

INCLUSION OF GEOSYNTHETICS AS A BASALLY REINFORCEMENT INTO BASE-COURSE OVER SOFT SOIL

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Abstract

Wheels of vehicles at surface of pavement will pass through it lot of times. Therefore, pavement or base course over soft soil always needs reinforcement. Inclusion of geosynthetics into base-course as basally reinforcement and influence of a repeated loading are presented. Several existing methods such as Giroud-Han, USA Corps of Engineers and DuPont Typar method to calculate thickness of base course over soft soil using reinforcement material either geotextile or geogrid are presented and the influence of a repeated load will be compared. Results from calculation and analysis indicate that Giroud-Han method gives thickness of base course higher than other methods when CBR values of subgrade at least 2 %.

Keywords: *Geosynthetics; reinforcement; repeated load; base-course; soft soil.*

INTRODUCTION

When type of subgrade is soft soil, reinforcement using geosynthetics are usual be done as a treatment. Type of reinforcement for soft soil is *restraint subgrade* whereas reinforcement for base course is *base course reinforcement*. Subgrades having a low bearing capacity that lower than CBR 3 % is poor soil even soft soil. Bearing capacity of subgrade can also use another parameter, namely undrained shear strength (C_u). Soil reinforcement using geosynthetic material (geotextile and/or geogrid) accommodated in some methods as Giroud-Han, USA Corps of Engineers and DuPont Typar method respectively, but they give divergence results. For instance USA Corps of Engineers is applied for low traffic originally in the forest region particularly in USA and did not accommodate the repeated loading and DuPont Typar method only focuses on reinforcement using geotextile. Otherwise, Giroud-Han method provides a design of soil reinforcement using both geotextile and geogrid, and it accommodates a repeated load of vehicles. The last method is an improvement of previous one so-called Giroud-Noiray method [1].

In some parts in the world are covered by soft soils either peat or organic soil. In south east of Asia for peat soil there is more or less 20 million hectares and in Indonesia almost 30 percent of land area was covered by soft soil comprising of peat and organic soil [2]. Use of geosynthetics can increase the bearing capacity of base course at top surface for case of soil improvement and on the other hand it can also reduce the thickness of base course for case of base course reinforcement [3].

LITERATURE REVIEW

Bearing Capacity of Soft Soil

Bearing capacity for soft soil can be revealed as CBR, C_u and q_u . The bearing capacity for soil without confining pressure is:

$$q_u = 2 \cdot C_u \quad (1)$$

Before a complete failure of soil subgrade occurs, local-stressing in shear takes place and results in punching shear failure or local failure in the soil. The bearing capacity of the subgrade under such conditions is low and can be quantified by:

$$q_u = \square \cdot C_u \quad (2)$$

When localized shear failure of the subgrade can be prevented in the case any reinforcement for soil (i.e. a general shear failure can be reached), the bearing capacity of the subgrade can be increased to:

$$q_u = \alpha \cdot C_u \tag{3}$$

Several methods give value of α and β as shown Table 1.

Table 1 Bearing capacity of subgrade

Researchers and/or Sources	Unreinforced	Reinforced
Giroud and Noiray (1981)	$q_u = 3.14 C_u$	$q_u = 5.14 C_u$
Barenberg (1992)	$q_u = 3 C_u$	$q_u = 6 C_u$
Philips (1987)	$q_u = 2.8 C_u$	$q_u = 5 C_u$
Rodin (1965)	$q_u = 3.14 C_u$	$q_u = 6.2 C_u$
DuPont Typar SF (2010)	$q_u = 3.14$	$q_u = (2+\pi) C_u$
Roadex III (2008)	$q_u = 4 C_u$	-

Empirical relation between CBR value and undrained shear strength can be used if subgrade value is provided:

$$C_u = 30 \cdot \text{CBR} \tag{4}$$

Many conventional pavement design methods can be applied when subgrade has CBR value minimum 3 %.

