Pressuremeter Tests in Russia and Their Application

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Abstract

A series of 12 preboring pressuremeter tests were performed for the foundation design of a tall building in St. Petersburg, Russia. The site is on the North shore of the Neva River Delta. The soil layers at the site consist of Quaternary soft saturated soils of marine, glacial-lake origin and hard Vendian clay. The test procedure was the one recommended by the Russian standard which calls for much longer pressure steps than the ASTM Standard. Modulus of deformation and limit pressure profiles were obtained for 24–40 m depth in the Vendian clay. Such pressuremeter test results are often used for the foundation design of tall buildings.

Keywords

Pressuremeter • Modulus • Limit pressure

1 Introduction

A series of 12 preboring pressuremeter tests were performed for the foundation design of a tall building in St. Petersburg, Russia. The site is on the North shore of the Neva River Delta. The soil layers at the site consist of Quaternary soft saturated soils of marine, glacial-lake origin and hard Vendian clay. The test procedure was the one described in the Russian standard which calls for much longer pressure steps than the ASTM Standard. Modulus of deformation and limit pressure profiles were obtained from depth of 24–40 m in the Vendian clay.

2 Background on the Pressuremeter

The idea of the pressuremeter is credited to Louis Menard who, as a student at the Ecole Nationale des Ponts et Chausees, proposed it as part of his graduation report in 1957. The pressuremeter gives an in situ stress strain curve for the material tested (see Fig. 1) from which many useful parameters can be derived including a modulus, a yield pressure, and a limit pressure. Briaud in 1978 developed a simpler version of Menard's pressuremeter now called the TEXAM (see Fig. 2). The TEXAM was the pressuremeter used for the tests reported here. The probe is monocellular and is inflated by forcing water out of a cylinder through a crank powered piston. The probe was inserted in a prebored borehole prepared by wet rotary drilling with injection of prepared drilling mud. The probe can be inflated in equal pressure steps or equal volume steps; the tests reported here were equal pressure steps tests. Each pressure step should be held for one minute according to the ASTM standard (2016) but until no noticeable increase in radius is detected according to the Russian standard (GOST 2012) which was followed for the tests reported here.

3 Site Geology

The two main strata in St. Petersburg (see Fig. 3) are surficial non-lithified saturated sand-with-clay deposits of Quaternary age which are about 400,000 years old underlain by an older lithified clay strata called the Vendian clay which is about 600 million years old. The Vendian clay was considered as the bearing layer for a foundation. The hard clay is found at the depth of 24 m. The Vendian clay is marine sediment. The sedimentation of the clay took place under placid tectonic conditions. The catagenic transformations of the clay were

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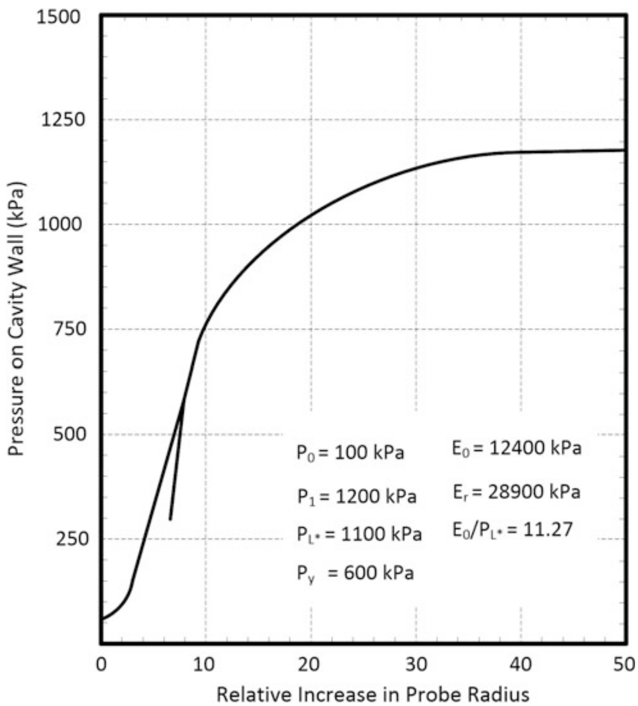

