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Load-Extension Testing of Geotextiles Confined In-Soil

Proprietés d'extension sous charge de géotextiles placés dans le sol

The paper describes an apparatus capable of testing in-soil, geotextiles subject to first-time loading, cyclic loading, creep and stress relaxation under a variety of environmental conditions. Comparative data from unconfined in-isolation and confined in-soil tests on woven, non-woven and composite geotextiles demonstrate that to obtain data for design purposes in-soil testing is essential.

L'article décrit un appareil capable de soumettre a l'essai de géote tiles dans le sol quand ils sout exposes à premiere charge, charge cyclique, fluage et relaxation de tension, sous une varieté de conditions exercées par l'env ronnement. Des données comparatives d'essais isoles non restreints, et d'essais compressés dans le sol, sur des géotextiles tissés, non-tissés et composites, demontrent que pour obtenir des données pour ce qui concerne la conception, des essais le sol sont essentiels.

INTRODUCTION:

Geotextiles are manufactured by a wide range of processes. This imparts quite different load-extension properties to the materials. With woven geotextiles, the properties of the constituent fibres may dominate the overall behaviour, however, with non-woven and composite geotextiles the dominant factor is their internal structure. Where the internal structure does dominate, it is usually the case that this structure is liable to change when subject to stress, either by tensile stressing in the plane of the geotextile or by compressive stressing transverse to it. Adding to this, the fact that many geotextiles are anisotropic, causing them to have a degree of sensitivity to boundary strain conditions and confining stresses greatly in excess of that found for most other engineering materials. It is essential therefore to fully appreciate the imposed edge boundary conditions and confining stresses imposed during any test on geotextiles and to match whenever possible the imposed test conditions with those operating when the geotextile is functioning in the soil.

It is of course recognised that load-extension testing of geotextiles may not always be directed towards determining their in-soil behaviour. For example, regular testing will usually be carried out by the manufacturer in the factory to ensure that the manufacturing process is producing a material within some predetermined limits of variability. Also engineers on site may selectively test geotextiles to ensure that those materials delivered on site conform to the manufacturers' or clients' specified minimum properties as is required by particular contract conditions. Such tests need not exactly replicate operational conditions for the geotextile and unconfined in-isolation tests are adequate (1). Such tests should, however, not be used as a basis for comparing the in-soil performance of geotextiles, particularly when they are manufactured by different processes, nor should they be employed to obtain properties for use in the design of soil-geotextile systems. For such purposes, data from specially developed test apparatus must be employed.

This paper describes the detailed construction of an apparatus in which the load-extension properties of geotextiles when confined in-soil can be determined and the sensitivity of various types of geotextiles to in-soil test conditions is demonstrated using data obtained from first time loading and creep tests.

IN-SOIL TEST APPARATUS

Constructional Features

Basically the apparatus consists of two metal boxes containing air activated rubber pressure bellows which are placed either side of a test specimen of geotextile and clamped together by two metal side plates, Fig. 1. A layer of soil is placed between the bellows and the geotextile and when the bellows are pressurised, a lateral confining stress is imposed on the geotextile by the soil. The apparatus is designed to exert a maximum confining stress of 250 kN/m^2.

Several problems arise with this arrangement and the solutions adopted for these are:

(i) Puncture of the bellows by the soil: To avoid the soil puncturing the bellows,

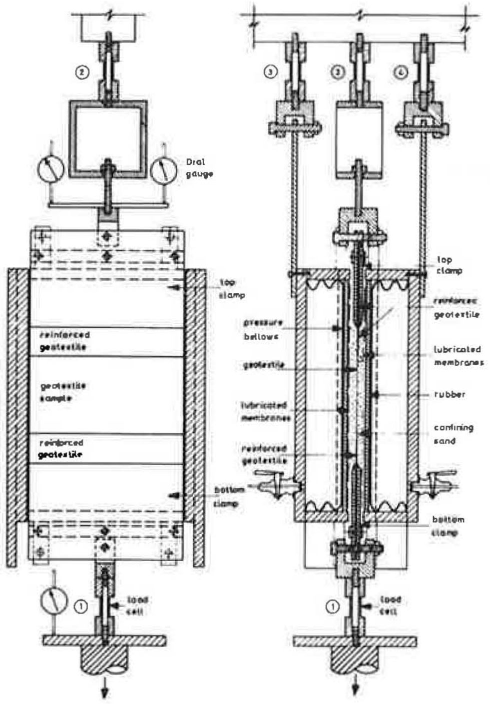


Fig. 1. Layout of the in-soil apparatus.

a layer of stiff rubber is placed between the soil and the bellows. This layer of rubber also helps to ensure the uniformity of the lateral confining stress.

