Composite Liners Interface Shear Resistance Versus Temperature

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ABSTRACT: The influence of the temperature on the shear resistance of geotextile-geomembrane and geonet-geomembrane interfaces has been investigated by means of a temperature-conditioned direct shear apparatus. The investigated temperatures range from 0 °C to 45 °C. The preliminary experimental results show that the influence of the temperature on the interface shear resistance may be important; therefore this factor has to be considered when the design interface shear resistances are selected.

1 INTRODUCTION

Composite liners, consisting of compacted clay and geosynthetic materials, are generally used in hazardous-waste landfills and new municipal solid-waste landfills as they have proved to be an effective defence against contamination of soils and groundwaters. However, the use of composite liners requires that greater attention be paid to the stability of the landfill, due to the presence of interfaces whose resistance in the shear plane can be very low and thus lead to potential plane failure. The importance of interface strengths was shown by the slope-stability failure in phase 1A of landfill B19 at the Kattleman Hills class I hazardous waste treatment and storage facility in Kattleman City, California (Mitchell et al., 1990 and Seed et al., 1990). Therefore, a great effort has recently been made to improve our knowledge of the shear resistance of the different interfaces present in composite covers and liner systems. (Negussey et al, 1989; O'Rourke et al.,1990; Matichard et al., 1991; Yegian and Lahalf, 1992; Pasqualini et al., 1993; Stark and Poppel, 1994) and an increasing amount of experimental data is now available. On the other hand, relatively little is known about the factors which could influence the interface shearing resistance, an understanding of which could explain the differences observed when some experimental data are compared. These differences can be due to the variety and properties of materials used (e.g. roughness, polymers, textures, deformability, thickness), or to the particular environmental conditions (e.g. dry, wet, submerged, relative specimen position, temperature, abrasion, dust, handling) (Pasqualini et al. 1993a).

The present paper focuses on the study of the influence of the temperature, which is usually very important for all polymeric materials. This aspect was investigated by means of a temperature-conditioned direct shear apparatus, which is now operating at the University of Ancona, Italy.

2 TEST EQUIPMENT

The interface shear equipment was obtained by modifying a Wikeam-Farrance 25000 direct shear testing apparatus. In particular new split boxes suitable for housing the geosynthetic specimens were designed, taking into account the following: a) the area of the contact surface between the tested materials has to be constant during the shear test to avoid possible sources of inaccuracy in the evolution of normal and shear stresses; b) the tests must be performed up to high relative displacements to evaluate the residual shear resistance; c) the tests have to be done on dry, wet and submerged specimens (in the presence of water or leachate) to reproduce the possible in situ conditions.

For details on the main features of the split boxes used at the University of Ancona see Pasqualini et al. (1993).

Further modifications and improvements have been made to investigate the influence of the temperature on the shear interface resistance: a) the shear interface equipment has been housed in a thermally-isolated box; b) a load cell and two displacement transducers have been installed whose measurements are temperature-independent; c) two thermocouples have been set up (see fig. 1): thermocouple 2 measures the temperature of the air (dry tests) or water (submerged tests) very close to the interface; thermocouple 1 measures the temperature of the split box. As the latter temperature always proved to be more stable than the former (see Fig. 2 and Tab. 1), thermocouple 1 was selected to control the conditioner which supplies the hot or cold air inside the thermally-isolated box; d) a data logger continuously records the shear loads, the vertical settlements and shear displacements, as well as the temperatures, and controls the temperature conditioner. For more details on these points see Stella (1993).

