Interaction between artificially frozen soils and constructions due to frost heave and results of laboratory tests

O. Oung, & H.E. Brassinga, Rotterdam Public Works, Rotterdam, The Netherlands

Discussion theme: 2

The success of artificial freezing techniques in geotechnics lies mainly on their possibility to create a temporary water-tight structure, which afterwards can just be discontinued. The shape of the frozen body can be designed in such a way that it fits the needs of standard and non standard geotechnical purposes. The applications most commonly observed are in the construction of cross-connecting tunnels between main bored tunnel linings or as a temporary retaining wall meeting a non standard geometry.

However to design such 'frozen structures' is not straightforward. The freezing process, if not under control, can generate relatively high pressures or large soil deformations, which can bring instability to constructions in its vicinity. Therefore during the design phase, it is crucial to investigate soil behaviours during freezing and their effects on structures.

To obtain a good insight in the behaviour of specific soils during freezing, it is highly recommended to have at least 1D-frost heave tests done. These tests provide a quantitative insight on one-directional heave, perpendicular to the freezing injection lances. These tests have been modelled and are summarised in the definition of the segregation potential, which is a measure of the velocity of the freezing front related to a difference of temperatures in the freezing area. Based on the determined segregation potential, the effects of frost heave can be mainly evaluated. However in some situations, additional information is needed to check whether more effects of frost have to be taken into account. This happens especially in situations for which the axial component of the frost heave, e.g. parallel to the freezing injection lances, may have a large impact on existing structures and therefore cannot be neglected.

For the extension of the Central Metro Station in Rotterdam, the artificial freezing technique turned out to be the optimal solution to be applied. The frozen structure, consisting of a retaining wall made of frozen soils, should embed the metro tunnel. The latter ends in the middle of the excavation pit and the metro line has to stay in activity during the existence of the excavation pit. From the tunnel slab downwards, freezing liquids will be injected into vertical lances. In this configuration, the tunnel could be uplifted due to two causes: firstly due to the axial frost heave and secondly the radial frost heave can indirectly exert vertical forces on the tunnel slab. To have the constructive stability of the metro tunnel under control especially during the freeze-up phase (e.g. the making of the 'ice wall'), it was essential to have laboratory tests carried out in order to evaluate the axial and radial components of frost heave. Both 1- and 3-dimensional frost heave tests have been carried out. Based on this information, stresses and soil deformations that can be generated by frost have been analysed using results of Finite-Element calculations.

In the paper, the 1-and 3D frost heave tests will be described. The results of the tests will be given. The interpretation of the results obtained will be presented. Finally, the total effects of freezing soil on the geotechnical construction will be discussed. Special attention will be drawn on situations where these effects must be carefully evaluated.

Author's address for correspondence:

Dr. O. Oung
Rotterdam Public Works
P.O. Box 6633
3002 AP Rotterdam
The Netherlands
Tel: +31 (0)10 489 7078
Fax: +31 (0)10 478 0595
O.Oung@gw.rotterdam.nl