Dynamic Creep Behaviour of Geosynthetics

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ABSTRACT: Dynamic creep or load versus strain behaviour under repetitive loading of three types of geosynthetic materials are presented in this paper. The geosynthetics include a woven polypropylene, a nonwoven polyester and a HDPE geogrid. Mathematical representation of behaviour of the woven geosynthetic is produced here. General trend of response of these materials under repetitive loading is also produced.

1 INTRODUCTION

Dynamic creep or repeated loading behaviour of geosynthetic materials are of paramount importance in a number of applications. These include reinforcement in paved and unpaved roads, reinforced retaining structures and slopes under large repetitive live loads, such as traffic and wave action. Although the importance of the topic is overwhelming, very little has been reported so far. Yasuhara, Hirao and Hyodo (1988) reported laboratory studies on repeated loading of geogrid reinforced mattress foundations on soft clays. Saha and Kabir (1988) reported use of repeated loading parameters in geosynthetics reinforced unpaved road designs.

This paper represents a progress report on studies on dynamic creep behavior of geosynthetic materials being carried out at the Bangladesh University of Engineering and Technology (BUET). The work include development of testing techniques, mathematical representation of behaviour and identification and establishing design parameters. In this paper a brief description of testing technique is presented. Dynamic creep behaviour of three types of geosynthetics are presented here. These include a woven polypropylene, a nonwoven polyester and a geogrid. Mathematical representation of the woven geosynthetics is presented here. Although, mathematical representation of other materials are yet to be established, some of the mechanisms of their strain response under repeated loading is reported here.

2 TESTING TECHNIQUES

Test apparatuses and procedures developed to study in-isolation dynamic creep behaviour of geosynthetics are described in the following sections.

2.1. Test apparatus

Test specimens were selected and prepared following the procedure described by Andrawes, McGown and Kabir (1984). Testing systems each comprising a basic rig and a loading system, consisting either a direct loading or a lever loading device were designed and constructed to conduct the

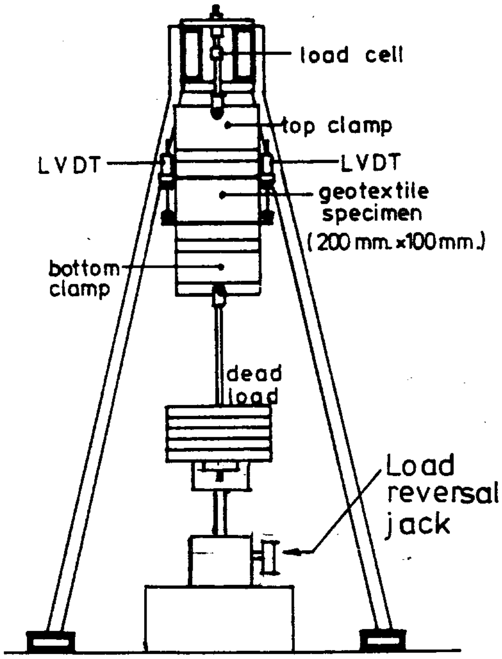

Fig. 1 Dynamic creep test rig

repetitive loading tests. Loadings and unloadings were performed by using mechanical jack systems. Deformations on the gauge length were measured using two linear transducers or dial gauges placed on either side of the specimen. A schematic diagram of the test apparatus is shown in Fig. 1.

2.2 Test procedure

Repetitive load tests were performed at a number of load levels with in the relevant operational range. The temperature of the test was maintained at all times at 27 + 2° C. The loads were sustained for half a minute and followed by unloading, also sustained for half a minute. Deformation readings were taken at the end of relevant loading and unloading cycles, carried upto 1000 cycles. The load versus time plot is presented in Fig.2.

3 MATERIALS USED

Geosynthetic materials of three generic types were used in this study. These included a woven tape polypropylene, a nonwoven needlepunched polyester and a stretched high density polyethylene (HDPE) geogrid. Characteristic properties of these materials are presented in Table.1.

