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DETERMINATION OF CLAY SOIL CREEPAGE CHARACTERISTICS

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Results of laboratory researches of clay soil creepage according to regulations of N.N. Maslov's physicotechnical theory are stated. Tests were conducted at constant speed of deformation and continuous registration of vertical and horizontal deformations and pressure. Dependence of durability and creepage parameters from duration of preliminary condensation is established.

Research in creepage, long durability of clay soils is of exclusive value for designing various constructions. To describe the properties of clay soil flow various methods based on mechanical models, on the theory of hereditary creepage, the physicotechnical theory of creepage, the theory of plastic current, the molecular theory of current which are in details stated in S.S. Vyalov's book are applied [1]. As a result, all these theories lead to various equations of condition containing some parameters that are subject to experimental determination. Determination of flow parameters demands, on the one hand, complex equipment and technique of laboratory and field tests, and on the other – calculation of the intense-deformed condition of soil massif in time by computer numerical methods. The experiments conducted by K. Tertsagi, S.S. Vyalov, M.N. Goldstein, N.N. Maslov, G.I. Ter-Stepanyan, V.A. Florin, N.A. Tsytovich, S.R. Meschyan, Z.G. Ner-Martirosyan, U.K. Zaretsky, et al, showed that creepage of clay soils occurs both at volumetric deformations and deformations of form change (shift), often proceeding together [1, 2]. Dependence on pressure, deformation and time (the condition equation) of clay soils is nonlinear. The process of soil deformation in time depends on the content of clay fractions, mineral hydrophility, soil density and humidity, drainage conditions, as well as on the value of operating normal and tangent pressures, and also duration of shifting loading action, temperature, means and mode of load application [3–6].

The purpose of the present research is to establish the influence of duration of condensing loadings on parameters of durability and creepage.

To determine these parameters the devices of one-plane section of Wille-Geotechnik Company (Fig. 1) were used. The device provides one-dimensional condensation of the sample vertically. Horizontal and vertical movements are fixed by digital indicators with the accuracy of 0,001 mm. The distinctive feature of this device is pressure and deformation digital registration and storage of these data in a computer.

The tests were conducted on clay samples of clay for the dam body near Galdensleben (Germany). The basic parameters of granulometric composition, condition and physical properties of soil are presented in Table 1.

In accordance with GOST 25100-95 – heavy soft-flexibility clay, by the Kazagrande classification -high-flexibility clay (Fig. 2).

Table 1. *Main characteristics of clay*

Parameter name	Value
Natural humidity, %	43,2
Density, g/sm^3	1,780
Density of oil particles, g/sm^3	2,713
Porosity, д.ед.	0,53
Porosity coefficient, д.ед.	1,12
Degree of water-saturation, д.ед.	0,95
Top limit of plasticity, %	68,1
Bottom limit of plasticity, %	19,5
Number of plasticity, %	48,6
Condensation parameter, д.ед.	0,51
Content of clay fraction, %	62,3
Content of dusty fraction, %	25,5
Content of sand fraction, %	12,2

Three series of tests were conducted, at that variable magnitudes were the size of normal loading and time of its action. For error estimation the series of test were conducted parallelly at three installations.

The samples of identical density 1,75 g/sm^3 and humidity 43,2 % were prepared for the tests. The identical density was provided by constant mass of the ring 244,5 g with ring area 70 sm^2 and height 20 mm. Constant humidity was provided by accommodation of tests in special premise at constant temperature of 20 °C and air relative humidity of 100 %.

The tests were conducted under the scheme «consolidated-drainage section». The value of vertical loadings was taken as 100, 200, 400 kH/m^2, the speed loading application was set equal to 10 kH/m^2 per minute and was maintained then for 2880, 4320 and 8640 minutes. After condensation, without unloading the device, the shift was conducted.

The section was carried out at a constant section speed in time $\dot{\gamma}$=0,02 mm/min – the so-called kinematic loading at which the tangent loading is applied continuously. The shift proceeded on the average for 12...14 ours up to the maximal value of 15 mm.

Each 10 seconds were registered during the tests: normal σ and tangential τ pressures, magnitude of vertical and horizontal deformations of the sample from enclosed loading influence during condensation as well as shift. The maximal (peak) $\tau_{мах}$ and the residual τ_{rest} tangents of pressure, corners of internal friction φ and cohesion c at maximal and residual tangent pressure we-

