Lecture 37

APPLICATIONS OF GEOSYNTHETICS IN UNPAVED ROADS

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- Functions of geosynthetics in pavements
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Introduction

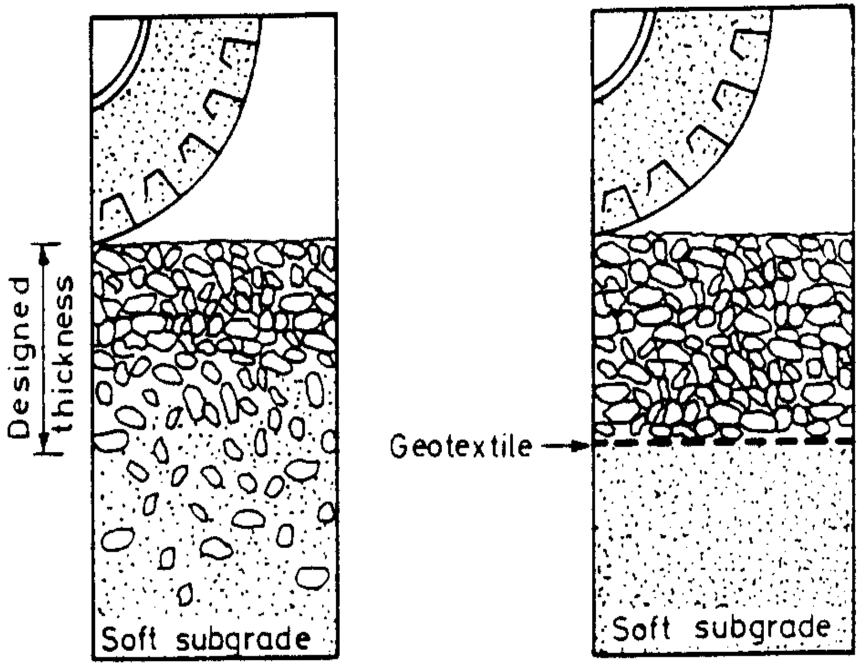
Use of geosynthetics results in significant savings, improved performance and very good serviceability in both short term and long term

Geosynthetics have made it possible to construct roads and pavements in seemingly difficult situations such as marshy stretches, soft and organic deposits and in expansive soil areas

Functions of Geosynthetics in Roadways

1. Acts as a separator to prevent two dissimilar materials (subgrade soils and aggregates) from intermixing. Geotextiles and geogrids perform this function by preventing penetration of the aggregate into the subgrade (localized bearing failures)

2. Soft subgrade soils are most susceptible to disturbance during construction activities such as clearing, grubbing, and initial aggregate placement. Geosynthetics can help minimize subgrade disturbance and prevent loss of aggregate during construction



Concept of Geotextile Separation

Functions of Geosynthetics (contd..)

3. The system performance may also be influenced by secondary functions of filtration, drainage, and reinforcement. The geotextile acts as a filter to prevent fines from migrating up into the aggregate due to high pore water pressures induced by dynamic wheel loads

