PREFABRICATED SUBSURFACE DRAINS

Kent A. Healy and Richard P. Long, Department of Civil Engineering, University of Connecticut

The design of a prefabricated subsurface drain system based on well screen criteria is presented. This drain is fabricated by using synthetic cloth and a channelized core that ensures proper filtration and permeability. Laboratory and full-scale field test results are given and show the prefabricated subsurface drains to be an effective substitute for conventional mineral aggregate subsurface drains. Mineral aggregate filters are reviewed. The difficulties inherent in their design and construction and the advantages of prefabricated subsurface drains are discussed.

•SUBSURFACE DRAINS have been used for many years to remove excess water from the ground to improve crop growth, strengthen pavement foundations, stabilize slopes, and reduce water pressure against retaining walls. The water is often carried away from a site by a perforated pipe, and a filter material must be provided between the soil and the pipe that will retain the soil while allowing the free flow of water into the pipe. The conventional subsurface drain uses a filter of mineral aggregate that has been graded to match the soil (1). This type of filter performs satisfactorily only if designed and constructed carefully.

A subsurface drain system that uses synthetic materials and that fulfills the requirements of filtration and water flow has been developed. Because this system can be prefabricated in lengths that are easily handled and installed in the field, many of the construction problems of mineral aggregate drains are eliminated.

DESCRIPTION OF PREFABRICATED SUBSURFACE DRAINS

The prefabricated drain is shown in Figure 1 and consists of a slotted pipe, a channelized vertical core inserted into the pipe slot, and a fine-mesh filter cloth enclosing the pipe and the core. The cloth retains the soil and keeps the core channels open. The groundwater drains through the cloth, down the channels, into the pipe, and away from the site.

The selection of the filter cloth is based on criteria established in the 1930's for well screens (2). A properly designed well screen retains only the coarsest particles of a soil; these particles will retain the finer particles.

The openings in the screen should be just small enough to retain the coarsest 20 percent of the particles (D_{80}) in a well-graded soil and the coarsest 40 percent (D_{60}) in a uniform soil (3). The percentage of open area of the screen should be approximately the same as the porosity of the soil to prevent restriction of water flow. Well screens meeting these criteria have remained effective for many years in soils ranging from fine sand to gravel.

The filter cloth used on the prefabricated drains functions in the same way as a well screen. An advantage of using cloth as a filter is its high permeability even with small openings. Cloth with mesh openings between 0.075 and 0.150 mm and a minimum 15 percent open area will retain most soils that can be effectively drained by gravity and will not restrict the flow of water from the soil.

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Materials Used

The materials used in the prefabricated surface drains are given as follows:

1. Filter cloth—Two types of cloth have been tested and used as filters—a nylon chiffon and a polyester butterfly (Fig. 2). Both materials have good tensile strength and resist decomposition in the ground. The chiffon has a mesh opening of 0.15 mm and a 45 percent open area. The butterfly has a mesh opening of 0.075 mm and a 15 percent open area. Long-term model tests have shown that both cloths will filter soils ranging from a fine silty sand to a glacial till with no sign of soil erosion or clogging. The butterfly cloth with 15 percent open area has adequate permeability for soils containing silt. The chiffon having a greater percent of open area is preferable for draining more permeable soil. Both cloths are more permeable than a 2-in. layer of coarse gravel. The gradation of particle sizes and permeability of soils successfully filtered by nylon chiffon cloth are shown in Figure 3. These soils, ranging from a medium sand to a glacial till with a high percentage of silt, were tested in the laboratory under a hydraulic gradient much higher than that occurring in the field.

2. Core—The core must support the cloth and provide channels large enough to carry the water into the pipe as quickly as it flows from the soil. The following materials have been used as cores in field-test installations and are shown in Figure 4: Type 1, expanded aluminum sheet, purchased from U.S. Steel, having the commercial name Armorweave; and Type 2, vinyl tube fencing, purchased from Sears, Roebuck and Co. The core materials were tested for crushing strength and water-carrying ability. The expanded aluminum showed little deformation under a pressure of 200 lb/sq in., and the vinyl tube fencing had a crushing strength of 160 lb/sq in. Intrusion of the cloth into the channels decreases the area through which the water can flow and is a possible source of malfunction. Tests with the vinyl tube fencing showed that, under an earth pressure of 4.0 kip/sq ft, the cloth intruded less than 0.025 in. and that a 1-ft wide

