Developing the Compacted Hyeprelements Method (CHM) for Calculation of Green's Functions in Irregular Media

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Abstract

The main purpose of this thesis is to obtain numerical Green's functions for a laminated media consisting of irregular boundaries subjected to Rayleigh waves. The formulation of this problem is developed on the basis of the thin layer method (TLM). Existing natural boundaries such as foundations, faults, etc. which are definitely non-vertical in soil shows the importance of developing irregular consistent boundaries. In this research, the stiffness matrix of the irregular boundary is constructed by using the stiffness matrix attributed to a vertical boundary by means of considering hypothetic degrees of freedom along the depth of the stratum. Then these degrees of freedom are accommodated within the original degrees of freedom of the bounded region by subdividing the zone limited at top to the non-vertical boundary by a sufficient number of hyperelements. Since the stiffness matrix for each hyperelement is available, producing the total stiffness matrix for the irregular boundary region is straightforward. Then, applying a static condensation procedure to eliminate the hypothetic degrees of freedom, the dynamic stiffness matrix of the nodes existing only on the irregular boundary is obtained. Now the analysis of the bounded region with irregular boundaries is possible and if the forces or excitations are unit loads, the responses of the region will actually be the Green's functions for the region. In the case of the seismic waves, two types of waves propagating in the earth are considered, namely, the Love waves with the direction motion of particles perpendicular to the plane of propagation (out-of-plane displacements) and the Rayleigh waves with the motion of particles taking place in the plane of propagation (in-plane displacements). In the case of Love waves there is just one degree of freedom perpendicular to plane of propagation while in case of Rayleigh waves there are two degrees of freedom in the plane of propagation. It has been proven that equations of these two types of waves are independent from each other in the two-dimensional case. Then it is possible in this case to consider only a single wave type for analyzing the soil model beside considering soil as a two dimensional region does not imply huge estimation in the process of analysis. Mentioning that the proposed method dealing with irregular boundaries has already been applied successfully to the propagation of Love waves, in this thesis the method is extended to the case of Rayleigh waves. The presented method is called the compacted hyperelements method (CHM) and is verified by several examples showing very good accuracy with regard to other methods. These examples are problems which solved by other numerical or explicit methods. In each of these examples it could be seen that the CHM method is an accurate and efficient method to analyze the unbounded strata. Varying the number of the hyperelements and the thickness of the thin layers, it is shown that the suggested method has a superior efficiency over the existing methods for dynamic analysis of infinite media.

Keywords: Green's functions, Rayleigh wave propagation, Thin layer method, irregular boundaries, the Compacted Hyperelements method (CHM).