Increasing Loads on Existing Foundations

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Summary

As buildings and bridges are rehabilitated, sometimes for uses that were not foreseen by the original designer, there is often a desire to expand the structure, or put the building to some new use that results in additional loads on the existing foundations. The uncertainties involved in assessing existing foundations can be greatly reduced by employing state-of-the-art non-destructive testing (NDT) methods. When used in conjunction with load-tests and computer modelling of soil/structure interaction, these methods can provide the engineer with valuable information concerning the reliability and capacity of the foundations. This paper provides a review of currently-available methods for assessment of existing foundations, and compares their capabilities. Case histories are presented to illustrate the benefits of the various methodologies.

Keywords: Existing foundation, soil/structure interaction, nondestructive testing, UPV, computer modelling, increased loads, axial capacity, impulse response, parallel seismic, crosshole sonic log.

1. Introduction

Rehabilitation of older structures often involves change of use, and/or expansion, resulting in increased loads on the existing foundations. In many environments it is cost-prohibitive to construct additional foundation elements. In addition, sustainable construction has become highly desirable as owners and engineers seek to have their new structures certified under the Leadership in Energy and Environmental Design (LEED) program, and reuse of existing foundations can result in a significant reduction in materials and energy used.

The authors have worked on a number of projects in the last few years that have included increasing the load on, or re-using, existing foundations. It has not been just the load-bearing elements that have been reused. In some cases earth retention structures from the original construction project on a redevelopment site, such as sheet pile walls, have been reused as part of the excavation support structure for the redevelopment. In each case, vital information about foundation type and depth has been gained from the use of specialized nondestructive tests. In many cases, the authors also utilized archive information that included soil borings in the vicinity to correlate with test data. This paper discusses the methods used to assess existing foundations to allow increasing their load or incorporating them into the new foundation.

Some of the methods and analytical approach used for this work were originally described in a Transportation Research Board (TRB) conference paper, [1] and subsequently updated in a presentation to the ASCE Geo-Institute conference GeoDenver 2007. That presentation was later published as a feature article in Civil Engineering magazine [2]. This paper describes some additional techniques for assessing foundations, together with case histories.

2. Assessing the Foundations

The four nondestructive test (NDT) methods that were used for the work discussed in this paper are the Ultrasonic Pulse Velocity test, the Crosshole Sonic Logging test, the Impulse Response test and

the Parallel Seismic test. These methods are described in detail in several current recent publications, so they are not described here. For more detailed descriptions refer to American Concrete Institute Report No.228.2R [3] or "Nondestructive Testing of Deep Foundations" [4].

3. Case Histories

3.1 Railroad Bridge Expansion, Cedar Rapids

A railroad bridge over the Cedar River was originally planned as a twin-track structure in the 1920's, but only one half of the superstructure was built, as a single-track bridge. When the owner decided to complete the second track portion of the bridge in the 1990's there was some concern over the condition of the foundations and piers. The integrity of the underwater concrete was assessed by placing pipes in the water on either side of the pier, and performing crosshole sonic log (CSL) tests, a downhole version of the ultrasonic pulse velocity (UPV) test, through the concrete, using the pipes to guide and stabilize the test transducers against the flow of the river. The concrete above the water was assessed with a combination of UPV and impulse response testing. The test results showed the piers and the foundations above the mud-line to be in dire need of repair.

3.2 Baseball Stadium Expansion, Quad Cities

The owners of a municipal baseball stadium wished to increase the capacity of the stands and add sky-boxes. The municipality's initial plan was to install additional foundation shafts and extend the existing pile caps. The authors were of the opinion that the additional shafts were probably unnecessary. Test pits were dug to expose the top of one the shafts beneath several three-shaft pile-caps. In two test pits, a 3ft (1m) long section of the exposed shaft was sawn out. This permitted visual confirmation of type, impulse response testing to measure shaft depth, laboratory assessment of concrete quality, and load testing to confirm shaft capacity, using the structure as reaction mass. This work showed the existing foundations to be adequate, and was completed for less than $15,000. The savings for the municipality were estimated to be more than $230,000.

3.3 High-rise Building, Chicago

A new high-rise building is currently being constructed in Chicago, Illinois, on the site of a former 10-story structure. Dozens of hand-dug caisson foundations remained from the previous structure. The tops of several shafts were exposed, and full depth cores were taken from two of the shafts, both to confirm length and to allow laboratory analysis of the concrete strength. Laboratory testing included measurement of Ultrasonic Pulse Velocity (UPV). Impulse response tests were then performed on all the shafts that were exposed. Calculation of shaft depth was made using a stress wave velocity derived from the UPV measured in the laboratory tests. As a result of this data, a total of 26 shafts are now being reused. The estimated savings generated were more than $570,000.

4. Continuing Development

Work continues on development of the NDT methods discussed in this paper. Several teams in the US and Europe are working on variations of the Impulse Response test, or the simpler Impulse-Echo test, using two or more geophones to help identify and remove unwanted responses from an existing structure above the foundation in question. Some limited success has been achieved with these methods, but the analysis process is not yet ready for the commercial market [4], [5].

One other significant fact has emerged from the foundation evaluation work performed by STS. The generation of computer models to predict structure/soil interaction is heavily dependent on accurate and consistent information about the physical properties of the soil. Experience on multiple projects around the world has shown a substantial variation in the quality of geotechnical data, depending on local practices, the availability of appropriate equipment, and the training of the personnel.

5. Conclusion

A properly designed program of testing, archive research and modeling, performed by trained specialists, and interpreted by experienced personnel, allied with sound geotechnical engineering, can generate substantial cost and environmental benefits for projects involving demolition and redevelopment of existing sites, or rehabilitation/expansion of existing structures, by allowing increased loads and/or reuse of existing foundations.