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SYNOPSIS: In practice there are different processes which are used to support excavations and to maintain the groundwater level in excavations which go down to this level. In urban areas the diaphragm wall is frequently used to protect the excavation and as underground water packing against groundwater flowing in form the side. In addition, the lowering of groundwater is necessary using a well point within the excavation.

A new fondation trench sheeting has been developed by the author of this paper. This new method is an improvement on the diaphragm wall by which not only is the earth shored up, but the lowering of the groundwater within the excavation can also be carried out. In accordance with the function of this method, we refer to the new type of foundation trench sheeting as drainage walling. This drainage walling is manufactured in a similar way to the diaphragm wall.

We have observed drainage walling on building sites which differ greatly from each other. The results of our observations are intended to demonstrate the advantages and also the problems involved in this new process to the planning and project engineers.

INTRODUCTION

A planning engineer is continually faced with the task of choosing a method of excavation support for a given structure. He then has to decide on all ensuing details. It is not until building has been completed that it becomes clear whether the correct choice was made and whether the building methods were economically viable.

The choice of excavation support is not easy as the choice is dependent not only on technical factors but also on non-technical factors and conditions. By technical factors we mean such factors as the size and depths of the excavation, a possible adjoining excavation and the type of subsoil. The non-technical factors, such as the necessity of there being no change in the underground water level outside the excavation can be numerous and of import.

The many demands made on an excavation mean that there is a tendancy to set up various types of support next to each other. The required conditions are thus met locally, but this method is highly unsatisfactory as far as the whole excavation is concerned. For this reason a diaphragm wall and a grouting wall are often combined with a sheet pile or another kind of support. This leads to various subgrade surfaces beneath the structure and usually to difficulties such as differences in settlement which then have to be equalized.

If one compiles a list of the demands made on excavation support, it soon becomes clear that there are numerous solutions available at present but that these are unsatisfactory in certain cases. This report aims at introducing a new type of excavation support which should close this gap to building specialists. I intend to base my explanations of this new type of excavation support on current practices and thus show the necessary basis for planning. This method of excavation will then be demonstrated by an existing example.

EXCAVATIONS BELOW GROUNDWATER LEVEL

Nowadays there are many different types of excavation support available. If the excavation is more than two storeys in depth, the number of possibilities is reduced. This is especially the case in an urban area, as vertical excavation walls are required here in general.

These deep excavations frequently reach the groundwater level. The excavation must be free from water for construction work, which means that the groundwater must not be allowed to penetrate into the excavation, but must be diverted before this can happen. It is possible to seal off the groundwater. In the following diagram normal procedures are shown which are independent of the type of support.

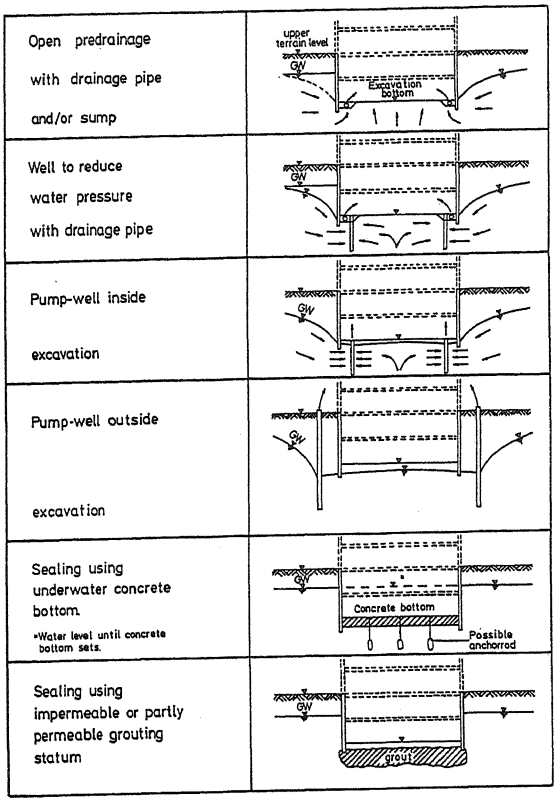

Fig 1: excavations below groundwater level

- open dewatering with drainage conduit and/or sump. Simplest type but groundwater lowering only possible up to 1-2 metres at a maximum; danger of hydraulic seepage into the excavation bottom.
- well to reduce tension with drainage conduit: especially advantageous in excavations where coheseive and pebbly soils alternate; lowering of groundwater possible up to a maximum of three metres.

