Lecture 36

APPLICATIONS IN FILTRATION AND DRAINAGE & EROSION CONTROL

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Geotextile filter requirements:

- Retention criteria
- Permeability criteria
- Anti-clogging criteria
- Serviceability criteria
- Durability criteria

Soil retention

A process in which the particle movement is resisted by granular forces

Useful design parameters

1. **Coefficient of Uniformity, C_u**

2. **Linear Coefficient of Uniformity, C_u'**

3. **Coefficient of Curvature, C_c**

Design Charts

Determination of soil retention requirements such as particle size distribution, Atterberg limits, dispersion potential, soil density conditions indicating the effect of confining stress, are all considered and design charts are prepared by Giroud (1988).

Typical hydraulic gradients (Giroud, 1988).

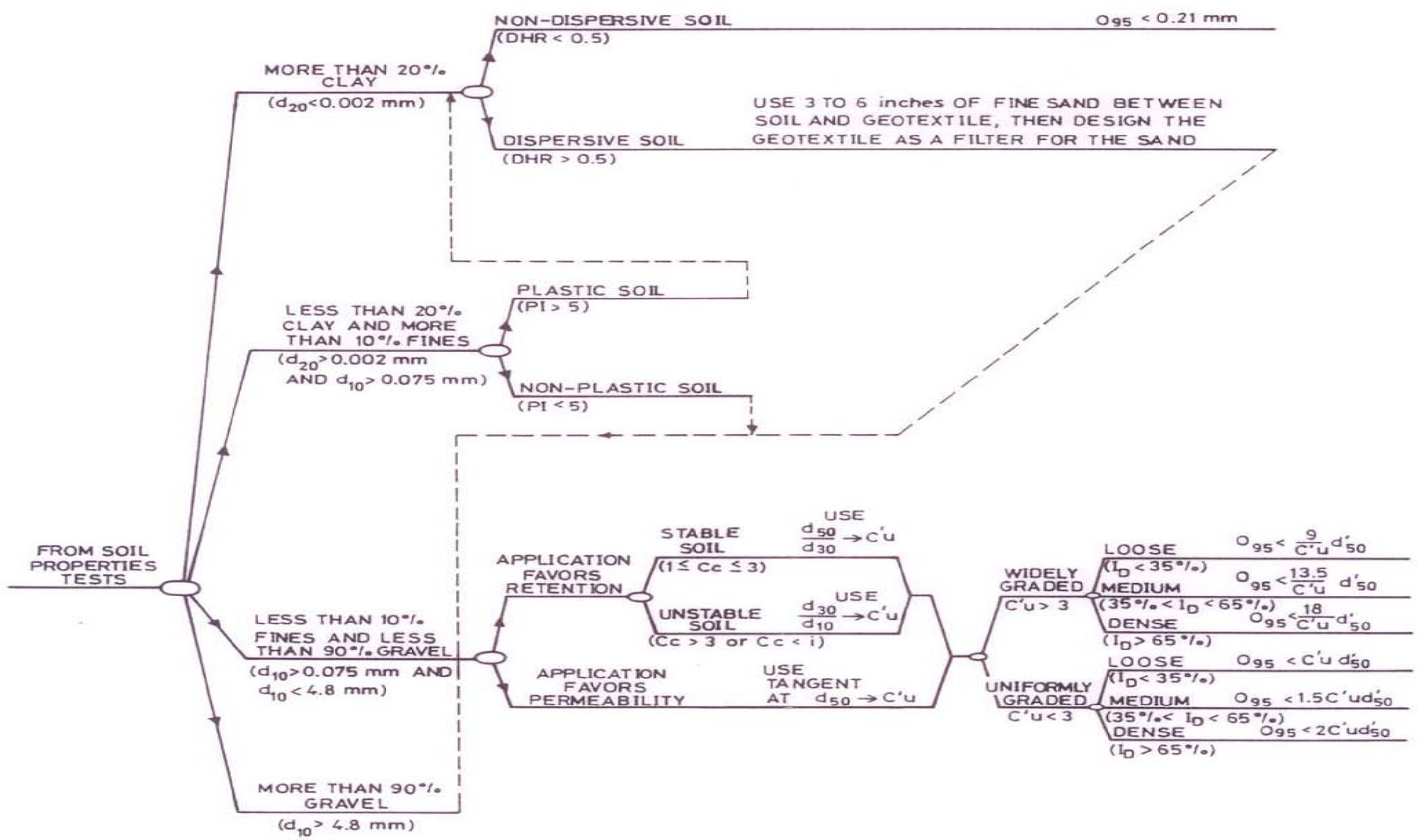
Drainage Application	Typical Hydraulic Gradient
Standard Dewatering Trench	1.0
Vertical Wall Drain	1.5
Pavement Edge Drain	1
Landfill LCDRS	1.5
Landfill LCRS	1.5
Landfill SWCRS	1.5
Dams	10
Inland Channel Protection	1
Shoreline Protection	10
Liquid Impoundment	10

