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A SIMPLIFIED DESIGN METHOD FOR SILT FENCES

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INTRODUCTION

Many States are currently developing very simplified design standards for silt fences, such simplified guidelines are the result of use restrictions resulting from new and more rigorous State sedimentation control regulations, and of past silt fence failures. Such operational failures of silt fences are clear indicators that such systems are not engineered nor properly maintained. The simplified design method presented here incorporates significant usage limitations on silt fence systems to greatly simplify traditional surface water runoff and erosion calculations. The resulting engineered silt fence designs are conservative in function, yet provide very economical sedimentation control structures due to the inexpensive nature of geosynthetic silt fences.

APPLICATION RESTRICTIONS

The most common application of silt fences is to control sediment flow leaving new construction sites. As such, the simplified design method for silt fences developed here assumes that the design life of the silt fence is less than 6 months and that the ground surface tributary to the silt fence remains unvegetated during this time interval. Guidelines are also presented for silt fences having a longer design life but all nomographs included in this paper are intended for short-term, new construction applications.

Silt fences must also be limited to applications where the erosion occurs in the form of sheet erosion and where there is no concentration of water flowing to the barrier. To ensure such conditions, the flow velocity of the water reaching the silt fence must be less than 1 ft/sec. The flow velocity of surface water is a function of the slope steepness, slope length, and smoothness of the grounds surface. Making the conservative assumption that the ground surface is smooth, the flow velocity of surface water can be limited by reducing the allowable slope length as the inclination of the slope increases as given in Table 1.

TABLE 1

Slope Steepness vs. Slope Length

Slope Steepness	Maximum Slope Length, ft.
<2%	100 ft.
2-5%	75 ft.
5-10%	50 ft.
10-20%	25 ft.
>20%	15 ft.

This limits the drainage area for overland flow to a silt fence to less than 1/4 acre per 100 feet of fence. Greater slope lengths can be used if nonerosional outlets are provided as part of the silt fence barrier. Such outlets, however, indicate a sophistication of design not associated with the simple applications covered by this paper.

Additional limitations may be placed on the geometry of geosynthetic silt fences by State sediment control regulations. For instance, the height of the silt fence is limited to 18-inches in North Carolina and 36-inches in Georgia. Such height restrictions limit the sediment storage capacity behind the fence and result in the need for additional parallel rows of silt fencing.

ESTIMATING RUNOFF VOLUME

The silt fence system must be designed to provide a containment volume greater than the anticipated volume of runoff water. If this cannot be accomplished, then the silt fences must incorporate nonerosional outlets to allow controlled over topping of the fence. The calculation of runoff volumes for the small watershed areas appropriate for silt fence applications is best performed using the Rational Method given as follows:

$$Q = CiA \qquad \text{Eq. 1}$$

where

Q = runoff, cubic feet per second
C = surface runoff coefficient
i = rainfall intensity, inch/hour
A = area, acres

While the English units of the variables do not appear to match, the conversion from acre-inch/hour to cubic feet per second is approximately unity and can be omitted. The silt fence system must be designed to have sufficient containment volume to hold the total runoff volume of the design storm.

The runoff coefficient C represents the land use of the drainage field. Under the assumption that the silt fence is being used at new construction sites, it is assumed that the runoff field is bare soils. For silt fences having a design life of less than 6 months this is appropriate. The value of C for bare packed soils ranges from 0.6 for a smooth surface to 0.2 for a rough surface. Thus, a conservative estimate of the weighted value of C is assumed to be 0.5. For longer design lives, this may be reduced if seeding is performed during the first 6 months.

Rainfall intensity, i, reflects both the regional rainfall history and the assumed return period of the design storm. The design return period of the storm is typically defined by State regulations and is commonly a 10-year storm. Figure 1 provides a map of 10-year rainfalls appropriate for use in designing silt fences. Note that the variation in rainfall intensity within many states is so small that a single rainfall intensity could be used, resulting in even more simplification of the design process. It should also be noted that, in the rigorous application of the rational method, the rainfall intensity is adjusted based on the time of concentration, T_c, for the drainage field. This is defined as the time it takes the farthest overland flow to reach the silt fence. For the small drainage fields associated with the silt fences, the value of T_c is small enough that the full rainfall intensity from Figure 1 must be assumed in design.

