Barry R. Christopher,[1] Scott A. Hayden,[2] and Aigen Zhao[3]

Roadway Base and Subgrade Geocomposite Drainage Layers

Reference: Christopher, B. R., Hayden, S. A., and Zhao, A., **"Roadway Base and Subgrade Geocomposite Drainage Layers,"** *Testing and Performance of Geosynthetics in Subsurface Drainage, ASTM STP 1390,* J. B. Goddard, L. D. Suits and J. S. Baldwin, Eds., American Society for Testing and Materials, West Conshohocken, PA, 2000.

Abstract: The Maine Department of Transportation (DOT) in conjunction with the University of Maine and the U.S. Army Cold Regions Research Laboratory evaluated the use of a special geocomposite drainage net as a drainage layer and capillary barrier (to mitigate frost heave) on a section of road plagued with weak, frost-susceptible subgrade soils and poor pavement performance. The special geocomposite drainage net that is being used has a higher flow capacity than conventional geonets and, based on tests performed by the University of Illinois, does not deform significantly under heavy traffic loading. For the 425-m-long test section, the geonet drainage geocomposite was placed horizontally across the entire roadway but varied in vertical location to form three separate subsections for evaluating drainage of 1) the base coarse aggregate, 2) the asphaltic concrete pavement, and 3) the subgrade to allow for a capillary break in order to reduce frost action. An integral drainage collection system was installed to collect the water flowing in the geonet. This paper includes a project description, material and construction specifications, installation procedures, instrumentation, and test results based upon two seasons of monitoring. Laboratory characterization and performance testing initially used to evaluate the geocomposite are compared with the monitored results.

Keywords: drainage, drain, frost heave, geocomposite, geonet, instrumentation, pavement, roadway

Introduction

In order to evaluate the potential application of geosynthetics as a roadway drainage layer, the Maine Department of Transportation (DOT) constructed a test section with a special geocomposite drainage net placed horizontally within the pavement section of a

[1]Geotechnical Consultant, Christopher Consultants, 210 Boxelder Lane, Roswell, GA 30076.
[2]Certified Geologist, Maine Department of Transportation, Geotechnical Section, 219 Hogan Road, Bangor, ME 04401.
[3]Technical Director, Tenax Inc., 4800 East Monument Street, Baltimore, MD 21205.

road plagued with weak, frost-susceptible subgrade soils and poor pavement performance. Several drainage schemes were evaluated including use of the geocomposite as a roadway aggregate-base drainage layer, a surface pavement drainage layer and a drainage layer to provide a subgrade capillary break to mitigate frost problems. A special geocomposite drainage net was used which had sufficient flow capacity to drain the roadway section and adequate compression stiffness to withstand the anticipated traffic conditions without significant deformation over the life of the pavement. The test section was constructed during the 1997 construction season. This paper provides a project description, material and construction specifications, installation procedures, instrumentation, and test results based upon two seasons of monitoring. Laboratory characterization and performance testing initially used to evaluate the geocomposite are compared to the monitored results.

Drainage in Pavement Systems

Water in pavement systems is one of the principal causes of pavement distress. It is well known that improved roadway drainage extends the life of a roadway system. The Romans found very quickly that drainage was essential for their roads to last (remnants of which still remain!). In the 19th century, MacAdam recognized that it was necessary to have good drainage if adequate support was to be maintained and the road was to last. Adequate drainage is predicted to extend the life of a pavement system up to 2 to 3 times [*1,2*] over that of undrained pavement sections.

Another drainage issue relates to frost heave and subsequent thaw which causes significant weakening in soils resulting in extensive damage to roadway systems. Frost heave occurs due to the formation of ice lenses in soil which can grow up to several centimeters in thickness and cause expansion of the soil. During thaw, either a void or very soft wet soil replaces the ice lenses resulting in a very weak support condition. Conditions necessary for frost heave include: freezing temperatures, the presence of frost-susceptible soil and availability of water to the freezing front. If water is available, it can migrate through capillary action towards the freezing front and form ice lenses even where the water table is a meter or more below the depth of frost penetration [*3*]. In Maine and many other cold regions traffic weight restrictions must be posted during the spring thaw.

