Analytical approach to long-term creep behaviors of geosynthetic reinforcements

Jeon, H.Y.
Division of Nano-Systems Engineering, INHA University, Incheon, Korea

Gong, H.B.
Mekamore Co. Ltd., Seongnam, Korea

Kang, S.G.
Mekamore Co. Ltd., Seongnam, Korea

Keywords: long-term design strength, geogrids, creep deformation, creep criteria, more site-specific

ABSTRACT: This paper is focusing on the test method that used for evaluating the long-term design strength of the various type of geogrid and suggestion of improved test method. The tests were performed about two kinds of geogrid (textile geogrid and membrane drawn geogrid). Estimated long-term creep deformation indicate that the 65% of T_{ult} loading level is the optimum value that satisfying the creep criteria in the case of woven geogrid and 60% in warp knitted geogrid and 30~35 % in membrane drawn geogrid. From this review and proposal of new procedure of installation damage test, more site-specific and more material-specific index test results are expected.

1 INTRODUCTION

The increased use of polymer geogrids has led to the need to better understand their material properties and the potential for short and long-term property changes due to field installation and exposure. Geogrids placed in compacted earth works are susceptible to mechanical damage from fill placement and fill compaction during earth work construction. (Koerner and Soong 2001)

Such construction induced damage may cause changes in geogrid properties such as short-term tensile load response, long-term tensile load response (creep), or resistance to chemical or biological degradation. (Thornton 2001) So, as a part of the design it is therefore required to evaluate what kind of mechanical damage might be expected and what are the consequences of the damage in terms of ability to fulfill its intended function in the structure.

The purpose of this paper is to review the existed evaluating methods and propose more site-specific, more subdivision and more detailed index test.

2 RECONSIDERATION OF THEORETICAL BACKGROUND

Time-temperature superposition (TTS) principle is the commonly used as an acceleration method to evaluate creep behavior of polymeric materials. Creep curves obtained at elevated temperatures can be shifted to the creep curve at reference temperature along a log-time scale (i.e., horizontally). The curve created by the superposition is master curve covering a large range of times (e.g., 100years in geosynthetic designing). The distance of horizontal shift in the plot of creep modulus vs. log-time is determined by iteratively varying a creep curve under consideration until the beginning portion of the creep curve is well-overlapped with the end portion of the creep curve at previous temperature. Also, horizontal shift factor is dependent on the reference temperature and the material properties of the polymer.

However, extensive use of TTS for polyester products had been inhibited by some factors as which conspire to make the TTS process for PET so uncertain that may replicate samples are needed to establish the shift factors and the proper strain level locations for shifted creep curves. So, the stepped isothermal method (SIM) was introduced to overcome these defects. The stepped isothermal method (SIM) is a test procedure involving a specific application of time-temperature superposition (TTS) principle.

Although individual specimen per one temperature is used on TTS, the master curve by

SIM is generated on a single specimen through the application of a series of timed isothermal exposures at elevated temperature steps under constant load. Thus, the method prevents the problems of multi-specimen variation that limit the accuracy of time-temperature superposition.

3 RESULTS AND DISCUSSION

3.1 *Thickness and compressive stress*

Table 1 shows the specifications of geogrids used in this study and Fig. 1 represent the results of tensile elongations of commercially used geogrids according to the tensile speed. From this, it is seen that the maximum elongation of membrane drawn type geogrid increased with deceasing rate of strain (500 to 5 mm/min).

