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CREEP AND STRESS RELAXATION OF GEOTEXTILES

FLUAGE ET REDUCTION DE TENSION DES GEOTEXTILES

KRIECHVERHALTEN UND SPANNUNGSABBAU (RELAXATION) VON GEOTEXTILIEN

This paper discusses the relevance of creep and stress relaxation in geotextiles. It describes the testing procedure on geotextile fibre and presents data for polypropylene and polyester.

In diesem Beitrag wird die Bedeutung von Kriechneigung und Spannungsabbau bei Geotextilien behandelt; Pruefmethoden werden beschrieben und typische Daten fuer Polypropylen und Polyester vorgestellt.

1 INTRODUCTION

Geotextiles are increasingly being included in permanent structures and are often an important element in a sophisticated design procedure. Considerable efforts have been made to understand more fully the stress/strain relationship of the geotextile and also the load transfer mechanism between the soil and the geotextile. However, the permanence of many of the resulting reinforced constructions requires a better understanding of the long term load bearing and deformation characteristics of geotextiles.

Creep of geotextiles is a simple concept and is best illustrated by a reinforced vertical wall. Should the geotextile be prone to continued deformation under constant load, the structure will soon become unstable. The concept of stress relaxation is not easily visualized but can often be of equal importance to that of creep.

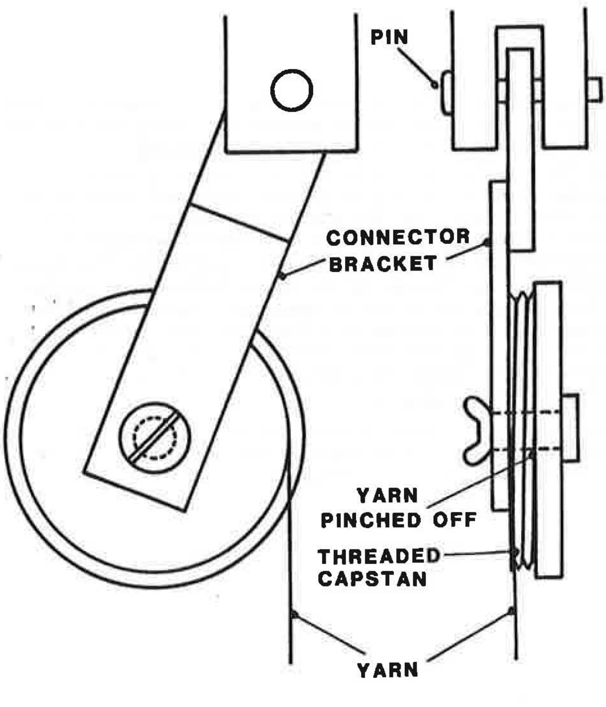
The tensile property of geotextiles is increasingly used to improve the stability or factor of safety against the collapse of soil structures. Strain measurements on installed geotextiles show the inevitable built-in stresses that occur due to construction and settlement. This often means that the forces sustaining stability within a reinforced structure are shared between the geotextile and the soil properties (primarily the shear strength), even though little or no deformation in the profile of the structure is apparent. However, if the geotextile is subjected to relaxation and unable to sustain its acquired load, then the stability of the structure may change radically without any warning movements taking place.

This paper describes the measurements of the creep characteristics of a geotextile and particularly highlights the importance of polymer selection.

2 TEST METHODS

Creep testing was carried out by suspending lengths of fibre under load, using either dead weights or lever loaded machines. Various forms of grip were tried, the most satisfactory of which was the threaded capstan type developed originally for coated silica optical fibres and illustrated in Figure 1. The yarn is laid in the threads of a 50mm diameter drawn over several turns and pinched off against a flat face in the final thread. If the friction is adjusted to be neither too high nor too low, the yarn sees a gradual decrease in stress between the gauge length and the end, with no undue concentration of stress.

