AN EXPERIMENTAL STUDY ON THE CREEP BEHAVIOUR OF GEOGRIDS AT DIFFERENT TEMPERATURE

Jun Tong[1], Biwei Gong[2] & Jun Liu[3]

[1] *Key Laboratory of Geotechnical Mechanics and Engineering of the Ministry of Water Resources, Wuhan, 430010, China. (e-mail: tongjun888@gmail.com)*
[2] *Key Laboratory of Geotechnical Mechanics and Engineering of the Ministry of Water Resources, Wuhan, 430010, China. (e-mail: bwgong@126.com)*
[3] *Key Laboratory of Geotechnical Mechanics and Engineering of the Ministry of Water Resources, Wuhan, 430010, China. (e-mail: liujuncky@163.com)*

Abstract: The creep behaviour of geogrids is fundamental to evaluating the long-term performance of geogrid-reinforced earth structures under long-term external loading. Creep tests are carried out under different loading levels at the ambient temperature of 20,40,60 degrees, respectively. Then the characteristics of the creep curves and the isochronous load-strain relationship of geogrid are obtained. The experimental results show that the higher the ambient temperature and the loading level are, the more rapidly creep strain develops, the quicker the geogrid fails. The creep deformation during the beginning 1 hour takes major portion of the total creep deformation. The subsequent creep deformation increases prominently with the rise in temperature.

Keywords: HDPE, geogrid, creep, temperature

INTRODUCTION

Geosynthetic reinforcement structures are characterized by the advantages of easy-operation, low-cost, *etc*. As a new type of geosynthetics, geogrids are widely used in the embankment, slope and retaining wall, *etc.* The creep behaviour of geogrids is fundamental to evaluating the long-term performance of geogrid-reinforced earth structures under long-term external loading. The conventional methods are time-consuming, require high environmental control for a long period of time and are, therefore, expensive. Generally, long-term creep behaviour at normal temperature has been predicted by short-term creep tests at high temperature (Barns *et al*. 2002; Thornton *et al*. 2002). However, the study on the creep behaviour at high temperature is limited (Bush, 1990; Luan *et al*.2006). It is very imperative to study on the creep behaviour at different temperature to propose more effective methods predicting the long-term creep behaviour of the geogrid.

In this paper, creep tests are conducted to study creep behaviour of geogrid at 2 different ambient temperatures. Based on the test results, comprehensive analyses of creep properties are made at different combination of temperatures and loading levels.

CREEP TESTS

Test Material

The uniaxial oriented HDPE geogrid PE50 is used in present test. The mechanical properties are obtained by unconfined tensile test, as shown in Table 1.

Table 1. Physical properties of the geogrid used in the present study

Tensile strength (kN/m)	Extension (%)	Strength corresp. to ext. of 2％(kN/m)	Strength corresp. to ext. of 5％(kN/m)
64.56	11.98	15.81	29.83

Test Apparatus

The unconfined creep tests are carried out on the computer-controlled creep test apparatus. The apparatus consists of independent loading systems, clamping system and a sharing environmental chamber, as shown in Figure 1. Three creep tests can be carried out simultaneously. The temperature is controlled within ±2℃.

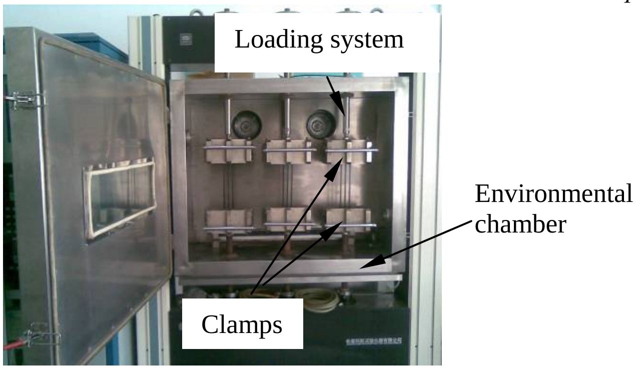

Figure 1. Photo for the creep test apparatus

Test Scheme

First, two of the most significant factors related with the creep behaviour, which are temperature and loading levels, have been taken into account in this paper. Based on the tensile strength obtained by unconfined tensile tests, the loading levels of 20%, 30%, 40%and 50% are chosen as the creep tensile loadings, respectively. The detailed test scheme is presented in Table 2.

