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MYLES, B. and CARSWELL, I. G.
ICI Fibres Geotextile Group, Lydney, Glos., United Kingdom
Royal Military College Science, Shrivenham, Wilts., United Kingdom

TENSILE TESTING OF GEOTEXTILES
ESSAIS DE TRACTION POUR LES GEOTEXTILES
ZUGPRÜFUNG VON GEOTEXTILIEN

This paper considers the requirements of uni-directional tensile testing of geotextiles with particular reference to the practice of high strength wide width testing.

Der Beitrag behandelt die Anforderungen an die einaxiale Zugpruefung von Geotextilien und geht besonders auf den breiten Zugversuch ein.

1 INTRODUCTION

The uni-directional tensile strength of a geotextile is one of the most common properties used, and specified, within the construction industry. The nature of the property means that it is readily understood in engineering terms, although its simplicity of concept has, paradoxically, often led to misunderstanding and misinterpretation.

The tensile property requirement for a geotextile is twofold:

1) It must be capable of acting as a tensile element within a soil structure.

2) It must have adequate tensile strength to allow the geotextile to perform.

The type of testing described in this paper relates principally to requirement (1), where the tension is uniform and directional within the plane of the fabric and where forces are generated by deformation of the total soil structure.

The tensile property requirement in (2) is generally generated by local forces impinging on the fabric perpendicular to the plane. There are several well defined tests (CBR, Mullen Burst grab) which indirectly assess this tensile property. These tests are not considered here, but it can be stated that widespread use is made of the uni-directional tensile testing mode to assess geotextiles also for their suitability as filters and separators.

It must be remembered that the test methods described relate to geotextiles in isolation, whereas in practice nearly all geotextiles are encapsulated within a soil mass. Whilst, in general, the in-isolation tests describe the geotextile behaviour well, the test will not totally describe the exact stress/strain behaviour of the geotextile in use. Considerable effort has been made to avoid the shortcomings of standard textile testing, particularly in the selection of sample format and the rate of imposition of load.

2 TENSILE TESTING SYSTEMS

Traditionally, textiles have been tested for tensile properties by means of the 50mm uni-directional method with high rates of strain. A variation on this procedure has been the grab method, which assesses also the capability to distribute a load through a fabric structure.

Fibre and yarn producers test on single fibres or single ends with relatively high rates of strain. This type of testing is inappropriate for geotextiles and will not adequately reflect the properties of the product tested. More worringly, it may seriously over estimate the true strength of the geotextile.

In a large proportion of geotextile end uses today tensile strength is not necessarily the prime requirement, and arguments can be put forward that puncture type tests give a better indication of the robustness or suitability for use as a filter or separator. The authors, in general, agree with this viewpoint and for this type of test would recommend the DIN54307 plunger test.

However, this paper deals with uni-directional testing and the experiences gained in progressing the sample width to 200mm and beyond.

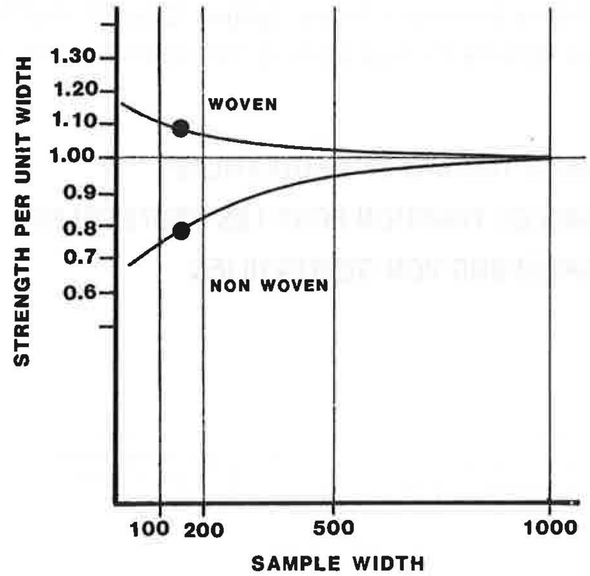
3 UNI-DIRECTIONAL TENSILE TESTING - PROPERTIES AND DATA

The properties referred to in this section will relate to those produced from direct tensile testing. Long term properties are not covered in this paper. The following are the major properties and data that should be reported for a uni-directional test:

