt LLC, with the participation of the author, a new type of pressiometer was created to study the deformation, including subsidence, properties of loess soils. The goal was set for the author - to study the operability of

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the new design in bench and in-situ conditions and to compare these results with known standard methods.

The design of the pressiometer proposed by the authors is based on the axial compression of the graded sand cylinder inside the borehole (Fig. 1).

A sand cylinder with an aspect ratio of at least $d/h = 1/2$ is formed by filling its measured amount into the borehole above the GWH (Fig. 1). Sand is poured into the borehole on the surface of the lower round plate (3) connected to the vertical rod (5) (inside the rod) mounted on the bottom of the borehole. A second upper plate in the form of a doughnut (4) is mounted on the upper end of the sand cylinder, mounted on the end of a hollow rod made of a thick-walled pipe. The rod (5) moves freely inside the hollow rod. The diameters of the lower and upper plates of the pressiometer, as well as the borhole are 76 mm. Vertical pressure on the sand cylinder is carried out by using the opposite movement inward of the lower and upper dies.

The proposed method for determining the deformation characteristics of soils is as follows. A borehole is being erected at the research object by drilling with a hand motor drill or a drill with a diameter of 71 mm and a depth of 1.5-6 m from the bottom of the pit. To obtain the exact specified diameter of the borehole, a hollow cutting pipe with a diameter of 75 mm is driven into it to the design level. A rod with a lower disk plate with a diameter of 75 mm is lowered into the borehole. The central disk plate is connected to the shaft by a screw connection. The vertical shaft consists of a section 80 cm long and, if necessary, is extended by means of a screw connection. A measured amount of sand is poured into the borehole, which forms a cylinder diameter of 76 mm and a height of 15-20 sm. A thick-walled pipe built up using a threaded connection is put on top of the rod. It serves both for conducting test cases and for filling a measured amount of sand into the borehole. The lower plate is made in the form of a disk with a thickness of 4 mm and a diameter of 76 mm. Axial loading of the sand cylinder is carried out using weights suspended on levers. The force transmitted by the lever system increases in multiples of the ratio of the shoulders of the mechanism (10 times). The vertical movement of the plates is measured by the Maximov deflection meter with a division accuracy of 0.1 mm. Radial deformation and stresses on the walls of the borehole are determined by analytical calculation [19].
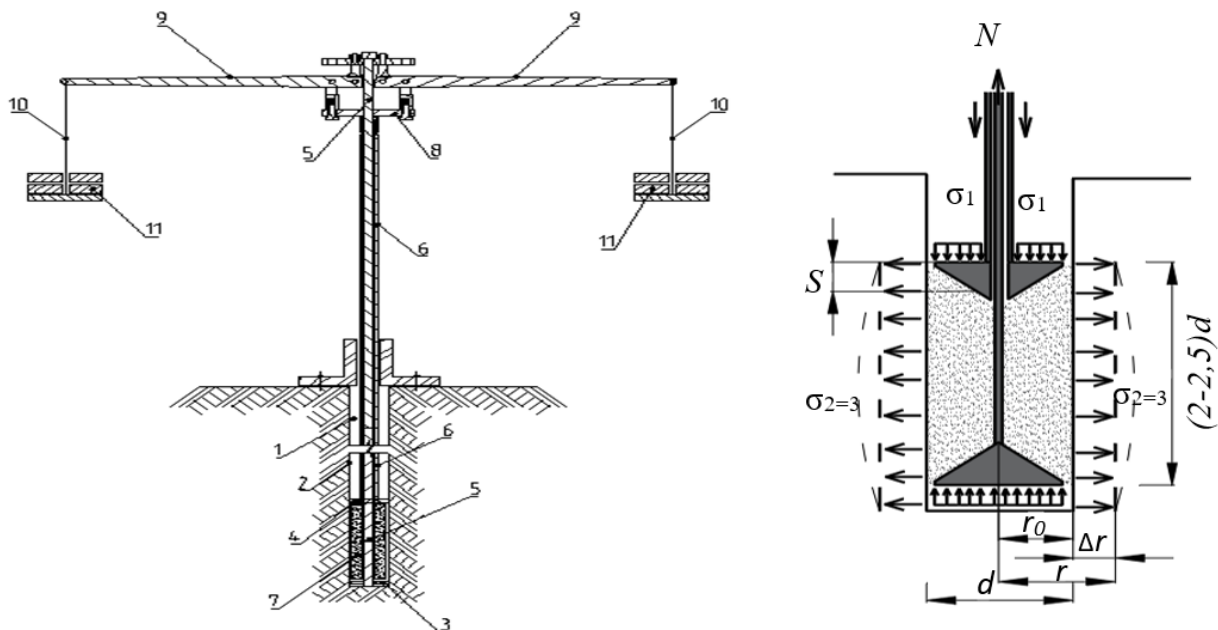

