

SEAMING OF GEOSYNTHETICS

Prepared by

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The purpose for overlapping or sewing adjacent geotextile panels in uniaxial reinforcement applications such as mechanically stabilized earth walls, slopes, and embankments is primarily to maintain 100% coverage during the backfilling operation. Maintaining 100% coverage provides 100% of the design strength of the reinforcement to offset the driving soil forces for a specific design. This is the most common design approach for geosynthetic-reinforced soil structures.

Seaming adjacent geotextile panels, either in the factory or in the field, is a means of ensuring that 100% coverage will be maintained during the backfilling operation and is commonly performed when weak sub grade conditions exist as the platform for direct geotextile placement. Seaming adjacent geotextile panels also allows for the rapid deployment of geotextile over a large area and is particularly useful when the sub grade conditions are weak and/or the access is poor, such as when underwater placement is required. Figure 1 is an illustration of a fabricated geotextile panel being installed in an area where weak sub grade conditions are present.

OVERLAPPING VS. SEAMING

The decision to use an overlap or seam is based on the following: 1) the weakness of the sub grade upon which the geosynthetic is directly placed with respect to the potential for mud waving during the backfill operation, 2) the material and labor costs of deploying individual geosynthetic panels with extra material required for the overlap versus the material and labor costs of seaming and installing large, fabricated panels, 3) the feasibility of deploying individual geosynthetic panels in poor access and/or climatic conditions and 4) required seam strength being achievable.



Figure 1. Seamed Geotextile Panel

Table 1 is provided as a guide for determining overlap requirements for separation/stabilization applications based on sub grade strength and suggest that when the sub grade soils upon which the geotextile is directly placed provides a shear strength less than $CBR = 0.5$, the designer should require adjacent geotextile panels to be seamed. A simple cost analysis generally indicates sewing to be economical when overlaps of 1 m (3 ft) or greater are required. Therefore, further consideration should be given to seaming adjacent geotextile panels when the sub grade shear strength is between $CBR = 0.5$ to 1.0.

Table 1. AASHTO M288-06 Guidelines for Geosynthetic Overlap Requirements as a Function of Soil Sub grade Strength

Soil CBR	Minimum Overlaps
>3	0.3 – 0.45 meters
1 – 3	0.6 – 1 meters
0.5 – 1	1 meter or sewn
< 0.5	sewn

SEAM TYPES, APPURTENANCES AND EFFICIENCIES

To ensure that adequate seam strength is developed for a specific project, the designer should consider the factors that affect the seam strength, such as geotextile type and strength, thread type, stitch density and type, seam type, and sewing equipment. However, the designer should emphasize the need for specific seam strength rather than detailing the specific methods to be used to develop the seam strength.

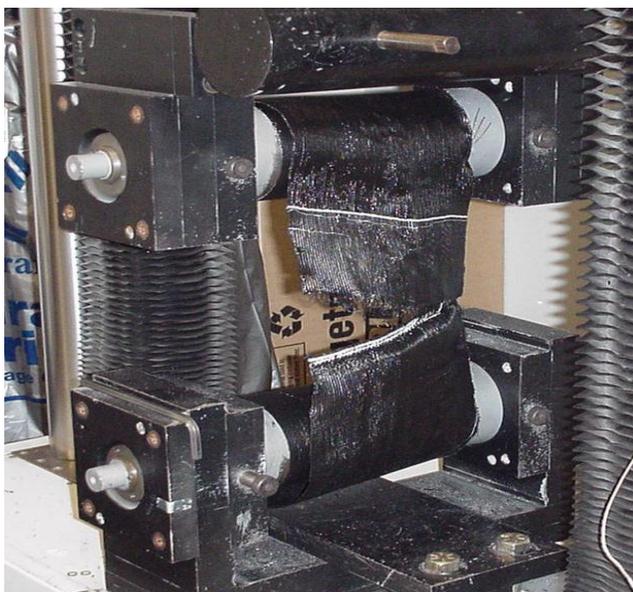


Figure 2. Wide Width Seam Test

Geotextile: The geotextile's ultimate wide width tensile strength in the cross-machine direction is the main component for achieving a required seam strength and is determined based on ASTM D4595 "Standard Test Method for Tensile Properties of Geotextiles by the Wide Width Strip Method". The seam strength test is also conducted on a wide specimen in accordance with ASTM D4884 "Standard Test Method for Seam Strength of Sewn Geotextiles". Figure 2 shows a wide width seam test per ASTM D4884. Although some promising techniques are being researched to provide very high seam efficiencies, seam strengths can often be achieved up to 60% or more of the ultimate wide width tensile strength in the cross-machine direction.

