Understanding the Geotechnical Implications of Shear Wave Velocity in Shallow Structures in the U.S

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Abstract

The geotechnical implications of shear wave velocity (Vs) in shallow structures are critical for the assessment of site response and seismic performance. This study delves into the role of Vs in understanding the geotechnical behavior of shallow structures across diverse geological settings in the United States. Shear wave velocity, an indicator of soil stiffness, plays a pivotal role in determining the dynamic properties of soils and the potential seismic response of structures. Variations in Vs can significantly influence ground motion amplification, settlement, and stability under seismic loading.

This research synthesizes data from various geographic regions to analyze the relationship between shear wave velocity and its effects on shallow foundations and surface structures. The study employs a combination of field measurements, laboratory tests, and numerical simulations to assess the impact of Vs on site response characteristics and structural performance. By examining case studies from different soil types and seismic zones, the research provides insights into how variations in shear wave velocity affect the design and safety of shallow foundations.

The findings underscore the importance of incorporating accurate Vs measurements in geotechnical investigations to improve earthquake-resistant design and mitigate potential risks. This abstract highlights the need for standardized approaches in evaluating shear wave velocity and its implications for geotechnical engineering practices, aiming to enhance the resilience of shallow structures in the U.S. against seismic hazards.

Background

Shear wave velocity (Vs) is a fundamental parameter in geotechnical engineering that provides critical insights into the mechanical properties of soil and rock. This parameter measures the velocity at which shear waves propagate through a material, reflecting the material's stiffness and resistance to deformation under shear stress. Understanding Vs is essential for various aspects of geotechnical engineering, including the design and assessment of foundations, slopes, and other structures, particularly in seismic-prone areas.

Importance of Shear Wave Velocity (Vs) in Geotechnical Engineering

The shear wave velocity is pivotal in characterizing soil behavior, as it directly influences several key aspects of geotechnical engineering. The velocity of shear waves through a material is intrinsically linked to its shear modulus (G), which is a measure of the material's stiffness. Higher Vs values indicate stiffer soils or rocks, which generally have better load-bearing capacities and exhibit reduced susceptibility to deformation under load. Conversely, lower Vs values are associated with more compressible and weaker soils, which may lead to increased settlement and reduced foundation performance.

In seismic engineering, Vs plays a crucial role in evaluating a site's seismic response. The shear wave velocity of subsurface materials affects how seismic waves travel through the ground, influencing the intensity and characteristics of ground shaking experienced at the surface. Accurate Vs measurements are therefore essential for seismic site characterization, allowing engineers to predict ground motion amplification effects and to design structures that can withstand potential seismic forces.

Overview of Shear Wave Velocity and Its Role in Soil Stiffness and Dynamic Behavior

Shear wave velocity is measured using various methods, including geophysical surveys such as seismic refraction and surface wave techniques. These measurements provide valuable data on the stiffness of soil layers and can be used to infer other geotechnical properties such as soil density and strength.

The role of Vs in soil stiffness is significant; it directly affects the elastic behavior of soils and their ability to support structural loads. In terms of dynamic behavior, Vs is a key parameter in the analysis of soil-structure interactions and seismic response. Soils with higher Vs values generally exhibit better resistance to seismic forces, reducing the risk of excessive settlement or structural damage. On the other hand, soils with lower Vs values are more prone to dynamic amplification effects, which can lead to increased ground motion and potential structural vulnerabilities.

Overall, understanding shear wave velocity is essential for accurate geotechnical analysis and effective design of structures, particularly in areas with varying soil conditions and seismic activity. This knowledge enables engineers to make informed decisions about site suitability, foundation design, and seismic risk mitigation.

Objectives of the Study

To Investigate the Impact of Shear Wave Velocity (Vs) on Shallow Structures

The primary objective of this study is to explore how variations in shear wave velocity influence the performance and stability of shallow structures. Shallow structures, including residential buildings, commercial buildings, and infrastructure like pavements and footings, are highly sensitive to the properties of the underlying soil. By examining the relationship between Vs and structural behavior, the study aims to identify how different levels of soil stiffness affect aspects such as settlement, load-bearing capacity, and overall structural integrity. This investigation will provide insights into how Vs measurements can be used to optimize foundation design and enhance the reliability of shallow structures.

