TECHNICAL NOTE

GEOSYNTHETIC REINFORCEMENT AND SEPARATION

Prepared by:

TenCate Geosynthetics Americas
South Holland Drive
Pendergrass, GA 30567
Tel 706 693 2226
www.tencategeo.us

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The Federal Highway Administration (FHWA) Geosynthetics Engineering Manual (Holtz et al., 1998) lists four geosynthetic functions that may have effect in a pavement structure: separation, filtration, drainage, and reinforcement.

The benefits listed in the FHWA manual have been verified both through research and design methods supported by over 30 years of experience. The GMA White Paper II, June 27, 2000, defines these functions during the performance life of the roadway structure as;

- Separation - prevention of subgrade soil intruding into aggregate base (or sub- base), and prevention of aggregate base (or sub-base) migrating into the subgrade.
- Filtration - restricting the movement of soil particles, while allowing water to move from the filtered soil to the coarser soil adjacent to it.
- Lateral Drainage (i.e., transmissivity) -the lateral movement of water within the plane of the geosynthetic.
- Reinforcement - the addition of structural or load-carrying capacity to a pavement system by the transfer of load to the geosynthetic material.

Separation

In geotechnical engineering, the alternative to utilizing a separation geotextile is to incorporate an additional soil layer to create a graded aggregate filter, which can be cost prohibitive. The physical requirements for a separation geotextile for retention of soil particles at the subgrade-base course interface is well documented.

- Retention: The separation geotextile must have an opening size small enough to prevent the migration of subgrade fines into base course under dynamic vehicle loads.
- Survivability: A damaged geotextile with punctures and tears may allow soil particle migration to occur. The geotextile must possess adequate strength and a construction suitable to survive installation and in-service conditions.

Quantifying Separation

For the past 30 years, engineers have known that separation was a key geosynthetic function. However, until recently, the separation function could not be quantified. Today with the emergence of the Separation Factor, engineers can now quantify a products ability to separate.

Definition of Separation Factor

The Separation Factor (SF) for a specific geosynthetic with respect to a given soil is defined as the ratio of the soil mass retained (M_R) on top of a geosynthetic sieve to the total soil mass (M_T) in this study. The SF can be calculated using the following equation:

$$SF = M_R / M_T$$

The SF can be analyzed relative to other measurable indexes, primarily the coefficient of interaction (confinement) and AOS (filtration), as shown in Figure 1.