Table 1. Specifications of geogrids used in this study

Specimen	Raw material	Manufacturing type	Nominal strength (t/m)
Textile Geogrid (TG-1)	PET yarn	Warp knitting	8
Textile Geogrid (TG-2)	PET yarn	Weaving	
Membrane Drawn Geogrid (MG-1)	HDPE	Extrusion & drawing	
Membrane Drawn Geogrid (MG-2)	PP	Extrusion & drawing	

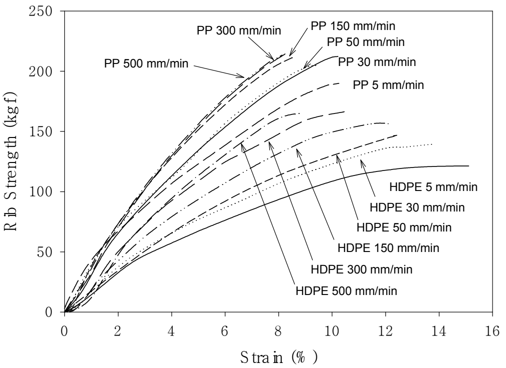


Figure 1. Comparison of rib strength of membrane drawn geogirds with various tensile rate

Fig. 2~5 show that the rib strength-strain response of geogrids sensibly independent on the strain rate-time loading path. These Figures prove clearly that the membrane drawn geogrid has the potential of extra-elongation property. That means the membrane drawn geogrid could be secondly oriented during the very slow tensile force are applied to the membrane drawn geogrid again. It is due to the special quality of membrane drawn geogrid product itself.

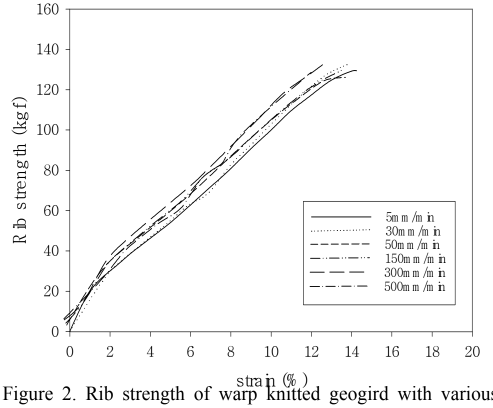


Figure 2. Rib strength of warp knitted geogird with various tensile rate (TG-1)

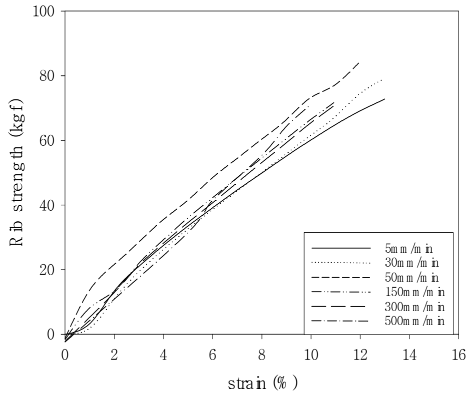


Figure 3. Rib strength of warp knitted geogird with various tensile rate (TG-2)

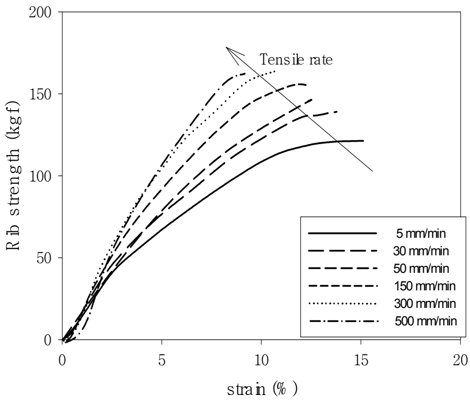


Figure 4. Rib strength of HDPE membrane drawn geogird with various tensile rate (MG-1)

