DRILL DRAIN®

The horizontal drilled drainage

- Control of slope seepage water
- Retaining wall without hydrostatic pressure
- Retention of positive soil properties
- Reduction of pore water pressure
- No ice pressure during periods of freezing
- Retention of cohesion
- Retention of internal friction \( \varphi \)
DRILL DRAIN® – The underlying concept
The new drainage system consists of the well established directly drilled soil nail (or TITAN pressure grouted anchor to DIN 14199) and a grout body made from a filter material which has a permeability coefficient of $k_f = 10^{-4}$ m/s to DIN 18130.

To fully understand the concept it is worth considering the three phase soil model, where soil is considered to consist of water, air and solid particles. A soil can be classified as gravel, sand, silt or clay, depending on its particle size. The pores in the soil can fill with water and air and account for approximately 30 – 50% of the volume. The air trapped within the pores of a soil is compressible and this explains the dynamic behaviour of water saturated soils when they are subjected to surcharge, vibration, liquefaction etc. The installation of DRILL DRAIN® allows the dynamic behaviour of the soil to be altered.

Where precipitation does not seep into deeper strata quick enough, the infiltration rate through a stratum with low permeability (for example $k_f = 10^{-7}$ m/s) is reduced leading to water building up. Such a build up of water is always at a higher level than that of the natural water table (piezometric line) and can cause soil movement due to changes in soil parameters.

DRILL DRAIN® is a directly drilled drain (inclination $>10^\circ$ upwards), reinforced with a hollow steel tendon. The filter material is pressure injected into the holes enabling the excess water to be drained away, thus reducing the increased pore water pressures. Piezometers can be used to verify the reduction and monitor the pore water pressures.

### Allocation of permeability coefficient $k_f$ to various soils according to DIN 18130

<table>
<thead>
<tr>
<th>Soil</th>
<th>Permeability $k_f$ (m/s)</th>
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</thead>
<tbody>
<tr>
<td>Gravel</td>
<td>$1 \times 10^0$</td>
</tr>
<tr>
<td>Sandy gravel</td>
<td>$2 \times 10^{-2} \div 10^{-4}$</td>
</tr>
<tr>
<td>Sand</td>
<td>$1 \times 10^{-2} \div 10^{-5}$</td>
</tr>
<tr>
<td>Silty sand</td>
<td>$5 \times 10^{-5} \div 10^{-7}$</td>
</tr>
<tr>
<td>Silt</td>
<td>$5 \times 10^{-6} \div 10^{-8}$</td>
</tr>
<tr>
<td>Clay</td>
<td>$1 \times 10^{-8} \div 10^{-10}$</td>
</tr>
</tbody>
</table>

### Classification of permeability to DIN 18130

<table>
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<tr>
<th>Classification</th>
<th>Permeability $k_f$ (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>very high permeability</td>
<td>$&lt; 1 \times 10^{-2}$</td>
</tr>
<tr>
<td>high permeability</td>
<td>$10^{-4} &lt; k_f &lt; 10^{-2}$</td>
</tr>
<tr>
<td>moderate permeability</td>
<td>$10^{-6} &lt; k_f &lt; 10^{-4}$</td>
</tr>
<tr>
<td>low permeability</td>
<td>$10^{-6} &lt; k_f &lt; 10^{-8}$</td>
</tr>
<tr>
<td>very low permeability</td>
<td>$&lt; 1 \times 10^{-8}$</td>
</tr>
</tbody>
</table>

Temperature has a great influence on permeability. Therefore, a reference temperature of $10^\circ$C is adopted for soil tests, as this is the average for ground water temperature. The permeability values measured are always related to $k_f$ values.

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DRILL DRAIN® – the filter material

![DRILL DRAIN® grout (finished)](image1)
![Filter material viewed via the microscope, 10x magnification](image2)
![Granular DRILL DRAIN® grout](image3)
This project involved the construction of a nailed wall and required slope drainage between October 2007 and May 2008. The photographs of the wall show that after a period of dry weather, the drainages towards the base of the wall are active. We can therefore conclude that the slope seepage water had dropped to a relatively low level. After the first snowfalls the drainages located higher up the wall also became active. These higher drainages are intercepting the slope seepage water, not allowing the water to infiltrate any lower. This project is an impressive example confirming the function of the drainages.

**DRILL DRAIN® – simple installation**

1. Drill with Drill-Suspension for bore hole stabilisation (if necessary).
   - Drill upwards (≥ 10°).
   - Mix ratio Drill-Suspension to Water 1:50
2. Inject TITAN DRILL DRAIN Grout (filter material) through hollow bar TITAN 40/27.
   - Mix ratio DRILL DRAIN Grout to water 2:1

**DRILL DRAIN® – application 1**

Kappl, Tyrol.