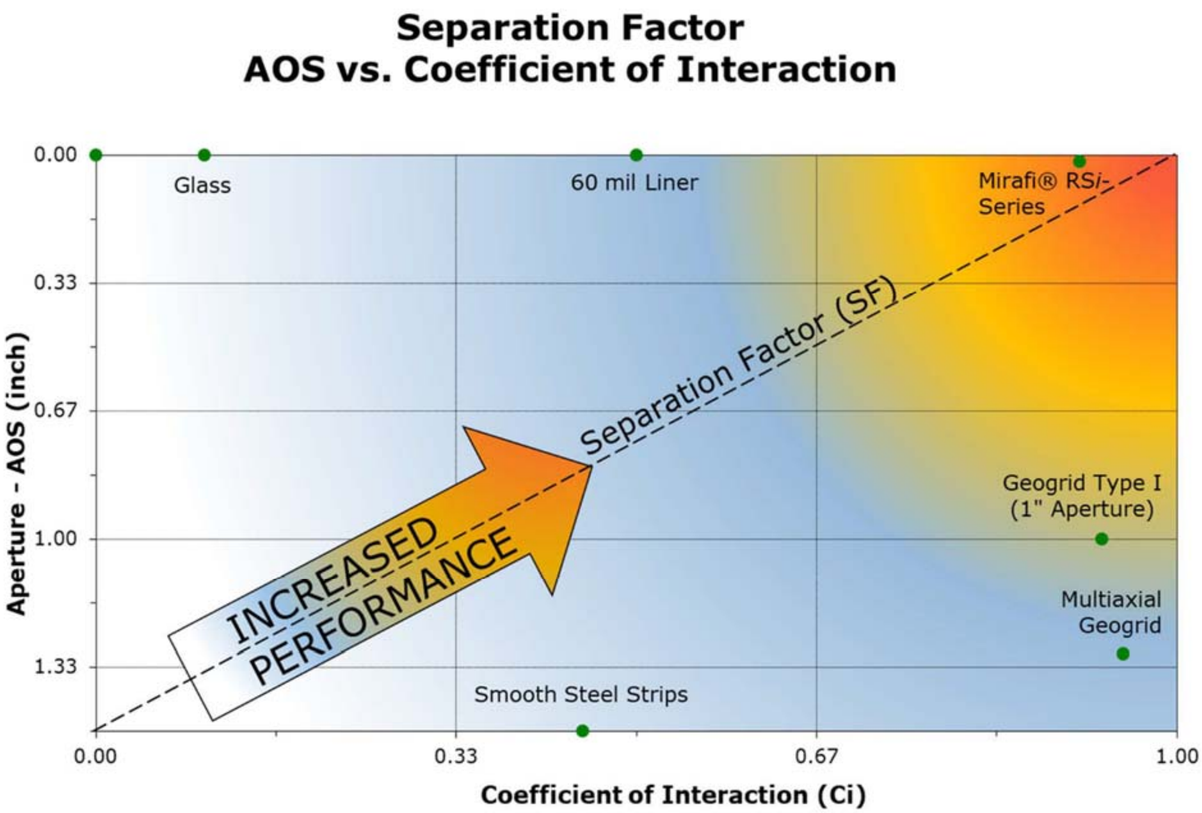


Figure 1

As with all geosynthetic products, key properties define a product's ability to be used successfully in a particular application. For years, we have specified quality control index properties such as tensile strength, puncture, trap tear, etc. in a round-about way to specify separation. The use of the Separation Factor finally gives us a way to truly quantify the separation ability of the geosynthetic material.

Filtration & Drainage

- Filtration requires a geotextile to retain particles through separation while allowing the free flow of water through the plane of the geotextile.
- The ability of a geotextile to allow for liquid flow with limited soil loss within the plane of the geotextile is referred to drainage.
- Retention and permeability requirements relate to the geotextile's apparent opening size and opening distribution.
- Permeability: The number of openings and their size in the separation geotextile must be large enough not to adversely affect the flow of liquid or air in either a downward or an upward direction. The geotextile must be capable of relieving any pore water pressure build up within the soil structure – particularly during traffic loading. Without sufficient drainage – the pore water pressure may support the wheel loads – causing the soil to pump under load.
- Transmissivity: This is similar to permeability except that this term refers to the geotextile's in-plane ability to drain water out of a civil structure.

Reinforcement

Geosynthetic reinforcement can be defined in terms of the specific application in roadways;

- Pavement System Reinforcement - Use of a geosynthetic to aid in support of traffic loads, where loads may be vehicular loads over the life of the pavement, or construction equipment loads on the unpaved base course or sub-base during construction.
- Base Reinforcement - Base (or sub-base) reinforcement may occur when a geosynthetic is placed as a tensile element at the bottom of a base (or subbase) or within a base course to: (1) improve the service life and/or; (2) obtain equivalent performance with a reduced structural section. The mechanisms of reinforcement leading to these two benefits are described in detail in Section 2.4 of the GMA White Paper II. Base reinforcement is applicable for the support of vehicular traffic over the life of the pavement and is designed to address the pavement distress mode of permanent surface deformation or rutting and asphalt fatigue cracking.
- Subgrade Restraint - Subgrade restraint may occur when a geosynthetic is placed at the subgrade/sub-base or subgrade/base interface to increase the support of construction equipment over a weak or low subgrade. "The primary mechanism with this application is increased bearing capacity, although lateral restraint and/or tension membrane effects may also contribute to load carrying capacity. Subgrade restraint