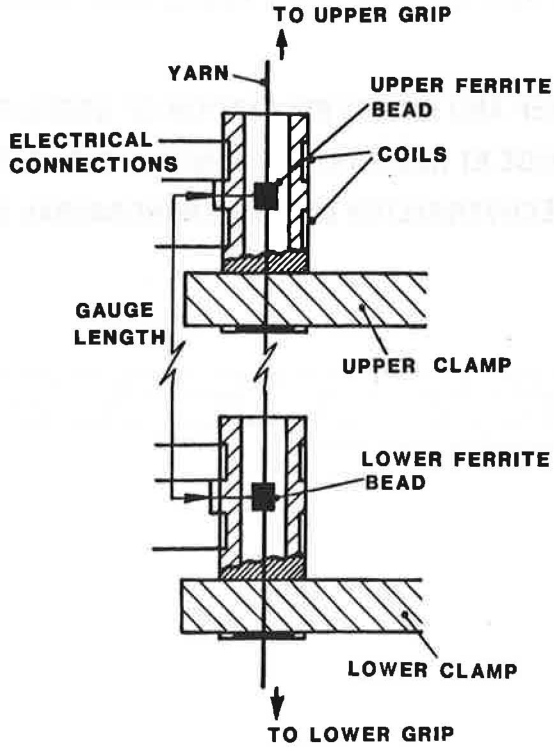
The strain measuring method was chosen to be automatic and compatible with the existing ERA Creep Laboratory system, by which creep strains are automatically recorded, processed and finally presented digitally or graphically. In the induction bridge extensometry method chosen, a high frequency alternating potential is applied to two coils wound in opposition thus generating an alternating magnetic field. The output at a common central tapping point is modified linearly with the displacement of a ferrite bead along the coil's axis and can be amplified to produce a voltage signal. The method was adapted to textile fibres by threading the yarn through two hollow ferrite beads which are then stuck with adhesive to the yarn a fixed distance apart. The yarn, with the beads, is then threaded through the extensometer coils, gripped and loaded. The elongation of the fibre is deduced automatically from the movement of the ferrite beads as measured by the extensometer coil outputs (Figure 2).



CAPSTAN GRIPS

FIG.1

FIG.2



ADAPTATION OF ERA EXTENSOMETRY

The movement of the beads is limited to the linear range of the extensometer coils and there must be no slippage in the grips. For higher strains, or where there was extensive slippage, it was necessary to use a conventional linear variable differential transformer (LVDT) which also consists of a core and a coil, but is longer, is wound differently and can therefore accommodate greater movements. In this case a hollow ferrite core was supported on a ceramic bead glued to the fibre, while suspended by a light hollow tube from the upper ceramic bend in such a way that it was level with and surrounded the core. The output of the extensometer is therefore a direct measure of the movement between upper and lower beads. The forces exerted by the extensometry are negligible in comparison with the creep loads, and the beads adhered to the yarn until it had stretched by over 50%.

All tests were carried out at 23±2°C.

3 TEST RESULTS

i) Polyester

Testing was carried out on 1100 denier polyester yarn (ICI) with a breaking load of 69N and had at the time of writing lasted for 10,000 hrs. Loads of 15, 30 and 45N were used, corresponding to approximately 20, 40 and 60% of the breaking strength. Figure 3 shows the results, plotted as total strain (ie: elastic plus viscoelastic strain) against the logarithm of time. On the same diagram are plotted the results on four samples of 'Parafil' rope that have been running for seven years (60,000 hrs).