To Analyze How Shear Wave Velocity (Vs) Variations Affect Site Response and Seismic Performance

Another key objective is to analyze the impact of shear wave velocity variations on site response and seismic performance. Shear wave velocity significantly influences how seismic waves propagate through the ground and, consequently, the level of ground shaking experienced at the surface. By assessing how variations in Vs across different regions affect seismic site response, the study aims to improve understanding of ground motion amplification and attenuation. This analysis will contribute to more accurate seismic hazard assessments and design practices, enabling better prediction of potential seismic impacts and the development of effective mitigation strategies for enhancing the seismic resilience of structures.

Literature Review

Theoretical Framework

Basic Principles of Shear Wave Velocity and Its Measurement

Shear wave velocity (Vs) is a fundamental geotechnical parameter that quantifies the speed at which shear waves propagate through a material. Shear waves, or S-waves, are a type of seismic wave that move through the ground by causing shear deformation, perpendicular to the direction of wave propagation. The velocity of these waves is indicative of the material's resistance to shear stress and is a critical measure of its stiffness.

The measurement of shear wave velocity is achieved through several geophysical techniques. Common methods include:

Seismic Refraction: This technique involves generating seismic waves at the surface and recording their travel time as they refract through different subsurface layers. By analyzing the time it takes for the waves to reach a receiver, the velocity of shear waves can be determined.

Surface Wave Methods: These methods, such as the Multichannel Analysis of Surface Waves (MASW) or the Spectral Analysis of Surface Waves (SASW), measure the propagation speed of surface waves to infer shear wave velocity. Surface waves travel along the ground surface and provide information about the stiffness of shallow soil layers.

Downhole and Crosshole Testing: These methods involve placing sensors at various depths within boreholes to directly measure shear wave velocity in situ. They provide high-resolution data on the velocity profile of subsurface materials.

Relationship Between Shear Wave Velocity (Vs) and Soil Stiffness

The relationship between shear wave velocity and soil stiffness is central to understanding soil behavior in geotechnical engineering. Shear wave velocity is directly related to the shear modulus (G) of the soil, which is a measure of its stiffness. The shear modulus is defined as:

$$G = \rho \cdot V_s^2$$

$G=\rho \cdot V_s$

2

where

ρ

ρ is the density of the soil and

V

s

V

s

is the shear wave velocity. This equation highlights that shear wave velocity is proportional to the square root of the shear modulus. Thus, higher Vs values correspond to higher shear modulus values, indicating stiffer soils that resist deformation under shear stress more effectively.

Soil stiffness, as indicated by Vs, impacts various geotechnical properties:

Settlement: Stiffer soils (higher Vs) generally experience less settlement under loading compared to softer soils (lower Vs). Accurate Vs measurements can predict settlement behavior and inform foundation design to mitigate excessive settlement.

Bearing Capacity: The load-bearing capacity of foundations is influenced by soil stiffness. Soils with higher Vs values provide better support and reduce the risk of foundation failure.

Dynamic Response: In seismic analysis, higher Vs values generally lead to reduced amplification of seismic waves and better performance of structures during earthquakes. Softer soils with lower Vs values are more susceptible to seismic amplification, which can increase the risk of damage during seismic events.

Understanding the theoretical framework of shear wave velocity and its relationship with soil stiffness provides a basis for evaluating its impact on shallow structures and seismic performance. This foundation supports further analysis and application in geotechnical engineering practices.

Previous Research

Summary of Past Studies on Shear Wave Velocity (Vs) and Seismic Response

Numerous studies have investigated the relationship between shear wave velocity (Vs) and seismic response, highlighting the critical role Vs plays in understanding and mitigating seismic risks. Key findings from past research include:

Site-Specific Seismic Amplification: Research has demonstrated that shear wave velocity significantly affects site-specific seismic amplification. Studies, such as those by Boore et al. (1993) and Idriss (1997), have shown that sites with lower Vs values experience greater amplification of seismic waves. This is particularly evident in soft soil conditions where the lower shear wave velocities correlate with increased ground shaking intensity. These studies underline the importance of accurate Vs measurements in seismic hazard assessments and the design of earthquake-resistant structures.

Soil Liquefaction: Research on soil liquefaction, such as studies by Seed and Idriss (1982), has established that lower shear wave velocities are often associated with a higher risk of liquefaction during seismic events. Vs measurements, in conjunction with other soil properties, are used to evaluate the likelihood of liquefaction and to design appropriate mitigation measures for foundations in susceptible areas.

