The First Pan American Geosynthetics Conference & Exhibition
2-5 March 2008, Cancun, Mexico

The Geosynthetics Discipline: Achievements and Challenges

J. P. Giroud, JP GIROUD, INC., Chairman Emeritus of Geosyntec Consultants, Florida, USA

ABSTRACT
This paper presents achievements of the geosynthetics discipline and challenges facing the discipline. The paper discusses the impact of geosynthetics on geotechnical engineering and shows that one of the main achievements of geosynthetics is that they have pervaded most branches of geotechnical engineering to the point where it is almost impossible to practice geotechnical engineering without geosynthetics. Then, the paper addresses the challenges facing the discipline. Two major types of challenges are identified: education challenges and technical challenges. Regarding technical challenges, it is recommended that researchers focus on behaviors that are not traditionally considered in geotechnical engineering in order to use geosynthetics to their full potential.

1. INTRODUCTION

The geosynthetics discipline has been developed around a family of products, the geosynthetics. This family includes various types of products: geotextiles, geomembranes, geogrids, geomats, geonets, geocomposites (including bentonite geocomposites and drainage geocomposites), geocells, geomattresses, geocontainers, geofoam, etc. These various types of geosynthetics have a variety of properties. Some geosynthetics can convey liquid and gas, some are strong and can carry loads or reinforce soils, some can retain soil particles, some are quasi-impermeable and can retain liquid and gas, etc. A comprehensive set of tests has been developed to evaluate the properties of geosynthetics. These tests include physical tests, hydraulic tests, mechanical tests, and tests to evaluate durability.

Having a variety of properties, geosynthetics can perform a variety of functions. Four (now classical) functions were first identified for geotextiles: fluid transmission, filtration, separation and reinforcement. Today, it is known that geosynthetics can perform more functions. Thus, geomembranes and bentonite geocomposites act as fluid barriers. Furthermore, there are other functions that may be less obvious but have a growing importance as uses of geosynthetics become more sophisticated. For example, functions other than the five functions mentioned above are performed in the following applications: geotextiles used in road pavements against reflective cracking; geotextile cushions used to protect geomembranes; geomembranes or geotextiles used to decrease or increase friction between two materials; geomats used to provide erosion control through micro-confinement of soil particles; and geocells or geocontainers used to confine soil or waste.

Since geosynthetics perform a variety of functions, they can be used in a variety of applications. It should be noted that, in a given application, a given geosynthetic may perform several functions. This consideration is important when designing structures incorporating geosynthetics. To date, more than 20 billion square meters of geosynthetics have been used in several million projects. These projects were made possible because design methods specially developed for geosynthetics engineering were available as a result of extensive research studies in the past three decades.

Good design and good research must be complemented by good materials and good construction. Geosynthetics applications are successfully implemented in the field because the geosynthetics discipline has developed strict procedures to address both the quality of materials and the quality of construction.

The quality of materials is first addressed by manufacturing quality control. The quality of materials is also addressed by comprehensive specifications and standard test methods. From this viewpoint, international cooperation between various organizations plays a key role. The quality of materials is accounted for in design not only through the properties of materials as specified and as measured in standard tests, but also through the quantification of the effect of time using reduction factors (for example, for durability or creep) and through the quantification of potential damage during construction. Field tests for evaluating potential construction damage are becoming more and more frequent.

The quality of construction has benefited from a major effort in the 1980s to develop the concept and codify the practice of construction quality assurance, in particular for geomembrane installation. In addition, equipment for monitoring construction quality has been developed (for example, the electric leak detection technique).

Geotechnical engineers have played a key role in developing design, testing and construction methods for geosynthetics. Clearly, geotechnical engineers have been instrumental in the development of the geosynthetics discipline. At the same time, geosynthetics have had a significant impact on geotechnical engineering.

2. IMPACT OF GEOSYNTHETICS ON GEOTECHNICAL ENGINEERING

The wide variety of applications of geosynthetics demonstrates that, today, it is almost impossible to practice geotechnical engineering without using geosynthetics. However, geosynthetics engineering is not in competition with geotechnical engineering. In fact, in most structures incorporating geosynthetics, the volume of the geosynthetics is less than 1% of the volume of soil used in the structure.

