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PERFORMANCE AND CREEP CHARACTERISTICS OF SYNTHETIC GEOGRIDS FOLLOWING HOT DRY CLIMATE

" تأثير الشبكيات البوليميريه فى تحسين خواص التربه فى الاجواء الحاره "

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الملخص

تهدف هذه الورقه الى دراسه مدى تاثر الشبكيات البوليميريه - المستخدمه في اغراض تحسين خواص الاتربه - نتيجه التعرض للظروف الجويه و بالذات التغيير فى درجات الحراره و الاشعه فوق البنفسجيه و كذلك التاثير نتيجه لدفن المواد فى التربه على عمقي .٥ م و ١.٥ م

هذا و قد تم اختيار منطقه الشويخ بدوله الكويت لاجراء هذا البحث نظرا لتعرضها لتغير كبير فى درجات الحرار(صفر - ٥٥ درجه مئويه) بالاضافه الى طول فتره التعرض للاشعه فوق البنفسجيه(التي تمتد الي ١٦ ساعه في اليوم دون اي سحابت في معظم الاحيان). و قد تم اختيار احد الشبكيات ذات الاتجاه الواحد و اخر من الشبكيات ذات الاتجاهين لهذا البحث لما لهده المنتجات من استعمالات متعدده في مجال تسليح الاتربه .

و قد تم استخراج العينات بعد فترات زمنيه ٣ و ٦ و ١٢ شهرا حيث تم اجراء عدد من الاختبارات هي الشد و الزحف(الشد تحت تاثير حمل ثابت لمدد زمنيه حتى ١٠٠٠ ساعه). و قد بينت النتائج ان بعض العينات قد تاثرت كثيرا عند التعرض لفترات طويله بينما لم تتاثر العينات الاخرى تاثيرا واضحا.

1. ABSTRACT

This paper investigates the behaviour of geogrids (as geotextile related materials) at exposure, storage and burial in soil in a hot dry climate. Kuwait was chosen as it experiences a wide range of annual temperature throughout the year, with air temperature rising to 45°C in summer and dropping to 0°C in winter. It also has an extremely high UV radiation level with long hours of uninterrupted sunshine on most of the days of the years. Two geogrids presently used for reinforcement and soil retainning wall applications in Kuwait, were fully exposed, stored out of sunlight and buried in soil at the depth of 0.5 m and 1.5 m. The two geogrids were an high density polyethelen (HDPE) uniaxial grid and a polypropylene(PP) biaxial grid.

The samples of the material provided by the manufacturers were tested on delivery, then after sustaining exposure, storage and burial in soil for 3, 6 and 12 months. The tests carried were constant rate tensile test and wide width sustained load (creep) test with a loading period up to 1,000 hours. These results revealed some remarkably different responses from the two products.

2. INTRODUCTION AND HISTORY OF USE OF GEOGRIDS.

Geotextiles and related materials are permeable textile material (usually synthetic) used with soil or rock to enhance the performance or to reduce the cost of man-made products structures. Geotextiles are often classified as "Woven or Non-woven"[3]. However, there is another group of materials which are used called geotextile related materials. These include "Grids", "Nets", "Meshes" and "Composites". They are not made by traditional methods but by means of new innovative processes[2]. It has been a common practice for many centuries to reinforce large earth structures with bundles or woven mats of reeds, rushes or bamboo.Bamboo fascines are still used in embankment construction in South East Asia. Natural fabric (cotton) was used to reinforce roads where results showed a reduction in cracking and localized road failures. The first adoption of synthetic woven geotextile was by Agerschou (1961), in coastal protection works [1]. Barrett (1966) reported that geosynthetics were first used in connection with erosion control applications and as an alternative for granular soil. From 1968,the American Federal Highway Administration monitored many pavement overlay repair schemes where geotextiles and geogrids were installed to control reflective cracking in the asphalt surfacing.

Only now with the recent development of geogrids and new installation methods does the use of pavement reinforcement look justifiable[2].

Geonets and meshes started to become established around 1968 when the Japanese used polyethylene nets exported from Britain by Netlon Ltd as a mean of alleviating the damage caused to embankments by seismic activity and heavy rainfall. Moreover geogrids were used to reduce the risk of base failures for embankments constructed over weak soil and increase stability. McGown and Ozelton (1973) identified the three functions of"Separation", "Filtration"and"Reinforcement" for geotextiles and related materials ,while Leflaive and Puig (1974) added "Drainage" as a fourth function[7].

Moreover, McGown, Andrawes and others have run a programme from the 1970's to the present at Strathclyde University to develop testing techniques for geotextiles and related material. The objective of this programme not only included the development of rapid easy tests to perform, so called "Index Tests", it also included tests which could be used to obtain data for use in analytical design techniques, so called "Performance Tests"[10]. Different geosynthetic materials were considered in this programme including Tensar geogrids(SR80,SS1,SS2 and AR1)[11]

3. Manufacturing,Properties,and Functions of Synthetic Geogrids.

3.1 manufacturing of Polymer grids

Polymer grids are manufactured from polymer sheets using the production sequence shown in Fig.1a. The first stage involves precise punching of a regular pattern of holes into the sheet[11]. This is followed by carefully controlled stretching of the sheet in one direction while it is gently heated. The action of stretching the sheet aligns the long chain molecules of the polymer in the direction of stretch, giving the grid a high tensile stiffness in this direction. If no further processing is carried out , the greatest strength properties lie in this direction. This type of grid is named "Uniaxial Grid", Fig.1b. Another form of grid may be produced by incorporating a second stretching stage when the uniaxial grid is pulled in the transverse direction to give a "Biaxial Grid" with square aperture shapes, Fig.1c. In this case the term "biaxial" means that both the stretched ribs are aligned in two directions.

Subsequent to the development of "true" grids, "Welded Strip Grids" have appeared. These consist of two sets of geotextile strips intersect at 90°C and are heat welded. In this grid, the stretching of the polymer's molecule chains is carried out during extrusion of the filaments that are used for the core material. In this manner it is possible to use polymers with superior creep and tensile properties, as well as achieving a greater degree of polymer alignment within the prime strength directions[7],[2],[5].

3.2. Geogrids Properties

Short term tensile load deformation and long term sustained loading (Creep) properties are the main properties affecting the behaviour of geogrids[4].

3.2.1 Tensile load-deformation properties

Axial tensile tests performed under constant rate measured in Kn/m give an indication of the tensile strength and the axial strain at rupture. These values are greatly affected by strain rate and temperature since all polymers are visco-elastic materials. For geogrids, the values of breaking load should be viewed in the context that all polymer products exhibit time-dependent behaviour which is a function of the stress level and temperature. The test is performed according to British Standard BS 6906 (Part I) using 3 ribs for uniaxial geogrids and 5 ribs for biaxial geogrids.

3.2.2 Sustained load-deformation properties[4],[10],[11]:

Although the results of short term constant rate of strain tensile tests give reasonable assessment of rupture strength and strain which might be used to low-risk reinforcing applications such as unpaved roads, they give little indication of how rupture loads or stains change with time. The latter information is very important for the design of reinforced structures such as steep sided embankments or vertical faced reinforced wall. Creep test is always performed on a number of samples, each sample loaded with different value (usually a percentage of the maximum load obtained from the short term tensile load test).All samples are loaded for long times up to 1,000 hours and strain reading is taken every 5 seconds in the first 2 hours and every 2 hours for the following 24 hours and then daily. Plots of % strain versus time and Isochronous Curves (Load-strain values are 1, 10, 100 and 1000 hours) are obtained.

