GEOTEXTILES

CONSTRUCTION CRITERIA

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ABSTRACT

Designers of geotextile systems must place greater emphasis on a review of construction criteria as compared to typical Civil Engineerining design. This enhanced awareness of the construction procedure and relavant criteria is caused by the lack of significant construction experience in the use of these materials by most contractors and field personel . This paper reviews the four primary functions of geotextiles and discusses specific construction criteria for each. Information presented in this paper has been obtained primarily from two editions of the Geotextile Engineering Manual as prepared for the Federal Highway Administration (1,2) and from actual field and contractual experience of the authors.

INTRODUCTION - CONSTRUCTION CRITERIA

Civil Engineering designers in todays practice rarely are concerned with specific construction details associated with the implementation of their designs. Specifications are performance and not construction oriented . Thus a structural engineer does not typically review or specify construction procedures to be used in the erection of a particular building. Tradition and legal precedent have worked to make the contractor responsible for construction procedures. A sucessful contractor is one that understands the general mechanics of the structure and uses this knowledge or experience to efficiently sequence the construction. The use of geotextiles is, however, in such an early stage of development that few contractors, and many designers do not understand the roles or capacities of geotextiles in systems under construction. When this condition is anticipated, the design engineer must provide clear construction criteria that will minimize field problems. It should be noted, however, that these criteria may be construed as enlargening the legal liability of the designer.

Successful construction criteria ensures that the geotextile will survive installation and that the construction sequencing will not lead to failure of the existing subgraded. As such, this criteria may be dependent on fabric properties and upon the role that the geotextile is intended to perform in the completed structure. This paper reviews common installation criteria associated with fabric survivability and the four major roles played by geotextiles; these being 1) Drainage, 2) Erosion control, 3) Separation, and 4) Reinforcement. The geotextile will play several of these roles in most designs such that the construction criteria must reflect all roles.

Construction related problems that are common with the use of geotextiles can generally be associated with the following conditions:

1) Field fill placement or compaction techniques damage geotextile.

2) Installation loads significantly in excess of design loads leading to failure during construction.

3) Construction environment leads to a significant reduction in assumed fabric properties causing a failure of the completed project.

4) Field seaming or overlap of the geotextile fails to fully develop desired fabric mechanical properties.

5) Instabilities during various construction phases may render a design inadequate even though the final profile would have been stable.

This paper reviews both general geotextile and construction criteria developed to minimize field installation problems. Field inspection by a qualified engineer must be considered an vital to the successful installation in all performance modes.

GEOTEXTILE SURVIVABILITY

The ability of a geotextile to survive installation is dependent upon both the physical properties of the fabric and the direct environment that it is placed in. Important properties of a geotextile based on constructability considerations are listed in Table 1 for the four primary role functions (3). Existing textile related ASTM tests for these properties are presented when possible although the reader should be cautioned that all tests are currently under revision by ASTM D-35 for specific application to geotextiles. In general the geotextile must have properties that enable its design function to be performed and at the same time must not create unusual field handling problems. A typical field handling problem is generated by exceptionally large rolls of fabric that have been exposed to rain, absorbed a significant quantity of water, and pose a major problem to the contractor to simply move and unroll. The geotextile in this case may be damage by its own self weight.

Assuming that an appropriate geotextile has been selected, the next challenge to its survivability is placing the first layer of fill upon it. This contact layer of fill may consist of sand, gravel or even 500 lb. rip-rap. The survivability of the fabric is dependent upon the condition of the existing subgrade that it covers, the nature of the material placed upon it, and the manner in which the material is placed. The degree of fabric strength required to ensure survivability as a function of subgrade conditions, construction, and cover material is shown in Table 2 (2). Recommended minimum physical geotextile properties for the four major roles are given on Table 3 (4). The definition of protected and unprotected fabrics is role dependent and is defined on Table 3.

TABLE 1

IMPORTANT GEOTEXTILE PROPERTIES - CONSTRUCTABILITY

Physical Property	ROLE Drainage	Erosion	Separat.	Reinfor.	Test Procedure
1) Adsorption	YES	YES	YES	YES	NONE
2) Cutting Resistance	YES	YES	YES	YES	NONE
3) Flamibility		YES			NONE
4) Flexibility	YES	YES	YES		ASTM D-1388
5) Modulus			YES	YES	Proposed D-35
6) Puncture Resistance	YES	YES	YES	YES	ASTM D-751
7) Roll Dimensions	YES	YES	YES	YES	N/A
8) Seam Strength		YES		YES	ASTM D-1682 Mtd.16
9) Specific Gravity		YES	YES		ASTM D-854
10) Tear Strength	YES	YES	YES	YES	ASTM D-1117
11) Tensile Strength	YES	YES	YES	YES	ASTM D-1682 Mtd.16
12) Temperature Stabil.				YES	NONE
13) UV Stability	YES	YES	YES	YES	ASTM D-4355
14) Weight	YES	YES	YES	YES	N/A
15) Wet & Dry Stability				YES	NONE

CONSTRUCTION CRITERIA - DRAINAGE

Drainage applications using geotextiles are those where the flow of water is primarily in the plane of the fabric. These applications include both vertical and base drains in retaining walls, and gas or water drains below membranes or other impervious layers. Drainage layers may play multiple roles in the design including reinforcement if placed horizontal and filtration if the anticipated flow of water includes a sizable component normal to the geotextile. When a multiple role is required, then the construction criteria for both roles should be included in the project specifications.

