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The Development of Fin Drains for Structure Drainage

Le développement des drains en épi pour le drainage des ouvrages

Fin drains, a combination of a plastic core and a synthetic fabric, are now becoming widely used in ground and structure drainage. The plastic core is required for its hydraulic conductivity and the surrounding fabric operates as a filter. Sometimes the combination is completed by including a plastic pipe. This paper examines their use as a replacement for conventional materials in structural drainage. The hydraulic conductivity and filtration properties of conventional drainage materials are reviewed briefly as a background to the technical demands placed on fin drains. Laboratory testing methods to examine the hydraulic flow and filtration properties of fin drains under varying conditions are presented. A limited number of fin drains are put forward together with their published specifications. Comment on fin drain applications is made with a view to illustrating the installation systems employed and to identify the advantages to be gained from using this type of structure drainage.

Les drains en épi des combinaisons d'une âme en plastique et d'un géotextile en fibres synthetiques, sont de plus en plus utilisés pour le drainage des structures et des terrains. La conductivité hydraulique necessite l'âme en plastique et le géotextile joue le rôle d'un filtre. Un tuyeau en plastique est parfois utilisé pour compléter l'ensemble. Cette communication examine l'exploi des drains en épi pour remplacer des materiaux conventionnels pour le drainage des structures. Le permeabilité et les propriétés de filtration des materiaux conventionnels sont examinées en bref comme fond aux exigences techniques aux drains en épi. Les essais de laboratoire examinent le débit d'eau et les propriétés filtrantes de ces drains sous des conditions variées sont presentés. Quelques-uns de ces drains sont presentés avec leurs propriétés publiées. Des applications sont décrite pour illustrer les systèmes de pose et pour montrer les avantages que ce type de drain peut offrir.

1 Introduction

In 1968 the US Joint Highway Research Advisory Council sponsored the development of a prefabricated underdrain system in the Civil Engineering Dept of the University of Connecticut. The object was to reduce or eliminate the problems associated with the use of conventional aggregate filters. The prefabricated system of a plastic core fitting into a slit plastic pipe and protected by synthetic fabric was described in detail by Healy and Long at the Paris Conference in 1977 (1). The current availability of a range of synthetic fin drains is evidence of the success of this American development.

This discussion limits itself to the drainage of structures, an application ideally suited to fin drains which offer:-

i a readily available material with known filtration and hydraulic flow properties;

ii easy installation, thereby offering construction economies;

iii a protection of any water proofing applied to the exterior of the structure.

The objectives of the paper are to identify the drainage and filtration requirements of structural drainage and to ascertain how well fin drains meet these demands.

There is a discussion of the testing of fin drains and their components as well as mention of a limited number of products and applications.

2 Hydrostatic Pressure Effect on Buried Structures

It is important to control the hydraulic activity within the backfill against buried structures. A rising water level due to seepage within the backfill can produce a hydrostatic pressure on the structure much greater than the active thrust exerted on the structure by the unsaturated soil alone (fig. 1). As a result it is important to reduce or eliminate water pressure by the provision of drainage. This drainage layer is normally placed immediately against the structure with a drainage outlet at the base either through weep holes in the structure or by means of a pipe or a combination of both.

Apart from reducing pressure such drainage will also prevent:-

i softening and subsequent loss of strength of cohesive material;

ii control water movement through fissures resulting from dry weather;

iii reduce or eliminate the pressure effect resulting from frost.

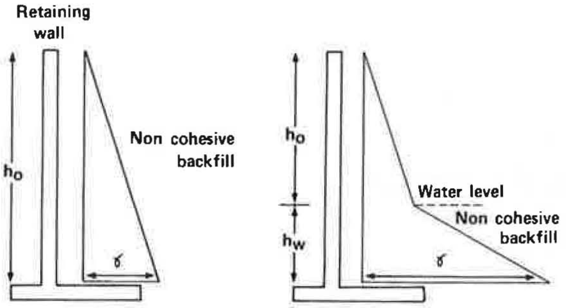


Fig. 1. EFFECT OF INCREASED WATER LEVEL ON EARTH RETAINING STRUCTURES.