3.3. Functions of Geogrids[3],[5],[8]:

Geogrids always perform at least one of the basic functions:

a) Reinforcement; or/and b) Erosion control.

a) Reinforcement

Geogrids reinforcement improve the strength of a soil in three different ways: 1)Membrane reinforcement when a vertical load is applied to a geosynthetic on a deformable soil;

- Shear reinforcement when geosynthetic placed on a soil loaded in a normal direction and then the two materials are sheared.
- Anchorage reinforcement when a tensile force develops and

prevents its pulling out of the soil.

b) Erosion control

A geotextile or related material, placed on a slope, functions as an erosion control mat when it restricts movements and prevents dispersion of soil particles subjected to erosion actions of rain or wind, often while vegetation, which will eventually perform this function, is growing.

4.TEST SITE, MATERIALS,AND TESTING PROGRAMME

4.1 TEST SITE

Test site is located in kuwait mainland with the following properties:

a)Soil types: The soil profiles show that:

(i) The soil on the site is mostly yellow, fine to medium sand.

(ii) A little silt is present at a depth of 2 m.

(iii) Free silt particles are present only near the surface.

b) **Particle size distribution**: Particle size distribution test results show:

(i) All samples contained particles passing BS Sieve No 4 (4.76 mm) and the percentage passing BS Sieve No 200 (0.074 mm) does not exceed 5% in any case.

(ii) The coefficient of uniformity (C_u) ranges between 1.8 and 2.5 which means that the soil is poorly graded.

c) **Water table and water content:** No evidence of a water table was found down to a depth of 4 m. The water content increased with increasing depth, ranging from less than 2 per cent at a depth of 0.25 m to just over 12 percent at 1.5 m.

d) **Soil consistency**: The soil was found to be non-plastic. Liquid limit value ranged between 17.3% and no plastic limit(**NP** soil)

e) **CBR values:** CBR values measured at the optimum dry density and were found to be in the range of 3.5 to 5%.

f) **Soil Chemistry**: Chemical analysis of soil showed that:

(i) Chloride content 'C1', ranging between 0.007 and 0.176%.

(ii) Sulphate content as SO_4 content, ranges between 1.0 and 4.1%. The amount of SO_3 ranges between 0.9 and 1.47%.

(iii) Organic matter content ranges between 0.003 and 0.056%.

4.2 Types of Geogrids [11]:

Two geogrids (Tensar SS1 biaxial, and Tensar SR80 uniaxial geogrid) were selected. The main reason for choosing these particular materials is that they represent the range of materials widely in use and also these they represent different physical structures and polymer.

The polymer type used to manufacture the uniaxial geogrid is high density polyethylene(HDPE) and long term protection from ultra violet attack is provided. The biaxial geogrid is manufactured from polypropylene(PP) and protected from ultraviolet degradation. Specifications are shown in fig(1).

4.3 Site Testing Programme

Samples were cut into a series of lengths sufficient to obtain all the required test specimens for each situation to be tested. The size of the samples were 1.0 m in the machine direction of the roll of 4.0 m in the cross machine direction. The numbersof samples were as follows:

a) One sample of each type of material was tested immediately to obtain the basic "Control" set of data.

b) Four samples of each type were left open to all weathering conditions at the site, including direct sunlight. These samples were called "Exposed" and samples removed for testing after 3, 6 and 12 months. The same test procedures were applied to test these samples as were used for the Control samples.

c) Four samples of each type of material were subjected to all weathering conditions except direct sunlight. These samples were called "Storage".

d) Four samples of each type of material embedded in soil at the depth of 0.5 m from ground level.

e) Four samples of each type were embedded in soil at the depth of 1.5 m from ground level.

4.4 Laboratory Testing Programme

a) Tensile test apparatus and procedure

The principle of the test procedure was to grip a test specimen across its entire width in a tensile testing machine which operated at a specified rate of strain and to apply a tensile force to the test specimen until it ruptures.

The test specimens were mounted centrally in the jaws (where the distance between the jaws was determined as 315 mm for the uniaxial grid and 200 mm for the biaxial grid). For the geogrids, special clamps were used. The top and bottom bars of the uniaxial grid test specimen were held directly by them, while for the biaxial grid a special technique of alloy casting was applied. After setting the machine to a rate of strain of 10 per cent per minute, the machine was started. The test was continued until the breaking point of the specimen. The failure mode of the specimen was noted. The test data were recorded as follows:

a) The maximum load for each material was measured after sustaining the different conditions and compared to the control data.

b) The strain at maximum load for each material after sustaining the different conditions were compared to the control test data.

c) The breaking load for each material after sustaining the different conditions were compared to the control sample test data.

d) The strain at breaking load for each material after sustaining the different conditions.

b)Sustained Loading Test (Creep Test)[10],[11]:

Geotextiles and related materials generally exhibit visco-elasto/plastic behaviour. Where performance data are to employed in fundamental analytical designs of reinforced soil structures, long term load-strain-temperature data, often termed the "creep" test is used[4]. The clamps and the clamping technique must be designed to ensure that no slippage of the material occurs during load application, that no stress concentration occurs at any point along the clamp edge and that no change in physical or chemical properties occurs due to clamping[11]. The dead loads used were lead bars chosen for the advantages of low cost and high density. Two LVDT's were used to monitor the displacements. A programmable data logger capable of plotting curves of strain versus time automatically was used.

5.TEST RESULTS AND DISCUSSION

a) Constant Rate of Strain Tensile Test Results:

This test was conducted on geogrids in accordance with BS 6906 part 1.

1. Effects on the average maximum load of geogrids.
A comparison of the behaviour of average maximum load of geogrids over the period of 12 months based on the control value are summarized in Table (1). From results shown in the table, it is concluded that for uniaxial grids there is a small increase in the force while there is no significant change in the biaxial grid.

2. Effects on strain at maximum load of geogrids
A comparison of the performance of the strain at maximum load of geogrids over the period of 12 months based on the control value are be summarized in Table (2). From results shown in the table, it is concluded that no remarkable changes on geogrids were observed.

3. Effects on the average break load of geogrids
A comparison of the performance of the average break load of geogrids over the period of 12 months based on the control value are summarized in Table (3). The results show that the effects on the average breaking load on geogrids undergo the same effect as the average maximum load.

4. Effects on strain at break load of geogrids
A comparison of the behaviour of the strain at break load of geogrids over the period of 12 months based on the control value are in Table (4).

From the above data, it is concluded that there is a very small reduction in the strength of the product which was buried at the depth of 1.5 and 0.5 m for a period ranging upto one year for undistributed soil exposure. But, statistically it is not a significant deterioration in strength if it is compared to the exposed and storage deterioration. At the same time there is some decrease in the displacement of the material.

b) Creep Test Results

Samples of creep results for all types are shown in fig(2) to fig(4):

(i) The biaxial geogrid has a large creep especially suspended by high loads for long terms. But, for short terms it has a rapid and useful stress/strain response curve making it ideal for a soil reinforcement. This behaviour is due to the oriented polypropylene which shows after time and high loads entirely rupture of macrochains and subsequent molecular regrouping and the "Pulling out" of chains from crystallites. The uniaxial geogrids show a good resistance to creep because of the good properties of high density polyethylene.

(ii) There was no significant change in the behaviour of uniaxial grid on short or long terms in exposed, storage or buried conditions. No change was observed in the biaxial on short term under all conditions on 10%, 20% and 40%, but a lot of samples of 60% were broken.