Typical relative densities (I_D) for granular soils

Soil Conditions	Low Confining Pressures (TYP ≤ 50 kPa)	High Confining Pressures (TYP > 50 kPa)
Unconsolidated Sedimentary Deposits or Uncompacted Hydraulic Fill	$I_D \leq 35\%$	$35\% < I_D < 5\%$
Consolidated Residual Deposits or Compacted Fill	$35\% < I_D < 65\%$	$I_D > 65\%$

CHART 1

SOIL RETENTION CRITERIA FOR STEADY-STATE FLOW CONDITIONS



NOTES :

d_x is the particle size of which x percent is smaller

$C'u = \sqrt{\dfrac{d_{100}}{d_0}}$ where d_{100} and d_0 are the extremeties of a straight line drawn through the particle-size distribution as directed above : and d_{50} is the midpoint of this line

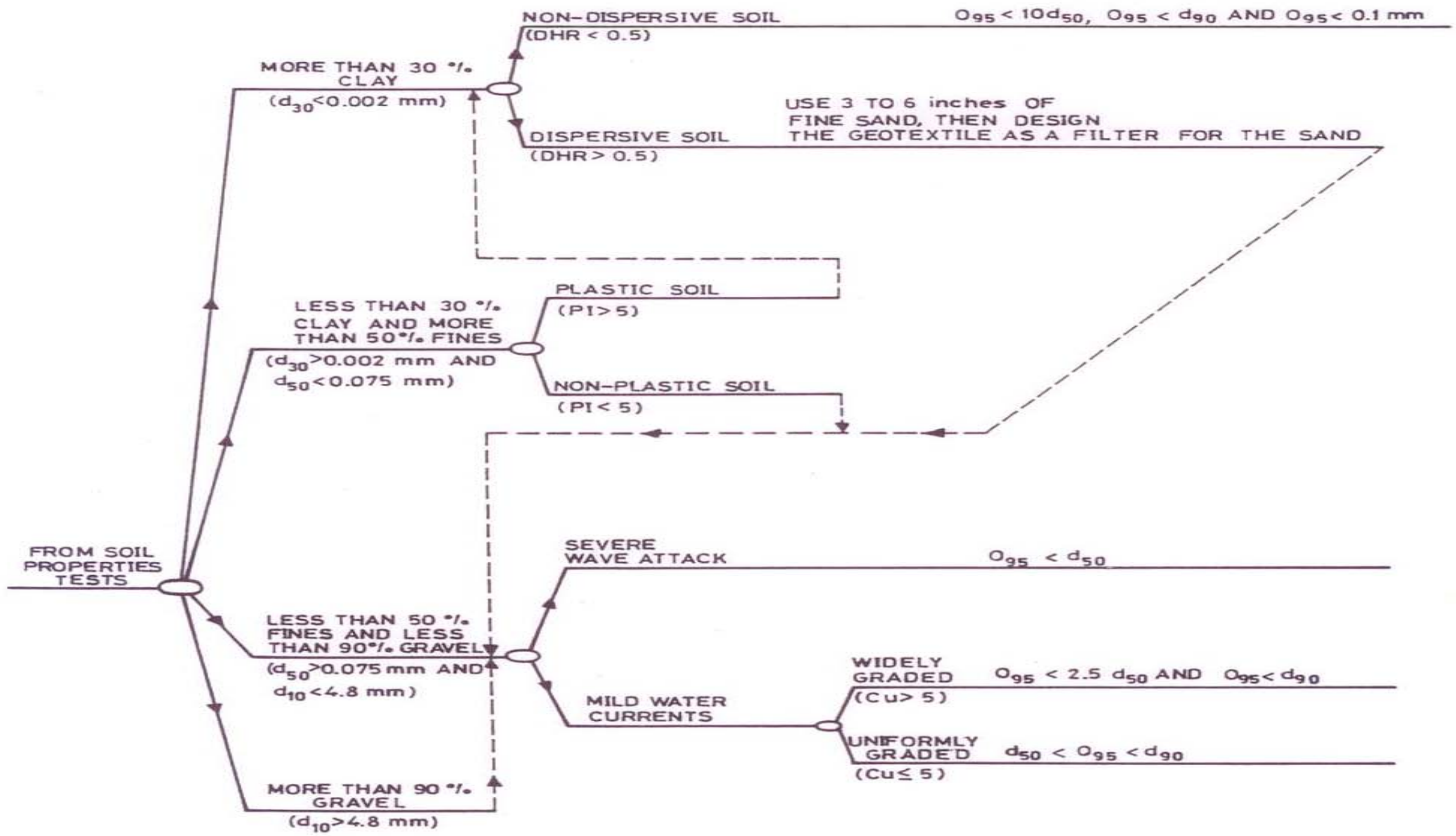
$Cc = \dfrac{(d_{30})^2}{d_{60} \times d_{10}}$

