USE OF GEOSYNTHETICS FOR FILTRATION AND DRAINAGE

Prof. G L Sivakumar Babu
Department of Civil Engineering
Indian Institute of Science
Bangalore 560012

Functions of a Filter

Retain particles of the base soil to be filtered

Avoid piping

- **Allow free flow of water**
  - **upstream of the filter**

    Avoid *external* clogging

    (With unstable soils)
  - **through the filter**

    Avoid *internal* clogging
- **Survive construction and environmental stresses**
- **Function can be provided by either natural aggregates or by Geotextiles**

	AGGREGATES	***GEOSYNTHETICS***
SIMILARITIES		
- Risks of internal clogging by **1. finer particles of the soils to be filtered** **2. aerobic bacterial activity (ochre clogging)** **3. deicing salt precipitation** **4. ice lens formation within the frost penetration zone**		
DIFFERENCES		
- Thickness	**High ($>$150 mm)**	**Low ($<$ 30 mm)**
- Porosity	**25 - 40 %**	**75 - 95 %**
- Capillary rise h_c	**Important ($h_c <$ 500 mm)**	**Low to none ($h_c <$ 50 mm)**
- Tensile strength	**None**	**Low to high**
- Compressibility	**Negligible**	**Medium to high**
- Transmissivity under confining stress	**Invariable**	**Variable**
- Uniformity	**Variable gradation as per borrow pit**	**Factory-controlled mass per unit area and thickness**
- Durability	**Completely inert**	**Altered by ultraviolet rays**
- Installation	**Must not be contamined by the surrounding soil.** **Compaction needed**	**Must be installed in intimate contact with the soil to be filtered** **Installation eased by seaming of the joints**
- Risk of damage	**None**	**Subject to puncture and tearing**

Filtration Behaviour

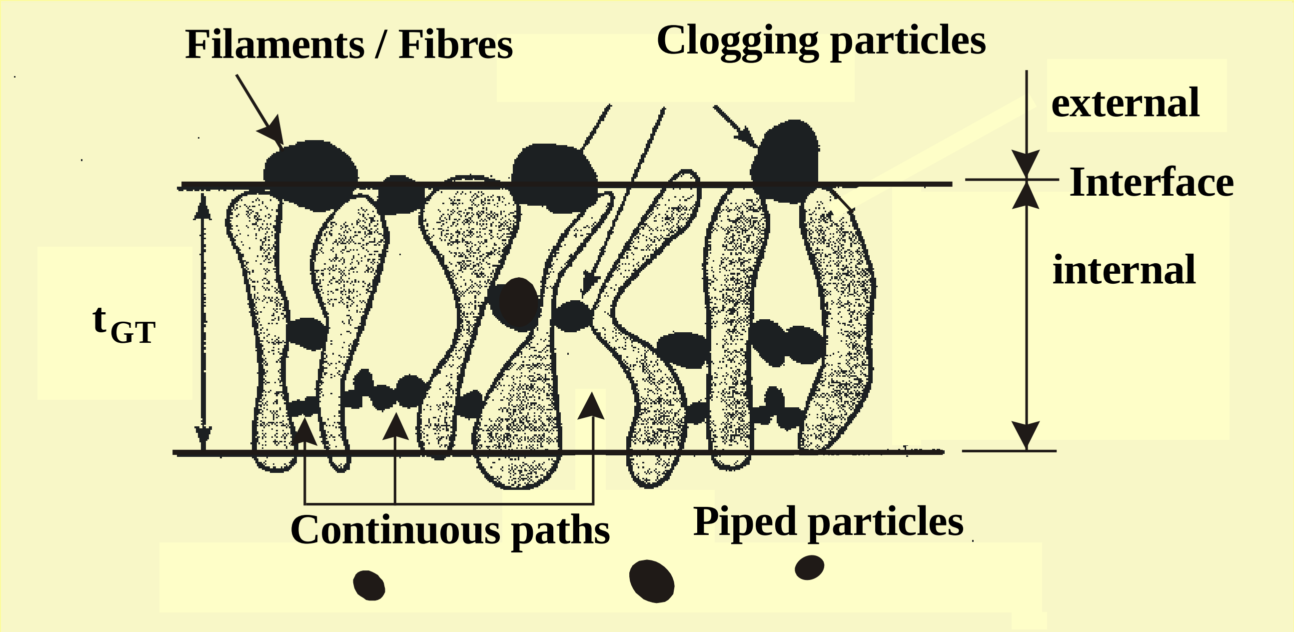
- **Clogging: the voids of a medium are progressively filled by solid matter to the point that the passage of water is compromised**

  - **Decrease in hydraulic conductivity**

- **Internal clogging**

  - **By mineral particles**
  - **By precipitation and chemical deposition in the voids by water containing iron, de-icing salts**
  - **By biological growth encrustation in aerobic conditions**

