

STRUCTURAL STRENGTH AND STABILITY ASSESSMENT, RISKS AND POTENTIAL HAZARDS IN THE ARCTIC ENVIRONMENT

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Abstract

The paper deals with the assessment of the strength and stability of structures in Arctic soil conditions. The main attention is paid to the unique properties of such soils, which affect the reliability of structures. These include extremely low temperatures, permafrost, high humidity and the presence of permafrost. It is noted that the existing methods for assessing strength and stability require further development and adaptation. The specifics of Arctic soils should be taken into account when choosing research methods and approaches. The operation of structures in the Arctic is associated with risks of deformation and destruction due to loads associated with soil features. Problems may also occur due to changes in temperature and humidity. To reduce risks and improve the reliability of structures, it is proposed to develop and implement comprehensive security measures. They should take into account the specifics of Arctic soils at all stages—from design to operation of infrastructure facilities. This may include the use of special materials, the adaptation of design solutions, and the development of new methods for monitoring the state of structure. The results of the study can be useful in the design and operation of facilities in the Arctic, as well as in the development of regulatory documents and standards for construction in difficult ground conditions. This will ensure the safety and efficiency of structures in extreme climatic conditions.

Keywords: strength, calculations, construction, arctic soils, stability, safety.

I. Introduction

In the conditions of the Far North, the construction and operation of engineering structures face a number of unique challenges related to the peculiarities of Arctic soils. One of the key aspects determining the success of projects in this region is the calculation of the strength and stability of structures, taking into account the specifics of interaction with soils. The purpose of this study is to carry out calculations aimed at assessing the strength and stability of engineering structures in Arctic soil conditions. To achieve this goal, calculation methods have been developed that take into account the specific characteristics of the region. As part of the study, calculations were carried out aimed at determining the main parameters affecting the strength and stability of structures when interacting with Arctic soils. Aspects such as the mechanical properties of soils, their deformation characteristics, as well as the influence of climatic factors on soil behavior were studied. The results obtained make it possible to more accurately assess the behavior of engineering structures in the Far North and develop measures to ensure their strength and stability. Further research in this area can contribute to more efficient use of the Arctic territories and reduce the risks associated with the operation of engineering structures in this region.

II. Methods

Methods for calculating the strength and stability of structures in Arctic soils [6; 7; 19]:

1) Preparatory stage:

- Study of technical documentation and data on soil characteristics in the construction area.
- Collecting information about previous research and construction experience in similar conditions.
- Determination of the type and dimensions of the structure, as well as its operating conditions.

2) Strength calculation:

- Determination of the effective loads on the structure [1; 2; 3].
- Calculation of stresses in the structural material [4; 5; 8].
- Comparison of the obtained values with the permissible strength values [4; 16].
- If necessary, adjust the size or material of the structure.

3) Stability calculation:

- Determination of soil parameters (adhesion, angle of internal friction, density, etc.).
- Calculation of soil stability under the influence of structural loads [6].
- Comparison of the obtained values with the stability criteria.
- If necessary, additional soil studies [6; 7].

4) Analysis of the results:

- Evaluation of the obtained values of strength and stability.
- Comparison with the results of previous research and construction experience.
- Identification of possible risks and problems.

5) Recommendations:

- Development of measures to ensure the strength and stability of the structure.
- Making changes to the project or construction technology.
- Monitoring compliance with recommendations at all stages of construction.

6) Further research:

- Conducting additional studies of the soil and structures in similar conditions.
- Collecting data on the behavior of structures during operation.
- Analysis of the results obtained and development of recommendations for future projects.

This method makes it possible to more accurately assess the behavior of engineering structures in the Far North and develop measures to ensure their strength and stability. Further research in this area can contribute to more efficient use of the Arctic territories and reduce the risks associated with the operation of engineering structures in this region. With the help of non-destructive testing, you can find out the strength of reinforced concrete structures of a building and for this purpose an ultrasonic method was used which measured the speed of ultrasound vibrations with "UK-1401" tester (see Figure 1, 2) [8; 10; 12; 14].



Figure 1: Building in the Arctic zone and in which the measurements of the structures were carried out



Figure 2: Ultrasonic tester UK-1401 [9]

After ultrasonic measurements, the measurement points of reinforced concrete structures are shown in the diagrams (see figure 3-4).

