# DESIGNER'S FORUM

## Swamp roads and ramblings

**By Gregory N. Richardson, Ph.D., P.E.**

THIS MONTH, I THOUGHT IT WOULD be interesting to revisit one of the first geosynthetic applications: geotextile separators in roadways over soft (CBR < 3, cohesion < 1800 psf) soils. **Photo 1** on page 18 shows a typical swamp road application—plenty of water and low soil strengths.

This has been a classic geotextile application since it caught the industry's focus in the 1970s. At that time, patents held by the Reinforced Earth Co. precluded the marketing of geosynthetic-reinforced soil applications, and geosynthetic environmental applications were still trapped within the imagination of Congress. This was a decade when "geosynthetics" meant "geotextiles," J.P Giroud was a young, recently emigrated, French engineer working for Woodward-Clyde in Chicago, Bob Koerner was known for his work in acoustic emissions, and Europe dominated the geosynthetics technology.

In the United States, elaborate field tests were being performed on roadways by the Army Corps of Engineers, Law Engineering, and the University of Illinois. During this same time, Jerry Raymond of Queens University, Kingston, Ontario, Canada, and I were independently monitoring geotextile separation applications on railroads. Fun was being had by all.

## Geotextile design

Two very different design roles for geotextile separators on soft clayey soils emerged during this period: first, geotextiles provide a localized restraint (**Figure 1**) and, second, they can provide reinforcement (**Figure 2**). Localized restraint requires very low geotextile strengths, so that typical applications are controlled by the geotextile strength required to survive installation.

The April *Designer's Forum* presented the current American Association of State Highway and Transportation Officials (AASHTO) M288-96 geotextile survivability selection applicable for the localized-restraint mechanism. (Although these guidelines were approved in 1996, they are not official until the AASHTO specifications are published—this is expected to happen before August.)

Localized restraint is the mechanism incorporated in the design charts first presented by Steward, et.al., (1977) for the U.S. Forest Service. In this case, the geotextile's role is quantified by modifying the bearing capacity equation for the underlying subgrade. The bearing capacity, $q_{ult}$, for a continuous footing on a cohesive subgrade is provided by

$$q_{ult} = cN_c + \gamma D$$

where

$c$ = the cohesion of the subgrade
$N_c$ = a bearing capacity factor
$\gamma$ = the unit weight of the stone/etc. above the geotextile
$D$ = the depth of stone/etc.

For typical foundation applications, $N_c$ is approximately 5.5. This bearing capacity factor is adjusted when a geotextile is introduced between the soft subgrade and the base stone as follows:

- $N_c$ = **2.8** produces little rutting under large traffic loads without a geotextile
- $N_c$ = **3.3** produces large rutting under light traffic loads without a geotextile
- $N_c$ = **5.0** produces little rutting under large traffic loads with a geotextile
- $N_c$ = **6.0** produces large rutting under light traffic loads with a geotextile.

