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Strength properties of peat in Tungol Field (Tomsk Oblast)

V V Kramarenko [1], A V Kolesnikova [1], I A Lappo [2] and I A Matveenko[1]
[1] Tomsk Polytechnic University, Tomsk, Russia
[2] Tomsk subsidiary of Avers, Tomsk, Russia

E-mail: mia2046@yandex.ru

Abstract. The article is devoted to the study of non-drained peat strength in the site of Tungol oil field determined by the core sampling with the help of impeller. The authors present the research results in peat composition, physical, and strength characteristics, changes in properties with depth, revealed relationships between the indicators, the regression equation obtained on their basis for prediction of composition and characteristics. Based on the cluster analysis including all studied indicators the peat classification is performed, three main classes are distinguished, typical values of characteristics as well as recommendations for using peat of every class as construction foundation and corresponding load bearing capacity are given.

1. Introduction

Data on structural behavior of peat soil is applied in calculation of deposit carrying capacity and vehicle flotation at arranging deposit facilities, in this context the relevance of the research in this field is doubtless.

The study of peat shear strength characteristics and peaty soil was carried out in works by L.S. Amaryan, E.T. Bazin, Kosovo V.I., N.N. Morareskul, V.N. Bronin, P.A.Konovalov, G.V. Sorokina as well as Golebiewska A., Kanmuri, H., Kato, M., Suzuki O., Hirose, E., Landva, A.O, Ogino, T., Oikawa, H., Tsushima, M., Mitachi, T , Miyakawa, I, Radforth, J. , Sodha V.G., Helenelund K.V. [1, 4, 8-11, 14]. Great contribution to the research of peat in Western Siberia was made by M.K. Baryshnikov, M.I. Neishtadt, G.Ya. Bronzova, S.N. Tyuremnov, V.M. Yeliseyev and other scholars.

The peculiarities of Western Siberian peat have stipulated the development of regional classifications in botanical composition. Distinguishing new species in botanical classifications is explained by their heritable resistance, geographic and geomorphologic location, and peat qualitative features. Such attempts were made for both definite regions and the entire territory of Western Siberia.

Wetland zoning in Western Siberia for different purposes was performed by S.N. Tyuremnov, N.Ya. Katz, M.I. Neishtadt, M.F. Loginov, L.V. Shumilov, O.L. Liss, N.A. Berezina, G.G. Kulikova, Yu.A. L’vov, Ye.A. Romanova, V.G. Matukhin, L.S. Mikhant’eva, V.M. Altukhov and others.

In Tomsk Oblast the research in vegetation and wetland conditions was made by the workers of Tomsk State University – Yu.A. L’vov, Ye.D. Lapshina, V.A. Bazanov.

The research is based on the data obtained in the course of engineering surveys made in Tudol field in 2013 by “Avers 1” Ltd company [12]. The first geological engineering surveys on the investigated site were carried out in 1947-1948 by the Order of the USSR Government on Oil and Gas Exploration as well as Planned Geological Surveys Performance on West Siberian Plain.

In recent years the large-scale geoengineering survey has been performed in order to equip the local construction sites and oil exploration wells, as well as the sites for gathering pipeline construction, etc.

The designed site is located in Alexandrovskoye region, Tomsk Oblast, 145 km eastward from the regional center – Alexandrovskoye settlement.

The regional climate is sharply continental, with long cold winters, late spring and early autumn. The maximum precipitation (75%) occurs in April-October (436 mm), the minimum – in February. Some days nearly month precipitation can fall down. The maximum one-day rainfall takes place in warm season and can reach 62 mm. Taking into account the average monthly negative temperature in the area of Alexandrovskoye meteorological station the calculated specified depth of seasonal peat freezing is 0.75 m.

The site is located in the central part of West Siberian Plain, which is a large platform composed of Paleozoic folded basement formations. Basement formations are overlaid with sedimentary mantle of Mesozoic-Kainozoic deposition. The upper part of the section is made up of Middle Quaternary lacustrine and alluvial deposit of Suzgunskaya Suite (laQIIsz) and modern cap biogenic formations (bQH). According to the previous data, the thickness of Suzgunskaya Suite on the explored area can reach 28 m.

The geomorphologic and lithologic conditions enable interception and swamp formation on the plain interfluve area (figure 1).