Table 2

REQUIRED DEGREE OF FABRIC SURVIVABILITY AS A FUNCTION OF SUBGRADE CONDITIONS AND CONSTRUCTION EQUIPMENT

Subgrade Conditions	Construction Equipment and 6 In.-12 In. Cover Material Initial Lift Thickness		
	Low Ground Pressure Equipment (≤ 4 psi)	Medium Ground Pressure Equipment (> 4 psi, ≤ 8 psi)	High Ground Pressure Equipment (> 8 psi)
Subgrade has been cleared of all obstacles except grass, weeds, leaves, and fine wood debris. Surface is smooth and level such than any shallow depressions and humps do not exceed 6 in. in depth and height. All larger depressions are filled. Alternatively, a smooth working table may be placed.	Low	Moderate	High
Subgrade has been cleared of obstacles larger than small- to moderate-sized tree limbs and rocks. Tree trunks and stumps should be removed or covered with a partial working table. Depressions and humps should not exceed 18 in. in depth and height. Larger depressions should be filled.	Moderate	High	Very High
Minimal site preparation is required. Trees may be felled, delimbed, and left in place. Stumps should be cut to project not more than 6 in.+ above subgrade. Fabric may be draped directly over the tree trunks, stumps, large depressions and humps, holes, stream channels, and large boulders. Items should be removed only if placing the fabric and cover material over them will distort the finished road surface.	High	Very High	Not Recommended

NOTE:

1. Recommendations are for 6 in.-12 in. initial lift thickness. For other initial lift thicknesses:
   - 12 in.-18 in.: Reduce survivability requirement 1 level
   - 18 in.-24 in.: Reduce survivability requirement 2 levels
   - > 24 in.: Reduce survivability requirement 3 levels

   Survivability levels are, in increasing order: low, moderate, high, and very high.

2. For special construction techniques such as pre-rutting, increase fabric survivability requirement 1 level.

3. Placement of excessive initial cover material thickness may cause bearing failure of soft subgrades.

Table 3 Minimum Geotextile Properties

PROPERITIES	FILTRATION Unprot.	FILTRATION Protect	EROSION Unprot.	EROSION Protect	SEPARATION/REINFORCEMENT V.High	High	Moderate	Low
Grab Strength (ASTM D-1682)	180 lb	80	200	90	270	180	130	90
Puncture Strength (ASTM D-751-68)	80 lb	25	80	40	110	75	40	30
Burst Strength (ASTM D-751-68)	290 psi	130	320	145	430	290	210	145
Trapezoidal Tear (ASTM D-1117)	50 lb	25	50	30	75	50	40	30
Elongation @ Failure (ASTM D-1682)			20%	20%				
Protection/Rating Criteria	Fabric is protected when: Used in drainage trenches or below concrete.		If cushioned by layer of sand or zero height drop		Reference Table 2 for application of minimum fabric ratings.			

In a purely drainage mode, the geotextile's function is not impaired by reasonable penetrations through the fabric. The in-plane flow of water can simply flow around any intrusions without causing a significant decrease in the drainage capacity. A drain formed using a geotextile can be damaged during construction only if the requisite collector drains, weep-holes, etc. are either faulty in design or construction.

Composite drainage systems consist of a high porosity layer such as a mat sandwiched between one or two layers of geotextile. This composite system offers significantly higher values of transmissibility than geotextiles alone but may be collapsed if the normal pressures acting on the system become excessive. An example of this concern is the use of a composite drainage system on the back face of a retaining wall. If excessive compaction forces are used in the compaction of fill behind the wall, then the composite system could be collapsed and fail to function as a drainage layer. It is easy to see that a similiar failure could occur on a horizontal drainage layer due to excessive vehicle loading during construction.

CONSTRUCTION CRITERIA - EROSION CONTROL

Erosion control is primarily a filtration function where the flow of water may be either normal or tangential to the surface of the geotextile. Unlike drainage, erosion control is concerned with the flow of water normal to the fabric and not within its plane. As such, erosion control applications are more sensistive to construction generated penetrations or tears. Erosion control applications include trench drains, silt fences, and reverse filters such as used in embankment protection and surface erosion control.

Construction specifications for trench drains and associated systems should include the following criteria:

* Trench sides and base should be excavated to provide a smooth and fairly level surface. Zones of the sidewall that have collapsed should be cleaned and all major depressions filled with granular material so that the geotextile will not be distorted or torn.

* Care should be taken to place the fabric tightly against the soil so that no void space exists behind the fabric. Fabric roll ends should be overlapped a minimum of 12 inches or seamed together.

* The granular filter material placed within the trench should be compacted using a vibratory roller to a minimum compaction of 95% Standard Proctor. Compaction seats the fabric granular system against the natural subgrade to reduce voids and minimize settlement to the shoulder area.

* After placement of the granular fill, the two edges of the geotextile protruding at the top of the trench are overlapped on top of the granular filter material and then soil, or other materials should be placed in the trench and compacted to the desired grade.

