Geosynthetics Engineering: In Theory & Practice

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Lecture No - 21
GEOSYNTHETIC ENGINEERING: IN THEORY AND PRACTICE

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Module-5
LECTURE- 21
GEOSYNTHETICS IN PAVEMENTS

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RECAP of previous lecture.....

- Introduction
- Mechanisms and concepts of pavement
- Applications
- Design of unpaved roads
- Unreinforced roads
Reinforced roads:

- In unreinforced case, the stone aggregates punch into the sub-grade soil under traffic loading. The effective thickness of the pavement will reduce.

- The intermixing of stone aggregates and the sub-grade soil can be prevented by introducing a layer of geosynthetic material between the aggregate fill and the sub-grade. Although it will maintain the original aggregate thickness, it will not eliminate the rutting.

- Formation of rut deforms the geotextile and consequently, induces tensile force \( (T) \) in the geotextile resulting in the upward pressure \( (p_g) \).
The downward pressure on soil sub-grade before rut formation is $p$.

The resulting pressure on the sub-grade ($p^*$) = $p - p_g$

That means $p_g$ is the reduction of pressure due to the placement of geotextile.

Geotextile not only acts as a separator but also as the reinforcement.

Since ruts are allowed to develop, the net pressure applied on the subgrade ($p^*$) is allowed to increase up to the ultimate load bearing capacity of subgrade soil ($q_u$).

Therefore, $p^* = p - p_g = q_u$
Deformation of soil subgrade under set of dual wheel loads

Assume deformed shape of the geotextile between points A and B is a parabola.

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Schematic of the deformed shape of geotextile

\[ 2a p_g = 2T \cos \beta \]

\[ p_g = \frac{T \cos \beta}{a} \]

Again, \( T = E. \varepsilon \)

\( T \) = tension developed in the geotextile, 
\( \varepsilon \) = elongation or strain in geotextile, and 
\( E \) = secant modulus of geotextile

\[ p_g = \frac{T \cos \beta}{a} = \frac{E \varepsilon \cos \beta}{a} = \frac{E \varepsilon}{a \sec \beta} \]

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From property of parabola,

\[
\tan \beta = \frac{a}{2s}
\]

\[s = \text{settlement or rut depth under the wheel}\]

\[\sec \beta = \sqrt{1 + \tan^2 \beta}\]

\[P_g = \frac{E\varepsilon}{a\sqrt{1 + \left(\frac{a}{2s}\right)^2}}\]

\[(\pi + 2)c_u = \frac{P}{2(B + 2h \tan \alpha)(L + 2h \tan \alpha)} - \frac{E\varepsilon}{a\sqrt{1 + \left(\frac{a}{2s}\right)^2}}\]

The reduction in aggregate thickness due to placement of geotextile (\(\Delta h\)),

\[\Delta h = h_0 - h\]

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Dynamic Design

So far, we have discussed on static analysis without considering traffic loading. It is possible to estimate the required aggregate thickness in unreinforced condition \((h_o')\) under traffic loading.

\[
h_o' = \frac{0.19 \log_{10} N_s}{(\text{C.B.R.})^{0.63}} \]

\(N_S = \text{Number of passes of 80 kN standard axle load}, \ \text{CBR} = \text{California bearing ratio}\)

Other than standard axle load \((P_s) = 80 \text{ kN}\), it is proposed to compute \(N_p\) from the relationship,

\[
\frac{N_s}{N_p} = \left( \frac{P}{P_s} \right)^{3.95} \]

\(N_P = \text{Equivalent number of passes of standard axle load} \ P\)

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For rut depth other than 0.075m, the $N_S$ is modified by,

$$\log_{10} N_S \rightarrow \log_{10} N_S - 2.34(r - 0.075)$$

The empirical formula for undrained cohesion,

$$c_u \ (\text{in kPa}) = 30 \times \text{CBR}$$

The final equation is derived as,

$$h_0' = \frac{119.24 \log N_p + 470.98 \log P - 279.01r - 2283.34}{c_u^{0.63}}$$

The formula is based on extrapolation and applicable only for number of passages under 10,000.

