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PUNCTURE AND IMPACT RESISTANCE OF GEOSYNTHETICS
RESISTANCE A LA PONCTION ET AU CHOC DE GEOSYNTHETIQUES
DURCHSTANZ- UND DURCHSCHLAGSVERHALTEN VON GEOSYNTHETICS

Presented in this paper are methods for evaluating puncture and impact resistance of geotextiles, geomembranes and their composites. A number of different mass per unit area needlepunched nonwoven geotextiles were evaluated as were various geomembranes of the same thicknesses. Obvious trends in data resulted from these tests. When geotextiles and geomembranes are used in composite form, significant improvements result in geomembrane behavior used by itself. A separate study on geomembrane thickness equivalency of using a geotextile with the geomembrane is also presented.

Methoden zur Auswertung der Stempeldurchdrück- und Stoss-Widerstandsfähigkeit von Geotextilien, Geomembranen und deren Zusammensetzung sind in dieser Veröffentlichung beschrieben. Eine Anzahl von vernadelten, nicht gewebten Geotextilien mit verschiedener Masse pro Flächeneinheit wurden bewertet, sowie verschiedene Geomembranen von gleicher Dicke. Bei diesen Tests kam man zu offenkundigen Ergebnissen und Tendenzen. Es wurden auffallende Verbesserungen im Verhalten der Geomembrane beobachtet, wenn Geotextilien und Geomembrane in zusammengesetzter Form verwendet wurden. Des weiteren sind die Ergebnisse einer Sonderstudie über die Equivalenz der Geomembran-Dicke bei Verwendung von Geotextilien mit einer Geomembrane beschrieben.

INTRODUCTION

In the design of geosynthetic materials (geotextiles, geogrids, geomembranes or geocomposites), focus is generally placed on the primary function that the material will be asked to serve. Such design by function should lead to a required set of properties which the candidate product should equal or exceed (1,2). Whatever the required set of properties, however, the geosynthetic must be capable of being transported, installed and covered in its final position without failure. In short, it must survive to the point where it can function as it was designed. Of the various survivability guides that are available (3), all address some form of puncture or impact strength that the candidate geosynthetic must be capable of sustaining.

It should also be noted that the tests are usually performed on the geosynthetic products in isolation without soil adjacent to them. As such, they have sometimes been called index tests (4). Yet each can also be evaluated with soil adjacent to the particular product in such a way so as to stimulate in-situ performance (5). Thus the utility of the tests could eventually be used in design. Some models of this type of design are available (2).

This paper will present puncture and impact behavior of geosynthetics as separate topics, but when evaluated on the same products it will be seen that parallel behavior exists. Concentration will be on needlepunched nonwoven geotextiles of different mass per unit area and a variety of nonreinforced geomembranes. The same geotextiles and geomembranes are then tested together to evaluate what synergistic effect, if any, results.

PUNCTURE TEST DETAILS

The puncture test used in this study is a modified form of ASTM D3738 with the puncturing ball being replaced by a 7.9 mm (5/16 in.) diameter blunt end steel piston, see Figure 1. This piston is pushed through a horizontally clamped test specimen in a support cylinder of 4.5 cm diameter at a rate of 25 cm/min. The maximum load registered is recorded. In the case of geocomposites which have materials of different elongation properties, dual peaks are often obtained. In such cases the initial value is the one recorded.

The geotextiles evaluated were continuous filament, polypropylene, needlepunched nonwovens of 200, 400 and 600 gm/m^2 mass per unit area. The geomembranes used were 0.75 mm nonreinforced chlorinated polyethylene (CPE), ethylene propylene diene monomer (EPDM), high density polyethylene (HDPE) and polyvinyl chloride (PVC). A separate study on geomembrane thickness versus geocomposites was also performed. The geomembrane used in this portion of the study was HDPE in thicknesses of 1.0, 1.5, 2.0 and 2.5 mm.

