

FUGRO Elbtower Project, Germany

Fugro LOADTEST have performed Osterberg-cell® tests on the deepest piles in Hamburg.

Client: BAUER Spezialtiefbau GmbH
 Period: July 2019
 Location: Hamburg, Germany
 Piling Contractor: BAUER Spezialtiefbau GmbH

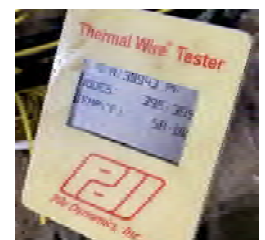


PROJECT SUMMARY

Fugro has successfully completed a comprehensive full scale load-testing programme on Germany's longest bored piles as part of the foundation design verification for the planned Elbtower construction in Hamburg, Germany. On completion, the 244 m high Elbtower will be the third tallest skyscraper in Germany and forms part of a 157 hectare megaproject to redevelop the former harbour and industrial areas in the Hafen City district of Hamburg.



Full scale static load testing using Osterberg-cells was planned as the method is specifically appropriate for the test loads required and on piles of this size and bearing capacity. The results allow confirmation and potentially optimisation of their foundation design without the need for costly and time-consuming installation of the reaction piles used in conventional load testing.



Several instrumentation systems were fitted on the deepest ever bored piles in Germany, which had concreted lengths of over 110 m. The instrumentation included an O-cell® loading assembly capable of 64 MN; fibre optics and vibrating wire strain gauges distributed along the length of the piles to assess the mobilised

CASE STUDY



Reaction. The piles were also fitted with the longest ever Thermal Integrity Profiling strings to verify the structural integrity of the constructed piles.

Located on relatively soft ground near the Elbe river, the Elbtower will rest on long piles to transfer the load to a deep load-bearing soil. Deep foundation contractor BAUER Spezialtiefbau GmbH constructed four bored test piles up to 111.4 m long and of 1850 mm diameter.

Utilizing the SONICaliper® a full 360-degree profile was provided, allowing the bore diameter to be assessed together with the verticality and total volume.

Fugro provided unique load-testing and measurement technology for the pile-testing programme.



Pile reinforcement installation with O-cell® assembly

TEST RESULTS

The test revealed both the upwards behaviour of the skin friction above the O-cell® assembly, and the downward skin friction and end bearing characteristics under loading. To assess the behaviour of the piles there was sufficient movement to allow Cemsolve® load movement analysis to be used to determine the ultimate end bearing load and stiffness which, together with Cemset® allowed a pile head load / settlement prediction to be made.



Thermal Integrity Profiling loggers

CONCLUSIONS

The O-cell® tests were able to safely mobilise the end bearing and also the skin friction, revealing the geotechnical behaviour of the pile. These results were critical for the tower foundation designers.

The bi-directional load-testing results and comprehensive pile instrumentation provided by Fugro will help the design firm to understand the ground's deformation behaviour and the piles' bearing capacities to design a safe and cost-effective foundation design for the Elbtower.



Fugro Loadtest: Static Load test in progress

LOADTEST O-Cell® Technology in Frankfurt, Germany



Project: **FrankfurtHochVier**

Location: Frankfurt am Main, Germany

Developer: MAB joint venture with BPF

Geotechnical Engineer: Ingenieursozietät Professor Dr.-Ing. Katzenbach GmbH
Dr Matthias Vogler

Foundation Contractor: Bilfinger Berger AG, Bauer Spezialtiefbau GmbH, and Hochtief Construction AG

Fugro Loadtest Germany: Scanrock GmbH: Carlos Fischer

Project Description: The Zeil, Frankfurt am Main was the site of the first Osterberg cell test in Germany. In April 2004, the largest static load pile test on German soil was performed using Osterberg cells, in the heart of Frankfurt. The bi-directional load test was aimed at confirming the foundation design, before demolition of some of the surrounding older structures. The test was performed on a 1.68 m diameter test pile 47 m long, installed 12 m into the Frankfurt limestone.



