Geocomposite Edge Drain System Design

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Since their inception and introduction in the early 1980s, geocomposites have received wide acceptance as edge drains, particularly on Interstate highway rehabilitation projects. During that time the industry has learned a great deal about the design requirements of the system to ensure acceptable performance. Through a review of laboratory tests, site investigations, and literature, a guide to systems design with emphasis on controlling factors is offered. Structural, hydraulic, and installation criteria are included.

The need for adequate drainage of highway bases has been known for centuries. Drainage methods have included free-draining bases, french drains, pipe and aggregate subdrains, and, most recently, geocomposite edge drains, the development of which was driven by the design of the Interstate highway system with dense, relatively impervious base-course materials and limited underdrain design. The trapping of water between the pavement and base has led to drastically shortened highway life (*1*).

The design of the geocomposite edge drain is intended to improve response time or rate of the introduction of free water by increasing the surface area in contact with the base-course material and by placing the product in intimate contact with the pavement edge and the base-pavement interface. The products currently in use have been proven to perform this function to a lesser or greater extent. Since the introduction of the first geocomposite edge drain in 1982, a great deal has been learned about the design requirements for these products and the special construction problems related to them.

Although vastly different in design and construction, the currently available geocomposite edge drains are all intended to perform the same function. Each product design, however, is focused on a few design parameters, and specifications promoted by each manufacturer emphasize those areas of focus in efforts to eliminate other products from competition. Further, laboratory research has been done focusing on a single property and has been promoted without regard to actual findings in the field and without addressing the interaction of the various component parts of the design. Actual field problems have been disregarded or downplayed as isolated construction-related problems and have not been addressed. In fact, some products have been modified to make them cheaper in a highly competitive marketplace in a manner that completely disregards field problems and, in fact, aggravates the installation problems—for instance, increased post spacing and flexibility or reduced flow capacity.

A clear focus on the product design requirements with emphasis on actual field performance needs and a complete system design are long overdue. Such a focus on system needs should result in the development of a product performance specification permitting adequate competition and ensuring system constructibility and performance.

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SYSTEM DESIGN

Before development of a product performance specification, it is necessary to establish the performance criteria demanded by the application. Specifically, hydraulic flow capacity, hydraulic inlet capacity, structural capability of the composite, constructibility, geotextile selection, system components, packaging, and outlet configuration and design must all be considered and, where appropriate, limits or minimums set. Uniform construction standards must also be established.

Hydraulic design involves a number of different parameters that must be considered as a whole, with each parameter met by the system design. There is good agreement on in-place flow capacity requirements at this time. The minimum in-plane flow capacity for any edge drain design, based on in-plane transmissivity tests conducted in accordance with ASTM D-4716 with a hydraulic gradient of 0.1 and a pressure of 10 psi for 100 hr on a 12-in. long, full-width sample, should be 15 gal/min/ft of width. The 100-hr time requirement under load should detect product weaknesses due to core or fabric creep. On the basis of tests conducted on geocomposite panels 12 in. wide and 20 ft long at 0 percent slope, this value translates into approximately 700 gal/hr at full flow (12 in.) (*2*).

Work by Dempsey (*3*) recommends that system design be such that a continuous flow capacity of 150 gal/hr at 0 percent slope with a water elevation in the geocomposite at or below the base-subbase interface should be required. This design determines the size of the geocomposite more often than the other parameters. It may also permit a variation in geocomposite height, depending on specific product performance characteristics.

Geocomposite inlet capacity is a subject of some debate. Recent work by Koerner and others (see the third paper in this Record) has revealed that the permeability of the base material and the infiltration rate through the pavement seams and cracks are always less than the inlet capacity of the geocomposite for all commercially available products. Table 1 presents the flow available from a range of base and soil conditions both in inlet flow per foot of 12-in. panel and total flow available to a typical 500-ft length of panel (*4,5*).

From Table 1 it can be seen that in-plane flow capacity is the system hydraulic control for soils that have the permeability of coarse sand or better. For other soils, with reasonable outlet spacing the soil permeability will control system flow. In no case does inlet capacity of the geocomposite control, at least with the designs currently available.