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No similar dynamic design approach exists for geotextile reinforced pavement.

- It may be assumed that the saving in aggregate thickness ($\Delta h$) would be the same for both static and dynamic condition.

- Aggregate thickness for unreinforced case considering traffic load is $h_0' \text{ m}$.

- Aggregate thickness for reinforced case is $h' = (h_0' - \Delta h) \text{ m}$
DESIGN PARAMETERS

- Foundation soil properties
- Shear strength
- California Bearing Ration (CBR)
- Soil type
- Traffic expected
- Axle load/wheel load
- Number of axles
- Number of passes
- Minimum acceptable rut depth
A complete program has been written by Choudhury (2001) based on the design method for highway pavement by Giroud and Noiray (1981). The outputs generated from the program are presented in the form of design charts for practical use.

Design of geotextile reinforced pavement can be simplified using the design charts.
Design chart for on-highway trucks: Axle load = 80 kN, tire inflation pressure = 480 kPa, rut depth = 0.15 m (Choudhury, 2001 after Giroud and Noiray, 1981)

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Design chart for on-highway trucks: Axle load = 80 kN, tire inflation pressure = 620 kPa, rut depth = 0.15 m (Choudhury, 2001 after Giroud and Noiray, 1981)
Horizontal axis represents the undrained shear strength ($c_u$) of the sub-grade soil.

If CBR is provided, it can be converted into an equivalent undrained shear strength, $c_u = 30 \times \text{CBR}\%$ in kN/m$^2$.

Vertical axis represents the required aggregate thickness under dynamic traffic load in unreinforced condition ($h_o'$). It also represents the reduction in thickness ($\Delta h$) due to the presence of geotextile reinforcement.

As the geotextile modulus ($E$) increases, the magnitude of $\Delta h$ increases.

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Design procedure

Step 1: Determine California Bearing Ratio (CBR) or undrained shear strength of the sub-grade soil

Step 2: Estimate the amount of traffic i.e., number of passages (10, 100, 1000 and 10,000)

Step 3: Determine the axial load (80 kN, 130 kN)

Step 4: Determine tire pressure (480 kPa or 620 kPa)

Step 5: Determine tolerable rutting (0.075 m, 0.15m, 0.45 m)
Step 6: Determine geotextile modulus (K)  
K = 10, 100, 200, 500, 1000

Step 7: Determine the desired aggregate thickness without geotextile (h_o') and the reduction in aggregate thickness with geotextile (∆h) from the design charts.

Step 8: Determine the required aggregate thickness with geotextile (h') = = h_o' − ∆h.
**Example:**

Single axle load, $P = 80 \text{ kN}$,  
Tire pressure, $p_c = 480 \text{ kPa}$,  
Sub-grade cohesion, $c_u = 30 \text{ kPa}$,  
Modulus of geotextile, $E = k = 100 \text{ kN/m}$,  
Allowable rut depth, $r = 0.15 \text{ m}$,  
Number of passes, $N = 1000$  
Determine the geotextile reinforced pavement thickness.

**Solution:**

From the design charts,  
$h_o' = 0.5$ for $c_u = 30 \text{ kPa}$, and $N = 1000$  
$\Delta h = 0.13$ for $c_u = 30 \text{ kPa}$, and $E = K = 100 \text{ kN/m}$  

The required thickness of pavement using geotextile,  
$h' = h_o' - \Delta h = 0.5 - 0.13 = 0.37 \text{ m}$  

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Step 9: Check the filtration and drainage characteristics of geosynthetic.

**Geotextile filter for highway:**
For woven geotextiles: \( \text{AOS or } O_{95} \leq D_{85} \)
For nonwoven geotextiles: \( \text{AOS or } O_{95} \leq 1.8 \ D_{85} \)
For both, \( \text{AOS or } O_{95} \leq 0.3 \text{ mm} \)

For less critical application: \( K_{\text{geotextile}} \geq K_{\text{soil}} \)
For critical application: \( K_{\text{geotextile}} \geq 10 \ K_{\text{soil}} \)

The geotextile permittivity, \( \Psi = \frac{K_{\text{geotextile}}}{t_{\text{geotextile}}} \geq 0.1 \text{ sec}^{-1} \)

Step 10: Determine the strength of geotextile for survivability (AASHTO, 1997)
Step 11: Specify installation procedures and site preparation

(i) Prepare initial ground surface

Remove all unsuitable materials like top soil vegetation, trees, boulders, and shrubs from the site. Level out unevenness.