Example - sand backfill, dry.

σ = Ka x γd x h
= 0.22 x 18 x h
when h = 10 m
= 39.6 kN/m^2

Example - sand backfill, partially saturated

= (Ka x γd x h_o) + (Ka_{sat} x γ_{sat} x h_w)
= (0.22 x 18 x h_o) + (1 x 27 x h_w)
when h_o = 7m and h_w = 3m
= 108.72 kN/m^2

3 Drainage Design Requirements

a Hydraulic conductivity

To provide an indication of the flow rates which might be expected for structural drainage, it is useful to examine some national examples and specifications.

United Kingdom

Two situations are examined using agricultural and urban drainage design criteria for a structure of 4 m height and a run off area of 4 m per lin metre of structure.

Agricultural drainage

Designs are based on M.A.F.F. recommendations (2), which uses 0.9 x rainfall at a specified probability. For this example the design rainfall relates to Buckinghamshire, which would occur over 5 consecutive days when the soil is already saturated and which is exceeded 10 times in 20 years. This rainfall would be 6 mm/day and therefore run off would be 5.4 mm/day. Total run off for this example would be 5.4 mm x 4 m resulting in 21.6 L/day m = 0.00025 L/s m.

Urban drainage

Assuming a storm subsequent to backfilling and prior to road surfacing and completion of positive surface drainage. A heavy rainfall at a rate of 50 mm/hour for a period of 5 minutes would result in a flow rate of 0.057 L/s m. (3)

West Germany

According to DIN 1185 agricultural drainage requires an uptake of 2 L/s hectare corresponding to a flow of 0.02 L/s m for a 100 m run off.

For dam construction (DIN 1184) to cope with water seepage a drainage standard on subgrades of low to very high permeabilities, varies from 0.01 to 0.05 L/s m respectively.

In DIN 4095, Drainage of subsoil for the protection of structures, no flow rates are quoted, but drainage materials are recommended, refer Fig. 2.

Sweden

The recommended drainage for buildings is 0.03 - 0.06 L/s m (4).

b Filtration

Having introduced a drainage system into a structure design, it is important to ensure it remains effective over the lifetime of the structure. Problems can arise if soil particles migrate into the drain leading to reduced flow and perhaps eventual blockage.

Soil is a structured mass of particles and movement of water can disturb the equilibrium, leading to soil instability. Dynamic seepage forces are capable of physically transporting particles. Migration increases as particle size decreases until cohesive forces bind together fine grained soils, eg clay. Well graded soils are more stable than uniform or gap graded materials. Adequate references are available to decide which soils cause filtration problems (5, 6). Broadly speaking particles in the range of fine sands to medium/coarse silts and where velocities are high enough to transport them can ultimately cause clogging.

Having decided a filter is necessary, design recommendations are available for conventional granular filters (7) which may have to be multi layer to be truly effective. An example of such a design quoted in DIN 4095 is shown (Fig 2).

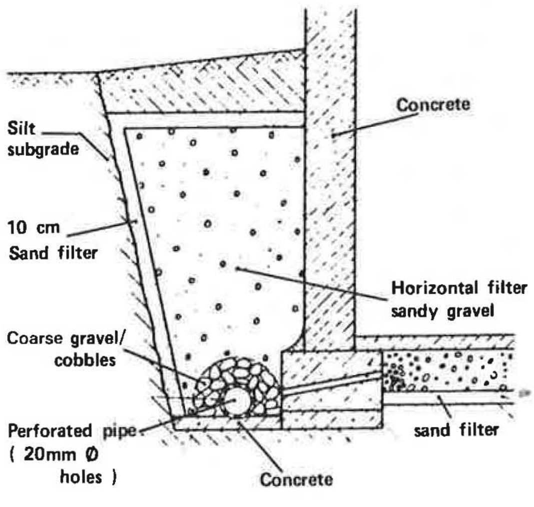


Fig. 2. EXAMPLE OF TWO STAGE FILTER DRAIN. Din 4095.

