MURRAY, R. T., Transport and Road Research Laboratory, United Kingdom
McGOWN, A., ANDRAWES, K. Z. and SWAN, D., University of Strathclyde, United Kingdom

TESTING JOINTS IN GEOTEXTILES AND GEOGRIDS

ESSAIS SUR LES JOINTS DANS LES GEOTEXTILES ET GEOTREILLIS

PRÜFUNG DER NÄHTE BEI GEOTEXTILIEN UND GEOGITTERN

Constant rate of strain tensile tests have been conducted on woven and non-woven geotextiles and on geogrids samples jointed by a variety of different methods. The geotextiles have been jointed by sewing or bonding and the geogrids by the use of inserted rods through their openings (bodkin joint). The data obtained from the study showed that some adhesive bonded joints, prepared under laboratory conditions, developed strengths equal to those of the parent materials but all other joints tested were found to be weaker. Moreover, many of the joints developed significant deformations under load which may be important in certain applications.

Die an Mustern von gewebten und nich-gewebten Geotextilien und Geogittern mittels verschiedener Methoden hergestellten Nähte wurden einer Reihe von Konstant spannungs - Zugversuchen unterzogen. Dabei waren die Geotextilien durch Nähen oder Kleben und die Geogitter durch "Zusammenschnüren" ihrer Öffnungen mit Durchsteckstangen zusammengefügt worden. Die mit Hilfe der Studie ermittelten Daten zeigten, daβ einige unter Versuchsverhaltnissen durch Kleben hergestellte Nähte in ihrer Stärke den ursprünglichen Materialien gleichkamen, wohingegen sich alle übrigen Nähte als schwächer erwiesen. An vielen Nähten entwickelten sich auβerdem unter Belastung signifikante Verformungen, was für bestimmte Anwendungen von Bedeutung sein kann.

1. INTRODUCTION

When two pieces of similar or dissimilar geotextiles (or related materials) are attached to each other, this is known as a 'JOINT', and when a geotextile is physically linked to, or cast into another material (e.g the facing panel of a retaining wall), this is known as a 'CONNECTION'. Where no physical attachment is involved between two geotextiles or a geotextile and another material, this is known as an 'OVERLAP'.

This paper describes a comprehensive study into the effectiveness of various techniques for jointing geotextiles. In addition to presenting details of a number of these jointing techniques, results are provided of their effectiveness, in terms of both load and deformation, for various geotextiles of different generic types. The results obtained are considered to form a useful data-base to enable assessments to be made of the performance of these jointing methods tested.

2. JOINT ASSESSMENT

Geotextiles may be joined mechanically, by sewing or stapling, or chemically using an adhesive bond. For materials such as nets, meshes and grids, on the other hand, a bodkin joint may be employed whereby two overlapping sections are coupled together using a bar passed through the apertures.

Ideally joints should have the same performance characteristics as the parent materials. Moreover, the test methods used to assess the joints should correspond closely to those proceudres employed when determining the properties of the parent materials.

An important criterion for assessing joint performance is load transmission. In some applications it may be essential that the load transfer capability is equal to that of the parent material. For other situations a more important criterion may be the magnitude of the deformation of the joint under load. There is thus a need to develop a standard approach for assessing the load transmission performance of various jointing procedures commonly employed for geotextiles and related materials.

In attempting to achieve such an objective it is important to appreciate that where, for example, joints are subject to long-term sustained loading then the testing regime proposed should incorporate sustained load (creep) tests. Such an approach similarly applies for repeated loading or other modes of anticipated loadings and displacements. Such tests are likely to prove expensive and time consuming but they are nonetheless essential if reliable data are to be obtained on joint performance for these regimes. For a large number of situations, however, the data required for specification purposes may be obtained from tensile tests carried out at a constant rate of strain and it is for these applications that the results obtained in this study may be employed.

3. TEST PROGRAMME

3.1. Materials Tested

Four parent materials were tested:

A a woven geotextile, 100% polypropylene tapes of 120 g/m^2

B a non-woven needle punched geotextile, 100% polyester continuous filaments of 210 g/m^2.

