SCANDINAVIAN DRILLED MICRO PILE WALLS

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ABSTRACT

An excavation in an urban environment often requires vertical walls due to lack of space for slopes since there are streets, foundations, pipes and so on. Further, the soil usually contains obstacles, like boulders and concrete debris, to mention a few. In Scandinavia, Micro Pile Walls have been developed for such conditions. The development relies very much on improved drilling technology, but design methods have also been refined. Tests have been made in order to utilize the full capacity of drilled, concrete filled, small diameter, thin walled steel tubes.

The use of drilled micro pile walls is not confined to city projects: This technique has also proven very useful for excavations in factories, where production must go on during the piling stage, and the time schedule must be guaranteed. And even at locations where there are no buildings or other objects nearby, drilled Micro Pile Walls may be the only solution due to the presence of obstacles impossible to penetrate with conventional secant pile wall boring equipment, or other methods.

INTRODUCTION

A drilled pile wall is made up by a number of components, illustrated in Figure 1. They main parts are

- drilled steel tubes, spaced at regular intervals
- supporting members
- infill members to cover the space between the tubes

The tubes are usually in the range 100 - 400 mm in diameter and the corresponding wall thickness is 5 -15 mm. The tubes can be filled with concrete and also supplied with reinforcement bars, or an H-beam, in order to increase bending capacity.

The horizontal support can be provided by soil or rock anchors, or any type of support suitable for the conditions. If the wall has limited height and the tubes are drilled into competent rock, the wall can function as a cantilever beam.

The cover between the drilled tubes can be covered by wood, steel plates or shot concrete. The choice is determined by cost considerations and the durability requirements.

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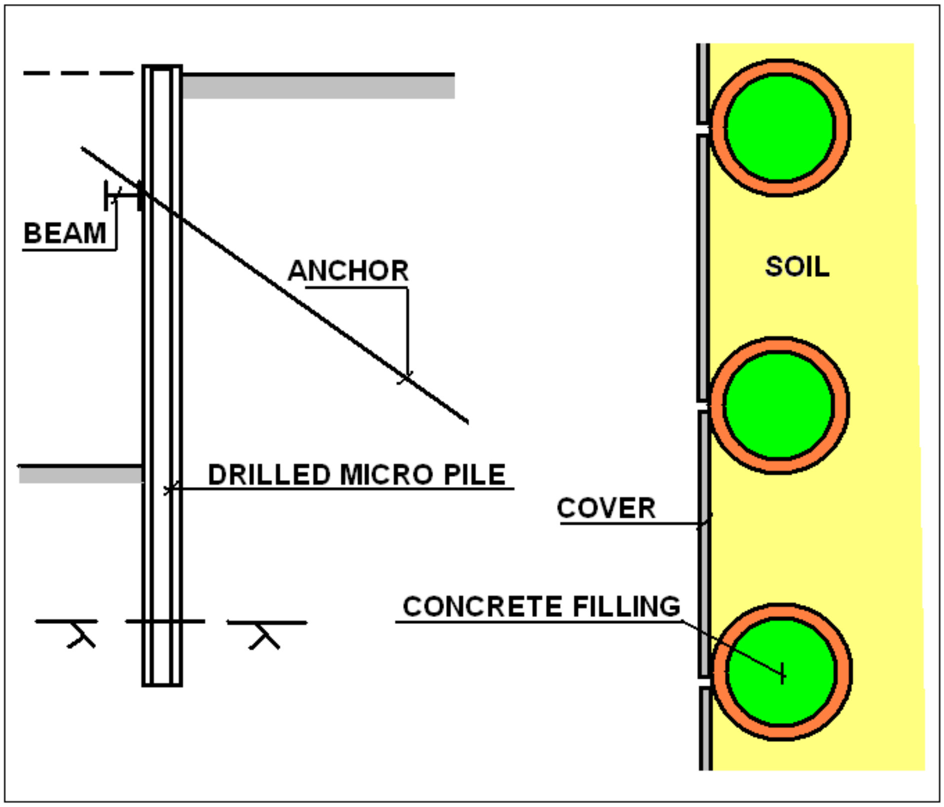

Fig1. Drilled Micro Pile Wall components

APPLICATIONS

As mentioned above, the most common use of this technology is found in urban excavation sites where the ground contains obstacles difficult or impossible to penetrate with usual sheet piling equipment. Small tube diameter walls can also be required by the working space available, as for example piling indoor in a basement. Further, noise and other environmental related construction restrictions may call for small sized equipment.