Mixing on site: 2 parts filter material to 1 part water

Injecting the filter material

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October 2007

November 2007

May 2008
DRILL DRAIN® – controlling slope seepage water

Slope situation without drainage
Slope seepage water flows through soil to retaining wall and exerts pressure on this

Retaining wall without weepholes
Without drainage, the slope seepage water would build up behind the retaining wall and hence generate hydrostatic pressure. As this pressure would subject the wall to extreme stresses, this situation must be avoided at all costs. Drilling weepholes through the sprayed concrete wall is the conventional way of relieving the hydrostatic pressure.

Use of conventional weepholes
Slope seepage water flows through soil to retaining wall and is drained away through weepholes

Retaining wall with weepholes
The slope seepage water continues to flow uncontrolled down to the retaining wall and can have an unfavourable influence on the soil and the wall. In winter the water can freeze down to the depth affected by frost and thus close off the weepholes. Once the holes are blocked by ice, the hydrostatic pressure can build up slowly and exert a much higher load on the wall than was originally envisaged.

Use of DRILL DRAIN®
Slope seepage water no longer flows through soil behind retaining wall

Retaining wall with DRILL DRAIN®
DRILL DRAIN® intercepts the slope seepage water deep behind the retaining wall. DRILL DRAIN® prevents the slope seepage water from even approaching the wall. Consequently, a moist area behind the wall is guaranteed. The soil parameters are no longer affected by a build-up of slope seepage water.
DRILL DRAIN® – application 2
Embankment with an ancient slip plane.

Piezometers and inclinometers were used to monitor and measure the effectiveness of the DRILL DRAIN®.
This was a joint research project, entitled “Stabilisation of river dykes at risk of failure with reinforcement and elements for draining percolating water”. The research was carried out by the University of Karlsruhe (Institute of Soil and Rock Mechanics), the University of Kassel (Professor Dr.-Ing. Kempfert of the Institute of Geotechnics) and Saxony Textile Research Institute (STFI) in Chemnitz. The aim of the research project was to establish how existing dykes can be upgraded for the short and medium term, with minimal cost and construction work. Another important requirement was the short term emergency protection in the event of flooding. Besides proving the principle of stabilising old dykes, at risk of failure, with reinforcement and drainage of percolating water, the project needed to the practical viability. The plan is to install drainage elements in to saturated dykes, to enable the build up of water at the base of the dyke to be intercepted and thus preventing failure.

DRILL DRAIN® – example of a practical application
Cutting embankment, France (section)
Standard specification for horizontal drilled drainage

Drilled drains for deep drainage consist of a filter material with a single grain size of 1 mm.

The permeability of the filter material is \( k = 10^{-4} \) to \( 10^{-3} \) m/s in accordance with DIN 18130. The filter material is injected through a disposable drilling rod, (which has a min. internal diameter of 25 mm), to a sacrificial drill bit (typically 90 mm in diameter) were the material is emitted.

<table>
<thead>
<tr>
<th>Filter material</th>
<th>e. g. Ischebeck DRILL DRAIN®</th>
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<tbody>
<tr>
<td>Drain length</td>
<td>10 m</td>
</tr>
<tr>
<td>Drain inclination</td>
<td>10° upwards</td>
</tr>
</tbody>
</table>

The stability of the drill hole is dependent on the soil conditions and is maintained by pressure grouting of the void with the filter material, until the return flows from the top of the drill hole.

The maximum allowable distance between drainage hole and mixing station is 35 m. A construction/drilling log should be compiled for every drilled drain. A filter material consumption of 3 kg/m should be allowed for.

DRILL DRAIN® – summary

The new Euronorm pr EN14490 for the first time brings both soil nailing and drainage into a single set of construction guidelines.

Prior to this there was very limited information on procedures for the drainage of critical earth slopes. Commonly, expensive dewatering or relief wells, typically 150 mm in diameter by 30 m in length were installed down to impermeable stratum. With varying strata it was difficult to find a filter pipe with sufficient filter resistance and filter stability. In addition migration, erosion, liquefaction in fine grained soils were unavoidable risks.

The new DRILL DRAIN® has been used successfully on a number of projects. The system is built around the long established directly bored TITAN 40/27 soil nail and a grout body of filter material that is highly permeable to water and air.

The maximum allowable distance between drainage hole and mixing station is 35 m. A construction/drilling log should be compiled for every drilled drain. A filter material consumption of 3 kg/m should be allowed for.
Refurbishment of an anchored timber retaining wall carried out by contractor HTB, Innsbruck, using DRILL DRAIN® with TITAN 40/27 injection soil nail.

DIN EN ISO 9001

Your contact for further information: