DESIGN METHOD FOR GEOGRID REINFORCEMENT OF ROAD BASES

P. Rimoldi [1], M. Scotto[2], and D. Ghosal[3]
[1] Officine Maccaferri SpA, Italy; Tel: +39-051-6436000; Fax: +39-051-6436201;
Email: pietro.rimoldi@gmail.com
[2] Officine Maccaferri SpA, Italy; Tel: +39-051-6436000; Fax: +39-051-6436201;
Email: moreno.scotto@gmail.com
[3]Maccaferri Malaysia Sdn Bhd, Tel: +60-3-79557800; Fax: +60-3-79557801;
Email: ghoshal@maccaferri-asia.com

ABSTRACT

Geogrids are extensively used for reinforcing paved and unpaved road bases on soft soils. Anyway the present design methods provide no indication for the number of required layers and the mechanical characteristics of reinforcing geogrids. Hence a new design method has been developed which affords the design of geogrids for road base reinforcement, based on a 4 layers model: asphalt (binder and wearing course), in case of paved roads; base, subbase, subgrade. Once the base and/or subbase thickness has been defined with one of the available methods (as an example: Giroud – Han method, Leng- Gabr method, etc.), the proposed design method affords to calculate the tensile forces in reinforcing geogrids generated by: self weight of the different layers; wheel load of heavy vehicles; membrane effect at the base (or subbase) – subgrade interface. It is then possible to set the number and the mechanical characteristics of geogrid layers required for absorbing the horizontal forces generated by the above listed mechanisms. Hence the proposed design method affords the design of geogrids in the safe construction of paved and unpaved roads on soft soil.

Keywords: Geogrids, road bases, design method

INTRODUCTION

The design methods for paved and unpaved roads (as an example: Giroud – Han method, Leng-Gabr method, etc.) usually assume that the road base is reinforced with just one geogrid layer, but the actual required geogrid reinforcement needs to be designed on the base of sound engineering principles.

Geogrids provide the following reinforcing mechanisms:

- base course lateral restrain mechanism for horizontal stresses generated by the soil self weight;
- base course lateral restrain mechanism for horizontal stresses generated by wheels loading;
- tensioned membrane mechanism at the base or subbase – subgrade interface.

Each of these three mechanisms produce tensile forces in geogrid reinforcement layers.

Sound engineering principles dictate to calculate these tensile forces, and the overall tensile forces generated in each layer of geogrids, and then to select the appropriate geogrid for each layer based on a limit state criterion.

When we are dealing with paved or unpaved roads, the limit state criterion cannot be the failure but rather the operating condition criterion, that is the deformations shall be limited.

To achieve this goal we must put a limit on geogrid strain: both theory and practical experience suggest that geogrid strain shall be limited to 5 %.

Obviously, more important is the road structure we are designing and lower the design geogrid strain shall be. Hence for important structures the geogrid strain shall be limited to 2 %, while for less important structures (or when the design conditions afford slightly larger deformations) 3 %, 4 % or 5 % geogrid strain can be acceptable. We must take into account the fact that roads are never subject to long lasting applied load, rather they are subject to instant loads when there is wheels passage. Hence the geogrid strain limit shall be applied to short term tensile strength, as measured in a wide width tensile test according to EN ISO 10319 standard.

The scope of the present paper is to present a method for defining the tensile forces produced on geogrid layers by the three active mechanism above identified, then for designing the number and vertical position of the required geogrid layers, once the required base and/or subbase thickness has been defined with the available design methods for paved and unpaved roads.

MULTI-LAYER MODEL

The general scheme of a road or a parking deck may include the following layers:

- asphalt course AC (wearing course and binder layer are considered as one only layer whose thickness is the total thickness of the two ones);
- base course BC;
- subbase course SB;
- subgrade SG.

Therefore a 4 layers model has been developed for geogrid design: the general scheme of the model and all symbols, that will be used for subsequent calculations, are shown in Fig. 1.

