Drilled pile technology in retaining wall construction and energy transfer

Application de la technologie des pieux forés à la construction des murs de soutènement et au tranfert d´énergie

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ABSTRACT: The use of steel piles has grown substantially in the Nordic countries during the last few decades. The growth has been supported by active research and development contributing a versatile collection of pile types and applications. Open section drilling is an example of new micropile inventions. Drilled pile walls and energy transfer applications extend the use of drilled piles to sites where conventional piling has previously not been seen as an option and where the drilled piles can be seen as hybrid structures functioning partly as vertically loaded piles, partly as lateral capacity of the retaining wall, or a heating/cooling distribution system.

RÉSUMÉ : L'utilisation des pieux en acier a connu une forte croissance dans les pays nordiques au cours des dernières décennies. Cette croissance a été soutenue par beaucoup de recherche et de développement en contribuant une collection variée de types de pieux et d'applications. Le forage à section ouverte est un exemple de nouvelles inventions des micropieux. Les parois de pieux forés et les applications pour le transfert d'énergie étendent l'utilisation des pieux forés à des sites où les pieux conventionnel n'ont pas été considérés auparavant et où les pieux forés peuvent être vus comme des structures hybrides qui fonctionnent en partie comme des pieux chargés verticalement, et en partie comme la capacité latérale du mur de soutènement ou comme une installation pour la distribution de chaleur /refroidissement.

KEYWORDS: steel pile, micropile, open section drilling, energy pile, drilled pile wall.

1 INTRODUCTION

Development of drilled micropiles and versatile micropile applications have been subjects of extensive international cooperation since the 1990s. As a regular meeting, the International Workshop on Micropiles IWM has been held eleven times from 1997 until 2012. Since 2006, the IWM has been organised by the International Society for Micropiles (ISM 2013).

In Northern Europe, micropiles are commonly end bearing, in diameter 75…300 mm, drilled or impact driven, sometimes jacked, screwed or vibrated piles (Lehtonen 2011). Use of micropiles has grown significantly since 1980s; in Sweden, for instance, from 150.000 m/a (1991) to 687.000 m/a (2011) when the total market varied from 1.620.000 m (1991) to 2.200.000 (2001) (Swedish Commission on Pile Reseach 2012). Micropiles are in common use mainly for following purposes:

(i) Underpinning.

Hundreds of houses - detached or multi-storey houses - have been underpinned in Scandinavia by impact driven, steel micropiles. The main reason for underpinning is decay of existing wooden piles, which were an acceptable ground engineering method for houses up 1970s. Typical applications are driven or drilled piles of type RR115 (114,3x6,3) or RD140 (139,7x10) giving a service load about 300…1000 kN.

(ii) Light load on soft soil.

Typical load under a structural wall of detached or semi-detached houses is 20…30 kN/m giving a service load to a pile about 100…200 kN. A common application is a slender driven steel pile, as type RR90 (88,9x6,3) or RR115 (114,3x6,3).

(iii) Industrial construction.

There are a great number of manufacturing buildings in Scandinavia locating on very soft soils. Additional construction – between existing buildings and production machinery – is

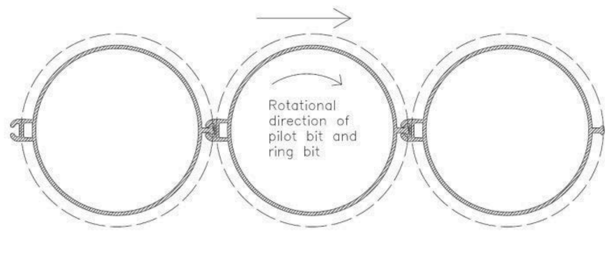

Figure 1. Drilled pile wall.

continued typically with driven micropiles of type RR140 or drilled RD170 (168,3x10), a service load respectively about 500…1400 kN.

The latest innovations in steel pile technology cover mainly drilling. There are several new methods for concentric and eccentric drilling developed in Finland since 1990s. Drilled piles have been used for new applications contributing hybrid techniques where the steel pile can be a part of a drilled retaining wall (Fig. 1) or energy transfer distribution system.