Fig. 1. Devices for determining soil deformation: 1-borehole; 2- borehole wall; 3-lower plate; 4-upper plate; 5-rod; 6-section pipes (rod); 7-cylinder (sand); 8-stop plate; 9-arms with equal shoulders; 10-pendant; 11-kettlebell.

2. Experimental bench studies of the operation of a sand cylinder inside a borehole and determination of the SDS around it.

To simulate the strengthened state of an axisymmetrically compressed cylinder and soil located around it, we performed laboratory bench tests. The main purpose of the tests is to study the vertical and horizontal displacements of the soil of the working body of the sand pressiometer in the form of a cylinder. Previously, such studies with sands were carried out on triaxial compression devices using stabilometers [20]. The results of such tests and devices are given in [17,20,21].

In this work, the object of study is a soil layer filled into the borehole in the form of a cylinder with dimensions: diameter 76 mm, height 150 mm. This

soil is the working body of the sand pressiometer to determine the deformation characteristics of the soil layers in depth. Fine-grained sands are accepted as the soil of the working body of the pressiometer. The following are experimental results.

Results of model bench experiments with a sand pressiometer. Ways to solve the task are carried out using the volumetric tray, which allows you to simulate the interaction of structures and soil base under various external loads. The volumetric tray with dimensions AxBxH = 45x45x30 cm^3 is made in the form of a box-like structure and a loaded frame. The bench is designed for model, plate and pressiometric tests of various configurations. A general view of the bench is shown in (Fig. 2). The results of the experiments are shown in (Table No. 1) and in the form of graphs are presented in (Fig. 3-4).
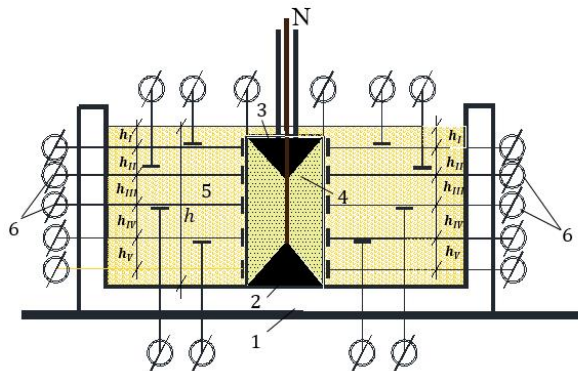

Fig-2. Bench scheme of indicators for measuring displacements, general view of the bech of measuring equipment: 1-volume tray with dimensions AxBxH = 45x45x30 cm^3; 2-lower plate of the pressiometer; 3-upper plate of the pressiometer; 4-tared finely grained sand; 5 - coarse sand; 6-masses; h_I-V-horizontally directed indicators.

Table No.1. The results of experiments of vertical and horizontal movements

Vertical movement of the plate, mm				Lateral (horizontal) movements, mm. The distance from the bottom is 10, 37, 69, 102, 132 mm.				
N, kg	A	P	$S_{ш}$	h-10	h-3,7	h-6,9	h-10,2	h-13,2
0	43,07	0	0	0	0	0	0	0
19	43,07	0,44	5	0,015	0,025	0,115	0,195	0,35
29	43,07	0,67	16	0,015	0,04	0,185	0,255	0,41
39	43,07	0,90	30	0,03	0,29	0,445	0,615	0,675
49	43,07	1,14	71	0,06	0,38	0,935	1,155	0,99
59	43,07	1,37	119	0,11	0,785	1,565	1,775	1,235
69	43,07	1,60	181	0,14	1,365	2,415	2,515	1,365
79	43,07	1,83	284	0,155	2,43	4,045	3,8	2,35
89	43,07	2,06	410	0,155	3,9	6,93	5,375	2,38

