GEOSYNTHETIC REINFORCEMENT OF THE AGGREGATE BASE/SUBBASE COURSES OF PAVEMENT STRUCTURES

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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The Geosynthetic Materials Association (GMA) contracted independent consultants to prepare a *White Paper* (WP II) on the use of geosynthetic reinforcement of the aggregate base and sub base courses of pavement structures. This *White Paper* is a non-biased, industry-adopted document developed to support the efforts of the AASHTO 4E Task Group in its efforts to develop specifications for geosynthetic reinforcements in this application. Specific objectives of the *White Paper* are as follows:

- Define geosynthetic reinforcement applications in roads,
- Conduct a literature review on the use of geosynthetics in these referenced applications
- Define the value added to pavement structures by the use of reinforcement,
- Provide a recommended design practice, and
- Provide design and material specifications

The purpose of this Technical Note is to summarize each of these specific objectives of the *White Paper* as presented by the authors**,** with revisions and updates based on recent developments.

Definition of Applications

Pavement System Reinforcement -the use of a geosynthetic to aid in support of traffic loads. Traffic loads may be vehicular loads experienced over the life of the pavement or construction equipment loads on the unpaved base course or sub base imposed during construction.

Base (or Subbase) Reinforcement -the use of a geosynthetic as a tensile element at the bottom of a base (or sub base) or within a base course to:

1) improve the service life, and/or
2) obtain equivalent performance with a reduced structural section.

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 -the use of a geosynthetic at the subgrade/sub base or subgrade/base interface to increase the support of construction equipment over a weak or low strength subgrade. The primary result of this application is increased bearing capacity. Lateral restraint and/or tension membrane effects may also contribute to load-carrying capacity. Subgrade restraint is the reinforcing component of stabilization.

Demonstration of Value-Added to Pavement Structure

The following benefits of using geosynthetics in roadways are identified:

1. Reducing the intensity of stress on the subgrade (function: separation).

2. Preventing subgrade fines from pumping into the base (function: filtration).
3. Preventing contamination of the base materials allowing more open-graded, free-draining aggregates to be considered in the design (function: filtration).
4. Reducing the depth of excavation required for the removal of unsuitable subgrade materials (function: separation and reinforcement).
5. Reducing the thickness of aggregate required to stabilize the subgrade (function: separation and reinforcement).
6. Minimizing disturbance of the subgrade during construction (function: separation and reinforcement).
7. Assisting the increase in subgrade strength over time (function: filtration).
8. Minimizing the differential settlement of the roadway, which helps maintain pavement integrity and uniformity (function: reinforcement).
9. Minimizing maintenance and extending the life of the pavement (functions: all).

Benefit, or value-added, is expressed in terms of "life extension" or "savings in base course thickness". Extension of life is defined in terms of a Traffic Benefit Ratio (TBR). TBR is defined as the ratio of the number of cycles necessary to reach a given rut depth for a test section containing reinforcement to the number of cycles necessary to reach this same rut depth for an unreinforced section with the same section thickness and subgrade properties. The base course reduction (BCR) is expressed as a percentage savings of the unreinforced base thickness.

The results of laboratory and field test sections have been found to vary substantially. There are many variables that may affect the performance results of a particular test such as geosynthetic type and properties, subgrade strength, loading conditions, base course thickness and properties. A summary of results from laboratory and field test sections is provided in Table 1.

Table 1. Summary of laboratory and field test sections

	TBR	BCR
Geotextiles: Range Typical Values	 1 - 220 1.5 - 10	22 - 33%
Geogrids: Range Typical Values	 0.8 – 670 1.5 - 70	30 - 50%
Geogrid/Geotextile Composite: Range Typical Values	 * *	 * *

* Insufficient data to provide range or typical values
Other important findings from laboratory and/or field studies include the following:

1) Several studies indicated an optimum benefit when the geosynthetic was placed at the bottom of a 200-300 mm thick base layer.
2) For thicker base sections, the most beneficial reinforcement location appeared to be in the middle of the base, where geogrids were found to perform best.
3) For thin bases (less than 200 mm), lack of separation was noted as a potential problem for geogrids. Geotextiles or GG-GT composites tend to perform better for the thin bases, especially where subgrade strengths were below a CBR of 3.
4) Reinforcement benefits were observed with subgrade strengths up to a CBR of 8. In at least one study, some benefit was found at even greater subgrade strengths. However, there does appear to be a relation of decreasing reinforcement benefits with increasing subgrade strength.

