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Soil reinforcement for unpaved roads

Renforcement des sols pour les routes non pavées

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ABSTRACT: Reinforcement of soils can be used to improve the performance of pavement subgrades and granular layers of paved and unpaved roads. This paper presents the results of laboratory tests (Wheel Tracking tests) performed on reinforced and unreinforced wearing layers for construction of unpaved roads. Four different types of soils were considered, each one with different percentages of sand, silt and clay. A geogrid was used as the reinforcement. A compressive material (a rigid sponge) was used to simulate the existence of a weak and deformable soil beneath the wearing layer of the unpaved road. This was necessary because the soil layer under study on the Wheel Tracking apparatus is considered thin and it is placed on a rigid steel base, therefore simulating a strong subgrade. The main conclusions are: (1) soil D, with the highest percentage of fine particles, showed the best performance under the Wheel Tracking load at its optimum moisture content, with and without the reinforcement; (2) soil A, with no fine particles, was the soil with the worst performance; (3) all the soils, with a geogrid reinforcement, improved their performance; (4) soils B and C seem to be good options for construction and maintenance of the wearing layer.

RÉSUMÉ: Le renforcement des sols peut être utilisé pour améliorer les performance des fondations de la chaussée et des couches granulaires de routes pavées et non pavées. Ce document présente les résultats d’essais en laboratoire (essais d'orniérage) effectués sur des couches de roulement renforcées et non renforcées pour la construction de routes non pavées. Quatre types de sols différents ont été considérés, chacun avec des différents pourcentages de sable, de silt et d'argile. Une géogrille à était utilisée comme renforcement. Un matériau compressif (une éponge rigide) a été utilisé sous les couches de sol pour simuler l’existence d’un sol faible et déformable sous la couche de la route non pavée. Cela à était nécessaire parce que la couche de sol en étude sur l'appareil de repérage des roues est considérée comme étant mince, ainsi elle a été placé sur une base en acier rigide, simulant une couche forte. Les principales conclusions sont: (1) sol D, avec la plus élevé pourcentage de particules fines a obtenue les meilleures performances sous la charge de la trajectoire de la roue, à son taux d'humidité optimal, sans et avec aucun renforcement; (2) le sol A, sans particules fines, a était le sol le moins performant; (3) avec un renforcement en géogrille, tous les sols ont amélioré leurs performances; (4) les sols B et C semblent être bonne options pour la construction et l’entretien de la couche de roulement.

Keywords: Unpaved road; Wheel Tracking test; Reinforcement; Geosynthetics

1 INTRODUCTION

Generally, unpaved roads are the result of the growth of tracks, or narrow paths for pedestrians and small vehicles, which developed naturally to connect rural and urban areas to provide the population with services and to allow exchange of products (mainly agricultural, forestry and livestock). Accessibility was important for economic, social and cultural reasons.

Unpaved roads have been used essentially because of their low construction cost and great deformation tolerance. However, most of these roads cannot withstand the loads of today‘s daily traffic of trucks and large agricultural machines.This is especially true when it rains and their capacity to support loads is diminished, making them even more vulnerable to deformation, localized rupture and erosion. Furthermore, these roads are often built on subgrades with very low load carrying capacity. The safety and comfort of the people, products and vehicles is a concern and therefore it is necessary to adopt maintenance measures after these roads are built and brought into use. These measures are important for all types of roads, but especially for unpaved roads.

The improvement and reinforcement of the soil reduces deformability, increases resistance and, therefore, improves the performance of the road. The frequency of the road maintenance operations is therefore reduced. Several reinforcement techniques might be considered, including the one that uses geosynthetic materials (e.g. Wu et al. 2015, Calvarano et al. 2017). Geosynthetics, when used as reinforcement, increase strength and improve load carrying capacity due to a better stress redistribution, separation and membrane effect (IGS@ 2018).

The study described herein investigates the behaviour of four different types of soils, with different percentages of sand, silt and clay, when subjected to the passage of vehicles, simulated by the use of the Wheel Tracking machine.

2 LABORATORY PROGRAM

2.1 Materials

Four different types of soils were used in the study, each one with different percentages of sand, silt and clay. Soil A has the highest percentage of sand and D the highest percentage of fine particles. They were prepared by mixing different proportions of the three soils that were available in laboratory. Characterization tests were performed, namely particle size analysis, density of solid particles, consistency limits, compaction test (Proctor), and California Bearing Ratio (CBR). The results are presented in Table 1. The compaction curves for the soils are presented in Figure 1.