Conventional Solutions

Incorporating free draining base aggregate into the design provides a good solution to the drainage problem and is the current trend in long life roadway design as documented by NCHRP synthesis 239 [*4*]. However, free draining aggregate typically requires an asphaltic or cement stabilization binder to facilitate construction and either a graded granular or geotextile filter to prevent migration of subgrade fines into the open graded base, adding significantly to the cost of the roadway. The geotechnical solution to the frost heave problem usually is to remove the frost susceptible soils down to frost depth and replace the soil with non-frost susceptible material. This may require excavation and replacement of over a meter or more of material. Because of the expense of over excavation and the non-frost susceptible select granular material, this solution is often not performed to the extent necessary. Because of the increasing cost of clean granular material, often the backfill contains significant fines and is still somewhat frost susceptible. Another solution to this problem is to use deep drainage trenches to lower the water table and provide transition zones to limit over excavation; however, it is often difficult to lower the water table to a satisfactory depth.

A layer of granular soil has also been placed above the water table as a capillary break and backfilled with frost-susceptible soils to minimize frost heave and related damage in pavements [*5*]. This concept used geotextile filters above and below the granular layer to prevent intrusion of the adjacent soils. However, high construction costs have deterred the use of this alternative. Thick nonwoven geotextiles have also been evaluated for their potential to provide a capillary break [*3,6*]. Although the use of a nonwoven geotextile seemed promising, recent work by Henry [*7*] suggest that they are unlikely to act as a capillary barrier for long term field conditions.

Potential Geocomposite Drainage Layer Solutions

A potential alternative for both improved drainage and reduction in frost heave would be to incorporate a low compression, geocomposite drainage layer tied into roadway edge drains as shown in Figure 1. The geocomposite drain could be placed between the base and the subgrade, dramatically shortening the drainage path for the base (i.e., to just the thickness of the base versus the width of the road) thus allowing for less select base materials with a higher fines content as shown in Figure 1a). As the pavement ages and cracks are formed, a majority of the water will enter through the pavement surface. Thus it may be more advantageous to locate a drainage layer directly beneath the pavement surface to collect any infiltration before it enters the base and provide more rapid removal as shown in Figure 1b.

For deep frost penetration, the geocomposite net could be placed at a lower depth as a capillary break, replacing the granular layer shown in Figure 1c. Frost-susceptible backfill could then be placed directly over the geocomposite to the pavement base grade level. In this case, the system could be tied into drainage outlets to maintain the groundwater table at or below that depth. This may potentially eliminate the development of ice lenses which in turn could result in the removal of posting traffic weight restrictions during the spring thaw in cold regions.

