Guide for design and construction of pile foundations in permafrost
National Research Council of Canada. Division of Building Research

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PREFACE

This translation of the Soviet building code dealing with the design of pile foundations for permafrost areas is of particular interest to the Division of Building Research in its investigations of permafrost and building problems in northern Canada. The U.S.S.R. has been involved in construction on permafrost for many years in Siberia and experiences in that country are of great interest to those who are involved in this activity in northern Canada. There is no similar building code available in Canada at present.

This is the third Russian building code for construction in permafrost regions which has been translated for the Division of Building Research. The first, which deals with the design of all types of foundations for permafrost areas, was issued in 1963 (TT-1033). The second, dealing with the design of foundations for discontinuous permafrost areas, was issued in 1967 (TT-1298).

Comments upon the contents of this translation from any who have had experience with building in permafrost areas will be welcomed by the Division. Such mutual exchange of information will be of great assistance to the Division in its task of providing essential information, especially upon unusual building problems for use of the entire building industry of Canada.

The translation has been prepared by R.J.E. Brown, a research officer of the Division of Building Research. Mr. V. Poppe of the Translations Section of the National Research Council kindly checked the translation for which appreciation is here recorded.

Ottawa
May 1968

Robert F. Legget,
Director

Standards for the design and construction of pile foundations in permafrost represent an expansion of SNiP 11-A, 10-62 and 11-B, 5-62, and engineering spacifications for the design of foundations in permafrost (SN 91-60), based on the experience in design and installation of pile foundations in Noril'sk, Yakutsk and other regions, and research data from various organizations.

In these standards, recommendations are given for surveys, design, construction, inspection and testing of piles.

The standards were developed in Krasnoyarsk by the Construction Research Institute, attached to the State Committee of the Council of Ministers (R.S.F.S.R.) for Building Problems (Gostroi R.S.F.S.R.).

NATIONAL RESEARCH COUNCIL OF CANADA

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Title: Guide for design and construction of pile foundations in permafrost (RSN-14-62)

(Ukazaniya po proektirovaniyu i ustroistvu svainykh fundamentov na vechnomerzlykh gruntakh (RSN-14-62))

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Translator: R.J.E. Brown, Division of Building Research, National Research Council

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GUIDE FOR DESIGN AND CONSTRUCTION OF PILE FOUNDATIONS IN PERMAFROST (RSN-14-62)

Introduction

In planning the development of the national economy of the Soviet Union during the present seven years and for the future, problems of developing capital construction in regions of permafrost and severe climate have occupied a large and important position.

The adoption of modern methods of foundation design in permafrost is one of the main problems for construction men in these regions.

Experience with foundation construction in Noril'sk, Yakutsk and other regions confirms the absolute engineering economic preference of pile foundations over all other types of foundations in the construction of buildings and industrial structures where the permafrost condition of the foundation soils is to be preserved.

The increasing necessity of creating standards for the design and construction of pile foundations which will contribute to a wide adoption of the latter in permafrost regions is associated with this.

These standards were developed by the Construction Research Institute in Krasnoyarsk on instructions from Gosstroi of the U.S.S.R. To compile these standards, material was obtained from the Zavenyagin Combine of the Krasnoyarsk Council of National Economy in Noril'sk, the Foundation Soils and Subsurface Structures Research Institute, the Permafrost Institute of the Academy of Construction and Architecture of the U.S.S.R., Fundamentproekt and Lenmorniiproekt Design Institutes, Yakutproekt, and the Yakut Construction Board of the Council Ministers of the Yakut A.S.S.R.

The standards were compiled by members of the Construction Research Institute in Krasnoyarsk,M.V. Kim and G.F. Shishkanov; Part IV was written in cooperation with engineer Y.M. Goncharov.

The standards were edited by a commission comprised of representatives from the following organizations: the Permafrost Institute of the U.S.S.R. Academy of Construction and Architecture (S.S. Vyalov), the Foundation Soils and Underground Structures Research Institute of the above Academy (M.F. Kiselev), the Foundation Design Institute of the R.S.F.S.R. Ministry of Construction (D.P. Kochetkov), and the Construction Research Institute in Krasnoyarsk (Sh. F. Aklulatov, M.V. Kim and G.F. Shishkanov).

I. GENERAL CONSIDERATIONS

1. These standards include the design and construction of pile foundations of industrial and public buildings and structures erected with the aim of preserving the perennially frozen state of the foundation soils.

2. The suitability of using pile foundations in specific conditions will be decided by the design organization keeping in mind:

(a) The reasons for adopting the given method of using the foundation soils based on the frost and hydrogeological conditions of the site and also the possible changes in these conditions during construction and use of the buildings and structures;

(b) The designation of the buildings or structures and operating conditions;

(c) The lowest labour force and cost.

3. In relation to the permafrost and hydrogeological conditions, working conditions, engineering and economic expediencies, and construction experience, it is possible to use several types of frozen-in piles under the following subdivisions:

(a) Material - wood, reinforced concrete and metal.

(b) Form - cylindrical (pipe and solid), prismatic (square and rectangular) and composite profile (H piles, cross-shaped, etc.).

(c) Embedment method in the ground - piles embedded in previously drilled holes; piles embedded in previously thawed soils; drill-driven piles embedded in previously drilled holes or thawed soil with the diameter of the hole or cross-section of the thawed zone being less than the greatest cross-section of the pile; driven piles embedded in frozen soils.

Regardless of the embedment method, all piles are designated as frozen-in if their bearing capacity is determined, mainly by the strength of the frozen foundation soils.

4. The control of carrying out these construction standards rests with the architectural-construction inspectors and also with the permafrost stations organized as outlined in SN 91-60, paragraph 4 (NRC TT-1033).

The operation of buildings and structures on pile foundations is carried out by the operations office in accordance with "The Instructions for the Operation of Buildings Erected by the Method of Retaining the Foundation Soils in a Frozen State".

II. ADDITIONAL REQUIREMENTS TO INVESTIGATIONS ON THE DESIGN OF PILE FOUNDATIONS

5. The requirements listed in this part apply to the investigations carried out at the working design stage of pile foundations.

6. Engineering investigations for the working design stage must be carried out not less than a year before the beginning of construction to obtain knowledge of the annual ground temperature regime; moreover all data of previous investigations are to be used and compiled.

7. In the case of homogeneous permafrost soil conditions, the designation of the number of holes within the perimeter of the designed building is carried out according to the standards. The number of holes should not be less than two.

In complex permafrost soil conditions (existence of thawed zones, areas with high temperatures close to thawing, ice layers, variable soils), the number of holes should be sufficient to reveal the various permafrost soil characteristics of the site.

8. The depth of the holes is determined by calculations depending on the composition, properties and temperatures of the soils surrounding the pile to a depth of 3 metres below its tip. It must not be less than 8 metres in total.

Where a whole block of buildings is to be erected, not less than three holes should be put down to the depth of zero annual amplitude, or to a depth of at least 15.0 metres.

9. The drilling of holes in frozen soils is carried out by hand or mechanical methods and cores are obtained throughout the depth of the hole.

The use of water and heating of drills is forbidden in the boring of exploratory holes. If one of these measures is used in an emergency, the hole must be drilled again at a distance of not less than 3 metres from the previous hole.

10. Preliminary temperature observations are taken in the hole with the aim of:

(a) choosing characteristic holes for establishing long-term observations;

(b) clarifying the type and character of permafrost and the presence of thawed zones at the site.

11. Temperature observations in the hole are carried out in accordance with "Standards for Organizing and Carrying Out Observations on the Change in the Water-temperature Regime of Permafrost for Foundation Construction Purposes".

This is done as follows:

(a) Temperature holes for short term observations are cased in the summer to a depth of 2 - 4 metres; holes for long-term observations are cased throughout the entire depth.

(b) Observations on the holes are begun 10 - 15 days after the end of drilling.

(c) Temperature observations are carried out at 1 metre intervals through the depth of the holes with slow reading thermometers, electrical resistance thermometers, thermistors or thermocouples.

An accuracy of not less than $\pm 0.2^{\circ}C$ must be guaranteed where the temperature at the depth of zero annual amplitude is $-1^{\circ}C$ and lower, and not less than $\pm 0.1^{\circ}C$ where the temperature is above $-1^{\circ}C$.

