BOUNDARY ELEMENT FORMULATIONS FOR NONLINEAR SOIL-STRUCTURE INTERACTION

By

Ahmed Fady Mahmoud Farid

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
Requirements for the Degree of
DOCTOR OF PHILOSOPHY
in
Structural Engineering

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
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Under the Supervision of

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Secretary General of
Supreme Council of Universities in Egypt

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FACULTY OF ENGINEERING, CAIRO UNIVERSITY
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Title of Thesis:
Boundary element formulations for nonlinear soil-structure interaction

Key Words:
Boundary element method; Soil-structure interaction; Nonlinear analysis; piled raft; Overall building analysis

Summary:

In this thesis, a comprehensive study to overcome soil-structure interaction problems that are present in nonlinear analysis of piled rafts. Direct boundary element formulations are used to perform nonlinear analysis of piled rafts. The raft is considered as a shear-deformable plate, whereas the soil is modeled as either Winkler springs or elastic half space (EHS). Piles are modeled using their actual geometry including all interaction effects. Two different direct boundary element formulations are reviewed: a) Plate stiffness matrix formulation (FEM-like formulation), and b) adding stiffness matrices to the plate integral equation formulation (BEM-like formulation) are used.

Firstly, the proposed BEM plate stiffness matrix formulation is extended to analyze plates on elastic-plastic Winkler foundations. Iterative methodology is used to perform nonlinear analysis of plate on elastic-plastic Winkler foundations. This methodology is also extended to analyze plates on elastic-plastic and tensionless Winkler foundations.

Subsequently, nonlinear analysis of piled rafts is developed. Nonlinear analysis of piled rafts at certain load level is developed using three different formulations and two nonlinear numerical techniques. These formulations are automated and implemented in ***PLPAK*** software under title of "full load analysis". In addition, two nonlinear formulations are extended to predict the load-settlement curve of the piled raft. The load-settlement curve prediction is implemented in the ***PLPAK*** software under title of "failure incremental analysis". Interface is developed to help user in the analysis called "***NLPAK***" (Nonlinear package).

Finally, overall building analysis system using ***PLPAK*** software is presented. Innovative coupling technique of the super and substructure is presented to analyze overall building. Coupling technique is implemented into ***PLPAK*** software. Nonlinear package developed in thesis is coupled with superstructure package to analyze overall building. Laterally loaded piles are considered in approximate way. In addition, coupling technique is used to study stage of construction analysis including soil structure interaction on the overall building, which yielded interesting results.

Several numerical examples and practical examples are presented to verify the proposed techniques. Results are compared to commercial software packages and previously published results. The examples provide proof of concept, yet push the limits of accurate numerical analysis of overall structures on nonlinear soil.

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Dedication

I am dedicating this thesis to three beloved people who have meant and continue to mean so much to me.

First and foremost, to ***my mother Hoda*** *although she is no longer of this world, their memories continue to regulate my life, whose love for me knew no bounds and, who taught me the value of hard work. Thank you so much "Mama", I will never forget you, and I hope you to be with me in these moments.*

Next, ***my wife "Semsem" Asmaa*** *who raised me, loved me, and support me. Whish Allah give us a happy life with you forever.*

Last but not least I am dedicating this to my baby ***youssef ahmed fady*** *to encourage him to be a man bears responsibility.*

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