TENAX

Technical Reference TDS007

DESIGN OF UNPAVED ROADS
WITH TENAX GEOGRIDS

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Design of Unpaved Roads With Tenax Geogrids

1. Introduction

This technical reference describes the design steps of unpaved roads that include temporary haul roads and access roads. The design methods proposed by Giroud - Noiray (1981), and Giroud - Ah-Line-Bonaparte (1985) are adopted here in conjunction with the properties of Tenax geogrids. An interactive computer program is developed allowing one to compute the required aggregate thickness of unpaved road. Design of both unreinforced and reinforced unpaved roads is included. The use of Tenax geogrids in unpaved road application can result in a reduction in the aggregate thickness.

2. Design Steps

The design procedure of unpaved roads is presented in the following five steps:
Step 1: Calculate the required aggregate thickness, $\mathbf{h'_o}$ for the unreinforced road with traffic using Equation 1

$$h'_o = \frac{125.70\log(N) + 496.50\log(1000P) - 294.14r - 2412.42}{(1000c_u)^{0.63}} \tag{1}$$

where, $\mathbf{h'_o}$ is in meters, **P** is the single axle load in kN, **r** is the allowed rut depth in meters, **N** is the number of traffic passages, $\mathbf{c_u}$ is the undrained shear strength of the soft subgrade in kPa. An empirical relation between CBR value and the undrained shear strength can be used if subgrade CBR value is provided

$$c_u = 30 * CBR\ (kPa) \tag{2}$$

The above design equation (1) is valid for traffic passes no greater than 10,000 as identified by Giroud - Noiray (1981) and it is graphically shown in figure 1.

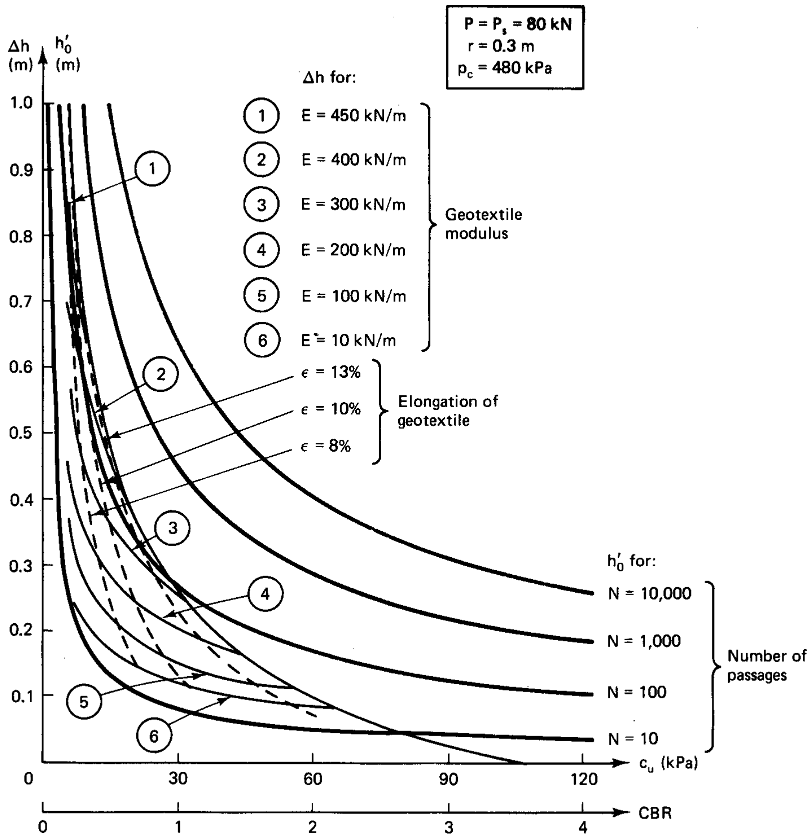

Figure 1. Required aggregate thickness, $\mathbf{h'_o}$ for the unreinforced road with traffic using Equation 1 graphically solved.

