SAN SEBASTIAN - DONOSTIA

In the North of Spain, overlooking the Bay of Biscay, lies the beautiful Basque city of San Sebastian-Donostía. A haven for sun seekers and food lovers alike, this city was the location of a research project undertaken by the University of Madrid with the help of O-cell Technology.

Summary:

San Sebastian sits at the mouth of the River Urumea. The city was originally built on the flood plain and river terraces of the Urumea over the last two centuries. In the first half of the 20th century, the river was diverted and canalized. Since this time, San Sebastian has flourished and continued expansion meant that new bridges have had to be built over the river.

This project was situated on the site of the construction of the latest of these new bridges. The underlying Flysch rock made this location the idea site for the research project of the University of Madrid assisted by the Rodeo Kronsa Group who provided the piling expertise.

One of the bridges across the Urumea River

Research Background:

Pile design in rock has always been difficult. Many papers have been written around the world and many differing specifications for design are in use. More often than not, these pile designs have been over-conservative.

In order to further the research, Professors Olalla and Serrano have been investigating the behaviour of the shaft friction of piles in rock and have published two articles in the IJRMMS (2004, vol 39(1) and 2006, vol 43 (5)). These articles describe a new theory based on other properties of the rock, similar to the Hoek and Brown (1980) findings. To check these and other empirical theories, further investigation using in situ testing to determine ultimate capacities was required.

A secondary objective was to determine the pile end bearing resistance. Two further papers had been written on this topic in IJRMMS (2002, vol 39 (7) Parts I and II).

Bi-directional load test arrangement:

In order to achieve useable data for this research, controlled loading of a fixed shaft length in the rock was required. The simplest way to achieve a precise length is by use of a multi-level test arrangement. Two levels of O-cell are placed so that the mid-section is a know length and therefore the skin friction area is readily quantifiable.

The pile bore was made 17m long and one O-cell level was set very close to the toe to measure the end bearing properties. The second upper level was placed exactly 2.5 metres above this level. A zero shear sleeve section was inserted into the top section of the pile to give a second 2.5 metre section between the upper O-cell level and the zero shear zone.

Strain gauges were placed at levels in the pile bore to assess the force distribution within the pile shaft above and below the upper O-cell assembly.

The choice of O-cell loading arrangement was made using assumptions of rock strength from the theoretical design. Limited to a pile bore diameter of 1000 mm, an arrangement of 2 Nr 330 mm diameter O-cells at each level was chosen. These provide a 7.8MN loading to the base and to the rock sections below and above the upper O-cell level. It was considered that this loading should provide sufficient capacity to obtain ultimate values of both the end bearing resistance and skin friction in the rock.

Pile Test:

The pile was loaded in two stages, the initial stage loading the toe of the pile using the upper section of the pile as resistance. Once the toe of the pile has moved downwards, the bottom O-cell level provided zero resistance to downward movement when the upper level of O-cell is loaded in the second stage.

Stage one loading provided a total maximum of 8.5 MN to the base, but the ultimate end bearing had not been mobilised sufficiently to fully characterise the base behaviour.

Stage two loading of the upper O-cell level was then performed, loading an independent section of pile above and below the O-cell arrangement of 2.5 metres. At the maximum rated O-cell capacity, the rock still held steady and even with increasing the pressure by an additional 50% the friction could not be fully mobilised in the rock; achieving less than 1.5 mm movement above and below the upper O-cell level.

University of Madrid, Rodeo Kronsa and Fugro Loadtest personnel.

Conclusions:

The objectives of the test were to mobilise the end bearing to close to failure and fully mobilise either segment of 2.5 metres pile in the Flysch rock. Optimism was shared by all that pile had been fitted with sufficient loading capacity to achieve the objectives.

The maximum mobilised reaction from the bi-directional test was 32.5 MN, far in excess of the value predicted before testing commenced. Values of skin friction obtained for the rock, were significantly higher than predicted by nearly an order of magnitude and despite valiant efforts to maximise the load applied, it was not possible to provide ultimate values of either the end bearing or for each of the 2.5 m sections of the shaft friction during this test.

Post test analysis of the behaviour using Cemsolve allowed a prediction of the ultimate end bearing at in excess of 20 MN (twice the scheduled test capacity). The predicted ultimate values of the combined rock socket above and below the upper O-cell would be of the order of 40 MN.

Further research will continue on this subject but the testing has proved that sometimes even the most pessimistic of design parameters taken still results in very conservative values for pile design in rock.

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