3) Isochronous Curves[2],[10]:

The Isochronous curve, is the relationship between load per unit length of a geosynthetic and the corresponding strain value at a specific time of loading. Fig(5) and Fig(6) show samples:

(a)The load limit for linear viscoelastic range;and

(b)The maximum possible load to be used for any specific time interval.

6. CONCLUSIONS AND RECOMMENDATIONS

i) Biaxial Grid

The results of testing Netlon SS1 biaxial grids showed that load-strain curves are quite similar in shape for all loading times and method and duration of storing. Moreover, the following comments are recorded:

(1) Long term loading resulted in great increase of strain values. For instance, for control samples strain after 100 hours loading time was 14% while after 1,000 hours loading time it reached to 61%. The same is applicable to sample buried at 0.5 m in soil for 3 months.

(2) Maximum load at the same strain has decreased under all duration and condition of storing than that of the control conditions. For examples at 10% strain maximum loads were as following:

(3) For samples buried 1.5 m in soil there was no change at all in respect of duration of burying. The three curves of load-strain curves for 3, 6 and 12 months of burying samples at that depth are quite identical for all loading times.

(4) It seems that duration of exposing samples has no significant effect on SS1 samples. Load strain curves for samples exposed to all weather conditions are actually the same irrespective of duration.

(5) Similarly duration of storing samples subjected to all weather conditions except direct sunlight, has no effect on the load-strain curve. The three samples loaded at 60% of maximum load (7.8 KN/m) which were stored for 3, 6 and 12 months were broken down while the three samples loaded for 100 hours have the same strain (approx. 20%) at maximum load.

ii) Uni-axial Grid

Load-strain curves for uniaxial SR80, manufactured by Netlon Company, UK, showed regular performance under all storing conditions and duration. The following results are drawn:-

(1) Neither the storing condition nor the storing duration has significant

effect on load-strain curves for short and medium term loading. The maximum variability in strain values at maximum load is in the range ± 1% at loading times 1, 10 and 100 hours for load 10%, 20% and 40% of the maximum load.

(2) Four cases of failure at strain ranges between 5 and 6% where maximum load reached 28 KN/m. It means that this value should be considered for safe design.

(3) Load Strain curves of different loading times are very close to each other for each case and duration of loading. For instance at load of 26 KN/m, strains for 1, 10, 100 and 1000 hours are ranging from 4% to 5.5% for all durations and conditions of storing. Range of strain values is reduced at lower loads.

(4) Result showed excellent performance at all weather conditions over the whole period of exposure on Short and Long terms or under high loads.

7. REFRENCES:

1. Agerschou, H.A.(1961)"Synthetic Material Filters in Coastal Protection." ASCE Journal (Waterways & Harbours Div), 87. No. WW1. pp 111-124.
2. El-Shabrawy M.,F.El-shibini,H.Al-mudhaf(1991),"An Introduction to the Use of Geosynthetics in Civil Engineering",MEJ,V .No.1.pp - .
3. Giroud, J.P. (1981). "Designing With Geotextiles." Rilem Mat. & Structure Res & Test. Vol. 14, No. 82. pp 257-272.
4. Jones, C.J. (1989). "Earth Reinforcement & Soil Structures" Butterworths Publ., London.
5. Koerner, R.M., & Welsh, J.P. (1980). "Construction & Geotechnical Engineering Using Synthetic Fabrics."Wiley-Interscience Publication,NY.
6. Murray,R.T.,McGown,A.,AdrawesK.Z.&SwanD.(1986)"TestingJointsin Geotextiles&Geogris"Proc.3rdIntConfonGeotextiles,pp731-736,Vienna
7. McGown, A., Andrawes, K.Z. & Kabir, M.H.(1984)"Rapid Loading Creep Testing of Geotextiles and Related Materials."TRRL No. DGR 474/91.
8. Netlon Ltd., Tensar. (1984) "Test Methods & Physical Properties of Tensar Geogrids." Netlon Blackburn,England.

Table (1)

Maximum loads from wide width strip test results compared to control values

Maximum Force	Exposed	Storage	1.5 m	0.5 m
SR 80	3% Increase	3% Increase	2% Increase	Constant
SS1	Constant	Constant	Constant	Constant

Table (2)

Strain maximum loads from wide width strip test results compared to control values

Strain at Maximum Load	Exposed	Storage	1.5 m	0.5 m
SR 80	6% Decrease	4% Decrease	Constant	3% Decrease
SS1	8% Decrease	6% Decrease	2% Decrease	4% dECREASE

Table (3)

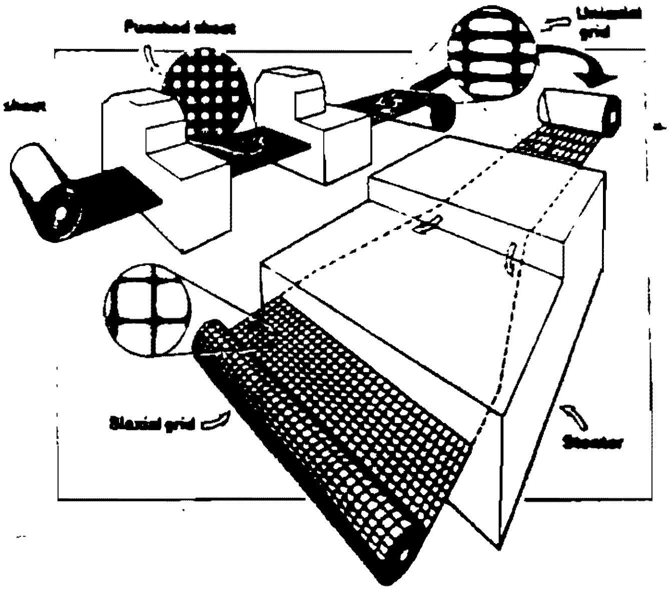
Break Load from wide width trip test results compared to control value.

Average Break Load	Exposed	Storage	1.5 m	0.5 m
SR 80	5% increase	5% increase	4% increase	8% increase
SS1	Constant	Constant	2% Increase	Constant

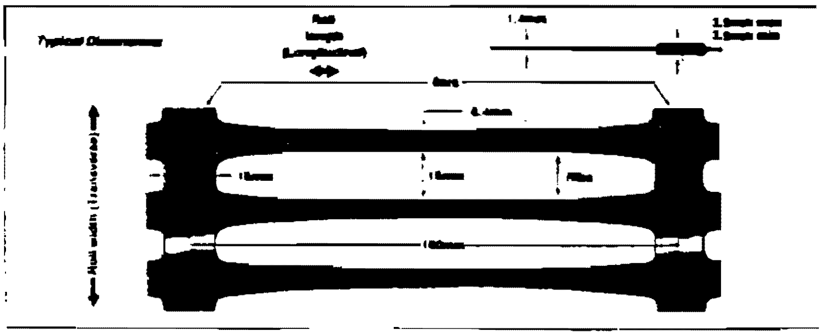
Table (4)

Strain at break Load from wide width trip test results compared to control value

Strain at Maximum Load	Exposed	Storage	1.5 m	0.5 m
SR 80	3% Increase	2% Increase	Constant	Constant
SS1	4% increase	4% Increase	Constant	2% Increase

