Experimental Study on the Influence Factors of Durability of Composite Geomembrane

Geng Zhizhou12*, Zheng Chengfeng1, Xu Kai12

1Geotechnical Engineering Department, Nanjing Hydraulic Research Institute, Nanjing 210024, China
2Key Laboratory of Earth-Rock Dam Failure Mechanism and Safety Control Techniques, Ministry of Water Resources, Nanjing 210029, China

*Corresponding author’s e-mail: zzgeng@nhri.cn

Abstract. The durability of composite geomembrane materials may decrease under the long-term influence of natural environment such as light and temperature. In order to study the influence of different factors on the durability of composite geomembrane, the durability of composite geomembrane with different aging time was tested by artificial accelerated aging test. The experimental results show that the longitudinal tensile strength of composite geomembrane material decreases slightly with the increase of time. Additionally, the longitudinal elongation of composite geomembrane materials is proved to be located in a reasonable range, and there is no obvious upward or downward trend. The permeability coefficient of composite geomembrane material varies with the aging time, however, the test result remains in the same order of magnitude. The longitudinal tensile strength of composite geomembrane in dry state is larger than that in immersed state. The strength of the welded joint of geomembrane is larger than that of the bonded joint. The yield strength and breaking strength of geomembrane materials increase slightly with time, and there exists no significant changes in terms of the yield elongation and breaking elongation.

1. Introduction

As a kind of geotechnical materials, composite geomembrane has been widely used in highways, railway construction, agriculture and environmental protections. Composite geomembrane is of great significance to promote industry progress and national economic construction. Under the natural environment conditions, the composite geomembrane material is affected by factors such as light, temperature and load. The molecular structure of the material will change, the mechanical properties will gradually weaken, and the durability will decrease.

The durability test of the composite geomembrane is the effect of various environmental factors involved in the field conditions of the composite geomembrane on the durability of the material. Specifically, the temperature and humidity cycle in the climate environment, extreme high and low temperature as well as other environmental conditions can be simulated through various environmental test equipment. The method can be used to accelerate the failure of the excitation material, and to verify whether the material meets the requirements in research and development, design and manufacture[1]. The basic idea of the accelerated test is to use the temperature and humidity cycle, the aging characteristics of the material under extreme high and low temperature conditions to extrapolate the relevant characteristics of the material under normal temperature and humidity conditions. The key is to establish the relationship between the aging characteristics of the material and the experimental
environmental conditions which makes it possible to extrapolate the material characteristics under field conditions \[2-3\]. The long-term stability of geomembrane has been studied by some engineers and researchers.

Due to the natural operating conditions, the stage of the consumption of composite geomembrane antioxidant (stabilizer) often takes decades or hundred years in the common anti-seepage project. Therefore, the natural climate aging test research is less feasible. Researchers often use artificial accelerated aging methods to study the durability of composite geomembrane such as using laboratory test equipment to accelerate the aging of geomembrane. According to the requirements of on-site conditions, the environmental factors such as temperature, humidity, light source intensity, and illumination time higher than the natural environmental conditions are controlled to accelerate the aging of the geomembrane. Under unnatural test conditions, the material durability is reduced at a faster rate than in natural climatic conditions, and the test time required for the material to achieve a certain durability loss is shorter. Although this test method is insufficient in quantitative estimation and simulation conditions, the test results of the relevant physical and mechanical properties of the materials measured by the indoor accelerated aging test are still of high value \[4-5\].

In this paper, in order to study the influence of different factors on the durability of composite geomembrane, the artificial accelerated aging test, wide-width tensile test, trapezoidal tearing test, tensile test as well as penetration test of composite geomembrane with different aging time were conducted.

2. Test schemes

The geomembrane used in this paper is two layers of 400 g/m² polyester filament geotextile and 0.6 mm low density polyethylene film. Because the properties of geotextiles and geomembranes may vary in different batches during the production progress, all geotextiles and geomembranes are produced in the same batch and production line to ensure the stability of laboratory test materials.

The geomembranes were tested according to the following three situations: 1. In view of the application of composite geomembrane above the average storage water level in the operation period, without considering the influence of water, some of the membrane above the average water level is under a long-term drying state. 2. In view of the operation period, the application of composite geomembrane under the average water level is immersed in wet solution with high sediment content, mainly considering the influence of temperature water change. 3. Considering the influence of humidity on the membrane material in the area of the change of water level. In accordance with the Specification for Testing Geosynthetics (SL235-2012), wide-width tensile test, trapezoidal tearing test, tensile test as well as penetration test were carried out.