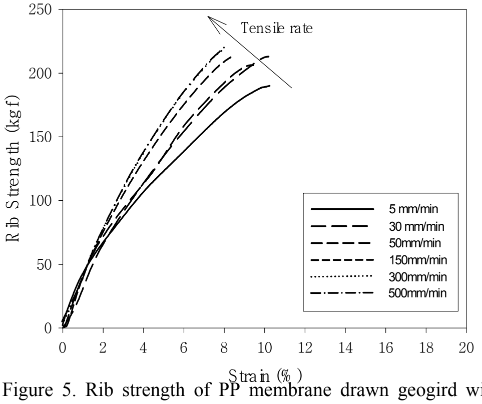
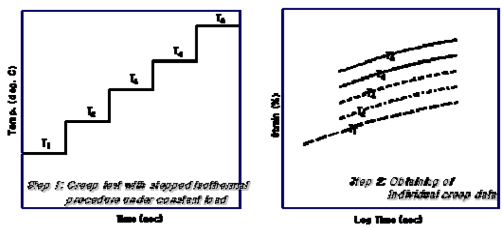


Figure 5. Rib strength of PP membrane drawn geogird with various tensile rate (MG-2)

3.2 *Limit creep strain*

The creep behavior of geosynthetics is generally presented as strain versus time or (log time) curves and strain rate versus time. From these typical creep curves it is possible to identify 3 different creep stages, respectively named primary creep, secondary creep and tertiary creep. As general trend, the first stage where the strains develop very rapidly it followed by a transition period between primary and secondary creep where the strain rate is decreasing. However the final sudden creep strain increase before rupture does not necessarily occur: it is typical for PE (polyethylene) and PP (polypropylene) not for PET (polyester) at standard load levels and temperatures. And to investigate more specifically the long-term tensile creep of geosynthetics, it is necessary to know the effect of each of the above mentioned factors on load-strain behavior. Nevertheless, polymer structure parameters, such as molecular weight, molecular orientation, and crystalline volume, degree of branching and draw molecular ratio are also very important to evaluated creep sensitivity of polymers. Typical strain-time curves at any temperature and various loads levels, expressed as a percentage of the tensile strength, are showed in Fig. 6. A further method of presenting the test data is to plot the creep strain rate against the cumulative strain as illustrated to obtain Sherby-Dorm curves.



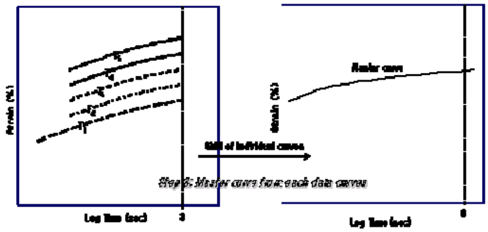


Figure 6. Basic concept of data shifting in SIM

This plot clearly shows whether the material approaching failure or vice versa a state of stable equilibrium and can thus assist in the avoidance of long-term instability. Therefore, we can convert the strain vs. log time curves to the Sherby-Dorm plots (Fig. 7).

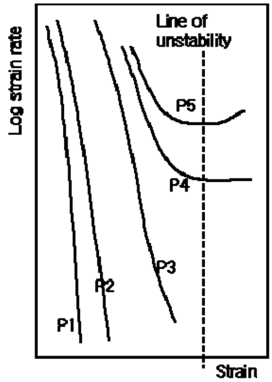


Figure 7. Sherby-Dorm plots for creep behavior analysis at various load levels (P1, P2, P3, P4 and P5)

In here, the strain value that the increase of strain rate is started will be the performance limit strain value. After decision this performance limit strain, the strain vs. log time curves at various loading levels is converted to the isochronous creep strain curves. If the deformation is constant, the stress resisting that deformation will decrease time. The physical mechanism that causes a plastic to undergo creep also applies to the phenomenon of stress relaxation.

3.3 *Proposal of determining method of FS_{CR}*

To estimate the long-term tensile property of the geogrid by creep test, it is very important to determine the changing point of creep stage from secondary to tertiary. Above this boundary the rupture of geogrid samples will be started. This changing point at a strain will be a performance limit strain value. Fig. 8 shows the concept of this performance limit strain. GRI test method GG-4 recommended that the creep limit strain at a long-term tensile test as a strain value that should becomes asymptotic to a constant strain line of 10 percent or less regardless of its kind. In other words, the changing point of creep stage (secondary to tertiary) is 10% for all of the stiff and rigid geogrid. But this is very rough and dangerous criteria because it didn't consider the material properties of samples. So, exact determination of this performance limit strain is very important to reducing the errors and to the more correct design. It is difficult more or less to determine the performance limit strain from strain vs. log time curves.