2 OPEN SECTION DRILLING

Traditionally, the drilled piles have been made of hollow steel sections and the drilling methods are often originally developed for oil or water well drilling. Drilled piles are embedded using either top hammer or down-the-hole (DTH) techniques. Drilled piles can be grouted or non-grouted; grouting can be done simultaneously during embedding or after drilling, using gravity of pressured grouting.

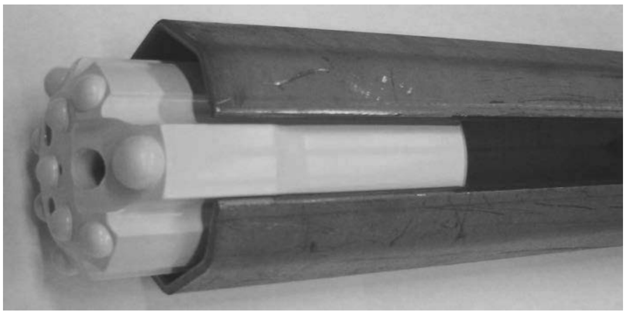

Figure 2. Drilling of an open C section can be done using an eccentric drilling bit.

A new invention has been introduced in Finland to drill an open section as a structural body of a drilled pile. Open section drilling can be done using an eccentric drilling bit (Fig. 2) and the eccentric part of the machinery can be removed from the pile body through the open side of the steel section. The drilling bit has been developed by Robit Rocktools Ltd and the C section has been developed by Emeca Oy. Drilling has been tested (Table 1) until now using the top hammer method but the DTH drilling could be applicable, too.

Table 1. Test sites for open section drilling in Finland.

Site	*Soil layers*	*Pile diameter*	*Lengthening coupler*
Masku 2010	gravel, bedrock	80 mm	no
Espoo 2011	gravel, clay	80 mm	no
Naantali 2012	clay, moraine	80 mm	yes

3 ENERGY PILES

The use of energy piles has grown since 1980s when concrete piles were started to utilize to transfer heating or cooling energy. When the end bearing steel pipe piles have become very common in the Nordic countries, development of energy type micropiles has been an interesting opportunity to face demand of greener energy and lower energy consumption. (Uotinen et al 2012)

3.1 *Steel pipe piles*

The pipe piles are easy applicable to use as energy piles due to hollow structure of the pile. Steel material has a good thermal conductivity reducing the thermal resistance of the energy pile. Steel pipe piles can be installed by driving, drilling, jacking or vibrating. The minimum outer pile diameter considering the heat collecting pipes is 88,9 mm but typically diameter for drilled energy piles is close to 200 mm or more.

3.2 *Heat collecting components*

Normally, the heat collecting pipes are made from high density polyethene, diameter between 20 to 40 mm. One or two U loops of collecting systems (Fig. 3) are installed inside of a steel pipe pile. Water-ethanol mixture is the most common liquid used in energy piles. (Uotinen et al 2012)

3.3 *Case study: an office building in Finland*

The first energy pile building in Finland was constructed to Jyväskylä. The 6-storey office building, base area ca. 1700 m^2,

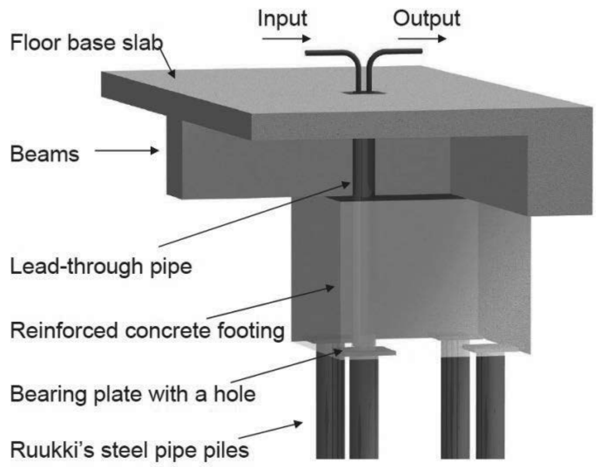

Figure 3. Loops of energy collecting components are installed inside of a steel pipe pile.

