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Can the seismic wave attenuation characteristics of various soils be identified using distributed acoustic sensing?

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A B S T R A C T

Seismic waves exhibit distinct attenuation characteristics that are contingent upon the medium they traverse. The attenuation characteristics can be employed to monitor engineering activities, such as detecting gas pipeline leaks and third-party intrusions, by the utilization of Distributed Acoustic Sensing (DAS) technology. This study aims to explore the feasibility of identifying the seismic wave attenuation characteristics of different soils using DAS. A circular experimental pit with a diameter of 1 m was designed to measure the responses of various soils. Seismic waves were recorded while propagating through sand and clay under different overlying pressure conditions, encompassing both dry and wet states. The waveform data, collected at various distance from the point of excitation, were analyzed using Power Spectral Density (PSD), Continuous Wavelet Transform (CWT), and quality factor analysis. The energy attenuation amplitude of seismic waves shows an opposite pattern in sand and clay as water content increased. By utilizing the seismic wave attenuation characteristics, it is possible to issue timely warnings for identifying third-party intrusions around urban underground tunnels and pipelines to mitigate potential damage to underground infrastructure.

1. Introduction

Seismic wave attenuation is a crucial and extensively researched topic within fields such as geophysics and geotechnical engineering. During the propagation of seismic waves, microstructures within the medium, such as pores and cracks, play a significant role in causing attenuation. Attenuation refers to the gradual loss of energy or decrease in the amplitude of the seismic waves as they travel over a specific distance. As seismic waves encounter these microstructures, the energy of the waves is dispersed and converted into heat due to frictional interactions. This energy dissipation leads to a decrease in the wave's amplitude and intensity. When the waves interact with pores and cracks, the propagation speed and direction may change, as well, resulting in alterations in the shape of the wavefront and the times of arrival. This phenomenon can lead to the distortion of the phase of the seismic waves. The attenuation characteristics of seismic waves vary according to intrinsic properties of the propagation medium, including density, saturation, and uniformity. By utilizing these attenuation characteristics, various events such as pipeline leaks (Muggleton et al., 2020), rock bursts (Wu et al., 2022), as well as the processes like geological storage of carbon dioxide (Azuma et al., 2014), and underground cavities (Grandjean and Leparoux, 2004) can be monitored. Geophysical method is an effective and widely used non-destructive monitoring method.

Theoretical explanations for seismic wave attenuation can be divided into several categories: (1) When seismic waves propagate through inhomogeneous media, energy attenuation occurs due to scattering effects. Chernov et al. proposed a scalar wave propagation theory, and Knopoff et al. verified the energy attenuation phenomenon of seismic waves propagating in porous media (Hudson and Knopoff, 1989; Varela et al., 1993; Chernov et al., 1961); (2) Based on the assumption of viscoelastic media, various seismic wave energy attenuation models such as Maxwell, Kelvin-Voight, and SLS were developed (Carcione et al., 1988). (3) Based on the assumption that underground media is a biphasic medium, Biot theory (Biot, 1956) and jet flow theory (Dvorkin and Nur, 1993) were developed. Murphy et al. verified that jet flow mechanisms in sediments are the main cause of attenuation of shear wave and compression wave (Murphy, 1982). Therefore, the site media conditions and propagation distance are the main factors affecting the attenuation characteristics of seismic waves.

Distributed Acoustic Sensing (DAS) based on optical fiber (Hartog

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