4 Conventional Structure Drainage Materials

To provide a background to fin drain property requirements it is useful to review materials which are currently being specified.

UK

The Dept of Transport specify the following permeable backing to earth retaining structures, (8).

i A minimum thickness of 300 mm of Type A material complying with Clause 505..

ii Porous no-fines concrete, cast in situ, 225 mm thick complying with the requirements of Clause 1617.

iii Precast porous concrete blocks complying with the requirements for Type B2.8 of BS 2028, 1364 laid in stretcher bond with dry joints in 225 mm thick walling.

iv When the filling adjacent to the structure is pulverised fuel ash, the permeable backing shall be a minimum thickness of 300 mm of sand with a grading within Zone 1 or 2 of Table 2, BS 882 or other approved material.

Measurements were taken on items i and iv using uncompacted materials from within the grading bands specified, using a soil/fabric permeameter (12). Mean results are shown in table 1. Items ii and iii offer higher permeabilities, but their filtration properties, particularly iii, cannot be specified.

materials should follow criteria established by Terzaghi.

5 Specification Parameters for Fin Drains in Structure Drainage

Fin drains must offer sufficient hydraulic conductivity to ensure there is no increase in pressure exerted by the soil (fig 1) and possess a filter which will ensure long term maintenance of drainage performance.

a Hydraulic Conductivity - vertical

With a knowledge of the permeability of the backfill/adjacent soil and rainfall intensity it is possible to calculate the flow required within the fin drain to avoid hydrostatic pressure building up in the backfill.

Most drainage demand next to the structure will exist when excavated material is used as backfill. Unless well compacted this backfill will have a higher pore volume than when in its original state and could be fissured. Eventually, the excavated material will return to its original condition resulting in backfill and adjacent soil having similar permeabilities. This situation, especially if the soil is not of high permeability will require an outlet for water against the structure leading to either pipe and/or weep holes at the base of the structure.

TABLE 1. PERMEABLE BACKING TO EARTH RETAINING STRUCTURES. (U.K.)

Material	Layer Thickness	Evaluation Method	Vertical Flow Capacity	Transverse Permeability	D_{50}	D_{10}
				(Gradient i = 1)		
	mm		L/s m	mm/s	mm	mm
Type A granular filter	300	Measured	0.21	0.7	2.2	0.4
		Specified	-	-	max 12.0 min 0.8	0.7 0.15
Zone 1 sand	300	Measured	0.12	0.4	1.2	0.2
		Specified	-	-	Zone 1 max 1.8 min 0.8	0.4 0.15
					Zone 2 max 1.0 min 0.45	0.3 0.15

W. Germany

DIN 4095 (Subsoil drainage for buildings) puts forward the following:-

i a granular filter of sandy gravel in silty sand soils;

ii as in i. but surrounded by a 10 cm layer of filter and in silty soils.

It recommends that the grading of these filter

If the backfill is of higher permeability than the adjacent soil, water will rapidly gravitate to the drainage outlet at the base as soon as it enters this more permeable zone. In this situation the demand on the fin drain is less critical which can be regarded as a reserve capacity to the permeable backfill.

Muth (9) puts forward drainage outflow rates (Fig 3) based on the two situations above.