In this paper, Austroads (1992) using chart method to calculate thickness of base course is presented as a comparison with other methods. The method presents thickness of unreinforced base course. Minimum CBR value for subgrade in this design method is 2 %. It is impossible to design thickness of pavement if the subgrade has the bearing capacity (CBR value) below 2 %, as shown in Figure 1.

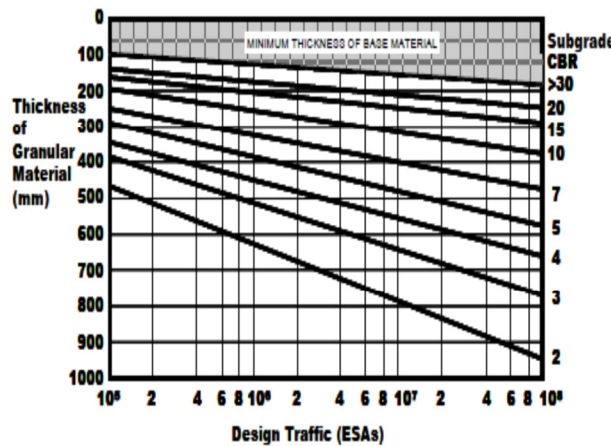


Figure 1 Pavement thickness chart for thin-surface granular [4]

Geosynthetic reinforcement

J.P. Giroud and Jie Han (2004) published a design method in the August edition of the American Society Civil Engineers ([1], [7]).

$$h = \frac{0.868 + (0.661 - 1.006J^2) \left(\frac{r}{h}\right)^{1.5} \log N}{\left[1 + 0.204 \left(\frac{3.48 CBR_{bc}^{0.3}}{CBR_{sg}} - 1\right)\right]} \left(\sqrt{\frac{\frac{P}{\pi r^2}}{N_c f_c CBR_{sg}} - 1} \right) r \tag{5}$$

where:

$N_c = 3.14$ and $J=0$ for unreinforced base course

$N_c = 5.14$ and $J=0$ for geotextile-reinforced base course

$N_c = 5.71$ and $J=0.32$ m-N/degree for Tensar BX 1100 reinforced base course

$N_c = 5.71$ and $J=0.65$ m-N/degree for Tensar BX 1200 reinforced base course

In February 2003, the Corps of Engineers published a design method consideration the use of geogrids and geotextiles for paved and unpaved roads [1]. Its approach for unpaved surface based on methodology originally by US Forest Service, distinguishes the performance of geogrids and geotextiles as reinforcement component. Bearing capacity factor, N_c , for the geosynthetic type being considered. The corps recommended the following N_c values: $N_c = 2.8$ without a geosynthetic, $N_c = 3.6$ with a geotextile for conservative designs and $N_c = 5.8$ with a geogrid.

The in situ shear strength can be measured directly using vane shear devices or indirectly using bearing capacity correlation from California Bearing ratio (CBR) or Dynamic Cone Penetrometer (DCP) tests. The 75th percentile strength is the value at which 75 percent of recorded soil strength readings are higher than this value. Figure 2 can be used to convert design strength from cone index values and CBR to shear strength (C) in psi.

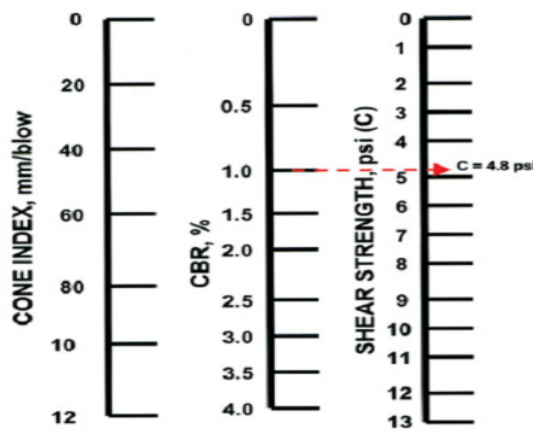


Figure 2 Relationship between cone index, CBR, and shear strength [5]

$$\text{Subgrade bearing capacity} = C \cdot N_c \tag{6}$$

This method uses graphical way to determine thickness of reinforced base course depending on wheel configuration.

