CONSTRUCTION UNDER SPECIAL SOIL CONDITIONS

BORING AND PILE DRIVING INTO PERMAFROST

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Piles are presently sunk into permanently frozen ground mainly either by prethawing of the soil or by boring holes and filling them with grout. In both cases the resistance of the piles to loads is secured by subsequent freezing together of the soil and pile, which requires time, the longer, the higher the temperature of the permafrost. Therefore, SNiP II-B.6-66 [1] recommends using the indicated methods only for permanently frozen soils with a low temperature (if artificial cooling of the supporting soils is not stipulated). In soils with a relatively high temperature whose time of freezing to the ground piles is from several weeks to a year, SNiP II-B 6-66 recommends using the so-called boring-driving and driving methods of sinking piles. The first involves driving the pile into a prebored hole the diameter of which is smaller than the pile’s cross-section, and the second involves driving the pile directly into the permafrost. However, until recently these methods were for all practical purposes inadequately developed, which hampered the introduction of the most efficient pile foundations for permafrost in an extensive area of plastic-frozen soils.

Methods of boring large-diameter holes in low-temperature permafrost are also inadequately developed, and the cable rigs used for this purpose at present are inefficient.

The possibility of driving piles into holes of smaller diameter and directly into permanently frozen ground was first demonstrated by experiments at Igarka in 1951-1952 [2].

Later experimental pile driving into permafrost was carried out in Vorkuta by the Research Institute of Bases and its Northern Affiliate in collaboration with the All-Union Research Institute of Construction and Road Machinery, and also in Alaska and Canada where wooden piles [3] and piles (up to 15 m long) of open-end steel tubes and of channels [6] were driven by diesel hammers into plastic-frozen ground.

The experiments at Igarka involved mechanical driving, by a 660-kg hammer, of wooden piles (up to 22 cm in diameter and 6 m long) into silt-clay permafrost ground.

Driving with presinking of guide (lead) holes was done in soils with a temperature from -0.1 to -1.2°, having both massive (with a water content of 35-40%) and bedded structures with numerous ice interbeds 5-8 cm thick (with a total water content of 65-100%).

Piles were driven into soils with a temperature of -0.1 and -0.3° not having large ice interbeds directly into the permafrost stratum without boring holes. The piles were equipped with shoes, and the refusal from the last blows at a hammer drop height of 1 m was 7.5 mm.

When driving into guide holes and directly into the permafrost stratum the bearing capacity increases in comparison with "frozen-in" piles, since radial soil-pressing forces develop which increase the skin friction. The point resistance also increases. The skin friction of clay soils (at a temperature of -0.1, -0.3°) for piles with preliminary steam treatment was 0.1 kg/cm²; for piles hammer-driven into steam-treated holes with a diameter 0.8 of the pile diameter, 0.15-0.2 kg/cm²; for piles hammer-driven into a bored hole with a diameter 0.85 of the pile diameter, 0.3 kg/cm²; and for piles hammer-driven directly into the permafrost, 0.35-0.4 kg/cm².

Experimental driving of piles and boring of holes in Vorkuta were conducted at the engineering field of the Northern Affiliate of the Research Institute of Bases. The soils of this site were represented by silty loams of upper and lower moraines containing gravel and pebbles measuring 2-4 cm, in a quantity from 20 to 40%. There were no large ice inclusions, the total water content was 20-25%. The soil temperature at a depth of 4-8 m was -0.7, -1°.

In 1961-1964, V. N. Eroshenko [3], at Vorkuta, experimentally drove 13 round reinforced-concrete and two steel piles 5-10 m long directly into the permafrost stratum by means of S-268 and S-330 diesel hammers. The rate of pile driving was from 30 to 100 cm/min, pile refusals at the last blows were 1-6 mm.

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In 1966 at this same site the All-Union Research Institute of Construction and Road Machinery (VNIIStroidormash) conducted experimental driving of piles by means of tubular diesel hammers, which showed the good prospects of these pile-driving mechanisms.

