EB125 PERMANENT ROAD FOUNDATION

BACKGROUND

Worldwide, the use of geosynthetics for the enhancement of transportation infrastructure is dominated by nonwoven geotextiles. When geotextiles were introduced in the United States, there was a strong push for the use of woven, slit film geotextiles, stemming from carpet backing and other woven industries. The result was the establishment of AASHTO M 288, a national guideline specification for geotextiles in transportation applications. M 288 was a compromise to allow both woven and nonwoven geotextiles. AASHTO M 288, Table 1, does recognize the superior durability of nonwovens by requiring much higher strength in wovens to perform on par with lower strength nonwovens.

Class 1		Class 2		Class 3	
Elongation		Elongation		Elongation	
woven	nonwoven	woven	nonwoven	woven	nonwoven
<50%	≥50%	<50%	≥50%	<50%	≥50%
315 lbs	203 lbs	248 lbs	158 lbs	180 lbs	113 lbs
55% more strength required	‘—	57% more strength required	‘—	59% more strength required	‘—

From Table 1 - AASHTO M288-17 geotextile grab strength requirements– ASTM D4632

There are many reasons why nonwoven geotextiles perform better and should be the geosynthetic of choice for most flexible and rigid pavement applications. This document addresses the features, advantages and benefits of using nonwoven geotextiles compared to woven geotextiles or geogrids.

Though all geosynthetics stabilize roads through confinement, restraint and reinforcement, the most important function is separation. Stabilization can add 20 to 30% structural benefit to a road, but up to 50% structural strength is often lost due to the subgrade contamination of aggregate bases. As little as 15% fines contamination in an aggregate base layer can cut its bearing capacity by 50% (Jorenby and Hicks), and only 8% fines can clog the permeability of the aggregate layer leading to base saturation and total loss of strength due to pore pressure build up (Cedergren). Many DOTs think they are minimizing base contamination by using a tight, well-graded aggregate base, but these bases are still progressively contaminated, especially in the presence of moisture (Al Qadi). The strength of these tight bases must also be discounted, per AASHTO '93 pavement design, due to their inability to rapidly drain.

Figure 1 - Subgrade pumping

Figure 2 - Total loss of aggregate base due to contamination

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In a road, the ideal placement of the geosynthetic is at the subgrade soil/base aggregate interface. Using the proper geosynthetic and a competent base aggregate, engineers can create a Permanent Road Foundation (PRF) (aka Perpetual Aggregate Base (PAB)). This eliminates the need for full depth reclamation/reconstruction by indefinitely preserving the road foundation so that only surficial repairs will ever be necessary. Separation, is the key to pavement longevity using any design methodology, including AASHTO's AASHTOWareME Mechanistic Empirical Pavement Design Guide (MEPDG) and 1993 Guide for Design of Pavement Structures.

Nonwovens in this document refer to needle-punched nonwoven geotextiles. The following paragraphs describe why nonwovens offer the greatest performance and the most cost effective solution for transportation infrastructure.

HYDRAULIC AND SOIL RETENTION ADVANTAGES

Effects of moisture, freeze thaw and base course contamination degrade the stiffness and strength of the base layer. Premature pavement failure can occur from excess subgrade rutting and pumping, aggregate contamination or degradation, loss of fines, poor drainage, frost action and swelling soils. (FHWA Geotechnical Aspects of Pavements Reference Manual).

To address these pavement challenges, the ideal geosynthetic is placed between the subgrade and base course layer to provide the dual functions of separation/stabilization. The geosynthetic should be durable, an excellent filter, highly permeable, and structurally compatible with the adjacent layers.

FILTRATION

The structure of a needle-punched nonwoven geotextile is comprised of a myriad of fine fibers, needle-punched into a tight, strong, stable fabric structure. This 3-D structure easily allows the passage of significant amounts of air or water while providing a uniform, fibrous matrix with fine pore spaces to restrict the passage of soil particles. There has been a significant amount of separation research conducted, simulating the pumping action under pavements and demonstrating the superiority of needle-punched nonwoven geotextiles in keeping subgrade soil fines out of the aggregate base. Nonwovens protect against the widest variety of soils, particularly in the presence of moisture.

