Use of high-performance reinforcement geosynthetics to stabilize access roads

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Abstract. With the rapid infrastructure development, the availability of competent soils is decreasing. The access roads and tracks practicability should be ensured when crossing these weak soils. The practicability of access roads and tracks is therefore important. Depending on the mechanical properties of the subgrade, the construction of access roads requires the use of granular foundation materials of significant thickness, which can result in substantial costs and construction delays. This is especially true when the runway is to be constructed on soft subgrade and possibly in the presence of water. This article presents the use of a high-performance reinforcement geosynthetic to stabilize unpaved access roads, control settlement and prevent contamination between the subgrade and the foundation. A laboratory case well documented is used. Two calculation methodologies based on the subgrade soil characteristics are provided and compared.

1 Literature review

Several design methods (Hammitt [1], Giroud & Noiray [2], Giroud & Han [3]) were developed since 1970 to determine the required base course thickness over a weak subgrade (reinforced or not). All the design equations involve the rutting criterion, traffic conditions (passage number, wheel load), CBR of the subgrade and the tire contact area.

In 1981, Giroud & Noiray [2] proposed a theorical design method for unreinforced unpaved roads. This method design was further elaborated by Giroud including the reinforcement by a geotextile as a stress distribution improvement and a normal stress difference due to the tension membrane effect.

More recent researches have been carried out in this field and other analytical methods were developed (Giroud & Han [3], Leng & Gabr [4]). In fact, Giroud & Han [3] improved the methods developed earlier to determine the base course thickness of unreinforced, geotextile-reinforced, and geogrid-reinforced unpaved roads as a function of the stresses at the subgrade-base interface and the subgrade bearing capacity.

Considering the use of a geogrid, the interlocking between the granular material of the base course and the geogrid aperture was considered by Giroud & Han [3]. The reinforcement

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geosynthetic mechanical characteristics (plane aperture stability modulus, stiffness, tensile strength) and stress distribution angle degradation with cycles were also considered.

When a reinforcement geosynthetic is used to improve the soil bearing capacity, two mechanisms will occur:

- The stabilization mechanism at a low deformation: the reinforcement geosynthetic provides stabilization of the subgrade by increasing the system load-carrying capacity and allows the separation function (in case of the use of a geogrid/geotextile composite) between the soft subgrade and the sub-base materials. The interaction due to the geogrid interlocking with the aggregate and the friction mechanisms with the geotextile will allow to minimize the lateral aggregate particles movements under the surcharges as it increases the base course stiffness and the load distribution angle θ,
- The Reinforcement mechanism for a higher deformation level: the geogrid ability to be deformed and to absorb the vertical load initially perpendicular to its surfaces called the membrane effect. Tensile stresses will be mobilized in the reinforcement, and a vertical component of this tensile membrane resistance will help to support the applied wheel loads.

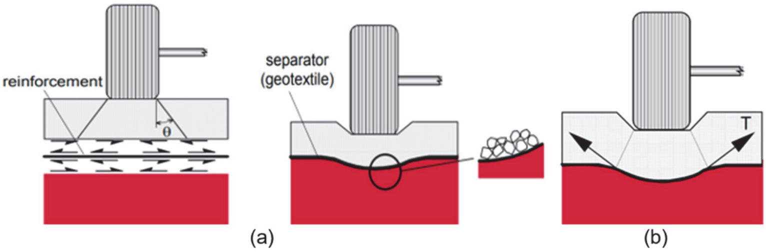


Fig. 1. (a) Stabilization & Separation function, (b) Reinforcement function: Tension membrane effect.

In the study from Khoueiry [5], it was shown that for a base course layer thickness of 350 mm, the geogrid had almost no effect on soil bearing capacity, although the effect was important for a thickness of 220 mm. However, another study carried out by Kalumba & Musenero [6] demonstrated that the use of multiple layers of geogrids enhances the bearing capacity of soft subgrade. Furthermore, the number of geogrid layers (N) has an impact on the bearing capacity of the soft subgrade. Their experimental results have shown that the peak bearable load increased with increasing N. The increase in peak of bearable applied load was more significant from N = 0 to N = 3. However, for N values higher than 3, a negligible increase in the maximum bearable load was recorded.

In the case where the thickness of the base course layer is greater than 300 mm, the use of a second geogrid is recommended. In fact, from a thickness of 300 mm, the geogrid is far from the load, so the granular particles can no longer push the geogrid laterally, and so there is no longer any interlocking effect.