-pump well inside the excavation; groundwater can be lowered to any depth; watertight excavation support has additional advantages; hydraulic seepage is largely avoided; the preparation of watertight foundation slab can cause hindrances.

- pump well outside the excavation; groundwater can be lowered to any depth; extreme depths mean large amounts of water which have to be pumped off; any type of excavation support can be applied; no hindrance caused by the preparation of watertight foundation slab.

- sealing off using underwater concrete bottom: watertight excavation support necessary; underwater concrete is introduced after completion of underwater excavation; buoyancy anchor rods may be necessary as an extra buoyancy guarantee; the lowering of the groundwater level should not take place until buoyancy reliability has been obtained.

- impermeable grouting bottom: watertight excavation support necessary; excavation down the groundwater level; production of grounting element, strength and depth depend on buoyancy security.

- partly permeable grouting bottom, production as above although it merely serves as a braking stratum (comparable to a cohesive interim stratum); remaining water has to be pumped off using open predrainage.

The main difficulty with excavations below the groundwater level is avoiding hydraulic seepage. This can be done using pump wells (inside or outside the excavation) or tail water concrete bottom and a grouting stratum. It must be borne in mind here that the latter two methods often tend to be expensive. The use of the pump well within the excavation ensures good control of the groundwater lowering but it is relatively difficult to seal the foundation slab against pressure from the groundwater. The reason for this is that the wells are in full use during building. This problem does not occur with wells outside the excavation. It is, however, often difficult to arrange wells outside the excavation, as excavation support is often situated at the edge of the building site and the wells would have to be set up on adjoining building sites.

PRINCIPLE OF DRAINAGE WALLING

Taking the possibilities of supporting deep excavations with predrainage as a starting point, it becomes apparent that the above-mentioned solutions often do not correspond with the wishes of the builders and contractors or with the building conditions. For this reason the demands made by deep excavations below the groundwaterlevel have been listed:

- The excavation should be deeper than foundations of directly adjoining buildings

- The excavation bottom should be flat to ensure full use of the lowest storey (as a storeroom or carpark).

- The excavation or excavation support should be set up directly along the edge of the plot.

- A terracing of the excavation bottom is not permitted as this would mean the loss of otherwise usuable volume of building work.

- The excavation must be completely open during building, i.e. no shoring should reach into the excavation.

- It is not permitted to make demands on neighbouringbuilding sites, although this may be possible for a short period during a difficult stage of building.

- A predrainage of the groundwater must not be allowed to infringe on building work and the excavation bottom in particular should be kept clear.

- No hydraulic seepage in the excavation must be allowed to occur through predrainage.

- The excavation support should be at least technically watertight so that a later sealing of the lower groundfloors against groundwater would not have to be carried out in entirety.

- The excavation support should be includes into the planned structure as far as possible in order to keep costs down.

- The foundation slab must be adjoined to the excavation support in such a way as to be watertight.

- As soon as buoyancy of the structure is guaranteed, predrainage should be stopped.

- The possibility of a later groundwater lowering should be left open to avoid subsequent work on the foundation slab and cellar walls leading to flooding.

- A continuous drawing off of groundwater is to be reckoned with to ensure that available water for washing plants and heat pumps etc. is available.

- Groundwater must not seep into cellars when water is being made available for use.

If one accepts these points, excavation support must fulfil five different requirements:

1. Support of the excavation against soil.
2. Predrainage of groundwater.
3. Sealing against groundwater.
4. Removal of building loads.
5. Possibility of later drawing off of water for use.

