Tensile and Creep Behaviour of Geotextiles

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ABSTRACT: To design permanent reinforced structures, the short or long term mechanical behaviour of geotextiles must be well known . Different tests - conventional tensile and non standard creep tests - are performed on four different geotextiles commonly used in the civil engineering construction. Two types of materials are used : polyester and polypropylene also differing by their structure : woven and non-woven. The environment of the geotextile is considered "free" and "confined". The confined configuration is obtained by a pressure applied on a dry fine sand layer placed on both sides of the geotextile. A special creep cell has been used and improved to perform confined tests. Confined tensile and creep test results are presented and discussed. This discussion is led in relation with the type of material and structure and with the in-isolation and in-soil configuration. The main results concern the stress-strain behaviour of the geotextiles and some recommendations are proposed for the short or long time behaviour in design.

1 INTRODUCTION

Reinforced structures are now commonly used in civil engineering construction. Reinforced walls have taken a great place among these different types of structures. They are mainly built along highways as embankments or retaining walls. The success and the development of reinforced walls firstly depend on the construction method which is easy and quick to work out. Therefore, the coming out of new products has also contributed to this development. Many research programs are carried out to improve the performances of materials called geotextiles and geomembranes and to perform design methods of reinforced permanent structures. Regarding design, the short or long term mechanical behaviour of geotextiles must be well known so as to estimate the duration of life of the reinforced structures. So, a research program based on tensile and creep tests has been performed in laboratory, to bring to designers some recommendations issued from the tensile and creep properties.

2 TESTED MATERIALS

So as to be representative of the geotextiles used in reinforced structures, the choice of the tested materials might be discerning and limited in numbers. This restriction is due to the duration of the creep tests. Finally, four geotextiles have been selected. They differ from one another in structure and in material. Two types of structures have been considered : woven (noted W) and non woven (noted NW). Also two kinds of polymers have been chosen : polyester (referenced PET) and polypropylene (referenced PP).The basic mechanical properties are given below in table I, for the four geotextiles.

Table I : Mechanical characteristics of tested materials.

Structure	W1	W2	NW1	NW2
Polymer	PP	PET	PP	PET
Failure resistance T_f (kN/m)	35 *32**	50 *53**	20,5 *20**	21 *17,8**
Failure strain ε_f (%)	10 *8**	10 *9,5**	30 *30**	40 *60**

* checked values by laboratory tensile tests on 500 x 100 mm samples, 20° C temperature.

3 NON CONFINED CREEP TEST

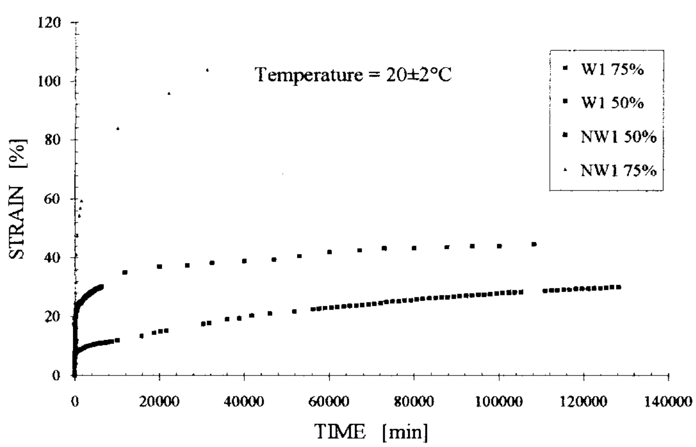
3.1 Tests conditions

The non confined tests are governed by two main specific experimental conditions, namely : applied load and temperature. The applied load represents a percentage of the tensile failure resistance. The chosen value for this ratio is relatively close to the failure value so as to obtain the failure and observe it during the creep test in a reasonable time duration.

The referenced temperature is 20° C (see tensile test results in table I) but non confined creep tests may be run out at 20° C and 40° C. Only results obtained at 20°C are presented below. The experimental set up includes two geotextile samples submitted to the axial permanent load by a servo-electrical jacket. Two displacement transducers, are placed on each sample side and a force transducer controls in time the applied load. The sizes of the sample are 500 mm wide and 100 mm high.