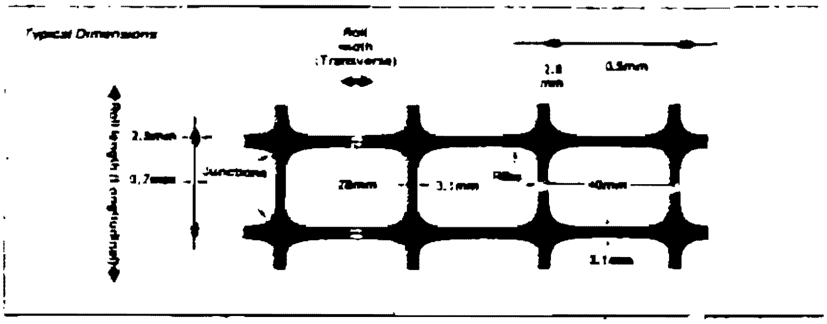


a) Production of Geogrids



TENSAR SR80 GEOGRID
Polymer = High density polyethylene
Weight = 0.7 kg/m^2
Quality Control Strength = 80 kN/m
Characteristic Strength (longitudinal)
[120 year design life]
: 30.5 kN/m (in-soil temperature 20°C)
: 32.5 kN/m in-soil temperature 10°C)
Roll dimensions: 30 x 1 m

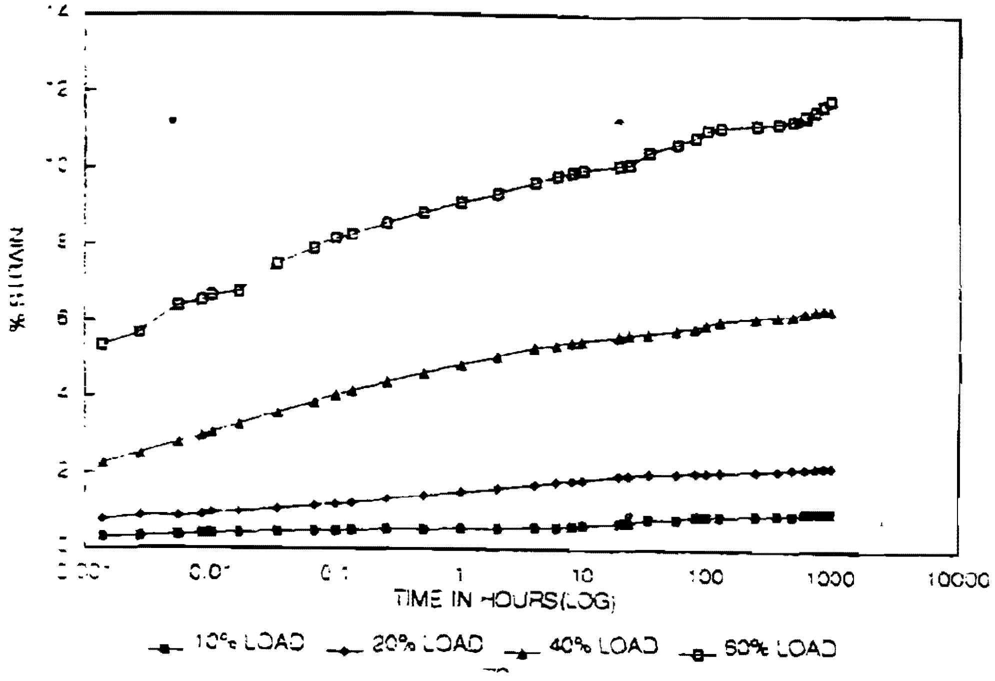
b) Uniaxial Geogrid



TENSAR SS1 GEOGRID
for weak soils with moderate traffic intensities and axle loadings. The fill should be well-graded and should have a significant proportion of particles between 5 mm and 50 mm.
Polymer: polypropylene
Weight: 0.20 kg/m^2
Quality Control Strength
Transverse: 20.5 kN/m
Longitudinal: 12.5 kN/m
Roll dimensions: 50 m x 4 m

) Biaxial Geogrid

FIG (1). Production and Shapes of Geogrids



Fig(2a) Creep Data for Uniaxial Grid SR80, Control Condition,1000 Hours Loading Time

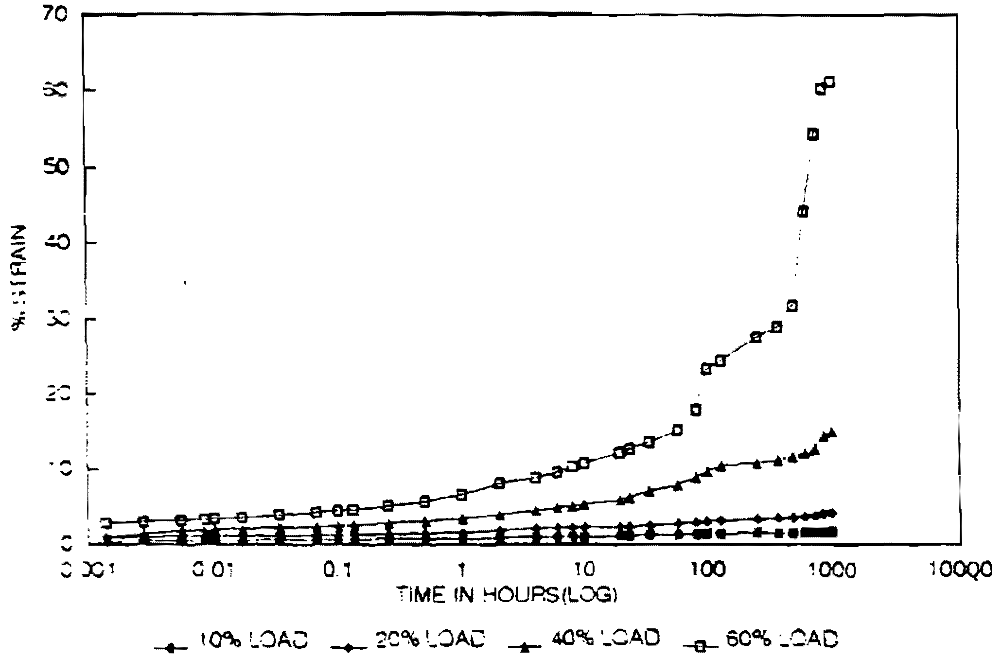
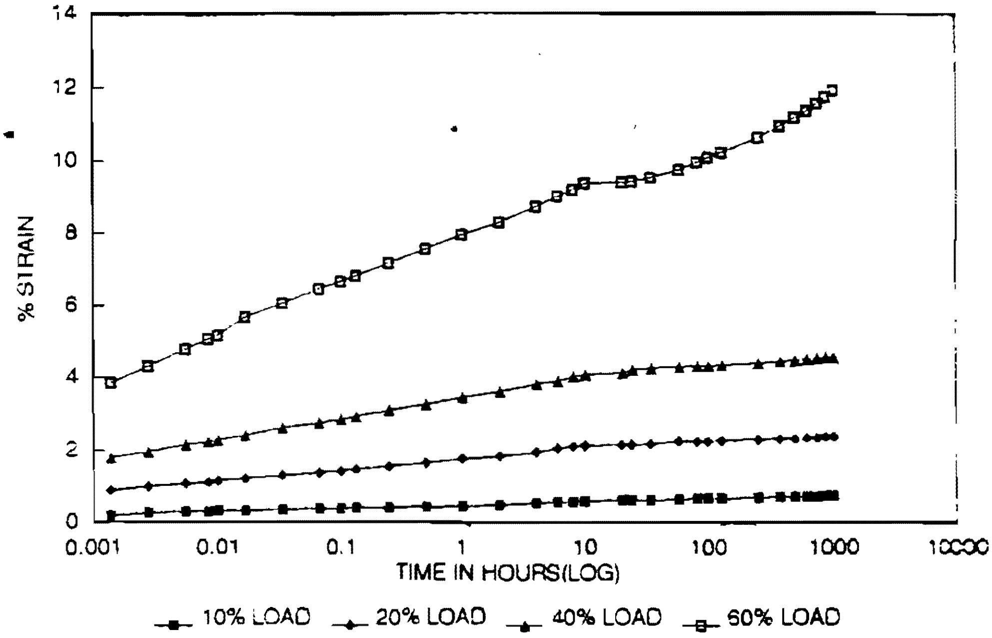
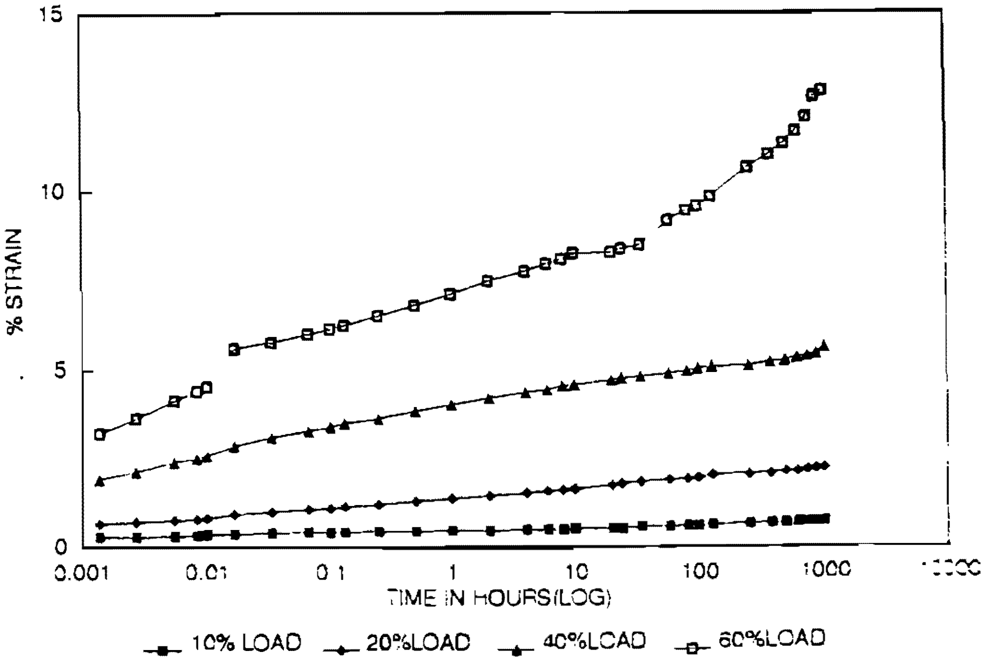