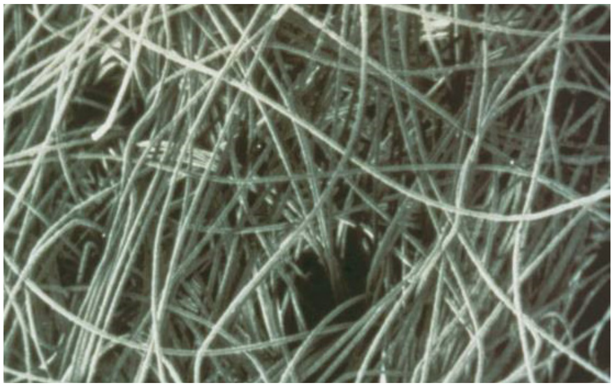

Figure 3 - Nonwoven structure

Geogrids, with their large apertures, cannot separate and prevent the contamination of the aggregate base layer. If a geogrid is to be chosen for enhancing the aggregate base course, the aperture needs to be at least 1.2 times the maximum size of the aggregate of the base course (NCHRP 01-50). The photos below clearly show that geogrids offer no benefit to prevent contamination of base course layers.

Figure 4 - Geogrid aperture size

Figure 5 - Geogrid aperture size

Geogrids should never be used at the subgrade/base interface without an accompanying nonwoven geotextile placed underneath. There are claims that for some cases of soil and aggregate gradations, a well graded aggregate base can function as a separator layer. This is based on soil piping equations. However, these equations were developed for graded granular filters, for one-way flow, for drainage systems; and do not apply to the hydraulic pumping of fines at the subgrade/base interface. Failed road exhumations show how fines have worked their way up through geogrids into tight well-graded aggregate bases.

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Slit film woven geotextiles are not permitted in drainage and filtration applications per AASHTO M 288 and should not be selected as a base course separator. Note that although there are specialized woven geotextiles that utilize monofilament yarns in their construction to enhance permittivity, those geotextiles are considerably more costly than an equivalent M288, >50% elongation, nonwoven separators. Woven geotextiles are not as good of a separator as nonwovens since, under strain, the woven strands tend neck down, creating larger openings for fines intrusion. Nonwoven filtration tightens under strain.

WATER FLOW RATE

Nonwoven geotextiles have the highest permittivity and water flow rate, up to 25 times the flow rate of woven geotextile

Fabric Structure	Nonwoven					Woven		
Product Name	401	601	801	1001	1201	250ST	350ST	Unit
Permittivity	1.7	1.5	1.4	1.25	1.0	0.1	035	1 Sec^{-1}
Water Flow Rate	140	110	100	80	75	6.37	30	gpm/sf

Table 2 - Comparison of AASHTO M288 geotextiles

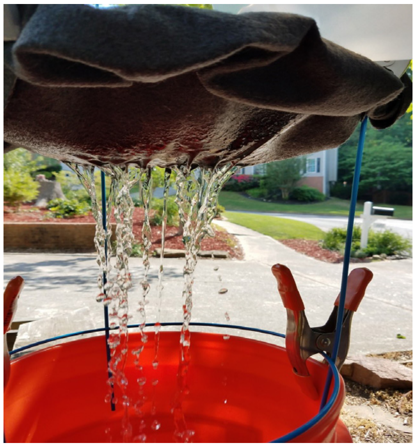

Figure 6 - class 1 nonwoven Figure 7 - class 1 woven

In service, wovens experience clogging of some of their limited pores and their low permittivity is further decreased. The use of woven geotextiles, especially slit film woven geotextiles, can impact system performance by creating a barrier to water flow. The result is base saturation, causing localized pore water pressure build up. The excess moisture weakens the interface friction of the base and/or subgrade resulting in harmful movement of the base aggregate over the geosynthetic. Transportation structures enhanced with a nonwoven geotextile will never be negatively impacted by the impedance of water trying to flow through the system.

