02 Jun 1993, 2:30 pm - 5:00 pm

Instrumented Caissons at the IBM Building, Baltimore

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Proceedings: Third International Conference on Case Histories in Geotechnical Engineering, St. Louis, Missouri, June 1-4, 1993, Paper No. 7.30

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SYNOPSIS: Two of the caissons supporting the 26-story IBM office building were instrumented to evaluate the load transfer mechanism from caissons to the surrounding soil and rock. These drilled shafts extended through loose alluvial stratum, a stratum of dense sands and silts, a disintegrated rock stratum, and were founded in the underlying Amphibolite bedrock. Evaluation of mobilized skin friction and end bearing for one of the caissons are presented in this study. Instrumentation consisted of vibrating wire total load cells and embedded strain gauges. Total load cells were installed at the bottom of the caissons to measure the end bearing pressure. Embedment strain gauges were installed in groups of three in the middle of the general strata and at the approximate level of strata change to evaluate skin friction. In-situ measurements from the gauges were recorded during the construction of the building. From these strain gauge readings load distribution with depth, the average skin friction in each stratum and end bearing pressure were calculated and presented. Finally, these mobilized values were compared with the initial design parameters and the performance of the foundation was evaluated.

INTRODUCTION

The IBM office building is located in downtown Baltimore, on East Pratt Street and Light street. The building is 26-stories high and has a plan area approximately 200 feet by 65 feet. The foundation consists of 68 high capacity caissons (drilled shafts) with lengths ranging from 50 to 80 feet and varying in diameter from 4 to 6 feet. The caissons were extended through the soil strata namely alluvial, Potomac Group sands and residual deposits and founded on underlying Amphibolite bedrock. The caissons were designed to transfer load through skin friction as well as end bearing pressure.

Two caissons namely TA/T7 and TK/T1 were instrumented with embedded strain gauges and total load cells. Cables connecting the gauges in caisson TK/T1 were damaged during construction immediately after installation and data gathering from this caisson was terminated. Gauge readings from caisson TA/T7 were gathered during the construction period of the building and the data was analyzed and presented in this study.

SOIL PROFILE AND DESIGN PARAMETERS

The subsurface condition of the site was identified as following general strata; Fill (Stratum A), Alluvial (Stratum B), Potomac Group (Stratum C), Disintegrated Rock (Stratum E), and Amphibolite Rock. The typical soil profile near the caisson TA/T7 is shown on Fig. 1. Fill and alluvial strata consisted of generally loose density soils (N=2 to 18). The Potomac Group sand stratum was generally compact (N=20 to 100+), and the disintegrated rock stratum was very compact (N=86 to 100+).

The as-built cross-section of caisson TA/T7 is given in Fig. 2. The caisson was designed to carry a column load of 2800 kips and the load was assumed to be transferred from caisson to surrounding soils and rock through both skin friction and end bearing. A design value for end bearing was assumed as 80 ksf. A value for skin friction of 2.8 ksf for the Potomac Group stratum and 5.0 ksf for disintegrated rock were assumed as design values. These design values were taken from the previous load test results in similar soil conditions. No skin friction values were assigned to fill and alluvial stratum.

INSTRUMENTATION

Instrumentation was aimed in assessing the in-situ load transfer mechanism from caisson to each soil strata and the rock. It consisted of total load cells and embedded strain gauges of vibrating wire type. The layout of instrumentation for caisson TA/T7 is depicted in Fig. 3.

Eighteen EM-5 vibrating wire concrete strain gauges were installed at six elevations, at each elevation three gauges were installed in an axi-symmetric 120 degree rosette. These gauges were used to evaluate load transfer mechanism by skin friction within each strata. A gauge group was placed in the column above the caisson to measure the total load transferred to the caisson. Another group of gauges was placed 5 feet from the bottom to estimate the end bearing pressure. The gauges were attached to the reinforcement steel by means of a specially fabricated bucket supplied by the gauge manufacturer.