1) Breaking load
2) Extension at breaking load
3) Modulus
4) Daylight point
5) Offset strain
6) Rate of strain
7) Gauge length and sample width
8) Direction of test in relation to manufacture
9) Pre-load
10) Gripping method
11) Strain measurement method
12) Temperature and humidity

The geotextile construction and polymer constituent can have a considerable effect on the stress/strain behaviour. Figure 1 shows typical plots of stress/strain behaviour for an orientated (woven) geotextile showing a primarily linear response, and for a randomly laid fibre geotextile (non-woven) showing a non-linear load/extension response.

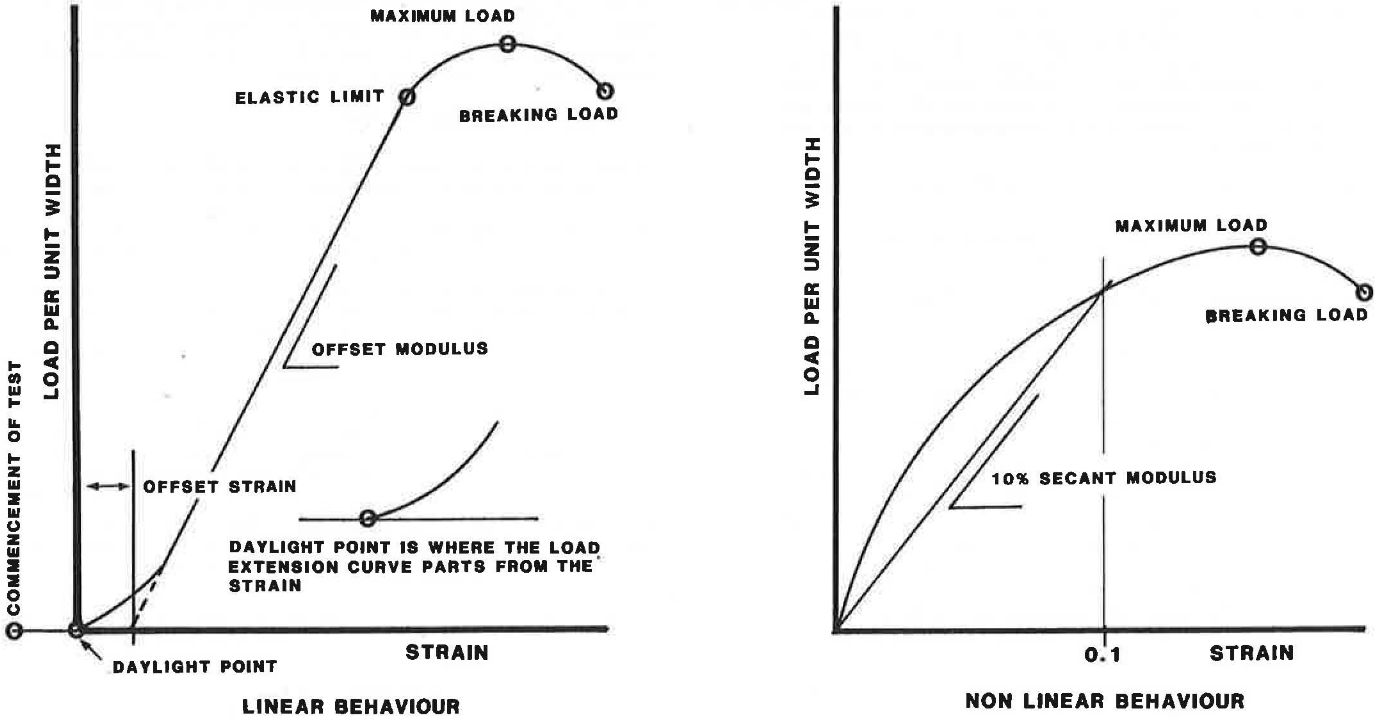
The beginning of the stress/strain curve is of particular importance for geotextiles. This point is often difficult to define and it is for this reason that the concept of the daylight point, ie: the point at which the stress/strain curve leaves the strain axis, is used as the strain commencement point. Most orientated products and some randomly laid products require a certain amount of strain before the inherent stress/strain characteristic of the geotextile fibre develops. A measure of this initial deformation is referred to as the offset strain, ie: the distance between the daylight point and the intercept of the extended modulus line with the strain axis.



