

The Development of Junction Strength Tests for Geosynthetics

F. Montanelli

RDB Plastotecnica SpA, Vigano, Italy

P. Rimoldi

Tenax SpA, Vigano, Italy

ABSTRACT: Many types of geotextile related products (GRP) have a structure composed of single elements connected by "junctions": geogrids and geocells are the most obvious examples. Other types of GRP, namely the geocomposites, are made of single GRP connected in different ways (thermal bonding, glue, hot melt, etc.) but generally the contact between two elements occurs along lines or in specific points, and not uniformly on the whole surface: therefore these lines or points may be regarded as "junctions". In many applications the connections assume a structural importance, hence their mechanical strength needs to be tested thoroughly. The paper presents an organic proposal about the connection tests for geogrids, geocells and geocomposites. Preliminary results are also presented.

1 INTRODUCTION

The connections of a Geotextile Related Product (GRP) assume a structural importance when a load must be transferred from one element of the junction to the other (Koerner, 1989). The load can be a tensile, compressive or shear load. The connection is able to withstand a certain maximum load of each type: beyond this maximum strength, it fails, yields or breaks.

When this happens to a connection, the load is immediately transferred to the adjacent ones, which may fail to fulfill their functions. Therefore it is important to measure the strength of the connections, regarding all the possible failure mechanisms.

The connection strength must be evaluated when:

- a) each connection has to support a load (tensile, compressive, shear or whatever);
- b) when the applied load may cause the failure of one or more connections, and the failure may propagate along the GRP (example: geogrids or geocells);
- c) when the applied load may lead to the separation of the single elements connected in the junction, on part or on the whole surface of the single elements (example: geocomposites);
- d) when the tools (example: pins, stakes, staples, ropes, etc.) used to fix a GRP to the ground or to any surface (example: to a wall) across the junctions may produce local overstressing, causing failure of the junctions themselves.

2 CONNECTION FAILURE MECHANISMS

A connection may fail for 5 different mechanisms:

- 1) shear failure (example: geogrids, see Fig. 1a; geocells, see Fig. 1b; geocomposites, see Fig. 1c);
- 2) peel or delamination failure (example: geocells, see Fig. 1d; geocomposites, see Fig. 1e);
- 3) tensile stress failure (example: geocells, see Fig. 1f);
- 4) impact stress failure (example: geogrids, geomembranes, see fig. 1g);
- 5) local fastening plasticization due to compressive stress (example: pins with geocells, see Fig. 1h).

The last one can be considered as a performance property, in the same way as for the tensile test on seams/joints.

It is therefore impossible to define only one testing method for measuring the connection strength: the test standard must include the principles for testing the 5 mechanisms above explained. The principles must be adapted to each single product.

3 DEFINITIONS

For the purpose of this paper the following definitions apply.

- Connection: any way of connecting a geosynthetic to another or to an adjacent soil boundary or structure; or any structural junction produced during manufacturing.
- Seam: the system used to connect together two separate geosynthetics. This system may be composed of a third element such as: melted polymer for extruded weldings;

