EFFECTS OF INSTALLATION PROCEDURES UPON POINT RESISTANCE OF PILES

L'EFFET DU PROCEDE D'INSTALLATION SUR LA RESISTANCE DE LA POINTE DE PIEU

ВЛИЯНИЕ МЕТОДА ПОГРУЖЕНИЯ СВАЙ НА СОПРОТИВЛЕНИЕ ИХ ОСТРИЯ

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SYNOPSIS. Presently, various procedures are available for piling, and the bearing capacity of piles varies greatly with the procedures. The authors discuss, in this paper, first the bearing capacity of driven piles and then the effects of installation procedures upon their point resistance. With about 100 driven piles and bored piles of the types now used in Japan subjected to loading tests, analysis of the test results was made. These piles were installed at sites of various conditions under various procedures. Particularly, for 55 piles of which the skin friction was measured, a detailed analysis was made with respect to the point resistance and skin friction individually.

INTRODUCTION

In Japan, important structures are often built on areas which have a thick alluvial deposit, and the settlement of ground are usually observed there. It is considered that considerably large negative friction has been applied to piles installed at such areas. Consequently, proper evaluation of the relationship between the negative friction and the point resistance of piles becomes most important at the time of designing. Therefore, we attempted to clarify on the relationship between the piling procedure and the point resistance of pile by analyzing the results of the load tests of piles which had been installed at various locations by different piling procedures.

Selection of the Load Test Results

It is also observed that what can be obtained from the results of generally-conducted load tests are values representing a sum of point resistance and side friction. For this reason, it is necessary to separate these two values from each other.

Here, we have selected especially 55 piles which have highly accurate results of load test by following either procedure, from about 100 piles which have been used the various considerations to this study.

* The case which have obtained the point resistance and the side friction individually by testing method of dual tubular system.

* The case which have measured the strain of several point by strain guage fitted in the body of a pile.

The Piling Procedures and Kind of Piles

The kind of piles and piling procedures which have been used in the consideration of this study are shown in Table 1. In piling procedure, "Internal drilling procedure" to precast reinforced concrete pipe pile means a process in which open-tip piles are pressed into the ground by means of excavation of the pile-tip soil using a screw auger, etc. installed inside the pile. And "Internal drilling and driving procedure" means a procedure which combine the driving work after "Internal drilling procedure work.

Table 1

Kind of pile	Steel pile	Precast reinforced concrete pile			Cast-in-place concrete pile (pedestal pile)	Cast-in-place concrete pile (bored pile)
Section	Pipe	Pipe (by centrifugal process)			Circle (cylinder)	Circle
Number	17	11	7	4	2	14
Piling procedure	Driving	Driving	Internal drilling and driving	Internal drilling	Driving (pile-tipe point only)	Casting concrete after boring

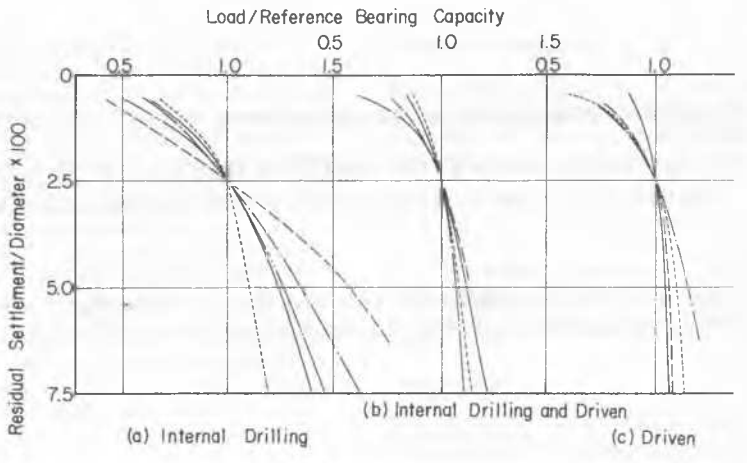

Fig 1. Load~Settlement Curves at the Head of Pile Installed by Various Piling Procedures

Discussion on Bearing Capacity of Pile Head

Various countries in the world have their own reference values and many researchers have proposed various kind of reference values of bearing capacity of pile (head). We must decide a most proper means to point out our reference value of bearing capacity of pile. After examining the "load-settlement" curve of pile head and the "actual force-settlement" curve of pile tip to all load test results of pile, we have obtained following conclusions and opinions.

(1) Residual settlement value of pile head almost agrees with settlement value of pile tip.

(2) If the residual settlement of pile head, which is equivalent to 2.5% of the diameter of pile, is taken as the reference value of the settlement, it is very effectively for the engineering point of view to take the load correspond to the above mentioned reference value for the reference bearing capacity of piles. The reference value in this conclusion coincides with a standard value adopted in DIN.