INFLUENCE OF SAMPLE WIDTH ON STRENGTH

FIG. 2

Considerable evidence exists, and is well documented to show the variation of breaking load on a sample with aspect ratio and product type. Figure 2 highlights the difference between a robust high strength woven geotextile and a lightweight non-woven geotextile. It can be seen that single end testing in orientated geotextiles can overestimate the strength by 10-15% whereas the non-woven shows a considerable improvement in the estimation of strength when the sample width is increased to 200mm.



LOAD - STRAIN CURVES FOR GEOTEXTILES

FIG.1

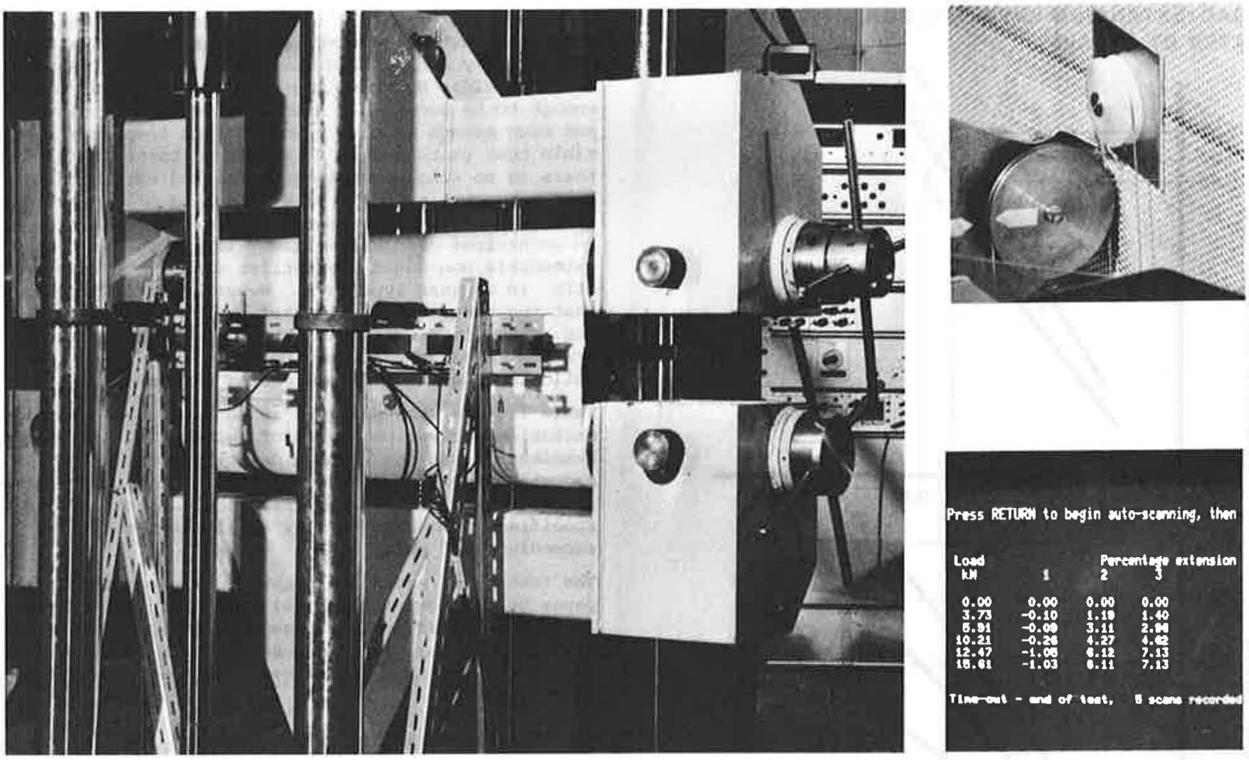


FIG 6 ONE METRE WIDE TESTING RIG

Mindful of the overall dimensions of geotextiles used, (production widths often exceed 4 metres) and in order to establish a realistic strength per metre, a 1 metre investigative test procedure has been developed. The effect on non-wovens in testing narrow samples is to seriously underestimate the real strength of the fabric and once again the selection of the 200mm wide sample width gives a close approximation to the true strength of the fabric (see Fig 2). However, it should also be borne in mind that non-woven structures are not primarily used as tensile performance geotextiles.