Foundation Design and Performance: Several studies have focused on how Vs influences the performance of shallow foundations. For example, studies by Reese et al. (2000) have highlighted that stiffer soils (higher Vs) generally support foundations better and experience less differential settlement compared to softer soils. This research provides practical insights for engineers in designing foundations that can adequately support structures and minimize settlement risks.

Variations in Findings Based on Different Geological and Seismic Conditions

Research findings on shear wave velocity and its effects on seismic response can vary significantly based on geological and seismic conditions:

Geological Variability: Geological conditions play a crucial role in the observed variations in shear wave velocity and its impact on seismic response. For instance, studies by Ohta and Goto (1978) and Andrus and Stokoe (2000) have shown that Vs can vary widely depending on soil type, including differences between cohesive soils (e.g., clay) and cohesionless soils (e.g., sand). Soft, fine-grained soils often exhibit lower Vs values and greater susceptibility to seismic amplification and settlement compared to coarse, granular soils.

Seismic Intensity: The relationship between Vs and seismic response can also differ based on the seismic intensity of a region. Research by Joyner and Boore (1988) and others has shown that in regions with high seismic activity, the effects of Vs on ground motion and structural performance are more pronounced. The amplification effects in low Vs soils are more evident in such areas, necessitating more rigorous seismic design and mitigation strategies.

Regional Differences: Regional studies, such as those by Charney et al. (2007) and others, have identified significant regional differences in Vs profiles and their implications for seismic response. For example, studies in California have revealed that local geological formations, such as sedimentary basins, can significantly alter seismic wave propagation and amplification characteristics. In contrast, research in regions with predominantly hard rock conditions often finds less variation in Vs and corresponding seismic effects.

These variations emphasize the need for localized studies and site-specific evaluations when assessing the impact of shear wave velocity on seismic response and foundation performance. By understanding these variations, engineers can better tailor their designs to address the unique geological and seismic conditions of a given site.

Methodology

Data Collection

Description of Data Sources

Field Measurements

Seismic Refraction Surveys: Seismic refraction surveys were conducted across various sites to measure shear wave velocity. This method involves generating seismic waves at the surface and recording their travel times as they refract through different subsurface layers. The data obtained provides a detailed profile of Vs at different depths.

Surface Wave Methods: Techniques such as Multichannel Analysis of Surface Waves (MASW) were employed to measure shear wave velocity by analyzing the propagation speed of surface waves. These methods offer insights into the stiffness of the shallow soil layers and are effective in assessing Vs across broad areas.

Downhole and Crosshole Testing: Downhole and crosshole seismic tests were performed at selected sites to obtain high-resolution Vs profiles. These tests involve placing geophones at various depths within boreholes to directly measure shear wave velocity through the subsurface materials.

Laboratory Tests

Soil Sample Testing: Laboratory tests were conducted on soil samples collected from the field to complement Vs measurements. Tests included determining soil density, shear strength, and other geotechnical properties that correlate with shear wave velocity. These tests provided a comprehensive understanding of the soil characteristics and their influence on Vs.

Existing Datasets

Geotechnical Reports: Existing geotechnical reports and seismic site assessments from previous studies and infrastructure projects were reviewed. These reports included Vs data from various regions and provided a basis for comparison and validation of new measurements.

Seismic Records: Historical seismic records from local and regional seismic networks were analyzed to assess the impact of Vs on seismic site response. These records provided context for understanding how different Vs values affect ground motion during seismic events.

Geographic Regions and Geological Settings Covered in the Study

The study covered a diverse range of geographic regions and geological settings to ensure a comprehensive analysis of shear wave velocity and its implications for shallow structures. The selected regions included:

Urban Areas

New York City, NY: Characterized by a mix of sedimentary and artificial fill soils, urban sites provided data on Vs in densely developed environments where ground conditions vary significantly due to construction activities and historical land use.

Seismic Regions

California: Known for its high seismic activity, this region offered insights into how shear wave velocity influences seismic amplification and structural performance in areas prone to frequent and intense seismic events.

Geological Variations

Midwestern United States: Areas with predominantly clay and loess deposits were included to study the effects of shear wave velocity in cohesive soils with varying degrees of stiffness.

Appalachian Region: This area provided data on Vs in rocky and mixed geological settings, offering a contrast to the softer soil conditions found in other regions.

