Overview of Geosynthetic Materials, Their Characteristics, Applications, and Design Considerations

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Outline of Presentation

- Introduction
- Geosynthetic Products
- Primary Functions
- Material Characteristics
- Applications
- Design Considerations

Geosynthetics

- Geo: Earth - soil or rock
- Synthetics:

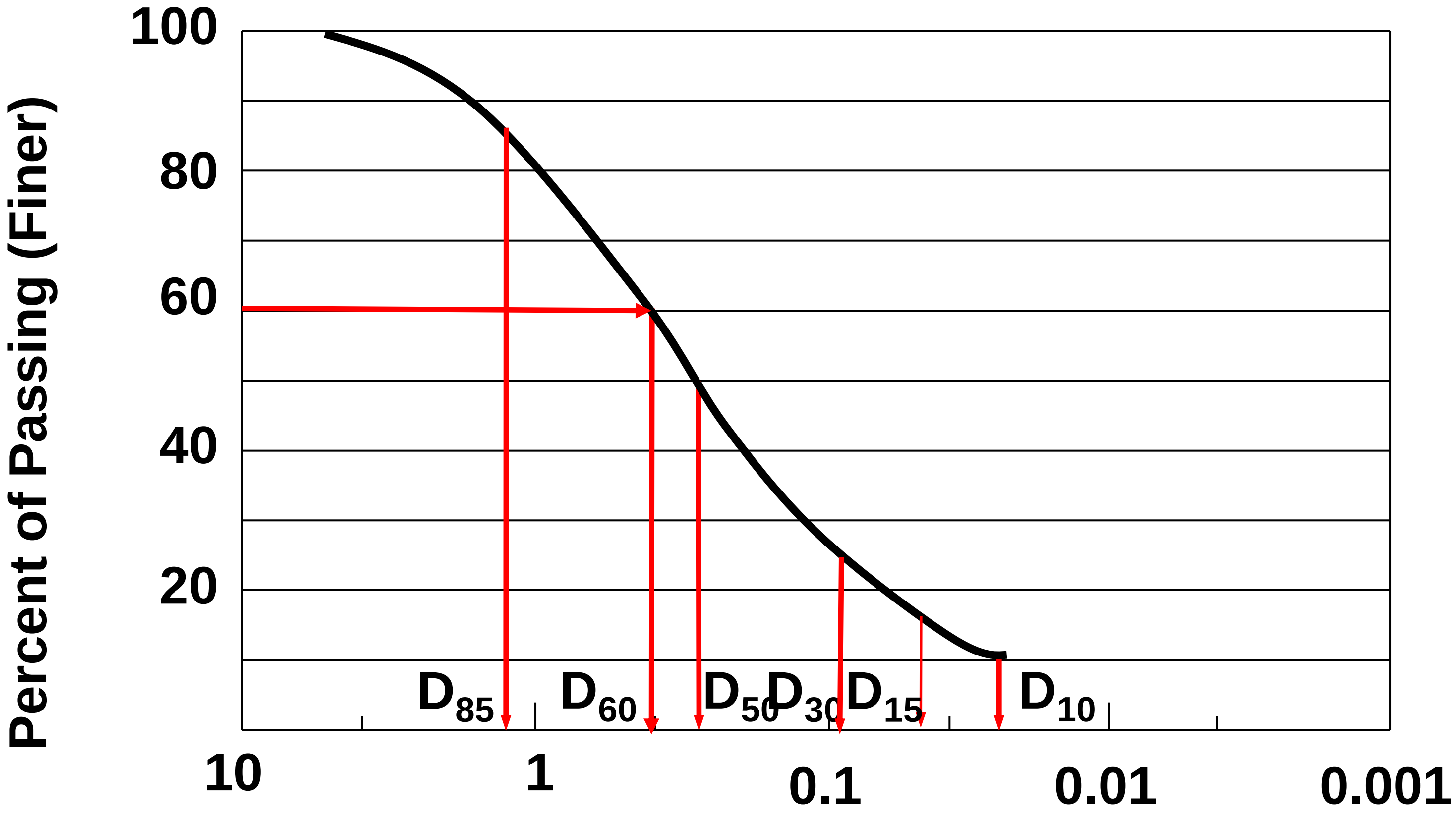
  Man-made products, mainly polymers

Textural Soil Classification

Soil Name	Particle Size (in.)	U.S. Sieve No.
Boulders	> 12	
Cobbles	12 - 3	
Gravel		
Coarse	3 – 3/4	3 - 3/4 in.
Fine	3/4 – 0.19	3/4 in. to No. 4
Sand		
Coarse	0.19 – 0.079	No. 4 to No. 10
Medium	0.079 - 0.017	No. 10 to No. 40
Fine	0.017 - 0.003	No. 40 to No. 200
Clays and silts	< 0.003	

State of Soil

Particle Sizes



Particle Size (in.) – log Scale

Soil Gradation

Coefficient of uniformity

$$C_u = \frac{D_{60}}{D_{10}}$$

Coefficient of curvature

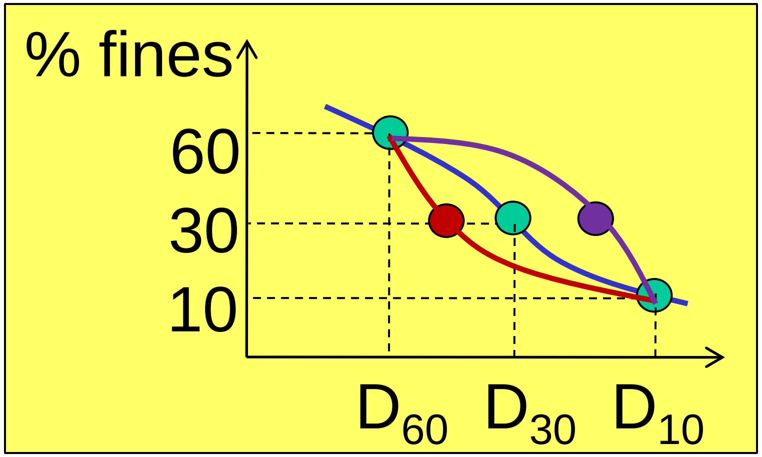
$$C_c = \frac{\left(D_{30}\right)^2}{D_{60} D_{10}}$$

Cu > 4 (gravel) or 6 (sand)

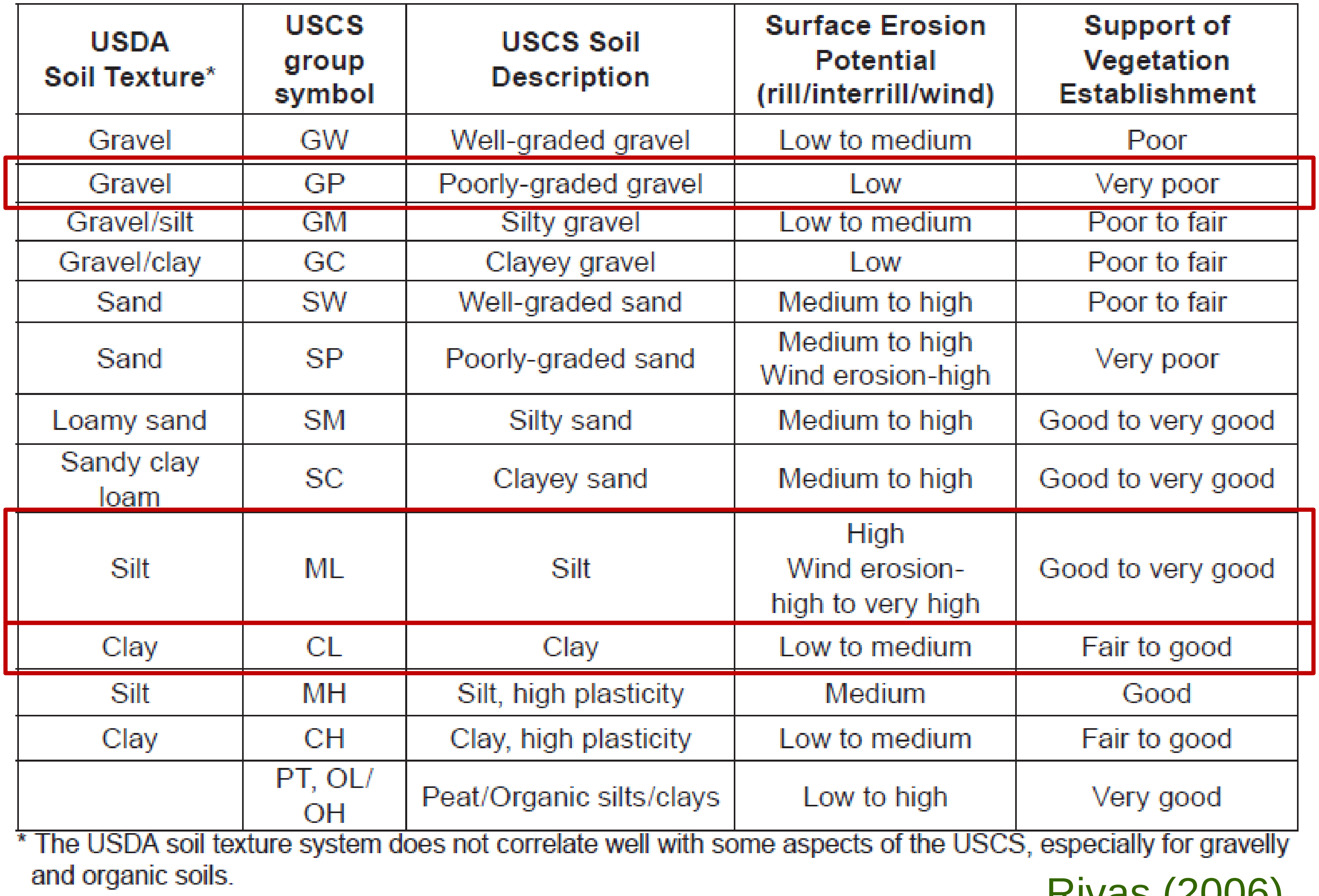
1 < Cc < 3

Well-graded (W)

Others Poorly-graded (P)



Surface Erosion Potential and Plant Growth Capability

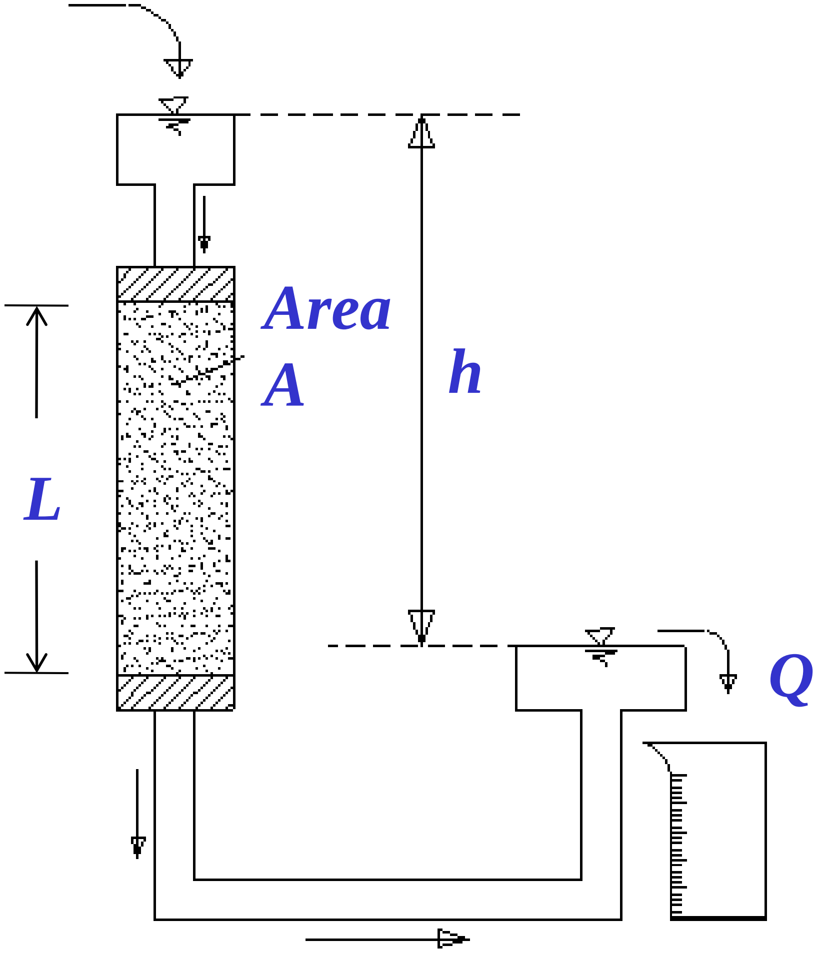


USDA Soil Texture*	USCS group symbol	USCS Soil Description	Surface Erosion Potential (rill/interrill/wind)	Support of Vegetation Establishment
Gravel	GW	Well-graded gravel	Low to medium	Poor
Gravel	GP	Poorly-graded gravel	Low	Very poor
Gravel/silt	GM	Silty gravel	Low to medium	Poor to fair
Gravel/clay	GC	Clayey gravel	Low	Poor to fair
Sand	SW	Well-graded sand	Medium to high	Poor to fair
Sand	SP	Poorly-graded sand	Medium to high Wind erosion-high	Very poor
Loamy sand	SM	Silty sand	Medium to high	Good to very good
Sandy clay loam	SC	Clayey sand	Medium to high	Good to very good
Silt	ML	Silt	High Wind erosion-high to very high	Good to very good
Clay	CL	Clay	Low to medium	Fair to good
Silt	MH	Silt, high plasticity	Medium	Good
Clay	CH	Clay, high plasticity	Low to medium	Fair to good
	PT, OL/OH	Peat/Organic silts/clays	Low to high	Very good

* The USDA soil texture system does not correlate well with some aspects of the USCS, especially for gravelly and organic soils.

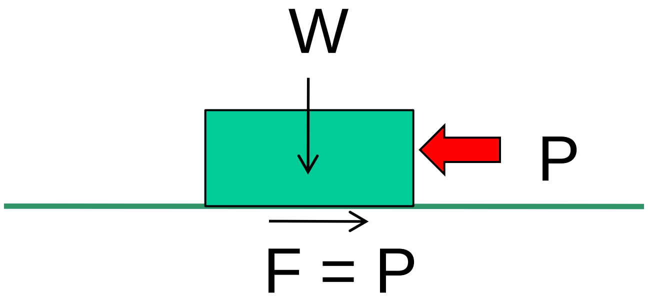
Rivas (2006)

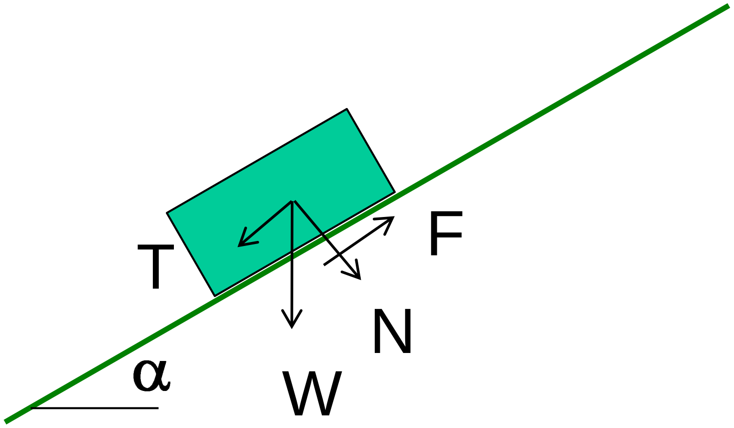
Soil Permeability



Permeability $$k = \frac{QL}{Ah}$$

Basics of Physics





Frictional coefficient

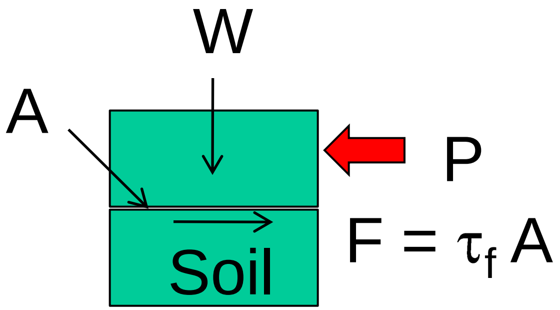
$$f = \frac{F}{W} = \tan\phi$$

ϕ = frictional angle

Factor of Safety

$$FoS = \frac{F}{T} = \frac{\tan\phi}{\tan\alpha}$$

Soil Strength



Shear strength

$$\tau_f = c + \frac{W}{A} \tan\phi$$

c = cohesion
ϕ = frictional angle

Short term

c = 0 for uncemented sand
(air dry or saturated)

c > 0 for clay
(air dry or saturated)

Long term

c = 0 for uncemented sand

c = 0 for clay (saturated)

Apparent Cohesion

Shear strength

$$\tau_f = c_a + \frac{W}{A} tan \phi$$

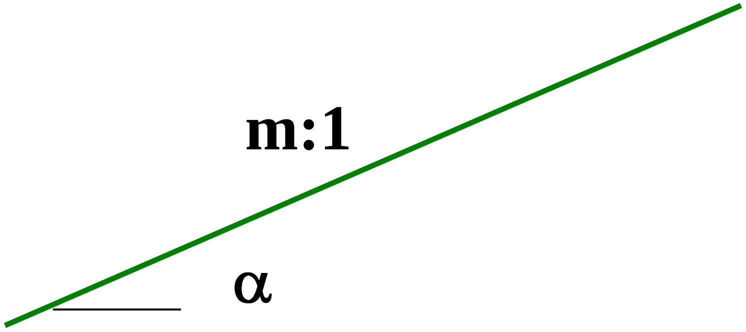
c_a = apparent cohesion
ϕ = frictional angle

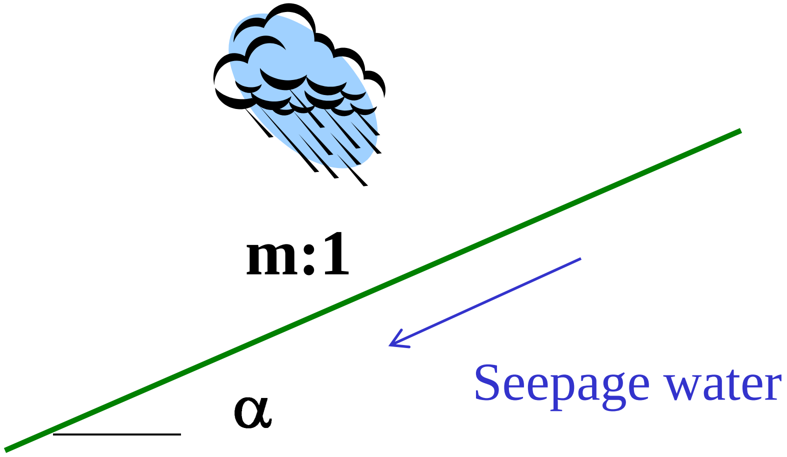
Apparent cohesion

- Exist when soil is unsaturated due to capillary action (i.e., suction), but disappear when soil is saturated or dry

