Stability of foundations in cryolithic zone under the conditions of technogenic inundation and salting

Stabilisation des fondations dans une zone cryolitologique sous les conditions technogénétiques d'inondation et de salinisation

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ABSTRACT: Technogenic inundation and salting cause reduction of the bearing ability of the ground and destruction of bases. These phenomena in regions of glaciogenesis and cryolithogenesis are especially dangerous. Environmental pollution have brought to appearance of the aggressive ground moisture in relation to underground designs. Geotechnical engineering measures were developed for the newly built and reconstructed objects. The special engineering methods stabilize a cryolithogenic conditions and improve conditions of the bases exploitation.

RESUME: Les inondations et la salinisation technogénétiques induisent une diminution de la capacité portée des terrains et la destruction des fondations. Ces phénomènes sont les plus dangereux dans les régions caractérisées por la présence de glaciers ou de permafrosts pollution de ces environements por des résidus industriels a rendu l'eau du sol agressive vis-ă-vis de la partie souterraine des constructions. Les ingénieurs géotechniciens ont élaboré des techniques pour construire or reconstruire les bâtiments modernes. Ces techniques particuliéres stabilisent les conditions environementales du permafrost et améliorent les conditions de mise en place des fondations.

INTRODUCTION

Problem of technogenic inundation and salting of the grounds in large industrial centres became actual in last decades. These processes cause the grounds structure becoming weak, cause the reduction of their density, decrease of strength, violation of a hydrogeological regime, rising of the ground waters level, and other negative phenomena. In the North and in mountain regions the problem becomes more actual with the destruction of cryolithogenic and glacial complexes, development of dangerous cryogenic processes, reduction of bearing ability of the frozen bases, as well as accumulation of pollutants in the active layer, which are very aggressive relation to the bases material (Grebenets et al., 1994).

During 1987-95, in Norilsk (northern Siberia) intensive researches of technogenic inundation and salting of the ground complexes were conducted. The research incensed not only territories with permafrost but also sites on which constructions were built with the use of rocky ground bases.

METHOD

The previous researches have shown that in large cities in cryolithic zone the degradation of permafrost under the influence of technogenic factors occur. Main of them are: violations in operation of cold ventilated undergrounds; heating effect of the underground engineering communications; warehousing of snow embankments; high filtrating ability of technogenic artificial grounds; industrial salting of grounds. It was established that the tendency of permafrost degradation in cities is not connected with the global climatic heating.

DISCUSSION AND NEW OBSERVATIONS

Inundation is a result of different reasons: outflows from the engineering communications; technological water flows from the enterprises; melting of snow and rains. The main part of water penetrates into the active layer, increasing its depth and filtrating ability. Inundation brings to the melting of underground ice. Thermokarst arises, cryolithogenic complexes change, constructions can be destroyed.

Environmental pollution is a big problem in industrial zones. Metallurgical plants in Norilsk throw out into atmosphere about 2 million tons of sulfuric dioxide, dozens thousands tons of chlorine, nitrogen, dust annually. About 80 million m^3 of sewage waters are being merged annually. As a whole, ground water characterized by sulfat-chlorid aggression to the bases material. In tundra (60 kms from Norilsk), ground moisture (active layer) contain 50-250 mg/L of SO_4^{2-} and up to 10-15 mg/L Cl^-, and moisture of technogenic grounds (bases of steel shop) accordingly 1500-2000 mg/L up to 16000-18000 mg/L and 150-250 mg/L by places - up to 330-350 mg/L. It should be noted, that even a snow near metallurgical factory contains 350-380 mg/L of SO_4^{2-}, while in tundra on a distance of 120 km from a city - 0,81 mg/L. Ground moisture containes HCO_3^{2-}, CO_3^{2-} and other pollutants, destroying iron-concrete material of the bases and underground parts of buildings. The results of natural determinations of the pollutants contained in the ground moisture of active layer in Norilsk region are shown in the table 1.

Concentrations in ground moisture of chlorides and sulfates (on separate tests) negatively effecting on the material are shown on the fig 1.

As seen from tab. 1 and fig. 1, the technogenic pollution of grounds in urban zones repeatedly exceeds the natural level. Together with filtrating waters of active layer pollutants penetrate into the rivers, falling finally into the Arctic ocean.