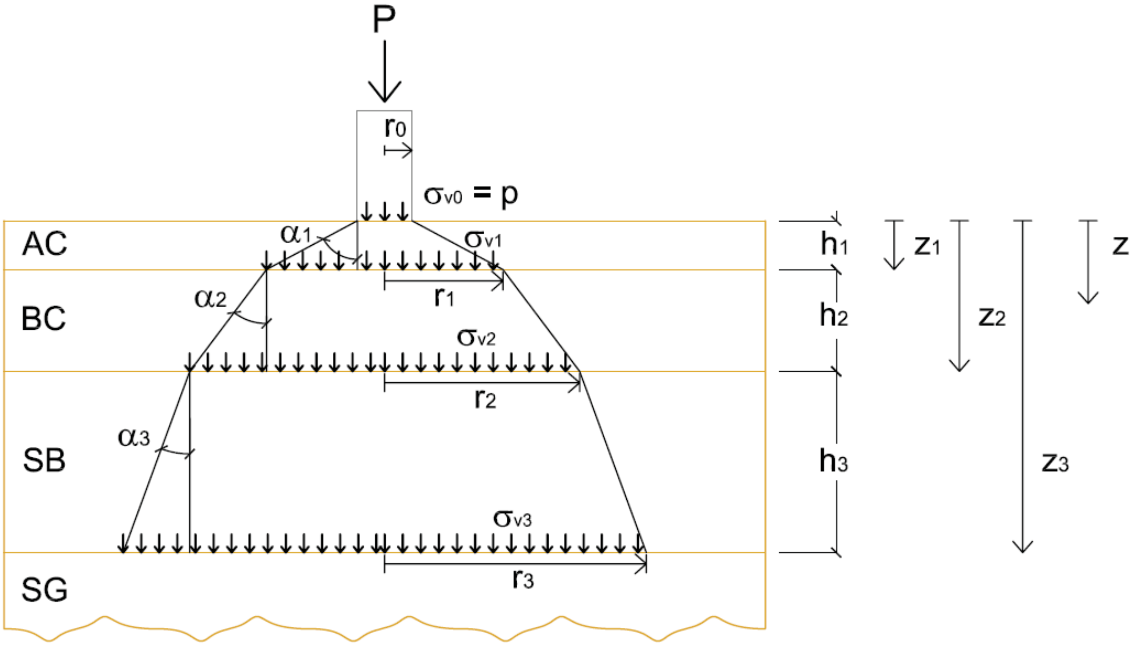


Fig. 1 - General scheme of the 3 layers model

The model assumes that the wheel load is applied as a uniform vertical pressure $\sigma_{v0} = p$ (tyre inflation pressure) on a circular area with equivalent radius r_0; this load spreads in the 3 layers of the road structure (AC, BC and SB) according to their load spreading angles α_1, α_2, α_3.

At least the base course shall be present and shall be reinforced with geogrids; the asphalt course may not be present (in case of an unpaved road) and, if present, it is not reinforced; the subbase course may be present or not; when it is present, it may be either reinforced with geogrids or unreinforced.

FORCE DUE TO HORIZONTAL SOIL THRUST

The tensile force T_{zi}, generated in the i-th geogrid layer by the horizontal thrust of the soil above it, can be easily calculated based on classic geotechnical theory.

The vertical stress at depth Z_1, due to asphalt self weight, is:

$$\sigma_{vi} = \gamma_1 Z_1 \tag{1}$$

where:
γ_1 = unit weight of the asphalt layer (kN/m³)

For $Z_1 < Z < Z_2$:

$$\sigma_v = \gamma_1 Z_1 + \gamma_2 (Z - Z_1) \tag{2}$$

The related horizontal stress is:

$$\sigma_h = K_2 \sigma_v \tag{3}$$

where:
$K_2 = \tan^2(45° - \varphi_2 / 2)$ = active soil thrust parameter for BC (4)
φ_2 = friction angle of BC

Then we assume that the tensile force T_{zi} generated in the i-th geogrid in the base course is the integral of the horizontal soil stresses between the i-th geogrid layer and the (i-1)th geogrid layer:

$$T_{zi} = 0{,}5\, K_2 [\, \gamma_2 (Z_{i2} - Z_{i2-1}) + \gamma_1 Z_1 \,] \tag{5}$$

For $Z_2 < Z < Z_3$:

$$\sigma_v = \gamma_1 Z_1 + \gamma_2 (Z_2 - Z_1) + \gamma_3 (Z - Z_2) \tag{6}$$

The related horizontal stress is:

$$\sigma_h = K_3 \ \sigma_v \tag{7}$$

where:
$K_3 = \tan^2(45° - \varphi_3 / 2)$ = active soil thrust parameter for SB (8)
φ_3 = friction angle of SB

The tensile force T_{zi} generated in the i-th geogrid in the subbase course is:

$$T_{zi} = 0{,}5\ K_3\ [\ \gamma_3\ (Z_{i2} - Z_{i2-1}) + \gamma_1\ Z_1 + \\ +\ \gamma_2\ (Z_2 - Z_1)\ ] \tag{9}$$

FORCE DUE TO HORIZONTAL STRESSES GENERATED BY WHEELS LOADING

If we assume that the wheel load is applied on a circular area of equivalent radius r_0 and that the load spreads in the layers below as a cone whose generatrix is inclined of the load spreading angle α_i, then the radius r at depth Z below the top surface is:

