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IMPROVING STABILITY OF SUBGRADES ON DEFORMABLE BASES

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Abstract. *The stability of subgrades on deformable bases is a crucial aspect of modern transportation infrastructure, especially in regions influenced by anthropogenic activities and hydrogeological changes. This study addresses the challenges of maintaining subgrade stability under high-speed, heavy-load traffic in complex engineering-geological conditions. Traditional stability assessment methods often fall short in accounting for dynamic moving loads and the composite behavior of layered soil structures. This research proposes a novel approach utilizing variational calculus to evaluate stability without differentiating between local and global stability losses. The method enables precise modeling of sliding surfaces within composite systems, considering all possible forms of stability loss, including interactions between composite elements and passive structural components. Additionally, a sequential methodology is introduced to assess the impact of moving loads on the stability of layered soil systems, establishing safe speed limits to maintain transport infrastructure stability. The findings contribute to the development of resilient and durable subgrade structures, enhancing safety and operational efficiency in deformable geological settings.*

Key words: *subgrade stability, deformable bases, layered soil systems, dynamic moving loads, variational calculus, composite structures, transport infrastructure, safety, engineering-geological conditions, stability assessment methods.*

Introduction.

A significant portion of road networks passes through regions with deformable foundations, affected by both human activities and changes in the hydrogeological regime. As a result, ensuring the stability of subgrades on such deformable bases is a critical challenge in modern infrastructure management.

The operation of road structures under high vehicle speeds and increased load capacities requires precise predictions of subgrade stability in complex engineering-geological conditions. The efficiency of transportation largely depends on the throughput capacity of road infrastructure. The state of road structures, their adherence to regulatory parameters, and the quality of construction and soil structures are vital to fully utilizing road resources. Many existing roads feature problematic sections, with operational capabilities influenced by natural and anthropogenic factors alike.

Main text.

The primary operational characteristics of subgrades are defined by their planned and profile positioning. Sections of roads on deformable foundations show both horizontal and vertical displacements of structural elements from their intended positions. These displacements can manifest as vertical and horizontal curves on linear sections and as changes in the radii of design curves, negatively affecting vehicle motion smoothness. Speed limits defined in project plans may not ensure safety under conditions of subgrade deformation, as field surveys reveal deformation magnitudes ranging from several centimeters to multiple meters, depending on the foundation's deformation rate.

The safety of vehicles in deformation zones is contingent upon maintaining permissible speed intervals. Assessing subgrade stability involves evaluating the spatial distribution of moving loads with arbitrarily positioned resultant forces. However, this model is complex, requiring the superposition principle and decomposition into simpler tasks that account for the arbitrary placement of moving loads. Traditional stability assessment methods struggle to accommodate such dynamic loads effectively. Classical techniques for soil structure stability typically determine stability coefficients by substituting temporary vertical loads with an equivalent soil layer but lack the capability to incorporate vehicle speed into the analysis. Additionally, these methods do not account for the horizontal and vertical components of moving loads, which is critical for accurate modeling.

The stratification of subgrades, whether natural or artificial (e.g., through reinforcement), complicates stability analysis under dynamically moving loads with varying speeds. Load movement over a stratified construction with altered plan and profile introduces additional forces that must be considered when designing new structures, reconstructing existing ones, and evaluating current transportation infrastructure.

Efforts to describe foundation displacement due to natural and human-induced factors have not yielded a definitive distribution law. This challenge stems from the multifactorial nature of displacement, influenced by construction, technological, geological, hydrogeological, and anthropogenic factors. Evaluating displacement impacts in different directions is particularly important when considering the arbitrary orientation of moving loads, which affects the stability of layered structures and the ultimate state of individual elements and the entire structure.

