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Study on Shaft Resistance of Nodular Pile by Model Tests

INTRODUCTION

This discussion shows model tests to study the mechanism of shaft resistance of a nodular pile in relation to a stone column. Nodular pile has been widely used as a friction pile and/or as a pile to improve loose ground for more than 60 years in Japan. Fig.1 shows an example of the nodular pile. It is a precast pile with a hollow circular section. A nodular pile is made of prestressed high strength concrete.
As shown in Fig.2, a nodular pile is usually driven into the ground with gravel around the pile.

Fig.1 Nodular Pile

METHODS OF MODEL TESTS

Fig.3 shows the apparatus of model tests to study the mechanism of shaft resistance of nodular pile as compared with non-nodular pile. In these tests, after the model pile is installed, dry sand is placed in the tank. The model pile is penetrated statically by hydraulic jack into the sand. Lead shots are buried in the sand to monitor the behavior of the sand around the pile through X-ray photographs.
The sand is pressurized by the vertical stress, σv, and horizontal stress, σh. Each value is maintained at a constant level throughout a test.

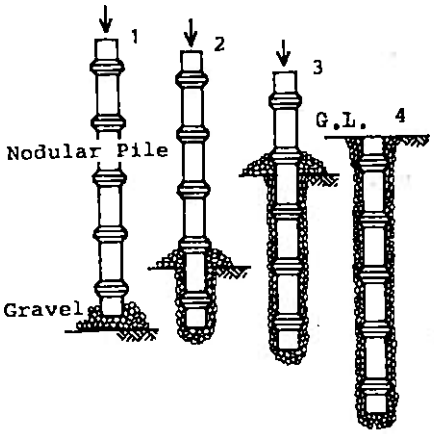

Fig.2 Procedure of Installation

RESULTS OF MODEL TESTS

The shaft resistance of the nodular pile increases with pile penetration, while the pile settlement, So, is small. When So is about 15mm, the shaft resistance reaches the maximum value, Pn. After So exceeds 15mm, the shaft resistance decreases gradually.
As shown in Fig.4, Pn is about twice as large as Ps, and about 2.5 times as large as Ps'. Here in, Ps is the shear strength of the sand on the cylindrical surface whose diameter is assumed to be equal to the nodule's one. Ps is calculated by the internal friction angle of the sand. Ps' is the maximum frictional resistance of non-nodular pile with diameter equal to the nodule's diameter. Ps' is calculated from the test results of non-nodular pile.
Fig.5 (a)~(c) are displacement vector diagrams of lead shots observed in the test. In small settlement (Fig.5 (a),(b)), the sand under a nodule moves outward similarly to the sand below the pile end. Therefore, nodule works similarly to the pile end. After shaft resistance reaches the maximum value, a cylindrical slip surface forms around the pile. The diameter is larger than the nodule's one in Fig.5(c). The sand under a nodule moves still outward. Therefore, the shaft resistance of the nodular pile becomes larger than that of non-nodular pile.

