

# The CBR Puncture Test Applied to Geomembranes

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**ABSTRACT:** The paper discusses the CBR Puncture Resistance Test method applied to geomembranes and geotextile/geomembrane systems where the geomembranes are protected by geotextiles. Effects of penetration velocity were analysed using several kinds of geomembranes and a nonwoven needled punched geotextile. The following polymers, PVC, EPDM and IIR (Butyl) were used when testing geomembranes, and PET when testing geotextiles. The friction interface geotextile/geomembranes behavior is also discussed.

## 1 INTRODUCTION

The CBR Puncture Resistance Test is a standard method in several countries: Germany (DIN54307), USA (GRI-GS1), and it is in final standardization procedure used by the European Committee for Standardization (CEN) and the Brazilian Association for Technical Standard (ABNT).

This test is used to characterize both geotextiles and geomembranes as an index test of puncture resistance. Several papers discuss this method for geotextiles and compare it with other axisymmetric or tensile strength tests (Cazzuffi et al., 1986, Frobel and Montalvo, 1993).

The main purpose of this work is to analyse the variability of the results and the penetration velocity effect when this test is applied to geomembranes and geotextile/geomembrane systems where the geomembrane is protected by the geotextile.

## 2 MATERIAL CHARACTERISTICS

Four different geomembranes presenting three different types of polymer and one geotextile were chosen for testing. For the purpose of comparison, the geomembranes have almost the same thickness and two different PVC geomembrane manufacturers were chosen. Table 1 presents the physical properties of the geosynthetics.

-geomembranes:

- EPDM - ethylene-propylene-diene monomer (Incopil)
- IIR - copoly (isobutylene-isoprene) (butyl) (Incopil)
- PVC - polyvinyl chloride (a-Plavinil, b-Sansuy)

-geotextile: non woven, needle-punched, continuous filaments, polyester (PET) (Bidim)

Table 1. Physical properties

polymer	thickness <sup>a</sup>		mass per unit area <sup>b</sup>	
	mm	C.V. (%)	g/m <sup>2</sup>	C.V (%)
geomembranes				
IIR	0.82	1.64	1026	1.03
EPDM	0.80	1.38	986	1.60
PVCa	0.77	0.68	1052	0.52
PVCb	0.89	2.17	1249	1.51
geotextile				
PET	2.13	9.5	211	8.3

<sup>a</sup> ISO 9863

<sup>b</sup> ISO 9864

## 3 DESCRIPTION OF THE TEST METHOD

The CBR Puncture Resistance Test employs the same apparatus as the traditional California Bearing Ratio (CBR) Test (see Figure 1).

A test specimen is clamped without tension between two circular plates attached to a California Bearing Ratio mold. A force is exerted on the center of the specimen by a steel CBR plunger 50 mm in diameter. The stress area is 176.6 cm<sup>2</sup> (15 cm diameter) and the plunger driven at a vertical speed of 50 mm/min in a standard test.

To analyse the penetration velocity effects, tests at a speed of 10 mm/min were also performed.

When testing geomembranes protected by a nonwoven geotextile, the geotextile specimen was placed over a geomembrane specimen and they are clamped together between the circular plates.

#### 4 TEST VARIABILITY

Frobel and Montalvo (1993) have observed good reproducability in the standard CBR Puncture Resistance Test on geotextiles specimen.

Vidal and Costa (1993) testing the geomembranes chosen for this work, at several thicknesses, have arrived at the same conclusion. A summary of these results and a comparison with the variability in geomembrane physical properties are present in Table 2. The variability observed in CBR Puncture Tests (5 specimens per test) is very close to that observed in physical propeties tests (10 specimens per test).

The nonwoven continuous filament polyester geotextiles exhibit a high variability in their physical properties (see Table 1), with coefficients of variation above those exhibited by geomembranes.

The geotextiles tested by Vidal and Costa (1993) showed a coefficient of variation for the break force in a CBR Puncture Test of between 0.7 and 4.4% while this coefficient is between 4.1 and 8.3 % for the Mass per Unit Area Test.

The CBR Puncture Tests on geomembranes protected by these geotextiles are also affected by this variation. The coefficient of variation values obtained are between:

- 0.8 and 6.4% for break force
- 0 and 5.7% for maximum penetration.

