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Discussions: Testing and materials

• QUESTION TO KARUNARATNE

Q : E. Gartung
(LGA Nurnberg, Germany)

Mr. Karunaratne, you presented very interesting particularities of testing methods for the determination of some index properties of jute. Is it in general possible to apply the standards which have been developed for testing of synthetic geotextiles to the testing of jute, or do we need a special set of testing standards for natural fiber reinforcement?

A : G.P. Karunaratne
(National University of Singapore, Singapore)

We have found the standards for synthetic geotextiles to be applicable to jute, in general. Some variations found with jute were the aspect ratio and the strain rates specified for synthetics. These need not necessarily apply to jute as shown in the paper.

• QUESTION TO DATYE

Q : E. Gartung
(LGA Nurnberg, Germany)

In some Asian countries there is a long tradition in the application of natural materials for earth reinforcement. Now, Mr. Datye presents a modern system of engineered earth reinforcement. Is it possible to exercise a quality assurance programme for the natural reinforcing materials equivalent to the quality control of geosynthetics, or does the application of natural materials remain primarily an art- and craftsmanship based construction method?

A : K.R. Datye
(Consulting Engineer, India)

I should say that our position is not well defined with regard to geotextile material but I see no reason why the experience of using jute for bagging, with regard to its fiber properties, could not be used. Then I would like to emphasize that the durability point remain as far as the small diameter and thin fibers are concerned. I think that at this stage we would rather use comparatively heavy materials for example wood and bamboo on which there is sufficient experience. Relating to the standardization of the material we will have to go back to timber engineering practices.

• COMMENT

K.C. San
(University of Delaware, U.S.A.)

The use of low cost natural biological material in civil engineering, such as weed and bamboo, has its potential to develop under the modern technology, with both economical and environmental interests. For example, if bamboo can be used as a construction material, the demand of the use of timber could be reduced. More forests could be preserved. Some research works of weed and bamboo reinforcements, which have been done more than 30 years ago, are discussed.

The manufacture and engineering properties of the weed reinforced hollow brick were described by San(1958). He also provided the study of environmental impacts, such as chemical properties, water content and temperature of the top soil, on the growth of the weed. The physical and mechanical properties of the weed reinforced hollow brick were analyzed. It showed that the unit weight of the weed reinforced hollow brick was about 20% of that of the conventional brick. The coefficient of conductivity of heat was about 10% of that of the conventional brick. The purpose of the use of the weed reinforced hollow brick was not for the structural wall, however, it was strong enough to be used for the non-structural wall.

Several case histories of the application of bamboo pile were studied by San(1959). The structure, durability and bearing capacity of the bamboo pile were described. He gave an example of bamboo piles used in Vietnam which were in good condition after 60 years. He also provided equations to calculate the bearing capacity of the bamboo pile. Field test of about 40 bamboo and timber piles were performed. The analytical calculation of the bearing capacity, being based on the proposed equations, agreed the test data very well. The ultimate load of the bamboo pile of 4m long length was found to be about $25x10^3 kN$ comparing with $40x10^3 kN$ of the timber pile with similar diameter and length.

Bamboo can be used as reinforcement in reinforced soil and reinforced concrete. Some research results on the durability of bamboo reinforcement were described by San(1960). The bamboo reinforced concrete was used in China about 80 years ago and bamboo reinforced soil was used in China about 500 year ago. The tensile strength of bamboo reinforcement is about $13x10^8 kN/m^2$. Factors causing damage of bamboo reinforcement were analyzed. Methods to prevent such damage and to improve the durability of bamboo reinforcement were also provided. For example, the reduction of water content of the bamboo reinforcement to a certain level could be usefully to prevent the decay of the bamboo reinforcement by biological agents.

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• QUESTION TO AKAGI

Q : E. Gartung
(LGA Nurnberg, Germany)

Mr. Jailloux expressed his concern about the durability of the fine, randomly distributed polyester yarns in the cement treated soil, because polyester can undergo processes of hydrolysis in alkaline environments under certain conditions. In this context it would be interesting to know whether calcium ions of the cement can easily be mobilized. Did you determine the pH or the Ca^{++}-content of the water during your permeability tests before it entered the test specimens and after it was discharged?

A : T. Akagi, T. Ishida and S. Okawara
(Toyo University, Japan)

In response to Mr. Jailloux's question regarding degradation potential of polyester yarn in an alkaline environment created in a soil mixed with cement, we regret to report that we took no measurements of pH values nor Ca^{++} contents of water contained in our cement-treated specimens.

