RESEARCH NOTES

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THE OFFICE OF EARTHQUAKE ENGINEERING

Caltrans

Full Scale Cyclic Large Deflection Testing of Foundation Support Systems for Highway Bridges

***RESULTS:** Caltrans, in partnership with the University of California, Los Angeles investigated the seismic performance of several foundation components and systems by physical testing. Computer models were used to predict the behavior of these components and systems. The results of the testing were used to calibrate the computer models in order to more accurately analyze the soil-structure interaction of bridge foundations in a variety of conditions.*

Why We Pursued This Research

Understanding the effects of soil structure interaction is essential to understanding the seismic performance of bridge foundations. Current engineering practice requires the use of “soil springs” in computer models to simulate the effects of the soil on foundation behavior. However, the knowledge base for developing these soil springs is limited and has been based on small or scaled-down foundation components. One goal of this research was to test full-scale foundation systems and individual components in order to estimate effects such as shaft diameter and group efficiency when developing soil springs for computer models.

The seismic performance of abutment back-walls is not well understood. In addition to the foundation testing, a typical abutment back-wall was pushed against a standard Caltrans back-fill material in order to assess the back-wall’s behavior. The results will be used to provide guidance to engineers when modeling bridge abutments.

Bridge foundations are typically very expensive to construct, and the results of this project will allow engineers to design foundations that are cost effective while meeting all design requirements.

What We Did

Full scale physical testing was performed on 5 bridge components. 1) A 6’ diameter drilled shaft foundation and bridge column 2) A 2’ diameter drilled shaft foundation and bridge column 3) a single 2’ diameter fixed head pile 4) a 9 pile (2 ft. diameter) fixed head group 5) a 5’ 6” high abutment back wall placed in a silty sand backfill that meets Caltrans standards. These components were designed according to Caltrans standards.

Test borings of the soil were performed and the soil properties were logged. The test specimens were cycled under increasing loads until failure occurred. During the testing, measurements of displacements, rotations, curvatures, and strains were made.

Placing Backfill for Abutment Test

In addition to physical testing, the researchers developed computer algorithms to estimate soil spring parameters and soil-structure interaction models that would predict the specimen’s behavior during testing.

Prior to testing of the bridge components, the researchers performed a “blind” prediction for each specimen. The blind predictions were compared to the actual results and the computer models were recalibrated for the next test.

Excavation after Abutment Back-wall Test

Methodology

UCLA's approach was to test full-scale models of bridge foundation components. Each component was tested under cyclic loading until failure occurred. During the testing, researchers at UCLA were recording and analyzing data from instruments placed in the specimens. Soil and structural material properties were also recorded. Results from the physical testing were compared to results obtained from computer simulations of the test specimen.

Research Results

The results showed that the current method (American Petroleum Institute - API) of estimating p-y curves under-estimates their capacity and stiffness at shallow depths. The capacity may be increased by a factor from two to three at these depths. In addition, the end condition (fixed head or unrestrained head) did not result in a significant difference in p-y curves and no change in Caltrans' current practice is recommended.

The current practice of using group reduction factors for pile groups that are independent of displacement levels may underestimate the group's resistance particularly at large displacements. However, while the current practice is somewhat conservative, it is adequate in most cases.

The results of the abutment backwall test indicate that current techniques for estimating soil resistance are overly conservative. Additional abutment back-wall tests should be performed so that height and skew effects can be modeled.

A final report for this project will soon be available online at:

http://www.dot.ca.gov/hq/esc/earthquake_engineering/Research/techreps.html.

2 Ft. Flagpole Test

Conclusions

The modeling of bridge foundations and their behavior during seismic events is often a difficult procedure. The current practice for estimating abutment back-wall capacity and stiffness is overly conservative and the results of this research will be used to re-evaluate these parameters when modeling abutments.

Engineers often "envelope" bridge foundation parameters in order to ensure the foundations meet design requirements. This could result in foundations that are larger than necessary, thus increasing construction costs. The results from this project will allow engineers to design more efficient foundations by using group reduction factors more effectively and thus potentially reduce construction costs and impact on traffic.

The results from this project will be incorporated into the Seismic Design Criteria (SDC).