CHAPTER 11

Geotextiles

Other techniques are available for improving the condition of a soil besides mechanical blending and chemical stabilization. These techniques incorporate geotextiles in various pavement applications.

The term geotextile refers to any permeable textile used with foundation, soil, rock, earth, or any other geotechnical engineering-related material as an integral part of a human-made project, structure, or system. Geotextiles are commonly referred to as geofabrics, engineering fabrics, or just fabrics.

APPLICATIONS

Geotextiles serve four primary functions:

- Reinforcement.
- Separation.
- Drainage.
- Filtration.

In many situations, using these fabrics can replace soil, which saves time, materials, and equipment costs. In theater-of-operations horizontal construction, the primary concern is with separating and reinforcing low load-bearing soils to reduce construction time.

Reinforcement

The design engineer attempts to reduce the thickness of a pavement structure whenever possible. Tests show that for low load-bearing soils (generally ≤ 5), the use of geofabrics can often decrease the amount of subbase and base course materials required. The fabric lends its tensile strength to the soil to increase the overall design strength. *Figure 11-1,* shows an example of this concept.

Swamps, peat bogs, and beach sands can also be quickly stabilized by the use of geofabrics. Tank trails have been successfully built across peat bogs using commercial geofabric.

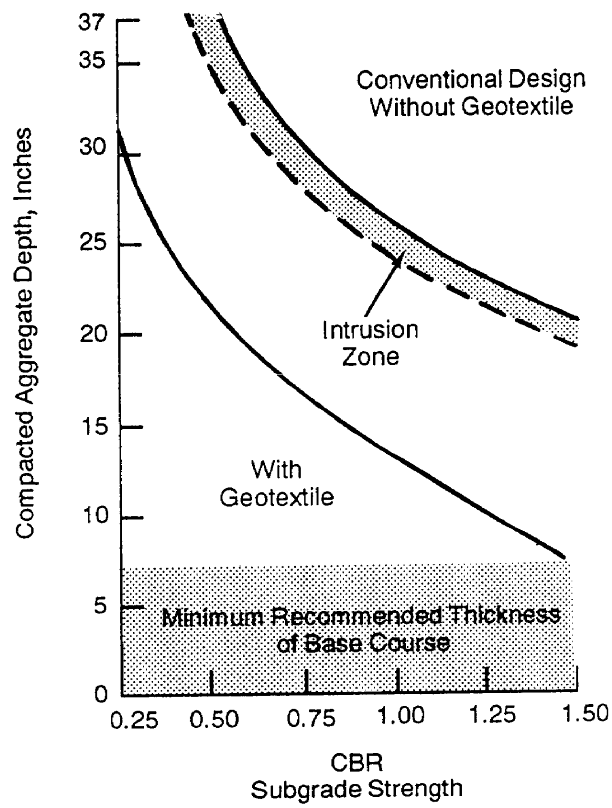

Figure 11-1. Comparison of aggregate depth requirements with and without a geotextile.

Separation

Construction across soft soils creates a dilemma for the engineer. The construction proceeds at a slow pace because much time is spent recovering equipment mired in muck and hauling large quantities of fill to provide adequate bearing strength. Traditionally, the following options may be considered:

- Bypass the area.
- Remove and replace the soil.
- Build directly on the soft soil.
- Stabilize mechanically or with an admixture.

Bypass. This course of action is often negated by the tactical situation or other physical boundaries.

Remove and Replace. Commonly referred to as "mucking," this option is sometimes a very difficult and time-consuming procedure. It can only be used if the area has good, stable soil underneath the poor soil. Furthermore, a suitable fill material must be found nearby.

Build On Directly. Base course construction material is often placed directly on the weak soil; however, the base course layer is usually very thick and the solution is temporary. A "pumping" action causes fines to intrude into the base course, which causes the base course to sink into the weak soil (see *Figure 11-2).* As a result, the base course itself becomes weak. The remedy is to dump more material on the site.

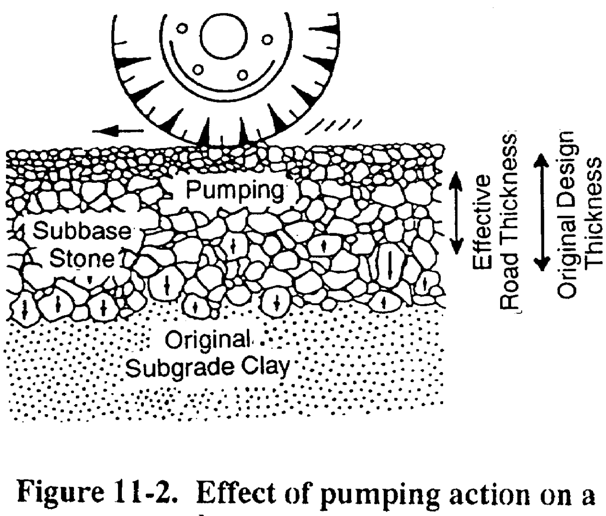

Figure 11-2. Effect of pumping action on a base course.

Stabilize. As discussed in *Chapter 10,* stabilizing can be done mechanically or with an admixture could be used, but it may be very time consuming and costly.

