International Journal of Offshore and Polar Engineering
Vol. 3, No. 3, September 1993 (ISSN 1053-5381)
Copyright © by The International Society of Offshore and Polar Engineers

Uplift Capacity of Rigid Vertical Metal Piles in Clay Under Inclined Pull

Braja M. Das* and Eun C. Shin*
Southern Illinois University at Carbondale, Carbondale, Illinois, USA

ABSTRACT

Laboratory model test results for the net ultimate uplift capacity of rigid vertical aluminum piles embedded in saturated or near-saturated clay and subjected to inclined pull have been presented. The length-to-diameter ratios of the piles for these tests were kept at 10, 12 and 15. The load inclination with respect to the vertical varied from zero to 50°. Based on the present model test results and the results of existing studies for piles subjected to vertical uplift, an empirical relation has been developed. This relationship can be used to estimate the net ultimate uplift capacity of piles under inclined pull for load inclination θ varying from zero to 50°.

INTRODUCTION

In many circumstances anchor piles (or tension piles) are used for various types of offshore construction work. Although many theoretical and experimental studies related to the ultimate bearing capacity of various types of piles embedded in sand and clayey soil subjected to downward loading are presently available in literature, published research data for estimation of the holding capacity of similar piles subjected to uplifting load are rather scarce. Laboratory model test results for the ultimate uplift capacity of rough vertical piles embedded in sand and subjected to vertical uplift can be found in the studies of investigators such as Das (1983); Das and Rozendal (1983); Das and Seeley (1975); Das, Seeley and Pfeifle (1977); Esquivel-Diaz (1967); and Ireland (1975). Meyerhof (1973) evaluated the pullout resistance of rough inclined piles embedded in sand and subjected to axial loading. Field test results for the ultimate uplift capacity of vertical cast in situ concrete piles embedded in clayey soils and subjected to axial uplifting load were reported by Mohan and Chandra (1961); Patterson and Urie (1964); Turner (1962); and Sowa (1970). However, for offshore works, the piles generally used are metal piles. Also, due to several combinations of loading conditions, a vertical pile may be subjected to inclined uplifting load. At the present time, experimental studies related to the ultimate uplift capacity of metal piles subjected to inclined loading are practically nonexistent. The purposes of this paper are: (a) to present some recent laboratory model test results for the pullout resistance of rigid model aluminum piles embedded in saturated or near-saturated clay and subjected to inclined loading; and (b) to develop a semiempirical relationship for the uplift capacity of rigid metal piles based on the existing studies and present model test results.

ULTIMATE UPLIFT CAPACITY

Fig. 1 shows a rigid metal pile fully embedded in a saturated clay with an undrained shear strength of c_u. The length and diameter of the pile are L and D respectively. The pile is subjected to a load inclined at an angle θ with respect to the vertical. The

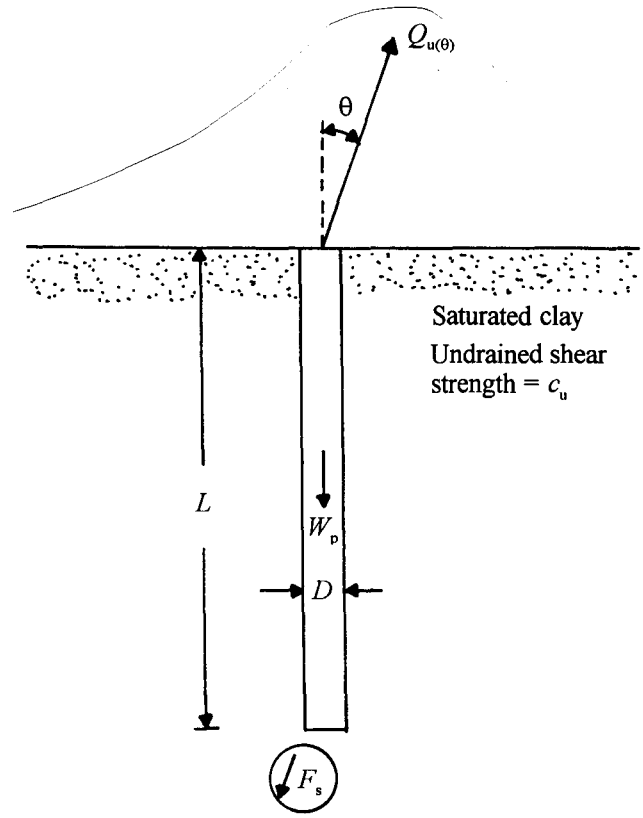

Fig. 1 Rigid metal pile subjected to inclined uplift load

gross ultimate uplift capacity of the pile can be expressed as:

$$Q_{u(\theta)} = Q_{n(\theta)} + W_p \cos\theta + F_s \quad (1)$$

where $Q_{u(\theta)}$ = gross ultimate uplift capacity, $Q_{n(\theta)}$ = net ultimate uplift capacity, W_p = effective self-weight of the pile, and F_s = mud suction force.

The mud suction force is very important in very soft to soft saturated clayey soils. However, as the strength of clay increases, the magnitude of the mud suction force decreases. Assuming that the mud suction force is eliminated or is negligible (i.e., $F_s = 0$), for saturated clayey soil, the net ultimate uplift capacity is a function of the adhesion (c_a) at the soil-pile interface, the length of the

*ISOPE Member.
Received May 21, 1992: revised manuscript received by the editors April 1, 1993. The original version (prior to the final revised manuscript) was presented at the Second International Offshore and Polar Engineering Conference (ISOPE-92), San Francisco, USA, June 14-19, 1992.
KEY WORDS: Clay, inclined load, uplift capacity, vertical pile.