2 Case study

The laboratory tests carried out by Khoueiry [5] presented as the case reference. Cyclic loadings were taken into consideration, but only static loads will be considered in this paper. An unpaved road is studied with a static constraint of 571 kPa. The CBR of the soft subgrade is equal to 2%. A geosynthetic reinforcement is then required according to the FHWA standard [7]. The required CBR for the granular platform is 20% (FHWA [7]). The allowable rut depth is 75 (FHWA [7]). Two base course thicknesses were considered, 220 mm and 350 mm.

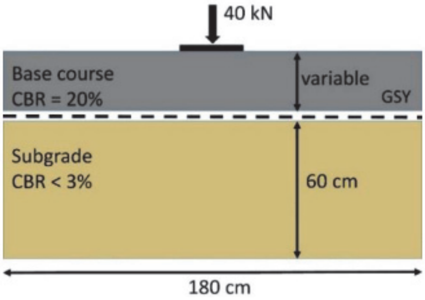


Fig. 2. Platform soil layers constitution (FHWA [7]).

The selected reinforcement geosynthetic is a GEOTER FN PET made with warp-knitted high tenacity polyester (PET) cables knitted with a non-woven (PP) geotextile (figure 3). It was used at the interface between soft subgrade layer and the subbase course layer to improve the bearing capacity and prevent migration of fines from the subgrade to the coarse aggregate layer. The manufacturing process of the geosynthetic guarantees a high level of reinforcement with reduced elongation as the cables are inserted without undulation during the knitting process. It also allows dissociating the separation and reinforcement functions. Indeed, because the high-tenacity polymer yarns provide the reinforcement capability of the product, the non-woven geotextile keeps its filtration opening size constant regardless of the tensile strength of the geosynthetic. The composition of the high-tenacity yarns (PET, PVA, etc.) is selected according to the type of structure and the nature of the surrounding soils.

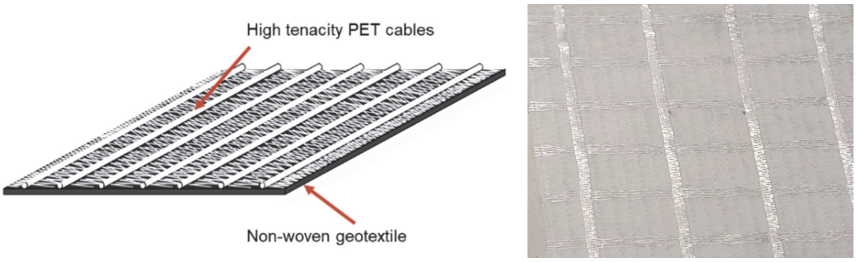


Fig. 3. Warp-knitted high tenacity reinforcement geosynthetic Geoter FN PET.

To estimate the base course thickness needed over the geogrid layer and the tensile strength of the reinforcement geosynthetic that will be used between the subgrade and the granular material, two design methods were considered:

- Giroud & Han’s method based on CBRsub and CBRtop value is used,
- The bearing capacity method presented in the Design of granular working platforms for construction plant [8]. The LimitState: GEO software, (developed by the company LimitState Ltd.) was used to carry out the simulations. The Discontinuity Layout Optimization (DLO) approach used to solve geotechnical analysis problems is underpinned by the rigorous Limit Analysis theory. The software makes it possible to identify the critical slip-line mechanisms without assuming an initial failure shape (like the classical circular failure surface) and, to calculate the safety factor.

3 Results

According to Giroud & Han’s design model, the base course thickness calculation requires iterations. In the reference case study, the base course layer thickness values and the tensile strength of the reinforcement geosynthetic were fixed to test its performance. The maximum tensile strength is equal in both directions to 100 kN/m. Two procedures are suggested for designing reinforced unpaved roads. The first one consists in determining the adequate ultimate tensile strength to attend the CBRtop required according to the design charts for geosynthetic-reinforced subgrades. The thickness of the subgrade is determined by the soil bearing capacity and the bearing capacity target to be reached.

For a base course layer of 220 mm, a reinforcement geosynthetic with an ultimate tensile strength value of 75 kN/m is needed to reach a CBRtop=20% (Figure 4). For a greater base course layer of 350 mm thickness, the reinforcement geosynthetic ultimate tensile strength can be reduced to 50 kN/m.

