Geosynthetics in Unpaved Roads

Prof. E.C. Shin
University of Incheon, Korea
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The common use of geosynthetics is in road and pavement construction. Geotextiles increase stability and improve performance of weak subgrade soils primarily by separating the aggregate from the subgrade. Geogrids and some geotextiles can provide strength through friction or interlock developed between the aggregate and the geosynthetics. Geotextiles can also provide filtration and drainage by allowing excess pore water pressures in the subgrade to dissipate into the aggregate base course and, in cases of poor-quality aggregate, through the geotextile plane itself.
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- The use of geogrids to reinforce soft and/or compressible foundation soils for unpaved aggregate roads is a major application area. Many successes have been reported, together with several attempts at a design method.
Overview

• The mechanisms of reinforcement are increased soil strength, enhanced load spreading, and membrane support via controlled rutting.

• The difference in required thickness of stone base is then compared with the cost of the installed geogrid. If the latter is less expensive (as it usually is for soft soil subgrades), it is recommended for use.

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• For the geogrid-reinforced case, new concepts are developed that include the above mentioned beneficial mechanisms attributed to inclusion of the geogrid.

• An increase in soil subgrade strength from the nonreinforced case to the reinforced case as indicated by a comparison of the following equation:

\[
P_e = \pi c_{uN} + \gamma h_0 \quad P_{\text{lim}} = (\pi + 2)c_{uN} + \gamma h
\]

- \( P_e \): bearing capacity pressure based on the elastic limit (nonreinforced case)
- \( P_{\text{lim}} \): bearing capacity pressure based on the plastic limit (reinforced case)
- \( c_{uN} \): undrained soil strength at the Nth vehicle passage
- \( \gamma \): unit weight of aggregate
- \( h_0 \): aggregate thickness without reinforcement
- \( h \): aggregate thickness with reinforcement
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- An improved load distribution to the soil subgrade due to load spreading, which is quantified on the basis of pyramidal geogrid shape.

- Fig. 1 shows the angle $\alpha$ for the nonreinforced case versus a similar construction for the reinforced to nonreinforced situations is expressed as a ratio of $\tan \alpha / \tan \alpha_0$ which is greater than 1.0.

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- The membrane effect has been conservatively neglected. On the right of the graph, for a standard axle load of 80 kN and any number of vehicle passes from 10 to 10,000, a thickness of nonreinforced stone base ($h_b$) can be obtained upon estimation of the soil subgrade strength.
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- The rut depth turns out to be relatively insignificant. This value is then horizontally extended to the left side of the figure, where it intersects with one of the following:

- Curve 1, for BX 1200 geogrids, which assumes a large number of vehicle passes (N>1000) where there is a significant likelihood of aggregate contamination without the geogrid.
- Curve 2, also for BX 1200 geogrids which assumes a low number of vehicle passes and low likelihood of aggregate contamination.
- Curve 3, for UX 1200 geogrids, which assumes a low number of vehicles passes and low likelihood of aggregate contamination.

This results in an $R$ value that is used in the following equations to determine the aggregate thickness using geogrid reinforcement, $h$. The difference between $h_0$ (nonreinforced) and $h$ (reinforced) is the amount of aggregate saved, $\Delta h$.

- $h = Rh_0$ for $r < 150$mm and no channelizes traffic pattern.
- $h = 0.9Rh_0$ for $r \geq 150$mm with a channelizes traffic pattern.
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- Geogrids and geotextiles provide reinforcement through three possible mechanisms.

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

![Lateral Restraint](image1)

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

![Bearing Capacity Increase](image2)
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3. **Membrane support** of the wheel loads.

