Closing
Reports

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Report on Sessions 2A, 3A, 4A, and 5A Drainage

Rapport des sessions 2A, 3A, 4A, et 5A Drainage

Thirty one papers originating from ten countries were presented in the four sessions on drainage. These papers can be grouped into three categories: reports on investigated in situ applications, analysis of results obtained in laboratory research programs and proposed flow models and filtration criteria. The property of non-woven geotextiles mostly investigated was the transmittivity of fabrics. It was well established that this property offers drainage capacity very useful in geotechnical applications even when the geotextiles are under compression. In this paper, I will report on the presented papers: the investigated in situ applications, the drainage capacity offered by non-woven geotextiles, results obtained in laboratory test programs. Finally I will underline fields into wich more investigations are needed in the future.

Trente-et-un articles ont été présentés lors des quatre sessions sur le drainage et ils peuvent être regroupés en trois catégories: des rapports sur l'examen de travaux accomplis, des analyses de données obtenues en laboratoire et enfin des critères de filtration proposés. Cependant, la transmittivité des géotextiles non-tissés a été certainement la propriété la plus étudiée et discutée. Il a été démontré que cette propriété peut être utilisée dans plusieurs applications en géotechnique même lorsque les géotextiles sont soumis à des compressions importantes. Dans cet article, je présenterai les articles en fonction des applications examinées, des mesures de la capacité de drainage des géotextiles, des résultats obtenus en laboratoire et finalement je soulignerai les domaines qui devront être étudiés dans l'avenir.

From all geotextile functions, filtration and drainage capacities of synthetic fabrics to be used in geotechnical applications are certainly the most utilized. But more important for the engineers is the guarantee that following the installation of a geotextile in a work their properties can be conserved and that blocking or clogging of the fabrics do not alter their original values to such an extent as to offer unsafe conditions. Because of the lack of knowledge in geotextiles' behaviour in contact with soils of different nature, scientific investigations were performed in laboratories to simulate filtration and drainage applications and in situ examinations of installed geotextiles were done. Innovative designs were developed to optimise their utilization in many applications.

Most of the presented papers in the drainage sessions fall into one of these categories. As shown on Figure-1, 31 papers were presented originating from 10 countries. Eight of the papers were reporting in situ investigations, twenty papers were analysing laboratory test results while the other papers presented empirical and theoritical analysis to obtain filtration criteria and flow models. Finally, a paper indicated psychological hang-ups to overcome.

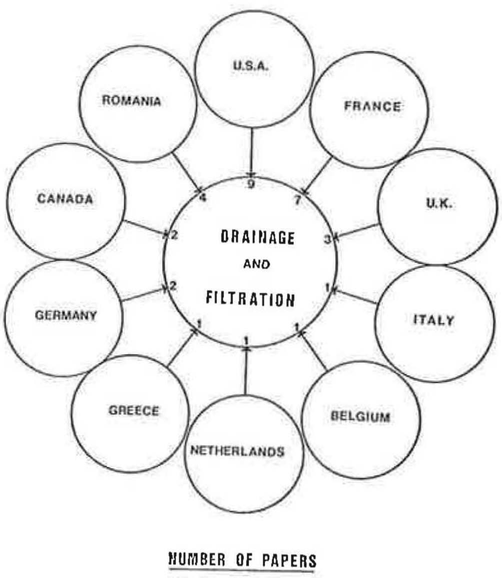

Fig. 1 Number of papers presented in the drainage sessions.

IN SITU APPLICATIONS INVESTIGATED

As shown on Figure-2, eight papers were presented on the analysis of geotextiles' behaviour in applications. These investigations covered most of well known applications such as vertical drainage, trench drains, ponds, depth drains, fin drains, protection of geomembranes and seadikes and inland waterways.

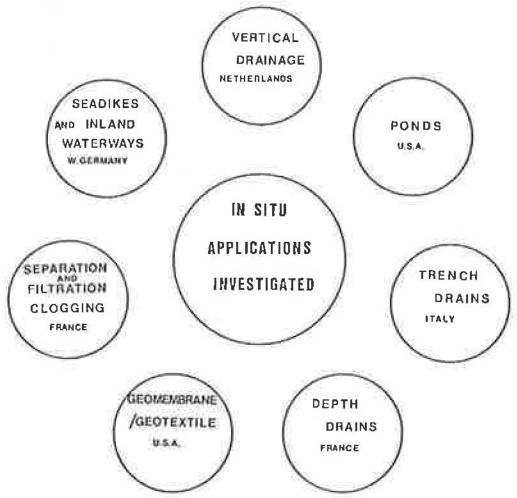

Fig. 2 In situ applications investigated.

The behaviour of five types of prefabricated vertical drains have been compared and the results indicated large differences of behaviour amongst the functionning of the drain in the tested areas (DE JAGER). Further analysis of these results is needed to indicate wich properties of the drain materials have resulted to the observed differences in behaviour.

Withdrawn samples of geotextile and surrounding soil from a trench drain was performed after 30 months of utilization (CANCELLI). The analysed samples indicated only slight variation in the permittivity and transmittivity of the contaminated geotextiles and that a cake was formed upstream of the fabric with the coarser soil particles adjacent to the geotextile.

Both field and laboratory tests were conducted on geotextiles used as an underlining of geomembranes in pond construction to insure puncture protection, gas release and abrasion resistance (COLLINS). It was found that thick non-woven geotextiles in a weight range of 400 to 600 g/m^2 provided a satisfactory behaviour.

From field experiences, it was shown that design of geotextiles associated with geomembranes used for ponds, canals and dams do not have the drawbacks of granular materials (GIROUD). Several examples are presented to illustrate how to use properly geotextiles to alleviate effects of underpressures and mechanical actions

A ten meters depth drain along a motorway was achieved in saturated clays and technical checks were performed after four months of performance (PUIG). The results indicated good efficiency of the drain and no disturbance in the protected slopes.

Laboratory testings were performed to examine the hydraulic flow and filtration properties of fin drains to be used in ground and structure drainage (HUNT). It was found that fin drains, constituted of a plastic core and a synthetic fabric, were capable of meeting the demands for structure drainage.

Intensive field investigations on long-term behaviour of geotextiles in coastal structures were carried out and geotextiles were dug out after many years in function (HEERTEN). Their filtration properties were measured. It was found that a great amount of soil particles were incorporated into the non-woven fabrics and that the thickness of the fabrics increased when compared to the thickness of these fabrics after the soil particles were washed out (90% of soil particles could be removed from the washing procedure).

Clogging of several geotextiles dug out of geotechnical works after 12 years of installation was analysed using a morphological approach (SOTTON). Three types of clogging have been defined and it was found that agglomeration of fibres in a geotextile structure constituted clogging sites. More important are the obtained photographs (shown in the paper) that suggest different soil particles level of attraction to fibres depending on the polymer and their surface treatment.

RESULTS OF LABORATORY TEST PROGRAMS

Results of laboratory investigations were analysed and presented in twenty papers. These research programs can be grouped under many filtration and drainage behaviours, as shown on Figure-3, such as permittivity and transmittivity measurements, fin drain flow behaviour, clogging mecanisms, pore size characterization, filtration of suspended soil particles, siphon ability, hydric properties and others.

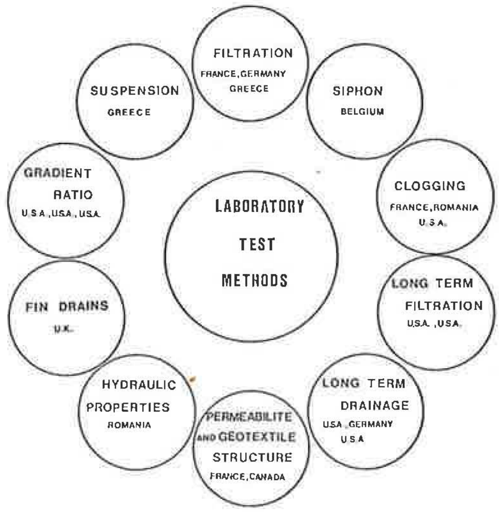

Fig. 3 Laboratory test programs

An experimental investigation indicated that in some circumstances, some types of geotextiles can perform in a siphon function (GAMSKI). The conditions are discussed and laboratory test apparatus are described. More work is needed.

Experiments were conducted in a design laboratory apparatus to assess the solids removal efficiency of geotextiles in filtration of suspension of Kaolinite and Grundite particles (ATMATZIDIS). A filterability index, used to measure mass removal efficiency, indicated poor behaviour as fabrics for filter systems.

A second study of use of fabrics as filtering elements was presented (KELLNER). It was found that many of the geotextiles used were manifesting a susceptibility to retain fines due to the action of electrochemical forces.