TABLE 1 FREE WATER FLOW THROUGH SOIL-GRAVEL MEDIUM

Flow Medium	Flow/Sq.Ft. of Contact Area (GPM/Ft²)	Flow/500 L.F.- 1 Side GPM/Ft of Height
1½" to 1" Gravel	6.8	3,400
1" to ½" Gravel	2.3	1,150
3/8" to #4 Gravel	0.36	180
Coarse Sand	4.5×10^{-2}	22.5
Fine Sand	4.5×10^{-4}	0.225
Silt	4.5×10^{-7}	2.25×10^{-4}
Clay	4.5×10^{-10}	2.25×10^{-7}

Comparing the in-plane flow of these products with pipe systems and gravel drains provides some insight into how these products perform in moving water from one point to another. Table 2 indicates the cross-sectional area of certain soils or gravels necessary to transport quantities of water equal to those carried by a typical edge-drain product (*4*).

Comparing this flow capacity with that of pipes, a typical smooth-interior, 4-in.-diameter pipe will have 4 to 5 times the flow capacity of a 12-in. edge drain. A 6-in.-diameter pipe will have 12 to 15 times the flow capacity of a 12-in. edge drain.

The structural capacity of these materials is probably the most controversial property of these products. Although in situ tests have indicated very low pressures in the plane of the geocomposite, with a maximum pressure of 12 psi being recorded during compaction of backfill and a duration over 8 psi of only 10 sec, claims as high as 93 psi for required design compression normal to the plane have been made. Unfortunately, tests used to justify this level of loading are made with flat steel plates; only the core load capacity is tested in one plane and the effects of such a load on the geotextile are ignored.

Similar tests using neoprene sheet or fine sand between the geocomposite and the plates provide a somewhat more realistic view of the actual installation condition. Even this test is very "kind" to the geotextile in that it does not include the vibration or pulse loading experienced by these products when installed adjacent to the pavement. Even so, a typical geocomposite with posts or cuspations spaced at 1¼-in. centers experienced ⅜- to ½-in. intrusion of the geotextile into the core after 72 hr at a constant pressure of 5 psi when placed between 1-in.-thick layers of neoprene with a firmness at 25 percent compression of 6 psi (41 kPa) (ASTM D1056). This is still less severe than anticipated soil loadings. Actual excavation of installed panels has shown similar intrusion patterns (Figures 1–3).

A parallel plate test using steel plates against the core with loads normal to the plane of the geocomposite is an index test only and does not reflect actual installed loads. Again, excavation of installed geocomposites in highway edge-drain applications has revealed significant geocomposite deformation, obviously from loads exerted at angles other than perpendicular to the core. These forces may occur during installation and initial backfill and compaction or may occur during soil settlement. The necessity of developing a laboratory test to represent the requirement for geocomposite stability has been clearly shown by site investigations in a number of states. The principal question is the appropriate shear angle to be selected for the test. Frobel, in another paper in this Record, has suggested angled loadings from 10 to 50 degrees, with the requirement that the load-carrying capacity be some percentage of the stiffness normal to the plane.

Two methods of angled loading are being considered: (a) applying the angled load directly through fixed angled loading plates or (b) applying the load through angled sliding teflon blocks. Both methods provide an indication of the stability of the core. Questions still remain as to the selection of the relevant angle for the test. One proposal using the fixed plates suggests that the cores should retain 50 percent of their strength under loads normal to the core at a 50-degree angle. Using the sliding blocks with a 10-degree angle, the allowable reduction in stiffness should be limited to 15 percent.

The selection of geotextile for use in the geocomposite has also become an issue. Generally, manufacturers of geocomposites have standardized on a single geotextile for use with their system. This geotextile-core combination, the geocom-

TABLE 2 FLOW CAPACITY

Flow Medium	Area Needed For Equal Discharge (Ft²)
12" Edgedrain (15 GPM)	0.083
1½" to 1" Gravel	2.2
1" to ½" Gravel	6.5
3/8" to #4 Gravel	46.7
Coarse Sand	333.0
Fine Sand	33,300.0
Silt	3.33×10^7
Clay	3.33×10^9

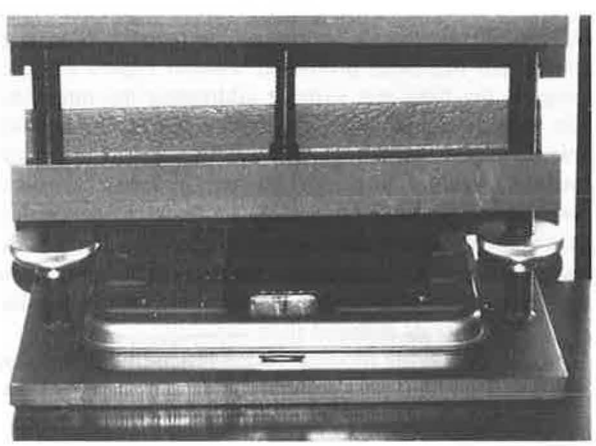

FIGURE 1 Simple compression frame with neoprene sheet over geocomposite face.