12. The length of temperature observations in the holes must be sufficient to establish the design temperature regime of the foundation soils around the pile and to determine the design thickness of the active layer.

13. The investigations must reveal the causes for local disturbances of the temperature regime of the ground (engineering services, peculiarities in the hydrogeological regime of the site, existing structures, thick snow accumulation, etc.).

14. When construction is finished, all holes used for long-term temperature observations are turned over to the operations office for the continuation of ground temperature observations during the use of the building or structure.

15. The record which is compiled from the results of the engineering, geological and permafrost investigations must contain an explanatory note with a description of the permafrost and hydrogeological characteristics of the site, recommendations for designating the design temperature regime of the foundation soils, the design characteristics of the soils, and appendices containing:

(a) a topographic plan of the site showing the location of excavations and temperature holes;

(b) geological cross-sections and profiles with a description of the texture (structure) of the frozen ground;

(c) ground temperature graphs (isopleths) for each borehole; tables of temperature observations for each hole, temperature profile for the holes showing the maximum temperatures of the permafrost in the foundation soils;

(d) data on laboratory investigations of the physico-mechanical properties of the soils (grain-size composition, moisture content and unit weight).

One copy of the record is turned over to the permafrost station.

III. DESIGN OF PILE FOUNDATIONS

16. The requirements of this division extend only to the design of foundations consisting of pile frozen into the permafrost; the preservation of the design temperature regime of the foundation soils during the use of the structure must be guaranteed by a system of measures specified in the design.

17. In the design, the method of installing piles must be selected in accordance with the permafrost conditions of the construction site, standard and design characteristics of foundation soils must be determined and explained, and the dimensions of the main elements of pile foundations must be designated.

The choice of pile design, material and installation method must be made from technical and economic considerations and comparisons of various types of pile foundations; moreover, the requirements of the "Technical Rules for the Economical Utilization of Metal, Wood and Cement in Construction" (TP 101-61), the maximum mechanization of foundation construction, and also local construction experience must be considered.

Recommended construction methods are presented in Table I.

Explanatory note: Metal piles can be used only in special cases with an appropriate explanation.

Table I

Recommended methods of installing frozen-in piles

Ground conditions \ Temperature conditions	Ground temperature at level of zero annual amplitude		
	-0.5°C and lower	-1.0°C and lower	-1.0°C and higher
Soil containing more than 10% gravel	Piles embeded in drilled holes	-	-
Sandy soils	"	Embeded piles in thawed soil	-
Clayey soils	"	"	Installation of driven and drill-driven piles

Explanatory notes:

1. The use of driven and drill-driven piles is permitted only after experimental driving has given positive results, and if these piles are suitable

for work in the summer-fall period.

2. To accelerate the adfreezing of the soil to the pile in near freezing temperatures, artificial freezing of the foundation soils is recommended.

18. In the construction of pile foundations it is recommended to use reinforced concrete piles and prefabricated reinforced load transfer structures*.

For prefabricated elements it is recommended to use a design quality of concrete of not less than 200, and for monoliths not less than 150. Wood piles are used mainly in the construction of temporary structures. If wood piles are used in the foundations of large buildings and structures, conditions guaranteeing the durability of the wood must be maintained.

19. In soils with agressive groundwater, measures must be specified for protecting the piles and load transfer structures from corrosion in accordance with the recommendations of the standards.

20. Calculations for piles, foundation soils, load transfer structures, and combinations of them, i.e. pile foundations, are carried out for the ultimate limiting condition in accordance with the basic considerations outlined in SNiP II-A, 10-62.

The design of piles, pile foundations and load transfer structures are based on the first limiting condition, i.e. the strength.

The second limiting condition - deformation, is considered only in calculations referring to pile foundation soils which are close to thawing.

The third limiting condition - fracture stability, is used when designing piles in accordance with the general requirements set forth for elements of reinforced concrete construction and conditions defined in clauses 2.4 and 4.12 SNiP II-B, 5-62.

21. The design of pile foundations is carried out in the following sequence:

(a) the determination of the design strength of the pile for the given temperature and soil conditions and the selected type of pile;

(b) determination of the design loads acting on the pile foundation;

(c) determination of the number of piles in the foundation for which the active design load on the pile would not exceed the design strength of the

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* The Russian word "rostverk" does not have an English single word equivalent. This term refers to the structure which transfers the load exerted by the building to the top of the pile. It may consist of a pile cap, a beam resting on a row of piles, or a slab, depending on the design. The term "load transfer structure" is used in this translation to include these variations.

pile, i.e. the following conditions would be satisfied:

$$P^{p} \leqslant P \tag{1}$$

P^p - design load on the pile in tons,

P - design strength of the pile in tons;

(d) tests to determine whether heaving would take place.

22. The determination of the design strength of foundation soil of a single pile is carried out assuming joint performance of the pile and soil around and beneath the pile.

The joint performance of the pile and the soil depends on the shear strength of the soil along the lateral surface of the pile and the strength of the frozen soil beneath the lower tip of the pile.

The limiting condition of the foundation soil is conditionally assumed with the attainment of ultimate long-term strength, i.e. of that strength which when exceeded leads to non-attenuating plastic deformation.

23. The design strength of a pile subjected to an axial compression load is determined from the design strength of the materials of the pile, by regarding the latter as the central-compressed element (in soil - without considering the longitudinal deflection) according to the corresponding design standards of construction, and also from the design strength of the foundation soils according to formulae (2) or (3) by taking the lesser of the obtained values of the design strength - P.

$$P = \kappa m \, (u \Sigma S_i^{"} \, l_i \; + F p^{"}) \tag{2}$$

k - coefficient of homogeneity of soil (see Table II);

m - coefficient of working conditions, assumed to be unity;

u - perimeter of the pile, or shortest length measured along the probable contour of shear of frozen soil for a pile of a complex cross-section, in metres;

S_i^H - standard shear resistance of frozen soil along the lateral surface of pile, or shear contour, corresponding to the design temperature in the i-th layer, in tons/m²;

l_i - length of pile section in the i-th layer of perennially frozen ground, in which the design temperature is assumed to be constant, in metres;

Σl_i - design depth of pile embedment in frozen ground;

F - area of pile cross-section at lower end in square metres;

p^H - standard strength of frozen foundation soil in the plane of the lower end of the pile corresponding to the design temperature of the foundation soil at this depth, in tons/m².

An example of determining the design strength of the foundation soil of a pile is given in Appendix 1.

Table II

Homogeneity coefficients

No.	Embedment method	K
1	Embedment of piles in drilled holes and in previously thawed soil	0.7
2	Driven, drill-driven piles and piles installed in drilled holes using a sand slurry compacted with a vibrator	0.8

24. The strength of a thawed foundation soil is considered only for drill-driven piles in non-heaving soils.

The design strength of the foundation soil of a pile in this case is determined by formula (3):

$$P = km\,[(u\Sigma S^{н}_{i}\, l_{i} + Fp^{н}) + u_{1}\, f^{н}\, l_{д}] \qquad (3)$$

k, m, u, S^{H}_{i}, l_{i}, F, p^{H} - same values as in formula (2);

f^{H} - the standard strength of soil along the lateral surface of a pile in the active layer taken from Table II in SNiP II-B, 5-62;

$l_{Д}$ - the length of the pile in thawed ground equal to the design depth to the permafrost table (excluding soil fill);

u_{1} - mean perimeter of pile in active layer.

25. The standard characteristics of permafrost are taken from Tables III and IV.

Explanatory notes:

1. The values shown in the tables correspond to limiting long-term strengths. They can be corrected on the basis of long-term construction experience and tests, including static pile tests.

2. For intermediate temperatures, the values for S^{H} and p^{H} are determined by linear interpolation.

3. It is forbidden to use the values of S^{H} and p^{H} shown in Tables III and IV in saline soils with a concentration of salt ($NaCl$, $CaCl_2$) greater than 0.1%.

4. In the design of driven and drill-driven piles the values of S^{H}, shown in Table III, are reduced by 50% for the soil layer containing ice in the form

of layers and lenses exceeding 2 centimetres in thickness and occupying more than 50% of the total thickness of the layer.