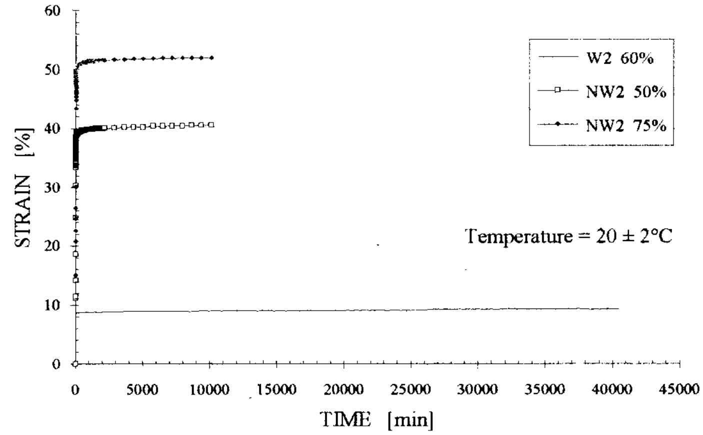
3.2 Creeping curves

From these non-confined creep tests, creep-time curves are directly deduced for the four geotextiles, according to the applied load rate. Figures 1 a and 1 b give the creep-time curves for the different constitutive tested materials. Two load rates considered are 50 and 75 %. The curve profiles correspond to usual creeping curves with various states of the creep of the material. The mains results are recapitulated in table II which gives the slopes n of the curves : lg(ε) - lg(t)



(a)

Figure 1a Strain-time creeping curves (non-confined tests). a: polypropylene; b: polyester. 50% and 75% are the load rates.



(b)

Figure 1b Strain-time creeping curves (non-confined tests). a: polypropylene; b: polyester. 50% and 75% are the load rates.

Table II - Non confined creep tests for different materials at 20° C temperature. The slope n is calculated from the logarithmic curve [lg(ε) - lg(t)].

Geotextile	W1	W2	NW1	NW2
Curve slope : n	0,104 *0,133**	(0,012)	0,116 *0,179**	0,016 *0,013**
Test duration (min)	128160 *44**	(40516)	108225 *31000**	10095 *10095**
Failure strain ε_f(%)	F 30 *F 11,5**	(9,4)	44,6 *104**	30,5 *37**

Load rate 50 %, except * values 75 % and ( ) values at 60%. F indicates that the failure occurs.

Non confined creep tests have revealed that the creep of polypropylene material in terms of lg(ε) - lg(t) is 10 times the polyester one. Polypropylene creeping curve presents the third part called tertiary creeping which duration depends on the load rate. When considering the same basic material, there is no significant influence due to the structure (woven or non woven), except for the initial strains.

4 CONFINED CREEP TESTS

4.1 Test conditions

To compare with the non confined creep tests results, the same conditions are kept (load rates, temperature), except for the limit conditions of the geotextile. A confining pressure is applied normally to the plane of the sample through a sand layer set out on every side. Special monitoring is used to perform these confined tests. A cell conceived in the University of Strathclyde (Kabir, 1980) is adapted for these tests and some arrangements have been made. Geotextile samples are 100 mm high and 200 mm wide. they are prepared from 300 x 200 mm pieces which extremities are impregnated with resins.

The preparation of the confined creep test begins by the installation of the sample inside the cell between two layers of 5 mm of dry fine sand. Using a first half of the cell, a rubber sheet (5 mm thick) is put on the membrane pumped up to 5 kPa. Then, the sample is placed on this part. The uniform fine sand (d_{50} = 0,2 mm) is poured on the geotextile. The cell is assembled, returned and the second layer is installed. A framework permits to run out the creep tests. The creep cell is hooked under a beam. The load is applied by a static load system and controlled by three load cells. To measure the displacement due to the creeping effect, four displacement transducers are set on the cell. They follow the movement of two thin rods fixed directly on the sample which stand out along the cell (figure 2).

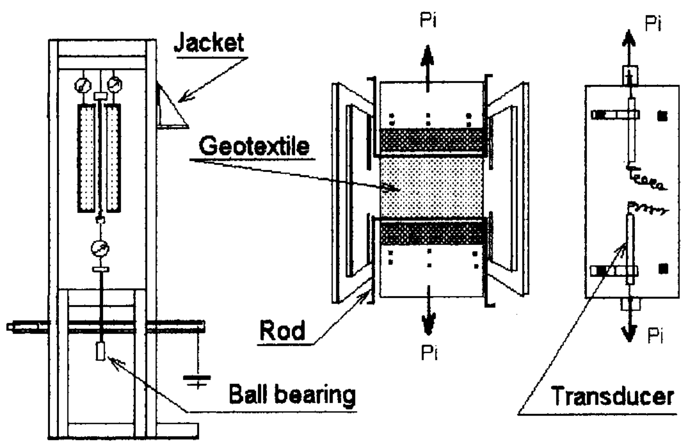


Figure 2 Creep cell on the framework.