As an example, Fig.1 shows load-settlement curves, which have been obtained by modified scale, in respect of precast concrete piles in stalled by various piling procedures. From Fig.1, we can find out the inclination that piles which have been installed by the driving procedure or internal drilling and driving procedure show a sudden large increase in settlement after the reference value is passed over, whereas non-driven piles which have been installed by the internal drilling procedure along - without driving and with a tip treatment such as grouting show no sudden large increase in settlement due to a load increment, and the same trend has been observed in the case of bored piles (such as Benote pile) which do not require driving operation.

Relation between The Piling Procedure and Reference Point Resistance of Pile

Here, we will consider for the point resistance of pile where the reference settlement proposed by us occurs (we call it the "reference point resistance" and denote it by R_p).

The relationship between the reference point resistance of pile for various piling procedures and the N value of the soil around the pile tip is shown in Fig.2. This N value is taken as a mean value of $\bar{N}$ value in a sphere around the pile tip as shown Fig.3. (This means have been proposed by Vander Veen and Boersma in 1959).

Moreover we must describe to avoid the misunderstanding on the way to obtain the reference point resistance value (ton/m^2) in Fig.2. Namely the area of pile tip, which has used to calculate this reference resistance value (per unit area), has taken the closed section of pile.

From Fig.2 (a) the following relationship is observed between the $\bar{N}$ value and R_p for precast concrete pile applied the "driven procedure" or the "internal drilling and driven procedure" and cast-in-place concrete pile (Pedestal Pile) applied the "driven procedure".

$$R_p = (15 \text{ to } 30)\,\bar{N} \fallingdotseq 20\bar{N}\ (t/m^2) \quad \ldots\ldots\ldots (1)$$

The case where a safety factor of 1.5 is adopted is shown in the figure by line shown as $R_p = 20\bar{N}/1.5$. It is also observed that almost all the values obtained from load tests are larger than the above-mentioned R_p value.

Therefore, it is judged reasonable in practice to adopt the following value, when it is required to estimate point resistance of pile without carrying out a load test:

$$R_p = 20/1.5\,\bar{N} \fallingdotseq 13\bar{N}\ (t/m^2) \quad \ldots\ldots\ldots\ldots (2)$$

In the case of driven steel pile, Fig.2 (b) shows clearly that the point resistance is very small. Consequently from this figure it will be found out that plugging effect of open tip of driven steel pipe pile is considerably small.