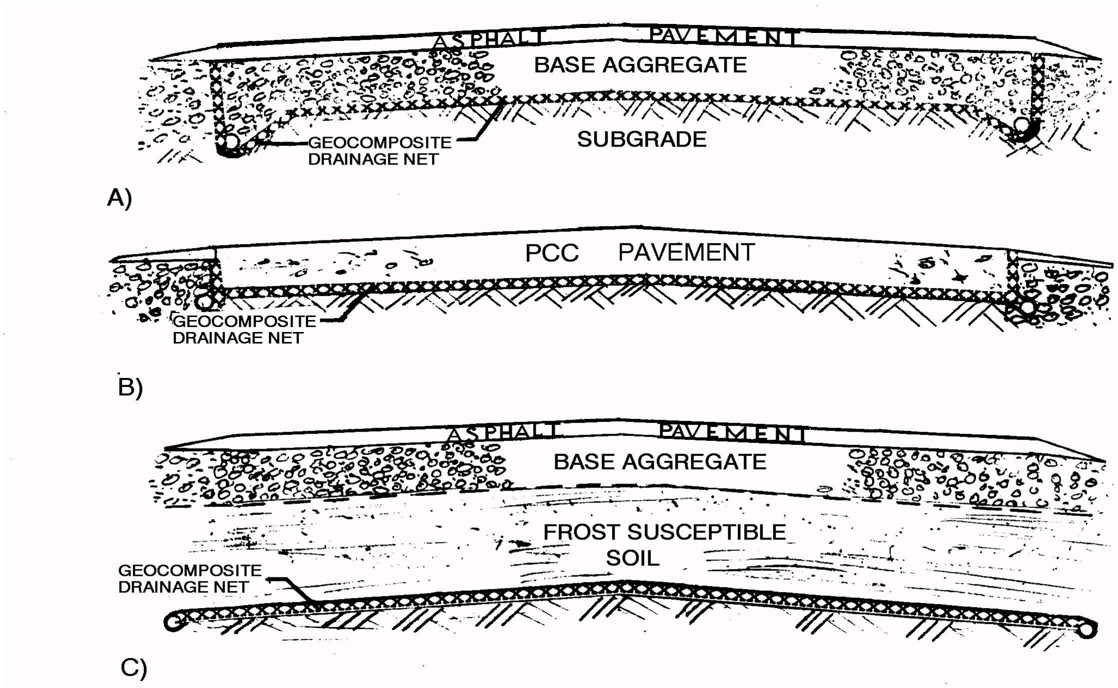


Figure 1. *Potential Use of Horizontal Geocomposite Drainage Layers Including a) Drainage of Roadway Base or Subbase Aggregate, b) Drainage of Surface Asphalt or Concrete Pavement, and c) Drainage of Subgrade to Form a Capillary Break*

Geocomposite Property Requirement

The geocomposite must have the stiffness required to support traffic without significant deformation under cyclic traffic loading. At the same time, the geocomposite must have a flow capacity to rapidly drain the pavement section and prevent saturation of the base. Outflow capacity in relation to the requirements for a roadway system typically require complete drainage within 2 hours. Conventionally a 100 mm thick open-graded base layer has proven adequate to meet the flow requirement [*4*]. This layer has a minimum permeability of 300 m/day and preferably 600 to 900 m/day. For comparison with a geocomposite, this layer would have a transmissivity of 0.00035 to 0.001 m^2/sec. With a typical roadway gradient of 0.02 (for a 2% grade), this layer provides a flow capacity ranging from 0.6 to 2 m^3/day per meter length of road.

With regard to traffic loads and tolerable deformation, the anticipated stress level on the geocomposite in a high use roadway is on the order of 80 to 600 kPa depending on the location of the geocomposite within the pavement section. Although many geocomposite drainage materials have a crush resistance greater than these values, most materials would deform significantly under the upper load range. In addition, dynamic traffic loading could induce significant creep deformation and potential collapse. Considering the high cost of pavement replacement, it is prudent to only consider high modulus, high compressive resistance geocomposites such as geonet drainage composites.

Unfortunately at the required gradient and load levels, most commercially available geonet drainage composites do not have a sufficient flow capacity to match the gravel layer drainage level. Typical in-soil transmissivity values of geonet with two 270 g/m^2 needlepunched nonwoven geotextiles laminated to both sides is on the order 1 x 10^{-4} m^2/sec to 5 x 10^{-4} m^2/sec [*8,9*] or even lower [*10*]. Further reduction in these transmissivity values due to long-term compressive creep of the geonet must also be taken into account. This may be why geonet drainage composites have not reportedly been used in this application. Although lower flow rates may be acceptable for some projects, considering this was a first trial, an equivalent flow rate to the gravel layer was desired. In addition, to provide a capillary break, it is critical that an air void exist within the geocomposite [*7*]. Geotextile intrusion on typical, relatively thin geonets is often sufficient to allow the geotextile filters on opposite sides of the geonet to touch, thus eliminating the air void. This was especially a concern for the lower drainage layer, which would be placed between soft clayey soils and have an increased geotextile intrusion potential. On the basis of these two considerations a thicker, higher flow capacity geonet drainage composite than typically available was desirable.

