The clay specimens were subsequently dried in a desiccator at 105°C. In this case the water content and shrinkage were determined analogously. It follows from Fig. 3 that shrinkage of clay continues in the entire range of variation of the water content. The rate of shrinkage of clays at a water content below 0.10-0.21 decreases sharply, which is characterized on the graph by a break of the curve \( \delta_s = f(W) \). Most shrinkage (75-85%) of Khvalynian clays occurs before the break point on the graph \( \delta_s = f(W) \), which can be one of the values of the water content in the interval from 0.10 to 0.21. Since shrinkage deformations continue during drying of clays to arbitrarily small values of water content, it is necessary to recognize the conditionality of the concept of shrinkage limit as the water content below which volume deformations do not occur.

In determining the total shrinkage its active zone (see Fig. 2) was divided into elementary layers 50 cm thick. The average water content of each elementary layer after drying and shrinkage was calculated along the profile of the final predicted distribution of water content (curve 2 in Fig. 2). By means of a graph (see Fig. 3) the relative linear shrinkage was determined as a function of the average water content successively for all elementary layers of the active zone. The total shrinkage of the bed of Khvalynian clays under the edge of the smokestack foundation in zone No. 2 was calculated as the sum of the shrinkage deformations of all elementary layers.

After the additional semicircular gas flue was put into operation in May 1976 the tilt of the smokestack began to decrease noticeably. To check the actual shrinkage, depth markers were placed in each soil layer and wall markers were placed in the pedestal of the smokestack. The tilt was measured by a transit theodolite and the vertical displacements of the smokestack were determined by leveling. The results of the measurements are given in Table 3 and Fig. 4.

With consideration that the development of shrinkage slows with time, after 3-yr operation of the smokestack its tilt decreased to a value less than 0.005. The vertical displacement of marker No. 4 installed in the pedestal of the smokestack on the side opposite the tilt most fully characterizes the absolute shrinkage of the layer of Khvalynian clays. The 85-mm displacement measured by means of it practically coincides with the calculated value of shrinkage deformation obtained by the method presented above.

INVESTIGATION OF THE BEARING CAPACITY OF PILES
DRIVEN IN PLASTIC FROZEN SOIL

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Pile foundations are being used widely in the construction of buildings and structures along the route of the Baikal-Amur Mainline, and therefore it is important to determine the bearing capacity of piles in permafrost and, in particular, in plastic frozen soils, which depends on many factors, including on the method of driving the piles into the ground.

To determine the bearing capacity of piles in plastic frozen ground the authors conducted field experiments on driving piles by a vibratory hammer and their subsequent long-time tests under the effect of a graduated static load under conditions of the Amur region on a plot at the Skovorodino permafrost station of the TsNIIS.

The soils of the experimental plot to a depth of 6 m were represented by silty loams having a water content of about 25%, with interlayers of clayey and silty loamy sand and small content of gravel-rubble inclusions increasing from a depth of 2.3 m. Below 6 m there was fine sand with a water content to 35%, passing into gravelly sand. The consistency of the loams and loamy sands in a thawed state was different—from plastic to very stiff. Such variations of consistency were due to the inhomogeneous ice content of the soils

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Fig. 1. Self-propelled track-borne pile driver with a VMS-1 vibratory hammer.

which varied with depth from 0.04 to 0.3. The total water content of the plastic frozen soils increased markedly from a depth of 3.5-4 m and reached 35%, but was distributed unevenly. The frozen ground belonged to the confluent type; the temperature of the ground at a depth of 6-7 m was -0.5°C; the maximum thawing depth was 2.3-2.5 m. Reinforced-concrete piles measuring 30 × 30 cm in section and 7 m long, of type S 7-30, meeting the State Standard GOST 19804-74, driven to a depth of 6 m in pilot holes were tested.

The holes were drilled and the piles driven in them by means of a track-borne pile driver (Fig. 1) whose working tool is a 56-kW VMS-1 vibratory hammer (designed by TsNIIS of the Ministry of Transportation Construction) with a 3-ton ram and impact frequency of 730/min.

The ratio of the cross-sectional areas of the boreholes and piles was varied from 0.46 to 1.58, which made it possible to drive piles into the holes and to lower them with slurry filler. It should be noted that the vibratory hammer drove the leader pipe to the design mark, penetrating in so doing the ground only around the perimeter of the hole. Then the pipe was extracted together with the soil filling it, which on the surface was removed from the pipe as undisturbed cores. During driving of piles into plastic frozen soil a part of the energy of the high-frequency impacts of the vibratory hammer was converted to heat energy, causing thawing of the soil around the perimeter of the borehole, as a consequence of which the structure and frost texture of the soil changed at the contact with the pile skin. These changes had a substantial effect on its bearing capacity.

During the test a static load was transmitted to the pile by means of a 200-ton capacity DG-200 hydraulic jack powered from the pump of a diesel engine.

By selecting the appropriate actuating and monitoring instruments, the given load increments were maintained in time with a difference from 0.5 to 1%. The force of the reaction was absorbed by a support beam connected by tie-rods to two anchor H-beams driven to a depth of 8.5 m.