For practical purposes pre-load on the geotextile specimen is necessary prior to the commencement of the textile test. The amount of pre-load will depend upon:

1) Fabric structure
2) Method of gripping
3) The ultimate tensile strength of the geotextile

The amount of pre-load used should be sufficient to bed the fabric into the gripping mechanism and also to produce a uniform tension throughout the fabric. A practical minimum for 200mm wide testing will be approximately 0.1 kN but for coarsely woven robust fabrics a pre-load of 1% of the ultimate load may be required. In all tests the amount of pre-load should be noted and reported.

The uni-directional test is an investigation of the stress/strain response of a geotextile. However, it must be borne in mind that in the field the application of load will rarely be uniform and will occur at a much lower rate than that experienced during the test. In addition, the geotextile will be confined within a soil mass which in general will have a stiffening effect upon the geotextile's behaviour. Geotextiles with higher tensile properties and defined orientated structures will be less affected by soil encapsulation than randomly orientated fibre structures.

The rate of strain will also have an effect on the stress/strain behaviour. Polymer composition also has an effect - for example, polyester has been shown to be less sensitive to strain effects than polyolefins. Figure 3 gives an indication of the response of different polymers to differing rates of strain.

4 PRACTICALITIES AND METHODS OF TEST

i) Gripping and Strain Measurement

Traditionally, most tensile testing procedures assume a positive gripping mechanism which not only provides a positive load transfer but also defines the gauge length of the specimen, thus giving a means of measuring extension by monitoring the crosshead movement.

The accommodation of the gripping forces in conventional materials is often achieved by modifying the cross-section of the sample to be tested. Unfortunately this is rarely possible in a geotextile. The simplified positive gripping mechanism is applicable to geotextiles in the low to medium strength range. For higher strength geotextiles and for geotextiles with a more complex structure, novel methods have to be adopted which can entail separating the gripping and load transfer mechanism from the measurement of extension. The three main ways of gripping geotextiles are:

LOAD/EXTENSION ENVELOPE FOR DIFFERING RATES OF STRAIN

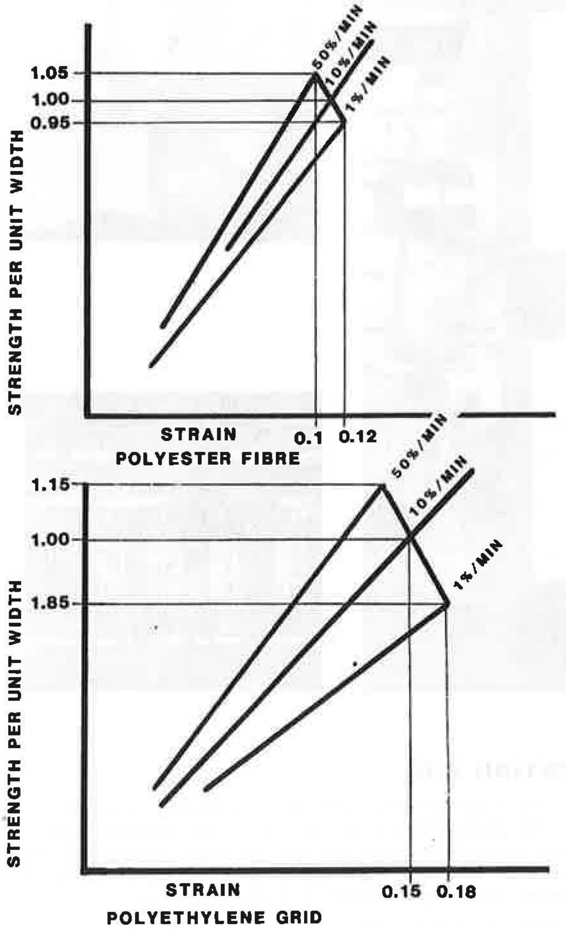


FIG.3

1) Mechanical wedge (Figure 4a)
2) Encapsulation with either epoxy or a low melting point metal (Figure 4b)
3) Roller or capstan grips (Figure 4c)

