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TAILINGS COFFERDAMS ON PERMAFROST FOUNDATIONS IN YAKUTSKAYA ASSR
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G.I. Kuznetsov and S.V. Zaslavskiy

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COLD REGIONS RESEARCH AND ENGINEERING LABORATORY
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This report provides an analysis of problems of the design, construction and operation of tailings dumps on permafrost foundations. Analysis of data from engineering surveys, planning documents and features of the operation of tailings dumps provides an opportunity to evaluate the permafrost-geomineralogical features of the foundations of dams.

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DRAFT TRANSLATION 629

ENGLISH TITLE: TAILINGS COFFERDAMS ON PERMAFROST FOUNDATIONS IN YAKUTSKAYA ASSR

FOREIGH TITLE: (OGRAZHDAYUSHCHIYE DAMBY KHVOSTOKHRANILISHCH NA VECHNOMERZLYKH OSNOVANIYAKH V YAASSR)

AUTHOR: G.I. Kuznetsov and S.V. Zaslavskiy

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NOTICE

The development of the mining industry in Yakutskaya ASSR makes thorough analysis of problems of the design, construction and operation of tailings dumps on permafrost foundations an urgent task.

Analysis of data from engineering surveys, planning documents and features of the operation of tailings dumps provides an opportunity to evaluate the permafrost-geomineralogical features of the foundations of dams.

All dams are characterized to a greater or lesser extent by the following foundation structure. Frozen, strongly fractured, and in places icy bedrock is made up of homogeneous or vertically and horizontally alternating strata of clay, marl and limestone (aleurolites and sandstones are occasionally encountered). As these rocks thaw under the influence of the heating action of tailings dumps, constant filtration occurs in the fractured strata, accelerating the permafrost degradation process. The filtration discharges continue throughout the year, as indicated by the heavy flows of filtration waters that seep out in the lower reach, producing large ice formations in the winter.

Strata of dense clay, intermittent in plan and alternating with strata of strongly fractured rock, cannot be regarded as a reliable natural upstream puddle blanket during the planning of the underground contour of dams, although in many cases they do exhibit a local curtain effect.

The presence of a stratum of frozen Quaternary sediments, varying in thickness, and gradually changing into moraine sediments, is a characteristic feature of all the tailings dumps located in stream valleys and in ravines with gently sloping sides.

Slide rock and alluvial-slide rock Quaternary sediments are characterized by a varying degree of ice saturation and sometimes include thick (more than 1 m) strata and lenses of ice. They are basically [one word illegible], weakly compacted, rubble soils, consisting of clay, loamy sand, loam and semi-[illegible], [two words illegible] marl and limestone, weathered to the condition of loamy clay. The sand-gravel, gravel-rubble and sand-[one word illegible] rocks, which become water permeable after thawing, [one word illegible] in the form of closed strata [one or two words illegible] primarily in the bed section of [one word illegible] (r^vines), [one word illegible] for the construction of tailings dumps. Inclusions of these [one word illegible] sharply reduce the natural filtration resistance of the argillaceous Quaternary sediments that are mixed in with them. The use of these argillaceous rocks as a natural upstream puddle blanket is effective in the absence of direct contact between the tailings dump and coarse gravel-rubble, sand-rubble soils. Cutting a deep tooth trench for a dam, intersecting lenses of filtering rocks, does not guarantee that filtration will not occur. In many cases [one or two words illegible] teeth have turned out to be [three words illegible] strongly fractured seams of rock, characterized by substantial water permeability after thawing of the ice and [one word illegible] the development of argillaceous filler in cracks.

Experience in the operation of tailings dumps convincingly demonstrates the need for a careful approach to the construction of the trend of a future tailings dump and organization of [one word illegible] argillaceous soils for the fill of pioneer dams in the immediate vicinity of their section lines. Only in the [possibly absence] of quarries in the upper reach of [one word illegible] of icy and [two or three words illegible] practical sense can argillaceous Quaternary sediments be viewed in plans as a natural upstream puddle blanket, possessing some antifiltration, and because of water permeability, also heat insulating effects, retarding the thawing of the bed.

