Drilled Shaft Load Testing: Made Easy and Inexpensive

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Earlier this year, the American Bridge Company was awarded the contract for the construction of Phase 2B extension of the existing Berth 211/210 Crane Rail foundations at the Tampa Port Authority's Container Terminal in Tampa, Florida. The foundations included 32-inch diameter rock-socketed drilled shafts constructed with permanent steel casings. Load testing was required to verify the foundation design parameters and installation method. The contractor proposed, and the engineer agreed, to perform Dynamic Load Testing on four of the shafts utilizing the PDA field instrumentation system and related CAPWAP® data analysis to verify a load bearing capacity of 1820 kips per shaft. This article highlights the testing program, which was made easy and inexpensive utilizing dynamic methods.

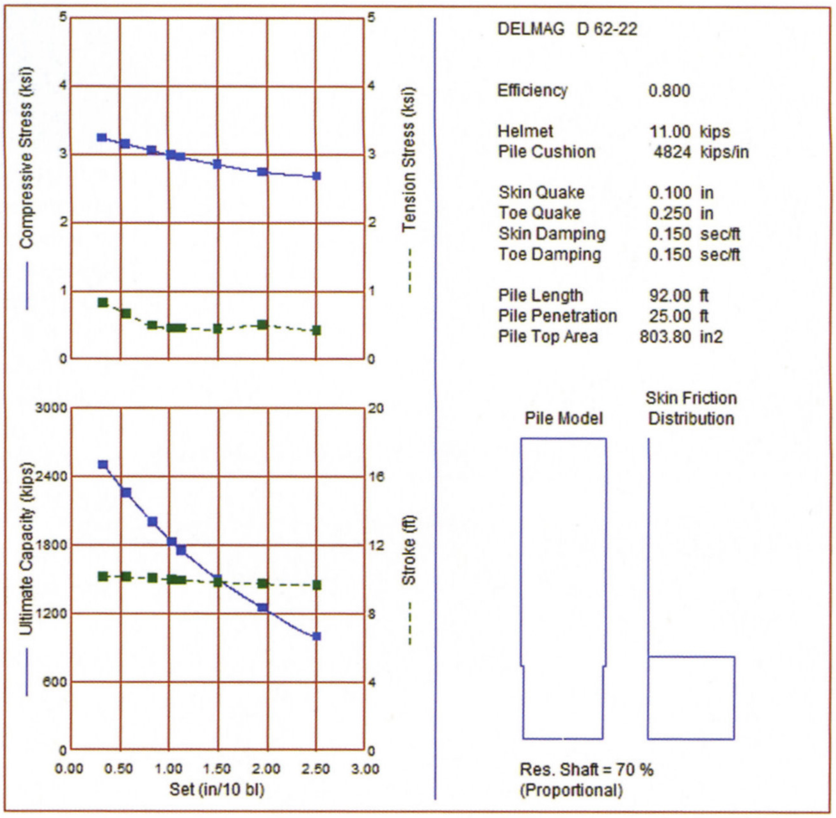

Figure 1: GRLWEAP Wave Equation Analyses results.

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Figure 2: General view of jobsite.

The subsurface conditions consisted of approximately 40 feet of water and soft overburden soils over weathered limestone ranging in consistency from soft to very hard to a termination depth of 60 feet below the mudline. The new foundations work consisted of both the driving of 20-inch diameter steel pipe piles for the support of the landside crane rail and the installation of the 32-inch diameter steel casings with 20-foot deep drilled rock-sockets for the waterside crane rail support. An HPSI 400* vibro-hammer was utilized to initially install the 32-inch diameter by 0.5-inch wall thickness ASTM A 252 steel pipe casings to the designed tip elevations of approximately -55 feet. Following the vibro installations of the steel casings, an American 9310 crawler crane fitted with a drill and 30-inch drill and clean-out bucket was used for the drilling and rock socket constructions. The final drilled shafts tip elevations were approximately -78 feet, providing for a 20 to 25 foot long rock socket into the weathered limestone formation. The shaft construction included full length vertical steel reinforcement of 12 No. 11 bars and No. 5 ties with 12 inch spacing. High early strength 28-day 5000 psi concrete mix was used.

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For the installation of the deep foundations for this project, the contractor used a number of diesel hammers for impact pile driving. For hammer selection for the purpose of Dynamic Load Testing (DLT) of the completed drilled shafts, the GRLWEAP wave equation analysis program was used to assess the dynamic compatibility and confirm the suitability of a Delmag D62* hammer system to impact the piles. A shaft model was constructed based on the details and dimensions of the drilled rock socket and concrete filled steel casings. A 12-inch thick steel striker plate was used to distribute the hammer impacts at the shaft top, and a 6-inch thick plywood pad was used to cushion the hammer impacts at the shaft top. The purpose of the dynamic wave equation analyses was to make sure that the proposed hammer system would be able to cause sufficient movement of the shaft under individual impacts to mobilize the required load bearing capacity, within tolerable levels of dynamic stresses. Figure 1 presents a typical preliminary GRLWEAP analysis results. Based on the findings from the wave equation analyses, the Contractor's Delmag D62 hammer was approved for the Dynamic Load Testing of the 32-inch diameter rock-socketed shafts. Figure 2 shows a general view of the site and hammer placement on top of one of the tested shafts.

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Figure 3: Shaft and PDA testing equipment.

