Amirkabir Journal of Civil Engineering

Amirkabir J. Civil Eng., 51(6) (2020)359-362
DOI: 10.22060/ceej.2018.14276.5611

Design and construction of inclined plane device for modeling the interface interaction of geo-synthetic layers

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ABSTRACT: One of the important applications of geo-synthetics in the earth's slopes, such as landfills and waste disposal areas, is to use them as liner system. Proper assessment of the interaction of geo-synthetics at slopes, such as landfill, is an important issue in preventing the slip and instability of the slopes. The inclined plane is a suitable method for assessing the interaction between the geo-synthetics interacting in a sloping and tilted state under low normal stresses. The European Standard EN ISO 12957-2 provides a "standard displacement" for estimating the geo-synthetic interface's friction angle. In this paper, inclined plane device, which for the first time in Iran was completely designed and constructed, describes the technical characteristics of the device and prepares the sample. This apparatus has the ability to perform experiments to investigate the interaction of soil-soil, soil/geo-synthetics and geo-synthetic/geo-synthetic interfaces at low normal stress. Experiments are carried out on geo-membrane and geotextile types to investigate the interaction of their surface. By changing the type of geo-synthetics, it was observed that friction angle of geo-synthetic interfaces is not constant and depends on the type of geo-membrane and the woven or non-woven geo-textile. The geo-membrane/geo-textile interface is the least amount of geo-membrane with hard polyethylene, and the highest amount is used when polyvinyl chloride is used.

Review History:
Received: 4/6/2018
Revised: 6/2/2018
Accepted: 8/5/2018
Available Online: 8/20/2018

Keywords:
Geo-synthetic
Laboratory study
Inclined plane device
Interface interaction
Geo-membrane/geo-textile

1. INTRODUCTION

Recent years have seen a large growth in engineering solutions involving the implementation of geo-synthetic (GSY) materials. One of the key issues concerning the mechanical characterization of geo-synthetics is the friction at soil/geo-synthetic and geo-synthetic/geo-synthetic interfaces. An estimation of this property is very important in optimizing construction solutions such as slope-liner systems, which are very commonly used in landfills and basins, for instance. Many failures of slope-liner systems have been observed [1], often due to a poor characterization of interfacial friction [2] or incorrect choices in the construction sequence [3]. Liner systems used on slopes combine different components such as geo-synthetics and soil (Figure 1).

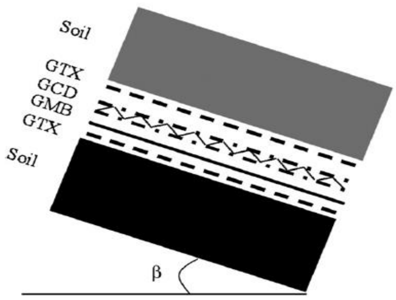

Fig. 1. Typical liner system on slope [4].

2. LITERATURE REVIEW

Direct shear box and inclined plane experiments have been applied in the definition of two standard tests (EN ISO 12957-1, 2005; EN ISO 12957-2, 2005) recommended for characterization of interfacial friction behavior [5,6].

Various researchers such as Wasti, Y. and Ozduzgun, Z.B. (2001), and Koutsourais et al. (1991) tested the direct shear box [7, 8], Palmeira, E.M. (2009 and 2002) and carbon L. (2015 and 2012) an examined the effect of interaction interface geo-synthetics by incline plane test [9-11]. By investigation the results of both experiments, it was found that the inclined plane is a more appropriate device for the characterization of geo-synthetic friction under normal stresses lower than 5 kPa, whereas the direct shear box performs well under higher normal stresses

2.1. "Standard Displacement Procedure"

The standard EN ISO 12957-2 describes a method for determining the friction angle d of geo-synthetic interfaces in contact with soils at low normal stress using an inclined plane (called also a tilting-plane) apparatus with specific variations for geo-synthetic/geo-synthetic interfaces. In any friction method, the normal force to the interface, w.cosβ, must be evenly applied to obtain a regular distribution of the normal

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Fig. 2. Inclined-plane apparatus

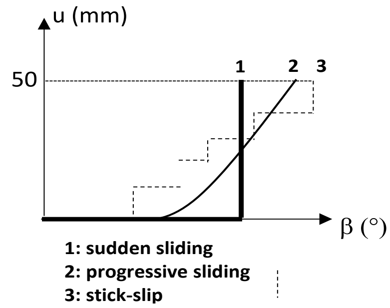

Fig. 3. Different mechanisms of sliding upper box [4].