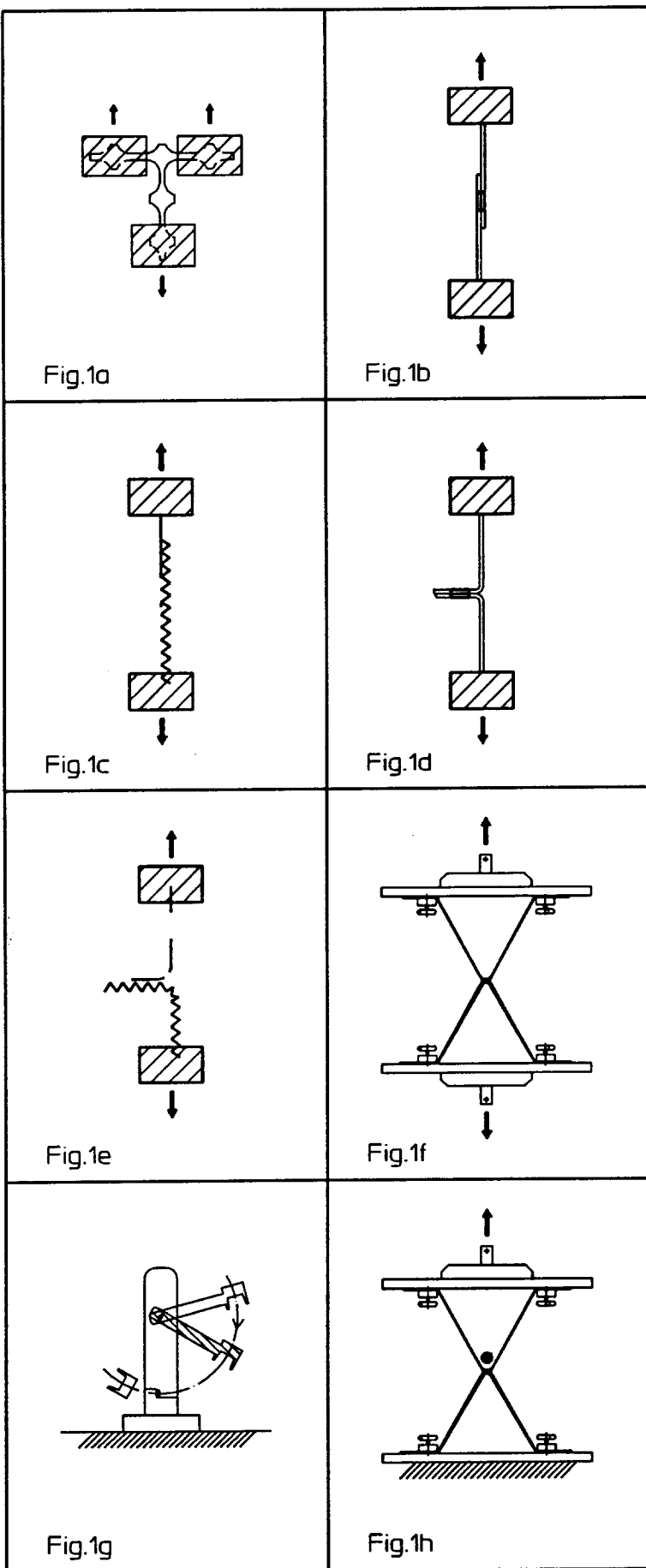


Fig. 1 Connection failure mechanisms

adhesive for some liner types; threads for geotextile sewings.

- Joint: the system used to connect two geosynthetic layers by mean of external elements such as bars, rods, hog rings, spirals and cable ties.

- Fastening: the system used to connect a geosynthetic layer to the adjacent structure or soil. This is the case of "U" shaped rods and wooden staples for geogrids and geocells, metal bars and bolts for synthetic liners.

- Junction: the system used, during the manufacturing process, to connect structural elements of a geosynthetics. With the word "junction" we define those integral connections in the geosynthetic itself; i.e. the longitudinal and transversal strands of an extruded geogrid are integrally connected by junctions since it is impossible to identify the exact point of connection of the two structural elements.

- Juncture: when the connection borders are clearly identifiable, then we define it as a "juncture". Thus a "juncture" is a connection of structural elements of a geosynthetic, made during the manufacturing, that is not integral. This is the case of the woven connections of the tensile elements in a woven type geogrid, the heat bonded connections between a geotextile and a geonet of a geocomposite.

The connecting element may be generated by the geosynthetic layers itself as in the case for the seams of hot wedge weldings of liners, or the connective system may be generated without the mean of an external material such as for joining two layers of cusped geocomposite where the integrity is provided by the interlock of several rows of the cusped elements.

4 DESCRIPTION OF THE TEST METHODS

The tests performed to characterize the geosynthetic connections for different states of stress are the following ones.

For geogrids:

A1) Tensile shear: a "T" shaped specimen composed of one longitudinal rib and one transversal bar is mounted in a bottom clamp which holds the longitudinal rib in the junction, and in a top clamp which holds the transversal bar. The top clamp has a central area where the geogrid is not gripped, thus allowing a shear failure to occur at the connection between the longitudinal rib and the transversal bar. The clamps are inserted in a constant rate of strain tensile testing machine and the specimen is pulled until the rupture of the top junction is obtained. The peak resistance of the junctions is measured and reported. This procedure is described by the GRI-GG2 test method (Fig. 1a).

