Geosynthetics in Forestry Application

By

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Presentation Outline

- Background information on Geosynthetics.
- Look at examples of geosynthetics in Forestry Applications.
- Review currently accepted design standards.
- Where applicable, identify simplified design procedures to promote the use of geosynthetics.

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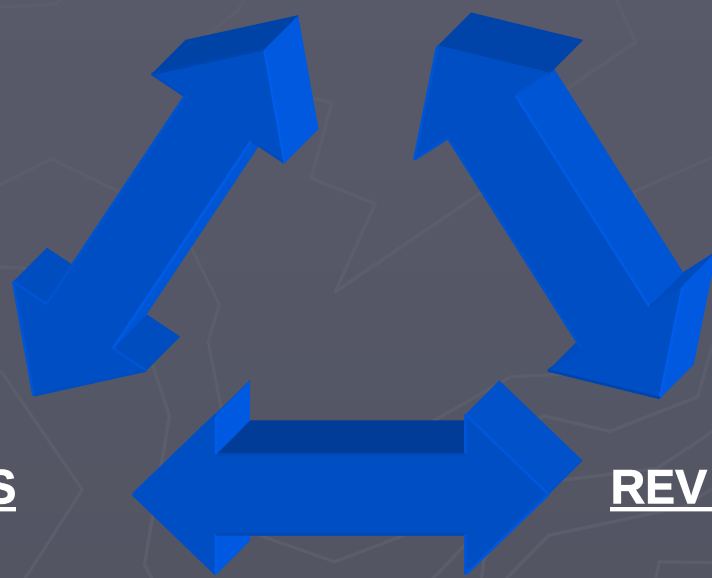
GOAL

GEOSYNTHETICS
KNOWLEDGE
DESIGN STANDARDS



PRACTITIONERS
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REVIEW TEAM AGENCIES
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Geosynthetics Defined

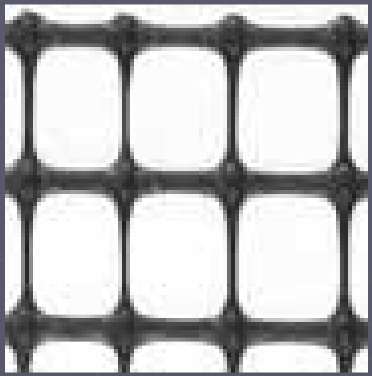
"Planar, polymeric material used with soil, rock, earth, or other geotechnical-related material as an integral part of an engineered project, structure, or system."

ASTM, 1994

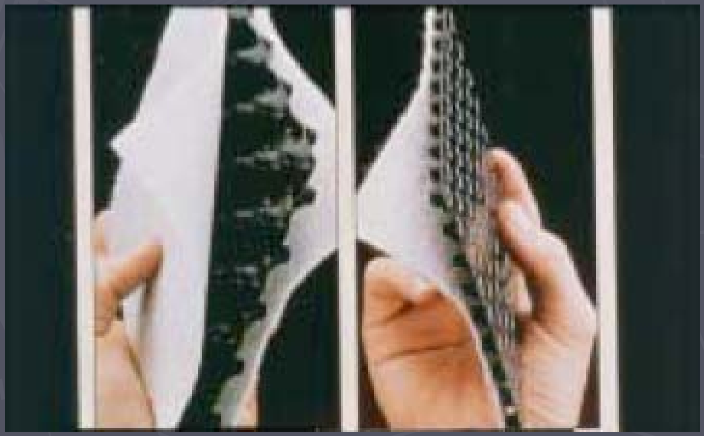
Common Geosynthetics in Forest Applications

Geotextiles

Geogrids



Geocomposites

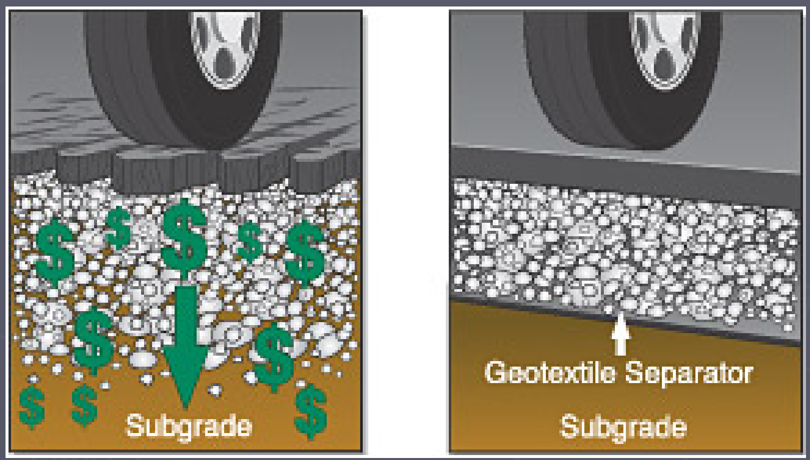


Geocells

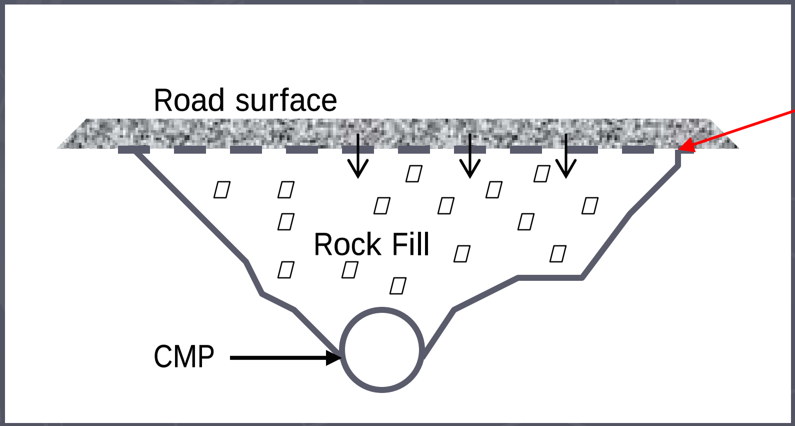
Common Geosynthetic functions in Forest Applications

- Separation
- Filtration
- In-plane Drainage
- Reinforcement
- Protection/Cushion
- Fluid Barrier

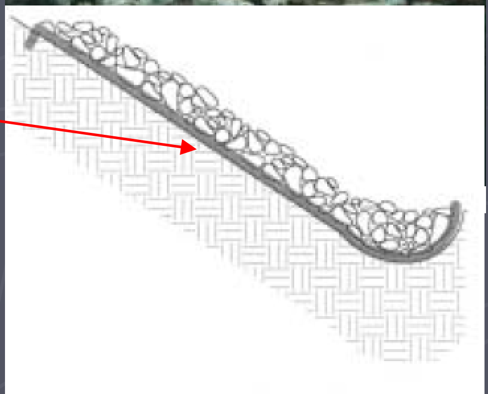
Separation



Tensar



Geotextile



Filtration

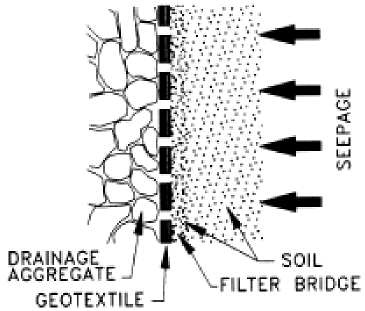


Figure 2-2 Filter bridge formation.

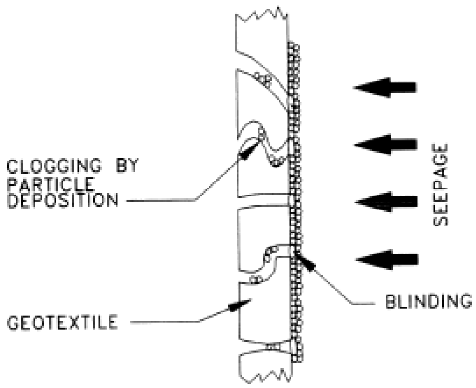


Figure 2-3 Definitions of clogging and blinding (Bell and Hicks, 1980).

Wrapped aggregate drains

Filter fabric

Geocomposites

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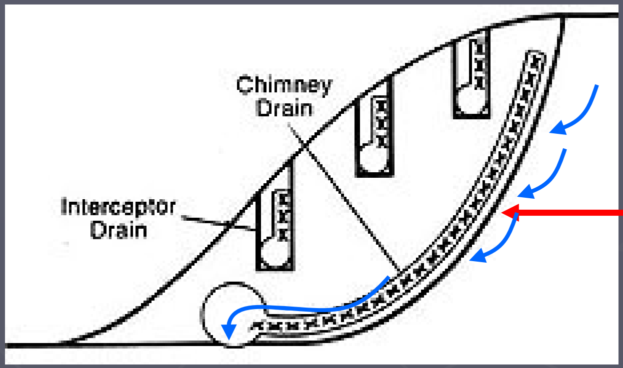
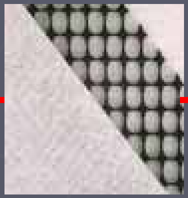
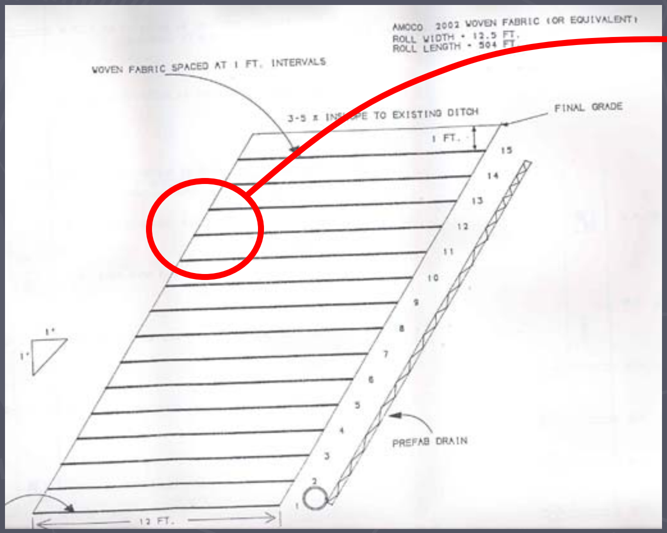
In-Plane Drainage

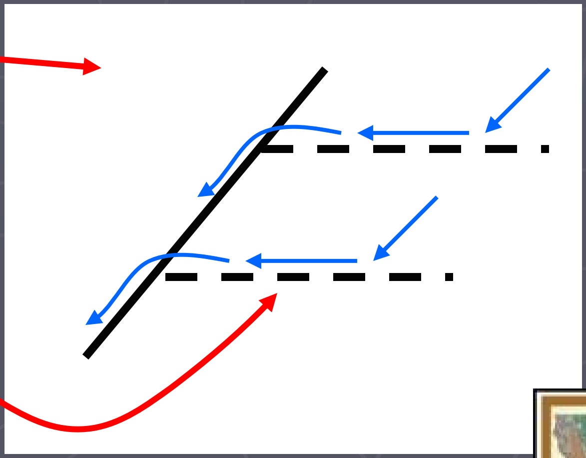




Geocomposite



Nonwoven



Reinforcement

- Geosynthetics increase soil shear resistance by increasing tensional and passive resistant forces.

