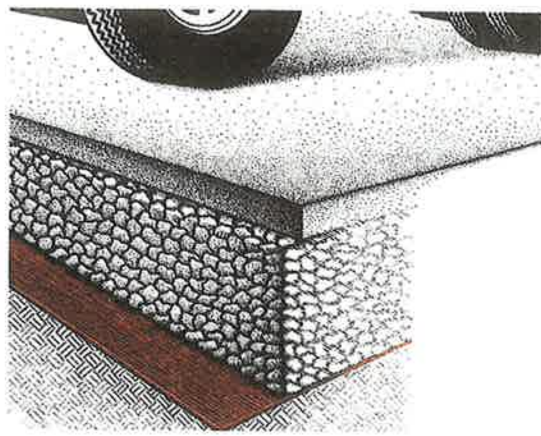
DESIGNER'S FORUM

Geogrids vs. geotextiles in roadway applications

By Greg Richardson

IN THE LAST DESIGNER'S FORUM (September *GFR*, page 20), John Paulson reviewed design considerations for geosynthetic-reinforced retaining walls using granular backfill. Currently, Mark Wayne of Tensar is preparing an article on the design of such structures using on-site materials that may be cohesive and anything but free draining. Before I leave road applications of geosynthetics to begin a series on waste containment applications (my favorite), I would like to address the most commonly asked question during the recent Amoco-sponsored geotextile training courses: "What is the difference in the use of geotextiles and geogrids in unpaved and paved roadways?" I know this should elicit some enthusiastic discussion. As with all of the columns I author, the opinions expressed here are mine!

Given that the Romans began paved roadway construction over 1,800 years ago, and asphalt was first used in Paris in 1854, the relative age and experience of geotextiles and geogrids in roadway systems is very young. The use of geotextiles in roadway systems dates from the early '70s. References in papers presented at the First International Conference on Geotextiles, held in Paris in 1977, contain no significant work from the '60s. In fact, some of the work reported is so novel that the papers contain no references! The use of geogrids in North America dates back to 1983. Even middle-aged roadway engineers (baby-boomers), then, were trained in the absence of geosynthetics.



