

Flexible Pavement Design using TenCate Mirafi[®] Geosynthetics

Prepared by:

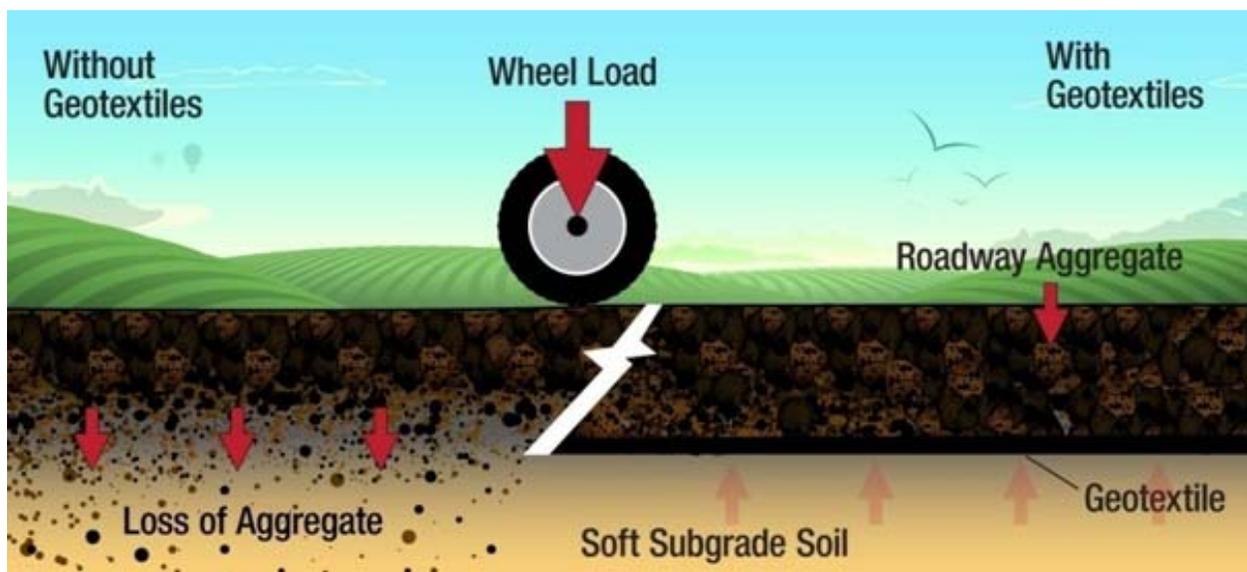
TenCate Geosynthetics North America
365 South Holland Drive
Pendergrass, GA 30567
Tel. (706) 693 – 2226
Fax (706) 693 – 2044
www.Mirafi.com

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TenCate Mirafi® geosynthetics have been designed into flexible pavement systems since the early 1980's¹, and into other roadway applications since the 1970's². The reasons that geosynthetics are used in roadway design are simple and compelling: to reduce construction time; to reduce construction materials; to reduce construction costs; and to increase the usable life of the roadway. The benefits that geosynthetics provide in road construction are well-documented. The United States Department of Transportation Federal Highway Administration offers their appreciation of the benefits of geosynthetics in roadways: "Geosynthetics have been found to provide significant improvement in pavement construction and performance..." The most common of all uses of geosynthetics is in road and pavement construction. Geotextiles placed on the subgrade increase stability and improve performance of pavements constructed on high fines subgrade soils (i.e., soils containing high quantities of silt and/or clay fractions) during construction..."³

One of the primary functions that geosynthetics used in road construction provide is tensile stress relief at the bottom of the base course layer and across the top of the subgrade surface. Without using geosynthetics, these tensile stresses will cause tension cracks to develop in the bottom of the base course. Due to dynamic traffic loads these cracks allow fines from the subgrade to migrate upward into the base course layer while base course aggregate simultaneously migrates downward into the subgrade. The net effect of all this particle movement is to reduce the strength and overall thickness of the base course due to fines contamination from the bottom-up. Strength loss in the base course progresses as the number of cracks, and the width and depth of the cracks increase over the life of the roadway. This beneficial tensile stress relief can be accomplished using geotextiles and geogrids with high tensile modulus values at low strains (i.e. 1%, 2%) and high frictional capacities.



