The Effect of Seam Geometry on Mechanical Properties of Geotextiles

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ABSTRACT: This paper presents the findings of an investigative study on the effects of seam geometries on the mechanical properties of seamed geotextiles. In this study, wide width tensile strip, grab and CBR cone plunger mechanical tests were conducted on three types of non-wovens with similar unit weight. The seamed geotextile specimens were jointed together with different seam geometries, flat, lapped, capped, butterfly and J seams respectively. In order to reduce the influence of the stitch geometries and the frictional effect of sewing threads, either single or double rows of 401 type chain stitches, formed with a lightweight, smooth sewing thread were adopted in the tests. With respect to the tensile strip and grab test results, tensile pulling and frictional type of seam, capped and lapped seams with double rows of stitches have demonstrated that they were suitable for all types of geotextile, even needle punched, and their performance showed superiority over the other seam types depending on the tensile pulling of the flat, butterfly and J seams respectively. All seams withstood punching well, due to the beam effect. In conclusion, a tighter seam can produce a higher strength ratio. Tensile pulling and frictional types of seams, or lapped and capped, provide economical and effective joints. Double stitching rows can provide a better degree of security to the seam, guaranteeing service performance.

1 INTRODUCTION

In engineering projects where geotextiles are employed to serve one or more designated functions, overlapping of fabrics is necessary if fabrics are not sewn together by stitching.

Generally, in Hong Kong projects, the amount of overlapping may vary from 0.5 m to 1 m depending on the functional application and installation environment. Since overlapping of geotextiles does not provide structural continuity of fabrics, which is very important especially in areas of application where very soft soil must be stabilised in land reclamation work, the geotextile is to be laid directly on soft sea mud or where large deformation may be expected and subjected to tidal waves and possible mud waves caused by dumping of fill. The structural integrity of a geotextile is also a pertinent requirement in areas where hazardous conditions are to be found.

In the context of Hong Kong experience in reclamation work, geotextiles are used as a separator to separate the base soil and the granular fill drainage layer. Four to five rolls of geotextiles are usually joined together on the barge by mechanical means, making use of hand-held portable sewing machines, before lowering on to the sea bed with the assistance of divers. The amount of fabric areas which are to be simply overlapped should be kept to a minimum. The major purpose of joining rows of geotextiles together by means of sewing is to reduce the amount of geotextiles consumed and thus the projects can be run cost effectively.

2 SEAMING OF GEOTEXTILES

When two or more pieces of geotextiles are joined together by a sewing operation, the joint between the sewn parts is generally referred to as a seam, which consists of a sequence of stitches. A stitch is formed by either interlacing or interlooping (stitch geometry) of sewing threads through a folded or lapped fabric structure (seam geometry) in a sewing operation.

The interlaced stitch is called the lock stitch, whereas the interlooped stitch is called the chain stitch. Generally, chain stitch types of stitches are commonly employed and have proven effective in performance in geotextiles in field sewing operations in Hong Kong projects. They are usually performed insitu by hand held portable sewing machines.

The two types of chain stitch used in Hong Kong are the 101 and 401 chain stitch types. The 101 chain stitch is a single thread chain stitch, formed by penetration of needle thread loops through the geotextile and interlooped with each other end to end in a row on the under side of the fabrics. The 401 chain stitch is a multithread chain stitch, usually two thread chain stitch, and is formed by penetration of needle thread loops through the fabrics and interlooped with the bobbin thread on the under side of the fabrics. The two types of chain stitch are as shown in Figure 1.

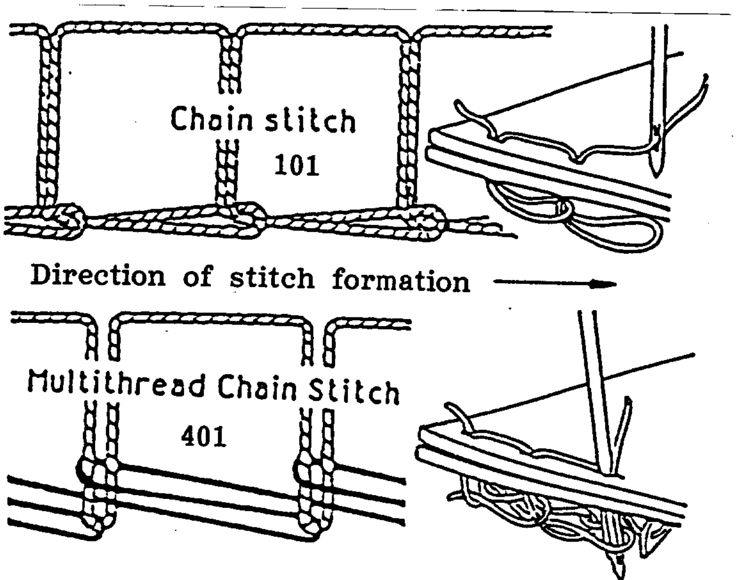


Figure 1 Stitch geometry

The 401 chain stitch type offers superior seam strength and provides additional protection to the structural integrity of the seam as a result of possible breakage of sewn thread at the seam caused by the geotextile scratching onto the insitu sharp protruding objects during field installation. Individual threads in the 401 chain stitch must be broken before the seam can be said to have failed.