Cage and O-cell assembly fabricated off-site

This large site is located within the heart of the Frankfurt city centre, on the main shopping street, "Zeil". This street is amongst those of the highest pedestrian traffic in Germany. The "FrankfurtHochVier" project is a Class-A mixed-use project. Only a small part of the existing structure will remain, namely, the historical building known as the porticos of the "Thurn und Taxis Palais". The development is one of the most significant in Europe of its time.

Six O-cells were installed on two separate levels to allow the behavior of three elements of the pile in the rock socket to be evaluated independently. The cage assembly with O-cells was manufactured off-site in sections and assembled over the bore during installation. Utilizing a feature unique to bi-directional tests, only the section of pile in the rock socket was concreted and the remainder of the bore (35 m) backfilled with granular material for stabilization. Subsequently the pile was base grouted and a 5 m test section shaft grouted (It is typical practice to shaft and base grout piles in the Frankfurt limestone).



Test Reference Beam and instrumentation

The load test was carried out in two stages as is necessary with a multilevel O-cell arrangement:

- In the first stage, the upper 5 m of rock socket was loaded to 24 MN;
- In the second stage, the lower 5 m section was loaded against the bottom 2.5 m of pile.

Until now, designers have had to rely on full scale loading test data from 146 mm diameter anchors. In practice, there would have been insufficient space to perform a traditional top down loading test even to lesser loads on reduced size test piles and interpretation of the results from the rock socket would have been extremely difficult. The test succeeded in mobilising a total capacity of 78 MN in the rock socket.



Installation of the bottom section of reinforcing cage with both O-cell arrangements



LOADTEST O-Cell® Technology in Friedetalbrücke, Germany



Project: **BAB A38 Friedetal Bridge, Germany**
Location: Friedetalbrücke, Germany
Client: DEGES

Project Description: The new Göttingen to Halle autobahn BAB A38 will alleviate heavy traffic flow on the B80 in Germany. A viaduct is required where the route crosses Peace Valley (Friedetal) near Sollstedt in the state of Thüringen. This viaduct will have a total span of 485 m formed in 6 sections with the largest span of 130 m.



Installation of the lower assembly arrangement with 3x 405mm diameter O-cells

Ground conditions required a unique solution for pile testing and subsequent pile design. Washout of the Gypsum layers at around 26 m is already evident in the middle of the valley. At the location of the piers, some gypsum still exists and the concern about its long term behaviour, local mining subsidence and consequential settlement of the upper soils necessitated a means for minimizing potential negative skin friction in the working piles. The piled foundation design required founding in the lower stable soil layers and utilizing a skin friction reducing mechanism to assure the 120 year design life required.

A test pile incorporating two levels of O-cells allowed the upper O-cell arrangement to evaluate the effectiveness of the friction reducing mechanism; and the lower level of O-cells, placed just above the toe, determined skin friction and end bearing. Three 405 mm diameter O-cells were installed at both levels. The pile cages with O-cells were assembled off-site in a workshop and then transported to site for installation in the 1200 mm diameter cable and grab bored shaft.



Installation of test pile cage

A 1000 mm diameter viscous bitumen coated sleeve arrangement was used to reduce the skin friction in the upper layers. This steel tube was instrumented with an array of Geokon 4810X-1MPa contact pressure cells and a 6300 series vibrating wire inclinometer string used within this section of the pile for monitoring during the lateral load test. The placement of this sleeve above the O-cell arrangements and the complexity of the instrumentation presented some challenges for the installation procedure. Careful alignment of the cage and sleeve combination was required.



Lateral testing in progress

As is conventional in a multilevel test, the lower assembly was pressurised first and achieved a bi-directional load of 36MN. The pressure in the lower assembly was then released and the upper assembly pressurised to a level at which the upper section (with the friction reducing agent) was fully mobilised. On completion of the bi-directional testing, a lateral test with a loading of 600 kN was then performed whilst monitoring the pressure cells and inclinometer string.

Despite the complexity of the pile instrumentation and test configuration, the testing proved to be a great success with all phases being completed satisfactorily.