A sharp increase of the water permeability of fractured bedrock during inevitable thawing as the reservoir fills requires thorough analysis of [possibly filtration] to the fracture zones of the foundation of a dam during the planning of its underground contour and organization of full-scale [prefix illegible]-metric observations. According to data of OIZ [Expansion unknown] of the [one word illegible] Institute, the filtration factor of analogous fractured rocks reaches 324 m/day.

Analysis of the plans of pioneer dams, full-scale observations, data on deformations and permafrost processes, the results of analysis of some of the properties of tailings sediments (see Table, Figure 2) leads to preliminary conclusions, [one word illegible] cofferdams be planned and built without sufficiently complete analysis of the consequences of the inevitable thawing of permafrost rocks in their foundation and in the pool of a tailings dump. The [possibly subsidence] properties of the upper ice-saturated horizons of Quaternary sediments are taken into consideration only during [one word illegible] of the volume and height of earth-fill dams for compensating their [one word illegible]. The underground contour, antifiltration and drainage systems are planned and built without consideration of changes of the filtration properties of permafrost foundation rocks as a result of thawing. Antifiltration systems made of sufficiently water-impermeable materials, in tight contact with nonfiltering foundation rocks, were not provided for certain dams. Drainage systems, protected from freezing and preventing the seepage of filtration waters onto the [one word illegible] slopes of the dams, were not built. The increased water permeability of fractured strata of the upper zone of the bedrock, in which strong filtration occurs, resulting in the development of ice formations, has been underestimated.

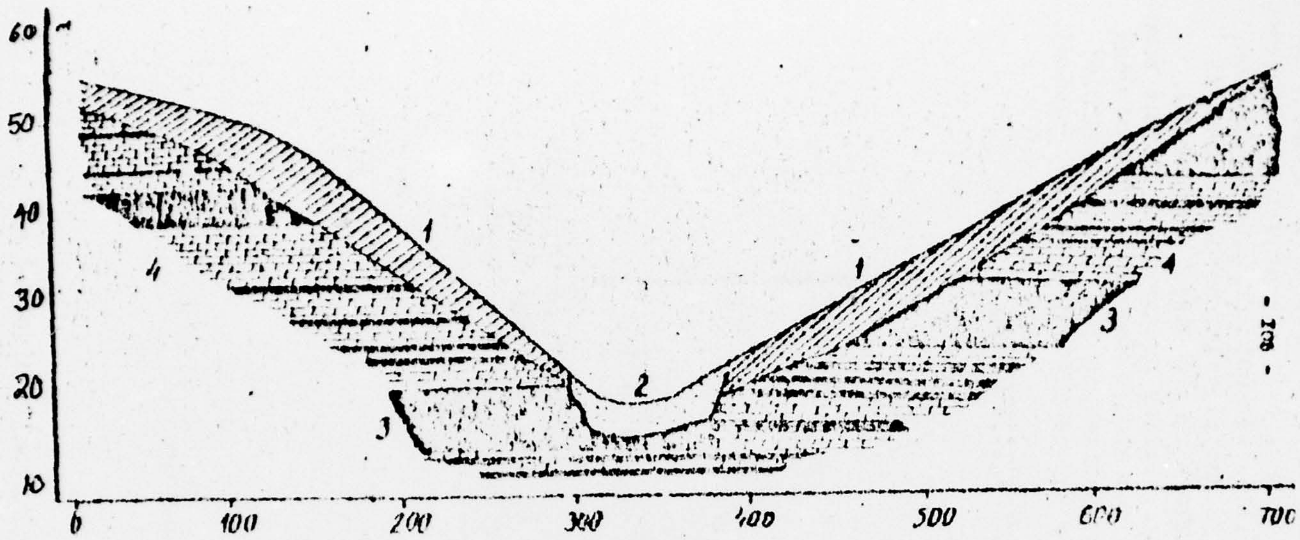

Figure 1. Characteristic permafrost-geological conditions in section line of dam: 1 -- ice-saturated loose clay and silt soils; 2 -- filtering [one word illegible] sediments; 3 -- argillaceous permafrost bedrock; 4 -- fractured rock, filtering after thawing.

