CHAPTER 1

INTRODUCTION

Vibro-Concrete Column (VCC) technology lacks a standard design procedure for accurately estimating axial capacity. This report presents the results of an evaluation of current axial capacity design procedures for VCCs and provides limited recommendations for the development of a new design procedure. The study was completed as part of the Strategic Highway Research Program 2 (SHRP 2) Project Number R02 *Geotechnical Solutions for Soil Improvement, Rapid Embankment Construction, and Stabilization of the Pavement Working Platform* (Project R02) which is described in the next section.

1.1 SHRP 2 RO2 PROJECT BACKGROUND

Although in existence for several decades, many geoconstruction technologies face both technical and non-technical obstacles preventing broader utilization in transportation infrastructure projects. The research team for Strategic Highway Research Program 2, Project Number R02 (SHRP 2 R02) has investigated the state of practices of transportation project engineering, geotechnical engineering, and earthwork construction to identify and assess methods to advance the use of geoconstruction technologies. Such technologies are often underutilized in current practice, and they offer significant potential to achieve one or more of the SHRP 2 Renewal objectives of: (i) rapid renewal of transportation facilities; (ii) minimal disruption of traffic; and (iii) production of long-lived facilities. Project R02 encompasses a broad spectrum of materials, processes, and technologies within geotechnical engineering and geoconstruction that are applicable to one or more of the following “elements” of construction (as defined in the Project R02 scope): (1) new embankment and roadway construction over unstable soils; (2) roadway and embankment widening; and (3) stabilization of pavement working platforms.

The overall vision established for the project is “to make geotechnical solutions more accessible to public agencies in the United States for rapid renewal and improvement of the transportation infrastructure.” Phase 1 of the R02 project (completed in August 2008) consisted of six tasks focused on identifying those geotechnical materials, systems, and technologies that best achieve the SHRP 2 Renewal strategic objectives for the three elements. Explicit in the tasks was the identification and evaluation of technical issues, project development/delivery methods, performance criteria and quality control and quality assurance (QC/QA) procedures, and non-technical issues that significantly constrain utilization of geotechnical materials, systems and technologies. Through identification of obstacles, both technical and nontechnical, that constrain usage of geoconstruction methods, and mitigation strategies to overcome the obstacles, the research team developed an approach to identify existing and innovative technologies to enhance geotechnical solutions for transportation infrastructure.

Vibro-Concrete Column (VCC) technology is one of the forty-six geotechnical materials, systems, and technologies evaluated in phase 2 of the SHRP2 R02 project. During the evaluation, existing design guidance, QC/QA procedures, and specifications were collected and reviewed. Recommendations based on these reviews, along with other supporting information, are provided on the SHRP2 R02 project website. For VCCs, the project team identified discrepancies in current axial capacity design procedures and recommended the development of a new standard design procedure for VCCs.

1.2 VCC TECHNOLOGY DESCRIPTION

VCCs were first developed in Europe in 1976 as an alternative to stone columns when the soil surrounding the column is very soft and compressible. Since stone columns derive their strength and settlement characteristics from the surrounding soil, they do not perform well in very soft clay or peat. Instead of feeding stone to the tip of the vibrator, concrete is pumped through an auxiliary tube to the bottom of the vibrator. As the vibrator is extracted from the ground, concrete is pumped to fill the void, creating a concrete column. Typically, VCCs are installed through the soft soils to a deeper bearing stratum as shown in Figure 1-1, and derive most of their capacity from end bearing.

VCCs have been used as the column of choice on numerous column supported embankments projects throughout the United States. The columns can be installed rapidly through soft soil deposits to depths of 70 feet. Typical column dimensions are an 18 to 24-inch column diameter with a 24 to 36-inch bulb at the bottom and top of the column. The structural capacity of an 18-inch diameter unreinforced column is approximately 250 kips. Typical VCC projects verify the load carrying capacity of the column with pile load tests.

Additional background on VCCs can be found on the SHRP2 R02 project website.