Base - Filter Interaction



APPLICATIONS : DRAINAGE

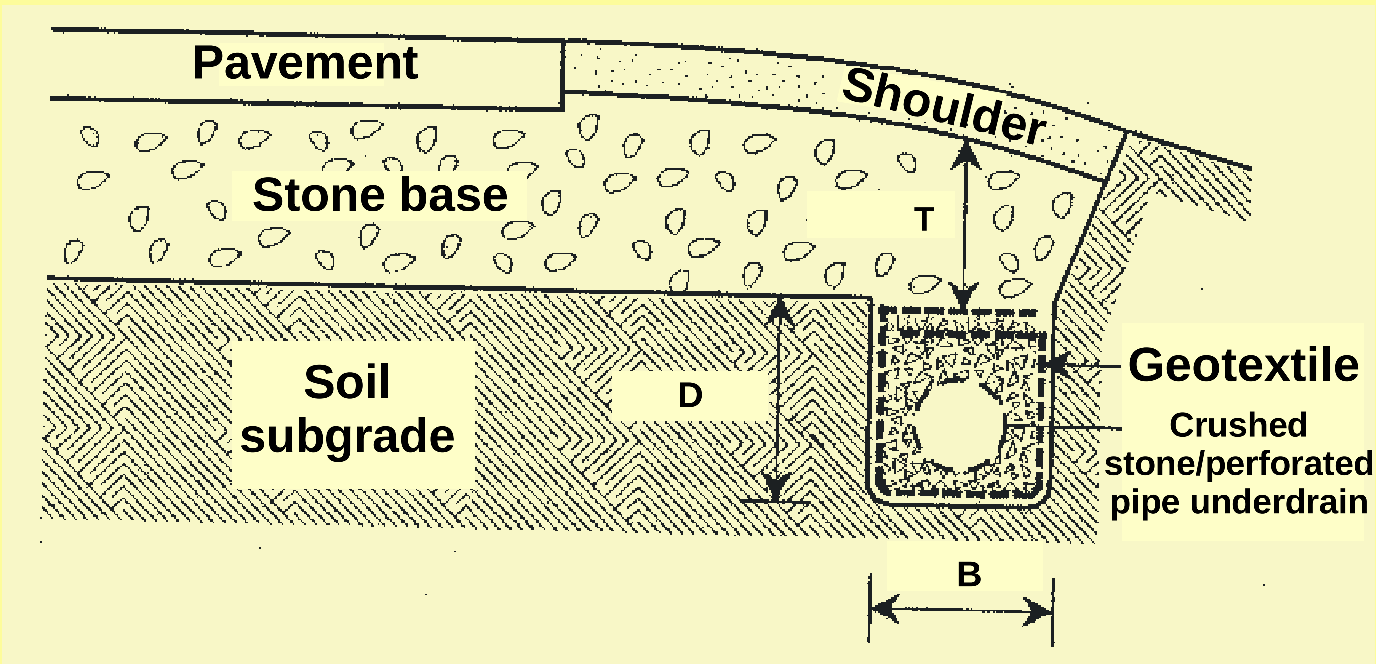
- **Around trench drains and edge drains**
- **Beneath pavement bases and base courses**
- **Retaining walls and bridge abutments**
- **Drain and well pipes**
- **Slope stabilization**
- **Earth dams and Levees**

APPLICATIONS : EROSION CONTROL

- **Protection of runoff collection**
- **Slope protection**
- **Along stream banks**
- **Scour protection around structures**
- **Construction facilities across/adjacent to water bodies**
- **Culverts, drop inlets, artificial stream channels**