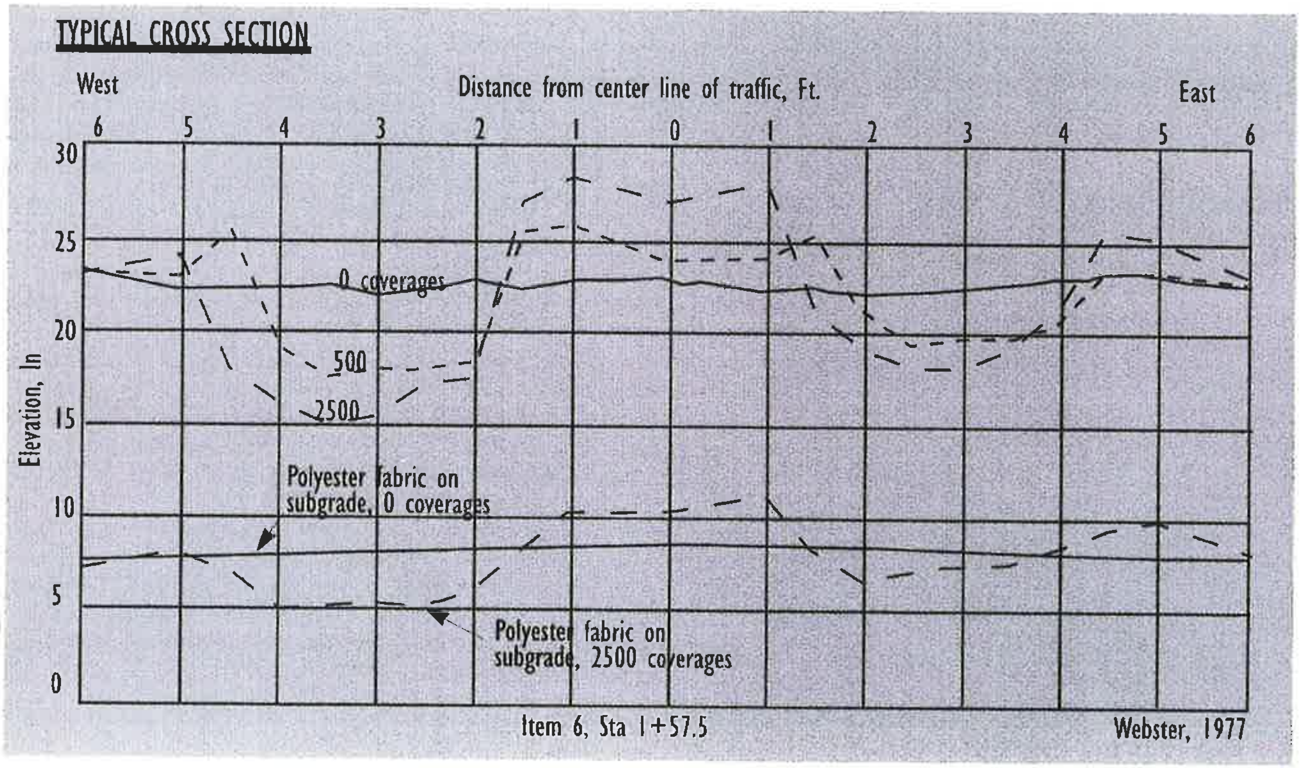
Roadway cross section with geotextile

As is customary, I will present my comparison of geogrids and geotextiles as they apply to two distinct roadway types: temporary gravel-surfaced haul roads and permanent roadway structures.

Pre-geosynthetics technical discussions of such roads is typified by that of Rodin[1] who developed a road design procedure for use by "earth moving plants" (i.e., rubber-tired construction equipment). Rodin indicates that acceptable service pressure on a subgrade of shear strength, c, will be between the following known limits:

$q_u = 6.2\ c$	ultimate bearing capacity for rigid surface footing
$p = \pi\ c$	pressure causing initiation of subgrade over-stressing for flexible footing

Rodin postulated that bearing capacity assumptions between these two extremes



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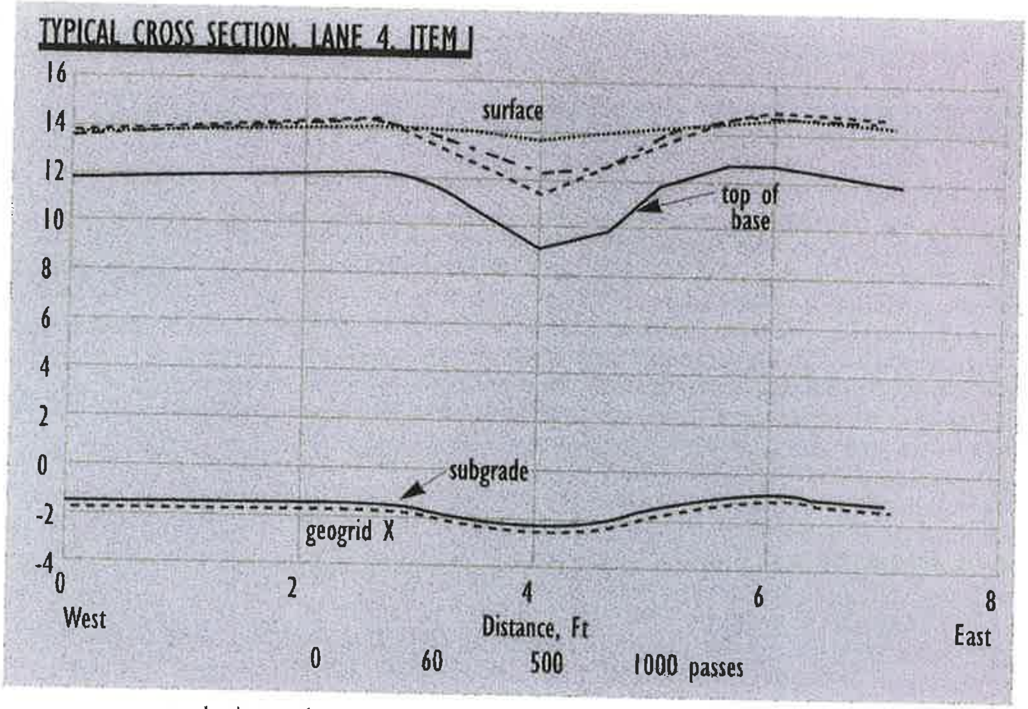
would reflect varying rutting depths and clearly indicated that there is no accurate method to relate a rut depth to a given contact pressure. Lacking data relating rut depth to contact pressure, Rodin theorized that a contact stress of πc would cause little rutting and a contact stress of 6.2c would cause excessive rutting. He postulated that the approximate mean ($6.2 = \pi = 9.6/2 \approx 5$) of these two limits would result in 2 in. of rutting. It should be noted that this recommendation was directed at contractors to assist them in maintaining the integrity of their haul roads.



