ABSTRACT

In the present study, a small scale 1-g model test has been developed in the laboratory to study the behaviour of a long flexible single pile embedded in a slope of soft clay with different slope angles and *L/D* ratios, and subjected to a static lateral loads using loading frame and frictionless pulley arrangements. A steel tank of size 2 m × 1 m × 1 m and an aluminum model pipe pile were used to carry out the experimental studies. The size of steel tank and the model pile were designed to suit the present study. An aluminum instrumented model pile of length 810 mm, 25.46 mm outer diameter and 1 mm thickness was used for the present study. The clay sample which was used in the present study was collected from coastal district Nagappatinam of Tamil Nadu (INDIA). A series of model test has been carried out on a clayey soil of soft consistency (Consistency Index I_c = 0.42).The model aluminum pile was embedded on different slopes (1V:1H, 1V:1.5H, 1V:2H, 1V:3H and 1V:5H) and subjected to static lateral loads. To obtain the long flexible behaviour of model pile, the length (*L*) to diameter (*D*) ratio of 20, 25 and 30 was considered and also the relative stiffness factor (*R*) for clayey soil was kept more than 3.5. The tests were also carried out on a horizontal ground surface for comparison.

From the experimental studies, the lateral pile head deflection, bending moments and the lateral deflection behaviour along the depth of pile were studied. And also, the effect of *L/D* ratios and slopes on lateral deflections and maximum bending moments were studied in detail. In order to include the effect of *L/D* ratios and slopes on pile capacity and maximum bending moments, an expression was developed by multiple regression analysis and proposed a correction factor. From the bending moments and deflections' profile, the *p*-*y* curves (soil resistance (*p*) and lateral deflection (*y*) along the pile shaft) for a single pile embedded on a

crest of soft clay with different slopes and *L/D* ratios were developed, a case for which no such curves exist so far. The effect of slopes and *L/D* ratios on *p-y* curves was also studied. The results from experimental studies reveals that when ground surface changes from horizontal to 1V:1H or 1V:1.5H or 1V:2H or 1V:3H or 1V:5H slopes; the lateral load capacity was reduced significantly for all the length (*L*) to diameter (*D*) ratio of 20, 25 and 30. This reduction in pile capacity for sloping ground was due to the reduction in passive resistance of soil in front of the pile. It was also observed that the lateral loads – deflection behavior of 1V:5H slope was almost same as horizontal ground surface for all the *L/D* ratios. From the bending moment behaviour, it was found that the maximum bending moments increases with increase in applied loads. And also, the increase in *L/D* ratio changes the behaviour of bending moment behaviour significantly along the depth of the pile. It was observed that as *L/D* ratio increases, the bending moment decreases. This behavior was due increase in the long flexible behaviour of the model pile. In order to include the effect of *L/D* ratios and slopes on lateral load capacity of the pile and the maximum bending moments of pile, an expression was developed by multiple regression analysis and a correction factor was proposed considering slope effect on lateral load for calculating the pile capacity for sloping ground surfaces.

The variation of depth of fixity due to change in *L/D* ratios and ground slopes was also studied. From the results, it was observed that the depth at which maximum bending moment occurs (depth of fixity) decreases with increase in the *L/D* ratios from 20 to 30. It was observed that the depth of fixity occurs almost at a depth of 14.3D, 12.3D and 8.5D (D=diameter of pile) below the pile head for the length (*L*) to diameter ratio(*D*) of 20, 25 and 30 respectively. This was due to increase in the relative stiffness of the pile and the soil. It was also observed that the depth of fixity not changes much due to change in ground slopes.

A non-dimensional design chart has been produced between dimensionless applied load and dimensionless bending moment which enable to value maximum bending moment promptly for laterally loaded piles in sloping ground with in the given parameters. The applicability of the correction factors and non-dimensional chart are suitable for within the chosen experimental parameters.

Also, a new set of *p-y* curves were also developed for a single pile embedded on crest of soft clay with different the length (*L*) to diameter(*D*) ratio (20, 25and 30) and slopes (1V:1H, 1V:1.5H, 1V:2H, 1V:3H and 1V:5H). The effect of slopes on *p-y* curves for different *L/D* ratios was also studied. From the results, it was observed that the soil resistance was found to be increasing with increase in soil depth irrespective of slopes. This behavior was observed almost till the depth of fixity. The soil resistance beyond depth of fixity was not significantly changes the behaviour of *p-y* curves. It was observed that for the length (*L*) to diameter (*D*) ratio of 25, beyond the depth of 9.4D (D=diameter of pile) below the soil surface, the behaviour of *p-y* curves were not significantly changes irrespective of slopes, whereas, for the length (*L*) to diameter (*D*) ratio of 30, this depth was found to be 8.4D below the soil surface. Further, a set of non-dimensional *p-y* curves were also developed for single pile in sloping ground, which enable to obtain the deflection of laterally loaded pile in sloping ground.

In addition, the experimental results were validated by numerical analysis using PLAXIS 3D Foundation. The numerical results were compared with that of experimental results and found to be good agreement. The numerical results slightly underestimate the experimental values. For all the cases, the difference between experimental results and numerical values were less than 10%, which is generally an acceptable range. Further, the sensitivity analysis of model was also carried out by changing the soil parameters.

Finally, the behaviour of group of piles located on sloping ground surface was also studied by numerical analysis. A field test performed by Rollins et al. (1998) on a 3x3 group of piles was used for numerical study. A 3x3 pile group of piles having 9.1m length was used for the analysis. The soil profile which was used for the present analysis consists of soft to medium-stiff clays and silts underlain by sand. The numerical model was validated and a parametric study was conducted. The group of piles was placed on a crest of slopes (1V:5H and 1V:3H) to study their behaviour due to lateral static loads. The effect of slopes on pile capacity and the behaviour of lateral deflection and bending moments along the length of group piles for different rows were studied.