In regard to the degradation due to alkalinity, however, we have the following data furnished by the manufacturer of the polyester yarn we have used in our experiments:

After polyester threads were immersed in a 10% NaOH solution having a pH value exceeding 14 at a temperature of 95°C for 20 hours and 100 hours, the tensile strengths decreased to 50-70% and to less than 50%, respectively, of the original strength. Also, when the threads were soaked for 100 hours in a 95°C suspension saturated by Portland cement having a pH value of approximately 12, the tensile strength reduced to 50-70% of the original strength. Similar results were obtained when they were soaked for 15 hours in the same suspension at 180°C.

Thus it is apparent that this type of polyester yarn could deteriorate substantially if it is exposed to such extreme alkalinity conditions at high temperatures. It is unlikely, however, that the same degree of deterioration would result under the conditions in which we have used the yarn.

It has been reported by Halse, et. al.(1987) that some types of polyester nonwoven fabrics may lose strength to a degree comparable to the above test results even in solutions having lower pH values of 10 and 12, but the degree of deterioration may vary widely from fabric to fabric, falling in a range between 0 and 53%.

We will look into this problem of possible degradation of the polyester yarn under environments of relatively low alkalinity, but have to point out that there is another aspect of the problem, i.e., how much strength should the yarn retain to remain as an effective reinforcing element of a mass of yarn-reinforced sand?

In fact we have observed no threads being cut off when any of our specimens undergo large displacements exposing threads and pulling them apart. In other words, polyester yarn remains strong enough to withstand tensile stresses and it is the sand that fails long before the polyester threads might possibly be sheared off.

Since our interest lies in the improvement of yarn-reinforced soil by adding only a small amount of cement, say, 1-2%, we feel that possible degradation of the polyester yarn under normal field conditions would not go beyond a tolerable limit and some significant improvement will be attained in terms of the overall strength and durability of the cement-treated and yarn-reinforced sand. We will, however, look into this to see if it is indeed the case.

In response to Mr. Gartung's comment on how to mix a small amount of cement with sand, we propose the sand be premixed with cement thoroughly before it is brought to the nozzle and mixed with yarn at the site. It is important to ensure that cement is distributed in sand as uniformly as practicable particularly when only a small amount is to be added.

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Halse, Y., R. M. Koerner & A. E. Lord Jr. 1987. Effect of high alkalinity levels on geotextiles. Part 2: NaOH solution. Geotextiles and Geomembranes 6:295-305

• QUESTION TO JAILLOUX

Q : E. Gartung
(*LGA Nurnberg, Germany*)

Mr. Jailloux, the metal reinforcement of the system Terre Armee consists of galvanized steel. Do your statements concerning corrosion resistance and service life time refer to the zinc coating only, or do they include the resistance of the steel ?

Another questions that is often asked in connection with earth reinforced structures where the reinforcement consists of geosynthetic material, refers to damage during installation. When you exhumed steel reinforcements of Terre Armee, were there any indications of damage during installation?

A : J.M. Jailloux
(*Terre Armee Internationale, France*)

The testing program conducted by Austin (1992) provides data that describe the temperature ingress in a concrete panel subjected to fire for half an hour. The author relates that the polyethylene geogrid, embedded in concrete at a distance of about 90 mm from the heated surface, experienced a temperature of 32 °C at the end of the test. We have raised concern about the temperature increase after the panel is removed from the furnace because the heat accumulated in the panel will dissipate slowly. If the temperature at the facing decreases rapidly, the accumulated heat will continue to progress through the panel and increase the temperature well beyond the values recorded after only 30 minutes.

Segrestin (1988) showed how to compute temperature in soil or in concrete. We have used the calculation tools developed on that occasion to determine the shape of the temperature vs. time curves at different depth in the concrete. The figure 1 shows the results obtained. At a distance of 90 mm, the temperature reaches 100 °C 30 minutes after the panel is left to cool in air at 14 °C. This is much higher than the 32 °C recorded at the end of heating; note that this value is obtained also by calculation. It would have been very interesting to perform the mechanical tests on the reinforcing geogrids while the panel was heated. Testing after everything has cooled down is not very useful since in a real structure the tension will remain during the fire.