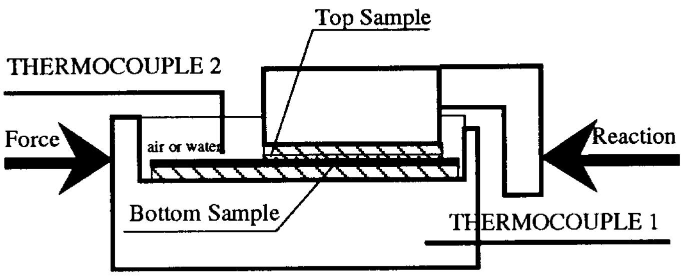
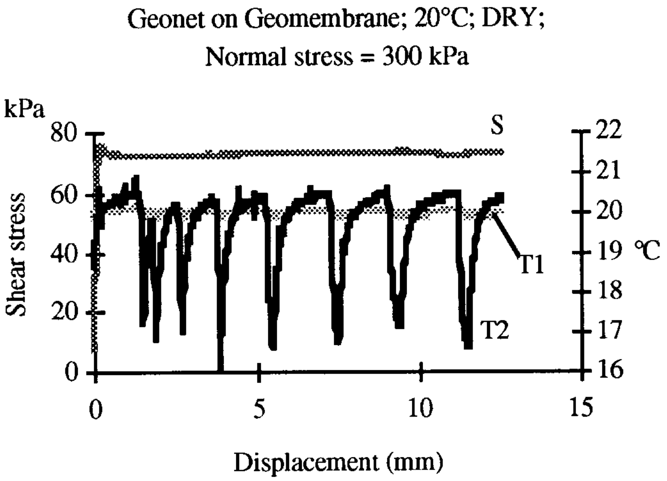


Figure 1 Split box and location of the thermocouples.



T1 = Control temperature;
T2 = Air Temperature near geomembrane;
S = Shear-Displacement curve.

Figure 2 Example of test results with the measurement of the air (or water) temperature and control temperature.

Table 1 Average temperatures and standard deviations during tests.

GM= Geomembrane; GT= Geotextile; GN= Geonet.

A	B	C	D	E	F
0°C	GT/GM	-0.13	0.24	0.05	1.07
DRY	GN/GM	0.05	0.14	0.02	1.61
1°C	GT/GM	1.12	0.32	1.26	0.24
SUBMERGED	GN/GM	1.01	0.15	1.32	0.29
10°C SUBMERGED	GT/GM	10.07	0.08	9.97	0.11
20°C	GT/GM	20.01	0.104	19.82	0.47
DRY	GN/GM	20.02	0.06	19.79	0.96
20°C	GT/GM	20.25	0.08	19.79	0.12
SUBMERGED	GN/GM	20.02	0.07	19.88	0.11
45°C	GT/GM	44.72	1.307	44.94	2.307
DRY	GN/GM	44.98	0.68	44.90	1.76
45°C	GT/GM	49.69	1.05	44.91	0.77
SUBMERGED	GN/GM	46.39	1.08	45.74	0.92

A- Temperature setting;
B- Interface;
C – Average control temperature (thermocouple 1);
D – Standard deviation;
E – Average temperature of air or water (thermocouple 2);
F – Standard deviation.

3 TEST PROGRAM

At present, only two kinds of interface have been methodically investigated (see Tab. 2), i.e. geonet on geomembrane (GN/GM) and geotextile on geomembrane (GT/GM). The tests were performed both dry and submerged at three or four different temperatures and at three different vertical stresses. To avoid problems related to the presence of ice, the submerged tests were carried out above 0°C.

Before testing, each interface was kept for at least five days in a refrigerator or in an oven at temperatures very close to those selected for the direct shear tests.