Fig. 1 A pressuremeter curve

influenced by several processes: gravitational consolidation of the deposits through the pressure of overlays; tectonic activity at the junction of the Russian Plate and the Baltic Basement; and change in thermodynamic and physico-chemical conditions (Dashko 2003). The Vendian clay is fissured because of influence of tectonic and non-tectonic factors. The tectonic activity at the junction of the Russian Plate and the Baltic Basement manifests itself through tectonic fissures within the clay that form two main systems of North-Western and North-Eastern course; there also are sublateral and submeridional tectonic fissures. Non-tectonic fissuring is largely typical for the upper zone of the clay section. In the upper zone of the clay regressive lithogenesis, formation of fissures of elastic reaction and of weathering in alternating temperatures and in crystallization of salts took place. In the glacial period the fissures were formed through glaciotectonics (wedges traced to the depth of 20–25 m) and through frost weathering (Dashko 2003).

4 Soil Properties

Research on the Vendian clay done by Dashko (2003) shows that this clay should be considered as block fissured deposits (Dashko 2003). The clay properties are likely to be affected by fissuring and scale effect. Fissures are weaken mostly the strength and deformability of the clay. Table 1 shows features of macrostructure such as a block size of the clay and related water content. The index properties of the Vendian clay obtained at the site are shown in Table 2. The unit weight of solids was measured and averaged 27.0 kN/m^3.

5 Pressuremeter Test Results in St. Petersburg

A series of 12 tests were performed at depth of 25–40 m below the surface. For each test, the pressure and the increase in volume of the probe was recorded. The data

