Biaxial Strength of Geotextiles

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ABSTRACT : On a biaxial tensile testing machine developed at INSTITUT TEXTILE DE FRANCE, cross-shaped test specimens are submitted to normal stresses on each side. The axes of strength are perpendicular and the elongations are recorded with a C C D camera and treated with suitable image analysis system.

Trials are performed on four produits : two nonwovens and two woven products. These products are also tested according to monoaxial tensile test (NF G 38-014 and ISO 1013. Wide-width tensile test).

Comparison of results obtained by monoaxial and biaxial tensile test shows a rigidness of fabrics when stresses are applied perpendicularly to the pulling direction.

1 INTRODUCTION

When geotextiles are used for reinforcement, the most important characteristics to consider are the tensile strength and the stiffness. Indeed these characteristics which determine the behaviour of the geotextile in the works are introduced in the stability calculations. In order that the design methods are successfull these characteristics have to be well determined.

In the seventies, the method used for measuring the tensile strength of geotextiles is the textile standard ISO 5081. This test appeared rapidly unsatisfactory and works led in France ended to the standard NF G 38-014 (Sept. 1983) which is a wide-width tensile test and now the ISO 10319. In these two last tests, the behaviour of the wide-width test sample is more representative of the one of the geotextile in its use, but the stresses in the perpendicular sense to the pulling direction are not taken in account.

The purpose of this communication is to submit test-samples to a biaxial tensile test on a biaxial machine developed by the FRENCH TEXTILE INSTITUTE at LYON in collaboration with the Mechanics and Material Laboratory, Université CLAUDE BERNARD LYON 1, with the financial support of the Rhône-Alpes Regional Council and to compare the results obtained with those coming from uniaxial test.

2 MATERIALS AND TEST METHODS

2.1 Materials

Trials are carried on four materials, two nonwoven geotextiles and two woven geotextiles. In this communication, these products are referenced as following :

GTnw pp	Polypropylen nonwoven,
GTnw pet	Polyester nonwoven,
GTw pp	Polypropylen woven,
GRw pet	Polyester woven (machine
direction is	polyester and cross direction is
polypropylene)	

The two GTw are high resistance fabrics, some characteristics of GTnw are given in table 1.

Table 1 - Characteristics of GTnw

	GTnw pp	GTnew pet
Mass per unit area (g/m^2)	700	700
Thickness (2 kPa) mm	5,3	5,3

Thanks to OMV-BIDIM GEOSYNTHETICS who provided the samples.

2.2 Monoaxial tensile test

The GTnw are tested according to the NF G 38-014 in which the dimensions of the test-specimen are : gauge length 10 cm, width 50 cm. The elongation ε is given by the following formula :

$$\varepsilon = \varepsilon_1 - \varepsilon_2 - \varepsilon_1 \varepsilon_2 / 100$$

where e1 is the longitudinal elongation taken between the jaws and ε_2 is the transversal elongation.

The GTw are tested according to the ISO 10319 in which the dimensions of the test-specimen are : gauge length 10 cm, width 20 cm. The elongation is determined with an extensometer.

For GTnw and GTw, the rate of loading is 50 mm/min.

2.3 Biaxial tensile test

Biaxial trials are carried out on cross-shaped test specimen which are subjected to normal stress on each side. The machine includes two independent perpendicular axis and the jaws are moved by means of finely threated screws connected to speed reducers powered by stepping motors (fig. 1). The loading speed varies from 0 to 60 mm/s and the loading speed can be different on each axis. The clamping of the test specimen is realised with hydropneumatic jaws articulated for maintaining the alignment of the test specimen during the test. The maximum load capacity is 150kN. The total length of the cross-shaped test specimen is 90 cm in each perpendicular direction and its central part is a 30 x 30 cm square.

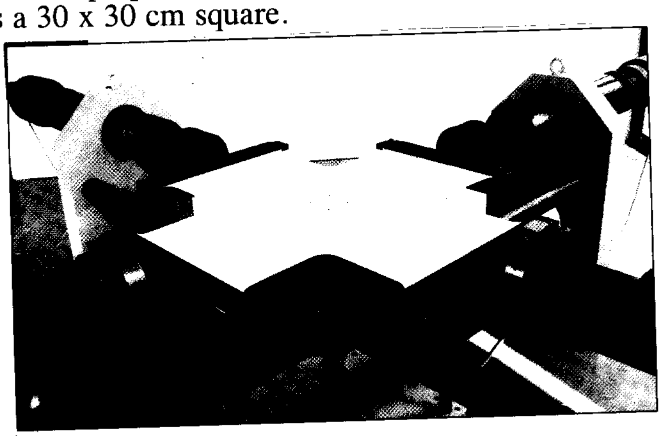
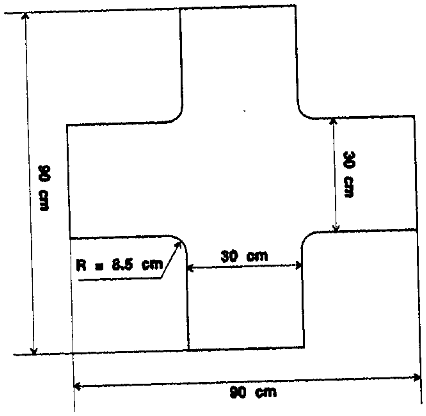