A2) Tensile shear with normal compressive force: this test is performed as explained in A1), but a constant normal compressive stress is applied to the connection thus simulating the soil pressure. This normal load can be easily applied over the tested connection by the mean of a small piston activated by a compressed spring or air pressure (Fig. 2).

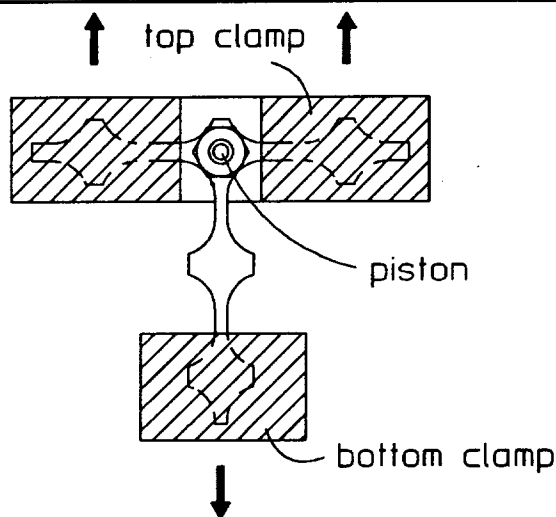


Fig.2a

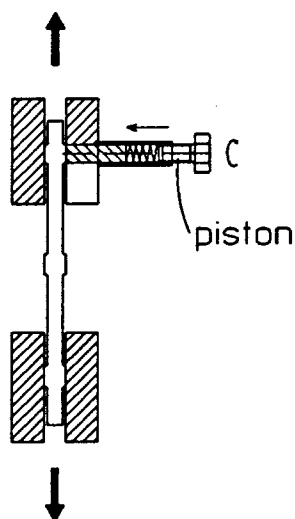


Fig.2b

Fig. 2 - Tensile shear with normal compressive force.

A3) Tensile shear along the diagonal direction: a specimen composed of a full mesh (4 junctions with two MD and TD strands) is clamped in two junctions along the diagonal direction and then stressed in tension (Fig. 3).

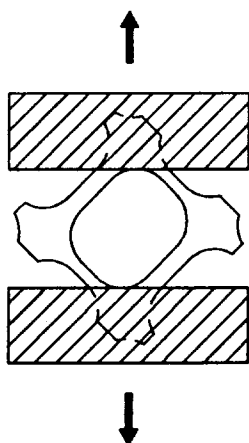


Fig.3

Fig. 3 - Tensile shear along diagonal direction.

This test simulates a typical diagonal load applied during a base reinforcement application such as a road or parking lot. The center junctions fail in shear mode giving an indication of both the junction strength and tensile properties along the diagonal direction.

A4) Impact stress: a specimen of geogrid is mounted in a Charpy type pendulum. The junction is mounted unnotched transversally to the hitting hammer. Then the hammer is released and the junction impact resistance energy is computed by difference between the initial and the residual energy. This test is very useful to indicate the brittleness of certain extruded junctions and this value is an index of the construction damages resistance of the products (Fig. 1g).

For geocomposites:

B1) Tensile shear (Fig. 1c): after cutting a wide width type specimen, the Geotextile (GTX) making the juncture is delaminated from the other for a certain length at each opposed edge; the delaminated portion is mounted in a clamp of a tensile testing machine, while the GRP at the opposite edge of the specimen is mounted in the other clamp.

The specimen is tested at constant rate of strain until shear failure of the juncture or tensile failure of either the GTX or GRP occurs. The test may be repeated with different lengths of the undelaminated portion of the two GTX or GRP in the specimen, until determining the maximum length at which shear failure, and not tensile failure, occurs: the corresponding tensile shear resistance is measured and recorded together with the minimum length.

B2) Peel (Fig. 1e): after cutting a wide width type specimen, the GTX making the juncture is delaminated from the other for a certain length at one edge; the delaminated portions of the GTX and GRP are each mounted in one clamp of a tensile testing machine. The specimen is tested until the peeling of one from the other one occurs, or until one of the GTX or GRP breaks. The test may be repeated with different lengths of the undelaminated portion of the specimen, until determining the minimum length at which peeling, and not tensile failure, occurs: the corresponding peeling resistance is measured and recorded together with the minimum length.