For $0 < Z < Z_1$:

$$r = r0 + Z \tan \alpha 1 \tag{10}$$

Since it must be: $\pi\ r_0^2\ \sigma_{v0} = \pi\ r_i^2\ \sigma_{vi}$
then the vertical stress produced by the wheel load at depth Z is:

$$\sigma_v = \sigma_{v0}\ r_0^2 / r_i^2 \tag{11}$$

For $Z_1 < Z < Z_2$:

$$r = r_1 + (Z - Z_1) \tan \alpha_2 \tag{12}$$

$$\sigma_v = \sigma_{v1}\ r_1^2 / r_i^2 \tag{13}$$

$$\sigma_h = K_2\ \sigma_v \tag{14}$$

Then we assume that the tensile force T_{Pi} generated in the i-th geogrid in the base course by the wheel load is the integral of the horizontal soil stresses between the i-th geogrid layer and the (i-1)th geogrid layer, which can be exprees as:

$$T_{Pi} = 0{,}5\ (\sigma_{hi} + \sigma_{hi-1})\ (Z_i - Z_{i-1}) \tag{15}$$

For $Z_2 < Z < Z_3$:

$$r = r^2 + (Z - Z_2) \tan \alpha_3 \tag{16}$$

$$\sigma_v = \sigma_{v2}\ r_2^2 / r_i^2 \tag{17}$$

$$\sigma_h = K_3\ \sigma_v \tag{18}$$

The tensile force T_{Pi} generated in the i-th geogrid in the subbase course is:

$$T_{Pi} = 0{,}5\ (\sigma_{hi} + \sigma_{hi-1})\ (Z_i - Z_{i-1}) \tag{19}$$

FORCE DUE TO MEMBRANE MECHANISM AT THE INTERFACE WITH SUBGRADE

The first geogrid layer, at the interface with the subgrade, is subject to the highest vertical deformations, when the first soil layer is spread and compacted, due to the settlement of the soft subgrade; the next geogrid layers, instead, are far less subject to vertical displacements.

Hence we can reasonably assume that the first geogrid layer is subject to the tensioned membrane mechanism, that is the first geogrid can be considered as a catenary layer, while for the next layers such mechanism is negligible.

We will refer to the scheme shown in Fig. 2.

First Case: When the Subbase is not Present.

According to tensioned membrane theory (Giroud et Al, 1990), the uniform vertical load WTC on the catenary layer of reinforcement is:

WTC = [(volume V of load cone below the wheel) · (fill density γ) + wheel load P – subgrade reaction R] / (area A at reinforcement catenary layer)

For the geogrid layer at base course bottom V and A become:

$$V = 1/3\ \pi\ r_f^2\ h_f - 1/3\ \pi\ r_0^2\ (h_f - Z_f) \tag{20}$$

$$A = \pi\ r_f^2 \tag{21}$$

where: Z_f = depth of first base course lift (m)
h_f = height of the load cone (m)

The wheel load P and the tyre pressure p in this case are referred to a truck or dumper used at the job site for carrying the soil.

Since we are dealing with the first lift of aggregate placed on a soft soil, very heavy vehicles shall not be used.

Hence we can reasonably assume the same wheel load P and tyre pressure p used for road design.

We can reasonably assume that the subgrade reaction R is equal to the allowable bearing capacity of a cohesive soil layer with geogrid reinforcement (Rodin, 1965), that is:

$$R = 2\ \pi\ c_u\ A / FS = 2\ \pi\ (30\ CBR_{SG})\ A / FS = \\ = 60\ \pi\ CBR_{SG}\ A / FS \tag{22}$$

where:
FS = Factor of Safety for subgrade bearing capacity
c_u = undrained cohesion of subgrade
CBR_{SG} = California Bearing Ratio of subgrade

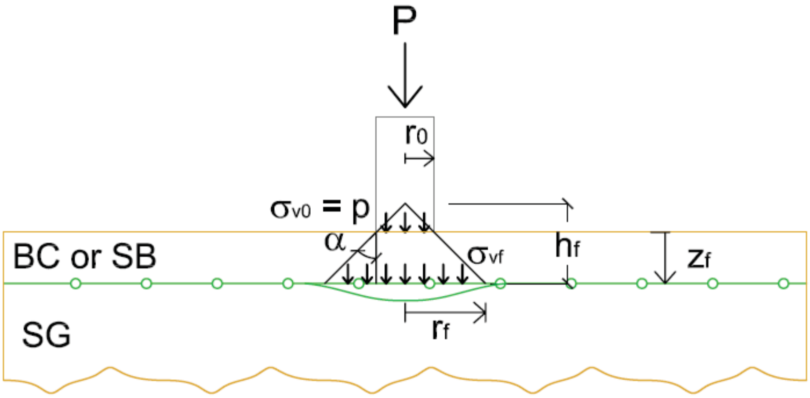


Fig. 2 - Scheme of the first geogrid layer

Since it is:

