ABSTRACT

Experimental investigations on model pile groups of configuration 1x1(single pile), 2x1, 3x1, 2x2 and 3x2 subjected to oblique pulling loads were conducted in dry Ennore sand obtained from Chennai, India. The variables used in the experimental investigations are embedment length to diameter ratio (L/d=12 and 38), pile friction angle,δ, spacing of pile groups (3 to 6 pile diameter), angle of obliquity of the load ($\theta = 0^0$, 30^0, 60^0 and 90^0), placement density (medium and dense) and pile group geometry/configuration (single, line, square and rectangular groups). Parametric study on the influence of the variables involved has been carried out on the load displacement response, modes of failure, ultimate resistance and group efficiency of the pile groups. The experimental results are presented through Figs and Tables.

The observed load-displacement response is non-linear in nature. Three types of displacement curves are observed for the pile groups under oblique pull. They are oblique pull versus axial displacement, lateral displacement and rotation. Axial failure is associated with smaller axial movement for rough pile groups compared to the smooth pile groups. The ultimate resistance per pile in a group, under axial, lateral and oblique pull increases with increase in spacing. Rough pile groups offer more resistance than the smooth ones indicating the significant effect of pile friction angle,δ. For long (L/d=38) and rough pile groups, it decreases with an increase in number of piles in a group and with the pile group configuration (line pile groups to square and rectangular pile groups). The ultimate resistance of a pile group under oblique pull depends on the pile friction angle, pile geometry, pile spacing and soil density. Group efficiency increases with increase in spacing. Short (L/d=12) rough pile groups are more efficient than short smooth pile groups. However, higher efficiencies are observed for smooth long (L/d=38) pile groups. For rough long pile groups, the efficiency decreases with an increase in number of piles in a group and with the pile group configuration (line pile group to square and rectangular pile group). The ultimate resistance of a pile group under oblique pull is a continuous function of the inclination of the pull. It depends on the uplift capacity and ultimate

lateral resistance of the group. The modes of failure of a pile group i.e., axial failure or bending failure, depend on the length, surface characteristics of the piles and inclination of the load.

Based on the experimental results and suitable assumptions made, analytical methods are developed to predict the axial uplift capacity, lateral and oblique ultimate resistance of pile groups. These methods take into consideration the variables such as embedment length, diameter of pile, pile friction angle, pile spacing, inclination of the load, configuration of pile group and angle of shearing resistance of sand. In order to validate the analytical methods comparison has been made between the predictions and the results of the present investigation and of others'. The predictions from the proposed analytical methods are quantitatively and qualitatively in reasonable agreement with the present experimental results and with those of other researchers' on the ultimate resistance of pile groups.

The thesis consists of **seven chapters**:

1) Chapter-I: An **introduction** to the problem has been put forward, indicating the necessity and importance of the problem from the point of view of research, analysis and design. Scope of the study has been outlined at the end of the chapter.

2) Chapter-II: The detailed **review** of the existing available literature on the subject by the earlier investigators has been furnished. Literature on ultimate resistance of pile groups under uplift and lateral loads have been considered first and on ultimate resistance under oblique pull subsequently.

3) Chapter-III: To generate systematic data on the ultimate resistance of group of piles in sand under oblique pulling loads **laboratory model testing programme** has been undertaken. The experimental setup, testing procedure and the testing programme have been described.
4) Chapter-IV: The results of the **experimental investigations** have been presented through Figures and Tables at appropriate sections and discussed. Effect of