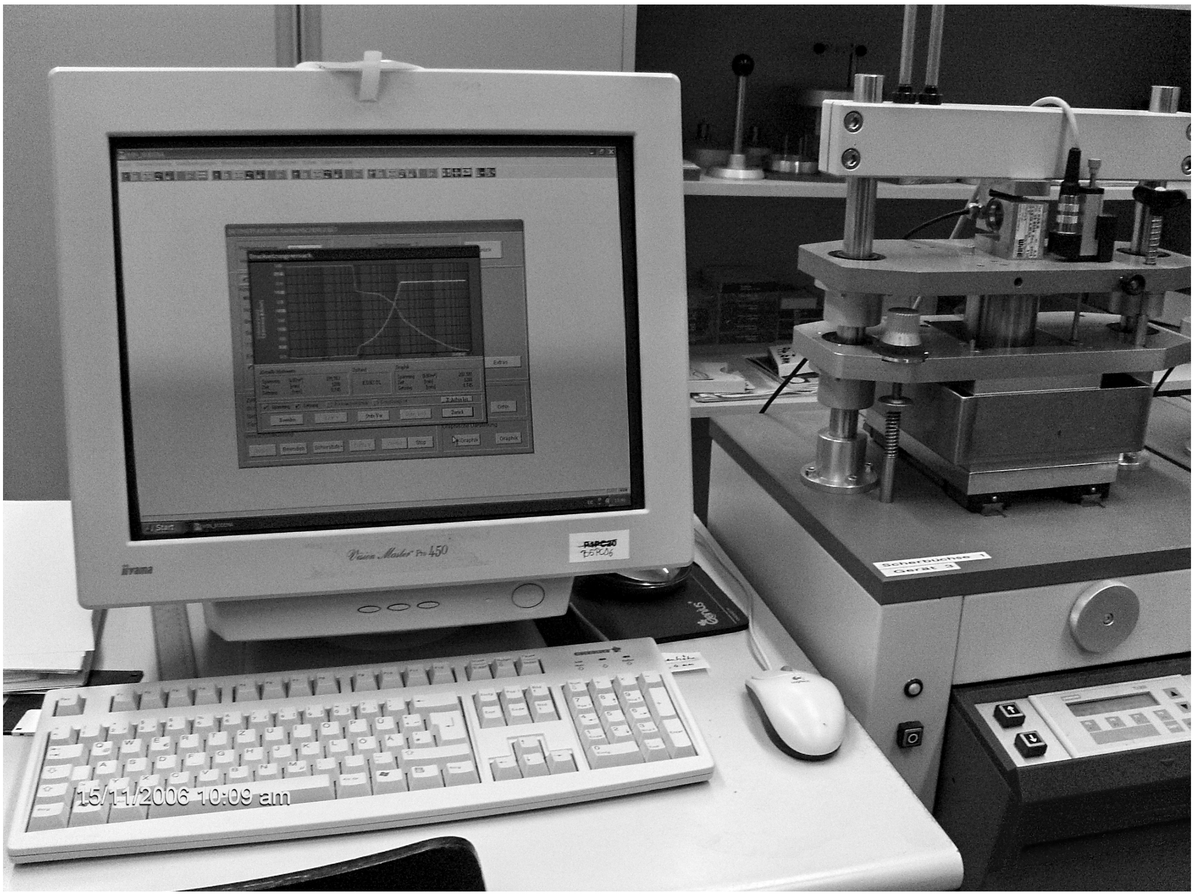

Fig. 1. The device for determination of compressibility and durability parameters made by Wille Geotechnik Company

re defined by the results of the test. The results of soil shift tests are shown in Table 2.

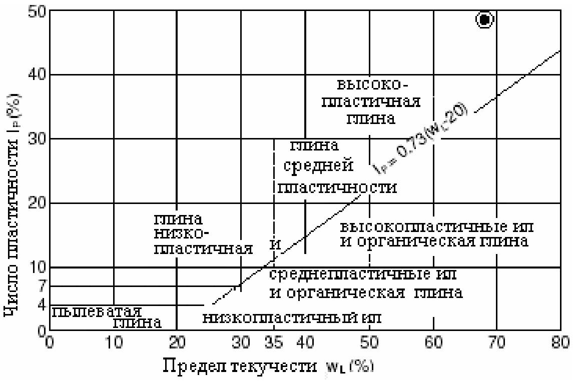

Fig. 2. The Kazagrande graph for soil classification,⦿ – the investigated soil

Explanation to Fig. 2:
Число пластичности – Number of plasticity Высокопластичная глина – High-flexibility clay
Глина средней пластичности – Medium-flexibility clay Глина низкопластичная – Low-flexibility clay
Высокопластичные ил и органическая глина – High-flexibility silt and organic clay
Среднепластичные ил и органическая глина – Medium-flexibility silt and organic clay
Пылеватая глина – Dusty clay Низкопластичный ил – Low-flexibility silt

The dependence of tangents pressure value on value and duration of normal pressure is precisely stated by results of the shift test. The increment of tangent pressure makes up 30...35 % at doubling of the enclosed normal pressures. The increase in duration of condensing loadings influence gives an increment of the maximal tangential pressure on 1,15...1,4 %.

