WORLD RECORD STATIC LOAD TEST
Ohio River Bridges Downtown Crossing USA

Project:	Ohio River Bridges Downtown Crossing
Location:	Louisville-Southern Indiana - USA
Foundation design :	Jacobs Engineering
Main Contractor:	Walsh Construction Company
Owner:	INDOT and KYTC joint project

Reinforcement cage installation with O-cells

O-cell at the end of reinforcement cage

Project Overview

The Louisville-Southern Indiana Ohio River Bridges Project is a major design-build infrastructure project intended to improve road safety and alleviate traffic congestion by connecting highways across the river to provide major economic stimulus to the entire region. The project includes both the Downtown and East End Crossings over the Ohio River along with the associated highways that connect them. With a project budget at approximately $2.5 billion, this will be the largest transportation project ever constructed connecting the two states.

Project Summary

The foundations for both the Downtown and the East End Crossings were tested using O-cell® bi-directional static testing technique to confirm the geotechnical parameters and allow for both economising of the design and risk management.

Geotechnical conditions throughout the bridge location indicated the presence of a significant layer of high strength limestone into which the bridge bearing piles could be founded. Accommodating the lateral design loading of the bridges required a minimum rock socket length. With a standard geotechnical design approach, the axial design loads required socket lengths deeper than those required for the lateral loading conditions. As the conventional design was thought to be over conservative, the design and build team sought to overcome some of this conservatism by carrying out a full scale load test. The O-cell® bi-directional load testing technique was the ideal technology to be able to achieve their goal.

WORLD RECORD STATIC LOAD TEST
Ohio River Bridges Downtown Crossing - USA

Installation of the O-cell cage

New World Record Test Set-up

Bi-directional load test arrangement

The test pile required at the Downtown Crossing was to not only test the pile capacity but also the piling technique. The dedicated test pile was drilled though overburden soils and socketed into the underlying limestone. The loading arrangement configuration in the test pile used four 860 mm diameter O-cells arranged in a single level located 1.1 metres above the pile toe to provide the maximum test load required of 213 MN at rated capacities.

Test results

Fugro Loadtest performed the bi-directional static load test using the O-Cell® method and exceeded the rated load capacity and achieved a maximum test load of **322 MN** by overpressurising the O-cells, creating a new **World Record** for a static load test of a single foundation element.

Conclusions

Although a new World Record load was achieved, the rock was far from failure and additional pile capacity was available, and illustrates the magnitude of conservatism often used in pile design in rock.

Using the O-cell technique it is possible to achieve very high average unit skin friction and end bearing resistances in hard rock formations. This allows the design to be optimised, resulting in shorter rock sockets, more economical foundation construction and reductions in program time.

Rendering of Downtown Crossing courtesy of http://kyinbridges.com/

LOADTEST
O-Cell® Technology in St. Louis, MO

Project	I-70 Bridge over the Mississippi River
Location	St. Louis, Missouri
Client	Massman, Traylor Bros. and Alberici, JV
Project Description	

With a main span of 1,500 feet, the new Mississippi River Bridge in St. Louis, Missouri will be the third longest cable-stayed bridge in the United States. But it did set a new world record for the highest load ever recorded during a static load test. The previous world record of 62,700 kips (278 MN) was set in South Korea by Loadtest at the site of the new Incheon Bridge. The old record was surpassed by 9,400 kips on July 17, 2010. The maximum load applied during the St. Louis load test was 72,100 kips (320 MN).

Lowering Reinforcing Cage

The Mississippi River crossings in downtown St. Louis and southwestern Illinois are some of the busiest in the U.S. where several interstates carry traffic across the river. The new bridge is expected to transport up to 55,000 vehicles daily, re-routing Interstate 70 from an overly-congested nearby bridge.

When the massive eight-lane original bridge design was deemed uneconomical, co-owners Missouri DOT and Illinois DOT opted for a sleek 1,500ft main deck carrying four lanes across the Mississippi, although the design calls for room to restripe to six lanes as needed.