Under construction
April 2009



Source: Structurae



LOADTEST

O-Cell® Technology on Neubau Rheinbrücke, Wesel, Germany



Project: Rhine Bridge

Location: Wesel, Germany

Client: Bundersrepublik Deutschland

Geotechnical engineers: ARCADIS Consult GmbH

Loadtest office Germany: Scanrock GmbH

Piling Contractor: Bilfinger Berger AG

Project Description: The previous Rhine road bridge in Wesel was built in 1952 using the original pier foundations of the earlier 1916 bridge. This bridge has now been replaced by a new and exciting cable stay design that carries the Bundesstrasse B58 into the town of Wesel, Westphalia, Germany. The new bridge for the B58 at Wesel consists of a cable stayed semi-fan arrangement with an asymmetric inverted Y pylon. The bridge is 775 m in total length with a central span of 334 m. The height of the pylon is 130 m. It allows four lanes of traffic to flow along the Bundesstrasse B52 and gives clearance to the very high flow of shipping traffic along the Rhine. The bridge was completed in 2009.



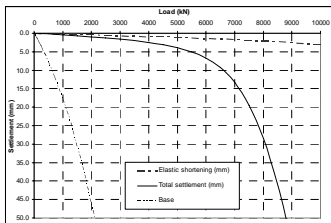
Pile cage assembly built in a workshop and later transported to site for installation



Test pile construction showing the previous bridge over the Rhine



Bi-directional test in progress. Nitrogen gas is used to 'set' the A9 extensometer string



Cemset® prediction of pile head load-movement behaviour for one of the piles



Source: Wikipedia

Bi-directional load test arrangement:

The nature of the soils, mainly terrace gravels and sands, and the physical length of the project of over ¾ km, required four tests to be carried out at various positions along the planned route of the bridge.

Each pile required one O-cell to be installed within the pile shaft, size of cell and location within the shaft dependant upon the load required and the expected soil strengths.

The pile cages with O-cells were assembled off-site in a workshop and then transported to site for installation in the 1200 mm diameter cable and grab bored shafts. The pile loads achieved during testing ranged from 5.5 MN to 12.4 MN and movements of over 140 mm were recorded for some tests.

As with many preliminary load testing projects, the aim of the testing programme was to confirm the design which was based on site investigation and soil parameters. The final design could be optimised as a result of the tests performed.

The use of an A9 strain extensometer string from Geokon above the O-cell level, model 4911 sister bar strain gauges below the O-cell level and direct measurement of toe movement with telltales allowed load distribution along the pile shaft to be determined and unit skin friction to be assessed.

Cemsolve® analyses were performed to the upward and downward settlements of the elements of the pile against applied load. The interpreted skin friction and end bearing components were then recombined to provide a Cemset® prediction of pile head load-settlement behaviour.

By using this analytical approach it has been possible to distinguish components for end bearing and skin friction to allow confirmation of the pile design.



LOADTEST O-Cell® Technology at Weida Bridge, Germany



Project: **Weidatalbrücke**

Location: **Esperstedt, Germany**

Client: **DEGES**

Geotechnical engineers: **ARCADIS Consult GmbH**

Foundation Contractor: **Züblin Spezialtiefbau GmbH**

Loadtest office Germany: **Scanrock GmbH**

Project Description: The project - BAB A 38, Göttingen – Halle Süd (A143) BW 4616/06A is located over the Weidatalbrücke, Esperstedt, Germany. Consisting of a 435 m long box girder bridge of seven spans; the longest 158 m. The project was due for completion in April 2007 at a cost of 16.8 million Euros. The bridge is located within a nature reserve and is therefore in an environmentally sensitive area.



Installation of O-cells and pressure cell on the bottom of the carrying frame



Installation of the O-cells on the steel carrying frame into the pile bore



Lifting of the steel frame showing two O-cells at two levels

Tests were performed on two 1200 mm diameter piles approximately 27 m deep fitted with a multilevel O-cell arrangement mounted in a purpose built carrying frame rather than a conventional reinforcing cage. Two 540 mm diameter O-cells were installed in each carrying frame with a pile-tip pressure cell mounted at the bottom of each test pile. The lower O-cell was 2.4 m above the pile tip and at the start of the limestone strata and the second O-cell level set at 9.4 m above the pile toe.

