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SIMULATING SOIL-BUILDING INTERACTION WITH A FEM/BEM APPROACH

Dimas B. Ribeiro[1] and João B. Paiva[*2]

[1] Department of Structural and Geotecnical Engineering, Polytechnic School of the University of São Paulo, Av. Prof. Almeida Prado tv. 2, n. 83, São Paulo, SP, Brazil, 05508-070, dimas.ribeiro@usp.br

[2] Department of Structural Engineering, Engineering School of São Carlos, University of São Paulo, Av. Trabalhador Sãocarlense, 400, São Carlos, SP, Brazil, 13566-590, paiva@sc.usp.br

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The contribution of this paper is to combine formulations developed for soil-structure interaction analysis and apply it to buildings supported by piled rafts. The soil is modeled with the boundary element method (BEM) as a layered solid which may be finite for the vertical direction, but is always infinite for radial directions. Piles in the soil, as well as pillars and beams in the building, are modeled with the finite element method (FEM) using one dimensional elements. The raft that supports the building and its slabs are also modeled with the FEM, but with two dimensional elements.

Kelvin fundamental solutions are used in the BEM and the alternative multi-region technique presented in [1] is employed. Establishing relations between the displacement fundamental solutions of the different domains, this alternative technique allows analyzing all domains as one unique solid, not requiring equilibrium or compatibility equations. This formulation also leads to a smaller system of equations when compared to the usual multi-region technique, and the results obtained are even more accurate. The infinite boundary element (IBE) presented in [2] is employed for the far field simulation, allowing computational cost reduction without compromising the result accuracy. This IBE formulation is based on a triangular boundary element with linear shape functions instead of the quadrilateral IBEs usually found in the literature. One advantage of this approach is that no additional degrees of freedom are added to the original BE mesh by the presence of the IBEs. Thus, the IBEs allow the mesh to be reduced without compromising the accuracy of the result. The techniques presented in [1] and [2] used together result an advantageous formulation for infinite layered domains, as demonstrated in [3].

In the one dimensional elements used for the piles, displacements and tractions along the shaft are approximated by polynomial functions. Fourth degree polynomials are used for horizontal displacements, third degree polynomials for horizontal tractions and vertical displacements, second degree polynomials for vertical tractions and the traction at the base is considered constant. One dimensional elements are employed for pillars and beams as well, but in this case with two nodes and six degrees of freedom for each node, three displacements and three rotations.

The triangular three-node FE employed for the raft and the slabs is obtained by superposing two types of effects. The first one is a plate effect, which is represented by an element type "DKT". The second one is a membrane effect, being computed by an element type "FF". When these formulations are superposed one obtains the raft element employed in this work, which totalizes six degrees of freedom per node.

For the FEM-BEM coupling, the BEM tractions are considered as nodal reactions between the contact surfaces. The coupling is established using equilibrium and compatibility equations, obtaining a single system of equations that represents the complete pile-raft-soil problem.

The proposed formulation is applied in two examples. In the first one a squared raft resting on an infinite layered domain is considered. Results are compared with other formulations available in the literature, including an analytical approach and good agreement is observed. The objective of the second example is to show all functionalities of the proposed formulation, so a complete building resting on a piled raft interacting with a layered soil is considered. No comparison with other authors is presented, nevertheless the results obtained may be considered coherent. Finally, it is concluded that the presented formulation may be considered a practical and attractive alternative in the field of soil-structure interaction simulation.

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