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Experimental Study on Shear Strength of Geomembrane Welding Seams under Different Inflation Time and Pressure

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Abstract. The shear strength of geomembrane welding seams (GWSs) is one of the key factors for the reliability of geotechnical anti-seepage system. In order to study the evolution law of shear strength of GWSs under different inflation time and pressure, the weld shear strength tests of seven different thicknesses of HDPE geomembrane were carried out under different inflation time and pressure conditions. The test results show that the weld shear strength increases with the increasing geomembrane thickness under the same inflation time (3min or 10min) or the same test inflation pressure (0.1MPa or 0.2MPa). Additionally, the trend of all test curves is similar. The hot-welding method shows good stability in weld shear strength of different thicknesses of HDPE geomembrane. The shear strength values of GWSs of the same thickness under different inflation pressures and inflation times are similar. During the shearing process of the welds, the weakened area of the material at the joint between the edge of the weld and the geomembrane base material is most likely to be destroyed. The corresponding test results can provide reference for GWS inspection and related engineering.

1. Introduction

Due to the light weight and quick construction characteristics, geomembrane is widely used in various anti-seepage engineering. The implementation of a large number of existing projects also verified the superior anti-seepage performance of geomembrane. For geomembrane joints, some researchers did a lot of meaningful works. On the other hand, for the construction technology of geomembrane, Shu et al. [1] carried out laboratory and in-site experimental research on the splicing process of geomembrane such as welding and gluing. Then the welding, bonding, splicing in the groove, peripheral anchoring, top connection as well as laying process of PE and PVC geomembranes which are commonly used are systematically researched and summarized combined with the actual engineering. For the mechanical properties of the geomembrane in the construction process, Shu studied the geomembrane welding seam (GWS) under different ambient temperatures and welding temperatures combined with the anti-seepage membrane used in the actual engineering. Through the tensile and peeling tests, the relationship between ambient temperature and optimum welding temperature was obtained. Thus, the importance of keeping the welding parts clean and dry in a complex construction environment to ensure the quality of welding was verified through welding test for the welding specimens that with adhesion of moisture, dust and fibres[2].

L Zhang [3] valuated the effect of weld on the durability and tensile strength of geomembrane based on studing the mechanical properties of the geomembrane before and after welding. N Touze-Foltz [4] studied the change law of the physical and mechanical properties of the HDPE geomembrane under different environmental conditions in the 30 years aging time. Rowe et al[5] studied the effect of thickness on the service life by testing the HDPE geomembrane under five temperature conditions (55 ° C, 65 ° C, 70 ° C, 75 ° C, 85 ° C). The results show that the service life of the geomembrane material can be extended by increasing the thickness of the geomembrane when the other conditions are identical.

At present, geomembrane weld inspection is divided into two categories: damage detection and non-destructive inspection. For non-destructive testing, the SL/T231-1998 polyethylene (PE) geomembrane anti-seepage engineering technical specification and the SL18-2004 channel anti-seepage engineering technical specification are used in the actual engineering by the inflation method. Therefore, three problems also exist. First, great arbitrariness will happen during the application of inflation pressure and the inflation time. Secondly, the same inflation pressure is not suitable for the geomembrane with different thickness. For the geomembrane with smaller thickness, the inflation phenomenon has been generated under the inflation pressure of 0.2 MPa. At this time, the so-called non-destructive testing will turn into lossy detection. At last, the basis for the quality judgment of the weld is not quantified, and the judgment of the result is often artificial.

In order to improve the quality of GWS, the shear strength tests of HDPE geomembrane with 7 different thicknesses under different inflation time and inflation pressure were carried out, and the shear strength of GWS under different inflation time and inflation pressure was obtained. The law of evolution, the corresponding results and laws can provide reference for geomembrane weld inspection and related engineering.

2. Test schemes

HDPE geomembrane with 7 different thicknesses were selected in the shear tests. The thicknesses of the geomembrane used in the test were 0.25 mm, 0.35 mm, 0.5 mm, 0.75 mm, 1.00 mm, 1.50 mm, 2.00 mm, respectively. Four inflation schemes are 0.1 MPa inflation pressure and 3 min inflation time, 0.1 MPa inflation pressure and 10 min inflation time, 0.2 MPa inflation pressure and 3 min inflation time, 0.2 MPa inflation pressure and 10 min inflation time, respectively. The shear test of the HDPE geomembrane weld after the aeration test was carried out, and the test results were compared with the weld shear strength under the non-inflated state. The influence of the inflation time and the inflation pressure on the weld shear strength was analysed.

3. Test principle and method

The procedures of GWS shear test are similar to the tensile test. The dumbbell method is used in the test. In order to facilitate the comparison with the weld strength, the strip is also stretched on the geomembrane material, and the width is 50mm. The ends of the membrane was fixed with two clamps, the clamping length was 100 mm, and the tensile process was performed at a rate of 50 mm/min until the sample was broken, thus the stress-strain curve was drawn. The test was operated by a microcomputer-controlled electronic universal testing machine and was carried out in accordance with the relevant provisions of the Geosynthetics Testing Procedures (SL235-2012).

4. Test results and analysis

The results of shear strength test of all test schemes are shown in Table 1. The relationships between the shear strength of welds and the thickness of geomembrane are shown in Figure 1.

