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Applications of the Scaled Boundary Finite-Element Method in Modeling Geotechnical Engineering Problems

Mohammad Hossein Bazyar, Ali Alipour
Assistant Professor, Department of Civil Engineering, Yasouj University, Yasouj, Iran
mhbazyar@mail.yu.ac.ir

Abstract

The Scaled Boundary Finite-Element Method (SBFEM) is a novel semi-analytical technique for numerical simulation of both bounded and unbounded domains. It not only combines many advantages of the finite-element and boundary element methods but also presents appealing features of its own. Only the boundary is discretized as in the boundary element method. No fundamental solution is necessary as in the finite element method. This paper reviews the solution procedures of the method for statics, frequency- and time-domain analyses. Using numerical examples with emphasis on those possessing unbounded domains, the applications of the method in modeling different geotechnical engineering problems are illustrated.

Keywords: scaled boundary finite-element method, unbounded domain, bounded domain, dynamic-stiffness matrix, unit-impulse response

1. INTRODUCTION

The scaled boundary finite-element method, a fundamental-solution-less boundary element method, is an attractive alternative to the numerical schemes in computational mechanics. It not only combines some important advantages of the finite-element and boundary element methods but also has its own salient features. This method, which is semi-analytical, is based on the finite-element technology so that it does not require fundamental solutions. The radiation condition at infinity is satisfied rigorously. Like the boundary element method only the boundary is discretized reducing the spatial discretization by one and leading to the increase of computational efficiency. Problems involving stress singularities and discontinuities can be modeled accurately. Anisotropic media can be handled without additional computational efforts.

The scaled boundary finite-element method was developed by Wolf and Song in Switzerland during the 1990s. This novel development is of substantial features and merits which have not been reported before in the naive original ideas. The scaled boundary finite-element method has been originally developed for the dynamic analysis of unbounded domains [1]. It was named at that time the consistent infinitesimal finite-element cell method as the original derivation for two-dimensional scalar waves was mechanically-based [1]. A finite element cell with the exterior boundary similar to the interior one was introduced in the radial direction adjacent to the structure-medium interface. The relationship based on similarity and the limit of the infinitesimal cell width tending to zero led to the consistent infinitesimal finite-element cell equation. This equation is derived in the frequency domain and then transformed into the time domain. This technique was later extended to two-dimensional vector waves [2] and three-dimensional waves [3]. Reference [4] applies this technique to two- and three-dimensional statics, dynamics and diffusion in unbounded and bounded media. The crack tip stress intensity factors in fracture mechanics were also calculated.

In this paper, firstly a summary of the original and recently developed solution procedures for the method is stated. Secondly, to demonstrate the versatile applications of the method, geotechnical engineering examples in statics, frequency and time domains are analyzed.

2. THE SCALED BOUNDARY FINITE-ELEMENT METHOD

In the scaled boundary finite-element method, a so-called scaling center O is chosen in a zone from which the total boundary, other than the straight surfaces passing through the scaling center must be visible (Figure 1a). Only the boundary S directly visible from the scaling center O is discretized as shown in Figure1a. One-dimensional line element is used (Figure 1b). The

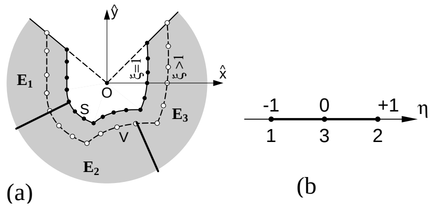

Figure 1. (a) Spatial discretization for an unbounded domain in scaled boundary finite-element method; (b) three-node line element on boundary