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Evaluation of Natural Frequency of Single and Grouped Helical Piles

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Abstract : The importance of a systems' natural frequency (fn) emerges when the vibration force frequency is equivalent to foundation's fn which causes response amplitude (resonance) that may cause irreversible damage to the structure. Several factors such as pile geometry (e.g., length and diameter), soil density, load magnitude, pile condition, and physical structure affect the fn of a soil-pile system; some of these parameters are evaluated in this study. Although experimental and analytical studies have assessed the fn of a soil-pile system, few have included individual and grouped helical piles. Thus, the current study aims to provide quantitative data on dynamic characteristics of helical pile-soil systems from full-scale shake table tests that will allow engineers to predict more realistic dynamic response under motions with variable frequency ranges. To evaluate the fn of single and grouped helical piles in dry dense sand, full-scale shake table tests were conducted in a laminar box (6.7 m x 3.0 m with 4.6 m high). Two different diameters (8.8 cm and 14 cm) helical piles were embedded in the soil box with corresponding lengths of 3.66m (excluding one pile with length of 3.96) and 4.27m. Different configurations were implemented to evaluate conditions such as fixed and pinned connections. In the group configuration, all four piles with similar geometry were tied together. Simulated real earthquake motions, in addition to white noise, were applied to evaluate the wide range of soil-pile system behavior. The Fast Fourier Transform (FFT) of measured time history responses using installed strain gages and accelerometers were used to evaluate fn. Both time-history records using accelerometer or strain gages were found to be acceptable for calculating fn. In this study, the existence of a pile reduced the fn of the soil slightly. Greater fn occurred on single piles with larger l/d ratios (higher slenderness ratio). Also, regardless of the connection type, the more slender pile group which is obviously surrounded by more soil, yielded higher natural frequencies under white noise, which may be due to exhibiting more passive soil resistance around it. Relatively speaking, within both pile groups, a pinned connection led to a lower fn than a fixed connection (e.g., for the same pile group the fn's are 5.23Hz and 4.65Hz for fixed and pinned connections, respectively). Generally speaking, a stronger motion causes nonlinear behavior and degrades stiffness which reduces a pile's fn; even more, reduction occurs in soil with a lower density. Moreover, fn of dense sand under white noise signal was obtained 5.03 which is reduced by 44% when an earthquake with the acceleration of 0.5g was applied. By knowing the factors affecting fn, the designer can effectively match the properties of the soil to a type of pile and structure to attempt to avoid resonance. The quantitative results in this study assist engineers in predicting a probable range of fn for helical pile foundations under potential future earthquake, and machine loading applied forces.

Keywords : helical pile, natural frequency, pile group, shake table, stiffness
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