PUNCTURE TEST RESULTS

The results of the puncture tests on the three weights of needlepunched nonwovens are given in Figure 2. The results presented here are an average of five tests per fabric weight, resulting in an approximate linear relationship between the fabrics. Figure 3 presents the puncture results for the four different geomembranes evaluated. Since all are the same thickness, they can be compared to one another with EPDM being the lowest and HDPE the highest.

The composite behavior of the geotextile on front, back or both sides of the geomembrane can now be addressed and compared to the behavior of the various materials tested by themselves. Figures 4(a)-4(c) show the benefits obtained by combining geotextiles with geomembranes with the geotextile being in front, or behind, and on both sides of the geomembrane. Easily noted is a dramatic improvement in composite behavior versus the geomembrane itself which is given a relative value of 1.0. Obviously, a geotextile on both sides of the geomembrane gives further increase in the puncture strength over a single geotextile on front or back. It is also seen that the lowest increase is seen for the 200 g/m^2, then the 400 g/m^2, and was highest for the 600 g/m^2.

In order to estimate the puncture resistance equivalency of a given geotextile added to a geomembrane versus using a thicker geomembrane by itself, a separate study was performed. Here different HDPE geomembrane thicknesses were evaluated by themselves and then along with geotextiles on the front, back and both sides of the geomembranes. Results are shown in Figure 5 for the 400 gm/m^2 geotextile. Here the increase in geomembrane puncture resistance from a single geotextile in very pronounced and with a double geotextile even more so. As an example of quantifying this improvement, if one desires 1000 N puncture resistance it can be obtained by any one of the following:

(a) 2.40 mm HDPE geomembrane by itself
(b) 1.50 mm HDPE geomembrane and a 400 gm/m^2 geotextile on front or back
(c) 0.40 mm HDPE geomembrane and two 400 gm/m^2 geotextiles, one on front the other on back

The economic implications of thinner geomembranes with a geotextile versus the thicker geomembrane by itself are obvious. See Monteleone (5) for results of the 200 and 600 g/m^2 geotextiles.

IMPACT TEST DETAILS

The impact test device used for this study was a modification of ASTM E 23, known as Riehle Impact Tester. It is based on the energy absorbed by impact form a free swinging pendulum weight. The test is commonly used in Metallurgical Engineering to determine the impact strength of notched metal bars. It is favored here over other impact devices in the geotextile literature (6,7) due to its high impact energy capacity which is 326 J. This capacity is required by some of the heavier geotextiles and geocomposites.

The test specimen is placed within a 10 cm x 25 cm U-shaped clamping frame fastened to the base of the pendulum frame. It is then clamped in this frame under zero tension, see Figure 6. The pendulum arm is fitted with a pointed cone of 30° apex angle measuring 2.5 cm diameter and 2.5 cm height. It strikes the test specimen at its centroid penetrating it and then follows through with a knife edge over its upper surface. Maximum impact resistance is registered as the point passes through the test specimen. Its magnitude is read directly in units of joules (J).

This portion of the test program on impact behavior followed an exact parallel with the puncture study insofar as geotextiles, geomembranes and composites are concerned.

IMPACT TEST RESULTS

The results of the impact tests on the 200, 400 and 600 gm/m^2 needlepunched, nonwoven goetextiles are shown on Figure 7. Here an exponential trend is observed when the average value of the five tests per fabric are connected. The heavier weight fabric results in significantly greater impact resistance than the lighter weight fabrics.

The impact test results for the four different 0.75 mm thick geomembranes is shown in Figure 8. Here the PVC and HDPE are the highest in impact resistance, while the EPDM and CPE are the lowest. Thus the geomembranes are seen to behave somewhat differently in impact than they did in puncture.

