Statistical Analysis of the Influence of Test Environment on Geomembrane Physical Test

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Abstract. Temperature and relative humidity affect the test of geomembrane. Here, using mathematical statistics, we analyzed the influence of temperature and relative humidity during state regulation and test on the results. The test data of geomembrane were obtained by changing the temperature and relative humidity ranging from 18\textdegree{}C to 25\textdegree{}C and from 50\% to 70\% respectively. Variation characteristics of discreteness and numerical value of test results with temperature and relative humidity are obtained by statistical analysis method. The results show that the influence of temperature and relative humidity on the test results stability is the change of numerical value and distribution characteristics. Under different temperature and relative humidity, the coefficient of variation of the test value of mass per unit area is 3.4\% ~ 4.1\%, and the coefficient of variation of average value is 0.3\%, which shows good stability; the coefficient of variation of thickness test value is 2.9\% ~ 7.0\%, and the coefficient of variation of average value is 6.8\%, and the value decreases with the increase of temperature.

1. Introduction

Geomembrane is a kind of polymer material, which is thin and flake, which can effectively prevent the permeation of liquid and gas \cite{1}. Geomembrane also has the advantages of good flexibility at low temperature, good deformation adaptability, simple overall connection and convenient construction \cite{2,3}. It is used as anti-seepage material and widely used in environmental protection engineering, water conservancy engineering, geotechnical engineering and landscape engineering \cite{4-7}.

For engineering quality and safety, geomembrane needs to be tested. During the test, the tester, test method, equipment, materials, environmental temperature and humidity, management system \cite{8,9} will affect the accuracy of the results. Among them, some research achievements have been made on the influence of test methods on test results \cite{10-13}. Although the influence of environmental temperature and humidity on the test results of geomembrane has always attracted much attention, there are few researches. There are two main views on the influence of environment on the experimental results: one is that the general indoor temperature and humidity has little impact on the test results; the other is that it has a certain impact on the test results, which cannot be ignored.

Considering the influence of temperature on the performance of geomembrane, most test standards of geomembrane have the requirements of temperature and relative humidity. However, different standards have different regulations, and the degree of influence of temperature and humidity on the test results of geomembrane is not explained. In the process of formulating a geosynthetic test standard...
for water transportation engineering, in order to put forward reasonable temperature and relative humidity requirements for geomembrane testing, an experimental study was conducted on the influence of general indoor temperature and humidity on the stability of geomembrane test results.

2. Test design

2.1. Sample
The test material was linear low-density polyethylene (LLDPE) geomembrane mixed with 5% double resistant carbon black master batch. The mass test per unit area and thickness test were carried out. Sampled evenly on the sample and cut the sample with a punching knife. The number of specimens was 10 per group. There was only one group of thickness samples. Repeated the thickness test under different temperature and humidity, and fixed the position of measurement to avoid the measurement error caused by the inhomogeneity of samples.

2.2. Test method
The temperature and humidity conditions include the temperature and humidity of the state regulation and the test environment during the test. The purpose of state adjustment is to make the geomembrane adapt to the temperature and humidity of the test environment before the test, fully release the temperature stress, and achieve humidity balance. The temperature and humidity control during the test can avoid the new stress and strain of geomembrane due to the temperature and humidity fluctuation.

Generally, the test standard specifies that the state adjustment temperature of geomembrane is (20±2) °C or (23±2) °C, the relative humidity is (50±10)% or (60±10)%, and the adjustment time is 88h, 24h, 4h or 1h. The temperature and relative humidity during the test are the same as those of the state regulation. However, many test standards do not specify the relative humidity during condition adjustment and test.

Considering the low temperature and humidity in winter in the north, the commonly used test temperature range was extended to 18°C ~ 25°C, and the relative humidity range was expanded to 30% ~ 70%. This is also the temperature and relative humidity that the laboratory can easily reach without special temperature and humidity regulation equipment. The temperature of 18°C, 21°C and 25°C and the relative humidity of 30%, 50% and 70% were selected to form nine different temperature and humidity conditions. The sample was adjusted for 24h to make it fully deformed to stable under the set temperature and humidity, and then the test samples were prepared. The temperature and humidity in the test room were consistent with those during the conditioning.

The factors affecting the test results are many and complex. To ensure the reliability and comparability of the test results, a number of measures were taken during the test to reduce the impact of other factors on the test results, such as selecting products with stable quality, uniformly cutting samples in different regions, fixing test equipment and testers, etc.

2.3. Statistical methods
The influence of external factors on the test results is manifested as changes in the central tendency, dispersion degree and distribution shape of the sequence distribution, as well as changes in the relationship between parameters. Since most of the test results are normally distributed, and the correlations between the parameters are not considered, the influence of temperature and humidity conditions on the results is manifested as changes in numerical values and discrete characteristics. Using mathematical statistics, the following parameters were selected to analyze the test data and their average values under different temperature and humidity.

(1)Arithmetic average: represents the average level of a set of test values, reflects the central tendency and the characteristics of inevitability, and is easily affected by extreme values.