Problem of Unpaved road
Compared to the unpaved road without reinforcement

- Reduction of fill thickness
- Separates aggregate from soft soil if a geotextile is used
- Increases soft soil bearing capacity
- Reduce fill lateral deformation
- Widens the spreading of vertical stress increments
- Reduce vertical deformation due to membrane effect
- Increases the lifetime of the road
- Requires less periodical maintenance
- Reduce construction and operational costs of the road

Efficiency of unpaved road using geosynthetics (1)

- Reduces the aggregate requirement
- Maintains separation of subgrade and select fill
- Helps minimize rutting
- Reduces amount of select fill required
- Minimizes site preparation
- Extends life of road structure
- Prevents contamination of subbase & base layer by fines
Efficiency of unpaved road using geosynthetics (2)

- Allows use of free-draining, open-graded base materials
- Distributes pavement load & reduces load intensity to the subgrade
- Reduces depth of excavation
- Minimizes site preparation
- Extends pavement life & prevents pavement failure
Reinforcement

Geosynthetics Reinforcing Mechanisms

1. Provide lateral restraint of base and subgrade

2. Increase system bearing capacity

3. Offer tension membrane support of wheel loads
Typical degradation mechanism in unreinforced unpaved road

Influence of geosynthetic reinforcement on unpaved road behaviour

- Separation
- Better stress distribution
- Membrane effect
Typical design chart

Membrane tension support
Construction of a reinforced unpaved road
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Increase of paved road life time due to the use of geosynthetic reinforcement

\[ E = \frac{N_r}{N_u} \]

\( N_r \) = number of load repetitions up to failure for the reinforced pavement.

\( N_u \) = number of load repetitions up to failure for the unreinforced pavement.
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Effectiveness of Geosynthetics 1

Reduce or avoid reflective cracking

Work as a barrier to avoid pumping of soil fines

Effectiveness of Geosynthetics 2

Reduce asphalt cap thickness

Reduce pavement thickness
**Geosynthetic Reinforcement for Pavement Systems**

**Purpose of using geosynthetic**
1. increase pavement fatigue life
2. minimize differential and total settlement
3. reduce rutting-surface and subgrade
4. prohibit or limit reflective cracking
5. increase resistance to cracking due to frost heave
6. reduce natural mineral usage
7. reduce maintenance costs
8. increase of bearing capacity
9. bridging over voids
10. construction platform

**Benefit of Geosynthetics Reinforcement (1)**

Base thickness reduction (developed in the Netherlands)

Test road at Hitra, in Norway
- the rehabilitation works had been successful
- no substantial rutting or cracking
**Benefit of Geosynthetics Reinforcement (2)**

Rutting depth comparison (three year service)

(Wyoming DOT, USA)

- Conventional: 430mm
- Geogrid reinforced: 150mm

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Initially, the reinforced pavement costs more but after a certain period of time the reinforced pavement is a lower total cost.

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**Conceptual life-cycle cost illustration**

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**Differential Settlement Problem (Incheon International Airport)**

- Runway crossing area over underground box culvert
- Different rigidity of soil and concrete box culvert
- Different compactability of backfill area adjacent to the box culvert
- Large concentrated loading by the wt. of aircraft
- 3cm different settlement would occur
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Alternative methods
- 20cm thick concrete slab
- Insertion of tensile resistant element
- Cement stabilized sub-base layer
- Bearing capacity test
- Chemical compatibility study between cement stabilized soil and geogrid
Installation of Geogrid
Railway System

Reinforcement by geosynthetics

Mud pumping
**Mud Pumping Under Railway Track**

Void created as stones move apart under wheel load on sleeper

Mud moves in to fill the void as wheel load passes

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**Rail**

**Ballast**

**Sleepers**

**Pumping action**

**Sub-base**
**Geosynthetics in Unpaved Roads**

**8ICG Training Course, 18-22 Sep. 2006, Yokohama**

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![Image of a geosynthetic material in an unpaved road setting.](image1.jpg)

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![Image of rocky soil and possible geosynthetic installation.](image2.jpg)
In-situ test
Ground Stabilisation for Railway track in Port of Tianjin

Mud Pumping Prevention of SNCB, National Railway Company of Belgium
Thank you for your attention!