DuPont Tytar SF [5] presents a design method using geotextile to calculate thickness of reinforced base course. Bearing capacity for soft soil can use the correlation chart for estimating the subgrade CBR value as Figure 3 below:

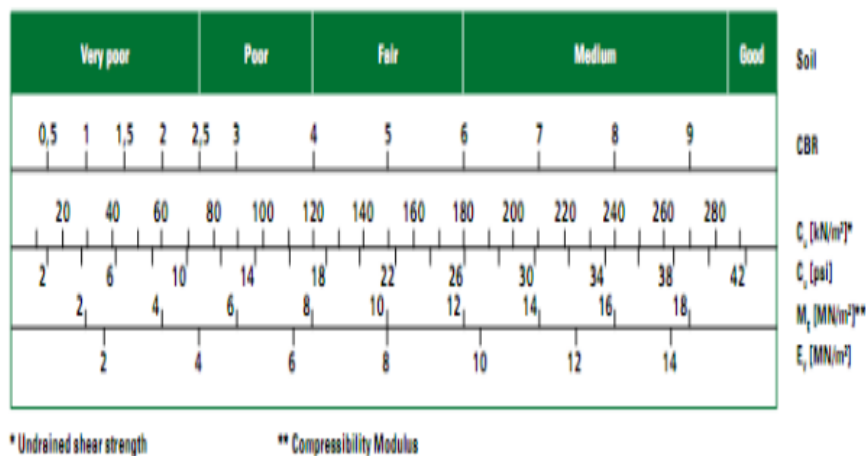


Figure 3 Correlation chart for estimating the subgrade CBR value [6]

Factors to determine T_o using this method as shown in Table 2 and thickness of base course for T_o is equal to a repetition of 1000 times.

Table 2 Factors to determine T_o [5]

CBR [%]	P_1 [kN]	P_2 [lbs]
0.5	45.31	0.119
1	32.37	0.085
1.5	25.89	0.068
2	22.47	0.059
3	20.56	0.054
4	18.66	0.049
5	17.14	0.045
6	16.00	0.042
7	14.85	0.039
8	13.71	0.036
9	12.95	0.034
10	12.19	0.032

T_o (mm) = $P_1 \sqrt{\text{Axle Load (kN)}}$		
T_o (in) = $P_2 \sqrt{\text{Axle Load (lbs)}}$		

Thickness of reinforced base course using this method is:

$$T = C \cdot T_o = (0.27 \log (\square Ni \cdot \text{ESAL}) + 0.19) T_o \tag{7}$$

$$\text{ESAL} = (P_i / P_o)^{3.95} \tag{8}$$

$$N_e = \square Ni \cdot \text{ESAL} \tag{9}$$

THICKNESS OF BASE-COURSE

Thicknesses of base courses using input parameters for reinforced and unreinforced base courses which subjected to a repeated load with some methods are presented.

Input Data for Calculation

Input data for calculation using several design methods to calculate thickness of base course without reinforcement and with reinforcement are needed. Input data comprise of axle load, wheel configuration, bearing capacity of subgrade, number of load passing. Input data used in this calculation as listed in Table 3.

Table 3 Input data for calculation

Input Data	Value	Unit
Standard Axle load	80	KN
Tire pressure	82	psi
Number of passes	1 to 1.000.000	-
Base course strength	CBR 80	%
Subgrade strength	CBR 0.5 to 4	%
Radius of tire contact	15	centimeter
Rut depth	50.8	milimeter

Thickness of Base Course

Calculations for thickness of base course using several methods both reinforced and unreinforced are presented in Table 4(a) to 4(c) below. These tables comprise of three kinds of calculation i.e., thickness of unreinforced base course, thickness of geotextile-reinforced base course and thickness of geogrid-reinforced base course, based on number of repeated load (N).

