USE OF HIGH CAPACITY PILES IN BRIDGE FOUNDATIONS WITH FULL SCALE TEST RESULTS

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James A. Mason, California Department of Transportation, Office of Structure Design, Sacramento California

Analysis of existing viaducts in the San Francisco Bay Area directly after the 1989 Loma Prieta earthquake showed that numerous foundations were inadequate for large seismic demands. Since then, Caltrans has invested a portion of its resources to this problem. This paper will briefly explore the problem of inadequate foundation moment and shear capacities of existing footings. Also, two recent FULL SCALE PILE TEST RESULTS are presented. Both tests were conducted in San Francisco, California, with the predominant soil type being SOFT BAY MUD.

First, the "Pile Load Test", was conducted to investigate the adhesion capacity of axially loaded piles that were founded through deep soft Bay Mud. This full-scale test was conducted in 1992 to get some "real numbers" for the tension and compression capacities of standard plan piles and of high capacity proprietary piles. A total of 81 compression and/or tension tests were conducted. All piles were loaded until they reached GEOTECHNICAL FAILURE, i.e. a slip state.

The second test was of two full scale PILE GROUPS IN LATERAL LOADING. This report presents some of the original test results. It should be noted that each pile group was pushed to a slip state through the soil mass. From this, preliminary conclusions can be drawn about the degradation of the group stiffness at large strains. Analysis of one pile group capacity was conducted to investigate codified group reduction factors.

PILE LOAD TEST RESULTS

INTRODUCTION

The main reason for the PILE LOAD TEST has been the uncertainty of the tension capacity, the adhesion, of deep soft bay muds. Because of the uncertainty, Caltrans designers took a very conservative approach for the tension design of piles in soft Bay Mud, in effect ignoring its capacity for this special Geotechnical case. This assumption forced the design of the pile group moment couple to be resisted wholly by compression piles, i.e. a moment arm. Footings that were designed in this manner proved to be very costly. It was felt that a proof test would easily justify any funds invested and provide substantial information to rectify this uncertainty. A full-scale pile load tests, of numerous pile types, was conducted in San Francisco in 1992 to get some “real numbers” for the tension and compression capacities of standard plan piles and of high capacity proprietary piles in this unique soil type.

The Caltrans piles were 1) 16” I.D. Steel Pipe Pile (PP16x0.500), 2) Pre-Loaded Steel Pipe Pile / Tie-down, 3) Steel H-Pile (HP14x89), 4) 14”x14” Prestressed Concrete Pile, and 5) a Timber Pile.

The participating companies with the high capacity pies were 1) Fundex of Holland represented by American Piledriving Company of Pleasanton, California, 2) Monotube Piling Company of Canton, Ohio, 3) Nicholson Construction Company of Bridgeville, Pennsylvania, and 4) Halliburton / Brown and Root of Houston, Texas.

This paper will present the tabulated results for seismic and ultimate capacities from the recently finished testing. Load and deflection seismic design criteria and implications will be discussed. Some recommended seismic footing design concepts are also presented.

SETTING UP THE TEST

Soil Profile

The soil profile at the test site in San Francisco is described as follows. There is a 20' layer of hard compact fill material with a lot of rubble and unknown material on top. This fill material was segregated from the test as described in LONG PILES / SHORT PILES below. Beneath the fill is a 90' layer of the soft Bay Mud. It is fairly homogenous in composition. Hard sands lay under the Bay Mud.

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Long Piles / Short Piles

One of the main goals of the test was to investigate the capacity of the soft clay. This was achieved by having short piles, i.e. piles installed only in the soft clays, right along side of piles that were founded in the dense sands. By having the piles side by side, the capacity of the two soil zones could be separated and quantified. Then the granular material capacity could be separated from the clay capacity. IT should be pointed out that all of the piles were installed inside a casing that extended through the 20' of fill material. The tests piles had no interaction with this casing and therefore had no interaction with the fill material. The reaction piles were all backfilled with pea gravel to provide lateral stability for the load frame.

The Test

The Foundation Testing and Instrumentation Branch of The Office of Geotechnical Engineering, Division of New Technology, Materials, and Research, Caltrans conducted the testing. The tests were performed per the ASTM D1143 for compression piles and ASTM D3689 for the tension piles. These are the standard axial load tests for piles.

SEISMIC DESIGN IMPLICATIONS

The importance of a competent substructure cannot be overly emphasized. Analogous to good tires on a car, the foundation is the connection, the grounding of the superstructure. The foundation system of a structure is the mechanism for transmission of seismic loading into that structure. It is also the mechanism for the seismically induced inertial forces of the superstructure back into the ground. In seismic design, the importance of maintaining the foundation elements in the elastic stress/strain range will force any sort of plastic hinging of the columns above the top of the pilecap. This makes repair of any earthquake damage accessible.

SEISMIC FOOTING DESIGN CONCEPTS

Development of the Moment Couple

When looking at a pile group in section, it is easy to see the development of the moment couple via the compression and tension piles. And in the past, Caltrans designers have typically used one-half of the compression capacity for the tension capacity for granular, and stiff cohesive soils. See BRIDGE DESING SPECIFICATIONS 4.3.4.6.1. In deep soft Bay Muds, the tension capacity was taken as zero. And now, because of the Pile Test results, inclusion of the State designed Cl.150 Pipe Pile Tiedown and the high capacity proprietary piles, the tension capacity can equal the compression capacity in the deep bay muds. Thus making for a more economical moment couple footing design.

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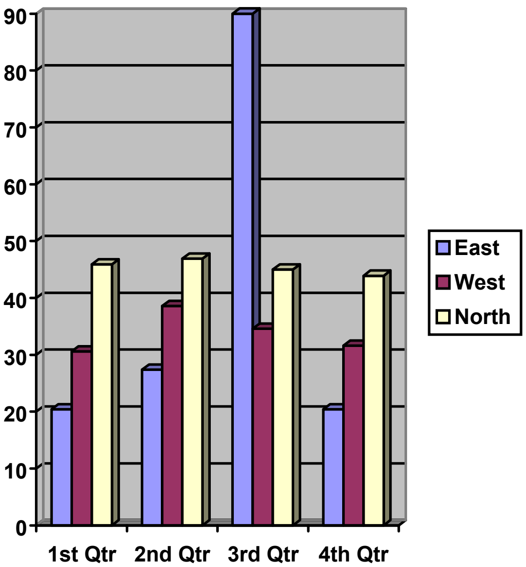

Nodal Demands / Nodal Capacities

For large seismic loads, the applied moment at the bottom of the column can be, at maximum, the plastic moment capacity. In addition to the moment demand is the axial column load and plastic shear of the column. These loads would be distributed throughout the group. The pile with the greatest demand would se the lower limit for capacity of each pile in the group. This is true for either the State Standard Plan Piles or the proprietary high capacity piles. The plans would show the same pile capacity, for every pile, for each footing. This listing would specify the compression, tension and axial stiffness requirements. The grouping of the pile axial capacity, i.e. type of “Class”, would be in 50 kip increments for the high capacity proprietary piles. The lateral stiffness specification should be developed through “p-y analysis” for the soft bay muds.

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Personal Conversation with Mr. Adali Goldschmidt, Caltrans Geologist.