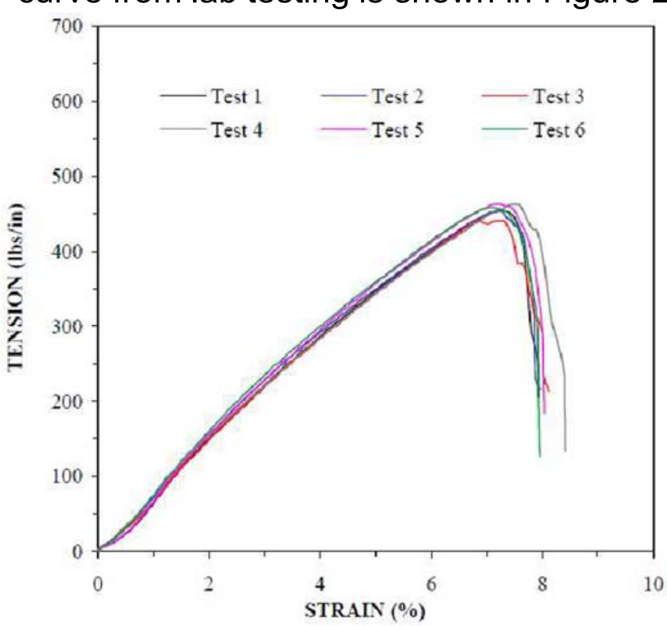
 is the reinforcing component of stabilization”. Berg et al. (2000).

Quantifying Reinforcement

Originally, geosynthetic strength properties were measured in terms of textile testing methods (first geosynthetics were all textiles), e.g., Grab Tensile Strength (ASTM D- 4632), index test reported as a force (pounds or newtons). As the industry progressed and the requirement for more design applicable data developed, the need arose for strength measurements that could provide tensile stiffness per unit width for project designs. These design parameters are commonly determined using the wide-width tensile test (ASTM D4595) for geotextiles.

In solid mechanics, Young's modulus (E) is a measure of the stiffness of a given material and is typically reported in terms of force per cross-sectional area, pounds per square inch (psi) or kilonewtons per square meter (kN/m^2).

Geosynthetic modulus is defined as the ratio of the rate of change in stress with strain, such as the pound strength at a given elongation and is reported as force per unit width, such as lbs/in width. A typical stress/strain curve from lab testing is shown in Figure 2. In the analysis of geosynthetic reinforced pavements, tensile forces are mobilized in the geosynthetic through deformation of the subgrade. As these tensile forces are developed, the amount of deformation of the geosynthetic and therefore the subgrade, are dependent on the modulus characteristics of the geosynthetic. In order to minimize the depth of rutting within the aggregate, the use of a geosynthetic that achieves high tensile strengths at low strains (higher modulus) is imperative.



Typical Stress-Strain curve for a Mirafi High Performance/Enhanced Geotextile

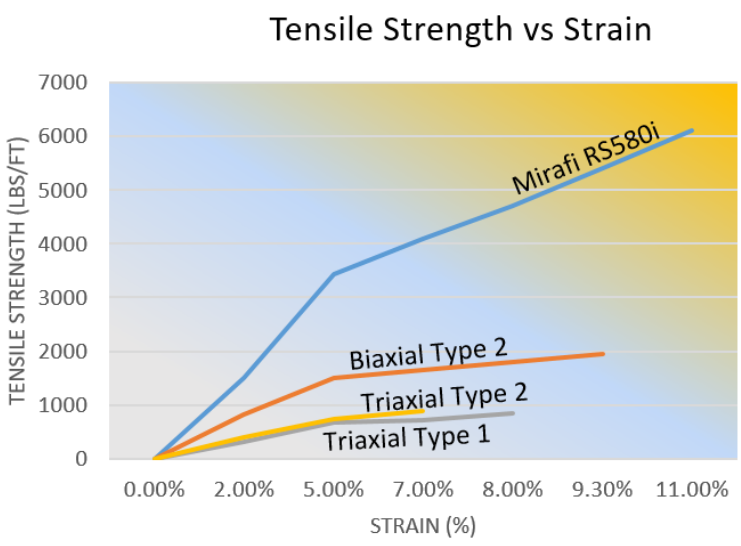
Figure 2

Two products in one

Geogrids are formed from plastics sheets and strips or woven from high tenacity yarns into a very open, grid like configuration. By ASTM definition, geogrids have openings larger than ¼ inch (6.35mm). Geogrids may be coated with polymers to provide additional protection. Geogrids function almost exclusively as reinforcement materials and offer little to no soil separation or filtering.

