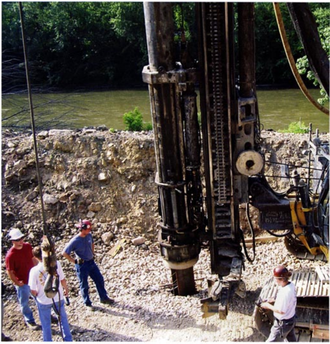
Dynamic pile testing

Investing in geo-data can save money

By Arlan H. Ripple, P.E., F.ASCE, D.GE



Using the PAK Model Pile Driving Analyzer engineers can gather data from strain transducers and accelerometers attached to piles during the driving process. *GRL Engineers*

As the transportation industry continues its focus on repair, replacement, and renovation of the nation's aging bridges and roads, it's possible that what's under the ground will drive activities above.

We're all familiar with the load and resistance factor design (LRFD) specification required by the Federal Highway Administration (FHWA) for bridge superstructure design and renovation. Now, those same requirements must be applied to bridge foundations, thereby connecting the superstructure and substructure. In fact, all new bridges designed after October 2010 must be load rated using the load and resistance factor rating. For those living in earthquake-prone areas, new seismic conditions must also be incorporated.

This is a particularly relevant shift when reconstructing or upgrading a bridge, as it is very likely that LRFD specifications and modern seismic requirements were not imposed during the original design. Thus, engineers must determine new resistance factor ratings. Traditionally, bridge design engineers have relied on predictive methods to determine allowable pile capacities.

However, recent case studies indicate that predictive methods could over- or under-predict support capacities when comparing estimated capacities based on conventional drilling and testing to actual load testing. Such load testing provides a better assessment of the pile capacity, but it can cost the contractor significant time and money. Increasingly, in situ testing, such as dynamic pile-driving measurements, can give more meaningful results that better fit with LRFD requirements. In accordance with the LRFD bridge design specifications, dynamic pile driving analysis methods allow the engineer to use a higher resistance factor — as much as 60 percent higher — as compared to solely using conventional predictive methods. This differential reflects the uncertainty and variability in the predictive methods.

The conventional application of Allowable Stress Design (ASD) requires the use of higher factors of safety when determining allowable pile capacities. Inherent in the LRFD design specifications are procedures to reduce the levels of uncertainty with thorough investigations of the site relevant to the project.

In situ dynamic testing in Texas

Dynamic pile testing is used to monitor the performance of the driving system and evaluate the pile capacity. Commonly used analytical methods to predict the static capacity include SPT (Meyerhof), FHWA's DRIVEN program, and GRL-WEAP simplified SPT Analysis.

In a project that involved the replacement of a number of bridges for a railroad alignment, Kleinfelder's team set out to evaluate methods to select the best combination of pile type(s) and length for each bridge location. The bridges are located southwest of Houston in a region underlain by fluvial and delta sands with intervening layers of clays, silty clays, sandy clays, and clayey silts. These sediments extend to depths exceeding 200 feet. Because of the variable nature of the sediments, a one-size-fits-all approach was not considered appropriate considering costs and performance. Two pile types were being considered for use, 14x89 H-piles and 20-inch-diameter closed-end pipe (CEP) piles. The goal of the test pile program was to determine which predictive design method would be best for each pile type at each bridge location.

The pile testing program for this bridge replacement project consisted of dynamically monitoring three test piles, two 14x89 H-piles and one 20-inch-diameter CEP pile, during initial driving and at the beginning of restrike. The engineering team used a PAK Model Pile Driving Analyzer (PDA) to acquire data from strain transducers and accelerometers installed on the three test piles. CAPWAP was used to compute the soil resistance forces and approximate distribution using the force velocity data recorded in the field. Each test pile was installed in two, 60-foot-long segments.

During installation, the driving resistance was observed with the PDA during the end of drive of the initial pile segment (ID), the end of drive of both segments (EOD), and the beginning of the restrike (BOR) one to seven days after EOD. The delayed restrike was done to see if there was support capacity gained by allowing soil pore pressures elevated by the driving to dissipate with time. The shaft resistance for each soil layer was estimated from the CAPWAP unit resistance results. As expected, the observations revealed that most of the pile support was provided by shaft resistance (skin friction), except where a discontinuous dense sand layer was encountered at depth.