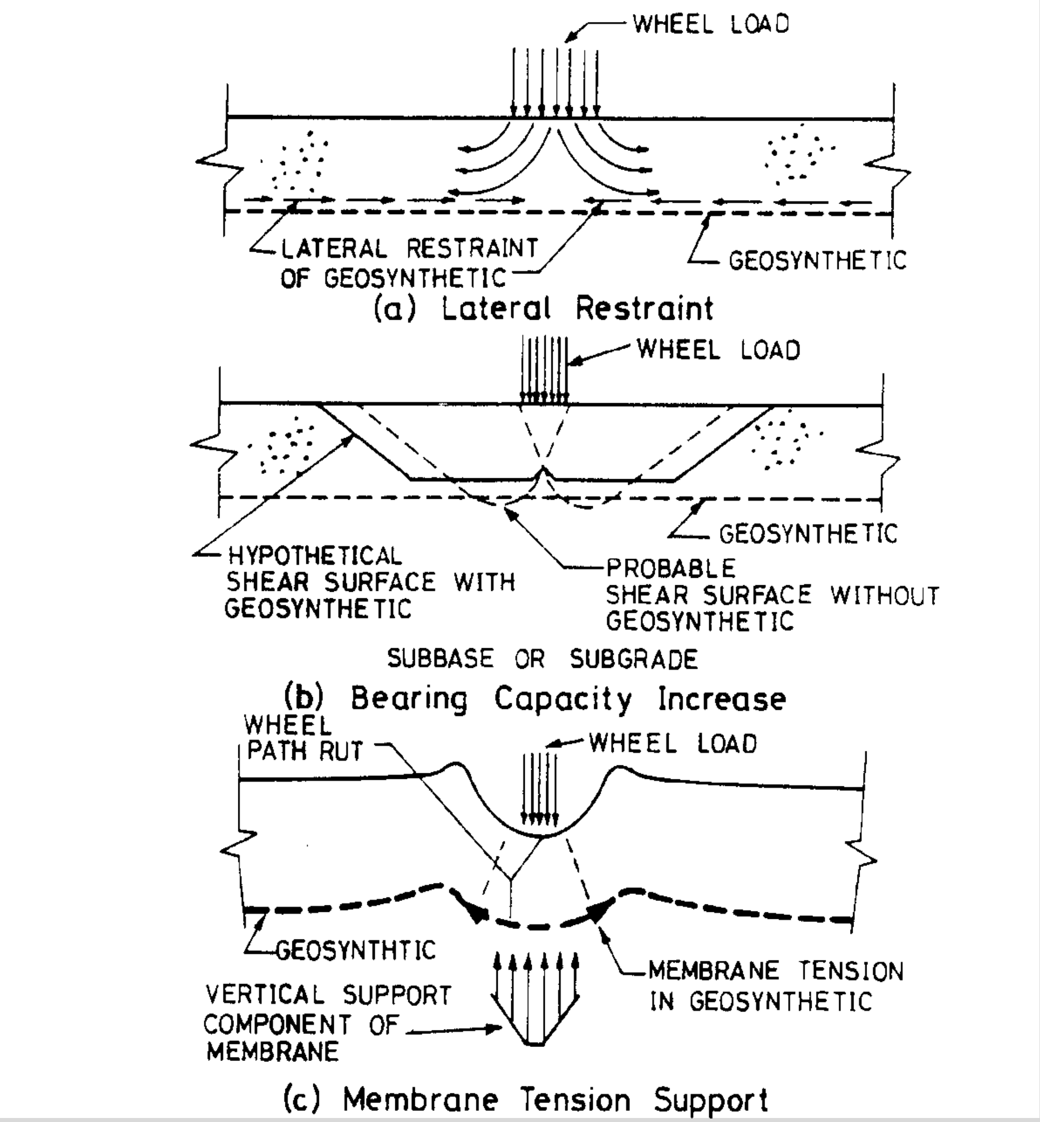
4. It also acts as a drain, allowing the excess pore pressures to dissipate through the geotextile and the subgrade soils to gain strength through consolidation and improve with time

Mechanisms

1. Lateral restrainment of the base and subgrade through friction and interlock between the aggregate, soil and the geosynthetic

2. Increase the system bearing capacity by forcing the potential bearing capacity failure surface to develop along alternate, higher shear strength surfaces

3. Membrane support of the wheel loads



Reinforcement Functions

Benefits

- Reducing the intensity of stress on the subgrade
- Preventing subgrade fines from pumping
- Preventing contamination of base materials
- Reducing the depth of excavation
- Reducing the thickness of aggregate required for stabilization of subgrade

S	F	R
✦		
✦	✦	
	✦	
✦		✦
✦		✦

(S-Separation, F-Filtration, R-Reinforcement)

Benefits

- Reducing disturbance of subgrade during construction
- Allowing an increase in strength over time
- Reducing differential settlement in roadway

  and in transition areas from cut to fill
- Reducing maintenance and extending the life of the pavement

S	F	R
✦		✦
	✦	
		✦
✦	✦	✦

(S-Separation, F-Filtration, R-Reinforcement)

