

# Improvement of lateral and oblique pull-out capacity of piles in sand-An experimental study

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## Abstract

This paper presents the details of two series of experiments carried out on model piles embedded in sand. The first part of the paper presents details of tests carried out on model piles, under lateral loads, where four attachments were made onto the pile to improve its lateral capacity. The test results are compared with the results obtained from an equivalent plain pile. The additions of attachments have shown considerable increase in the lateral capacity of a pile. For these piles, theoretical estimates are made and compared with the experimental results. The theoretical estimates and the experimental results are found to be in good agreement. The second part of the paper presents the details of the test series carried out on model vertical piles under oblique pull. Experiments were carried out on three model piles of different lengths. The load was applied, on each pile, at three angles of obliquity. The load and the displacement of the pile head were observed till failure of the pile. The uplift capacity is analyzed as a function of obliquity of load. The theoretical estimates of the pile capacity under oblique pull were made. A good agreement between the experimental results and the theoretical estimates is observed.

**Key word:** Pull-out capacity, Oblique pull-out capacity of pile, Pile attachments.

## 1. Introduction

Lateral resistance of pile increases with depth up to a critical depth. Beyond this depth, the lateral capacity of a pile does not increase significantly with depth. The lateral capacity of a pile, in such a situation, can be improved by increasing its lateral dimensions. Broms has suggested a few attachments to pile [1, 2] at shallow depths, to improve its capacity to lateral loads. So far no attempts appear to have been made, either in laboratory or in field, to examine the effect of these attachments on the lateral capacity of a pile. An experimental investigation was carried out on model piles to study the effect of four attachments, suggested by Broms, in improving the lateral capacity of a pile. A number of investigations on vertical piles under inclined downward forces were reported [3, 4,5,6] however, only a few references are available on the behavior of piles under oblique pull[7,8,9] the second part of this paper presents the details of an experimental investigation carried out on vertical model piles under oblique pull. The tests were carried out under different oblique angles. The ultimate pullout capacity of pile under oblique load observed during experiments is compared with the theoretical estimates. In the rest of this paper the details of the two series of experiments are presented. The experimental results are compared with the respective theoretical estimates.

## 2. Soil Properties

The sand used in both the test series was a dry angular silica sand having  $D_{10} = 0.3\text{mm}$  and uniformity coefficient  $C_u = 2.8$  was used. Direct shear test indicated a friction angle ( $\phi$ ) of  $35^\circ$  for the initial porosity of  $n = 41\%$  used in the tests, corresponding to a unit weight ( $\gamma$ ) of  $16 \text{ KN/m}^3$  and a relative density of  $D_r = 0.6$  (60%).