The composite behavior of the three geotextiles and the various geomembranes is given in Figure 9(a)-9(c). Here the relative performance of the geotextile placed in front, back and both sides of the geomembrane are indicated. Also shown is the geomembrane by itself where it is assigned a relative value of 1.0. Substantial improvement in all cases is seen, with the geotextile on both sides being obviously the greatest. As with the puncture results presented earlier, the results show the impact resistance to improve as the heavier weight geotextiles are used, i.e., 200 g/m^2 is the lowest and 600 g/m^2 is the highest.

Figure 10 presents the information gained from the HDPE geomembrane thickness variation study by itself and then with the 400 g/m^2 geotextile on front, back and both sides of the geomembranes. The results can be viewed in the same light as with the puncture study whereby if one desired 50 J impact resistance it can be obtained by any one of the following:

(a) 1.66 mm HDPE geomembrane by itself
(b) 1.52 mm HDPE geomembrane and a 400 g/m^2 geotextile on front
(c) 1.37 mm HDPE geomembrane and a 400 g/m^2 geotextile on back
(d) 1.22 mm HDPE geomembrane and two 400 g/m^2 geotextiles, one on front and the other on back.

Note that these values are not as pronounced of a difference as with the puncture study, but are sizeable nonetheless. See Monteleone (5) for results of the 200 and 600 g/m^2 geotextiles.

SUMMARY AND CONCLUSIONS

This study has presented puncture and impact resistance tests which have been performed on the same geotextiles, geomembranes and their various combinations. Both tests have sufficient capacity to handle most situations envisioned. It has been shown that:

- Increasing mass per unit area of geotextile increases both puncture and impact resistance.
- Different geomembranes (of the same thickness) differ widely in both puncture and impact resistance.
- A geotextile either in front or back of a geomembrane significantly increases the puncture and impact resistance over the geomembrane by itself.
- The increase is even more pronounced when two geotextiles are used, one in front and one in back of the geomembrane.
- As far as general effectiveness was concerned, the 200 g/m^2 geotextile gave the least composite improvement, the 400 g/m^2 next, and the 600 g/m^2 geotextile the greatest.
- Increasing the thickness of the HDPE geomembrane increases both puncture and impact resistances in a linear manner.
- The results of the HDPE geomembrane thickness equivalency study showed that thinner geomembranes can be used with a geotextile to give comparable performance as a thicker geomembrane in both puncture and impact resistance. The engineering and economic benefits that would result from this geocomposite system can easily be quantified.
- Both test methods can be extended to include soil adjacent to the geosynthetic such that performance data may eventually result. This could aid in separation design which generally involves both puncture and impact.

REFERENCES

(1) Koerner, R. M., "A Note on Geotextile Design Methods," Geotechnical Fabrics Report, IFAI, Vol. 2, No. 2, Fall, 1984, pp. 27-28.

(2) Koerner, R. M., Designing with Geosynthetics, Prentice Hall Book Co., Englewood Cliffs, New Jersey, 1986.

(3) -----, Task Force 25 (AASHTO-AGC-ARTBA) Guidelines in Minimum Mechanical Properties, 1984.

(4) Murray, R. T. and McGown, "The Selection of Testing Procedures for the Specification of Geotextiles," Proc. 2nd Intl. Conf. on Geotextiles, 1982, IFAI, pp. 291-296.

(5) Monteleone, M. J., "Puncture and Impact Behavior of Various Geosynthetics," MSCE Thesis, Drexel University, 1986.

(6) Calhoun, C. C., Jr., "Development of Design Criteria and Acceptance Specifications for Plastic Filter Cloth," Tech. Rpt. F-72-7, US Army WES, Vicksburg, Miss., 1972.

(7) Alfheim, S. L. and Sorlie, A., "Testing and Classification of Fabrics for Application in Road Construction," C. R. Coll. Int. Soils Text., 1977, pp. 333-338.