HIGH LATERAL TRANSMISSIVITY— PORE PRESSURE RELIEF OF BASE COURSE

Nonwoven geotextiles have high porosity and the ability to transmit high volumes of water laterally, within the plane of the geotextile. This lateral flow is proportional to the normal load on the geotextile, but even at high normal loads, like 200 kPa (29 psi), the confined nonwoven retains significant lateral water transmission capabilities. This important lateral drainage function, not possible within a woven geotextile or a geogrid, is easily employed beneath pavement structures when the nonwoven geotextile is allowed an exit point for water to drain. Day-lighting the nonwoven at the shoulder of the road, tying it into an edge drain or tying to a drainable layer in the shoulder are three methods to achieve lateral drainage. This ability to rapidly evacuate water can relieve pore pressure that would otherwise build up in subgrade or aggregate bases under truck traffic loading. Damaging pore pressure can override the bearing capacity of these support layers, leading to premature pavement failure. Particularly beneath poorly draining aggregate layers and especially in non-arid climates, a nonwoven with weight of 8 to 12 oz/sy should be used to prevent pore water pressure build up and to laterally transmit water out of the pavement section. “Added moisture in unbound aggregate base and subbase is anticipated to result in a loss of stiffness on the order of 50% or more…..Saturated fine-grain roadbed soil could experience modulus reductions of more than 50%.” (FHWA Geotechnical Aspects of Pavements Reference Manual). “Road base saturation even 10% of the time can reduce pavement life by 50%.” (Cedergren, 1987).

In interlayer trials at the University of Minnesota, the resiliency of a nonwoven with 14 oz/sy weight was found to perform like a pump under repeated truck traffic loading, rapidly evacuating water from of the pavement structure (Drainage Capabilities of a Nonwoven Fabric Interlayer in an Unbonded Concrete Overlay, Lederle, Hoegh, Burnham, Khazanovich, TRB 2013).

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ABILITY TO WICK WATER

Along with the ability to laterally transmit water driven by gravity or pore pressure, nonwovens have the ability to wick water and to passively transmit water away from transportation structures. The presence of water can weaken the structure, lubricate failure planes, and can cause problems such as frost heave in cold climates. Woven geotextiles with special wicking yarns placed in the transverse roll direction can wick minor amounts of water, but nonwovens have the ability to wick more water to greater distances to better evacuate damaging pore water.

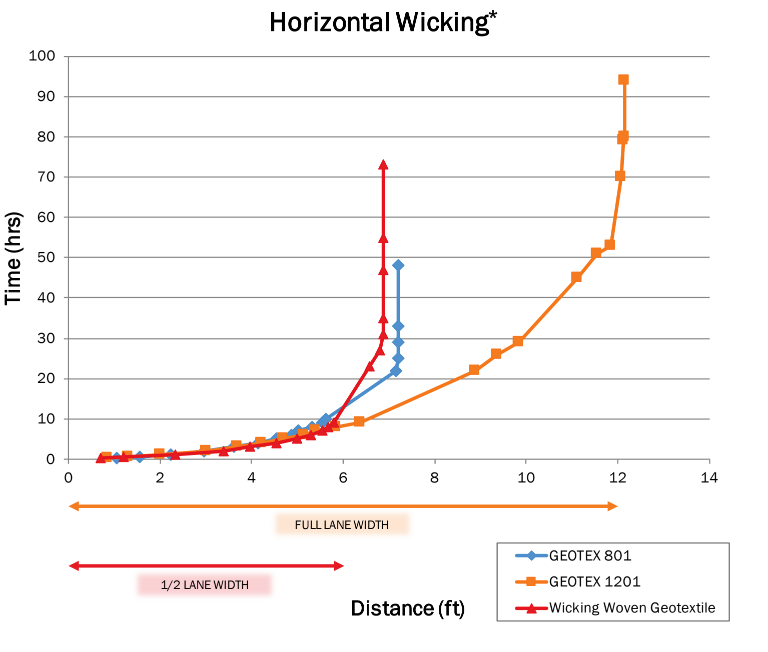

Figure 8 - geotextile horizontal wicking - distance vs time – Testing based on ASTM C1559