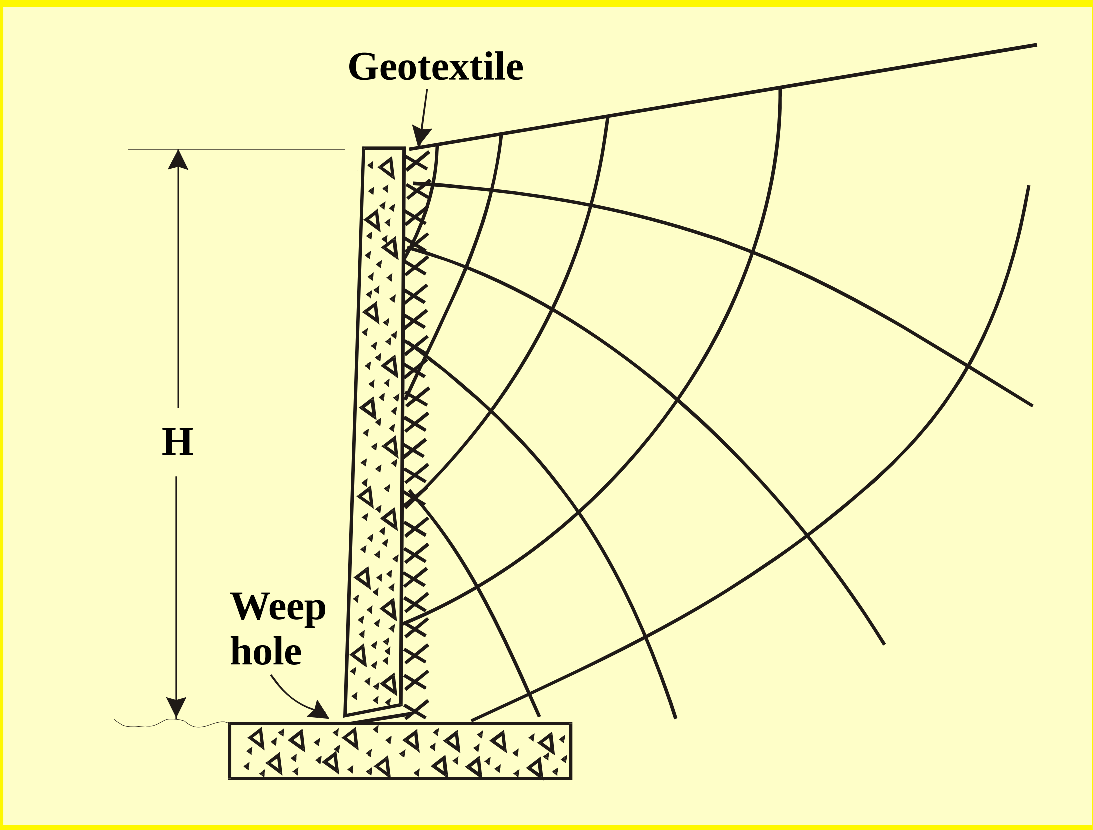
Filter Applications

- **Wrapping of trench drains (Koerner, 1998)**



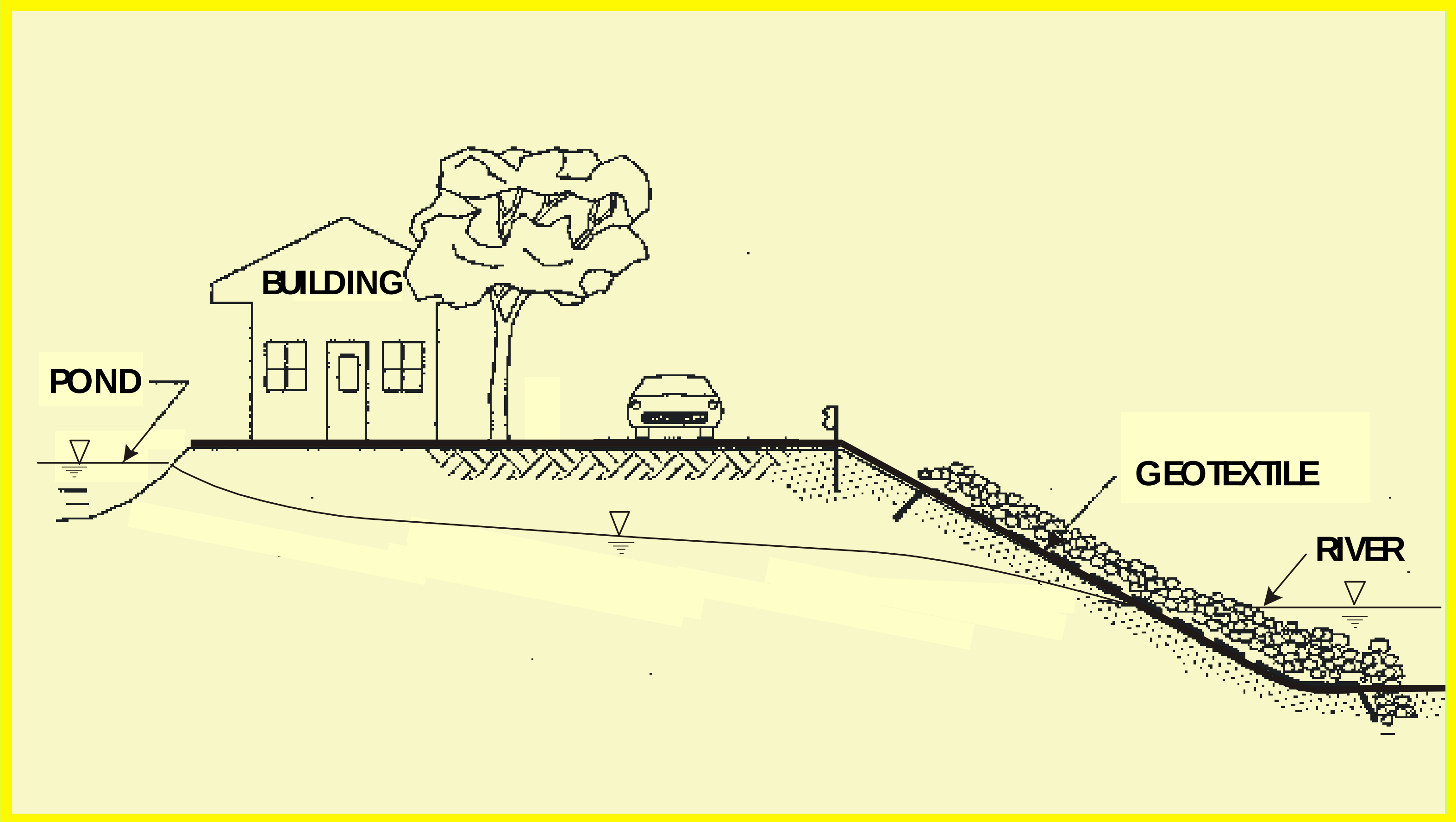
Filter Applications

- **Wall drains**



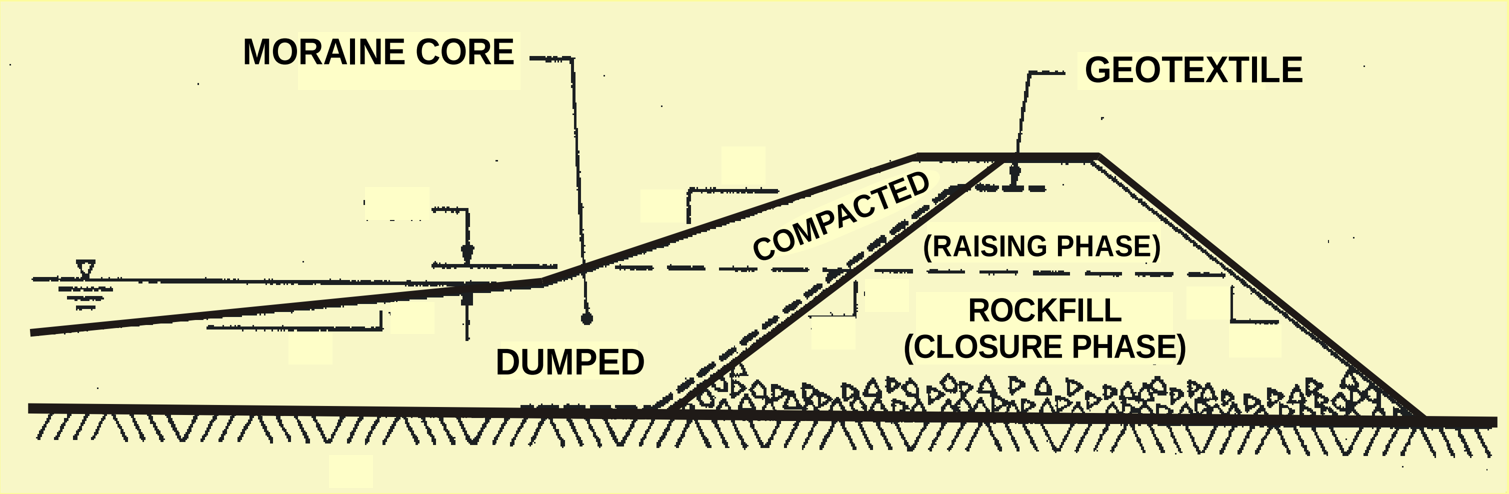
Filter Applications

- Erosion protection



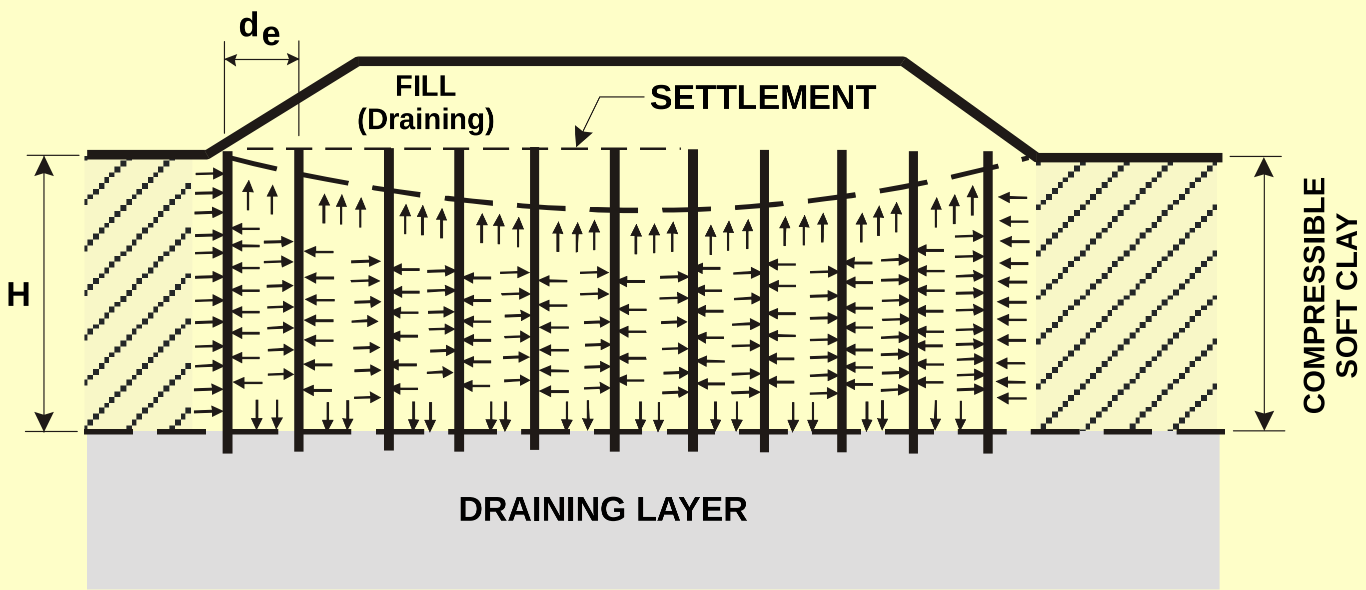
Filter Applications

- **Earth and rockfill dams**

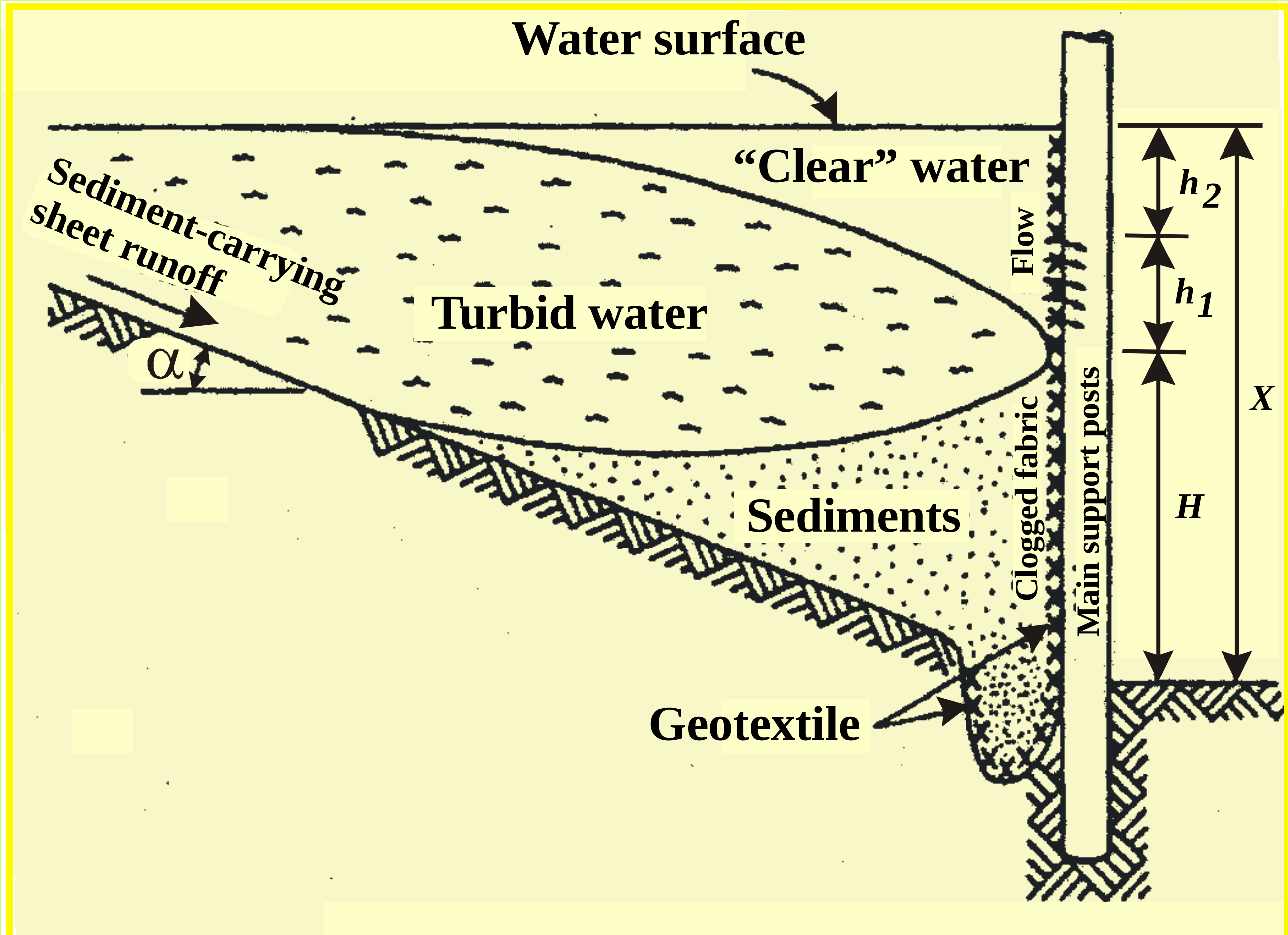


Filter Applications

- **Vertical consolidation drains**



Filter Applications



Filtration Flow Conditions

- **Dynamic vs static**

DYNAMIC, PULSATING, CYCLIC	STATIC, UNIDIRECTIONAL
EROSION PROTECTION (WAVES, CURRENT)	WALL DRAINS
ROAD DRAINAGE (TRAFIC STRESSES)	SILT FENCES
CONDITIONS MORE SEVERE	VERTICAL CONSOLIDATION DRAINS
