

## **The use of geosynthetics as vertical drainage screens in road construction**

## **Utilisation d'écrans drainants verticaux en géotextiles dans la construction de routes**

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**ABSTRACT.** Road maintenance works today often hold up the flow of traffic to an unacceptable extent. Poor drainage of the subbase may contribute to such problems by causing damage to the pavement. The paper describes a solution for waterlogged subbases using edge drains made with geosynthetic drainage screens to replace the classical mineral drains. Additionally, geosynthetic drains of this kind may solve other problems in road construction, such as instability in drainage ditches and roadside embankments. With the objective of testing official directives on the re-use of lightly contaminated minerals such as re-cycled asphalt containing tar in newly constructed road bases, the Dutch government has commissioned the construction of the building of several pilot road sections incorporating vertical drainage screens. These screens serve to intercept and divert the flow of water in the soil, so that no pollutants are washed out of the recycled materials used in construction.

**RÉSUMÉ.** Le présent article explique comment le remplacement des drains minéraux classiques par des écrans drainants en géotextiles posés en rive de chaussée peut résoudre les problèmes engendrés par la saturation en eau de la couche de forme. Ce type d'écran est également capable de résoudre d'autres problèmes rencontrés dans la construction de routes, tels que l'instabilité des pentes des fossés de drainage et des talus. Dans le but de tester ses directives concernant la réutilisation dans la couche de forme des nouvelles routes de minéraux légèrement contaminés, tels que le macadam recyclé contenant du goudron, le gouvernement néerlandais a commandité la construction de plusieurs sections de route pilotes incorporant des écrans de drainage verticaux. Ces derniers servent à intercepter et à dévier l'écoulement de l'eau dans le sol afin qu'aucun polluant ne soit libéré des matériaux recyclés utilisés dans la construction.

## 1. Definition of a vertical drainage screen

The vertical drainage screens in question were introduced in the UK in the early seventies under the trade name Findrain. This has almost become the generic designation for unsupported flat drainage screens -- not supported by any structure such as a wall, that is.

The depth of the screens is limited to about 2 m. The screen is a composite consisting of a flat core that takes care of the vertical drainage transportation to a pipe that then carries the water to specific points from which it is discharged to open watercourses. Both core and pipe are wholly enclosed in a geotextile filter which prevents the ingress of silt particles. In cross-section, the system is suggestive of the fin of a fish, hence the name Findrain (see Figure 1).

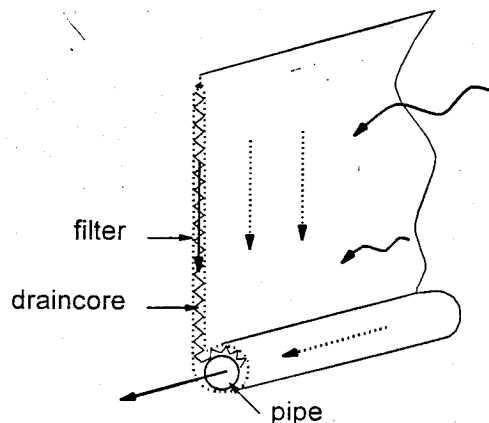


Figure 1: "Findrain" type of draincomposite

Initially the drain was chiefly used as edge drain along roads, as a substitute for the so-called French drain: an excavation filled with granular filter material which may (but need not) be enveloped in a geotextile. Today, Findrain has a broader range of applications.

## 2. Findrain applications

Current uses of Findrain in road construction include:

- Edge drain skirting paved roads.

- Drainage screens in roadside drain ditch slopes.
- Drainage screen in high road embankments.
- Groundwater deflection screen for use with road bases constructed in lightly contaminated building materials.

The following sections will comment in some detail on each of these uses.