If settlement criteria dictates the need for densities greater than that that defined by Standard Proctor, then care should be taken to ensure that the additional compaction effort does not damage the geotextile. In these situations geotextiles having a higher resistance to puncture should be used, see Tables 2 and 3.

Reverse filters commonly associated with erosion control require construction specifications that reflect the need to control the flow of water over the surface of the fabric. As such, specific construction criteria should include the following:

* Slopes in excess of 2.5 to 1 should not be used.

* Slopes should be grade to provide a smooth, fairly level surface. The fabric should be laid with the machine direction of the fabric placed parallel to the slope. Folds and wrinkles of the fabric should be avoided.

* Adjacent rolls should be overlapped 12 inches or should be seamed. A J-type seam using dual seams is preferred for these applications. Overlapped seams should be secured using metal pins. The Corps of Engineers specify steel securing pins, nominally 3/16-in. diameter, 18 inch long, pointed at one end and fitted with 1.5-in. diameter washers at the other end for use in securing fabrics in firm soils. The pin spacing is a function of the slope with the following spacings recommended:

Slope	Pin Spacing per Row
3:1	2 ft.
3:1 to 4:1	3 ft.
4:1	5 ft.
All Slopes	6 ft. between parallel rows of pins

* The placement of stone cover should begin at the base of the slope and at the center of the geotextile covered zone. The placement of the cover material should result in the tensioning of the undedrlying geotextile.

* For fabrics having properties exceeding that required for protected applications (Table 3) but with no cushion, the height-of-drop for stones less than 250 lbs. should be less than 1 ft. and stones weighing more than 250 lbs. should be placed without free-fall.

* For 'protected' fabrics with a cushion and fabrics having properties exceeding that for 'unprotected' applications,

the height-of-drop for stones less than 250 lbs. should be less than 3 ft., with stones greater than 250 lbs. placed with no free-fall.

* If stones greater than 250 lbs. must be dropped, or if a height-of-drop exceeding 3 ft. must be used, then field trials should be performed to determine the maximum height of safe drop without damaging the fabric.

* Stones weighing in excess of 100 lbs. should not be allowed to roll along the surface of the fabric.

* Contouring of the stones should be achieved during their initial placement, with no grading of the stones after placement allowed.

Erosion control fabrics can be easily damaged both by exceeding height-of-drop criteria and by placing or moving the cover stones in such a manner that the pinned joints of the fabric open. For these reasons it is important that a qualified geotechnical engineer monitor the installation of such fabrics.

Silt fences constructed with geotextiles were extensively studied by the Virginia Department of Highways and Transportation after an initial study indicated that less than 20% of such installations were effective. Based on this study (5,6), the following installation procedure is currently recommended for silt fences constructed using geotextiles:

* The height of the filter fabric silt fence should not exceed 36 inches.

* The filter fabric should be purchased in a continuous roll and cut to the length of the barrier to avoid the use of joints.

* Wood or steels post are set securely on line no more than 10 ft. apart. Wood posts should be at least 3 inches in diameter and a minimum of 5 ft. long. Only T-shaped posts weighing more than 1.33 lbs./ft., measuring no less than 5 ft. long, and having projections for fastening the wire to the fence should be used.

* A trench is excavated 4 inches wide and 4 inches deep along the line of posts and upslope from the barrier.

* When a wire mesh support fence is used, the wire should be a minimum of 14.5-gage woven wire and must be securely fastened to the upslope side of the posts. The wire should extend flush to the ground.

* The filter fabric is stapled or wired to the fence with the fabric being allowed to extend to the bottom of the trench.

* With wooden posts, the wire staples must be No. 9 and be at least 1.5 inches long. Where steel posts are used, 17-gage wire is used in lieu of wire staples.

* The trench is backfilled and the soil compacted over the filter fabric.

* If a filter fabric silt fence is to be constructed across a ditch line or drainageway, the barrier should be of sufficient length to eliminate end flow and the plan configuration should resemble a horseshoe, with the ends pointing upslope.

The general sequences in the construction of geotextile silt fences is shown on Figure 1.

CONSTRUCTION CRITERIA - SEPARATION

The Separation role performed by a geotextile is to prevent the movement of adjacent soil layers together. This follows a basic tenet in geotechnical engineering (7) that soils with vastly different particle sizes and particle size distributions cannot be placed together. Similiarly, if the strength of the finer soil is low in relation to the stresses the larger-size material can exert against it, the larger-size soil will penetrate into the finer material. Geotextiles act to distribute the more concentrated pressures applied by the larger-size material to minimize local bearing failures and at the same time prevent migration of the finer particles through the coarser matrix. It is typical for geotextiles providing separation that some addition reinforcement role is also provided.

Geotextiles as separators are being used in applications including paved and unpaved roadways, in developing temporary working platforms over weak subgrades, in both new and existing railroad track installations to prevent ballast fouling, and in new areas such as separating landfill covers from the underlying fill material.

Typical construction problems related to the placement of a separator layer include the following:

* Ripping or puncturing the fabric during the construction activity.

* Insufficient cover over the fabric during placement of the cover material resulting in failure of the subgrade due to excessive pressure generated by construction equipment.

* Rutting of the underlying subgrade prior to placement of the geotextile resulting in excessive deformation of the fabric during placement of the cover material.

* Placing lift thicknesses or dumping the cover material in piles that produce contact stresses at the subgrade that exceed the bearing capacity of the soil.

