Journal of Industrial Engineering Research, 1(3) May 2015, Pages: 24-29

IWNEST PUBLISHER

Journal of Industrial Engineering Research

(ISSN: 2077-4559)

Journal home page: http://www.iwnest.com/AACE/

Selection of Woven Geosynthitics and Geofabrics for Subsoil Stabilization & Reinforcement

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ARTICLE INFO

Article history:
Received Jan 2015.
Accepted Feb 2015.
Available online Feb 2015.

Keywords:
Geosynthetics, Composite, Geofabrics, Soil, Subsoil, Bearing Capacity, Stabilization and Reinforcement, Embankment, Polyester,Geogrid, Polypropylene, Polethylene, Warp, Weft, Weave.

ABSTRACT

When a high tensile strength geosynthetic is installed in soils, which have been placed and compacted in layers, it forms a composite of geosynthetic and soil (see fig.1). The geosynthetic acts as reinforcement due to its high frictional properties and its ability to absorb combined tensile forces. Geofabric of great tensile strength produced from high modulus polyester and polypropylene withstand high tensile forces even at low elongation and creep after a long period of high stress ratio. Thus, it is suitable in many applications where soil reinforcement is required in earthworks having small, acceptable deformations. The research contains a description of how to choose the best proper type of tested woven geofabric to solve the problems encountered during the construction of mounds and embankments on cohesive soil with low bearing capacity calling for measures preventing loss of stability. It was found that using geofabrics as integral element for subsoil stabilization and reinforcement can save up to 50% of the aggregate layer thickness.

To Cite This Article: Mohamed. A. Saad., Selection of Woven Geosynthitics and Geofabrics as an Integral Element for Subsoil Stabilization & Reinforcement. **J. Ind. Eng. Res.,** ***1(3),*** *24-29, 2015*

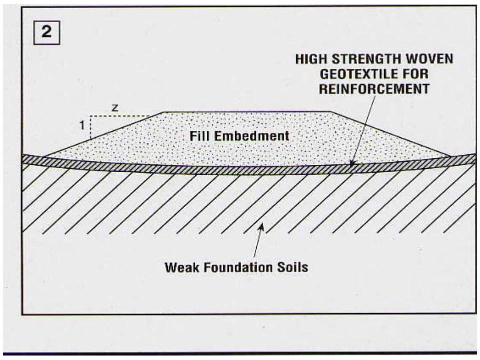

Fig. 1: Embankment over soft subsoil [1].

2) Functions of woven reinforcement geofabric:

The function of this fabric laid out horizontally between mound or embankments and a weak soil, and serving to improve the stability, must be regarded as the introduction of a strong, cohesive layer limiting the forms of giving way or collapsing. Fig 2a and 2b show the two cases of embankments with and without reinforcement geofabric.

Details show fabric deformation during initial settlements:

By laying out a woven reinforcement geofabric on a weak subsoil the top layer is provided with a strong cohesive layer, which at the base of the mound leads to the formation of a tensile reinforcement.

Two conditions of equilibrium must be reached rapidly, i-e before the development of substantial plastic deformations in both the mound and the subsoil according to v.Leeuwen en volman and others (2) These two conditions are illustrated in fig 3a and 3b.

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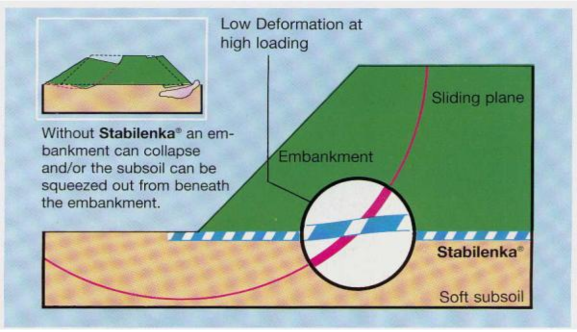

Fig. 2: Embankments with geofabric remain stable.

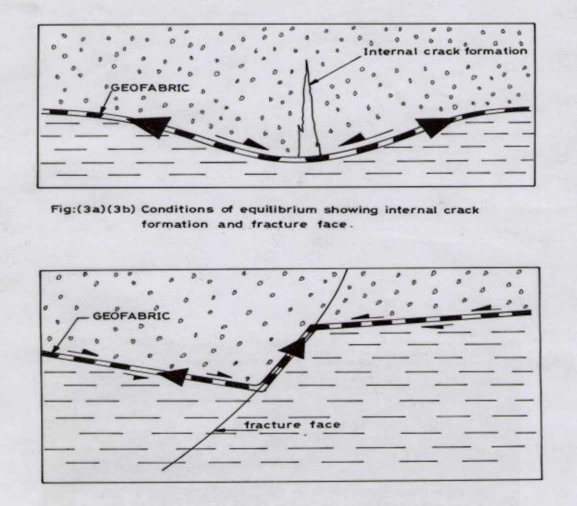

Fig. 3: Two conditions of equilibrium.

The coefficient of safety (f) for subsoil mainly consisting of clay should be higher than the value for peaty subsoil. This requires an additional cohesion (c) which will often turn out to be higher than the available cohesion (Cu) of the soil.