Table 2 Interfaces tested

Displacement rate = 0,119 mm/min
GM = Geomembrane smooth HDPE P800-20 (2mm thickness)
GT = Geotextile PE/S 300 nonwoven needle-punched
GN = Geonet HDPE 900 (5mm thickness)

Interface	Testing Conditions	Temperatures (°C)	Normal stress (kPa)
GT/GM	DRY	0, 20, 45	50, 150, 300
GT/GM	SUBMERGED	1, 10, 20, 45	50, 150, 300
GN/GM	DRY	0, 20, 45	50, 150, 300
GN/GM	SUBMERGED	1, 20, 45	50, 150, 300

4 TEST RESULTS

4.1 Geotextile-Geomembrane interface

Figures 3 and 4 show examples of typical shear-stress displacement curves obtained at different temperatures in dry and submerged conditions respectively. Based on the results of all tests, the following considerations are given:

- at all investigated temperatures, a well defined peak shear strength located at very low displacement is always present; after that, by increasing the displacement shear resistance decreases and reaches the residual shear strength;
- in both dry and submerged conditions the shear strength obtained at low temperatures (less than 10°C) is greater than that obtained at intermediate (~20°C) and high temperatures (~45°C);
- no significant differences are observed when the shear-stress displacement curves obtained at intermediate and high temperatures are compared.

4.2 Geonet-Geomembrane interface

The analysis of the experimental results of the geonet-geomembrane interface is not so simple and immediate as that concerning the geotextile-geomembrane interface. For this reason figures 5 and 6 show all the obtained experimental data, thus allowing the reader to formulate his own opinion.

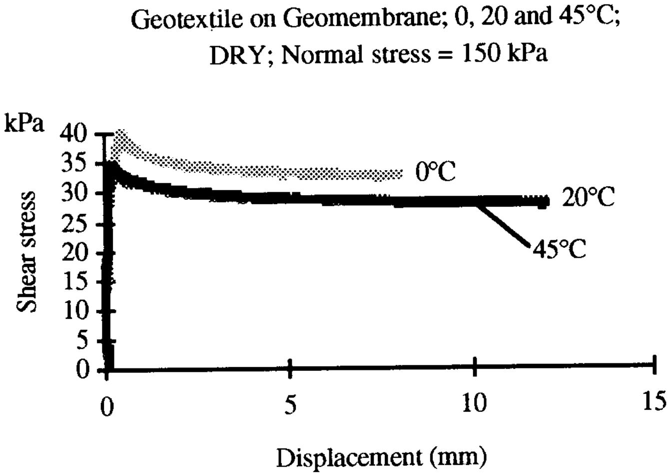


Figure 3 Example of interface shear test results; DRY condition.

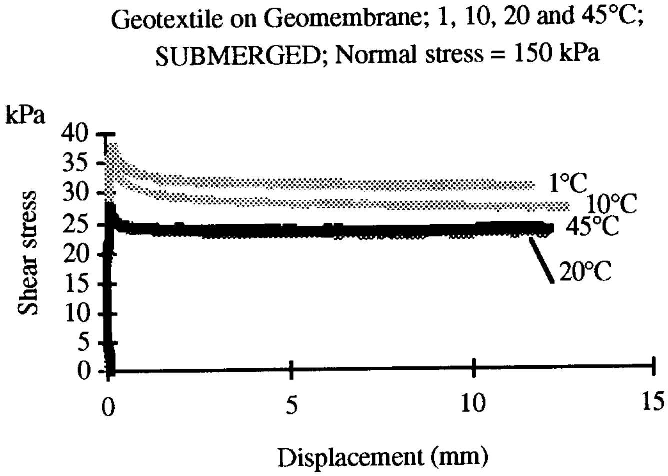


Figure 4 Example of interface shear test results; SUBMERGED condition.

The writers point out the following:

- at low temperature (close to 0°C), a well defined peak shear resistance at very low displacement followed by a decrease of the shear resistance down to a residual value has been clearly observed in all the tests performed, both in dry and submerged conditions;
- at high temperature (close to 45°C), it is not possible to define a peak and a residual interface shear resistance, since an increase of shear resistance with the increase of the displacement has always been measured;
- the behaviour of this interface at high temperature could be due to a compenetration between geomembrane and geonet during the test.
- at the intermediate temperature (~20°C) the behaviour of the interface presents some charactheristics of both high and low temperature behaviours.