5. If the pile rests directly on ice, the strength of its lower end is not considered.

Table III

Standard shear strength of frozen soil S^H in tons/m²

°C	-0.5	-1.0	-1.5	-2.0	-2.5	-3.0	-3.5	-4.0 and lower
S^H	5.0	10.0	12.5	15.0	17.5	20.0	22.5	25.0

Table IV

Standard strength of soils in the plan of lower ends of piles (p^H) at design depth of pile embedment in permafrost of not less than 2.0 m

No.	Soil	p^H in tons/m² at design temperature at lower end of pile °C							
		-0.5	-1.0	-1.5	-2.0	-2.5	-3.0	-3.5	-4.0 and lower
1	Coarse-grained soils	350	375	400	425	425	425	425	425
2	Sandy soils	250	260	280	300	300	300	300	300
3	Clayey soils and silty sand without visual ice inclusions (layers)	70	90	110	130	150	200	200	200
4	All types of soils with presence in the half-metre layer below pile tip of visible ice layers	40	45	50	60	70	80	90	100

26. On developed construction sites where long-term geothermal data are available, the design temperature at various depths in the zone of pile embedment in permafrost and the design temperature at the lower end of the pile are determined from temperature observations.

The temperature in each layer is found as the average of several measurements made at this depth in at least two holes during the period of deepest thawing in the active layer.

27. In the absence of long-term temperature observations at the construction site, the design temperature of the soils at various depths can be determined approximately by formula (4) for rough calculations at the design stage, in relation to the ground temperature at the depth of zero annual amplitude:

$$t_h = 0{,}17\, t_o\, h_i \tag{4}$$

t_h - temperature at the base of a frozen-in pile;

t_o - temperature at the depth of zero annual amplitude;

h_i - depth from the design permafrost table to the depth where the design temperature is determined but not greater than 6 - 7 m.

Formula (4) should be used with temperatures at the depth of zero annual amplitude of -2^{o}C and lower.

With temperatures above -2^{o}C, the design temperature in the zone of embedment of the pile is assumed to be constant and equal to -0.5^{o}C.

Explanatory note:

In the absence of long-term observations, the ground temperature measured in a borehole at a depth of 15 m may be taken as the temperature at the depth of zero annual amplitude.

28. The design position of the permafrost table, which determines the embedment depth of the pile, is established in the autumn on the basis of temperature measurements in foundation soils of occupied buildings which are similar to those under construction.

In the absence of observation data, the design position of the permafrost table of the merging type (i.e. reached by the active layer) can be assumed equal to the design thickness of the active layer, which is determined from formula (5):

$$H^{p} = m_t\, H^{н} \tag{5}$$

H^{p} - design thickness of the active layer in metres;

H^{H} - standard thickness of the active layer determined according to SN 91-60;

m_t - the coefficient accounting for the decrease of the active layer during occupation of the building in relation to the temperature regime on the first floor and design of the basement, taken from Table V.

Table V

Coefficient m_t

Thermal regime of building	m_t - for foundations	
	Under outside walls	Under inside walls
Unheated rooms, cold basements and first floors	0.9	0.8
All types of heated buildings with ventilated cellars	1.0	0.8

Explanatory note:

With the laying of a thermal insulating cover on the soil in the basement and also ducts for artificial or natural ventilation of the basement, the determination of the design thickness of the active layer is carried out by thermotechnical calculations.

29. The design thickness of the active layer may be measured from the top of the fill, if the fill was placed during the engineering preparation of the site, well ahead of actual construction.

30. In heavy construction and the erection of important structures, the design strength of the foundation soils determined from formula (2) or (3) is corrected as a result of testing piles under static load during construction under supervision by the design organization according to recommendations in Appendix 12 of these standards.

31. The design strength of foundation soils of the pile - P from testing results is determined by formula (6):

$$P = 0.7\ P^{H} \tag{6}$$

P^{H} - standard strength of foundation soils assumed equal to the average of three values of the limiting strength of soils determined in tests under similar temperature-soil conditions.

The limiting strength of foundation soils under axial loading is determined by the load, which results in a non-attenuating shifting of the pile at a rate of 0.5 mm per day or slightly higher.

Explanatory notes:

1. If the pile during the test is not brought up to the limiting condition, then the load in which the test can be discontinued must be not less than 1.5 P, determined from formula (2) or (3).

2. The design strength of the foundation soils subjected to horizontal forces is found from a curve illustrating the shift of the top of the pile versus load in static tests.

3. The design strength of foundation soils must not exceed the design force which the pile can withstand based on its strength and resistance to cracking.

32. The design strength of foundation soils which tend to pull out the pile P_B is determined without considering the strength of the soil in the active layer using formula (7):

$$P_{\text{в}} = \kappa m\, u \Sigma S_i^{н}\, l_i \qquad (7)$$

where k, u, S_i, l_i have the same values as in formula (2);

m - coefficient of working conditions; for piles embedded in permafrost to a depth of up to 2.0 m it is assumed to be 0.9, and 1.0 at greater depths.

The standard shear strengths of frozen soil in formula (7) are assumed for the design temperature regime of foundation soils determined in accordance with sections 26 or 27 of the present standards.

The design strength of foundation soil, determined from formula (7), must be pinpointed by special pull-out tests as outlined in section 30.

When determining the design strength of foundation soils tending to pull out the pile, it is necessary to consider the requirement of section 31 and the recommendations for tests on experimental piles (See Appendix 12.).

33. Checking of single piles with respect to the second limiting condition (section 20) is carried out by testing the pile under a static load. The settlement of the pile under standard loading must not exceed the limiting deformation given in the design, taking into account the possibility of differential settlement.

34. The sequence for calculating loads and combination of loads acting on pile foundations is described in Chapter II-62 of SNiP 11-A and also in the design standards for various buildings and structures. The following additional considerations also apply:

(a) temporary loads (wind, snow, etc.) are assumed equal to their maximum values observed over a number of years (at least 10) in the autumn (when the active layer is thickest);

(b) short-term loads are assumed without considering the dynamic coefficient and are reduced by 50% for effective loads of cranes and by 25% for mobile traffic on roadways.

Explanatory note:

The loads are not reduced when the piles are designed for strength and regarded as structural elements.

35. The design load on piles P^p in formula (1), when the piles are arranged in rows, is determined as the sum of the reactions of the neighbouring spans in the load transfer structure, disregarding its rigidity.

In a random distribution of piles joined by a rigid load transfer structure, the design load on a pile is determined by formula (8):

$$P^p = \frac{N}{n} \pm \frac{M_x y}{\Sigma y_i^2} \pm \frac{M_y x}{\Sigma x_i^2} \qquad (8)$$

N, M_x, M_y - the normal compressive strength in tons and the design moments in TM (ton-metres) relative to the main axes in the plane of the bottom of the pile foundation;

n - number of piles in the foundation;

x_i, y_i - distance in metres from the main axes in the plan of the pile foundation to the axis of each pile;

x and y - distance in metres from the main axes in the plan of the pile foundation to the axis of the pile for which the load is being calculated.

36. The smallest amount of pile embedment in permafrost is assumed to be 2 metres, to ensure safety and durability of the building or structure.

37. If piles are placed in permafrost close to service conduits, the depth of embedment, which has been calculated or determined as outlined in section 3b, must be increased to take possible local thawing of the permafrost into account.

The zone of thermal influence of service lines in ventilated conduits is assumed to extend 2 metres from the outer walls of the conduits; for other cases it must be determined by heat engineering methods.

38. In the presence of an active layer consisting of clay soils, the resistance of piles to heaving must be checked by formula (9):

$$n_1 u\tau^H - n_2 N^H \leq P_B \qquad (9)$$

N^H - standard vertical load on a single pile from the action of constant forces only, in tons;

P_B - design resistance of the pile to pull-out determined from formula (7);

u - perimeter of pile in metres;

τ^H - standard relative heaving force in tons per linear metre of the pile perimeter, assumed in the absence of test data to be 9 tons/m for an active layer of up to 1.0 metres in thickness, and 15 tons/m, if the active layer is thicker;

n_1 and n_2 - coefficients of overloading assumed equal to $n_1 = 1.1$ and $n_2 = 0.9$.

Explanatory notes:

1. In the presence of the pull-out force N^H, its value is substituted into the formula with a minus sign. The coefficient n_2 is assumed in this case to be equal to 1.1.

2. The stability of the piles must be verified also during the construction stage; in this case N^H is assumed equal to the actual weight of the unfinished building in the fall-winter period. If the condition of formula (9) is not fulfilled in this test, it is necessary to protect the soil in the active layer from freezing.

