Groundwater Drainage:

Geocomposites vs. Gravel

Technical Note

Introduction

The practical difficulties along with the environmental and monetary costs of obtaining and placing drainage gravel are well-known. Recognition of the inadequacies of the traditional methods and the increasing use of geotextiles as filters led to the development of drainage geocomposites. These geocomposites have been an accepted form of drainage in a range of civil engineering applications for over 35 years and are now available in a variety of forms. This document discusses how water flow rates are assessed in both drainage gravel and drainage geocomposites.

Groundwater Drainage Applications

Groundwater drainage applications are wide ranging including vertical (e.g. drainage behind a retaining wall or basement), horizontal (e.g. drainage on a podium deck), and various sloped situations (e.g. drainage systems within landfills or ground dewatering systems). The flow capacity of a granular drainage layer depends on its size (cross sectional area), the hydraulic gradient, the permeability of the drainage medium, and, in the case of drainage geocomposites, the confining pressure.

Groundwater flow in Drainage Gravel

The defining properties specified for a granular drainage layer are its size (cross sectional area) and the permeability of the granular material.

Permeability of Granular Material

The permeability (k) of granular materials is typically measured in a laboratory and is reported as a value in m/s. Typical values of permeability for commonly used drainage gravels are shown in Table 1.

Table 1: Permeability of Typical Drainage Gravel

Name	Description	Permeability, k (m/s)
Type B Filter Stone (highest permeability)	Quarried, graded stone in accordance with UK DTp SHW Series 500.	1×10^{-1}
Type A Filter Stone / Class 6C Stone	Quarried, graded stone in accordance with UK DTp SHW Series 500 (Type A Filter Stone), or Series 600 (Class 6C Stone).	5×10^{-2}
Coarse, clean gravel	Gravel with particle sizes typically 2-20mm. Zero fines.	$(5 \text{ to } 25) \times 10^{-3}$
Low fines sandy gravel	Sandy gravel with particle sizes typically 0.1-20mm. Less than 5% fines.	$(1 \text{ to } 5) \times 10^{-3}$
Sandy gravel	Sandy gravel with particle sizes typically 0.1-20mm.	10^{-3} to 10^{-5}
Sand (lowest permeability)	Sand with particle sizes typically 0.06-2.0mm.	10^{-4} to 10^{-6}

Notes:

1. The permeability values have been assessed based on laboratory tests on freshly quarried stone and samples taken from site. They are an estimate of typical values and should not be relied upon for design. Site-specific testing is strongly recommended along with flow-reduction factors to account for crushing of stone during installation and long term clogging risks.
2. For further information on the permeability of soils generally, refer to the ABG Technical Note on the subject (ABG, 2020b).

In order to maintain the laboratory measured permeability once installed on site, the drainage gravel needs to be wrapped in a geotextile or encased within porous concrete to prevent fine grained soil from mixing with the gravel and clogging the voids – which greatly reduces the permeability of the gravel.

Calculating the Flow Capacity of Drainage Gravel

Using Darcy's Law for the movement of water, the flow capacity through a granular material is given by:

$$Q = k \cdot i \cdot A$$

Where Q = Water flow (l/s)
k = Permeability (m/s)
i = Hydraulic gradient (decimal)
A = Cross sectional area of flow (mm x m)

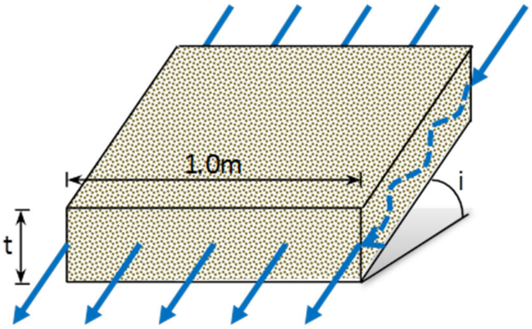


Figure 1: Granular drainage layer layout

Consider a one metre width of filter stone, of thickness 't':

$$Q = k \cdot i \cdot (t \cdot 1)$$
$$= k \cdot i \cdot t \text{ l/m·s (l/s per m width)}$$

The specified permeability of filter stone typically varies from 10^{-1}m/s to 10^{-4}m/s, and buried structures typically have hydraulic gradients of 0.01 to 1.0 (equivalent to near horizontal and vertical applications, respectively). So the maximum drainage capacity for a typical 300mm thick granular drainage layer can be anywhere in the range of 30 l/m·s to 0.0003 l/m·s.

