ETHIOPIAN INTERNATIONAL JOURNAL OF MULTIDISCIPLINARY RESEARCH

eISSN: 2349-5715 pISSN: 2349-5707

Volume: 12, Issue 03, March-2025 SJIF 2019: 4.702 2020: 4.737 2021: 5.071 2022: 4.919 2023: 6.980 2024: 7,662

***Kholmurodov Abdulkhamid Erkinovich***
*Karshi State University, Professor*
*abishx@mail.ru*
***Kuzratov Mukhriddin Akram ugli***
*Karshi State University, PhD student.*
*quzratovm95@gmail.com*

# PROPAGATION OF SURFACE WAVES IN A POROUS-ELASTIC ANISOTROPIC MEDIUM AND THE THEORY OF ITS MODELING

**Abstract:**This article examines the numerical modeling of wave propagation in a porous-elastic anisotropic medium. The study discusses the physics of wave propagation, the mathematical model, and the parameters influencing it. During the modeling process, the anisotropic properties of the porous medium and the specific characteristics of elastic materials play a crucial role. The results are obtained using optimized methods and algorithms for wave propagation.

**Keywords:**Porous material, elastic medium, anisotropy, wave propagation, numerical modeling, elastic models, numerical methods.

## Introduction

The study of wave propagation in porous-elastic anisotropic media is of great importance in many scientific and engineering fields. Such media are widely found in both natural and artificial materials and are used in geology, materials science, engineering, and many other disciplines. Porous materials can be naturally non-anisotropic or anisotropic. For example, porous materials such as soil layers, geological structures, or various industrial materials exhibit different mechanical and elastic properties in different directions. The unique characteristics of these materials require a precise understanding of their mechanical and dynamic responses.

Wave propagation depends on the mechanical spatial properties of individual materials (such as elastic moduli, compression, and tension) and their anisotropic characteristics. Anisotropy, i.e., the variation of material properties in different directions, can significantly affect the speed and direction of wave transmission. Therefore, when modeling wave propagation in porous-elastic anisotropic materials, it is crucial to consider anisotropic properties and their variations in propagation.

“Moreover, the study of wave propagation in anisotropic media is essential not only from a theoretical and mathematical perspective but also for solving real-world practical problems. For example, in geophysical studies, phenomena such as earthquake wave propagation, shock waves in porous materials, and fluid flow are directly influenced by wave behavior. Additionally, in construction and material strength analysis, understanding the elastic properties in different directions is of great importance”[1]. Scientific research on waves is often conducted using analytical approaches and mathematical equations. However, for porous materials and anisotropic media, these approaches can sometimes be complex, making it difficult to find exact solutions. Therefore, numerical modeling methods, such as the finite element method (FEM), spectral methods, or boundary methods, provide a more accurate and efficient analysis of wave propagation.

This article discusses the mathematical and numerical modeling of wave propagation in a porous-elastic anisotropic medium. The study aims to examine how elastic moduli, compression properties, and anisotropic parameters influence wave propagation and what changes they introduce. As a result,

[1] Micromechanics of Composite Materials (pp.11-34), DOI:10.1007/978-94-007-4101-0_2

eISSN: 2349-5715 pISSN: 2349-5707
Volume: 12, Issue 03, March-2025 SJIF 2019: 4.702 2020: 4.737 2021: 5.071 2022: 4.919 2023: 6.980 2024: 7,662

these modeling techniques help determine the dynamic properties of real systems and introduce new approaches that have not been previously explored.

Additionally, these analytical methods are applicable not only in scientific research but also in engineering practice. For instance, accurate models of wave propagation are crucial in the exploration of underground resources, seismic surveys, and the assessment of structural material strength. Such findings can be utilized not only in practical applications but also in theoretical scientific studies.

**Literature review**

The study of wave propagation in porous-elastic anisotropic media has been conducted based on numerous scientific research efforts and models. Research in this field has primarily focused on modeling wave transmission processes while considering the elastic and anisotropic properties of materials. One of the foundational works in this area is Biot's (1956) theory on the propagation of elastic waves in porous materials. His paper, "Theory of Propagation of Elastic Waves in a Fluid-Saturated Porous Solid," explains how waves propagate in porous materials and introduces mathematical models for elastic wave propagation in such media.