39. For piles placed in drilled holes and thawed soil, use may be made of square shapes as well as cross-sections with a developed perimeter. The area of cross-section depends on the maximum utilization of the material of the pile (pipe pile, H pile, etc.). Piles with a complex cross-section are accepted on the basis of engineering and economic considerations. Piles embedded in drilled holes are placed without being pointed and, in the case of a monolithic load transfer structure, the piles are reinforced to provide stable connections with the latter.

In the case of pipe piles, the portion embedded in permafrost is filled with sand; in the active layer the pipe is filled with mark 100 concrete.

40. Under the bearing walls of buildings a single row of piles should be provided in the design; the axis of the row of piles is arranged as a rule along the axis of the wall of the first floor.

In the case of large off-centre loads, the axis of the row of piles is best placed to decrease the eccentricity of the vertical forces. The placing of piles under the corners of brick walls and at the intersections of the axes of bearing walls of panel buildings is compulsory. It is not recommended to place piles under window and door openings.

41. Where piles are placed in clusters, the minimum distance between piles embedded in drilled holes must be 0.5 metre. In other methods of embedment, the minimum distance between the pile centres at the depth of the lower ends is assumed equal to 3d, where d is the diameter or the side of the pile.

The arrangement of piles in the plan of this foundation is such that the resultant of constant forces which act on the pile foundation is transmitted close to its centre of gravity at the depth of the lower end of the piles.

42. In the installation of piles, the requirements in section 21 must be satisfied; underloading of individual piles must not exceed 20%.

43. Where the active layer consists of clay soils, the load transfer structure must be elevated above the ground surface to the height of soil heaving observed in the given region.

44. Reinforced concrete load transfer structures (beams, slabs) are designed according to present design standards of reinforced concrete units. In the case of a row of piles under walls of buildings, the load transfer structure is designed as a fastening beam bearing on the pile. The minimum width of load transfer structure is designated as 40 cm.

Determination of the height of the load transfer structure and the cross-section of reinforcement is carried out by calculation. The smallest height of the load transfer structure must be such as to enable the concrete cross-section to withstand the transverse force without installing curved reinforcements, but must be at least 0.3 metre.

Explanatory note:

When laying brick walls in winter, the strength of the load transfer structure is checked by considering the load from the weight of the thawed material.

45. In a monolithic load transfer structure it is not recommended to leave gaps. Where joints are unavoidable, they must coincide with temperature joints in the walls.

46. The top of the load transfer structure is best placed at the level of the floor of the ventilated crawl space; the floor slabs are placed directly on the load transfer structure.

An example of a pile foundation design is given in Appendix 2.

47. Where there is a considerable slope to the ground surface, or where the height of the ventilated crawl space varies, the installation of the load transfer structures at various levels is permitted.

48. On the blueprints, the axes of the rows of piles must be joined to the axes of the walls and marked. The piles in the plan must be numbered along the axes of the rows of piles.

IV. INSTALLATION OF PILE FOUNDATIONS

49. The following methods of installing frozen-in piles are regulated by instructions given in this part:

(a) installation of piles in drilled holes;

(b) installation of piles in soil which was thawed prior to construction;

(c) driving of piles into holes of smaller diameter or into frozen ground with a temperature close to thawing.

50. The engineering preparation of the area must precede the installation of piles.

Freezing of taliks (thawed zones) and areas with soils close to thawing discovered on installing the piles is carried out as a special project. The design organization must be informed of these measures in good time.

51. Reinforced concrete piles are manufactured with close adherence to all requirements in TU 120-55 and engineering instructions for the preparation of the piles. Greasing of the pile linings is done with clay or lime paste; use of oil emulsions are prohibited.

The piles are brought to the construction site when concrete has reached 100 per cent design strength.

Explanatory note:

The preparation of piles equipped with pipes for temperature measurement is carried out in conjunction with the design specifications. The number of such piles under the building varies from four to six.

52. Deviations from the specified position of piles embedded by any method must not exceed the values given in Table VI.

Piles Installed in Drilled Holes

53. Holes are drilled with percussion and rotary drills adapted for boring frozen soils. The technical characteristics of the most common machines for boring holes are given in Appendices 3 and 4.

54. The drill rigs are placed above the top of the hole and the drilling is carried out as follows:

(a) the base of the rig must be placed horizontally, which is done by levelling the drilling site;

(b) the axis of the drill must coincide with the design axis of the hole.

An example of work organization in the construction pile foundations is given in Appendix 5.

Table VI

Permissible deviation of piles from specified position

No.	Deviation	Allowance in mm	
		Monolithic load transfer structure	Assembled load transfer structure
1	Deviations from the axis of a row of piles at the level of the load transfer structure, when the piles are placed in rows along and across the load transfer structure	±50	±30
2	Deviations from the axis in any direction, when the piles are placed in clusters	½ diameter or side of pile	±50
3	Deviations from the design height of the top of pile	±50	±30

Explanatory note:

When the piles are placed in rows, ultimate deviations in one direction are permitted for not more than four adjacent piles.

55. The diameter of the hole must be 5 centimetres greater than the largest diameter of the pile.

56. It is recommended to case the holes throughout the layer of thawed soil.

57. In the case of a monolithic load transfer structure, the hole dimensions must not deviate from specified dimensions by values exceeding those in Table VII.

Table VII

Permissible deviations in drilled holes

No.	Deviation	Allowance in mm
1	Misalignment of hole axis with pile axis at base of load transfer structure along and across row of piles	±50
2	Deviation from design depth of hole (a) overdrilling (b) drilling to insufficient depth	 not standardized 50
3	Deviation from hole diameter in zone of pile embedment	-20

Explanatory notes:

1. For prefabricated reinforced concrete load transfer structures, insufficient depth of drilling of not more than 30 millimetres is allowed.

2. Deviations from design dimensions and other data are entered in the log on boreholes and pile installation (Appendix 6).

58. The installation of a pile into a drilled hole is carried out in the summer not more than three hours after completion of the drilling, and in winter, not more than three days after completion of the drilling. Prior to pile embedment the hole must be protected with a removable cover.

59. The hole may be filled with solution at the time of embedment or afterwards. In the first case the pile must be placed in the hole immediately after it is filled with solution. The recommended solutions are given in Table VIII.

In the second case, sand slurry only is used; the slurry must be vibrated during placement. It is essential to ensure that the space between the pile and the walls of the hole is completely filled with slurry.

Table VIII

Recommended slurry compositions

Condition of application	Composition and temperature of slurry at the time of use	Where prepared
With positive air temperatures (autumn - summer period)	Drilling slurry, fine sand Settlement of cone 10-13 cm Not heated	Construction site
With negative air temperatures (spring - winter period)	Clay soil, fine sand, composition 1:4 - 1:12 by volume Settlement of cone 10-13 cm Temperature +30°, +40°C	Slurry mixing site

Explanatory note:

The quality of slurry is controlled by the construction laboratory and is shown in the log of the physico-mechanical properties of slurry (Appendix 7). Temperature measurements of the slurry prior to pile placement are taken by the foreman.

60. It is recommended that the slurry be transported by truck, after which it is discharged into a measuring bin and moved into the drill hole. The quantity of slurry used must be such as to fill completely the space between the piles and the walls of the hole, with allowances for overdrilling and possible enlargement of the drill hole.

61. Prior to placement, the pile must be protected from snow and ice and visually examined. Any water in the hole must be pumped out. The placing of a pile into a hole is carried out by a jib crane or a tower crane. The embedment of a pile takes place usually under its own weight.

Piles Embedded in Ground Thawed Prior to Construction

62. The thawing of the ground at the site of the installation or driving of piles can be accomplished with steam, water, electric current, etc.

The requirements given below apply to thawing by steam points and placing the piles in the ground which has been waterlogged during steam thawing.

63. To thaw the ground with steam, the following equipment and materials are necessary:

(a) steam boiler - recommended types of boilers and their characteristics are given in Appendix 8;

(b) network of steamlines;

(c) steam points;

(d) distributing manifold with flexible hoses for carrying steam to the points;

(e) inventory trestles - crane carriages for placing points and supporting them in a vertical position during embedment.

64. The steam boiler should be placed along the axis of the building being constructed. A temporary structure is set up to accommodate the boiler. The boiler may be left in the open only in the summer or in the fall.

