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Geotechnik mit Geokunststoffen

geotechnics with geosynthetics

Geosynthetic Drainage – German Design Approach

1. Introduction
2. Influencing Factors for Drainage Systems
3. Design of Drainage Systems
4. Economic and Ecologic advantages of Drainage Geocomposites
5. Installation
6. Conclusions

Introduction

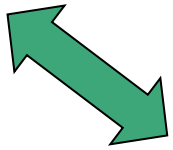
Approval Process for Geosynthetic Drainage Systems in Germany

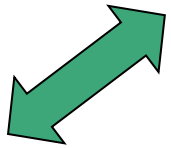
Federal States

Approval

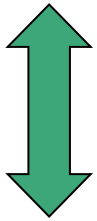
BAM/DepV

Geosynthetic Requirements





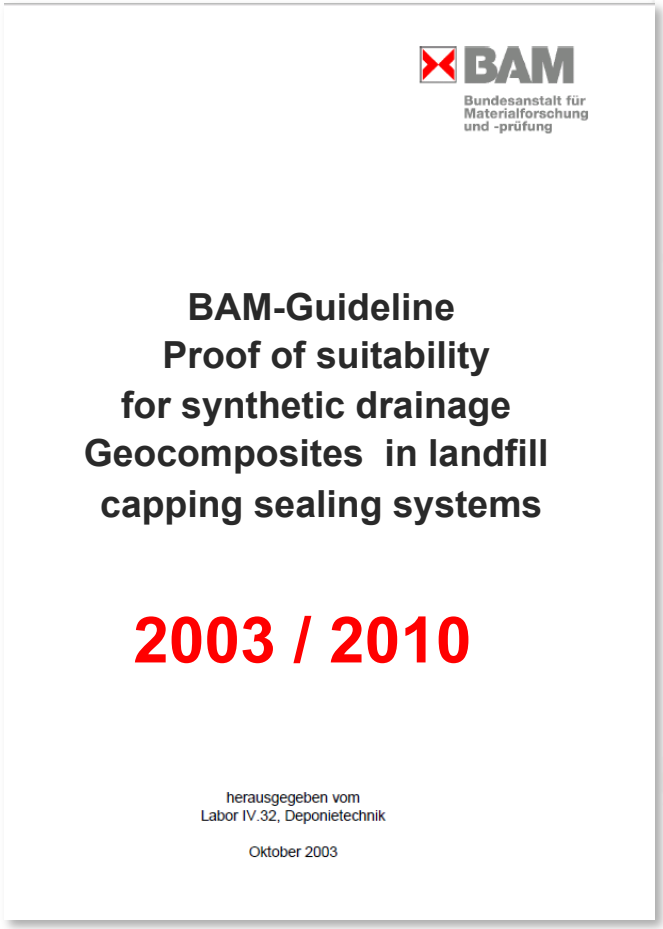
Drainage Geocomposites in Landfill Capping Sealing Systems

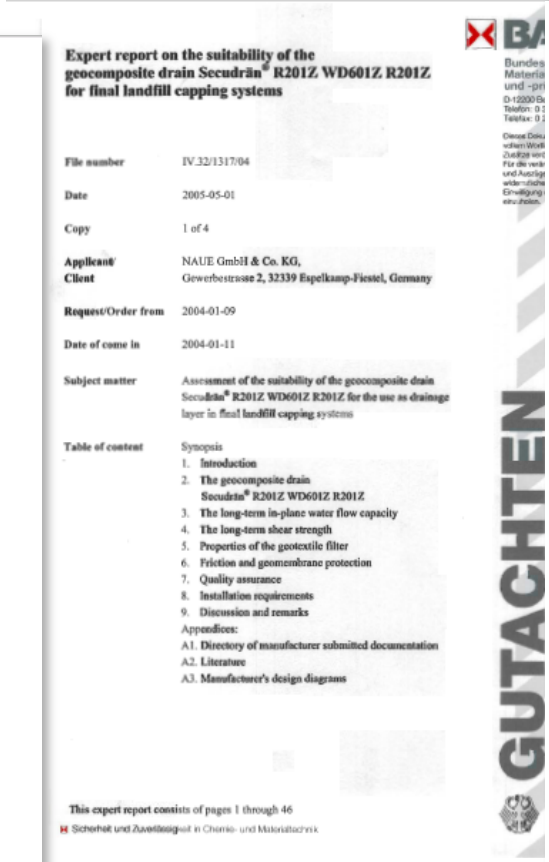


Recommendations of WG 6.1 GDA of the German Geotechnical Society (DGGT e.V.)

Introduction

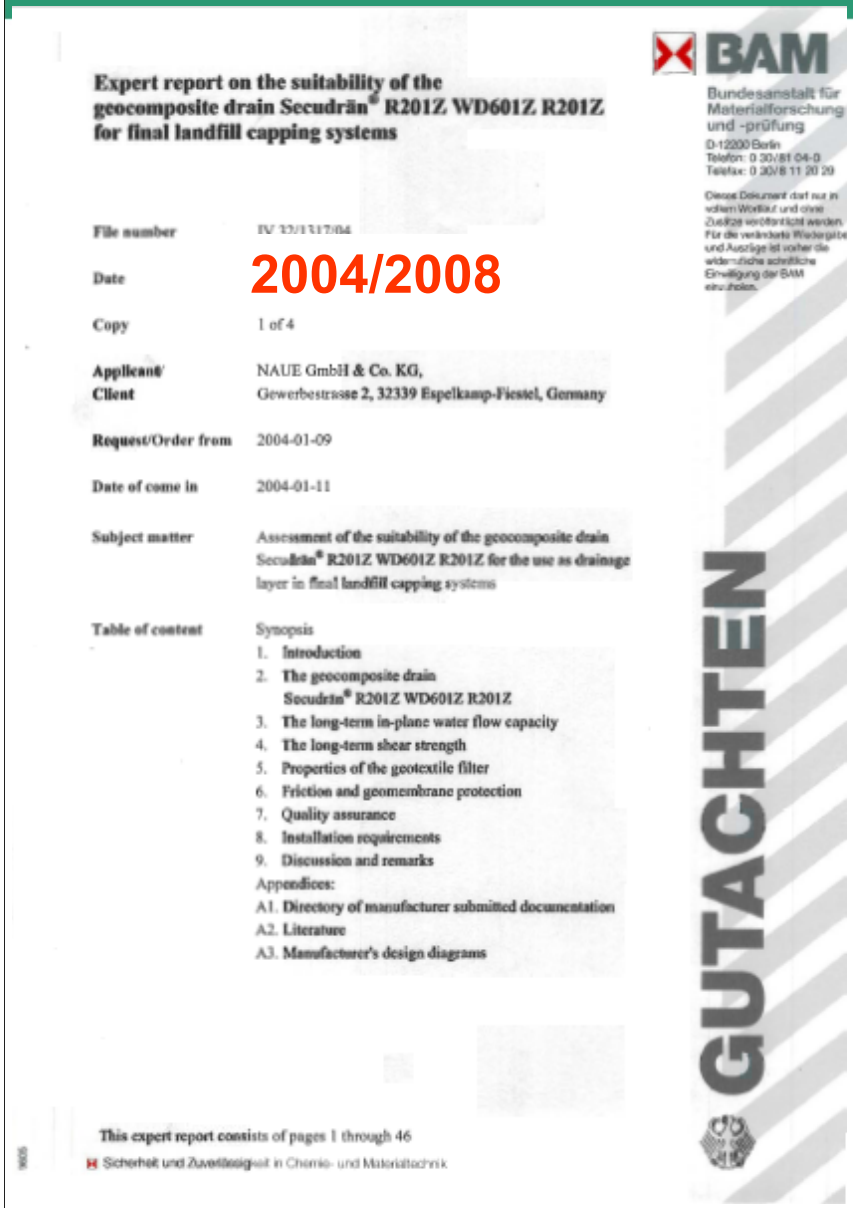
Approval Process for Geosynthetic Drainage Systems in Germany





(in accordance to GM approval)

Introduction



Expert report on the suitability of the geocomposite drain Secudrän® R201Z WD601Z R201Z for final landfill capping systems

BAM
Bundesanstalt für Materialforschung und -prüfung
D-12200 Berlin
Telefon: 0 30/81 04-0
Telefax: 0 30/8 11 20 29

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File number	IV.33/1317/04
Date	2004/2008
Copy	1 of 4
Applicant/ Client	NAUE GmbH & Co. KG, Gewerbestrasse 2, 32339 Espelkamp-Fiestel, Germany
Request/Order from	2004-01-09
Date of come in	2004-01-11
Subject matter	Assessment of the suitability of the geocomposite drain Secudrän® R201Z WD601Z R201Z for the use as drainage layer in final landfill capping systems

Table of content

Synopsis
1. Introduction
2. The geocomposite drain Secudrän® R201Z WD601Z R201Z
3. The long-term in-plane water flow capacity
4. The long-term shear strength
5. Properties of the geotextile filter
6. Friction and geomembrane protection
7. Quality assurance
8. Installation requirements
9. Discussion and remarks

Appendices:
A1. Directory of manufacturer submitted documentation
A2. Literature
A3. Manufacturer's design diagrams

