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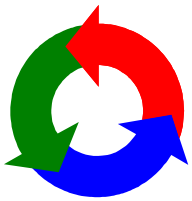

Center for Geotechnology

Geomaterials Research Project

Geofoam and Geocomb Geosynthetics: A Bibliography Through the Second Millennium A.D.

Research Report No. CGT-2001-1

by

John S. Horvath, Ph.D., P.E.
Professor of Civil Engineering
Director/Center for Geotechnology

Manhattan College
School of Engineering
Center for Geotechnology
Bronx, New York
U.S.A.

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This report plus others in the Manhattan College *Center for Geotechnology* (CGT) and Civil Engineering Department geotechnical engineering program (CE/GE) research report series are available in PDF format via the Internet at <www.engineering.manhattan.edu/civil/CGT.html>.

Prof. John S. Horvath, Ph.D., P.E.
Manhattan College
Civil Engineering Department
Bronx, New York 10471-4098
U.S.A.

e-mail: <jhorvath@manhattan.edu>
personal webpage: <www.manhattan.edu/~jhorvath/>
direct-dial telephone: +1-718-8627177
telefax: +1-718-8628035

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The Manhattan College School of Engineering *Center for Geotechnology* and Its Mission

The Manhattan College School of Engineering *Center for Geotechnology* (CGT) is a unique organization that strives to be more than the typical academic research center or institute. It was founded in 2001 at the initiative of Prof. John S. Horvath, Ph.D., P.E. of the Civil Engineering Department who serves as its first Director. The CGT is the result of Prof. Horvath's evolutionary realization after almost 30 years of geotechnical engineering practice that the explosive growth in geotechnical and geoenvironmental engineering technology has made it difficult for the engineering practitioner to keep abreast of new technical developments. The traditional academic approach of simply publishing research results in narrowly disseminated technical reports and papers (a philosophy of "if you print it, they will learn") has proven to be an increasingly ineffective way of reaching practitioners and moving the state of art to the state of practice. The critical need for a total rethinking of how life-long continuing education is achieved not only for engineering practitioners but academicians themselves is evidenced by the appearance of "teach-the-teacher" training courses in drilled shaft foundations and geosynthetics beginning in the late 1980s. If even academicians cannot keep up with new developments by reading journal papers and conference proceedings, how can practitioners be expected to? The stagnation of geotechnology also affects current engineering students and perpetuates the cycle. The desirability of involving the practitioner in the process of formulating research programs so that they may have a more direct and immediate benefit to practice is also something that is now recognized more and more.

The CGT seeks to address the current need for effective, meaningful continuing education by recognizing that the cycle of growth for any technology has three interdependent components, what can be called the "trilogy of technology". Like a three-legged stool, each of these components must be of equal length and strength if a given technology is to succeed. Thus the CGT has adopted a holistic strategy of supporting geotechnology growth by recognizing the need to concurrently address:

- *Technology advancement* through research and development that involves not only the engineering practitioner but also other end users of geotechnology such as construction contractors and material manufacturers to the greatest extent practicable.

- *Technology transfer* through education of engineers, contractors and manufacturers in a multi-faceted, proactive way.

- *Technology documentation* through standards development so that all end users (practitioners, contractors and manufacturers) of a given technology work to a common set of guidelines.

This trilogy of technology growth is the cornerstone of all activities of the CGT. It is important to note that the interaction of these three components, which is embodied in the CGT logo that is shown on the cover of this report, is never completed but assumes a constant cycle that leads to continuous growth of a technology.

The CGT receives no direct financial support from Manhattan College for any of its activities. Thus the success and growth of the CGT is totally a function of outside funding from individuals and organizations whose philanthropic philosophies are consistent with the stated goal of the CGT to treat technology growth in a more holistic fashion than is typically done in academia and considers the entire process from research to standards with end-user input at all stages. In addition, as part of its mission to promote technology transfer through education to the greatest extent practicable the CGT is willing to partner with industry and other academic institutions not

only in research but also technology transfer and standards activities on any topic relevant to geotechnical or geoenvironmental engineering. The new Manhattan College School of Engineering William J. Scala Academy Room, which is located on the main floor of the Leo Engineering Building and available for CGT activities, offers modern facilities for hosting technology transfer activities. One benefit of Manhattan College's location on the northern edge of New York City is that it is quite accessible (including free off-street parking adjacent to Leo Engineering Building) from both within and outside the City. More information about the CGT can be found on the Internet at <www.engineering.manhattan.edu/civil/CGT.html>.

Preface

Within a few months after becoming employed full time in academia in August 1987, I developed an awareness from several technical papers of the intriguing concept of *controlled yielding* within the ground as a means of reducing stresses from earth materials acting on earth retaining structures. Because of my practice-oriented research perspective developed as a result of many years in engineering practice, I immediately began a search for relatively compressible material(s) that could realistically be used to accomplish controlled yielding routinely in actual applications, something that prior research into this topic by others had largely ignored. As a result of reading a landmark paper by Partos and Kazaniwsky that had been published in a somewhat obscure conference proceedings in the 1980s, this search soon led me to polymeric (plastic) foams and identifying their use as what we now call *compressible inclusions*, a significant research interest of mine from 1988 to the present.