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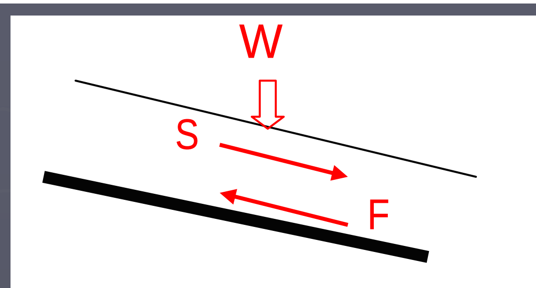
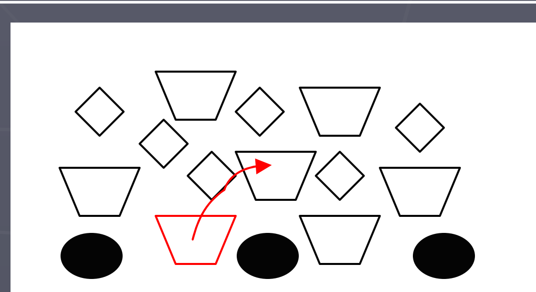
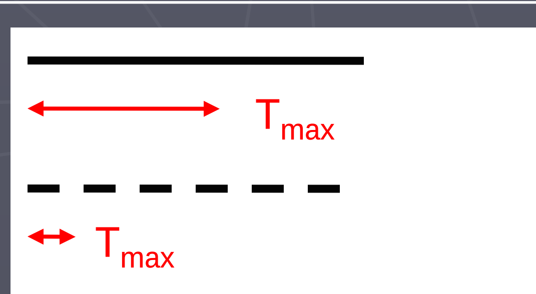
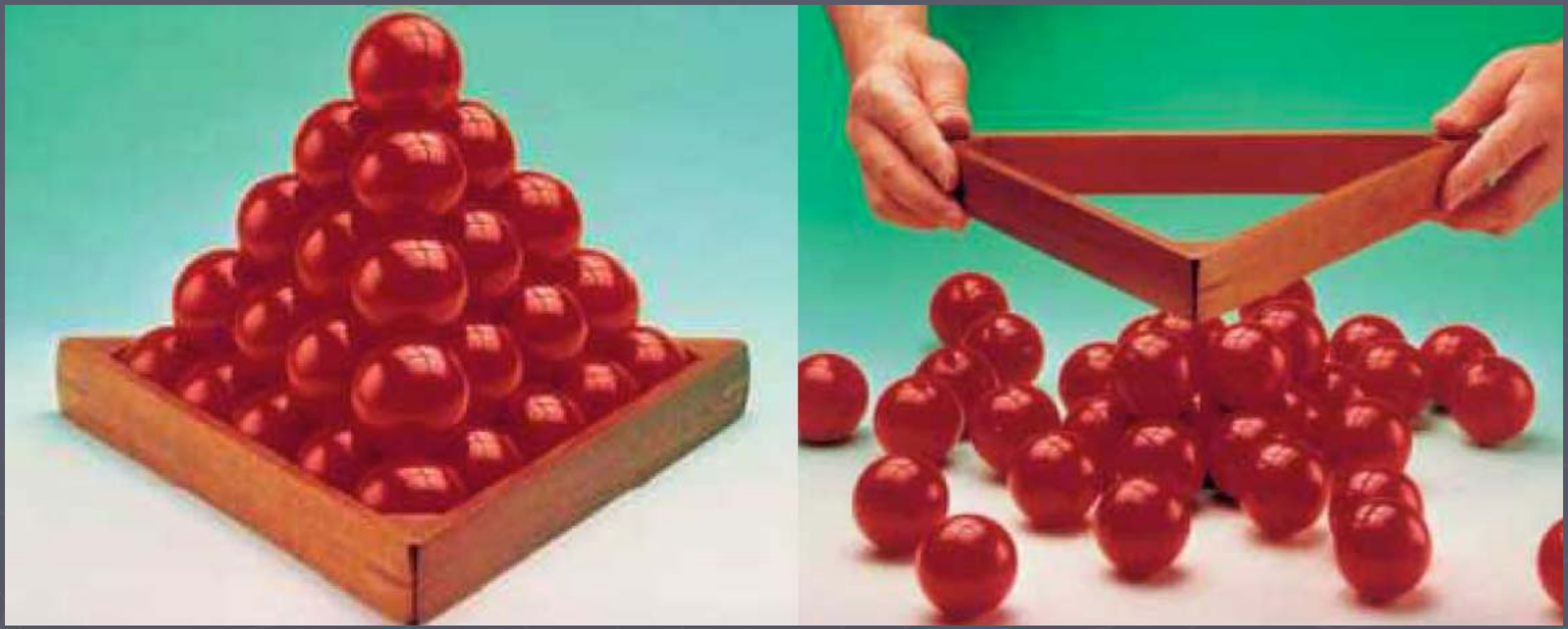
Mechanics of Reinforcement

		GEOGRID	GEOTEXTILE
Friction between geosynthetic and soil		HIGH	LOW
Confinement (Dilation)		HIGH	LOW to NA
Extensibility of geosynthetic		LOW	HIGH

Confinement:



Dr. Jie Han, PE

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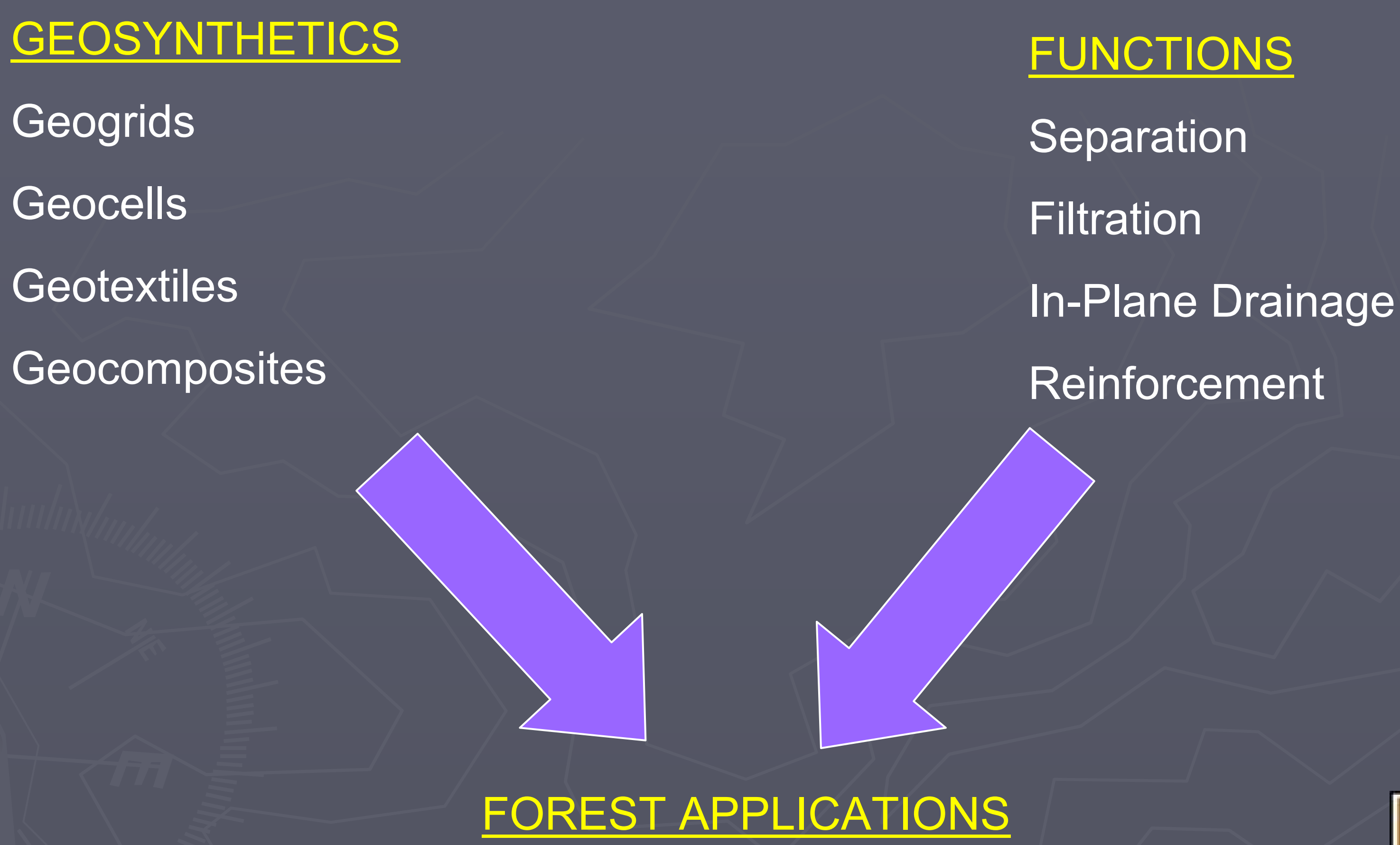
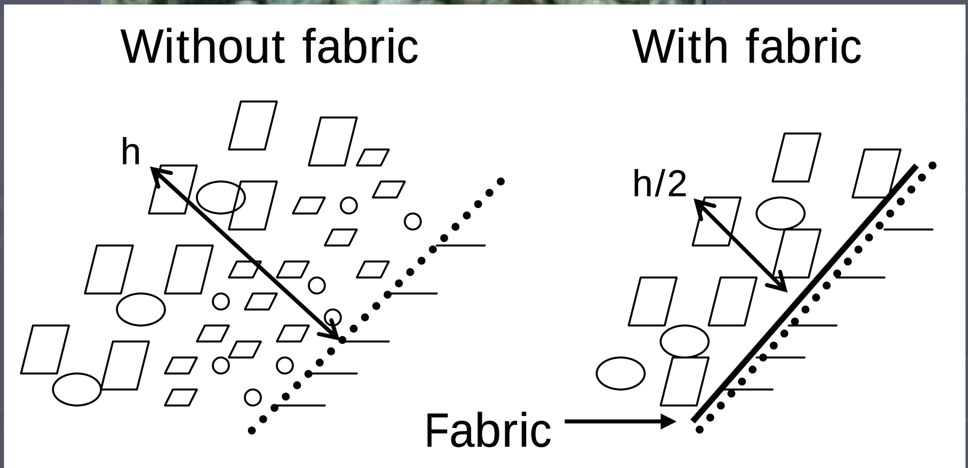