Although maximum seam strengths achieved to date are in excess of 175 kN/m (1000 lbs/in) under factory conditions for a geotextile with a cross-machine direction strength of 350 kN/m (2000 lbs/in) (Koerner, 1994), most standard woven geotextiles available on the market are designed to provide seam strengths up to 52.5 kN/m (300 lb/in.) in the field assuming 50% seam efficiencies are achieved. Geotextiles are often produced for project specific applications in which higher seam strengths are required. However,

higher seam strength requirements result in higher geotextile costs and longer production and delivery schedules.

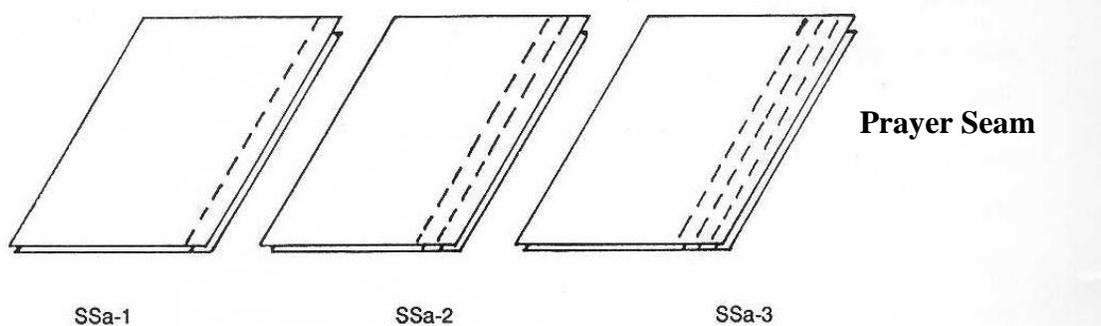
Threads: Thread is most commonly available in Kevlar, nylon, polyester, and polypropylene. Typically, polyester thread is used for seaming higher strength geotextiles with cross-machine direction strengths of 52.5 kN/m (300 lb/in.) or more. Polypropylene thread may be suitable for seaming lower strength geotextiles. Kevlar thread, although very strong, is very expensive. Little benefit has been realized with the use of Kevlar thread since the seam strength is ultimately controlled by the cross-machine direction tensile strength of the base geotextile that is significantly weaker in proportion to the Kevlar thread.

