TECHNICAL NOTE

DEFINING, UNDERSTANDING, AND QUANTIFYING SEPARATION & REINFORCEMENT

Prepared by:

TenCate[TM] Geosynthetics North America
365 South Holland Drive
Pendergrass, GA 30567
Tel 706 693 2226
Fax 706 693 4400
www.tencate.com

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There are four key functions of geosynthetics in pavement structures as noted by the Federal Highway Administration (FHWA) Geosynthetics Engineering Manual (Holtz et al., 1998). These functions include separation, filtration, drainage, and reinforcement. Through extensive research and design, combined with over 30 years of experience, the benefits of these functions have been tested and proven. And, these functions have been clearly defined based on the performance life of roadway structures by the GMA White Paper II (June 27, 2000). These definitions are as follows:

	**Separation**	prevention of sub-grade soil from intrusion into the aggregate base (or sub-base); prevention of the aggregate base's migration into the sub-grade
	**Filtration**	restriction of movement of soil particles, while allowing movement of water from filtered soil to coarser soil
	**Drainage**	transmission of water laterally within the plane of the geosynthetic
	**Reinforcement**	addition of structural or load-carrying capacity to a pavement system by transferring the load onto the geosynthetic material

<u>Separation</u>

In geotechnical engineering, separation can occur in two ways. One way is by the incorporation of an additional layer of soil; however, this means of separation can be very costly. The other more cost-efficient and effective way is by using a separation geotextile. Well-documented requirements for the separation of geotextiles at the sub-grade base-course interface include retention, permeability, and survivability. For proper retention, the separation geotextile must have an opening small enough to prevent sub-grade fine particles from migrating into the base course under the pressure of dynamic vehicle loads. Permeability warrants numerous openings with various sizes to be large enough to allow for the proper flow of liquid/air in an upward or downward direction. Survivability requires that the geotextile possess adequate strength and construction in order to survive installation and in-service conditions (GRI). Retention and permeability relate primarily to the geotextiles' opening size and distribution, while survivability focuses on strength and flexibility.

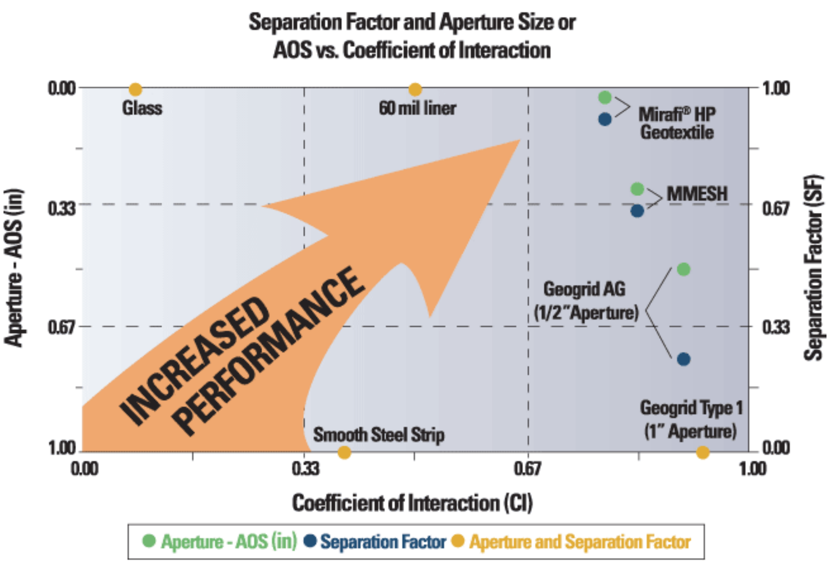
Quantifying Separation

Engineers have known for more than thirty years that separation was a key geosynthetic function; however, the problem with separation was that it could not be quantified. Thanks to the introduction of the Separation Factor (SF), engineers can now calculate a product's separation capability.

Definition of the 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 (MR) on top of a geosynthetic sieve to the total soil mass (MT). The Separation Factor can now be calculated by using the following equation:

SF = M R / M T

Once calculated, the Separation Factor is analyzed relative to other measurable indexes, primarily the coefficient of interaction (confinement) and AOS (filtration).