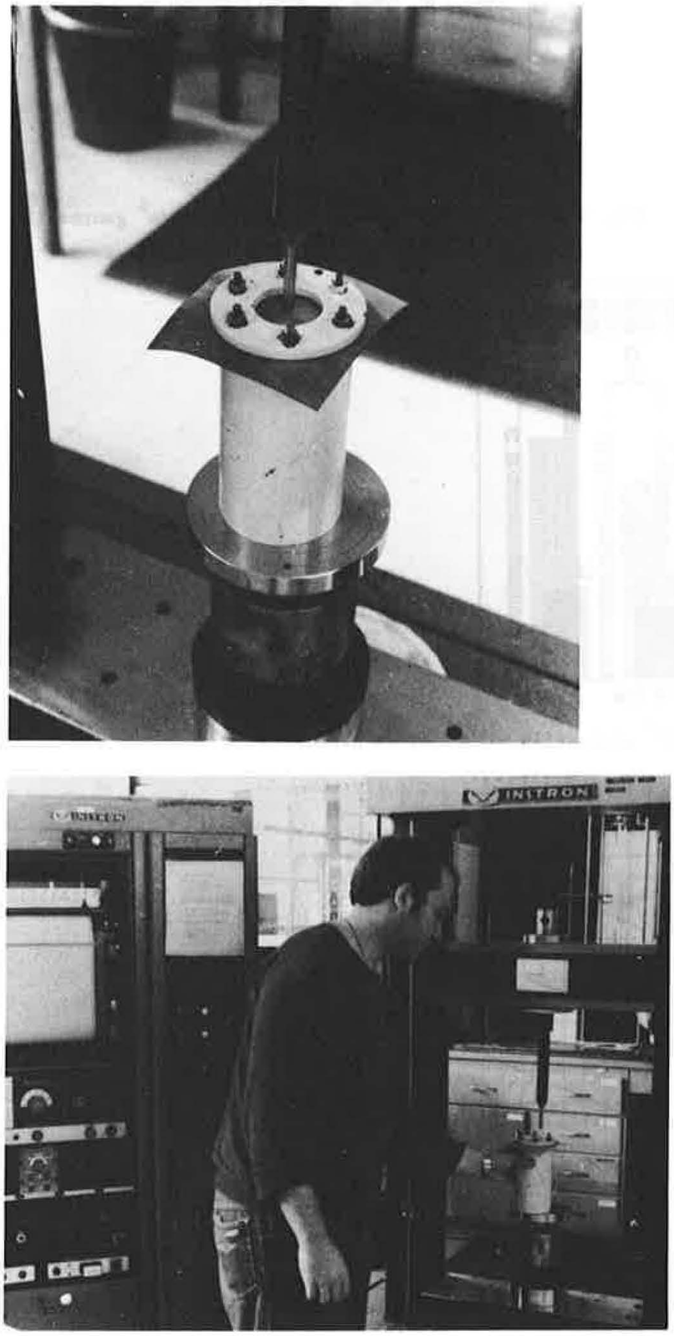

Fig. 1. - Photographs of puncture test setup used in this study

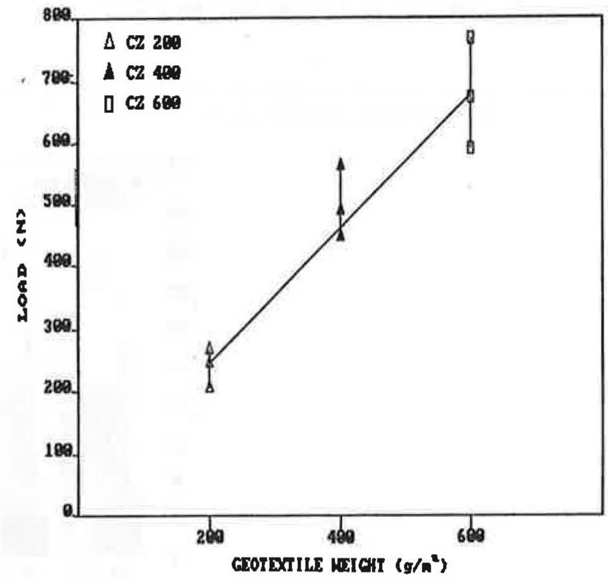

Fig. 2. - Puncture test results of various needled nonwovens geotextiles

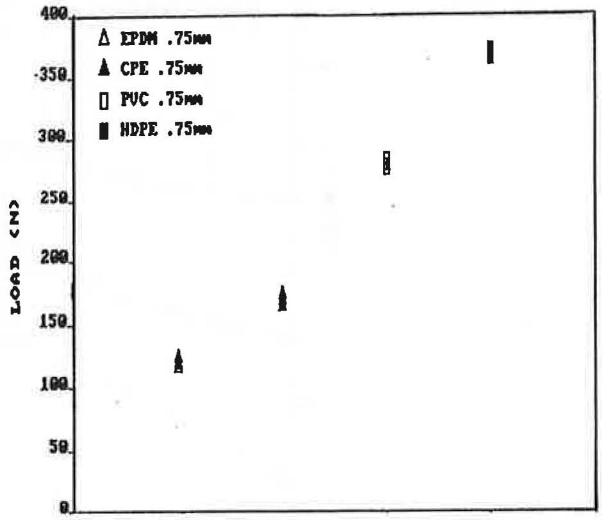

Fig. 3. - Puncture test results of various 0.75 mm thick geomembranes

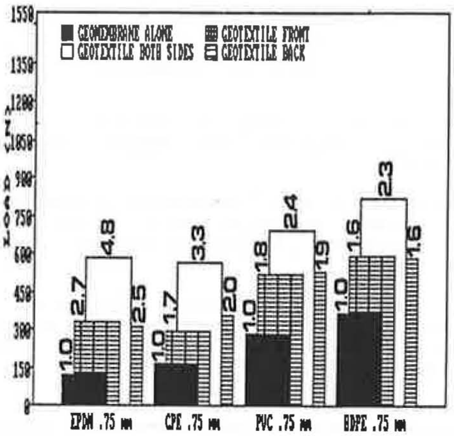

