DESIGN PROCEDURES FOR AXIALLY LOADED DRILLED SHAFTS

By

Gerardo W. Quiros and
Lymon C. Reese

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Foreword

Research Report No. 176-5 is the fifth and final report in a series of reports from Research Project 3-5-72-176 of the Cooperative Highway Research Program. This report presents a summary of the former procedures for the design of drilled shafts under axial loads, a review of the results from full-scale field load tests, and recommended design procedures. Two computer programs were written to facilitate designs and are described.

Introduction

Since 1965, the Center for Highway Research at The University of Texas at Austin, in cooperation with the State Department of Highways and Public Transportation, has conducted extensive research on the behavior of axially loaded drilled shafts. A series of reports has been published on the topic, with Report No. 89-1, by Reese and Hudson (1968), laying the foundation for the investigations.

Including the first report and this one, a total of 16 reports have been published from Research Projects 3-5-65-89 and 3-5-72-176. The reports deal with many aspects of the behavior of drilled shafts, considering both axial and lateral loading.

From 1968 to 1975, a total of 19 full-scale drilled shafts were tested under axial load by the Center for Highway Research (CFHR). The test shafts were installed at sites having different soil types, such as clay, clay shale, and sand. The majority of the shafts were located in Texas. Two drilled shafts were tested in Puerto Rico.

Evaluations of load tests performed in clay and in shale were reported by several authors. Results of load tests conducted in sand were also reported. In a majority of these reports, construction procedures are discussed as well as their effects on soil-shaft interaction.

A study was performed in which a drilled shaft supporting a bridge was instrumented and the behavior of the shaft under in-service loading was studied. The shaft was installed in a stiff clay in Houston and no significant settlement or change in load distribution was observed over a two-year period.

Another of the objectives of the drilled shaft project was to investigate the behavior of laterally loaded drilled shafts. A full-scale, instrumented shaft was subjected to repeated lateral loads. From the observations, a procedure was developed for predicting the response of a stiff clay to short-term static loading or to repeated loading.

In a separate investigation, combined axial and lateral load tests were performed on small-sized piles installed in sand. From the test results axial and lateral interaction curves were generated for use in design.

During the period from September 1970 to February 1973, the Arizona Highway Department in cooperation with the Federal Highway Administration of the U.S. Department of Transportation sponsored an extensive investigation of the load-carrying capacity of drilled shafts. The objective of that study was to determine the support that drilled shafts can derive from very coarse granular deposits and from cemented, fine-grained, fan deposits. This type of soil predominates in the heavily populated areas of central and southern Arizona.

A total of 27 drilled shafts were tested during that investigation. Seven load tests were performed in coarse granular soils and 20 tests were conducted in cemented, alluvial fan deposits. The results of that study are summarized in Report 176-5F.

The purpose of this report is to review existing design procedures for axially loaded drilled shafts and to propose any revisions deemed desirable. In addition, two computer programs were developed to serve as time-saving tools in the design computations of drilled-shaft foundations. These programs, SHAFT1 and BSHAFT, are described in detail in this report.

Recommended Design Procedures

A reevaluation was made of the previous design procedures for drilled shafts in clay, clay-shale, sand, and fine-grained alluvial fan deposits. This study revealed a need for modifying certain previous recommendations for the design of shafts in clay and in sand.

Design procedures are classified under two main categories: primary and secondary. The term "primary design procedure" refers to the procedure employed in computing the total ultimate resistance of a shaft when the engineer has reasonably good information on soil properties. Knowledge of these properties is obtained from an extensive field exploration effort combined with a complete laboratory testing program.

Many times a situation arises where an engineer has very little information regarding actual soil engineering properties obtained from laboratory tests. The only information available may be results from a dynamic penetration test, and, from such meager data, an engineer must try to determine the soil properties necessary to design drilled shafts. The term "secondary design procedure" refers to such a method of designing drilled shafts. The ultimate base resistance in the secondary procedure is computed through use of an ultimate unit bearing pressure obtained from a direct correlation with dynamic penetrometer blowcounts.