65. Main and distributing steamlines must be placed on low trestles or wood blocks sloping toward the boiler. For convenience of assembly, the distributing steamlines must consist of separate sections and be joined to the main steamline by means of a valve. Plugs are placed on the main steamline at the connections with the distribution lines. It is essential to insulate all steamlines.

The steamlines must be kept in good working order. The escape of steam and the discharge of condensate on the building site must be prevented.

66. The distribution manifold must have the same diameter as the distribution steamlines; outlets for switching on the steam points are welded to it. Valves are fixed onto the outlets of the distribution manifold.

A monometer for registering steam pressure in the steam points is placed in front of the distribution manifold. The steam points are joined to the distribution manifold by flexible high pressure hoses. The steam points and their details are given in Figure 1.

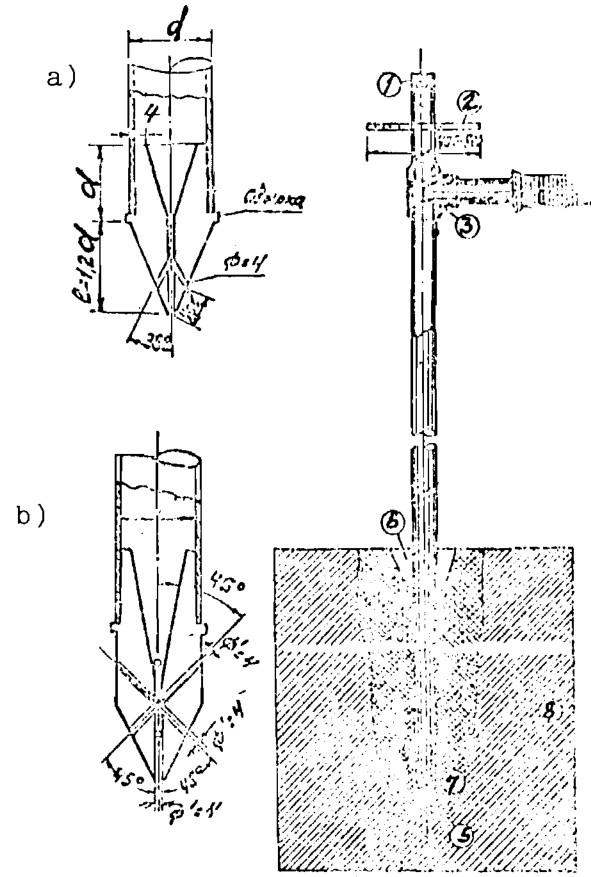


Fig. 1

Construction of steam point

1 - end cap, 2 - handle, 3 - T-joint
4 - flexible hose, 5 - cap, 6 - hole
in frozen ground, 7 - thawed ground,
8 - permafrost; (a) ordinary point,
(b) ripper point

67. To fix the correct position of steam points, it is recommended to excavate holes or use gauges at the pile locations. If it is established by drilling that it will be impossible to penetrate the surface layer of fill with steam points, a trench must be excavated to the entire depth of the fill.

68. The thawing of frozen ground at the pile locations is carried out by one or several steam points working simultaneously. The optimum number of points must be selected by trial and error in relation to the type of ground, temperature and cross-section of the pile.

In determining the number of holes to be steamed simultaneously, the decision must stem from the fact that one steam point must have four to five square metres of heating surface of the boiler.

69. To ensure that the steam points penetrate vertically into the ground, wood or metal trestle-type scaffolding is used; a diagram of the scaffolding is given in Figure 2.

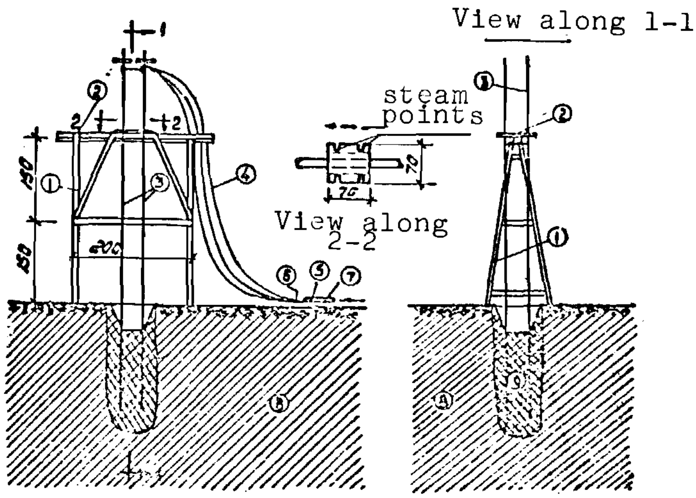


Fig. 2

Scaffolding for mounting steam points

1 - trestle, 2 - platform for steam points,
3 - steam points, 4 - flexible hoses,
5 - distribution manifold, 6 - valves,
7 - distribution steamlines, 8 - frozen
ground, 9 - thawed ground

70. The process of thawing frozen ground is regulated by steam pressure, the length of time that the steam points are in the ground, and the amount of steam that goes through the points.

To obtain the optimum size of talik corresponding to the cross-section of the pile, it is recommended that:

(a) The steam pressure at the distribution manifold, for each steam point (with other points closed) is set at 3 - 4 atmospheres for clay soils without coarse fragmentary material; 4 - 6 atmospheres for sandy soils; 6 - 8 atmospheres for sandy soils with gravel and stones up to 10% by volume.

(b) The length of time one steam point (or group of points) is left at one location is assumed to be up to 10 minutes in clay soils and 15 - 20 minutes in sandy soils; the penetration of steam points, after their exposure at one level, is by rotating them with the help of a handle until they reach frozen ground again.

(c) At the initial moment of thawing the soil, the output of steam is set at the minimum. As the points penetrate deeper into the ground, the steam will stop coming to the surface and at this point the steam output is gradually increased to the maximum for a given pressure.

(d) In clay soils it is possible to use the following methods: the steam point is quickly lowered to the design depth and the thawing of soil occurs during withdrawal of the steam point from the ground in 0.5 metre intervals.

71. The diameter of the thawed zone is set at 10 - 25 cm greater than the cross-section area of the pile.

72. In soils with mixtures of stones or small boulders, steaming is carried out 0.5 - 1.0 metre below the design depth and the steam point is held at this depth for 20 - 30 minutes.

Explanatory note:

When working in such soils, it is expedient to supply the steam point with a sharp cap for loosening the ground, or a cap combined with a chisel.

73. The embedment of piles in previously thawed soils is carried out not more than one day after completion of steam thawing in winter and spring, 2 days - in summer, and 4 days - in autumn.

74. For the embedment of piles, jib or tower cranes are used. The installation of piles is carried out with the aid of a sling with a spring hook. The spring prevents the hook from slipping off a collar fitted onto the pile. For embedment in thawed soil, the pile is dropped abruptly from a height of 2 - 3 metres. In the event of the pile being pinched in the ground, it is necessary to raise it again and drop it abruptly several times to the depth of embedment at the design level or drive it in.

75. If the pile does not go down to the design depth because of the formation of a plug of coarse material at the bottom of the hole, it is necessary to carry out additional thawing of the soil as outlined in section 72, in order to move the coarse material into the thawed ground below the end of the pile.

76. If the piles are installed in the fall, measures must be taken to prevent the piles from heaving during freezing of the active layer; for example, by providing temporary thermal insulation around the piles.

77. Where pile foundations are installed in sandy soils, the embedment of the piles can be carried out simultaneously with the thawing of the ground. The pile, together with the steam points securely attached to it, is placed in the hole. The vertical orientation of the pile is ensured by a pile driver or guides suspended from a crane-type excavator. A diagram for carrying out this work is given in Figure 3.

The pile sinks under its own weight as the soil thaws beneath its end. If the sinking of the pile is insufficient, use may be made of a pile driver or vibrator.

78. The steam thawing of the soil should be started on the higher parts of the construction area and proceed gradually to the lower sections.