C a non-woven melt bonded geotextile, 67% polypropylene and 33% polyethylene continuous filaments of 140 g/m^2

D a grid, 100% H.D.P.E., stretched punched sheets of 950 g/m^2.

The test specimen sizes were 100 ± 1 mm long x 200 ± 2 mm wide for the geotextiles, and 5 bars long x 15 ribs wide for the geogrids.

3.2. Types of Joints

Three different types of joints were investigated. Sewn and bonded joints were used with the geotextiles and bodkin type joints were used with the geogrids.

3.2.1. Sewn Joints

A total of five seam types were invesitgated as shown in Fig. 1 and referred to with the symbols A to E. The joints were made using a portable sewing machine which produced stitch lengths in the range 3 to 8.5 mm and a maximum seam thickness of 9.5 mm. Although all of the seam types were sewn with a single thread chain stitch (class 101) it was possible with this type of machine to also produce a double thread stitch (class 401). Threads made from nylon and 'Kevlar' were used with the woven geotextile, whereas polyester and polypropylene threads were used with the non-woven needle punched and melt bonded geotextiles respectively. All the threads had tensile strengths in the range of 80 to 360 N. Two needle sizes were used, a standard size (200/080) and a larger size (230/090). The seam allowance (defined as the distance from the stitch line to the edge of the fabric) was in the range of 30 to 100 mm. For the 'J-Fold' and 'Butterfly' joints, the distance from the fold line to the stitch line (L, in Fig. 1) was also varied.

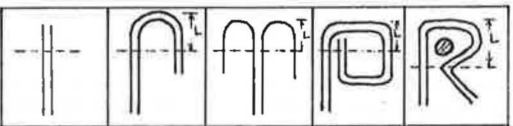
DETAILED SHAPE					
SEAM TYPE	A	B	C	D	E
FEDERAL STANDARD NO 751 (a) INDEX CODE	SSa	SSn	SSd	SSp	-
COMMON NAME	Prayer	J-Fold	Butterfly		

Fig. 1. Seam Types for Sewn Joints

3.2.2. Bonded Joints

Two types of bonded joints were examined, namely shear and tensile joints as shown in Fig. 2. Both liquid adhesives (ADHESIVES) and double-sided adhesive tapes (TAPES) were used for bonding purposes and details of these materials are given in Table 1. Before bonding it was ensured that the surfaces to be jointed were dry and clean.

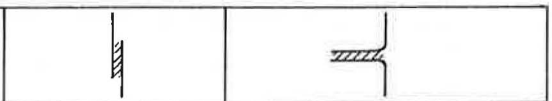
DETAILED SHAPE		
	Shear joint: measuring the longitudinal shear strength of the joint	Tensile joint: measuring the peel strength (or tensile strength along the bond line in the line of pull) of the joint

Fig. 2. Types of Bonded Joints

3.2.3. Bodkin Joints

Three types of joints were examined, as shown in Fig. 3, for a range of bodkins with the following cross-sections; (a) circular, with diameters 10 to 25 mm and made of high density polythylene (HDPE); (b) rectangular, 12 or 18 mm wide by 2.8 or 4.5 mm thick, made of HDPE; (c) rectangular, 4 x 20 mm, made of PVC; (d) a cross-bar cut from the parent material, 4.5 x 15 mm.

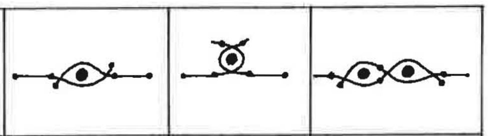
DETAILED SHAPE			
JOINT TYPE	A	B	C

Fig. 3. Bodkin Joint Types

3.3. Test Procedures

The test machine used was capable of applying a constant rate of displacement and all the tests were carried out at a temperature of 20± 2°C, relative humidity of 65± 5% and a constant rate of strain of 2% per minute. For the geotextiles the clamps used contained a pair of serrated jaws with a self-tightening wedge, but for the geogrid, the clamps were designed to constrain the outer-most transverse members (bars) whilst allowing the longitudinal members (ribs) to strain freely. All clamps had universal joints attached in the line of pull to allow rotational freedom during the tests.