Table 1 Characteristic Properties of Geosynthetics.

Geosynthetics / Properties	Woven tape	Nonwoven needle punched	Geogrid
Trade Name	UCO 40/40	Geofabric A-29	Tensar SR
Polymer	Polypro -pylene	Polyester	HDPE
Unit Wt. (gsm) ASTM D 3776	300	230	925
Tensile Strength (kN/m) ASTM D 4595	40	20	55
Elongation (%) ASTM D 4595	30	80	20

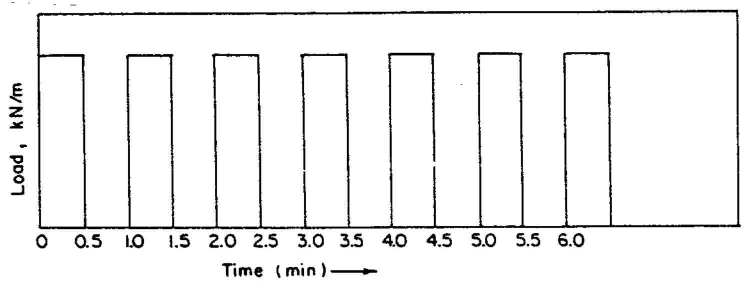

Fig. 2 Loading sequence versus time plot

4 MATHEMATICAL REPRESENTATION

In developing the mathematical representation of dynamic creep or load (P) - strain (ϵ) - load repetition N behaviour of geosynthetics, their mechanical response was conceptualized as follows:

(a) The load versus strain behaviour, at a particular load repetition N, may be defined by a limit load and curvature of the curve.

(b) In case of the wovens for a limit strain, with in the operational range the corresponding limit loads for iso N values will decrease as a function of N. The curvature of the curves upto the limit strain will also decrease as a function of N.

(c) The nonwovens normally show reverse curvature compared with the wovens. Therefore a limit load in place of a limit strain (for wovens) is selected with in the operational range. The corresponding limit strains for iso N values will generally increase as a function of N. The curvature of the curves upto the limit load will generally increase as a function of N.

(d) The mathematical formulation is achieved by establishing correlation between limit strain (or load) with load repetition values N. The other correlation required is that between curvature and N.The curvature of the curves are defined here by hyperbolic functions, Both of these correlation may be obtained by curve fitting of the test data.

4.1 Woven Geosynthetics

Data analysis procedure for woven geosynthetics is elaborated here in steps. This include graphical representation and curve fitting of the test data to evaluate dynamic creep parameters.

(a) Plot A: Plot strain as a function of logarithm of load repetition N, shown in Fig. 3. A curve is obtained for each load level.

(b) Plot B: Plot Iso N load versus strain diagrams for as many N-values as possible (Fig.4) select normalizing limit strain level ϵ_n with in the working range. Read the loads, P_n for different N values.

(c) Plot C: Plot a family of normalised Load $P_r(P/P_n)$ versus strain ϵ_r (ϵ/ϵ_n) curves, for Iso-N's (Fig.5)

(d) Plod D: Plot data in Fig. 5 in hyperbolic form that is ϵ_r/P_r versus ϵ_r to obtain another family of lines for different N values. (Fig.6)

(e) Plot E: Plot intercept I_n as a function of log N. Fit a polynomial to obtain constants for best fit (Fig.7). Values of I_n will uniquely define the curvatures as the slopes of the lines in Fig.7 are $(1-I_n)$. Small values of I_n will mean large curvature and I_n approaching or equal to unity means straight line correlation.

(f) Plot F: Plot P_n as a function of LogN to obtain the best correlation (Fig.8).