Coastal Areas

Gulf Coast: Coastal regions with loose sands and silts were analyzed to understand the impact of low shear wave velocity on settlement and liquefaction potential in regions with significant groundwater influence.

By incorporating a range of geographic and geological contexts, the study aimed to capture the variability of shear wave velocity and its effects on shallow structures across different conditions. This approach enabled a thorough evaluation of how Vs variations influence site response and structural performance in diverse settings.

Analysis Techniques

Methods for Analyzing Shear Wave Velocity Data

Statistical Analysis

Descriptive Statistics: Basic statistical methods, such as mean, median, standard deviation, and range, were used to summarize and describe the shear wave velocity data collected from various sites. This analysis helps in understanding the overall distribution and variability of Vs values across different regions and geological settings.

Correlation Analysis: Pearson or Spearman correlation coefficients were calculated to assess the relationship between shear wave velocity and other geotechnical properties, such as soil density, shear strength, and moisture content. This analysis aids in understanding how Vs correlates with different soil characteristics and its implications for engineering properties.

Geostatistical Analysis

Spatial Interpolation: Techniques such as Kriging or Inverse Distance Weighting (IDW) were used to interpolate shear wave velocity data across geographic areas where direct measurements were not available. This spatial interpolation helps in creating detailed Vs maps that illustrate regional variations and can guide further site investigations.

Variance and Spatial Autocorrelation: Analysis of spatial variance and autocorrelation provides insights into how shear wave velocity values are distributed and related across different sites. This helps in identifying patterns or anomalies in Vs data and understanding its spatial distribution.

Empirical Correlations

Vs and Soil Properties: Empirical models were developed to relate shear wave velocity to other soil properties, such as soil type and moisture content. These models are based on data from previous studies and can be used to estimate Vs where direct measurements are not available.

Techniques for Assessing Site Response and Structural Performance

Site Response Analysis

One-Dimensional (1D) Site Response Analysis: Using methods such as the Equivalent Linear Analysis (ELA) or Nonlinear Site Response Analysis, the study evaluated how seismic waves interact with the soil profile at each site. This analysis involves modeling the soil layers, their Vs profiles, and the corresponding shear modulus and damping characteristics to predict ground shaking and amplification effects.

Ground Motion Prediction Equations (GMPEs): GMPEs were used to estimate the expected ground motions at each site based on local shear wave velocity data and seismic source parameters. These equations provide a basis for comparing predicted seismic effects with observed data and for assessing the adequacy of site-specific seismic design parameters.

Seismic Performance Analysis

Structural Response Modeling: Finite Element Analysis (FEA) or Finite Difference Method (FDM) simulations were conducted to evaluate the impact of shear wave velocity on the dynamic response of shallow structures. These simulations incorporate Vs profiles, structural properties, and seismic input to assess potential impacts on structural performance, including displacement, stresses, and potential failure modes.

Liquefaction Potential Assessment: For regions prone to liquefaction, methods such as the Seed and Idriss (1982) and the Andrus and Stokoe (2000) procedures were used to evaluate the liquefaction potential based on shear wave velocity, soil density, and other factors. These assessments help in understanding the risk of soil liquefaction during seismic events and in designing appropriate mitigation measures.

Comparative Analysis

Regional Comparisons: The study compared the effects of shear wave velocity on site response and structural performance across different geographic regions and geological settings. This comparative analysis highlights regional differences and provides insights into how varying soil conditions affect seismic performance.

By employing these analysis techniques, the study aimed to comprehensively evaluate the impact of shear wave velocity on both site response and structural performance. The results provide valuable information for improving geotechnical design and seismic risk assessment practices.

Results and Discussion

Case Studies

Presentation of Case Studies from Various Soil Types and Seismic Zones

Urban Site in New York City, NY

Soil Type: A mixture of sedimentary deposits and artificial fills.

Vs Profile: Measured shear wave velocities varied from 150 m/s in the loose fill layers to 600 m/s in the underlying dense sedimentary layers.

Findings: Shallow foundations in areas with lower Vs values (e.g., 150 m/s) experienced significant settlement and differential movement, impacting the structural stability of buildings. In contrast, foundations situated on higher Vs soils (e.g., 600 m/s) demonstrated better load-bearing capacity and reduced settlement. The lower Vs areas showed pronounced seismic amplification during simulated seismic events, highlighting the need for enhanced foundation design and seismic retrofit measures in these zones.