This expert report consists of pages 1 through 46

Sicherheit und Zuverlässigkeit in Chemie- und Materialtechnik

GUTACHTEN

EXPERT REPORT

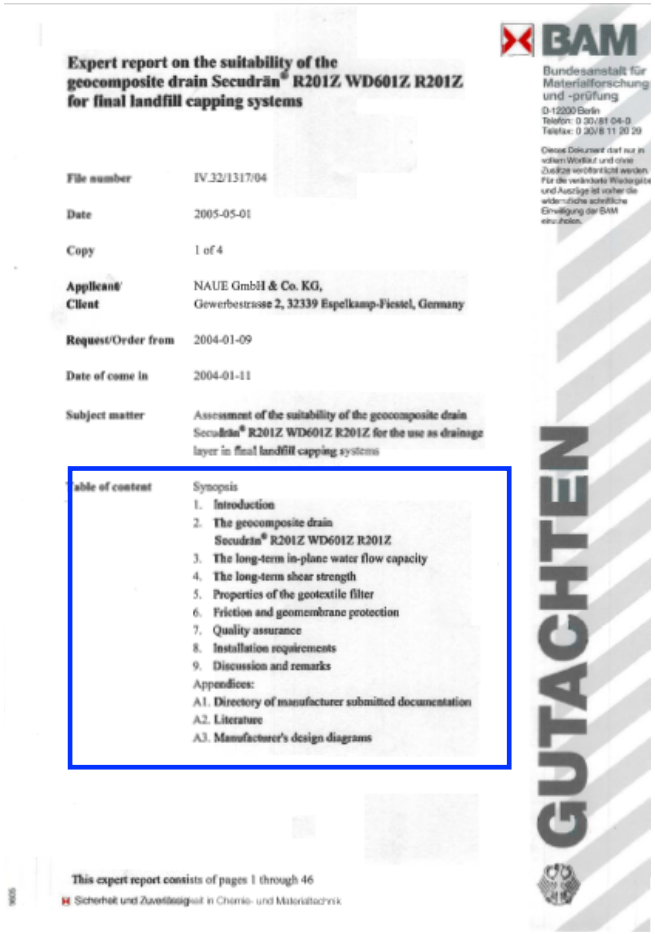
Realisation of BAM-Guideline "Proof of suitability for synthetic drainage elements in landfill capping sealing systems" (2003)

Durability > 100 years

Equivalence to 30 cm gravel with $k = 1 \cdot 10^{-3}$ m/s

Introduction

Approval Process for Geosynthetic Drainage Systems in Germany



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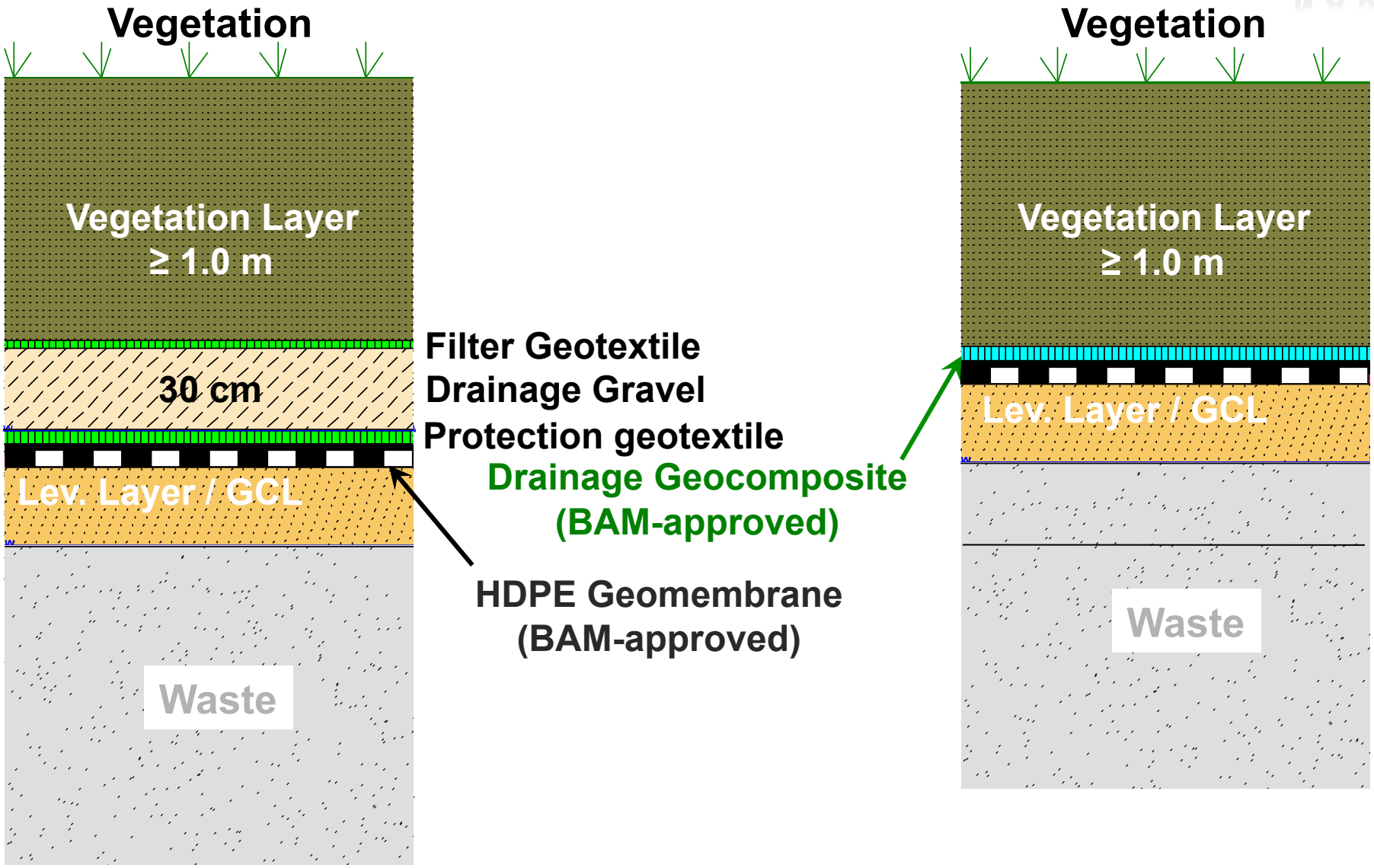
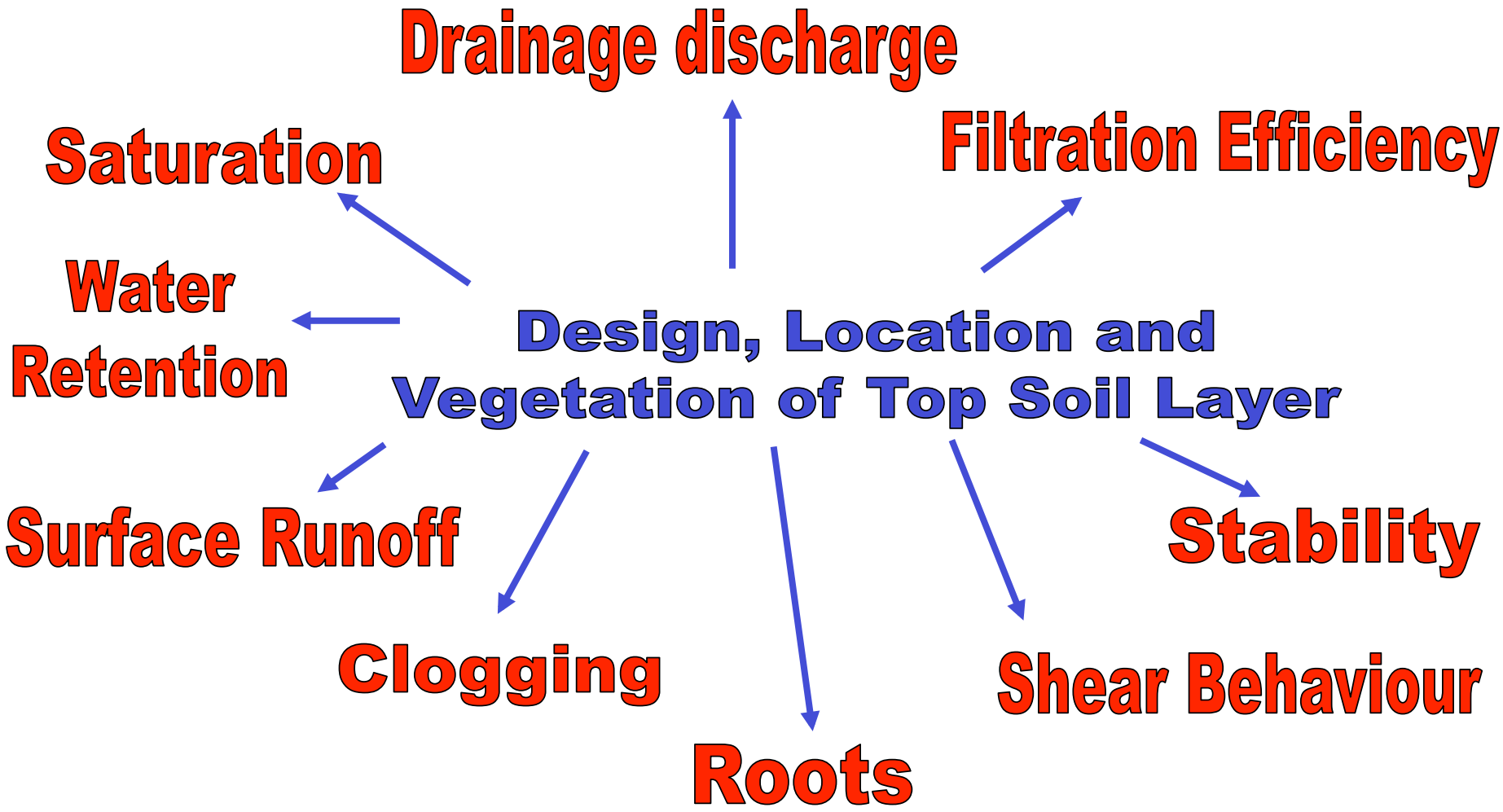
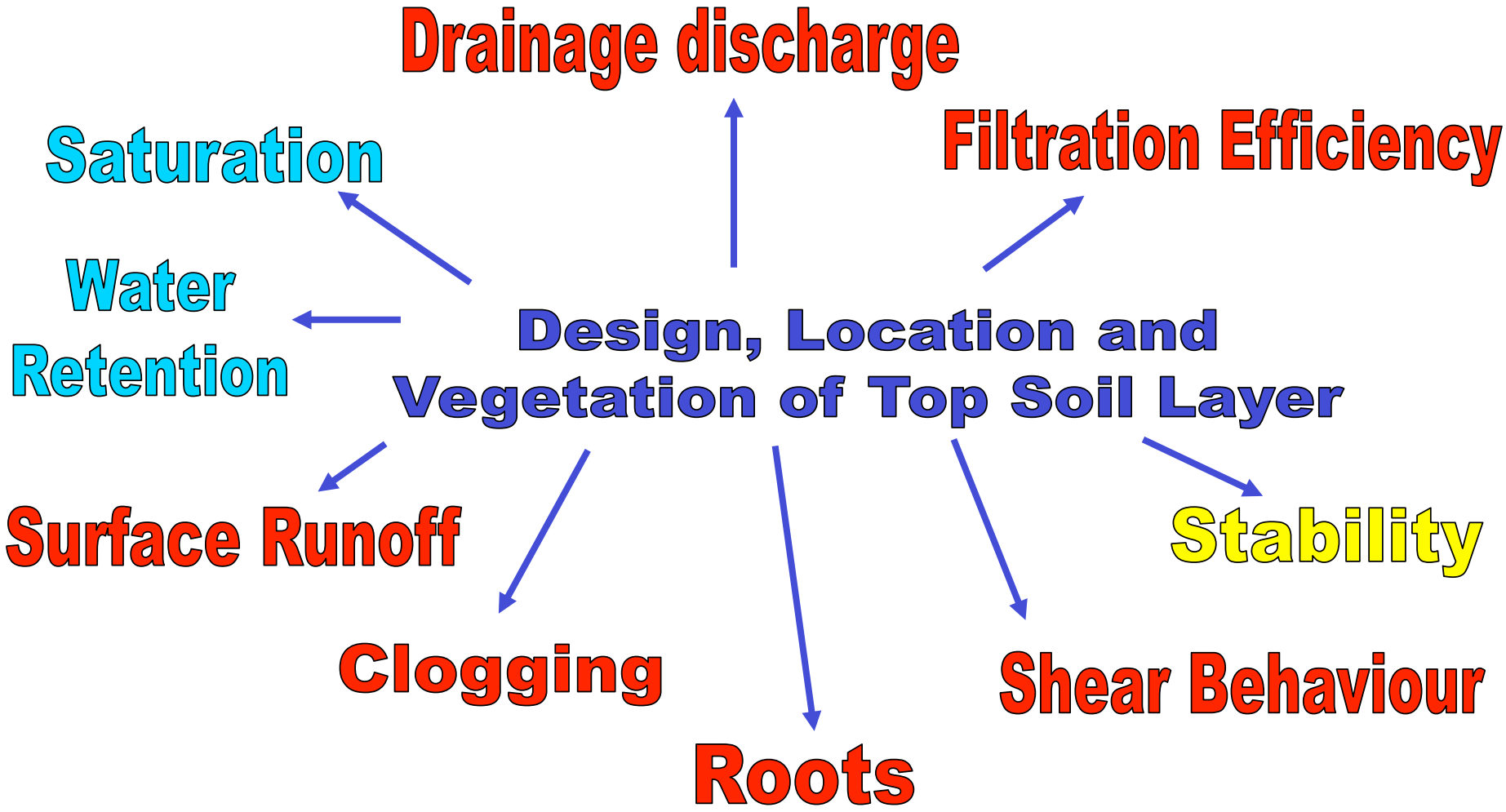


