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Fabric filters on pre-fabricated underdrains
Fibres textiles pour drains profonds préfabriqués

Résumé

On décrit les éléments d'etoffes neccessaires qui serviraient de filtres pour les fossés d'écoulement souterrains prefabriqués, et le guide à suivre en choisissant des étoffes tissées, non tissées, ou feutrées selon les diverses espèces de terre. Les épreuves verifient que les étoffes tissées serviraient à un grand numbre d'espèces de terre, avec grand succès. On décrit des essais sur champ où des fossés d'écoulement souterrains prefabriqués, enveloppés en étoffe tissée, sut été utilisés avec succès.

Introduction

Fabrics, used as filters, simplify underdrain design and construction. A fabric, properly selected, can fulfill the requirements of an ideal filter mentioned by Sisson [1]: (1) easily handled and transported, (2) little resistance to the flow of water, (3) relatively inert to physical and chemical actions and (4) openings small enough to exclude soil particles from moving into the drain.

When used in underdrains, fabrics commonly line the walls of a trench. The trench is then filled with mineral aggregates. A pipe may or may not be included in the trench depending on the amount of water anticipated and the length of trench. Described herein is the design and testing of fabric and other components of a prefabricated underdrain unit, and the results of several field installations. The unit is self contained and does not require mineral aggregates. Characteristics of fabrics and their influence on drainage of soil are discussed.

Description of the Drain

The prefabricated underdrain shown in Fig. 1 has three components: (1) a core having vertical channels, (2) a pipe at the bottom of the core to collect the water, and (3) a fabric enveloping the core and pipe. The channels are connected to the pipe by inserting the core into a longitudinal slot cut in the top of the pipe. Water enters the system through the fabric, runs down the channels, into the pipe and away from the site.

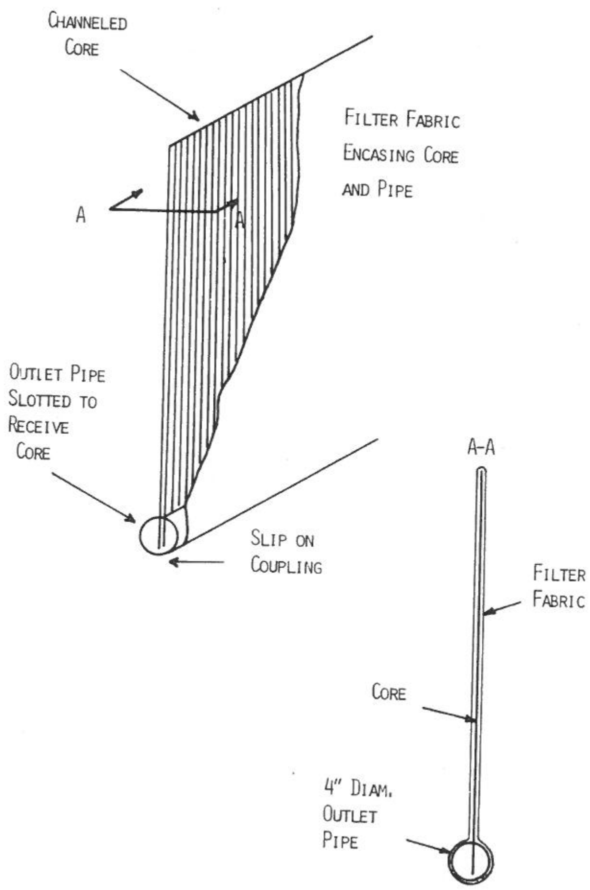

Figure 1 - Components of Prefabricated Underdrain

The core supports the fabric and provides channels large enough to carry the water into the pipe as quickly as it flows from the soil. The cross sectional area of the channels must be larger than the openings in the fabric, to allow the few soil particles that may initially wash through the openings to continue into the pipe and out of the system.

General Requirements of Fabrics in Underdrains

The characteristics of the soil to be drained must be considered when selecting a fabric for an underdarin. Three types of soil will be discussed in relation to the fabrics: (1) uniformly graded, in which the particles are approximately the same size, (2) wellgraded, in which a relatively large range of soil particle sizes are present in equal amounts by weight and (3) non-homogeneous soils, in which the characteristics of the soil vary significantly along the line of the underdrain.