For the last three options, the poor soil eventually intrudes into the base course, such as in a swampy area, or simply moves under the loads. By using geofabrics, the poor soils can be separated and confined to prevent intrusion or loss of soil (see *Figure 11-3).*

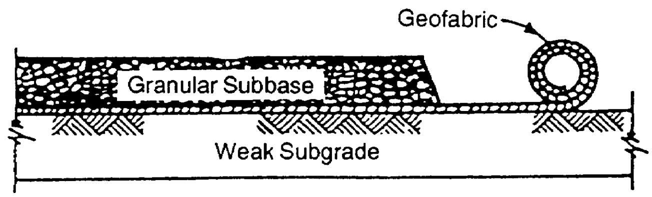

Figure 11-3. Separating a weak subgrade from a granular subbase with a geofabric.

Drainage

Geotextiles placed in situations where water is transmitted in the plane of their structure provide a drainage junction. Examples are geotextiles used as a substitute for granular material in trench drains, blanket drains, and drainage columns next to structures. This woven fabric offers poor drainage characteristics; thick nonwoven fabrics have considerably more void space in their structure available for water transmission. A good drainage geotextile allows free water flow (but not soil loss) in the plane of the fabric.

Filtration

In filter applications, the geotextile is placed in contact with soil to be drained and allows water and any particles suspended in the water to flow out of the soil while preventing unsuspended soil particles from being carried away by the seepage. Filter fabrics are routinely used under riprap in coastal, river, and stream bank protection systems to prevent bank erosion. Another example of using a geotextile as a filter is a geotextile-lined drainage ditch along the edge of a road pavement.

UNPAVED AGGREGATE ROAD DESIGN

The widespread acceptance of geotextiles for use in engineering design has led to a proliferation of geotextile manufacturers and a multitude of geofabrics, each with different engineering characteristics. The design guidelines and methodology that follow will assist in selecting the right geofabric to meet construction requirements.

Site Reconnaissance

As with any construction project, a site reconnaissance provides the designer insight into the requirements and the problems that might be encountered during construction.

Subgrade Soil Type and Strength

Identify the subgrade soil and determine its strength as outlined in *Chapter 9*. If possible, determine the soil's shear strength (C) in psi. If you are unable to determine C, use the nomograph in *Figure 11-4* to convert the CBR value or Cone Index to C.

Subgrade Soil Permissible Load

The amount of load that can be applied without causing the subgrade soil to fail is referred to as the permissible stress (S).

- Permissible subgrade stress without a geotextile:

  $S = (2.8)\ C$

- Permissible subgrade stress with a geotextile:

  $S = (5.0)\ C$

Wheel Load, Contact Pressure, and Contact Area

Estimate wheel load, contact pressure, and contact area dimensions (see *Table 11-1, page* 11-4). For the purpose of geotextile design, both single and dual wheels are represented as single-wheel loads (L) equal to one-half the axle load. The wheel load exerted by a single wheel is applied at a surface contact pressure (P) equal to the tire inflation pressure. Dual wheel loads apply a P equal to 75 percent of the tire inflation pressure. Tandem axles exert 20 percent more than their actual weight to the subgrade soil due to overlapping stress from the adjacent axle in the tandem set.

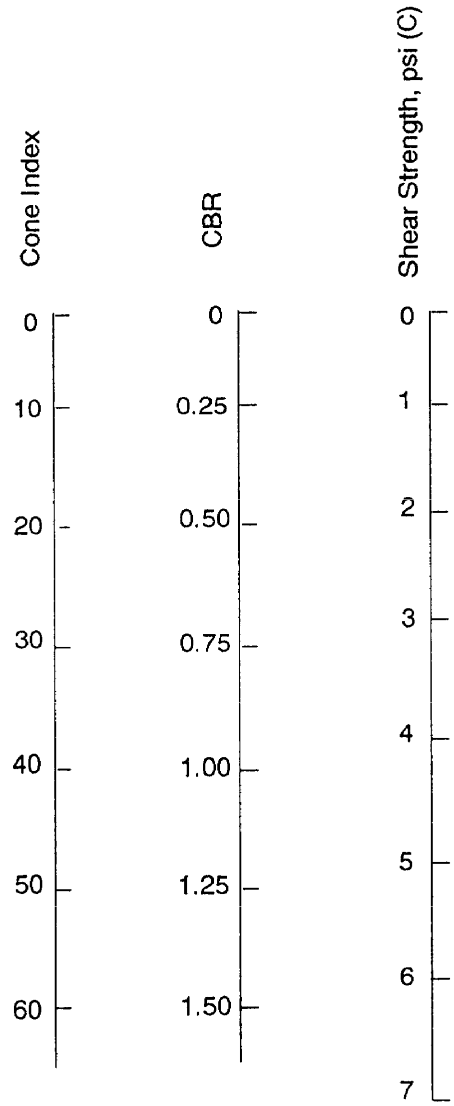

Figure 11-4. Determining the soil's shear strength by converting CBR value or Cone Index.

Estimate the area being loaded (B^2):

$$B^2 = \frac{L}{P}$$

$B = \sqrt{B^2}$ = length of one side of the square contact area

Table 11-1. Vehicle input parameters.