O-cell Assembly Placement

The $640 million project includes the 1.22-mile bridge, supported by symmetrical cable-stayed delta towers, over 400 feet tall. Two large concrete footings, one near each bank, anchor the bridge below. Each pier rests on a series of concrete-filled drilled shafts, extending over 100 feet socketed into the limestone bedrock.

Massman, Traylor Bros. and Alberici (MTA) presented an Alternative Technical Concept that included plans for six 11.5 ft. diameter drilled shafts, as opposed to the fourteen 10 ft. diameter shafts initially proposed. This new design, using fewer but wider supporting columns, is significantly more cost-effective since it halves construction time for the bridge foundation. The design has the additional advantage of a reduced environmental footprint with fewer drilled shafts.

Final Assembly Check

Rendering of the New River Bridge, scheduled to open in early 2014

LOADTEST
O-Cell® Technology in St. Louis, MO

Automated O-cell Test Apparatus

A world record assembly
=
4 x 34" O-cells

Ready to go!

Bi-directional load test arrangement

To perform the world record test, a 119ft deep test shaft was drilled into the sub-surface, which consisted primarily of sand and gravel underlain by solid rock. A core barrel roller bit and core extractor were used to excavate the rock socket, which was then airlifted after drilling was completed. A SONICALIPER was then used to profile the shaft excavation sidewalls.

Four 34in O-cells attached to a steel reinforcing frame were installed at the base of the 11.5ft diameter drilled shaft and reinforced concrete poured in to fill the socket and encase the cell. After concrete curing, the O-cell assembly was pressurized, loading the shaft in 19 loading increments with each successive load increment held constant for eight minutes.

The shaft was loaded to a maximum bi-directional load of over 18,000 tons, mobilizing a combined end bearing and side shear resistance of 36,067 tons (321 MN).

Summary

As is the case on many projects, the results of the O-cell test confirmed the use of an optimized engineering design, by verifying MTA's alternative technical concept and allowing them to utilize a much more economical alternative than the original conventional design. Additionally, the testing footprint was minimal, despite the record-breaking loads applied. Loadtest's company objective, which is to provide an accurate, high-quality tool for value-engineering, proved to be an invaluable benefit to this project.

Architectural rendering of the New River Bridge - St. Louis, MO.

LOADTEST
O-cell Technology in Maryland USA

Project:	**College Park: A. James Clark Hall**
Location:	**Maryland, USA**
Foundation Contractor:	**Seaboard Foundations, Inc.**
Owner:	**University of Maryland**

Set to open in 2017, the A. James Clark Hall at the University of Maryland will be a new six-story, 57,000 m² building that will serve as home to the advancement of engineering and biomedical research. A combination of cutting edge laboratories, research facilities, classrooms and office space, the new building will bring together students, faculty and scientists from many disciplines with the common goal of health advancement through teaching, research and development.

A. James Clark and Dr. Robert E. Fishcell, both graduates of the University of Maryland, donated $15 million and $6 million respectively to make the $120 million project possible.

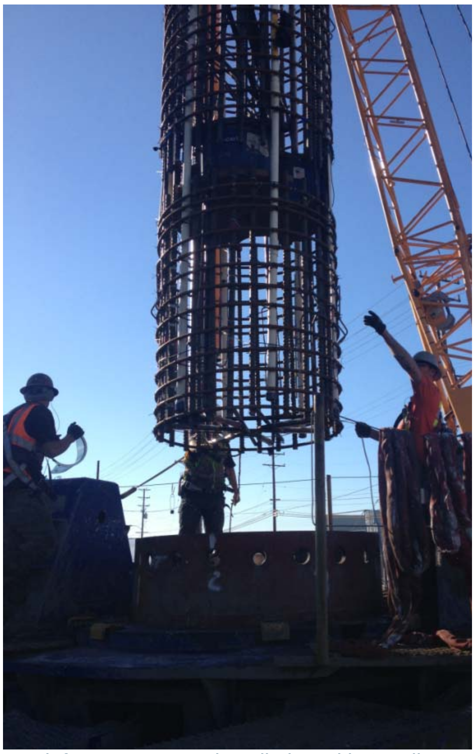
Fugro Loadtest was employed to provide foundation testing experience and equipment to Seaboard Foundations, Inc. in order to optimize the design parameters for foundations of the new building. Full scale O-cell load testing was performed prior to the ground breaking ceremony on a 29 m deep bored pile. Construction of the pile included multiple casings in the overburden soils and a 2 m long socket into bedrock.

