Case Study Bi-directional Loadtest Bassin Austerlitz, Paris

Dr. Melvin England [i], Paul Cheesman [ii], Michel Maron [iii] and Maarten Profittlich [iv]

i) Director Foundation Testing, Fugro, 14 Scotts Avenue, Sunbury on Thames, Middlesex, TW16 7HZ, United Kingdom.

ii) Operations Manager Foundation Testing, Fugro, 14 Scotts Avenue, Sunbury on Thames, Middlesex, TW16 7HZ, United Kingdom.

iii) Engineer & Pile Monitoring Specialist, Fugro, 34 Allée du Lac d'Aiguebelette, 73370 Le Bourget-du-Lac, France.

iv) Deputy Manager Foundation Testing, Fugro, Veurse Achterweg 10, 2264 SG Leidschendam, Netherlands.

ABSTRACT

The bi-directional testing team of Fugro Foundation Testing (Loadtest) is often presented with interesting projects which are a little out of the ordinary. Be they geotechnical, logistic or just deemed to be extremely difficult to do, they always rise to the challenge. The project detailed in this case study is one such project. Originally, thought to be impossible to perform by traditional load testing means in which all the load is applied at the head of the foundation element, a solution was found using the bi-directional static load test method using Osterberg cell technology. The load test was a conventional O-cell bi-directional test in the way it was finally undertaken, but the application was certainly unusual.

Keywords: Case Study Bassin Austerlitz Paris, bi-directional static load test, Osterberg cell technology

1 INTRODUCTION

Common to many major cities Worldwide, Paris storm drain systems are antiquated and require a complete modernisation. In 1910, Paris experienced the worst floods of the 20th Century, an event that would be classed as a 1 in 100 year occurrence. See figure 1.

Fig. 1. Paris Flood in 1910 (1).

The river Seine reached heights of over 8.5 m above normal around the station at Austerlitz. Amazingly only one person died in those floods but the devastation was immense. Over 20,000 buildings flooded and 150,000 to 200,000 people were displaced. The estimated cost was the equivalent to 1.4 Billion Euros in today's prices (2).

The systems put in place then to alleviate any subsequent flooding are now more than 100 years old. Desk studies have shown these systems are now woefully inadequate. As more and more properties are located by the banks of rivers and as the rivers themselves are straightened to allow faster flow, together with loss of flood plains further up-river, there is a potential for an even greater catastrophe in years to come. The overflow from drainage systems in major cities often flow uncontrolled into major rivers, causing an enormous amount of damage and pollution. In the case of Paris, the rivers Seine and Marne have also proven to be the cause of the flood waters and have the potential to swamp the current draining system yet again. Steps have been taken to deepen the Seine so that there is now 10% more capacity in the river volume and the area surrounding the river has at the same time been raised. However, recent history and climate change has illustrated that what was once a 100 year event is now far more common. Even these measures are likely to provide inadequate protection in the future.

2 IMPROVEMENT DRAINAGE SYSTEM

Consequently, a new and improved drainage system for Paris has been designed and is now under construction, to take the Paris drainage system into a new era.

Several large capacity storage water cleaning plants have been installed upstream of central Paris. Bassin Austerlitz has been designed to be a buffer when the water cleaning plants are saturated, taking excess storm surge water out of the system, hold it for a period and release it once the flow has decreased.

The site for these works is located directly next to the River Seine in the heart of the city of Paris. See figure 2.