- Rooted soil has apparent cohesion

Long-term Stability of Natural Slope





$$FS = \frac{\tan\phi}{\tan\alpha} \geq 1.0$$

$$FS \approx 0.5\frac{\tan\phi}{\tan\alpha} \geq 1.0$$

For typical soil, $\phi = 30^o$

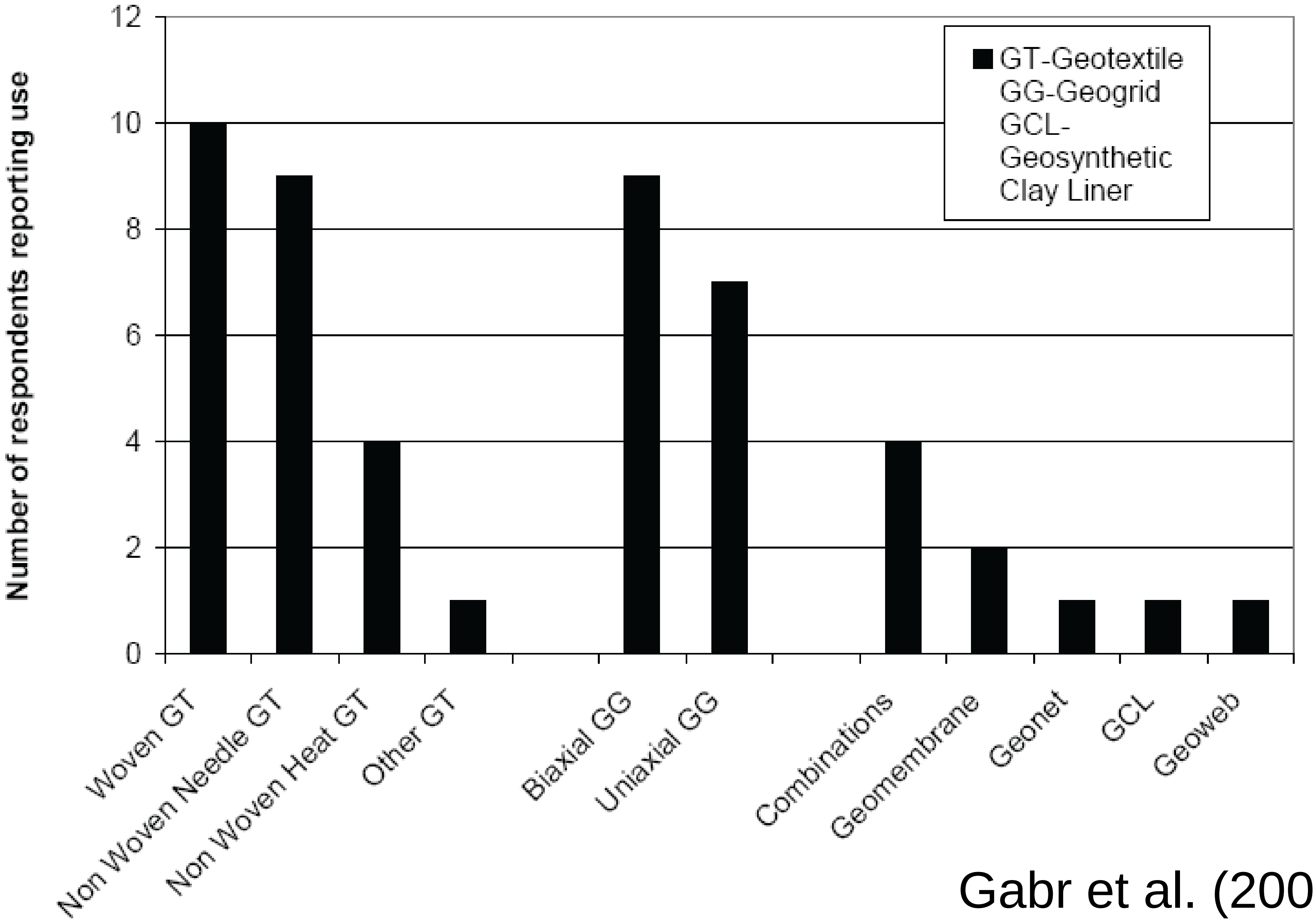
2(H):1(V) slope (27^o) Stable 4(H):1(V) slope (14^o)

Products of Geosynthetics

Geosynthetic Products

- Geotextile (GT)
- Geogrid (GG)
- Geonet (GN)
- Geomembrane (GM)
- Geosynthetic Clay Liner (GCL)
- Geocell/geoweb (GW)
- Geocomposite (GC)
- Geotube (GTB)
- Erosion mat (EM)
- Others

Types of Geosynthetics Used



Woven GT	10
Non Woven Needle GT	9
Non Woven Heat GT	4
Other GT	1
Biaxial GG	9
Uniaxial GG	7
Combinations	4
Geomembrane	2
Geonet	1
GCL	1
Geoweb	1

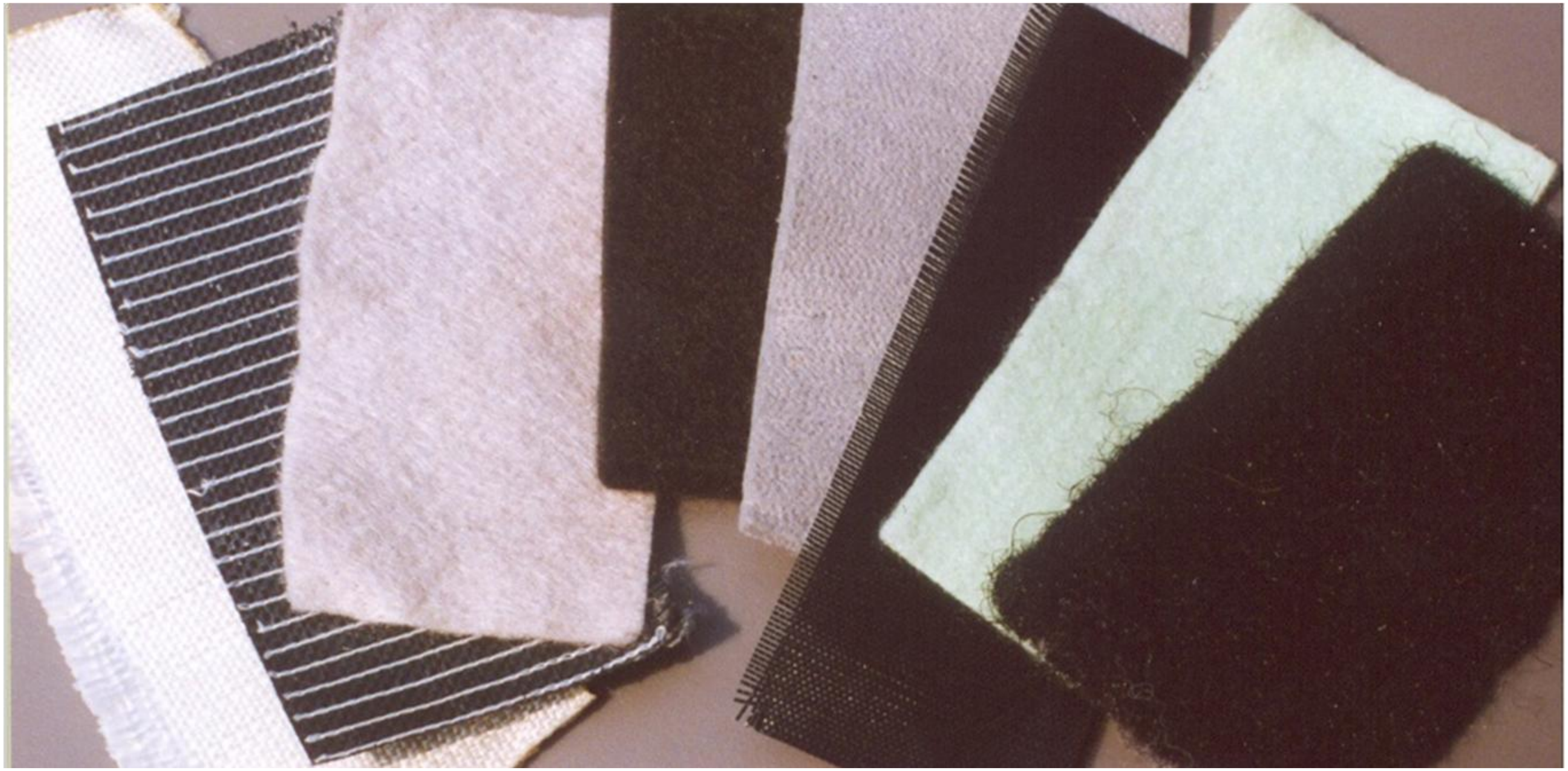
Gabr et al. (2006)

Type of Polymer

- Polypropylene (PP)
- Polyester (PET)
- Polyethylene (PE)
- Polyamide (nylon)
- Others

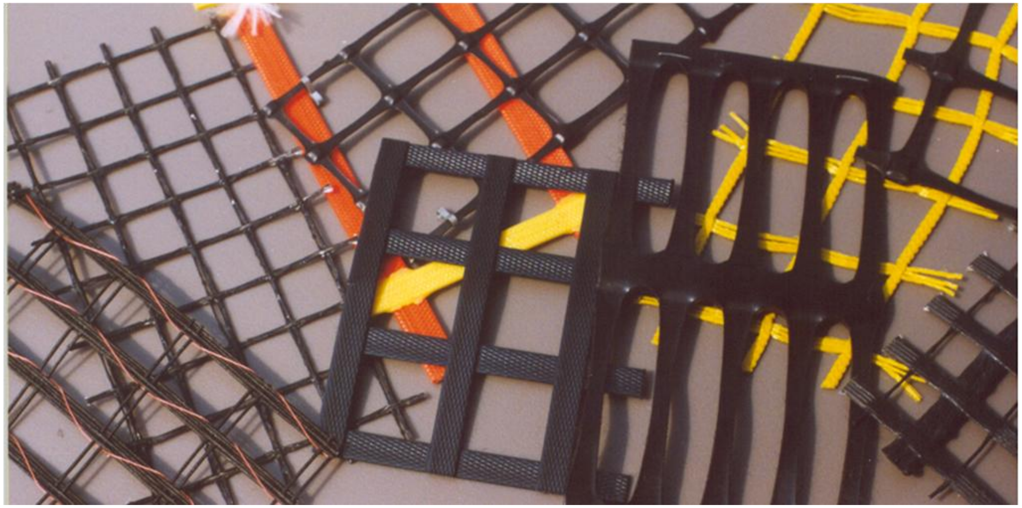
Geotextiles

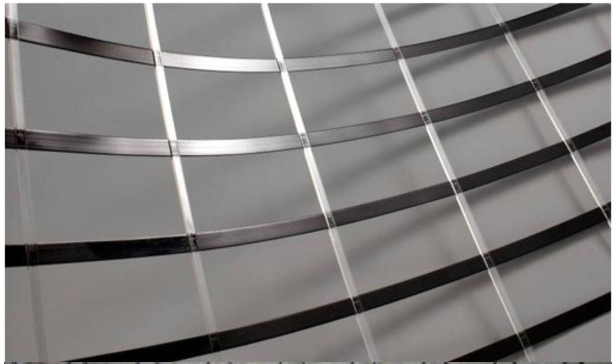
- Nonwoven Geotextiles: bonded or needle-punched
- Woven Geotextiles

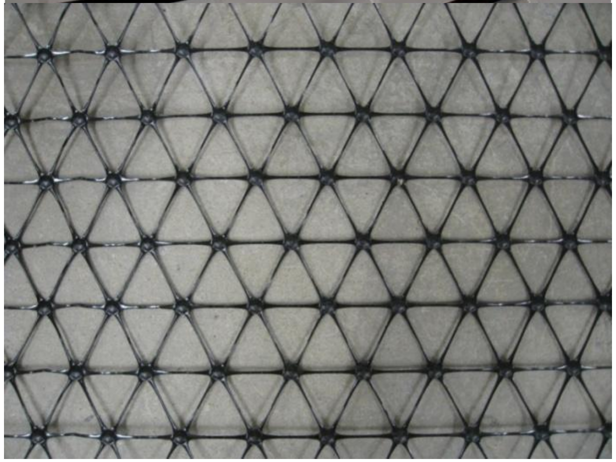


Geogrids

- Consist of apertures with ribs
- UX, BX, or TX geogrid
- Punched and drawn, coated woven or wielded

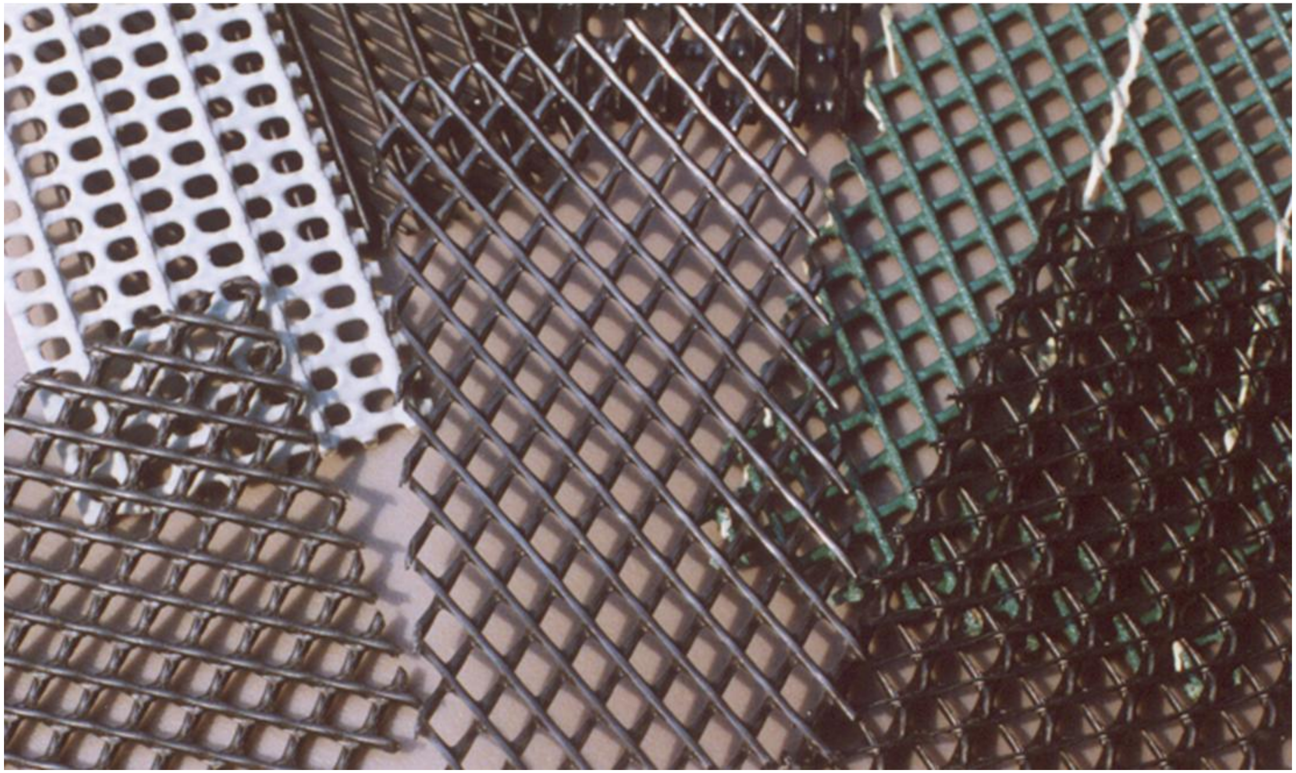






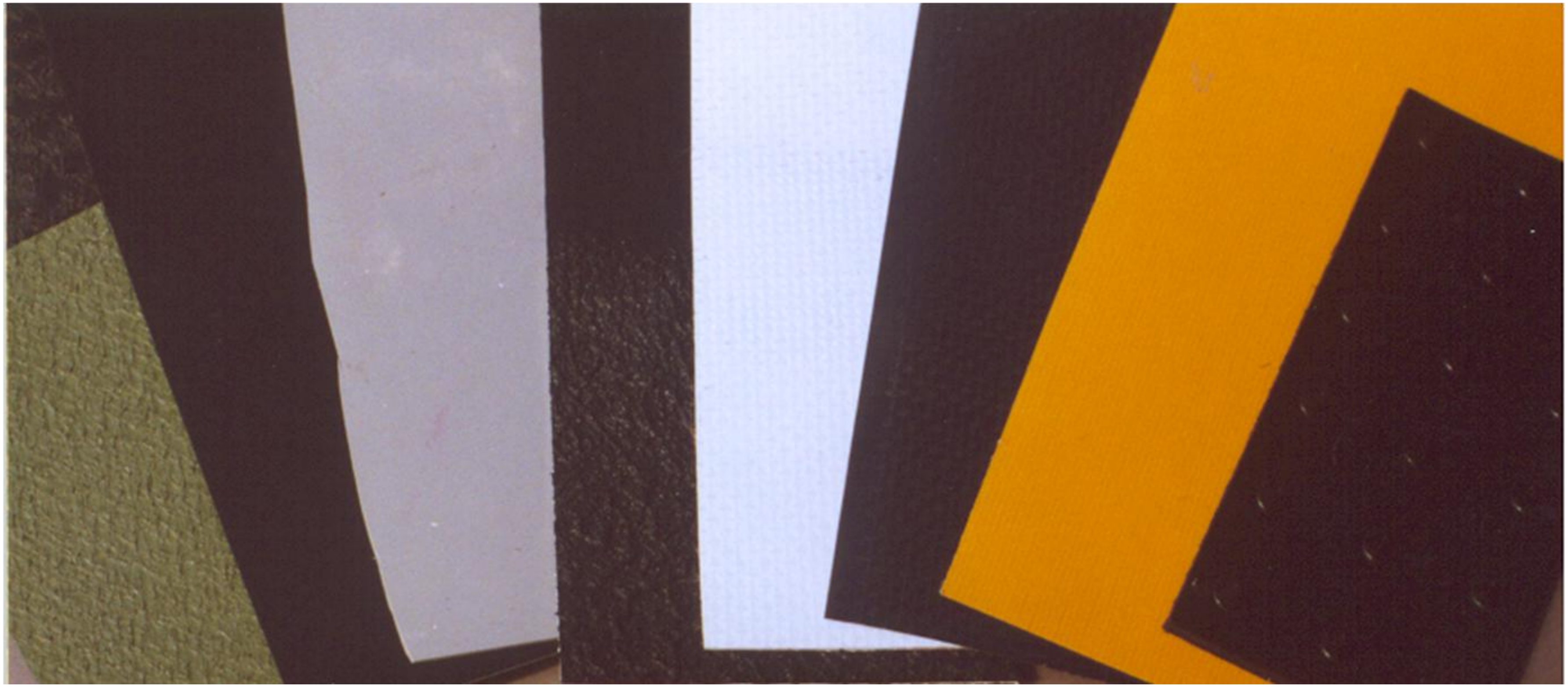
Geonets

- **Grid-like materials, made of polyethylene (PE)**
- **Have thickness difference in ribs**
- **Used for in-plane drainage**



Geomembranes

- PE dominates, sometimes PP or PVC
- Manufactured by extrusion
- Smooth or rough (textured) surfaces
- Impermeable materials, mainly used as barriers

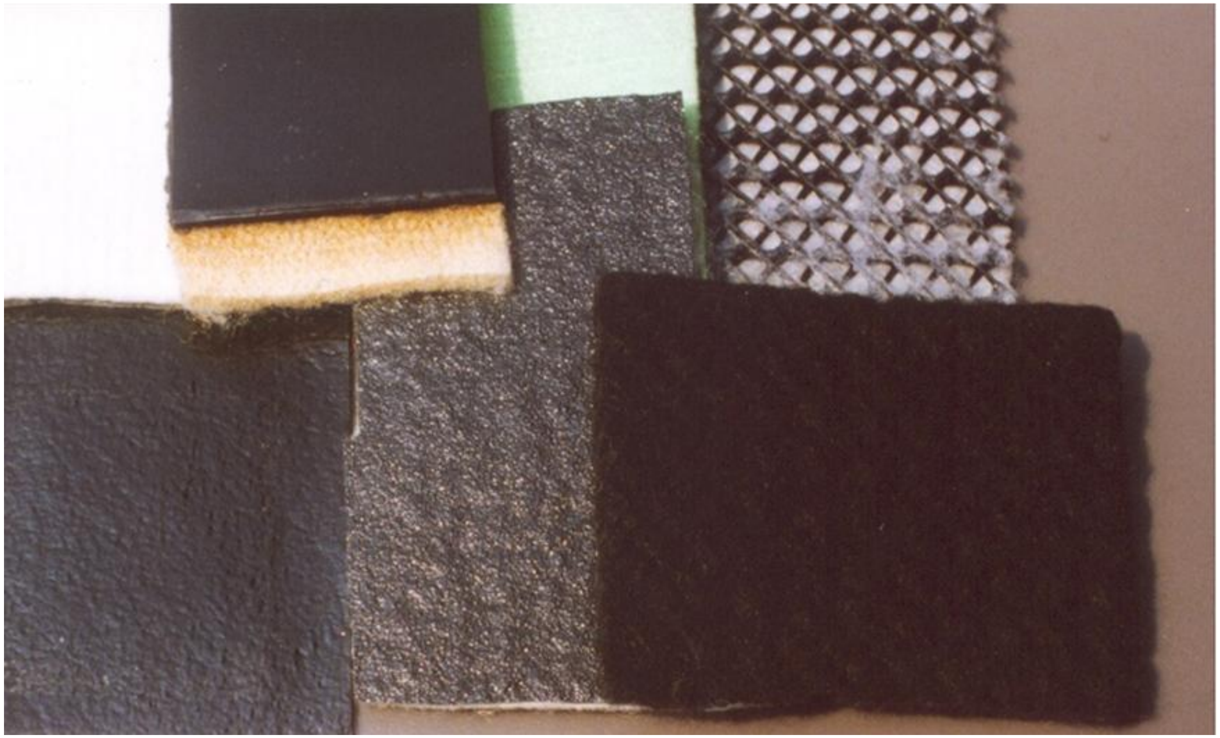


Geosynthetic Clay Liners

- Bentonite clay bonded between two geotextiles
- Used as replacement for compacted clay liners or geomembranes