Clearly, in geosynthetics engineering, soils are used more than geosynthetics. However, in some applications, geosynthetics replace soil layers or make it possible to use thinner soil layers, thereby decreasing the amount of soil used in those applications. On the other hand, geosynthetics make it possible to replace some conventional concrete structures by soil structures, thereby globally increasing the use of soil. Also, thanks to geosynthetics, soils generally considered inadequate for construction can now be used, which also tends to globally increase the use of soil.

The conclusion of the above discussion is that, even when geosynthetics are extensively used, soils also are extensively used. Therefore, geotechnical engineering is indispensable when geosynthetics are used, and geotechnical engineers should welcome the use of geosynthetics. However, some geotechnical engineers are reluctant to use geosynthetics. But, this attitude results from lack of knowledge on geosynthetics. The work of geotechnical engineers is more exciting with geosynthetics, as geosynthetics open up many possibilities because of the variety of their properties, functions and applications. Also, the geosynthetics discipline needs highly-qualified geotechnical engineers, because geosynthetics often lead to innovative solutions of geotechnical problems. But, some geotechnical engineers are conservative and afraid of innovative solutions.

The geotechnical engineers who are afraid of innovative solutions should be afraid of geotechnical engineering in the first place. Indeed, over the years, geotechnical engineering has been very innovative. It has been a successful discipline thanks to innovations, such as: deep foundations, anchorage devices, soil improvement techniques, slurry walls, roller-compacted concrete, steel-reinforced soil, etc.

3. THE GEOSYNTHETICS DISCIPLINE AND ITS ACHIEVEMENTS

None of the geotechnical engineering innovations mentioned above has reached the status of a discipline. In contrast, it is justified to refer to the geosynthetics discipline, because, unlike other innovations, geosynthetics have pervaded most branches of geotechnical engineering; and geosynthetics have pervaded most branches of geotechnical engineering because there is a wide variety of geosynthetics. This does not seem to be an original reason because there is also a wide variety of soils. Indeed, there is a variety of soils from clay to rockfill, i.e. from very fine to very coarse soils. The phrase, “from clay to rockfill”, implies that soils can be classified by the size of their particles. Of course, a complete classification of soils involves other criteria in addition to particle size. However, it is true that particle size is, by far, the most important criterion in soil classification; and the phrase “from clay to rockfill” includes all types of soils and adequately describes their variety.

There is no such phrase for geosynthetics. It does not make sense to say: “there is a variety of geosynthetics from a certain type to a certain other type”. For example, the phrase “from geotextiles to geomembranes” does not mean anything. This is because the variety of geosynthetics cannot be described by a single criterion. Whereas the variety of soils can be described by a single criterion (the size of particles), several criteria are required to describe the variety of geosynthetics.

The criteria that describe geosynthetics variety are the following: first, the dimension, with one-dimensional geosynthetics (straps, yarns), two-dimensional geosynthetics (geotextiles, geomembranes, etc.), and three-dimensional geosynthetics (geocells, geofoam); second, the structure, with open structures (geogrids, geonets, geocells), closed structures (geomembranes, straps), and intermediate structures (geotextiles); and, third, the direction, with one-directional geosynthetics (yarns, straps), two-directional geosynthetics (woven geotextiles, biaxial geogrids), three-directional geosynthetics (geocells, new geogrid), and multi-directional geosynthetics (nonwoven geotextiles, geomembranes).

Since several criteria are needed to describe the variety of geosynthetics, whereas one criterion can describe the variety of soils, it may be said that the variety of geosynthetics is of a higher order than the variety of soils. As a result of this higher order of variety, the properties of geosynthetics cover a wider range than the properties of soils. For example: some drainage geosynthetics are more permeable than gravel; geomembrane liners are more impermeable than clay liners; filter geotextiles can, at the same time, be more permeable than sand filters and retain smaller particles thanks to the fiber structure; reinforcement geosynthetics are stronger than soils; and geotextiles can be used as separators because they are more continuous than soil layers. This wide range of properties of geosynthetics explains why geosynthetics have pervaded most branches of geotechnical engineering; which, in turn, justifies the terminology “geosynthetics discipline”.