$$r_f = r_0 + Z_f \tan \alpha_2 \qquad (23)$$

$$h_f = r_f / \tan \alpha_2 \qquad (24)$$

$$(h_f - Z_f) = r_0 / \tan \alpha_2 \qquad (25)$$

$$P = \pi \, r_0^2 \, p \qquad (26)$$

We finally get, for the first lift of the base course:

$$WTC_2 = [(\gamma_2 / 3) \; (r_f^3 - r_0^3) / (r_f^2 \tan \alpha_2)] + + p \, (r_0^2 / r_f^2) + 60 \, \pi \, CBR_{SG} \, A / FS \qquad (27)$$

The tensile load in the catenary reinforcement at base course bottom is determined based on tensioned membrane theory and is a function of the amount of strain in the reinforcement. The tension in the reinforcement is determined from the following equation:

$$T_{m2} = WTC_2 \;\; \Omega \;\; r_f \qquad (28)$$

where:
Ω = dimensionless factor from tensioned membrane theory, as a function of reinforcement strain ε_r (Table 1)

Table 1 – Values of dimensionless factor Ω

ε_r (%)	Ω
1	2,07
2	1,47
3	1,23
4	1,08
5	0,97

If the bearing capacity of the subgrade is enough to support the first lift of the base course and the wheel load, WTC_2 becomes negative; in such case no tensioned membrane mechanism occur, hence:

$T_{m2} = 0$ (29)

Second Case: When the Subbase is Present.

In such case the geogrid at base course bottom is not subject to the tensioned membrane mechanism, hence:

$$T_{m2} = 0 \qquad (30)$$

The geogrid layer at subbase bottom instead is subject to the tensioned membrane mechanism; hence, considering the first lift of subbase course, we get:

$$r_f = r_0 + Z_f \tan \alpha_3 \qquad (31)$$

$$h_f = r_f / \tan \alpha_3 \qquad (32)$$

$$(h_f - Z_1) = r_0 / \tan \alpha_3 \qquad (33)$$

$$WTC_3 = [(\gamma_3 / 3) \; (r_f^3 - r_0^3) / (r_f^2 \tan \alpha_3)] + p \, (r_0^2 / r_f^2) + 60 \, \pi \, CBR_{SG} \, A / FS \qquad (34)$$

$$T_{m3} = WTC_3 \;\; \Omega \;\; r_f \qquad (35)$$

Also in this case, if the bearing capacity of the subgrade is enough to support the first lift of the subbase course and the wheel load, WTC_3 becomes negative; in such case no tensioned membrane mechanism occur, hence:

$$T_{m3} = 0 \qquad (36)$$

TOTAL HORIZONTAL FORCE

The total horizontal force that the i-th geogrid layer has to withstand is then:

$$T_{tot\text{-}i} = T_{zi} + T_{Pi} + T_m \qquad (37)$$

Where Tm, as said, applies only to the first geogrid layer at the interface with the subgrade, either of the base course or of the subbase course.

GEOGRIDS DESIGN

The i-th geogrid layer shall be able to provide a tensile force equal to or larger than T_{tot-i} at a maximum strain of 5 %.

More important is the road structure we are designing and lower the design geogrid strain shall be. Hence for important structures the geogrid strain shall be limited to 1 – 2 %, while for less important structures (or when the design conditions afford slightly larger deformations) 3 %, 4 % or 5 % geogrid strain can be acceptable.

The above mentioned limit strain criterion shall be applied to the short term tensile strength of geogrids, as measured in a wide width tensile test according to EN ISO 10319 standard.

Hence for designing the geogrids for a reinforced base and / or subbase, the Engineer shall have at hand the tensile strengths at 1%, 2 %, 3 %, 4 % and 5 % for a whole range of bidirectional geogrids, with ultimate tensile strengths in the indicative range of 20 – 50 kN/m.

EXAMPLE 1

Let's design the paved road structure shown in Table 3 with the traffic data shown in Table 4; let's design with reinforced base and reinforced subbase.

Design of the road structure is carried out with AASHTO 1993 method for unreinforced road, and with modified AASHTO 1993 method for reinforced road.

For reinforced road design we assume to use extruded biaxial geogrids, with 20 x 20 kN/m tensile strength (GG20) for base reinforcement, and with 40x40 kN/m tensile strength (GG40) for subbase reinforcement.

For these geogrids Manufacturer's technical data report the following Layer Coefficient ratio (LCR):

$$LCR_{GG20} = 1.506 \qquad (38)$$

$$LCR_{GG40} = 1.800 \qquad (39)$$

Design with AASHTO 1993 method results in the unreinforced road structure shown in Fig. 3, and the reinforced road structure shown in Fig. 4.

