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Structural behaviour of collar construction made of frozen soils in a deep excavation

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Discussion theme: 2

For the renewing and extension of the Central Metro Station at Rotterdam, a construction of a retaining wall made of frozen soils turned out to be the optimal solution for various reasons.

Because of the dimensions of the excavation pit (220 x 50 m^2), the water-tightness of the “ice wall” and its connections to the diaphragm walls was strongly required. Among soil improvement techniques, the freezing technique implies less risks of leakage than the others. The “ice wall” as well as the connected diaphragm walls ended at a depth of 38 m below soil surface (NAP –38 m).

The non standard geometry of the excavation pit at stake was also a reason for the application of the freezing technique. The metro tunnel was to cross the limits of the excavation pit and therefore had to be wrapped by the “ice wall”. Besides, the “frozen wall” has to cut-off the excavation pit from flow and to retain soil and water pressures during an excavation down to a depth of 14 m under the soil surface level (NAP –14 m). The horizontal forces acting on the “ice wall” have to be uniformly spread in order to limit their action on the connected diaphragm walls, especially at the junctions between panels. To this respect, it was anticipated that a wall with the shape of a semi-circular collar would better fit this requirement than a rectangular one.

In the case of the excavation pit of Central Metro Station at Rotterdam, a soil investigation and laboratory tests have been performed on frozen soils in order to have a better insight on the behaviour of a frozen soil body. The soils samples were taken in the vicinity of the location of the ‘ice wall’. The uniaxial oedometer and triaxial tests on the frozen soils were carried out to determine the strength and stiffness parameters. In the testing programme, effects of temperature (e.g. -10 ^{o}C and -20 ^{o}C) were evaluated as well as effects of time on the settlement of the frozen soils. The time effects on the settlement or ‘creep’ effects of frozen soils were carried out in uniaxial oedometer tests with a constant strain rate.

The design of the “ice wall” was to be checked. Based on the determined parameters on the frozen soils, Finite Element analyses were carried out to evaluate the structural behaviour of the “ice wall” and its action on the tunnel during the excavation phase. In-situ measurements of the deformations and soil stresses in and nearby the frozen wall were obtained and compared to the results of the 2-dimensional Finite Elements calculations.
Besides the effects of the horizontal soil forces acting on the diaphragm walls, which were connected to the “ice wall”, were estimated in 3-dimensioinal Finite Element calculations. The actual deformation of these diaphragm walls and stresses exerted by the frozen wall were measured and compared to the calculated ones.

The paper describes the soil investigation and laboratory tests. The parameters obtained on various frozen soil types will be presented and discussed. The model of 2D and 3D Finite Element calculations will be outlined. The results obtained will be analysed using in-situ measurements. Attention will be drawn on the use of a structure made of frozen soils as retaining wall in a deep excavation pit.

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