The objective of the preliminary load test was to prove the redefined design parameters in the rock socket. Vibrating wire strain gauges were installed at five elevations along the length of the pile to determine the load distribution through the varying soil layers. The O-cell was placed near the toe of the pile to ensure the end bearing in the rock socket would be mobilised. A combined end-bearing and skin friction resistance of 12.5 MN was mobilised during the test. The test results demonstrated a mobilised unit end-bearing resistance of 10 MPa at just over 25 mm of displacement. Strain gauge data showed an average unit skin friction of 800 kPa in the rock socket was mobilised.

O-cells in the Gerald Desmond Bridge
Long Beach, CA, USA

Project:	Gerald Desmond Bridge Replacement
Location:	Long Beach, CA, USA
Engineer :	ARUP and Group Delta
Design Build Team:	Shimmick-FCC-Impregilo J.V.
Owner:	Caltrans


Artist rendering of proposed bridge


Reinforcement cage installation with O-cells


Late Night concrete Pour

Port of Long Beach Gets Ready

The $1.3 billion Gerald Desmond Bridge Replacement Project will feature one of the tallest cable-stayed bridges in the USA, carrying traffic across the Cerritos Channel to Terminal Island at the Port of Long Beach. The wider, taller design of the new superstructure, over 150 metres (500 feet), 50 stories tall and spanning 300 metres (1,000 feet) across, will easily accommodate large post-Panamax ships as well as allow for smooth high-volume traffic flow.

The bridge's foundation includes nearly 350 cast-in-drilled-hole piles drilled into layers of interspersed silt, clay and sand. Fugro Loadtest was engaged in carrying out the full scale static load testing for this signature bridge. Testing was initially performed on a 1800 mm (71") diameter pile 54 m (177 feet) in length. The toe of the pile was injected with high pressure grout in order to increase the allowable end bearing pressure. The loading assembly consisted of three 13 MN (3,000 kip) O-cells® located approximately 2 m (7 feet) above the pile tip.

Loading was performed in two cycles, with the first cycle applying a total mobilized load of 24 MN (5,400 kips) and the second cycle achieving a total mobilized load of 54 MN (12,000 kips). A maximum unit side shear value of 500 kPa (10.3 ksf) was calculated using strain gage data and a maximum unit end bearing pressure of 9 MPa (189 ksf) was achieved.

After full scale loading of the initial test pile was completed, six additional piles were tested over the following nine months. Tests piles ranged from 59 inches to 98 inches in diameter and between 157 feet and 188 feet in length.

High pressure tip grouting was performed on all piles prior to testing. The loading assemblies consisted of three O-cells located on single plane for four test piles, four O-cells on a single plane for one test pile, and one multi-level configuration consisting of three O-cells each on two planes.

O-cells in the Gerald Desmond Bridge
Long Beach, CA

Artist rendering of proposed bridge

Total test loads ranged from 37 MN (8,481 kips) to 116 MN (26,177 kips). Maximum unit end bearing pressures of the tip grouted piles ranged from 5 to 12 MPa (110 to 266 ksf).

The testing of multiple piles allowed precise analysis of the different soil conditions encountered on the site. The testing program also provided much needed data with respect to the effects of tip grouting on the capacity of the piles. Modifications and improvements were made to the grouting procedures between each test to refine the procedures. The data provided by Loadtest allowed the pile lengths for the individual bents to be refined to account for the actual skin friction and end bearing capacity of the soils.