### 2.1 Edge drain skirting paved roads

Water in a road base reduces bearing capacity and can have disastrous effects. Road traffic causes dynamic loads that transmit a pumping impulse on the water under the pavement. This results in erosion of the road base, followed by damage to the pavement. Figure 2 illustrates that water has many ways of penetrating the road base:

- Through the asphalt itself, especially when it is cracked
- Direct through the verges or by way of the verges from higher road embankments
- By capillary action of the groundwater
- By a rise in the water table
- By rising water vapour followed by condensation

Of these water movements, (a) and (b) can be intercepted and deflected away from the road base by means of synthetic drainage screens installed alongside the road. Figure 3 shows a typical design of the kind included in the Highway Construction Details of the UK Department of Transport. In this design, the drainage screen has the sole purpose of catching and diverting the water that has penetrated the road base through the pavement. Where the shoulder is higher than the pavement, water from the verge can also flow to the screen and in this case the drain's action is double-sided.

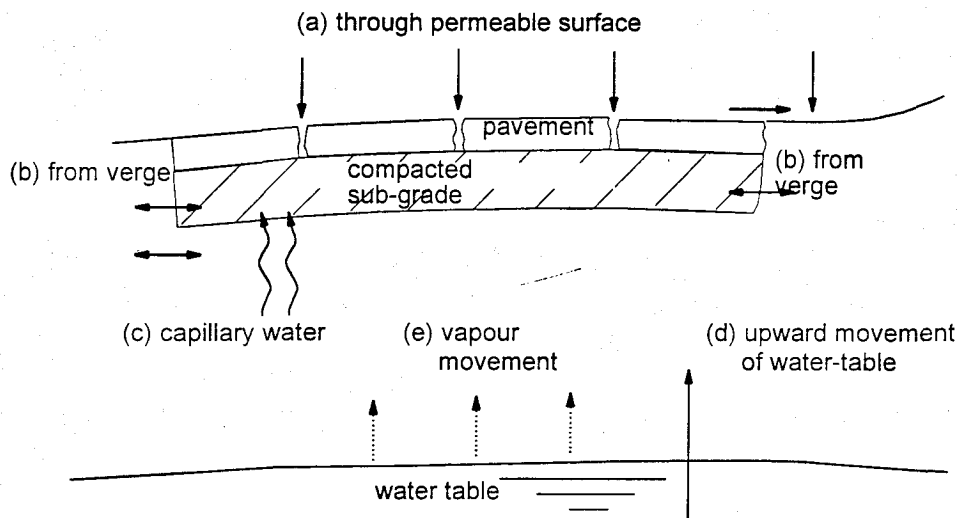


Figure 2: Watermovement in a road structure

## 2.2 Drainage screens in watercourse side slopes

Water under pressure in the banks of a watercourse reduces soil cohesion and may well result in slope instability. The seepage can furthermore entrain soil particles, thereby further reducing stability (Figure 4).

The screen reduces water pressure and by the same token increases slope stability. The water intercepted by the screen is run to the ditch by way of pipes placed at right angles to the screen.

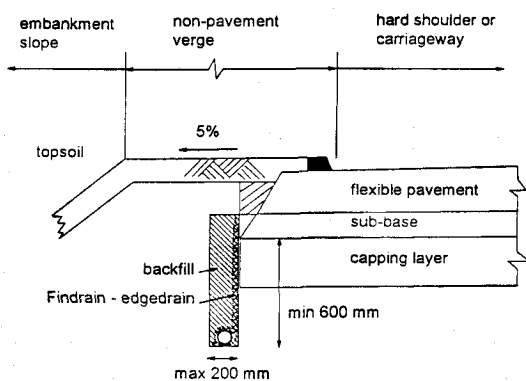


Figure 3: Findrain in a typical edgedrainage construction

This situation is typical for drainage ditches skirting lowland and polder motorways. Installation of a drainage screen some 0.5 m away from the slope line will intercept the groundwater before it can enter the critical part of the slope where the counteracting soil pressure is absent.

