Optimum Design of Unpaved Roads Reinforced With Geotextiles: Comparison of Internationally Published Methodologies

Styliani Karavasili[1], Sousana Tastani[2] and Ioannis Markou[2]
[1]*Techincal Support, Thrace Nonwovens and Geosynthetics, Magiko Xanthi, GR 67132, Greece*
[2]*Department of Civil Engineering, Democritus University of Thrace, Xanthi, GR 67132, Greece*
karavasili@thraceplastics.gr, stastani@civil.duth.gr, imarkou@civil.duth.gr

Extended Abstract

Unpaved roadways are defined as roads constructed by covering the soft subsoil with aggregates (sand or gravel), forming the bases of the road surface, without any asphalt layer on top. Such projects are characterized as either temporary (construction site use) or permanent (log life) based on the traffic load they are designed to curry. Improved mechanical behavior of unpaved roads is encompassed by the use of geotextiles. Soil having negligible tensile response is unable to undertake tensile stresses induced by traffic loading. The application of geotextiles in roadways as an effective reinforcing technique began in early 70's aiming to undertake these tensile stresses thus favorably influencing the load-carrying capacity of the composite structure. Geotextiles are manufactured from polymers and are effectively mobilized in tension when they are placed between a soil of low undrained shear strength (i.e., , California Bearing Ration (CBR) in between 1 to 3, note CBR = 1 is approximately equal to $c_u \approx$ 30kPa) and the aggregate base intending to a more rigid response as a result of the uniformly distributed reinforcement. In these cases the geotextile also serves as separator, preventing the penetration of fine-grained soil particles in the coarse-grained aggregate base. For moderate CBR values (up to 8) these materials are used for stabilization (less effective as reinforcement, more effective as separator). Another advantage of the geotextiles is the use of aggregates of lower quality [1]. Geotextiles are classified in two basic categories, the woven and non-woven; the former are stiffer materials (their modulus of elasticity E ranges between 100 to 1000kN/m with an ultimate strain in between 10-18%) as compared with the non-woven which have a broader strain capacity (the corresponding values are 15 - 100kN/m and 40-70%).

At the same period, the empirical application of geotextiles in reinforcing unpaved roadways was supported with the development of design guidelines [1-4] for the calculation of the aggregate base thickness as a function of several parameters, namely the soil mechanical properties, the traffic load (axle load an number of passes), the rut depth induced by the vehicles tires and the mechanical properties of the geotextiles. Through these design methods the engineers can improve the function of the roadway either by increasing the traffic load that can be sustained by a certain thickness of the base, or by reducing the thickness of the aggregate base for a target traffic load, or a combination of both scenarios.

In this paper, the internationally established methods (Giroud & Noiray; Giroud et. al (1985) [3, 4]; Stewart; Williamson & Mohney (1977) [2]; Giroud & Han (2004) [1]) for the design of unpaved roadways reinforced with geotextiles are compared aiming to analytically explore their parametric sensitivity and the degree of their convergence in the analytical results (i.e., regarding the calculated aggregate base thickness), as show in in Table 1. For this purpose spreadsheets with embedded subroutines are developed aiming for the iterative solution of the governing equations (equilibrium and kinematics). After confirmation of the analytical results obtained through these spreadsheets in comparison with internationally published examples[5], these practical design tools were used in performing parametric analyses (Fig. 1, see also reference[7]) considering common variables (number of vehicle passes, axle load, tire pressure of the vehicle, rut depth due to traffic and the subsoil characteristics based on the CBR) as well as a more detailed definition of the geotextile effective tensile strain. The latter can be either a preset elastic design limit (i.e. less than the 1/3 of the ultimate strain) or it is calculated from the deformation pattern of the geotextile induced both by the rut depth and the distance between vehicle wheels[6] (to be accepted, this strain should be in the elastic range of the material tensile response). The difference between these two alternatives of geotextile strain definition can be interpreted as follows: when the designer choses a preset, arbitrary limit, this means that the material probably is not going to develop such a magnitude thus the resulting aggregate base thickness is actually

referred to a reduced performance to a lower number of vehicle passes. This is more critical when designing for practically non-deformed roads (the rut depth is minimum) and the material stiffness is high but it moderates for lower values of *E*. Finally, from the analysis it may be concluded that the higher the rut depth and the number of vehicle passes are for a given soil of poor-to-moderate shear strength, the stronger the geotextile (i.e. the higher its Elastic Modulus) is deemed appropriate for an efficient thickness of the stone-aggregate layer.