Table 2. Test scheme of the creep behaviour at different temperatures

Temperature（℃） / Loading level(%)	60	40
20	T60L20	T40L20
30	T60L30	T40L30
40	T60L40	T40L40
50	T60L50	T40L50

Test Procedures

First, three longitudinal ribs of the HDPE50 geogrid are fixed by clamps. Acicular liners are placed in the clamps to hold samples tightly. Then the temperature of the environmental chamber is set to be constant. Keep the samples clamped for 24 hours in the environmental chamber with steady temperature and initial tensile loading. Then net distance between the top and low clamps is measured to obtain initial length. Apply the tensile loading and start the creep test. The creep deformation data are logged at the assigned intervals by the computer automatically. The value of creep deformation divided by the measured initial length yields the corresponding creep strain.

EXPERIMENTAL RESULTS AND ANALYSIS

First, the creep characteristic and isochronous loading-strain relation curves of the PE50 geogrid under different loading levels at the temperature of 60 and 40℃ are investigated comprehensively. Then a comparison of the creep curves under the same loading level at different temperature is made, revealing the impact of the temperature on the creep behaviour of geogrids. Finally, the creep curves are fit by linear logarithm equation and the comparisons of the fitting coefficient at different temperature are made.

Creep behaviour of geogrid at 60℃

Figure 2 shows the change of creep strain for geogrid with time at the temperature of 60℃. The logarithm equation is introduced to fit the creep curves when elapsed time is more than 0.1 hour.

$$\varepsilon = a + b \lg t \qquad \text{(Eq.1)}$$

Where ε is the creep strain, t is the elapsed time of the creep test, a, b are the coefficients of the fitting curve, respectively.

The deformations of the sample T60L20 and T60L30 still remain stable after 23 hours with the final extension being less than 9.5%, and their curves of creep strain are in reasonable agreement with the fitting curves. Whereas the sample T60L40 fails with the extension being greater than 30% after 24 hours. However, the sample T60L50 fails accompanied with large deformation in the beginning 2 hours. The creep curves of T60L40 and T60L40 cannot be predicted by Eq.1 because of the sharp deformation at early stage of the creep process.

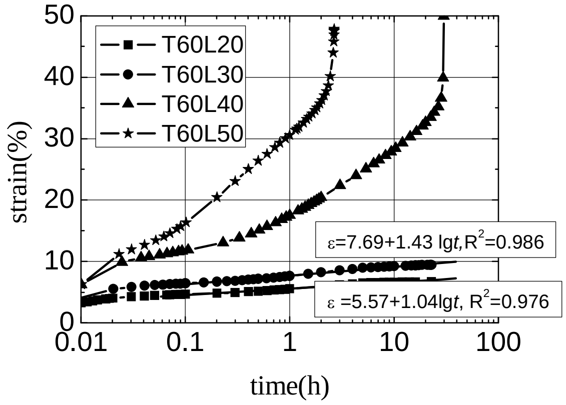

Figure 2. Creep strain curves of geogrid under different load levels at the temperature of 60℃

In order to investigate the stress-strain relationship at different times, the isochronous loading-strain relations of geogrid PE50 curves are obtained from the creep strain curves of different loading levels. Figure 3 shows the isochrones of loading against strain at 6 representative times. It can be obtained from the graph that the isochrones have very similar tendency. They increase relatively slow when the loading level is less than 30%. Once the loading level is greater than 30%, their slopes turn to develop sharply. These 6 isochrones show little discrepancy when the loading level is less than 30%, but more significantly when the loading level is greater than 30%. It can be deduced that the loading level of 30% may be considered as the threshold value of the creep behaviour at the temperature of 60℃.

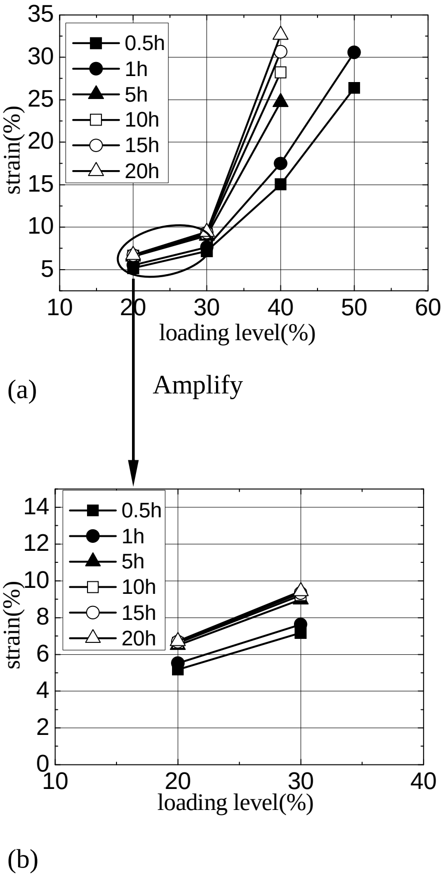

Figure 3. The isochronous loading-strain relations of geogrid PE50 at the temperature of 60℃