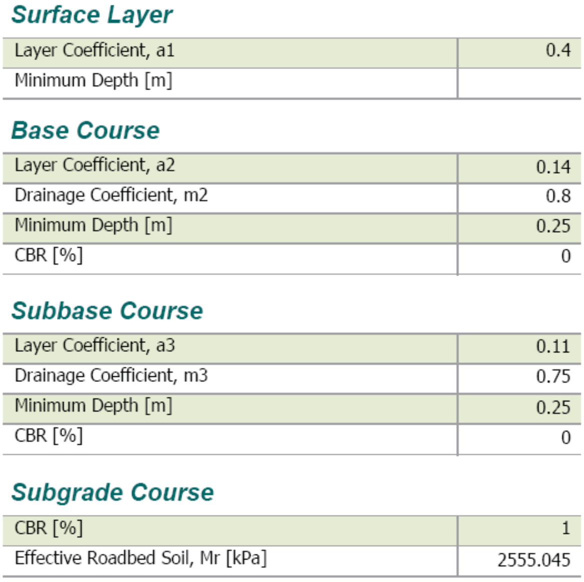
Note that the modified AASHTO 1993 method assumes that both base and subbase are reinforced with 1 layer only of geogrid.

Now let's apply the geogrid design method above explained.

Let's use extruded biaxial geogrids with the tensile strenths at given strain ε_r reported in Table 5.

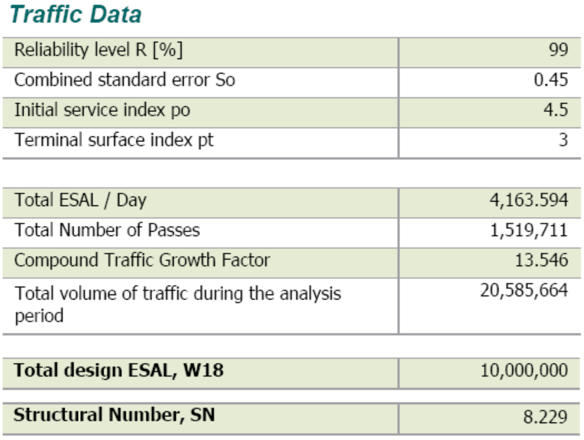
The input data for calculation, related to traffic loads and to materials and soils properties are reported in Table 6.

Table 3 – Road data for Example 1



Surface Layer	
Layer Coefficient, a1	0.4
Minimum Depth [m]	
Base Course	
Layer Coefficient, a2	0.14
Drainage Coefficient, m2	0.8
Minimum Depth [m]	0.25
CBR [%]	0
Subbase Course	
Layer Coefficient, a3	0.11
Drainage Coefficient, m3	0.75
Minimum Depth [m]	0.25
CBR [%]	0
Subgrade Course	
CBR [%]	1
Effective Roadbed Soil, Mr [kPa]	2555.045

Table 4 – Traffic data for the Example 1



Traffic Data	
Reliability level R [%]	99
Combined standard error So	0.45
Initial service index po	4.5
Terminal surface index pt	3
Total ESAL / Day	4,163.594
Total Number of Passes	1,519,711
Compound Traffic Growth Factor	13.546
Total volume of traffic during the analysis period	20,585,664
Total design ESAL, W18	10,000,000
Structural Number, SN	8.229

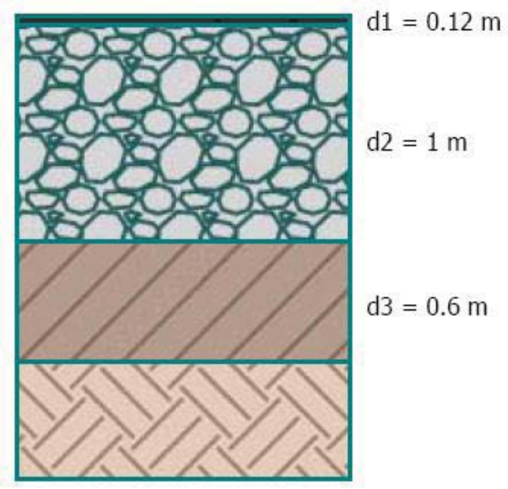


Fig. 3 Unreinforced road structure resulting from calculation with AASHTO 1993 method

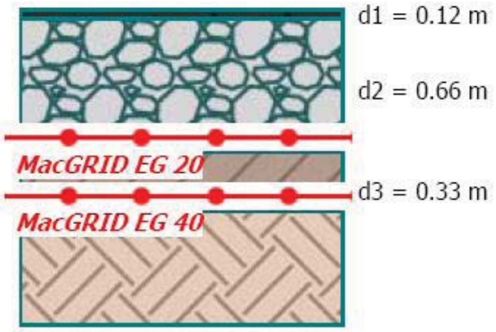


Fig. 4 Reinforced road structure resulting from calculation with modified AASHTO 1993 method

