Fresh Concrete - Geomembrane Interface Friction Tests with Ramp Equipment

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ABSTRACT

Many lined facilities use concrete as a protection layer for geomembranes. One important issue in geomembrane lined channels is the interface friction, especially when the lining is installed along the slope. This paper presents results of geomembrane-concrete friction tests using ramp-type equipment. With this equipment it is possible to simulate in the laboratory the same conditions prevailing on the construction site. Three types of geomembrane were used: smooth, low-roughness and high-roughness geomembranes. Fresh concrete conventionally used for lining protection was used in the tests. The results show the importance of interface roughness on the friction behaviour.

1. INTRODUCTION

Geomembranes are frequently used to line channels. When possible, geomembranes are left exposed and this can be considered one of the lowest cost solutions in lining channels (e.g. Abramento & Duarte, 2002). In some cases, however, the geomembrane must be protected mechanically in order to avoid being damaged. One typical solution for mechanical protection is to cover the geomembrane with unreinforced (or reinforced) concrete. The concrete is cast over the geomembrane and must be levelled to achieve the desired thickness. The concrete must remain in place during levelling and curing and friction interface is the key issued related to the cover stability. Small scale devices like direct shear equipment cannot be used to address this issue due to the aggregate size of the concrete. Moreover, tests must be carried out using low confining stresses, corresponding to the concrete thickness which is normally used for protecting geomembranes. Therefore a large ramp apparatus was used to determine the friction interface characteristics of concrete-geomembrane. This paper describes the ramp equipment, the geomembranes tested, the concrete proportions and the friction results.

2. MATERIALS AND METHODS

2.1. Ramp Equipment

A large inclined plane test apparatus (Palmeira et al. 2002) was used to perform the tests. A general view of the equipment is shown in Figure 1. Various sizes of boxes can be used to confine the material being tested. In the present study a box with internal dimensions of 0.4m x 0.5m was used. The concrete thickness was fixed as 5cm. The geosynthetics to be tested can be clamped to the plane anchorage system (at the plane extremity). The clamps used to fix the geosynthetic are connected to load cells to measure the tensile load mobilised at the geosynthetic end during the test (Figure 2). The anchorage of the geosynthetic extremity to the plane simulates the conditions found in the field for linings in slopes in the region close to the slope crest. Weights can be used to provide surcharge on the system, increasing the stress level on the interfaces. Displacement transducers measured the relative displacements between the geomembrane with respect to the plane surface. During the test the inclination of the plane with the horizontal was continuously increased up to the slide along the weakest interface. Tests were performed under initial normal stresses (plane at the horizontal position) varying between 2.5kPa and 10kPa. More details are presented by Viana and Palmeira (2008, 2009).

Figure 1. General view of equipment.

Figure 2. Detail of anchoring system.

2.2. Geomembranes

Figure 3 shows the geomembranes tested using ramp equipment. Three types of HDPE geomembranes were tested, all with 1.0mm thickness:

a) Smooth geomembrane;
b) High asperity textured geomembrane, with average asperity height of 0.25mm (GRI GM 13);
c) Low asperity sand-impregnated geomembrane, with average asperity height of 0.14mm (GRI GM 13).

a) Smooth Geomembrane b) High-asperity textured GM c) Low-asperity sand impregnated GM

Figure 3. Geomembranes used in the tests.

2.3. Concrete

Table 1 shows the concrete proportion used in the tests. It corresponds to the normal proportion that is used in lining channels in Brazil.

Table 1. Proportions of Concrete used in the tests.

fck MPa	Trace in Weight for 1m3					Slump cm	Air (%)	Cement Type (Portland) Poty	Unit Weight (kgf/m^3)	Strength fck (MPa) Age		
	Cement	Sand	Stone	Water	Water-cement					3 days	7 days	28 days
15	250	925	1.085	175	0,70	5±1	1,00	CPII Z 32 RS	2.435	13.8	15.1	20.2

Note: fck = concrete characteristic compressive strength.

2.4. Test Procedure

Three confining stresses were used in the tests: 2.5; 5 and 10kPa. This low range of confining stresses corresponds to the typical stress level expected in the field. The following steps were used for each of the tests:

- The geomembrane sample was installed over the ramp equipment surface and was anchored to load measurement system.
- All reading instruments (load cells and LVDTs) were installed.
- The concrete was prepared to reach the desired slump.
- The ramp box was filled with 5cm of concrete.
- The surcharge load was applied over the sample (2.5, 5 or 10kPa).
- The ramp was tilted and readings were obtained until interface failure.

3. RESULTS

Figure 4 shows typical results for the ramp test for the high-relief GM sample. Figure 4a shows the mobilized force at the geomembrane extremity as a function of ramp incline. Figure 4b shows the displacement at the geomembrane extremity as a function of ramp incline. Figure 5 shows the failure envelopes and Table 2 presents a summary of results.

