Effects of Various Stress Histories Including Creep Loading on Strength of a Geogrid

크리프 하중을 포함한 응력이력이 지오그리드 강도에 미치는 영향

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SYNOPSIS : PVC로 코팅된 폴리에스테르 섬유로 만들어진 지오그리드 보강재에 대해 변형률을 달리하여 단일 또는 다단 크리프 하중단계를 포함한 하중을 연속적으로 작용시킴으로써 그 인장파괴강도를 검토하였다. 연구결과, 동일한 변형률에서 지오그리드의 인장파괴강도는 극한인장파괴가 되기 전에 작용된 응력이력에 의해서 거의 영향을 받지 않는다. 또한 지오그리드의 설계파단강도는 적정한 변형률하에서 정의되어야 하며, 변형률 속도가 빠른 인장시험을 통해 지오그리드의 설계파단강도를 얻을 경우 이에 대한 보정이 필요할 것으로 사료된다.

Key words : geogrid, stress history, creep, rupture strength

1. Intorduction

Geosynthetics are increasingly being used as reinforcement in permanent earth structures constructed in conjunction with transportation facilities(Tatsuoka and Leshchinsky, 1993), including retaining walls, steep slopes, and bridge abutments. In many cases, the inclusion of geosynthetics in soils allows construction of structures at significantly reduced cost as compared to unreinforced soil structures. As the worldwide use of geosynthetics to make economic and stable structures, the evaluation and interpretation of time-dependent tensile stress-strain behavior, creep, of geosynthetics under sustained loading has been of great significance. It is the current design practice to reduce by a relatively large creep reduction factor the peak strength obtained from tensile rupture test with fast strain rate to obtain the design tensile rupture strength at a specific long design life time. The use of creep reduction factor for creep effects is implicitly based on the assumption that creep is a degradation phenomenon for the tensile strength of geosynthetics.

This paper will demonstrate that there is very little, if any, degradation of short-term tensile strength over the life of the structure due to creep loading, and that tensile rupture strength at failure for constant strain rate could be rather independent of creep deformation histories that are applied before the ultimate tensile rupture.

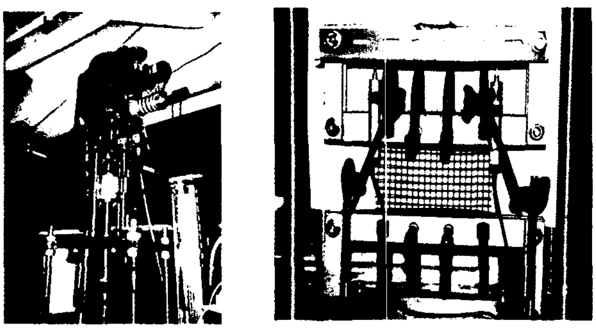
2. Test configuration and Material

The reinforcement used in this study is a polyester geogrid. Index properties of the geogrid provided by the manufacturer are listed in Table 1. To obtain the tensile load-elongation behavior of a geogrid, wide-width and in-air tensile test as suggested by ASTM(D4595) was performed. A photograph of wide-width tensile test machine and a schematic diagram of gripping are shown in Fig.1(a) and Fig.1(b), respectively. The test apparatus has a capacity of 50kN and is of precision gear type with practically no backlash when the loading direction is reversed, and it is able to control axial strains to 4.8mm/min at maximum. More details of this loading system are described in Tatsuoka et al.(1994) and Santucci de Magistris et al.(1999). By using this loading system, it becomes possible a) to smoothly switch the loading phase between strain control loading and stress control loading, and between creep loading and constant strain rate loading and, b) to perform loading at any given history of strain rate, unload/reload cycles loading. The specimens were 300mm-long, 200mm-wide with test length of 100mm. All wide-width tensile tests for the geogrid are carried out at a relatively constant temperature, usually 23±2 degrees Celsius.