Creep behaviour of geogrid at 40℃

Figure 4 shows the change of creep strain with time at the temperature of 40℃. The deformation of sample T40L20 still maintains stability after 60 hours with final creep extension being less than 8.2%, whereas the total creep extension of sample T40L40 is about 11.6% with the steady creep state. However, sample T40L50 fails with the creep strain more than 30%. The creep strain curves of sample T40L20, T40L30 and T40L40 agree well with the fitting curves of Eq.1.

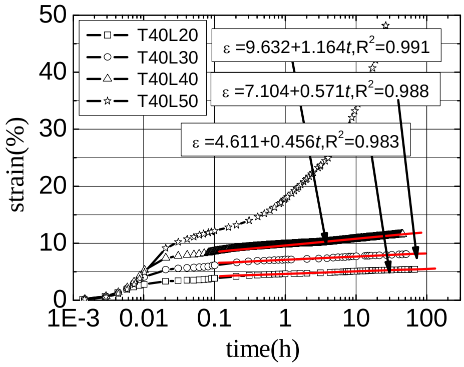

Figure 4. Creep strain curves of geogrid under different loading levels at 40℃

Figure 5 shows the isochronous stress-strain curves at 7 representative times at 40℃. The isochrones have the same tendency as that at 60℃. The obvious different is that the threshold value of the creep behaviour increases from 30% to 40%, and the isochrones shows less discrepancy when the loading level is less than the threshold value comparing the isochrones at 60℃.It suggests that the rise in the temperature enlarge the difference induced by the loading levels.

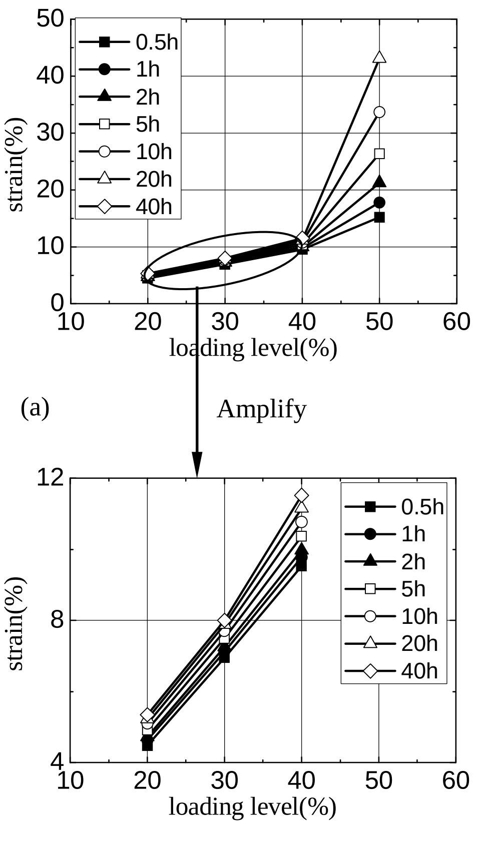

Figure 5. The isochronous loading-strain relation curves of creep test at the temperature of 40℃

Comparison of creep behaviour at different ambient temperatures

Figure 6 shows the comparisons of the curves of creep behaviour at different temperatures. It can be obtained that the higher the temperature is, the lower the loading level that the failure occurs. In order to describe the creep behaviour at different temperatures quantitatively, the strains and the proportion to the final strain for all samples are summarized in Table 3.The creep deformations increase with the rise in temperature. At the temperature of 60 and 40℃, the creep deformation during the beginning 1 hour takes a major portion of the total deformation, about more than 80%. The subsequent creep deformation increases prominently with the rise in temperature.

