A large-scale ramp model test on GT/GM/GCL liner systems

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ABSTRACT: Composite liner systems comprising geosynthetics are widely used in landfills. In this paper, a large-scale ramp model test was carried out to simulate the sliding along an interface of GT/GM/GCL liner. The simulation test was performed by using a purposely-design set-up in the Zhejiang University large model box for foundation and slope engineering. The composite liner laid on a sloping foundation was loaded to a vertical stress level of 75 kPa, and a sliding along the GT/GM interface was successfully simulated by exerting a force on the transmission board. The softening behavior of the GT/GM interface during the sliding process was revealed. The results showed that although the large-displacement shear strength of GM/GCL interface was less than that of GT/GM interface, slippage would not happen along GM/GCL interface The results also showed that when the external shear stress exceeds the peak shear strength of the GT/GM interface, the GT/GM interface quickly fell into a residual shearing condition.

1 INTRODUCTION

Composite liner systems comprising geosynthetics are widely used in landfills. They offer the particular advantage of being easy to install compared with traditional solutions and provide an interesting alternative from the economic point of view. These systems are composed of a geosynthetic complex comprising one or several layers of geosynthetics with layers of granular soil above and below it.

Geosynthetics placed on side slopes of a landfill can experience tension due to various factors (Thusyanthana, 2007). For example, during construction of the liner systems, wind up-lift on uncovered areas, movement of heavy vehicles such as bulldozers and frictional forces from the cover soil can all cause tension in the geomembrane. After the closure of a landfill, the down-drag caused by settling waste (Jones and Dixon, 2005) also induces tension in the geosynthetics.

Ramp tests have been performed by several researchers on different combinations of apparatus characteristics, soils and materials to study the tension in geosynthetics (Giroud et al., 1990; Palmeira et al., 2002, 2003).Generally, in these works the area of the interface tested varied between 0.005 and 1 m2 and the typical stress level applied to the interface only between 1 and 5 kPa. In spite of the rather large number of works with the ramp test, the authors are not aware of such tests being performed for the investigation of the effects of strain-softening to increase the tension transferred to geosynthetics. In this paper, a large-scale ramp model apparatus on the composite liner system was developed with a higher stress level. The stability test on the GT/GM/GCL liner system was studied.

2 THE LARGE-SCALE RAMP MODEL APPARUTS FOR LINER SYSTEMS

The apparatus shown in Figure 1 is mainly composted of a sloping ground, reinforced concrete base board and transmission board, framework, the relative displacement measurement system, the tension measurement system; the sliding control systems, and sand bags. The various components of the design and use are introduced as following:

2.1 *Reinforced Concrete Base Board and Transmission Board*

Base board and transmission board are both made of reinforced concrete. The base board is 4.95 m long×1.7 m wide×0.2 m thick (weigh 40kN), and would placed on the sloping ground filling with gravel. It is used to support the entire test system. The transmission board is 4.5 m long×1.35 m wide (the lower surface is 1 m wide)×0.2 m thick (weigh 28.8 kN). Since the framework would takes a considerable amount of space, the cross-section of the transmission board is design as a T-shape, and the upper surface is 1.35 m width or the lower surface is 1 m width. Ten steel plates with a size of 0.1m×0.1m×0.01m would be embedded in the edge of the upper surface, used for welding the vertical steel pipe of the framework and the board together. The lower surface of the transmission board must be roughened in order to increase the interface shear strength of transmission board/GT. The rough surface is used to prevent sliding along the transmission board/GT interface.

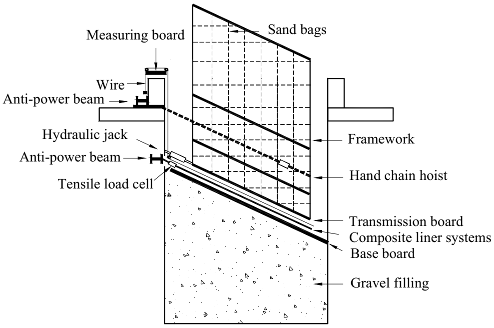

Fig. 1 The large-scale ramp test apparatus

2.2 *Framework*

Framework is made of scaffolding structures and used for filling sand bags, shown in Figure 1. To meet the mechanical requirements, the framework are designed as follows: (1) vertical steel tube and embedded steel plate were welded together; (2) vertical steel tube and the horizontal steel tube steel are arranged 0.5 m intervals, the cross would be connected by vertical jig; In order to safeguard the stability of the whole framework structure, six inclined strut are set up;

2.3 *The Relative Displacement Measurement System*

The relative displacement measurement system is composed of 1 mm diameter wires, measuring board as well as pulley wheels, as shown in Figure 2. Pairs of fishhooks were glued to each of the geosynthetics, and a stainless wire was attached to the fishhooks to measure the relative displacement (Dniel et al. 1998; Frownes et al. 2007). Each wires extended from the fishhooks run, via two pulley wheels, over displacement measuring boards (Fig. 2) with each tensioned using a 300 g static weight. The fishhooks were attached to each of the geosynthetics at five locations along the slope.