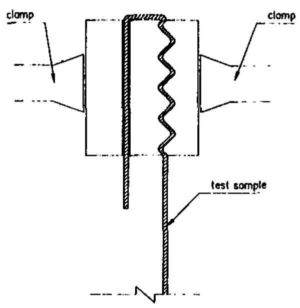
Table 1. Index properties of a geogrid

Index properties	Value*
Mass per unit area	250 g/m^2
Tensile strength	39.2 kN/m
Elongation at break	22%

* These values were obtained for a strand of geogrid by test method as JIS L 1096



(a) Photograph of tensile test apparatus
(L: Loading Frame, R: Main Frame)



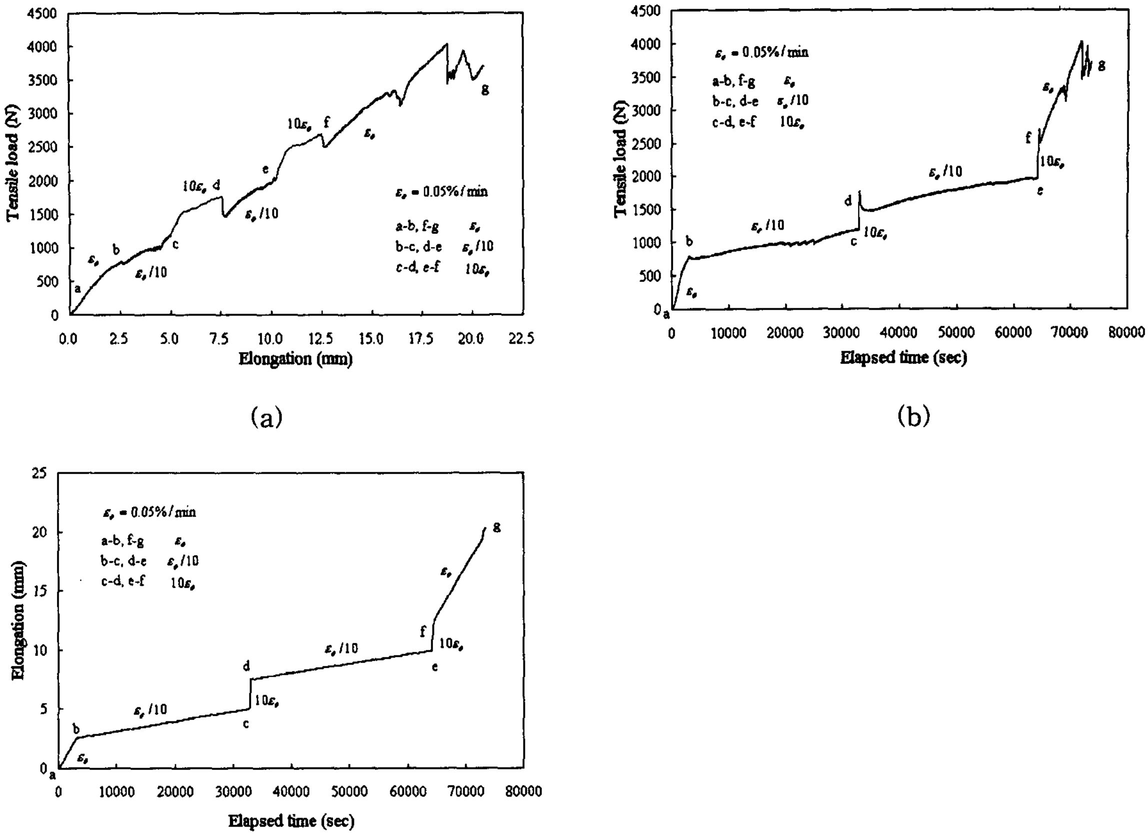
(b) Schematic view of gripping part

Fig.1 Tensile test apparatus

3. Test results and discussion

3.1 Effect of stepwise strain rate on strength of a geogrid

Fig.2 shows the results from tensile test, the variation of tensile load of a geogrid with stepwise strain rate. To clarify the difference of strength with strain rates, 0.005mm/min($\dot{\varepsilon}_1$) and 0.5mm/min ($\dot{\varepsilon}_2$) of strain rate were selected($\dot{\varepsilon}_2/\dot{\varepsilon}_1=100$). From these figures, it is found that the behavior of a geogrid traces its inherent way of the time with no change of strain rate though strain rate is changed stepwise.



(c)

Fig.2 Tensile load test with stepwise strain rate : (a) Relationship between elongation and tensile load, (b) Variation of tensile load with elapsed time, (c) Variation of elongation with elapsed time.