Making the above assumptions in Equation 1 results in the following expression for the total storage volume required of the silt fence:

$$\text{Volume (acre-inch)} = 0.5 \, i \, A \qquad \text{Eq. 2}$$

Where i is the rainfall intensity in inches obtained from Figure 1 and A is the area of the drainage field in acres. This can also be express wholly in terms of feet as follows:

$$\text{Volume (cubic feet)} = 0.04 \, i \, A \qquad \text{Eq. 3}$$

Where the drainage field area, A, is now expressed in square feet.

ESTIMATING SEDIMENT VOLUME

The volume of sediment removed by rainfall during the 6-month design life of the silt fences can be estimated using the Soil Conversation Service's Universal Soil Loss Equation (USLE). The USLE is expressed as follows:

$$A = RKLSCP \qquad \text{Eq. 4}$$

Where

A = Soil Loss (Tons/Acre/Year)
R = Rainfall Erosion Index
K = Soil Erodibility Factor
LS = Slope length and steepness factor
C = Vegetative cover factor
P = Erosion control practice factor.

For new construction sites, this equation can be simplified by assuming no vegetative cover (C = 1) and minimal erosion control practices (P = 1).

The rainfall erosion index can be obtained from Figure 2. As with rainfall intensity, note that it would be possible to assign a single design value of R within many States. Additionally, the use of Figure 2 for those regions west of the 104° latitude is not recommended.

Due to the limited slop lengths and steepness factors applicable to slit fence applications, it is possible to greatly simplify the empirical solution for LS and at the same time integrate the soil erodibility factor, K. The resulting relationship is shown on Figure 3. Thus, it is possible to readily obtain the product KLS knowing only the average slope angle and general soil classification.

Solution of Equation 4 results in an estimate of the tons of sediment per acre of drainage field served per year. Use of this full estimated <u>annual</u> sediment tonnage for the 6 month slit fence provides a reasonable safety factor to prevent the sediment volume from exceeding the storage volume of the fence. The annual soil loss tonnage can be converted into a design volume by assuming that the sediments have a unit weight of 50 pounds per cubic foot.

CONSTRUCTION CONSIDERATIONS

The geotextile used in the construction of a silt fence must be sufficiently strong so that it will not burst under the load applied by the pooled water and sediments. This minimum strength is a function of the height of impoundment and the spacing of the posts supporting the fence. Figure 4 shows the required geotextile tensile strength for a range of impoundment heights and post spacings. Generally, the use of geotextiles alone is restricted to impoundment depths less than 24 inches and with post spacings less than 4 feet. Silt fences exceeding these limitations should incorporate a woven wire reinforcement (14 gauge, maximum 6-inch mesh spacing) to prevent burst failure of the geotextile. The physical demands on the fence posts also increase with increasing fence height and post spacing as shown on Figure 5. In general, post related problems are not encountered if the fence height is less than 24-inches, the post spacing is 4-feet, and the minimum post embedment depth is 16 inches.

General construction guidelines for silt fences are as follows:

1. Silt Fence Fabric: The geotextile shall meet the minimum specifications as defined by TF25 as follows:

Fabric Properties	Minimum	Test Method
Grab Tensile Strength (lb)	90	ASTM D1682
Elongation at Failure (%)	50	ASTM D1682
Mullen Burst Strength (PSi)	190	ASTM D3786
Puncture Strength (lb)	40	ASTM D751
Equivalent Opening Size	40-80	CW-02215
Ultraviolet Radiation Stability (%)	90	ASTM 9-26

2. Construct the filter fabric from a continuous roll cut to the length of the barrier to avoid joints.

3. Wood or steel posts are set on line at a spacing determined from Figure 5. In general, the spacing should be <u>less</u> than 3 times the height of the fence.

4. The upstream bottom of the filter fabric must be anchored in a soil or gravel trench as shown on Figure 6.

5. Do not install silt fences across streams, ditches, or waterways.

6. Tie the ends of the fences to the land contours in such a manner that flow around the ends of the fence is prevented.

7. If the fence may be overtopped, provide stabilized outlets to protect the fence system.

MAINTENANCE CONSIDERATIONS

A silt fence has a finite volume for collection of sediments. Regular inspection of the fence should be made after each storm to see if cleanout or replacement is required. Many State sediment control regulations now require replacement or cleanout of silt fences when the sediment depth exceeds half the fence height. If the silt fence is full, but the sediment cannot be removed, the sediments must be seeded and a new silt fence constructed down stream of the existing one.