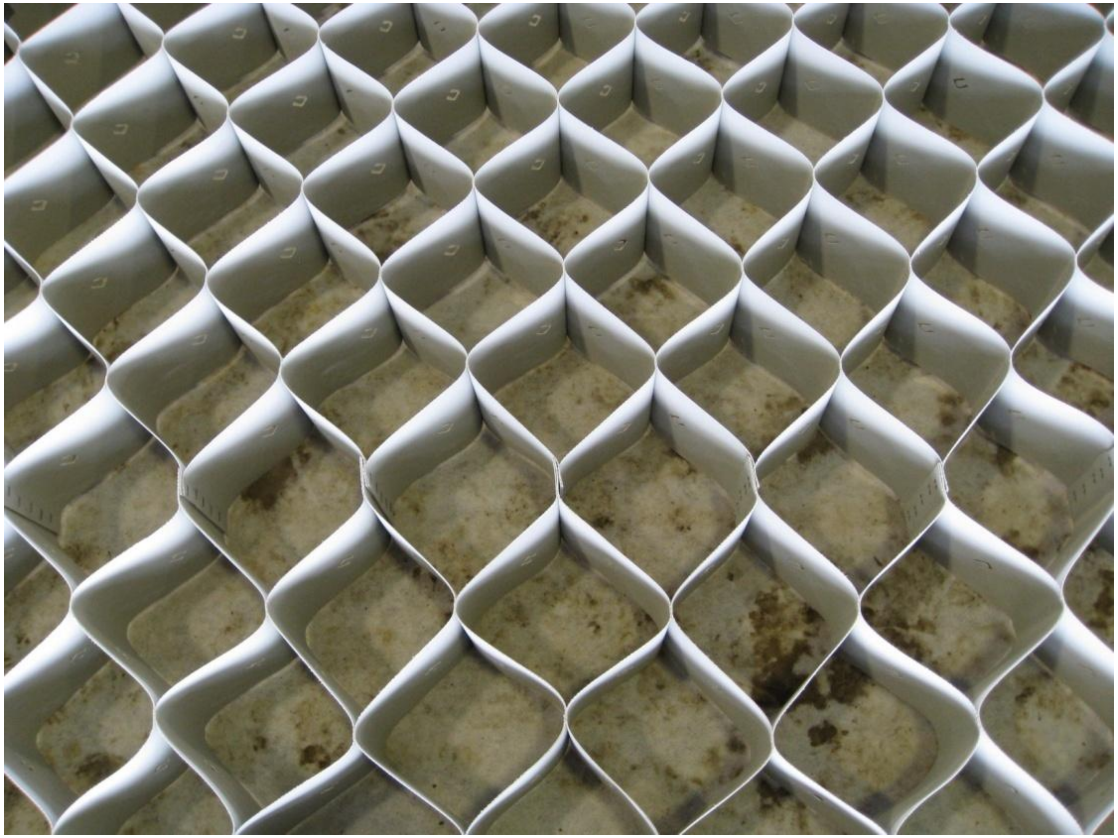
Geocomposites

- Combine two or more geosynthetic products to one product
- Geotextile-geonet composites
- Geotextile-geogrid composites



Geocell or Geoweb

- An expandable three-dimensional honeycomb-like structure
- Used for soil confinement



Geotubes

- **Sediment-filled sleeves of geotextile with an oval cross section**

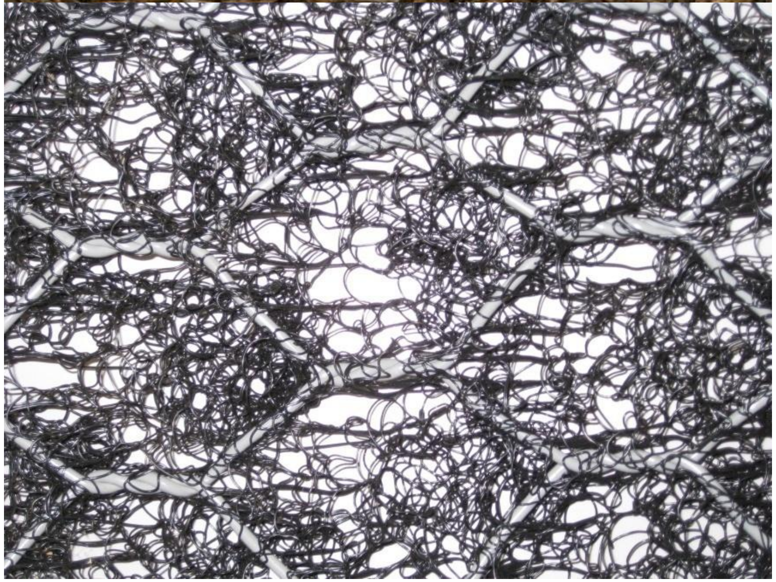
- **Mainly used for erosion protection along shores and waterfronts**

Erosion Blanket or Mats

- **Protect ground surfaces (especially slopes) from loss of soil due to water**

- **Temporary erosion mats are used for flatter slopes (<45º) and degraded after development of vegetation (i.e., Erosion-control blanket)**

- **Permanent erosion mats are used for steep slopes (≥45º) (i.e., Turf Reinforcement Mat)**



Functions of Geosynthetics

Primary Functions of Geosynthetics

- **Separation**
- **Filtration**
- **Drainage**
- **Reinforcement**
- **Containment (barrier)**
- **Erosion protection**

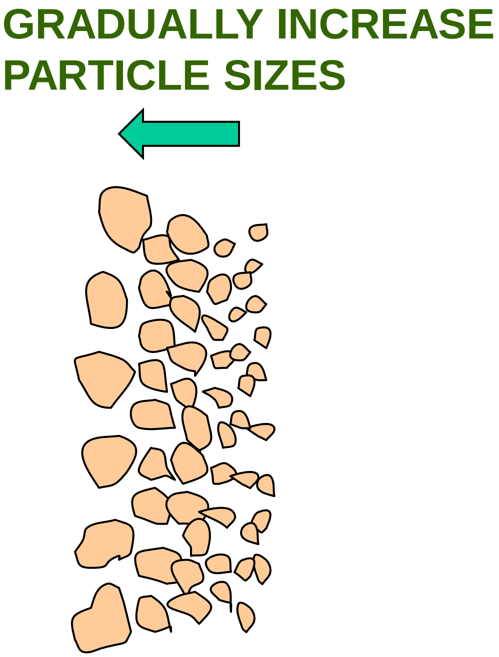
Separation Function

- Keep the integrity and functioning of two dissimilar materials intact
- Prevent stone aggregate intruding into fine soil
- Prevent soil fines pumping into aggregate

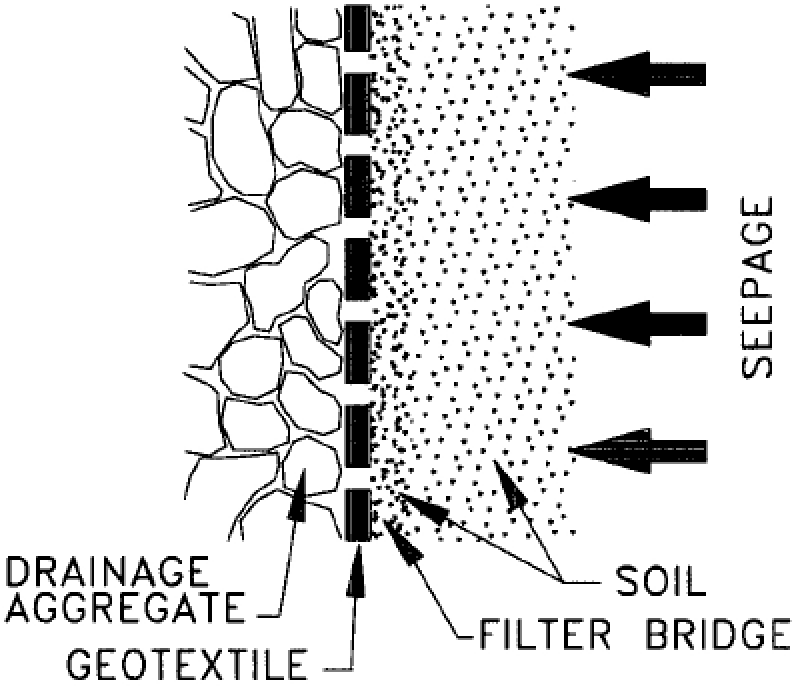
Courtesy of Christopher

Filtration Function

- **Allow for adequate liquid flow**
- **Limit soil loss across the interface plane**



Natural filter

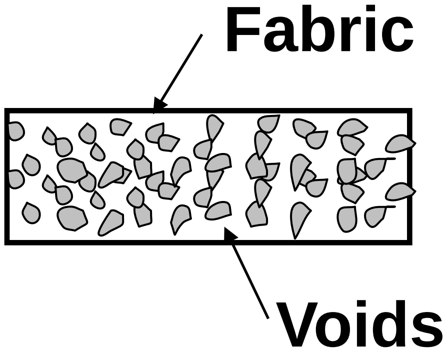


FHWA NHI-07-092

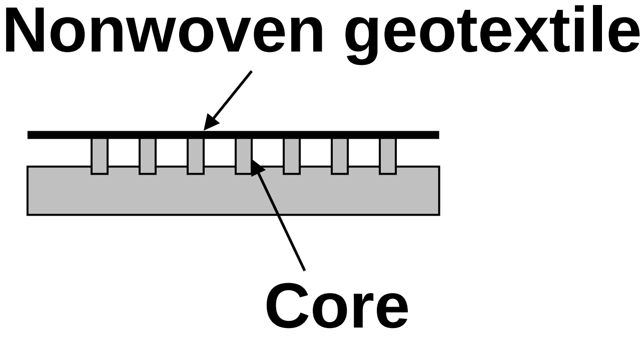
Geotextile filter

Drainage Function

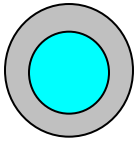
- **Large porosity or open space to allow water quickly flow through**



Nonwoven geotextile



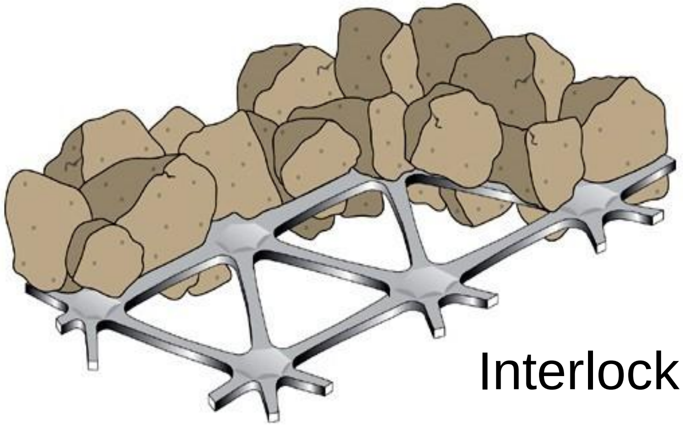
Geocomposite



Geopipe

Reinforcement Function

- **Provide (tensile) strength necessary for soil**
- **Increase shear (interlocking) resistance**
- **Increase stiffness & minimize deformation (confinement)**

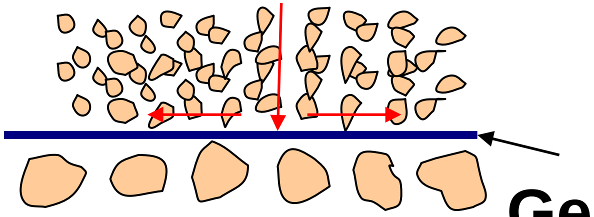


Interlocking

Confinement

Containment Function

- **Low permeable materials minimize liquid flow**



Erosion Protection Function

- Avoid water drops directly hitting on soil surface
- Reduce rate of water flow
- Contain and retain soil particles

Summary of Primary Functions of Geosynthetics

Type	SP	RF	FT	DN	CT	EP
NWV GT	√	X	√	√	X	√
WV GT	√	√	√	X	X	√
GG	X	√	X	X	X	X
GN	X	X	X	√	X	X
GM	√	X	X	X	√	√
GCL	√	X	X	X	√	√
GW	X	√	X	X	√	√
GP	X	X	X	√	X	X
GC	D	D	D	D	D	D
GTB	√	X	√	√	X	√

SP=Separation

RF=Reinf.

FT=Filtration

DN=Drainage

CT=Containment

EP=Erosion Protection

Properties of Geosynthetics

Properties of Geosynthetics

Physical properties

- Mainly for quality control and assurance

Hydraulic properties

- Important for separation, filtration, drainage, and containment applications

Mechanical properties

- Important for reinforcement applications and constructability

Durability properties

- Important for long-term performance

Physical Properties

- Polymer (PE, PP, PET, etc.)
- Mass per unit area (oz/yd^2 or g/m^2)
- Thickness (mil = 1/1000 inch, mm)
- Roll length
- Roll width
- Roll diameter
- Specific gravity and density
- Surface characteristics

Hydraulic Properties

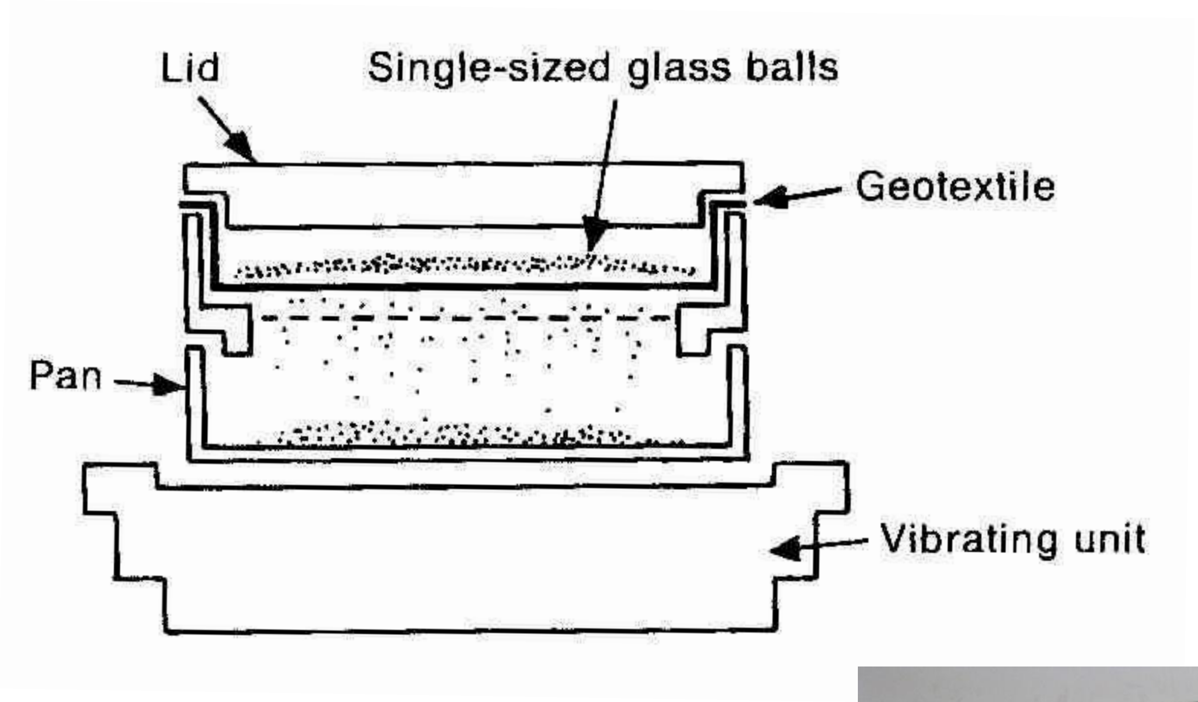
- Opening characteristic (geotextile)
  - ➢ Apparent Opening Size (AOS)
  - ➢ Percent Open Area (POA)
  - ➢ Porosity (n)
- Permeability and permittivity
- In-plane flow capacity (transmissivity)

Apparent Opening Size (AOS)

Test procedures

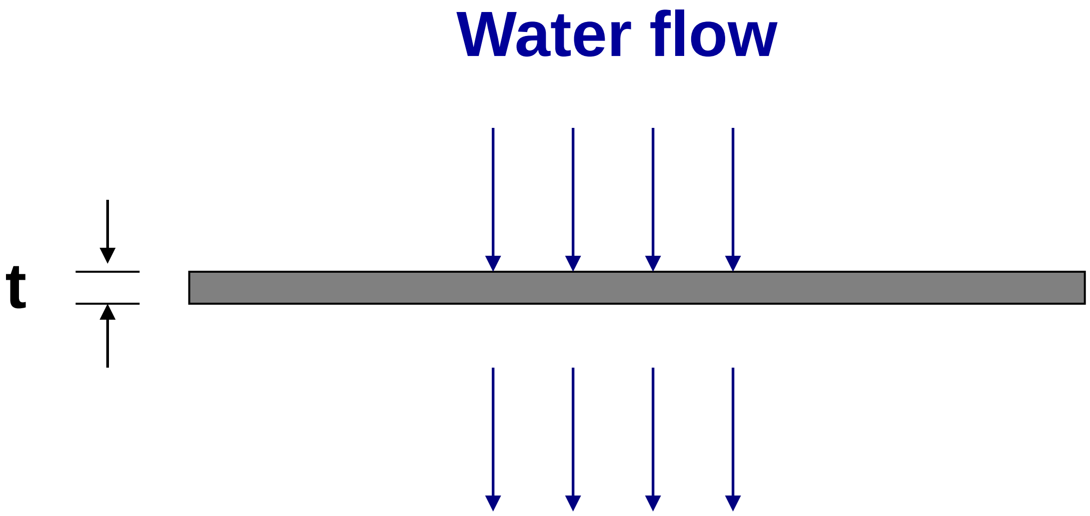
- Place geotextile sample into the sieve frame
- Start with the smallest diameter beads
- Place 50g of one size glass beads on the center of geotextile
- Shake the sieve for 10 min.
- Weigh the glass beads that pass through the specimen
- Repeat the test using larger bead size fractions until the weight of beads passing through the specimen to be 5% or less

AOS or O_{95} = the size of the beads of which 5% or less pass

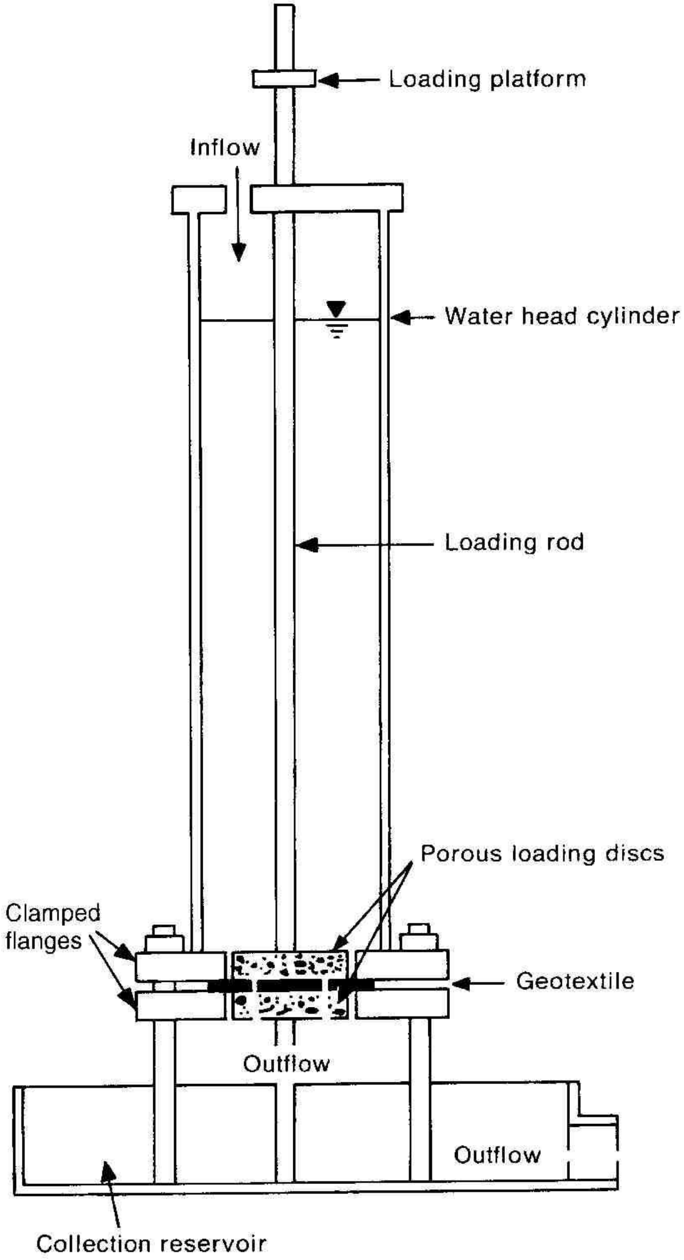

Lid
Single-sized glass balls
Geotextile
Pan
Vibrating unit

Test for AOS

Permittivity

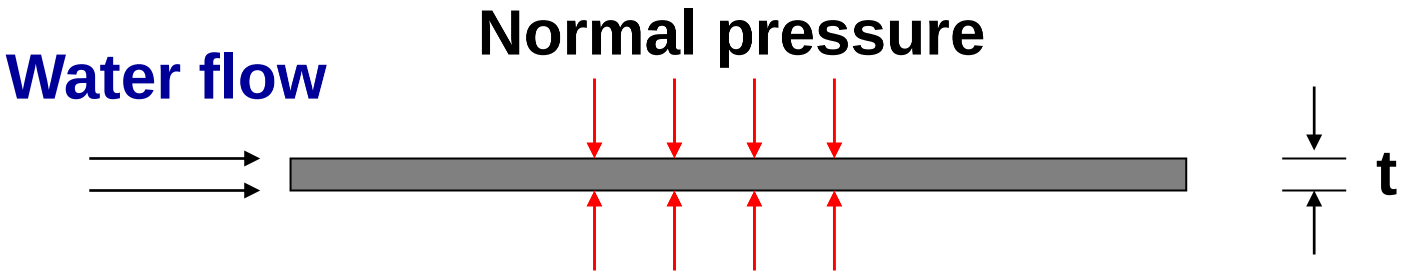


$$\psi = \frac{k_n}{t}$$



ψ = Permittivity
k_n = Cross-plane permeability oefficient
t = Thickness at a specified normal pressure