I_D is the reactive density of the soil

PI is the plasticity index of the soil

DHR is the double-hydrometer ratio of the soil

CHART 2
SOIL RETENTION CRITERIA
FOR DYNAMIC FLOW CONDITIONS



NOTES :

$$Cu = \frac{d_{60}}{d_{10}}$$

d_x is the soil particle size of which x percent is smaller

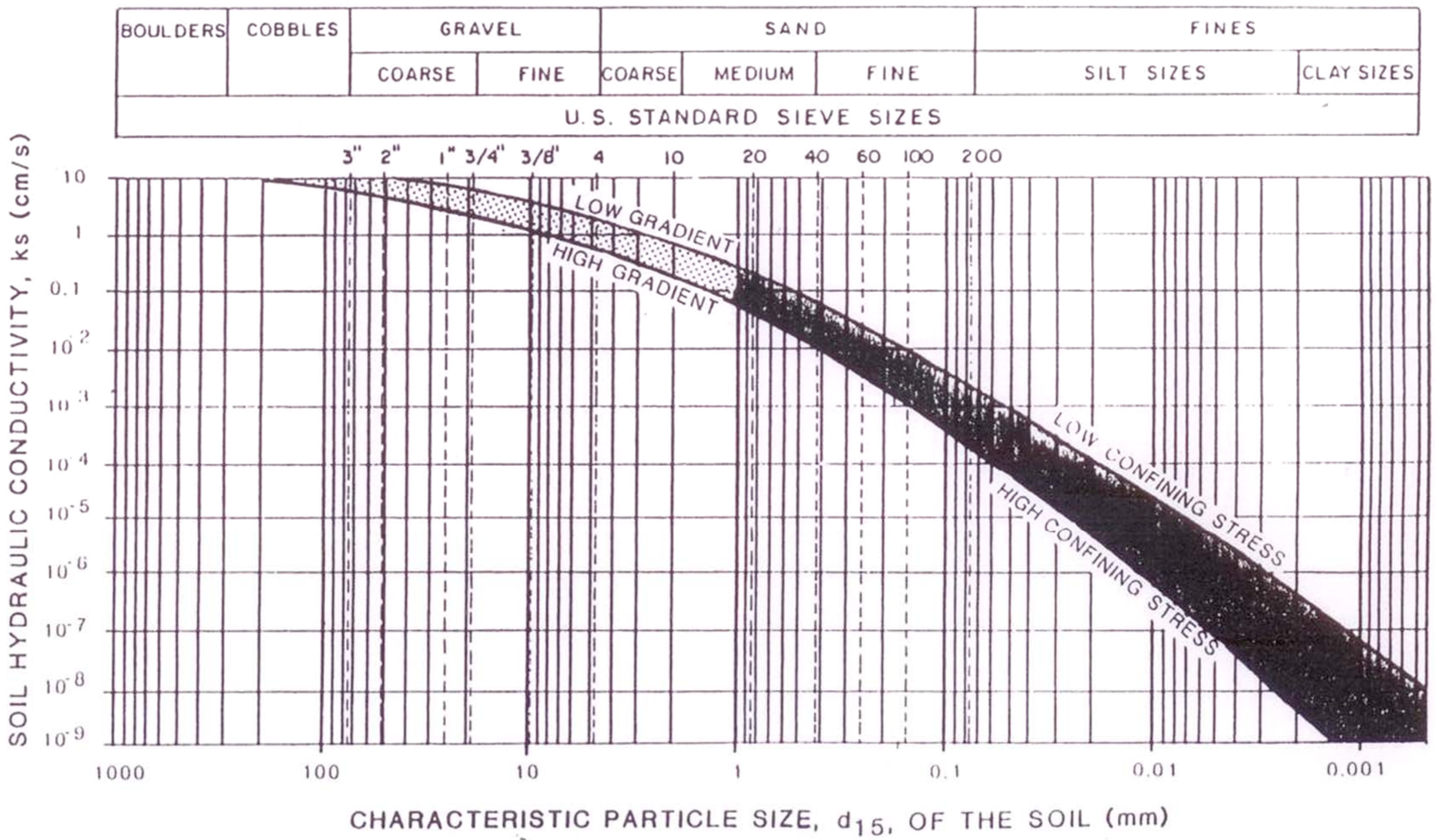
PI is the plasticity index of the soil

DHR is the double-hydrometer ratio of the soil

O_{95} is the geotextile opening size

FIGURE 1

TYPICAL HYDRAULIC CONDUCTIVITY VALUES



Survivability Criteria

FIGURE 2

SURVIVABILITY STRENGTH REQUIREMENTS [a]

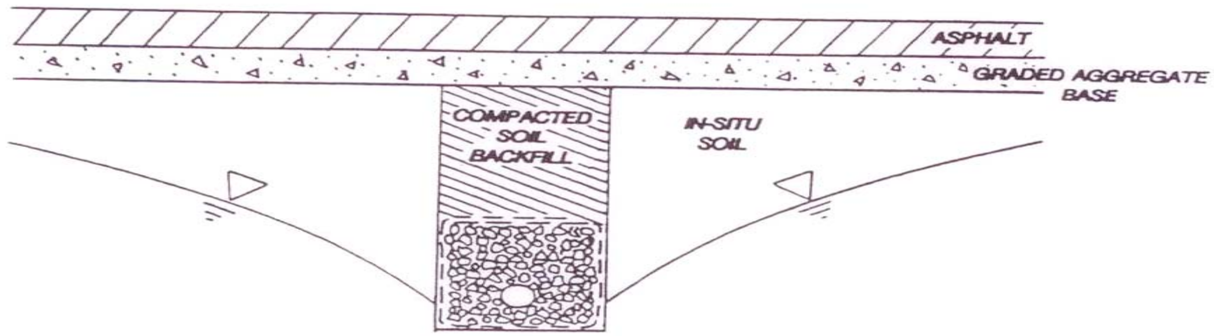
Installation Conditions	Contact Stresses	GEOTEXTILE PROPERTY [b] GRAB STRENGTH (lbs)	ELONGATION (%)	SEWN SEAM STRENGTH (lbs)	PUNCTURE STRENGTH (lbs)	BURST STRENGTH (psi)	TRAPEZOID TEAR (lbs)
MODERATE INSTALLATION CONDITIONS (TYPICAL DRAINAGE APPLICATIONS)	HIGH CONTACT STRESSES (ANGULAR DRAINAGE MEDIA) (HEAVY COMPACTATION) OR (HEAVY CONFINING STRESS)	180	N/A	160	80	290	50
	LOW CONTACT STRESSES (ROUNDED DRAINAGE MEDIA) (LIGHT COMPACTION) AND (LIGHT CONFINING STRESS)	80	N/A	70	25	130	25
SEVERE INSTALLATION CONDITIONS (SHORELINE PROTECTION AND ARMOURED SYSTEMS APPLICATIONS)	HIGH CONTACT STRESSES (DIRECT STONE PLACEMENT) (DROP HEIGHT > 3 ft)	200	15	180	80	320	50
	LOW CONTACT STRESSES (SAND OR GEOTEXTILE CUSHION) (DROP HEIGHT < 3 ft)	90	15	80	40	140	30

NOTE: (a) After FHWA, 1985.
(b) Test methods for determining geotextile properties given in Table 4-6 in "Geotextile Filter Design Manual"