Experience shows that drilling is superior to many other pile installation methods as far as the ability to stay within construction time schedule is concerned. The kind of drilling assumed is drilling capable of penetrating hard bedrock and boulders, as for example the ODEX or the SYMMETRIX method. These two methods represent the two main drilling techniques used, namely the eccentric and the concentric method, respectively, se figure 2.

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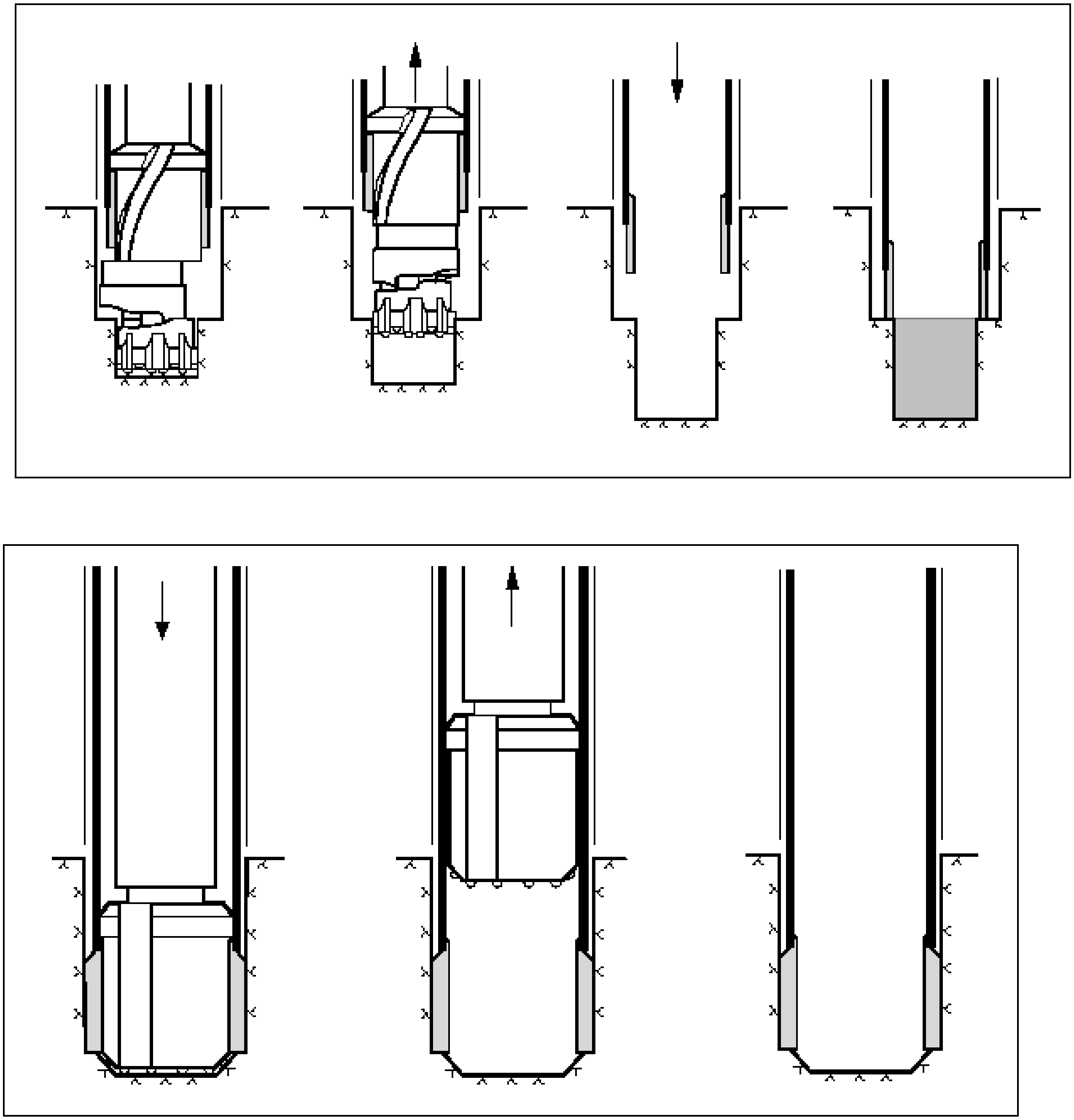