Groundwater Flow in Drainage Geocomposites

What are Drainage Geocomposites?

Drainage geocomposites typically comprise a High Density Polyethylene (HDPE) geospacer (aka HDPE core) with a Polypropylene (PP) geotextile laminated to one or both sides, and are typically characterized by their core type (see Figure 2). They are a lightweight, cost-effective, and have equivalent or better drainage capacity compared to more traditional granular drainage solutions wrapped in a geotextile or encased within porous concrete.

a) Random fibre **b) Geonet** **c) Corrugated** **d) Cuspated**

Figure 2: Typical Drainage Geocomposites

Drainage geocomposites allow water to flow much faster than in granular drainage media. This means that, for example, a 6mm thick drainage geocomposite can manage the same water flow as a 300mm thick granular drainage layer. This means that the effective permeability of a drainage geocomposite is around 50 times that of drainage gravel due to the open void structure provided. Considering the relative densities of each material, this means the 1kg of drainage geocomposite has the same flow rate as 1000kg of drainage gravel (Bamforth, 2008).

How is Drainage Geocomposite Water Flow Measured?

Water flow in a drainage geocomposite is known as in-plane flow (flow within the HDPE core) and is measured in a laboratory in accordance with EN ISO 12958 or ASTM D4716. These tests place the geocomposite under a constant pressure and measure the water flow at a constant hydraulic gradient. Multiple tests at varying pressures and hydraulic gradients can be used to build up a flow chart to understand flow behaviour in different conditions. The test result is usually reported in litres per second per metre width (l/m·s). One of the key parameters of this test is how the pressure is applied to the geocomposite. This is because, when a geocomposite is installed adjacent to a deformable medium, such as soil, the geotextile may be pushed into the HDPE core which may throttle flow. The test methods allow the use of either hard or soft platens. The soft platens simulate installation in soil or similar conditions and it is important to ensure that test results that are used for design are those that best reflect the conditions on site in which the geocomposite is to be used. For more information ABG can provide a technical paper on this topic (Bamforth, 2008).

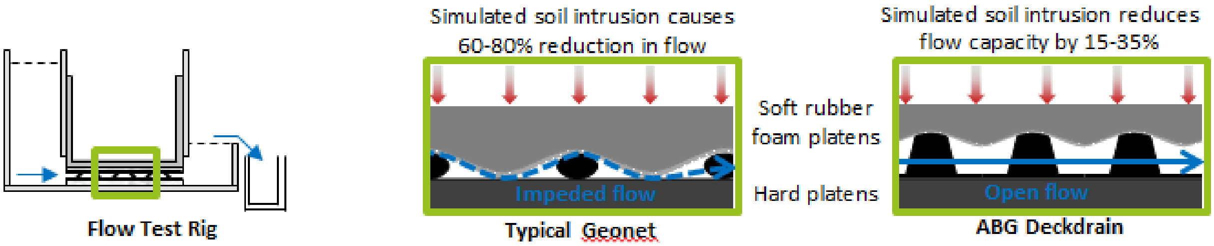


Figure 3: In-plane flow testing simulating soil intrusion in geocomposite drainage products

Calculating the Flow Capacity of a Drainage Geocomposite

To assess an allowable flow capacity (q_{allow}) in a geocomposite several reduction factors should be considered as outlined below (Koerner, 2012).

$$q_{\text{allow}} = \frac{q_{\text{ult}}}{RF_{IN}RF_{CR}RF_{PC}RF_{CC}RF_{BC}}$$

Where q_{ult} = geocomposite flow rate as determined from in-plane flow testing.

In addition to the reduction factors outlined above and in Table 2, a global factor of safety should be applied to both the granular filter flows and geocomposite flows to give the final design flows (Koerner, 2012).

$$FS = \frac{q_{\text{allow}}}{q_{\text{reqd}}}$$

Where FS = global factor of safety (applied to both granular and geocomposite flows)
q_{allow} = allowable flow rate
q_{reqd} = required flow rate as obtained from the design of the overall system.