The general construction procedure for a separator system is shown on Figure 2. If the geotextile is to provide a reinforcing role in addition to providing separation, then construction criteria for that role should be reviewed and incorporated into the project specifications.

Construction criteria recommended for a geotextile separator system in roadways are as follows (2):

* The site should be cleared, grubbed, and overexcavated to design grade, taking care to strip all topsoil, soft soils or other unsuitable material. Isolated pockets where over excavation is required should be pitched or backfilled to promote positive drainage.

* During stripping operations, care should be taken not to disturb the subgrade. This may require use of lightweight dozers, etc. for low strength soils such as saturated cohesionless or low cohesion soils. Subgrade preparation should reflect the survivability criteria presented on Table 2.

* Once the subgrade along a particular segment of road alignment has been prepared, the geotextile is unrolled in line with the placement of the new aggregate. The fabric should not be dragged across the subgrade and the entire fabric should be placed and rolled out as smoothly as possible.

* Parallel rolls of fabric should be overlapped or sewn as required. recommended minimum overlaps are as follows:

CBR	Minimum Overlap
Greater than 2	1-1.5 ft
1-2	2-3 ft
0.5-1	3 ft or sewn
Less than 0.5	sewn only
All roll ends	3 ft or sewn

The fabric should be pinned at all overlaps to maintain them during construction activities.

* Fabric widths should be selected such that overlaps of parallel rolls occur at the centerline and at the shoulder. Overlaps should not be placed along anticipated main wheel path locations.

* Overlaps at the end of rolls should be in the direction of the aggregate placement with the previous roll on top.

* When fabric intersects an existing pavement area, the fabric should extend to the edge of the old system and consideration should be given to anchoring the end of the fabric.

* The subbase aggregate should be end-dumped on the fabric from the edge of the fabric over previously placed aggregate to eliminate equipment contact with the fabric. For very weak subgrades, the pile heights should be limited to prevent construction induced road failure.

* Before covering, the condition of the fabric should be observed by a qualified engineer to determine that no holes or rips exist in the fabric. All such occurences should be repaired by placing a new layer of fabric extending beyond the defect in all directions a distance equal to the minimum overlap required for adjacent rolls.

* The first layer of aggregate should be graded down from the previously placed fill to a thickness of 12 inches or the maximum design thickness. At no time should equipment be allowed on the fabric with less than 8 inches of aggregate between the wheels and the fabric. Construction vehicles should be limited in size and weight such that rutting in the initial lift is less than 3 inches. If rut depths exceed 3 inch, then the size and weight of the equipment must be reduced.

* The first lift should be compacted by "tracking" with a dozer and then compacted with a smooth-drum vibratory roller to obtain a minimum compacted density. For soft soils the design density of the first layer should be 5% less than for the remaining layers. Use of the vibratory roller should be closely monitored in applications where the existing subgrade consists of saturated, loose cohesionless soils. Liquefaction of these soils due to excess pore water pressures can lead to bearing capacity failure of the subgrade.

* Turning of construction equipment should not be permitted on the first layer of aggregate placed upon the fabric.

* Any ruts that form during construction should be filled with new aggregate to maintain an adequate depth of cover over the fabric as shown on Figure 3. In no case should ruts be bladed down as this decreases the amount of aggregate cover between the ruts.

* All remaining lifts of subbase aggregate should be placed in lifts not exceeding 9 inch loose thickness.

If the geotextile is to provide additional roles beyond separation, then construction criteria for those roles should be reviewed and incorporated into the project specifications.

CONSTRUCTION CRITERIA - REINFORCEMENT

Geotextile systems designed to use the fabric in a Reinforcement mode include geotextile reinforced retaining walls, support of embankments built upon soft soils, and soil encapsulation. The basic premise to all design is for the fabric to either supply tensile capacity lacking in the unreinforced soil or to apply a psuedo confining pressure that results in an increase in the ultimate strength of the soil.

Construction problems in the placement of a reinforcement layer typically related to conditions that reduce the tensile capacity of the fabric. Some of these construction problems include

* Ripping or puncturing the fabric during construction leading to failure of the fabric.

* Failure of joining seams.

* Failure of the fabric itself in tension.

An additional failure mode associated with embankments built upon soft subgrades is localized bearing capacity failure of the subgrade.

Clear definition of construction criteria for embankments built upon soft soils is important since the desired fill placement procedure is not the same as for conventional embankments. For this category of structure, the construction criteria include the following:

* The site should be prepared to the most exhaustive criteria defined on Table 2 per fabric survivability. Large depressions should be lined with the geotextile with 6 feet of material projecting beyond the depression. The depression should be filled with granular material level to the surrounding surface prior to placement of the primary geotextile layer.

* Seams should be of the 'butterfly' or 'J' type as shown on Figure 4. A lock-type stitch should be used with double seams no farther than 1/4 to 1/2 inch apart required for all critical applications. A successful seam should be assumed to provide 2/3 of the fabric tensile strength.

* Before covering, the fabric should be inspected by a qualified engineer for damage and to ensure that the fabric is rolled out as smoothly as possible. All wrinkles and folds in the fabric should be removed by stretching and staking as required.