The normalizing limit strain for the woven polypropylene geotextile was taken as 5%. A three degree polynomial yielded a satisfactory fit through the data points of intercept I_n versus log N. In this curve fitting it was assumed that the load strain behaviour will approach a straight line correlation at large values of N. A straight line fit was found suitable for P_n versus logN plot. The load (P) - strain (ϵ) and load repetition (N) equation takes the form which is a hyperbolic equation:

$$\epsilon = AP/(B + C.P) \qquad (1)$$

where,

$A = I_n.\epsilon_n$

$\epsilon_n = 5\% : I_n = a_o + a_1.n + a_2.n^2 + a_3n^3$

$n = \log N : a_o = 0.69,\ a_1=0.228$

$a_2 = -0.0479,\ a_3=0.00335$

$B = P_{n1} - b.n$

$P_{n1}= 13.46$ kN/m $: b = 1.7333$

$C = I_n - 1.$

A comparative diagram is presented in Fig.9 showing the results from Eq.1 fits the test data satisfactorily.

4.2. Nonwoven geosynthetics

Data analysis procedure for non woven geosynthetics is similar to that for the wovens, the only exception being a limit load in the operational range is chosen in place of a limit strain. Equivalents of plots A through E for nonwoven geosynthetics is presented in Figs.10 through 14. Plot F is the curve of the family of curves in Fig.10, appropriate for the limit load.

The normalising limit load for the nonwoven polyester geosynthetics was taken as 4 kN/m. The load(P)-strain(ϵ) and load repetition(N) behaviour of non woven geosynthetics may also be represented by Eq.1, where the definition of the coefficients are different from that for the wovens. These are defined in the following.

A $= \epsilon_n$, which is the distribution of strain as a function of N, defined by the top curve in Fig.10. This shows a S-shaped curve of double curvature. Definition of the inflection point and equations for the two branches of the curve is required for mathematical formulation, which will be reported in a future paper.

$B= I_n = ao + a_1 \text{ Log } N$ (Fig.14)

where, $ao=0.567$ and $a_1= -0.0473$

$C= 1-I_n.$

A satisfactory mathematical representation of

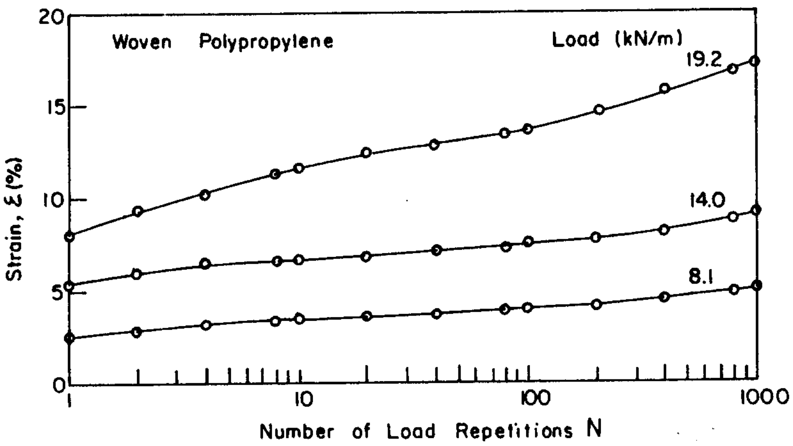

Fig. 3 Total strain versus log N plot (woven geosynthetic)

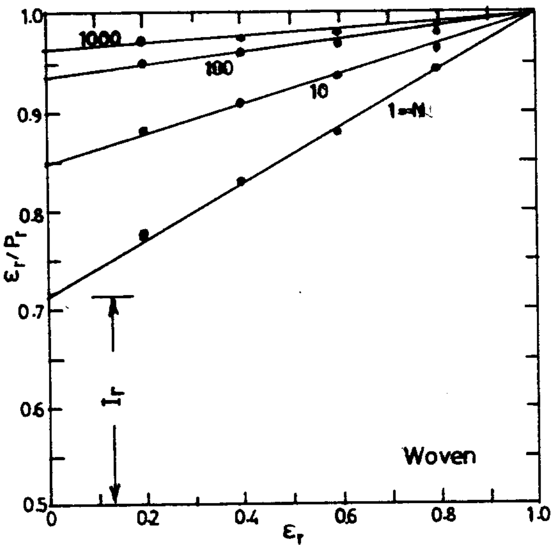

Fig. 6 Iso N hyperbolic normalised load versus strain diagrams (woven geosynthetic)