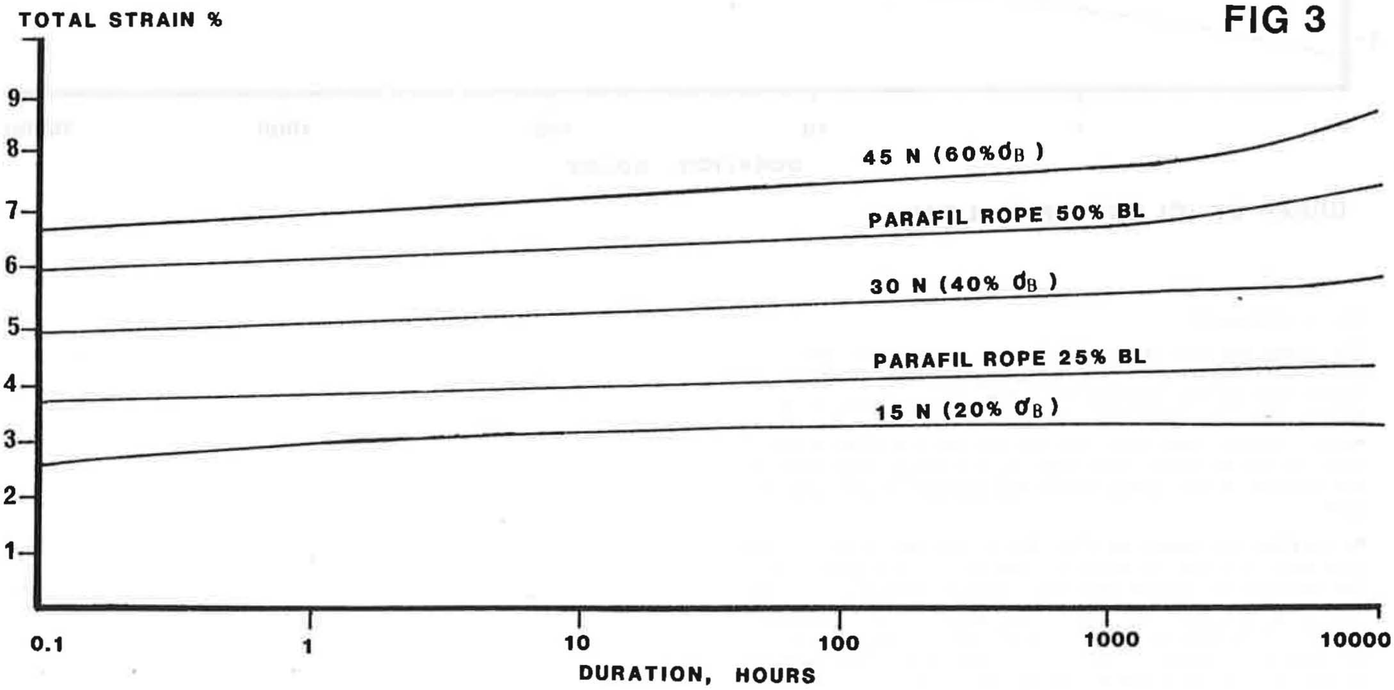
The results show that polyester yarns have a relatively high elongation on loading and during the first hour, but that the subsequent creep is low. Plotted against the logarithm of time it appears linear, except at very high loads and time when there is an apparent upturn, although this is not a real acceleration because of the logarithmic scale. The stress-dependence is non-linear (unequal spacings between the curves at 15, 30 and 45N load). The lines are of the same gradient as those of earlier tests (Ref. 1 Finnigan) and of independent results on polyester yarns (Ref. 2,3 Meffert).

ii) Polypropylene

By contrast, polypropylene stretches relatively little on loading but then shows a continuous creep. Figure 4 shows the results for a 9000 denier polypropylene yarn (ICI) with a breaking load of 294N, tested at 60, 120 and 180N, approximately the same proportions of the breaking strength as for the polyester for 10,000 hrs. Not only the initial loading, but also the subsequent creep behaviour, depends upon stress in a non-linear manner. At 60% of breaking strength the creep is very much higher and, on a logarithmic scale, appears to accelerate, although this is not a real acceleration as mentioned above.