A 500 psi capacity, 9-inch diameter oil filled total pressure cell (TPC) was placed at the bottom of each caisson. Thin mortar layers were placed on the top and the bottom of the TPC to protect the cell. The wires connecting the gauges were brought to the top surface by a 2 inch PVC vertical conduit built within the caisson. The gauges were constructed to a single junction box at the top of the caisson.

DATA ACQUISITION

The micro-strain reading along with the gauge temperature were collected from the read-out box twice a month during the construction of the building. A computer database using spreadsheet program was developed to store and analyze the data. The data acquisition took place from August 1990 through September 1991. Data gathering was terminated at substantial completion of the building construction.

Pressure readings from the TPC at the base of the shaft became inconsistent during the course of the data gathering. Also the strain gauge groups at elevations -9.5 feet and -59.5 feet failed during the period of study.

ANALYSIS AND RESULTS

Strain readings after the caisson were poured were recorded as the initial strain readings for each strain gauges. Incremental load in the caisson cross-section at the instrument elevations were computed from the change in strain and the sectional properties of the caisson (Dunnicliff, 1988; Bowles, 1988).

$$P = E\,A\,(e - e_o) \tag{1}$$

where 'P' is incremental total load due to building at the section, 'e' is the recorded strain reading, 'e_o' is the initial strain gauge reading, 'E' is the modulus of deformation of concrete, and 'A' is the area of caisson at the point of interest. The load in the caisson at the gauge elevations were calculated from the corresponding strain gauge readings. Typical load readings are shown in Fig. 4.

Load carried by each stratum calculated by difference between top and the bottom loads of the stratum.

$$P_{str} = P_t - P_b \tag{2}$$

where 'P_{str}' is the stratum load, 'P_t' is load at the top of the stratum and 'P_b' load at the bottom of the stratum. Variation of load distribution among stratum with time is shown in Fig. 5. The total load carried by the caisson at the end of the construction period was about 1200 kips. No load was assured to be carried by alluvial and fill stratum during these calculations.

The average skin friction in each stratum is given as

$$t_{str} = P_{str} \;/\; S_{str}. \tag{3}$$

where 't_{str}' is the average skin friction of the stratum and 'S_{str}' is the surface area of the caisson within the stratum. The average end bearing pressure is given as

$$b_{end} = P_{end} \;/\; A_{end} \tag{4}$$

where 'b_{end}' is the average end bearing pressure, 'P_{end}' is the load at the tip and 'A_{end}' the tip area. Variation of average skin friction and end bearing pressure with time are plotted in Fig. 6. The skin friction values at the end of study period were 1.3 ksf and 1.1 ksf for the Potomac Group and disintegrated rock strata respectively. The value of end bearing pressure at the end of construction was 10 ksf.

Mobilization of average skin friction with approximate pile deformation was considered next. The calculated pile deformation was composed of concrete compression and elastic settlement of the rock at the base of the shaft (Bowles, 1988). The pile compression was calculated from micro-strain readings and tip settlement was calculated as elastic settlement using an assumed value for modulus of deformation of rock (72,000 ksf). Variation of average skin friction with pile deformation for both strata are given in Fig. 7. These curves indicate that the mobilized skin friction values are within the elastic range.

CONCLUSION

At the end of the study period, the load on the caisson was about 43 percent of the design value. About 10 percent of this load was carried in end bearing, 40 percent of the load was transferred by skin friction in Potomac Group stratum, and 50 percent of the load was supported by skin friction mobilized in the disintegrated rock. In-situ measurement showed that the Potomac Group soils contributed more load carrying capacity (as percentage of total load) than the value evaluated during the design stages.

Average skin friction was mobilized in Potomac Group and disintegrated soil are 46 percent and 22 percent of the design values respectively. Only 13 percent of design value of end bearing pressure was mobilized at the end of the construction period. It was also noted that the skin friction values in both soils exceeded 1.0 ksf, the conventional limiting skin friction suggested for drilled caissons (NAVFAC DM - 7.2).