Fig 2. Eccentric and concentric method, ODEX (upper) and SYMMETRIX (lower) methods

This attractive characteristic of drilling is utilized where it is of particular importance to keep the planned piling schedule, as for example making a pile wall in a factory, where a fixed period has been set to stop production in order to install a new piece of

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machinery in the excavation. A delay in piling schedule under such circumstances may represent a much higher cost the complete construction fee, even if a piling technology very costly compared to cheaper solutions is employed. Figure 3 shows a very small drilling rig frequently used for the installation of drilled micro pile walls inside buildings.

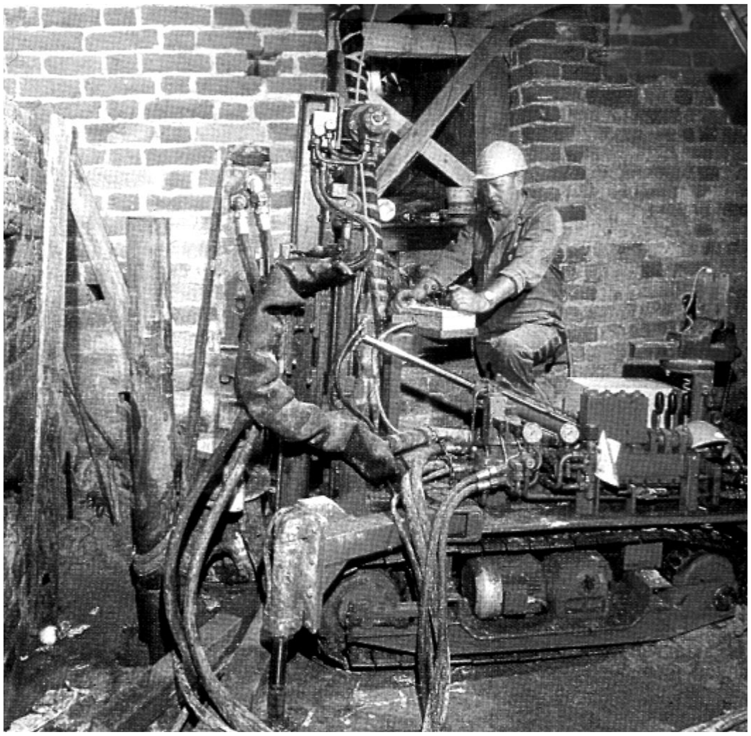

Fig 3. Small rig for installation of drilled tubes in narrow areas.

Drilled piles walls are usually left in place after the purpose is fulfilled. Many times it is possible to use the piles as members of the permanent structure. In figure 4, the drilled pile wall will serve as bearing foundation piles for a residential building to be made close to the existing supporting wall shown.

The use of a drilled micro pile wall for both temporary and permanent purposes is a solution that can save considerable amounts of time and money. To make such a multipurpose design happen, it is necessary to consider it at an early stage of the planning process. Often, the permanent foundation design is not possible or practical to change when the temporary construction elements are chosen. In this way, the client usually can't benefit from the possible savings hidden in planning of foundation design. The remedy is to include foundation technique at early stages in the process, preferably already when the architects are doing their task.

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Fig 4. A finalized drilled micro pile wall which, after its role as a temporary structure is completed will support a permanent building.

The possibility using the same structure for both temporary and permanent purposes is of course very cost effective. Heavier wall types, like diaphragm walls and secant pile walls, are usually utilized this way, but it is also possible with small diameter drilled steel tube walls.