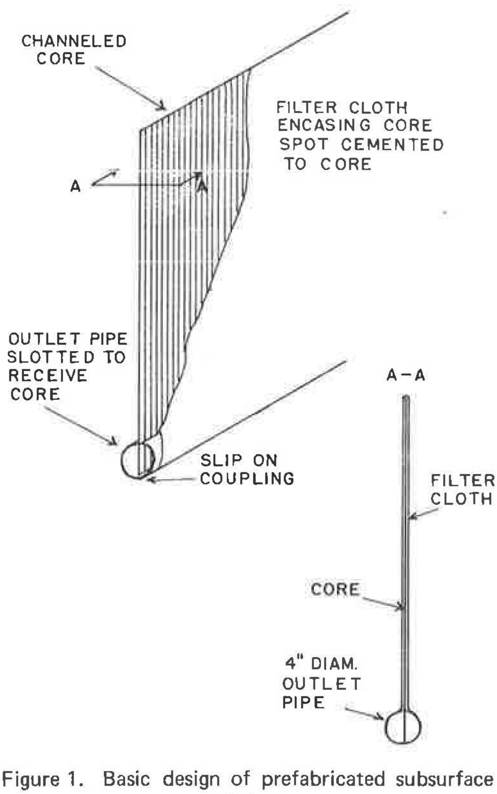

Figure 1. Basic design of prefabricated subsurface drains.

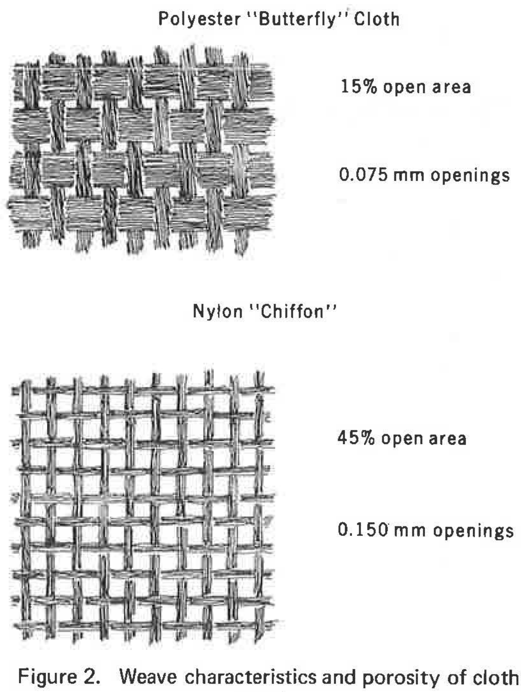

Figure 2. Weave characteristics and porosity of cloth used.

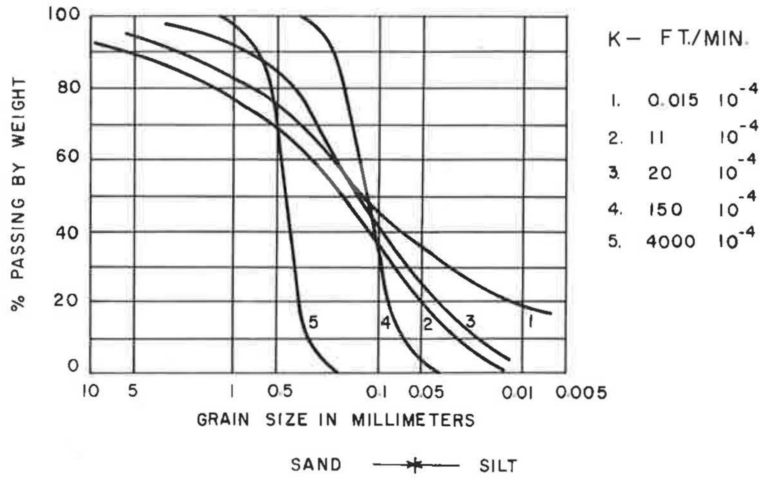

Figure 3. Soils successfully filtered by nylon chiffon.

section of the drain, when vertical, could carry 2.5 gal/min. This is sufficient to drain a soil with a permeability of 5×10^{-2} ft/min. Tests on the expanded aluminum core showed similar flow characteristics under stress.

3. Pipe—A hard plastic pipe with a 4-in. diameter and a 1/8-in. wall thickness has been used for the field sections. The slot was cut on a table saw. This pipe is available in 10-ft lengths from building supply companies and has a crushing strength of 0.9 kip/ft.