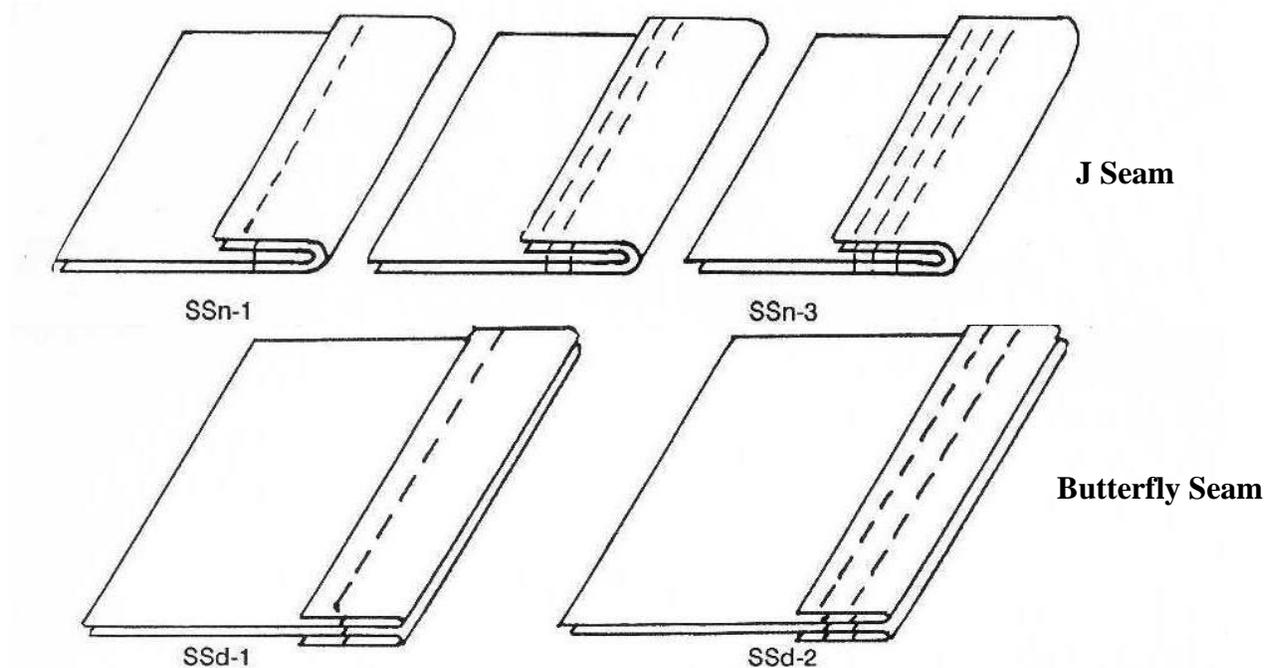
Sewing thread is often specified by weight or denier. Generally, the higher the denier for a certain thread type, the higher the tensile strength of the thread. Therefore, a combination of stitch density and thread size yields the stitch strength per unit length.

Stitch Density: Stitch densities of 3 to 6 stitches per 2.5 cm (1 in.) are commonly used. Higher stitch densities (5 - 6 spi) tend to yield higher seam efficiencies with geotextiles having heavier, tighter base yarns. Consequently, lighter stitch densities yield higher seam efficiencies with "lighter" geotextiles. However, stitches that are too close and/or thread tensions that are too tight tend to cut the geotextile resulting in low seam efficiencies. Therefore, higher stitch densities with "lighter" geotextiles tend to yield poor seam efficiencies because of the excess damage that occurs to the base geotextile yarns by the needle and the cutting action from high sewing thread tensions.

Stitch Type: The industry standard stitch is the type 401 double thread 'lock stitch'. A single row of stitch may be suitable for seaming low strength geotextiles. For required seam strengths of more than 35.0 kN/m (200 lb/in.) or when seaming heavier, higher strength geotextiles, at least two rows of the double thread lock stitch is more commonly preferred.

Seam Type: Three types of seams are commonly used: 1) "flat" or "prayer" seam, 2) "J" seam, and 3) "butterfly" seam. The following diagrams indicate the three seam types.





The "prayer" seam is the easiest to produce and is commonly used for required seam strengths of 17.5 kN/m (100 lb/in) or less. The "J" and "butterfly" seams are more difficult to produce and are commonly used to develop higher seam strengths.

Sewing Equipment: The equipment chosen must be able to fabricate a given stitch geometry with the proper thread type and denier, and should be chosen based on the type of installation, geotextile structure, and the absolute seam strength requirement.



Two types of sewing equipment are most commonly used: a) a single needle, hand-held sewing machine, and b) double needle stitch sewing machine which is typically table-mounted. Figure 3 illustrates the field sewing of geotextiles using the hand-held machine.

Figure 3. Field Sewing with hand-held machine

Figure 4 illustrates factory seaming using a double-needle stitch sewing machine.



Figure 4. Factory Sewing with double-needle machine

Both methods can be used either in the field or in the factory.

Hand-operated sewing machines are often used to develop seam strengths of 17.5 kN/m (100 lb/in) or less for polypropylene fabrics (polyester fabrics will achieve lower seam strengths when sewn with a hand-operated sewing machine), however, a double pass may be required. For higher required seam strengths, the double-needle stitch machine is preferred. It is recommended to have a seam sample tested prior to installation to ensure seam meets project requirements.