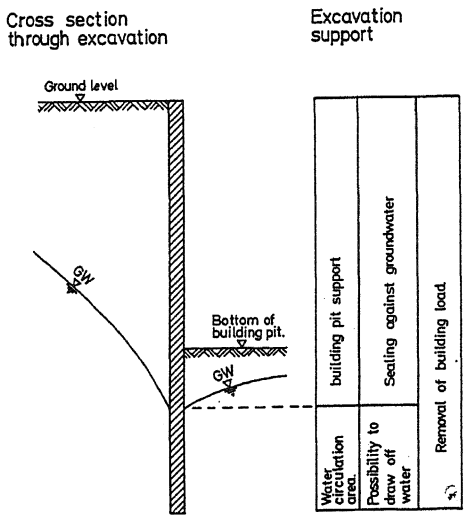

Fig 2: Area distribution of the requirements made on excavation support.

Excavation in present general use cannot fulfil these requirements. In order to find a new solution, the area distribution of the requirements must be looked at from the excavation support. Figure 2 is included for this reason.

Area A: Support of the excavation, sealing against groundwater and removal of building loads; in such cases ordinary excavation support such as a diaphragm wall or an overlapping bored pile wall can be used.

Area B: Groundwater lowering, subsequent drawing off of water for use and removal of building loads; the well function and bearing capacity can be combined with a permeable load-bearing building material for development of this area. Pervious concrete is a possible permeable building material with load-bearing qualities.

A type of axcavation support shich fulfils both of these conditions is known as drainage walling. In principle, the diaphragm wall, pile wall or single pile could be used as excavation support. Figure 3 shows a cross-section of drainage piles.

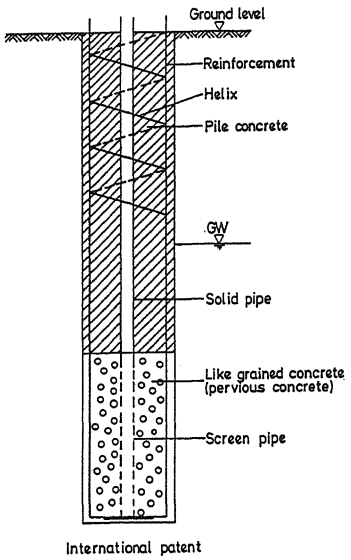

Fig 3: Structure of drainage piles

As opposed to the ordinary pile, a drainage pipe is additionally built into the middle. The lower part of this pipe (via which the groundwater lowering should take place) consists of a screen pipe and the upper part of a solid pipe. In addition, pervious concrete is built into the lower part instead of the normal pile concrete. This enables underground draining to take place via the pipe in addition to the fact that the pile has a load-bearing capacity and is able to absorb bending moments.

The same structure can of course be carried out on one element of a diaphragm wall. In this case we speak of a single drainage wall.

APPLICATION

The new drainage walling represents an extension of excavation support in general use at present. Using the drainage pile described above as a starting points, four different types of drainage support can be listened here.