Significant deviations from plans, not justified by technical-economic calculations, have been permitted to occur during the construction of earth-fill dams and subsequent buildup with tailings by the hydraulic fill method. Some sections of a dam are dumped and filled without adequate compaction, with unsatisfactory slope steepness. The antifiltration zones, made of [possibly binding] soils, are filled without the required geochemical monitoring and do not prevent filtration. During preparations of the foundation icy silts, top soil and peat are not always removed, zones of [one word illegible] of buried ice, often encountered in [one word illegible] horizons at many construction sites, are not completely [possibly bonded].

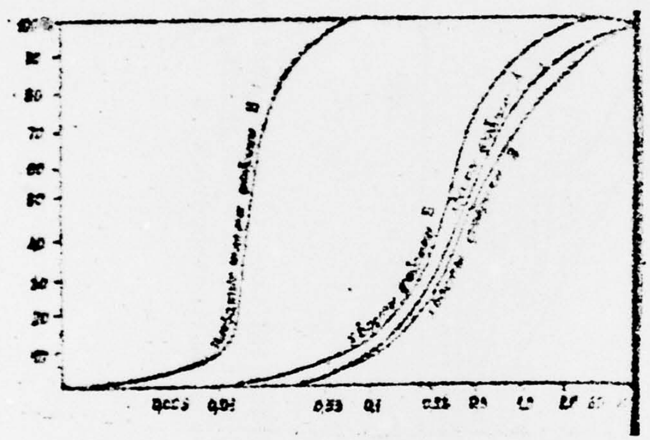

Figure 2. Average granulometric composition of tailings sediments: 1 -- tailings dump A; 2 -- tailings dump [one word illegible] (ordinary tailings); 3 -- same, silt [one word illegible]; 4 -- tailings dump C.

Figure not reproducible

Figure 3. Constant winter filtration, manifested as concentrated seepage on upper [one word illegible] ice formation.

During the buildup of dams the tailings, densely [possibly packed] on the upper slope and crest, are loosened by bulldozers and are dumped uncompacted on the lower slope, which, as a result of this technology, acquires an unacceptably steep [one word illegible], reaching 1:1 and even 1:0.7-0.8. Such slopes readily collapse, even without the influence of external factors, and to a substantial depth (3-5 m), and are eroded by rain and thaw waters. Gullys are cut deep into the body of the dam and threaten its stability.

During the construction of cofferdams by the hydraulic fill method separation of tailings, ensuring the laying of coarser fractions in the body of the dam and discharge of fine clay and silt particles into the pond, is not always employed. In many cases incorrect buildup technology leads to a situation where low parts on the [one word illegible] and crest of the dam are filled with finely dispersed silt and clay particles, forming a seam with considerable thickness (up to 1 m) and length. These seams, filled from the top, are not consolidated, remain in the oversaturated state for a long time and represent ideal [one word illegible] for sliding of filled masses.

During the first years of operation the filling of ice strata with tailings was permitted because of late buildup of the [one word illegible] and capacity of the tailings dump. This occurred basically during winter after ice-filled holes were filled with tailings and slurry was later injected under the ice. Sometimes ice that had not yet thawed by the beginning of summer was filled with tailings. Because of the heat-insulating effect of the layer of tailings, covering the filled mass and ice seams, the latter thaws very slowly. The thawing of ice is accompanied by the formation of thermokarst pits and loosening of the tailings filled from above. In early winter, before the formation of a stable ice cover, slurry is permitted to be filled on the frozen [possibly beach], resulting in the formation of lenses of filled ice and lamellar [one or two words illegible] of icy tailing sediments, which is particularly dangerous to the stability of dams.