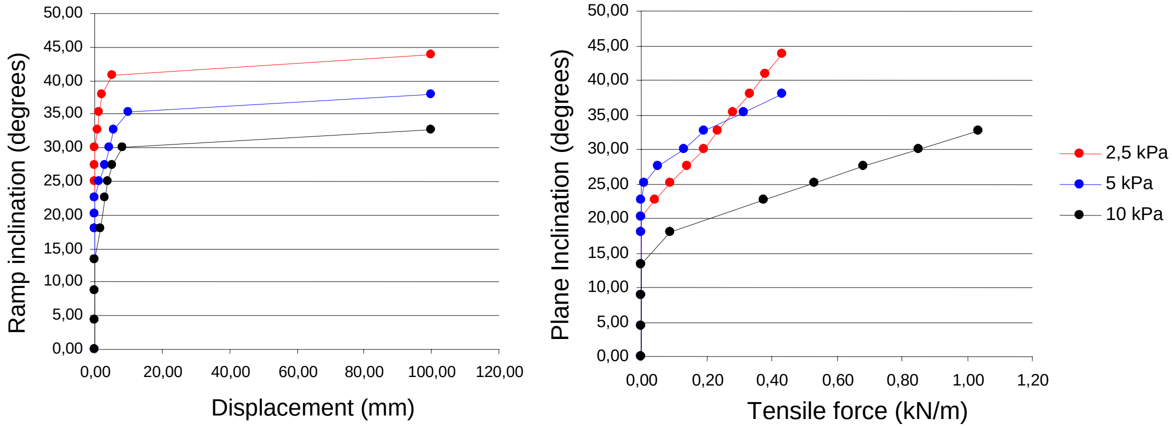

Figure 4. Typical test results for the ramp equipment with high-asperity GM sample.

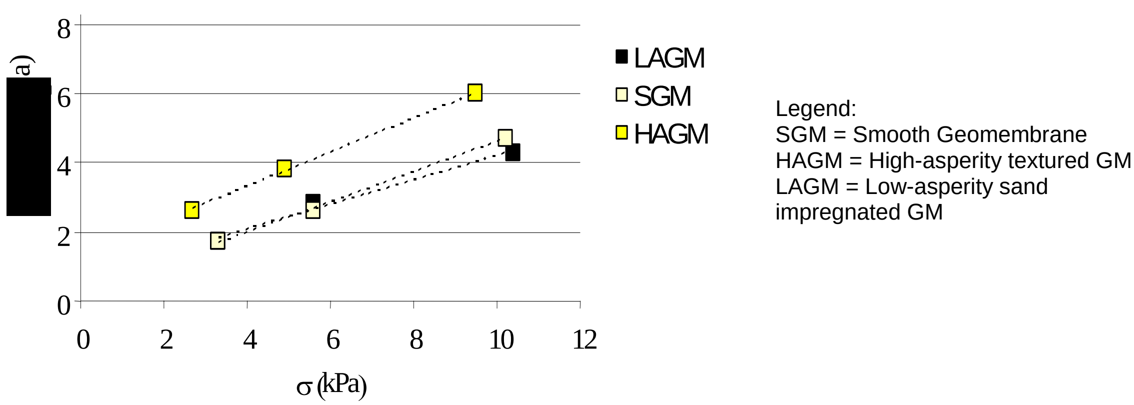

Figure 5. Failure envelopes for three types of geomembranes and fresh concrete.

Table 2. Summary of shear strength parameters for fresh concrete – geomembrane interface.

Parameter	Smooth GM	Low-asperity GM	High-asperity GM
Friction, degrees	22^o to 23^o	20^o to 22^o	27^o to 28^o
Cohesion Intercept, kPa	0.3	0.4	1.3

As expected, the high-asperity GM shows the highest interface friction when compared with the other geomembranes. Surprisingly, however, the smooth GM showed similar friction values when compared with the low-asperity GM. This may be partially explained by the general scratching that the coarse aggregate has caused on the smooth geomembrane surface. In general the cohesion intercept is marginal, in the order of 0.3 to 1.3kPa for all geomembranes tested. Abramento et al. (2010) present further details on the testing as well as comparisons with field trials.

3. CONCLUSIONS

The following conclusions can be summarized from this paper:

- Geomembranes-lined channels are sometimes required to be protected with concrete, which is poured directly over the geomembrane surface.
- Geomembrane-fresh concrete strength parameters are important to assess the stability of concrete during pouring.
- Geomembrane-fresh concrete strength parameters cannot be determined using conventional geotechnical equipment like, for example, direct shear tests due to the coarse aggregate size.
- A large ramp-type equipment was used to adequately assess the geomembrane-concrete friction angle.
- Fresh concrete with a trace normally used for protecting lined channels in Brazil was employed in the tests.
- Three types of geomembrane were used: smooth, high-asperity and low-asperity (sand impregnated).
- The results show friction angles in the order of 27^o for the high-asperity geomembrane interface. The friction angle for the smooth and the low-asperity geomembranes were in the order of 22^o and 20^o, respectively.
- The cohesion intercept was very low for all geomembranes tested, varying from 0.2 to 1.3kPa.

4. ACKNOWLEDGEMENTS

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5. REFERENCES

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