GC21D-0871

Human-Modified Permafrost Complexes in Urbanized Areas of the Russian North

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Assessment of the level of deformation of buildings and structures on the Russian permafrost

Deformed (assessment by the beginning of XX century)

- Yakutsk – 48% (without old wooden houses)
- Vilyuysk – appr. 70%
- Tiksy – 22 %
- Vorkuta – 80 %
- Chita – 60 %
- Small towns of Buryatia – 50 -70 % (without old wooden houses)
- Dudinka – 35 % (without old wooden houses)
- Norilsk – appr 25 %
- Igarka – appr 60 % (and appr 100 % for old wooden houses)
- Amderma – 50 %
- Dickson – 35 % (without old wooden houses)
- Pevek - 50 %
- Urban settlements of Magadan region – 40 - 55 %
- Ethnical villages of the Far North – close to 100%
- Small ground dams with frozen antifiltration cores – close to 100%

(By Y. Kronik (2001, 2006, 2011), V. Zemal (2006), L. Khrustalev (2000, 2006, 2011), V. Grebenets (2000, 2009), V. Gur'anov (2007), D. Shesternev (2007), N. Kutvitskaya (2000, 2005))

During 1997 - 2007 GG in the Norilsk industrial region about 30 large 5-and 9-storey residential buildings have been subjected to time-consuming dismantling

Dismantling of a 9-storey house on the street Laureates in Norilsk after 21 years of operation, 2001
Photo by A. Maslakov

Deformation of buildings and structures in permafrost caused by a complex of reasons:

a) regarding the "objective" - global or regional climate change, disaster processes, unpredictable development of dangerous cryogenic engineering processes under the influence of technogenic and others;

b) the "subjective" - a variety of errors and irregularities in the implementation of survey, design, construction and operation of facilities; worsening socio-economic situation in the northern regions, etc.

Geotechnical stability of the environment and the stability of permafrost and environmental situation is determined by:

A) natural conditions, primarily permafrost;

B) Technogenic impact:
-Type of impact;
- Intensity (temperature of the contact);
- Extensive factor (square of the contact);
duration of exposure

Deformation of engineering structures on permafrost

Objective:
- global or regional climate trends;
- disaster processes

Subjective:
- hazardous cryogenic processes;
- reducing the bearing capacity of foundations frozen with climatic trends and buildup technogenesis;
- activation of frost heaving in the seasonally thawed layer

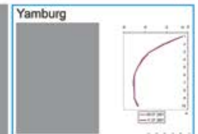
Changing permafrost within urban territories

On permafrost conditions in the cities affected by the type, structure and density of development, methods of installation of foundations, modes of operation of the facilities, the conditions of the surface water disposal, etc.

Progress outdoor temperature in Dixon in Norilsk: no trends to climate warming in the region

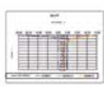
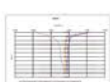
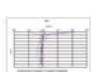
However, measurements in a deep well (1959 - 1985 years) in the center of Norilsk show a rise of soil temperature at a depth of 20-60 m in the 0.5-1°C

Yamburg



Norilsk

Conditions in cities: Man-caused flooding heating + saline ground water in the seasonally thawed layer of snow deposits redistribution + the accumulation of "cultural layer" + ...

№	Natural-technogenic geocryological complexes	Activation of processes	Ground temperature change
1	Linearly stretched flooded areas along the roads along the pipeline	Frost heave, frost cracking, water logging, increase inactive layer	
2	Linearly extended relatively drained areas in violation of the moss-plant cover and mechanical action on the underlying soils (around poles - thermostabilization)	Potential increase in active layer with a possible increase of thermokarst and thermal erosion	
3	Flooded areas in the depressions caused by the installation of piles	Potential change in active layer, bulging piles, water-logging	
4	Linearly extended portions of the breakdown of vegetation	Potential change in active layer, frost cracking	
5	Cluttered areas after parking camps builders with disturbed vegetation	Potential change in active layer, frost cracking	
6	Areas with peat substitute for sandy soil	Potential change in active layer	
7	Cutting of heaving mounds and peat (bearings with termo-stabilization)	Potential change in active layer, frost cracking, frost heave, waterlogging	
8	Areas with frost cracking peatlands formed as a result of cutting of vegetation	Potential change in active layer, frost cracking, frost heave, waterlogging, degradation of permafrost	
9	Linearly extended sites including replacement of soil on non-heaved and unsettled	Potential change in active layer	
10	Linearly extended areas with carved track for a pipeline	Potential change in active layer, frost cracking, frost heave, waterlogging,	