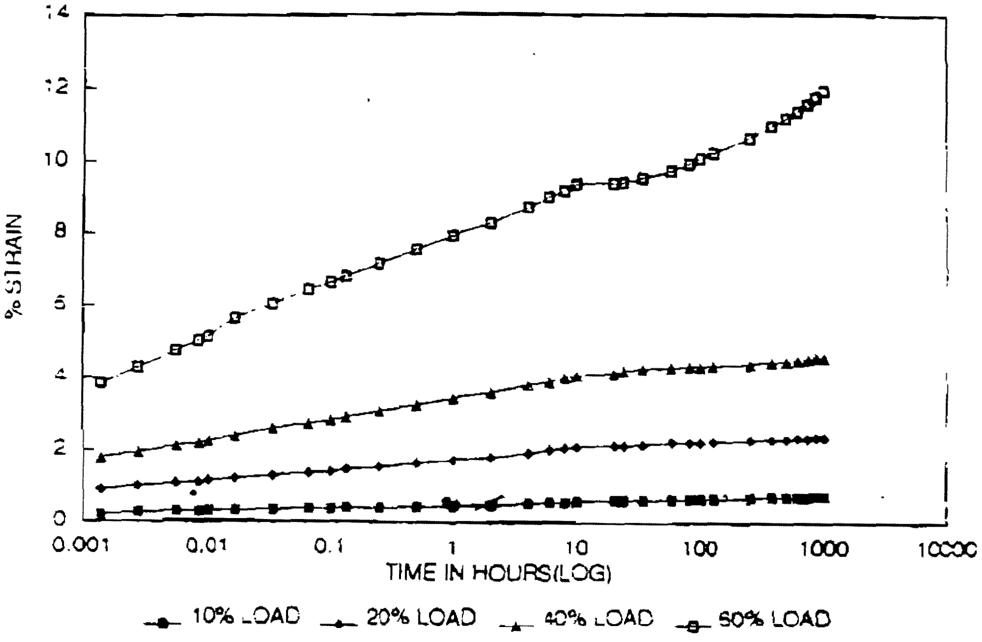
Fig 2b) Creep Data for Biaxial Grid SS1, Control Condition,1000 Hours Loading Time



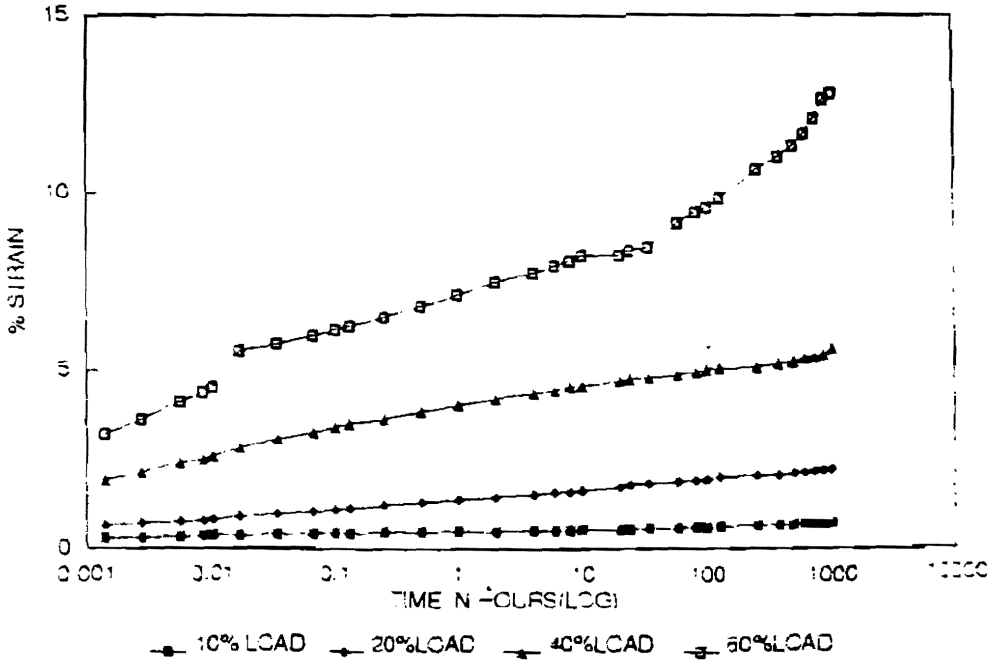
Fig(3a) Creep Data for Uniaxial Grid SR80, 0.5m Buired in Soil,1000 Hours Loading Time