To measure horizontal displacements in the radial direction along the outer surface of the sand cylinder in height (h_I =10 mm, h_{II} = 37 mm, h_{III} = 69 mm, h_{IV} = 102 mm, h_V = 132 mm), special indicators were installed (Fig-2). The movements of the indicators are measured by the mass. The dependences between axial stresses and their radial movements are presented in (Fig. 3). During axial loading, the central part of the cylinder expands more dynamically than its edge parts.
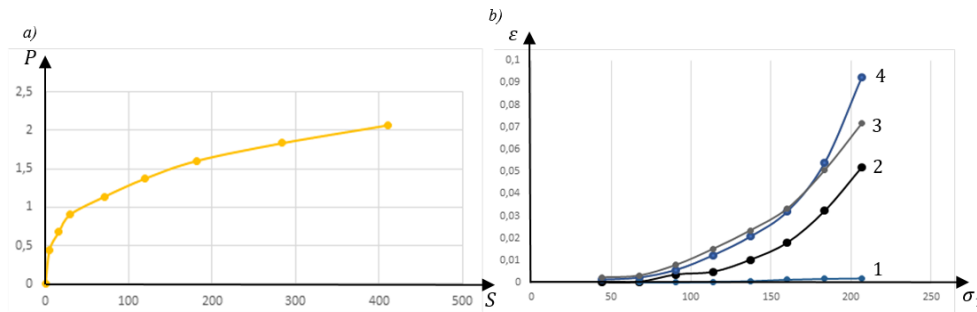
Fig.3.a) Vertical movement of the plate, mm; b) Lateral (horizontal) movements from the distance of the indicators from below; 1) indicator No. 1-10 mm, 2) indicator No. 2-37 mm, 3) indicator No. 3-102 mm, 4) indicator No. 4-69 mm.

The same is observed when conducting triaxial stabilometric tests. The graph of the relationship between the relative lateral strains and the axial pressure $\varepsilon_{2=3} = f(\sigma_1)$ for different points is shown in (Fig. 4). As can be seen from the graphs, the nonlinearity and their absolute displacements in the vertical direction occur more intensively than for lateral displacements.

$$E = n[1 - 2\xi\mu]\frac{\sigma_1}{\varepsilon_1} = k\frac{\sigma_1}{\varepsilon_1}.$$
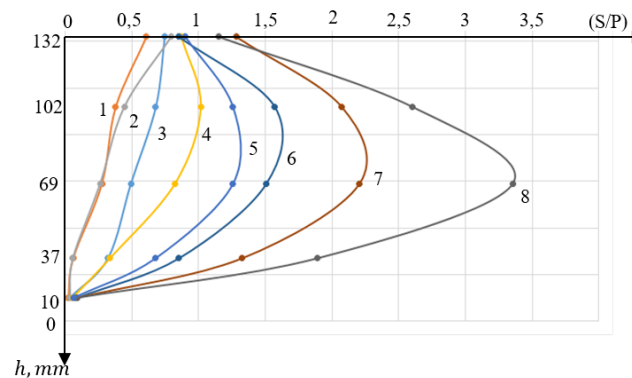

Fig. 4. Schedule lateral movements of beacons, installed on the height of the sand cylinder. The values of points 1-8 for deformation are presented in table No.1.

3. Experimental studies of the sand pressiometer in real engineering and geological conditions and comparing them with the results of plate testing and other methods.

Consider the basic equations that mathematically relate the radial stresses and strains characteristic of radial pressiometers. Given the theoretical solutions discussed above in the coordinate system, the expressions of the cylindrical deformation will have the following form:

$$\varepsilon_x = \frac{\Delta r}{r_0} = \mu\varepsilon_z = \mu\frac{\Delta S}{h_0}, \quad (1)$$

where

$$\Delta r = \mu r_0 \frac{\Delta S}{h_0}; \quad (2)$$

$$\sigma_3 = \xi\sigma_1. \quad (3)$$

The parameters, lateral expansion coefficients, and pressure μ, ξ for medium or fine sands are determined by the results of triaxial stabilometric tests in laboratory conditions with limited lateral displacements. In these expressions, ΔS_z is the measured vertical displacement of the sand cylinder during compression, mm; $\sigma_1 = \frac{N}{A}$ is the vertical stress at the ends of the sand cylinder, kPa; N and A - respectively, the vertical load, kN and the area of the dies, minus the transverse area of the vertical inner rod, sm².