Long term filtration tests were performed in many laboratories (KOERNER, LOUBINOUX, RYCROFT). It was found that the initial flow of water through the system soil/fabric is governed by the soil but that the final range is governed by the soil/fabric interaction. The minimum time required for such tests varies from few hours to hundred of hours depending on the nature of the soil. Also, depending on the experiments performed, the permittivity deacreases were negligeable to very important as a function on the silt and clay content of soils. But more important is that the permittivity decrases rapidly in the initial stages of the filtration to level off with filtration time.

Studies of clogging of geotextiles using gradient ratio test method were performed (HALIBURTON, KOERNER). Gradient ratio values were found to increase rapidly with increasing soil silt content such that there is no unique value of gradient ratio.

The mostly investigated properties of non-woven geotextiles were the transmittivity and the permittivity under compression (RAUMANN,LOUDIERE, ANDREI, IONESCU, GOURC, ROLLIN,McGOWN, KOERNER). It was found that these properties vary slightly with an increase of compression ranging from values of 0 to 1000 kPa and that the load influence becomes negligeable for values greater than 200 kPa. As shown on Figure-4, the transmittivity varies more than the permittivity such that both properties are reaching similar values at high compression level. On the other hand, structure analysis of compressed non-woven fabrics indicated that the distance between fibres decreases dramatically from average value of 140 μm at 25 kPa to value of 40μm at 800 kPa. These findings are suggesting different filtration behaviour of geotextiles under compression (clogging levels, particle size retention, ...).

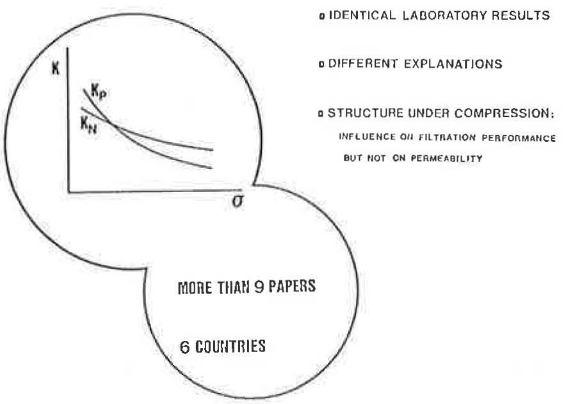

Fig. 4 The field the most intensively investigated

Pore size characterization was also a field investigated by many researchers (FAYOUX, ROLLIN, HALIBURTON, ANDREI, LOUDIERE, GOURC, McGOWN). Except for direct measurement obtained with the Image Analyser, various wet and dry sieving techniques have been developped. The data obtained " are not entirely consistent but can provide an approximate estimate of largest pore sizes of geotextiles in uncompressed state " (McGown).

PROPOSED FLOW MODELS AND FILTRATION CRITERIA

Models to represent the flow of water through geotextiles and filtration criterion were proposed by many authors (PUIG, GOURC, ROLLIN, FAYOUX, WITTMAN, GIROUD, TAN, IONESCU, RAUMANN, McGOWN).

The mostly used filtration criteria were basically a comparision between the O_{95} of the pore histogram of a geotextile to the uniformity coefficient and density of the soil as a retention criterion and also to insure that the permeability of a geotextile is greater than the permeability of the soil. It should be noted that on the other hand many other criteria were used through out the presented papers such that it becomes clear that more work is needed in this field.

The influence of size of fibres on their hydraulic characteristics was determined from analysed models and corraborate from laboratory experiments (FAYOUX).

It was also shown, that the permittivity and the transmittivity of geotextiles could be calculated from the fabric porosity, the fibres' shape, the fibres' density and the polymer specific mass (RAUMANN, GOURC, ROLLIN).

It was also indicated that the flow through a geotextile should not be assimilated to flow through a soil both materials being structuraly different.

Finally, a model was developped to predict earth fills consolidation using fabrics (AURIAULT).

FIELDS TO BE INVESTIGATED IN THE FUTURE

Following the study of the presented papers in the drainage sessions, it becomes apparent that in some areas more investigations are needed to understand the soil/fabric behaviours.

FILTRATION CRITERIA

Because of the many filtration criteria proposed and used, it is believed that the cake formation as well as the retention of particles are resulting from mecanisms that are influenced by the geotextile structure and the soil granulometry and nature. Also, it is now well recognised that geotextiles retention of particles and their resulting clogging level vary greatly upon the state of the system soil/fabric . A system sollicitated by dynamic hydraulic conditions (cyclic systems, suspended particles, flow in both direction,...) behaves differently than one where a stabilisation of the soil has happened and where the hydraulic sollicitaions are continuous. All these situations suggest that filtration criteria must be different.

PORE SIZE CHARACTERIZATION

Decrepencies observed between results obtained from wet and dry sieving techniques utilised suggest that an investigation should be done to gather and analyse these results to try to corrolate them with actual geotextiles' structures. This is a very complex problem because the ability of particles to pass through thick non-woven geotextiles for example is function of the distance between fibres and the thickness of the fabrics, the electrochemical forces between the soil particles and the fibres, the fibres' surface treatment, the nature of the soils, and many other factors. It should be noted also, that these sieving methods are applicable only to geotextiles under uncompressed state. To what extent can the obtained results be applied to fabrics installed in geotechnical works where the fabrics are under appreciable loads?

COMPOSITE GEOTEXTILES

In recent years, more and more composite fabrics are used for specific needs in civil engineering works. They are constructed of a) two or more layers of different fibres with varying diameter, b) woven fabric incorporated in non-woven structure, c) non-woven fabric thermically treated or strenthed with chemical bounding agents and d) others. Very few investigations were performed on these geotextiles to forecast their filtration behaviours.

OTHERS PROPERTIES TO INVESTIGATE

The wettability of geotextiles should be investigated to determine the critical water head needed to insure flow of water through fabrics. This property is critical in many drainage works.

The siphoning ability to transport water within the plane of some geotextiles from capillary effect is very important in some applications.

Long term filtration and drainage experiments must be done with soils very hazardeous in order to establish " le bien fondé " of using geotextiles in these cases. Also in many applications, the installation procedures must be performed with great care to protect the work such that more experiments must be performed on filtration of suspended particles.

Finally, as indicated in CEDERGREN paper, emphasis should be given to overcome psychological hang-ups by publicizing the necessity of using fabrics to increase drainage capacity of civil engineering works using well documented case studies.

These fields to investigate and others are schematically represented on Figure-5.

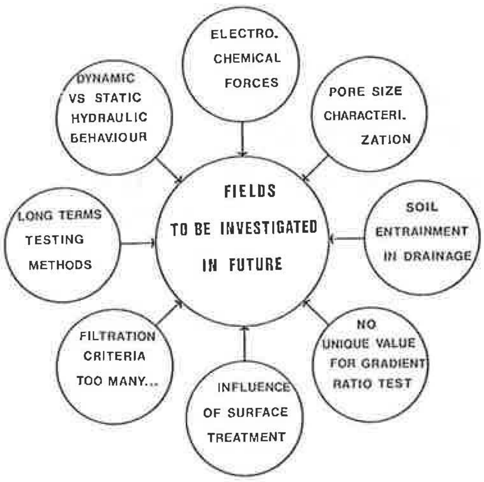

Fig. 5 Fields to be investigated in the future.

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Report on Sessions 6A, 7A, and 8A Dams and Erosion Control

Rapport des sessions 6A, 7A, et 8A Barrages et contrôle de l'érosion

INTRODUCTION

One session at this Conference was devoted to dams and two sessions to erosion control, with a total of 18 papers in these. Of these, 12 papers described various aspects of major permanent works whilst 6 papers were devoted to field trials. The types of projects covered were dams, tailing dykes, temporary dykes in the form of "super sandbags", canal bank linings, scour protection in harbours and land reclamation works, control of wind erosion of sand and lastly, surface water erosion of slopes. This exemplifies the large range of problems in which geotextiles are now being used and the wide geographical distribution of the various works described also illustrates the growing awareness of the potential for geotextile usage all over the world.

In the following sections of this report, I shall briefly summarise the papers in the various sessions and identify some of the main points made in them. On the bases of these points, I shall attempt to draw some overall conclusions from this part of the Conference and make some recommendations for future work in these areas of geotextile application.

SESSION 6A - DAMS

The papers by BENTAL et al and SCHEURENBERG described the use of geotextiles within drains incorporated in tailing dykes in South Africa. Both highlighted the problem of ferrous compounds in the groundwater becoming oxidised near the surface and ferric precipitates then forming on the geotextiles with consequent reduction in their hydraulic conductivity. Apart from this one problem, both reported satisfaction with the use of geotextiles and indicated that drains which included them were chosen as they represented the cheapest and simplest method of construction. Much of the paper by HAAS indeed dealt with the subject of selection and use of geotextiles in tailing dykes. At the end of it he sets out a very useful check list for this in which he emphasises the need to modify construction procedures and choose appropriate construction plant for dykes in which geotextiles are employed.

