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A Review of Soil Creep Characteristics and Advancements in Modelling Research

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Introduction

Soil creep is a critical geological process that affects the stability and longevity of slopes, infrastructure, and landscapes. It refers to the slow, continuous deformation of soil under constant stress, which can lead to gradual slope failure and other geotechnical issues. Understanding soil creep is essential for civil engineers, geologists, and environmental scientists who design and maintain structures on or within soil masses. This review aims to provide a comprehensive overview of soil creep characteristics and recent advancements in modelling research, highlighting key developments, methodologies, and future directions. Soil creep is characterized by its gradual and imperceptible movement, often only noticeable over long periods. The primary factors influencing soil creep include soil composition, moisture content, temperature, slope gradient, and vegetation cover [1].

The type of soil and its grain size distribution significantly affect creep behaviour. Fine-grained soils, such as clays, exhibit higher creep potential due to their ability to retain water and undergo plastic deformation. Coarse-grained soils, like sands and gravels, typically show less creep activity. Water acts as a lubricant in soil, reducing friction between particles and promoting creep. Variations in moisture content due to seasonal changes, precipitation, or human activities can significantly impact the rate of soil creep. Temperature fluctuations influence soil creep by causing expansion and contraction cycles in soil particles. Freeze-thaw cycles in colder climates are particularly effective in promoting soil creep. The angle of the slope directly correlates with the rate of soil creep. Steeper slopes experience higher gravitational forces, increasing the likelihood of soil movement [2-5].

Modelling soil creep is essential for predicting and mitigating its impact on engineering structures and landscapes. Recent advancements in soil creep modelling have focused on developing more accurate and comprehensive models that incorporate various factors influencing soil behaviour. Empirical models use observational data to predict soil creep behaviour. These models are relatively simple and rely on established relationships between soil properties and creep rates. While useful for preliminary assessments, empirical models may lack the precision needed for complex geotechnical applications. Mechanistic models aim to capture the underlying physical processes driving soil creep. These models are based on principles of soil mechanics and require detailed input parameters, such as soil strength, stress-strain behaviour, and environmental conditions. Mechanistic models provide more accurate predictions but are often computationally intensive.

Soil creep is a complex and critical process with significant implications for geotechnical engineering, infrastructure development, and environmental management. Understanding its characteristics and developing accurate models are essential for predicting and mitigating its impacts. Recent advancements in empirical, mechanistic, numerical, viscoelastic, viscoelastic, constitutive, and machine learning models have enhanced our ability to study and predict soil creep. However, challenges remain, and future research should focus on improving model accuracy, multi-scale modelling, understanding climate change impacts, fostering interdisciplinary collaboration, enhancing field monitoring, and integrating advanced technologies. By addressing these challenges, researchers can develop more reliable models that will help ensure the stability and safety of slopes, structures, and landscapes in the face of soil creep.

Description

Coarse-grained soils such as sands and gravels typically show less creep compared to fine-grained soils. However, poorly graded or loosely packed sands can still exhibit significant creep under certain conditions. Silts, which are intermediate in grain size between clays and sands, can exhibit creep behaviour that is influenced by both water content and particle arrangement. The moisture content of soil plays a crucial role in its creep behaviour. Water acts as a lubricant, reducing inter-particle friction and enhancing soil's ability to deform. The degree of saturation affects soil strength and stiffness. Fully saturated soils may exhibit higher creep rates due to reduced effective stress and increased pore water pressure. Seasonal changes in moisture content, due to rainfall or evaporation, can lead to cyclic loading and unloading, exacerbating soil creep over time. In cold climates, freeze-thaw cycles are a significant driver of soil creep. Water in the soil freezes, expands, and exerts pressure on soil particles, causing displacement. Upon thawing, the soil structure weakens, promoting further movement.

Temperature variations within a soil mass can create thermal gradients that induce differential expansion and contraction, contributing to creep. The gradient of a slope directly affects the gravitational forces acting on the soil mass. Steeper slopes experience higher gravitational forces, leading to increased shear stress and higher rates of creep. Slope stability analysis must account for these factors to ensure safe design and maintenance. Even gentle slopes can exhibit significant creep over long periods, particularly if other factors such as moisture and soil composition are conducive to creep. Vegetation impacts soil creep through both mechanical and biological processes. Plant roots provide mechanical stabilization by binding soil particles and reducing the potential for movement. The type, density, and depth of root systems influence the degree of reinforcement. Biological processes such as root growth and decay, as well as soil fauna activity, can alter soil structure and moisture content, influencing creep behaviour.

Conclusion

Understanding soil creep and developing accurate models are critical for ensuring the stability and safety of slopes, infrastructure, and landscapes. Recent advancements in empirical, mechanistic, numerical, viscoelastic, viscoelastic, constitutive, and machine learning models have significantly enhanced our ability to predict and mitigate the impacts of soil creep. However, challenges remain, and future research should focus on improving model accuracy, integrating multi-scale processes, understanding climate change impacts, fostering interdisciplinary collaboration, enhancing field monitoring, and leveraging advanced technologies. By addressing these challenges, researchers can develop more reliable models that will help safeguard against the long-term effects of soil creep.

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Conflict of Interest

None.

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