Fig. 4(a) - Puncture test results of 200 g/m^2 geotextile with various geomembranes

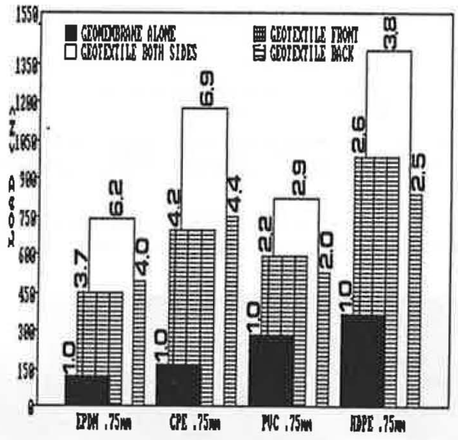

Fig. 4(b) - Puncture test results of 400 g/m^2 geotextile with various geomembranes

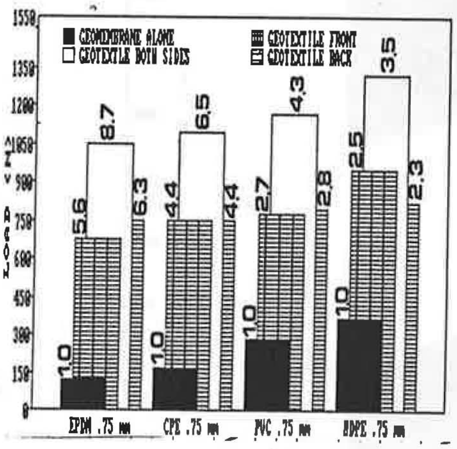

Fig. 4(c) - Puncture test results of 600 g/m^2 geotextile with various geomembranes

