ON THE LOADING TESTS ON PILES OF BENOTO-TYPE IN AMAGASAKI DISTRICT OF NAGOYA-KOBE EXPRESSWAY

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1. Foreword : The Benoto piling method which the Amagasaki Construction Office of Japan Highway Public Corporation has proposed this time for the use in laying foundations of the bridge piers on the Nagoya-Kobe Expressway may be regarded as one of those examples depicting recent engineering progress. The field test for these peculiar piles was assigned to and carried out by Hazama-Gumi, Ltd.

2. Soil Properties at the Piling Sites : Two sites with different geological properties are selected for the piling test. These are Sonoda and Kukuchi sites, both on the proposed route of the Nagoya-Kobe Expressway.

The soil properties are encountered at the testing sites are shown in Fig. 1.

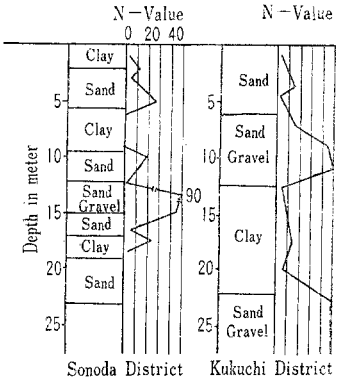

Fig. 1 Baring Log.

3. Test Program : The field piling test is divided into two namely a performance test and a loading test. This report, however, deals with the loading test only. In planning and carrying out these field tests, similar conventional practices were observed. Descriptions are made in accordance with the sequence of tests performed.

(1) Vertical load tests on single pile.
(2) Horizontal loading test on single pile.
(3) Vertical & horizontal loading test on single pile.
(4) Pulling test on single pile.
(5) Horizontal load test on pile group.

For each of the above listed tests, instruments such as reinforcement meter, earth pressure gauge, strain gauge, thermometer and clinometer are used either singly or jointly as required. To determine displacement, a dial gauge of 1/100 mm was used. Of the above listed tests, the results of items (1), (2) and (5) alone are outlined in this report.

4. Vertical Loading Test on Single Piles : Inasmuch as the test of single piles carried out in Sonoda district revealed that the settlement was relatively small, the deformation and pile-tip settlement of pile were calculated. The load-settlement diagram of pile is shown in Fig. 2. The loading tests were conducted in four cycles with 50, 100, 150 and 200 tons at maximum respectively. The figures in Table-1 below are obtained from the readings of reinforcement meter at maximum loading in each cycle.

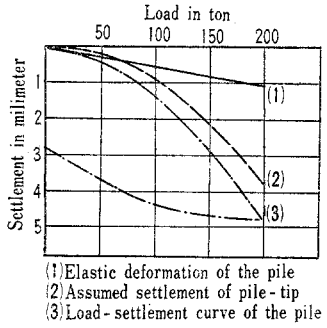

Fig. 2 Load-Settlement Curve.

Table 1

Cycle	Max. stress in pile (t)	ε (mm)	ε_0 (mm)	$\varepsilon/\varepsilon_0$	Cumulative deformation (mm)
1	59.2	0.256	0.404	0.634	0.36
2	103.6	0.504	0.703	0.690	1.80
3	156.3	0.821	1.070	0.767	2.74
4	208.1	1.107	1.420	0.780	4.80

In the above table, ε denotes the amount of elastic deformation of pile for each load, and ε_0, that of elastic deformation of pile, when it is considered a perfect bearing pile.

The above table shows that as the load increases, the ratio of the bearing capacity at the pile-tip to the skin friction increases, showing a tendency that the load at pile-top is gradually transmitted down to the pile-tip.

From this fact it may be concluded that although the piles may react in various different ways according to the geological conditions, the skin friction of pile gradually loses its effect with the increase in the pile settlement and finally all the friction effect will completely disappear.

Fig. 2, also shows the estimated settlement of the tip of pile, taking into account the elastic deformation on the basis of the load-settlement curve. When the load exceeds 100 tons, pile settlement increases lineally with the increase of load. If the bearing sand stratum is assumed to be elastic, the pile is expected to show a settlement of 6.3×10^{-2} mm/t/sq.m.

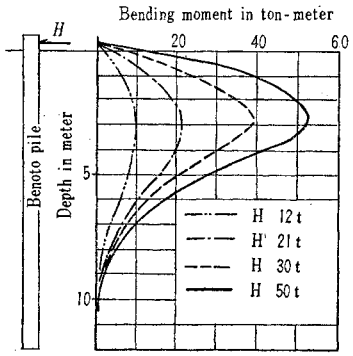

Fig. 3 Relation between depth and bending moment.

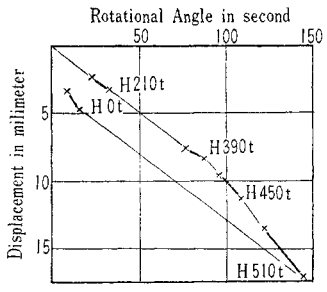

Fig. 4 Relation between displacement and rotational angle of footing.

5. Horizontal Load tests of Single pile: The following are the findings therefrom:

(1) Maximum bending moment in pile occurs at a point 2 to 3 meters below the ground surface;

(2) Horizontal load at pile top is approximately proportional to the maximum bending moment;

(3) When a compact stratum exists at a depth relatively near the ground surface as in the case of Kukuchi district, an abrupt change of the bending moment happens in that stratum, below which the pile is hardly affected by bending moment.

(4) Bending moment at any depth below 7 meters or more from the ground surface may be considered practically zero.

(5) In case a crack develops in the pile section, the bending moment does not increase, even if the deflection increases.

6. Horizontal Test on Pile Group:

Inclination of footing due to the horizontal load was measured by means of a bubble-type clinometer installed at the center of footing. Correlation of footing displacement with its inclination is as shown in Fig. 4 and it has been revealed that the inclination of footing varies almost linearly with the horizontal displacement. An attention is to be paid to this matter especially in case of a tower-like structure whose center of gravity is comparatively high.

Especially in such structures as bridge piers which are subject to rotational moment as well as to horizontal force, the horizontal displacement at the top of structure is considered to be the sum of 3 factors, namely, the displacement due to the horizontal force, the displacement due to the rotation caused by horizontal displacement and the displacemet due to rotation movement. Because of this, piles should be designed always with sufficient bearing capacities.

7. Postscript: Generally, in case of load test of a short duration, earth shows somewhat larger strength against such a load, and the settlement and displacement of piles are expected to be small.

It is hoped, however, that although limited in scope, the analytical results may prove to be of some use in designing the Benoto piles for foundation.