A positive factor that promotes an improvement of the strength of dams is the [one word illegible] natural surface of their [one word illegible] of the lower slope. However, the size of frozen zones and [one word illegible] in the body and foundation of a dam is unknown, since the [one or two words illegible] temperature mode and the actual is not [one word illegible]. Therefore, when evaluating the stability [three words illegible] their size at the present time, one must not give preference to the [one word illegible], confining role of the deep [possibly frozen] [one or two words illegible] of the slope without considering the actual density of [one or two words illegible] tailings, their physicomechanical, filtration and [possibly thermophysical] properties in the frozen and thawed states.

The set of natural factors, technological factors and other defects, inadequate substantiation and [one word illegible] of certain planning decisions, the absence of diligent technical control, [possibly regular] observations of the filtration and [one word illegible] of foundations and earth-fill structures lead to the development of specific kinds of deformations, permafrost and filtration phenomena in existing dumps. The following factors exert the greatest influence on the stability of dams:

a) uncontrolled filtration through the body of a dam in the contour with water discharge systems and through water-permeable [one word illegible] zones of thawing permafrost foundations [two or three words illegible] (Figure 3);

b) ineffective operation of antifiltration and drainage systems in the body of dams or the absence of such systems;

c) the deformability of [one word illegible] foundations, not considered during the construction of dams;

d) the annual development of ice formations as the direct and explicit [one word illegible] consequence of filtration (Figure 4);

e) the formation of accumulations of silty, water-saturated [one word illegible] unstable sludge in hydraulic fill installations;

f) the [one word illegible] of ice thaw and the formation of layers of frozen tailings, which are unstable after thawing, during buildup on [one word illegible] during periods of negative temperatures (Figure 5);

g) the uncertainty of the temperature mode of dams, the absence in plans of forecasts of thawing of the floor of tailings dumps;

h) the absence in the [possibly upstream] puddle blanket of a permanently operating monitoring-measuring system, adapted for operation under severe local conditions;

i) deviations from the plans during the buildup of dams, resulting in excessive slope steepness, [one word illegible] without the required leveling and compaction, the slope relief is rarely photographed and in insufficient volume;

j) the absence of standard technical documentation, [possibly clearly] and objectively reflecting the actual condition of tailings dumps and the development of deformations, [possibly filtration]-icing phenomena in them, etc.;

k) the absence of standard geoengineering [possibly monitoring] during the buildup and filling of dams (density, distribution of fractions, etc.).

A cycle of filtration studies was completed for the highest and most characteristic tailings dump, as a result of which it was possible to establish the form and position of the boundary [possibly depression] by considering data of field determinations of the filtration coefficient of tailings; the influence of the water permeability of a loamy clay pioneer dam and of the thawing layer of loamy clay in the base of a hydraulic fill dam on the form and position of the [possibly curve] of the [prefix illegible]-pression and seepage section was analyzed; the discharge [one word illegible] of filtration flows on the seepage section with a well developed ice formation on the surface of the slope were determined; the effect of the buildup of ice on the size of the seepage section and the position of the [prefix illegible]-pression curve was established; the filtration back pressure that develops under ice formations on the surface of the lower slope and the negative influence that this has on its stability were determined.

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Figure 4. Annual ice formation developing on slope as result of constant filtration.

Figure not reproducible

Figure 5. Thermokarst [possibly sag] in mass of tailing sediments containing ice inclusions.

Filtration was modeled in an ETDA-9/60 electro[illegible]. The effect of ice buildup on the discharge characteristics of the filtration flow and length of the seepage section are explained in Figure 6.

In consideration of the water permeability of the thawed layer of loamy clay in the base and body of a pioneer dam, filled from such material (K_f = 0.18 m/day), the [possibly magnitude] of the hydrodynamic resistance under the ice formation increases substantially, and the discharge gradients in the [possibly lower] part of the seepage zone increased to an even greater extent.

As the ice formation builds up from a height of 12.0 to 17.3 m both the hydrodynamic resistance under the ice and the discharge gradients in the lower part of the seepage section increase. At the same time the length of the seepage section decreases appreciably.