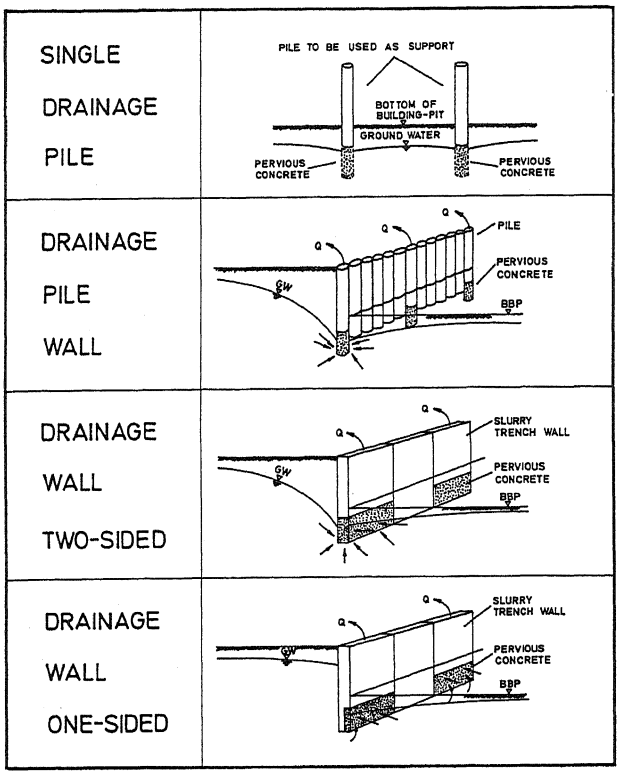

Fig 4: Drainage walling Systems

Single Drainage Pile: Any single pile can be built into a drainage pile and it does not necessarily have to be used as excavation support. The single drainage pile is of especial interest for covered-in building methods, as it ensures that very large excavations can be opened and the surface course, which is appropriate to the terrain, supports itself in the deeper building plot by this drainage pile. At the same time the whole predraining process can be carried out by means of the drainage piles.

Drainage Pile Wall: Single drainage piles can be arranged in the pile wall as excavation support to ensure the predrainage of the excavation. In Fig. 5 we can see a drainage wall under construction. Whether the drainage pile has to be deeper than the other piles or not now depends entirely on the subsoil conditions. A decisive reason for making the drainage pile deeper is the pressure of the groundwater and the permeability of the subsoil.

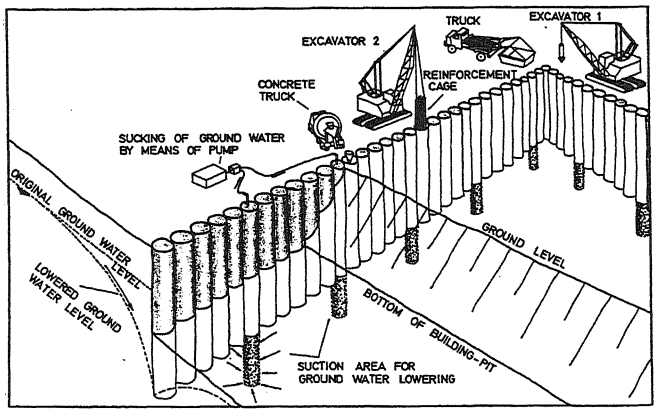

Fig 5: Construction of Drainage Pile Wall

Drainage Wall Two sided: As in the drainage pile wall a drainage element is built into the lower part of the diaphragm wall. In this way the same effect is attained as in the drainage pile wall. A diagram did not appear necessary in this case.

Drainage Wall One-sided: Using the diaphragm wall as a departing point, a drainage element is built into single elements of the lower part on one side only. This, of course, demands very great precision in all stages of work. The advantages are, however, of great import. The one-sided sinking arrangments make it possible to extract water from within the excavation and more or less retain the level of the groundwater outside the excavation at the same time. This method is of special importance in urban excavations where a normal lowering of the groundwater would lead to settlement of adjoining buildings. A one-sided drainage wall under construction can be seen in Fig. 6.

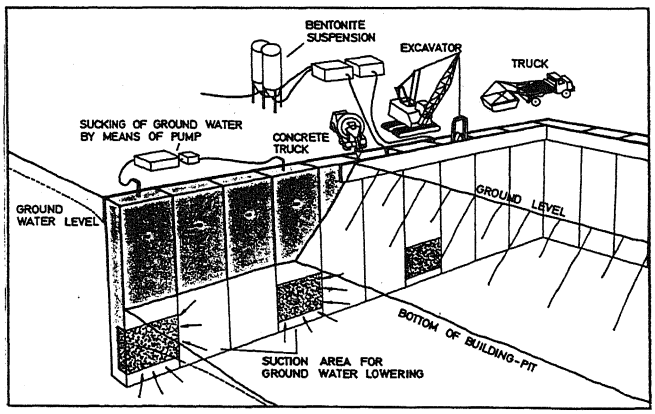

Fig 6: Construction of one-sided Drainage Wall

The one-sided drainage wall is not only advantageous for the excavation itself but also for environmental reasons. For example, the natural groundwater stream underneath a rubbish tip or a contaminated waste depot can be cut off by using a one-sided drainage wall and an artificial stream underneath the tip can be forced. In this way the groundwater which has been soiled by seepage

water can be drawn off and a filter plant can be put into use.