Example 1

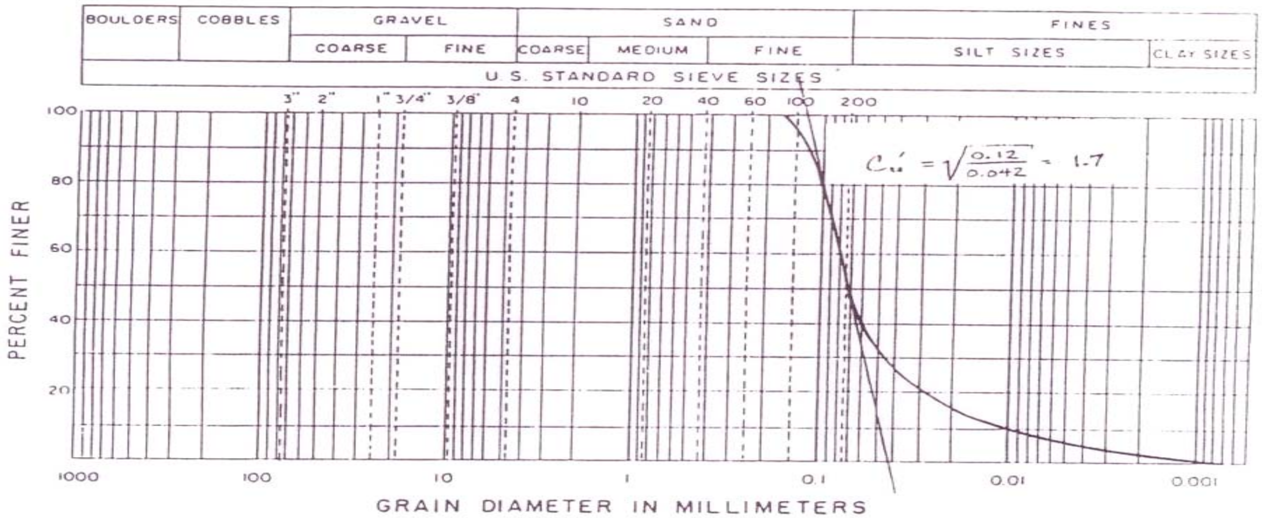
Project specifications state that dewatering trenches be installed at every 7.6m for the dewatering of parking lot. The drains are at least 1.2m below the finished grade (Fig.E1).

The drains should be constructed with open gravel wrapped in a geotextile layer.
A 10cm diameter perforated pipe is placed.
The in-situ soil is a residual sandy silt (%fines = 51%, %clay = 4%, PI = 0, $C_u' = 1.7$, refer Fig.E2).



The soil conditions are a residual sandy silt, which classifies as an ML (sandy silt), in accordance with ASTM D2487.

Fig. E1



COEFFICIENT OF UNIFORMITY (C_u) 10.8

COEFFICIENT OF CURVATURE (C_c) 2.9

LIQUID LIMIT (LL) N/A

PLASTIC LIMIT (PL) NON-PLASTIC

PLASTICITY INDEX (PI) 0

UNIFIED SOIL CLASSIFICATION (USC) ML (SANDY SILT)

(1)Soil retention criteria

Since drainage medium is gravel, application favors permeability

I_D is in the range of 35% and 65%

From chart 1,

Geotextile apparent opening size

$$
\begin{aligned}
o_{95} &\leq 1.5\ Cu'\ d_{50} \\
&\leq 1.5 \times 1.7 \times 0.071 \\
&\leq 0.18\text{mm}
\end{aligned}
$$

(2) Permeability criteria

From charts, corresponding to d_{15} = 0.017mm,
$K_s = 5(10^{-5})$ cm/s
From Tables, typical hydraulic gradient, i = 1.0

Minimum allowable geotextile permeability,

$$K_g \geq i_s K_s$$
$$\geq 1.0 \times (5.0\times10^{-5}\ \text{cm/s})$$
$$\geq 5.0\times10^{-5}\ \text{cm/s.}$$

(3) Anti - Clogging requirements

From anti-clogging requirements, use the largest available O_{95}, which satisfies the retention criteria, or O_{95} = 0.18mm.

If the geotextile is non-woven, porosity should be more than 30%.

If the geotextile is woven, percent open area $\geq$ 4 %

(4) Survivability Criteria

Choose a geotextile material that satisfies the criteria in Fig.2, corresponding to moderate installation conditions and low contact stress.