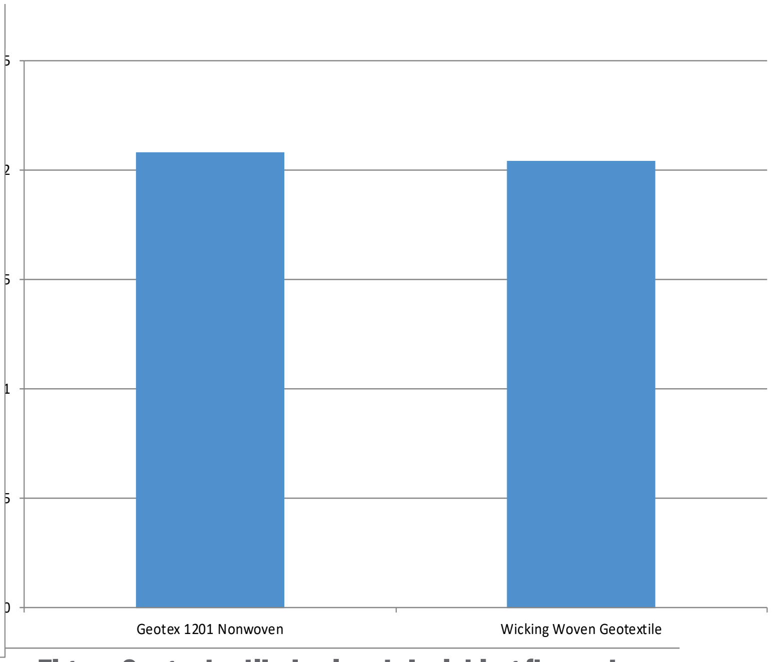

Figure 9 - geotextile horizontal wicking flow rate: test based on ASTM C1559

CAPILLARY BREAK

Heavyweight nonwoven geotextiles can provide a capillary break to stop ground water, which can rise in fine grained soils through the process of soil suction. If this rising pore water moves into the shallow earth frost zones in cold climates, damaging ice lenses and frost heave of roads can develop. Again, in this application, some wicking and lateral flow may occur within the geotextile, so the water needs a way to exit laterally out of the roads.

"In reality, capillary effects and the absence of a driving head of water often cause dense graded base to act like a sponge at low hydraulic gradients. This results in trapped water in the pavement section and "very poor" drainage." (FHWA Geotechnical Aspects of Pavements Reference Manual).

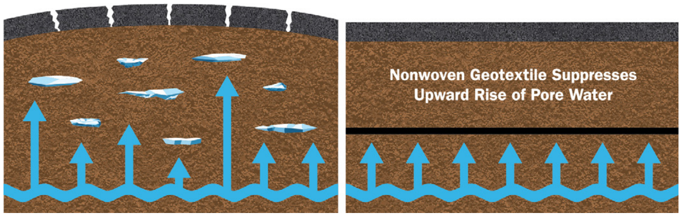

Figure 10 - Function of a capillary break

STRENGTH, FLEXIBILITY & SURFACE INTERACTION ADVANTAGES OF NONWOVENS

The most important structural benefit afforded by a geosynthetic placed at the subgrade soil/aggregate base interface is its frictional confinement of the base aggregate. Geotextile strength is not a critical property for performance unless an extremely soft subgrade soil is encountered. The interface friction properties of geogrids, and woven and nonwoven geotextiles were tested in real road simulation direct shear testing, by ASTM D 5321. The results are shown on the following graph.

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As may be seen, both the geogrids **and** the nonwoven geotextile have frictional properties in line with the internal friction angle of typical base course aggregates. This means you are not introducing a slip plane into the road support system and the aggregate is confined by the geosynthetics. Even higher-friction woven geotextiles with a coarse surface texture achieved only about 70% interface efficiency. Woven geotextiles cannot effectively translate their strength to the system and resist lateral displacement of the aggregate, since the weakest link is the slip plane it produces. An important component of the nonwoven interface friction is how, when compacted, the bottom aggregate typically seats into the geotextile and the subgrade soil, as an interlocking surface formed to the bottom of the aggregate layer. When the layered system is damp or wet, the nonwoven frictional advantage is increased.