The length of each jointed test specimen was equal to that of the parent material plus the length of the joint in the test direction. The width of each jointed test specimen was maintained equal to that of the parent material for bonded and bodkin joints. For sewn joints this width was increased at the seam by 30 mm, (approximately 15 mm each side), if there was any tendency for the stitching to unravel. The jointed test specimens were always taken from the same batch as the parent material test specimens in order to reduce the effects of sample variations.

The rate of displacement for all sewn and bodkin jointed test specimens was increased to take account of their greater gauge length, thus keeping the rate of strain for the parent material and jointed test specimens the same. However, the bonded joints were assumed to be rigid hence the same rate of displacement was used for bonded joint specimens as for the parent material to obtain the same rate of strain.

Prior to commencement of the test on bodkin joints, an initial pre-tension of between 4 and 10 kN/m was applied to the specimen to take up the slack in the joint.

All tests were continued until the peak or rupture load was reached. An automatic graphical recorder was used to provide a continuous load-displacement curve. Photographs of the test specimens were taken at various stages of the tests up to and including rupture.

4. TEST RESULTS

Load-deformation data were obtained from at least 10 specimens of each parent material. Data were similarly obtained from the jointed specimens. It was noted that in spite of taking the test specimens from a single batch, there were variations in the results. If different batches had been used then even larger variations would be expected. Thus it is essential that test specimens for both joints and parent materials are taken from the same batch to minimise the influence of parent material variability when calculating the efficiency of jointing methods.

From the test data, the "Joint Load Carrying Efficiency", (defined as the ratio of the average peak strength of the joint to the average peak strength of the parent material) was calculated. In addition, the "Joint Deformability", (defined as the difference in displacements between the jointed and parent material specimens at any given load), was calculated. In this way, joint load carrying efficiencies and joint deformabilities were obtained for the joints tests and these data together with the observed modes of failure were recorded as shown in Tables 2 to 9 and Plates 1 to 7.

5. DISCUSSION OF RESULTS

5.1. Sewn Joints

For the woven geotextile tested, joint load carrying efficiences of up to 80% were obtained using the "Butterfly" and "J-Fold" types. These were accompanied by large joint displacements of 100 mm or more at peak loads. Greater joint load carrying efficiency and lower joint displacements were, however, obtained by using the modified "J-Fold" type with a solid bar pushed through the loop created by the fold-over. Moreover, the results showed that the "Prayer" type joint gave the lowest load carrying efficiency.

For the non-woven geotextiles tested, fairly high joint load carrying efficiencies (of about 90%) at joint displacements of only 10 to 20 mm were achieved by sewing, provided that the needle sizes and the stitch densities were kept to a minimum. In order to achieve this level of performance, it was found necessary to use "Prayer" joint with a seam allowance of 30 to 50 mm. This is encouraging as this method is the simplest and most straightforward and can be easily fabricated on site.

5.2. Bonded Joints

Some adhesives formed excellent bonds by flowing through the pore spaces of the geotextiles to form a rigid bonded area. Joint load carrying efficiences of about 100% with joint displacements of 0 to 15 mm were achieved for the three geotextiles tested, using 50 mm 'Shear' joints. 'Tensile' joints and tape joints were found to be ineffective. Further, it should be appreciated that fabrication of all types of bonded joints requires that the bonded surfaces be clean and dry, which may prove to be difficult to achieve under normal site conditions.

5.3. Bodkin Joints

These easily fabricated joints were found to be highly effective methods of joining grids. They exhibited joint load carrying efficiencies of over 90% with joint displacements of 15 to 30 mm after pre-tensioning. Care must, however, be taken to ensure that:

(a) the bodkins have sufficient cross-sectional area and strength to avoid them excessively deforming or shearing, yet not be so large as to greatly distort the parent material at the joint and so cause stress concentrations.

(b) the joints are pre-tensioned prior to loading on site in order to reduce joint displacements as the components lock together.