In this investigative study, in order to eliminate the effects of different seam geometries on the mechanical characteristic behaviour of seams, only one stitch type was adopted throughout for all of the seam tests. Chain stitch type 401 was selected for the study, the stitches formed on the fabrics being either in single, or double rows. The distances between the edges of the fabrics and the first row of stitches, and between the rows of stitches, were each 15mm.

Ko (1987) reported that the seaming geometries can be categorized into four basic classes. However, in this study, a different interpretation of the seaming geometries is presented. The types of seam geometries adopted in this study were flat, lapped, capped, butterfly and J seams. They are as shown in Table 2.

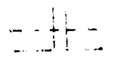
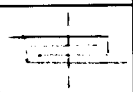
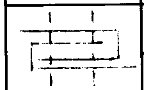
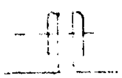
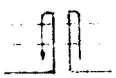
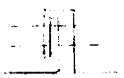
The structural backbone of a seam is the sewing threads. They are usually in the form of highly twisted linear fibre assemblies available in a wide range of sizes. The size of a sewing thread is usually expressed in terms of the linear density unit, tex; the weight in grams of 1000 m of yarn. The typical size of geotextile sewing thread is in the range of 46 to 560 tex. The majority of sewing threads are made of polyester and polypropylene, as are the geotextiles themselves. Appropriate fibre type, twisted geometry and sewing thread size can be designed and manufactured to meet different engineering end use requirements. Since the seams are formed by interlacing or interlooping the sewing threads through geotextiles, the frictional behaviour and the stress-strain behaviour of thread in looped configuration should be taken into consideration during selection (Diaz, 1985). The

Table 1 Physical and mechanical properties of geotextiles

Properties	Type	GT1	GT2	GT3
Prolymer		PET.cf[a]	PP.cf[b]	PP.cf[b]
Manufacturing process		Spun bonded	Heat bonded	Needle punched
μ (g/m^2)		132.4	135.4	128.9
Tensile strength (kN/m)	MD	5.47	5.3	7.78
	XD	4.58	6.56	6.34
ε_f(%)	MD	30.4	79	142.2
	XD	31.2	94.3	95
Grab (N)	MD	580	588	724
	XD	460	680	706
ε_f(%)	MD	32.53	54.13	105.2
	XD	30.4	73.84	74.93
Tear strength (N)	MD	137.41	304.84	380.84
	XD	157.47	377.72	342.76
CBR plugner strength (N)		916.3	1178.3	1280.2
Puncture energy (Nm)		14.1	23.9	29.7

a. PET.cf=Continuous polyester filament.
b. PP.cf=Continuous polypropylene filament.

Table 2 Mechanical strength ratios of seamed to unseamed, S_s/S_u of geotextiles for different seam geometries

Geotextile type			GT1 (Spun Bonded)			GT2 (Heat Bonded)			GT3 (Needle Punched)		
Seam geometry		Strength	WW tensile	Grab	CBR	WW tensile	Grab	CBR	WW tensile	Grab	CBR
			S_s/S_u	S_s/S_u	S_s/S_u	S_s/S_u	S_s/S_u	S_s/S_u	S_s/S_u	S_s/S_u	S_s/S_u
Virgin		MD	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
		XD	1.00	1.00		1.00	1.00		1.00	1.00	
Flat seam		MD			0.96						
		XD			0.83						
		MD	0.68	0.53	1.03	0.77	0.50	0.73	0.54	0.49	0.90
		XD	0.64	0.78		0.51	0.35		0.73	0.63	
Lapped seam		MD			1.26						
		XD			1.33						
		MD	1.05	1.11	1.35	1.14	1.11	1.46	0.98	0.95	1.45
		XD	1.20	1.22		0.78	0.85		0.94	0.96	
Capped seam		MD	0.66	0.77	1.64				0.41	0.50	1.49
		XD	1.00	0.90	1.63				0.44	0.40	0.86
		MD	1.03	0.99	1.83	1.15	1.09	2.37	0.69	0.82	1.98
		XD	1.23	1.23	1.96	0.90	0.88		0.85	0.70	1.89
Butterfly seam		MD	0.77	0.71	1.22				0.37	0.46	1.75
		XD	0.89	0.90	1.44				0.37	0.40	1.28
		MD	0.72	0.76	1.68				0.34	0.36	1.88
		XD	0.73	0.91	2.51				0.46	0.29	1.53
J seam		MD	0.68	0.67	1.20				0.36	0.65	1.32
		XD	0.80	0.85	1.68				0.42	0.49	1.35
		MD	0.74	0.67	1.70				0.33	0.45	1.91
		XD	0.70	0.82	1.96				0.63	0.50	1.23

Legend : MD = machine direction. For samples with seam, the seam is joining both fabrics in the machine direction.
XD = cross direction. For samples with seam, the seam is joining both fabrics in the cross direction.