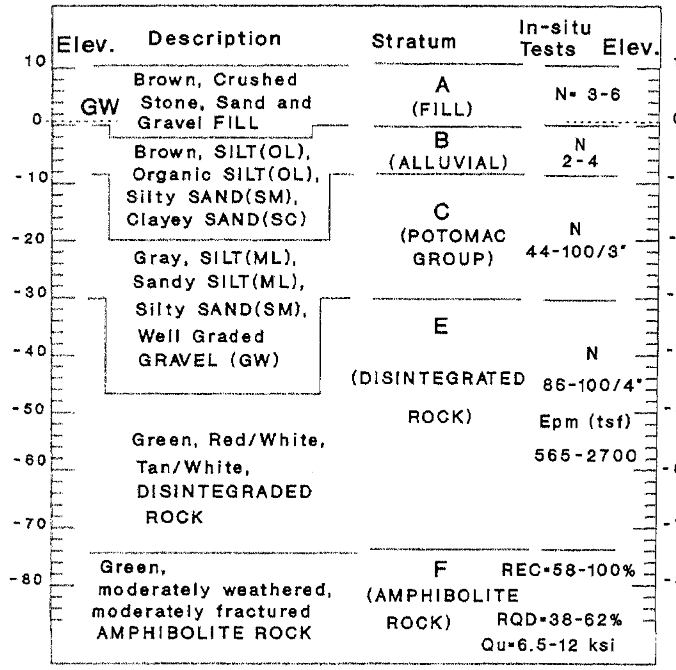

Fig. 1. Subsoil Profile at Caisson TA/T7

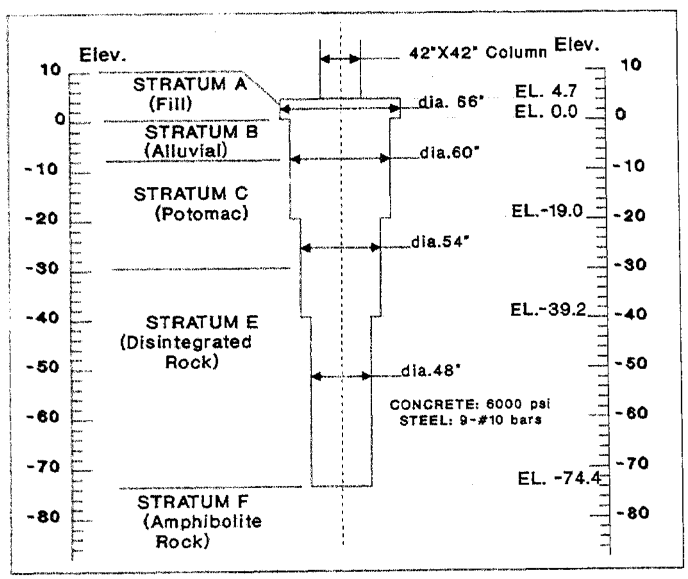

Fig. 2. Cross-section of Caisson TA/T7 (As-Built)