The overall form of the depression curve for practical purposes does not depend on the size of the ice formation and water permeability of the

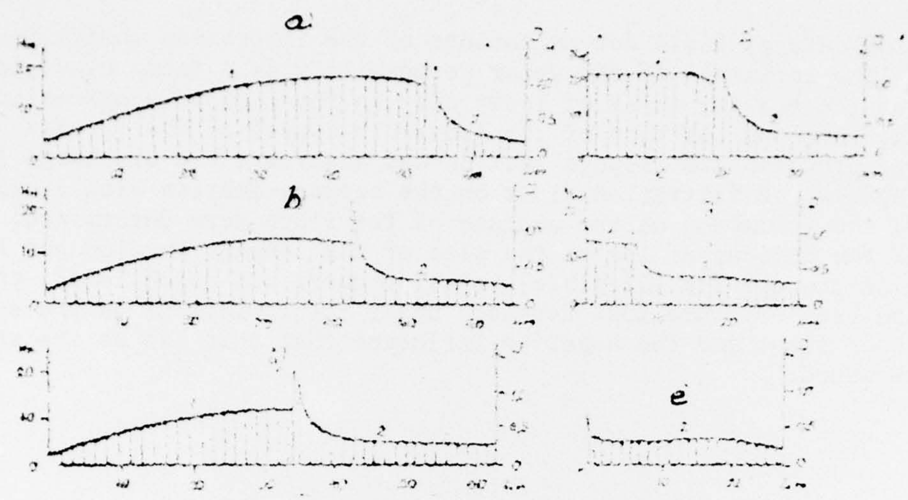


Figure 6. Diagrams of filtration back pressure under ice formation and discharge gradients of filtration flow in seepage zone: 1 -- back pressure diagrams; 2 -- discharge gradient diagrams; H -- magnitude of back pressure, M; I -- magnitude of discharge gradient; a, b, c -- in consideration of the water permeability of loamy clay [one word illegible] and foundation; d, e, f -- water permeability not considered [remainder of caption illegible].

thawed layer of [one word illegible] in the foundation and loamy clay in a pioneer dam for [one word illegible] K_f^o and K_f^x within 0 to 0.08 (K_f^x = 2.99 m/day).

As the height of the ice decreases from 17.3 to 12 m the curve [one word illegible] falls by a value not exceeding 3 m.

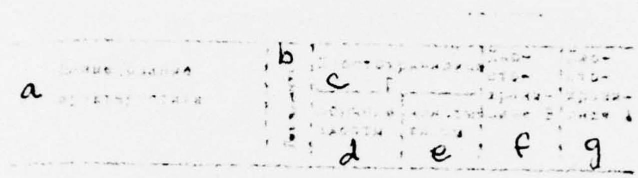
The results of electromodeling, added to actual piezometric observation data, were used to evaluate the stability of the slope.

The buildup of ice on the slope has an unfavorable effect on the [one word illegible] hydrodynamic characteristics of the filtration [one word illegible] and reduces the local stability of the slope in the [possibly seepage] section.

The following suggestions are offered for reducing the negative influence of filtration and [possibly icing] on the stability of a tailings dump:

1) at existing tailings dumps -- slope drainage and filling on rocks [one word illegible] of constant seepage of the filtration flow and icing (the drainage system is protected from freezing by filling with a heat-insulating layer of local [one word illegible] soil);

Table



Key: a, [One word illegible] characteristics; b, [Illegible]; c, Tailings dump; d, Ordinary tailings; e, Silt [one word illegible]; f, Tailings dump B; g, Tailings dump A; 1, Density of tailings in [two words illegible]; 2, Density of tailings skeleton of [possibly undamaged] structure; 3, [Possibly weight] moisture content; 4, Density of tailings; 5, Filtration coefficient of tailing sediments; 6, Internal friction angle on surface; 7, Mean weighted particle diameter; 8, Particle diameter; 9, Actual diameter; 10, Inhomogeneity factor.

2) at planned tailings dumps -- antifiltration system and internal drainage, built in consideration of thawing and sharp increase of filtration in fractured zones of the permafrost foundation.