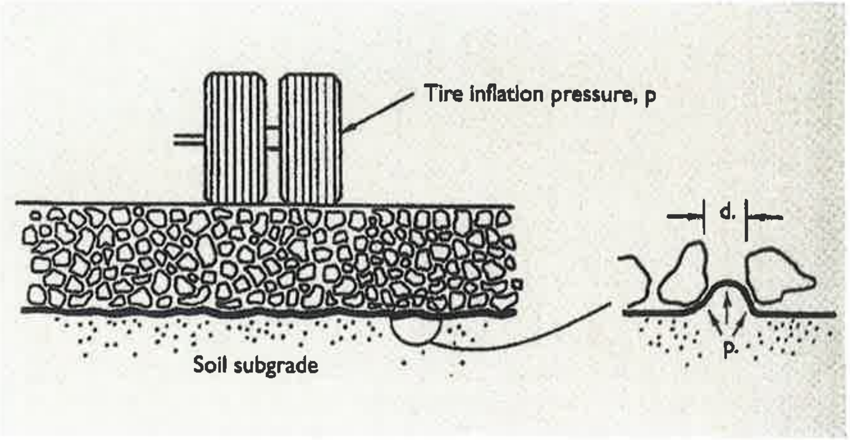


**Figure 1.** Localized bearing failure.

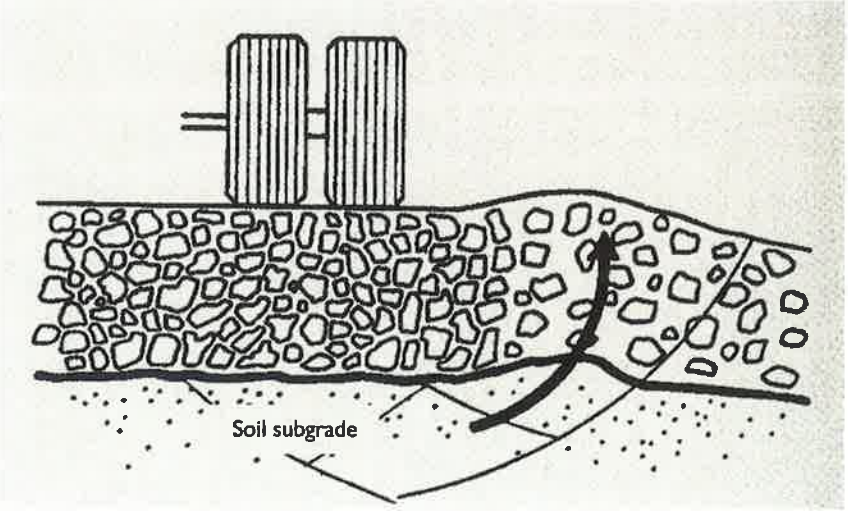


**Figure 2.** Bearing capacity failure.

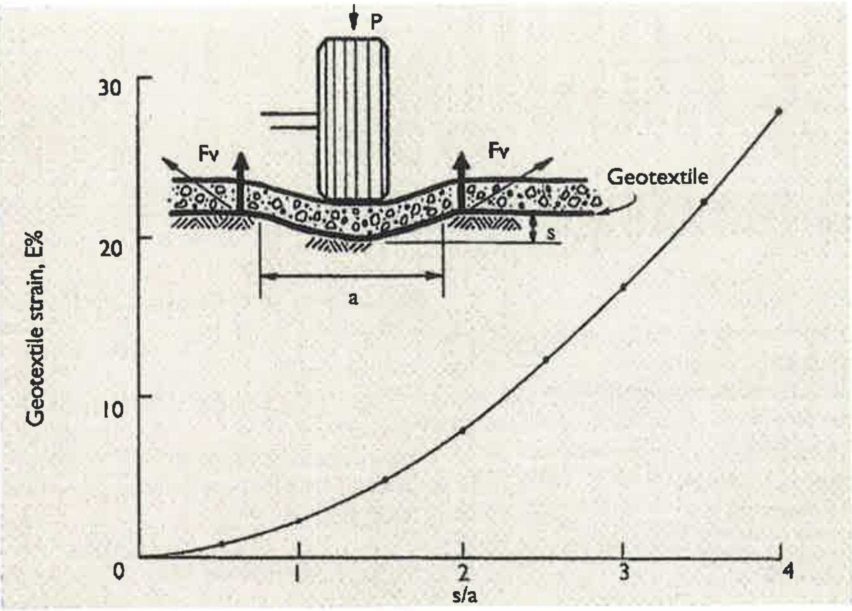


**Figure 3.** Tensioned geomembrane model.

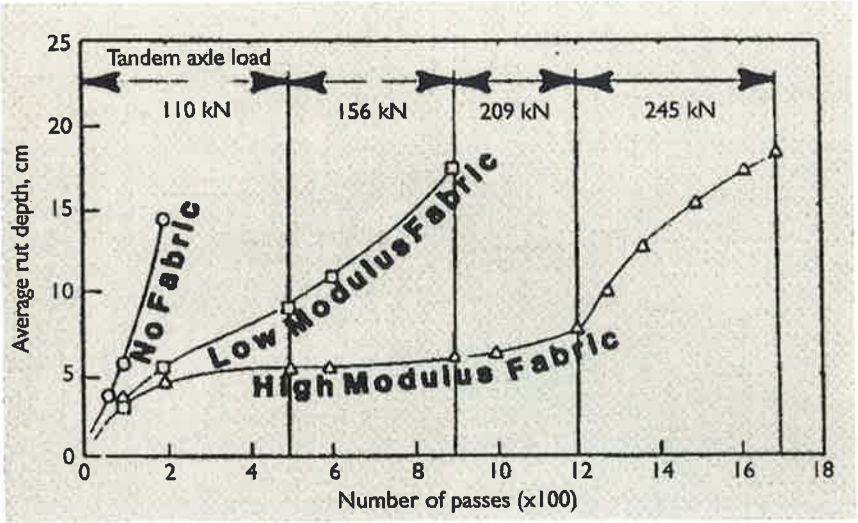


**Figure 4.** Rut depth as a function of vehicle passes.

**Photo 1.** This swamp road is a classic example of a geotextile separation application.

The geotextile stabilizer performs a vital role in keeping fines from intruding into the stone and in preventing local bearing capacity failure of individual stones with the subgrade.

Use of a geotextile allows the granular sub-base to be treated as a rigid footing concrete in that localized penetration of stone into the clay is prevented. Typically the analysis is performed by assuming either a Boussinesq elastic condition or a simple 60-degree angle for estimating the distribution of the applied surface load through the stone. The thickness of stone is adjusted so that the stress applied to the subgrade is less than $q_{ult}$. It has always amazed me how small a difference in stone thickness can separate a marginal road from one that will provide years of service.