Transmissivity



Normal pressure

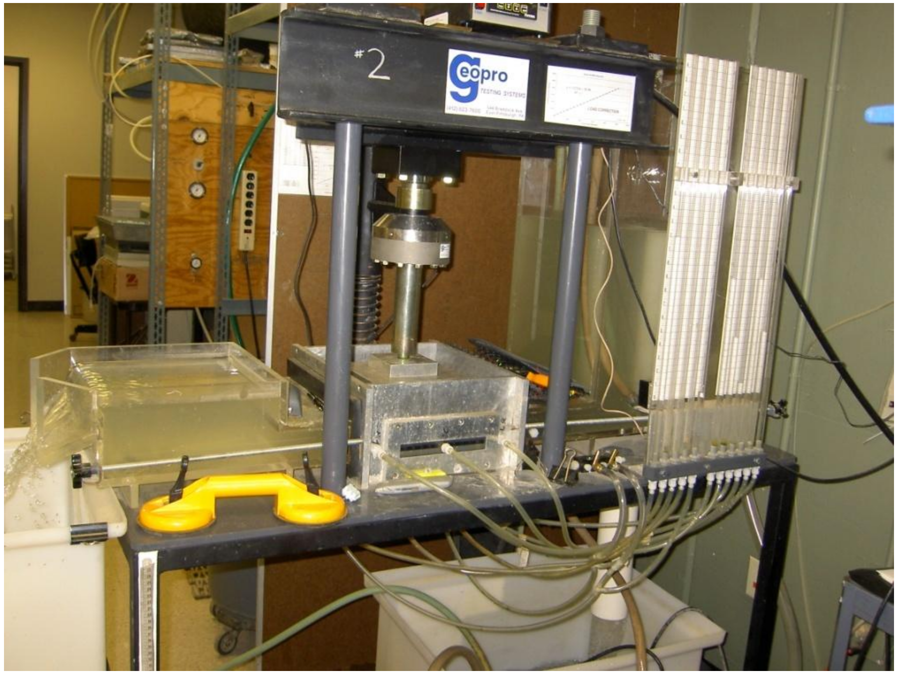
Water flow

t

$$\theta = k_p t$$

θ = Transmissivity

k = In-plane permeability coefficient



Allowable Flow Rate of Geosynthetic Filter or Drainage

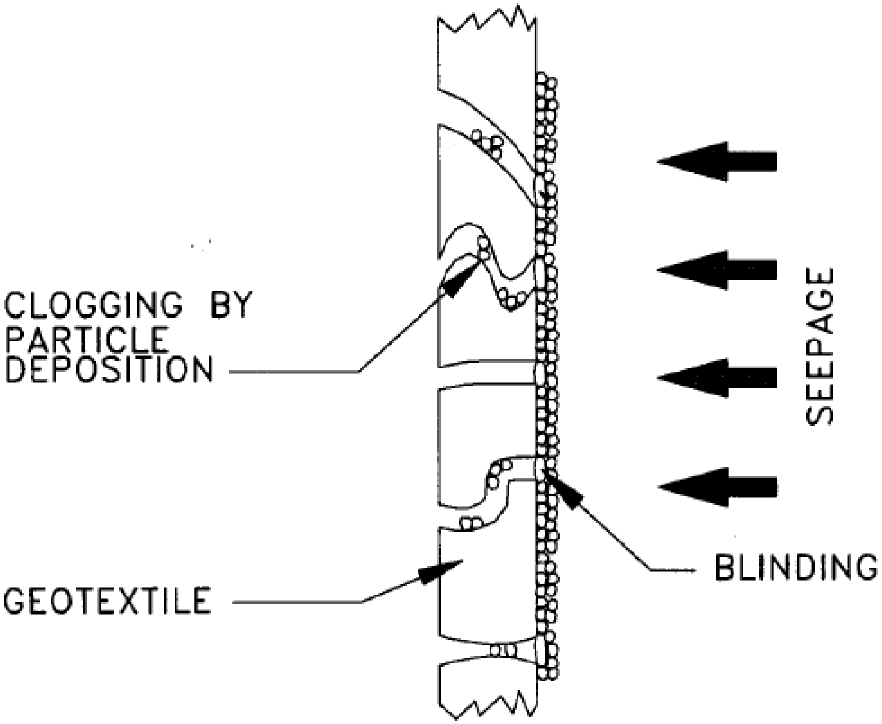
$$q_a = q_{ult} \frac{1}{RF_{SCB} \times RF_{CR} \times RF_{IN} \times RF_{CC} \times RF_{BC}} = q_{ult} \frac{1}{RF}$$

q_a = allowable flow rate
T_{ult} = ultimate flow rate
RF = overall reduction factor
RF_{SCB} = RF for soil clogging and blinding (2 – 10)
RF_{CR} = RF for creep reduction of void space (1 – 2)
RF_{IN} = RF for adjacent materials intruding into void space of geosynthetics (1 – 1.2)
RF_{CC} = RF for chemical clogging (1 – 1.5)
RF_{BC} = RF for biological clogging (1 – 4)

Geotextile Clogging and Blinding

Sand or Root Penetration

Reduction Factor ?



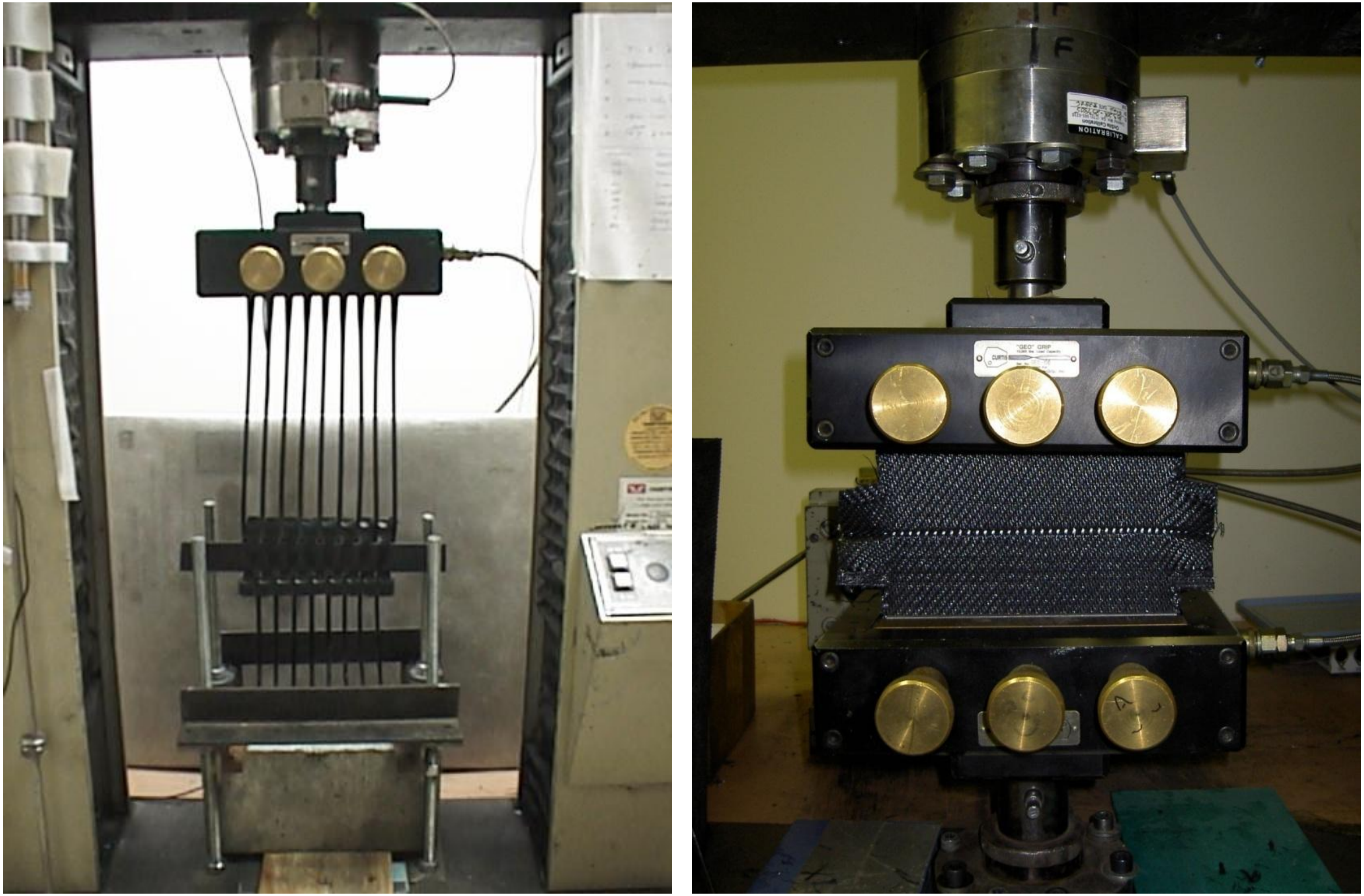
Richardson

Bell and Hicks (1980)

Mechanical Properties

- Tensile strength
  - Grab strength (geotextile or geomembrane)
  - Single rib strength (geogrid)
  - Narrow strip strength (geomembrane)
  - Wide-width strength (geotextile or geogrid)
- Junction strength (geogrid)
- Creep resistance
- Seam strength (geotextile or geomembrane)
- Tear strength (geotextile or geomembrane)
- Burst strength (geotextile or geomembrane)
- Puncture strength (geotextile or geomembrane)
- Penetration Resistance

Tensile Strength Test



Creep Test

Courtesy of Leshchinsky

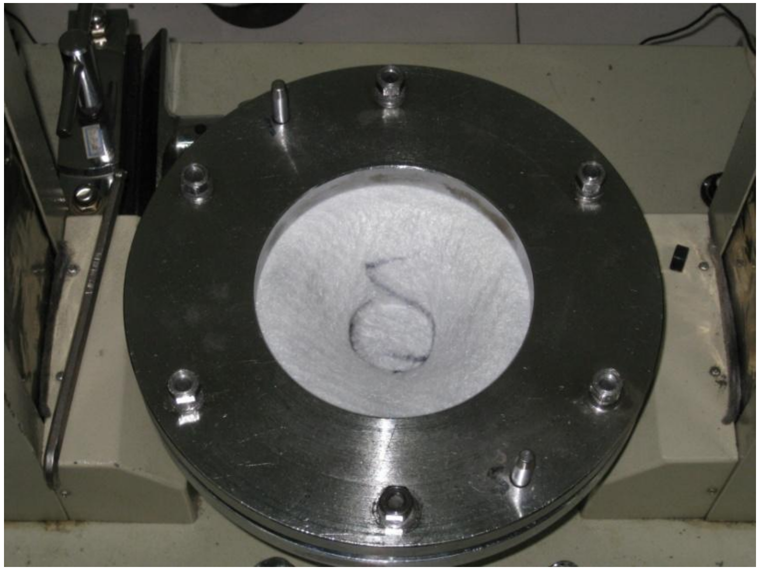
Yuan

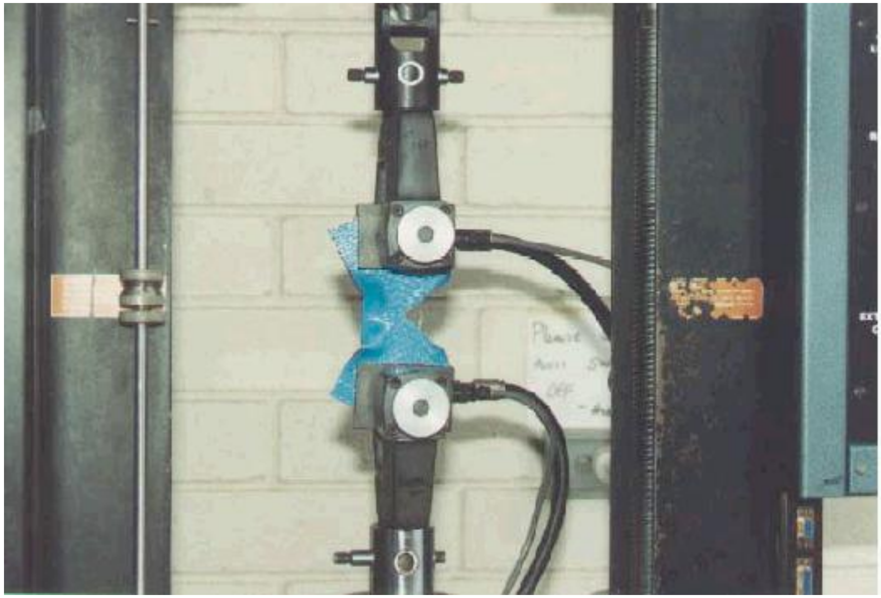
Creep Reduction Factors

Polymer Type	Creep reduction factor, RF_{CR}
Polyester (PET)	1.6 to 2.5
Polypropylene (PP)	4.0 to 5.0
High Density Polyethylene (HDPE)	2.6 to 5.0

(FHWA NHI-00-043)

Resistance Tests





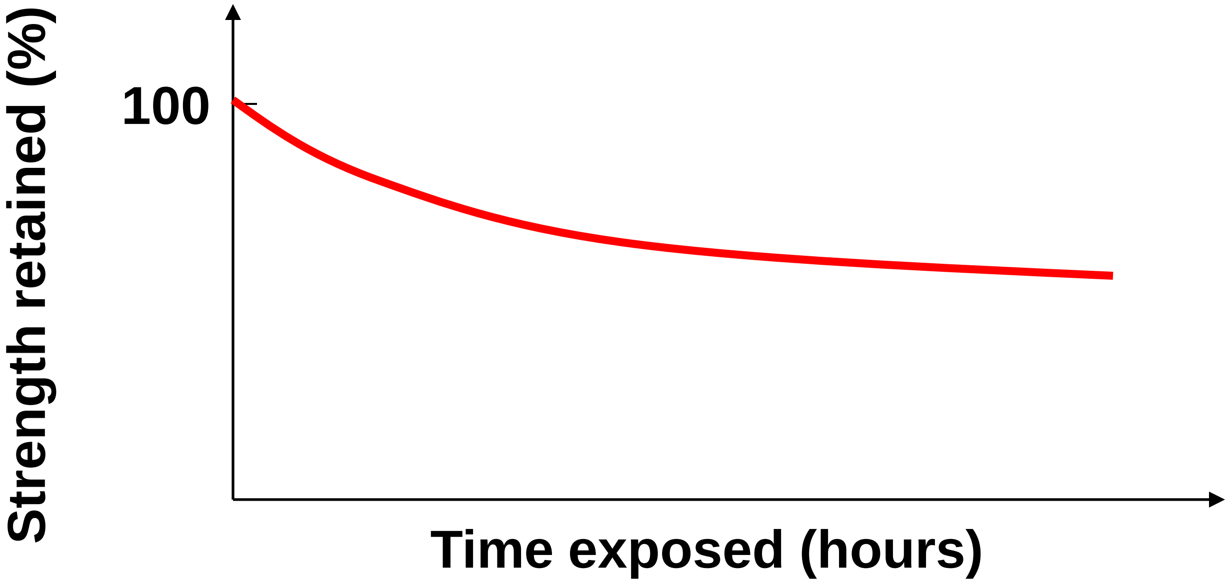
Durability Properties

- Abrasion resistance
- UV resistance
- Chemical resistance
- Biological resistance
- Temperature stability

Sunlight (UV) Degradation

Laboratory exposure test

- Xenon-arc exposure test (ASTM D4355)
- Ultraviolet Fluorescent light test (ASTM G53 and D5208)



Resistance of Polymers to Specific Environment

Soil Environment	Polymer		
	PET	PE	PP
Acid Sulphate Soils	NE	?	?
Organic Soils	NE	NE	NE
Saline Soils pH < 9	NE	NE	NE
Calcareous Soils	?	NE	NE
Modified Soils/Lime, Cement	?	NE	NE
Sodic Soils, pH > 9	?	NE	NE
Soils with Transition Metals	NE	?	?

NE = No Effect ? = Questionable, exposure test required

(FHWA NHI-00-043)

Allowable Tensile Strength of Geosynthetic

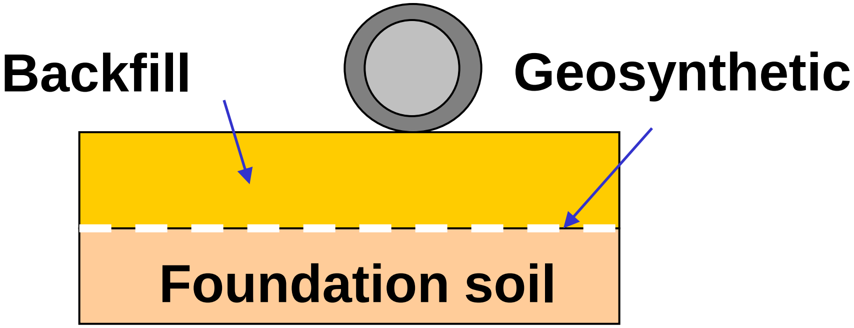
$$T_a = T_{ult} \frac{1}{RF_{ID} \times RF_{CR} \times RF_{CD} \times RF_{BD}} = T_{ult} \frac{1}{RF}$$

T_a = allowable tensile strength
T_{ult} = ultimate tensile strength in lab
RF_{ID} = reduction factor for installation damage
RF_{CR} = reduction factor for creep
RF_{CD} = reduction factor for chemical degradation
RF_{BD} = reduction factor for biological degradation
RF = overall reduction factor

Installation Damage Test

Step 1:Place geosynthetic and backfill

Step 2:Compaction

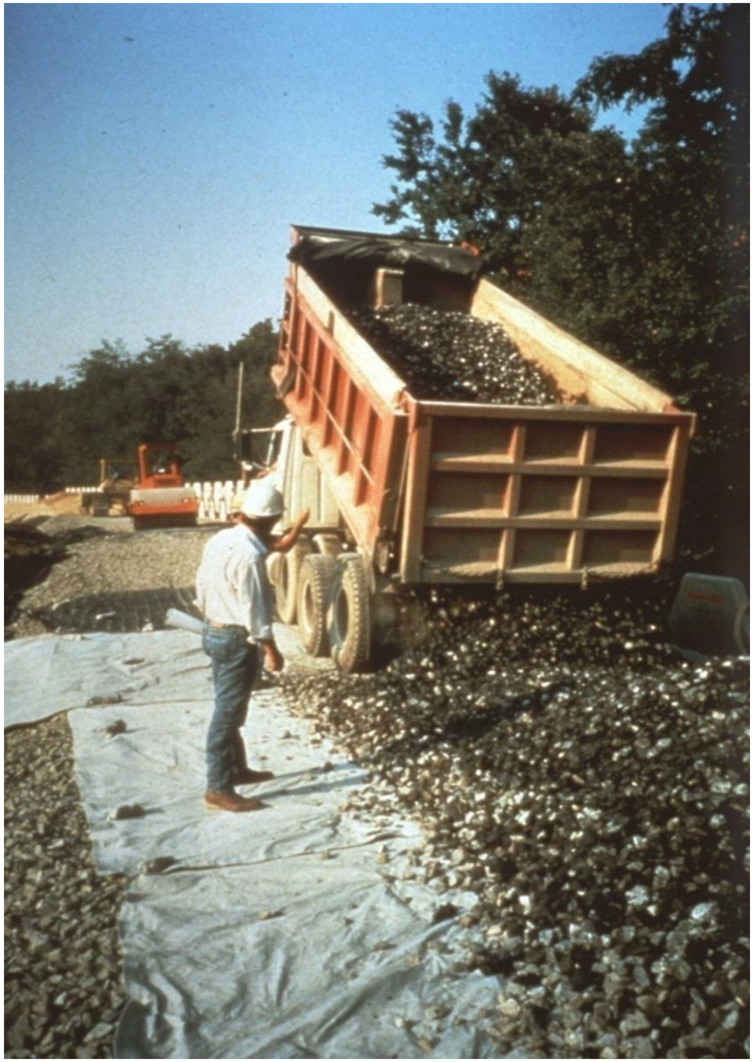


Step 3:Exhume geosynthetic sample

Step 4: Test for tensile strength

Step 5: Determine reduction factor

$RF= T_{control} / T_{damaged}$



Courtesy of Leshchinsky

Installation Damage Reduction Factors

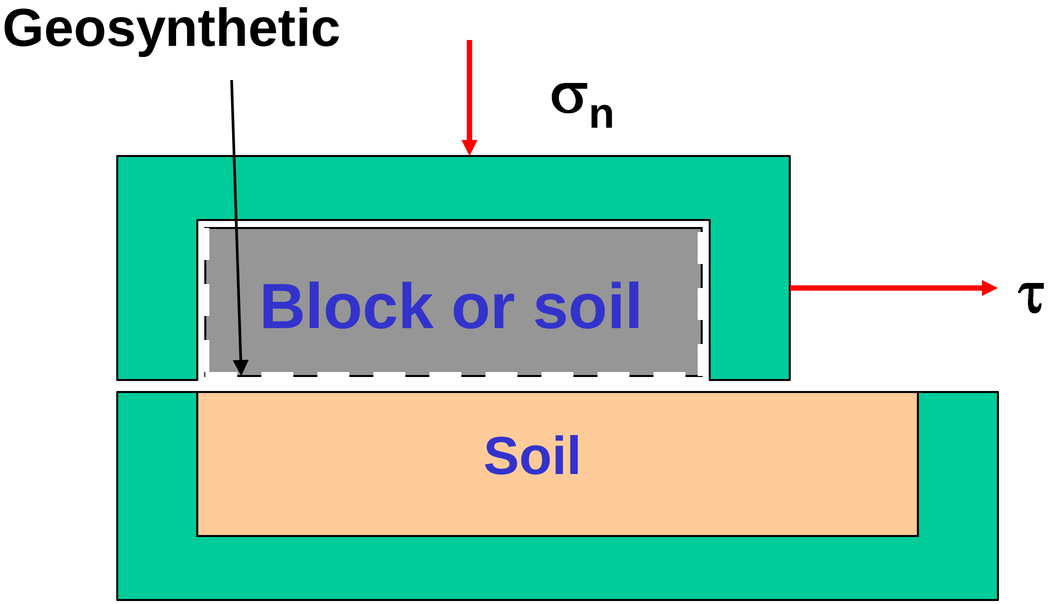
	Reduction Factor, RF_{ID}	
Geosynthetic	**Type 1 Backfill**	**Type 2 Backfill**
HDPE UX geogrid	1.20 - 1.45	1.10 - 1.20
PP BX geogrid	1.20 - 1.45	1.10 - 1.20
PVC coated PET geogrid	1.30 - 1.85	1.10 - 1.30
Acrylic coated PET geogrid	1.30 - 2.05	1.20 - 1.40
Woven geotextiles (PP&PET)	1.40 - 2.20	1.10 - 1.40
Nonwoven geotextiles (PP&PET)	1.40 - 2.50	1.10 - 1.40
Slit filmwoven geotextiles (PP)	1.60 - 3.00	1.10 - 2.00