Seam Efficiencies: Seam efficiency, determined as the ratio of seam strength to the cross-machine direction geotextile strength, indicates the percentage of strength that can be transferred from one geotextile panel to another. Sewn seams are weaker than the cross-direction strength of the geotextile due to needle damage and stress concentrations at the stitch. Although seam strengths can reach 75% of the cross-direction strength of the geotextile (Sprague, 1992), seam strengths for woven geotextiles most commonly provide efficiencies of 40% to 60% based on ASTM D4884. Table 2 is a guide for seam strength efficiencies based on both of the Grab Tensile Method, ASTM D4632, and the Wide Width Method, ASTM D4884.

It should be noted that, due to a more controlled environment, factory seams generally provide higher seam efficiencies than those developed in the field.

Table 2. Typical Seam Efficiencies

Geotextile Type	Typical Seam Efficiency (% of cross-directional strength)	
	Grab Method (ASTM D4632)	Wide Width Method (ASTM D4884)
Nonwoven	90%	--
Slit-film woven	90%	40% - 60%
Monofilament woven	90%	40% - 60%
High-strength PET woven	90%	30% - 60%

Knowledge of the variables that affect the seam efficiency is essential to a design engineer. There are many possible seam and stitch combinations that can be used with a range of geotextiles to achieve a required seam strength. Table 3 is intended to provide guidance for determining suitable combinations to achieve a required seam strength. It is often difficult for a designer to specify the best method of sewing geotextile sections together with so many variables. Therefore, the design engineer is encouraged to specify seam strength requirements in terms of an absolute value.

Table 3. Guidance for Developing Seam Strengths

Required Seam Strength kN/m (lbs/in)	Suggested Geotextile Cross-Direction Strength kN/m (lbs/in)	¹ Seam Type P / J / BF	Stitch Type (single/double)
18 (100)	35 (200)	P / J	single
35 (200)	53 (300) – 70 (400)	J / BF	double
53 (300)	70 (400) – 105 (600)	J / BF	double
70 (400)	105 (600) – 140 (800)	J / BF	double
88 (500)	175 (1000) – 220 (1250)	J / BF	double
105 (600)	210 (1200) – 263 (1500)	J / BF	double
123 (700)	245 (1400) – 306 (1750)	J / BF	double

¹Where P = Prayer seam, J = "J" seam, and BF = Butterfly seam

DETERMINING SEAM STRENGTH REQUIREMENTS

The requirements for high-strength seams began to surface in the late 1970's and early 1980's as the US Army Corps of Engineers began designing and constructing embankments on weak foundation soils. The Corps began designing with high-strength geotextiles to permit better equipment mobility, allow expedient construction, and provide reinforcement of the embankment to allow construction to the design elevations without failure (Fowler, 1989). Failed seams during fill placement procedures of these experimental projects caused the Corps to more extensively evaluate seam strength requirements for specific site conditions.

As mentioned previously, the need for seaming adjacent geotextile panels' increases as the sub grade shear strength upon which the geotextile is placed decreases. For sub grade shear strengths possessing a CBR = 0.5 or less, roadway design would require the construction of a small embankment of at least 1 m (3 ft.), and the adjacent geotextile panels used for reinforcement underneath the embankment are required to be seamed. In addition to facilitating installation and maintaining separation between the newly placed fill and the poor foundation soils, the seam requirement is such to ensure continuity across individual geotextile panels so that 100% coverage, and therefore 100% of the designed strength, is provided. Thus, the seam strength provided between adjacent geotextile panels can be critical.

The seam is under the greatest stress during the initial fill placement, as the soil forces are unbalanced across the seam. In order to construct over such a weak foundation, the initial lift of fill in these applications may need to be as much as 0.6 to 1m (2 to 3 ft.). Under such a load, the weak foundation soils underneath the geotextile may have a tendency to laterally and longitudinally squeeze. If foundation squeeze occurs, friction will develop on the underside of the geotextile and cause a drag force across the seam. Note that in the application of reinforcing an embankment constructed on weak foundation soils, the geotextile is placed with the seams oriented perpendicular to the centerline of the embankment, and the fill is spread across the seams.

