When wetted, soils prone to slump-type settlement give rise to forces of negative friction (FNF) to develop on the lateral surface of piles adding to their unloading forces. This leads to a reduction in the bearing capacity of the pile (BCP) along the lateral surface, and to distribution of the load transferred onto the bed.

To study the performance of cast-in-place piles subject to long-term wetting of a stratum prone to slump-type settlement, we conducted investigations from 1980 through 1983 on an experimental site for the Energomash Plant in Volgodonsk [2, 3], which included observations of the settlements of marks and piles during prolonged (one year) wetting of a test pit, and for a period of one year after cessation of wetting, and also static testing of piles in conformity with GOST 5686.

Geologic-Engineering Conditions at Test Site

Physical characteristics of the soils at the experimental site, which were obtained by the Kazakh Technical Civil-Engineering Institute, are presented in Table 1. According to survey data acquired in the construction area, the geologic-engineering elements (GEE) have a constant layer thickness and depth of embedment. With respect to physical properties, the soils in the upper part of the section (GEE-1-3b, 4, 4a), which are comprised of loess-like clayey loams to a depth of 36 m, are most uniform. Residing below these are alluvial soils with interlayers of saturated silty sand (GEE-4c, 5, 6).

The hydrogeologic conditions at the site are determined by the development of an artesian water-bearing horizon. Interlayers of silty sands in the impervious alluvial clays of GEE-6 are the holding deposits for this water. The ground-water table (GWT) in holes resides at a depth of 29.5 m.

According to laboratory tests, the soils of the section are classed according to Building Code [4] as prone to slump-type settlement (relative proneness to slump-type settlement $\epsilon_{sl} \geq 0.01$) at depths ranging from 11 to 26 m, and not prone to slump-type settlement ($\epsilon_{sl} < 0.01$) at depths of 0-11 and 26-35 m. The computed slump-type settlement of the soils due to their own weight $S_{sl,g}$ is 36 cm, and the relative
proneness to slump-type settlement $e_{sl}$ is 0.046 at depths of from 11 to 26 m. The depth beginning from which slump-type settlements of the soils occur due to their own weight when wetted is 4 m according to the Rostov-na-Donu Civil Engineering Institute, 12-13 m according to the Kazakh Technical Civil Engineering Institute, and 10-11 m based on results of the Moscow Civil Engineering Institute [3].

Slump-Type Settlements of Soils Wetted in Test Pit

Cast-in-place piles with shaft diameters of 600 mm and length of 28 m and a broadened base with a diameter of 1,600 mm were installed in a test pit with a depth of 1.7 m and planform dimensions of $30 \times 30$ m.

The piles were fitted with sensors and instruments [1] to investigate their stress-strain state and the soil mass that surrounds them.

Soil-pressure transducers (load-cell strain gages) were installed at the contact between the shaft of the pile and soil, and vibrating-wire strain and temperature transducers in the concrete of the piles. Moisture-content transducers were placed in the soil of the near-contact zone around the pile at depths of 7, 14, 19, and 27 m (up to 20 cm). Soil-pressure transducers were installed from a hole drilled at a distance of 3 m from the pile. At a depth of ~ 21 m, the piles were fitted with dynamometers to measure the force within the shaft. According to [5], this depth corresponds to the level at which slump-type settlement of the soil due to its own weight $S_{sl,g}$ is equal to the limiting allowable settlement of the structure under design $[S]_u = 80$ mm.

$3 \times 3$-m weep holes each 28 m deep were preliminarily installed in the test pit for wetting of the stratum prone to slump-type settlement, and the bottom of the pit was covered with a layer of crushed stone. Surface (SM) and deep marks (DM) were also installed in the pit to observe slump-type settlements of the surface of the soil and its deformations at various levels. Surface marks were also installed at a distance of up to 50 m beyond the limits of the pit, and DM at depths of 6, 10, 14, 18, 22, 25, 28, 33, and 36 m along the axial length of the pit. Wetting was begun 5-6 months after installation of the piles.

Five days after the start of wetting, the moisture-content sensors installed near the shafts of the test piles indicated complete flooding of the soils at a depth of 27 and 19 m, and an increase in their

\[
\begin{array}{|c|cccccccccc|}
\hline
\text{Indicators} & 1 & 2 & 2b & 3 & 3b & 4 & 4a & 4c & 5 & 6 \\
\hline
\text{Depth, m} & 0-8.5 & 8.5-12.5 & 12.5-13.5 & 13.5-18.3 & 18.3-19.5 & 19.5-24.5 & 24.5-29.0 & 29.0-30.0 & 30.0-35.2 & >35.2 \\
\text{In-situ moisture} & 0.16 & 0.16 & 0.15 & 0.20 & 0.19 & 0.20 & 0.22 & 0.20 & 0.23 \\
\text{content} w & 0.16 & 0.16 & 0.15 & 0.20 & 0.19 & 0.20 & 0.22 & 0.20 & 0.23 \\
\text{Soil density } \gamma & 17.6 & 18.1 & 18.0 & 18.8 & 19.1 & 19.8 & 17.6 & 20.2 & 19.6 \\
\text{Dry-soil density } \gamma_d & 15.1 & 15.7 & 15.3 & 15.6 & 16.0 & 16.5 & 16.5 & 16.9 & 16.0 \\
\text{Void ratio } e & 0.79 & 0.73 & 0.75 & 0.74 & 0.71 & 0.65 & 0.66 & 0.63 & 0.71 \\
\text{Degree of saturation } S_r & 0.67 & 0.52 & 0.56 & 0.72 & 0.72 & 0.87 & 0.91 & 0.83 & 0.90 \\
\text{Plasticity index } I_p & 0.12 & 0.13 & 0.10 & 0.18 & 0.13 & 0.14 & 0.15 & 0.14 & 0.15 \\
\text{Cohesion } C, \text{ kPa} & 16 & 23 & 19 & 28 & 31 & 48 & 51 & 60 & 65 \\
\text{Angle of internal friction } \phi, \text{ deg} & 22 & 26 & 24 & 23 & 23 & 24 & 24 & 21 & 20 \\
\hline
\end{array}
\]