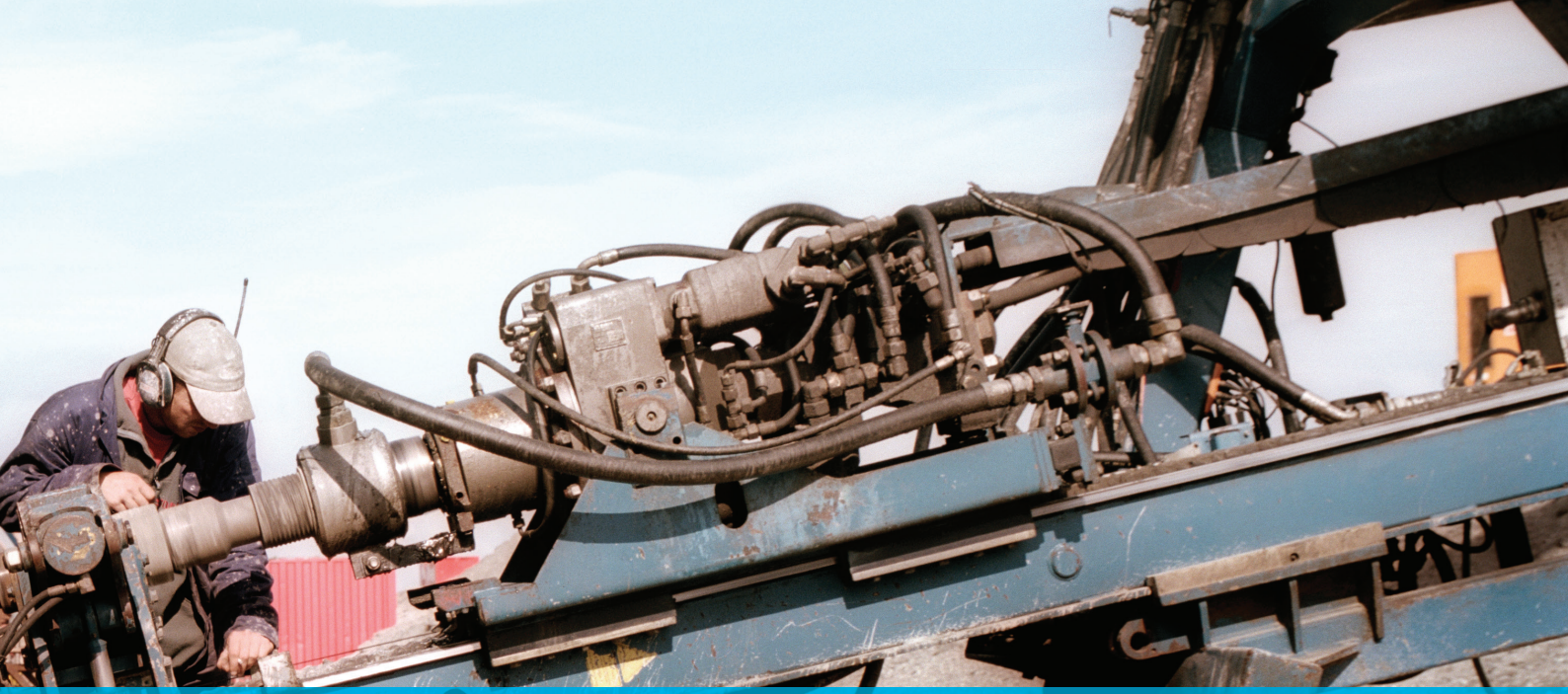

PLAXIS Expert Services update
2D Thermal analysis of soil freezing with flowing water

Joseph Sopko, Director, Ground Freezing, Moretrench

Plaxis was contracted by Moretrench in the USA to provide assistance in setting-up 2D finite element models for the analysis of time-dependent temperature development in frozen ground with flowing water. Thanks to PLAXIS Expert Services, valuable results have been obtained in terms of evaluating the time required to obtain a satisfactory frozen wall thickness depending on the water flow intensity generated by neighbouring dewatering.

Introduction

The aim of the project is the construction of a 6 m wide and 8 m tunnel by means of ground freezing in a soil formation. This construction will stabilise soil so that it will not collapse during tunnel excavation. It will also avoid water penetration inside the excavated zone due the impermeable nature of the frozen wall. During ground freezing, groundwater flow can have a significant influence because heat flow via convection is often more effective at moving heat than conduction alone. Numerical analysis of the conduction-convection process requires a coupling of the heat and water transfer equations. This project presents the analysis of a heat transfer analysis involving groundwater flowing around freeze pipes.

Finite element modelling

The dimension of the FE model is 50 m by 50 m. The model contains a total of 4,500 elements and 36,000 nodes (so roughly 150,000 degree of freedom). The freezing pipes have been modelled by means of 3.81 cm radius circles along which convection heat transfer is being applied (30 in total around the perimeter of the zone to be excavated). The thermal boundary conditions at around of the PLAXIS model along with the initial temperature are 15°C. The hydraulic boundary conditions were selected in this analysis to establish a lateral groundwater flux of various intensity ranging from 0.25 m/day to 1.5 m/day.

The main thermal properties (volumetric heat capacity and heat conductivity) are specified independently for the dry soil on the one hand and the water and ice materials on the other hand. PLAXIS will consider the overall thermal properties for the porous medium (as a mixture of soil, water and ice) through geometric means depending on the value of the unfrozen water content, which is temperature dependent and must also be given as a specified user input. Finally, specific latent heat of fusion releases energy during thawing (ice to liquid) and absorbs energy during freezing (liquid to ice) must also be specified. It has to be noted that PLAXIS handles the coupled physics (heat transfer for the temperature and mass water balance for the pore water pressure) with the same calculation program.

PLAXIS Expert Services added value

- Demonstrate the ability of the PLAXIS 2D Thermal module regarding temperature development in frozen soil with flowing water
- Benchmark PLAXIS thermal capabilities in terms of accuracy and performance
- Next business-day advanced technical assistance

"The PLAXIS approach to freezing with groundwater velocity supersedes anything commercially available. It avoids numerical instability typically associated with these types of models. PLAXIS Expert Services provided the necessary training to use these programs as well as prompt and thorough assistance in completing our models. This is a major advancement in our industry"

About Moretrench

Moretrench is a geotechnical contractor delivering geotechnical solutions to the underground, industrial and environmental remediation industries. Moretrench offers a wide range of specialised services with skilled and experienced engineering teams in the field of dewatering and groundwater control, ground freezing, earth retention and anchors, deep foundations, underpinning, grouting and ground improvement, as well as environmental remediation.

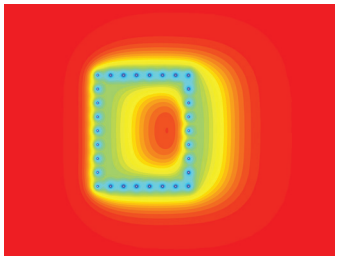

Figure 1: Temperature distribution around freezing pipes

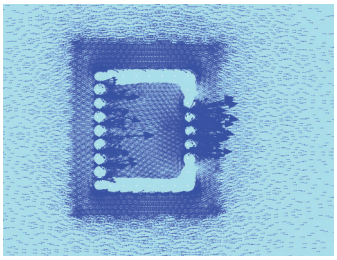

Figure 2: Water flow around freezing pipes