Notes : Values presented are mean value from a minimum of five test results.
Wide width strip tensile tests were performed on 100mm width samples.

frictional behaviour of the sewing thread is usually expressed in terms of the coefficient of kinetic friction. A nylon thread will exhibit a coefficient of kinetic friction of 0.44, whereas a value of 0.32 is typical of cotton thread. Generally, the coefficient of friction increases with moisture content increase, and the rise in temperature will enhance friction in thermoplastic thread.

Since the main purpose of this study was to examine the effects of seam geometries on the mechanical properties of seams, a standard sewing thread with an average unit weight of 34.3 tex, a coefficient of kinetic friction of 0.17, average tensile breaking strength of 983 gm, strain at failure of 18.8% and having a corresponding work done of 3791 gm-cm was adopted and used in this study.

The types of geotextiles under investigation in this study were (a) GTI: continuous polyester filament spun bonded nonwoven with heat treatment on one side of the fabric;
(b) GT2: continuous polypropylene filament heat bonded nonwoven; and
(c) GT3: continuous polypropylene filament needle punched nonwoven.

The physical and mechanical properties of the virgin geotextile samples are shown in Table 1.

The seam strength depends on the complex interaction between stitch geometry, seam geometry, sewing thread and the geotextile structure. However, in this study, by elimination of the variabilities caused by the stitch geometries and the sewing threads, the efficiencies of seam geometries on the fabric structures could be fully investigated.

The mechanical properties of the unseamed and seamed geotextile samples under study were wide width strip strength, grab strength and CBR cone plunger strength.

In order to make a comparison between different seam geometries and the number of rows of stitches, the mechanical strength ratios, S_s/S_u of the seamed fabric to the controlled virgin fabrics are as tabulated in Table 2.

3 COMPARISON OF RESULTS BETWEEN DIFFERENT SEAM GEOMETRIES

There were two failure mechanisms observed in the tests on seamed fabrics:

(i) Pure tensile pulling at seam; and
(ii) Tensile pulling with frictional interactions between thread-fabrics, and fabric-fabric itself.

Type (i) type of failure modes were observed in flat, butterfly and J types of seams, whereas type (ii) type of failure were observed in lapped and capped types of seams.

In the type (i) type of failure mechanism, when the seamed fabric was subjected to a tensile load, the load was totally exerted on to the sewing threads at the seam, and very little thread-fabric friction was generated to enhance the resistance against tensile pulling. Thus, the seam failed as the applied load exceeded the tensile pulling capacity of the thread or the maximum tensile strength of fabrics, depending on which had the maximum. Failure at the seams was observed in all flat, butterfly and J seams for all geotextiles tested. However, the loose construction and uneven thickness of the needle punched fabric, GT3 could not provide a tight seam and thus exhibited very low tensile strength ratios. Generally, the tightness of the seam will promote the effectiveness of the seam. Hard, rigid spun bonded or heat bonded structures can generally provide good, tight seams and therefore higher tensile strength ratios.

In lapped and capped seams, failures were found in the sample fabrics themselves instead of at the seams. Except for GT3 samples, when capped seams were tested with single rows of stitches, failures occurred at the seams. These may be attributable to poor sewing workmanship and possible fraying of fibres in the fabrics.

In all CBR plunger tests, all the failures occurred at the seams. Due to the "beam" effect, like a beam to a flat slab, by increasing the depth of beam, a stiffer slab can be provided. It is thus shown that thicker seams yield greater punching resistance.

4 CONCLUSION

It may be seen that the lapped seam with two rows of stitches provided the best seam effectiveness in terms of tensile seam strength, followed in second place by the capped seam. Similar results have been reported by the Clothing Institute (Ko, 1987). Nevertheless, these two types of seams may present difficulties for insitu handling, since they must be factory manufactured. By increasing the tensile strength and tex of the sewing thread and stitch density, butterfly and J seams may be considered for on site operation. All the seam types performed well when punching tests were carried out.

REFERENCES

Diaz,V. (1985) Thread selection for geotextiles, *Geotechnical Fabric Report*, Jan/Feb.

Ko, F.K. (1987) Seaming and joining methods, *International Journal of Geotextiles and Geomembranes*, 6:93-107