HIGH-CAPACITY PILES

Confirming the Viability of Cost-Efficient Bridge Designs

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On many bridge projects, the California Department of Transportation (Caltrans) has achieved substantial cost savings and has reduced construction time by using large-diameter, high-capacity piles. With the region's high seismic loads, many bridges have column loadings of 3,000 to 6,000 kips (13 to 26 meganewtons). Designers prefer single piles instead of pile groups to carry the loads, especially in deep scour sites, where drilled shafts are not feasible. In some circumstances, high-capacity piles have produced savings estimated at up to 25 percent of the total structure cost and at up to 75 percent of the foundation construction time.

Problem

Engineering estimates of cost and time savings interested Caltrans in the use of high-capacity piles. Questions about pile capacity, however, deterred the implementation.

The static design of high-capacity piles is problematic, because the design procedures were developed for smaller piles. The calculation of pile capacities with the various static formulae yields significant variations—and questions about reliability. Selecting the most conservative value has led to constructability problems, with contractors attempting to drive piles deeper than is feasible, to meet the design tip elevations. The resulting damage and wasted time and effort have led to successful contractor claims of up to $1,300,000 on individual projects.

In addition, measuring and analyzing dynamic information in the field to confirm driven pile capacity has been unreliable, whether using simple dynamic formulae or sophisticated computer analysis software and site-specific information.

Generally, use of high-capacity piles results in fewer piles and little or no redundancy; verification of capacity, therefore, is essential. The information on the behavior of high-capacity piles was not definitive, but the potential for significant cost savings encouraged further investigation. If the performance of high-capacity piles could be determined, then Caltrans could use the piles with confidence and could benefit from the savings.

Caltrans crew applies 8-million-pound load to test pile at Santa Clara River Bridge, U.S. 101.

Solution

Static pile load testing is the most definitive method for determining pile capacity. Caltrans purchased a $1.03 million static pile load test system with an 8,000,000-pound (35 meganewtons) capacity to test high-capacity piles. The components for the 8,000,000-pound capacity system matched the size and weight that could be transported safely and easily on the state's highways.

The objective of the research was to verify pile capacities on individual projects and to provide information about load-deflection behavior characteristics that could enhance designer knowledge of—and confidence in—static design procedures for high-capacity piles. The research results encourage designers to consider high-capacity piles whenever the economic benefits of use outweigh the cost of testing.

The pile load test system has a large steel reaction frame to transfer load from hydraulic jacks atop the test pile to four reaction piles. The main beam of the reaction frame is 64 feet (19.5 meters) long, 6 feet (1.8 meters) wide, and 9.3 feet (2.8 meters) high, and is composed of 160,000 pounds (72,500 kilograms) of Grade 70 high-performance steel.

Four 24-inch (61-centimeter) stroke high-pressure hydraulic jacks, each capable of applying 2,000,000 pounds, apply the load on the test pile. Electronic load cells measure the force applied to the test pile, and electronic displacement transducers measure the deflection. Each load test costs approximately $30,000 (including crane rental, transportation, and labor), and the four reaction piles installed for each test cost $225,000.

To quantify the capacity of high-capacity piles, Caltrans tested the first piles installed on several trial projects. An additional pile also was tested if the geologic conditions were variable. Experienced Caltrans technicians and engineers performed the testing and analysis.

The load-deflection information from the test was combined with pile stress and hammer energy information, measured during installation, to provide site-specific pile acceptance criteria. The test results verified that high-capacity piles could be designed and installed. Caltrans also intends to develop a large database of quality load tests to assist in developing improved static and dynamic pile models.

Application

The replacement of the Santa Clara River Bridge on Interstate 5 in Northern Los Angeles County in 2002 was the first project to specify high-capacity piles. The load test system tested piles up to the maximum capacity of 8,000,000 pounds.

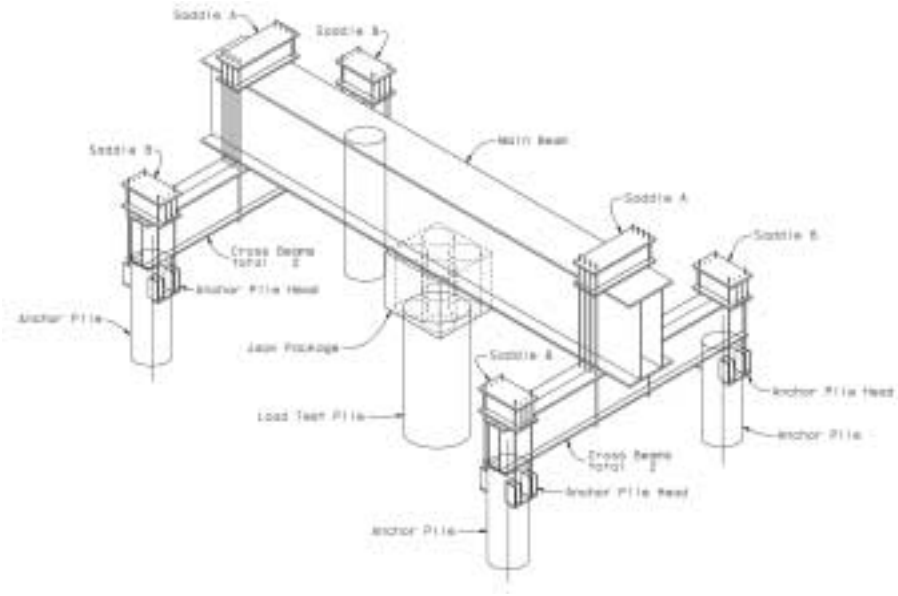
Static design methods indicated that the pile would be minimally adequate, and the observed pile-driving behavior predicted that the pile capacity was insufficient without lengthening the pile. The field test, however, showed that the capacity of the installed pile was well above the design requirements and that shorter piles would suffice. The length of the piles was reduced by 10 feet. Two load tests on another Santa Clara River bridge on Highway 101 also resulted in significant savings.

Benefits

The new 8,000,000-pound pile load test program is an ongoing research project with immediate and quantifiable benefits. The program has proved that high-capacity piles can be adequately designed and constructed.

On the two Santa Clara River bridge projects, the pile testing permitted use of high-capacity piles, with an estimated savings of $14 million. In addition, high-capacity pile installation realized significant time savings in the construction schedule, compared with alternative methods.

Pile load testing confirmed that the length of the piles could be shortened and yet meet the required capacity. Testing also alleviated concerns about the lack of redundancy.



Schematic identifying major components of pile load system (isometric view).

Six tests are scheduled in the next two years, and some tests of large drilled shafts are being planned. High-capacity piles allow designers to avoid pile caps that require deep excavations, especially watertight cofferdam enclosures, saving time and money. The piles allow designers to optimize the span lengths of bridges and to maximize the economic efficiency of the entire structure.

The high-capacity driven piles have produced fewer claims than alternative foundation methods. As more information is gathered from pile load tests, foundation designers will be able to take advantage of more rational static design of piles, increasing the efficiency of the design, as well as confidence in the constructed product.

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Suggestions for "Research Pays Off" topics are welcome. Contact G. P. Jayaprakash, Transportation Research Board, 500 Fifth Street, NW, Washington, DC 20001 (telephone 202-334-2952, e-mail gjayaprakash@nas.edu).