Temporary roads: geotextiles

In 1974, Barenburg[2] performed laboratory model tests using aggregate and fabric over soft soils (CBR<3) and concluded that the bearing capacity factors N_c (where $q_{allowable} = N_c\ c$) are:

- $N_c = 3.3$ deep rutting (>4 in.) with number of loads <100 without a geotextile
- $N_c = 6.0$ deep rutting (>4 in.) with number of loads (<100) with a geotextile.

Based on actual field tests on U.S. Forest Service log roads, this was extended by Steward[3] in 1977 to its current recognizable form:

- $N_c = 2.8$ minor rutting (<2 in.) with number of loads <1000 without a geotextile
- $N_c = 3.3$ deep rutting (>4 in.) with number of loads <100 without a geotextile
- $N_c = 5.0$ minor rutting (<2 in.) with number of loads <1000 with a geotextile
- $N_c = 6.0$ deep rutting (>4 in.) with number of loads <100 with a geotextile.

This increase in allowable bearing capacity is attributed to localized restraint of the subgrade by the geotextile. Since cohesion is the key subgrade shear strength criterion, it is obvious that these methods were meant for clay or silt subgrades. Note that the strength properties of the geotextiles do not play a role in this method as long as they survive installation and the number of load cycles is very low.

Based on laboratory model tests, Kinney[4] extended the work of Barenburg to include the influence of the tensile modulus of the geotextile. Simultaneously, Webster[5] was investigating means of constructing temporary military roads across soft subgrades (post-Vietnam). **Figure 1** shows subgrade profiles that developed in a soft clay (CBR=1) due to trafficking by a military truck. Here, failure was defined as a surface rut of 11 in. (0.3m), since the truck could no longer pass. Based on Webster's work, Giroud[6] developed a membrane model that incorporates the tensile modulus of the geotextile and agrees well with Webster's data. The model remains in use to this day.

The most important function for the geotextile is that of a separator to keep active fines in the subgrade from pumping into the aggregate and degrading its strength and modulus. This function can be designed using the guidelines presented in the June/July 1997 issue of *GFR*. The value of separation is obviously dependent on the presence of active clay fines in the subgrade and a base stone that is initially clean and easily penetrated by the soft clay. Thus, a geotextile separator would be of little value over sandy soils or if the base stone contained a significant sand and silt fraction common to subbase aggregates.

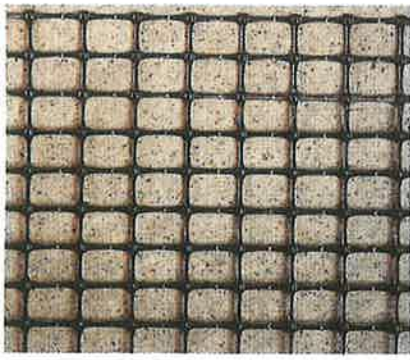
Nearly two decades of experience and additional field tests[7,8] have confirmed these three benefits/functions for geotextiles in temporary roads over cohesive soils, and little controversy exists regarding the advantages of their use.

Temporary roads: geogrids

The use of a geogrid within (typically in the lower third) or at the bottom of the aggregate layer significantly improves the stiffness of that layer. This stiffening spreads the applied surface loads over a larger area of the subgrade and therefore limits or slows rutting. This spreading of the applied load was studied by Giroud[9] using an elastic finite element model. Based on this very simplified analysis, Giroud developed a design procedure for reinforcement of unpaved roads with geogrids that has to my surprise agreed with many field observations[7].