4.2 Tensile confined tests

Before performing confined creep tests, tensile conventional confined tests have been carried out on the four chosen geotextiles (confining pressure: 100 kPa, temperature always 20° C). Main comparative results are given in table III. For the woven geotextiles no influence occurs when stiffening at low strains is observed for non-woven geotextiles (Blivet et al, 1992)

Table III - Mechanical characteristics (confined tests).

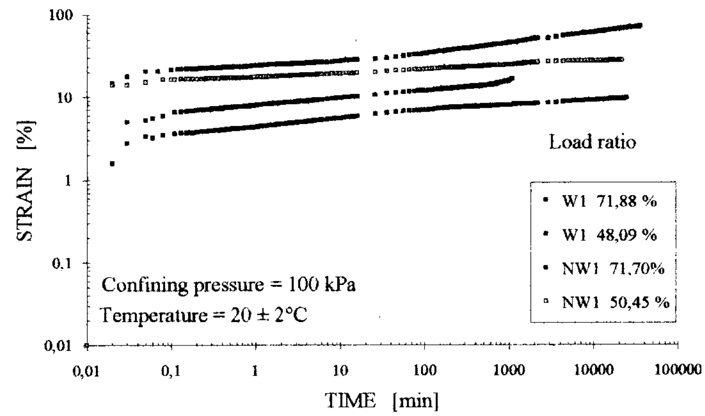
Geotextile	W1	W2	NW1	NW2
Polymer	PP	PET	PP	PET
Failure resistance T_f (kN/m)	30	43 (53)	23,5 (20)	17,7 (17,8)
Failure strain ε_f (%)	13 (8)	11 (9,5)	40 (30)	47 (60)

( ) indicated values issued from non-confined tests.

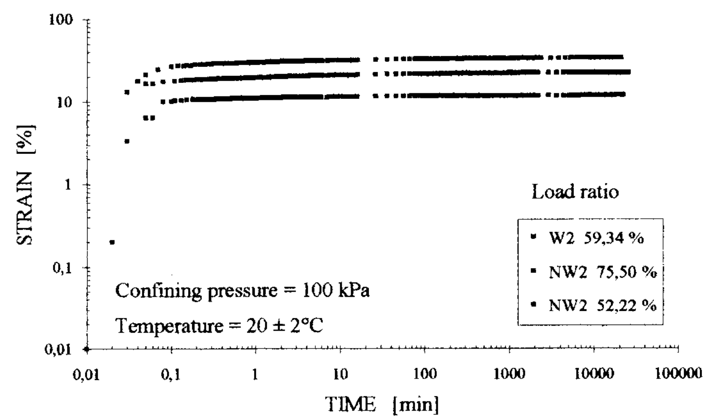
4.3 Creep confining tests

4.3.1 Tests at 20° C

To illustrate the load rate influence during the creep confining tests, the strain-time behaviour is given in figures 3 a and 3 b for the polypropylene and polyester material under different loads. Table IV gives the main values.



(a)



(b)

Figure 3 Strain-time relationships (confined tests at 20°C). a: polypropylene ; b: polyester.

Table IV - Confined creep tests at 20° C temperature.

Geotextile	W1	W2	NW1	NW2
Curve slope : n	0,082 *0,096**	(0,0105)	0,100 *0,129**	0,018 *0,013***
Test duration (min)	24885 *1070**	(19820)	24035 *26520**	24080 *20900*
Failure strain ε_f (%)	10 *F 17,5**	(12,5)	18,9 *65,3**	20,8 *34,55*

Average load rate 50 %, except * values 70 %, ** values 75 %, ( ) values 60 %.