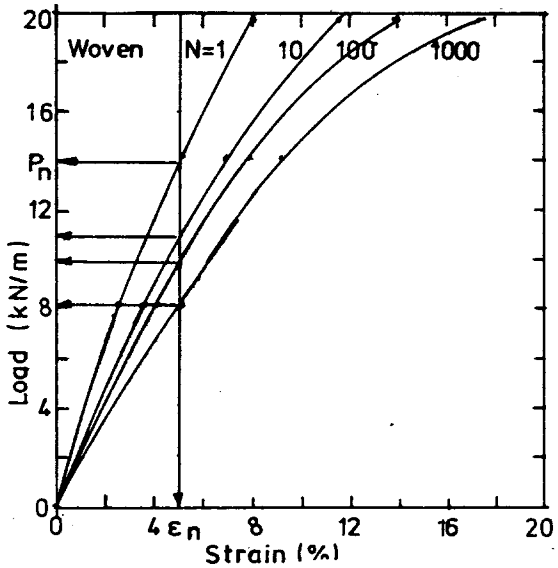

Fig. 4 Iso N load versus strain diagrams defining limit strain and loads (woven geosynthetic)

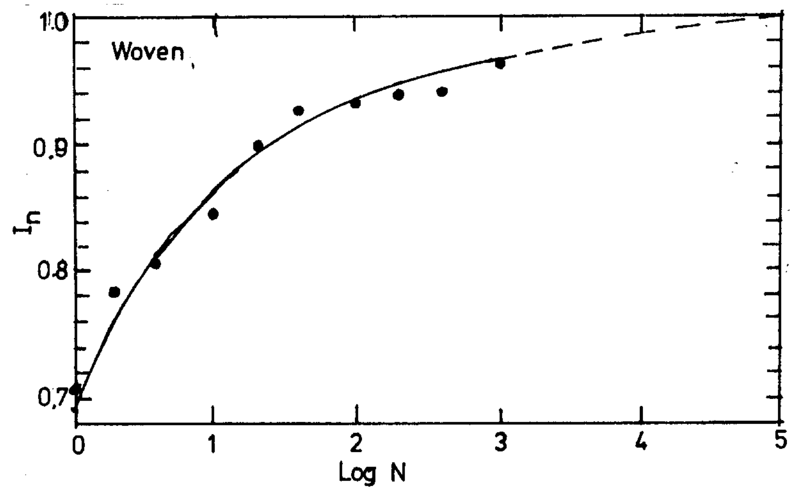

Fig. 7 Intercept, I_n versus log N correlation (woven geosynthetic)

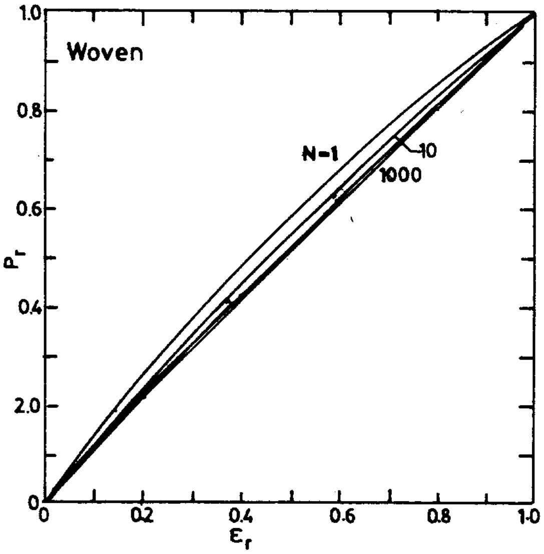

Fig. 5 Iso N normalised load versus strain diagrams (woven geosynthetic)