Figure 1 - Biaxial Tensile Machine

For limiting the stress concentrations, the corner fillets are rounded (R = 8,5 cm) (fig. 2).

Figure 2 : Biaxial test specimens



The deformations are taken in the central part of the test specimen and recorded with a CCD black and white camera with appropriate optics and treated with the system visidef which comprises :

- an IBM Computer,
- a frame-grabber board,
- a printer for output of numerical data and graphic results,
- and a special image analysis software the aim of which is the tracking of a network of marks previously positionned on the surface textile.

For trials performed on each of the four fabrics, three conditions are retained :

- same rate of loading in the two directions 0,3 mm/s,
- rate of loading in the machine direction twice as this in cross direction,
- and rate of loading in the cross direction twice as this in machine direction.

For the two last conditions the greatest rate is 0,3 mm/s.

3 RESULTS

On figures 3 and 4 are drawn curves representative of the behaviour of nonwoven and wovengeotextiles tested in cross and machine direction. In each of these figures, the representative curve is the curve among the five obtained which is the nearest of the mean. The data concerning the mean values of maximum force, elongation at maximum force and initial tensile stiffness are given in table 2.

Table 2 : Meanvalue of maximum force, elongation at maximum force and initial textile stiffness

	Maximum force kN/m MD	CD
GTnw pp	43	79
GTnw pet	61	37
GTw pp	78	12,7
GTw pet	104	10,5

	Elongation at maximum force % CD	MD
GTnw pp	29	81
GTnw pet	51	37
GTw pp	68	11,2
GTw pet	63	15

	Initial tensile kN/m CD	Stiffness MD
GTnw pp	1,6	0,8
GTnw pet	2,5	2
GTw pp	4,35	6
GTw pet	19,6	7,75

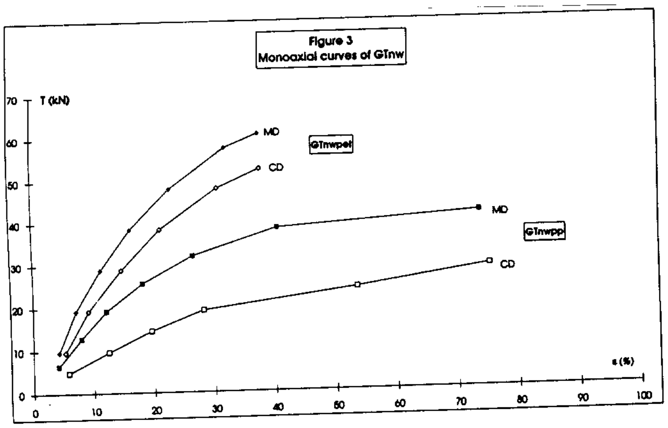


Figure 3
Monoaxial curves of GTnw

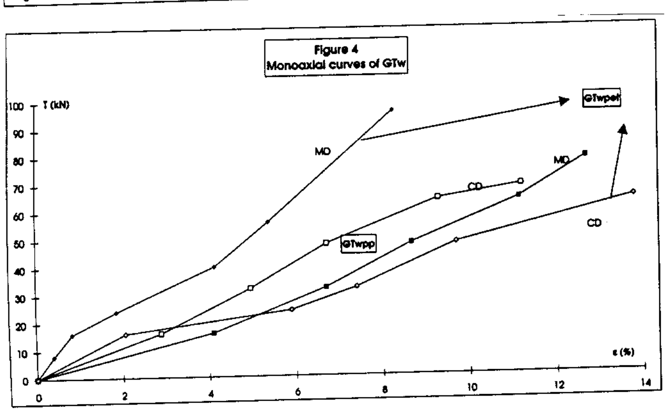


Figure 4
Monoaxial curves of GTw

The curves giving the MD and CD behaviour of the four tested fabrics with the rate ratio 1.1, 1.2 and 2.1 are shown in figures 5, 6, 7 and 8. For helping the comparison between the monoaxial and biaxial trials the scale of figures 3, 5 and 6 are the same. It is the same thing for figures 4, 7 and 8.