A geogrid was used for reinforcement and the properties are presented in Table 2.

A 11.05 mm thick rigid sponge was used in some of the tests, as a compressive material placed beneath the specimens, to simulate the existence of a weak and deformable soil beneath the wearing layer of the unpaved road.

2.2 Test apparatus and procedure

The equipment used for the experimental study is the Wheel Tracking machine. This equipment (Wessex S867) allows the measurement of the deformation of the specimen due to the passage of a wheel, thus simulating the passage of vehicles (Figure 2).

Table 1. Soil properties

	Soil A	Soil B	Soil C	Soil D
Density of solid particles (-)	2.75	2.76	2.79	2.78
Liquid limit (%)	-	-	-	23.2
Plasticity limit (%)	-	-	-	21.6
Maximum dry unit weight (kN/m^3)	19.9	20.6	20.6	19.6
Optimum water content (%)	8.1	7.6	8.8	10.2
California Bearing Ratio (%)	6.3	4.4	3.8	3.5
Classification (USCS: ASTM D2487-09)	Sandy silt	Sandy silt	Sandy silt	Silty sand
Classification (AASHTO: ASTM D3282-09)	A1b	A2-4	A4	A4
Classification (particle size: Ferret's Triangle)	Sand	Sandy silt	Sandy silt	Sandy silt

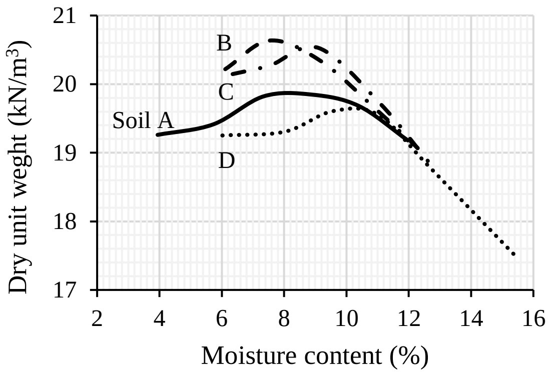

Figure 1. Compaction curves

This machine is currently used to test bituminous pavements and, consequently, the number of wheel pass cycles during the test program is limited to 10,000 or the deformation of the soil is limited to 20 mm (EN 12697-22, 2007).

Table 2. Geogrid properties

	Polyester Secugrid 200/40 R6
Aperture (mm x mm)	71 x 25
Tensile strength (kN/m)	200/40
Tensile strength at 5% elongation, machine direction (kN/m)	140

To prepare the specimen, the soil was placed and densified in the test box at the optimum water moisture content level. Each specimen was prepared in three layers, each about 3 cm thick, and densification was performed by a

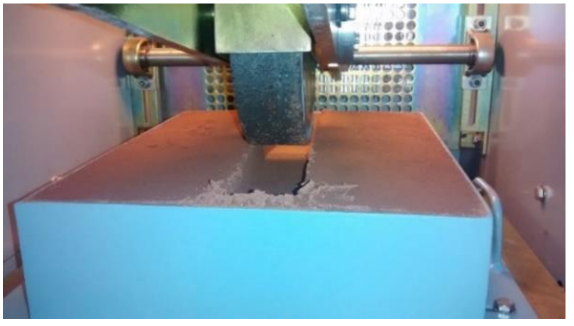

Figure 2. View of a specimen after being tested

10kN load applied by a compression machine (Servosis Model ME-402). Finally, the same dry unit weight of the soil as in the heavy compaction tests (optimum situation) was achieved.

Three different specimen arrangements were tested, which can be seen in Figure 3. All specimens were prepared and tested with the respective optimum water content and the maximum unit weight (Table 1 and Figure 1).

The test box is made of steel and is 375 mm long x 305 mm wide x 98 mm high, which are the maximum dimensions suitable for the test box to fit in the Wheel Tracking machine.

3 RESULTS AND ANALYSIS

3.1 Influence of the type of soil and the strength of the subgrade

Tests were performed to study the influence of the type of soil and therefore their suitability for use in unpaved road construction, either on strong or in weak subgrade. The results of these tests are presented in Figures 4 and 5. The first figure shows results for the situation represented in Figure 3 a), simulating a strong subgrade, while in the latter, the results refer to the situation in Figure 3 b), with the use of a sponge underneath the soil layers, i.e. simulating a weak subgrade.