(ii) Transfer of applied axial load through the soil to the body of the apparatus: Firstly to minimise axial load transference into the apparatus, thin layers of rubber membrane separated by silicone grease are placed between the stiff rubber and the soil to reduce soil/ rubber friction. Secondly, the whole apparatus is fixed to the load frame and load cells are incorporated into the fixtures to measure any residual transfer of axial load. This arrangement is identified as load cells 3 and 4 in Fig. 1. Thirdly, the net axial load imposed on the geotextile is measured independently by load cell 2 and a check made that the load applied through load cell 1 equals the combined load measured in load cells 2, 3 and 4. Calibration tests have been previously reported by McGown et al (2).

(iii) Maintenance of contact between soil and geotextile during straining: The end clamps are the same thickness as the soil layer in contact with the geotextile. The leading edges of the clamps are sloped back

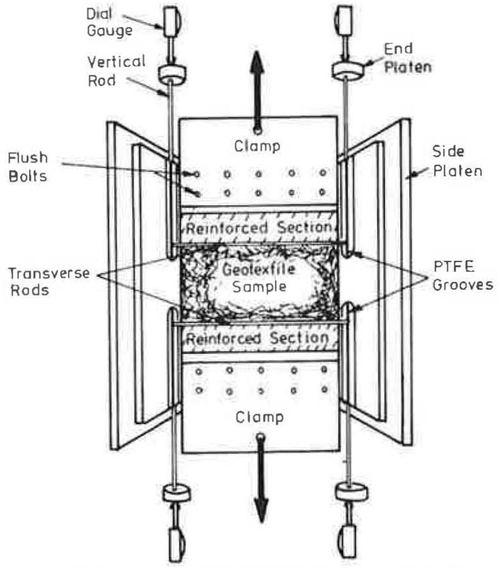


Fig. 2. Scheme for measuring the extension of test specimen in-soil.

and flush bolted into the very stiff resin reinforced ends of the test specimen. The reinforced ends of the specimen extend beyond the clamp into the soil. The soil is therefore initially in contact with the unreinforced and the exposed reinforced sections of the geotextile. The length of the exposed end of the reinforced geotextile is chosen to be greater than the maximum extension of the unreinforced section during the test. This ensures that the extent of the confining soil is greater than that of the unreinforced section of geotextile at all times during the test.

(iv) Measurement of the extension of the unreinforced section of the test specimen within the soil: It cannot be assumed that slippage between the clamp and specimen does not occur, nor that the very stiff reinforced sections of the geotextile are rigid. The extension of the unreinforced section of geotextile must therefore be measured directly. To do this, a thin steel rod is bonded onto each of the leading edges of the reinforced geotextile. The tips of the rods are machined to fit into slots in the two side plates. These slots are lined with P.T.F.E. which has extremely low frictional resistance. Further steel rods are located in the slots and extend out of the apparatus to end platens. The transverse rods connect into the rods within the slots and any movements are therefore transferred out of the apparatus. Dial gauges resting on the end platens outside the apparatus measure the internal movements. The arrangement is shown schematically in Fig. 2.

Test Specimen Sizes

To establish suitable sizes and shapes of test specimens, an unconfined in-isolation test programme was undertaken with various types of geotextile. To ensure that local variations in geotextile construction were taken into account, a minimum dimension of 100 mm was adopted. Tests were then conducted on test specimens with a height of 100 mm and various widths up to 500 mm. It was found that needle punched geotextiles were the most critically affected by the shape and size of the test specimen but that for test specimen sizes beyond 200 mm wide and in the strain range of 0 to 40 per cent, little significant difference was recorded in their measured load-strain properties, Fig. 3. Thus 200 mm wide by 100 mm high test specimens were adopted as standard minimum sizes, (3).