Influencing Factors for Drainage Layers



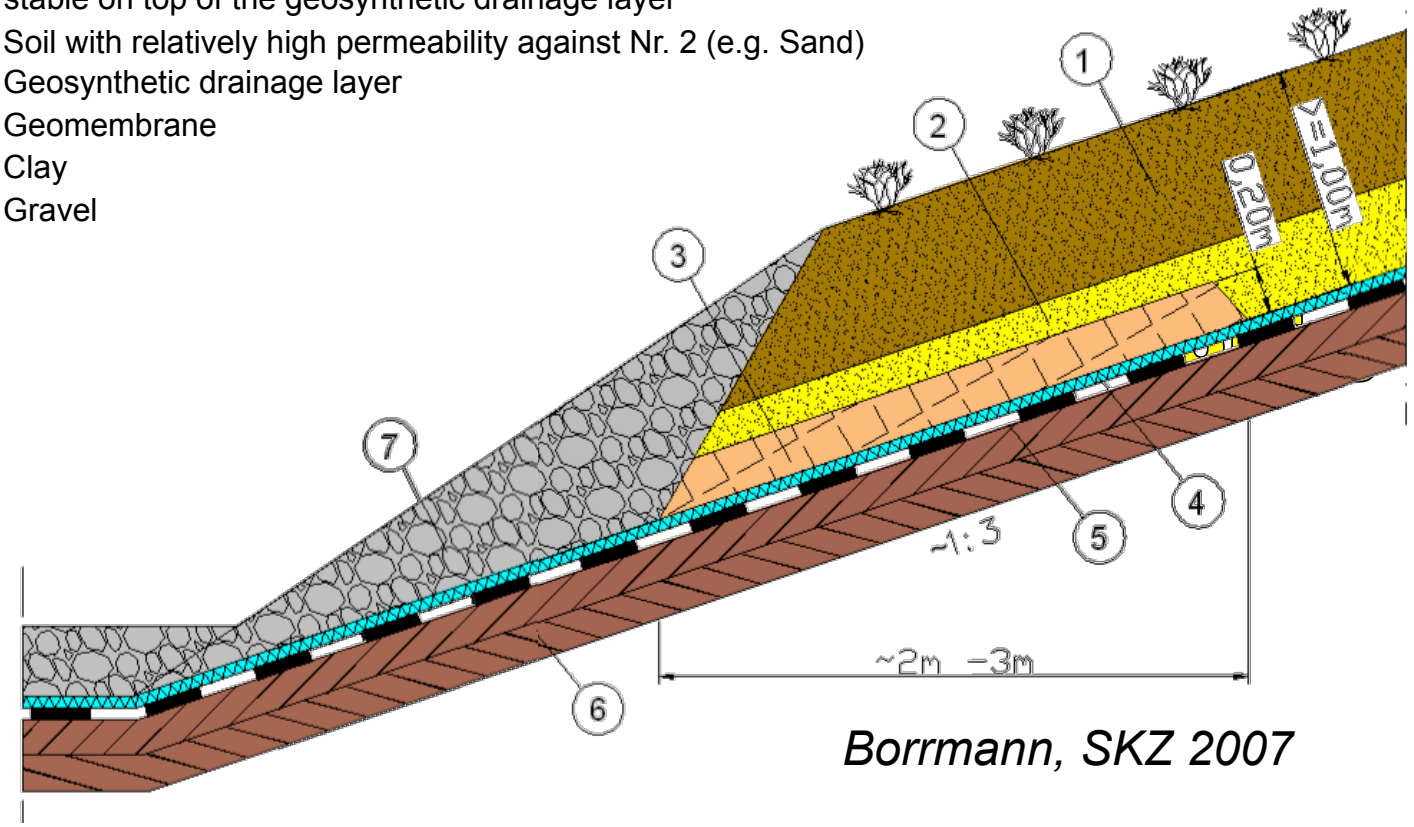
Influencing Factors for Drainage Layers



Influencing Factors for Drainage Layers

(decisive are slope toe areas!)

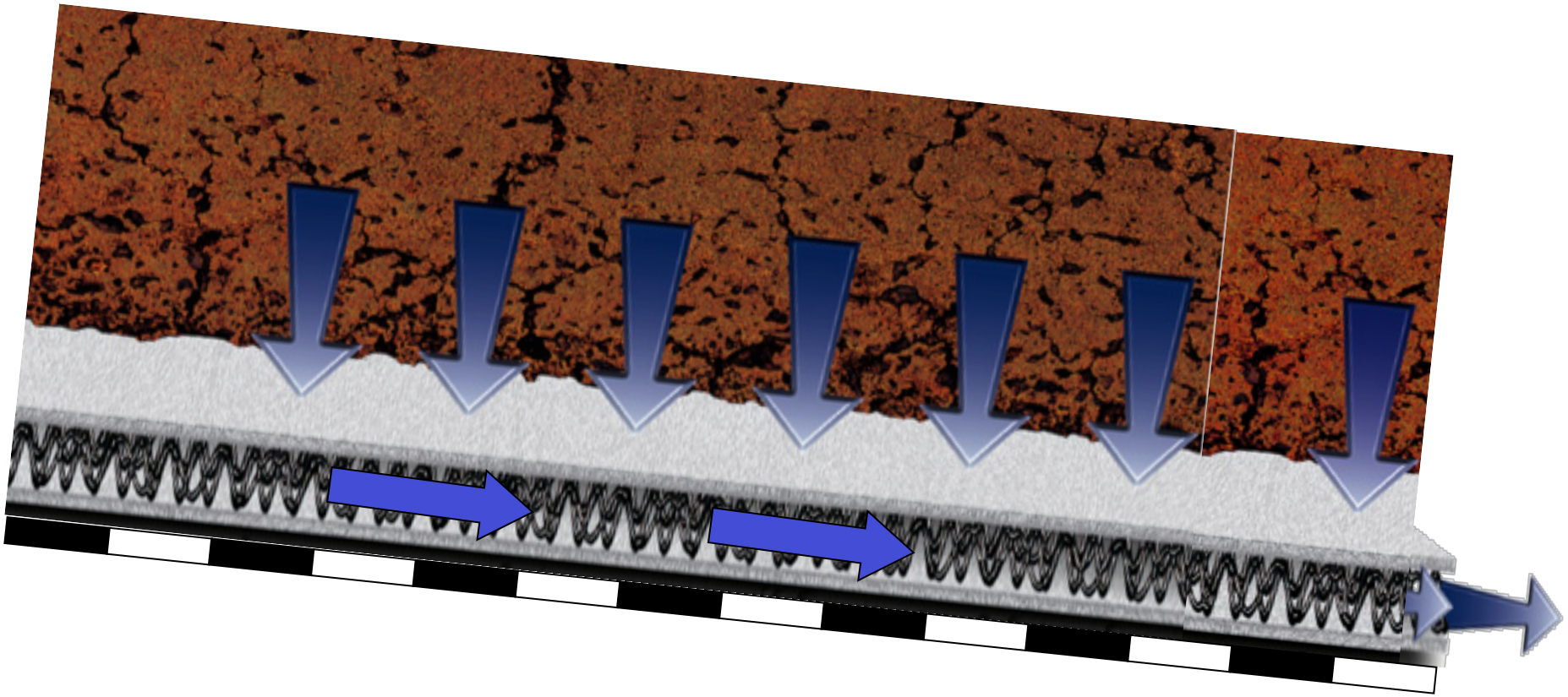
1. Vegetation Layer
2. Vegetation Layer (lower layer) which under consolidated, undrained conditions is stable on top of the geosynthetic drainage layer
3. Soil with relatively high permeability against Nr. 2 (e.g. Sand)
4. Geosynthetic drainage layer
5. Geomembrane
6. Clay
7. Gravel



Borrmann, SKZ 2007

Design of Drainage Systems

1. Filtration Efficiency
2. Drainage discharge of seepage water inside the core (flow rate)
3. Protection Efficiency, e.g. against geomembrane



Relevant for suitability (> 100 years): Retain Soil from Vegetation layer and water shall be drained freely into drainage layer!