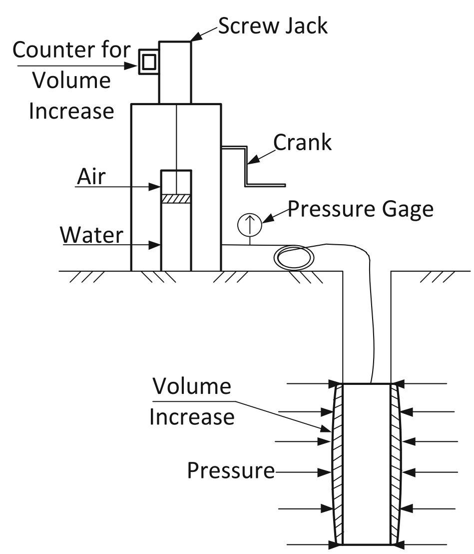

Fig. 2 TEXAM pressuremeter

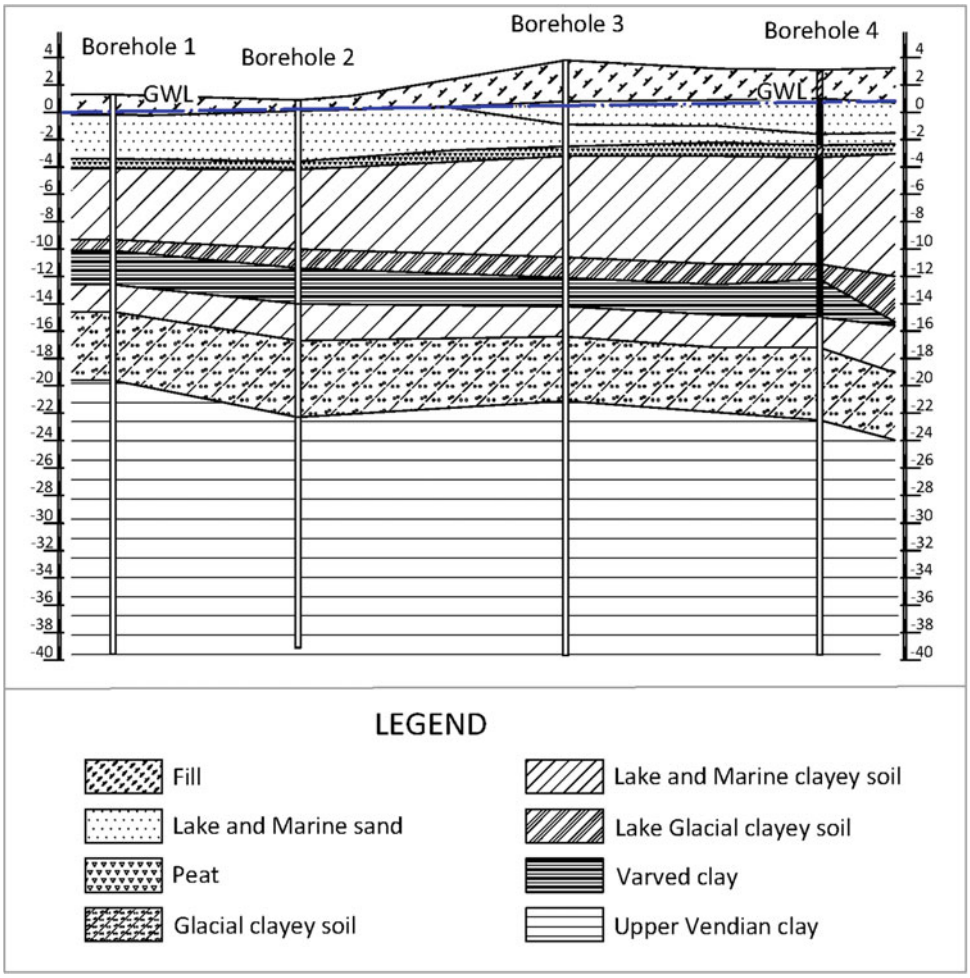

Fig. 3 Stratigraphy of the site

Table 1 Vendian clay structure and properties (Dashko 2003)

Zone No.	Layer No.	Depth from upper boundary (m)	Block size (m)	Water content (%)
I	1	0–20	0.1–0.5	12–23
	2	20–40	0.5–0.7	10–20
II	3	40–60	0.7–1.0	10–19
	4	60–75	1.2	10–17
	5	>75	>1.2	9–15

reduction included the data correction and then the development of a test curve such as the one shown on Fig. 1. From each curve, a set of PMT parameters were obtained including the first load pressuremeter modulus E_o (see Fig. 4), a yield pressure p_y (see Fig. 5), and a limit pressure p_L (see Fig. 6). In some of the tests and due to the limits of the equipment, it was not possible to expand the probe sufficiently to determine the yield pressure and the limit pressure. In those cases, correlations based on the other tests where such data could be collected were used to estimate the missing parameters. These data points appear followed by question marks on Figs. 5 and 6. The yield pressure is used to check that the pressure under the foundation does not exceed p_y. The limit pressure p_L is used to calculate the ultimate bearing capacity of the foundation (Briaud 2013).

Table 2 Index properties of the Vendian clay

PMT	Borehole #	Depth (m)	Grain size distribution			Unit weight (kN/m^3)	Water content (%)	PI (%)	Void ratio (e)
			% clay particles	% silt particles	% sand particles				
1	1	25.5	23	43	34	20.6	19	18	0.560
3		30.4	32	50	18	20.8	15	17	0.500
4		32.9	38	49	13	21.2	14.5	16	0.460
5		35	20	52	28	21.8	14	16	0.413
6		40	25	50	25	22.0	13	17	0.385
7	2	26	36	51	13	20.6	19	18	0.560
8		28	18	51	31	20.8	16	19	0.508
9		32.5	34	40	26	21.0	15	18	0.475
10		36	22	48	30	21.9	14	17	0.406
11		40	27	38	35	22.2	12	17	0.363
12	3	25.5	30	30	40	20.6	18	19	0.525
13		28	30	48	22	20.8	16.5	19	0.508