Vehicle Type (Choose Category Nearest the Actual Design Vehicles)	Axles S - Single T - Tandem	Wheels S - Single D - Dual	Axle Loads (lb)	Wheel Loads[1] L (lb)	Typical[2] Tire Inflation Pressure (psi)	Contact Pressure[3] P (psi)	Wheel Contact Area B^2 (in^2)	One Side of Square Contact Area B (in)
Highway Legal Vehicles								
Haul trucks[4] - F Axle (stone, concrete)	S	S	18,000	9,000	110	110	82	9.0
R Axle	T	D	18,000	10,800	110	83	130	11.4
Tractor trailer - F Axle	S	S	18,000	9,000	120	120	75	8.7
(18 wheeler) - R Axle	T	D	18,000	10,800	120	90	120	11.0
Off Highway Vehicles[5]								
35-ton trucks - F Axle	S	S	48,000	24,000	90	90	267	16.3
(CAT 769C) - R Axle	S	D	89,200	44,600	90	68	656	25.6
Wheel loader - F Axle	S	S	24,000	12,000	50	50	240	15.5
(CAT 910) - R Axle	S	S	10,000	5,000	50	50	100	10.0
Wheel loader - F Axle	S	S	37,000	18,500	60	60	308	17.6
(CAT 930) - R Axle	S	S	14,000	7,000	60	60	117	10.8
Wheel loader - F Axle	S	S	65,000	32,000	60	60	542	23.3
(CAT 966C) - R Axle	S	S	25,000	12,500	60	60	208	14.4
Wheel loader - F Axle	S	S	136,000	68,000	85	85	800	28.3
(CAT 988B) - R Axle	S	S	55,000	27,500	85	85	324	18.0
Wheel loader - F Axle	S	S	290,000	145,000	70	70	2071	45.5
(CAT 992) - R Axle	S	S	120,000	60,000	60	60	1000	31.6
Scraper - F Axle	S	S	88,600	44,300	80	80	554	23.5
(CAT 631D) - R Axle	S	S	75,400	37,700	75	75	503	22.4
Scraper - F Axle	S	S	120,000	60,000	85	85	706	26.6
(CAT 651B) - R Axle	S	S	110,800	55,400	80	80	692	26.3

NOTES:
1. Wheel load is one-half the axle load and increased by 20% if the wheel is on a tandem axle.
2. Maximum tire inflation pressure is given for each class of vehicle. Using tires with lower inflation pressures would lower the contact pressures and allow for less thickness of the aggregate structural section.
3. Same as tire inflation pressure except that a factor of 0.75 times the inflation pressure must be used for all dual wheels.
4. Trucks used on- and off-highway use generally use lower inflation pressure tires requiring only 75 to 90 psi.
5. Manufacturers' specifications should be consulted for off-highway vehicles. Wide ranges of different inflation pressure tires are available for these vehicles.

Aggregate Base Thickness

Assuming that wheel loads will be applied over a square area, use the Boussinesq theory of load distribution to determine the aggregate section thickness required to support the design load. The Boussinesq theory coefficients are found in *Table 11-2*.

- First, solve for X:

Without a geotextile: $$X = \frac{S}{(4)P}$$

With a geotextile:

$$X \text{ geotextile} = \frac{S \text{ geotextile}}{(4)\,P}$$

- Using the calculated values of X and X geotextile, use *Table 11-2* to find the corresponding value of M and M geotextile.
- Then solve for the aggregate base thickness H and H geotextile.

Without a geotextile: $$H = \frac{B \text{ (inches)}}{(2)\,M}$$

With a geotextile:

$$H \text{ geotextile} = \frac{B}{(2)\,M \text{ geotextile}}$$

Table 11-2. Boussinesq theory coefficients.

If X =	Then M =
0.005	0.10
0.011	0.15
0.018	0.20
0.026	0.25
0.037	0.30
0.048	0.35
0.060	0.40
0.072	0.45
0.084	0.50
0.096	0.55
0.107	0.60
0.118	0.65
0.128	0.70
0.138	0.75
0.146	0.80
0.155	0.85
0.162	0.90
0.169	0.95
0.175	1.00
0.186	1.10
0.196	1.20
0.207	1.35
0.215	1.50
0.224	1.75
0.232	2.00
0.237	2.25
0.240	2.50
0.242	2.75
0.244	3.00
0.247	4.00
0.249	5.00
0.249	7.50
0.250	10.00
0.250	∞

The difference between H and H geotextile is the aggregate savings due to the geotextile.

Aggregate Quality. Adjust the aggregate section thickness for aggregate quality. The design method is based on the assumption that a good quality of aggregate (with a minimum CBR value of 80) is used. If a lower quality is used, the aggregate section thickness must be adjusted.

Table 11-3, page 11-6, contains typical compacted strength properties of common structural materials. These values are approximations; use more specific data if it is available. Extract the appropriate thickness equivalent factor from *Table 11-3, page 11-6,* then divide H by that factor to determine the adjusted aggregate section thickness.

Service Life. Adjust the aggregate base thickness for the service life. The design method assumes that the pavement will be subjected to one thousand 18,000-pound equivalent vehicle passes. If you anticipate more than 1,000 equivalent passes, you will need to increase the design thickness by 30 percent and monitor the performance of the road.

A second method of determining minimum required cover above a subgrade for wheeled vehicles with and without a geotextile requires fewer input parameters. Again, use *Figure 11-4, page 11-3,* to correct CBR or cone index values to a C value. Determine the permissible stress (S) on the subgrade soil by multiplying C times 2.8 without a geotextile and 5.0 with a geotextile. Select the heaviest vehicle using the road and the design vehicle for each wheel load configuration: single, dual, or tandem. Using the appropriate graph (see *Figures 11-5, 11-6, or 11-7, pages 11-7 and 11-8)* enter the graph at S. Round the design-vehicle wheel loads to the next higher wheel-load weight curve (for example, a dual wheel load of 10,500 pounds is rounded to 12,000 pounds *(see Figure 11-6, page 11-7)).* Determine the intersection between the appropriate wheel-load curve and S (with and without a geotextile) then read the minimum required thickness on the left axis. Use the greatest thickness values as the design thickness with and without a geotextile. Corn pare the cost of the material saved with the cost of the geotextile to determine if using the geotextile is cost effective.