DESIGN EXAMPLE

Design a silt fence profile for a site in Raleigh, North Carolina for a site having an average slope of 5% and consisting of silty clays.

(1) Maximum Slope Length: From the Table 1, the maximum, slope length is found to be 75 feet. The maximum spacing between parallel silt fences is therefore 75 feet.

(2) Runoff Volume:

$$\text{Runoff Volume (cubic feet)} = 0.04\ i\ A \qquad \text{Eq. 3}$$

where $i = 4$ inches (Figure 1)

$A = 1 \times 75 = 75$ sq. ft./ft. fence

Runoff Volume = 12 cubic ft./ft. fence

(3) Sediment Volume:

Soil loss, A (Tons/Acre/Year) = RKLS

where R = 250 (Figure 2)

KLS - 0.16 (Figure 3)

Soil Loss A = 40 Tons/Acre/Year

= 137 lbs./ft. fence/year

= 2.75 cu. ft./ft. fence/year

Design is controlled by Runoff Volume!

(4) Fence Height:

Try 18-inch fence, Volume = $1.5^2/.05$

= 45 cu. ft./ft. fence

Minimum 18-inch high fence is adequate!

(5) Posts/Spacing:

Try 3 x fence height = 4.5 feet

Figure 5, all typical posts work

Figure 4, all geotextiles work

Maximum 4.5 feet post spacing is adequate.

SUMMARY

The simplified silt fence design procedures presented here allows even silt fences on small sites to be rigorously evaluated.

Additionally, the procedure can be further simplified within those governmental regions where a singe value for rainfall and erosion related variables can be assumed. Such simplifications will provide significant user simplicity for major metropolitan areas.

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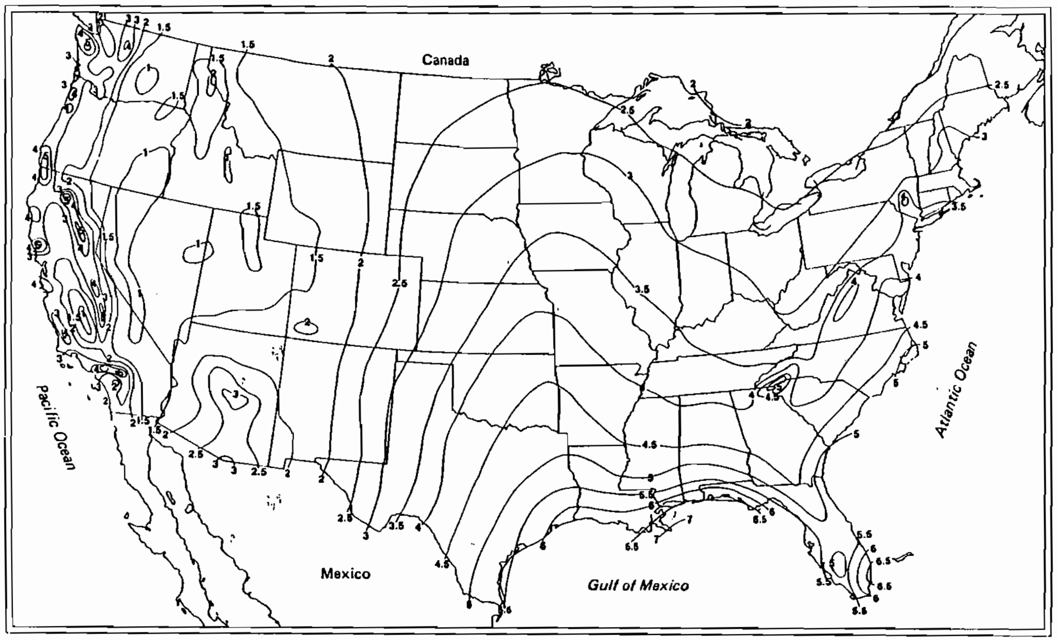
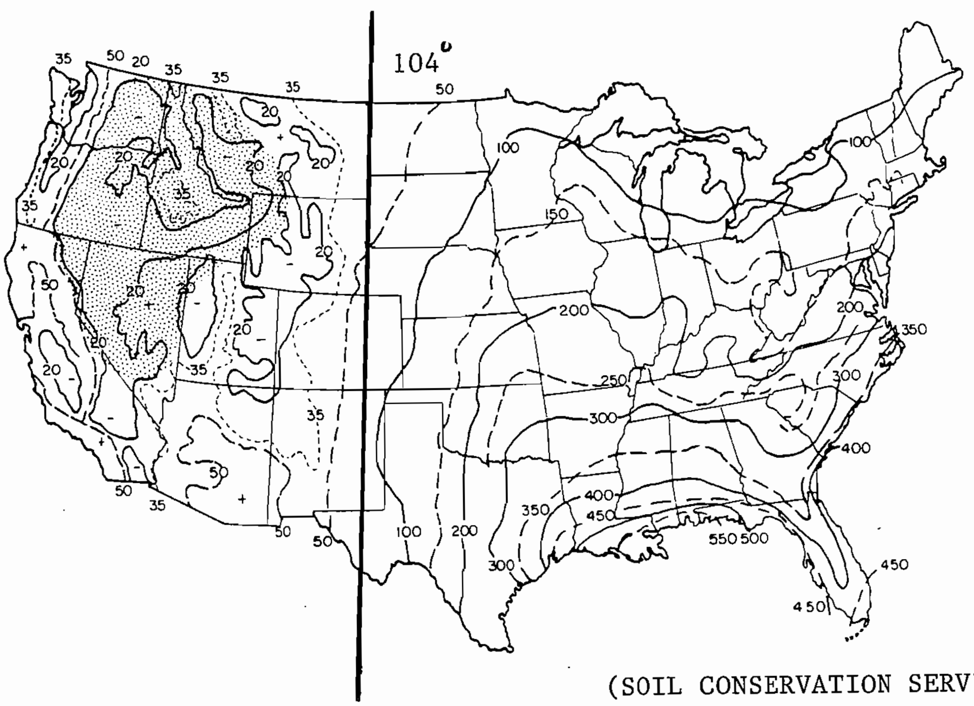