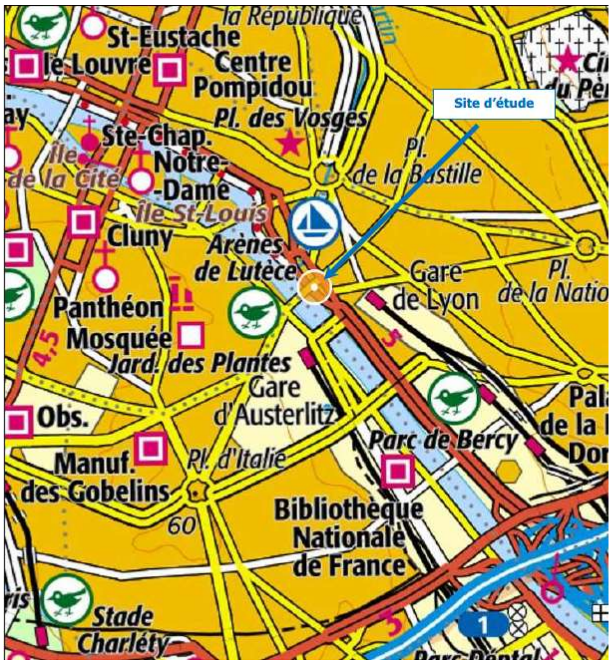

Fig. 2. Locations Austerlitz Bassin in the heart of the city Paris (Site d'étude).

3 FOUNDATION DESIGN AND REQUIRED LOAD CAPACITY

The design of this underground overflow reservoir basin requires the storage area to be contained within barrette diaphragm walling (D-Wall) and resting on barrettes constructed below the base, consisting of barrette units measuring 2,800 mm x 1,000 mm. The base of these barrettes being over 70 m below ground level.

From a loading point of view, the main issue is that the basin is required to only take occasional full load when it is required, but it would be mostly empty during normal periods when it was not required. A secondary issue is that the bottom of the basin is some 30 m below ground level and covered. The load bearing capacity of the soils in the area was poorly characterised and there were concerns about base heave and whether the material at the base of the basin could cope, geotechnically, with the load and unloading requirements of the drainage system and ensure the reservoir did not become buoyant.

A test program was designed to load a single barrette excavated from ground level and to obtain information on the specific load bearing strata at basement level. From a testing perspective, there was no concrete to ground level, just an empty shaft (backfilled with sand for safety), so testing an element for load displacement from ground level was not an option. The anticipated maximum test load required (up to 70 MN) was estimated based on geotechnical data and was far and beyond that which could be applied from ground level, even if the load required could have been applied without an area of influence from anchors disturbing the surrounding ground.

4 SOIL CONDITIONS

As would be expected of soils located around the flow of major rivers, they consist mainly of river deposits. However, these deposits of sands and clays were not of structural geotechnical importance since they were above the bottom of the basin. Of main concern was the soils at and below the basin floor, consisting of sandy and clayey marl and chalk deposits. These would be subjected to the compressive loads during times when the basin was full and subsequent release of tension stresses when the basin was empty. A schematic section of the test barrette in relation to the soil conditions can be found in figure 3 (at the next page).

5 BI-DIRECTIONAL INSTRUMENTATION AND ASSEMBLY

Conventional static load testing would require anchors to be installed and the concrete to be brought to ground level so that the test load could be applied, but more importantly, such high loads envisaged in the design could be physically or safely applied top down.

Fortunately, Dr Jori Osterberg's development in the 1980's of the bi-directional static load testing methodology using the O-cell allows such loads to be applied safely and at depth.

Once the type of test had been agreed, the question was then, how to perform the testing? Should the load be applied at the base of the foundation and the section pushed upwards, or should the load be applied at the top of the base of the basin, using the soils above as reaction? Since the most important requirement for the test was to determine the parameters of the marl and chalk layers, it was decided that the loading should be only within these strata with the concrete level placed so that the strata above was not loaded. A balance point for the O-cell assembly was determined at 7 m from the bottom of the barrette and the O-cell arrangement was installed at this position. Geokon sister bar strain gauges (SG) model 4911-4 were placed around the perimeter of the reinforcement, 6 at each of 6 levels within the marl and chalk, to determine the skin friction parameters and load distribution, providing vital information for the designers.

Since there is no requirement to bring concrete to the surface for a bi-directional test, the concrete could be left at depth so that no load would be transmitted to the upper soil levels with the empty shaft being filled with dry sand for safety.