SELECTING A GEOTEXTILE

Up to this point in the geotextile design process, we have been concerned with general design properties for designing unpaved aggregate roads. Now you must decide which

Table 11-3. Compacted strength properties of common structural materials.

Material	CBR Range	Thickness Equivalency Factor
Asphalt, concrete plant mix, high stability	>100	3.00
Crushed hard rock	80-100	1.00
Crushed medium-hard rock	60-80	0.85
Well-graded gravel	40-70	0.80
Shell	40-60	0.75
Sand-gravel mixtures	20-50	0.50
Soft rock	20-40	0.45
Clean sand	10-30	0.40
Lime-treated base[1]	>100	1.00-2.00
Cement-treated base[1,2]		
650 psi or more	>100	1.60
400 psi to 650 psi	>100	1.40
400 psi or less	>100	1.05

1 The strength of lime-treated and cement-treated bases depends on soil properties and construction procedures. Treated bases are also subject to long-term failure due to continuing chemical reactions over time.

2 Compressive strength at 7 days.

Note: The values listed above are general guidelines. More exact thickness equivalency factors can be determined by comparing the CBR of the available aggregate to the design CBR of 80. For example, an aggregate with a CBR of 55 would have an approximate thickness equivalency factor of 55/80 = 0.69.

geotextile fabric best meets your project requirements.

There are two major types of geotextile fabric: woven and nonwoven. Woven fabrics have filaments woven into a regular, usually rectangular, pattern with openings that are fairly evenly spaced and sized. Nonwoven fabrics have filaments connected in a method other than weaving, typically needle punching or head bonding at intersection points of the filaments. The pattern and the spacing and size of the openings are irregular in nonwoven fabrics. Woven fabrics are usually stronger than nonwoven fabrics of the same fabric weight. Woven geotextiles typically reach peak strength at between 5 and 25 percent strain. Nonwoven fabrics have a high elongation of 50 percent or more at maximum strength.

Table 11-4, page 11-9, provides information on important criteria and principle properties to consider when selecting or specifying a geotextile for a particular application. The type of equipment used to construct the road or airfield pavement structure on top of the geotextile must be considered. Equipment ground pressure (in psi) is an important factor in determining the geotextile fabric thickness. A thicker fabric is necessary to stand up to high equipment ground pressure *(see Table 11-5, page 11-10).*

Once the required degree of geotextile survivability is determined, minimum specification requirements can be established based on ASTM standards *(see Table 11-6, page 11-10).* After determining the set of testing standards the geotextile will be required to

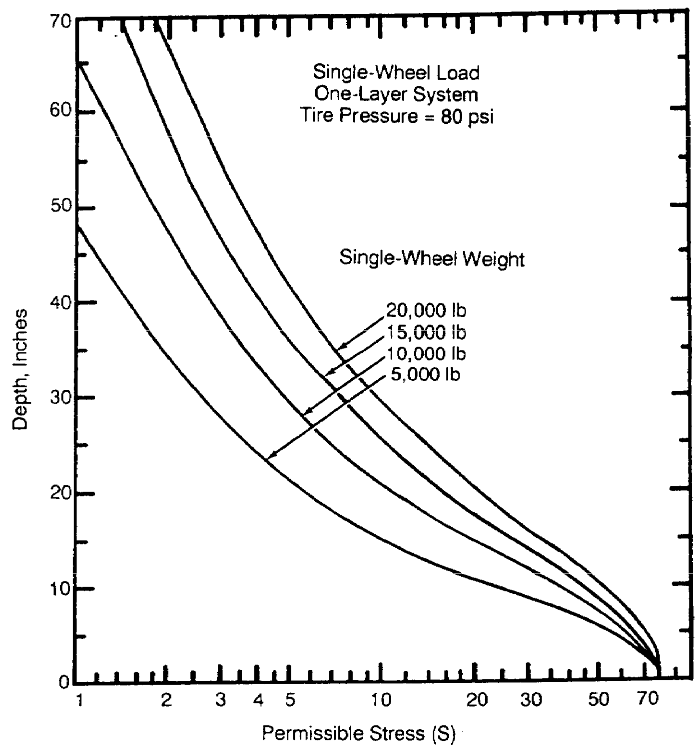

Figure 11-5. Thickness design curve for single-wheel load on gravel-surfaced pavements.