5 FINAL CONSIDERATIONS

- The obtained experimental data, althongh preliminary and concerning only two interfaces, clearly show that the

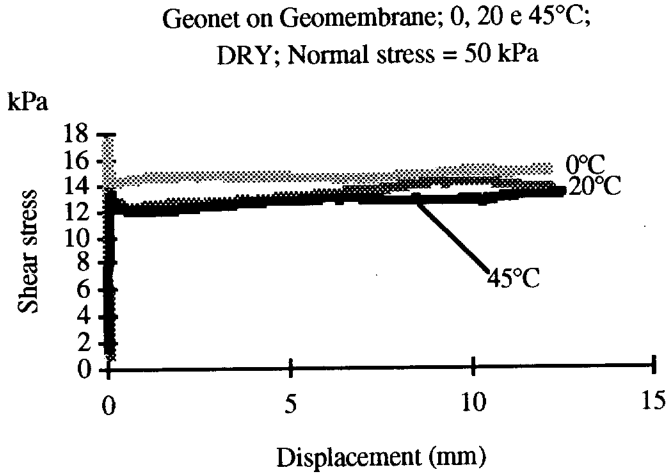


Figure 5.a

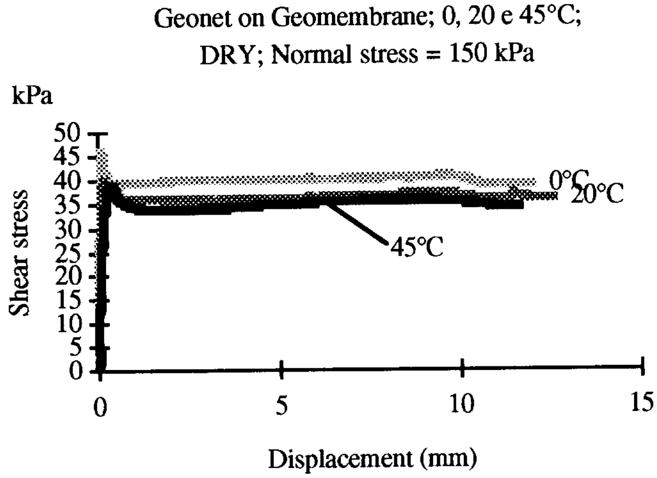


Figure 5.b

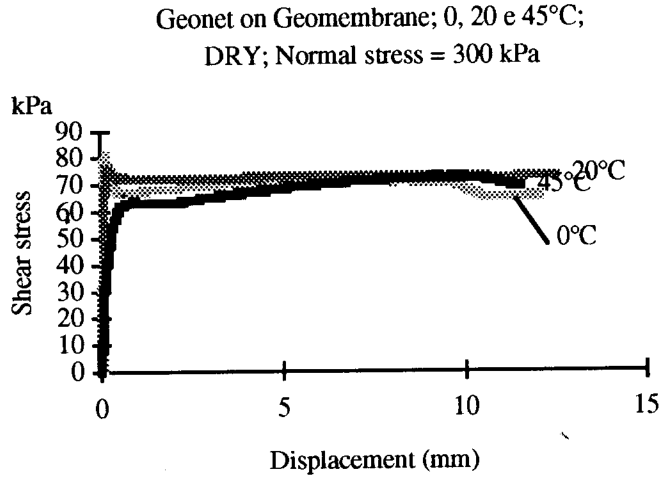


Figure 5.c

Figures 5 Influence of the temperature on the geonet-geomembrane interface; DRY condition.