Type I backfill: Max. particle size of 102mm & D_{50} of 30mm

Type II backfill: Max. particle size of 20mm & D_{50} of 0.7mm

(FHWA NHI-00-043)

Interface Shear Test



Geosynthetic

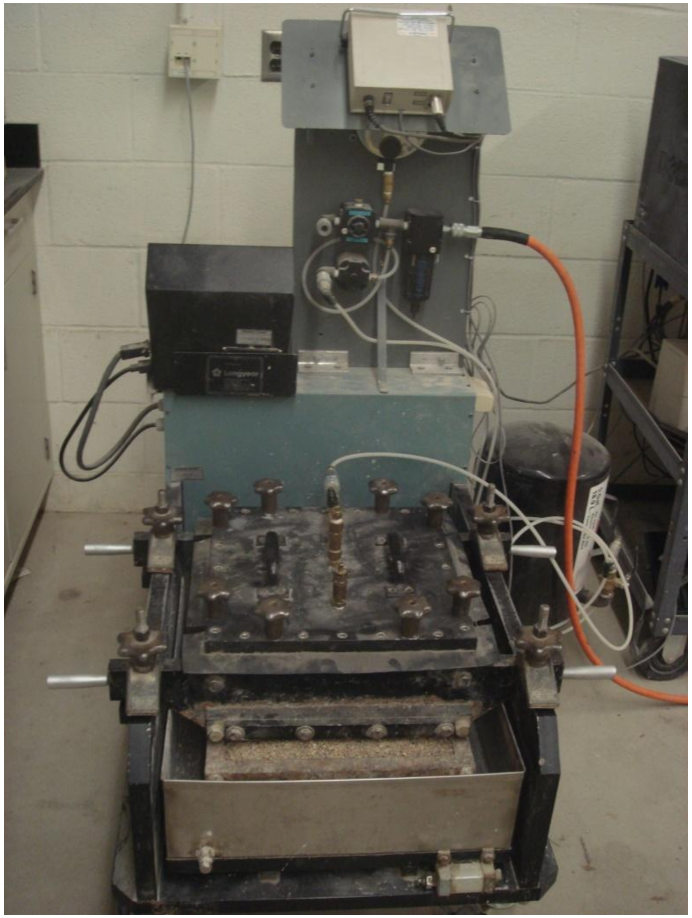
σ_n

Block or soil

τ

Soil

ASTM D5321



Interaction coefficient:

$$C_i = \frac{\text{Interface strength}}{\text{Soil strength}}$$

Geotextile/Soil Friction Angles

	Soil Type		
Getextile	**Concrete sand ($\phi=30^0$)**	**Ottawa sand ($\phi=30^0$)**	**Mica schist sand ($\phi=26^0$)**
Nonwoven needle-punched	30^0	26^0	25^0
Nonwoven heat-bonded	26^0	-	-
Woven monofilament	26^0	-	-
Woven slit-film	24^0	24^0	23^0

$$C_i = \frac{\textbf{Interface strength}}{\textbf{Soil strength}} = \frac{\tan\,(24^o)}{\tan\,(30^o)} = 0.8$$

Martin et al. (1984)

Geosynthetic Applications

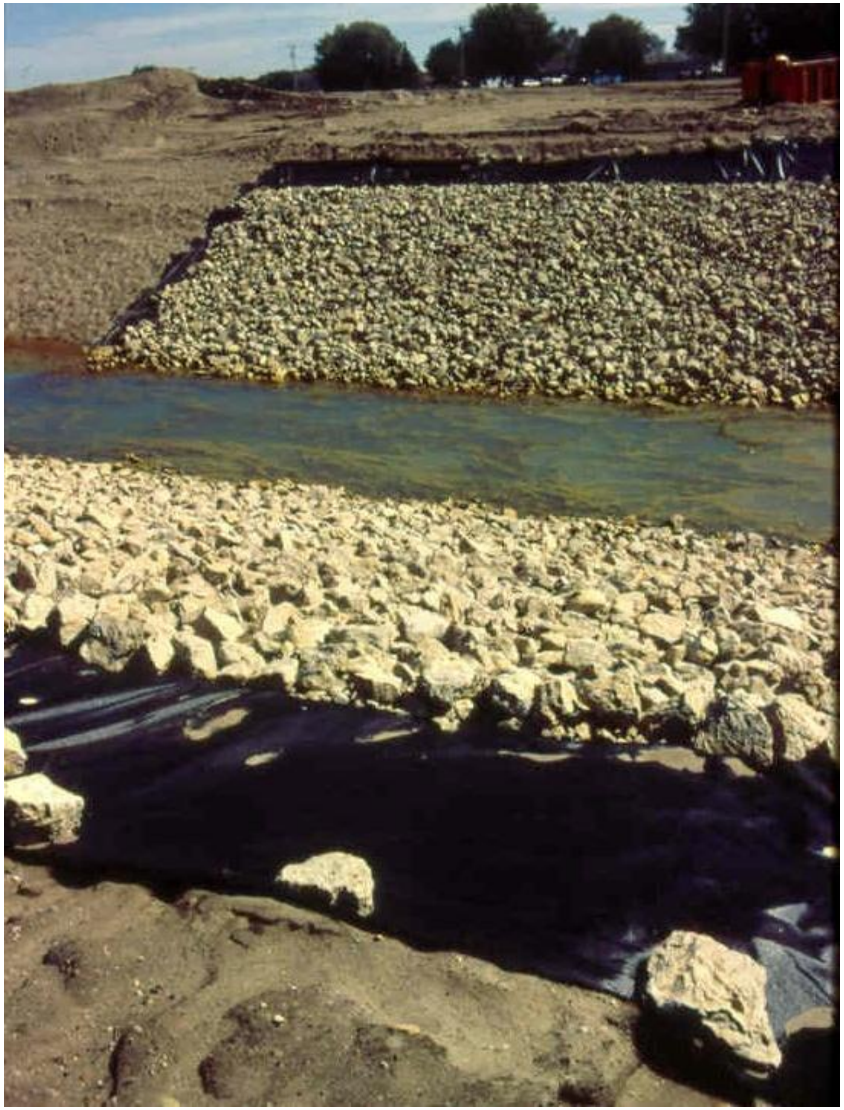
Soft Soil Stabilization

Erosion Control

- Erosion Mat or Blanket
- Enhance seed germination and erosion resistance
- UV protected

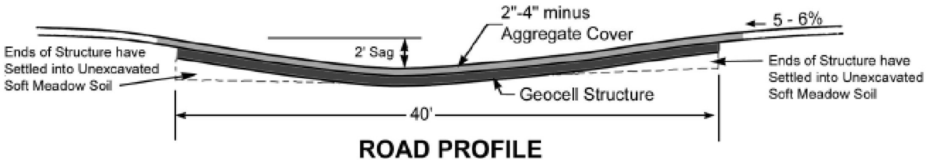
Village at Westlake - Austin, TX

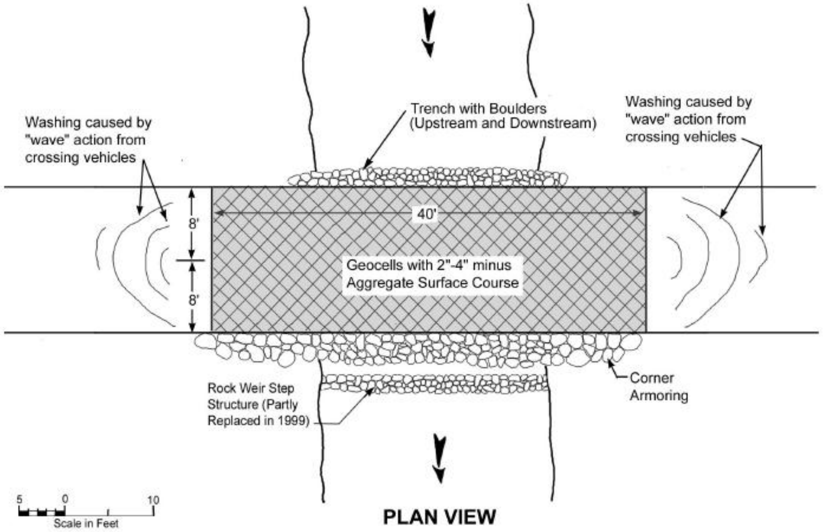
Stream/River Bank Protection



FHWA NHI-07-092

Geocell for Low-water Crossing



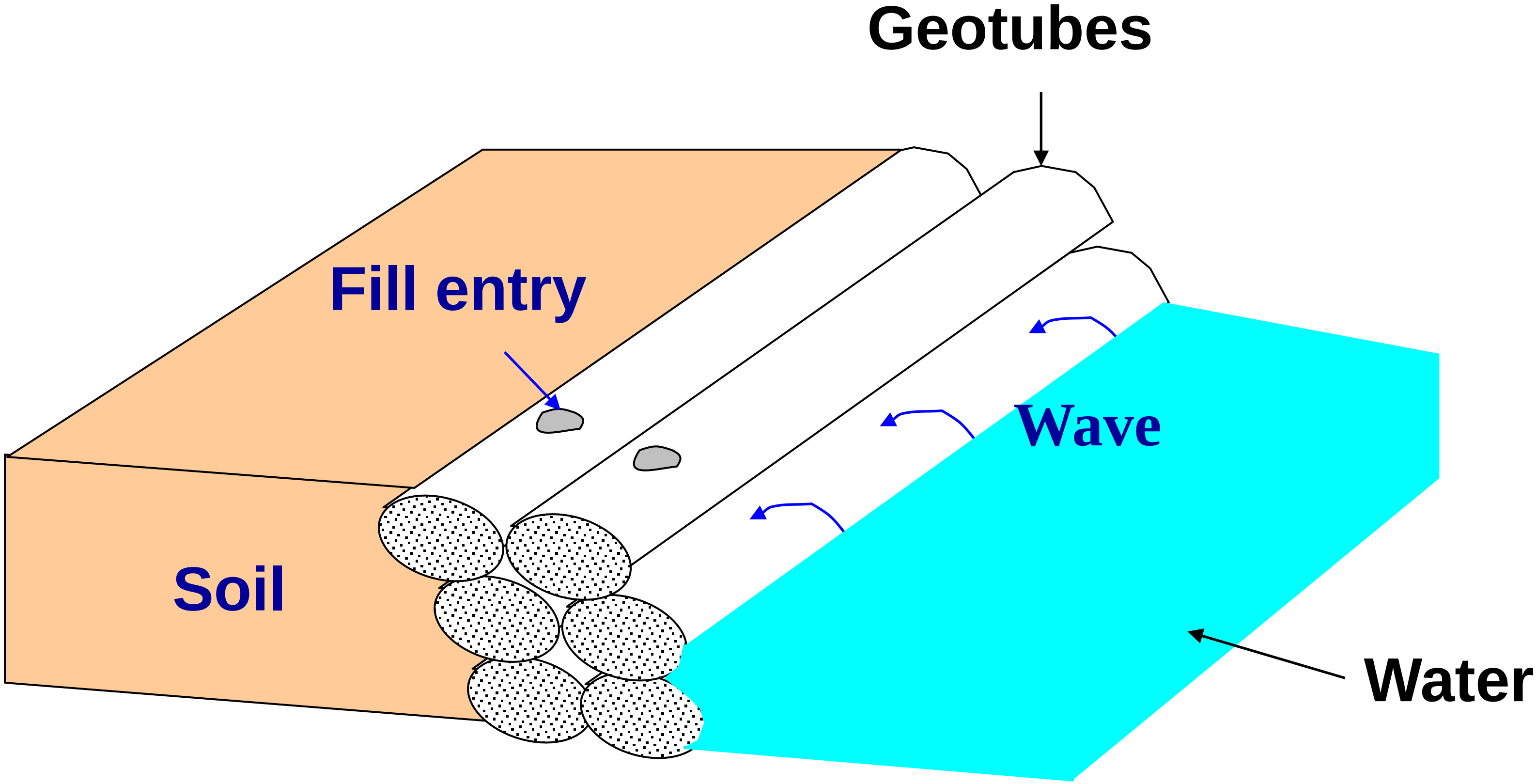


Clarkin et al. (2006)