REDUCE FILTER OPENING SIZE	EARTH & ROCKFILL DAMS

Table 1.Guidelines for evaluation of critical nature of severity for filtration, drainage and erosion control applications (Carroll, 1983)

A. Critical Nature of the Project

Item	Critical	Less Critical
1. Risk of loss of life and/or structural damage due to drain failure:	High	None
2. Repair costs versus installation costs of drain:	>>>	Equal or less
3. Evidence of drain clogging before potential catastrophic failure:	None	Yes

Guidelines (Continued)

B. Severity of the Conditions		
Item	**Severe**	**Less Severe**
1. Soil to be drained:	Gap-graded, pipable, Or dispersible	Well-graded or uniform
2. Hydraulic gradient:	High	Low
3. Flow conditions:	Dynamic, cyclic, or pulsating	Steady state

Granular filter design criteria

a)Retention Criteria:

$$\frac{d_{15}(\text{filter})}{d_{85}(\text{soil})} < 4 \text{ to } 5$$

b)Permeability Criteria:

$$\frac{d_{15}(\text{filter})}{d_{15}(\text{soil})} > 4 \text{ to } 5$$

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	$35\% < I_D < 65\%$	$I_D > 65\%$

Retention Criteria:

$$O_{e(geotextile)} \leq B\ D_{(soil)}$$

where:

O_e = effective opening size in the geotextile for which e is the present openings that are smaller than the opening size O (mm), usually the O_{90} or O_{95};

B = a coefficient (dimensionless); and

$D_{(soil)}$= representative soil particle size (mm), usually the medium to larger fractions or D_{85}.

