Geosynthetics Engineering: In Theory & Practice

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Lecture No - 20
GEOSYNTHETICS ENGINEERING: IN THEORY AND PRACTICE

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Module-5
LECTURE- 20
GEOSYNTHETICS IN PAVEMENTS
OUTLINE

- Introduction
- Mechanisms and concepts of pavement
- Design of unpaved roads
- Design charts of U.S. Forest Service (USFS) for unpaved roads
- Modified California Bearing Ratio (CBR) tests
- Design of pavement in unreinforced and reinforced conditions
- Development of design methods for geosynthetic reinforced flexible airfield pavements
- Pavement overlays
- Geosynthetics in railroads
- Geosynthetics in roadway repair and extension
- Stabilization of pavement using NANO material

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Basic concepts

Soil mechanics

Interaction

Polymer properties

Applications

Soft soil applications

Unpaved roads

Embankments

Reinforced fill applications

Steep slopes

Retaining walls

(Short term reinforcement strength required)

(Long term reinforcement strength required)

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Roads and highway are the backbone of any country in the world for development. India has the second largest road network and fastest growing airport infrastructures. Indian railway has a network of 63,465 route kilometers.

Rut formation under heavy vehicle loads is a major concern for unpaved roads over soft subgrade. It is required to minimize the rut formation to prevent local shear failure.

It can be achieved by increasing the thickness of the base layer with good quality of fill materials. In that case, the ground pressure on subgrade gets reduced due to wider load distribution. However, it will increase the cost of construction.

The subgrade soil can also be improved by stabilization systems using lime, cement and chemicals. This will also lead to a higher construction cost.

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Placement of geosynthetics over subgrade soil can substantially reduce the required fill thickness. It can provide the following benefits:

- Separation layer
- Reduce vertical and lateral deformation
- Reduce construction and operational costs
- Increase the bearing capacity of soft soil
- Increase lifetime of the road
- Better drainage
- Rapid consolidation
- Less periodical maintenance
- Saving of construction cost

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Geosynthetics and geogrids are generally used in pavements.

Hybrid geosynthetics can be used as good drainage, filtration and reinforcement materials.

Geosynthetics should properly be selected, specified and installed.

Use of geosynthetics ensures 36% improvement in highway quality and 10% saving in cost.

The beauty of geosynthetic is that it not only acts for separation but also acts for filtration, drainage and reinforcement. That is why it is called multi functional.
MECHANISMS AND CONCEPTS OF PAVEMENT

- Stone aggregates enter into the fine subgrade soil and lose its strength

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Soil pumps up into the voids of stone aggregates causing the stone aggregate to loose its drainage capacity.
Geosynthetics Engineering: In Theory and Practice

**Separation Mechanism**

- Geosynthetics prevent granular materials from penetrating into the soft underlying subgrade as well as prevent fine-grained subgrade soil from being pumped up into permeable granular materials.

- The geosynthetics may tear off due to sharp edged grains of the ballast under the dynamic loads of railways. Therefore, sandy gravel as a protective layer is placed under the ballast.

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Filtration and Drainage Mechanism

Separation, Filtration and drainage mechanism of geotextile

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Mechanism of Reinforcement

Soil: Good in compression and poor in tension

Geosynthetic: Good in tension and poor in compression

Combination of geosynthetic and soil ensures an excellent bond and form a composite material.

Geosynthetic has three main reinforcement mechanisms:

- Lateral restrain
- Bearing capacity
- Tension Membrane
Lateral restrain: Mobilization of friction and/or interlocking between base or subgrade course and geosynthetic
Bearing capacity: Due to geosynthetic, failure zone possesses higher volume and hence, increase in bearing capacity.

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Tension Membrane: Development of tension in geosynthetic due to wheel loads resulted in vertical thrust.
Problem of Unpaved road
Unpaved Roads

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Applications:

- Temporary roadways
- Haul roads
- Access roads
- Permanent roads
- Airport taxiways
- Railway tracks
- Parking lots
Type of Geosynthetics used in pavement:

- Woven and non-woven geotextile
- Extruded geogrid (PP, PE)
- Welded geogrid (PET, PP, PE)
- Knitted or woven geogrid (PET, PP)
- Bonded geogrid-geotextile composite (GG-GT composite)
- Unbonded geogrid-geotextile composite (GG is laid over GT)
Type of subgrades

1. **Firm subgrade:**
   CBR \( \geq 8 \)
   Shear strength \( \geq 240 \) kPa
   Resilient modulus > 80 MPa

2. **Moderate subgrade:**
   \( 3 \leq \text{CBR} \leq 8 \)
   Shear strength lies between 90 kPa and 240 kPa
   Resilient modulus lies between 30 MPa and 80 MPa

3. **Low subgrade:**
   CBR \( \leq 3 \)
   Shear strength \( \leq 90 \) kPa
   Resilient modulus < 30 MPa

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Design of Geosynthetics reinforced pavement requires an overall knowledge of the following areas.