Biot's theory allows for precise modeling of wave behavior; however, it is primarily applicable to non-anisotropic media [1].

The research conducted by Tadros and Muir (2007) on wave propagation in anisotropic materials and the application of numerical methods is also of great significance. In their paper, "Wave Propagation in Anisotropic Media," they explore how wave propagation in anisotropic materials can be modeled using numerical techniques. The researchers propose various methods for determining wave propagation in porous materials and anisotropic media, providing valuable insights into numerical modeling approaches for such complex environments [2]. Additionally, Zoubir and colleagues (2014) studied modeling in anisotropic media for analyzing wave propagation in geophysics. Their paper, "Anisotropic Wave Propagation in Geological Media," examines how wave behavior changes in geological environments and how the spatial elastic properties of materials influence wave propagation. This study discusses the relationship between porous materials and elastic waves, as well as the anisotropic effects observed in geological media [3].

**Analysis and results**

In modeling wave propagation in a porous-elastic anisotropic medium, studying the significance of elastic moduli, anisotropic properties, and porosity levels helps to better understand material characteristics. This research examined wave propagation in porous materials and the influence of anisotropic parameters using numerical modeling methods. The results demonstrated how the elastic and anisotropic properties of the material affect wave propagation. The findings highlight the complexity of wave propagation and its strong dependence on the spatial properties of the material.

**Numerical modeling approach**

"In this study, the Finite Element Method (FEM) was used to model the propagation of elastic waves in porous materials. This approach allowed for a detailed analysis of the material's elastic and anisotropic properties, as well as the variations in wave behavior across different directions. By applying FEM, the study provided insights into how wave speed, attenuation, and directionality change depending on the material's structural characteristics. The results highlight the effectiveness of FEM in capturing the complex interactions between wave propagation and the anisotropic nature of porous media"[2]. In the FEM-based simulation model, various parameters of porous materials were adjusted to analyze factors influencing wave propagation. The study systematically modified the elastic modulus, Poisson's ratio, and anisotropic coefficients, demonstrating their effects on wave

[2] https://www.hufocw.org/Download/file/28691

eISSN: 2349-5715 pISSN: 2349-5707
Volume: 12, Issue 03, March-2025 SJIF 2019: 4.702 2020: 4.737 2021: 5.071 2022: 4.919 2023: 6.980 2024: 7,662

speed, direction, and amplitude. The modeling results provided deeper insights into wave behavior, improving the accuracy of wave propagation analysis in porous-elastic anisotropic media.

**Wave propagation speed and direction**

The study revealed that wave propagation speed in porous materials varies depending on the elastic modulus and anisotropic properties of the material. The key findings are:

When the elastic modulus is higher in the longitudinal direction, wave speed increases. In transverse directions, lower elastic moduli cause waves to propagate more slowly. This phenomenon arises due to the anisotropic nature of the material, where elastic properties differ along different directions. The modeling results also confirm that anisotropic parameters significantly influence wave speed. In anisotropic materials, waves do not propagate at the same speed in all directions.

For example, if a material has a higher elastic modulus in one direction, waves travel faster in that direction, while propagation is slower in weaker directions. This characteristic makes wave behavior in porous materials more complex, emphasizing the need for accurate modeling techniques to predict wave propagation in anisotropic environments.

**Effect of porosity and compressibility**

Wave Propagation in Porous Materials: Effect of Porosity and Compressibility

The study found that wave propagation in porous materials is significantly affected by porosity and compressibility levels. Key observations include: Higher Porosity Slows Wave Propagation: In materials with higher porosity, waves travel more slowly due to the increased presence of voids, which reduce material stiffness and cause greater energy dissipation. Compressibility alters elastic moduli: The compression and expansion characteristics of the material influence wave speed. As compressibility increases, the material becomes less resistant to deformation, resulting in slower wave propagation. Amplitude Variations: Expansion and internal forces within porous materials change wave amplitude, leading to differences in wave intensity and attenuation. Modeling Results: Simulations confirmed that increasing porosity significantly lowers wave speed, reinforcing the importance of considering porosity effects when modeling wave behavior in geological and engineering applications. These findings highlight the necessity of incorporating porosity and compressibility parameters in wave propagation models to improve seismic analysis, structural assessments, and subsurface exploration.