CONCLUSIONS

On the basis of this study, load carrying efficiencies up to 100 per cent with low deformability were shown to be attainable for both woven and non-woven geotextiles by the use of shear-type bonded joints employing liquid adhesives. It is emphasised, however, that these values were achieved under laboratory conditions and may prove more difficult to attain under adverse site conditions. Bonded joints employing double-sided adhesive tapes showed a large variability in load carrying efficiency ranging from about 10 to 40 per cent and were not considered satisfactory.

Sewn joints were shown to attain load carrying efficiencies of up to 90 per cent but they exhibitied rather large joint deformations. Also the most effective form of sewn joint was shown to be dependent on the geotextile type.

The technique of jointing grids and similarly structured materials by means of a bodkin joint proved to be an effective procedure whereby load carrying efficiences of about 90 per cent were obtained. However, it must be noted that it is important to pre-tension these joints in order to reduce deformations.

ACKNOWLEDGEMENTS

The work was carried out at the University of Strathclyde under contract to the Transport and Road Research Laboratory, U.K.

This paper is published by kind permission of the Director of the Transport and Road Research Laboratory, U.K. The views expressed are not necessarily those of the Department of Transport.

Table 1. Details of bonding materials

BONDING MATERIAL		DESCRIPTION	COMMERCIAL NAME
ADHESIVES	A	Solvent-borne synthetic rubber/resin	Bostik IGA 516
	B	Solvent-borne nitrile rubber/resin	Bostik 1755
	C	Solvent-borne clear elastomeric	Scotchgrip 4693
	D	Solvent-borne light coloured spray	Scotchgrip 5A 76
	E	Contact adhesive	Evostick
TAPES	A	Woven polypropylene fabric backing coated with synthetic elastomer adhesive	Scotch Industrial Tape No 397
	B	Clear synthetic rubber adhesive, double sided, with a polyester film backing	Scotch Industrial Tape No 396
	C	Clear transfer double-sided adhesive on a tan paper liner	Scotch Industrial Tape No 950

Table 2. Modes of failure

TYPE	DESCRIPTION OF FAILURE
I	Parent material failure
II	Parent material failure at joint
III	Joint slippage
IV	Joint separation
V	Thread snapped
VI	Longitudinal filaments splitting and sliding through stitch line
VII	Longitudinal filaments sliding until transverse filaments in loop have bunched up close to stitch line. Thereafter as VI
VIII	Slight slippage of joint. Separation of layers within parent material

Table 3. Data for sewn joints, Geotextile 'A'

NEEDLE SIZE: Standard* or Large+			AVERAGE VALUES				
SEAM TYPE	STITCH DENSITY (spi)	SEAM ALLOWANCE (mm)	Peak Load (kN/m)	Strain at Peak Load (%)	Joint Load Carrying Efficiency (%)	Joint Deformability at Peak Load (mm)	MODE OF FAILURE
A	4	60	6.02	70.0	38.6	64.0	VI
A	4	100	6.93	89.7	44.4	82.5	VI
A	8	100	7.58	95.3	48.6	87.0	VI
B L=20mm	8	30	11.79	106.5	75.5	92.5	VII
B L=10mm	8	40	11.15	53.7	71.4	40.0	VII
B L=20mm	4	30	12.44	119.2	79.7	104.0	VII
C L=20mm	8	30	11.02	109.7	70.6	96.0	VII
C L=10mm	8	40	11.34	51.5	72.6	38.0	VII
C L=20mm	4	30	12.76	111.3	81.7	95.5	VII
C L=20mm	4	100	12.53	111.2	80.3	96.0	VII
D L=20mm M=20mm	8	20	11.26	100.7	72.1	87.0	VII
E L=20mm	8	30	14.95	49.2	95.8	29.0	II/VII
A	8	100	8.02	86.5	51.4	77.0	VI
B L=10mm	8	40	13.80	51.8	88.4	33.5	VII
C L=10mm	8	40	13.90	54.8	89.0	36.0	VII

Table 4. Data for sewn joints, Geotextile 'B'