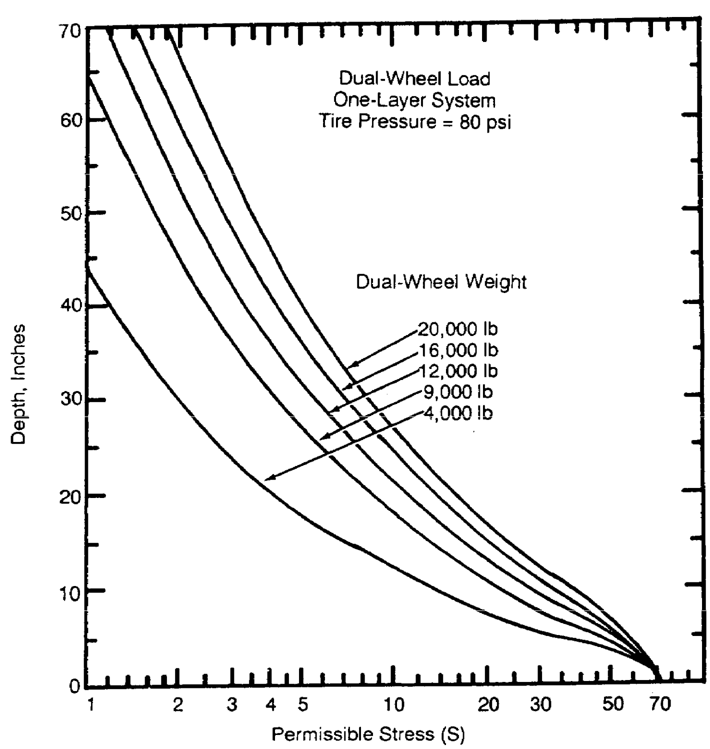

Figure 11-6. Thickness design curve for dual-wheel load on gravel-surfaced pavements.

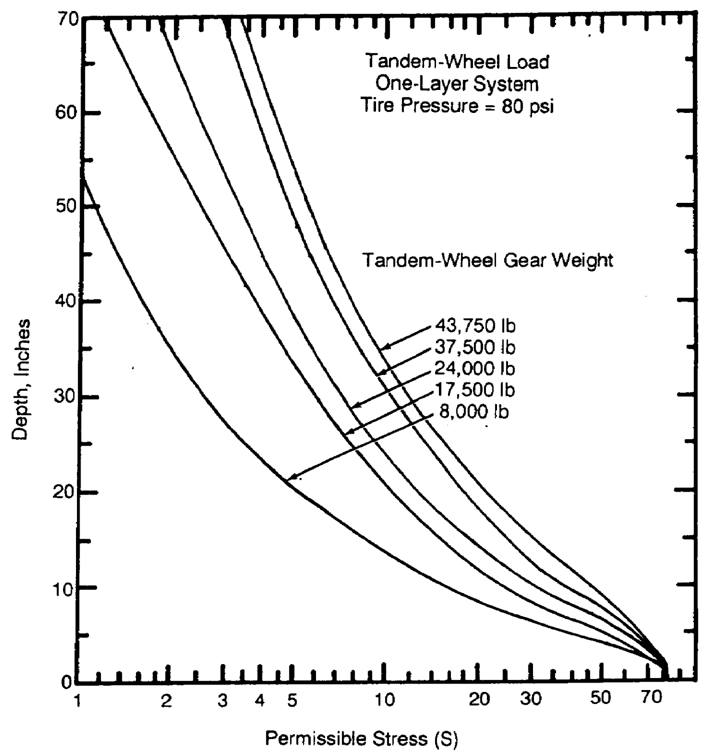

Figure 11-7. Thickness design curve for tandem-wheel load on gravel-surfaced pavements.

withstand to meet the use and construction requirements, either specify a geotextile for ordering or evaluate on-hand stock.

Roadway Construction

There is no singular way to construct with geofabrics. However, there are several applications and general guidelines that can be used.

Prepare the Site. Clear, grub, and excavate the site to design grade, filling in ruts and surface irregularities deeper than 3 inches (see *Figure 11-8, page 11-11*). Lightly compact the subgrade if the soil is CBR 1. The light compaction aids in locating unsuitable materials that may damage the fabric. Remove these materials when it is practical to do so.

When constructing over extremely soft soils, such as peat bogs, the surface materials, such as the root mat, may be advantageous and should be disturbed as little as possible. Use sand or sawdust to cover protruding roots, stumps, or stalks to cushion the geotextile and reduce the potential for fabric puncture. Nonwoven geotextiles, with their high elongation properties, are preferred when the soil surface is uneven.

Lay the Fabric. The fabric should be rolled out by hand, ahead of the backfilling and directly on the soil subgrade. The fabric is commonly, but not always, laid in the direction of the roadway. Where the subgrade cross section has large areas and leveling is not practical, the fabric may be cut and laid transverse to the roadway. Large wrinkles should be avoided. In the case of wide roads, multiple widths of fabric are laid to overlap. The lap length normally depends on the subgrade strength. *Table 11-7, page 11-12,* provides general guidelines for lap lengths.

Lay the Base. If angular rock is to form the base, it is a common procedure to first place a protective layer of 6 to 8 inches of finer material. The base material is then dumped directly onto the previously spread load,

Table 11-4. Criteria and properties for geotextile evaluation.

Criteria and Parameter	Property	Application			
		F	D	S	R
Design Requirements					
Mechanical strength					
Tensile strength	Wide-width strength	–	–	–	x
Tensile modulus	Wide-width modulus	–	–	–	x
Seam strength	Wide width	–	–	–	x
Tension creep	Creep	–	–	–	x
Soil-fabric friction	Friction angle	–	–	–	x
Hydraulic					
Flow capacity	Permeability,	x	x	x	x
	Transmissivity	–	x	–	–
Piping resistance	Apparent opening size (AOS)	x	–	x	x
Clogging resistance	Pommetry	x	–	x	x
	Gradient ratio	x	–	–	–
Constructability Requirements					
Tensile strength	Grab strength	x	x	x	x
Seam strength	Grab strength	x	x	x	x
Bursting resistance	Mullen burst	x	x	x	x
Puncture resistance	Red puncture	x	x	x	x
Tear resistance	Trapesoidal tear	x	x	x	x

F – Filtration
D – Drainage
S – Separation
R – Reinforcement

pushed out over the fabric, and spread from the center using a bulldozer. It is critical that the vehicles not drive directly on the fabric nor puncture it. Small tracked bulldozers with a maximum ground pressure of 2 psi are commonly used. The blade is kept high to avoid driving rock down into the fabric. Finally, compaction and grading can be carried out with standard compaction equipment. If the installation has side drains, these are constructed after the pavement.