The addition of a geosynthetic as a reinforcement layer within a flexible pavement section allows the pavement to take on a larger load carrying capacity without increased surface deformation. Geosynthetics reinforce the pavement section through: lateral restraint; increased bearing capacity; and tensile membrane support. Utilizing a geosynthetic under the aggregate base layer of a pavement section increases the stability of the layer. This attribute is commonly called lateral restraint and results in reducing the shear stresses and strains on the underlying subgrade. The overall bearing capacity of a flexible pavement system can be increased by the tensile capacity of a reinforcement geosynthetic forcing the potential shear failure zones to develop along higher shear strength failure surfaces. Geosynthetics can also reinforce a flexible pavement section through tensile membrane support over very soft subgrade soils. To perform this function, the weight of the pavement layer thickness must anchor the geosynthetic along the perimeter, outside of the trafficked area. The cross-machine direction tensile strength of the geosynthetic at low strain, combined with high interface friction, allows for support of wheel loads through a trampoline effect.

A primary function of geotextiles used in roadway construction is the separation between dissimilar construction materials. Using nonwoven and high permittivity woven geotextiles also offers a filtration and drainage benefit that is part of the separation function. High permittivity geotextiles allow water to pass while filtering out fine subgrade soil particles from penetrating into the base course layer, thereby keeping the integrity of the base course intact throughout the service life of the pavement. The filtration-drainage function is vital to the performance of geosynthetics in road construction as any pore water pressure that develops in the subgrade must be dissipated quickly. Without a geosynthetic to offer filtration-drainage, the shear strength and bearing capacity of the subgrade soil can be exceeded. Only high permittivity geotextiles ($> 0.2 \text{ s}^{-1}$) should be used on subgrade soils that contain a significant amount of fines ($> 15\%$), are wet or will possibly become saturated at some point in the roadway's life-cycle. While nonwoven geotextiles can provide separation and filtration-drainage functions, their low tensile moduli can allow excessive surface deformations that are not appropriate for flexible pavements, unless they are used in combination with a biaxial geogrid. For this reason, Mirafi[®] RS/-Series and H₂R/ geotextiles are the preferred geosynthetic solution to use for flexible pavement design and construction on low California Bearing Ratio (CBR) strength subgrade soils. They offer ideal tensile modulus values at low tensile strain levels, exceeding biaxial and multi-axial geogrids, and the filtration-drainage benefit of high permittivity geotextiles. A side-effect of these benefits is an enhanced drainage coefficient for the aggregate layer placed over the geotextile³.

The strength of the subgrade soils along the roadway also have a significant impact on the level of tensile stress relief and pore pressure dissipation that a geosynthetic can provide to the roadway. The softer the subgrade soil, the more tensile strength is mobilized in the geosynthetic and the larger the volume of excess pore water that will be removed from the roadway over its lifetime^{5,6,7}. Geogrids are not generally considered adequate for separation applications due to the large size of the geogrid apertures. Geogrids should not be used in soft soil conditions without also using a filtration geotextile. If a geogrid is to be used over subgrade soils with a CBR less than 3, an AASHTO Class 2 nonwoven separator (Mirafi[®] 160N) should be placed underneath the geogrid to provide the needed separation-drainage function. Very soft subgrades (CBR $< 1\%$) will require a stronger nonwoven geotextile.

The level of tensile and separation benefit from the geosynthetics used in roadway design and construction can vary from product to product. Table 1, below, shows this benefit in the form of an estimated base course reduction percentage of unreinforced vs. reinforced aggregate base thickness for several Mirafi® RS*i*-Series and H₂R*i* geotextiles.

Table 1: Estimated Base Course Thickness Reduction Using Mirafi® RS*i*-Series and H₂R*i* Woven Geotextiles.

Subgrade Strength CBR (%)	Estimated Base Course Reduction (Percent) Resulting from Including Mirafi® Geosynthetics below the Base Course: ¹		
	H ₂ R <i>i</i> ²	RS580 <i>i</i> ²	RS380 <i>i</i> ²
15.0	26%	24%	20%
10.0	31%	29%	26%
5.0	40%	39%	34%
2.5	46%	45%	40%
1.0	57%	56%	51%

Notes: ¹ Estimates are for low plasticity subgrade soil; single asphalt and single base course layers; and ESAL's < 1,500,000. ² Recommended minimum base course thickness not less than 6" for RS*i*-Series and H₂R*i*.

Standard practice recommends that the laboratory CBR (ASTM D1883) strength measurement should be used to quantify a subgrade soil's strength, but practices vary state to state. This CBR value is not a field strength measurement, but rather the laboratory tested soaked CBR strength of the soil. The CBR samples should be taken at multiple locations along the roadway, with the lowest strength value governing the roadway design.