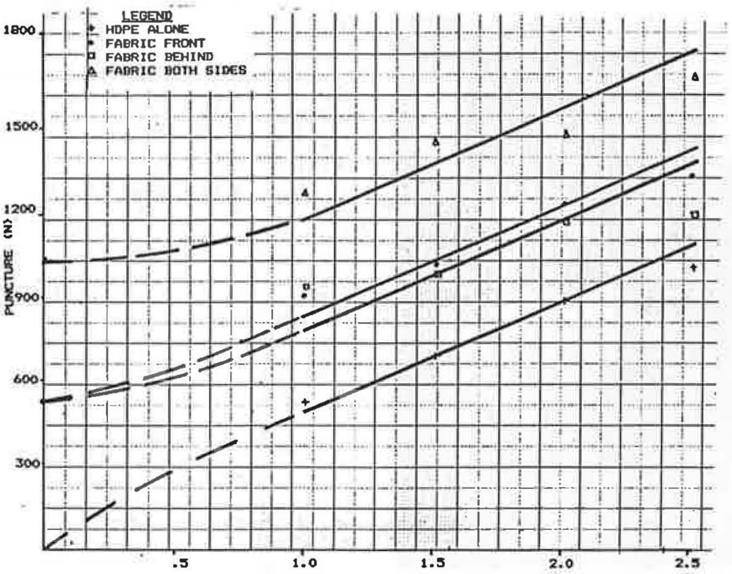

Fig. 5. - Puncture test results of geomembrane by itself versus various geotextile-geomembrane combinations