## Tensile reinforcement

An alternative tensile reinforcement mechanism was being researched in the 1970s by the Army Corps of Engineers, the University of Illinois, and Georgia Tech University. I used to think of this as a woven vs. nonwoven model, since in those early years many manufacturers carried one or the other type of geotextile. **Figure 3** shows the essential fabric-tensioning mechanism. As the rut develops, the fabric is tensioned and begins to contribute a vertical force component that helps support the wheel load. Many of the researchers, and certainly all woven geotextile manufacturers, believed that low-strain modulus was the most important property for a geotextile in this application.

The work at Georgia Tech showed that

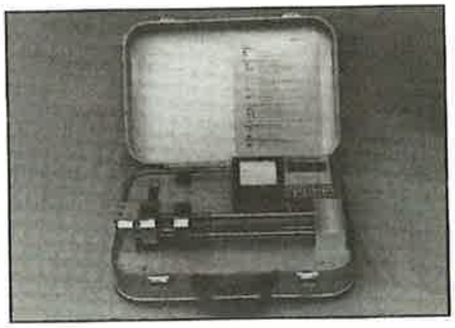
*continued on page 23*

*continued from page 18*

the modulus of the geotextile significantly influenced the *rate,* not the magnitude, at which rutting developed, as shown on **Figure 4.** Design procedures for "tensioned" geotextiles became more complex than those previously developed by Steward, and I suspect that most designers have used the charts prepared by Giroud, since they are easily found in Koerner's *Designing with Geosynthetics* textbook.

My interpretation of my own data and that of the previously mentioned studies was that, regardless of modulus, a geotextile-stabilized roadway with the ruts maintained, i.e., filled, would deform at the ruts to produce a bearing capacity factor of safety of 3.0 with the subgrade.