From these curves it is clearly seen that the initial tensile stiffness of biaxial trials are higher than those of monoaxial axis while the elongation at maximum force are lower. During the biaxial trials, it appears a rigidity of fabrics. It is interesting to note the specific behaviour of the nonwoven geotextiles, with the rate ratio 2.1, i. e. when the rate in machine direction is twice this one in cross direction. The increase of stress in cross direction is not able to prevent the shrinkage which would take place in a monoaxial test. The fact that this phenomena does not appear with the rate ratio 1.2 is probably due to the manufacturing process of nonwoven geotextiles. The mean values of initial stiffness are listed in table 3.

Table 3 - Biaxial tests meanvalue of initial stiffness

	Rate Ratio 1.1 kN/m MD	CD
GTnw pp	1,9	10
GTnw pet	3,7	11
GTw pp	9,5	11,2
GTw pet	11,2	3,7

	Rate Ratio 1.2 kN/m MD	CD
GTnw pp	3,4	1,4
GTnw pet	7	4
GTw pp	6,7	8,4
GTw pet	19	3,5

	Rate Ratio 1.2 kN/m MD	CD
GTnw pp	1,7	--
GTnw pet	2,9	--
GTw pp	11,2	6,7
GTw pet	33	4

From data of tables 2 and 3, it is clearly seem that initial stiffness obtained with biaxial tests are higher than those coming from monoaxial tests.