(5) Durability Criteria

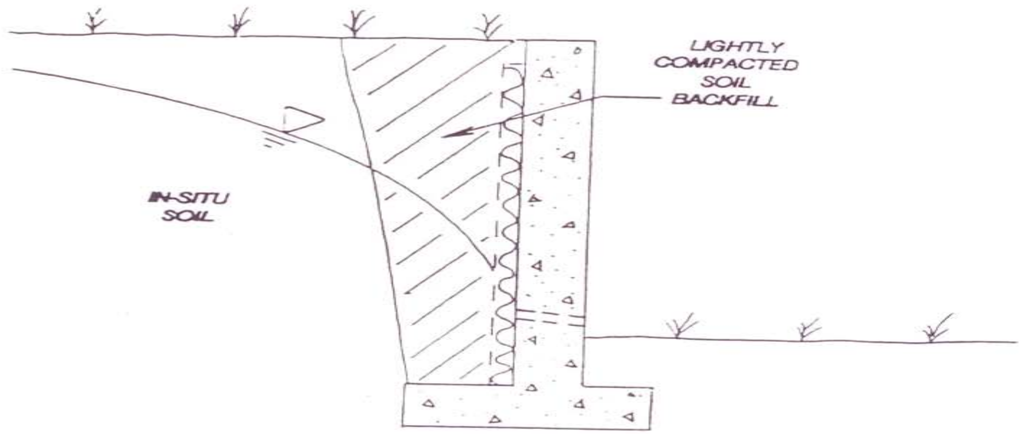
Ultra violet resistance is not expected to be a problem owing to the complete burial of the geotextile.

In addition, chemical resistance requirements are not serious, as the permeant is uncontaminated ground water.

Example 2

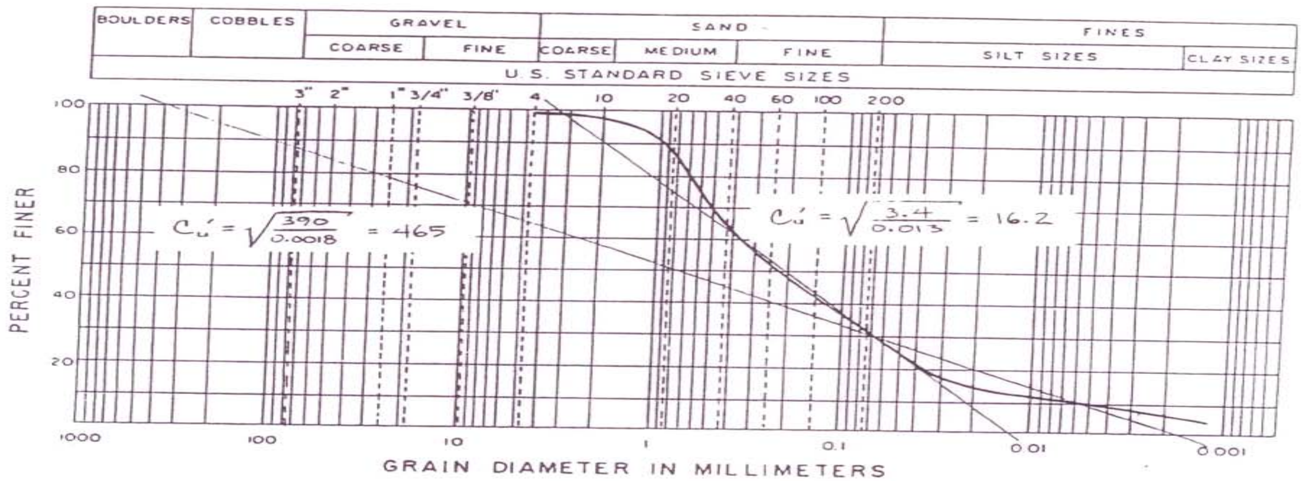
For a continuous retaining wall of 3m height, a continuous wall drain be installed on the backside of wall (Fig.E3). The drain is to be constructed with either gravel or geosynthetic drainage material with a geotextile filter. The retaining wall has lightly compacted backfill, classified as silty sand and the properties are given in Fig.E4.

Following soil properties are known.
(Percent fines = 32%, percent clay = 7%, PI = 0)



The soil conditions are a lightly compacted soil backfill. The soil classifies as an SM (silty sand), in accordance with ASTM D2487

Fig E3



COEFFICIENT OF UNIFORMITY (C_U) 67

COEFFICIENT OF CURVATURE (C_C) 3.1

LIQUID LIMIT (LL) N/A

PLASTIC LIMIT (PL) NON-PLASTIC

PLASTICITY INDEX (PI) 0

UNIFIED SOIL CLASSIFICATION (USC) SM (SILTY SAND)

(1) Soil retention Criteria

Assuming that the application favors permeability,

$$Cu' = \sqrt{d_{60}/d_{10}} = \sqrt{3.4/0.013} = 16.2$$

From chart I, $I_D < 35\%$ and

$$O_{95} \leq (9/Cu')\, d_{50}$$

$$\leq (9/16.2)\ 0.22$$

$$\leq 0.11\text{mm}$$

(2) Permeability Criteria

From charts,

for d_{15} = 0.02mm, $K_s = 5(10^{-5})$,

From Tables, i = 1.5

Minimum allowable geotextile permeability

$$K_g \geq i_s K_s$$
$$\geq 1.5 \times (5.0 \times 10^{-5}\ \text{cm/s})$$
$$\geq 7.5 \times 10^{-5}\ \text{cm/s.}$$

(3) Anti - Clogging requirements

Use the largest available O_{95} that satisfies the retention criteria.