For geocells:

C1) Tensile shear (Fig. 1b): two opposite strips occurring in a geocell junction are mounted in the clamps of a tensile testing machine. The specimen is tested at constant rate of strain, and the peak tensile shear resistance is measured and recorded.

C2) Peel (Fig. 1d): two adjacent strips occurring in a geocell junction are mounted in the clamps of a tensile testing machine and tested at constant rate of strain until a peel failure of the junction occurs. The peak peel resistance is measured and recorded.

C3) Split (Fig. 1f): a X-shaped specimen is cut; two strips are on the right side of the junction in the production direction and two strips on the left side. The four strips are mounted in two special clamps which maintain the edges of

the strips at a predefined distance, which simulate the aperture of the cells when installed. The two clamps are inserted in a tensile testing machine and tested at constant rate of strain until a tensile split failure of the junction occurs. The peak split resistance is measured and recorded.

C4) Fastening efficiency (Fig. 1h and Fig. 5): a X-shaped specimen is cut; two strips are in the upper side and two are in the lower side of the junction in the production direction. The four strips are mounted in two special clamps which maintain the edges of the strips at a predefined distance, which simulates the aperture of the cells when installed. The two clamps are mounted in a tensile testing machine. A steel rod is placed across the junction and over it, and fixed to the basement of the testing machine, thus simulating the fastening. The specimen is tested until a failure occurs due to plasticization of the junction by the steel rod. The maximum tensile resistance is measured and recorded. The rod shall simulate the type and size of the fastening actually used in the field.

5 TEST RESULTS

The products tested are listed in table 1.

Table 1: Geosynthetics tested

	Product name	Geosynthetic type	Polymer type
1	TENAX TT401 SAMP	Uniaxial geogrid	HDPE
2	TENSAR SR80	Uniaxial geogrid	HDPE
3	FORTRAC 80/30-20	Woven geogrid	PET
4	TENAX LBO 303 SAMP	Biaxial geogrid	PP
5	TENSAR SS2	Biaxial geogrid	PP
6	TENAX TNT 100	Geocomposite	HDPE+PP
7	TENAX TENWEB 300	Geocell	HDPE

Table 2 shows the tensile properties of the geogrids tested. In particular it is worth to notice that the woven geogrid has peak tensile properties similar to the uniaxial geogrids but

strength at 2% and 5% strain is similar to the biaxial geogrids.

Table 2: Tensile strength properties.

Test method: GRI-GG1

Geogrid type (Tab.1)	Strength at 2% strain	Strength at 5% strain	Peak tensile strength	Strain at peak
	kN/m	kN/m	kN/m	%
1 - MD	28.79	53.29	91.63	12.3
2 - MD	28.66	50.28	79.68	9.9
3 - MD	16.07	23.25	85.34	12.4
3 - TD	7.86	14.38	36.55	9.9
4 - MD	10.10	17.75	24.16	12.1
4 - TD	13.81	26.48	36.77	8.6
5 - MD	8.72	15.83	19.01	10.4
5 - TD	15.23	29.01	34.48	8.5

MD = Machine direction

TD = Transverse direction

Table 3 shows how the junction strength properties vary with the products tested.

Table 3: Connection strength results for the geogrids.

Test method	A1a	A1b	A3	A4
Geogrid type (Tab. 1)	kN/m	%	kN/m	J
1 - MD	76.48	83.5	-	15.5
2 - MD	81.84	102.7	-	10.1
3 - MD	3.10	3.6	2.30	3.5
3 - TD	3.28	9.0	2.40	-
4 - MD	24.40	101.0	19.30	-
4 - TD	31.05	84.5	21.50	-
5 - MD	19.24	101.2	16.50	-
5 - TD	32.26	93.6	24.20	-