Laboratory Filter Characterization

- **Opening size O_{90} by wet sieving**

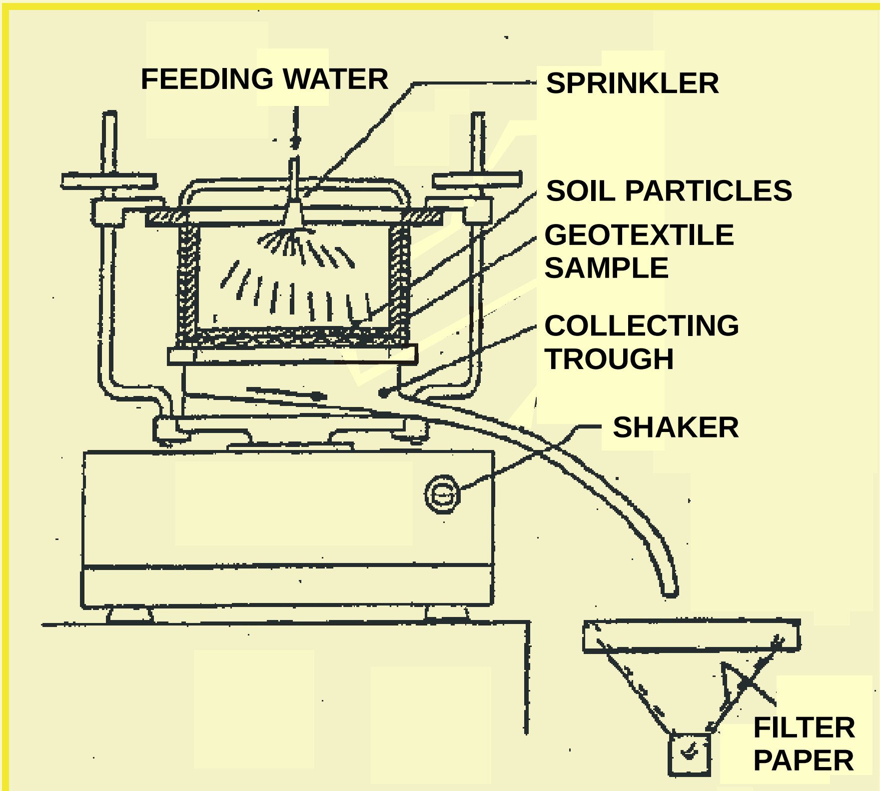
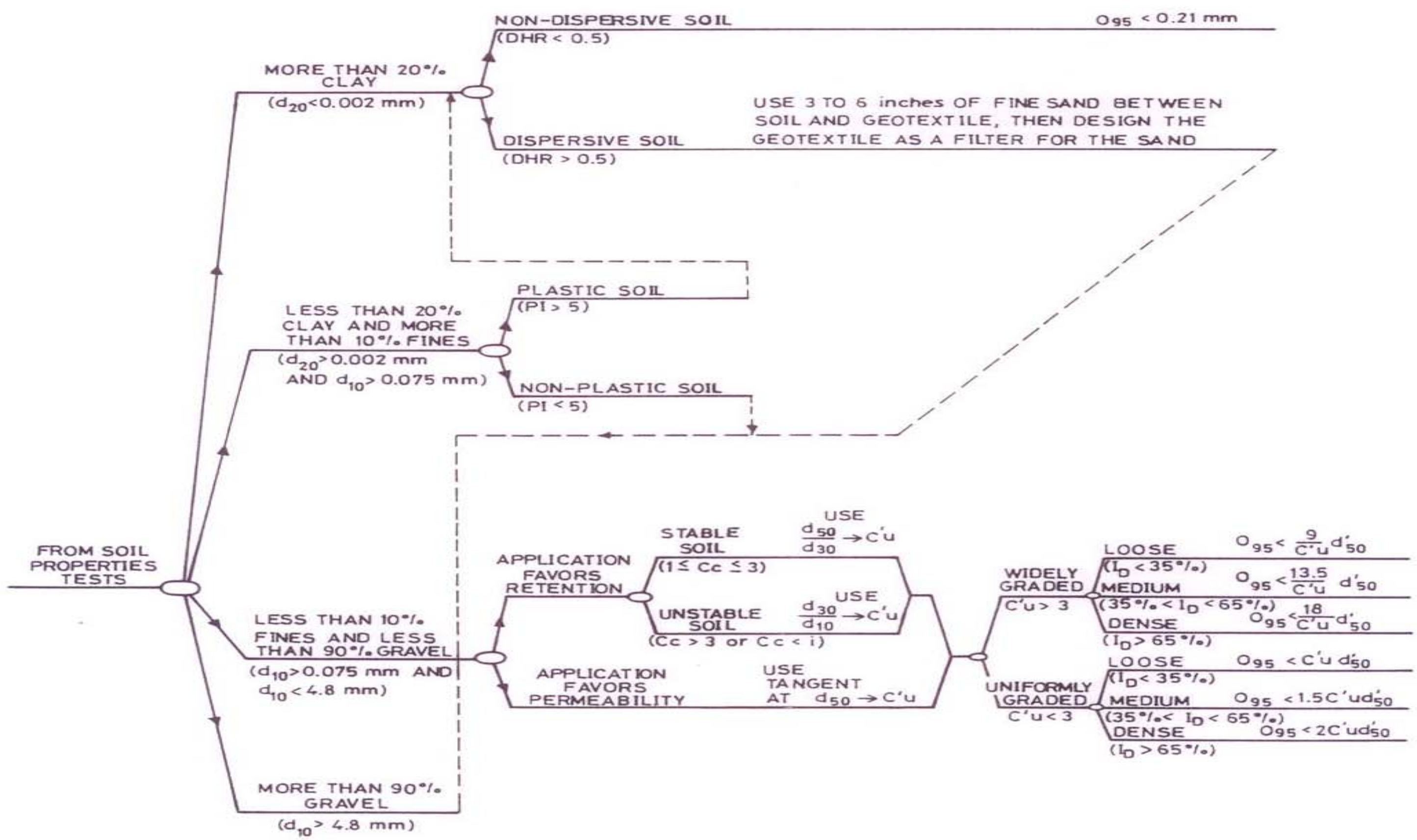