Table 2. Coefficients of variation interval for geomembranes

polymer	variability interval (%)		
	mass	thickness	CBR Puncture
IIR	0.71-1.03	0.97-1.64	0.6-1.5
EPDM	1.22-1.60	0.96-1.38	0.5-1.3
PVCa	0.52-0.55	0.68-0.78	0.5-0.7
PVCb	0.74-1.51	0.63-2.17	2.5-3.5

#### 5 PENETRATION VELOCITY EFFECTS

Figure 2 presents the CBR Puncture Resistance Test results obtained for selected geomembranes. The PVC geomembranes are significantly affected by the penetration

velocity whereas this effect is negligible for IIR and EPDM geomembranes. The reasons for this are probably:

- PVC geomembranes are in glassy state at ambient temperature (they exhibit permanent deformation). An amorphous orientated structure in this state is very sensitive to strain rate modifications,
- IIR and EPDM geomembranes are in visco-elastic state. In this case, the penetration velocity interval (10 to 50 mm/min) is not sufficient to highlight the strain rate influence. Fayoux and Loudiere (1984) observed a time test effect in a large time interval. Bartenev and Zuyev (1968) noted that under static load these materials could exhibit a significant strength reduction.

The nonwoven polyester geotextile is only slightly affected by the penetration velocity in the CBR Puncture Resistance Tests, as shown in Figure 3. The penetration at rupture is near 50 mm on 50% of the standard tests made with this geotextile specimen at several thickness.

Figure 4 presents the CBR Puncture Test results when the geomembranes are protected by the nonwoven polyester geotextile. In all the tests it is only the geotextile which ruptures. Some effects observed could be due to the fabric variability in the geotextile, but all the tested specimens exhibit an increasing of penetration at rupture when the penetration velocity decreases.

In our opinion, the penetration velocity effects illusted in Figure 4 are not due to the protection element behavior alone, but also to a better interface interaction and tension distribution. For this reason a correlation with the friction behavior must be found.

#### 6 FRICTION INTERFACE BEHAVIOR

Direct Shear Tests on a 30 x 30 cm shear box were performed to allow the geotextile/geomembrane interface friction behavior to be studied. The geomembrane specimen was attached to a rigid steel plate anchored on top of the lower box, as is shown in figure 5. The experiments were conducted under normal stress levels from 25 to 150 kPa.. Table 3 presents the tests results.

Table 3. Friction geotextile/geomembrane properties			
geomembrane	friction angle (°)	J <sub>i</sub> * (kPa/m) <sup>a</sup>	
		(25 kPa)	(150 kPa) <sup>b</sup>
EPDM	18	800	5700
IIR	17	700	5500
PVCa	15	1400	7000
PVCb	15	880	5000

<sup>a</sup> Initial Tangent Modulus (see Figure 6)