Earth Retaining Walls

As with road construction, there is no specific or preferred method for using geotextiles for retaining walls. *Figure 11-9, page 11-13,* shows one method that can be adapted to the specific needs of the engineer. The backfill material can be coarse-grained, fine-grained, or alternating layers of coarse- and fine-g-rained materials.

Construction on Sand

Construction on sand, such as a beach or a desert, presents a severe trafficability problem. The construction of an expedient road through this soil can be expedited by using a plastic geocell material called “sand grid”. This material is in the Army’s inventory stockage (National Stock Number (NSN) 5680-01-198-7955). The sand grid is a honeycomb-shaped geotextile measuring 20 feet long, 8 feet wide, and 8 inches deep when

Table 11-5. Geotextile survivability for cover material and construction equipment.

Cover Material	6- to 12- Inch Initial Lift Thickness		12- to 18- Inch Initial Lift Thickness		18- to -24 Inch Initial Lift Thickness	>24-Inch Initial Lift Thickness
	Low Ground-Pressure Equipment <4 psi	Medium Ground-Pressure Equipment >4 psi, <8 psi	Medium Ground-Pressure Equipment > 4 psi, <8 psi	High Ground-Pressure Equipment >8 psi	High Ground-Pressure Equipment >8 psi	High Ground-Pressure Equipment >8 psi
Fine sand to ±2-inch-diameter gravel, round to subangular	Low	Moderate	Low	Moderate	Low	Low
Coarse aggregate with diameter up to one-half proposed lift thickness, may be angular	Moderate	High	Moderate	High	Moderate	Low
Some to most aggregate with diameter greater than one-half proposed lift thickness, angular and sharp-edged, few fines	High	Very high	High	Very high	High	Moderate

Notes: 1. For special construction techniques such as prerutting, increase geotextile survivability requirement one level.
2. Placement of excessive initial-cover material thickness may cause bearing failure of soft subgrades.

Table 11-6. Minimum properties for geotextile survivability.

Required Degree of Geotextile Survivability	Grab Strength [1] lb	Puncture Strength [2] lb	Burst Strength [3] psi	Trap Tear [4] lb
Very high	270	110	430	75
High	180	75	290	50
Moderate	130	40	210	40
Low	90	30	145	30

[1] ASTM D 4632
[2] ASTM D 4833
[3] ASTM D 3786
[4] ASTM D 4533, either principal direction

Note: All values represent minimum average roll values (for example, any roll in a lot should meet or exceed the minimum values in this table). These values are normally 20 percent lower than manufacturer-reported typical values.