Design of Drainage Systems

1. Filtration Efficiency
2. Drainage discharge of seepage water inside the core (flow rate)
3. Protection Efficiency, e.g. against geomembrane

1. Mechanical Filter Efficiency

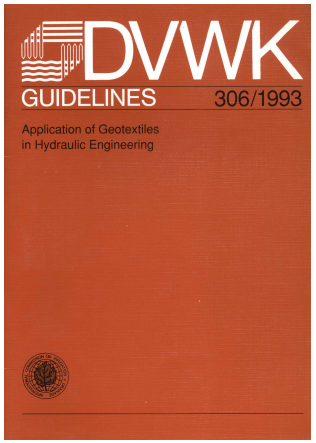
Opening size $O_{90,w,selected}$:

(90% Soil retention capacity of the geotextile)

$(0.8 \text{ to } 1.0) \bullet O_{90,w,required}$

Thickness d:

$\geq (25 \text{ to } 50) \bullet O_{90,w,required}$



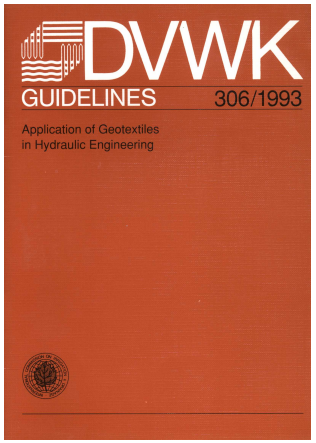
Design of Drainage Systems

1. Filtration Efficiency
2. Drainage discharge of seepage water inside the core (flow rate)
3. Protection Efficiency, e.g. against geomembrane

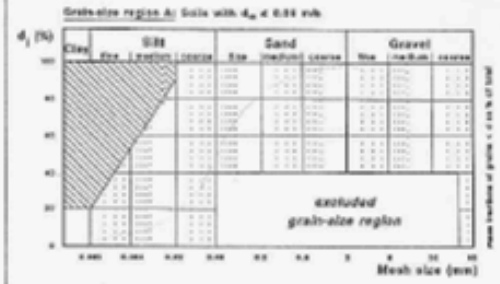
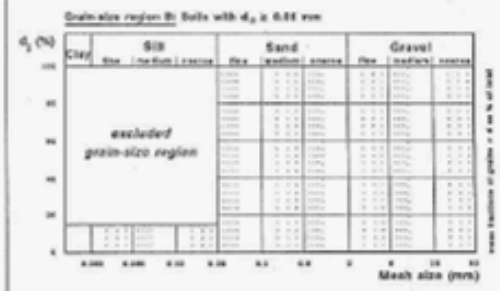
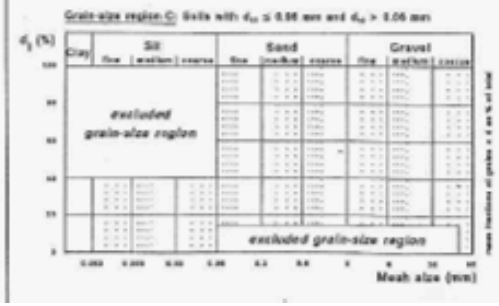
2. Hydraulic Filter Efficiency

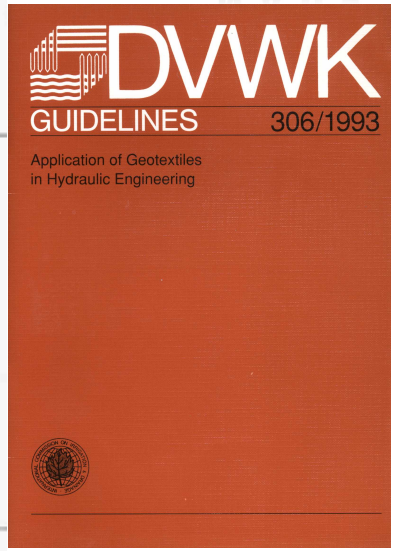
Permeability :

$$k_v = 50 \bullet k_{soil}$$



Design of Drainage Systems

Grain-size region	Scope in grain-size distribution diagram	Criteria for a soil with high single-grain mobility	Dimensioning of mechanical filter effectiveness	Dimensioning of hydraulic filter effectiveness
A $d_{60} \leq 0.06$ mm		1. Grain fraction < 0.06 mm $c_U = d_{60} / d_{10} < 15$ 2. 0.02 mm < d < 0.1 mm > 50 % 3. $I_P < 0.15 = 15\,\%$ or alternatively clay fraction/silt fraction < 0.5	a) Hydrostatic load $O_{90,w} < 10 \cdot d_{90}$ – in addition, for soils with high single-grain mobility $O_{90,w} < d_{90}$ – permissible for soils with long-term stable cohesion $O_{90,w} < 2 \cdot d_{90}$ b) Hydrodynamic load $O_{90,w} < d_{90}$ and $O_{90,w} < 0.3$ mm	$\eta \cdot k_V \geq k$
B $d_{15} \geq 0.06$ mm		1. Grain fraction < 0.06 mm and $c_U = d_{60} / d_{10} < 15$ 2. 0.02 mm < d < 0.1 mm > 50 %	a) Hydrostatic load $O_{90,w} < 5 \cdot d_{10} \sqrt{c_U}$ and $O_{90,w} < 2 \cdot d_{90}$ – in addition, for soils with high single-grain mobility $O_{90,w} < d_{90}$ b) Hydrodynamic load $O_{90,w} < 1.5 \cdot d_{10} \sqrt{c_U}$ and $O_{90,w} < d_{50}$	$\eta \cdot k_V \geq k$
C $d_{15} \leq 0.06$ mm and $d_{60} > 0.06$ mm		1. Grain fraction < 0.06 mm and $c_U = d_{60} / d_{10} < 15$ 2. 0.02 mm < d < 0.1 mm > 50 % 3. $I_P < 0.15 = 15\,\%$ or alternatively clay fraction/silt fraction < 0.5	Dimensioning as for soils in grain-size region B, but with additional tests to determine the suffusion stability of the soil For critical suffusion stability see DVWK (1989)	$\eta \cdot k_V \geq k$



Design of Drainage Systems

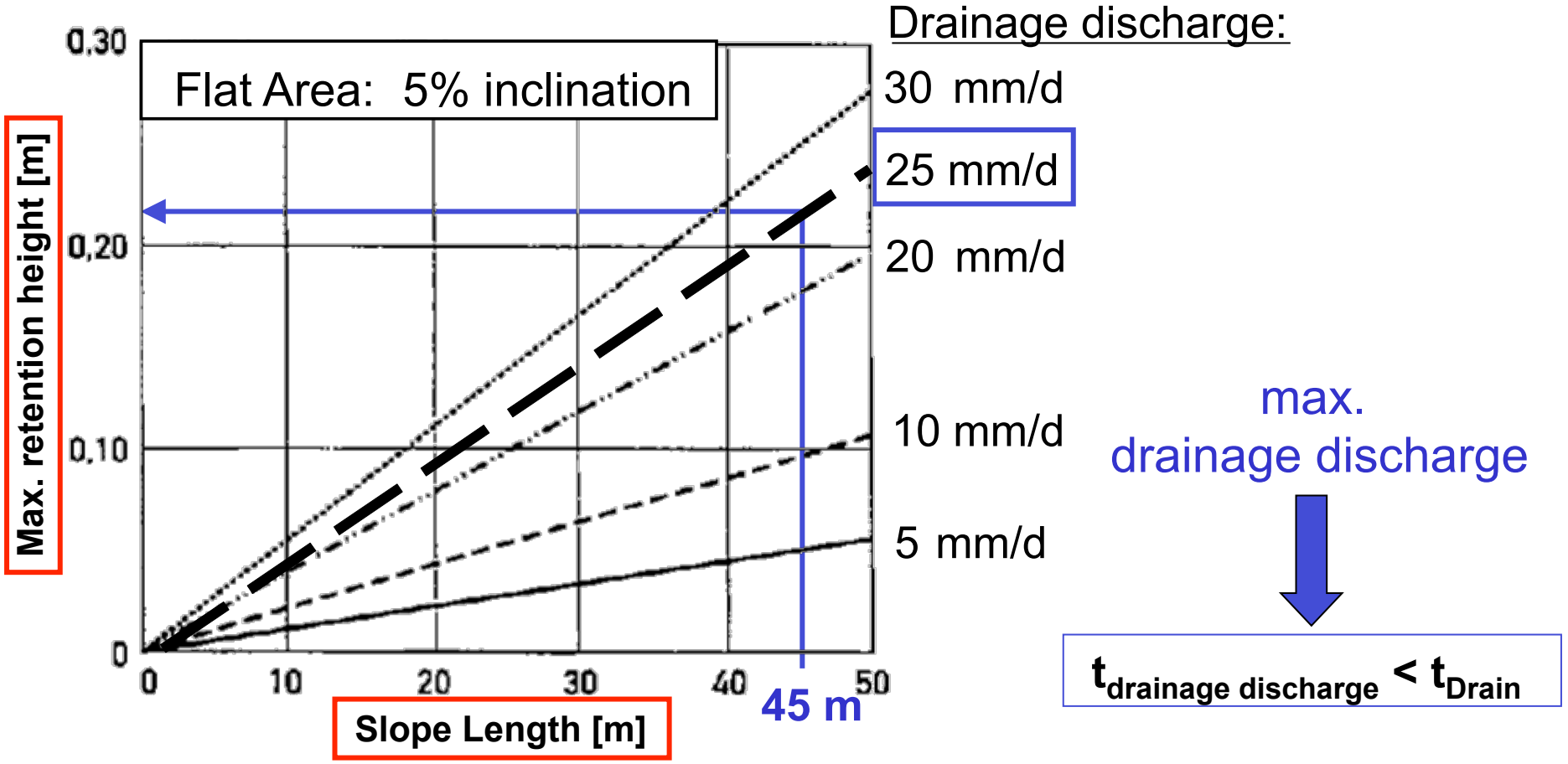
1. Filtration Efficiency
2. Drainage discharge of seepage water inside the core (flow rate)
3. Protection Efficiency, e.g. against geomembrane

Gravel Drainage Layer

Low Pore Volume
High flow resistance!