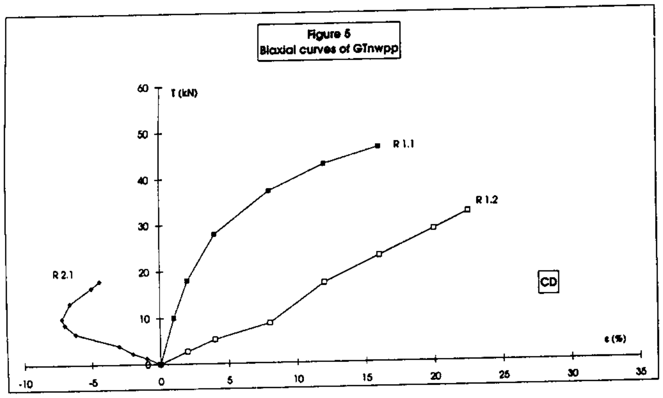


Figure 5
Biaxial curves of GTnwpp

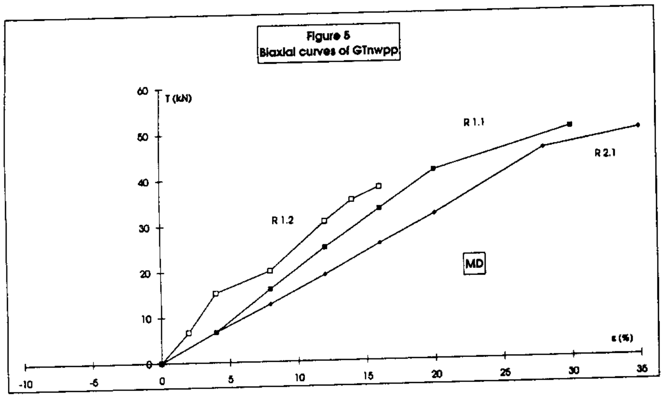


Figure 5
Biaxial curves of GTnwpp

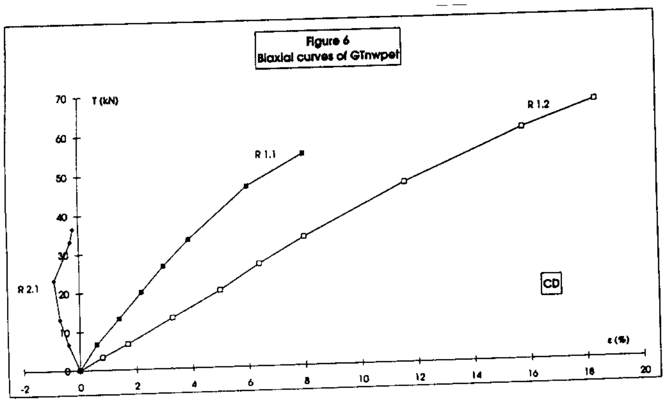


Figure 6
Biaxial curves of GTnwpet

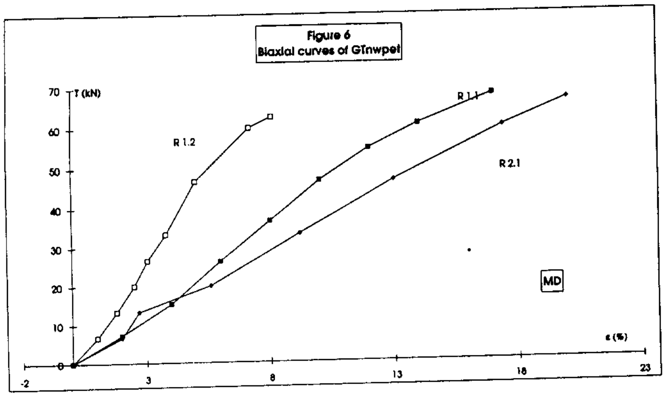


Figure 6
Biaxial curves of GTnwpet

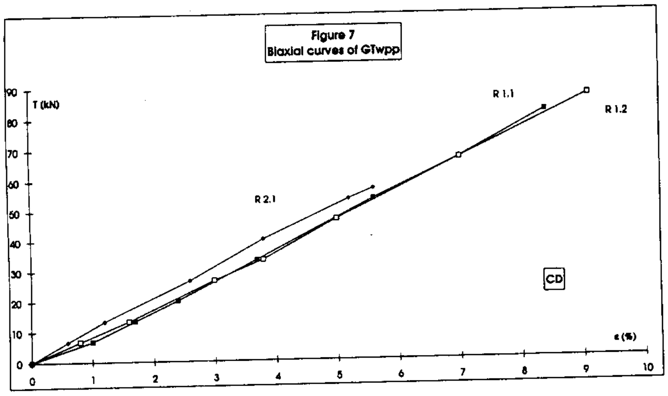


Figure 7
Biaxial curves of GTwpp

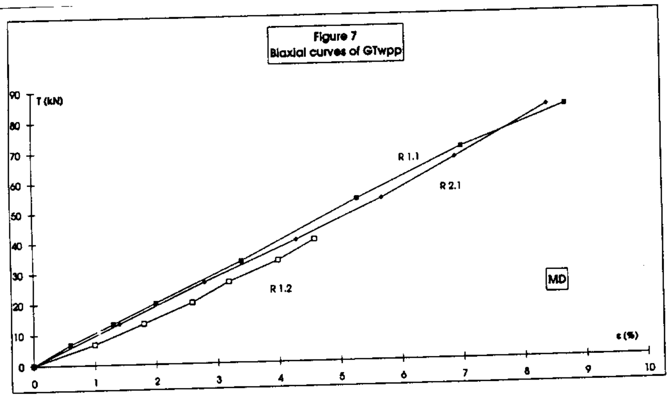


Figure 7
Biaxial curves of GTwpp

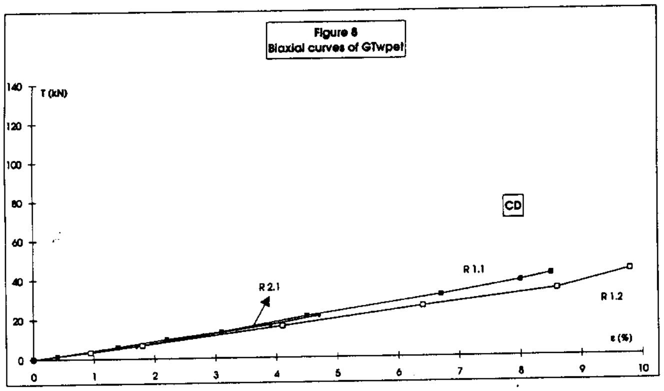


Figure 8
Biaxial curves of GTwpet

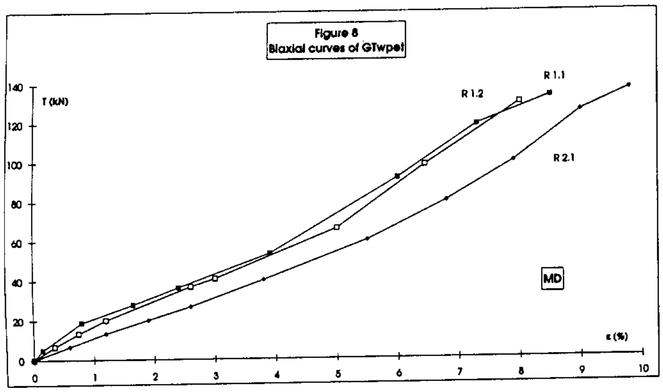


Figure 8
Biaxial curves of GTwpet

4 CONCLUSIONS

From these monoaxial and biaxial tensile tests, it appears that the bahaviour of a fabric is influenced by the stresses applied perpendicularly to the pulling direction. The action of these stresses is constrised by a rigidity of fabrics. It follows that values of elongation and stiffness introduced in design methods are underestimated ant that the used safety coefficients should be surestimated. Tests on site seam corroborate this hypothesis. Biaxial tests should have to improve these safety coefficients. Such biaxial tests are already used in France for designing textiles structures such as TGV railways stations.

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