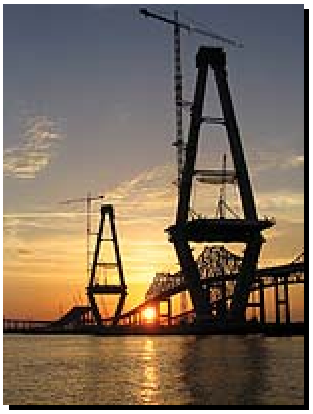

Artist rendering of proposed bridge

The test piles utilized sectional oscillated casing that reached the tip of the piles. When this method is combined with a tip-grouting device, drilling contractors often assume they can leave their piles open for an extended period of time without sacrificing end-bearing capacity or stiffness. The test results indicated otherwise. The test piles that showed the best end bearing values were constructed in a manner that did not allow for any significant time between reaching the toe, installing the rebar cage, and pouring the concrete. The dependency on stiffening piles by applying load through a tip-grout device shouldn't allow for rectification of poor construction techniques.

Subtle differences in the construction of the test piles can be used to potentially explain anomalies in the test results. Expertise in quality control, drilled pile inspection, etc., during all phases of construction during the load test programs and in production becomes extremely important.

LOADTEST
Arthur Ravenel Jr. Bridge – Charleston, SC.

Project	**Arthur Ravenel Jr. Bridge**
Location	Charleston, S.C.
Client	South Carolina DOT, Parsons Brinckerhoff
Period	Fall 2000 and February 2002
Project Description	Completed in 2005, the Arthur Ravenel Jr. Bridge, honoring the South Carolina Senator, is the longest suspension bridge on the east coast of the United States.



The bridge's 1,546-ft main span is supported by two 575-ft-high, diamond-shaped towers Source: constructoragc.construction.com

Contractors constructed more than 400 drilled shafts to support the 2.5 mile bridge from Charleston S.C. to Mt. Pleasant S.C. spanning the Cooper River. The South Carolina Department of Transportation and Parsons Brinckerhoff utilized Osterberg Cell technology to confirm shaft design. Loadtest completed a total of 14 O-cell tests on this project.

The first 12 tests (five single-level and seven multi-levels) were performed for TreviIcos Corporation during the fall of 2000 on dedicated test shafts. The shaft diameters were 72 in. and 96 in. and depths from 100 ft. to 150 ft.

Loadtest also performed CSL and Sonic Calipering quality control testing for TreviIcos during this testing phase. Representatives of TreviIcos, S&ME and the South Carolina Department of Transportation observed the shaft construction and testing.

Insertion of rebar cage and O-cell assembly

Loadtest returned to Charleston in February 2002 to test two 60 in diameter production shafts for Case Atlantic Co. These multi-level O-cell tests yielded loads of combined side shear and end bearing load of 14,064 kips (63MN) for the 222 ft. deep shaft and 13,295 kips (59MN) for the 225 ft. deep shaft. Representatives of Palmetto Bridge Constructors and Parsons Brinckerhoff were present to observe the testing. Mr. Michael Ahrens, P.E. was the Project Manager for Loadtest

Arthur Ravenel Jr. Bridge

Source: wikipedia

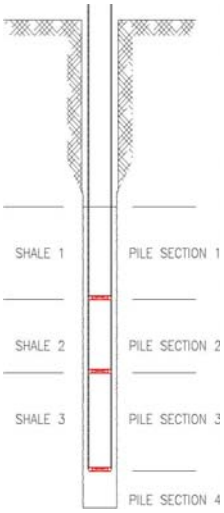
LOADTEST
Amelia Earhart Memorial Bridge - Atchison, KS.

Project	**Amelia Earhart Memorial Bridge**
Location	Missouri River near Atchison, Kansas
Client	Kansas DOT
Period	April 2006
Project Description	Named in honor of the pioneering aviator, the original Amelia Earhart Memorial Bridge, spanning the Missouri River near her birthplace in Atchison, KS, was built in 1938. Nearing the end of its service life, the steel cantilever truss structure is slated for replacement by the Kansas DOT (KDOT). In order to facilitate the design of a new bridge, and possibly eliminate the mid-river support column of the current bridge, KDOT called on Loadtest to perform a first-ever Triple-Level O-cell test.

