THE IMPLEMENTATION OF BOUNDARY ELEMENT CODES IN GEOTECHNICAL ENGINEERING

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SYNOPSIS

The application of simple boundary element techniques in the field of geotechnical engineering is discussed. Particular emphasis is placed upon the coupling of standard finite elements to soil boundary elements in order to solve soil-structure interaction problems. Two computer programs which incorporate these techniques in the areas of foundation and pile/wall analysis and design are briefly described. In addition the use of these programs is demonstrated with respect to several case histories in which the agreement between predicted and observed behaviour is most encouraging.

INTRODUCTION

In the field of geotechnical engineering the semi-infinite nature of the soil domain may be efficiently modelled using boundary element techniques. Finite element programs which will handle the modelling of three-dimensional continua exist, but for semi-infinite domains the computation involved may become excessive. Furthermore, in the context of foundation design the three dimensional nature of the distribution of structural loads is such that the reduction of the problem to a two-dimensional axi-symmetric, plane stress or plane strain model, in order to facilitate economic analysis, is inappropriate. In order to exploit the potential offered by the boundary element approach two computer programs RAFTS and LAWPILE (Wood, 1978a and 1979a) have been written specifically for the analysis of foundations and, piles and walls subject to lateral loads. Both are based upon the coupling of standard structural finite elements with soil boundary elements.

The soil boundary elements are formulated on the basis of linear elastic behaviour but incorporate procedures to enable the effects of non-linear soil response to be assessed. Appro-
ximate extensions of the basic element formulation have been implemented in order to model layered (not necessarily horizontal layers) and transversely isotropic continua. It is felt that these approximations based upon the solutions obtained by Mindlin (1936) and Gerrard and Harrison (1970) for homogeneous elastic continua, are acceptable in the context of soil where the assumption of elastic behaviour is itself questionable. Indeed the performance of the simple boundary element adopted has been shown to produce results which lie well within the normal tolerances associated with geotechnical design procedures, and suggest that the soil model is compatible with the level of soils information usually available.

The application of the simple boundary element is discussed below with respect to two general soil-structure interaction situations. Consideration is first given to predicting the behaviour of raft foundations using the program RAFTS and then to the use of a sister program LAWPILE for determining the behaviour of piles or walls subject to lateral forces. For both comparisons are shown between the actual recorded performance of structures and that predicted by back-analysis. The results are most encouraging and confirm the predictive power of this, albeit approximate, approach.

RAFTS

The development of the basic soil boundary element has taken place over a number of years and the acceptability of the approximate extension for layered elastic continua has been demonstrated by Wood (1977) with respect to a wide variety of inhomogeneous situations and elastic layers of finite extent. Subsequently the element has been enhanced (Hooper and Wood, 1977; Wood, 1978b) to include transversely isotropic behaviour. That is, a continuum within which the stiffness in the vertical direction differs from that in the horizontal plane. Thus, the elastic properties of the continuum are defined by five independent constants:

\[ E_v, E_h, \nu_{vh}, \nu_{hh}, \text{ and } G_{vh}; \]

where \( E \) and \( \nu \) are Young's modulus and Poisson's ratio respectively, \( G \) is the shear modulus and suffixes \( v \) and \( h \) refer to the vertical and horizontal planes.

The use of a purely elastic analysis with regard to the design of raft foundations may give rise in some instances to somewhat unrealistic soil reactions under the edges of the foundation. This is particularly so in the case of stiff structures. Although, the adoption of a non-linear soil model (Wood and Larnach, 1975) produces a more realistic assessment of the raft behaviour, the increase in computational effort with respect to three-dimensional situations is rarely justi-