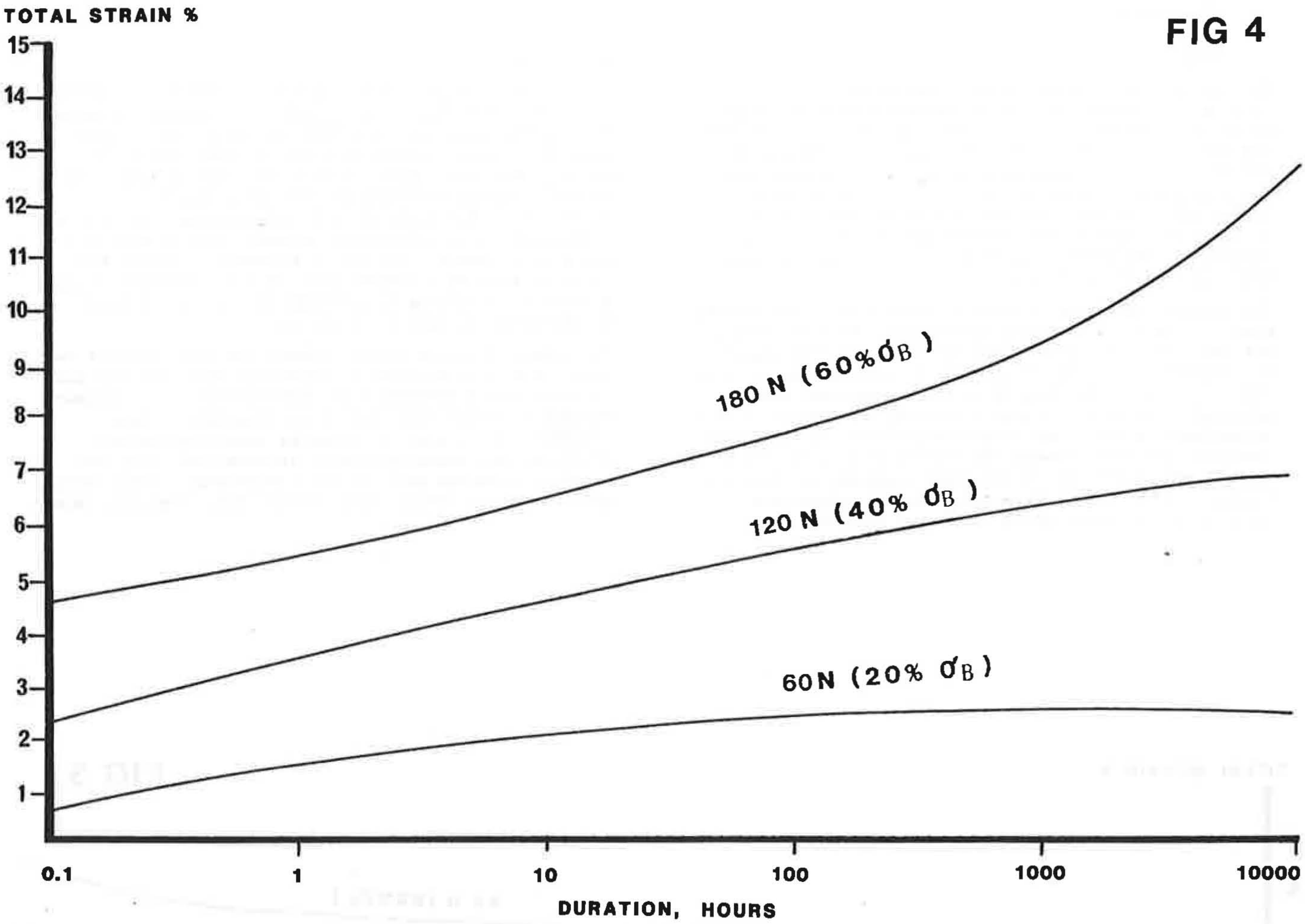
The creep of polypropylene fibres has been studied in detail but only with short durations and with the aim of providing a mathematical description of non-linear behaviour rather than real long-term data. More extended curves were obtained by time-temperature shifting, and agree generally in magnitude with our results, although plotted on a logarithmic scale they appear concave rather than convex (Ref. 4 Morgan, Ward).

FIG 3



CREEP OF POLYESTER YARN

FIG 4



CREEP OF ICI POLYPROPYLENE

iii) Polyaramid

The creep and rupture of polyaramid fibres has been measured and documented extensively because of their importance as reinforcements. Ref. 5 Ericksen, is a recent and very detailed review. Practically all the work, however, has been carried out on the high stiffness Kevlar 49 fibre from DuPont, although some results are quoted on the lower stiffness Kevlar 29 polyaramid yarn.

We carried out tests on 1500 denier Kevlar 29 polyaramid yarn with a breaking load of 274N at 55, 110 and 165N. The results confirmed that the overall strain lever and the creep are both extremely low, apart from a certain amount of 'settling in' within the first few minutes. The overall levels of long-term creep were 0.04% per decade at 55N load and 0.08% at 110N. This is within the range quoted in Ref. 5 Ericksen. At 165N the yarn ruptured after 126 hrs, and a second specimen broke after 265 hrs.

4 DISCUSSION

i) Extrapolation of the Results

Creep curves can be extrapolated by eye, or by fitting a mathematical formula such as a power law. The advantages of such a mathematical description are that it can be developed to predict the behaviour under other forms of loading such as creep recovery (contraction when the load is removed) or stress relaxation (application of a fixed strain with a subsequent fall in stress). Ideally, it should be possible to apply a formula which is directly attributable to a physical mechanism such as a thermally activated process with an activation energy modified by the application of stress (Eyring rate equation). A formula without a physical basis may appear more credible than a line drawn by eye; in reality it has little more justification.

So far it has not been possible to apply physically based mathematical formulae to these fibres. For polyester and polyaramid, however, the data approximates well to straight lines relating to creep log (time), which can be extrapolated by extending the lines. It must be emphasized that all extrapolation, whether by eye or calculation, whether supported or unsupported by physical explanation, depends on the mechanisms of creep remaining the same; if they change, then the extrapolation is invalid. ERA's practice is therefore:

- to extrapolate by no more than a factor between three and ten, depending on the complexity and the familiarity of the system.
- to observe closely whether the mechanisms governing creep are the same throughout the ranges of time, temperature and stress applied.
- when a series of tests is completed and an extrapolation made, to leave a limited number of tests running in order to give early warning of any change of mechanism and creep behaviour that may occur after long exposures.