Design of Drainage Systems

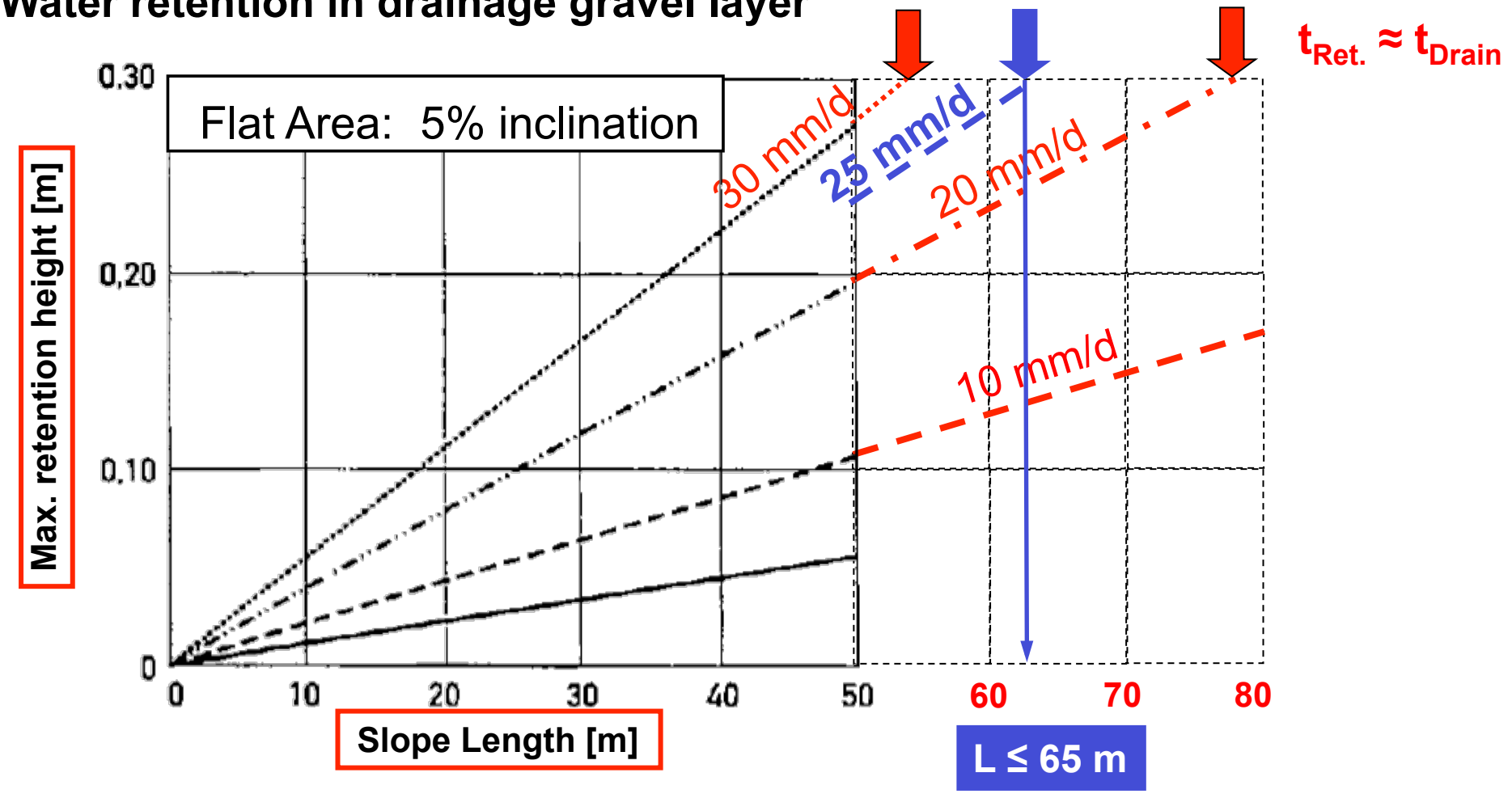
Water retention in drainage gravel layer



Water retention in drainage gravel according to LESAFFRE – Influence of slope length at $k_f = 1 \times 10^{-3}$ m/s (Source: GDA E2-20 (1997))

Design of Drainage Systems

Water retention in drainage gravel layer



Water retention in drainage gravel according to LESAFFRE – Influence of slope length at $k_f = 1 \times 10^{-3}$ m/s (Source: GDA E2-20 (1997))

Design of Drainage Systems

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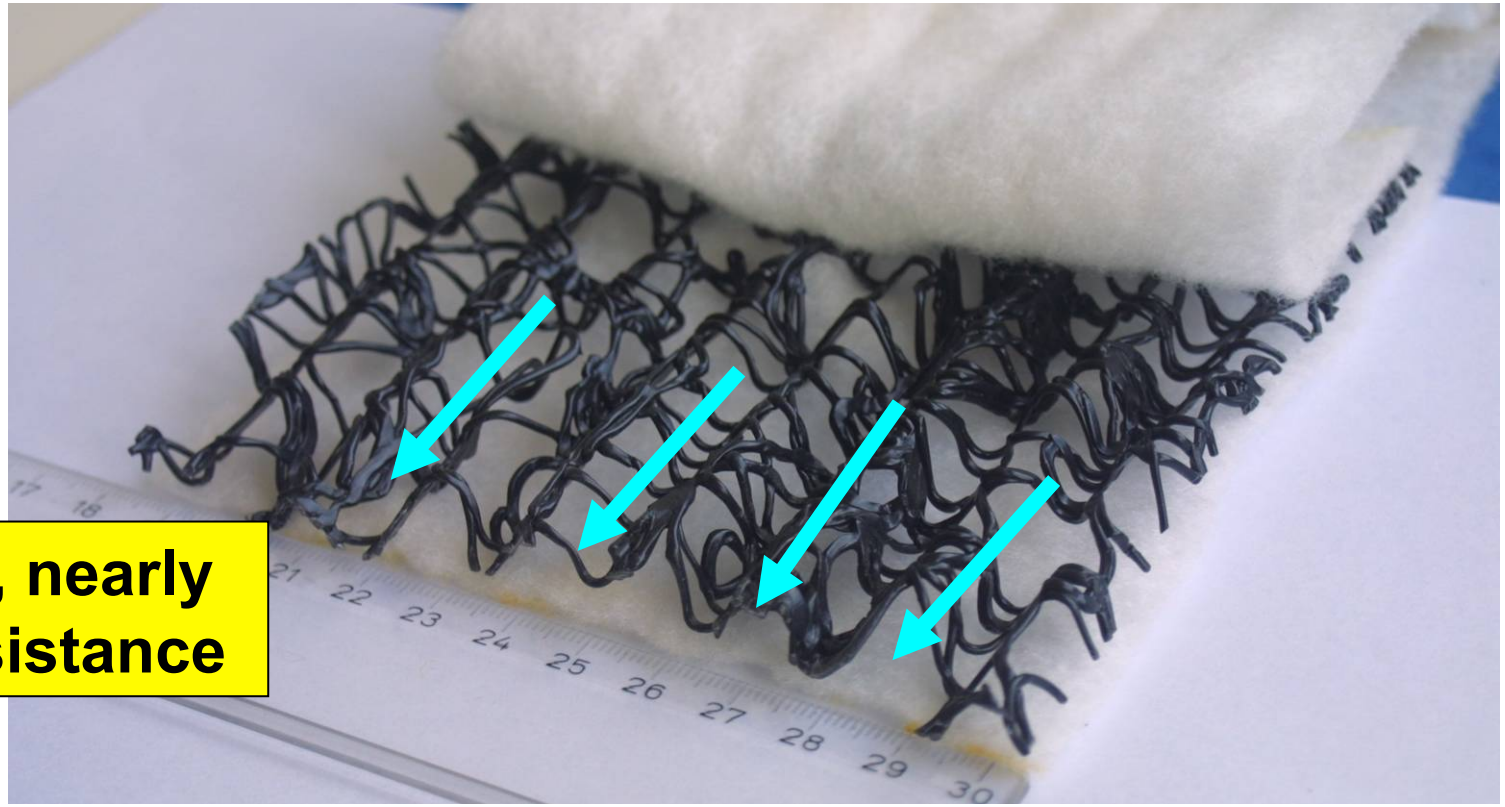
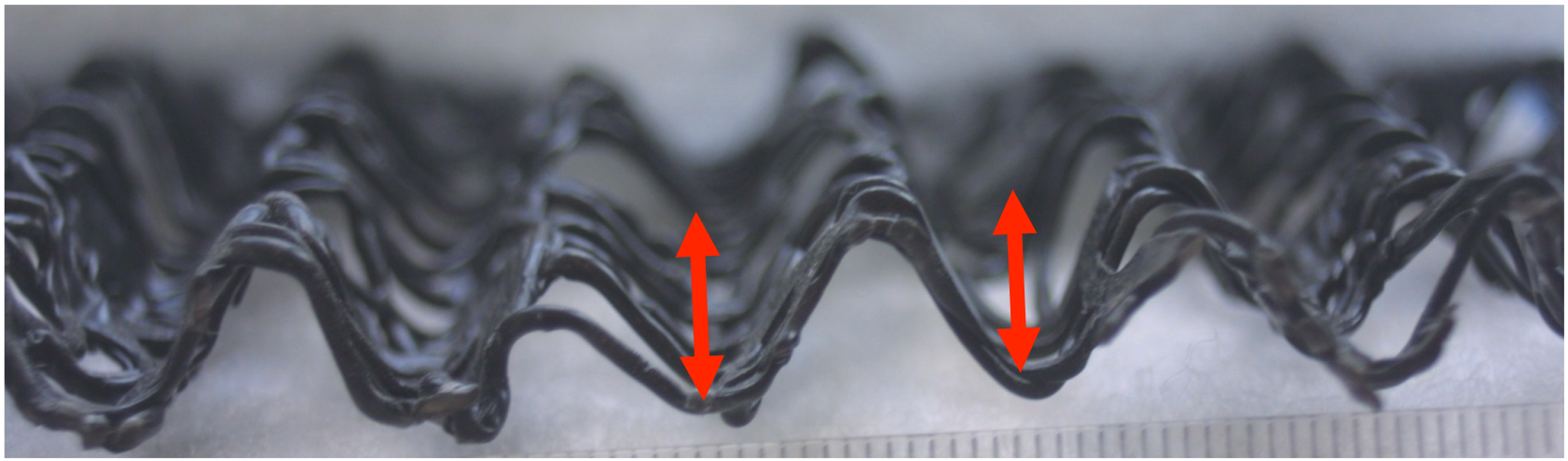


