The drivability of friction piles based on penetration testing

Possibilité de foncement de pieux flottants étudiée par des essais de pénétration

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SYNOPSIS: Soil investigations in connection with piling projects are usually carried out in order to estimate pile lengths, the bearing capacity of friction piles, the risk of loosing piles etc.

When it comes to the determination of the drivability of a given pile (the possibility to install a pile), we normally have to trust our own experience instead of using the result of the investigation. It is therefore more a rule than an exception, that the real piling capacity - mostly for friction piles - diverge from the calculated one.

This report deals with the estimation of the drivability of a pile, based upon the results of the soil investigations.

A large number of tests were carried out in order to determine the properties of the soils at 12 different places in Sweden. Some of the methods used are well known and often used in Norway, Finland and Sweden i.e. weight sounding (WST) and dynamic probing (DPA).

1 INTRODUCTION

The use of concrete piles has many practical advantages and therefore, it has become the most common type of piles used in foundation engineering in Sweden.

The methods of installation and production of piles vary with regard to subsoil conditions and local tradition.

The concrete to be used for the production of precast piles has to be of very high quality in order to withstand the severe treatment of pile driving. In particular, the toughness of the concrete is important as the number of blows of the pile hammer, required to reach the expected bearing capacity, can be very large and lead to destruction of the pile.

The width of the precast piles in this study is 0,27 x 0,27 m and the length limited to 25-30 m.

The splices have been constructed with the capacity of taking up as large tension forces and bending moments as the pile itself. The precast concrete pile is used as a displacement pile which displaces an equivalent soil volume by compaction or by lateral or vertical displacement of the soil.

Displacement piles are driven into the soil, generally by means of a gravity hammer, which simply is a weight (usually 3-4 t) which is lifted a certain distance with a hoist line and then released to fall and strike a drive cap.

2 MEASURING METHODS

The object of soil investigation is to establish a reliable picture of the building site conditions with regard to geological and geotechnical characteristics, necessary as a basis for design. In connection with piling projects the soil investigation is usually carried out in order to estimate pile lengths, the bearing capacity of friction piles, the risk of loosing piles etc.

When it comes to the determination of the drivability of a given pile (the possibility to install a pile) we normally have to trust our experience instead of using the result of the soil investigation. It is therefore more a rule than an exception, that the real piling capacity - mostly for friction piles - diverge from the calculated one.

What kind of information do we need in order to estimate the drivability of a pile? Normally, we begin with some type of penetration testing, the results of which may give valuable information about how the subsoil conditions vary at the site. More advanced methods of soil investigation can then be determined with due regard to soil type, variation in sounding results and type of project in question.

The most common types of sounding methods in Sweden are the weight sounding (WST) and dynamic probing (HfA), reminding of SPT.

Dynamic probing in Europe includes several methods which are summarised in Table 1. The main difference between the methods is the driving energy.

The dynamic probing used, type HfA, is different from the others as the Table 1 shows.

All the penetration methods above, have been standardised under the auspices of the International Society for Soil Mechanics and Foundation Engineering (ISSMFE).

Some other methods than the above mentioned were also used i.e. Cone Penetration Test (CPT), Dilatometer Test (DMT) and dynamic probing with stress wave measurements, but they did not give any correlation to drivability.

One could imagine that a dynamic method would imitate the course of action when piling with displacement piles. It soon showed out that an energy study could give some information.

TABLE 1
Data various dynamic probing methods.

Method	DPA	DPB	HfA
Point diam, mm	62	51	45
Point length, mm	62	51	90
Point angle, degr.	90	90	90
Rod diam, mm	40-45	32	32
Insertion	preboring	preboring	no preboring
Hammer, kg	63,5	63,5	63,5
Drop height, m	1,75	0,75	0,50

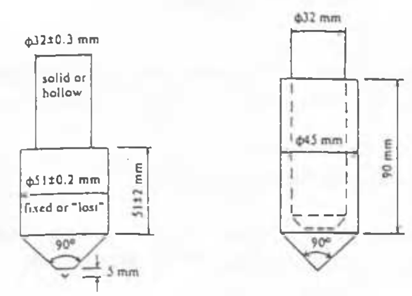

Fig 1 Dynamic probing equipment types DPB (left) and Hfa.