Methods of measuring the extension of the fabric can be:

1) By measuring the travel of the positive gripping mechanism
2) By extension measurement independent of the gripping mechanism. This can be done by direct optical reading (Figure 5), indirect optical reading, and linear and rotary transducers (Figures 4c and 6)

ii) Practical Testing Arrangements

Test arrangements have developed from the compressive mechanical grip, often incorporating a wedge mechanism, through epoxy and soft metal wedges, and finally to capstan and rotary grips. This development has followed the increasing strength of the geotextiles to be tested and the 200mm wide sample has dominated much of this work.

The development of extensometers for geotextiles has enabled not only more accurate measurement to be made but has also enabled more detailed and localised measurement. Ideally, the load cell mechanism and extensometer readings should be incorporated simultaneously either by chart recorder or rapid interval computerised output.

Constant rate of strain load application is most commonly used when testing geotextiles, the rate of strain used is considerably higher than that experienced by geotextiles in the field. However, the rate of strain 10%/min is low enough to be acceptable from a geotechnical point of view and high enough to give practical and commercially acceptable test procedures. It should be borne in mind that there is no single simple gripping and extension measurement method to suit the total spectrum of geotextiles, just as high strength geotextiles are difficult to grip in mechanical compressive jaws, low strength, highly extendible non-woven geotextiles can often prove problematic in capstan type jaws. Nevertheless it is hoped that the tensile test standards being written by different authorities will give the testing house adequate freedom to adapt their equipment whilst at the same time following the required procedures and parameters.

Table 1 gives some guidance as to the choice of gripping mechanism for various types of geotextile. It should be remembered that the 200mm wide strip tensile test is becoming widely used and accepted, and it is now commonplace to see 400-600 kN/m breaking load geotextiles specified, with commercially available geotextiles exceeding 1000 kN/m.

The testing of seams and joints is not covered in this paper but the uni-directional wide width test procedure can easily be adapted to assess jointing methods. An ASTM test method for seam assessment is in draft form at the present time and is based on the 200mm wide strip tensile method.

iii) Testing Machinery

The increase in size of sample format together with the introduction of high strength geotextiles places demands upon testing machinery far beyond those normally encountered in standard textile testing. Minimum requirement for capacity based upon the 200mm wide test should be 100 kN; more adequate cover and security is given if the capacity is closer to 300 kN.

The conflicting requirement of high load capacity and larger crosshead travel often exists in tensile testing machines. As a guide for the 200mm wide test a crosshead travel of between 250-300mm is desirable and a free working area, below the load cell prior to extension, of 500mm x 750mm.

iv) Sample Preparation

Non-woven products, in general, present little problem and can easily be cut to size by either scissors or a sharp knife and have little or no tendency to fray or distort.

Woven and orientated products often present difficulties being both hard to cut, and having a tendency to fray and unravel. Products with a high strength in length to cross direction bias are prone also to distortion.

A hot knife can be particularly useful when preparing polyester and polypropylene samples as it provides an edge seal as well as a cut.

For gripping the samples, use of epoxy and soft metals can be costly and time consuming. However, they have the advantage of being adaptable to a wide range of fabric types and require a minimum of fabric.

Capstan and roller grips provide an effective and rapid method but require large sample lengths. For high strength products a length of 1-3 metres is not uncommon. However, due to the format of geotextiles this is rarely a problem.