Open layer, nearly no flow resistance

Design of Drainage Systems

1. Filtration Efficiency
2. Drainage discharge of seepage water inside the core (flow rate)
3. Protection Efficiency, e.g. against geomembrane

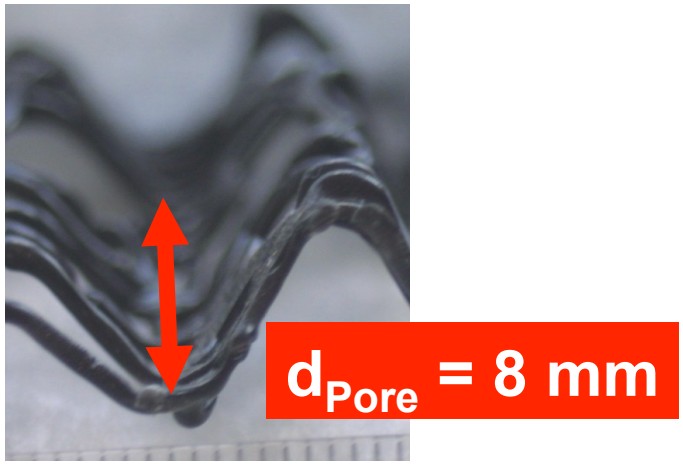
"Infinite wide rectangular tube"



„Alternate thickness of pores“

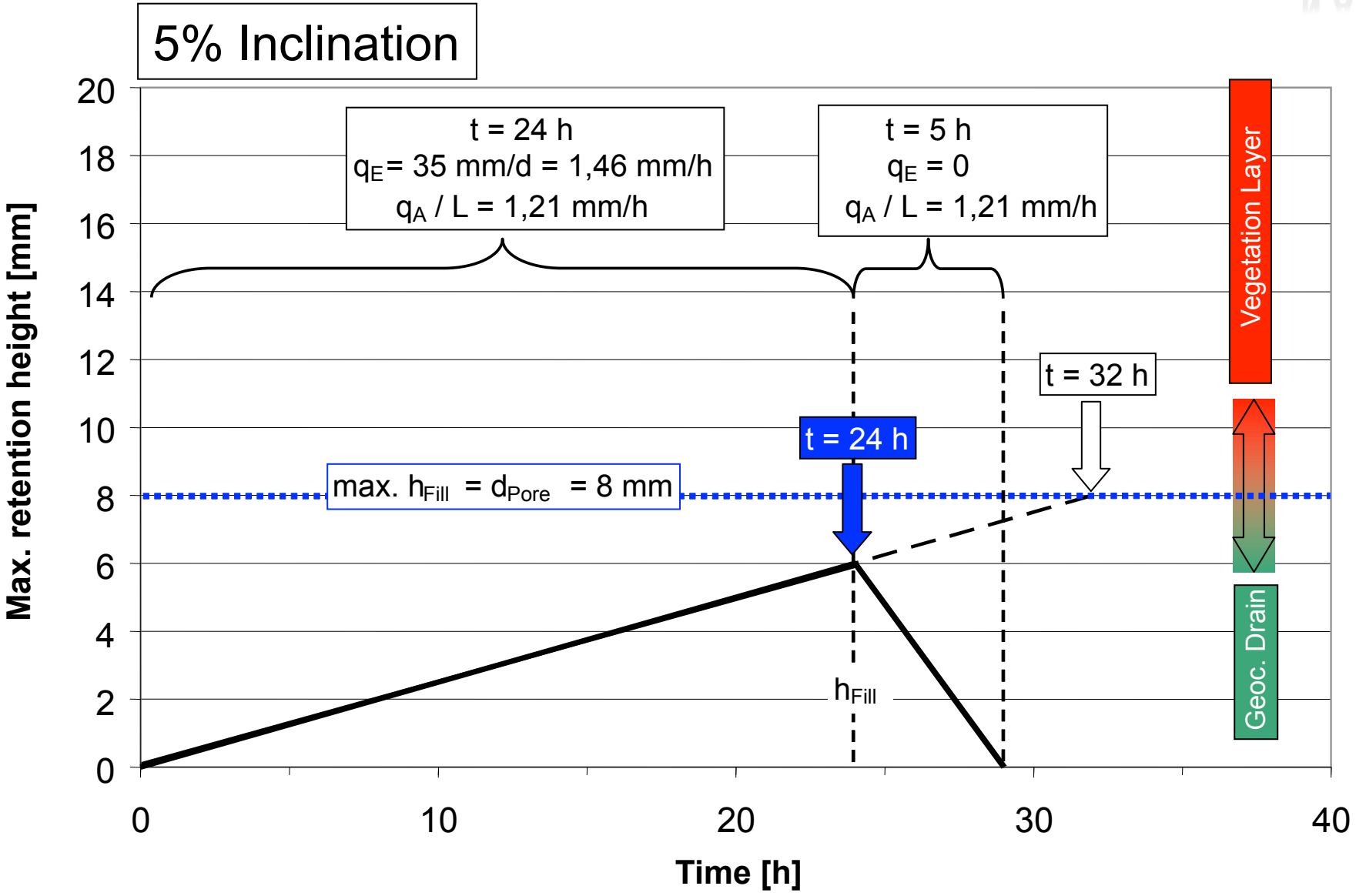
Boundary Conditions:

- Long-term thickness (>100a) at inclination of 5% and
- 1 m vegetation layer (BAM) = 9.1 mm
- Bedding hard/soft (BAM)
- Drainage length L = 170 m
- Drainage discharge: 35 mm/d (+40% compared to 25 mm/d)

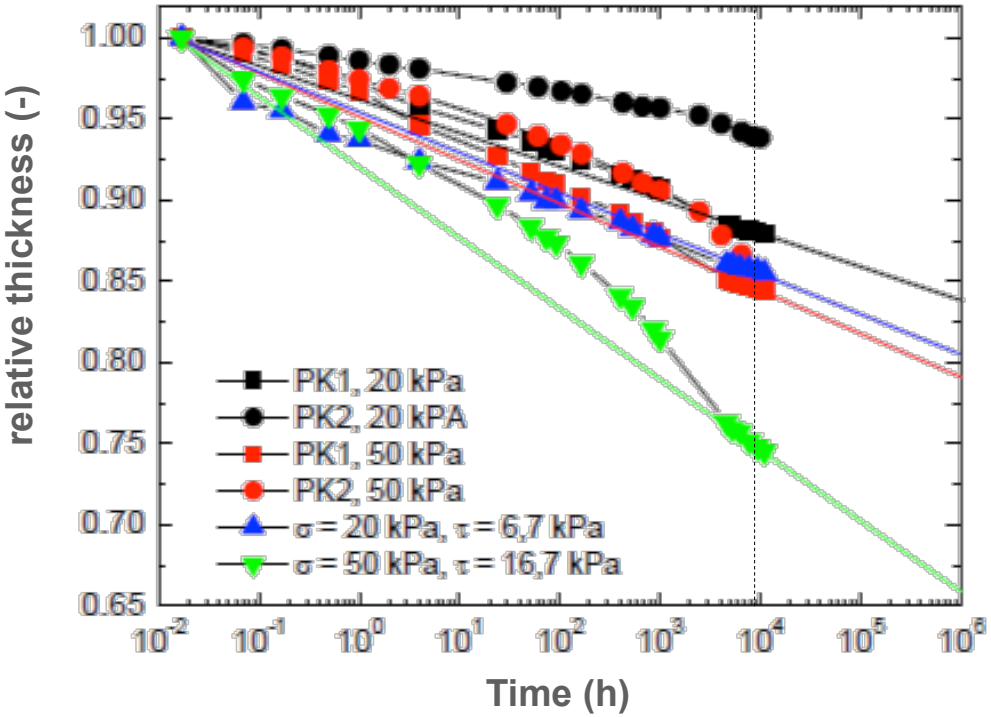


"Infinite wide and 8 mm thick rectangular tube"

Design of Drainage Systems



Long-term Creep Tests



For flat areas as e.g. Plateau (1:20) only creep resulting from compressive stress is relevant.

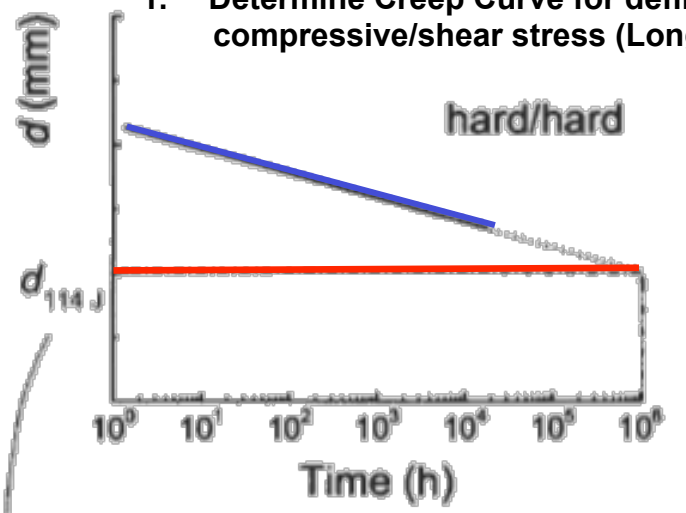
For slope sections (1:3), creep as a result of combined compressive/shear stress is examined.