For test specimens with the minimum standard dimensions, the in-soil apparatus was designed with a 10 mm thick soil layer on each side of the test specimen. This limited the types of soil that could be tested to sand sizes and finer. To accommodate larger soil particle sizes and allow the testing of larger geotextile specimen sizes, another version of the apparatus was designed to test up to 500 mm wide by 250 mm high geotextile specimens with a 25 mm thick layer of soil on each side of it. The two sizes of apparatus are shown mounted in their loading frames with their associated data logging equipment in Fig. 4.

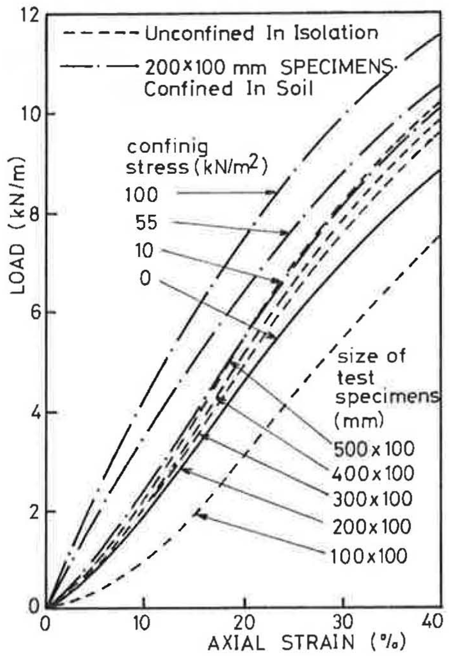


Fig. 3. Unconfined in-isolation and confined in-soil load-axial strain data for Bidim U24.

Test Conditions

As these tests are primarily intended to measure properties of geotextiles appropriate for use in design calculations, it is important that the environmental conditions of the test be similar to the operational conditions, (1). For this reason the geotextile specimens should be tested in a soaked condition and at temperatures relating to the in-soil temperatures, which in United Kingdom is approximately 10 °C. To

Fig. 4. General view of in-soil apparatus

accomplish this temperature control, insulated temperature cabinets have been constructed to fit around the apparatus and tests may be conducted within these at temperatures from 0 °C to + 40°C.

When fitted in the loading frames shown in Fig. 4, axial loads up to 10 tonnes may be applied at constant rates of strain in the range 20 to 0.0002 per cent per minute. When the load frames are fitted with a suitable activator, cyclic loading may be carried out. To accommodate creep load testing, specially designed rigs were constructed, which are shown schematically in Fig. 5. A creep test

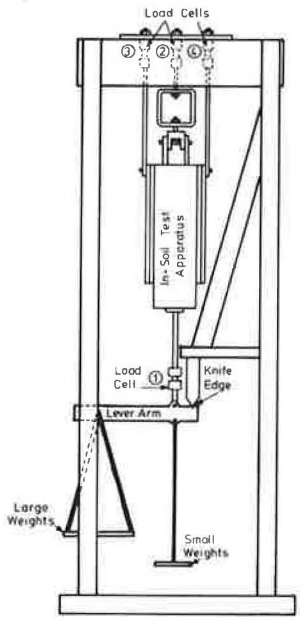


Fig. 5. Creep test rig.

Table 1. Basic Characteristics of Geotextiles Tested.

CHARACTERISTIC	LOTRAK 16/15	TERRAM 1000	BIDIM U24	PROPEX 6067
Method of Construction	Woven tapes	Non-woven Melt bonded filaments	Non-woven needle punched filaments	Composite Woven and needle punched
Polymer(s) Composition	100% Polypropylene	67% Polypropylene 33% Polyethylene	100% Polyester	100% Polypropylene
Specific Gravity	0.91	0.9	1.39	0.91
Weight/ Unit Area (g/m^2)	120	140	210	650
Nominal Thickness (mm)	0.3	0.7	1.9	3.5

set up with a 200 x 100 mm sample size apparatus is shown in Fig. 6. By modifying the lever system to provide fixed extension of the geotextile with measurement of the applied loads, stress relaxion tests may also be conducted in this set-up.