LIMITING FACTORS, DRILLING ISSUES

It is obvious that a wall with open spaces between the members can't be used below ground water level, or where the soil is too soft to stay behind the openings. Further, if the soil is very dry or of uniform grain size, even sand and gravel may turn out to flow into excavation in relatively small openings. In such cases jet grouting covering the spaces can be made prior to excavation. The grout is aiming at not give so much strength mixed with the soil that the excavation will be hampered; a mix just strong enough to prevent inflow of soil in the spaces is the target, se fig 5.

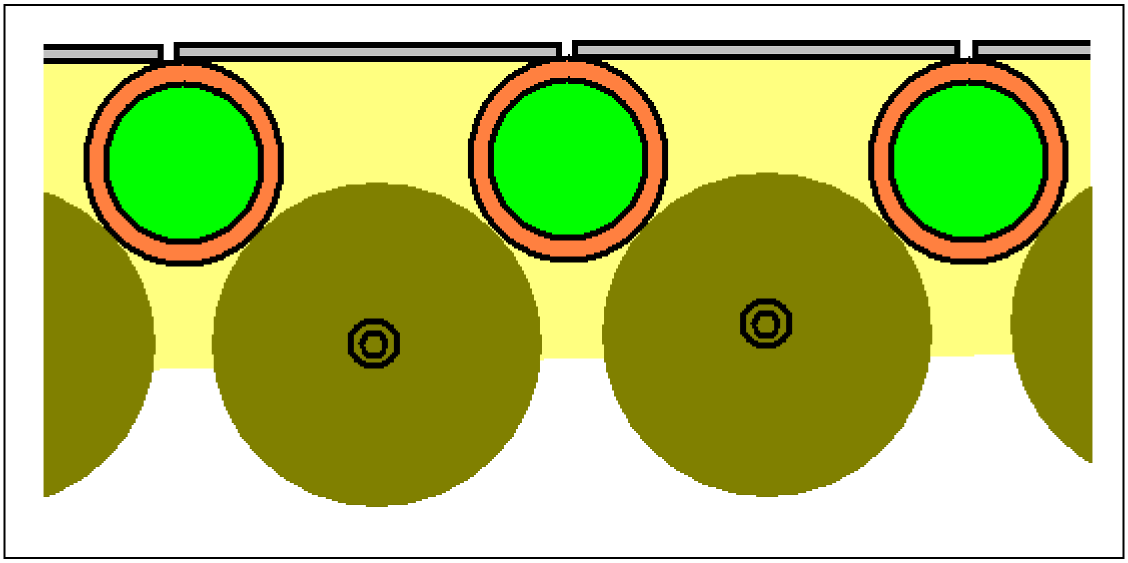

Fig 5. Jet grouting to prevent soil flow through a drilled pile wall

This technique has been used in Scandinavian esker formations, where rock boulders and very uniform grain distribution of sand and gravel are common. Where excavation has been extended below ground water level, the excavation has been made in water and concrete walls and a bottom slab has been cast in water before pumping the working space dry.

Another limitation for the method is where steel debris is encountered during drilling, but this will stop other piling methods too.

Using a down the hole hammer (a DTH), below ground water level in fine grained soils may result in excessive removal of soil during drilling. The ideal extracted volume corresponds to the volume of the tube installed, but difficult drilling conditions and not so clever workmanship may result in a much larger amount of soil brought to the surface, resulting in considerable subsidence around the drilling spot. The inflow of soil into the casing is due to the exhaust of air driving the hammer; the air returns to the surface through the tube, producing a pressure drop and corresponding inflow of water and soil particles at the tip of the tube being drilled down.

The use of water as driving media instead of air has proven useful to reduce this risk. However, the back side then is that the necessary lift for the soil to be brought up and out of the tube is decreased. Another technology used is the so called reversed circulation flow system.

A very important factor is the skill of the driller. It takes considerable time and efforts to master the profession. Not everyone is able to master foundation drilling, no matter how sophisticated the equipment is.

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It should be mentioned also that drilling involves many relatively dangerous moments, as dealing with heavy, powerful rotation components, lifting of heavy parts (drilling pipes, for example), and so on. Add a noisy, dusty, muddy work site environment, often in very confined spaces together with other moving construction machines. Thus, not surprisingly, the accident rate is very high here.

