Panel discussion: A contractor's view of the risks involved with deep excavations in water-bearing soils

Débat de spécialistes: Le point de vue de l'entrepreneur sur les risques que présentent les fouilles profondes dans des couches aquifères

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The development of our cities and the building of large engineering structures in increasing numbers demand the construction of large-size excavation pits, often entering deep into the existing ground water. Conventional methods to provide a dry excavation pit by means of ground water lowering are being pushed more and more into the background with the increase and greater importance of economic water control and environmental aspects. Ground water lowering should also be avoided in the event that it infringes on existing water rights or would cause unacceptable settlement of nearby buildings.

These days, with the help of impermeable vertical shoring walls and suitable horizontal sealing measures, it is possible to construct nearly watertight excavation pits, which avoid negative influences on the surrounding area and groundwater.

For horizontal sealing, existing impermeable layers within the ground formation can be used, provided that the vertical sealing walls can be extended down into them. Where natural impermeable layers do not exist, it has become common practice to install artificial layers to form a horizontal cut-off, such as uplift-safe or uplift- secured underwater concrete slabs, or injected slabs using various grouting techniques.

These horizontal grouted slabs, which have been used as a construction method by ground engineering contractors since the mid-sixties, are the subject of this short contribution.

Due to the high alkalinity that is introduced into the ground water by the use of sodium silicate based injections these horizontal slabs are increasingly executed by the jet grouting technique, by which standard cement based grouts can be used.

Typical specifications today require the contractors of such watertight troughs to guarantee the seepage flow as follows,

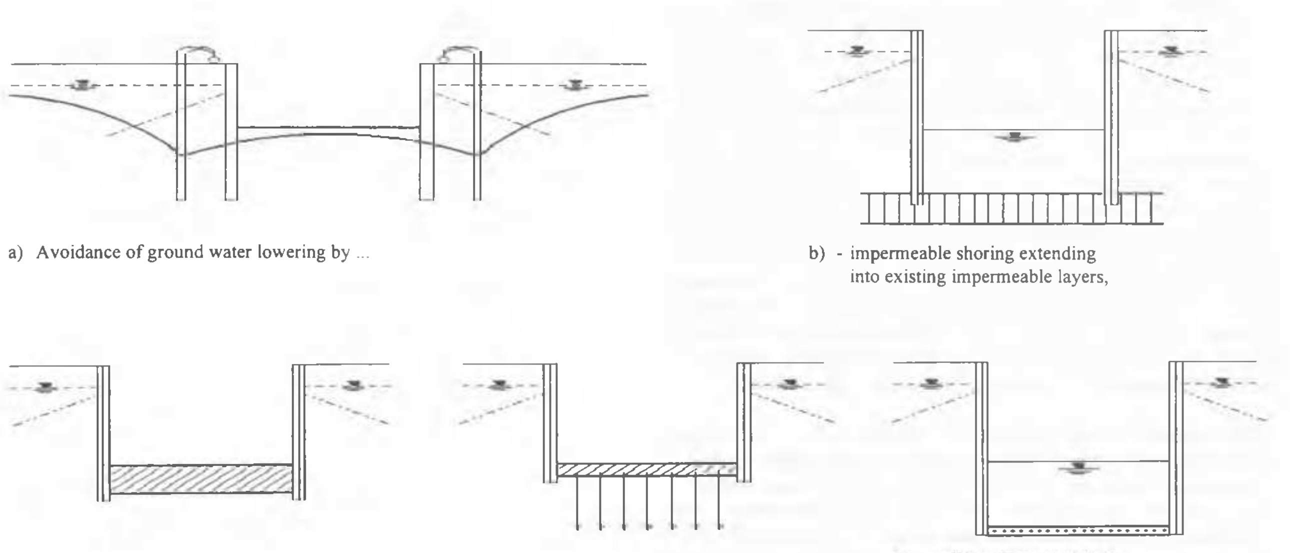
- flow through diaphragm walls 0,5 l/s per 1000 m²
- flow through bored pile walls 0,75 l/s per 1000 m²
- flow through horizontal slabs 1,5 l/s per 1000 m²

and excavation generally cannot commence until the allowable flow rate has been achieved and proven by a pumping test. Whilst these are indeed very stringent criteria as they stand, the efforts of the licensing authorities to further reduce the quantity of seepage into the pits are becoming more noticeable.

I have to admit that I am concered about this development, since it neglects the fact that a jet grout slab, as any other in-situ ground improvement method, is highly dependant on the prevailing ground conditions and that also modern ground engineering technologies, even with the best quality assurance system, do occasionally go wrong. Fact is, that the success of such a sealing operation depends to a very large extent on a smooth and good co-operation between all parties concerned. Misinterpretations of the soil conditions and performance defects can easily lead to almost undetectable leaks in the slab and walls, which can only be repaired with excessive time and at great financial cost.