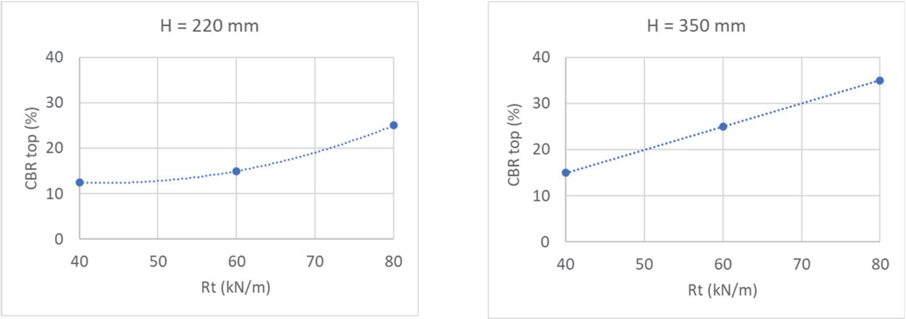


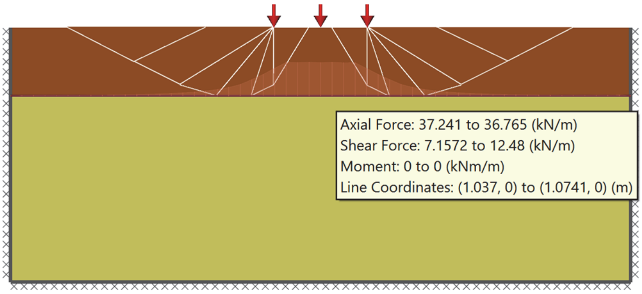
Fig. 4. Results obtained using the Giroud & Han method.

When considering the soil bearing capacity method, the volumetric weights, the cohesions and the friction angles of the considered layers should be used. These properties were given by Khoueiry [5]. In the calculations, the following parameters were considered:

- Base course : γ= 18 kN/m3, c = 10 kPa, ϕ = 37°,
- Base course : γ= 19 kN/m3, c = 19 kPa, ϕ = 28°.

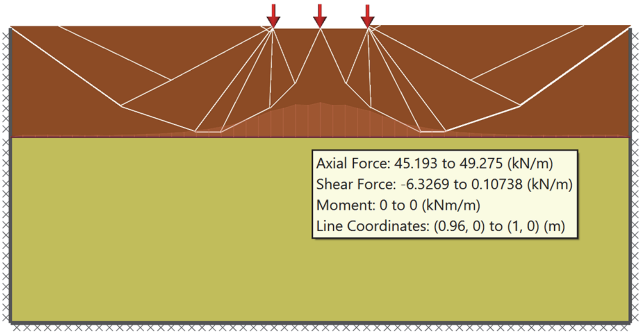
In this kind of calculation, a safety factor is calculated after optimization of the failure zones. The maximum tensile strength is also given by the calculation (Figures 5 and 6). The results obtained show that a reinforcement geosynthetic ultimate tensile strength of 38 kN/m and 50 kN/m are respectively necessary for the cases where H= 220 mm and 350 mm. The safety factors obtained (Approach 2 of Eurocode 7) are twice higher than the unity. The failure shape does not reach the geogrid in the case of H=350 mm.

The comparison between these two design methods shows that the results evolve in a contrary way. The reinforcement geosynthetic ultimate tensile strength increases with H for the soil bearing capacity method and decreases with H with the Giroud & Han's method.



Axial Force: 37.241 to 36.765 (kN/m)
Shear Force: 7.1572 to 12.48 (kN/m)
Moment: 0 to 0 (kNm/m)
Line Coordinates: (1.037, 0) to (1.0741, 0) (m)

Fig. 5. Results obtained using the soil bearing capacity method (H=220mm, FS = 1.02 using approach 2 of Eurocode 7)



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Axial Force: 45.193 to 49.275 (kN/m)
Shear Force: -6.3269 to 0.10738 (kN/m)
Moment: 0 to 0 (kNm/m)
Line Coordinates: (0.96, 0) to (1, 0) (m)
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Fig. 6. Results obtained using the soil bearing capacity method (H=350mm, FS = 1.13 using approach 2 of Eurocode 7)

4 Conclusions

Based on a reference case study (laboratory experiments), two design methods (soil bearing capacity and Giroud & Han) were applied to design the geogrid ultimate tensile strength. The results showed that the soil bearing capacity method seems to be less conservative than the Giroud & Han's one. Nevertheless, the main problem is based on the fact that they evolve in a contrary way with the base course thickness. More research should be done to define more accurately what is the method which is able to model with accuracy what is obtained when using a geogrid to improve the soil bearing capacity.

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