DESIGN METHODS

The vertical wall members are horizontally loaded by earth pressure. Above excavation level the pressure acts at the complete wall area, whereas the soil below the excavation level usually is assumed to exist at a width equal to 3*pile diameter in friction material and have a value of 9cu in cohesion materials (cu = undrained shear strength). These assumptions are illustrated in figure 6.

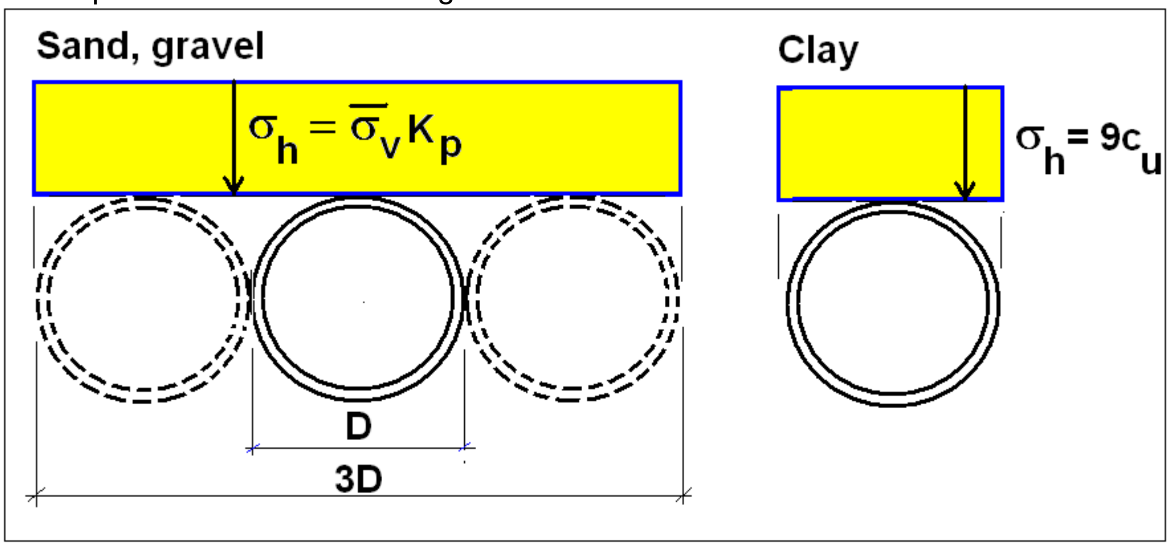

Figure 6. Passivel pressure at a drilled pile wall, for different soils

The bending capacity of the wall tubes, sometimes more poetic called "soldier beams" (since the stay straight in line, in a well made wall, maybe), is of course of important for the cost of wall design at a particular site - the higher the bending capacity, the bigger the horizontal distance between supporting levels and the larger the distance between tubes can be chosen. However, the spacing for the tubes must also take into account the soil, and this is often a limiting value.

Several tests has been carried out in order to evaluate the bending capacity of concrete filled steel tubes, with or without reinforcing elements as bars, a beam, a tube or a steel core. Such tests are usually not related to foundation design; concrete filled steel tubes are by different reasons attractive as bearing elements in buildings and bridges. It turns out, not surprisingly, that the ultimate bending capacity corresponds to a complete plastic state of all members represented in the cross section, figure 8.