(2)Standard deviation (SD): is used to analyze the dispersion of the same set of test values, and is an important indicator of accuracy and stability in repeatability measurement.
3. Results and analysis

3.1. Mass per unit area

Statistical analysis results of unit area mass of geomembrane are shown in Table 1. Under different temperature and humidity, the coefficients of variation and extreme value relative deviations of mass test value per unit area are small, and the data have a good concentration trend and a small data distribution width. Temperature and humidity have little effect on the standard deviation, coefficient of variation and relative deviation of value of the test values. The standard deviation, coefficient of variation, and extreme relative deviations of the average mass per unit area at different temperature and humidity are very small, and the extreme relative deviations are only -0.4% and 0.3%, showing a good central tendency. It can be considered that the unit area mass test of geomembrane has good stability, and the temperature and relative humidity changes in the range of 18°C ~ 25°C and 30% ~ 70% have no obvious influence on the dispersion distribution and numerical value of the test values.

Table 1. Statistical analysis results of mass per unit area.

| Temp and RH | Avg (g.m⁻²) | SD (g.m⁻²) | CV (%) | RSD of Min (%) | RSD of Max (%) |
|-------------|-------------|------------|--------|----------------|----------------|
| 18°C,30%    | 159.1       | 5.6        | 3.5    | -6.5           | 3.6            |
| 18°C,50%    | 159.7       | 5.5        | 3.4    | -6.5           | 3.3            |
| 18°C,70%    | 159.2       | 5.6        | 3.5    | -6.5           | 3.6            |
| 21°C,30%    | 159.9       | 5.5        | 3.4    | -6.4           | 3.4            |
| 21°C,50%    | 159.9       | 6.6        | 4.1    | -6.9           | 6.7            |
| 21°C,70%    | 159.8       | 5.5        | 3.4    | -6.1           | 3.4            |
| 25°C,30%    | 158.8       | 5.6        | 3.5    | -6.5           | 3.5            |
| 25°C,50%    | 159.2       | 5.5        | 3.5    | -6.5           | 3.5            |
| 25°C,70%    | 159.5       | 5.6        | 3.5    | -6.3           | 3.6            |
| Avg under different Temp and RH | 159.5 | 0.4 | 0.3 | -0.4 | 0.3 |

3.2. Thickness

Statistical analysis results of the thickness of geomembrane are shown in Table 2. The coefficients of variation of the thickness measured at 9 temperatures and humidities range from 2.9% to 7.0%, showing a small degree of dispersion and variation, and a small distribution width. Compared with the mass per unit area, the stability of thickness measurement data is poor, which is due to the small area and poor representativeness of the measuring points of thickness, which is easily affected by the heterogeneity of materials. Figure 1 shows the relationship between the coefficient of variation of thickness test values and temperature under different humidity. It can be seen from Figure 1 and Table 2 that the relationship between coefficient of variation and temperature and humidity is not obvious. The test data has a better central tendency at 21°C, and the humidity has a greater influence on its dispersion at 25°C.
Table 2. Statistical analysis results of the thickness.

| Temp and RH | Avg (mm) | SD (mm) | CV (%) | RSD of Min (%) | RSD of Max (%) |
|-------------|----------|---------|--------|----------------|----------------|
| 18°C,30%    | 0.153    | 0.006   | 3.9    | -4.6           | 7.2            |
| 18°C,50%    | 0.156    | 0.008   | 5.1    | -7.1           | 7.7            |
| 18°C,70%    | 0.159    | 0.009   | 5.7    | -11.9          | 6.3            |
| 21°C,30%    | 0.161    | 0.006   | 3.7    | -4.3           | 8.1            |
| 21°C,50%    | 0.141    | 0.006   | 4.3    | -6.4           | 7.8            |
| 21°C,70%    | 0.136    | 0.006   | 4.4    | -4.4           | 9.6            |
| 25°C,30%    | 0.143    | 0.010   | 7.0    | -11.2          | 10.5           |
| 25°C,50%    | 0.136    | 0.004   | 2.9    | -4.4           | 6.6            |
| 25°C,70%    | 0.141    | 0.008   | 5.7    | -7.8           | 9.9            |
| Avg under different Temp and RH | 0.147    | 0.010   | 6.8    | -7.5           | 9.5            |

Figure 1. Variation coefficient of thickness

It can be seen from Table 2 that the coefficient of variation of the average thickness under different temperature and humidity is 6.8%, and the relative deviation of the minimum value and maximum value are -7.5% and 9.5% respectively, which are relatively small, but the data still has certain dispersion and distribution width. The relationship between thickness and temperature under different humidity is shown in Figure 2. The thickness decreases with the increase of temperature, and the change trend with humidity is not obvious. This is because the geomembrane will stretch and deform as the temperature increases to release the temperature stress, and thus the thickness is reduced. Therefore, for the geomembrane with a smaller thickness, the influence of state adjustment and temperature changes during the test on the stability of the thickness results should not be ignored.

Figure 2. Thickness of geomembrane.
4. Conclusions
Through statistical analysis of the data under different temperature and humidity conditions, the following conclusions can be obtained:

(1) The influence of temperature and relative humidity on the test results stability is the change of numerical value and distribution characteristics.

(2) The mass per unit area test of geomembrane has good stability. The change of temperature and relative humidity in the range of 18°C~25°C and 30%~70% has no obvious influence on the data dispersion and the numerical value of the test results.

(3) The thickness test results of geomembrane have good stability, but it will be affected by the unevenness of the material, and the thickness will decrease with the increase of temperature.

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