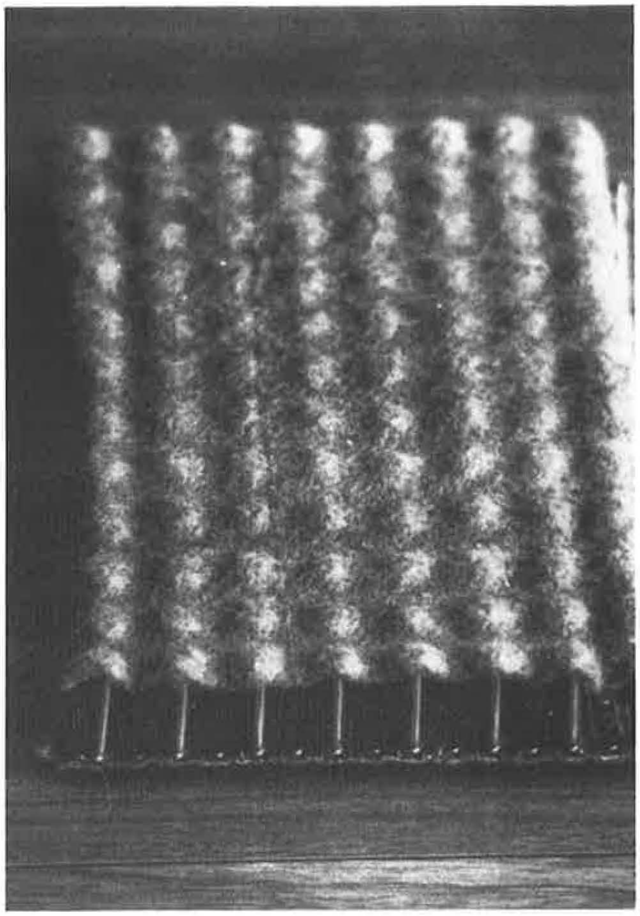

FIGURE 2 Residual geotextile intrusion after loading to 5 psi in the frame shown in Figure 1.

FIGURE 3 Excavated geocomposite showing similar fabric intrusion to that in Figure 2.

posite, has been promoted as a single package, with both core and selected geotextile properties promoted as applicable for all highway edge-drain applications. The initial concern was fabric plugging, and in defense of the selections made by the manufacturers, the author is not aware of a single case in which an edge-drain geotextile used in any geocomposite design became plugged. There have, however, been a number of cases of heavily silted cores—in some cases they were fully closed—with either very fine soils or cementitious fines released in pavement rubblizing (Figure 4). This would indicate that selection of the geotextile should be site specific. Koerner has recommended that a much heavier fabric (i.e., with a smaller apparent opening size) be used as a standard. Such a general change in fabric may, however, simply shift the problem from infiltration of fines into the core to fabric plugging. It should be noted that some reduction in fabric permittivity is acceptable, because the quantity of water available is always substantially less than the ability of the geocomposite to accept it.

Fabric selection criteria beyond A.O.S. and permittivity are largely dependent on core design. In most geocomposite designs, the geotextile serves as the outer boundary—the envelope or filter—and a structural member. In order to be an effective outer boundary, the geotextile must bridge the distance between cuspations or posts with a minimum of intrusion into the core under load. This dictates a high-modulus fabric; the wider the spacing of cuspations or posts, the higher the required modulus. Although no study of this intrusion phenomenon for highway edge-drain geocomposites is available, Koerner studied an 8-oz needle-punched fabric on a geonet and provided some insight into the problem; fabric

FIGURE 4 Geocomposite completely plugged by fines from I-65 in Kentucky.

intrusion into the core or net reduced flow capacity 60 or 70 percent at a soil pressure of 35 psi. This degree of flow restriction on a net with ⅜-in. continuous fabric support spacing should raise some concerns over cores with 1 to 1¼-in. cuspation or post spacing and demonstrates a clear need for compression tests made on the complete panel with some medium around the geocomposite that more closely represents the anticipated soil environment.