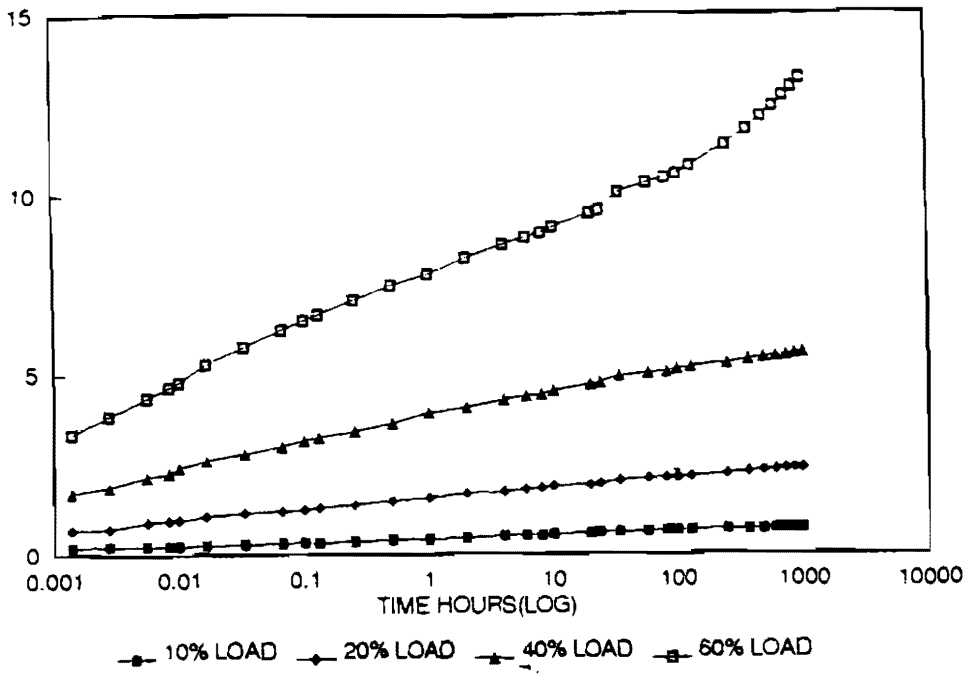
Fig(3b) Creep Data for Uniaxial Grid SR80, 1.5m Buried in Soil,1000 Hours Loading Time



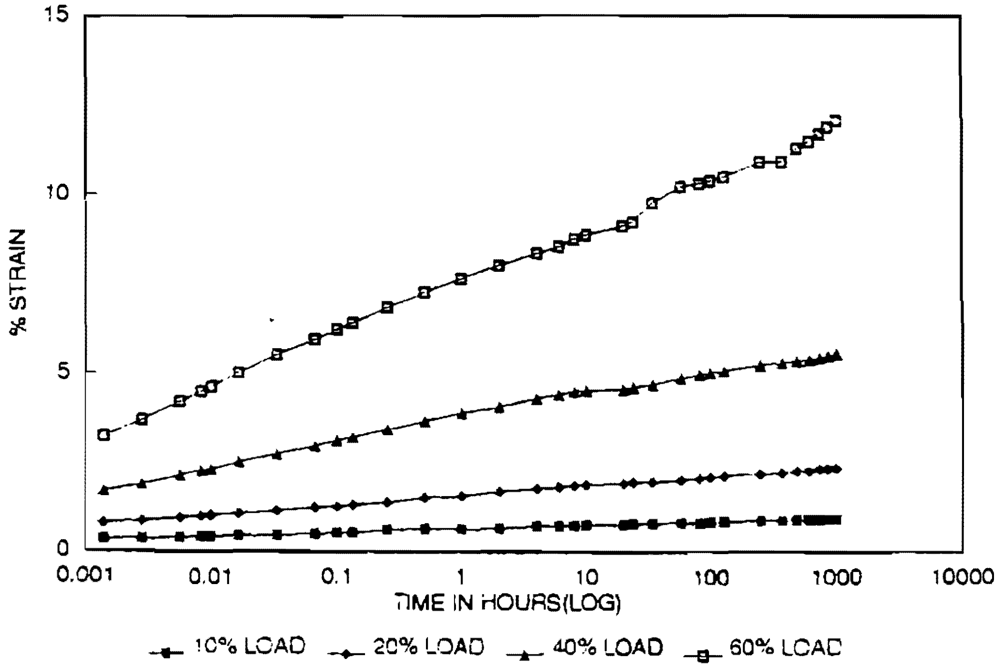
Fig(3a) Creep Data for Uniaxial Grid SR80,
0.5m Buired in Soil,1000 Hours Loading Time



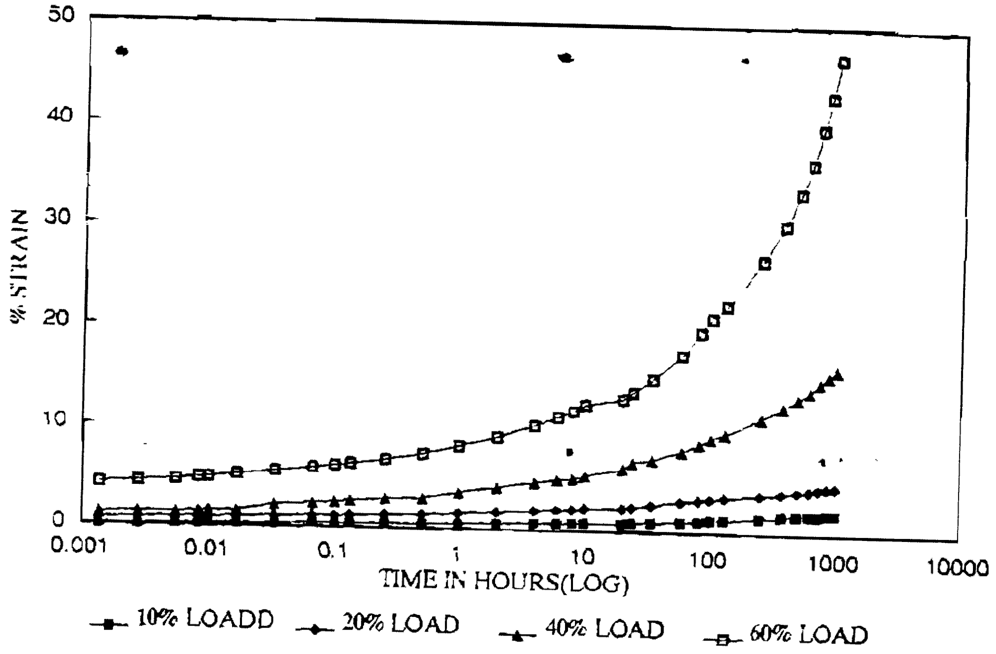
Fig(3b) Creep Data for Uniaxial Grid SR80,
1.5m Buried in Soil,1000 Hours Loading Time