(ii) Deployment of the geosynthetic

Placement of geotextile directly over the smooth ground surface
Rolling out on Prepared Formation
(iii) Placement of filling aggregates

Vehicles are not directly allowed on the geotextile. A minimum aggregate thickness of about 150 mm to 300 mm must be maintained between the geotextile and truck tires. Then aggregates are back dumped on the previously placed layer.

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Back Dumping Aggregate

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(iv) Spreading of the aggregates

Spreading of the aggregates up to the desired design thickness

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Spreading Aggregate

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(v) Compact the aggregate

Compact the aggregate with the aid of smooth drum vibratory roller or dozer tracks to achieve minimum 95 percent compaction density.

Compaction of the aggregates by smooth roller

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Compaction of Aggregate
Step 12: Sampling, testing and acceptance
The sampling of geotextile for testing and acceptance shall be verified with ASTM D4354. The number of geotextile specimens required should be as per ASTM D4759.

Step 13: Storage and shipment
All geotextiles should be labeled before storage and shipment as per ASTM D 4873.

Step 14: Selection and field inspection
Correct choice of geosynthetics and their proper application is required for stable and economical design.

Construction quality control (C Q C), construction quality assurance (CQ A), manufacturer quality control (M Q C) and manufacture quality assurance (M Q A) must be maintained for successful application of geosynthetics in various projects around the world.

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JOINING OF GEOTEXTILE

- Adjacent geotextiles can be joined by stitching, sewing, welding and overlapping.
- The thread should be high strength polyester or polypropylene.
- Double sewing with 5 to 10 mm spacing is required.
- The welding width is greater than or equal to 10 cm.
- The minimum overlap of geotextile depends on the CBR value or strength of the subgrade.
- For geogrids bodkin joints, overlap joints, interlocking or tying with wire are needed.

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Minimum overlap specifications for geotextile
(After FHWA-HI-98, 1998)

<table>
<thead>
<tr>
<th>CBR</th>
<th>Minimum overlap</th>
</tr>
</thead>
<tbody>
<tr>
<td>Greater than 3</td>
<td>300 – 450 mm</td>
</tr>
<tr>
<td>1-3</td>
<td>600 -900 mm</td>
</tr>
<tr>
<td>0.5 – 1.0</td>
<td>1 m or sewn</td>
</tr>
<tr>
<td>Less than 0.5</td>
<td>Sewn</td>
</tr>
<tr>
<td>All rolled ends</td>
<td>1 m or sewn</td>
</tr>
</tbody>
</table>
Different types of stitching procedures to join geotextiles

(After Diaz, 1985)

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Different placement techniques of geotextiles at the turns of pavements

Fold

Cut pieces

(After Task force 25 report, AASHTO-AGC-ARTB Joint Committee, 1990)

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Rut repair

During construction on soft soils, rut may form. In such cases, all ruts must be filled with new base materials.

Repairing of ruts with new base material
(After FHWA-HI-98, 1998)

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Increase of pavement lifetime for geosynthetic reinforcement

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What will be the critical dead weight of vibro-roller?

D = Depth of granular fill

$C_u$ = Undrained Shear strength of soft soil

Weight of roller (W) in kg (After Fellenius)

$= 11.3 \times S \times C_u = 11.3 \times 0.4 \times D \times C_u = 4.5 \times D \times C_u$

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Example:

Fill Depth (D) = 0.3m
Undrained shear strength of soil \((C_u) = 1000\) kg/m²
Calculate the permissible weight of the roller.

Solution:

According to Fellenius,

Weight of roller \((W)\)

\[= 4.5 \times D \times C_u = 1350\] kg
Please let us hear from you

Any question?
THANKS FOR LISTENING