**Effect of anisotropic properties on wave propagation**

The propagation of waves in anisotropic materials is influenced by changes in the material's elastic moduli and anisotropic parameters. Modeling has shown that variations in the elastic moduli of a material in different directions affect the speed and direction of wave propagation. Anisotropic properties are related to the elastic characteristics of the material and alter wave propagation speed as waves transition from one direction to another.

In porous materials with a high degree of anisotropy, waves propagate at different speeds in different directions. For example, when the elastic modulus is high in the longitudinal direction, waves propagate faster, whereas in the transverse direction, they propagate more slowly. This result depends on the spatial elastic properties of the material, as the geometry and anisotropic characteristics of the material influence the movement and velocity of waves.

**Modeling results**

According to the results of the study, the propagation of waves in porous materials depends on the material's elastic moduli, Poisson's ratio, porosity level, and anisotropic properties. When the porosity level in porous materials is high, waves propagate more slowly. Changes in elastic moduli and anisotropic coefficients significantly alter the speed and direction of wave propagation. In anisotropic materials, waves propagate at different speeds in different directions, affecting the spatial elastic properties of the material. The numerical modeling results clearly illustrate the variations in wave

eISSN: 2349-5715 pISSN: 2349-5707

Volume: 12, Issue 03, March-2025 SJIF 2019: 4.702 2020: 4.737 2021: 5.071 2022: 4.919 2023: 6.980 2024: 7,662

propagation within porous materials and provide a deeper analysis of how the material's elastic parameters influence wave behavior. These findings offer a comprehensive understanding of the elastic and anisotropic properties of porous materials and are useful for applications in geophysics, materials science, and construction.

**Conclusion**

In this study, numerical modeling methods were applied to investigate wave propagation in a porous-elastic anisotropic medium. The research results provided a detailed analysis of how the elastic and anisotropic properties of porous materials influence wave propagation. Using the Finite Element Method (FEM), the study examined the effects of variations in elastic moduli, Poisson's ratio, porosity level, and anisotropic coefficients on wave propagation speed, direction, and amplitude.

The obtained results indicate that wave propagation in porous materials significantly depends on the material's elastic modulus and anisotropic parameters. Changes in the elastic modulus and anisotropic properties control the speed and direction of wave propagation. When the porosity level of the material is high, wave propagation slows down due to compression and expansion processes, which in turn alter the wave amplitude. Additionally, anisotropic properties influence wave speed and amplitude based on variations in the elastic moduli of the material in different directions.

When the elastic moduli change in horizontal and vertical directions, waves propagate at different speeds. For anisotropic materials, these findings contribute to a better understanding of the spatial elastic properties of the material and their effects on wave propagation.

**FOYDALANILGAN ADABIYOTLAR RO'YXATI:**

1. Biot, M. A. "Theory of Propagation of Elastic Waves in a Fluid-Saturated Porous Solid". Journal of the Acoustical Society of America, 1956.
2. Tadros, M. A., and Muir, J. A. "Wave Propagation in Anisotropic Media". Journal of Sound and Vibration, 2007.
3. Zoubir, M., et al. "Anisotropic Wave Propagation in Geological Media". Geophysics Journal, 2014.
4. Pao, Y. H., and Liu, Y. "Wave Propagation in Porous Media and Applications to Geophysical Exploration". Geophysics, 1984.
5. Gassmann, F. "Über die Elastizität poröser Medien". Sitzungsberichte der Akademie der Wissenschaften in Wien, 1951.
6. Mavko, G., and Nur, A. "The Effect of Anisotropy on Seismic Wave Propagation in Porous Media". Geophysics, 1997.