Table 5 Geogrids tensile characteristics for the examples

εr (%)	GG20	GG40
	Tr (kN/m)	Tr (kN/m)
1	4.90	10.00
2	7.00	14.00
3	9.80	19.00
4	12.60	25.00
5	14.00	34.00

The vertical stresses at layers interfaces are reported in Table 7.
Geogrid design calculations, carried out according to the method and equations shown in the present paper, are reported in Tab. 8 for base reinforcement and in Table 9 for subbase reinforcement.

Hence the final layout is the following:
- the road structure shall include a 0,33 m thick subbase, a 0,66 m thick base and 0,12 m thick asphalt layer;
- the subbase shall be reinforced with a 40x40 kN/m extruded biaxial geogrid, working at 2 % strain, placed at subbase - subgrade interface;
- the base course shall be reinforced with 2 layers of 20x20 kN/m extruded biaxial geogrids; the first one shall be placed at subbase – base course interface, working at 1 % strain; the second one, working at 1 % strain as well, shall be placed 0,33 m above the first one.

The design layout is shown in Fig. 5.

The example clearly shows that the geogrid reinforcement required for thick base and / or subbase layers may require more than the 1 only layer supposed to be enough by road design methods.

Table 6 Input data for the Example 1

WHEEL LOAD	**SYMBOL**	**VALUE**	**UNIT**
Design axle load	**W**	80	kN
Wheel load	**P**	40	kN
Tyre inflation pressure	**p**	600	kPa
Radius of equivalent contact area	**r0**	0.146	m
Equivalent Standard Axle Load (ESAL)	**Pa**	80	kN
ASPHALT COURSE	**SYMBOL**	**VALUE**	**UNIT**
Unit weight	γ1	24	kN/m³
Thickness	h1	0.12	m
Load spreading angle	α1	55	deg
BASE COURSE	**SYMBOL**	**VALUE**	**UNIT**
Unit weight	γ2	20	kN/m³
Friction angle	φ2	35	deg
Cohesion	c2	0	kPa
Base course thickness	h2	0.66	0
Load spreading angle	α2	45	deg
Number of layers	Nr2	2	0
Average geogrid spacing	Sv2	0.33	m
Active pressure coefficient	K2	0.27	0.00
SUBBASE COURSE	**SYMBOL**	**VALUE**	**UNIT**
Unit weight	γ3	19	kN/m³
Friction angle	φ3	30	deg
Cohesion	c3	0	kPa
Subbase course thickness	h3	0.33	0
Load spreading angle	α3	40	deg
Number of layers	Nr3	1	0
Average geogrid spacing	Sv3	0.33	m
Active pressure coefficient	K3	0.33	0.00
SUBGRADE	**SYMBOL**	**VALUE**	**UNIT**
CBR	CBR	1.00	0
FS BEARING CAPACITY	FS	3.00	0

Table 7 Vertical stresses at layers interfaces for the Example 1

VALUES AT LAYERS INTERFACES		
Asphalt layer bottom		
z1	0.12	m
r1	0.32	m
σv1	126.66	kPa
Base course bottom		
z2	0.78	m
r2	0.98	m
σv2	13.34	kPa
Subbase bottom		
z3	1.11	m
r3	1.25	m
σv3	8.10	kPa

Table 8 Geogrid design for base course in Example1

LAYER NUMBER	**1**	**2**
H (m) - from base course bottom	0	0.33
Z (m) - from top	0.78	0.45
Tz (kN/m)	1.49	0.94
r (m)	0.98	0.65
σv (kPa)	13.34	30.41
Tp (kN/m)	1.96	1.85
εr (%)	1	0
Ω	2.07	0.00
rf (m)	0.48	0.00
Wtc2 (kPa)	0.00	0.00
Tm2 (kN/m)	0.00	0.00
Ttot (kN/m)	3.45	2.79
Geogrid strength MD x TD (kN/m)	GG20	GG20
Design strain εr (%)	1	1
Tr GG (kN/m)	4.90	4.90