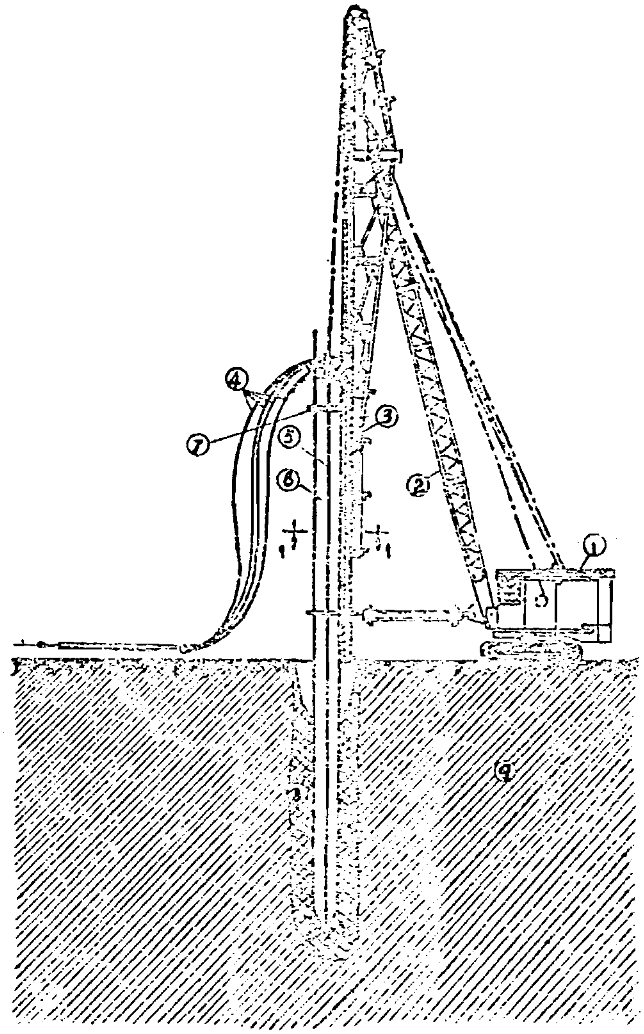


Fig. 3

Installation of pile while ground is being thawed

1 - excavator, 2 - boom, 3 - suspended direction guide, 4 - flexible hoses, 5 - steam points, 6 - pile, 7 - collar for holding points to pile, 8 - thawed ground, 9 - frozen ground

It is essential to maintain continuity of the entire operation which is achieved as follows:

(a) the site is divided into individual sections along the length of building or structure; the number of sections depends on the length of the buildings;

(b) thawing is started in the first section;

(c) while the soil is being thawed in the second section, piles are installed in the first section.

79. Safety regulations in steam thawing operations are worked out and maintained by the construction organization in relation to the method of penetration used, available equipment and other local peculiarities.

In other methods of pile foundation construction use should be made of safety regulations for the corresponding types of work under normal conditions.

80. The contractor must keep a record of all operations involving steam thawing of soil and installation of piles as shown in Appendix 9.

Drill-driven and Driven Piles

81. The drilling of holes or thawing of ground for installing drill-driven piles is carried out as outlined in sections 53, 54, 68 and 70 of this code.

82. The diameter of the hole for drill-driven piles is determined experimentally. Initially, the diameter of the hole or thawed zone is set at 50 mm smaller than the diameter of the pile. The depth of the hole must not exceed the depth of embedment of the pile less the length of its tip.

83. The pile driving is carried out according to existing norms and instructions for work in unfrozen soils.

84. If test driving does not succeed in embedding the pile to the design depth, drill-driven piles should be used.

85. It is expedient to use a large hammer for driving piles in frozen soils with the weight of the hammer being 1.5 times the weight of the pile.

86. The contractor (the superintendent) must keep a record of pile driving operations (Appendix 10).

Construction of Load Transfer Structures

87. In concreting and assembly of load transfer structures it is essential to follow "Provisional Instructions for Construction-Assembly Work in the Far North and Permafrost Regions (VU 2-60)".

88. The construction of a load transfer structure is allowed only after the installallation and acceptance of the piles and not before ground temperature observations have ascertained complete adfreezing of the soil to the piles (mean temperatures below $-0.5^{\circ}C$) within permafrost.

V. ACCEPTANCE OF PILE FOUNDATIONS

89. The acceptance of pile foundations is done by a commission consisting of representatives of the contractor and the client, who check whether the installed pile foundation corresponds to the design and requirements of this code.

90. The construction organization presents the following records to the commission:

(a) factory ratings of reinforced concrete elements (piles, reinforced concrete beams);

(b) the plan of the pile cluster, indicating any deviations of piles from specified positions and double piles (if present);

(c) general report of installed (driven) piles (Appendix 11);

(d) work log (depending on the method used, see Appendices 6, 9 or 10);

(e) certificate of acceptance of reinforcements, records of concrete work, records showing the selection and testing of control samples, and records of electrical and steam heating of concrete (in the case of continuous load transfer, structure and floor);

(f) geodesic layout of pile cluster.

91. The builder (permafrost station) submits to the commission processed temperature data (logs and graphs) sufficient for an understanding of the temperature regime of the soils at the piles and on the construction site.

92. On the basis of the acceptance of pile foundations by the commission, two documents are prepared:

(a) a certificate of acceptance of the pile foundation;

(b) a certificate of examination of permafrost conditions at the piles during the installation of the foundation.

93. Permission to continue construction of the building and loading of the pile foundations is given by the commission on the basis of the estimate of the design strength of the pile, keeping in mind the observed temperature regime of the ground at the pile.

If the temperature regime at the pile differs essentially from the design, the commission notes in the document the thermal technical measures and establishes the possibility of continuing construction with allowances for gradual storey-by-storey loading of the foundation in relation to the re-establishment of the permafrost regime.

The control of recommended heat engineering measures based on these recommendations and an estimate of their effectiveness at various stages of completion are carried out by the permafrost station.

94. The structure is handed over to the client only after the temperature regime of the foundation soil reaches that assumed in the design.

APPENDIX 1

AN EXAMPLE OF DETERMINING THE DESIGN STRENGTH OF THE FOUNDATION SOIL OF A PILE FOR CONDITIONS AT NORIL'SK

A prismatic, 8.0 metre long, reinforced concrete pile with a cross-section of 32 x 32 cm is installed in a drilled hole. The soils are: to a depth of 0.5 metres - coarsely fragmented soil (fill) placed in advance; 0.5 - 5.0 metres - sandy soil; 5.0 - 10.0 metres - clay loam with ice layers of various form and orientation.

The design thickness of the active layer based on the results of long-term geothermal observations at a test site, with allowances for the thermal influence of buildings, is assumed equal to: for clay soils - 1.8 metres, for sandy soils - 2.0 metres, for coarse, fragmented soils - 2.5 metres.

The design temperatures in the zone of embedment of the pile in permafrost were determined from observations in three holes. Mean monthly ground temperatures are given in the table for a period in October, when the depth of thaw was at its maximum.

Depth in m	2	3	4	5	6	7
Temp. in ^{o}C	-0.5	-1.7	-2.8	-3.7	-4.4	-4.8

The design strength of foundation soil is determined from formula (2):

$$P = km\ (u\Sigma S_i^{н}\ l_i + Fp^{н})$$

The values of factors in the formula are: m = 1.0; k = 0.7 (Table II); u = 4 x 0.32 = 1.28 m; F = 0.32 x 0.32 = 0.1 m².

To determine S^H and p^H, we find the design temperatures for individual layers. Let us assume a division into layers of up to 2 metres in thickness. The design temperatures for the various layers are:

$$\text{I layer } t_{p_1} = \frac{-0.5 + -2.8}{2} = -1.65^{o}C$$

we assume that $t_{p_1} = -1.7°C$;

$$\text{II layer } t_{p_2} = \frac{-2.8 + -4.4}{2} = -3.6°$$

we assume that $t_{p_2} = -3.6°C$;

$$\text{III layer } t_{p_3} = \frac{-4.4 + -4.8}{2} = -4.6°C$$

we assume that $t_{p_3} = -4.6°C$.

The design temperature at the lower end of pile is assumed to be $t_{p.o.} = 4.8^{o}C$.

Standard strengths S^H and p^H for the design temperatures are taken from Tables III and IV

$$S_1^H = 13.5 \text{ tons/m}^2, \qquad S_2^H = 23 \text{ tons/m}^2,$$

$$S_3^H = 25 \text{ tons/m}^2, \quad p^H = 100 \text{ tons/m}^2.$$

$$\Sigma S^H l_i = 13.5\times 2 + 23.0\times 2 + 25.0\times 1 = 98$$

Substituting the obtained values into formula (1), we obtain:

$$P = 0.7\times 1\ (1.28\times 98 + 0.1\times 100) = 94.8 \text{ tons}.$$

For approximate calculations, the design temperature can be taken as the arithmatic mean of temperatures observed at various depths in the zone of pile embedment.