GEOSYNTHETICS
Geogrids
Geocells
Geotextiles
Geocomposites
FUNCTIONS
Separation
Filtration
In-Plane Drainage
Reinforcement
FOREST APPLICATIONS

Forest Applications

- Erosion Control Systems
- Soft Subgrade Reinforcement and Separation
- Subsurface Drainage
- Reinforced Slopes

Erosion Control Systems



- Used instead of graded granular materials in hard armor structures such as:
  - Beneath rock slope protection along stream channels and bridge abutments (separation, filtration)
  - Beneath armor stone on cut and fill slopes (separation, filtration)

Erosion Control Systems

Clarkin K. et. al., 2006 (USFS)

- Used as scour protection in low-water stream crossings (separation, reinforcement)

Geocell

Erosion Control Systems

Ed Rose, USFS

- Used to temporarily control and minimize erosion and sediment transport until vegetation can be established. Examples include:
  - Erosion control blankets and mats.

Erosion Control Systems

Advantages:

- Reduce the use of costly granular aggregate material.
- Expedite construction.
- Provide protection while promoting vegetation growth.

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Erosion Control Systems

Disadvantages:

- Additional time to place and workaround.
- Use of improper geosynthetic for the given function and site conditions (oversight).
- Improper installation (oversight).

Forest Applications

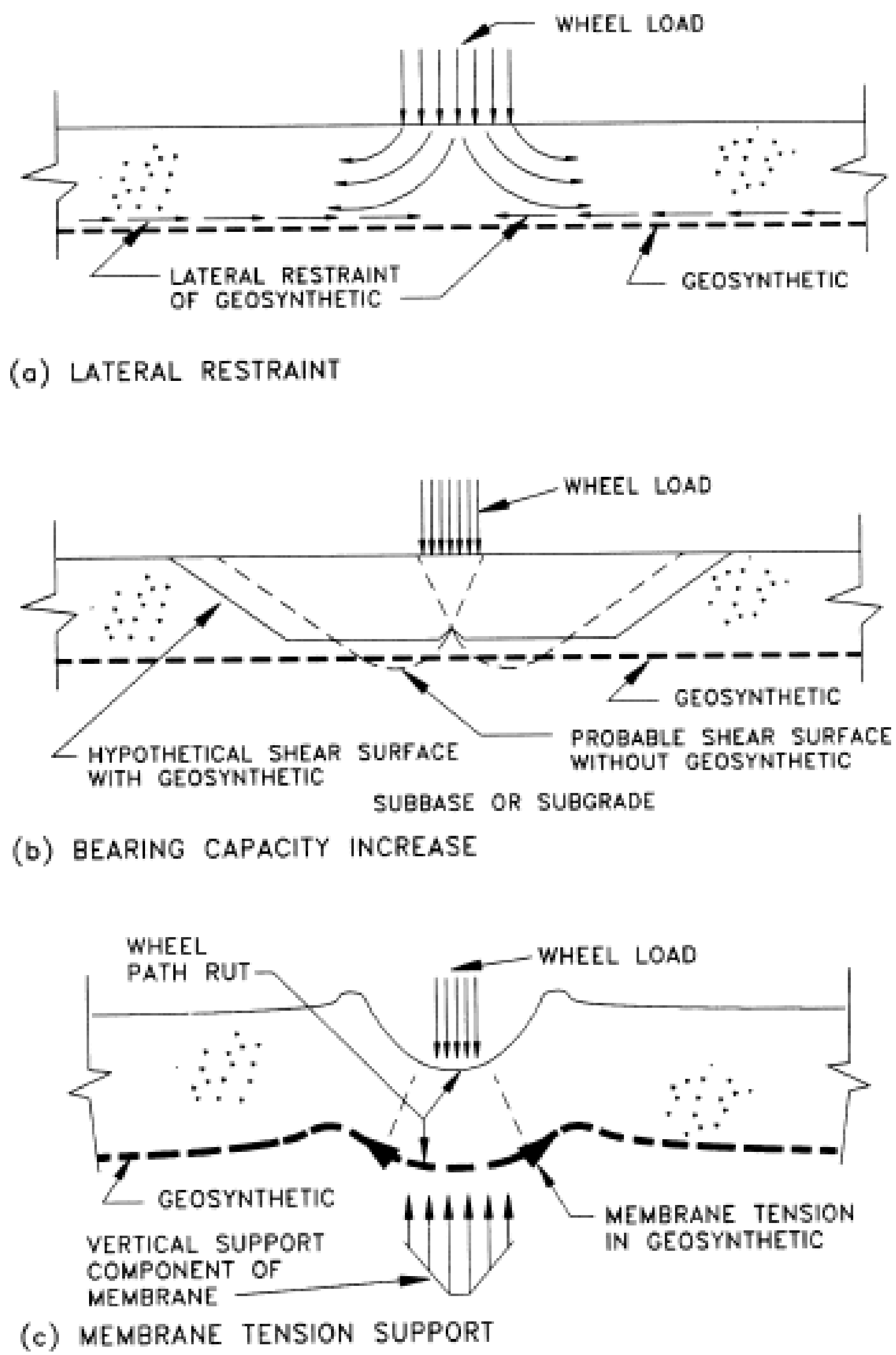
- Erosion Control Systems
- Soft Subgrade Reinforcement and Separation
- Subsurface Drainage
- Reinforced Slopes

Soft Subgrade Reinforcement and Separation

Geosynthetic Materials Association

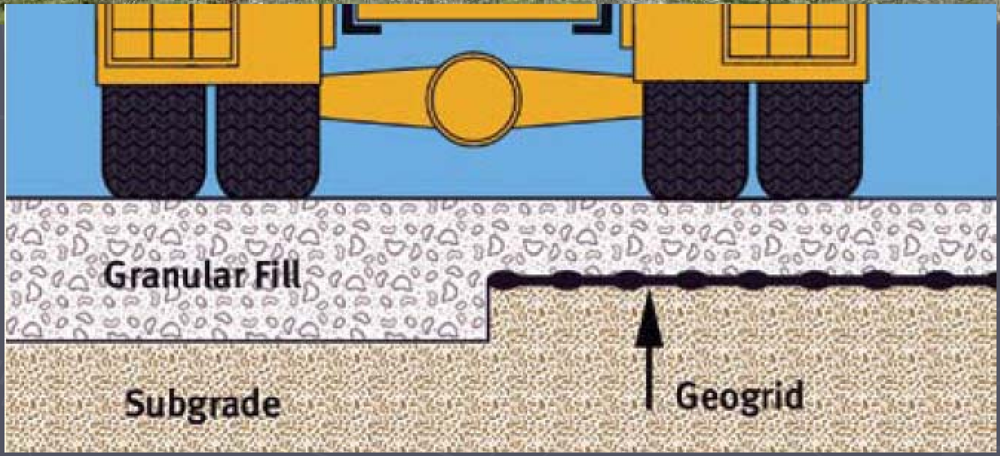
- The cost to rock roads can be substantially lowered when the road has a soft, yielding subgrade.
- Achieved by providing three functions:
  - Reinforcement
  - Separation
  - Filtration (less common)

Soft Subgrade Reinforcement



FHWA HI-95-038

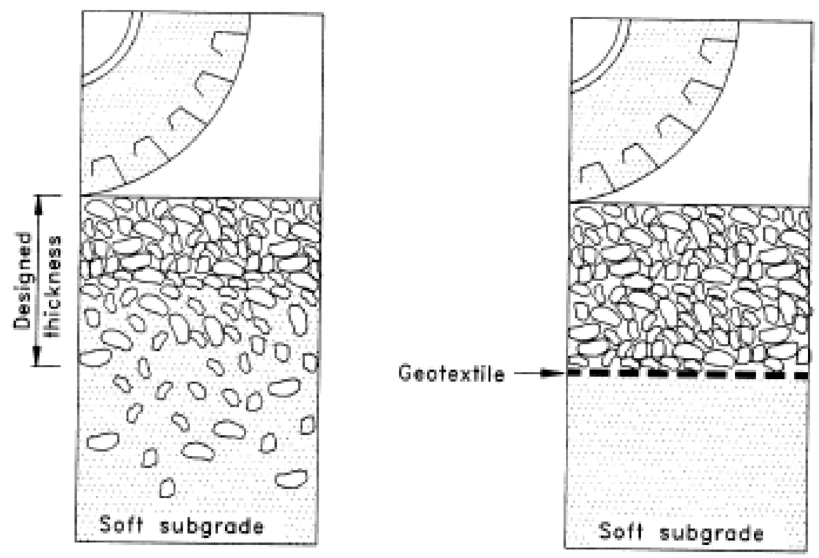
Soft Subgrade Reinforcement



Tensar BX1200 supports continued traffic of fully loaded trucks. This section is immediately behind failed section on previous photo that did not have BX1200 reinforcement.