Amelia Earhart

Summary
The primary purpose of the test program was to assess shear capacities of the three distinct underlying shale layers, to facilitate the design of the replacement bridge foundations. Given the high anticipated capacity of the 60 inch (1525 mm) diameter, 160 foot (48.7 m) deep test pile and the need to fully mobilize all sections of the test pile, a first-ever triple-level O-cell test configuration was selected.

Bi-directional load test arrangement
Three levels of 4000 ton (27 MN) capacity O-cells were installed on a purpose-built carrying frame, along with the necessary instrumentation. The top and middle O-cells were positioned at the boundary between the upper, middle and lower shales. The bottom O-cell was positioned near the pile tip in order to gain information about the bearing capacity of the lower shale layer. In order to match the design assumptions regarding scour (always a possibility on the fast-moving, flood-prone Missouri River), the concrete was only poured up to the top of the shale, with a temporary casing through the overburden used to keep the shaft open until completion of the test.



Schematic elevation of test piles showing position of three levels of O-cells and deep concrete cut-off

Pile Test Results
The combined load reached during four stages of testing ranged was 17,800 tons (158 MN), the second-highest pile test load ever achieved in North America. The maximum displacement of any of the four pile sections was 0.42 in (10.7 mm).

Analysis
The resulting four load-movement curves, along with the estimated pile stiffness and other design parameters were supplied as inputs to a commercially-available geotechnical Finite-Element Analysis (FEA) program. A top-down load analysis was run in order to estimate the settlements due to an axial top-down load. Use of the FEA allowed the load-movement properties of the four pile sections, which were isolated and measured independently by the O-cell test, to be re-integrated to produce a single load-settlement curve. In addition to integrating the test data into a load-settlement prediction, a copy of the FEA input file can be made available to the client, allowing him to investigate other design scenarios and optimize the pile foundation design, using actual measured response as the model input.

Artist's Rendering of Completed Bridge

Source: City of Atchison

LOADTEST
O-Cell® Technology on the Sandy River Bridge

Project	**Sandy River Bridge**
Location	Troutdale, OR
Client	Malcolm Drilling

Project Description

Three 6000 kip O-cells Assembled with Plates

Malcolm's 2500-mm Grab

Temporary Bridge Constructed by Hamilton

Bob Simpson and Jon Sinnreich Running the Load Test

The Oregon Department of Transportation adopted a plan to replace the aging Interstate 84 bridges over the Sandy River with two new steel box girder bridges. Challenging design conditions, including seismic, environmental and flooding concerns, created the need for smaller and fewer piles. Loadtest assisted in verifying drilled shaft capacity and determining the effect of post grouting the shaft tips

Each test assembly consisted of three 6,000 kip O-cells on a single level. Test Shaft 1 was not tip grouted and Test Shaft 2 was. Malcolm Drilling excavated the shafts and performed the tip grouting. Both shafts were tipped in similar materials (dense sand) at similar depths. The shafts were tipped in the Troutdale Formation according to the Engineer. Foundation Engineering and ODOT observed construction and testing. The shafts were constructed and tested on a work trestle. Malcolm used a 2500mm rotator casing to tip and a 2500mm grab to excavate and clean the shaft bottom. For the post grouted shaft, the grouting occurred a few days after concreting.

The results of the O-cell test Served to confirm the engineering design. Although some project specialists were hoping for higher loads at given displacements, the results were similar to what was expected. Additionally, the test shafts were used as production shafts, saving the owner money since there were only eight shafts on the project's main span.

Because the second test shaft was post grouted, the tests represent one of only two full scale large capacity O-cell test programs worldwide that compared grouted and ungrouted shafts in similar materials and depths on a small project footprint. The tests showed substantially improved stiffness response (service limit state) but only a small improvement to the ultimate (limit state).

Loadtest's strength, which is to provide definitive full scale load movement, and unit shear and end bearing data on very highly loaded deep foundation elements, proved invaluable for this project.

Looking at a Railroad Bridge From the Temporary Work Bridge.

LOADTEST
US 82 Bridge Project - Greenville, MS.

