
TENAX

Technical Reference GRID-DE-1

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 as will be shown in the following sections.

2. Design Steps

The design procedure of unpaved roads is presented in the following five steps:

(1) Calculate the required aggregate thickness, h'_o for the unreinforced road with traffic using Equation 1

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

where, 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, c_u is the undrained shear strength of the soft subgrade in kPa. The above design equation is valid for traffic passes no greater than 10,000 as identified by Giroud - Noiray (1981).

(2) Calculate the required aggregate thickness, h_o , for the unreinforced road with a single passage of traffic using a quasi-static analysis as presented in Equation 2, (see Figure 1)

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

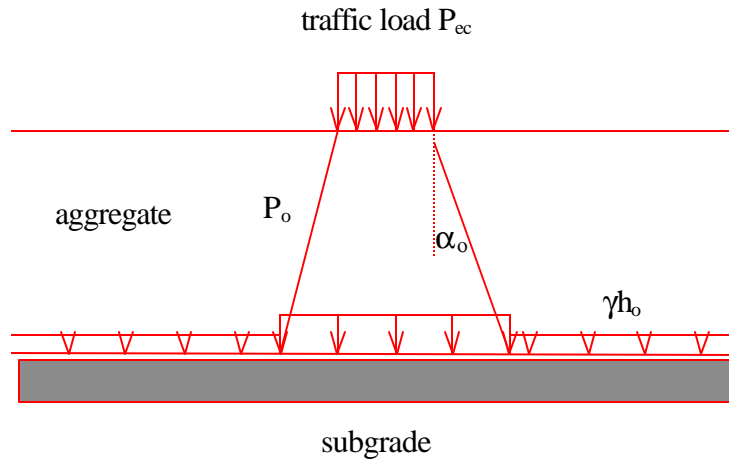


Figure 1. Load Distribution by Aggregate Layer

Where,

$$c_1 = \frac{P}{2 \mathbf{p}_u}$$

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

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

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

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

$$h = \frac{-(B+L) + \sqrt{(B+L)^2 - 4(BL - c_2)}}{4 \tan \mathbf{a}} \dots\dots\dots(3)$$

where

$$c_2 = \frac{P}{2 \left[(\mathbf{p} + 2)c_u + \frac{K\mathbf{e}}{a \sqrt{1 + \left(\frac{a}{2s}\right)^2}} \right]}$$

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

$$a = 0.5(B + 2h \tan \mathbf{a})$$

$$a' = 0.5(e - B - 2h \tan \mathbf{a})$$

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

if $a' > a$

$$s = \frac{ra'}{a + a'}$$

$$\mathbf{e} = \frac{b + b'}{a + a'} - 1$$

and if $a' < a$

$$s = \frac{2ra^2}{2a^2 + 3aa' - a'^2}$$

$$\mathbf{e} = \frac{b}{a} - 1$$

The geogrid strain ϵ could be solved for using 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 $\tan \alpha / \tan \alpha_0$, where α_0 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:

$$\tan \alpha / \tan \alpha_0 = 1.1 + 0.0005 * K$$

(4) Calculate the reduction of aggregate thickness, Δh , due to the inclusion of Tenax geogrid

$$\Delta h = h_0 - h$$

(5) Calculate the required aggregate thickness, h' , for the reinforced road with traffic

$$h' = h_0 - \Delta h$$

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	MS220	MS330	MS500	MS1000	MS2000	LBO201	LBO301
Machine Direction	220	305	300	205	270	225	300
Transverse Direction	325	450	500	310	435	330	500

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 $P_c = 480$ kPa

Distance between midpoints of two sets of wheels $e = 1.9$ m

Passage of **off-highway** traffic $N = 100$

Undrained shear strength of subgrade $c_u = 15$ kPa

Permissible rut depth $r = 0.15$ m

Tensile modulus of Tenax MS 330 geogrid at 2% strain $K= 450$ kN/m

Design solution:

Aggregate thickness for unreinforced roads $h_o = 0.536$ m

Aggregate thickness for reinforced roads with Tenax MS 330 is $h' = 0.275$ m

Reduction of aggregate thickness due to Tenax geogrid is $Dh = 0.261$ m (48.7% saving of the aggregate fill)

Actual strain developed in geogrid $e = 1.76\%$

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 designing of the 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. The worksheet contains background information on Tenax MS geogrid series and the specification sheets of MS220, MS330, and MS500 geogrids. Microsoft Office[®] 97 (or more recent version) is required to open this worksheet, with "Enabling Macro" option

6. References

Giroud, J.P. and Noiray, L. (1981) “Geotextile-reinforced unpaved road design”, *Journal of Geotechnical Engineering, ASCE*, 107, 1233-1254.

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