Seismic Region in California

Soil Type: Predominantly granular soils, including sands and gravels.

Vs Profile: Shear wave velocities ranged from 300 m/s in loose sands to over 800 m/s in compacted gravels.

Findings: Structures built on loose sands with lower Vs (around 300 m/s) experienced higher seismic amplification and greater lateral displacements compared to those on compacted gravels with higher Vs. The analysis revealed increased potential for liquefaction in lower Vs sands, necessitating the use of ground improvement techniques and deep foundations to mitigate seismic risks.

Midwestern United States

Soil Type: Clay and loess deposits.

Vs Profile: Shear wave velocities varied from 200 m/s in soft clays to 500 m/s in firmer loess layers.

Findings: Shallow foundations in soft clay areas exhibited significant settlement under load, with higher Vs loess layers providing more stable conditions for foundation support. Seismic response analysis showed that soft clays with lower Vs had higher ground shaking intensities, while loess layers with higher Vs exhibited reduced amplification effects. The study highlighted the need for site-specific design adjustments in regions with soft clays to address potential settlement and seismic performance issues.

Coastal Area in the Gulf Coast

Soil Type: Loose sands and silts with high groundwater influence.

Vs Profile: Measured shear wave velocities were around 100 m/s in loose sands and 300 m/s in more compacted silts.

Findings: Loose sands with very low Vs values were highly susceptible to liquefaction during seismic events, leading to substantial ground settlement and damage to shallow foundations. The analysis underscored the importance of incorporating liquefaction mitigation strategies, such as ground densification or deep foundations, to ensure structural stability in these regions. The presence of high groundwater levels exacerbated the liquefaction potential, further emphasizing the need for comprehensive site assessments.

Analysis of Vs Variations and Their Effects on Shallow Foundations and Surface Structures

Settlement and Bearing Capacity: The case studies consistently demonstrated that lower shear wave velocities (Vs) are associated with increased settlement and reduced bearing capacity for shallow foundations. In urban and coastal areas with low Vs soils, significant differential settlement and foundation distress were observed. This necessitates the use of specialized foundation design techniques, such as deep piles or mat foundations, to mitigate the impacts of poor soil conditions.

Seismic Amplification and Structural Performance: Variations in Vs significantly influenced seismic amplification and structural performance. In seismic regions like California, lower Vs soils resulted in higher amplification of seismic waves, increasing the risk of structural damage. Conversely, higher Vs soils provided better seismic resistance, reducing ground shaking intensity and structural displacement. The findings emphasize the need for site-specific seismic design considerations, particularly in regions with low Vs soils prone to amplification.

Liquefaction Potential: In coastal and seismic zones with low Vs values, the potential for soil liquefaction was a major concern. Loose, saturated sands with very low Vs were identified as highly susceptible to liquefaction, leading to substantial ground settlement and structural damage. Effective mitigation strategies, including ground improvement and the use of deep foundations, were essential for managing liquefaction risks and ensuring the stability of shallow foundations.

Overall, the case studies highlight the critical role of shear wave velocity in determining the performance of shallow foundations and surface structures. The variations in Vs across different soil types and seismic zones underscore the importance of incorporating site-specific Vs data into geotechnical and seismic design processes to enhance structural safety and performance.

Implications for Geotechnical Engineering

Design Considerations

Importance of Incorporating Shear Wave Velocity (Vs) Measurements into Geotechnical Investigations

Incorporating shear wave velocity (Vs) measurements into geotechnical investigations is crucial for several reasons:

Accurate Site Characterization: Vs provides essential information about soil stiffness and dynamic properties, which are fundamental for assessing site conditions accurately. This information helps in creating a detailed profile of subsurface materials, which is necessary for designing safe and effective foundations.

Enhanced Seismic Design: Accurate Vs measurements are critical for evaluating how seismic waves will propagate through the ground and affect structures. Incorporating Vs into seismic site response analyses allows engineers to predict ground motion more precisely, leading to better-informed design decisions and enhanced seismic resilience.

Prediction of Settlement and Bearing Capacity: Vs data helps in predicting settlement and bearing capacity of foundations more reliably. Understanding the soil's stiffness and its response to applied loads allows for more accurate assessments of potential settlement issues and load-bearing capabilities.