It is important to realize that the geogrid functions through improvement of the aggregate layer. If separation is required, a geotextile must be provided at the subgrade-aggregate interface. Separation may not be required if the aggregate contains a significant sand and silt fraction or if the subgrade CBR>4%. In general, grids have been very effective at reinforcing thinner sections of poor-quality aggregate where a separator geotextile is not required.

Webster[11] found that a geogrid over a loose sand subgrade reduced the displacements caused by a large truck. A separator geotextile did not. Unfortunately, Webster did not try using a high modulus reinforcement geotextile—my dollar says it would also reduce displacements.

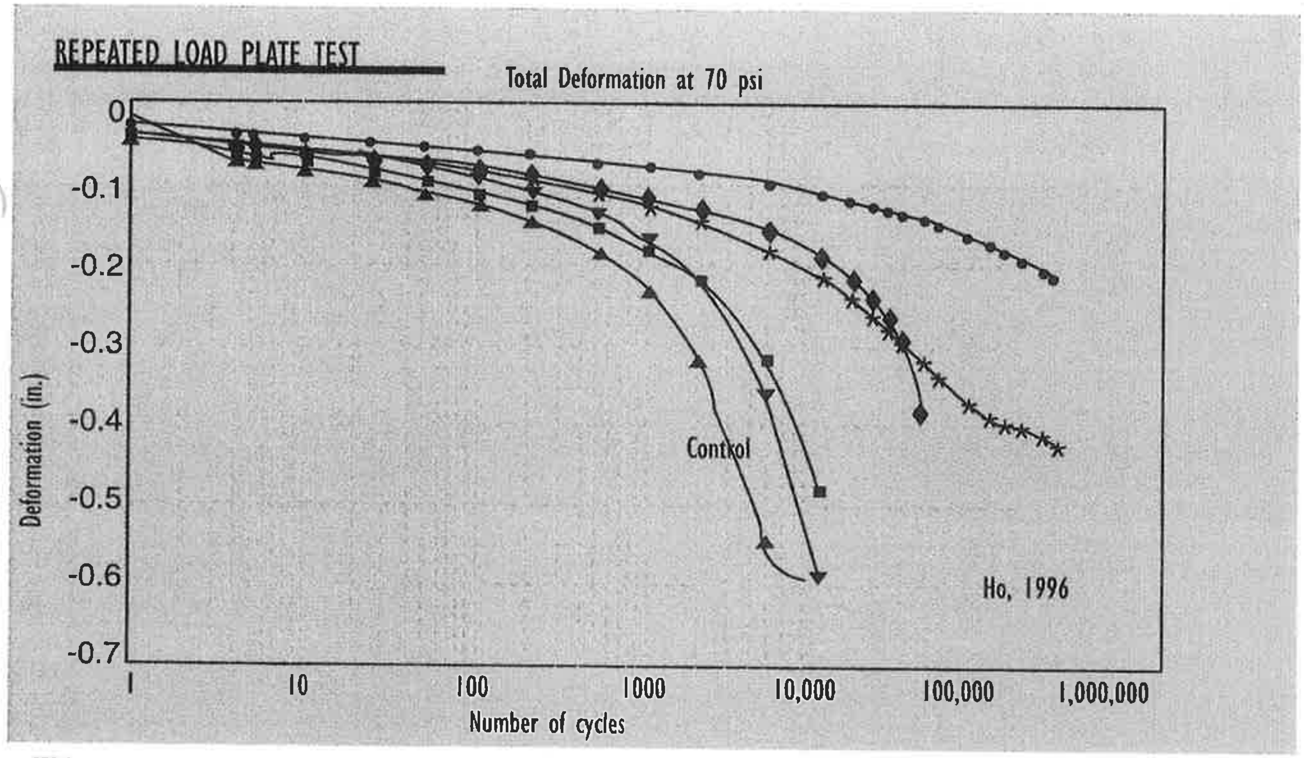


A geogrid for use in road applications.