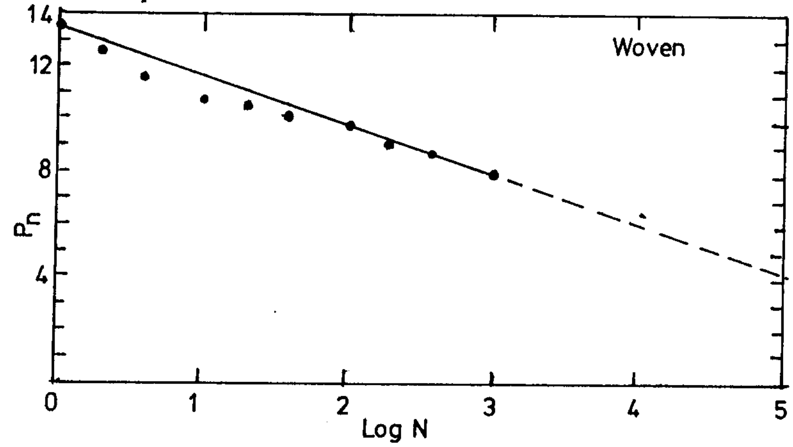

Fig. 8 Limit load P_n versus log N correlation (woven geosynthetic)

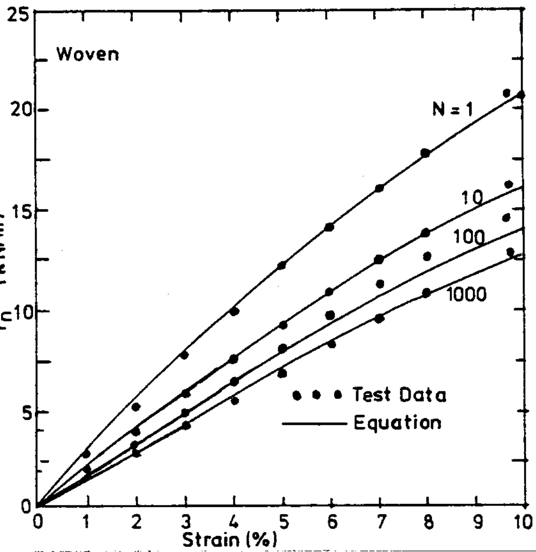

Fig. 9 Iso N load versus strain diagrams (woven geosynthetic)

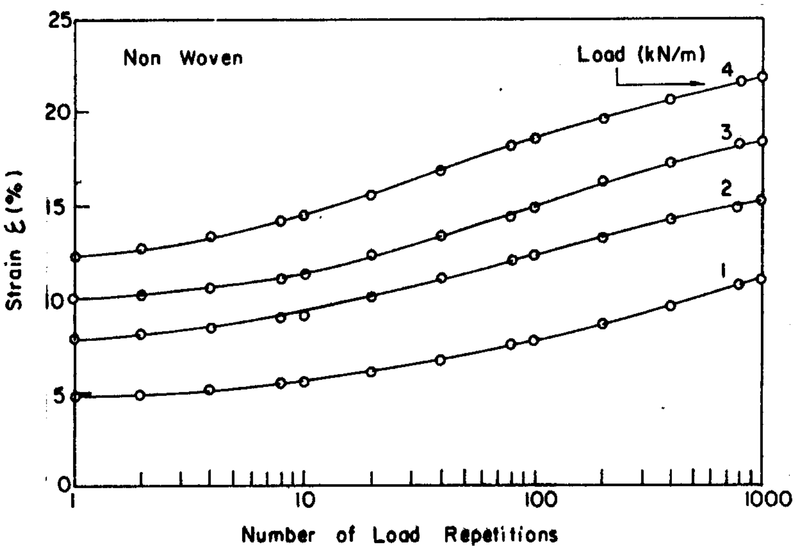

Fig. 10 Total strain versus log N plot (nonwoven geosynthetic)