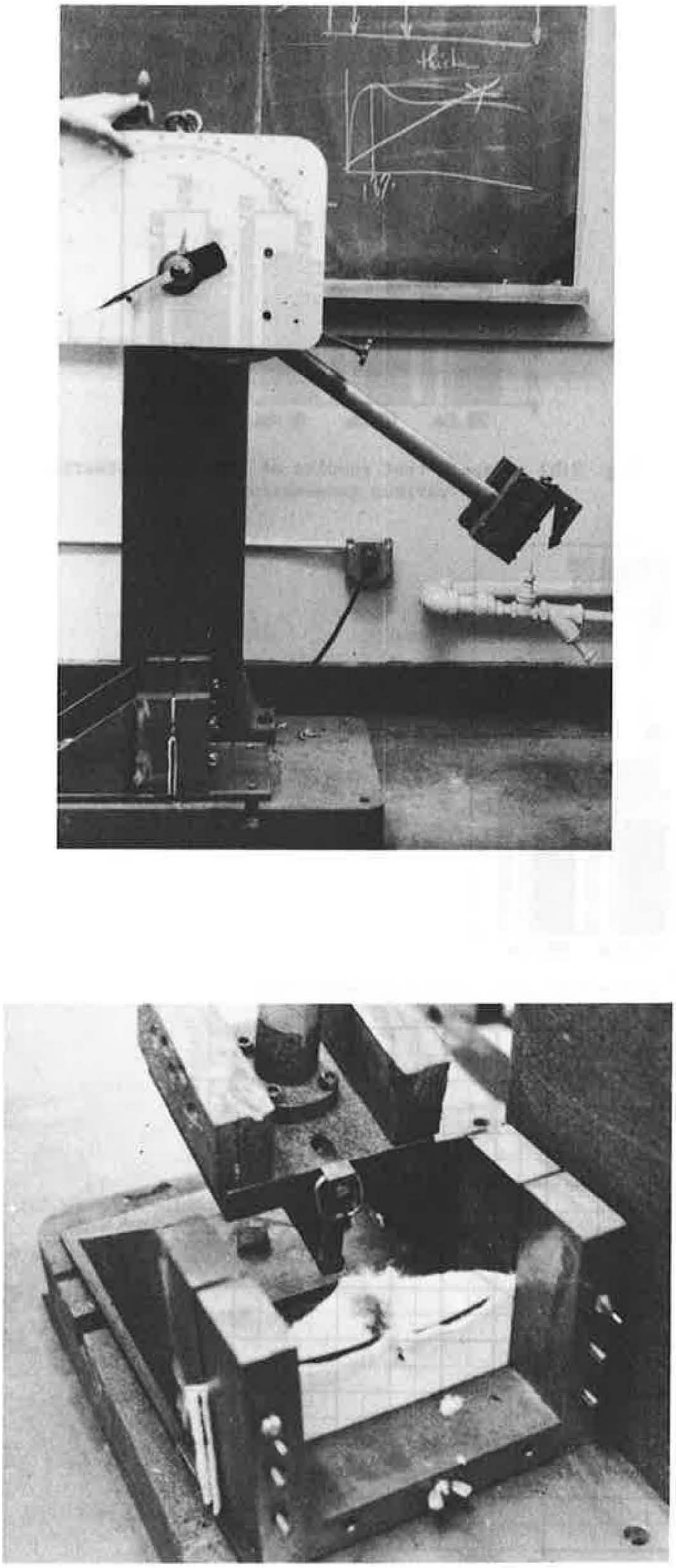

Fig. 6. - Photographs of impact test setup used in this study

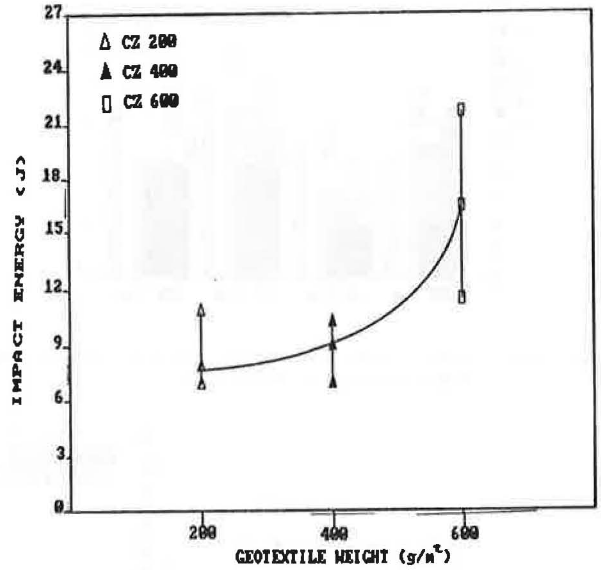

Fig. 7. - Impact test results of various neeedled non-woven geotextiles

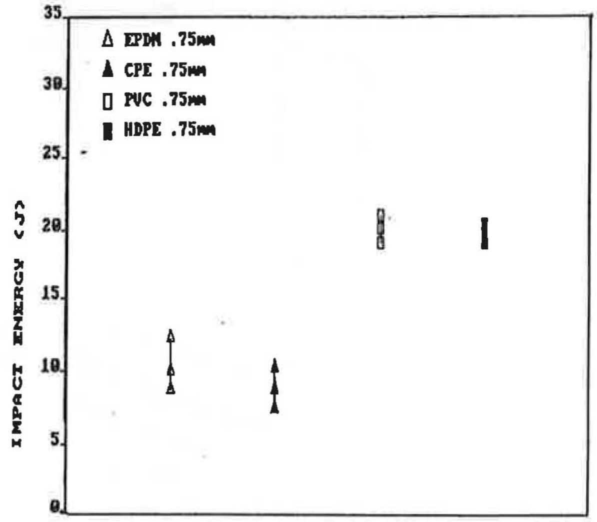

Fig. 8. - Impact test results of various 0.7 mm thick geomembranes

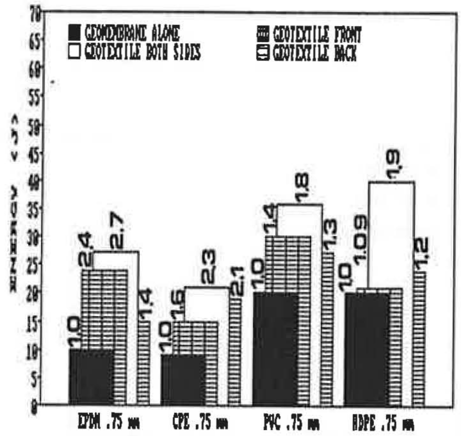

Fig. 9(a) - Impact test results of 200 g/m^2 geotextile with various geomembranes