Tensar

Soft Subgrade Separation



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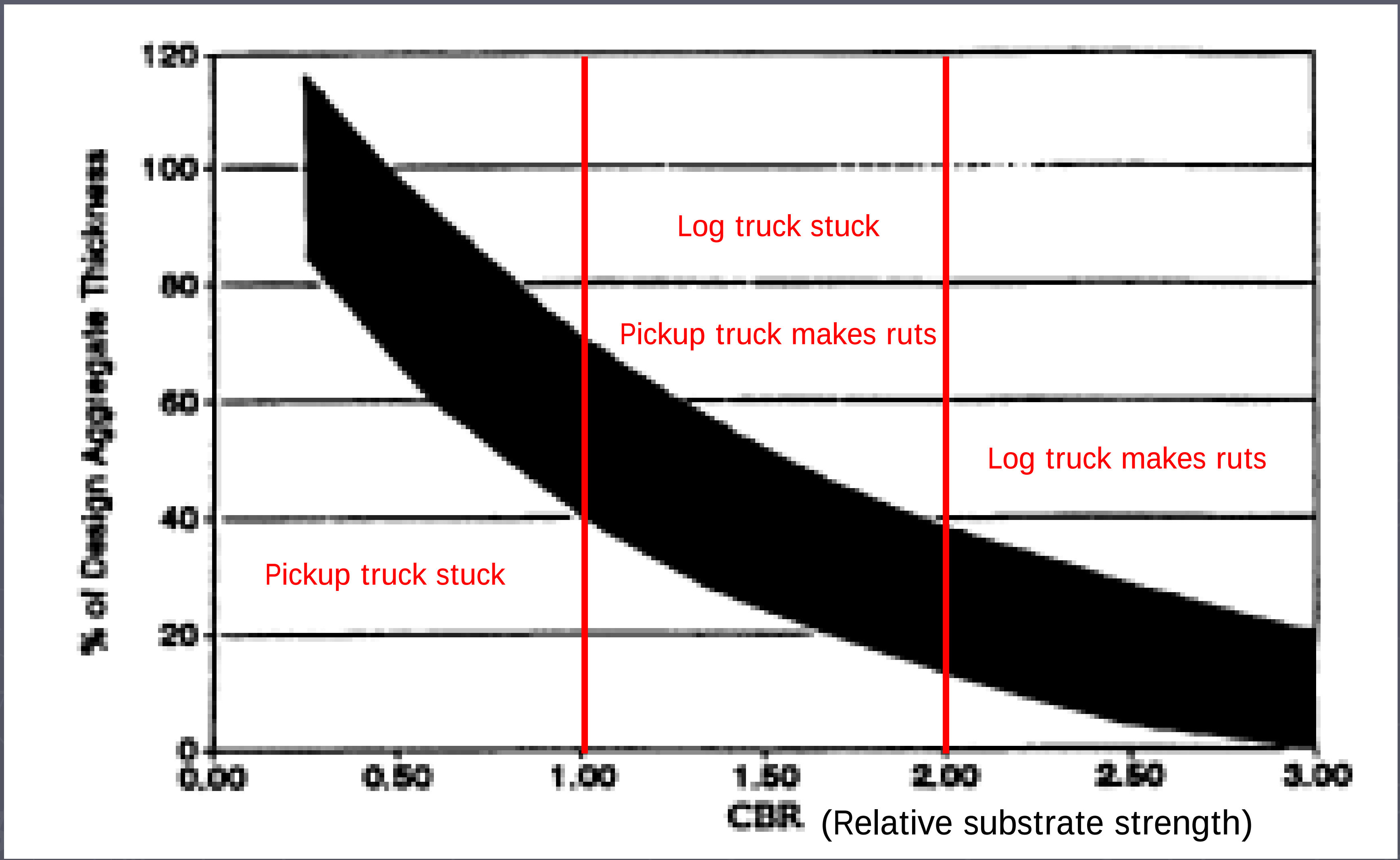
Tensar

Soft Subgrade Reinforcement and Separation



Aggregate lost to weak subgrades

FHWA HI-95-038

Soft Subgrade Reinforcement and Separation

Advantages:

- Reduces stresses in subgrade (reinforcement).
- Prevents contamination of surface rock (separation, filtration).
- Reduces excavation of unsuitable subgrade materials (separation, reinforcement).
- Reduces the thickness of aggregate required to stabilize the subgrade (separation, reinforcement).
- Aids in compaction of surface rock (separation, reinforcement, drainage).
- Reduces maintenance and extends the life of the road surface (filtration, separation, drainage, reinforcement).

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Soft Subgrade Reinforcement and Separation

Disadvantages:

- Price of geosynthetics? (about $3/ft. road).
- Use of improper geosynthetic for the given function and site conditions (specifications and/or oversight).

Forest Applications

- Erosion Control Systems
- Soft Subgrade Reinforcement and Separation
- Subsurface Drainage
- Reinforced Slopes

Subsurface Drainage

- Geosynthetics can be used as a replacement for, or in conjunction with, conventional graded granular filters.
- Examples:
  - Geocomposite drains
  - Wrapped aggregate drains (burrito drains, wrapped underdrains)

Geocomposite Drain

Ed Rose, USFS

Geocomposite Drain

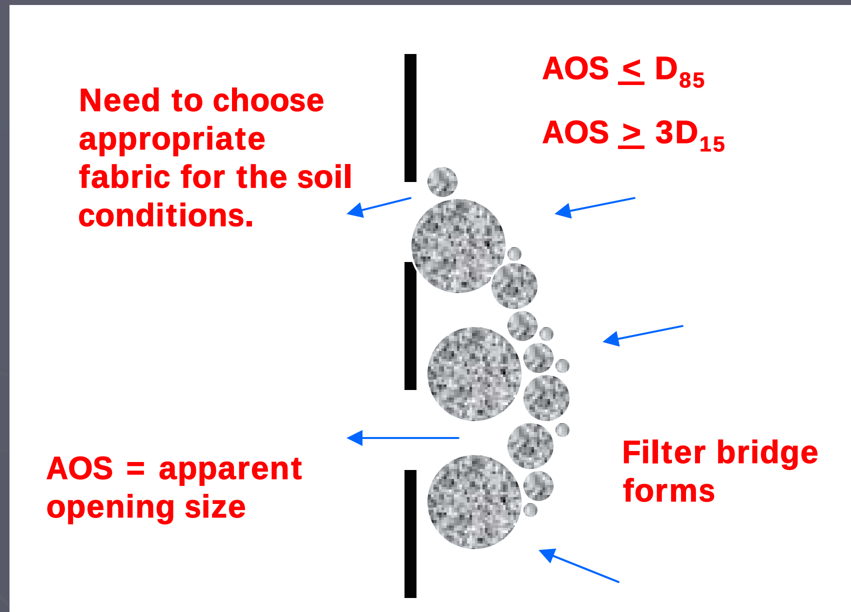
Ed Rose, USFS

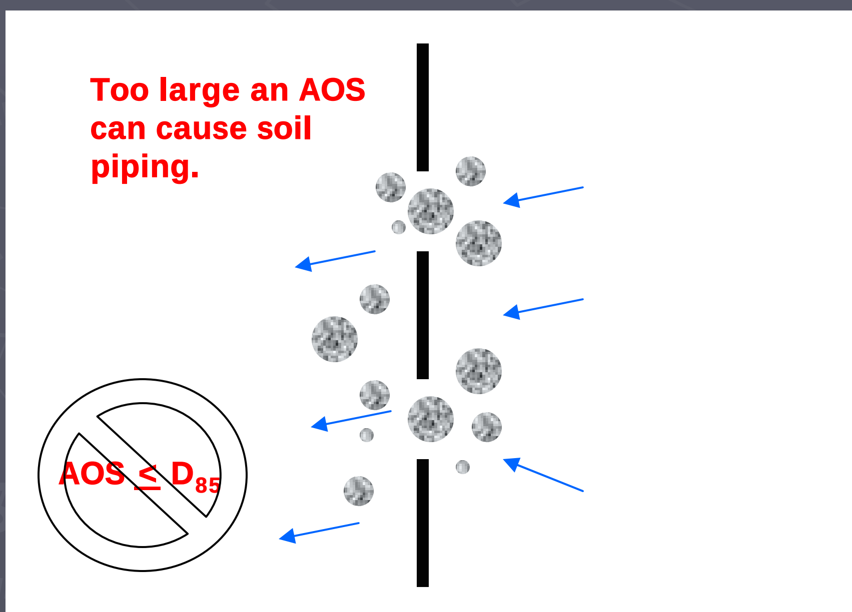
Wrapped Aggregate Drain

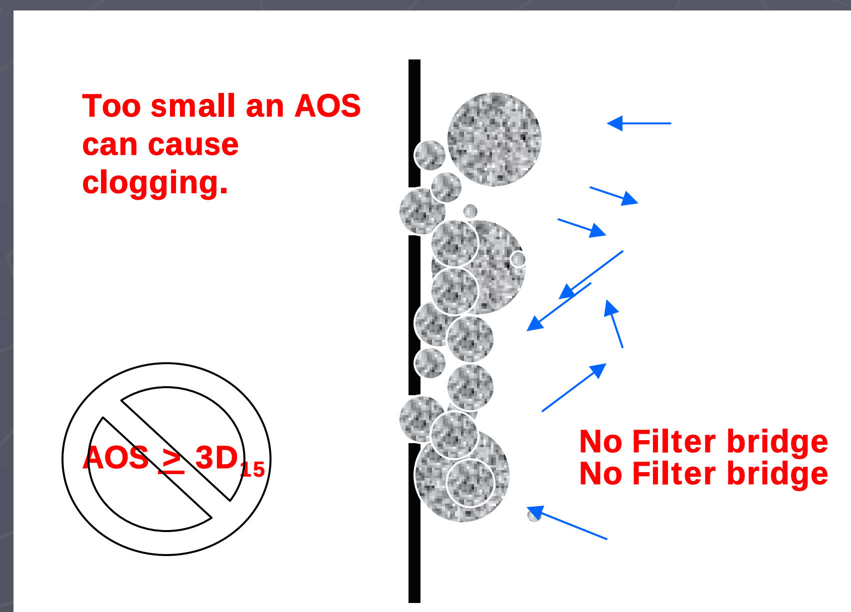
Ed Rose, USFS

Precautions to prevent damage from construction:

Precautions to prevent clogging:







Subsurface Drainage

Advantages:

- Prevents fines from contaminating the drain rock while allowing water to pass (filtration).
- Allows for the use of less-costly drainage aggregate (separation, filtration).
- Expedites construction.