By the early 1990s, I had become aware of the broader geotechnical applications of polymeric foams, especially expanded polystyrene (EPS), and broadened my research activities accordingly. I was intrigued by these materials, EPS in particular, and the fact that they had been used as geomaterials in some countries since at least the early 1960s. This usage included the U.S.A. where several pioneering patents for polymeric foams in geotechnical applications had been issued in the mod 1960s and early 1970s. Despite this generally successful early usage, most geotechnical engineers in many countries (especially the U.S.A.) were completely unaware of the use of polymeric foams as geomaterials and thus were certainly not using them circa 1990. This underutilization of what I perceived to be a fascinating family of geomaterials motivated me to broaden my research activities. To begin with, the generic definition of *geofoam* as any closed-cell foam used in a geotechnical application was established by me in the early 1990s (I did not learn until November 1997 that the word geofoam had actually been coined as early as the 1970s). I also promoted the recognition of geofoam as a geosynthetic product category, a significant departure from the traditional (and still common) perception that geosynthetics are only relatively thin planar products and something that still does not sit well with some geosynthetics purists.

One aspect of my broadened interest in and research into geofoams was obtaining and reviewing all known publications and other technical information related to them. I focused my efforts on EPS because of its rather amazing range of proven and potential geotechnical applications as well as its durability and relatively low cost which has led to its being the geofoam material of choice is most applications. I soon realized that there would be a benefit in synthesizing the surprising large body of information I found on EPS geofoam, most of which had been published in obscure venues not readily known or easily obtained (part of the reason why so few engineers knew about geofoams), and publishing it in a single volume. This goal was realized with the self publication of my monograph "*Geofoam Geosynthetic*" in July 1995. This monograph also contained a complete bibliography of all publications obtained and reviewed by me as of mid 1995.

Even after publication of "*Geofoam Geosynthetic*", I continued acquiring geofoam related documents as they were published or otherwise became available to me. To keep track of this ongoing effort, I created and kept updated a geofoam bibliography file on my computer. I also expanded this bibliography to include publications I became aware of but which I had not been able to acquire. In September 1999, I again expanded this bibliography to include *geocombs*, a term I coined earlier that year for another new geosynthetic product category for materials with an open-cell, honeycomb structure.

In recent years, this digital geofoam and geocomb bibliography was posted as a work-in-progress document on *The Geofoam WWW Site*™. This now-defunct Internet website was created by me in July 1996 and operated independently by me for over four years. With the true end of the second millennium anno domini (A.D.) on December 31, 2000, it seemed appropriate to prepare a final (true) millennial version of this bibliography as a Manhattan College research report. It is also

fitting that this report is the first published under the aegis of the new (as of 2001) Manhattan College School of Engineering *Center for Geotechnology* (CGT) that I am privileged to serve as its first Director. This report is a major contribution to the Geomaterials Research Project which is one of three initial research areas of the CGT. I will leave it to others to carry this bibliography into the third millennium A.D. and add entries for geofoam materials such as cementitious foams and foam grouts that I have not had the time to research and document to any significant extent. There are undoubtedly inadvertent errors and omissions in this bibliography that will require correction as well.

This bibliography is intended to be a resource document for both practicing engineers as well as academic researchers. Thus the listings in this bibliography are organized in three ways to facilitate use:

- by topic (alphabetically by author within each topic),
- alphabetically by author and
- chronologically (alphabetically by author within each year).

Those publications that I have not been able to obtain and review are shown in lighter (gray) type. Note that some of the entries for such publications are incomplete (e.g. publisher or date of publication unknown) but this simply reflects the information as I know it at the time I prepared this report.

Consistent with the original bibliography published in my monograph "*Geofoam Geosynthetic*", virtually all manufacturer's literature was intentionally omitted from this bibliography for several reasons. First of all, it is impossible to keep track of such literature, especially on a international basis. Thus it is impossible to include all literature which would inadvertently offend some company. Second, most of this literature changes frequently so has little or no lasting value from a documentation perspective. Third, the distinction between sales hype and truly useful technical data is sometimes difficult to distinguish in such literature so I feel it had no place in a document of this nature. Where I have included a citation for a publication by a material manufacturer it is typically an authorized reprint of some national design code or similar type of document.

Finally, although this report is the end product of over a decade of my personal effort, it would not exist without the generous assistance provided by innumerable individuals and business entities from around the world. The generous sharing of acquired knowledge by these sources has led to the enormous global growth in the recognition and use of EPS-geofoam technology in particular during the 1990s after decades of obscurity. This collective effort has unequivocally demonstrated that technology transfer is a crucial component in the development and growth of any technology. Quite simply, if someone does not know about a technology it is fundamentally impossible for them to use it and thus that technology will languish.

John S. Horvath, Ph.D., P.E.
Bronx, New York, U.S.A.
May 2001

TOPICAL LISTING

General (discuss both geofoam and geocomb)

Horvath, J. S., "*Designing with geofoam geosynthetic*", notes prepared for participants at the American Society of Civil Engineers/Branch River Foam Plastics, Inc. continuing education seminar, Randolph, Mass., U.S.A., October 1999.

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General (discuss both geofoam and geocomb)

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