NEEDLE SIZE: Standard* or Large+			AVERAGE VALUES				
SEAM TYPE	STITCH DENSITY (spi)	SEAM ALLOWANCE (mm)	Peak Load (kN/m)	Strain at Peak Load (%)	Joint Load Carrying Efficiency (%)	Joint Deformability at Peak Load (mm)	MODE OF FAILURE
A	4*	30	11.02	56.14	88.3	14.0	V
A	4*	30	11.23	57.08	90.0	13.5	I/II
A	4*	50	11.30	57.66	90.5	13.5	I
A	8*	30	9.99	48.26	80.0	11.0	II
A	4+	30	9.77	55.73	78.3	18.5	II
B L=20mm	4*	30	10.48	57.30	84.0	17.0	II
C L=20mm	4*	30	10.04	46.55	80.4	9.5	II

Table 5. Data for sewn joints, Geotextile 'C'

NEEDLE SIZE: Standard* or Large+			AVERAGE VALUES				
SEAM TYPE	STITCH DENSITY (spi)	SEAM ALLOWANCE (mm)	Peak Load (kN/m)	Strain at Peak Load (%)	Joint Load Carrying Efficiency (%)	Joint Deformability at Peak Load (mm)	MODE OF FAILURE
A	4+	30	5.85	35.15	80.9	20.0	II
A	4+	50	6.35	37.05	87.8	20.0	II
A	4+	70	6.14	34.94	84.9	18.0	II
A	8+	50	5.71	26.28	79.0	11.5	II
B L=20mm	4+	50	6.07	35.47	84.0	18.5	II
C L=20mm	4+	50	6.54	37.37	90.5	18.5	II
A	4*	50	6.33	36.73	87.6	19.5	II
B L=20mm	4*	50	6.59	38.42	91.1	19.5	II

Table 6. Data for bonded joints, Geotextile 'A'

ADHESIVE/TAPE TYPE	DESCRIPTION OF JOINT	AVERAGE VALUES				MODE OF FAILURE
		Peak Load (kN/m)	Strain at Peak Load (%)	Joint Load Carrying Efficiency (%)	Joint Deformability at Peak Load (mm)	
ADHESIVE D	50 mm tensile joint; 24 hours curing time	1.23	30.4	7.9	29.5	IV
ADHESIVE A	50 mm shear joint; 2 days curing time	9.28	21.4	59.4	10.5	III
ADHESIVE A	50 mm shear joint; 4 days curing time	15.17	31.24	97.2	10.0	III
ADHESIVE C	50 mm shear joint; 24 hours curing time	16.33	31.25	104.6	5.0	I
ADHESIVE D	50 mm shear joint; 24 hours curing time	14.06	27.79	90.1	9.0	III
ADHESIVE C	50 mm shear joint; 3 days curing time	8.58	15.2	55.0	6.0	III
TAPE C	25 mm shear joint	1.17	5.7	7.5	5.0	III
TAPE C	50 mm shear joint	2.03	7.6	13.0	5.0	III
TAPE A	25 mm shear joint	1.04	4.75	6.7	4.0	III

Table 7. Data for bonded joints, Geotextile 'B'

ADHESIVE/TAPE TYPE	DESCRIPTION OF JOINT	AVERAGE VALUES				MODE OF FAILURE
		Peak Load (kN/m)	Strain at Peak Load (%)	Joint Load Carrying Efficiency (%)	Joint Deformability at Peak Load (mm)	
ADHESIVE A	50 mm shear joint; 24 hours curing time	8.36	50.9	67.0	18.5	III
"	50 mm shear joint; 3 days curing time	11.74	59.25	94.1	13.0	I/III
ADHESIVE D	50 mm shear joint; 24 hours curing time	5.26	28.34	42.1	8.0	III
"	50 mm shear joint; 3 days curing time	12.00	61.5	96.2	14.5	I/III
"	75 mm shear joint; 3 days curing time	11.91	62.07	95.4	15.0	I/III
ADHESIVE E	50 mm shear joint; 24 hours curing time	11.95	55.1	95.8	8.0	I
ADHESIVE C	50 mm shear joint; 3 days curing time	0.52	4.75	4.2	0.0	IV
ADHESIVE D	50 mm tensile joint; 3 days during time	2.51	26.6	20.1	15.0	IV
ADHESIVE E	50 mm tensile joint; 24 hours curing time	1.23	34.2	9.9	27.0	IV
ADHESIVE D	50 mm tensile joint; 24 hours curing time	3.65	53.3	29.2	38.0	IV
ADHESIVE A	50 mm tensile joint; 3 days curing time	5.14	57.0	41.2	37.0	IV
ADHESIVE D	50 mm shear joint; 24 hours curing time	10.29	59.3	82.5	20.0	III
TAPE C	25 mm shear joint	0.78	19.0	6.2	14.0	III
TAPE C	50 mm shear joint	1.64	20.9	13.1	12.0	III
TAPE B	50 mm shear joint	1.30	17.1	10.4	10.0	III