If the selected geotextile is nonwoven, the porosity is more than or equal to 30%.

If it is non-woven, percent open area > 4%

(4) Survivability Criteria

Choose a geotextile material that satisfies the survivability criteria, corresponding to moderate installation conditions and low contact stress.

(5) Durability Criteria

Ultra violet resistance is not expected to be a problem owing to the complete burial of the geotextile.

In addition, chemical resistance requirements are not serious, as the permeant is uncontaminated ground water.

Case studies:

Filtration & Separation - Titan Stadium- Oshkosh, WL

- The objective of this work was to design the field cross section to provide maximum drainage for stormwater, provide adequate structural stability for construction equipment and facilitate deployment of the artificial surface.
- Mirafi® FW402 & Mirafi® 170N was the geotextile product used in filtration and separation.

- Mirafi® FW402 is a woven monofilament polypropylene geotextile fabric. It was chosen because it has both the high strength needed for durability and a high percent open area for long term clogging resistance that also promotes a high water-flow rate. Its high tensile strength was essential to support the anticipated equipment loads that occur during construction and deployment of the artificial surface.
- It was used between the drainage layer and sand layer to provide separation and filtration.

Backfill deployment on Mirafi® FW402 geotextile.

Instillation of Mirafi® FW402 geotextile.

- The geotextile was placed on top of the drainage layer to provide filtration and separation between dissimilar materials. The edges of adjacent geotextile panels were overlapped to provide full coverage over the area.
- A total of 11,700 m^2 (14,000 yd^2) of Mirafi® FW402 were used on this project to provide separation, filtration and drainage, and stabilization. The construction went smoothly and the new multipurpose field was completed in time to be used at the start of the Fall 2004 football season.


Geosynthetics in Erosion Protection

Geosynthetics in Sediment and Erosion Control

- Introduction and Applications
- What is it?
- Erosion control is a means of keeping a soil in place or catching a soil after it has been displaced but before it moves into surface waters.

Why Is It Needed?

There are public laws that :

- preclude the polluting of surface waters with sediments
- preserve topographic integrity
- preserve soil for farming
- preserve foundation integrity for structures founded on soil.

Rill and Gully Slope Erosion

Riverbank Erosion, Including Sapping (Formation of Caves)

Where Is It Needed?

- It is needed on construction and agricultural sites and natural places where water causes soils to displace.

- In short: where soil and moving water interact at the ground surface

Factors Influencing Types of Erosion

- Rainfall-induced erosion factors:
  - intensity and duration of rainfall
  - slope of land
  - soil type
- All affect the amount of erosion and the erosion control measures selected.