Table 4(a) Thickness of unreinforced-base course

CBR _{sg} (%)	Thickness of Unreinforced Base Courses for N in mm							
	Austroads Method		Giroud-Han Method				USACoE Method	DuPont Typar
	10 ⁵	10 ⁶	N=1	10 ³	10 ⁵	10 ⁶	N=1	To=> N=10 ³
0.5	>470	>625	120	383	462	494	686	405
1	>470	>625	170	467	548	581	508	289
1.5	>470	>625	199	502	584	617	432	232
2	470	625	200	514	597	630	355	201
2.5	430	580	190	516	599	633	317	192
3	390	510	166	510	595	628	279	184
3.5	370	485	138	444	588	620	254	175
4	350	450	119	432	578	610	229	167

Table 4 (b) and Table 4 (c) indicate the thickness of base course using reinforcement of geotextile and geogrid respectively for several methods as previously mentioned.

Table 4(b) Thickness of geotextile-reinforced base course

CBR _{sg} (%)	Thickness of Base-Courses Using Geotextile for N in mm									
	USACoE Method		Giroud Han Method				DuPont Typar SF			
	N=1		N=1	10 ³	10 ⁵	10 ⁶	N=1	10 ³	10 ⁵	10 ⁶
0.5	635		80	290	365	394	77	405	624	733
1	432		90	346	426	458	55	289	446	524
1.5	343		90	366	449	482	44	232	357	419
2	305		84	370	455	489	38	201	309	364
2.5	254		78	366	453	486	36	192	296	348
3	229		71	357	445	479	35	184	283	333
3.5	203		66	345	435	470	33	175	270	317
4	191		58	331	423	458	32	167	257	302

Table 4(c) Thickness of geogrid-reinforced base course

CBR _{sg} (%)	Thickness of Base Courses Using Geogrid for N in mm									
	Giroud-Han Method								USACoE Method	
	Geogrid Uniaxial TX110				Geogrid Biaxial BX220					
	N=1	10 ³	10 ⁵	10 ⁶	N=1	10 ³	10 ⁵	10 ⁶	N=1	
0.5	74	253	321	350	74	171	215	234	483	
1	82	300	375	405	82	202	255	278	305	
1.5	80	316	395	426	80	209	268	292	228	
2	75	317	398	430	75	205	268	293	190	
2.5	69	310	394	427	69	194	259	286	152	
3	63	301	386	418	63	179	246	274	100	
3.5	56	286	374	407	56	163	230	259	89	
4	50	271	361	395	50	146	214	243	89	

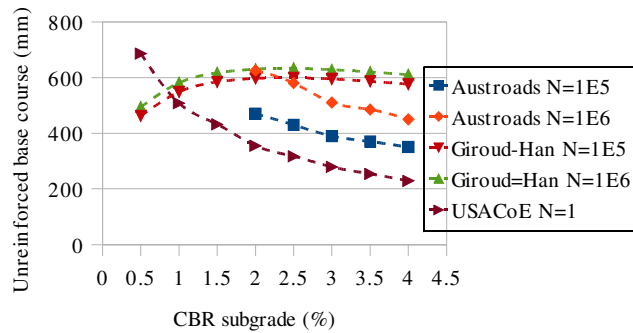
RESULTS AND DISCUSSIONS

Bearing Capacity

Bearing capacity for very poor soil using Barenberg chart is lower than CBR 2.5 % and poor soil between 2.5 and 4 % in CBR value. Bearing capacity in several methods use undrained shear strength (Cu) therefore empirical relation for CBR value and Cu value have to be taken. Undrained shear strength is taken 30 times CBR value.

Thickness of Base Course

From Table 4 above can be depicted the trend line in other to give illustration better. Thickness of unreinforced base course from three methods namely Austroads, Giroud-Han and US Army Corps of



Engineer, respectively as shown in Figure 4.

Figure 4 Thickness of unreinforced base course

Thickness of unreinforced base course using US Army method is lowest for CBR subgrade value more than 2 %. Thickness base course using Giroud-Han method is highest but for CBR subgrade values lower than 2 % indicate wrong trend line because softer subgrades will need thicker base course layers. Thickness resulted from Giroud-Han is higher than thickness using Austroads method for the same number of repetition N=1E5 and N=1E6.