* Placement of the first layer of fill upon the geotextile must follow the guidelines previously presented herein for the separation mode. It is particularly important that the

rut depth be maintained at less than 3 inches and that fresh stone material should be added to all ruts as they develop.

* After placement of the first layer of stone, the geotextile can be pre-tensioned by proofrolling with a heavily loaded rubber tired vehicle. The wheel load should be equivalent to the maximum expected for the site. The vehicle should make at least four passes over the first lift repeatedly following in the same tracks and with a ruts filled between passes.

* Heavy compaction equipment should not be used on the first layer of fill and vibratory rollers should be avoided if the underlying subgrade is a saturated, loose cohesionless soil.

* Fill placement for embankments placed upon soft soils must follow the scheme shown on Figure 5 (8,9,10). This scheme places fill first on the edges of the fabric to anchor the fabric and then tensions or 'sets' the fabric by placing the center fill as shown on Figure 6.

Embankments built upon subgrades so soft that mud-waves develop require controlls beyond that described here.

Retaining walls constructed using fabric reinforcement must build each layer using criteria similiar to that developed for the first fill layer in separation or reinforcement applications. The only additional criteria is to specify that all lifts be placed at a 1% slope contoured to provide drainage away from the face of the wall. This minimizes the potential for ponding due to heavy rains during construction.

SUMMARY

Construction criteria have been presented for use in developing each of the four primary roles of geotextiles. A important criteria common to all roles is that fabrics lacking UV protection should be placed and covered within 5 days and those fabrics that are UV stabilized should be placed and covered within 30 days. Applications such as silt fences must be constructed with the understanding that all fabrics degrade in direct sunlight so that such structure are temporary measures at best.

An additional common denominator to all function modes is the need to have a qualified engineer present in the field to ensure that the fabric and the first layer of fill are properly placed. A major difficulty here is defining what a 'qualified' engineer should be since many geotechnical engineers are not familiar with geotextiles and their proper design or installation.

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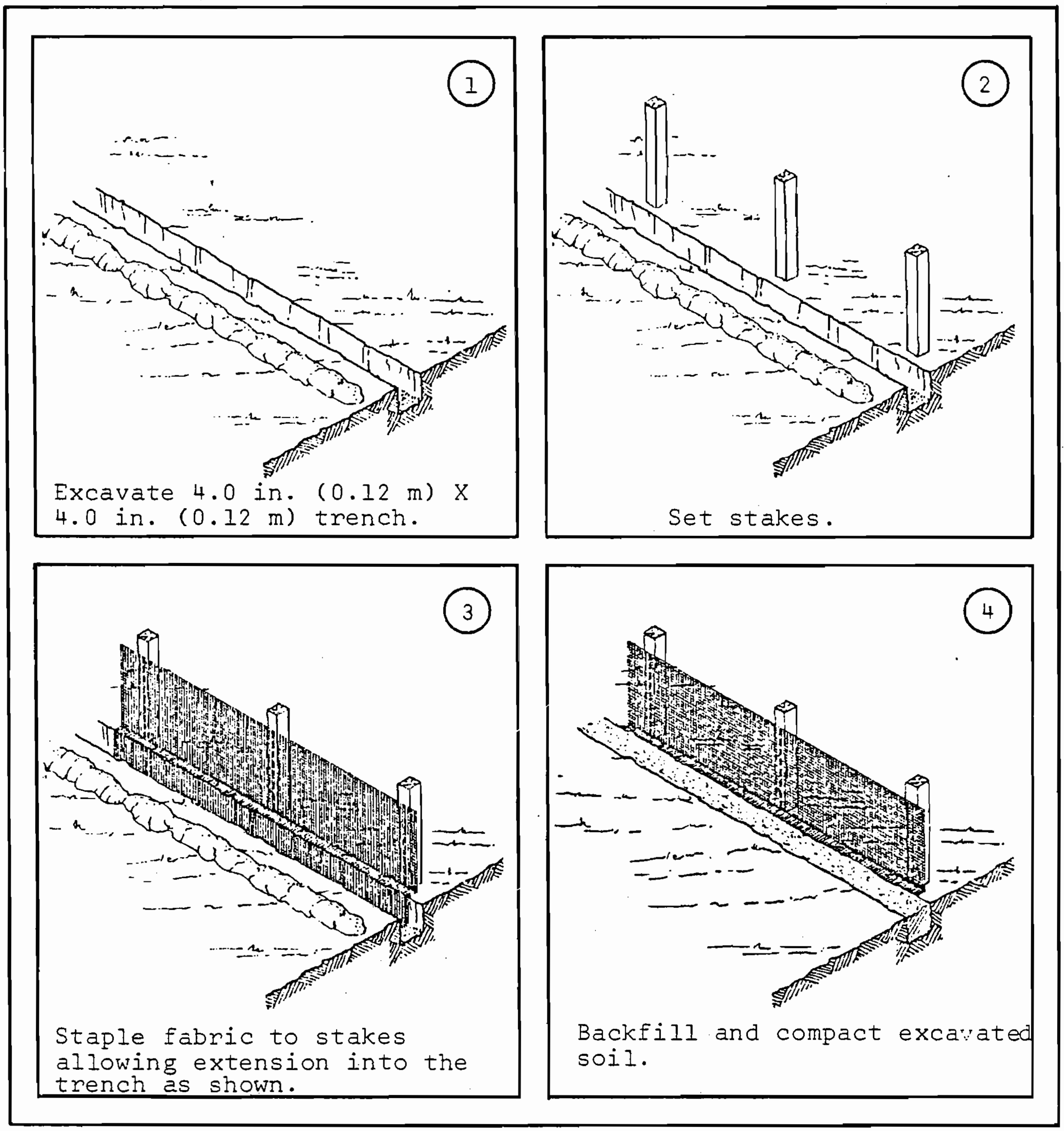