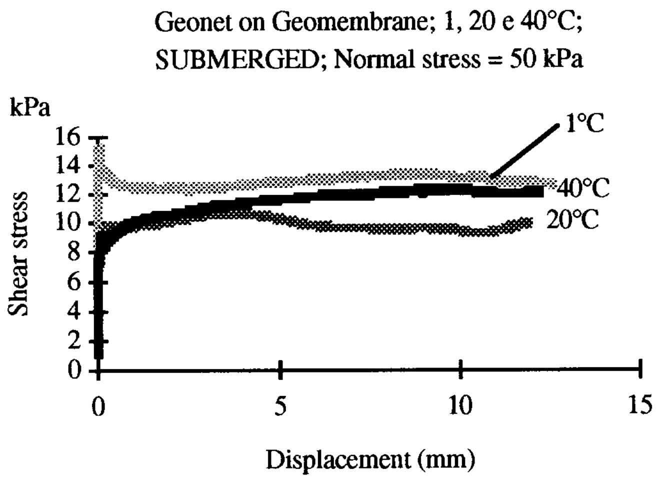


Figure 6.a

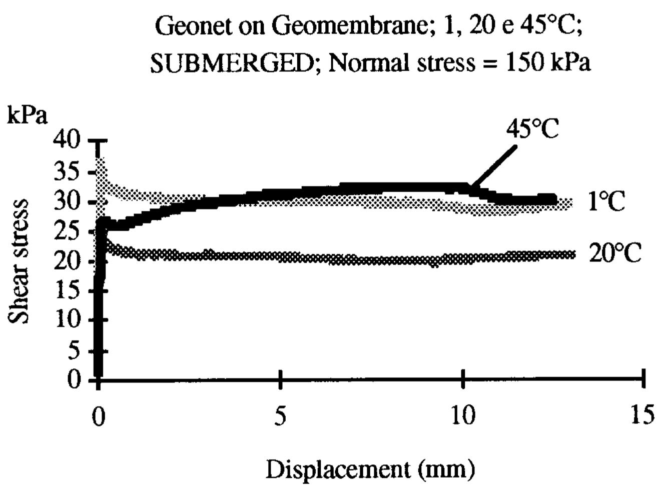


Figure 6.b

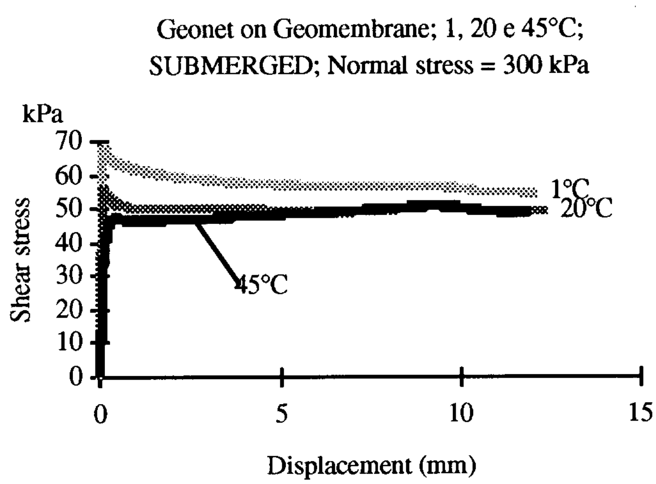


Figure 6.c

Figures 6 Influence of the temperature on the geonet-geomembrane interface; SUBMERGED condition

influence of temperature on the interface shear resistance is not negligible. It is therefore necessary, in order to correctly define the design parameters to use in stability analyses of composite liners and covers, to perform laboratory tests at different temperatures within the expected range of temperature in the field;

- furthermore, the geonet-geomembrane interface, when tested at a high temperature, does not exhibit a well-defined peak and residual shear resistance; in these cases it should be convenient to select the design shear resistance interface at a given level of displacement of the interface which can be considered safe for the stability and/or serviceability of the landfill.

Acknowledgements

The work described in this paper is part of a research performed in cooperation with Ingegneria Geotecnica S.r.l. (Turin) and Società Italiana per il Gas p.a. (Turin). The latter also provided financial support. Finally, this research forms part of a research project of national interest funded by M.U.R.S.T. (Ministero dell'Università e della Ricerca Scientifica).

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