Subsurface Drainage

Disadvantages:

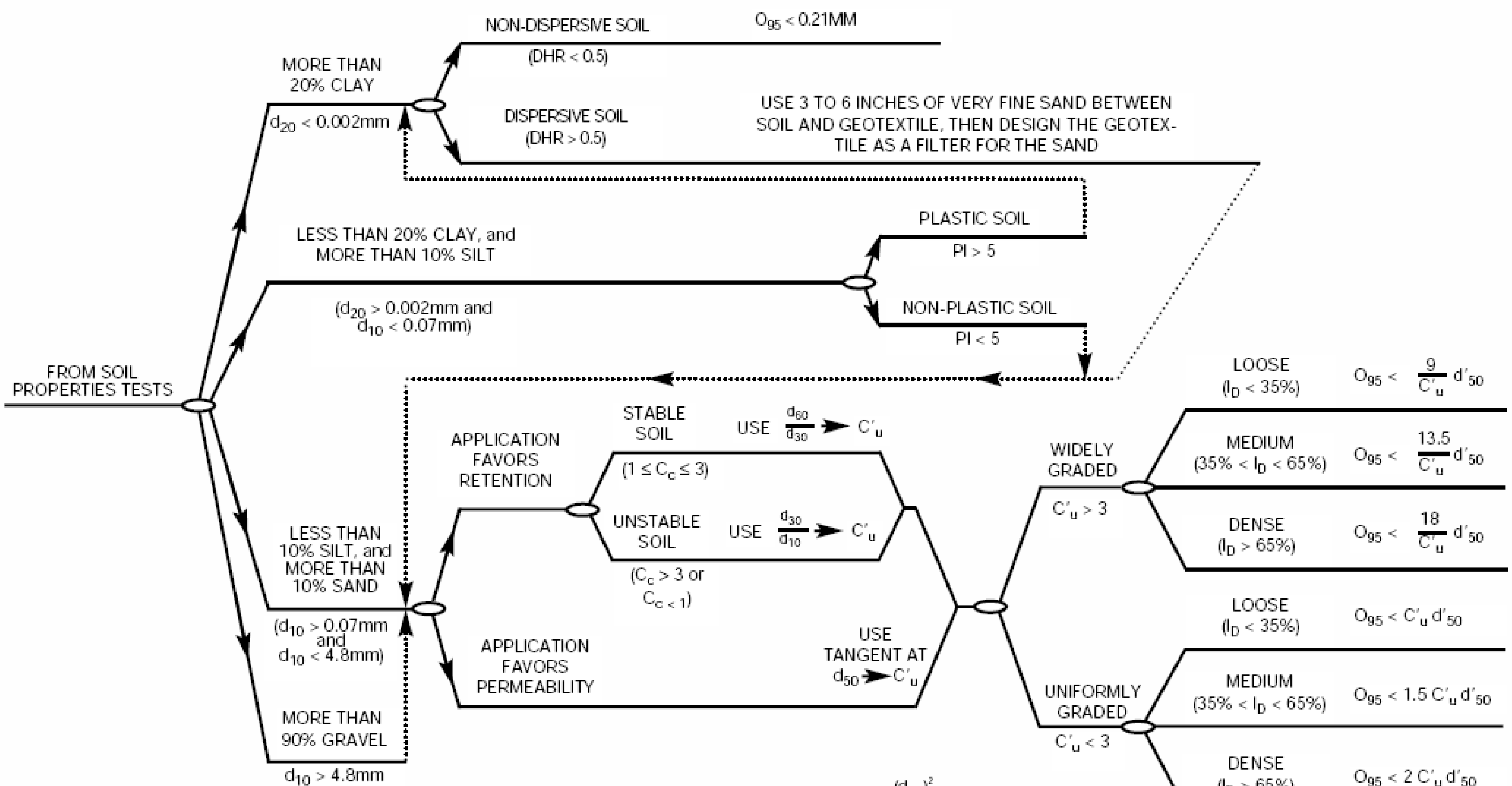
- Use of improper geosynthetic for the given function and site conditions (specifications and oversight).
- Poor installation.

Accepted Design Procedure

1. Evaluate the critical nature of the application.
2. Obtain soil samples and perform necessary tests (gradation, hydrometer, Atterberg limits).
3. Determine the dimensions of the drain system.
4. Determine geotextile hydraulic requirments (retention, flow, clogging).
5. Determine geotextile survivability requirements.
6. Prepare Specifications.
7. Monitor Installation.

Adapted from FHWA HI-95-038

Chart 1. Soil Retention Criteria of Steady-State Flow Conditions



NOTES:

d_x = particle diameter of which size *x* percent is smaller

$C'_u = \sqrt{\frac{d'_{100}}{d'_0}}$ 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

$$C_c = \frac{(d_{30})^2}{d_{60} \times d_{10}}$$

I_D = relative density of the soil
PI = plasticity index of the soil
DHR = double-hydrometer ratio of the soil
O_{95} = geotextile opening size

MIRAFI

geotextile filter design, application, and product selection guide

Table 3-1. Geotextile Filter Design Criteria.

Protected Soil (Percent Passing No. 200 Sieve)	Piping[1]	Permeability: Woven	Permeability: Nonwoven[2]
Less than 5%	AOS (mm) <0.6 (mm) (Greater than #30 US Standard Sieve)	POA[3] > 10%	$k_G > 5k_S$
5 to 50%	AOS (mm) < 0.6 (mm) (Greater than #30 US Standard Sieve)	POA > 4%	$k_G > 5k_S$
50 to 85%	AOS (mm) < 0.297 (mm) (Greater than #50 US Standard Sieve)	POA > 4%	$k_G > 5k_S$
Greater than 85%	AOS (mm) < 0.297 (mm) (Greater than #50 US Standard Sieve)		$k_G > 5k_S$

[1] When the protected soil contains appreciable quantities of material retained on the No. 4 sieve use only the soil passing the No. 4 sieve in selecting the AOS of the geotextile.

[2] k_G is the permeability of the nonwoven geotextile and k_S is the permeability of the protected soil.

[3] POA = Percent Open Area.

UFC 3-220-08FA
16 January 2004

UNIFIED FACILITIES CRITERIA (UFC)

ENGINEERING USE OF GEOTEXTILES

DEPARTMENT OF DEFENSE · UNITED STATES OF AMERICA

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Geofabric

NONWOVEN	WOVEN
High porosity + High permeability = High flow for longer.	High permeability but Percent open area (POS) is more prone to clogging.

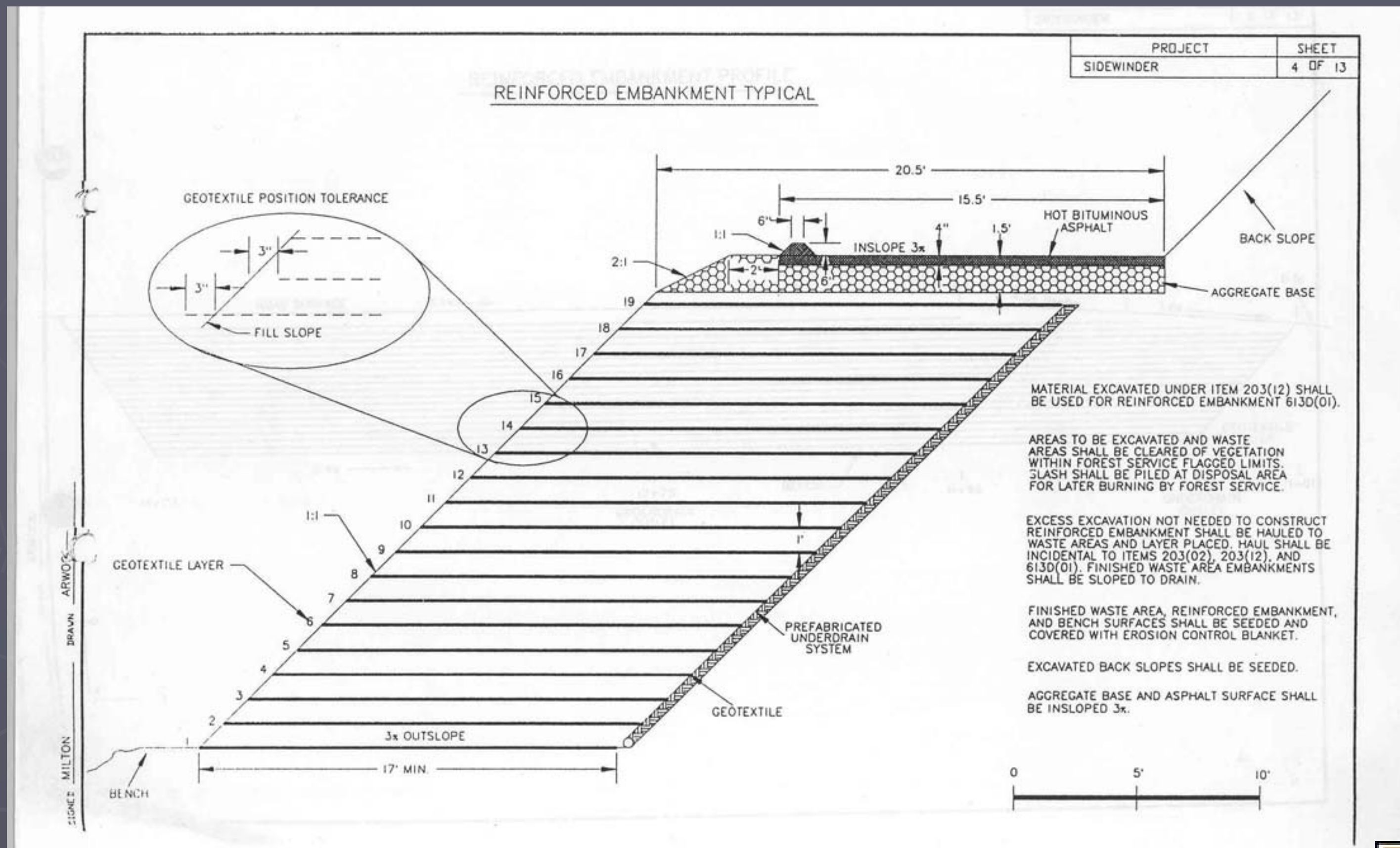
Forest Applications

- Erosion Control Systems
- Soft Subgrade Reinforcement and Separation
- Subsurface Drainage
- Reinforced Slopes…..Finally the good stuff!