A1a : Junction Strength GRI-GG2

A1b : Junction Efficiency GRI-GG2

A3 : Junction Strength diagonal direction

A4 : Junction Impact Resistance Energy

Table 3 The junction efficiency is calculated by the ratio of the junction strength over the peak tensile property. For geogrid 1, 2 and 3 the design loads is approximately 40% of the peak tensile strength (Rimoldi and Montanelli, 1993), thus for geogrid 1 and 2 the junction efficiency is more than double the design load while for geogrid 3 is less than one tenth. The connection strength along diagonal direction gives a strong indication of how the product behaves in that direction. The two unclamped junctions are stressed until they split and tear apart. This is a significant property for base reinforcement applications where load may be applied in the diagonal direction, and not only in longitudinal and transverse one. The connection impact resistance energy is an indication of the junction resistance to impacts generated during construction backfilling and compaction. The results show tendency to severe splitting and tearing respectively for geogrid 2 and 3. Table 4 shows the juncture strength of geogrid 3 for several applied normal pressures, using the test method shown in Fig. 2. With a normal pressure, equivalent to 60 m of nominal soil depth, the juncture efficiency is still considerably low (8%).

Table 4: Juncture strength of Geogrid 3 MD versus applied normal pressure. Test method: A2

Normal pressure kPa	Equivalent soil depth m	Juncture strength kN/m	Juncture efficiency %
0	0	3.10	3.6
600	30	6.59	7.7
1200	60	6.81	8.0
2400	120	10.73	12.6

Table 5 shows the test results for the Geocomposite 6. It is noted that the tensile shear resistance is affected by the length of the juncture while the peel test is not. Table 6 shows the results of the proposed tests on geocell.

Table 5 : Juncture strength of Geocomposite 6

Test type	Unit	Test results	Undelaminated length
Tensile Strength	kN/m	20	
Tensile shear, B1	kN/m	4.5	100 mm
Tensile shear, B1	kN/m	2.5	50 mm
Tensile peel, B2	kN/m	0.7	100 mm
Tensile peel, B2	kN/m	0.7	50 mm

Table 6 : Results of junction tests for geocells.

Type	Unit	Geocell 7
Cells height	mm	75
Unit weight of open panels	g/sqm	800
Tensile strength, single strip	kN/strip	1.2
Tensile strength, double strip	kN/2 strips	2.6
Tensile shear, C1	kN/junction	0.8
Tensile peel, C2	kN/junction	0.35
Junction split, C3	kN/junction	1.1
Fastening eff. Ø (10 mm), C4	kN/junction	1.1

CONCLUSIONS

The mechanical properties of several connection types have been investigated. It has been shown that the connection properties are not related to the tensile properties of the product itself.

For woven geogrids the juncture tensile strength is only a small fraction of the long term design strength.

For integral geogrids, the junction tensile strength is always at least twice the long term design strength.

Similar results have been obtained by the diagonal junction strength test, showing the applicability of this test as an index for both junction strength and tensile properties along diagonal direction. By reviewing the results coming from this test, the woven geogrids do not seem, to the author's opinion, ideal for base reinforcement applications or other applications where loads are not directly aligned with the main tensile direction of the geogrid.

The impact junction test provides a good correlation between results and actual resistance of different types of geogrids to the stresses imposed during backfilling and compaction and the consequent splitting of ribs and junctions. The test can be easily standardized as an index test which may be performed in laboratory at several temperatures of the specimens simulating different climate conditions. The ranking of tested products obtained with this test appears to reflect well the results of full scale tests (Wright and Greenwood, 1994).

The juncture strength of the woven geogrids do not largely improve with the application of soil pressure: with a soil pressure equivalent to 60 m of soil, the juncture efficiency is still considerably low (8%) and only double the one with no pressure applied, anyway there is an evident influence of the pressure applied on the connection strength of woven

geogrids. A reference pressure shall, therefore, be selected in order to standardize the test.

The geocomposite shear strength is almost proportional to the length of the area to be delaminated, while the peeling resistance is mainly constant with it. Thus, for geocomposite shear resistance tests it is very important to define the specimen geometry including the baffles length, and the undelaminated length.

For the peel test, the length of the undelaminated portion and of the specimen shall be defined in order to test the specimen at an angle of 180° (see fig. 4b). The suggested specimen dimensions are shown in Fig. 4.