Using to advantage a feature unique to multi-level bi-directional tests, the load was applied in stages, mobilising different portions of the test pile. The information provided skin friction values for specific zones along the pile shaft and unit end bearing information. The load tests mobilised 32 MN and 35.2MN combined skin friction and end bearing for the two test piles.

The pile-tip pressure cells allowed the end bearing to be separated from the skin friction.

Bi-directional load testing using the Osterberg Cell proved to be the most environmentally friendly solution for testing in this highly sensitive location. The alternative traditional top-down solution would have meant transporting and erecting kentledge or installing extra anchor piles and vary large steel beams to create a reaction system. Instead, only the test piles had to be constructed and truck movements, for pile spoil removal and concrete deliveries were all reduced to a minimum.



Underside of the completed bridge

source: www.uni-kassel.de



LOADTEST O-Cell® Technology in Fundex Piles



Foundation Contractor:

Gebr. Neumann GmbH. & Co. KG.

Geotechnical Consultants: Schmitz and Beilke Ingenieure GmbH of Gruppe Ingenieurbau.

Project Management: Enercon GmbH.

Fugro LOADTEST Germany: Scanrock GmbH.

Summary

A new wind farm by Enercon GmbH near Barenburg, Germany had several geotechnical issues. The site is located within an onshore oil field. A number of wind turbines have already been constructed with more underway, founded on large excavated raft foundations.



Excavated raft foundation of wind turbine

Due to the location of this project within the German oil fields, many of the remaining locations would mean excavation of potentially contaminated materials. The option of a displacement pile foundation solution would be an attractive environmentally friendly alternative avoiding contaminated spoils.

Pile type profile



One pile type considered was the Fundex screw displacement pile. A sacrificial cast iron boring tip is sealed to a hollow pipe drilling mandrel, installed by using torque and crowd force from a rotary head on the hydraulic piling rig. By monitoring the

hydraulic pressure applied to the rotary table, a relative measure of ground resistance can be obtained. Once the pile tip has penetrated sufficiently into the desired bearing strata and/or the desired depth has been reached, a steel reinforcing cage is lowered into the hollow section mandrel and concrete is placed.

The mandrel is then extracted by oscillation leaving the pile tip, concrete and cage in place, creating a cast-in-situ reinforced concrete displacement pile. Test piles to prove the system in the foundation material were required, one method of testing used the O-cell bi-directional loading technique and the other would be using traditional static loading from the top using reaction beams and anchor piles.

For the test piles, the pile tip was fitted with a pipe from the top of the mandrel to inject high fluidity grout under pressure while the pile is penetrating the soil. This assists the penetration by increasing the pore pressure at the tip and temporarily reducing the effective stress of the soil below.

Although this enhanced technique has been used elsewhere, this is the first time grout tip injection has been used on German soil.

Pile Tests

A single 330 mm diameter O-cell, capable of mobilising 7.8 MN in each direction, was attached to the base of the reinforcement cage and lowered into the mandrel. As with the normal construction technique, all instrumentation connections, hoses and pipes required for testing were attached to the inside of the reinforcement cage. Since this technique does not require the use of a tremie pipe, the size of the O-cell used is only limited to the internal diameter of the mandrel.

Load testing program

The testing was programmed under the direction of the geotechnical engineers Schmitz and Beilke Ingenieure GmbH.

Since the traditional top down test was on identical piles in close proximity, it was a good opportunity to correlate the results from the two test methods.



O-cell test alongside a traditional top down assembly

Conclusion

Bi-directional testing of the Fundex pile allowed direct measurement of the characteristics of the pile tip under loading. It had not been possible to measure the end bearing characteristics of this pile type previously.



LOADTEST O-cell® Technology in Stuttgart, Germany



Project: **SWR Media Building**
Location: Stuttgart, Germany
Client: SWR
Consulting Engineers: Henke and Partner GmbH
Foundation Contractor: Franki Grundbau GmbH
Loadtest office Germany: Scanrock GmbH

Project Description: SWR, Stuttgart's premier radio and television station have found themselves needing to expand by extending their existing premises in a heavily built up area of Stuttgart.