The same models of calculation have been used for calculating the effect of which a thin very strong cohesive layer on the ground surface –i.e. geofabric – has on the stability in question. To this end, the contribution of this fabric has been converted into an additional cohesion (C*) which also acts as a shearing resistance along the entire critical sliding surface. Now, the additional cohesion (C*) plus the available cohesion (Cu) must be equal to the cohesion (Cu*) necessary for obtaining the required coefficient of safety (f).

3) Installation of Geofabric[3]:

Stabilizing a site and reinforcing the subsoil with a geofabric is a straight forward procedure involving three basic steps:

- Subgrade preparation
- Fabric placement
- Aggregate placement
- Aggregate compaction

As preliminary conditions, careful planning and preparation for each installation step will speed construction and insure good performance and full benefit of the fabric including:

1- Embankment high and subsoil thickness.
2- Breaking strength and survivability of the fabric.

4) Determination of the required load carrying capacity (S) of the woven reinforcement fabric:

The answer for this key issue parameter starts form the required additional cohesion (c*) versus the sum of the layer thickness of the weak subsoil (h) bounded by a horizontal tangent to the slip circle and half the thickness of the mound (H/2).

Thereupon, the adapted type of geofabric can be chosen, fig (4) shows parameters with due observance.

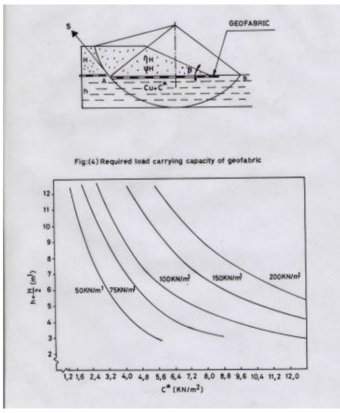

Fig. 4: Parameters wit due observance

5) Physical and Mechanical Properties of Tested Geofabrics:

For the purpose of the study, available woven geofabric of high strength material were tested for their mechanical and physical properties, this included:

- Seven Standard samples made of high tenacity polyester (GE PET).
- Five Standard fabrics made of high tenacity polyester (ST PES 1-7).
- Four standard geogrid fabrics made of multifilament polyester yarns (GE PES Grid).
- Eight standard geogrid fabrics made of multifilament polypropylene (GE PP Grid), and
- Four Local manufactured high density polyethylene (HD PE) – plain conventional weave

Both types of polyester fabrics (GE &ST) had a plain weave containing high modulus multifilament yarns straight in the longitudinal (warp) direction while (GE Grid) polyester & polypropylene fabric had a twill weave structure and convent ally woven , as shown in fig (5) and fig (6) .

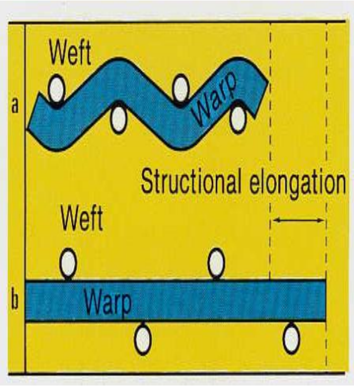

Fig. 5: a) conventional weave and b) straight – warp- weave.

Fig (7) shows the relationship between fabric weight and tensile strength at 10 % elongation for all kinds of materials available for the application in the relevant subject, the range of (20- 1000 KN) can be obtained.

(ST) PET fabrics gave higher values of the strength in the longitudinal direction than other tested materials at the same weight levels, this is due to the special method of weaving they had that is the straight warp weaving method. ST PES fabrics, also, gave higher values of the same property than GE PES fabrics this may be due to the difference of origin of the same type of materials.

6) Design Approaches for High Deformation Systems:

The following information’s given in this part has been abstracted from reference (4). High deformation systems usually incorporate a single layer of compactable aggregate to distribute the anticipated load over the sub grad. Thickness of the sub grade layer on sub grad strength and other design parameters. The procedure of road or motorway constriction using a reinforcing fabric can be accomplished using two models:

6.1) Fabric Tension Model (FTM):

This model quantifies the effects of fabric modulus, or deformation resistance on the performance of soil\fabric\aggregate (SFA) systems .The design calculations are carried out in the following steps:

6.1.1) Determine the maximum wheel load and contact pressures anticipated on the surface of the haul road or area.

6.1.2) Determine the maximum permissible stress or the subgrade (δ per)
δ per = C (π) A …. (According to Rodin 4)

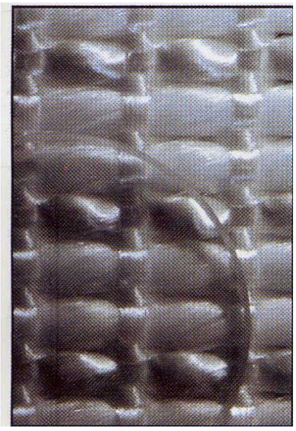

Fig. 6: show SEM of straight warp weaves.

