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Vertical and Lateral Load Testing of Drilled Shafts Socketed into Rock at the Pomeroy-Mason Bridge over the Ohio River

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ABSTRACT

Drilled shafts socketed into rock have been widely used as a foundation for bridges to resist both vertical and lateral loads. Although numerous research efforts on rock socketed drilled shafts under vertical loads have been carried out, research on rock socketed shafts under lateral loads has been lacking. This paper presents the results of a testing program designed to validate the design capacity of the drilled shafts socketed into rock for both vertical and lateral loads. The test was conducted on two 8 feet (2.44 m) diameter drilled shafts. The two shafts were instrumented with Osterberg load cells (O-CellTM) for bi-directional vertical load testing, and fully instrumented for lateral load testing as detailed in the paper. The effect of the overburden soil around test shaft 2 was isolated by installing 11 feet diameter casing which was advanced to the top of rock. Test shaft 1 was terminated in shale while test shaft 2 was constructed 10 feet deeper to bear on hard siltstone bedrock. With a maximum applied load of 36,100 Kips (161 MN), the vertical load testing on shaft 2 broke the world record in 2003. The lateral load test was conducted after the vertical testing was completed, and the maximum load induced a movement of approximately 0.25 inches at the top of rock. The results of this load testing program verified the adequacy of the design assumptions and was used to verify the existing published analysis methods that are still in their early stage of development due to limited lateral load test data.

1. INTRODUCTION

Drilled shafts socketed into rock have been widely used as a foundation for bridges to support both axial and lateral loads. Although numerous research efforts have been carried out on rock socketed drilled shafts under vertical loads and several documented vertical load tests on drilled shafts socketed into rock using the Osterberg Cell (O-CellTM) are available in the literature, the designers are still using low values for end bearing in rock compared to the allowable end bearing from the load testing, in addition, research efforts on rock socketed drilled shafts under lateral loads have been lacking.

A review of literature suggests that very few existing field lateral load testing data are available on rock socketed drilled shafts. The few existing analysis methods for rock socketed drilled shafts under lateral loads, such as the methods by Carter and Kulhawy (1992), Reese (1997) and Zhang et al. (2000), could benefit from additional verification with actual field load test results.

To improve the analysis methods for laterally loaded drilled shafts socketed in rock, there is a need for additional high quality lateral load test data. The main objective of this paper was to present the results of vertical load tests and a lateral load test on two fully instrumented drilled shafts (8 feet (2.44 m) in diameter, 101.0 feet and 112.0 feet (30.78 and 34.14) in length) socketed in rock (shale).

2. VERTICAL LOAD TEST RESULTS

At the time of testing Shaft 1, the concrete unconfined compressive strength was 4,205 psi (29.0 MPa). The Shaft was successfully loaded to a combined side shear and end bearing of 1,850 kips (2.39 MN). For a top loading of 1,850 kips (2.39 MN), the adjusted test data indicate this shaft settled approximately 6.4 inches (162.6 mm). Figure 9 shows the load-movement curve.

At the time of testing Shaft 2, the concrete unconfined compressive strength was 5,115 psi (35.3 MPa). The shaft was successfully loaded to a combined side shear and end bearing of more than 36,100 kips (161 MN). For a top loading of 5,800 kips (25.8 MN), the adjusted test data indicate this shaft would settle approximately 0.25 inches (6.4 mm) of which 0.14 inches (3.3 mm) is estimated elastic compression. For a top loading of 20,000 kips (89.0 MN), the adjusted test data indicate this shaft would settle approximately 1.0 inches (25.4 mm) of which 0.47 inches (11.9 mm) is estimated elastic compression. Figure 6 shows the load-movement curve, Figure 7 shows the equivalent top load-movement curves, and Figure 8 shows the calculated load distribution curves from strain gages along the drilled shaft rock socket.

3. LATERAL LOAD TEST RESULTS

Figures 10(a) and 10(b) presents the load-deflection response measured at the loading point for test shafts 1 and 2, respectively. The deflections were averaged from the two dial gage readings for each shaft at each load increment. It can be seen that the deflections of shaft 2 at the loading point is much larger than those of shaft 1 which may be attributed to the use of casing to isolate the shaft above bedrock. Because shaft 1 mainly served as a reaction shaft and the rock-shaft interaction was not fully engaged due to the thick layer of overburden soil, only inclinometer readings of test shaft 2 are presented. The deflection versus depth of test shaft 2 at each load increment along the length of the shaft was measured with the inclinometer. The deflection at the elevation of the top of rock was approximately 0.20 inches (5.1 mm).

4. FINDINGS

Based on the results of the vertical (O-CellTM) load tests and lateral load test on 8 feet (2.44 m) diameter drilled shafts socketed into rock, a comparison was made between the allowable unit bearing pressure and unit side friction used in the design and the ones calculated from the load testing for both the sandstone and the shale layers. The data presented in this paper show that the design ultimate bearing pressure and side friction for the rock at the site is significantly less than the test results, which support the idea of increasing the ultimate design values taking into consideration the serviceability requirements of the structure.

Based on the load test and analyses results, the following conclusions can be drawn:

- The back-calculated p-y curves can capture the rock response under lateral loads. These curves can be used for the redesign of drilled shafts at the same site where the test was performed.
- The interim rock p-y criterion of Reese (1997) can provide good prediction by modifying the rock properties.
- It is difficult to characterize the engineering properties of a rock mass, especially highly weathered rock, in the laboratory. In-situ testing like pressuremeter is recommended for estimating design parameters.
- Evaluation suggest the need of further development of the analysis of laterally loaded drilled shafts in rock mass, especially for cases were the unconfined compressive strength of rock is higher than 55 TSF (5.2 MPa).

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