Other fabric parameters largely pose survivability issues. Puncture resistance, trapezoidal tear, tensile strength, seam strength, and probably abrasion resistance (due to handling and abrasion by the installation boot) should all be considered. How critical each of these properties is will vary with core design; as a general rule, the larger the spacings between supports for the fabric, the higher the values for each of these items should be.

Manufacturers have argued about assembly of the geocomposite (the attachment of the fabric to the core) for several years. Simply stated, for designs in which the fabric is a structural member, it must be fully attached by gluing or thermal welding to each post or cuspation tip and to the core back. For geocomposite designs in which the fabric acts only as the separator and filter, a tight sleeve around the core is all that is necessary. In both cases, a relatively high-modulus fabric should probably be used.

Complete system design requires a minimum of fittings. All that is necessary is a coupling, a side outlet, an end outlet, and an end cap. The most critical of these is the coupling, which must keep the geocomposite sections connected through the installation process without restricting flow through the system. The past practice of stapling (with box staples) and taping sections together damages the core and reduces flow capacity (Figure 5).

Any coupling method that infringes on the flow channel, blocking or reducing flow or providing sites for collection and buildup of solids, should not be permitted. Any coupling method damaging the core in any way should not be permitted.

Complete system design must include installation practice, particularly geocomposite location, size, and backfill. Generally the geocomposite edge drain is installed in a narrow trench (2 to 5 in. wide) dug directly against the pavement edge at the pavement-shoulder joint. The top of the geocomposite is typically held slightly above the pavement-base interface (1 to 1½ in.). Further, the geocomposite should be sized so that the bottom of the panel is far enough below the lowest point to be drained so that 150 gal/hr can be removed without the water level in the geocomposite being above that level. This may vary with the individual product (Figure 6).

General practice has been to backfill the geocomposite with the material excavated from the trench. This is acceptable as long as that material is compactable, contains no large material that may bridge or wedge between the panel and the trench wall, and is somewhat permeable. There has been good success backfilling with a graded sand, compacted mechanically.

The geocomposite has been placed away from the pavement edge for a number of reasons, particularly because trenching caused voids under the pavement edge. Moving the geocomposite away from the pavement edge is avoided mainly because response time is reduced substantially, and quick response time is the advantage of these systems. The farther away the geocomposite is placed, the more the response time is affected. Further, backfill between the geocomposite and the pavement edge must be highly permeable but cannot permit piping of base-course fines.

RECOMMENDATIONS AND SUMMARY

Geocomposite highway edge drains have been used extensively enough that better material and construction specifications can and should be developed on the basis of the performance experience to date. The following issues need to be covered in any specification.

Hydraulics

Geocomposite flow capacity is the critical hydraulic parameter affecting performance. Specifications should require a mini-

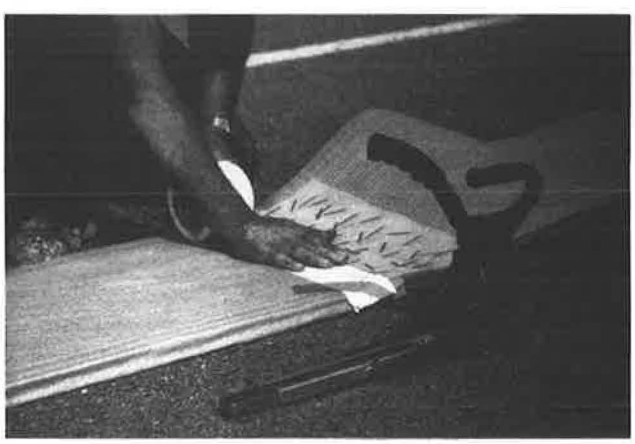

FIGURE 5 Stapled connection in which core has been partially crushed by staple placement.