2.4 *Tension Measurement System*

Tension measurement system is composed of clamps, load cells, and the anti-power beam. The tension acting on the geosynthetics at the anchorage were measured by tensile load cells between clamp and the anti-power beam.

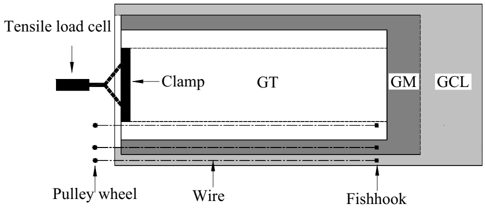

Fig. 2 Tension and displacement measure systems

2.5 *Hydraulic jack loading system*

Hydraulic jack loading system is mainly composed of a hydraulic jack (50kN) and a load cell (50kN), which would be placed between the top center of the transmission board and the sidewall of the model. The system was used for pushing the transmission board, simulating the external force is larger than the interface shear strength of the liner system.

2.6 *Sliding Control Systems*

Sliding control systems is composed of two hand chain hoists, a tensile load cell (50 kN limit), a steel cable (20 mm diameter), a steel plate and an anti-power beam, which was used for controlling slippage of the entire system along an interface. The hand chain hoists are the core of this system, which was connected by the steel cable. The two hand chain hoists were released in step to control the framework movement. The tensile load cell was positioned between the steel cable and the hand chain hoist to measure the tension in the hand chain hoists. If the vertical steel tubes were directly surrounded by the connecting steel cable, the vertical steel tubes were easily damaged due to stress concentration. Therefore, a steel plate (120 cm long × 50 cm wide × 1 cm thick) was employed. Channel steel is used for keeping the steel cable in a fixed location. Three steel tubes were welded on the steel plate back, making it possible to fix the steel plate to the framework.

2.7 *Vertical loading*

For convenience, sand bags were adopted for vertical loading. In order to achieve a maximum normal stress 75kPa desired on the interface, approximately 700 sand bags (total weight of 350 kN) were needed.

3 PROCEDURE FOR GT/GM/GCL LINER SYSTEMS TEST

GT/GM/GCL liner systems test was adopted a liner system composed of GT, GM and GCL geosynthetics, as shown in Figure 3.

GT specimen (4.2 m×1.3 m) was cut in the machine direction during production. The additional 0.2 m long portion of GT specimen was used for clamping the specimens and the additional 0.3 m wide portion of GT specimen was used for the relative displacement measurement. GM specimen (4.8 m×1.6 m) was cut oriented in the machine direction. To maintain a constant contact area during sliding, the GM specimen is 4.8 m long (i.e., 0.4 m longer than the GT specimen). Also the additional 0.6 m wide portion of GM specimen was used for the relative displacement measurement. GCL specimen also (4.95 m×1.9 m) was cut oriented in the machine direction. GCL specimen was prehydrated under 15kPa for 4 days and the water content of GCL was 150% after hydration completion.

In order to avoid any slippage along an interface in the composite liner system during vertical loading process, slope angle of 25° was adopted. A normal stress of 75kPa was selected. After vertical loading accomplishment, a thrust was exerted on the transmission board by the hydraulic jack until a slippage could happen actively.

The specific procedures were described by Lin (2009) and are not presented here.

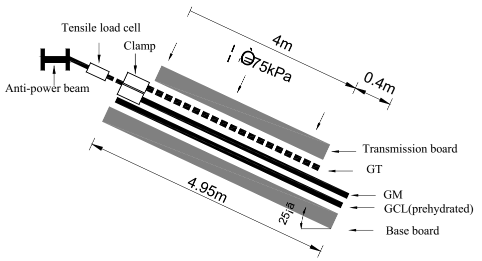

Fig. 3 GT/GM/GCL liner system test

4 RESULTS FOR GT/GM SINGLE-INTERFACE TEST

4.1 *Results during the Loading Process*

Figure 4 shows that the tension at the GT and GM anchorage and in the hand chain hoist varied with the total weight during loading process.Both of the tension had a very slow increasing trend. Finally, the tension of GT and GM and the hoist were 1.25kN/m and 0.79 kN/m, respectively.