Reinforced Slopes

- Geosynthetic-reinforced slopes allow the ability to construct slopes steeper than those constructed using more traditional means.
- Two common types of reinforcement:
  - Geogrid
  - Geotextile

Ed Rose, USFS



PROJECT
SHEET
SIDEWINDER
4 OF 13
REINFORCED EMBANKMENT TYPICAL
GEOTEXTILE POSITION TOLERANCE
3"
3"
FILL SLOPE
20.5'
15.5'
HOT BITUMINOUS ASPHALT
BACK SLOPE
1:1
6"
4"
1.5'
INSLOPE 3%
2:1
2"
6"
AGGREGATE BASE
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
1:1
1'
GEOTEXTILE LAYER
PREFABRICATED UNDERDRAIN SYSTEM
GEOTEXTILE
3% OUTSLOPE
17' MIN.
BENCH
MATERIAL EXCAVATED UNDER ITEM 203(12) SHALL BE USED FOR REINFORCED EMBANKMENT 613D(01).
AREAS TO BE EXCAVATED AND WASTE AREAS SHALL BE CLEARED OF VEGETATION WITHIN FOREST SERVICE FLAGGED LIMITS. SLASH SHALL BE PILED AT DISPOSAL AREA FOR LATER BURNING BY FOREST SERVICE.
EXCESS EXCAVATION NOT NEEDED TO CONSTRUCT REINFORCED EMBANKMENT SHALL BE HAULED TO WASTE AREAS AND LAYER PLACED. HAUL SHALL BE INCIDENTAL TO ITEMS 203(02), 203(12), AND 613D(01). FINISHED WASTE AREA EMBANKMENTS SHALL BE SLOPED TO DRAIN.
FINISHED WASTE AREA, REINFORCED EMBANKMENT, AND BENCH SURFACES SHALL BE SEEDED AND COVERED WITH EROSION CONTROL BLANKET.
EXCAVATED BACK SLOPES SHALL BE SEEDED.
AGGREGATE BASE AND ASPHALT SURFACE SHALL BE INSLOPED 3%.
0
5'
10'
ARWOOD
DRAWN
MILTON
SIGNED

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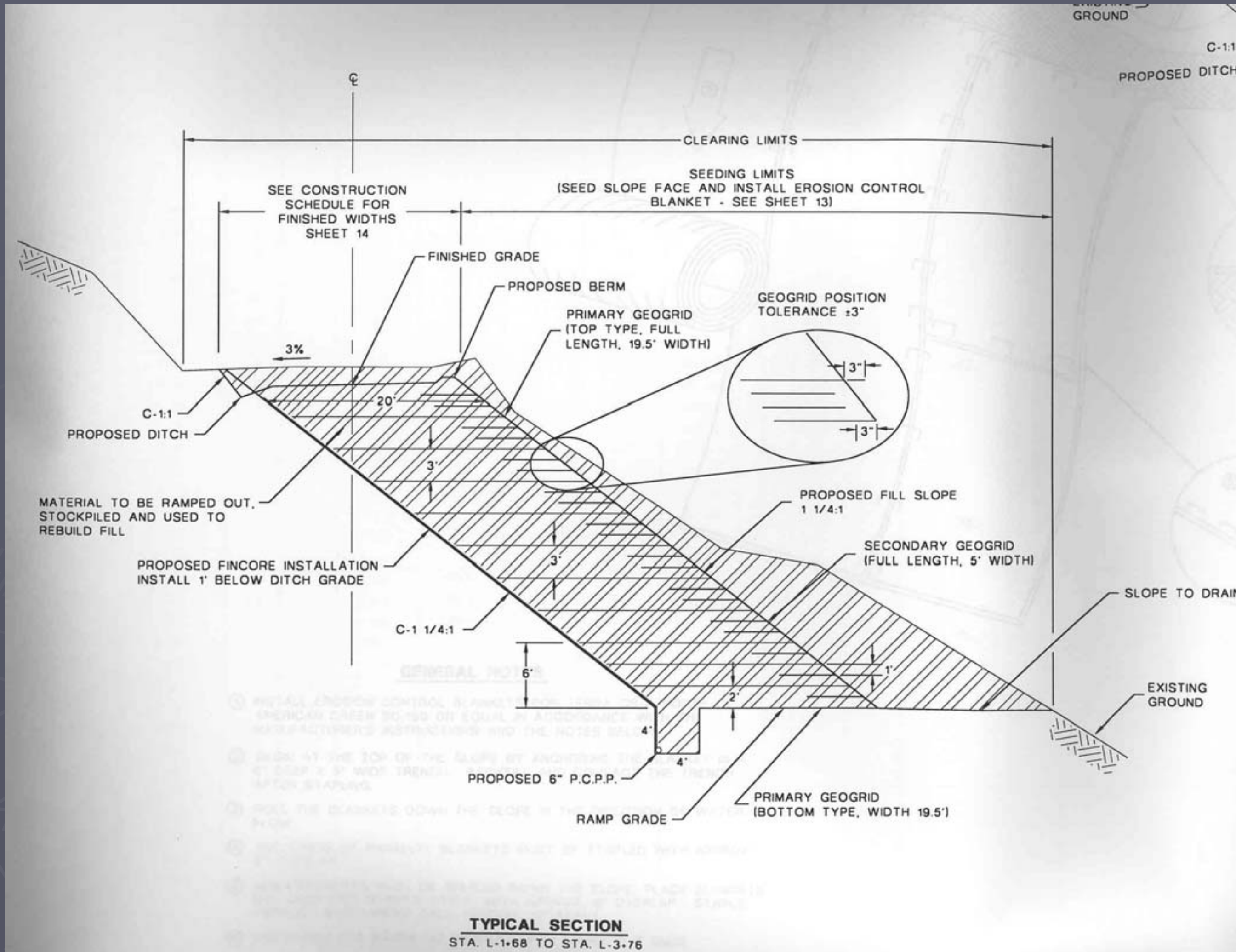

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Reinforced Slopes

Advantages:

- Allows for the use of on-site, native material rather then importing select material (reinforcement).
- Can eliminate the need for buttress elements such as rip-rap, k-rails, etc. (reinforcement).
- Reduces the area and volume of fills (reinforcement).
- Aids in compaction during construction (separation, reinforcement, drainage).
- Can stabilize large landslides by unloading the head, reinforcing the toe, and providing internal drainage (separation, reinforcement, drainage).

Reinforced Slopes

Disadvantages:

- Consultant fees for design.
- Use of improper geosynthetic for the given function and site conditions.
- Requires more complex construction techniques (keying, benching) and more stringent construction specifications (moisture conditioning, compaction).

Accepted Design Procedure

1. Address cause of original failure.
2. Establish the geometric, loading, and performance requirements for design.
3. Determine the subsurface stratigraphy and the engineering properties of the natural soils.
4. Determine the engineering properties of the available fill soils.
5. Establish design parameters for the reinforcement (design reinforcement strength, durability criteria, soil-reinforcement interaction).
6. Determine the factor of safety of the unreinforced slope.
7. Design reinforcement to provide stable slope.
8. Check external stability.
9. Evaluate requirements for subsurface and surface water control.

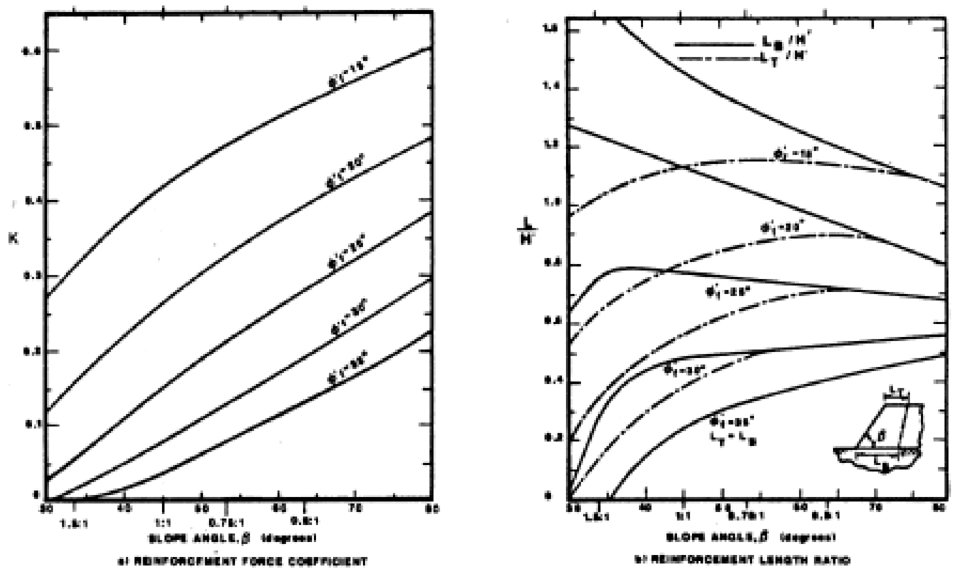


CHART PROCEDURE:

1) Determine force coefficient K from figure above, where ϕ_r = friction angle of reinforced fill:

$$\phi_f = \tan^{-1}\left(\frac{\tan \phi_r}{FS_R}\right)$$

2) Determine:

$$T_{S\text{-}MAX} = 0.5\, K\, \gamma_r\, (H')^2$$

where: $H' = H + q/\gamma_r$
q = a uniform load

3) Determine the required reinforcement length at the top L_T and bottom L_B of the slope from the figure above.

LIMITING ASSUMPTIONS

- Extensible reinforcement.
- Slopes constructed with uniform, cohesionless soil, c = 0).
- No pore pressures within slope.
- Competent, level foundation soils.
- No seismic forces.
- Uniform surcharge nor greater than $0.2\, \gamma_r\, H$.
- Relatively high soil/reinforcement interface friction angle, $\phi_{sg} = 0.9\, \phi_r$ (may not be appropriate for some geotextiles).

Figure 8-6 Sliding wedge approach to determine the coefficient of earth pressure K (after Schmertmann, et al., 1987).

NOTE: Charts © The Tensar Corporation.