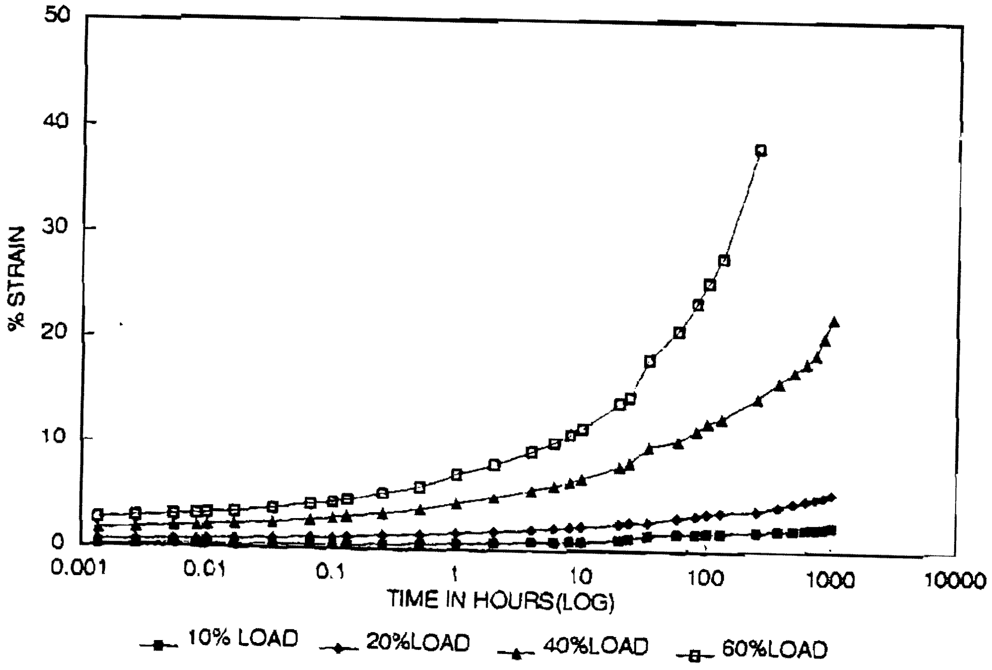
Fig(3c) Creep Data for Uniaxial Grid SR80,
Storage Conditcn, 1000 Hours Loading Time



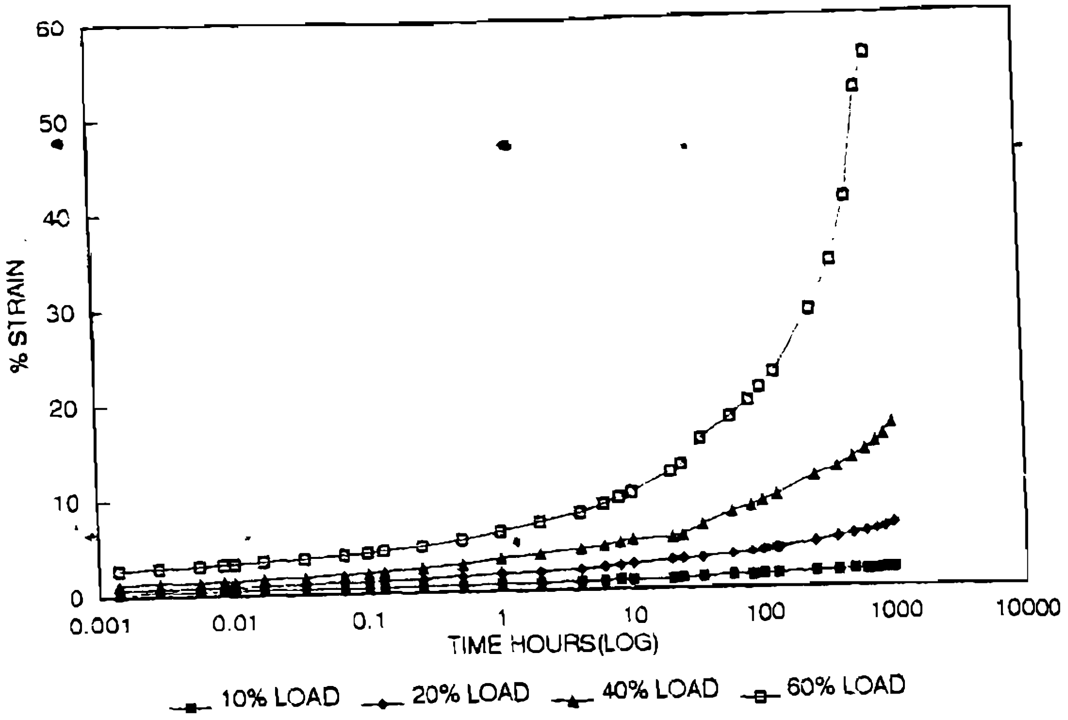
Fig(3d) Creep Data for Uniaxial Grid SR80,
Exposed Condition, 1000 Hours Loading Time



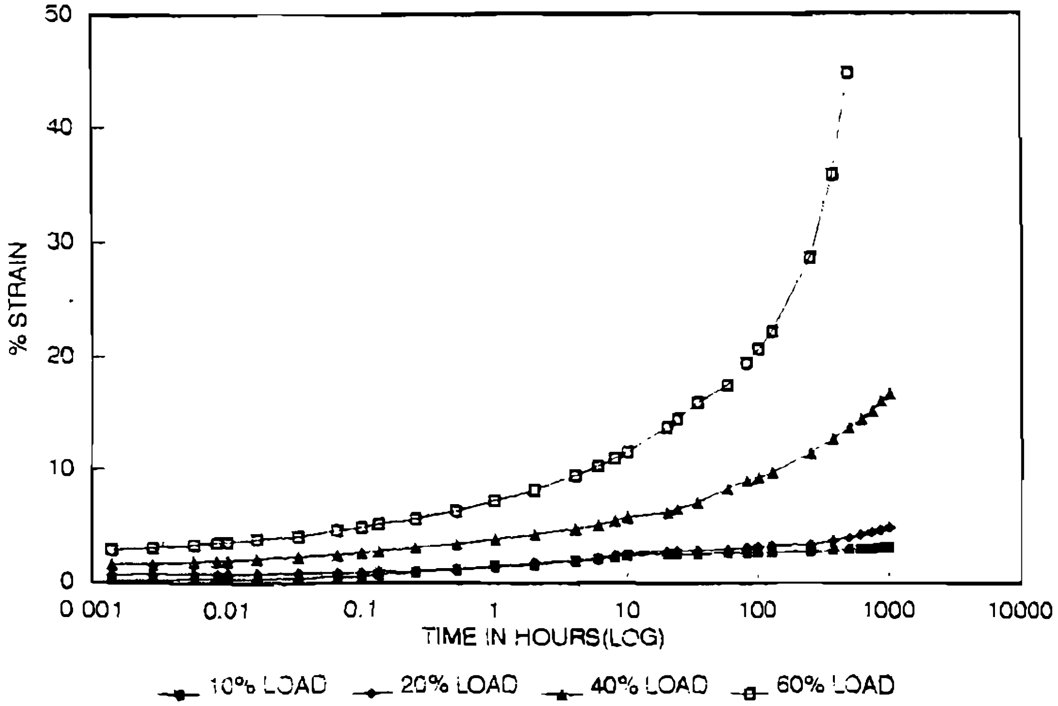
Fig(4a) Creep Data for Biaxial Grid SS1, 0.5m Buried in Soil,1000 Hours Loading Time



Fig(4b) Creep Data for Biaxial Grid SS1, 1.5m Buried in Soil,1000 Hours Loading Time



Fig(4c) Creep Data for Biaxial Grid SS1, Storage Condition, 1000 Hours Loading Time



Fig(4d) Creep Data for Biaxial Grid SS1, Exposed condition, 1000 Hours Loading Time

