Design, Testing and Automated Monitoring of ACIP Piles in Residual Soils

Stephen W. Lacz¹, M. ASCE, P.E. and Richard C. Wells², F. ASCE, P.E.

¹Senior Professional, Trigon|Kleinfelder, Inc., 313 Gallimore Dairy Road, Greensboro, NC 27409; slacz@kleinfelder.com
²Vice President Corporate Development, Trigon|Kleinfelder, Inc., 313 Gallimore Dairy Road, Greensboro, NC 27409; rwells@kleinfelder.com

ABSTRACT: The new FedEx Mid-Atlantic Hub Sort/Truck Building contains an automated network of scanners and conveyors, moving the packages for mainly air to air transfer. Original site topography included a significant drainage feature and pond transecting the site directly below the proposed structure. Deep structural soil fill depths up to 18.3 m (60 feet) were placed by the grading contractor to level the site prior to property transfer.

Due to the variable subsurface profile, including deep alluvial soils and depth to partially weathered rock, groundwater elevation, economics and an accelerated construction schedule, augered cast-in-place (ACIP) piles were selected. The 406.4 mm (16 inch) diameter ACIP piles were designed using an allowable load of 889.6 kN (100 tons) each, bearing in partially weathered rock. A load test program consisting of two compression tests and three tensile tests was performed to confirm the design parameters.

As part of the Quality Control Program and due to the subsurface variability, all of the piles installed on site were monitored using an automated monitoring equipment (AME) system to measure the drilling and grouting parameters. The benefit of this system included efficient drilling, operator confidence and not drilling “blind” between borings.

Careful consideration of the subsurface profile, structure performance criteria and deep foundation system design, load testing and installation, combined with good design team communication, resulted in the successful execution of this phase of the project.

INTRODUCTION

The Federal Express Mid-Atlantic Hub is located on the northeast side of Piedmont Triad International Airport (PTIA) in Greensboro, North Carolina. The hub will be
capable of sorting 24,000 packages per hour and be served by 20-25 aircraft each weekday. The site for the FedEx facility encompasses approximately 68.8 hectares (170 acres) and includes various buildings for sorting, trucking and support. Adjacent to and surrounding these buildings are aircraft apron areas, parking, and access drives for on-site traffic.

The heart of the facility is the Sort/Truck Building encompassing approximately 28,465 square meters (306,400 square feet) in the planned area, with maximum building dimensions of approximately 155.4 m (510 feet) by 192.0 m (630 feet) and a height of 18.3 m (60 feet). Maximum column loads were estimated at 4114.6 kN (925 kips) in compression, 667.2 kN (150 kips) in uplift and 200.2 kN (45 kips) in shear during the design phase.

Floor loading was anticipated to be moderate to heavy, with floor loads of approximately 23.9 kPa (500 pounds per square foot). To reduce the settlement potential of the newly placed structural fill, future floor slabs and sorting equipment, the Sort/Truck Building area was surcharged using a minimum 38.3 kPa (800 psf) load as shown in Figure 1. Monitoring of the settlement was performed by others using settlement hubs. Between 20.3 mm (0.8 inches) to 152.4 mm (6.0 inches) of settlement was recorded in the monitoring program. This range indicates the amount of significant differential settlement across the building site that would have occurred under an equivalent loading condition similar to the surcharge loading.

![Piedmont Triad International Airport](image)

**FIG. 1. Surcharge loading of the Sort/Truck Building area**
GEOLOGY AND SUBSURFACE CONDITIONS

The site is located in the Carolina Slate Belt of the Piedmont Physiographic Province of North Carolina. The parent bedrock underlying the property generally consists of well-foliated metamorphosed granitic parent bedrock. The on-site residual soils are the product of the in-place weathering of the parent bedrock. The subsurface conditions at the site generally consisted of soil fill, alluvial, residual soils and partially weathered rock.

FIG. 2. Original Site Topography

Prior to current grading activities, the site contained open areas with grass and weed ground cover, as well as wooded areas. The northern portion of the site generally sloped downward from the south towards the north. Several drainage features were located in this portion of the site, some of which contained wetland areas. Spring activity was likely present in the drainage features, as evidenced by standing water and numerous wetland areas. A small pond and dam was present in an area located below the proposed Sort/Truck building. French drains were installed in the drainage features outside of the building areas. The extreme northern portion of the site was bordered by a large wetland area. Elevations across the site ranged from a high of approximately 275.8 m (905 feet) to a low of approximately 243.8 m (800 feet) at the wetland areas located in the northern portion of the site. Cut and fill depths on the order of 7.6 m (25 feet) and 18.3 m (60 feet), respectively, were required to bring the
site to the proposed subgrade elevation of 265.7 m (871.8 feet) prior to property transfer from PTIA to FedEx. Several deep fill areas on site contained 50.8 mm (2 foot) thick zones of rockfill, as permitted by the site grading contract. At the time of the subsurface investigation, groundwater was observed at depths ranging between 4.6 m to 13.6 m (15.0 to 44.6 feet) below the existing ground surface. The original site topography and location of the Sort/Truck Building, future expansion and rock fill area are shown in Figure 2.