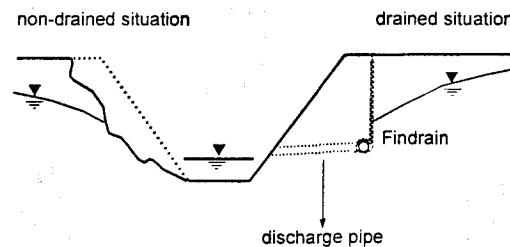


Figure 4: Drainage of sides of ditches

### 2.3 Drainage screens in high roadside embankments

The sort of instability problem encountered in ditch slopes can also occur in embankments. Roads constructed in hilly or undulating country may be blocked by the occasional shallow landslide set off by pressurised water in embankments of varying steepness and with varying degrees of plant cover. Superficial, non-circular slips can be prevented by installation of vertical drainage screens to intercept the water (see Figure 5).

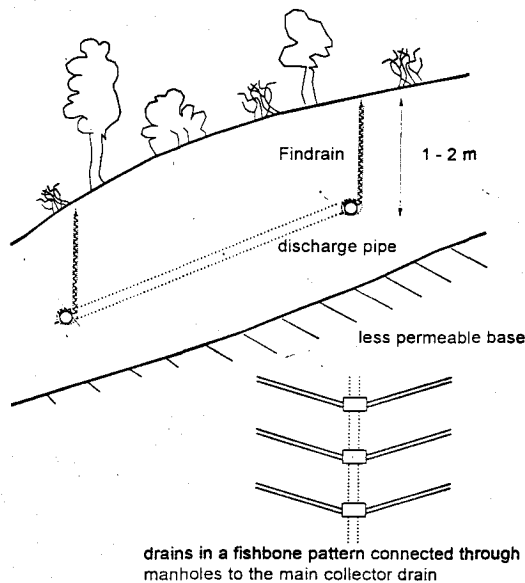


Figure 5: Sub-surface drain screens in long slopes

### 2.4 Findrain as an isolation screen for road bases built in lightly contaminated materials

The Dutch government has formulated directives for the re-use of so-called secondary materials. Such secondary materials typically include recycled tar-containing asphalt granulate. The directives cover specifications, recommendations, and standard uses.

Secondary materials may be used in raising ground (whether prior to construction works or not), filling in holes and depressions, and creating layers that will absorb and distribute loads (as in road and railway construction). To test the validity of the directives with regard to the standard uses listed therein, trial sections have been installed over the past few years in a variety of road construction projects.

The basic principle in the use of secondary materials is that the material needs to be isolated from infiltration by water and hence from the leaching out and transport of harmful substances. One standard use described in the directives is for the isolation of tar-containing asphalt in a road base.

The pavement, which is specified to be either asphaltic or cement concrete, isolates the road base from the top. The isolation from the sides is provided by a Findrain screen (Figure 6).

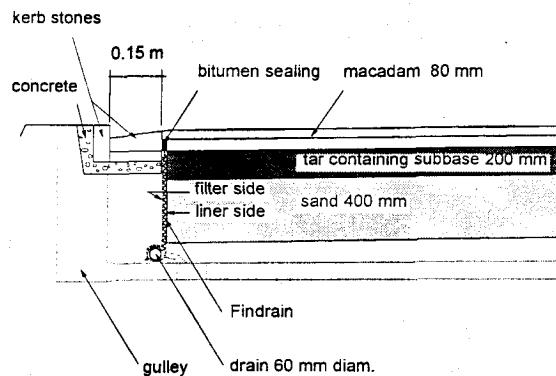


Figure 6: Isolation of subbase layer of recycled tar-containing macadam containing tar

For this particular application the side of the screen that faces the subbase is lined with a watertight film. This makes for better isolation from groundwater flows in the base material. The surface run-off from the road is carried by a gutter, which is placed on the outside of the Findrain screen. Where the pavement and the gutter abut, the joint is sealed with a bituminous paste.

Alternative options to the Findrain drain-and-shield system are impermeable screens and bentonite shields. These alternatives have the drawback that they stop water but do not carry it. They therefore have to meet higher specifications seeing that the water pressure on the barrier can become quite high.

### 3. Findrain engineering specifications

#### 3.1 Mechanical properties

The mechanical properties are chiefly a factor during installation. As regards tensile strength, it makes a difference whether the Findrain is installed manually or by machine.