As discussed, stresses across the seam result from foundation movement where soils are very soft and create a mud "wave" or "flow" that drags on the underside of the geotextile. By knowing the shear strength of the mud wave and the length along which it drags against the underneath portion of the geotextile, the spreading force induced on the underside of the geotextile can be calculated. This condition, of course, is only applicable if foundation squeeze is likely to occur during the initial fill placement. Therefore, it is essential to first determine whether foundation squeeze will occur from the maximum loading condition associated with the initial fill lift and the construction equipment used for placing the fill.

Foundation squeeze will occur if the active or driving pressure associated with the initial fill and construction equipment, exceeds the passive or resisting pressure from the underlying foundation soils acting to resist squeeze. The calculation for determining foundation squeeze potential is as follows:

$$P_a - P_p = -4c + (\square) + q \quad (1)$$

where P_a = active pressure, P_p = passive pressure, c = foundation shear strength, \square = overburden from initial lift of fill, and q surcharge load from construction equipment.

If P_a is greater than P_p , foundation squeeze will likely occur (Fowler, 1989); therefore, seam strength is required.

Performing this calculation for 1 m (3 ft) of fill and 28 kPa (4 psi) ground pressure equipment, the required cohesion of the underlying foundation soils to resist foundation squeeze is approximately 12 kPa (240 psf). Therefore, the requirement to seam geotextiles seems justified when sub grade shear strengths of CBR = 0.5 (310 psf) or less are present.

The seam strength required to resist the unbalanced soil forces present during the filling operation can be calculated as follows (Fowler, 1989):

$$\text{Seam Strength} = (L_d) (C_r) (FS) \quad (2)$$

where: L_d = expected length of mud wave movement
 C_r = remolded shear strength of foundation soils
 FS = factor-of-safety (1.5 typical)

For example, the seam strength required when placing fill on a sub grade with a shear strength of 2.4 kPa (50 psf), assuming a length of mud wave movement of 15 m (49 ft) is:

$$\text{Seam Strength} = (15 \text{ m})(2.4 \text{ kPa})(1.5) = 54 \text{ kN/m} (310 \text{ lb/in})$$

The difficulty with this calculation is in the estimation of the expected length of mud wave movement, unless, of course the length of geotextile placed ahead of the fill placement is controlled. Then the length of mud wave movement can conservatively be taken as the length of geotextile placed ahead of the fill. However, in reality, the length of mud wave movement is a function of the remolded shear strength of the foundation soils with lower shear strength soils developing larger and longer mud wave movements. Therefore, it is reasonable to expect that the required seam strength should increase with weaker foundation shear strengths. For guidance purposes, Table 4 provides minimum recommended seam strengths as a function of the remolded foundation shear strengths. These values are developed based on TenCate Geosynthetics North America's experience with consideration given to the above calculations and are entirely sensitive to the fill weight, proper fill placement and operation procedures. It should be noted that the construction procedures and equipment utilized in placing fill on a geotextile underlain by weak foundation soils is critical to the seam performance. For details regarding proper fill placement techniques, the designer should refer to Fowler, 1989.

Table 4. Recommended Seam Strengths

Remolded Foundation Shear Strength kPa (psf)	Recommended Minimum Seam Strengths kN/m (lbs/in)
< 2.4 (50)	70 (400) +
2.4 (50) – 7.2 (150)	53 (300) – 70 (400)
7.2 (150) – 12.0 (250)	35 (200) – 53 (300)
12.0 (250) – 16.8 (350)	18 (100) – 35 (200)

It should be noted that the remolded shear strength can be as low as 10% to 20% of the in-situ shear strength of the sub grade.

SUMMARY

Seaming adjacent geotextile panels is a means of ensuring that 100% coverage will be maintained during the backfilling operation and is commonly performed when weak sub grade conditions exist as the platform for direct geotextile placement. Seaming adjacent geotextile panels also allows for the rapid deployment of geotextile over a large area.