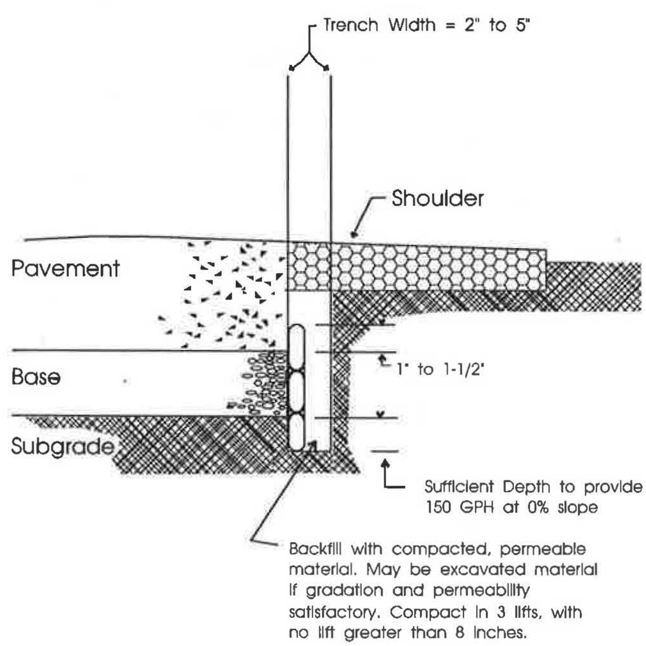

FIGURE 6 Geocomposite edge-drain installation.

mum flow capacity of 15 gal/min/ft of width when tested in accordance with ASTM D4716 at a gradient of 0.1 with a soil pressure of 10 psi for 100 hr on a 12-in.-long, full-width sample.

It is also appropriate that a test be developed to determine the level of flow in a geocomposite at 0 percent slope at 2.5 gal/min (150 gal/hr) with the geocomposite in its normal orientation.

Geocomposite inlet capacity should be greater than the maximum anticipated flow through the surrounding material times some safety factor from 5 to 10 for geotextile plugging over time. Allowance should be made for that part of the geotextile blocked by the core structure (20 to 45 percent depending on core design). For most highway base conditions, a geotextile with a permittivity of 0.2 sec^{-1} will exceed this requirement.

Structural Design

Any structural requirement must be based on the strength of the geocomposite (geotextile and core) and not just on that of the core. Tests must consider the effects of fill around the geocomposite, in which a soft medium is used around the sample during testing. Measurement of both fabric intrusion and core collapse must be made with the worst case governing. Further, the designs must be stable, as shown by a loading test at a shear angle of 50 degrees with a retention of at least 50 percent of the "normal" strength or with a sliding block test at a 10 degree angle with 85 percent of the "normal" strength retained.

A minimum compressive strength value of 3,000 psf (21 psi) for loads normal to the plane and for loads exerted at a 50-degree angle using fixed plates or with sliding blocks at 10 degrees appears appropriate. This exceeds maximum field measured loads by roughly a factor of 2 and equals the worst-case theoretical loading using Boussinesq analysis.

Geotextile

Geotextile selection for geocomposites is both site and core design specific. Individual sites or applications may require specific maximum A.O.S. requirements. For geocomposite designs in which the geotextile acts only as soil filter, Task Force 25, a joint AASHTO–Associated General Contractors–American Road and Transportation Builders' Association committee, considers Class B drainage geotextiles appropriate. For geocomposite designs in which the geotextile functions as a structural component, Class A drainage geotextiles per Task Force 25 should be required. In all cases, the geotextile should be nonwoven polypropylene or polyester.

Where the geotextile is a structural component of the geocomposite, it must be bonded to the core by gluing or heat bonding. If the geotextile is not a structural component, it may be tightly wrapped.

Installation

The geocomposite should be installed directly under the shoulder-pavement joint and in contact with the pavement edge whenever possible. If it must be installed away from this location, careful selection of the backfill material is required.

Couplings and Fittings

Couplings cannot interfere with or reduce flow in any way. Outlets must be designed to carry full panel flow.

Inspection

Installed geocomposites should be inspected for core damage before project acceptance. Borescope inspection at random points seems most practical.

REFERENCES

1. H. R. Cedergren. Why All Important Pavements Should Be Well Drained. In Transportation Research Record 1188, TRB, National Research Council, Washington, D.C., 1988, pp. 56–62.
2. B. J. Dempsey. *Core Flow Capacity Requirements of Geocomposite Fin-Drain Materials Utilized in Pavement Subdrainage*. University of Illinois, Urbana, 1988.
3. B. J. Dempsey. Hydraulic Requirements of Geocomposite Fin-Drain Materials Utilized in Pavement Subdrainage. In *Geotextiles and Geomembranes*, Elsevier Science Publishers, London, 1989.
4. H. R. Cedergren. *Seepage, Drainage, and Flow Nets*, 2nd ed. John Wiley & Sons, New York, 1977.
5. H. R. Cedergren. *Drainage of Highway and Airfield Pavements*. John Wiley & Sons, New York, 1974.