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Stabilization of Paved Roads Using Geosynthetics

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Keywords: Geosynthetics, stabilization, pavements, transportation

Geosynthetics have been used as reinforcement inclusions to improve pavement performance. While there are clear field evidences of the benefit of using geosynthetic reinforcements, the specific conditions or mechanisms that govern the reinforcement of pavements are, at best, unclear and have remained largely unmeasured. Significant research has been recently conducted with the objectives of: (i) determining the relevant properties of geosynthetics that contribute to the enhanced performance of pavement systems, (ii) developing appropriate analytical, laboratory and field methods capable of quantifying the pavement performance, and (iii) enabling the prediction of pavement performance as a function of the properties of the various types of geosynthetics.

Geosynthetics have been used in pavement design to address the functions of separation, filtration, lateral drainage, sealing, and reinforcement. Specifically, geosynthetics have been used for separation in pavement projects to minimize intrusion of subgrade soil into the aggregate base or sub-base. Also, geosynthetics have been used to perform a filtration function by restricting the movement of soil particles from the subgrade while allowing water to move to the coarser adjacent base material. In-plane drainage function of a geosynthetic can provide lateral drainage within its plane. In addition, geosynthetics have been used to mitigate the propagation of cracks by sealing the asphalt layer when used in pavement overlays. Finally, geosynthetics have been used in flexible pavements for reinforcement, which is the main focus of this paper. While the reinforcement function has often been accomplished using geogrids, geotextiles have also been used as reinforcement inclusions in transportation applications. The geosynthetic reinforcement is often placed at the interface between the base and sub-base layers or the interface between the sub-base and subgrade layers or within the base course layer of the flexible pavement. This leads to lower stresses over the subgrade than in unreinforced flexible pavements.

The improved performance of the pavement due to geosynthetic reinforcement has been attributed to three mechanisms: (1) lateral restraint, (2) increased bearing capacity, and (3) tensioned membrane effect. The primary mechanism associated with the reinforcement function for flexible pavements is lateral restraint or confinement. The name of this mechanism may be misleading as lateral restraint develops through interfacial friction between the geosynthetic and the aggregate, thus the mechanism is one of a shear-resisting interface. When an aggregate layer is subjected to traffic loading, the aggregate tends to move laterally unless it is restrained by the subgrade or by geosynthetic reinforcement. Interaction between the base aggregate and the geosynthetic allows transfer of the shearing load from the base layer to a tensile load in the geosynthetic. The tensile stiffness of the geosynthetic limits the lateral strains in the base layer. Furthermore, a geosynthetic layer confines the base course layer thereby increasing its mean stress and leading to an increase in shear strength. Both frictional and interlocking characteristics at the interface between the soil and the geosynthetic contribute to this mechanism. Consequently the geogrid apertures and base soil particles must be properly sized. A geotextile with good frictional capabilities can also provide tensile resistance to lateral aggregate movement.

The aforementioned mechanisms require different magnitudes of deformation in the pavement system to be mobilized. In the case of unpaved roads, significant rutting depths (in excess of 25 mm) may be tolerable. The increased bearing capacity and tensioned membrane support mechanisms have been considered for paved roads. However, the deformation needed to mobilize these mechanisms generally exceeds the serviceability requirements of flexible pavements. Thus, for the case of flexible pavements, lateral restraint is considered to contribute the most for their improved performance.

The results of field, laboratory and numerical studies have demonstrated the benefits of using geosynthetics to improve the performance of pavements. However, selection criteria for geosynthetics to be used in reinforced pavements are not well established yet. The purpose of this paper was to summarize information generated so far to quantify the improvement of geosynthetics when used as reinforcement inclusions in flexible pavement projects.