At the time of the project, a high flow geonet drainage composite (Tendrain 100-2 by the Tenax Corporation) had recently been introduced that met the flow requirements and did not allow the geotextile layers to touch. This new geocomposite consists of three extruded net layers to form a tri-planar geonet inner core with a needlepunched nonwoven geotextile laminated to either side. The composite has a transmissivity of 0.0022 m^2/sec under a normal load of 720 kPa and a gradient of 0.1, with corresponding flow capacity of 19 m^3/day/m at a gradient of 0.1 and 3.8 m^3/day/m at a gradient of 0.02, based on ASTM Test Method for Constant Head Hydraulic Transmissivity (In-Plane Flow) of Geotextiles and Geotextile Related Products (D 4716). Typical transmissivity data indicate that the transmissivity of a geonet decreases with increasing gradients. Consequently, the use of a laboratory-transmissivity value at a gradient higher than the actual field value (i.e., 0.1 gradient for 2% grade) will be conservative for evaluating flow capacity. The hydraulic characteristic thus corresponds very well with the horizontal drainage layer requirements for roadway drainable base. In addition, long term compressive creep tests on the tri-planar geonet core indicated that the material retained over 60% thickness after 10,000 hours under sustained normal load of 1200 kPa.

To further evaluate the performance of this geocomposite in a roadway system, cyclic loading tests were performed at the University of Illinois, Advanced Transportation Research and Engineering Laboratory [*11*]. Cyclic fatigue testing was performed on a concrete beam supported by the geocomposite overlying a clay subgrade and compared to results from a beam supported by the subgrade alone. The tests were performed at stress ratios of 0.76 and 0.83. The test setup along with representative results are shown in Figure 2. The results found insignificant additional deformation in the concrete when the geocomposite was used. The test at the 0.83 stress ratio showed some improvement in fatigue life (visually cracked beam) and the test at 0.76 stress ratio showed some reduction in fatigue life. Although the test results were inconclusive in relation to fatigue life, the geocomposite improved post-cracking behavior of the beam at both stress levels (i.e., minimized continued widening of the crack after break). This improvement in beam performance was attributed to an improvement in the uniformity of support under the beam after cracking and/or frictional improvement at the bottom of the beam which reduced the post-cracking deflection.

Figure 2. *Fatigue Test Setup and Results the University of Illinois, Advanced Transportation Research and Engineering Laboratory [11]*

Field Test Project Description

The project where field testing of the geocomposite drainage concepts was performed involved reconstruction of a 3.0 km portion of U.S. Route 1A in Frankfort and Winterport, Maine. The existing pavement along this project had been plagued by cracking, rutting, and potholes. The highway required frequent maintenance to maintain a trafficable pavement surface. The conditions prompted the reconstruction project.