Boring of Test Pile 1 adjacent to existing SWR building

Variable underlying strata and the presence of highly prized mineral water source lead to the planning of an O-cell testing program. A primary concern of this project was not to breach or contaminate a mineral water aquifer. Pile length should be long enough to hold the load but short enough not to risk infiltration of the water source. Utilizing a multilevel O-cell test allowed the characteristics of two separate soil strata consisting of clays and sands with the toe founded in a limestone rock socket to be ascertained.

Preparation of the reinforcement cages with O-cell assemblies was undertaken off-site in a steel fabrication workshop. The completed assemblies were then shipped to site for installation into the auger bored piles constructed by Franki Grundbau GmbH.

The second pile was situated along a narrow one way street with a complex array of overhead cables. The test was installed on the pathway beside the road. One half of the narrow street was closed to traffic for safe site access.



Transportation of the pile cage along narrow street

Test pile one consisted of an 873 mm auger bored pile with multilevel O-cell assemblies located at depths of 2 m and 8 m above the pile toe. Each assembly was made up of 2 x 330 mm diameter O-cells. The pile was bored to a depth of 25 m with the final concrete level approximately 6.5 m below ground level. The second pile was a single level bi-directional test, constructed 23.25 m deep with the O-cell arrangement placed at 5.34 m above the toe. The top of concrete was 5.0 m below ground level.

Isolation of pile sections on test pile one was only possible by multilevel bi-directional means. The inclusion of strain gauges within the pile section gave mobilised unit friction values previously unknown in these materials. If the second pile had been tested by top-down means, it would have required complete closure of the road adjacent to the test location. Bi-directional testing has allowed the pile design to be optimized to ensure the piles do not penetrate the valuable mineral water reserves located directly below the site. The multilevel test mobilised an excess of 30MN.



Compact test arrangement on the pavement



Rendering of new SWR building

Source: swr.de



LOADTEST O-Cell® Technology in Leipzig, Germany



Project: **City Tunnel Project**

Location: Railway Station, Leipzig, Germany

Client: City of Leipzig

Project Description: The City Tunnel of Leipzig is the last and central component of the railway system restructuring process in Greater Leipzig. Not only can the suburban train system be restructured after the tunnel has been put into operation, but traffic connections between the region and the City will be improved, giving major impetus to the development of the City's traffic system. One section of the tunnel was scheduled to go under the existing Railway Station.



Leipzig Railway Station

The main Leipzig Railway Station is the biggest terminus and most significant passenger station in Europe. There are 26 platforms and 5 external platforms. The station has a shopping area on three floors with a total of 30,000 m² for strolling, shopping and eating.



Shops in the Railway Station

Under the affected area of the shopping centre, there are several piles which may have been undermined by the tunnel construction. A method of improving their capacity and the effect of the potential processes were to be evaluated on similar dummy test piles.

The challenge was to evaluate the change in pile performance, while under load, as injection grouting was being performed to improve the general capacity of the piles. For this evaluation to take place, a series of expendable test piles were installed adjacent to the affected piles, so that several injection processes and techniques could be evaluated. Traditional top-loading would have encroached on the process equipment and seriously impeded execution of the process.



O-cell Assembly Placement

Tests were performed on one control pile, two process evaluation piles and one dedicated pile to determine the in-situ end bearing performance of these 1500 mm diameter piles. The piles were constructed under limited headroom to depths of approximately 22 m and fitted with Geokon model 4855 pile-tip pressure cells.

Three 405 mm diameter O-cells were installed in each pile, giving a maximum loading capacity of 30 MN. This allowed upward evaluation of level reduction, application of constant load during boring for low pressure and high pressure injection grouting and evaluation of the friction and end bearing of the lower section of the pile (below the level of influence of the tunnel), without interfering with the numerous other site activities.



Test in progress (diaphragm wall grab and tunneling machine in the background)

In order to achieve sufficient reaction on the upper section of one of the test piles, shaft grouting and jet grouting was employed, allowing the test load to exceed 17 MN in each direction.

Skin friction was less than expected, making the enhancement of skin friction challenging without causing additional unwanted settlement. Ultimate end bearing capacity was excellent and larger than expected.



Tunnel scheduled for opening In 2010

Source: Strabag.com

