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Soil Structure Interaction Analysis for Pile Foundations

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A soil structure interaction analysis framework is developed using the variational principles of mechanics for laterally loaded piles embedded in multi-layered soil. The differential equations governing the pile deflections and soil displacements in different soil layers, due to a concentrated static force and/or moment acting at the pile head, were obtained using energy principles and calculus of variations. Pile deflection, slope of the deflected curve, bending moment, shear force and soil resistance (pressure) were explicitly obtained by this method. The pile-deflection equations were solved analytically, while the soil-displacement equations were solved using the one-dimensional finite difference method. The analysis takes explicit account of the three-dimensional interaction between the pile and the surrounding soil, and produces results that have the same level of accuracy as that of a three-dimensional finite element analysis. But the time required for running this analysis is only a small fraction of an equivalent three-dimensional finite element analysis.

The nonlinear pile-soil interaction is taken into account by incorporating a nonlinear-elastic iterative algorithm using a secant modulus approach. The nonlinear approach takes into account the decrease of soil modulus with increase in soil strain (or stress). Thus, the nonlinear load-deflection response of piles can be efficiently predicted using this method.

The method is further extended to analyze axially loaded piles. Recently, the random heterogeneity of soil has been introduced into the framework by considering the mean, variance and correlation length of the soil properties. Further research on analysis of pile groups is in progress. The framework will be further generalized to incorporate the elasto-plastic soil constitutive models that accurately predict the stress-path dependent, multi-axial stress-strain behavior of soil. The framework will be subsequently used to analyze mat foundations and piled rafts.