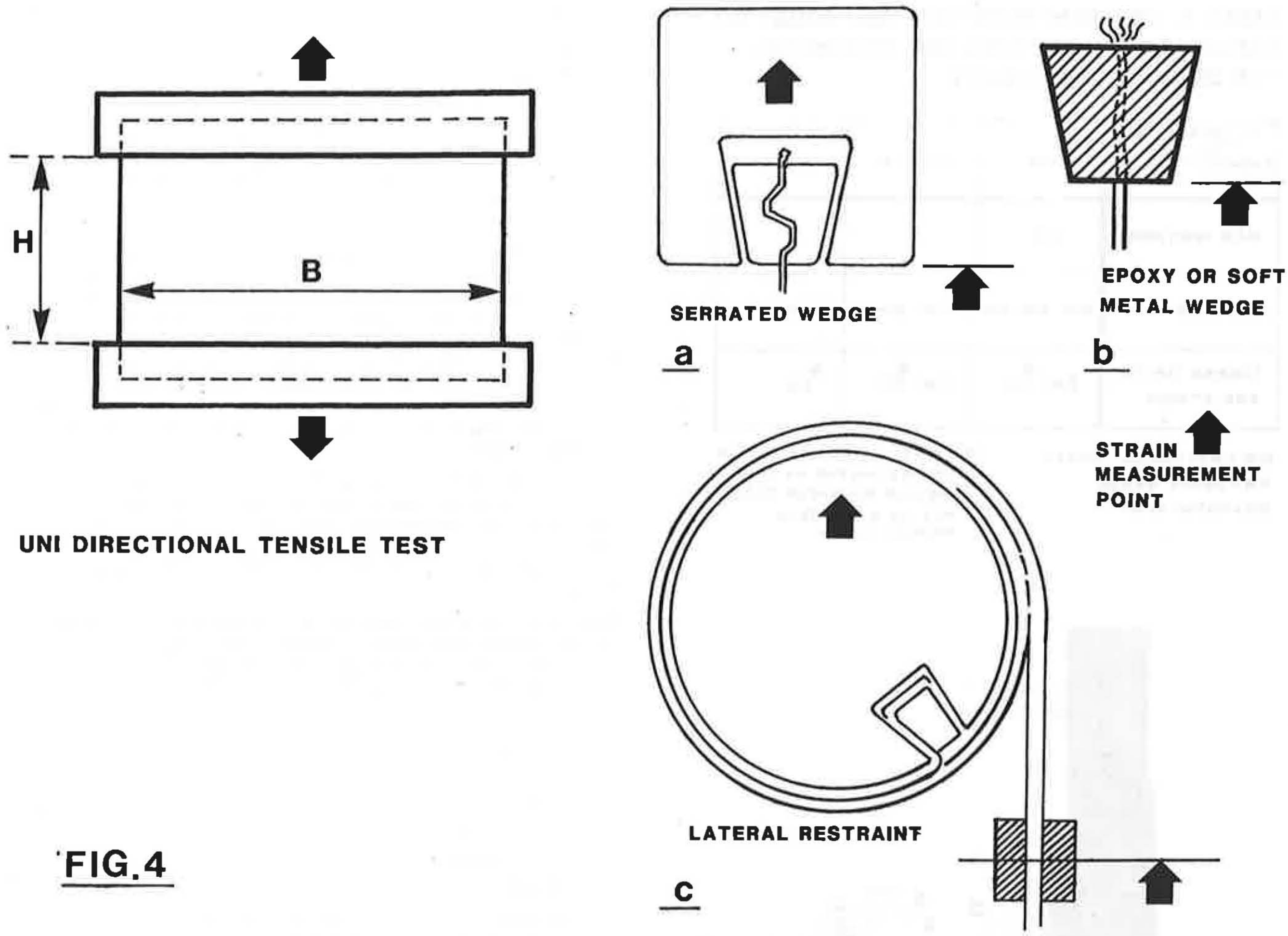
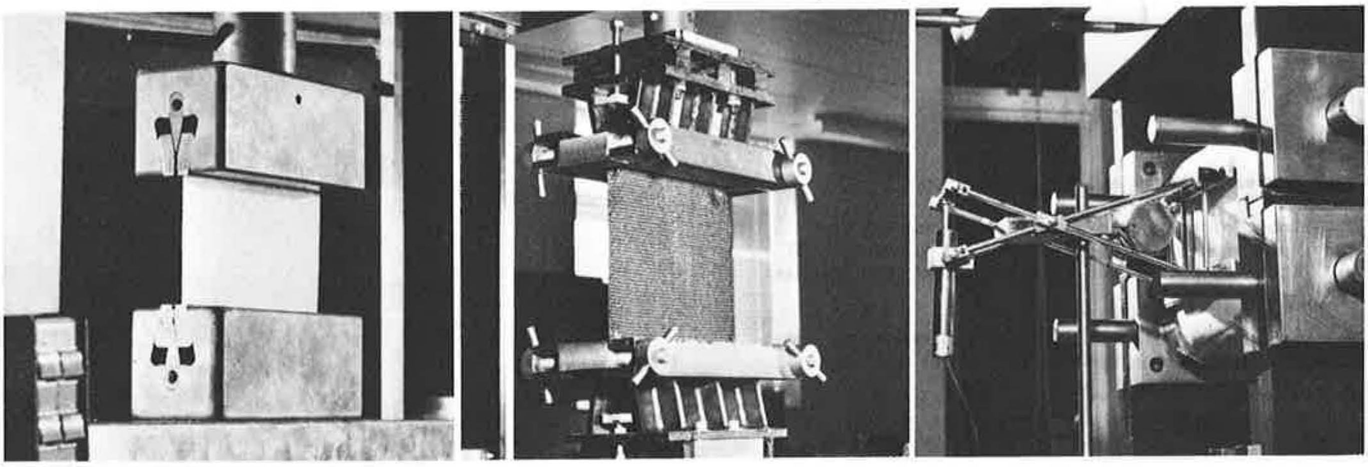