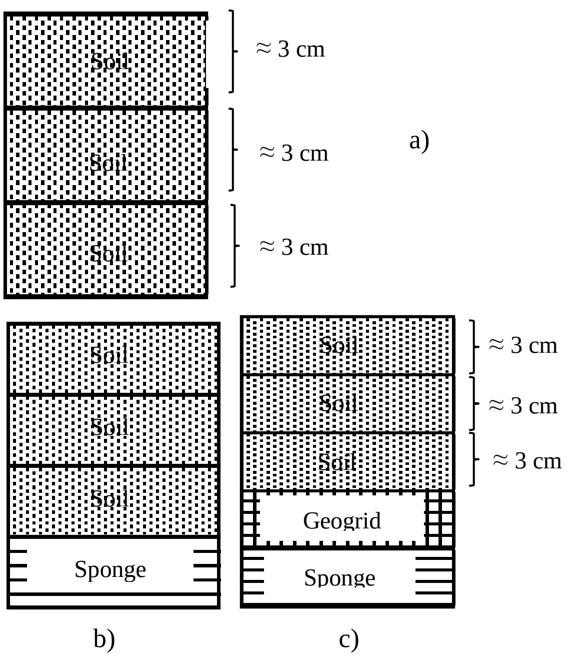

Figure 3. Schemes of test specimens (not drawn to scale) with (a) soil alone, (b) the sponge and (c) the sponge and the reinforcement

Each specimen was subjected to 3,000 cycles, which was enough to reach a constant deformation.

During the duration of the tests, the results are very consistent. Soil A, the coarsest soil, which has almost no fine particles, which means it has a lower capacity for soil particle aggregation development, presents the greatest deformation (13.1 mm). On the other hand, soil D, which contains the highest amount of fine particles, presents the lowest level of deformation (1.5 mm). Particle soil aggregation therefore seems to be an important characteristic of the soil. Soils B and C present the intermediate percentages of both fine and more coarse particles, and they show intermediate values for deformation (4.1 mm and 2.1 mm for B and C, respectively). Moreover, these two soils, with similar granulometry, show some different deformability behaviour. That means that even a small difference in the fine particle content influences the soil‘s deformability.

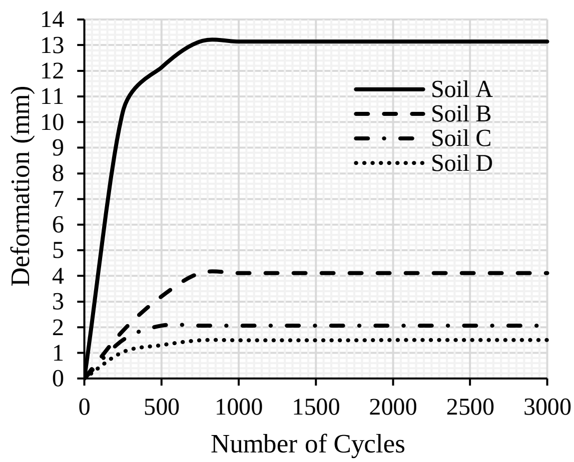

Figure 4. Rut deformation - strong subgrade

With the weak subgrade, all the soils would be expected to behave worse, and that was indeed confirmed. Although the sponge has an elastic behaviour, i.e. it deforms with the weight of the wheel and recovers immediately after it passes, the soil does not. The soil develops cracking more easily during deformation (both during compression as well during expansion) of the sponge with the consequent increment of the rut depth. Soil A remains the soil with the worst behaviour, and at the end of about 72 cycles it reached the maximum allowable deformation (20 mm) and the test was therefore stopped.

The results of this study lead to the conclusion that soils C and D are the most suitable soils (due most probably to their grain size composition, since they allow soil particle aggregation), as they were the ones that suffered less deformation under the Wheel Tracking load.

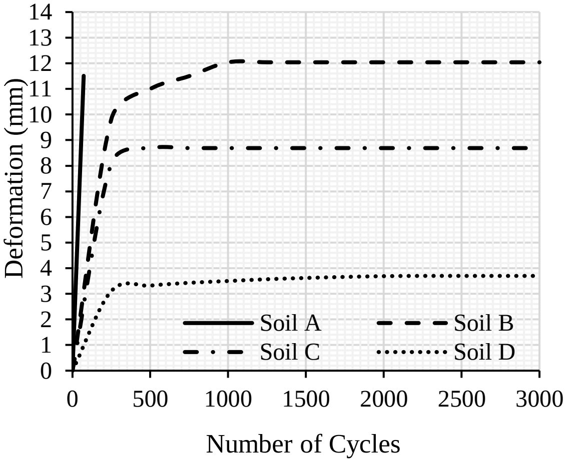

Figure 5. Rut deformation - weak subgrade

3.2 Influence of the reinforcement placed on top of the weak subgrade

One of the objectives of the study is the verification of the benefit of introducing a reinforcement element, namely a geogrid, on top of the weak foundation (the sponge) and beneath the soil layers. A general decrease in the deformation would be expected, since the reinforcement has some rigidity and therefore would restrain the lateral deformation of the soil by the friction and the interlocking that can be developed between the soil particles and the geogrid, besides other mechanisms.