Permanent roads: geotextiles and geogrids

With permanent roads, the number of equivalent single axle (ESAL) design loadings easily increases to more than 200,000, and the allowable surface rutting is commonly limited to 1 in. (25mm) to limit damage to the surface pavement. Two significant studies emerged in the past decade: using a 1500-lb. wheel load, Barksdale[10] evaluated both geotextile separators and geogrid reinforcement for flexible paving on a weak silty clay subgrade, and Webster[11] used a 30,000 lb wheel load to evaluate geotextile separators and geogrid reinforcement for flexible paving on a weak, highly-plastic clay subgrade. It should be readily apparent that one of the problems in interpreting historical performance data results from significant differences in loading mechanisms, material types, variations in subgrade strengths and total number of loads applied. More on this later.

Barksdale found that none of the geosynthetics had an effect on design sections for more than ESAL of about 200,000. Additionally, he found that placement of the grid at the subgrade surface did not have a beneficial effect—displacements actually increased. Since these tests used a relatively clean aggregate, the grid failure due to aggregate contamination is not a surprise. Grids performed better when placed in the lower third of the aggregate, away from the fines intrusion. He also observed that the geogrid provided a better "contact efficiency" with the clean aggregate and CBR = 2.5% subgrade used, and thus better reinforcement of the aggregate—again, no surprise. Based on these test conditions, Barksdale recommended that a minimum 5% secant modulus of 4,000 lb/in. for geotextiles and 1500 lb/in. for geogrids be used in such applications. This reflects the better interlock between the grid and the clean aggregate.

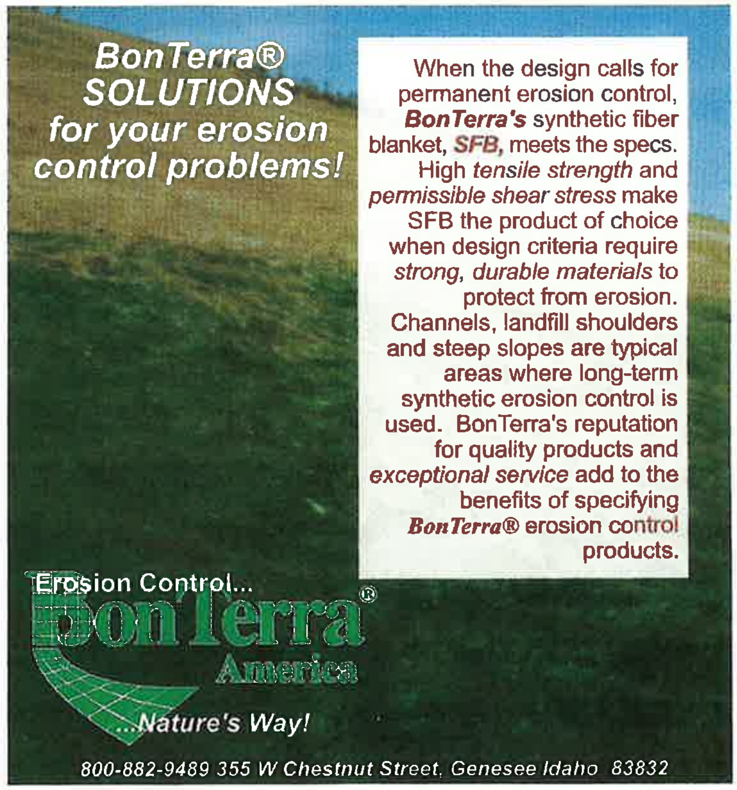


Webster obviously wins the award for biggest wheel—30,000 lbs! These tests used a poor-quality aggregate selected to maximize the potential improvement from geogrids. This minimizes the potential for a separation problem and none was observed. Not surprisingly, the grid now performed best when placed at the base of the aggregate since no fines intrusion occurred. Interestingly, not all of the grids performed well. Webster postulated that the grid aperture stability was a critical factor—junction strength is apparently important for the most significant reinforcement in this application . In one example, the degree of reinforcement decreased rapidly as the thickness of the aggregate increased (40% increase @ 10 in. of stone and 5% @ 20 in. of stone).

Researchers for both geogrids and geotextiles have attempted to develop empirical relationships that give the influence of the geosynthetic on the pavement structural number, SN. This is commonly done by measuring surface rut deformation versus number of load cycles and back calculating a new SN value that corresponds to the reduced rate of deformation. Penner[12] developed such relationships for Tensar grid used over soft sands. Smith et al.[13] did similar work for geotextiles over sandy silts. The reader is cautioned to understand clearly the number of load cycles, subgrade conditions, etc. that are incorporated in these empirical relationships. To illustrate this concern, **Figure 2** shows cyclic load vs. displacement recently measured by Ho[14]. Note how the performance of geosynthetic-"enhanced" roadway sections begins to degrade rapidly after 10,000 load cycles, making large ESAL projections dangerous. Few researchers are performing tests using more than 20,000 cycles because of time and equipment restraints. The projection of these data without confirmation testing poses a risk.