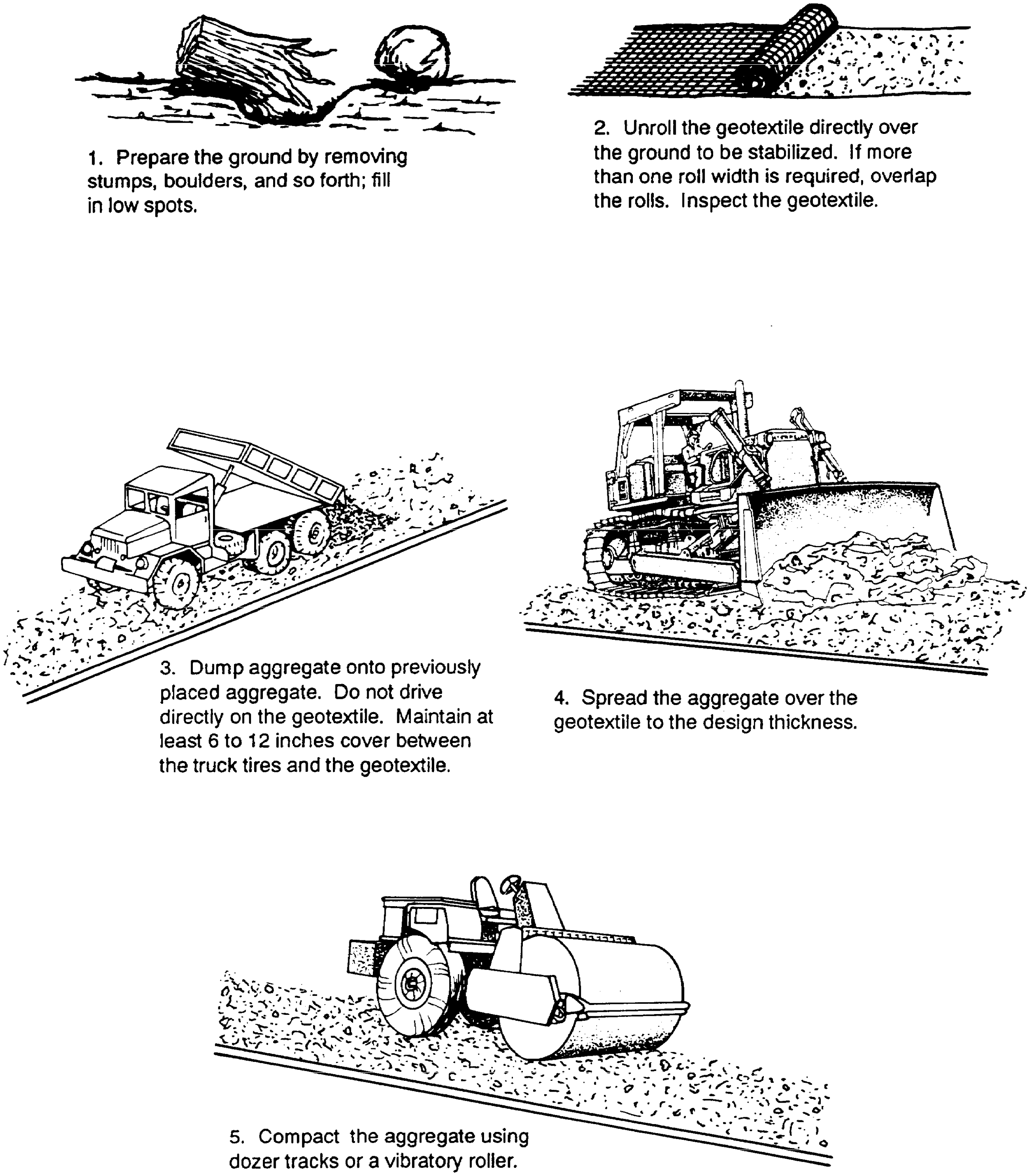

Figure 11-8. Construction sequence using geotextiles.

Table 11-7. Recommended minimum overlap requirements.

CBR	Minimum Overlap
> 2	1 – 1.5 feet
1 – 2	2 – 3 feet
0.5 – 1	3 feet or sewn
< 0.5	Sewn
All roll ends	3 feet or sewn

fully expanded (see *Figure 11-10, page 11-14).*

Sand grids are very useful when developing a beachhead for logistics-over-the-shore (LOTS) operations. Construction of sand-grid roadways proceeds rapidly. A squad-sized element augmented with a scoop loader, light bulldozers, and compaction equipment are all that is required to construct a sand-grid road.

Procechures. Use the following construction procedures for a sand-grid road:

- Lay out the road. Establish a centerline that follows the course of the proposed road.
- Perform the earthwork necessary to level the roadway.
- Distribute folded sand grids along the roadway.
- Expand the sand-grid sections and secure them in place. Use shovels to fill the end cells and some of the side cells with sand.
- Use a scoop loader to fill the grids. They should be overfilled to allow for densification when compacted.
- Compact the sand, using compaction equipment.
- Use a scoop loader to back drag excess sand to the road shoulder area if asphalt or gravel surfacing is used.
- If available, apply an asphalt surface treatment over the filled sand grids to enhance their service life.

Sand grids perform well under wheeled-vehicle traffic. Tracked-vehicle traffic is very destructive to the sand-grid road. Asphalt surface treatments reduce sand-grid damage when a limited number of tracked vehicles must use the road.

Maintenance. Sand-grid roads are easily maintained. Entire damaged sections can be removed or the damaged portion can be cut and removed and a new grid fitted in its place.

Sand grids have many uses in the theater of operations other than just roads. They can also be used to construct bunkers, revetments, retaining walls, and a host of other expedient structures.