3. Test results and analysis

Under the condition of indoor accelerated aging test under humid-heat and temperature cycling, the mechanical properties such as longitudinal tensile strength, longitudinal elongation, longitudinal tear strength, weld strength, bond strength and strength of geomembrane under different aging time were analysed. For the three types of samples in dry, wet and immersed state, a certain size sample is taken every four cycle, and then the laboratory test is carried out by trapezoidal sampling method. The relationships between mechanical properties and aging time are shown in Fig. 1-Fig. 7.

It is proved that the longitudinal tensile strength of composite geomembrane materials decreased slightly with time, but the strength decreased less from 30 °C ~ -20 °C ~ 30 °C cycling, after 7 complete cycles and under three environmental conditions. The last three cycles tend to be stable. The longitudinal elongation of composite geomembrane is located in a reasonable range, and there is no obvious increase or decrease trend. Although the permeability coefficient changes with the increase of aging time, it still maintains the same order of magnitude, which can meet the design requirements of anti-seepage.

The longitudinal tensile strength of the composite geomembrane in the dry state is generally larger than that under the immersed state. There are two possibilities for this reason: First, the friction
between the filaments of the geotextile fibers in the wet state leads to the reduction of tensile strength of the geomembrane. The second reason is that the conditions of water immersion and freeze-thaw cycles have a certain influence on the composite agent used for filament geomembrane.

In addition, the tensile strength of the geomembrane welded joints remains stable, and the strength of the welded joint is greater than the strength of the joint in the seven complete temperature cycles. The fracture of the geomembrane weld seam is located at the base metal, and the joint breakage is broken at the colloid, which is related to the type of glue.

From the curves of tensile strength of geomembrane versus time, it can be seen that in 7 complete temperature cycles, the yield strength and fracture strength of geomembrane increase slightly with time, but the amplitude is small. The yield elongation and elongation of the geomembrane are have no significant changes with the aging time.

![Figure 1. Relation curves of longitudinal tensile strength of geomembrane versus time](image1)

![Figure 2. Relation curves of longitudinal elongation of geomembrane versus time](image2)
Figure 3. Relation curves of longitudinal tear strength of geomembrane versus time

Figure 4. Relation curves of tensile strength of welding adhesive joints of geomembrane versus time

Figure 5. Relation curves of yield strength and fracture strength of geomembrane versus time
Figure 6. Relation curves of permeability coefficient of geomembrane versus time

4. Conclusions
It is proved that the longitudinal tensile strength of composite geomembrane materials decreased slightly with time. The permeability coefficient changes with the increase of aging time. The longitudinal tensile strength in the dry state is generally larger than that under the immersed state. In addition, the strength of the welded joint is greater than the strength of the joint in the seven complete temperature cycles. The yield strength and fracture strength of geomembrane increase slightly with time, but the amplitude is small. The yield elongation and elongation of the geomembrane are have no significant changes with the aging time.

Acknowledgments
The authors gratefully acknowledge the financial support from the Development Program of China (51809181) and the project from NHRI (Y319007).

References
[1] Qiao Hai-xia, GU Dong-ya, Zeng Jing-chen. (2007). Accelerated Aging Methods of Polymeric Composites and the State of the Art. Materials Review, 21(4): 48–51.
[2] Taghizadeh-Saheli, P., Rowe, R. K., Petersen, E. J., & O’Carroll, D. (2017). Diffusion of multiwall carbon nanotubes (MWCNTs) through an HDPE geomembrane (No. Science of the Total Environment).
[3] Zhang, L., Bouazza, A., Rowe, R. K., & Scheirs, J. (2017). Effect of welding parameters on properties of HDPE geomembrane seams. Geosynthetics International, 24(4), 408-418.
[4] Touze-Foltz, N., & Farcas, F. (2017). Long-term performance and binder chemical structure evolution of elastomeric bituminous geomembranes. Geotextiles and Geomembranes, 45(2), 121-130.
[5] Rowe, R. K., & Shoaib, M. (2017). Long-term performance of high-density polyethylene (HDPE) geomembrane seams in municipal solid waste (MSW) leachate. Canadian Geotechnical Journal, 54(12), 1623-1636.