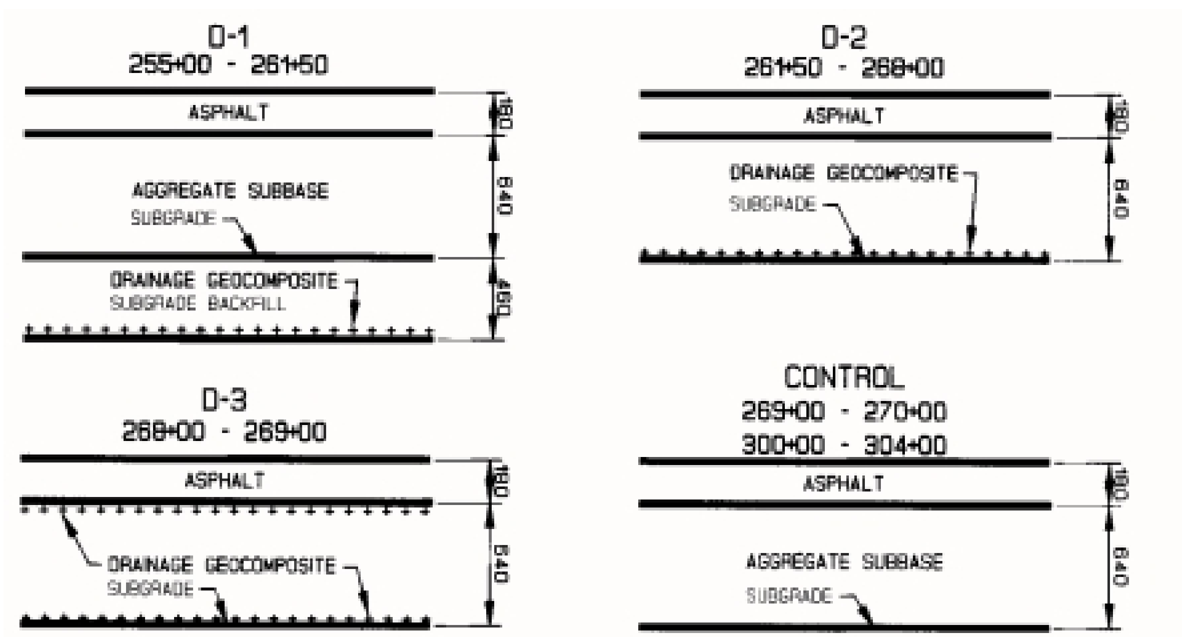
A subsurface investigation [12] encountered moist clay soils (locally known as the Presumpscot Formation) along the entire length of the project. These soils are plastic and moist with water contents greater than 20%. Based on soil conditions and past roadway construction experiences, designers initially recommended that the subgrade soils be undercut by 150 mm and replaced with granular soil to create a stable working surface prior to placing the overlying subbase course. It was anticipated that a greater depth of undercut would be required in some areas. However, with the use of geosynthetics (including the geocomposite drainage layers), the designers felt that undercutting would be unnecessary.

Prior to reconstruction water was observed seeping out of pavement sections, even though this was the second driest summer on record in the state of Maine. Water in the pavement section was obviously one of the existing pavement section failure mechanisms. Thus 425 m long drainage test sections were incorporated into a broader study on the effectiveness of geosynthetics in roadway construction [*13,14*]. In order to evaluate the three drainage schemes discussed in the Drainage of Pavement section, the test section was divided into 3 smaller subsections (labeled D-1, D-2 and D-3) and a control section as shown in Figure 3. The geonet drainage composite was placed at 460 mm below subgrade (subsection D-1), at subgrade (subsection D-2), and both directly beneath the pavement and at the subgrade (subsection D-3). In subsection D-1, the undercut subgrade material consisted of a mixture of native clay soils and old base course material. The geocomposite was covered with the material originating from the undercut. In each of the drainage test sections an internal drainage collection system was installed on both sides of the road directly beneath the shoulder break to collect water captured in the geonet drainage composite (Figure 4).

The high flow capacity geonet drainage composite discussed in the previous section was used in each of the test sections. The selection of the geotextile laminated to surfaces of the geonet was based on the FHWA filtration design criteria [*15*] considering the gradation and flow requirements for both the base course aggregate and the subgrade. The properties of the geonet core, geotextile and geocomposite are shown in Table 1.

Construction began May 1997 and extended into November 1997. Even though extremely favorable climatic conditions existed soil problems were still encountered. One of the control sections, which was built without geosynthetics and a stabilization lift, failed during construction (June, 1997). Subsequently, the clay soils in this area were undercut 600 mm and replaced with gravel. A 820 mm pavement section was then constructed over the undercut. In addition to the soil problem in the control section, other undesirable soil locations were identified during construction in the drainage section as well as other test sections. The contractor requested that these areas be undercut. However, since these locations were in areas where geosynthetics were to be utilized, the request for undercutting was denied. Subsequently, construction equipment and traffic were able to operate along these areas in the test sections without incident.