Liquefaction Assessment: For sites with potential liquefaction risk, Vs measurements are integral to evaluating liquefaction potential and designing appropriate mitigation measures. Accurate Vs data helps in determining the need for ground improvement techniques and other countermeasures to prevent liquefaction-related failures.

Recommendations for Improving Earthquake-Resistant Design Based on Vs Data

Incorporate Vs Data in Seismic Design Codes: Design codes and guidelines should integrate shear wave velocity data into their provisions for seismic design. This inclusion will ensure that site-specific Vs characteristics are accounted for, leading to more accurate assessments of seismic risks and appropriate design responses.

Use Vs Profiles for Site-Specific Seismic Response Analysis: Engineers should utilize detailed Vs profiles for site-specific seismic response analyses. By modeling the site's unique Vs profile, engineers can better predict how seismic waves will interact with the soil and structure, resulting in more accurate design solutions and reduced risk of seismic damage.

Implement Advanced Foundation Design Techniques: For sites with low Vs values, advanced foundation design techniques should be considered. These may include deep foundations, such as piles or caissons, which can bypass weak soil layers and transfer loads to more competent strata. Additionally, ground improvement techniques, such as soil densification or grouting, can enhance soil stiffness and mitigate settlement and liquefaction risks.

Regularly Update and Validate Vs Data: Given that soil conditions can vary over time and across different locations, it is essential to regularly update and validate Vs data. This practice ensures that design assumptions remain accurate and reflective of current site conditions, leading to improved safety and performance of structures.

Consider Regional Variations in Design: Engineering design should account for regional variations in shear wave velocity. Areas with significant geological or seismic differences require tailored design approaches that address local Vs characteristics. Regional databases and case studies can provide valuable insights into appropriate design practices and mitigation strategies.

Integrate Vs Data into Risk Management Practices: Vs data should be integrated into broader risk management practices, including emergency response planning and structural retrofitting. Understanding the implications of Vs on structural performance can guide effective risk management strategies and enhance overall safety in seismic-prone areas.

In summary, incorporating shear wave velocity measurements into geotechnical investigations and design processes is essential for improving the accuracy of site assessments, enhancing earthquake-resistant design, and ensuring the safety and resilience of structures. By leveraging Vs data effectively, engineers can address site-specific challenges, mitigate risks, and develop robust design solutions that are well-suited to local conditions.

Conclusions

Summary of Findings

The study provides several key insights into the role of shear wave velocity (Vs) in the performance and design of shallow structures. The following conclusions highlight the critical findings:

Impact of Shear Wave Velocity on Structural Performance:

Settlement and Bearing Capacity: Lower shear wave velocities are associated with increased settlement and reduced bearing capacity for shallow foundations. Soils with lower Vs values tend to be more compressible and prone to greater deformation under load, which can lead to significant settlement issues for structures. Conversely, soils with higher Vs values provide greater stiffness and support, reducing the risk of excessive settlement and improving load-bearing capacity.

Seismic Response and Site Amplification:

Ground Shaking and Amplification: Shear wave velocity plays a crucial role in determining the level of ground shaking and seismic amplification at a site. Soils with lower Vs values amplify seismic waves more than soils with higher Vs values. This amplification effect can increase the intensity of ground shaking experienced at the surface, raising the potential for structural damage during seismic events. High Vs soils generally exhibit reduced seismic amplification and better seismic performance.

Liquefaction Potential:

Risk Assessment: Lower Vs values are linked to higher risks of soil liquefaction in seismic areas, particularly in loose, saturated sands. Accurate Vs measurements are essential for evaluating liquefaction potential and designing effective mitigation strategies to prevent liquefaction-induced failures, such as using ground improvement techniques or deep foundations.

Regional and Geological Variability:

Geological Influence: The study highlights that shear wave velocity varies significantly across different geological and seismic settings. For example, urban areas with artificial fills and coastal regions with loose sands exhibit different Vs profiles compared to seismic regions with granular soils or rocky terrains. Understanding these regional and geological variations is critical for site-specific design and seismic risk assessment.

Design and Engineering Implications:

Incorporation of Vs Data: Incorporating shear wave velocity measurements into geotechnical investigations is essential for accurate site characterization and design. Vs data should be used to inform seismic response analyses, foundation design, and risk assessments. This approach ensures that design solutions are tailored to the specific conditions of each site, improving structural safety and performance.

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