The observations and analyses at the Texas project indicated that the ultimate shaft resistance predicted using the FHWA DRIVEN program appear to be considerably larger (2.6 to 20 times) than the ultimate shaft resistance measured by the dynamic load testing (CAPWAP) analysis for all the piles tested. Therefore, for this location, this method was eliminated from further use in pile selection. In addition, the WEAP-STP method also appeared to over predict the skin friction resistance (1.9 to 8 times) for the H-Piles. On the other hand, the STP (Meyerhof) method appeared to provide a more reasonable estimate (1.14 to 1.51 times) of the ultimate shaft resistance for these materials. In contrast, the WEAP-STP appeared to provide a reasonable estimate (1.11 to 1.37 times) of the shaft resistance for the CEP piles. Based on these results, the STP (Meyerhof) method was used to evaluate the use of H-piles, whereas the WEAP-STP was used for the CEP piles. The test pile program allowed the designers and contractor to optimize the selection of the pile type and length that best fit the subsurface conditions identified at each replacement bridge location in this geologic setting.

Overall, the study confirms that the shaft resistance in fluvial sediments can be very difficult to estimate with commonly used predictive methods. Thus, the use of dynamic pile testing can provide the designer better information that can be used to refine shaft resistance estimates, and in turn, reduce project costs.

Keep in mind that according to the LRFD code, the use of dynamic testing allows the engineer to use a higher resistance factor, which means a lower factor of safety than commonly used in ASD practices. This is because dynamic testing provides a more accurate measure of pile capacities considering actual site conditions, thereby justifying using a higher resistance factor. Interestingly, in some instances, appropriate application of current LRFD design procedures have provided nominal pile load capacities substantially greater than commonly used presumptive capacities. This has been observed even without the advantage of increasing the resistance factor allowed by the LRFD code when driving resistances are verified with a PDA or conventional load testing.

Geo-professionals unite

In October 2008, practicing geo-professionals founded the Academy of Geo-Professionals (AGP) to improve the practice, elevate the standards, and advance the geotechnical engineering profession through a post-license specialty certification program.

Arlan H. Rippe, P.E., F.ASCE, D.GE, founding president of AGP said, "Specialty certification provides an advanced certificate of achievement, which greatly enhances the engineer's career development. It also gives the public further confidence in the competence of our geo-professionals."

The specialty certification program was led by the ASCE with the participation of the ASCE Institutes and oversight by Civil Engineering Certification, Inc.

The AGP held its Inaugural Diplomat Induction Ceremony in March 2009. An initial group of about 50 eminent geotechnical engineers received certificates granting them status of Diplomat, Geotechnical Engineering. For more information, go to www.geoprofessionals.org.

Similarly, engineers can use dynamic testing to better meet seismic requirements during the rehabilitation and replacement of bridges in earthquake-prone areas. Repaired or seismically upgraded bridges typically rely on existing foundations. In some cases, additional vertical and lateral support may be required to supplement the capacities of the existing foundations. For some of these situations, the lateral load resistance can become a significant factor that may not have been considered in the original design.

For example, the I-5 Willamette River Bridge, originally built in 1962, is a vital link in the transportation corridor between California and the Pacific Northwest. The existing interstate bridge was weight restricted and has been decommissioned. It could not be repaired cost-effectively or widened to accommodate projected traffic increases. For these reasons, a new permanent bridge is needed. Construction of replacement bridges are beginning this summer. By incorporating pile dynamic analysis during construction, the LRFD approach allowed higher design capacities that provided a balanced design for both vertical and lateral loads, which in turn will reduce project costs.

Dynamic pile driving does introduce some tangible and intangible cost and time considerations. With good reason, pile driving contractors want to have as little interference with their activities as possible. However, dynamic pile tests require the use of special equipment that must be used during pile driving. Therefore, the entire activity must be a mutually cooperative activity between the engineer and the contractor.

For instance, on the I-5 Willamette River Bridge, the construction manager, general contractor, and design engineer worked in parallel to perform dynamic pile analysis on test piles prior to commencement of actual pile driving. Interestingly, they found that using this collaborative approach allowed for a better selection of pile type and anticipated pile length. This can benefit the project by reducing uncertainty considering the need to cut off or splice piles — both of which require additional operations.

Dynamic pile driving is not the only test method that allows use of higher resistance factors. The standard load test still provides the most accurate and reliable results. However, it is much more costly and time consuming even though it remains "the standard" to which all other methods are compared. This type of testing requires the construction of a loading frame against which the contractor uses a hydraulic jack to push the test pile into the ground.

Overall, in situ resistance testing, such as dynamic pile driving, is an increasingly valuable tool and better fits with LRFD requirements. In these days of limited budgets combined with a great need for infrastructure improvement, an investment in geotechnical testing and evaluation could save considerable time and money, while delivering more reliable, longer-lasting bridges and roads. ▼

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