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Calculations of thermal stabilization of transport embankments and their bases

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Abstract

During the construction of roads and railways in permafrost conditions methods of stabilization of soils using Thermosyphons have become very popular. In the design of such systems only an estimate of temperature field in the soil is carried out. At the same time it have been noted that the freezing of thawed soil is accompanied by the processes of frost heaving. There is a definite interest in the use of inclined and horizontal thermosyphons. In the article the examples of the calculations of changes of temperature fields and the stress-strain state of the embankment and its base in the annual cycle with the use of inclined thermosyphons are presented. The known program «Termoground» developed with the participation of the authors was used for the calculations. It is suggested that in the design of thermal stabilization of soil the calculations only of change of temperature fields in the soil are insufficient. It is also necessary the forecast of the deformations of heaving and thawing.

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Keywords: thermosyphon, frost heaving, stress-strain state

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1. Introduction

Subgrade of roads and railways in permafrost areas in some cases is executed by dumping of embankment at high temperature frozen soils that include thawed zones. Large popularity in this case the methods of the stabilization of the soils performed by setting Thermosyphons are acquired. During the designing of such systems only calculations of the temperature fields in the soil are carried out. At the same time freezing of thawed soils is accompanied by the development of the processes of frost heaving which should be taken into account in the design of roads with the relatively rigid surface. There is a definite interest in the solution with the use of inclined and horizontal thermosyphons submerged from slopes to the center of the embankment.

The automobile route P297 “Amur” has a long history of designing and construction. The need for the construction of the highway – the understudy of the Trans-Siberian railroad which passed at the state border – was clear even in the prewar period. The temporary road was built by September 1941. In the postwar period since 1967 the road construction was imputed into the responsibility of the Ministry of Defense of the USSR and the troops have started to build it.

In the post-perestroika time activation of the construction works was renewed in 2002. Without hard coating the road was put into operation in 2004, after coating with bitumen – in 2007. After that some parts of the road were asphalted. However the numerous defects in the coating called colloquially “Amur waves” became apparent immediately after the introduction of sections into the operation. At present the worst state is timed to the sections of route in the Chita province, namely in the Prishilkinskiy region and in the western part of Amur-Zeya plain. They are the areas of continuous permafrost.

The reasons for the deformations of subgrade and the coating of the road are the subsidences caused by seasonal thawing and also the lifts caused by the action of the frost heaving of soils. In order to minimize the influence of these processes and phenomena there are proposals to reduce the thawing and subsequent freezing of the soils with the use of seasonal refrigeration constructions (SRC).

Constructions of SRC are continuously improved. At first glance a very effective solution could be the use of inclined thermosyphons submerged from berms to the center of an embankment. In this article this proposal is analyzed for one of the sections of route “Amur”, namely section in the region 978 km.

2. Calculated analysis of inclined SRC

The known program «Termoground» [1] was used for the calculated analysis. The program is based on the finite element solutions of heat conduction problems [2] and simulation of freezing/thawing processes in soil [3]. The other assumptions, the mathematical models and the examples of numerical calculations are given in [4-15].

Table 1. Thermophysical characteristics of the soils of embankment and of its base.

Name	Thermal conductivity, kJ/Year·m·°C		Heat capacity, kJ/ m^3·°C	
	frozen	thawed	frozen	thawed
Bituminous concrete	63072	63072	1700	1700
Crushed stone of small degree of saturation	63072	63072	1700	1700
Bulk layer	63072	63072	1700	1700
Berm of loamy soil with stone aggregate	76826	61461	2410	3170
Gravel ground filled with hard sandy loam	98910	79128	2410	3170
Pebble primer filled with the icy sandy loam	98910	79128	2410	3170
Gravel ground filled with the icy sandy loam	98910	79128	2410	3170