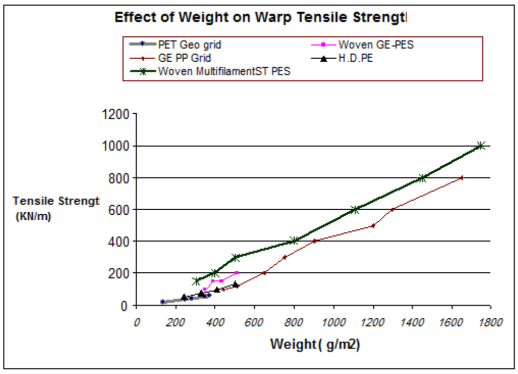

Fig. 7: Relationship between fabric weight and tensile strength at 10 %elongation.

Where:
δ per = permissible stress on the subgrade
A = 2, the recommended coefficient based on University of I lions research, for the soil confining effect of geofabric stabilization, fabric
C: the shear strength of the soil in psi
6.1.3) Estimate the rut width and desired maximum rut depth , and from those determine the geometry of the rut

The geometry of the rut can be estimated as follows:

$$R = \frac{gw^2}{80d} + \frac{5}{16}d$$

$$\theta = 2\tan^{-1}\left(\frac{10d}{6w}\right)$$

Where:
R = the calculated radius in inches
D = the estimated rut width in inches
W = the estimated rut width in inches
Θ = the calculated arc expressed in degrees
6.1.4) Using the assumed rut geometry , calculate the percent strain in the fabric $^{(\varepsilon f}$)

$$\xi f = \left[\frac{(4\Pi R\theta)}{135W} - 2\right] \times 100$$

Where:
R: rut radius
θ :rut angle
W: estimated rut width
6.1.5) Determine the tension in the fabric by multiplying the percent strain by the fabric modulus
$^{t}f = {}^{f}m \times {}^{\varepsilon}f$
Where:
t f = fabric tension in pound / inch
f m = fabric modulus
$^{\varepsilon}f$ = percent strain

6.1.6) Determination of the differential normal stress carried by the fabric due to the uplifting effect of the fabric under tension. The differential normal stress ($\Delta \delta_{z\text{-}f}$) between the top side of the fabric and the fabric / subgrade interface summed for the loaded area of the fabric represents that portion of the applied load carried by the fabric

$$\Delta\delta_{z-f} = \frac{tf}{R}$$

$\Delta \delta_{2\text{-}f}$ = The differential normal stress across the fabric in pounds per square inch (psi)
t_f = the tension in the fabric in pounds per inch as determined in step (5) R = the radius of the circular defected shape in inches as determined in step (3).
6.1.7) Determine the permissible vertical stress on the top of the fabric ($\delta_{p\text{-}f}$)

$$\delta_{p-f} = \Delta\delta_{z-f} + A(\Pi)C$$

6.1.8) Determine the aggregate thickness required for the imposed wheel load using the following equation:

$$\delta = P\left[1 - \left(\frac{1}{1+\left(\frac{a}{z}\right)^{2}}\right.\right]^{3/2} \quad [\ ]$$

Where
P = the average surface contact pressure from wheel load in pounds per square inch
Z = the thickness of the aggregate layer in inches
A = the radius of the loaded area determined from the following equation

$$a = \sqrt{\frac{L}{\Pi P}}$$

L = the total applied load in pounds

By equating the permissible stress on the fabric with the actual stress, and solving for z, the required aggregate thickness is given by:

$$z = \left[\frac{\frac{L}{\Pi P}}{\frac{1}{\left(1-\frac{\delta_{p-f}}{p}\right)^{2/3}}} - 1\right]^{1/2}$$

This is the thickness of the aggregate required with geofabric to achieve stability. Under given assumptions from step 1 to step 8 the engineer can specify the suitable geofabric for the haul rood design which results in 48 % savings in aggregate.

Assomptions : C = 3 psi, p = 50 psi, L =10.000 lb

6.2) Bishop Model:

6-2-1) Determination of the load carrying of geofabric:

According to Bishop Model, which has been elaborated in pilot and moreau (5), the required stability (N) at pre-determined factor of safety (F) can be obtained as follows:

$$\boxed{N = \frac{Cu^{\times}}{\wp_H . H}}$$

Where:

N = stability value at F = 1.1 or F = 1.3

$c^x_{u:}$ necessary cohesion for obtaining factor of safety and stability aggregate .

$\wp$H: density (KN/m^3)

H: thickness of aggregate layer or mound.

$c^x_{u\,:}$ can be obtained given other parameters (or assumed) , thus the value of additional friction c^x is obtained :

$c^x = c^x_u$ - cu

Where (Cu) = the available cohesion of the soil

The load carrying capacity (S) of a geofabric can be obtained from fig (4)

7) Conclusions:

Using woven geofabric for reinforcing and stabilizing a weak subsoil can save up to 50% of the aggregate layer thickness.

1- By determining the additional cohesion to obtain a certain level of stability and high value of factor of safety, the suitable style geofabric can be chosen.

2- Woven ST polyester fabrics showed higher load capacity than other materials while polyethylene geofabric showed the lowest load capacity.

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