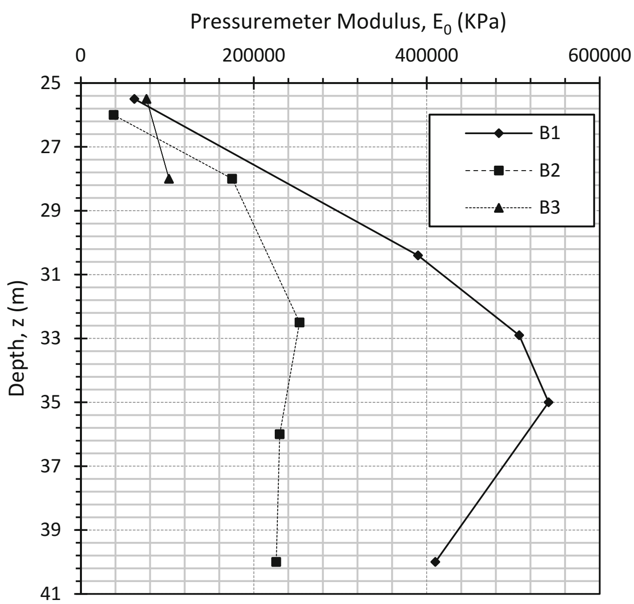

Fig. 4 PMT first load modulus profiles

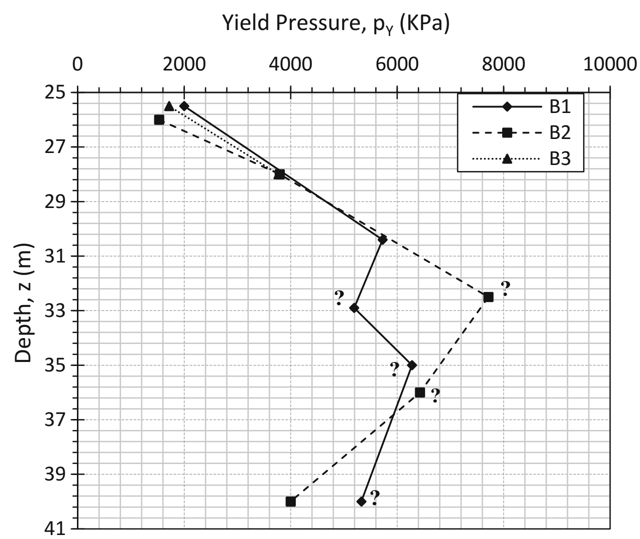

Fig. 5 Yield pressure profiles

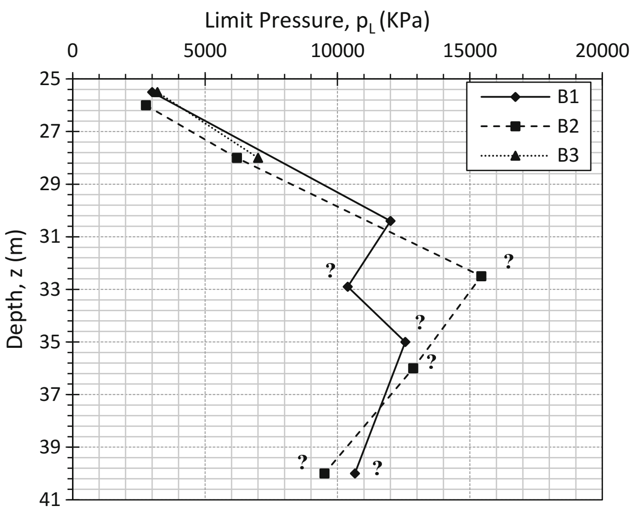

Fig. 6 PMT limit pressure profiles

6 Conclusions

This paper presents the results of a series of 12 pressuremeter tests performed for the foundation design of a tall building in St. Petersburg, Russia. The site geology and soil profile consist of soft saturated soil underlain by a hard Vendian clay. The pressuremeter tests were performed in this hard Vendian clay. The test data was corrected and soil parameters were obtained for the foundation design. These parameters are the PMT modulus, the PMT yield pressure and the PMT limit pressure. The relationship between these parameters and depth was obtained. The modulus, yield pressure and limit pressure vary with depth and the profiles are presented. These parameters are useful in the calculation of the ultimate bearing pressure and the settlement of foundation.

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