Three types of fabrics will be discussed: (1) woven, (2) non-woven, and (3) mat. The term "woven" is used for fabrics that have the traditional warp and fill threads. The prime characteristics of this type fabric are the uniformity of the size and frequency of openings. The non-woven fabrics have a wide range of opening sizes, and the frequency of openings varies from point to point, and are essentially two dimensional.

The term mat is used for non-woven fabrics in which the water must pass through tortuous channels instead of holes. The dividing line between non-woven and mats is not distinct and for discussion a mat is arbitrarily defined as having a thickness greater than twice the size of the largest opening.

General requirements for underdrain fabrics are listed in Table 1. The opening sizes are related to particle sizes in the soil to be drained e.g., D_{60} indicates that 60% of the particles by weight in the sample are smaller than this size. The values shown in Table 1 result from laboratory and field experience. The numbers given are based on the authors'

			Type of Fabric	
	Fabric Property	Woven	Non-Woven	Mat
Type of Soil: Uniform	Opening Size	$< D_{60}$	$D_{20} \le$ O.S.[a] $\le D_{60}$	Sieving Test Retains D_{50}
	Open Area	> 5%	> 5%[b]	--
	Permeability	--	--	$k_{mat} > 2k_{soil}$[c]
Type of Soil: Well Graded	Opening Size	$D_{30} <$ O.S. $< D_{85}$	$D_{30} <$ O.S. $< D_{85}$	Sieving Test Retains D_{85}
	Open Area	> 5%	> 10%[b]	--
	Permeability	--	--	$k_{mat} > 5k_{soil}$[c]
Type of Soil: Non-Homogeneous	Opening Size	$D_{20} <$ O.S. $< D_{80}$[d]	$D_{20} <$ O.S. $< D_{80}$[d]	Sieving Test Retains D_{80}[d]
	Open Area	> 10%	> 15%[b]	--
	Permeability	--	--	$k_{mat} > 2k_{coarse\ soil}$

a. O.S. = opening sizes
b. Between these sizes
c. Under design pressure
d. Based on finest soil

Table 1

General Requirements for Underdrain Fabrics judgment. While these numbers are not precise they represent consideration of observed physical phenomena.

The fabric must be able to filter the soil particles while allowing the water to flow out of the soil freely. Filtration depends on the maximum opening size. The free flow of water depends on the size and frequency of the openings and the resulting percent open area. Studies indicate that the frequency of openings is the most important parameter, if the size of the openings is sufficient. [2][3] Table 1 reflects these requirements. Woven fabrics are the easiest to select for a given soil. Most woven plastic fabrics have a slight variation in opening sizes, however, particles tend to bridge across openings, and selecting the opening size by Table 1 ensures filtration of the soil and enough fabric conductivity. For the woven fabric against well-graded and non-homogeneous soils upper and lower limits of opening sizes are listed. If the openings in the fabric are too small, the overall conductivity will be reduced because small soil particles will be retained next to the fabric.

The same criteria are applied to the non-woven fabric. Enough area should consist of opening sizes between the soil sizes listed to ensure the small particles will not reduce the hydraulic conductivity of the fabric. As the range of soil sizes increases, more area with hole sizes between the indicated size limits must be provided to insure free flow of water.

For a mat, a sieving test appears to be the only way of determining the filtration characteristics. [4] Mats have channels that may

