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Finite element modelling of unpaved road reinforced with geosynthetics

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Abstract

The technique of soil mechanical stabilization, using geosynthetics, is extensively used in the construction of unpaved roads with a low volume of traffic. Unpaved roads consist of unbound granular bases overlying cohesive subgrades. When built on weak subgrades, these roads are subject to problems like excessive rutting and mud-pumping, increasing maintenance costs and usually leading to periodic interruptions to traffic. Particularly, the field applications of geosynthetic reinforcement placed above a weak subgrade can markedly improve the performance of these roads decreasing permanent vertical deformations, increasing lateral restraint ability, which results in increased pavement service life or reduced base thickness to carry the same number of load repetitions. This paper focuses on providing a numerical investigation using a bi-dimensional Finite Element Method (FEM), using ABAQUS software, to analyze the improvement of reinforced unpaved road under repeated wheel traffic load conditions in terms of aggregate base course thickness saving.

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Keywords: Geosynthetics, unpaved road, design methods, FEM analysis.

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1. Introduction

The technique of soil-improvement using geosynthetics is extensively used in the construction of unpaved roads. Unpaved roads are usually used for temporary roads. They remain in service for only short periods (often less than 1 year) and are subjected to low volume traffic (less than 10000 load applications). Unpaved roads typically consist of an aggregate layer resting on the subgrade. The aggregate base distributes the load. The subgrade carries the vehicular load. When the subgrade is weak, due to its poor consistency and high compressibility, a geosynthetic reinforcement is generally placed at the base-subgrade interface to improve the road performance. This technique is particularly effective because the performances of reinforced unpaved roads are enhanced: either by reducing permanent rut deformation for a given number of axle loads and a given base layer thickness, or by increasing the road service life for a given allowable rut depth and a given base layer thickness. Alternatively, for the same traffic and allowable rut depth, the use of geogrid reinforcement allows a reduction in the construction cost by decreasing the base layer thickness in comparison with the thickness required when the base layer is unreinforced (if the cost of the geosynthetic reinforcement is less than the cost of the saved base material). Anyway, the use of reinforcement leads to a decrease of the time required for the construction road and for the periodic maintenance interventions [1, 2].

Geosynthetics used in unpaved roads are essentially geotextiles and geogrids. In this paper, the attention is focused on the use of geogrids as reinforcement, which offer improved interface resistance due to interlocking as compared to geotextile. The confinement due to the geogrid interlocking with aggregate minimizes lateral movement of aggregate particles and increases the modulus of the base course, which leads to a wider vertical stress distribution over the subgrade and consequently a reduction of vertical and lateral pavement deformations (Fig. 1 a) [3]. The degree of interlocking depends on the relationship between the geogrid aperture size and the aggregate particle size (Fig. 1 b) [3, 4, 5, 6, 7, 8, 9, 10, 11 and 12]. On contrary, the effectiveness of interlocking depends on the in-plane stiffness of the geogrid and on the geogrid ribs and junctions stability [13]. Because of interlocking, the mechanisms of reinforced unpaved structure are different for geotextiles and geogrids. Two are the main reinforcement mechanisms: lateral confinement effect and tension membrane effect, which require different depth values of rutting in order to be mobilized. At small permanent deformation magnitudes, the lateral restraint mechanism is developed by the ability of the base aggregate of interlocking with the geogrid. As the permanent deformations (which are often acceptable in unpaved roads) increase the tension membrane mechanism [14, 15] develops. If the geosynthetic has a sufficiently high tensile modulus, tensile stresses will be mobilized in the reinforcement, and a vertical component of this tensile membrane resistance will help to support the applied wheel loads.

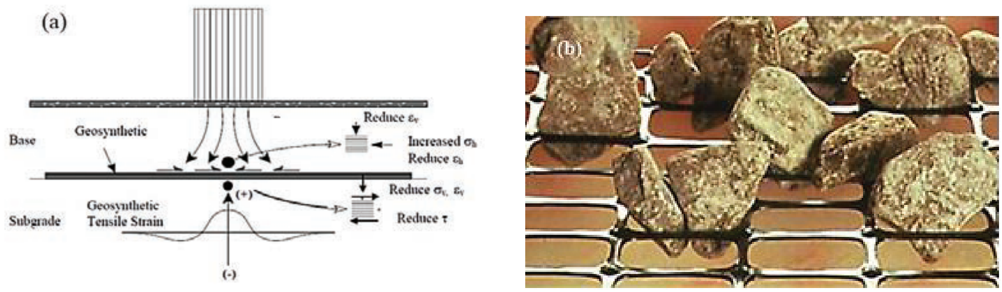

Fig. 1. (a) Mechanisms of reinforcement; (b) Example of good interlocking between aggregates and geogrid.

Over the years, various design methods aimed at estimating the aggregate base course (ABC) thickness required for reinforced unpaved roads have been evolved. The earliest design techniques for geosynthetic reinforced unpaved road, with a low volume of traffic, were proposed by Barenberg et al. [14] and by Giroud and Noiray [15] and both include the membrane effect assuming that significant rutting occurs. A comparison between the above mentioned procedures was carried out by Calvarano et al. [16]. Further headways were made by Giroud and Han [3, 17] and Leng and Gabr [18]. The last above cited design procedures take into account the effects of degradation of base