To illustrate this, I reinterpreted the recent excellent work by Fannin and Sigurdsson, 1996. (My hats off to those brave enough to actually do field tests.) **Figure 5** (page 24) shows the rut depths measured as a function of base course thickness for one of the study's test geotextiles. The base course depth corresponding to a $q_{applied} = 3c$ is, by my calculations, 0.4 m. Fannin and Sigurdsson indicate that the "rut depth" and a base course thickness of 0.5 m was due to gravel compaction alone, and not rutting



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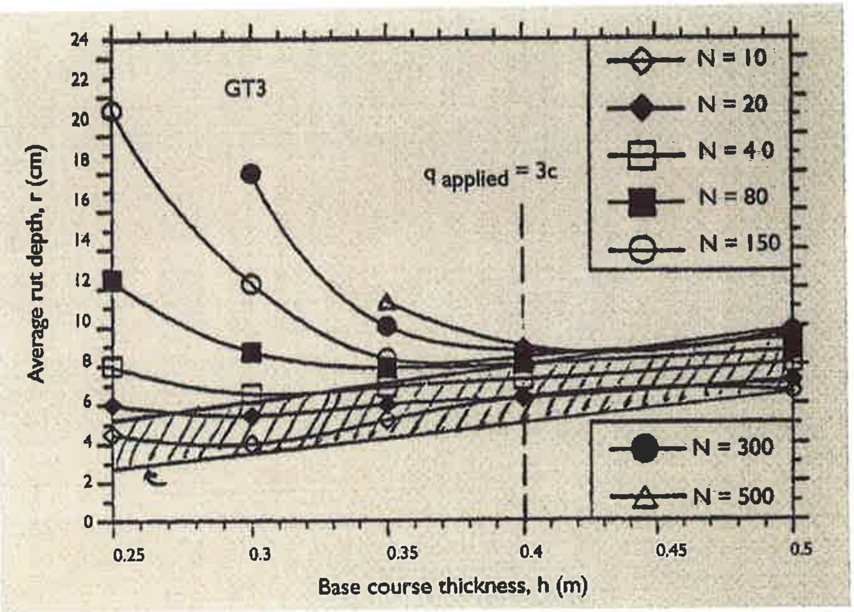

**Figure 5.** Average rut depth vs. base course thickness (adapted from Fannin and Sigurdsson).

of the subgrade.

For the geotextiles and geogrids tested, the rutting at 0.4 m thickness of stone was actually slightly less than for 0.5 m stone thickness. This is probably because there was less stone to compact with both having no rutting of the subgrade. Fannin and Sigurdsson did not repair the ruts (**Figure 6** on page 26), so the rut depth for 0.25 m of base course increases dramatically.

By Fannin and Sigurdsson's interpretation, this testing confirmed the importance of fabric modulus of the performance of such haul roads. My interpretation is significantly different. Looking at the data, it tells me that either quick repair of rutting by the adding more stone or using the initial design for $q_{applied}$ = 3c will produce a very stable road at a lower cost than relying on fabric modulus. The difference between using an initial stone thickness of 0.25 m to 0.4 m in this test would be less than 7 cents per square foot of stone—hardly a reason to begin designing with high-modulus geotextiles or geogrids.

Note how fast the rutting develops. Also note that if $q_{applied}$ = 5c is assumed, then the stone thickness is approximately 0.25m and significant rutting still develops! I'm afraid that the subgrade soil remolds so that the actual-service undrained shear strength will be significantly reduced. The subgrade soils used in the above test have a sensitivity of 7 and would easily strain and be reduced in strength. Very quickly in the life of the roadway, we would need the extra stone we tried to eliminate with the geosynthetic stabilizer.

I believe the use of a tension membrane model for the geotextile stabilizer is a waste of time for the designer and a waste of money for the owner, since many of these roadways are now being developed for long-term service. I do, however, think the geotextile stabilizer performs a vital role in keeping fines from intruding into the stone and in preventing local bearing capacity failure of individual stones with the subgrade.

