EXPERIMENTAL AND NUMERICAL STUDIES ON PILE BEHAVIOR UNDER COMBINED LATERAL AND UPLIFT LOADS

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EXPERIMENTAL AND NUMERICAL STUDIES ON PILE BEHAVIOR UNDER COMBINED LATERAL AND UPLIFT LOADS

by

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Submitted

in fullfllment of the requirements of the degree of

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Dedicated to My Beloved Father

Late Shri. K. Chandra Reddy

and

My Family

CERTIFICATE

This is to certify that the thesis entitled **"EXPERIMENTAL AND NUMERICAL STUDIES ON PILE BEHAVIOR UNDER COMBINED LATERAL AND UPLIFT LOADS"** submitted by **Mr. K. Madhusudan Reddy** to the Indian Institute of Technology Delhi, is a record of the bonafide research work carried out by him under my supervision and guidance. This thesis work, in my opinion, has reached the standard, fulfilling the requirements for **Doctor of Philosophy** degree. The research report and the results presented in this thesis have not been submitted, in part or full, to any other university or institute, for the award of any degree or diploma.

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ABSTRACT

Pile foundations are generally used to support vertical compressive loads from superstructures, but may also be subjected to lateral, uplift and moment loading in a few structures such as transmission towers, mooring systems for ocean surface or submerged platforms, tall chimneys, jetty structures, etc. Under these circumstances, the pile would resultantly be subjected to combined loading and moments. Hence, an understanding of pile behavior under the combined loads/moments is very important for design. The present study primarily aims at investigating the pile behavior under combined lateral and uplift loads.

1-*g* model experiments were conducted in the laboratory for studying pile behavior under combined lateral and uplift loading. Model aluminium single pile of different *L/D* ratios: 18, 28 and 38 were used. Sand having varying density conditions: loose-medium dense, dense and very dense (RD = 40 %, 70 % and 90 %) were simulated. Model piles were subjected to both independent lateral/uplift load and combined load tests. Combined loading tests were done in two series: (i) lateral pile load tests with constant uplift load to investigate the effect of constant uplift load on pile behavior under lateral load and (ii) uplift load tests with constant lateral load to investigate the effect of constant lateral load on pile behavior under uplift load.

The ultimate pile capacity under lateral and uplift modes under combined loading were interpreted from the load-deflection/displacement curves measured from experiments. It was found that the ultimate pile capacity in both lateral and uplift modes was significantly affected by the combined loading. The pile head displacement/deflection during the combined loading was also measured and analyzed. It was seen that the displacement/deflection had increased substantially

under combined loading compared to independent loading, which indicates that the displacement/deflection which are considered to be within the limits under independent loading, may exceed the limits under combined loading. This indicates that the effect of combined loading needs to be properly accounted for in the practical design. Combined load capacity factor for both lateral and uplift modes are defined and presented in this study.

The finite element modeling of the soil-pile system subjected to combined loading was also carried out using PLAXIS 3D software. The pile was idealized as a linear elastic material. The soil was modeled using hardening soil model. 16-noded interface elements were used between soil and pile to simulate the pile-soil interface characteristics with a strength reduction factor of 0.7. Initial stress conditions were simulated by considering K_0-procedure. The standard fixities were applied to the boundaries. Validation of FE model was done using the load test data reported in literature for independent lateral and uplift loading. The data of model experiments conducted at RD = 70 % were considered to compare the predicted pile behavior under combined loading by FE modeling. The results predicted by the FE analysis were compared with the experimentally measured pile behavior under combined loading and it was found that the FE model was able to predict the pile behavior under combined lateral and uplift loading with good accuracy. The limitations of model experiments are also highlighted and suggestions for future research are given.

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