In machine installation, friction in the laying machine and especially in the 'box' or sheet guide will produce a tension in the product, so that a certain minimum strength of the product and of any joints is required.

Which mode of installation is chosen depends first of all on the stability of the soil. Where the soil is unstable, machine installation is the better option. And where stability is sufficient, project size and the number of discontinuities for manholes and gulleys are further factors in weighing the utility and efficiency of bringing in large machinery.

The gulleys serve to receive the water carried by the pipe in the Findrain system and discharge it to open water. The number of such gulleys is often determined by the gradient of the ground. The drain filter needs to feature a certain resistance to puncturing by stones. It is customary to backfill the trenches dug for the drains with the excavated material.

Under the constant pressure of the soil, the filter may gradually be pushed into the drain core, thereby reducing the drain's carrying capacity.

Nonwoven filters with a high modulus of elasticity -- i.e. a high stress/strain ratio -- are less vulnerable in this regard than are mechanically bonded filters. The effect of soil intrusion is also dependent on the drain core configuration.

In the applications described in the foregoing, filters of the following specifications have been fully satisfactory:

- Tensile strength  $\geq 5$  kN/m
- Strength at 5% elongation  $\geq 2.5$  kN/m
- Elongation at break  $\geq 30\%$
- Puncture resistance  $\geq 1$  kN

#### 3.2 Hydraulic properties

The principal hydraulic specifications applying to Findrain are:

*for the drain* core adequate capacity

*for the filter* ability to stop ingress of soil without compromising permeability

*for the drain* pipe adequate capacity.

##### 3.2.1 Drain core

While the capacity required of the drain core is project-specific, it is possible to give an approximate value. Installation of edge drains is functional only in soils that inherently possess insufficient drainage capacity.

Sandy soils with a permeability (expressed in terms of the permeability coefficient  $K_S$ ) of  $K_S \geq 10^{-5}$  m/s drain well enough without assistance. Only when the silt percentage increases and  $K_S \leq 10^{-5}$  m/s do additional drainage measures become necessary.

An exception is when only the subbase needs to be drained, as in the edge drain application described in 2.1, than the value of  $K_S$  for the subbase could exceed  $10^{-5}$  m/s. Here the Findrain takes care of the direct discharge and avoids any build-up of hydrostatic pressure in the subbase. Theoretically, such well-draining material could present a large amount of water to the edge drain but in fact very little water passes through the pavement.

The drain only is expected to provide a conduit for the water that the soil presents to it. It cannot absorb flooding, given the fact that open area at the top is too small for this purpose.

The water flow ( $Q_A$ ) to the drain, in cubic metres per metre of length, can therefore be calculated from the formula:

$$Q_A = \{(K_{s1} \times i_1) + (K_{s2} \times i_2)\} h \quad (1)$$

m<sup>3</sup>/s per m

where:

$K_{s1,2}$  = Soil permeability coefficients both sides the drain, in m/s

$i_{1,2}$  = Hydraulic gradient both sides the drain

$h$  = vertical dimension of drain screen, in m

As indicated above,  $K_s$  will be lower than  $10^{-5}$  m/s in most cases. The vertical dimension ( $h$ ) of the screens is usually 1 m and rarely > 2 m. The hydraulic gradient ( $i$ ) is rather more elusive. For an order of magnitude calculation,  $i=1$  may be assumed, but in drainage screens in high road embankments the value of  $i$  may well exceed unity.

The volume of water ( $Q_A$ ) absorbed by the vertical drain will flow into the pipe at the foot of the screen under the acting soil pressure. When  $h \leq 2$  m, the load on the screen during compaction will be much higher than the as-installed static load. However Findrains are often used in situations where correct compaction of the backfill is not possible.