Based on current state-of-practice guidelines, designers should require seaming of adjacent geotextile panels when the sub grade CBR is 0.5 or less. However, further consideration should be given to seaming geotextiles as a more economical means of deployment when the CER is between 0.5 and 1.0 where a 1 m (3 ft.) overlap is otherwise required or where difficult access conditions exist.

Factors that affect the seam strength of a geotextile include geotextile cross-direction strength, seam type, thread type, stitch type and density, and sewing equipment. However, the designer should emphasize the need for specific seam strength rather than detailing the specific methods to be used to develop the seam strength. Although seam strengths can reach efficiencies greater than 75% of the ultimate cross-direction strength of the geotextile, typical seam efficiencies are between 40% to 60%. Most standard woven geotextiles are designed to provide seam strengths up to 52.5 kN/m (300 lb/in.). However, geotextiles are often produced for project specific applications in which higher seam strengths are required.

Finally, guidance for developing seam strengths and a means of determining seam strength requirements based on project specific conditions have been provided. However, the construction procedures and equipment utilized in placing fill on a geotextile underlain by weak foundation soils is critical to the seam performance.

REFERENCES

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APPENDIX A

GEOTEXTILE SEAMING QUICK REFERENCE GUIDE

GEOTEXTILE SEAMING TECHNIQUES

Introduction

Geotextile connections can be a critical part of any project or specification requirement. This document is meant to clarify potential confusion regarding geotextile seams and to provide general guidelines for seaming geotextiles.

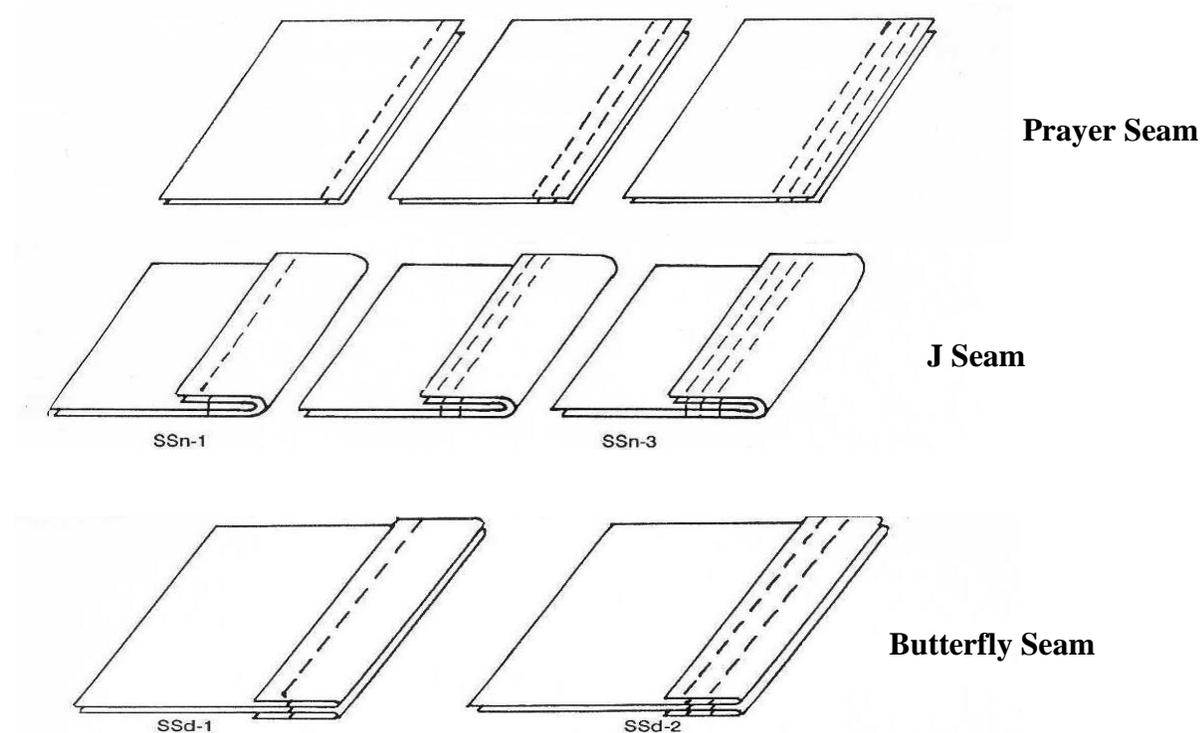
General

In some applications, sewing is used as a means of eliminating the expense and time of overlaps. Normally, a sewn seam will require a few inches of geotextile from each roll, compared to overlap which may use two to three feet. Both woven and nonwoven geotextiles can be sewn.