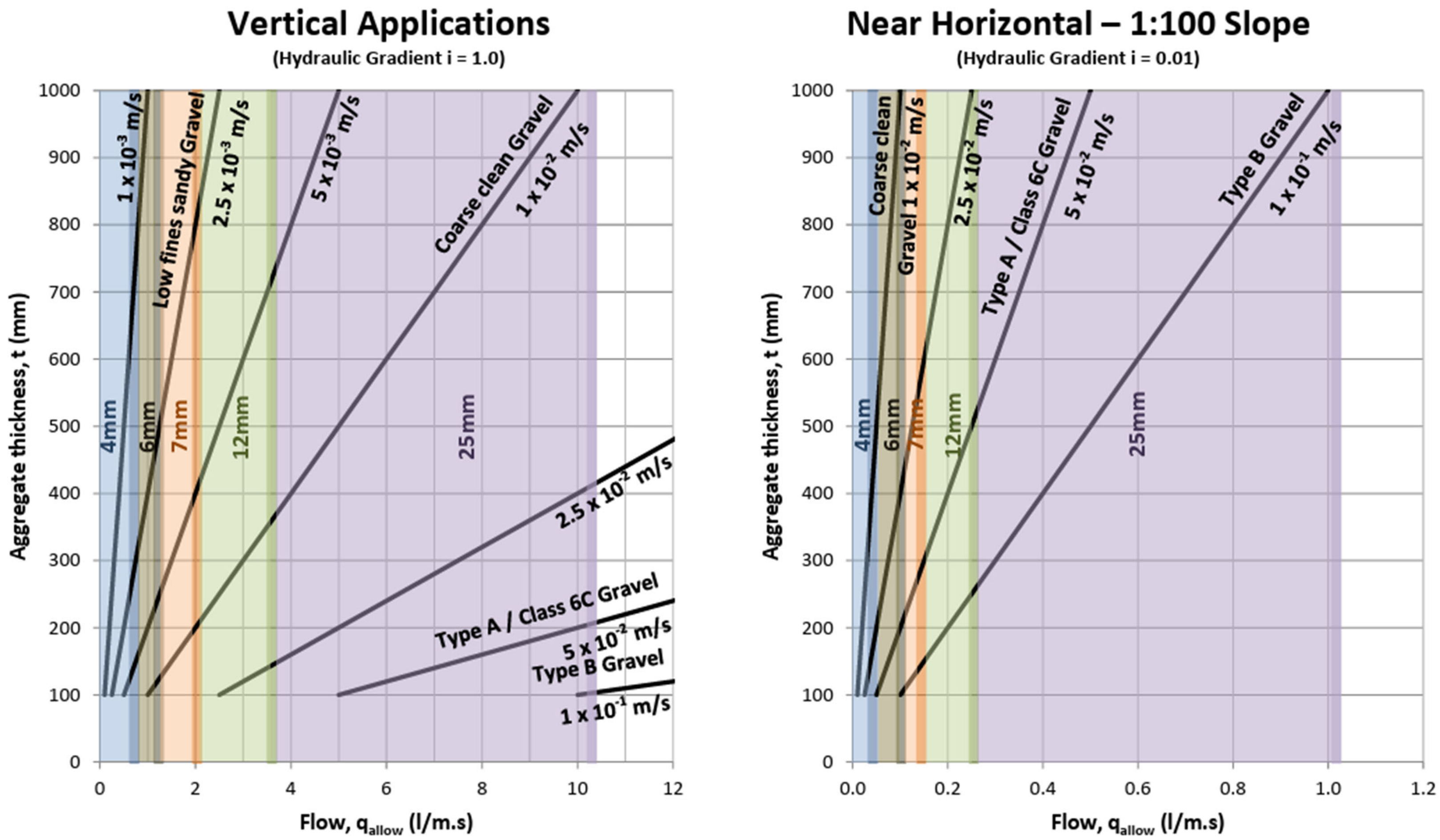
Table 2: Flow Reduction Factors

Reduction Factor	Description	Typical Values
RF_{IN}	**Geotextile intrusion into the core** When installed underground the soil pushes against the geocomposite and can push the geotextile into the core of the geocomposite. When this happens, the in-plane water flow capacity can be reduced. This can be accounted for by using soft foam platens to model the effect of geotextile intrusion. It is highly recommended that testing with soft foam platens is undertaken as the reduction factor can be taken as 1.0. Test results from measurements with hard platens are rarely relevant and should be disregarded in most instances as RF_{IN} can be as high as 2.5 to 5.0 as is the case with many geonet products.	$RF_{IN} = 1.0$
RF_{CR}	**Long-term creep compression** All materials creep over time and plastics are no exception. As the core of the geocomposite compresses slightly over time, the flow capacity reduces. Selecting a suitable strength geocomposite for the specific project is important to ensure that creep compression is minimised.	$RF_{CR} = 1.1\text{-}1.2$
RF_{PC}	**Particulate clogging of the core** All good quality drainage geocomposites will include a filter geotextile that is appropriate for use in standard soil conditions and hence particulates will not be able to enter the core. In non-standard soil conditions a specialist geotextile may be required (ABG, 2020a).	$RF_{PC} = 1.0$ (standard soil conditions)
RF_{CC} & RF_{BC}	**Chemical (RF_{CC}) and biological (RF_{BC}) clogging of the geotextile** This factor should be applied to both granular and geocomposite drainage layers. In standard soil conditions there is relatively little biological activity or chemical effects that could cause clogging of the geotextile.	$RF_{CC} = 1.0$ $RF_{BC} = 1.0$ (standard soil conditions)

Flow Capacity Comparison

As demonstrated above, for a given hydraulic gradient (slope), the flow capacity of a granular drainage layer depends on the thickness of the layer and the permeability of the stone used. For a drainage geocomposite the governing properties are; the dimensions, strength and stiffness of the geocomposite, and the magnitude and manner of the pressure applied. Shown below in Figures 5 is a comparison of water flow in typical granular and geocomposite drainage systems in vertical and near horizontal applications.