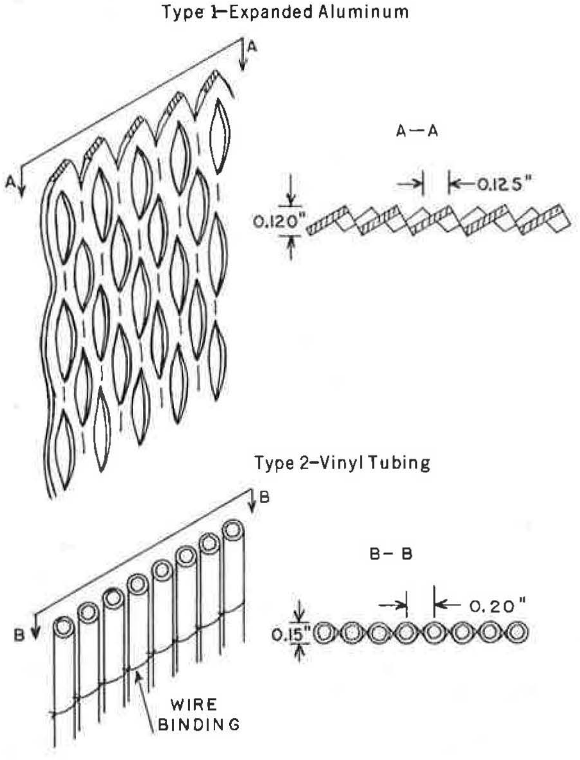

Figure 4. Core configuration.

Installation Methods

Prefabricated drains are easily installed on slopes or in trenches, as shown in Figure 5. Drain sections 10 ft long weigh less than 20 lb and can be placed and connected with slip couplings from the ground surface. Trenches need be only wide enough to receive the drain, thereby making attractive the use of trenching machines in suitable soil.

The core is flexible enough to be pressed tightly against 1 face of the exposed natural soil, as shown in Figure 5. In this manner the more permeable strata in the native soil can be drained quickly. The type of backfill depends on the drainage desired at the site. If most of the water enters the drain from 1 side, as on a slope, the native soil may be used as backfill against the opposite face. When the drain receives water from both sides, sand may be used as backfill. This ensures that the natural drainage channels in the soil are not blocked and makes the compaction easier in a trench section. The short flow path through the sand to the core of the drain will not impede the free movement of water.

The prefabrication of the drain sections ensures proper operation even when installed by people who are unfamiliar with filter principles. The drain sections can be fabricated in any height and length to suit the installation.

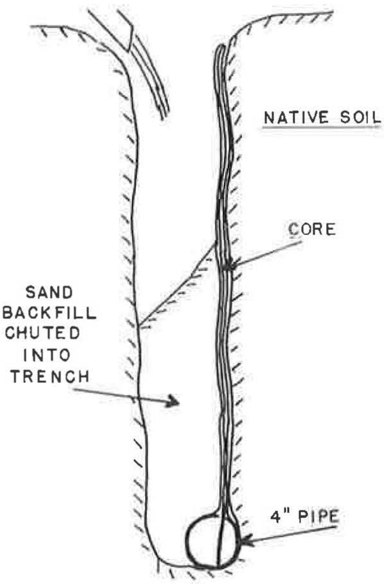

Figure 5. Prefabricated drain installed in trench.

FIELD TESTS

Sites

Prefabricated drains were installed in 2 small wet areas in 1968 and performed well. In the spring of 1969, 600 ft of drain were installed to stabilize a cut slope that was sloughing because of excess water. This installation is described in detail in this paper.

During the late summer and early fall of 1970, installations were made at 3 other sites. These 3 installations are mentioned especially to illustrate other applications for the prefabricated underdrains. Field measurements on them are continuing. One installation surrounds a septic system leach field to control the groundwater in the vicinity. Another installation was placed to intercept the groundwater flowing into a lot on which a home is to be built. The third installation was placed beside a road to control frost heave by lowering the local groundwater table.

Description of Unstable Slope

The slope, a plan of which is shown in Figure 6, is the northwest side of a drumlin, located on the University of Connecticut campus and formed when the hill was cut back from a natural slope of 1 on 3.3 (17 deg) to a 1 on 2 slope to allow the placement of a sanitary line and sidewalk. The slope started sloughing after the first heavy rain, and it was a continual maintenance problem to keep the walk clear of mud in the spring and ice in the winter. The soil in its natural state is a dense, well-graded glacial till with particles varying from cobbles to clay size. Disturbed samples of the soil have a permeability of approximately 1×10^{-6} ft/min, as measured by a falling head permeameter. Slow direct shear tests showed an effective stress friction angle of 41 deg. The natural undisturbed soil is slightly cemented and contains numerous small channels parallel to the surface that seep water below the water table in an open cut.

Installation

In July 1969, 2 lines of prefabricated drains with type 1 core and butterfly cloth were installed along the slope, as shown in Figure 6. It had originally been planned to install the upper drain line by cutting a berm with a bulldozer. However, at the time of installation the slope was too wet, and a berm had to be dug by backhoe from below. Figure 7 shows a typical cross section and the method used to place the drains. A trench was dug for the lower drain and was backfilled with sand for ease of compaction. In the very wet areas, the upper drain sections were partially backfilled with the backhoe immediately after placement to prevent local sliding. Figure 8 shows the upper drain partially backfilled. Final backfilling and grading were completed by a bulldozer, as shown in Figure 9. The lower trench installation is shown in Figure 10.

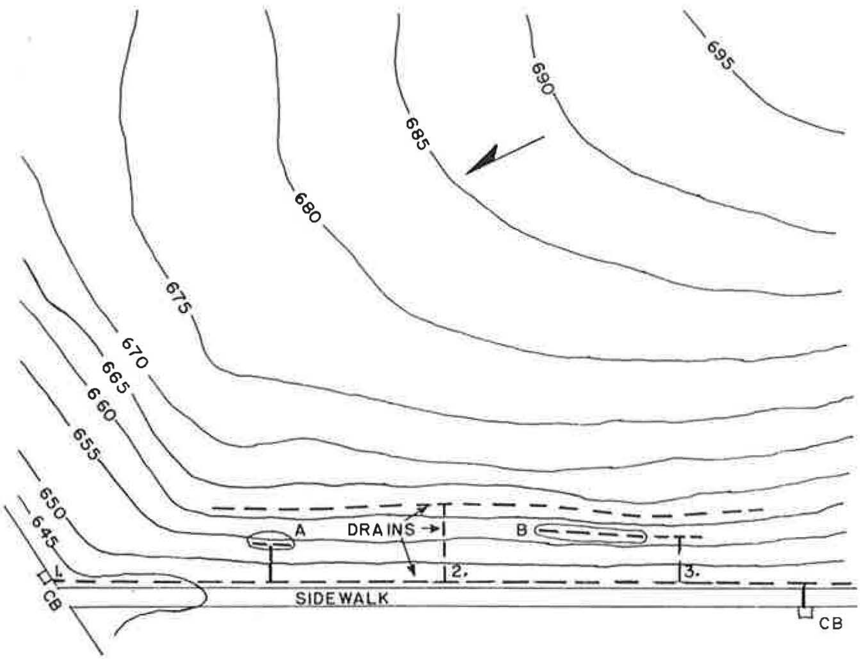

Figure 6. Plan of field installation.

In the fall of 1969, heavy rains caused surface erosion, and in 2 areas, marked A and B in Figure 6, the natural drainage channels were such that water was exiting under the upper drain, causing sloughing below. An additional 20-ft length of drain was installed by hand at the south end of the area B halfway up the slope, and this portion was

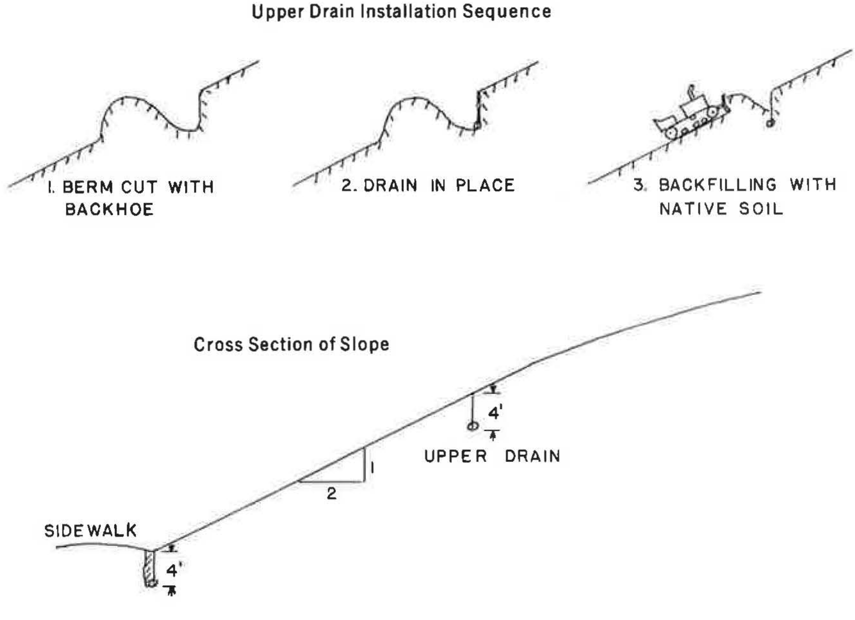

Figure 7. Cross section of field installation.

stabilized. In the spring of 1970, 90 ft of drain with type 2 core and chiffon filter cloth was installed with a backhoe and bulldozer in the remaining portion of area B, and 20 ft of drain was installed in area A. Observation pipes were installed at points marked 1, 2, and 3 in Figure 6, and the water flow in the drain pipes can be measured at these points by using calibrated probes.

