RESEARCH SUMMARY

Experimental Investigations on Mechanical Behavior of Unsaturated Subgrade Soil with Lime Stabilization and Fiber Reinforcement Problem

Problem

One of the top priorities of highway administrations is to improve the nation's highways performance. Pavement performance of will largely rely on the mechanical behavior of pavement and subgrade soil layers. In order to increase the capacity of transportation of highway systems, it is recommended to use the higher payload of trucks to improve road productivity as the higher payload reduces both the total number of vehicles in operations and the cost of truck freight transport that is about $140 billon per annum (TPA, 1985). The higher payload, however, increases the rate of road deterioration due to a higher level of shear stress within pavement and subgrade layers. The higher level of shear stress induced by traffic loads not only affects performance of the road surface but also impacts interaction between pavement and subgrade soil layers. Therefore, it is important to investigate the composite subgrade soil with better mechanical properties that can significantly improve road quality under the vehicle-induced shear force. In the present investigations, subgrade soil mixed with fiber and lime powder is utilized for shear tests because geofiber contributes extra tensile and shear resistance to reinforce subgrade soil, and lime provides additional binding and cohesive force to stabilize subgrade soil.

Objective

The experimental investigations on mechanical behavior of the fiber-reinforced and lime-stabilized subgrade soil were conducted thoroughly using conventional static and dynamic triaxial apparatus in the laboratory. The results from the research investigations may serve as a useful tool, references or guidelines for engineers or professionals to apply the composite soils in highway engineering or in the transportation industry. The research finding and results can be applied to highway designs not only in roadbeds but also in soil slopes, embankments, footings and foundations where the fiber-reinforced and lime-stabilized soil is employed.

Description

Investigations in this two-year study included two phases. In the first phase, the investigation looked at the static behavior of composite subgrade soil under the compressive shear loading. In the second phase, the investigation emphasized dynamic behavior of reinforced and stabilized soil under cyclic shear loading. The main concern of this proposal was to investigate the static and dynamic behavior of stabilized and reinforced soils under mono and cyclic shear loading induced by vehicles and other forces (e.g., earthquakes). The investigations in the proposed research program included the following six aspects: 1) the linear and nonlinear elastic stress-strain relations under static and cyclic shear loading, 2) effects of lime stabilization and fiber reinforcement on mechanical behavior such as the stress-strain relation, elastic modulus, and failure or strength, 3) investigations of the nonlinear model under static loading as well as calibration of the constitutive parameters, 4) investigations of the linear model under cyclic loading and calibration of the constitutive parameters, 5) justification and verification of the new constitutive relations through experimental investigations, and 6) studies of the elastic shear moduli such as the tangential modulus under static loading and the resilient modulus under cyclic loading.

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Results

The results were presented in three aspects. First, new constitutive models for static and dynamic loading were established for composite material. In the present report, the elastic constitutive relationship was assumed to describe both the linear and nonlinear stress-strain relations of composite material. Static behavior was described with a nonlinear elastic model, and dynamic behavior was expressed with a linear elastic model. For the nonlinear model, elastic shear modulus was assumed to be a function of multiple variables such as shear strain, contents of fiber and lime, confining pressure, and the curing period of samples. In contrast, for the linear model, elastic modulus was not only defined as a function of confining pressure, contents of fiber and lime, and the aging period of samples but also repetitions of cyclic loading. Second, experimental investigations and calibration of constitutive models were conducted. Experimental data from laboratory tests verified and justified the linear or nonlinear elastic model. Constitutive parameters of linear and nonlinear models were investigated and calibrated using experimental results from both static and dynamic triaxial shear tests. The linear regression method was adopted to find constitutive parameters. The elastic shear moduli were investigated and determined, for example, the initial shear and tangential moduli in the nonlinear elastic model under static loading and the shear or resilient modulus in the linear model under cyclic loading. Moreover, for static loading, the Coulomb – Mohr's failure criterion was applied. The strength indices c and ö were studied for the composite soil with fiber and lime. The strength parameters c and ö found having a linear relation with fiber and lime contents, and the sample-curing period. The coefficients of the linear relation for parameters c and ö versus fiber and lime content and sample aging time were determined using the experimental data. Finally, impacts of fiber and lime as well as other factors that affected mechanical behavior of the composite material were discussed. Impact factors on shear moduli were introduced for both the linear and nonlinear models. The impact factors for the nonlinear model under static loading exhibited effect of variables such as cell pressure, fiber and lime contents, and the sample-curing period on the initial modulus and soil strength, namely parameters 1/A and 1/B related to the shear modulus. In contrast, the impact factors for the linear model under cyclic loading showed effect of the same variables (ó 0, mF, mL and t) plus the repetition of cyclic loading on the resilient modulus and dynamic behavior of composite soils. In brief, the results such as the established linear and nonlinear stress-strain models, the found elastic moduli, and the introduced impact factors are useful tools for designs and applications in highway engineering such as roadbeds, soil slopes, embankments, footings and foundations where the fiber-reinforced and lime stabilized soils are to be applied, and static and dynamic forces are to be considered.

Report Information

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