Flexible pavement designs can be accomplished using different design methods, although the many editions of the American Association of State Highway and Transportation Officials (AASHTO) design method⁴ are the most used and accepted in the United States. In the AASHTO flexible pavement design process, traffic loads, frequency, direction, truck load factors, subgrade strength, reliability level, pavement deterioration, pavement system layer materials, material thickness, drainage capacities, and structural contribution are all considered in the analysis. The focus of the analysis is to determine the required structural number (SN) value for the project to support the anticipated level of traffic. The SN is calculated by multiplying the individual layer thickness (D), by structural coefficients (a), and drainage coefficients (m) for each material layer. The value for each layer is then summed to get an overall SN for the flexible pavement cross section. An example SN calculation for "n" number of pavement system layers is as follows:

$$SN = a_1 \times D_1 + a_2 \times D_2 \times m_2 + \dots + a_n \times D_n \times m_n$$

The benefit that a geosynthetic will provide to the roadway is accounted for easily in the SN calculation by incorporating a geosynthetic structural coefficient (GSC)⁸ into the calculations. In the US, a roadway geosynthetic is usually placed on the subgrade surface,

so the structural benefit is typically applied to the base or subbase course layers placed and compacted on the geosynthetic. However, recent studies¹⁰ have shown that the pavement system as a whole benefits from incorporating Mirafi RSi-Series geotextiles into the cross section. Other pavement layers (i.e. asphalt surface and base layers) receive a benefit similar to the pavement layer constructed directly on the geosynthetic. The SN calculation for a two-layered flexible pavement to be constructed on a geosynthetic using an aggregate base course layer and an asphalt surface layer is as follows:

$$SN_G = a_1 \times D_1 + a_2 \times D_2 \times m_2 \times GSC$$

Below is an example design calculation that provides an analysis for the calculated savings in the amount of aggregate needed and related cost savings for a typical pavement section over soft subgrade soils, and designed using Mirafi[®] RS580i.

Example Analysis:

A pavement section requiring a SN of 5.0 is to be constructed on a soft subgrade with a CBR value of 1.0. The maximum hot mix asphalt (HMA) thickness is 4.5 inches, including both surface and base courses. Total traffic over the design life of the pavement is 1,120,000 ESAL's.

Calculate the cost savings per lane mile that results from using Mirafi[®] RS580i in the pavement section, below the aggregate base course.

Given:

HMA surface structural coefficient (a_1) = 0.43

HMA surface thickness (D_1) = 1.0 inches

HMA base structural coefficient (a_2) = 0.38

HMA base thickness (D_2) = 3.0 inches

Aggregate base course structural coefficient (a_3) = 0.14

Aggregate base course gradation contains 10% fines (10% passing the No. 200 Sieve)

Aggregate base course drainage coefficient without geotextile (m_2) = 0.90

Subgrade CBR = 1.0%

Subgrade soil is low elasticity sandy silt sand with some mica (ML)

Total ESAL's = 1,120,000

Solution:

1. Calculate the base course aggregate thickness required to achieve a SN of 5.0 without a geosynthetic, using AASHTO SN calculations:

$$SN = 5.0 = a_1 \times D_1 + a_2 \times D_2 + a_3 \times D_3 \times m_3$$

$$5.0 = 0.43 \times 1.0" + 0.38 \times 3.0 + 0.14 \times D_3 \times 0.90$$

$$D_3 = 27.22"$$

$$\text{Actual SN} = 0.43 \times 1.0" + 0.38 \times 3.0" + 0.14 \times 27.22" \times 0.90 = 5.0$$

27.25" of aggregate is required **without** a geosynthetic.

2. Calculate the aggregate thickness required to achieve the same SN with Mirafi® RS580i, using the same AASHTO SN calculations:

The GSC for RS580i for the project subgrade CBR and traffic condition is 2.286

$$SN = 5.0 = 0.43 \times 1.0" + 0.38 \times 3.0" + 0.14 \times D_{3R} \times 0.90 \times 2.286$$

$$\text{Solving for } D_{3R}: D_{3R} = 11.91"$$

Only 12.0" of aggregate is required **with Mirafi® RS580i**.

Savings

The aggregate base course thickness can be reduced by approximately 15.25" using Mirafi® RS580i. If aggregate cost \$30/ton, just the aggregate material cost savings alone would be approximately \$163,000 per lane mile (12 ft wide lane, 5,280 ft/mile, 135 lb/ft³ density).

Conclusion

The example above shows only the aggregate material cost savings that can be realized by using a Mirafi® RS580i geotextile in a flexible pavement. Other benefits of Mirafi® RSi and HP-Series geotextiles are construction cost savings in undercut, hauling and labor costs, as well as shortened construction schedules. Long-term savings are realized through increased pavement life and a reduction in maintenance and rehabilitation costs. Sometimes the use of a Mirafi® RSi or H₂Ri geotextiles makes an otherwise impossible project become feasible.

Visit the "Tech Info" section of our website, www.Mirafi.com, for case studies, installation guidelines, technical data sheets and design guidelines for other civil and geotechnical engineering applications.

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