(Extrapolation of 10^4 h to long-term thickness (10^6 h/114 years)

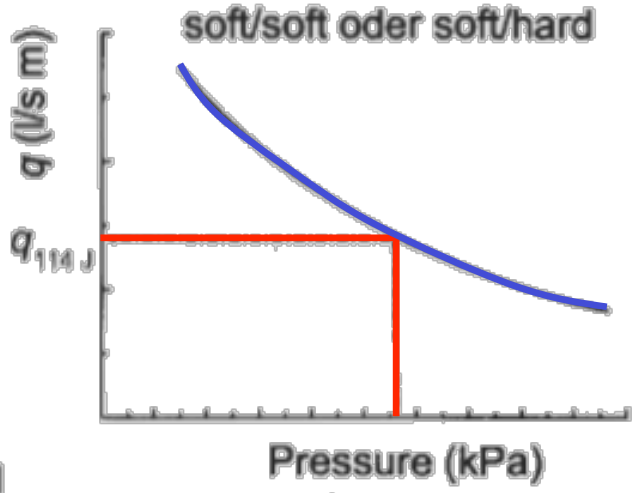
Stress	20 kPa	50 kPa	20 kPa, 3:1	50 kPa, 3:1
Final thickness (114 years)	9.1 mm	8.3 mm	8.8 mm	6.9 mm
Based on initial thickness	83 %	79 %	80 %	66 %
Respective compressive stress	73 kPa	91 kPa	80 kPa	129 kPa

Selected Procedure for assessing the long-term water flow capacity

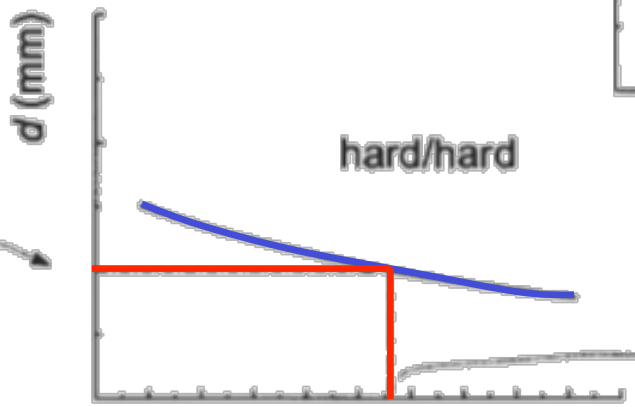
1. Determine Creep Curve for defined compressive stress or compressive/shear stress (Long-term test)



3. Determine long-term water flow capacity for different bedding conditions at relevant compressive stress



Long-term thickness (hard/hard)



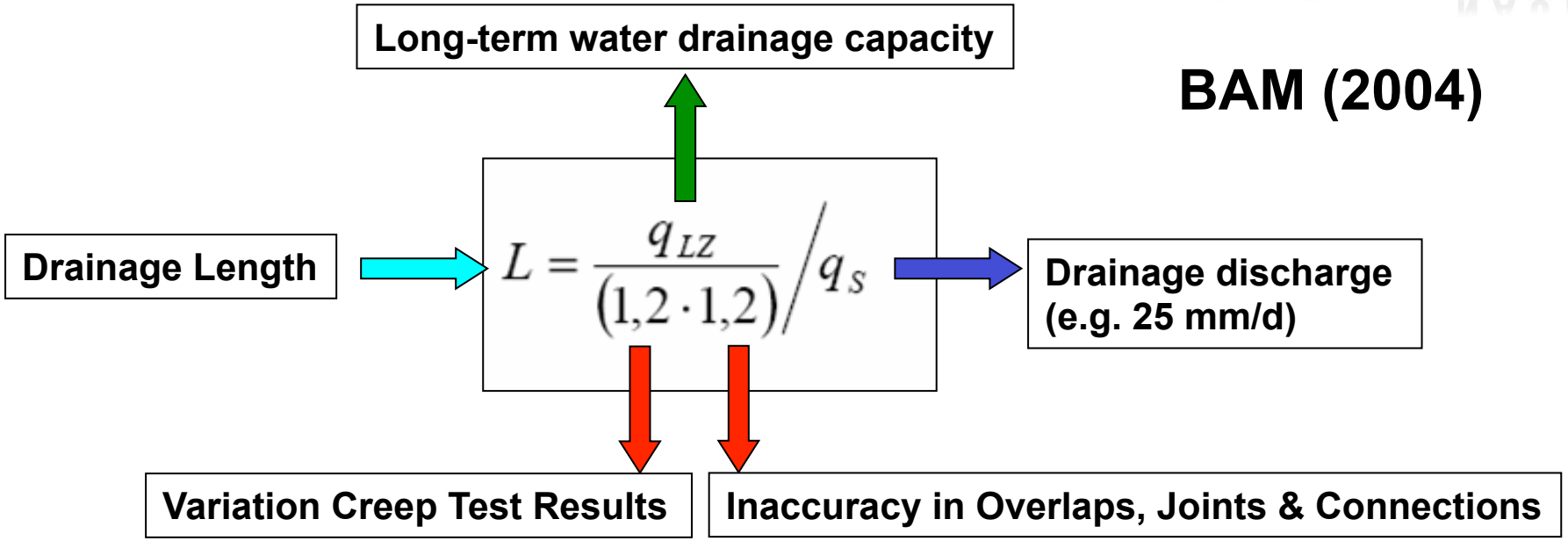
Compressive Stress at long-term thickness (hard/hard)

2. Determine relevant compressive stress level at long-term thickness (Short-term test)

Design of Drainage Systems

Water-flow capacity (l / m · s)				
	i = 0,05	*i* = 0,1	*i* = 0,3	*i* = 1,0
hard/hard				
20 kPa	**0,18**	**0,29**	Not relevant	Not relevant
50 kPa	**0,11**	**0,19**	Not relevant	Not relevant
20 kPa, 6,7 kPa	Not relevant	Not relevant	**0,51**	**1,12**
50 kPa, 16,7 kPa	Not relevant	Not relevant	**0,18**	**0,42**
soft/hard				
20 kPa	**0,12**	**0,19**	Not relevant	Not relevant
50 kPa	**0,09**	**0,14**	Not relevant	Not relevant
20 kPa, 6,7 kPa	Not relevant	Not relevant	**0,35**	**0,78**
50 kPa, 16,7 kPa	Not relevant	Not relevant	**0,17**	**0,39**
soft/soft				
20 kPa	**0,06**	**0,1**	Not relevant	Not relevant
50 kPa	**0,04**	**0,07**	Not relevant	Not relevant
20 kPa, 6,7 kPa	Not relevant	Not relevant	**0,19**	**0,42**
50 kPa, 16,7 kPa	-	-	**0,05**	**0,12**

Design of Drainage Systems



Extract from BAM (2004), Secudrän

Table 3.4: Drainage lengths still permissible (without consideration for collectors)

Bedding	Plateau, $i = 0.05$, compressive stress		Slope, $i = 0.3$, compressive stress	
	20 kPa	50 kPa	20 kPa	50 kPa
	25 mm/d			
hard/soft	288 m	216 m	840 m	408 m
soft/soft	34 m	14 m	106 m	-

without water retention!

Design of Drainage Systems

How much does the drainage efficiency reduce under consideration of influences from installation conditions?

Design Equation: $$q_{entw} = q_{exp} \cdot \left(\frac{1}{FS_{IN} \cdot FS_{CR} \cdot FS_{CC} \cdot FS_{BC}} \right) \cdot \frac{1}{FS_{SY}}$$

q_{entw}: acceptable seepage water inflow

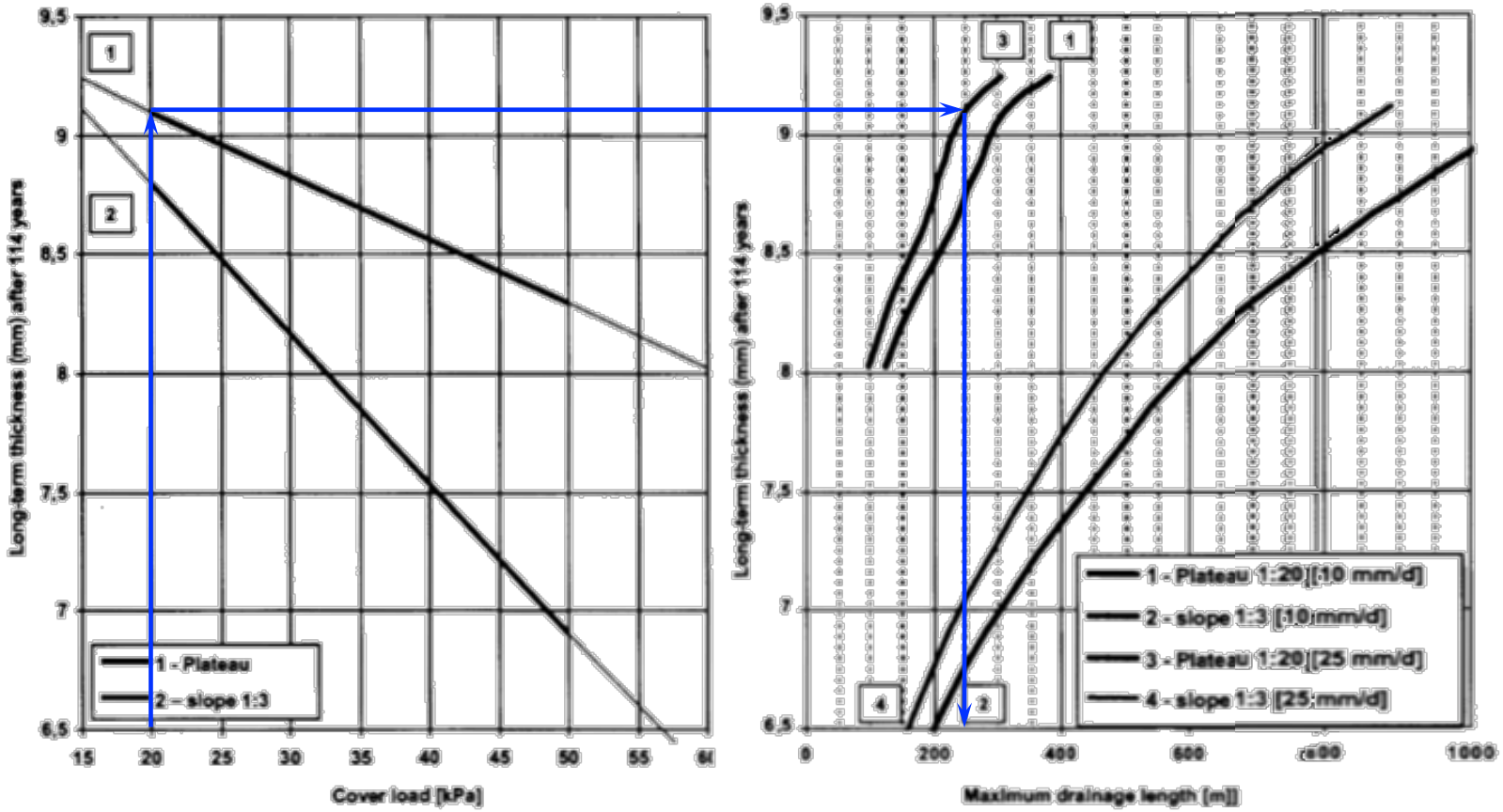
q_{exp}: water flow capacity as determined in short-term test