The papers by LIST and LEDEUIL both dealt with dam projects. In the cases they reported, the use of geotextiles allowed various local fill materials to be incorporated which otherwise might not have been. The role of the geotextiles was primarily to prevent piping of water through the dams. Both authors carried out their designs in the mid-1970's and it is perhaps surprising that geotextiles were considered for use in such important structures so early in their development.

BOGASSIAN et al dealt with the use of geotextiles in the form of large cylinders to form low cost temporary dyke constructions in Brazil. They described in detail the problems of filling them and the solution they developed for this.

SESSIONS 7A and 8A - EROSION CONTROL

The use of geotextiles to prevent surface erosion by wind was described in the paper by AURAIT. He stressed the importance of following up the initial stabilisation of the eroding surface with a vegetation planting programme in order to ensure the long term benefits of the works. Such a combination of geotextiles and vegetation for long term slope stabilisation was also recommended by SMOLTCZYK and MALCHAREK but using different geotextiles and plants and in situations where steep slopes were required. SIMON et al also dealt with stabilising the surface of relatively steep soil slopes. In their paper they type of geotextile used was of a relatively new honeycomb construction.

River and canal bank protection was dealt with in four papers. In the paper by COUCH and that by VELDHUIJZEN VAN ZANTEN and THABET the approach to major protection works was described. This involves full scale tests and detailed consideration of the influence of soil types and construction techniques on long term performance. These papers contrast sharply with those of BOTZAN et al and STEPHENSON which both look at the use of sand bag type protection techniques. These are essentially low cost and relatively short term solutions but nevertheless serve a useful function.

GYSSELS discussed in his paper the use of geotextile within conventional willow fascine mattresses to protect the sea-bed against scour on the seaward side of Zeebrugge Harbour in Belgium. This project lies immediately south of the mouth of the River Schelde. The remaining four papers in this section in fact all dealt with the massive Oosterschelde Storm-Barrier Project and in particular with the design, development and application of the scour protection mats used in this project. VISSER and MOUW first gave an overview of the project and the functions of the scour protection mat used within it. DORR and DE HAAN then described in detail the construction of the mat and the gravel bags used to protect the mortar between the massive storm barrier piers and the mat. Next VAN HARTEN described the analysis and testing associated with the mat whilst WISSE and BIRKENFELD dealt with the long term stability of the polymers in the geotextiles used.

DISCUSSION

Emerging from the papers on major projects within these sessions is the fact that they were generally conceived and designed in the mid to late 1970's. Considering that the Paris Conference on geotextiles was not held until 1977 it is surprising that the decisions to use them in such large projects could be made. The amount of technical data on the geotextiles and the availability of design techniques was extremely limited at that time. Perhaps this is why field trials prior to final construction were commonly employed. These field trials also assisted in the development of suitable construction techniques and the identification of the importance of these is one of the major contributions of this session.

Once appropriate construction procedures had been developed many of the authors commented on the ease of construction with geotextiles. A few of the papers on major projects and trials did not go beyond this and did not therefore consider the long term behaviour of the structures. Of those that did consider long term behaviour few identified any major problems. One recurring factor influencing long term filtration/hydraulic conductivity of the geotextiles did, however, emerge and that was the clogging of pores with iron compounds emerging as precipitates on the geotextile close to groundwater surfaces at shallow depths in soil.

The trials reported appeared to have two functions. The first function was to prove the use of geotextiles of fairly standard type in sections of major works prior to the adoption of this form of construction for the entire project. The development of construction techniques appears to be the principal benefit of this. The second function is to demonstrate the use of new geotextiles. Again the development of construction techniques appears to be the main objective of these. In all the cases reported one common feature was the lack of instrumentation to monitor performance.

Taking these various points together suggests that the papers in this section are almost exclusively dealing with the practical aspects of the inclusion of geotextiles in soil structures. Since the projects reported were conceived in the mid to late 1970's, there was perhaps little else to be reported. Few theoretical studies or testing data were available at that time. Thus there is a distinct time gap between the practical work in these sessions and the research and testing work reported elsewhere in the Conference. This is inevitable, but the fact that only in a few of the projects was any attempt made to measure the long-term performance of the soil-geotextile systems, was not inevitable and is certainly not desirable. In view of the novel nature of the form of construction used, the systems' performance should have been monitored. Thus in most of the cases reported it is likely that little warning of possible failures will be available and the causes of such failures will be very difficult to diagnose.

CONCLUSIONS

1. Some massive and high risk projects have now employed geotextiles to perform functions which must be sustained long term. Those projects reported to this Conference date back to the mid to late 1970's and there is therefore little or no use made in these of the research work reported to this Conference. The judgements on which these goetextiles were employed long term were thus based on very limited data.

2. The sessions were dominated by descriptions of construction techniques developed during field trials prior to major works or developed while proving new types of geotextile materials or applications. These all showed that once appropriate construction techniques were identified, construction with geotextiles was usually free from major difficulties. However, few of the trials and full scale works contained instrumentation to monitor the long term performance of the systems built. No major failures were reported and few problems were anticipated, the latter perhaps due to the lack of instrumentation.

3. On the bases of the data presented in the papers and the discussions on these at the Conference a number of recommendations for future development in these areas can be made. These recommendations are as follows:

a) That practising engineers continue to incorporate new construction ideas and materials in their projects after carrying out field trials as so many of the authors to these sessions have done. Only in this way can progress in construction technology be made.

b) International and national groups and associations should promote educational and communications links between researchers and practising engineers to provide the latest technology to the practising engineer at the earliest date possible and thus increase the bases on which practical judgements are made.

c) Failures should be sought out and widely reported. This might be encouraged by having a session on failures at the next conference on geotextiles.

d) That every effort be made to encourage the development of instrumentation to monitor the performance of geotextile systems over long periods of time. The performance of soil-geotextile systems should always be measured against alternative systems and performance assessments should be made in terms of technical performance, capital costs and maintenance costs.

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Report on Sessions 2C, 3C, 4C, and 5C Walls and Foundations, Slopes and Embankments

Rapport des sessions 2C, 3C, 4C, et 5C Murs et fondations, Pentes et remblais

This report covers the papers submitted to and discussed at Session 2C through 5C of the Conference. Session 2C focused on the use of geotextiles in walls and foundations, while the others covered various aspects of slopes and embankments. Several papers reported on properties of geotextile-reinforced soils. In almost every case, the primary function of the geotextile was that of reinforcement, although secondary functions of especially separation and drainage were apparent in some instances.

Of the 28 papers published in Volume III of the Proceedings of the Conference, 23 were presented orally in the technical sessions. In the period following formal presentation, many excellent questions were asked by members of the audience, and in most sessions, the discussion was quite lively.

I have classified the 28 papers into the following four categories. The number of papers primarily in each category is also indicated.

Case Histories (actual working construction or full scale tests): 11

Field Tests: 1

Laboratory Tests (including Model Tests): 7

Primarily Theoretical/Analytical: 9

CASE HISTORIES

In my opinion, the value of a case history to the profession is in the detailed description of (1) a non-conventional approach to the problem, either in terms of the design or the construction techniques utilized; (2) the design assumptions, and (3) verification of the design assumptions. Verification can be either quantitative, that is from field measurements, or it can be qualitative, that is, based on a description of the performance. It was disappointing that a number of case histories presented at the Conference did not adequately consider these three requirements.

Two of the ten case histories were, in my opinion, excellent in all respects, and both involved embankments. The first was the Almere embankment test in Holland (Brakel and co-authors, p. 727), which is a particularly well-documented report of a full scale loading test carried to failure. A companion unreinforced embankment was similarly instrumented and tested. A simple method for calculating the stability was proposed and good agreement with observations was found.

The second well-documented case history was from Mexico (Olivera, p. 625), where two embankment test sections were constructed on peats and other highly compressible soils. In each case, a non-reinforced test section was also constructed as a control. Although specific design calculations are not given, the construction and instrumentation are particularly well described. Results of the measurements and the overall behavior of the test sections suggest that (1) the fabric may have acted more as a separation layer and construction aid rather than strictly as reinforcement; (2) the stress distribution under the embankment was altered by the reinforcement; and (3) the settlements were made more uniform by the geotextile.

Space does not permit a detailed summary of the other case histories, so only a few pertinent comments will be made. Murray's presentation (p. 707) of an innovative slope stabilization technique was an excellent description of the practical execution of the project. He also provided a simple design procedure.