The soil deformation modulus is determined for the linear plot of the graph $\Delta r = f(p)$ by the formula:

$$E = \frac{(1+\mu)r_0 \Delta p}{\Delta r} \quad (4)$$

or in accordance with [20]

$$E = K_r r_o \frac{\Delta p}{\Delta r}, \quad (5)$$

where, K_r - correction factor; r_o - initial radius of the borehole, sm; Δp - pressure increment on the borehole wall, MPa; Δr - increment of displacement of the borehole wall (along the radius), see.

As a rule, pressure increments are determined in the second deformation zone when the initial pressure exceeds the natural pressure $P > Pg$.

The value of the coefficient K_r for a particular type of soil is determined by comparative plate and pressiometric tests. In the absence of such capabilities, it is determined in accordance with the requirements of GOST [1]. In particular, according to our studies, it was found that the correlation coefficient K_r for boreholes up to 6 m deep for clay soils: at $I_L < 0.25$; $K_r = 2$, and at $I_L > 0.5$; $K_r = 3$.

For the proposed type of pressiometer, the deformation modulus is determined by the expression:

$$\varepsilon_x = \frac{\Delta r}{r_0} = \frac{\sigma_x}{E} - \frac{\mu}{E}(\sigma_y + \sigma_z). \qquad (6)$$

$$\varepsilon_x = \frac{\Delta r}{r_0} = \frac{1-\mu}{E}\sigma_{x=y} - \frac{\mu}{E}\sigma_z = \frac{\sigma_z}{E}[(1-\mu)\xi - \mu]. \quad (7)$$

$$E = \frac{r_0\,\sigma_z}{\Delta r}[(1-\mu)\xi - \mu]. \qquad (8)$$

In view of (6) and (7) we write in the following form:

$$E = \frac{r_0\,\sigma_z}{\mu r_0 \frac{\Delta S}{h_0}}[(1-\mu)\xi - \mu] = \frac{h_0\sigma_z}{\Delta S}\left[\left(\frac{1}{\mu}-1\right)\xi - 1\right] =$$

$$K_r^S \frac{h_0\sigma_z}{\Delta S}, \qquad (9)$$

where K_r^S - correction factor for the proposed pressiometer. To solve practical tasks, the coefficient K_r^S is determined by the comparative results of stamping and pressiometric tests.

To reduce the error of the device due to compression of sand, at the beginning of the experiment, instead of a borehole, a metal pipe with a diameter of 76 mm was used. Based on the results of these experiments, a calibration curve is constructed for the S_z draft versus stresses - P. The sand cylinder draft is determined taking into account the calibration curve graph (Fig. 5):

$$\Delta S = (S_2 - S_{t2}) - (S_1 - S_{t1}), \qquad (10)$$

where S_2, S_1 -is the vertical sediment of the sand cylinder inside the borehole corresponding to the stress P_2, P_1; S_{t2}, S_{t1} is the same as determined by the calibration curve inside the metal pipes.
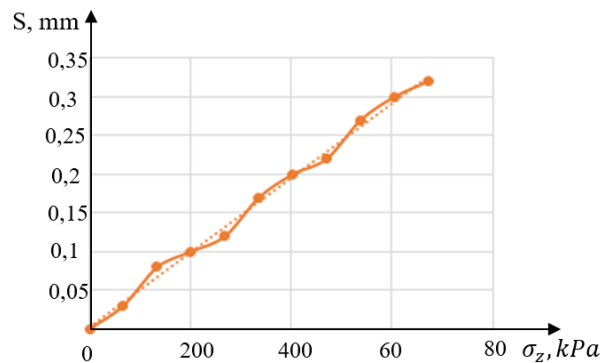

Fig.5. Calibration graph of the upset S versus axial pressure σ_z.