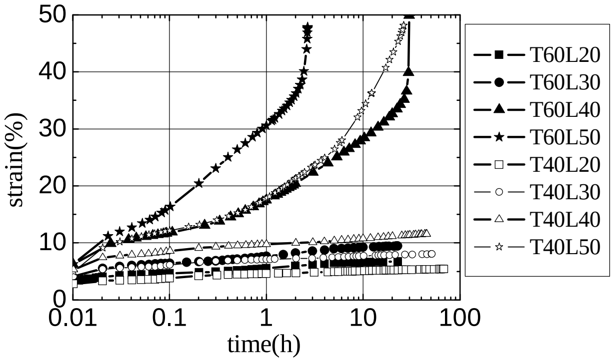

Figure 6. Comparisons of the curves of creep behaviour at different temperatures

Table 3. Creep strain at different temperatures

Sample	T40L20		T40L30		T40L40		T60L20		T60L30	
Strain / Time	Strain (%)	Ratio (%)	Strain (%)	Ratio (%)	Strain (%)	Ratio (%)	Strain (%)	Ratio (%)	Strain (%)	Ratio (%)
1h	4.63	85.6	7.12	87.7	9.78	84.3	5.53	82.2	7.63	80.7
10h	5.10	94.3	7.70	94.8	10.77	92.8	6.62	98.4	9.21	97.4
20h	5.23	96.7	7.88	97.0	11.15	96.1	6.72	99.9	9.43	99.7
Final	5.41	100.0	8.12	100.0	11.60	100.0	6.73	100.0	9.46	100.0

Figure 7 shows the comparison of the creep coefficient *b* under different loading levels at temperatures of 40 and 60℃. When temperature increases from 40 to 60℃, the corresponding creep coefficient *b* increases by more than 2 times. It can be deduced that the creep behaviour of the geogrid is very susceptible to temperature. Further investigation is needed to study the relationship between creep coefficient and loading level.

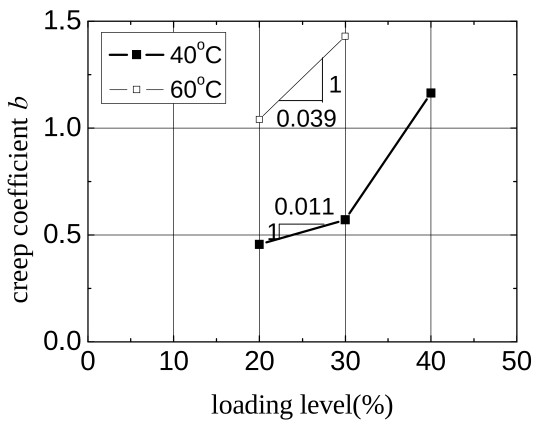

Figure 7. The change of creep coefficient with loading levels

CONCLUSIONS

- For a given geogrid, the higher the ambient temperature and the loading level are, the more rapidly creep strain develops，the quicker geogrid fails. The ambient temperature has prominent effect on the creep behaviour of the geogrid.
- The creep behaviour of the geogrid is very susceptible to temperature. The total creep deformation increases with the rise in temperature. When the loading is unchangeable, the duration that reaches a certain strain under lower ambient temperature is much longer than that under higher temperature. Whereas the creep temperature is invariable, the duration that reaches to a definite strain at low loading level is much longer than that at high loading level.
- The creep deformation during the beginning 1 hour takes major portion of the total creep deformation, about more than 80%. The subsequent creep deformation increases prominently with the rise in temperature.

Acknowledgements: The authors would like to acknowledge the financial support received from Changjiang River Scientific Research Institute.

Corresponding author: Mr Jun Tong, Key Laboratory of Geotechnical Mechanics and Engineering of the Ministry of Water Resources, HuangPu Rd.23#, Wuhan, Hubei, 430010, China. Tel: 86-27-62121683. Email: tongjun888@gmail.com.

REFERENCES

Bush, D.I. 1990. Variation of long term design strength of geosynthetics in temperatures up to 40℃. Proceeding of the 4th International Conference on Geotextiles, The Hague, 673-676.

Barns, L.C.S.， Bueno, B.S. and Costa, C.M.L. 2002. On the evaluation of stepped isothermal method for characterizing creep properties of geosynthetics. Proceeding of 7th International Conference on Geosynthetics, Nice, Brazil, 1515-1518.

Luan Maotian, Xiao Chengzhi Yang Qing. 2006. An experimental study on the creep behaviour of geogrids under long-term external loading .China Civil Engineering Journal, 39(4), 87-91. (In Chinese)

Thornton, J.S. and Baker, T.L. 2002. Comparison of SIM and conventional methods for determining creep-rupture behaviour of a polypropylene geotexitle. Proceeding of 7th International Conference on Geosynthetics, Nice, Brazil, 1545-1550.