The testing program comprised of a single barrette test. An O-cell assembly consisting of two 690 mm diameter O-cells, capable of loading to more than 35,000 kN in each direction, was installed in the test barrette to give total gross loading capacity of 70,000 kN. Interesting to note that the Eiffel Tower is estimated to weigh 8,000 tons, more or less, so would just about provide the right top down reaction at 80,000 kN, although a little impractical to move to the test location.

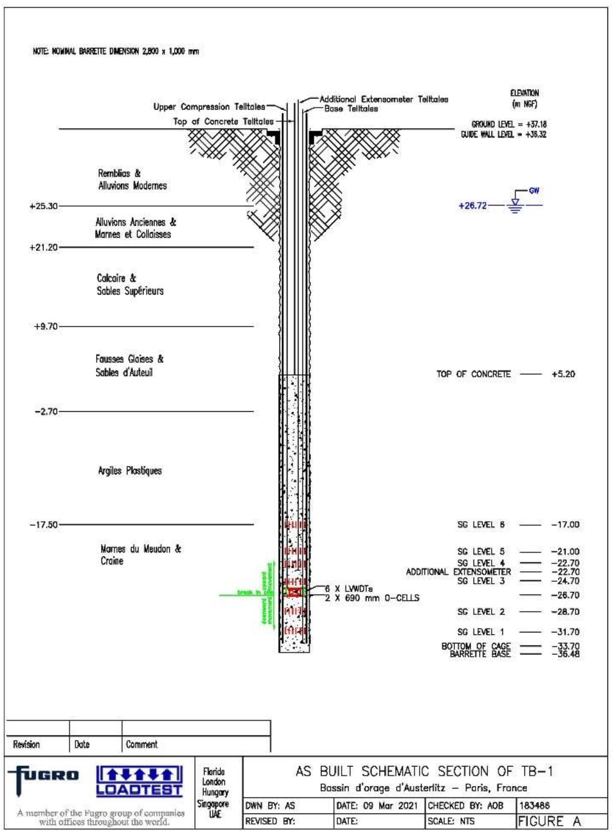

Fig. 3. Schematic section of the test barrette with strain gauges (SG) levels in relation to the soil conditions.

After construction of the 2,800 mm x 1,000 mm, 73.7 m deep barrette, the bottom 41.7 m concreted section was left to cure with the strain gauges being monitored to attempt to identify any micro-fracturing and stress build-up occurring during the curing process.

Fig. 4. Insertion of the reinforcement containing the O-cell assembly.

Vertical movements of the top of concrete, top of competent chalk, compression above the O-cell assembly and barrette base were monitored using telltale extensometers.

6 CURING PHASE AND RESULTS

Some evidence was found of micro-fracturing in some levels of strain gauges in the softer soil strata during curing (see also figure 5). This occurred quite some time after the concrete was poured at around 14 days, although there was some evidence of earlier potential micro-fracturing at around 7 days from casting. The changes in stress measured by the strain gauges corresponded in general, to the temperature change as the concrete cures.

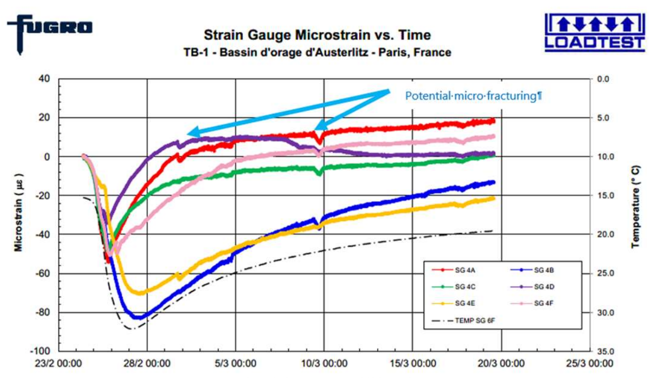

Fig. 5. Strain Gauge Microstrain v. Time with signs of potential micro fracturing.

7 TESTING PHASE AND RESULTS

The testing phase was undertaken in a single cycle of loading in 18 increments to a maximum sustained load of 26.4 MN, above and below the O-cell assembly, 52.8 MN total gross loading. At this load, the displacements were sufficient for the analysis and the test was concluded. The O-cell test was performed in general accordance with the EN ISO 22477-1-E specification incorporating the recommendations published in (3). The footprint of the testing phase is the same as the foundation element. See figure 6.