Fig.2 (c) shows the result of examination about the bored

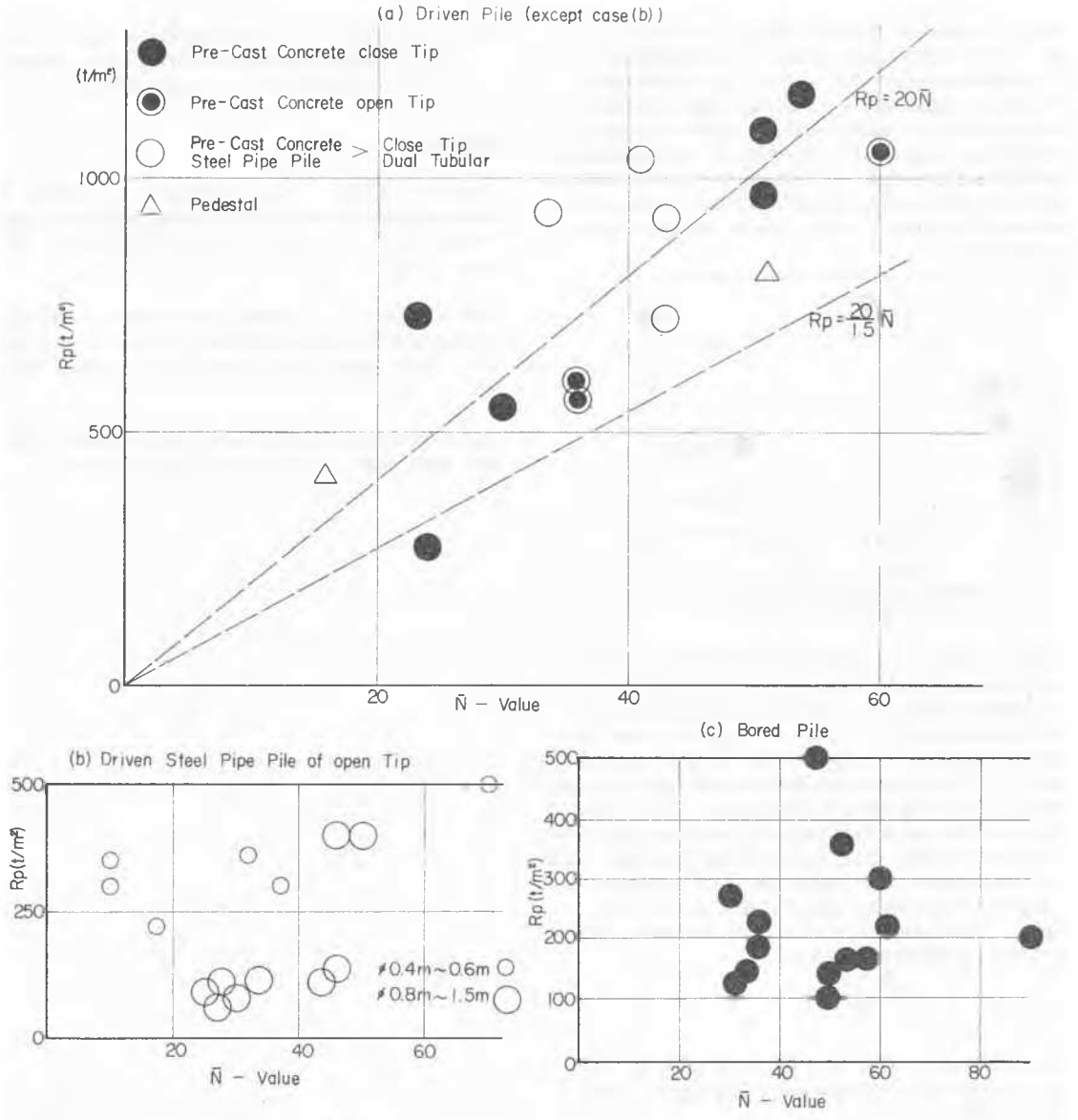

Fig 2. Relation between $\bar{N}$-Value and Reference Point Resistance (Rp)

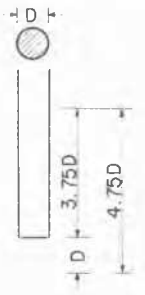

Fig 3

pile such as Benoto Pile. As is evident from this figure, we cannot find out the tendency with respect to the relationship between the $\bar{N}$ value and reference point resistance value. We have estimated as following about the result of Fig.2 (c). Namely the wide dispersion of plotted points in this figure is caused by the various effect of soil conditions and installation procedures for these bored piles.

Next, we will describe the bearing capacity of precast concrete piles installed by the internal drilling procedure which has become increasing popular in recent years. This procedure has been developed as a kind of noiseless vibrationless procedures. The drawbacks of this procedure are: (1) since open-tip piles are used, it cannot be expected to obtain closing (plugging) effectiveness at the pile tip by this procedure alone, and (2) the soil at the pile tip becomes

loose due to excavation, thereby reducing the bearing capacity. As a result, such corrective measures as giving a certain degree of driving force to the pile while it is in the supporting layer or as giving a tip treatment like grouting have been taken usually. Unless a driving force is applied, the quantity of settlement of piles applied internal drilling procedure is very large. Fig.4 show our examination on what degree of driving force is required in order to obtain the same bearing capacity as that of ordinary driven piles.

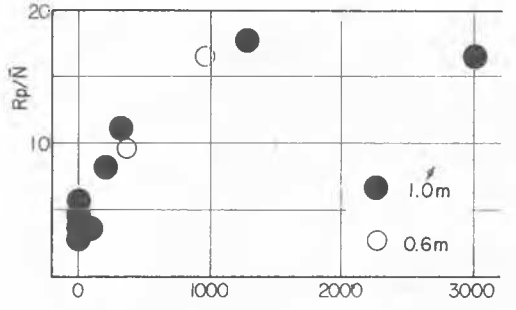

Fig 4 Relation between the number of times of driving and $R_p/\bar{N}$

In this figures, the x-axis represents the number of times of driving, and the y-axis represents $R_p/\bar{N}$. If bearing capacity similar to that of an ordinary driven pile can be obtained by adopting $R_p/\bar{N}$ 15 in this figures, about 700 times of driving will be required. Most of these piles have a diameter of 1 m and have been driven by 40 type of diesel pile driver. Then it is observed that about 2 m length of pile penetrates into the supporting layer by about 700 times of driving. From other data, it can be observed that as the quantity of settlement is increased, the point resistance of a bored pile can be gradually approximated to that of a driven pile. This point has already been clarified by the studies by BCP Committee in Japan.

CONCLUSIONS

After analyzing a large number of load test results, the following conclusions has been drawn regarding the point resistance of piles:

(1) "Driven Piles" (except open-tip, steel pipe pile)

* It is meaningful from the point of view of engineering to use as a reference the load at which the reference settlement (residual settlement which corresponds to 25% of the diameter of the pile) occurs, when the results of load tests are to be analyzed.

* The load at which the reference settlement occurs can be estimated by formula (1) from the $\bar{N}$-value.

(2) Bored Piles and Open-Tip Steel-Pipe Pile

* There is no tendency with respect to the relationship between the $\bar{N}$ value and reference point resistance value about these pile. Therefore it is necessary to consider them separately from general used driven piles.

(3) If driving force of considerable strength is applied to a pile installed by internal drilling and driving procedure, the pile may be considered a driven pile.

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