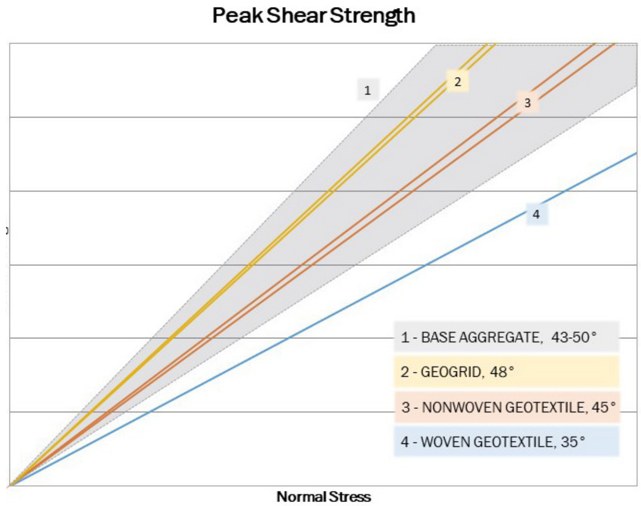

Figure 11 - Geosynthetic interface friction relative to road base aggregate

The application of a separation/stabilization geotextile beneath an unpaved road must use a nonwoven for the appropriate friction to help hold the unbound surface aggregate in place. Unpaved roads have higher shear stress since the aggregate layer is not confined by a pavement surface. It is important that the geosynthetic lock into the base course and subgrade and not create a failure shear plane.

Laboratory, open air, index strength testing of nonwoven geotextiles grossly underestimates their confined, in-service strength. The way the nonwoven geotextiles are constructed, any confinement resists their tensile failure mode, which is the unraveling of the fibers, not breaking of the fibers. When confined, simulating in-service conditions, needle-punched nonwovens exhibit a dramatic increase in their tensile strength, with lower strain, and a higher modulus.

Increases in stiffness of nonwoven geotextiles under soil confinement have been reported by McGown, Holtz, et al. (1982), Palmeira et al. (1996)and Yuan et al. (1998) showing that the stiffness of a needle-punched nonwoven polypropylene geotextile increases up to 300% under a confining pressure simulating in-service loading. Woven geotextiles and geogrids exhibit the same tensile strength properties whether they are confined in service or tested open in the laboratory.

BEST CONSTRUCTION SURVIVABILITY.

Needle-punched nonwovens are strong yet they have the ability to locally elongate, when necessary, to avoid puncture and tearing. The local elongation of nonwovens also helps them conform to the bottom of the aggregate layer as the bottom stones seat into the subgrade soil—for excellent aggregate lock up and confinement.

This makes them more appropriate for placement over severe subgrade conditions, with little surface preparation. Woven geotextiles and geogrids have fixed low elongation strands which are susceptible to rupture and zipper type tearing over sharp objects or under excess traffic induced strain. Nonwovens are also much more resistant to abrasion. For durability, railroads use a heavy nonwoven beneath new railroad ballast stone, which is usually placed over some existing stone. Nonwovens are also recommended beneath large riprap stone due to their resistance to damage. Toughness measures both the strength and the ability to strain without rupture.

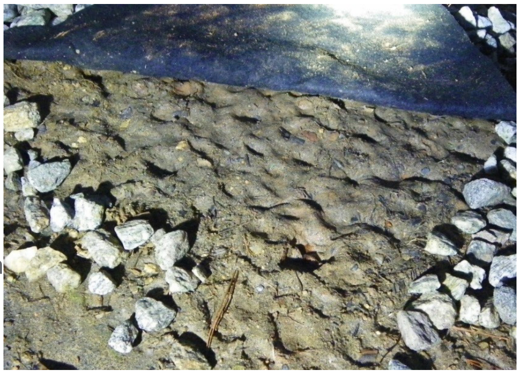

Figure 12 - Rock interlock on subgrade - excellent aggregate confinement with nonwovens