Geocell for Channel Protection



Geotubes for Erosion Control



Geotube Applications

Installation

Covered and vegetated

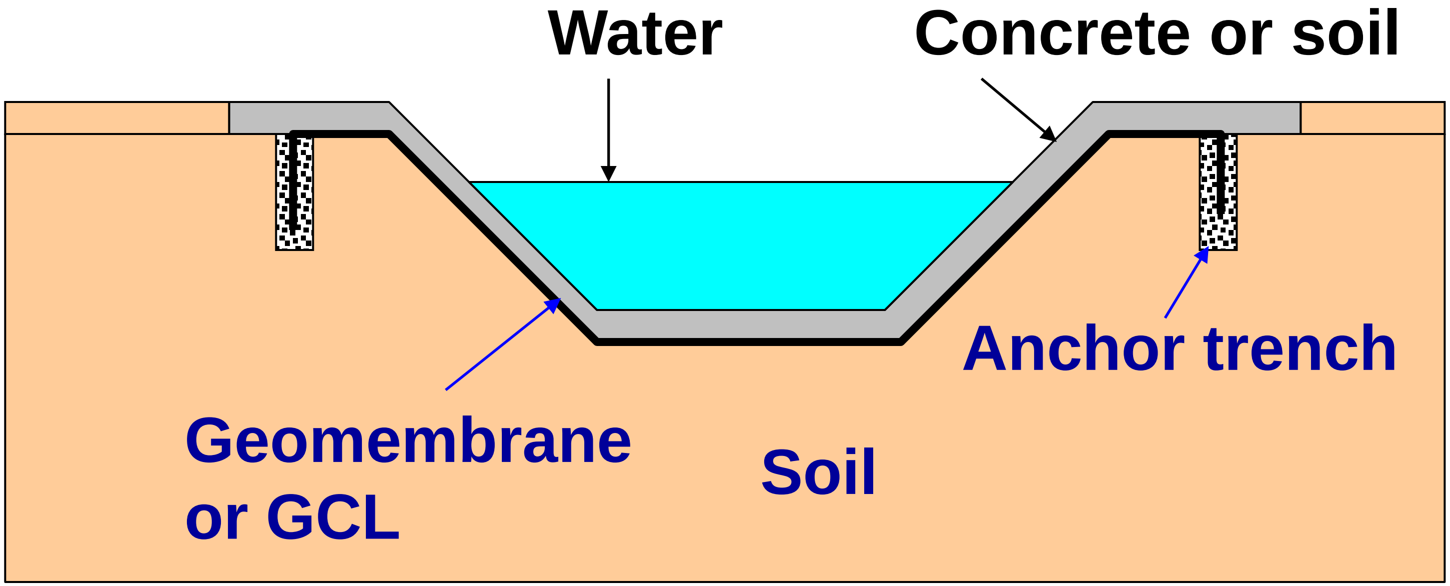
Exposed

Maintenance

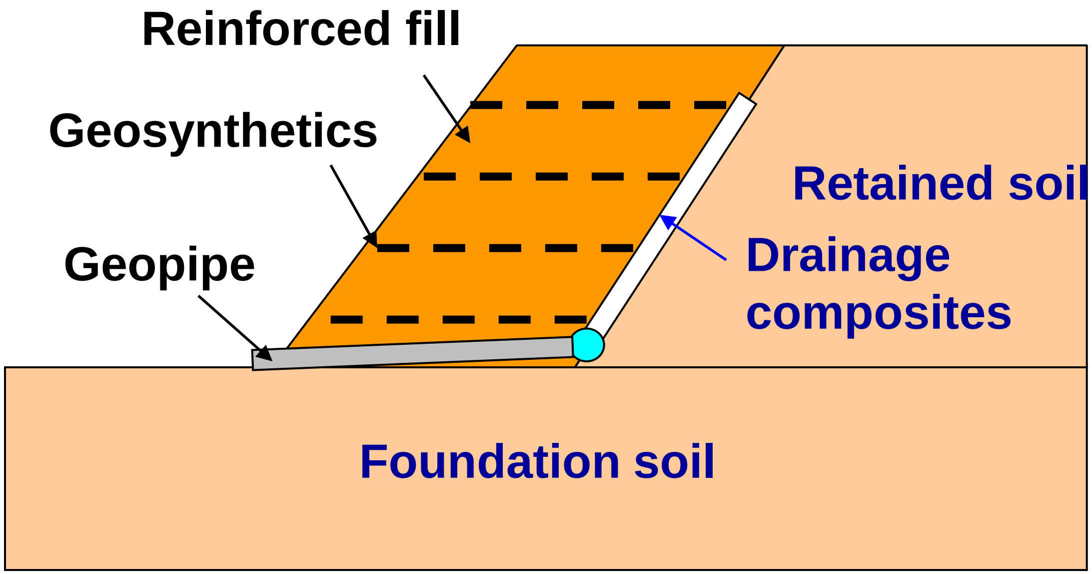
Marine Mattress for Coastal Revetment

Rubber Dam by Geotube

Canal Liner


Water
Concrete or soil
Anchor trench
Geomembrane or GCL
Soil

Geosynthetic-Reinforced Slope



Reinforced fill

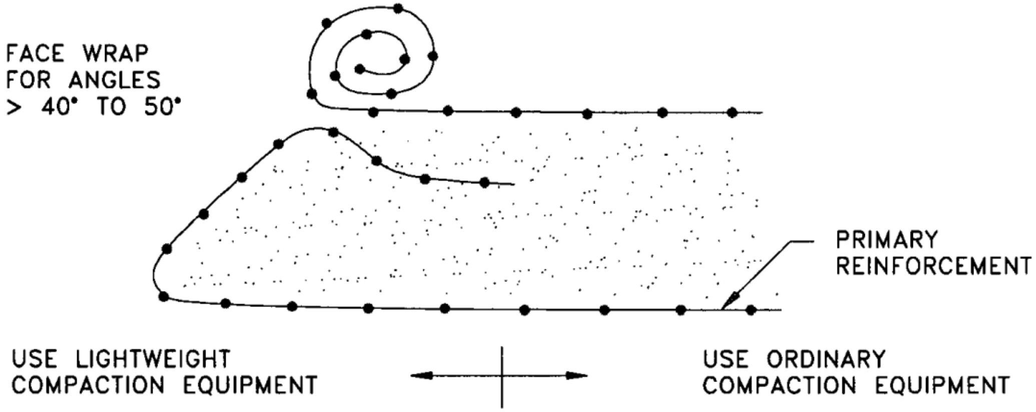
Geosynthetics

Geopipe

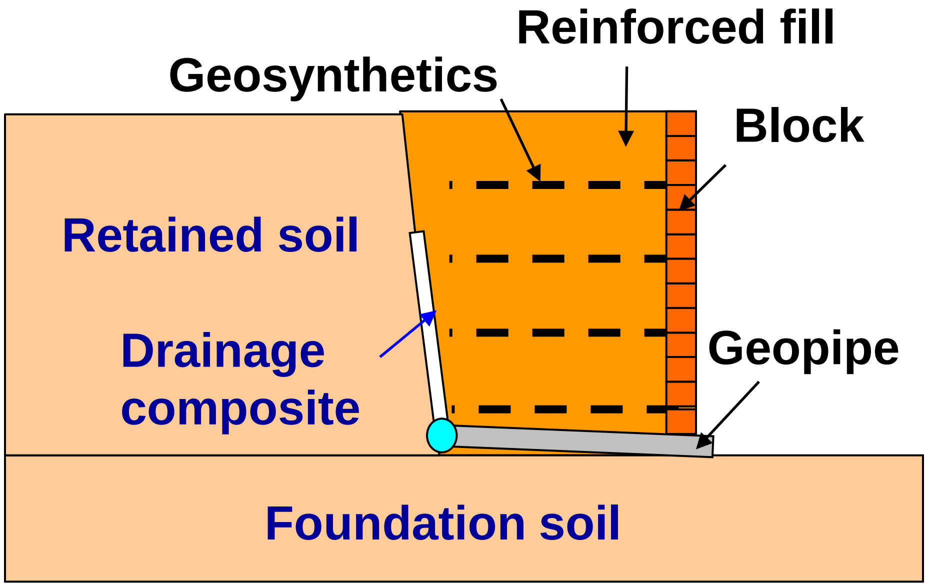
Retained soil

Drainage composites

Foundation soil



Mechanically Stabilized Earth (MSE) Wall


Reinforced fill

Geosynthetics

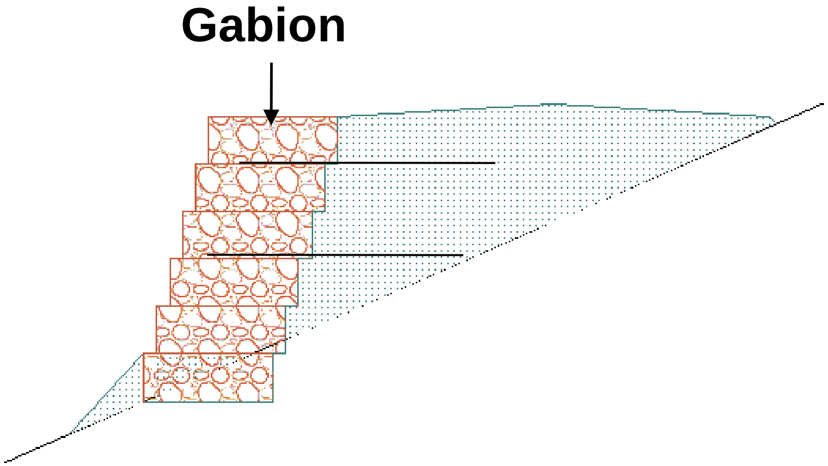
Block

Retained soil

Drainage composite

Geopipe

Foundation soil


Gabion

Design Considerations

Channel Design Criteria

- Based on peak flow capacity

- Consider site conditions

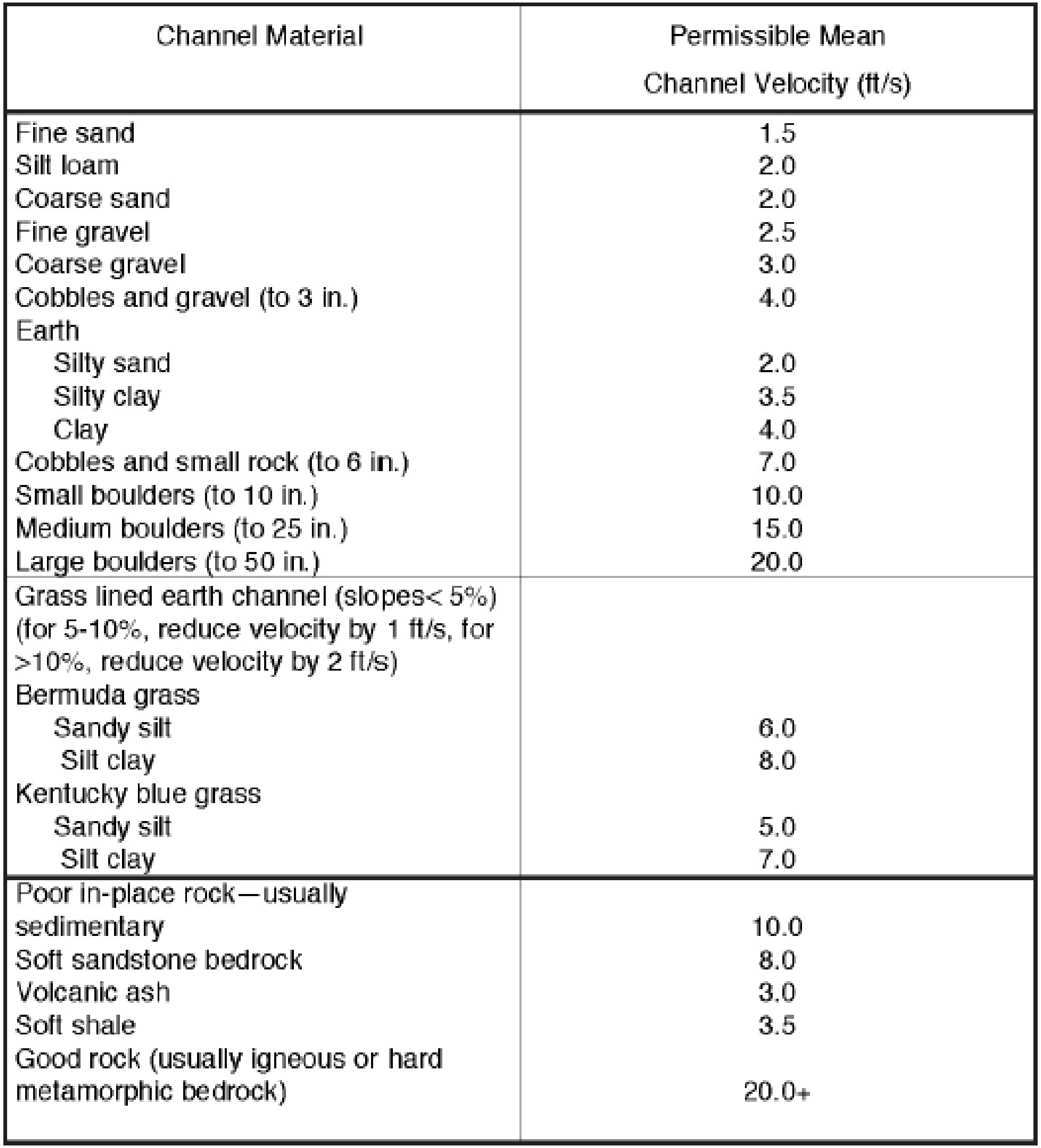
- Design channel lining to ensure the stability

    - Vegetation
    - Riprap
    - Geosynthetic liner

Design Methods

- Maximum permissible velocity method
  - Predicted mean velocity < maximum permissible velocity
- Tractive force (shear stress) method
  - Predicted shear stress < maximum allowable shear stress

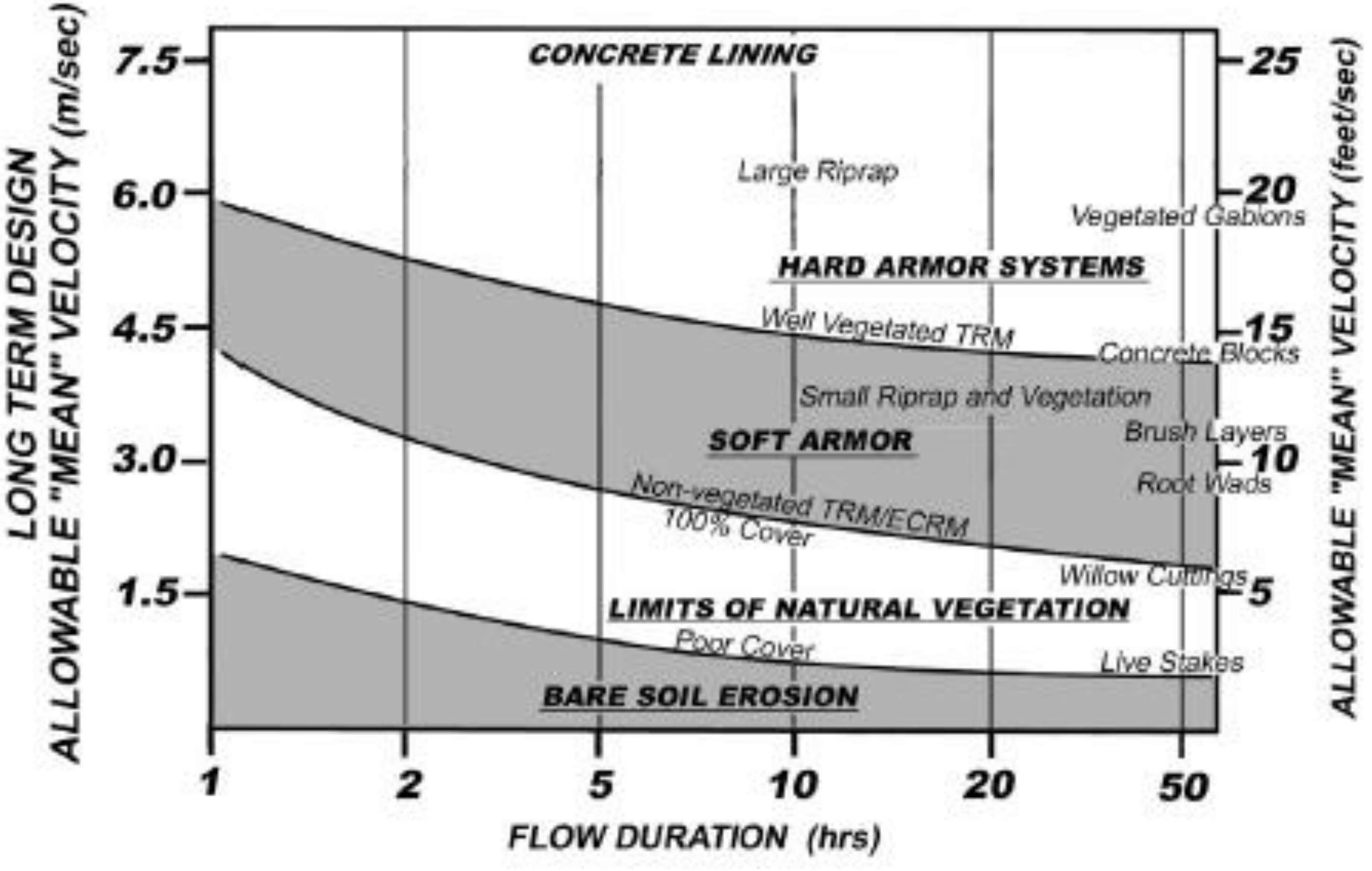
Maximum Permissible Mean Channel Velocity



Channel Material	Permissible Mean Channel Velocity (ft/s)
Fine sand	1.5
Silt loam	2.0
Coarse sand	2.0
Fine gravel	2.5
Coarse gravel	3.0
Cobbles and gravel (to 3 in.)	4.0
Earth	
Silty sand	2.0
Silty clay	3.5
Clay	4.0
Cobbles and small rock (to 6 in.)	7.0
Small boulders (to 10 in.)	10.0
Medium boulders (to 25 in.)	15.0
Large boulders (to 50 in.)	20.0
Grass lined earth channel (slopes< 5%) (for 5-10%, reduce velocity by 1 ft/s, for >10%, reduce velocity by 2 ft/s)	
Bermuda grass	
Sandy silt	6.0
Silt clay	8.0
Kentucky blue grass	
Sandy silt	5.0
Silt clay	7.0
Poor in-place rock—usually sedimentary	10.0
Soft sandstone bedrock	8.0
Volcanic ash	3.0
Soft shale	3.5
Good rock (usually igneous or hard metamorphic bedrock)	20.0+

USACE (1991)

Max. Design Velocity and Flow Duration for Erosion Resistance

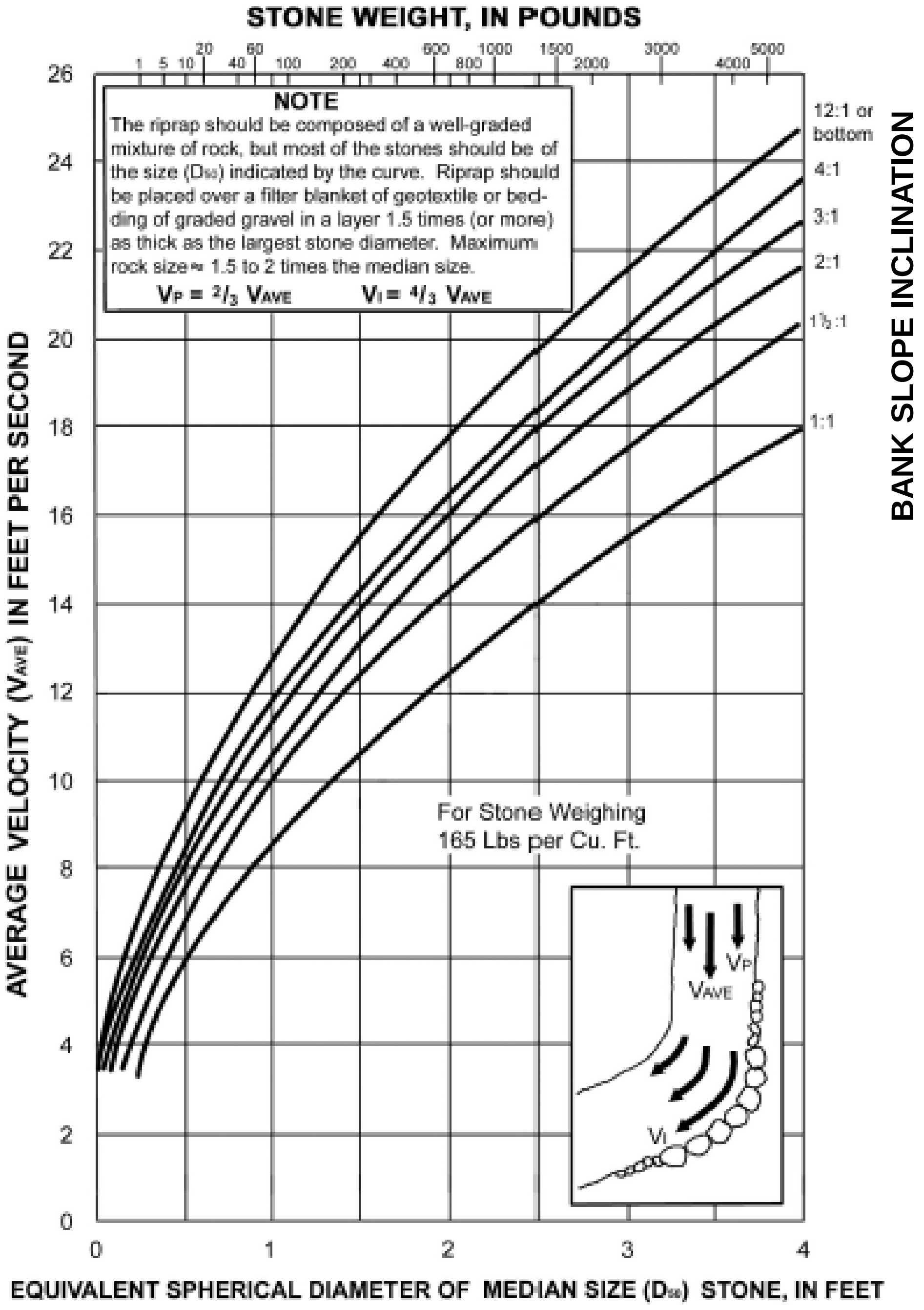


NOTES:

1. **Hard Armor** - *includes Concrete, Riprap, Gabions, Concrete Blocks, etc.*
2. **Soft Armor** - *includes Turf Reinforcement Mats (TRM), Erosion Control Revegetation Mats (ECRM), Vegetated Geocells, and many Biotechnical Treatments.*
3. *Available data shows considerable variability in the Allowable Velocity Limits.*

Hewlett et al. (1987)
Theisen (1992),
Clarkin et al. (2006)

Required Size of Riprap Stone



NOTE

The riprap should be composed of a well-graded mixture of rock, but most of the stones should be of the size (D_{50}) indicated by the curve. Riprap should be placed over a filter blanket of geotextile or bedding of graded gravel in a layer 1.5 times (or more) as thick as the largest stone diameter. Maximum rock size ≈ 1.5 to 2 times the median size.

$V_P = {}^2/_3\ V_{AVE}$ $V_I = {}^4/_3\ V_{AVE}$

For Stone Weighing 165 Lbs per Cu. Ft.

FHWA (1967)

Predicted and Maximum Allowable Shear Stresses

Shear Stress $\tau = \gamma_w \cdot d \cdot s$

γ_w = unit weight of water, d = depth of flow

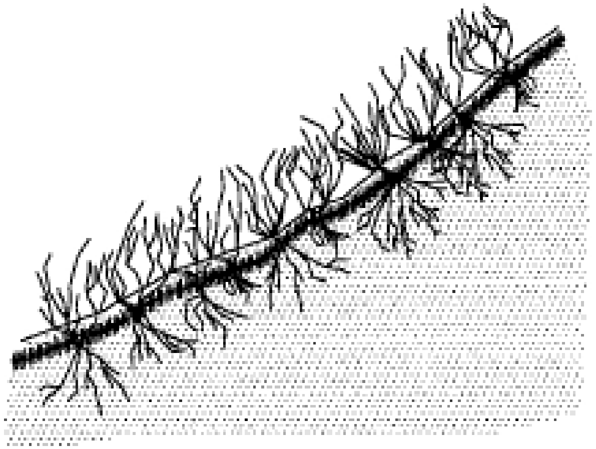
s = channel slope

General Guide for Maximum Allowable Shear Stress (psf)

Vegetation (unreinforced)	3
Erosion control blanket	3
Rip-rap (18” stone)	6
Rip-rap (24” stone)	8
Typical turf reinforcement mat	8
Articulating concrete block	15
Fabric-formed concrete	20

Bio-stabilization

$$FS \approx \frac{2c}{\gamma H\, sin\, 2\alpha} + 0.5\frac{tan\,\phi}{tan\,\alpha}$$



Example:

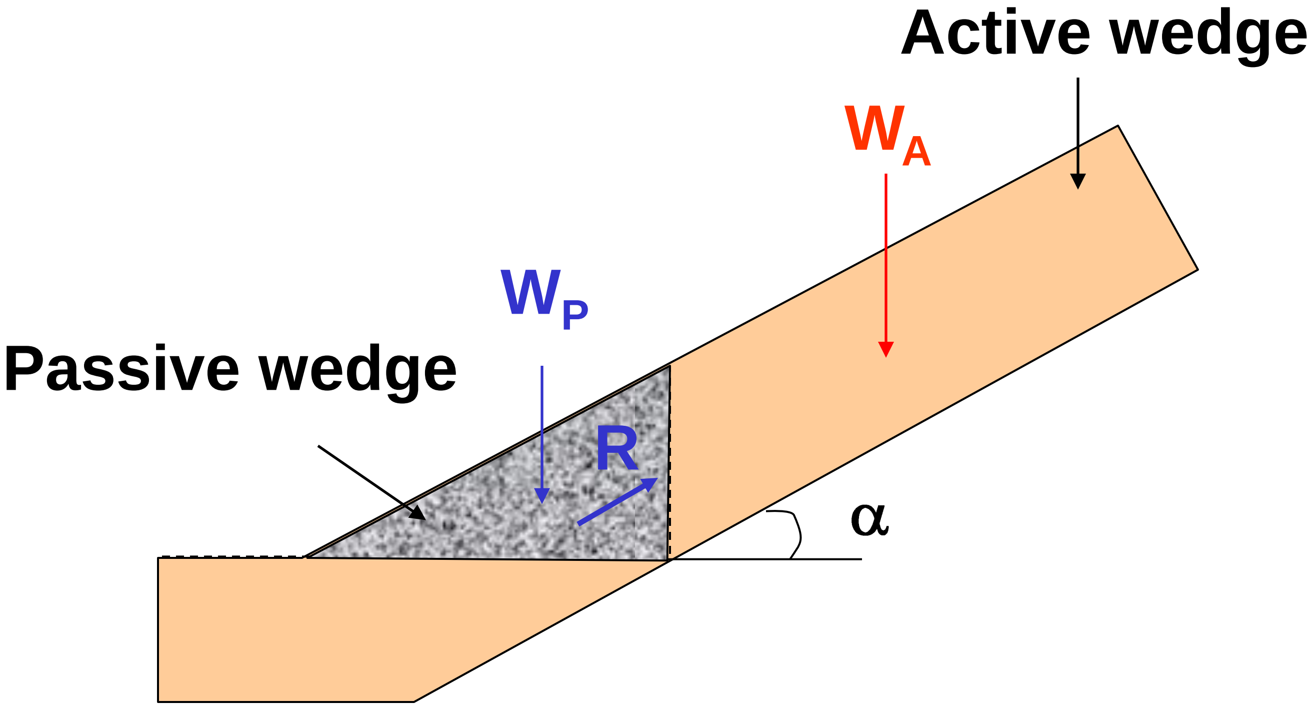
c_a = 50 psf, H = 2 ft, γ = 120 pcf, ϕ = 30^{o}