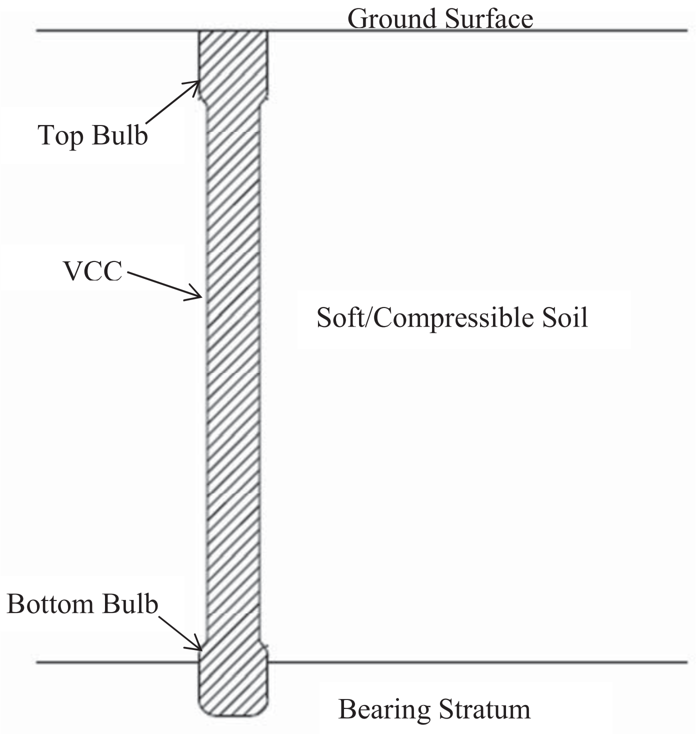

Figure 1-1. VCC schematic.

1.3 PROBLEM STATEMENT

In current practice, VCCs are designed using modified drilled shaft or driven pile design methods. Drilled shaft design methods tend to under predict capacity, while driven pile methods tend to over predict capacity. Our goal was to assess current design procedures based on available load test data and, to the extent possible, develop a standard design methodology for VCCs which more accurately predicts axial capacity.

1.4 APPROACH

A straightforward and simple approach was used in this study. The approach is summarized by the following steps.

1. VCC case history and load test information was collected.
2. Load test results were analyzed to determine "actual" VCC axial capacities based on different interpretation methods.
3. Soil conditions and VCC geometry was used to determine design axial capacities based on different design procedures.

4. “Actual” and design capacities were compared and recommendations provided based on the results.

1.5 OVERVIEW

Over the course of this study, data from 17 VCC load tests have been collected representing seven different projects. All of the case histories were provided by private industry, one of which is also described in the literature. Although significantly more case histories exist in the literature, many of these did not contain the level of detail required for this study.

For each of the case histories the following information was collected:

- Axial capacity of column – load test results (load-settlement curve) preferred
  - Static load tests allow for consistent interpretation
- Column geometry – detailed column installation records preferred
  - Depth of column embedment
  - Bottom column bulb diameter
  - Shaft diameter (typically an average value)
- Soil profile in vicinity of column – adjacent boring preferred
  - Depth to GWT
  - Soil description and layering
- Soil parameters in vicinity of column – adjacent boring with SPT data preferred
  - Friction angles and cohesion ideal, but not generally determined in practice
  - Soil unit weight

Actual axial capacity was estimated based on the load test results with consideration for the column geometry. Further discussion on the interpretation of load test results is presented in *Chapter 2*.

Predicted design axial capacities were determined using a variety of design procedures and consider the column geometry, soil profile, and soil parameters in the analysis. Further discussion on the analysis of design capacities is presented in *Chapter 3*.

As required in all engineering analyses, simplifications must be made in order to reduce the problem to a manageable level of complexity. For this problem, the column geometry was simplified for determination of actual and design capacities. When interpreting load test results, the shaft diameter and full length of column embedment were used to calculate elastic compression of the column. The bottom bulb diameter was used in deflection offset calculations for load test interpretation. In the design axial capacity analyses, the bottom bulb diameter at the bottom depth of embedment was used in calculations of end bearing capacity. Side friction was calculated based on the shaft diameter and full length of column embedment. The two most apparent simplifications are that the top bulb is completely ignored and changes in the shaft diameter are also ignored. Specifically, the increased shaft diameter near the bottom of the column (due to the bottom bulb) is not accounted for in the side friction analysis. Depending on the column geometry and problem parameters, these simplifications could tend to reduce or to increase the calculated values for design capacity.

In this study, design axial capacities were calculated for each tested column and compared with actual column capacity in order to assess the accuracy of design procedures. If design capacities tend to over predict actual capacity, a higher factor of safety or larger reduction factor would be recommended. Thus, in this back analysis, it is more conservative to introduce simplifications that tend to increase the calculated values for design capacity. Likewise, in order to maintain this conservatism in practice when using the procedures recommended herein, it would be desirable to remove simplifications that increase calculated capacity and include simplifications that reduce it. Although this will not be discussed further in the report, it is important for the reader to understand these concepts when applying the recommendations herein.

The results and recommendations of this study are presented in *Chapter 4*.

The project and analysis information for each VCC is summarized in table form in *Appendix A*. ID numbers are specified for each VCC.

Graphs of the load test results for each VCC by ID number are provided in *Appendix B*.

The input and calculated design capacities for each VCC are provided in *Appendix C.*

Appendix D includes an example problem used to verify the calculations.