In 1963-1964, the Central Research Institute of Transportation Construction of the Ministry of Transportation Construction together with the Research Institute of Bases (NII) and the Northern Affiliate of the Research Institute of Bases (SO NII) conducted experimental sinking of wells in permafrost at Vorkuta in the engineering field [10]. By means of VM-7 and VM-9 vibratory hammers holes up to 3.5 m deep were sunk by 300- and 426-mm-diameter guide pipes. The soil core was ejected from the pipes through a hole at the bottom.

In 1963-1966, NII and SO NII together with VNIIStroidormash carried out experiments in Vorkuta on sinking of holes and driving of piles into permafrost by means of various vibratory machines [1, 7, 8, 9]. The results of these experiments enabled "Vorkutugol" (Vorkuta Coal Company) and "Pechorshakhststroy" (Pechora Mine Construction Company) to begin, as early as 1964, the wide introduction of driving and boring-driving methods of pile sinking in permafrost.

At the engineering field of SO NII various vibratory machines (S-836, S-838, S-467 A, S-467M designed by VNIIStroidormash, and also VPU-30 and VP-1) were used to sink about 50 holes up to 550 mm in diameter and to 8 m deep and to drive into guide holes and directly into the permafrost about 30 reinforced-concrete piles 25 × 25, 30 × 30, and 35 × 35 cm in section. Furthermore, more than a thousand holes were sunk into the active layer and partially into permanently frozen ground at other sites of the Vorkuta region.

While sinking holes and driving piles under field and experimental conditions, D. P. Vysotskii (VNIIStroidormash) tested pile-driving machines under various operating conditions and developed and investigated various modifications of guide pipes (leaders) and tips for them, which largely determined the success of the experimental work.

The holes were sunk by special leaders designed by VNIIStroidormash, which were steel pipes equipped at the bottom with cutting tips, with inside and outside projections, enabling firstly reduction of the friction of the core on the pipe wall, thus facilitating its extrusion, and secondly increase of the diameter of the hole in comparison with the pipe's diameter and facilitating its extraction.

When sinking holes by these leaders additional operations are not needed to free the pipe from the core of frozen ground.

As the leader is sunk the core inside the pipe is pushed upward from the previous drive; to remove it from the pipe a special hole is made in the upper part of the leader.

Several holes were sunk by square leaders.

The vibratory mechanisms used were of both the vibratory and vibratory-percussive type of action (in the latter case the S-838 vibration pile driver with a percussive attachment and the S-836 and S-467M vibrohammers were used). The 1-10011 and 1-1254 excavators served as the base machines.

The average rate of sinking 330-550-mm-diameter holes in plastic-frozen loams with pebble-bed inclusions and with a temperature of -0.7 and -1 °C was 100-50 cm/min, and the time of sinking the leader to a depth of 7 m was 5-10 min. Extraction of the leader was accomplished by the tow cable of the excavator within 1 min. Holes were sunk also through the active layer at the start, middle, and end of winter at a soil temperature of the active layer from -5 to -13 °C. The rate of sinking holes with a diameter from 300 to 430 mm in the active-layer soils was 20-30 cm/min. The productivity of the work in sinking holes with a diameter of 0.35-0.33 m and depth to 8 m by the various vibratory machines (and also by the S-330 diesel hammers) was 10-33 linear meters per hour.

Driving of piles into leader holes was done by the same machines. Piles with a cross-section of 25 × 25, 30 × 30, and 35 × 35 cm were driven into holes with a diameter of 219-290 mm and depth to 7 m. At first pile driving was sufficiently intense to a depth of 4-5 m (for several minutes), but then the driving speed slowed, evidently as a result of the formation of a soil plug under the pile point.

The driving rate was low when the piles were driven into permafrost by the vibratory mechanisms. For instance, when the S-838 vibration pile driver was used, square reinforced-concrete piles 30 × 30 and 35 × 35 cm in section and round steel piles (33 and 24 cm) with a closed end were driven at a rate of 5-15 cm/min into clay soils with a temperature to -1 °C.