Geotextiles and Geomembranes xxx (2017) 1–6

Contents lists available at ScienceDirect

Geotextiles and Geomembranes

journal homepage: www.elsevier.com/locate/geotexmem

Technical note

Study of factors that influence geomembrane air expansion deformation under ring-restrained conditions

Fang Xu, Wang-lin Li*, Zhan-lei Liu, Bo-fan Zhang, Bing-yu Zhang

College of Resource and Environment, University of Jinan, Jinan, 250002, China

A R T I C L E I N F O

Article history:
Received 4 May 2016
Received in revised form
13 January 2017
Accepted 14 January 2017
Available online xxx

Keywords:
Geosynthetics
Air expansion
Influence factor
Test apparatus diameter
Loading rate
Defect

A B S T R A C T

In studies on the geomembrane air expansion in plain reservoirs, the forced deformation of a geomembrane is generally simplified as geomembrane air expansion deformation under ring-restrained conditions. In this study, a test apparatus was developed to measure geomembrane air expansion deformation, and a number of factors that can affect geomembrane air expansion deformation were investigated, including the test apparatus diameter, loading rate, and geomembrane defects. The results of this study show that under ring-restrained conditions, as the test apparatus diameter increases, the burst pressure decreases, and the burst crown height increases. Moreover, the burst pressure and the burst crown height gradually increase as the loading rate increases. Geomembrane defects, such as holes, folds, and scratches, decrease both the burst pressure and the burst crown height.

1. Introduction

Geomembranes are quasi-impermeable materials that are widely used in landfill and mining applications (Brachman and Sabir, 2013; Chen et al., 2015; Emmanuel and Akinseye, 2015; Gallagher et al., 2016; Rowe, 2011; Rowe et al., 2012, 2016; Rowe, 2013; Rowe and Abdelaal, 2016; Rowe and Ewais, 2015; Sun et al., 2015; Sunil, 2015; Take et al., 2015). Recently they have been used in China as horizontal seepage control systems at the bottom of plain reservoirs. To regulate water resources in the North China Plain, thousands of regulating reservoirs have been constructed in lowland or abandoned river areas by digging or building dams on the ground; these reservoirs are known as plain reservoirs. In China, a seepage control method in which a plain reservoir is completely lined with geomembranes was proposed to improve the seepage resistance of plain reservoirs, such as the Datun Reservoir and the Shengli Reservoir. However, geomembrane air expansion has been observed in certain plain reservoirs that are completely lined with a geomembrane, such as the Xincheng Reservoir (Shandong Province). A few studies have demonstrated that ground construction, a rapid decrease in the reservoir water level, an increase in the underground water table and geomembrane defects cause air to accumulate in the pores of unsaturated soil under the geomembrane, resulting in air expansion (Cao et al., 2015; Guo et al., 2016; Li et al., 2013). These factors have different effects on the geomembrane air expansion deformation. Air expansion and the resulting geomembrane failure increase the risk of reservoir leakage, which can cause problems such as inundating farmland. Therefore, the study of geomembrane air expansion deformation is significant.

In recent years, domestic and foreign scholars have experimentally studied the mechanical properties of geomembranes in uniaxial and biaxial tension (Bray and Merry, 1999; Chen et al., 2008; Galliot and Luchsinger, 2011; Itoh et al., 1986; Merry and Bray, 1996). One study on the axisymmetric tensions of geomembranes focused on deriving the stress-strain formula (Merry et al., 1993). However, few studies have explored the burst pressure and burst crown height of geomembrane air expansion deformation, and even fewer studies have examined the factors that influence the burst pressure and burst crown height during geomembrane air expansion deformation under ring-restrained conditions.

Because geomembranes are viscoelastic materials, temperature greatly influences their mechanical properties; thus, their physical and mechanical properties change with temperature. Temperature changes cause expansion and contraction of the geomembrane and

---

* Corresponding author.
E-mail addresses: xufang13121@163.com (F. Xu), cswlwe@sina.com (W.-l. Li).

http://dx.doi.org/10.1016/j.geotexmem.2017.01.009
0266-1144/© 2017 Elsevier Ltd. All rights reserved.

Please cite this article in press as: Xu, F., et al., Study of factors that influence geomembrane air expansion deformation under ring-restrained conditions, Geotextiles and Geomembranes (2017), http://dx.doi.org/10.1016/j.geotexmem.2017.01.009

simultaneous changes in the thickness. Studies have indicated that the geomembrane yield stress has a negative linear correlation with temperature (Aya and Nakayarna, 1997; Merah et al., 2006). A decrease in temperature causes contraction of the geomembrane, increasing its elastic modulus and tensile strength, as shown by Imaizumi et al. (1999).