Table 1. Test results of shear strength of each test scheme

Thickness /mm	Shear strength of the welds N/50mm					
	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Average value
0.25	175	175	169	158	165	168
0.35	275	262	268	280	271	271
0.50	487	489	478	486	476	483
0.75	707	698	681	696	667	690

1.00	910	883	905	895	889	896
1.50	1575	1594	1586	1574	1591	1584
2.00	2387	2397	2367	2253	2337	2348.2

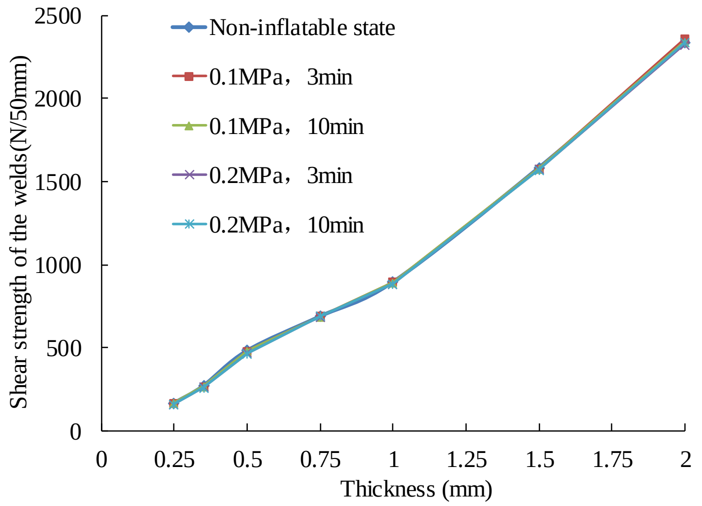

Figure 1. Relationship curves of shear strength of GWS via thickness of Geomembrane.

4.1. Effect of inflation pressure on shear strength of welds

In this study, the test conditions can be divided into two types, 3min weld inflation with 0.1MPa and 0.2MPa pressure, 10min weld inflation with 0.1MPa and 0.2MPa pressure. Firstly, the results of the test under the conditions of 3 min weld inflation were analyzed. The non-inflated test results, 0.1 MPa inflation pressure and 3 min inflation time, 0.2 MPa inflation pressure and 3 min inflation time were compared and analyzed.

From Table 1 and Figure 1, it can be seen that the shear strength of the GWSs of the three samples increases with the increase of the geomembrane thickness under the test condition of 3 min inflated. The reason is that the thickness of base metal of geomembrane weld plays a decisive role in the shear strength of the weld. In addition, the trend of the curves are consistent. The test curve obtained under the condition 10 min weld inflation is close to the test curve obtained by 3 min weld inflation. Therefore, it can be considered that the inflation pressure has little effect on the shear strength of the GWS and thus can be ignored.

4.2. Effect of inflation time on shear strength of welds

In this study, the test conditions can be divided into two types, 0.1MPa inflation pressure with 3 min inflation time and 10 min inflation time, 0.2MPa inflation pressure with 3 min inflation time and 10 min inflation time. Firstly, the results of the test under the conditions of 0.1MPa inflation pressure were analyzed. The non-inflated test results, 0.1 MPa inflation pressure and 3 min inflation time, 0.1MPa inflation pressure and 10 min inflation time were compared and analyzed. From Table 1 and Figure 1, it can be seen that the test curves are very close under different inflation time, so it can be considered that the effect of inflation time on shear strength of geomembrane weld is also small.

In general, in all test schemes, the shear strength of GWSs increases with the increasing geomembrane thickness under different inflation pressure and inflation time, and the relation curves change almost uniformly. The shear strength value and its change are similar. The influence of inflation pressure on the shear strength of geomembrane weld is very small for geomembrane welds of all test schemes under the same thickness. From the test process, it is found that the damage of the membrane is mainly caused at the joint between the weld edge and the geomembrane base metal. The reason is mainly because the thermal structure of the geomembrane changes the internal molecular structure of the material at the hot-weld part, and the macroscopic representation is that the material becomes soft and slightly thinned during the formation of the welds (Figure 1). Thus, there exists a weak area at the joint between the edge of the weld and the geomembrane base material. The inflation pressure and the inflation time have little effect on the weak area. The weld zone formed by heat welding is thermally bonded together by the geomembrane base metal, and the strength of this area is large. The strength of the geomembrane base material away from the weld zone during the heat welding process will hardly changes. Therefore, during the shearing process of the GWS, the weak material of the joint between the edge of the weld and the geomembrane base material will yield firstly and then breaks. In the actual engineering, attention should be paid toward the weak zone around the GWS.

5. Conclusions
Under the same inflation time (3min or 10min) or the same inflation pressure (0.1MPa or 0.2MPa), the shear strength of GWS increases with the increasing thickness of the geomembrane, and the trends of the curves are merely consistent. The hot welding method presents good stability in the shear strength of HDPE geomembrane with different thicknesses. The shear strength of GWSs with the same thickness under different inflation pressures and inflation times is similar. During the shearing process of the GWS, the weak zone of the joint between the edge of the weld and the geomembrane base material can be destructed easily.

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