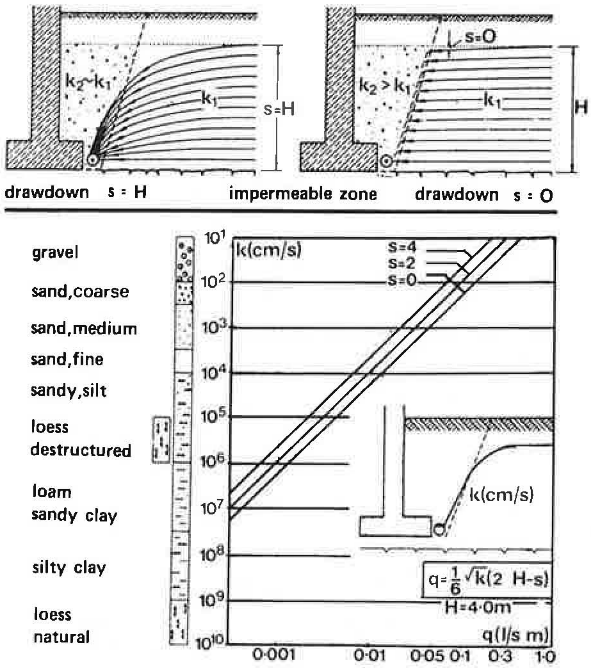


Fig. 3. DRAINAGE OUTFLOW DEPENDENT ON SOIL TYPE (MUTH).

b Hydraulic Conductivity - horizontal

Horizontal structural drainage, eg underground car parks, requires separate consideration due to the slight falls (3% - 10%) resulting in lower flow rates through the fin drain. Regular outflows into pipes are required to ensure the fin drain is emptied before it reaches full capacity.

It is important to place the fin drain on a flat base to ensure continual water flow and no ponding.

c Filtration

Considerable research has resulted in design criteria being drawn up for geotextile filters (13, 14, 15). Reference to these guidelines will enable a suitable choice of filter to be made. Knowing the particle size distribution of the backfill it is possible to choose a filter with suitable pore sizes to prevent excessive piping and with significantly higher permeability even under pressure, than that of the soil.

It is worth noting that soil is seldom a uniform homogenous material, but can be of the utmost variety with characteristics changing from natural to destructured state, from layer to layer and from one area to another. As a result filtration criteria rarely provide an exact solution, but form a useful guide.

d Compression

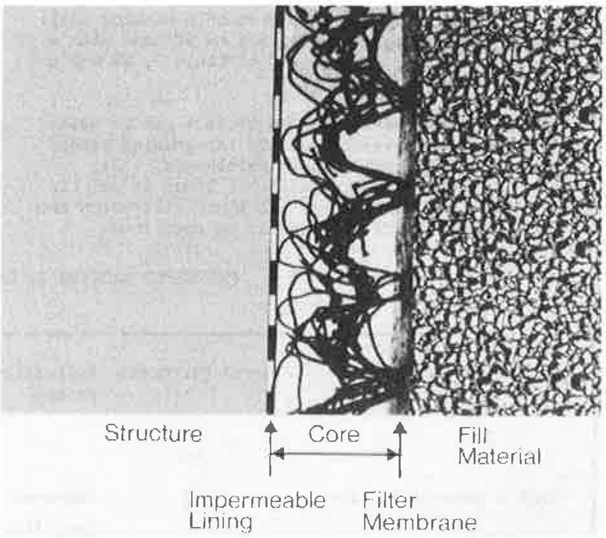
The depth at which a fin drain is installed will have a bearing on its performance, its hydraulic conductivity, and with thicker filters even its permeability being reduced as pressures increase.

Pressure on the drain will depend on the type of backfill, its compaction and moisture content. At 5 m depth backfill pressure will be in the region of 35 - 45 kN/m².

6 Examples of Fin Drains and their Properties

Enkadrain - manufactured by Enka BV, Netherlands.

Weight	- 750 g/m²
Thickness	- 20 mm
Filter	- Colback, non woven, heat bonded filaments comprising copolymers nylon 6/polyester
Core	- Nylon 6 monofilament
Roll Size	- 30 m x 1.0 m
Hydraulic Capacity	- Vertical