3.2 Effect of various stress histories on strength of a geogrid

Fig.3 shows the effect of various stress histories including creep loading and small cycles loading on strength of a geogrid. The test was performed 3 times small cycles loading(5 cycles unloading/reloading, 100N amplitude) and 2 times creep loading(24 hours, respectively) at the same strain rate of 0.048mm/min. From these figures, the followings can be seen. a) When the loading is resumed under the same strain rate after a creep stage, the stress-strain relationship rejoins the original stress-strain relationship that will be obtained if the loading would be continued without intermission. b) As compared with the stress-strain relationship and the peak strength of geogrid from Fig.2, the peak strength is independent of the loading pattern that has been applied until the failure. That is to say, the peak strength is the same whether or not a creep stage (or stages) is (or are) involved before failure. c) Creep deformation is not a degrading process for a geogrid, but it has positive effects that increase the stiffness when loading is resumed, without reducing the ultimate peak strength.

Therefore, it is found that the tensile rupture strength for the same strain rate is hardly affected by stress histories that are applied before the ultimate tensile rupture failure.

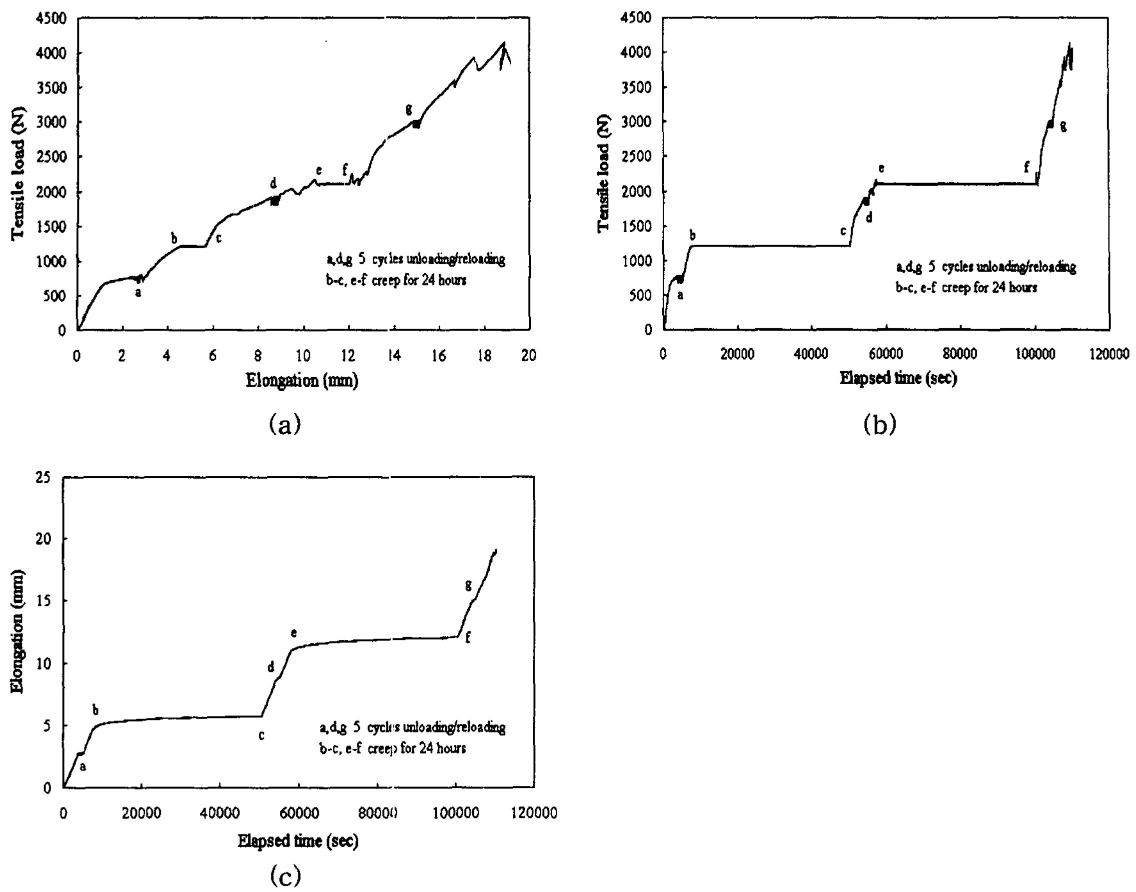


Fig. 3 Tensile load test including creep loading at constant strain rate(0.048mm/min) ; (a) Relationship between elongation and tensile load, (b) Variation of tensile load with elapsed time, (c) Variation of elongation with elapsed time.

4. Conclusions

The following conclusions can be derived from the results presented above :

1) The tensile rupture strength for the same strain rate is hardly affected by stress histories that are applied before the ultimate tensile rupture failure.
2) Creep deformation is not a degrading process for a geosynthetic.

Acknowledgement

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