Despite these findings, which are known by the specialists dealing with sealing walls and slabs on behalf of the client (Consulting Engineers and Contractors), and despite some painful mishaps, there are regrettably no visible attempts at a meaningful joint effort to increase quality and safety of the system "watertight trough".

Instead, it is becoming usual practise to demand from the contractor a sealing slab with a contractually fixed quality, which controls the final acceptance of the contracted works.



a) Avoidance of ground water lowering by ...

b) - impermeable shoring extending into existing impermeable layers,

c) - uplift-safe under water concrete slab

d) - anchored under water concrete or jet grouted slab

e) - uplift-safe grouted slab

Figure 1 Deep excavations in water-bearing soils

With that, the risk for the ground conditions is transferred to the contractor, which is not normally the case for ground engineering activities, unless specially agreed in advance, and inspite of the fact that the efficiency of any grouting operation is dependant, to a very large extent, upon certain appropriate ground conditions being present.

Such a form of contract is extremely biased, as the burden is exclusively placed onto the ground engineering contractor and, in case of failure, far reaching and costly consequences with respect to payment, guarantee, programme and in particular insurance cover will result. In the case of a failure, the possible cost effects are generally not sensibly related to the original contract value, and from the economic point of view, the acceptance of such a contract can therefore hardly be justified.

This contribution should therefore be considered as an appeal to maintain the basic principle of good construction practice for all ground engineering work, including of course the installation of grouted slabs, in that:-

The risk for the construction ground lies with the client.

When looking at the evolution of the grouting techniques in contractual regard, one will notice how the grouting of sediments has departed from rock grouting. Admittedly, we are today, within certain limits, in a position to produce grouted soil bodies for bearing and sealing purposes with defined sizes and characteristics. Prudence is however necessary when choosing the appropriate factors of safety for design purposes. It must be remembered that the completed grouted or jet grouted body is not homogeneous, and therefore generally does not exhibit a constant strength or hydraulic characteristic. Due to the variability of the foundation soil, an uneven distribution of strength and permeability can occur, and any static calculation as well as the requirements for quality control should be based on average values only.

Therefore the question must be raised as to whether these thin membrane-type sealing slabs, with their most important characteristic being impermeability, can in practice, and with sufficient reliability, be produced to such stringent specifications. As long as no proven methods are available to detect and locate leakages, which may occasionally occur, this question has to be denied.

It is therefore proposed to determine the construction parameters for a jet grouted slab according to the state of the art and by taking into account the findings of the soils report. These parameters are then to be verified on site prior to the commencement of the works. When choosing the distance between the jet grout columns, consideration has to be given to the drilling deviations as well as to any variances in the soil strength, its density and granulometry. All parameters, which should be established jointly by the contractor and the Consulting Engineer, are to be maintained, monitored and recorded by the specialist contractor and it is his responsibility to carry out the works strictly in accordance with these determinations. Specified seepage flows are then target values only and in the event that additional grouting work becomes necessary, in spite of adherence to all parameters, it has to be borne by the client.

As we, unfortunately, cannot assume that such a radical change of contract conditions can be achieved quickly nor that the requirements relating to the construction of excavation pits in ground water will be relaxed easily, the efforts of all concerned parties must be concentrated to increase the safety of the system. Specialist contractors, which will in future deal with watertight troughs, will have to increase the already considerable amount of controls and monitoring; but this alone will not be sufficient:

With regard to slabs, not only a sufficient factor of safety against erosion under a given hydraulic gradient should determine their thickness. With increasing depth, inaccuracies of the construction procedure also increase in proportion, and therefore an appropriate increase in the slab thickness should be adopted.Therefore the minimum thickness of a jet grouted slab should be 1.0 m. The thickness should be increased by 0.1 m for every meter in excess of 10.0 m depth.

- In view of the difficulty to locate leakage zones, the excavation pits should be separated into hydraulically independant compartments, which should not exceed 2000 m^2 in plan.

- The joint between vertical wall and horizontal slab requires special attention. It is recommended to increase the slab thickness in the immediate vicinity of the wall.

- Different elevations within the slab should be avoided. Likewise a slab should not be located within soils containing organic material or cobbles and boulders.

- The time schedule should foresee sufficient time for remedial work to be performed should it become necessary.

Many of these proposals may lead to an increase in costs for excavation pits in ground water, however, their acceptance could prove to be a wise decision from a general economic point of view, as the safety of the system would be enhanced, which is ultimately in the interest of all.