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Mitigation of short term rutting by interlocking layer developed around a geogrid-sensitivity analysis

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Abstract

This paper presents a numerical investigation of the mitigation of the rutting process developed in the early stages of the utilization of a flexible pavement structure. The analysis is supported by the results of experimental research available in the technical literature. The mitigation of rutting achieved by application of a geogrid is tackled in the framework of sensitivity theory. The fact that the installation of a geogrid results in a decrease of permanent deformations is associated with the interlocking action that develops around a geogrid. It creates the formation of a new, stiffer layer of composite material. The experimental results on the rutting process provide information in terms of accumulated permanent deformations caused by repetitive load of constant magnitude. The constitutive model adopted for analysis is a type of rigid, perfectly plastic material. It is described by a modified Hooke's model that incorporates a modulus of permanent deformation. The functional of permanent displacement is formulated with respect to an unreinforced pavement system with the aid of a suitable adjoint system. The changes of permanent displacements caused by the insertion of a geogrid at the midst of the base layer are described as changes (first variation) of modulus of permanent deformation of the composite layer developed around the known location of the geogrid. Sensitivity theory allows for an extension of the constitutive equation due to the postulate that material characteristics are also considered as variables. The simplifications of the constitutive relationships expressed in variational form result from the fact that variations of permanent displacement are imposed on primary structure in the presence of constant load. The determined final form of the sensitivity equation of permanent displacement due to the changes of modulus of permanent deformation of the composite layer forms the basis for the numerical investigations. They are

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performed by means of the finite element method (FEM) for each (N)-th load repetition. The results in terms of permanent modulus of deformation of the composite layer surrounding the geogrid for some discrete values of its thickness demonstrate a considerable increase in stiffness of the newly developed layer as compared with an unreinforced pavement.

1. Introduction

A geogrid provides a useful and cost-effective way of preventing sudden failure, collapse and rutting when building roads, railways and infrastructures sensitive to continuous and discontinuous subsides [1–8].

Numerous published studies like Bender and Barenberg [9], Chan et al. [2], Hass et al. [10], Jewell [11], Koerner [12], Moghaddas-Nejad and Small [13] and Wong and Small [14] indicate that, a function of reinforcement that the geogrid provides to the pavement system, is a complex set of mechanisms. The geogrid, when placed in a granular base course made of crushed stones, increases its stiffness and modulus. The lateral confinement is intended to resist the tendency for the base course to "walk out" from beneath as the result of repetitive vehicle load. The potential benefits resulting from the application of geogrid inclusions into base course include a decrease in the short term permanent deformations, increase in tensile strength, reduction of fatigue cracking, increase in durability of the pavement structure, and lowering the life cost of the pavement structure. The mechanism of stress transfer from the soil to the geogrid insertion depends primarily on the geometric properties of the inclusions. In particular, for geogrid, it depends on the more efficient interlocking principle. When stressed, the inclusion must be capable of sustaining the load without rupture and without generating unacceptably large deformations during the design lifetime of the pavement structure.

Rutting is defined as the process of development of permanent deformations along the wheel paths. This type of unrecoverable deformation can unfold in the early stages of the application of the repetitive loads (short term rutting) or in the final stage of service life of the pavement structure. The former is attributed to the progressive stiffening process of the base layer. The latter is connected with two different mechanisms that define failure criteria in damage analysis [15]. Consequently, the first failure criterion defined with respect to fatigue cracking combines the admissible number of load applications with tensile strains developed at the bottom of the top asphalt layer as the result of the fatigue of the material having a given resilient modulus. The second failure criterion with respect to permanent deformations connects the number of load repetitions (producing damage of the pavement) to the compressive strains developed on the top of subgrade. All these criteria aim at a limit of excessive permanent deformations that affect performance of the pavement and reflect on its serviceability. One of the possible remedies improving the performance of a pavement in terms of mitigating the development of permanent deformations can be achieved by the installation of a geogrid within the granular course. The reported research on the application of geogrids to pavement systems located