- Unreinforced pavement design
- Reinforced pavement design
- Life-cycle cost analysis
- Value added cost benefit
- Specification
- Product-specific specification or Generic material property specification
- 20%-50% subbase or base course thickness reduction (Maximum 75-125 mm is used)
Giroud and Noiray (1981) developed an analytical method for designing the geotextile reinforced unpaved road on soft sub-grade soil. The following assumptions are taken into consideration:

- Soil sub-grade is saturated fine-grained clay and silt.
- Soil sub-grade is under undrained condition.
- Shear strength of the soil sub-grade is represented by cohesion.
- The bearing pressure can be transferred to the elastic limit range for unreinforced soil.
- The bearing pressure can be transferred to the plastic limit range for reinforced soil.
- The wheel pressure transfers like a pyramidal shape.
Wheel load distribution without geotextile (left) and with geotextile (right) (Giroud and Noiray, 1981)

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Equivalent tire contact pressure:

\[ p_{ec} = \frac{P}{2LB} \]

P = Axle load, Wheel load = P/2
B x L = contact area of the wheel

**Without geotextile:**

\[ p_{ec}LB = (B + 2h_0 \tan \alpha_0)(L + 2h_0 \tan \alpha_0)(p_0 - \gamma h_0) \]

h_0 = aggregate thickness without geotextile,
\( \alpha_0 \) = angle of load distribution = (45 - \( \phi \)/2), or =26°,
p_0 = stress on the soil sub-grade without geotextile,
\( \gamma \) = unit weight of stone aggregate,

**With geotextile:**

\[ p_{ec}LB = (B + 2h \tan \alpha)(L + 2h \tan \alpha)(p - \gamma h) \]

h = aggregate thickness with geotextile,
\( \alpha \) = angle of load distribution with geotextile
(assumed equal to \( \alpha_0 \)), and
p = stress on the soil sub-grade with geotextile,
From the previous equations, the following equations can be written,

**Stress on the soil sub-grade without geotextile \((p_o)\)**

\[
p_o = \frac{P}{2(B + 2h_0 \tan \alpha_0)(L + 2h_0 \tan \alpha_0)} + \gamma h_0
\]

**Stress on the soil sub-grade with geotextile \((p)\)**

\[
p = \frac{P}{2(B + 2h \tan \alpha)(L + 2h \tan \alpha)} + \gamma h
\]

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Unreinforced roads:

When there is no geotextile, stress on the sub-grade soil \( (p_0) \) should not exceed the elastic bearing capacity of the sub-grade soil \( (q_e) \). So we can write,

\[
q_e = p_0 = \pi c_u + \gamma h_0
\]

\( c_u = \) undrained shear strength of the sub-grade

\[
p_0 = \frac{P}{2(B + 2h_0 \tan \alpha_0)(L + 2h_0 \tan \alpha_0)} + \gamma h_0
\]

\[
c_u = \frac{P}{2\pi (B + 2h_0 \tan \alpha_0)(L + 2h_0 \tan \alpha_0)}
\]
Again, for on-highway vehicles:

\[
L = \frac{B}{\sqrt{2}} \quad B = \sqrt{\frac{P}{p_c}}
\]

For off-highway vehicles:

\[
L = \frac{B}{2}
\]

For on-highway vehicles,

\[
c_u = \frac{P}{2\pi \left( \sqrt{\frac{P}{p_c}} + 2 h_0 \tan \alpha_0 \right) \left( \sqrt{\frac{P}{2p_c}} + 2 h_0 \tan \alpha_0 \right)}
\]

For off-highway vehicles,

\[
c_u = \frac{P}{2\pi \left( \sqrt{\frac{(P\sqrt{2})}{p_c}} + 2 h_0 \tan \alpha_0 \right) \left( \sqrt{\frac{P}{\sqrt{2}p_c}} + 2 h_0 \tan \alpha_0 \right)}
\]

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If we know undrained shear strength of the sub-grade \( (c_u) \), axle load \( (P) \), tire pressure \( (p_c) \) and angle of load distribution \( (\alpha_o) = 26^\circ \), the required theoretical thickness of granular layer fill \( (h_0) \) can be determined.

If the CBR value is known, \( c_u = 30 \times \text{CBR}\% \text{ kN/m}^2 \)

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Please let us hear from you

Any question?

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THANKS FOR LISTENING