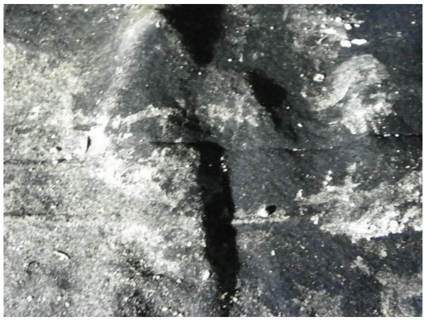

Figure 13 - Nonwoven durability over rock

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A 10 oz/sy nonwoven can survive better than even a high strength woven geotextile and should be considered as a superior alternative for AASHTO M 288 Class 1A "Enhancement" applications.

Figure 14 - Woven tearing over rock

COST RELATED ADVANTAGES

1. The Most Cost Effective Geosynthetic

Considering the versatile functions that nonwoven geotextiles provide, they are the most cost effective geosynthetic product. This is why most of the world and the many State DOTs prefer to specify nonwoven geotextiles. If they specify a woven geotextile, it must be a far more expensive woven with specialized yarns and weave patterns to try and match some of the hydraulic properties of nonwovens. Still, the wovens cannot match the durability, friction and the physical property advantages of nonwovens, discussed above. The AASHTO M288 Class 1 >50% elongation, nonwoven, Geotex 801 had the most cost-effective performance out of 14 more expensive geosynthetics tested in the recent highly monitored in-road research at the Western Transportation Institute.(Relative Operational Performance of Geosynthetics Used as Subgrade Stabilization FHWA MT-14-002/7712-251).

Nonwoven geotextiles used in roadway separation/stabilization generally cost less than one inch of base course aggregate costs.

Figure 15 - Nonwoven deployed on subgrade

2. Allowing More Effective Base Aggregate Usage

Many DOTs have turned to using a tight, well-graded aggregate base, such as crusher run, in an attempt to slow subgrade soil intrusion. The intrusion is not stopped using this approach. The tight base aggregate has very low permeability leading to reduced bearing capacity when the aggregate base is saturated. The use of a nonwoven geotextile for separation and filtration allows the use of a more open graded, free-draining aggregate base. According to AASHTO '93 Pavement Design, aggregate base with good drainage properties can provide up to double the strength per inch thickness as a poorly draining aggregate base.

3. Long-Term Aggregate Base & Subbase Preservation

The durability and hydraulic properties of nonwoven geotextiles make them the most appropriate choice for long-term preservation of the aggregate base and subbase courses. Polypropylene geotextiles up to 40 years in service have been exhumed and tested showing nearly their original properties. This preservation of the aggregate base and subbase as a Permanent Road Foundation (PRF) can prevent the need for full depth reclamation reconstruction. The benefit is that only surficial pavement treatments such as seal coats or overlays will ever be necessary. Without the need for reconstruction and road downtime and construction related accidents and deaths are minimized.

Nonwoven geotextiles may also be justified as a design safety factor, ensuring that the original design thickness of the pavement support layers is maintained throughout the life of the pavement. As an inexpensive safety factor, the nonwoven geotextile can compensate for an area of weak subgrade soil or an area of the road that experiences excess moisture in service. The nonwoven geotextile is a much more cost-effective solution than the recommended use of additional subbase or sacrificial stone as a safety factor.

4. Transportation Asset Management

DOTs must carefully manage their infrastructure assets to maximize their service life and to minimize their maintenance and reconstruction costs. One of the largest Transportation assets for DOTs is their unbound aggregate base layers. Creating a Permanent Road Foundation (PRF) using a separation/ stabilization nonwoven geotextile and a competent aggregate, will preserve the integrity of this asset and prevent future full depth reclamation/reconstruction. Avoiding reconstruction will dramatically lower the life cycle cost (LCC) of a road and will prevent road down time and the related congestion and construction related traffic deaths.