<sup>b</sup> Normal Stress

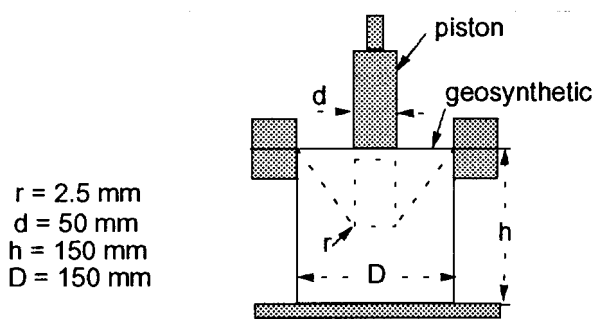


Figure 1. CBR Puncture Resistance Test Apparatus

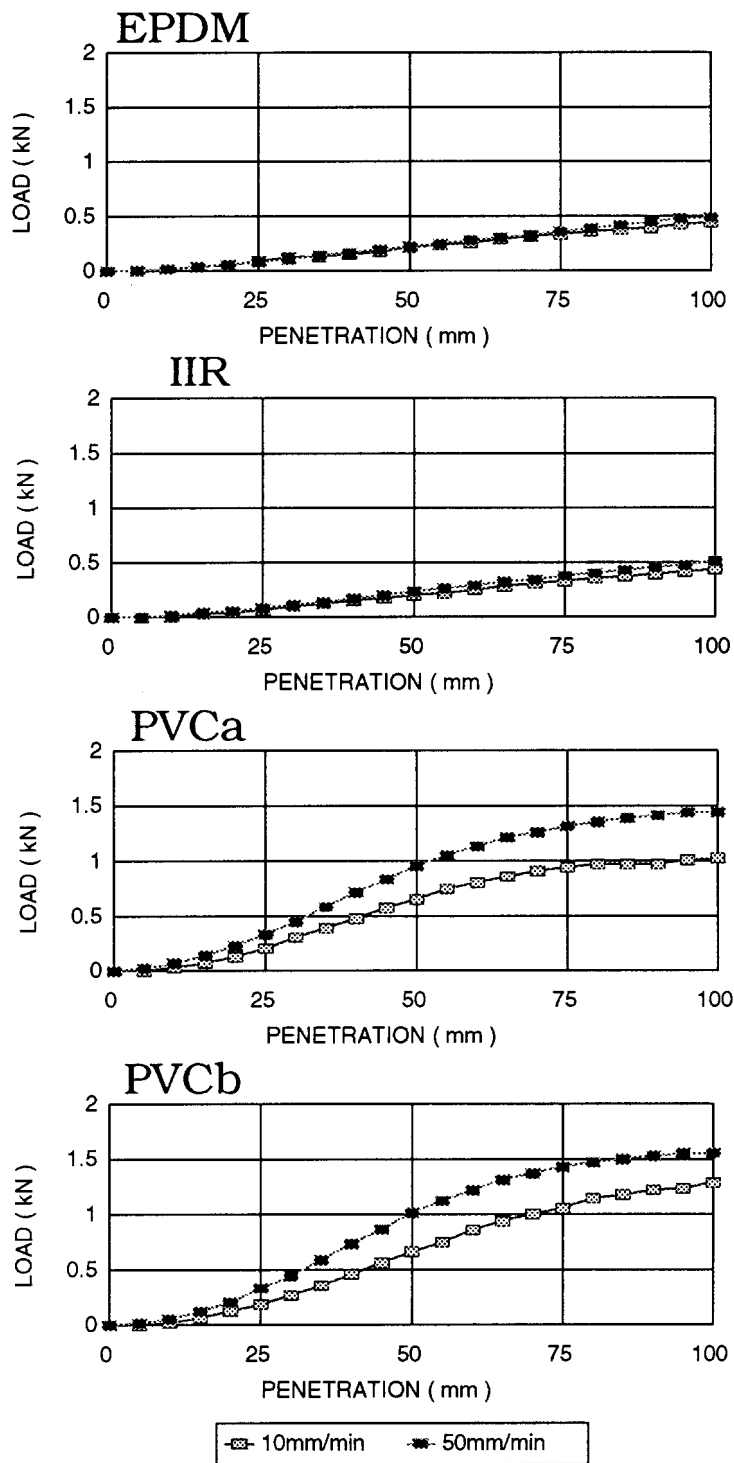


Figure 2. Effect of penetration velocity on CBR Puncture Resistance Tests.