FIG.4

GEOTEXTILE CLAMPING SYSTEMS



a) b) c)

TABLE 1. RECOMMENDED TEST METHODS FOR VARIOUS PRODUCT TYPES AND STRENGTHS FOR 200mm STRIP TENSILE

STRENGTH / FABRIC TYPE	LOW	MEDIUM	HIGH
NON WOVENS	MW		
WOVENS	MW, EW, RG	EW, RG	RG
LINEAR GRIDS AND STRIPS	EW, RG*	EW, RG*	RG*

MW = Mechanical Wedge
EW = Epoxy Wedge
RG = Roller Grip

* Linear Grids and Strips can be tested by this method provided they are of a flexible enough nature

FIG.5

v) Number of Tests and Accuracy

The number of tests per geotextile direction can vary between 4-8. The coefficient of variation (γ) will indicate the number of tests (n) by the formula:

$$n = 0.154\gamma^2$$

For new fabrics this will obviously necessitate trial testing to establish the coefficient of variation.

For reasons connected with the production process, non-wovens may require a higher number of tests due to product variation, whereas it can be expected that products based on industrial high tenacity yarns will show much greater uniformity. However, coefficients of variation above 10% should give cause for concern, particularly if these occur in high strength geotextiles.

The accuracy of strain measurement should always be within 0.5% with an expectation of greater accuracy if transducer methods are employed.

5 CONCLUSIONS

The increasing necessity to understand better the physical properties of geotextiles is closely linked with the widespread use of these products into permanent long term applications where they are to perform lasting, and in many cases, critical functions. It is therefore essential that the geotextile industry should not offer and promote products without total analysis of the appropriate properties.

The widening range of polymer composition, construction and, not least, performance has resulted in the formation of committees, national testing and specifications; and a considerable amount of research. Testing procedures, gripping mechanisms, extensometers etc, are now available adequately to monitor the stress/strain characteristics of all the commercially available geotextiles in a way which will satisfy the geotechnical engineer's desire to receive reliable and understandable data.

However, the data and properties obtained from wide width testing, no matter how accurate, must be combined with information and characteristics concerning the compatability of load transfer mechanism of the geotextile and also the long term behaviour of the polymer used.

Armed with this information the geotechnical engineer can integrate performance geotextiles within soils structures, and the designer should never be satisfied with less than the adequate property data.

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