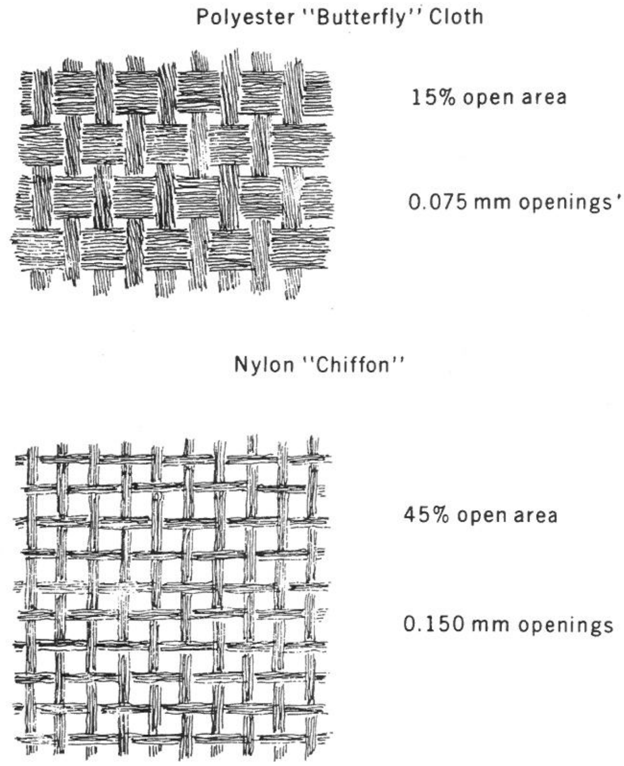

Figure 3 - Fabrics Used

listed in Table 1 should ensure that the permeability of the mat will not be reduced to a

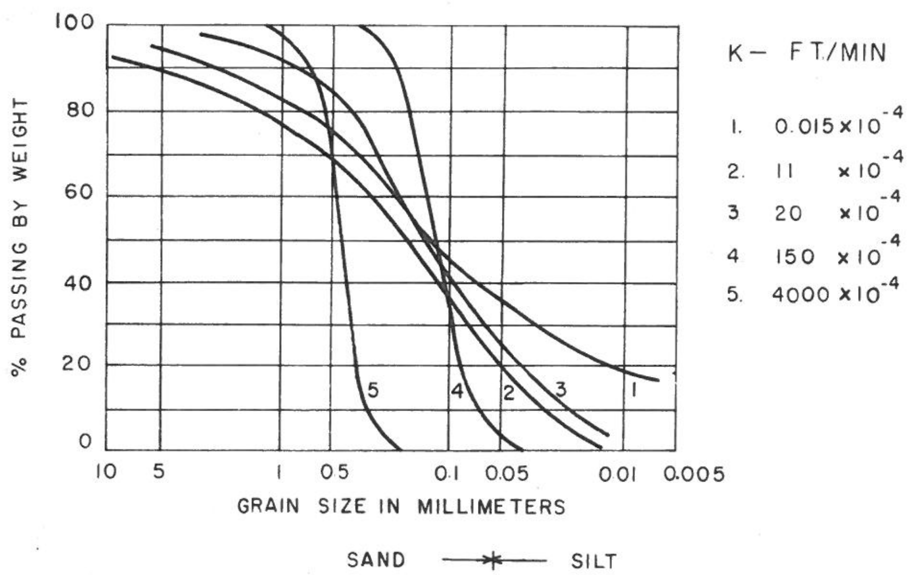

Figure 2 - Soils used in Tests

value that interferes with the free flow of water.

Design is most difficult for non-homogeneous soil, since filtration and hydraulic conductivity must be provided for a spectrum of soils with one fabric. Particle size tests should be conducted on the coarsest and finest soils present.

Selecting Fabric for Prefabricated Underdrains

The object of the research carried out at The University of Connecticut was to develop a prefabricated underdrain capable of filtering and draining a variety of soils found in Northeastern United States. Examples of the soils tested are shown in Fig. 2. Woven fabric is more easily selected to handle this range of soils. Two types of woven fabric were tested for use in the prefabricated underdrain. These fabrics are shown in Fig. 3. Both fabrics are resistant to deterioration when buried. One is a polyester "Butterfly" cloth having an open area of 15% and an opening size of about 0.075 mm. The other is a nylon chiffon having an open area of 45% and an opening size of about 0.150 mm. Both fabrics were tested in the laboratory and found to successfully filter the soils shown in Fig. 2, with negligible retardation of flow. Description of the tests on the fabrics and other components of the prefabricated underdrain are published elsewhere. [5][6] Pertinent results will be presented here.