Project	**US 82 Greenville Bridge**
Location	Mississippi River Greenville, MS
Client	Mississippi DOT, Kansas DOT
Designer	HNTB Corporation
Contractor - JV	Massman Construction / Traylor Bros.
Period	2002

Project Description

With more than $2^{1/2}$ miles (4 km) of bridge deck, two concrete towers soaring 425 ft (130m) above the Mississippi River, concrete piers anchored 120 ft (36m) into the riverbed and four fans of pre-stressing strand steel cable, the new US 82 bridge at Greenville, Mississippi, is a spectacular crossing over America's most storied river.

Source: Turnasure.com

Completed in 2006, the bridge's main span of 1378 ft (420 m) is also the longest cable stayed span in the United States, the third longest cable stayed span in North America, and one of the longest bridge spans of any type on the Mississippi River. Among the project's other features:

- The new bridge has three spans, of 591/1378/591 ft (180/420/180 m)
- The Mississippi approach to the bridge includes 2970 ft (905m) of new roadway and 6406 ft (1952m) of approach bridge.
- The Arkansas approach to the bridge includes 3752 ft (1143m) of roadway and 4602 ft (1402m) of approach bridge.
- The total length of the project (bridge, approaches and new roadway) is 3.8 miles (6 km)
- The new bridge is located some 2800 ft (861m) downstream from the existing bridge, greatly decreasing the likelihood of barge collisions.

1 of 8 O-cell tests ready for placement

The new bridge carries four lanes of traffic (two in each direction), each 12 feet wide. The bridge has a 12-foot outside shoulder and an 8-foot inside shoulder vs. two 12-foot lanes and no shoulders for the old bridge.

Courtesy Arkansas State Highway and Transportation Department

LOADTEST
O-Cell® Technology in Continuous Flight Auger Piles

Osterberg cell (O-cell) bi-directional load tests have been performed in numerous CFA piles around the world. Osterberg Cell's have been mounted in the reinforcing cage together with the instrumentation for load testing of a wide range of sizes and depths, some of which are believed to be among the largest and deepest CFA piles constructed.

CFA test pile O-cell assembly ready for placement

Fugro Loadtest has been engaged by HJ Foundation, Inc., a leading CFA contractor, to test some world class foundations on separate projects in Miami, Florida. These projects required CFA piles to depths exceeding 30m and for working loads of around 8MN.

The ground conditions on these projects are typical for Florida, comprised primarily of a thin deposit of fill, sand or shore deposits, followed by a soft oolitic limestone of the Miami Formation.

Assembly of a multi-level O-cell arrangement

Beneath this are layers of sand of varying density intermixed and interbedded with the soft sedimentary rock formations including limestones, sandstones, cemented sands and shells.

+20 MN CFA test in progress

The O-cells and instrumentation were assembled into the reinforcing cages in preparation for insertion into the wet piles. Crane-mounted hydraulic CFA drill rigs advanced the 30m+ and the piles were backfilled with a cementitious grout mix during auger extraction as usual. The grout mix used had typical strengths of 55N/mm^2, slumps of around 200mm, small sized aggregate have also been used.

The full length reinforcing steel cages with the O-cells affixed were lowered into the grouted holes. The O-cell and cage assembly slipped smoothly through the grout with minimal resistance. Some of these are the deepest O-cells installed and used in CFA piles.

In 2006, Fugro Loadtest performed their first multilevel O-cell installation and test. Cages were able to reach tip elevations without incident or difficulty and the O-cells were placed precisely at their predetermined elevation. Testing started after the grout reached the required 28-day strength. All of the piles have been proven to be robust and test loads exceeded ultimate design capacities on each of the projects. If the load tests had been performed by application of load at the pile head, stresses in excess of 40N/mm^2 would have been required.

Maximum size/loads tested to date				
Pile Diameter [mm]	600	750	900	900
Pile Length [m]	38	40	35	36
O-cell Diameter [mm]	405	540	660	2x540
Mobilised Load [MN]	17.5	32	32	46

www.fugro-loadtest.com