Summary

Both geotextiles and geogrids can play an important role in extending the life of a roadway system—or they can be used in a totally irrelevant manner. My personal rules-of-thumb for the use of these geosynthetics in roadways are as follows:



Temporary Roads

(This includes working platforms for a permanent road construction)

- Clayey or Silty Subgrades with CBR<4: If clean base aggregate is to be used (and I don't recommend its use here), then a nonwoven separator geotextile must be used. If a "choked aggregate," like general crusher run, is going to be used, then use either a geotextile or a biaxial geogrid that has good aperture stability and appropriate size. For a design ESAL less than 1000, I would use a woven geotextile designed for both separation and membrane roles—that is, consider the geotextile's modulus. For larger ESAL, use a woven or nonwoven geotextile designed simply for separation. The reinforcement role of the geogrid seems safe for approximately 10,000 ESAL.
- Sandy Subgrades with CBR<3: Select a biaxial grid with good aperture stability and appropriate size or a woven geotextile that has a reasonable interface friction with the sand and the aggregate. If a woven geotextile is considered, care should be taken to ensure that it does not actually create a slick slip-plane beneath the aggregate; i.e., look at the interface friction.

Permanent Roads

(ESAL>200,000)

- Clayey or Silty Subgrades with CBR<3: Consider building a working platform using the temporary road methods upon which your conventional road can be constructed. Neglect the working platform in calculating the structural number SN of the pavement, but consider it in estimating the subgrade resilient modulus. This is essentially the approach proposed by Christopher and Holtz[15,16].
- Clayey or Silty Subgrades with 3<CBR<8: If there is any potential for degradation due to water intrusion, frost heave, etc., then include a separator geotextile to protect the base aggregate during these periods.
- Sandy Subgrades with CBR<3: Use a biaxial geogrid that has good aperture stability and appropriate size to reinforce the base aggregate. This is particularly helpful when poor quality stone must be used and when the aggregate thickness is small, <10 in.

I can only warn the reader to be very cautious in evaluating claims by both researchers and manufacturers. All testing programs require some "equivalence" assumptions to be made. How does a 30,000-lb tire load relate to a 9,000-lb tire load? How does applying the load through a rigid plate with a fixed location relate to actual loading by a moving tire? Make sure you agree with the "equivalence" assumptions, and make sure that the performance under a limited number of load cycles is not being extrapolated several orders of magnitude for permanent ESAL. Academics are not resistant to exaggeration, either.

The bottom line is that both geotextiles and geogrids can offer significant improvement in roadway performance when used appropriately! I must thank Deron Austin of Synthetic Industries and Robert (Andy) Anderson of Tensar for their review comments on this column. Both were very honest in their comments and surprised me with the to degree which they are in general agreement. If you have had a poor experience with geotextile or geogrids in roadway applications, take a minute and see if you

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broke one of my rules-of-thumb. Let's do a follow-up column next year with a revised list of our combined experiences. Let me know at greg@gnra.com. GR

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Foot-notes

1. Rodin, S., "Ability of Clay Fill to Support Construction Plant," Civil Engineering and Public Works Review, England, February, 1965.
2. Barenburg, E.J., Dowland, J.H., and Hales,J.H., "Evaluation of Soil Aggregate Systems with Mirafi Fabric," Civil Engineering Studies, Department of Civil Engineering, University of Illinois, August, 1975.
3. Steward, J,, Williamson, R., and Mohney, J., Guidelines for Use of Fabrics in Construction and Maintenance of Low-Volume Roads, USDA, Forest Service, Portland, OR, 1977.
4. Kinney, T.C., The Influence of Fabric on Stresses in a Soil Fabric Aggregate System, Ph.D. Thesis, University of Illinois, Urbana, 1978.
5. Webster, Steve, Watkins, James E.,