Figure 1 Construction of Geotextile Silt Fences

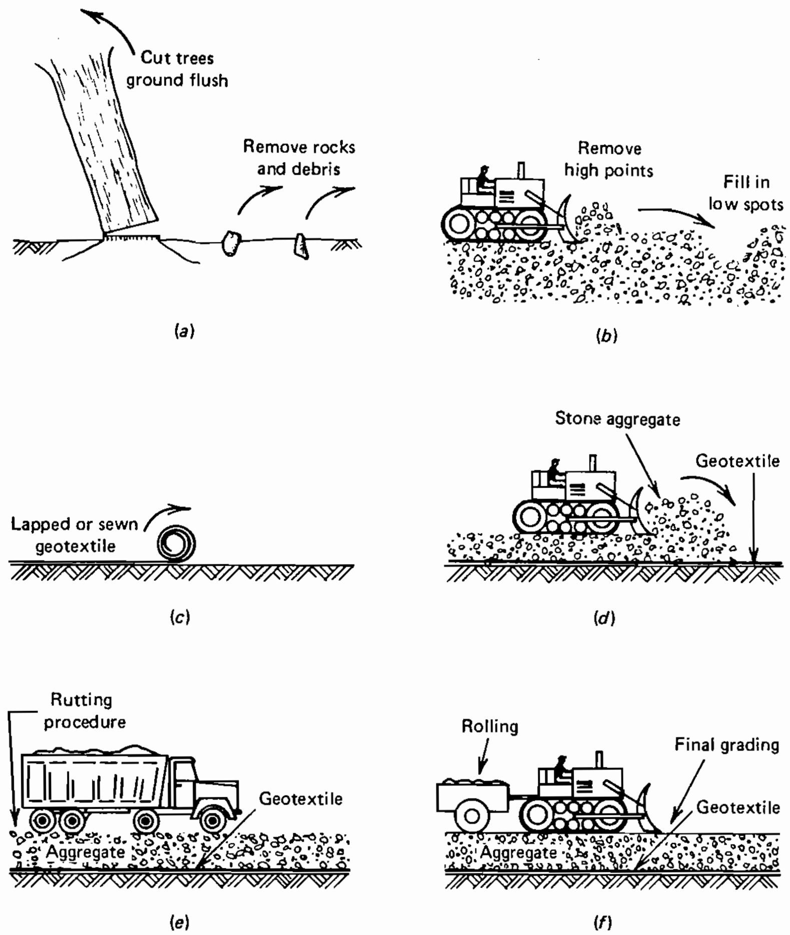


Figure 7.6 General procedures for using geotextiles in the construction of an unpaved road. (*a*) Clear trees, stumps, and large brush. (*b*) Level ground surface as much as possible. (*c*) Roll out geotextile by hand or machine. (*d*) Spread aggregate, working from previously placed aggregate. (*e*) Rut aggregate and geotextile system with truck. (*f*) Fill in ruts, grade aggregate, and roll finished surface.

(Koerner, 1984)