Papers with innovative construction techniques for embankments on soft ground included those by Barsvary, McClean, and Cragg (p. 647), Hannon (p. 653), and Yasuhara and Tsukamoto (p. 635). These authors also gave some useful performance data, while the latter paper described a design method based on model laboratory tests. One anomaly that calls for additional investigation is the decrease in fabric elongations in both directions with time observed by Barsvary, et al. (Fig. 4, p. 649). This phenomenon would seem to be appropriate for a detailed analysis by the finite element method.

The Wolfe and Christopher paper (p. 641), although primarily descriptive, deserves careful consideration by engineers faced with all phases of waste disposal. The subject is of increasing importance in the industrialized world. The paper could have been placed in other conference sessions, as it deals with several geotextile applications besides embankment stabilization.

Most papers on geotextile-reinforced retaining walls were disappointing, because the design assumptions were missing and good follow-up measurements and observations were often lacking. The paper by John and his co-workers (p. 569) described the rather impressive instrumentation of a Websol-reinforced wall. The Websol system appears to be similar to the reinforcement systems of the Reinforced Earth Co. and the York method of construction. It is not clear what function the geotextile itself performs, since it is not attached to the wall face. Coincidentally, the inventor of the York method was Jones (p. 581), who describes the construction of walls reinforced with both geotextiles and geogrids. The large scale retaining wall tests described by Fukuoka and Imamura (p. 575) were well-instrumented and utilized cohesive backfills--but the fabric was used only as the facing. The primary reinforcing elements were multiple anchor "tie backs". Walls with fabric facings were also described by Schwantes (p. 605), but since no design details or measurements were given, the value of the paper to future designers is unfortunately minimal.

FIELD TESTS

It was disappointing that there were not more papers like Hutchins' (p. 617) who used an in situ test, a plate load test, to evaluate the field performance of a geotextile-reinforced embankment. In situ tests are becoming increasingly important in geotechnical engineering practice, and their use to assist in both the design and the evaluation of geotextile performance should also increase.

LABORATORY TESTS

Valuable data on certain properties of cohesive soils reinforced by sands was reported in the papers by Christie (p. 659) and Ingold and Miller (p. 587 and 593). Such data is essential if fills are to be constructed of compacted cohesive soils. Akinmusuru, Akinbolade, and Odigie (p. 599) utilized a natural fiber rope material instead of man-made fibers in model footing tests on reinforced sands. These tests were very similar to some reported by the same authors in the Journal of the Geotechnical Engineering Division, ASCE, June, 1981, and by Binquet and Lee, same journal, Dec. 1975. Because of problems with durability, there is considerable question as to the practicality of using natural fibers as reinforcement for permanent foundation construction.

A rather fundamental study of sands reinforced externally (encapsulation) and internally by layers or sheets was reported by Gray, Athanasopoulos, and Ohashi (p. 611). Encapsulated soils have been of interest to the U.S. military for expedient construction of roads, bridge abutments, etc. It is not clear how encapsulation and layering of foundation elements can be practically carried out in the field, although Gray suggested that mandrels might be employed in soft clays.

The laboratory study by Leflaive (p. 721) will be discussed separately later in this report.

Much can be learned by laboratory-scale model tests. Already mentioned was the design method developed by Yasuhara and Tsukamoto (p. 635) for embankments on very soft ground. Papers reporting on the use of model tests to verify theoretical computations include those by Petrik, Baslik, and Leitner (p. 631) and by Andrawes, et al. (p. 695).

THEORETICAL/ANALYTICAL WORK

Papers on theoretical/analytical work are mentioned last, since it is here that I feel the most progress has been made since the Paris Conference in 1977. There have been some exciting developments in this area.

Four papers report on research utilizing analytical techniques such as the finite element method (FEM) or finite differences. These techniques, especially the finite element method, require large digital computers for solutions. From the results of these analyses, behavioral models of the performance of reinforced embankments, slopes, and walls are obtained. Blancier and Gielly (p. 621) used finite differences to investigate the stability of reinforced embankment slopes. Rowe (p. 677) and Petrick and his co-workers (p. 631) used the FEM to investigate the behavior of geotextile-reinforced embankments on soft foundations. Jeyapalan and Lytton (p. 701) in a study very similar to that carried out on circular culverts by Nowatzki, Sanan, and Sogge (1980, Portland ASCE Convention), used the FEM to investigate the effect of geotextile layers over flexible metal box culverts. In both papers, the geotextile overlying the crown of the culvert tended to reduce such stresses and crown deflections. The final FEM paper was by the "Strathclyde Mafia" of Andrawes, McGown, and their students. The response of a footing resting on a dense sand reinforced at different depths with a single layer of geotextile was investigated. Predictions were excellent up to about 85% of maximum load, provided the stress-strain behavior of the sand could be characterized accurately.

Several authors proposed design methods and procedures based on rather conventional limiting equilibrium principles for, primarily, embankments on soft foundations. Noteworthy in this regard are the papers by Fowler (p. 665), Jewell (p. 671), and Ingold (p. 683). Similar techniques were applied by Murray (p. 707) to the slopes of embankments and excavations and by Christie (p. 659) to the slopes of dams and embankments. These methods are simple and easy to understand, and they require only "back of the envelope" type calculations, or calculators or small computers which today are found in every CE design office.

As Peter Jarrett, Leader for Session 4C, remarked: we now have a sufficient number of design methods available so that we can begin to check some of the case histories we've collected since the Paris Conference.

Finally Bell, Green, and Laverty (p. 689) give a convenient check list for the properties and other important considerations affecting the choice of geotextiles for most reinforcement applications.

MOST INNOVATIVE IDEA

Finally, for the most innovative paper presented at these sessions of the Conference, I would like to nominate the paper by Leflaive entitled "Reinforcement of Granular Materials with Continuous Fibres and Filaments" (p. 721). This paper reports on developments since the suggestion by Hoare (1977) at the Paris Conference. The idea is "far out" but promising, and the paper is highly recommended.

CONCLUSIONS

We have made significant progress in the years since the Paris Conference. Our analytical techniques and capabilities have markedly increased, and even relatively simple design procedures have been proposed with apparent success. We still lack reliable geotextile-soil property data for our design calculations. How to appropriately characterize the stress-strain relationships for the soil-geotextile system is not fully established.

The introduction of reinforcing elements in cohesive soils is still in its infancy, but important work on this aspect has been reported at this conference. Normally, we aren't used to being very concerned with the rheological properties of sands (as we are with clay soils), but, such behavior becomes important when granular materials are reinforced with geotextiles.

The durability of especially geotextile wall facings is still a problem, but it is hoped that designers can turn to papers in Session 8B for some assistance. Some of the durability problems with geotextile wall facings could be ameliorated by the development of simple repair procedures for such installations.

Other still-to-be-solved problems remain. Scale effects between laboratory tests and the field plague conventional geotechnical engineering practice, and the introduction of geotextiles into the system doesn't simplify matters any. Additional research in this area is greatly needed.

The continuing publication of full scale field trials and other case histories is encouraging. However, greater attention must be paid to the characteristics of a good case history given earlier in this report. Better design information and detailed reports on how well the design assumptions checked field observations are crucial to the proper evaluation of a case history.

It is hoped that a greater use of in situ tests will take place in the future to assist in site characterization as well as the evaluation of geotextile performance.

Finally, geotextiles as reinforcing and stabilization materials for increasing the stability of especially embankments on soft ground, earth retaining structures, cut slopes in natural soils, and high embankment slopes are significant additions to the techniques usually available to geotechnical engineers for such problems. This point was established only tentatively at the time of the Paris Conference. Today, only five years later at the completion of the Second International Conference, geotextiles as reinforcement are firmly established in civil engineering practice.

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Report on Sessions 3B, 4B, and 5B Unpaved Roads

Rapport des sessions, 3B, 4B, et 5B Routes non revêtues

This subject has been dealt with in three sessions comprising 18 contributions from manufacturers, engineering companies, authorities and research establishments.

The system treated is largely granular layer on top of a soft subsoil. This top layer could be an embankement on a soft soil, the embankement being protected by geotextile, or an unpaved road layer which is separated from the subsoil by a geotextile. Application of geotextiles for stabilization of retarding walls has also been demonstrated.

The basic technical effects of geotextiles are:

- drainage
- separation
- filtration
- reeinforcement

The drainage aspect has not been given much attention in the present contributions, although it has been established that there must be drainage. The geotextile can for instance not be replaced by an impermeable membrane, although consideration of mechanical properties may suggest it.

It is agreed by the contributors that there are two reinforcing effects

- membrane or catenaria effect
- lateral restraint of aggregate

The latter implies that under the influence of wheel loads the granular material outside the action area of the vertical forces from the wheel are restricted from lateral motion and hence engage a wider area of the granular layer to participate in load spreading. Such invasion of soil will be prevented in the presence of geotextiles, i.e. the separation effect will in a sense protect fatigue life.