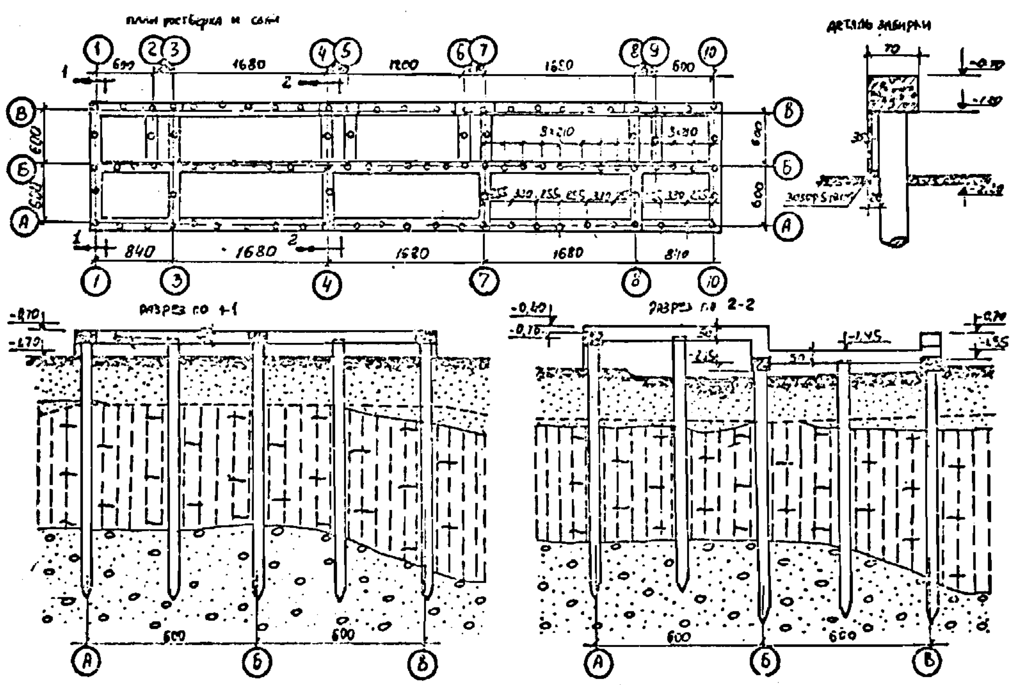
$$t_p = \frac{-(0.5+1.7+2.8+3.7+4.4+4.8)}{6} = -2.98^\circ C.$$

Let us assume that $t_p = -3.0^\circ C$, $S^H = 20$ tons/m². In this case the design strength of the foundation soil is equal to

$$P = 0.7\times 1.0\ (1.28\times 20\times 5 + 0.1\times 100) = 96.6 \text{ tons}.$$

APPENDIX 2

AN EXAMPLE OF A DESIGN OF A PILE FOUNDATION FOR A SERIES 1-447 BUILDING



APPENDIX 3

TECHNICAL CHARACTERISTICS OF PERCUSSION POWER DRILL

Specifications	"Uralets" BU-2	"Uralets" BS-2	BU 20-2M
Diameter of drill, in mm	300	300*	400*
Weight of drill, in kg	850-1300	1700	1200
Height of hoist above drive, in mm	450-1000	500-760	520-700
Number of blows per minute	52-54	48-52	50-52
Rate of movement, in km/hr	0.9	0.9	0.9
Specific pressure on ground, kg/cm^2	0.58	0.7	-
Electric motor (type)	MA-203-2/6	MA-204-2/6	A-72-6
Revolutions of drum per minute	975	930	960
Power, in kilowatts	20	32	20
Composition of crew (Noril'sk experience), men	2	2	2
Output of machine (standards for Noril'sk combine)**			
Running m/hr in soils			
III category		1.5	1.20
IV category		0.7	0.55
V category		0.3	0.25
Cost of drilling in rubles per linear metre in soils:			
III category		3.20	
IV category		5.20	6.33
V category		10.21	11.28
(Estimates of Noril'sk combine)			

* The machines work in Noril'sk with reconditioned factory bits, 350 and 400 mm in diameter. Hence standards and estimates are given for holes 350 and 400 mm in diameter.

** IV category: thawed gravelly-stony soils, very dense clays, slates and marls; frozen soils - clay loam, sandy loam; V category: frozen gravelly-stony soils.

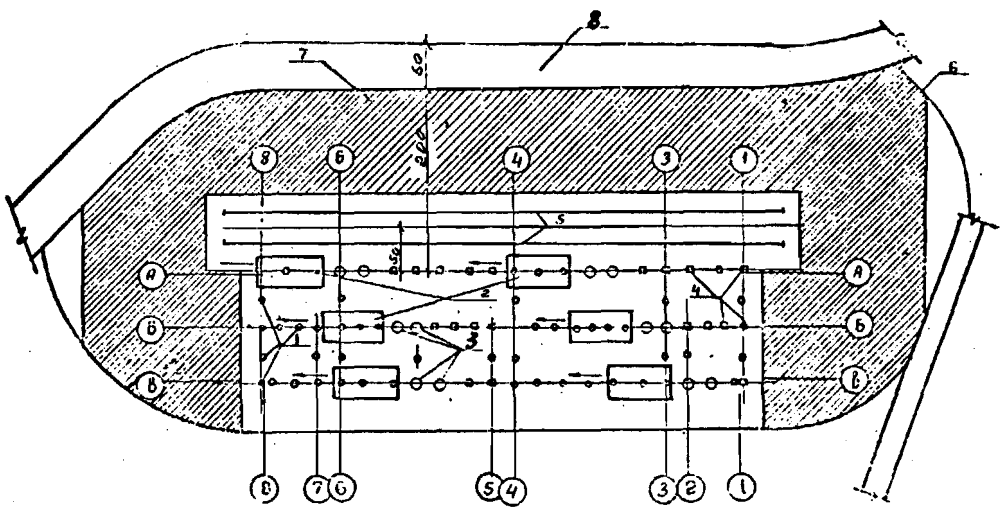
APPENDIX 4

TECHNICAL CHARACTERISTICS OF ROTARY POWER DRILLS

Specifications	BTS-2	ShAK-2
Diameter of drill, in mm	Up to 350	250
Depth of drill, in m	Up to 30	Up to 40
Operation of drill	Mechanical	Mechanical
Carrier	Tractor S-80	Tractor S-80
Man production	Yes	No
Output in m/hr in frozen clays and sands (IV category)	3 - 4	-

APPENDIX 5

PILE INSTALLATION IN DRILLED HOLES



1 - pins for fixing holes; 2 - percussion drills; 3 - drilled holes; 4 - piles installed in drilled holes; 5 - crane route; 6 - outline of area covered by boom of tower crane; 7 - storage area; 8 - temporary road

APPENDIX 6

Name of construction organization Drill ________________ Type & size

________________________________ Bits ________________________

Project ________________________ Crane for embedding piles ____________

Type and dimensions of piles ____________

Temperature of frozen ground ____________

____

WORK LOG

For drilling holes and installing piles

No.	Date of drilling	No. of holes on plan	Drilling of holes		Depth of holes, m		Depth of pile embedment, m		Remarks	Foreman's signature
			Start hours	Finish hours	design	actual	design	actual		
1	2	3	4	5	6	7	8	9	10	11

APPENDIX 7

Name of construction organization ________________

LOG

Physico-mechanical properties of clay-sand slurry

Construction project	Date	Fractions		Unit weight gm/cm³	Moisture content by weight in %	Plasticity (settlement cone)	Temperature of slurry	Signature
		>0.1 мм	<0.1 мм					
1	2	3	4	5	6	7	8	9

