Monitoring of arctic infrastructure in Svalbard

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Abstract

A settlement monitoring campaign for building foundations in the small cities of Longyearbyen, Barentsburg, Svea, and Pyramiden in Svalbard was initiated in summer 2017. Permafrost exists to a depth of hundred meters or more at these locations. Reference points were established on the foundations of selected buildings, and a survey was conducted by differential leveling. Existing older buildings and recent buildings were selected for the study, with different bearing structures and different types of foundations. Recent time-series observations and climate model predictions show that significant climate warming will occur in Svalbard in the 21st century. The objective of the monitoring campaign is to document the conditions of the selected foundations and to provide a basis for repeated surveying of settlements in a 10-20 years perspective. Combined with long-term data series of air and ground temperatures at several sites in Svalbard, the survey may provide valuable information on settlement rate of various buildings and foundations, useful for decision making for maintenance of existing structures and selection of foundation materials and design of future constructions.

Keywords: permafrost, settlement of foundations, climate change, frozen ground, foundations in permafrost.

Introduction

Climate change is considered one of the major global challenges for humanity in 21st century. Projected climate changes are most pronounced in the polar regions. It is believed that the impacts on permafrost conditions in the arctic may lead to significant damage to infrastructure. As pointed out by [1, 2], the effects of construction and maintenance of infrastructure may also significantly affect the ground thermal regime locally in the permafrost ground, and may add to problems related to stability of foundations.

Long-term field measurements are useful for the design and documentation of performance of foundations. The results of systematic monitoring of vertical positions of foundations, in conjunction with records of hydro-meteorological parameters and maintenance history of a building, may help to identify the primary factors causing severe damage to foundations or decrease of building serviceability.

Svalbard is well suited for the present study because several building types and foundation systems are easily accessed at the four geographical locations, and at the same time climate projections suggest significant climate warming towards year 2100 [3, 4]. Consequences of warming of permafrost and increase in the active layer thickness and subsequent soil strength loss and settlements is thus quite likely. In order to provide data on a range of foundation solutions, the survey covers new and old buildings, supported on shallow plate and strip foundations, as well as deeper pile foundations. Quite significant settlements were observed for some of the buildings, while others were mostly without deformations.

Methods

The initial heights of the reference points on the building foundations were determined by performing a standard manual differential leveling. This basic method is widely used due to a number of advantages, which include high accuracy and rapid measurements, simple and inexpensive equipment, and allowing measurements under difficult conditions. Requirements for such works are found in standards for monitoring of infrastructure [5, 6].

The Digital level *Leica Sprinter 250 M* instrument and a barcode staff *Leica GSS 111* rod were used for the survey. Leveling was performed in forward and reverse directions using approximately equal distances, and in closed paths around each building with two repetitions.

The following works were carried out in 2017:

1) Identification and/or establishment of reference points (fixed ground points) in the vicinity of the buildings. As far as possible these were points that could be assumed to not develop significant vertical movement in a long-term (decades) perspective, e.g., massive piled concrete foundations.

2) Installation of fixed bolts on the base or foundation structure of the buildings, in easily accessible positions. Bolts were installed on the corners of the buildings and at points closely spaced along the building sides, drilled and hammered into piles or characteristic foundation points at every 4-5 meters.

3) Leveling of the marked points.

The precision of a level run is described in terms of a maximum allowable error of the closed path. The survey was conducted in accordance with the allowable errors defined in [5].

Description of surveyed buildings

Longyearbyen

The apartment building UNIS Guest House and the hotel "Elvesletta Byggetrinn 1" under construction were surveyed. The first is a two-story wooden module building, standing on wooden piles deployed in the ground to a depth of ca. 9 m. Crawl space protected by decorative planks allows air flow below the building (sun shelter in summer, cooling in winter). The building is in plan approximately 15 by 70 m. The building was constructed in 2009–2011. The second building is a three-story wooden building, founded on 140 by 140 mm square hollow steel sections deployed to a depth of ca. 18 m. Crawl space is also sheltered by decorative planks. The building is approximately 16 by 30 m, and is due to be finished in early 2018.

Barentsburg

The three-story building "Komplex GRZ", constructed in 1975–1978, was selected for the survey. The building is approximately 50 by 15 m. The building is constructed of concrete beams and columns, with infill and exterior brick walls, and is supported on concrete piles. The piles have an estimated length of 10 meters. The opening under the building provides free flow of air. Some observed damage is most likely caused by previous settlements, visible as surface cracks on the southern wall.

Pyramiden

A multi-purpose garage built in 1981–1983 was selected for the survey. The building has brick walls and is supported on pillars on concrete piles. It is believed that the piles are 10 m long. The space below the building permits free airflow in the crawl space. Cracks were observed on the western wall of the building.

Svea

In the mining city of Svea, the two-story barrack building "New green barrack" and a multi-purpose garage were surveyed. The first was constructed in 2010, from prefabricated wooden modules supported on a beam frame on wooden piles. Standard ventilated space and cover planks allows air flow below the building. Small deformations are visible on the South-East and East side, likely caused by foundation movements. The building is shaped in a horizontal angle (equal legs), total length of north side is 80 m, southern side is 90 m, and the width of the building body is 11 m. The multi-purpose garage for material storage is a light.weight structure comprising a steel framework and sandwich steel façade walls, on a concrete slab with integrated closely spaced ventilation cooling ducts, supported directly on the ground. Duct ends are to be manually closed/opened in summer/winter.

Results

Elevation data for monitoring points on the buildings were collected, these data establish a present ("as-today") dataset for each building. Data are stored in the project archive, which will be publically available at a later stage from the Research-In-Svalbard (RiS) database.

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