Mechanical properties of Vendian clays at the site "Lakhta" in St. Petersburg, Russia

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Abstract

Vendian clays are widely spread in St. Petersburg. They are bedded at depth of 20 m and further throughout entire thickness of investigated soils. Investigation of Vendian clays is necessary for St. Petersburg, because these deposits are used as the base of pile foundation. For estimation of mechanical behavior of Vendian clay compression tests with loading in vertical and horizontal directions to the foliation were made. All these tests were accompanied with determination of anisotropy factor, OCR, water content, liquid and plastic limit. It was found that all parameters of mechanical properties differ from each other depending on sampling depth. Samples from greater depth have higher strength, oedometer modulus, anisotropy factor, lower water content. As a rule oedometer modulus in horizontal direction is higher than in vertical. It can be explained by fissile structure of Vendian clay.

Keywords: Vendian clay, fissile structure, mechanical properties, laboratory tests

1 Introduction

In terms of tall building practice, Saint Petersburg is characterized by extremely complex geological engineering conditions, because the surface layers consist of soft soils down to the depth of 20-30 m. However, the rock ground, which are the most desirable bed for high-rise buildings, are located at the depth of more than 200 m, making it unreachable as the base, since capabilities and experience of contemporary industrial technologies is limited by embedding piles down to the depth of 100-120 m, let alone the cost inefficiency of such a foundation. Taking into account the above-listed factors, the solution was made to use the Vendian clays (lying 20-40 m deep) as the base of pile foundation. The basic issue for supporting the piles by Vendian clays is lack of experience of using this kind of ground for high-rise buildings. Vendian clays (Fig. 1) are relatively solid, being the clay and semirocky soil at the same time. In the countries, where this kind of soils is widespread, there is a special term – "mudstone". The Vendian clays relate to Upper Proterozoic deposits of the Vendian system of the Kotlin horizon (Vkt2). Actually, these are not clays, but loams, in essence of solid consistency. The fissile mostly horizontal structure with cemented sandstone inclusions makes these soils rather heterogeneous in its physical and mechanical characteristics.

2 Mechanical properties of Vendian clays

For the estimation of mechanical behavior of Vendian clay field and laboratory tests were made. Due to the fissile structure of soil one of the most important parameter was anisotropy factor. So, compression tests with loading in horizontal and vertical directions to the foliation were made. The importance of the structure and complexity of problems urged drawing quite a number of organizations. The geological engineering searches were commissioned to SU-construction administration -299. Laboratory tests were conducted by laboratory Vedeneev VNIIG and Lomonosov MGU. Pressure metric tests were made by Geodynamic Studies Centre. The research institute Gersevanov NIIOSP provided scientific and technical support for all these investigations. As an employee of the Gersevanov NIIOSP (Moscow), I made laboratory tests of 16 samples taken from the depths of 27 m to 115 m to determine mechanical properties of soils.

Fig. 1: The Fissile structure of Vendian clays.

According to the results of these laboratory tests, oedometer modulus in vertical direction varies from 27 to 545 MPa, oedometer modulus in horizontal direction varies from 27 to 900 MPa, anisotropy factor varies from 0,64 to 4,64, overconsolidation ratio (according to Casagrande) varies from 0,54 to 7,58, water content varies from 0,105 to 0,215, plastic limit varies from 0,170 to 0,040, liquid limit varies from -1,25 to -0,14. Changes in oedometer modulus in vertical direction are shown in Figure 2. According to this graph, E_{oed} increases with the increase of the depth. After approximately one hundred meter depth a drop in oedometer modulus can be observed. This drop is caused by the change of the structure of clays – a water aquifer lies after 100m depth. This water aquifer consists of fractured sandy clays which serve as water-containing soils.