The figure 3 presented in Austin's paper shows also an interesting feature when comparing the evolution of temperature at 25 mm and 50 mm (and not 30 mm as written in the figure). We think the variation in the rates can be explained by the build up of a crack that reduced the transmission of heat. The state of the panel was not clearly reported in the paper although it says "*During the fire test limited spalling of the heated face occurred, as expected*"; Looking at the results, the spalling might have affected several centimetres of concrete.

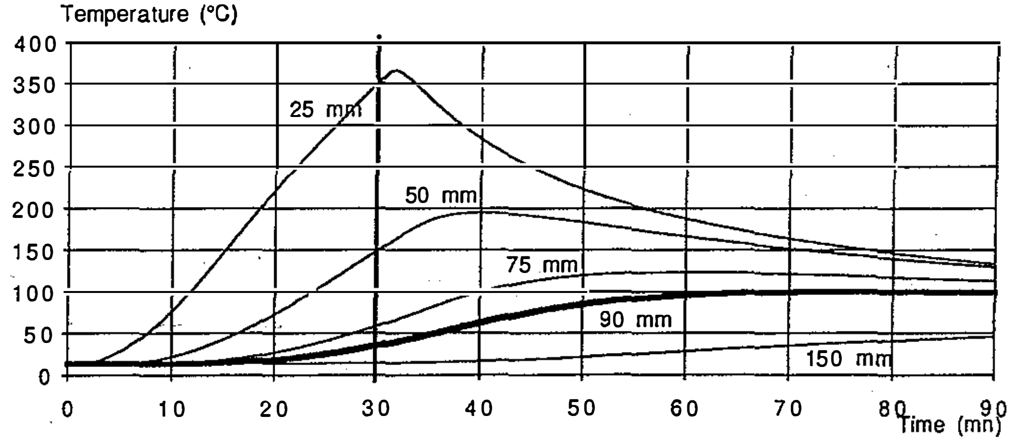

Fig. 1 Computed temperatures at different distances to the facing in a 150 mm thick panel.

In conclusion, the experiment presented by Austin suffers lack of realism. We believe the designers are wise to remain "*cautious about using polymeric reinforcement materials where there is a possibility of the finished structure being subjected to accidental fire damage*".

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• COMMENT

J.G. Collin
(Tensar Earth Technologies, U.S.A.)

There are several misleading statements made by the authors of this article that need clarification. First, the Geosynthetic Research Institute GRI test standard GM-5 is an index test for unoriented polyethylene geomembranes. The test is run at 50°C in a surfactant on notched, 20% of depth of samples (not 30% as conducted in this study) . The test does not provide information on the long-term performance of the material being tested but rather provides a means of comparatively ranking different geomembranes. Long-term performance is predicted through long-term creep tests at stress level well below those conducted by the authors.

Type 1 Specimen Test Results - the tests conducted on the type 1 specimens only failed one sample at the notch, the failure mode of this sample was ductile. All other samples failed in the vicinity of the clamp, where a hole was drilled in the transverse rib, all failures at the clamp should be disregarded as anomalies due to the testing set up.

Type 2 Specimen Results - The authors chose to drastically alter the geometry of the geogrid for this series of tests. 90^0 corners were cut into the geogrid at the transition from the longitudinal rib to the transverse rib. This altering of the engineering geometry of the geogrid substantially altered its performance. In material science it is a well known fact that 90^0 corners create stress concentrations that can result in increases in stress of 2 to 3 times. This in addition to the hole drilled through the node for clamping (Figure 1) are the reason failures occured in the type 2 specimen.

Finally, high density polyethylene has been used in critical application such as plastic pipe for

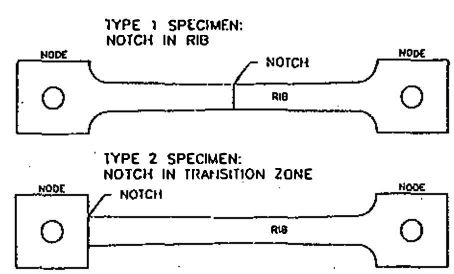

Figure 1

natural gas distribution since the 1950's. Many advances in the polymer science have occurred since this time including the development of engineered resins which were developed specifically to resist stress cracking. Tensar structural geogrids are manufactured from such a resin.

A better indicator of long-term performance is long-term creep testing (10,000 hours) conducted at both in service and elevated temperatures. Through well known extrapolation procedures developed by Jewell and Greenwood performance of high density polyethylene geogrids can be established with confidence.