(HERSHFIELD, 1961)

Figure 1 10-Year Design Rainfall, inches



(SOIL CONSERVATION SERVICE, 1977)

Figure 2 Rainfall Erosion Index, R

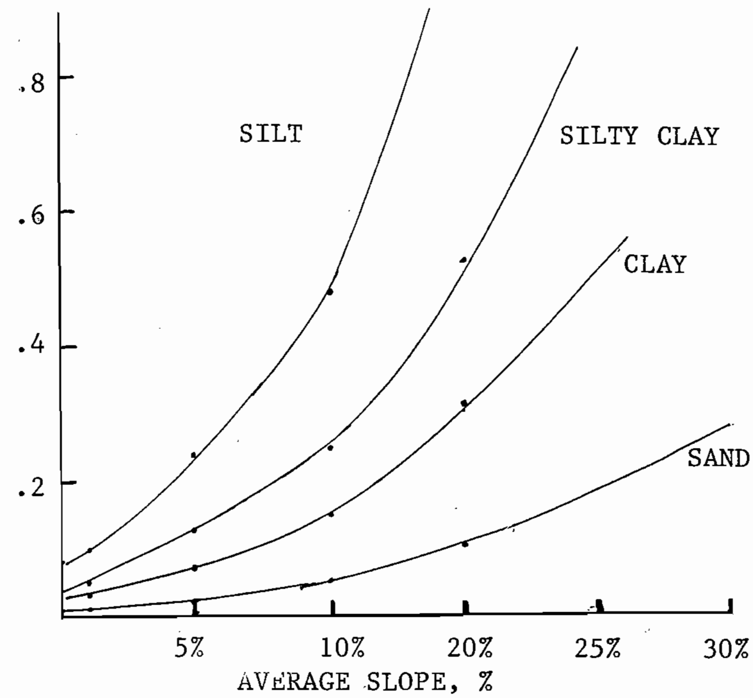
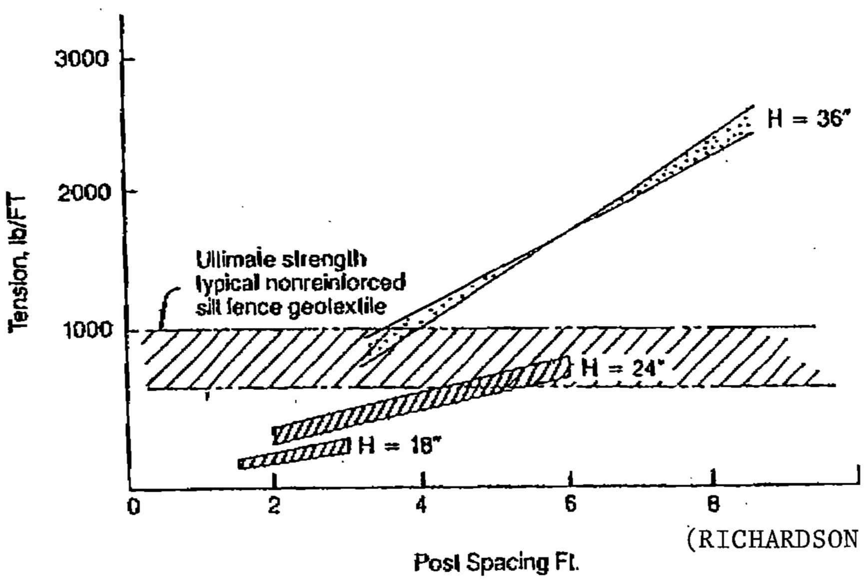
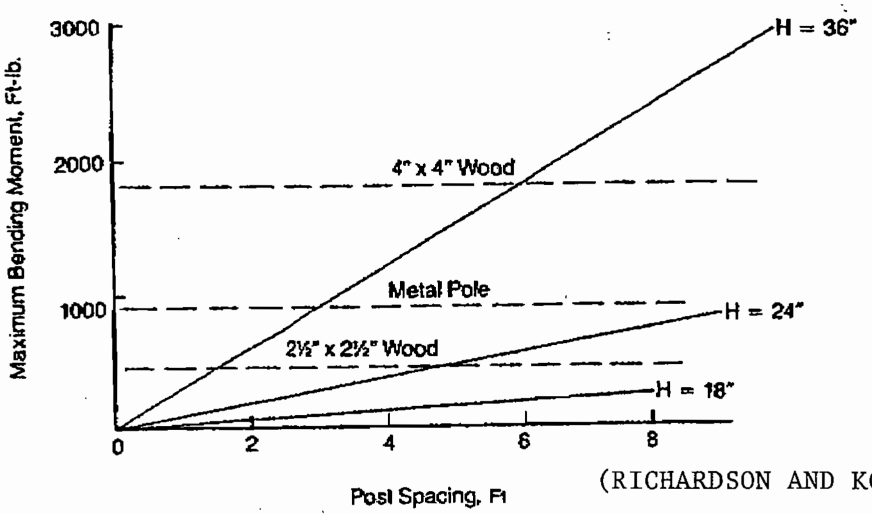


Figure 3 Universal Soil Loss KLS vs Slope