Now to illustrate the sensitivity of various types of geotextile to in-soil test conditions, data from first time loading tests on four commercially available geotextiles and creep tests on two of them are detailed.

FIRST TIME LOADING TESTS

Tests were conducted on four geotextiles manufactured by various processes and possessing differeing properties, as identified in Table 1. All the test specimens were 200 mm wide. In the opposite direction they had 100 mm unreinforced central section with a 100 mm resin impregnated reinforced section on either end. The clamps were bolted through the outer 60 mm of the reinforced ends to leave 40 mm of reinforced geotextile exposed on each side of the central section. Unconfined in-isolation tests were carried out on some of these specimens in a dry condition at 20 °C and at a constant rate of strain of 2 per cent per minute. The others were tested under the same environmental conditions but were confined in-soil at a pressure of 100 kN/m^2, The confining soil was Leighton Buzzard sand with a particle size range of 0.3 to 2.0 mm, mean diameter of 0.85 mm and uniformity coefficient of 1.22.

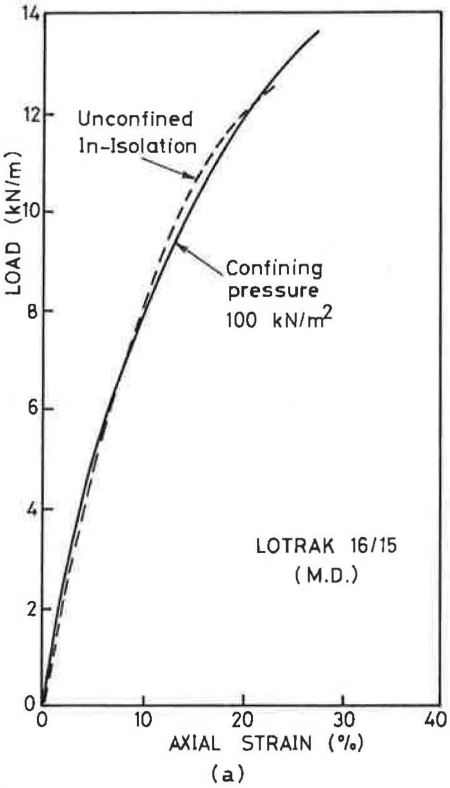
The test data obtained from these comparative tests are shown in Fig. 7. They demonstrate that the structured non-woven and composite geotextiles exhibit significant changes in the shape of their load-strain curves when tested in-soil. The woven geotextile does not show much change as it depends for its strength on aligned tapes which are not greatly affected by embedment in the sand used. The changes in the shape of the curves of all the materials are quantified in terms of the percentage change in the initial and secant slopes in Table 2. These data show that the difference between unconfined in-isolation testing and confined in-soil testing can indeed be very significant.

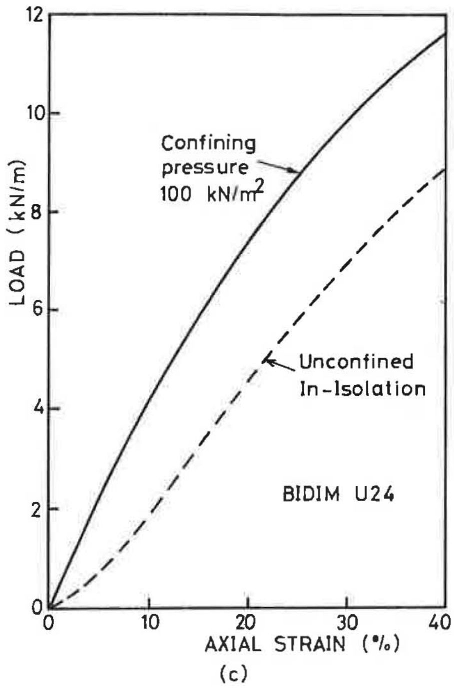
Fig. 6. General view of creep test rig.

