



Large scale tests on geosynthetic reinforced unpaved roads subjected to surface maintenance

Ennio M. Palmeira*, Luiz G.S. Antunes¹

University of Brasília, Department of Civil and Environmental Engineering, FT, 70910-900 Brasília, DF, Brazil

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ABSTRACT

Geosynthetic can be effectively used as reinforcement in paved and unpaved roads. This paper presents a study on the use of geosynthetic to reinforce unpaved roads on poor subgrade. A large equipment was used to perform the tests under cyclic loading and a nonwoven geotextile and a geogrid were used as reinforcing layers installed at the fill-subgrade interface. Displacements along the fill surface and stresses and strains in the subgrade were measured during the tests. Three cyclic loading stages were applied in each test up to a rut depth at the fill surface of 25 mm be reached in each stage. At the end of a loading stage the fill surface was repaired for the following loading stage. Monotonic loading tests were also carried out for comparisons. The results obtained show the significant contribution of the presence of the reinforcement layer in increasing the number of load cycles for a given rut depth to be reached and in reducing the stresses and strains in the subgrade, particularly when geogrid reinforcement was used. It was also observed that monotonic loading tests underestimated the contribution from the reinforcement. A simple cost-effectiveness analysis showed that the reduction of maintenance works due to the use of geosynthetic reinforcement may yield to significant savings in this type of problem, seldom considered in the analysis of the economics of this type of application on a routine basis.

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1. Introduction

A country's economical development is intimately related to its transportation infrastructure. For instance, in the USA trucks carry approximately 60 percent of total freight shipments by weight and 70 percent by value (not including shipments moved by truck in combination with another mode) and a significant amount of resources is allocated for the maintenance and constructions of pavements (FHWA, 2006). In Brazil, approximately 61% of the freights are hauled by roads, with almost 90% of the total length of the road network consisting of unpaved roads (GEIPOT, 2008), which may have traffic periodically disrupted due to poor maintenance. In this context, geosynthetic can be used as reinforcement to improve the mechanical characteristics of paved and unpaved roads, yielding to significant increases in road life time and reductions in maintenance costs.

Several works in the literature have shown the benefits of reinforcing pavements with geosynthetics (Perkins and Ismeik, 1997a,b). The presence of the reinforcement layer increases

lateral restraint or passive resistance of the fill material, increasing the rigidity of the system and reducing vertical and lateral pavement deformations (Perkins, 1999a,b; Al-Qadi et al., 2007). The reinforcement can also yield to reductions of pavement thickness, with obvious favourable economical repercussions (Anderson and Killeavy, 1989; Al-Qadi et al., 1994; Cancelli et al., 1996; Perkins, 1999b). Anderson and Killeavy (1989) and Cancelli et al. (1996) have shown that the presence of geosynthetic reinforcement can reduce the pavement thickness between 20% and 50%. Knapton and Austin (1996) found reductions of pavement surface rut depths up to 50% for a given number of load cycles due to the use of geosynthetic reinforcement. Abduljawwad et al. (1994) reached similar conclusions performing laboratory tests on reinforced and unreinforced pavements.

The presence of the reinforcement in unpaved roads can also markedly improve the performance these roads when built on weak subgrades (Palmeira, 1981; Ramalho-Ortigao and Palmeira, 1982; Love et al., 1987; Palmeira and Cunha, 1993; Palmeira and Ferreira, 1994; Fannin and Sigurdsson, 1996; Palmeira, 1998; Som and Sahu, 1999; USACE, 2003; Hufenus et al., 2006; Zhou and Wen, 2008; Basu et al., 2009). The position of the reinforcement layer in the fill also influences the performance of the road (Ismail and Raymond, 1995; Perkins and Ismeik, 1997a; Raymond and

* Corresponding author. Tel.: +55 61 3107 0969; fax: +55 61 3273 4644.

E-mail address: palmeira@unb.br (E.M. Palmeira).

¹ Tel.: +55 61 3964 5250; fax: +55 61 3273 4644. E-mail: luizgustavo@unb.br.

Ismail, 2003; Subaida et al., 2009; Bhandari and Han, 2010). Besides reinforcing the system, depending on the geosynthetic characteristics, separation between a high quality fill material and a poor foundation soil can avoid or minimise the impregnation of the voids of the former by particles of the latter, increasing the life time of the road. Under large strain conditions the membrane effect provides additional benefits for road reinforcement (Giroud and Noiray, 1981; Palmeira, 1998).

Geosynthetic reinforced unpaved roads are also easier and quicker solutions compared to traditional alternatives, such as the use of greater fill heights or the substitution of the poor foundation soil by a more competent one, which are solutions detrimental to the environment. Goldfingle (2009) reports on the construction of a 5 to 6 m wide and 65 km long geogrid reinforced access road for the construction of a 60-turbine wind farm in Scotland which took only four months.