Thickness of base-course that is reinforced by geotextiles from three methods namely Giroud-Han, US-Army, and DuPont-Typar are shown in Figure 5(a).

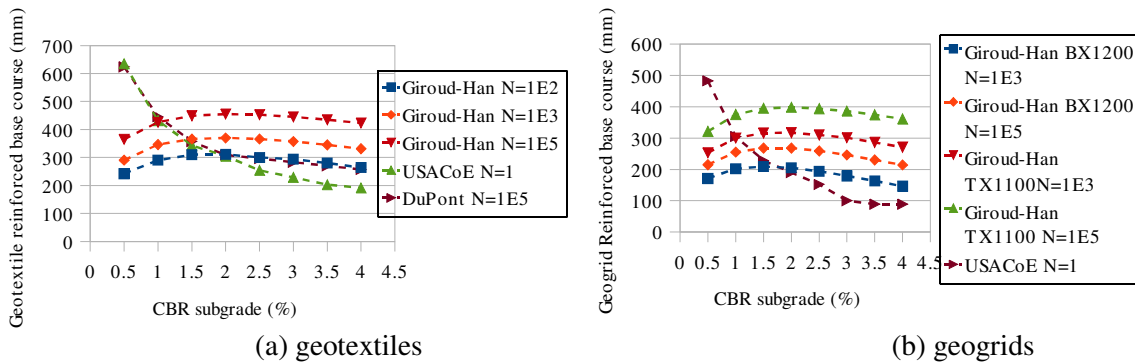


Figure 5 Thickness of geosynthetic-reinforced base course

Thickness of geotextile reinforced base course using USArmy Corps of Engineer is lowest. In contrary, Giroud-Han method gives the highest. It is interesting that the thickness for CBR subgrade values more than 2 % between the method of DuPont N=1E5 and Giroud-Han method N=1E2 superimposes each other whereas CBR subgrade values lower than 2 % between US Army Corps of Engineer and DuPont Typar SF N=1E5. Furthermore, Giroud-Han method gives wrong trend line for CBR subgrade lower than 2 %.

Thickness of geogrid reinforced base course from three methods namely Giroud-Han, US Army Corps of Engineer, DuPont Typar as depicted in Figure 5(b).

Geogrid reinforcement for biaxial gives lower thickness of base course compared to uniaxial using Giroud-Han method. It is like previous trend line using Giroud-Han method indicates wrong trend line for CBR subgrade lower than 2 %. It is also similar trend line for US Army Corps of Engineers method that presents lowest result.

CONCLUSIONS

From description and explanation above that Giroud-Han method gives a design pavement method relatively safe than other for CBR subgrade value more than 2 % and misleading when applied on lower CBR values of subgrade . US Army Corps of Engineer method actually only was applied for a low traffic volume so that gives lowest thickness of base course. Finally, Austroads method actually is not addressed for designing a pavement over soft soil. Herein, it is aimed to make comparison when CBR subgrade at least 2 % and more. Geogrid reinforcement gives higher reduction of base course thickness than geotextile as well biaxial geogrid than uniaxial one.

REFERENCES

- S. Archer, (2008), *Subgrade Improvement for Paved and Unpaved Surfaces Using Geogrids*, Professional Development Series.
- Puslitbang,(2001), *Panduan Geoteknik-4, Desain dan Konstruksi*, Puslitbang Prasarana Transportasi WSP International.
- Tencate Mirafi (2010), *Geosynthetic reinforcement of the aggregate base/subbase course of pavement structures*, Technical Note, TenCate Geosynthetic North America.
- G.W. Jameson, (1996), *Original of Austrroads design procedures for granular pavements*, Research Report ARR 292, ARRB Transport Research.
- Technical Handbook (2010), *DuPont Typar SF Introduction*.
- E.J. Barenberg, (1992), *Subgrade stabilization, in design primer: Geotextiles and related materials*, IFAI, 10-20.
- Tenax Corporation. (2001), *Design of soft soil stabilization with Tenax geogrids*, Technical reference GRID-DE-3.