Table 1: Results of the aggregate base thickness of an unpaved reinforced road from the collected methodologies.

Calculation of the aggregate base thickness	Giroud and Noiray[3] and Giroud et al.[4]		Holtz and Sivakugan[5]	Giroud and Han[1]	Steward, Williamson and Mahoney[2]
	Common parameters for all methods: CBR = 1, axle load P=80kN, Tire inflation pressure p_c =480kPa, Number is passes *N=1000 (and 10.000)*, Rut depth *s=75mm, E=200kN/m* *Note: Values in parenthesis refer to N=10.000*				
h_o (mm)	313 (313)		-	-	-
h_o' (mm)	570 (760)		555 (740)	465 (510)	475 (475)
h (mm)	Calculated strain: 0.013 (0.014)	160 (160)	-	-	-
	Preset strain 0.1	113 (113)			
h' (mm)	Calculated strain: 0.013 (0.014)	417 (607)	432 (616)	315 (365)	325 (325)
	Preset strain 0.1	370 (560)			

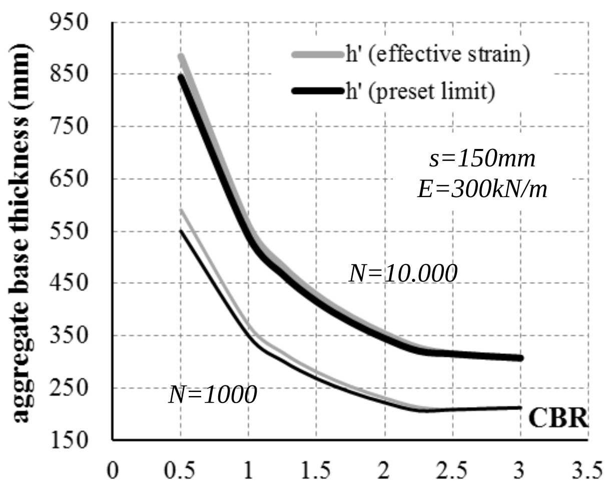

Figure 1: Required aggregate thickness h' versus CBR values considering the two alternatives in definition of the fabric strain for two vehicles passes N and s=150mm. The explicitly defined effective strain of the geotextile ranges between 0.045 and 0.07 and the preset limit is 0.1 (values for other constants are: p_c=550kPa, a_o=a=26^o, e=2m)

References

[1] Giroud, J. P., Han, J. (2004), 'Design Method for Geogrid-Reinforced Unpaved Roads. II. Calibration and Applications', J. of Geotechnical and Geoenviromental Engineering, Vol. 130, No. 8, pp. 787-797.

[2] Steward J.E., Williamson R., and Mohney I. (1977), Guidelines for use of fabrics in construction and maintenance of low-volume roads, Rep. FHWA-TS-78-205, U.S. Department of Transportation, Federal Highway Administration, Washington, D.C.

[3] Giroud, J. P., and Noiray, L. (1981), 'Geotextile-reinforced unpaved road design', Journal of Geotechnical Engineering, Vol. 107, No. 9, pp. 1233–1254.

[4] Giroud, J. P., Ah-Line, C., and Bonaparte, R. (1985). 'Design of unpaved roads and trafficked areas with geogrids', Polymer grid reinforcement, Thomas Telford Limited, London, 116–127.

[5] Holtz, R., and Sivakugan, N. (1987), 'Design Charts for Roads with Geotextiles', J. of Geotextiles and Geomembranes, Vol. 5, No. 3, pp 191-200.

[6] Bearden, J.B., Labuz, J.F. (1998), Fabric for Reinforcement and Separation in Unpaved Roads, Dep. of Civil Engng, Institute of Technology, Univ. of Minnesota, Minnesota US.

[7] Karavasili, S., Tastani, S., Markou, I. (2016), 'Optimum Design of Unpaved Roads Reinforced With Geotextiles: Comparison of Internationally Published Methodologies', Procs, 11th HSTAM International Congress on Mechanics, Athens.