Subgrade Conditions in which Geosynthetics are useful

- Poor soils
  (USCS: SC, CL, CH, ML, MH, OL, OH, and PT)
  (AASHTO: A-5, A-6, A-7-5, and A-7-6)

- Low undrained shear strength
  $\tau_f = C_u < 90ka$
  CBR<3 {Note: CBR as determined with ASTMD 4429 Bearing Ratio of Soils in Place}
  $M_R \approx 30MPa$

- High water table

- High sensitivity

Summary Recommendation

Effectiveness of Geosynthetics as a function of subgrade strength

Undrained Shear Strength(kPa)	Subgrade CBR	Functions
60 - 90	2 - 3	Filtration and possibly separation
30 - 60	1 -2	Filtration, separation, and possibly Reinforcement
< 30	< 1	All functions, including reinforcement

Design

Two main approaches

1. No reinforcing effect of the geotextiles

Conservative, applicable for thin roadway sections with relatively small live loads, where ruts are 50 to 100mm

2. Reinforcing effect is considered

Applicable for large live loads on thin roadways, where deep ruts (>100mm) may occur and for thicker roadways on softer subgrade

Based on both theoretical analysis and empirical tests on geotextiles, Steward, Williamson and Mohney (1977), reports the bearing capacity factors for different ruts and traffic conditions both with and without geotextile separators

Design	**Ruts (mm)**	**Traffic (Passes of 80 kN axle equivalents)**	**Bearing Capacity Factor, N_o**
Without Geotextile:	<50	>1000	2.8
	>100	<100	3.3
With Geotextile	<50	>1000	5.0
	>100	<100	6.0

