Two-dimensional transient thermal analysis of drilled-pile wall exposed to extreme temperatures and discussion on frost mitigation methods.

Santeri Tammi M.Sc., Summer Shahzad Ph.D.

Ramboll Finland Oy, Espoo, Finland

Eero Särkkä M.Sc., Mikko Hyyrynen M.Sc.

Ramboll Finland Oy, Tampere, Finland

Contact: summer.shahzad@ramboll.fi

Abstract

This paper analyzes earth-retaining walls made of drilled or bored large-diameter steel piles filled with concrete subject to Nordic temperature loads, especially focusing on Finnish temperature conditions and their effects and mitigation methods. Two-dimensional numerical analysis is carried out with Finite Element Method (FEM) software Comsol Multiphysics 6.1. The result's order of magnitude is validated by a literature review and by a one-dimensional analytical model. The paper aims to understand the frost depths with and without thermal insulation and to find their optimal locations. Results show that the thermal insulation layers might not give the intended benefits if the thermal bridges are not mitigated carefully. Moreover, it is evident from analysis that the horizontal part of the insulation covering the top of the ground plays an important role in decreasing the frost depth. The important findings will help designers reduce material waste, save public money in big infrastructure projects, and preserve the environment.

Keywords: frost depth; cold bridges, frost heave; thermal insulation; extreme temperature loads; retaining wall; bored-pile wall; sustainability; non transient thermal analysis; heat transfer; numerical analysis.

1 Introduction

Temperature loads on structures have a significant impact on their structural behaviour and performance. These loads arise from the expansion and contraction of materials due to temperature variations, leading to thermal stresses and deformations. Understanding the effects of temperature loads is crucial for the design and analysis of these structures to ensure their stability, structural integrity, longevity, durability, and watertightness.

One of the causes of temperature loads include frost heave, which leads to additional loads on the structure. Because these loads are difficult to estimate due to the complexity of the problem, so usually mitigation methods are used to prevent the frost heave phenomena and therefore the knowledge of frost depths becomes indispensable.

The frost depth in the ground can be estimated using literature-based measurement results or by solving analytical equations in simple cases only. However, in a case of a retaining wall the approach is not applicable due to the complexity of the geometry. In addition to the horizontal boundary (surface of the ground) there's also a vertical boundary from which heat transfer occurs. Thus, the problem should be viewed at least in two dimensions. In addition to the increased dimensions, there's a possibility that the retaining wall forms a thermal bridge, which has a detrimental effect on frost depth.

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