Table 2. *Average values of oil shift tests results*

Condensation time, t, min	Angle of internal friction, φ_{max}	Cohesion c_{max}, kH/m^2	Angle of internal friction, φ_{rest}	Cohe sion, c_{rest}, kH/m^2	Normal exertion, σ kH/m^2	Maxi mal tangen tial exertion, τ_{Max}, kH/m^2	Residualexertion, τ_{rest}, kH/m^2	Vertical deformation at shift, s_2, mm	Full sedimentation at shift, S_{rest}, mm	Sedimentation at condensation, s_1, mm
2880	14,54	16,73	11,82	15,91	100	42,28	36,85	0,16	0,31	2,11
					200	70,14	57,76	0,23	0,41	3,79
					400	122,71	99,71	0,25	0,38	5,06
4320	13,97	19,4	11,14	16,87	100	42,80	35,94	0,12	0,29	2,51
					200	70,54	57,20	0,17	0,36	3,30
					400	124,15	95,31	0,20	0,37	5,01
8640	13,88	19,7	11,54	17,87	100	43,17	36,24	0,16	0,28	1,32
					200	71,48	58,13	0,20	0,33	2,02
					400	127,48	100,3	0,23	0,37	5,11

After shift completion the humidity from the shift zone was defined. With increase of applied loading by 100 kH/m^2 oil humidity decreased respectively by 4,2...4,6 % (Fig. 3).

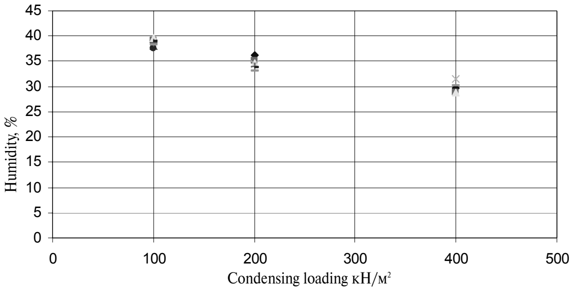

Fig. 3. *Sample humidity change after the shift*

Determination of flow parameters was performed by the Maslov's technique [2, 5]. Schedules of soil horizontal deformation dependence from time $\lambda=f(t)$ and growth of shearing effort τ in time were constructed based on test results. Under schedules of dependence $\tau=f(t)$ The threshold of creepage $\tau_{\lim}$ as well as crossing of tangents to two curve sites (Fig. 4) was defined based on dependencies graph $\tau=f(t)$. The analysis of the constructed graphs showed that with increase of sample preliminary condensation time the interval of time before sample destruction $t_{кр}$ under action of tangent pressures increases, thus the difference $\tau_{\max}-\tau_{\lim}$ (Table 3) also decreases. The threshold of creepage comes to the maximal tangential pressure with time increase of the preliminary condensation.

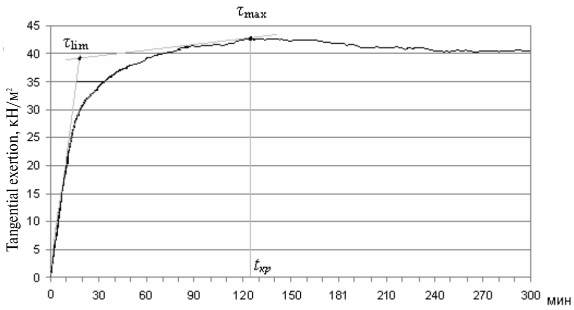

Fig. 4. *Determination of creepage threshold*

The intensity of creepage process is estimated by coefficient of dynamic viscosity η calculated by N.N. Maslov's formula [2. P. 138]:

$$\eta = \frac{\tau_{\max} - \tau_{\lim}}{\dot{\gamma}} d,$$

where $\tau_{\max}$ is the maximal (peak) tangential pressure at shift; $\tau_{\lim}$ is the creepage threshold, $\dot{\gamma}$ is the deformation speed of sample shift equal to 0,02 mm/min; d is the height of the sample before shift, mm. Results of creepage parameters determination are presented in Table 3.

Table 3. *Parameters of soil creepage*

Time of preliminary condensation, min	Normal pressure, kH/m^2	Durability threshold at shift, $\tau_{\max}$, кН/m^2	Creepage threshold, $\tau_{\lim}$, кН/m^2	Dynamic viscosity coefficient, Pa·s	Shift deformation, λ, mm	Time before sample destruction, $t_{кр}$, min
2880	100	42,28	38,18	$2{,}22\cdot10^8$	2,64	124
	200	70,14	62,5	$3{,}75\cdot10^8$	3,33	166
	400	122,71	117,5	$2{,}35\cdot10^8$	4,31	215
4320	100	42,80	38,5	$2{,}28\cdot10^8$	2,77	138
	200	70,54	67,3	$1{,}64\cdot10^8$	3,57	178
	400	124,15	118,4	$2{,}61\cdot10^8$	4,76	238
8640	100	43,17	41,8	$7{,}76\cdot10^7$	3,31	169
	200	71,48	71,1	$2{,}07\cdot10^7$	4,51	225
	400	127,48	126,6	$3{,}65\cdot10^7$	5,77	288

Vertical soil deformations at shift, so-called dilatancy is the phenomenon of material volume change caused by shift deformations, discovered in 1885 by O. Reynolds, was noticed at soil test by sensors.

Thus, the obtained results of experimental researches showed that duration of condensing loading action before section renders essential influence on structure and properties of clays being reflected in parameters of durability and creepage. These results represented practical interest at forecast of land-slide deformations and also at horizontal displacement of the projected dam base.

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