is equipped with 38 energy piles when totally 246 piles of 22 to 29 m length has been driven to fill, clay, silt and moraine layers.The piles are type RR170/10, RR220/10 and RR220/12,5, the pile load respectively 691 kN to 1350 kN. In addition, there are 65 precast concrete piles; all piles were driven with Junttan PM 20 LC piling rig and with 4 ton hydraulic hammer. The space between the energy piles varies from 5,5 m to 7,8 m. (Uotinen et al 2012)

4 DRILLED PILE WALLS

Drilled piles have been used for retaining walls have been constructed in Finland, Sweden and Norway since 2008. (Uotinen and Jokiniemi 2012) Drilled pile walls can be used in demanding soil conditions where installation of conventional sheet piles can face penetration problems or vibration risks. In Northern Scandinavia and Finland, hard and large boulders are common obstacles in the overburden limiting use of conventional sheet pile and retaining wall methods.

Two variations of drilled pile walls have been introduced based on either (i) Ruukki´s drilled steel pipe piles (RD piles) or (ii) an application of open section drilling utilizing C and CT profiles (Fig. 4). The RD pile wall cases are collected to Table 2 covering large variations of diameter and interlocking systems. Totally 2150 piles or 24500 m piles have been used for drilled RD walls until now.

The drilled pile walls can be used as a temporary or a permanent structure. Typically, the wall has capacity to take both high vertical and lateral loads when needed. (Uotinen & Jokiniemi 2012)

5 CONCLUSION

The market share of micropiles and other steel piles is remarkably high in the Nordic countries, partly due to active research and development during the past decades. There are versatile collection of applications available and many e.g. drilled pile techniques extend the use of piles to design solutions which are totally new for piles. The energy piles and the drilled pile walls have great potential for future ground engineering. Further research and development efforts will be needed to get all potential benefits linked to the inventions.

Table 2. The RD pile walls. (Uotinen & Vesamäki 2013)

Site	*Interlock*	*Oversize of the ring bit (mm)*	*Pile type*	*Pile length (m)*
Ylitornio, Finland 2009	Ruukki E21	47	test RD400	6
Ruoholahti, Finland 2009	Ruukki E21	47	test RD400	12
Motala, Sweden 2010	Ruukki E21	30	RD400	8-12
Trondheim, Norway 2010-2011	modified WOM-WOF	30	RD600	10-32
Tampere, Finland 2010	modified WOM-WOF	30	test RD170	3
Nummela, Finland 2010-2011	modified WOM-WOF	30	test RD400	12
Kiruna, Sweden 2010	Ruukki E21	47	RD500	10-15
Kalasatama, Helsinki 2011-2012	modified WOM-WOF	47/30	RD600	3-14
Metro sites, Helsinki 2011-2012	modified WOM-WOF	30	RD400 RD600	16-20
Messukeskus, Helsinki 2011	modified WOM-WOF	30	RD170	6
Tampere 2012	RM/RF	27	test RD400	6
Keskuskuilu, Espoo 2012	RM/RF	27	RD220	8-9
Fredriksdal, Stockholm 2012	RM/RF	27	RD400	10-15
Strömkajen, Stockholm 2012	RM/RD	27	RD220	5-9

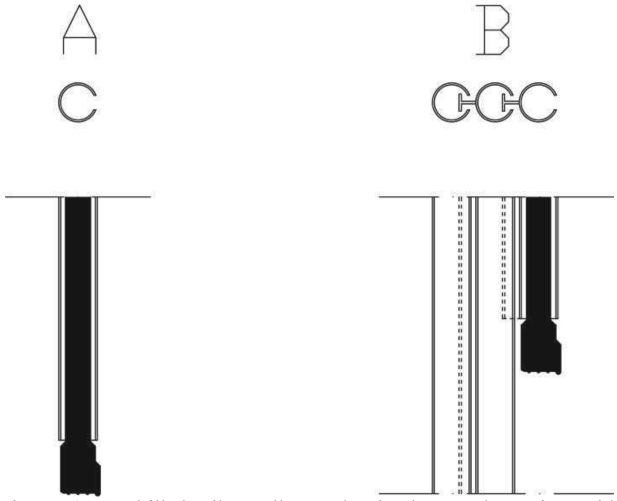

Figure 4. A drilled pile wall can be implemented starting with embedding of an open C section (phase A) and the wall can be extended using CT profiles.

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