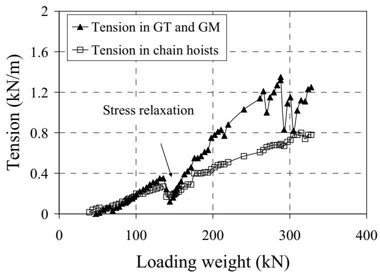

Fig. 4 The tension varied with the total weight during loading process

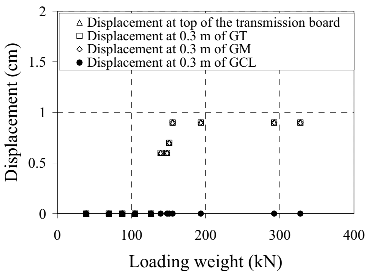

Fig. 5 The displacement varied with the total weight during loading process

Figure 5 shows that the displacement near the anchorage of GT, GM and GCL, as well as that at the top of the transmission board varied with the total weight. The variation could be divided into two stages. At the initial stage, the displacement remained almost unchanged, and when loaded to 148 kN, the displacement near the anchorage of GT and GM arrived at 0.5 cm. Finally, the displacements at 0.3 m of GT and GM were both 0.9 cm.

4.2 *Results during the Sliding Process*

Figure 6 shows that the tension at the GT anchorage and in the hand chain hoist, as well as the sum of them, and the force in the hydraulic jack varied with the controlled displacement during sliding process. The thrust exerted by the hydraulic jack achieve the max at the beginning, and gradually decrease until an active slip happened.

There is an initial increase in tension of GT as soon as displacement starts, with a rapid increase in GT tension with increasing displacement, followed by a sudden decrease. At last the GT was broken. There was no any tension produced in the hand chain hoist during the passive slip process, then it increase with the active slip process. When the displacement arrived at 30 cm, the tension increase suddenly, after that the tension gradually increased and at last reached the maximum value of 38.9 kN/m. The sum of the two tension stresses gradually increased with the displacement. When the displacement arrived at 42 cm, the sum reached the maximum value of 44.5kN/m.

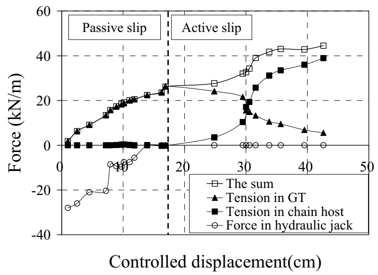

Fig. 6 Force varied with the displacement during sliding process

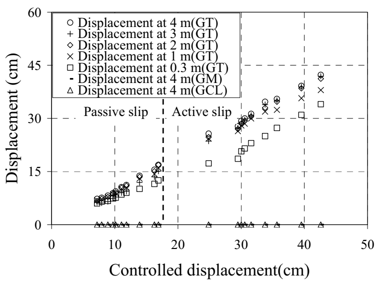

Fig. 7 The displacement varied with controlled displacement during sliding process

Figure 7 shows that the displacement of the five different positions at GT varied with the controlled displacement during sliding process, as well as the displacement at 4 m of GM and GCL. The displacement at 0.3 m of GT increases slower than the controlled displacement ,and the displacement at 1 m, 2 m, 3m and 4m almost kept the same as the controlled displacement. However, the displacement at 4 m of GM and GCL did not change during sliding process.

5 DISCUSSION

From the results during the loading process, the peak shear strength of GT/GM interface and GM/GCL interface were greater than the external shear stress, the shear strength of GT/GM interface and GM/GCL interface were still in elastic stage. When the thrust exerted on the transmission board, the peak shear strength of GT/GM interface is less than the external shear stress, the shear strength of GT/GM interface could not balance the external shear stress, and the transmission board would slip along the GT/GM interface passively. Since the shear strength of GT/GM interface gradually becomes smaller with strain-softening, when the shear strength was less than the external shear stress by gravitational processes on slope, the transmission board would slip along the GT/GM interface actively. When the controlled displacement was greater than 35 cm, the GT/GM interface would present a large-displacement strength.

6 CONCLUSIONS

This paper presents the large-scale ramp model test set-up purposely-designed for the simulation of sliding along a composite liner system. A sliding along the GT/GM interface was successfully simulated by the use of the set-up. The softening behavior of the GT/GM interface during the sliding process was revealed. The experimental results of GT/GM/GCL liner system show that although the large-displacement shear strength of GM/GCL interface was less than that of GT/GM interface, slippage would not happen along GM/GCL interface The results also showed that when the external shear stress exceeds the peak shear strength of the GT/GM interface, the GT/GM interface quickly fell into a residual shearing condition.

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