A rupture curve for the actual geogrid structure could be developed from creep tests however, at the design stress levels rupture of the geogrids would not occur within 100 years (Figure 2).

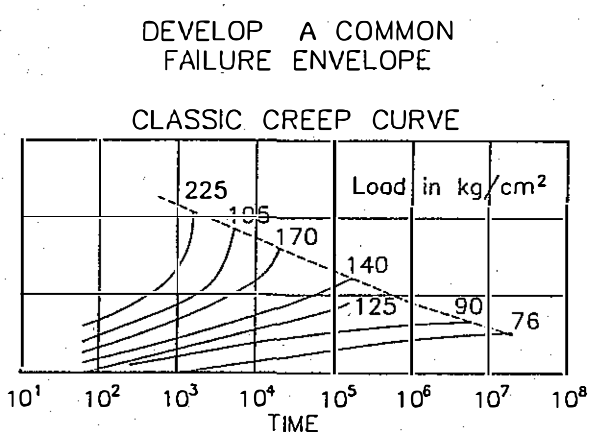

Figure 2

• COMMENT

G.W. Won
(Roads & Traffic Authority, Australia)

The Roads & Traffic Authority (NSW) has been monitoring the long term corrosion durability of a Reinforced Earth structure built some 14 years ago on the Parramatta Bypass west of Sydney. This structure was the fifth such RE wall to be built in Australia at that time and represents possibly the only wall where a long term corrosion monitoring program has been initiated.

Table 1
Soil properties of Parramatta By-pass Reinforced Earth wall

	Average (SPT samples)	Range (all samples)
Resistivity (ohm-cm)	3010	2070 – 3400
Moisture Content (%)	12.7	8.0 – 15.5
pH	8.8	8.7 – 9.5
Salt content (ppm)	nil	nil
Soluble salts (ppm)	0.11	0.078 - 0.133

At this location the wall height is 6 metres and is subject to expressway traffic surcharge. The wall has a total face coverage of 2300 square metres. Backfill consists of compacted crushed sandstone and clayey sands. The soil properties for the RE wall are given in Table 1.

The condition of the backfill with respect to resistivity could be described as only slightly aggressive and comply with the electrochemical requirements for select fill for RE structures. The cohesion and friction for the material from direct shear tests is 4 Kpa and 41 degrees respectively.

During construction 36 galvanised test strips were incorporated behind the wall panels to monitor the effect of corrosion on the tensile strength of the tie strips. These strips comprised 12 ribbed, 12 plain, 12 bitumen coated with lengths 1.5 metres.

In May 1992, a total of 9 strips were extracted from the wall (3 ribbed 3 plain and 3 bitumen coated) for examination.

The tests strips are in very good condition, their protection coming from a sacrificial layer of zinc galvanizing, which has deteriorated only slightly and appears to be corroding uniformily. This zinc layer has been examined under the microscope and chemically tested. Both analysis showing a current thickness of zinc averaging 103um for the ribbed strips and 38um for the plain and bitumen coated strips.

In conclusion, the remaining life expectancy of the remaining test strips and tie strips is estimated to be of the order of 150 to 200 years.

This case supports the information presented in Section 6.3 of the paper entitled " Twenty five years of corrosion control in RE Structures " by Messrs M.J. Bastick & J-M. Jailloux in respect of a suggested corrosion monitoring interval of 15 years for better quality backfills.

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• COMMENT

H.I. Ling and F. Tatsuoka
(University of Tokyo, Japan)
J.T.H. Wu
(University of Colorado, Denver, U.S.A.)

The first discusser directed the question to Dr. Yeo (McGown et al., 1992) regarding in-soil test (McGown et al., 1981, 1982) for obtaining the tensile properties of geotextiles under stress-confinement condition. The similar question was also directed to Prof. Rigo related to European Standard on the in-soil test (Rigo and Delmas, 1992).

The discussers believed that the so-called 'in-soil test' (Figure 1), as proposed by McGown et al. (1981, 1982), is not the proper test for measuring confined tensile properties of a geosynthetic in typical operational conditions of a reinforced soil structure. In this sophisticated apparatus, a geotextile specimen was confined with soil on both sides using two air pressure bellows enclosed in the metal cases. Tensile load was applied by pulling one end of the geotextile specimen with relative to the confined soil while the other end was fixed. The soil used to confine the geotextile was kept stationary, and therefore, its tensile strain would not be mobilized unless the shear resistance at the soil-geotextile interface has been overcome. As a consequence, the measured load was a coupling effect of the following three components:

1. tensile load in geotextile under confinement condition,
2. shear resistance between the soil and the geotextile,
3. tensile load of the soil and the rubber membrane.