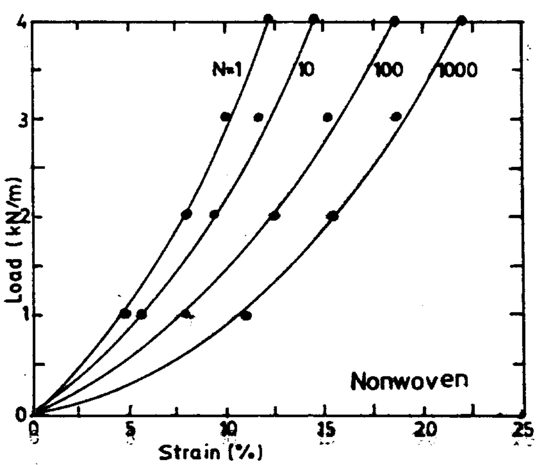

Fig. 11 Iso N load versus strain diagrams defining limit load and strains (nonwoven geosynthetic)

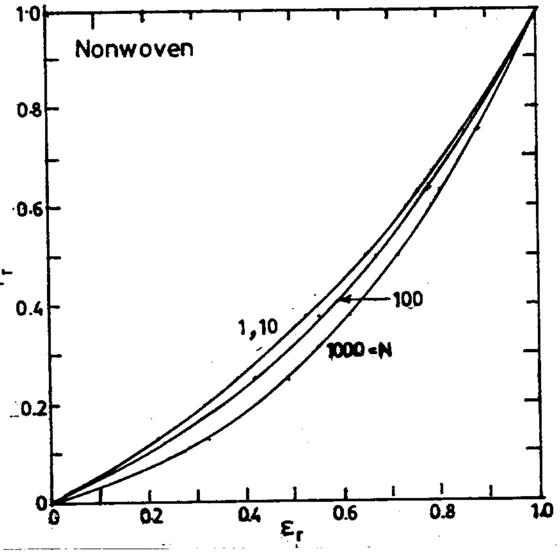

Fig. 12 Iso N normalised load versus strain diagrams (nonwoven geosynthetic)

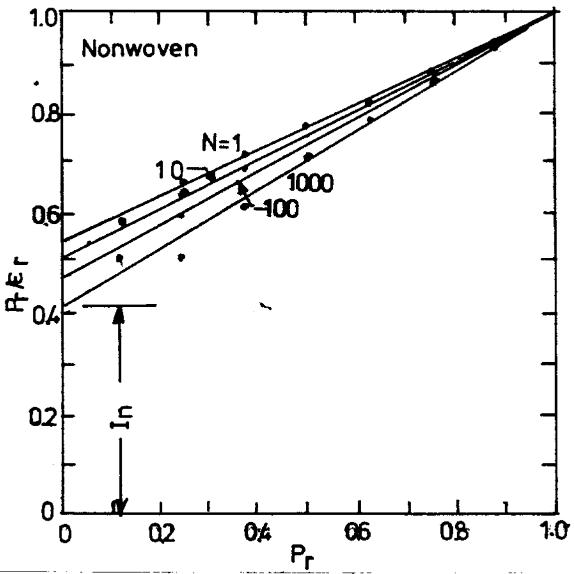

Fig. 13 Iso N hyperbolic normalised load versus strain diagrams (nonwoven geosynthetic)