Table 8. Data for bonded joints, Geotextile 'C'

ADHESIVE/TAPE TYPE	DESCRIPTION OF JOINT	AVERAGE VALUES				MODE OF FAILURE
		Peak Load (kN/m)	Strain at Peak Load (%)	Joint Load Carrying Efficiency (%)	Joint Deformability at Peak Load (mm)	
ADHESIVE C	50 mm shear joint; 3 days curing time	7.14	29.42	98.8	6.0	IV
ADHESIVE E	50 mm shear joint; 24 hours curing time	2.50	7.84	36.4	4.0	IV
ADHESIVE D	50 mm shear joint; 24 hours curing time	7.38	38.00	102.1	7.0	VIII
ADHESIVE A	50 mm shear joint; 24 hours curing time	6.07	26.28	84.0	10.0	IV
"	50 mm shear joint; 2 days curing time	7.61	35.47	105.2	4.0	VIII
ADHESIVE B	50 mm shear joint; 24 hours curing time	6.31	29.45	87.3	12.0	III
"	50 mm shear joint; 2 days curing time	8.24	39.42	114.0	0.0	I
TAPE C	25 mm shear joint	2.75	7.44	38.0	3.0	III
"	50 mm shear joint	3.24	10.13	44.8	3.5	III

Table 9. Data for bodkin joints, Geogrid 'D'

JOINT TYPE	CROSS-SECTIONAL DIMENSIONS	AVERAGE VALUES			
		Peak Load (kN/m)	Strain at Peak Load (%)	Joint Load Carrying Efficiency (%)	Joint Deformability at Peak Load (mm)
1	Circular 10 mm dia	61.37	20.44	97.3	29.5
"	Circular 12 mm dia	61.03	20.72	96.7	35.0
"	Circular 15 mm dia	62.01	19.60	98.3	24.0
"	Circular 20 mm dia	60.62	19.87	96.1	32.0
"	Circular 25 mm dia	60.32	18.75	95.6	27.0
2	Circular 10 mm dia	51.07	14.54	80.9	29.5
"	Circular 12 mm dia	60.27	20.01	95.5	35.0
"	Circular 15 mm dia	59.85	16.61	94.8	17.0
"	Circular 20 mm dia	59.53	17.26	94.3	22.0
"	Circular 25 mm dia	59.55	16.95	94.4	20.5
3	Circular 10 mm dia	60.22	16.76	95.4	18.5
"	Circular 12 mm dia	59.69	16.93	94.6	25.5
"	Circular 15 mm dia	60.81	17.74	96.3	22.5
"	Circular 20 mm dia	61.09	17.47	96.8	19.0
"	Circular 25 mm dia	61.26	18.67	97.0	25.5
1	Rectangular 18mm wide x 4.5mm thick	61.91	17.69	98.2	25.0
"	Rectangular 12mm wide x 4.5mm thick	61.99	17.59	98.3	24.5
"	Rectangular 18mm wide x 2.8mm thick	56.34	15.33	89.4	30.0
"	Bar from parent material 15mm wide x 4.5mm thick	60.20	18.04	95.4	24.0
"	P.V.C. bar 20mm wide x 4 mm thick	61.37	18.36	97.2	18.5