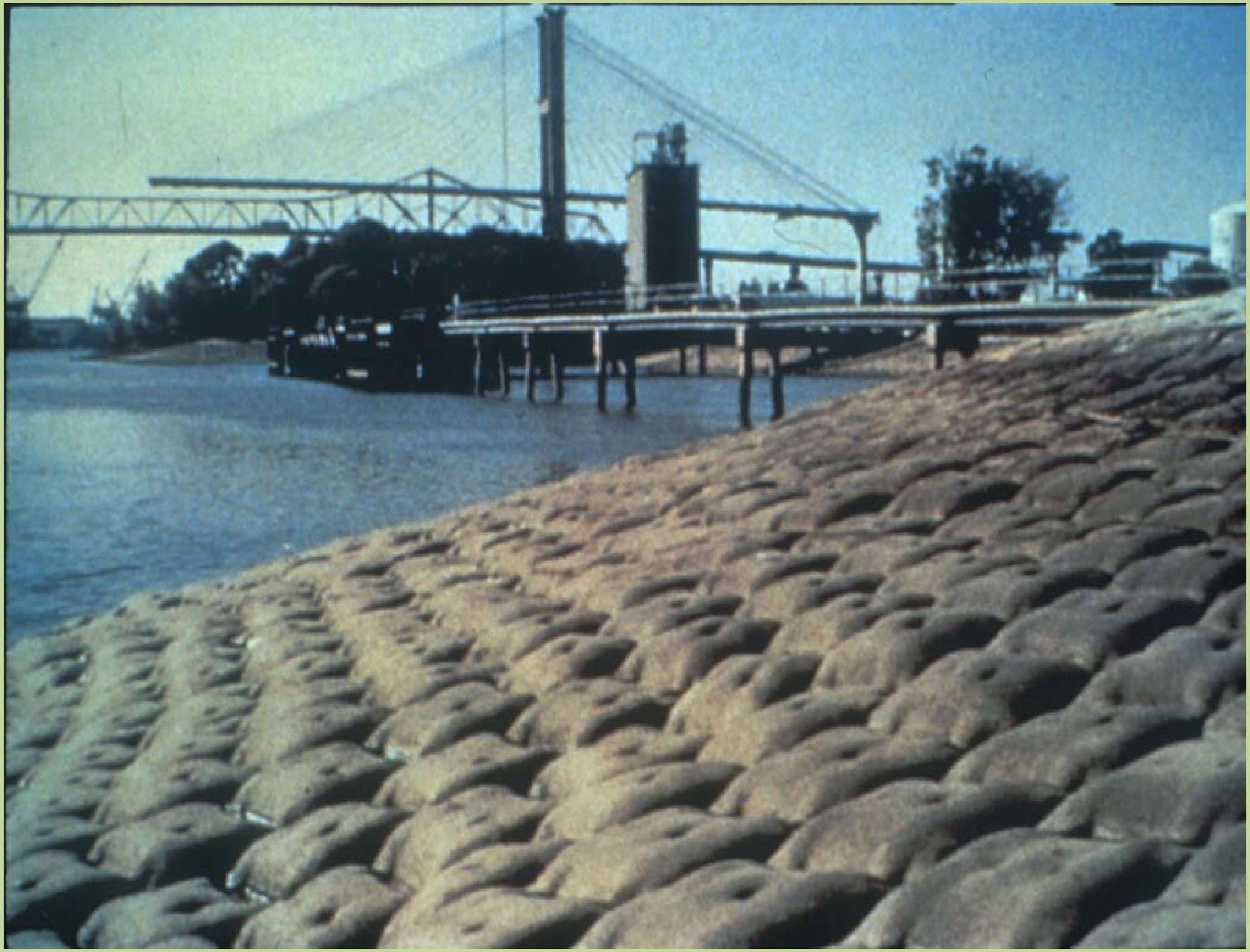
Factors Influencing Types Of Erosion (Continued)

- Shoreline erosion factors:
  - soil type
  - wave height
  - beach slope
  - duration and intensity of storm
- All affect the amount of erosion.

Factors Influencing Types Of Erosion (Continued)

- Scour:
  - The amount of scour, around bridge piers for example, is affected by pier shape, depth of stream, storm duration and channel shape, in addition to soil type.

Hard Armor Erosion Control on Riverbank



Concrete cast in a geotextile former; geotextile filter underneath (not visible)

Design Approach

- Slopes and Channels

Channel erosion damage caused by inadequate filter beneath hard armor

Strategy

- Choose least costly erosion control measure and evaluate:
  - **LOW** cost — nothing (fallow ground)
plants
degradable RECPs
permanent RECPs
permanent TRMs
soft armor
  - **HIGH** cost — hard armor w/geotextile filter
- In conjunction with these choices, consider:
  - reducing flow in any manner
  - flattening slopes
  - widening channels

Design Procedures for Erosion Control in Slopes and Channels

Slopes

- There are several methods of estimating soil loss. The most commonly used in the US is:
- **USLE - Universal Soil Loss Equation:**

$$\mathbf{A = R \times K \times LS \times C \times P}$$

where: A = computed soil loss (tons/acre or kg/hectare) for a given storm period or time interval

R = rainfall factor

K = soil erodibility value

LS = slope length and steepness factor

C = vegetation or cover factor

P = erosion control practice factor

- All factors, except C, do not vary more than one order of magnitude. C changes several orders of magnitudes.
- **NOTE**: many of these factors are described in USDA (1997)

Concluding Remarks

- Applications of geosynthetics is significant in filtration, drainage and erosion control applications. Considerable information exist in the area and manufacturers of these products, International Geosynthetic Society and other organizations have significantly contributed in implementing these technologies in practice.