FS = 1.0

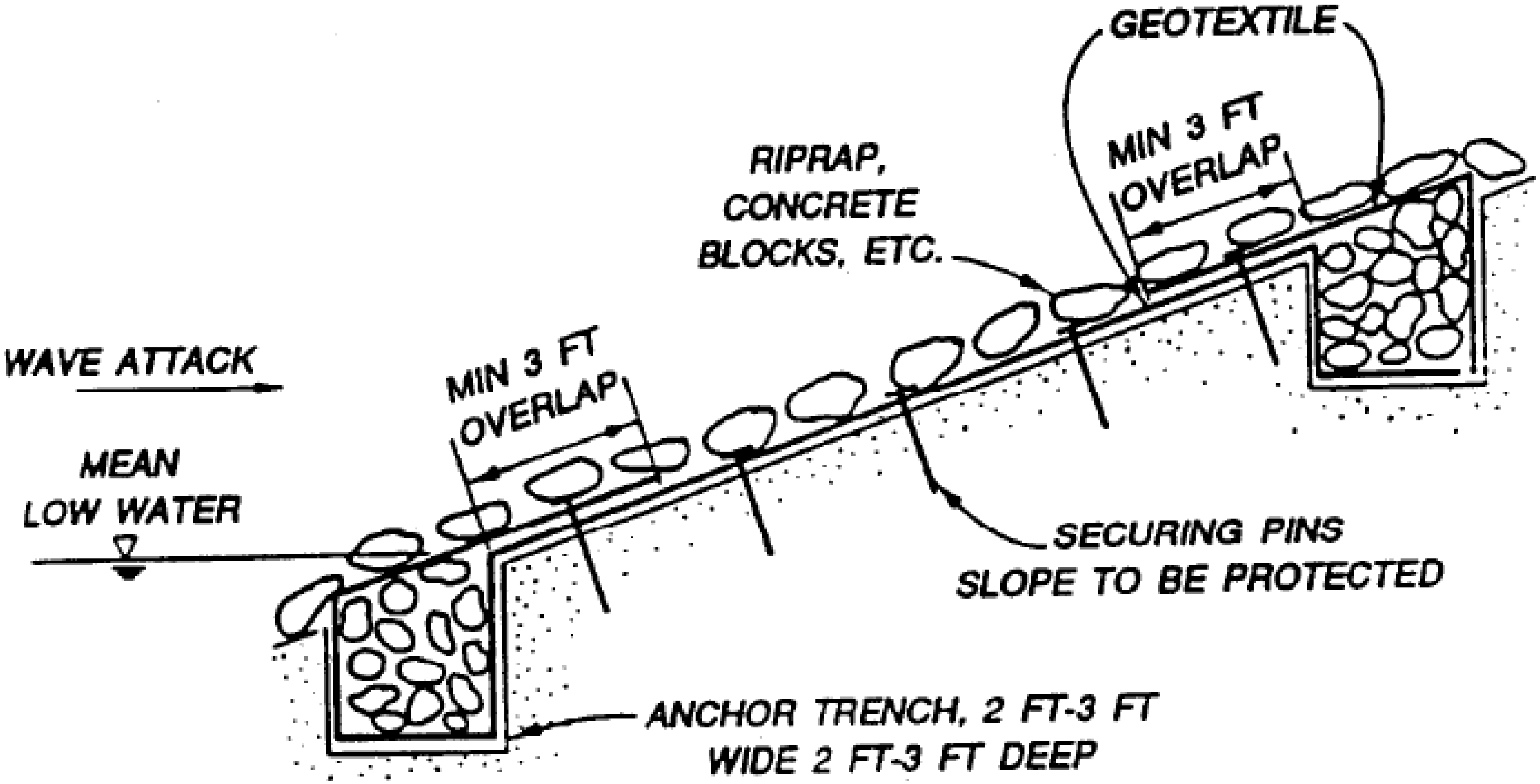
α = 40^{o} (1:1 slope, no-seepage condition)

α = 27^{o} (2:1 slope, seepage condition)

Toe Protection or Support



Anchorage Requirements in Erosion Control Applications



ARMY TM 5-818-8 (1995)

Pin Spacing Requirements in Erosion Control Applications

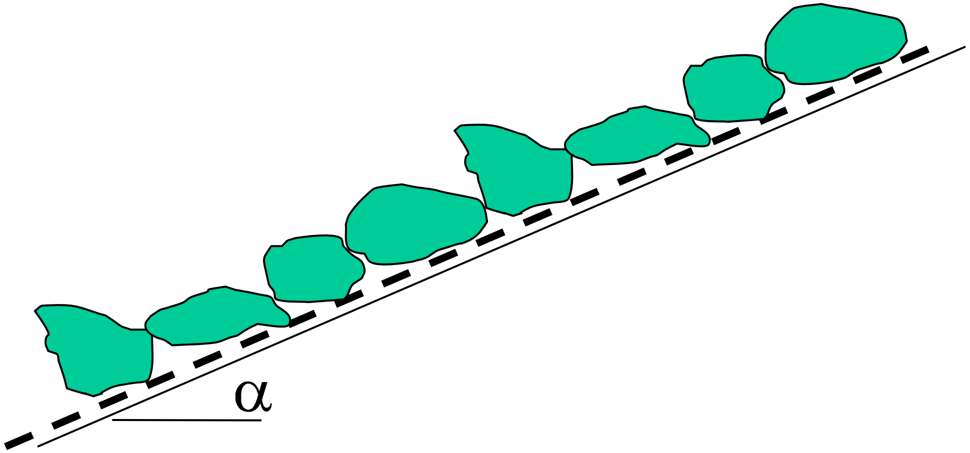
Slope	Pin Spacing (ft)
Steeper than 3(H) : 1(V)	2
3(H) : 1(V) to 4(H) : 1(V)	3
Flatter than 4(H) : 1(V)	5

Steel securing pins: 8/16 in. (diameter), 18 in. (long), fitted with a 1.5-inch metal washer

Longer pins are advisable for use in loose soils

ARMY TM 5-818-8 (1995)

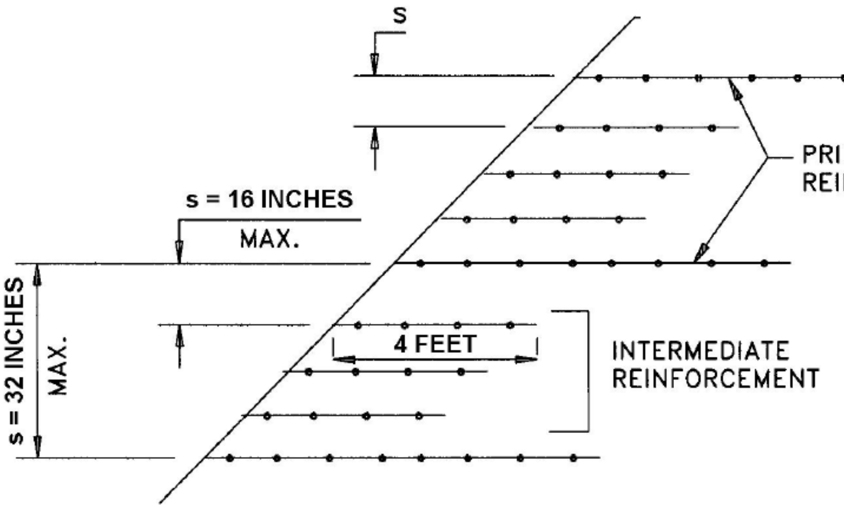
Why is Anchorage Needed Sometimes ?

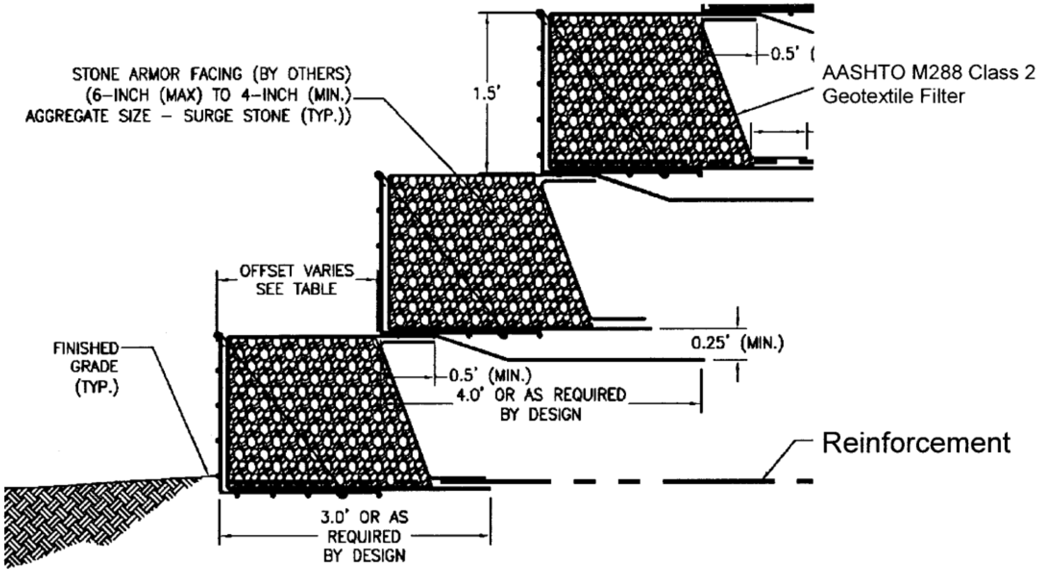


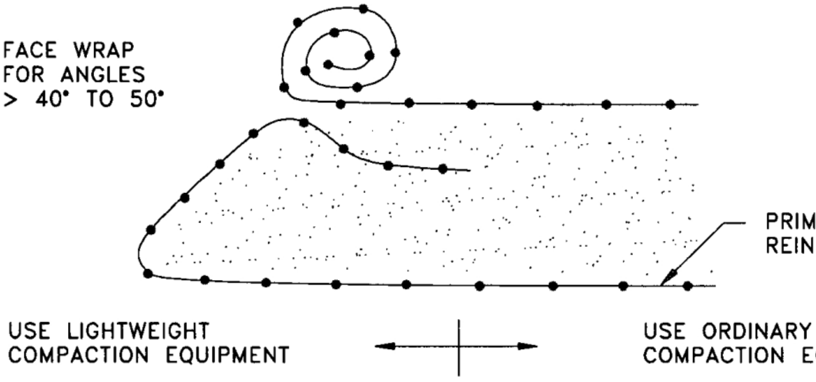
$$FoS = \frac{\tan\delta}{\tan\alpha} = \frac{C_i \tan\phi}{\tan\alpha}$$

Typical C_i = 0.6 to 0.8

Typical Geosynthetic Layout for Reinforced Slope

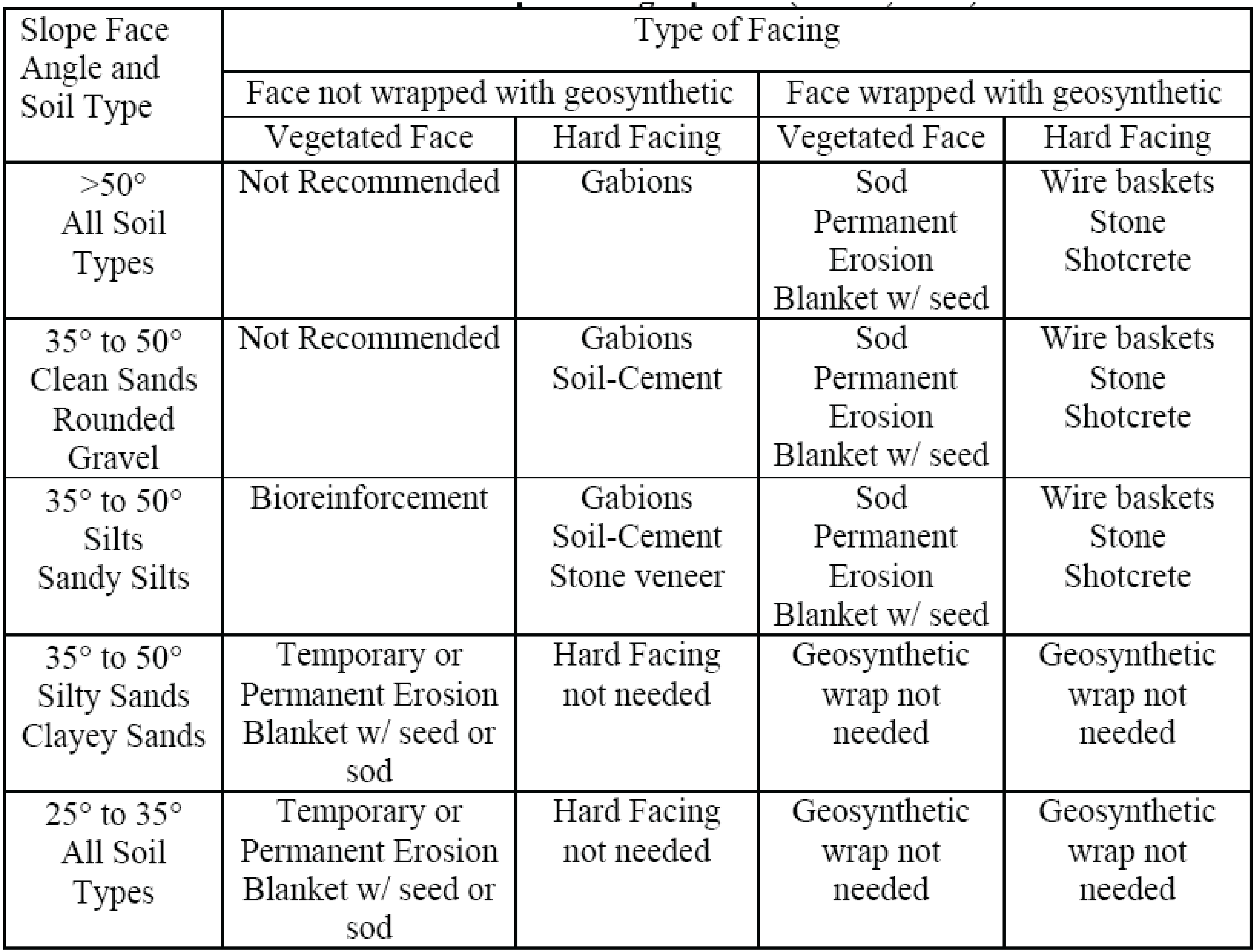






FHWA NHI-07-092

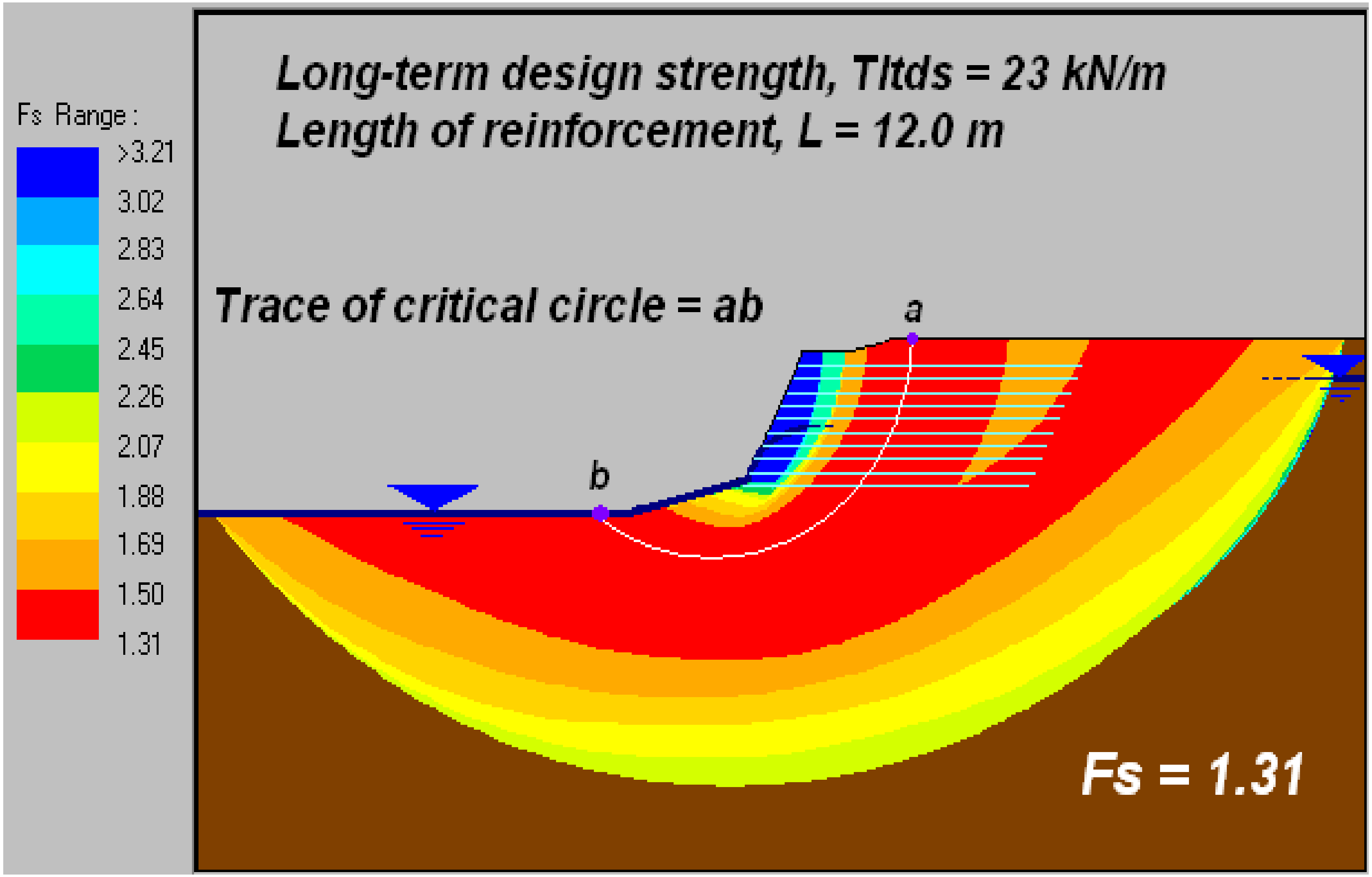
Face Options for Reinforced Slopes



Slope Face Angle and Soil Type	Type of Facing			
	Face not wrapped with geosynthetic		Face wrapped with geosynthetic	
	Vegetated Face	Hard Facing	Vegetated Face	Hard Facing
>50° All Soil Types	Not Recommended	Gabions	Sod Permanent Erosion Blanket w/ seed	Wire baskets Stone Shotcrete
35° to 50° Clean Sands Rounded Gravel	Not Recommended	Gabions Soil-Cement	Sod Permanent Erosion Blanket w/ seed	Wire baskets Stone Shotcrete
35° to 50° Silts Sandy Silts	Bioreinforcement	Gabions Soil-Cement Stone veneer	Sod Permanent Erosion Blanket w/ seed	Wire baskets Stone Shotcrete
35° to 50° Silty Sands Clayey Sands	Temporary or Permanent Erosion Blanket w/ seed or sod	Hard Facing not needed	Geosynthetic wrap not needed	Geosynthetic wrap not needed
25° to 35° All Soil Types	Temporary or Permanent Erosion Blanket w/ seed or sod	Hard Facing not needed	Geosynthetic wrap not needed	Geosynthetic wrap not needed

Collin (1996)