Figure 2 Construction of Separation/Reinforcement System

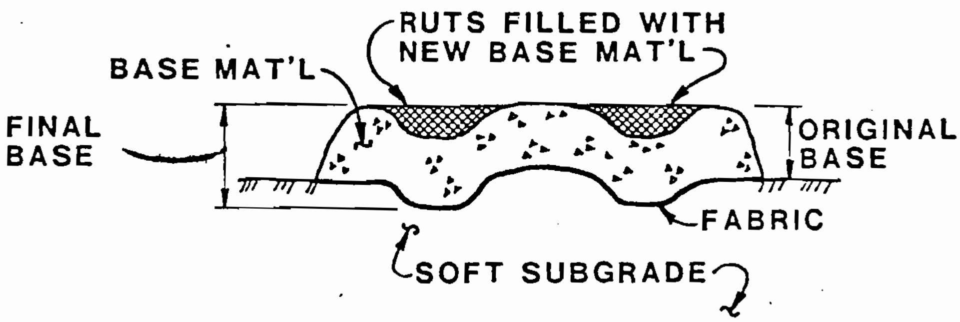


Figure 3 Repair of Rutting with Additional Base Material

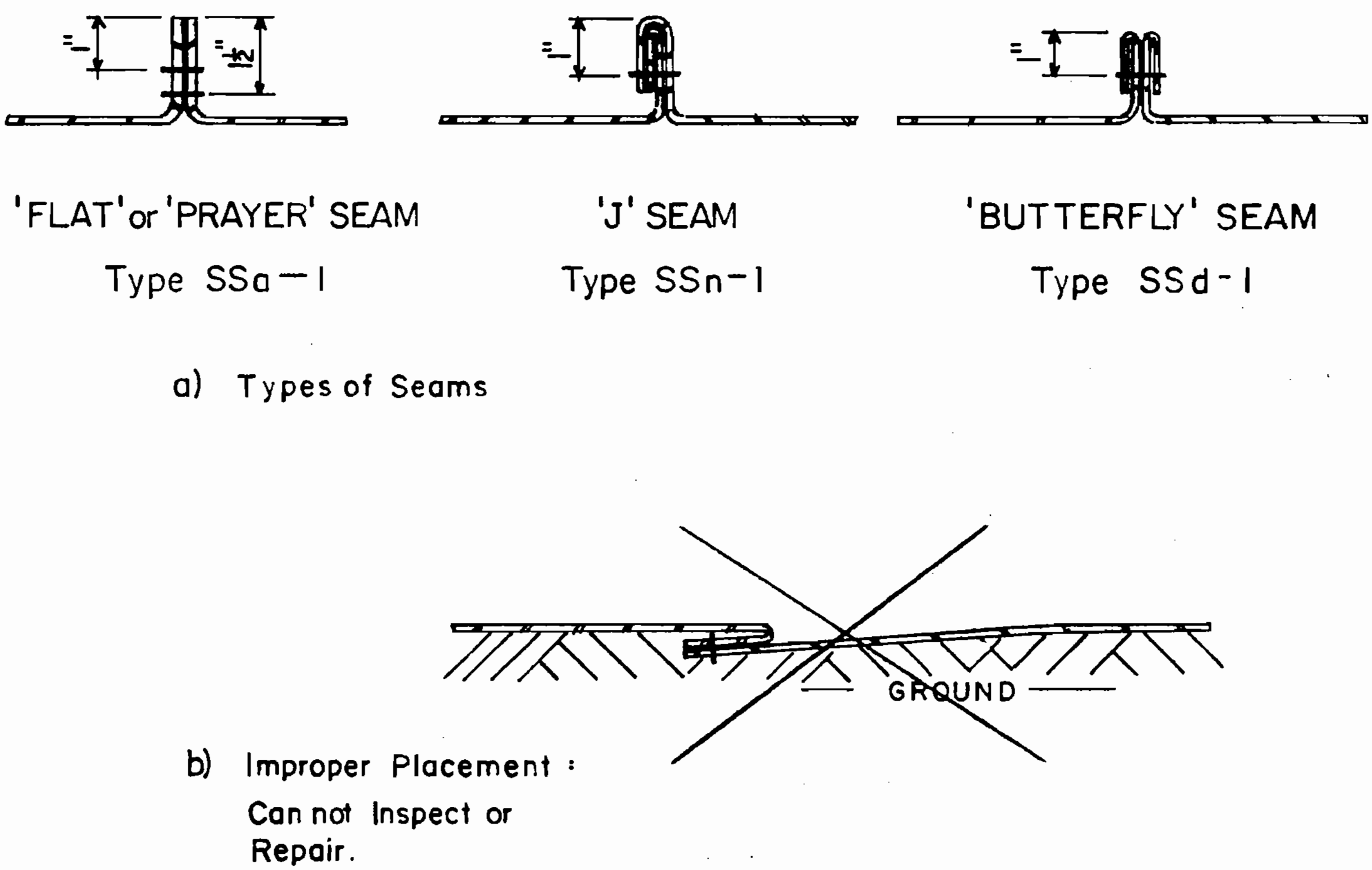
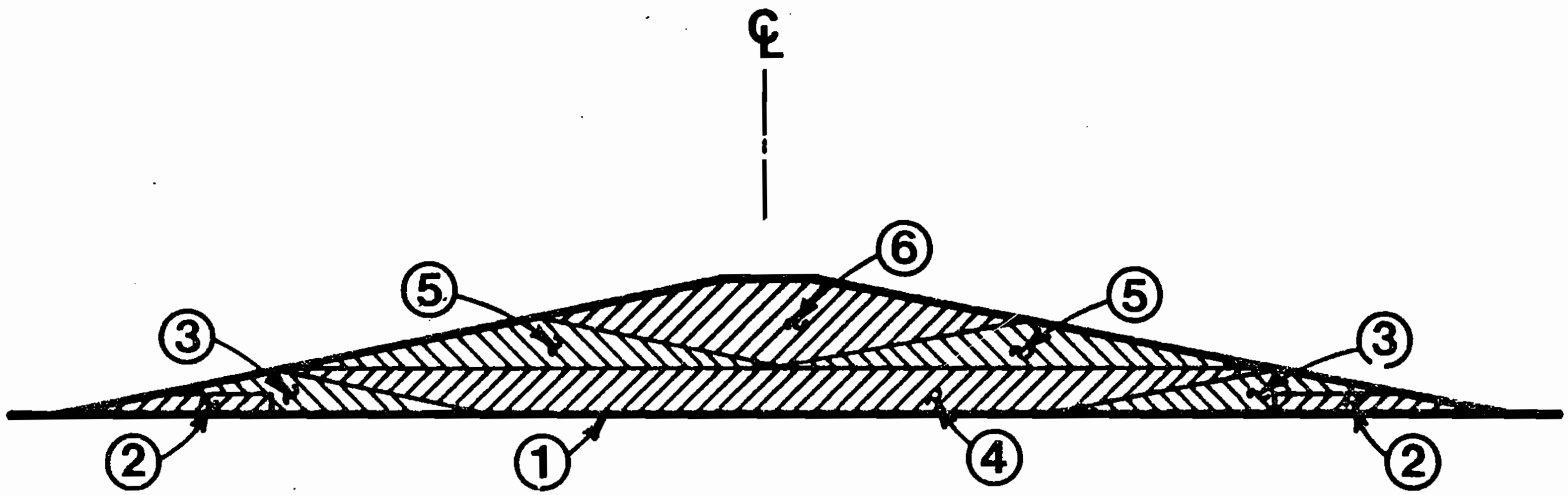