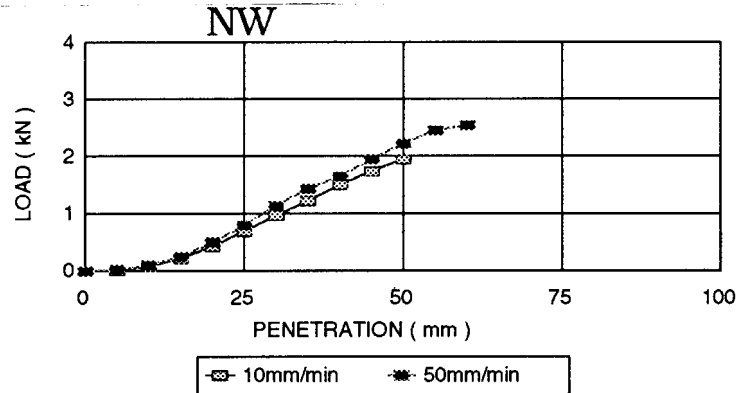


Figure 3. CBR Puncture Resistance for the geotextile

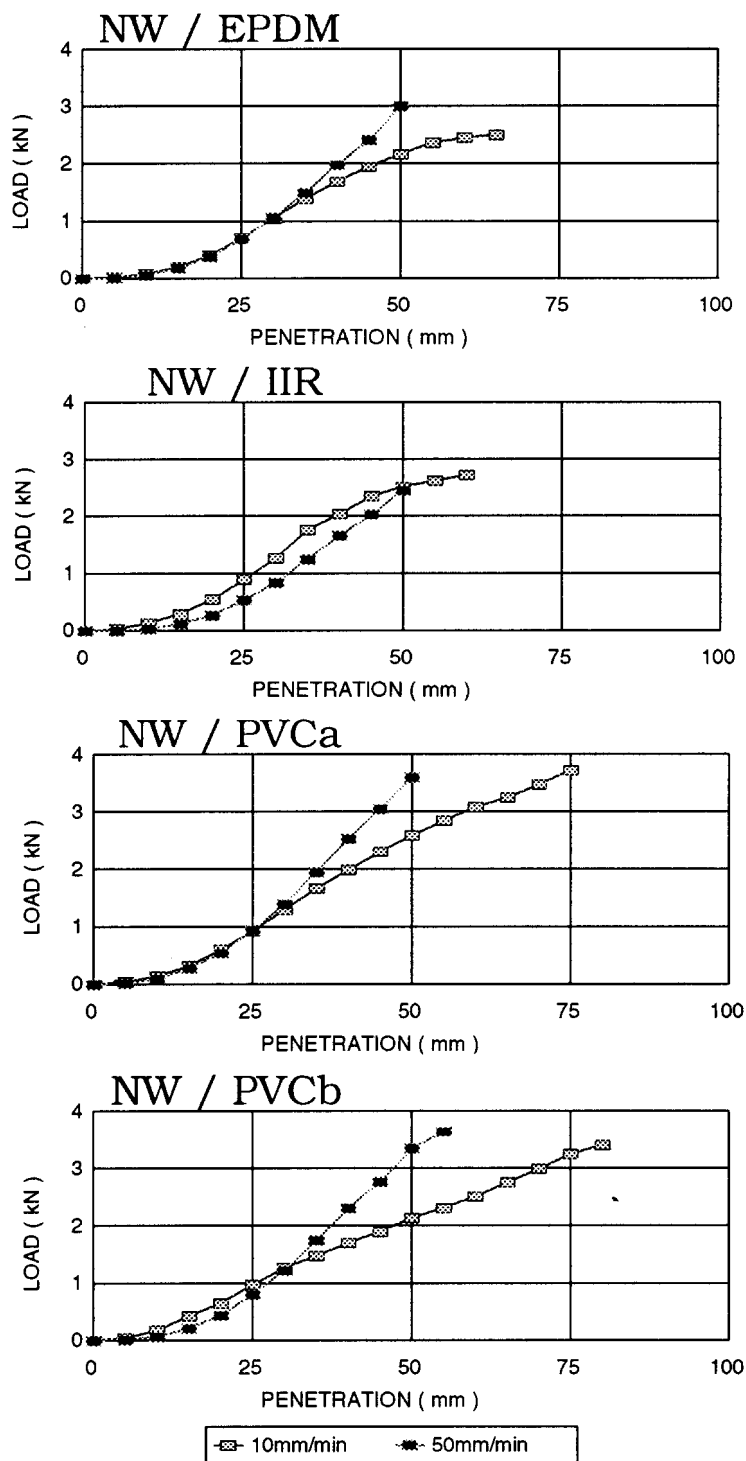


Figure 4. Geomembranes protected by geotextiles: penetration velocity effect in the CBR Puncture Resistance



The friction interface behavior in CBR Puncture Tests is complex but certainly if there is a displacement between the two geosynthetics, it must be small and the Initial Tangent Modulus ( $J_i^*$ ) analysis is more appropriate than the friction angle measurement. Figure 6 shows the Direct Shear Test results obtained with the nonwoven geotextile and the PVC geomembranes.