4. Conclusion:

1. Experimentally obtained graphs of the relationship between the axial and lateral deformations of the sandy soil inside the borehole during its axisymmetric loading.

2. Based on the experiments, an analytical expression of the lateral stress coefficient is obtained in the absence of restrictions on the movement of the borehole wall.

3. It is proved that with the help of a sand pressiometer designed by GEOFUNDAMENTPROEKT LLC, it is possible, with practical accuracy, in in-situ conditions, to determine the value of the soil deformation modulus (1)-(10).

References:

1. (2012). GOST 20276-2012. In-situ methods for determining the characteristics of strength and deformability.
2. Bugrov, A. K. (1984). *Field methods for determining the characteristics of soils*: textbook. (p.43). L.: Publishing house LPI.
3. (2000). ENV 1997-2:2000. Eurocode 7. Geotechnical design. Part 2. Design assisted by laboratory testing. UK: British Standards Institution.
4. (2000). ENV 1997-3:2000. Eurocode 7. Geotechnical design. Part 3. Design assisted by field testing. UK: British Standards Institution.

5. (2009). EN ISO 22476-8: Geotechnical investigation and testing. Field testing. European Union, 2005–2009. p.18.

6. Trofimenkov, Yu. G., &Vorobkov, L. N. (1981). *Field methods for studying the building properties of soils*. (p.215). Moscow: Stroyizdat.

7. Denisov, V.N., & Mineev, L. N. (1978). Automated pressiometer for soil research. *Foundations, foundations and soil mechanics,* No. 4, pp. 16–18.

8. Menard, L. (1957). Mesures in situ des proprietes physique des sols / *Annales des Fonts et Chaussees*, V. 127, pp.357–377.

9. Baguelin, F., Jezequel, J. F., & Shields, D. H. (1978). The pressuremeter and foundation engineering // *Trans Tech Publications,* V. 2, № 4, p.617. http://www.cambridge-insitu.com/specs/Instruments/CPM.html.

10. (2001). GOST 19912-2001. Soils. Field test methods by static and dynamic sounding. Moscow: Gosstroy RF.

11. (2010). Engineering survey November. Testing of soils by the methods of penetration. Part I. Boldyrev G.G. Professor of the Department of Foundations and Foundations of the Penza State University of Architecture and Construction, member of the Russian National Committee for Soil Mechanics and Foundation Engineering, Technical Director of NPP Geotek LLC, Penza, g-boldyrev@geoteck.ru.

12. Boldyrev, G. G., & Khryanina, O. V. (2012). Methods of field tests of soils. Part VI. *Engineering surveys* 3/2012, pp. 46-55.

13. (1999). ASTM D1586-99 Standard test method for penetration test and split-barrel sampling of soils. Philadelphia, USA: American Society for Testing and Materials.

14. Khasanov, A. Z., & Khasanov, Z. A. (2006). Foundations and foundations on loess subsidence soils. (p.154). Tashkent. IPD "Uzbekistan".

15. Ziangirov, R. S., & Koshelev, A. G. (2010). Determination of the deformation modulus of soils by the method of loading a stamp // *Engineering research*, No. 2, pp. 26–31.

16. (2017). GOST ISO 22476-4-2017. Test by Menard pressiometer. (ISO 22476-4: 2012, Geotechnical investigation and testing - Field testing - Part 4: Mdnard pressuremeter test, IDT). Moscow Standartinform 2018.

17. Ukhov, S.B. (2004). *Soil mechanics, foundations and foundations*. Higher School Moscow.

18. Mavlyanov, G. A. (1958). "*Genetic types of loess and loess-like rocks of the Central and Southern parts of Central Asia"*. Publishing house of the Academy of Sciences of the UzSSR. (p.609). Tashkent.

19. Glushkov, G. S., & Sindeev, V. A. (1965). *"A course of materials resistance",* (pp.538-542). Moscow: publishing house "Higher school".

20. Khasanov, A. Z., & Khasanov, Z.A. (2015). *Experimental and theoretical studies of the strength and stability of soils*. (p.126). Samarkand: GP publishing house "Zarafshon".

21. Khasanov, A. Z., & Khasanov, Z. A. (2018). *Engineer geology wa gruntlar mekhaniki.* (p.200). Samarkand: IPTD "Zarafshon".