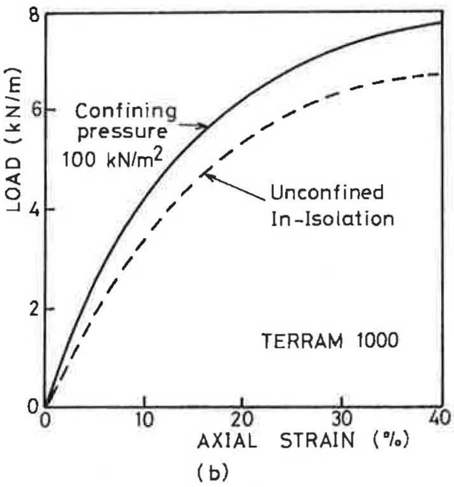
In order to demonstrate for structured geotextiles the relative importance of in-soil confining stresses to the width to height ratio of test specimens, further tests were carried out on Bidim U24 specimens at confining stresses of 10 and 55 kN/m^2. These data have been plotted over the unconfined in-isolation test data obtained for this geotextile from test specimens with different width to height ratios, as shown in Fig. 3. From this it can be ssen that the in-soil tests with 10 kN/m^2 confining stress in-soil on 200 x 100 mm specimens produced a load-strain curve similar to that of a 500 x 100 mm wide unconfined in-isilation test specimens, however, confining stresses of 55 and 100 kN/m^2 on 200 x 100 mm specimens produced quite different shapes of curve in the strain range 0 to 40 per cent. Thus testing such a geotextile confined in-soil cannot be replicated simply by testing wide specimens.

Table 2. Changes from Unconfined In-Isolation Load-Strain Curves Due to Confinement In-Soil at 100 kN/m^2 Confining Stress

MEASURED VALUE	LOTRAK 16/15	TERRAM 1000	BIDIM U24	PROPEX 6067
Initial Slope	+8%	+78%	+270%	+254%
5 per cent Secant slope	+1%	+46%	+206%	+ 39%
20 per cent Secant slope	-1%	+16%	+64%	+ 16% (18% strain)







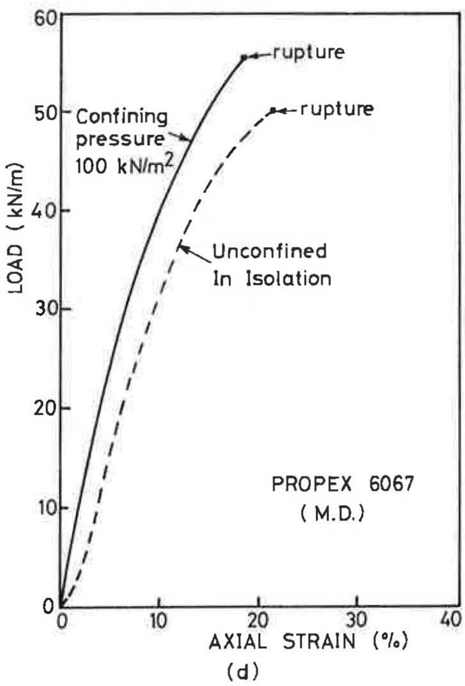


Fig. 7. Load strain data for the geotextiles tested.