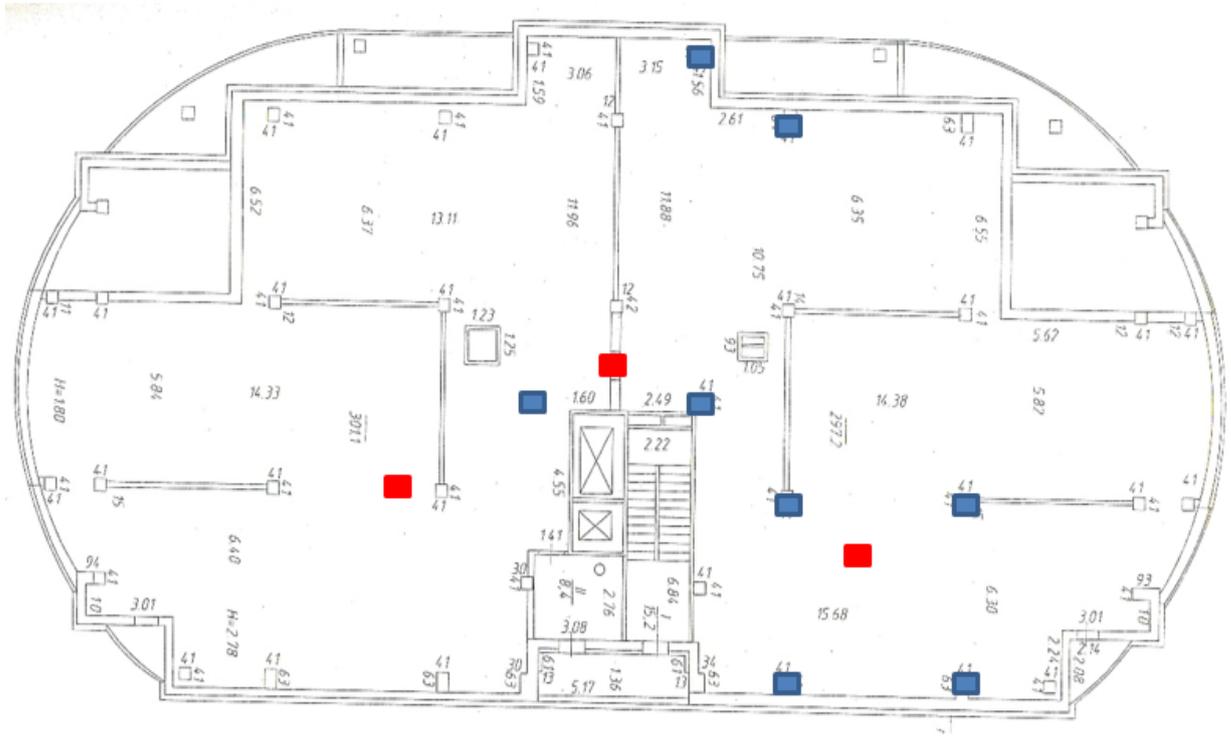


Figure 3: The scheme of ultrasound examinations of the technical floor of the building (blue-reinforced concrete columns; red-reinforced concrete slabs)