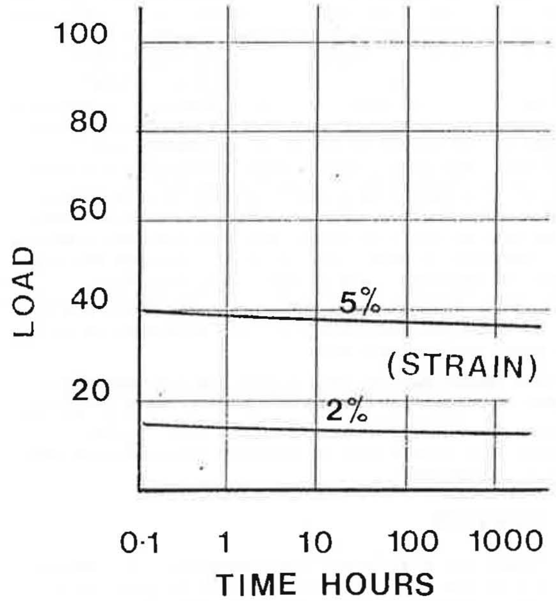
The results on 'Parafil' ropes which started earlier, appear to confirm the extrapolation made by extending the line, but the apparent upturn at long durations and higher stresses suggest that there may be a change in mechanism which could be a slow approach to rupture.

ii) Stress Relaxation

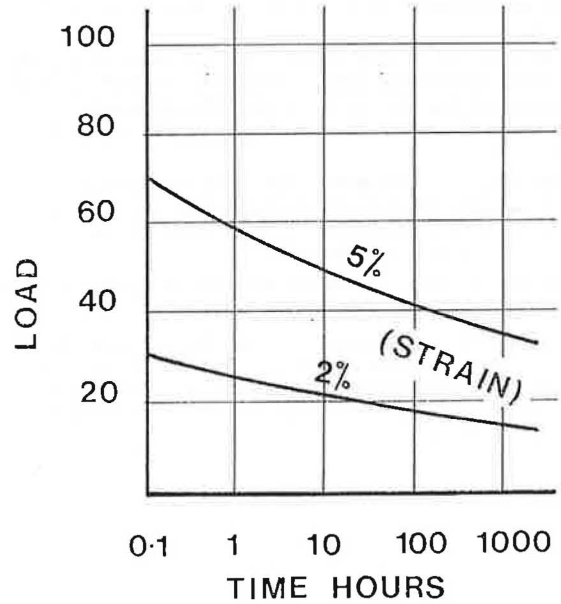
If the creep is linear in stress and if a mathematical description can be applied to the creep behaviour, then it is possible to derive the behaviour in stress relaxation. These fibres are non-linear in stress and their behaviour cannot be fully described mathematically. Work is in hand to provide a method for predicting the stress-relaxation behaviour using existing mathematical methods and to confirm it experimentally. An estimate of the stress relaxation behaviour can be made from the isometric curves, which are curves of constant strain, plotted as a diagram of stress against logarithm of time (Figure 5).

iii) Application to Woven Fabrics

The relation between the properties of yarn and woven fabrics were examines in detail by Meffert (Ref. 2, 3) including the biaxial effects of stress in one direction upon strain in another. In general, it appears that the less the creep in the yarn, the greater is the relative effect of the weave. Most of the reported values for the creep of woven polyester are considerably higher than the values for yarn, while for polypropylene the creep results quoted for woven and unwoven fabrics, although lasting no more than 1000 hrs and more concave than Figure 4, are of the same general appearance. No measurements have been reported for woven polyaramid fabrics, but by analogy with polyester the creep would be expected to be higher than for the yarn.



POLYESTER (ICI)



POLYPROPYLENE (ICI)

FIG.5

5 CONCLUSION

The creep measurements on different geotextile fibres show no direct relationship to the short term stress/strain relationship but are rather dominated instead by polymer composition. The extensive creep testing of polyester beyond 60,000 hrs should give confidence in extrapolating their performance, particularly if the stress level is below 40% of the short term breaking load. The polypropylene shows a high deformation on the load in time. However, a comparison based on strain is somewhat misleading, as the polypropylene selected is of an extremely high tenacity. The polyaramid showed promising deformation results with time, particularly at low stress levels. The failure of the higher stress specimen may be due to testing procedures and further tests will continue in order to define the reason for the premature rupture. The higher creep results reported in fabrics when compared with fibre may be reduced when the geotextile is encapsulated in a soil mass (Ref. 6 McGown).

The test described in this paper and the reported results are part of an extensive long term property evaluation of geotextiles which includes other polymers and variations of testing environments and loading parameters.

6 REFERENCES

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