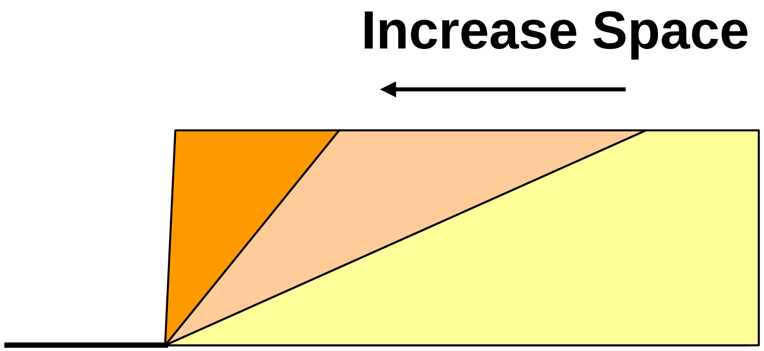
Slope Stability Analysis



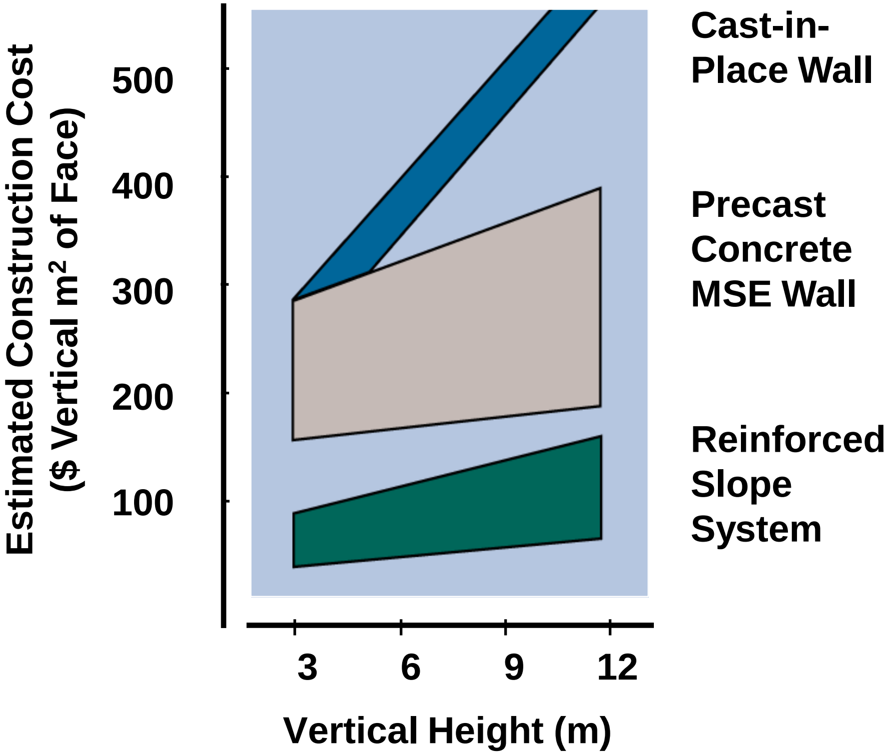
From ReSSA Software

Courtesy of Leshchinsky

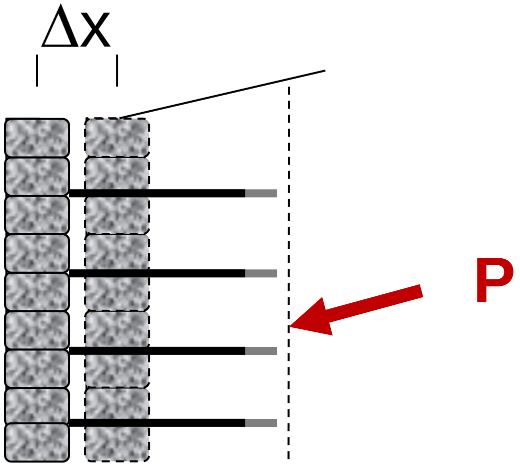
MSE Wall vs. Reinforced Slope



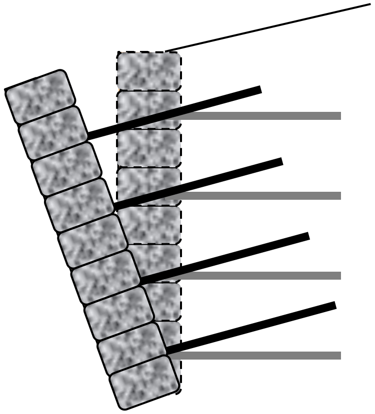
- **Slope: Face inclination ≤ 70^0**
- **Solution driven by many factors**
    - **Space**
    - **Cost**
    - **Vegetation**
    - **Backfill**



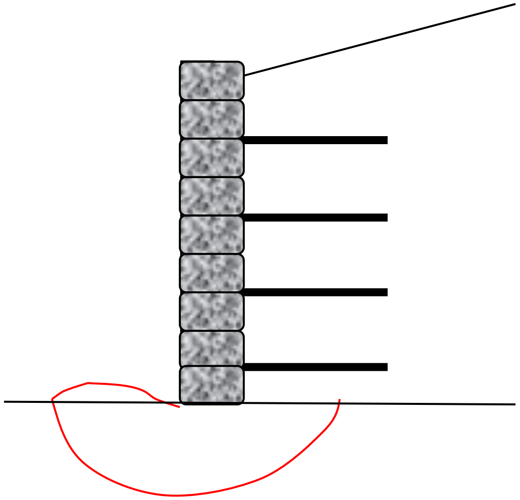
MSE Wall Design



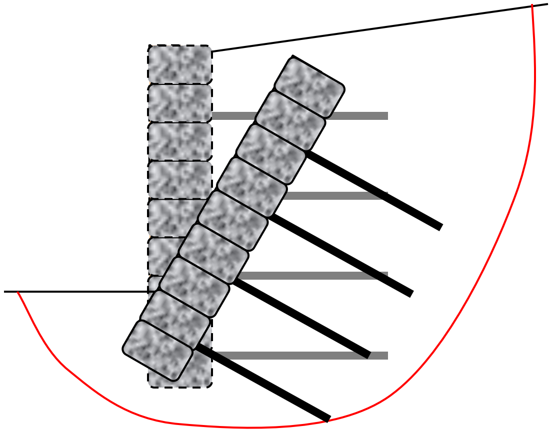
(a) Sliding



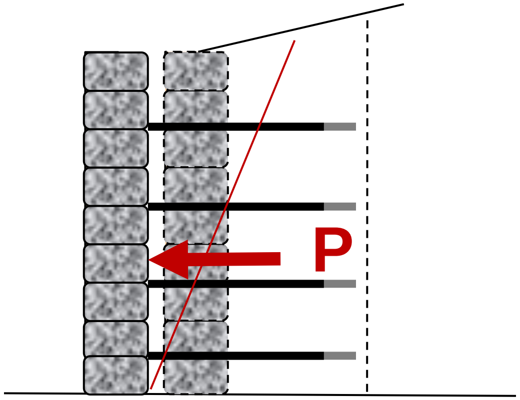
(b) Overturning



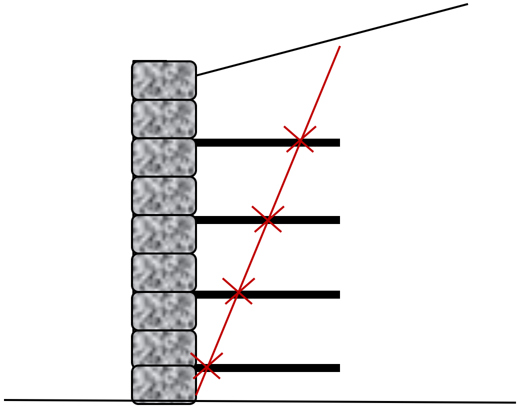
(c) Bearing



(d) Global failure



(e) Pullout



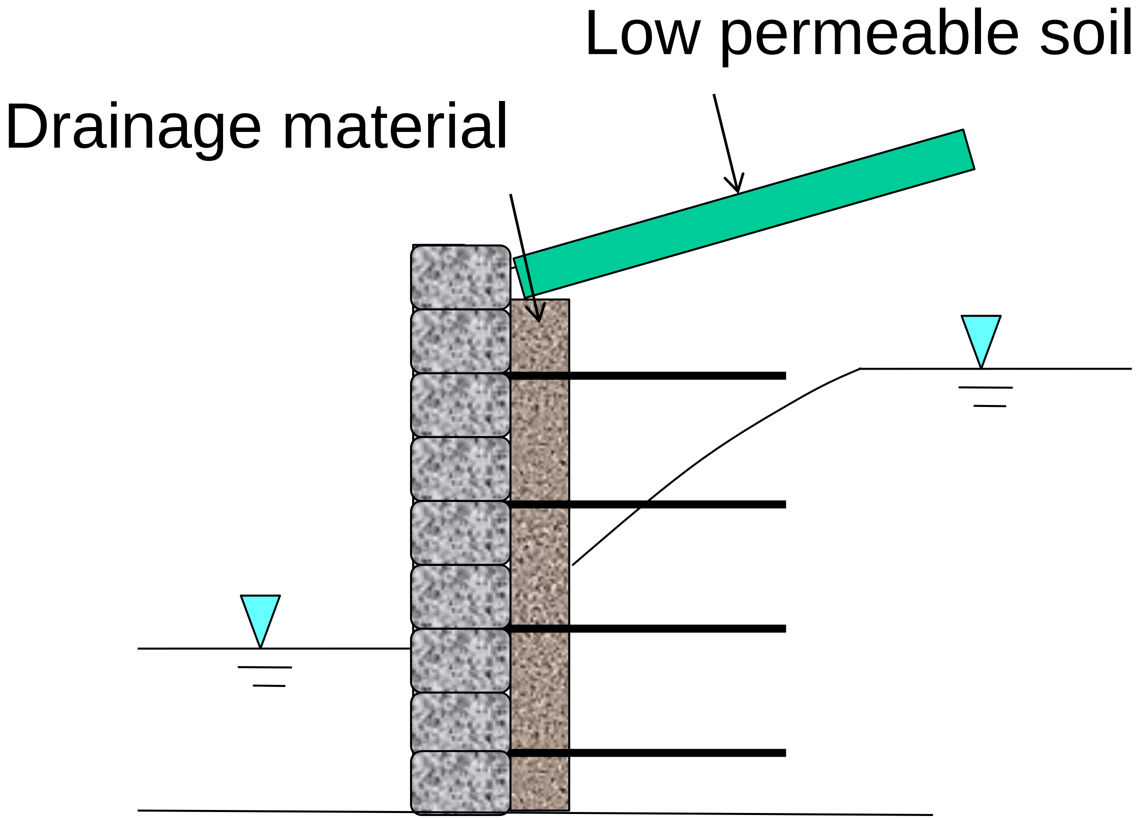
(f) Rupture

Backfill Requirements for MSE Wall

Sieve size	% passing
4 in.	100 – 75
No. 4	100 – 20
No. 40	0 – 60
No. 200	0 - 35

Plasticity Index (PI) of fine fraction < 20

MSE Wall Drainage Design



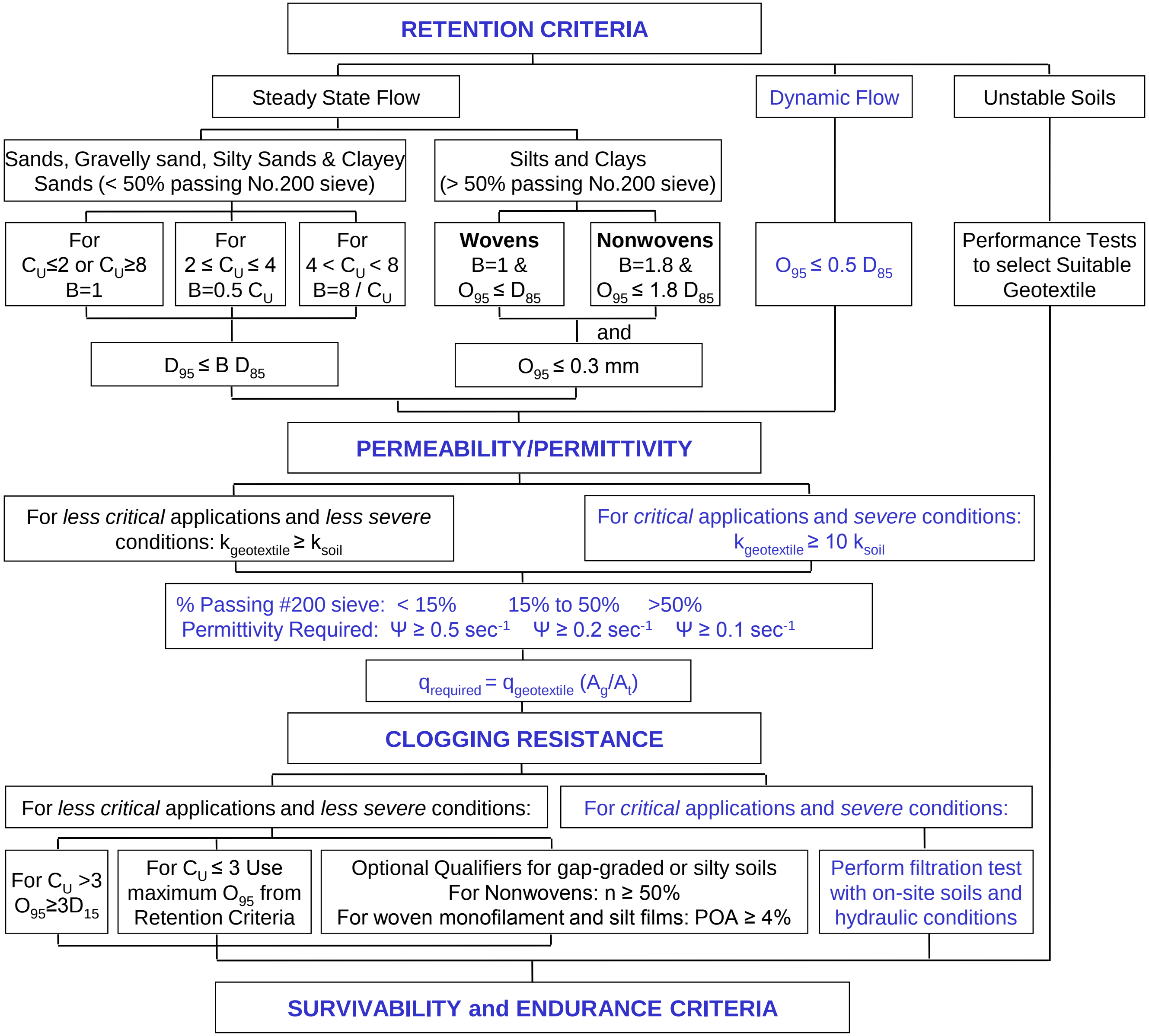
Design Procedure for Geotextile Filter beneath Hard Armor

Step 1: Evaluate critical nature of site conditions
Step 2: Obtain soil samples from site and test
Step 3: Evaluate armor material and placement
Step 4: Determine anticipated reversing flow through system
Step 5: Determine geotextile requirements

- A. Retention (i.e., AOS)
- B. Permeability/permittivity ($k_{geotextile} > k_{soil}$ or 10 k_{soil})
- C. Clogging (i.e., O_{95}, porosity, POA)
- D. Survivability (i.e., geotextile class)

Step 6: Estimate costs
Step 7: Prepare specification
Step 8: Obtain samples of geotextile before acceptance
Step 9: Monitor installation and performance

FHWA Filter Design Procedure



RETENTION CRITERIA

Steady State Flow

Sands, Gravelly sand, Silty Sands & Clayey Sands (< 50% passing No.200 sieve)

For $C_U \leq 2$ or $C_U \geq 8$ B=1

For $2 \leq C_U \leq 4$ $B = 0.5\ C_U$

For $4 < C_U < 8$ $B = 8 / C_U$

$D_{95} \leq B\ D_{85}$

Silts and Clays (> 50% passing No.200 sieve)

Wovens B=1 & $O_{95} \leq D_{85}$

Nonwovens B=1.8 & $O_{95} \leq 1.8\ D_{85}$

and

$O_{95} \leq 0.3$ mm

Dynamic Flow

$O_{95} \leq 0.5\ D_{85}$

Unstable Soils

Performance Tests to select Suitable Geotextile

PERMEABILITY/PERMITTIVITY

For *less critical* applications and *less severe* conditions: $k_{geotextile} \geq k_{soil}$

For *critical* applications and *severe* conditions: $k_{geotextile} \geq 10\ k_{soil}$

% Passing #200 sieve:	< 15%	15% to 50%	>50%
Permittivity Required:	$\Psi \geq 0.5$ sec^{-1}	$\Psi \geq 0.2$ sec^{-1}	$\Psi \geq 0.1$ sec^{-1}

$q_{required} = q_{geotextile}\ (A_g/A_t)$

CLOGGING RESISTANCE

For *less critical* applications and *less severe* conditions:

For $C_U > 3$ $O_{95} \geq 3D_{15}$

For $C_U \leq 3$ Use maximum O_{95} from Retention Criteria

Optional Qualifiers for gap-graded or silty soils
For Nonwovens: $n \geq 50\%$
For woven monofilament and silt films: POA ≥ 4%

For *critical* applications and *severe* conditions:

Perform filtration test with on-site soils and hydraulic conditions

SURVIVABILITY and ENDURANCE CRITERIA

Classifications of Geotextiles in AASHTO M288-96 Specifications

Class 1:

For severe or harsh survivability conditions where there is a greater potential for geotextile damage

Class 2:

For typical survivability conditions; this is the default classification to be used in the absence of site specific information

Class 3:

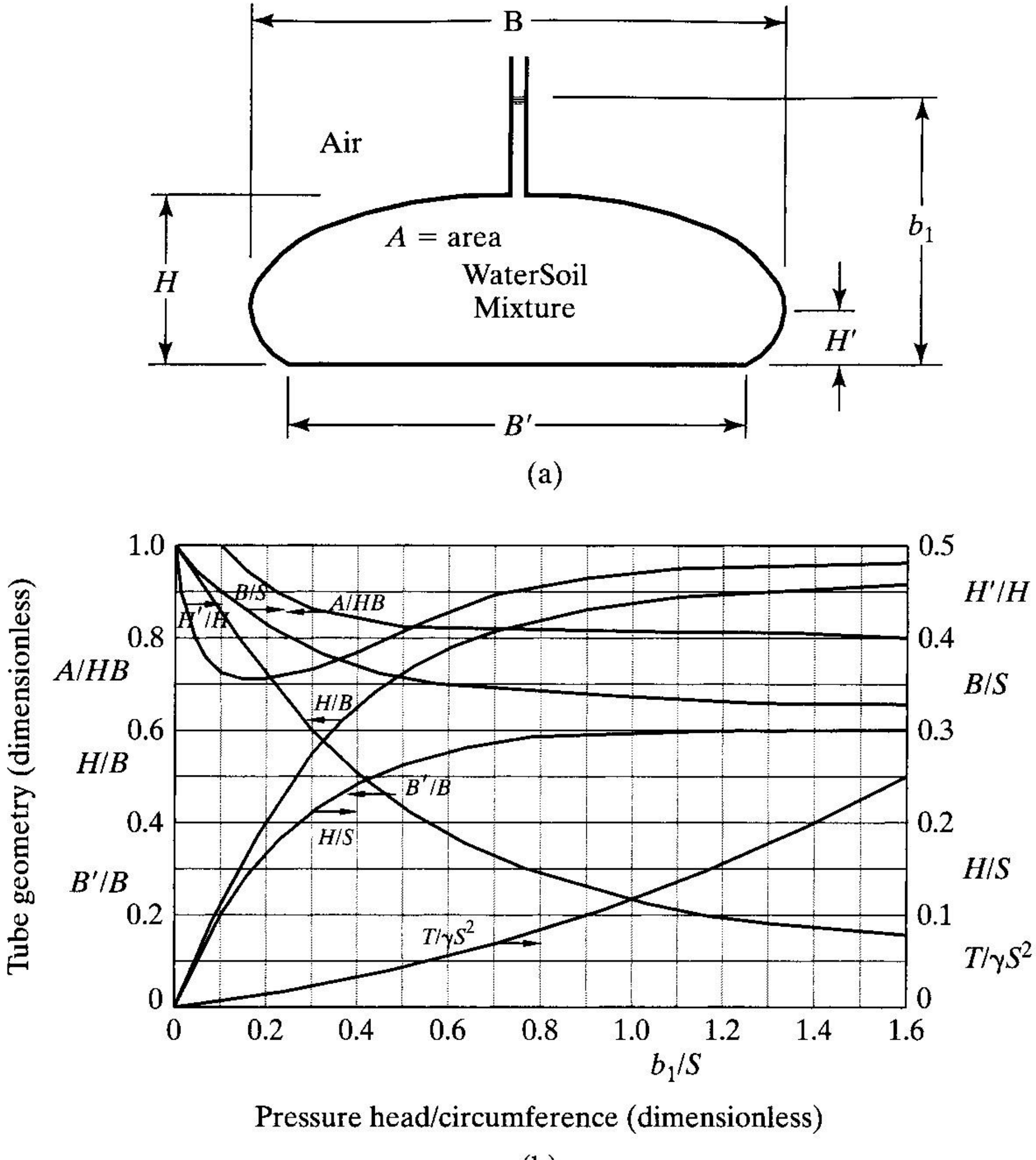
For mild survivability conditions

Geotextile Strength Property Requirements for Permanent Erosion Control

		Geotextile Class			
		Class 1		Class 2	
		Elongation (%)			
	Units	< 50	≥ 50	<50	≥50
Grab strength	lb	315	200	250	157
Sewn seam strength	lb	280	180	220	140
Tear strength	lb	110	80	90	56
Puncture strength	lb	620	433	495	309
Ultraviolet stability	50% retained strength after 500 hours of exposure				

AASHTO (2006)

Design of Geotube



(a)

(b)

Input:

- Pressure head, b_1
- Circumference, S

Output:

- Tube heights, H, H’
- Tube width, B, B’
- Geotextile strength, T

Next Presentation: Case Studies

- Simple Slope with Temporary Toe Protection
- Reinforced Vegetation with Temp. Toe Protection
- Reinforced Slope with Permanent Toe Protection
- Hard Armor Structures
- Retaining Structures

Questions?