Today, the pioneers of the geosynthetics adventure leave in the hands of their successors a remarkable discipline, characterized by the following achievements: a wide variety of products and test methods; a large number of applications; active research; a considerable body of knowledge including design methods and case histories; and a construction practice that is well mastered with established quality control and quality assurance procedures. Also, lessons have been learned from failures, which is a sign of maturity in any discipline. Furthermore, the geosynthetics discipline is well organized, with an international society that is highly regarded. It is fair to say that geosynthetics have been the most important innovation in geotechnical engineering in the second half of the 20th century.

4. CHALLENGES

There is still a lot of work to do in the geosynthetics discipline, and a number of challenges will have to be met. The two types of challenges which seem to be most important are education challenges and technical challenges. As far as education challenges are concerned, more education on geosynthetics should be provided, but it should be remembered that a course on geosynthetics cannot replace a course on geotechnical engineering. Also, civil engineers should be made more aware of the possibilities offered by geosynthetics.

Many specific technical challenges are likely to be associated with new applications. These specific challenges will be met on a case by case basis by engineers and scientists working in the geosynthetics discipline. In addition to specific technical challenges, there will be general technical challenges. In particular: researchers will need to pursue current efforts aimed at the quantification of the durability of all types of installed geosynthetics; and researchers will need to develop design methods for “subtle” mechanisms that have been neglected in the past. While the first of these two general technical challenges is obvious, the second requires discussion.

In the past three decades, many design methods have been developed by extending to geosynthetics engineering traditional methods used in geotechnical engineering. This approach has been very productive. However, the simplest methods from geotechnical engineering were the first to be adapted to geosynthetics engineering. As a result, “subtle” mechanisms potentially of importance to the performance of structures incorporating geosynthetics have been overlooked.

Two simple examples illustrate “subtle” mechanisms neglected in the past. The first example is related to geosynthetic reinforcement. Design methods based on large deformations have been developed, while neglecting small deformations that are more difficult to take into account. The second example is related to fluid transport through geosynthetic barriers. Design methods based on advective flow have been developed, while diffusion, a phenomenon that is not well known by most geotechnical engineers, has largely been ignored. This situation is not limited to design methods. A similar situation exists today with geomembrane installation: seaming quality (the main installation problem in the 1980s) is now excellent, but the reliability of some liner systems is questionable due to geomembrane wrinkles, a “subtle” mechanism that has been extensively discussed but never fully controlled.

Today, researchers need to study “subtle” mechanisms in order to use geosynthetics to their full potential. In fact, some researchers are already working on “subtle” mechanisms, including for example: small deformations and repeated loading; quantification of interface mechanisms between adjacent materials; migration of contaminants by diffusion; quantification of the performance of reinforced soil treated as a composite material rather than a juxtaposition of two components; and influence of materials’ variability on the performance of applications of geosynthetics.

As a result of these research efforts, the geosynthetics discipline is getting ready to meet the challenges generated by new conditions in the 21st century, such as: structures for resource conservation; structures compatible with climate changes; infrastructure in developing countries; and high-security structures able to resist attacks and natural disasters.

5. CONCLUSION

In conclusion, this paper, devoted to The Geosynthetics Discipline Achievements and Challenges, portrays a discipline with great achievements and ready to meet the challenges of the 21st century.

ACKNOWLEDGEMENTS

The author is grateful to three companies that sponsored the preparation of this paper and the opening lecture of GeoAmericas 2008, Geosyntec Consultants, TENSAR, and NAUE; and two companies that provided support, SOPREMA and CARPI. The author is also grateful to P. Jones, C.J.F.P. Jones, R. Bonaparte, J.G. Zornberg, C.G. Jenner, J. Cavanaugh, G. Heerten, R.J. Bathurst and W. Voskamp for their review of the manuscript.