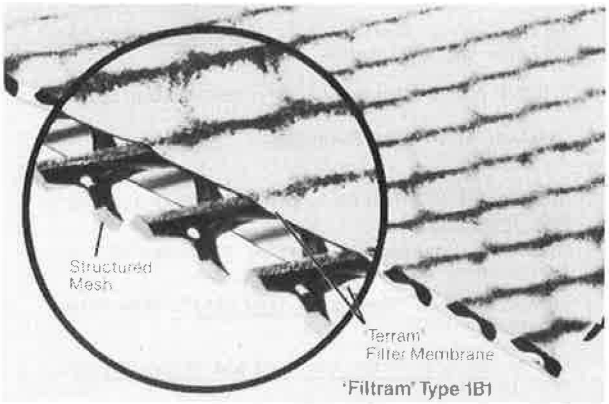


Pressure	Thickness	Installation Depth (sand)	Permeability	Hydraulic Flow (i=1)
kN/m²	mm	m	mm/s	L/s m
0	20	0	50.0	10.4
15	9	2.5	20.0	2.8
50	5	7.0	7.0	1.1

Information extracted from published literature.

Filtram - manufactured by ICI Fibres, UK.

Weight	- 980 g/m²
Thickness	- 4.5 mm
Filter Fabric	- 'Terram', non woven, heat bonded continuous filaments comprising polyethylene/polypropylene
Core	- Polyethylene
Roll Size	- 25 m x 1.6 m
Hydraulic Capacity	- Vertical



Pressure	Thickness	Installation Depth (sand)	Hydraulic flow (i = 1)
kN/m^2	mm	m	L/s m
0	4.5	0	0.5
50	4.3	7	0.48
100	4.1	15	0.4

Filter (quality 1B1)

Permeability (100 mm head) - 36 L/s m^2
Pore size O_{90} - 0.11 mm
O_{50} - 0.07 mm

Eljen - available from Eljen Development Corporation, USA, and comprises:-

i a flexible dimpled styrene sheet providing channels each side of 3 mm depth, sheets normally 3 m x 1.5 m;

ii a non woven thin polypropylene filter fabric;

iii a perforated plastic pipe (100 mm) inserted along the base of each section.

For lengths less than 15 m in sand and 60 m in clay the core has sufficient hydraulic conductivity to obviate the need for a pipe.

Maximum hydraulic efficiency is unimpaired providing installations do not exceed 12 m, quoting a perpendicular pressure of 95.8 kN/m^2.

Hydraulic capacity (i = 1)

0.43 L/s m 95.8 kN/m^2

Filter

Thickness $<$ 1.0 mm
Open Area $>$ 10%
Max. pore size $\not>$ 0.8 mm
$<$ 10% of the holes $>$ 0.2 mm
permeability - (50 mm head) - 30 mm/s

Information extracted from published literature.

7 Laboratory Testing Methods for Fin Drains

a Hydraulic flow

Extensive testing (9) has been undertaken in West Germany on a variety of synthetic drainage systems. One piece of testing apparatus (fig 9) consists of a wave tank with the sample under test providing a horizontal hydraulic flow path. A normal pressure can be applied to the sample. If required a particle layer can be incorporated which under compression simulates soil pressure in the filter surface.

ICI use a similar horizontal planar flow test and is developing a vertical flow apparatus.

b Filtration

To ensure the filter component of the fin drain has adequate permeability and filtration properties in relation to that of the adjacent soil a range of tests have been developed.

The filter permeability must be higher than that of the soil to ensure no build up of hydrostatic pressure. It can be argued that to quote a K value for a very thin fabric ($<$ 1 mm thickness) is hardly appropriate when in reality such a value refers to flow through a mass (soil). It is more useful to determine the flow rate through the fabric. To this end the ASTM is drawing up a geotextile permittivity testing method to measure flow rates. Other permeability tests have been developed by (11) and ICI.

With regard to filtration properties the pore size distribution of the filter must be known to ensure compatibility between the fabric and adjacent soil. Wet (10, 11) and dry (ICI) using static eliminators have been developed.

Apparatus is available to test the soil/fabric system. The ICI method has been reported (12) and measures the flow of the system over a period at a defined hydraulic gradient. Modifications now enable the measurement of piping to be made.

c Compression

As detailed (9) compression representing soil pressure can be applied to the fin drain during hydraulic flow testing.

Any dry test must simulate the effect of soil pressure on the filter and must be capable of identifying the remaining core space available for water conductivity. Ideally subsequent calculations must take into account the nature of the water flow at varying gradients.

