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O-CELL TESTING OF REINFORCED CONCRETE DRIVEN PILES

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ABSTRACT

Precast and prestressed concrete piles, approximately 12 to 18 inch diameter or width are frequently used to support heavy building and bridge structures. Fly ash has long been recognized as a construction material used frequently in several Portland cement and concrete products, structural fills, embankments, and road bases/subbases. However, use of Illinois PCC bottom ash in construction of precast concrete piles so far has been very limited, if any, mainly due to the lack of technical data to convince the engineering community that bottom ash could be used in precast and prestressed concrete piles without jeopardizing their performance and the structural integrity to resist the anticipated loads. The main objective of this investigation was to evaluate the effect of using Illinois PCC bottom ash on the performance of precast concrete driven piles when subjected to axial loads using O-Cell. This goal was accomplished by performing field tests on full-size piles made with concrete composites containing Illinois PCC bottom ash and comparing their performance with the performance of a similar pile made with an equivalent conventional concrete. The test results show that that the performance of piles made with concrete composites was similar to that of piles made with an equivalent conventional concrete.

Key Words: Bottom ash, coal combustion, concrete composites, foundations, precast piles

INTRODUCTION

Mankind has used pile foundations for more than 2000 years. The early piles were always made of wood and thus were limited in length, capacity, and durability. However, in last 200 years, precast concrete and steel piles have become a part of every other construction project in the world. Pile foundations are subjected to compression loads mainly due to dead and live loads from superstructure, and uplift and lateral loads due primarily to wind and earthquake. Pile foundations resist load due to friction between the sides of pile and end bearing at the tip of pile (Bowles, 1996; and Das, 1999). The allowable load that a pile can resist is smaller of the structural capacity of the foundation element, or resistance provided by the soil in which the foundation element is installed.

The most common approach to determine the capacity of deep foundations is to install a full-size prototype pile at the site and load it to failure (Coduto, 1994). However, because of the cost to perform field tests on full-size piles, these tests are not performed routinely. Piles are designed using load test data and design methods available in literature. Therefore, availability of data demonstrating the performance of any type of piles made from new concrete composites, under actual loading conditions is necessary to develop confidence in the engineering community. Osterberg cell (O-Cell) method of testing drilled shafts has been in existence for some time and several studies have been done to estimate load bearing capacity of drilled shafts using the O-Cell. However, use of O-Cell method of testing for precast concrete piles is still limited. The O-Cell method of pile or drilled shaft testing can be completed relatively quickly and both, the end bearing capacity and side shear resistance, can be measured simultaneously during the same test. Use of the O-Cell to test piles or drilled shafts also alleviates some problems associated with testing using the conventional methods of testing.

Coal continues to be the dominant fuel source for electricity in the United States. Use of coal in generation of electricity has resulted in production and accumulation of large quantities of coal combustion products (CCPs). During 2001, about 900 million metric tons (Mt) of coal was burned, and about 107 Mt of coal combustion products were generated by electric utilities and non-utilities (Kalyoncu 2003). According to Dube (1994), only 10% of the total ash produced was being used in early 90s. In 2001, approximately 33 percent of the total CCPs were used in various applications (Kalyoncu 2003) whereas in 2000 approximately 29 percent (28.59 Mt) of CCPs were used (Kelly and Kalyoncu 2002). The major utilization of CCPs has been in construction-related applications. Within the past 30 years several case histories of utilization of coal combustion products in construction projects are available (ACAA, 2001; GAI, 1988; Golden, 1986; Hosin, 2001; Korcak, 1998; Kumar and Stewart, 2003a and b; Kumar et al., 2003; Kumar and vaddu, 2003; Lovell et al. 1997; Naik et. al., 1997; Ng, 2001; Schroeder, 1994; Seals et al. 1972; Tikalsky and Carrasquillo, 1989).

Use of coal combustion products in construction of precast and prestressed concrete piles so far has been very limited. This is primarily due to the lack of available data demonstrating the effective use of coal combustion products in precast and prestressed concrete piles. This investigation was initiated with an objective to develop suitable composites containing coal combustion products that could be used to construct reinforced concrete precast piles. Several mixtures containing different matrix constituents and proportions were prepared and tested to determine strength, stiffness, and durability characteristics of the mixtures. Based on the laboratory tests on concrete composites, several piles were constructed, installed at a site in Illinois, and tested for impact loads, axial compression and axial pullout loads, and lateral loads. Test results presented show that field performance of the precast concrete piles constructed using concrete composites containing PCC bottom ash is similar to that of shafts constructed using an equivalent conventional concrete.