## Design recommendations

With the previous considerations in mind, and in keeping with pragmatic design habits, I recommend designing long-term service "swamp" roads as follows:

### Step 1

Use a stone thickness that produces a subgrade pressure $q_{applied} = 4c$ and realize that now operations can simply grade the ruts and forget about hauling additional stone in to fill them. (This keeps the field maintenance people happy.) The 4c results in sufficient stone being placed initially to fill the

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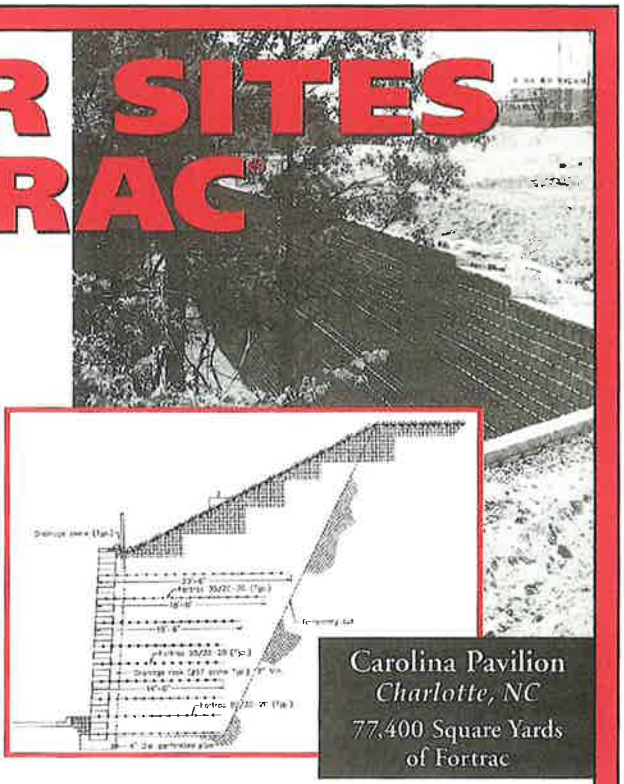

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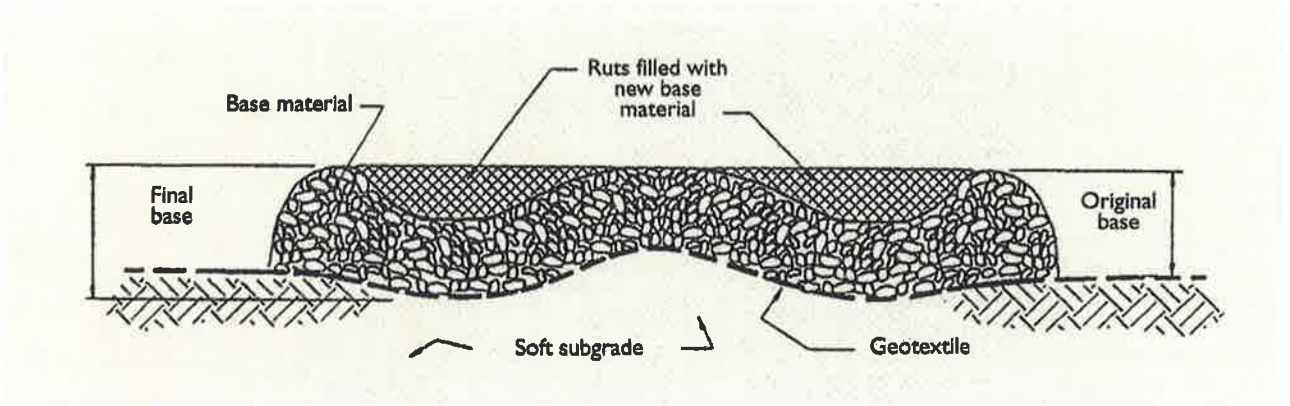

**Figure 6.** Repair of rutting.

ruts that will develop as the geotextile/ stone deforms to develop the 3c subgrade long-term stress beneath the traffic lanes.

### Step 2

Determine the geotextile's minimum survivability requirements by using the AASHTO M 288-96 guidelines in **Table 1**. This should be a Class 1 geotextile with the minimum average roll value (MARV) strength in **Table 2**.

### Step 3

Determine the geotextile's minimum hydraulic requirements by using the AASHTO M 288-96 guidelines for stabilization drainage. This requires a permittivity of the geotextile greater than 0.05 $sec^{-1}$ (the more the better) and an apparent opening size (AOS) less than 0.43 mm. I prefer a minimum permittivity of 0.05 $sec^{-1}$ for all geotextiles.