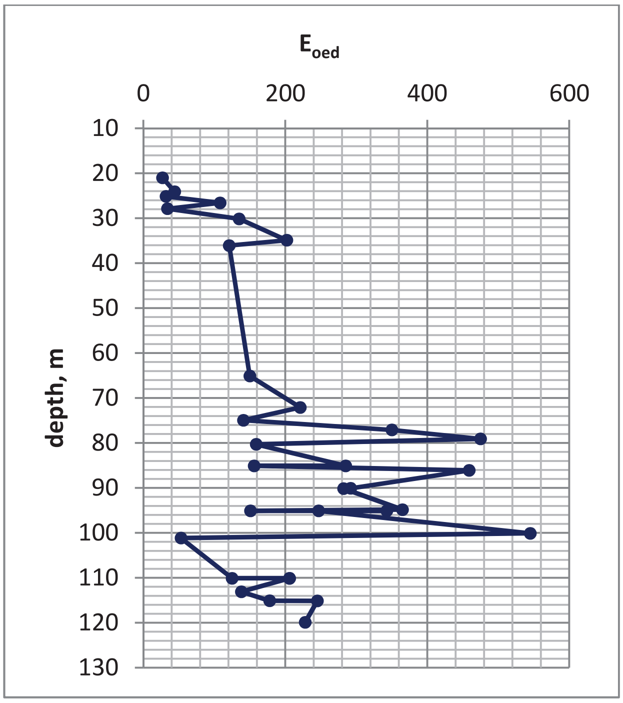

Fig. 2: Changes in oedometer modulus in vertical direction versus the depth

Changes in oedometer modulus in horizontal direction show the same behaviour as in vertical direction (Fig. 3). One can see the increase in values with the increase of the depth. Anisotropy factor also has a tendency to increase with the depth.

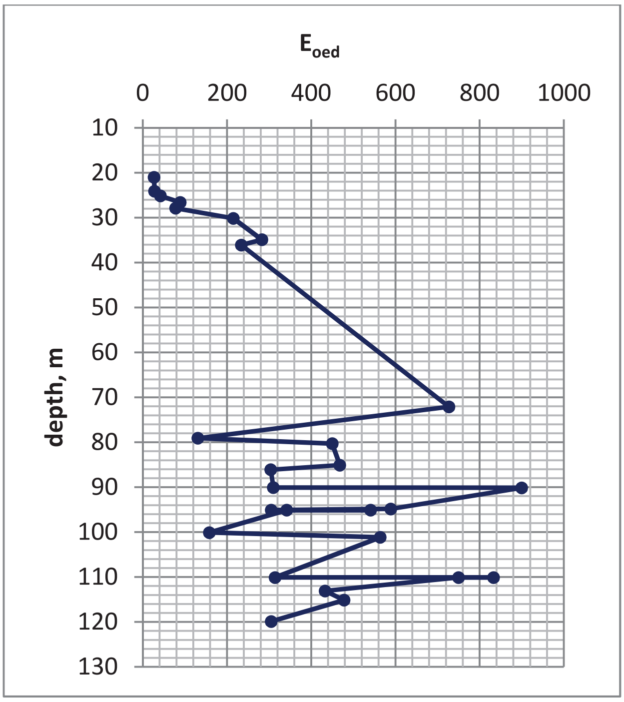

Fig. 3: Changes in oedometer modulus in horisontal direction versus the depth

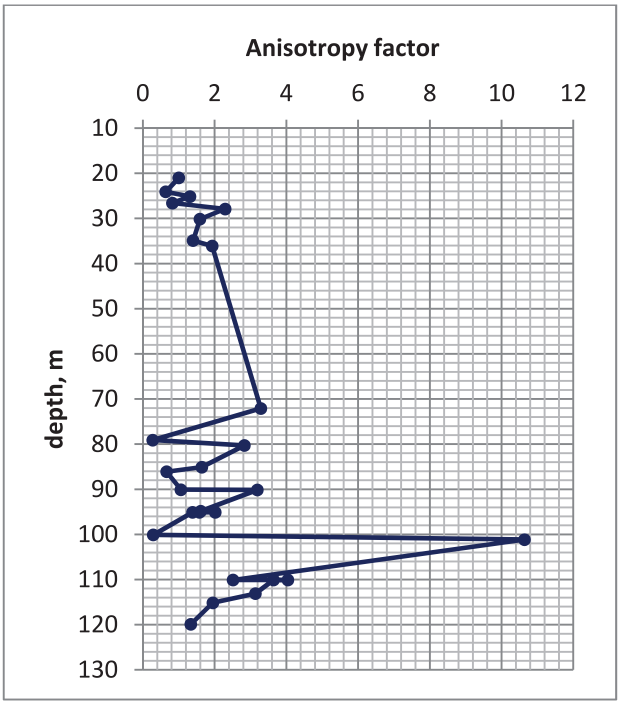

Fig. 4: Changes in anisotropy factor versus the depth

Overconsolidation ratio decreases with the increase of the depth. Soil samples up to approximately 90 m have OCR>1, which corresponds to the stage of overconsolidation. Samples taken from 90 m and deeper have OCR approximately equal to 1 (Fig. 5).