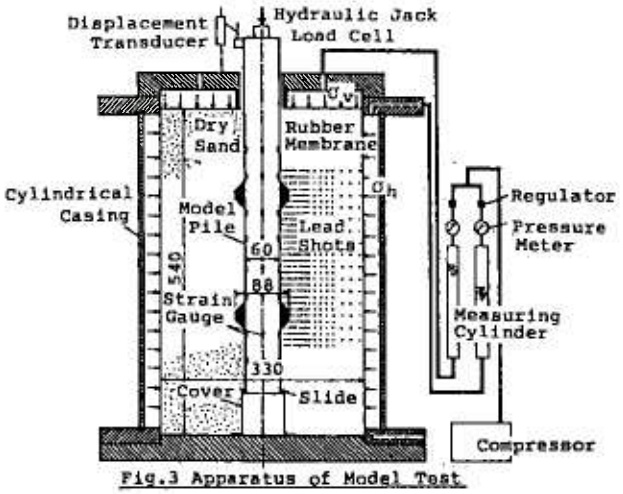

Fig.3 Apparatus of Model Test

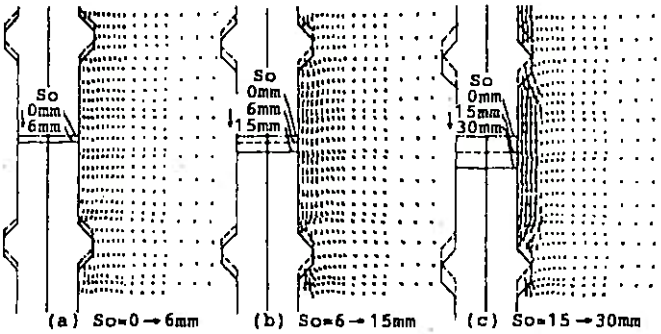

Fig.5 Displacement Vector Diagrams
(σ_v=1.28kgf/cm², σ_h=0.64kgf/cm²)

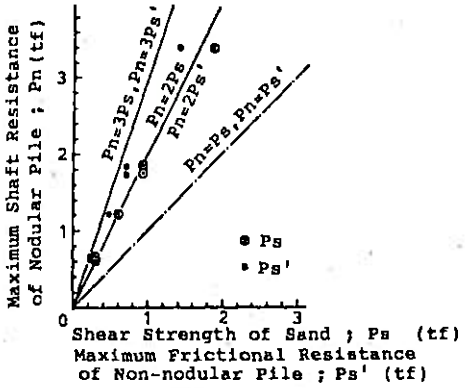

Fig.4 Maximum Shaft Resistance of Nodular Pile in relation with Ps and Ps'

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Latest Expericences of Ret-Ser Engineering Agency on PDA and CAPWAP

Conclusions in the paper entitled "Applicability Study of Pile Driving Analyzer in Taiwan Region" were drawn at least one and a half years ago. In the past several months, Ret-Ser Engineering Agency had a chance to perform another series of test, which included wave equation analysis, PDA tests, CAPWAP analysis, as well as static loading tests on six piles in one single site.

The site for the latest testing project is located at Hsin-Ta in Southern Taiwan. In general, it is silty sand around pile and silt at the toe of pile. PDA tests were performed at the end of initial driving and at restrike which was conducted about 7 days after initial driving. CAPWAP analysis were performed on both initial driving signals and restrike signals. Static loading tests were performed about 3 to 4 weeks after initial driving.

Althrough we have not finished all the detailed analysis on data collected in this latest test, general conclusions can be summerized as follows to serve as a supplement to the paper we presented to the conference.

1. Results obtained at the end of initial driving show much more variation on bearing capacities. In Hsin-Ta, results of CAPWAP analysis using initial driving signals are only 35 to 55% of the bearing capacities estimated by static loading tests. So it is less reliable when using initial driving signals.

2. Since CAPWAP analysis using restrike signals recorded by PDA can make very good estimation on damping constant and quake value of soil, as well as stress wave propagation velocity along the pile, so bearing capacities estimated using these parameters were much more consistant for those piles tested in the same site.

In Hsin-Ta, CAPWAP analysis using restrike signals gave 85 to 92% of the capacities predicted by static loading tests. They are rather close, and the variation is relatively small.

3. Tables established by researchers showing damping constants for different types of soil can only be used as referencce. Using these damping constants without the varification of CAPWAP analysis, PDA results may be misleaded. For instance, damping constant for silty sand from talbes should be between 0.2 to 0.4. After CAPWAP analysis, the damping constant for silty sand in Hsin-Ta is between 0.5 to 0.6.

So, it would be fair to say that PDA test together with CAPWAP analysis will be much more valuable than just PDA test alone.
As a closing remark, I would like to quote the conclusion we made in the paper presented to this conference. " The PDA test together with associated dynamic analysis is an invaluable tool for providing better understanding of hammer-pile-soil interaction", and I would like to emphasize the following words,"PDA is not a simple tool, anyone trying to use it without careful thinking and engineering judgement will not succeed".

Reference

Li, John C., Yeh, Hsang-Yang, Ong, Bing, Shih, Chaur-Song.
"Applicability Study of Pile Driving Analyzer in Taiwan Region", Proceeding of VIII Asian Regional Conference on Soil Mechanics and Foundation Engineering, Volume I, Kyoto, Japan, July, 1987.