Technogenic inundation and salting negatively effect frozen grounds and bases. The modern buildings lean on piles, possessing depth (depending on properties of grounds, number of floors and design features of buildings) from 6-8 m to 30 - 35 m. According to the modern industrial technology, iron concrete or the metal piles are established in bore holes, previously drilled in permafrost and possessing greater than pile diameter. Free space between the pile and the walls of the hole is filled in by the ground solution. which gradually freeze. The bearing ability of piles is provided by the forces of freezing between surface and the ground. Lower the permafrost temperature more the bearing ability. For example, at the temperature -4 ^{0}C each square centimeter of a lateral surface of a pile, frozen with clay, provides bearing ability of 250 kPa. While the increase of temperature of permafrost up to -0,5 ^{0}C, the bearing ability decreases up to 60 kPa. The salted clay ground ($D_{sal.}$ % = 0,5) at temperature -4 ^{0}C provides 120 kPa. After the frozen grounds melting the freezing force disappears, and piles under a load move downwards. Grounds in cryolithic zone have large variability of properties: composition, structure, density, ice containing, cryogenic structure. Processes of melting and permafrost heating are not equal within the limits of one structure, also different are the loads on piles, therefore the sizes of piles deformations are various, the deformations of building begin. In

Table 1. Analysis of ground water samples, in mg/L, Norilsk, Siberia. Active layer. The beginning of 90th.

	Sample No				
	1	2	3	4	5
Ca^{2+}	113	1078	197	277	4430
Mg^{2+}	40	20	43	18	1152
Na^+K^+	22	456	30	882	637
Cl^-	3	118	45	164	220
SO_4^{2-}	220	2502	552	1687	15682
HCO_3^-	30	1416	140	248	622
pH	2.5	7.8	8	10	6

Sample 1: tundra, 60 kms from Norilsk;
samples 2-3: border of the Norilsk urban zone;
sample 4: metallurgical plant;
sample 5: zone of warehousing of the firm wastes (bad land).

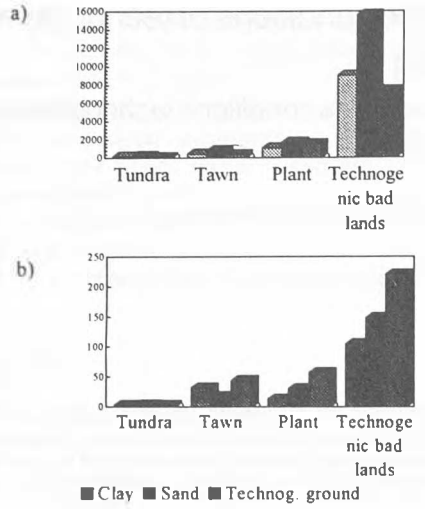

Fig. 1. The Contents of SO_4^{2-} (a) and Cl^- (b) in ground moisture of active layer (1993). Norilsk, Siberia.

Norilsk, about 25 % of large buildings have infringements of cryolithogenic conditions of the bases, about 200 buildings are deformed. During last 5 years the quantity of the permafrost bases which lost the bearing ability under influence of technogenesis become more than at the previous 50 years of the city existence. While the general tendency of permafrost degradation occur, the negative effect of local melting and warming of ground become stronger and put more significant economic and ecological damage.

The most effective geotechnical measure which stoping the degradation of permafrost and improving properties of grounds is artificial grounds freezing with the use of resources of natural cold. Seasonally cooling devices are: atmospheric (ventilation of channels or piles in winter), liquid and steam-fluid thermal piles. Positive experience (Grebenets, 1990) of using of the similar methods for cryolithogenic conditions stabilizing have been accumulated.

The method of piles compressing to separate rocky horizons is worth to be noted. The results of the compressing of three piles in the bases of the 9-floor house are shown on the fig 2. After 15 years explotating period permafrost melted, the piles unevenly moved downwards, and the building ruined. The depths of piles - 15 - 18 m. Geotechnical decision was to compress the piles by the powerful pressing machines.