APPENDIX 8

Technical characteristics of steaming arrangement for pile installation

Specifications \ Types of boilers	Vertical boilers			Portable		
	ShS-2	ShS-4	VTKB 0.5-8	P-38	P-1	P-75
Steam output, kg/hr	400—455	1000	400—500	250	270	850
Maximum pressure, atm	8	8	8	15	12	12
Heating surface, m^2	15.7—16.2	27—38	13.7—14.5	10.15	10.8	21
Length (in mm)	—	—	—	4050	3890	4380
Width (in mm)	—	—	—	1560	1770	1990
Height (in mm)	3000	3689—3633	4165	2530	2880	3150
Outside diameter, mm	1156	1544—1450	1424	—	—	—
Weight, kg	2080—2300	4190	3910	3600	5350	7500

APPENDIX 9

WORK LOG

For thawing ground and installing piles

Name of construction organization ______

Project ______

Type of boiler, heating surface, m^2 ______

Steam pressure, atm ______

Crane for installing piles ______

Type and dimensions of piles ______

Date	No. of piles on plan	Steam pressure in distribution manifold, atm	No. of steam points used simultaneously	Type of steam point	Time of passage of steam point through one depth	Time of ground thawing in hrs: Beginning	Time of ground thawing in hrs: End	Date of pile installation	Height of installed pile: Design	Height of installed pile: Actual	Average diameter of thawed zone, in cm	Remarks	Signature of foreman
1	2	3	4	5	6	7	8	8a	9	10	11	12	13

Explanatory note: Log is filled out on each shift. The reasons for not reaching the specified depth of embedment and the duration of additional steam thawing around installed pile are noted in column 12.

APPENDIX 10

Name of construction organization ____________________

Project (structure) ____________________

LOG

For installing driven and drill-driven piles

Pile driver ____________________

Type of hammer ____________________

Weight of percussion part of hammer ____________________

Energy of blow of diesel-hammer (rated) ____________________

Steam (air) pressure in cylinder ____________________

Material of pile ____________________

Permafrost conditions ____________________

____

Diameter of first hole ____________________

Method of advancing holes ____________________

____

____

____

____

Pile no. ____________________

No. of pile as manufactured ____________________

Length of pile, m ____________________

Cross-section of pile, cm ____________________

Surface elevation at pile ____________________

Depth of lower end of pile ____________________ (design)

____________________ (actual)

Duration of operation of hammer, minutes ____________________

Steam (air) pressure (manometer reading) ____________________

No.	Height of lift of percussion part of hammer, in cm	No. of ground section	Number of blows in the ground section	Depth of pile embedment, in cm	Refusal, in cm	Remarks

Signature: ____________________

APPENDIX 11

Name of construction organization ____________________

Project ____________________

Composite record of installed piles

No.	No. of pile: On the plan	No. of pile: As manfactured	Length of piles, in cm	Cross-section of pile in m^2	Date of instal-lation	Depth of embed-ment, in m: Design	Depth of embed-ment, in m: Actual	Absolute eleva-tions: Ground surface	Absolute eleva-tions: Pile tip	Deviation from design height, cm	Deviation of piles, in cm: Along axis	Deviation of piles, in cm: Across axis	Refusal, in cm, For driven & drill-driven piles: On driv-ing	Refusal, in cm, For driven & drill-driven piles: On addi-tional driving	Remarks (method of installing piles, equipment used)
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16

Signature: ____________________

APPENDIX 12

RECOMMENDATIONS FOR TESTING PILES UNDER STATIC LOADS

1. The necessity of carrying out static tests on experimental piles, their number and design, is established by the planning organization in relation to the available experience, purpose of construction and working conditions.

The tests are carried out by the planning organization with the participation of the permafrost station or research organization where necessary.

The cost of static tests is included by the planning organization in the construction estimates.

2. The equipment for testing the piles is specified in the plan. The recommended installation for testing piles in axial compressive loading is given in Figure 4. Figure 5 shows the reference installation.

3. The ultimate strength of foundation soils of the pile is determined when the ground temperature reaches its maximum at the time of greatest thaw of the active layer in the autumn.

4. The tests are carried out on the construction site after the engineering preparations have been completed.

5. To eliminate the effect of the active layer, the pile may be separated from the ground during tests within the design thickness of the active layer and the resultant space filled with material of low thermal conductivity.

6. The test pile must be provided with a tube for possible temperature measurements along the pile and at its lower end. The location of additional temperature holes at the testing installation is indicated on the plan.

7. The pile tests are allowed to begin when it is established that the thermal regime in the foundation soils is close to that specified.

8. Loading of the experimental pile is carried out in stages. The first two stages of loading are assumed equal to 0.5 P, where P is the design strength of foundation soils determined according to section 23.

The subsequent stages are assumed equal to 0.5 P. Each stage of loading is continued until settlement ceases but for not less than 3 days.

The settlement of the pile of not more than 0.5 mm during the last day of the tests is taken as attenuating settlement, which makes it possible to proceed to the next loading stage.

9. The pile tests are stopped if continuous settlement greater than 0.5 mm per day is observed in one stage of loading over a 10-day period.

10. The unloading of the pile is carried out in stages equal to the loading stages, with each stage lasting at least one day.

11. The tests establish the following:

(a) the ultimate strength of the pile, equal to the load under which the pile continues to settle for a period of 10 days at a rate equal to or somewhat exceeding 0.5 mm per day;

(b) design settlement - the settlement under the design load;

(c) the rate of settlement of the pile during each stage of loading;

(d) elastic and residual deformation of the pile.

12. During the pile tests, records are kept in accordance with GOST 5685-51. Test records must contain the following:

(a) observation logs of ground temperatures and pile settlements;

(b) "settlement vs. loading" curve constructed on a scale: 1 cm = 1 mm of settlement, 1 cm = 5 tons of load;

(c) settlement vs. time curve on a scale: 1 mm = 1 hr, 1 cm = 1 mm of settlement;

(d) rate of pile movement vs. time curve on a scale: 1 mm = 0.2 mm/hr, 1 mm = 1 hr;

(e) a soil profile showing the soil types, main properties and thickness of soil layers;

(f) temperature profiles and graphs of isopleths in the soil at the pile;

(g) temperature graphs of foundation soils at the moment when the piles reach their ultimate condition.

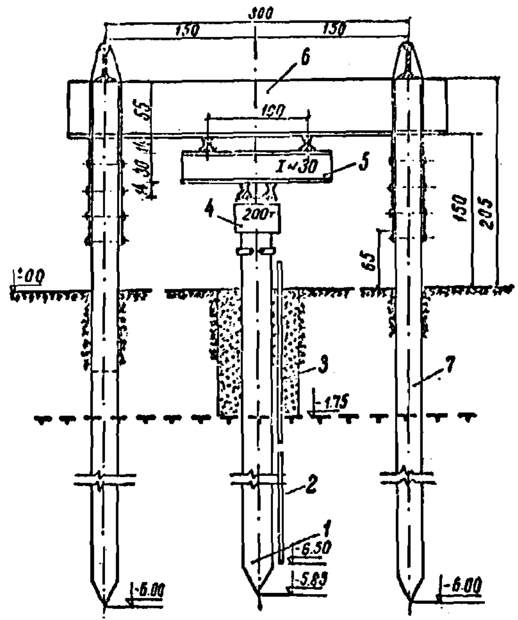


Fig. 4

Arrangement for testing piles

1 - pile being tested, 2 - pipe for temperature measurement, 3 - thermal insulation, 4 - jack, 5 - regulating beam, 6 - main beam, 7 - anchor piles

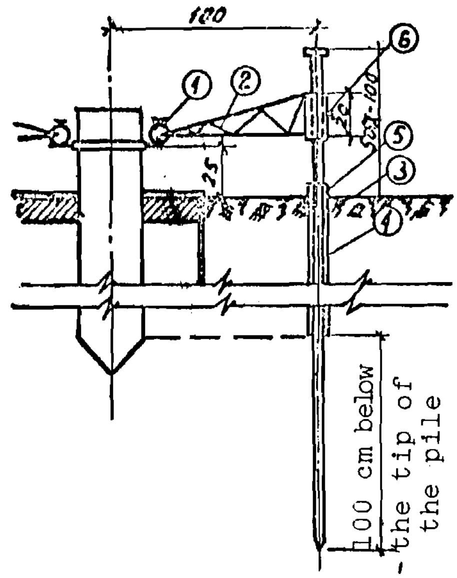


Fig. 5

Construction of reference installation

1 - indicator, 2 - reinforcing truss, 3 - casing, 4 - reference pipe, 40 mm diameter, 5 - clearance between pipes filled with grease, 6 - clamp to hold truss