Fig. 6. Testing underway, footprint is the same as the foundation element. The beam is for datum reference only.

The results of the displacements of the top and base of the barrette related to the gross load are shown in figure 7.

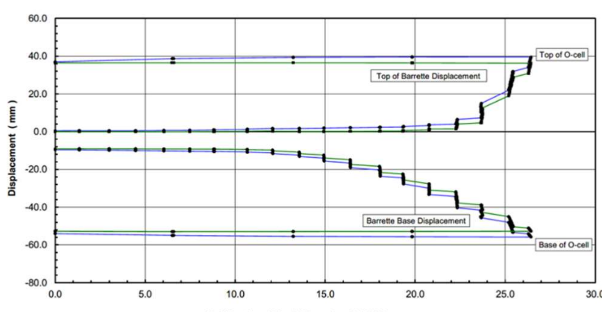

Fig. 7. Load - displacement top and base of O-cell movement.

The strain gauge load distribution in figure 8 illustrated that the lower marl/chalk layer was uniform in structure, with the load being generally equally distributed throughout the layer.

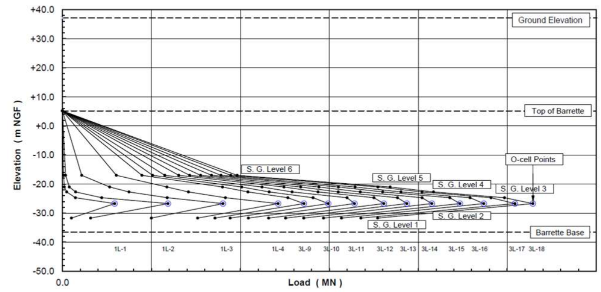

Fig. 8. Strain gauge (SG) load distribution.

8 LOAD-DISPLACEMENT ANALYSIS

To obtain an assessment of the full geotechnical soil parameters, a Cemsolve® analysis was made, modelling the load-displacement data upwards and downwards. These models determine the ultimate barrette skin friction and end bearing characteristics, together with an assessment of the stiffness of the soils at the barrette base. An equivalent load – movement curve using the combined results with Cemset® to assess the movements at the top of concrete elevation in compression is shown in Figure 9.

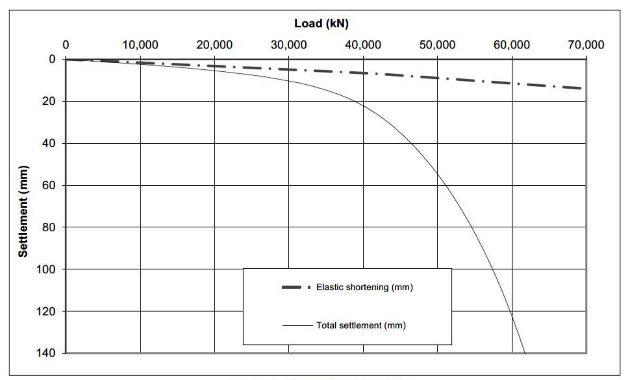

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Fig. 9. Total Load-Settlement behavior.

9 CONCLUSIONS

A very difficult loading task using traditional methods was undertaken using the O-cell bi-directional static load testing method with ease. No anchors were needed, and concrete was not required to be brought to the surface in order to load the foundation element at depth.

The results of the testing could be used for the design of the basin and provide assurance for the design team that the loads and stresses incurred with a full or empty reservoir of the basin could be taken by the soil stratum at depth.

The geotechnical properties of the marl and chalk deposits were unknown prior to testing.

The analysis of the strain gauges allowed the parameters for the bearing strata to be determined. Skin friction values and their distribution along the shaft

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could now be put into the design calculations. These parameters could then be used by the designers of the basin to estimate movements under loading and to provide safety factors for the load capacity of the basin floor.

ACKNOWLEDGEMENTS

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