After a certain amount of traffic ruts appear the road surface must be repaired to allow the continuing traffic of vehicles under safe and economical conditions. An important contribution from the reinforcement is to reduce road maintenance works (Palmeira and Ferreira, 1994; Palmeira, 1998). This contribution is seldom considered when evaluating the costs of using reinforcement in unpaved roads. Palmeira and Cunha (1993) have shown that the performance of the reinforced unpaved road can be significantly better than that of the unreinforced one under large rutting conditions because of the enhancement of the membrane effect after successive surface maintenances.

The efficiency of the geosynthetic as a reinforcement in a road can be quantified by the Traffic Benefit Ratio, defined as:

$$TBR = \frac{N_r}{N_u} \quad (1)$$

where TBR is the traffic benefit ratio, N_r is the number of load cycles on the reinforced road for a given rut depth and N_u in the number of load cycles on the unreinforced road for the same rut depth. Koerner (1994) reports values of TBR varying between 2 and 16, depending on the soil and geosynthetic characteristics.

This work presents a study on the performance of unreinforced and geosynthetic reinforced unpaved roads using a large scale experimental setup. The authors believe that it provides a relevant contribution to the state-of-the-art on the subject, as it addresses the performance of these roads after successive maintenances of the road surface. In addition, it also examines the influence of the reinforcement type and the economics of this type of geosynthetic application.

2. Equipment, materials and testing methodology

2.1. Equipment

The equipment used in the tests is shown in Fig. 1. It consisted of a large steel container 1.2 m high, 1.6 m wide and 1.6 m long. The vertical stress on the fill surface was applied by a 300 mm diameter steel plate underneath a jack connected to a hydraulic system. Tests under monotonic and cyclic loadings were carried out. The cyclic loading tests were performed with a load application frequency of 1 Hz and a plate stress of 566 kPa, corresponding to a typical truck axle load of 80 kN. One of the sides of the container can be opened at the end of the tests to allow the visualisation of the conditions of the soils, uniformity of the layers and to help soil removal and cleaning operations of the container for the next test.

The tests were performed with three loading stages. The first loading stage was carried out until a maximum settlement of the loading plate of 25 mm was reached. Then the test was interrupted

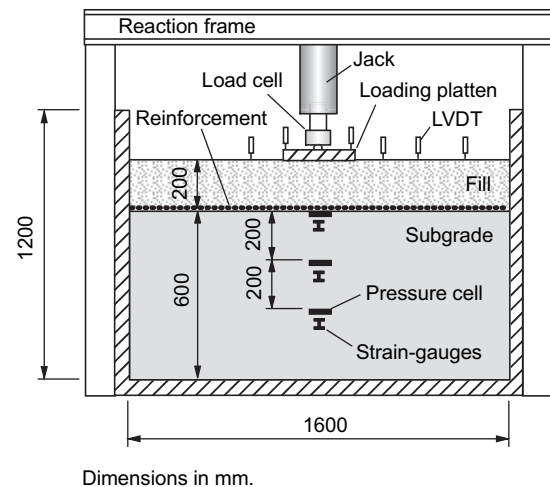


Fig. 1. Equipment used in the tests.

and the fill surface was repaired with the addition and compaction of gravel to fill the basin at the fill surface. A second stage of loading was then started up to a 25 mm plate settlement had been reached when the fill surface was repaired again for the final third loading stage.

The instrumentation of the tests consisted of displacement transducers (LVDTs) to measure vertical displacements of the loading plate and along the fill surface. A load cell attached to the jack measured the loads applied on the fill surface. Total pressure cells positioned at different positions along the subsoil depth allowed for the measurement of stress increments during the tests (Fig. 1). Vertical strain measurement devices were also positioned at different location in the foundation soil. These devices consisted of extensible strain-gauges with the extremities fixed to horizontal epoxy plates (Fernandes et al., 2008). A 32 channels data acquisition system (model Lynx ADS 2000), connected to a microcomputer, acquired the readings from the instrumentation during the tests.

Tests were also performed under monotonic loading for comparison purposes. In this case only unreinforced and geogrid reinforced tests were performed. The test arrangement, dimensions and instrumentation used in the monotonic loading tests were the same used in the cyclic loading tests. Monotonic tests were subjected to only one loading stage.

2.2. Materials

A local fine grained tropical soil was used in the preparation of the subgrade. The main geotechnical properties of the foundation soil are summarised in Table 1. According to the Unified Classification System (UCS) this soil would be classified as SM and according to AASHTO it would be classified as A-7-5. The subgrade soil was compacted with a moisture content of 27% and a unit weight of 15 kN/m³ to a total final thickness of 600 mm. Under such conditions the California Bearing Ratio of the foundation soil measured in the laboratory was approximately equal to 8%. At the end of the tests samples of the subgrade were collected for CBR tests. Values of CBR at the subgrade surface after the tests varied between 7.8% and 8.7%. Several works in the literature report greater benefits brought by geosynthetic reinforcement for subgrades with lower values of CBR. However, significant benefits from the presence of the reinforcement have also been observed in tests with values of CBR similar to the one used in this work (Haas et al., 1988; Webster, 1992, 1993; Perkins and Ismeik, 1997a, for instance).

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