Note that the flow rates shown in Figure 5 assume that the granular layer is fully wrapped in a suitable geotextile or no-fines concrete to prevent fines migrating into the layer and that the granular material is highly resistant to abrasion/fragmentation. The flow rates shown for the granular layer therefore represent best case scenarios. The flow rates for the drainage geocomposites are based on ABG cuspated drainage geocomposites of various thicknesses under a pressure of 20kPa using soft foam platens.



Vertical Applications

(Hydraulic Gradient i = 1.0)

Near Horizontal – 1:100 Slope

(Hydraulic Gradient i = 0.01)

Figure 5: Flow Capacity Equivalence – Geocomposites vs. Gravel

The flow rates shown for the granular drainage layers represent best case scenarios. The flow rates for the drainage geocomposites are based on ABG cuspated drainage geocomposites of various thicknesses under a pressure of 20kPa using soft foam platens.

Additional Benefits

As well as offering drainage performance, drainage geosynthetics also offer significant environmental, economic, and safety benefits as they are lighter and easier to install than traditional methods. The greenhouse gas emissions of a drainage geosynthetic solution is 50-90% lower than traditional solutions due to the significantly reduced mass of material required, reduced transport emissions, quicker and easier installation. For the same reasons, the emission of harmful nitrogen oxides (NO_x – mostly from diesel engines) is reduced by 70-95% (Heritage and Shercliff, 2020). The same source identifies costs are reduced by 80-95%, and discusses the safety benefits from the reduced vehicle movements that are in conflict with pedestrian movements (aka exposure time).

Conclusion

As demonstrated above, drainage geocomposites can be used to replace granular drainage in almost all applications. The methods in this technical note describe the process by which a drainage gravel design can be compared with a drainage geocomposite. In addition, drainage geocomposites are better for the environment, more cost effective, and safer to install compared with traditional gravel drainage. For a specific illustration for your site contact ABG for a calculation based on this Technical Note.

References

ASTM D4716 / D4716M-20, *Standard Test Method for Determining the (In-plane) Flow Rate per Unit Width and Hydraulic Transmissivity of a Geosynthetic Using a Constant Head*, ASTM International, West Conshohocken, PA, 2020, www.astm.org

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Heritage, R. & Shercliff, D. (2020) *Plastic or Concrete? The use of drainage geosynthetics to replace unnecessary environmentally damaging alternatives*. Paper to be presented at the 7th European Geosynthetics Conference, Poland (currently delayed due to the COVID19 pandemic)