Recommended Design Practice

***Base Reinforcement*.** The mechanisms of geosynthetic base reinforcement are not fully understood. Therefore, performance of geosynthetics in base reinforcement applications must be determined by product-specific testing. Laboratory and/or field tests with specific products, similar pavement materials and cross-sections, and similar subgrade conditions are required to quantify the contribution of the geosynthetic reinforcement to the pavement performance. Design procedures incorporate the results of product-specific testing and use a traffic benefit ratio (TBR), base course reduction (BCR) percentage, or layer coefficient ratio (LCR) value.

Base reinforcement design includes the following steps: 1) assess applicability, 2) perform an unreinforced design, 3) select the target benefit in terms of service life improvement and/or reduced structural section, 4) evaluate the benefit offered by various geosynthetics in terms of TBR, BCR, or LCR, 5) perform base course reinforcement design, 6) perform life-cycle cost analysis.

Subgrade Restraint. Design procedures for subgrade restraint/stabilization are well documented in technical literature and include Barenberg (1980); Steward et al. (1977); Giroud and Noiray (1982); and FHWA (Christopher and Holtz, 1985; Holtz et al., 1998). Subgrade restraint design is essentially the same as stabilization design, except that a reinforcement modulus value may be required in addition to the properties of interest in stabilization, which are related to filtration and survivability.

For some projects, particularly those with a base and sub base, two layers of geosynthetic reinforcement may be used to provide both subgrade restraint and base reinforcement. Each layer of reinforcement may be independently designed for such applications.

Material Properties

The manner in which geosynthetic material properties affect reinforcement benefit, defined by TBR, BCR, and LCR, are not fully understood at this time. Therefore, TBR, BCR, and LCR values must be developed by product-specific testing in each unique environment. While the ratio coefficients are considered to be product-specific for base and sub base reinforcement applications, the following properties are considered to influence performance: tensile strength at 1%, 2% and 5% strain, coefficients of pullout and direct shear, aperture size (grids), and percent open area (geotextiles). More recent tests indicate a possible correlation between aggregate confinement and performance. Junction strength is viewed as an index property specific to the manufacture method of products. Research has not conclusively demonstrated the affect, if any, of stiffness properties including flexural rigidity and aperture stability on geosynthetic performance. For subgrade restraint applications, the properties of tensile strength at 2% and 5% strain are primarily related to geosynthetic performance.

Mirafi® Construction Products -Position Statement

Mirafi® Construction Products(Mirafi® CP) offers the widest range of products available in the geosynthetic market. Therefore, without bias toward any particular product, Mirafi® CP proposes the use of specific products for the appropriate application with the ultimate objective of maximizing performance.

There are three general applications for the use of geosynthetic reinforcement in pavements. Mirafi® CP offers the following guidance for these three distinct applications:

1. *Weak Subgrade (CBR < 3).* When a weak subgrade exists, a Mirafi® **HP-Series**, high-performance, woven geotextile should be placed at the subgrade interface. In addition, if the required base course section is greater than 250 mm (10 in), a second layer of reinforcement, a rigid, biaxial geogrid, the **BasXgrid®** series, should be placed in the middle of the base course section. Figure 1 illustrates the application of Mirafi® CP products when weak subgrade conditions exist.