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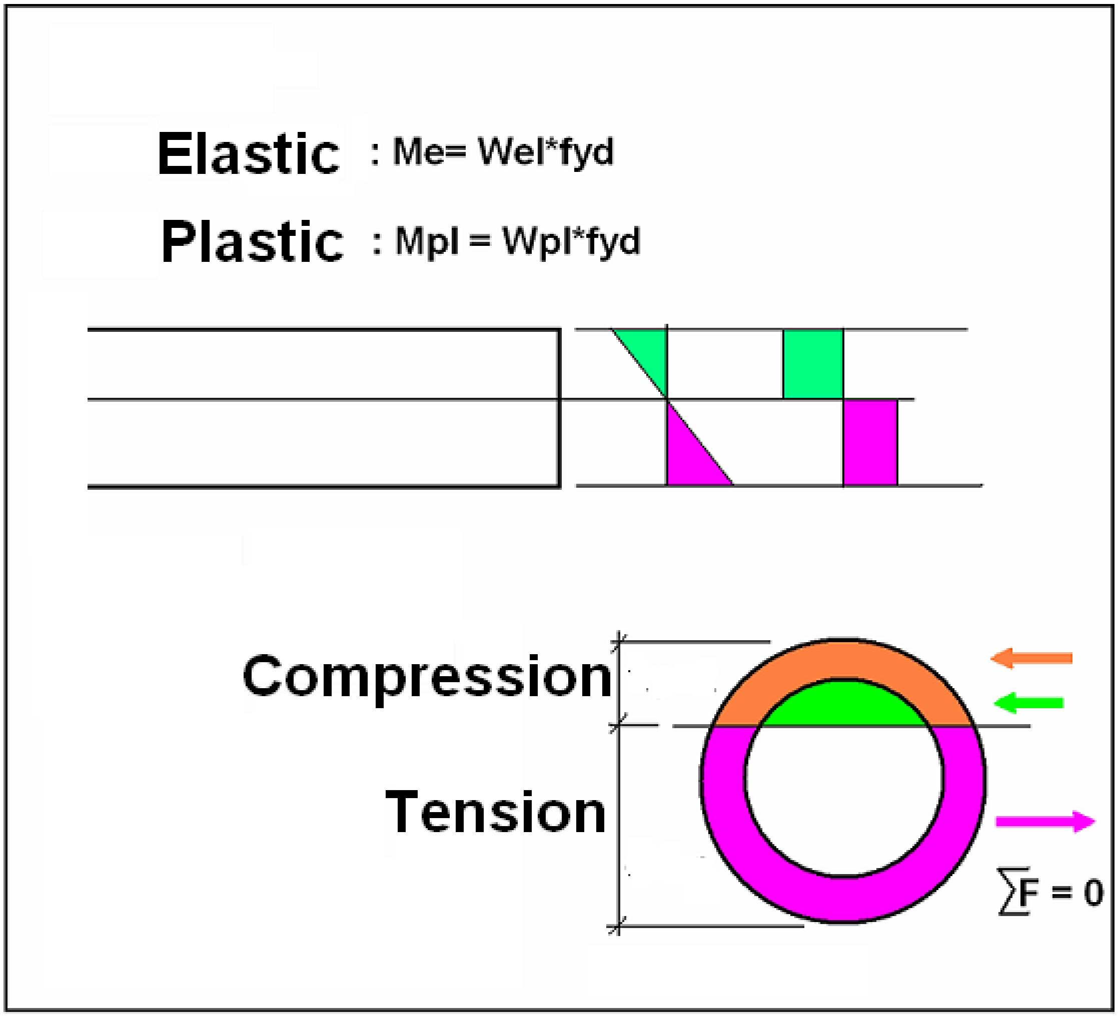

Figure 8. Completely plastic cross section, concrete filled steel tube.

The bending moment capacity for a cross section in this state is not difficult to evaluate. The areas representing tension and compression shall deliver the same force and the moment capacity is simply this force multiplied with the distance between the compression and tension force resultants respectively. Thus, although exact expressions exist for many configurations, the easiest way to arrive at the desired capacity is to make your PC run iterations for a second or two until force satisfactory equilibrium is reached. A limiting factor may be the allowable strain of the grout, typically 2 to 3.5 o/oo.

The drilled tubes are usually also loaded by axial force, from vertical components of tie backs and possible external loads. Since the tubes are relatively slender, the risk of buckling must be checked. In the Scandinavian and European building codes, the basic axial capacity is multiplied by a reduction factor. The value of this factor depends on slenderness ratio, initial deflection assumed, and cross section geometry, built in stresses and so on.

The combined effect of acting bending moment (Ms) and axial load (Ns) is analyzed by an interaction formula, as for example

$$Ns/Nd + Ms/Md < 1 \qquad \dots (1)$$

where Nd and Md is the axial and bending moment capacity respectively.

Also the risk of local buckling of thin walled tubes, as for example the tube at the end of its life time, after design value of corrosion wall thickness reduction, should be checked in this respect. Concrete, or mortar, filling is an effective way of increase the local buckling capacity and the filling also eliminates inside corrosion.