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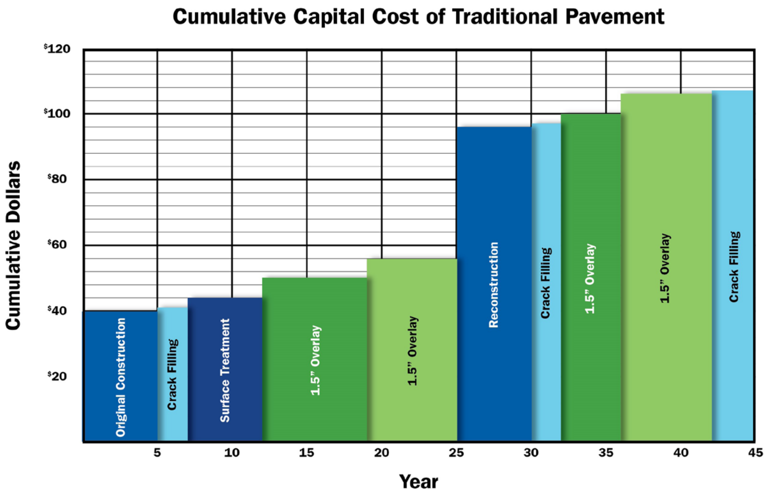

Figure 16 - Traditional construction: Pavement age vs pavement cumulative cost

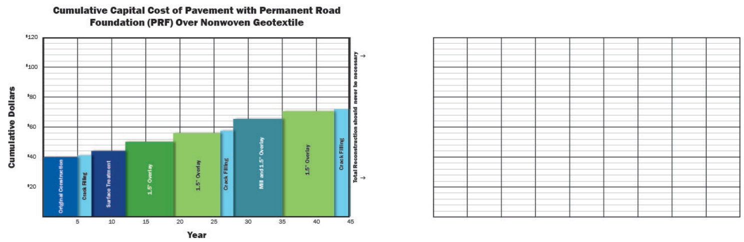

Figure 17 - Road built over a Permanent Road Foundation (PRF) with Nonwoven Geotextile

Figure 16 depicts a normal road expenditure cycle. In Figure 17 a nonwoven separation/stabilization geotextile was used to eliminate the reconstruction cost, dramatically decreasing the life cycle cost of the road.

SUMMARY

For the reasons discussed above, a nonwoven geotextile should be placed beneath every new or reconstructed pavement and unpaved road. Oklahoma DOT is one example of an agency that has used this strategy for over 20 years and has reaped the benefit of both more cost-effective designs and dramatically lower maintenance costs, with no total reconstruction necessary. Smart agencies have implemented the same preservation approach by incorporating the requirement for a separation geotextile into their local design and development code regulations for all local and subdivision roads. Otherwise, subdivision roads are under designed to handle the home construction traffic. As a result, the road foundation fails prior to the local agency inheriting expensive maintenance responsibilities.

The effective separation function of these geotextiles at the subgrade soil/aggregate base interface typically prevents the loss of more than 4 inches of aggregate base due to subgrade soil upward intrusion and contamination, which destroys the strength and permeability of the base layer. The stabilization function of these geotextiles has been widely proven to increase the bearing capacity of the subgrade soil by 80% and to confine and strengthen the aggregate base layer. These benefits provide superior capital and life-cycle cost savings.

Do not think that a separation/stabilization geotextile is only appropriate to use over weak subgrade soils (less than CBR 3). A nonwoven geotextile should be employed under every road, because even very competent subgrade soils can be negatively affected in the presence of water in a road structural section. Traffic pumping action will slurry the fines and allow them to migrate up into the aggregate if not separated using a nonwoven geotextile.

If you believe you do not need a separation/stabilization geotextile, we encourage you to forensically examine the remaining base aggregate in any road you excavate for reconstruction. Here, you will see the subgrade soil contamination of the aggregate base that was probably the root cause for the loss of support and premature failure of the pavement. Out of one mile of pavement, if even 50’ of reconstruction is necessary due to an area of weak subgrade or excessive moisture, the placement of a nonwoven separation/stabilization geotextile under the entire road to prevent this would have been less expensive than the small repair.