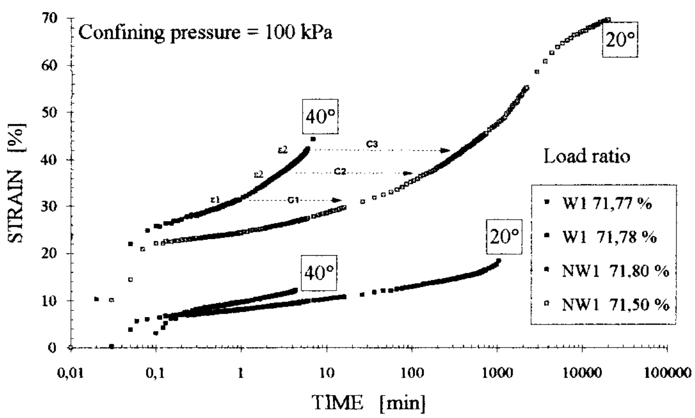
F indicates that the failure occurs.

On figure 3, whatever the applied load rates, creeping curves have the same profiles for one type of polymer. As the rates increase, the total strain also increase. It seems that, the creep behaviour does not depend on the structure of polypropylene or polyester geotextiles.

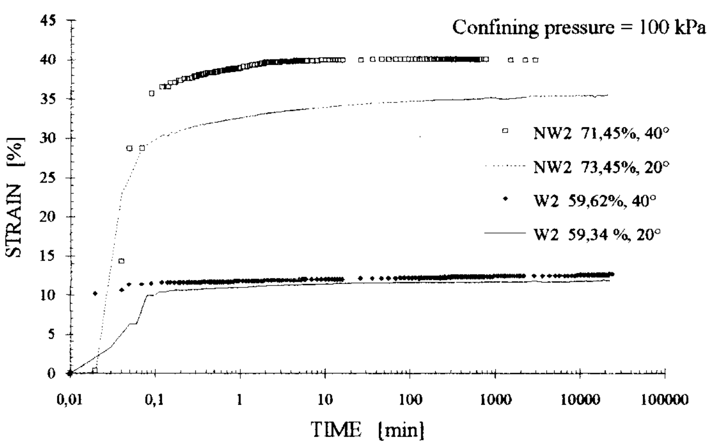
4.3.2 Tests at 40° C

Two temperatures were chosen : 20° C and 40° C, 20°C is the current temperature in fields, 40° C allows an acceleration of the test. For these high temperature tests and for the two basis materials, the strain-time curves shows clearly the behaviour differences. Figure 4 gives these relationships and on table V the specific values.

Temperature accelerates the creep of geotextiles where some differences can be noted. Slope n (issued from the "lg(ε) - lg(t)" curve) only increases for polypropylene products.



(a)



(b)

Figure 4 Strain-time relationships (confined tests at 20°C and 40°C). a: polypropylene; b: polyester.

Tableau V - Confined creep tests at 40° C temperature.

Geotextile	W1	W2	NW1	NW2
Curve slope : n	0,145	(0,0115)	0,175	0,016*
Test duration (min)	3	15565	6	1500*
Failure strain (%) ε_f	*F 17,5**	12,5	36	F 48,5

Load rate 76 %, except * values 70 %, ( ) values 60 %

5 GENERAL CONCLUSIONS

5.1 Influence of polymer

Rate of deformation n (slope of curves lg(ε)-lg(t)) for polypropylene are about 10 times rate for polyester. This ratio does not seem to be influenced by confining. For polypropylene failure is reached during creep tests. Temperature (20°C / 40°C) has an influence only on polypropylene; this observation proves that there is no creep due to the nature of the polymer for polyester.

5.2 Woven geotextiles

The creep behaviour of polypropylene W1 geotextile slightly depends on confining. The decreasing of slope n nears 20 % for a load rate of 50 %. This geotextile is made of twisted strips which give a more important contact zone between sand grains and the geotextiles ; confining pressure reduces the creep deformation.

W2 geotextile is made of polyester threads which has the appearance of a net. The contact sand / geotextile is different. The confining influence is negligible.

5.3 Non woven geotextiles

NW1 is slightly sensible to confining pressure as W1.

For the polyester NW2, the slope n is about the same in the two kinds of tests performed : non confined or confined. The strain time curve or creeping curve is strongly influenced by the confining at the beginning of the creep test; this is due to an higher stiffness in confined environment that in "free" test for non woven geotextiles.

6 REFERENCES

Kabir, N. (1984) In-isolation and in-soil behaviour of geotextiles *Thesis*, University of Strathclyde, Glasgow

Blivet, J.C., Msouti, F., Matichard, Y., Levacher,D. (1992) Mechanical behaviour of geotextiles in design of permanent reinforced structures, *Proc. Earth Reinforcement Practice,* Kyushu, 35-38