Step 2: Calculate the required aggregate thickness, $\mathbf{h_o}$, for the unreinforced road with a single passage of traffic using a quasi-static analysis as presented in Equation 3, (see Figure 2)

$$h_o = \frac{-(B+L)+\sqrt{(B+L)^2 - 4(BL - c_1)}}{4\tan\ \alpha_o} \qquad (3)$$

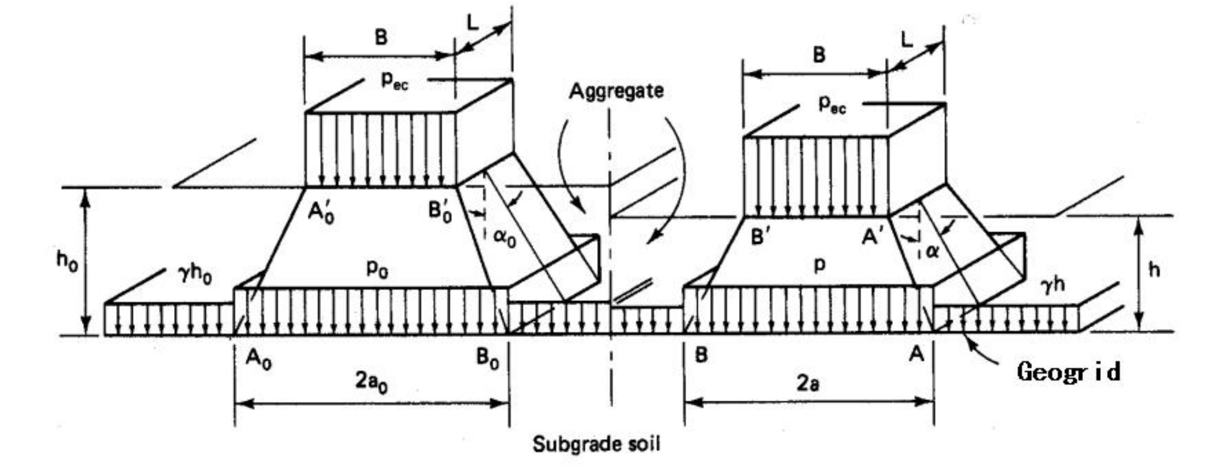

Figure 2. Load Distribution by Aggregate Layer for Unreinforced and reinforced road section

Where,

$$c_1 = \frac{P}{2\pi c_u}$$

$$B = \sqrt{\frac{P}{P_c}} \qquad L = \frac{B}{\sqrt{2}} \qquad \text{for on - highway trucks}$$

$$B = \sqrt{\frac{P\sqrt{2}}{P_c}} \qquad L = \frac{B}{2} \qquad \text{for off - highway trucks}$$

and $\mathbf{P_c}$ is tire inflation pressure in kPa, α_o is angle of load distribution pyramid in degrees, **tan** α_o **= 0.6** as suggested by Giroud-Noiray.

Step 3: Calculate the required aggregate thickness, **h**, for the reinforced road with a single passage of traffic by quasi-static analysis. An iteration scheme is required in order to solve **h** from Equation (4).

$$h = \frac{-(B+L)+\sqrt{(B+L)^2-4(BL-c_2)}}{4\tan\ \alpha} \qquad \text{...(4)}$$

where

$$c_2 = \frac{P}{2\left[(\pi+2)c_u + \dfrac{K\varepsilon}{a\sqrt{1+(\dfrac{a}{2s})^2}}\right]}$$

K and ε are secant tensile modulus and tensile strain of geogrid reinforcement respectively.

$$a = 0.5(B + 2h\tan\alpha)$$

$$a' = 0.5(e - B - 2h\tan\alpha)$$

Where **e** is the distance between midpoints of two sets of wheels

if a` > a: $s = \dfrac{ra'}{a + a'}$ $\varepsilon = \dfrac{b + b'}{a + a'} - 1$

and if a` < a $s = \dfrac{2ra^2}{2a^2 + 3aa' - a'^2}$ $\varepsilon = \dfrac{b}{a} - 1$

The geogrid strain ε is determined from the following two equations:

$$\frac{b}{a} - 1 = \frac{1}{2}\left[\sqrt{1 + \left(\frac{2s}{a}\right)^2} + \frac{a}{2s}\ln\left(\frac{2s}{a} + \sqrt{1 + \left(\frac{2s}{a}\right)^2}\right) - 2\right]$$

$$\frac{b'}{a'} - 1 = \frac{1}{2}\left[\sqrt{1 + \left(\frac{2(r-s)}{a'}\right)^2} + \frac{a'}{2(r-s)}\ln\left(\frac{2(r-s)}{a'} + \sqrt{1 + \left(\frac{2(r-s)}{a'}\right)^2}\right) - 2\right]$$

Geogrid reinforcement improves the load distribution through geogrid-aggregate interlocking mechanism. The improvement of the load distribution can be quantified by the increase in the angle of the load distribution pyramid, or load distribution improvement ratio **tan α/ tan** α_o, where α_o and α are angles of load distribution pyramid in degrees without and with geogrid reinforcement. The load distribution improvement ratio was found between 1.1 and 2.5 by Giroud et al. This ratio is dependent on the expected degree of confinement and separation that the geogrid provides to the system. For Tenax geogrids this ratio is suggested to be modeled by a linear function of the tensile modulus at 2% as follows:

$$\tan\alpha / \tan\alpha_o = 1.1 + 0.0015 * K$$

Step 4: Calculate the reduction of aggregate thickness, Δh, due to the inclusion of Tenax geogrid

$$\Delta h = h_o - h$$

Step 5: Calculate the required aggregate thickness, **h'**, for the reinforced road with traffic

$$h' = h'_o - \Delta h$$

Note that the aggregate in the above calculations is assumed to have a CBR of at least 80, and the properties required to ensure a proper distribution of the applied load.