The membrane effect is a result of the forces at right angles to the membrane, resulting from membrane tension. They are according to elementary laws of mechanics in in the first approximation proportional to the tension and inversely proportional to the radius of curvature) of the fabric, which means that an undeformed fabric (i.e. lying on a flat subgrade surface) would yield no membrane effect of this kind.

An additional effect of the membrane is protection against certain mechanisms, which are suggested to occur in repeated loading. These mechanisms are

- tensile cracking of the granular layer
- punching out of the loaded section of the granular layer

At each load repetition a small amount of soil material will enter the tensile cracks and the result will be reduced load spreading, and finally the load spreading function of the granular layer will cease. Punching of the granular layer section adjacent to the loading wheels, which occurs at heavy loads, will also allow soil material to enter the cracks in the granular layer with the same result as indicated above.

Mathematical models of the load spreading and membrane effects following a mechanistic approach according to the fundamental properties indicated above have been derived by several authors. Assumptions then have to be made regarding the mechanical behaviour of the soil as well as the fabric, and the fit of such models is strongly related to the assumptions made. Non-linear behaviour of soil has to be considered, as well as timedependent behaviour of the fabric. FEM-models are also included. Model experiments as well as full scale field tests have given excellent agreement between computed and observed behaviour.

A model implying an additional fabric halfway down the granular layer has also been considered and found successful in improvement of bearing capacity.

From the models it is possible to find the parameters, which are required in road design. The importance of proper design in application of geotextiles has been emphasized by several authors.

Fabric parameters of primary importance are:

- tensile modulus
- tensile elongation at break
- tensile stress at break.

There is not full agreement on the relative importance of these parameters. For the catenaria effect a high modulus is required but also a high breaking length, since the catenaria effect is favoured by high deflection. The question of woven or non-woven fabrics has a bearing on the relative importance of these parameters. A medium level modulus was stated as preferable, and wovens are ruled out by some authors.

The importence of anchoring the fabric has been emphasized by some authors and also supported by theory. The catenaria effect actually means that the granular layer partly hangs in the fabric.

One author has in a model experiment tried circular fabrics of different diameters without anchoring and found a considerable load spreading effect when the diameter was greater than that of the bottom of the "load spreading cone".

In one paper an approach based on energy consideration was suggested but not proved and in another paper a probabilistic approach was worked out, which considers failure of a fabric system due to fabric failure and fabric pull-out. Experimental verification of the theory was not reported.

Contribution to bearing capacity based on the catenaria effect requires rather heavy rutting, since the forces at right angles to the fabric require zero curvature. This effect can therefore not be utilized in permanent roads where heavy rutting is not tolerated. This could however be overcome by allowing for some rutting in an early stage followed by an early overlay.

Considerable benificial effect of rut repair has been reported. The most important bearing capacity effect in permanent roads - if there is one - will however be derived from the protection against soil invasion in fatigue cracks mentioned above. Additional indirect effects come from separation and filtration.

Papers dealing with separation and filtration properties confirm quantitatively the existence of such properties and their relation to fabric properties. Filtration of much smaller particles than the effective characteristic pore size occurs, and it is established that penetration of soil particles occurs at contact points between fabric and aggregate. Considerable penetration has been observed only when fabrics have been torn.

There has also been established a relation between contamination and pore pressure dissipation time.

It is quite possible to have a geotextile replace the granular separation layer on the subgrade, specified by some authorities. For this purpose a thick relatively incompressible fabric with appropriate filter properties has been recommended.

It is agreed that the use of fabric is meaningless at CBR > 1 %. Bearing capacity therefore should be measured by some other test such as the vane test.

Experiments with freeze-thaw cycles indicate that near the liquid limit small changes in water content may be critical for the functioning of the geotextile.

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Report on Session 5B Special Applications

Rapport de la session 5B Applications spéciales

This session presented to the audience a great diversity of topics but one theme found in three of the papers was the use of geotextiles as flexible forming systems. When made as an enclosed form, the geotextile can be filled with neat cement grout, cement rich mortar, plasticized concrete, resinous grout, flyash/cement mixes, asphaltic grout, sand or, even, bentonite clay. The Lupton, Brandl and Welsh and Dominske papers all treated this general topic. Lupton presented three case histories, the major one being the use of a double layer geotextile to form an underwater strut between two sheet piles. Brandl illustrated the use of geotextiles to form insitu piles which could eliminate negative skin friction and for use as sand filled "stockings" to accept radial drainage as in conventional sand drains. In this latter case, the vertical drain now has considerable tensile resistance with which to resist a possible shear failure. The Welsh and Dominske paper traces patents on flexible forming systems and then proceeds to summarize their extensive experience via a number of case histories. These are the following:

1. As mattresses for erosion control structures whereby a double layer of fabric is inflated by a cement grout conforming to the soil slope on which it is formed. Pore pressure dissipation can be made by the inclusion of filter points within the mattresses.

2. As a pile restoration technique, fabrics have been wrapped around deterioriated piles in the form of a jacket and pumped up with cement grout (even reinforced cement grout). The finished product often has a strength greater than the original pile.

3. As in-situ columns in abandoned mines and limestone cavities, fabric tubes have been inserted in predrilled holes and inflated with cement grout. The tubes yield where there is no resistance, i.e. the void, and the final deflected shape gives support where it is required. They can be placed on as close a spacing as deemed necessary.

4. As tubes or bags for concrete placement underwater. Such areas where scour has occurred beneath bridge piers, or beneath pipelines, or for good load distribution of piers or footings, have been areas of particularly successful applications.

The Clough and French paper is a departure from the above in that a geotextile/plastic insert/geotextile composite material was used as a capillary moisture break. Its use was illustrated in arid areas of Saudi Arabia where the near surface salt laden groundwater raises via capillary force to the ground surface. Here it destroys vegetation, agriculture and even road aggregate and building foundations. The authors conducted a series of small scale, then large scale tests to see if their capillary break composite geotextile would eliminate the problem. Based on the positive results of these tests, field trials are now ongoing.

Purdon and Resal present their experience with the use of geotextiles in athletic fields. Their technique is to encapsulate a free draining gravel between two geotextiles with a 6 cm soil cap above. The primary function of the system is drainage, but proper flexibility is also significant. In this latter regard, a "sportest" has been devised whereby a displacement transducer is deployed and attached to a storage oscilloscope to give a real time trace of both the deformation and rebound as an athlete traverses the surface. The interface with biomechanics and biomedical engineering in the proper tuning of an athletic field is of great significance.

This reporter found the session most exciting and stimulating as far as the incredible range of geotextile applications that exists. Those major items which come to mind are:

- Flexible form techniques for new construction activities.
- Flexible formwork techniques for all kinds of remedial construction problems.
- Use of a wide range of composite geotextile systems, designed and manufactured for specific applications.
- Development and deployment of insitu tests to instantaneously assess and monitor the results of a specific geotextile installation.

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Report on Session 6B Railroads

Rapport de la session 6B Chemins de fer

This session produced six papers, of which three were laboratory oriented and three were field oriented.

Regarding the laboratory oriented papers, the Saxena and Chiu and Friedli and Anderson papers both used large size triaxial specimens to assess the reinforcement ability of geotextiles in soft soils. Each found a pronounced improvement in the aggregate/geotextile/soil system over a standard aggregate/soil system. This membrane type reinforcement effect was evidenced by an increase in deviator stress, an increase in resilient modulus and a decrease in elongation at failure. At a larger, but still laboratory, scale, Saxena and Wang evaluated a simulated railroad track, finding that the deflection of the ties were reduced and that lower strains in the subgrade were observed when using a geotextile. A major finding was that the ballast/geotextile/soil system can be modeled using elastic theory. Thus existing numerical techniques, e.g., finite element models, can be utilized or appropriately modified for use.

Regarding the field oriented papers, Raymond's provides excellent detail in regard to abrasion resistance versus depth of ballast beneath the railroad tie when the geotextile is placed in the system. Here an optimum depth of ballast of 12", with a minimum value of 10", is recommended. Primary functions of a geotextile in railroad work (according to Raymond) are listed as:

- lateral drainage
- abrasion resistance
- separation
- degradation resistance

Clearly stated is that tensile reinforcement is "not a primary requirement in track rehabilitation work". Raymond further recommends that the geotextile should be needle punched, acrylic resin dipped and force air dried with an equivalent opening size (EOS) of 200 or, as small as, 400.