Therefore, the measured tensile properties (stiffness and strength) should be regarded as overestimated values, which are generally unsafe for design of reinforced soil structures. Moreover, even if component 3 can be subtracted from the measured value, the shear resistance (component 2), whose magnitude and distribution are nonuniform over the whole length of the geotextile specimen, is very difficult if not impossible to be evaluated correctly.

Unfortunately, the 'in-soil' test as proposed by McGown et al. (1981, 1982) have misled many researchers, who attempted to duplicate a similar apparatus (e.g., Nishigata and Yamaoka, 1989; Kokkalis and Papacharisis, 1989, among others). The simulation by this apparatus is in contradiction to the actual mechanisms of load transfer from the soil to the geotextile in the reinforced soil structures. The discussers would suggest the designer to using the unconfined tensile properties of geotextile, obtained by testing a specimen with an adequate aspect ratio, instead of those obtained by such an 'in-soil' test.

However, a new testing procedure has been devised for measuring the confined tensile properties of geotextiles under typical operational conditions (Wu, 1991; Ling et al., 1991, 1992). It was briefly summarized following this written discussion.

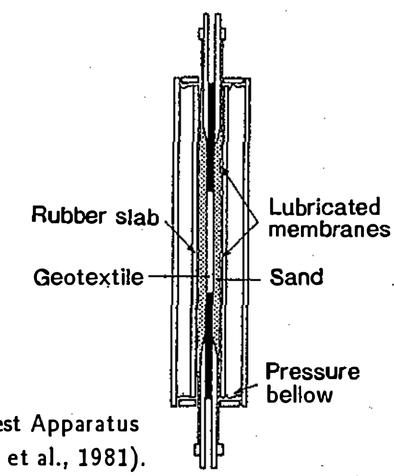

Figure 1.
In-Soil Test Apparatus
(McGown et al., 1981).

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• COMMENT

H.I. Ling and F. Tatsuoka
(University of Tokyo, Japan)
J.T.H. Wu
(University of Colorado, Denver, U.S.A.)

A new testing procedure has been proposed by the discussers to measure the confined tensile properties of geotextiles under typical operational conditions in a reinforced soil structure (Ling et al., 1991, 1992; Wu, 1991). This test apparatus (Figure 1) allowed the soil to serve only as the purpose of confinement under a prescribed confining pressure, without inducing any shear resistance between the soil and geotextile by maintaining a compatibility of strain between the soil and geotextile during testing. Tensile load was applied by pulling the geotextile and soil, which was enclosed in a rubber membrane, as in the conventional triaxial extension test. Moreover, a separate extension test on soil enclosed with rubber membrane was performed under otherwise identical conditions so that its tensile load can be subtracted from the measured value for obtaining actual confined tensile load applied to the geotextile. An aspect ratio of 8 was used to avoid significant necking of the geotextile specimen in unconfined and confined conditions.

For a soil-confinement test, it has been shown that confinement effect increased the strength and stiffness of the needle-punched geotextiles, but not the heat-bonded geotextiles (Figure 2). However, the test results given by McGown et al. (1982) showed significant effect of soil-confinement on the heat-bonded geotextile, which was actually due to the shear resistance between the soil and geotextile in their in-soil testing method. Such a testing procedure overestimates the tensile stiffness and strength of the geotextile, and therefore, should not be recommended for obtaining the parameters for the design and analysis of reinforced soil structures.

Similar tests have been performed using the discussers' test apparatus in which a geotextile specimen was confined directly by a rubber membrane without presence of the soil. It was shown that the membrane-confinement