Table 1. Physical properties of the tested geo-synthetics.

Kind of GSY	Name of GSY	Mass per unit (g/m^2)	Thick. (m)	color
$GMB_{(HDPE)}$	GMB1	400	0.01	black
$GMB_{(PP)}$	GMB2	300	0.01	black
$GMB_{(PVC)}$	GMB3	260	0.01	gray
$GTX_{(w)}$	GTX1	50	0.001	black
$GTX_{(nw)}$	GTX2	100	0.0025	white

stress over the entire surface of the specimen. EN ISO 12957-2 specified that the applied normal force must be such that the initial normal stress (for β=0) is equal to 5.0 ± 0.1 kPa. The value of the standard interface friction angle, ($\delta_{stan)}$, is obtained by Equation 1 as following:

$$\tan \delta_{stan} = \frac{W_s \cdot \sin \beta_{50} + Fr(\beta_{50})}{W_s \cdot \cos \beta_{50}} \quad (1)$$

Thus allowing Equation 1 to determine the value of the standard friction angle, δ_{stan}, by taking into account the weight of the soil contained in the upper box (w_s), the plane-inclination angle (β_{50}) and the force required to restrain the empty upper box Fr (β_{50}) for a displacement u of the upper box equal to 50 mm. The plane must be equipped with a mechanism for tilting the plane slowly and at a constant rate, i.e., dβ/dt = 3.0 ± 0.5°/min. The apparatus is composed of a lower box onto which is fitted an upper box (Figure 2). The upper box can move along a system of wheels on rails located on either side of the lower box. The upper box was generally filled with a soil as a load. The frictional interface by dimension upper box=1.20×0.60 m and lower box=2.00×0.80 m made it possible to conduct tests on geo-synthetic samples of large dimensions.

2.2. Analysis of sliding

Researchers showed that according to the type of geo-synthetics, the sliding could occur in three different way (Figure 3).

1. Sudden sliding: abrupt displacement of the upper box.
2. Progressive sliding: gradual sliding: displacement u increases with inclination β.
3. Stick-slip: increasing or displaying a stick-slip mode [8].

3. METHODOLOGY

In this study, three kinds of geo-membrane made high-density[1], polyethylene[2] and polyvinyl chloride[3] and two kinds of woven geo-textile[4] and non-woven geo-textile[5] were used (Table 1). The soil used as a vertical overhead is a mixture soil. The test method is to ensure that all parts of the machine are first cleaned and the rails are lubricated to minimize the friction between the rails and the bearings. Then a geo-membrane layer is spread over the lower box and connected to it by the clamp. A geo-textile layer is located on the geo-membrane layer and under the upper box and connected to it by the clamp. The upper box is filled up to 0.25 m from the mixture soil without applying the compression and simply to apply the vertical overhead (2 kPa) according to the standard recommendation. After starting the test and taking off the lower box, the upper box at an angle equal to (β_{50}) will have a displacement of 0.05 m. Finally, with the value of Fr (β_{50}) and angle (β_{50}), which are obtained by incline and calibers respectively, and according to Equation 1, the standard friction angle (δ_{stan}) is calculated.

In this study, different states of geo-membrane/geotextile combination have been tested to evaluate their interaction. It is worth noting that in order to provide repeatability conditions, each test is repeated three times, in total 18 experiments.

4. RESULTS AND DISCUSSION

4.1. Friction angles of $GMB^{(L)} – GTX^{(U)}_{(w)}$

After performing various experiments, it was observed that changing the type of geo-membrane would slip and move the upper box, so that for the hard geo-membrane, a sudden slip and for other geo-membranes, other scrolls would occur (Figure 4).