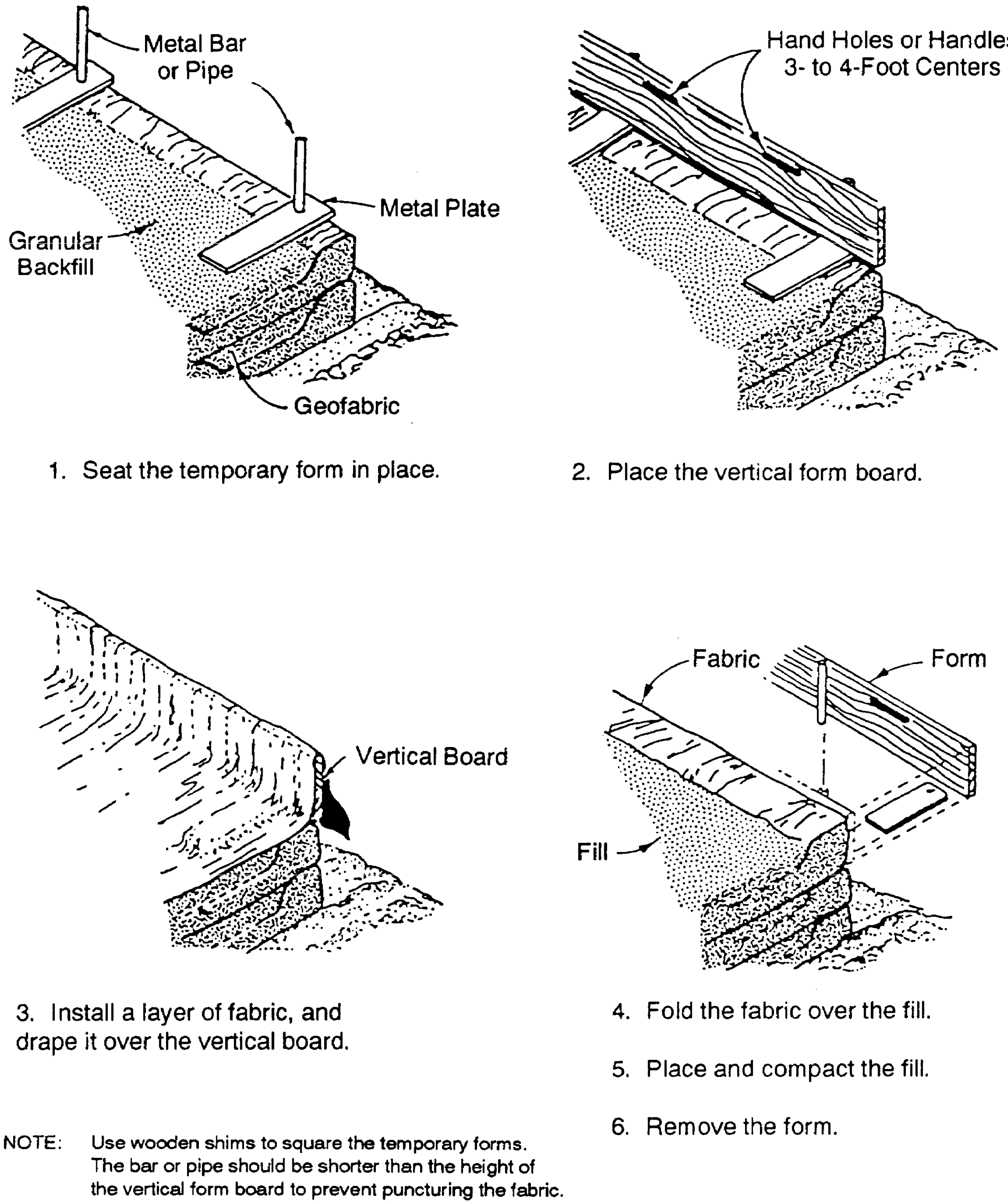

Figure 11-9. Constructing an earth retaining wall using geofabrics.

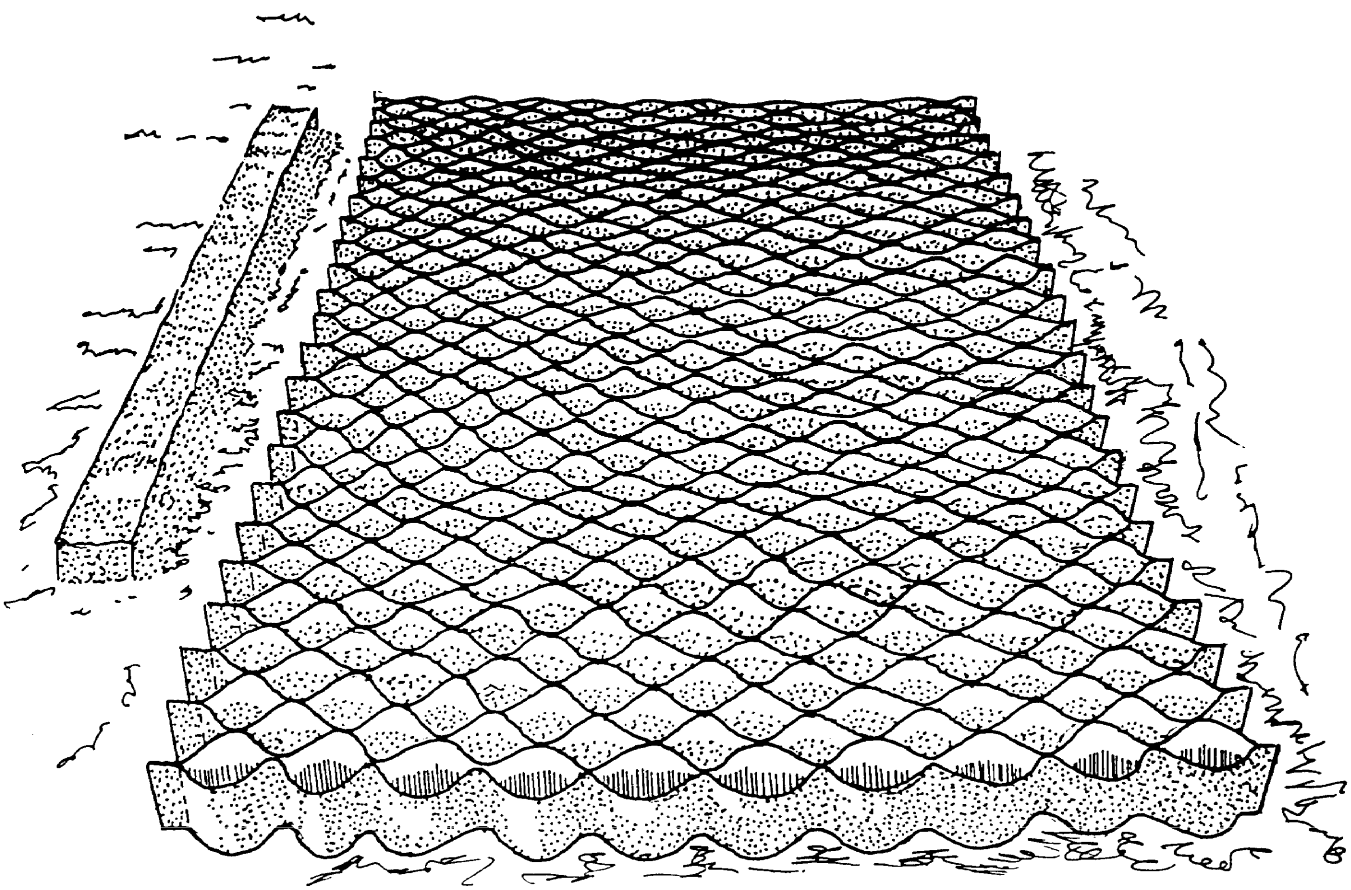

Figure 11-10. Sand grid.