A model underdrain with butterfly cloth was tested for 18 months in the laboratory. The soil against the fabric was glacial till (soil no. 1 in Fig. 2). The initial flow of water through the drain carried small soil particles but the water cleared in about 30 seconds and continued to flow clear at the same rate for the duration of the test which included wetting and drying cycles. In granular soil, arching was found to play a significant role in filtration. The soil particles filtered are about one-half to one-third the size of the openings. However, the effect of changing hydraulic gradients may temporarily destroy the arching, so the more conservative criteria was used.

The prefabricated underdrain was tested and found to have sufficient crushing resistance and sufficient tensile strength of the fabric, etc. [4][5]

Field Tests

Six full-sized field installations in various soils were made to test the design of the

Location of underdrain installation	Date installed	Type of Fabric	Soil Type	Permeability of disturbed samples in centimeters per second
Tennis court slope	June, 1969 June, 1970	Butterfly Chiffon	Sand, silt, and clay	7.6×10^{-7}
Route 44-A	August, 1970	Chiffon	Fractured rock to sandy silt	1.0×10^{-3}
Fellon Road	October, 1970	Chiffon	Sandy silt	5.6×10^{-4}
Route 82 Haddam, Conn.	June, 1971	Chiffon	Silty sand	1.0×10^{-4}
Retaining wall	August, 1971	Chiffon	Clayey silt and sand	3.4×10^{-5}
Chaplin, Conn.	September, 1974	Chiffon	Sandy gravel	2.0×10^{-2}

Table 2

Summary of Observations on Field Installations underdrain and selection of the fabric. Evaluation of the installations is based on the achievement of each engineering objective and the continued ability of each installation to drain water through yearly cycles. The installations are summarized in Table 2. A brief description of each installation follows:

(1) The Tennis Court Installation was made to stabilize a sloughing drumlin slope. Two lines of drains were installed. The drumlin is composed of dense glacial till with many permeable lenses.

(2) The Route 44-A installation was made in a trench to intercept ground water causing frost heave.

(3) The Fellon Road installation was made to control ground water in a site for home construction.

(4) The Route 82 installation was also to stabilize a sloughing slope.

(5) The retaining wall installation was made to control ground water on a building lot.

(6) The Chaplin, Conn. installation was made to control ground water on a building lot.

All of these installations have been in place long enough to show the suitability of properly selected fabric to filter and drain water from soil. The Tennis Court slope has been in place for six and one-half years and continues to function well as do the others.

This type of underdrain has also been used to stabilize the track foundation in a Coal Mine.

The Design of Drainage Systems

Although properly selected fabric can filter and drain water from soil, the other components of the underdrain system also require consideration. The core, under pressure, must be capable of passing the water to the pipe, and the pipe must be large enough to carry the water away from the site. The hydraulics of the total system must be considered in the design.

Conclusions

Fabric, properly selected from filtration and hydraulic conductivity, can be an efficient component for removing water from soil. Requirements for selecting woven, non-woven and mats for this purpose have been presented. Woven fabrics are generally more suitable for a wide range of soils than the other fabrics.

Acknowledgement

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References

1. Sisson, D.R., "Envelope Materials: Their Use in Agricultural Drainage," Proceedings American Society of Agricultural Engineers, Drainage for Efficient Production Conference, Chicago, Ill. 1965.

2. Schwab, G.A., De Boer, D.W. and Johnson, H.P., "Effect of Openings on Design of Subsurface Drains," Proceedings American Society of Civil Engineers, Journal of Irrigation and Drainage Division, Vol. 95, No. IR1, Mar. 1969, pg. 199.

3. Casagrande, A., "Control of Seepage Through Foundations and Abutments of Dams," Geotechnique, Vol. XI, 1961, pg. 161.

4. Ogink, H.J.M., Investigations on the Hydraulic Characteristics of Synthetic Fabrics, Delft Hydraulics Laboratory publication No. 146, May 1975.

5. Healy, K.A. and Long, R.P., "Prefabricated Subsurface Drains," Highway Research Record 360, 1971, pg. 57.

6. Healy, K.A. and Long, R.P., "Prefabricated Filter-Fin for Subsurface Drains," Proceedings American Society of Civil Engineers, Journal of the Irrigation and Drainage Division, Vol. 98, No. IR4, Dec. 1972, pg. 543.