On the basis of past field experience, Newby comes to the conclusion that the ideal railroad geotextile is a needled polyester nonwoven fabric of nine denier filament, 6" long fibers with a minimum tenacity of 4 grams per denier. Lateral drainage is emphasized in the text of the paper in addition to filtration, separation and tensile strength. In his field oriented paper, Fluet lists a variety of geotextile properties as being critical. These are abrasion resistance, lateral drainage, burst strength and puncture resistance. His paper is basically a checklist, or guideline on how to assess a geotextiles' performance in railroad stabilization. It presents excellent comments on the proper setup of a field monitoring program.

In reviewing these papers, and listening to their presentations, a number of generalized comments can be offered.

1. Laboratory work is emphasizing membrane type reinforcement, whereas field work relegates this function to lesser importance than drainage, abrasion resistance, and other functions.

2. Laboratory work emphasizes woven slit film polypropylene geotextiles, whereas field work seems to be using rather thick and heavy (as high as 29 oz./yd^2, as per Raymond) needled polyester or polypropylene fabrics.

3. Field work places drainage, and in particular lateral drainage (thereby using the geotextiles' transmissivity characteristics), as the major geotextile function. This obviously requires a thick or bulky geotextile, hence the needled nonwoven recommendation by the authors of the field oriented papers.

4. Neither laboratory nor field oriented papers make note of the lateral restraint of the ballast given by the geotextile. This reinforcement type of action (albeit not of the membrane type), has appeared in the literature by authors other than those represented at this session.

5. The general area seems to be in desperate need of quantified field data. Fluet makes note of this need in his paper and of the need to publish the information in the open literature. These comments are heartily endorsed by this reporter.

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Report on Session 7B Paved Roads

Rapport de la sessions 7B Routes revêtues

This session contained seven papers, of which five concentrated on the use of geotextiles in crack reflection prevention. In this application an existing pavement, which is obviously distressed, is covered with a suitably treated geotextile and then paved over with a bituminous layer. Benefits are hoped to be realized by either using an equivalent thickness of overlay pavement as with no geotextile, for longer lifetime; or to use a thinner thickness of overlay pavement, for an equivalent lifetime. In this regard, the design technique offered by Majidzadeh, et. al., is of considerable interest. The technique is based on fatigue life enhancement by the fabric (as per laboratory tests) and both fatigue and rutting distress are incorporated. The authors of this paper state that the method must be field evaluated.

Regarding laboratory testing of geotextiles used to prevent crack reflection, papers by Button et. al., (who evaluated 8 fabrics in 6 different types of laboratory tests) and Murray (who evaluated 5 fabrics in 2 different tests) were presented. Both found a decided improvement in flexural fatigue by factors of up to 12 and 15 times, respectively, over nonreinforced control specimens. The most relevant fabric property seems to be the geotextiles' stiffness which in one case, i.e., Murray's, is best estimated by its 5% secant modulus.

The field assessment papers, there were two of them, both showed improvement in retarding crack reflection when using geotextiles. Colombier, et. al., have observed five such sections which were constructed as early as 1977, and found that crack propogation is retarded by about two years over nonreinforced sections. Furthermore the cracks, when they do appear, are more diffused and branched when a geotextile is used. Caution is expressed regarding poorly fit fabrics and fabrics that are too compressible. Both situations lead to accelerated crack damage. The Hugo, et. al., paper presents a ten year study on a major freeway on the use of a very open mesh woven polyester fabric with a high modulus. The work was based on earlier laboratory and small pilot scale tests which illustrated the advisability of a "bond breaker" over the initial crack. This bond breaker was best realized by placing a narrow 5 mm thick fine sand over the crack before placement of the geotextile. Presumably, high stress concentrations are avoided by this technique. The crack pattern has been nicely quantified and, after eight years of service, is now accelerating in its deterioration. Adjacent nonreinforced sections have long since cracked and failed. Deflections were critically evaluated and their conclusion is that the fabric worked this long because of the prevention of ingress of water to the structure and not due to increasing the structural capability of the system. Therefore, Hugo, et. al., concluded that fabric in crack reflection work is a waterproofing mechanism, not a reinforcement one.

Two other papers in this session dealt with low volume roads and, although appropriately placed in this session on paved roads, they function quite differently than in the above described crack reflection papers. Leflaive, et. al., describe a surface coating method whereby a composite system of subgrade soil/oil treatment/geotextile/oil treatment/bituminous wearing course is utilized. The geotextile imparted a cohesiveness to the system (also confirmed by simulated laboratory tests) and is definitely used for its reinforcement capabilities. It will be field tested under actual traffic conditions in the near future. The Lawson and Ingles paper presented two case histories involving membrane encapsulated soil layers (MESL). Here an unsuitable soil, e.g., high water content clay, expansive clay, frost susceptible soil, etc., is completely wrapped in a geotextile. The geotextile is treated to reduce its permeability to the point where only minor amounts of water can pass (or better, where only water vapor can pass) thus assuring controlled moisture in the MESL. Basic functions are separation, reinforcement and moisture control. Both case histories presented in this paper are excellently documented and evaluated. The first site had no failures in either the MESL or control sections. It is important to note, however, that the MESL section was tapered down to as little as 100 mm in thickness and still performed as good as the control section. In the second site the MESL performed excellently, but the control sections (on each side of the MESL) were completely failed. The mechanisms involved are due to separation and reinforcement since moisture was not involved.

By way of general comments, this reporter feels that in the use of geotextiles in reflective cracking prevention, the basic mechanism is still uncertain. Do geotextile reinforce or not? Laboratory tests all show a definite reinforcement effect, while field tests generally do not show reinforcement. Thus, in the field, moisture prevention, and its subsequent negative effects, seem to be the prime mechanism contributing to improved performance. Obviously, controlled field tests are definitely needed, as basic insight into the mechanisms taking place is still not available.

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Report on Session 8B Durability

Rapport de la session 8B Durabilité

To every owner, public agency, or responsible party of a geotextile involved construction project, the question of durability is essential. Basically, one demands to know if the geotextile will deteriorate with age, and, if so, what is the nature of this deterioration. Thus, it is our duty, to evaluate the phenomena involved and to report the findings. This session was addressed to this situation. The fundamental phenomena involved are the following:

- direct and indirect ultraviolet light degradation
- chemical attack and aging
- biological attack and aging
- long term burial degradation

Although the number of variables involved is tremendous, this session provided considerable insight into the various aspects of the problem.

On UV degradation, Raumann reported on eleven fabrics tested in outdoor exposure in Florida, Arizona and North Carolina. Samples were withdrawn for up to 52 weeks (or failure) and tested for grab strength and elongation. Almost all types of fabrics were represented with weights ranging from 100 to 360 gm/m^2. Results were categorized into the following groups: (a) poor performers (severe strength loss in 24 weeks or less), which were the bonded polypropylenes, (b) intermediate performers (severe strength loss in 24 to 40 weeks or less), which were the woven slit films, and (c) long term performers (negligible strength loss after 32 weeks or longer), which were the needled polyesters and the woven polypropylene monofiliment fabrics. In general, low strength was usually accompanied by a loss of elongation, i.e. the fabrics became brittle, which was excellently illustrated by means of scanning electron micrographs. Raumann cautions that in no case should a geotextile be left exposed to light for permanent installations.

On polymer aging, Sutton and Leclercq evaluated a wide range of conditions and compared these by means of tensile tests and scanning electron micrographs. Effects are shown on the basis of fundamental polymer type and exposure time. Outdoor exposure tests were conducted which showed weakening of the fabric, but burying the fabrics in basic, acid and sea water had no negative effects.

On biological degradation, Ionescu, et. al., evaluated six fabrics (four polypropylenes, a polyester and a composite) in eight media for times of 5-17 months. The media were distilled water (the control test), sea water, compost, soil, iron bacteria, levansynthesizing bacteria, desulfavibrios bacteria, and a liquid mineral. Evaluation was by permeability, wide width tensile strength and infrared spectroscopy. Results show no measurable effect on permeability (although some roots were growing in the fabric), only small variations in tensile strength and no structural changes visible on the infrared spectroscopy.

On burial degradation, Sutton, et. al., looked at exhumed samples which has been in place for up to twelve years. Mechanical properties were emphasized in the paper (hydraulic properties are published elsewhere) and these were found to loose less than 30% of their strength over the time period involved. Considerable detail, on a wide range of geotextiles, in a wide variety of applications, is presented in this important paper.

By way of summary, this reporter feels that with required lifetimes of up to 100 years, the long term functioning of geotextiles is mandatory. The group of papers in this session was essential in spreading the word that chemical, biological and burial deterioration are not particularly detrimental to the typical construction geotextile. Conversely, ultraviolet light degradation deteriorates almost all types of polymers, and demands that construction activity be controlled to place the fabric in its final, and buried, position as soon as possible. For those cases where exposure of the geotextile is necessary, e.g., silt fences, polyester fabrics or woven monofiliment polypropylenes seem more resistant to light than others, which would give them the longest lifetime.