Figure 1. Water saturation of territory Tungol field

Therefore, the explored area type is referred to watershed raised moor with specific vegetation: sphagnum moss, dwarf birch, ledum (figure 2). In terms of botanic-geographic zoning vegetation corresponds to the subzone of Middle taiga of Western Siberia. The prevailing vegetation type is mixed forest and peatland.

Among the natural processes on the investigated area, the most dangerous are high rate of water-logging process, peatland microrelief transformation as a result of peat formation, forest and peat fires.

Figure 2. Typical vegetation on the area of well #5, Tungol field

The area is located within the Irtysh-Yenisei hydrogeologic basin. The bog water breaks up just under frozen layer. The occurrence depth is less than 3 m. Hemic and sapric peats are water bearing. The thickness of boggy deposits within the area can reach 1.0-4.0 m, that of the access road is 2.0-6.4 m. Peat is mainly sphagnum, grass-moss with grass inclusions (mostly sedge), without and with wooden culls up to 5-10% including sunken trunks.

2. Methods

Work was carried out in accordance with the methods provided in existing regulatory standards [5, 6, 7]. Peats were sampled from 16 wells, the grain size was determined, the density (ρ), the density of the solids (ρ_s), the density of the dry soil (ρ_d), water content (w), Atterberg limits for clay soils (w_L and w_p); the parameters of the state, such as the void ratio (e), porosity, saturated limit, plasticity limit and consistency index for clay soils, ash content (D_{as}) and the degree of decomposition were obtained by the gravimetric method (D_{dp}) for peat.

Field tests for determination of undrained shear strength for soil with natural (c_u) and disturbed structure (c_{ud}), as well as sensitivity ($S=c_u/c_{ud}$) were carried out by soil using vane shear test, according to [5, 7; analogues 2, 3]. The field soil test was performed by shear-meter impeller (figure 3).

Figure 3. The general view of the impeller

3. Results and discussion

According to the field description and laboratory data, there distinguished 2 kinds of peat presenting different engineering-geologic features (table 1).

Table 1. Characteristics of Engineering-geologic Features.

1 kind	Hemic, medium-ash peat. Light-brown, brown color, with wooden inclusions. Thickness is up to 3.3 m.
2 kind	Sapric, medium-ash peat. Brown, dark-brown color, with wooden inclusions. Thickness is up to 6.4 m.

In the course of peat laboratory research its physical features (density, water content) as well as ash content, decomposition degree, botanical composition have been determined. The data obtained were classified and processed with Statistica software, the correlation analysis for all indicators was made (table 2), as a result of which the maximum dependence factors were stated.

Table 2. Correlation coefficients.

	Depth, h	Undrened strength , c_u	Undrained strength (disturbed), c_{ud}	Sensiviy S	Water content, w	Ash content D_{as}
Undrened strength , c_u	0,32	1,00				
Undrained strength (disturbed), c_{ud}	0,11	0,89	1,00			
Sensitivity, S	-0,59	-0,07	0,35	1,00		
Water content, w	-0,83	-0,51	-0,20	0,48	1,00	
Ash content, D_{as}	0,04	-0,28	0,24	0,76	0,08	1,00
Degree of decomposition, D_{dp}	0,44	0,18	-0,07	-0,55	-0,26	-0,71

The degree of peat decomposition increases with depth (r=0,44), this is due to the composition of sediments, age, and its drainage during formation, which promotes decomposition. The sphagnum peat has the maximum decomposition degree. It is explained by the release of organic acids by sphagnum mosses and presence of sphagnole (phenol-based glycoside) that condition their biochemical stability having a bactericide effect and retaining the remains of bog plants. The negative correlation coefficient shows that decomposition degree decreases with water content growth, which is a typical dependence for sphagnum mosses.

The results of the correlation analysis showed that the water content decreases with depth, which is also determined by the presence of sphagnum moss in the upper section. Since natural peat density varies from 1.0 to 1.09 g/cm3, the relations turned out to be insignificant. The closest correlations were established between c_{ud} and c_u (table 2).

The ash content of peat does not basically exceed 5%, only several samples have increased the value of that parameter more than 20%. For sphagnum peat types the minimal values of ash content is typical that grows with the rise in water content.

Correlation analysis has shown that decomposition degree decreases with increasing density, since minimal density is typical for grass-moss peat type. Peat decomposition rate grows with depth that is connected with drainage contributing to decomposition.