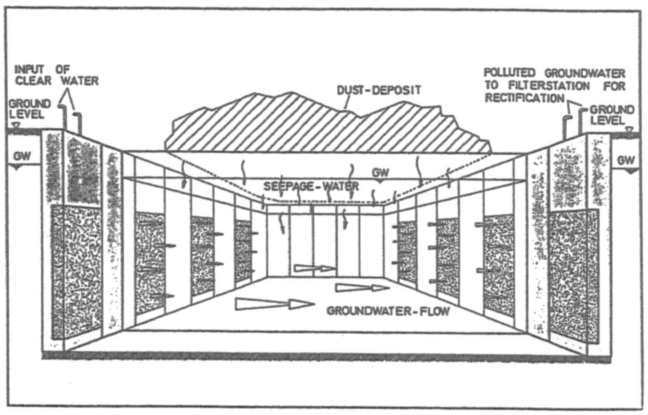

Fig 7: Drainage Wall under Rubbish Tip

The one-sided drainage wall can also be used to an advantage in the case of a tank store as shown in Fig. 8. Should a leak occur in the tank, then soiled groundwater can be pumped off and purification carried out.

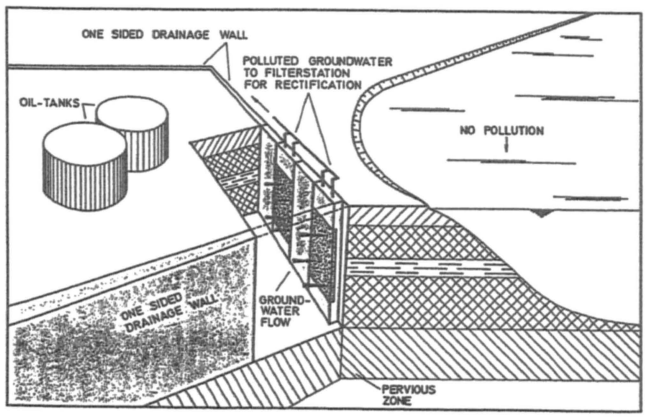

Fig 8: Drainage Walling as a Security Mesure with Oil Tanks

The different uses of a drainage wall have certainly not yet been fully recognized. Future use will bring a number of improvements in technical realazation and production. It is, therefore, especially important for the future that engineers and contracting firms work closely together during production and calculation of drainage walls.

SITUATION OF BUILDING SITE

Drainage walling was first put into use at an excavation for the construction of a power plant in Wald in Salzburg. The excavation support was intended for the first building phase at a depth of approx. 12 metres. The soil to be supported in this area consists mainly of boulder detritius on a slope consisting of all particle sizes ranging from silt and stones to large stones. The subsoil is densely compacted. which means relatively good characteristic values for the dimensioning of the excavation support. Fig. 9 shows a cross-section through the excavation giving the most important data.

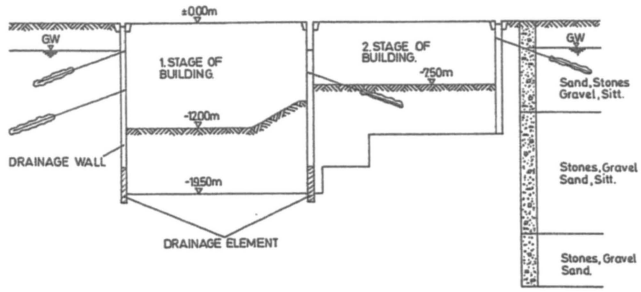

Fig 9: Cross-section through an excavation

An additional lowering of the groundwater was necessary for excavating since the groundwater level was measured at approx. 1.5 metres below the upper edge of the excavation. As far as permeability was concerned, the subsoil in and unter the bottom of the excavation was relatively dense. From the beginning it was not necessary to reckon with high groundwater flow as the permeability was k = 0.0005cm/sec. For this reason it was decided to arrange four drainage elements in the chosen diaphragm wall in order to relieve tension on the subsoil from groundwater pressure in the excavating phase

Because of the detailed soil stratum water pressure of between 2 and 5 l/sec. maximum was calculated for the entire excavation. The water should then be drawn off from the subsoil via the four drainage elements. A pumping off of the water found in the excavation area was also provided for during excavation via additional open predrainage. The entire excavation should then be kept dry by using the four built-in drainage elements.