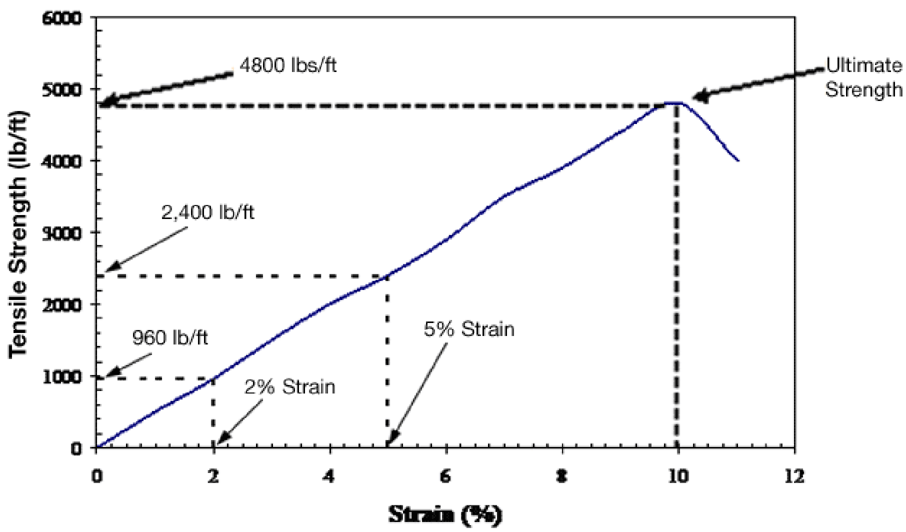
<u>**Reinforcement**</u>
Geosynthetic reinforcement can be defined in terms of the three categories: pavement system reinforcement, base reinforcement, and sub-grade restraint. Pavement system reinforcement involves the use of geosynthetic material to support traffic loads, whether they be vehicular loads over the life of the pavement or construction equipment loads on unpaved base or sub-base during road construction. Base or sub-base reinforcement involves using a geosynthetic material as a tensile strength element at the bottom of a base/sub-base or within a base course. This reinforcement material improves the service life of the pavement with vehicular traffic. It also allows for equal performance within a reduced structural section and aids in pavement surface deformation or rutting and asphalt-fatigue cracking. Sub-grade restraint involves placing a geosynthetic at the sub-grade/sub-base or sub-grade/sub-base interface. The function of the geosynthetic

material is to provide and to increase support to construction equipment over a weak/low sub-grade. Its primary means is to increase bearing capacity; however, lateral restraint and tension membranes may also add to load-carrying capacity. The reinforcing component of stabilization is sub-grade restraint, as recorded in the GMA-White Paper II (June 27, 2000).

Quantifying Reinforcement

Geosynthetic strength properties were once measured by textile-testing methods because the very first geosynthetic materials were textiles. Grab Tensile Strength (ASTM D-4632) is an example of a textile-testing method that was reported as a force in pounds or newtons. As the industry evolved and the requirements for more design-applicable data developed, engineers needed a way to measure strength in tensile stiffness; thus the wide-width tensile test (ASTM D-4595) was developed.

In solid mechanics, Young's modulus (E) measures the stiffness of a given material and reports the results in terms of force-per-cross-sectional area, pounds-per-square inch (psi) or kilonewtons- per-square meter (kN/m2). Geosynthetic modulus is defined as the ratio (for small strains) of the rate of change of stress with strain, such as the pound strength at a given elongation. The result is reported as force-per-width, such as lbs/foot width. A typical stress with strain curve is shown in Figure 1.



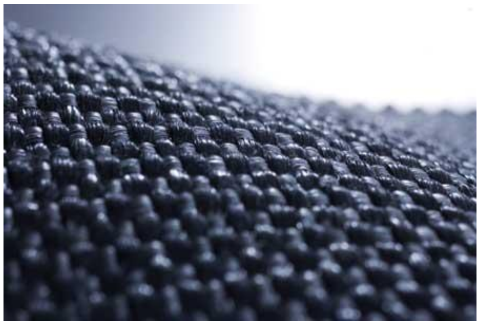
(Figure 1-Tensile Strength v. Strain)

When analyzing geosynthetic reinforced pavements, tensile forces are mobilized in the geosynthetic through deformation of the sub-grade. As these tensile forces develop, the amount of geosynthetic and sub-grade deformation is dependent on the modulus characteristics of the geosynthetic. To effectively minimize the depth of rutting within the aggregate, it is imperative that the proper geosynthetic material be used in order to achieve high-tensile strengths at low strains (higher modulus).