4.2. Friction angles of $GMB^{(L)} – GTX^{(U)}_{(nw)}$

Figure 5 shows that the upper box for a non-woven geo-textile (GTX 2) with a high-density polyethylene geo-

1 High-density polyethylene geomembrane (GMB_{HDPE})

2 Polypropylene geomembrane (GMB_{PP})

3 Polyvinyl chloride geomembrane (GMB_{PVC})

4 Woven geotextile (GTX_w)

5 Non-woven geotextile (GTX_{nw})

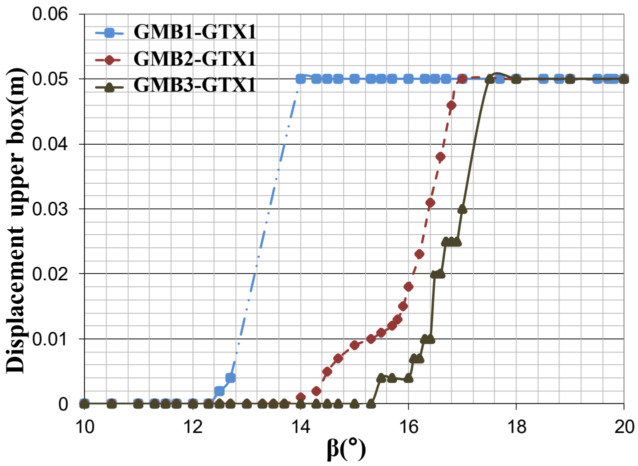

Fig. 4. Different mechanisms of sliding upper box

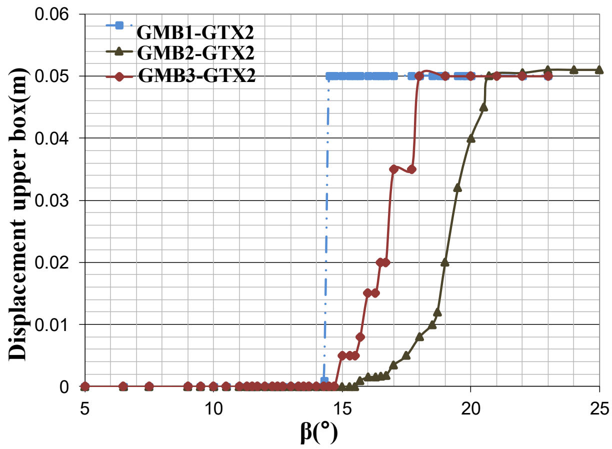

Fig. 5. Different mechanisms of sliding upper box

membrane (GMB1) has a suddenly sliding, for polypropylene geo-membrane (GMB2) with non-woven geo-textile (GTX2) has gradual sliding- progressive, and for polyvinyl chloride geo-membrane (GMB3) with non-woven geotextile (GTX2) has gradual stick-slip type which shows the type of geo-membrane influences how the upper box is sliding.

5. CONCLUSIONS

By studying different diagrams, it was observed that the type of geo-membrane would have a direct effect on the type of slip of the box, so that with the choice of GMB_{HDPE} the upper box has a suddenly slip, GMB_{pp} has a gradual progressive sliding and a gradual stick-slip with a choice of GMB_{PVC}. Also, the choice of geo-membrane type will affect the degree of standard friction angle of the geo-membrane/geo-textile interface obtained from the above method. By comparing the modes of GMB_{pp}, GMB_{PVC} and GMB_{HDPE}, it is observed that the standard friction angle is 35 and 44% when in contact with woven geo-textile and respectively 27 and 36 percent in contact with non-woven geo-textile. On the other hand, the choice of the type of geo-textile will also affect the amount of friction angle, so that, with the passage of non-woven geo-textile, the standard friction angle for states GMB_{HDPE}, GMB_{PP} and GMB_{PVC} increased by 22, 14 and 15%, respectively.

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HOW TO CITE THIS ARTICLE

P. Shaykhi, S.H. Lajevardi, Design and construction of inclined plane device for modeling the interface interaction of geo-synthetic layers, Amirkabir J. Civil Eng., 51(6) (2020) 359-362.

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