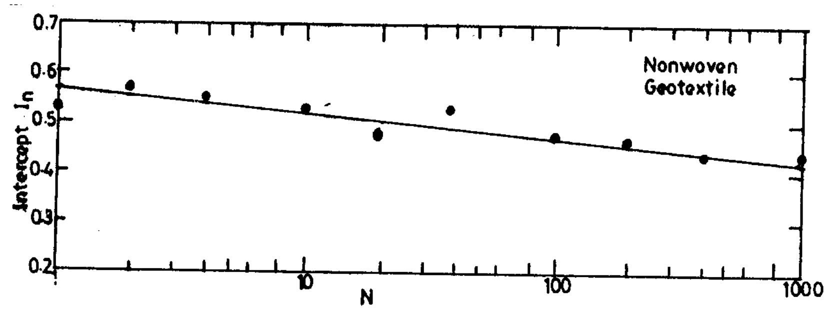

Fig. 14 Intercept, I_n versus log N correlation (nonwoven geosynthetic)

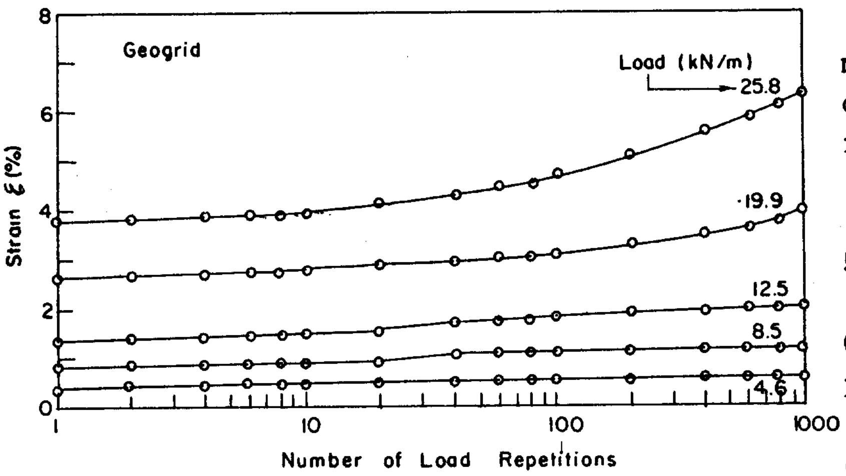

Fig. 15 Total strain versus log N plot (geogrid)

the S-shaped strain (ϵ) versus log N relation at the limit load will lead to the establishment of the mathematical model for non wovens.

4.3 Geogrid

A Tensar SR geogrid (Table 1) was tested under repeated loading at four different load levels. The strain response as a function of Log N at different load levels are presented in Fig.15. The mathematical formulation of the behaviour are being established. Some salient features of behaviour of this material is highlighted here as follows.

a) At lower load levels the ϵ vs Log N distribution exhibits a S-shaped double curvature pattern.

b) Upto a limit load, the relevant N-value at the inflection point of the S-shaped curve is a function of load level, which increases with load.

c) At any load upto a limit load, the material exhibits plastic deformation upto a strain level. At this strain the material seems to enter in a hysteresis loop. This strain level is also a function of load level, which increases with load.

d) Formation of the hysteresis loop depends on the load level. Beyond a limit load level no hysteresis loop will form and the material will go on suffering plastic deformation. At higher load levels the material will approach failure by suffering large plastic deformation.

The authors intend to present an elaborate mechanical and mathematical description of dynamic creep behaviour of geogrids in a future paper.

5 CONCLUDING REMARKS

On the basis of the study reported in this paper, the following remarks could be made.

a) The mathematical representation of dynamic creep behaviour of geosynthetics, using degradation of limit load or strain and curvature of the load strain diagram due to repeated loading was proved to be a sound concept.

b) The proposed curve fitting technique enabled satisfactory evaluation of dynamic creep parameters of a woven geosynthetic. Mathematical representation of behaviour, on the basis of the computed parameters, was very satisfactory for the woven geosynthetic.

c) The proposed method was also found to be very promising for the nonwoven geosynthetic.

d) Behaviour of the geogrid under repeated loading was different from those of the woven and nonwoven geosynthetics. Unlike the woven and nonwoven geosynthetics the geogrid was found to enter into hysteresis loops under low loading conditions.

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