SINTEF

Anatolii Sinitsyn
Yared Bekele

Impact of Changing Climate on Infrastructure in Longyearbyen: Stability of Foundations on Slope Terrain – Case Study

Popular Science Report

The Svalbard Archipelago has experienced significant warming in the last three decades[1]. Future climate projections indicate a continuation of the warming trend, increasing of precipitation levels and storm frequency. Observations in the last years exhibit record-breaking values of air temperatures, high amounts of precipitation and severe storms, triggering subsequent hazards such as slope failures and coastal erosion. One may relate the observed events as manifestation of a changing climate.

It is believed that global climate warming may impose serious impact on infrastructure in the Arctic via increased actions and loads on structures, manifestation of geohazards (as landslides), and extreme weather phenomena. Svalbard is located in a zone of continuous permafrost. Increase in air temperatures leads to warming and degradation of permafrost and an increase in the thickness of the active layer (the layer which freezes in the winter and thaws in the summer). These lead to a decrease in the bearing capacity of foundations and an increase in thaw settlements. Increased intensity of rainfall may increase the risk of landslides in permafrost, which may be facilitated by increased summer air temperatures.

In Longyearbyen, one may observe a solifluction phenomenon, which is a slow downslope flow of unfrozen soil in the thawing season with rates of few centimeters per year or higher. Solifluction may affect foundations built on sloping terrains in Longyearbyen. Action of solifluction was not taken into account in the design of foundations for many buildings in Longyearbyen. Several issues related to solifluction can be observed today. An important question to be answered is "Will existing infrastructure on sloping terrains hold up in new conditions taking place due to climate change?" Therefore, an assessment is needed in order to identify what kind of countermeasure needs to be considered in order maintain the functionality of existing buildings which are affected.

The project initiative entitled "Impact of Changing Climate on Infrastructure in Longyearbyen: Stability of Foundations on Slope Terrain – Case Study" (FST Project) performed a vulnerability assessment of the slope above Building 16 on Road 232 and the performance of the timber pile foundations of House 33 on Road 236, which is located on a slope terrain. Ground investigations at these locations were performed in the springs of 2017 and 2018 together with students from the Arctic Technology Department at UNIS. These sites were equipped with thermistor strings, devices to monitor and record the ground temperatures of permafrost. These measurements may be used in future research and development projects.

[1] https://www.met.no/nyhetsarkiv/svalbard-blir-et-ufrivillig-laboratorium-for-klimaendringene

Fieldworks above Building 16 on Road 232 in spring 2017 (Photo: Anatoly Sinitsyn).

Analytical and numerical methods were used to model ground temperatures, slope stability and the performance of pile foundations in this study.

A generic study based on local conditions in Longyearbyen was performed during the first part of the study. Permafrost temperatures were modelled up to the year 2050[2]. Latest local climate projections on the air temperatures in Longyearbyen were kindly provided by the Norwegian Meteorological Institute. The projections were used to model ground temperatures. The ground temperatures were used to evaluate the stability of representative slopes in the study area and to analyze the performance of pile foundations. The capacity of single piles on a slope subjected to lateral loads was investigated by considering various factors such as slope angle, location of pile on slope, pile material and geometry.

The analyses showed an increase in the active layer up to 2 m or more and an increase in ground temperatures corresponding to the projected air temperatures. A representative slope was found to be stable for active layer thicknesses up to 2 m. However, accurate estimation of material properties is required for a definitive slope stability evaluation. Effects of increased lateral forces on pile foundations due to increased active layer thickness and solifluction were also investigated. As expected, it was found that the deflections of pile foundations and internal forces increase with increasing slope angles and active layer thicknesses. It was also found that the effect of deflections and internal forces is especially critical for timber piles where the capacity is expected (and shown) to reduce with aging. Many buildings in the area are still supported on timber piles.

[2] For RCP 8.5 forecast that corresponds to high greenhouse gas emissions.

The first part of the study highlighted the importance of assessing the effect of climate change on existing infrastructure to ensure safety and serviceability. The knowledge gained from the study also highlighted the necessity of the consideration of climate change in the design of new infrastructure to be built in affected areas.

Fieldwork with student from Arctic Technology Department at UNIS at the house Nr. 33 at the road 236 in spring 2018 (Photo: Anatoly Sinitsyn).

In the second part of the study, the performance of a building supported on timber pile foundations was evaluated. Residential house Nr. 33 at the road 236 was selected for the assessment. The house is located on a slope terrain. Findings from the first part of the study were applied to investigate the selected building. The effects of increased lateral loads due to solifluction, as a result of thawing and warming permafrost, on the pile foundations of the selected building were investigated through numerical analyses. A range of active layer thicknesses were considered in the analyses taking current and projected climate scenarios into account. The axial loads on the piles were estimated based on standard methods for residential buildings and variations are considered to account for uncertainties. The lateral loads on the piles were assumed to mainly originate from slope movements and loads transferred from the crest of the slope through earth pressure. It was shown that the pile head deflections are expected to increase as the active layer thicknesses increase. A similar trend of increase is observed in the internal forces generated in the piles. The results may be considered to be representative for other similar buildings in the area.

The study performed examined the impact of climate change on slope stability and the performance of pile foundations on sloping terrains in Longyearbyen. The results may be applicable to exiting buildings and to the design of new structures in the area. The importance of taking the impact of climate change into account was demonstrated. The areas with slope terrain in Longyearbyen are not and should not be excluded from the planning of residential buildings and other infrastructures, but foundation solutions shall be obtained to fulfil necessary requirements.