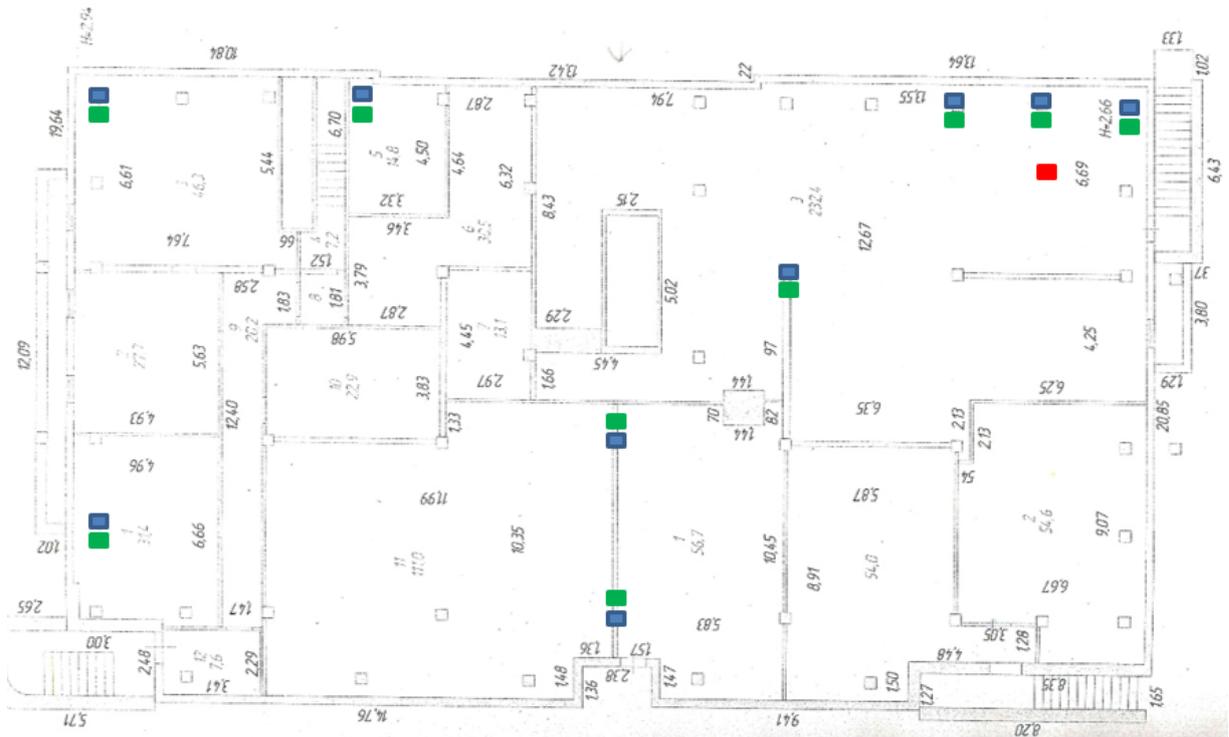


Figure 4: The scheme of ultrasound examinations of the basement of the building (blue-reinforced concrete columns; green-reinforced concrete grilling's; red-reinforced concrete slabs)

III. Results

To more accurately determine the strength of reinforced concrete structures, the obtained speed values are set in the formula

$$R=0,016 \times V-27,3 \quad (1)$$

According to the obtained data on the speed of ultrasound transmission, the formula can be used to estimate the strength of materials of structural elements of a building [1; 2]. The obtained strength values are converted to the concrete grade or class. The results of ultrasound examinations are presented in Table 1, 2.

Table 1: The results of the ultrasound examination of the structural elements of the technical floor of the building (see mfigure 3)

Segment	Value			Arithmetic mean.	Sigma	0,95	Average, strength, MPa
	1	2	3				
reinforced concrete column, point No 1							
1	2120	2130	2150	2133,33	15,28	2108	14,60
2	2090	2080	2090	2086,67	5,77	2077	14,39
3	2110	2120	2130	2120,00	10,00	2103	14,57
Mean value							14,52
reinforced concrete column, point No 2							
1	2560	2580	2590	2576,67	15,28	2551	17,70
2	2530	2510	2510	2516,67	11,55	2497	17,33
3	2050	2090	2080	2073,33	20,82	2038	14,12
Mean value							16,38
reinforced concrete column, point No 3							
1	2290	2230	2300	2273,33	37,86	2210	15,31
2	2300	2310	2330	2313,33	15,28	2288	15,86
3	2090	2080	2070	2080,00	10,00	2063	14,29
Mean value							15,16
reinforced concrete column, point No 4							
1	2110	2130	2150	2130,00	20,00	2096	14,52
2	2160	2170	2180	2170,00	10,00	2153	14,92
3	2230	2230	2210	2223,33	11,55	2204	15,28
Mean value							14,91
reinforced concrete column, point No 5							
1	2670	2630	2650	2650,00	20,00	2616	18,16
2	2610	2600	2610	2606,67	5,77	2597	18,03
3	2160	2180	2170	2170,00	10,00	2153	14,92
4	2130	2130	2140	2133,33	5,77	2124	14,71
Mean value							16,46
reinforced concrete column, point No 6							
1	2350	2370	2380	2366,67	15,28	2341	16,23
2	2300	2340	2330	2323,33	20,82	2288	15,87
3	2180	2180	2170	2176,67	5,77	2167	15,02
Mean value							15,71
reinforced concrete column, point No 7							
1	2180	2190	2200	2190,00	10,00	2173	15,06
2	2130	2140	2150	2140,00	10,00	2123	14,71
3	2130	2130	2170	2143,33	23,09	2104	14,58
Mean value							14,78
reinforced concrete column, point No 8							