FOUNDATION RECOMMENDATIONS

Based on the proposed column loads and sorting equipment settlement criteria, several deep foundation systems were considered for support of the Sort/Truck structure including auger cast piles, H-piles, pipe piles, drilled shafts and precast concrete piles. The majority of these methods were removed from consideration due to the variable bearing material elevation, groundwater elevation or inapplicability for the project conditions. Auger pressure grouted displacement (APGD) piles were initially considered due to the limited amount of spoils generated but were not deemed practical for the entire foundation area due to dense layers (greater than 25 bpf) in the subsurface soils. Ultimately, 406.4 mm (16 inch) diameter auger cast piles bearing on partially weathered rock, with a 889.6 kN (100 ton) allowable design capacity, were recommended due their ease in handling variations in the subsurface conditions and project schedule.

INSTALLATION MONITORING

The use of automated monitoring equipment (AME) during the installation process was utilized for the load test program and the productions piles. Berkel and Company Contractors, the auger cast pile contractor for the project, selected the PIR-A pile installation recorder, manufactured and installed by Pile Dynamics, Inc., The parameters measured by the PIR-A included time, depth and hydraulic pressure during drilling and time, depth, grout volume and grout pressure during grouting. Components of the AME included a display unit (Figure 3), depth sensor, magnetic flow meter (Figure 4), grout pressure sensor, field printer, torque pressure sensor and angle analyzer.

FIG. 3. Control unit mounted inside the crane cab
As this was the first time an AME was used by the project team, conventional auger cast pile observations were performed including shaft diameter, drilling procedures, eccentricity, plumbness, bearing materials, grout usage, and grout procedures.

**TEST PILE PROGRAM**

In order to confirm the design parameter and capacity, two static load tests (TP-1 and TP-2) and three tension load tests (TP-3, TP-4 and TP-5) were performed for the project at select boring locations. TP-1 was 19.8 m (65 feet) long and was located in the former pond, an area with deep fills underlain by alluvial, residual soils and weathered rock. TP-2 was 16.8 m (55 feet) long and installed in a shallow fill zone. TP-3 and TP-4 were both 12.2 m (40 feet) long and installed in areas of residual soils and moderate fill depths underlain by partially weathered rock, respectively. TP-5 was also installed in the former pond area to a depth of 18.3 m (60 feet).

The compression test piles were load tested in general accordance with ASTM D-1143, with a final test load of 200 percent of the 889.6 kN (100 ton) design load or 1,779.2 kN (200 tons). After unloading, the test pile was loaded to 2,668.8 kN (300 tons) or 300 percent of the design load. The tension test piles were load tested in general accordance with ASTM D-3689, with a final test load of 200 percent of the 400.3 kN (45 ton) design load or 800.6 kN (90 tons). The compression and tension load test setups are shown in Figure 5 and Figure 6.

All test piles were installed using the equipment proposed for the production piles (Figure 7). This included a crawler mounted crane with 27.4 m (90 feet) of auger, a 2,268 kg (5,000 pound) gear box capable of 50.14 kNm (36,985 ft-lbs) of torque and a Reinert P-3 grout pump with a pumping capacity of up to 30.4 cubic meters per hour (40 cubic yards per hour).
A secondary function of the load test program was to calibrate the automated monitoring system with the subsurface conditions. This was planned by having each of the test piles installed in close proximity to a soil test boring performed during the subsurface investigation phase of the project. This allowed for the correlation of the recorded PIR-A parameters to the subsurface conditions with respect to the top of partially weathered rock. As a result, the penetration rate and gear box pressure (torque) were used, in part, as production pile installation criteria for determination of auger penetration into the required bearing material.
Production Pile Installation

Using the information gathered during the load test program, and the installation criteria correlated by the PIR-A parameters, a total of 821 auger cast piles were successfully installed from October 25, 2006 to December 4, 2006. Pile lengths ranged between 14.6 m (48 feet) to 23.6 m (77.5 feet) below grade.

The installation of the piles progressed steadily and ahead of schedule with the exception of one anomaly. Although the majority of the existing rockfill was understood to be undercut and backfilled prior to pile installation, several pile locations still encountered large shot rock fragments that required excavation. Good communication and coordination between the parties was essential to working around this issue.

Conclusions

Careful consideration of the subsurface profile, structure performance criteria and deep foundation system design, load testing and installation, combined with good design team communication, resulted in an economical solution and the successful execution of this phase of the project (Figure 8). It is the opinion of the author that using the automated monitoring equipment allowed for an efficient, confident installation by giving the operator real time feedback while drilling in these variable Piedmont subsurface conditions. Use of the AME, and essentially not drilling “blind” between boring locations, also gave the contractor and design team added assurance that the completed auger cast piles were installed to the required specifications.
FIG. 8. View of the Sort/Truck Building nearing completion

ACKNOWLEDGEMENTS

The authors would like to thank the following members of the design and construction team involved with the auger cast pile installation: FedEx, Frankfurt Short Bruza/Texas, Rentenbach, Kajima and Berkel and Company Contractors. A special thanks to Mr. Xavier Barrett, P.E., Mr. Thomas Wells, E.I., and Mr. Nazeer Brifkani, E.I. for their assistance during the load test program and production pile installation.

REFERENCES


NeSmith, W.M (2006), Personal communication.