The Giroud and Noiray approach

Normal highway vehicles including lorries

$$B = \sqrt{P/p_t}$$

$$L = 0.707B$$

Heavy construction plant with wide or double tyres

$$B = \sqrt{1.414P/p_t}$$

$$L = 0.5B$$

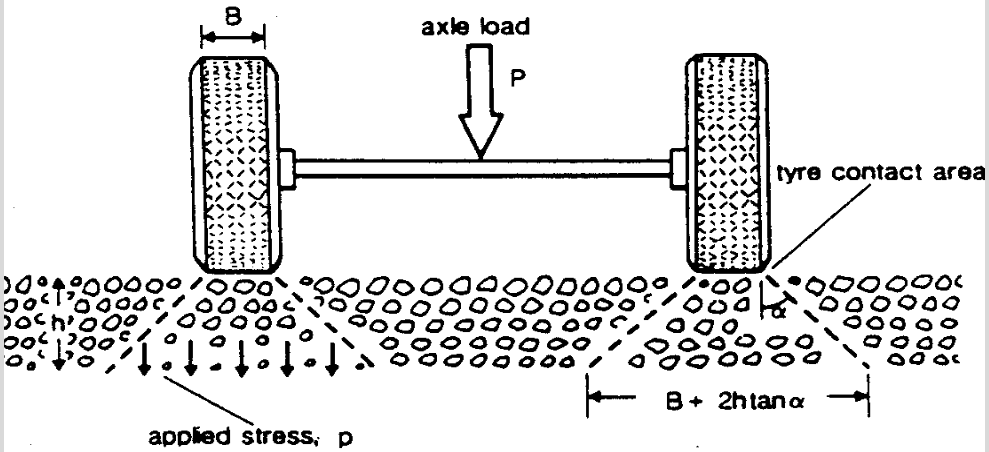


Fig. 3 (a) Notation for Giroud and Noiray analysis

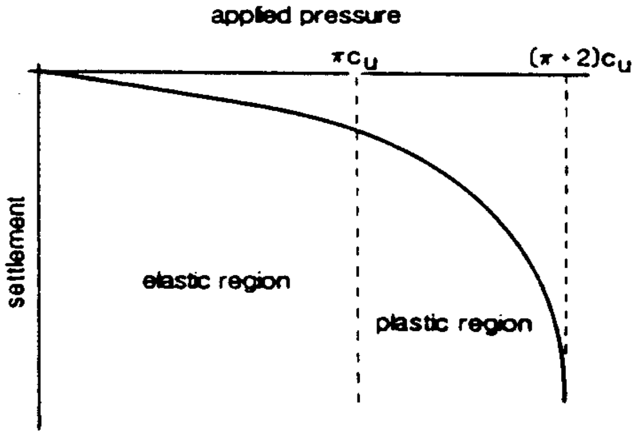


Figure 9.3 Settlement at the centre of a loaded plate

Load Dispersion, Applied Pressure vs. Settlement

For construction plant, a typical value of p_t is 620 kN/m^2. The stress p applied to the cohesive formation by the axle is

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

As the analysis is not very sensitive to the exact value of tanα and experiments indicate that tanα lies between 0.5 and 0.7, tanα may be taken as 0.6

$$p = \frac{P}{2(B + 1.2h)(L + 1.2h)}$$

Making use of the net elastic bearing capacity (q_c) and the ultimate or plastic bearing capacity (q_p), defined as:

$$q_e = \pi C_u$$

$$q_p = (\pi + 2) C_u$$

where C_u is the undrained cohesion of the underlying soil

To control any contamination of the aggregate, it is suggested that in the absence of a geotextile, the applied load from the axle be limited to q_e

for $p = q_e$

$$\pi C_u = \frac{P}{2(B + 1.2h)(L + 1.2h)}$$

The value of h_o remains valid for very light traffic, upto about 20 axle passes. However, the aggregate depth must be increased to h_o for heavier traffic, using

$$h_o = \frac{[(125\log N - 294(r - 0.075)]}{C_u^{0.63}}$$

where N is the number of passes of a standard axle(80 kN)

r is the rut depth in m

C_u is undrained soil cohesion in N/m^2 (not in kN/m^2)

h_o is the aggregate depth in m

The loading is expressed in terms of a number of passes (N′), of an axle load other than the standard axle load, it can be converted into an equivalent number of standard axle passes (N) using

$$N/N' = (P'/P)^{3.93}$$

The suitability of this equation is doubtful and an alternative, theoretically an appropriate equation for the conversion of axle loads is given by

$$N/N' = (P'/P)^{6.2}$$

Factors contributing to the extra stability arising from the presence of a geotextile in an unpaved road use:

1. **Enhanced confinement of the subgrade soil**
2. **Greater spread of the loading**
3. **An uplift force due to the geotextile tension**

Also,

- **Confinement of the subgrade soil by a geotextile controls the local shear, enabling the design to be based on the plastic (or ultimate) bearing capacity**
- **The openings in woven and non-woven geotextile sheets are sufficiently small to guarantee this confining effect**

Assuming that the geosynthetic deforms to a parabolic shape, the uplift force (F_g) is

$$F_g = \frac{JE(1 + (a/2S)^2)^{-1/2}}{a}$$

Where J is the tensile stiffness of the geosynthetic
E is the geosynthetic strain
A is 1/2 (B+1.2h) and
S is the settlement beneath the tyre

The force F_g reduces the load p and hence the corresponding relationship is given by

$$(\pi+2)C_u = \frac{P}{2(B + 2h\tan\alpha hta + 2h\tan\alpha h} - \frac{JE}{a\sqrt{1 + (a/2S)^2}}$$

The benefit from the geotextile uplift force is negligible when the rut depth is 75 mm or less and a reduction of 10% or less in road base is obtained when the rut depth is 150 mm

Due to the confining effect, the ultimate bearing capacity is given by

$$(\pi+2)C_u = \frac{P}{2(B + 1.2h_G) - (L + 1.2h_G)}$$

where h_G is the required fill depth with a geotextile. The saving in aggregate depth due to the presence of geotextile (Δh) is given by

$$\Delta h = h_o - h_G$$

Example

An unpaved road 5 m wide is to be subjected to 1000 passes of a buckle (two axles) (each axle load 120 kN). On each axle of truck, there are four 0.2 m wide tyres, inflated to a pressure 700 kN/m^2. The underlying soil has an undrained cohesion of 30 kN/m^2 and the road aggregate is sharp (d_{50} = 20 mm) and has unit weight of 18 kN/m^3. Of the acceptable rut depth is 150 mm, determine the road base width using Giroud and Noiray approach.