Segment	Value			Arithmetic mean.	Sigma	0,95	Average, strength, MPa
	1	2	3				
1	1930	1970	1990	1963,33	30,55	1912	13,23
2	2020	2050	2050	2040,00	17,32	2011	13,92
3	2130	2130	2140	2133,33	5,77	2124	14,71
Mean value							13,96
reinforced concrete slabs, point No 1							
1	2170	2180	2170	2173,33	5,77	2164	14,99
2	2270	2230	2210	2236,67	30,55	2185	15,14
3	2500	2530	2580	2536,67	40,41	2469	17,13
4	2510	2510	2520	2513,33	5,77	2504	17,37
Mean value							16,16
reinforced concrete slabs, point No 2							
1	2310	2340	2380	2343,33	35,12	2284	15,84
2	2310	2290	2280	2293,33	15,28	2268	15,72
3	2130	2130	2140	2133,33	5,77	2124	14,71
4	2520	2510	2530	2520,00	10,00	2503	17,37
5	2410	2480	2430	2440,00	36,06	2379	16,50
6	2390	2370	2380	2380,00	10,00	2363	16,39
Mean value							16,09
reinforced concrete slabs, point No 3							
1	2180	2160	2170	2170,00	10,00	2153	14,92
2	2130	2150	2160	2146,67	15,28	2121	14,69
3	2230	2180	2170	2193,33	32,15	2139	14,82
Mean value							14,81

Conclusion:

- the strength of reinforced concrete columns has a range of values from 13,96 – 16,46 MPa (up to 15% of the maximum), the average values range from 13,23 – 18,16 MPa, which corresponds to concrete classes B10 – B12,5;

- the strength of reinforced concrete floor slabs has a range of values from 14.69 – 17.37 MPa (up to 15% of the maximum), the average values range from 14.81 – 16.16 MPa, which corresponds to concrete classes B10 – B12.5.

Table 2: The results of the ultrasound examination of the structural elements of the basement of the building (see figure 4)

Segment	Value			Arithmetic mean.	Sigma	0,95	Average, strength, MPa
	1	2	3				
reinforced concrete column, point No 1							
1	2530	2570	2540	2546,67	20,82	2512	17,43
2	2880	2890	2880	2883,33	5,77	2874	18,68
3	2700	2770	2730	2733,33	35,12	2674	18,57
Mean value							18,22
reinforced concrete column, point No 2							
1	2440	2360	2300	2366,67	70,24	2248	15,59
2	3020	3080	3030	3043,33	32,15	2989	20,53
3	2960	2940	2940	2946,67	11,55	2927	19,54
Mean value							18,55
reinforced concrete column, point No 3							
1	3030	3010	3050	3030,00	20,00	2996	20,64
2	2560	2570	2570	2566,67	5,77	2557	17,75
3	2540	2530	2410	2493,33	72,34	2371	16,45

Segment	Value			Arithmetic mean.	Sigma	0,95	Average, strength, MPa
	1	2	3				
Mean value							18,28
reinforced concrete column, point No 4							
1	2940	2950	2930	2940,00	10,00	2923	19,47
2	2880	2870	2830	2860,00	26,46	2815	17,75
3	2660	2640	2630	2643,33	15,28	2618	18,17
Mean value							18,46
reinforced concrete column, point No 5							
1	2200	2230	2240	2223,33	20,82	2188	15,17
2	2300	2310	2320	2310,00	10,00	2293	15,90
3	2340	2300	2310	2316,67	20,82	2282	15,82
Mean value							15,63
reinforced concrete column, point No 6							
1	2330	2340	2300	2323,33	20,82	2288	15,87
2	2350	2300	2220	2290,00	65,57	2179	15,10
3	2190	2180	2170	2180,00	10,00	2163	14,99
Mean value							15,32
reinforced concrete columns, point No 7							
1	2300	2310	2340	2316,67	20,82	2282	15,82
2	2320	2310	2310	2313,33	5,77	2304	15,97
3	2200	2180	2180	2186,67	11,55	2167	15,02
Mean value							15,60
reinforced concrete column, point No 8							
1	2850	2830	2840	2840,00	10,00	2823	17,87
2	2750	2740	2730	2740,00	10,00	2723	18,91
3	2700	2750	2720	2723,33	25,17	2681	18,61
Mean value							18,46
reinforced concrete column, point No 9							
1	2840	2830	2850	2840,00	10,00	2823	17,87
2	2400	2450	2470	2440,00	36,06	2379	16,50
3	2700	2750	2730	2726,67	25,17	2684	18,64
Mean value							17,67
reinforced concrete slabs, point No 1							
1	2300	2290	2300	2296,67	5,77	2287	15,86
2	2970	2950	2940	2953,33	15,28	2928	19,54
3	2280	2270	2270	2273,33	5,77	2264	15,69
Mean value							17,03
reinforced concrete grillwork, point No 1							
1	2370	2380	2330	2360,00	26,46	2315	16,06
2	2900	2970	2980	2950,00	43,59	2877	18,72
3	2350	2340	2330	2340,00	10,00	2323	16,11
Mean value							16,96
reinforced concrete grillwork, point No 2							
1	1950	1970	1970	1963,33	11,55	1944	13,46
2	2040	2040	2050	2043,33	5,77	2034	14,08
3	2240	2270	2240	2250,00	17,32	2221	15,39
Mean value							14,31
reinforced concrete grillwork, point No 3							
1	2110	2120	2120	2116,67	5,77	2107	14,60
2	2160	2130	2150	2146,67	15,28	2121	14,69
3	2020	2080	2060	2053,33	30,55	2002	13,86
Mean value							14,38