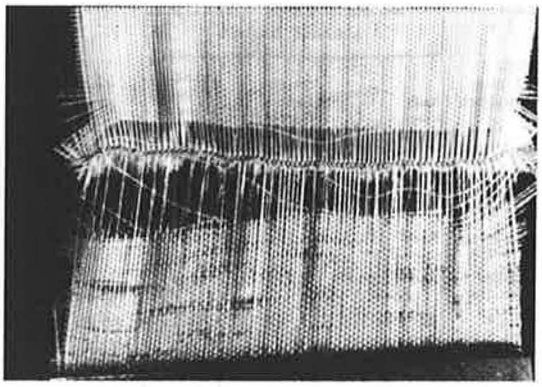


PLATE 1. SEWN JOINT - GEOTEXTILE 'A'

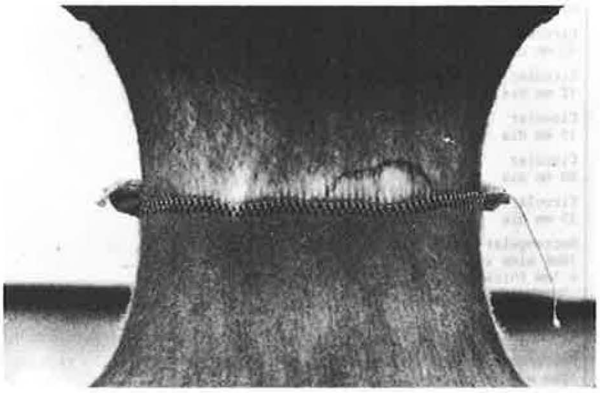


PLATE 2. SEWN JOINT - GEOTEXTILE 'B'

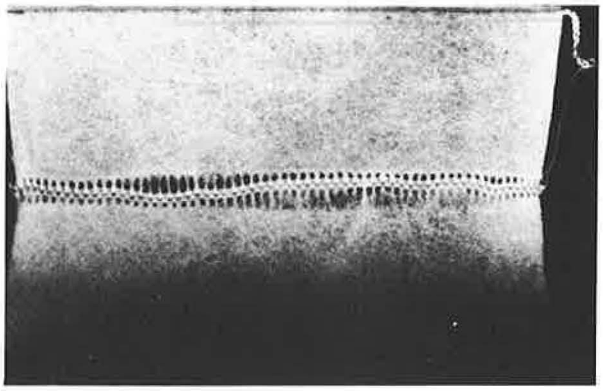


PLATE 3. SEWN JOINT - GEOTEXTILE 'C'

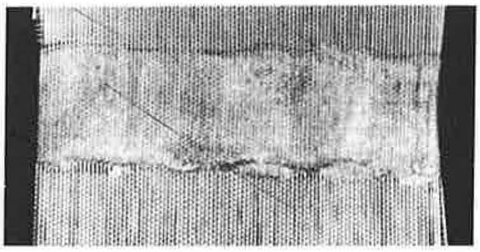


PLATE 4. BONDED JOINT - GEOTEXTILE 'A'

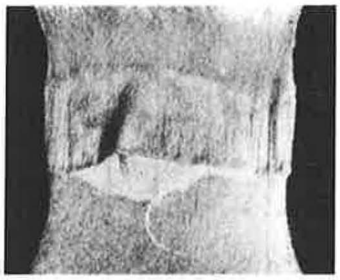


PLATE 5. BONDED JOINT - GEOTEXTILE 'B'

PLATE 6. BONDED JOINT - GEOTEXTILE 'C'

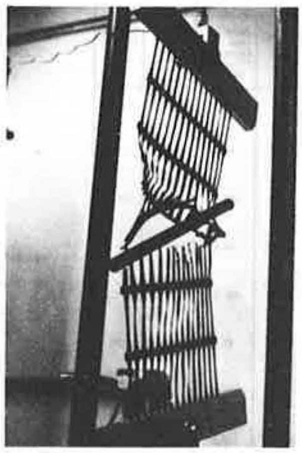


PLATE 7.

BODKIN JOINT - GEOGRID 'D'