PILE INSTRUMENTATION AND CONSTRUCTION

All piles were constructed at Egyptian Concrete Company, in Salem, Illinois. A total of 19 piles having cross-section of 12 x 12 in and lengths between 20 and 22 feet were constructed using two different concrete composites and an equivalent conventional concrete. The concrete composite, B100, refers to the concrete prepared by replacing 100 percent of natural fine aggregate with Illinois PCC bottom ash and concrete composite, B50, refers to the concrete prepared by replacing 50 percent of natural fine aggregate with Illinois PCC bottom ash and concrete, CM, refers to an equivalent conventional concrete.

Out of the 19 piles constructed, 16 were per-cast concrete piles (5 piles from the concrete composite, B100, 6 piles from the concrete composite, B50, and 5 piles from the control mix, CM, and 3 piles were pre-stressed concrete piles (one pile from each of the concrete composites and one pile from the control mix). All piles were appropriately reinforced and instrumented to obtain the performance data during testing. Reinforcement cages for all piles were first prepared and then instrumentation was attached to the reinforcement cage. Seven-inch diameter O-Cells, Boxed in steel cases of the same cross-section as that of piles, were used for piles tested using O-Cells. Figures 1 and 2 show the instrumentation and construction of piles for axial load tests using O-Cell, respectively. The completed reinforcement cages were placed in the forms and concrete was placed using free fall method. Fresh concrete in the form was appropriately vibrated. After two days, piles were taken out of the forms and stacked. Piles were allowed to cure by placing plastic cover on them. All piles were then transported to the site in Carterville, Illinois.

Figure 1. Instrumentation of the pile

Figure 2. Construction of pile with O-Cell

The concrete composites used to construct the piles were made by using ASTM Type 1 cement, natural fine sand, crushed rock as coarse aggregate, Illinois PCC bottom ash. The crushed limestone coarse aggregate and natural fine aggregate were obtained from a Southern Illinois Quarry, Anna, Illinois. Illinois PCC dry bottom ash was obtained from City Water Light and Power (CWLP) in Springfield, Illinois. The moisture content of the bottom ash was monitored daily until it reached less than one percent. The moisture content of all raw materials was monitored biweekly except for Portland cement. The concrete used in the construction of all piles had compression strength of over 5,000 pounds per square inch (psi) after 28 days of curing.

PILE INSTALLATION

Piles were driven at a site located in the Carterville, Illinois campus of SIUC. A single-acting diesel hammer, Delmag D15, with a rated energy of approximately 27,100 ft-lbs was used to drive the piles. Each pile was first driven two feet into the ground and then was checked for plumbness. The pile was then driven into the ground till it encountered the specified resistance. Resistance to pile driving was measured through driving of piles in terms of number of blows required to drive each of the pile. Figure 3 shows a picture of installation of piles in progress.

Figure 3. Pile installation in Progress

The soil stratigraphy at the site consisted of medium stiff to stiff, brown silty clay to depths of approximately 21 feet. The silty clay is underlain by very stiff to hard, sandy clay shale to the maximum depths explored 25.5 feet. Both the borings were terminated at spoon refusal (more than 50 blows required to penetrate first 6 in of the split spoon). Laboratory testing was performed on the soil samples to estimate pertinent engineering and index properties of the soil. Moisture contents were determined for cohesive samples and Atterberg limit tests were accomplished on selected samples. Unconfined compression tests were performed on selected Shelby tube samples. The results of field and laboratory testing indicate that the compressive strength of the silty clay generally range between 0.75 to 1.75 ton per square foot. The moisture content of the silty clay generally varies between 15 and 29 percent.

TESTING PROCEDURE

O-Cell tests started by pressurizing the O-cell in order to break the tack welds that hold the cell closed (for handling and construction of the shaft). After the break occured, O-cell was immediately depressurized and then loading was started. O-cell load testing was performed by pressurizing the O-cell. The applied load was determined from the cell's pressure versus load calibration. The load was increased until the ultimate capacity of the side shear resistance above the O-cell was reached and/or the maximum stroke of the O-cell was approached.

TEST RESULTS AND DISCUSSION

Figure 4 shows a picture of pile testing in progress. Pile movements at the top of pile and at the O-Cell level, and compression of the shaft due to application of the load was measured during the O-Cell testing. Since the load was applied at the tip of the piles, the piles were pushed out of the ground during the testing. Figure 5 shows a picture of the pile pushed out of the ground.