A Pullout Stiffness Test (PST) was recently developed at the University of Texas, Austin in order to quantify the soil-geosynthetic interaction in reinforced pavements. The equipment involves a modified large-scale pullout test modified to capture the stiffness of the soil-geosynthetic interface under

Zornberg, J.G. (2015). "Stabilization of Paved Roads using Geosynthetics." Keynote Lecture, Proceedings of the *15th Asian Conference of Soil Mechanics and Geotechnical Engineering,* 09-13 November, Fukuoka, Japan (CD-ROM).

small displacements. Research conducted using the PST has shown that monotonic pullout tests aimed at characterizing the soil-geosynthetic interaction under low displacements are promising. Although these pullout tests did not replicate the cyclic nature of traffic load conditions, it simulated the interface transfer mechanisms between soil and geosynthetic reinforcements that are expected in the field.

An analytical model was proposed to predict the confined load-strain characteristics of soil-geosynthetic systems under small displacements using the results obtained from the PST. This approach takes into account both the confined stiffness (J_c) and ability of geosynthetic to mobilize shear or interlock (τ_y), which are two important parameters governing the performance of geosynthetic interfaces. The two parameters can be combined to define a unique coefficient of soil-geosynthetic composite (K_{SGC}) that characterizes the soil-reinforcement interface. This coefficient is computed as:

$$K_{SGC} = 4.\tau_y.J_C$$

(1)

A comprehensive field monitoring program is under way to relate the field performance to laboratory PST results for a number of geosynthetic reinforcements. While ongoing field monitoring is still in progress, good agreement has been obtained so far between the field performance and the properties defined from PST testing. Thus, a new performance-based test method in the form of a pullout stiffness test is promising as a performance-based test to evaluate the soil-geosynthetic confinement.

An overall assessment of the various tests developed so far for geosynthetic-reinforced pavements indicates that unconfined tests are simple, economical and expeditious, although they do not capture the important aspects associated with confinement and the type of soil. Also, unconfined tests have provided only index measures of the actual mechanisms, requiring subsequent correlations with field performance. It should be noted that field studies sometimes led to performance trends that contradicted the trends obtained using properties from unconfined tests. Accordingly, and based on the current body of literature, unconfined tests are considered inadequate for assessment of the performance of geosynthetic-reinforced pavements.

Previous research has led to a reasonably good understanding of the benefits achieved with the use of geosynthetics in pavement design but, for the most part, only from the empirical point of view. That is, while methods have been developed for designing geosynthetic-reinforced flexible pavements, quantification of the reinforcement mechanisms, identification of properties governing the pavement performance and, ultimately, acceptable design guidelines are yet unavailable.

Efforts are currently under way in the US to develop design models consistent with the AASHTO and mechanistic-empirical (M-E) approaches. The TBR and BCR ratios have been used in the AASHTO approach but are limited because the approaches are specific to the products and test conditions under which these ratios have been calibrated. Thus, M-E methods are considered more generic and, consequently, more promising as framework to incorporate the use of geosynthetics in current pavement design. However, due to the complex nature of flexible pavements, research to identify and quantify the properties governing the performance of reinforced pavements and its incorporation into M-E design is still under way.

The available literature involving field and laboratory test results is conclusive in that the mechanical properties of the geosynthetics used for pavement applications are improved under the confinement provided by the soil. Field test sections showed improved performance in the reinforced sections over the unreinforced sections in terms of reduced surface deflections. Overall, available experimental evidence indicates that the improved performance of geosynthetic-reinforced pavements can be attributed to lateral restraint mechanisms. Attempts have been made to quantify the lateral restraint in terms of the interface shear stiffness property of the soil-geosynthetic system.

A number of confined laboratory tests have been recently developed with the objective of quantifying the interface shear stiffness of the soil-geosynthetic system. Several of these tests have applied cyclic loads to the soil-geosynthetic system in an attempt to simulate the dynamic nature of traffic-induced loading. However, probably due to the fact that measurements are sensitive to small changes in displacements, currently available methods have resulted in significant scatter in test results. This has compromised the repeatability of the approaches and has made it difficult to differentiate the performance among different geosynthetics. Ongoing research focusing on confined testing under low displacements using monotonic loading pullout stiffness test appears promising to quantify relevant mechanisms in pavement reinforcement design.

Overall, it may be concluded that significant advances have been made in the area of geosynthetic reinforcement of pavements. While the state of practice is rapidly improving, further research is still needed to provide a better theoretical basis to the currently available empirical design approaches.