The static load acting on the vertical screen is:

$$e_a = \gamma \times K_a \times h \quad \text{kN/m}^2 \quad (2)$$

where:

$e_a$  = active earth pressure, in kN/m<sup>2</sup>

$\gamma$  = soil density, in kN/m<sup>3</sup>

$K_a$  = coefficient of active earth pressure

$h$  = vertical dimension of the screen, in m

The  $K_a$  of the silt-containing soils in question is 0.3 to 0.4, and the maximum value of  $\gamma$  is 20 kN/m<sup>3</sup>. For a 2m high screen, the static load will therefore be approximately 15 kN/m<sup>2</sup>.

Assuming the use of a circular or rectangular vibrating compaction plate, the vertical dynamic load  $\sigma_z$  is 70-80 kN/m<sup>2</sup> (Converse). In these circumstances, the horizontal load acting on the screen is:

$$\sigma_h = K_a \times \sigma_z \quad \text{kN/m}^2 \quad (3)$$

where:

$\sigma_h$  = horizontal load, in kN/m<sup>2</sup>

$K_a$  = coefficient of active soil pressure (0.3 - 0.4)

$\sigma_z$  = dynamic load (70 - 80 kN/m<sup>2</sup>)

The maximum load generated by this compaction is 35 kN/m<sup>2</sup>.

Depending on the recovery capacity of the drain core, the volume of water  $Q_A$  computed by (1) that has to be discharged will have to be absorbed under a pressure on the drain of 35 kN/m<sup>2</sup>. The position of the screen is vertical, and the hydraulic gradient ( $i$ ) inside the screen is therefore 1. The capacity  $Q_D$  of the drain can be determined in accordance with prEN ISO 12958. As soil pressure on the screen is exerted from both sides, the measurement needs to be performed with the drain sandwiched in between two deformable foam layers, serving to simulate soil pressure.

The required drain capacity (in m<sup>3</sup>/s per linear metre of drain) can therefore be calculated as follows:

$$Q_{D(p, i)} \geq f_s \times Q_a \quad \text{m}^3/\text{s.m} \quad (4)$$

where:

$Q_{D(p, i)}$  = required drainage capacity (in m<sup>3</sup>/s.m) to be measured in accordance with ISO 12958 for the specified pressure  $p$  and  $i = 1$

$f_s$  = safety factor covering long-term behaviour and other conditions

$Q_a$  = water flow to the screen (in m<sup>3</sup>/s.m)

### 3.2.2 Filter

Like the permeability of the soil, that of a synthetic non-woven filter is expressed in a permeability coefficient  $K_g$ .

For a the large majority of products, the approximate value of  $K_g = 10^{-3}$  m/s. As we saw in 3.2.1, the soils to be filtered have  $K_s \leq 10^{-5}$  m/s. It follows that most filters are roughly one hundred times more permeable than the contiguous soil, so that few (if any) problems can arise.

The soil retaining capacity of geotextile filters in Findrain applications was investigated in field tests by Maunsell and Partners under a commission from the UK Department of Transport, and the results were placed on record in TRRL Report 221.

The report recommends a filter opening in terms of the  $O_{90}$  value (EN ISO 12956) of 0.1 mm to 0.3 mm. Many countries have issued national directives stating rules for filters.

### 3.2.3 Drain pipe

The choice of drain pipe can be made based on the required carrying capacity (in  $m^3/s$ ) calculated from the formula:

$$Q_p = L \times Q_a \times f_s \quad m^3/s \quad (5)$$

where:

$Q_p$  = carrying capacity of the drain pipe, in  $m^3/s$

$L$  = required distance between gulleys, in m

$Q_a$  = water flow to the screen calculated from Eqn (1), in  $m^3/s.m$

$f_s$  = safety factor covering long-term behaviour and other conditions.

Distance  $L$  is determined per project, depending on the hydraulic gradient.

The manufacturers diagrams showing capacity in relation to hydraulic gradient permit selection of type and diameter of drain pipe.

## 4. Conclusions

Geosynthetic drainage screens (Findrains) have found broad application in road construction to solve subsurface drainage problems. They have been demonstrated to be at least equivalent to the mineral drains they replace.

## 5. References

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