Method of static pressing is very expensive, long and solves just local problems of stabilizing of the separate building when the dense rocky ground lies closely to the piles bottom. The more essential effect gives a complex of special geotechnical measures, directed on cryolithogenic conditions stabilizing in large cities of permafrost zone (Grebenets, et al. 1994).

The problems connected with technogenic inundation and salting, arise not only on territories with permafrost, but also on sites, where the bed rock lies closely to the surface.

On rocky grounds in Norilsk, the largest metallurgical factories and other industrial objects are built. Powerful iron-concrete piles were used for the bases. As considered earlier, the similar technology will ensure long (not less than 75 years) trouble-free operation of buildings.

The observations of about 8,5 thousand piles of bases have shown that they are subjected to active destruction. Dependening on the conditions and explotating period the wear of the material of bases in aggressive conditions of industrial zones makes up from 10-15% to 65-80 % from design significances of the material.

The reduction of reliability of bases is a result of two main reasons: bearing ability of rocky bases decreases and material of bases is destroyed.

The decrease of the bearing ability of bases occur under the effect of the technological factors (formation of cracks in rocky grounds when using the explosions while the bases constructions), as well as under effect of the technogenic inundation of the artificial grounds. Artificial technogenic grounds are poorly sorted, have high factors of filtration, therefore the drainage of technological and atmospheric water strengthens the erosion of rocks.

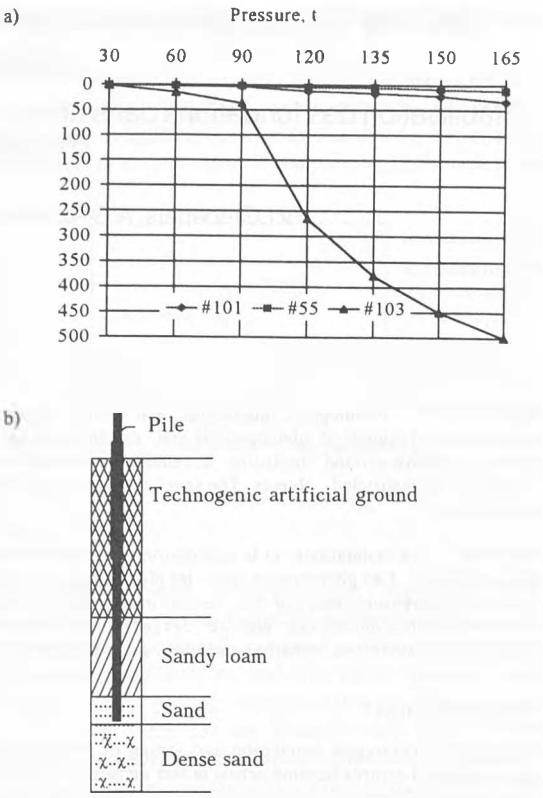

Fig. 2. The 3 results of static compressing of piles (1995) in Talnakh (Norilsk, Siberia). a) moving of the pile; b) typical litological section.

The observations have shown that the surface of dense rocks which are used as the bases of nickel factory, after 8 years of operation was covered by a net of cracks.

Somewhere it was broken (eroded) to small pieces. The bearing ability of bases decreased from 24 MPa up to 18,5 MPa. In the Norilsk region, inundation also strengthens the cryopelitisating process of the frozen rocks were freezing-melting process occur. Water in cracks destroys the rocky surface. The cryolithogenic factor strengthens concentration of pollutants in the bases of factories while freezing-melting pollutants are pressed out from non-built territories to the melted zones, existing under large industrial objects. Because of the destruction of the iron-concrete material of the bases, numerous deformations of buildings are marked.

CONCLUSION

Technogenic pollution and inundation of the grounds result in destruction of the bases and application of special methods of their protection is necessary.

Special measures on maintenance of reliability of underground constructions are recently developed. While the drilling-explosive method is excluded, modern engineering is applied, with the help of which sedimentary rocks remove. Free space is filled by non-filtrating material, waterproofing of bases and grounds is executed. The most damaged bases are been repaired, iron-concrete refills are being put into the cracks.

The problem of technogenic inundation and salting of the grounds of the urban territories is put forward in the engineering-geological researches in the North.

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