Field testing of the 32-inch diameter shafts was performed following confirmation by concrete cylinder breaks that the concrete in the shafts had achieved the required 5000 psi strength. A Pile Dynamics, Inc.* manufactured PDA, Model PAX, system was used for the data acquisition and initial processing of the dynamic test data on site. Shaft instrumentation for the dynamic load testing consisted of four each reusable strain transducers and accelerometers bolted to the steel casing around its circumference at a distance of approximately seven feet below the shaft top. Before and after the high-strain dynamic load testing with the diesel hammer, low-strain measurements were obtained on the shafts by a Pile Integrity Tester (PIT) system to verify the shafts' structural integrity. Low-strain integrity testing is performed utilizing the impacts of a small hand-held hammer and is based on the stresswave pulse-echo principles. Testing results showed good shaft structural integrity and full-length continuity.

High-strain load testing generally consisted of applying five to ten hammer impacts to each shaft, and measuring the shaft strain and acceleration using the PDA instruments, as well as the shaft set using a laser pointer, string line-scale, and a surveyor's level. Figure 3 shows the instrumentation on one of the tested shafts. Selected dynamic test records obtained by the PDA during the field testing of each shaft were analyzed using the CAPWAP computer program, which is a rigorous numerical analysis utilizing a system identification process by employing signal matching techniques. The analysis results include shaft load bearing capacity mobilized under the test conditions, shaft resistance distribution, end bearing, soil/rock damping and stiffness parameters, and a simulated static load test plot showing shaft top and bottom load-movement graphs.

Mobilized load bearing capacities greater than 1900 kips were verified by the dynamic load testing of the four Test Shafts, thus satisfying the requirements of the project specifications. Figure 4 presents the Dynamic Load Test results obtained from one of the shafts showing, from top to bottom: measured force and velocity records, shaft impedance profile, match between measured and computed shaft force versus time, skin friction distribution, load transfer plot of shaft forces at maximum load along shaft length, and static load-movement at shaft top and bottom. This shaft's test result shows a mobilized load bearing capacity of 2300 kips (1525 kips in skin friction and 775 in end bearing resistances).

Dynamic Load Testing provided a quick and economical means for the confirmation of the drilled shafts' load bearing capacity requirements of this project. Four shafts were tested in two days, although they could all have been easily tested in one day if it wasn't for an interruption caused by circumstances unrelated to the load testing itself. The cost of testing was less than $2000 per shaft. This project demonstrates the advantages of dynamic testing as a time-saving and cost-effective method of load bearing capacity evaluation for drilled shafts.

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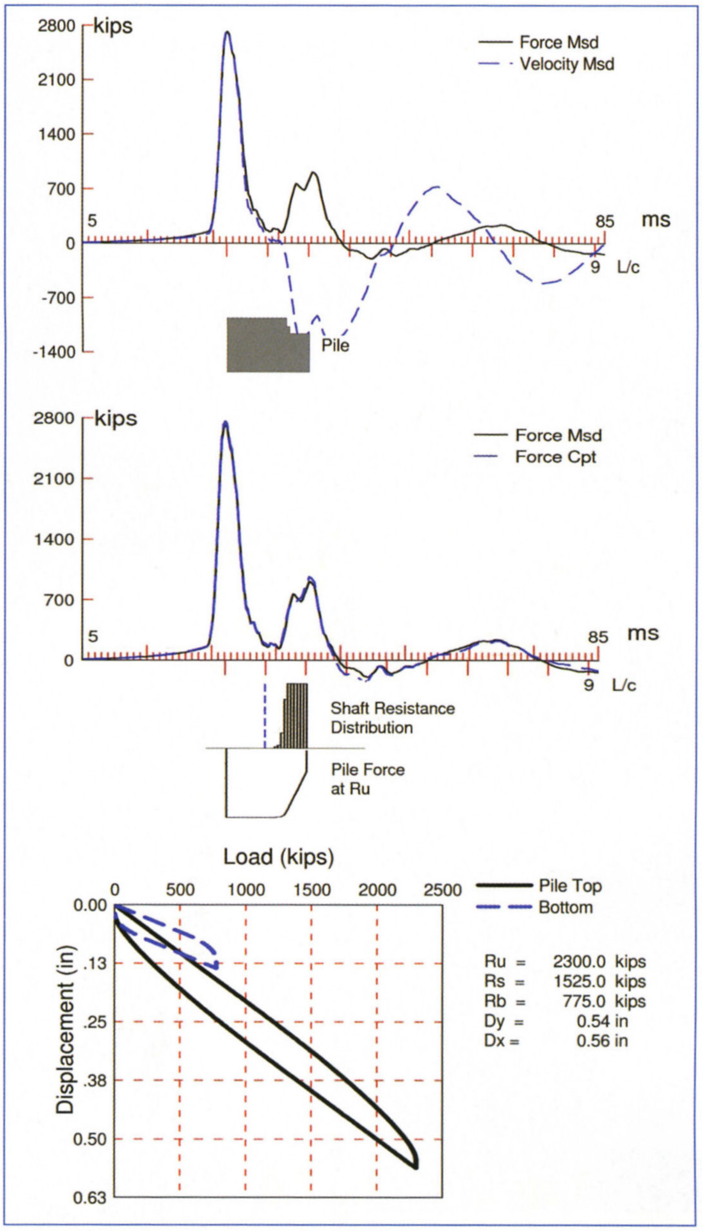

Figure 4: CAPWAP data analysis results.

PROJECT TEAM

Project Owner:	Tampa Port Authority
Project Management:	Batson-Cook Company
Structural Engineers:	Moffatt & Nichol
Geotechnical Engineers:	Ardaman & Associates, Inc.
Contractor:	American Bridge Company
Testing Company:	GRL Engineers, Inc.*

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