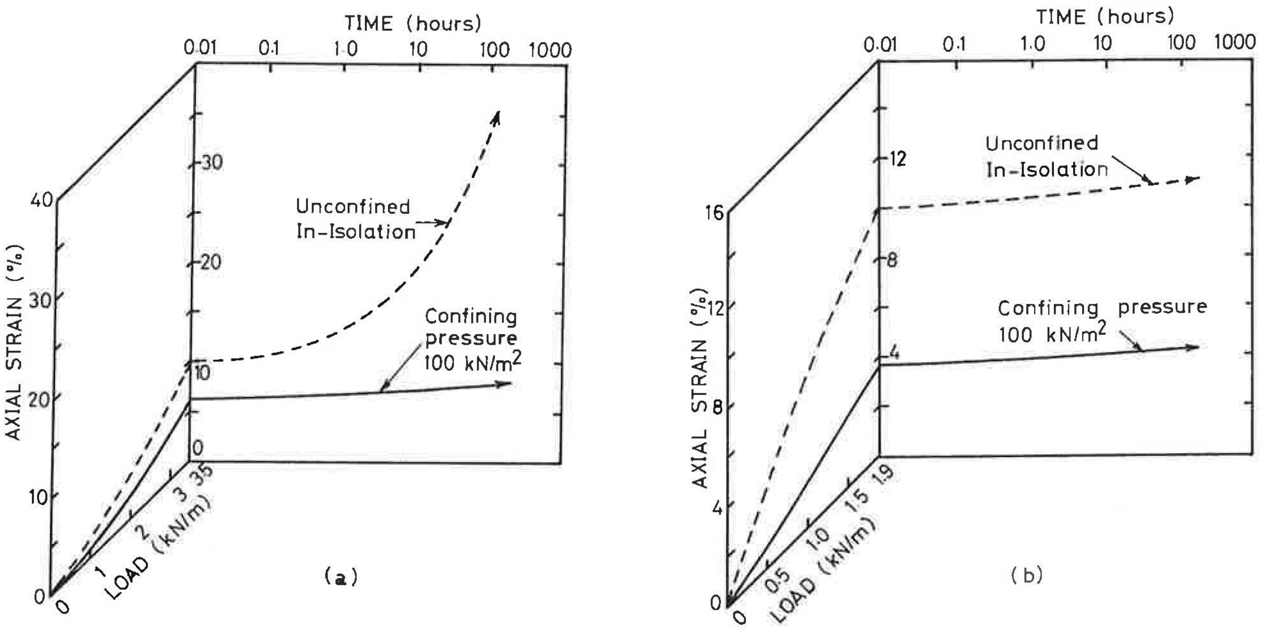


Fig. 8. Creep test data for (a) Terram 1000 and (b) Bidim U24.

CREEP TESTS

Further specimens of Bidim U24 and Terram 1000 prepared in the same way as the first time load test specimens, were subjected to creep testing unconfined in-isolation and confined in-soil under the same environmental conditions as before. The confining soil was the same and the confining stress was maintained at 100 kN/m^2. The level of loading used was that to produce 10 per cent strain in each geotextile when tested unconfined in-isolation. The loads for the Bidim and Terram specimens were 1.9 and 3.5 kN/m respectively, as indicated in Fig. 7.

The comparative data obtained from these tests are given in Fig. 8. The substantial reductions in strain when the geotextiles are confined in-soil can be seen to have two components; a reduction in initial strains and a reduction in creep strains. Clearly unconfined in-isolation creep testing grossly overestimates long term operational strains in these geotextiles.

CONCLUSIONS

1. The in-soil test apparatus described in this paper is capable of testing geotextiles subject to first time loading, cyclic loading, creep and stress relaxation under a variety of environmental conditions when confined by soil.

2. Comparative data from unconfined in-isolation and confined in-soil tests, conducted at a rate of strain of 2 per cent per minute on dry geotextiles at 20 °C when confined in a uniform sand, showed that highly structured non-woven and composite geotextiles significantly change the shape of their load-strain curves when tested in-soil. The woven geotextile with a simpler structural arrangement did not exhibit such a change.

3. Further comparative first time loading test data obtained under the same conditions for a needle punched geotextile, showed that in-isolation testing of very wide unconfined test specimen does not replicate confined in-soil behaviour.

4. Comparitive creep test data obtained from unconfined in-isolation and confined in-soil tests on two non-woven geotextiles showed that a significant reduction in their long term strains occurred when they were confined in-soil.

5. To obtain load-extension data for design purposes, confined in-soil testing appears to be essential, particularly for non-woven and composite geotextiles.

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REFERENCES

(1) MURRAY, R.T. and McGOWN, A. "Selection of Testing Procedures for the Specification of Geotextiles". Proc. 2nd Int. Conf. on Geotextiles. Las Vegas. (1982).

(3) McGOWN, A., ANDRAWES, K.Z., WILSON-FAHMY, R.F. and BRADY, K.C. "A New Method of Determining the Load-Extension Properties of Geotechnical Fabrics". Department of Environment, Department of Transport, Report SR 704. (1981). 14 pp.

(3) McGOWN, A., ANDRAWES, K.Z., WILSON-FAHMY, R.F. and BRADY, K.C. "Strength Testing of Geotechnical Fabrics". Department of Environment, Department of Transport, T.R.R.L. Report SR 703. (1981). 12 pp.