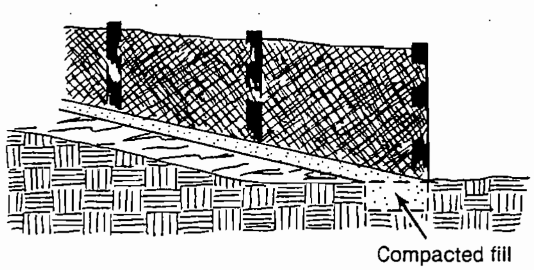
(RICHARDSON AND KOERNER, 1989)

Figure 4 Geotextile Strength vs Post Spacing



(RICHARDSON AND KOERNER, 1989)

Figure 5 Post Requirements vs Post Spacing



(RICHARDSON AND KOERNER, 1989)

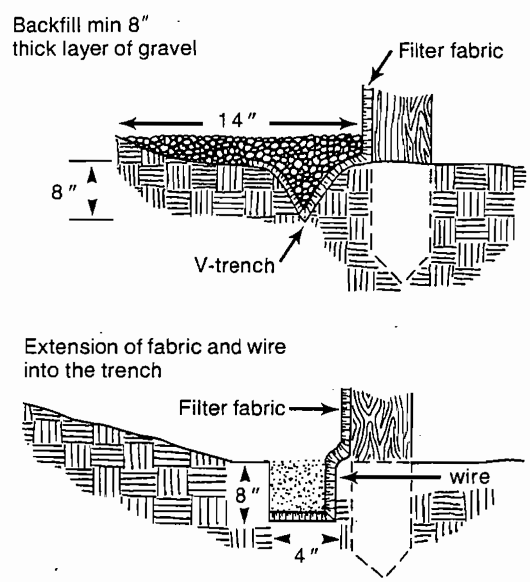


Figure 6 Anchorage of Silt Fence Base