Artificial layered structures require specific stability calculations, considering their behavior as composite systems. These systems can experience two forms of stability loss: local and global. The lack of a mathematical model that accurately reflects the physical behavior of composite systems underscores the need for an analytical solution. Such a solution, potentially based on variational calculus, could assess stability without differentiating between local and global losses. This approach facilitates determining the sliding surface of composite systems while accounting for all possible forms of stability loss, including localized elements and the interactions between composite and passive structural components.

The impact of moving loads on the stability of layered soil systems can be addressed through a sequential approach. First, the stability of layered systems under useful moving loads is analyzed. Then, permissible vehicle speed limits are established to ensure the required stability margins of the layered soil systems.

The multilayered nature of the structure, composed of various heterogeneous elements with each layer being homogeneous, is modeled using boundary conditions known as adhesion conditions. These govern the coupling of the sliding curve at boundary sections. The stability loss form of such structures is described using variational calculus as the sum of functionals for each layer, corresponding to the ultimate state of individual structural elements.

Stability functionals for each layer are defined by integrals over the analyzed section, while the overall stability functional is the sum of integrals across all layers and potential stability loss forms. The resulting differential equation is solved numerically, achieving a specified accuracy level to predict the stability of the subgrade under dynamic conditions (fig. 1).

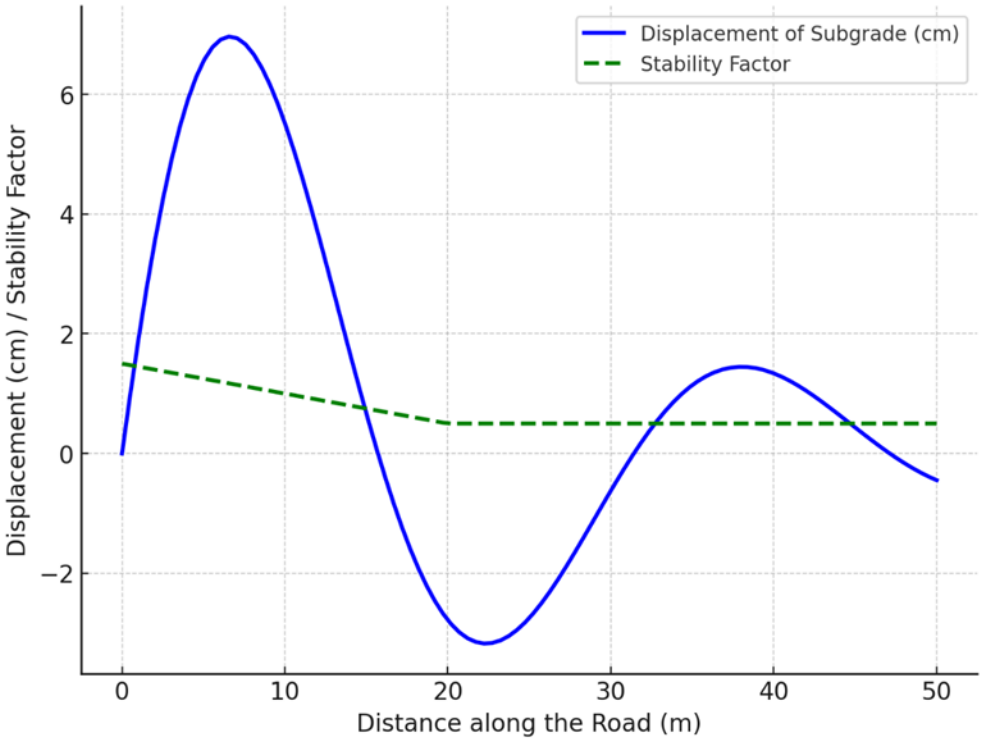

Figure 1 – Stability and displacement of subgrades on deformable bases

Authoring

Summary and conclusions.

This advanced approach to modeling and ensuring the stability of subgrades on deformable foundations blends modern analytical methods with practical engineering requirements. It provides a robust framework for designing resilient and durable transportation infrastructure in challenging geological environments, supporting the safe and efficient operation of modern road networks.

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