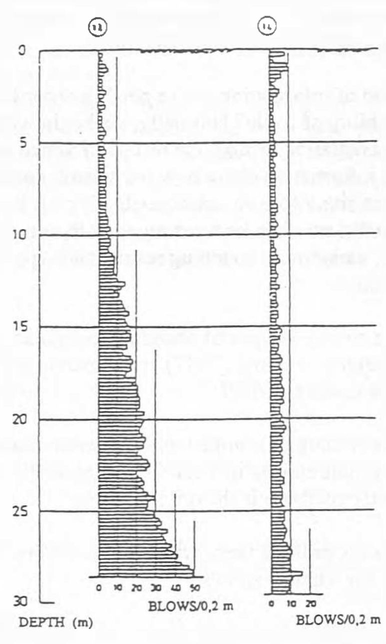

Fig.2 Comparison between sounding resistance at dynamic probing in sand with and without turning. (Bergdahl ∉ Dahlberg, 1973)

The main difference between the various methods, is the driving energy. The number of blows required for every 0,2 m of penetration is recorded in the site log.

The points and rods to match dynamic probing, types DPB and HfA, are shown in Figure 1.

It is important to notice that a sounding resistance less than 50 blows/0,2 m the standard says that the rod should be rotated 2 turns at every 50:th blow. The reason is that without rotation the rods tend to deviate and therefore giving a misleading result. Besides, one will get a more proper description of the stratification about the soil, as the Figure 2 shows.

3 RESULTS AND DISCUSSION

The study was limited to soils where problems arise with a large number of blows, diminishing pile lengths due to compaction of the soil or a combination of these factors:

* Friction piles in silt or silty soils
* Friction/pointbearing piles in wellgraded sandy or gravelly soils (sediments)

It was not possible to estimate the drivability of a pile from the result of the weight sounding (WST). Hence, the interest was focused on the dynamic probing instead. This method has a lot of similarities with the full scale piling and a correlation was therefore anticipated between the two methods.

From the results of twelve piling objects from different parts of Sweden, a basis was found for a study of the energies needed for driving a rod respectively a pile to certain depths.

In all of these places, a proper description of the soil, by weight sounding, dynamic probing and soil sampling, were made. Together with piling logs from the test piles, a comparison between the dynamic probing and the piling could be made.

The calculated energies were plotted on a graph, Figure 3

We know from earlier projects, that the equipments for probing and pile driving, have an efficiency which differs from the nominal one.

At the standardised dynamic probing, HfA, we can calculate with a nominal energy of 311 Nm. Therefore, Eriksson (1992) found in a study with different equipments, that the real efficiency only was 60-65% of the nominal.

When studying the driving equipment for piles it has been found that the efficiency is about 60%

Normally, the efficiency in Sweden for the type of pile driving equipment, usually used, can be set to 80%. In this

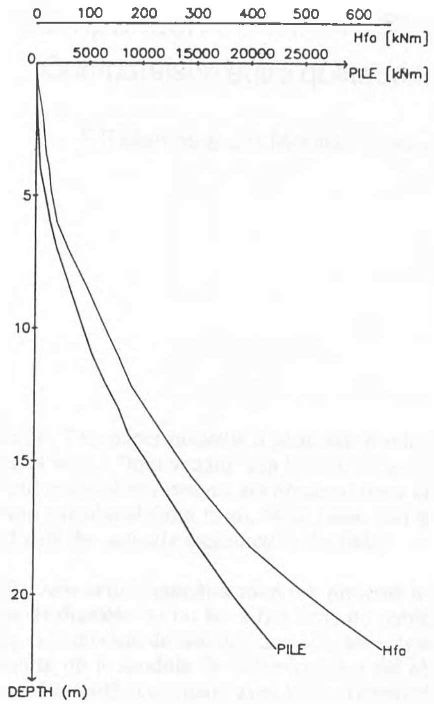

Fig.3 Summation - energy diagram for testpile P 412 at Branäs.