In the O-cell tests, the upward shaft movement provides information about frictional resistance between the concrete and the surrounding soil whereas the downward O-cell movement only provides information on the capacity of the soil/rock to resist pressure applies. Therefore, only upward shaft movement results are provided. Figure 5 shows response of load versus upward movement at the O-cell level for three piles tested using O-cell. This figure shows that performance of the piles constructed with concrete composites is similar to that of the piles constructed using conventional concrete.

Figure 4. Pile testing in Progress

Figure 5. Pile pushed out of Ground during Osterberg Cell Test

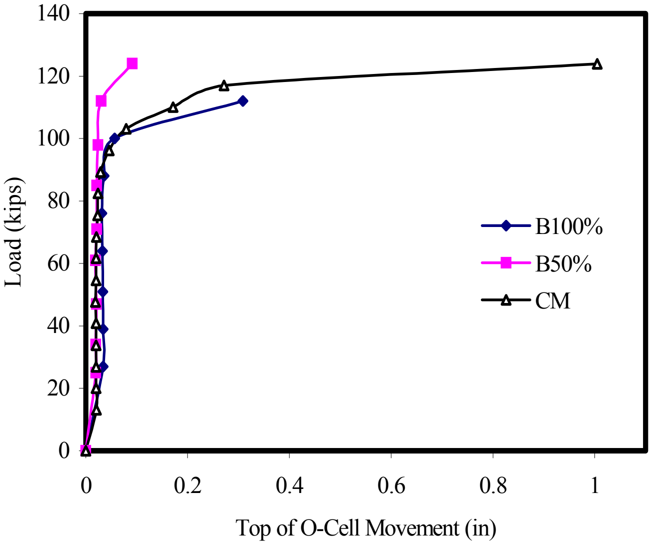

Figure 6: Load versus Upward Movement at O-Cell Level

Figure 7 shows the shaft compression response for all three piles tested using the O-Cell. The shaft compression was measured using compression telletales. Results presented show that the ultimate shaft compression of piles made with concrete composites, B100 and B50, is similar to that observed for pile made with conventional concrete. However, during the initial phase of the testing, it appears that the shaft compression of the pile made with conventional concrete, CM, is less than that of piles made with concrete composites. The data obtained suggest that the instrumentation in the pile made with conventional concrete, CM, malfunctioned during initial part of the test and no change in the reading was observed. Based on the results obtained, it was concluded that reinforced concrete piles made with concrete composites are likely to perform similar to the piles made with conventional concrete.

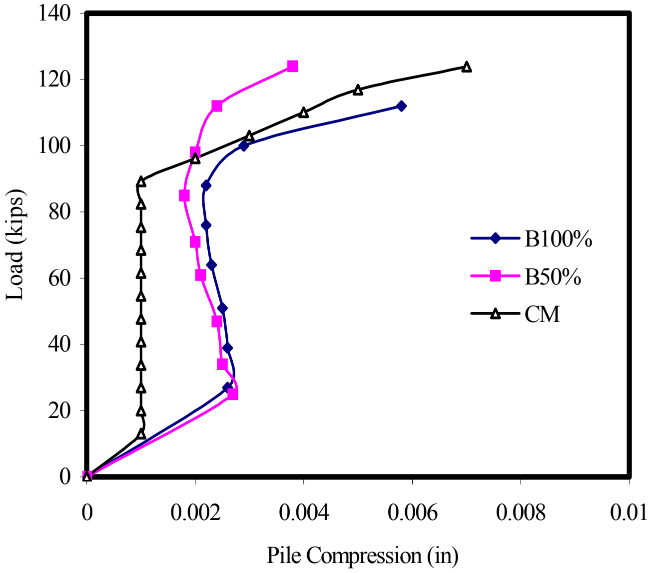

Figure 7: Load versus Pile Compression

CONCLUSIONS

A total of three piles, made from three different concrete mixtures, were tested using Osterberg Cell (O-Cell). One pile was made with concrete composite prepared by replacing 100 percent of natural fine aggregate with Illinois PCC bottom ash, the other pile was made with concrete composite prepared by replacing 50 percent of natural fine aggregate with Illinois PCC bottom ash and the third pile was made with an equivalent conventional concrete. Detailed discussion on the testing procedure and testing of the paper is provided in the paper. The test results show that that the performance of piles made with concrete composites was similar to that of piles made with an equivalent conventional concrete.

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