Figure 1. Application of Mirafi® Products in Weak Subgrade Conditions

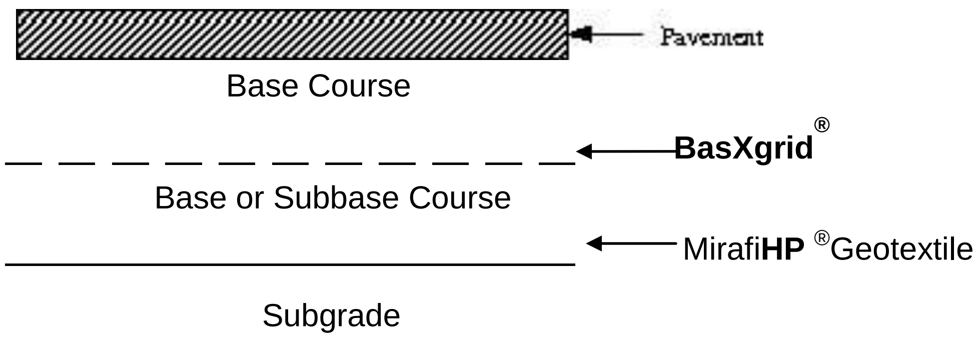
(a). Weak Subgrade, Base Course Section ≤ 250 mm

Base Course

Mirafi ®**HP**Geotextile

Subgrade

(b).Weak Subgrade, Base Course Section > 250 mm

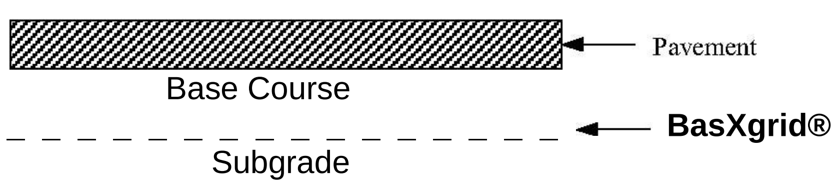


2. *Firm Subgrade (CBR > 3), Thin (≤ 250 mm) Base Sections.* When a firm subgrade and relatively thin base course section is designed, Mirafi® CP suggests placing a rigid, biaxial geogrid, the **BasXgrid®** series, at the subgrade interface. Figure 2a illustrates the application of Mirafi® CP products for this condition.

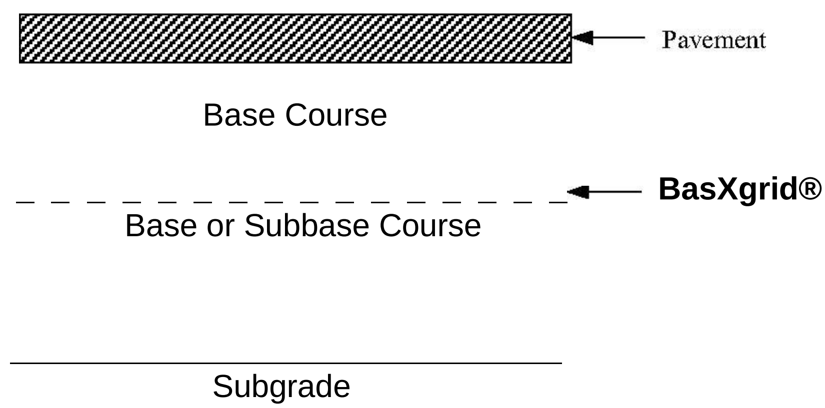
3. *Firm Subgrade (CBR > 3), Thick (> 250 mm) Base Sections.* When a firm subgrade and relatively thick base course section is designed, Mirafi® CP suggests placing a rigid, biaxial geogrid, the **BasXgrid®** series, in the middle of the base course section. Figure 2b illustrates the application of Mirafi® CP products for this condition.

Figure 2. Application of Mirafi® CP Products in Firm Subgrade Conditions Mirafi® Construction Products' Specifications

(a). Firm Subgrade, Base Course Section ≤ 250 mm



(b). Firm Subgrade, Base Course Section > 250 mm



Mirafi® Construction Products offers standard CSI format specifications for Base.

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