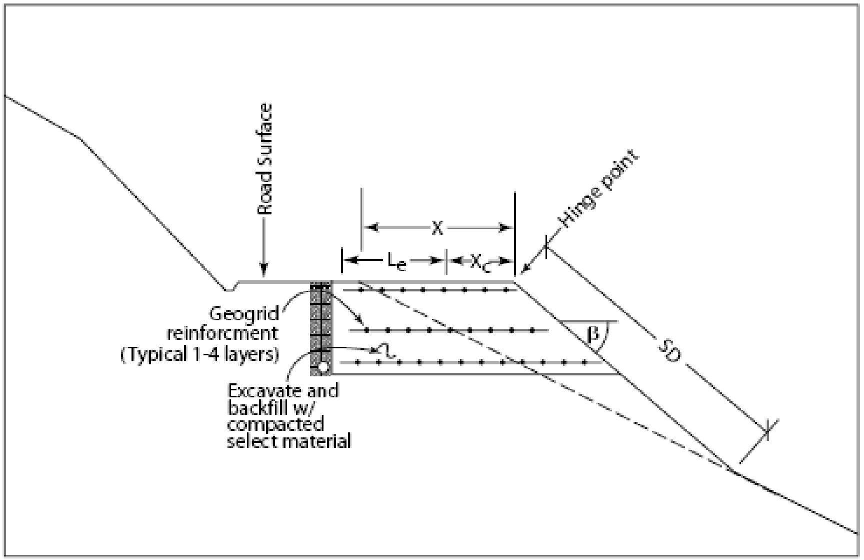
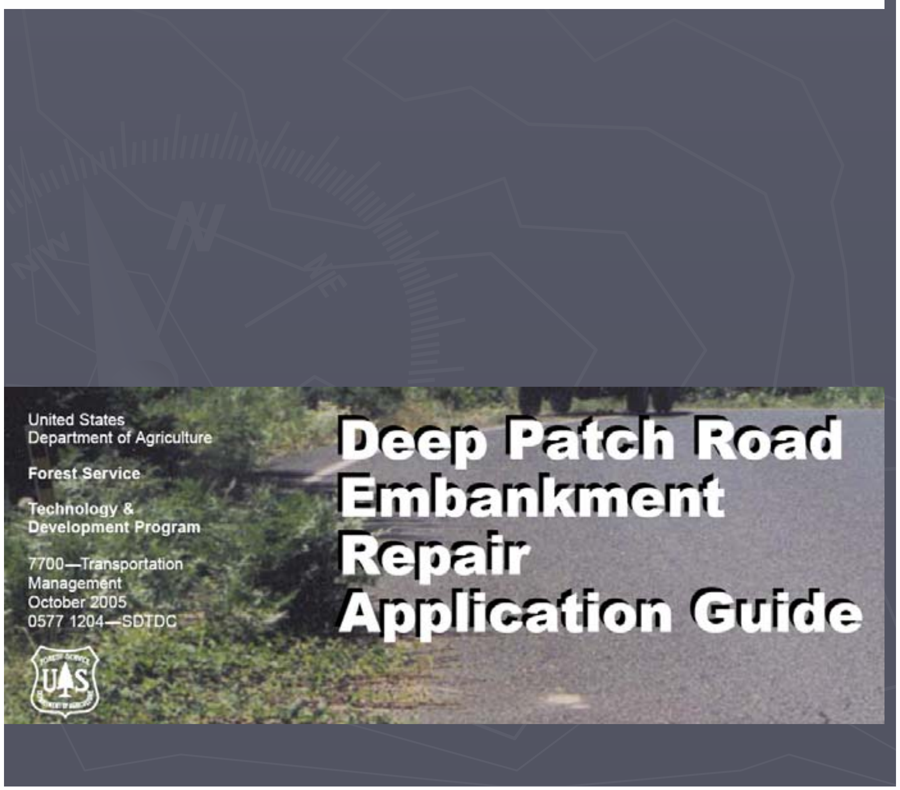


Figure 3—Cross section of typical deep patch road embankment repair.



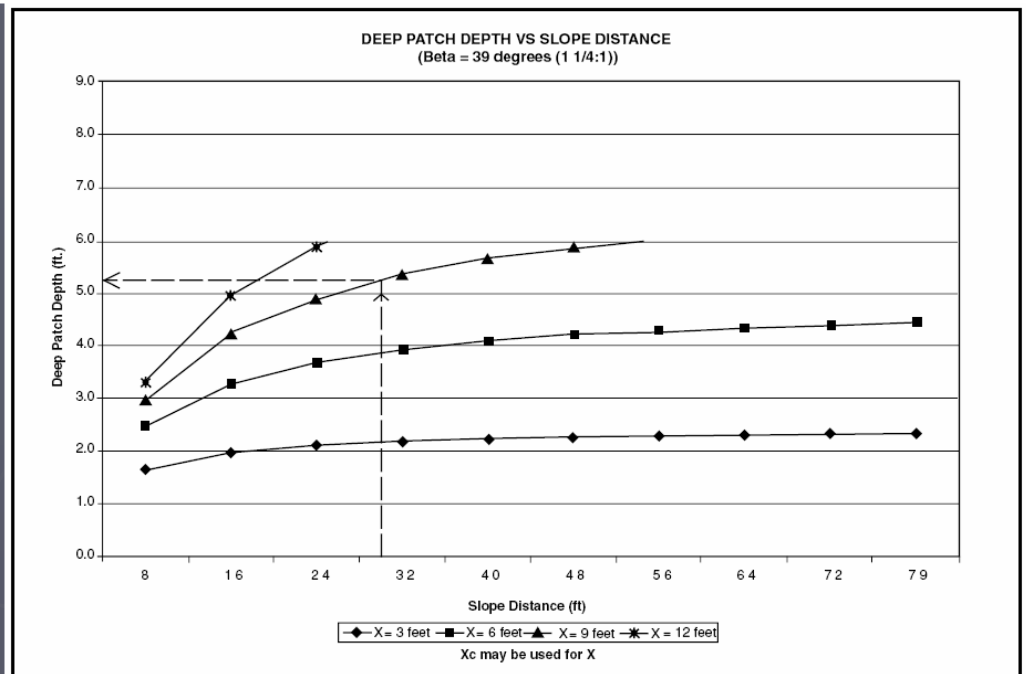


Figure 14—Deep patch depth vs. slope distance.

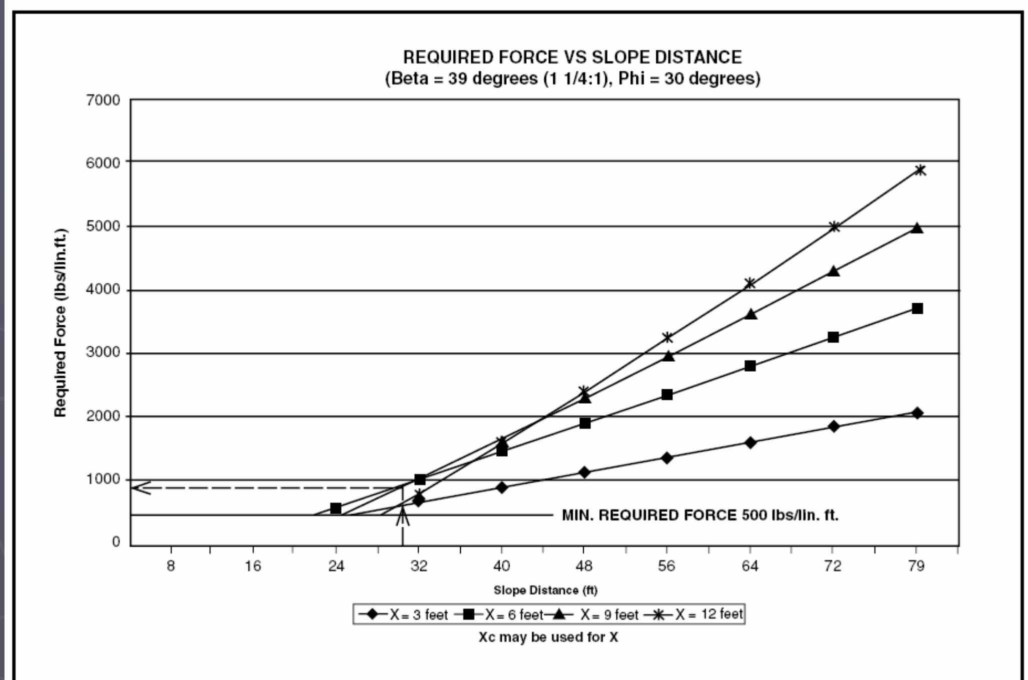
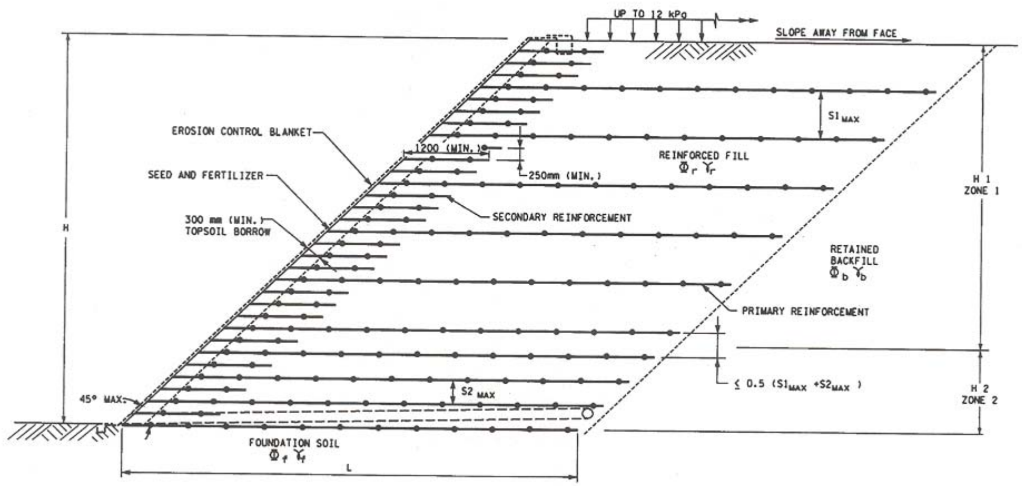


Figure 15—Required force vs. slope distance.



TYPICAL SECTION
CASE 1a & 1b

REINFORCED SOIL SLOPES

CASE 1a - 45° Maximum Slope Angle, Granular Borrow Reinforced Soil Fill

Max. Slope Angle (degrees)	Reinforced Soil Fill Friction Angle (degrees)	Minimum Reinforcement Length, L (m)	Primary Soil Reinforcement		Maximum Slope Height (m)	Zone 1		Zone 2	
			Type	Long Term Strength (T_{al}) (kN/m)		H1 (m)	$S1_{max}$ (m)	H2 (m)	$S2_{max}$ (m)
45	30	1.1 H	Type I	10	8.0	3.5	1.0	4.5	0.5
					8.0	8.0	0.6	-	-
			Type II	15	8.0	6.5	1.0	1.5	0.5
					8.0	5.4	1.2	2.6	0.6
			Type III	20	8.0	8.0	1.2	-	-

CASE 1b - 45° Maximum Slope Angle, Modified Select Granular Borrow Reinforced Soil Fill

Max. Slope Angle (degrees)	Reinforced Soil Fill Friction Angle (degrees)	Minimum Reinforcement Length, L (m)	Primary Soil Reinforcement		Maximum Slope Height (m)	Zone 1		Zone 2	
			Type	Long Term Strength (T_{al}) (kN/m)		H1 (m)	$S1_{max}$ (m)	H2 (m)	$S2_{max}$ (m)
45	35	0.8 H	Type I	10	8.0	8.0	1.0	-	-
					8.0	5.4	1.2	2.6	0.6
			Type II	15	8.0	8.0	1.2	-	-
			Type III	20	8.0	8.0	1.2	-	-

NOTE:
SECONDARY REINFORCEMENT SHALL HAVE A MINIMUM LONG TERM STRENGTH OF 6 kN/m.