8 Comment on Fin Drain Installations

A Underground Structures

A buried structure requires external waterproofing protection and an exterior drainage layer. Frequently this waterproofing is an impermeable membrane onto which a stone drainage layer has to be placed. The membrane will require protection especially during the construction period. Conventionally the drainage layer will be loose or cement bound gravel. A gravel layer on an underground roof increases the weight on the structure, which has to be taken into account in the design.

A fin drain overcomes these problems. It provides a protection for the waterproofing membrane. It obviates the need for shuttering to contain any sloping or vertical stone layer. Its lightweight is an advan-

-tage in reducing the roof loading. To this list one must add the advantages relating to handling and installation time.

B Bridge Abutments and Retaining Walls

In the UK the normal drainage layer behind abutments comprises porous concrete blocks or, when filling with PFA, a 300 mm wide layer of sand (refer section 4). The transport and handling onto site can be expensive and time consuming; their installation is equally labour intensive and costly. Likewise a sand layer poses constructional problems.

A fin drain is an attractive alternative in that it is a lightweight drainage system available in roll form. Designers recognise the advantage of being able to specify a product, which is not subject to any local limitations of material supply.

The fin drain has to be held in place prior to backfilling. Installation systems vary from suspending the material loosely from the top of the structure to using adhesive or nailing methods.

Jointing of fin drains is normally undertaken by overlapping the filter material onto the adjoining sheet. Some products are provided with a 10 - 15 cm overlap along one edge.

C Pipe Connections

The pipes used with fin drains are often plastic in keeping with the character of this drainage system ie being light in weight and easy to handle. With thin fin drains an integrated system is possible with the fin drain being inserted into a slit pipe. Another form of integration is to continue the filter fabric protecting the drainage core around a perforated or porous pipe thereby preventing contamination. Three design systems are shown below. (Fig 4)

9 Conclusion

From this brief review it can be seen that fin drains are capable of meeting the demands of structure drainage. Where conventional material possesses high hydraulic conductivity it generally lacks specific filtration properties. Fin drains are also versatile and can be modified to meet specific requirements. Being cheap to transport and internationally available they offer designers the opportunity to specify material which do not pose local site problems of availability.

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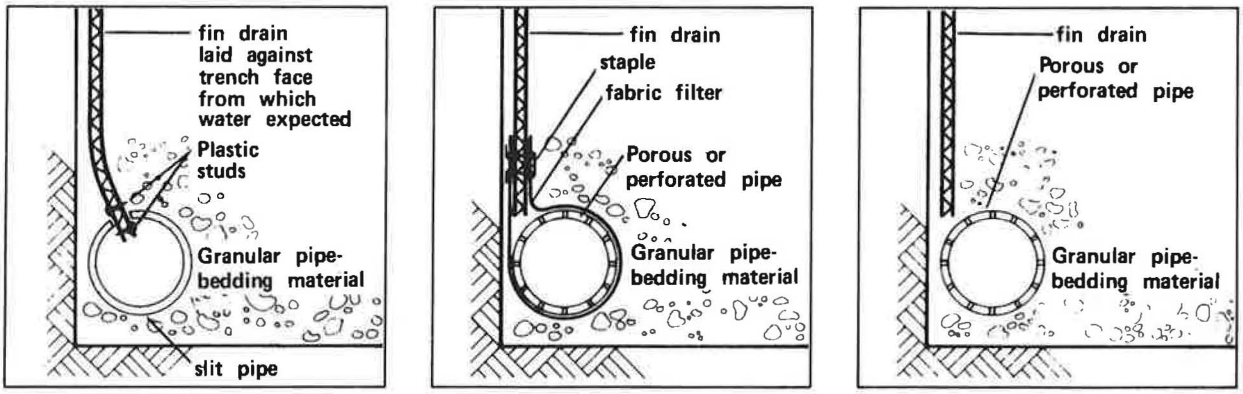

Fig. 4. EXAMPLES OF FIN DRAIN / PIPE COMBINATIONS.