By no means, however, do the papers in this session close the door on this type of testing. The number of variables involved, the types of test, and the suitability of accelerated laboratory aging tests all need further inquiry. Future research efforts should be aimed in these directions.

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Report on Sessions 2B, 5C, 6C, and 7C International Standards, Properties and Tests

Rapport des sessions 2B, 5C, 6C, and 7C Standards internationaux, Propriétés et essais

In a general way are reported in this text :

- International and national Association's positions regardins tests, standards and properties of geotextiles.
- Progress made since the First International Conference on Geotextile in Paris, relating to research work on testing geotextiles. Two great tendancies have been ascertained :
  - . tests on larges samples (up to 500 x 100 mm) : tensile test, tearing, punching (practical and theorical approaches).
  - . tests able to reveal geotextiles fitness to support long term stresses (creep, fatigue with or without presence of soil).

Sont rapportés dans ce texte d'une manière générale :

- Les positions des Associations nationales et internationales en ce qui concerne les tests, normes et propriétés des géotextiles.
- Les progrès effectués depuis le Colloque de Paris en ce qui concerne les recherches de tests. Deux grandes tendances ont pu être dégagées :
  - . essais sur éprouvettes de géotextiles de grandes dimensions : test de traction, de déchirure, poinçonnement (aspects pratiques et théoriques).
  - . tests susceptibles de révéler l'aptitude des géotextiles à supporter des contraintes à long terme (fluage, fatigue en présence de sol ou non).

Les tests sur géotextiles sont restés l'un des thèmes majeurs abordé lors de ce colloque de LAS VEGAS. On peut être tenté de faire des comparaisons par rapport au premier colloque de PARIS afin d'essayer d'apprécier, au terme de cette rencontre américaine, les efforts et progrès accomplis dans le chapitre des propriétés et essais.

Le colloque de Paris avait posé en termes très clairs un certain nombre de questions et laissé transparaître un certain nombre de préoccupations :

- souci de précision dans la dénomination et la description des géotextiles ;

- souci de caractérisation et qualification ensuite ;

- souci de recommandations ou spécifications enfin.

On peut affirmer aujourd'hui que des éléments concrets sont désormais apportés en réponse aux préoccupations exprimées à Paris. Ces remarquables résultats sont les fruits légitimes des rapprochements qui se sont produits entre géotechniciens et textiliens. Ces groupements qui, selon les pays, ont pris nom : Comité, Commission, Association, etc... sont venus s'exprimer en tant que tels à la tribune pour témoigner de leur existence, de leur dynamisme, mais aussi pour faire part des résultats de leurs travaux, de leurs décisions, de leurs ambitions et également parfois de leurs difficultés et de leurs interrogations.

D'une manière générale, les démarches réalisées par ces groupes apparaissent exemplaires :

- exemplaire déjà par la qualité des rassemblements qui se sont constitués un peu partout autour de l'idée.

- exemplaire ensuite par le profil des travaux qui ont été réalisés et qui ont permis de proposer dans certains cas :

. un langage de travail, une terminologie ;
. des méthodes d'essais pour la détermination des principales caractéristiques des géotextiles ;
. des recommandations et spécifications pour les utilisations les plus courantes.

En ce qui concerne le langage d'abord, un certain nombre de définitions semblent désormais bien acquises et même si le néologisme "géotextile" fait encore l'objet de certaines réticences et interrogations, le large emploi qui en a été fait pendant la durée de ce colloque devrait définitivement faire tomber toute résistance. Ce langage a déjà permis, dans certains pays, de proposer des "fiches standards" de désignation et de description des géotextiles qui devraient permettre de lever toute confusion et ambiguïté au niveau des utilisateurs.

En ce qui concerne le problème général des tests et spécifications, il convient de souligner que, même si les différents auteurs qui se sont exprimés à ce sujet ont pu sembler diverger dans leurs prises de position, l'analyse plus fine des textes laisse néanmoins apparaître un "tronc commun" important :

. Tout le monde semble d'accord sur la nécessité de choisir des tests simples pour l'identification des géotextiles et une quasi unanimité s'est faite sur la sélection de tels tests, qu'il s'agisse de la mesure de la masse surfacique ou de celle de l'épaisseur...

. Tout le monde semble d'accord sur la nécessité de choisir des tests de caractérisation des géotextiles et, là encore, une tendance se dégage en faveur d'essais simples, reproductibles en traction et déchirure sur bande large, des mesures de perméabilité et filtration. Mais, par contre, des désaccords sérieux existent sur l'utilisation finale qui peut ou doit être faite des résultats de ces tests :

- pour certains, ces tests constituent essentiellement des méthodes de qualification des géotextiles et permettent simplement de suivre les différentes productions des fabricants en vue de comparaisons (aide à la décision de l'Ingénieur ou du Prescripteur).

- pour d'autres, ces tests apparaissent déjà suffisamment représentatifs, c'est-à-dire permettent une simulation suffisamment satisfaisante du comportement des géotextiles dans leurs utilisations les plus courantes, pour que les valeurs numériques obtenues aient une signification physique claire et utile pour l'Ingénieur, mais puissent aussi servir à l'établissement de recommandations et de spécifications. Dans la mesure où la restriction est posée, à savoir, que de telles recommandations pour les utilisations communes des géotextiles sont établies en se référant d'une part, à l'expérience acquise, et, d'autre part, aux résultats de ces tests, le désaccord semble déjà moins grand... Et, ces utilisations courantes représentent pour les producteurs plus de 90 % du marché !...

Enfin, et bien sûr, tout le monde est d'accord sur le fait qu'il est nécessaire d'établir des spécifications sur les bases d'essais particuliers, chaque fois qu'un géotextile est appelé à jouer un rôle majeur dans un ouvrage et, notamment, chaque fois qu'il doit assurer des fonctions à long terme. Evidemment, les essais particuliers doivent simuler au mieux les contraintes et l'environnement. Ce point a été bien senti par exemple par les équipes hollandaises, pour les problèmes de drainage vertical, pour lesquels, un essai standard s'avère difficile à proposer : les spécifications de drainage doivent être établies pour chaque type d'ouvrage. Par contre, dans beaucoup de cas, il n'existe pas encore de méthodologie acceptable :

- l'exemple du fluage est à retenir : aucune méthode ne permet d'étudier et prévoir le fluage tel qu'il se produit sur le terrain ;

- la prévision de la tenue au vieillissement chimique, photochimique, pose également les mêmes problèmes.

Il convient toutefois de souligner qu'au-delà de toutes ces discussions et réflexions sur les tests, certaines associations nationales et internationales sont très avancées dans leurs démarches d'établissement de méthodes d'essais et de recommandations d'usage des produits (cas de la Suisse, de la France, de la Belgique, de la Finlande, de l'Association Permanente Internationale des Congrès de la Route, de la RILEM...).

Pour en venir plus précisément aux tests, le Colloque s'est révélé fertile puisque 22 communications ont été présentées dans les sessions réservées à ce thème.

Sans rentrer dans le détail de ces communications, on peut rapporter ici deux tendances qui sont apparues lors de ce Colloque et qui correspondent à une deuxième génération de publications révélatrice à coup sûr de la maturité de la recherche sur les géotextiles :

- La première tendance est relative aux essais mécaniques sur éprouvettes larges, qui s'écartent donc délibérément des tests traditionnels textiles :

essais de traction tout d'abord sur des éprouvettes de grandes dimensions pouvant atteindre 500 x 100 mm. Test simple, relativement rapide et qui peut sans difficultés majeures être utilisé pour les géotextiles actuels aussi bien tissés que nontissés. Les notions matérielles de coût et temps d'essai n'ont pas échappé aux conférenciers qui ont pu constater que les nontissés, du fait de la dispersion de masse surfacique dans les différentes directions de l'éprouvette, exigeaient plus d'essais que les tissés, pour obtenir un coefficient de variation donné.
Néanmoins, ce type d'essai fournit des valeurs présentant une signification physique claire pour l'Ingénieur qui a besoin de faire des calculs de dimensionnement. Certains conférenciers se sont interrogés sur l'intérêt de choisir des caractéristiques mécaniques ultimes du géotextile, c'est-à-dire aux limites de rupture, caractéristiques qui sont dépendantes des formes et dimensions d'éprouvettes...
La mesure du module à 10-20 % de la déformation de rupture, qui semble indépendant de la dimension d'éprouvette, serait peut-être judicieuse ?... Il convient néanmoins d'être prudent sur la valeur pratique d'un tel module mesuré sur un géotextile neuf, lorsque l'on sait que le module peut changer (amélioration) fortement à mesure que l'intimité sol-fibres devient plus grande à l'usage.
Plusieurs conférenciers sont allés bien au-delà de la simple affirmation de leur choix pour ce type d'essai "bande large" en en justifiant théoriquement la validité. L'essai de traction sur bandes larges permet de reproduire ce qui se passe en réalité dans l'association sol et textile, à savoir : les effets de particules de sol sur les fibres qui empêchent ces dernières de se déformer trop et qui limitent la réorganisation du géotextile. Les résultats de cet essai se situent donc très proches de ceux fournis par le test référence de ST BRIEUC, ou par ceux de tests conduits en présence de sol, ainsi qu'ils se pratiquent à l'Université de GLASGOW.
Toutes ces réflexions théoriques et pratiques sur le comportement en traction des géotextiles ont permis d'introduire un concept qui devrait devenir essentiel : celui de la plus ou moins grande aptitude ou résistance d'un textile à changer de "masse surfacique" sous l'effet d'une contrainte (résistance à la déformation surfacique). En passant, avec les modélisations proposées, on peut dire qu'à LAS VEGAS, la Mécanique des géotextiles a fait un bond en avant, qui devrait servir la cause de la Mécanique textile en général et aider l'Ingénieur dans la conception de produits très spécifiques.