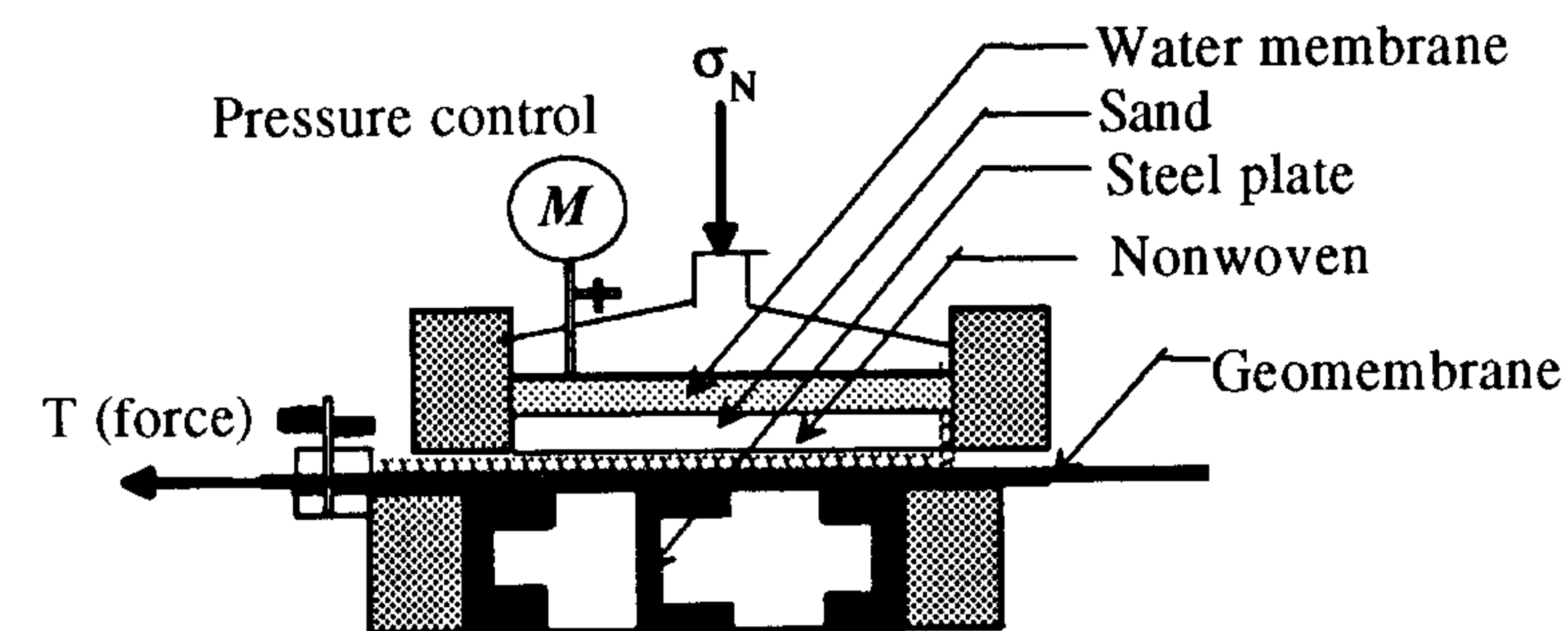


Figure 5. Direct Shear Test Apparatus

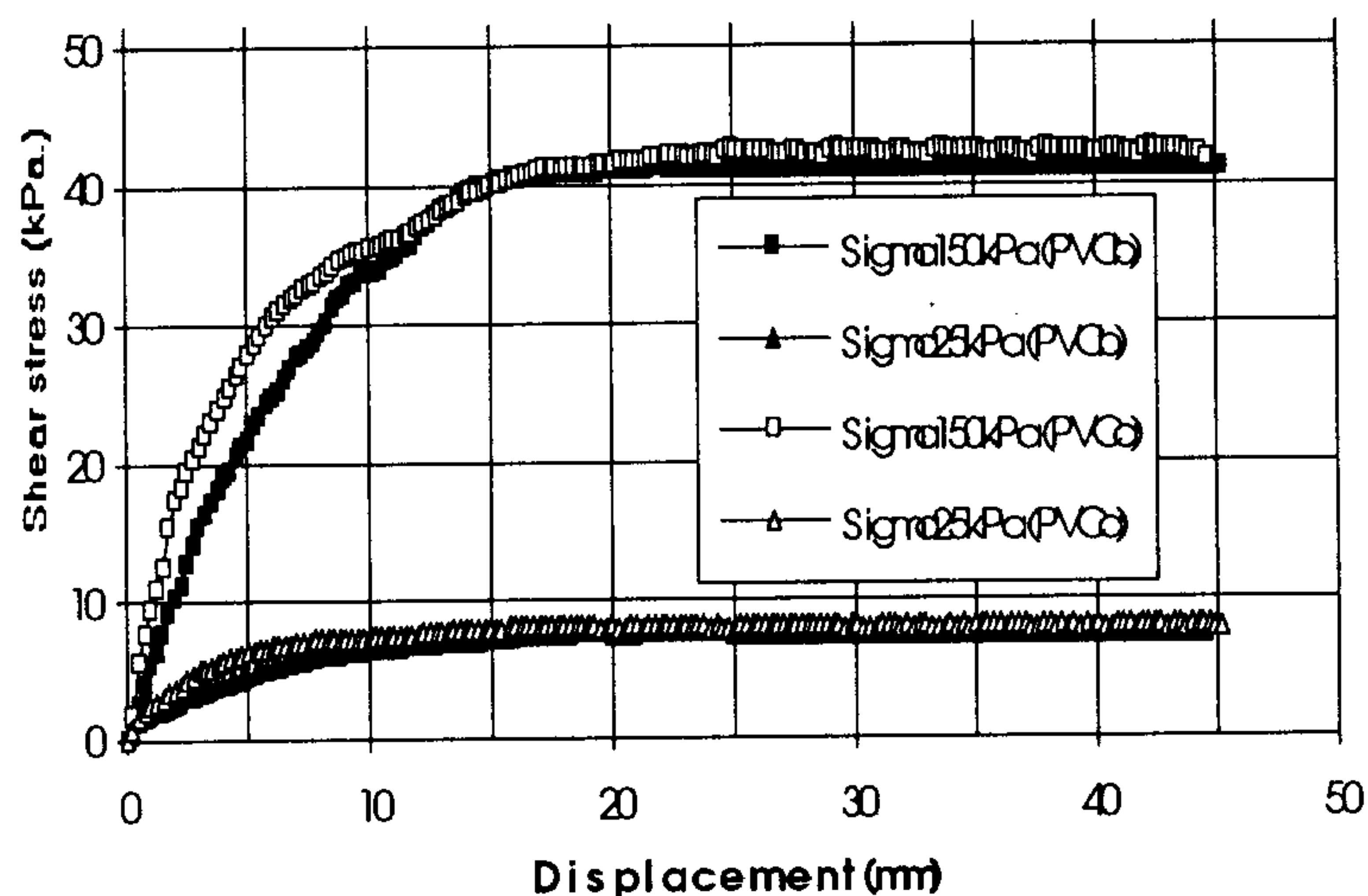


Figure 6. Friction behavior between the geotextile and the geomembranes.

The highest shear stress developed between the nonwoven geotextile and the PVCa geomembrane can perhaps justify a value of the CBR Puncture break force slightly above the one obtained when the protected geomembrane is PVCb. These materials show the inverse behavior in tests without protection.

## 7 DISCUSSION

The CBR Puncture Resistance Test is easily performed in all geotechnical laboratories and it presents a variability in line with the product's variability.

This test is sometimes considered as a rough simple test to analyse multiaxial strength behavior, even if it causes a tensile concentration near the plunger. However, it can not be directly correlated to a uniaxial tensile test because the request are very different and the materials are not really isotropic.

The variability of the break stress values obtained by Motan et al. (1993), studying geomembrane protection by

geotextiles using a Mullen Burst Test (ASTM D4786) and a Index Puncture Resistance Test (ASTM D4833), on small specimens confirms the need for larger specimens.

A plunger penetration of 10 cm (encountered in the CBR Test apparatus) may not be sufficient to cause rupture when testing geomembranes without protection (only PVC geomembranes were broken at a rupture penetration value near 100mm).

The CBR Puncture Test is a high speed test. The results show that for some materials, like EPDM and IIR, the penetration velocity effect is negligible in rate interval studied. For PVC materials we have observed an effective reduction in the tensile stiffness when the test speed decreases.

When the geomembrane is protected by a polyester nonwoven geotextile, the break force value in a CBR Puncture Resistance Test is only slightly affected by the test speed, with exception of EPDM which exhibited 16% reduction at 10mm/min. However, the penetration at rupture increases if the penetration velocity decreases.

These results are relevant for penetration velocities between 10mm/min and 50mm/min.

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