№	Natural-technogenic geocryological complexes	Activation of processes	Ground temperature change
11	Linearly extended the mound for the protection of the thermokarst lakes	Potential change in active layer, frost cracking, frost heave, waterlogging	
12	Artificial decrease linearly extended (without temperature stabilization of soils)	Potential change in active layer, frost cracking, frost heave, gullying	
13	Linearly extended areas with gravel backfill soil cut	Potential change in active layer	
14	Linearly extended under the road embankment	Potential change in active layer, frost cracking, frost heave, waterlogging	
15	Linearly extended waterlogged sites	Degradation of permafrost, frost heave	
16	Linearly extended areas with active gully along the road	Potential change in active layer, frost cracking, frost heave, waterlogging	
17	Lots of failures of soil around the pile	Potential change in active layer, frost cracking, frost heave	
18	Linearly extended waterlogged areas along the pipeline	Potential change in active layer, frost heave, waterlogging, degradation of permafrost	
19	Linearly extended areas with protection from thermal erosion	Potential change in active layer	
20	Linearly extended areas with trenches along the pipeline to cracking along the sides of the trench	Potential change in active layer, frost cracking, frost heave, waterlogging,	

№	Natural-technogenic geocryological complexes	Activation of processes
21	Linearly extended areas with trenches along the pipeline to cracking along the sides of the trench and waterlogging	Potential change in active layer, frost cracking, frost heave, waterlogging, degradation of permafrost
22	Linearly extended areas with trenches along the pipeline to cracking along the sides of the trench and pipeline drawdown	Potential change in active layer, frost cracking, frost heave, waterlogging, degradation of permafrost
23	Linearly extended areas with bare pipe and extra-weight	Potential change in active layer, frost cracking, frost heave, waterlogging
24	Linearly extended pipe runs from the bed of the stream	Potential change in active layer, frost cracking, frost heave, waterlogging
25	Linearly extended pipe runs with a protective cushion	Potential change in active layer, subsidence
26	Areas with tile erosion protection	Potential change in active layer
27	Linearly extended sections of the pipeline with watered trenches	Potential change in active layer, frost cracking, frost heave, waterlogging
28	Linearly extended pipe runs with it's ascent	Potential change in active layer, termoabrasion
29	Areas after a fire near the pipeline	Potential change in active layer, frost cracking, frost heave
30	Bankings of sand under the facilities	Potential change in active layer

№	Natural-technogenic geocryological complexes	
31	Sections of the pipeline passing through the sand bulges	Activation of aeolian processes
32	Helipads with clearing snow in winter	Potential change in active layer

For instance, field reconnaissance of permafrost and geological conditions resulted in 17 NTGC types in Norilsk industrial area, 11 types in Yamburg gas condensate field, Taz Peninsula, and 32 types along overground and underground gas and oil pipelines in the north of Western Siberia.

NTGC dynamics, depending on the scale of urban system, on the set of its elements and on duration of impact upon nature as well as on degree of stability of natural permafrost, attracts the particular interest. A key point here is assessing the direction of climate change (in terms of influence on the engineering of the permafrost environment) in different areas of the cryolithozone.

Peculiar natural-technogenic geocryological complexes (NTGC) are formed in the urban territories, which are remarkable by the vector of permafrost evolution, by the set of cryogenic processes, by temperature trends and the other characteristics. NTGC types depend on initial natural settings and on kinds, intensity and duration of technogenic pressure.