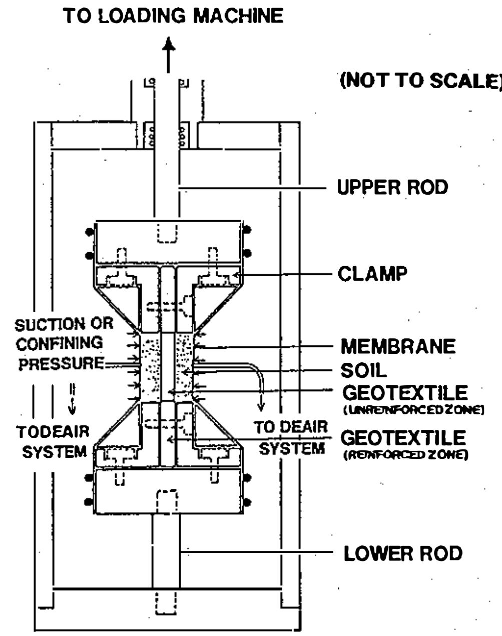

Figure 1. Soil-Confinement Test Apparatus

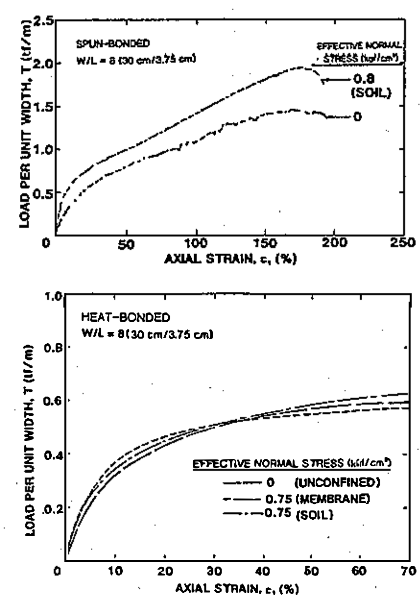

Figure 2. Effect of Stress-Confinement on (a) Needle-Punched and (b) Heat-Bonded geotextiles

test yielded a close result as the soil-confinement test (Figure 3). Therefore, for the purpose of measuring the confined tensile properties of geotextile, the material used for confinement, whether it is soil or membrane, should not render significant differences in the result if a true confinement test has been performed.

Membrane-confinement test is a more convenient test to be performed, and it is regarded as superior alternative to the soil-confinement test. It is highly recommended for purposes of specifications. The discussers

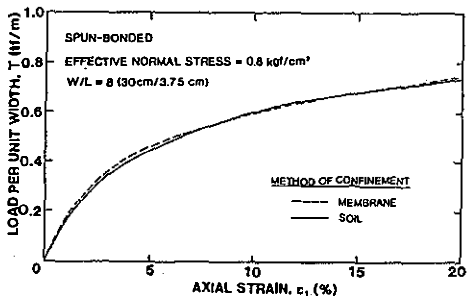

Figure 3. Effect of Stress-Confinement using Soil and Membrane

believe that it should be adopted by the geotextile manufacturers for supplying the confined tensile properties of pressure-sensitive geotextiles.

REFERENCES:
(see the discussers' preceding written discussion)

• QUESTION TO WHITTLE

Q : E. Gartung
(LGA Nurnberg, Germany)

Mr. Whittle, from your presentation I understand that the APSR cell is a very interesting device for the study of stresses that develop in geosynthetic inclusions in soils under deviatoric states of stress. Is it possible to use the APSR cell for the study of geomembranes in contact with cohesive soils under stress conditions which occur below the slopes of solid waste deposits?

A : A. Whittle
(Massachusetts Institute of Technology, U.S.A.)

In principle, it is possible to perform these types of test. The APSR cell can indeed be used with cohesive as well as cohesionless soils, and we are currently performing tests on different classes of geosynthetics. In practice, the use of cohesive soils will require some modification of the current test procedures which we have not yet fully assessed. The long term interaction of the geomembrane and clay liner can also be studied through computer controlled creep tests in the APSR cell. However, we have much work in our current research agenda prior to tackling these time consuming tests.

Q : E. Gartung

One set of tests that interest me very much, if it is possible by this device, to determine the tensile stress in a geomembrane below a slope we have a deviatoric stress state and there must be some effect on the geomembrane. The geomembrane should not act as a reinforcing membrane, but how do we know that it does not. Can we test that in your device?

A : A. Whittle

Yes, it is definitely possible to perform these tests. In fact, we did initially plan to make measurements of load-transfer for HDPE sheets. However, the complex material behavior of HDPE makes the interpretation of these tests very difficult. Instead, we are currently focussing on the load-transfer of Nylon-66 sheets, which have a well defined linear range of behavior. If these tests are successful, we then begin work with HDPE liner materials.

Q : E. Gartung

You mean the phenomenon that such tests can be done but you don't use the geomembrane that we use in construction?

A : A. Whittle

We are currently using materials which have simple, interpretable deformation properties. In the future, we hope to use some of the material products used in practical applications, such as HDPE, which have more complex time dependent response.