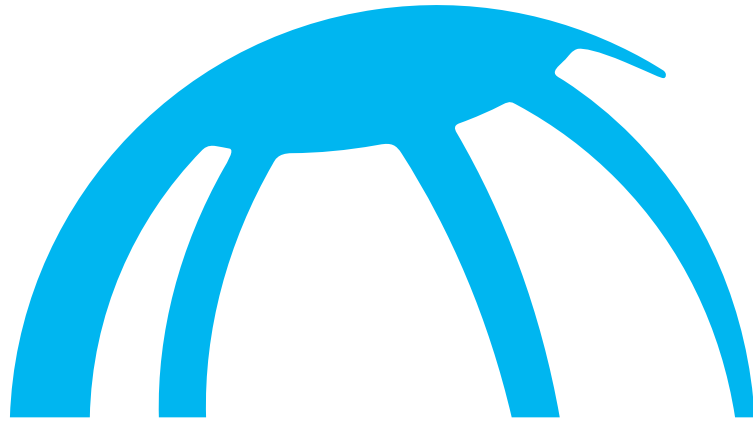
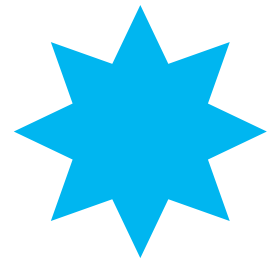




XI. INTERNATIONAL CONFERENCE ON PERMAFROST

POTSDAM, GERMANY
20-24 JUNE 2016

Exploring Permafrost
In a Future Earth

BOOK OF ABSTRACTS

Edited by Frank Günther and Anne Morgenstern

www.icop2016.org

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20 – 24 June 2016, Potsdam, Germany

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Co-editors:

Hans-Wolfgang Hubberten, Lydia Polakowski, Matthias Fuchs, Ingmar Nitze,
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Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research
International Permafrost Association

Recommended citation

Günther, F. and Morgenstern, A. (Eds.) (2016): XI. International Conference On Permafrost – Book of Abstracts, 20–24 June 2016, Potsdam, Germany. Bibliothek Wissenschaftspark Albert Einstein, doi:[10.2312/GFZ.LIS.2016.001](https://doi.org/10.2312/GFZ.LIS.2016.001)

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Imprint

Publisher

Bibliothek Wissenschaftspark Albert Einstein
Telegrafenberg
14473 Potsdam
Published in Potsdam, Germany

Editors

Frank Günther
Anne Morgenstern
doi:[10.2312/GFZ.LIS.2016.001](https://doi.org/10.2312/GFZ.LIS.2016.001)

Cone penetration testing for railways on permafrost

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The Vorkuta railroad is experiencing continuous deformation due to permafrost thaw settlement. The railroad was built in early 1940's. Today the railroad is loaded to only 30 % of its capacity to serve coal and passenger traffic. The low traffic capacity is caused by continuing deformation of the railroad tracks, which are relevelled each year. The railroad connects Vorkuta, Labytnangy and Bovanenkovo with the European part of Russia. If the railroad extends to Sabetta port on Yamal peninsula, the railroad capacity must be increased up to 100 % of its capacity to satisfy growing traffic demand. Thus, continuing deformation of the railroad tracks must be fixed. Many sections of the studied railroad have deformed due to permafrost thawing and differential settlement. One of the sections, called "101st km", is discussed to describe a possible technique for the problem detection. The railway embankment varies from 2 meters up to 6 meters high above the local ground surface. Thermokarst lakes are located on both sides of the railroad. Surface and groundwater flows through the railway embankment, particularly near the pipe culvert. The profile near the culvert pipe at the distance of 5 meters from the railway tracks is as follows: 1.5 meters of crushed rocks, then 1 meter of sand mix with native soils and construction waste; native soil – grey-brown soft clay – found below 2.5 meters. Permafrost table was found at the depth of 1.5-1.7 meters at a distance from the pipe culvert. Technologically, it was impossible to detect permafrost table right under the pipe culvert. Geotechnical borehole drilling is not practical on a railway in operation. Ground penetrating radar did not detect permafrost table, only showing thawed soils down to 4 meters. Geodetic survey showed that the differential settlement of the railway embankment was 62 cm. Periodic leveling of the railway embankment was performed to maintain the railway in operating condition. The task from the railway engineers was to find a new technique which is able to diagnose and/or confirm the problem, precisely describe the extent of the problem and provide enough

information to find a feasible technical solution. The main restrictions for the technique include the following: demand for non-disruptive or low-disruptive testing, test time limit for 3 hours. Cone Penetration Testing (CPT) is a method used to determine the mechanical properties of soils and stratigraphy. CPT is one of the most common methods used and accepted for soil investigation worldwide. For permafrost soil investigation, CPT is now standardized in the updated Russian code 25.13330.2012 "Bases and Foundations on Permafrost Soils", Appendix JI "Determination of mechanical properties and pile bearing capacity of permafrost soils on CPT results". Based on CPT results, it is possible to estimate Deformation Modulus (E_f , MPa), Equivalent Cohesion (C_{eq} , kPa) (i.e. soil strength) and Pile Bearing Capacity (F_u , kN). The applied method consists of pushing an instrumented cone, with the tip facing down, into the ground at a controlled rate of about 2 cm/s. The cone is instrumented with a typical cone tip having a cross-sectional area of 15 cm², which corresponds to the cone diameter of 4.4 cm. The friction sleeve is also installed to quantify the sleeve friction and estimate soil cohesive strength. The cone tip measured cone resistance q_{cv} . The shear sleeve measured sleeve friction f_{sv} . In addition to them, at the cone tip the temperature sensor is installed to measure soil temperature. The accuracy of the temperature sensor is 0.01 textdegree C. The total penetration was reach at the depth of 12 meters. Two soil units were identified which correlates to the borehole data obtained several years before by a separate operator. For each element mechanical properties were estimated according to SP 25.13330.2012, which are $E_f = 42$ MPa and $C_{eq} = 480$ kPa for the first element (sand mix) and $E_f = 22$ MPa and $C_{eq} = 84$ kPa for the second element (native soils). CPT profile showed that permafrost is located from 4 meters down to 12 meters and lower. Six temperature measurements with thermal dissipation were performed which showed subzero values between -0.1 textdegree C and -0.7 textdegree C. Thus at the

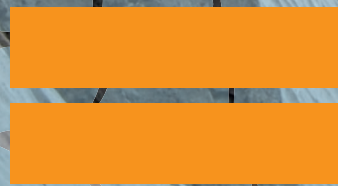
tested location, the permafrost remained frozen and had not thawed as it was expected. However, the railway track differential settlement is a strong evidence of permafrost degradation which should be investigated in more details. The results of the test clearly showed that the reason of the thaw settlement is not connected to only thermal-radiation regime alteration caused by the railway embankment. Talik zone should be investigated in more details to indentify the true reason of permafrost degradation and to develop a

technical solution to fully seize the deformation of the embankment. The trial CPT test on Vorkuta proved its applicability for permafrost investigations. Moreover, this example clearly presents the benefits of CPT compared to geotechnical borehole drilling in the view of time, cost, information content, etc.

In 2016 geotechnical campaign will continue CPT application for more detailed investigation of the deformed sections of the Vorkuta railway embankment.



Figure 1: Differential Thaw Settlement of Railways on Permafrost Terrain



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