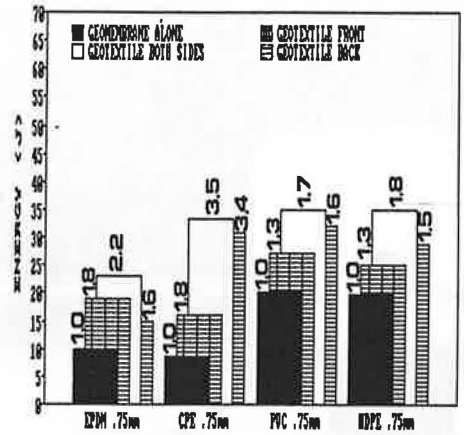

Fig. 9(b) - Impact test results of 400 g/m^2 geotextile with various geomembranes

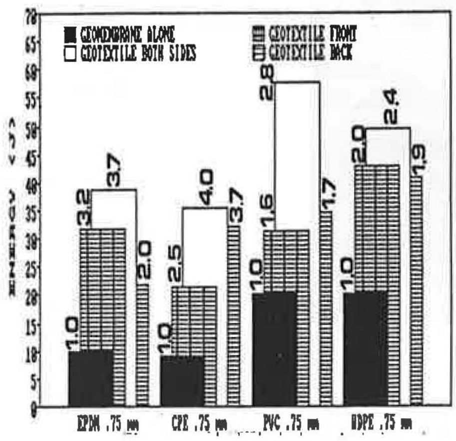

Fig. 9(c) - Impact results of 600 g/m^2 geotextile with various geomembranes

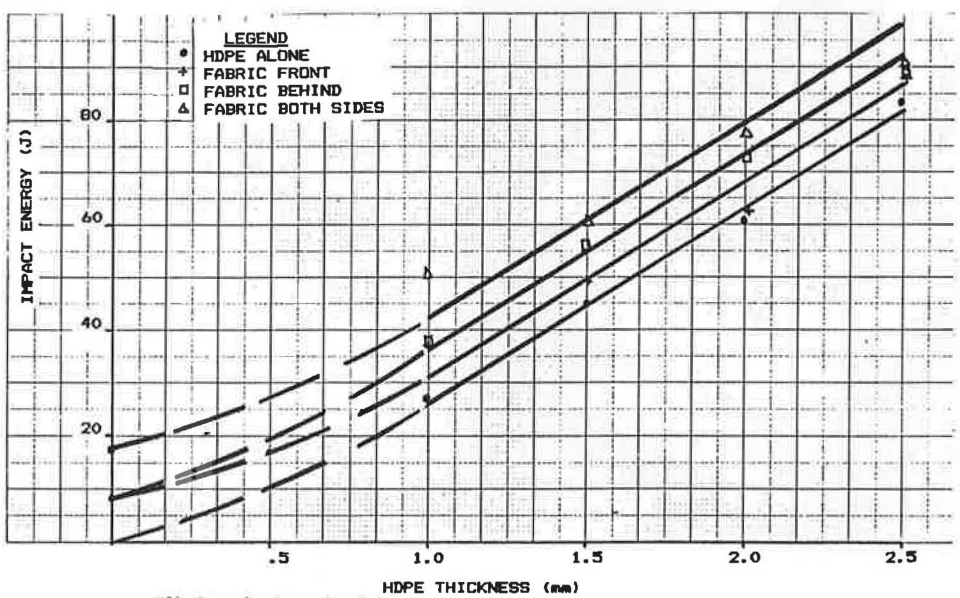

Fig. 10 - Impact test results of geomembrane thickness by itself versus various geotextile-geomembrane combinations