If an application requires stress transfer from one geotextile roll to another, sewing becomes necessary and critical. As the strength required across the seam increases, details of the sewn seam such as seam type, sewing equipment, sewing thread, and field versus factory sewing become more important.

Seam Type

The three seam types commonly used for geotextiles are shown below. Each of these seam types can be sewn with varying threads, stitch types, varying numbers of stitch lines and number of stitches per inch of seam.



Two stitch lines are sometimes required when a high degree of confidence in the seam integrity is necessary. Lightweight fabrics with low strength requirements may only require one row of stitches. Typical stitch counts, or stitches per inch, range from and 3 to 7, depending on sewing machine, seam type, and geotextile strength. The following table is recommended seam type and stitch type for various required seam strengths.

Required Seam Strength kN/m (lbs/in)	Suggested Geotextile Cross-Direction Strength kN/m (lbs/in)	¹ Seam Type P / J / BF	Stitch Type (single/double)
18 (100)	35 (200)	P / J	single
35 (200)	53 (300) – 70 (400)	J / BF	double
53 (300)	70 (400) – 105 (600)	J / BF	double
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¹Where P = Prayer seam, J = “J” seam, and BF = Butterfly seam

Sewing Machinery and Equipment

Sewing machinery is divided into two categories. The first is portable or hand-held equipment, used for lightweight, low strength geotextile seams. These hand-held machines sew one stitch line and, depending on the manufacturer, utilize either a lockstitch or chain stitch. Union Special 2200 hand held portable machines are typically used for hand-held seaming. Field-sewn seams requiring two stitch lines will need two passes with a lightweight sewing machine.

When seam strengths over 35.0 kN/m (200 lbs/in) are required, or when heavier fabrics are specified, a heavy-duty sewing machine must be used. This is required for the needle to penetrate the fabric and/or to accommodate a larger needle to carry the sewing thread. These machines normally are table or equipment mounted and come with both single head and double head connections. The standard stitch type is a lockstitch. Union Special 80200Z heavy-duty machines are typically used for double-needle seaming.

Sewing Thread

Thread is most commonly available in Kevlar, nylon, polyester, and polypropylene. Typically, polyester thread is used for seaming higher strength geotextiles with cross-machine direction strengths of 52.5 kN/m (300 lb/in.) or more. Polypropylene thread may be suitable for seaming lower strength geotextiles. Kevlar thread, although very strong, is also very expensive. Little benefit has been realized with the use of Kevlar thread since the seam strength is ultimately controlled by the cross-machine direction tensile strength of the base geotextile which is significantly weaker in proportion to the Kevlar thread.

Additional Seaming Tips from:

“Your Guide to Sewing Geosynthetics” provided by Union Special Industrial Sewing Equipment

Tip #1 Use three people. Three people make the job move faster and reduce the chance of job downtime. The first person holds and helps support the weight of the two pieces of geotextile and aligns the two edges of the geotextile. The second person holds and guides the sewing machine, being careful not to allow the weight of the geotextile to put excessive stress on the sewing machine needle, causing the needle to break. The third person helps support the geotextile after it has been sewn and checks the quality of the stitching.

Tip #2 Two sewing machines at the job site. It is much less expensive to purchase a second sewing machine as a backup than to pay idle workers and idle earth moving equipment should the first sewing machine be down for maintenance.

Tip #3 Keep the wind from blowing the thread off the cones. On windy days, the thread may have a tendency to ravel off the cones. What you can do is cut the feet out of ladies' nylons, snip off the toe and put them over the thread cones to keep the thread from blowing in the wind.

Tip #4 There is a short learning curve using a sewing machine, so try to choose the same people to operate the sewing machine throughout the project.