Due to the size effect, the test apparatus diameter (specimen scale) directly affects the mechanical parameters of the geomembrane, such as the tensile strength. Merry and Bray (1995) conducted a multi-axial test to investigate the specimen scale (102 mm, 203 mm, 356 mm, 508 mm) effect on high-density polyethylene (HDPE) and polyvinylchloride (PVC) geomembranes and suggested that the test apparatus diameter should be 60 times larger than the geomembrane thickness; however, they did not study the burst pressure or burst crown height. Shu and Ye (2013) conducted a Mullen test using a 0.35-mm-thick HDPE geomembrane with five different diameters (10 mm, 20 mm, 30 mm, 40 mm, and 50 mm). The test results showed that as the test apparatus diameter increased, the burst pressure sharply decreased at first and then gradually decreased.

For reservoirs that are completely lined with geomembranes, ground construction, a rapid decrease in the reservoir water level, an increase in the underground water table and geomembrane defects can cause air to accumulate in the pores of unsaturated soil under the geomembrane, resulting in air expansion. Furthermore, the speed of ground construction and the difference between the rate of reservoir water level decline and the speed at which the ground water table rises affect the accumulation rate of pore air in unsaturated soil, which affects geomembrane deformation. Therefore, the loading rate may affect geomembrane air expansion deformation under ring-restrained conditions.

Geomembrane defects are almost unavoidable during transport and construction processes. These defects change the failure mechanisms of geomembranes, and studies have demonstrated that defects such as holes, scratches and wrinkles affect the mechanical properties (Giroud and Morel, 1992; Gudina and Brachman, 2011; Shu and Pan, 2005; Xu et al., 2004).

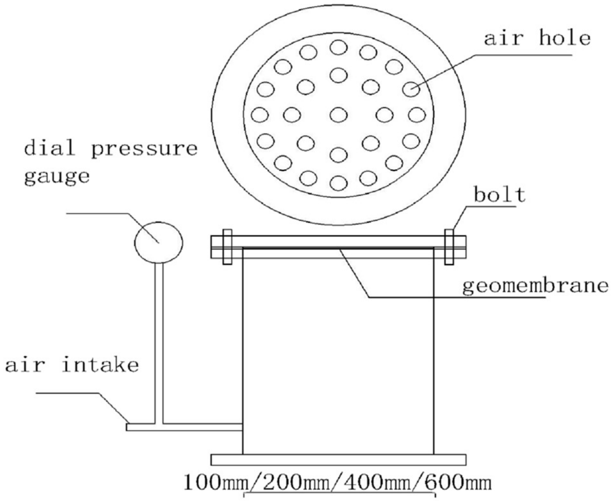
Thus, the test apparatus diameter, temperature, loading rate and geomembrane defects affect the geomembrane air expansion deformation under ring-restrained conditions. This study experimentally analyzed and verified the effects of the test apparatus diameter, loading rate and geomembrane defects on the geomembrane air expansion deformation using a test apparatus that was developed to study geomembrane air expansion. In addition, the burst pressure and burst crown height were analyzed to provide guidelines for the engineering design of these materials.

2. Test design

2.1. Test apparatus

To study the characteristics of geomembrane air expansion in plain reservoirs, a test apparatus with four different diameters (inner diameters of 80, 180, 380 and 580 mm; external diameters of 100, 200, 400, and 600 mm, respectively) was developed. This test apparatus was constructed of organic glass and was conceptually similar to the test apparatus used in the Multi-Axial Tension Test for Geosynthetics (ASTM D5617, 2015). Fig. 1(a) shows the test apparatus with a 180-mm diameter, and Fig. 1(b) shows the schematic of the test apparatus. The test apparatus comprised three parts: an air expansion device, a pressure system, and a measurement system. The air expansion device consisted of a pressure vessel and a restraint flange; the pressure vessel is a cylindrical container with air holes in the top. The pressure system consisted of an air pump with an air regulator that can adjust loading rate. The measurement system consisted of a measuring device for the crown height and a dial pressure gauge(±1.6 kPa) that was used to measure the pressure inside the pressure vessel during the test. The measuring device directly measured the crown height using a laser displacement sensor (FT80 RLA-500-S1 L8,±1.25 mm) that was fixed to the device using a bracket.

(a) Test apparatus with a 180-mm diameter



(b) Schematic of the test apparatus

Fig. 1. Test apparatus.

Prior to the test, the geomembrane specimen was fixed using a flange. To prevent gas leakage, the pressure vessel had a groove that contained a rubber sealing ring. During the test, geomembrane air expansion deformation under ring-restrained conditions was introduced by an air pump.

Please cite this article in press as: Xu, F., et al., Study of factors that influence geomembrane air expansion deformation under ring-restrained conditions, Geotextiles and Geomembranes (2017), http://dx.doi.org/10.1016/j.geotexmem.2017.01.009