QUALITY CONTROL

A drilled micro pile wall can be checked against given tolerances and quality demands much better than many other types of wall structures installed in the ground. For example, the integrity and the spatial location of every installed tube can be checked before excavation starts.

Drilling also means that the tubes can be more accurately positioned than driven or vibrated elements. This is particularly true for concentric drilling methods. When pile wall elements must be installed close to existing structures buried in the ground and near bearing piles its of course important to be able to follow the path of the tube brought down.

FUTURE DEVELOPMENT

Although development of technical improvements in foundation technology is known to be notoriously slow, as in building industry all together, technology is improved as the years goes by. What can we expect as far as drilled micro pile walls are considered?

- drilling technology will continue to improve productivity and adaptation to demands related to environmental requirements. Today the normal upper limit of steel tube diameter for tubes of drilled walls is around 300 mm, but the tendency is that this figure is increasing all the time.

- the use of high strength concrete for filling the tubes may result in largely increase axial and bending capacities. However, several efforts to bring these compounds to use at sites must be made. Its one thing to make a solution work in the laboratory but it’s a different cup of tea to make it function in production. Not to mention the acceptance from the authorities issuing codes.

- splicing techniques can be very much improved - today welding is the most used technique for splicing tubes, but the control prescribed and the difficulty to meet the code requirements in production, makes alternatives urgently needed.

- general solutions for typical situations - today every drilled micro pile project must be handled as if done never before - a number of general accepted designs could simplify the use (maybe consultants disagree …)

- making it possible to withdraw and retrieve the tubes and other wall elements for future use. Today they are usually left in place, which is contradictory to the policy of reuse of material and components, sometimes even regardless of the price tag connected …

CASE STORIES

CASE STORY 1

The first case story describes a drilled micro pile wall inside a glass mill - The name of the industry is Rexam and the supply the world demand of Absolute Vodka bottles. In the summer 2007 they have built a new glass melting facility - creating the need for a 60 m long, 16 m wide and 6 m deep excavation inside the production plant in full action - further, the ground water in the sandy silt had to be lowered 5 meters prior to excavation.

The solution was to make a drilled micro pile wall around the pit. Drilling was also utilized for the dewatering equipment. A picture from the site is shown in fig 9. A cross section as well as some details of the design, is shown in figure 10. In fig 11 the use of drilled micro piles for temporary support of columns is illustrated.

Figure 9. Drilled Micro Pile wall for the Rexam glass industry in Limmared, 2007

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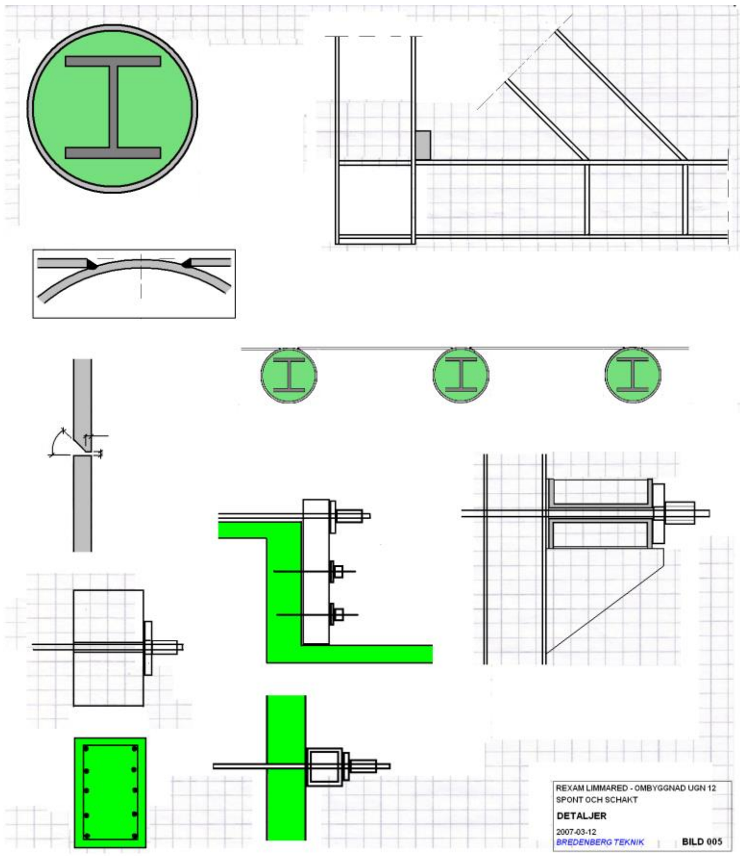