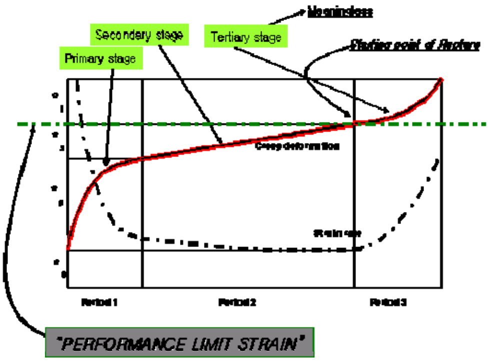


Figure 8. Basic concept of creep curve

Fig. 9 shows the determination of isochronous creep strain curves from strain-time data. From these curves, the new regression curve at any strain value can be obtained, and this curve is plotted as load ratio (%) vs. log time. Lastly, the factor-of-safety for creep is determined from this strain regression curve for the given design life. For example, if we suppose the performance limit strain of a creep test material as 10% and the design life as 100 years, then 10% strain regression curve is plotted. Finally, isochronous creep curve could be obtained through load ratio (%) at 100 years by repeating this procedure.

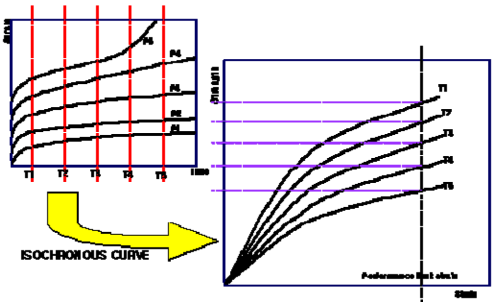


Figure 9. Isochronous curves from strain-time curves.

3.4 *New creep data interpretation*

The following procedure that evaluating more material and structure specific performance limit creep strain and estimate exact long-term creep reduction factor was proposed. (Fig. 10)

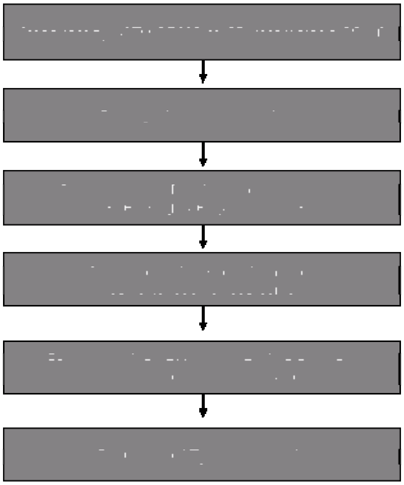


Figure 10. Creep test procedure with the proposed method.

4 CONCLUSION

Short-term tensile properties of the membrane drawn geogrid were very good merely compared to other types of geogrids. From additional short term tensile test, this poor elongation property was found. Experimental data interpretation is very important for accurate design. For the better consideration of the long-term property of geogrid, the field closed review by test methods must be considered. Creep data interpretation is performed by using performance limit strain and isochoronous curve. From this procedure we can obtain more accurate creep reduction factor at the aim design life.

ACKNOWLEDGEMENT

This work was supported by grant No. RTI04-01-04 from the Regional Technology Innovation Program of the Ministry of Knowledge Economy (MKE).

REFERENCES

Thornton, J. S. 2001. Characterization of short and long term creep and relaxation properties of a polypropylene Geogrid", *Proc. of Geosynthetics Conference 2001*, pp. 835-845.

Koerner, R. M. and Soong, T. Y. 2001. Creep testing and data extrapolation of reinforced GCLs", *Geotextiles and Geomembranes*, Vol. 19, pp. 413-425.