Figure 4 Geotextile Seaming Techniques



SEQUENCE OF CONSTRUCTION

1. LAY FABRIC IN CONTINUOUS TRANSVERSE STRIPS, SEW STRIPS TOGETHER.
2. END DUMP ACCESS ROADS.
3. CONSTRUCT OUTSIDE SECTIONS TO ANCHOR FABRIC
4. CONSTRUCT INTERIOR SECTION TO "SET" FABRIC.
5. CONSTRUCT INTERMEDIATE SECTIONS TO TENSION FABRIC.
6. CONSTRUCT FINAL CENTER SECTION.

Figure 5 Recommended Construction Sequence for Fabric-Reinforced Embankments

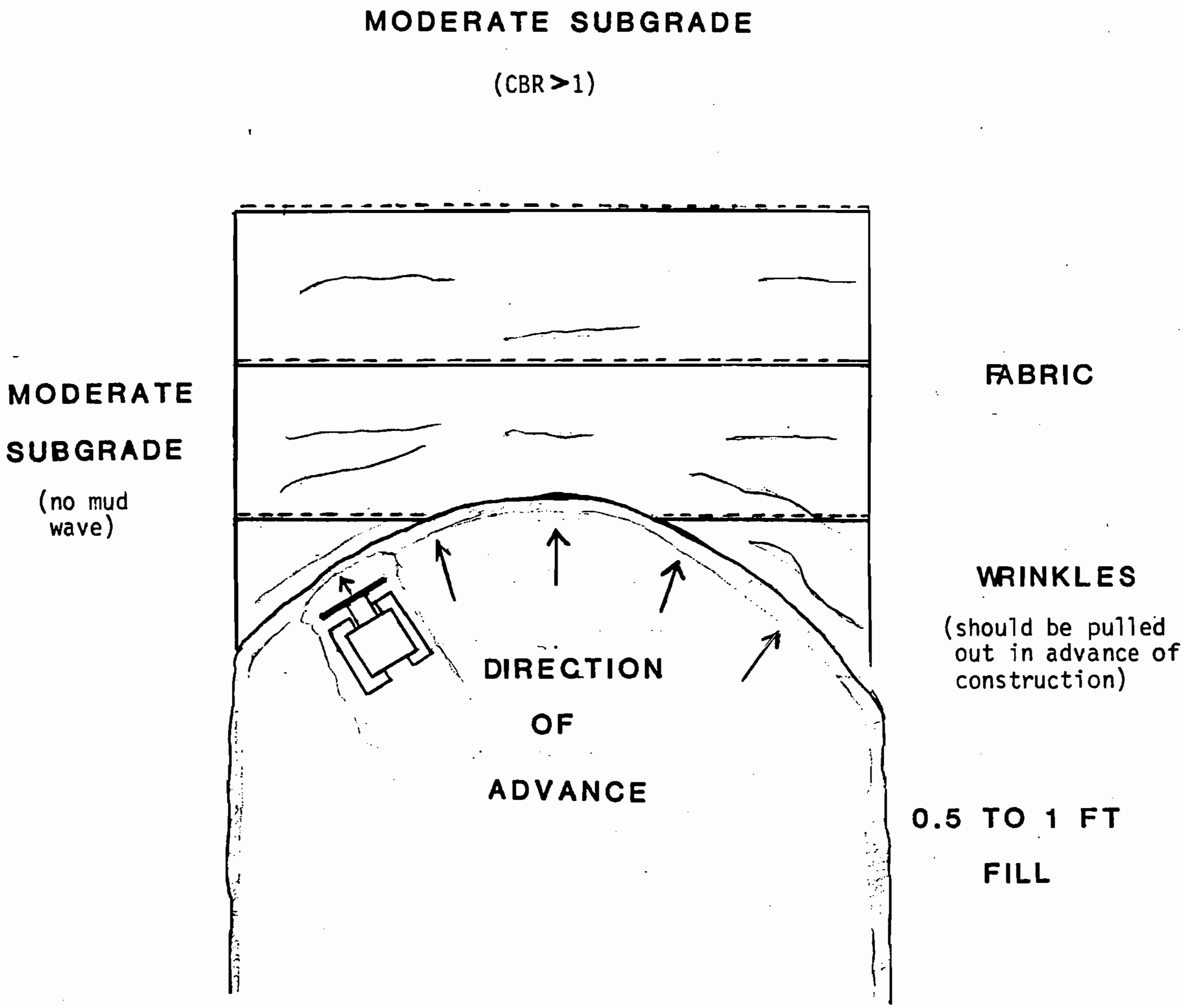


Figure 6 Placement of First Lift to Tension Fabrics on Moderate Ground Conditions