Experimental and Numerical Studies on Response of Tapered Piles under Combined Vertical Compression and Lateral Loading

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Abstract

When shallow foundations fail to meet design criteria for bearing capacity and settlement, pile foundations are used to transfer building loads to stronger layers at greater depths. Tapered piles offer better load-carrying capacity than uniform-diameter piles, but their limited usage may be due to a lack of understanding and design guidelines. This study investigates the response of tapered piles and their ultimate resistance in different soil conditions and taper angles. While there have been various studies on tapered piles under various static loading situations, such as vertical, lateral, and uplift loads, there is a lack of research on their behaviour under combined loading. Most existing studies assume simultaneous application of loads, but sequential loading is more realistic. Therefore, further research is needed to simulate combined loads applied sequentially on pile foundations. Thus, this study analysed tapered pile foundation response under sequentially applied combined loading.

In the present study, 1-*g* model experiments were carried out using model-reinforced concrete piles embedded in sandy soil with different relative densities. Two sets of sequential combined loading tests were performed to analyse the interaction of lateral and axial loading, applying constant loads of 0.4 and 0.6 times the respective ultimate axial or lateral load values. Results show that axial capacity increases with pile taper angle until a critical angle of about 1.0º, beyond which the axial capacity of the pile does not increase with the taper angle. The ultimate lateral load increases even beyond the critical taper angle (1º) observed in the ultimate axial load value, which indicates that the critical taper angle is different for axial and lateral loading.

In the 1-*g* model test, it was not possible to understand the zone of deformation; hence the whole problem is numerically analysed using PLAXIS 3D. The bending moment profiles predicted by the numerical analysis are in close agreement with the model test data, however, the elastic analysis overestimated the bending moment value. The ultimate load values obtained from the predicted load-deformation curve are also compared with 1-*g* model test results, which show very close agreement. A comprehensive numerical analysis, considering prototype pile dimensions and various loading combinations, shows significant influences of pile length, relative density, and taper angle on ultimate axial load values under independent loading. Longer piles, higher relative density, and lower taper angles show gradual increases in axial capacity, while higher taper angles, especially with longer piles, notably increases axial capacity. Semi-empirical equations derived via linear regression facilitate predicting ultimate axial and lateral load values under combined loading, offering a comprehensive framework for capacity estimation.