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Effects of artificial boundaries on SH-waves propagation in a Weiskopf type anisotropic liquid-filled porous medium

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ABSTRACT

Reported in the present paper are the results of the study of SH-waves propagation in a Weiskopf-type anisotropic porous medium. The finite difference method has been applied with artificial absorbing and reflecting boundaries to model the wave propagation and to study the reflections at the boundaries. Stability criteria have also been developed to make the finite difference scheme convergent and stable. Numerical values of the reflection coefficients are calculated at the left and right boundaries for different values of angle of incidence, anisotropic parameter and porosity parameter. A source term is considered to generate a wave field in the medium. Two-dimensional SH-waves profiles are generated and are depicted graphically to study the absorbing capabilities of the non-reflecting boundaries at different propagation times.

Keywords: Finite difference method, SH-Waves propagation, Artificial boundaries, Anisotropic liquid-filled porous medium, Earthquakes

INTRODUCTION

Earthquakes occur due to the movement and collision of tectonic plates inside the earth which generate two types of seismic waves. The first which travels through the earth's inner layers are body waves and the second surface waves move through the earth's crust. These surface waves, which propagate through the earth's crust, are mostly responsible for the damage and destruction during earthquakes. The geological structure of earth's surface may be presumed as a liquid-saturated anisotropic porous medium. Biot (1956) in his well-known work presented the idea of seismic wave propagation in an anisotropic porous media. Based on the theory of Biot (1956), the problems of wave propagation in porous media in different structures have been discussed by several authors, including Deresiewicz (1961), Bose (1962), Chakraborty and Dey (1982), Chattopadhyay and De (1983), Kalyani and Kar (1986) and others.

Many authors have developed various techniques to study seismic wave propagation in different media. Among them, the finite difference methods are mostly used because these methods are stable and converge to the exact solution rapidly. During the earthquakes, seismic waves are generated and propagate through an infinite medium. In the implementation of finite difference methods, computation is limited to a finite domain only, as it is restricted by artificial boundaries. Reynolds (1978) in his well-known research work showed that Dirichlet and Neumann boundary conditions cause reflection of the waves from the boundaries. Whereas, in the actual phenomenon, seismic waves propagate through these boundaries without reflection. To reduce edge reflections at the boundaries, the author implemented absorbing boundary conditions by factorizing second-order differential operators into first-order differential operators and showed a considerable reduction in edge reflection using synthetic seismograms. In related work, Zhang et. al. (1993) discussed the effects of absorbing boundary conditions near a free surface and at the corners of the computational domain in a 2D transversely isotropic (TI) medium by factorizing a second-order differential operator. Clayton and Engquist (1977) implemented absorbing boundary conditions with a finite difference method successfully for waves travelling with an incident angle less than 45^0. Based on this concept, Keys (1985), Cerjan et al. (1985), Sochacki et al. (1987) and Burns (1992) suggested an improved absorbing boundary condition by extending the computational domain. Further, Grote and Keller (2000) implemented absorbing boundary conditions for the time-dependent elastic wave equation in three dimensions using a finite difference scheme showing the superiority of their method over other existing finite difference methods.

Alpert et al. (2002) described a new approach to study scalar wave equations wherein they used non-reflecting boundary conditions. Comparing their numerical results with the various existing methods, they revealed that their proposed methods achieved superiority in terms of accuracy. Peng and Toksoz (1994) used a finite difference method to model 2D and 3D acoustic and elastic wave propagation by developing optimal absorbing boundary conditions. Tsynkov (2003) in his work numerically simulated time-dependent acoustic waves for unbounded unobstructed space implemented for non-local artificial boundary conditions. Further, Ju and Wang (2001), applied the concept of Higdon's one-way first-order boundary operator, to model unbounded elastic wave problems using a time-dependent absorbing boundary condition. Givoli and Neta (2003) proposed a high-order non-reflecting boundary condition for time-dependent wave problems in an unbounded domain. Hagstrom et al. (2008) improved and extended high-order local absorbing boundary conditions for two-dimensional waveguides. Hall and Wang