Figure 3. *Test Section Schematics (after [13])*



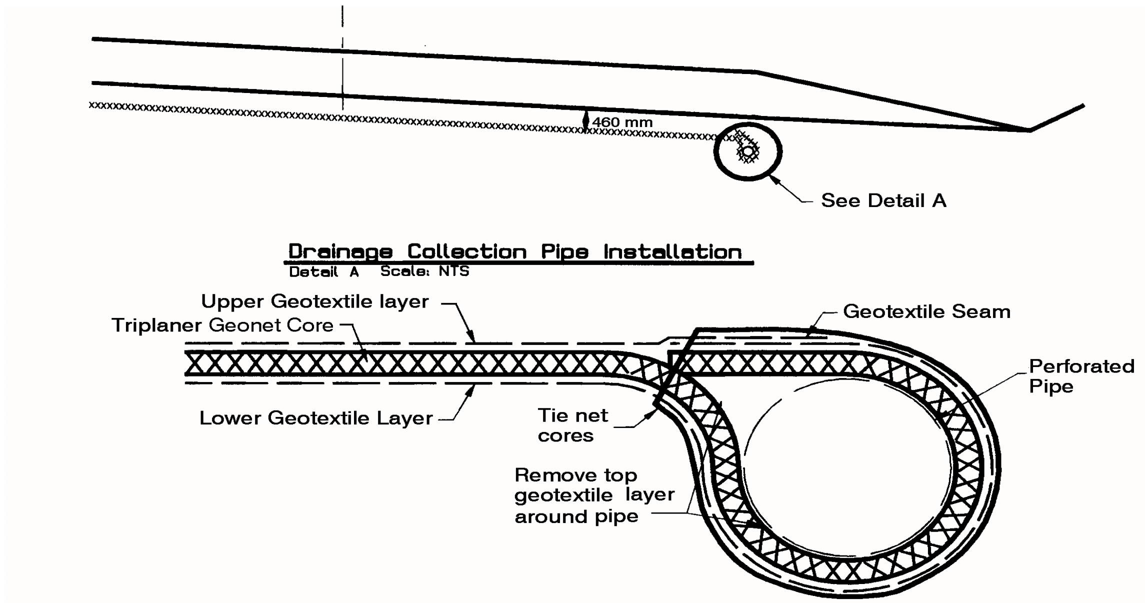


Figure 4. *Drainage Collection System Schematic*

Table 1. *Geonet Drainage Composite Properties*

GEONET			
Tensile Strength (MD)	ASTM D4595	kN/m	14
Compression Behavior % Retained Thickness @ 2400 kPa (short term) @1200 kPa (10,000 hours)	ASTM D1621	% %	50 60
Resin Density	ASTM D1505	g/cm^3	0.940
Resin Melt Index	ASTM D1238	g/10 min.	1.0
Carbon Black Content	ASTM D4218	%	2.0
Thickness	ASTM D5199	mm	7.0
GEOTEXTILE			
AOS	ASTM D4751	mm	0.125
Permitivity	ASTM D4491	sec $^{-1}$	1.26
Permeability	ASTM D4491	cm/sec	0.3
Grab Tensile Strength	ASTM D4632	Kn	1000
GEOCOMPOSITE			
Thickness	ASTM D5199	mm	9
Ply Adhesion	ASTM D413	g/cm	178
In-Soil Transmissivity @gradient 0.1and normal load 725kPa	ASTM D4716	m^3/sec-m	$2.2*10^{-3}$

Drainage Instrumentation

Water is allowed to drain from the drainage collection system at eight separate locations labeled outlet A through H. Monitoring stations were constructed at six outlet locations A through F (Table 2). At each of the monitored locations the outlet pipe is connected to a tilt bucket (Figure 5) housed in a protective wooden structure. A micro switch is positioned on the tilt buckets and is actuated every other time the tilt bucket dumps. The micro switch is, in turn, connected to a traffic counter which records the number of dump cycles of each tilt bucket. Data is collected continually 24 hours a day. The traffic counter software then provides daily or monthly reports, which presents the total number of dump cycles per hour, per day. This information is then downloaded over phone lines from the traffic counter on project to the Maine Department of Transportation offices.

Stand pipe type well points were installed outside the roadway at three locations along the drainage test section to provide ground water level information. These were read manually with a tape. Although the well points could not provide water level values directly under the roadway, they were useful in identifying the general relationship between ground water and roadway drainage.

Table 2. *Monitored Outlet Locations and Details*

Monitored Outlet Locations