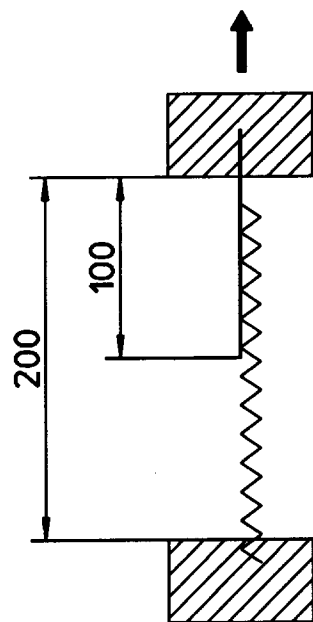


Fig.4a

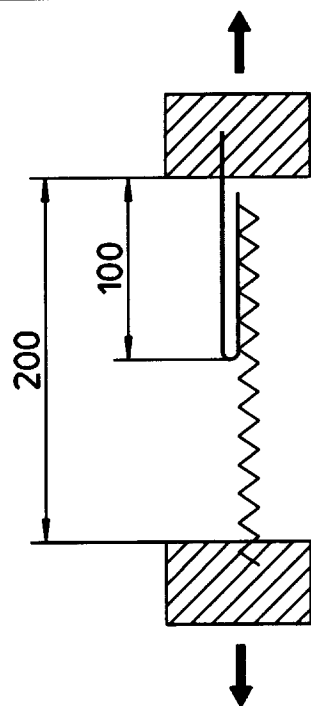
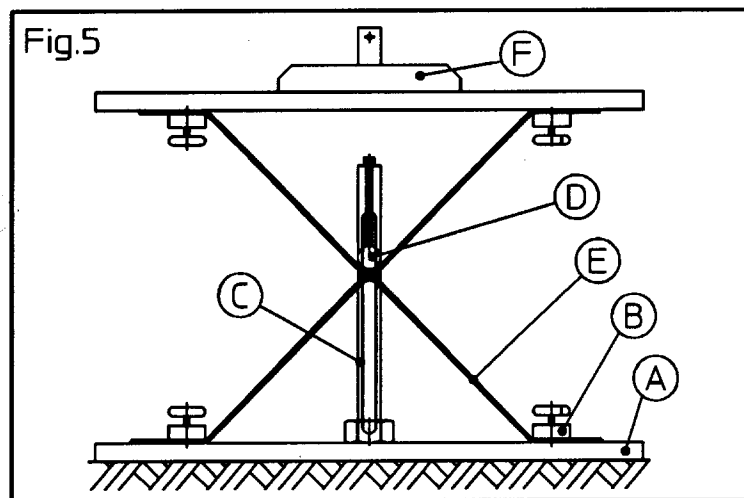


Fig.4b

Fig. 4 Suggested specimens for the shear and the peel connection test for geocomposites.

For geocells, several different connection failure mechanisms have been investigated. It seems that the weakest resistance is yielded by the peel test, anyway care shall be taken while designing with the geocells because other failure mechanisms may become critical time by time. Hence, a standard for geocell connections shall include all the failure modes considered in Table 6 (Fig. 5).

Fig. 5 Apparatus for the fastening efficiency test for geocells: A) basement; B) sliding bars to clamp the geocell strips; C) fastening sliding support; D) steel bar simulating the fastening; E) geocell specimen; F) upper clamp.



REFERENCES

- Cancelli A., Rimoldi P. and Montanelli F. (1993) Index and performance tests for geocells in different applications, *Geosynthetic soil reinforcement testing procedures*, ASTM STP 1190, Philadelphia (64-75).
- GRI-GG1 -87 (1987) *Geogrid rib tensile strength*, Geosynthetic Research Institute, Philadelphia.
- GRI-GG2-87 (1987) *Geogrid junction strength*, Geosynthetic Research Institute, Philadelphia.
- ISO 10139 (1992) *Geotextiles Wide width tensile test*, International Organization for Standardization, ISO.
- Koerner, R.M. (1989) *The Seaming of Geosynthetics* Proceeding of the 3rd GRI Seminar, Geosynthetic Research Institute, Philadelphia.
- Rimoldi P. and Montanelli F. (1993) Creep and accelerated creep testing for geogrids, *Proc. Geosynthetics '93*, Vancouver, (773-788)
- Wright W.C.A. and Greenwood J.H. (1994) Interlaboratory trials on installation damage in geotextiles and comparison with site trials, *ERA report 93-0915*, Leatherhead, UK.