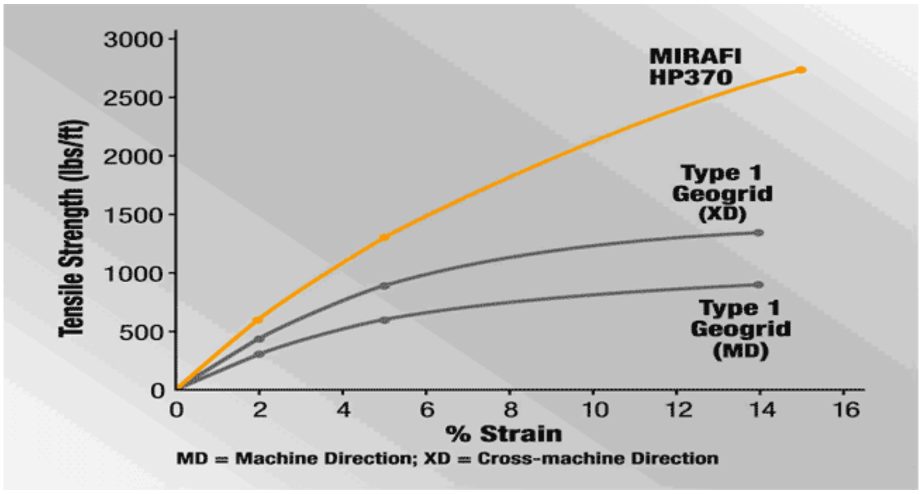
Having the Best of Both Worlds

In the past, the need for separation and reinforcement had been accomplished by using a geogrid (which provided reinforcement, but no separation) along with a non-woven geotextile (which provided separation, but no reinforcement). Geogrids are made from plastic sheets/strips or woven from high-tenacity yarns into an open grid with large apertures. Geogrids can be coated with polymers for added protection.

On the other hand, geotextiles consists of synthetic fibers (as opposed to natural fibers like cotton, wool, or silk) that are crafted into a flexible, porous textiles by standard weaving machinery, or matted together in a random, non-woven pattern, or knitted. Biodegradation is not a problem with synthetic fibers. The most important element of these synthetic geotextiles is that they are porous enough to allow water to flow across and within their manufactured plane, but to a widely varying degree.



Today, separation and reinforcement can be accomplished by using only one layer of a high-performance, polypropylene geotextile with an ultimate tensile strength greater than or equal to 35 kN/m (200 lbs/in) per ASTM D-4595, as seen in Figure 2. However, the key to performance lies in the tensile modulus, which provides strength at low strains. Geogrids and high-performance geotextiles both provide high strength at low-tensile strains. Unfortunately, geogrids do not provide the additional benefit of separation due to their construction.



(Figure 2-Tensile Strength v. % Strain)

The high-strength geotextile quickly mobilizes its strength and transfers it directly to the soil due to the high-tensile modulus values. Many different types of geotextiles meet the required 35 kN/m at ultimate to be classified as a high-performance geotextile; however, in critical strain levels approaching 6%, geosynthetics manufactured from high-modulus polypropylene yarns, such as **Mirafi® HP370** and **Mirafi® HP570**, yielded modulus strengths 50% to 250% higher than lightweight woven slit-film geotextiles. **Mirafi® HP370** and **Mirafi® HP570** also demonstrate excellent balance of high-tensile strength at low strains in both principle directions. While other hybrid geotextile products showed excellent stress-strain characteristics in the cross direction, these hybrids performed poorly in the machine direction due to the lack of high-modulus yarns in the machine direction, as well as, the nature of the weave used to construct them. Additionally, Mirafi® HP-Series geotextiles provide very good hydraulic properties, aiding in filtration and drainage.

In closing, **Mirafi® HP** high-performance geotextiles provide both high separation and reinforcement, as seen in the following chart.

Geosynthetic Selection Guidelines

Function/Product	HP570	BXG12	HP370	BXG11	HP270
Separation	Excellent	Poor	Excellent	Poor	Excellent
Reinforcement	Very High	Very High	High	High	Moderate
Water Flow Capacity	High	N / A	High	N / A	High
Survivability	Very High	Very High	High	High	Moderate

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