Undrained shear strength grows with increase in density and occurrence depth in natural state. The value of sensitivity factor decreases with depth, therefore, the strongest peat occurs at the surface as it is less decomposed. For upland bogs a rather strong layer – peat top spit – is typical, which presents a surface vegetation cover of living and dead mosses and grass forming a springing floor of bog tree and bush roots unaffected by peat formation and comparatively easily separated from lower peat layer.

As a result the closest relationship among the properties of the following characteristics was revealed, which can be used for similar peat deposits:

c_{ud}= 0,006ln(c_u) + 0,037 (r^2= 0,82),
c_u = -0,00ln(w) + 0,069 (r^2 = 0,26),
S = -0,10ln(h) + 0,697 (r^2= 0, 28),
w= 1053 $h^{-0,35}$ (r^2 = 0,64),
ρ = 0,5574$w^{0,0894}$ (r^2 = 0,86),
p= 1,039 $h^{-0,03}$ (r^2 = 0,60),
D_{dp} = 40,73$h^{0,286}$ (r^2 = 0,20),
D_{dp} = 82,72$D_{as}^{-0,42}$ (r^2 = 0,66),
D_{as} = $3,147h^{0,13}$ (r^2 = 0,21).

Cluster analysis allows distinguishing 3 main peat groups based on all revealed features. The groups are characterized in detail, the average, minimal and maximal values are calculated (table 3), the building types and road capacity types are defined in terms of shear stress test and L.S. Amaryan's classification [1], and the conditions of pipelaying are stated according to "The Instruction of Road Design for Oilfield of Western Siberia" [13].

Table 3. Classification of peats of Tudol field.

Characteristics	Group of the peat		
	A	**B**	**C**
Undrened shear strength c_u, MPa	0,007	0,010	0,014
Undrained shear strength for soil with disturbed structure c_{ud}, МПа	0,003	0,007	0,008
Sensiviy S	0,40	0,75	0,57
Water content W, %	853	987	782
Density ρ, g/cm^3	1,01	1,05	1,04
Ash content D_{as}, %	2,35	5,94	12,25
Degree of decomposition D_{dp} %	61,5	52,0	56,5

Summary

According to the results obtained, group A is the least strong. It is referred to the 3-d building type – soil is squeezed off at load transmission due to insufficient strength in natural state and insufficient strengthening at thickening. In terms of pipelaying condition classification the type is characterized in the following way: bogs that are completely filled with baken peat up to mineral bed. Peaty soil is a reliable foundation for pipelines. Trafficability is designed in terms of shear strength test results (undrained strength, $c_{u,}$ kPa). In the present instance the passibilty condition are specific, in which undrained deep peat deposits with ponds and weedy pools are typical. Organic slime is deposited on the bottom of ponds or at the depth of less than 2m. Floating mats are of different thickness. In this condition the passage of tracked drifting transport or arch-tired vehicles is possible. The road is available in winter, but not in warm winter.

Group B is referred to the 2-nd building type – soil not possessing sufficient strength in natural state, but at quick load transmission from banked earth it is squeezed off, whereas at slow load transmission it thickens and hardens to an extend that it is not squeezed, but compacted. In terms of pipelaying conditions it is a bog completely filled up with stable consistency peat up to the mineral bed. Peat can be used as a carrying foundation for pipelines. The passibilty conditions are hard: low-drained and undrained peatland filled up with peat, afforested. Organic slime underlays on the bottom of ponds or at the depth of less than 2 m. Floating mats are of different thickness. The passage of special drifting transport with specific pressure of less than 15 kPa is possible. It is necessary to remove trees before it.

Among the three groups described here, group C is the most stable. It is referred to the 1-st building type: soil possesses sufficient strength in natural state and at load transmission from banked earth it is compressed regardless of load transmission rate. In terms of pipelaying conditions it is a bog completely filled up with stable peat up to mineral bed. Peat can be used as a carrying foundation for pipelines. In terms of passage conditions the group is referred to the average one: previously drained peatland with removed tree stratum, low-drained small deposits of depth less than 1.5 m. The passage of tracked drifting tractors and off-road vehicles as well as arch-tired transport is possible.

Thus, we have characterized the peat strength features of Tungol oil field, revealed the correlations between properties (density, water content, ash content, and decomposition rate) on the basis of which we obtained the regression equations. As a result of cluster analysis their classification was performed. 3 groups were distinguished. The research results can be applied for the peat deposits of similar composition.

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