

## In-situ Acoustic Velocity Measurement Method in Soft Rock Formations Based on Guided Wave Characteristics of Fluid-Filled Pipes Postprint

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### Abstract

Accurately obtaining acoustic velocity parameters of soft rock formations (such as near-surface soils and seabed sediments) is crucial for calculating their key mechanical parameters (Young's modulus, Poisson's ratio). However, existing in-situ acoustic velocity measurement techniques have limitations: cross-hole testing has a depth range that does not match shallow engineering applications and ignores guided wave characteristics and dispersion effects; the shallow shear wave refraction method relies on the assumption of near-surface horizontal layers and performs poorly under complex geological conditions. To address these issues, this paper proposes an in-situ measurement method based on guided wave propagation characteristics in fluid-filled pipes, aiming to directly obtain acoustic velocities of soft rock formations and provide critical input for subsequent mechanical parameter calculations. The core of this method lies in: first, theoretically solving the guided wave dispersion equation for a fluid-filled pipe-soft rock formation coupled model, thoroughly analyzing the propagation characteristics of modal waves, and discovering that their attenuation characteristics are highly sensitive to changes in formation acoustic velocity, thereby establishing a theoretical model for inverting formation acoustic velocity using  $L(0,1)$  mode guided waves. Second, based on this model, an experimental prototype system suitable for in-situ measurement (attachable to seabed cone penetration test devices) was successfully developed, including key components such as acoustic transmitting/receiving transducers and core functional circuit boards, and a complete testing platform was constructed. Finally, through systematic performance experiments, the acoustic signal characteristics of guided waves excited inside the pipe were comparatively analyzed when the external medium changed (air, water, and simulated sediments). Theoretical and measured results consistently demonstrate that the attenuation characteristics of guided waves ( $L(0,1)$  mode) in fluid-filled pipes are significantly controlled by the acoustic velocity

of the external soft rock formation. This key feature provides an effective approach for in-situ inversion of formation acoustic velocity. Experimental data fully validate the feasibility and effectiveness of this method, offering a new technical approach for in-situ measurement of mechanical parameters in soft rock formations.

## Full Text

# In-situ Measurement of Acoustic Velocity in Soft Rock Formations Using Characteristics of Fluid-Filled Pipe-Guided Waves

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## Abstract

Accurately obtaining acoustic velocity parameters of soft rock formations (such as near-surface soils and seabed sediments) is crucial for calculating their key mechanical parameters (Young's modulus, Poisson's ratio). However, existing in-situ acoustic velocity measurement techniques have limitations: cross-well testing depth ranges do not match shallow engineering requirements, and guided wave characteristics and dispersion effects are ignored; shallow shear wave refraction methods rely on assumptions of near-surface horizontal layering, making them ineffective under complex geological conditions. To address these issues, this paper proposes an in-situ measurement method based on the propagation characteristics of guided waves in fluid-filled pipes, aiming to directly obtain acoustic velocities of soft rock formations to provide critical input for subsequent mechanical parameter calculations.

The core of this method lies in three aspects. First, the guided wave dispersion equation for a fluid-filled pipe-soft rock formation coupled model was theoretically solved, the propagation characteristics of modal waves were deeply analyzed, and it was discovered that their attenuation features are highly sensitive to formation acoustic velocity changes, thereby establishing a theoretical model for inverting formation acoustic velocity using  $L(0,1)$  modal guided waves. Second, based on this model, an experimental prototype system suitable for in-situ

measurement (which can be attached to seabed cone penetration test apparatus) was successfully developed, including key components such as acoustic transmitting/receiving transducers and core functional circuit boards, and a complete testing platform was established. Finally, through systematic performance experiments, the acoustic signal characteristics of guided waves excited within the pipe were comparatively analyzed when the external medium (air, water, and simulated sediments) changed. Theoretical and measured results consistently demonstrate that the attenuation characteristics of guided waves (L(0,1) mode) in fluid-filled pipes are significantly controlled by the acoustic velocity of the external soft rock formation. This key feature provides an effective approach for in-situ inversion of formation acoustic velocity. Experimental data fully validates the feasibility and effectiveness of this method, providing a new technical approach for in-situ measurement of mechanical parameters in soft rock formations.

**Keywords:** soft rock formation; in-situ acoustic velocity; guided wave; Poisson's ratio

*Note: Figure translations are in progress. See original paper for figures.*

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