Figure 10. Details from an in-house drilled micro pile wall

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Figure 11 Drilled micro piles for temporary support of columns

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In fig 11 a section of the micro pile wall for this project is seen together with such piles used for temporary support of a column situated in the excavation area. The load of each of these piles was about 500 kN in compression and 200 kN in tension, the tensile load caused by wind loads for the building. The micro piles were made by TITAN-piles drilled down through the soil and anchored in the bedrock below. On the free standing length the drilled piles were cast into a steel casing in order to increase buckling load capacity. The site supervisor did not fully trust the design, so he put in a few extra bracings seen in the picture.

CASE STORY 2

The second case story comes from a recent foundation project in downtown Stockholm. A 7 m deep excavation close to an exiting main city road and bridge had to be carried out for a new hotel project. The soil consisted of granite rock fill boulders making it impossible to use anything else but drilled casings to form a drilled micro pile wall.

A cross section of the drilled micro pile wall is shown in figure 12. Some photos are shown below. The tubes were 168 mm diameter tubes with 5 mm steel. In the tubes, a 4” H-beam was installed. The space between the beam and thee tube was filled with mortar. The spacing between the tubes was 1000 mm. Such a large gap was possible due to the nature of the fill.

The wall was supported by 1:1 drilled rock anchors, 3 x 15 mm VSL-strands drilled 4 m into bedrock. The same crew and same drilling equipment, a KLEMM 806, was used for both the wall and the anchors.

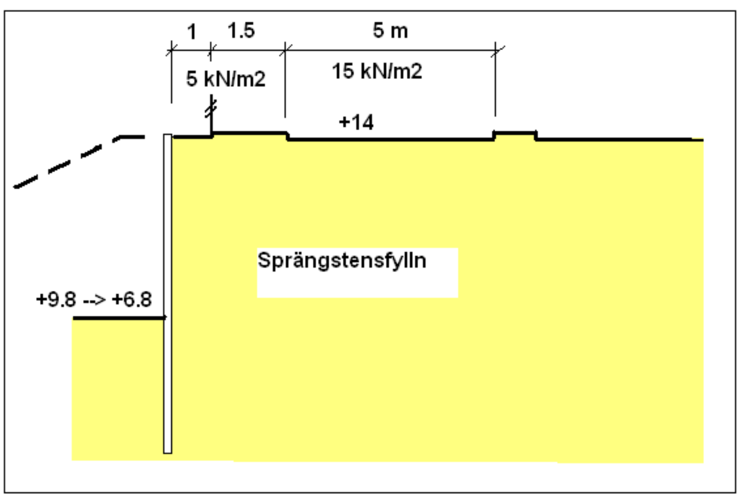

Fig 12. Excavation at a drilled micro pile wall at Kungsholmen, Stockholm, 2007

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Fig 13 Excavation between drilled tubes

Fig 13 shows the boulders embedded in the fill. Covering the gaps between the tubes with steel plates may in such a soil profile call for filling the voids behind the plates. Therefore, shotcrete eliminates the need for this. In fig 14 the finalized wall at this location is shown.

Fig 14. Shotcrete used to fill gaps between drilled tubes.

OTHER PROJECTS

There are a large number of successful applications of the method described in Scandinavia. Among them one can mention:

- Drilled wall for the Frederiksberg MiniMetro station, Copenhagen, Denmark, 2001
- Drilled wall for turbine intake in Harspånget rock fill dam, Sweden
- Drilled wall for the Kiruna - Narvik railroad Sweden - Norway
- Drilled wall for filter building at nuclear power plant, Ringhals, Sweden
- Drilled wall for the Liljeholmen City project, Stockholm, Sweden

… and many others

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