Primary and secondary design procedures are presented in detail in the full report for clay and for sand. Single methods are presented for clay-shale and for cemented alluvial fan deposits.

Figure 1 is presented to indicate the comparison between results from experimental work and from analyses. As may be seen in the figure, the prediction method is somewhat conservative on the average.

Computer Programs

Program SHAFT1 was developed to assist the designer in the use of the primary design procedure. Program BSHAFT is based on the use of the secondary design procedure. These programs can be employed to obtain curves showing ultimate axial load capacity of a drilled shaft as a function of depth. The programs also give the number of cubic yards of concrete that must be utilized for a particular design; thus, parametric studies are facilitated that allow the designer to select the most economical geometry for an axially loaded drilled shaft.

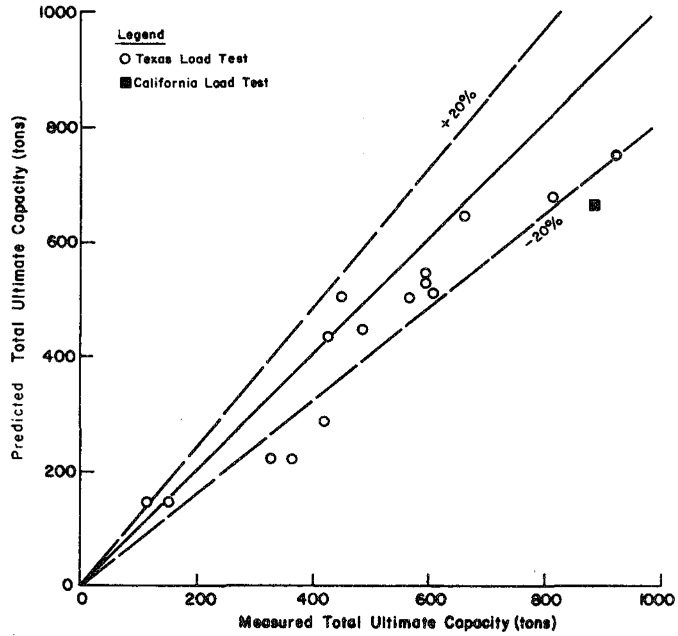

Fig. 1. Comparison of predicted and measured total ultimate capacities for Texas and California load tests, revised primary design procedure.

Conclusions and Recommendations

Based on the results of the study, conclusions can be drawn as follows:

(1) The design parameters that are proposed give satisfactory predictions of ultimate capacities of drilled shafts under axial load.

(2) The secondary design procedure should be used with caution because of the many factors that can affect the penetration resistance. The method should not be employed for soils with properties and conditions significantly different from those that were studied.

(3) Uncertainty of in situ soil properties remains a major obstacle in establishing a more generalized design procedure. Existing sampling

techniques and testing methods are often inadequate for accurate determination of in situ soil properties. This situation was especially evident in the Arizona soils investigation. The pressuremeter shows great promise as an in situ testing device.

(4) The developed computer programs SHAFT1 and BSHAFT are time-saving tools that should be used as design aids. The programs can be easily modified should future research so indicate.

The following recommendations are made in connection with future research in the area of drilled shafts:

(1) More instrumented shafts should be tested to improve the present design procedures or to verify more definitely the existing criteria.

(2) An effort should be made to test shafts in soils different from those thus far encountered.

(3) Emphasis should also be placed on improving present sampling techniques and developing reliable in situ soil testing methods.

KEY WORDS: drilled shafts, axially loaded, design procedures, clays, clay-shales, sand, cemented fine-grained alluvial fan deposits.

The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

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The full text of Research Report 176-5F can be obtained from Mr. Phillip L. Wilson, State Planning Engineer, Transportation; Transportation Planning Division; File D-10R; State Department of Highways and Public Transportation; P. O. Box 5051; Austin, Texas 78763.