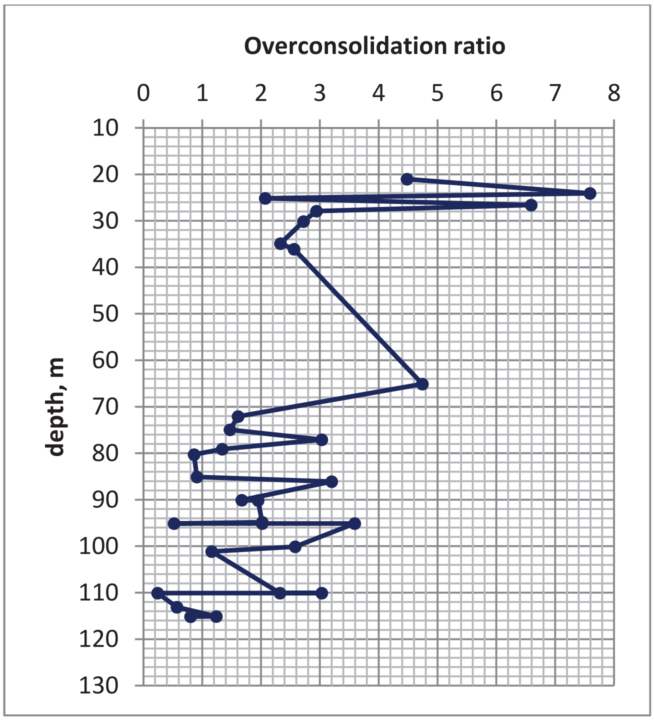

Fig. 5: Changes in OCR versus the depth

Analysis of all these graphs shows that the dependency of different properties on the sampling depth is not gradual. All the observed parameters, i.e., anisotropy factor, E_{oed} in vertical and horizontal directions and in OCR change by leaps and bounds. It can be explained by fissile structure of Vendian clays.

3 Construction of the business center at the site "Lakhta"

All the investigations were made for the building of the Gazprom neft business center in Lakhta, in Primorsky district of Saint Petersburg, at the exit from the city between the Gulf of Finland and Primorskoye highway. The planned height of the building is 476 m; number of floors – 67; the basic load is 330 thousand tons; the diameter of the tower's footprint is approximately 50 meters (Fig. 3a, b). Underground part is also pentagonal and each facet is 56 m long; foundation area is 5700 sq. m. The structural scheme with the central core bearing most of vertical and horizontal loads surrounded by perimeter columns and a few outriggers, which is applied here, is getting even more popular within tall industry. The outriggers are the extra-stiff beams with 2-floor high section, placed at several levels of the elevation to resist horizontal loads. General stability is ensured by the joint three-dimensional work of strong central stem, perimeter columns, floor slabs and outrigger beams. The central stem is the ferroconcrete pipe with 2 m thick walls at the base, which are gradually getting the higher, the thinner. The central stem is partitioned inside with walls and slabs of elevator and stairway shafts, which reinforce the structural strength [PETRUCHIN, V. et al. (2010)].

a) b)

Fig. 3: The society business center: a) The structural scheme; b)the design

4 Conclusion

To sum up, Vendian clays have high strength, but their mechanical and physical parameters are not constant and vary in high ranges depending on the depth. Samples from greater depth have higher strength, oedometer modulus and anisotropy factor and have lower water content. Taking into account all these factors, Vendian clays, being really stiff soils, can be a stable geological basement for a tall building on the one hand, but on the other hand they can be unstable due to their fissile structure.

Literature

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