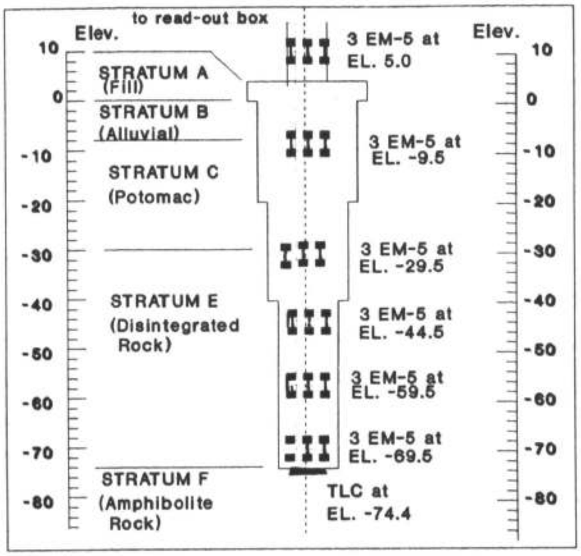

Fig. 3. Instrumentation Layout for Caisson TA/T7

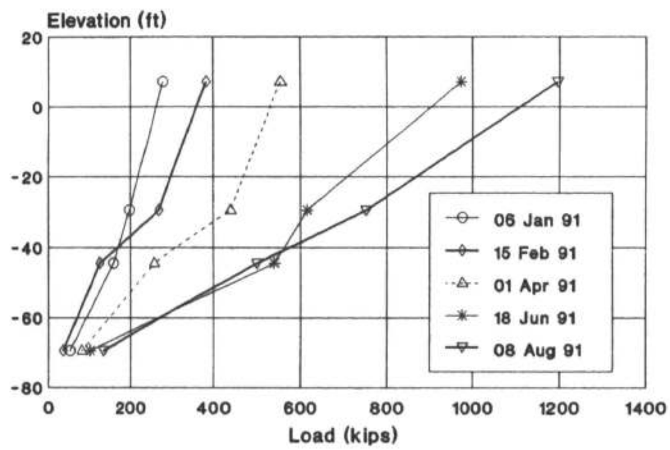

Fig. 4. Typical Load Measurements at Instrument Elevations

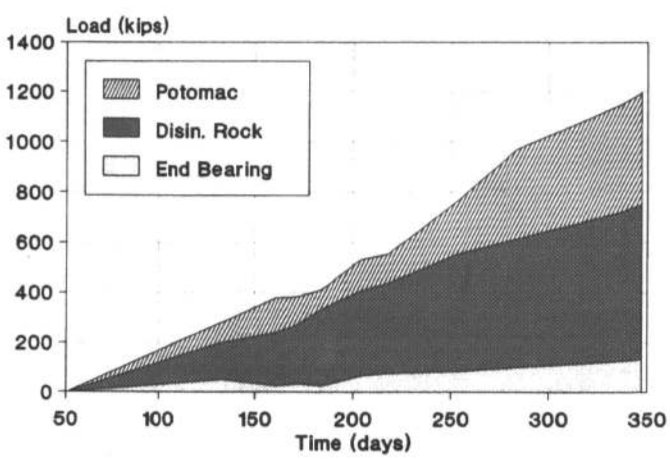

Fig. 5. Load Distribution among Strata during Construction

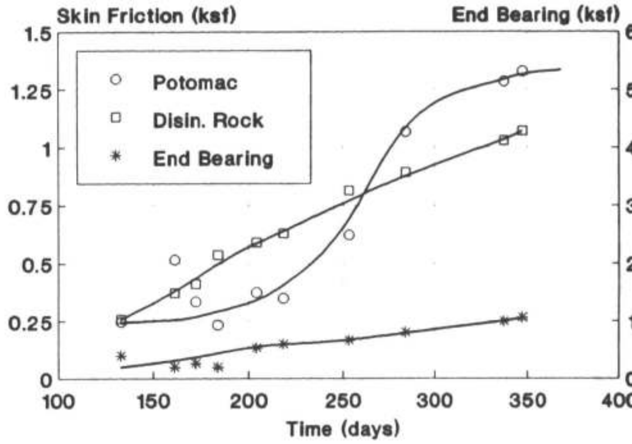

Fig. 6. Variation of skin friction and end bearing with tim

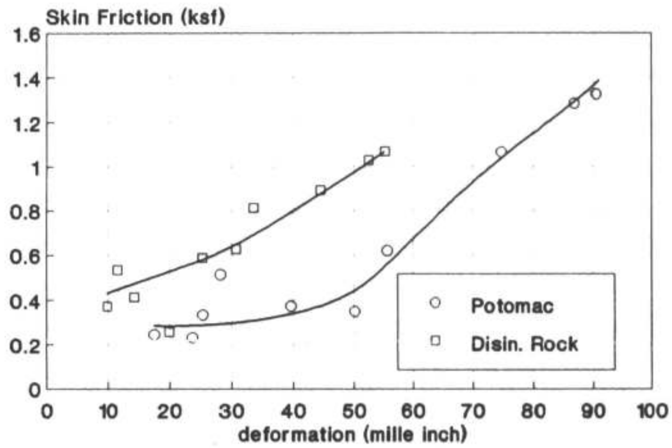

Fig. 7. Mobilization of Skin Friction with Pile Deformation

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