GDA: E 2-20 Drainage Systems in Landfill Caps		
FS_{IN}	1.0 - 1.5 ☑	Local deformations
FS_{CR}	1.2 - 1.4 ☑	Creep deformations
FS_{CC}	**1.0 - 1.2**	Reduction of drainage cross section due to Chemical influences
FS_{BC}	**1.2 – 1.5**	Reduction of drainage cross section due to Biological influences
FS_{SY}	1.0 or 2.0	General system uncertainty for transfer of experimental data to field conditions

☑ **(already considered in BAM-approval)**

Design of Drainage Systems

Design Nomograph (GDA-recommendations) on maximum drainage length, without using collectors, for Secudrän® R201Z WD601Z R201Z



Remarks:

- only for bedding hard/soft
- $q_{1,2}$ determined via creep curves for bedding hard/hard, percentage reduction from initial values for hard/soft (see section 9.2, BAM-expert report, file number IV.32/1317/04)
- using factor of safety according to Naue Fasertechnik / BBG: FS_{ID} = 1,25; FS_{CR} = 1,0; FS_{CC} = 1,05; FS_{CB} = 1,3; total: FS = 1,7
- using seepage water discharge and factors of safety according toGDA-E2-20 (1997): 10 mm/d FS_{TY} = 2,0; bei 25 mm/d FS_{TY} = 1,0

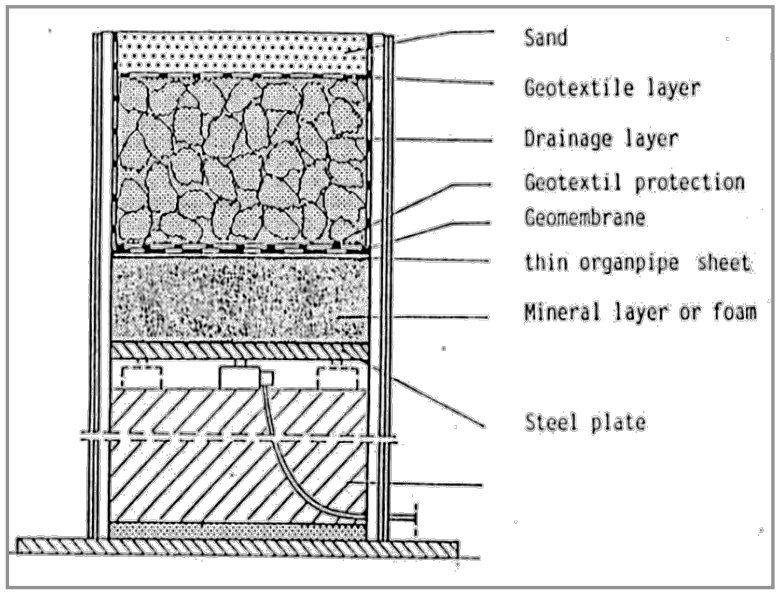
Design of Drainage Systems

1. Filtration Efficiency
2. Drainage discharge of seepage water inside the core (flow rate)
3. Protection Efficiency, e.g. against geomembrane

Compression test DIN EN 13719 (BAM Method)

$L = \gamma \cdot h \cdot 1.5 \cdot \eta t \cdot \eta °C$

L = Test load
γ = Unit weight of waste
h = Height of waste
ηt = Safety factor time (1000 h = 1; 100 h = 1.5)
$\eta °C$ = Safety factor temperature (40°C =1; 21°C = 1.5)



Design of Drainage Systems

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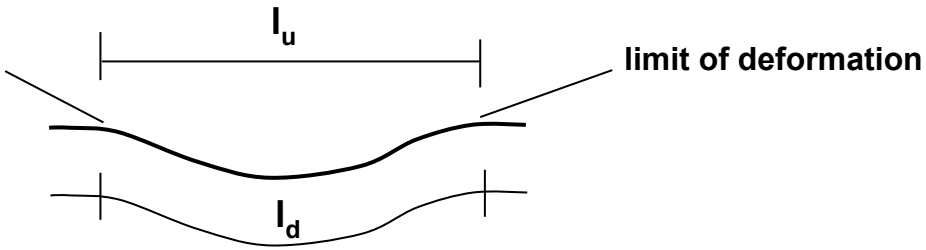
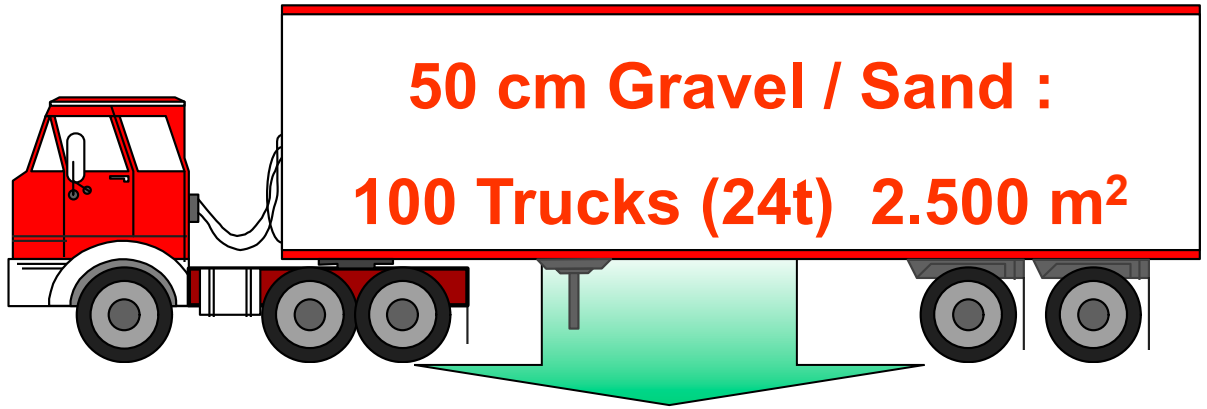
2. Drainage discharge of seepage water inside the core (flow rate)
3. Protection Efficiency, e.g. against geomembrane



Arch Strain:

$$\varepsilon = (l_d - l_u) / l_u \leq 0.25\%$$

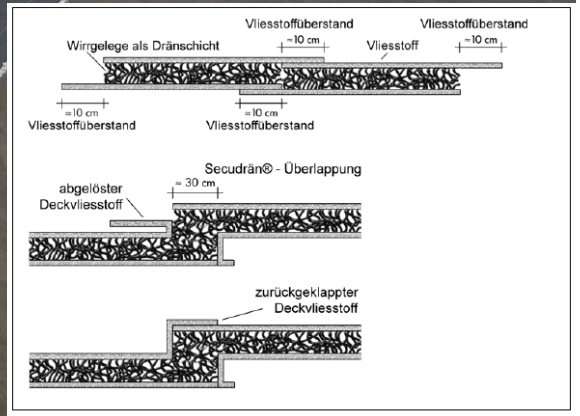
Economic & Ecologic Advantages of Drainage Geocomposites

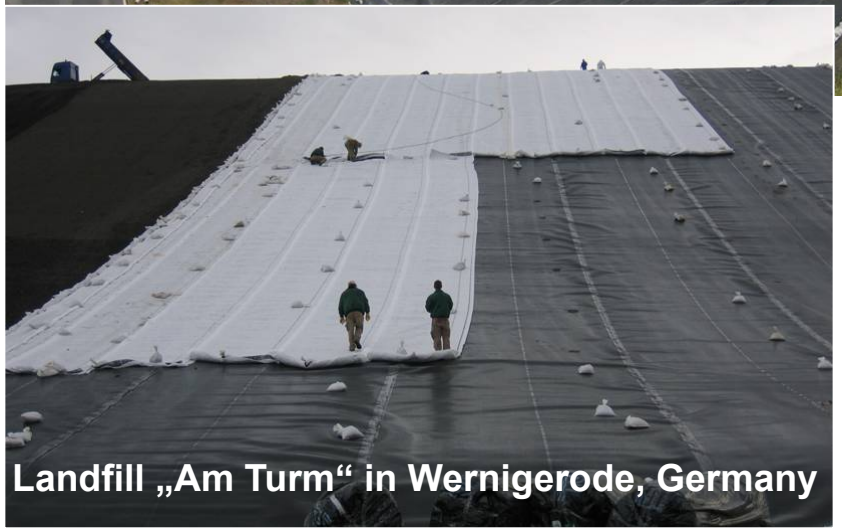


Economic & Ecologic Advantages of Drainage Geocomposites

Installation

Landfill „Am Turm“ in Wernigerode, Germany





Landfill „Am Turm“ in Wernigerode, Germany

Installation

Landfill Friedländer Berg, Germany

Installation

Installation

Landfill UBIG in Wünschendorf, Germany

Conclusions

Under consideration, that as drainage layer a **drainage geocomposite** with high robustness **for a design life > 100 years** (BAM-Approval) is designed, installed, covered and inspected appropriately, an **extraordinary high servicability** of the drainage layer can be expected.

Field tests and excavations provide valuable information

Additional mineral drainage layers are **not required!**

Decisive for the **Stability of the system** is the Design of the Vegetation Layer and the toe of the slope.

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