Therefore, the geogrid was placed longways in the test box, i. e. with highest tensile strength and largest aperture dimension in the longitudinal direction of the road (Figure 6). The results obtained for these tests are shown in Figure 7.

As can be seen in Figure 7, soil A again shows the worst behaviour, deforming 20 mm in less than 100 cycles. The influence of the geogrid was hardly felt in this soil. All the other soil types show significantly better results when compared to the non-reinforced tests.

A possible explanation could be the dimensions of the apertures of the geogrid that might be too large for the laboratory model. The apertures should perhaps be smaller so that there would be more volume of soil with the influence of the reinforcement. It should be noted that the geogrid used in this test program is a commercial geogrid used for reinforcement in real construction works and not a geogrid scaled to the same scale of the test model.

Figure 6. View of the geogrid placed on top of the sponge during specimen preparation

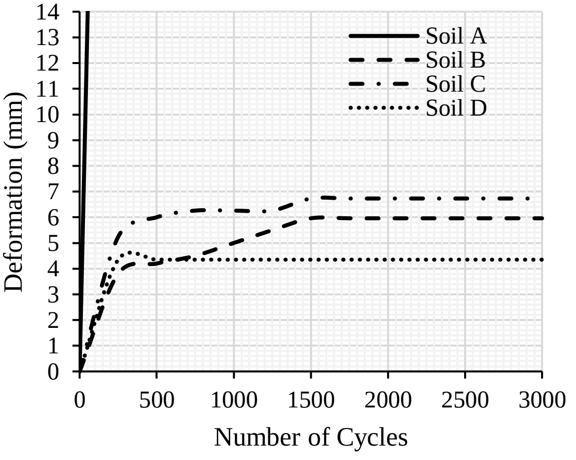

Figure 7. Rut deformation - weak subgrade – with reinforcement in longitudinal direction

In order to clarify this, some other tests were performed afterwards with the geogrid placed perpendicular to the previous position, i. e. with highest tensile strength and largest aperture in the transversal direction of the road. The results for these tests are shown in Figure 8.

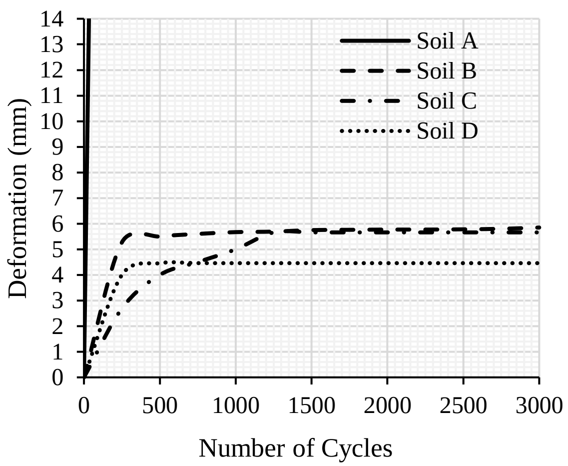

Figure 8. Rut deformation - weak subgrade – with reinforcement in transversal direction

Soil A again had the worst behaviour as the deformation reached 20 mm after a very few number of cycles. The other soils generally behaved better than in non-reinforced tests (Figure 5). Comparing the two positions of the geogrid, there is a significant improvement in the reduction of the deformation with the geogrid in the new transversal position.

4 CONCLUSIONS

From this study the following main conclusions can be drawn:

- for all the test conditions, soil A, with almost no fine particles, has the worst performance, while soil D, which has the highest percentage of fine particles shows the best performance of all;
- the strength of the subgrade is a very important factor, as lower strength means greater deformation, for all types of soils;
- the inclusion of a reinforcement layer on top of the weak subgrade improved the performance of all types of soils;
- soils B and C seem to be good options for construction and maintenance of wearing layer;
- there is good evidence that the Wheel Tracking machine is suitable for performing this type of study.

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