3. Incorporating Tenax Geogrids

The input data for Tenax geogrids in this design method are their secant tensile moduli. Table 1 shows the tensile moduli of Tenax geogrids at 2% strain.

Table 1. Tensile Moduli of Tenax Geogrids (kN/m)

Geogrid	LBO 220 SAMP	LBO 330 SAMP	LBO 440 SAMP	LBO 202 SAMP	LBO 302 SAMP	MS 500	MS 550
Machine Direction	350	525	700	225	350	300	750
Transverse Direction	350	525	700	330	600	500	750

Note that the secant modulus in the transverse direction of the geogrid reinforcement should be used in the design, since geogrid rolls are typically installed along the roadway longitudinal direction.

4. Design Example

Given data:
An unpaved haul road needs to be designed
Equivalent single axle load **P** = 80 kN
Tire inflation pressure $\mathbf{P_c}$ = 750 kPa
Distance between midpoints of two sets of wheels **e** = 1.9 m
Passage of **off-highway** traffic **N** =10'000
Undrained shear strength of subgrade $\mathbf{c_u}$ = 15 kPa
Permissible rut depth **r** = 0.15 m
Tensile modulus of Tenax LBO 330 SAMP geogrid at 2% strain **K**= 525 kN/m

Design solution:
Aggregate thickness for unreinforced roads $\mathbf{h_o}$ = 1.12 m

Aggregate thickness for reinforced roads with Tenax LBO 330 SAMP is **h'** = 0.77 m
Reduction of aggregate thickness due to Tenax geogrid is **Δh** = 0.36 m (32% saving of the aggregate fill)
Actual strain developed in geogrid ε= 1.8 %

Note that if the calculated strain in the geogrid is higher than the initially assumed 2% strain, another calculation is required to account for the corresponding tensile modulus based on the stress-strain curve. Using the tensile modulus at 2% strain is conservative for lower calculated strains.

5. Design Worksheet UnpaveRoad

The above described set of design calculations are simplified in a Microsoft Excel® worksheet called **UnpaveRoad** to assist in the design of unpaved/ haul roads with and without the use of Tenax's Geogrids. Enclosed is a diskette/ CD with a copy of **UnpaveRoad** worksheet.

Using the worksheet is straightforward; by inserting the input data in the corresponding cells, and hitting the "CALCULATE" button, the designed cross section with and without using geogrid will be displayed on the output cells. Please note that each time any of the input data are changed, or the type of trucks is changed, the "CALCULATE" button has to be clicked.

INPUT DATA*

Distance between midpoints of two sets of Wheels:	e (m)	1.9
Number of Traffic passages:	N	10'000
Single Axle Load:	P (kN)	80
Allowed Rut Depth:	r (m)	0.15
Undrained Shear Strength:	C_u (kPa)	15
Tire Inflation Pressure:	P_c (kPa)	750
Tensile Modulus of Tenax's Geogrid:	k (kN/m)	525

OUTPUT DATA

Required Aggregate Thickness

h'_o with no Reinforcement:	1.12	m
h' with Reinforcement:	0.77	m
h'_o - h' :	0.36	m
Reduction:	32	%
Tensile Strain of Geogrid	1.8	%

6. References

1) Giroud, J.P. and Noiray, L. (1981) "Geotextile-reinforced unpaved road design", Journal of Geotechnical Engineering, ASCE, 107, 1233-1254.
2) Giroud, J.P., Ah-Line, C. and Bonaparte, R. (1985) "Design of unpaved roads and trafficked areas with geogrids", Proc. Symp. on Polymer Grid Reinforcement in Civil Engineering , pp.9-12, London.
3) Hausmann, M.R. (1987). "Geotextiles for unpaved roads-A review of design procedures", Journal of Geotextiles and Geomembranes, 5, 201-233.
4) Holtz, R.D. and Sivakugan, N. (1987). "Design charts for roads with geotextiles", Journal of Geotextiles and Geomembranes, 5, 191-199.