Geotextiles consist of synthetic fibers made from the same polymers as geogrids, typically polypropylene (PP) and polyester (PET). These synthetic fibers are made into a flexible, porous fabric by weaving (woven geotextile) or entangling fibers together (nonwoven geotextile). Geotextiles are permeable to water flow across their manufactured plane and within their plane (transmissivity), but to a widely varying degree. This ability to combine high water flow, filtration and tensile strength is key to the geotextiles performance.

Industry guidelines have always indicated the need for separation in soft and fine grained soils. The U.S. Army Corps of Engineers "Use of Geogrid in Pavements" (ETL1110-1-189) recommends a geotextile separator for subgrade soils with a CBR less than or equal to 4. A combination geogrid with a nonwoven filter fabric could provide the combined functions of reinforcement and separation. However, this requires 2 products, additional handling and installation or a composite material. A better alternative when reinforcement and separation are needed is a single layer High performance (aka "enhanced") woven polypropylene geotextile. A High Performance/ Enhanced geotextile is defined per AASHTO M288-17 as a geotextile that has an ultimate tensile strength greater than or equal to 70 kN/m (400 lbs/in) per ASTM D 4595. Figure 2 shows independent lab test results for a Mirafi® High Performance/ Enhanced geotextile that easily exceeds 400 lbs/in.



Values Determined from Results of Independent Testing and Geosynthetic Calibrations Reported by WTI / MTSU "Relative Operational Performance of Geosynthetics Used as Subgrade Stabilization." (Reference 2)

Figure 3

Research has shown that high tensile modulus (strength at low strains) is key to geosynthetic performance in roadway applications (Reference 2). Geogrids and high-performance geotextiles provide reinforcement and stabilization due to relatively high strength at low tensile strain. However, geogrids are limited in tensile strength and are not able to provide the additional benefit of separation due to their construction with large open apertures. High performance geotextiles with high tensile modulus values can quickly mobilize their strength and transfer this strength to soil to reduce wheel rutting in roadway applications. In the past, geogrids offered the highest tensile strength at the lowest strains, but this is no longer the case. High performance geotextiles offer much higher strengths (even at very low strains) compared to typical roadway geogrids, as shown in Figure 3. Mirafi® RS580*i* yields a tensile strength at only 2% strain that is approximately twice as high as a rectangular aperture geogrid and 4 times higher than the triangle aperture geogrid, as shown in Figure 3 above.

Additionally, Mirafi® RS*i*-Series geotextiles can provide very good hydraulic properties to aid with filtration and drainage requirements of a pavement structure. Mirafi® RS*i* geotextiles offer water flow rates of at least 70 gam/min/SF – this is higher than many typical filter fabrics. As shown in the Chart 1, below, Mirafi® RS*i* high performance geotextiles integrate a combination of high reinforcement strength, high water flow, high survivability and separation.

Geosynthetic for Roadway Reinforcement Selection Guidelines					
Function/ Product	RS580*i* High Performance Geotextile	BXG120 Geogrid	RS380*i* High Performance Geotextile	BXG110 Geogrid	RS280i High Performance Geotextile
Separation	Excellent	Poor	Excellent	Poor	Excellent
Reinforcement	Very High	Moderate	High	Moderate	Moderate
Water Flow Capacity with Separation	High	N / A	High	N / A	High
Survivability	Very High	Very High	Very High	High	High

Chart 1

TenCate Geosynthetics provides formatted CSI specifications for Mirafi® RS*i* high performance geotextiles. Go to our website at www.tencategeo.com, click on technical data, and then CSI Specifications.

References

Holtz, R. D., Christopher, B. R., and Berg, R. R. (1998). "Geosynthetic Design and Construction Guidelines." Publication No. FHWA HI-95-038. Federal Highway Administration, Washington, DC, 459 pgs

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Berg R.R., Christopher B.R., Perkins S., Geosynthetic Reinforcement of the Aggregate Base/Subbase Courses of Pavement Structures, GMA White Paper II, Ryan R. Berg & Associates, Inc. June 27, 2000

U.S. Army Corps of Engineers, "Use of Geogrids in Pavement Construction", ETL110-1-189, 2003.