Figure 8. Upper drain partially backfilled.

Evaluation of Field Installation

Some piezometers were installed, but they did not reflect apparent water conditions accurately. This may be due to the nonhomogeneous permeability characteristics of the soil. The evaluation of the field installation has therefore, been based on the overall stability of the slope and measurements of water flow out of the drains.

The slope, which was unstable over essentially its whole length, has been stabilized. Surface seeping has been almost eliminated, and the slope surface drys up within a few days after a heavy rain.

Water flow from the drains has been monitored continually since installation. The 250-ft upper drain removes water from the soil at a rate of 2 gal/min during wet periods. Calculations, assuming a hydraulic gradient in the soil of 0.2, show the field permeability to be 1.6×10^{-3} ft/min. This increase of 1,000 times over the permeability from lab tests on disturbed samples may be due to the natural channels occurring in the deposit. There has been no indication of fines being removed from the soil by the drain, indicating that the cloth is filtering properly.

Costs

The upper drain was installed where it would have been nearly impossible to install a conventional trench drain, so that cost comparisons are difficult to make, but the prefabricated drains appear to be competitive with conventional drain systems. The material cost of the prefabricated drain using vinyl tube core and chiffon is less than \$1.35/ft for a 4-ft deep section. The main drainage core can be provided in almost any height and length at a cost of approximately \$0.25/sq ft.

COMPARISON OF MINERAL AGGREGATE AND PREFABRICATED SUBSURFACE DRAINS

Most subsurface drains are constructed from mineral aggregates, and a comparison with prefabricated drains is appropriate.

Figure 9. Dozer backfilling upper drain.

Figure 10. Installing lower drain in trench.

Filter Requirements

Tests run by Bertram in 1940 (4) and at the U.S. Army Engineer Waterways Experiment Station (5) resulted in the development of the following criteria for mineral aggregate filters:

1. Preventing continuous movement of soil particles requires that the effective pore size (assumed to be 1/5 D_{15} of the filter) be smaller than the coarsest 15 percent (D_{85}) of the soil being drained. This is normally expressed as

$$\frac{D_{15}\text{ (filter)}}{D_{85}\text{ (soil)}} \leq 5$$

$$\frac{D_{50}\text{ (filter)}}{D_{50}\text{ (soil)}} \leq 25$$

2. Preventing restriction of water flow by the filter requires

$$\frac{D_{15}\text{ (filter)}}{D_{15}\text{ (soil)}} > 4 \text{ to } 5$$

Preventing movement of the filter particles into the pipe, if a perforated pipe is used to remove the water from the filter, requires

$$\frac{D_{85}\text{ (filter)}}{\text{pipe-opening size}} > 1$$

In the prefabricated subsurface drain, all filtration is accomplished by the cloth with openings constituting at least 15 percent of the area and having a size between 0.075 and 0.150 mm.

Design and Construction

In many situations the criteria for mineral aggregate filters must be applied with great care. The Vicksburg criteria implicitly assume well-graded soil (1). If the soil to be filtered and drained is gap-graded, the number of large particles may be insufficient to prevent movement of the smaller particles, and the filter must be designed to retain a size smaller than the coarsest 15 percent of the soil particles.

Filters placed against soil deposits, whose gradation varies from point to point, must be designed to hold the finest particles in place, and a graded mineral aggregate filter may be required to allow free drainage.

Some of the important points (1) in constructing the mineral aggregate filter are as follows:

1. Filter materials must be handled and placed with care to avoid segregation and contamination;
2. The filter must be well compacted to reduce the possibility of dropping fines of the filter through void spaces; and
3. A single improperly constructed portion of the filter can lead to failure of the drainage system.

Construction control for the prefabricated subsurface drain is less demanding. The prefabrication ensures that the system can be easily and correctly installed by personnel unfamiliar with filter criteria.

CONCLUSIONS

Laboratory and field tests have indicated the following:

1. A fine mesh cloth is suitable as an effective filter for a wide range of soil types;
2. A thin channelized core allows free movement of water into the outlet pipe;
3. Prefabricated subsurface drains are easily handled and installed in the field and allow placement where conventional drains would be difficult to construct; and
4. Prefabricated subsurface drains are economically competitive with conventional mineral aggregate systems.

ACKNOWLEDGMENT

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