CONSTRUCTION OF THE DRAINAGE WALL

As mentioned above a diaphragm wall was intended from the beginning as excavation support. The difference between this and drainage walling lies merely in the integrating of the drainage element into an element of the diaphragm wall. Few extra

construction steps were necessary in addition to the construction of a normal diaphragm wall to construct this drainage element which was arranged in all four cases at a depth of between 17.5 and 2o.5 metres. Drainage piping was inserted into every one of the four elements as shown in Fig. 1o. The drainage piping consisted of a 4 metre long filter pipe with a solid pipe above. The filter element was thus only placed within the area of the drainage element.

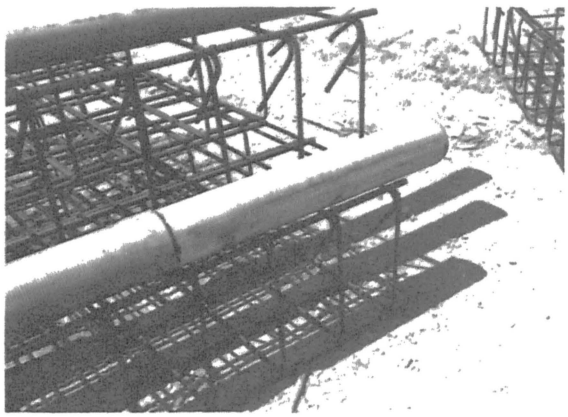

Fig 1o: Drainage Pipe and Reinforcement for the Diaphragm Wall

Fig. 11 shows the drainage wall element before concreting. As can be seen from the diagram two concreting pipes were used to obtain a constant pouring level for the filter concrete. Filter concrete was then inserted via the concrete pipe. The filter concrete consisted of filter gravel 4–32 mm and 25o kilos of cement per cubic metre of precast-concrete. An additive was included before concreting which fixed the cement glue to the gravel grains.

Fig 11: Preparation for Concreting for a Drainage Element

After bringing the filter concrete into the desired position the remaining part was concreted with normal precast-concrete as with ordinary diaphragm walls. After hardening over a period of approx. ten days, the bentonite suspension was removed from the drainage pipe and the layer of precast-concrete. This was achieved by extremely powerful shocking (powerful, rapid pressure changes) as when sand is removed from a well. Immersion pumps were then built into the drainage piping and pumping off of the groundwater could commence. In Fig. 12 we can see water pumped off using a drainage element. The pumped off water amounts corresponded approx. to those previously calculated theoretically for reducing the groundwater level.

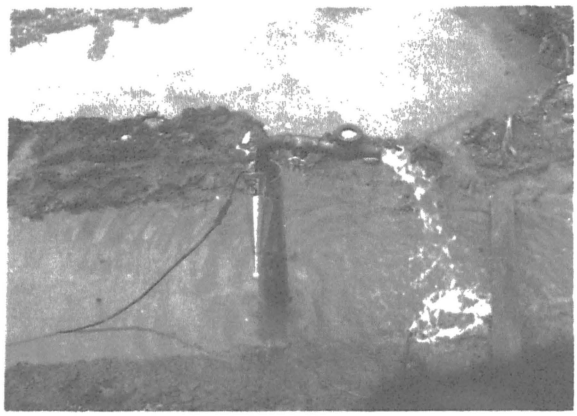

Fig 12: Pumped off Groundwater using a Drainage Element

CONCLUSION

This paper aims to introduce a new type of excavation support to specialists. Taking present solutions as a starting point, this excavation support represents an extension whereby groundwater lowering can be carried out within the excavation support for the first time.

It was possible to use this new type of drainage support for an excavation used for a power plant. The pumped off amounts of water corresponded exactly with these which had been previously theoretically calculated.

It is hoped that this new possibility of groundwater lowering will be used in future in structures and in cennection with excavation support. It is also hoped that the economic viability will thus be proved.

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