FHWA HI-00-043

Challenges of Simplified Design

- Assessment of on-site materials.
- Assessment of Global Stability.
- Accountability that the work was performed as designed. Needs oversight by designer or designee.
- Evaluating the appropriateness of the proposed repairs.

Developing Soil Strengths

UNIFIED SOIL CLASSIFICATION AND SYMBOL CHART		
COARSE-GRAINED SOILS (more than 50% of material is larger than No. 200 sieve size.)		
	Clean Gravels (Less than 5% fines)	
GRAVELS More than 50% of coarse fraction larger than No. 4 sieve size	GW	Well-graded gravels, gravel-sand mixtures, little or no fines
	GP	Poorly-graded gravels, gravel-sand mixtures, little or no fines
	Gravels with fines (More than 12% fines)	
	GM	Silty gravels, gravel-sand-silt mixtures
	GC	Clayey gravels, gravel-sand-clay mixtures
	Clean Sands (Less than 5% fines)	
SANDS 50% or more of coarse fraction smaller than No. 4 sieve size	SW	Well-graded sands, gravelly sands, little or no fines
	SP	Poorly graded sands, gravelly sands, little or no fines
	Sands with fines (More than 12% fines)	
	SM	Silty sands, sand-silt mixtures
	SC	Clayey sands, sand-clay mixtures
FINE-GRAINED SOILS (50% or more of material is smaller than No. 200 sieve size.)		
SILTS AND CLAYS Liquid limit less than 50%	ML	Inorganic silts and very fine sands, rock flour, silty of clayey fine sands or clayey silts with slight plasticity
	CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
	OL	Organic silts and organic silty clays of low plasticity
SILTS AND CLAYS Liquid limit 50% or greater	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts
	CH	Inorganic clays of high plasticity, fat clays
	OH	Organic clays of medium to high plasticity, organic silts
HIGHLY ORGANIC SOILS	PT	Peat and other highly organic soils

LABORATORY CLASSIFICATION CRITERIA		
GW	$C_u = \frac{D_{60}}{D_{10}}$ greater than 4; $C_c = \frac{D_{30}}{D_{10} \times D_{60}}$ between 1 and 3	
GP	Not meeting all gradation requirements for GW	
GM	Atterberg limits below "A" line or P.I. less than 4	Above "A" line with P.I. between 4 and 7 are borderline cases requiring use of dual symbols
GC	Atterberg limits above "A" line with P.I. greater than 7	
SW	$C_u = \frac{D_{60}}{D_{10}}$ greater than 4; $C_c = \frac{D_{30}}{D_{10} \times D_{60}}$ between 1 and 3	
SP	Not meeting all gradation requirements for GW	
SM	Atterberg limits below "A" line or P.I. less than 4	Limits plotting in shaded zone with P.I. between 4 and 7 are borderline cases requiring use of dual symbols.
SC	Atterberg limits above "A" line with P.I. greater than 7	

Determine percentages of sand and gravel from grain-size curve. Depending on percentage of fines (fraction smaller than No. 200 sieve size), coarse-grained soils are classified as follows:

Less than 5 percent ---------------- GW, GP, SW, SP
More than 12 percent ---------------- GM, GC, SM, SC
5 to 12 percent ---------------- Borderline cases requiring dual symbols

PLASTICITY CHART

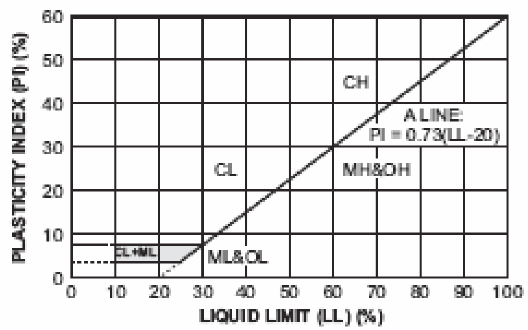


Table 5.5—Reported values of γ_d, C'_s and ϕ' for silts, sands, and gravels

USC	% D_r	γ_d, pcf	C'_s, psf	ϕ', deg.
GW loose				
	0–35	*[3]	0	35–38
	"	118–128	0	28–33.5
	0	98–111	0	36.3–39.3
GW medium-dense				
	35–65	*	0	38–41
	"	128–135	0	33.5–38.5
	58	127	0	38.4–39
GW dense to very dense				
	65–100	*	0	41–45
	"	135–145	0	38.5–45
	"	125–135	0	> 38
	*	119.5–137	0	39–46
	70	123–125.4	790-1140	38.0-41.4
GP loose				
	0–35	*	0	33–36
	"	108–118	0	27.5–32.5
GP medium-dense				
	35–65	*	0	36–39
	"	118–124	0	32.5–37
	50	117–122	288–432	38.7–40.4
GP dense to very dense				
	65–100	*	0	39–43
	"	124–134	0	37–42.5
	"	115–125	0	> 37
	*	111–124	0	38–42
	70	126.5	432	40.4
	90	129.1	432	44.4
GM loose				
	0–35	*	0	33–36
	0	114	*	*
	*	51.5–91	104–200	33.6–43

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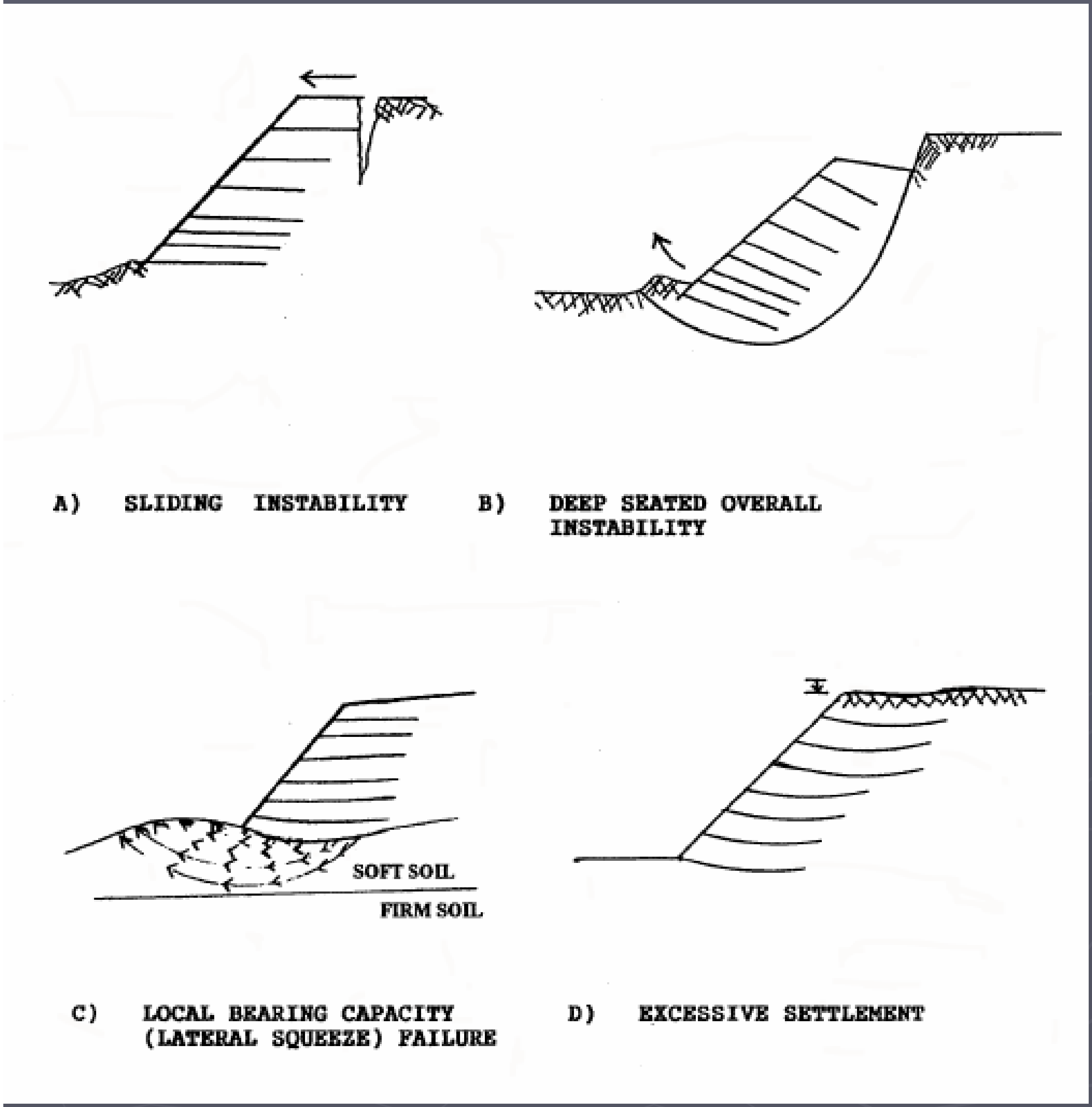
TRA#1	USCS
Sand =	SW-SP
Sandy loam =	SC-SM
Loam =	SC-SM
Silt loam =	ML
Clay loam =	CL-ML
Clay =	CL-CH

Global Stability Issues



FHWA HI-00-043

Summary

- Erosion Control Systems
  - Training.
  - Easy access to available information.

- Soft Subgrade Reinforcement and Separation
  - Training.
  - Easy access to available information.

Summary

- Subsurface Drainage
  - Training.
  - Easy access to available information.
  - Simplified design guidelines.
- Reinforced Slopes
  - Training.
  - Easy access to available information.
  - Simplified design guidelines.

QUESTIONS?