TECHNICAL NOTE

DESIGN METHOD FOR GEOGRID REINFORCED UNPAVED ROADS: I DEVELOPMENT OF DESIGN METHOD

Prepared by:

TenCate™ Geosynthetics North America
365 South Holland Drive
Pendergrass, GA 30567
Tel   706 693 2226
Fax 706 693 4400
www.tencate.com

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We commend Giroud & Han on their paper that adds significantly to the body of knowledge for engineering analysis of unpaved roads. The development of the truncated cone stress distribution represents a technical advancement and simplifies the calculations for this application. The proposed design method also incorporates the modulus of the aggregate base course and subgrade soil as a ratio, permitting quantification of geosynthetic improvement on that ratio, known as the stress distribution angle. The manner in which the geogrid improvement on that modulus ratio or stress distribution angle is formulated and presented in the design method is the focus of this discussion.

Selection of Aperture Stability Modulus for Geogrid Performance

Giroud & Han selected Aperture Stability Modulus (ASM) of geogrid reinforcement as the only performance property upon which to calibrate this new design method for unpaved roads. The basis for this selection are two studies on geogrid reinforcement for paved roads (p 779), that have far different performance / failure criteria than the limiting rut depths (50mm-100mm) stated as a limitation of the design method (p 781) and appear to be based on the testing of a proprietary geogrid with ribs and formed junctions. There is no standardized test method for ASM (J), unlike, say, CBR, the design parameter for aggregate course base and subgrade strength. There are no provisions in the design method to account for installation damage and other environmental factors known to affect synthetic polymer products used in soil reinforcement. This is unique to, and particularly important for, the Giroud-Han method since it attributes a significant amount of the aggregate savings to the ASM (J) of the geogrid reinforcement. Other unpaved road design methods do not rely as much on any geosynthetic strength being present throughout the service life, but rather the geosynthetic improving subgrade bearing capacity performance.

Use of ASM is a departure from established standard practice of geosynthetic tensile strength established in Giroud & Noiray (1981), Bender & Barenberg (1978), and the long standing work by the US Forest Service, see Steward, et. al. (1977). Additionally, Berg et. al. (2000) previously reviewed those same paved road studies and concluded that "there was not clear, quantifiable values for these properties (ASM) specifically related to performance." Recommending instead generic stabilization specifications using "secant moduli," which is related to "tensile strength."

We suggest that the proposed geogrid-reinforced unpaved road design method would be more appropriate to products available in the marketplace today, if it was developed around the average tensile strength at 5% strain in two directions, versus ASM. The numerical difference is illustrated below:

B11 ASM = 0.32 avg T = 11.0 kN/m = (8.5 + 13.4) /2 B12 ASM = 0.65 avg T = 15.8 kN/m = (11.8 + 19.8) /2

This change in ratio between the performance properties of B11 and B12 from
2.03 for ASM, to 1.44 for average tensile strength at 5% strain should lead to better correlation with observed performance in the lab and field studies (see Figures 5 & 6).

Typical Aggregate Base Course Thickness for Design Method

Figures 5 & 6 clearly show the decreased influence of the proprietary geogrid performance properties with increasing aggregate base course thickness. Therefore, it appears to be more appropriate to develop the design method on the performance of the 0.25m section, which is more representative of typical unpaved road aggregate base thickness, which range from 0.2m to 0.6m. This would also produce a conservative approximation of geogrid reinforcement effects on aggregate base course thickness less than 0.25m, a more desirable approach than a potentially unconservative aggregate base course thickness over 0.15m, as currently proposed by Giroud & Han. It is important to maintain a degree of conservatism when attempting to aggressively advance the design procedures relative to the established design practices that have performed well. This is especially the case when the lab and field research data used to establish this design method rarely went over 1,000 load cycles and most tests went less than 500 cycles.

Comparison of Unpaved Road Design Methods

To quantify the aggregate base course reduction proposed in the Giroud-Han design method using ASM, we performed calculations using comparable, current practice design methods and present the results in Tables 1 & 2. For our comparison, the average tensile strength at 5% strain for B11 & B12 was used in both the Giroud & Noiray (1981) and Bender & Barenberg (1978) methods as the geosynthetic performance property, resulting in identical aggregate thickness regardless of product type, geogrid or geotextile. Contrast this with the Giroud-Han method, which utilizes a lower bearing capacity factor for geotextiles of similar strength as a geogrid, and eliminates any benefit of the tension membrane effect for geotextiles.

Table 1 results are all similar between the three methods except the Giroud-Han design for B12 geogrid, (high J, ASM). However, when significant load cycles are considered, like in Table 2, the unreinforced aggregate thicknesses are quite different. Although geotextile aggregate thickness compare favorably in Table 2, the unreinforced and geogrid aggregate thickness for Giroud-Han are significantly less than current practice would utilize.

The approximate 70% reduction in aggregate thickness due to incorporation of the B12 geogrid seems particularly aggressive when compared to the 48% reduction for B11 geogrid, and the roughly 35% reduction due to geotextile reinforcement calculated by the Giroud-Han method. Particularly when considering the performance characteristics between these three geosynthetics does not appear to be that significant.

These comments and comparative analyses are provided, such that more consideration be given to secant moduli (i.e., average tensile strength at 5% strain) versus ASM, as the geogrid performance property. It is also suggested that the design method be reformulated based on a typical aggregate thickness of 0.25m versus 0.15m.

Table 1: Comparison of Aggregate Thickness for Unpaved Road Design Methods 100 cycles of 80 kN Axle Load, rut 75mm, CBR = 1.0

Method		Unreinforced	Geogrid	Geotextile
Giroud & Han	w/ B11	**0.41m**	**0.21m**	**0.26m**
Giroud & Noiray	w/ B11	0.38m	0.25m	0.25m
Bender & Barenberg	w/ B11	0.43m	0.26m	0.26m
Giroud & Han	w/ B12	**0.41m**	**0.13m**	**0.26m**
Giroud & Noiray	w/ B12	0.38m	0.25m	0.25m
Bender & Barenberg	w/ B12	0.43m	0.24m	0.24m

Table 2: Comparison of Aggregate Thickness for Unpaved Road Design Methods 1000 cycles of 80 kN Axle Load, rut 100mm, CBR = 1.0

Method		Unreinforced	Geogrid	Geotextile
Giroud & Han	w/ B11	**0.38m**	**0.20m**	**0.25m**
Giroud & Noiray	w/ B11	0.53m	0.40m	0.40m
Bender & Barenberg	w/ B11	0.56m	0.30m	0.30m
Giroud & Han	w/ B12	**0.38m**	**0.11m**	**0.25m**
Giroud & Noiray	w/ B12	0.53m	0.40m	0.40m
Bender & Barenberg	w/ B12	0.56m	0.28m	0.28m

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DOI: 10.1061/(ASCE)1090-0241(2004)130:8(775) by: Michael R. Simac, PE, M-ASCE[1] David J. Elton, PhD, PE, M-ASCE[2], and Stephan M. Gale, PE, F-ASCE[3]

Principal Engineer, Earth Improvement Technologies, P. O. Box 397, Cramerton, NC 28032, e-mail: simac.eit@earthlink.net

Associate Professor, Department of Civil Engineering, Auburn University, Auburn, AL e-mail: elton@eng.auburn.edu

Principal Engineer, Gale-Tec Engineering, Inc. Wayzata, MN, e-mail: smg@gale-tec.com

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