Procedia Engineering

Volume 143, 2016, Pages 682–688

Advances in Transportation Geotechnics 3 . The 3rd International Conference on Transportation Geotechnics (ICTG 2016)

The Impact of Freezing-thawing Process on Slope Stability of Earth Structure in Cold Climate

Alexey A. Korshunov[1]and Sergey P. Doroshenko[1] and Alexander L. Nevzorov[1]

Northern (Arctic) Federal University, Archangelsk, Russia

a.a.korshunov@yandex.ru, s_p_doroshenko@yahoo.com, a.l.nevzorov@yandex.ru

Abstract

The paper deals with assessment of impact of freezing-thawing process on slope stability. Numerical simulation with using coupled thermal–hydraulic–mechanical analysis (software "Geostudio 2012", Canada) was implemented to make accurate time-dependent forecast of safety factor and defined probable slope failure mechanism of earth structures in cold climate. Results of modelling showed safety factor value was decreased from 2.15 to 1.13 when earth structure's slope is thawing. Significant increase of hydraulic gradient (from 0.1 to 14) was observed in the toe of dam.

Keywords: Safety factor, cold climate, slope stability, numerical simulation, coupled convective thermal model, Morgenstern-Price method.

1 Introduction

Transport and hydrotechnical engineering in cold climate is challenge for geotechnical engineers, primarily which is associated with need for dams' and roads' safety in time related to processes of freezing or thawing of soils as well as frost heaving on frost-susceptible soils.

The main task for geotechnical engineers is to ensure the safety of transport and hydrotechnical structures in cold climate. First, it can be achieved by maintaining of appropriate thermal mode of soils to predict possible slope failure when soil is going melting. The second, it can be ensured by keeping of estimated water level into earth structure. Freezing of slopes will lead to freezing water in the downstream slope what is reason for rising of depression curve in place of output flow. Melting of soils can lead to dramatically increase hydraulic gradients (higher than critical values), soil strength reduction and finally to getting of slope failure (Andersland, 2004).

In order to make forecast of earth structure behavior in cold climate and assess of probability of failure time-dependent safety analysis should be implemented and is to be based on coupled thermal–hydraulic–mechanical model. For this purpose we analyzed the behavior of earth structure – tailings

Selection and peer-review under responsibility of the Scientific Programme Committee of ICTG 2016

doi:10.1016/j.proeng.2016.06.100

dam placed in northern part of Arkhangelsk region. The cross-section of the dam is shown on Figure 1.

Tailings dam is constructed from overburden rocks obtained as a result of mining and waste materials (tailings) which are washed on face of each dam's tier as a result of kimberlite ore dressing. The dam (on the 3rd tier) has a length of 2450 m, a height is about 20 m. Width of tailings beach is 40-70 m The slope of upstream face varies from 1:.. 5 to 1: 8. The slope of downstream - 1: 2 to 1: 2.5.

Quaternary deposits are bedded below first tier of the dam and are represented by semi-decayed peat, medium density silty sands, clays in a stiff and very stiff state with gravel content up to 10 %. The bedding is non-homogeneous, there are lenses, layers and interlayers of different thickness, thinning at some places. The tailings of kimberlite ore dressing are used for forming the bedding of the 2-nd and 3-rd tiers of the dam.

The geotechnical monitoring indicates that tailings are represented by coarse sands, medium sands, fine sands and silty sands with the content of clay particles up to 20%. The main component of clay is saponite (montmorillonite).

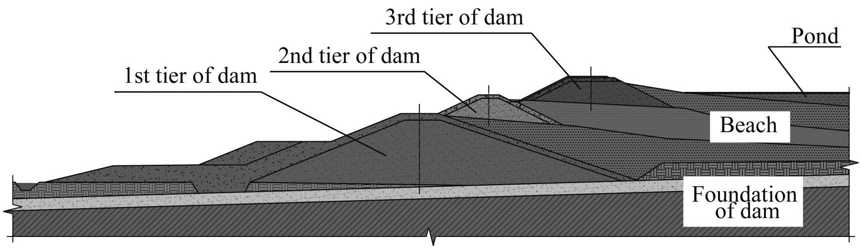

Figure 1: Cross-section of tailings dam

2 Numerical Simulation

Numerical simulation of freezing earth structures was carried out in GeoStudio 2012 (Canada) with using following finite element modules TEMP/W, SEEP/W and SLOPE/W (Figure 2). The first two modules are applied to simulate the effect of water transport on heat transfer and it cannot deal with physical coupling between soil/water and ice during heaving. Thus finite element model doesn't consider ice lens formation. The third module is used for slope stability analysis with limit equilibrium methods (e.g. Morgenstern-Price).

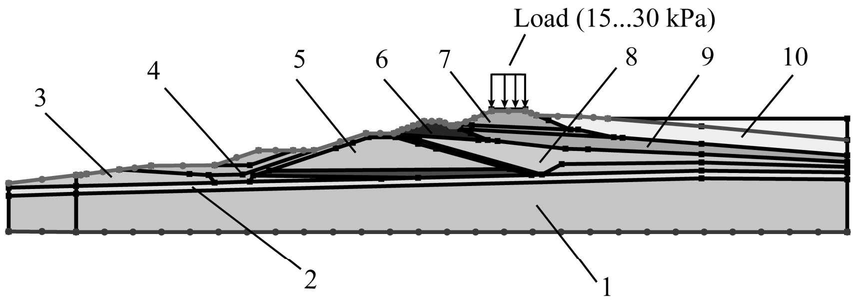

Figure 2: Numerical model of dam:
1-clay (CL); 2 – Sand; 3 – Peat; 4 – Crashed rock; 5,6,7 –soils of 1, 2, 3 tiers of dam respectively; 8, 9, 10 – tailings of 1, 2, 3 tiers of dam respectively.