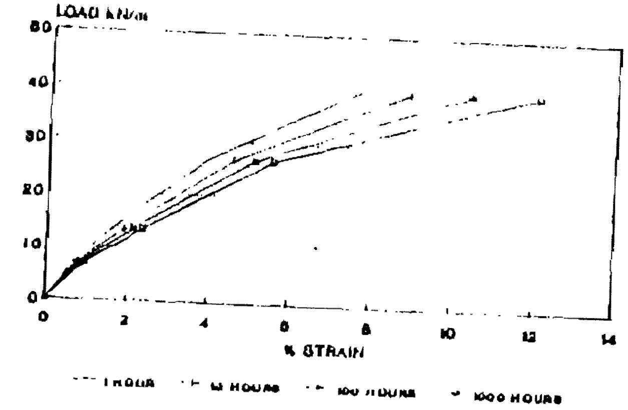


FIG 6a ISOCHRONOUS CHART FOR SR80,
0 - 12 MONTHS, EXPOSED

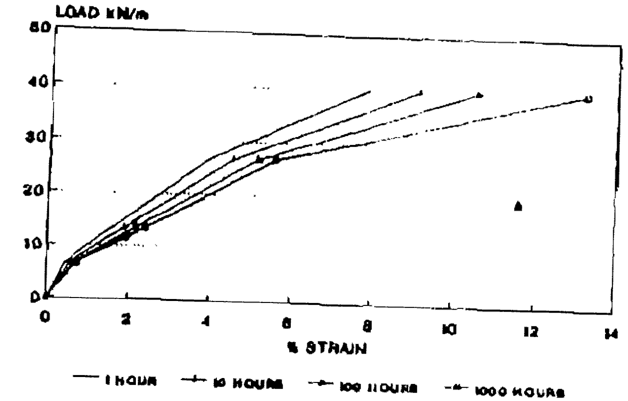


FIG 6b ISOCHRONOUS CHART FOR SR80,
0 - 12 MONTHS, STORAGE

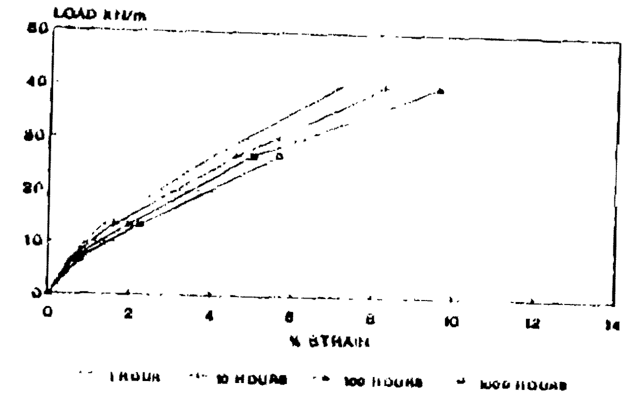


FIG 6c ISOCHRONOUS CHART FOR SR80,
0 - 12 MONTHS, 1.5 m DEPTH

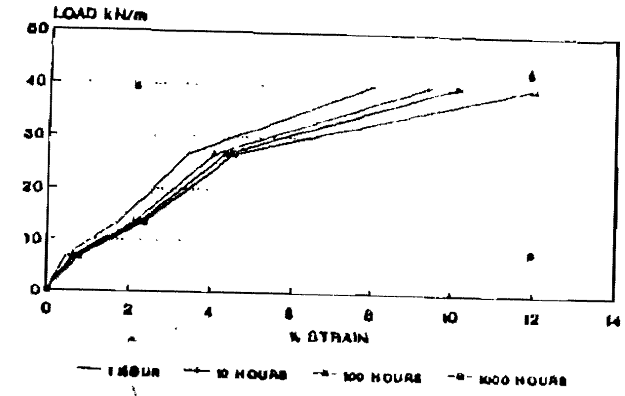


FIG 6d ISOCHRONOUS CHART FOR SR80,
0 - 12 MONTHS, 0.5 m DEPTH

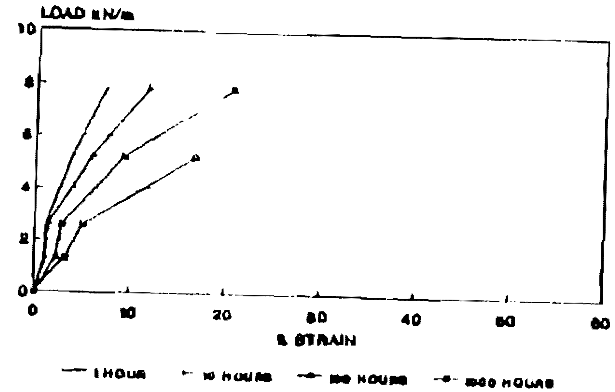


FIG 6a ISOCHRONOUS CHART FOR SS1,
0 - 18 MONTHS, EXPOSED

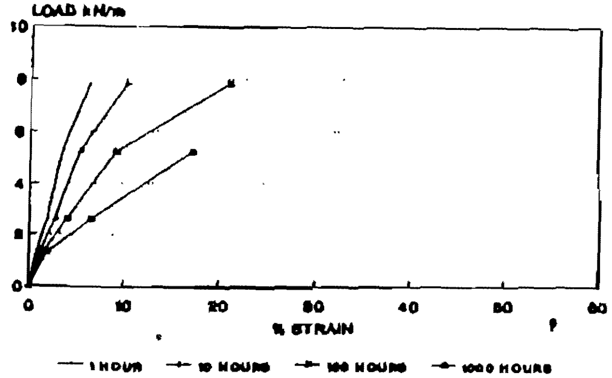


FIG 6b ISOCHRONOUS CHART FOR SS1,
0 - 18 MONTHS, STORAGE

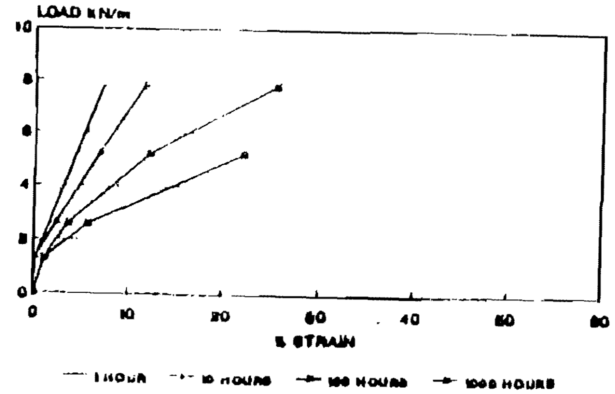


FIG 6c ISOCHRONOUS CHART FOR SS1,
0 - 18 MONTHS, 1.5 m DEPTH

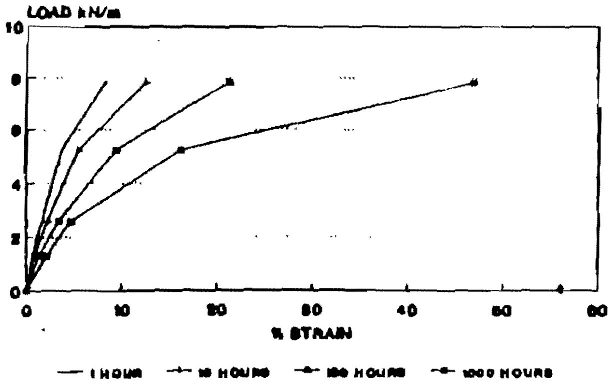


FIG 6d ISOCHRONOUS CHART FOR SS1,
0 - 18 MONTHS, 0.5 m DEPTH