essais de résistance à la déchirure ou à la perforation qui prennent également en compte des éprouvettes larges. Signalons à ce propos l'intérêt de machines d'essais dynamiques, telles celles construites au Laboratoire des Ponts et Chaussées en France qui permettent d'appliquer aux éprouvettes des déformations à des vitesses pouvant atteindre 3,5 m/seconde (outil précieux pour l'Ingénieur et susceptible de lui fournir une bonne évaluation des risques de déchirure dans les travaux où ce type d'endommagement est à craindre).

Le test CBR étant toujours très utilisé dans les laboratoires de Mécanique des Sols, des essais ont été faits pour essayer de corréler la résistance à la déchirure et au poinçonnement des géotextiles mesurée selon cette méthode et celle mesurée par dynamométrie sur bande large. Les résultats sont assez identiques, mais le test CBR, outre le fait qu'il ne fournit aucune valeur numérique de déformation, donne des résultats très hétérogènes compte tenu de l'inhomogénéité des géotextiles.

- La seconde tendance concerne toutes les communications nombreuses, qui ont traité des tests suceptibles de révéler l'aptitude des géotextiles à supporter des contraintes à long terme.
Il faut rapporter les études sur la tenue au fluage et à la fatigue, conduites aussi bien par les équipes américaines qu'européennes, avec ou sans présence de sol. Ces essais ont même été réalisés sur des éprouvettes de grandes dimensions en essayant de simuler au mieux les conditions d'environnement rencontrées en situation réelle. Il a été parfaitement démontré que la tenue au fluage des géotextiles est fortement améliorée, surtout dans le cas des nontissés, en situation de confinement, lorsque s'établissent de fortes intéractions sol-fibres. Il a été proposé par certains, d'étudier l'effet de la pression de confinement des géotextiles sur le fluage, en choisissant 3 sols typiques. Par contre, en ce qui concerne la mesure des coefficients de frottement sol-géotextiles, qui rejoint les mêmes préoccupations, il a été proposé de développer et d'appliquer une méthode normalisée en mettant en oeuvre cette fois le sol à stabiliser.

Il faut également évoquer les études sur la tenue des géotextiles aux basses températures, lumière, abrasion (application : ballast de voie ferrée), aux agents chimiques et biologiques. Ces travaux ont d'ores et déjà permis d'accumuler des données fort intéressantes, mais il reste à trouver le bon niveau de sévérité pour de tels tests et à mieux interpréter les résultats qu'ils fournissent en développant des corrélations entre modifications structurales et modifications de propriétés, corrélations qui pourraient être utilisables sur le plan pratique.

Nous terminerons cette analyse en citant des travaux qui permettent de mesurer des propriétés particulières, telle que la flexibilité des géotextiles et dont la connaissance peut être très utile pour apprécier a priori la plus ou moins grande facilité de mise en oeuvre sur le chantier (aptitude du géotextile à se dérouler, à épouser les irrégularités du sol support...).

Il est certain que tout ce travail devrait contribuer à rendre la tâche de l'utilisateur de géotextiles plus facile, à développer la réputation des géotextiles et le marché qu'ils représentent et à susciter enfin de nouvelles utilisations encore plus originales et encore plus audacieuses.

Il n'est pas sûr néanmoins que toutes les initiatives nationales ne compliquent pas quelque peu la tâche des producteurs dans leurs entreprises technico-commerciales... Espérons, que la coordination internationale qui se met en place oeuvrera pour le développement harmonieux de la recherche et du commerce international des géotextiles.

GIROUD, Jean-Pierre
Woodward-Clyde Consultants, Chicago, IL, USA
Conference Chairman

Closure Address
Allocution de clôture

Ladies and gentlemen

The first steps towards the formation of an international society on geotextiles have been taken. These steps were taken as a result of the meeting held on Wednesday evening.

The meeting was a big success. It was attended by approximately one hundred and fifty people from many different countries. A large number of the attendees contributed valuable ideas. A straw vote taken at the meeting showed that an overwhelming majority of attendees were in favor of the creation of some sort of an international society, few abstained, none voted against.

The attendees voted in favor of motions which can be summarized as follows:

- An Interim Committee will be formed with a lifetime of two years.
- The Interim Committee will prepare a set of bylaws for the operation of the International Society and will take appropriate steps to assure the start of the International Society.
- The Interim Committee will entertain submissions from organizations desiring to sponsor and organize a Third International Conference on Geotextiles and it will select the site after a careful review of proposals.

During the Wednesday meeting, nineteen persons volunteered to work in the Interim Committee, two more volunteered shortly afterwards. The twenty one members of the Interim Committee come from eleven countries and four continents. During the meeting professor Charles Schaerer was appointed chairman of the Interim Committee.

The Interim Committee met twice yesterday and decided to organize into three groups: one coordinating group, and two task groups. The coordinating group includes:

- professor Schaerer, chairman;
- Mr Fluet, secretary-treasurer;
- Mr Rankilor, vice secretary-vice treasurer;
- Dr Massenaux, vice chairman and leader of task group 1; and
- Dr Giroud, vice chairman and leader of task group 2.

Task group no. 1 includes twelve members. Its task is to prepare the bylaws and to take appropriate steps to assure the start of the International Society. Task group no. 2 includes six members from four continents. Its task is to prepare guidelines for the selection of a location for the Third International Conference, to entertain and review submissions from potential sponsors of the Third International Conference, and to select one of them.

The Interim Committee needs to be in contact with people interested in geotextiles worldwide. There are eleven countries represented in the Interim Committee. In addition, corresponding members from other countries or regions of the world are most welcome. In some countries there are already national committees on geotextiles and they are the natural corresponding members. In other countries, existing organizations or persons can be corresponding members. Those desiring to act as correspondents please contact professor Schaerer by mail.

The Interim Committee will work essentially by correspondence. Members of the Interim Committee will take the opportunity of various conferences to meet and, therefore, expenses will be kept as low as possible. However, expenses will be incurred for items such as correspondence and stationary. Several people have already voluntarily contributed, and any of you who also wish to contribute may see Chairman Charles Schaerer and Treasurer Joe Fluet after this meeting.

In conclusion, I can say that historical steps have been taken this week.

The fact that members from eleven different countries volunteered to put their time and effort into the organization of the International Society is clear evidence of the cooperative spirit of the international community. I pray that the society we are trying to form will enjoy the same cooperative spirit throughout its life.

It is almost time now to say goodbye, but, before that, I would like to thank on behalf of the Executive Committee those who contributed to the success of this conference. Once again, I would like to thank all the sponsors, especially the IFAI, and I extend special thanks to the IFAI staff who was very helpful during this conference and ensured its success.

I would also like to congratulate the translators for their highly professional work. I was even told that some presentations were improved through the translation!

Congratulations also to the audio-visual technicians. Slide projections were absolutely perfect. The first conference ever with no slide upside down!

And of course the technical success of this conference is the result of the impressive work done by authors, speakers, session leaders and general reporters.

Finally I would like to thank again the members of the organizing committee for the considerable amount of work they accomplished in two years. During the past month, I overwhelmed them with work and work and work, and they found the time to prepare the very thoughtful presentation they made last night at the banquet. I am very grateful and I will never forget this.

I tried as much as I could to delay the moment when we would have to say goodbye, but, as all the speakers at the technical sessions, I have limited time to deliver my speech and I have to abide by the rule of the yellow light, especially since Dick Bell, the chairman of our Technical Program Committee, is now in charge of the timer.

So goodbye and see you all at the Third International Conference.