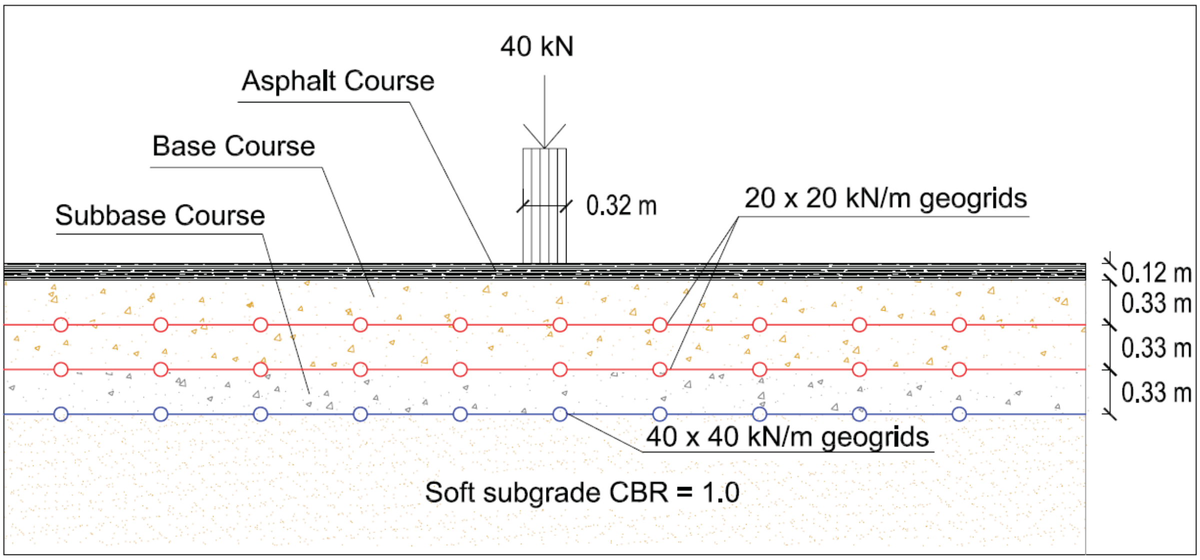


Fig. 5 Design layout for Example 1

Table 9 Geogrid design for subbase course in Example 1

LAYER NUMBER	1
H (m) - from base course bottom	0
Z (m) - from top	1.11
Tz (kN/m)	4.66
r (m)	1.25
σv (kPa)	8.10
Tp (kN/m)	1.18
εr (%)	2
Ω	1.47
rf (m)	0.42
Wtc3 (kPa)	11.53
Tm3 (kN/m)	7.16
Ttot (kN/m)	13.00
Geogrid strength MD x TD (kN/m)	GG40
Design strain εr (%)	2
Tr GG (kN/m)	14.00

EXAMPLE 2

Let's design an unpaved road structure for construction site access, where very heavy trucks need to pass for many months. The subgrade is made up of very soft clay with $CBR_{SG} = 1.3$ ($C_u = 40$ kPa).

Design of the unpaved road structure is carried out with the Leng - Gabr method (Leng and Gabr, 2006).

Input data shown in Table 10; both a light woven geotextile and an extruded biaxial geogrid with 40x40 kN/m tensile strength (see Table 5) are considered for road reinforcement.

Calculated data are reported in Table 11; base thickness design for unreinforced road, road reinforced with geotextile reinforcement and road reinforced with geogrid reinforcement are reported in Table 12.

We select the geogrid reinforced road, for which the base thickness shall be equal to 0.60 m.

Note that also the Leng - Gabr method assumes that the base is reinforced with 1 layer only of geogrid.

Now let's apply the geogrid design method above explained: since the base thickness is high, we check the reinforcement with 2 layers of geogrids.

Such geogrid design is reported in Table 13 and shown in Fig. 6:

- the base course shall be reinforced with 2 layers of 40x40 kN/m extruded biaxial geogrids; the first one shall be placed at subgrade – base course interface, working at 3 % strain; the second one, working at 5 % strain, shall be placed 0,35 m above the first one.

Hence also this example clearly shows that the geogrid reinforcement required for thick base and / or subbase layers may require more than the 1 only layer supposed to be enough by road design methods.

Table 10. Input data for Example 2

DATA	SYMBOL	VALUE	UNIT
Design axle load	W	147	kN
Wheel load	P	73	kN
Tyre inflation pressure	p	827	kPa
Radius of equivalent contact area	a	0.168	m
Equivalent Standard Axle Load (ESAL)	Pa	80	kN
Number of passages of design axle load	Nw	500 000	0
Number of ESALs	Np	5 667 650	0
CBR of base course	CBRbc	15.0	0
CBR of subgrade	CBRsg	2.0	0
Allowable rut depth (mm)	r	40.00	mm
Allowable rut depth (m)	r	0.040	m
Tensile strength of geotextile reinforcement at 2 % strain	T 2%	3.00	kN/m
Tensile strength of geogrid reinforcement at 2 % strain	T 2%	14.00	kN/m