Segment	Value			Arithmetic mean.	Sigma	0,95	Average, strength, MPa
	1	2	3				
reinforced concrete grillwork, point No 4							
1	2140	2150	2170	2153,33	15,28	2128	14,74
2	2220	2300	2310	2276,67	49,33	2194	15,20
3	2350	2340	2330	2340,00	10,00	2323	16,11
Mean value							15,35
reinforced concrete grillwork, point No 5							
1	2460	2470	2480	2470,00	10,00	2453	17,02
2	2430	2430	2400	2420,00	17,32	2391	16,58
3	2110	2120	2150	2126,67	20,82	2092	14,49
Mean value							16,03
reinforced concrete grillwork, point No 6							
1	2140	2150	2170	2153,33	15,28	2128	14,74
2	2180	2150	2200	2176,67	25,17	2134	14,79
3	2220	2230	2220	2223,33	5,77	2214	15,34
Mean value							14,96
reinforced concrete grillwork, point No 7							
1	2090	2070	2080	2080,00	10,00	2063	14,29
2	2190	2170	2180	2180,00	10,00	2163	14,99
3	2200	2210	2220	2210,00	10,00	2193	15,20
Mean value							14,83
reinforced concrete grillwork, point No 8							
1	1940	1970	1950	1953,33	15,28	1928	13,34
2	2010	2020	2030	2020,00	10,00	2003	13,87
3	2050	2070	2030	2050,00	20,00	2016	13,96
Mean value							13,72
reinforced concrete grillwork, point No 9							
1	2140	2150	2170	2153,33	15,28	2128	14,74
2	2110	2120	2130	2120,00	10,00	2103	14,57
3	2170	2180	2190	2180,00	10,00	2163	14,99
Mean value							14,77

Conclusion:

- the strength of reinforced concrete columns ranges from 14.99 – 20.64 MPa (up to 27% of the maximum), with average values ranging from 15.32 – 18.55 MPa, which corresponds to concrete grades B12.5 – B15;

- the strength of reinforced concrete slabs has a range of values from 15.69 – 19.54 MPa (up to 20% of the maximum), the average value is 17.03 MPa, which corresponds to the concrete class B12.5;

- the strength of reinforced concrete grillings has a range of values from 13.34 – 18.72 MPa (up to 29% of the maximum), the average values range from 13.72 – 16.96 MPa, which corresponds to concrete classes B10 – B12.5.

IV. Conclusions

The following results were obtained during ultrasound method of examination (see Table 3) [13; 17; 18].

Table 3: *General results of ultrasound examination of building structural elements*

Segment	Structural element	Concrete class (taking into account the influence of the plaster layer)	Range of values in % of the maximum
Technical floor	reinforced concrete columns	B10-B12,5	To 15%
	reinforced concrete floor slabs	B10-B12,5	To 15%
Basement	reinforced concrete columns	B12,5-B15	To 27%
	reinforced concrete floor slabs	B12,5	To 20%
	reinforced concrete grillings	B10-B12,5	To 29%

According to the requirements of the norms p. 6.1.6 "For reinforced concrete structures, the concrete compressive strength class should be used not lower than B15" SP 63.13330.2018 "Concrete and reinforced concrete structures", the results of the survey show that the strength of structural elements exceeds the standard values [2; 11; 15].

As a result of calculations of calculations of structural strength and stability in Arctic soil conditions, the following conclusions can be drawn:

- Arctic soils have unique properties that significantly affect the strength and stability of structures. These properties must be taken into account when designing and building in the Arctic.
- Existing methods for assessing strength and stability in Arctic soil conditions have the following advantages: it has its own limitations and needs to be improved based on the specifics of the region.
- The operation of structures in the Arctic is associated with a number of risks and potential hazards, including extreme climatic conditions, permafrost, cryogenic processes.
- To reduce risks and improve the reliability of structures, it is necessary to develop and implement comprehensive approaches that take into account the specifics of Arctic soils. This may include the use of special materials, the adaptation of design solutions, and the development of new methods for monitoring and controlling the condition of structures.
- The results of the study can be used in the design and operation of facilities in the Arctic, as well as in the development of regulatory documents and standards for construction in difficult ground conditions. This will ensure the safety and efficiency of structures in the region.

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