ULTIMATE UPLIFT CAPACITY OF GROUP PILES IN CLAY

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NOTATIONS

c_a = Adhesion between pile-clay interface

c_u = Undrained cohesion of saturated or near-saturated clay

D = Diameter of piles

L = Length of embedment of piles in clay

n = number of piles in a group

p = Perimeter of the pile cross-section

Q = Net uplifting load

Q_u = Net ultimate uplift capacity

Q'_u = Gross ultimate uplift capacity

$Q_{u(g)}$ = Net ultimate uplift capacity of the group

$Q'_{u(g)}$ = Gross ultimate uplift capacity of the group

S = Center-to-center spacing of piles

W = Self-weight of the pile

W_g = Self-weight of the piles and cap

α = Adhesion factor

γ = Unit weight

Δ = Vertical pile displacement

ΔL = Finite length of pile embedded in clay

μ = Micron

η = Group efficiency

Chapter I

INTRODUCTION

Piles are structural columns that are made of steel, concrete, or timber and are used as deep-set foundations. Although piles cost considerably more than the conventional shallow foundations, there are situations that warrant the use of pile foundations.

Under normal conditions, pile foundations are designed to carry compressive loads transmitted by superstructures to hard, load-bearing stratum. It may be necessary to do this if, for example, the upper soil layer is too weak to support the load. Pile foundations are also especially suited for use in the construction of earth-retaining structures and tall buildings that are subjected to high winds or earthquake forces. This is due to the fact that when subjected to horizontal forces, pile foundations can resist bending and still support the vertical load. If expansive soil is encountered, then it would be disastrous to use shallow foundations under certain circumstances. This is due to the fact that these soils swell enormously upon wetting. In such cases, pile foundations can be used since they go deeper than the active zone and rest in stable soil and are thus not lifted with the swelling soil.

Numerous theoretical and experimental studies have been conducted during the last 30 to 40 years to understand the mechanism of load transfer from various types of piles to soil layers. This is a highly complicated process and several aspects of soil-pile interaction are yet to be understood.

In many circumstances, piles are used for construction of foundations which are likely to be subjected to uplifting loads. Common examples of such construction are found in the transmission tower foundations, foundations on expansive soils, and mat foundations located close to ground water table, etc. In contrast to the research works conducted so far regarding the assessment of the ultimate compressive load bearing capacity of piles, only a limited number of studies have been published to date which relate to the ultimate uplift capacity of piles embedded in sand and clay.

During the last 15 to 20 years, the results of several studies for estimation of the ultimate uplift capacity of piles embedded in sand have been published. Table 1.1 provides a summary of these works.

At this time, a very limited amount of work regarding the ultimate uplift capacity of piles embedded in clay has been published in the literature. Most of these published studies are summarized in Table 1.2.

Table 1.1

Studies Related to Ultimate Uplift

Capacity of Piles in Sand

Investigator(s)	Year	Remarks
Esquivel-Diaz	1967	Laboratory Model Test
Ireland	1957	Field Test
Meyerhof and Adams	1968	Laboratory Model Test
Meyerhof	1973	Theoretical Evaluation, Model Test
Meyerhof	1973	Theoretical Evaluation, Laboratory Model Test
Seeley, Das and Smith	1975	State-of-the-Art Review
Das and Seeley	1975	Laboratory Model Test
Das, Seeley and Smith	1976	Model Test--Group Piles
Das, Seeley and Pfeifle	1977	Laboratory Model Test
Das	1983	Model Test Evaluation, and a Procedure for Uplift Capacity Evaluation
Chaudhuri and Symons	1983	Model Test--Single Piles
Chaudhuri, Ghataori and Symons	1982	Model Test--Single Piles and Groups

Table 1.2

Summary of Studies Related to the Ultimate Uplift Capacity of Piles Embedded in Clay

Investigator(s)	Year	Remarks
Ali	1968	Model Tests in Soft Bentonite Clay
Bhatnagar	1969	Model Tests in Stiff Clay
Das and Seeley	1982	Laboratory Model Test
Mohan and Chandra	1961	Field Test
Patterson and Urie	1964	Field Test
Sowa	1970	Review of Existing Test Results
Turner	1962	Field Test

All of the studies summarized in Table 1.2 are related to the ultimate uplift capacity of single piles embedded in saturated or near-saturated clay. A review of the existing literature also shows that no attempt has yet been made to evaluate the uplift capacity of group piles in clay.

It is clear now that more experimental and theoretical studies for estimating the ultimate uplift capacity of single and group piles in clay are needed for the development of standard procedures for use in the design and construction of pile-supported foundations likely to be subjected to uplifting loads. The purposes of the present study are as follows:

(1) To conduct a number of laboratory pullout tests on model piles embedded in saturated or nearly saturated clays. The embedment ratios and the consistency of clays will be varied.

(2) To conduct a number of laboratory pullout tests on model group piles embedded in clay. The configurations and center-to-center pile spacings will be varied.

(3) The results of the laboratory pullout tests will be compared with the existing theories.

Chapter II

REVIEW OF THE EXISTING STUDIES

2.1 Definition of Net and Gross Ultimate Uplift Capacity of Piles

Figure 2.1 shows a pile embedded in a saturated clay and being subjected to a gross uplifting load Q'_u. The pile has a circular cross-sectional area with a diameter D. The length of embedment of the pile in clay is equal to L.

The gross ultimate uplift capacity of the pile is equal to Q'_u, which is the sum of the self weight of the pile and the adhesive resistance developed at the pile-soil interface during the period of application of uplifting load. Hence,

$$Q'_u = Q_u + W \tag{2.1}$$

or,

$$Q_u = Q'_u - W \tag{2.2}$$

where,

Q_u = net ultimate uplift capacity

W = self weight of the pile.