Solution

Step 1. N’ = 2000

We have

$$\frac{N}{N'} = \left(\frac{P'}{P}\right)^{6.2}, \quad N = 2000 \times \left(\frac{120}{80}\right)^{6.2} = 24705.6$$

Step2. Hence the loading is equivalent to 24705.6 pass of standard load of 80 kN

We have

$$h_o = \frac{125 \log N - 294(r - 0.075)}{C_u^{0.63}}$$

$$\text{So } h_0 = \frac{(30{,}000)^{0.23}}{\text{[illegible]}}$$

$$= 0.796 = 0.80 \text{ m}$$

Step3. For construction plant with wide or double tires

$$B = \sqrt{1.414P/P_t} \text{ and } L = 0.5B\text{, Hence}$$

$$B = \sqrt{1.414\text{x } \frac{120}{700}} = 0.50 \text{ m and } L = 0.25 \text{ m}$$

Step 4. Elastic bearing capacity

$$\pi C_u = \frac{P}{2(B + 1.2h_o)(L + 1.2h_o)}$$

$$= \frac{120}{2(0.50 + 1.2h_o)(0.25 + 1.2h_o)}$$

Solving for h_o, $h_o = 0.357$ m ≅ 0.36 m

Step 5. Ultimate bearing capacity

$$(\pi+2)C_u = \frac{P}{2(B + 1.2h_g)(L + 1.2h_g)} = 0.22\text{m}$$

$$\Delta h = 0.36\text{-}0.22 = 0.14$$

Hence depth with geotextile = 0.8-0.14 = 0.66 m

Step 6: Contribution due to tension of the geosynthetic

Consideration of tension increases the ultimate bearing capacity by the term

$$\frac{JE}{a\sqrt{1 + (a/2S)^2}}$$

For the stiffness being 100 kN/m and strain is 10%, corresponding to a settlement of 30 cm, the thickness with geosynthetic reduces to 0.18 m

Hence $\Delta h = 0.36-0.18 = 0.19$

Hence, depth with geosynthetic is 0.8-0.19 = 0.61 cm

Geotextile Survivability

Selecting a geotextile for either permanent or temporary roads depends upon one thing – the survivability criteria. These survivability requirements are not based on any systematic research but on the properties of geotextiles, which have performed satisfactorily as separators in temporary roads and in similar applications. However, in the absence of any other information, they should be used as minimum property values. Geotextile survivability for major projects should be verified by conducting field tests under site-specific conditions.

Application in Paved Roads

Appropriate location for placements of geotextiles in a paved road structure are

- At the interface between the granular sub-base and the subgrade soil
- Near the underside of the wearing course
- Beneath a surface overlay to a damaged pavement

Subgrade to Sub-base Interface

Placement of geotextile at this level reduces the possibilities of rutting and to some effect reduces the thickness of the sub-base, besides controlling the contamination of the sub-base by fines from the subgrade soil

Pavement Wearing Course

The advantage of using a geotextile within a wearing course helps in

- restriction of reflection cracking
- reduced rutting
- restriction of fatigue cracking

In areas subject to high contact stress, such as heavily trafficked areas, taxiways, the effect is beneficial. Extensive research carried at U.K. clearly indicates that use of geotextiles and geogrids considerably reduces rutting

Pavement Overlays

- Geotextile can be used as alternatives to stress-relieving granular layers, seal coats, rubberized asphalts, etc. for controlling surface moisture infiltration and retarding reflection cracks in pavement overlays
- Properly installed, asphalt-saturated geotextiles function as a moisture barrier that protects the underlying pavement structure from further degradation due to ingress of surface water. In addition, geotextiles can provide cushioning for the overlay, thus functioning as a stress-relieving interlayer
- When properly installed, both functions combine to extend the life of the overlay and the pavement section

Thank you