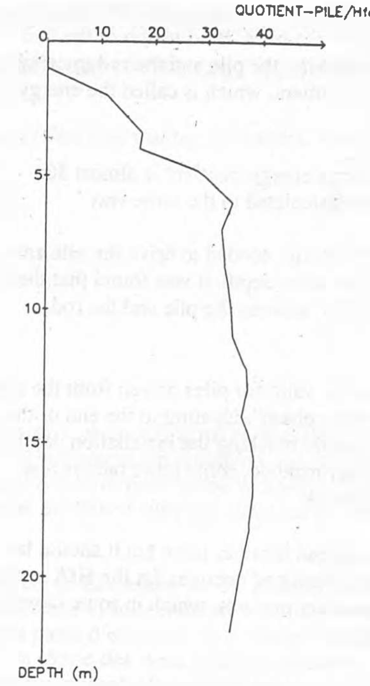

Fig. 4 The energy quotient for P 412 at Branäs.

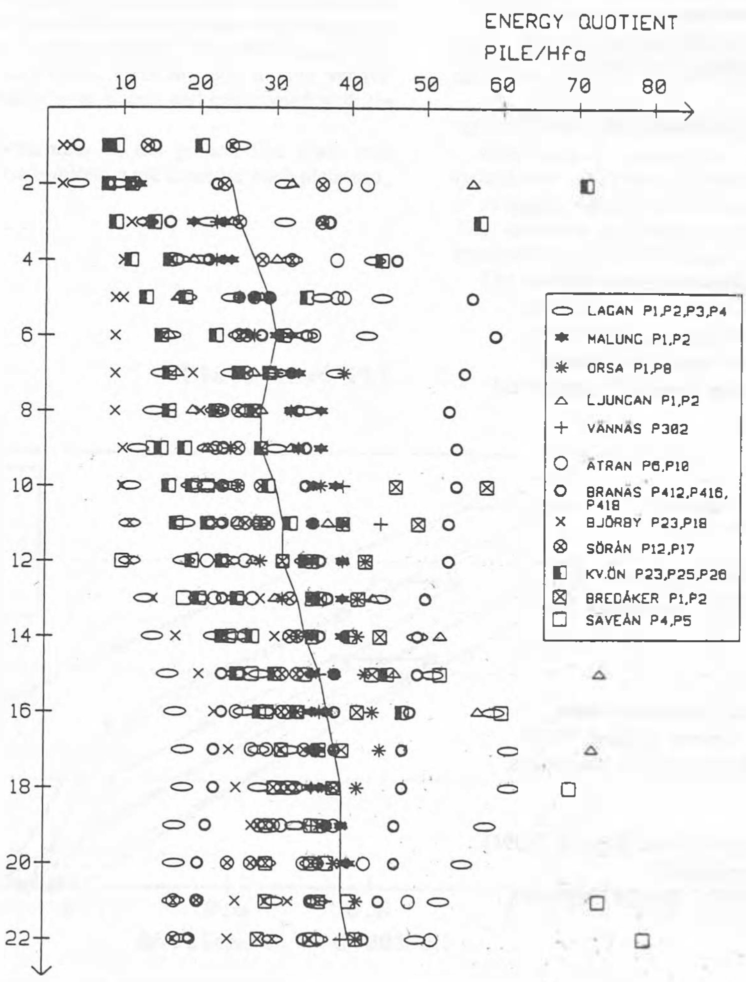

Fig. 5 Quotient between the necessary energies to drive the piles and the rods at 12 piling sites in Sweden.

study, we have used the nominal energy for the rod and 80% of the nominal for the piles. By division of the two energies, needed for driving the pile and the rod to certain depths you can get a quotient, which is called the energy quotient, Figure 4.

As the figure shows, the energy quotient is almost 30. Totally 44 piles were calculated in the same way.

When comparing the energy needed to drive the pile and the probing rod, to the same depth, it was found that there was a scale factor of 30 between the pile and the rod, Figure 5.

The scale factor is only valid for piles driven from the start and during the "driving phase". Coming to the end of the piling, when the piles are reaching the installation depth and when further piles are installed, some other factors also influence the piling work.

For some sites, the spread is rather large but it should be emphasized that the calculated energies for the HfA and the piles are taken from older projects, which in some cases gave poor logging results.

Due to the densification of soil during pile driving, we could also find at a certain depth, that the quotient increased from about 30 to even higher values with the depth, which could indicate that the pile had reached the stop driving phase.

A continued study from this pile driving phase (drivability) to the stop driving phase could therefore include a comparison between an energy study like this with the results from the bearing capacity studies with for instance CAPWAP.

In this way, a rough estimation of the designed pile lengths could be procured.

4 ACKNOWLEDGEMENTS

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