CHART 1

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

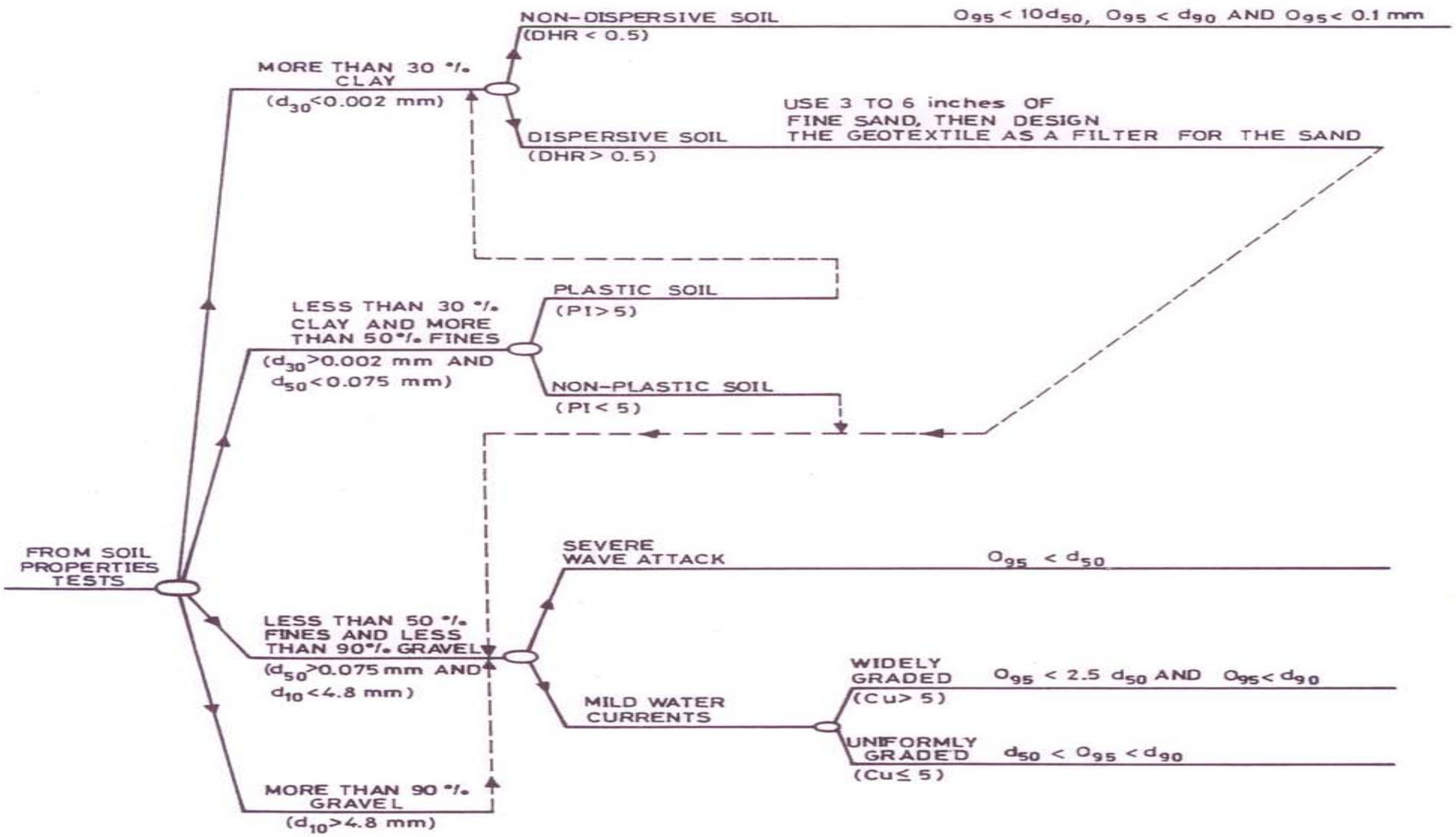
$Cc = \dfrac{(d_{30})^2}{d_{60} \times d_{10}}$