### Step 4

Select a suitable geotextile that meets the criteria in Steps 2 and 3. Almost any woven or nonwoven geotextile can be used if it meets the requirements in Steps 2 an 3. The geotextile specifications, therefore, can be written as follows:

- The geotextile shall be a woven or needlepunched nonwoven fabric.
- The geotextile shall have MARV

strength properties meeting the requirements of an AASHTO M 288-96 Class 1 geotextile.

- The geotextile shall have MARV hydraulic properties meeting the requirements of AASHTO M 288-96 geotextile criteria for stabilization.

Thus, the design of the swamp road is simple and the engineer can better spend his or her time worrying about construction details and the wetlands permits required for a majority of such sites. I encourage readers who favor the "tensioned membrane" alternative to write a "counter-point" article for future publication in this column. Certainly on very weak soils the value of fabric modulus may be important—anyone have a criteria to suggest? Or, how about an opinion on long-term vs. short-term applications? Your comments and suggestions are always welcome (see page 29). GFR

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TABLE 1. AASHTO M 288-96 GEOTEXTILE SURVIVABILITY REQUIREMENTS

| Property | ASTM test method | Units | Geotextile class | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Class I | | Class 2 | | Class 3 | |
| | | | <W 50% | >NW 50% | <W 50% | >NW 50% | <W 50% | >NW 50% |
| Grab strength | D 4632 | N (lb) | 1400 (315) | 900 (205) | 1100 (250) | 700 (160) | 800 (180) | 600 (115) |
| Seam strength | D 4632 | N (lb) | 1260 (280) | 810 (185) | 990 (220) | 630 (140) | 720 (165) | 450 (100) |
| Tear strength | D 4533 | N (lb) | 500 (115) | 350 (80) | 400 (90) | 250 (55) | 300 (70) | 180 (40) |
| Puncture strength | D 4833 | N (lb) | 500 (115) | 350 (80) | 400 (90) | 250 (55) | 300 (70) | 180 (40) |
| Burst strength | D 3786 | kPa (psi) | 3500 (510) | 1700 (255) | 2700 (400) | 1300 (200) | 2100 (305) | 950 (140) |

- Elongation at break as measured in accordance with ASTM D 4632

TABLE 2. MINIMUM STRENGTH VALUES NEEDED FOR STEP 2 OF THE SEPARATION EXAMPLE

| Property | ASTM test method | Units | Woven geotextiles | Nonwoven geotextiles |
|---|---|---|---|---|
| Grab | D 4632 | lbs | 315 | 205 |
| Seam | D 4632 | lbs | 280 | 185 |
| Tear | D 4533 | lbs | 115 | 80 |
| Puncture | D 4833 | lbs | 115 | 80 |
| Burst | D 3786 | lbs | 510 | 255 |

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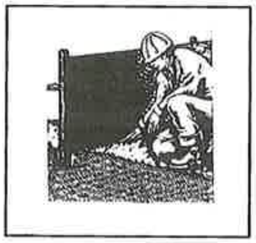

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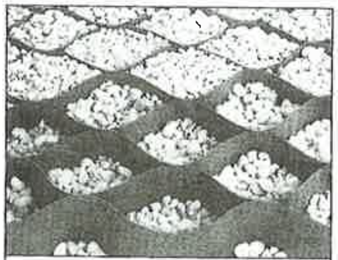

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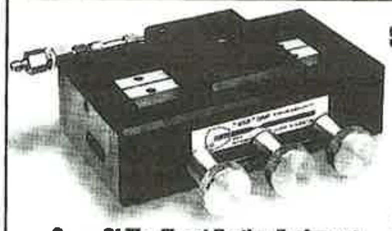

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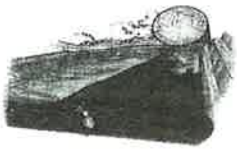

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