Table 11 Calculated data for Example 2

DATA	SYMBOL	VALUE	UNIT
Experimental coefficient Fbc	**Fbc**	36.0	kPa
Experimental coefficient Fsg	**Fsg**	10.0	kPa
Reaction Modulus of base course	E_1	81.1	kPa
Poisson Modulus of base course	μ_1	0.35	
Reaction Modulus of subgrade	E_2	20.0	kPa
Poisson Modulus of subgrade	μ_2	0.42	
Ratio E1/E2	E_1/E_2	4.1	
Experimental coefficient Fc	F_c	30	kPa
Undrained cohesion of subgrade	c_u	60.0	
Critical ruth depth	r_{cr}	0.059	m
Unreinforced road			
Bearing capacity factor	N_c	3.80	
Geotextile reinforced road			
Bearing capacity factor	N_c	5.69	
Geogrid reinforced road			
Bearing capacity factor	N_c	6.04	

Table 12 Base thickness design for Example 2

DESIGN THICKNESS			
Unreinforced road	**hu**	**1.41**	**m**
Geotextile reinforced road	**hgtx**	**1.08**	**m**
Geogrid reinforced road	**hgg**	**0.60**	**m**

Table 13 Geogrid design for Example 2

LAYER NUMBER	1	2
H (m) - from base course bottom	0	0.35
Z (m) - from top	0.6	0.25
Tz (kN/m)	0.77	0.16
r (m)	0.77	0.42
σv (kPa)	39.65	133.78
Tp (kN/m)	8.22	32.55
εr (%)	3	0
Ω	1.23	0.00
rf (m)	0.52	0.00
Wtc2 (kPa)	8.61	0.00
Tm2 (kN/m)	5.49	0.00
Ttot (kN/m)	14.48	32.71
Geogrid strength MD x TD (kN/m)	40x40	40x40
Design strain εr (%)	3	5
Tr GG (kN/m)	19.00	34.00

LIMITATIONS

The design method herein presented is based on static stress distribution, and has to be used once the empirical methods based on dynamic stress distribution has already been applied to set the base / subbase required thickness.

Laboratory and field testing are still required for the full validation of the present design method.

REFERENCES

American Association of State Highway and Transportation Officials, AASHTO Guide for Design of Pavement Structures, 1993.

Giroud, J.P., Bonaparte, R., Beech, J.F., and Gross, B.A. (1990), Design of soil layer-geosynthetic systems overlying voids. Geotextiles and Geomembrane, Elsevier, 9(1).

Leng, J. E Gabr, M. A., (2006), Deformation-resistance model for geogrid-reinforced unpaved road, Journal of Transportation Research Board, National Research Council, Washington, D.C., 1975:146-154.

Rodin, S. (1965), Ability of a clay fill to support construction plant, Journal of Terramechanics, 2: 51-68.

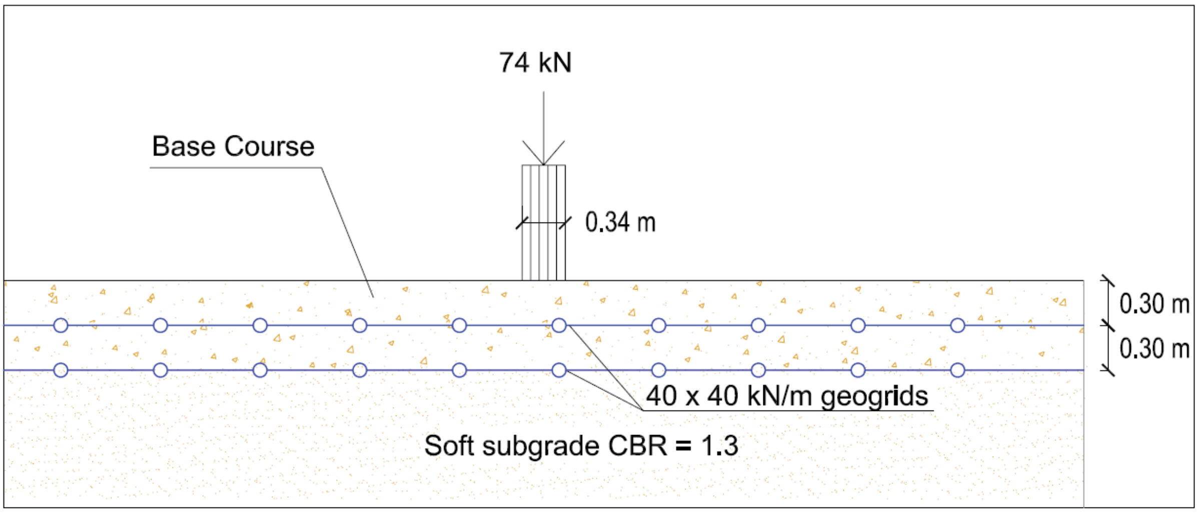


Fig. 6 Geogrid layout for Example 2