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

Permeability criteria

Giroud Criteria $K_g > i_s K_s$ Where $i_s > 1.0$

FWHA Criteria $K_{geotextile} \geq FS \bullet k_{soil}$

$\psi_{allow} \geq FS \bullet \psi_{required}$

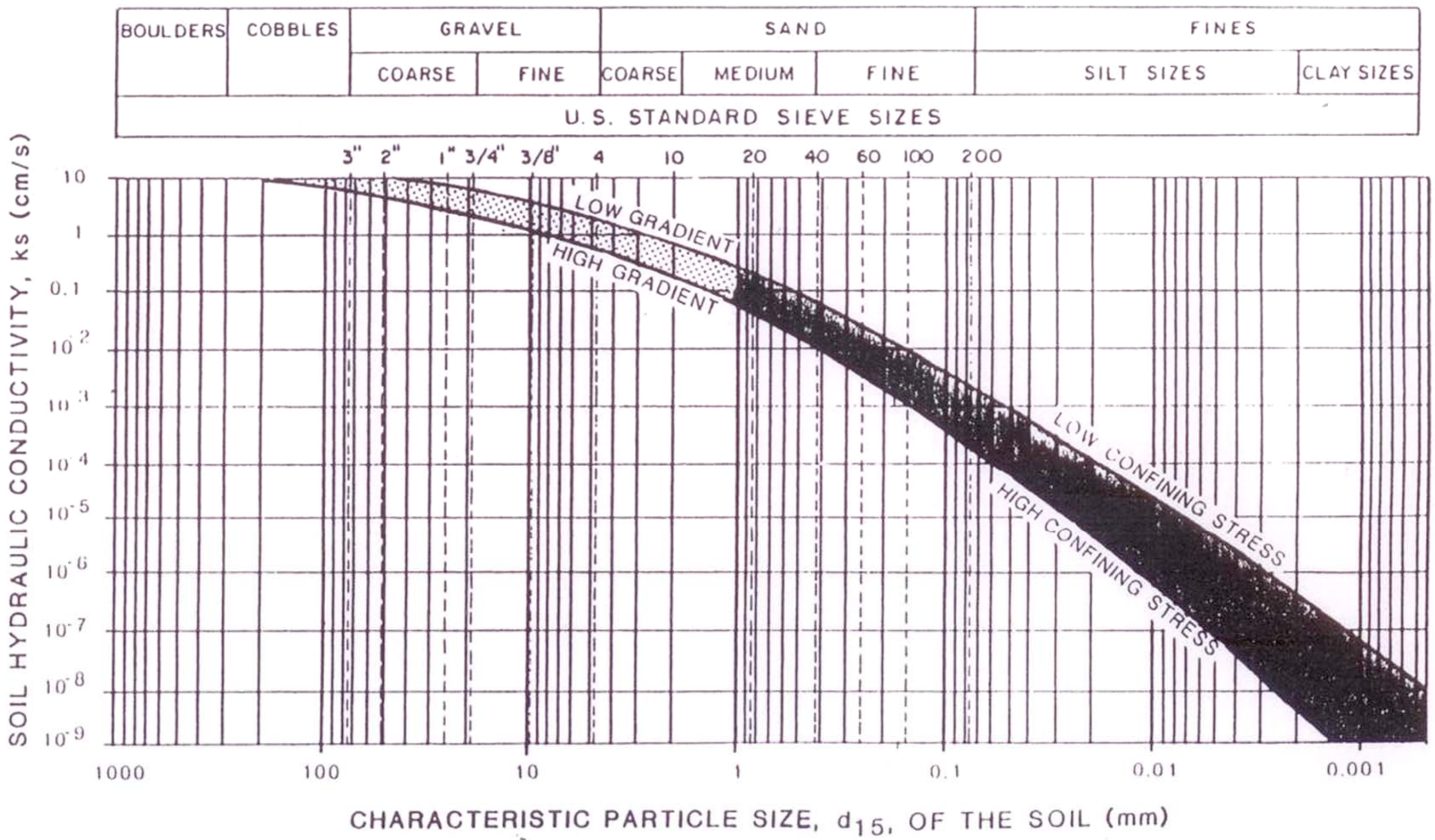
For less critical conditions $K_{geotextile} \geq k_{soil}$

For Severe conditions $K_{geotextile} \geq 10\ k_{soil}$

Min. permittivity conditions $\psi \geq 0.1$ to $1\ sec^{-1}$

FIGURE 1

TYPICAL HYDRAULIC CONDUCTIVITY VALUES



Anti - Clogging Criteria

Use the largest available opening size satisfying the retention criteria

For nonwovens, porosity > 30%
For woven geotextiles percent open area $\geq$ 4%

The porosity of a nonwoven geotextile is given by

$$n = (1-\mu/(t_g\rho)) * 100$$

μ is the mass per unit area of geotextile
t_g is the geotextile thickness and ρ is the density of filament

Survivability Criteria

FIGURE 2

SURVIVABILITY STRENGTH REQUIREMENTS [a]

		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"

Durability Criteria

- Aspects such as geotextiles resistance to ultraviolet and adverse chemical environments need be studied in specific application.

- Exposure to sunlight extensively during must be protected by anti-oxidants such a carbon black or titanium oxide.

- Geotextiles should also be resistant to chemicals.